GEWEX WCRP
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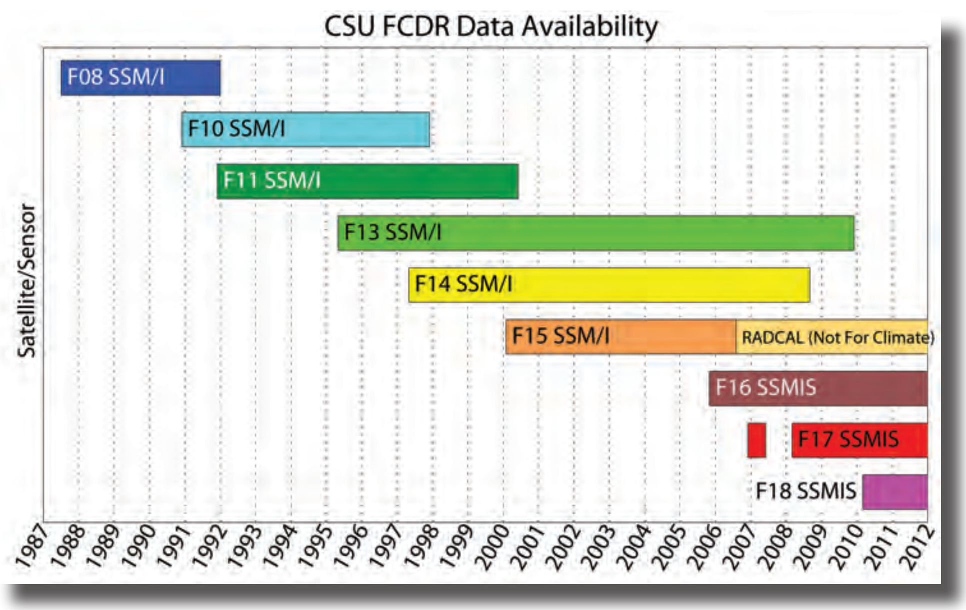
25-Year SSM/I and SSMIS Global Data Record: A Valuable Resource for Global Water Cycle Studies



The launch of the Special Sensor Microwave/Imager (SSM/I) on board the Defense Meteorological Satellite Program's (DMSP) F08 spacecraft in June 1987 marked the beginning of a nearly continuous 25-year record of high-quality global window-channel microwave observations. Shown is the availability of intercalibrated Colorado State University Fundamental Climate Data Record (FCDR) brightness temperature data from the SSM/I and Special Sensor Microwave Imager Sounder (SSMIS) sensors. See article by W. Berg et al. on page 4.

GEWEX is now "Global Energy and Water Exchanges" *(See Page 2)*

Help us with the creation of a new logo for GEWEX.
Send us your ideas in jpg format and we will post them on: http://www.gewex.org

Also Inside

Commentary

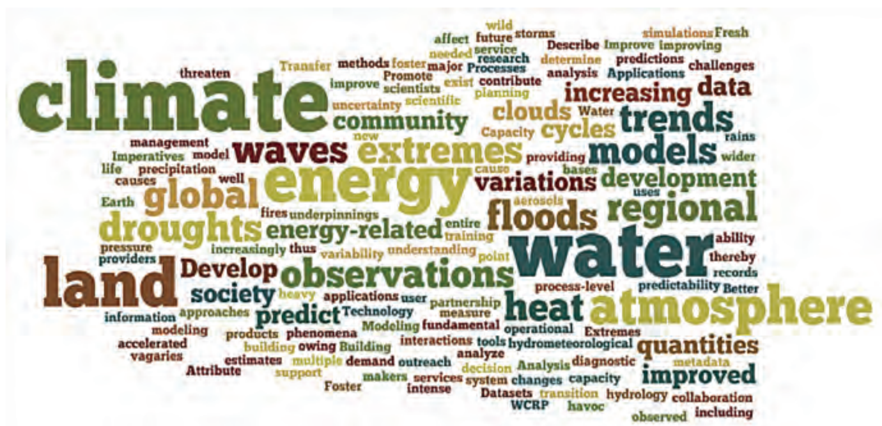
Global Energy and Water Exchanges: "GEWEX"

Kevin E. Trenberth
Chair, GEWEX Scientific Steering Group

As many of you know, we have been exploring the possibility of a new name for GEWEX. This is part and parcel of the revamped World Climate Research Programme (WCRP) post-2013 era, where projects are redefined, new councils are implemented, and we move forward into the challenges of the Anthropocene and Future Earth. We initiated a commentary period with regard to the GEWEX name, and finally settled on a poll among three choices:

1. No change – keep Global Energy and Water Cycle Experiment (GEWEX)
2. Redefine GEWEX as Global Energy and Water Exchanges
3. Change name to CLEW (Climate, Land, Energy and Water)

The latter arises from a Wordle of our mission, vision, and Imperatives statements, and the words "climate," "land," "energy," and "water" emerge as dominant themes in our proposed endeavors. The word "CLEW" is fairly unique when Googled and in Greek mythology refers to the ball of thread used by Theseus to find his way out of the labyrinth. Perhaps not a bad name as it shows the way and at least we would not be "clewless."



The poll resulted in 127 responses, and many comments revealed a strong resistance to re-branding GEWEX but with the recognition that the old name is obsolete—we are no longer an experiment. One comment we received was that we must not lose the "x-factor!"

Accordingly, the choice was clear: retain the GEWEX acronym but modify what it means. This has now been approved as a way forward by the WCRP Joint Scientific Committee (JSC) and gives us license to revamp the logo, its color and font. My off-the-cuff attempt at a logo is on the next page. Suggestions are welcomed.

GEWEX Name Poll Results
Choices Ranked 1, 2, 3 or Scored 0 to 10

Redefine GEWEX:	1.58	7.10
No Name Change:	2.09	4.54
Change the Name:	2.32	3.40

Other WCRP projects are in a similar situation: The Climate and Cyrosphere Project (CliC), which was the newest of the WCRP projects, will remain as it is. The Stratospheric Processes and their Role in Climate (SPARC) Project and the Climate Variability and Predictability Project (CLIVAR) will be retained but likely with a different meaning or acronym.

There was a lot of discussion over the Internet that ensued as part of this process. Many considered the stove-piping into land-atmosphere (GEWEX), ocean-atmosphere (CLIVAR), stratosphere-atmosphere (SPARC) and the cryosphere to be an obsolete concept since we must deal with the entire climate system. This is certainly true, but the management of projects is best broken up into bite-sized chunks and shared. While some projects may not need the WCRP framework, many do. Scientists from smaller and developing countries especially look to WCRP for leadership and as a way to leverage their contributions. However, a major concern which I raised at the recent JSC meeting was about the synthesis and global aspects of climate: how will all of the project contributions be integrated into a view of the entire climate system? Global data sets provide one perspective, for instance as fostered in GEWEX Data and Assessments Panel (GDAP), while global modeling on either seasonal to interannual [WCRP Working Group on Seasonal-to-Interannual Prediction (WGSIP)] or longer [WCRP Working Group on Coupled Modeling (WGCM)] activities provide another. Previously, CLIVAR has had a focus on climate variability and predictability on multiple time scales, and hence there is a concern that if CLIVAR narrows its perspective to be primarily oceans, some of this could be lost.

Accordingly, proposals were floated about the GEWEX Global Atmospheric System Studies (GASS) Panel, which leads WCRP activities on atmospheric processes in combination with SPARC, which deals with the troposphere-stratospheric interactions, and the World Meteorological Organization/ WCRP Working Group for Numerical Experimentation

(WGNE), which deals with some modeling aspects. Further, a global monsoon project is proposed that focuses on processes and phenomena, the large-scale dynamics, and common factors, with further activities in regions within this setting to deal with the unique aspects of the Asian-Australian, African, and American monsoons. Extreme events is another area that cuts across WCRP and requires an integrated approach, although with GEWEX playing a major or perhaps leading role. These projects should not be confined to land or ocean, but should be global. Nevertheless, they are likely to be hosted within one of the projects (e.g., GEWEX, CLIVAR), which will take the lead on organizational matters through the project offices.

