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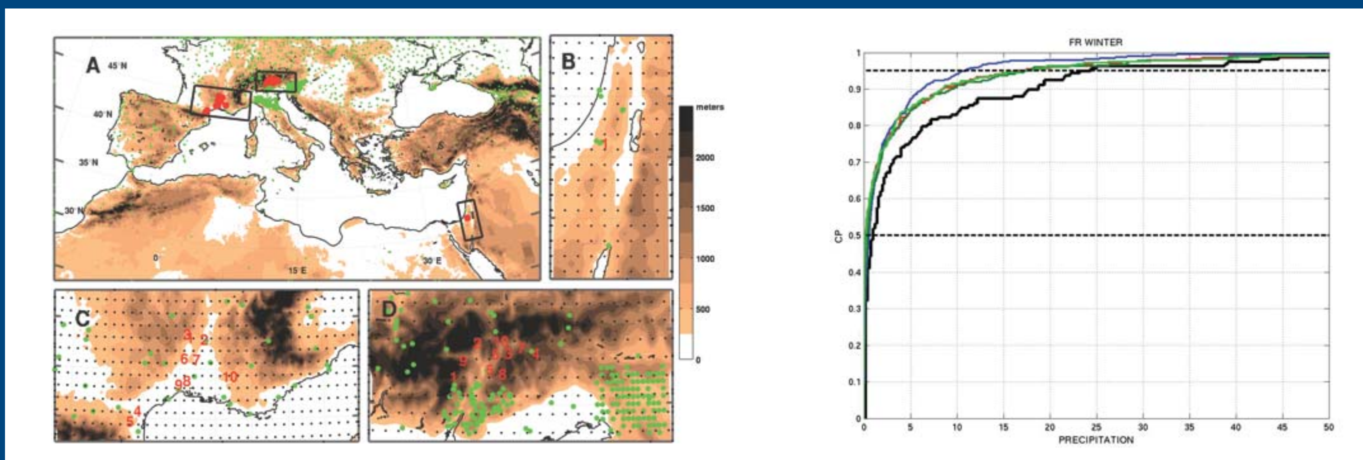
First Results From HyMeX, the Newest GEWEX Regional Hydroclimate Project



Left: *HyMeX stations (red numbers) used for the uncertainties assessment of the European Climate Assessment (ECA) data set (grid in black dots), and stations used for the ECA data set construction (green dots). (A) Mediterranean domain used for CORDEX climate simulations. Enlarged areas show stations in Israel (B), France (C), and Italy (D).* ***Right:*** *Rainfall from the regional dynamical Weather Research and Forecasting Model (WRF; colors) and the statistical Common Data Format Model (CDF-t; black), both forced by the ECMWF Reanalysis-I (ERA-I; blue), are compared to observations of HyMeX and High Elevation sites in Italy. For more comparisons, see article by P. Drobinsk et al. on page 10.*

Preliminary Results Show COSMOS Provides Reliable Method for Area Average Continental-Scale Soil Moisture Data

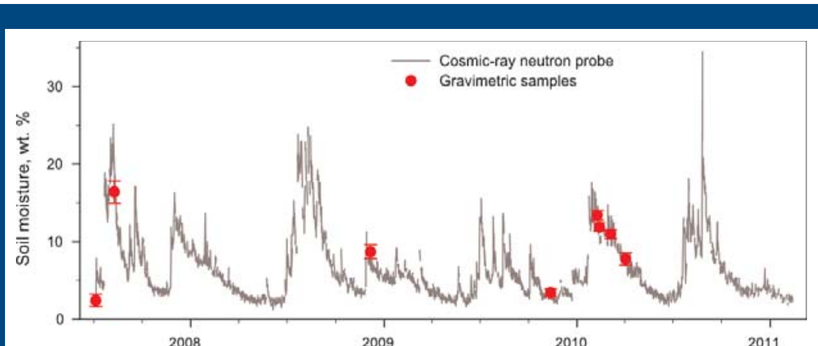


Figure 3. Soil moisture from cosmic-ray neutron measurements (line) compared to that of gravimetric samples collected within the cosmic-ray footprint (symbols; each symbol is an average of several tens of soil samples), San Pedro River Valley, Arizona. The mean of eight absolute differences between the two is 1.1 percent. See article by M. Zreda et al. on page 6.

Also Inside

4th WCRP International Conference on Reanalyses

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Commentary

Getting Involved with GEWEX

Peter J. van Oevelen
Director, International GEWEX Project Office

The International GEWEX Project Office (IGPO) has been very busy supporting the organization of the World Climate Research Programme (WCRP) Open Science Conference, which will be held in Denver, Colorado on 24–28 October (*http://www.wcrp-climate.org/conference2011/*). This is going to be a very exciting conference with a high number of attendees, as well as many contributions from the GEWEX community.

IGPO is also organizing the 4th WCRP International Conference on Reanalyses, which is planned for 7–11 May 2012 in Silver Spring, Maryland (*http://icr4.org*). The Conference is expected to provide a more intensive focus and in-depth discussion on reanalyses than could be attained at the WCRP Open Science Conference. Reanalysis data have become a widely used tool for weather and climate research over the past 15 years. The Conference on Reanalyses will bring together the global community involved in observations (spaceborne, in particular), research and modeling associated with reanalyses (including the current uncertainties), consistency of the time series, and the complexity of the Earth system.

In this Newsletter issue, the cover features an example of early results from the recently approved GEWEX Hydrological Cycle in the Mediterranean Experiment (HyMeX) Regional Hydroclimate Project (RHP). Beginning on pages 12 and 14 are reports from two recent exploratory planning workshops for new RHPs, the Canadian Saskatchewan River Basin (SRB) and the Terrestrial Regional North American Hydro-Climate Experiment (TRACE). Both SRB and TRACE are very promising initiatives that deserve the broad support of the science community.

There are two articles related to GEWEX Cloud System Study (GCSS) activities—one about a GCSS partnership to provide a framework for model developers to make improvements to the physics schemes in global weather and climate models (page 3); and the other about a joint GCSS, WCRP and European Union Project to improve the representation of clouds in global models. Also, a good overview of the COsmic-ray Soil Moisture Observing System (COSMOS), a novel technique to measure large soil moisture content, starts on page 6.

On a different note, you may be familiar with the phrase "never change a winning team." In my opinion, this is far from the truth. You should always look for ways to improve an organization, keeping things fresh and interesting. In that spirit IGPO is looking for people who want to become active contributors to GEWEX. There are many ways to do this, the easiest of which is to stay informed through our quarterly Newsletter, our monthly E-Newsletter and our website. Scientists are always welcome to contribute articles to the Newsletter on research related to GEWEX activities. I also encourage collaboration with other GEWEX community members, and the IGPO is always willing to help find the most appropriate people or channels for a task.

Furthermore, GEWEX seeks qualified individuals to serve on its panels and projects, which formulate goals and strategies, initiate and coordinate activities, and work with agencies and other international partners. The intent is to advance the progress of understanding the dynamics and thermodynamics of the atmosphere and interactions with the Earth's surface, particularly with regard to addressing relevant objectives of WCRP. Qualified individuals should represent the broader interests of the research community, be willing and able to engage in scientific, as well as programmatic discussions leading to the activities of the particular group, and work alongside with other members of the GEWEX organization. If you have not already become involved with GEWEX, I encourage you to find out how to do so at: *http://www.gewex.org/gewex_getinvolved.html*.

I wish you an enjoyable and informative read, and look forward to seeing you at the WCRP Open Science Conference in October.

Contents

A Global Model Intercomparison of the Physical Processes Associated with the Madden–Julian Oscillation

Jon Petch[1], Duane Waliser[2], Xianan Jiang[3], Prince Xavier[1], and Steve Woolnough[4]

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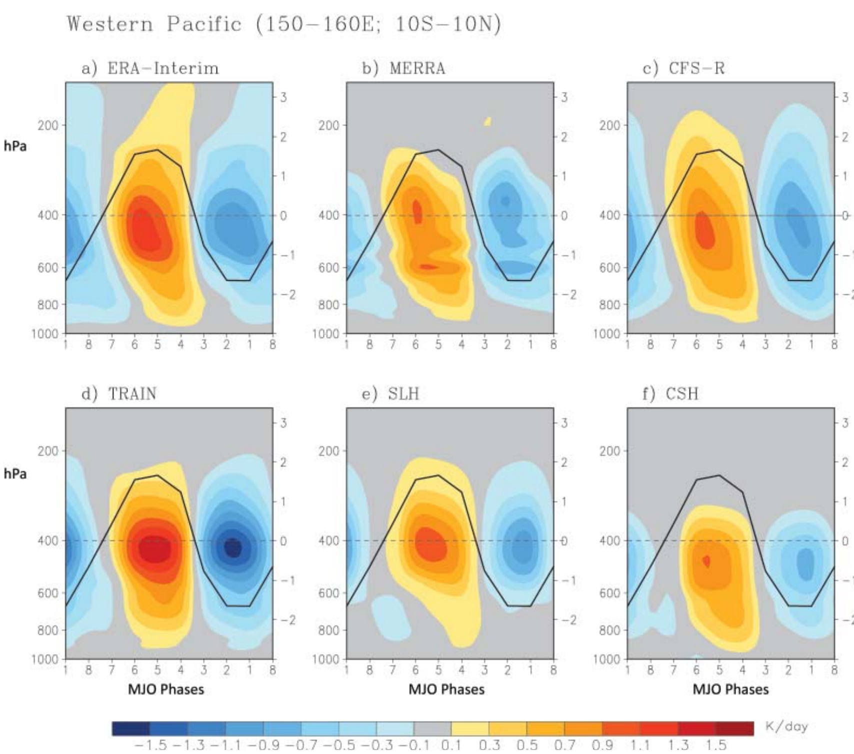
As a dominant subseasonal mode of tropical atmospheric variability, the Madden–Julian Oscillation (MJO; Madden and Julian 1971; 1994) exerts pronounced influences on global climate and weather systems (see reviews by Lau and Waliser 2005; Zhang, 2005), and represents the primary source of predictability on subseasonal time scales (e.g., Waliser, 2005; Gottschalck et al., 2010). Current general circulation models (GCMs), however, exhibit limited capability in representing this prominent tropical variability mode (e.g., Slingo et al., 1996; Slingo et al., 2005; Lin et al., 2006; Kim et al., 2009) and the fundamental physics of the MJO are still elusive.

A new joint project for a global model intercomparison of the physical processes associated with the MJO is being launched by the GEWEX Cloud System Study (GCSS) and the World Climate Research Programme-World Weather Research Programme/The Observing System Research and Predictability Experiment (THORPEX) MJO Task Force. The Project brings together communities that have expertise in model physics development and tropical dynamics, and will use the European Centre for Medium-Range Weather Forecasts (ECMWF) analysis produced as a part of the Year of Tropical Convection (YOTC; *http://www.ucar.edu/yotc*), complimented by data from satellites, such as the Tropical Rainfall Measuring Mission (TRMM), CloudSat, the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO), and the Atmospheric Infrared Sounder (AIRS).

