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Assessment of the status of the development of the standards for the Terrestrial Essential Climate Variables

GTOS

Essential Climate Variables

GTOS 56

RIVER

River Discharge

WMO UNESCO UNEP ICSU FAO FIAT PANIS

T1

Assessment of the status
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Terrestrial Essential Climate Variables

RIVER

River Discharge

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Global Terrestrial Observing System
Rome, 2009

Version 9
11 May 2009

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NRL, Food and Agriculture Organization of the United Nations (FAO)

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List of Acronyms

ADCP	Acoustic Doppler Current Profilers
DEM	Digital Elevation Model
ERS	European Remote Sensing
ESRI	Environmental Systems Research Institute
FTP	File transfer protocol
GARP	Global Atmospheric Research Program
GCM	General/Global Circulation Model
GCOS	Global Climate Observing System
GEO	Group on Earth Observations
GeoRep	Geographical Reference Code
GIS	Geographic Information System
GPR	Ground-penetrating Radar
GRDC	Global Runoff Data Centre
GTN-H	Global Terrestrial Network for Hydrology
GTN-R	Global Terrestrial Network for River Discharge
IGOS	Integrated Global Observing System
NOAA	National Oceanic and Atmospheric Administration
NRT	Near Real Time
RivDis	River Discharge
SAR	Synthetic Aperture Radar
STN	Simulated Network Topology
TOPC	Terrestrial Observation Panel for Climate
UNESCO	United Nations Educational Scientific and Cultural Organization
WaterGAP	Water Global Assessment and Prognosis Model
WHYCOS	World Hydrological Cycle Observing System
WMO	World Meteorological Organization

Executive Summary

River discharge has a role in driving the climate system, as the freshwater inflow to the world's oceans may influence oceanic circulation patterns at interannual to decadal time scales. At the same time river discharge serves as an indicator for climatic change and variability as it reflect's changes in precipitation and evapotranspiration. River discharge, which is expressed as volume per unit time, is the rate at which water flows through a cross-section. The unit used to measure river discharge is usually m^3/s (cubic meters per second, or cumecs).

Currently *in situ* methods are the most cost-effective and reliable options for river discharge measurement. Discharge measurements are made at each gauging station to determine the discharge rating for the site. The discharge rating is a relation between stage and discharge influenced by stage, slope, rate of change of stage and other factors. The depth of flow in the cross-section is measured at verticals using different techniques. As the depth is measured, observations of velocity are obtained at one or more points in the vertical. The measured widths, depths, and velocities permit computation of discharge for each segment of the cross-section. The summation of these segment discharges is the total discharge.

River discharge measurements are described in detail in the Technical Regulations of Hydrology and Guide to hydrological practices of the World Meteorological Organization (WMO). WMO also provides a Manual on stream gauging consisting of Volume I-Fieldwork and Volume II-Computation of discharge. The ISO Technical Committee 113 is dealing with all standards related to Hydrometry. Numerous standards covering the majority of the observation methods have been published and are under development. Both WMO documentation and ISO standards are revised when needed, to incorporate latest technical and methodological developments. Existing *in situ* methods and standards meet the needed requirements.

For many rivers, discharge measurements are either non-existent or not promptly available. During flood season, it is usually impossible or impractical to measure peak discharges, even though peak information is very important. When floods occur the use of conventional methods is not safe, consequently many peak discharges must be determined by indirect methods after the flood has passed. Methods to determine river discharge based on remotely sensed data would be most advantageous. However, the currently available methods still need to be refined in terms of accuracy and spatial resolution in order to supplement or substitute *in situ* river discharge measurements.

Most countries operate national or regional river discharge monitoring networks and corresponding data archives. The need for an International River Discharge Data Centre to provide discharge data for continental or global studies has been realized by the WMO and as a result the Global Runoff Data Center (GRDC) was established in 1988. This international river discharge data repository is mandated through WMO resolutions to collect, archive and redistribute river discharge data from WMO members. Due to different national data policies, technical, political or administrative obstacles the amount of discharge data captured in the GRDC is only a fraction of the total available discharge data and in many cases outdated.

