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Global Terrestrial Network – Hydrology (GTN-H)

Report of the 5th GTN-H Coordination Panel Meeting

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with amendments up to July 2012

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Acknowledgments

The GTN-H Coordination Panel is most grateful to the University of Tokyo and especially Professor Toshio Koike and his entire group for hosting this meeting in Tokyo, Japan under the most unfavorable and sorrowful conditions during the time after the Tsunami hit Japan. All participants are highly appreciated for their continued stay after the catastrophic event including the Fukushima nuclear reactor disaster.

In memory of all people who suffered untold hardship and those who lost their lives during this national catastrophe

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Foreword

The 5th GTN-H Coordination Panel was held under most difficult circumstances right after the Tsunami hit Japan on 11 March 2011. Therefore, only a fraction of the core participants had been able to attend the meeting and others contributed after the meeting by providing additional information for this report.

On the other hand, participants from some ten Asian countries having a parallel water-related meeting at the University of Tokyo used the GTN-H meeting as a welcomed opportunity to learn about the activities of GTN-H on a global level. Due to the circumstances of the meeting, the back-to-back seventh annual Integrated Global Water Cycle Observations (IGWCO) Community of Practice (COP) science and planning meeting scheduled for March 14 and 15 2011, was cancelled.

The report presented here thus reports on progress made since the 4th GTN-H Panel meeting in 2009 but it also summarizes achievements of GTN-H since its inception in 2001 including the identification of gaps and further opportunities.

Further, the report provides information on the future coordination of GTN-H since the change of coordinators in July 2012 and the review of activities to be undertaken by GTN-H partners.

It is amply demonstrated that GTN-H has a firm place in providing access to critical data for a large array of applications including for services to be provided by the WMO Global Framework for Climate Services (GFCS). Likewise, its close links to the WMO co-sponsored Global Climate Observing System (GCOS) and the GEOSS Integrated Global Water Cycle Observations (IGWCO) Community of Practice (CoP) is highlighted.

What is needed in the further implementation of GTN-H is the dedicated input from GTN-H partners in the development of joint products based on the contents of global data centres representing essential climate variables and to strengthen linkages with cooperating programmes including through cooperation with WMO’s Hydrology and Water Resources Programme, GEOSS and other international agencies and national as well as regional partners.

Introduction

The Global Terrestrial Network for Hydrology established in 2000 to integrate hydrological observations has passed its first decade of existence that is long enough time to pause and revisit what was accomplished and what are still missing. The GTN-H concept was laid out in at Geisenheim, Germany meeting in 2001 and refined in follow up Coordination Panel Meetings first held in Toronto, Canada (2002) and Koblenz, Germany (2005 and 2007) in conjunction with the steering committee meeting of the Global Runoff Data Center, which is also a key member in GTN-H. After the 3rd meeting, it was decided that holding GTN-H meetings at various places would be beneficial increase the exposure of GTN-H to new potential users and collaborating partners.

The 4th meeting was held in New York hosted by the current GTN-H coordinators and at the New York meeting it was decided that the best place to organized the 5th GTN-H meeting was Tokyo, Japan hosted by the University of Tokyo in conjunction with the Integrated Global Water Cycle Observation Community of Practice (IGWCO CoP) of the Global Earth Observing Systems (GEOSS) planned for March 14-15. The GTN-H meeting immediately followed the Asian Water Cycle Initiative (AWCI) conference, but participants of the AWCI meeting were encouraged to stay for the extra couple of days of the GTN-H/IGWCO

The goal of the 5th GTN-H meeting was to establish new linkages between on-going international efforts to better monitor key components of the water cycle and engage with new potential user community. The anticipated outcome of the meeting was a revised vision plan that links GTN-H with other international activities such as the Global Water Systems Project (GWSP) and reinforces the collaboration with GTN-H partners.

Despite careful planning and lengthy preparation, nature had other plans by hitting the Pacific coast of Tohuku (373 km from Tokyo) on March 11 with a magnitude 9 earthquake (the largest ever recorded in Japan and amongst the five largest in ever recorded in modern history) followed by devastating tsunami. While some of the participants were already in Tokyo the majority were still en route. Those who received the messages from hosts of the meeting recommending return home before they boarded their air planes heading for Japan where able to change their travel plan, but those who were already in the air ended up landing in Japan shortly after the earthquake.

Given the disruption of the public transportation after the earthquake only a smaller group of the participants who were already in Tokyo were able to meet for an informal meeting on the first day March 12, but decided to stay and hold a curtailed GTN-H/IGWCO meeting from March 13 – 15 despite the alarming news about the anticipated failure of the severely damaged Fukushima Nuclear power plant.

In spite of the circumstances the meeting was largely successful in revisiting the progress GTN-H made in its first decade; assess the achievements and areas, where progress lagged behind original expectations. The meeting also outlined strategies for future development of GTN-H. The future directions of GTN-H were discussed further during a two days meeting at the City College of New York 11-12 July 2012, while the CrossRoads team handed over the coordination tasks to the new GTN-H coordinator.

The present report summarizes the GTN-H meeting and the ongoing efforts without strictly reconstructing the events of the meeting itself. Instead we intend to provide a short strategy document that we hope will define the next decade of GTN-H.

1. Background

GTN-H was born out of the desire to provide hydrology relevant information in a comprehensive and consistent manner. GTN-H, which predates the Global Earth Observing System of Systems (GEOSS) recognized early on that there is a need to link various data centers focusing on different aspects of the hydrological cycle to allow integrated water resources assessments (**Figure 1**). GTN-H invented the "*network of networks*" concept which ultimately became the observational arm of the Integrated Global Water Cycle Observations Community of Practice (IGWCO-CoP) of GEO. Focus of efforts of GTN-H is to improve access to data and information and develop observations-based products.

The goal of GTN-H is to meet the needs of the international science community for hydrological data and information to address global and regional climate, water resources and environmental issues, including improved climate and weather prediction; detection and quantification of climate change; assessment of impacts of climate change; assessment of freshwater sustainability; and understanding the global water cycle.

