The Hydrology Bureau of the Global Geophysical Fluids Center

Clark R. Wilson and Jianli Chen

University of Texas at Austin, Cnter for Space Research, Austin, TX 78712, USA.

1 Goals of the Special Bureau for Hydrology (SBH)

The purpose of the SBH is to provide a bridge between the communities of climate sciences and geodesy. Modern space geodetic observations are influenced in a direct way by the variable distribution of water mass. The geodetic community requires a measure of the time variable load of water on the land surface over the entire Earth, as a function of time, in order to estimate both local effects on geodetic site displacements, and global effects on earth rotation, geocenter, and gravity field changes. The hydrologic problem of estimating water redistribution is considered one of the fundamental challenges in climate science. It is pursued aggressively by a community much larger than the geodetic community. Thus, it is sensible to tap the resources of the climate science enterprise, especially employing results from global numerical data-assimilating models.

We intend to use the SBH web page to distribute both water load time series data in gridded form, and commonly used global integrals of it. These global integrals would include time series of excitation functions of earth rotation changes, and variations in the global gravity field Stokes coefficients. The real challenge is to identify data resources, and to collaborate with those developing state-of-the-art land-surface models, and other data sources. There are two promising future resources for estimating water load variations on a global basis. One is the GRACE satellite mission, which will provide variations in Earth's gravity spherical harmonic coefficients on a monthly basis. A second resource would be estimates from Global Land Surface Models (LSM) under development at Goddard Space Flight Center, and perhaps at other centers. There exist other data resources on the web pertaining to global water budgets. For example, there is an interesting site at http://climate.geog.udel.edu/~climate/ the web site (University of Delaware) holding gridded monthly mean soil moisture and snow load fields, and there may be other resources as well to be added.

2 SBH Website Current Contents

ECMWF and NCEP-NCAR models produce global gridded atmospheric reanalysis of all available weather observations for the past several decades. In a reanalysis, the numerical model is fixed. The surface boundary over land is given a primitive hydrologic cycle with some coupling to the atmospheric model. Generally, hydrologic parameters of the land surface are not connected to a river runoff model. Instead the hydrologic parameters are used to provide proper boundary conditions for the atmospheric calculations, that are of primary importance. Because the land surface model is of secondary importance, it is difficult to understand exactly how soil and snow values are calculated. Documentation tends to be poor because the hydrologic boundary conditions are not of primary interest. For both the NCEP-NCAR and ECMWF results we have drawn conclusions based on an inspection of the time series and global maps of the average seasonal behavior.

Variability in total water load is the sum of water changes in several soil layers, plus a snow load component. The water load changes are not based on observed precipitation and runoff, and may be considered representative, but not good measures of time variability. There is no obvious way to assess quantitatively the size of the errors in these time series. Qualitatively, we observe that NCEP-NCAR results show little inter-annual variation (they are dominated by near-sinusoidal annual variations). On the other hand, average seasonal ECMWF water loads resemble the global seasonal water balance climatology published in the mid-1980's by Willmott and Rowe. This climatology is not nearly so sinusoidal, and is based on many decades of evaporation, precipitation, and runoff data averaged by month, and gridded for the globe. ECMWF coupling to the atmosphere model seems to provide some interannual variability. Because neither NCEP-NCAR nor ECMWF includes coupling to ground water or continental ice sheets (both long term storage reservoirs), it is likely that no gridded model output now available correctly estimates long-term load variations that may arise in the hydrologic system.

Daily continental water storage, defined as the sum of soil wetness and snow water, is computed from the two reanalysis models. We obtained ECMWF results from a UCAR website (http://dss.ucar.edu/pub/ec-reanalysis.htm) instead of the official website (www.ecmwf.int). Refer to the websites for descriptions of the reanalysis models. The table lists information about data sets currently in the SBH website.

	NCEP/NCAR	ECMWF
Time-span	Jan.1979-Dec.2001	Jan.1979-Dec.1993
Resolution(degrees)	2	2.5
soil layers	2	4
layer thickness(cm)	10, 190	7, 21, 72, 189
sampling	daily	6 hours
Monthly Means	1993-1998	
1 x 1 degree		
NCEP Snow and soil		
LOD and PM daily exc.	1948-2001	
Daily grid water load	1948-2001	
NetCDF format		

In addition to gridded values we have time series of storage of water in individual artificial reservoirs, provided by Ben Chao.

3 New Data Sets and New Directions in Land Surface and Climate Models

Although there is at present no global land surface model operating along the lines of the atmospheric models (NCEP, ECMWF, etc) there are candidate data sets for additions to the web site:

University of Delaware gridded storage variations: These are monthly mean variations in water storage estimated for a global grid using a simple water balance model. Time series for the period 1950-99 are available. We are currently processing this dataset and will convert it into global 1 x 1 degree gridded format (in NetCDF and ASCII) and have them available through the SBH website.