The GRDC has launched a project called Global Terrestrial Network for River Discharge (GTN-R). The basic idea of the GTN-R project is to draw together the already available heterogeneous information on near-real-time river discharge data provided by individual National Hydrological Services and redistribute it in a harmonized way. The GTN-R activity is a contribution to the Global Terrestrial Network for Hydrology (GTN-H) of the Global Climate Observing System (GCOS) and the WMO. The implementation of the GTN-R is progressing at a slow pace, due to the hesitation of many countries to fully participate and provide the relevant data.

Recommendations:

- For *in situ* river discharge measurement existing standards set by ISO and guides from the WMO (WMO Technical Regulations of Hydrology, WMO Guide to Hydrological Practices, WMO Manual on Stream Gauging Volume I-Fieldwork and Volume II-Computation of Discharge, Standards related to Hydrometry set by the ISO Technical Committee 113) should be adhered to. The revision process of these standards and guides to accommodate latest developments is well established and adequate.
- The development of remote sensing techniques and the supporting satellite systems for the monitoring of river discharge must be encouraged. Remotely sensed data has advantages for many rivers where discharge measurements are not available or where the maintenance of a dense network of stream gauges is too expensive. Flood monitoring could also be achieved without the risks and shortcomings currently associated with this task.
- The free and unrestricted exchange of hydrological information must be further encouraged so that the data can be received by the international data centers in time for up-to-date assessments and forecasts.
- The decline of hydrological monitoring networks needs to be addressed and financial support is sought to establish a global baseline river discharge monitoring programme.
- Integration of data and information derived from monitoring of individual essential climate variables is required.

1. Introduction

River discharge has a role in driving the climate system as the freshwater inflow to the worlds oceans may influence oceanic circulation patterns at inter-annual to decadal time scales.

At the same time river discharge serves as an indicator for climatic change and variability as it reflect changes in precipitation and evapotranspiration.

From a scientific perspective river discharge is a critical water cycle variable, as it integrates all the processes (e.g. runoff and evapotranspiration) occurring within a basin and provides on hydrological output variable that can be readily measured. As a result it is a very important parameter for the calibration and evaluation of hydrological and coupled land-atmosphere models, the calibration of satellite data, trend analysis and socio-economic investigations.

Traditionally long-term river discharge measurements are the essential information source for many water resource applications, including water engineering designs, flood protection, irrigation scheduling, international water allocation agreements, ecosystem management and water management plans (*IGOS*, 2004).

2. Definition and units of measure

River discharge is the volume of water flowing through a cross section of a waterway per time unit and it includes runoff. The unit used to measure river discharge is usually m^3/s (cubic meters per second, or cumecs). Symbol for river discharge is Q.

The term "runoff," is the depth to which a river basin, State, or other geographic area would be covered with water if all the streamflow within the area during a single year was uniformly distributed upon it. Runoff quantifies the magnitude of water flowing through the Nation's rivers and streams in measurement units that can be compared from one area to another. The runoff value for a geographic area is computed as the median runoff value for all streamgages in that geographic area. For example, the runoff value for a state is the median for all streamgages in that state, and the median for the Nation is the median value for all streamgages in the Nation. http://water.usgs.gov/waterwatch/2006summary/

3. Existing measurements methods and standards

3.1 *In situ* measurement

Currently there are no cost-effective, reliable options for river discharge measurement, apart from *in situ* methods (*IGOS*, 2004). River discharge, which is expressed as volume per unit time, is the rate at which water flows through a cross-section. Discharge at a given time can be measured by several different methods encountered at a particular site: The raw data recorded by satellite instruments represent spectral radiances that can be converted into other geophysical parameters.

- the conventional current-meter method;
- the moving-boat method;
- the tracer dilution method;
- the acoustic current Doppler profile method;
- other miscellaneous methods.

The conventional current-meter method is most commonly used in gauging streams (Rantz, 1982), but the acoustic current Doppler profile method is quickly gaining popularity.

Discharge measurements are made at each gauging station to determine the discharge rating for the site. The discharge rating may be a simple relation between stage and discharge or a more complex relation in which discharge is a function of stage, slope, rate of change of stage, or other factors.