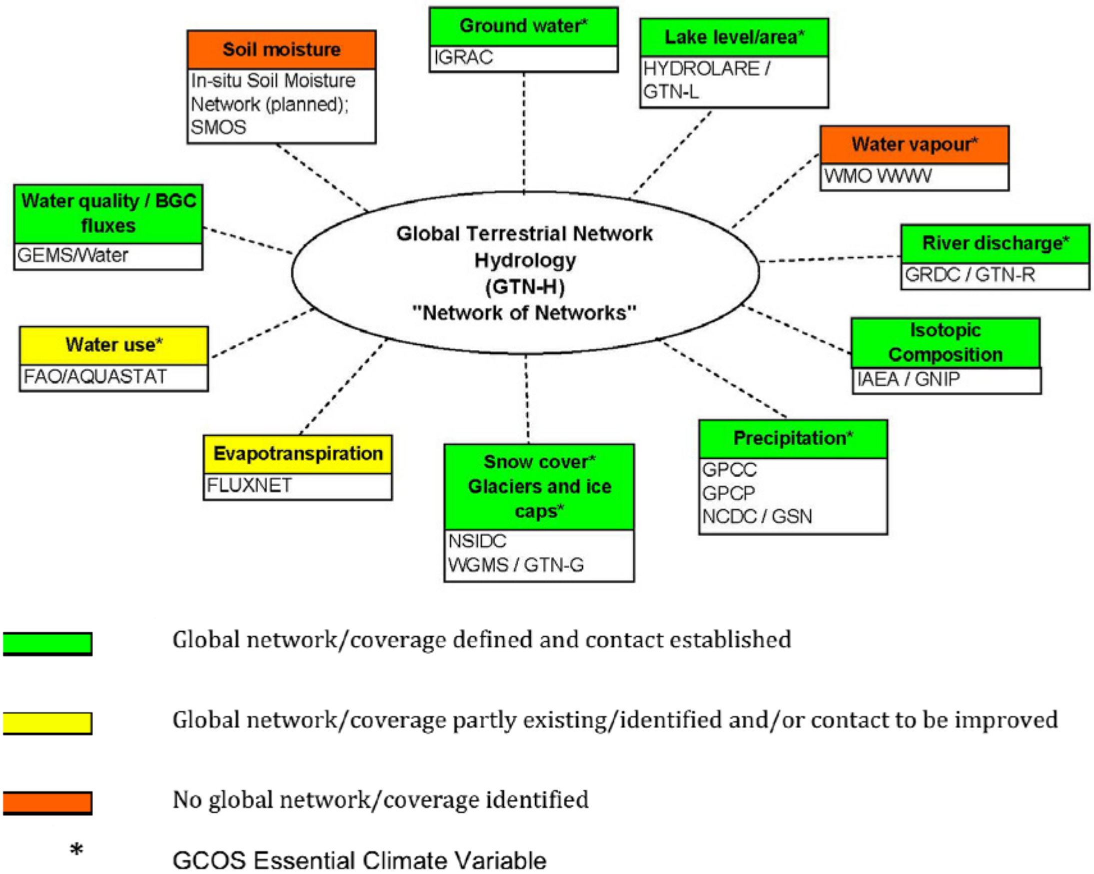


***Figure 1:** GTN-H Configuration in 2011*

The GTN-H configuration depicted in **Figure 1** remained unchanged from the start, but the different contributing components (colored boxes) gradually turned from orange through yellow to green as new entities were formed that fulfilled the tasks to provide information on different facets of the hydrological cycle. The announcement of new partners contributing soil moisture was anticipated for the 5th GTN-H turning one of the last remaining orange boxes to green.

GTN-H coordinators originally were volunteering individuals from hydro-meteorological agencies (Jurate Landwehr, USGS and David Harvey, Environment Canada). The first web-site[1] was developed by Environment Canada, but it was hosted from University of New Hampshire, which had more relaxed policies operating web-services. The 3rd Global Terrestrial Network for Hydrology (GTN-H) Coordination Panel in September 2007 entrusted the Water Systems Analysis Group at the University of New Hampshire, USA (UNH) with the coordination tasks, which also worked closely with the Arctic research community and operated similar dedicated facilities as ArcticRIMS[2]. The panel also decided that the 4th GTN-H Coordinating Panel meeting to be held at the coordinators' host institution.

Shortly after the 3rd Coordinating Panel meeting lead participating members of the WSAG team (Professor Charles Vörösmarty, who was the director) and a few members of the WSAG team left UNH to form a new research group, at the City University of New York under its "*Decade of Science*" effort to build a new Advanced Science Research Center (ASRC). CUNY realizing the importance of environmental research defined the Environmental Cross-roads Initiative hosted in The City College of New York as one of the main pillars of the newly forming ASRC.

Since key GTN-H contributors left UNH, the 4th Coordinating Panel meeting was held at CCNY in New York, New York in 2009, which was combined with a two days GTN-H workshop to take advantage the proximity of leading researchers from the US to join the meeting and learn more about the GTN-H efforts while providing inputs both as potential contributors and users. The success of the GTN-H workshop confirmed the value of rotating the GTN-H hosting and one of the outcome of the meeting was to organize the next meeting somewhere in Asia.

Following the 4th GTN-H Coordination Panel Meeting, the CrossRoads team also hosted the 7th Integrated Global Water Cycle Observations (IGWCO) Community of Practice (COP) science and planning meeting in 2010, where IGWCO and GTN-H partners decided to organize the next meeting in tandem, so synergies between the two international efforts can be explored. Professor Toshio Koike offered generous invitation to hold the joined GTN-H/IGWCO meeting in Tokyo, Japan at the University of Tokyo.

[1] http://www.gtn-h.net

[2] http://rims.unh.edu

2. GTN-H Operation

The coordination activities involve integrating data products from GTN-H partners and developing new value added products. Perhaps the best example of the envisioned value added products was the UNH-GRDC Composite Runoff Fields developed more than a decade ago (Fekete et al. 2002, 1999), which demonstrated the value of applying a discharge data assimilation scheme to produce global runoff estimates that are constrained by observed discharge data records, but maintain spatial specificity from high resolution water balance calculations. A revised version of the UNH-GRDC composite runoff fields was incorporated into the International Satellite Land Surface Climatology Project[3], Initiative II (ISLSCP-II).

The UNH-GRDC composite fields were a huge success that could be demonstrated by the number of publications that relied and still relies on this data. While this popularity clearly shows the value of such data assimilation to provide the best estimates of the available water resources, it is somewhat disappointing that 10 years later, nobody (including the original developing team) was able to produce any improvements or update.

As GTN-H coordinator, the CrossRoads team strived to achieve a number of goals. First and foremost to produce water balance model estimates of key components of the hydrological cycle combined with discharge observations, when available as an operational implementation of the UNH-GRDC composite runoff fields. We also hoped that GTN-H would become a focal point for regional initiatives e.g. ArcticRIMS. Beyond the daily operation of GTN-H, the CrossRoads team intent was to promote GTN-H and GTN-H partners and assist improved earth system observations.

2.1. Integrated Data Products

The Environmental CrossRoads Initiative developed and operates a flexible modeling infrastructure called Framework for Aquatic Modeling of the Earth System (FrAMES) (Wollheim et al. 2008; Wisser et al. 2010a; Cohen et al. 2011), which allows implementation and operation of complex hydrological model at various scales. FrAMES is becoming a development platform that goes beyond water balance and transport modeling and increasingly includes additional features such as irrigation and reservoir operation (Wisser et al. 2008, 2010b), nutrient transport (Wollheim et al. 2008) water temperature (Stewart et al. 2010) sediment transport (Cohen et al. 2011).

2.1.1. Near Real-time Climate Data Archive

FrAMES and the accompanying comprehensive data archive serving the input data necessary for hydrological simulations allow rapid production of hydrological modeling outputs from wide range of input forcings.

