

and organic carbon (thermal method), and total mass (gravimetry). In addition total concentrations (residual + interstitial) are determined with a third inlet (Whole Air Inlet) and a cloud impactor sampling the liquid phase allow an independent control on the partitioning.

From our measurements, we do not confirm the large contribution of organic aerosols to cloud condensation nuclei concentrations as observed by several authors such as Novakov and Penner (1993). While carbonaceous species contribute to 93% of the interstitial composition, it only accounts for 21% of the CCN composition. Residual organic carbon accounts for only 15% of total (interstitial + residual) organic mass. This is much lower than the scavenging efficiency of the ionic species for which 85% of the mass is present in the residual phase.

Size dependent scavenging efficiencies are determined for all classes of carbonaceous species (as defined by their volatility), organic acids, major soluble nuclei and total mass. There is a clear change in the scavenging properties of particles smaller than 0.3 μm compared to scavenging properties of particles larger than 0.3 μm as expected from the activation diameter. However, at a given particle diameter, the scavenging of carbon species is much lower than that of ionic species, indicating some degrees of external mixing of particles. Moreover, it appears that black carbon is more efficiently scavenged than other organic compounds. This possibly indicates that aging of carbonaceous material may be the key factor for modifying the hygroscopic properties of the organic aerosols.

A22A-0119 1330h POSTER

Laboratory Studies of the Kinetics of Aqueous Phase Reactions of SO_4^{2-} and OH Radicals with Organo-Sulfur Compounds of Atmospheric Interest

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As dimethyl sulfide (DMS) undergoes gas-phase oxidation in the atmosphere, the products become progressively less volatile and can be partially partitioned into the condensed phase. Therefore condensed phase transformations may play an important role in the atmospheric chemistry of these species. As part of a research program aimed at developing a detailed understanding of DMS oxidation and its role in the global climate system, we are investigating the aqueous phase reactions between radicals commonly found in the atmospheric condensed phase and organo-sulfur compounds of atmospheric interest. The present study employs a Laser Flash Photolysis-Long Path UV-Visible Absorption technique to investigate the aqueous phase reactions of SO_4^{2-} and OH radicals with the organo-sulfur species dimethyl sulfoxide (DMSO), dimethyl sulfone (DMSO₂), methane sulfinate (MSI), and methane sulfonate (MS).

Laser flash photolysis of either $\text{S}_2\text{O}_8^{2-}$ or H_2O_2 at 248 nm is used to produce the free radicals. Reactions of SO_4^{2-} radicals are studied by monitoring the time dependence of the SO_4^{2-} absorption at 450 nm under pseudo-first order conditions with the organo-sulfur compounds in large excess over SO_4^{2-} . A competitive kinetics technique is employed in the studies of OH reactions, where the reaction rates of the organo-sulfur species with OH are measured relative to the rate of the reaction of SCN^- with OH. The product $(\text{SCN})_2^-$ from reactions of SCN^- with OH ($\text{SCN}^- + \text{OH} \rightarrow \text{SCN} + \text{OH}^-$, $\text{SCN} + \text{SCN}^- \rightarrow (\text{SCN})_2^-$), whose concentration decreases with increasing concentration of the organo-sulfur species, is monitored as the kinetic probe (at 475 nm). Room temperature (293 \pm 1 K) rate coefficients for SO_4^{2-} reactions with DMSO, DMSO₂, MSI, and MS in units of $\text{M}^{-1}\text{s}^{-1}$ are found to be $(2.6 \pm 0.3) \times 10^9$, $(3.4 \pm 0.3) \times 10^6$, $> 5 \times 10^8$, and $(1.2 \pm 0.1) \times 10^4$, respectively, while OH reaction rates in the same units are found to be $(5.9 \pm 1.0) \times 10^9$, $(1.4 \pm 0.5) \times 10^7$, $(1.1 \pm 0.5) \times 10^9$, and $(1.0 \pm 0.2) \times 10^7$, respectively. Rate coefficients for the $\text{SO}_4^{2-} + \text{DMSO}_2$ and MS reactions have not previously been reported. Both previous studies and our studies demonstrate that DMSO and MSI are very reactive species, while DMSO₂ and MS are much less reactive. The rate coefficient we report for the OH + MS reaction is much smaller than previously reported values.

Temperature-dependent kinetics studies are now in progress and updated results from these studies will be reported.

