

# Water and Energy Cycle contributions for CEOP & IGWCO

**NASA Science Mission  
Directorate**



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# Water and Energy Cycle



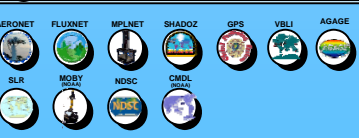
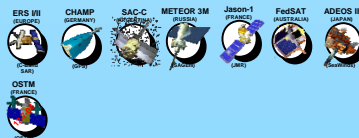
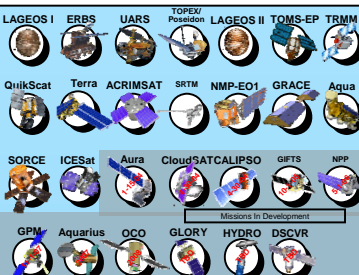


# Earth Science System Components

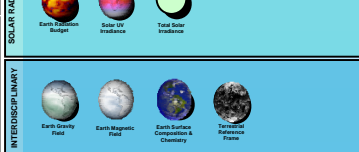
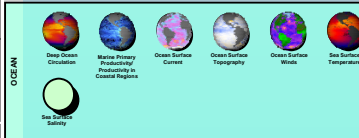
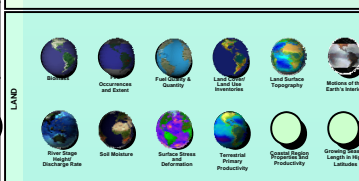
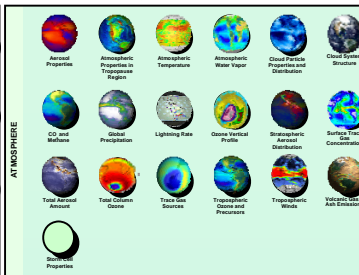


DRAFT-Working Document

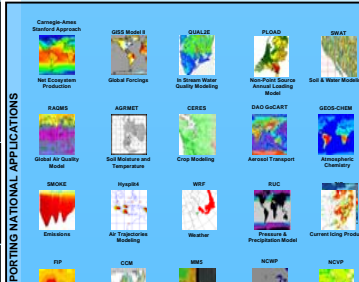
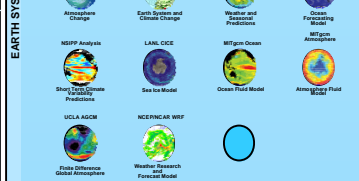
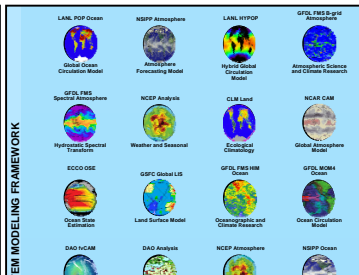
## Earth Observation Sources



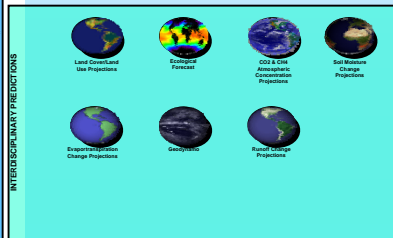
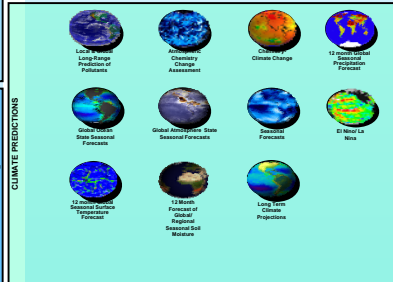
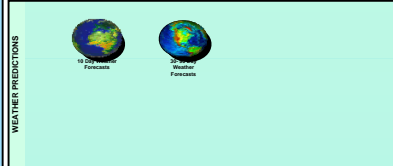
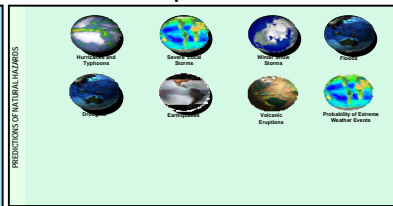
## Geophysical Parameters



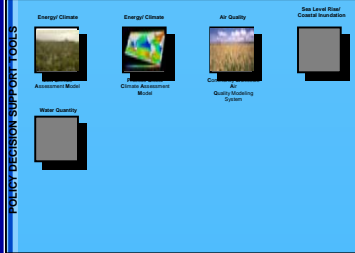
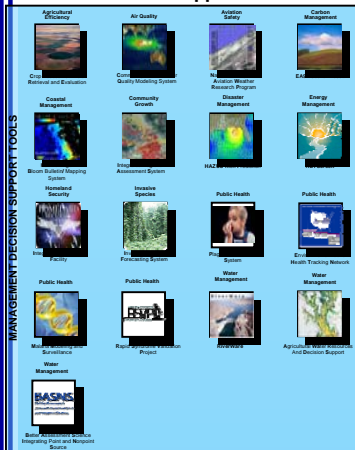
## Models