A major topic at the JSC meeting was the proposed Grand Challenges, which also falls under global synthesis efforts. The four Grand Science Questions adopted by GEWEX have been discussed (see the November 2011 issue of *GEWEX News*), and a four-page description of each has been developed and will be circulated soon. It appears that there will also be six **WCRP Grand Challenges (see below) that provide a focus for tractable and actionable science over the next 5–10 years.**

1. Skillful regional climate information consisting of three initiatives: (i) intraseasonal to seasonal and interannual prediction (CLIVAR lead); (ii) decadal prediction (CLIVAR lead); and (iii) long-term regional climate information (WGCM will support the initial planning phase).
2. Regional sea level rise, which will include a global component (CLIVAR lead, with input by GEWEX and CliC).
3. Cryosphere in a changing climate (CliC lead).
4. Cloud and climate sensitivity (led by WGCM with strong GEWEX/GASS involvement).
5. Changes in water availability (GEWEX lead).
6. Prediction and attribution of extreme events (GEWEX lead).

Future Earth (*http://www.icsu.org/future-earth/;* see article on page 16) is the name being given by the International Council for Science (ICSU) to the new program to replace the Earth System Science Partnership (ESSP) and embrace the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme on Global Environmental Change (IHDP), and DIVERSITAS. Future Earth is a 10-year international research initiative that will develop the knowledge for responding effectively to the risks and opportunities of global environmental change and for supporting transformation towards global sustainability in the coming decades. Future Earth was announced at the March 2012 IGBP-led Planet Under Pressure Conference (*http://www.planetunderpressure2012.net/*) held in London, at which I was privileged to contribute.

A large component of Future Earth is related to the **Belmont Forum** (*http://igfagcr.org/index.php/belmont-forum;* see article on page 14) activities among the leading funding agencies (IGFA is the International Group of Funding Agencies) around the world. The combined forces of ICSU and IGFA have designed this new approach to sustainability science appropriate for the Anthropocene as human influences dominate environmental change as well as climate change. The magnitude of the problem we face was brought home to me at the JSC meeting by James Syvitski who chairs the IGBP. When you contemplate that there will be nine billion people living on Earth by perhaps 2050, it means adding a city of a million people every week from here on out. Wow!

This new framing of WCRP and GEWEX presents exciting opportunities for us in GEWEX and in WCRP, but also challenges in terms of encouraging scientists to join us, ensuring that funding is forthcoming, and that we have the infrastructure to support the efforts. I look forward to these challenges and I hope you all will join us.

Contents

A Fundamental Climate Data Record of Microwave Brightness Temperature Data from 25 Years of SSM/I and SSMIS Observations

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The launch of the Special Sensor Microwave/Imager (SSM/I) on board the Defense Meteorological Satellite Program's (DMSP) F08 spacecraft in June of 1987 marked the beginning of a nearly continuous 25-year record of high-quality global window-channel microwave observations. Since that first launch, a total of six SSM/I sensors and three of the next generation Special Sensor Microwave Imager Sounders (SSMIS) have flown on board the polar-orbiting DMSP satellite series. The figure on page 1 shows the availability of data from these nine sensors, which currently comprise over 70 satellite years of observations.

The long time series provided by these operational sensors along with their frequent sampling, global coverage, excellent stability, and sensitivity makes these data extremely valuable for global water cycle studies. The SSM/I and SSMIS window channels are sensitive to emission by water vapor, cloud water, and precipitating hydrometeors as well as scattering by large liquid and ice particles, although unlike visible and infrared observations, nonprecipitating clouds are relatively transparent at these microwave frequencies. This makes the data well suited for estimates of precipitation rate, column water vapor, and cloud liquid water, and surface parameters such as ocean surface wind speed, sea ice extent and concentration, snow cover, soil moisture, and land surface emissivity. The operational focus of these sensors, however, limits their use for many climate applications. To maximize the use of the data for long-term monitoring, the National Oceanographic and Atmospheric Administration (NOAA) funded the development of a Fundamental Climate Data Record (FCDR) of intercalibrated brightness temperature (Tb) data from the SSM/I and SSMIS sensors. The National Research Council (2004) defines an FCDR as "sensor data (e.g., calibrated radiances, brightness temperatures, radar backscatter) that have been improved and quality controlled over time, together with the ancillary data used to calibrate them."

The mission of NOAA's Climate Data Record Program is to "develop and implement a robust, sustainable, and scientifically defensible approach to producing and preserving climate records from satellite data." This requires a fully documented and transparent process with the capability to reprocess the data record as knowledge and techniques evolve (e.g., radiative transfer models), to extend the data record as new sensors become available, and to understand exactly what was done to create the existing FCDR so that mistakes of the past are not repeated. Lessons from previous CDR development efforts, such as the satellite tropospheric temperature record (Spencer and Cristy, 1992; Cristy et al., 2000; Mears and Wentz, 2005, 2009) emphasize the importance of a well-documented and transparent process. For the SSMI(S) FCDR, the original temperature data record (TDR) data were first reformatted into "BASE" files, which with the exception of duplicate scans, contain all of the original data broken into single orbit granules and written in NetCDF4 with associated metadata. The BASE files preserve the original data in a standard self-documenting format, provide a clean data set for FCDR processing, and allow for subsequent reprocessing. The FCDR processing code contains all of the corrections applied to the data in a single piece of software with a one-to-one correspondence between input and output data files. The code is also available as part of the documentation. Due to significant differences between the instruments, one code was developed for the six SSM/I sensors and another for the three SSMIS sensors. For the SSMIS sensors, the additional sounding channels are included in the output FCDR files, although many of the corrections and the intercalibration adjustments were only applied to the SSM/I equivalent window channels.

The SSMI(S) FCDR development involved rigorous quality control of the original TDR data, corrections for known issues/problems, adjustments for residual intercalibration differences using multiple independent approaches, active collaborations with a wide range of CDR developers to solicit feedback, and of course detailed documentation of every aspect of the process. The early data record from the 1980s and 1990s in particular suffered from frequent data transmission and processing errors, thus necessitating the development of multiple quality control procedures to identify and eliminate problem data. These include checks for abrupt changes from climatological mean values, large geolocation errors related to timing issues, and anomalous spikes in the gain values used to compute the antenna temperatures. Corrections for cross-track biases were developed and applied to account for the falloff at the edge of the scan due to partial beam blockage, which varies significantly by channel and between sensors. For SSMIS, solar and lunar intrusions into the warm load leading to calibration errors are a significant issue for F16 and to a lesser extent for F17 and F18 due to the addition of a fence designed to eliminate direct intrusions. An approach developed for the operational processing was implemented to identify and remove gain anomalies resulting from these intrusions (Kunkee et al., 2008).

Poe and Conway (1990) investigated errors in the SSM/I pixel geolocation from DMSP F08 in excess of 20–30 km. Because land surfaces have much higher surface emissivity values than oceans at these frequencies, window channel radiometers show a sharp land/ocean contrast, which they subsequently used to estimate offsets to the spacecraft attitude based on analysis of high-resolution coastlines. For the SSMI(S) FCDR, Berg et al. (2012) developed an automated approach to estimate time-dependent offsets in spacecraft attitude between sensors by minimizing Tb differences between ascending and descending satellite passes. While slight errors in the pixel geolocation may not be a significant issue for many applications, the observed Tb are sensitive to variations in the Earth Incidence Angle (EIA) due to associated changes in the surface emissivity and the depth of the atmosphere along the slant path. As a result, accurate estimates of the EIA are needed both for the intercalibration and for subsequent use in geophysical retrieval algorithms. Corrections made to the satellite attitude based on the geolocation analysis (Berg et al., 2012) indicates residual uncertainties in the calculation of EIA of less than 0.1 degrees, which translates to errors in the calibration of less than 0.2 K for all channels. Precise estimates of EIA are critical since a decrease in the mean EIA over time due to the decay of the DMSP orbits leads to a change in the mean Tb, which can produce an artificial climate trend if not properly accounted for by the geophysical retrieval algorithms.

