New Capabilities for Hurricane Measurements - HIWRAP

Gerald Heymsfield, Code 613.1, NASA GSFC

Wind measurements are crucial for understanding and forecasting tropical storms since they are closely tied to the overall dynamics of the storm. The High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) is a dual-frequency (Ka- and Ku-band) conical scan system, designed for operation on the high-altitude (20 km) Global Hawk UAV. The HIWRAP is able to measure line-of-sight and ocean surface winds at higher spatial and temporal resolution than obtained by current satellites and lower-altitude instrumented aircraft.

- First science flights on the Global Hawk during the Genesis and Rapid Intensification Processes (GRIP) campaign during August and September 2010.
- Hurricanes (Karl, Earl, and Matthew) were overflown with HIWRAP during GRIP.
- First conical scan airborne radar data from high altitudes will provide important information on the hurricane genesis and rapid intensification.

Figure 1. HIWRAP instrument and Global Hawk with radome.

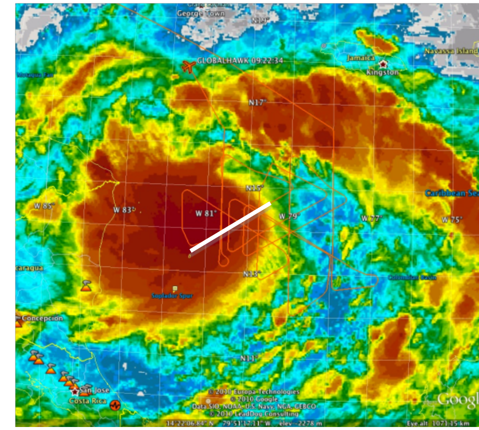


Figure 2: Hurricane Matthew on 24 August 2010 with Global Hawk flight tracks (red) and flight leg (white) superimposed.

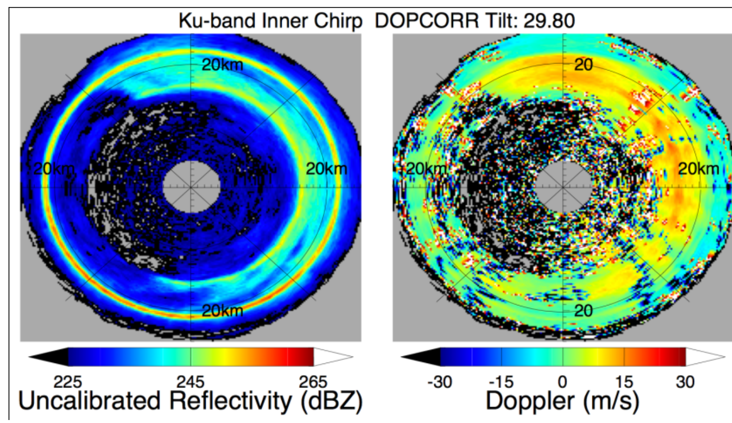
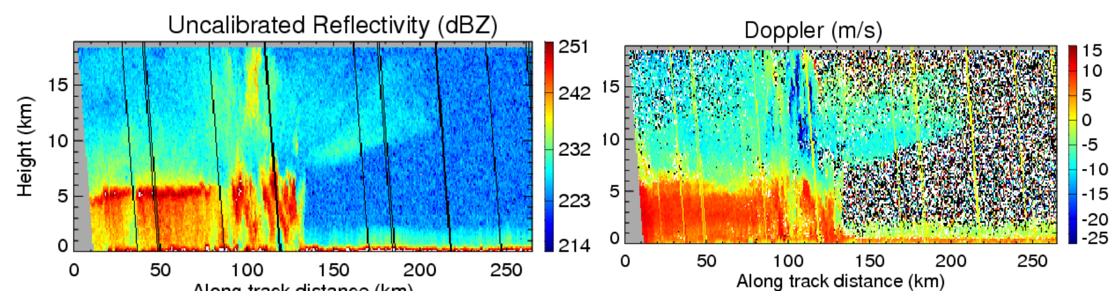


Figure 3. Polar plot of power and line-of-sight Doppler from one sweep of HIWRAP's inner beam in precipitation.

