The Mass of the Atmosphere: A Constraint on Global Analyses

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The total mass of the atmosphere varies mainly from changes in water vapor loading; the former is proportional to global mean surface pressure and the water vapor component is computed directly from specific humidity and precipitable water, using the ERA-40 reanalyses from the European Centre for Medium Range Weather Forecasts (ECMWF). Their difference, the mass of the dry atmosphere is estimated to be constant for the equivalent surface pressure to within 0.01 hPa based on changes in atmospheric composition, and global reanalyses satisfy this constraint for monthly means for 1979-2001 with a standard deviation of 0.065 hPa. New estimates of the total mass of the atmosphere and its dry component, and their corresponding surface pressures, are larger than previous estimates owing to new topography of the Earth's surface that is 5.5 m lower for the global mean. Global mean total surface pressure is 985.50 hPa, 0.9 hPa higher than previous best estimates. The total mean mass of the atmosphere is 5.1480x10^18 kg with an annual range due to water vapor of 1.2 or 1.x10^15 kg depending on whether surface pressure or water vapor data are used; somewhat smaller than the previous estimate. The mean mass of water vapor is estimated as 1.27x10^16 kg and the dry air mass as 5.1352±0.0003x10^18 kg. The water vapor contribution varies with an annual cycle of 0.29 hPa range, a maximum in July in of 2.62 hPa and a minimum in December of 2.33 hPa, although the total global surface pressure has a slightly smaller range. During the 1982-83 and 1997-98 El Niño events, water vapor amounts and thus total mass increased by about 0.1 hPa in surface pressure or 0.5x10^15 kg for several months. Some evidence exists for slight decreases following the Mount Pinatubo eruption in 1991 and also for upward trends associated with increasing global mean temperatures, but uncertainties due to the changing observing system compromise the evidence.

The physical constraint of conservation of dry air mass is violated in the reanalyses with increasing magnitude prior to the assimilation of satellite data in both ERA-40 and NCEP/NCAR reanalyses. The problem areas are shown to occur especially over the southern oceans. Substantial spurious changes are also found in surface pressures due to water vapor, especially in the Tropics and subtropics prior to 1979.

Test of the Validity of the Budyko-Sellers Parameterizations for the TOA Fluxes Using an Atmospheric GCM

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It is generally accepted that globally averaged sensitivity of the TOA budget to sea surface temeprature (SST) perturbations lies approximately within 2-3 W/m2/K interval. It is this value that has been used in many energy balance models of various complexity. In this study we run an aquaplanet atmospheric GCM with a series of fixed zonally symmetric SST profiles in order to look at quasi-stationary response of the TOA and the surface fluxes to SST anomalies on different horizonal scales. The analysis is done with perturbations, which represent zonally symmetric spherical harmonics. The global average sensitivity of the TOA budget with respect to the SST (proportional to the correlation coefficient) is close to 2 W/m2. The point-by-point correlation between SST perturbations and changes in the TOA budget is very good for latitudes polewards of 30 degrees, but this is not the case in the tropics. Even for large scale perturbation, especially anti-symmetric about the equator, the correlation is very poor. This is explained by the fact that the structure of the Hadley cell controls most of the properties of the tropical atmosphere. This conclusion is supported by the analysis of the corellation between SST and TOA perturbations in the wavenumber domain. For the given GCM for very large scale SST perturbations (wavenumbers 0-2) the correlation is quite good - the TOA response has most of the energy in the same wavenumber. For higher wavenumbers the correlation becomes worse and a lot of energy in the TOA response goes to other harmonics.

This presentation also serves as a supporting poster for another abstract by the same author entitled "On the non-locality of the atmospheric response and polar amplification of the global warming".

LT-3

Variability of Global Zonal Atmospheric Circulation: Interannual and Decadal Time-Scale

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The new circulation index – velocity circulation of zonal wind along the latitude circle – was introduced by Petrossiants and Gushchina. This index was shown to be helpful in investigation of global atmospheric circulation patterns and in testing of atmospheric general circulation models.

The spectral characteristics of the velocity circulation in various latitude bands are analyzed in the upper (200 hPa), middle (500 hPa) and low (850 hPa) troposphere for winter season. The NCEP/NCAR reanalysis data are used as “observations” for the period 1958-1998.

In the whole troposphere and in all latitude bans two main period of oscillation can be distinguished in the wavelet spectrum: short interannual oscillations with the period from 2 up to 6 years and long interannual oscillations with the period 8-16 years. However within this time intervals the localization of spectral maximum varies significantly depending on the latitude bands and isobaric surfaces. The asymmetry between two hemispheres was detected, i.e. in the same latitude band the oscillations with different periods dominate in Southern and Northern hemisphere.

It was shown that intensity of oscillations change not only with latitude but with time. The analysis of wavelet coefficient distribution demonstrate that the spectrum of velocity

circulation exhibit a strong decadal variability, i.e. the oscillation with some periods are very intensive in one decade and are almost lacking during the following decade. The spectral maximum can also shift forward shorter or longer period on the decadal time-scale. Thus we can conclude that the spectral characteristics of circulation are not constant in time, so the well known oscillations like quasibiennial oscillation in tropics or ENSO-like oscillation could be more or less pronounced on the decadal time-scale.

To estimate the simulation of velocity circulation in general circulation model from the point of view of spectral characteristics the analogous calculations on the ground of data from ARPEGE model are carried out in the upper (200 hPa) troposphere. The comparison between model and reanalysis results showed that ARPEGE simulate the spectral structure of the velocity circulation worth than its spatial-time distribution.

LT-4

Qualitative Comparison of Air Temperature Trends Based on NCAR/NCEP Reanalysis Data, Model Simulations Data and Aerological Observations

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In the present study we discuss two points. The first one is related with applicability of reanalysis data to investigating climate variability. We present results of comparison of long-term air temperature trends for the troposphere and the low stratosphere calculated using monthly averaged NCAR/NCEP reanalysis data on one hand and direct rawinsond observations from 443 stations on the other. The trends and other statistical characteristics are calculated for two overlapping time periods, namely 1964 through 1998, and 1979 through 1998. These two intervals were chosen in order to examine the influence of satellite observations on the reanalysis data, given that most satellite data have appeared after 1979. Vertical profiles of air temperature trends are also analyzed using the two types of data for different seasons. A special criterion is applied to evaluate the degree of coincidence by sign between the air temperature trends derived from the two types of data. Vertical sections of the linear trend averaged over the 10-degrees zones for the both hemispheres are analyzed. It is shown that the two types of data exhibit good coincidence in the terms of the trend sign for the low and middle troposphere and low stratosphere over the areas well covered by the rawinsond observation net. Significant differences of the air temperature trend values are observed near the land surface and in the tropopause layer. The absolute value of the cooling rate of the tropical low stratosphere based on the rawinsond data is larger then that based on the reanalysis data. The presence of a positive trend in the low troposphere in the belt from ~40°N to ~70°N is evident in the two data sets. A comparative analysis of the trends for the both periods of observation shows that introducing satellite information in the reanalysis data resulted in an increase of the number of stations where the signs of

the trend derived from the two sets of data coincide, especially in the southeastern part of Eurasia.

The second part of the present study is related with another question. How do well climate model simulations match temperature observations throughout the atmosphere? Estimates of monthly-mean troposphere and stratospheric temperature trends over the past twenty years, from different hydrodynamical models (INM - model of Institute of Numerical Mathematics, RHMC - model of Hydrometeorological Center of Russia, HADCM3 - Hadley Center Coupled atmosphere - ocean general circulation model) are compared both with each other and with the observed trend analyses using aerological observations. The modeled temperature trends are driven by changes in carbon dioxide and without any forcing. We verified if the agreement is good between models and observations in term of cooling in the lower stratosphere and the tropospheric warming, which are strong indicators of climate change. Spatial inconsistencies between the observed and modelled vertical patterns of temperature change are identified.

LT-5

Assessing Long Period Changes in the Upper-Air Temperature Series: Abrupt Changes and Their Effect on Trends

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The abrupt changes in climate time series, invoked both by inhomogeneities and by natural climate processes, are the main source of uncertainty in our knowledge of long-term climate variations. The upper-air temperature series are in focus of many groups of researchers, but their efforts to obtain "unbiased", "homogenous" series lead to results that are not consistent enough with each other.

The approach based on ARIMA procedure and metadata historical information, enables to assess the moments and magnitudes of step-like changes in the climate time series. The difference between this approach and the other ones existing for the upper-air temperature time series, is that it enables to assess numerous variants of consideration (or non-consideration) possible candidate points of abrupt changes and their effect on trend values, without necessary obtaining the so called "corrected" series themselves. Numerous examples of this approach in estimating the magnitudes of abrupt changes in the RIHMI-WDC radiosonde-based climate series of upper-air temperature for the troposphere and lower stratosphere, are contained in the paper.

LT-6

Long-Term Variability of the South Asia High and its Relation to Atmospheric Circulation and Global Sea Surface Temperature

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The long-term variability of the 100 hPa South Asia High (SAH) in summer is examined by using the NCEP/NCAR reanalysis data from 1958-1999. The characteristics of the SAH are studied both from its location and intensity. The bimodality character of the SAH in its longitude location is prominent and exhibits a distinct decadal to interdecadal variability. From the late 1970s, the alternation of the SAH bimodality in its longitude location takes on a more low-frequency variability. More Tibetan mode cases appear in 1980s and more Iranian mode cases in 1990s. The detrend time series of the SAH intensity index shows that the signals with large variability mainly happen on the decadal to interdecadal timescales. There is a remarkable phase transition occurring in late 1970s. The interannual variability is weak, especially before the mid-1980s.

The SAH is significantly, positively correlated to the middle-upper tropospheric geopotential height (TGH) over the Northern Hemisphere (NH) in summer and their spatial patterns exhibit a consistently zonal structure. The correlation between the SAH and the sea level pressure (SLP) is substantially weak and even out of phase, implying a vertical baroclinic structure of the TGH related to the SAH. The correlation of the SAH intensity index and the preceding wintertime TGH shows a more evidently zonal structure at middle-upper troposphere. The barotropic vertical structure is evident in winter correlation pattern. The correlation maps also show some wave-like teleconnection features of Pacific-North American (PNA) and Arctic Oscillation (AO) from the upper troposphere to the surface at high latitudes. The presence of features of the PNA and AO in the correlation maps suggests a covariability between the summer SAH and wintertime atmospheric patterns on a long timescale.

The long-term correlation of the SAH and the global sea surface temperature (SST) is the most significant over the tropical Indian ocean and tropical Atlantic, especially when summer SAH is related to winter season SST. It suggests that the local air-sea interaction plays an important role in the long-term variability of the SAH.

LT-7

Association of Atmospheric Features with Decadal Variability of Storm Frequency in Bay of Bengal

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Investigation of storm frequency and Sea Surface temperature (SST) variability in Bay of Bengal during summer monsoon season for the 44-years period from 1958-2002 shows interdecadal variation. A decrease in storm frequency is observed from mid–1980. in contrast, SST anomalies are negative from 1958 to mid-1980 & changes to positive thereafter. Thus the storm frequency & SST variations are out-of-phase. The storm frequency decreases from mid-1980 in-spite of increasing SST. The period 1958 to mid-1980 is referred to as epoch1 & post mid–1980 as epoch2. Both storm frequency and SST variability in the two epochs are statistically significant.

This prompted us to study if such a decrease in storm frequency is reflected in atmospheric features over Bay of Bengal on decadal scale(Mandke & Bhide, 2003). The atmospheric parameters averaged over Bay of Bengal during summer monsoon season such as relative vorticity at 850hPa, horizontal shear of zonal wind, mean sea level pressure and vertically integrated moisture flux differ in epoch1 & epoch2 with statistical significance. The vertical shear in two epochs is statistical significant only over small region in North Bay of Bengal. Storm frequency over Bay of Bengal for monsoon season is taken from India Meteorological Department. The atmospheric parameters are from monthly mean NCEP/NCAR reanalysis data for the period 1958-2002. The SST data used is GISST(Global Sea-Ice and Sea Surface Temperature). Results suggest that the changes in all the atmospheric parameters from epoch1 to spoch2 are related to decreasing storm frequency in - spite of favorable SSTs.References: 1) Mandke Sujata K. & Usha V. Bhide, 2003; “A study of decreasing storm frequency over Bay of Bengal”, J. Ind. Geophys. Union , Vol. 7 No. 2, P.P. 53 to 58.

LT-8

Methodology and Methods for Restoration of Missing Data and Long-Term Time Series of Meteorological Characteristics

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Time series of observed meteorological characteristics have different period of observations and lack of information (missing data) in some years. Such situation is not suitable for decision of such main problems of modern climatology as:

- restoration of the information in the points of regular grids for GSMs application, because the accuracy of interpolation can be differ for different time periods;
- classification, regionalization and extrapolation of long-term climate change tendencies over the space, because records of observations have different size and period that lead to different assessments of long-term climate changes.