After eliminating bad data and applying the various corrections, multiple intercalibration approaches were used to determine residual calibration differences between the sensors (Sapiano et al., 2012). Using multiple approaches helps identify potential issues with the individual techniques, increases confidence in the results, and provides an estimate of the residual uncertainties. The techniques implemented included direct polar matchups, differencing against model simulations from reanalysis data, double differencing against matchups with the Tropical Rainfall Measuring Mission (TRMM) Microwave Imager, vicarious cold calibration (Ruf, 2000) and an Amazon warm calibration (Brown and Ruf, 2005). All of these approaches involve computing simulated Tb for each sensor using radiative transfer and surface emissivity models along with atmospheric profile and surface parameters to account for expected sensor differences resulting from differences in EIA and other sensor characteristics. Since the largest source of uncertainty for several of these techniques is the atmospheric profile and surface parameters used to compute the simulated Tb, multiple sources were used, including the interim reanalysis from the European Centre for Medium Range Weather Forecasting (ECMWF), NASA's Modern Era Reanalysis (MERRA), and an optimal estimation retrieval developed by Elsaesser and Kummerow (2008). This resulted in a total of ten different estimates of the intercalibration differences between sensors, although not all approaches could be applied to all the sensors, particularly the early sensors including F08 and F10. The total spread between the techniques was generally less than 0.5 K for all channels with an uncertainty in the mean intercalibration on the order of a few tenths of a Kelvin. It is important to note, however, that while the final intercalibrated FCDR Tb are physically consistent, differences in channel frequencies (e.g., 85.5 GHz for SSM/I vs. 91.655 for SSMIS), view angles, spatial resolution, and observation time, etc. remain. As a result, geophysical retrieval algorithms must take into account these sensor differences.

The SSMI(S) FCDR from Colorado State University (CSU) will be publicly distributed by NOAA's National Climatic Data Center (NCDC) beginning in early 2013. Interested users may contact the authors directly, however, for access to an early beta release of the data. The data are stored as NetCDF4 files using internal data compression to reduce the total data volume. Even so, the total data volume exceeds three terabytes and contains over 70 satellite years of data. Note that a radar calibration (RADCAL) beacon on DMSP F15 was activated in August 2006 that caused substantial interference in the 22.235 GHz channel. Although a correction was applied to remove the RADCAL contamination, the residual error in the correction was determined to be on the order of several Kelvin and thus the data from August 2006 forward is not deemed suitable for climate applications, although it is made available. Additional information and documentation related to the project is available on the web at: *http://rain.atmos.colostate.edu/FCDR*.

Acknowledgments

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4th WCRP International Conference on Reanalyses: Conclusions and Recommendations

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The World Climate Research Programme (WCRP) International Conference on Reanalyses (ICR4) held on 7–11 May 2012 in Silver Spring, Maryland, provided an opportunity for the international community to review observational and modeling research, as well as process studies and uncertainties associated with reanalysis of the Earth system and its components. Presentations from the Conference and the final Conference report with a listing of all authors and contributors is available at: *http://icr4.org/*.

Atmospheric, oceanic and land reanalyses have become fundamental tools for weather, ocean, hydrology and climate research. They continue to evolve with improvements in data assimilation, numerical modeling, and observation recovery and quality control, and have become long-term climate and environmental records. Reanalyses are natural integrative tools, yet coupling the components of the Earth system in reanalyses remains a challenge.

Observations are the key resource in producing reanalyses, and improvements in algorithms and quality control are still advancing. Additional challenges remain to account for model bias as new data are assimilated and the observation record evolves (e.g., new instruments replace old ones). These issues are especially important for using reanalyses in climate research. Extending the reanalysis record back in time is a fundamental need of the weather and climate research community. Considering these challenges, the Conference had the following objectives:

- Sharing current understanding of the major challenges facing reanalyses: the changing observing system and integrated Earth system.
- Assessing the state of the disciplinary atmospheric, ocean, and land reanalyses, including the needs of the research community for weather, ocean, hydrology and climate reanalyses.
- Reviewing the new developments in the reanalyses, models and observations for study of the Earth system.
- Exploring international collaboration in reanalyses including its role in regional and global climate services.

The Conference received strong support from the U.S. National Science Foundation, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the U.S. Department of Energy, the European Space Agency, and the European Geophysical Union.

Conference Conclusions

Reanalyses have become an integral part of Earth system science research across many disciplines. While originating in the atmospheric sciences and numerical weather prediction, the essential methodology has been adopted in the fields of oceanography and terrestrial ecosystems and hydrology, with emerging research in atmospheric composition, cryosphere and carbon cycle disciplines. Major challenges lie ahead as the disparate nature of each become joined in Earth system analyses. Clearly, substantial progress has been made since the last reanalysis conference held in January 2008 in Tokyo Japan. The Modern Era Retrospective-analysis for Research and Applications (MERRA, see figure on next page), the Climate Forecasting System Reanalysis (CFSR) and the ECMWF Interim Reanalysis (ERA) have been evaluated in depth, and many strengths and weaknesses identified. First results are available from Japanese 55-year reanalysis (JRA-55). There is also much to be learned from the Earth System Research Laboratory (ESRL) 20CR surface pressure reanalysis. Ocean reanalyses are demonstrating that ensembles of multiple reanalysis systems can provide valuable information.

While there are a number of reanalyses at present, the community consensus is that there remains much to be exploited from the sets of different reanalyses. These results are reflected in the developing plans of agencies, notably the Japan Meteorological Agency (JMA) and European Centre for Medium-Range Weather Forecasts (ECMWF), which are leaning towards "families" of reanalyses, where each system produces various configurations of reanalysis. Yet, there is much to be learned from observations, data assimilation, modeling, and coupling of the whole Earth system.

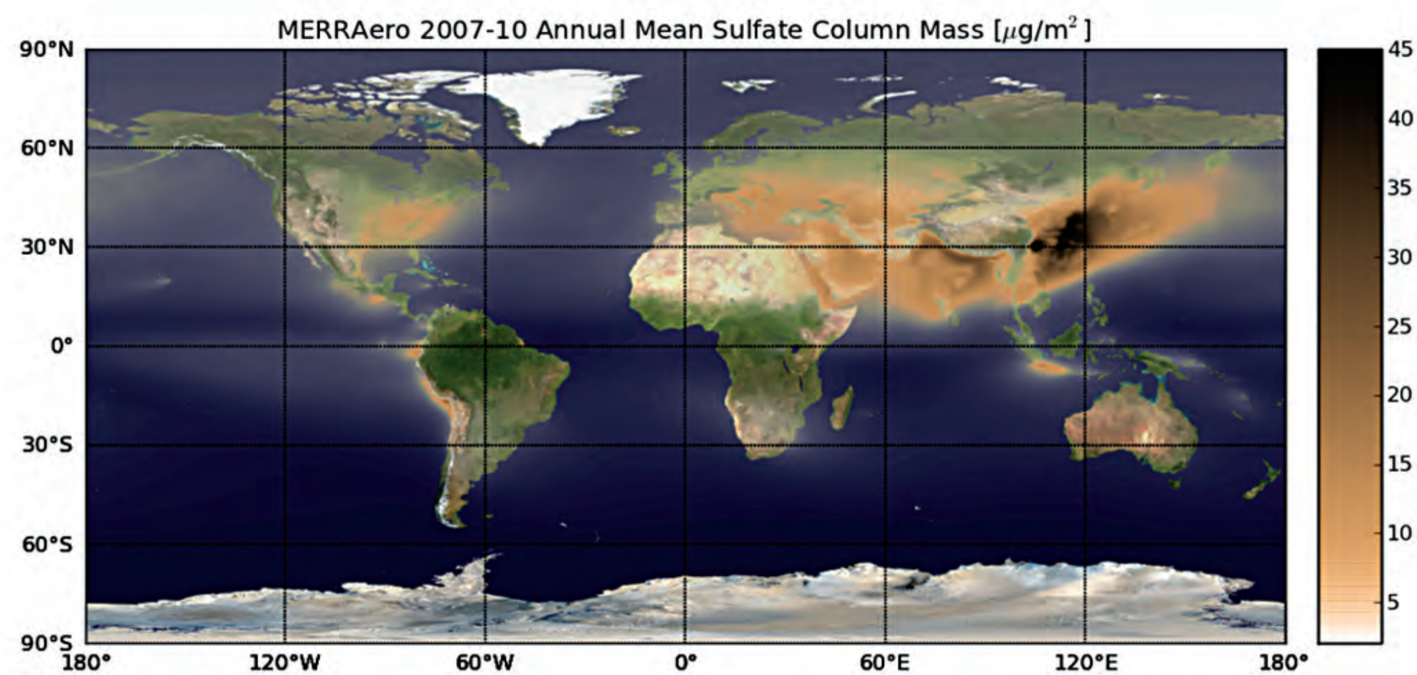
The importance of observing systems cannot be overstated, especially in the stratosphere and deep ocean, to anchor reanalyses. Assessing robust observational and model error covariances, preferably varying over time, is complex and expensive. While many producing and research agencies have developed and investigated bias correction methods, it should be stressed that both models and data contain biases. Preliminary results indicate the potential benefit of coupling the ocean and atmosphere domains for improved forecasts and reanalyses. Data assimilation is also helpful in designing observing systems and in identifying erroneous data but should be consistent with the processes it aims to resolve and requires appropriate model development for that purpose. Air-sea fluxes and deep sea circulation remain challenging quantities to be estimated. Given the discontinuous nature of the observational record, data assimilation techniques will be the primary way to develop more temporally continuous reanalysis output data.