Figure 4. Vertical cross sections of uncalibrated reflectivity (left) and vertical component of hydrometeor velocity reconstructed from fore and aft looks along nadir.



Laboratory for Atmospheres

Name: Gerald Heymsfield, NASA/GSFC, Code 613.1
E-mail: gerald.heymsfield@nasa.gov
Phone: 301-614-6369

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2) Heymsfield, G., L. Li, J. Carswell, D. Schaubert, 2011: Status of the High-altitude Imaging Wind and Rain Airborne Profiler (HIWRAP), NASA Science Technology Conference (NTSC 2008), College Park, MD, 4 pp.
3) Heymsfield, G. M., L. Tian, A. J. Heymsfield, L. Li, and S. Guimond, 2009: Characteristics of deep and subtropical convection from nadir viewing high-altitude airborne radar. *Journal of the Atmospheric Sciences,* **67***,* 285-308.

Contributors: L. Li (GSFC), M. Mclinden (GSFC), M. Perrine (GSFC), L. Tian (UMBC/GEST), A. Reynolds (GSFC), S. Guimond (NASA/NPP)

Technical Description of Figures:
The High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) is a dual-frequency (Ka- and Ku-band), dual-beam (30^0 and 40^0 incidence angles), conical scan system, designed for operation on the high-altitude (20 km) Global Hawk UAV. The HIWRAP is able to measure line-of-sight winds through volume backscattering from clouds and precipitation, enabling calculation of horizontal winds in these regions. It also has the capability to measure ocean surface winds through scatterometry techniques, similar to QuikScat.
Figure 1: The HIWRAP instrument is located in Zone 25 of the Global Hawk, and it uses the new "deep radome" that has been modified for HIWRAP and other instruments.
Figure 2: Real Time Mission Monitor (RTMM) display during Hurricane Matthew flight. The Global Hawk flight tracks are superimposed in bright red, and the solid white line is the flight leg displayed in Figs. 3 and 4.
Figure 3: Polar display of uncalibrated Ku-band reflectivity and line-of-sight Doppler for the inner beam (30 deg incidence) for one scan of HIWRAP as it was passing across precipitation. The aircraft and radar are located at the center each polar plot, and the surface is located at approximately 20 km range. The freezing level is at approximately 15 km from the Global Hawk, or near the 5 km altitude level. The Doppler velocity (right panel) has aircraft motions removed so it provides the line-of-sight speed of the hydrometeors.
Figure 4: Vertical cross section of reflectivity and vertical component of hydrometeor motions calculated from one HIWRAP flight line across Hurricane Matthew. The Doppler winds from the fore and aft looks along nadir each have a horizontal component that's cancels when combined, resulting in an estimate for the vertical component. The result is similar to what is measured directly by the EDOP nadir-pointing radar but of lower resolution.

Scientific significance: The HIWRAP flying on the Global Hawk provides a unique capability to study the dynamics of hurricane genesis and intensification processes. Horizontal winds are derived from HIWRAP within precipitation and cloud regions over the long duration of a Global Hawk flight. This is a capability filled neither by current satellites or manned aircraft.

Relevance for future science and relationship to Decadal Survey: The HIWRAP is at the same frequencies at the Global Precipitation Mission (GPM) radar and will be used in a nadir pointing mode for field campaign validation activities. HIWRAP also has one of the frequencies (Ka-band) that is planned for the Aerosol Chemistry Ecosystems (ACE) Decadal Survey Mission

Acknowledgement: This instrument was developed under the NASA Instrument Incubator Program

First Global Measurements of Vegetation Fluorescence from Space

Joanna Joiner, Yasuko Yoshida, Alexander Vasilkov, Code 613.3, NASA GSFC,

Yukio Yoshida, NIES, Japan, Lawrence Corp, Elizabeth Middleton, Code 614.4, NASA GSFC

To date, most satellite-derived information about vegetation health has come from "greenness" indicators that provide estimates of maximum photosynthesis.

