carried out, and boundary layer air data covering almost 113 000 km were obtained without significant contamination from the train. A secondary CH4 maximum occurs in the annual cycle in summer: highly elevated levels of CH4 were observed in late June - August over the West Siberian lowlands which generally decreased towards East Siberia, except for the far eastern region, where frequent biomass burning events were registered. The isotopic signatures of sampled CH4 point to the wetlands as the dominant source of methane emissions, with some indications of natural gas release. Diurnal variations of 222Rn, CO2 and CH4 due to both micrometeorological conditions and varying soil and vegetation types, were used to estimate ecosystem fluxes of CO2 and CH4. Whilst background CO levels over the west Siberian wetlands were close to background values at mid-to-high northern latitudes, high CO concentrations, exceeding 1000 nmol/mol, were registered east of Chita, as a consequence of forest and other vegetation fires, which significantly affect the chemical composition of the air over Russia. O3 also showed increases in East Siberia and the far eastern region: high night-time O3 values during spring and summer coincided with CO concentration increases. Back-trajectory analyses suggest that boreal forest fires in far eastern Siberia had a significant impact on the observed CO and O3 mixing ratios.

URL: http://www.mpch-mainz.mpg.de/~dunker/Troica/index.htm

## A21C MC: 133 Tuesday 0830h

## The Arctic Oscillation and the North Atlantic Oscillation: Definitions and Mechanisms *(joint with OS)*

***Presiding:*** **N Gillett,** University of Oxford**; J Perlwitz,** NASA Goddard Institute for Space Studies

### A21C-01 0840h

### The Pacific Center of Action of the Northern Hemisphere Annular Mode: Real or Artifact?

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The leading empirical orthogonal function (EOF) of the sea-level pressure field, referred to as the Arctic Oscillation (AO) or Northern Hemisphere annular mode (NAM), consists of a dipole between the polar cap region and the surrounding zonal ring centered along 45 N. Embedded within the outer ring are centers of action over the Euro-Atlantic and Pacific sectors in which pressure fluctuates in phase. That the observed pressure fluctuations at these two centers of action are virtually uncorrelated in the observations raises the question of whether the Pacific center in the annular mode could be an artifact of EOF analysis. It is argued that sea-level pressure fluctuations at the Pacific and Euro-Atlantic centers of action of the AO/NAM would be more strongly correlated were it not for the coexistence of a second hemispheric mode in which geopotential height fluctuations over the North Atlantic and North Pacific vary out of phase. Evidence of the coexistence of such a pattern, whose signature in the 500-mb height field resembles an augmented of the Pacific/North American pattern, with a wavetrain over the Euro-Atlantic sector is presented. The inter-sectoral linkages in the outer ring of the Southern Hemisphere annular mode are obscured by coexisting modes of variability in a similar manner, but to a lesser extent.

### A21C-02 0900h

### Significance of the Interannual Seesaw Between the Aleutian and Icelandic Lows in the Interannual Variability Over the Wintertime Northern Hemisphere

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The late-winter formation of an interannual seesaw between the surface Aleutian and Icelandic lows (AL and IL, respectively) is shown to significantly impact the covariance structure of the leading mode of the interannual variability in the geopotential height field over the extratropical Northern Hemisphere. The tropospheric leading mode for early winter (November-January) is characterized by a polar-midlatitude dipole over the Euro-Atlantic sector with a high degree of the annularity, coupled with the anomalous lower-stratospheric polar vortex. Over the North Pacific, no significant anomalies are associated with this mode. After the formation of the AL-IL seesaw, however, the dipole no longer dominates in the upper-tropospheric variability. The dipole signature is masked in late winter (February-April) by the predominant combined signature of the so-called Pacific/North American pattern and a meridional dipole over the Northwestern Atlantic as an upper-level manifestation of the seesaw. Though somewhat less pronounced, the leading mode of the near-surface variability is modified accordingly in late winter by the superposition of the distinct signature of the AL-IL seesaw. The annularity of the leading mode of the tropospheric variability is thus reduced in late winter particularly at the upper levels. Nevertheless, because of the particular geographical alignment between the anomalous AL and IL, their seesaw changes the zonal wind coherently between the two ocean basins, yielding a strong projection on the meridional plane whose latitudinal profile is almost indistinguishable from the counterpart of the Arctic-midlatitude dipole.

