NASA Water Remote Sensing and Models are Part of the Solution

NASA Panel in order of Presentation:
David Toll, NASA/GSFC
Vanessa Escobar, NASA/GSFC
Ted Engman, NASA Consultant
Rick Lawford, NASA Consultant

Panel Contribution from:
N Harshadeep/World Bank
John Pasch/USAID
Amin Shaban/CNRS

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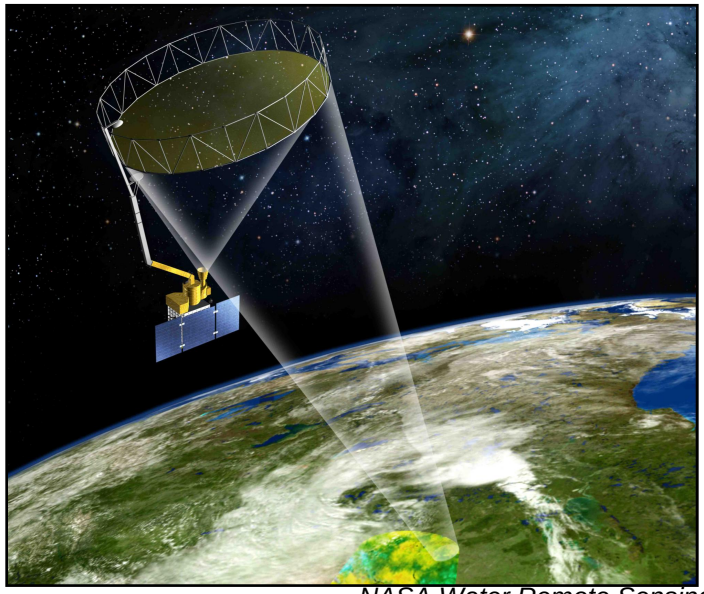
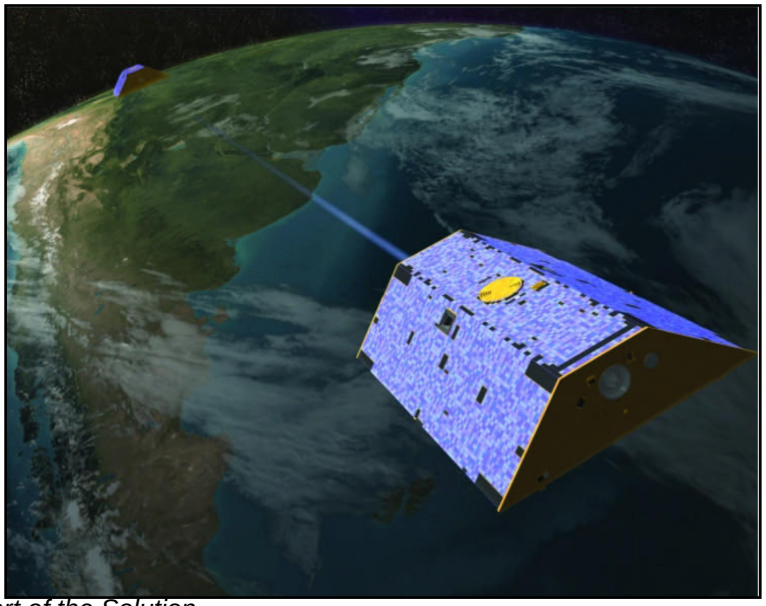
NASA Panel Background

- **Solution – Using remote sensing & related tool for improved water management.**
- **NASA has a strong provision of free and open exchange of all data.**
- **Data are available across political and physical boundaries enabling data sharing.**
- **Remote Sensing provides synoptic (local to global) and multi-temporal (retrospective, in near real-time and predictive) capability.**
- **Partnering with other groups is optimal for leveraging activities .**





OUTLINE

I. Using Remote Sensing Technology for Improved Water Management

- NASA & Earth Science Water Satellites – Vanessa Escobar
- Merging Satellite with modeling and other GEO spatial data - Ted Engman
- Highlights of Successful Water Remote Sensing Applications – Rick Lawford
- Example Project Highlights – Dave Toll

II. Example Partnering on Using Remote Sensing for Improved Water Management

- World Bank – N Harshadeep
- USAID – John Pasch
- CNRS (National Center for Science Research), Remote Sensing Center, Lebanon - Amin Shaban

III. Wrap-up and Panel Discussion (Moderator -Ted Engman)

- NASA Satellite Early Adopter Program - Vanessa Escobar
- Solution: Using Remote Sensing to Explore Collaborative Opportunities. How to make use of remote sensing with partnering groups - Dave Toll

IV. Discussion Period

NASA WATER SCIENCE & APPLICATIONS

MISSIONS FOR WATER SOLUTIONS: NASA's MISSIONS FOR WATER RESOURCES PLANNING AND MANAGEMENT

VANESSA M. ESCOBAR

NASA/GSFC

USING GLOBAL OBSERVATIONS TO DRIVE SOLUTIONS

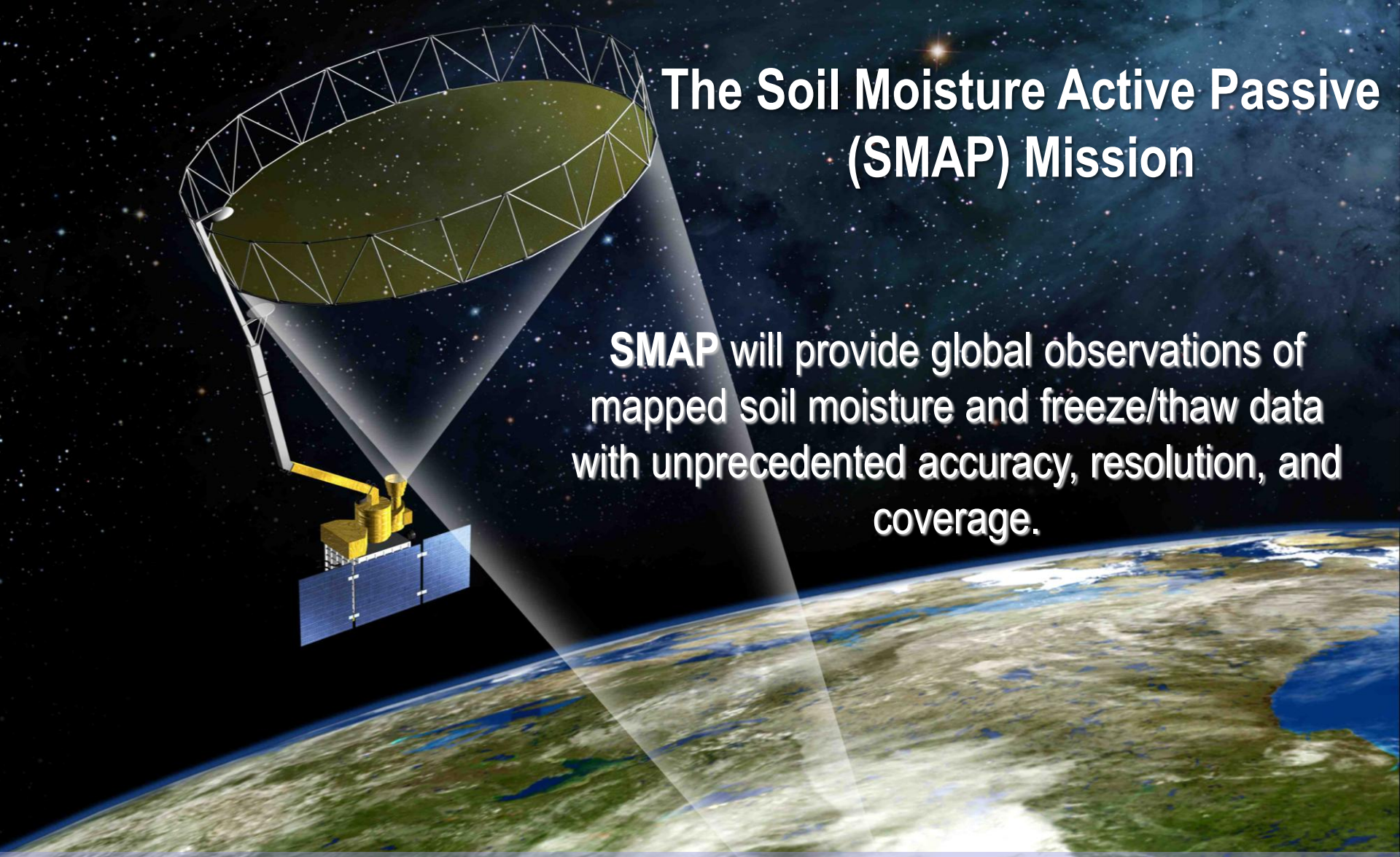
How can NASA contribute to "Water Solutions"

1. Provide FREE Satellite and Assimilation data.
   Future Hydrology Missions:
   SMAP (2014), GRACE (Ongoing), GPM(2013) and ICEsat2(2016), SWOT (2019)

2. Engage with communities about NASA's Applied Science Concentration for each mission

3. Foster relationships and facilitate communication between the Scientist and end user so data are easily used.
   the Mission Early Adopter Program

WATERCENTRIC MISSIONS



The Soil Moisture Active Passive (SMAP) Mission

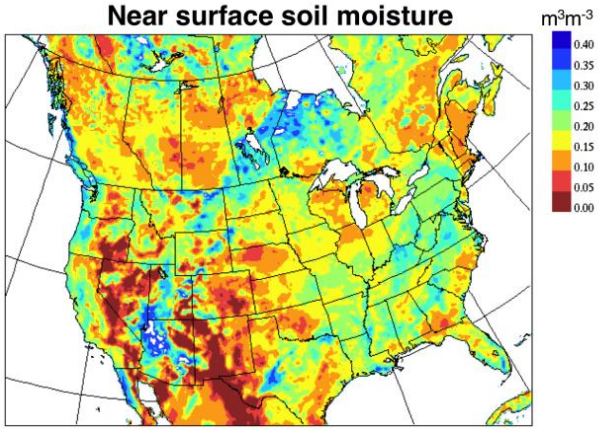
SMAP will provide global observations of mapped soil moisture and freeze/thaw data with unprecedented accuracy, resolution, and coverage.

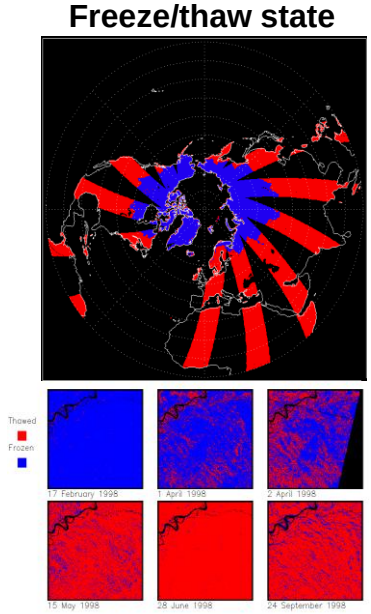
A primary goal for the SMAP Mission is to engage SMAP end users and build broad support for SMAP applications through a transparent and inclusive process

The Soil Moisture Active Passive (SMAP) Mission

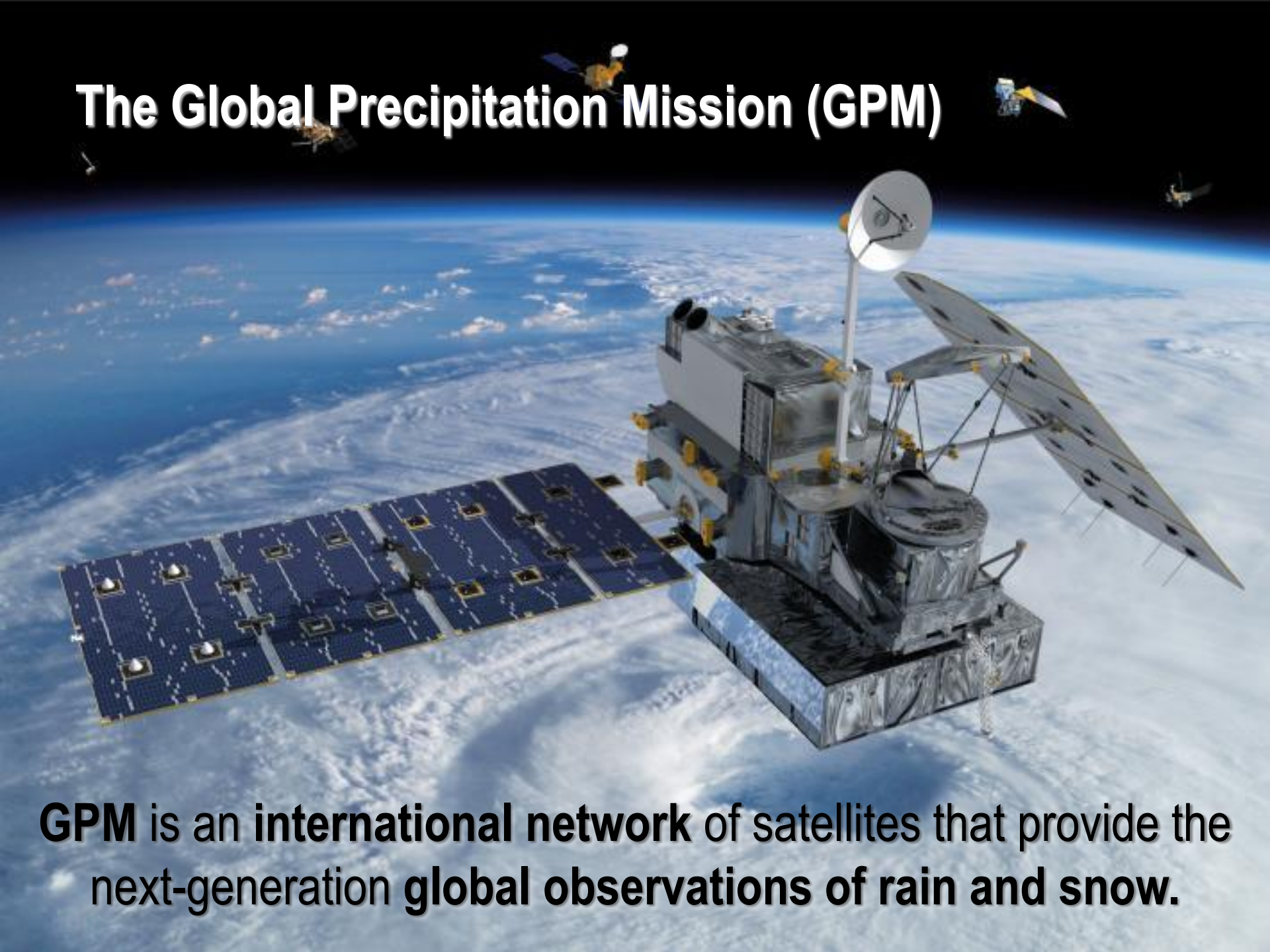
SMAP will help users:

- **Understand processes** that link the terrestrial water, energy and carbon cycles
- **Estimate global water** and energy fluxes at the land surface
- **Quantify** net carbon flux in boreal landscapes
- **Enhance** weather and climate forecast skill
- Develop **improved flood prediction and drought monitoring** capabilities





The Global Precipitation Mission (GPM)



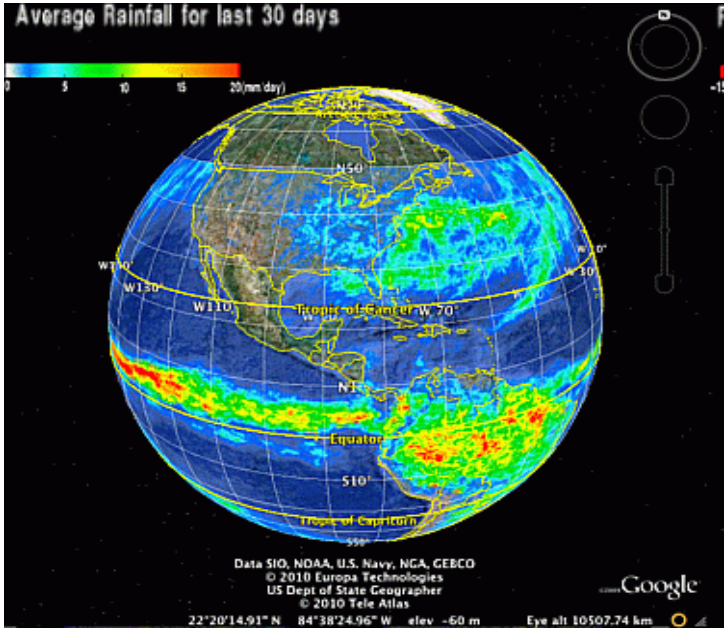
GPM is an **international network** of satellites that provide the next-generation **global observations of rain and snow.**

The Global Precipitation (GPM) Mission

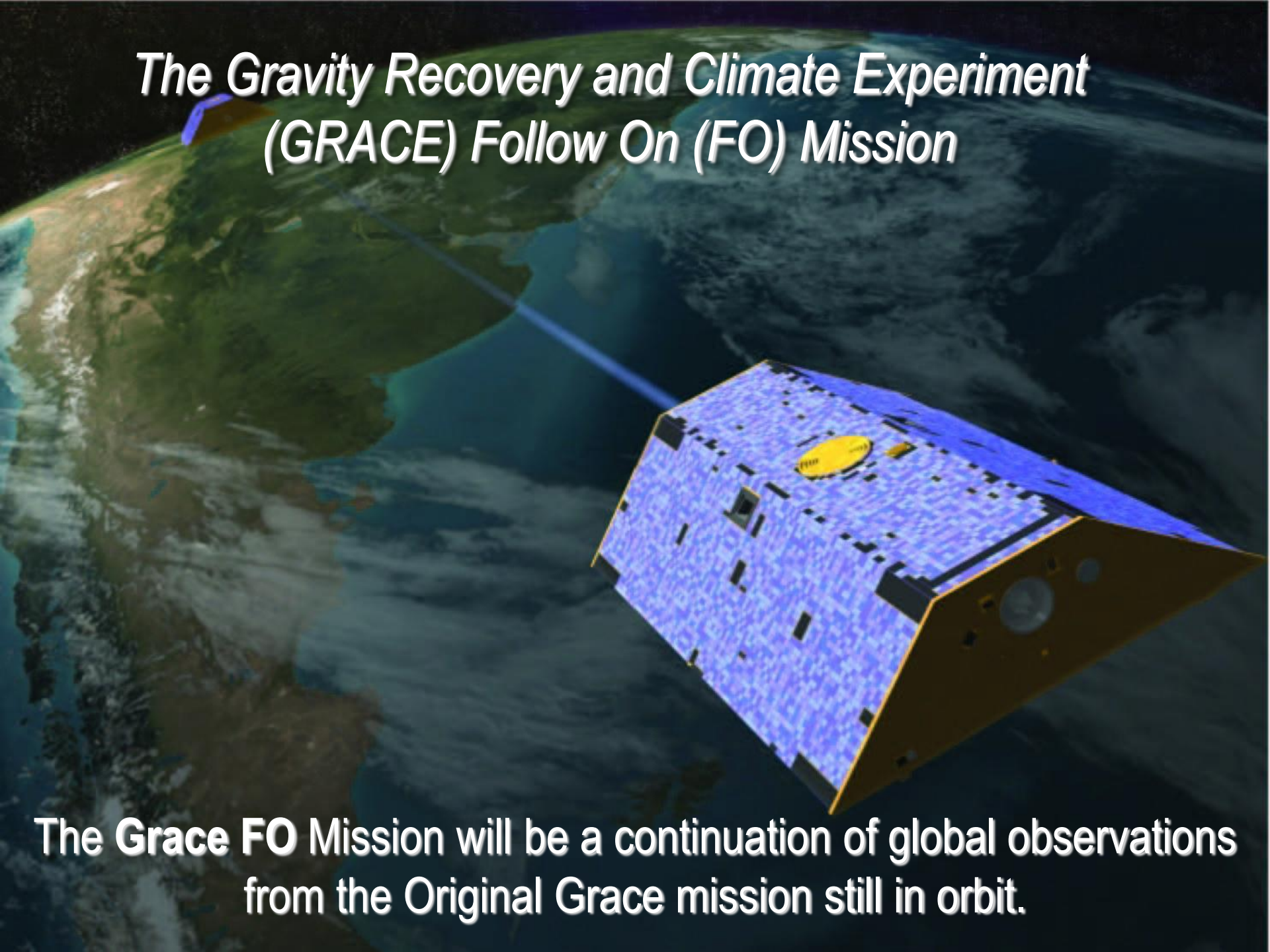
GPM will provide users with:

- **Global precipitation measurements** with improved accuracy, coverage and dynamic range.
- The next-generation **observations of rain and snow** worldwide **every three hours**.
- Advanced understanding of the **water and energy** cycles, **climate change** and **climate sensitivity**
- **Improved forecasting** capabilities for natural hazards, including floods, droughts and landslides

GMP 30 day average rainfall data displayed in Google Earth



The Gravity Recovery and Climate Experiment (GRACE) Follow On (FO) Mission

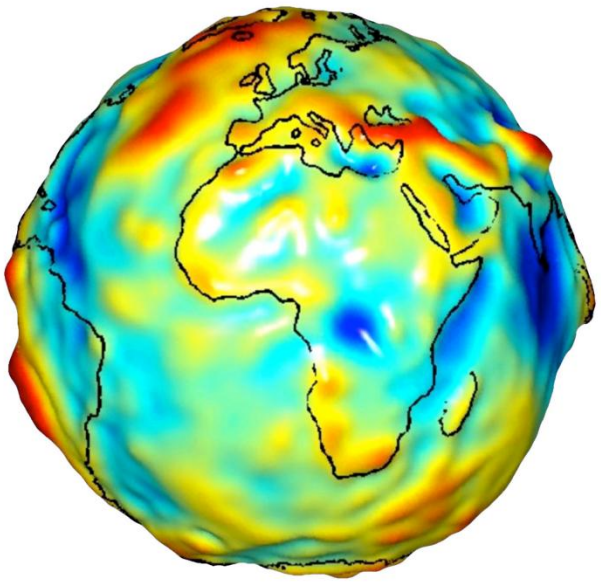


The **Grace FO** Mission will be a continuation of global observations from the Original Grace mission still in orbit.