A22A-0120 1330h POSTER

Modeling Study of Aerosol Global Distribution and Radiative Forcing

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An aerosol transport-radiation model is developed for simulating the global distributions and radiative properties of the main tropospheric aerosols, i.e., carbonaceous (black carbon (BC) and organic carbon (OC)), sulfate, soil dust, and sea salt, simultaneously. The model is coupled with the Center for Climate System Research (CCSR), University of Tokyo/National Institute for Environmental Studies (NIES), Japan, atmospheric general circulation model. The atmospheric field can be also nudged by reanalysis data. The main aerosol transport processes are emission, advection, diffusion, sulfur chemistry, wet deposition, dry deposition, and gravitational settling. The aerosol optical parameters are calculated considering differences in size distributions, hygroscopic growth, and refractive indices among each aerosol species. The model results are mainly compared with the optical thickness, Angstrom exponent and single scattering albedo retrieved from radiance data of satellite and ground-based remote sensing. The comparison shows that the simulated aerosol optical properties are in general agreement with observations regionally, seasonally, and quantitatively. Anthropogenic carbonaceous and sulfate aerosols generate a large optical thickness with a large Angstrom exponent at industrial regions of mid- and high-latitudes of the Northern Hemisphere where the single scattering albedo is about 0.9 at visible wavelengths. The direct radiative forcing for each aerosol species and the mixed state of all species is then calculated after the careful comparison on a global scale. The annual global mean direct forcing is estimated to be -0.32 W m⁻² for anthropogenic sulfate aerosols, +0.19 and -0.05 W m⁻² for fossil fuel BC and OC, and +0.15 and -0.16 W m⁻² for biomass burning BC and OC, respectively. The anthropogenic indirect radiative forcing is also calculated to be -1.0 W m⁻² using a simple relationship between aerosol particle and cloud droplet number concentrations.

A22A-0121 1330h POSTER

Asian Aerosols in North America: Extent and Frequency of Anthropogenic Pollutants

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Both natural and anthropogenic aerosols have been detected in transport across the northern Pacific Ocean. These aerosols play important roles in both climatic and geochemical processes across the North Pacific and temperate and arctic North America. Understanding the anthropogenic component of these aerosols permits separation of natural and anthropogenic effects at hemispheric scales. Using soil linked to Asian deserts as a marker for Asian air masses, we identified a set of several hundred transpacific transport events captured in aerosol samplers operated by the IMPROVE network. Using statistical methods, we then identified a suite of combustion-derived aerosol components associated with Asian transport. From these data, we developed statistics on the distribution of Asian pollutants in North America over the decade of the 1990s.

A22A-0122 1330h POSTER

ACE-Asia Circulation and Transport Events and Patterns

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Circulation features over a wide range of spatial scales were responsible for the variety of meteorological events and the consequent aerosol source, transport

and removal patterns encountered and observed during the field phase of the ACE-Asia campaign. Meteorological analysis of two cases will be presented to illustrate the relationship between the more compact and rapidly developing transient features and the steadier planetary-scale flows in which they are embedded. One case is the major dust outbreak which took place in early April and the second is an urban/industrial pollution plume event observed on April 29. The aerosol transport patterns which were observed in these and other events will be placed in the context of the larger-scale circulation using a schematic composite analysis technique. Indices based on dust reports from surface meteorological stations in Asia from this period will be contrasted with corresponding data in prior years.

A22A-0123 1330h POSTER

Aerosol Forcing Efficiency Determined From ACE-Asia Aircraft Measurements

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A suite of radiometers flown on the NCAR C-130 aircraft throughout the ACE-Asia experiment collected broadband and spectral flux data. Identical instruments were placed in the zenith and nadir positions, allowing net flux and optical depth to be determined. The radiative forcing efficiency (aerosol forcing per unit optical depth) near the surface, below the aerosol layer (about 30 meters altitude), was measured in the spectral ranges from 220 to 3910 nm (total solar forcing), from 680 to 3300 nm (near infrared) and in seven spectral channels covering contiguously the visible range from 400 to 700 nm. The radiative forcing was also measured above the lower aerosol layer, which allowed us to estimate the forcing efficiency of the aerosol layer above (generally dust). The combination of forcing measurements above and below the lower aerosol layer (generally pollution aerosols) allowed us to estimate the solar heating in this layer.

A22B MC: 133 Tuesday 1330h

The Arctic Oscillation and the North Atlantic Oscillation: Coupling to the Stratosphere (joint with OS)

Presiding: J Hurrell, Nation Center for Atmospheric Research; M Baldwin, Northwest Research Associates

A22B-01 1330h

How Does the Stratosphere Influence the Troposphere?

