DP-1

Circulation Changes in NH during the Last 50 Years

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Changes in the NH circulation are studied with the aid of empirical orthogonal functions (EOF). EOF analysis is applied to daily 1000 hPa geopotential height analyses from NCEP for the period 1951-2000. The annual cycle is not removed in computation of the covariance matrix used in the EOF analysis, as is usually done in recent studies dealing with e.g., the Arctic Oscillation (AO). This means that the spatial pattern of the leading EOF (EOF-1) is not the one associated with the AO, but is showing the land-sea contrast. The AO pattern is recovered as the 2nd EOF (EOF-2) and is similar to AO patterns published in several recent studies. The EOF approach used in the present study reproduces some of the well documented features of the AO, but also gives some new information on the circulation changes in NH during the last 50 years.

The time-dependent coefficients of the two leading EOF components show an annual cycle. The daily average (over 50 years) of the EOF-1 coefficient shows a quasi-sinusoidal annual cycle, with negative values in winter and positive in summer. This EOF reflects the winter-time Siberian high and the Eurasian summer low. On the other hand, this EOF also tends to deepen/weaken the Icelandic and Aleutian lows in winter/summer. The annual cycle in the EOF-2 coefficient, the AO index, is less dominant than that in the EOF-1 coefficient, but can anyhow be clearly seen in the 50-year daily averaged time series. The year-to-year differences in the behaviour of the EOF-2 coefficient are very large.

The yearly mean values of the two leading EOF coefficients show a clear trend during the last 50 years. The value of the EOF-1 coefficient has decreased and that of the EOF-2 increased. This suggests that the annual variation in the land-sea pressure contrast has become smaller, and that the polar vortex has intensified, i.e. the positive phase of the AO has become more frequent.

The EOF coefficients for two periods, 1951-1970 and 1981-2000, reveal decadal changes that have taken place. The coefficient of EOF-1 has decreased from 1951-1970 to 1981-2000 in all seasons except winter, most significantly in summer. This indicates that the Eurasian summer low is no longer as deep as it used to be. The change in the EOF-2 coefficient suggests that the polar vortex has lately become more intense during the cold season, but a less significant change is seen in summer and early fall.

DP-2

Deduction of Climate Variability from the Total Ozone Record: 1964-2002

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Analysis of the ozone field in the Northern Hemisphere, using both TOMS and Dobson data, has shown that the total ozone field can be separated into three distinct meteorological regimes. These are defined as (1) the tropical regime - between the equator and the upper troposphere subtropical front (2) the midlatitude regime - between the subtropical and polar fronts, (3) the polar regime - between the polar front and the polar vortex. Within each regime, the daily mean total ozone is relatively constant, with a clearly separate value for each regime. The trends in total ozone for the latitude zone between 25 and 60 N for the period 1979-92 within each regime are all less than -1.6% per decade, much less than the trend of -3.2 % per decade obtained for the whole zone. This apparent discrepancy can only be resolved if, during the period 1979 to 1992, there was a northward movement of the subtropical and polar fronts. The zonal average now includes a larger area of the tropical regime (lower ozone), and a smaller area of the polar regime (higher ozone), leading to a larger negative trend.

A movement of the sub-tropical and polar fronts implies a change in the weather patterns associated with these fronts, i.e. a climate change. Methods have been devised to obtain the relative areas of the tropical, mid-latitude and polar regimes from both the TOMS and Dobson data sets over the period 1964 to 2002. This paper presents an analysis of the movement of the polar and sub-tropical fronts for the period between 1964 and 2002. The movement will be compared with several climate indices.

DP-3

Mechanisms and Predictabilty of Decadal Fluctuations in Atlantic/European Climate (PREDICATE)

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PREDICATE was a three year project funded by the European Union under its Framework 5 programme. The project involved a collaboration between 8 leading European climate research establishments and addressed issues in the understanding and quantification of decadal climate variability and predictability, with a focus on the Atlantic-European region. This poster will present highlight results from the project.

DP-4

Development of a Decadal Climate Prediction System

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The design of a system for climate prediction on the seasonal to decadal timescale will be described. Results from a set of hindcasts using the first version of this prediction system will be presented.

Prediction beyond a few weeks ahead requires the initialisation of both the ocean and atmosphere. The initialisation process involves the assimilation of analyses of

observations into a coupled ocean-atmosphere GCM (HadCM3). Initial states for the period 1979-93 were created by assimilating a time series of ECMWF Re-Analyses into the atmosphere component of the coupled model, while the ocean component simultaneously assimilated a time series of 3-D analyses of temperature and salinity created by optimal interpolation of observations. Hindcasts were produced by integrating HadCM3 from initial states taken from the assimilation integration, and included the effects of external forcing changes arising from anthropogenic, solar and volcanic influences.

Results will be presented from a set of 60 hindcasts, initialised from 1st March, June, September and December in each year from 1979 to 1993. Each hindcast consists of an ensemble of four integrations initialised from consecutive days immediately preceding the forecast period. Forecast skill on the seasonal time scale will be compared against other models and skill on the interannual to decadal time scale, as yet untested using a comprehensive modelling approach, will also be assessed, using a combination of both deterministic and probabilistic-based skill scores. Various sources of predictive skill on different time scales will be identified, together with unpredictable sources of interannual variability.

DP-5

Long-Term Predictability Potential of Coupled AOGCM

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On seasonal timescales ENSO prediction has become feasible in an operational framework in the last years. On decadal to multi-decadal timescales the variability of the oceanic circulation is assumed to provide a potential for climate prediction. To investigate the long-term predictability potential of the coupled atmosphere-ocean general circulation model ECHAM5/MPI-OM a 500-year long control integration and 'perfect model' ensemble experiments are analyzed. The results show that the sea surface temperatures SST) of the North Atlantic, Nordic Seas and Southern Ocean exhibit a predictability potential on multi-decadal timescales. The predictability of surface air temperatures (SAT) is very similar to that of SST. Over land there exists an indication of significant decadal to multi-decadal predictability of SAT, especially at some maritime influenced European regions. The predictability of air temperatures weakens with height, but remains partly significant in the lower troposphere. Other atmospheric variables, such as precipitation or sea level pressure, exhibit a lower predictability potential.

DP-6

Internal Variability, External Forcing and Climate Trends in Multi-Decadal AGCM Ensembles

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An atmospheric general circulation model of intermediate complexity is used to investigate the origin and structure of the climate change in the second half of the 20th century. The variability of the atmospheric flow is considered as a superposition of an internal part, due tointrinsic dynamical variability, and an external part, due to the variations of the sea surface temperature (SST) forcing. The two components are identified by performing a 50 member ensemble of atmospheric simulations with prescribed, observed SSTs in the period 1949-2002. The large number of realizations allows the estimation of statistics of the atmospheric variability with a high confidence level, even on the inter-decadal time-scale.The first part of the analysis performed focuses on interdecadal and interannual variability of 500 hPa geopotential height in the Northern Hemisphere during winter. The model reproduces well the structure of the observed trend, particularly in the Pacific-North Americanregion, and about half of the amplitude of the signal. SST changes associated with the El Nino Southern Oscillation are responsible for about 50 % of the signal of the 500 hPa height trend in the Pacific. The significance of the trend is assessed from the variability displayed by individual ensemble members, and its sensitivity to (explicit) changes in CO_2-related radiative properties is also estimated.In the second part of the analysis, the impact of decadal and interannual SST changes on the summer monsoon circulation in some tropical regions is assessed. Consistent with observational results on decadal trends in dynamical monsoon indices, we find a trend towards a weakened Indian and African summer monsoon circulation in the second half of the 20th century. Experiments in which SST anomalies are suppressed in specific ocean basins are used to assess the relative role of forcing originated in different regions of the tropical oceans.