In situ observations are fundamental to reanalyses in many aspects and vice-versa. They complement the remote sensing network and provide reference data sets for calibration, validation and bias correction purposes. Reanalyses would benefit from a greater range of high quality monitoring products for validation purposes. For example, new precipitation data products from the Global Precipitation Climatology Centre (GPCC) and the Hadley Centre high resolution climate data set over land (HadISD) may provide valuable high quality input data. Data archives such as International Comprehensive Ocean-Atmosphere Data Set (ICOADS) and International Global Radiosonde Archive (IGRA) are being continuously populated by newly rescued data. Efforts such as those of the Atmospheric Circulation Reconstructions over the Earth (ACRE) and the International Environmental Data Rescue Organization (IEDRO) are crucial to rescuing and archiving historical data. The International Surface Temperature Initiative (ISTI) has the potential to become a valuable land data source in the future. Reanalyses are used to identify and correct particular data sets, such as those from radiosondes. The identification of breakpoints in data time series is critical to the success of adjustment methods and subsequent derivation of climate trends.

Remote sensing provides useful input data for reanalyses, mostly for the last three decades. Older imagery might also be exploited with ad-hoc processing; however, satellite data present some unique challenges. They require intercalibration and regular reprocessing, and spectral response functions may also require corrections. As more climate data records become available to the scientific community, proper long-term evolution of forcing fields is important for all pilot reanalyses.

Integrating the components of the Earth system in a reanalysis framework exposes the complexity of an observing and modeling system approach. For example, direct and indirect (cloud albedo) aerosol negative radiative forcing will provide feedback on the other analyzed components. Empirical optical depth retrieval and variable transformation are some of the techniques being used to that effect. Forward proxy modeling approaches using ensemble mean increments modifying single members are able to decrease the computational burden of reanalyses and improve overall skill. Land atmosphere interaction is well represented in the CFSR. The high resolution (30 km) Arctic System Reanalysis (ASR)-Interim shows superior skill to ERA-Interim on many parameters and a new release at 10 km is expected in September 2012.

There is a move towards using reanalyses for monitoring some aspects of the climate (e.g., State of the Climate in 2011, *Bulletin of the American Meteorological Society*). The potential value of reanalyses in this respect is great. However, there are still some considerable limitations regarding long-term monitoring that do need to be addressed. These are mainly temporal homogeneity across the entry and drop out of various observing systems [e.g., Advanced TIROS Operational Vertical Sounder entry in 1997], and balancing the water budget especially over the oceans. Used with caution, reanalyses are highly valuable as long-term records and it is recognized that some level of review may be useful to provide context for future use as monitoring products.



Integrating aerosol species of the Earth system in reanalyses, MERRAero analyzed annual mean aerosol column mass for sulfate aerosols for a 4-year period (2007–2010). The MERRAero pilot project assimilates MODIS (to be expanded in later versions), and a new data set covering the 2003–2012 period should be released in 2012.

Reanalyses will most likely increase in number and complexity in the coming years. Incorporating reanalyses in improved data systems, such as the Earth System Grid (designed to facilitate the Intergovernmental Panel on Climate Change assessments) would also facilitate the comparisons among reanalyses and independent observations, and would shed more light on the quality and variability among reanalyses. International coordination across the disciplines and agencies is needed to improve communications across the community of users and developers. In addition, input observations are improving and increasing (through data rescue efforts), and reanalyses projects need clear guidance on the latest developments in the observations community.

The need for reanalyses is as clear now as it was when the concept was first put forward more than two decades ago. Progress has been made, yet significant challenges remain. Continuing research and development will improve the most serious deficiencies, but communications across the communities will facilitate that research. Sustained and focused support for reanalyses research by the funding agencies will ensure greater progress in this budding field, which has great potential in demonstrating the complimentary power of observations and models to offer science-based information for decision makers in addressing the challenges and opportunities associated with weather, climate and ultimately environmental services.

Recommendations from the Conference

While progress has been made across major aspects of reanalyses, significant limitations persist. Four broad directions to continue the advancement of reanalysis were identified.

1. Quantitative Uncertainty

Reanalyses are based on observations, and can include the errors of observations and the assimilating system. **It is recommended to have reanalysis data available in a common framework so as to facilitate the analysis of their strengths and weaknesses.** The idea of families of reanalyses will likewise expose the impact of assimilating observations on the analyses. Ensemble methods can also provide quantitative uncertainty estimates. Lastly, passing observations and the innovations through to an easily accessible data format can promote deeper investigation of the use of observations in the reanalyses.

2. Qualitative Uncertainty

Often, researchers inquire about the applicability of a reanalysis for a given phenomenon, or even, which reanalysis is best. Often, this is not satisfactorily known, varies with application and requires significant time and research. Therefore, **sharing reanalysis knowledge and research in a timely manner, among researchers and developers is a critical need to allow subsequent exploitation by the climate community.** The website at *http://reanalysis.org* has provided an initial effort along these lines, but more participation is encouraged. In addition, *http://climatedataguide.ucar.edu/* provides informed commentaries on analysis and other data sets.

3. Earth System Coupling

The natural course of reanalysis development is toward longer data sets with coupled Earth system components that will ultimately contribute to improved coupled predictions. The use of more varied observations (e.g., aerosols) will reinforce the physical representation of the Earth system processes in the reanalysis systems. There is a need to **develop independent and innovative modeling, coupling and data assimilation methods to represent the Earth system throughout the time span of the observational record**. More interdisciplinary collaborations in the system development and observational research will begin to address this need.

4. Reanalyses, Observations, and Stewardship

While the observational records have been greatly improved since the first reanalyses through research, reprocessing and homogenizations, research and improvements continue their development. **Reprocessing and intercalibrations of observed records are critical to improve the quality and consistency of reanalyses. In situ and satellite data need to be found, rescued, and archived into suitable formats to extend the reanalysis record back in time.** Reanalysis system data for the atmosphere, ocean, cryosphere, land, and coupled earth system are needed that maximize the use of observations as far back as each instrumental record will allow. It is important for the observational data developers and reanalysis developers to maintain communication, so the latest observations are used in reanalyses, and also that the output of reanalyses may contribute to the understanding of the observations. Such an endeavor should be coordinated at an international level.

BALTEX: 20 Years and Two Successful Phases in Baltic Sea Regional Studies

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The Baltic Sea Experiment (BALTEX) was founded in 1993 to study the hydrological cycle and energy fluxes between the atmosphere and the land surface, including rivers and lakes. It has been a GEWEX project since its creation and is the only Regional Hydroclimate Project (RHP) with an oceanographic focus centered on the Baltic Sea.

In its almost 20 years of existence, BALTEX has undergone remarkable development. Phase I (1993–2002) focused exclusively on hydrometeorological research—exploring and modeling the various mechanisms determining the space and time variability of energy and water budgets of the Baltic Sea region (BALTEX 1994). Ten years later, the scope of BALTEX was extended to topics related to climate variability and change, and water management and biogeochemistry, then termed "air and water quality" (Phase II, BALTEX 2004, 2006a). Further new aspects were the strengthened interaction with decision makers with an emphasis on regional climate change impact assessments, and education and outreach at the international level. Thus, the scope of BALTEX has been broadened considerably, with a dedicated extension to matter fluxes, regional climate change assessments, and outreach activities (Reckermann et al., 2011).