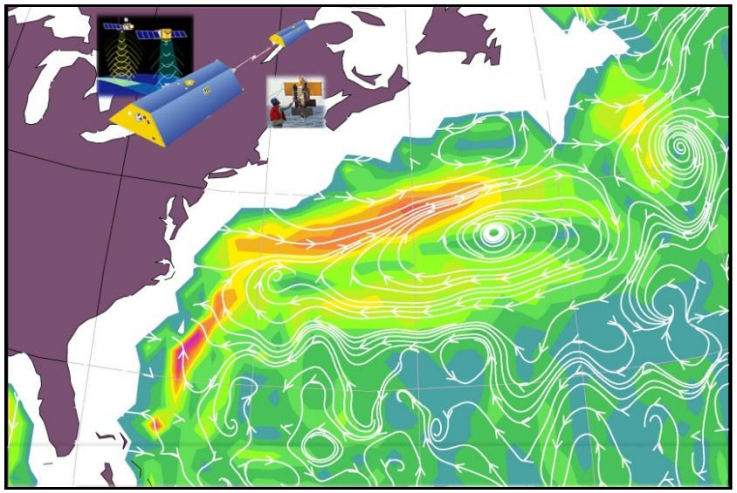
The Gravity Recovery and Climate Experiment (GRACE) Follow On (FO) Mission

The **Grace FO** will be used for applications including:

- Monitoring land water resources, including **groundwater**
- Monitoring of **ocean** bottom pressures and **currents**
- Measuring changing masses of **polar ice caps**
- Measuring **sea level change**; land-ocean mass exchange
- **Understanding** Earth forces that move tectonic plates (**earthquakes and volcanism**)

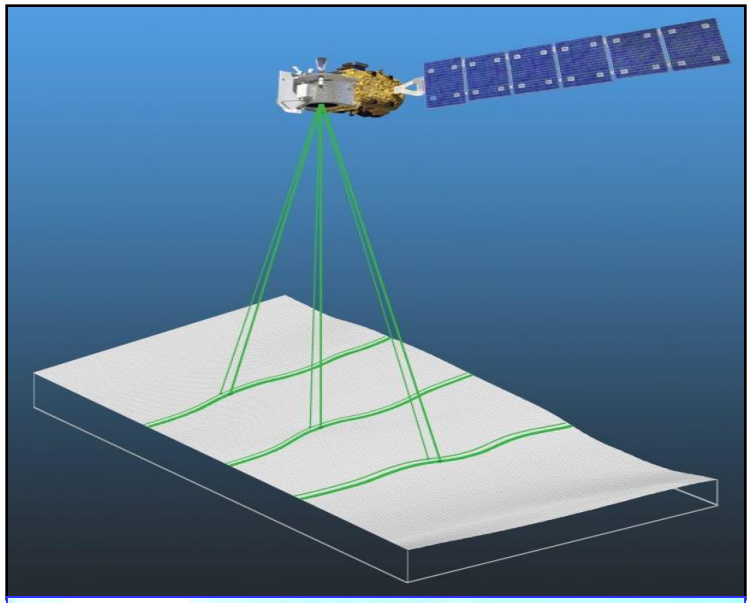


(Above) Earth Gravity Model (Below) Ocean circulation assimilation model



Images provided by University of Texas Center for Space Research and NASA

Ice Cloud and Elevation Satellite (ICESat)-2
Early in Mission Development



- Estimate **reservoir heights** and lake levels
- Polar ice-sheet change through time
- Estimate **sea-ice thickness** to examine exchanges of energy, mass and moisture.
- **Measure vegetation canopy height** as a basis for estimating biomass change.
- Enhance the utility of **other Earth observation systems-**will be used as a Joint Application with the soil moisture mission (SMAP)

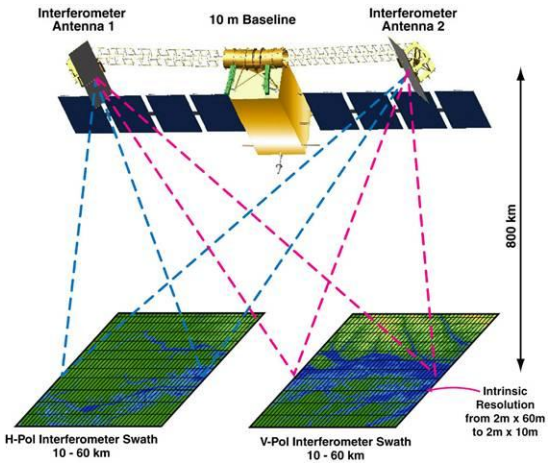
ICESat-2 is scheduled for launch in early 2018. Early Adopter Program soon to come!

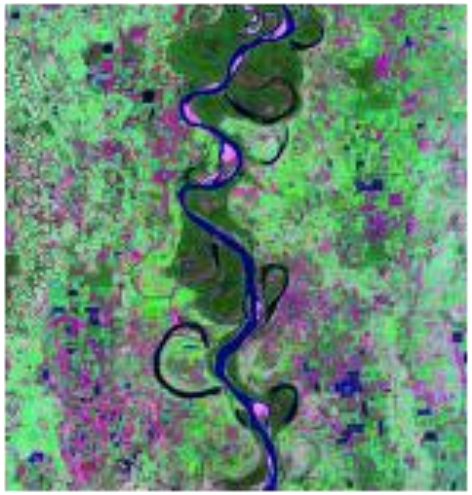
Surface Water Ocean Topography (SWOT)

Early in Mission Development
Launch in 2019

SWOT's motivations:

- Critical water cycle component
- Essential for water resource planning
- Global stream discharge and water height





All these data need processing…

Satellite Observations, Model outputs, Ground measurements COMBINED will provide the information we need for decision making…

NASA WATER SCIENCE & APPLICATIONS

DATA ASSIMILATION - THE MISSING LINK FOR THE PRACTICAL USE OF SATELLITE DATA FOR WATER RESOURCES PLANNING AND MANAGEMENT

Ted Engman

NASA/GSFC

Extending the societal and economic benefits of Earth science research, information, and technology …

The World Water Forum "SOLUTIONS" Challenge

The first step in implementing SOLUTIONS is to *quantify* the amount and condition of the water resources in space and time. Traditionally this has been done through in situ measurements of the major fluxes and storages (rain, stream flow, GW, snow, reservoir capacity, etc) and an assessment of the condition (quality). In many regions of the world these data do not exist or are unreliable. Traditional data collection activities are very expensive.

A NEW SOURCE OF WATER RESOURCES DATA-SATELLITES!

The major space agencies and met services maintain a vast array of Earth observing satellites capable of providing basic water cycle data. These data have the potential for providing critical inputs to sustainable water resources development and ICM.

Water Cycle Missions

Water and Energy Cycle Missions

Energy Cycle Missions

ICESat
- Ice elevation
- Cloud height

GRACE
- Column water-content

TRMM and GPM
- Global precipitation

HYDROS
- Surface wetness
- Frozen soil

EOS-Aura
- Atmospheric humidity
- Clouds

EOS-Terra
- Snow and ice
- Vegetation

CALIPSO
- Cloud properties

CloudSAT
- Cloud profiler

EOS-Aqua
- Atmospheric humidity
- Water storage
- Clouds
- Snow and ice

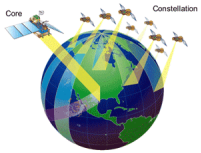
TOMS
- Total column ozone

SORCE
- Total Irradiance measurements

SAGE
- Air quality
- Climate change

UARS
- Carbon management
- Air quality

Global Precipitation Measurement



Complementary Water and Energy Cycle Missions

QuikSCAT
- Sea-surface wind velocity

EO-1 LANDSAT and NMP EO-1
- Land cover

NPOESS
- Global environmental conditions

GOES
- Weather

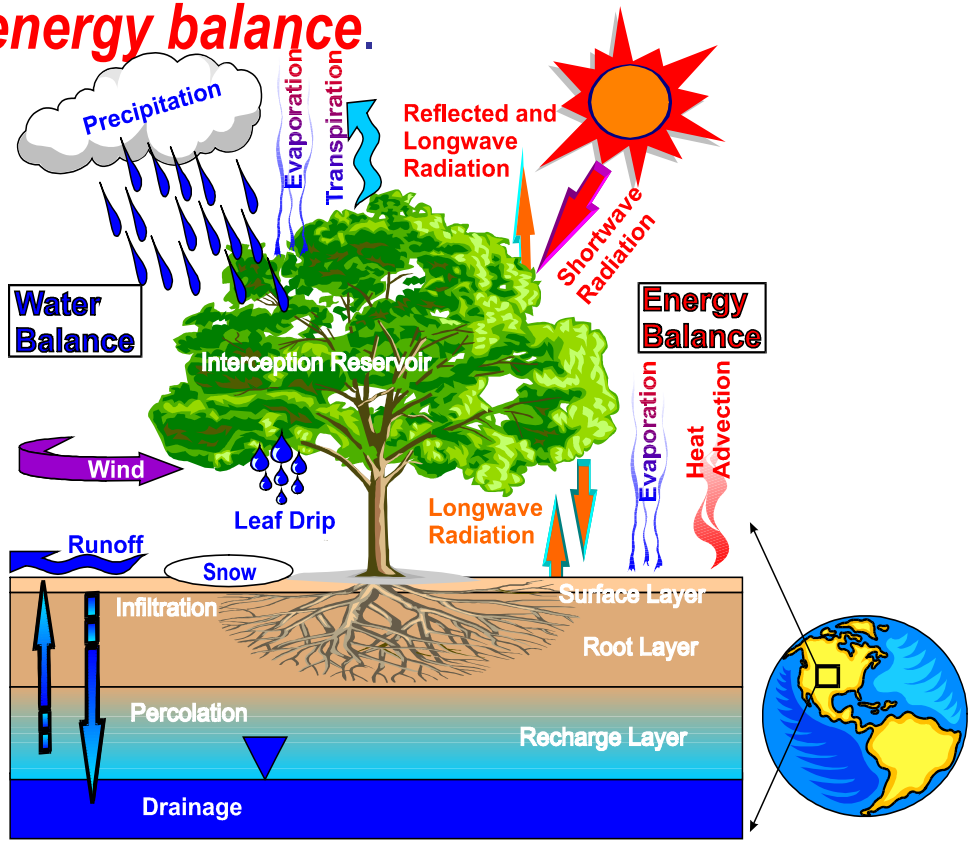
Aquarius
- Global sea surface salinity

UNFORTUNATELY, SATELLITES HAVE NOT LIVED UP TO OUR HOPES AND EXPECTATIONS, WHY?

For the most part, satellites do not provide a one-to-one correspondence or measurement that is identical to the type of data we are used to using. How do we overcome this problem?

What We Cannot **Measure** Directly, We Can Model

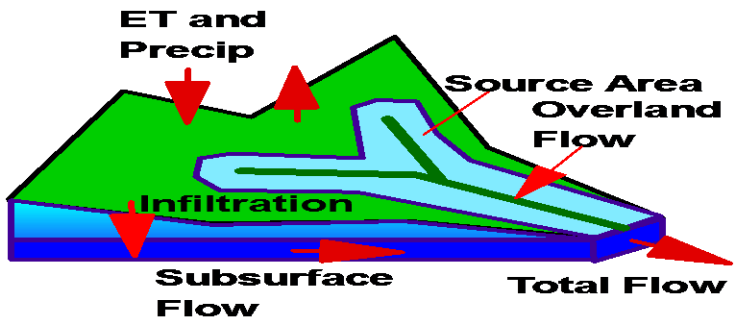
Land Surface Prediction: Accurate hydrologic model prediction is essential to estimate all fluxes and storages in time and space. Based on ***water and energy balance***.



Input - Output = Storage Change

$$P + Gin - (Q + ET + Gout) = \Delta S$$

$$Rn - G = Le + H$$



But There Are Still Discontinuities in Space and Time Among Measured Variables and Model Produced Variables, Solution:

4 - D Land Data Assimilation Systems:

Quantification and prediction of hydrologic variability (time and space)

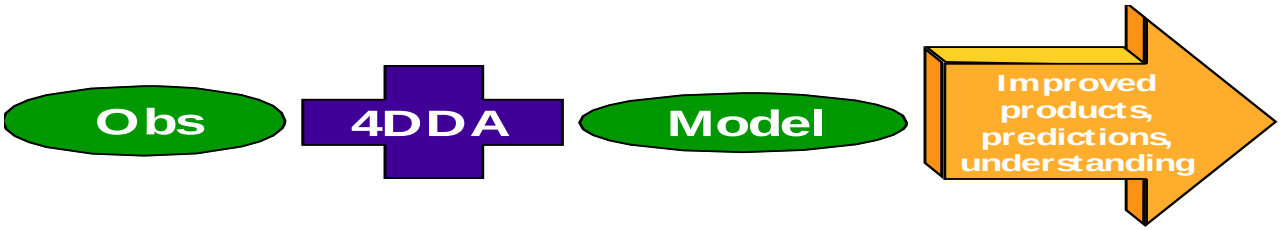
Maturing of hydrologic observation and prediction tools:

- Observation: Forcing, storages (states), fluxes, and parameters.
- Simulation: Land process models (Hydrology).
- Assimilation: Short-term state constraints (satellite & in situ data)

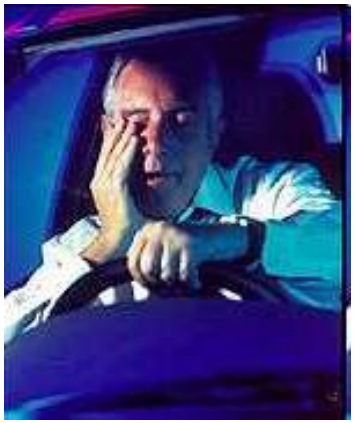
"LDAS" concept:

Bring state-of-the-art tools together to *operationally* obtain high quality land surface storages and fluxes.

- Continuous in time&space; multiple scales, realtime, and forecast

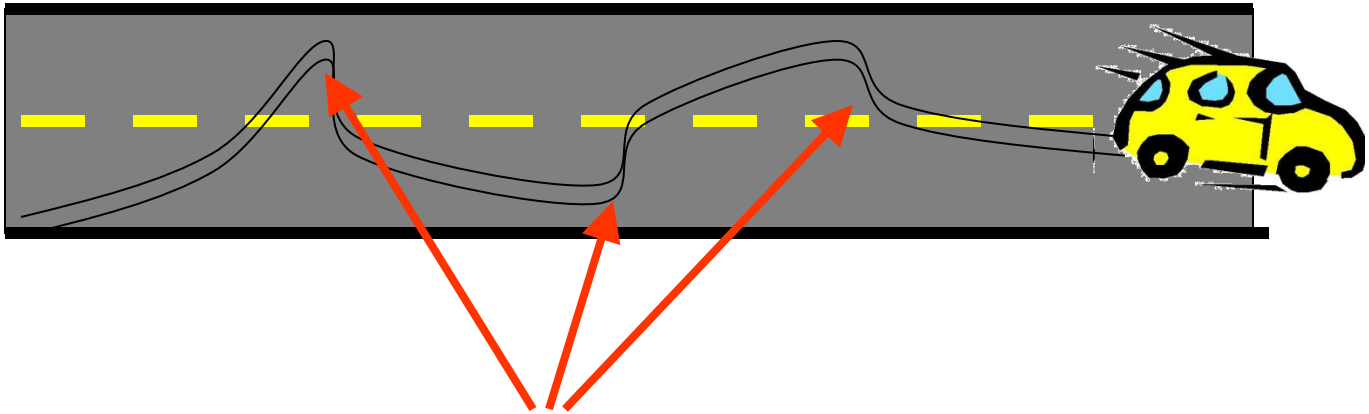


Data Assimilation
‘Sleepy Driver Scenario’



(Land surface model)

You are going in the right general direction…



…but when you open your eyes, you correct towards the center of the road

(Observations from gauge station, satellite)

DATA ASSIMILATION PRODUCTS

4D Data Assimilation takes model outputs, in situ measurements and satellite data collected at varying time and space scales to generate a comprehensive quantification of the water balance and the land surface energy balance. Thus we are able to provide estimates of rainfall, runoff, soil moisture, ET, etc. at a variety of time and space scales – from 25 km to 1 km and 6 hr to 1 hr.

SUMMARY

SATELLITE DATA AND DATA PRODUCTS SHOULD BE ABLE TO SUBSTITUTE FOR TRADITIONAL WATER CYCLE DATA TO USE FOR SOLVING WATER RESOURCES MANAGEMENT PROBLEMS WHEN TRADITIONAL DATA ARE NOT AVAILABLE OR UNRELIABLE. **DATA ASSIMILATION IS THE KEY FOR MAKING THESE DATA USABLE**

Solving Water Problems with NASA Satellite Data

World Water Forum VI
Marseilles France

Rick Lawford NASA Consultant
David Toll, NASA Scientist

NASA Water Management

EARTH SYSTEM MODELS

- **Mesoscale Models:** *MM5, CSU RAMS*
- **General Circulation models**: *GMAO (DAO & NSIPP), NCEP ETA*
- **LSMs:** *MOSAIC, Noah, VIC, Catchment, CLM2, SWAT*
- **In Stream Water Quality Model:** *QUAL2E*
- **Non-Point source annual loading model:** *PLOAD*
- **Watershed loading and transport models**: *HSPF*

**Supported Non-NASA Model*

Data

EARTH OBSERVATORIES

- **Surface Temperature:** ***Terra, Aqua, GOES***
- **Precipitation:** ***TRMM, Aqua, GOES***
- **Soil Moisture:** ***Aqua, TRMM, NPOESS***
- **Snow Cover:** ***Aqua, Terra***
- **Snow Quantity:** ***Aqua***
- **Groundwater Change:** ***Grace***
- **Land Use/Cover:** ***Terra, Aqua, Landsat***
- **Surface Radiation:** ***GOES, Terra, Aqua, Aster***

Predictions

- **Soil Moisture**
- **Evapotranspiration**
- **Precipitation**
- **Snow cover, accumulation, and water equivalent:**
- **Groundwater storage change**
- **Vegetation type**
- **River discharge height**
- **Flood and Drought Assessment and Prediction**
- **Seasonal Forecasts**

Observations

DECISION SUPPORT TOOLS

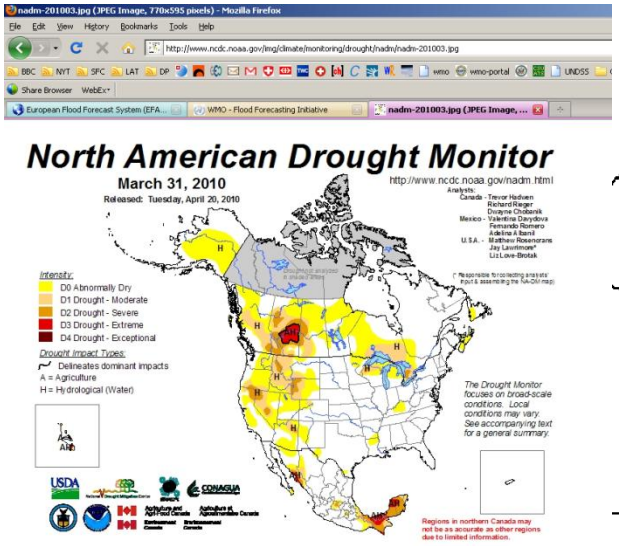
- **BASINS (Better Assessment Science Integrating Point and Non-point Sources**
  - **Facilitate examination of environmental information**
  - **Provides an integrated watershed and modeling framework**
  - **Support analysis of point and non-point source management alternatives**
  - **Urban/Rural land use evaluations**
- **AWARDS (Agricultural Water Resources Decision Support)**
  - **Estimates of water consumption by crops**
  - **Crop suitability assessment**
  - **Irrigation requirements**
- **RiverWare**
  - **Estimates of river flow and water loss to vegetation**
  - **River sustainability assessment**

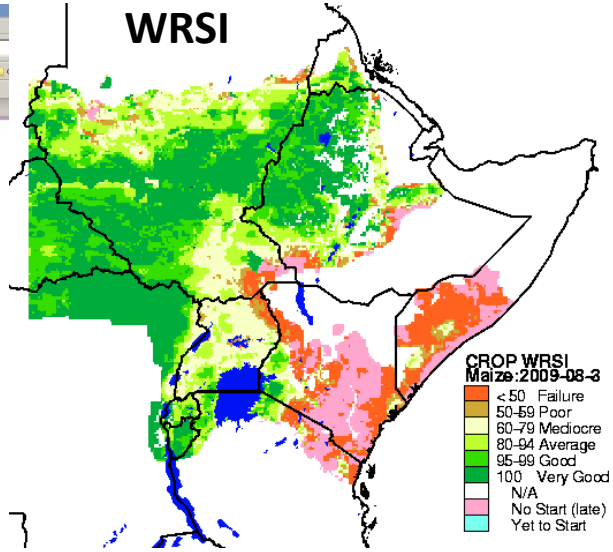
VALUE & BENEFITS

- **Improvements in identifying:**
  - ❖**impaired surface waters**
  - ❖**storm water management issues**
  - ❖**drinking water source protection**
- **Improvement in habitat management practices**
- **Improved efficiency of water use**
- **Increased Agricultural productivity**

Drought Issues: “When the rains don’t come”

Drought arises when the precipitation is substantially less than the water required to meet local demand for a substantial period of time.





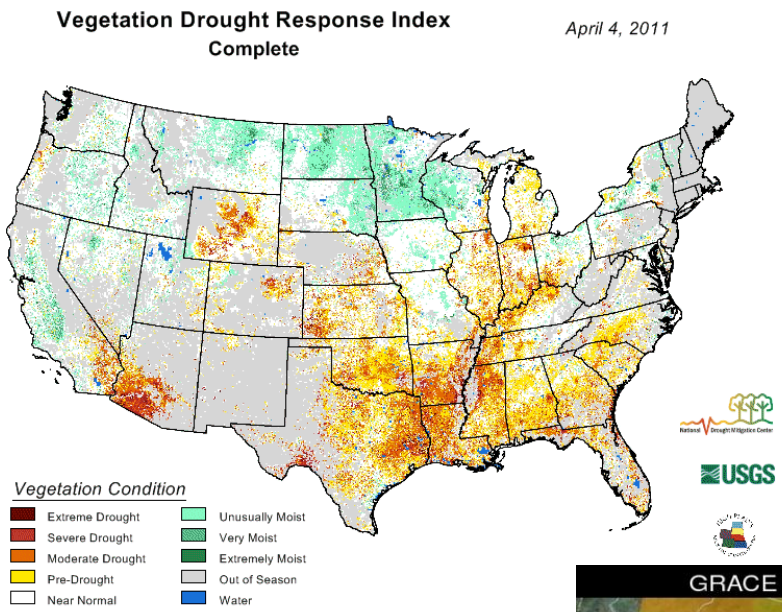
Some of the questions that must be addressed:

How bad is the drought now?

Who is being impacted and what damages are they experiencing?