In the afternoon, fluorescence from vegetation is correlated with photosynthesis. Fluorescence measurements from space provide estimates of instantaneous photosynthetic activity.

Fluorescence measurements may show plant stress before reductions in greenness take place and are therefore of interest to precision farming, forestry, and carbon assessment.

Using high spectral resolution observations from the Japanese GOSAT spectrometer, we have made the first regional global and seasonal measurements of fluorescence from space.

Measurements may also be made at higher spatial resolution with the NASA Orbiting Carbon Observatory 2 (OCO-2) that will be launched in the next few years.

Fluorescence is a value-added carbon-related product that can be derived from instruments that were not designed to measure it.

GOSAT Scaled Fluorescence 2009

MODIS EVI Enhanced Vegetation Index 2009

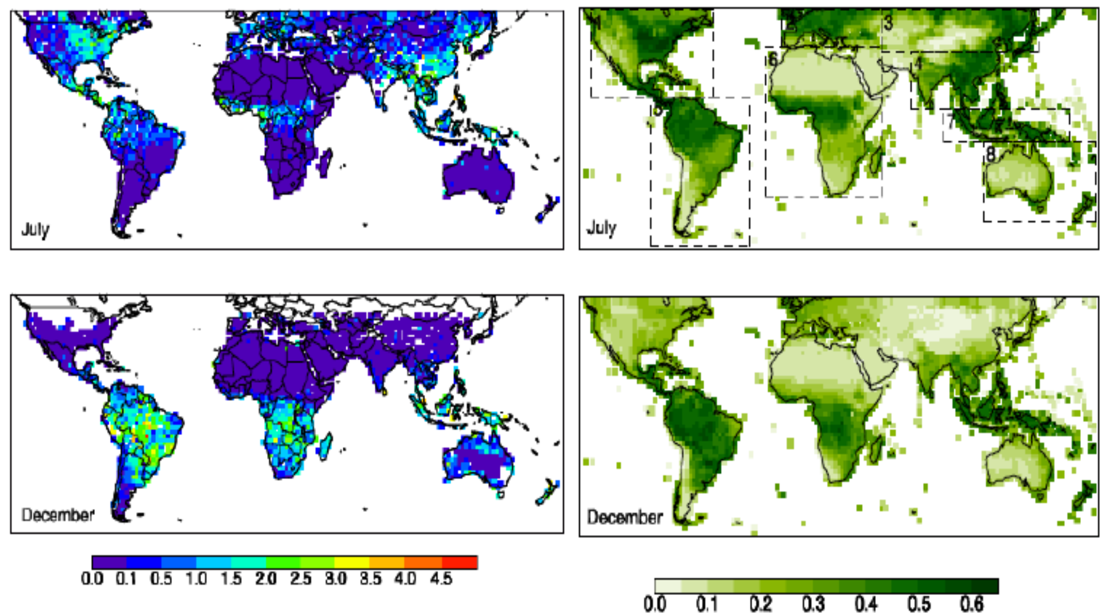


Figure 1: Left: Derived fluorescence scaled by incoming photosynthetically-active radiation (PAR) provides an estimate of the relative fluorescence efficiency of vegetation. The expected seasonal shift in photosynthetic activity in 2009 is clearly shown. Right: MODIS EVI (a greenness indicator) shows similar patterns. However, some differences, such as fluorescence on the Australia coast in December and lower values of fluorescence over Indonesia in July during an El Nino drought, are not clearly evident in the EVI. This indicates that fluorescence is providing independent information.

Name: Joanna Joiner, NASA/GSFC, Code 613.3
E-mail: Joanna.Joiner@nasa.gov
Phone: 301-614-6247

References:

Joiner, J., Yoshida, Y., Vasilkov, A. P., Yoshida, Y., Corp, L. A., and Middleton, E. M., 2010: First observations of global and seasonal terrestrial chlorophyll fluorescence from space, *Biogeosciences Discussions, 7* , 8281-8318, doi:10.5194/bgd-7-8281-2010, (under review).