BACC and BACC II

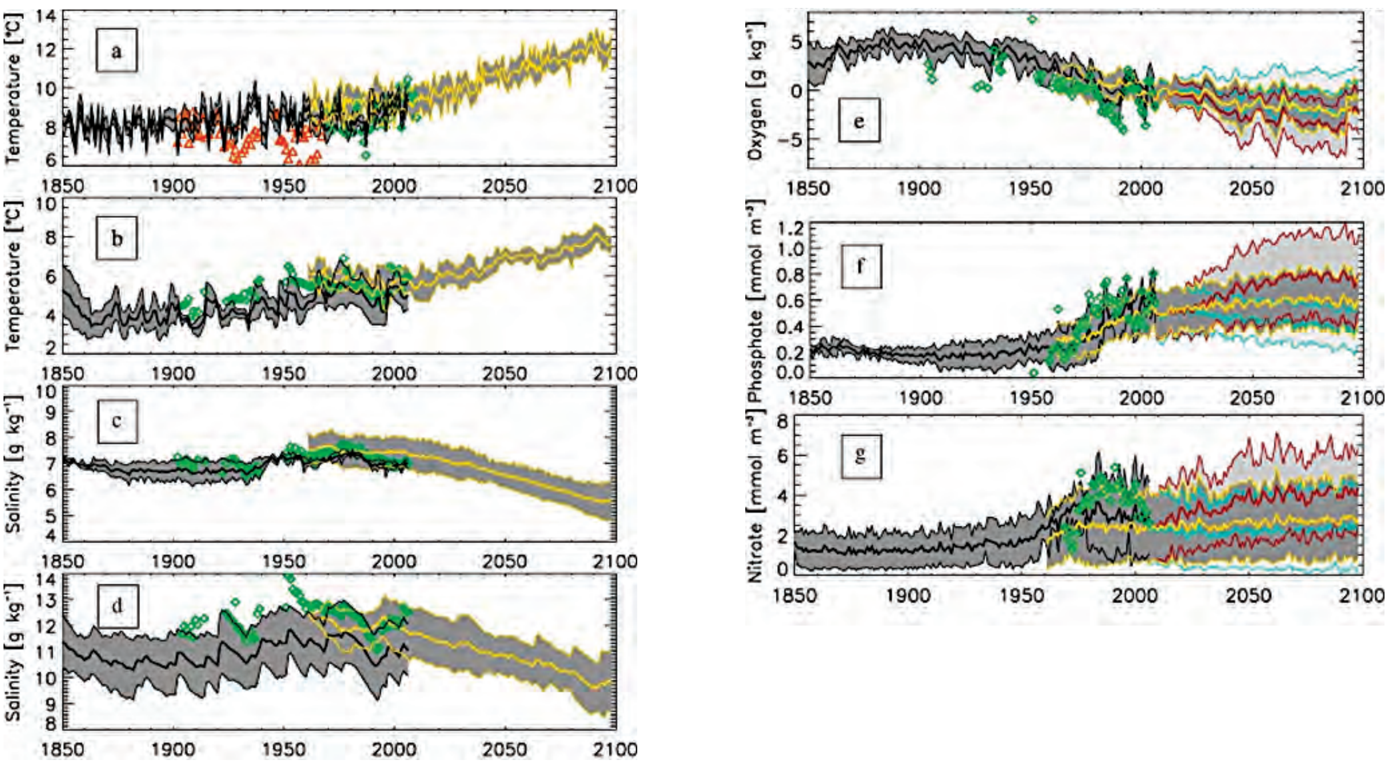
The aim of the BALTEX Assessment of Climate Change for the Baltic Sea Basin (BACC) is to bring together consolidated knowledge on climate change and its effects on the Baltic Sea Basin. The first BACC report was compiled by a consortium of 84 scientists from 13 countries neighboring the Baltic Sea (BACC Author Team, 2008) and covers various disciplines related to climate research and related impacts. The Baltic Sea region represents an old cultural landscape and the Baltic Sea itself is among the most studied areas in the world. Thus, there is a wealth of information in thousands of publications, concerning past climate conditions in the region. A large part of the information had not been available to the English-speaking research community, as the eastern part of the Baltic Sea Basin had been behind the "iron curtain" until the early 1990s. The challenge was to install a writing team that could do "paper mining" in its home countries and compile the material into a comprehensive, well-written assessment book. Besides looking at past and current climate change, the BACC report presents climate projections until the year 2100 using the most sophisticated regional climate models available, and an assessment of climate change impacts on terrestrial, freshwater, and marine ecosystems of the Baltic Sea basin. Now, six years after its publication, an update to the BACC book is in preparation.

In BACC II, scheduled for publication in 2014, more than 100 contributing authors will assemble the latest knowledge on climate change and its impacts in the Baltic Sea region and will integrate it with the findings of the first BACC report. Some of the aspects that will be emphasized in BACC II include sea level change, socio-economic impacts, impacts on urban regions, and an attempt to attribute regional impacts to anthropogenic climate change. The chapters are peer reviewed, and will be presented and discussed at the international BACC II Conference in Tallinn, Estonia in September 2012. For a summary of BACC, see BALTEX 2006b and Reckermann et al., 2008. Recent information on BACC II is available at: *http://www.baltex-research.eu/BACC2/*.

The BONUS Projects

BONUS is a funding scheme of the European Commission and national funding organizations established to "integrate Baltic Sea system research into a durable, cooperative, interdisciplinary, well-integrated, and focused multinational program in support of the region´s sustainable development" (*http://www.bonusportal.org*). Three BALTEX projects have been funded thus far, which are all concerned with the impact of the changing conditions in the future on the marine environment of the Baltic Sea: (1) the Assessment and Modeling of Baltic Ecosystem Response (AMBER); (2) Baltic-C; and (3) the advanced modeling tool for scenarios of the Baltic Sea Ecosystem to support decision-making (ECOSUPPORT). The latter two are briefly described below. They all contribute to the vision of a regional Earth Model System, but also have a very practical relevance for exploring options for developing software tools and models.

The goal of ECOSUPPORT is to assess the combined future impacts of climate change and industrial and agricultural practices in the Baltic Sea catchment basin of the Baltic Sea ecosystem. The major output of ECOSUPPORT is a multi-model system tool to support decision makers. The tool is based on scenarios from an existing state-of-the-art coupled atmosphere-ice-ocean-land surface model for the Baltic Sea catchment area, marine physical-biogeochemical models of differing complexity, a food web model, statistical fish population models, and new data on climate effects on marine biota. It is a challenging new approach to integrate different model "worlds" in order to generate benefits for Baltic Sea management. The **results suggest that the impact of changing climate on Baltic Sea biogeochemistry might indeed be significant** (see figure on page 10). The projected warming of the Baltic Sea is an important driver in relation to eutrophication and it is expected to reduce its water quality in terms of the chosen ecological quality indicators. According to the results, the efficiency of nutrient load reductions will be smaller in a future climate compared to the present climate, emphasizing the need for political action to reduce nutrient flows into the Baltic Sea (Meier et al., 2012a; Wake, 2012). A compilation of papers has just been published ("ECOSUPPORT–Different Ecosystem Drivers under Future Climate Scenarios in the Baltic Sea," AMBIO Special Issue; see also



Simulated ensemble averages and observed annual mean water temperatures (a, b) and salinities (c, d) at Gotland Deep in the central Baltic Sea at 1.5 m (a, c) and 200 m (b, d) depth, annual mean oxygen concentrations at 200 m depth (e), and winter (January–March) mean surface phosphate (f) and nitrate (g) concentrations. Shaded areas denote the ranges of plus/minus one standard deviation around the ensemble averages.

The various nutrient load scenarios (1961–2098) are shown by colored lines (REF–yellow, BSAP–blue, BAU–red) and the reconstruction (1850–2006) by the black line. Nutrient load scenarios were calculated as:

- *REF – current nutrient concentrations in rivers and current atmospheric deposition;*
- *BSAP – reduced nutrient concentrations in rivers following the Baltic Sea Action Plan (HELCOM, 2007b) and 50 percent reduced atmospheric nitrogen deposition;*
- *BAU – business-as-usual for loads from rivers assuming an exponential growth of agriculture in all Baltic Sea countries and current atmospheric deposition.*

For comparison, observations from monitoring cruises at Gotland Deep [green diamonds, in panel (a) since 1970 only] and from the ship Svenska Björn, operated during 1902–1968 [orange triangles in panel (a)], were used (from Meier et al., 2012a).

Meier et al., 2012b). For more information, see the website at: *http://www.baltex-research.eu/ecosupport/*.