[3] http://daac.ornl.gov/ISLSCP_II/islscpii.shtml

A core element of the data archive supporting FrAMES is a series of climate products from different sources. While the water balance model (Vörösmarty et al. 1998; Wisser et al. 2008, 2010b) implemented in FrAMES model is less sensitive to air temperature(Fekete et al. 2010b), but the precipitation inputs are critical(Fekete et al. 2004; Biemans et al. 2009), therefore data archive contains a wide range of precipitation data products (Global and regional, **Table 1**) from different sources (based on *in-situ* and satellite observations).

Table 1*: Precipitation data products in the CCNY data archive.*

Product	Source	Resolution	Domain	Period
CRU21	Climate Research Unit of East Anglia	30’	Global	1901-2002
GPCCfull	Global Precipitation Climatology Center	30’	Global	1901-2009
GPCCmon	Global Precipitation Climatology Center	60’	Global	2003-Present
GPCPv21	NASA Goddard Space Flight Center	60’	Global	1997-2009
GPCP1dd	NASA Goddard Space Flight Center	60’	Global	1997-2009
CMORPH	NOAA	15’	Global	2003-Present
TRMM	NASA/JAXA	15’	Global	1998-Present
PERSIANN	UC Irvine	15’	Global	2001-Present
NCEP	National Center for Environmental Predictions	150’	Global	1948-Present
NARR	National Center for Environmental Predictions	32km	N. America	1979-Present
NEXRAD	NOAA	4km	U.S.A.	1991-Present
QPE-NEXRAD	NOAA	0.1’	USA	2008-2010
UDelaware	University of Delaware	30’	Global	1901-2002
VAClimO	Global Precipitation Climatology Center	30’	Global	1951-2008

Besides the precipitation data, data archive mirrors a full range of atmospheric variables from the NCEP reanalysis (Kalnay et al. 1996; Kistler et al. 2001)and the North American Regional Reanalysis, which will be expanded this year with future climate scenarios from the Global Circulation Models submitted to the Climate Model Intercomparison Project (CMIP5) (Moss et al. 2010) for the upcoming IPCC Fifth Assessment Report.

2.1.2. River Channels

FrAMES enables rudimentary downscaling of the climate data forcing to any finer resolution network. The availability of recently completed Hydrological data and maps based on Shuttle

Elevation Derivatives at multiple Scales[4] (HydroSHEDS) (Lehner et al. 2008)is the most accurate representation of the river networks available today. HydroSHEDS, developed by the World Wildlife Fund, is based on 90 m resolution digital elevation from Shuttle Radar Topography Mission at ~500 m (15”) resolution.

Applying HydroSHEDS in a global analysis is a computationally intensive task therefore the CrossRoads team developed coarser resolution networks derived from HydroSHEDS (**Figure 2**) using a network re-gridding algorithm (Fekete et al. 2001). The multi-resolution gridded network allows the production of runoff and discharge estimates at multiple spatial resolution, which we anticipate to expand the potential user base for GTN-H products.

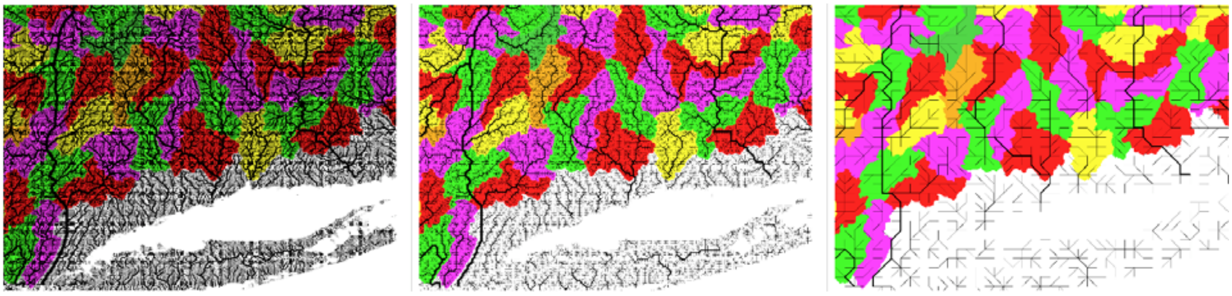


Figure 2: *Gridded networks at multiple scales in Connecticut. Aggregated HydroSHEDS(Lehner et al. 2008) gridded networks at 0.75', 1.5' and 3' resolutions constrained by sub-basins delineated from HydroSHEDS.*

The river networks are complemented with estimated riverbed geometry based on a combination of empirical formulas (Leopold et al. 1964) combined with theoretical considerations. Recent work (Dingman 2007) demonstrated the power function approximation of the river bed cross-section ($Y = \alpha w^{\beta}$, where Y denotes channel depth and w is river width) incorporated into the Chezy or Manning’s flow resistance equation is consistent with empirical relationships between discharge, mean depth, width and flow velocity expressed as a series of power functions.

2.1.3. Water Balance Model Estimates of the Hydrological Cycle

The CrossRoads team produced a series of model runs using different air temperature and precipitation forcings. Twenty Century monthly analyses (Wisser et al. 2010a) are based on air temperature from the Climate Research Unit of East Anglia (Mitchell et al. 2004; New et al. 2000) and University of Delaware (Willmott and Robeson 1995) combined with CRU, GPCC precipitations. Daily analyses for the second half of the 20th Century to present (starting in 1948) are using NCEP reanalysis air temperature combined with monthly precipitation estimates from GPCC downscaled via the daily precipitation fraction of the monthly precipitation from NCEP.

Currently, 11 model runs at 30’ and 6’ spatial resolution using pristine (without human alteration of the water cycle) and disturbed (incorporating irrigational water uptake and reservoir operations) were produced, where model runs with up to present forcing data are updated regularly. These updates provide the basis of the annual report that the CrossRoads

[4] http://hydrosheds.cr.usgs.gov

team provides to the special issue of the Bulletin of American Meteorological Society (BAMS) summarizing the "State of the Climate in …" each year.

FrAMES, the most recent water balance model implementation, the entire data archive and all the archived model runs are mirrored at the supercomputing facilities of the Community Surface Dynamic Model Systems[5] (CSDMS), which is accessible to CSDMS members.

2.1.4. Gridded Composite Runoff and Discharge Estimates

The time series implementation of the UNH-GRDC Composite Runoff Fields is long overdue. An experimental ten-year time series (1986-1995) was developed for ISLSCP-II and is still available, but this data set raised a number of problems that we could not resolve yet. The major challenge of producing time series composite runoff and discharge fields is to deal with stations coming on-line and dropping out. In the ISLSCP-II product, the inter-stations areas are reconfigured each year depending on the availability of the discharge data. This solution has an erroneous side effect, which leads to unrealistic changing in runoff and discharge estimates as a function of the operational network. A better solution would be to expand the time series of all stations suggested by Dai et al. (2009), but so far, the CrossRoads team did not succeed in implementing the time series extension.

