WELCOME TO
NASA APPLIED REMOTE SENSING TRAINING (ARSET)
WEBINAR SERIES

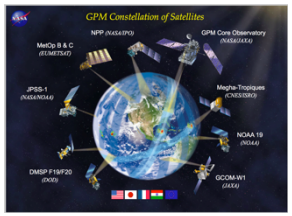
Water Resources Management Using NASA Earth Science Data

COURSE DATES: EVERY Tuesday, October 13, 20, 27; November 3, 10
TIME: 10 TO 11 AM AND 2 TO 3 PM Eastern US Time
(UTC-4 Hours for October and UTC-5 Hours for November)

Applied Remote Sensing Training

Webinar Outline

Week 1



NASA Remote Sensing Data and Applications for Water Resources Management

Week 2

Precipitation and Soil Moisture Data

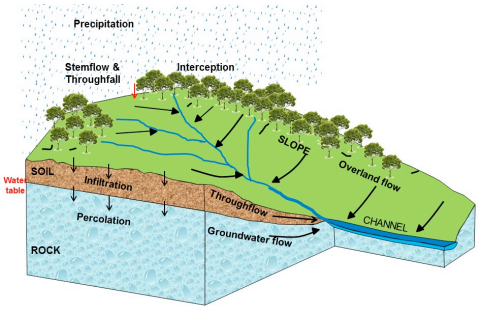
Week 3

Run off, Streamfow and Reservoir Level Data

Week 4

Evapotranspiration and Ground Water Data

Week 5



Land Data Assimilation for Water Budget Estimation and Case Studies with GIS Applications

Training Team

Instructors:

- Amita Mehta (ARSET): amita.v.mehta@nasa.gov
- Cynthia Schmidt (ARSET): cynthia.l.schmidt@nasa.gov (Week-4)
- Brock Blevins (ARSET): bblevins37@gmail.com

Guest Speakers:

- Eni Njoku(NASA-JPL): eni.g.njoku@jpl.nasa.gov (Week-2)
- Brian Thomas (NASA-JPL): Brian.F.Thomas@jpl.nasa.gov (Week-4)
- Sujay Kumar (NASA-GSFC): sujay.v.kumar@nasa.gov (Week-5)

Spanish Translation:

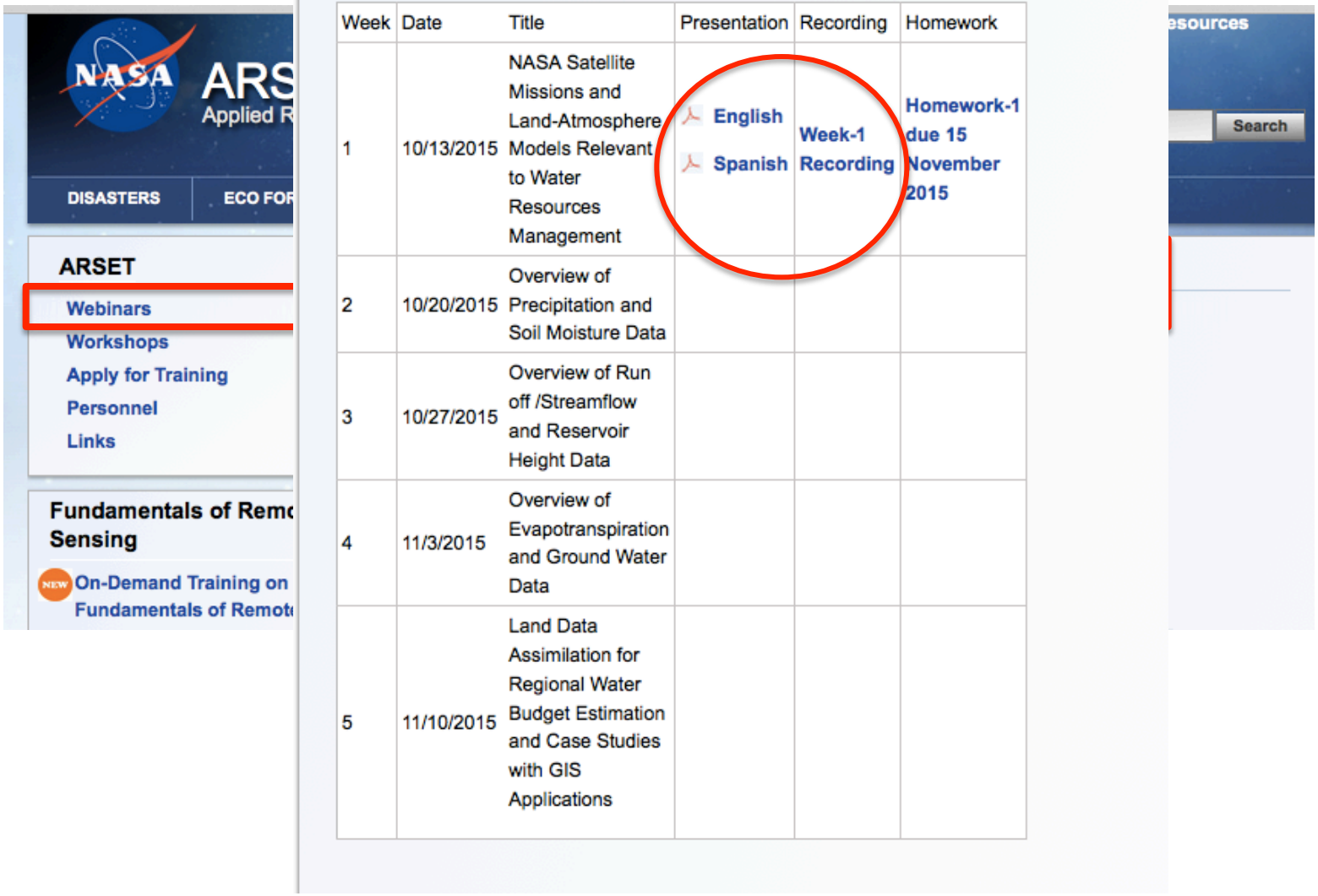
- David Barbato (ARSET): barbato1@umbc.edu

General Inquiries about ARSET:

- Brock Blevins (ARSET) bblevins37@gmail.com
- Ana Prados (ARSET) aprados@umbc.edu

ARSET Website

http://arset.gsfc.nasa.gov/



Presentations and Recordings

Week	Date	Title	Presentation	Recording	Homework
1	10/13/2015	NASA Satellite Missions and Land-Atmosphere Models Relevant to Water Resources Management	English Spanish	Week-1 Recording	Homework-1 due 15 November 2015
2	10/20/2015	Overview of Precipitation and Soil Moisture Data			
3	10/27/2015	Overview of Run off /Streamflow and Reservoir Height Data			
4	11/3/2015	Overview of Evapotranspiration and Ground Water Data			
5	11/10/2015	Land Data Assimilation for Regional Water Budget Estimation and Case Studies with GIS Applications			

Agenda for Week-3

Overview of Run Off/Streamflow and Lake Level Height

- Run Off/Streamflow Data and Access
- Lake Level Height Data and Access

Run Off and Streamflow Data

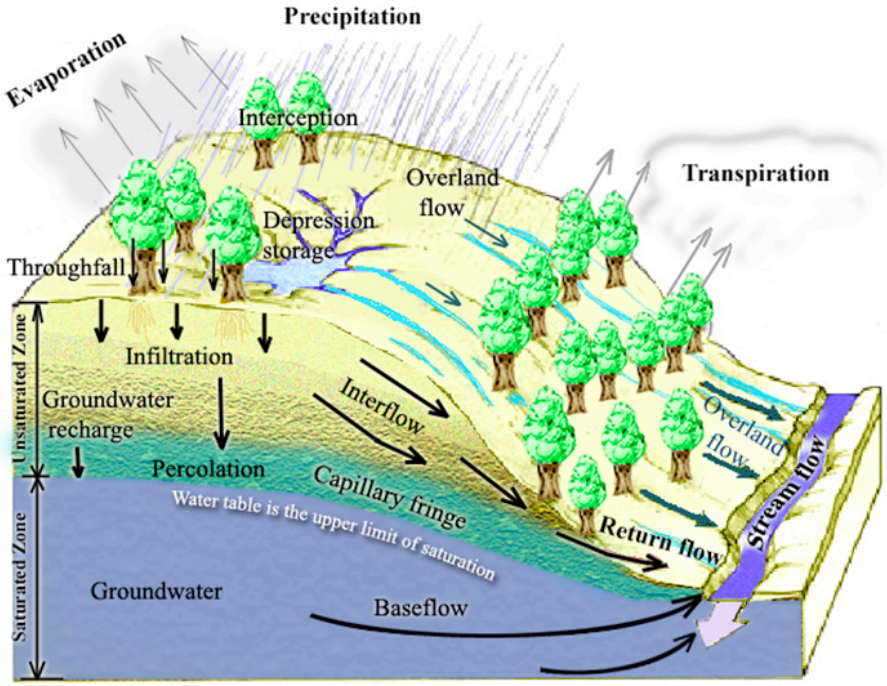
Surface and Sub-surface Run Off
Channel Run Off or Streamflow

Run Off

- Excess water from rain and/or snowmelt
- Depends on soil saturation and infiltration capacity, rain/snow melt intensity, terrain

Streamflow

- Flow of water in rivers, streams
- Runoff that carries water from land to ocean



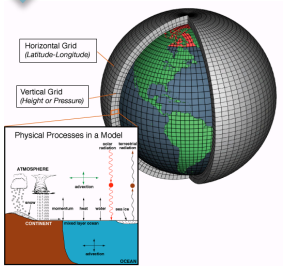
Major components of water cycle – responsible for erosion, flooding, water quality

NASA Surface Runoff and Streamflow Data

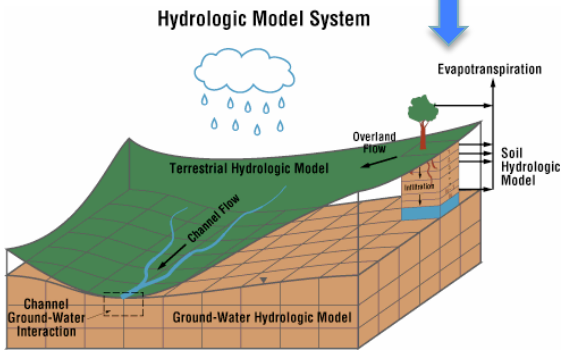
Calculated by using land-atmosphere and Hydrology Models

