NOAA Center for Weather and Climate Prediction

The department offers an exciting curriculum and a chance to undertake cutting-edge research with its outstanding faculty; teaching opportunities are also available.
The department has close relationship with the university's **Earth System Science Interdisciplinary Center**, Cooperative Institute for Climate and Satellites, and the Joint Global Change Research Institute. The imminent arrival of NOAA's **National Center for Weather and Climate Prediction (NCEP)** on the university's research campus will offer more possibilities.

Close proximity to the **Washington DC metro area** provides opportunity to interact with scientists at **NASA**, **NOAA**, **DOE**, and **EPA** laboratories, and also access to a number of cultural events and activities in and around the nation's capital.

The Department of Atmospheric & Oceanic Science seeks talented undergraduates with backgrounds in physical sciences, mathematics and/or engineering for graduate research assistantships in:

- Atmospheric and Oceanic Data Assimilation
- Analysis and Modeling of Climate Variability and Change
- Atmospheric Chemistry: Aerosols and Pollution
- Analysis and Modeling of Tropical Cyclones
- Remote Sensing of the Atmosphere and Oceans
- Earth System Science: Global Carbon & Water Cycles

The department graduate students are a distinguished, vibrant group (~60 strong) that includes several national fellowship recipients. Current stipend begins at $24,300 per year and is in addition to tuition remission and health benefits.

Visit our admissions page (http://www.atmos.umd.edu/education/prospective.html) for the online application procedure.
Apply by February 1 for best consideration.

Study@atmos.umd.edu
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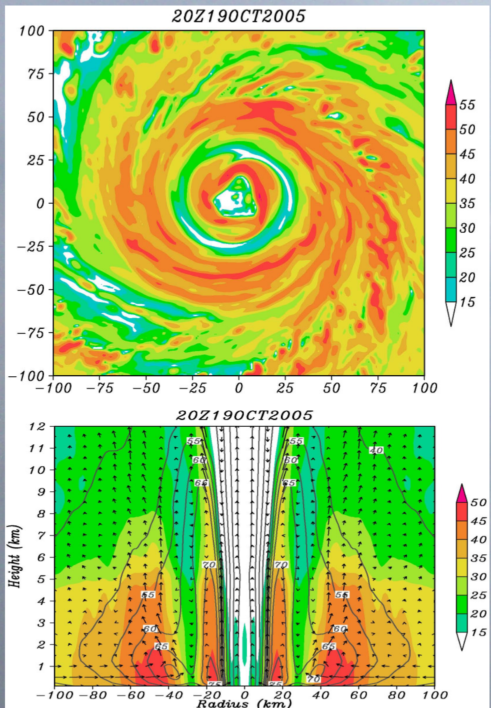
3409 Computer & Space Sci. Bldg.
University of Maryland
College Park, MD 20742-2425

UNIVERSITY OF MARYLAND

Graduate Studies in the

Department of Atmospheric and Oceanic Science

UNIVERSITY OF MARYLAND



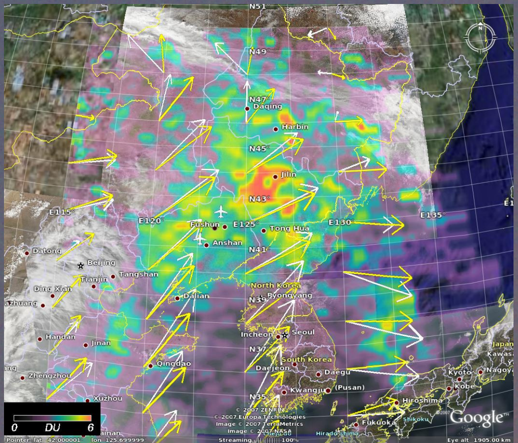
Prof. Da-Lin Zhang and his research group use the Weather Research and Forecast (WRF) model to study the three-dimensional structures and evolution, nonlinear dynamics, and processes leading to the development of **tropical cyclones**. The above figures are the model-produced radar reflectivity (shadings), tangential winds (solid lines), and vertical in-plane flows (arrows) showing the generation of double eyewalls associated with Hurricane Wilma (2005). In this project, the **WRF model**, with the finest grid resolution of 1 km, reproduces quite well the track and intensity change, particularly the rapid deepening rate of 9 hPa h^{-1} and the minimum central pressure of 882 hPa. During the rapid deepening period, the eyewall exhibits polygonal shapes, ranging from triangles to hexagons associated with mesovortices and **eyewall replacement** processes. The dynamically consistent model results provide much needed information for improving our understanding of **hurricane dynamics**, which will in turn help improve our prediction of hurricane track and intensity in the future.