The biggest obstacle remains the lack of near real-time monitoring data. While, discharge observations are becoming available from hydrometeorological agency, harvesting the published data via data mining turned out to be a difficult task. The Water Systems Analysis Group at UNH used to maintain an automated system to retrieve the near real-time discharge records from USGS, but continuous changes in the web protocols made it difficult to maintain the download without continuous supervision.

The CUAHSI[6] Hydrological Information System[7] seemed to simplify accessing large amount of station data by streamlining the retrieval using a well-defined protocol. Although, there are plans to offer USGS data via HIS data services, but these plans did not materialize for several years and so far the USGS archive only exist at the USGS servers in their old format.

2.2. GTN-H Website and Web-services

The GTN-H website is currently hosted at the University of New Hampshire. Operating and updating the website was one of the area, where achieved progress did not meet our expectation. The original intent was to move the web services to servers at the Environmental CrossRoads Initiative, but after the first set of experiments, it turned out that the network connection at UNH is superior to CCNY. While both institutions have similar bandwidth on paper, the CCNY network is prone to sudden drops in actual throughput that make data serving difficult. As a result, the web services are still served from UNH.

[5] http://csdms.colorado.edu

[6] Consortium of University for the Advancement of Hydrological Sciences, Inc.

[7] http://his.cuahsi.org

This split setup where the web server is operated at UNH and the data processing is carried out at CCNY having more powerful data processing servers and large and fast data storage, requires copying large amount of data from CCNY to UNH over the slow CCNY network.

Developing and maintaining the web-site became difficult over time as the UNH and CCNY teams departed over the course of the last few years, initiating new independent research efforts while wrapping up the shared projects. This graduate departure has lead that it is increasingly difficult to provide incentives to our UNH colleagues to perform updates or maintenance on the GTN-H website.

2.3. BAMS State of the Climate Contribution

The current GTN-H coordinators put considerable efforts in showcasing GTN-H. Dr. Fekete from the Environmental CrossRoads Initiative is a regular contributor the Bulletin of American Meteorological Society (BAMS), which publishes a special issue each year about the "*State of the Climate*". While the first year contribution (MacDonald et al. 2009) was largely a flag waving about the need for discharge monitoring, subsequent contribution (Fekete et al. 2010a; Fekete and MacDonald 2011)provided more and more in depth analyses based on water balance model estimates.

The biggest challenge in 2010 was to consolidate historical climate forcing records (particularly precipitation) with contemporary near real-time data products. The GPCC precipitation had severe difference between the "*full*" historical product and the more up-to-date "*monitoring*" products.

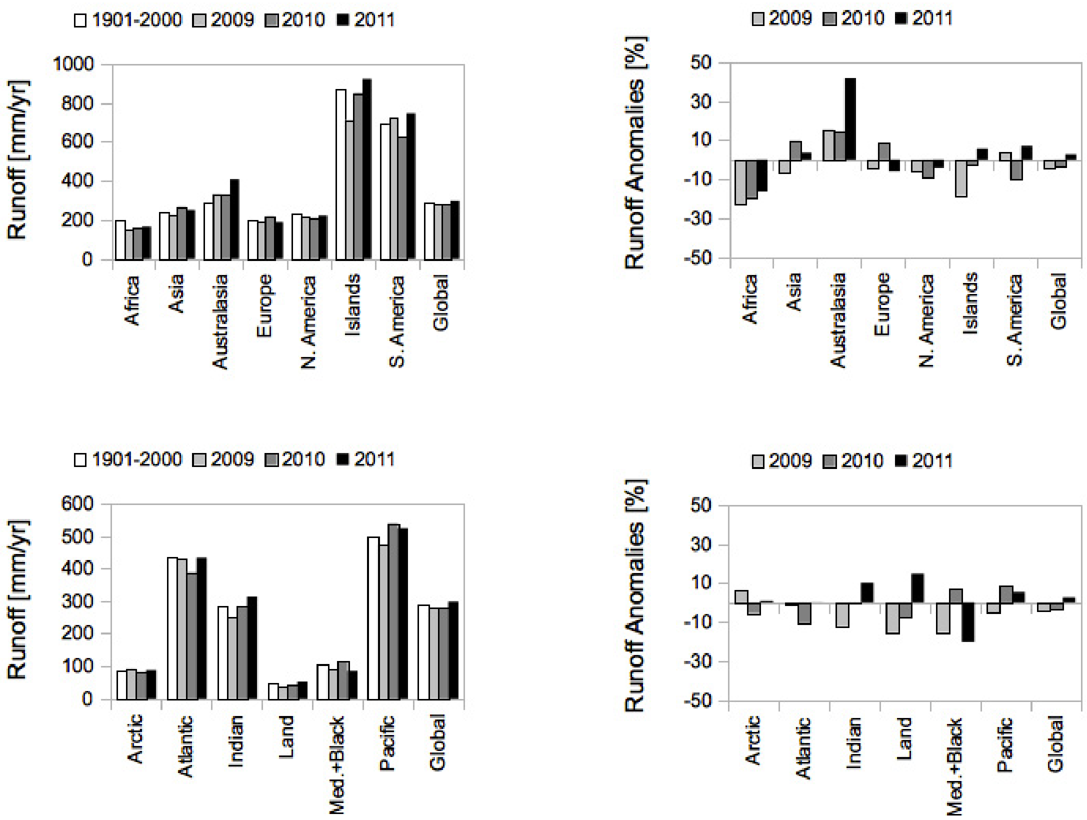


Figure 3: *Water balance model runoff estimates over continents (top row) and by receiving oceans (bottom row). The left column shows the long-term mean runoff (for the 1901-2000*

period) and annual runoff for each of the last three years (2009, 2010, 2011). The right column shows the annual anomalies of the last three years with respect to the 20th Century long-term average.

This year's contribution not only provided the usual comparison by continents and receiving ocans **Figure 3**, but demonstrated the water balance estimates contrasted with a few selected discharge gauges. Gauges from the USGS archive were all up to the end of 2011, while gauges for major Russian rivers from ArcticRIMS operated by UNH stopped in 2009. This stop coincides with the completion of UNH's project studying Arctic hydrology, which was not replaced with new research grants that could provide funding for continued access to Russian data.

This years BAMS contribution also showcased an interesting data compendium from the Dartmouth Flood Observatory[8], which ultimately was moved to University of Colorado[9]. This observatory is primarily dedicated to use remote sensing to observe major floods, but the maintainers of the website compiled a database of reported floods going back to 1985 based on news paper and other media reports (**Figure 4**). While this database is likely incomplete especially prior to the internet era, but it still represents an alternative depiction of the water related extreme events.