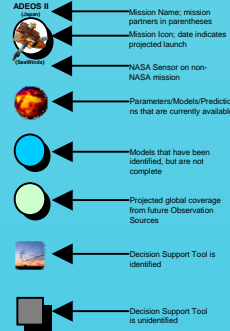
## Model Outputs / Predictions



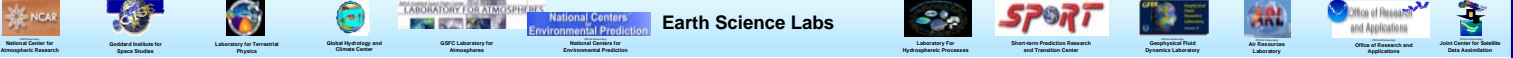
## Decision Support Tools



### Chart Legend



## Earth Science Labs



## Data Distribution and Handling Systems



## Technology



## Education



## Domestic Partners & Programs



## International Partners & Programs



- quantify and elucidate mechanisms of the mean state
- variability of the water cycle, e.g. quantification of precipitation, evaporation, runoff and water storages

- **Urbanization and precipitation/water**
- **Urbanization enabling more reliable short-**
- **term forecasts and accurate role of**
- **climate predictions**

**Global precipitation measurements (GPM)**

## Global estimates of ocean evaporation (Aquarius) and land evaporation –

## Vertical profiles of cloud structure and properties (Cloudsat/Calipso)

**Detection of gravity perturbations due to water distribution (GRACE)**

## EOS/in-situ observations of land surface state variables

Improved latent heating profiles and convective parameterizations within weather and climate models

- Reservoirs and tropical rainfall well quantified
- Difficulty balancing the water budget on any scale
- Inability to observe and predict precipitation globally

## Systematic measurements of precipitation, SST, land cover & snow

## Knowledge Base

NASA

## Partnership

Unfunded

 = field campaign  
T = Technology development required

2004

## 2006

**IPCC  
Report 2008**

2010

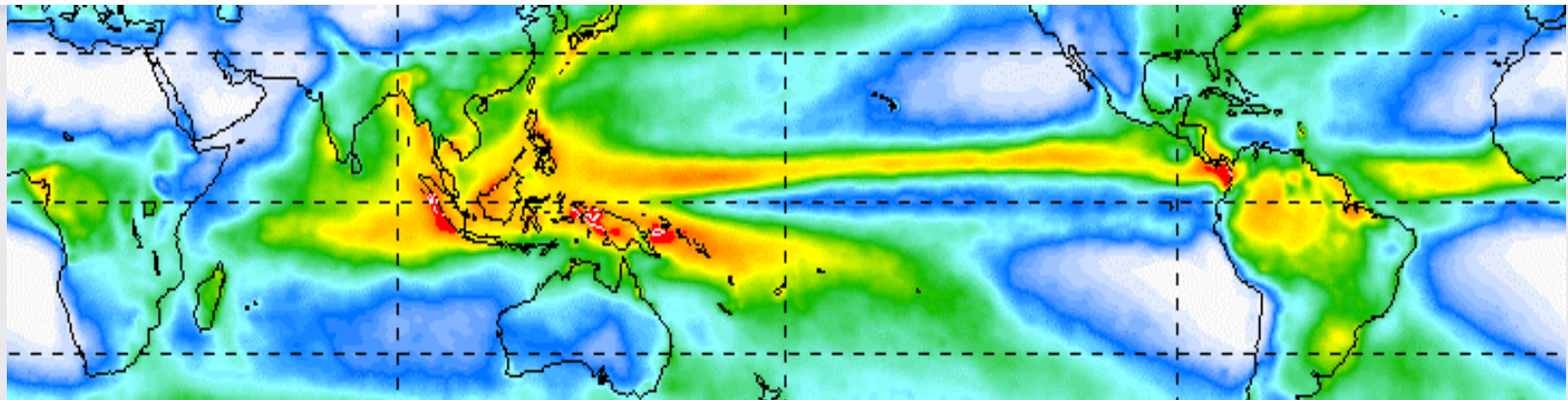
IPCC 2012  
Report

2014

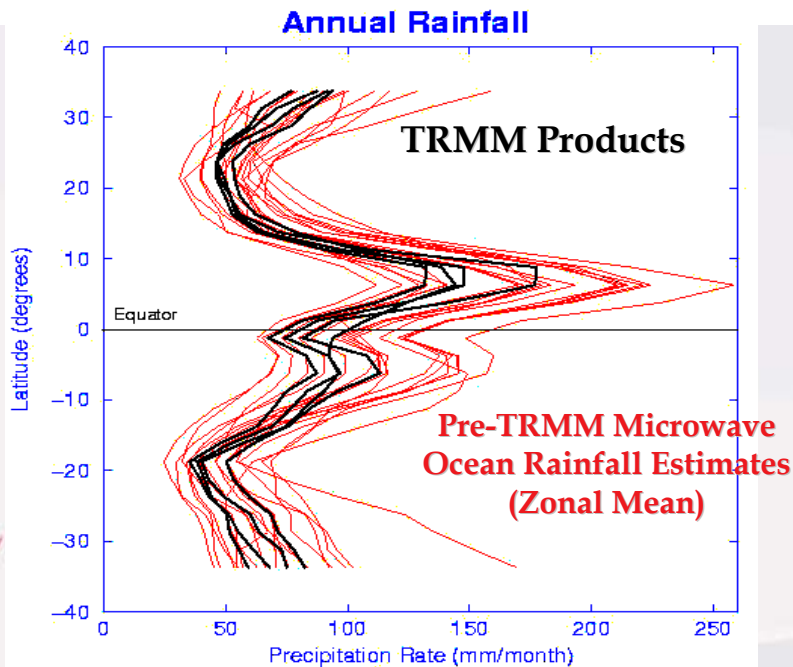
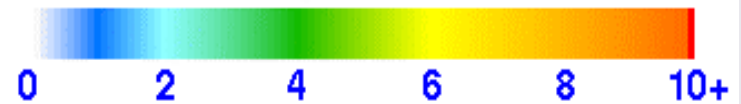
## 2016