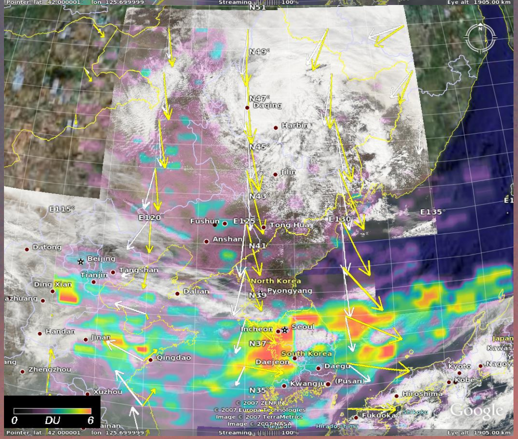
What are the linkages between climate change and atmospheric chemistry? Scientists with NASA's TC4 mission used three aircraft and numerous satellite instruments to quantify these linkages. The DC-8 research aircraft (background), which carries 50 scientists and crew to 12 km altitude, is shown during take off. The WB-57 and ER-2 aircraft (foreground), which reach altitudes of 17 and 20 km, respectively, flew along flight paths coordinated with the DC-8. Insets: interior of the DC-8 (left) and WB-57 pilots (left). *Photos courtesy of Prof Ross Salawitch, who helped plan this mission and leads a computer modeling data analysis effort.*

Prof. Ross Salawitch and his research group (www.atmos.umd.edu/~rjs) develop computer models used to compare to observations of chemical species obtained from orbital, air-borne, balloon, and ground based platforms. Their focus is on stratospheric **ozone** depletion and recovery, air quality, and the **global carbon cycle**. Their studies are motivated by the need to define how **atmospheric composition** is being altered by emission of pollutants and greenhouse gases that drive climate change. They participate in NASA atmospheric chemistry field campaigns, including the TC4 mission that took place in San Jose, Costa Rica during the summer of 2007 (www.espo.nasa.gov/tc4) and the ARCTAS mission that was based in Fairbanks, Alaska and Cold Lake, Canada during 2008 (www.espo.nasa.gov/arctas). The next **field campaign** will likely deploy from the Tropical Western Pacific region. We are also on the NASA Aura and ACOS (Atmospheric CO2 Observations from Space) science teams.

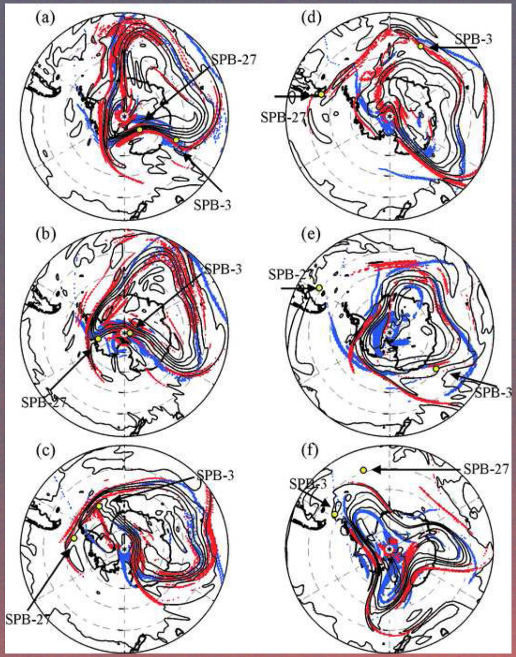
We offer exciting research opportunities in atmospheric chemistry that allow students to participate in satellite missions and field campaigns and interact with scientists at national laboratories such as NASA and NOAA.