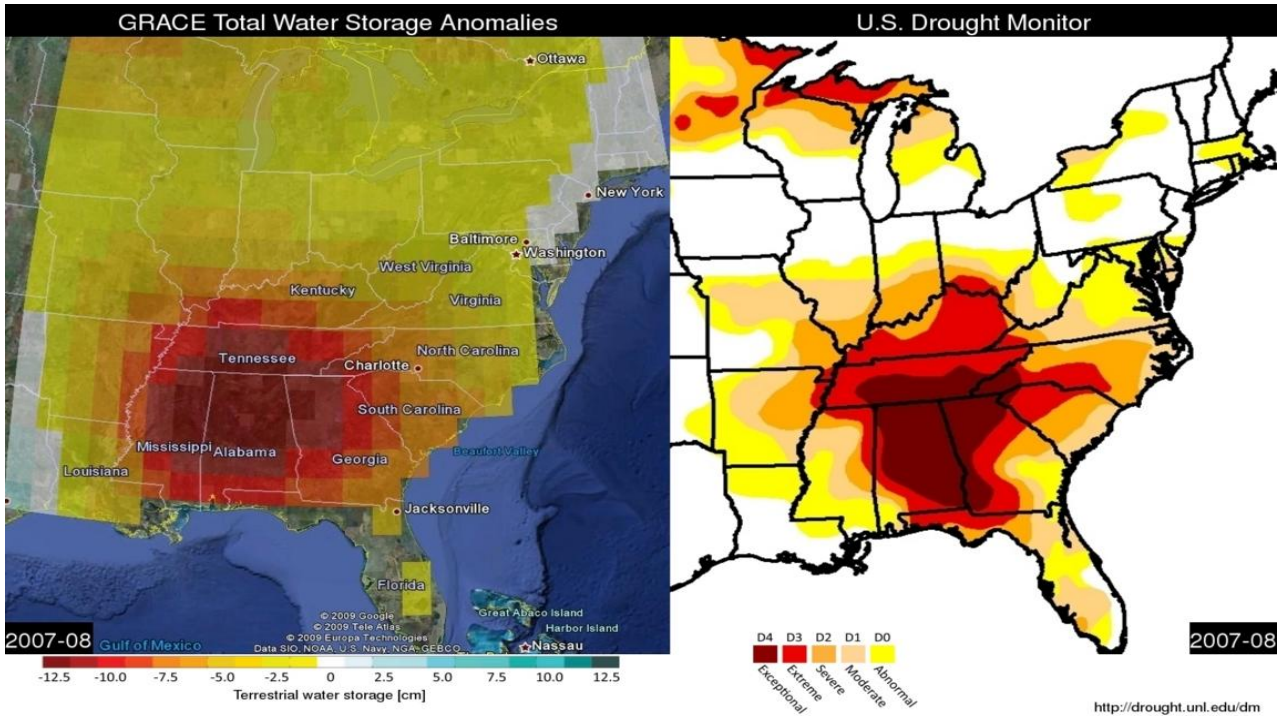
When will the drought end?

NASA assets provide benefits for assessing drought impacts



VegDRI provides an assessment of drought impacts on vegetation. It has been very successful in the US and is now being expanded from the USA to other parts of the world. It provides and assessment of the effects of drought on vegetation.

Analysis of products for 2007 – 2009 shows the good agreement between GRACE groundwater and the US Drought Monitor. (after M. Rodell)



SOLUTIONS DURING DROUGHT

NASA satellite data products and contributions to drought monitoring can help to determine when the following actions should be taken:

Increasing on-farm reservoir storage for water supply.

Assessing regional surface wetness to infer water availability for pumping for domestic supply.

Assessing aquifer levels supplying communities and farms.

Assessing lake levels for recreation and fishing.

Assessing the adequacy of water availability for hydroelectric generation.

Reasons to enhance flood warning and monitoring

1) Adequate warning of a flood event allows people an opportunity to leave the danger zone associated with an expected flood.

2) A knowledge of the extent and magnitude of the extreme is useful for guiding emergency operations (in floods) and relief efforts.

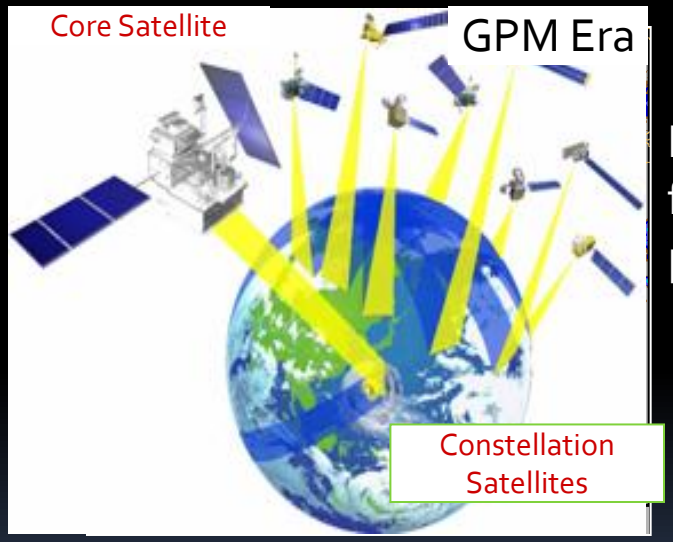
3) Extreme events often lead to programs that compensate those who have been adversely affected. Information is needed as guidance for these relief programs.

4) As the population increases the level of damage associated with floods increases. DEM data can be used to ensure people do not build or live on the flood plain.

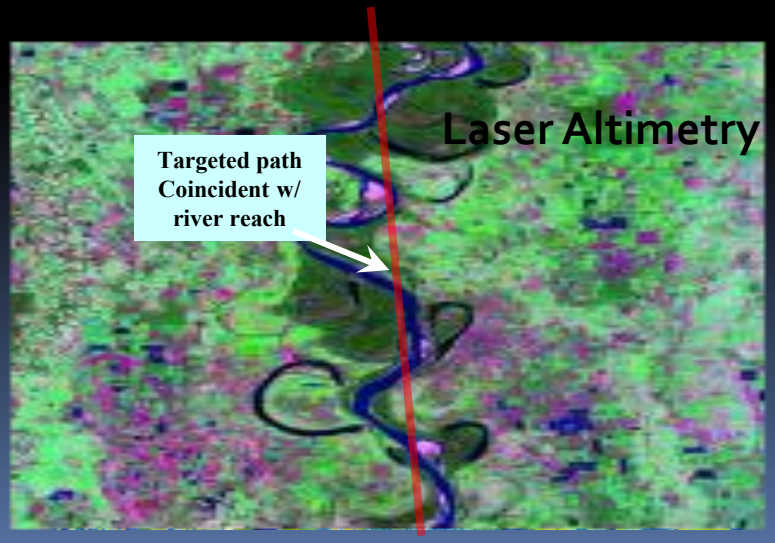
5) Climate change projections indicate that extremes will be more common and more intense in the future as the global water cycle accelerates (intensifies).

INFORMATION NEEDED TO COPE WITH FLOODS

Before the event: Soil moisture observations can be used to assess the vulnerability to flooding arising from saturated soils, full reservoirs, etc.



During the event: precipitation and flow forecasts can provide guidance on the probable magnitude of the flood.

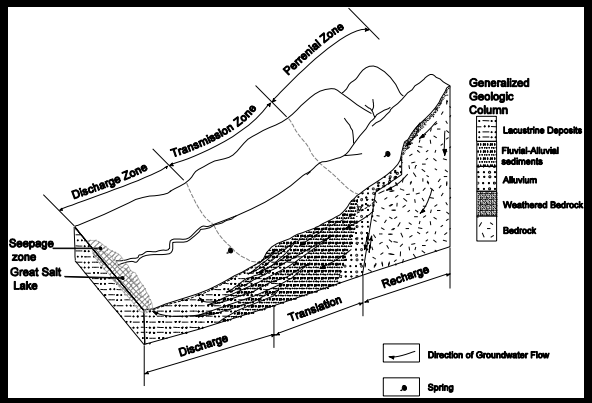


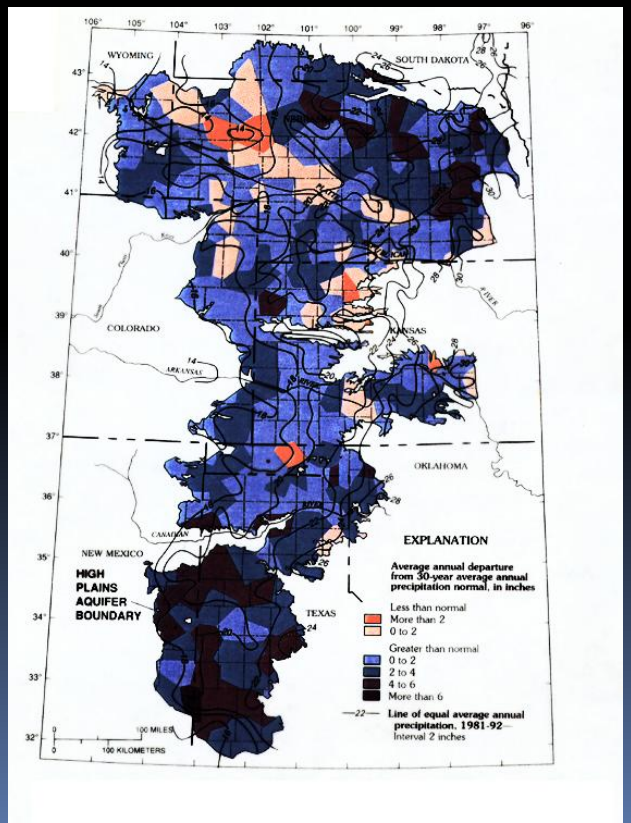
After the event: Satellites can map the innundated areas and flow measurements can guide the mop-up operations.

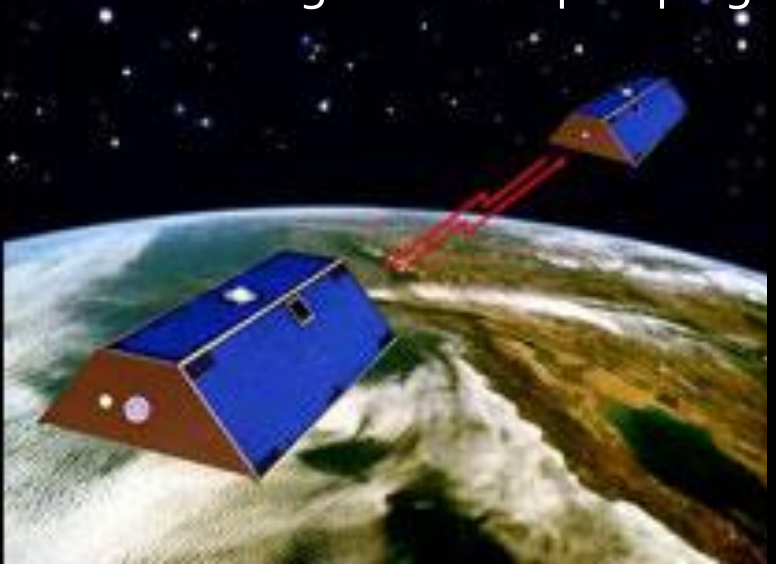
ASSESSING GROUNDWATER AVAILABILTY AND CHANGE

ISSUES:

Increasingly, water managers are turning to Groundwater to meet their needs for freshwater. As a result withdrawals exceed recharge in many areas and essentially fossil groundwater is "mined" . It is becoming critical to be able to more accurately assess the groundwater available in given aquifers and to monitor changes in groundwater levels that will allow attribution of changes to normal climate cycles or climate change and overpumping.

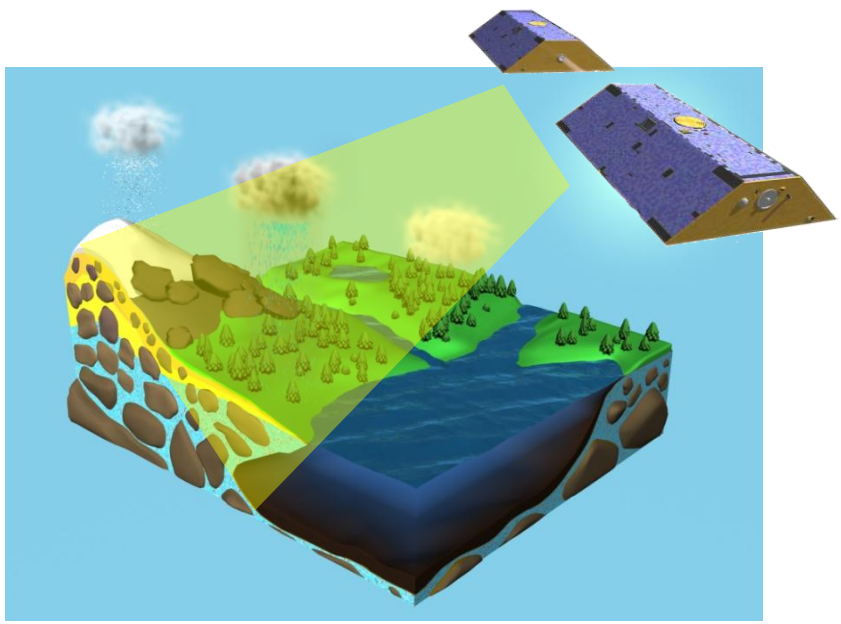




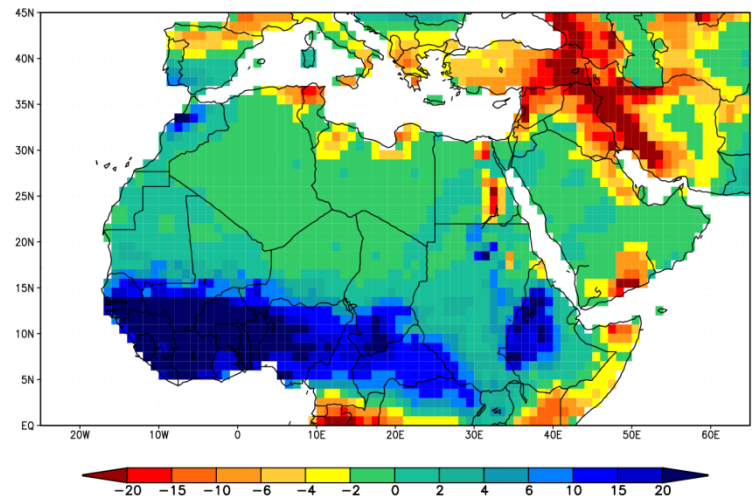


GRACE Satellite Data combined with modeling for aquifer monitoring

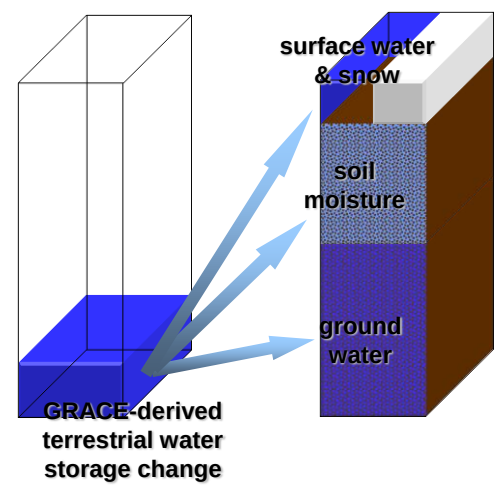
- **The Twin GRACE Satellites Measure Changes in Total Water Storage including Ground Water, Soil Moisture, Snow, and Surface Water.**
- **When combined with Land Surface Modeling, GRACE Data can be downscaled to ~25 km Resolution**



GRACE measures changes in total terrestrial water storage, including groundwater, soil moisture, snow, and surface water.



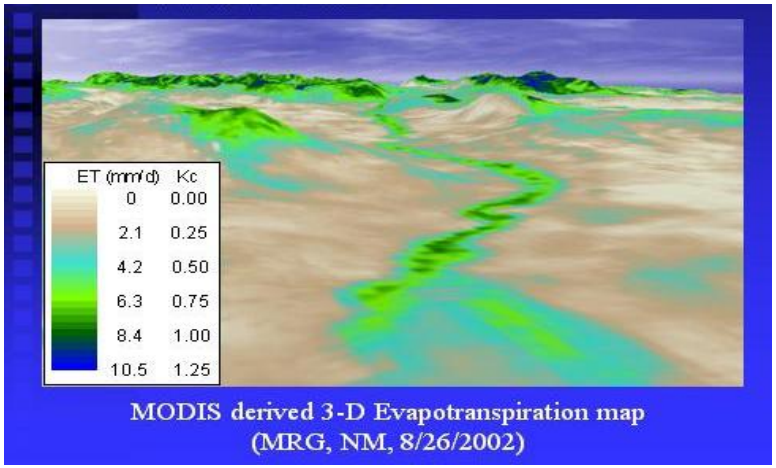
Above: GRACE derived terrestrial water storage anomalies (deviation from the mean at each location), September 2010



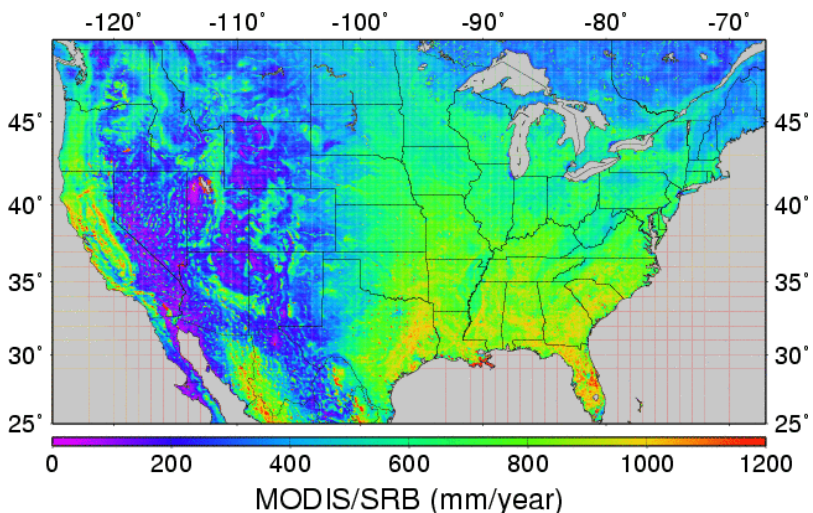
Rodell- NASA/GSFC

NASA Evapotranspiration products are contributing to Real-Time & Global Applications)

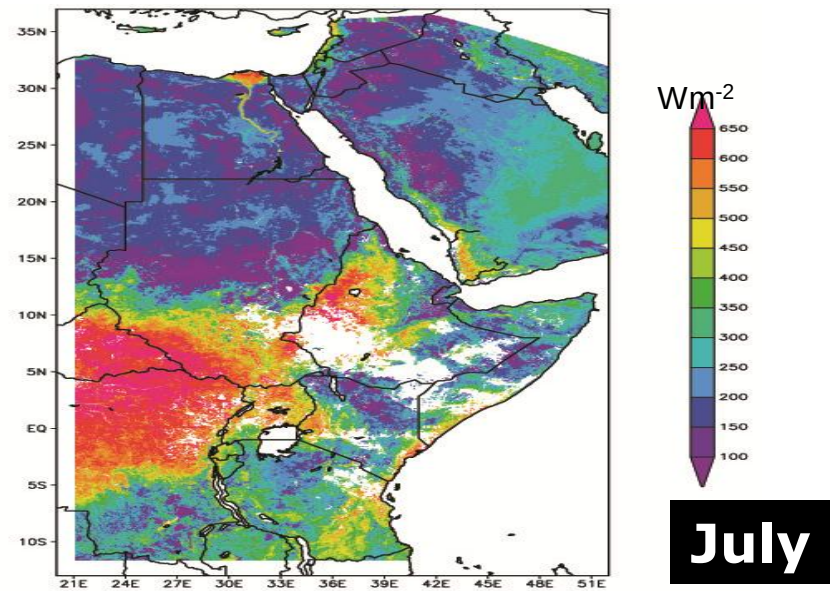
Translation of Landsat ET to MODIS ET for Local to Regional Applications (R. Allen)



One of two NASA MODIS & Related Products provided in Near Real Time- U Wash. Continental US 2001-2009.(to 1-km)



USDA-ARS 'Alexi-DisAlexi' for Regional to Local ET. Applied to Nile. {30m – 25km}



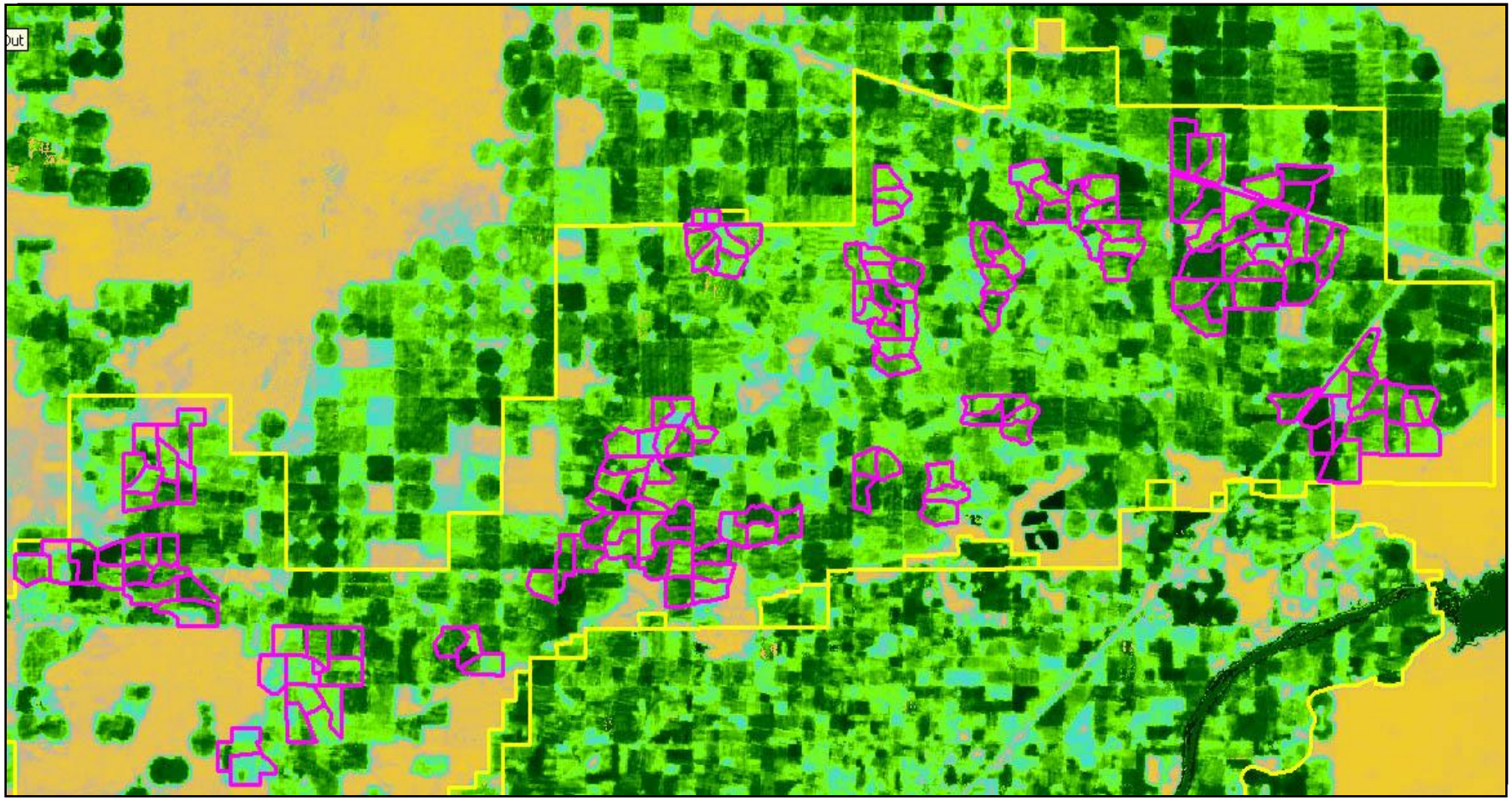
Normalized Evaporative Stress Index USDA/ARS

ET can account for 90% of the western US water use and is critical to local economies tied to agriculture, recreation, hydro- power, etc.

