as large or larger than the vertical variability, isotopic diffusion may be considered to act in three dimensions (rather than only vertically) when reconstructing seasonal climate parameters from isotopic records.

A51A CC: 220 C-E Friday 0830h

Atmospheric Sciences General Contributions Posters

Presiding: **B Crosson,** Global Hydrology and Climate Center

A51A-01 0830h POSTER

Climatology of large-scale cloud characteristics and precipitation amount in the East Asia

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The aerosol indirect effects of both the first and second kinds are still uncertain in climate issues as IPCC reports indicate. In particular, the second kind which deals with precipitation and cloud lifetime is more difficult. More and more pollutants are emitted recently in China due to rapid economical growth, so this influence on the atmosphere is of quite concern from social and scientific points of view. In this paper, we try to investigate the relationship between the low-level cloud fields and precipitation over China. We focus on low-level clouds here because of more interaction with aerosols compared to middle and higher clouds. We use the cloud properties such as the particle size and vertically integrated particle number obtained from AVHRR satellite remote sensing, and precipitation data that were collected from ground-based rain gauges. Then we compared monthly-mean cloud properties with precipitation amount. As for the comparison between the particle size and precipitation, we observe larger particle size as precipitation amounts increase. And as for the comparison between the cloud particle number and precipitation, less cloud droplet number can be seen as precipitation amounts increase. These phenomena are explained mainly as follows. Precipitation substantially scavenge CCN (cloud condensation nuclei) particles from the atmosphere, therefore the number of low-level cloud droplets decrease, and the cloud particle size can get larger in the less CCN environment, when precipitation increases. Larger cloud droplet size might become drizzle more easily as well in the wet condition of rainy season. In addition, we examine geographical correspondence between the low-level cloud fields and precipitation. Of course, the cold rain process such as precipitation associated with the Asian monsoon is predominant in this region. Thus we need to be careful to make direct comparisons as performed here. This sort of preliminary investigation would be, however, valuable as a primary step to get further understanding of the aerosol indirect effects of the second kind.

A51A-02 0830h POSTER

Broadband Meteorological Sensors for GPS, Geophysical and Atmospheric Measurements

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Broadband Meteorological Sensors are successfully used for GPS, geophysical and atmospheric applications. These sensor networks enable scientists to make very accurate position measurements and to detect very small pressure signals. Broadband meteorological sensors co-located with GPS networks may make it possible to detect or forecast a wide range of phenomena such as fog, rainfall, floods, storms, aircraft wake turbulence and wind shear as well as seismic and nuclear events.

URL: http://www.paroscientific.com/GPSMETSupport.htm

A51A-03 0830h POSTER

Full Spectrum Correlated-k for Shortwave Atmospheric Radiative Transfer

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Fast and accurate atmospheric radiation heating and cooling rate calculations are important for improving global climate and numerical weather prediction model performance. The radiative transfer calculations in atmospheric models must be fast so that the underlying methods can actually be implemented in the models and the calculations must be accurate so that heating and cooling rate errors do not introduce large errors into the model simulations. At present correlated-k approaches to handling gaseous absorption represent the state-of-the-art, but their efficiencies are limited by the requirement that the radiation sources be constant across relatively narrow spectral bands. In this presentation we will present the results of applying a new approach, called the full spectrum correlated-k approach, to atmospheric broadband shortwave heating rate calculations. As the full spectrum correlated-k approach does not require the radiation source to be constant across the spectrum, this approach produces clear-sky flux and heating rate errors less than 1% and 5%, respectively, using only two spectral bands. The first band extends from 0.24 - 0.68 microns and requires five quadrature points, while the second band extends from 0.68 - 4.60 microns and requires ten quadrature points. Requiring only 15 calculations for relatively accurate broadband shortwave heating rate calculations, the full spectrum correlated-k approach may turn out to be an attractive one for numerical model radiative transfer calculations.