IDP-7

The International Climate of the Twentieth Century (C20C) Project

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The International Climate of the Twentieth Century (C20C) Project, now a formal project of CLIVAR, involves the use of both ocean-forced atmospheric general circulation models (AGCMs) and observed data to study climate variations and changes over the last 130 years, together with their predictability and mechanisms. There is particular but not exclusive emphasis on the period since 1950. Fourteen institutions participate in the C20C project: the Bureau of Meteorology (BOM; Australia), the Center for Climate Science Research (Japan), the Center for Ocean-Land-Atmosphere Studies (COLA; USA), the Centro de Previsão de Tempos e Estudos Climáticos (CPTEC; Brazil), the Commonwealth Science and Industrial Research Organization (CSIRO;

Australia), the Department of Natural Resources of Queensland (DNR; Australia), the Goddard Space Flight Center (GSFC; USA), the Hadley Centre of the Met Office (UK), the Japan Meteorological Agency (Japan), the Main Geophysical Observatory (MGO; Russia), the National Climate Center (NCC; China), the National Institute of Water and Atmospheric Research (NIWA; New Zealand), Seoul National University (SNU; Korea), and the University of California at Los Angeles (UCLA; USA).

Results will be presented from the Third C20C Workshop to be held in April 2004 at the Abdus Salam International Centre for Theoretical Physics, Trieste, Italy, including progress in numerical simulations, in comparison with observations, of climate variability and trends made with different atmospheric general circulation models (AGCMs). All models are forced with the HadISST sea surface temperature and sea ice extent data set and external natural forcings. Further experiments are also being made with additional anthropogenic forcings.

Under a recommendation from CLIVAR, C20C is considering an expansion of its scope to include coupled ocean-atmosphere GCMs in coordination with the Working Group on Coupled Modeling (WGCM), the Working Group on Seasonal to Interannual Prediction (WGSIP) and the Working Group on Numerical Experimentation (WGNE). Representatives from these groups are being invited to the Third C20C Workshop. Coordination of such coupled and atmospheric model simulations will require an agreed set of external anthropogenic and natural forcings, a consensus on how these should be applied to climate models and strict protocols. This is a difficult activity which would need careful planning. A report on preliminary work in this direction by the Hadley Centre and NIWA will be illustrated. Finally a summary of the next phase of the C20C project and the development of validation data sets will also be presented.

P-8

KNMI-PATCH Project: The Fast and Flexible SPEEDO Coupled Model and Application to Patterns of Climate Change

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Large scale patterns of climate variability, such as the NAO, have a profound impact on regional climates. It is likely that these patterns will change due to antropogenic climate change. Recent studies have shown that decadal changes in extratropical climate patterns are partly driven from the tropics. The PATCH (PATterns of climate CHange) project aims at studying natural variability and antropogenic changes of tropics-extratropics interaction, with emphasis on climate patterns in Europe.

We present a flexible coupled model that has been developed for this project in collaboration with ICTP in Trieste (Molteni ao). The atmospheric component is a T30, 7 layer primitive equation model called Speedy. The model has a simplified physics

package which makes it computational efficient. The oceanic component consists of a hierarchy of models: a slab mixed layer, a slab with Ekman dynamics, a slab with Sverdrup dynamics, a linear shallow water model and the MICOM primitive equation model. A simple land and sea ice model is included. This coupled model has been nicknamed SPEEDO. The modular set up and the computational efficiency makes the model ideally suited for different configurations and sensitivity experiments.

The use of the SPEEDO model is demonstrated in coupled model studies on tropical Atlantic variability and its impact on the extratropics and studies on ENSO and its impact on the extratropics.

P-9

Interdecadal Variability and the Performance of Climate Models

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Assessing the reliability of dynamical AGCM models in reproducing the observed atmospheric circulation given the lower boundary conditions, and thus its ability to predict climate, has been a recurrent concern in seasonal-to-interannual climate prediction. The assessments have been carried out in several ways, including the comparison between the leading modes of variability from the observations and the models' outputs and comparison of the AGCM's skill with the skill of statistical models. In those studies there was frequently concern about the influence of seasonal variation on the models' skill, but no analysis has been carried out about the possible variation of the models' performance throughout the years. Is the long-term variability of the atmosphere and the oceans prone to influence the performance of models, as is the seasonal variability?

In the present study, the seasonal responses of two AGCMs (ECHAM3 and NCEP) to prescribed observed SST are compared to the observed seasonal anomalies (from the Reanalysis NCEP/NCAR) to verify whether the performance is affected by long-term variations.

The analysis is based on the simultaneous correlation between series of three-month mean model responses and reanalysis data, averaged over 20º latitude ˙ 40º longitude regions all over the globe, for the period 1950-1994.

The possible influence of the interdecadal variability on the models' performance is assessed through the computation of the global fields of simultaneous correlation coefficients (CC) between 11-year running series of the reanalysis data and of the models' output. The value considered for each year is a three-month mean of the analyzed parameter. Thus, the seasonal influence on the interdecadal variations can be detected. The variation of the CC is an indication of the interdecadal variation of the models' skill all over the globe. Also to see whether the models reproduce the interdecadal modulation of the ENSO impacts on the atmospheric circulation, global fields of simultaneous correlation are computed between 11-year running series of the SST in the Niño 3 region and streamfunction, zonal and meridional components of the wind at 200 hPa.

A possible connection between interdecadal modes of SST variability and the decadal/interdecadal variations of the models' skill was sought. The Empirical Ortogonal Functions (EOFs) of the global field of running correlations for streamfunction at 200 hPa were computed, and the two first principal components were correlated with the 11-year running mean of SST. This gives an indication about the relationship between the interdecadal variability of the models' skill and the interdecadal variability of SST. The statistical significance of this correlation was assessed by using a Monte Carlo procedure.

The interdecadal variation of the models´ performance is shown to be seasonally dependent. The results show a clear interdecadal modulation of the models´ skill and its relationship with known interdecadal SST modes of variability like those with maximal realization in the North and East Pacific. They raise issues like the need of coupled models for climate simulations, and interdecadal variations of predictability.

DP-10

Global Changes of the Water Cycle Intensity

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In this paper, we compare a number of 50-year general circulation model (GCM) climate simulations from different models forced with observed sea surface temperatures (SST). The anomalies and trends in the cycling rate and hydrologic variables of different GCMs are remarkably similar. The global annual anomalies of precipitation show a statistically significant upward trend related to the upward trend of surface temperature, during the latter half of the twentieth century. While this implies an increase in the hydrologic cycle intensity, a concomitant increase of total precipitable water again leads to a decrease in the calculated global cycling rate. An analysis of the land/sea differences shows that the simulated precipitation over land has a decreasing trend while the oceanic precipitation has an upward trend consistent with previous studies and the available observations. The decreasing continental trend in precipitation is located primarily over tropical land regions, with some other regions, such as North America experiencing an increasing trend. Precipitation trends are diagnosed further using the water tracers to delineate the precipitation that occurs because of continental evaporation, as opposed to oceanic evaporation. These diagnostics show that over global land areas, the recycling of continental moisture is decreasing in time. However, the recycling changes are not spatially uniform so that some regions, most notably over the United States, experience continental recycling of water that increases in time.

DP-11

The Influence of Large Scale Climate Variability on Winter Precipitation Extremes over the North America

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Extremes are important aspects of climate. Changes in the magnitude and frequency of climate extremes will have environmental and socio-economical consequences. Understanding the mechanism of changes in extremes is therefore very important. The North America climate is strongly influenced by large scale climate variability, such as El Nino/Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the North Atlantic Oscillation (NAO). The connections between seasonal precipitation totals over the region and those variabilities are relatively well understood. However, there are not many studies addressing the impacts of those large-scale climate variability on precipitation extremes. This study attempts to identify the statistical relationship between maximum daily precipitation in winter and large scale climate variability represented by ENSO, PDO, and NAO, by conducting extreme value modelling with the ENSO, PDO, and NAO indices being co-variates. It was found that the ENSO, PDO, and NAO indeed have profound impacts on winter extreme precipitation. For example, enhanced extreme precipitation occurs in the Pacific and Atlantic coasts of the North America in the El Nino years.