Satellite Data

surface Measurements and In-Situ Data



Atmosphere/ Land Models For Runoff



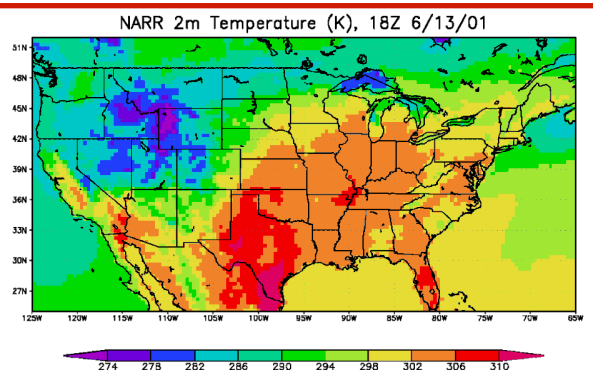
Hydrology Model for Streamflow

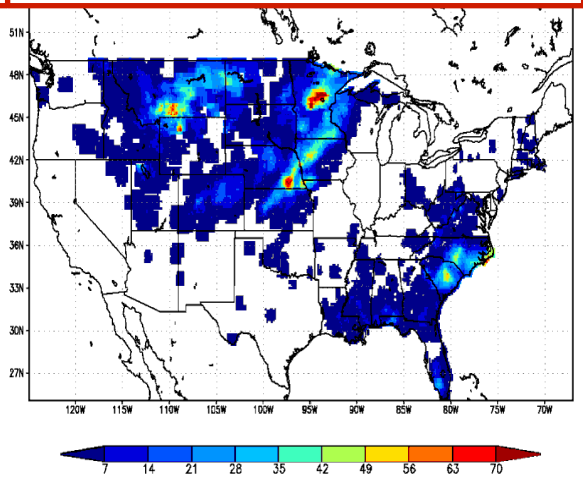
North American Land Data Assimilation System (NLDAS)

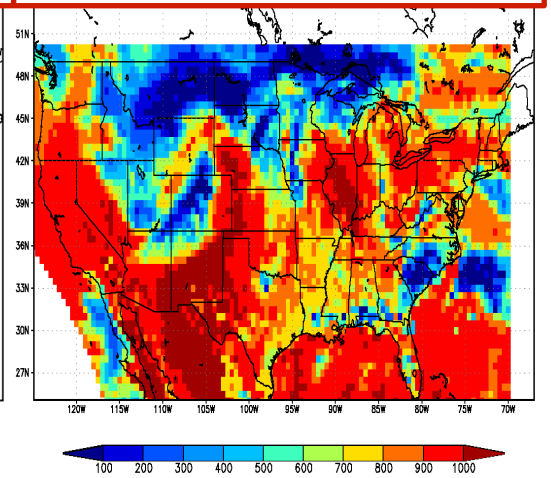
http://ldas.gsfc.nasa.gov/nldas

NLDAS combines a high-quality surface forcing dataset and land-surface modeling to produce consistent products

NARR near-surface meteorology	CPC Daily Precipitation Analysis	Bias-corrected SW radiation (SRB)





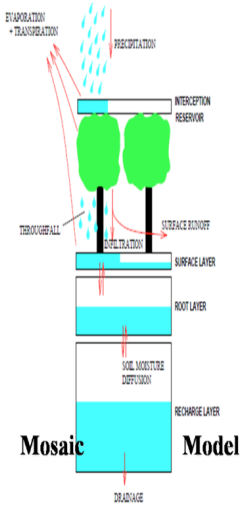


Courtesy: Daviid Mocko NASA-GSFC
david.mocko@nasa.gov

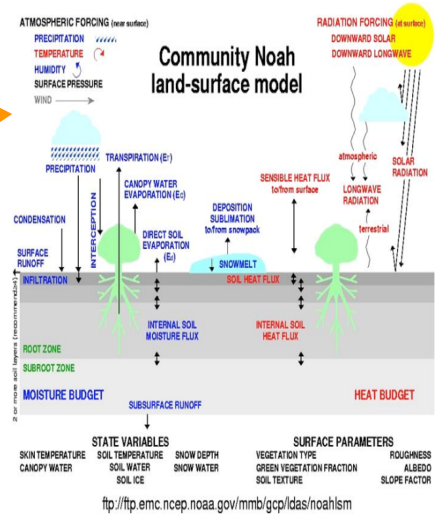
Stage II radar, CMORPH, other precipitation datasets, or NARR used to temporally disaggregate the CPC Daily Analysis into hourly precipitation

Collaboration between NOAA/NCEP/EMC and NASA/GSFC w/ other groups; it runs 4 LSMs (Noah, Mosaic, VIC, & SAC)

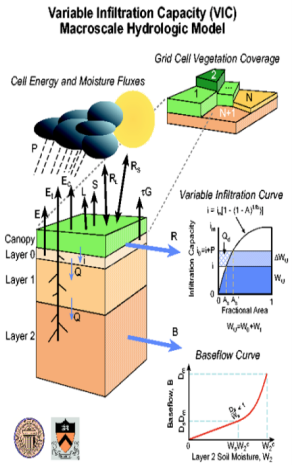
http://ldas.gsfc.nasa.gov/nldas/



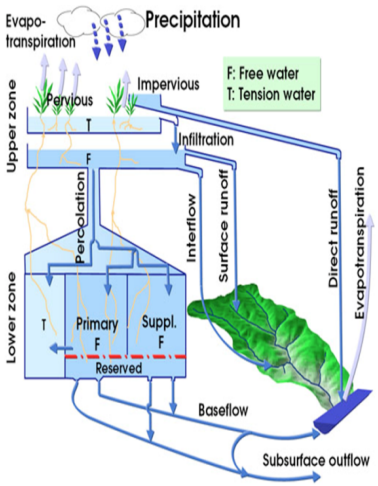
Mosaic (GSFC)



Noah (NCEP)



VIC (Princeton Univ. and Univ. of Washington)



SAC (OHD)

Sacramento Soil Moisture Accounting model (SAC-SMA)
Variable Infiltration Capacity (VIC)

Global Land Data Assimilation System(GLDAS)

http://ldas.gsfc.nasa.gov/

Integrate ground and satellite observations within sophisticated numerical models to produce physically consistent, high resolution fields of land surface states and fluxes

GLDAS uses Different Sources of Inputs (http://ldas.gsfc.nasa.gov/gldas/GLDASforcing.php)

Meteorological Analysis
Surface Solar Radiation
Precipitation
Soil Texture
Vegetation Classification and Leaf Area Index
Topography

Integrate Output for Water Resources

Soil Moisture
Evapotranspiration
Surface/Sub-surface Runoff
Snow Water Equivalent

Satellite Data used in LDAS: MODIS, TRMM Multi-satellite Precipitation Analysis, GOES

Rodell, M., et al; The Global Land Data Assimilation System, Bull. Amer. Meteor. Soc., 85(3), 381-394, 2004.

NLDAS & GLDAS Data Availability

http://disc.gsfc.nasa.gov/hydrology

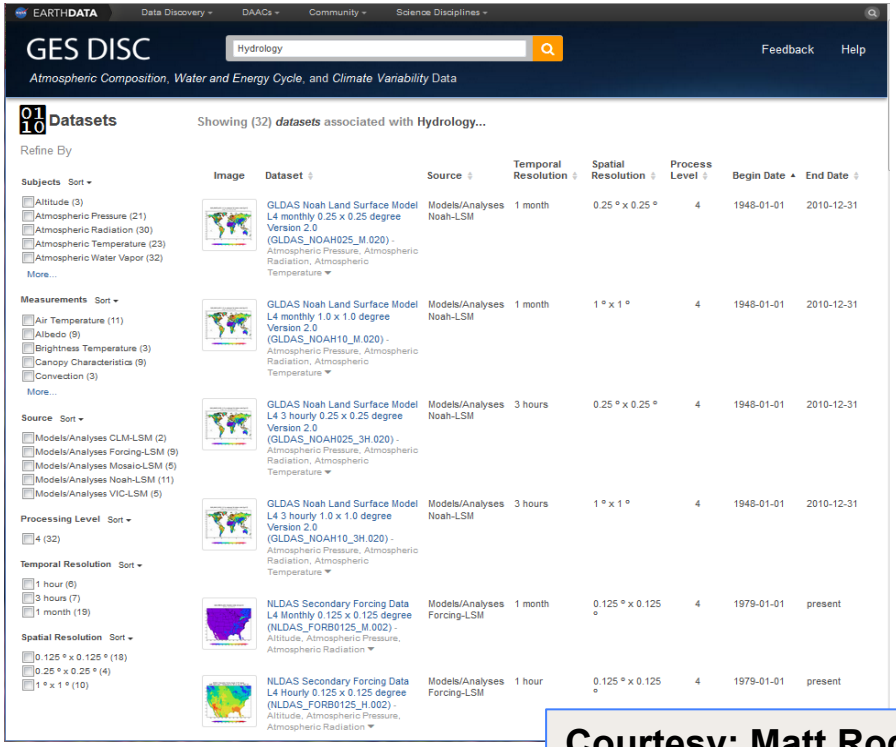
- Access via GDS, FTP, or quick-look visualization in Giovanni (below right)
- GRIB and NetCDF formats
- 3-hourly and monthly; 1.0° and 0.25° global grids
- On-the-fly subsetting (below left)
- Full documentation
- NLDAS & GLDAS support a growing number of national and international hydrometeorological investigations and water resources applications

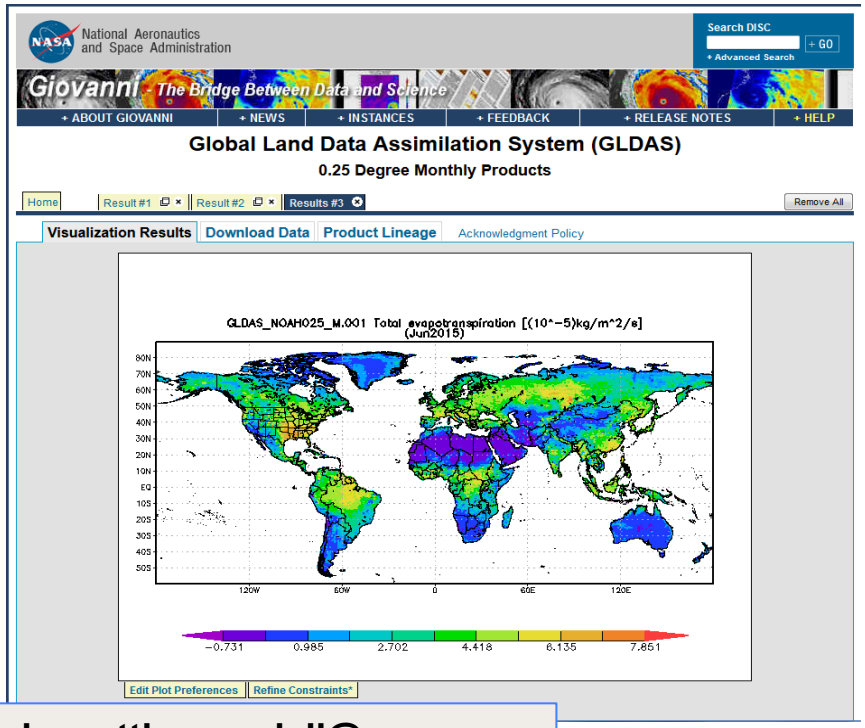
NLDAS
0.125°, 1979-present (operational at NOAA/NCEP, 3.5 day latency), 25 to 53N, -125 to -67W, hourly/monthly: Noah, Mosaic, VIC