The depth of flow in the cross-section is measured at verticals with a rod or sounding line. As the depth is measured, observations of velocity are obtained with a current meter at one or more points in the vertical. The measured widths, depths, and velocities permit computation of discharge for each segment of the cross-section. The summation of these segment discharges is the total discharge.

Frequency of measurement

Initially the discharge measurements are made with the frequency necessary to define the station rating, as early as possible, over a wide range of stages. Measurements are then made at periodic intervals to verify the rating or to define any changes in the rating caused by changes in the stream channel. Monthly observations of river discharge are generally sufficient, though daily data are needed to calculate the statistical parameters of river discharge. Manual water discharge observations are still in practice. However, in many countries even paper systems for continuous data recording have been almost entirely replaced by largely automated electronic logging, analysis and data transmission systems.

WMO (World Meteorological Organization) and ISO (International Organization for Standardization) Standards

River discharge measurements are described in detail in the Technical Regulations of Hydrology (WMO-No.49) and Guide to hydrological practices (WMO-No.168). The sections on river discharge specify the requirements in the establishment and operation of a hydrometric station for the measurement of stage or discharge, or both, in order to conform to the requirements of Technical Regulation [D.1.2] 3.3 and to meet the requirements for the accuracy of measurement indicated in

Technical Regulation [D.1.2] 3.5 and [D.1.2] 3.6. The material in the text is based on ISO 1100-1 (1996) entitled: “Measurement of liquid flow in open channels-Part I: Establishment and operation of a gauging station" and on ISO 748 (1997) entitled: "Measurement of liquid flow in open channels-Velocity area methods".

WMO (WMO-519) also provides a Manual on stream gauging consisting of Volume I-Fieldwork and Volume II-Computation of discharge. Volume I deals with the selection of gauging-station sites, measurement of stage and measurement of discharge and is aimed primarily at the hydrological technician. Volume II deals mainly with the computation of the stage-discharge relation and computation of daily mean discharge and is aimed at the junior engineer with a background in basic hydraulics.

The ISO Technical Committee 113 is dealing with all standards related to Hydrometry. Numerous standards have been published, are under development or are being revised. ISO 748 (2007) specifies methods for determining the velocity and cross sectional area of water flowing in open channels without ice cover, and for computing the discharge there from. It also covers methods of employing current meters or floats to measure the velocities. It deals only with single measurements of the discharge. The continuous recording of discharges over a period of time is covered in ISO 1100-1 (1996) and ISO 1100-2 (1998). Not all standards related to the determination of velocity area methods, flow measurement structures, instruments, equipment and data management are discussed here.

ISO/TS 24154

ISO/TS 24154 (2005) gives the principles of operation, construction, maintenance and application of acoustic Doppler current profilers (ADCP) for the measurement of velocity and discharge, and discusses calibration and verification issues. It is applicable to open-channel flow measurements with an instrument mounted on a moving vessel. Potential efficiency gains from the use of ADCP's could lead to better records of river discharge obtained at lower costs than conventional methods (Morlock, 1996).

Ground Penetrating Radar (GPR)

Costa (Costa *et al.* 2000) described an experiment to take non-contact, open-channel discharge measurements. Surface velocity can be measured at various points across the river using the principal of Bragg scatter of a high-frequency (10 GHz) pulsed Doppler radar signal. Cross-sectional areas can be measured by suspending conventional low-frequency (100 MHz) ground-penetrating radar (GPR) system over the water surface from a bridge or cableway and transiting it across the stream. In the absence of a bridge or cableway, GPR and radar systems have been mounted on a helicopter and flown across the river, producing discharge values comparable to conventional discharge measurements (Costa *et al.* 2000, *Hirsch et al.*, 2004). Continuous measurement of stream flow in this way could eliminate the need to maintain a stage discharge rating, because all the essential variables are measured directly and continuously. However, this local approach lacks the broad-scale view necessary for defining discharge in complex lowland terrain with water bodies and wetlands (Alsdorf *et al.*, 2001b).