Use of satellite data to resolve consumptive use issues

(after Dave Tuthill)

Landsat map used to assess 2006 evapotranspiration



Polygons of fields claimed to be water-short in 2006.

Result of Analysis (after Dave Tuthill)

Idaho Water Resources denied a request for water shortage compensation

A&B Irrigation district appealed (and lost)

Analysis based on

- Unbiased data sets
- Single data source
- Field-level data
- Archive data

Landsat resolution (30 m) enabled the analysis

BEFORE THE DEPARTMENT OF WATER RESOURCES

OF THE STATE OF IDAHO

IN THE MATTER OF THE PETITION FOR DELIVERY CALL OF A&B IRRIGATION DISTRICT FOR THE DELIVERY OF GROUND WATER AND FOR THE CREATION OF A GROUND WATER MANAGEMENT AREA	)	**ORDER**

This matter originally came before the Director of the Department of Water Resources ("Director" or "Department") on July 26, 1994 when the A&B Irrigation District ("A&B" or "District") filed a petition for delivery call, which sought administration of junior priority ground water rights diverting from the Eastern Snake Plain Aquifer ("ESPA"), as well as the designation of the ESPA as a ground water management area.

On May 1, 1995, A&B, the Department, and other participants entered into an agreement that stayed the petition for delivery call until such time as a motion to proceed was filed with the Director. On March 16, 2007, A&B filed a motion to proceed seeking the administration of junior priority ground water rights, as well as the designation of the ESPA as a ground water management area.

Based upon the Director's consideration of the available information and documents filed herein, the Director enters the following Findings of Fact, Conclusions of Law, and Order.

FINDINGS OF FACT

Procedural History

1. On July 26, 1994, A&B filed a Petition for Delivery Call ("Petition") with the Department. The boundary of the A&B Irrigation District is depicted in Attachment A. According to the Petition, A&B "is the beneficial owner of Water License No. 20736, now known as A-36-02080, which entitles the Irrigation District to divert eleven hundred (1100) cfs from one hundred seventy-seven (177) wells for the irrigation of sixty-two thousand six hundred four and three tenths (62,604.3) acres within the irrigation district, with a priority of September 9, 1948." *Petition* at 1, ¶ 2. "That said water right is held in trust by the United States, for the benefit of the owners of said 62,604.3 acres, all of whom are landowners within and are included within A&B Irrigation District." *Id.* at 1, ¶ 3. Additionally, the Petition stated that due to diversions from the ESPA by junior priority ground water users, A&B "is suffering material injury as a result of the lowering of the ground water pumping level within the E[SPA] by an

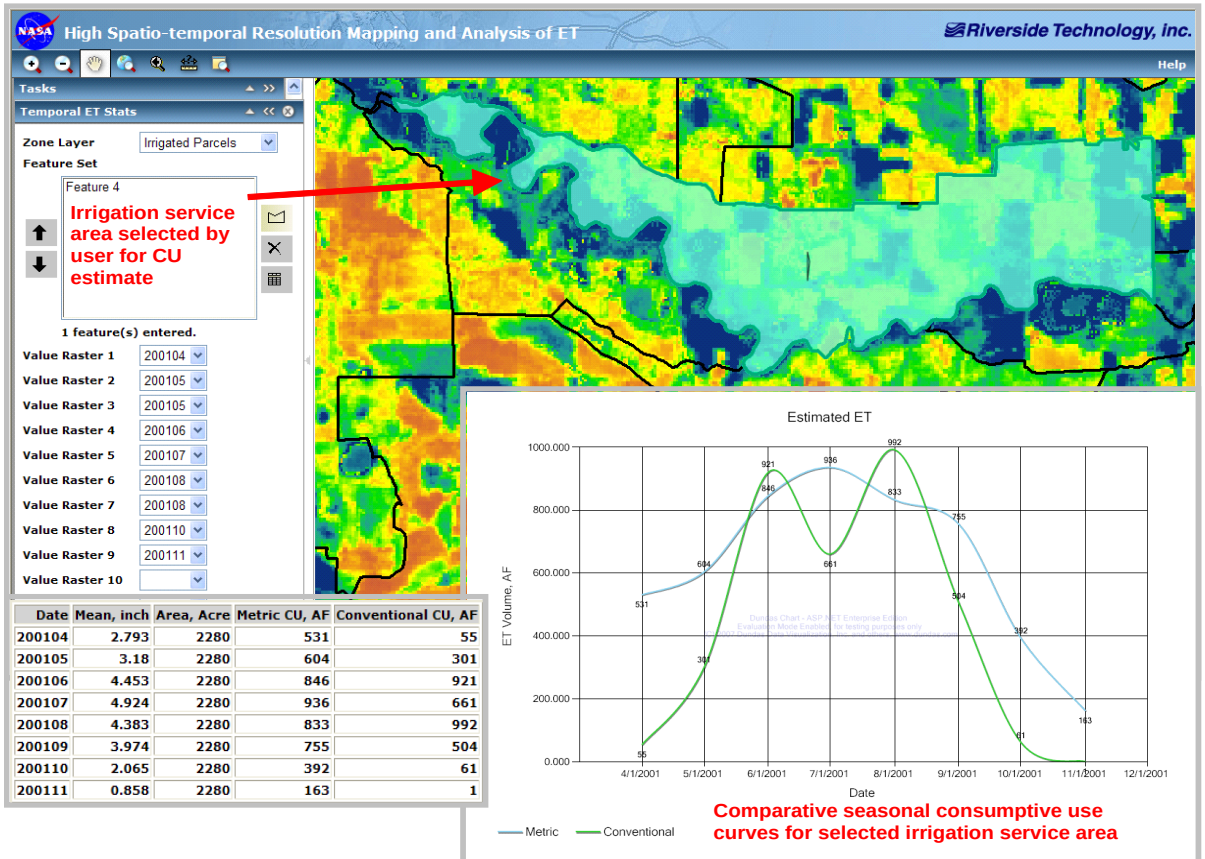
Tools for the easy application of NASA High Resolution Evapotranspiration data have been developed

User can select an area of interest (e.g. return flow contributing area) by digitizing on-screen, and computing ET from that area.

Internet map server powered by ESRI Arcserver technology. The web mapping tool has analytical geospatial capabilities.

The ET data flow directly into a Decision Support System.

This system, which was developed in the USA, is being applied in Morocco and many other countries.



Date	Mean, inch	Area, Acre	Metric CU, AF	Conventional CU, AF
200104	2.793	2280	531	55
200105	3.18	2280	604	301
200106	4.453	2280	846	921
200107	4.924	2280	936	661
200108	4.383	2280	833	992
200109	3.974	2280	755	504
200110	2.065	2280	392	61
200111	0.858	2280	163	1

Applications of Remote Sensing to Global Change issues:

Satellite data can be used to:

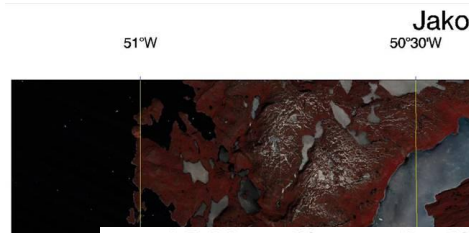
-Detect changes visually.

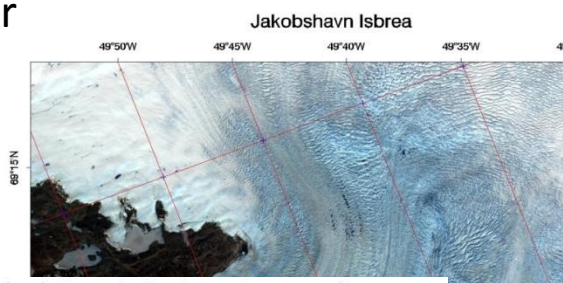
- Document the rates of change

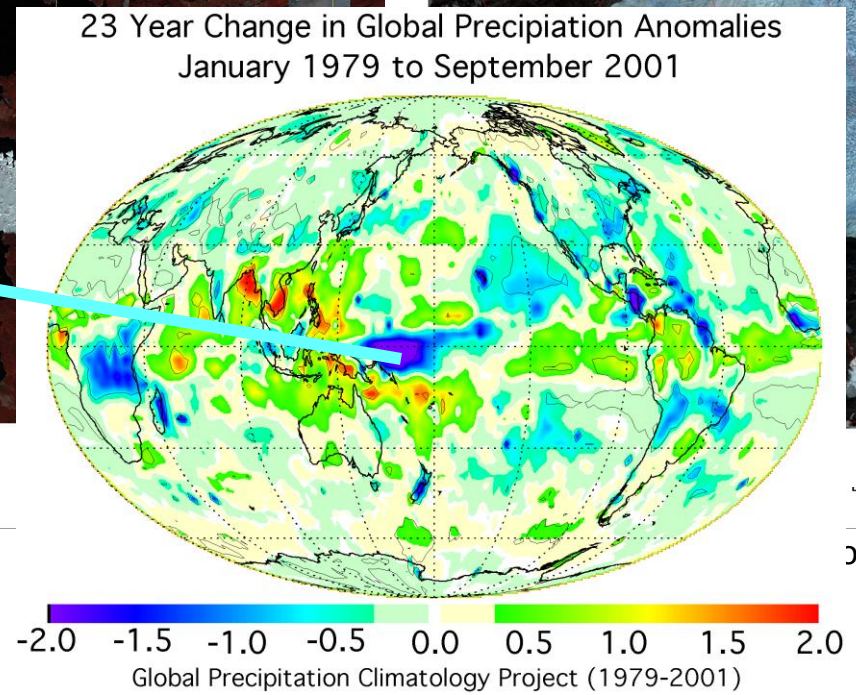
Regional processes can lead to local trends when none exist globally (GPCP Data)

- Identify climate processes particularly in areas where few in-situ observations are available.

Jakobshavn Isbrae glacier







-Validate models that are used in trend assessments. (This results in stringent requirements for long-term homogenous data sets.)

NASA satellites and models can help to identify areas where certain adaptations to Climate Change and Water Stress are feasible

- Rainwater Harvesting
- Artificial recharge of aquifers
- Water Reuse
- Other (harvest of fog and dew)

Water and Food Security

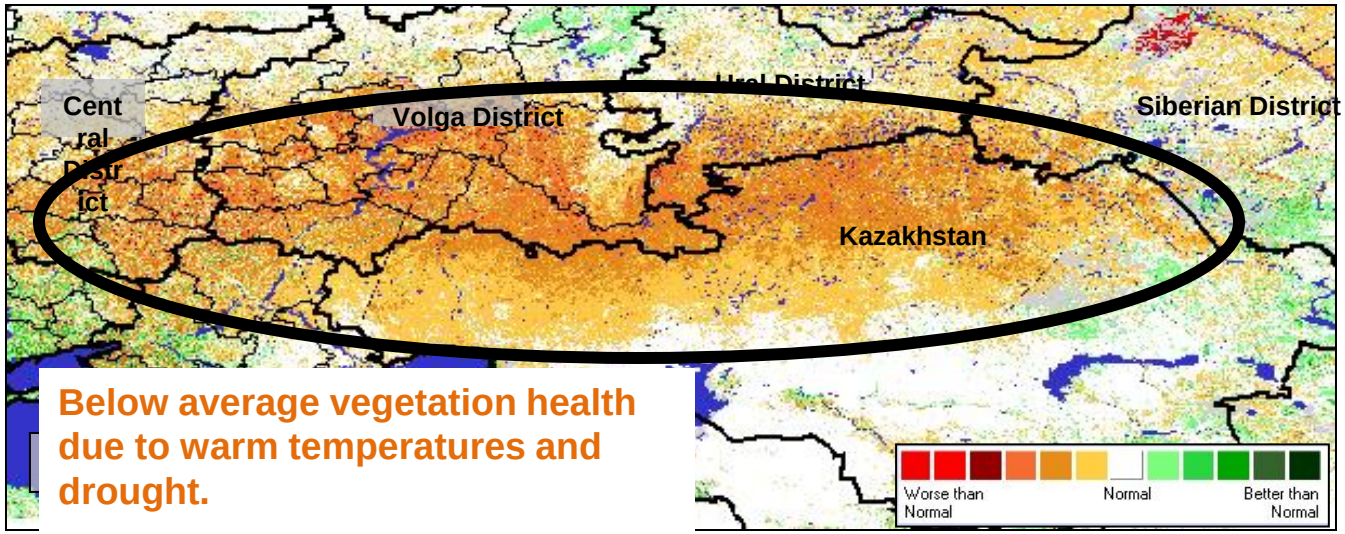
The 2011 World Economic Forum report identified three major risks for the global economy:

1. The macroeconomic balances nexus
2. The illegal economy nexus
3. **The water-food-energy nexus**

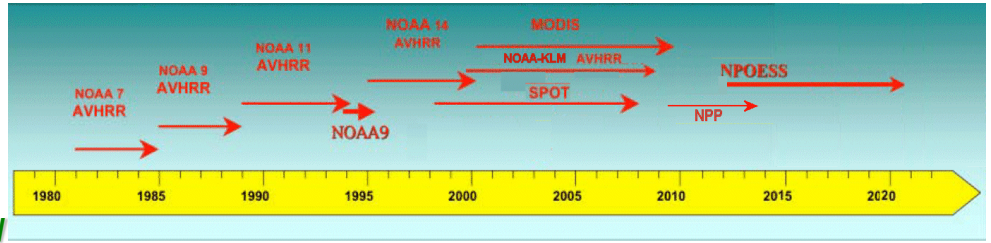
NASA is beginning to examine the factors that can enable the monitoring of the availability of water for agriculture, its usage in food production and the environmental effects of agricultural bi-products (e,g., nutrient loadings for soils and streams).

Satellite Data and Global Crop Monitoring (after Curt Reynolds)

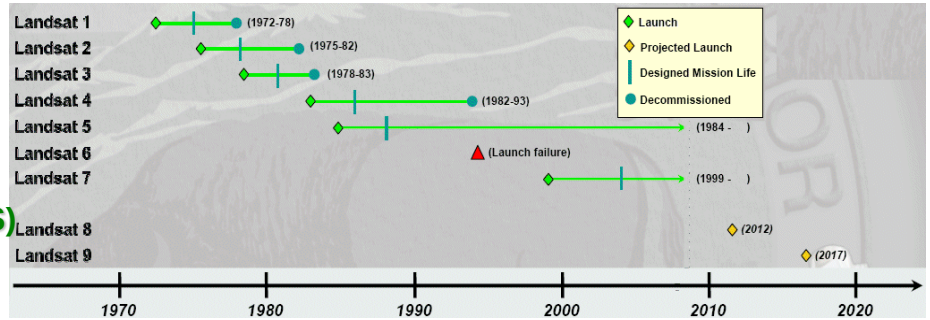
MODIS data shows areas where one year's grain production is low (in this case due to drought and record high temperatures).



Crop Yield
(AVHRR/MODIS/VIIRS)



Crop Area
(Landsat/AWiFS)



LandSat and MODIS have provided a valuable tool for the estimation of crop yield and crop area estimates that are the basis of estimates of the world's grain stocks (which is related to the price of grain).

Bottom Line:

NASA has many assets (data products, model outputs) that are freely available to use in addressing water-related problems that require good information for wise decisions.

NASA is developing applications in collaboration with US federal agencies. Through links with other countries arising from international programs such as GEWEX and GEO they reach out to other countries. In particular, work with US AID and the World Bank involves scientists directly in efforts that tailor the capabilities of NASA to meet the needs of societies to better manage water.

Application areas likely to gain more visibility in the future:

- developing strategies for adaptation to climate change.
- understanding the water-energy-food security nexus.

NASA Water Remote Sensing and Modeling Tools are Part of the Solution – Example Project Highlights

David Toll
NASA/GSFC
NASA Water Resources Program

15 March 2012
World Water Forum

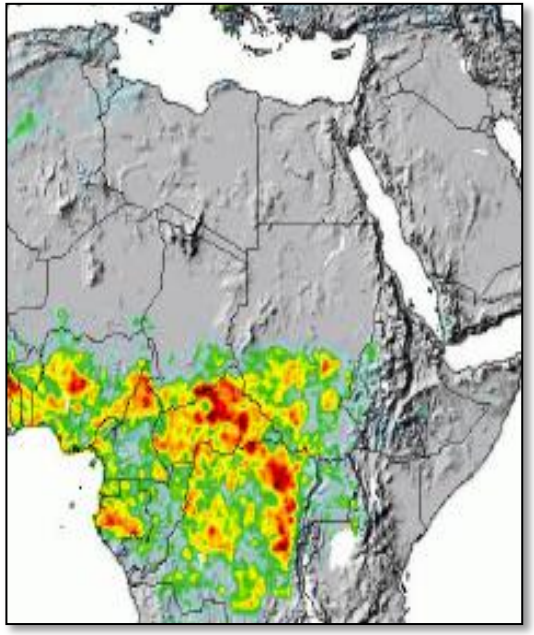
David.L.Toll@nasa.gov

SERVIR

(‘to Serve’ in Spanish)

What is SERVIR?

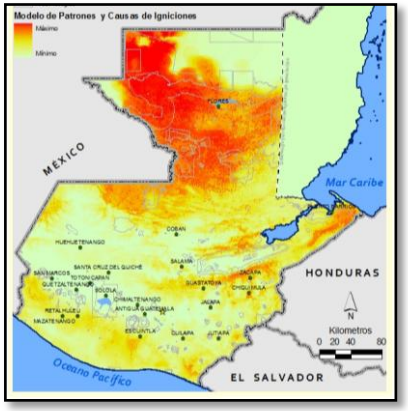
A NASA and USAID collaboration with countries and stakeholders to improve environmental management and resilience to climate change by strengthening the capacity to integrate earth observations and geospatial technologies into development decision-making. Three international SERVIR nodes with plans for additional nodes.



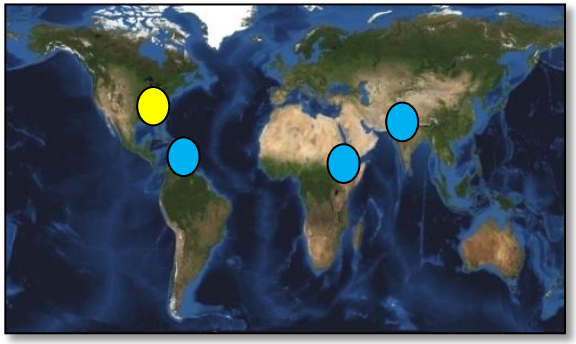
Flood Potential in Africa
(NASA/GSFC)

Training and Capacity Building

- **Remote Sensing Data/Models**
- **Integrated with other Geo Data**
- **Visualizations**
- **Decision Support**
- **Training/Capacity Building**
- **Partnerships**