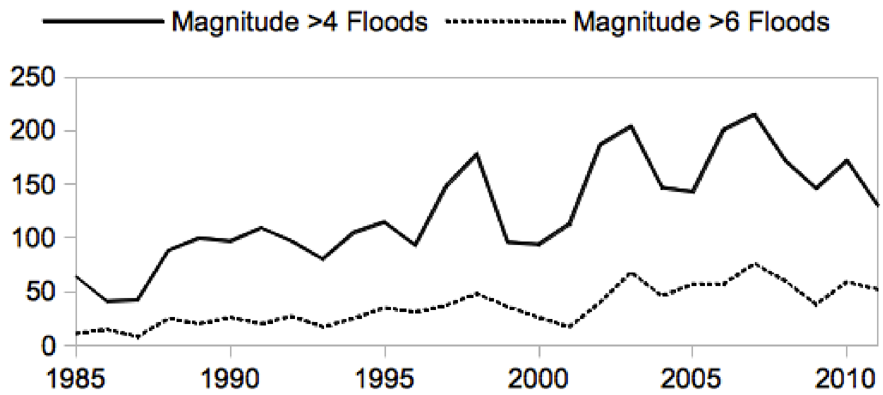


Figure 4: *Major floods world-wide from 1985-2011 according to the Dartmouth Flood Observatory database. Magnitude is defined as a product of the severity of the flood event (expressed as an index ranging between 1 – 2) the duration of the flood and the affected area.*

2.4. GTN-H Publications

Two papers and one book chapters were published or are in the process for publication directly related to GTN-H. Wisser et al. (2010a) describes the modeling and the data products prepared for GTN-H depicting the 20th Century hydrography.

[8] http://www.dartmouth.edu/~floods

[9] http://floodobservatory.colorado.edu

After long struggle, Dr. Fekete managed to publish an important paper providing rational for discharge monitoring on the ground (Fekete et al. 2012). This paper came out partially from a frustration of the lacking progress in improving the availability of *in-situ* discharge monitoring data and the repeatedly declined founding for HARON, while much more expensive remote sensing “solutions” are on the way to address discharge monitoring. Our paper articulates, why river discharge is a difficult target for remote sensing, while it can be done cost effectively on the ground. The paper demonstrates the complementary nature of *in-situ* and remote sensing monitoring.

Dr. Fekete also contributed a chapter to a book entitled “*Climate change impacts: mitigation strategies for inland waters and societies*” where he revisited the (in)famous “Stationarity is Dead” claim (Milly et al. 2008). The book chapter present original modeling exercise using state of the art GCM outputs from CMIP5 (Moss 2011) demonstrating that current generation GCMs are inadequate for water management and a better strategy is to rely on continued monitoring with frequent and regular updates that will inheritably will reflect the effect of climate change with slight lag that can be accommodated by adding extra safety buffer for water management planning. Operating adequate monitoring both in-situ and remote sensing is clearly the right strategy for climate change adaptation.

Both the peer reviewed paper and the book chapter points out that it should be considered as the minimum obligation for our generation to monitor our planet while it goes through significant changes. Even if our generation fails to act but providing a detailed record of how various facets of the Earth system changes will be essential for the next generation to reconstruct climate change.

As GTN-H coordinator, Dr Fekete felt obligated to write an advocacy blog[10] in response to the invitation from the Environmental Science Research Institute (ESRI), which is the leading GIS developer and their ArcGIS and associated products are the *de facto* standards. Given the wide acceptance of ESRI’s products and its large user community, we anticipated that this publication reaches a broad audience that might not have heard about on-going efforts to collect river discharge data.

[10] http://blogs.esri.com/esri/arcgis/2012/01/17/wmo-global-runoff-data-centre

3. GTN-H Partners

The biggest challenges ahead for GTN-H will be the better integration of the works of the partner organizations. This is easier with Global Precipitation Climate Center (GPCC), Offenbach, Germany and Global Runoff Data Centre (GRDC), Koblenz, Germany providing products that already form the basis for GTN-H services. The International Groundwater Resources Assessment Center (IGRAC) and International Data Center on Hydrology of Lakes and Reservoirs (HYDROLARE) are still building up their data products. The National Snow Ice Data Center (NSIDC) serves a niche that is primarily relevant for glaciated regions, while the UNEP Global Environmental Monitoring Systems/Water (GEMS/Water) is primarily seen as a potential user rather than hydrological data provider.

3.1. Global Precipitation Climate Center

The Global Precipitation Climate Center is among the most reliable data providers amongst the different data centers. GPCC maintains three main precipitation product lines. Their most recent "*full*" product covers the 1901-2009 period and incorporates all the precipitation records in their archive to establish spatially detailed monthly precipitation climatology at 30' spatial resolution. Precipitation anomalies calculated from the precipitation gauges operated in individual years are applied against the long-term precipitation climatology to provide monthly precipitation estimates in each year.

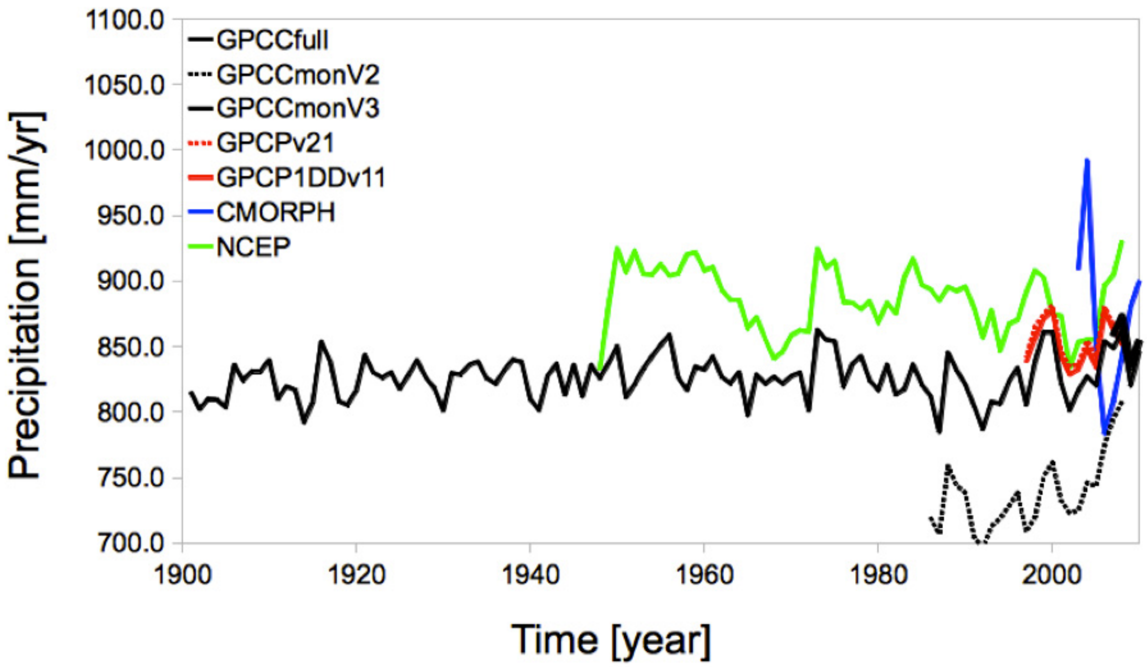


Figure 5: *Annual precipitation estimates over continents from different data sources*

The *monitoring* product uses precipitation records from WMOs real-time reporting meteorological stations. The monitoring product goes through thorough quality control before released to the public therefore updates are only available with one or two months lag. The *first guess* product fills the gap for near real-time applications offering a precipitation estimates shortly after the end of the month.