The overall objective of Baltic-C (building predictive capability regarding the Baltic Sea organic/inorganic carbon and oxygen systems) is to improve our understanding of the Baltic Sea carbon system, including the acid-base (pH) balance. This is done by developing and applying a new integrated ecosystem model framework based on the cycling of organic carbon (C_{org}) and carbon dioxide (CO_2) in the Baltic Sea and its drainage basin, taking into account fluxes across the atmosphere and sediment interfaces. Seawater pH is among the most important factors controlling life in marine systems, and acidification could severely alter and threaten marine ecosystems. Understanding pH changes in coastal regions characterized by high biological production and various anthropogenic mechanisms, such as climate change, land-use change, eutrophication, and overfishing, is therefore crucial. The overall aim of Baltic-C is to provide a tool which can be used to support the management of the Baltic Sea. For more information, see the Baltic-C website at: *http://www.baltex-research.eu/baltic-c/*.

Outreach Activities

The outreach activities in BALTEX Phase II have been manifold. BALTEX scientific conferences, summer schools, and publications in peer-reviewed journals, conference proceedings, books, a BALTEX publication series, and a newsletter are regular outreach channels. Collaborations with political stakeholders have been a special emphasis during recent years.

In connection with BACC and BACC II, there is close collaboration with the intergovernmental Baltic Marine Environment Protection Commission (Helsinki Commission, HELCOM; *http://www.helcom.fi*). HELCOM used the BACC report as the basis for the HELCOM Thematic Assessment 2007 on "Climate Change in the Baltic Sea Area" (HELCOM 2007a), which was officially adopted by representatives of the Baltic Sea riparian states in March 2007. This means that the countries adopt this material as recommendations for legislative measures. Another collaboration with a political organization in the Baltic Sea area was the joint international conference on "Adapting to Climate Change—Case Studies from the Baltic Sea Region" in Hamburg, Germany, together with the Baltic Sea States Subregional Cooperation (BSSSC). This organization represents the subregional political level (counties and municipalities) in all Baltic Sea states and fosters international collaboration of these entities.

In 2009, a summer school on "Climate Impacts on the Baltic Sea—From Science to Policy" was organized by BALTEX on the Danish Baltic Sea island of Bornholm. The expert lectures were turned into a textbook, mainly aimed at students and scientists, but also at political and administrative decision makers (Reckermann et al., 2012). As the Baltic Sea region has a well-developed international framework for monitoring, assessing, and managing its marine ecosystems, the book provides a good case study for other regions where such management is being organized.

An interesting BALTEX outreach product, which is based on the BACC book and regional climate scenarios processed and used by the Northern German Climate Office, is the booklet "Ostseeküste im Klimawandel (Baltic Coast in Climate Change)." This 63-page booklet, written in German, translates the main scientific findings on regional climate change and its implications into everyday language for the general public (Meinke and Reckermann, 2012). It is regarded as a pilot study for producing similar products based on BACC II material in English and all the Baltic Sea languages.

Workshops and conferences are the glue of a scientific community, and are particularly important in BALTEX. Since 2003 (launch of Phase 2), there have been 19 conferences and workshops organized by BALTEX, both for scientists and regional decision makers and environmental managers. The large study conferences on BALTEX, which are organized every three years, bring together the Baltic Sea research community to present and discuss BALTEX topics. The 7th Study Conference on BALTEX will take place 10–14 June 2013 on the Swedish island of Öland. A full list to conferences and publications (with links) is available on the BALTEX website at: *http://www.baltex-research.eu*.

Future Prospects

After two successful phases, BALTEX is now transitioning into something new. The new program may be renamed, as the scientific scope and organization may be different. Currently, a dedicated working group appointed by the BALTEX Science Steering Group (BSSG) is elaborating on recommendations for a future scientific program, including specified "grand challenges." These will be presented to the BSSG in September 2012 and the new program is expected to be officially launched at the 7th Study Conference on BALTEX. While concrete objectives and goals cannot be presented at this stage, it is nevertheless possible to anticipate the direction of the new program towards further promoting an interdisciplinary regional Earth system approach for the Baltic Sea Basin, encompassing the physical, chemical, biological, and socio-economic spheres as far as appropriate. In this respect, research towards an Earth system description and modeling on the regional scale in its various aspects is an ambitious challenge for the future.

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Murray-Darling Basin Regional Hydroclimate Project Wraps Up Phase I

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The Murray-Darling Basin (MDB) Water Budget Project was approved as a GEWEX Continental-Scale Experiment in January 2002 with the aim of enhancing the capability of numerical weather prediction models to provide a real-time surface water budget over the Murray-Darling Basin for application by water authorities. Along with changes at GEWEX, the Water Budget Project evolved into a Regional Hydroclimate Project (RHP). The MDB RHP was a program of research occurring across various Australian agencies [the Australian Nuclear Science Technology Organization (ANSTO), Bureau of Meteorology (BoM), the Commonwealth Scientific and Industrial Research Organization (CSIRO)] and universities. The MDB RHP objectives were:

- Produce and compile research quality data sets of the energy and water budgets in the MDB.
- Improve the understanding and modeling of the dynamics of the coupled water, energy, and carbon cycles in the MDB, a developed semi-arid zone basin.
- Improve predictive tools for water management, including real-time forecasting products for use by water agencies in the MDB.
- Strengthen interaction between the climate research community and decision makers.

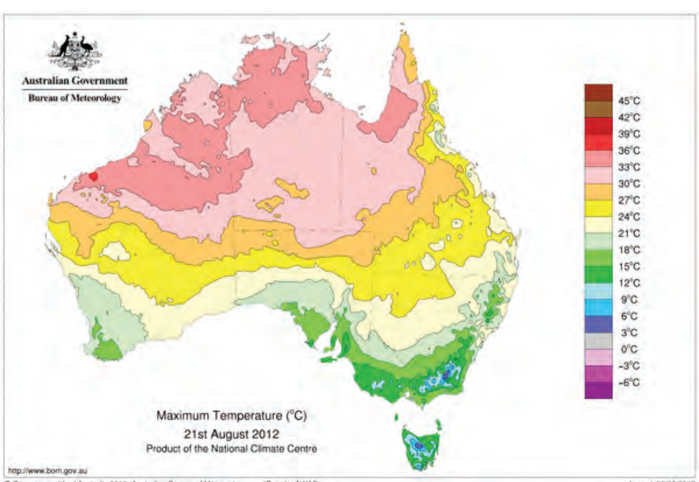
Over the decade of MDB research, many advances were made toward these objectives and presented in various journal articles, including a special section of *Water Resources Research* (Roderick, 2011; Evans et al., 2011). The following are two examples of projects that contributed to the RHP objectives and managed to transition from research to operational products within the RHP time frame, as well as a number of data collection projects that augment the standard climatological data network.

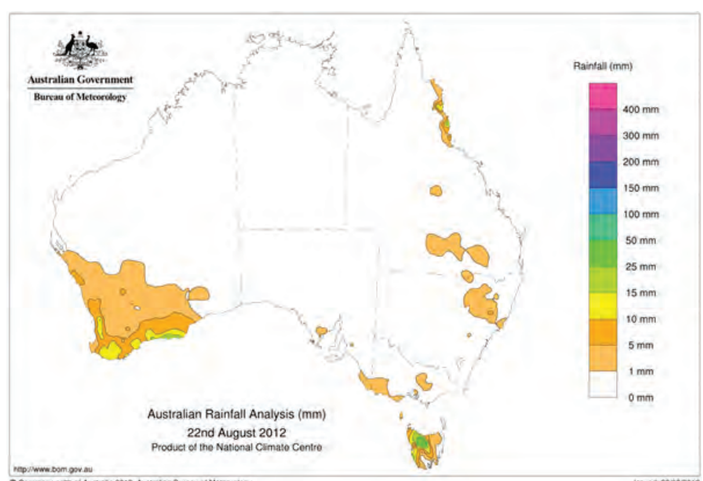
Australian Water Availability Project (AWAP)

This project developed an operational system for estimating soil moisture and other components of the water balance at spatial scales ranging from 5 km to all of Australia over time-periods ranging from daily to decades. The project had two components. The first was run by BoM, which has generated a range of improved meteorological gridded analyses over Australia for precipitation, temperature, vapor pressure, and solar exposure at a 5 km spatial scale and time periods from daily upwards. The second part of the project was run by CSIRO, which used a hydrological model driven by the above meteorological forcing to estimate the water balance components in near real time. The gridded meteorological analysis is now an operational product that is updated in near real time (see below).