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Recent observational studies suggest that the strength of the wintertime stratospheric polar vortex influences the subsequent tropospheric circulation, specifically the state of the Arctic oscillation (AO). Here, dynamical mechanisms that can explain these observations are explored. Two key observations are, first, that the AO is a robust mode of tropospheric variability, found in models lacking a well resolved stratosphere, and in observations in seasons when the troposphere and stratosphere are effectively uncoupled; secondly, that the meridional scale of the variations in the troposphere is significantly smaller than the scale of stratospheric variations in the strength of the polar vortex.

Based on these considerations, we propose a mechanism in which stratospheric forcing, through the mechanism of downward control, weakly forces the AO. This forcing is reinforced in the troposphere by interactions with transient eddies, the tropospheric zonal flow eddy interaction that is responsible for the intrinsic AO within the troposphere. This mechanism is demonstrated in a simple model. Tests in an idealized GCM, in which the dynamics of the troposphere and stratosphere are fully resolved, are described.

A22B-02 1350h

The Impact of the Stratospheric Component of the North Atlantic Oscillation on Tropopause Height and Surface Pressure

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Using monthly mean data, daily data, and theoretical arguments, relationships between surface pressure, tropopause height and the strength of the stratospheric vortex are established. Support is provided for a picture where an increase in the NAO index is associated with enhanced equatorward refraction of upward propagating Rossby waves, which in turn leads to an enhancing of the stratospheric jet. At tropopause level the effects of the deeper Icelandic low and stronger stratospheric polar vortex are opposite, resulting in a lower tropopause over Iceland and a higher tropopause over the Arctic. The higher Arctic tropopause leads to a stretching of the tropospheric column and is therefore associated with a lowering of the pressure at the North Pole. Because this lowering of the pressure at the North Pole projects onto the NAO pattern itself, it is hypothesised that the stratosphere acts as integrator of the NAO index.

A22B-03 1405h

Weekly Evolution of NAO Variability

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The NAO structure is examined using weekly averaged NCEP reanalysis, with a focus on the pre-mature phase evolution. This period is characterized by the rapid growth of both the zonally averaged and stationary wave anomalies, particularly in the Atlantic sector. The precursor zonal-mean zonal wind anomaly has a mostly mono-polar structure (with westerlies in the middle-to-high latitudes) and is confined to the stratosphere / upper-troposphere region. Its connection to the stratospheric polar vortex is indicated by the presence of largest amplitudes at 10 mb. The zonal wind amplitude and structure develop pronouncedly in the following period, particularly in the troposphere, culminating in the well-known dipole structure, which is robust in the NAO mature phase. The zonal wind evolution in the stratosphere is characterized by the descent in the level of maximum winds.

Earlier observational and modeling analyses by the authors have indicated zonal-eddy coupling, resulting from the interaction of zonal-mean zonal wind anomalies and climatological stationary waves (or eddies), to be important in the maintenance of NAOs mature-phase anomalies. Modeling experiments are underway to determine the role of zonal-eddy coupling in NAO evolution, particularly, in development of the precursor zonal-mean zonal wind anomalies in the upper troposphere. The relative impact of zonal-eddy coupling in the Atlantic and Pacific basins, and also troposphere and stratosphere, will be evaluated and discussed at the meeting.

A22B-04 1420h

Stratospheric connection to Northern Hemisphere wintertime weather: implications for prediction

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The dynamical coupling between the stratospheric and tropospheric circulations yields a statistically significant level of potential predictability for extreme cold events throughout much of the Northern Hemisphere (NH) mid-high latitudes on both month-to-month and winter-to-winter timescales. Pronounced

weakenings of the NH wintertime stratospheric polar vortex tend to be followed by episodes of anomalously low surface temperatures and increased frequency of occurrence of extreme cold events throughout densely populated regions such as eastern North America, northern Europe, and eastern Asia that persist for ~2 months. Strengthenings of the vortex tend to be followed by surface temperature anomalies in the opposite sense. The quasi-biennial oscillation (QBO) in the equatorial stratosphere has a similar but somewhat weaker impact on NH wintertime weather, presumably through its impact on the strength and stability of the stratospheric polar vortex: i.e., the easterly phase of the QBO favors an increased incidence of extreme cold events, and vice versa. The signature of the QBO in NH wintertime temperatures is roughly comparable in amplitude to that observed in relation to the El-Niño/Southern Oscillation phenomenon.