For restoration of long-term time series and lacks in observations with an aim to extend them for long-term and the same period, for example the period of last one century at least, the general methodology based on the space-time synchronism can be developed and suggested. This methodology has three main steps of consecutive realization, beginning with the most effective one:

- extending of short-term time observations on the basis of relationships with the particular analogues, which have the longest records, on the basis of simple and multiply regression (principle of long-term time synchronous among the neighbouring space points);
- restoration on the basis of regional relationships for different time sections (principle of synchronous inside a homogeneous region and the existing of space gradient);
- restoration of different characteristics in the same point (station) on the basis of relationships between different meteorological characteristics, for example, data in one month with data in other month using a seasonal function, etc.

The particular methods and statistical models have been developed for realization of each approach.

The next step of methodology connects with an assessment of efficiency of restored values. This assessment includes the following stages:

- development of the criteria for creation of effective model for the data restoration;
- assessment of efficiency for results of restoration on the basis of the same data which have been used for the processing;
- assessment of efficiency of restored values on the basis of independent data.

The criteria and indexes of efficiency have been developed for each stage of development of the model and assessment of efficiency and the result was the complex of criteria for assessment of efficiency of data restoration in the particular point.

The last problem of data restoration connects with the generalization of the results obtained by different methods of restoration and on the basis of different models. Methods of restoration based on the averaging of the results with weight coefficients inverse to their random errors as well as methods based on the distribution function of errors have been developed and suggested. As a result, such developed system of restoration of meteorological data allows take into account all space-time climatic properties and give the most effective assessment of data restoration in each point.

Application of suggested approach is given for processing and restoration of time series of monthly air temperature for the European part of Russia. More than 100 stations have been chosen with average period of observation in 80 years. In the result of step by step restoration the sizes of records have been extended up to 110-130 years in dependence on the particular month. For months of cold period of year the size of restored data was more than for warm period. Random errors of restoration obtained by independent way, as a rule, do not exceeded 20% to standard deviation of long-term time series.

LT-9

The Effect of Volcanism and Solar Irradiance on the Variability of European Climate during the Last 500 Years

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This study analyzes the role of the SVRF (Solar and Volcanic Radiative Forcing), including solar irradiance and volcanism, on the European climate during the last five centuries. The data are derived from two multicentennial global RF simulations using a time dependent RF (which includes, besides the SVRF, also the Green House Gases increase): a 1000-year long CTR (ConTRol) simulation with constant RF, and a chronicle-based paleo-reconstruction of the European monthly temperature fields. These data show multi-decadal and centennial T2 (2-meter Temperature) variability correlated with the SVRF. The meridional contrast in European P (Precipitation) and T2

correlated with the NAO (North Atlantic Oscillation) at all timescales are characteristic features of winter climate. At multi-decadal timescales, high/low SVRF conditions are associated with more frequent positive/negative NAO phases, and, moreover, the RF is responsible for a rotation of the NAO dipole, which reduces the transport of warm and moist air towards Northern Europe during the positive NAO phase. At inter-annual timescales neither the winter temperature and precipitation fields, nor the NAO are correlated with the SVRF and the correlation between the paleo-reconstruction and the RF simulation is not significant. Instead, summer climate shows a higher correlation with SVRF. Consequently, if based on SVRF alone, predictability of the European climate would be higher for summer than for winter, during which it would be restricted to the multi-decadal or longer timescales at which RF is dominant.

LT-10

The ENSO and Tropical Explosives Volcanic Eruptions. Two Sources of Climate Variability in the Great Caribbean

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Within the forcing factors of the climate variability, one of the better defined and more studied in the recent years, it is the event ENSO. Today it constitutes a fact widely known that the impact associated with the event ENSO reaches global magnitude, linked with the alterations establishment in the atmosphere circulation processes on a large scale. However, the task of identifying the signs ENSO within the variability of the climate does not result a simple task.

Excluding de external influence of solar activity variability, represented by the Relative Wolf Number, throughout the analysis of chronological climatic series, that reach a length century or more in some instances, in the present work is illustrated, how in the region of the Great Caribbean in general and of Cuba in particular, in studies of different scales atmospherical phenomena variability, (Tropical Cyclones, Cold Fronts and Severe Local Storms) and extreme events of the pluviometric regime, they have been detected similar impacts or possibly associates impacts, which can be attributed, at the same time, to different forcing sources, : in specific to ENSO and Explosive Volcanic Eruptions of the tropical zone. Using the Reanalysis Project dataset of period 1958-1998. they were postulated some physical considerations about the possible causes of such similarity.

It is discussed, furthermore, about the need of the integrated watch of these phenomena, or of the specific propagation or amplification mechanisms of their signs, in order to anticipate theirs potential to generate important weather and climate anomalies

in the region. Furthermore, considering that most of rainfalls and TC interannual and seasonal variability climate prediction methods give to the influence of ENSO - predictors, in occasions, an extremely large weight, is suggested that the introduction of someone volcanic activity indices in those methods, could contribute to improve their ability, particularly in those that permit to introduce the forcing at any moment. This requires, at the same time, the development and application of methodologies increasingly sophisticated statistics, for the isolation and integration signs.

LT-11

Trends and Variability in North Atlantic/Western European Winter Precipitation

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Our aim in this poster is to use modern statistical techniques to understand variations and trends in winter precipitation in the Northern Hemisphere (NH), with a focus on the North Atlantic Ocean/Western European region. In particular, we explore the role of sea-level pressure variations, both local and large scale such as those associated with the North Atlantic Oscillation. We examine the variability in pentad precipitation from the Global Precipitation Climatology Project dataset and compare it to sea level pressure (SLP) variations from the ERA-40 reanalysis. Generalized Linear Models (GLMs) have been applied with the Gamma distribution, rather than a multiple linear regression, which does not take account of the heavily skewed distribution of precipitation. Our preliminary results show that the mid-latitude oceanic storm tracks represent the dominant areas of NH variability in precipitation, and that time trends alone explain less than 10% of the variance of pentad precipitation. Variations in local SLP are inversely related to precipitation on the pentad time scale in the NH and explain up to 30% of the variance in precipitation. Local SLP explains less variance in the Western and Central storm track regions than in the east in both the Atlantic and Pacific. The North Atlantic Oscillation index explains considerable variability in western Atlantic and European pentad precipitation, but relatively little in the Pacific. We will examine the role of variability associated with the El Niño/Southern Oscillation, particularly in the Pacific, in connection with pentad precipitation.

LT-12

Interannual Variability of the South Atlantic High and Rainfall in Southeastern South America during Summer Months

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Monthly sea-level pressure (SLP) patterns over Southeastern South America were analyzed to explore near-surface circulation changes and their connection with the observed positive rainfall trends of the last 40 years. Rotated principal component analysis was performed on monthly SLP means obtained from the NCEP/NCAR reanalysis. The first two principal components (PC) accounts for almost 90% of the total variance. PC1 represents approximately the winter field dominated by the South Atlantic high (SAH) in its northernmost position of the year, while PC2 is the typical summer field with the SAH intensified and displaced to the south and the presence of the northwestern Chaco Low. The first factor loading (FL1) shows a negative linear trend and FL2 a positive one indicating a change in the annual SLP cycle over the region. Similar trends were obtained in a previous work using seasonal instead of monthly SLP fields indicating a southward shift of the western border of the SAH since 1950.

During summer, there is a significant negative correlation between FL2 and monthly rainfall in the eastern region between 25ºS-35ºS (comprising east of Argentina, Uruguay and southern Brazil) indicating a reduction of rainfall in those months in which the SAH is intensified and shifted southward of its mean position. On the other hand this correlation is positive and statistically significant in the region of the continental South Atlantic Convergence Zone (SACZ) and in western Argentina between 23ºS and 40ºS. The correlation field between monthly rainfall and FL1 is almost the opposite in sign to that described for FL2. If the correlation with precipitation is restricted to only extreme values of the factor loadings (larger or lower in one standard deviation from the average), the correlation patterns are similar but with considerable larger values (reaching 0.9 in some areas) in the SACZ region and in western Argentina. This means that for these extreme cases, monthly rainfall in this region was strongly conditioned by the SACZ position and intensity.

These results are relevant for developing regional scenarios of future climate since four global climate models (HADCM3, ECHAM4/OPYC3, GFDL-R30 and CSIRO-mk2) show that in their SRES-A2 scenarios the southward shift trend of the western border of the SAH will continue during the rest of the present century. Under this circulation scenario, it can be expected positive trends in summer rainfall at least in certain areas of the continental SACZ region and of western Argentina.

LT-13

Understanding Rainfall Variability in North West African Domain

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Most of weather systems occurs in the region during frontal excursion through the Atlantic and Europe bringing cold air and cloud and precipitation systems. The active precipitation period extends from October to May with almost 80% of the total rainfall. The dry season extends from June to September. The far south of the region

experiences some tropical influence during August period especially in the south of Algeria when the ITCZ migrates from the SAHEL area to its northernmost position in the region.

Several studies especially in mid 1990's have investigated rainfall variability in the region and emphisized the major role played by the north atlantic oscillation in modulating the main position of the active synoptic systems in the north Atlantic area and therefore in modulating the frequency and the intensity of the weather systems that impact the western part of the region. This finding was mainly based on computing correlation between indices such as between index of the northern Atlantic oscillation – NAOI - and Moroccan rainfall indices.

In this study more general approach is investgated based on EOF analysis applied on 500 mb geopotential field which in turn is coupled statistically with global SST. Significant teleconnection signal from the ocean particularly in the Atlantic and Pacific has been found. Applying this result on a particular year of 1984 where strong anomaly was abserved in the Atlantic SST has confirmed the rôle of this teleconnection signal. In fact the correlation analysis shows a likely connection between the observed anomaly in the 500 mb geopotential and the observed warming in the tropical Atlantic so that the later could be the source of the forcing behind the observed anomaly and therefore the observed very above average rainfall in most of the region.

LT-14

Precipitation Trends in the Mediterranean Basin during the Last Half-Century

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The global climate scenarios are in accordance with seasonal precipitation decreases in the Mediterranean Basin at the end of the 21st century and the regional ones with an increase of the annual maxima of precipitation in some parts of the area. Our objective is the research of a possible beginning of such rainfall changes during the second half of the 20th century.

The annual, seasonal and monthly rainfall totals, the >10mm, the 95th percentile and the >95th percentile monthly totals of 52 stations in the Mediterranean Basin during 50 years (from September 1950 to August 2000) have been regionalized by Rotated Principal Component Analyses (RPCA). Six very similar regions have been determined by the RPCA at the different studied time scales (Atlantic region, Gulfs of Valencia and of Lions, Gulf of Genoa, Greece, Middle East and Maghreb). Their scores trends have been calculated and tested at the 0.05 level by the Kendall test.

The annual, seasonal and monthly rainfall trends are mainly non significant. Generally they decrease non significantly except in the Atlantic region (March), in the Mediterranean Spain (October), in the Gulf of Lions (December, February), in the Gulf of Genoa (autumn, December, February), in Greece (year, January), in the Maghreb (January) and in the Middle East (winter) where the decrease is significant.

The >10mm monthly precipitation vary non significantly except when they diminish during the months and in the regions where the monthly totals decrease significantly (Gulf of Genoa, Greece and Atlantic region). In a few other cases their influence is compensated by the increase of the <10mm rainfall totals.

The 95th monthly percentiles generally decrease non significantly. The >95th percentile totals increase proportionally non significantly in the Western basin and decrease in the Eastern one. But when the monthly totals decrease significantly, most often the corresponding 95th monthly percentiles and the corresponding ratio of the >95th percentile to the monthly totals (50-60% on average) do the same.

The regional precipitation trends in the Mediterranean Basin during the second half of the 20th century correspond partly with the scenarios for the end of this century. A relatively general signal of non significant decrease of the precipitation totals and a few cases of significant icrease of the heavy precipitation (95th percentiles and >95th percentile totals) have been found.

LT-15

Variability and Risk Assesment of the Atmosphere Precipitation Extremes and River Run-Off Regime in the Republic Of Moldova

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The major problem of present climate perception is related to the increase of its variability. The analysis reveals that the extreme weather conditions are more vulnerable to the changes than the average conditions or even average dispersion. Therefore the changes in the extreme regime should be considered as the principal reflection of the climate changes occurred. It is important that the most of the features of climate extremes formation conform to the common viewpoint on global warming consequences. Particularly the increase in the rate of precipitation is occurred in the Northern Hemisphere regions that correspondingly contributes to run-off and evaporation boost.

In view of this the article seeks for summarizing and classification of the data on precipitation and run-off extremes that favours adverse weather conditions and climate on the territory of the Republic of Moldova situated in the South-Eastern Europe. The peculiarities of evolution of extreme precipitation stochastic structure are considered along with possibilities of rules application on stochastic process to describe their timeline for regional conditions of Moldova. It is revealed that variability of precipitation extremes and river run-off regime in the region can be fairy determined by Poisson processes. The probabilistic models of statistical interpretation of fluctuation in precipitation extremes are introduced as well as climatic risks of analyzed phenomena under modern climate conditions in Moldova including its potential variability in future are assessed. Also the article provides for assessment of main stochastic features stability of precipitation and run-off extremes dynamics for diverse phases of regional climate evolution that qualitatively differ by the degree of anthropogenic pressure and capacity to use data on target phenomena dynamics for further monitoring.