IDP-12

Mechanisms and Predictability of Long-Term Drought in the U.S. Great Plains

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During the 1930s the United States experienced one of the most devastating droughts of the last century. Results from an ensemble of 100-year simulations with the NASA Seasonal-to-Interannual Prediction Project (NSIPP-1) atmospheric general circulation model (AGCM) forced with observed SSTs show that the model reproduces the basic features of the 1930s drought. In this study we exploit this realism in the model simulation to examine in more detail the role of the SST and soil moisture in the development, and maintenance the 1930s drought. Results will be presented from simulations in which the SST anomalies are confined to the separate ocean basins, as well as from runs in which soil moisture feedback is turn off. We will compare the mechanisms and predictability of the 1930s drought with that of other major Great Plains droughts of the 20th century.

DP-13

Decreasing Reliability and Increasing Synchroneity of Western North American Stream Flow

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Emergent in the last three decades has been a spatially coherent trend in the variance and synchroneity of stream flow across the four major river basins in western North American region–Fraser, Columbia, Sacramento-San Joaquin, and Upper Colorado. This has occurred at a time when freshwater (and energy) supplied by these river basins has been relied upon to sustain the pace of development and growth in the West. The increase in the variance of stream flow has been unprecedented in the 20th century, and has been accompanied by an increased simultaneous incidence of wet and dry years across all four river basins. It is discovered that these changes in stream flow have covarying analogues in the Indo-Pacific ocean temperatures, thus raising important new questions on the detection, attribution, and projection of regional hydrologic change. Joint analysis of observations and climate model simulations explore the role of changing ocean temperatures (and changing statistics of ENSO) in forcing the observed incidence of expansive regional water resources stresses. The observed trends in the variance of stream flow point to uncertain water supplies, that coupled with demographic and socio-economic trends are likely to exacerbate water resources problems into the future.

DP-14

Recent Temperature and Precipitation Variability in Chile

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A review of the temperature and precipitation behavior in Chile was carried out with available data from the National Weather Service (Dirección Meteorológica de Chile) and the Marine Weather Service (Servicio Meteorológico de la Armada). Annual and seasonal time series of weather observations were analyzed using conventional statistics method.

Monthly minimum temperature anomalies showed an overall warming of about 0.3°C – 0. 7°C in most of the stations during the last century, except in Puerto Montt which revealed a slight cooling. The warming is higher during the winter (JJA) than the summer (DJF) season. Similar results were found in the northern tip of the Antarctic Peninsula, although a cooling has been taking place during the last 10-12 years. Analysis of the zero isotherm at Quintero station (32°47'S, 71°33'W, 8 masl) revealed a 150 (250) meters of elevation in winter (summer) during the last 25 years, suggesting an elevation of the snowline in central Chile.

Analysis of the different precipitation regimes show a high interannual and interdecadal variability. An increase of more frequent bellow average winter precipitation in central Chile has been detected mainly during the last 2-3 decades. An overall

precipitation decrease also was found in the southern cone of South America although an increase has been taking place after the mid-80'. In the Antarctic Peninsula, data from 1970 on ward, showed an overall increase of precipitation until around 1990, then a slight negative trend has been revealed by the analysis.

DP-15

Climate Variability during the Last 60 Years for the Sebou Drainage Basin in Morocco

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On a regional scale, some of the most profound impacts of climate change due to increases in greenhouse gases would probably be major changes in the hydrological cycle, in water availability, in agricultural production and in the use of energy. This paper gives a brief overview of studies carried out on climate change and possible impacts on hydrology and water resources in semi-arid region.

The hydroclimatic fluctuations of the Sebou drainage basin (Morocco) during the last 60 years are studied for the main rivers of the Sebou. Hydroclimatic patterns for 1940-1994 period, as determined by annual discharge rates, indicated an alternation of short dry periods and long humid periods (lasting 3 to 9 years). The basin was affected by a long dry period that began in 1980, water resources were not sufficient to meet needs during this period. Moreover, the discharge versus rainfall curve plotted for this period confirms the marked discrepancy. This situation could be explain by the extensive use of surface waters during the dry period and the construction of hydroelectric dams on Sebou River and tributaries. Hydrological measurements at the downstream station in Sebou basin revealed the same annual pattern as noted at all of the gauge stations (mean values). This indicates that the hydrological regime fluctuations encountered upstream could reflect general climatic trends for the whole basin.

DP-16

Trends in the Walker and Hadley Circulations as Expressed in Precipitation Records from Asia and Africa during the Latter Half of the 20th Century

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The geographically dispersed independent observation records in Africa and Asia such as West African summer rainfall, North China summer rainfall and a new climate proxy with a high elevation, the snow accumulation from the Dasuopu ice core in the southern Himalaya, have all experienced decreasing trends during the latter half of the 20th century. In this study, we investigate the existence of a common mechanism that

explains these geographically dispersed trends. In particular, we explore the hypothesis that these trends are related to changes in the Walker and Hadley circulations. The most striking is that the trends that we have identified in the Hadley and Walker circulations have a very similar structure to that obtained when these overturning circulations are regressed against the time series from West Africa, North China and the Himalaya. This indicates that the trends existed in the Walker and Hadley circulations are consistent with the observed changes in these precipitation records. This trend in the tropical overturning circulation, with considerable regional variability, has been confirmed not only by these geographically dispersed independent observation records but also by the satellite observations in the data sparse Pacific and tropical regions of Americas. We conclude that the trends in the Hadley and Walker circulations are contributing to the regional climate change in the tropical and subtropical regions such as West Africa, North China and South America. Our results also contribute to the understanding of the tropical climate changes over the past 50 years, especially the weakening relationship between monsoon-ENSO as well as strengthening one between Sahel rainfall-ENSO.

DP-17

The Antarctic Peninsula – A "Hotspot" for Decadal-to-Century-Scale Climatic Variability

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The Antarctic Peninsula and neighbouring islands possess the longest (50-100 years) unbroken instrumental climate records from high southern latitudes. Analysis of these records reveals that the climate of the Peninsula exhibits extreme variability on interannual to interdecadal timescales.

Unlike the rest of continental Antarctica, where temperature trends have been quite small since records began in the late 1950s, annual average near-surface temperatures on the west coast of the Antarctic Peninsula have warmed by about 3 degC since 1950. This is one of the largest regional warmings observed on Earth over this period. Although the warming has been most marked in the winter season, smaller but still significant warming has taken place during the summer, leading to increased melt rates and the rapid collapse of a number of ice shelves. Examination of radiosonde records shows that the large winter warming is confined to the lowest part of the troposphere, suggesting that atmosphere-ice-ocean interactions are acting to enhance climatic variability during this season. Limited records from the east coast of the Peninsula show a summer season warming of comparable magnitude to that observed in the west but no enhancement of this warming during the winter.

Interannual to interdecadal variations in Antarctic Peninsula climate show clear associations with the leading modes of variability of the Southern Hemisphere atmosphere – the Southern Annular Mode (SAM) and the Pacific South American (PSA) teleconnection pattern. Atmospheric reanalyses are of questionable reliability in high southern latitudes before about 1970 so it is not possible to determine whether secular

change in these modes is responsible for regional climate change in the Peninsula. Even if large-scale circulation changes are the ultimate driver of Peninsula climate change, its regional expression is likely to be strongly controlled by local interactions between atmosphere, ocean and sea ice.