A51A-04 0830h POSTER

Development of Quantitative Precipitation Forecast (QPF) Confidence Factor Using Short Range Ensemble Forecasts

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Hydrometeorological Prediction Center (HPC) produces a suit of deterministic quantitative precipitation forecast (QPF). The verification statistics shows a steady but gradual improvement. While these forecasts have proven to be useful as they are, they offer no information concerning the uncertainties of individual forecasts. The uncertainty in manually derived HPC QPF can be related directly to the inherent uncertainty in model predictions that is the basis for all HPC forecasts. The availability of ensemble forecasts has allowed forecasters to better assess the uncertainty of model forecast. This study is an attempt to objectively quantify the level of confidence that is justified in a particular HPC QPF by relating errors in HPC QPF to ensemble forecast spread. The first step was to seek out a relationship between the desired quantity, the absolute error (AE) of the HPC QPF, and a known quantity such as the spread from the short range ensemble forecast. Our study indicates that the AE of HPC QPF is highly correlated with ensemble QPF spread. Using the regression model equations derived at each horizontal grid point for each season, we predict an AE of HPC QPF associated with an individual ensemble QPF spread and 95% confidence interval (CI) of the AE. Based on the AE CI forecast and the QPF itself, we also predict 95% CI of the QPF. Currently the CI forecasts are processed for the continental US twice (00z and 12z) per day. The verifications for these CI forecasts have been (and will be) performed for a variety of seasons, geographical regions, various CI ranges, and QPF categories as well as overall regime.

A51A-05 0830h POSTER

The Low-Level Jet and Moisture Transports Over the Upper Mississippi Basin as Simulated by the Canadian Regional Climate Model

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The feedbacks between the low-level jet (LLJ) and the soil moisture are studied with the CRCM that includes a physically-based land-surface scheme (CLASS). Hypothesis testing experiments are designed to explore the connection between the location and temporal variability of the LLJ and sources of moisture over the continent and the Gulf of Mexico. The drought of 1988 and floods of 1993 were used as periods to evaluate the model and determine the equilibration time scale for the land scheme which was found to be about 18 months. The model is able to simulate precipitation and moisture fluxes that are similar in both magnitude and pattern to observational data during summers of 1988 and 1993. To explore the local influence of soil moisture, the simulated values of 1993 were replaced with those simulated for the 1988 summer moisture fields. The results show a significant reduction in precipitation but also an important change in the magnitude and location of a southerly LLJ over the Upper Mississippi basin region. Additional experiments have been designed to explore the influence that orography exerts over the local development of the southerly LLJ in particular the observed reversal occurring from winter to summer. The relative importance of thermal influences versus a mechanical explanation of the maintenance of the jet is evaluated.

A51A-06 0830h POSTER

Snow Sublimation and Canopy Radiation Issues in the Canadian Land Surface Scheme

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The Canadian Land Surface Scheme (CLASS) does not explicitly include multiple scattering below canopies although Nijssen and Lettenmaier (1999) have demonstrated that this can impact significantly on the energy budget when there is snow on the ground. The model also omits blowing snow sublimation. This paper targets the representation of sublimation from snow in canopies and in blowing snow through the incorporation of multiple scattering and an empirical fit to Piektuk model blowing snow results. Friction velocity and the determination of the blowing snow threshold wind velocity are keys to the transfer of Piektuk model results to CLASS.

A51A-07 0830h POSTER

Effects of Urban Heat Island Mitigation Strategies on Current and Future Meteorology of Atlanta, Georgia

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The characterization of land use/land cover is an integral component of an ongoing air quality modeling project focused on evaluating strategies for reducing the Urban Heat Island (UHI) and improving air quality in Atlanta, Georgia. The UHI mitigation strategies' applied in this project involve Cool Communities' principles of high albedo pavement and roofing as well as increased urban tree canopy. These strategies have been developed based on input from local stakeholders and represent conditions that are attainable assuming broad-based support from local government and the community. In order to evaluate the impact of these strategies on urban meteorology (principally near-surface air temperature) and ultimately on air quality, mesoscale model simulations have been performed for the Atlanta region based on land use for 1999 and projected to 2030 using the Spatial Growth Model assuming Business as Usual' development. Significant land use change associated with continuing urban sprawl is expected from now until 2030. Model simulations based on identical synoptic forcing were performed to evaluate the effects of local land use change on local and regional meteorology. For the 2030 case, results from Business as Usual' and UHI mitigation strategies' simulations will be compared. The impacts of higher urban albedo and increased tree cover will be examined separately and in combination.