The goal of the joint Project is to provide a framework for model developers to make improvements to the physics schemes in global weather and climate models. One component of the comparison will characterize, compare and evaluate the heating, moistening and momentum mixing processes associated with the MJO by gathering profiles of physical tendencies from the model on a timestep by timestep basis over large regions influenced by the MJO. The MJO will provide a rigorous testbed of the physics in our models and their interaction with large-scale dynamics. Moreover, the joint Project will serve as a useful candidate for comparing model-derived diabatic profiles associated with the MJO with those from global satellite observations (e.g., Tao et al., 2006; Jiang et al., 2009, 2011; Ling and Zhang, 2011).

The figure below illustrates a recent comparison of anomalous diabatic heating (Q1) profiles from three TRMM-derived products with three recent reanalyses: (1) ECMWF Reanalysis-Interim (ERA-I); (2) the National Aeronautics and Space Administration/Goddard Spaceflight Center Global Modeling and Assimilation Office Modern ERA Retrospective-Analysis for Research and Applications (MERRA); and (3) the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFS-R). Such profiles have yet to



Vertical-temporal (MJO phases) evolution of anomalous diabatic heating Q1 (shaded; units: K/day) over the western Pacific (150–160°E; Panels a-f) based on three reanalysis data sets (ERA-I, MERRA, and CFS-R) and three TRMM estimates [training algorithm (TRAIN), spectral latent heating (SLH) algorithm, and convective-stratiform heating (CSH) algorithm].

The black curve in each panel represents the evolution of the TRMM 3B42 product rainfall anomalies (see scales to the right of the Y-Axis with units of mm/day). All variables are averaged over 10°S–10°N. Both anomalous heating and rainfall associated with the MJO were derived based on a composite analysis with strong MJO events being selected by using the Wheel and Hendon Index during November–April from 1998 to 2008. (Adopted from Jiang et al., 2011).

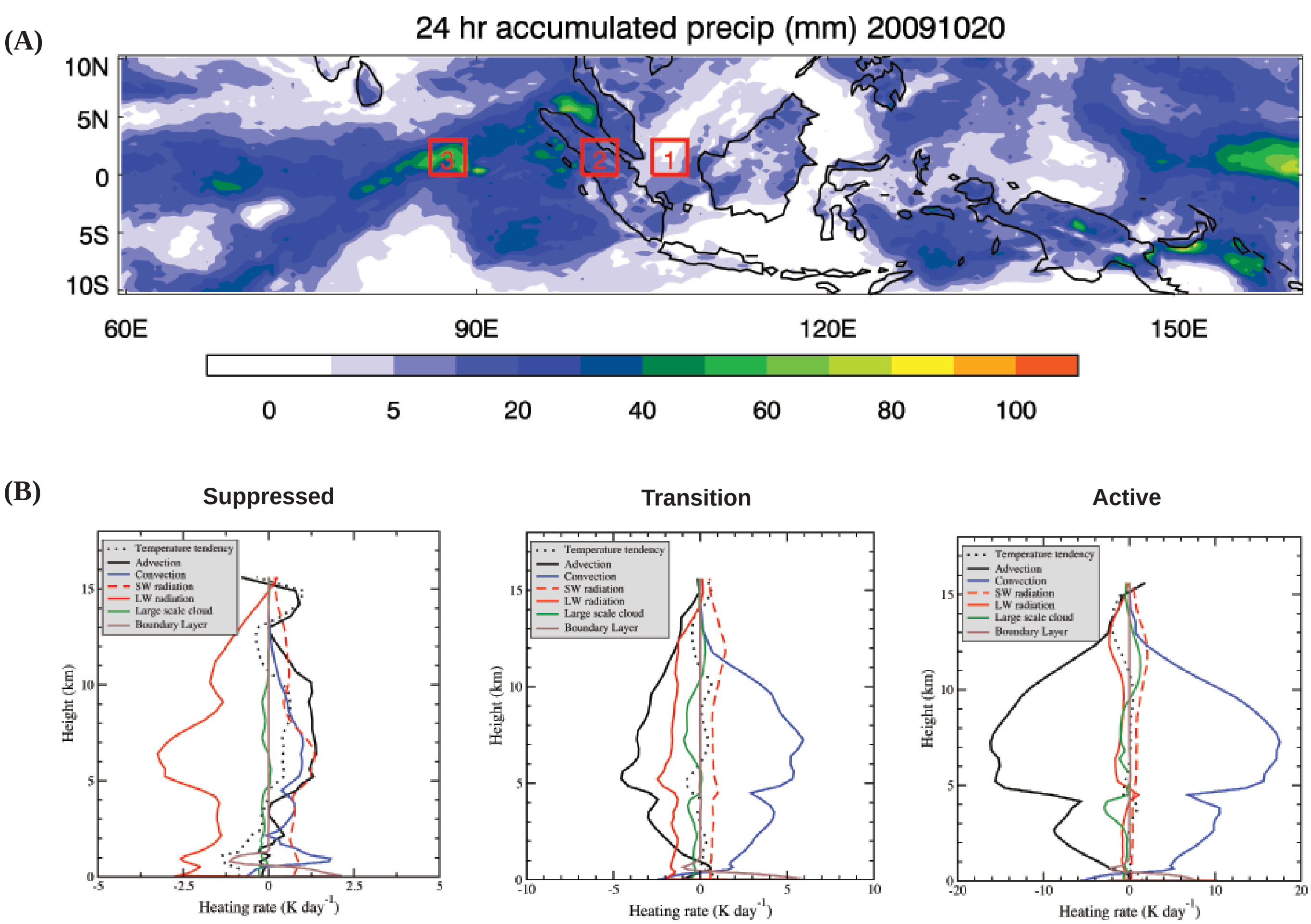
be utilized in a multi-model evaluation of the MJO, despite the fact that the vertical heating structure is a core element of MJO theory and evolution. One of the objectives of the Project is to determine the utility of the satellite and reanalysis values in evaluating model simulations of the MJO and provide feedback to the satellite formulation and algorithm communities regarding strengths, shortcomings and gaps in present-day products.

The experimental framework for the Project will take advantage of the known links between biases seen in short-range forecasts and long-term climate simulations (e.g., Boyle et al., 2008), and evaluate these in the context of the MJO. It will also consider how a model's representation of the MJO changes with forecast lead-time. For this reason, the following types of simulations will be carried out:

1. Twenty-year climate simulations that provide a characterization of the models' intrinsic capabilities of representing MJO variability. Model simulations from both ocean-coupled global models, as well as those that use specified sea-surface temperatures will be evaluated with metrics that broadly describe the models' performance in terms of the MJO [e.g., U.S. Climate Variability and Predictability Project (CLIVAR) MJO Working Group, 2009; Kim et al., 2009] and the associated vertical heating and moistening structures.

2. A series of daily initialized hindcasts for two MJO events within the YOTC period—specifically the two successive MJO events during Boreal Winter 2009-2010. A principal focus of this component of the experiment is on providing highly detailed and comprehensive (e.g., every timestep) model output over a select near-equatorial Indian Ocean/ Western Pacific Ocean domain for the initial two days of the hindcasts.

3. Analysis of the performance of the models' MJO representation as a function of forecast lead-time from one to 20 days, differing from (2) only in the level of detailed



(A) Twenty-four hour accumulated precipitation from the forecast initialized on 20 October 2009 from the MetUM. Three regions depicted by red boxes (each 3 x 3 degrees) are used for the heating budgets. (1) is a region of suppressed convection. (2) is a region of transition to deep convection and (3) is a deep convective region. (B) Temperature tendencies from different processes in the MetUM over the three regions indicated in (A). Total temperature tendency is plotted as black dashed line and represents the change over the 24-hour period; this is also equal to the sum of all other terms.

Key GCSS/THORPEX MJO Project Information and Dates

- The detailed case specification and model experimental framework is currently being developed and will be available at: *http://www.ucar.edu/yotc/mjodiab.html*.
- Contact Xianan Jiang (*xianan.jiang@jpl.nasa.gov*) and Prince Xavier (*prince.xavier@metoffice.gov.uk*) to express interest in participating in the Project and to sign up for Project's e-mail list.
- The deadline for submitting model results is November 2011.
- A joint YOTC/MJO Task Force and GCSS meeting is planned for late Boreal Spring 2012 to discuss the preliminary results of the experiment, with papers to be drafted by late 2012.
- GCSS is a project of the GEWEX Global Atmospheric System Studies Panel.

diagnosis. Hindcast components two and three will provide the framework from which analogous cases can be examined from the Dynamics of the MJO (DYNAMO)/ Cooperative Indian Ocean Experiment on Intraseasonal Variability in the Year 2011 (CINDY2011) field program that is taking place in Boreal Winter 2011–2012.

Unlike previous GCSS projects, this one will not include any process modeling in the beginning. Instead, the analysis of global models will be used to determine the most suitable follow-on process modeling studies and provide information on what is needed for future field experiments and observing systems.

The figure on page 4 is an example of the types of analyses to be performed. The top figure shows the 24-hour accumulated rainfall on 20 October 2009 from a 24-hour forecast from the Met Office Unified Model (MetUM). It has been initialized from the ECMWF YOTC analysis and run with a horizontal grid length of 40 km. Three regions are depicted as red boxes: Region 1 is in the suppressed phase of the MJO; Region 2 is in a transition region ahead of the propagating convection: and Region 3 is in the active phase of the MJO. The three panels at the bottom show the heating budgets averaged in these boxes with the physics terms divided according to parameterization schemes. Note that the x-axis increases by a factor of two as we go from suppressed to transition and again as we go from transition to active. There is much more analysis that can be peformed and close attention will be paid to the temporal variability of these terms on a timestep basis, as well as spatial variability on the grid-point basis.

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Cosmic-Ray Neutrons, An Innovative Method for Measuring Area-Average Soil Moisture

Marek Zreda[1], Xubin Zeng[2], Jim Shuttleworth[1], Chris Zweck[1], Ty Ferre[1], Trenton Franz[1], Rafael Rosolem[1], Darin Desilets[3], Sharon Desilets[3], and Gary Womack[4]

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It has been a challenge in past decades to measure area-average soil moisture, which is needed for a variety of applications. A new method that uses cosmic-ray neutrons represents a breakthrough to address this challenge. Cosmic-ray neutrons are monitored in the air above soil, and their concentrations are inversely correlated with soil hydrogen content and are nearly independent of anything else. The cosmic-ray soil moisture probe is being used in the **COsmic-ray Soil Moisture Observing System (COSMOS)** to provide continental-scale soil moisture data in the United States. Similar networks are being implemented in other countries.

Soils separate the atmosphere and land-surface from the subsurface environment and soil moisture controls the mass and energy exchange between the surface and atmosphere and the surface and subsurface. As such it is critical for many life and physical processes, including vegetation, weather and climate, and partitioning precipitation into runoff, infiltration and evapotranspiration. Many methods have been designed to measure soil moisture at a single point. Technical problems aside, these measurements share a critical shortcoming in that they are not representative of an area around the point of measurement because soil moisture is spatially heterogeneous (see Figure 1, top). Point measurements can be used to assess area-averaged soil moisture if enough points are collected to yield a desired precision. For example, for the soil moisture distribution in Figure 1, a three percent precision would require more than 40 point measurements (Figure 1, bottom). Consequently, such assessments are difficult, expensive, and often impractical. However, area-average soil moisture can be measured in the field using cosmic-ray neutron background radiation whose intensity depends primarily on soil moisture. The cosmic-ray soil moisture probe integrates soil moisture over an area approximately 700 m in diameter, replacing a network of tens of point measurement devices to yield a reliable measure of area-average soil moisture.