In the past, the three product lines suffered from strong biases that made it difficult to carry out long-term analysis with respect to near real-time climate conditions (**Figure 5**). GPCC recognized this bias and their newer monitoring products aligns better with their full products allowing contemporary water resources assessment in respect to past precipitation variations.

GPCC also deserves recognition for their sustained and timely data delivery. Their ability to use *in-situ* precipitation records largely undermines the main arguments promoting satellite solutions. While satellite precipitation products could provide significant contribution particularly in improving the spatial and temporal resolution, but so far satellite derived precipitation estimates lack the long-term coverage even during the satellite era. Satellite precipitation products are fragmented both in space and time. The Global Precipitation Climate Projects monthly precipitation estimate at 2.5° spatial resolution is far coarser than the GPCC products and stops in 2010. Other higher resolution products (CMORPH, PERSIANN, TRMM) don't cover the whole continental land mass and suffer from the same inconsistencies between precipitation product that GPCC managed to solve.

Satellites are often touted as the only solution to deliver Earth Observations in a timely manner. GPCC – operating under a limited budget that prevented them to send representative to our GTN-H meeting– appears as a glaring example of the opposite and shows that it is not the technology, but long-term dedication is the key to produce high quality observational products.

3.2. Global Runoff Data Centre

The Global Runoff Data Centre operating under the auspices of the WMO is another underappreciated data center that made significant progress since its existence to collect and archive discharge data world-wide. Their current holding lists over 8000 discharge gauges with some of them going back to the early 1800s. While the spatial distribution of the stations are uneven that advocates like to highlight (Alsdorf et al. 2007) in reality the discharge monitoring network is far more complete as appreciated (**Figure 6**), with a few wholes in Africa and India and China (Fekete et al. 2012).

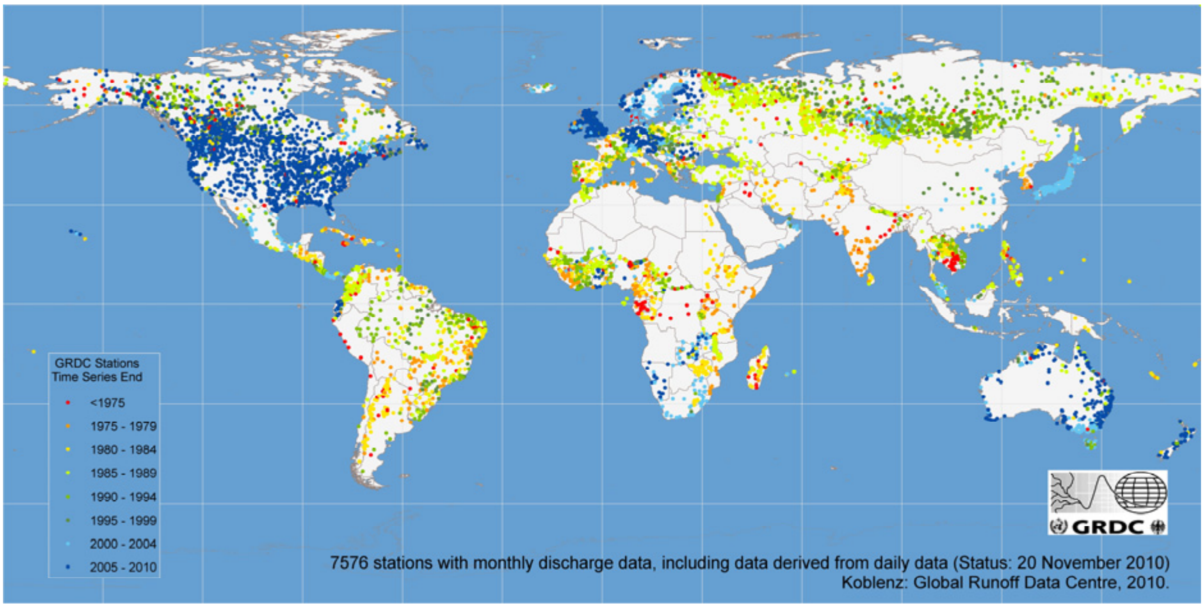


Figure 6: *Discharge Gauges in the data archive from the Global Runoff Data Centre*

The lag between the discharge observation and data records entering to GRDC data archive (**Figure 7**) that varies by countries and regions gives the misleading impression about the decline of the operating networks(Lorenz and Kunstmann 2012). While the steady decline of discharge monitoring is a serious problem (Shiklomanov et al. 2002; Vörösmarty et al. 2001) its magnitude is likely to be less severe as the GRDC data archive would indicate (Hannah et al. 2010).

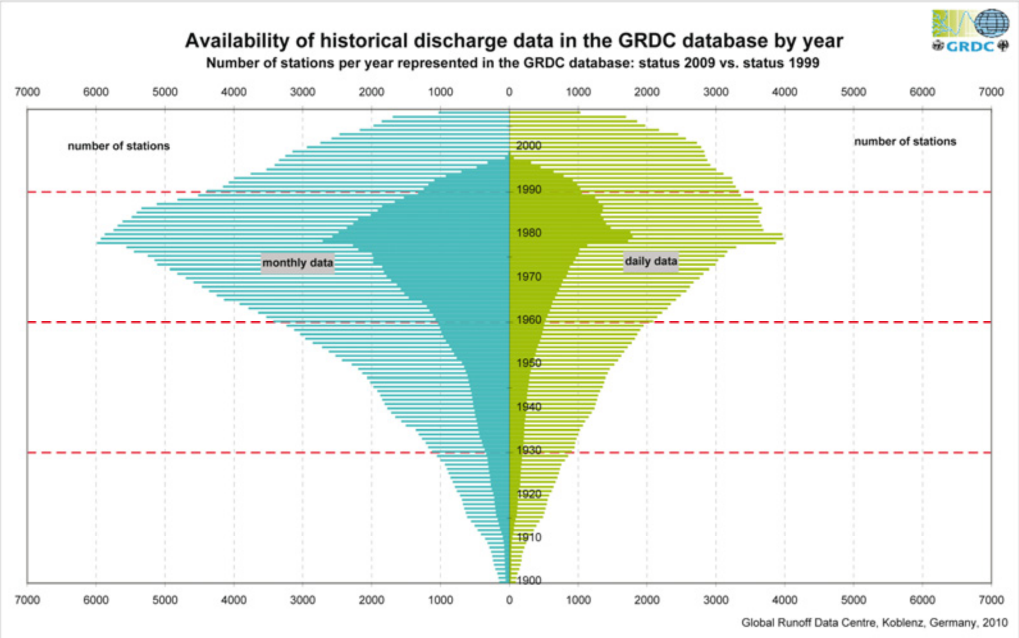
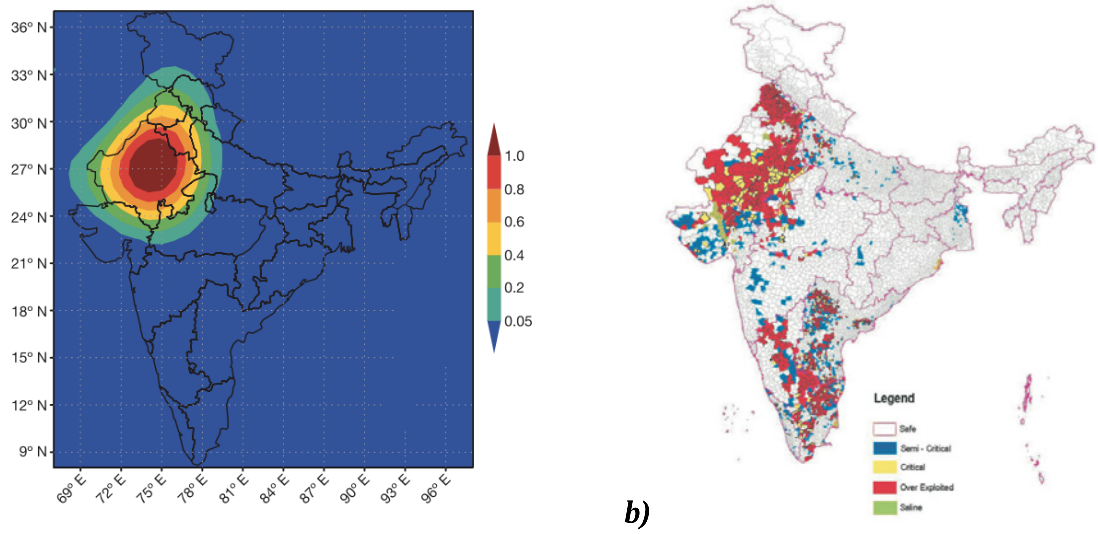