The Hadley Centre global atmosphere/ocean model HadCM3, forced with the observed 20th century increase in greenhouse gas concentrations does not accurately reproduce the observed patterns of climate variability in the Antarctic Peninsula. However, there are also serious errors in the model's representation of the mean climate of the Peninsula region. Until the model's performance is improved it will not be possible to use model results to attribute the observed changes in the Peninsula to natural or anthropogenic causes.

DP-18

The Relationship Between Tropics and Southern Extratropics During the 1980s

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The sea level pressure (SLP) over the Southern Ocean is characterized by a circumpolar trough around the Antarctic continent. The circumpolar trough has a half-year variation in its position and intensity, with a maxima during austral fall and spring. This Semi-Annual Oscillation (SAO) has changed since 1979 (van Loon et al., 1993; Hurrell and van Loon, 1994; Meehl et al., 1998) with a decrease of the second harmonic in SLP at mid and high southern latitudes. The position of the circumpolar trough shows enhanced variability at a period of 4 years, suggesting an influence of El-Niño Southern Oscillation (ENSO). In order to clarify the linkage between the tropics and the southern extratropics during the last 3 decades, we investigated the relationship between the zonal mean SLP at 65S and th\e global SLP and sea surface temperature (SST). For this analysis we used the SLP data set from National Center for Environmental Prediction (NCEP) - National Center for Atmospheric Research (NCAR) Reanalysis and the SST data set from National Oceanic and Atmospheric Research Administration (NOAA). Correlation maps reveal the Southern Annular Mode (SAM) pattern, consistent ith Thompson and Wallace (2000), and a zonal wave number 3 structure in the Southern Ocean SST. Positive correlations are also seen for SST over the equatorial Pacific and the SLP over the Indian Ocean and Asian continent, suggesting an influence of ENSO as well as the Indian Monsoon on SLP variations at 65S. Interestingly, correlation analysis applied to different periods showed that the 1980s has a completely different ehavior in relation to 1970s and 1990s. The two later decades display similar behaviour in many global features. It suggests a different linkage between SLP at southern high latitudes and the atmospheric circulation in the tropics during the 80s decade. Further analysis is underway to investigate the mechanisms responsible for this different behavior between the tropics and the southern extratropics during the 80s.

DP-19

South Pacific Origin of the Decadal ENSO-like Variation as Simulated by a Coupled GCM

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The hypothesis of the South Pacific origin of the decadal (7—35 years) ENSO-like variation is investigated based on 220-year outputs of the ECHAM4 (T106L19)/OPA/OASIS coupled GCM. Associated with the decadal warm (cold) SST anomalies in the tropical Pacific, an nomalous cyclonic (anticyclonic) circulation, which is tilted in a southeast-northwest direction, appears in the South Pacific. This results in anomalous upward (downward) Ekman pumping along the northeastern edge of the anomalous circulation and, hence, shallowing (deepening) the oceanic thermocline there. Such an external source of heat content tends to slowly discharge/recharge the tropical ocean on the decadal timescale. The above result is consistent with the observational study of Luo and Yamagata (2001). Besides, the model reproduces amazingly a high lagged-correlation between the global land surface temperature and the decadal Nino3 SST. Despite the model biases, this suggests a potential prediction skill of the global warming based on the ENSO-like decadal variation.

DP-20

Changes in Ocean Circulation Linked to Pacific Decadal Variability

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The Pacific Decadal Oscillation (PDO) is a fluctuation of the coupled ocean-atmosphere system having El Nino and La Nina-like patterns of spatial variability but time scales of a decade and longer. Understanding the mechanisms responsible for the PDO is a high priority because of its effects on Pacific marine ecosystems and fisheries, CO2 outgassing in the tropical Pacific, and the climate of North America. The PDO is also linked to decadal modulations in the amplitude and frequency of El Nino and La Nina events. In a recent publication we presented evidence to suggest a slowdown in the shallow meridional overturning circulation in the topical and subtropical Pacific from the PDO related "regime shift" of mid-1970s to the late 1990s. This slowdown was

associated with a reduction in equatorial upwelling rates and a rise equatorial sea surface temperatures over the same period of time. In this presentation we analyze surface wind and hydrographic data over the past five years to show that the shallow meridional overturning circulation in the tropical Pacific has accelerated since 1998. Implications of these results for understanding the PDO and the decadal modulation of El Nino and La Nina will be discussed.

DP-21

Long-Term Surface Temperature Variability in 20th Century at Middle and Low Latitudes

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Through applying EOF analysis on the ENSO removed global surface temperature datasets at middle and low latitudes, we decompos the surface temperature variability into physically meaningful modes. The dominant mode manifests the global warming, and the second mode represents the ENSO like decadal oscillation in the Pacific region.

Our analysis shows that two primary periods of global surface temperature increase in the last century, one is before middle of 1940s and the other is after middle of 1970s. There are more warming over the continents than over the oceans. These are consistent with previous researches.

The ENSO like decadal oscillation is a basin wide phenomenon in the Pacific Ocean. It has two well-known phase-shifts in the twentieth century, around 1944 and 1976, respectively. Our research indicates a third phase-shift happened around 1998, which has been hinted by the ecosystem and circulation changes in the Pacific Ocean.

By isolating the global warming and the ENSO like decadal oscillation into different EOF modes, it becomes easier to measure the weights of different climate variations on the regional climate changes. At the same time, our results provide hints of the mechanisms behind the long-term climate variability in the last century.

DP-22

ENSO and Tropical Pacific Decadal Variability in SODA-POP

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A new reanalysis using SODA (Simple Ocean Data Assimilation) and POP (Parallel Ocean Program) is used to explore the mechanisms responsible for low frequency (decadal) variability of ENSO in the Pacific Ocean. The ocean model resolution is 0.4 degrees of longitude, 0.28 degrees of latitude and has 40 vertical levels. The model was run from 1948 - 2003 using the NCEP reanalysis winds that have been bias-adjusted, GPCP precipitation, and bulk formulae for the surface heat flux. Temperature and Salinity are assimilated using the SODA implementation of the

optimum interpolation routines. The analysis is used to explore the pathways of temperature anomalies throughout the Pacific Ocean basin on decadal timescales. In particular we explore the subduction of temperature anomalies in the tropical south Pacific. Earlier work has shown that the Southern Hemisphere is an important region for the formation and propagation of anomalies on decadal timescales.

DP-23

Causes of Two Patterns of the Decadal Climate Variability over the North Pacific Ocean

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The upper 400m ocean heat content anomaly (OHCA) from JEDAC dataset (1955-2001) shows a fluctuation with a period of about 20 years in the Pacific Ocean. Wavelet analysis reveals that 20 year period of Pacific is significant in three bands, which are located in the Kuroshio extension, from 10N to 20N and south to the 5S, respectively. Kuroshio extension index and tropical index are respectively defined by averaging the first two regions. Spatial distributions of linear regression coefficients between these two indexes and Pacific OHCA respectively express two decadal variation patterns: Kuroshio extension pattern and tropical pattern. The result from complex empirical orthogonal function analysis well elucidates these two patterns. The first leading mode, accounting for 41%, shows that the tropical pattern originates from10N to 15N, 120E to dateline. It spreads to the east, and then near the dateline turns to the north-east. From COADS wind data, decadal variation of zonal wind is the leading factor to this pattern. 22-year period variation of solar radiation absorbed by the tropical ocean-atmosphere system is probably the ultimate determinant factor. The variation of Kuroshio extension pattern lags behind the tropical pattern, which resulted from the exchange between tropical and subtropical Pacific. The second mode (27%) shows an evident south-westward signal of baroclinic Rossby wave, whose period is about 10 years. This signal disappears in the north-east Pacific, and not returns to the tropic.