It is argued that what is called the Arctic Oscillation in some recent literature, defined as the leading mode of the sea-level pressure variability for the entire cold season, may be interpreted as a superposition of the AL-IL seesaw upon a dominant signal of the Arctic-midlatitude dipole. The corresponding leading mode for the upper troposphere primarily represents the variability associated with the seesaw. It is also argued that the late-winter tropospheric variability over the North Atlantic may not necessarily be associated with the Arctic-midlatitude dipole. The remote influence of the North Pacific variability accounts for as much as 30% to 50% of the variance in the vicinity of the IL for the data period considered.

### A21C-03 0915h

### Is the NAO Inseparable From the Arctic Oscillation?

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A rotated principal component analysis (RPCA) is performed on cosine adjusted monthly gridded hemispheric sea level pressure anomalies over latitudes 40N to 85N and period 1946-1998. The monthly data are grouped into traditional seasons (DJF, MAM, JJA, SON) and a 12-month-averaged annual analysis is performed. The number of components retained for rotation never exceeds ten, the limit often used in similar analyses published using lower latitude datasets (e.g., Barnston and Livezey, 1987; Rogers, 1990). The methodology here contrasts that of the unrotated EOF analysis used in the original discovery of the AO. In each non-winter season the RPCA reveals the NAO to be the first component. The second component is centered only over the Arctic Ocean basin, and is here called the AO. This result is achieved in non-winter seasons with only 5-7 EOFs retained for rotation. In winter, rotation of as many as 10 components fails to separate the NAO from the AO, a result also obtained for an annually-stratified run. It will be suggested that the winter inseparability may be due to a shared storm track between the northern Atlantic and the Arctic, extending over the region between Iceland and the Barents Sea and eastward. Finally, Summer cyclonic activity over the Arctic Ocean basin is largely independent of the northern Atlantic, and a highly significant relationship is found between the AO phase and the direction of rotation (cyclonic, anticyclonic) of the Arctic Ocean.

### A21C-04 0930h

### Correlation between North Atlantic Oscillation and North Pacific Oscillation: Evidence for a Combined Mode

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The geographical disparate NAO and NPO are found to be highly correlated in time: A temporal correlation coefficient of 0.43 is found between them with extremely high statistical significance. The NAO and NPO are here identified as the non-seasonal leading EOF/PC mode derived from the monthly surface pressure data provided by NCEP for 1958-2000. This overall correlation is analyzed in both time and frequency domains to reveal interesting behavior of the oscillations. The leading EOF/PC mode for the Northern Hemisphere (NH), identified as the NH Annular Mode (NAM), is also obtained. It bears strong resemblance to the amalgamation of NAO + NPO in the EOF pattern, and not surprisingly also highly correlated with both NAO (0.88) and NPO (0.76) in time. In particular, the decadal behavior of NAO and NPO closely follow each other, and with that of NAM, showing a long-term trend which had an abrupt change since around 1988. Based on the temporal correlations and the fact that NAM encompasses NAO and NPO geographically, we conclude that NAO and NPO are major partners constituting NAM. This strongly corroborates the notion put forth by Thompson and Wallace [1998; 2000].

Thompson, W.J., and J.M. Wallace, The Arctic Oscillation signature in the wintertime geopotential height and temperature fields, Geophys. Res. Lett., 25, 1297-1300, 1998.

Thompson, W.J., and J.M. Wallace, Annular Modes in the Extratropical Circulation. Part I: Month-to-Month Variability, J. Climate, 13, 1000-1016, 2000.

### A21C-05 0945h

### The Cyclic Climate Regime of the Recent Past

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We apply a variant of Non-linear Principal Component Analysis to atmospheric observations and simulations from a Global Climate Model. Analysis of tropospheric geopotential height fields for the Northern Hemisphere shows that climate variability in the extratropics during the second half of the twentieth century is due to the existence of 3 main weather regimes. These regimes are similar to those identified recently by various groups. We show that by introducing a fourth weather regime, it is possible to build a climate cycle for the recent past. We will describe this cyclic climate regime, its relation to stratospheric variability and its link to the Arctic Oscillation. We will also describe the structure of the cyclic regime present in climate simulations conducted with a Global Climate Model.