GLDAS v1
1.0°, 1979-present (1-2 month latency): Noah, Mosaic, VIC, CLM2
0.25°, 2000-present: Noah w/ MODIS snow cover assimilation

GLDAS v2
1.0° & 0.25°, 1948-2012: Noah

GLDAS v2.1 & v2.2 (coming soon)
1.0° & 0.25°, 1948-present, with multivariate data assimilation: Noah, Catchment, VIC, CLM4.5





Courtesy: Matt Rodel matthew.rodell@nasa.gov

Run Off Data Access

GLAS/NLDAS Run Off data are available from

Mirador (http://mirador.gsfc.nasa.gov)

Giovanni (http://giovanni.gsfc.nasa.gov/giovanni/)

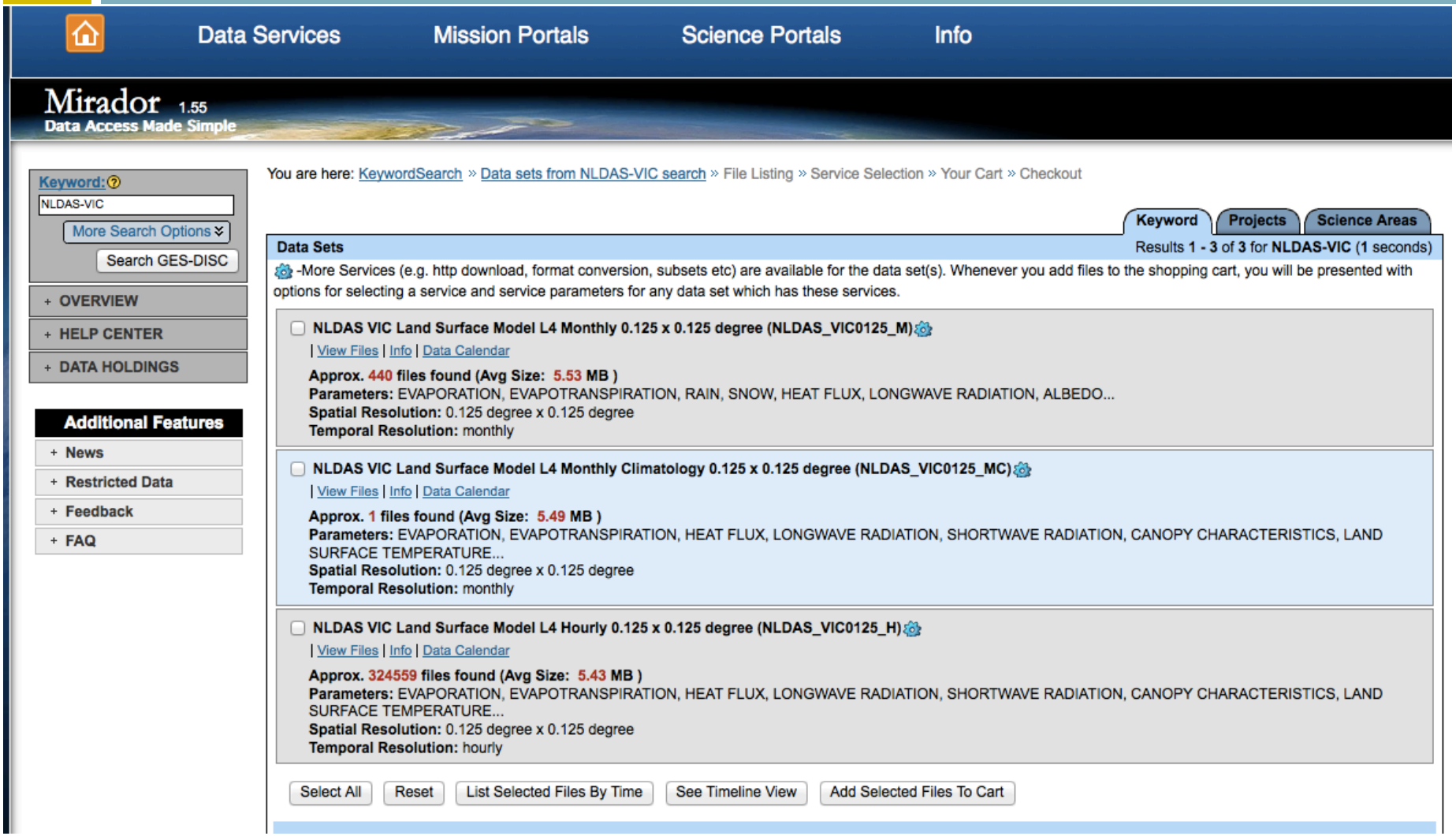
Model	Spatial Resolution	Temporal Resolution	Temporal Coverage
GLDAS (NOAH V 1)	0.25°x0.25° 1°x1°	3-hourly Monthly	2000-Present
NLDAS VIC	0.125°x0.125°	Hourly Monthly Climatology	1979-Present

GLDAS-VIC (Variable Infiltration Capacity) 1948-2000 Run Off Data

International Research Institute/Princeton University (1°x1° **Monthly Run Off, Climatology**)
(http://iridl.ldeo.columbia.edu/SOURCES/.Princeton/.VIC/.runoff/)