Historical Background

Cosmic rays are the mysterious radiation for which Victor Hess was awarded a Nobel Prize in physics in 1932. Ascending in a hot-air balloon, with an electroscope in hand, he found that the intensity of ionizing radiation increased with height above the ground surface, from which he concluded that the source was above rather than below, as previously thought. This radiation was later named "cosmic rays" by Millikan. Fermi (1938) and Bethe et al. (1940) showed that the intensity of low-energy cosmic-ray neutrons depends on the chemical makeup of the material, particularly its hydrogen content. Measurements by Hendrick and Edge (1966) showed that the intensity of "fast" neutrons above the ground depends on soil water content. To cosmic-ray physicists this was noise in the measurement of high-energy neutrons, but to hydrologists, who rediscovered these findings decades later, this was a signal reflecting surface moisture. Hydrologists developed ideas on how to measure soil moisture and snow-water equivalent using cosmic-ray neutron detectors buried in soil and in snow (Kodama et al., 1979; Kodama et al., 1985), with a footprint of decimeters, and placed above the ground surface (Zreda et al., 2008; Desilets et al., 2010), with a horizontal footprint of hectometers and vertical footprint of decimeters.

Neutrons and Hydrogen

Cosmic rays, which are mostly protons, create secondary neutrons in the atmosphere, which in turn produce even more particles, thus forming a self-propagating nucleonic

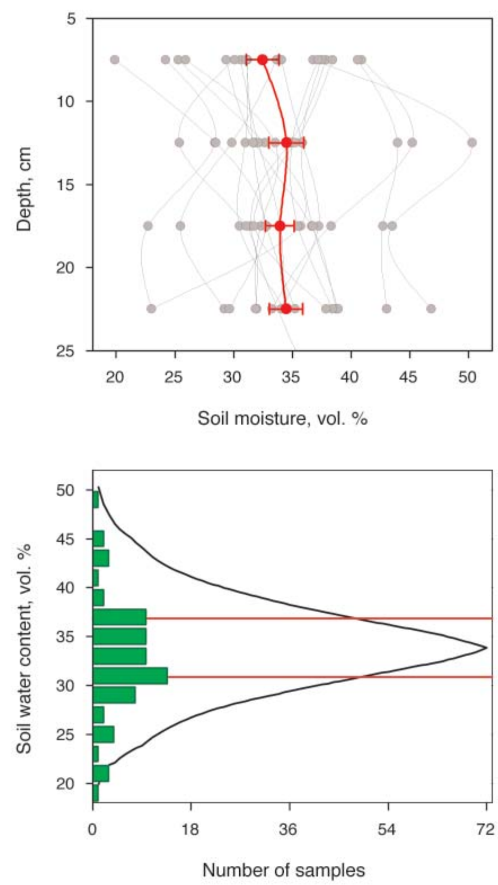

Figure 1. Top: Variations in soil moisture profiles in a 400 x 400 m field in Iowa. Eighteen four-point profiles (gray symbols connected by lines) were averaged to give the representative profile (red symbols connected by line). Bottom: Spread of average soil moisture values as a function of the number of point measurements used in averaging. Red lines indicate a three percent deviation from the mean; 48 point measurements are needed for the average to always remain within three percent from the 'true' mean based on all 72 samples.

shower. As the neutrons in the shower speed through the atmosphere and then through the top few meters of the liquid and solid Earth, fast neutrons are created. Fast neutrons are important in the determination of water at the Earth's surface because they are easily moderated by hydrogen atoms. The process of moderation (slowing or stopping) of neutrons depends on three factors that together define the neutron stopping power of a material: (1) the elemental scattering cross section or probability of scattering (hydrogen has a high probability of scattering a neutron); (2) the logarithmic decrement of energy per collision, which characterizes how efficient each collision is (hydrogen is by far the most efficient element); and (3) the number of atoms of an element per unit mass of material, which is proportional to the concentration of the element and to the inverse of its mass number (hydrogen makes up a high fraction of all atoms in most soils). Hydrogen has by far the highest stopping power (Zreda et al., 2008; Zreda et al., 2011), which is the physical basis of the cosmic-ray soil moisture measurement method.

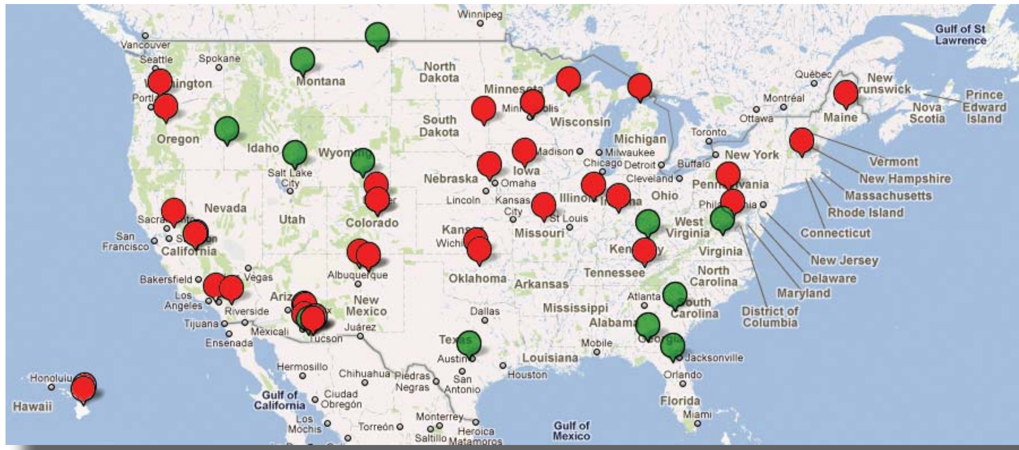

Figure 2. COSMOS sites in the U.S. that were installed as of July 2011 (red) and scheduled for installation by the end of 2011 (green). Up-to-date information on the sites is available at: http://cosmos.hwr.arizona.edu.

Response Function

The fast neutrons that are produced in air and soil travel in all directions within and between air and soil and in this way an equilibrium concentration of neutrons is established. The equilibrium is shifted in response to changes in the hydrogen content of the media, which in practice means changes in the amount of water on or in the soil (water content in the air is small compared to water in and on top of soil). Adding water to soil results in a more efficient moderation of neutrons by the soil, causing a decrease of fast neutron intensity above the soil surface. Removing water from the soil has the opposite effect. Thus, by measuring the fast neutron intensity in the air the moisture content of the soil can be inferred, for example using the following equation (Desilets et al., 2010):

$$M_N = \frac{a_0}{(N/N_0) - a_1} - a_2 \qquad (1)$$

where M_N is the neutron-derived moisture content, N is the measured neutron intensity, N_0 is the neutron intensity in air above a dry soil (this is a calibration parameter obtained from independent field soil-moisture data), and a_0, a_1, and a_2 are fitted constants that define the shape of the calibration function. Neutron transport modeling shows that the shape of the calibration function is similar for different chemical compositions of soil and soil textures (Zreda et al., 2008; Desilets et al., 2010), suggesting that a single "universal calibration" function might be used to convert neutron intensity to soil moisture. The COSMOS team is currently testing this hypothesis using field data and the initial results are positive.

Measurement Volume

The horizontal footprint, which is defined as the area around the probe from which 86 percent ($1\text{-}e^{-2}$) of counted neutrons arise, is a circle with a diameter of close to 700 m at sea level (Zreda et al., 2008) and is independent of soil moisture content. The effective depth of measurement, which is defined as the thickness of soil from which 86 percent ($1\text{-}e^{-2}$) of counted neutrons arise, depends strongly on soil moisture based on neutron transport simulations (Zreda et al., 2008). It decreases non-linearly from about 70 cm in very dry soils to about 15 cm in saturated soils, and is independent of surface atmospheric pressure. The horizontal footprint has been verified by field measurements although the vertical footprint currently remains unverified.

COsmic-ray Soil Moisture Observing System (COSMOS)

COSMOS will eventually have 500 cosmic-ray probes (see Figure 2) distributed throughout the U.S. Each probe has two neutron counters, a polyethylene-shielded counter to measure fast neutrons (energy >10 eV), and a bare counter to measure thermal neutrons (energy < 0.025 eV). The fast neutron data are used for measuring soil moisture, while the thermal neutron data are used for detecting and potentially quantifying water that is present above the land-surface in snow, vegetation, etc. Each counter has its own high-voltage power supply and a pulse module to analyze the signal generated by the neutron counter tube. Power is supplied by a rechargeable battery connected to a solar panel (or main power if available).

Data are sent at user-defined time intervals using an Iridium Satellite modem to a central COSMOS server where they are processed and placed in the public domain in near-real time (*http://cosmos.hwr.arizona.edu/*). These data include fast neutron count rates, thermal neutron count rates, ambient barometric pressure, and relative humidity and temperature inside the instrument box. The neutron count rates are cumulative over the prescribed time interval while the other measurements are instantaneous values.

COSMOS Rover

Assessments of soil moisture variations are possible using a mobile cosmic-ray neutron probe, or COSMOS Rover. Precise measurements require high count rates which can be achieved by using large and/or multiple counters, but which also makes the instrument bulky and heavy and therefore best mounted on a vehicle. Measurements can be made from a moving or a stationary vehicle. For areas inaccessible to vehicles (e.g., rugged topography or forests), a smaller version of the COSMOS Rover is required.

Several cosmic-ray rover surveys have been conducted in the past three years. The first set of measurements was taken along a transect from the west side to the east side of the Island of Hawaii (Desilets et al., 2010), and an aerial survey was done over a Soil Moisture Active and Passive (SMAP) pixel-sized area in northern Oklahoma.

San Pedro River Valley, Arizona

The San Pedro COSMOS probe has been used continuously since its installation in July 2007 and provides the longest record of fast neutrons. The probe has not required maintenance, which shows its suitability for long-term monitoring of neutron intensity. Figure 3 at the bottom of page 1 shows soil moisture computed from the measured (and normalized; Zreda et al., 2011) fast neutron intensity (N in Equation 1). Neutron-derived soil moisture ranges from less than 2 weight (wt) percent during summer dry periods to more than 38 wt percent during the monsoon of August 2010. These values can be converted to volumetric water contents using the average dry bulk density of 1.40 g/cm^3 obtained from 26 undisturbed soil samples collected inside the footprint. Two wet seasons are clearly discernible, one due to summer monsoons and the other due to winter frontal rains, separated by two dry seasons in the spring and fall. Drying trends following these two seasons are different: the spring drying is slower than the fall drying, reflecting lower evaporative demand in the spring. Superimposed on these seasonal trends are diurnal fluctuations with minima in mid-day and maxima at night, arguably due to redistribution of water within the soil column.