**GOAL: Models capable of predicting the water cycle, including floods and droughts, down to 10s of kms**

# Tropical Rainfall Measuring Mission



TRMM Average Precip 1998-2003 (mm/d)



**Improved Ocean Rainfall Estimation due to algorithm improvement from pre-TRMM (e.g. SSM/I) era**

**Uncertainties in Tropical Rainfall Estimates Reduced from ~50% to ~25% using TRMM**

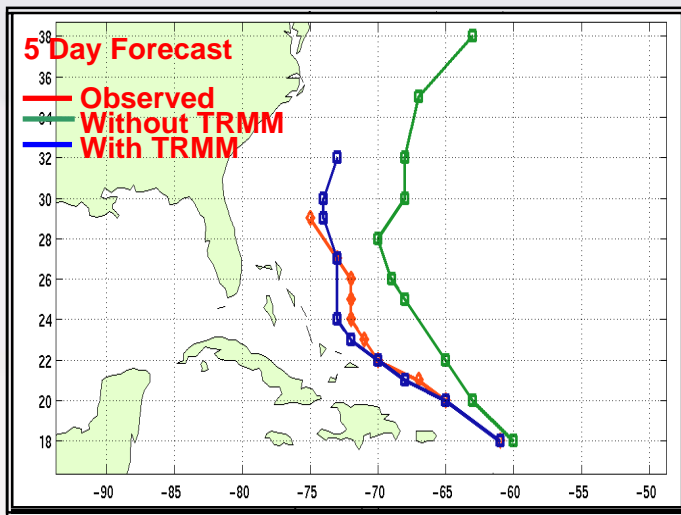




# Improved Hurricane Track Forecasts w/TRMM

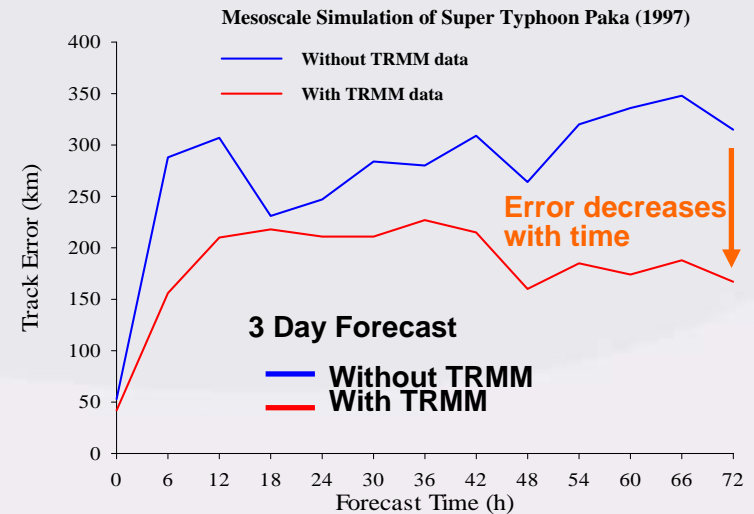
Assimilation of TRMM rainfall location, intensity and vertical structure into hurricane forecast models leads to improvements in forecasts of future position

## Hurricane Bonnie, Atlantic, Aug 1998



Dr. A. Hou, NASA DAO

## Typhoon Paka, Pacific, Dec 1997



Dr. X. Pu, NASA GSFC

Reduced track errors can save money (\$600,000 per mile of coast evacuated) and save lives by more precise prediction of eye location at landfall



# GPM Reference Concept

**OBJECTIVE:** *Provide Enough Sampling to Reduce Uncertainty in Short-term Rainfall Accumulations. Extend Scientific and Societal Applications.*

**OBJECTIVE:** *Understand the Horizontal and Vertical Structure of Rainfall and Its Microphysical Element. Provide Training for Constellation Radiometers.*

## Core Satellite

- Dual Frequency Radar
- Multi-frequency Radiometer
- H2-A Launch
- TRMM-like Spacecraft
- Non-Sun Synchronous Orbit
- ~65° Inclination
- ~400 - 500 km Altitude
- ~4 km Horizontal Resolution (Maximum)
- 250 m Vertical Resolution