Run Off Data Access Using Mirador

http://mirador.gsfc.nasa.gov/



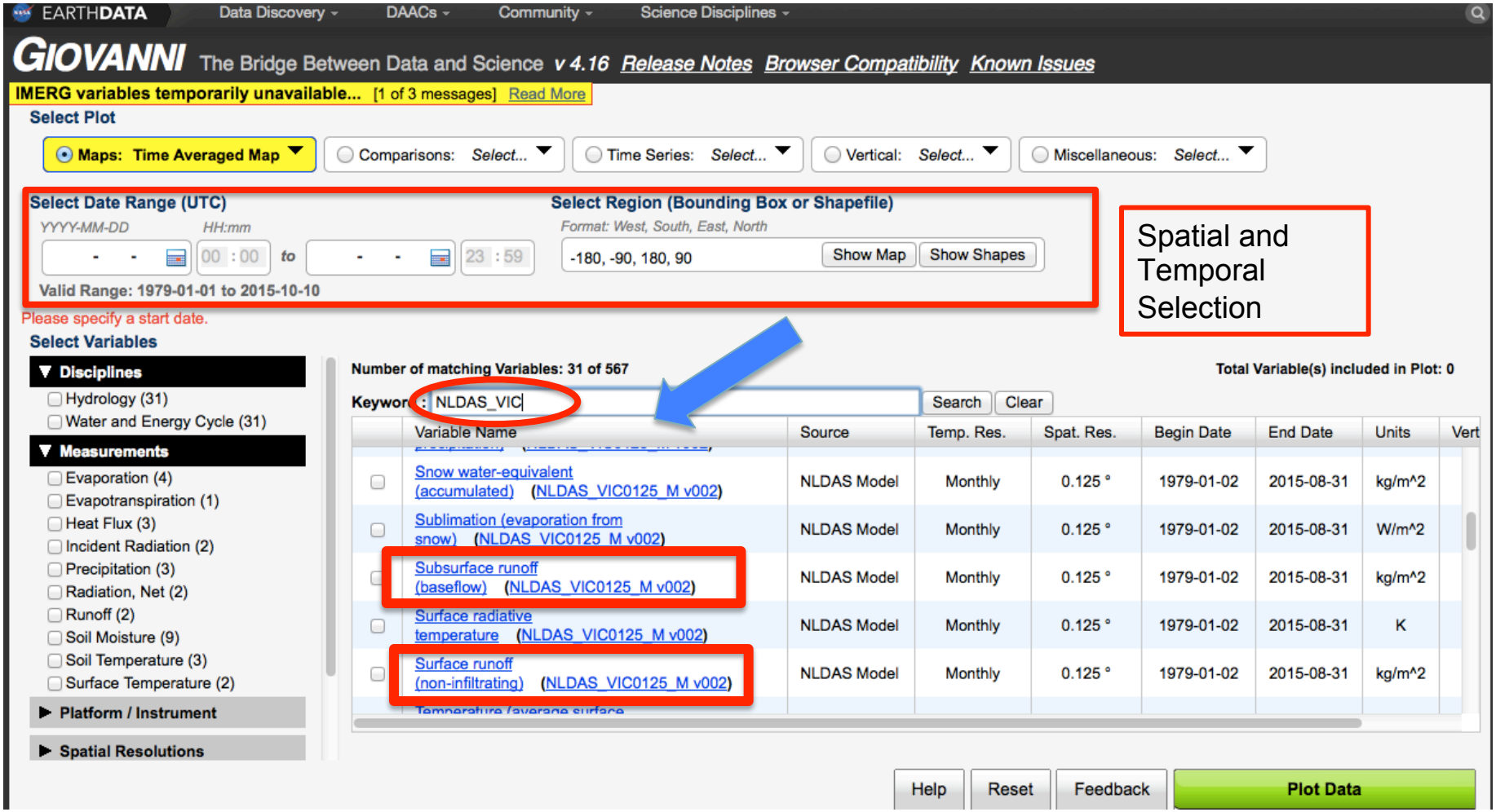
Mirador Live Demo

http://mirador.gsfc.nasa.gov/

For Bulk Data Download

Run Off Data Access Using Giovanni

http://giovanni.gsfc.nasa.gov/giovanni/



Giovanni Live Demo

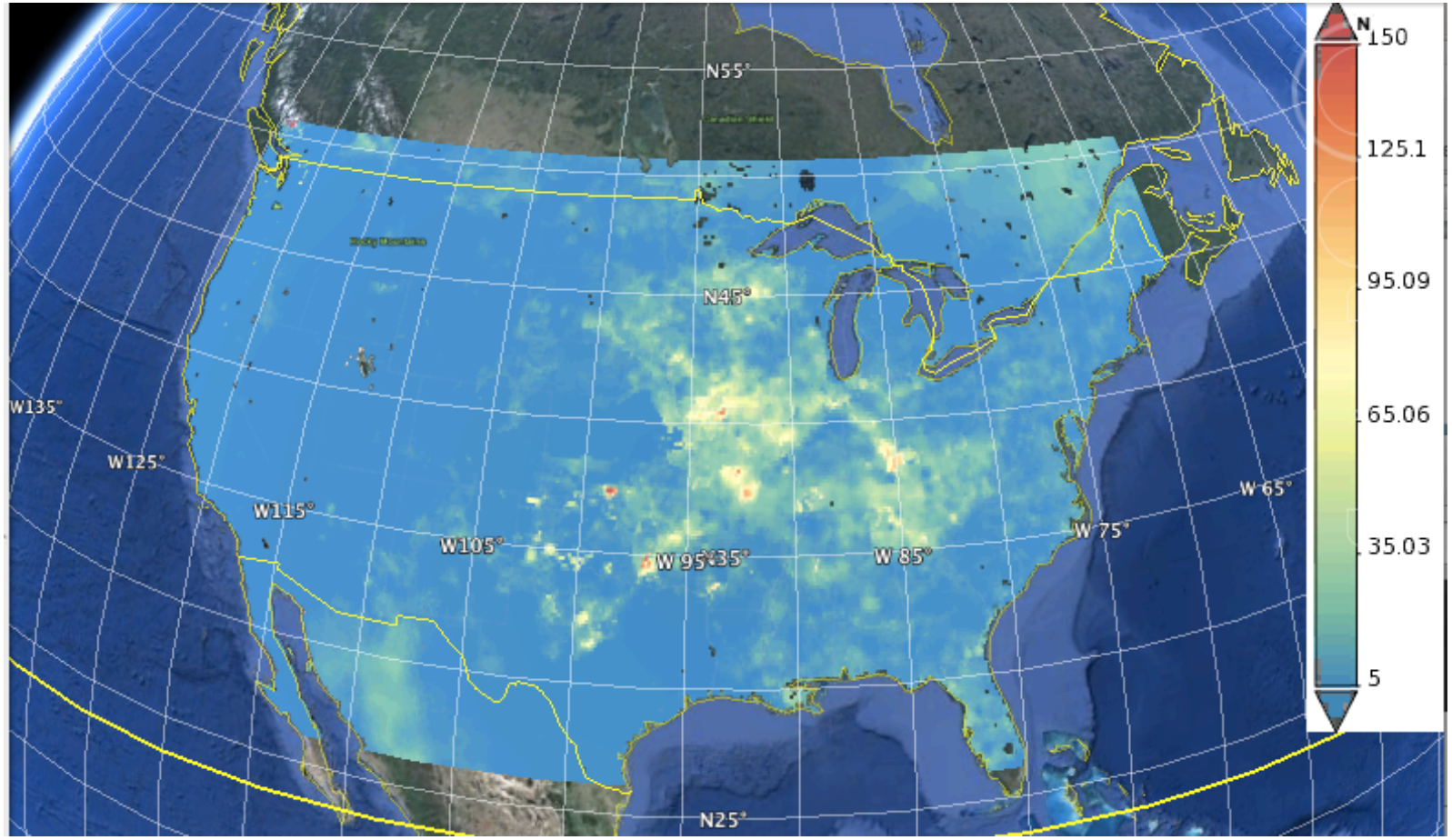
http://giovanni.gsfc.nasa.gov/giovanni/

For Analysis, Visualization, and Download

Run Off Data from NLDAS

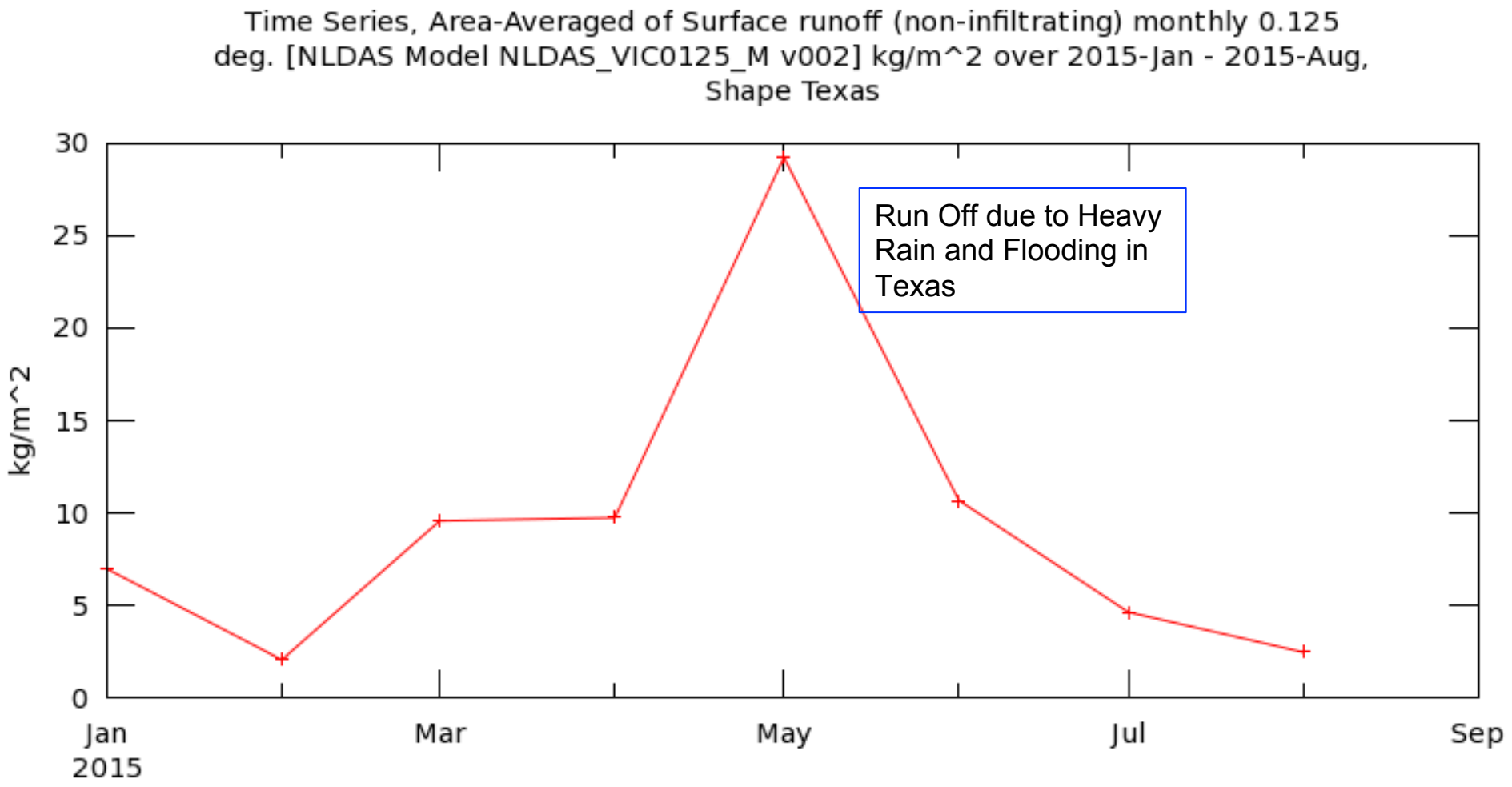
http://giovanni.gsfc.nasa.gov/giovanni/

Time Averaged Map of Surface runoff (non-infiltrating) monthly 0.125 deg. [NLDAS Model NLDAS_VIC0125_M v002] kg/m^2
over 2015-Jul, Region 125W, 26.1328N, 67W, 50.7422N



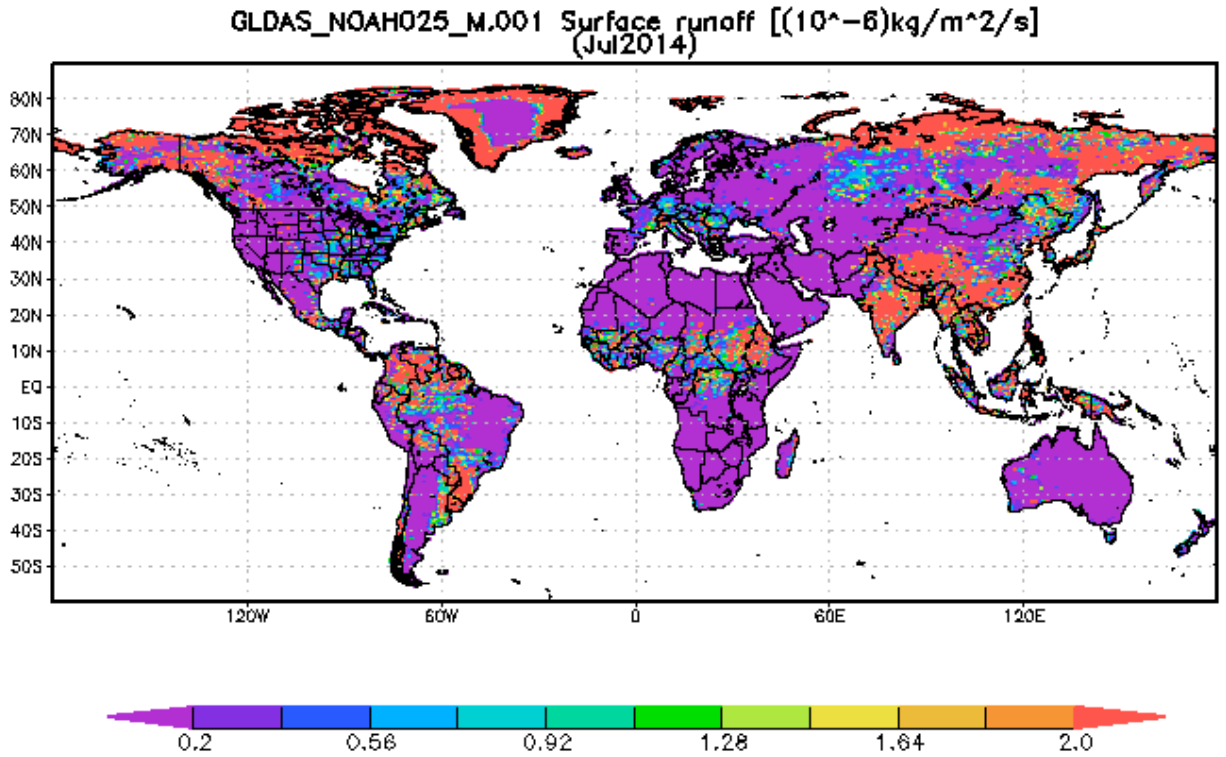
Run Off over Texas from NLDAS

http://giovanni.gsfc.nasa.gov/giovanni/



Run Off Data from GLDAS

http://giovanni.gsfc.nasa.gov/giovanni/



Current GLDAS Data Can be down loaded from **http://disc.gsfc.nasa.gov/hydrology**

But will be available from Giovanni by end of this year/early next year

LDAS Models Validation Papers

Run Off Data are difficult to validate, however, indirect validation by using streamfflow data for selected catchment areas suggest *reasonable* values. Validation for the area of interest is highly recommended.

Some useful Papers are:

Zaitchik, B.F., M. Rodell, and F. Olivera, Evaluation of the Global Land Data Assimilation System using global river discharge data and a source to sink routing scheme, Water Resour. Res., 46, W06507, doi:10.1029/2009WR007811, 2010.

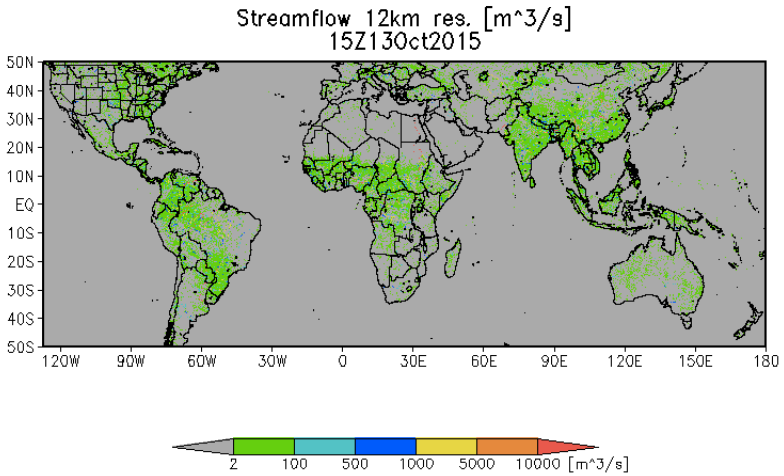
Lorenz, C., H. Kunstmann, B. Devaraju, M. J. Tourian, N. Sneeuw, J. Riegger, Large-scale Runoff from Lanmasses: A global Assessment of the closure of the hydrology and atmospheric water balances, J. Hydrometeorology, 15, 2111-2139, DOI: 10.1175/JHM-D-13-0157.1, 2014.