We obtained additional sets of soil samples at seven different times to check the neutron-derived soil moisture described above. Figure 3 shows the eight instantaneous soil moisture values determined using the standard oven-drying method on numerous field samples collected within the cosmic-ray footprint. The agreement between the neutron-derived and soil-sample-derived soil moisture values is very good regardless of the value of soil moisture. The average of absolute differences is 1.07 wt percent and there is no trend in absolute differences with time or with the magnitude of soil moisture. This result demonstrates the COSMOS probe's long-term stability. The probe calibrated at one time and at any moisture content gives correct soil moisture contents at other times over a 4-year period. Based on this result, longer-term stability can reasonably be expected.

Manitou Experimental Forest, Colorado

A COSMOS probe was installed in a pine forest near Woodland Park, Colorado in October 2009. The changes of fast and thermal neutrons reflect both soil moisture and snow. Here we concentrate on a short period in the winter of 2010/2011 when two snow events dominated the changes in the neutron signal (Figure 4). Following a snow event, the fast neutron

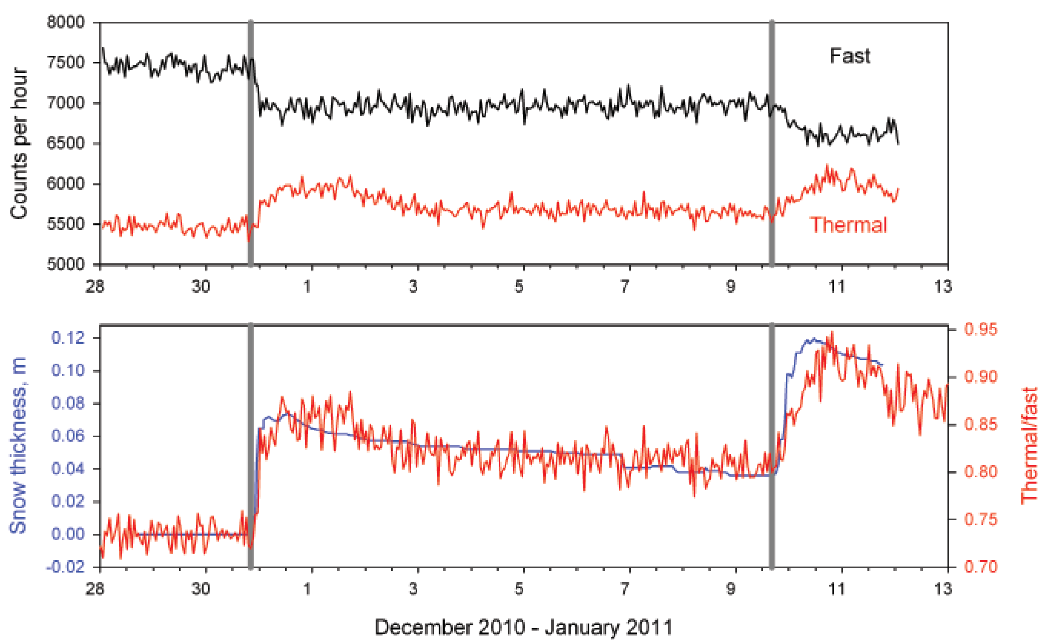

Figure 4. Snow detection with the cosmic-ray probe. Vertical bars indicate the onset of two snow events. Snow thickness in the bottom panel is from laser measurements (courtesy of Dave Gochis, NCAR).

intensity decreases and at the same time the thermal neutron intensity increases, which provides a clear signature with which the onset of a snow event can be readily distinguished. The effect of the subsequent loss of snow from the ground is not as dramatic because it takes a longer time for snow to disappear through melting or sublimation. Fast neutron count remains nearly constant after the snow event while thermal neutron count rates decrease slowly. The ratio of thermal to fast neutrons is the most prominent indicator of snow and correlates well with the snow depth measured with a laser snow gauge. Using independent measures of snow-water equivalent it is possible to calibrate the COSMOS probe for snow measurement (Desilets et al., 2010).

West-East Transect on Hawaii Island

In January 2010, a survey was conducted across Hawaii Island, from the wet, tradewind-dominated east side, across the saddle between Mauna Kea and Kohala, to the dry west side (Desilets et al., 2010). A two-counter COSMOS rover was placed in a vehicle driven at an average speed of 50 km/hr along the 37-km route. Fast neutron intensity integrated over one-minute intervals and barometric pressure, measured at the end of each interval, were recorded every minute. Neutron intensity was converted to soil moisture using Equation 1 on page 7. The results (see Figure 5 on page 20) display a clear trend from low soil moisture on the west side of the island to high soil moisture on the east side. This is consistent with annual precipitation, which ranges from less than 25 cm on the west coast to more than 200 cm on the east. The neutron-derived soil moisture values are also consistent with two point measurements of soil moisture from the Soil Climate Analysis Network (SCAN). These results show that mobile measurements of soil moisture are feasible, encouraging us to conduct more extensive roving surveys (Zreda et al., 2011), one of which is described below.

Determination of Soil Moisture Over an SMAP-Sized Pixel

The COSMOS Rover is potentially useful for calibration and validation of satellite microwave sensors such as SMOS and future SMAP systems. Using a COSMOS Rover, a satellite passive microwave pixel can be surveyed by car in one day. To demonstrate this potential we conducted an exploratory survey around the SMAP testbed site near Stillwater, Oklahoma (Figure 6). The mapped area is about 37 km x 42 km, which is broadly comparable with an SMAP pixel. The survey was made over approximately 11 hours using a car with the COSMOS Rover inside driven for approximately 300 km while 700 one-minute counts were collected. The COSMOS Rover was calibrated at the nearby stationary COSMOS sites.

During the survey time, latitude, longitude, elevation, pressure, temperature, humidity, and count rate were logged automatically. The pressure-corrected neutron count rates were converted to soil moisture and these soil moisture values were interpolated to contours using an inverse distance weighted algorithm. Soil moisture varied from 6 to 24 percent by volume and on average was 14.2 ± 1.8 percent (see Figure 6). The interpolated value at the stationary COSMOS site is approximately 15 percent, which is comparable to the average value of 12.5

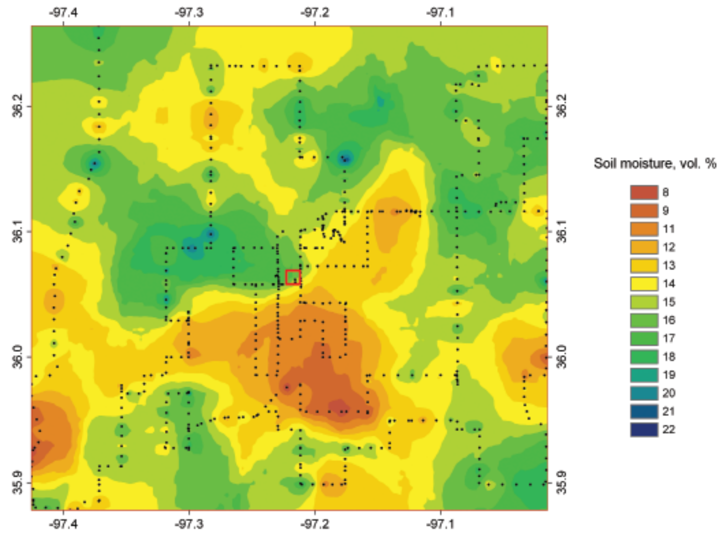

Figure 6. Soil moisture over an SMAP-sized area (37 km x 42 km) in Oklahoma derived from cosmic-ray neutron measurements taken with the COSMOS rover. Black dots mark the route. The red square is the location of the stationary COSMOS probe..

percent obtained from gravimetric determinations on 75 soil samples. These results show that the COSMOS Rover can be used to map soil moisture over large areas reasonably quickly. An SMAP-sized area was mapped in one day. Faster driving speeds and less dense routes would permit mapping larger areas albeit at the expense of precision and spatial resolution.

Outlook

The cosmic-ray method for measuring soil moisture has several useful characteristics. It gives area-average soil moisture, integrating spatial variability within the radius of approximately 350 m around the probe, and within a depth up to 70 cm. It can be used where soils are not continuous; for example, where rock outcroppings are present within the footprint, or in urban areas that are partly built-up. The probe is not influenced by soil texture; measurements can be obtained in soils containing stones or other objects. The method is non-invasive and allows measurement of undisturbed soil conditions. The probe is insensitive to temperature, salinity, soil mineral chemistry (except lattice water) or soil water chemistry. It can be used in a roving mode (the cosmic-ray rover), thereby permitting assessment of variations of soil moisture in space. The cosmic-ray neutron probe responds to all forms of moisture, including liquid and frozen soil water, snow, and water in or on vegetation, allowing for the assessment of the total surface moisture.

These advantages will allow COSMOS to provide soil moisture at a large number of sites with different physical characteristics, from simple and easy (flat grasslands) to complex and difficult (valleys with rock outcroppings, urban areas), and at the hitherto elusive horizontal scale of hectometers and vertical scale of decimeters. The COSMOS Rover could fill the space between the stationary sites. The availability of this new data will enable new research and advance our knowledge in several areas of Earth and atmospheric sciences, and in this way, we believe, lay the foundation of an emerging scientific discipline, cosmic-ray hydrometeorology. Moreover the potential impact of the COSMOS probe and the COSMOS Rover is beyond merely acquiring the state of soil moisture over an area. By providing field data that can be used either directly or through integration with models, potential applications will expand knowledge and improve techniques in many fields, including meteorology, climatology, hydrology, ecology, remote sensing, agriculture, and engineering.

Relevance of COSMOS to GEWEX and WCRP Activities

COSMOS can contribute to several GEWEX and World Climate Research Programme (WCRP) activities. For example, the COSMOS Rover would be ideal to calibrate and validate soil moisture data from satellite remote sensing (e.g., SMOS, SMAP), aircraft remote sensing during field experiments, and global surface soil moisture products from offline land-surface modeling forced by near-surface atmospheric data (as spearheaded by the GEWEX Global Soil Wetness Project and its follow-on activities). COSMOS soil moisture data could also become a baseline to help unify the monitoring and understanding of hydrological, meteorological, and agricultural drought, which has been emphasized by GEWEX and WCRP in recent years. COSMOS data could also be used in data assimilation to provide vertically layered soil moisture that is needed as initial condition and validation data for regional and global hydrometeorological prediction (e.g., led by the GEWEX Global Land/Atmosphere System Study Panel and GEWEX Hydroclimatology Panel). We invite the GEWEX community to work with us to address these issues using COSMOS data.

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HyMeX, the Newest GEWEX Regional Hydroclimate Project

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The Hydrological Cycle in the Mediterranean Experiment (HyMeX) was approved as a GEWEX Regional Hydroclimate Project (RHP) at the 23rd Session of the GEWEX Scientific Steering Group in August 2010. HyMeX will contribute to the GEWEX objectives of improving our understanding of the global hydrological cycle and the prediction of its evolution through a coordinated set of studies in the Mediterranean Sea Basin.

There are three HyMeX target areas (TAs) of study:

1. *Northwestern Mediterranean*—concentrates all the intense hydrometeorological phenomena of interest for HyMeX. Heavy precipitation systems and flash-flooding occur over the Spanish, French, and Italian coasts during the autumn, and the Gulf of Lions is one of the four major sites of dense water formation and deep ocean convection at the end of winter under the influence of the Mistral and Tramontana regional winds, and of the Gulf of Genoa cyclogenesis.