## Precipitation Validation Sites

- Global Ground Based Rain Measurement



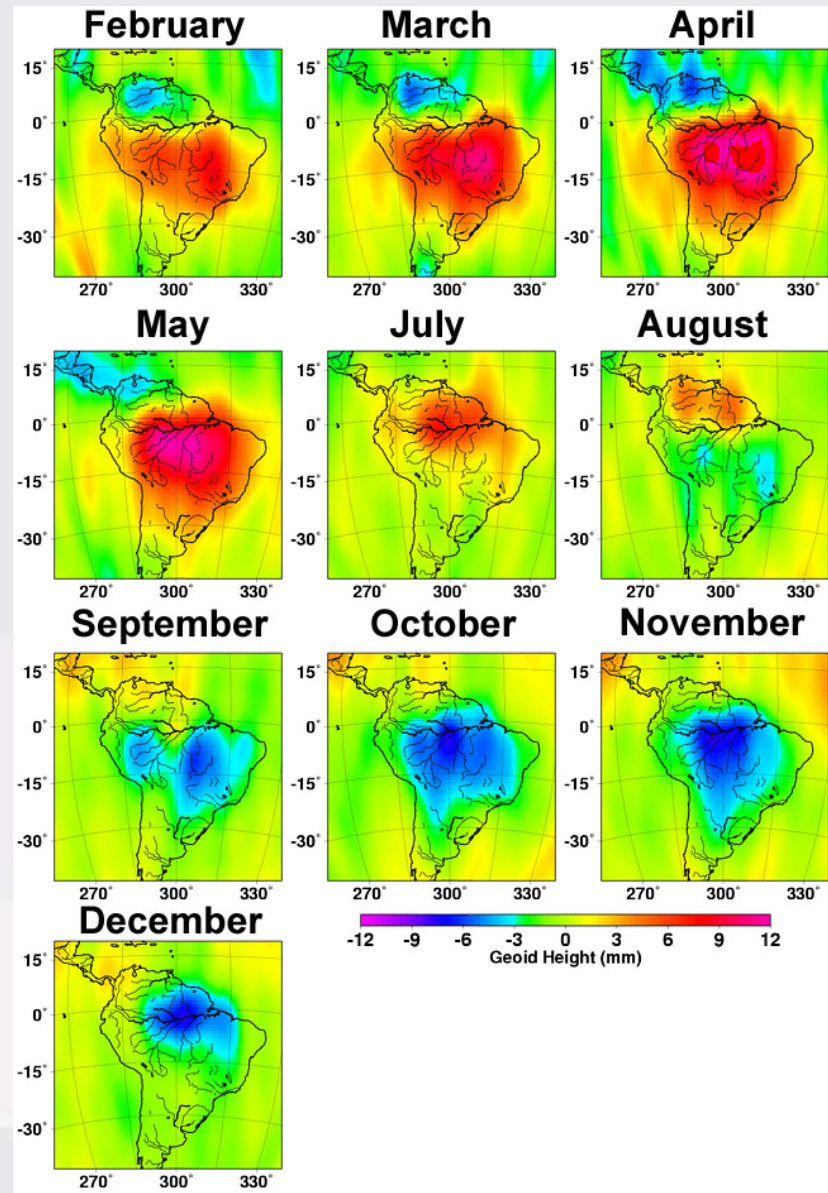
## Constellation Satellites

- Multiple Satellites with Microwave Radiometers
- Aggregate Revisit Time, 3 Hour goal
- Sun-Synchronous Polar Orbits
- ~600 km Altitude

## Global Precipitation Processing Center

- Capable of Producing Global Precip Data Products as Defined by GPM Partners

Results published *Science* show monthly changes in the distribution of water and ice masses could be estimated by measuring changes in Earth's gravity field. The GRACE data measured the weight of up to 10 centimeters (four inches) of groundwater accumulations from heavy tropical rains, particularly in the Amazon basin and Southeast Asia. Smaller signals caused by changes in ocean circulation were also visible.

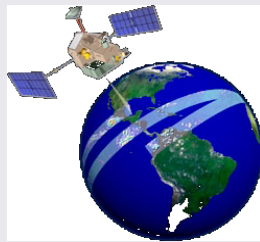




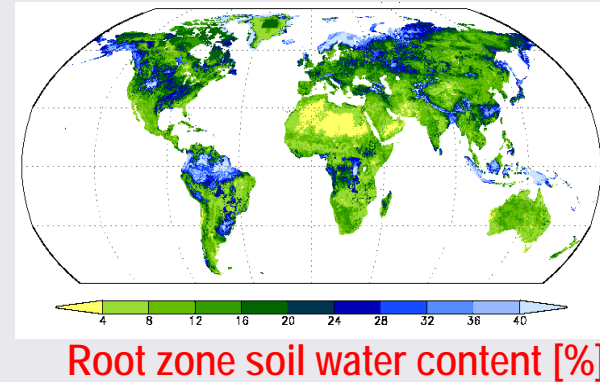
# Land Data Assimilation System (LDAS)

**GOAL:** Produce optimal output fields of land surface states and fluxes.

**APPROACH:** Parameterize, force, and constrain multiple, sophisticated land surface models with data from advanced ground and space-based observing systems.



**SIGNIFICANCE:** Results will be used for initialization of weather and climate prediction models and application investigations.



## FORCING DATA

- Precipitation
- Temperature
- Radiation
- Other variables

## PARAMETERS

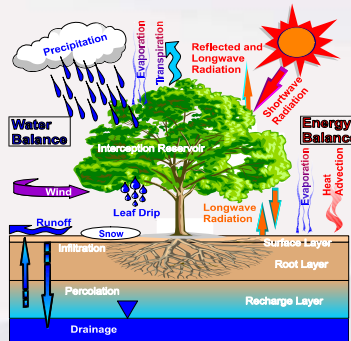
- Vegetation Types
- Soil Classes
- Elevation
- Other data