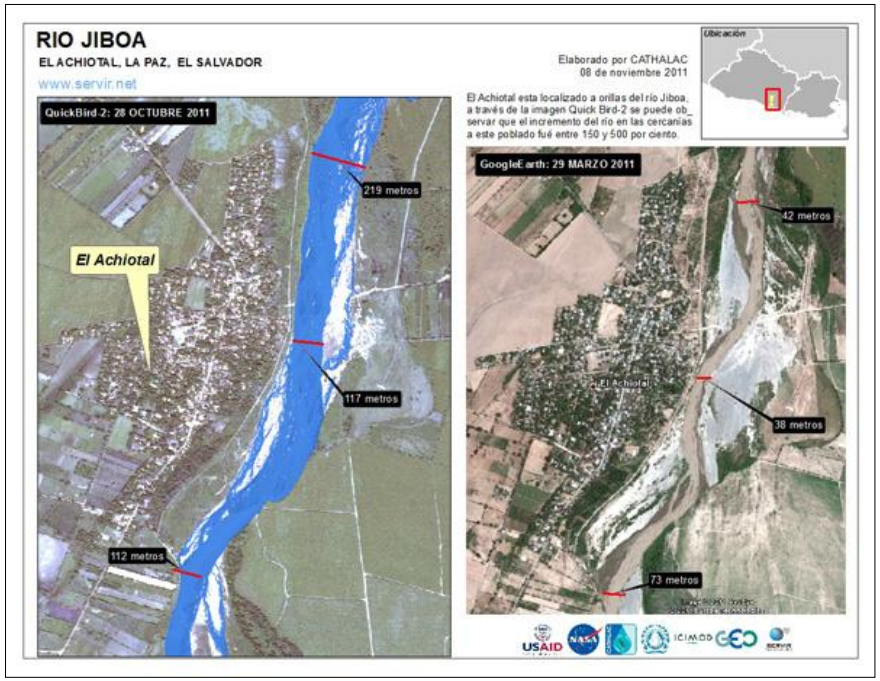
Fire Forecasting in Mesoamerica



SERVIR Network

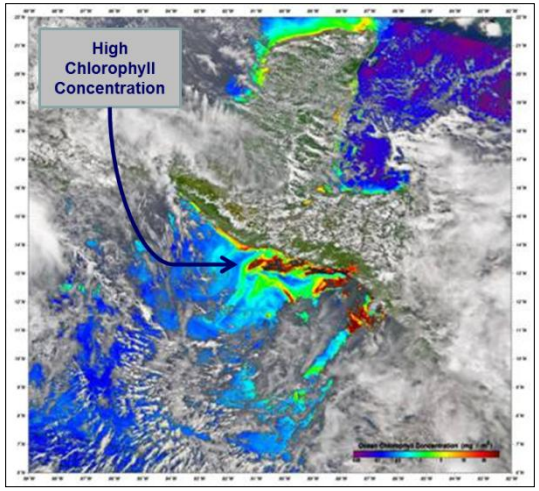
SERVIR - Mesoamerica & Water

Flood Monitoring and Post-Disaster Assessments



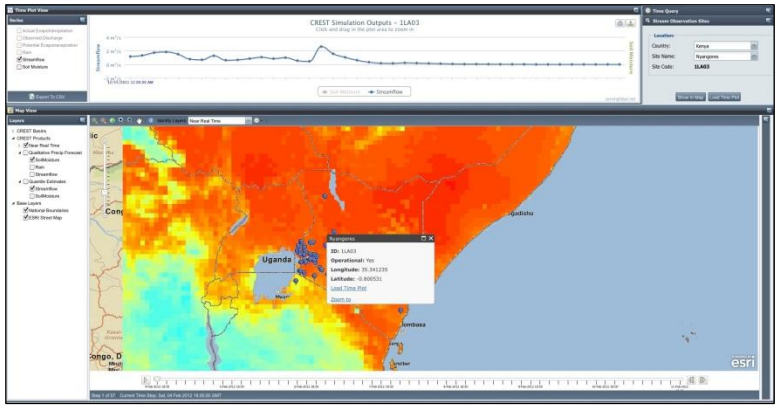
Monitoring Freshwater Lakes

Detecting and Monitoring High Chlorophyll Concentration in the Ocean

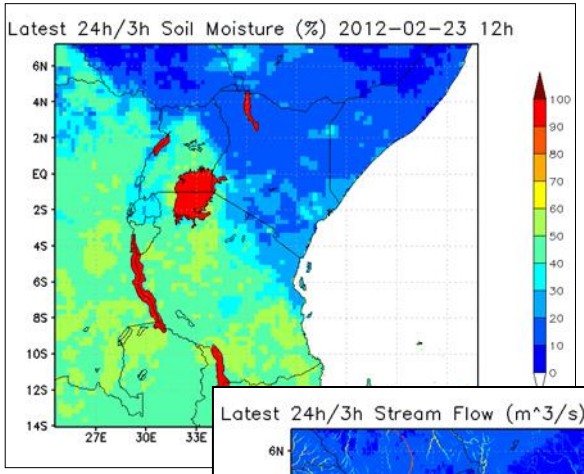


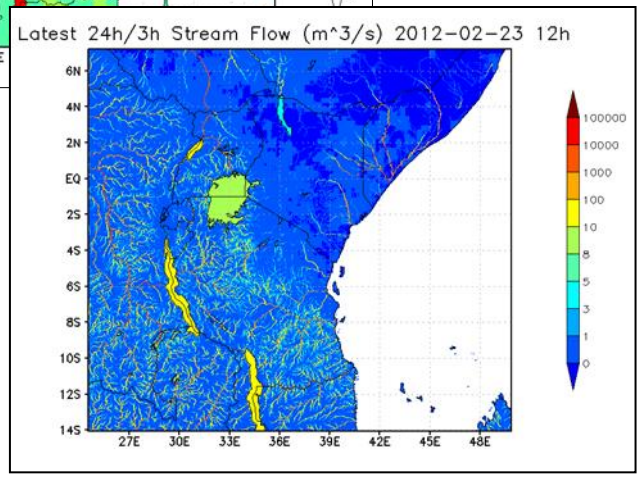
SERVIR-East Africa & Water

Flood Monitoring Tools

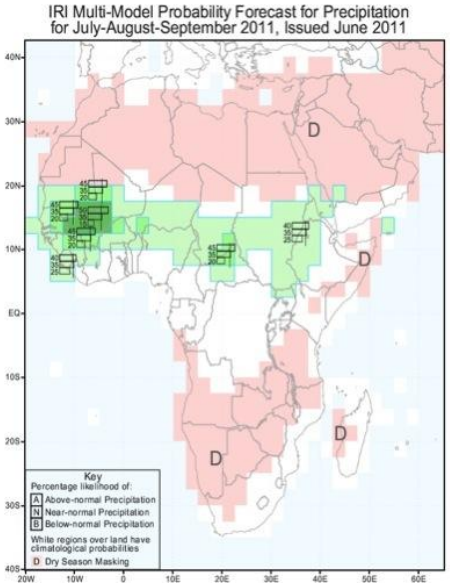


Soil Moisture: Short-Term Forecast



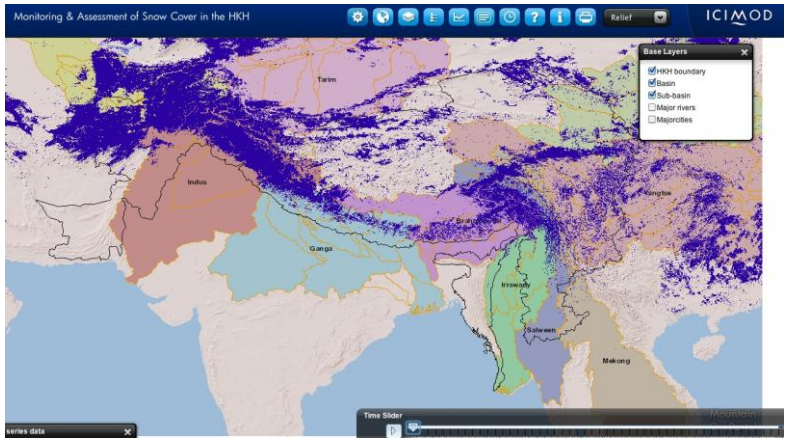


Stream Flow: Historic, Real Time, Short-Term Forecast



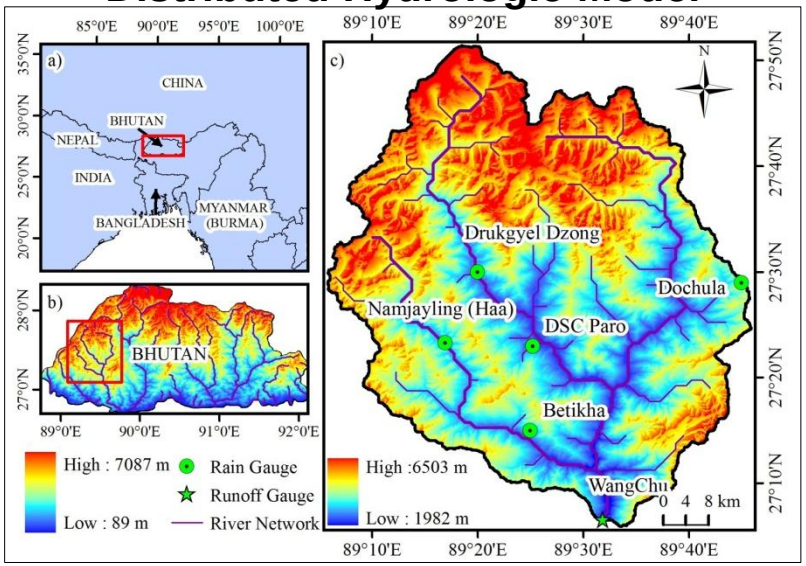
Seasonal Hydrologic Forecasts (future)

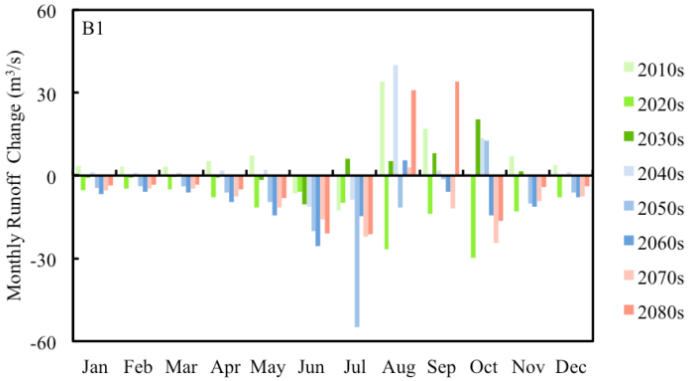
SERVIR-Himalaya & Water



Satellite Derived Snow Cover Datasets Help Decision Makers with Real-time Snowpack Conditions

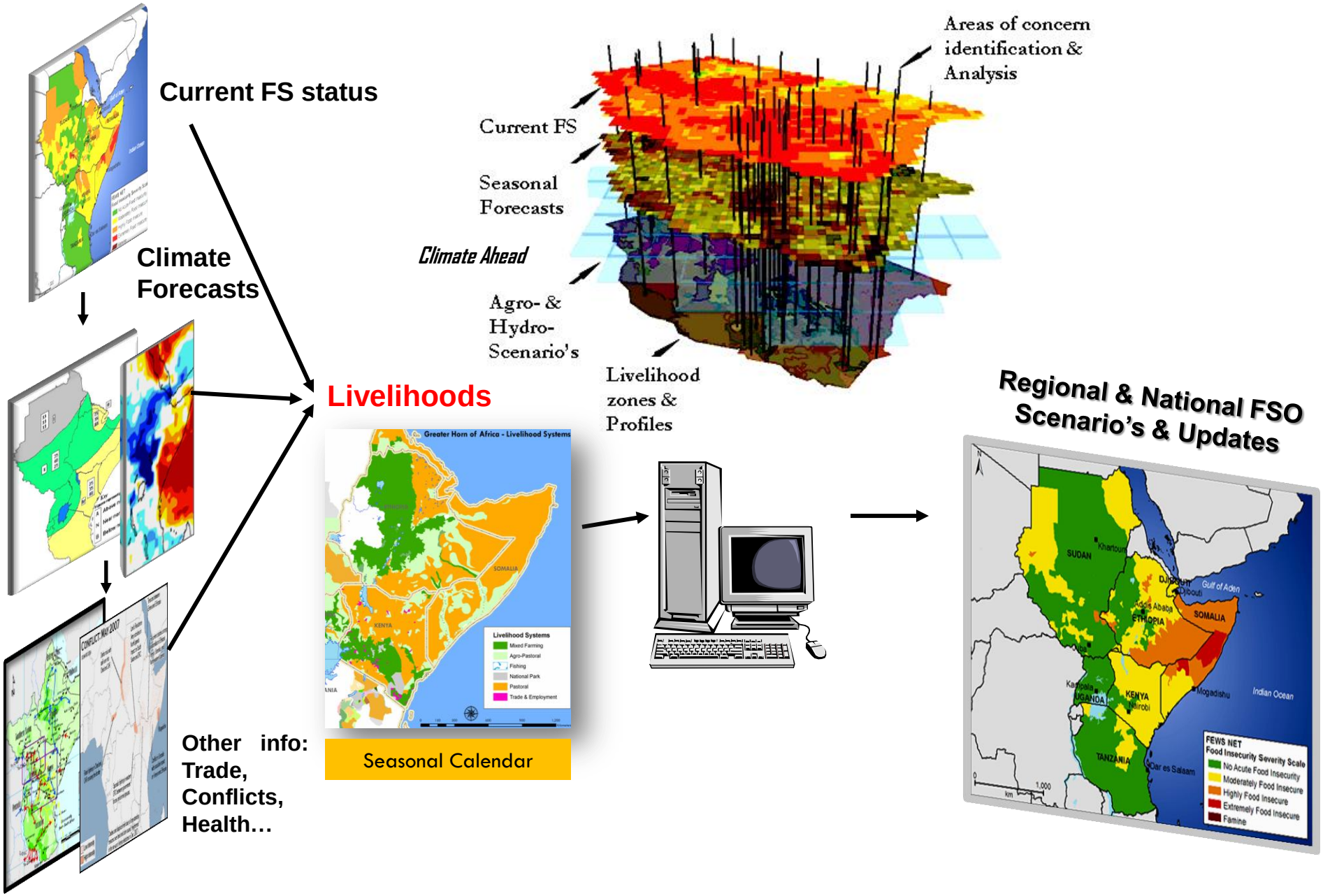
Bhutan Water Resource Assessment using IPCC Climate Change Scenarios and a Distributed Hydrologic Model





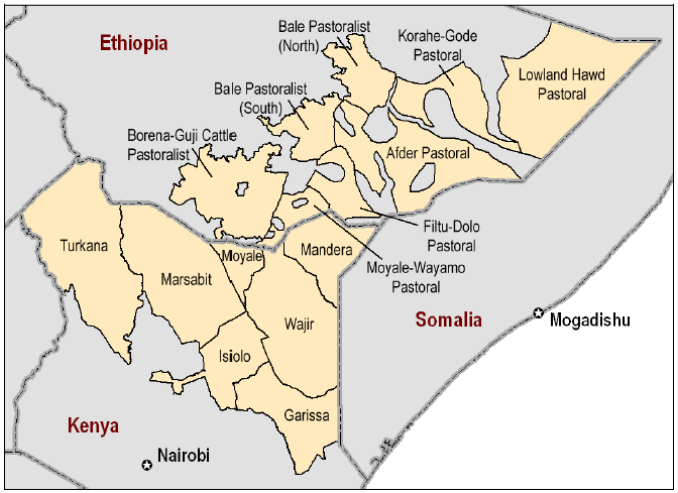
Assisting USAID’s FEWS NET

FEWS NET Food Security Outlooks



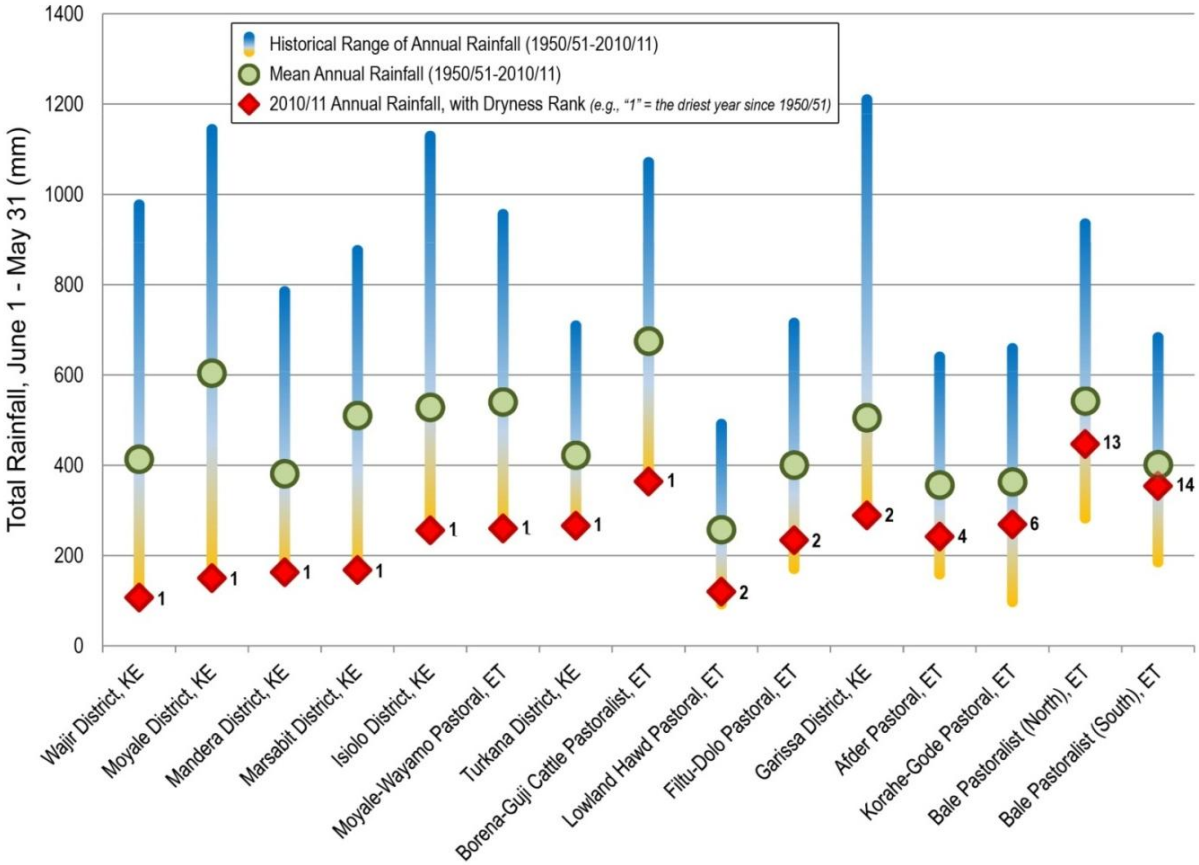
Declaration of Worst Drought in 60 Years

Figure 1. Selected drought-affected pastoral areas of northern Kenya and southern Ethiopia.



Chris Funk, USGS

2010/11 rainfall compared to historical totals since 1950/51 in select pastoral areas of Kenya and Ethiopia

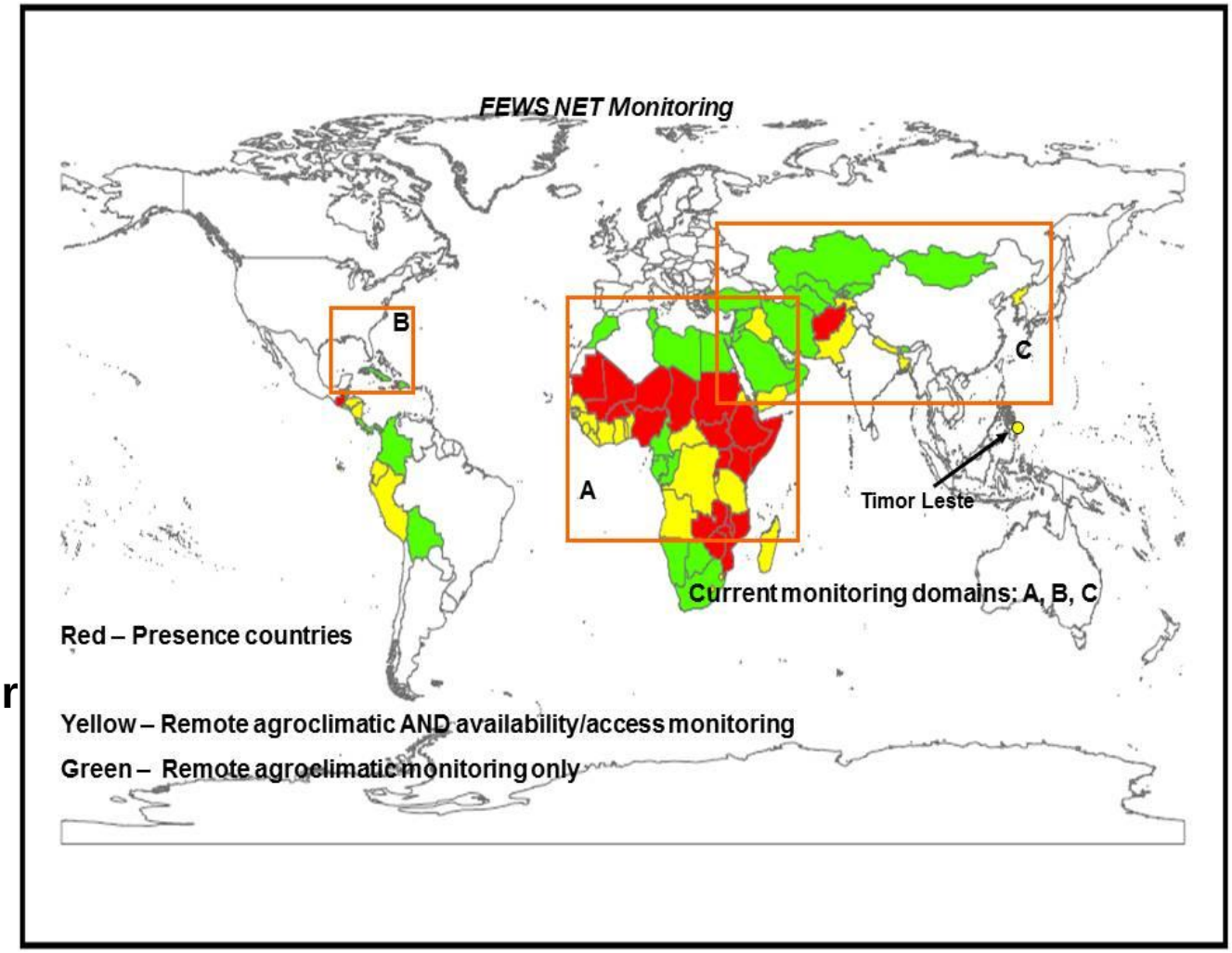


Source: *FEWS NET*

The USAID Famine Early Warning Systems Network

(FEWS NET)

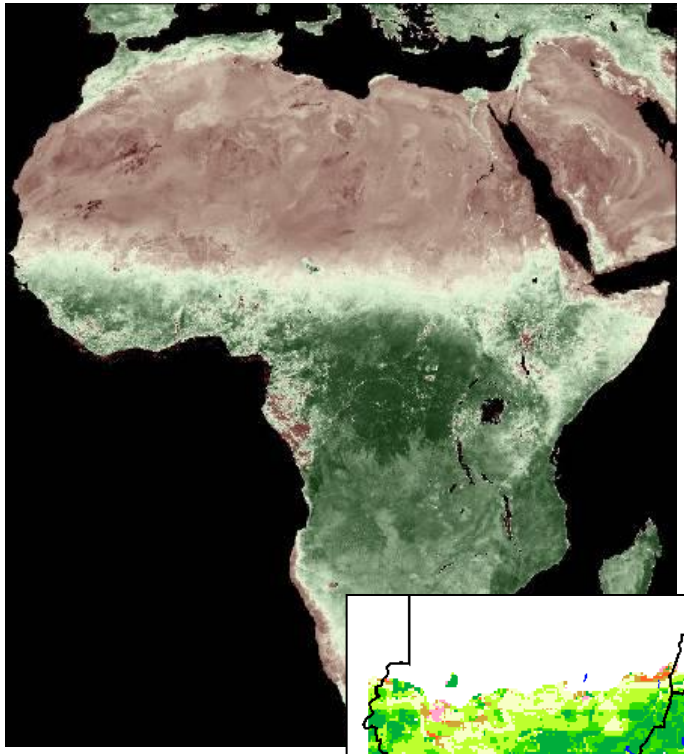
- **FEWS NET is Expanding to many additional Areas beyond Sub Saharan**
- **Remote Sensing and the new Land Information System (LIS) may assist with expansion**
  - ✓ **Satellite Precipitation**
  - ✓ **Satellite Snow Cover and Snow Water Equivalent**
  - ✓ **Satellite Vegetation Greenness**
  - ✓ **Yield Forecasting**



Verdin/USGS

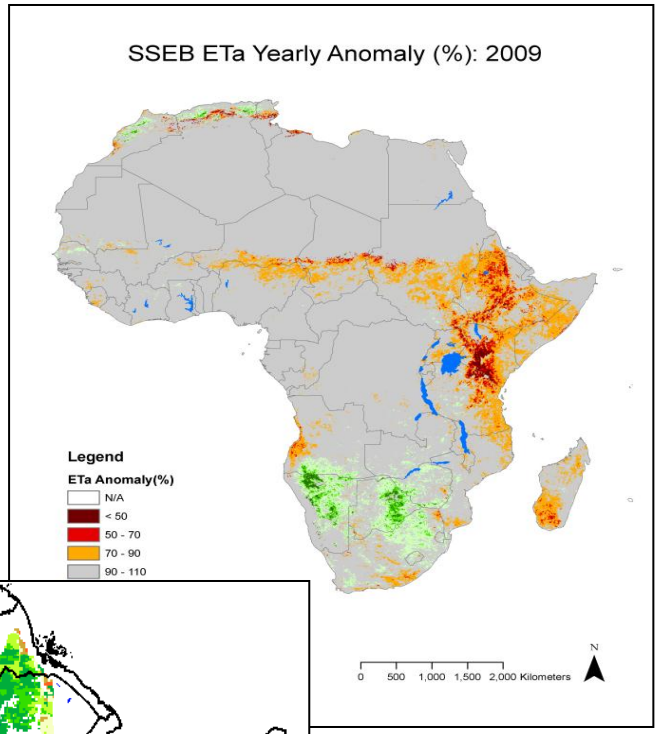
FEWS-NET - Satellite Assisted Data Products