A22B-05 1435h

Stratospheric Vacillation and the Dynamics of Annular Mode Variability

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The leading coupled mode of low-frequency variability in the troposphere and stratosphere during northern winter is the northern annular mode, or NAM. The near-surface manifestation of the NAM - the so-called Arctic Oscillation, or AO - is zonally symmetric to a first approximation, like the stratospheric NAM. Observations suggest that the near-surface and stratospheric AO/NAM anomalies are closely related and occur in conjunction with stratospheric warming events. In both positive and negative phases, NAM anomalies have a prevailing tendency to migrate downward from the mid- to lower stratosphere. The tropospheric NAM and its near-surface AO component approximately coincide with the arrival of a downward-migrating NAM anomaly at the tropopause.

These observations have inspired an investigation of stratospheric vacillation in a new type of model. Our numerical model is a sigma-coordinate primitive equation model run with spectral truncation at a single zonal wavenumber. Disturbances are forced by an interior potential vorticity source intended to simulate either asymmetric heating or wave generation resulting from baroclinic disturbances. The additional degrees of freedom obtained by having the disturbance and mean flow vary in latitude, as well as altitude, allows horizontal wave propagation to play a leading role in the vacillation dynamics.

Our model experiments produce poleward and downward propagating mean-flow anomalies associated with stratospheric warmings similar to those observed in the atmosphere. Experiments designed to isolate the various dynamical components show 1) how the vacillation depends on the wave refraction properties of the mean flow in the troposphere and lower stratosphere; 2) that the mean flow variations in the troposphere are significantly driven by wave-flux anomalies in the lower stratosphere, communicated downward to the surface by an induced mean meridional circulation, with nonzero surface pressure anomaly as implied by the theory of Haynes and Shepherd; and 3) wave reflection - from critical layers that form in subtropical and polar regions near the stratopause during the course of a stratospheric warming - modulates wave flux anomalies throughout the lower atmosphere. Transience of wave flux anomalies is largely responsible for the mean-flow evolution seen in the model, and the temporal development of flux anomalies gives rise to the downward migration of mean-flow anomalies.

A22B-06 1450h

The Vertical Structure of Wintertime Climate Regimes of the Northern Hemisphere Extratropical Circulation

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A nonlinear generalisation of Principal Component Analysis (PCA), denoted Nonlinear Principal Component Analysis (NLPCA), is applied to Northern Hemisphere wintertime geopotential heights at 1000 hPa, 700 hPa, 500 hPa, 300 hPa, and 20 hPa. It is found that the optimal nonlinear approximation to the data at the four tropospheric levels is characterised by three equivalent-barotropic regimes of circulation. The NLPCA time series provides a kinematic description of variability within the regimes and transitions between them. The occupation frequencies of the regimes demonstrate substantial interannual and interdecadal variability, some of which can be associated with the influence of El Niño/Southern Oscillation. The stratospheric geopotential height field is also characterised by three circulation regimes. Two of these characterise a vacillation of polar vortex shape and polar temperature. The third regime, which is occupied episodically, is characterised by dramatic reductions in the zonal-mean zonal wind and meridional temperature gradient at high latitudes. It is associated with stratospheric sudden warmings. Evidence is presented for a connection between the stratospheric and tropospheric regimes, including an association between stratospheric sudden warmings and North Atlantic blocks. Finally, these results are compared to previous studies of regime structure and to the Arctic Oscillation paradigm.

A22B-07 1525h

Structural Changes of Climate Variability

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NCEP reanalysis data are analyzed globally in the phase space of normal modes of the equations of motion in a layered atmosphere at rest. If the regime character of stratospheric circulation in boreal winter months is used to stratify the data set into months with strong and months with weak polar vortex, several interesting results appear:

1. Changes in the stratospheric regimes lead to structural changes of variability in the troposphere. The 4 clusters of 500 hPa geopotential height identified by Corti et al. (1999) can be interpreted as two pairs of variability structures under the conditions of weak and strong northern polar vortex, respectively.

2. A significant anticorrelation is found in sea level pressure between the Icelandic Low and the Aleutian Low in the strong polar vortex regime, but not in the weak one. It is found also in "control runs" of climate models since these often are biased towards the strong polar vortex regime.

3. The well known pattern of the "Arctic Oscillation" is mainly the result of the mean surface pressure difference between the two stratospheric regimes.