Assimilation



Land Surface Models



## Output

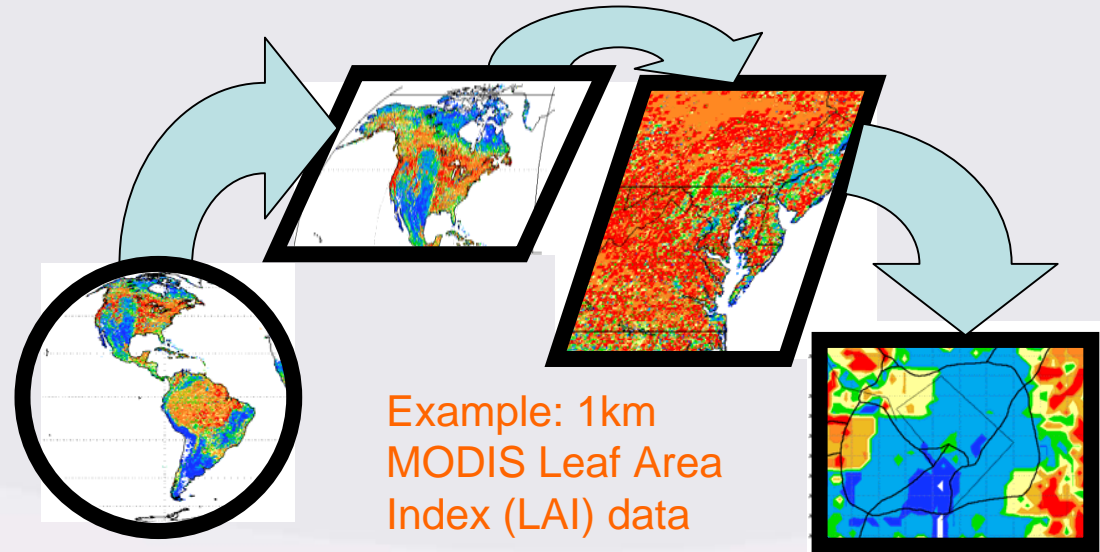
- Soil Moisture
- Evapotranspiration
- Energy fluxes
- River runoff
- Snowpack characteristics

# High Resolution Land Information System



**Objective:** A high performance, high resolution (1km), near-real-time (<1day/day execution time) global land modeling and assimilation system capable of demonstrating the impact of NASA observations on global water and energy cycles.

**Applications:** Weather and climate modeling, Flood and water resources forecasting, Precision agriculture, Mobility assessment, etc.

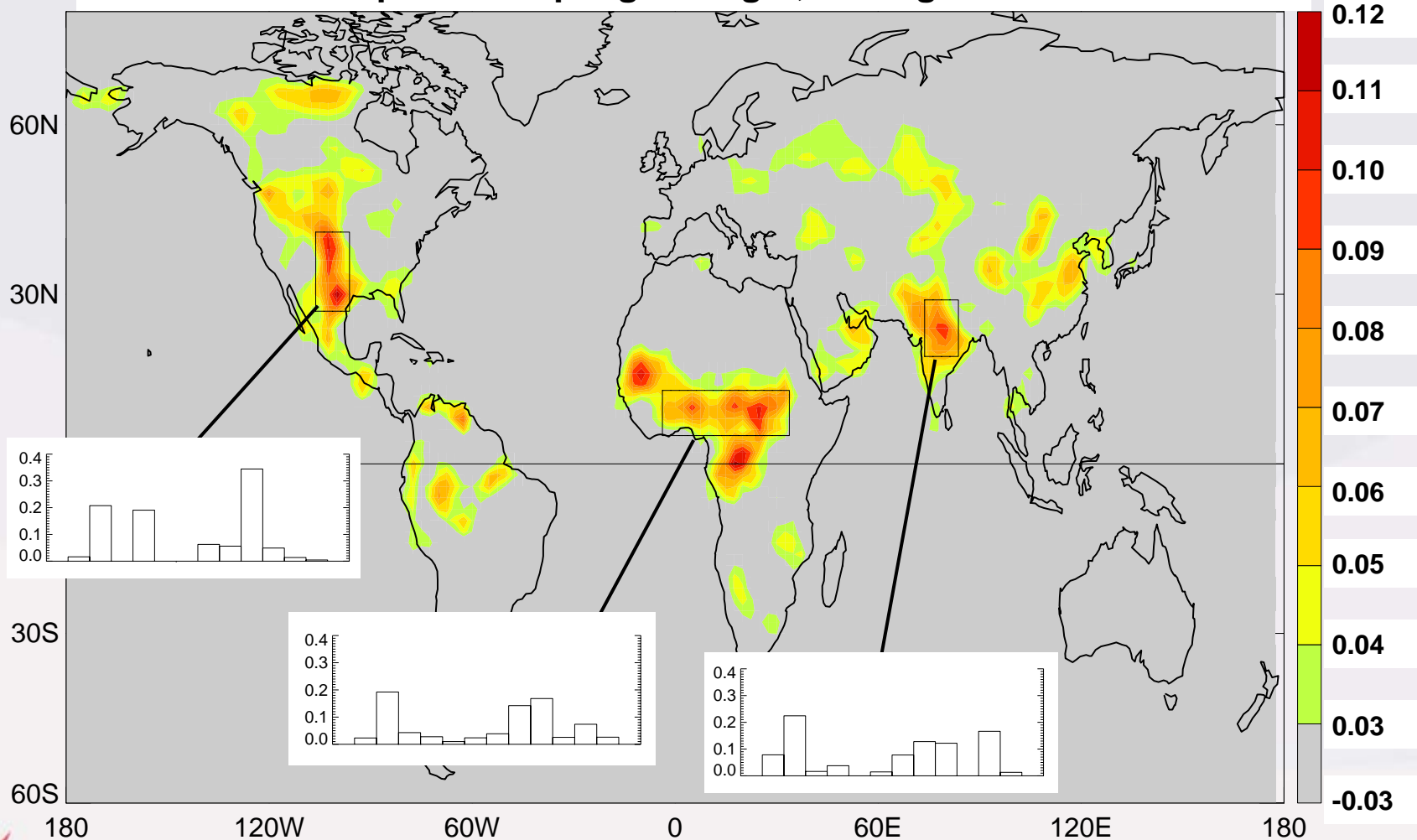


	GLDAS		LIS
Resolution	1/4 deg	5 km	1 km
Land Grid Points	2.43E+05	5.73E+06	1.44E+08
Disk Space/Day (Gb)	1	28	694
Memory (Gb)	3	62	1561