DP-24

On the Recent Shift in the State of the North Pacific

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The Pacific Decadal Oscillation (PDO) is the leading pattern of North Pacific climate variability. It underwent a major transition from a persistently negative to positive state in 1976/77; considerable recent discussion has centered on whether a return to a

negative phase in the PDO occurred during the winter of 1998/99. The spatial patterns in sea level pressure anomaly (SLPA) and sea surface temperature anomaly (SSTA) during the winters of 1999-2002 for the North Pacific actually bear little resemblance to those of the PDO. In essence, the southeastern (northern) portion of the North Pacific was subject to atmospheric forcing characteristic of that before (after) the regime shift of 1976/77. Recent major changes in the ecosystems off the west coast of the United States (increased productivity and the return of sub-Arctic species) and continued conditions similar to those after the 1976/77 shift in the Gulf of Alaska and Bering Sea are consistent with these SLPA and SSTA patterns. The lack of a consistent sense to the PDO since 1998 can be attributed, at least in part, to the concurrent lack of a systematic sense to El Nino/Southern Oscillation (ENSO). The PDO was significantly positive during the winter of 2003; it is uncertain whether this is just a temporary condition due to the moderate El Nino of 2003 or the beginning of a sustained positive PDO state. Our results illustrate that a single indicator such as the PDO is incomplete in characterizing the climate variability of the North Pacific.

PDP-25

Decadal Variations Of The Tropical Pacific Pycnocline Water Mass Properties

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Some theoretical and modeling studies suggest that changes in water mass properties of the tropical Pacific pycnocline are responsible for the decadal modulation of ENSO and basin scale ENSO-like Pacific Decadal Variability. However, these studies are limited by the lack of observational evidence for possible water mass changes in the tropical Pacific pycnocline. In this study we investigate these changes using 50-years of hydrographic data formed by the combination of NODC World Ocean Database 2001, WOCE sections, some newly available Argo float profiles, and PMEL CTD data collected from ships servicing TAO moorings.

Decadal time scale density compensated temperature anomalies are evident in the equatorial Pacific pycnocline with standard deviations of 7-year low-passed anomalies in the western, central, and eastern basins of 0.11, 0.08, and 0.23 degree C respectively. The signature of the 1976/77 regime shift is visible in the eastern basin with positive anomalies in the 1980s and 1990s and negative anomalies before. These pycnocline anomalies are highly correlated with the SST anomalies, both of which show an approximate 0.8 degree C increase from the 1970s to the 1990s. However, the equatorial pycnocline anomalies do not appear to be advected from higher latitudes by the mean circulation of the subtropical cells, but rather appear to be generated locally by circulation changes and equatorial mixing processes. The implications of these results for theories of Pacific decadal variability will be discussed.

DP-26

Generation of Interannual and Interdecadal Climate Oscillations through Nonlinear Subharmonic Resonance in Delay Oscillators

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The resonant behavior of delayed oscillators is studied using two simple prototype equations similar to that used by Suarez and Schopf [1988]. One prototype equation has a periodic modulation of simultaneous feedback, and the other prototype equation has a periodic external forcing term. The periodic modulation tends to yield even-multiple resonance to the modulation period, i.e., the resultant period of the oscillation is equivalent to the two, four, or six-multiples of modulation period. On the other hand, periodic forcing results in odd-multiple, i.e., the resultant period is equivalent to the three, five, or seven-multiples of the forcing period. The reason why these two-types of resonance occur in the each system is explained. The key mechanism for the resonance is that a positive feedback for small amplitudes set a threshold. Only when the sum of non-simultaneous terms (delay term plus forcing term) is larger than the threshold, a phase reversal can take place.

It is noteworthy that even small positive feedback can alter the nature of the system, from the case of the negative or neutral feedbacks. For example, a positive feedback as small as 1/(5-years) is enough for setting threshold nature, which can result in a decadal resonance behavior with appropriate external forcings; in this case, a 10-25-year delay time with an external forcing of 20-years can cause three-multiple resonance with the resultant period of 60-years. This may be consistent with the hypothesis that the North Pacific climatic regime shift in the 1920s, 1940s, and 1970s are associated with the simultaneous phase reversals of the 20-year and 50-70-year oscillations.

DP-27

Multiple Regimes and Low-Frequency Oscillations in the Northern Hemisphere's Zonal-Mean Flow

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We study multiple regimes and low-frequency oscillations in the Northern Hemisphere zonal-mean zonal flow, using 55 years of daily observational data. The probability density function (PDF) estimated in the phase space spanned by the two leading empirical orthogonal functions (EOFs) exhibits two distinct statistically significant maxima. The two regimes describe persistent zonal-flow states characterized by meridional displacements of the midlatitude jet poleward and equatorward of its time-mean position. Geopotential height anomalies associated with either regime have a pronounced zonally symmetric component, but largest-amplitude anomalies are located over the Atlantic and Pacific sectors. These regimes are maintained by the forcing due to high-frequency synoptic transients.

Significant oscillatory components with periods of 147 and 72 days are identified by spectral analysis of the zonal-flow time series. The 147-day oscillation involves zonal-flow anomalies that propagate poleward, while the 72-day oscillation's pattern is stationary. In the horizontal plane, both modes are characterized by synchronous centers of action located in the Atlantic and Pacific sectors; they describe changes in the midlatitude-jet position and intensity. Our persistent multiple regimes are shown to be associated with slow phases of either oscillation.

The occurrence frequency of either regime exhibits pronounced interdecadal variability over the whole data record. These variations are correlated, at multi-year lags, with sea-surface temperature variability characterized by centers of action along the North Atlantic ocean's western shore. This suggest that the regimes are affected, through midlatitude ocean—atmosphere interaction, by intrinsic ocean dynamics.□

.□□P-28

On Decadal Sea Surface Salinity Changes in the Western Tropical Pacific Ocean

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Decadal variability in the Pacific ocean has been evidenced in many studies, both in the ocean and the atmosphere, from in situ and model-derived data. When using observations, such variability has been found mainly in sea level pressure, surface wind, SST, and subsurface water temperature. Due to a scarcity of data, relatively few works exist about potential salinity changes at decadal time scales.

This poster will focus on sea surface salinity (SSS) changes in the western tropical Pacific ocean, 30°N-30°S, in using in situ observations derived from voluntary observing ships during 1970-2003. It will be shown that SSS exhibits significant changes during the so-called regime shift in the mid-1970, with a 0.1-0.3 increase (saltier after 1976) in the equatorial band and a 0.2 decrease poleward of about 10-15° latitudes, with a hint for opposite changes by the end of the 1990's. Assuming that they can be differentiated, the respective roles of ENSO and PDO in these changes will be discussed in light of proposed physical mechanisms accounting for these "oscillations".

P-29

Characterization of NOAA-AVHRR NDVI Time Series Power Spectra and its Linked Relationship with the Pacific Decadal Oscillation (PDO)

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Mean monthly Normalized Difference Vegetation Indices (NDVI) from 1982 to 1999 were derived from NOAA-AVHRR data and compared with coincidental multi-temporal mean monthly Pacific Decadal Oscillation (PDO) datasets. Power spectra for both datasets were derived using the Maximum Entropy Spectral Analysis (MESA) technique. Three continental test datasets were investigated namely, continental Africa, South America, and Australia. Initial results indicate high degree of coherency between NDVI and PDO power spectra. Low frequency coherency in the order of tri-decadal (30-year), 15-year, decadal and sub-decadal nature have been observed in all datasets. These Terrestrial Decadal Oscillations (TDO) seem to indicate to be modulated by the PDO based on the behaviour of the multi-year NDVI, as well as the former and the latter, by some form of solar forcing. Given these initial results of spectral coherency between NDVI and PDO, the former could be used as an environmental proxy for detection of climatic oscillations particularly that of the PDO.