Data Sources: Greenhouse-gases Observation "Ibuki" Satellite (GOSAT) Thermal And Near-infrared Sensor for carbon Observation-Fourier Transform Spectrometer (TANSO-FTS) and NASA Aqua MODIS enhanced vegetation index

Technical Description of Figure: We compare our GOSAT-derived fluorescence information with that provided by the MODIS Enhanced Vegetation Index (EVI) derived from satellite reflectances. This comparison shows that for several areas these two indices exhibit different seasonality and/or relative intensity variations. The derived fluorescence therefore provides information that is related to, but independent of the reflectance.

Scientific significance: Remote sensing of terrestrial vegetation fluorescence from space is of interest because it can potentially provide global coverage of the functional status of vegetation. For example, fluorescence observations may provide a means to detect vegetation stress before chlorophyll reductions take place. Although there have been many measurements of fluorescence from ground- and airborne-based instruments, there has been scant information available from satellites. In this work, we use high-spectral resolution data GOSAT that is in a sun-synchronous orbit with an equator crossing time near 13:00 LT. We use filling-in of the potassium (K) I solar Fraunhofer line near 770 nm to derive chlorophyll fluorescence and related parameters such as the fluorescence quantum yield at that wavelength.

This work is an important step forward in demonstrating that the health of terrestrial ecosystems can be monitored from space. Our research provides a basis for future satellite missions specifically designed to measure vegetation fluorescence such as the Florescence Explorer (FLEX) mission that was selected for assessment by the European Space Agency (ESA) in 2006. Our work also shows that plant fluorescence needs to be taken into account when making highly accurate measurements of cloud, aerosol, and surface pressure effects on oxygen-A band absorption. Oxygen-A band observations are included on GOSAT and OCO-2 to correct for these effects in CO_2 retrievals.

Relevance for future science and relationship to Decadal Survey: It will also be possible to retrieve fluorescence at a higher spatial resolution and with less cloud contamination using the NASA Orbiting Carbon Observatory-2 (OCO-2) to be launched in the next few years. Fluorescence will be an important value-added carbon-related product from OCO-2. There is currently no decadal survey mission specifically designed to measure fluorescence.

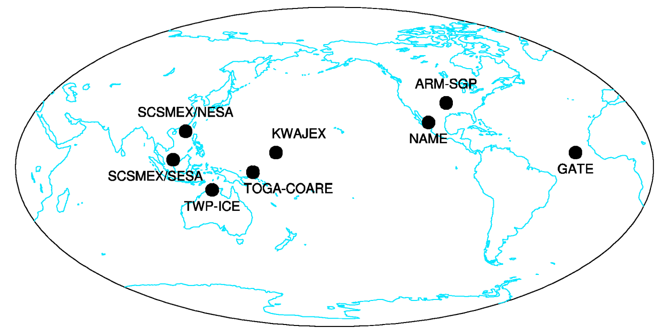
A Contribution by Ice Nuclei to Global Warming

Xiping Zeng, Wei-Kuo Tao, Arthur Y. Hou, Stephen Lang, Xiaowen Li, David O' C Starr

Code 613.1, NASA GSFC

Ice nuclei (IN) are aerosol particles in the atmosphere that potentially impact clouds by inducing the freezing of supercooled droplets. Simulations using the Goddard cloud-resolving model are used to quantify IN effects on radiative forcing in different geographic regions. Field campaign data (Fig. 1) are used to initialize and evaluate the model simulations. The sensitivity of radiative forcing versus latitude corresponding to a doubling of IN are shown in Fig. 2.

Global desertification and industrialization provide clues on the geographic variation of the increase in IN concentration since pre-industrial times. Their effect on global warming can compared to IPCC (2007) observations. A general match in geographic and seasonal variations between the inferred and observed warming suggests that IN may have contributed positively to global warming over the past decades, especially in middle and high latitudes.