Prof. Daniel Kirk-Davidoff is interested in how and why climate has changed in the past, and in how to devise better ways to test the models we use to predict climate change in the future. He and his students use computer climate models to understand how the climate system responds to changes at the **earth's surface**, whether due to geological processes like mountain building, or fast human processes like the construction of **wind turbines**. They work to develop tests of the climate models that are used to predict future climate by comparing **climate model predictions** of time-lagged correlations among climate variables with the same statistics in observations. In addition they are involved in an effort to develop an optimal satellite climate monitoring system (the NASA CLARREO mission), investigating the dependence of sampling errors on the orbital characteristics of the system.





The **Atmospheric Chemistry group** at UMD pursues both local and global **air quality** issues. The images on the left shows 5 April 2005, a polluted day over East Asia. Colors indicate SO_2 content as measured by the NASA OMI **satellite** instrument, with hotter colors reflecting greater pollution. Remotely sensed data were calibrated and evaluated with *in situ* **measurements** at the locations shown with small **aircraft** images. The passage of a cold front brought northerly winds and convective clouds that flushed out the pollutants, but also lofted them to high altitudes thus transforming a local air pollution problem into a regional climate problem.[***Dickerson** et al.*, 2007; *Krotkov et al.*, 2008].



Prof. Kayo Ide takes interdisciplinary approaches to study **geophysical fluid dynamics** and understand fundamental processes in complex systems by integrating observations, models, and mathematical **theories**. For example, large-scale stirring of air parcels during the warming of the Southern Hemisphere stratosphere was examined using a set of superpressure balloon (SPB) observations through the application of the dynamical systems theory to the wind field obtained by an operational Goddard Earth Observing System-5 (GEOS-5). The above figure shows potential vorticity map on November 21 (a) to December 2 (f) , 2005, along with the locations of the SPBs (green dots) and high values of finite time Lyapunov exponent (FTLE) in backward (red) and forward (blue) times. The FTLEs reveals vortex breakup and provide the **Lagrangian** template to explain chaotic motion of the SPBs during the period. Applications of dynamical systems theories can be used also to improve **data assimilation** methods used in the numerical weather prediction and ocean forecasting.

Research scientist **Dale Allen** and his students use regional and global models as tools to study the impact of anthropogenic and natural emissions on **tropospheric photochemistry and air quality**. Figure 1 compares how an eastern U.S. ozone pollution event is viewed from space by the OMI- and TES-instruments (ovals) on NASA's Aura **satellite** and simulated by the **WRF model** run with chemistry. Figure 2 shows the impact of lightning-NO emissions on NO_x amounts during Flight 5 of the INTEX-A field campaign as simulated with NASA's GMI model.

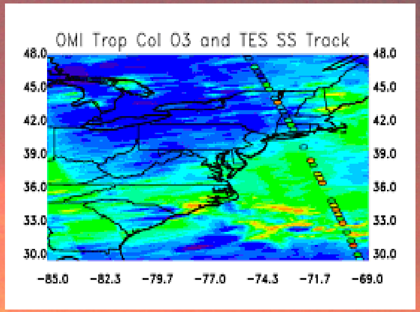


Figure 1. Tropospheric ozone column over the Mid-Atlantic region on 9 Jul 2007.