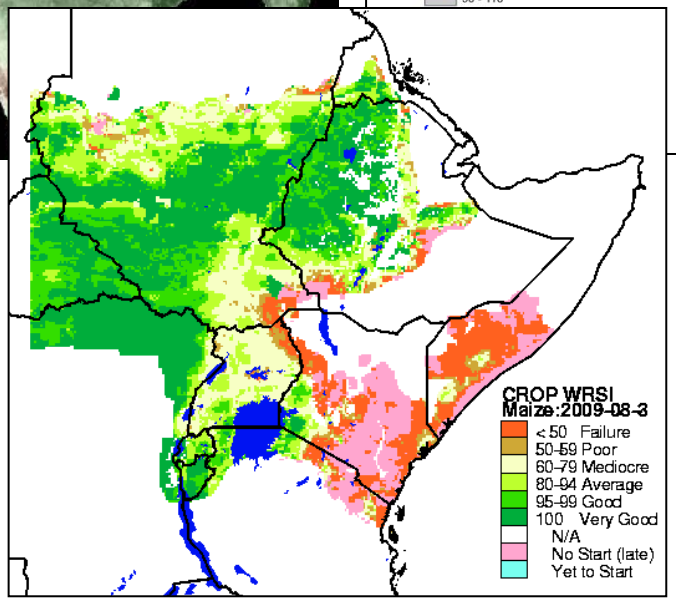
- **Near real time NASA products through 'LANCE'. Every 5 – days, 10 day composites are posted http://earlywarning.usgs.gov/fews/africa/index.php**
- **Vegetation density (NDVI) & precipitation**
- **Evapotranspiration or Consumptive Water Loss**
- **Modeled Food Production**



Near Real time 250m MODIS

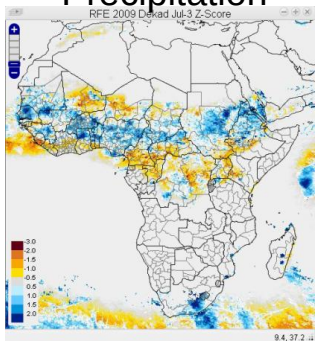
Actual ET from Satellite Data





Water Requirement Satisfaction Index

NASA Satellite Precipitation



Verdin/USGS

Developing Land Information System (LIS) Land Data Assimilation Capabilities

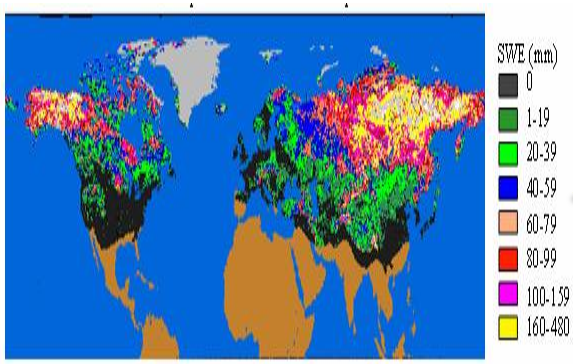
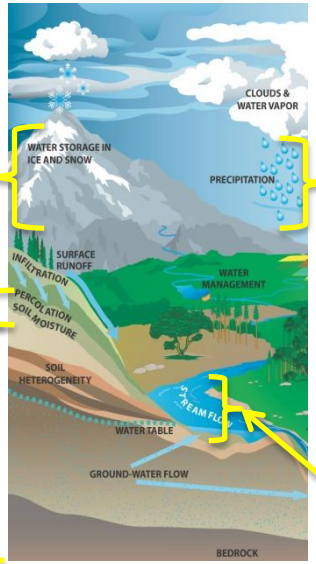


Figure 1: Snow water equivalent (SWE) based on Terra/MODIS and Aqua/AMSR-E. Future observations will be provided by JPSS/VIIRS and DWSS/MIS.



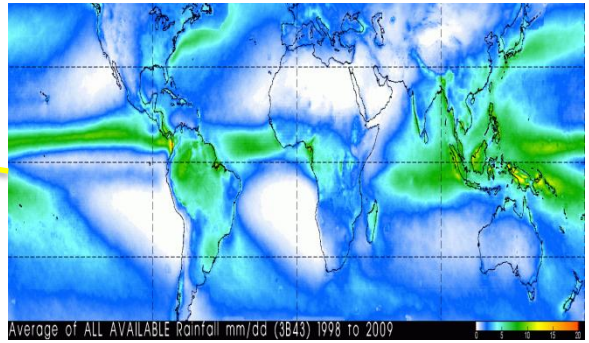


Figure 2: Annual average precipitation from 1998 to 2009 based on TRMM satellite observations. Future observations will be provided by GPM.

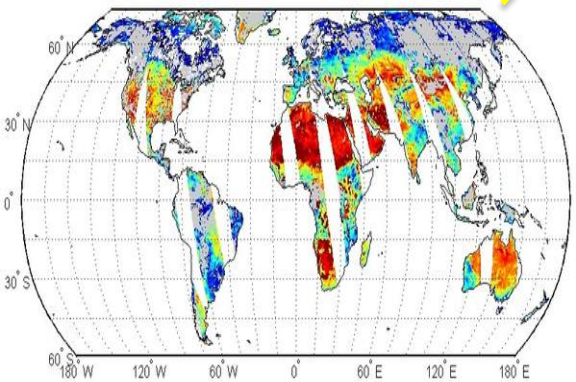


Figure 3: Daily soil moisture based on Aqua/AMSR-E. Future observations will be provided by SMAP.

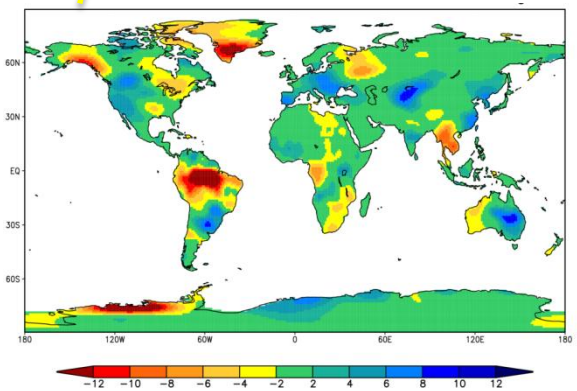


Figure 4: Changes in annual-average terrestrial water storage (the sum of groundwater, soil water, surface water, snow, and ice, as an equivalent height of water in cm) between 2009 and 2010, based on GRACE satellite observations. Future observations will be provided by GRACE-II.

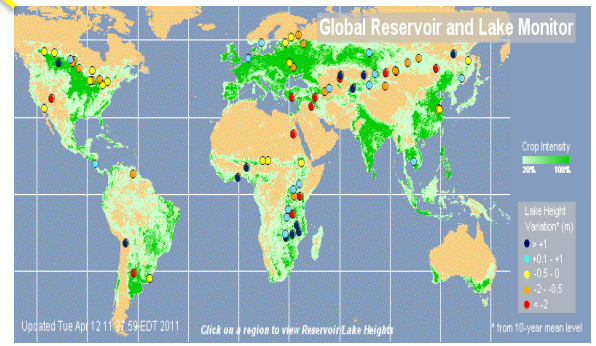


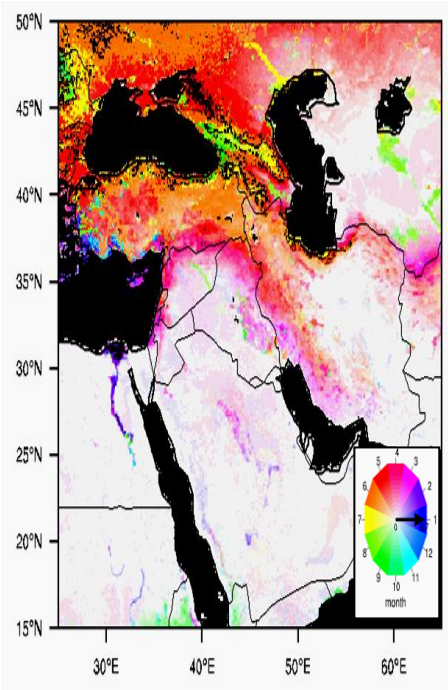
Figure 5: Current lakes and reservoirs monitored by OSTM/Jason-2. Shown are current height variations relative to 10-year average levels. Future observations will be provided by SWOT.

Peters-Lidard, NASA/GSFC

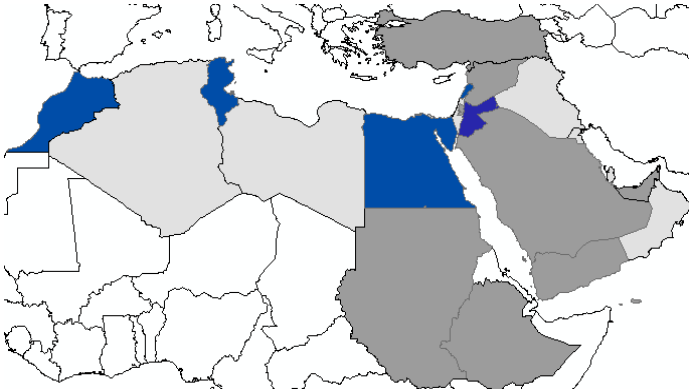
Middle East & North Africa (MENA)
Water Information System Platforms (WISPs)

NASA Water Information System Platforms (WISP's) for the 'MENA'

NASA Partnering with the World Bank, USAID & MENA Countries Using Earth Observation and Modeling Data for the Sustainable Use of Water Resources



Mapping Vegetation and Food Production



5 WISP's Planned for the MENA

Training and Capacity Building

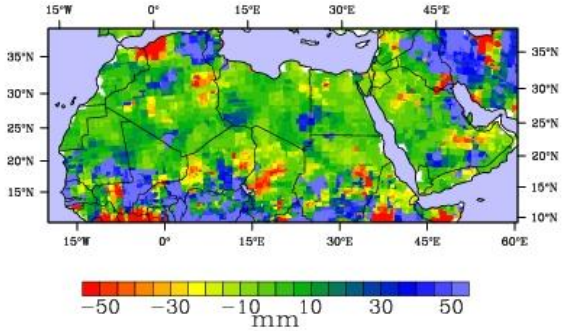
- **Satellite, Modeling, Ground Based Data**
- **Integrative Environmental Systems**
- **Visualizations**
- **Decision Support Tools**
- **Informed Policy Making**
- **Training & Partnership Opportunities**

Expected Outcomes of MENA WISP

1) Regional (1/8°) to local (1km and finer) water availability maps.
2) Monitoring & prediction of drought.
3) Assessment of climate and land use change impacts on water resources.
4) Crop yield and land cover change mapping.
5) Satellite based estimates of irrigation and evapotranspiration.
6) Data on ground water and terrestrial water storage changes.
7) Flood warning and inundation mapping.

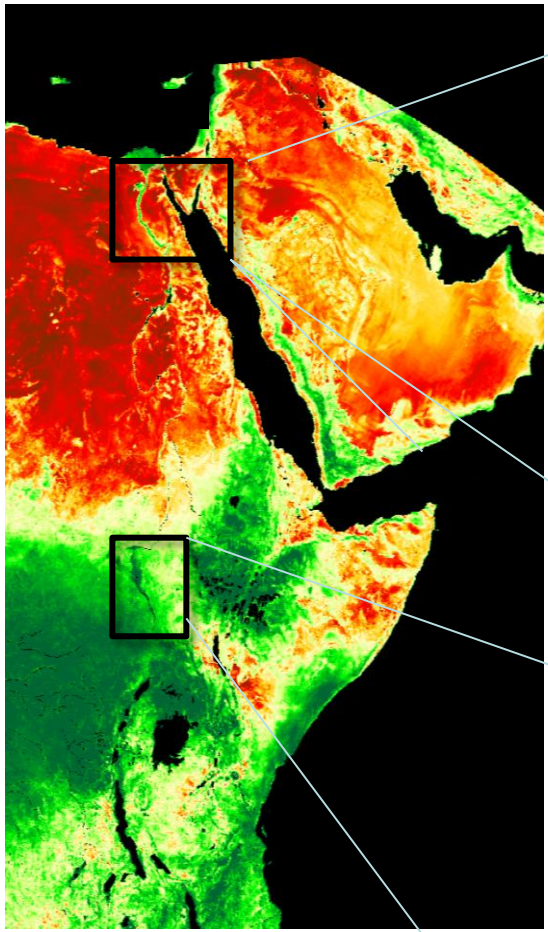
Water Information System Platforms	Egypt	Jordan	Lebanon	Morocco	Tunisia
Evapotranspiration (Consumptive Water Loss)	x	x	x	x	x
Drought	x	x	x	x	x
Flood Detection and Modeling	x			x	x
Climate Impacts	x	x	x	x	x
Irrigation and Crop Mapping		x	x	x	x
Locust Monitoring				x	x
Hydrological Modeling	x	x	x	x	x
Fires	x	x	x	x	x

GRACE Terrestrial Water Storage Changes

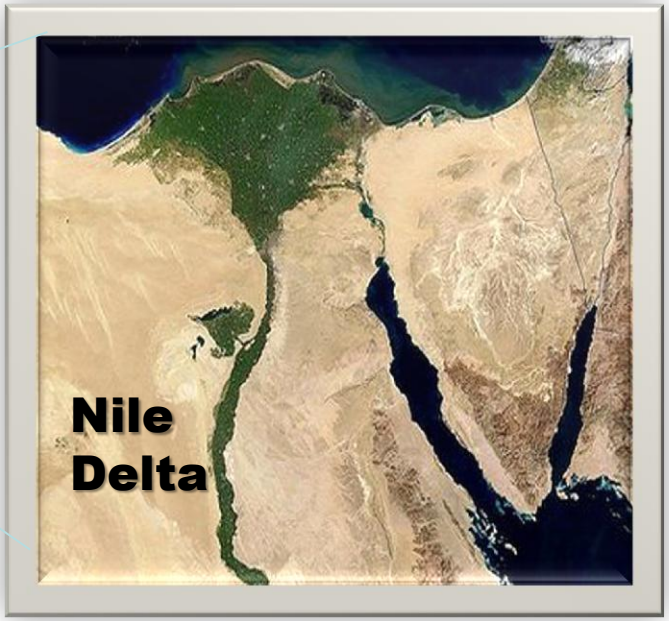


WISP Tools for Consumptive Water Loss (Evapotranspiration) & Drought Monitoring

- Primary emphasis on using from satellite IR data to estimate ET
  - Meteosat (~10 km)
  - MODIS (~1 km)
  - Landsat (~100 m)
- ET monitoring includes consumptive water loss from riparian and agricultural system.
- When normalized with 'Potential ET' provides index of drought
- When combined with modeling and/or 'LDAS' tools are extrapolated temporally.



Drought Index of Actual ET/Potential ET (2007-2010)

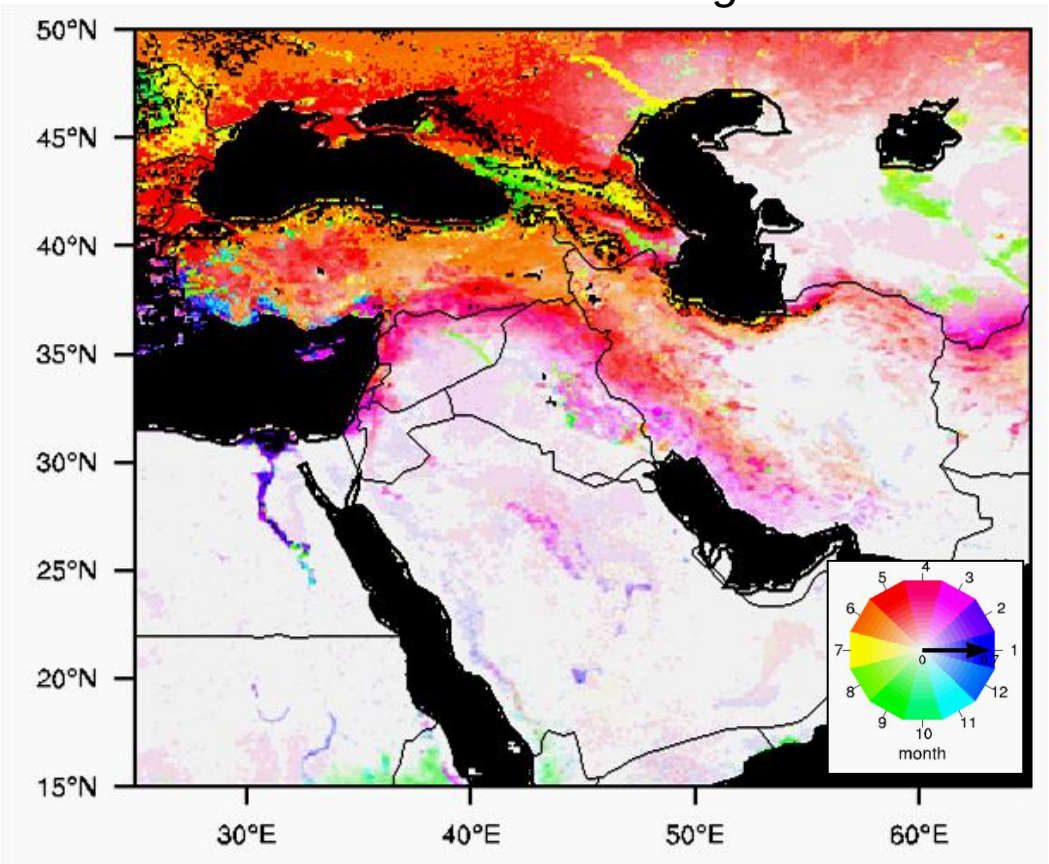


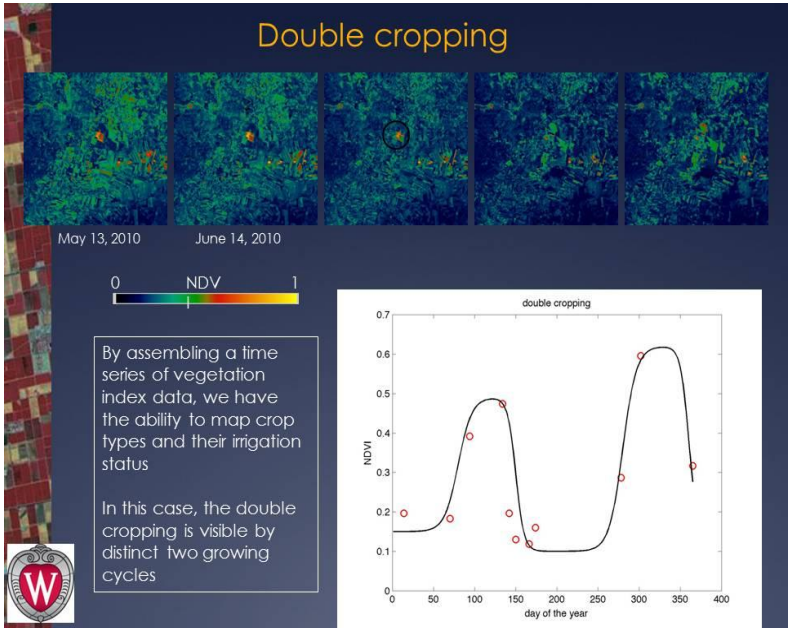
Anderson - USDA

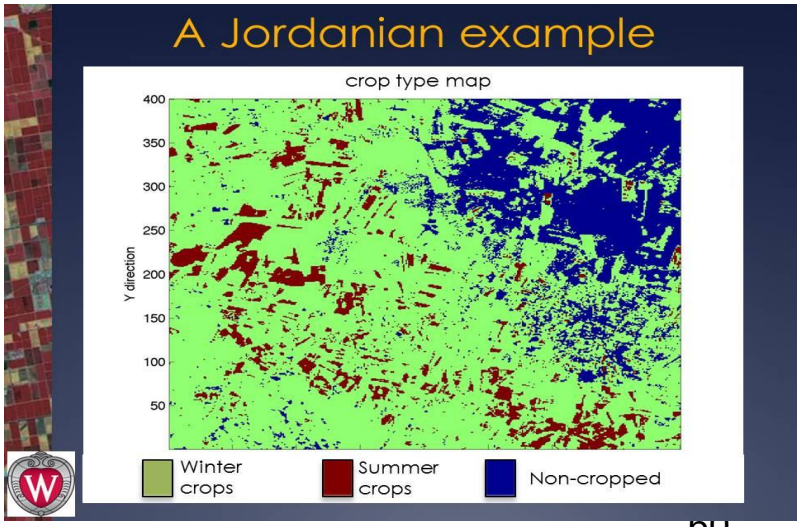
WISP's - Agriculture & Land Cover

Satellite Data Used for Mapping Irrigated Agriculture, Land Use Land Cover and Vegetation Productivity and Biomass

Satellite Vegetation Density for Agriculture and Livestock Monitoring







Zaitchik/JHU & Ozdogan U. Wisc

Side Panel Discussion
Partnering with NASA and others for Improved Water Management

NASA Water Remote Sensing and Modeling Tools are Part of the Solution – Lebanon

Amin Shabab
CNRS, Remote Sensing Center

15 March 2012
World Water Forum

Role of Remote Sensing in Studying Water Resources of Lebanon: Case of Ibrahim River Basin

Amin Shaban, Talal Darwich, Ghaleb Faour

National Council for Scientific Research,
Remote Sensing Center,
Beirut, Lebanon

6th World Water Forum
Marseilles 12-17 March 2012
NASA Side Event Panel to the US Pavilion

This briefly presentation includes:

- Remote Sensing in Lebanon
  - Studies on Water Resources
    - Applications of Remote Sensing on Water Resources

      CNRS, RSC Research Projects & Publications

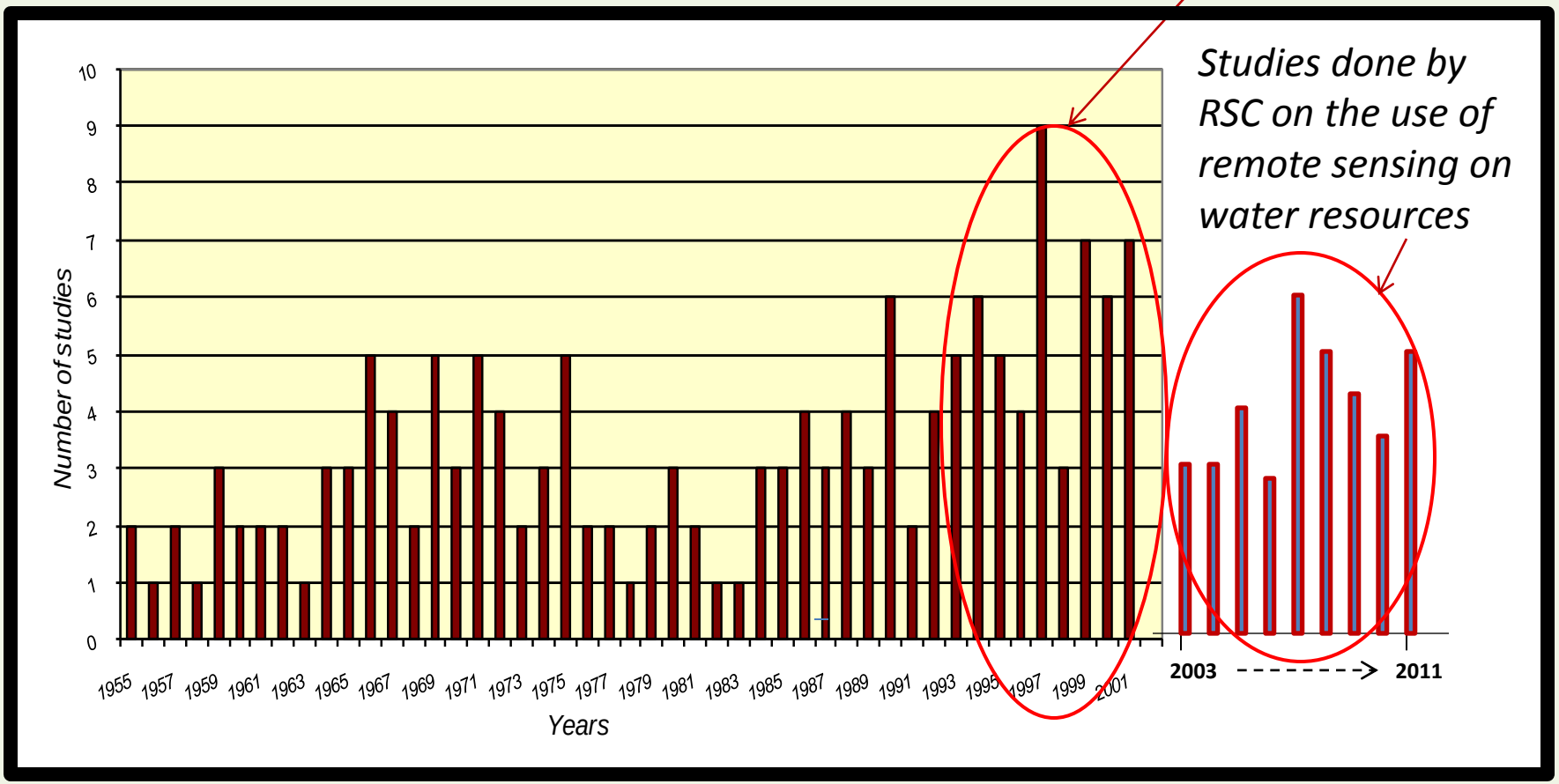
      Available tools and facilities
    - Water Problems in Lebanon
      - Case Studies (Typical Watershed)
      - Perspectives (GEF Project)

Remote Sensing in Lebanon

- Except aerial photos (1960s), there was no remotely sensed data in Lebanon before the beginning of 1985s.
- In the early of 1995 the Remote Sensing Center (RSC) was established as a part of the Lebanese National Council for Scientific Research.
- The center represents the major pillar of space science and remote sensing applications in Lebanon.
- Different applications on the use remote sensing have been done in some universities and institutes. However, they often cooperate with RSC..
- The RSC obtained many studies and introduced valuable contribution to the Lebanese society .
- There is impatience to rank the RSC as a Center of Excellence .