P-30

Observed and Simulated Links between ENSO and European Climate

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Long-term changes in the link between the Pacific and the North Atlantic winter climate can be detected in observational data of the 20th century. Three characteristic periods can be identified using a running 25 year window: During 1900-1925 and 1962-1987, El Niño-Southern Oscillation (ENSO) variability as measured by the NIÑO3-index is associated with higher than normal Sea Level Pressure over the Mediterranean Sea and North Africa in spring, while pressures are comparatively low over Scandinavia.

Correlations between the North Atlantic Oscillation (NAO) and the NIÑO3-index are weakly positive. Enhanced spring precipitation over central Europe and low rainfall in southern Europe and northern Africa are in agreement with these patterns. During 1931-1956, in contrast, positive NIÑO3 values tend to be associated with high pressure over northern Europe and low pressure over central Europe. This pattern is part of a dipole streching across the Atlantic Ocean into Europe. The projection on the NAO leads to a negative NAO-NIÑO3 correlation of r=-0.5. Rainfall is modified accordingly over northern Europe.

These observational relationships between temperatures in the tropical Pacific and pressure over the North Atlantic and Europe are reproduced by a control run of a coupled atmosphere-ocean GCM. A negative ENSO-NAO correlation (-0.3) is found for boreal winter. A mechanism potentially explaining the connection between the Pacific and the Atlantic includes the Pacific-North American (PNA) pattern and its influence on eddy activity over the Atlantic. This influence involves growth conditions (baroclinicity, latent heat availability) for the transient eddies over the Atlantic stormtrack's center at Newfoundland. Distinguishing between winters when this mechanism connects PNA and NAO positively and negatively, the observed and simulated correlation patterns between ENSO and Atlantic-European Sea Level Pressure are in good agreement.

ÐP-31

Analogous Pacific and Atlantic Meridional Modes of Tropical Atmosphere-Ocean Variability

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We identify from observational analysis an atmosphere-ocean mode in the central-eastern tropical Pacific, distinct from the El Nino-Southern Oscillation (ENSO), that resembles the meridional (aka gradient or interhemispheric) of interannual-decadal variability in the tropical Atlantic. The Atlantic and Pacific meridional modes share similar spatial and temporal characteristics, relationship to the seasonal cycle, and physical interpretation. Furthermore, the modes are forced by the dominant mode of wintertime atmospheric variability in their respective northern midlatitude basins, namely the North Atlantic Osicillation(NAO) and North Pacific Oscillation (NPO). ENSO nonlinearity projects significantly on the Pacific meridional mode, but we show that the mode exists independently of ENSO. We suggest that the Pacific and Atlantic meridional modes are analogous, governed by physics intrinsic to the ITCZ/cold tongue complex.

ÐP-32

Causes of Low Frequency North Atlantic SST Variability in a Coupled Model

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The low frequency sea surface temperature (SST) variability in the North Atlantic is studied using the Center for Ocean-Land-Atmosphere Studies (COLA) anomaly coupled general circulation model. The main focus is placed on the relative roles of stable and unstable coupled feedbacks in inducing the low frequency SST variability in various regions of the North Atlantic. To examine this question, a recently developed coupling technique, interactive ensembles, is applied to reduce the strength of "weather noise" in the model and isolate the atmospheric feedback to boundary forcing.

We find that the low frequency SST variability in the subtropical North Atlantic is mainly induced by stable coupled feedbacks in which the weather noise plays a central role. However, in the Gulf Stream extension area, the SST variability may be attributed to processes internal to the ocean. In this region the "weather noise" forcing the coupled system is generated by the ocean, and the coupled feedbacks are stable. Although the results are not definitive, there is no compelling evidence that unstable coupled feedbacks are important for low frequency SST variability in the North Atlantic in this model.

□□P-33

North Atlantic Decadal Variability: The Role of Ocean-Atmosphere Coupling and Oceanic Dynamics

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In this paper, the role of ocean-atmosphere coupling and oceanic dynamics in the North Atlantic decadal variability is explored in a series of coupled ocean-atmosphere simulations. Both observations and the model indicates that the North Atlantic decadal variability consists of two distinctive modes: a tripole (NAT) and a monopole (NAM) mode. Our coupled modeling surgery studies suggest the important role of the ocean-atmosphere coupling in sustaining the North Atlantic decadal oscillation. Without ocean-atmosphere coupling, the atmospheric stochastic forcing, although can drive the NAT and NAM, but can not generate any preferred decadal timescales. Furthermore, the coupled experiments initialized with a NAT and NAM mixed-layer temperature anomaly show a strong positive feedback between the atmosphere and the ocean. The subtropical gyre adjustment to the wind stress in the southern subtropics provides a delayed negative feedback in setting the timescale and switching the phase of the decadal oscillation.

Our modeling study also suggest that the Pacific climate variability can affect the North Atlantic decadal fluctuations. The Pacific decadal oscillation can lead to a kind of resonance in the Atlantic through the atmospheric teleconnection, but is not a necessary precondition for the North Atlantic decadal oscillation.

□□P-34

Seasonal to Decadal Variability of Vertical Shear over the Tropical Atlantic

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Tropical cyclone activity in the Atlantic exhibits variability that encompasses seasonal to decadal timescales. Past studies have shown that a key factor that influences Atlantic tropical cyclone activity is the variability of the vertical shear over the main development region (MDR), a large area in the Atlantic within which the majority of tropical cyclones develop. This significant finding points towards the need to better understand the factors that contribute to the variability of the MDR vertical shear in order to improve our knowledge as well as forecast skill of tropical cyclone activity.

In this study, we consider the seasonal to decadal variability of the MDR vertical shear. The objectives include the examination of the spatial and temporal characteristics of the vertical shear variability and their relationship with Atlantic sea surface temperatures, African rainfall and ENSO. This work is in progress and the results to be presented at the conference will emphasize the role of local and teleconnection processes that influence the vertical shear over the MDR.

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□DP-35

Oceanic Precipitation Variability Associated with the North Atlantic Oscillation: Tropical - Extratropical Interactions

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The North Atlantic Oscillation (NAO) is characterized by an inverse correlation of sea level pressure anomalies in the high and mid-latitudes over the Atlantic Ocean, and an associated alternation between faster than normal zonal flow (high index conditions) and weaker (low index) flow from North America to Europe. Pronounced temperature and precipitation anomalies on time scales from daily to seasonal associated with the NAO have been identified over eastern North America, Europe and the Mediterranean Sea, extending into the Middle East. The observed precipitation anomalies have been ascribed to systematic changes in the storm track over the North Atlantic. However, the NAO-related oceanic precipitation anomalies have so far been hardly investigated. Even less is known of the relationship between the NAO and tropical precipitation anomalies. The extended time series of global precipitation analyses produced by the Global Precipitation Climatology Project (GPCP) and the Climate Prediction Center (CMAP) enable us to describe the oceanic precipitation variations associated with the NAO for the period from 1979-present, and to examine NAO manifestations outside the North

Atlantic. In this poster, we will present a statistical description of the impact of the NAO on Atlantic precipitation and the associated variations in tropical precipitation. A reconstruction of oceanic precipitation for the period 1948-2000, based on empirical orthogonal functions derived from the 1979-2002 period, will be used to describe decadal variability in the observed relationship. The associated variations in moisture flux and moisture flux convergence will be described based on the NCEP/NCAR reanalysis, along with the variations in the large-scale mass and motion fields.

Implications of these findings for potential predictability of the NAO will be discussed.

IDP-36

Twentieth Century North Atlantic Climate Change. Assessing Determinism and Understanding the Effect of Indian Ocean Warming

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Boreal winter North Atlantic climate change since 1950 is well described by a trend in the leading spatial structure of variability, known as the North Atlantic Oscillation (NAO). Through diagnoses of ensembles of atmospheric general circulation model (AGCM) experiments, we demonstrate that this climate change is a virtually deterministic response to the temporal history of sea surface temperatures (SSTs), with variations in tropical SSTs of primary importance. In particular, the probability distribution function (PDF) of 50-year NAO index trends from the forced simulations are appreciably different from the PDF of a control simulation with no interannual SST variability, although chaotic atmospheric variations are shown to yield appreciable 50-year trends. Our results thus advance the view that the observed linear trend in the winter NAO index is a combination of a strong tropically forced signal and an appreciable “noise” component of the same phase.