### A21C-06 1000h

### Calculating the Fastest Growing Modes of the Atmosphere by Empirical Means.

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The study of instability and unstable modes has been instrumental in developing many parts of physics. In meteorology for instance, the theory of baroclinic instability is considered seminal. Usually instability calculations are based on manipulating the basic equations, such as they are known to us. Still many modes, such as the NAO, can not be readily related to theory. Here we follow an unbeaten track. We use a large data set (Reanalysis) of NH 500 mb daily data. We then breed growing modes by repeated application of the constructed analogue (CA) operator to an arbitrary (non-zero) initial state, while renormalizing the resulting fields to avoid e-folding to either zero or infinity. It will be shown that CA converges to complex growing time varying modes with calculable e-folding time and period. The 1st mode consists of 2 space patterns (orthogonal); their associated time-series (a deformed sine - cosine pair) are orthogonal too. The interpretation of these modes for the real world may not be entirly straightforward, but we do note that a zero frequency NAO like feature appears as the 2nd mode. Given slow growth, should these modes play a big role? Do these modes explain appreciable variance in the observations? Among the technical issues: how to calculate mode n from the data set, given that n-1 modes are already known. How does the definition of the areal extent (US) impact these modes.

### A21C-07 1040h

### Variable Coupling of the NAO to PNA

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The coupled general circulation (CGCM) model ECHAM4(T42)/OPYC3 produces a realistic representation of the winter mean PNA and NAO patterns. In this 300 year simulation their relation is strong (correlation -0.30) compared to observational data (40 years, correlation -0.15), but it appears that the same mid-latitude mechanisms are working in both the model and the real world. These mechanisms involve growth conditions (baroclinicity, latent heat availability) for transient eddies over the Atlantic stormtrack's center at Newfoundland. Sub-periods taken from the coupled run show variable correlations in a range between -0.5 an 0. Thus the rather weak observed variable coupling could be due to purely statistical reasons. We also found that ENSO variability does not play a crucial role for PNA-NAO coupling: An additional model run of ECHAM4(T30) coupled to a 50m fixed depth mixed layer ocean produces about the same patterns, correlations and mechanisms connecting PNA and NAO. The variability of the PNA-NAO relation for sub-periods is similar to the CGCM.

### A21C-08 1100h

### Annular modes in global daily surface pressure

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Annular modes are patterns characterized by synchronous fluctuations in surface pressure of one sign over the polar caps and the opposite sign at lower latitudes. The Southern Annular Mode (SAM) and Northern Annular Mode (NAM, also called the Arctic Oscillation) patterns are the leading empirical orthogonal functions (EOFs) of slowly-varying, hemispheric, cold-season, sea-level pressure anomalies (deviations from climatology). Daily indices of the SAM and NAM are a measure of the similarity between surface pressure anomaly patterns and the annular modes. Here it is shown that the first two EOF time series of daily, global, year-round, zonally-averaged surface pressure are nearly identical to the SAM and NAM indices. Together, they account for more than 57% of the daily variance of zonally-averaged surface pressure. The SAM and NAM patterns extend through the tropics, well into the opposite hemispheres. Fluctuations of the SAM and NAM indices are accompanied by interhemispheric transfer of mass.

The similarity between the first two EOFs of zonally-averaged surface pressure and the annular modes suggests that longitudinal asymmetries are not fundamental to the annular modes. The annular modes are not dependent on restricting the analysis to one hemisphere, the cold season, or to low-frequency variability. The use of global data demonstrates that the annular modes are not artifacts of the horizontal domain of the analysis. The striking symmetry between the northern and southern annular modes is evidence that the same physical process produces both modes.

### A21C-09 1115h

### Recent Advances in NAO Prediction: Forcing from the North Pacific

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Statistical forecasting schemes for the North Atlantic Oscillation (NAO)are presented. The forecasts are based on Pacific sea-level pressure trajectories. With 2 yr lead time, skills are significant but modest. At 15 month lead, forecasts are robust and skillful under stringent cross-validation, and further improve at 12 month lead. Cross-validated 1 yr forecasts correlate with 1925–2001 observations at $\sim$0.5. Other performance measures indicate similar skills, outperforming the best autoregressive models of the NAO Index. Importantly, the Pacific-based forecasts also easily outperform North-Atlantic-based forecasts using identical machinery. The results strongly suggest that the NAO is not exclusively an internal North Atlantic mode, lending credence to the notion of a hemispherically-coherent Arctic Oscillation.

URL: http://storm.uchicago.edu/~gidon/papers/nao/nao1.html

### A21C-10 1130h

### A Tilted-Trough Mechanism for AO/NAO

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The least damped mode of the linear atmospheric dynamic system with the zonal mean flow interacting with stationary waves is shown to bear much resemblance to the observed Arctic Oscillation (AO)in terms of both zonal and associated stationary wave components. This AO-like mode results from the dynamic self-organization among the components of zonal mean flow and the associated stationary waves through a so-called tilted-trough positive feedback. Namely, the anomalous AO-like sheared zonal flow generates the associated anomaly in stationary waves in such a way that the tilts of the total stationary waves are altered to reinforce the sheared zonal-flow anomaly through the anomalous momentum flux convergence. Thus the AO-like least damped mode, which can be excited by surface or other forcing, is expected to be dominant over monthly and longer time scales.