2. *Southeastern Mediterranean*—covers the Eastern and Southeastern Mediterranean area and consists of the western part of Crete Island, the transboundary river basin of the Evros River and three basins in Israel. The Crete site is proposed as a site for the study of heavy precipitation events and flash-flooding. In addition, this target area will allow the study of intense rainstorms and flash floods in the dryer climate areas of the Mediterranean.

3. *Adriatic*—comprised of the Friuli and Veneto regions in Italy, and the Dinaric Alps in Slovenia and Croatia, which are proposed as a target area for the study of heavy precipitation events and flash-flooding. This region is affected by strong regional Bora winds over the Dinaric Alps. Dense water also forms in the North and South of the Adriatic sub-basin.

HyMeX Observation Strategy

The HyMeX observation strategy is based on a three-level nested observation scheme. The Long-term Observation Period (LOP) began in September 2010 and will continue until 2020. It includes the whole Mediterranean Sea region, and the data will be used in developing a long-term time series required to study seasonal and interannual variability.

An Enhanced Observation Period (EOP) for both budget and process studies is planned for at least four years (2011–2015). EOP observations may only include specific parts of a year (e.g., autumns for heavy precipitation, extending to winter for severe cyclogenesis and strong winds).

Special Observation Periods (SOPs) will last for several months to provide detailed and specific observations for studying key processes of the water cycle in the HyMeX target areas. In addition to the EOP observation framework, dedicated ground-based, shipborne, and airborne means will be deployed during the SOPs. The first SOP is planned for the autumn of 2012 over the Northwestern Mediterranean target area.

HyMeX Modeling Plans

The HyMeX observation strategy is designed to serve the objectives of the modeling strategy, which includes: (1) the development of regional coupled systems (ocean-atmosphere, land-atmosphere, ocean-land-atmosphere) to reduce uncertainties of the regional projections of future climate; (2) the improvement of convective-scale deterministic forecast systems to improve the capability to predict Mediterranean high-impact weather events; and (3) the design of high-resolution ensemble modeling systems dedicated to the study of the predictability of Mediterranean heavy precipitation and severe cyclogenesis.

These ensemble forecast systems will be coupled with hydrological models to issue probabilistic forecasts of the impact in terms of hydrological response. Advances in the knowledge of the hydrological and hydraulic responses, as well as of the soil water content state before and during precipitation events should help to improve the initialization and process representation within the hydrological models used.

5th International HyMeX Workshop

The 5th HyMeX Workshop was held in Punta Prima, Menorca, Spain on 17–19 May 2011, prior to the start of the HyMeX EOP. The Workshop was preceded by a meeting of the working group and task team leaders in charge of coordinating the HyMeX international implementation phase. The HyMeX International Scientific Steering Committee met after the Workshop. At the same time, the French, Spanish, Italian, German and Croatian coordination groups met to strengthen intra-national links and discuss plans for improving the coordination and visibility of HyMeX at the national level.

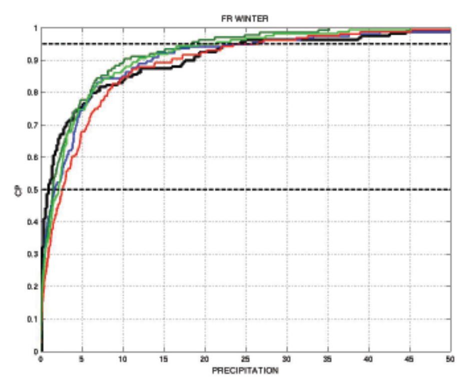
More than 150 participants from France, Spain, Italy, Croatia, Germany, Greece, the United States, Austria, Switzerland, The Netherlands, and Serbia attended the Workshop. Forty-eight talks and 82 posters presented scientific results on the main HyMeX topics, including the water budget of the Mediterranean hydrological cycle, precipitating events and floods, air-sea interaction processes, and socio-economic impacts. Plenary sessions were devoted to open interdisciplinary discussions about key scientific challenges and to further disseminate the experimental set-up plans for each of the three target areas. Nine parallel working sessions promoted discussions on the three observation periods, and on the hydrological, meteorological and climatological modeling strategies.

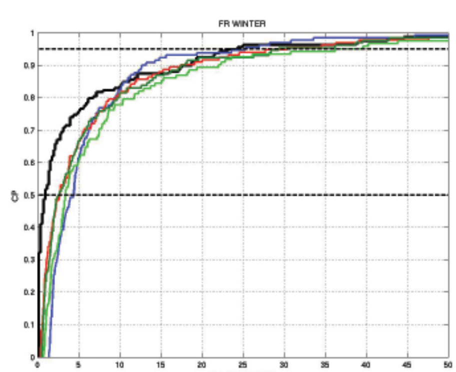
HyMeX First Results

First results from the HyMeX Long Observation Period data were also presented. Several heavy precipitation cases are being analyzed and many simulations have been performed both for process studies and regional climate investigations related to the Mediterranean Coordinated Regional Climate Downscaling Experiment (MED-CORDEX).

In the context of GEWEX, the first analysis of the data collected at the HyMeX sites in France, Italy and Israel and High Elevation (HE) areas (see top left figure on page 1) was presented. The objective of the study is the assessment of uncertainties for both dynamical and statistical downscaling techniques. Rainfall from the regional dynamical Weather Research and Forecasting (WRF) Model and the statistical Common Data Format (CDF-t) Model, both forced by the European Centre for Weather-Forecasts Reanalysis-Interim (ERA-I), were compared to observations of the HyMeX and HE sites. Results (for French sites only) are displayed in the top right figure on page 1 (and in the figure below) and show an underestimation of the median and the extreme values for all WRF simulations and ERA-I (with WRF performing better than ERA-I). The CDF-t model showed a robust good skill on downscaling rainfall regardless of the inputs. Applying a threshold value on the WRF and ERA-I rainfall to discriminate no rainfall versus rainfall events results closely agrees with the station measurements.

The Workshop program, presentations and more information about HyMex are available at: *http://www.hymex.org*.





CDF of observations (black), WRF simulations (colors), and ERA-I (blue). Top: rainfall with threshold set to have the same occurrence of rainy days in both the observations and the model/reanalyses. Bottom: CDF-t applied on all time series as shown at the top of page 1.

Meeting/Workshop Reports

Saskatchewan River Basin Regional Hydroclimate Project Exploratory Workshop

30 March 2011
Saskatoon, Saskatchewan, Canada

Richard Lawford[1], Howard Wheater[2], and Kate Wilson[2]
[1]University of Manitoba, Winnipeg, Manitoba, Canada; [2]University of Saskatchewan, Saskatoon, Canada

This Exploratory Workshop was held to examine the feasibility of launching a GEWEX Regional Hydroclimate Project (RHP) in the Saskatchewan River Basin (SRB). It was hosted by the Canadian National Hydrology Research Centre and organized by Howard Wheater, the Canada Excellence Research Chair (CERC) of Water Security at the University of Saskatchewan and Vice-Chair of the GEWEX Scientific Steering Group. In his opening remarks, Dr. Wheater gave an overview of the CERC Program and GEWEX, and described how an SRB RHP could bring Canadian climate, hydrology, water quality, and social science scientists together to provide a GEWEX science focus on issues in Canada, including rapid climate change, interprovincial water allocations, and water access licensing.

Rick Lawford presented a history of the GEWEX RHPs and their roles in determining the variability of water budgets in different regions and their contributions to process understanding and regional model development. Experience has shown how important it is to have well-defined science questions for RHPs, as well as information requirements for effective water resources management, science and data collection to support GEWEX goals, and the appropriate scoping of basin studies and modeling systems.

Deborah Belvedere presented the proposed plans for a new U.S.-led RHP called the Terrestrial Regional North American Hydroclimate Experiment (TRACE). It is planned as an interdisciplinary, international and interagency project for regional-scale climate prediction, to assess the availability of clean water, and for understanding and predicting water cycle extremes.

In his presentation, John Pomeroy noted that most of the streamflow in the SRB is generated in the headwaters of the Rocky Mountains and that three provinces use the water as it flows eastward to the Hudson Bay. The nature of the topography and soils in Saskatchewan and Manitoba leads to more local cycling of water, as very little runoff from these areas joins the streamflow in the main river channels that cut through the landscape. In light of hydrological nonstationarity, a better ability for modeling this complex system is needed to address the water management problems that are emerging in the SRB.

Ronald Stewart's presentation showed the importance of understanding the vertical moisture fluxes and large-scale circulation features of the atmospheric water cycle in the SRB in assessing how atmospheric and surface processes couple to create climate extremes. To fully understand these features, he recommended that SRB RHP research include the diurnal processes, the structure of precipitation, deep atmospheric convection, surface fluxes, sublimation/evaporation processes, and the variability of extremes.

In reviewing hydrological science requirements for the SRB RHP, John Pomeroy noted the issues in modeling processes such as snow accumulation and melt and the importance of defining the appropriate scale for studying these, as well as the role that slopes and vegetation play in snowmelt. He also reviewed the role of wetlands and sloughs in the prairie environment in terms of groundwater recharge and the need to model large areas that do not contribute to the flows in the rivers. Calibration data for base flows and water in storage are often absent leading to difficulties in modeling these processes. The understanding of processes, improved process models and the widespread use of remote sensing data to provide support for better parameterizations in models is needed.

Stuart Marshall showed how glaciers in the Rocky Mountains contribute to river systems on the prairies and how they are becoming a rapidly diminishing resource as glacier areas decrease due to melting.

Garth van der Kamp reported that groundwater data from the 100 separate wells in the SRB have recently been standardized and are available for analysis. He noted the need for a more representative groundwater model for the SRB that would include all the stores of subsurface moisture (e.g., soil moisture) and a data system that would integrate ground- and surface surface water data.

Howard Wheater noted that water quantity and quality issues in the SRB are the result of natural variability (i.e., temperature) and anthropogenic effects, and suggested that including more water quality studies in the RHP could enable GEWEX to expand its relevance to water managers. He added that the CERC Programme examines water quality, especially in the South Saskatchewan River to Saskatoon, where nutrients added to the river system by agricultural practices are leading to eutrophication in lake systems.

Amin Elshorbagy noted that the development of a modeling system that accurately represents managed water resource systems and infrastructure at different scales is a priority given the possible need to renegotiate federal-provincial water agreements and the interest in moving beyond naturalized flow modeling to the incorporation of specific human interventions in flow estimates.

Alain Pietroniro provided an overview of modeling systems available for simulations and predictions in the SRB, including the Global Environmental Multiscale Model (GEMS) Community Environmental Modeling System Surface and Hydrology System (MEC-MESH). GEMS has a modular structure that supports the use of source code development by different contributors, and is used to classify non-contributing areas. Issues requiring attention include non-contributing areas, snow accumulation and snowmelt, basin delineation in complex terrain, large-scale soil moisture representation, and a better system for the calculation of naturalized flows.

Patricia Gober described the challenges related to integrating different knowledge systems and viewpoints for effective water management, and finding ways to deal with the inevitable water resources uncertainty for effective policy development.

Based on the presentations, some of the issues identified for an SRB RHP included determining the optimum size for the RHP, the "black hole" in terms of knowledge of processes in the delta at the downstream end of the SRB, the effects of climate change on glaciers, water management, and socio-economic development of the basin, and the potential role that paleo-records could play in SRB RHP studies.