3.2 Satellite measurement

For many rivers, discharge measurements are either non-existent or not available quickly. This is especially true in developing countries, for which the cost of establishing and maintaining a dense network of stream gauges is prohibitive. During flood season, it is usually impossible or impractical to measure peak[1]

1 Annual maximum instantaneous peak streamflow and gage height.

Source: http://nwis.waterdata.usgs.gov/nwis/sw discharges, even though peak information is very important. When floods occur the use of conventional methods is not safe consequently, many peak discharges must be determined by indirect methods after the flood has passed. Thus, a method that uses remotely sensed data to estimate discharge would be beneficial from an economic or safety perspective and will enhance discharge monitoring methods. Satellite data could provide unprecedented global coverage of critical hydrologic data that are logistically and economically impossible to obtain through ground-based observation networks. The increasing number of satellites and airborne platforms, along with advances in computer hardware and software technology, make it possible to measure and evaluate large numbers of watershed physical characteristics and state variables.

Smith *et al.* (Smith, 1996; Smith, 1997) suggested that European remote sensing (ERS) synthetic aperture radar (SAR) data are suitable for estimating instantaneous discharge over several channels of a braided river. However, it is probably not possible to use this technique successfully for braided rivers smaller than the one Smith and co-workers studied, owing to the 25 m nominal spatial resolution of ERS SAR data. They used ground-penetrating radar and pulsed Doppler radar, to measure channel cross-sectional area and surface velocity respectively. Centimeter-scale water-level changes have been measured by using satellite radar altimeter data (Hirsch *et al.*, 2004) and interferometric processing of SAR data (Alsdorf *et al.*, 2000, 2001a). As altimetry is a profiling and not an imaging technique, it is applicable only to water bodies greater than about 1 km in width. Interferometric radar measurements of water-level changes require the acquisition of two SAR images from identical (or nearly identical) viewing geometries, and the two images are co registered to sub-pixel accuracy for subtraction of the complex phase and amplitude values of each pixel. Syed *et al*. (2009) utilized GRACE satellite (Gravity Recovery and Climate Experiment) derived data to estimate monthly freshwater discharge from drainage regions and continents. This approach seems promising in assessing regional to global water budgets. Research into interferometric and altimetry-based approaches to river discharge monitoring by the Space Agencies will be encouraged by GCOS, TOPC and GEO.

3.3 Summary of requirements and gaps

In situ discharge measurements and observations are well established and standardized. Changing measurement and observation techniques, new data transmission and processing techniques are constantly developed, tested and implemented. The technical aspects of monitoring have been well addressed. However, access to the discharge data and the provision of the discharge data to international data centers needs urgent attention.

Compliance with WMO resolutions for the free and unrestricted exchange of hydrological data and information and a timely provision of the discharge data to international data centers are needed.

Additional research into the development of altimetry and other sensing techniques and algorithms that may make it possible to derive more information about river discharge from existing and planned satellite systems is needed.

4. Contributing networks and agencies

Most countries operate national or regional river discharge monitoring networks to meet multiple needs. These include amongst others water resources management and development and disaster mitigation. At the same time the collected data can be utilized for regional and global research programmes to improve our understanding of the climate system.

Following the first Global Atmospheric Research Program (GARP) from 1967 – 1982 the WMO was entrusted with the collection of river discharge data sets from member countries to be used as inputs to or validation of Global Atmospheric Circulation Model studies.

Against this background the Global Runoff Data Center (GRDC) was established in 1988 as a WMO data center for discharge data. WMO resolutions 21 (WMO Cg-XII) and 25 (WMO Cg-XIII) have given the GRDC the mandate to collect river discharge data from all WMO members in a free and unrestricted manner. Currently the GRDC houses discharge data from more than 7 300 stations in 156 countries. The data is provided by numerous National Hydrological Services and utilized by United Nation programmes, science and research mainly for the study of changes in the climate system.

The Global Terrestrial Network for River Discharge (GTN-R)[2] is a project launched by the GRDC, aimed at providing access to near real-time river discharge data. The GTN-R activity is a contribution to the Global Terrestrial Network for Hydrology (GTN-H) of the Global Climate Observing System (GCOS) and the WMO.