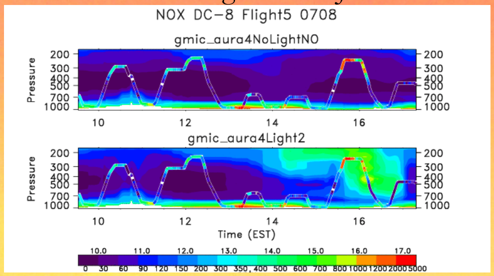
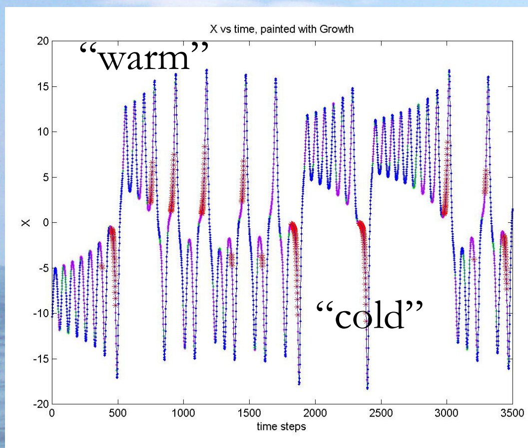


Figure 2. NO_x is compared to measured NO_x (ribbon) for GMI simulations without (top) and with lightning-NO emissions.

Prof. Eugenia Kalnay's research interests span **predictability** and **ensemble** forecasting, numerical weather prediction, **data assimilation**, coupled ocean-atmosphere **modeling**, climate change, and the atmosphere of **Mars**.

Forecasting Rules for the Lorenz Model:
(as discovered by Prof. Kalnay and her students)



Growth rate of **bred vectors**:

A * indicates fast growth (>1.8 in 8 steps)

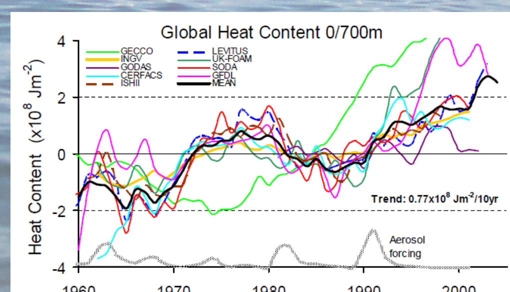
1. **Regime change**: The presence of red stars (fast BV growth) indicates that the next orbit will be the last one in the present regime.

2. **Regime duration:** One or two red stars, next regime will be short. Several red stars: the next regime will be long lasting.

These rules surprised Lorenz himself!

Prof. James Carton's research involves **physical oceanography** and its interaction with the atmosphere. The oceans play a crucial role in regulating our climate. However, key aspects of this role remain uncertain because of the limited number of historical observations and their uneven distribution. Carton and Giese (2008) address this uncertainty by combining numerical simulation and observations through data assimilation to produce the SODA **ocean reanalysis** -- essentially a gridded reconstruction of the history of ocean circulation, temperature, salinity, etc.

The **oceanic mixed layer** is the near-surface layer of the ocean that interacts directly with the atmosphere, exchanging heat, freshwater, and gases such as O2 and CO2. In Carton et al (2008) we explore year-to-year changes in the winter mixed layer. Here we see a basin-scale pattern of variability of the depth of the mixed layer which is related to the Pacific Decadal Oscillation.



Ocean reanalyses are gradually improving our ability to track long term changes in ocean properties such as **heat content**. Carton and Santorelli (2008) compare nine recent global estimates and find a general convergence toward an average rise of 0.77x108 Jm-2/10yr or 0.24Wm-2.

Prof. Raghu Murtugudde leads a multidisciplinary team in creating a suite of prediction tools on days to decadal time periods known as the **Chesapeake Bay Forecast System**. This 18-month-old project can compile and track how factors in the ecosystem, such as air quality, algae and human behavior, might combine to influence the regional environment, and the way its **climate** might change over the next four decades.

The researchers are providing answers to many of the questions facing government scientists equipped only with raw data: How do microbes respond to certain **scenarios**? How will people move within a given region? How might disease spread? Using existing soil and water assessments, regional atmospheric models and other “off-the-shelf” tools, the team adds information on pathogens and air and water quality, then delivers refined predictions to NASA and the National Oceanic and Atmospheric Administration, or NOAA.