4. The Southwest-Northeast tilt of the node line of the North Atlantic Oscillation pattern is the result of the undue application of linear statistics to nonlinear variability. It is due to the superposition of the mean difference in atmospheric pressure between the two stratospheric circulation regimes with a strictly meridional NAO pattern. Only the latter is a physical mode. The zonal North Pacific-North Atlantic connection (suggested to work via planetary waves) also influences the Southwest-Northeast tilt of the node line in the strong vortex regime.

A22B-08 1540h

Vertical Propagation and Temporal Growth of Perturbations in the Winter Atmosphere

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We present a general circulation model study of the temporal growth and vertically propagation of perturbations following vertical confined forcings. Both transient and sustained forcings are considered.

The motivation for the study is the recent recognition of downward propagation of anomalies from the stratosphere to the troposphere and its implications both for medium range forecasts and for a possible physical mechanism for stratospheric impacts on weather and climate. The dynamical link might also offer a mechanism for changes in the upper atmosphere to affect the tropospheric climate. Here we are thinking of changes in trace gases such as ozone, but also of modulations of the upper atmospheric structure related to the 11-year solar cycle.

The model atmosphere is chaotic and shows growth of perturbations no matter which level is forced. The perturbations grow to a size comparable to the variability of the unperturbed atmosphere on a time-scale of 20 - 25 days in the troposphere and 30 - 40 days in the

stratosphere. After the initial period of growth the perturbations have the same structure as the unperturbed atmosphere. Although the forcing is restricted to the northern hemisphere the perturbations encompass the whole atmosphere and develop on the same time scale on both hemispheres.

Perturbations grow with time squared both when zonal mean and single cell values are considered. Such a power law growth suggests the existence of a finite predictability time which is independent of the initial perturbation as long as it is small.

In the unperturbed atmosphere the stratospheric variability has the form of downward propagating stratospheric vacillations. However, in the initial period of growth the perturbations do not propagate downward and seem in general uncoupled to the background vacillations. This suggests that the downward propagation is a robust feature determined more by the processes in the troposphere than the state of the stratosphere. We note that downward propagation may still be a source for enhanced predictability of near-surface weather.

A22B-09 1555h INVITED

Long-term Solar Forcing of the Arctic Oscillation/North Atlantic Oscillation

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We examine the climate response to solar irradiance changes between the late 17th century Maunder Minimum and the late 18th century. Global average temperature changes are small (≈ 0.3 – 0.4 K) in both a climate model including stratospheric ozone feedbacks and in empirical reconstructions. Regional temperature changes, however, are quite large. In the model, these occur primarily through a forced decrease in the amplitude of the Arctic Oscillation/North Atlantic Oscillation (AO/NAO) variability pattern. This leads to colder temperatures over the Northern Hemisphere (NH) continents, especially in winter (1–2 K), in agreement with historical records and proxy data for surface temperatures.

A22B-10 1615h

Simulated excitation of the Arctic Oscillation by orbital forcing

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The observed solar forcing over the past 165,000 years is imposed on an atmosphere model coupled to a mixed layer ocean to study the response of the Arctic Oscillation to orbital forcing. The orbitally-forced changes in the surface pressure field project strongly onto the typical spatial patterns associated with both the Pacific and Atlantic centers of action of the Arctic Oscillation. Thus orbital forcing excites preferentially the characteristic mode of variability exhibited by the unforced climate system. Feedbacks between eddies and the mean flow are responsible for this, just as they are responsible for the existence of Arctic Oscillation in the unforced climate. When orbital forcing intensifies or weakens the northern hemisphere jet stream through an change in the equator-to-pole temperature

gradient, the anomaly of the jet stream is reinforced where eddy activity is large. This results in a larger pressure signal in the storm track regions. Thus perturbations to the mean flow, whether internally-generated or orbitally-forced, are amplified the most in the storm track regions. These results have interesting implications for past variations of the Arctic Oscillation and NAO, particularly over the past 10,000 years.

A22B-11 1630h

Mechanisms of Arctic Oscillation response to volcanic aerosols and ozone changes caused by the 1991 Mt. Pinatubo eruption

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All strong equatorial volcanic eruptions during the period of instrumental observations have forced a positive phase of the Arctic Oscillation (AO) for one or two years following each eruption. The conventional view is that the volcanic effect on the AO is caused by aerosol heating in the tropical lower stratosphere that produces a stronger polar vortex that prevents the propagation of planetary waves into the polar stratosphere. A shift from transparent to reflective (for planetary waves) stratosphere changes the "top boundary condition" for the tropospheric flow and affects the tropospheric circulation. Here we study the response of Arctic Oscillation to aerosols and observed ozone changes after the June 15, 1991 Mt. Pinatubo eruption in the SKYHI GCM to test the AO mechanism.