### A21C-11 1145h

### Characterisitcs of the NAO/AO

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The dynamics of the leading mode of boreal winter and its excitation by varying boundary conditions remain mostly unclear. A novel framework is presented to explain the evolution of this dominant winter mode. The framework presented will help clarify prior uncertainties associated with the dominant mode and provide excellent potential for the successful prediction of subsequent winter mean climate states.

## A22A MC: -1 Tuesday 1330h

## Current Understanding of Tropospheric Aerosol: Advances in Laboratory and Field Measurements IV

*Presiding:* **V H Grassian,** University of Iowa**; J Jayne,** Aerodyne Research Inc

### A22A-0083 1330h POSTER

### Five Years of Continuous Surface Aerosol Measurements From the DOE/ARM Southern Great Plains CART Site

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Continuous measurements of the optical and microphysical properties of aerosol particles have been made at the Department of Energy's Atmospheric Radiation Measurement Program (DOE/ARM) Southern Great Plains Cloud and Radiation Testbed (CART) site covering the five-year period from July 1996 through June 2001. Hourly, daily and monthly statistics have been calculated that illustrate aerosol variability over a range of time scales. A pronounced peak in total particle number, centered on the mid-afternoon hours (local time), is evident in the hourly statistics. A broad early morning peak in the concentration of particles larger than 0.1 $\mu$m aerodynamic diameter corresponds with a similar peak in aerosol light scattering coefficient, $\sigma_{sp}$. No strong cycles were observed in the daily statistics, suggesting that day-of-the-week has only a minor influence on the observed aerosol variability. The occurrence of an autumn decrease in single-scattering albedo, $\omega_0$, was observed and may be caused by regional-scale agricultural or transportation activities or seasonal changes in atmospheric flow patterns. The median value for $\omega_0$ over the five-year period was 0.95, but this value has decreased $\sim$0.5% per year presumably due to increased agricultural burning. The aerosol hygroscopic growth factor (f(RH)), corresponding to a relative humidity increase of 40% to 85%, showed a median value of 1.83 for the year 1999, although much lower values were observed during periods that were probably influenced by locally-generated smoke and dust aerosols. A long-term program of light aircraft flights over the site was started last year, and a statistical analysis of the aerosol properties at altitude and their relation to the surface aerosol properties is discussed. Some of the aerosol properties remain relatively constant (up to >3000 m altitude) in vertical profiles over the site while others show dramatic variation from the surface properties.

### A22A-0084 1330h POSTER

### Physical Properties of Marine Aerosols Measured on the R/V Mirai During ACE-Asia

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In order to study the process of aerosol transport from continental to the ocean, aerosol sampling and counting on surface and with kytoon system were performed in the Japanese ACE-Asia cruise, the R/V Mirai MR01-K02 (Japan Marine Science and Technology) over the Eastern region from Japan Islands during the periods from 14 to 28 May 2001. Various observations were started from Yokosuka to the point, 32 N, 152.5 E and heading northward along the 146.5 E line from 30 N to 38 N between 17 and 27 May, and returned to Sekinehama on 28 May.

Radon and thoron concentrations and aerosol size distribution with SMPS (3936N25) and two OPCs (RION KC18, KC01D) were measured on surface continuously. They decreased as leaving from the Japan Islands. Size dependent lifetime of aerosols was obtained from these data. After passing a low pressure system, the radon and super-micron aerosol concentration increased on 18 May, which was predicted by the Chemical Weather Forecasting System (CFORS).

Kytoon observation was performed at eight times along the 146.5 E line. Measurement of vertical profile up to 1000 m with OPC sonde (RION KR12) and sampling at the highest level with impactor were performed. Seven vertical profiles showed the decreasing or uniform concentration with the height increasing. However, the profile on 26 May showed the high concentration in the upper layer between 600 and 1000 m. Comparing the model prediction by the CFORS, this air mass seemed to be sulfate aerosol plumes from the Asian continent.

### A22A-0085 1330h POSTER

### Size-Dependent Aerosol Chemistry vs Altitude in Asian Outflow During ACE-Asia

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