Studies on Water Resources in Lebanon

This includes: watershed management approaches, monitoring groundwater flow and storage, identifying hydro-geological features, groundwater exploration, assessing surficial processes, etc.



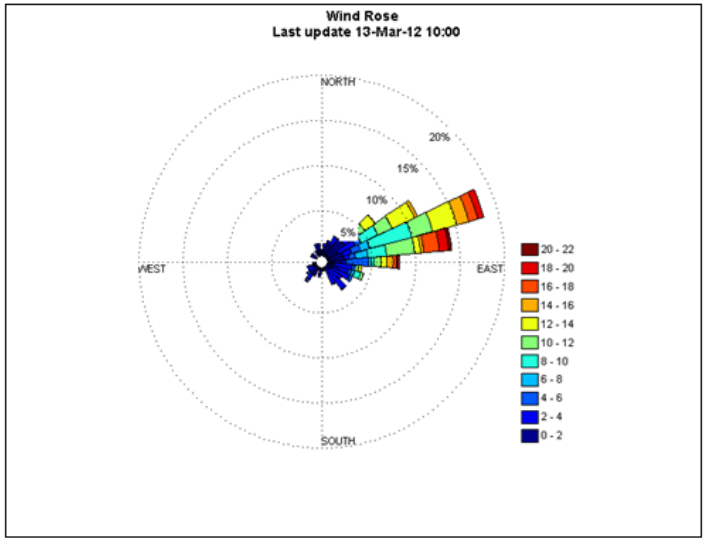
Achieved Projects on Water Resources

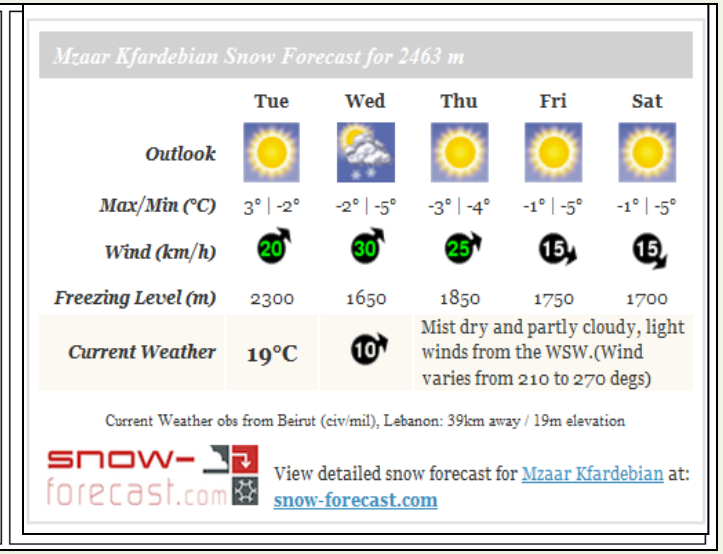
Project Title	Duration	Partners	Source of Funds
Airborne Thermal Infrared Survey to Identify Submarine Springs along the Northern Coastline of Lebanon	1997-2000	CNRS, GORS (Syria) , Ministry of Water Resources	Ministry of Water Resources
Assessment of Natural Resources in the Karstic Coastal Mediterranean	1998-2001	Mediterranean countries	European Commission
Application of Remote Sensing in Studying the Hydrogeology of Occidental Lebanon	2000-2002	CNRS, GORS,	CNRS, GORS,
Design a Co-operative Ecosystem Management Protocol for the Sustainable Development of the Akkar Watershed of Lebanon and Syria	2001-2003	IDRC (Canada), CNRS, GORS	IDRC
Sustainable Management of Scarce Resources in the Coastal Zones	2002-2006	Mediterranean countries	European Commission
Towards an Ecosystem Approach to the Sustainable Management of the Litani Watershed	2003-2007	IDRC, CNRS, LRA, DSA	IDRC

On-going projects on Water Resources

Project Title	Duration	Partners	Source of Funds
Mapping Watersheds for Sustainable Management in Lebanon	2007 - to date	CNRS	CNRS
Using Satellite Images to Monitoring Snow Cover Dynamics on the Lebanese Mountains	2008 - to date	CNRS	CNRS
In-Situ Investigation to Measure Snow Water/Equivalent in Mount Lebanon	2010 - to date	CNRS, IRD/CESBIO (France)	CNRS, IRD/CESBIO
Agriculture paysages dans la montagne libanaise a'l'Holocene : protection et durables des ressources naturelles en sol et en eau	2010 - to date	CNRS, CNRS, Toulouse	Program CEDRE
Investigation of Climatic and Hydrological Trends in Lebanon: Implications with Water Resources Management	2012-2013	CNRS, CNR (Italy)	CNRS, CNR

Example from CESIBO project (Data acquired from climatic station)



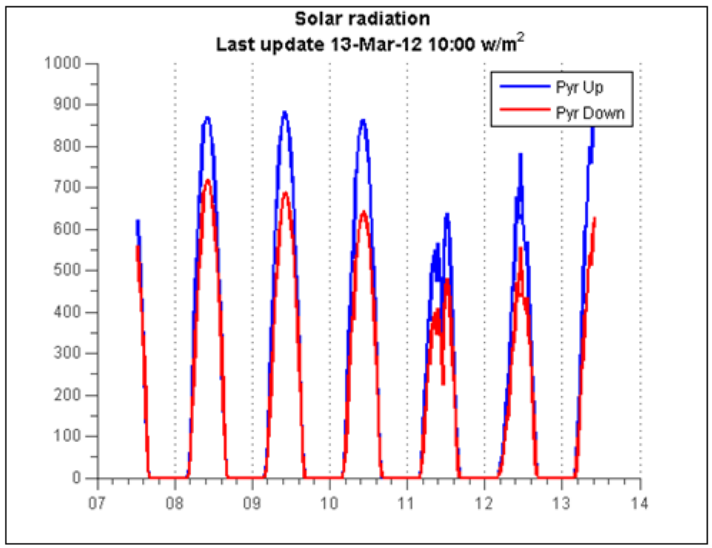


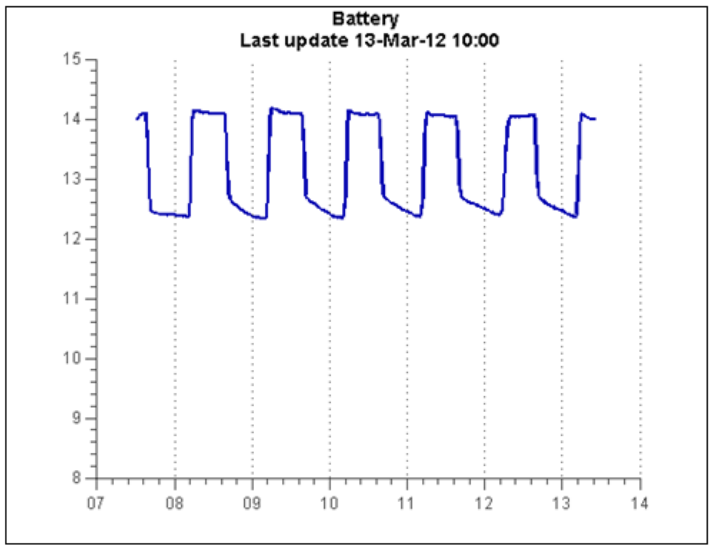
Mzaar Kfardebian Snow Forecast for 2463 m

	Tue	Wed	Thu	Fri	Sat
Outlook					
Max/Min (°C)	3° | -2°	-2° | -5°	-3° | -4°	-1° | -5°	-1° | -5°
Wind (km/h)	20	30	25	15	15
Freezing Level (m)	2300	1650	1850	1750	1700
Current Weather	19°C	10	Mist dry and partly cloudy, light winds from the WSW.(Wind varies from 210 to 270 degs)		

Current Weather obs from Beirut (civ/mil), Lebanon: 39km away / 19m elevation

View detailed snow forecast for Mzaar Kfardebian at: snow-forecast.com

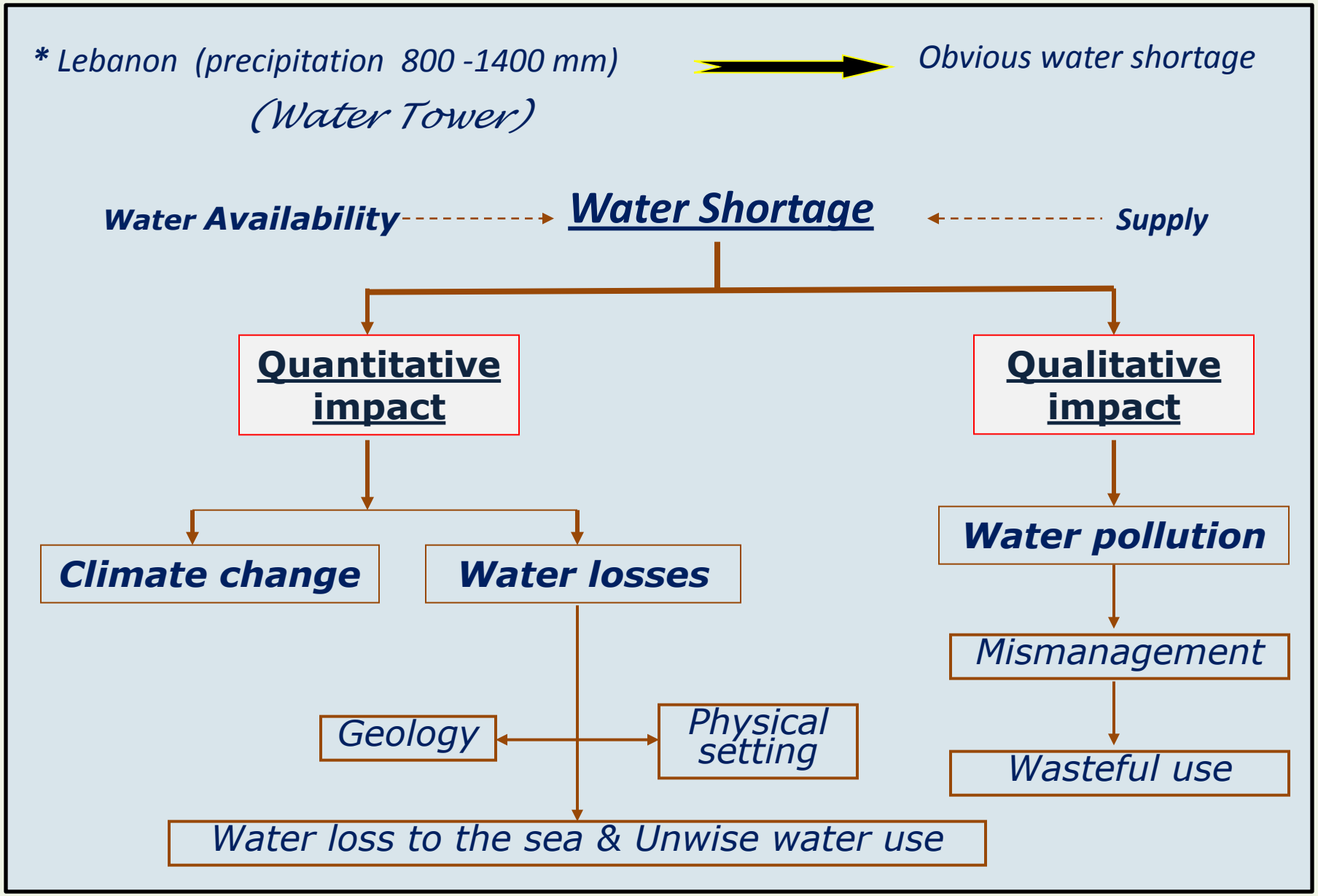




Achieved Researches on Water Resources (examples)

Study	Year	Publisher
Analyzing Climatic and Hydrologic Trends in Lebanon	2011	*Journal of Environmental Science and Engineering*
Support of space techniques for groundwater exploration in Lebanon	2010	*Journal of Water Research & Protection*
Using MODIS Images & TRMM data to correlate rainfall peaks and water discharges from the Lebanese coastal rivers	2009	*Journal of Water Research & Protection*
The relation between water-wells product & lineaments morphometry: Selected zones from Lebanon	2007	*Nordic Hydrology*
Lineament analysis through remote sensing as a contribution to study karstic caves in Occidental Lebanon	2006	*Revue Photo-interprétation*
Use of RS and GIS to determine recharge potentail zones: the case of Occidental Lebanon	2006	*Hydrogeology Journal*
Geologic controls of submarine groundwater discharge: applic ation of remote sensing to North Lebanon	2005	*Environmental Geology*
Remote Sensing application to estimate the volume of water in the form of snow on Mount Lebanon	2004	*Hydrological Sciences Journal*

Water Problems in Lebanon



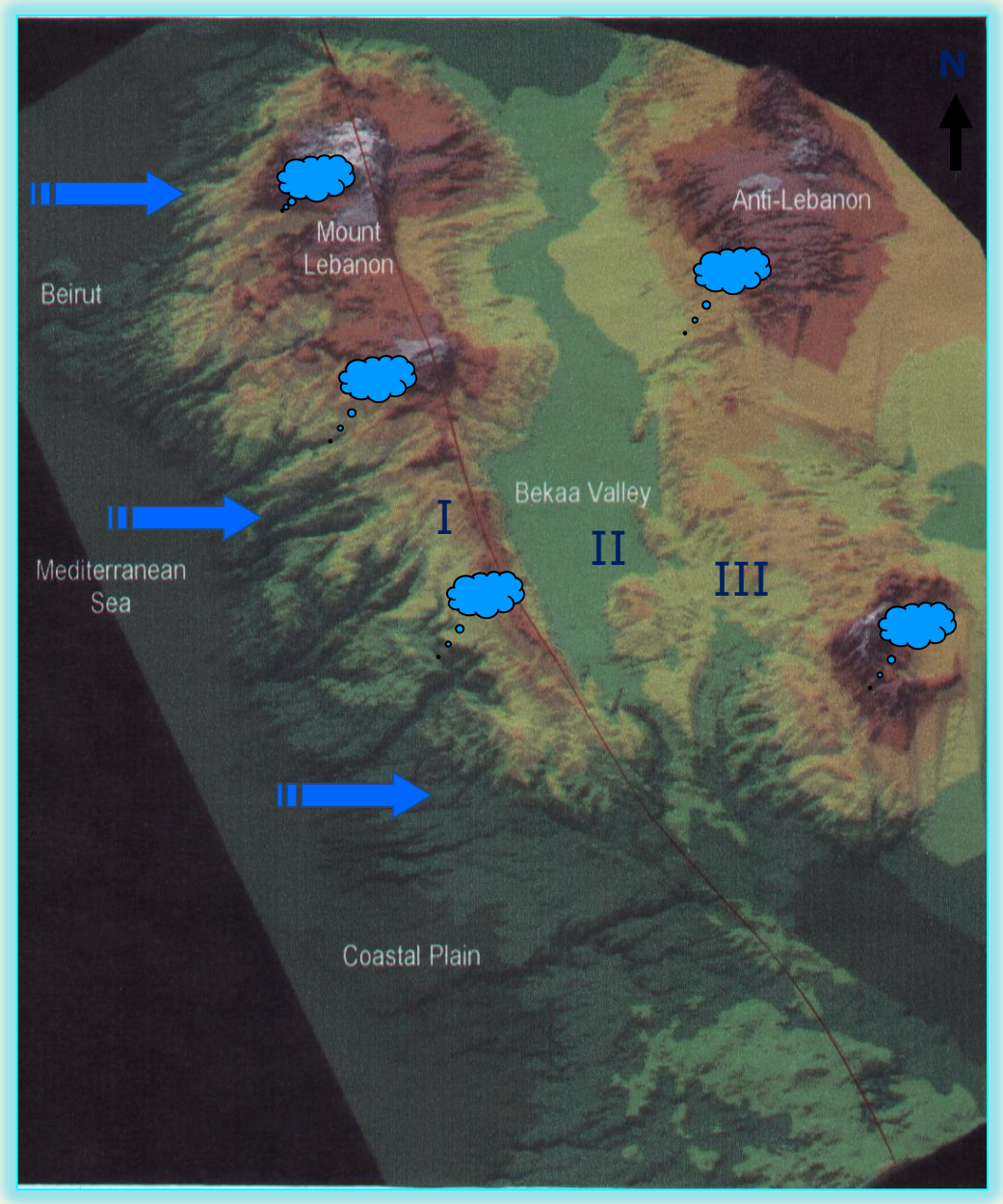
Physical characteristics (example)

-Precipitation

(800-1400mm)

-Snow covers

~2200 km²
(22%)

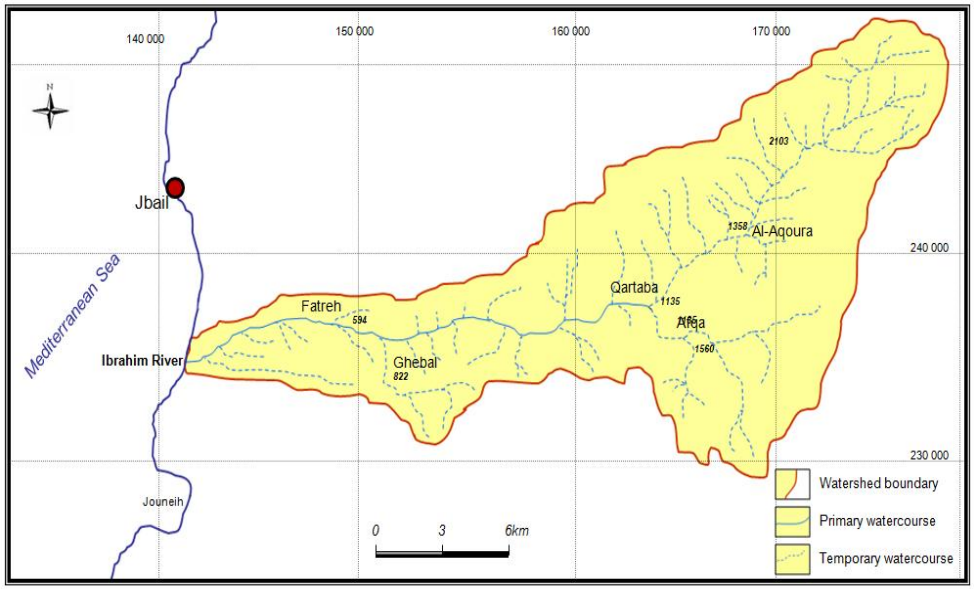


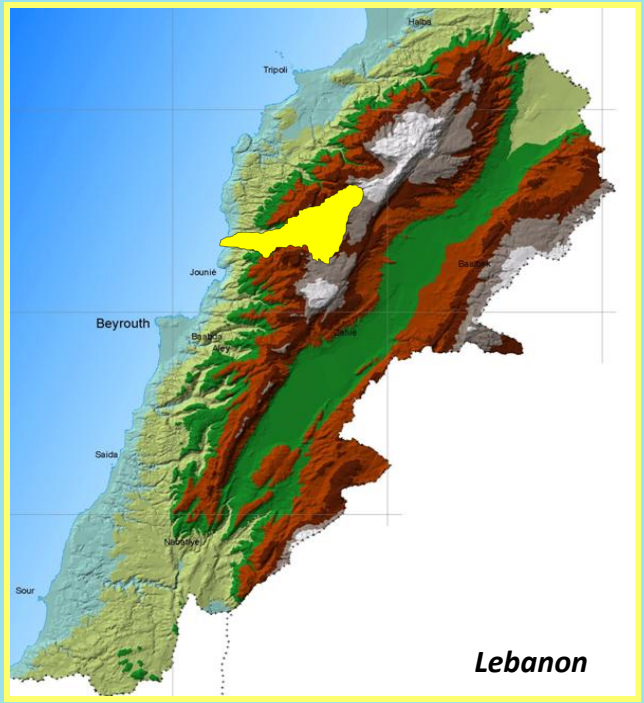
-Extensive fault and fracture systems

-Steep sloping terrain

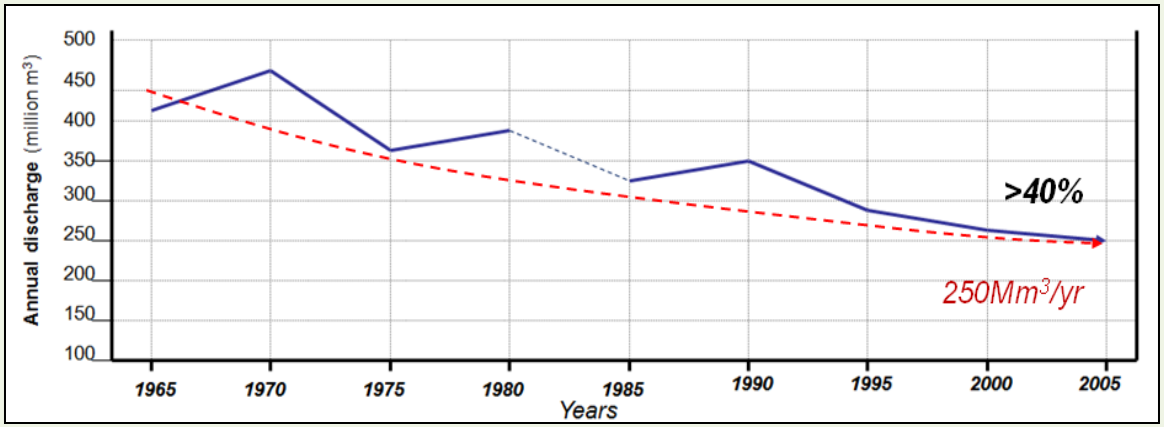
Case-study, Program CEDRE on a typical coastal Basin