Xia, Y. L., K. Mitchell, M. Ek, B. Cosgrove, J. Sheffield, L. F. Luo, C. Alonge,H. L. Wei, J. Meng, B. Livneh, et al., Continental-scale water and energy flux analysis and validation for North American Land Data Assimilation System project phase 2 (NLDAS-2): 2. Validation of model-simulated streamflow, J Geophys Res, 17, D03110, DOI: 10.1029/2011JD016051, 2012.

Streamflow Data from Global Flood Monitoring System (GFMS)

Global Flood Monitoring System (GFMS)

http://flood.umd.edu



Provides global maps, time series, and animations (50°S-50°N) of:

- **Instantaneous Rain**
- **Accumulated rain over 24, 72, and 168 hours**
- **Streamflow rates at 1/8th degree (~12 km) and also at 1 km**

From: Robert Adler, Huan Wu, University of Maryland

Global Flood Monitoring System (GFMS)

http://flood.umd.edu

Uses a hydrological model together with remote sensing data for flood detection

- **Inputs: TRMM and Multi-satellite Precipitation (TMPA)**
  Surface temperature and winds from MERRA*
- Runoff generation from U. Washington Land Surface Model (Variable Infiltration Capacity - VIC)
- Runoff routing model from the U. Maryland

***Modern Era Retrospective-analysis for Research and Applications (MERRA): Blends remote sensing and in situ data in to and atmospheric model**

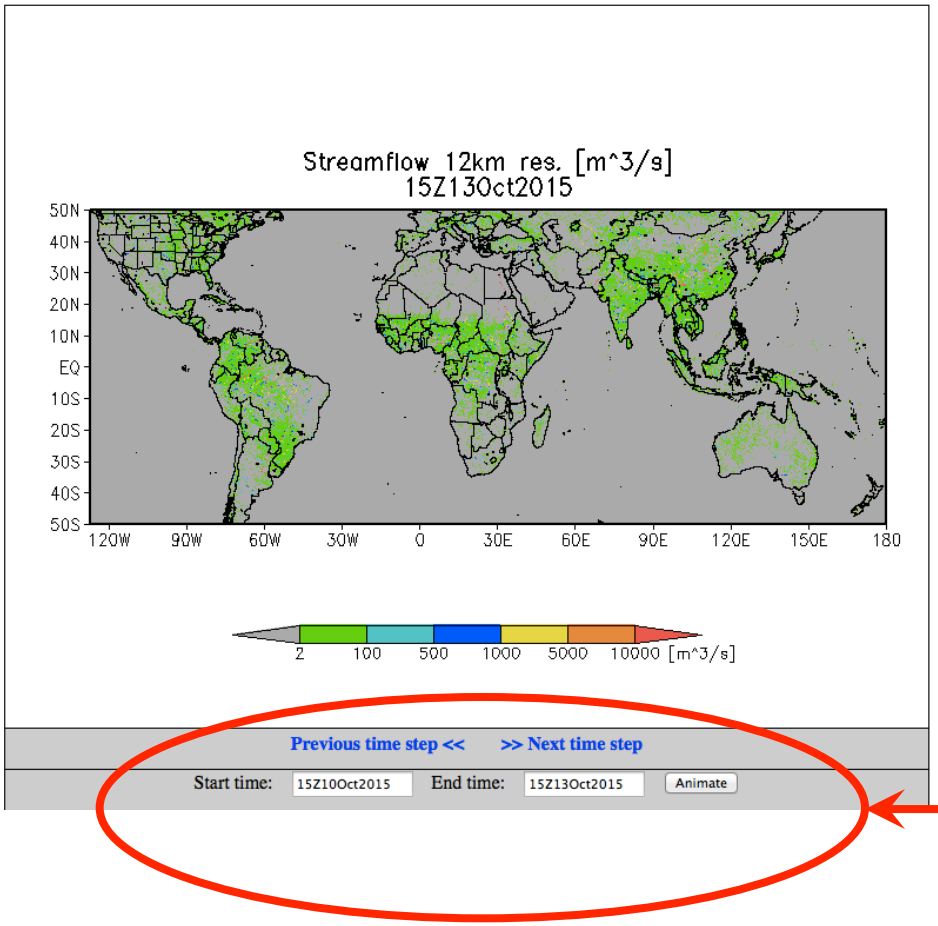
For details see:

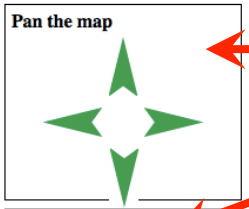
Wu, H., R. F. Adler, Y. Tian, G. J. Huffman, H. Li, and J. Wang (2014), Real-time global flood estimation using satellite-based precipitation and a coupled land surface and routing model, Water Resour. Res., 50, 2693.2717, doi:10.1002/2013WR014710.

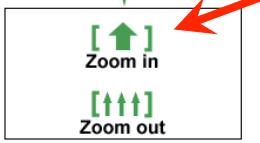
Wu H., R. F. Adler, Y. Hong, Y. Tian, and F. Policelli (2012), Evaluation of Global Flood Detection Using Satellite-Based Rainfall and a Hydrologic Model. J. Hydrometeor, 13, 1268.1284

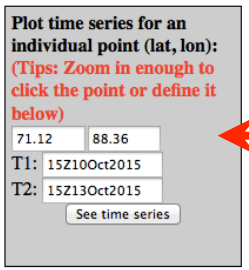
Global Flood Monitoring System (GFMS)

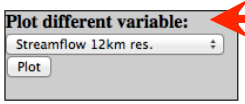
http://flood.umd.edu







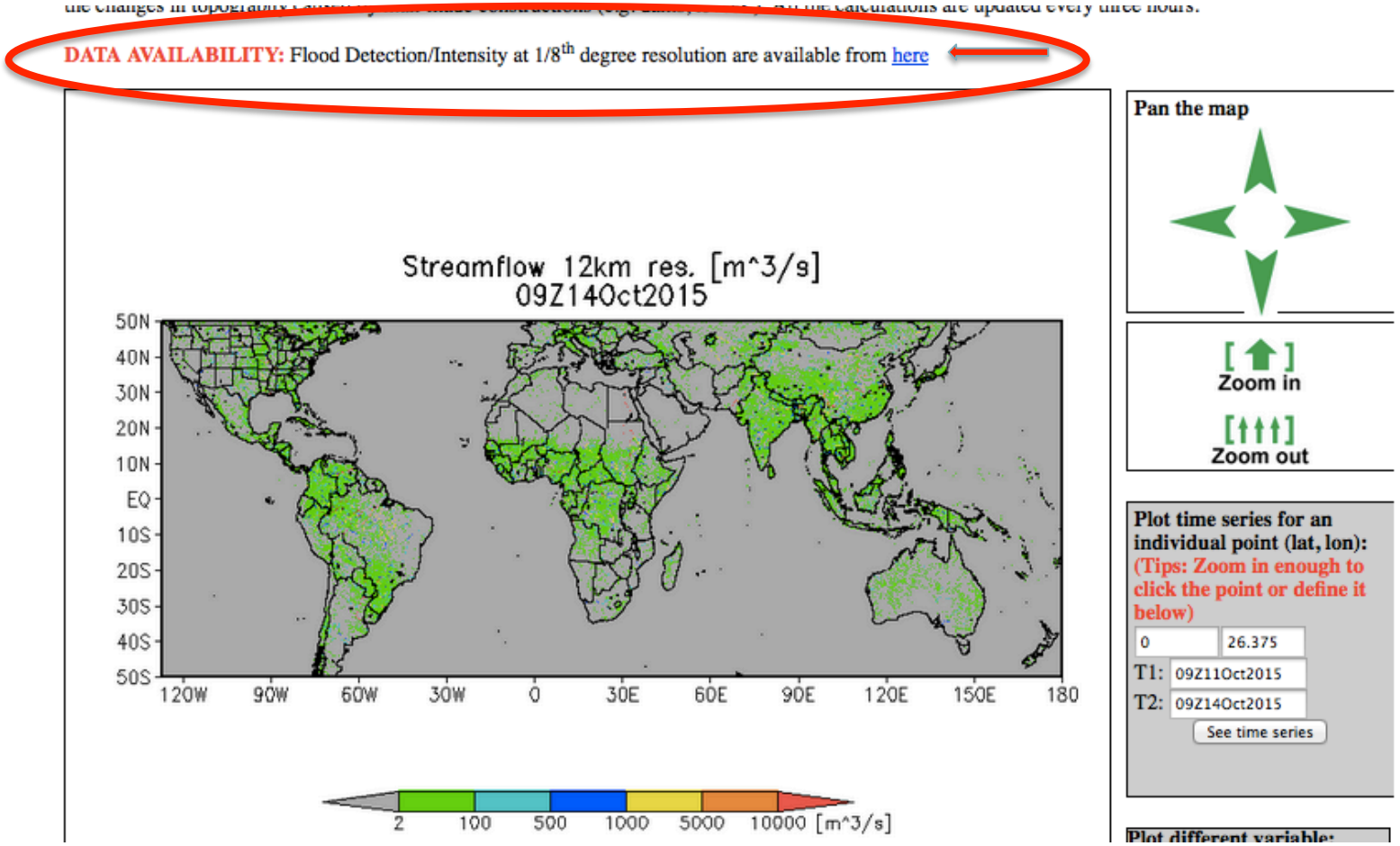




- Map navigation
- Zoom in/out
- Select individual grid point for data for time sequence
- Plot different variables
- 3-hourly output