FIELD CAMPAIGNS

Fig. 1 Location of the field campaigns that provided data to drive and evaluate cloud-resolving model simulations.

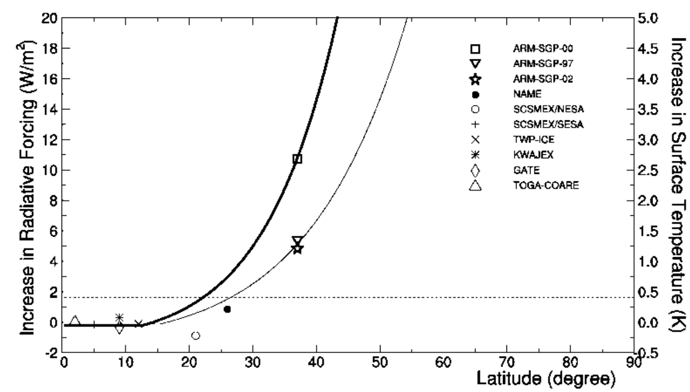


Fig. 2 The increase in the radiative forcing when IN concentrations are doubled varies with latitude. All the results obtained over the field campaigns are marked by symbols. Thick and thin solid lines are introduced to fit the results in spring and summer, respectively, based on ten-year TRMM observations. The dashed line represents an increase in the radiative forcing when CO_2 concentration increases from zero to the current value.

Name: Xiping Zeng, NASA-GSFC/GEST, Code 613.1
Email: xiping.zeng@nasa.gov
Phone: 301-614-6095

References:

1) Zeng, X., W.-K. Tao, M. Zhang, A. Y. Hou, S. Xie, S. Lang, X. Li, D. Starr, and X. Li, 2009: A contribution by ice nuclei to global warming. *Quarterly Journal of the Royal Meteorological Society*, **135**, 1614-1629.
2) Zeng, X., W.-K. Tao, M. Zhang, A. Y. Hou, S. Xie, S. Lang, X. Li, D. Starr, X. Li, and J. Simpson, 2009: An indirect effect of ice nuclei on atmospheric radiation. *Journal of the Atmospheric Sciences*, **66**, 41-61.

Data Sources:

Observational data from the NASA field campaigns in the Tropics and the DOE SGP site in middle latitudes (e.g., large-scale forcing data derived from sounding network, liquid and ice water contents from radar and satellite) were used to drive and evaluate long-term cloud-resolving model simulations. Ten years of TRMM data on stratiform precipitation fraction were used to organize the model results versus latitude.

Technical Description of Figures:

Figure 1 displays the geographic location of the field campaigns and ***Figure 2*** the effect of IN on radiative forcing against latitude. The Goddard Cumulus Ensemble model, a high-resolution cloud-resolving model, is used to perform numerical experiments. Nine field campaigns scattered over a broad area of the Earth's surface are chosen to provide large-scale forcing to drive the model and to provide cloud observations to evaluate the model. The nine field campaigns are: the ARM-SGP (the Atmospheric Radiation Measurement Program - Southern Great Plains site campaigns conducted in the summer of 1997, the spring of 2000 and the summer of 2002); GATE (the 1974 Global Atmospheric Research Program Atlantic Tropical Experiment); KWAJEX (the 1999 Kwajalein Experiment); TOGA-COARE (the Tropical Ocean Global Atmosphere Program's Coupled Ocean-Atmosphere Response Experiment conducted in 1992 and 1993); TWP-ICE (the 2006 Tropical Warm Pool – International Cloud Experiment); and SCSMEX/NESA and SESA (the 1998 South China Sea Monsoon Experiments over the northern and southern enhanced sounding array polygons, respectively).

Scientific Significance:

Anthropogenic CO_2 explains about half of the observed global warming over the past decades and does not satisfactorily explain the geographic pattern of the warming. An increase in ice nuclei (IN), such as produced by desertification, agricultural activity and industrialization, can lead to an increase in high cirrus clouds that in turn bring about warming (greenhouse) and cooling (umbrella) effects on the Earth. Satellite observations, field observations, and cloud model simulations are used here to evaluate the potential effect of IN on global climate. In the Tropics, the warming effect is balanced by the cooling one, but is stronger in middle and high latitudes. On a global average, the net warming effect from doubling IN concentration is close to that from doubling carbon dioxide. Moreover, the increase in IN from desertification and industrialization is consistent with the geographic pattern of the observed warming.