The outcomes of study prove that the variability of atmospheric precipitation is increasing in the region, but the moisture conditions become more unpredictable. The above brings to rise in frequency of extreme weather phenomena (droughts, floods and etc.). The high vulnerability of economy of the Republic of Moldova (due to agricultural orientation) stimulates growth of social and economic instability.

LT-16

Intra-Annual Variability in Winter Precipitation over North-West India

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The northwestern part of India occupies a vast landmass of about 9,26,607 sq km which roughly lies in the area bounded by 69ºE - 85ºE longitudes and 23ºN - 37°N latitudes of South Asia. The area can boardly be divided into three different geographical regions i.e. northern Himalayas, plains of Ganga and Indus, and Thar deserts. Northwestern parts of India has mainly two rainy seasons, summer and winter, when it receives considerable amount of precipitation. The winter season consists of months December to March. Although, winter season contributes only about 13% of the annual precipitation, the precipitation is very important for Rabi crops, particularly for wheat, as it supplements the crops with irrigation/moisture and maintains low temperature which is very necessary for the development of the crops. Moreover, the precipitation in the form of snow over the hilly regions of north west India helps in maintaining the Glaciers extend which serves as the vast store-house of the water in different seasons for the great rivers which take their birth there. The supply of water through these rivers to Dams and Carnals is used for power generation and irrigation through out the year. Therefore, the season is critically important for the agrarian economy of the country.

The precipitation is mainly associated with the sequence of mid-latitude synoptic systems, which is known in Indian meteorological language as 'western disturbances'. The precipitation has considerable spatial and temporal variability, with maximum precipitation occuring particularly over northern hilly regions, with decreasing influence southwards. The spatially coherent winter precipitation series has been prepared for the largest possible area comparasing nine subdivisions of north-west India which constitute about 28% of the total area of the country, having similar precipitation characteristics and associations with regional/global circulation parameters are merged and their area-weighted means computed for the period 1942-2003. The precipitation series has been statistically analysed to understand its characteristics and variability.

Based on 62 years precipitation data of the region for the winter months of December-March, the detailed climatology has been studied. The seasonal precipitation series is found to be homogeneous, Gaussian (Normal) distributed and free from persistence. Different statistical characteristics of the seasonal and monthly precipitation

of the region have been determined. The seasonal precipitation of the region has mean (`R ) 112 mm and standard deviation (S) 38.2 mm, with a Coefficient of Variation (CV) of 34%. There were 11 dry (Ri / 'R-S) and 11 wet (Ri / `R+S) years during 1942-2003. The intra-annual and intra-sesonal variability analysis shows that the correlation among the different months of the season is weak, but the correlation of different months with the season are strong. The highest precipitation recorded is 187.7mm (i.e., 168% of the normal) in 1954 and lowest 27.7mm (24.7% of the normal) in 1997. The precipitation variability has increased in the recent three decades. The series shows increasing trend from 1969 – 1991 and then decreasing trend from 1992 - 2003.

LT-17

Distribution of Temperature and Precipitation Extremes in Northern Eurasia in the 20th Century

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The daily air temperature and precipitation data obtained at about 150 regular meteorological stations of the former USSR are analyzed from the viewpoint of extreme values and their combinations. For the analysis, the following characteristics of temperature and precipitation extremes are used: - monthly number of days with precipitation sum larger than 30 mm; - the biggest pentad sum of precipitation in each month; - number of days in a month, corresponding to the drought criteria by precipitation and maximum air temperature (not counting its continuous length); - number of days in a month with minimum air temperature below the 10% probability limit; - monthly sum of minimum air temperature below the 10% probability limit; - number of days in a month with decreasing of average daily temperature since the previous day for 7°C and more; The listed characteristics are calculated as average for the reference period of 1951-1980, as well as for the period of contemporary global warming (1989-2001). The periods were chosen according to the variations of average annual air temperature in Russia, which increased by about 1°C, and its rise is statistically significant. The 10% probability limit for minimum air temperature for the reference period was used also for the global warming period. The spatial fields of the extreme characteristics for the mentioned time periods are plotted. Regions with different trends of the characteristics during the contemporary warming are revealed. In general, the winter weather has become less extreme in the end of 20th century. The number of days with extremely strong frosts in winter decreases significantly in a large part of Eurasia. The frequency of the strongest winter precipitation doesn't change so much, except for few regions in Western Siberia and in the Far East. Under the climate warming, the number of summer drought days increases in Western Siberia, in Aral region and in Kazakhstan, and decreases in some parts of Eastern Siberia and Ukraine. The most intensive precipitation in July has become heavier on the Black Sea coast of Caucasus and in the south of Far season increases in some parts of Siberia and near Baltic Sea, but in spite of the warming, decreases in the north and east of European Russia.

LT-18

Effect of Land Cover Change on Annual Rainfall Over South East Asia

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Global Vegetation Cover is strongly related to the climatic conditions. The strong effect of the rainfall has been found in controlling the global vegetation cover and agricultural crop yield. Based on the rainfall forecast the productivity of the crops and also the drought conditions are being monitored on routine basis. Since past several decades efforts have been made to understand the role of tropical forcing in the maintenance of general circulation in the atmosphere. It has been found that the low latitude condensation process and lateral coupling with the higher latitude energy shows as the most important driving force in the tropics. In the present paper, we have studied the variability of rainfall and vegetation in the South East Asian region. The detailed combined analysis using Fourier decomposition, combined EOF (CEOF) and other statistical methods shows dependence of rainfall and vegetation. It has been found that cropland in the South Asian Region controls the variability of rainfall in this region.

LT-19

Comparisons on Seasonal and Annual Variations of O-18 in Precipitation

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The spatial and temporal variations of stable oxygen isotope in precipitation under different time scales are analyzed according to the data from the IAEA/WMO stations with long survey series in the Northern Hemisphere. Temperature effect is mainly distributed in mid-high latitudes under seasonal scale except for Bamako and Addisababa stations. The O-18 ratios/temperature slope displays the positive correlation against altitude for most of the statistical stations. Amount effect appears primarily in the south of 30N and coast areas. The O-18 ratios/precipitation slope is indirectly proportional to precipitation amount. For partial sampling stations in mid-high latitudes where their seasonal distribution of precipitation is contrary to that of temperature, coupled with temperature effect, the amount effect appears synchronistically. Ether the temperature effect or the amount effect under seasonal scale, there are positive correlations of a certain extent between the annual weighted mean O-18 ratios and the annual mean temperature for almost all stations. The correlation between composite O-

18 ratios and temperature on spatial scale is much more marked, compared with that of individual station. There is a good agreement between 10-year moving average temperature curves I and II, with the values of the former all markedly smaller than corresponding ones of the latter, calculated by the monthly mean series group I and the annual mean series group II, respectively. However, two calculated slope O-18 ratios/temperature curves display the distinct difference: the variation amplitude of slope series II is larger than that of slope series I. Both curves had similar ascending trend from 1960's to 1970's, and then, their variations display the anti-phase. Moreover, the analyses show that there is negative correlation between slope series II and temperature series II. However, the status is different for slope series I and temperature series I. Both series have contrary trend from 1960's to 1970's, whereas same trend since 1980's.

LT-20

Influence of North Atlantic Oscillation on Interannual Variations of Hydrothermal Regime in Northern Eurasia: Observations and Modeling

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Based on monthly mean series of the North Atlantic Oscillation index (INAO) and meteorological parameters (air temperature, precipitation) on regular grid, fields of correlation coefficient between these parameters and INAO for each month are plotted for the territory of Northern Eurasia. Also, spatial fields of the temperature and precipitation for certain intervals of INAO are constructed. The climatic fields depend on the index in a complicated nonlinear way. The correlation between meteorological variables and INAO in winter decreases from west to east, but at the same time, with lower linear correlation with INAO in Asia, the temperature anomalies (both positive and negative) reach their maximums there. The fields of precipitation anomalies demonstrate ambiguous dependence from INAO as well, in particular, a non-symmetric change of the anomaly areas when the index changes from positive to negative values. The nonlinear influence of the North Atlantic Oscillation is revealed in river runoff, especially in Europe, integrating the changes in hydrothermal regime. The runoff and INAO time series for each season are studied with spectral analysis. The INAO signal is also evident in thevariability of annual Volga runoff for 1879-1991, and can be seen in quasi-periodicities of 7-7.5 and 12-14 years. Using a simplified model of energy/water exchange at the land surface, its evaluations are carried out for river basins in northern Eurasia for 1825-1996. The model equations are written in deviations from the average regime, so it allows one to study the role of certain anomalies. For the study, it was used with input deviations from the average climatic regime, caused only by temperature and precipitation anomalies connected to the variations of INAO. Successful evaluation of main interdecadal fluctuations of the discharge from several European river basins demonstrates its significant dependence on the North Atlantic Oscillation, while in Asia the influence of this circulation mechanism is weak. According to the modeling results, the runoff from basins in northern and southern Europe is most sensitive to changes of INAO. The central Europe basins are less sensitive to this mechanism.

LT-21

Hydrologic Variability over the Amazon Basin and Its Relationship with ENSO and NAO

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This study investigates the likelihood of linkages between hydrologic variability in the Amazon Basin and the large-scale atmospheric circulation. Time series of monthly discharges of the Amazon River for the period 1903 to 2002 have been used to study the time varing structure of the climate over Amazon Basin, using continuous wavelet transformed. A number of statistical analyses are carried out to illustrate the potential relationships between the river discharge anomalies, and El Niño/Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO) phenomena, since both of then are considered as potential source of natural climatic variability in the Amzon Basin.

Results of the wavelet power spectra of the monthly Amazon discharge anomalies reveal a strong non-stationary behavior and the existence of four dominants quase-periodic oscillations: interannual (2-3 yr, and 4-5 yr), interdecadal (8-10 yr), and quase-bidecadal (17-24 yr) scales at different periods of the data record. The oscillation at 2-3 yr scale is in broad agreement with previously proposed associations between the Amazon discharge anomalies and the ENSO, and 4-5 yr period appears to be related to the ENSO phenomenon as well. The interdecadal oscillation seems to be related to the NAO phenomenon. The cross-correlation analysis between the Amazon discharge anomalies and SOI and NAO index shows that the SOI and NAO lead Amazon discharge by 7-9 months and by 2 months, respectively. Further it is explored the relationship between the Amazon discharge anomalies and the SOI and NAO signal using the PDF analysis and the cross-wavelet transform technique.

This study provides a framework in order to conduct a more detailed analysis of the climate variability over the Amazon basin, and its linkages with the large-scale atmospheric circulation.

LT-22

Spectral Patterns of Streamflow and Climatic Series in South America

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We have tried to obtain relations between climatic variables structures with the streamflow in the south zone of Southamerica. We establish the theorical spectral structure of the streamflow series; as a general process the series seem to adjust at a

first order markovian model. We could see important periods around 25, 11, 9, 6, 3.5 and 2.3 years. We develop a methodology for the classification in homogeneous zones of streamflow and specific climatic variables. We establish inferences about the existence of teleconnections between climatic variables and streamflows also drought and wet periods are study and the low frequency are represented by simple models.

LT-23

Seasonal Precipitation Reconstruction in the Middle and Lower Reaches of the Yellow River for the Last 300 Years

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Based on snow and rainfall records derived from the archives in the Qing Dynasty (1736-1911AD), the agro-meteorological and meteorological observation data, according to soil physics model of rainfall infiltration and the surface water balance equation, the seasonal precipitation of 17 stations over the Middle and Lower Reaches of the Yellow River were reconstructed quantificationally during the period of 1736-1910, and the regional and four sub-regional (including Hebei, Jinnan, Weihe and Shandong) seasonal precipitation series for the last 300 years were reconstructed. The result shows that there exists 2-3 wetter and drier periods in the four sub-regions, and the precipitation series indicate wetter period in the 18-19th century, as well as drier period in the 20th century. The Mann-Kendall rank statistical test detected the climate abrupt change in around 1915 over the Middle and Lower Reaches of the Yellow River. At the three periods of 1791-1805, 1816-1830 and 1886-1990, the precipitation is above than the long-term mean obviously, but at the two periods of 1916-1945 and 1981-2000, the precipitation is lower significantly. Otherwise, the Spectral analysis indicates that there are three cycles of 22~25 years, 3.9 years and 2.7 years over the whole region.

LT-24

Shoreline Change Variation, Part of Central Tamilnadu Coast, India

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Today, some estimates suggest that up to 40 percent of the earth's human population lives an or near the coast, more than 50 percent of population are now thought to lives within 60kms of the coastline, the 75 percent of world's population lives within 100 km of the ocean. The present study included the major shore line changes of the particualr

region, part of east coast of Tamilnadu, India .The Indian east coast have enarmous natural resources and addition to that, sever wave action to be variation is encounted. The study normally deal by the thorough field orientation and with satellite imagery (IRS IC LISS III) and SOI ,also used for finding the change variation of particular coast in the past 75 years. The coast have more erosional activities and also findout the reason and period of the high wave erosion.Finally integrated through Geographical Information System(GIS).