Ibrahim River Basin





- **This basin has been subjected to several physical and anthropogenic changes and its discharge has been decreased by more than 40%.**



Amin Shaban

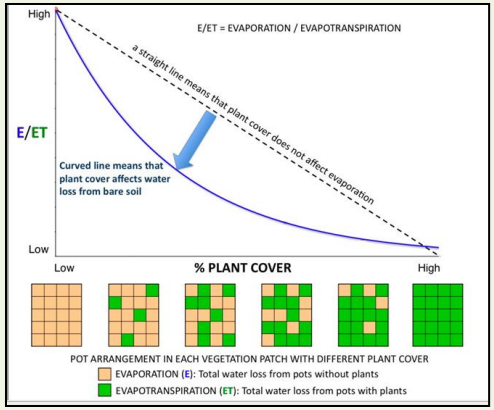
Ibrahim River Basin (Case-study)

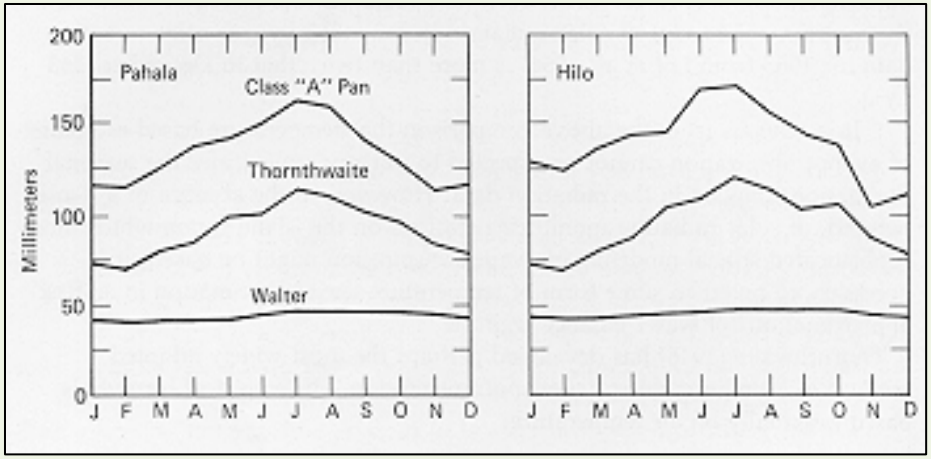
- **For Ibrahim River basin, there are several erroneous results in calculating water balance, assessing water flow, measuring snowmelt contribution, etc**

- **The need to use Remotely Sensed data was very crucial to build up a clear and comprehensive figure on water resources of the basin, as well as to study other related components (forests, agricultures, natural hazards, etc)**

Water Balance

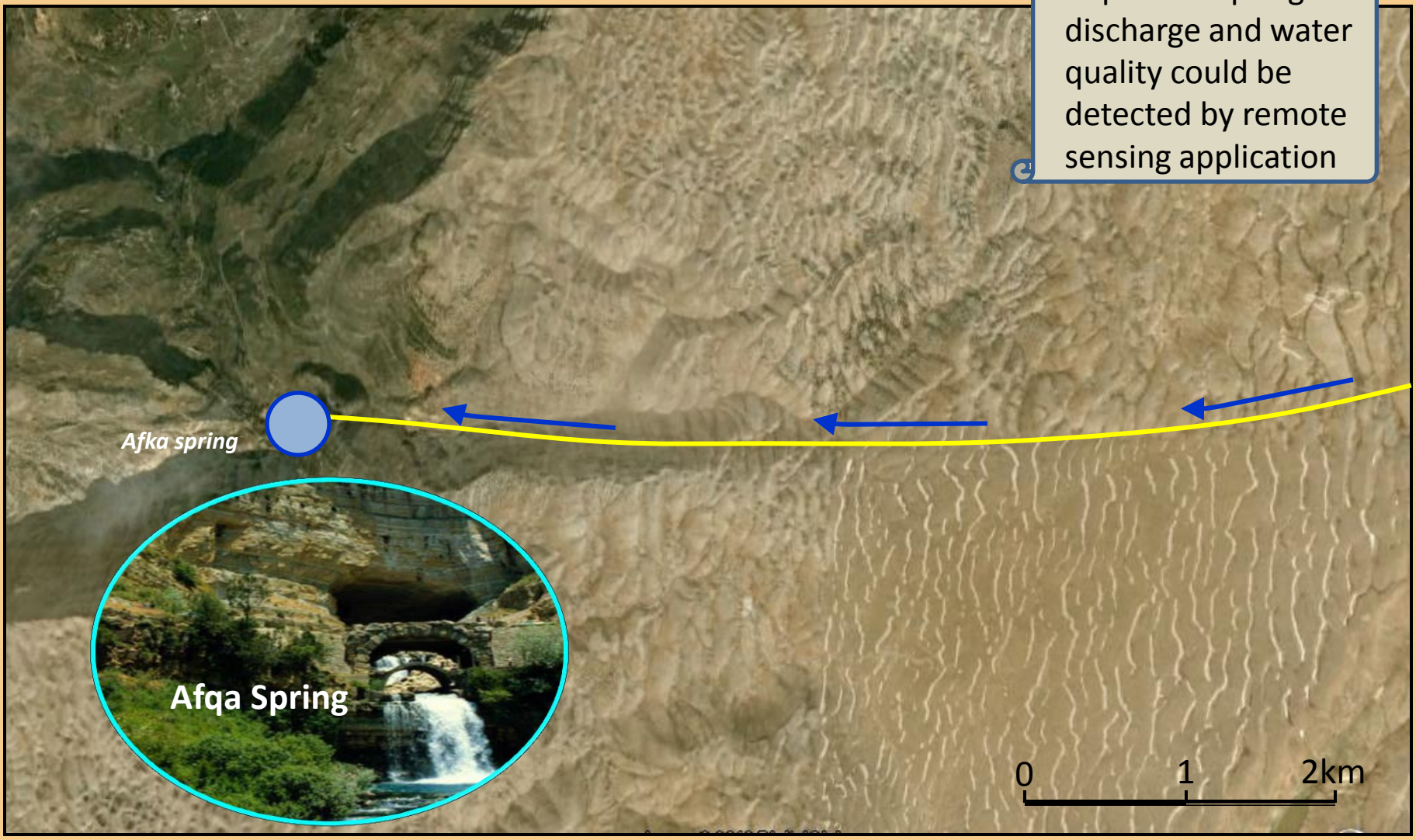
Input 163 Mm^3/yr ⇨ Output 250 Mm^3/yr





Ibrahim River Basin (Case-study)

Impact on springs discharge and water quality could be detected by remote sensing application



Ibrahim River Basin (Case-study)

- **A research project has been applied on Ibrahim River Basin** *(funded by CEDRE Program).*

- **The role (& need) for remote sensing applications was integral to accomplish the project.**

- **Title:** ***AGRICULTURE ET PAYSAGES DANS LA MONTAGNE LIBANAISE Al'HOLOCENE : PROTECTION ET GESTION DURABLE DES RESSOURCESNATURELLES EN SOL ET EN EAU***

- **Objectives:**

1. Appréhender l'histoire holocène de la couverture sédimentaire et des sols

2. Caractériser l'occupation du sol et son impact sur les ressources en sol et en eau

3. Reconstituer les paléoenvironnements des agrosystèmes montagnards et leursmutations jusqu'à l'actuel

Perspectives

How can we benefit from GEF/WB/USAID/NASA Project

1. Hydrological Measures

- **Evapotranspiration** (instrumentation & remotely sensed data)
- **Recharge potential** (remotely sensed data)
- **Water quality** (remotely sensed data)
- **Water discharge** (instrumentation)

2. Agricultural Measures

- **Crop yield and biomass production** (instrumentation & remotely sensed data)
- **Water consumption** (remotely sensed data)
- **Water retention** (remotely sensed data)
- **Soil salinity** (remotely sensed data, laboratory training)

Perspectives

How can we benefit from GEF/WB/USAID/NASA Project

3. Climatic Measures

- **Rainfall data** **(remotely sensed data)**
- **Snow cover** **(remotely sensed data "satellite images")**
- **Surface temperature** **(remotely sensed data)**
- **Drought monitoring** **(instrumentation, remotely sensed data)**
- **Climatic extremes** **(remotely sensed data)**

4. Related issues

- **Forest fire**
- **Natural hazards**
- **Geological applications**

Remotely sensed data *(sequential)*

Thank You

NASA Water Remote Sensing and Modeling Tools are Part of the Solution

- **$1.7 Billion (2011) NASA budget supports Earth science and remote sensing technology**
- **NASA has a strong free and open exchange of data that boundaries promoting data sharing.**
- **Several new planned satellite missions, including the hydrologic missions – 'SMAP', ;GPM', GRACE Follow On, 'SWOT' & 'ICESAT-II'**
- **NASA Applied Sciences Program: Spinoff NASA remote sensing for societal benefit**
- **Water Resources – numerous U.S. and international projects across 5 functional themes**
  1) Drought, 2) Streamflow, 3) Water Quality, 4) Consumptive Water Loss (ET) & 5) Climate Impacts
- **Although NASA and related information are free we need:**
  1) **Optimization and close collaborations between end users and data providers**
  2) **Assimilation and Integration of remote sensing to be effectively used in decision making**
- **Optimal way is to have collaborative relationships with partnering groups such as NASA, USAID, the World Bank and end user groups.**

  - Example collaboration is our NASA-World Bank-USAID Water Information System Project in the 'MENA' in collaboration with groups such as CNRS at Lebanon.

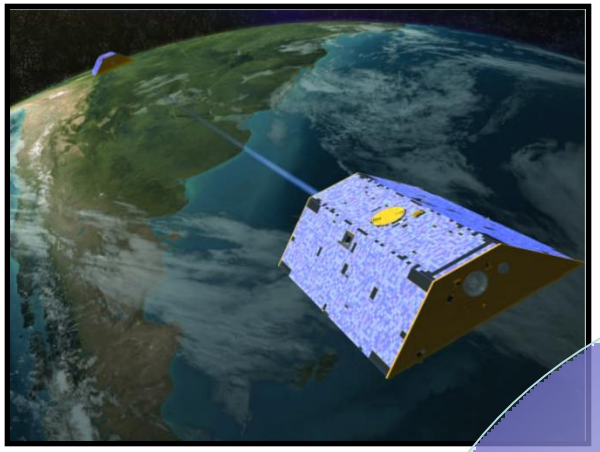
NASA WATER SCIENCE & APPLICATIONS

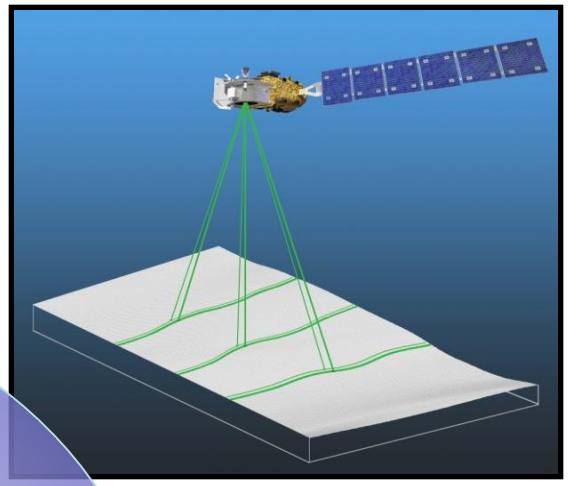
NASA'S EARLY ADOPTERS

VANESSA M. ESCOBAR
NASA/GSFC

BRIDGING SCIENCE AND SOCIETY FOR REAL WORLD APPLICATIONS

In case of Emergency
Break Tradition

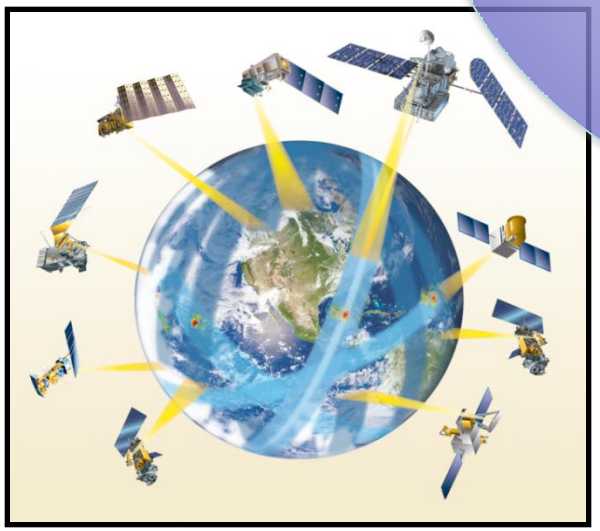


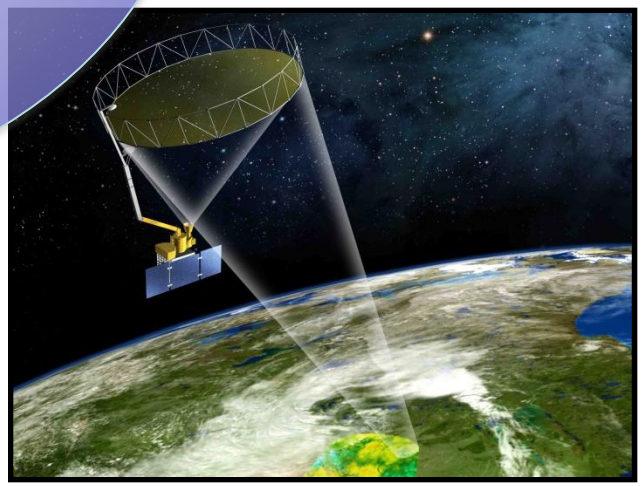


Significant effort is being being made to engage user communities BEFORE missions are lunched so data products include societal feedback

Joint Mission Focus sessions

Early Adopter Research





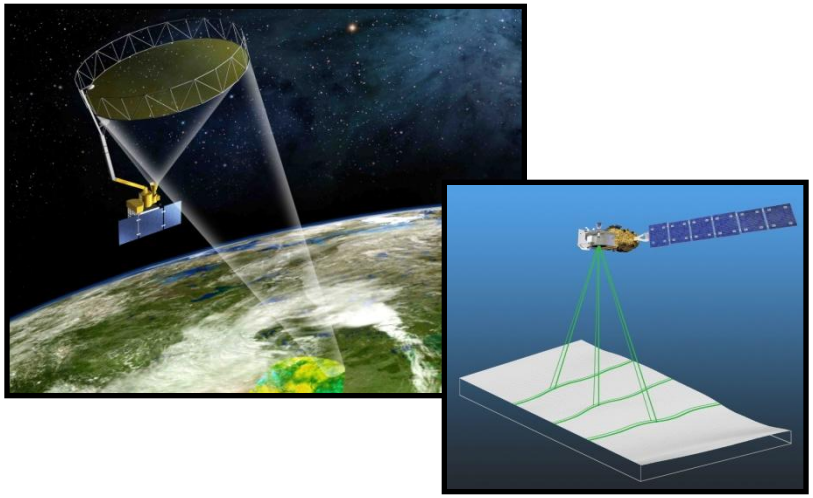
Early Adopter Program

Goal: To conduct pre-launch applications research to accelerate the use of mission products after the launch.

Target Early Adopters as mission pioneers of pre-launch product application. Use feedback for:

- Lessons learned
- Improvements to data distribution and management
- Suggestions for success to guide SDT into final algorithm design
- Continuing research and collaboration
- ***15 SMAP Early Adopters have been selected since October 2010.***

Through a Signed Agreement:



The SMAP Project will

- Provide Early Adopters with simulated SMAP data products; and/or with planned pre-launch calibration and validation cal/val data from SMAP field campaigns, modeling, and synergistic studies.

The Early Adopter will

- Engage in pre-launch research;
- Complete the project with quantitative metrics prior to launch; and
- Join the SMAP Applications Team.

Early Adopters are those groups or individuals who have a clearly defined need for SMAP-like soil moisture or freeze/thaw data and who are planning to apply their own resources to demonstrate the utility of SMAP data for their particular system or model.

Give Feedback to the SMAP Mission before it Launches:

http://smap.jpl.nasa.gov/science/wgroups/applicWG/

The Early Adopter Program is about relationships and communication

Contributions from the user communities are essential for mission success

GOALS OF WATER FORUM

GOALS OF NASA

- **Build and strengthen** institutional and human capacity at all levels(local, national and regional)
- **Increase** and better coordinate **diplomatic efforts**
- Mobilize financial support by **identifying avenues for support**
- Promote Science and technology-**share** U.S expertise
- **Build** and strengthen **partnerships** (you've heard a few today)

Three Goals to Accomplish Today

1. Make you aware of the changes NASA is making in mission development-*get involved in MISSION APPLICATIONS*.

2. Give you the data and expertise needed to answer societal questions-*Offer Data and Collaboration*

3. Facilitate a 2 way dialog between the scientist and the user communities so NASA can be better applied to the challenges you defined today- *Strengthen Relationship*

Give Feedback to the SMAP Mission before it Launches:
http://smap.jpl.nasa.gov/science/wgroups/applicWG/

Tell us HOW you plan to use Soil Moisture Data
https://www.surveymonkey.com/s/GRTXZJR

Questions and Contributions?

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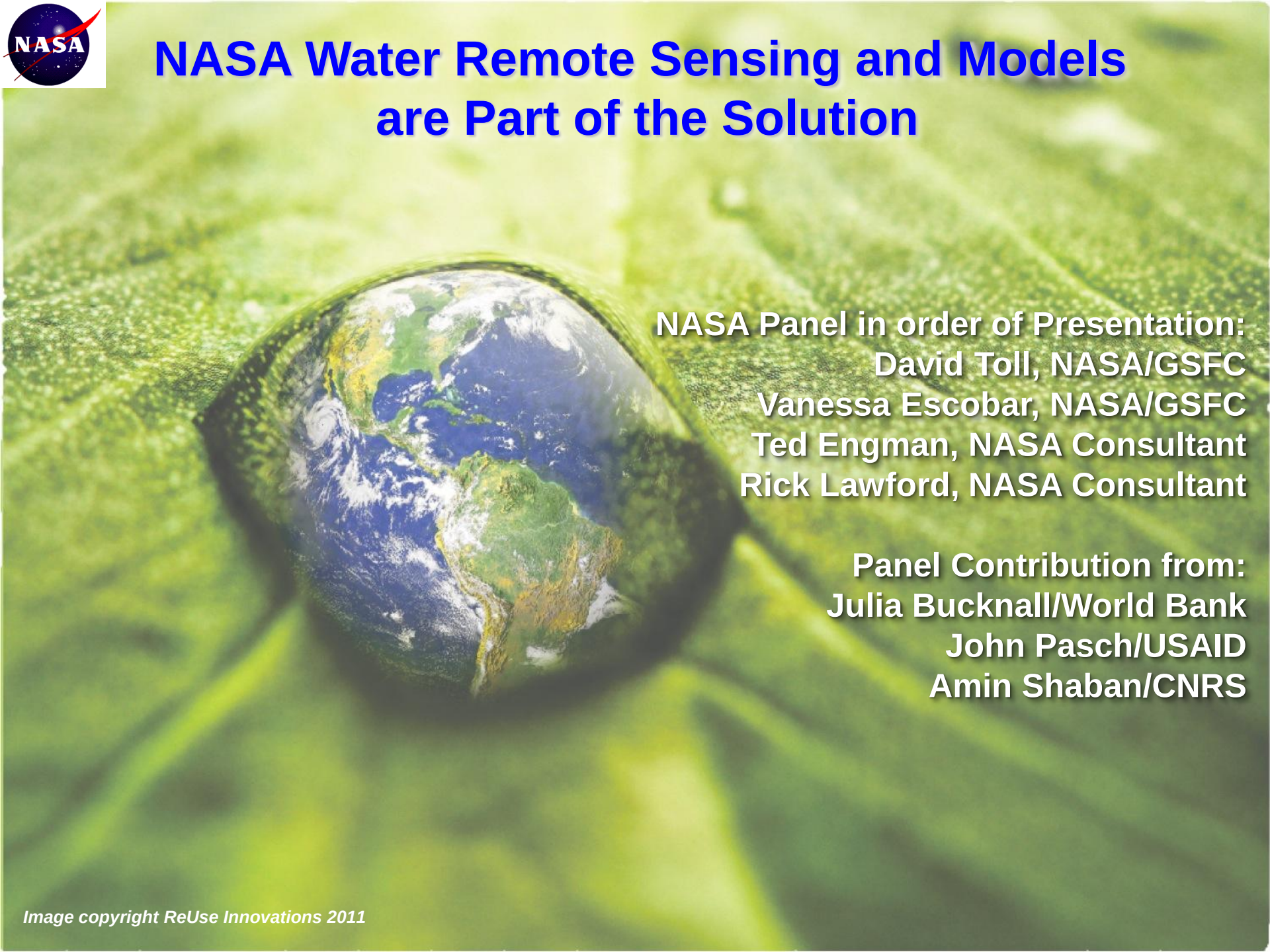
NASA Water Remote Sensing and Models are Part of the Solution



NASA Panel in order of Presentation:
David Toll, NASA/GSFC
Vanessa Escobar, NASA/GSFC
Ted Engman, NASA Consultant
Rick Lawford, NASA Consultant

Panel Contribution from:
Julia Bucknall/World Bank
John Pasch/USAID
Amin Shaban/CNRS

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