A51A-08 0830h POSTER

VHF radar observations of mean winds in the troposphere at Taiki-cho, Hokkaido and some comparison results with balloon wind measurements

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The Telecommunications Advancement Organization (TAO) has recently installed a new VHF radar at Taiki-cho, (420 29' 51" N, 1430 26' 31" E), Japan. This radar was developed in order to support the launch of a Stratospheric Platform for telecommunications and broadcasting. The radar operates at a frequency of 46.5 MHz, with a peak power of 12 kW. It consists of 48 linear dipoles. Continuous observations at Taiki-cho started in August 2002. The 46.5 MHz operating frequency enables the detection of tropospheric winds in the altitude range of approximately 250 m - 12 km. The height resolution varies from 75 m to 450 m (0.5 s - 3 s); these depend on the pulse width. Accordingly, below 4 km the height resolution is 75 m, and above 4 km the resolution changes to 450 m. For further detailed analysis, the radial wind velocities collected at every one minute are screened for sufficient signal-to-noise ratio, and then incoherently time-averaged to produce the hourly, daily or monthly mean zonal and meridional values of the winds. We have initiated the validation study of the radar winds by using the balloon winds which are collected at two nearby stations, Sapporo (433.4N, 14119.9E) and Nemuro (4319.7N, 14535.4E). Analysis of seven months data shows good agreement between the radar and balloon measurements. A correlation coefficient of 0.9 is found and this indicates the reliability of VHF radar winds.

A51A-09 0830h POSTER

Value-added Data Services at the Goddard Earth Sciences Data and Information Services Center

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The NASA Goddard Earth Sciences Data and Information Services Center (GES DISC), in addition to serving the Earth Science community as one of the major Distributed Active Archive Centers (DAACs), provides much more than just data. Among the value-added services available to general users are subsetting data spatially and/or by parameter, online analysis (to avoid downloading unnecessary all the data), and assistance in obtaining data from other centers. Services available to data producers and high-volume users include consulting on building new products with standard formats and metadata and construction of data management systems. A particularly useful service is data processing at the DISC (i.e., close to the input data) with the users' algorithms. This can take a number of different forms: as a configuration-managed algorithm within the main processing stream; as a standalone program next to the on-line data storage; as build-it-yourself code within the Near-Archive Data Mining (NADM) system; or as an on-the-fly analysis with simple algorithms embedded into the web-based tools. Partnerships between the GES DISC and scientists, both producers and users, allow the scientists concentrate on science, while the GES DISC handles the of data management, e.g., formats, integration and data processing. The existing data management infrastructure at the GES DISC supports a wide spectrum of options: from simple data support to sophisticated on-line analysis tools, producing economies of scale and rapid time-to-deploy. At the same time, such partnerships allow the GES DISC to serve the user community more efficiently and to better prioritize on-line holdings. Several examples of successful partnerships are described in the presentation.

URL: http://daac.gsfc.nasa.gov

A51A-10 0830h POSTER

An Ocean Surface Albedo Look-up Table for Atmospheric Radiative Transfer and Climate Modeling

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Unlike most land surfaces, the ocean surface albedo is highly dynamic. It varies greatly with solar zenith angle, wind speed, aerosol/cloud properties and volume scattering in sea water. Examples of spectral and broadband ocean surface albedo from in situ measurements are presented to show the effects on ocean albedo by solar elevation, wind speed, aerosol/cloud optical depth, and chlorophyll concentration. A coupled ocean-atmosphere radiative transfer model is used to simulate the measurements, and the validated model is then used to create an ocean surface albedo look up table for various atmospheric, oceanic and weather conditions. This table provides a more accurate ocean surface albedo database for radiative transfer and climate modeling of atmosphere and ocean and is available from http://www-cave.larc.nasa.gov/cave/. A Fortran code for reading the table is also provided and it is easy to be incorporated into any radiative transfer code. The table described here is used for routine processing of the CERES Surface and Atmosphere Radiation Budget. Ocean albedo under clear conditions has sharp sensitivities, some of which are surpsising, but they can be explained physically. Under clear conditions with low sun, there is a very large spectral variation in the ocean albedo, and the broadband value falls by 0.02 when the wind speed increases from 1 m/sec to 5 m/sec; the introduction of moderate aerosol loading (AOT = 0.4) further decreases the surface albedo by 0.04. We have the opposite with high sun, where aerosols slightly increase the surface albedo.