The basic idea of the GTN-R project is to draw together the already available heterogeneous information on near-real-time river discharge data provided by individual National Hydrological Services and redistribute it in a harmonized way.

GRDC has identified a priority network of river discharge reference stations that constitute the first application network for GTN-R as depicted in Figure 1. The core of GTN-R will be a software that collects near-real-time (NRT)-discharge data from distributed data sources over the Internet, harmonizes and summarizes it, and makes it available again in one standard format via a FTP-server. As a minimum requirement, it is envisaged that GRDC will receive regular updates for GTN-R stations within one year of their observation. However, as far as possible, countries are requested to provide more frequent and timely updates[3].

One product of the harmonized data will be a mapping tool that graphically displays the harmonized NRT-discharge stations in an interactively scaleable world map at a web page displaying current discharge values (Maurer 2005).

2 http://gtn-r.bafg.de

3 Metadata table of all GTN-R stations (file code: ECV-T1-riverdischarge-ref-24-Metadata table of all GTN-R stations-Copy of catalogue-gtn-r-2005_06_09.xls) available online at: http://gtn-r.bafg.de/servlet/is/Entry.2492.Display/

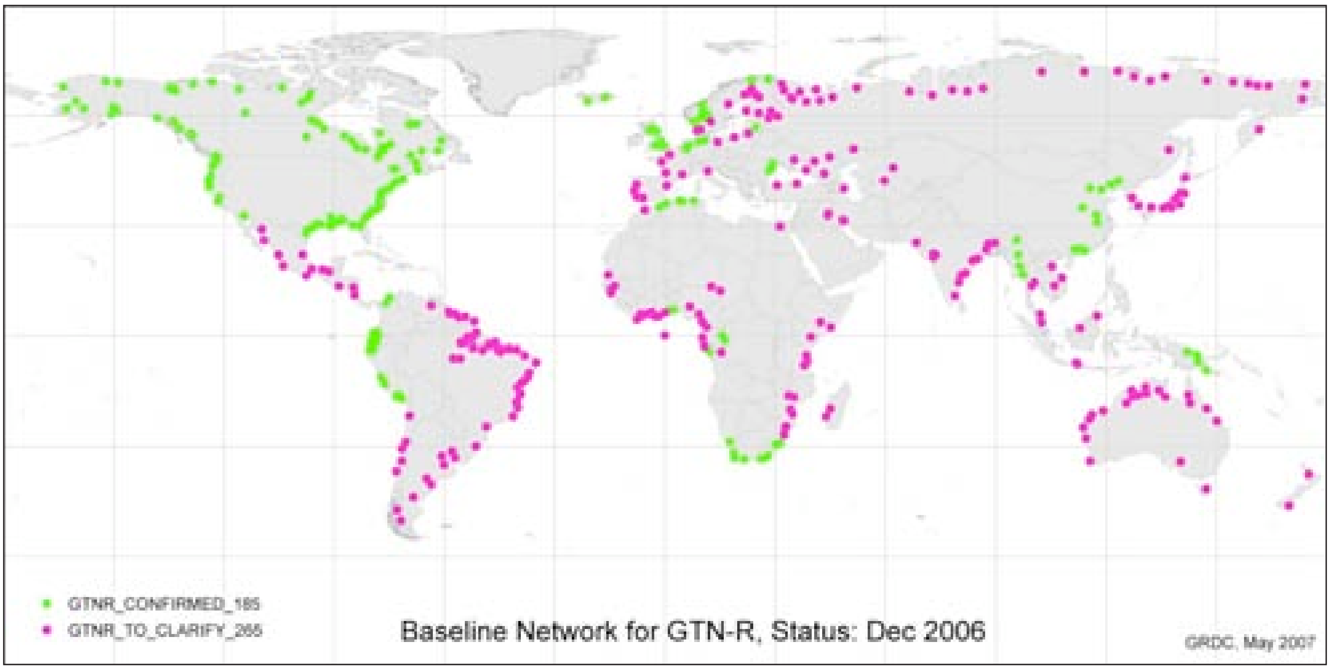

Figure 1: The baseline network of the GTN-R currently constitutes a total of 450 discharge stations (185 confirmed stations and 165 stations to be clarified)