Milestone achieved: LIS can now run approx. 3 days/day

# Soil Moisture Hot Spots

## JJA Land-Atmosphere Coupling Strength, Averaged Across AGCMs

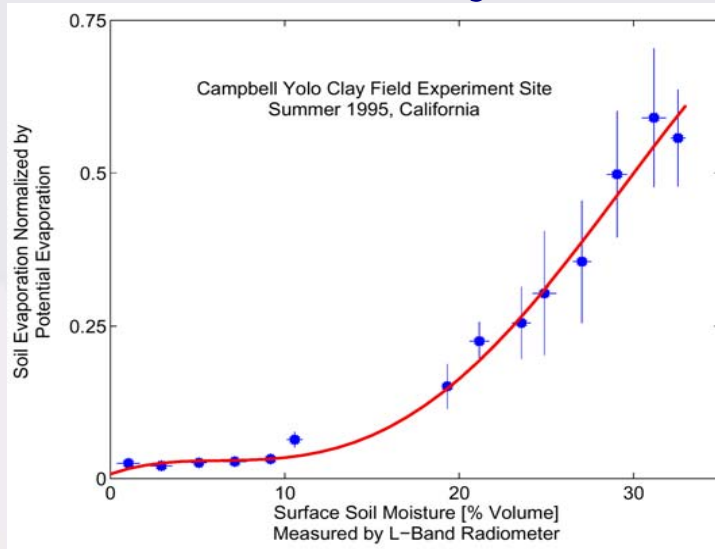




# Soil Moisture - HYDROS

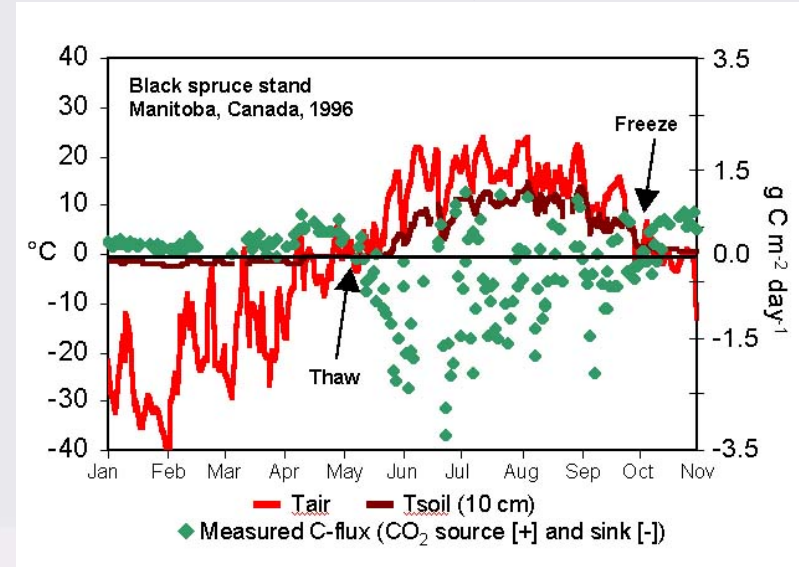
Soil Moisture a critical omission in observations suite (NASA, NOAA, USDA)

## Water Cycle



*Soil Moisture Strongly Influences Evaporation Rate and thus the Water and Energy Exchanges between Land & Atm.*

## Carbon Cycle



*Freeze/Thaw Condition Influences Growing Season Length and thus the Carbon Balance.*