URL: http://snowdog.larc.nasa.gov/jin/getocnlut.html

A51A-11 0830h POSTER

Examination of Heavy Metals and Particulate Matter Exposures and Effects in Susceptible Wards in the Washington, D.C. Region

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The District of Columbia has one of the greatest health disparities of cancer in the nation and ranks seventh highest as one of the unhealthiest places to live due to poor air quality (EPA Report, 1999). Also, a 1999 report from the Centers for Disease Control stated that the District had the highest overall rate of cancer incidence in the nation. Particulate matter is one of the major contributors to pollution in the environment. Quite often particulate matter is composed of toxic materials including heavy metals, pesticides, and spores. In some cases, the heavy metal particulates are considered carcinogenic. They are typically characterized as particles with diameters smaller than 1 μm and are easily deposited into the alveolar regions of the human lungs, which can impose threatening health risks. In this study, I will design and execute an environmental exposure assessment for PM2.5, PM10, and heavy metals like chromium, as well as lead, cadmium and arsenic, in four observed wards of Washington, DC. Most interestingly, spatial distributions of both aerosols and heavy metals will be characterized as a function of size and mass properties. This will formulate a limited climatology of both types of particulate matter and selected heavy metals for specific regions within the District of Columbia. This dataset will further be related to epidemiological data and health outcomes for the observed areas of study. The essence of this study lies in its notoriety as the first to generate a dataset that focuses on toxic air pollutants in particular wards and may be utilized in various aspects of public health.

A51A-12 0830h POSTER

Analytical Solutions for Number Densities in the Homosphere

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Atmospheric number densities are governed by a differential equation obtained from the hydrostatic equation and the perfect gas equation. In the homosphere, the average molecular weight of gases is constant and the density is governed by the altitudinal variation of gravitational acceleration and temperature only. Exact solutions for the number densities are obtained in the troposphere and mesosphere (where the temperature decreased linearly with altitude) and in the stratosphere (where the temperature increased linearly with altitude). The results are in close agreement with those given by the U. S. Standard Atmosphere in tabular form. The density profiles in logarithmic scale exhibit negative curvatures (convexity upwards) in the troposphere and mesosphere and positive curvature (concavity upwards) in the stratosphere. The magnitude of the curvature depends on the slope of the temperature profile and is the greatest in the troposphere followed by the mesosphere and stratosphere in that order. The inflection points in the density profiles (in logarithmic plot) mark the locations of the tropopause, stratopause and mesopause.

A51A-13 0830h POSTER

Observations of Mesospheric and Lower Thermospheric waves at Resolute Bay

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ERWIN - an E-region wind interferometer is a ground based field-widened Michelson Interferometer (Gault et. al. 1996) stationed since 1993 at the Early Polar Cap Observatory (EPCO) at Resolute Bay in the Canadian Arctic (74.9^o N, 94.9^o W). Erwin measures wind speeds in the upper mesosphere and lower thermosphere region (about 80 - 100 km altitude) using airglow emissions from three wavelengths, OI(557.7 nm), OH (6,2)P_1(3) (843.0 nm) and O2(0,1)(866.0 nm). Observations show prominent semi-diurnal and diurnal tidal and other planetary wave signatures, with some variability through the Arctic winter season. Spectral features of the observed wave activity will be presented. Correlation between stratospheric assimilated temperatures and atmospheric wave activity is also investigated.

URL: http://stpl.cress.yorku.ca/gordon

A51A-14 0830h POSTER

Monthly Estimates of Fossil Fuel Carbon Dioxide Emissions from Five European Countries: The United Kingdom, France, Spain, Italy and Poland