An enhanced positive phase of the AO is reproduced in the model when forced with either aerosols or ozone. For the ozone case, stratospheric cooling, caused by ozone depletion in winter and early spring in the north polar region, increases the temperature gradient between the pole and midlatitudes in the lower stratosphere strengthening the polar vortex and the AO.

Experiments without aerosol absorption (stratospheric heating) show as strong an AO response as with the total aerosol forcing. This suggests that aerosol stratospheric warming in the tropical lower stratosphere is not the dominant AO mechanism. Stratospheric aerosols can also affect the AO by cooling of the land surface and the lower troposphere. This cooling, which is strongest in low latitudes especially in winter, reduces the tropospheric meridional temperature gradient, which leads to a decrease of the mean zonal energy and amplitudes of planetary waves in the troposphere. The corresponding decrease of decelerating Eliassen-Palm flux into the lower stratosphere causes a strengthening of the polar vortex and triggers the "wave feedback," as previously discussed. We suggest that this mechanism can also be applicable to a long-term AO trend caused by greenhouse gases, because they, due to polar amplification, also weaken the tropospheric temperature gradient.

A22B-12 1645h

Anomalous Atmospheric Circulations Forced by Volcanic Aerosols

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A Principal Component Analysis (PCA) and Combined PCA (CPCA) is applied to 30 mbar and 300 mbar Northern Hemisphere geopotential height fields, with temperature as the combined field. In the stratosphere, CPCA is found to extract a strong volcanic signal. This method and the resulting volcanic modes are compared to the traditional PCA which extracts only a weak volcanic signal. The stratospheric volcanic modes, found with CPCA, are different patterns from the leading linear PCA mode, or Arctic Oscillation (AO), suggesting

that the system's response to the volcanic forcing is not obvious. No clear volcanic signal can be extracted from a tropospheric analysis, due in part to the weaker volcanic influence, the more chaotic nature of the lower atmosphere, and other forcings such as El Niño. However, a vertical CPCA, combining 30 mbar and 300 mbar heights, extracts the volcanic modes at both levels. The resulting tropospheric volcanic mode is shown to have similarities to a composite map of 300 mbar heights representing the difference between years with a strong polar night jet and years with a weak one.

A31A MC: 123 Wednesday 0830h

The Arctic Oscillation and the North Atlantic Oscillation: Ocean Coupling and Climate Change (joint with OS)

Presiding: J Wallace, University of Washington; D Shindell, NASA Goddard Institute for Space Studies

A31A-01 0830h INVITED

Tropical Origins for Recent North Atlantic Climate Change

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Using large ensembles of climate model simulations, evidence is presented that North Atlantic climate change since 1950 is linked to a progressive warming of tropical sea surface temperatures. The ocean changes alter the pattern and magnitude of tropical rainfall and atmospheric heating, the atmospheric response to which includes the spatial structure of the North Atlantic Oscillation (NAO). The slow, tropical ocean warming has thus forced a commensurate trend toward one extreme phase of the NAO during the last half-century.

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A Simple Model of the Arctic Ocean Response to Annular Atmospheric Modes

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A simple, analytic, model of an idealized Arctic Ocean is solved. The model is an annular, rotating disk of constant-density fluid (1-layer f-plane), which is subjected to annular wind-stress forcing. The forcing is scaled to simulate the observed trend between 1979 and 1993 in geostrophic winds over the Arctic, which has been tied to the essentially annular atmospheric mode, the Arctic Oscillation. The model includes top and bottom Ekman layers, and is solved for sea-surface tilt and the interior flow. The results are compared with the sea-surface height anomalies from the same period from (1) a high-resolution general circulation model and (2) tide gauge data. The simple model agrees reasonably well, quantitatively, with the observations and the numerical integration. We propose that the model reveals a straightforward dynamical mechanism, consistent with the observed variability in Arctic hydrography, which links the Arctic Ocean variability with large-scale atmospheric modes.

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A Large Ensemble Modeling Study of the Atmospheric AO/NAO Pattern and the Role of Surface Perturbations in Wintertime Atmospheric Variability

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