LT-25

Wave Climate Variability in the Mediterranean Sea

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This study analyzes the variability of the monthly SWH fields in the Mediterranean Sea. The wind fields of the ERA-40 re-analysis are used for driving the WAM model for the period 1958-2001. It is shown that, though results underestimate the actual SWH field, the computed patterns are a reliable representation of its real space-time variability. The annual cycle presents two main seasons: winter and summer, characterized by the Mistral and Etesian wind forcings, respectively. Spring and Fall are transitional periods between these two regimes, during which a southeasterly component (Libeccio and Sirocco) becomes important. The intensity of these regimes shows large interannual and interdecadal variability, with a statistically significant decreasing trend of wave height during winter. The winter variability of wave fields appears associated with two patterns: one with center of action above continental Europe and another with a dipole between Eastern Atlantic and Eastern Mediterranean. This implies that regional regimes are more important than hemispheric scale patterns for the variability of the average wave field.

LT-26

Climate Change in Lithuania

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As in other countries, also Lithuanian climate faces changeability challenges under influence of global climatic impacts as well as local geographical factors. The most general properties of Lithuanian climate are determined by geographical location of its territory. Lithuania lies in the northern part of the moderate climatic zone. Annually, our territory receives about 3600 MJ/m2 of solar energy. The second global factor is the prevailing westerly air flow. Lithuanian territory, as the whole European region, lies in the sphere of influence of the Atlantic and its westerly air flow, with the air temperature, precipitation and runoff patterns, sea level and other parameters being largely determined by the North Atlantic Oscillation (NAO). The dynamics of NAO indices reflects the long-term (annual, monthly, winter-time) fluctuation of the air temperature

over Lithuanian territory. The high air temperature is mostly predetermined by the positive phase of NAO and the low one by its negative phase. There exist seasonal differences of the links between the NAO and surface pressure and precipitation in Lithuania. In summer and autumn, during the positive NAO phase, the amount of precipitation is low; in winter (December – March) – high. The opposite situation occurs when the NAO phase is negative. The NAO predetermines the hydrothermal regime; during the positive NAO phase the hydrothermal index rises, and during the negative NAO phase it falls.

The winter cold anomalies in Lithuania during the positive NAO phase (blocking of westerly flow) are formed by atmospheric circulation in the Atlantic – European sector, characteristic for the negative NAO phase; in other cases the circulation over the North Atlantic remains zonal, whereas a blocking anticyclone develops over Europe. There occur favorable conditions for invasions of cold Arctic or continental air masses into the Baltic region, with Siberian, Scandinavian and North Sea anticyclones predetermining the weather in Lithuania.

Though Lithuania is not large, it is overpassed by quite a variety of air masses. There are averagely 211 days with cyclonic and 144 days with anticyclonic type of circulation processes annually. Besides the Atlantic and the Baltic Sea from one side, Lithuania is also influenced by the huge Eurasian continent. Therefore, the Lithuanian climate includes both maritime and continental patterns modified by local (orographic, etc) factors.

LT-27

Climatological Estimation of Extremely Warm and Dry Summer in 2003 over Croatia

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The summer 2003 has been the warmest during instrumental observations period at Zagreb Croatian capital. Average summer temperature was about 5°C above 1961-1990 mean. This is exceptionally high anomaly for a such long period (i.e. three month period). Similar conclusion to above presented is worth for the seasonal average minimum and maximum temperature. Thus, we could conclude that both daily and nighty periods have been extremely warm, resulting to an extremely high average summer temperature in 2003. However, it is noticed that absolute summer temperature maximum (of 36.7°C) in 2003, has not reached absolute maximum at Zagreb ever observed. Its value is 40.3°C observed 1950, which was also rather warm. At the same time, a trend of "warming" in last about ten years can be observed. Whether this warming is caused by a global climate warming it is difficult to say, although some studies indicate a chaotic nature of the atmosphere, what means that the Earth atmosphere could sensible on light external signals like that caused by an increasing green-house gasses in the atmosphere.

Climate Variability Impact on Road Condition and Crime Rate in the Coastal City of Nigeria

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Every rainy season is not the best of time for the vehicle owners in Lagos metropolis, because of presence of potholes on the roads. This deplorable state of the roads causes a lot of traffic congestion, which gives the armed robbery operations a new boost. Though, robbery is not new in Lagos State, but rainy seasons seemed to have provided more incentives for the robbers to unleash mayhem on the innocent citizens and take away their vehicles and personal properties unwillingly. With these antecedents, this study tries to investigate the relative climatic variations over Lagos. Also examined are the effects of weather on the rate of stolen of vehicles, the rate of its recovery and condition of the city's infrastructure e.g. roads. Also estimated is the rate of resources wastage (vehicles not recovered) attributable to the activities of these miscreants in the society.41 years rainfall data over Lagos was used. Also used is 7 years data on vehicle theft and recovery from the state police command headquarters. The methodologies used were the time series and variability analyses. Results showed that there are climatic variations which appeared as fluctuations of wet and dry years in every 2-3 years. Most of these variations are not unconnected with the inadvertent weather modification associated with the urbanization in the state. This often results in intense rainfalls of short duration, which leads to soil splashing, lost of soil and road deterioration. Further result showed a seasonal variation of vehicles stolen in the city, indicating that both weather and climate affects not only the road conditions, but also the crime rate. Weather has both positive and negative effects on the activities of the hoodlums. Sometimes when rainfall increases, it enhances their activities and more vehicles are stolen, and vice-versa, especially between the month of May and September. In contrast to this however, it is also observed that between October and January, which are less wet and festivity periods, inverse relationship existed between the rainfall magnitude and rate of stolen of vehicles. This study also revealed that these robbers employ different modes of operation for different seasons, but due to inertia, they have the tendency of continuing with a particular method, even when the prevailing weather condition has changed. Furthermore, results showed that weathers also influences the rate of recovery of stolen vehicles by the police. The peak of vehicle recovery occurred during the dry season indicating that the police may be under equipped to cope with the high rate of stolen of vehicles during the peak of rainy season. Resources wastage (stolen vehicles not recovered per year) attributable to the activities of the hoodlums in the state are in the range of 32-66.5%; with 1998 being the highest, followed by 1999.

Some Results of the Investigation of Climate Variability in Georgia

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To investigate climate variability mean values of air temperature, extremely high and low temperature occurrences, absolute maximum and minimum values of annual and monthly temperatures are used, based on the primary observed data. Considered time period is 1930-2002. Extremely high and low precipitation events are analyzed relied on mean monthly precipitation data, for the same time period. 10% of top and bottom values of ranged time series were taken, as criteria of extremes. Two thresholds (low and high) for each parameter are revealed and each occasion of exceeding thresholds are fixed. Mean values, extremely high and low maximum and minimum temperature and precipitation events recurrence is investigated for annual occasions, as well as for monthly ones. The time period is divided into two sub periods: previous - 1930-1960 and following - 1960-2002. Analyzes are carried out for each period separately.

On each station curves of distribution of mean values, occurrence of high and low maximum temperatures and precipitation, annual and summarized monthly values are constructed for each sub period. Picture of change of mean annual temperature is very complicated. In the most territory of East Georgia the increase of the temperature has been determined in the range of 0.1-0.7 0C. The opposite picture is revealed in West Georgia, namely the values of decrease of mean temperatures vary in the range of 0.1-0.5 0C. The increasing velocities are revealed from previous to following period that is proved by corresponding trends.

Analysis of material of East Georgia allowed to assume that mean maximum value increased on 1,70C from previous to following time period, threshold value increased on 10C and the occurrence insignificantly decreased. Threshold of low maximum temperatures increased on 0,80C, the occurrence of low maximum temperatures is reduced in both sub-periods. High minimum temperatures occurrence is reduced from previous to following period, mean minimum temperature increased on 1.50C, threshold – on 2.40C, low minimum temperatures threshold increased on 2.5 0C, but the recurrence in following period increased.

In West Georgia mean maximum temperature reduced by 0,4 0C, threshold – by 0,20C and its occurrence also decreased from previous to following time period. Low temperatures threshold increased by 0,70C and its occurrence increased, as well. Intensity and recurrence of high maximum temperatures reduced in West Georgia.

In West Georgia mean minimum temperature increased with almost 20C from previous to following time period and high and low threshold - with 2,30C and 2,10C accordingly and behavior of the recurrences of the high and low extreme minimum temperatures are the same. In previous sub period they increased and in following one have invariable trend.

According to analyzed graphs of the recurrence of the extreme precipitation it's possible to conclude that in East Georgia occurrence of extremely high annual precipitation decreased in following period, recurrence of extremely low annual

precipitation has tendency of increasing in both time periods. Changes of summarized occurrence of anomaly high monthly precipitation sums have more complex character, than annual ones. Occurrence of extremely high and low precipitation variations clearly is revealed on monthly scale that is not expressed on annual scale.

In West Georgia for both sub periods, occurrence of extremely high sums of monthly precipitation is differently characterized, namely occurrence of anomalous high sums of monthly precipitation have tendency of decreasing in previous sub period and clearly expressed tendency of increasing in following one.

LT-30

About Climate Variability in Armenia

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Climate change on the territory of Armenia is caused by summary effect of both global change and internal anthropogenic micro-climate changes. Verisimilar assessment of climate change make possible to develop scenarios, which could be used to estimate vulnerability and sensitivity of the concrete influenced object. The development of optimum adaptation measures depends on the precision of the scenarios.

Naturally it is possible to use climate models for solving problem of the estimation regional change of climate, which forms under the influence of large-scale atmospheric processes. However, limited territories, such as Armenia, fall in the under-grid area of the integration grid. Therefore along with the large-scale problems it is necessary to solve regional non-linear tasks for assessment of climate change. Solution of these problems will make possible to elaborate measures to reduce negative consequences, caused by climate change.

Based on generally accepted experimental-statistical methods, the changes of air temperature have been estimated both for separate stations and for whole the territory of Armenia. The trend results for fixed period vary within the limits –10C to 10C, and in general in the territory for recent 70 years the temperature has increased by 0.40C. However, depending on the length of data series, these values essentially change. So the forecast, made by linear extrapolation, have to be continuously adjusted.

For such an arrangement of the task we suggest to investigate not only the deviations of the temperature from norms, but also to estimate the deviations from an rigidly-fixed system, which will in future filter local macro-climate influences. Given approach makes possible to estimate climate change on the territories, where there are not observation data.

We tried to estimate in a simple way variability and predictability of the temperature, using large-scale (Toulouse, Moscow, Zahedan) and mezzo-scale (Athens, Rostov, Ankara) temperature systems.

Using monthly temperatures of these stations for the period 1955-1995 the missing values of temperature for many meteorological stations of Armenia have been restored.

Comparison of fact and calculated values shows that in first approximation this approach has some advantages comparing with the usual extrapolation method of

climate changes assessment. In the same time the empiric-statistical method is elaborated, which allow to estimate air temperature change in the territory of Armenia in dependence of global temperature change.

Using the same data series a method of annual, seasonal and monthly prediction of air temperature in Armenia is developed on the base of recurrent equation using Markov complex chain. The results of calculations show, that the forecast error decreases if we consider monthly temperature in connection with observation on other stations of concrete region.

This method has been developed on the basis of the monthly average temperatures of Yerevan for the period 1935-2000, and has been tested on data of 1991-2000. Results of calculations have shown, that for this ten years the maximal error of monthly temperature prediction makes 25%.

LT-31

Can Meteorology Help to Justify the Agony of Recurrent Droughts in Ethiopia?

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Recurrent droughts have significantly impacted on the socio-economy of Ethiopia. More noticeably, these droughts and the associated famine catastrophes inflict the worst agonies to many Ethiopians. However, the introduction over the last decade of seasonal climate forecasts based on various parameters has provided the basis for taking advantage of climate variability, rather than passively accepting the risks it generates. In this aspect, the National Meteorological Services Agency (NMSA) of Ethiopia has played a major role in mitigating the occurrence of recent droughts. Little had been done, however, in averting and mitigating the drought of 1984 and subsequent food crises that have perpetuated in the country. The author has, therefore, examined both interannual and interseasonal variability of Kiremt (June-September) rains in general and the 1984 Kiremt rains in particular and then compared them with regional and global oceanic/atmospheric forcing phenomena.

The result of this study has shown that there is a significant relationship between the extent of droughts and regional circulation fields and Sea Surface Temperatures (SSTs). In this regard, attempts are made to show the importance of pre-seasonal climate forecast, which is based on the trends of precursor indicators in the process of providing skilful and timely early warnings to minimize the risks associated with droughts. More emphasis is given, however, to examine the climatic causes for previous droughts and then assimilate their meteorological implications in the country.