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Human consumption of fossil fuels has greatly contributed to the rise of carbon dioxide (CO2) emissions in the Earth's atmosphere. To better understand the global carbon cycle, it is important to identify the major sources of these fossil fuel emissions. Annual analyses for fossil fuel carbon dioxide emissions have dominated the literature to this date. By studying the monthly consumption of fossil fuels in various countries, a better understanding of precisely when the carbon by-products of these fossil fuels are released into the atmosphere can be gained. Monthly sales quantities for the United Kingdom (UK), France, Spain, Italy and Poland were collected from 1984 through 1999 on natural gas and liquid fuels from an International Energy Agency dataset. In addition, sales figures for coal consumption in the UK were collected from the Energy Institute. These sales figures represent a major portion of the total fossil fuel consumption in the chosen countries. The proportion of a particular fossil fuel consumed in a given month was determined by dividing the monthly sales values for the fuel by the annual sales values for the year. This fraction was then multiplied by the annual carbon dioxide values reported by the Carbon Dioxide Information Analysis Center (CDIAC) at Oak Ridge National Laboratory (ORNL) to estimate the monthly carbon dioxide emissions from the respective fuels. The advantages of the methodology used are: 1) monthly fluxes are consistent with the annual flux as determined by the widely-accepted CDIAC values, and 2) its general application can be easily adapted to other nations for determining their sub-annual time scale emissions. The major disadvantage of this methodology is the proxy nature inherent to it. Only a fraction of the total emissions are used as an estimate in determining the seasonal cycle. The error inherent in this approach increases as the fraction of total emissions represented by the proxy decreases. In general, the monthly and annual CO2 emissions derived from liquid fuel and natural gas consumption in the five countries of interest increased over the observed fifteen year time scale. CO2 emissions from coal consumption in the UK, however, declined over time. Monthly CO2 emissions from all fuel types appeared higher in the fall and winter months than the spring and summer ones. It is anticipated that the results of this study and others like it will demonstrate that better knowledge of the monthly variation of the annual fossil fuel flux will lead to a better understanding of the global carbon cycle. This in turn holds promise for increased accuracy in global carbon cycle modeling. Finer spatial and temporal resolution of emissions data should also improve understanding of the relationship between human activities and the global carbon cycle and of the opportunities for reducing emissions.

A51A-15 0830h POSTER

Modeling Seasonality in Carbon Dioxide Emissions From Fossil Fuel Consumption

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Using United States data, a method is developed to estimate the monthly consumption of solid, liquid and gaseous fossil fuels using monthly sales data to estimate the relative monthly proportions of the total annual national fossil fuel use. These proportions are then used to estimate the total monthly carbon dioxide emissions for each state. From these data, the goal is to develop mathematical models that describe the seasonal flux in consumption for each type of fuel, as well as the total emissions for the nation. The time series models have two components. First, the general long-term yearly trend is determined with regression models for the annual totals. After removing the general trend, two alternatives are considered for modeling the seasonality. The first alternative uses the mean of the monthly proportions to predict the seasonal distribution. Because the seasonal patterns are fairly consistent in the United States, this is an effective modeling technique. Such regularity, however, may not be present with data from other nations. Therefore, as a second alternative, an ordinary least squares autoregressive model is used. This model is chosen for its ability to accurately describe dependent data and for its predictive capacity. It also has a meaningful interpretation, as each coefficient in the model quantifies the dependency for each corresponding time lag. Most importantly, it is dynamic, and able to adapt to anomalies and changing patterns. The order of the autoregressive model is chosen by the Akaike Information Criterion (AIC), which minimizes the predicted variance for all models of increasing complexity. To model the monthly fuel consumption, the annual trend is combined with the seasonal model. The models for each fuel type are then summed together to predict the total carbon dioxide emissions. The prediction error is estimated with the root mean square error (RMSE) from the actual estimated emission values. Overall, the models perform very well, with relative RMSE less than 10% for all fuel types, and under 5% for the national total emissions. Development of successful models is important to better understand and predict global environmental impacts from fossil fuel consumption.

A51B CC: 520 D Friday 0830h

Large-Scale Climate Trends and Processes *(joint with GC)*

Presiding: **G Schmidt,** NASA Goddard Institute for Space Studies**; P Rasch,** National Center for Atmospheric Research

A51B-01 0830h

Atmospheric Ar/N_2 Measurements as a Tracer for Air-Sea Heat Flux

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High-precision mass spectrometer measurements of the argon to nitrogen ratio (Ar/N_2) can be used as a tracer for air-sea heat flux. Because argon and nitrogen are, in effect, inert gases in the atmosphere, their concentrations depend significantly on changes in seawater gas solubility at the ocean surface. As water temperature rises, the solubility of each gas drops, and more gas is released to the atmosphere. The reverse happens as heat is released from the ocean and water temperatures cool. Ar/N_2 measurements allow us to address questions of how heat flux into and out of the ocean varies latitudinally and on seasonal and interannual time scales. Such issues are important to climatological questions on both local and global scales: How much heat is taken up by the ocean? How is it distributed within the ocean? Will such distributions and fluxes change in the future? As part of a long-term monitoring program, Ar/N_2 measurements will also be able to provide an independent estimate of the amount of heat taken up by the ocean due to global warming. We now have three years of Ar/N_2 data from our flask sampling program, consisting of nine stations along the Pacific rim from Alaska to Antarctica. Triplicate flasks are collected every two weeks and sent back to our lab for analysis. Annual cycles at our mid- and high-latitude stations already show some discrepancies with atmospheric transport predictions. In addition, we are in the initial stages of building a data set of continuous Ar/N_2 measurements at our La Jolla station. The first three months of data have already yielded insight that will help improve the flask measurement program.