Furthermore the WMO has implemented the World Hydrological Cycle Observing System (WHYCOS)[4]. WHYCOS is a programme aimed at improving the basic observation activities, strengthening the international cooperation and promoting free exchange of data in the field of hydrology. Besides a support component it exhibits an operational component, which achieves "on the ground" implementation at regional and international river basin levels. WMO is thus supporting the National Hydrological Services in strengthening and updating their observation networks, in adopting modern data collection and transmission technologies and in developing their data management capabilities. WHYCOS is based on a global network of reference stations, which transmit hydrological and meteorological data in near real-time, via satellites to National Hydrological Services and regional centers. However, the accessibility of WHYCOS data is very heterogeneous and thus difficult, both from an organizational and a technological point of view. Data policies are sometimes restrictive and not all data collected is being published. Where it is published it is not necessarily structured in a way for ease of access. A more standardized and automated method needs to be developed (GCOS 2003a and 2003d).

The GCOS/WMO-sponsored network the GTN-H has been implemented in 2001 to improve accessibility of already existing data. GTN-H aims at complementing the existing global terrestrial networks of GCOS and GTOS. Altogether ten different hydrologic variables (e.g. precipitation, soil moisture, water vapor pressure and discharge data) have to be collected within this initiative as near-real-time data. Once fully implemented, GTN H is expected to provide users with timely access to global hydrological data and metadata, and generate relevant products and related documentation in a time frame and of a quality that is required by users.

4 http://www.whycos.org/rubrique.php3?id_rubrique=2

5. Available data

Most countries monitor river discharge and archive the data after quality control measures. Differing national data policies lead to a wide variety of access to the discharge data. Some countries provide their discharge data without any restrictions for downloading from the Internet. Some countries provide their discharge data free of charge or against payment on request to specific users and some countries are not providing data at all. The reason for this can be manifold based on policy and/or technical limitations.

The objective of the GRDC[5] is to collect the discharge data from as many National Hydrological Services as possible, convert the data into a standardized format and provide the data to the eligible user community on request. This simplifies access to the data and the user has not to deal with data acquisition difficulties. The GRDC currently holds data for more than 270 000 station years monthly and 190 000 station years daily data. This information for more than 7 300 stations from 156 countries will be provided on request to the scientific community according to WMO data policy.

The Global River Discharge Database is extensively used for the compilation of river discharge information. One of the primary sources of information for the database development was the UNESCO river archives and the series of publications entitled: "The Discharge of Selected Rivers of the World" which was provided, in book form from 1969 through 1984. The series served as an important source of information on approximately 1 000 stations. These were checked against existing digital UNESCO station data (NOAA - National Geophysical Data Center; WMO - Global Runoff Data Center) to form a comprehensive set of discharge sites for which summary discharge data were developed. RivDis v1.0 provides discharge data from the original UNESCO publication series in a digital format that can be easily acquired and analyzed by researchers and planners in the water sciences community. The contents of RivDis v1.0 was published in book form (Vörösmarty *et al*. 1996, 1998) and can be obtained from UNESCO's International Hydrological Programme Headquarters.

An example (see: www.rivdis.sr.unh.edu/unesco/nagymar.gif) of the discharge data developed for each site shows a range of information on each site. Below is an overview of the methodology used to develop and error-check the data entries:

- The data were stored in two related tables, one with the discharge station information, and one table with the discharge data itself. An example of the tables that were created is here: www.rivdis.sr.unh.edu/unesco/tableexample.html. These two tables were linked via a common Geographical Reference Code (GeoRep).
- When the latitude and longitude for a site were not listed, the *Times* Atlas of the *World* was consulted to derive the coordinates. If the given discharge station name was not present in the *Times* Atlas, or in any local maps that were available to us, the latitude and longitude were calculated from the UNESCO GeoRep given. For example, iF03 = -80 longitude, 53 latitude. These points were imported into Arc/Info (ESRI, Redlands, California) and displayed over the ArcWorld (1:3 000 000) rivers coverage (ESRI), where their coordinates were adjusted to lie directly upon the appropriate river.
- When there was no GeoRep available, as was often the case with the digital data, the site was discarded.
- When a site had little or no associated descriptive data, the site was discarded.