LT-32

Global and Regional Climate Changes and Variability: Evidence of Climate Change in West Africa and Nigeria

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This paper discusses the known and suspected causes of global and regional climate change and reviewed available evidence of climate change in West Africa in general and Nigeria in particular. The analysis shows the essential features of West African atmosphere. The Subtropical High Pressure System of both hemispheres, the Tropical Easterly Jet (TEJ), the African Easterly Jet (AEJ), the African Easterly Waves, the Monsoon Systems, the Intertropical Discontinuity (ITD) Surface, the Hadley and Walker Circulation Systems, the Desert and Ocean Influences; all contribute in different ways to produce the kind of weather and climate experienced in West Africa. It was found that although weather pattern discernible on satellite imageries are the result of the interactions between these systems, these features are not well defined. Also the structure, characteristics, and primary functions of each of these various features in producing the observed weather over the West African region are still unclear and how these systems interact to produce rainfall of different intensities is still not quite known. The analysis however shows clearly that extensive bush burning and massive removal of forests along the West African coast has led to some discernible changes in the major components of the circulation systems over the years and influenced the observed climatic variability.

As the moist air from the Atlantic Ocean moves inland, the land areas experience different weather zones. A latitude-time diagram of Nigeria was generated and this shows the average surface position of the ITD as a function of latitude and time of the year. Zone A is dry and always under the influence of the Sahara air. Zone B is characterised by very little or moderate development of clouds. Zone C is a zone of vigorous convection and flooding frequently results from stationary and migratory convective cloud clusters. Zone D is characterised by layered clouds. The long duration of such precipitation events often leads to flooding. A special feature of Zone E is layered clouds with little or no rain and relatively lower temperatures. Thunderstorm distribution was also computed from twenty years data on rain days from meteorological stations in Nigeria and this was related to precipitation processes in the country.

The paper further investigated the basis for active participation of Nigeria in the evaluation of man-made causes of climate change and provided some benchmark landuse information on Nigeria, required for improving the reliability of climate change predictive models for West Africa.

LT-33

The Nigerian Coastal Climate in a Changing Global Climate

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Within the domain of Historical record there have been several occurrences of damages caused to both the aquatic lives, social economic and also the human lives. So, because of the damage normally caused by these phenomena, it is therefore necessary to look into a way of predicting the coastal changes. In view of this, standard anomalies are computed in form of a graph from the tables of necessary climatic

variables such as the maximum, minimum, and air temperature to give adequate processes by which the Nigerian Coastal areas are changing.

In computing my result and analysis, I found average means of maximum, minimum and air temperature for each of the stations, I also make some mathematical equation of finding the standard deviation to give an accurate changes in the coastal areas. When plotted the graph, a trend is also given to each graph to give quick recognition of a slightest change.

My results show that for the past 4 (four) decades (1961-2002) it could be seen that the maximum, minimum, air temperatures have gradually increased from my result and analysis I have found a way of predicting the changes in the Nigeria coastal area and also to give adequate warning to the coastal agriculturist in the type of drainage system to use in combating the flooding due. In the same time I have a way of predicting the marine lives in the coastal.

LT-34

Trends and Variation in Monthly Rainfall and Temperature in Suriname

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As Suriname lies within the equatorial trough zone, climate is mainly influenced by the movement and intensity of the Inter-tropical Convergence Zone and the El Nino Southern Oscillation. Scientist predict that global climate change will directly effect the hydrological cycle such as rainfall and temperature, and extreme events such as a El Nino and La Nina. The aim of this study is to analyze historical changes in monthly rainfall and temperature and to predict future changes, with respect to climate change (doubling of carbon dioxide (CO2) by 2100) and variability. Linear extrapolation and five Global Circulations Models (GCMs) (HadCM2, ECHAM4, GFDL-TR, CSIRO2-EQ, CCSR-NIES) will be used. Results of GCMs have showed that under global climate change by 2100, the monthly rainfall is predicted to change with -82 to 66 mm during January and August, and -36 to 47 mm during September and November. The monthly temperature is predicted to increase with 1.3 to 4.3°C by 2100. El Nino events have showed that along the coastal zone and in the center of Suriname, most months (>50%) during the year are drier than normal (88 to 316 mm), while in the west part of Suriname, most months (>50%) are wetter than normal (110 to 220 mm). La Nina events have showed that over entire Suriname, most of the months are wetter than normal (19 to 122 mm), with respect to the minimum rainfall. It can be concluded that the changes in rainfall due to El Nino and La Nina events may have significant impacts on the design, planning and management of water resources systems in Suriname and should therefore be incorporated in future water resources planning.

LT-35

Trends in the South American Border of the South Atlantic High

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The annual pattern of the sea level pressure (SLP) in the western border of the South Atlantic high between 25°S and 45°S has shifted southward since 1950. This trend was found, both in the NCEP reanalysis and in the South American coastal synoptic data.

This annual shift was related to a change in the annual SLP cycle. To describe this annual cycle in a synthetic form, principal component (PC) analysis in T mode was applied to the correlation matrix of seasonal SLP means. The domain of this analysis was between 25°S - 45°S and 65°W - 45°W including southeastern South America. In this region, mean SLP is characterized by the meridional gradient corresponding to the west flow in the south, the southwester border of the South Atlantic high in the east and the Chaco low in the northwest.

In winter, the field corresponding to the west flow spans northward of its mean annual position, while in summer the South Atlantic high intensifies and moves southward. The first two PC patterns represent the winter and the summer fields, and jointly explain 90 % of the variance Their loading factors have a growing trend in the summer mode contribution to the total variance at the expense of the winter mode contribution, which is consistent with the observed southward shift of the regional SLP field.

GCM experiments available in the IPCC web page were checked against NCEP reanalysis, and four of them, namely those from HADCM3, GFDL-R30, ECHAM4/OPYC3 and CSIRO-Mk2, simulate correctly the observed SLP climatology. The same PC technique was applied to the SLP of these experiments finding PC patterns, similar to those found with the NCEP reanalysis. Their respective loading factors also present similar trends, indicating that they not only capture the basic features of the observed annual cycle, but also its trend. Since in these experiments, greenhouse gasses (GHG) and aerosol concentrations increases with time, their SLP annual cycle change could be attributed to them.

Optimal detection in the multi-model average indicate that the observed regional changes can be attributed with high probability to the GCM experiments forcing, namely, the increasing GHG and aerosol concentrations. Further evidence of the attribution of these observed changes comes out from the 2000/2099 outputs of the four GCM experiments (SRES A2 scenarios) because the observed trend continues in the future climate scenarios reducing the uncertainty due to other sources of variability.

LT-36

High-Resolution Ice Cores Provide a Multi-Century Perspective on 20th Century Climate Changes and "Global Warming"

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Ice cores provide unique histories of the Earth's climate and environment ranging from changes in the atmosphere's chemistry and temperature to global-scale volcanism. Annually dated ice core records from Greenland show little stable isotopic enrichment over the last 50 years during which the globally averaged surface temperatures have warmed nearly 0.6 C. The cores indicate a modest warming since the 1920s that is stronger in southern half of Greenland. Just prior to the shift to warmer mean temperatures there is a widespread, strong but brief (1917 to 1920) cold event that may be Arctic wide. The stable isotopic record from the Windy Dome ice field (Franz Josef Land) also contains this abrupt event, but in the Russian Arctic the subsequent warming is much larger than that over Greenland. A statistical examination of the annual accumulation and isotopic records suggest that the influence of the North Atlantic Oscillation (NAO) varies spatially and temporally across Greenland.

The stable isotopic histories from these high Arctic ice cores are integrated with comparable records from the tropics and subtropics and the high southern latitudes to provide an ice core-derived global perspective for the 20th century warming. The high polar plateau in East Antarctica has not experienced this recent warming while the Antarctic Peninsula region has experienced one of the strongest warming trends in the meteorological records of the last 50 years. An ice core from the Dyer Plateau, atop the spine of the Antarctic Peninsula, has clearly recorded this sustained warming by stable isotopic enrichment and an increase in accumulation.

The most consistent and arguably the most compelling evidence for warming on the last 20th century comes from the high mountain ice fields in the tropics and subtropics. Not only are many of these ice caps and glaciers melting at an alarming rate, but they have preserved proxy records many centuries and in some cases for many millennia. These ice core histories provide a temporal perspective that highlights the unprecedented character of the warming in the second half of the 20th century when it is viewed in the context of the last one to two thousand years.

LT-37

Signatures of Variations in the General Circulation in Polar Isotope Records

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The stable isotopic content of ice from glacial cores provides information of climate change. While much is known of the processes that govern the final concentration of stable water isotopes in polar snow, numerous ambiguities exist as to how isotopic records capture the signature of general circulation. Climate reconstruction from ice core measurement has usually been undertaken with empirically based associations between the isotopic depletion and the climate parameter of interest, often temperature. While great effort is made to justify those relationships in a broad sense, new modeling and observational studies have begun to explore the richness of the ice

core records so that reconstruction may go beyond simple estimation of past temperature.

Results from an atmospheric general circulation model fitted with water isotope tracers show clear associations between circulation characteristics at mid-latitudes and polar isotopic conditions. Eddy activity in the mid-latitudes facilitates efficient heat transport to the poles by inducing poleward mass transport. Isotopic fractionation during condensation associated with poleward moisture transport gives rise to an eventual polar isotopic signal. Variation in the eddy activity modifies the mean meridional mass transport of the hemisphere, which is related to variation in the location of the westerly jets and storm tracks. This circulation is reflected in the isotopic state due to corresponding changes to the condensation regime. Model experiments reveal that isotopic signal can be considered a balance between depletion during poleward advection aloft and enrichment by turbulent mixing of locally evaporated water. These processes are related to both the meridional temperature gradient and the vertical stratification, which are ultimately constrained by the global energy and momentum budgets. Variations in the equator-to-pole temperature gradient, imposed in the model at the ocean surface, changes the strength of the eddy induced circulation allowing advected water masses to experience different transport and condensation histories. In contrast, the aspects circulation regime pertinent to the isotopic signal changes relatively little in response to tropical ocean temperature anomalies. As such only limited change is seen in the isotopic state of polar snow, and yields implications for the hope of detecting robust tropical signal in polar ice. Findings do not contradict the simplistic interpretation of isotopes as a temperature record, however they demonstrate that more substantive statements about the circulation regimes of the past can be made from isotopic records once they are combined with knowledge of appropriate geophysical constraints.

LT-38

Diatom-Rich Sediments from Palmer Deep, Antarctica: An Annually Laminated Record through the Last Deglaciation

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The Antarctic ice sheet is recognised as a central player in the global ocean and atmosphere system and the Antarctic Peninsula is one of the most dynamic regions of the continent. Here, ecological and cryospheric systems respond rapidly to climate fluctuations. Climatic warming of the peninsula over recent decades has been exemplified by the collapse of several ice sheets in the region.

Palmer Deep is a series of three fault-bounded basins situated on the inner continental shelf on the western side of the Antarctic Peninsula, approximately 20 km south of Anvers Island (~64° 55'S, 64°25'W). This natural sediment trap is currently

located beneath a region characterised by high seasonal primary productivity of diatoms. During the last deglaciation (~12,000-13,000 yrs BP) a three metre thick, laminated diatom ooze was preserved in Basin I of Palmer Deep, directly overlying the glaciomarine diamict (ODP Site 1098A), hence deposition occurred during a globally recognised period of rapid climate change.

Laminated to thinly bedded orange-brown diatom ooze (dominated by hyalochaete Chaetoceros spp. resting spores) alternates with blue-grey diatom-bearing terrigenous sediments in the deglacial sedimentary sequence. Highly polished thin sections prepared from the Palmer Deep deglacial laminated sediment interval have been analysed using SEM backscattered electron imagery (BSEI). The high sedimentation rate allows an extremely high resolution investigation of sediment fabrics and diatom assemblage changes on an annual and seasonal timescale.

Seasonal depositional events in diatom assemblages have been identified and can be summarised as follows: (1) Chaetoceros spp. dominate the early spring sedimentation associated with stratified surface waters and a freshwater cap promoting exceptionally high primary productivity; (2) a more typical, open ocean Antarctic assemblage of diatoms (e.g. Thalassiosira antarctica, Corethron criophilum and Coscinodiscus bouvet) characterise summer sedimentation, associated with increased terrigenous input, and related to ice-free, more oceanic, lower nutrient conditions following the total melt of seasonal sea ice. Occasionally spring laminae are overprinted with a nearly monospecific assemblage of Corethron criophilum and the top of some summer laminae have increased concentrations of Thalassiosira antarctica. The implications of large occurrences of these two poorly understood diatom taxa will be discussed within the seasonal context of post-glacial Palmer Deep.

Recent sediment cores recovered from East Antarctic Margin sites reveal that a very similar sediment facies was deposited in similar geomorphological settings during the same deglacial period. This time of greatly increased seasonal productivity is therefore likely to have been circum-Antarctic in extent.

LT-39

Nonlinear Paleoclimatology: Reconstructions in West Antarctica

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Proxy histories from ice cores, tree rings, and other indicators are required to extend understanding of climate change to the period before instrumental records. Available observational and instrumental records are too limited spatially and temporally to fully characterize natural variability, particularly in the polar regions. A suite of highly adaptive, nonlinear tools based on artificial neural networks (ANNs) provides improved knowledge of West Antarctic climate and paleoclimate, and can be applied to many other regions and proxy types.