Addresses Priority Soil Moisture Data Requirements Across Agencies

**NASA:** Monitor Process - Global Water, Energy, and Carbon Cycles

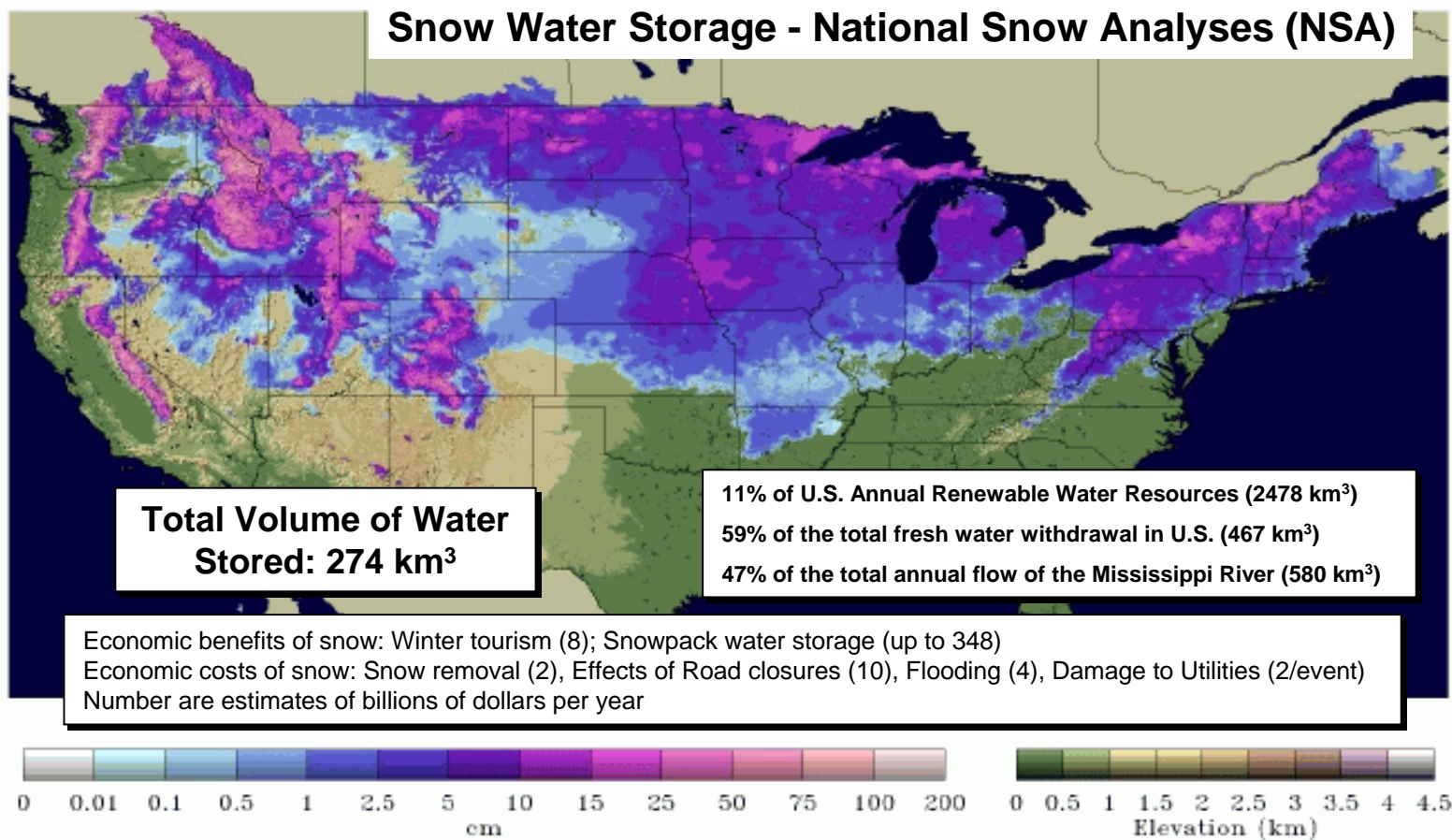
**NOAA:** Improve Weather and Climate Predictions: Flood and Drought

**DoD:** Applications in All Three Services (e.g. Terrain trafficability, Fog)

**USDA:** Agricultural Management, Drought Impact Mitigation



# Snow – Liquid Water Equivalent



Preliminary information from “The Value of Snow and Snow Information Services” – Office of the chief economist (NOAA, 2004)

“..improved snow information and services have potential benefits greater than \$1.3 billion annually.” “...investments that make only modest improvements in snow information will have substantial economic payoffs.”

# Field Experiment

## Cold Land Processes Experiment (CLPX) 2002-2003

### Nested Study Areas

1 Local-Scale  
Observation Site (LSOS)  
(1 ha)

9 Intensive Study  
Areas (ISA)  
(1-km x 1-km)

3 Meso-cell Study  
Areas (MSA)  
(25-km x 25-km)

1 Small-Regional  
Study Area  
(1.5° x 2.5°)

1 Large-Regional  
Study Area  
(3.5° x 4.5°)

**Multi-scale, multi-sensor approach** to build comprehensive data set of satellite and airborne remotely sensed and in situ observations needed to meet NASA Earth Science objectives.