Additional AGCM experiments reveal that the changes in tropical rainfall of greatest relevance include increased rainfall over the equatorial Indian Ocean, a change that has likely occurred in nature and is physically consistent with the observed, significant warming trend of the underlying sea surface. The simulated Northern Hemisphere atmospheric response to the linear trend component of Indian Ocean SST change since 1950 projects strongly onto the positive polarity of the NAO and is a hemispheric pattern distinguished by decreased (increased) Arctic (middle latitude) sea level pressure. The Indian Ocean influence is further established through the reproducibility of results across three different models forced with identical, idealized patterns of the observed warming. Examination of the transient atmospheric adjustment to a sudden “switch-on” of an Indian Ocean SST anomaly reveals that the North Atlantic response is not consistent with linear theory and most likely involves synoptic eddy feedbacks associated with changes in the North Atlantic storm track.

The tropical SST control exerted over 20th century regional climate underlies the importance of determining the future course of tropical SST for regional climate change and its uncertainty. Better understanding of the extratropical responses to different, plausible trajectories of the tropical oceans is key to such efforts.

□□P-37

NAO and Air-Sea CO2 Fluxes

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Extrapolation of data from one time-series station in the North Atlantic gyre suggests large interannual variability of air-sea CO2 fluxes, whereas ocean carbon cycle models simulate much smaller variability. To understand why ocean carbon cycles model predict that air-sea CO2 fluxes in one part of the North Atlantic are largely compensated by those in another part, we analyze the spatio-temporal variability of these fluxes and the processes which control them. We use a global ocean GCM (OPA) and a biogeochemical model, forced by the 50 years of NCEP reanalysis. The dominant modes of variability are extracted using Multi-Channel Singular Spectrum Analysis (MSSA). The CO2 fluxes and related physical variables such as sea-surface temperature (SST), mixed layer depth, wind, and sea-level pressure (SLP) were analyzed separately and in combination. Flux anomalies generally exhibit a complex quadrapolar structure with the center offshore of Newfoundland where SST gradients are important. Anomalies propagate mainly along the Gulf Stream and around the subpolar gyre. Occasionally this leads to a dipolar instead of the more usual quadrapolar structure. Preliminary results suggest that atmospheric forcing is directly responsible for driving the variability in the northern subpolar gyre. Slight differences are found between interannual and decadal variability. To quantify more precisely the processes driving variability of the flux anomalies, we analyzed the dissolved inorganic carbon (DIC) transport equation including sources minus sinks. We thus distinguish dynamic, thermodynamic, and biogeochemical terms and their impact on the different modes of variability. Simulations are made with forcing extracted from the MSSA analysis in order to confirm preliminary conclusions.

□□P-38

The Norwegian RegClim-Project: Uncertain Processes increases the Risks as Climate Change in Northern Europe

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RegClim - Regional Climate Development under Global Warming - is a Norwegian co-ordinated research effort aiming at downscaling global climate change

projections to Northern Europe and adjacent sea areas (target region), and to quantify uncertainties and associated risks due to natural variability and weak understanding of processes. In focus are the currents in the North Atlantic Ocean, and links between anthropogenic aerosols and climate. RegClim started in 1997 and this phase ends in 2006. Up to 30 scientists are involved at 5 institutes (met.no, the Universities of Oslo and Bergen, Inst. of Marine Research, Nansen Environment an Remote Sensing Centre). This poster includes contributions from all 5.

Dynamical (RCMs) and empirical (statistical) methods are used to downscale global climate projections. A version of the HIRHAM model is used as RCM in the atmosphere, and ROMS is used for selected oceanic regions. Our target region is close to a ocean area in which the Global Climate Models produce huge differences when simulating present-day climates (IPCC TAR, Fig 8.10). Results from RegClim on targeted 5-day Forcing Singular Vectors, indicate that SSTs in the Nordic and Barents Seas strongly influence the selection of atmospheric regimes in the target domain. Downscaling results of projections from the Hadley-Centre (HadAM3H) thus differ considerably from projections from MPI-Hamburg (ECHAM4), since their SSTs differ considerably. Treating these results as equally valid yields wider projected pdfs than inferred from standard data for present climate.

In order to increase our understanding of the processes in the North Atlantic Ocean, the Bergen Climate Model has been used to produce a 300-year control (CMIP) run. During the latter 250 years, the strength of the model's Atlantic Meridional Overturnimg (AMO) varies on multi-decadal time-scales between 16 and 19 Sv. An ensemble of CMIP2-runs have been started out from different strengths of the AMO. When the model starts form the weak AMO-mode, the climate at 2xCO_2 is similar to the Hadley-Centre's projection in our target region, whilst starting from a strong AMO produces a result similar to MPI-Hamburg's. Hence, there is a possibility that the differences can be due both to natural variability and differences between the model formulations.

Direct and indirect effects of anthropogenic aerosols are so far studied using a version of the CCM3-model of NCAR coupled to a slab ocean for climate equilibrium runs. Production, transport and deposition of sulfate and organic aerosols are included on-line in the model, and optical parameters and CCN-production is parameterized in order to calculate the direct and the two indirect effects. Impacts appear in particular in the tropics as a displacement southwards of ITCZ, as a concequence of the cooling of the northern relative to the southern hemisphere. Also the Asian Monsoon is thereby potentially influenced. Other regions experience significant but less drastic changes.

DP-39

The Effects of Model Parameterizations on Meridional Overturning Circulation Oscillations

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The role of the annual cycle of heat flux in driving interdecadal oscillations during the initial adjustment phase is studied using the MIT-ECCO primitive equations model. The model is configured in an idealized, single hemispheric basin of constant depth on

the sphere. The model is forced by zonally-averaged surface heat fluxes derived from the COADS climatology. Sea surface salinity is restored toward zonally-averaged values derived from the Levitus monthly climatology. Three different schemes for parameterizing processes that are not represented explicitly in the model are used: fixed horizontal/vertical diffusitivities, Redi/GM parameterization, and the nonlocal K-profile parameterization schema (KPP). When the model is forced by time-invariant surface fluxes, the sub-grid scale parameterization scheme does not have a major effect and the model settled into an equilibrium state in which no oscillations occurred. When the model is forced by climatological, seasonally varying heat fluxes, no oscillating behavior is found in experiments using fixed diffusitivities and Redi/GM parameterization. In contrast, strong non-periodic interdecadal oscillations arise using KPP. An additional Newtonian restoring term in the heat flux formulation, however, stabilizes the non-periodic oscillations leading to periodic behavior. Interdecadal oscillations are also found when, in addition to the buoyancy forcing, an idealized zonal wind profile is used to drive the subpolar and subtropical barotropic gyres. A shift of only 4 degrees of the wind profile, however, damps the interdecadal oscillations and stabilizes the circulation. Our results suggest that the period of the oscillation is determined by the time it takes for a positive (negative) SST anomaly generated in the north central region to reach the northwest corner, where the positive (negative) anomaly stabilizes (destabilizes) the stratification and reduces (enhances) the convective activity. Whether are a physical effect or an artifact of the KPP approach, still remains obscure.