***Figure 7**: Availability of historical discharge data in the GRDC database by year*

3.3. International Groundwater Resources Assessment Center

The International Groundwater Resource Assessment Centre (IGRAC) – which recently moved from Utrecht to Delft and currently housed in the UNESCO Institute for Water and Education (UNESCO-IHE) is a joint UNESCO and WMO center that facilitates and promotes global sharing of information and knowledge required for sustainable groundwater resources development and management. The IGRAC team's goal is to establish a global groundwater monitoring system allowing the assessment of groundwater resources on a regular basis. Instead of collecting raw groundwater observations, which is often difficult to access (due to the obstacles in international data sharing) and have limited representativeness without the intimate local knowledge, IGRAC opted to set up a web-based system, where aggregated groundwater information can be uploaded by regional experts

The Gravity Recovery and Climate Experiment (GRACE, Tapley et al., 2004) is often touted as an alternative to *in-situ* groundwater monitoring (Rodell et al. 2004; Rodell and Famiglietti 1999). While GRACE's sensitivity in depicting anomalies in the Earth's gravitational fields is undeniably remarkable it's utility for water management still remains questionable. Perhaps the most frequently cited demonstration of GRACE capabilities (Rodell et al. 2009) was the detection of severe groundwater depletion in India (**Figure 8**). While this work was shocking for the scientific community it was far less newsworthy for the water managers on the ground. As it turns out, the Central Ground Water Board of the Ministry of Water Resources in India produced a report[11] (that is readily available from the internet) three years before the GRACE study based on in-situ observations providing far greater details about the severity of the problem (**Figure 8b**).While the second study never made it into high profile journals it is clearly a much more thorough work than what GRACE can provide. GRACE clearly missed major groundwater depletion in Southern India, where the GRACE signal is probably heavily contaminated by high frequency mass variation of the Indian Ocean.



a) *b)*

Figure 8: *Groundwater depletion in India a) depicted from GRACE, b) from in-situ measurements*

The second author of the GRACE study recently published a blog[12] on National Geographic's web-site that discusses the dire state of our current knowledge about water resources. While his statements are largely undisputable, one has to conclude that if the visionary new means to assess water resources will rely on remote sensing and models as the author indicates without significant investment in *in-situ* measurements than predictably the situation will prevail for the foreseeable future.

3.4. HYDROLARE

The Global Centre for the Hydrology of Lakes and Reservoirs (HYDROLARE) continues to operate under the auspices of WMO. Main activities are at present to upload information from lakes around the world and eventually make lake data available through dedicated services. Since 1st September 2012, the new web address of HYDROLARE is: www.hydrolare.net

[11] http://www.indiawaterportal.org/sites/indiawaterportal.org/files/DGWR2004.pdf

[12] http://newswatch.nationalgeographic.com/2012/07/02/wanted-vision-and-leadership-to-ensure-a-sustainable-water-future-for-america

3.5. GEMS/Water

The United Nations Environmental Programme's (UNEP) GEMS/Water programme is about to go through major changes after the Canadian government decided to end its support for hosting GEMS/Water. This will end a long period when the continuation of the funding needed to operate GEMS/Water was uncertain. The future home of GEMS/Water is still undecided, but likely candidate is the team at the State Hydrological Institute in Koblenz, Germany, which already hosts the Global Runoff Data Centre.

While this new arrangement will secure the archival of the GEMS/Water database, but leave open, how much additional resources will be available to update and expand the existing water quality observations.

Perhaps one of the last major efforts that the current GEMS/Water operation team took on was co-locating water quality sampling locations between the GEMS/Water and the GRDC discharge data archive allowing the calculation of constituent fluxes.

GEMS/Water also hosted a workshop[13] in October 13-14, 2011 inviting modeling experts to explore opportunities to better utilize the GEMS/Water data archive in water quality modeling context. This workshop also lead to a study that was prepared by the CrossRoads team for UNEP to assess the feasibility to use GEMS/Water data in a data assimilation framework similar to the UNH-GRDC Composite Runoff Fields discussed earlier. This study revealed that the GEMS/Water data archive is far more comprehensive than the analyses of individual water quality parameters may suggest (**Table 2**).

***Table 2**: The number of stations, observations and observations by station for the twenty most frequently measured constituents in the GEMS/Water database*

Group	# ofStns	# of Obs.	Obs. / Stn
Nitrogen	2243	317641	142
Phosphorus	2180	161867	74
pH	1375	167481	122
Conductance	1306	158206	121
Temperature	1045	128793	123
Oxygen	1037	301304	291
Chloride	988	102031	103
Sulphate	884	80343	91
Magnesium	837	71245	85
Solids	819	67727	83
Alkalinity	816	80622	99
Calcium	802	71719	89
Potassium	763	51530	68
Sodium	744	61804	83
Iron	705	51737	73
Bacteria	689	59023	86
Zinc	545	39421	72
Coliform	540	35203	65
Copper	532	42190	79

Perhaps the biggest challenge in managing the collected water quality data is to identify means that make parameters reported differently more comparable. For instance, various forms of Nitrogen species combined with the measurements method represent 56 distinct parameters in the GEMS/Water database as a function of the Nitrogen species, water sampling and measurement method.