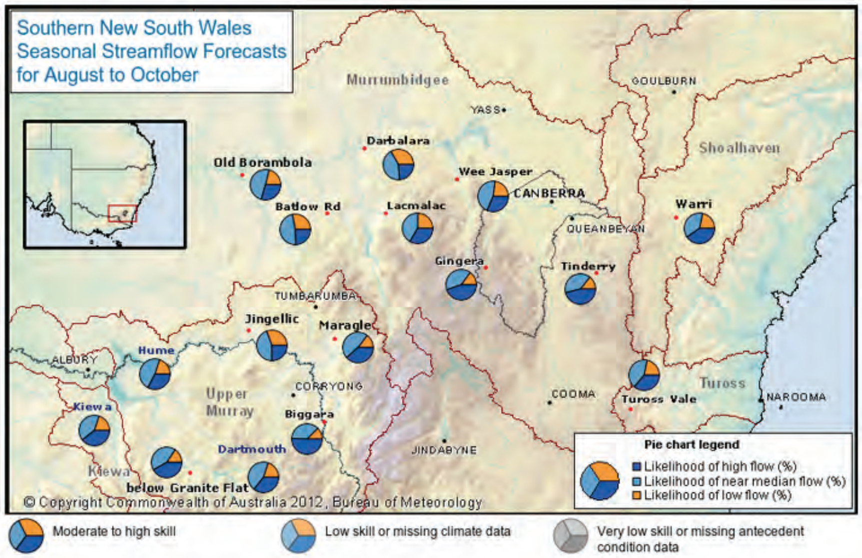
Water Information Research and Development Alliance (WIRADA)

The BoM water division formed a partnership with CSIRO to deliver new science and technology that will enable the Bureau to undertake real-time interactive analysis of water information and begin using advanced methods for forecasting of water availability and floods across Australia. The research being conducted covers many fields including data interoperability, hydrologic modeling, water accounting, and water resource assessment. As part of this task, it is developing the Australian Water Resources Information System (AWRIS: *http://www.bom.gov.au/water/awris.shtml*), an online information system that will collate and disseminate information about river flows, groundwater levels, reservoir storage volumes, water quality, water use, water entitlements, and water trades from more than 200 water sources across Australia. The system will evolve and expand over the next 10 years.





Examples of the gridded products available in near real-time from the Australian Bureau of Meteorology (http://www.bom.gov.au/jsp/awap/).



An example of the seasonal streamflow forecasts available through the Australian Bureau of Meteorology website.

A major area of progress has been in seasonal streamflow forecasts (see above figure). A statistical approach based on a Bayesian Joint Probability modeling system has been developed, tested, and deployed operationally. Seasonal streamflow forecasts for many rivers in eastern Australia are available at: *http://www.bom.gov.au/water/ssf/index.shtml*.

Hydrometeorological Data Collection

A number of projects that focused on data collection contributed to RHP objectives. One major effort has been the establishment of the Terrestrial Ecosystem Research Network (TERN: *http://www.tern.org.au/*), which expands the observational network of flux towers and other ecosystem measurements, as well as collating, calibrating, validating, and standardizing existing data sets. TERN is also investing in digital infrastructure to store and publish these data in a freely accessible and searchable way. The TERN data discovery portal is currently undergoing beta testing, with the fully operational portal scheduled for completion by the end of the year.

Another major observational effort was the National Airborne Field Experiment (*http://www.nafe.unimelb.edu.au/*), which is collecting data in support of soil moisture remote sensing research. It combines the collection of ground level in situ and flux tower data with multiple airborne campaigns and satellite-based data. The Project has produced a rich set of data for a section of the Murrumbidgee Catchment. This has evolved into the Australian Airborne Cal/val Experiment for the Soil Moisture and Ocean Salinity (SMOS) Mission (AACES: *http://www.moisturemap.monash.edu.au/aaces/*). Using a similarly rich set of data, the focus for this project is the evaluation and calibration of brightness temperature and soil moisture from the SMOS satellite data (Peischl et al., 2012). Work continues on the testing and improvement of SMOS soil moisture retrieval algorithms under the often dry conditions present in the MDB. Future campaigns will include a focus on the Aquarius and Soil Moisture Active Passive (SMAP) satellites.

MDB Next

Having produced some significant research advances concerning our knowledge of the hydroclimate system in the MDB, and successfully connecting this research with operational agencies, the MDB RHP has reached the end of its decade-long program. As often happens in research programs, as many questions are raised as advances are made. What happens next in hydroclimate research in the MDB is an open question currently being considered. Many of the observational programs are continuing, and the strengthening of international regional-scale climate research projects like the COordinated Regional climate Downscaling Experiment (CORDEX) provide a start for the development of a new RHP. Such a new RHP will also consider the developing WCRP Grand Challenges and GEWEX Grand Science Questions. Ultimately, the magnitude of water resource challenges faced by a developed semi-arid region in a globally warming world requires the regional coordination that a GEWEX RHP can provide in hydroclimate research.

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The Belmont Challenge — International Collaboration in Support of Global Change Research

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Global environmental change is increasingly studied by national and international researchers, but the lack of international collaboration and coordination is increasingly leading to inefficiencies and lost opportunities. The world's major funders of global change research are considering how best to align financial and human capital toward delivering the relevant knowledge that society will need in the 21st century. The Belmont Forum (named after the group's first meeting venue in the USA in 2009; *http://igfagcr.org/index.php/belmont-forum*) meets twice a year and is composed of funding executives from Australia, Austria, Brazil, Canada, China, France, Germany, India, Japan, Norway, South Africa, the United Kingdom, the United States, and the European Commission, together with the executive directors of the International Council for Science (ICSU) and International Social Sciences Council (ISSC).

The Belmont Forum is also the Council of Principals for the larger International Group of Funding Agencies for Global Change Research (IGFA; *http://igfagcr.org*), which includes the funding executives listed above as well as those from more than 20 additional countries. Action by the international funding community to form the Belmont Forum was initiated and led by Tim Killeen, then at the U.S. National Science Foundation, and Alan Thorpe, of the United Kingdom's Natural Environment Research Council (NERC). The Belmont Forum, is now led by Patrick Monfray of France's National Research Agency, and Albert van Jaarsfeld of South Africa's National Research Foundation. This coordinated movement represents a commitment to a collective action agenda to co-design, co-develop, and co-deliver research programs to examine the complex relationship of humans with the planet. In particular, the group aims to provide knowledge that can be used to confront the most significant challenges society faces in managing an increasingly congested and resource-hungry world.

These goals are captured by the Belmont Challenge (see box at right), which aims to deliver knowledge needed for societies to take action to mitigate and adapt to harmful environmental change and extreme hazardous events. The Belmont Forum emphasizes research collaborations among developed and developing nations in both the Northern and Southern hemispheres. Thus, its members include not only countries typically seen in collaborations on global change research but also large, emerging economies, such as Brazil, India, Russia, and South Africa. There is also a specific effort to harness the perspectives of both the social and natural sciences. This integrated approach is apparent both in the forum membership, which includes ISSC and ICSU, and in the emphasis on codesigned research projects. Central to this activity is the mobilization of international resources for the study of global environmental change.

The Belmont Challenge

To deliver knowledge needed for societies to take action to mitigate and adapt to harmful environmental change and extreme hazardous events.

This requires:

- Information on the state of the environment, through advanced observing systems.
- Assessments of risks, impacts and vulnerabilities, through regional and decadal analysis and prediction.
- Providing environmental information services to decision-makers and end users.
- Interdisciplinary and transdisciplinary research which takes account of coupled natural, social and economic systems.
- Effective integration and coordination mechanisms to address interdependencies and harness the necessary resources.

The first call for proposals under the Belmont Forum's International Opportunities Fund (IOF) was launched at the Planet Under Pressure Conference in London at the end of March 2012. The IOF call is jointly funded by the Belmont Forum and the G8 Heads of Research Councils (G8HORCs), in the amount of approximately €20 Million. The focus themes of this first round are coastal vulnerability and freshwater security. The freshwater security program targets the identification and characterization of the interactions between natural processes (physical and biological/ecological processes) and human practices (cultural, social, economic, technological, transfer, and water reuse) that govern water budgeting in selected regions. It also targets the development of approaches that support the evolution of resilient communities/regions through improved seasonal (months to multiyear) forecasting of droughts, taking into account natural and socioeconomic drivers.