Relevance for Future Science and Relationship to Decadal Survey:

Together with cloud-resolving model simulations and field campaign observations, advanced observations of clouds and aerosols, such as from the Aerosols, Clouds and Ecosystems (ACE) Decadal Survey mission, will be crucial to establish the global distribution of the IN effect which depend strongly on cloud types (e.g., convective versus stratiform clouds) and cloud microphysical structure.

Russia Heat Wave and Pakistan Flood, 2010: Teleconnection of Hydrometeorologic Extremes

William Lau, and Kyu-Myong Kim, NASA GSFC, Code 613.2

The two record setting hydrometeorologic extreme events during summer 2010, *i.e.,* the Russian heat wave/wildfires and Pakistan flood occurred almost contemporaneously. A recent study (Lau and Kim 2011) shows that these two seemingly unrelated events were indeed physically related. The torrential rain that caused the Pakistan flood was not an isolated event, but rather coupled to excess rain over the Himalaya foothill, and reduced rain over the Bay of Bengal and southern India (Fig. 1a). The intense heat wave and wildfires in Russia (Fig. 1b) was caused by a strong and prolonged atmospheric blocking event. The blocking initiated a surface-to-mid-troposphere high pressure system and a mid-to-upper level Rossby wave train propagating eastward and southeastward. Vorticity perturbations in the leading edge of the trough was instrumental in triggering of torrential rain over northern Pakistan.

Approximately 24-48 hours before the onset of heavy rain events over northern Pakistan (July 19, July 27, August 3), an upper-level V-shaped positive (cyclonic) vorticity filament formed at the southeastern edge of the 500 hPa anticyclone, entering the target region from the north (Fig. 2). The upper level vorticity perturbations triggered upward motion ahead (to the east), leading to the development of subtropical mid-tropospheric cyclones (MTC). The vertical motion associated with the MTC pumped moisture from the Bay of Bengal, and the northern Arabian Sea, feeding the extreme rainfall events over northern Pakistan.

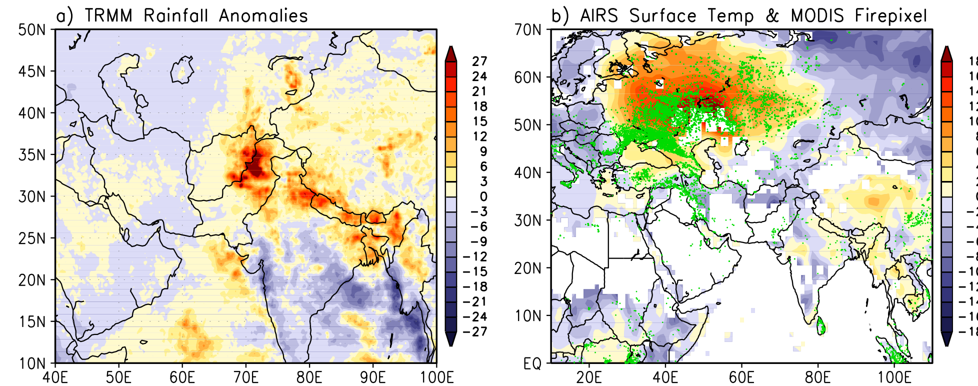


Figure 1: a) TRMM rainfall anomaly (mm day^{-1}), b) AIRS surface temperature (^{o}C) and MODIS fire pixels (green dots) during July 25 – August 8, 2010.

