A Strategy (Vision) for Integrated Water Cycle Observations from Space

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“Transforming observations into knowledge and decisions”
The need for enhanced observations

World programs in hydrology and water are looking to space-based observations to provide needed observations of sufficient accuracy for water resource applications.

What are the observation and accuracy needs for global water and energy cycle research, and for global climate change research?
    -- continental to global scales to augment climate networks.

What are the accuracy needs for water management—flood prediction, reservoir operation, agriculture and drought assessment?
    -- regional problems and real-time data needs to augment operational networks.

How can satellite-based observations be combined with in-situ data, or other remotely sensed data, to provide enhanced information?
-- Observe Globally

-- Initially Close Energy/Water Budgets at Continental-Scale

-- Couple (land/hydro - atmos) at the Mesoscale

-- Model & Predict Globally w / NWP
  [upgrade land sfc/hydro & cloud physics]

-- Apply Locally to Water Resources
The end-to-end nature of data provision, the feedback loop from user requirements, and the role of GEOSS
...for major floods, a critical problem

Extreme floods
1999

Location Map, 1999 Extreme Floods

(From Dartmouth Flood Observatory, Dartmouth University)
Digging for Water, Hambantota Dec 2001
Source: Dept of Social Service
…to help in water management

- 700% increase in water held by river systems
- Several years of residence time change in many basins
- Tripling of river runoff travel times globally (from 20 up to 60 days)
- Substantial impact on aquatic biodiversity
- Interception of 30% of continental TSS flux

…current capability for space-borne observations

Current missions have a capacity to monitor water cycle.

Poor or missing global observations: River/lake monitoring, Precipitation, Soil Moisture, Snow

Clouds

Soil Moisture?

Radiation (CERES)
Snow (AMSR-E)
Vegetation (MODIS)
Soil moisture (AMSR-E)

Liquid precipitation
Observations at high spatial and temporal scales for fast water cycle variables and processes:

- Surface temperature
- Precipitation
- Surface radiation
- Water vapor and clouds

Evapotranspiration from space
Simultaneous observations and retrievals of related water cycle variables, like precipitation and surface soil moisture.
Integrating observations to establish a more complete system description.

August 18, 2004

<table>
<thead>
<tr>
<th>Radar-Gauge Precipitation</th>
<th>TRMM/TMI/SMM/I Precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>20</strong></td>
<td><strong>50</strong></td>
</tr>
</tbody>
</table>

NASA establishes retrieval (and science) teams based on water cycle variables, leading to inconsistencies across products.
What is integration?

- **Integrating observations**, to establish a more complete system description.

- **Integrating model components**, to build an earth modeling system.

- **Integrating research results**, to establish end-user solutions.

- **Data Integration**, to allow for spatial and temporal rectification and to allow for the intercomparison and quality evaluation of disparate model and observation data;

- **Data-Model Integration**, to constrain data and its errors by physical processes using four dimensional data assimilation techniques.

- **Solution Integration**, to develop water cycle solutions by integrating observations into applications.
…a strategy for integrated observations

Water Cycle
Think Tank

Hydrology Laboratory
Integrated water cycle strategy requires a partnership among
- Space scientists (sensors and antenna development)
- Computer scientists (in data integration with ground sensors and models)
- Communication scientists (in merging satellite data with data from embedded networks, and in distributing products ‘seamlessly’ to society, and
- Hydrologists (water cycle scientists).
The strategy needs to develop

- Technology improvements in sensors and antenna
- New approaches for water cycle variable retrievals, building off of new sensor measurements and algorithms, and
- New approaches for assimilating observations into high resolution models to generate new water cycle products, and using these products for better management.
New technology for observations from geostationary orbits

For the 'fast branch' of the water and energy cycle involving processes whose dynamics vary significantly within a day, and at resolutions from $O(10 \text{ - } 100) \text{ m}$.

-- tracking storms and resulting precipitation
-- evolution of diurnal cycles in evapotranspiration

This suggests multi-spectral VIS, IR, MW from geostationary orbit at significantly higher resolutions than being obtained today.
Technology for GEO

Large (inflatable) antennae

Formation flying, Synthesized antennae
Control of Spacecraft Swarms Using Coulomb Forces

Lyon B. King
Gordon G. Parker
Jer-Hong Chong
Satwik Deshmukh
Department of Mechanical Engineering

This research made possible through funding from the NASA Institute for Advanced Concepts
The elements for an integrated environmental system from ground-to-sky that includes
- advanced embedded sensor webs,
- high-performance prediction systems,
- decision support tools
Distributed Information-System-in-the-Sky

- Interoperating Measurement Systems (Air / Spacecraft / In-situ) with modeling systems
- Flexible Measurement Network Architecture
- Direct Distribution of Derived Products
- Network Computing-in-the-Sky

Commercial Communication Network

Ka Crosslink

Optical Crosslink

In-situ User PC Based GS

Comm Gateway

Digital Library

Metadata Warehouse

Active Optical

Passive Optical

Ka

Ka

Ka

Ka

Ka
...elements of a strategy: data integration

<table>
<thead>
<tr>
<th>Resolution</th>
<th>1/4 deg</th>
<th>5 km</th>
<th>1 km</th>
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</thead>
<tbody>
<tr>
<td>Land Grid Points</td>
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<td>5.73E+06</td>
<td>1.44E+08</td>
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<tr>
<td>Disk Space/Day (Gb)</td>
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<td>28</td>
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<tr>
<td>Memory (Gb)</td>
<td>3</td>
<td>62</td>
<td>1561</td>
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</tbody>
</table>
**Today:**

- Large space-based Observatories
- Single sensor retrievals
- Spatial/temporal inconsistency
- Parameter-driven requirements

**Tomorrow:**

- Integrated environmental information system
- Smart Sensor Web
- Adaptive Resource Manager
- Multiple sensor retrievals
- Spatial/temporal consistency
- Integrated cross-sensor calibration
- System-driven requirements
- Reconfigurable ground and space information systems
1. **Advanced technology concepts** related to the water cycle need to be supported and encouraged. Too many are related to Space Science and too few for Earth Science.
2. Advanced modeling and data assimilation, especially the merging of space-borne and in-situ observations with models, needs to be supported and encouraged. The NASA Land Information System (LIS) is a start, but additional support to more research groups is needed to take it to the next level.
3. Integrated environmental information system that integrates satellites, models, grid computing and decision support tools for critical applications needs to be developed and tested. This requires a dedication to supporting applications of remotely sensed products.
Our perspective carries little weight in implementing a strategy for integrated water cycle observations.

But clear paths are evident to make scientific advances in water cycle research, and progress in advancing space observations for applications.

Thank you for your attention