The coastal vulnerability program targets the characterization of natural processes and human interactions that govern coastal vulnerability and resilience and the development of predictive frameworks and adaptive coastal management strategies that support the evolution of resilient coastal communities. The IOF is aimed at supporting excellent research on topics of global relevance best tackled through a multinational approach, recognising that global challenges need global solutions. Funding supports researchers to cooperate in consortia consisting of partners from at least three of the participating countries and bringing together natural scientists, social scientists and research users (policy makers, regulators, nongovernment organizations, communities and industry) for 2–3 year research projects, with funds in the range of €1 million to €2 million each. Capacity building in developing countries may also be supported. The pre-proposal stage of the IOF, which closed in July, was a resounding success with 137 submitted pre-proposals, involving 1109 partners from 56 countries.

The design of IOF programs relies heavily on input from the international research community about goals and refining the larger themes. In the first set of calls for proposals, as with future IOF themes, the aim is to catalyze research by providing a mechanism to support co-designed, international, cross-disciplinary and transdisciplinary collaboration. Planning of subsequent rounds of proposals for IOF programs are under way, focusing on Arctic change, hazards, biofuels, information technologies, food security, and rural-to-urban transition, each with internationally coordinated funding opportunities. Moreover, the Belmont Forum was one of the founding organizations to establish the Science and Technology Alliance for Global Sustainability at the Forum's meeting in Cape Town, South Africa in October 2010. The Alliance's first project is "Future Earth" (*http://www.icsu.org/future-earth*; see article on page 16), a 10-year initiative that was rolled out at the Rio +20 Conference in June 2012. The Belmont Forum's IOF will be one of the vehicles used to further the goals of Future Earth.

The Forum's international partnership among research funding organizations aims for active coordination of global change research funding, integration of relevant stakeholders (including industry, policymakers, and end users), and cross-disciplinary collaboration. To be most valuable, the knowledge generated from these research collaborations must be provided on temporal and spatial scales that enable effective decision making and support equitable economic and social development. IOF programs support new partnerships and research opportunities for science communities; promote cross-fertilization of ideas based on region-specific resources; and provide access to international expertise, facilities, and data. Harnessing complementary international global change research efforts will remain a challenge, but success will lead to better coordination, leveraging, and, especially, advancement on pressing science issues. The Belmont Forum's IOF will issues calls for proposals to offer the support needed to work toward achieving these goals.

The GEWEX community can play a significant role in helping the Belmont Forum develop future calls of the International Opportunities Fund. Participation in "listening sessions and ideas rallies" such as those planned at the American Geophysical Union meeting in December can be fruitful opportunities for the GEWEX community to provide insights and ideas on ways that international collaboration can provide the research needed to help meet the Belmont Challenge. GEWEX expertise and experience is critical in helping overcome key challenges of global environmental change by contributing to our collective understanding and providing access to:

1. Information on the state of the environment through advanced observing systems to verify the accuracy of predictions, assess proximity to disruptive change, and monitor the effectiveness of adaptation and mitigation strategies;

2. Data and knowledge to improve, verify, and refine model predictions at regional and decadal scales;

3. Data and knowledge to assess proximity to disruptive tipping points in order to identify vulnerable regions and societies, provide early warning of disruptive change (e.g., extreme hydrometeorological events, disruption of ecosystem services), and provide avoidance and adaptation strategies; and

4. Monitoring of stocks and fluxes of key environmental change variables for long-term survey, and to support markets and regulation.

To maximize the efficiency of existing capabilities, there is a need to improve coordination between existing observation and data systems, and between academic and operational systems. Many GEWEX activities are important partners of the major international programs aimed at improving the effectiveness and coordination of global and regional monitoring systems.

Meeting the Belmont Challenge requires predictive capabilities of risks, impacts, and vulnerabilities through regional and decadal analysis and prediction to provide foresight about changes in the Earth System, which takes full account of societal interactions and focus on changes that may cause abrupt and potentially irreversible and disastrous changes.

The GEWEX community could play a key role in developing predictive capabilities measuring the likelihood and severity of extreme hydrometeorological events and related geohazards, and their impacts on human socio-economic systems. Working with other international projects, GEWEX could help determine the likelihood of biodiversity loss for a given terrestrial, freshwater or marine region, under given climate and management scenarios, and predictions of the environmental and health impact of changes to other biogeochemical cycles. GEWEX could also provide analyses and predictions of coupled meteorological, biological, biogeochemical, hydrological, geological, and socio-economic processes, as well as developing the capability to "zoom in" and "zoom out" between global and regional-scale assessments.

International collaboration is a key tenet of the Belmont Forum and we expect that the GEWEX community will continue to play a critical role in working towards improving our understanding of the challenges and impact of global change.

Future Earth – Research for Global Sustainability

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Unveiled in March 2012 at "Planet Under Pressure," a major scientific conference organized in London by the global environmental change programs and the International Council for Science (ICSU), Future Earth, a new 10-year international initiative on global environmental research for sustainability, was launched at the Forum on Science, Technology and Innovation for Sustainable Development in Rio De Janeiro, Brazil on 14 June 2012 (*http://www.icsu.org/news-centre/rio20/science-and-technology-forum*), and shortly afterward at a very well-attended side event of the Rio+20 United Nations Conference on Sustainable Development (*http://www.icsu.org/future-earth/whats-new/events/future-earth-at-riocentro*). Future Earth will provide a cutting-edge platform to coordinate scientific research that is designed and produced in partnership with governments, business, and, more broadly, society. The initiative is scientifically sponsored by an Alliance of partners, including ICSU, the International Social Science Council (ISSC), the Belmont Forum of funding agencies, the United Nations University (UNU), the United Nations Environment Programme (UNEP), and the United Nations Educational, Scientific and Cultural Organization (UNESCO), with the World Meteorological Organization (WMO) as observer.

Future Earth is the fruit of a series of consultations on priorities for global environmental change research conducted by partners of the Alliance. One of these, the 2-year ICSU-ISSC Earth System Visioning, which concluded in 2011, identified the Grand Challenges for Earth System Science for Global Sustainability (see: *http://www.icsu.org/news-centre/press-releases/2010/scientific-grand-challenges-identified-to-address-global-sustainability/scientific-grand-challenges-identified-to-address-global-sustainability*) and recommended a new overarching institutional structure to promote more effective interdisciplinary research. Future Earth was then approved as a new interdisciplinary body by ICSU members at their 30th General Assembly in September 2011.

The initiative will build upon the strengths of existing ICSU co-sponsored global environmental change programs, their Earth System Science Partnership (ESSP), and their projects, by integrating their activities and also attracting new capacity. Three of the programs [DIVERSITAS, the International Geosphere-Biosphere Programme (IGBP), and the International Human Dimensions Programme (IHDP)] have signaled their willingness to merge into a new single organization. The World Climate Research Programme (WCRP) will be an independent partner, supporting Future Earth strategically and intellectually.

A multi-stakeholder committee, known as the Transition Team, was appointed by the Alliance in June 2011 to work on the design of Future Earth. The team focused on three main priorities, namely the research framework, organizational design options, and outreach strategy. It will conclude its mandate at the end of 2012. In 2013, Future Earth will start operations, with an interim Governing Council setting its strategic direction, and a Scientific Committee shaping its research agenda. By integrating across disciplines and sectors, Future Earth research will answer fundamental questions about how and why the global environment is changing; what are likely future changes; what the implications are for the wellbeing of humans and other species; what choices can be made to enhance resilience, create positive futures, and reduce harmful risks and vulnerabilities; and how this knowledge can support policy decisions and sustainable development.

To co-design the Future Earth research agenda, there will be further consultations, in 2012 and beyond, with the global environmental change research community and other stakeholders. Representatives of existing global environmental change projects have been invited to provide input on the initial draft research framework in the coming weeks. An online consultation will be launched in the coming months to extend the scope of consultation and dialogue that is an integral part of Future Earth. Workshops will be held in Africa, Asia, and Latin America between October and December 2012 to broaden the scope of co-design to key stakeholders in these regions.

For more information about Future Earth, please visit: *http://www.icsu.org/future-earth*.

GEWEX/WCRP Calendar

See the GEWEX website at:
http://www.gewex.org/

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