An SRB RHP would have a rich mosaic and heritage of experience and past projects to build upon that include historical data sets, models, and fieldwork infrastructure. Current projects that could be used as building blocks for some of the SRB RHP activities include the Prairie Adaptation Research Collaborative (PARC) research, which studies past, present, and future hydroclimatic variability of the North Saskatchewan River Basin; the CERC Programme's SRB studies, and the work by the International Institute of Sustainable Development (IISD), which concerns the role of loadings of phosphorus and nitrogen in runoff as a critical cause of eutrophication in Lake Winnipeg.

Projects that have built the extensive body of expertise that exists on the prairies include:

- the Mackenzie GEWEX Study (MAGS), one of the five original GEWEX RHPs;
- a proposed demonstration project to test the degree to which the process understanding and model capability developed in MAGS could explain the SRB's climate system known as the Saskatchewan River Basin GEWEX Experiment (SAGE);
- the Drought Research Initiative (DRI) and its efforts to better understand the physical characteristics and processes influencing Canadian prairie droughts and to contribute to their better prediction and improved societal preparation; and
- the models, data sets and observational infrastructure of the Boreal Ecosystem-Atmosphere Study (BOREAS)/Boreal Ecosystem Research and Monitoring Sites (BERMS).

Other heritage studies include the Improved Processes and Parameterization for Prediction in Cold Regions (IP3) Network, which documented and modeled cold season processes, and the Western Canadian Cryospheric Network (WC2N) comprehensive study of glaciers in Alberta and British Columbia, which documented historical glacier variability and recent changes in glacier extent.

The participants broke into three discussion groups (meteorological component, land-surface hydrological component, and water management and policy applications component) to consider science questions for the RHP and to address issues related to implementation. These groups developed a list of research questions around issues of extremes; prediction at

Location of the Saskatchewan River Basin and some of the observational components that could contribute to a Saskatchewan River Basin Regional Hydroclimate Project.

different time scales; hydrometeorological processes (including snow accumulation and snow melt); dynamic computation of non-contributing areas; hydrological processes in the foothills; groundwater processes; and past and future climates and their impacts on water resources including water quality.

Although critical data are missing, such as water use data, there was a general consensus that we are well positioned to begin with the synthesis of the many data sets that are available. Efforts related to modeling should focus on improving and coupling models and assessing the reliability of reanalysis products to determine which ones need to be improved.

The hydrological community felt that the SRB in its entirety should constitute the RHP and that the research agenda should focus on the vertical processes in this region (e.g., groundwater–surface water–atmosphere interactions). In order to improve the use of science in decision-making and knowledge transfer, the research should be transferable when the need or opportunity arises. Foresight experiments, analysis of ecosystem services, an effective data portal and user engagement through simulation exercises have the potential to increase the societal benefits from the SRB RHP.

Lake Diefenbaker was proposed as a testbed for examining possible effects on limnological stratification and the biogeochemical cycling of warmer temperatures associated with climate change. The importance of planning and budgeting for outreach and community involvement and the promotion of linkages was emphasized. It was also suggested that in light of regional oil developments there may be some possibilities to secure joint private sector and government funding for the SRB RHP.

In the discussion on next steps, it was noted that the results of the Workshop should be used to build toward a preliminary implementation plan and proposal. The proposal would focus on a broad, scientifically sound RHP that includes all of the science interests in the SRB, but highlights the components that are of most interest to GEWEX. Workshop participants stressed the need to ensure that the science questions chosen for the Project would be those that would generate an enthusiastic involvement from the science community.

Next steps include:

- Preparing a White Paper.
- Discussing plans with user groups, stakeholders and the science community to obtain collaboration.
- Identifying possible sources of funding and securing preliminary funding to launch the effort.
- Engaging senior government officials with Environment Canada, Agriculture and Agri-food Canada, as well as provincial program managers.
- Preparing a short document based on the White Paper and submitting it to the GEWEX Hydroclimatology Panel for feedback, endorsement, and support.

First Planning Workshop for the Terrestrial Regional North American Hydroclimate Experiment (TRACE)

18–20 April 2011
Silver Spring, Maryland, USA

Robert A. Schiffer and Sushel Unninayar
GESTAR/Universities Space Research Association, Columbia, Maryland, USA

A growing consensus among scientists is the importance of reliable, regional-scale climate predictions for assessing water supply availability and stresses. Understanding and predicting water cycle extremes in a changing climate has direct applications for preserving life, environment, and economic assets. The challenge is to provide skillful forecasts of extremes that are weeks, seasons, years, and even decades in advance. Current observation and prediction limitations include: (i) the inability to translate the observation- and model-based knowledge of regional, watershed, and continental-scale water budgets into better predictions of the hydrological cycle; (ii) limited knowledge of the contribution of land-surface processes to predictability; (iii) isolated in situ and remote sensing observing systems; (iv) incomplete coupled atmosphere-hydrology models; (v) lack of understanding of human and Earth system controls on the water cycle; and (vi) disconnected disciplinary research and operational programs.

The Terrestrial Regional North American Hydroclimate Experiment (TRACE) Workshop began a community-driven process for formulating a new Regional Hydroclimate Project (RHP). The Workshop outlined the needs and opportunities for regional and continental-scale hydroclimate studies in North America to address the controlling forces and processes associated with water cycle variations, extremes, and trends on a regional and quasi-continental scale, and to determine how these factors are simulated in climate models. It is envisioned that TRACE will address the broad range of high priority issues within national and international multi-agency programs, such as the U.S. Global Change Research Program (USGCRP), GEWEX, the World Climate Research Programme (WCRP), the International Geosphere-Biosphere Programme (IGBP), the Intergovernmental Group on Earth Observations (GEO)/ Global Earth Observation System of Systems (GEOSS), the World Meteorological Organization, the United Nations Educational, Scientific and Cultural Organization (UNESCO)-Hydrology for the Environment, Life and Policy (HELP), and the Global Water System Project (GWSP).

TRACE is planned as an interdisciplinary, international, and interagency effort that will make significant contributions to continental- and finer-scale hydroclimate science. The RHP would entrain, integrate, and coordinate the vast array of interdisciplinary observational and prediction resources available to significantly advance skill in predicting and managing changes in North American water resources, as an integral part of the global climate system. TRACE would build on previous contributions by GEWEX, but also include the broader climate, carbon, ecology, and applications communities.

Given the range of space and time scales involved, from subregional to continental, and days to decades, TRACE is envisaged as a 10-year collaborative program of regional hydroclimatic observations, process studies, and modeling through a combination of enhanced long-term in situ observational networks, integrated remote-sensing observing systems (surface- and space-based), and specific embedded field campaigns of shorter duration. TRACE would include global to regional to local submodels, as well as data assimilation and simulation and prediction models of hydroclimatic processes on all space and time scales. Both scientific research and operational application needs will be a part of the design considerations of TRACE in order to provide the basis for substantially improved capabilities in regard to the ultimate goal of delivering robust and credible end-products of societal benefit. The diagnostic analysis and projection of extreme events (e.g., extended droughts, wet spells, floods) and their impact on end-user hydroclimatic applications sectors would also be addressed.

GEWEX Regional Hydrological Projects (RHPs)

During the period of 1992–2010, the land-surface scientific community benefited from a number of strong RHPs in the U.S. and Canada. The first, the U.S.-led GEWEX Continental-Scale International Project (GCIP) covered the Mississippi River Basin. GCIP was later expanded into the GEWEX Americas Prediction Project (GAPP), which covered the entire U.S. and parts of Mexico in a study on the complete North American Monsoon System. In 2006, GAPP and the Pan American Climate Studies (PACS) Project were integrated into the Climate Prediction Program for the Americas (CPPA) Project, which ended in 2010. The Mackenzie GEWEX Study (MAGS; 1989–2005), which was led by Canada, addressed hydroclimate issues in the Mackenzie River Basin.

TRACE is expected to address the full range of GEWEX Imperatives (*http://www.gewex.org/Imperatives.pdf*), as well as the broader goals of WCRP and other programs, such as the North American Carbon Program and IGBP.

A major scientific question to be addressed by TRACE is: "How does climate change affect the hydrological cycle on a regional to continental scale and to what extent is it predictable?" Issues surrounding this question include the following:

- Limitations in regional-scale weather and climate prediction capabilities.
- The inability to translate the observation- and model-based knowledge of regional, watershed, and continental scale water budgets into better predictions of the hydrological cycle.
- Gaps in integrated hydrometeorological, in situ, and remote sensing observing systems.
- Improvements needed for coupled atmospheric-hydrologic science models to decision support models.
- Understanding the scientific underpinnings of a national climate system.
- Linkages to other relevant research programs and operational centers (e.g., National Centers for Environmental Prediction), as well as contributions to updated National Climate Assessments and agency-sponsored (e.g., U.S. Geological Survey) initiatives.

In response to these issues, TRACE would provide:

- Reliable regional-scale climate predictions that are essential for assessing the availability of and the stresses on clean water supplies;
- An understanding of and the ability to predict water cycle extremes in a changing climate, which have direct applications to preserving life, environment, and economic assets; and
- Skillful forecasts of extremes predicted weeks, seasons, years, and even decades in advance that are useful for water resources management, a more challenging task.

Potential TRACE activities include:

- Developing climate data records of atmosphere, water, and land- and energy-related quantities, including metadata and uncertainty estimates.
- Describing and analyzing hydroclimate variations, trends, and extremes.
- Developing approaches to improve process-level energy and water cycle understanding in support of improved models and predictions.
- Determining the contribution of land-surface states and their changes to regional hydroclimate prediction, and improving continental precipitation, cloud, and hydrology prediction through accelerated development of coupled atmospheric and land models.
- Determining the predictability of energy and water cycle changes and mitigative strategies on a continental basis.
- Developing and bringing new observations, models, diagnostic tools and methods, data management, and other research products to national operational applications.
- Promoting and fostering capacity building through training and outreach.

TRACE Workshop Foci

The Workshop was focused on a specific area of unambiguous societal benefit, namely, water sustainability west of the Mississippi, including Canada and Mexico. Issues include the impacts of land and water use on the hydrological cycle; changing extremes; droughts (their causes and prediction); large-scale climate context (ocean and teleconnections); and the impacts of land and water use, such as ecosystem disturbance (e.g., insects), urbanization, irrigation, water management, and agriculture, on the hydrological cycle. Transcending the scales between human and Earth system processes was also discussed, as were how to represent land and water use in models and the influence of land and water use interactions with climate variability and change. Discussions were divided into the three theme areas described below.