Moderate Snow Packs (~1 m)  
in the Fraser MSA



Shallow Snow Packs (~20 cm)  
in the North Park MSA



Deep Snow Packs (~2 m)  
in the Rabbit Ears MSA

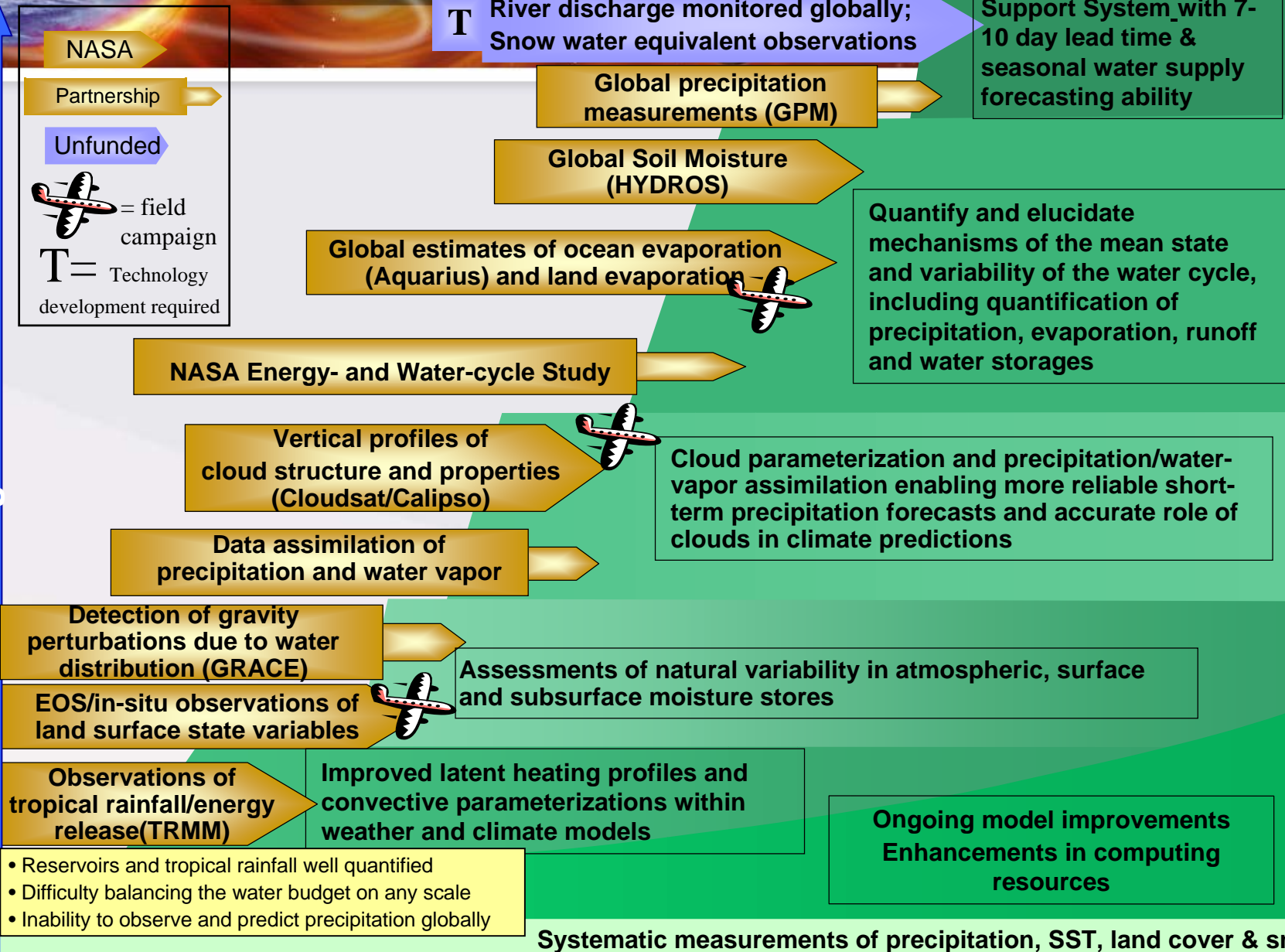


The nested study areas in Colorado, USA provide a comprehensive range of snow and frozen soil characteristics.



# Water & Energy Cycle

Knowledge Base



**GOAL: Models capable of predicting the water cycle, including floods and droughts, down to 10s of kms**

2004

2006

IPCC Report  
2008

2010

IPCC Report  
2012

2014

2016



## Focus Area Linkages

- C** = Carbon
- V** = Climate variability
- A** = Atmospheric composition
- W** = Weather
- S** = Surface & interior
- T** = Technology development
- +** = Field campaign
- = Funded **■** = Unfunded

## Exploiting current capabilities and preparing for the future

### Phase 1 Deliverables:

- First coordinated global W&E description
- Current prediction system evaluation
- Identify required system improvements

### Application

- Selected demonstrations
- Climatology baselines **V**
- Establish requirements **T**

### Prediction

- Land-cloud model **CVAW+**
- Multi-platform analysis **T** Physics-based modeling **T**
- New climate datasets **V** OSSEs **+**

### Observation

- Advanced Analysis **T**
- TRMM TERRA AQUA GRACE ICESAT **SCWAV**
- AURA CloudSAT CALIPSO **VAW**

Systematic observations of water

Focus Area Challenge:  
Document and enable improved, observation-based water and energy cycle consequence predictions (floods and droughts) of earth system variability and change

## Address deficiencies and build prediction system

### Phase 2 Deliverables:

- Fix model problems with new observations
- New measurement approaches developed
- End-to-end prediction system developed

- Observations used in planning
- Test prediction of extremes **WV**
- Develop application metrics

- Enhanced RT models **TVW+**
- Improved physics **CVW+** Model convergence
- Super-parameterization **T**
- Multi-platform analysis **T**

- Advanced multi-platform retrievals **T+**
- Experimental W&E observation system **T+**
- First Coordinated W&E Obs **WVC** Cold seasons **T+**
- GPM AQUARIUS HYDROS **T** Surface water **T+**

and energy cycle including national and international partners

## Address the ESE vision; deliver and evaluate system

### Phase 3 Deliverables:

- Dataset gaps filled and extended
- Intensive prediction system testing
- Prediction system delivery

### APPLICATION:

- Improved water & energy cycle forecasts for use in decision support systems

- Predict consequences of climate change
- Global hydrologic warning system **T**
- Demonstrate useful predictions **TWV**

### ANALYSIS & PREDICTION:

- Understand variability in stores and fluxes
- Accurate cloud prediction
- Improve latent heating & convection models

- Reprocess combined observation record **V**
- Demonstrate prediction capacity **WV**
- Full end-to-end system test **T**

- Comprehensive W&E cycle data management and retrieval system **T+**
- Coordinated W & E system **T**

### OBSERVATION:

- Quantify mean state, variability, and extremes of the water & energy cycles
- Flux, transport, and storage rate quantification

2004

IPCC Report

2006

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2016

IPCC Report

2018

Knowledge Base