The basin areas given by UNESCO were compared against basin areas generated for those sites by a 30 min. simulated network topology (STN-30).

5 http://grdc.bafg.de

Differences between the two were investigated to check the soundness of the UNESCO data as well the validity of the STN-30. Several differences were found that could not be attributed to errors in the STN-30 and were assumed to be an error on the part of UNESCO and have been noted in the database. An example a graph showing the comparison between these data sources is shown here: www.rivdis.sr.unh.edu/unesco/realVsDischarge.jpg.

Analysis products

Gauging stations are not homogeneously distributed in space. Moreover, time series are not necessarily continuously measured nor do they in general have overlapping time periods. To overcome these problems with regard to regular grid spacing used in GCMs[6], different methods can be applied to transform irregular data to regular so-called gridded runoff fields. Large numbers of GRDC station data have been used in a couple of global studies including: (i) the Global Composite Gridded Runoff Fields of mean monthly runoff[7] in cooperation with the University of New Hampshire, USA, and (ii) the Global Water Assessment and Prognosis model WaterGAP which also accounts for water uses in cooperation with the Center for Environmental Systems Research, University of Kassel, Germany.

Based on updated data the GRDC is currently reiterating its estimate of long-term mean annual freshwater surface water fluxes into the world oceans. Applying a new GIS based methodology involving a DEM (digital elevation model) it will be possible to estimate freshwater fluxes from arbitrary reaches of the coastline. Only a significant improvement of data availability will allow the extension of this analysis to estimates of individual years (GCOS 2003d).

6 General/Global Circulation Model.
7 http://www.grdc.sr.unh.edu/

6. Other issues

Most countries monitor river discharge, yet many are reluctant to release their data, in spite of WMO resolutions requesting free and unrestricted exchange of hydrological data and information. Additional difficulties arise because data are organized in a scattered and fragmented way, i.e. data are managed at regional or local levels, in different sectors and using different archival systems. Even for those data providers that release their data, delays of a number of years can occur before data are delivered to International Data Centers such as the GRDC.

In spite of the wide recognition that hydrological data in general and specifically river discharge data information is needed, the past two decades have seen a worldwide decline in the coverage and reliability of systems for the collection of hydrological data and too little has been achieved in the integration of data already available (GCOS 2003d).

7. Conclusions

The *in situ* measurement and observation of river discharge are well established and the methods are largely standardized through the WMO and ISO. Remote sensing based observation of river discharge is being developed and has potential but at this stage cannot replace *in situ* monitoring in terms of accuracy. Further development is needed here.

Data collection of river discharge is mostly happening in a fragmented manner at national or subnational level. Provision of river discharge data to international data centers is hampered by a number of obstacles ranging from technical difficulties to data policy, political and administrative issues. River discharge data provision to international data centers must be encouraged and institutionalized in order to fully utilize such an important dataset for climate system studies. The decline of river discharge monitoring networks and systems can be attributed to lack of funding and political will to continue especially long-term monitoring for the collection of data that might be relevant for climate change studies.

- The decline of hydrological monitoring networks needs to be addressed and financial support is sought to establish a global baseline river discharge monitoring programme.
- Integration of data and information derived from monitoring of individual essential climate variables is required.

8. Recommendations

8.1 Standards and methods

- For *in situ* river discharge measurement existing standards set by ISO and guides from the WMO (WMO Technical Regulations of Hydrology, WMO Guide to Hydrological Practices, WMO Manual on Stream Gauging Volume I-Fieldwork and Volume II-Computation of Discharge, Standards related to Hydrometry set by the ISO Technical Committee 113) should be adhered to. The revision process of these standards and guides to accommodate latest developments is well established and adequate.
- The development of remote sensing techniques and the supporting satellite systems for the monitoring of river discharge must be encouraged. Remotely sensed data has advantages for many rivers where discharge measurements are not available or where the maintenance of a dense network of stream gauges is too expensive. Flood monitoring could also be achieved without the risks and shortcomings currently associated with this task.