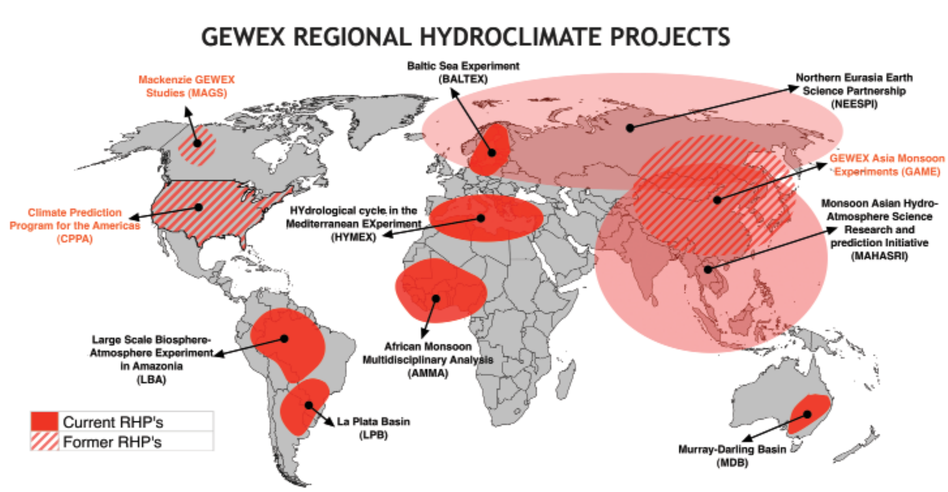
1. Atmosphere/Climate System Forcings on Terrestrial-Hydroclimatic Processes

This theme encompasses: (i) atmospheric and climate system forcings on regional and subregional terrestrial land-surface processes, such as the water cycle, carbon cycle, and energy cycle; (ii) cloud-precipitation processes; (iii) aerosol-cloud formation and cloud-radiation processes; and (iv) atmospheric dynamics, including forcings that lead to extreme events such as extended dry and wet periods. Surface considerations include hydrology, the radiation budget, vegetation, natural ecosystems, and agriculture. Observations and models are the focus of this theme, including various applications using the analytical information derived from the above.

2. Regional, Subregional Land-Surface, and Subsurface Processes

Regional, subregional land-surface, and subsurface hydrological processes and feedbacks with the atmosphere and climate system are grouped under this theme. These include surface fresh water storages and flows, soil moisture and moisture fluxes, ground water charge and recharge, and coupling with vadose zone and surface processes, such as evapotranspiration, sensible and latent heat fluxes, and energy balances. Hydrological processes that lead to extreme events are also included in this theme. The focus is again trained on observations and models, including various applications using the analytical information derived from the processes above.

Several major issues were considered concerning the lack of accuracy within global climate change projections and climate variability predictions, particularly in regard to water cycle variables, such as soil moisture. Addressing the continental to regional-scale in the context of the global climate system was thought to pose a significant observational and modeling challenge due to the range of scale interactions involved in hydroclimatic processes. Key scientific issues proposed for unraveling (i.e., observing and modeling) hydrological sensitivities and feedbacks in North American climate included the leading controls on water cycle sensitivity, and how terrestrial processes modify feedbacks and coupling to the North American climate system.



3. Prediction and Predictability

The current capabilities (reliability of prediction systems) require improvements in both observing systems and modeling systems to assess predictability and improve both climate change and hydrological predictions on time scales ranging from weeks to decades. The focus of this theme is on: (i) modeling systems (e.g., global coupled climate system, regional atmospheric models, land-surface information systems, and hydrological and water resources modeling systems), (ii) scaling issues (e.g., downscaling and upscaling, and error and bias corrections), and (iii) diagnostic- and model-derived research guidance information required to address adaptation issues related to local hydroclimatic change. Also included are subregional- to continental-scale paleo-hydroclimatic analysis and reconstructions that provide a validation testbed for simulation and prediction models.

Steps to provide a scientific basis for assessing the vulnerability of ecosystems and economies in North America to variability and extremes in climate were discussed. The processes involved arise from global and local forcings produced by natural climate variability and anthropogenic forcing. Considerations for TRACE studies include:

- Better characterization of extreme events associated with climate variability and change (e.g., droughts and floods), including both short (intraseasonal and interannual) and long-term (interdecadal and beyond) timescales.
- Connection to a distinct physical phenomenon where there is land-atmosphere-ocean interaction (e.g., monsoons, cold season precipitation).
- Focus on geographic locations and timescales where predictability is currently challenging, such as transition regions, which are characterized as those places with uncertainty in IPCC climate change projections.
- Characterization and modeling of land-atmosphere processes at the appropriate spatial scale, as these interplay with large-scale climate forcing (i.e., teleconnectivity).
- Reduction of uncertainty in climate change projections, with attention on mining the existing long-term observational record, as the climate change signal is present over the past 20–30 years and enough high quality data may be accessible to characterize continental-scale spatiotemporal variability over the last two decades.

Workshop Conclusions and Next Steps

The major scientific question of TRACE is, "How do climate change and climate variability affect the hydrological cycle on a regional to continental scale, and to what extent is it predictable?" Addressing this requires research focused on a broad range of observational, science, and applications issues, including documenting and investigating the past, present, and future projections of the occurrence of extremes, atmosphere-regional hydrosphere interactions and feedbacks, teleconnections between local scale processes and the global atmosphere-ocean-land (coupled) climate system, scale interactions (downscaling and upscaling), and the observations-based parameterizations of processes in a hierarchy of global to regional to local models. While considerable progress has been made over the past decade or two, several deficiencies remain in observing systems, data assimilation systems, and hydroclimatic modeling systems.

Planned improvements to both observing and modeling systems will address some of these deficiencies, such as improved global and regional precipitation and soil moisture estimates, but others warrant new approaches to improve observational, diagnostic, and predictive capabilities to provide the delivery of operational and research analysis products required by a vast array of user sectors. Some example areas include water resources management, the agricultural industry, hydropower generation and distribution, disaster preparedness and mitigation, urban planning and development, ecosystem conservation and management, the energy industry (including water demands of power plants and increased production of biofuels), and tourism and recreation.

Recent changes in the continental-to-regional hydroclimate point to the need for new observational strategies to monitor the increased variability of dry spells and droughts in western states, increased wet spells and flooding in middle and eastern states, changes in the intraseasonal variability and timing of winter snow fall and freeze-thaw timing, and possibly more intense storm systems. Some of these changes are attributable to decadal-scale oscillations of the climate system, some to changes in the radiation budget caused by increased greenhouse gases in the atmosphere, and some to a variety of regional and local changes in land use and land management practices. Other changes include the rapid shrinking of Arctic sea ice and the melting of land-locked glaciers and ice sheets, upon which many cities and regions depend for their fresh water supplies. Moreover, these changes, even on intraseasonal to seasonal and to interannual time scales, point to the need for research on how to address the non-stationarity of the continental to regional hydroclimatic regime, and in particular the manner in which historical data are to be statistically analyzed and the results applied to various decision-making matrices in operational applications sectors.

The TRACE Workshop defined a research framework for future observational and modeling studies as an initial planning effort aimed at substantially improving continental- to regional-scale hydroclimatic predictions on all time scales, while also striving to address a range of critical cross-cutting research and applications sector issues. Namely:

- Studying water sustainability west of the Mississippi River (including Canada and Mexico), and key indicators for monitoring and modeling the processes involved in determining the terrestrial hydrological cycle and its interactions with the global climate system. Particular emphasis on the treatment of extremes was recommended, as well as on the impacts of land and water use on the hydrological cycle. In turn, studies on the impacts of variability of the hydrological cycle on such things as ecosystem disturbances, urbanization, irrigation, water management, agriculture, and the energy industry were also advised.

- Understanding and quantifying the leading controls on the sensitivity of the North American water cycle, and how terrestrial processes modify feedbacks and coupling to the North American climate system.

- Providing a scientific basis for assessing the vulnerability of economies and ecosystems in North America to variability and extremes in hydroclimate that arise from both natural climate variability and anthropogenic forcings.

To facilitate research on the TRACE themes, an enhanced observing system is needed that is comprised of a long-term backbone system of transects across the differing hydroclimatic regimes in continental North America, as well as more specialized campaigns in selected subregions that measure a broader array of variables, taking advantage of existing facilities and the latest developments in technology. Such a combination is necessary to deliver early analytical and model-derived products for immediate use in operational water resource allocation.

An ad hoc Working Group was established to refine the scientific requirements and develop the basis for an implementation plan for TRACE through appropriate consultations with the community and various agencies. It was recognized that it is essential to involve the scientific community and governmental agencies to identify areas of relevance and common interest, and to initiate a dialogue that will bring the issues to the table through workshop presentations and discussion by community leaders with experience in the planning and implementation of RHPs, such as those associated with the GEWEX. TRACE is not sponsored by any federal agency or international program, but represents a scientific community initiative. At some point, appropriate sponsorship will be solicited. Material presented at the Workshop can be found on the TRACE website at: *http://www.trace-rhp.org*.

In order to exploit opportunities for consensus-building within the scientific community and with potential federal agency sponsors, it was recommended that a TRACE Science Steering Committee be formed and charged with developing and promoting a planning strategy that summarizes a scientific justification for a new North American RHP, outlining science goals, research priorities, potential programmatic partnerships, the timeline, metrics, estimated resource requirements, and opportunities for soliciting co-sponsorship. A target date of December 2012 was established for producing a first draft plan to be shared with agencies.

This report was submitted on behalf of the TRACE Planning Team: Paul Houser, Peter vanOevelen, Robert Schiffer, Sushel Unninayar, Christopher Castro, Ruby Leung, Richard Lawford, Eric Wood, David Gochis, Michael Ek, Michael Bosilovich, Ernesto Hugo Berbery, Deborah Belvedere, and Raymond Arritt, Adam Schlosser.

GCSS/CFMIP/EUCLIPSE Meeting on Cloud Processes and Climate Feedbacks

6–10 June 2011
The Met Office, Exeter, UK

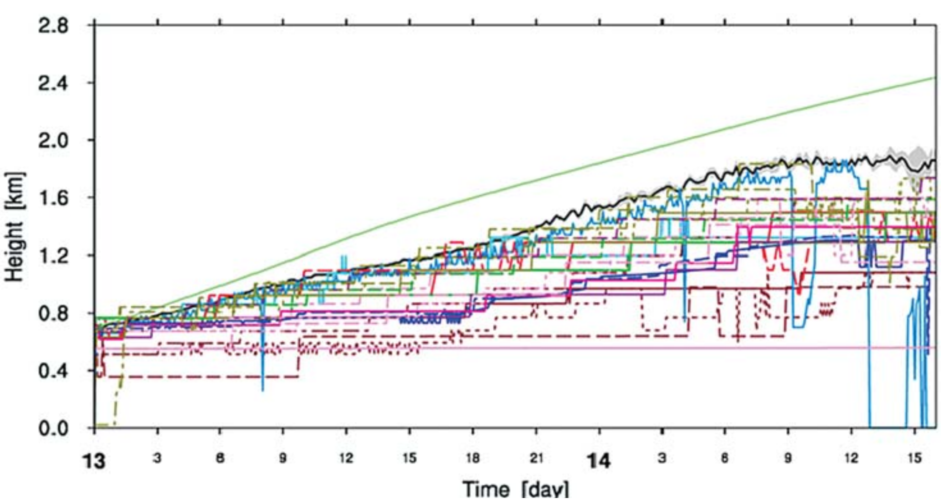
Adrian Lock
Boundary Layer Group, Met Office, Exeter, UK

Scientists from the GEWEX Cloud System Study (GCSS) Boundary Layer Cloud Working Group, the World Climate Research Programme (WCRP) Working Group on Coupled Modeling (WGCM) Cloud Feedback Model Intercomparison Project (CFMIP), and the European Union Cloud Intercomparison, Process Study and Evaluation Project (EUCLIPSE) met to discuss the representation of clouds in Global Circulation Models (GCMs). The areas of expertise represented by the scientists in these three groups encompass fine-scale modeling and observations of cloud processes, GCM climate modeling and evaluation, GCM physics parameterization, and satellite observations. The aim of this on-going close collaboration is to reduce the uncertainty in cloud feedbacks in projections of future climate, ultimately leading to better weather and climate predictions.