Streamflow Data Download
Global Flood Monitoring System (GFMS)

http://flood.umd.edu

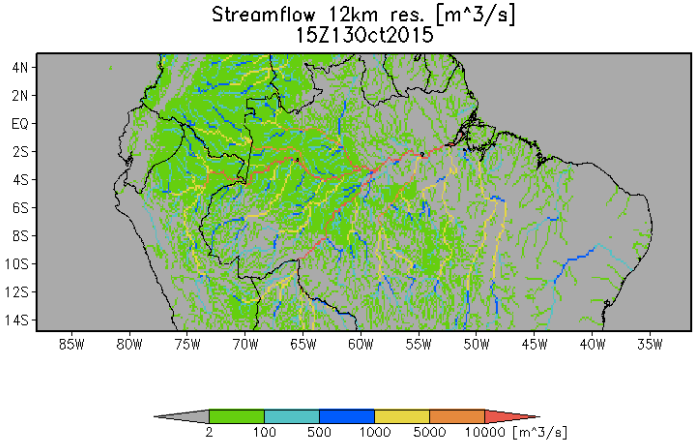


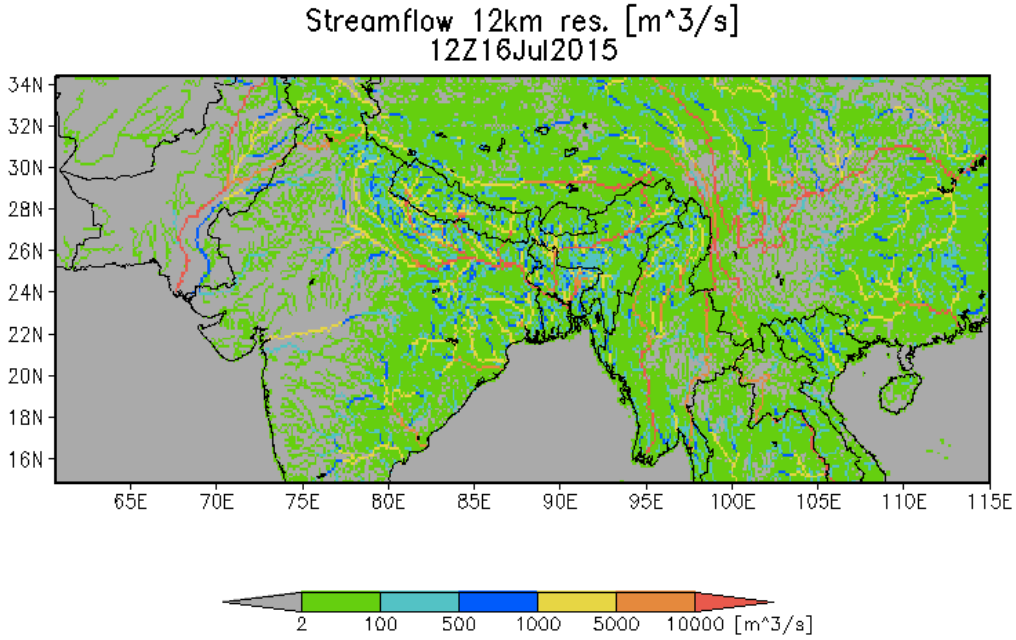
Live Demonstration of GFMS

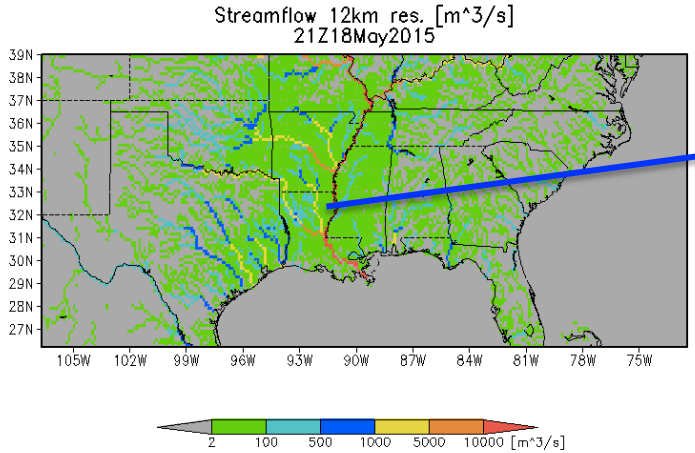
http://flood.umd.edu

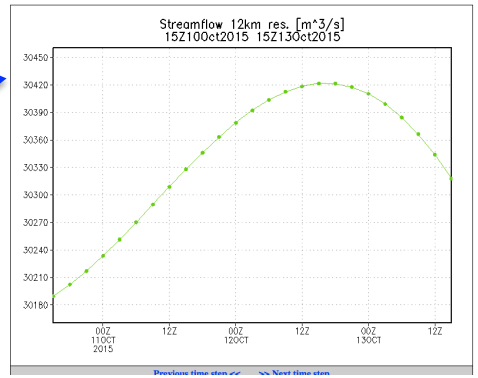
For Map, Animation, Time Series and Download Streamflow Data

Streamflow in m^3/s In Selected River Channels









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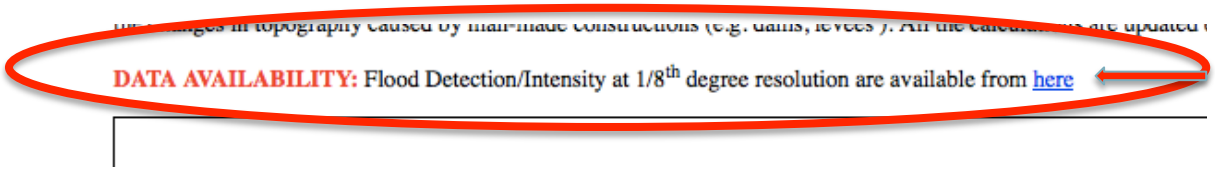


2013
2014
2015
2016
2017
2018

Data description

	File Name	Var. Name	Unit
1	Flood_byStor_yyyymmddhh.bin	Flood intensity (in depth) above threshold	mm
2	Flood_byQ_yyyymmddhh.bin	Streamflow above flood threshold	m^3/s
3	Q_yyymmddhh.bin	Streamflow	m^3/s
4	Routed_yyyymmddhh.bin	Surface water storage	mm
5	V_yyyymmddhh.bin	Channel water velocity	m/s
6	yyyymmddhh.inst.bin	Instant rain	mm/h
7	yyyymmddhh.1day.bin	1 day accumulated Rain	mm
8	yyyymmddhh.3days.bin	3 day accumulated Rain	mm
9	yyyymmddhh.7days.bin	7 day accumulated Rain	mm

Data in Binary Format

C code available for reading the data

Example of reading the data using C

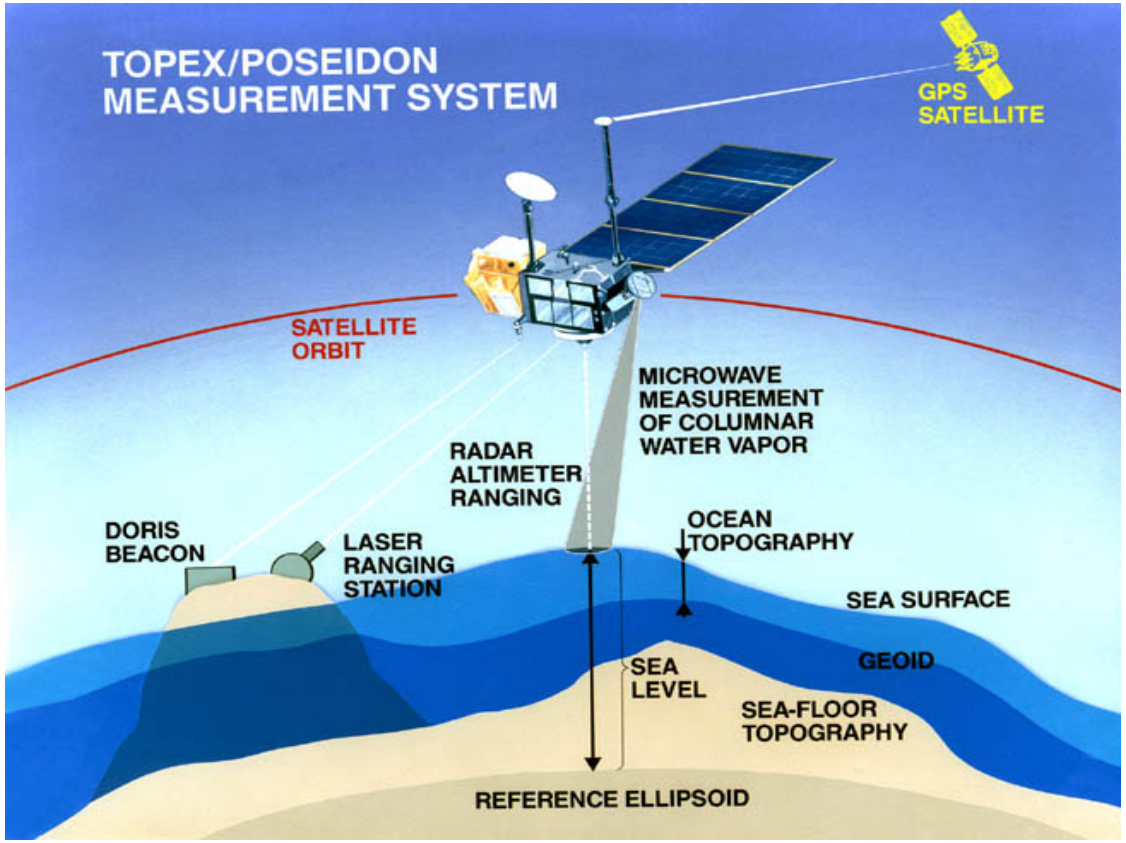
An episode of C code which can be used for reading the data is provided below.

Satellite-based determination of Reservoir and Lake Surface Water Heights

Courtesy: Dr. Charon M. Birkett
Earth System Science Interdisciplinary Center
University of Maryland, College Park
cmb@essic.umd.edu

Satellite-based determination of Reservoir and Lake Surface Water Heights

The Principles of Radar Altimetry



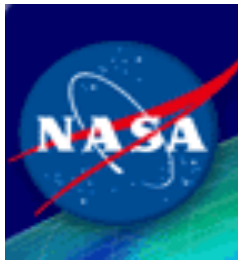
Altimeters were carried on a series of satellites since 1992. Currently Jason-2 is in orbit with an altimeter

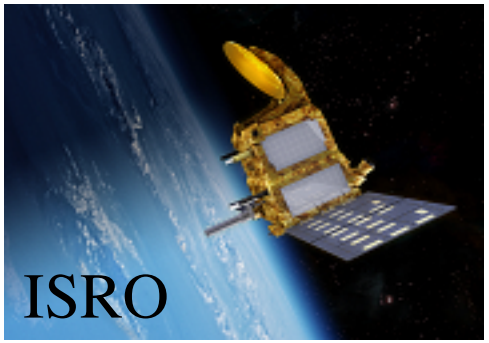
Radar Echoes and Surface Elevation

The instruments do not record an image but collect radar echoes along the ground track.

Altimetric "range" is derived and with knowledge of the satellite orbit location, and certain atmospheric and tidal corrections, the range can be converted to a surface elevation – usually given with respect to a reference ellipsoid datum.

