Remote Sensing and *in situ* terrestrial water cycle observation capabilities

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*Report of* Committee on Earth Observation Satellites
◆ Priority research areas in 2004 for CEOS
◆ Concerning terrestrial water cycle and water resources
◆ Case Studies - Remote Sensing Applications
◆ Conclusions
Integrated Global Observing Strategy (IGOS)

IGOS Themes

- Water Cycle Theme
- Atmospheric Chemistry Theme
- Ocean Theme
- Global Carbon Theme
- Geohazards Theme
- Coral Reef Sub-Theme

Graz, Austria, 13-16 September 2004
The priority areas of the Committee in 2004

- Global change (i.e. global environmental monitoring and protection),
- Disaster management
- Water resource management
- Data utilization and popularization
- Education and training
WATER: A GIFT TO MANKIND

- **IT IS ESSENTIAL FOR LIFE:** WHEN WATER WAS NOT AVAILABLE, NOMADIC PEOPLE MOVED TO ANOTHER LOCATION.

- **IT IS ESSENTIAL FOR PROSPERITY:** DAMS AND RESERVOIRS THAT COULD STABILIZE THE MONTH TO MONTH AND YEAR TO YEAR VARIABILITY IN SUPPLY.

- **IT IS ESSENTIAL FOR HEALTH:** NOT ALL WATER IS SAFE OR USEABLE.
The Earth Observing System -- systematic measurement of interactions among land, oceans, atmosphere, ice & life

Exploratory missions to probe key Earth system processes globally for the first time

SATELLITES COULD PROVIDE A NEW GLOBAL PERSPECTIVE ON THE WATER CYCLE

*FY02 launch (+ SAGE III)
^FY03 launch (+SeaWinds)
Concerning terrestrial water cycle and water resources

Hydrological cycle.

Units are thousand cubic km for storage and thousand cubic km/year for exchanges.
Estimation of Water Cycle Globally

- Precipitation: 9,000 km³
- Evaporation: 9,000 km³
- Glaciers
- Underground runoff: 2200 km³
- Juvenile water inflow
- Area of closed regions runoff: 30,000 km³
- Area of exorheic runoff: 119,000 km³
- Water expenses for hydration
- River runoff: 42,600 km³
- Precipitation on surface ocean: 458,000 km³
- Precipitation onto land surface: 110,000 km³
- Evaporation from land: 65,200 km³
- Evaporation from ocean: 502,800 km³
- Water vapour into the atmosphere
- Water vapour in atmosphere
- Ocean area: 361,000 km³
Concerning terrestrial water cycle and water resources

Theory of water cycle and water balance is one of the basic scientific issues for the studies on hydrology and water resources sciences

- Simulating the mechanism of water cycle dynamics
- maintaining of water resources renewable ability
- multi-dimension critical adjustment and control
- revealing the relationship between the functions of river system and reformation structures of water management
- developing the analyzing model for water resources evolvement
- presenting adjustment and control measures for the sustainable development of the water resources in the terrestrial regions
The frame of water cycle research based on RS/GIS

Remote Sensing data
- Surface temperature, Soil moisture, NDVI, NPP, Albedo, etc.
- T, u, v, q, (Cloud, Precipitation)
- Radiation and cloud information
- Hydrologic Model
  - Atmospheric water vapor divergence model
  - Dynamic Model

GIS Mesh-database
- Topography
- Land use and land cover
- DEM

Sensible heat transport/Radiation transport/Latent heat transport
- Vegetation transpiration
- Penetration
- Surface water flow
- Root expansion
- Subsurface water flow
- Ground Surface Model

Atmosphere Model
- Solar
Concerning terrestrial water cycle and water resources

towards an integrated water cycle observational system that integrates data from different sources (e.g., satellite systems, in-situ networks, field experiments, new data platforms) together with emerging data assimilation and modeling capabilities
Case Studies- Remote Sensing Applications

Yellow river basin covers a vast area. Now it is facing a harsh situation mixing with the problems in water resources shortage, water flood intensification, and the deterioration of the ecology and environment in the basin.
Case Studies- Remote Sensing Applications
Case Studies- Remote Sensing Applications
Water cycle at different scale
Case Studies - Remote Sensing Applications
Water cycle at different scale

Study area

Land cover

Sampling design

Grid data

Scaling up
Case Studies - Remote Sensing Applications

A typical test site

In large scale model: classification

Agricultural field

Road

Village

Forest

Bare soil
Case Studies - Remote Sensing Applications

In small scale model: 3D simulation needed
Case Studies - Remote Sensing Applications

Up-scaling

- Point Measurements
- Calibration
- High-resolution images (ETM+, IKONOS, etc)
- Aggregation

MODIS, NOAA Products
Case Studies- Remote Sensing Applications

**latent heat flux Model**

\[ LE = Rn - G - H \]

Instantaneous evaporation rate (i.e. latent heat flux \( LE \)) can be estimated as the residual term of energy balance formulation.

- \( Rn \): net radiation
- \( G \): soil heat flux
- \( H \): sensible heat flux

**Rn Model**

\[ Rn = RL + Rs \]

RL: long wave radiation
Rs: short wave radiation

**Sensible heat flux Model**

\[ H = \frac{\rho \, Cp(T0-Ta)/raa}{raa+r} \]

- \( T0 \): aerodynamic temperature
- \( Ta \): air temperature at reference height
- \( Tr \): radiometric surface temperature
The procedural sketch of ET estimated by remote sensed data

- Land cover fraction
- Land surface reflectance
- VI
- Albedo
- LST
- SW Rad
- Land cover classification
- Net Radiation
- Residual aerodynamic resistance
- Aerodynamic resistance
- Soil heat flux
- Sensible heat flux

Case Studies - Remote Sensing Applications

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Case Studies - Remote Sensing Applications

Evapotranspiration

NDVI 5/19/2002

Land cover

LAI 5/19/2002

Albedo 5/19/2002

Latent Heat Flux

LST

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Observing System of the Future

- Advanced Sensors
- Information Synthesis
- Access to Knowledge

- Sensorweb
  - Commercial
  - International

User Community
Conclusions

- Observing the Global Water Cycle is not possible without observations from satellites

- Satellite observations are limited as well, but are well-suited to partner with 4-dimensional data assimilation

- Novel approaches to data integration together with system approaches to satellite observations will be needed to adequately observe the regional water cycle

- More remote sensing data could be expect in the near future