DP-40

Advection of the "Great Salinity Anomaly" of the 1990s around the Northern North Atlantic and its Comparison with Previous Decadal-Scale Anomalies: Subarctic Gyre Spin-Up Confirmed

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Time series of temperature and salinity extending through 2002 are used to describe propagation of the "Great Salinity Anomaly" of the 1990s (GSA'90s). Comparison of the distance-time relations for the GSA'70s, '80s, and '90s reveals a substantial intensification of the large-scale circulation in the northern North Atlantic, especially in the Subarctic Gyre. The advection rate of the GSA'70s, '80s, and '90s between Newfoundland and the Faroe-Shetland Channel is conservatively estimated to have been 4, 10, and 10 cm/s, respectively. The circulation intensification apparently occurred within a decade between the GSA'70s and '80s. During the next decade the advection rate increased from 10 to 13 cm/s between Newfoundland and Iceland Basin. The GSA'90s was advected towards the Faroe-Shetland Channel by the northern (Iceland Basin's) branch of the North Atlantic Current, whereas the contribution of the southern branch via the Rockall Trough was minimal.

DP-41

Multi-Year Variability of Salinity in the Northern Hemisphere Oceans

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We use data from the "World Ocean Database 2001" (WOD01) to composite salinity data for five year periods for the northern hemisphere oceans with emphasis on the North Atlantic Ocean to explore the salinity variability in these regions over the last 50 years. Our analysis expands on previous work which used selected (mostly coastal) time series. Our composite fields have better spatial resolution, but irregular temporal resolution. Large scale trends of salt content for the North Atlantic and North Pacific in the upper 3000 meters point to an increased salt concentration in the North Atlantic and a decreased salt content in the North Pacific. Looking only at the sub-polar North Atlantic reveals a trend of decreasing salt content. There is a pattern of alternating periods of high and low salinity in the western North Atlantic. Relatively high salinities occurred in the western North Atlantic during 1945-50, 1962-66, 1975-79, and 1991-95. Relatively low salinities occurred in the same area during 1970-74 and 1982-86. The outlook for continued acquisition of historical salinity data is good, which will allow improved temporal resolution for future analyses.

PDP-42

The Simulated Composition of Arctic Fresh Water Variability 1950-2000

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The fresh water export from the Arctic exhibits decadal to multi-decadal variability that is the result of variability in the reservoir of fresh waterin the Arctic halocline, sea ice and various liquid fresh water inflows. Different not even connected time scales are introduced by:- the inflow paths' variability governed by different production processes- the very diffent trans-Arctic travel times depending on actual path- the sea ice induced source and sink often showing effects of time integration- the reservoir's storage capability.

We will present ocean-sea ice model results from hindcasts forced by NCEP reanalysis data that indicate a decline of the Arctic fresh water reservoir from the mid-1960s until today. A long-term trend is sumperimposed by several fresh water export events.We will discuss separately the origin of variability in the fresh water reservoirs and in the import regions to explain the formation of the variability in the export.

PDP-43

Vertical Structure of the Arctic Oscillation and Cold Ocean Warm Land Regimes and Their Role in the XX Century Climate

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When examined in terms of diagnostics of the atmospheric circulation, recent climate change may be interpreted in terms of increases or decreases in the frequency of occurrence of pre-existing preferred modes of atmospheric behaviour rather than a simple linear shift in the mean climate with superimposed noise. This contrasts with the characteristics of the observed changes in temperature-related diagnostics, which appear much closer to the simple linear picture. While not necessarily inconsistent, the implications of these two views of the nature of climate change need to be explored. In this framework the main purpose of this paper is to use both reanalysis products and multidecadal ensemble GCM simulations in order to explore the vertical structure of circulation regimes and illustrate the potential role of weather regimes and non-linearity in the emerging anthropogenic signal. A set of variables is considered and an empirical orthogonal function (EOF) analysis is first applied in order to define, for each variable, a reduced phase space based on the leading modes of variability. Then a simultaneous analysis of all fields is carried out performing a further EOF analysis in the subspace spanned by the leading EOFs of each field. This produced a multi-variable EOF picture of the large-scale vertical (and thermal) structure of the atmosphere. With the three-dimensional structure available, it is possible to assess whether the observed temperature changes are consistent with an increase in certain regime frequencies. Moreover the hypothesis that regime frequency change more than regime structure is checked by performing a regime analysis separately on the first and second part of the record.

□□P-44

Climate Impacts of the Arctic Oscillation and the Seasonal Frozen Soil on the Dust Storms in China

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Based upon the historical data (1954~2003) such as the dust storms records and the depth of seasonal frozen soil in China, , the arctic oscillation index provided by David W. J Thompson (Department of Atmospheric Science, Colorado State University, Fort Collins, USA), the geopotential height, temperature and wind fields at obligatory levels generated by NCEP/NCAR reanalysis dataset(2.5°2.5°Lat/Lon) for recent 50 years, the annual, inter-annual and decadal variations of dust storms are analyzed, the facts of dust storms in response to frozen soil in winter and the relationship with the atmospheric circulation anomaly are also investigated. The active dust storm years and the inactive dust storm years in China are selected respectively to contrast the difference on the large-scale atmospheric circulation and the relevant dynamical and thermodynamic factors. Our results show that: 1) Dust storm in China has an obviously inter-annual

change in recent 50 years. The frequency of dust storms has gradually decreased since recent 50 years over China, in which the highest rate of dust storms occurred in the 1950s, while the relative low rate of the dust storms emerged in the 1990s. 2) When the positive anomaly depth of frozen soil is dominated in the western regions of China (about west of 100ºE), correspondingly, the dust storms occur more frequently in China. On the Contrary, when the negative anomaly depth of frozen soil is dominated, the dust storms seldom occur in China. 3) When the depth of frozen soil exhibits positive anomaly in winter and the arctic oscillation is in negative episode in spring, correspondingly, the zonal circulation index exhibits negative anomaly and the westerly flow in middle and high latitude weakens, which promote cold air in polar areas to move southwards and make the Siberia high strengthened, thus result in dust storms increase; the same is in opposite. 4) The climatic backgrounds between more and less dust storms in China are evidently different. It is revealed the facts that the anomalies of the large-scale circulation and the relevant dynamic and thermodynamic factors can result in the formation of dust storms in China. Above preliminary results have some novel and applied value for the short-term climatic prediction of the dust storms in China. Key words: Dust storms in China; Seasonal frozen soil; Arctic oscillation; Annual and inter-annual variations; Dynamic and thermodynamic Impact factors; Short-term Climate prediction.

□DP-45

Climatology and Interannual Variability of Arctic Cyclone Activity, 1948 – 2002

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Arctic cyclone activity is investigated in the context of climate change and variability by using a modified automated cyclone identification and tracking algorithm, which differs from previously algorithm by single-counting each cyclone. The investigation extends earlier studies by lengthening the time period to 55 years (1948-2002) with 6-hourly time resolution, by documenting the seasonality and the dominant temporal modes of variability of cyclone activity, and by diagnosing regional activity as quantified by the cyclone activity index (CAI). The CAI integrates information on cyclone intensity, frequency and duration into a comprehensive index of cyclone activity. Arctic cyclone activity has increased during the second half of the 20th century, while midlatitude activity generally decreased from 1960 through the early 1990s, in agreement with previous studies. New findings include the following: (1) The number and intensity of cyclones entering the Arctic from the midlatitudes has increased, suggesting a shift of storm tracks into the Arctic, particularly in summer; (2) Positive

tendencies of midlatitude cyclone activity before and after the 1960-1993 period of decreasing activity correlate most strongly with variations of cyclone activity in the Eurasian sector; (3) Synchronized phase and amplitude variations in cyclone activity over the Arctic Ocean (70-90N) and the Arctic marginal zone (60-70N) play a critical role in determining the variations of cyclone activity in the Arctic as a whole; (4) Arctic cyclone activity displays significant low-frequency (50 - 60 years) variability, with a negative phase in 1960s and a positive phase in 1990s, upon which are superimposed 7.8-year and 4.1-year oscillations. The 7.8-year signal generally corresponds to the alternation of the cyclonic and anticyclonic regimes of the Arctic sea-ice and ocean motions.