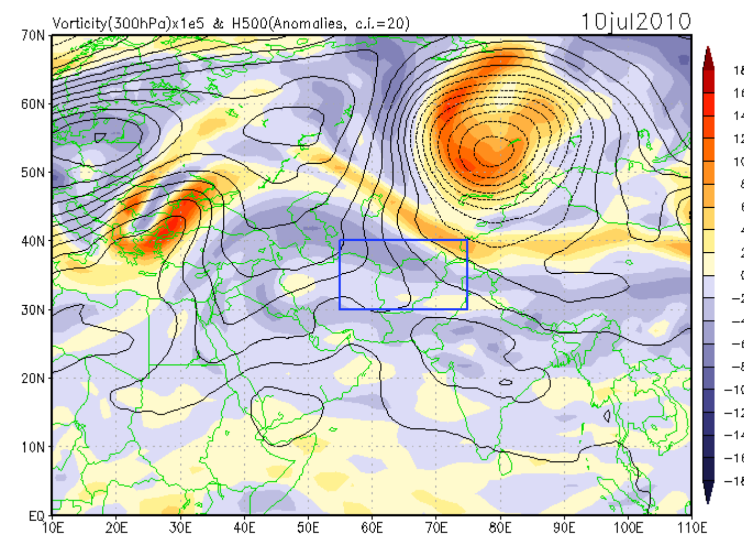


Figure 2: The movie shows the daily evolution of MERRA 300hPa vorticity (shading, 10^{-6} s^{-1}) and 500 hPa geopotential height (contour, with 20 m interval) anomalies during, July 10 – August 10, 2010. The blue box indicates the target region over northern Pakistan and adjacent regions.

Name: William Lau, NASA/GSFC, Code 613
E-mail: William.K.Lau@nasa.gov
Phone: 301-614-6332

References:

Lau, K-M., and K-M Kim, 2011: The 2010 Pakistan Flood and the Russia Heat Wave: Teleconnection of Hydrometeorologic Extremes. *Submitted to J. of Hydrometeorology.*

Data Sources: TRMM rainfall, AIRS surface temperature, MODIS fire pixel, and MERRA daily winds at 300hPa and geopotential height at 500hPa

Technical Description of Figures:
***Figure 1*:** Spatial distribution of a) TRMM rainfall anomaly over Pakistan and the Indian subcontinent for period July 25 – August 8, 2010, b) AIRS surface temperature anomaly, and the location of fire pixel (green dots) obtained from MODIS/Aqua for the same period. The rainfall anomaly (mm day^{-1}) was derived from the base period of 1988-2009, and the surface temperature anomaly (^{o}C) from the base period of 2003-2009.

Figure 2: The movie shows the daily evolution of MERRA 300hPa vorticity (shading, 10^{-6} s^{-1}) and 500 hPa geopotential height (contour, with 20 m interval) anomalies during, July 10 – August 10, 2010. Anomalies are defined as a departure from 31-year mean climatology based on daily MERRA data from 1979 to 2009. The blue box indicates the target region over northern Pakistan and adjacent regions.

Scientific significance: Our study provides observational evidence showing that the torrential rain over Pakistan during summer of 2010 was triggered by Rossby wave response to prolonged atmospheric blocking in western Russia, and fueled by enhanced moisture transport from the Bay of Bengal and the northern Arabian Sea. Also presented in the paper were evidences that each event was amplified through feedback mechanisms involving land-atmosphere interaction for the Russian heat wave, and development of mid-tropospheric cyclones for the heavy rain events over northern Pakistan. These observations are consistent with model projection that in a warmer climate unusual and extreme weather events tend to occurred more frequently. In this case, a pair of extreme events, with opposite polarity, i.e., Russian fire vs. Pakistan flood, separated by vast distances, were actually connected by unusually strong atmospheric Rossby waves.

Relevance for future science and relationship to Decadal Survey: Understandings of the variations of rainfall and soil moisture, and land-atmosphere feed back processes and aerosol-cloud-rainfall interactions are important physical processes in the climate system, closely related to the goals of the planned Global Precipitation Mission (GPM), and the Decadal Survey Missions of Soil Moisture – Active and Passive (SMAP), and Aerosol-Cloud-Ecosystems (ACE).