Available histories of West Antarctic surface conditions away from coastal stations are primarily from automatic weather stations (AWS), but are short and discontinuous owing to logistical difficulties. Feed-forward ANNs (FF-ANNs) and free-atmosphere reanalysis data from the European Centre for Medium-Range Weather

Forecasting (ECMWF ERA-15) have been used to extend and fill the AWS temperature and pressure data for the period 1979-1993, producing a more-consistent and more-accurate climate history than was previously available. Six West Antarctic AWS sites from the Ross Ice Shelf (Lettau, Elaine, Marilyn, Ferrell) and from elevation on the ice sheet (Siple Station, Byrd) are included in this data set.

To better understand the West Antarctic free-atmosphere, a major influence on the proxy records, ANN-based self-organizing maps (SOMs) were used to objectively extract without supervision the generalized patterns or archetypes from the multidimensional, nonlinear, noisy ERA-15 data sets. This classification groups years with similar patterns and also identifies transitional states not in the input data. Anomalous years such as the warm conditions of 1980 and 1988 are evident in surface conditions and are linked to large-scale free-atmosphere features including shifts in the position and strength of the Amundsen Sea Low.

The clear linkage between surface conditions and SOM "archetype" states allows reconstructions of local and large-scale conditions from both direct (e.g., AWS) and proxy (e.g., ice-core) data. FF-ANNs were trained to predict SOM states from high-resolution records of accumulation rate and ice-core chemistry. Within the ERA-15 time span (1979-1993), the predictions show skill, and for older times (1954-1978) different combinations of proxy indicators produce similar predictions. Greater skill appears likely if additional ice-core data and longer reanalysis records were available.

LT-40

Atmospheric Methane Emission and Degradation of Permafrost in the Amerasian Arctic

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The knowledge of the global carbon budget is a task at the forefront of natural sciences, because of strong imbalance in the carbon balance causes the greenhouse warming that can be increased drastically in the nearest future. The present greenhouse warming might appear not only in a mean temperature rise, but also in an increase of general atmospheric circulation, especially in the frequency of cyclones over the inland Arctic that should influence on the river run-off, hydrological and biogeochemical regimes in the adjacent shelf. Therefore, a positive feedback loop could operate between emission of CH4 and CO2 from northern terrestrial ecosystems and disturbed subsea permafrost , and changes in the atmospheric circulation and the land hydrology-shelf environment.

Because CO2 and CH4 interhemispheric gradients and amplitudes show that the northern environment is a major contributor to the Northern Hemisphere CO2 and CH4 maximum and seasonal variations, the role of terrestrial ecosystems, land surface hydrology, and the arctic seas as sources and sinks of these greenhouse gases must be evaluated. The role of Arctic lakes as sources and sinks of these greenhouse gases

should be investigated first. The presumable relationship between trace gases emission and permafrost degradation needs to be directly addressed.

In this report we present the data concerning with observed and possible emission of methane from the Siberian and Alaskan northern lakes and sub-sea permafrost. Modern methane/permafrost data can be used to understand better the atmospheric methane changes in past and future.

Lt-41

On the Non-Locality of the Atmospheric Response and Polar Amplification of the Global Warming

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Significant polar amplification was obtained in 2xCO2 runs in a simple model of the climate system with no ice-albedo feedback (Alexeev 2003, A03). Surface budget sensitivity operator (SBSO), which represents a quasi-stationary response of the surface budget to fixed SST perturbations was introduced (A03). A remarkable property of the operator – the least stable mode resembles the polar amplification pattern. In the present paper we analyze the polar amplification pattern obtained in A03. Given the importance of sea ice for the polar region, the obtained significant polar amplification pattern in the system with no sea ice seems to be a rather unexpected result. This suggests that there are other feedbacks affecting the polar amplification besides those associated with the ice albedo. Among obvious candidates could be feedbacks involving interaction of the atmospheric dynamics with the surface heat budget.

What is the polar amplification? Mathematically it can be roughly described as a combination of a constant plus first symmetric about the equator and zonally symmetric spherical harmonics. It was found in A03, that by using only three such lower order spherical harmonics one can effectively capture the pattern of the polar amplification obtained in the AGCM coupled to an oceanic upper mixed layer.

Two explanations for the polar amplification are offered - one mathematical, in terms of formal properties of SBSO and another in terms of the physics behind this operator and the composition of the total surface forcing.

Alexeev V.A. 2003. Sensitivity to CO2 doubling of an atmospheric GCM coupled to an oceanic mixed layer: Linear analysis. Clim.Dyn., 20, 775-787.

LT-42

A Multiproxy Analysis of El Niño Southern Oscillation (ENSO) Variability.

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The late Twentieth Century is recognised as containing a number of both extreme and prolonged El Niño Southern Oscillation (ENSO) episodes; with the two most intense events (1982 and 1997) and, the longest event (1990-95) of the instrumental record experienced in this period. Despite the demonstrated significance of ENSO to biotic, physical and economic processes, our ability to predict ENSO behaviour is limited due to the relatively short length of the instrumental period (~150 years). This research addresses some of the key uncertainties associated with the nature and long-term history of the ENSO phenomenon.

Indices of ENSO were assessed for their ability to adequately characterise both oceanic and atmospheric components of the phenomenon's contemporary behaviour. Pre-instrumental ENSO event evolution was then examined using a multiproxy network of high-resolution proxy-climatic records responding to different aspects of the ENSO phenomenon. The amplitude, frequency and duration of ENSO episodes and associated teleconnection patterns were investigated allowing large scale patterns of variability operating within the climate system over seasonal-century time scales to be evaluated.

Also presented are ~ 500 years of results from a near-continuous 4,000-year dendrochronological sequence from New Zealand, a region recognised by several international programmes including CLIVAR, PAGES and ARTS, as being an area of significant research priority. Recent research has demonstrated a significant relationship between growth of kauri (Agathis australis) and the Southern Oscillation Index (SOI). Modern kauri chronologies have been updated to better characterise this relationship. This has allowed the assessment of late C20th ENSO variability against a multi-centennial record. The sequence represents the longest tree-ring record of past ENSO variability available from the Western Pacific, and potentially the world. This long-term ENSO reconstruction from the currently "data sparse" Southern Hemisphere will allow, for the first time, the response from a southern mid-latitudes location to be incorporated into global climate reconstructions.

Resolving uncertainties surrounding past ENSO behaviour would not only represent a significant advance in the understanding of the global climate system, but would generate significant innovation in the prediction of ENSO. This has relevance to the development of appropriate mitigation strategies and the minimisation of potential impacts commonly associated with ENSO episodes.

LT-43

Climatological Context for Large-Scale Coral Bleaching Observed since 1979

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Coral bleaching is a pan-tropical phenomenon with serious ecological and economical impacts that has become increasingly frequent since 1979. Despite the extensive scientific research and increased public awareness of coral bleaching, it is not known if large-scale coral bleaching occurred prior to the recent observational record. This study uses three 132-year historical SST data sets, ERSST, HadISST1, and GISST 2.3b to identify persistent warm periods during the past 132 years. The results of this study show that while coral bleaching and anomalously warm SSTs have occurred over much of the world in recent decades, conditions favorable for thermally induced coral bleaching may have existed in the Caribbean and Northwest Hawaiian Islands prior to 1979.

LT-44

The Climate Variation during the Last 2000 Years in Eastern China

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China possesses numerous ancient writings which can provide rich materials for understanding climate change for the past time. Based on the flood and drought recorded in Chinese historical documents, the yearly drought/flood grade for 48 stations which located in eastern China (east of 105E, 25-40N) are assessed since 137BC. Because of the uneven spatial and temporal distribution of the drought/flood grade data, the dry/wet series for the last 1500 years in eastern China (including 3 sub-regions, i.e. the middle and lower reaches of the Yellow River, the Jiang-Huai Area, the south area of the Yangtze River) were adopted here to analyze the long-term precipitation change. Plus the winter half-year (October to April) temperature series, at 10-30 years' resolution, for the last 2000 years derived from the phenological cold/warm events in this area from previous reconstruction, the climatic variation during the last 2000 years in eastern China were revealed. In which, the precipitation variation in eastern China for the last 1500 years can be summarized as fellows: In the period of 500s-880s, it is relative dry with obvious dry/wet oscillation at the scale of several decades. From 890s to 980s, it is relative wet. The climate turns into dry since 990s, and persists for about 250 years till to 1230s with couple of short-scale fluctuations. In the period of 1240s-1420s, the climate turn to wet again. From 1430s to 1530s, it's dry again. Although the most severe dry for the last 1500-year happen in the period of 1630s-1640s, the climate in the period of 1540s-1910s is still in wet. Since 1920s, the climate turns to dry except for a relative wet period from the late of 1940s to 1960s. In additional, there exist a contrary change trend between the middle and lower reaches of the Yellow River and the south area of the Yangtze River. And the temperature variation during the last 2000 years would be divided into four warm epochs (0s-200s, 570s-770s, 930s-1310s and 1920s-1990s, which their average temperature are higher that of 1950s-1970s) and three cold epochs (210s-560s, 780s-920s, 1320s-1910s, which their average temperature are lower than

that of 1950s-1970s). While every each warm/cold epoch also includes obvious warm or cold stages on decadal scale, especially in the warm epoch during 930s-1310s, the duration for the cold stage in 1110s-1190s is over 90 years.

LT-45

A New Global Temperature Reconstruction for the Last Millenium.

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Several climate reconstructions have been made for the last millenium, with different and sometimes controversial results which mainly put forward the natural variability of global temperature (GT) (Esper, 2002, Broecker, 2001). These reconstructions, that extend the instrumental record backwards in time, are based on several proxy records of climate change contained mainly in naturally occurring archives, such as tree-rings, ice core layers, boreholes and glacial advances. Also, these GT reconstructions employ different statistical techniques in the calibration and backward extrapolations of climate records. This diversity of information and methods, in which climate reconstructions are recently based, produce a wealth of alternatives, but also possible significant differences in the results. It therefore appears necessary to test another alternatives for climate reconstruction which could give us more elements to evaluate and compare all of them, and this is what this contribution intends to do by presenting a new GT record for the last millenium recently reconstructed (Sánchez-Sesma, 2003a). This presentation will mainly consider the basis and results of a novel contribution to global climate reconstructions. This new reconstruction employs a single proxy record and a simple calibration procedure which emphasize low frequency climate oscillations. A comparison with previous GT reconstructions obtained by Mann et al, (1999), Esper et al, 2002, and Mann et al, (2003) has been made (Sánchez-Sesma, 2003b). This comparison has detected coincidences and also differences between the GT reconstructed records, confirming the occurrences of two well documented climate extremes known as the Medieval Warm Period (MWP) and the Little Ice Age (LIA), and giving elements to asses the natural contribution to the recent global warming.

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LT-46

Paleo-Environmental/Paleoclimatic Records from Sediment Cores in Bay of Bengal

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Bay of Bengal receives nearly 1015 g of sediments annually discharged through seven major rivers, the largest of them being the Ganga and Brahmaputra river system (G-B). A major amount of this suspended load is due to the physical weathering of Himalaya. While, relatively smaller amounts are discharged through Godavari, Mahanadi, Krishna, and Cauvery from the Indian subcontinent and through Irravaddy from Burma. Sediment composition of the Bay appears to be mainly governed by three processes viz. detrital, biogenic and diagenetic, with detrital being the dominant in this region. Two gravity cores 4032 (location ~13.36oN; 88.9oE, water depth - 3011m) from the central Bay of Bengal and 4040 (6.03oN; 89.94oE, water depth – 2788m) on the top of the 90oE ridge in the Bay of Bengal were collected and sampled at 1-2 cm intervals. Planktonic foraminifera separated from select depths were dated at the NSF Arizona AMS facility and 14C ages calibrated to calendar years using CALIB 4.1.

The sedimentation rate for 4032 varied from 1.5 to 18.6 cm/ka with a faster rate at ~20 Ka. The periods ~20 ka BP and 35-40 ka BP yielded the highest rates. It should be mentioned here that in the southeastern Arabian sea also experienced enhanced sedimentation rates by a factor of 3-4 high during LGM compared to other periods during the past ~30 ka. On the other hand, the sedimentation rate remained constant at 1.7cm/ka in 4040 at the top of 90oE ridge. The CaCO3 content varied from ~7 to ~53% in core 4032, whereas it is high and fairly constant (60-71%) in 4040. The Corg and N in core 4032 varied from 0.2-1.5% and 0.05-0.11% respectively with C/N (wt. ratio) ranging from ~2-20. In the case of 4032, it is seen that during the high deposition periods, the Corg was high, 1- 1.5% with a high C/N ratio of >15 indicating enhanced terrestrial input. In general similar pattern of CaCO3 which is indicative of productivity, is seen in the two cores with a decrease between ~40ka to LGM (~20 ka) and an increase till about the present. This pattern, with some local short scale variability is common to the region south of 14oN in western Bay of Bengal and the eastern Arabian Sea. Some other isotopic measurements are underway, which would provide information towards changes in detrital input in this region and the implications of climate change. A comprehensive account of the study will be presented.