ECMWF Reanalysis 1957-2001. This recently completed reanalysis should provide gridded time series of water storage variation suitable for geodetic purposes. We intend to get these when they become available through NCAR.

Milly-Shmakin 20 year time series (see below).

Goddard Land Surface Model time series (see below)

3.1 The Goddard Space Flight Center Land Surface Model

The Goddard Space Flight Center Land Surface Model (LSM) is currently being developed by Rodell and others. The model is a gridded data assimilating computation for the entire globe. We plan to summarize its status at the workshop.

The Milly-Shmakin Model: at the Geophysical Fluid Dynamics Laboratory (J. of Hydrometeorology, v. 3, p. 283, June 2002). Milly and Shmakin have developed an operating global land surface model that can be forced by global fields of precipitation and long wavelength radiation. With ground water storage, and a river runoff scheme, it provides the land surface elements suitable for a global coupled model. It has been tested with a standard data set, the ISLSCP set which summarizes calendar years 1987-88. Because available forcing data sets are usually monthly means, some adjustment to daily or subdaily forcing is required. The model has the potential to be forced by fields from data assimilating models like ECMWF or NCEP, but we do not know that this has been done. One version of the Milli-Shmakin model results was employed by van Dam and others (Crustal Displacements due to continental water loading, Geophysical Research Letters, 2000) to obtain global gridded (1 x 1 degree) load time series used to estimate crustal motion at GPS sites. Van Dam report in their paper that time series for the period 1979-1998 are available. This data set would be a reasonable addition to the SBH website archive. However, like the ECMWF and NCEP time series, there is no measure of the probable error in the estimates.

The NCAR CCSM: At the National Center for Atmospheric Research (NCAR) a fully coupled model has been constructed that conserves water within the global system via exchanges with atmosphere and oceans through a flux-coupler. The model is free-running, and does not simulate variations for specific calendar dates or periods.

3.2 Remote Sensing of the Hydrologic Cycle

Remote sensing of the hydrologic cycle, such as monitoring levels of surface water (rivers and lakes) offers the future possibility for driving data assimilating land-surface models. For the next few years this will be a research area, not expected to provide geodetically useful global measures of the water cycle The NASA River & Wetland Processes Working Group headed by Doug Alsdorf of UCLA is studying prospects for monitoring hydrology from space. The most promising technologies are active radar and lidar methods that measure inundation area, water heights, and changes. Radar altimetry has an along-track spatial resolution of km and absolute height accuracy over rivers and wetlands of cm. Lidar altimeters, such as the GLAS instrument (Geoscience Laser Altimeter System) onboard the upcoming ICESat mission (Ice, Cloud and land Elevation Satellite), are capable of ~70 m along-track spacing and cm-scale height measurements in clear weather. SAR antennae with wavelengths capable of canopy penetration, e.g., L-band, can image inundation area with decimeter scale spatial resolution whereas passive microwave radars, e.g., SSM/I (Special Sensor Microwave/Imager), utilize differences in polarized brightness temperatures to estimate flooded areas with kilometer scale spatial resolution.Radar altimeters, specifically designed for oceanic applications, may lack the along track resolution necessary to define smaller rivers and wetlands with important discharge. There have been promising studies of radar altimetry over lakes and rivers, showing that reprocessing of radar altimetry data may produce useful measures of the time variable level of rivers and lakes on at least a regional basis. It may be possible to significantly improve spatial resolution of radar altimeters via a SAR-like processing mode, and there are satellite proposals (none yet funded) that show the feasibility of this idea. Laser altimeters are limited by cloud cover.

3.3 Estimation of Loads from geodetic data.

Redistribution of mass on a global scale will generally have a spherical harmonic degree 1 component. Recently, Blewitt and others (Science, 2001, v. 294, 2342-2345) have shown that there are now sufficiently well-distributed continuous GPS stations to observe the degree 1 deformation of the earth. This deformation may be dominated by redistribution of water mass, at least on a seasonal basis. This observation raises the possibility of using the global network of GPS stations to constrain features of surface water load variations.

The other important geodetic observation soon available is from GRACE. There is certain to be interest in using the SBH website archives to compare with GRACE results, but ultimately, GRACE may prove to be a better estimator of global surface water load variability than any current numerical models.

3.4 Studies at Goddard Space Flight Center

Ben Chao and Andy Au plan a presentation on their recent work.

4 Discussion

For the moment, the big challenge is to locate available global gridded data sets and put them on the website archive. In the near future, collaboration with groups constructing global land surface data assimilating models should yield geodetically useful time series. Other issues that may be important: data formats for reporting gridded results; tracking changes in total water volume on the land surface, for the purpose of making consistent estimates when combined with ocean and atmosphere results, useful formats for global integrals (earth rotation excitation functions) and other global measures, such as Stokes Coefficients.