8.2 Other recommendations

- The free and unrestricted exchange of hydrological information must be further encouraged so that the data can be received by the international data centers in time for up-to-date assessments and forecasts.

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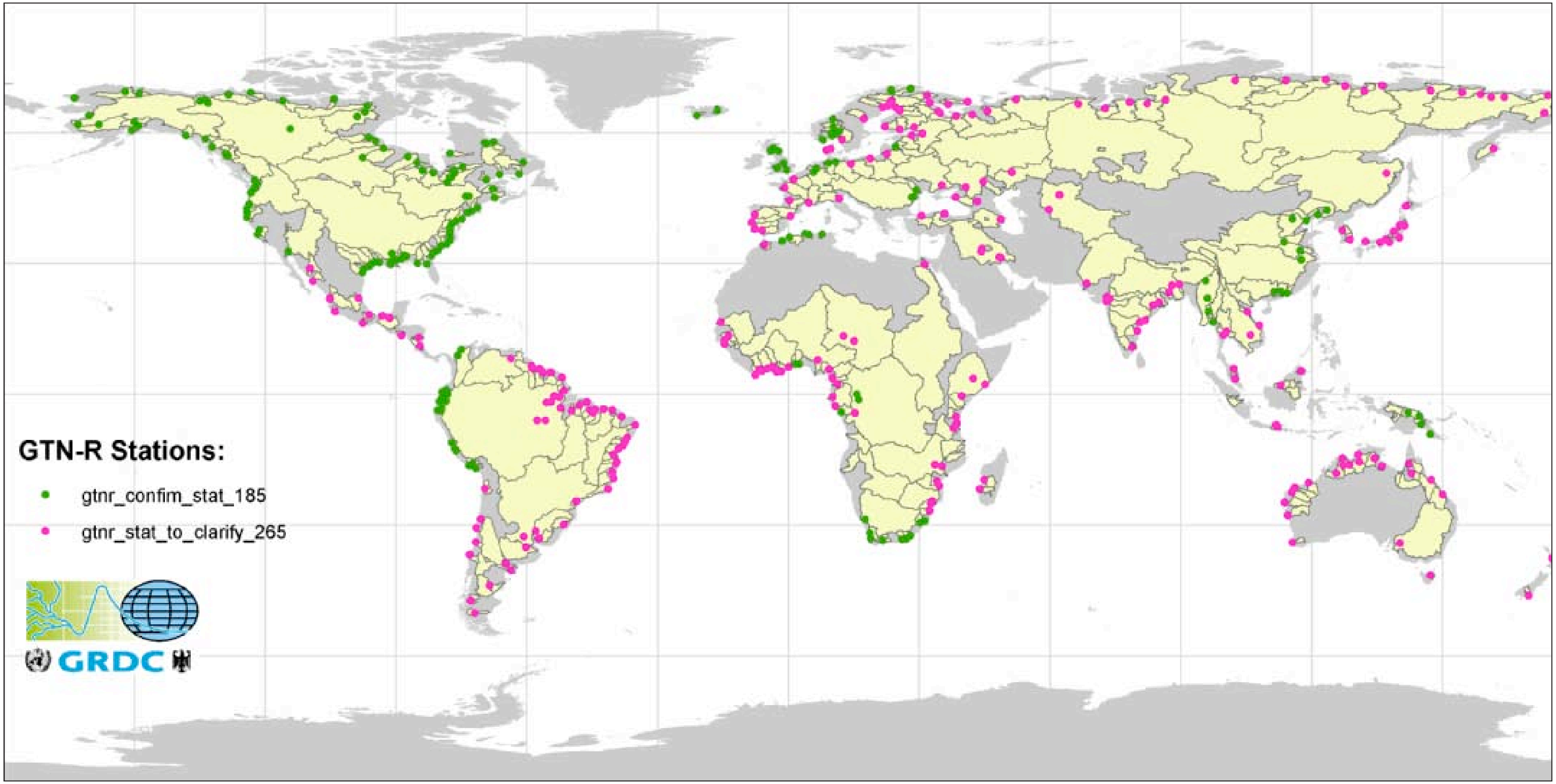
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