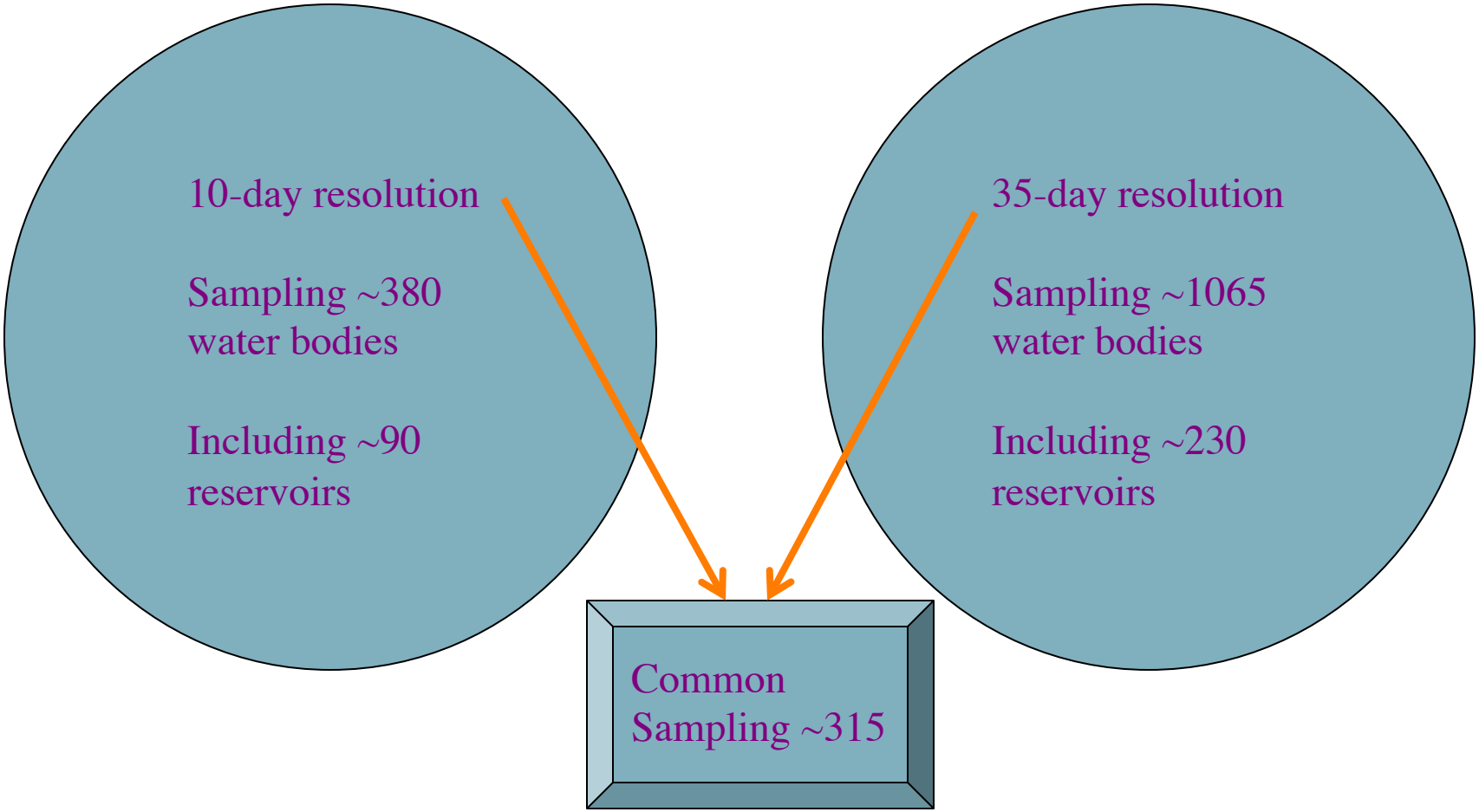
Satellite Radar Altimeter Missions



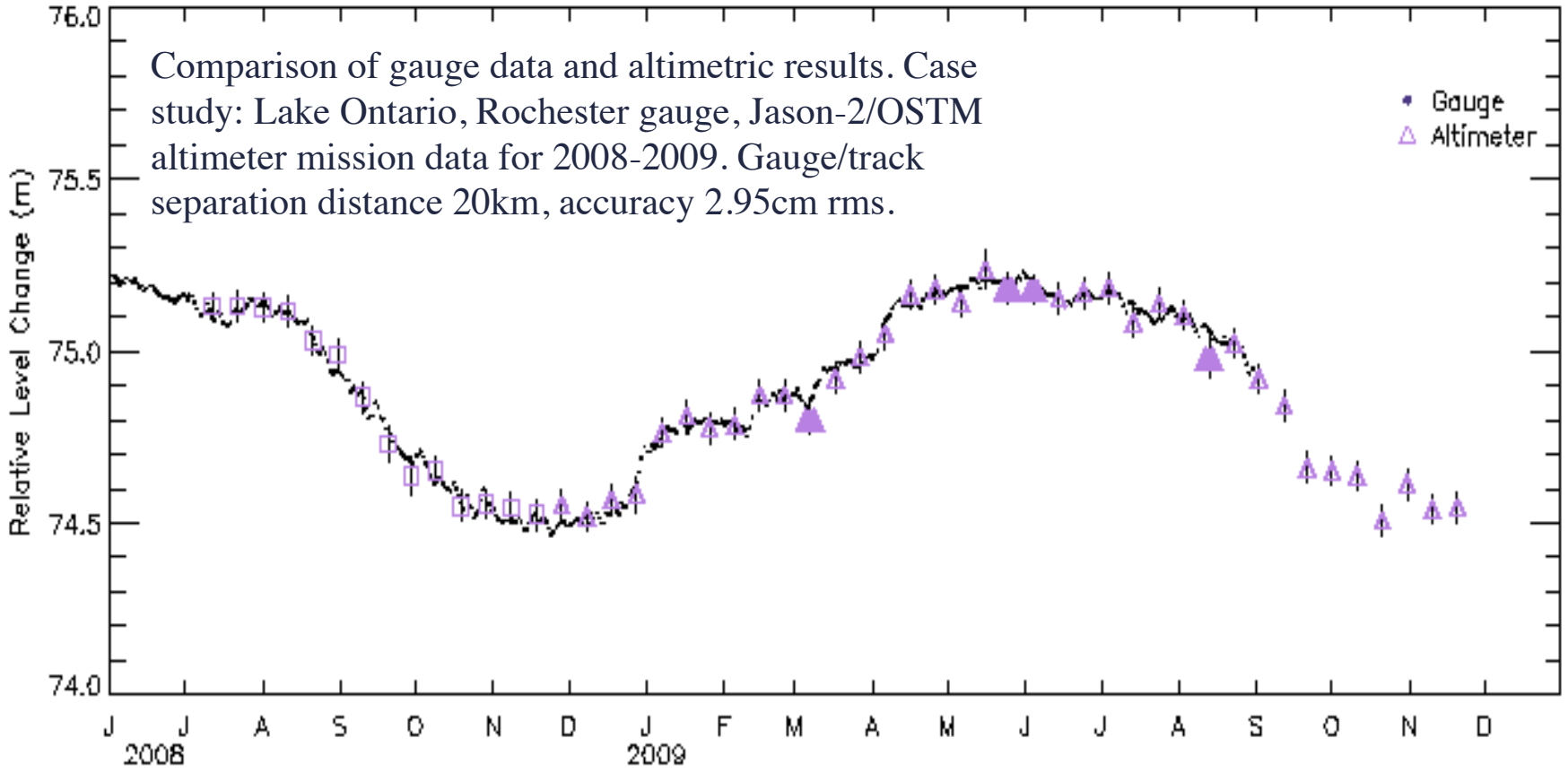


How Many Lakes and Reservoirs?

Current satellite radar altimeters only view a certain proportion of the world's largest water bodies, with a trade-off between temporal and spatial resolution.



Validation of Altimetric Height Variations



Radar Altimetry - Advantages and Limitations

ADVANTAGES

The contribution of new height information where traditional gauge (stage) data is absent.
Day/night and all weather operation.
Generally unhindered by vegetation or canopy cover.
Determined surface heights are with respect to one common reference frame.
Repeat orbits (to ±1km) enable systematic monitoring of rivers, lakes, wetlands, inland seas and floodplains.
Surface water heights are potentially obtainable for any target beneath the satellite overpass.
The ability to monitor seasonal to inter-annual variations during the lifetime of the missions.
Validated techniques.

LIMITATIONS

The satellite orbit scenario determines the spatial and temporal coverage.
Data can only be retrieved along a narrow nadir swath.
Highly undulating or complex topography may cause data loss.
Height accuracy (4-20 cm rms large open lakes) is dominated by the size and surface roughness of the target.
Major wind events, heavy precipitation, tidal effects, ice formation, will effect data quality and accuracy.
Minimum target size (50-100km^2) is also dependent on many factors and the retrieved heights are an "average" not a "spot" height at a specific location.

Reservoir and Lake Surface Water Heights Data Usage by USDA to Monitor Agricultural and Hydrological Droughts

The VOLUME of stored water for irrigation potential considerations.

USDA integrates Lake Surface Height data with a wide variety of data sets.

Information is input into a monthly ‘lockup’ process which sets global Crop Condition Production numbers and provides an ‘Early Warning of Events’.

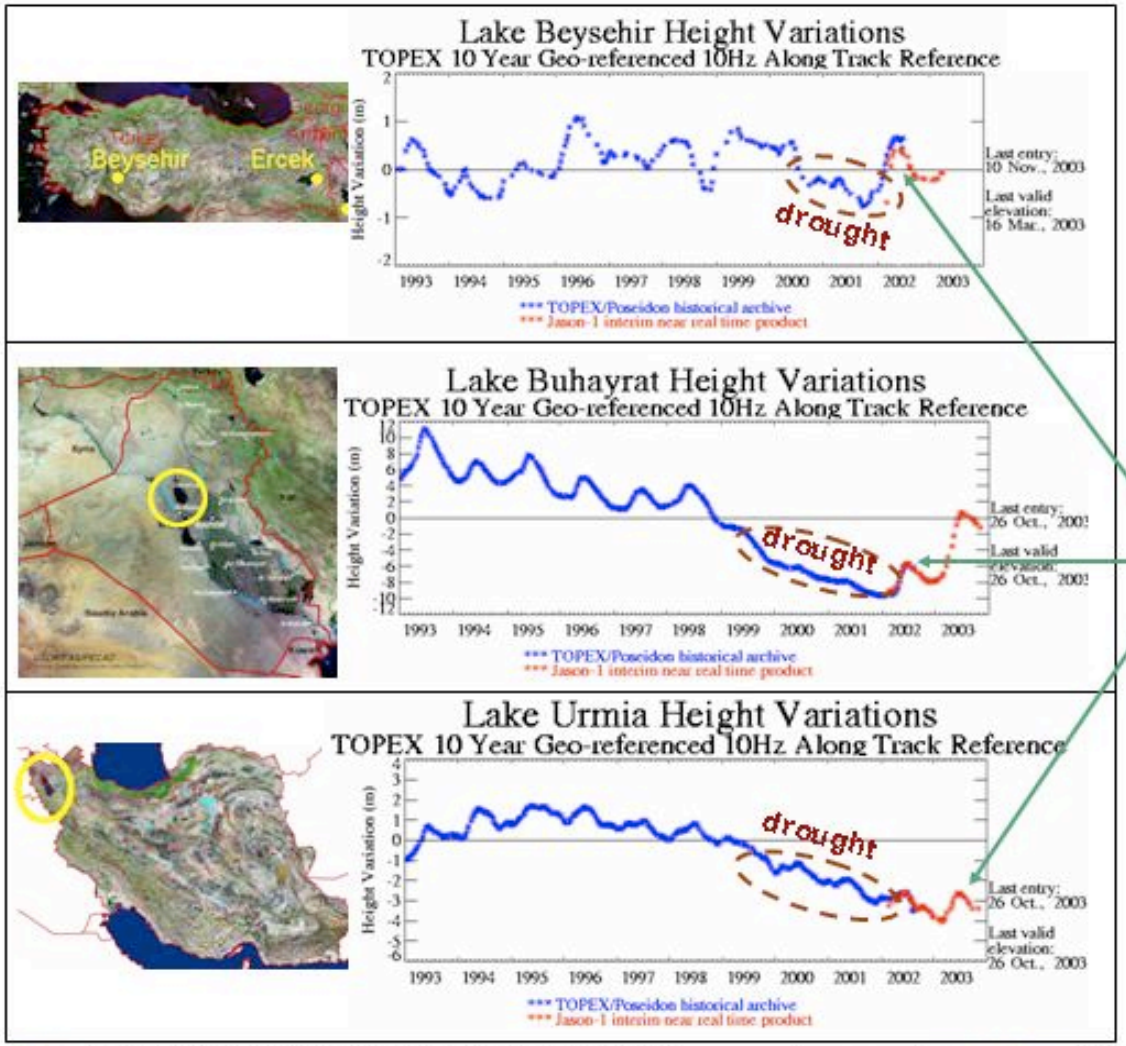
Output information is shared between USDA and US Gov agencies for various Decision Support Protocols.