A51B-02 0845h

The Role of Relative Humidity in Runaway Greenhouse and Radiative-Convective Multiple Equilibria

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A radiative-convective model has been a useful tool in studies of atmospheres and climate. Previous studies have demonstrated that such model exhibits a runaway greenhouse beyond a critical surface temperature, and that such model may exhibit multiple equilibria. However, relatively little attention has been paid to the role of relative humidity. We show that interactive relative humidity can give rise to a different kind of runaway greenhouse and multiple equilibria if the strength of relative humidity feedback exceeds a critical value. The framework we employ will serve as a diagnostic tool for further research on runaway greenhouse and radiative-convective multiple equilibria. Extending the theory for a gray atmosphere, we also derive conditions for the tropospheric radiation limit in a non-gray atmosphere.

A51B-03 0900h

A Rotating Dishpan Laboratory Experiment with both Baroclinicity and Planetary beta effect

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The most intrinsic nature of atmospheric motion as a geophysical fluid may be that the motion is a natural convection which is confined by strong gravity between two rotating concentric spherical shells. Two important factors which create this nature are considered as atmospheric baroclinicity and planetary beta effect. Both factor commonly due to spherical shape of the Earth. The baroclinicity creates not only the westerlies but also its meander. And the beta effect practice re-distribution of vorticity in planetary scale by using properties of planetary waves. The Earth's general circulation is maintained and changed through these actions. In traditional annular rotating water tank experiment, various regime of fluid motion were observed. However, the latitudinal structure is primarily decided, because its device has channel shape. In our preliminary dishpan type experiment, inner cooling cylinder is slimed down extremely. It was found that the flow field makes abrupt transition from axisymmetric to unaxisymmetric beyond a critical value of rotating speed. However we also can't discuss about spherical effect for latitudinal structure, because its device has no beta effect. On the other hand, in rotating dishpan experiment with not barolinicity but planetary beta effect only, it was found that the polar vortex sudden reversal (stratospheric sudden warming) is easily simulated. However, it is not a spontaneous general circulation model, because initial polar vortex and planetary waves are excited compulsorily. Motive of this study is to deepen the understanding of non-periodic phenomena such as abnormal weather or the blocking. The first step purpose of this study is development of new type rotating dishpan experiment system with not only baroclinicity but also planetary beta effect. Main result of our experiment are as follows. 1: By the analysis of surface flow field, it was found that the axisymmetricity break down according to the increase of system rotating speed. And this critical value is shifted to higher rotation side according to the increase of temperature difference between heating and cooling sections. And this tendency is consistent with the traditional annular experiment. 2: By analysis of inner structure of flow and temperature field, it was found that the westerly flow is more strong according to increase of height from the bottom and also the westerlies is more strong according to increase of temperature difference between heating and cooling sections. The relationship of flow and temperature field is consistent with the thermal wind relation. Thus, the basic structure of troposphere in the Earth's atmosphere was realized by laboratory experiment. Further development of this experiment is expected in order to understand various non-linear and non-periodic phenomena in the Earth's atmosphere.

A51B-04 0915h

The Effect of ENSO on Tibetan Plateau Snow Depth and the South Asian Monsoons: A Stationary Wave Teleconnection Mechanism

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An atmospheric stationary wave teleconnection mechanism is proposed to explain the effects of ENSO on Tibetan Plateau snow depth and the South Asian monsoons. Using statistical analysis, potential vorticity diagnostics and ray tracing, we show how wintertime ENSO conditions affect Tibetan Plateau snow pack accumulation. Anomalous atmospheric convection above the central and eastern equatorial Pacific Ocean, associated with El Nino conditions, produces northward and eastward propagating stationary barotropic Rossby waves in the troposphere. These waves refract off the North American jet, turning equatorward, and enter the North African-Asian jet over the eastern Atlantic Ocean. Once there, the waves move with the jet across North Africa, South Asia, the Himalayas, and China. Anomalous increases in upper tropospheric potential vorticity induced by these Rossby waves over the Tibetan Plateau favor convection and wintertime snowfall. This increased snowfall produces a larger Tibetan