The CrossRoads Team's study concluded that a water quality data assimilation combining in-situ observation was feasible and could provide spatially explicit assessment of the state of river systems. Such a data assimilation systems linked to remote sensing observation of large water bodies along river courses (lakes and reservoirs) and the coastal zones at river basin outlets could provide more complete picture of the aquatic systems.

[13] http://www.unep.org/gemswater/Portals/24154/common/pdfs/modelling_workshop-final_report.pdf

4. GTN-H Coordination

Informal talks about the potential transfer of GTN-H coordination started at the Tokyo meeting, and towards the end of 2011 the Federal Institute for Hydrology of Germany (BfG, Koblenz, Germany) agreed to take over the coordination responsibilities for GTN-H. Subsequently, during a consultation meeting at CCNY with Dr Fekete and Professor Vörösmarty, and representatives from WMO and the BfG, the GTN-H coordination was formally handed over to BfG.

4.1. Lessons Learned from the Last Four Years of GTN-H Operation

Operating data centers requires long-term commitment that is only guarantied if continued funding is available to support permanent personnel handling day-to-day tasks of data acquisition, processing, archiving and generating value added products. Academic institutions appear to be well suited for developing prototype products as the success of the UNH-GRDC Composite Runoff Fields (Fekete et al. 2002) demonstrates, but their short (3-5 years) funding cycles are clearly inadequate for long-term operations. Particular challenge for academic institutions is to justify the often repetitious and time consuming data management tasks on research oriented projects. The dependence on short-term grants leaves the operation of data services in a permanent risk of abrupt discontinuation or sluggish updates.

Hydro-meteorological services with firm and long-term resource commitment appear to be better suited to host operational data centers. Surrounded by academic research groups to help data centers developing new products could take advantage the strengths of the academic world while ensuring the continued operation from a government agency.

4.2. Transferring GTN-H Coordination

Recognizing the need for sustained resources and long-term commitments, the technical GTN-H coordination is being transferred to the Federal Institute of Hydrology (BfG) of Germany, which already hosts the Global Runoff Data Center. BfG will take over the data archive and the developed data products from the CrossRoads team and will build a new web interface to serve this data.

The new coordinator (Dr. Philipp Saile), WMO representative (Dr. Wolfgang Grabs) and CrossRoads representative (Dr. Balázs Fekete) held a meeting between 14 – 15 July, 2012 in New York, when they went over the logistics of the operation transfer.

BfG will take over the GTN-H domain[14], which is currently served from the University of New Hampshire (discussed in 2.2). BfG will investigate if its current network capacity will be sufficient for serving GTN-H or they will need to find hosting partner with more robust bandwidth. BfG will also develop new web-interface using Open Geospatial Consortium[15] (OGS) compliant solutions to replace the aging GTN-H implementation.

[14]http://www.gtn-h.edu

[15]http://www.opengeospatial.org

The CrossRoads team will continue to produce updates to the existing data products and make available new products as they mature operational use. The CrossRoads team will continue to serve on GTN=H's advisory board and assist the new GTN-H coordinators in the development of new services and streamline the operation of existing ones.

The CrossRoads team will also transfer all the input data providing the basis for GTN-H data products. BfG and the CrossRoads team will work out a roadmap for the data transfer and setting up the operation during the second half of the 2012.

The input data serving GTN-H is in the range of 200GByte, which includes the different precipitation and other climate forcings, simulated gridded networks, land-cover, soil and other geophysical data.

The data products are far bigger (4.5TByte) due to the high resolution of the gridded networks and will grow rapidly with further refinements going from the currently typical 30' spatial resolution to 6' or 3' resolutions. Since, the GTN-H products are derived from relatively small amount of data, BfG and the CrossRoads team will investigate if transferring the large amount of data or replicating the data production at BfG is more feasible.

4.3. Next Steps - Action List

The GTN-H coordination transfer meeting mentioned in the previous section together with the new and current coordinators and the WMO representative revised the action list from the 4th GTN-H coordination panel meeting (that was not discussed in the Tokyo meeting due to the extraordinary circumstances) and updated based on their status. The new coordinator has been tasked to further update the table and get partners in a working mode as a matter of urgency.

No.	Action	Who	Status/ next steps	State
1	Updated Meta-Database of "pristine" basins available at GRDC	Grabs, Lins, Looser	Ongoing; proposals coming in from various countries.	Continue
2	Clarify role of AQUASTAT as water use database with FAO (K. Frenken), and establish dialogue with GTN-H	Lehner (cc Bojinski)	Contact K. Frenken	Continue
3	Clarify how soil moisture network activities, including institutional data collection, move ahead	vanOevelen	Proposal by Portugal	Continue
4	Send new request letter on GTN-R to non-responding countries, and inform responding countries on progress	WMO	Upon request by GRDC	Continue
5	Identify and apply software product suitable to manage hydrological metadata; implement domain-specific metadata profile	GRDC		Nearly Complete
6	Develop concept for the implementation of a groundwater recharge project, jointly by GPCC, IGRAC, GTN-P, on a regional scale	Kukuric		Continue
7	IGRAC to use gridded precipitation data as a proxy of groundwater recharge, and explore the possibility of using GRACE and soil moisture data if available.	Kukuric		Continue
8	Jointly using river runoff and water quality data: new web-based flux computation	uncertain		Pending on the future of GEMS/Water
9	Organize an expert meeting on geochemical fluxes and establishing the working group on that	uncertain		Pending on the future of GEMS/Water
10	Explore the contribution of GPCC to the precipitation task of IGWCO	Lawford		Continue
11	GRDC, NSIDC collaboration in regions where glacier melt is particularly important (NSIDC identify important areas and river gauges; GRDC then act upon these requirements	Armstrong, Looser		Continue
12	Enhance NRT collection of lakes and reservoirs data by HYDROLARE in collaboration with all partner institutions; use SRTM-derived lake information dataset	HYDROLARE Team		Continue
13	GRDC to chart a process how the metadata standard and associated technology is being promoted into other domains and ECVs – should be a continuation of project 1.3, in reformulated form	Looser		Nearly Complete
14	Encourage all GTN-H partners to register their observational components in the GEO portal	All		Continue
15	Define relationship between GTN-H and WIGOS	WMO		Continue

16	Hold 3-monthly teleconferences of all GTN-H partners	GTN-H coordinator, WMO	Use GEO webex infrastructure	Continue
Communication and Outreach				
17	Engage on suggestions made by Communication and Outreach break-out group	GTN-H coordinator, to delegate where possible	To report back to Panel on progress	Continue
Data Integration				
18	Engage on suggestions made by Data Integration break-out group	GTN-H coordinator, to delegate where possible	To report back to Panel on progress	Continue
Demonstration Projects				
19	Trends in Runoff into the Arctic Ocean	N.N.	Develop 1p project outline using template	As part of ARCTIC-HYCOS
26	Use GTN-H data sets to enhance climate outlooks provided to developing countries	N.N. Grabs	To liaise with Dr. Kumar (WMO); Develop project outline using template	First half of 2013

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