LT-47

Understanding the Climate Signal in High Resolution Stalagmite Archives

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It is widely understood that stalagmites can contain annual resolution information, for example due to the presence of annual laminae, as well as the fact that they can also contain a climate signal. Explanation of how a surface climate signal is transmitted to a stalagmite via the soil and groundwater system, together with appropriate statistical analysis of the stalagmite climate series, is crucial if the new generation of high resolution stalagmite archives are to be utilised by the climate modelling community.

Each stalagmite will contain a different (or indeed no) climate signal. Stalagmites from near the surface are more likely to have less mixing with old water that has been stored in the ground water and a larger amount of “event” water. These samples will have a more rapid response to surface climate but also a non-linear response due to the highly fractured nature of shallow limestone bedrock. With increasing depth (decreasing hydrological accessibility) there will be a greater mixing of old (stored) water and event water, such that at deep cave sites stalagmites are unlikely to preserve any climate signal but instead the average of decades or centuries of ground water evolution. In between these two depths, there should be an optimum zone where stalagmites will contain both annual laminae, providing optimal chronological control, and also a climate signal. Laminae have been observed in stalagmites that have a modeled mixture of 80% old water, 20% event water: therefore the climate signal is filtered and high frequency climate information may be lost.

We present the results of simple numerical modeling and statistical analysis of an annual stalagmite climate proxy (annual growth rate) with respect to instrumental surface climate records and HadCM3 validation series. The observed stalagmite growth rate series over the instrumental period can be explained by a simple mixing model (smoothing function) of old and event waters, where faster growth occurs after dry and/or warm years. Statistical treatment of stalagmite, instrumental and model output confirms that the limestone aquifer in our example act as a filter that accentuates low frequency climate variations.

LT-48

The 1950's Abrupt Climate Change in East Asia

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An abrupt summer temperature change occurred in East Asia during early 1950’s. The temperature anomaly in southern Japan, Taiwan, and Vietnam increased dramatically by about 0.5°during the period from late 1940’s to early 1950’s. Simultaneously, the temperature anomalies in China, most part of Japan, and Korea dropped significantly by about the same magnitude. A wavelet analysis revealed that this abrupt change was a combination of a long-term trend and an interdecadal fluctuation with a period around 25 years. This temperature anomaly pattern was accompanied by the increased sea surface temperature (SST) anomaly in the East Asian marginal seas and the western

North Pacific between 30°N and 50°N, and the decreased SST anomalies in the Philippine Sea. The sea level pressure (SLP) anomalies were found to increase in the area of increasing SST and to decrease between the positive and negative SST anomalies. The abrupt temperature increase in southern Japan and Taiwan is the direct consequence of the enhancing and westward-extending subtropical anticyclonic ridge and the weakening monsoon trough. The SLP in the Asian continent was generally rising during the period. This phenomenon indicated the weakening of the Asian summer monsoon. Decreasing continental temperature and weakening continental low are consistent with each other. This abrupt change pattern lagged the abrupt change in the Pacific Decadal Oscillation (PDO) by about 3-5 years. The possible effect of the PDO on the pattern is being investigated. Similar abrupt changes were also observed in the Pacific, the Atlantic, North and South America, Australia, and Africa, etc. It is likely that this abrupt change is a global feature instead of a regional feature confined in East Asia.

LT-49

Abrupt Tropical Climate Change: Past and Present

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Unprecedented global changes in the 20th Century have heightened awareness of human vulnerability to potential climate changes in the next millennium. Half of the Earth's surface area lies between 30o N and 30o S and supports 70 percent of the population. Thus, variations in the occurrence and intensity of humanity. The studies described here were undertaken as part of a long-term program to acquire the global-scale, high resolution climatic and environmental history essential to better understand the linkages between the low and high latitudes.

The recent contribution of records extracted from ice caps in Asia, South America and Africa have provided a better understanding of the tropical climate regime and the global significance of the rapid climate change. The first results from ice cores recovered in 2002 from Bona-Churchill (Alaska and in 2003 from the Quelccaya and Coropuna ice

caps long-term perspective essential to distinguish natural variation in the climate system from the anthropogenic influences superimposed during the last century. These new tropical records raise additional questions about our understanding of the role of the tropics in global climate change. Moreover, they documenting major climate disruptions such as a drought ~4,000 years ago that was coincident with the "First Dark Age" and a wide spread abrupt cold-wet period 5,200 years ago. Evidence of the latter event, the largest isotopic depletion in the 10,700 year long Kilimanjaro ice core, also appears in other African records (i.e., Soreq Cave), in the tropical South America Andes and the Alps where rapidly advancing ice fields buried datable organic material (plants, Otzi) their path, and in the very narrow growth rings in the Irish and English oak chronologies. The potential role of the sun as the cause of this 5.2 ka event will be examined. The most consistent and arguably the most compelling evidence for the 20th Century warming is the widespread retreat of tropical mountain glaciers. Unfortunately, as these ice fields melt, they no longer preserve viable paleoclimatic records.

LT-50

Ocean Influences on Regional Moisture Regimes of the African Humid Period

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During the African Humid Period (AHP), which occurred at a time of higher summertime insolation in the Northern Hemisphere between 14.5 and 5.5 ka BP, large lakes were maintained in Sahelian Africa and the southern boundary of the Sahara was about 7º farther north. In addition, there is evidence from one location in Ghana of somewhat wetter conditions along the central Guinean coast region. Sea surface temperature constructions suggest that there were cooler ocean surfaces in the Gulf of Guinea on the equator and in the eastern Atlantic directly off Africa's west coast.

A regional climate model is used to investigate the consistency between the reconstructions of land conditions and sea surface temperatures (SSTs). A regional model, as compared with a global model, is advantageous for this study for several reasons. One reason is that focusing on the simulation of northern Africa allows the choice of model parameterizations that best reproduce the summertime African monsoon climate, without having to consider the overall global simulation. Another advantage is the capability of higher resolution in a regional model, which provides a significant improvement in the simulation compared with global models, and also brings the model closer to the regional, or even local, resolution expressed in geological reconstructions. Finally, the regional model is able to resolve mesoscale sea surface temperature anomalies, such as those associated with increased coastal upwelling thought to have occurred during the AHP.

Model results show that the simulation of Sahelian and Saharan precipitation regimes of the AHP, as well as the simulation along the Guinean coast, are in better agreement with the land-based geological evidence when the reconstructed cold eastern Atlantic sea surface temperatures are present. These results, therefore, support the idea that there was increased upwelling in the eastern Atlantic during the AHP, in conjunction with concurrent changes in the ocean and atmospheric circulation of the North Atlantic. In

contrast, the AHP simulation degrades when Gulf of Guinean surface waters are cold. This suggests than the cold SSTs of the Gulf of Guinea may have been confined to the winter season, or that the latitudinal space scale of the cooling was too small to influence the monsoon, as would be the case if the cold SSTs were associated with enhanced equatorial upwelling.

LT-51

ENSO Dynamics During the Last Glacial Maximum

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We present a numerical eigenmode analysis of an intermediate ENSO model which is driven by present-day observed background conditions as well as by simulated background conditions for the Last Glacial Maximum (LGM) about 21,000 years ago. The LGM simulation was performed with the NCAR Climate system Model (CSM1.4). Our analysis clearly shows that the leading present-day unstable recharge mode changes its stability as well as its frequency during LGM conditions. Simulated LGM background conditions were favorable to support large-amplitude self-sustained interannual ENSO variations in the tropical Pacific. Our analysis indicates that off-equatorial climate conditions as well as a shoaling of the thermocline play a crucial role in amplifying the LGM ENSO mode.

LT-52

The South Atlantic Circulation at Last Glacial Maximum

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The study of past climates plays an essential role in understanding the natural variability of climate system as well as testing model sensitivity for extreme climates. The heat and mass redistribution is one of the most important aspects of the climate system, given that changes in oceanic heat transport have been suggested as causes of abrupt climatic change. Understanding mechanisms of the oceanic heat and mass transport in the past are critical with to understanding the present state of climate and the possibilities of future changes. In this study we examine results from the paleoclimate version of the NCAR coupled climate system model (CCSM 1.4) for the Last Glacial Maximum (LGM) in order to understand changes related to the South Atlantic (SA) circulation. It is shown that results for the mass transport for the Present Day (PD) simulation are in very good agreement with existing observational estimates. Results

also show that the exchange between the SA and the other oceans at the Antarctic Circumpolar Current (ACC), increases linearly with the intensification of the zonal wind stress at the LGM. The ACC mass transport increase is closely related to a more intense Agulhas retroflection. At subsurface levels two distinct patterns are identified: i) intensification of the mass transport for the LGM in the southern SA (35ºS to 25ºS); ii) intensification of the mass transport for the PD in the northern SA (25ºS to the equator). At intermediate layers, there is an intensification of the subtropical gyre and a northward shift of the South Equatorial Current (SEC) bifurcation for the LGM. This leads to the intensification of the southward mass transport by the Brazil Current (BC) and the associated BC recirculation cell in the southern basin for the LGM. For the PD the southward position of the SEC bifurcation leads to an increase in the northward transport and also induces a strengthening of the western recirculation of the central SEC in the northern basin. At deeper layers, a shallower and weaker North Atlantic Deep Water (NADW) circulation at the LGM permits a higher intrusion of the Antarctic Bottom Water (AABW). This intrusion plus the increase of the Indian Water inflow is responsible for the northward transport intensification in the southern basin. For the PD, a stronger NADW leads to the intensification of the southward transport in the northern basin.

LT-53

South American Rainfall during the Last Glacial Maximum

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Geological reconstructions have not provided a consistent picture of South America rainfall during the Last Glacial Maximum (LGM). A better understanding of regional hydrodynamic connections, e.g., the high Andes and Amazon basin, would help us better understand the consistency of the paleoclimatic reconstructions from various regions. To contribute to this effort, a regional, mesoscale climate model with horizontal resolution of 60 km is used to better resolve the climatically important Andes topography, and to provide model output that approaches the resolution scale of the geological evidence.

Three circulation features are of central importance for the maintenance of rainfall over tropical and sub-tropical South America, namely, cross-equatorial flow from the equatorial North Atlantic Ocean into the western and central Amazon, the continental thermal low and it's associated inflow into the South Atlantic Convergence Zone (SACZ). With LGM conditions in the model, the northeasterly cross-equatorial flow and the continental thermal low are slow to develop in the austral spring and weaker in the austral summer than during the present day due to subdued springtime warming and generally cooler surface temperatures in the High Andes. Northwesterly inflow into the SACZ is weaker as a result, and moisture convergence and rainfall decrease over southern Brazil and Paraguay during the summer months. Over the Altiplano of Peru and Bolivia, moisture convergence and rainfall are enhanced both in spring and summer during the LGM due to the weakened inflow, even though the cross-equatorial flow from

the tropical Northern Atlantic is weaker. Over the central Amazon, moisture convergence and rainfall is reduced primarily during the spring due to weaker northeasterly flow from the tropical North Atlantic.

In summary, the model results indicate that during the LGM, the Altiplano was wetter and the Amazon was drier than present day. The primary drying in the Amazon occurs in the spring, when cold tropical Atlantic SSTs cause the monsoon inflow to be drier. The Altiplano is wetter because the summertime thermal low over Paraguay is weakened by cooler surface conditions, allowing moisture from the Amazon to penetrate into the high Andes.

LT-54

Fluctuations in Productivity and Denitrification Intensity along the Southwestern Continental Margin of India during the Late Quaternary

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Two gravity cores from the southwestern continental margin of India were studied for variations in the organic carbon (OC), total nitrogen (TN), calcium carbonate and nitrogen isotope (d15N) records to reconstruct, fluctuations in the productivity and the intensity of denitrification during the late Quaternary. The core off Mangalore exhibits OC values ranging between 0.8 and 2.4%, with TN values of 0.02-0.15% and calcium carbonate concentrations of about 15.8-30.2%. Whereas the core off Thiruvananthapuram exhibits higher OC ranging between 1.4 and 4.4%, with TN values of 0.07-0.43% and calcium carbonate ranging between 37.8 and 53.5%. The cores demonstrate higher concentrations of OC and TN indicating higher productivity during Last Glacial Maximum (LGM) and late Holocene and lower concentrations of OC and TN indicating lower productivity during early Holocene (10-11 ka BP). The d15N in the northern core fluctuates from lighter values of 5.8 and 5.4‰, suggesting reduced denitrification around 22 and 10 ka BP to heavier values of 7.3 and 6.7‰, indicating enhanced denitrification at about 17 and 7 ka BP. However, the d15N fluctuations are less prominent in the southern core exhibiting reduced denitrification around 18 ka BP (5‰) and enhanced denitrification peak about 11 ka BP (6.1‰) and 7 ka BP (6.2‰). Higher primary productivity during LGM might be due to convective winter mixing that resulted in increased nutrient supply and also oxygenating the subsurface waters. This would have suppressed the denitrification intensity. Towards the end of the LGM, the subsurface denitrification was however, intensified presumably due to decrease in oxygen supply from the surface. Reduced primary productivity at about 10-11 ka BP is surprising, as this period is known for intensified SW monsoon. It is likely that the enhanced precipitation fortified near-surface stratification reducing productivity. But the oxygen concentration could have been elevated through an intensified undercurrent reducing denitrification. Denitrification seems to have intensified again once such

conditions relax. No major fluctuation in subsurface oxygen distribution appears to have occurred since then.