Early results were presented from the new generation of climate model experiments being prepared for CMIP5 that will be used in the next Intergovernmental Panel on Climate Change (IPCC) assessment. Discussions focused on how to make the best use of new observational data sets to evaluate and improve the representation of clouds in global models. These include ground-based observations at selected locations (e.g., Illingworth et al., 2007) and from intensive field campaigns (e.g., Hourdin et al., 2010), as well as satellite data. This is an area in which significant progress has been made in recent years, driven by the development of satellite simulators such as the CFMIP Observations Simulator Package (COSP), a unified satellite-simulator interface for GCMs (Bodas-Salcedo et al., 2011).

Participants at the GCSS/CFMIP/EUCLIPSE Meeting.

A strong focus of the collaboration is the intercomparison of large-eddy simulation (LES) and single column (SCMs) versions of the GCMs for several boundary layer cloud regimes. Although this is a long-standing and highly productive methodology for GCSS, these two sets of simulations break new ground in several ways. The first intercomparison uses a set of simulations to study the stratocumulus to trade cumulus transition, one that is of climatological importance for understanding low cloud cover in the marine subtropics. There are four simulations in total. The first is a simulation of the first Lagrangian experiment of the Atlantic Stratocumulus to Cumulus Transition Experiment (ASTEX) field campaign (Albrecht, et al., 1995), which allows detailed comparisons with in situ aircraft observations. The other simulations explore the range of climatology of these transitions, with slow, medium, and fast transition cases based on satellite and reanalysis data (Sandu et al., 2010). Thus, the models are challenged to produce realistic transitions both in terms of detailed microphysics and turbulent fluxes, compared to in situ data, and in the sensitivity of the speed of transition to changes in environmental forcing seen in the satellite and reanalysis data. Running these long simulations with very high resolution (5 m in the vertical) is computationally challenging for LES



Preliminary results of cloud top height evolution for the ASTEX Lagrangian simulations. The LES ensemble mean and spread (one standard deviation) are plotted as the black line and grey shading. The colored lines are the SCMs.

models but initial results suggest that they do a good job of capturing these details, particularly when compared to the performance of many of the SCMs (see figure on previous page). One of the motivations for this intercomparison was that these transitions would present a challenge for SCMs, many of which would need to make the transition between different parameterizations of vertical mixing. Although many SCMs struggle to generate realistic transitions, it is encouraging that those organizations that have worked hard to develop these aspects of physical parameterizations can do a reasonable job.

The second collaborative model intercomparison study is the CFMIP-GCSS Intercomparison of Large Eddy Models and Single Column Models (CGILS, Zhang et al., 2010). The crucial and novel aspect of this intercomparison is using idealized large-scale dynamical conditions to perform pairs of simulations for a control and a perturbed climate. The goal is to use the LES both to improve understanding of the physical processes involved in subtropical marine boundary layer cloud feedbacks, and as a benchmark for the credibility of low cloud processes in the SCMs. Three cloud regimes are simulated: (1) trade cumulus, (2) well-mixed stratocumulus and (3) cumulus rising into stratocumulus. The latest results show a much smaller range of cloud feedbacks in the shallow cumulus regime for the LES than for the SCMs. For the stratocumulus regimes the LES models agree on many of the characteristics of the boundary layer response to climate warming (such as a tendency for the boundary layer to deepen and the cloud layer to decouple from the surface), and so remain very valuable constraints on the credibility of the SCMs. The LES disagree, however, on whether the clouds should thicken or thin. This illustrates the delicate balance between interacting processes that continue to make boundary layer clouds a fascinating and important area of study.

For links to all the model intercomparison studies, see: *http://www.euclipse.nl/wp3/.*

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GEWEX/WCRP Calendar

For the complete listing, see the GEWEX web site: http://www.gewex.org

30 Aug–1 Sept 2011—Third Pole Environment Workshop—Reykajavik, Iceland.

30 Aug–2 Sept 2011—GEWEX Radiation Panel Meeting—Tokyo, Japan.

5–9 Sept 2011—EUMESAT Meteorological Satellite Conference—Olso, Norway.

16–17 Sept 2011—iLEAPS Early-Career Scientist Workshop—Garmisch-Partenkirchen, Germany.

18–23 Sept 2011—3rd iLEAPS International Science Conference—Garmisch-Partenkirchen, Germany.

27–30 Sept 2011—30th ISCU General Assembly—Rome, Italy.

25–29 Sept 2011—International Water Resources Association's World Water Congress—Porto de Galinhas/PE, Brazil.

27–29 Sept 2011—5th International Conference on Flood Management—Tsukuba, Japan.

17–21 Oct 2011—27th Session of WGNE—Boulder, Colorado, USA.

19–21 Oct 2011—GHP Meeting—Boulder, Colorado, USA.

23 Oct 2011—GEWEX GLASS Meeting—Denver, Colorado, USA.

24–28 Oct 2011—WCRP Open Science Conference: Climate Research in Service to Society—Denver, Colorado, USA.

25 Oct 2011—GEWEX Executive Meeting—Denver, Colorado, USA.

7–10 Nov 2011—ECMWF-GEWEX/GABLS Workshop on Diurnal Cycles and the Stable Atmosphere Boundary Layer—Reading, UK.

14–18 Nov 2011—24th Session of the GEWEX SSG—CNR, Rome, Italy.

23–25 Nov 2011—EGU Leonardo Conference— Bratislava, Slovakia.

29 Nov – 2 Dec 2011—Earth Observation for Ocean-Atmosphere Interactions Science—Frascati, Italy.

5–9 Dec 2011—AGU Fall Meeting—San Francisco, California, USA.

22–26 Jan 2012— 92nd AMS Meeting— New Orleans, Louisiana, USA.

20–24 Feb 2012—Chapman Conference on Remote Sensing of the Water Cycle—Kona, Hawaii, USA.

12–15 March 2012—CLiC SSG Meeting—Innsbruck, Austria.

20–23 March 2012—Workshop on the Physics of Climate Models—Caltech, Pasadena, California, USA.

26–29 March 2012—ICSU/IGBP/IHDP/WCRP Conference: Planet Under Pressure: New Knowledge, New Solutions—London, UK.

7–11 May 2012—4th WCRP International Conference on Reanalyses—Silver Spring, Maryland, USA.

28 May – 2 June 2012—5th International Conference on Water, Climate and Environment (BALWOIS 2012)—Ohrid, Republic of Macedonia.

4–6 June 2012—United Nations Conference on Sustainable Development (Rio+20)—Rio de Janeiro, Brazil.

COSMOS Mobile Measurements of Soil Moisture Consistent with Precipitation

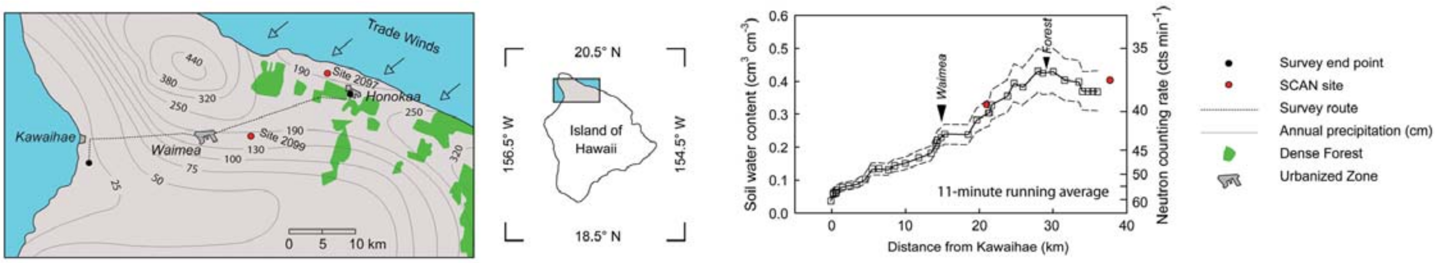
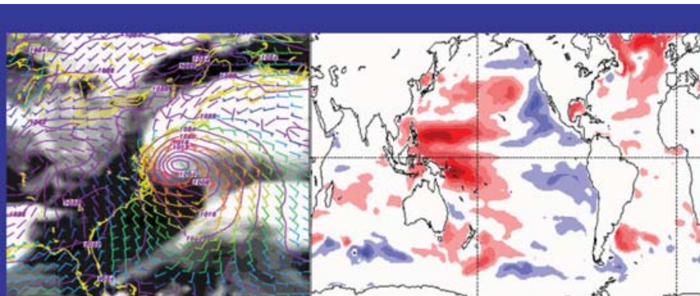


Figure 5. Roving soil moisture survey conducted on Hawaii Island from the wet, tradewind dominated east side, across the saddle between Mauna Kea and Kohala, to the dry west side (Desilets et al., 2010). The results display a clear trend from low soil moisture on the west side of the island to high soil moisture on the east side. This is consistent with annual precipitation which ranges from less than 25 cm on the west coast to more than 200 cm on the east. See article by M. Zreda et al. on page 6.



4th World Climate Research Programme International Conference on Reanalyses

7-11 May 2012
Silver Spring, Maryland, USA

CALL FOR ABSTRACTS

Abstract submittal will be available soon (Deadline is 6 January 2012)

Characterizing the uncertainty and quality of reanalyses is a task that reaches far beyond the community that develops them and into the network of interdisciplinary researchers, especially those who use the reanalyses products in their research and applications. The **4th WCRP International Conference on Reanalyses (ICR4)** provides an opportunity for the global community to review and discuss the major observations and modeling research associated with reanalyses, including uncertainties, such as consistency of the time series, and the complexity of the Earth system.

Conference Themes/Topics:

- **Status and Plans**: Major international reanalysis development, including broad disciplinary overviews (e.g., atmosphere, oceans, hydrology, cryosphere).
- **Validation and Metrics**: Intercomparison and validation studies; assessing the impact of the assimilation and analysis increments; innovative diagnostics that characterize the degree to which a reanalysis represents reality and ultimately applicability for weather and climate research.
- **Data Assimilation**: Data assimilation techniques and impact on eventual reanalysis data products, especially producing a climate quality time series.
- **Space and In Situ Observations**: Studies on the quality and stewardship of observations and their use in reanalyses and exploiting new data types and sources.
- **Application in Support of Climate, Weather and Environmental Services:** Innovative research using reanalysis to study the weather, ocean, hydrology and climate, including operational climate monitoring, study of extremes and high impact weather, climate assessment and end-to-end decision making studies.
- **International Collaborative Efforts**: Projects and plans for developing and using reanalysis to the benefit of the international community.
- **Program Level Panel Discussions**: Challenges and opportunities in reanalysis for the next decade.

Conference Website: http://icr4.org

Reanalyses Intercomparison and Analyses Website: http://reanalyses.org