LT-55

Holocene Sea Surface Temperature Trends in the Equatorial Pacific Ocean

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We present sea surface temperature (SST) reconstructions from the eastern and western equatorial Pacific Ocean, with sufficient detail to resolve long-term Holocene trends. Two methods are utilized: the unsaturation ratio of alkenones produced primarily by the coccolithophorid Emiliania huxlei; and the magnesium/calcium (Mg/Ca) ratio of fossil foraminifer (Globigerinoides ruber) calcite. Both classes of organisms depend on photosynthetic light for their growth and survival and are therefore confined to the photic zone of the upper ocean. Reconstructed SSTs from eastern and western Pacific sites are compared to assess Holocene trends in the zonal SST gradient. Alkenone SSTs from eastern and western sites indicate general warming of the equatorial Pacific by 0.5º-1.0ºC through the Holocene, but the data coverage is too sparse to resolve changes in the zonal gradient unambiguously. Conversely, foraminifer Mg/Ca data indicate contrasting east-west trends, with a broad SST minimum in the east and a maximum in the west between 9-4 ky BP. During this period (the early-to-middle Holocene) the data suggest a substantial enhancement of the zonal SST gradient by ~2ºC. This interval coincides with diverse evidence for a northward ITCZ displacement over South America and the tropical Atlantic at this time, and suggests a similar response of the marine ITCZ over the Pacific. Specifically, we propose that a northward retreat of the Pacific ITCZ in the mid-Holocene allowed persistent SE trades across the equator, maintaining vigorous upwelling and a stronger zonal gradient. The transition to the late Holocene climatic regime (0-4 ky BP) is consistent with a southward ITCZ displacement, relaxation of the equatorial trades, warming of the equatorial cold tongue, and cooling of the Indonesian warm pool. We further discuss these data in the context of Holocene ENSO evolution, and speculate on possible future perturbations of the ITCZ, equatorial SSTs, and ENSO, in a warming climate.

LT-56

Solar Irradiance Forcing of Centennial Climate Variability during the Holocene

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Centennial climate variability during the Holocene has been simulated in two 10,000 year experiments using the intermediate-complexity ECBilt model. ECBilt contains a dynamic atmosphere, a global 3-D ocean model and a thermodynamic sea-ice model. One experiment uses orbital forcing and solar irradiance forcing, which is based on the Stuiver et al. (1998) residual 14C record spliced into the Lean et al reconstruction. The other experiment uses orbital forcing alone. A timescale analysis shows that the response in atmospheric parameters to the irradiance forcing can be characterised as the direct response of a system with a large thermal inertia. This is evident in parameters like surface air temperature and monsoon precipitation, which show a stronger response for longer timescales. The oceanic response, on the other hand, is strongly modified by internal feedback processes. The solar irradiance forcing excites a (damped) mode of the thermohaline circulation (THC) in the North Atlantic ocean. This results in a significant peak (at timescales 200-250 yr) in the THC spectrum which is absent in the reference run. The THC response diminishes the sea surface temperature response at high latitudes, while it gives rise to a signal in the sea surface salinity. A comparison of the model results with observations shows a number of encouraging similarities.

Lt-57

Holocene Climate Variability along the North Atlantic European Margin: Evidence from Annually Resolved Speleothems

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The forcing mechanisms for sub-millennial scale climate variability are poorly understood and require well-dated, high-resolution paleoclimate records from a range of mid-latitude climatic and geographical settings to complement existing high-latitude ice core data. Speleothems are excellent paleoclimate proxies because precise dating is possible using U/Th techniques and, under favorable conditions of high growth rates, can provide high-resolution datasets. Annually resolved records of temperature and rainfall variability are recoverable.

While heat transport in the North Atlantic Ocean is a key variable in determining mid-latitude climate conditions, high frequency solar variability is increasingly offered as an alternative explanation for millennial-scale Holocene climate change. However, an amplification mechanism for relatively minor variations in solar irradiance (0.1 – 0.2 %) is required. Possible amplification mechanisms are 1) ocean forcing that would result in basin-wide cooling of the North Atlantic or 2) atmospheric forcing that would result in an NAO-type dipole pattern. Alternative amplifiers are testable using Holocene climate proxies by investigating whether evidence of such dipole patterns exists (as predicted by solar-forced GCMs). Enhanced westerlies during a positive phase of the NAO (associated with solar activity maxima) result in wetter and warmer conditions at mid-latitudes and heavier oxygen isotope ratios in precipitation. The models also predict coincident drier conditions in the west and north Mediterranean. Reduced westerlies (more frequent easterlies) during a negative phase of the NAO result in drier and colder conditions at mid-latitudes and lighter oxygen isotope ratios in precipitation. Until now few assessments of amplification mechanisms have been attempted, primarily because although well-dated high-resolution paleotemperature records exist for high-latitude regions (e.g. the Greenland ice cores), there is a paucity of suitable high-resolution data in the mid-latitudes and in the western Mediterranean.

Laser ablation oxygen and carbon isotope profiles from three well-dated speleothems from Crag Cave in southwest Ireland and El Refugio Cave in southern Spain, provide a high-resolution record of centennial-scale climate variability along a latitudinal transect of the North Atlantic during the Holocene. One speleothem from El Refugio Cave that commenced deposition at 5,302 yBP reveals delta 18-O ranging from –3.73 to –9.96 per mil (PDB) and delta 13-C ranging from –3.06 to –10.93 per mil (PDB). These delta 18-O ranges are broader and extend to lighter values than previously published data from Crag Cave (–1.78 to –5.26 per mil PDB). Intervals of delta 14-C excursions will be examined in detail to investigate potential links to solar variability.

LT-58

Ocean Feedback and Climate Mean Season Cycle and Variability during the Mid-Holocene

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The Paleoclimate Modeling Intercomparison Project (PMIP) was initiated in order to coordinate and encourage the systematic study of climate models for key periods in the past (Joussaume and Taylor, 1995; PMIP, 2000). Basic PMIP experiments were designed to test atmospheric general circulation models (AGCMs). However, in order to enhance our knowledge of the climate system, a number of complementary experiments were also performed by individual modelling groups. They explored, for example, the role of land-surface and ocean feedbacks on climate. In particular, several coupled ocean-atmosphere simulations are now available for the mid-Holocene, period chosen to test the response of the climate system to a change in the seasonal contrast of the incoming solar radiation at the top of the atmosphere (insolation). Since coupled ocean-atmosphere models (OAGCMs) have become the basic tool for projection of future climate change (IPCC 2001), it important to evaluate such models under the radically different climate conditions of the past. A working group on coupled ocean-atmosphere simulations has thus emerged within PMIP a few years ago, with the aim of documenting:

- the robust differences between OAGCM and AGCM simulations
- the role of the ocean response in the timing of the changes in the seasonal cycle
- how the simulated climates compare with palaeoenvironmental data

Using results of these coupled simulations, we will show how the response of the ocean to the insolation forcing help to enhance the monsoon season in West Africa. Results will also emphasize the role and the reasons of a late warming of sea surface temperature in the Indian ocean that contributes to enhance the late summer precipitation during the retreat of the Indian and southeast monsoon. Model responses over the north Atlantic are less consistent, and coupled simulation do not improve model-data comparisons results over Europe.

Coupled simulations also allow us to investigate the changes in the interannual variability. All the models produce a reduction of summer interannual variability both in temperature and precipitation within the tropics. A comparison of changes in Enso variability and Sahel precipitation will be shown. It raises several questions about the methods and the definition of climate variability that need to be addressed in order properly assess how coupled simulations represent changes in climate variability. This will be one of the focus of the second phase of PMIP which will be devoted to fully coupled simulations (http://www-lsce.eca.fr/pmip2).

LT-59

High-Resolution Late Holocene Glacier and Climate Reconstructions from Southern Norway

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The maritime plateau glacier Nordre (Nordre = northern) Folgefonna in western Norway has a short (subdecadal) response time. The glacier is therefore well suited for reconstructing high-resolution glacier fluctuations. A high-resolution (average time

resolution of 10 yrs pr sample) glacier-variation curve has been produced for the last 2000 calendar years. The reconstruction is based upon physical sediment parameters in a proglacial lake north of the ice cap. The record of glacier variations has been transferred into an equilibrium-line altitude (ELA) variation curve. Glaciers respond primarily to changes in summer temperature and winter precipitation. Based on a close exponential relationship between winter precipitation and summer temperature at the modern ELA of 10 Norwegian glaciers, it is possible to reconstruct former variations in winter precipitation by combining palaeo-ELAs with an independent proxy for summer temperature changes. By using the exponential relationship between summer temperature and winter precipitation, it is possible to isolate the most significant component leading to past changes in the ELA. As a proxy for summer temperature, a tree-ring width curve (annual data starting AD552) from Trøndelag, is used. A comparison between the tree-ring width curve and overlapping instrumental temperature data suggests that the tree ring width is mainly controlled by summer temperature. The Trøndelag tree-ring record suggests that summer temperatures in western Norway were relatively low between AD600 and 1000. The warmest summers were recorded around AD1100 and 1300. The summers during the early 18th century, when most Scandinavian glaciers advanced significantly during the 'Little Ice Age', were not particularly cold. A period with cool summers in the early 1920s was among the coldest in the entire record. By combining the Trøndelag tree-ring width curve with the Nordre Folgefonna ELA curve, decadal variations in winter precipitation have been reconstructed for the last ~1500 calendar years. At present there is a high correlation between the North Atlantic Oscillation (NAO) index and measured (since the early 1960s) net mass balance on maritime glaciers in western Norway ($r = \sim 0.8$). Therefore, the reconstructed winter precipitation curve from maritime western Norway reflects periods with significantly positive and negative NAO weather modes over the last ~1500 years. The Late Holocene (including the 'Little Ice Age') glacier advances of Nordre Folgefonna are mainly a result of increased winter precipitation and not lower summer temperatures as previously thought.

LT-60

Climate Variability from Estuarine Sediments: A Case Study in Chesapeake Bay

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The sedimentary records of many estuaries and other coastal systems allow the reconstruction of Holocene temperature and precipitation variability unavailable from historical and other proxy records. Estuaries are characterized by high sedimentation rates (0.1 to > 2cm/year), excellent chronology (C-14, Pb-210, Cs-137 dating), and faunal, floral, and geochemical proxies of salinity, temperature, dissolved oxygen, and sedimentation. Chesapeake Bay, the largest estuary in the U.S., located in the Mid-Atlantic region of the eastern U.S. is sensitive to NAO-like climate processes. Integrated studies of several long sediment cores reveal large temperature and precipitation changes over various timescales during the past 10 ka. Pollen assemblages sampled at decadal resolution indicate quasi-cyclic patterns of regional winter temperature and precipitation that appear to correlate with oceanic and ice-core records from the North Atlantic region. Isotopic and trace element records from estuarine foraminifers and ostracodes reveal centennial (150-200 yr) and multi-decadal (30-60 yr) late Holocene (2 ka-present) changes in precipitation and water temperature. Notable events include periods of elevated regional temperatures during the early Medieval Warm Period (~500-1000 AD), two major cool and dry periods during the Little Ice Age (~1500-1900 AD), and anomalous 20th century climate extremes in temperature. In contrast to late Holocene variability, the generally drier early Holocene (7-6 ka) experienced higher frequency and lower amplitude climate patterns. The eastern U.S. record of Holocene climate will be discussed in relation to paleoclimatic patterns from the North Atlantic Ocean region and their possible causes.

LT-61

Modeling Sensitivity of the Ocean Circulation to Freshwater Impacts during Eocene-Oligocene Cooling Climate Trend

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The sensitivity of the past ocean circulation to meltwater impacts may have been different from the present-day. It is important to understand what are these differences and what causes them. One obvious candidate for altering the character of the ocean and climate response to similar to present-day impacts is different land-ocean distribution. Since freshwater impacts in past geologic eras having different basins configurations may have been different from the present-day pattern, the sensitivity of the ocean circulation to sea surface density impacts and climate change could have been different as well.

To address this issue, we use the Eocene-Oligocene geometry and sea surface climatology to address the past ocean sensitivity to freshwater variability. The Eocene epoch is crucial as a transition from the warm Cretaceous ocean to cooler oceans that may have been subject to bi-polar millennial-scale oscillations of the deep ocean circulation caused by freshwater pulses of the developing southern cryosphere. In a series of numerical experiments, sea ice melting and sea water freezing around Antarctica were simulated by superimposing freshwater layers over zonally-averaged sea surface salinity. Eocene sea surface temperature and sea surface salinity are specified based on the paleoclimatic record and modeling. In our simulations, the Eocene ocean circulation is shown to be very sensitive to freshwater impacts in the

Southern Hemisphere. There are also noticeable sea level changes caused by the restructuring of the deep ocean thermal and haline fields linked to the changes in deep ocean circulation.