Estimates drive or influence markets, price discovery, trade and foreign policies, agriculture production, and farm and food programs.

Production Estimates and Crop Assessment Division
Foreign Agricultural Service

Product Application

Middle East and Turkey:
Warmer Than Normal and Plenty of Moisture



Shown are relative lake height variations for Lake Beysehir in Turkey, Lake Buhayrat in Central Iraq and Lake Urmia in northwest Iran. A period of drought occurred from 1999 to 2001. Rainfall in Turkey, northern Iraq and adjacent regions increased in both 2002 and 2003 and has gradually recharged reservoirs.

Initial recovery in water levels observed in 2002-2003. Drought began in 1999.

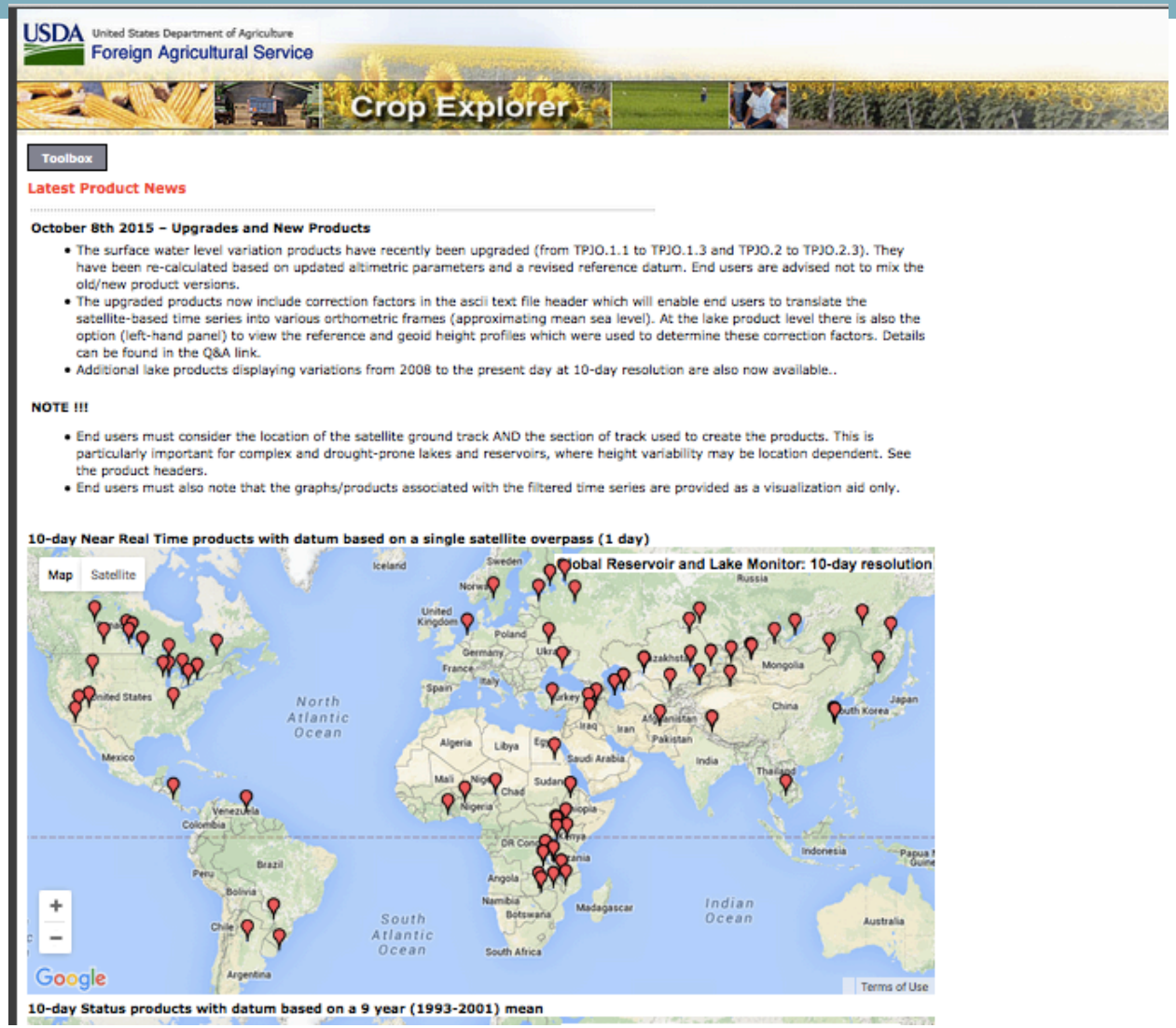
Production Estimates & Crop Assessment Division (PECAD)
Foreign Agricultural Service (FAS)
U.S. Department of Agriculture (USDA)
http://fas.usda.gov/pecad/pecad.html

ESSIC (Earth System Science Interdisciplinary Center), University of Maryland, College Park
NASA Goddard Space Flight Center, Greenbelt, Maryland

Reservoir and Lake Surface Water Heights Data Access

http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/

USDA United States Department of Agriculture Foreign Agricultural Service Crop Explorer



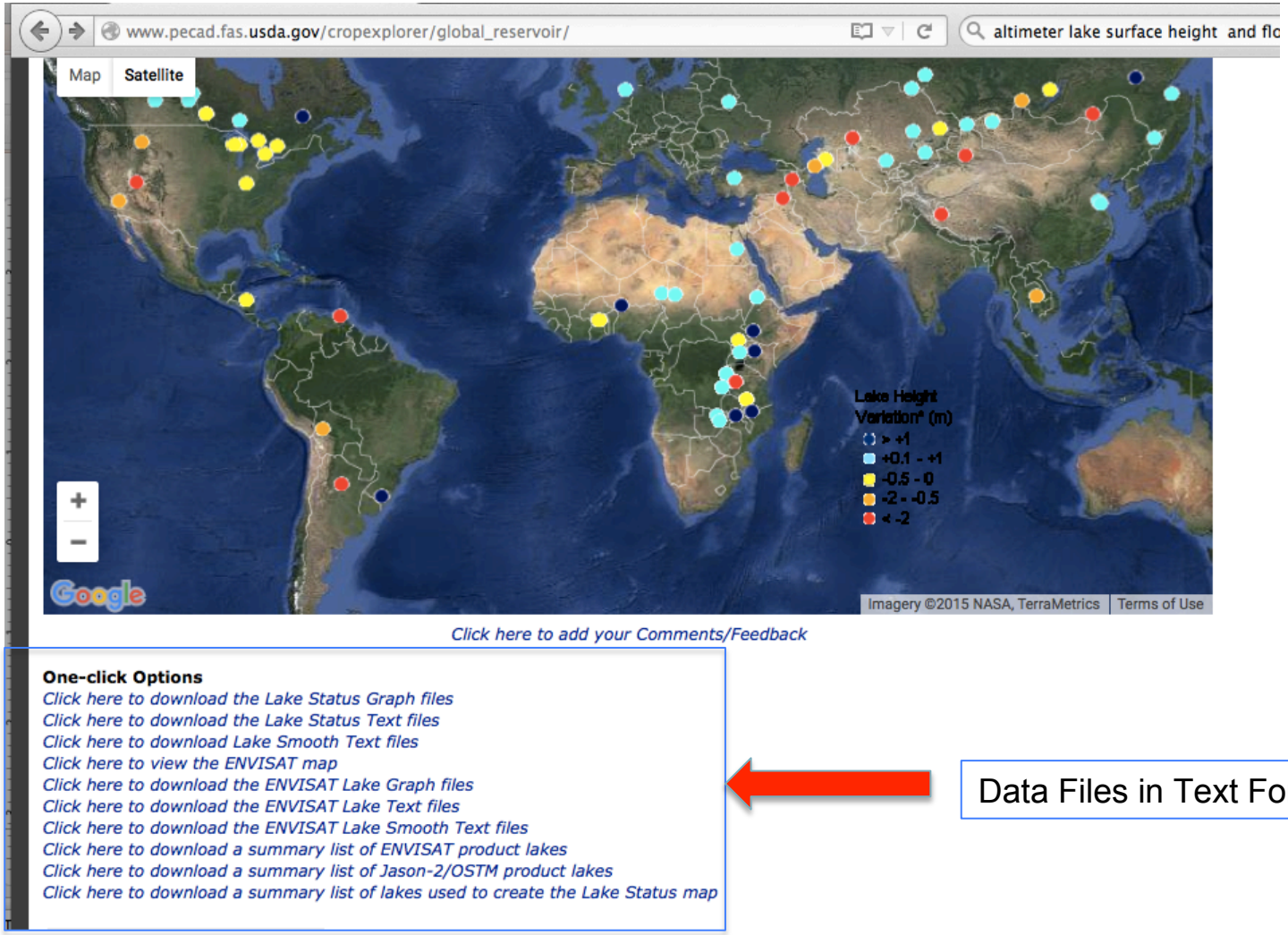
Live Demonstration of USDA-FAS-Crop Explorer

http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/

For Map, Time Series, and Download Data

Data Access from USDA-FAS-Crop Explorer

http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/



Data Files in Text Format

Data Access from USDA-FAS-Crop Explorer

http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/

Data Files in Text Format

```
TPJO.1.1                    : Data Processing Version ID
0012 Winnipeg              : Lake database id number and name
 52.00 262.00              : Latitude and longitude (degrees East) of lake mid-point
 52.75 261.11              : Start latitude and longitude (degrees East) of pass traversing
lake
 53.61 262.34              : End latitude and longitude (degrees East) of pass traversing
lake
 52.83  53.53              : Latitude range of pass traversing lake at which data is
accepted
   195   98                : Satellite pass and revolution number designation
 0.31                      : Jason-1 Bias adjustment (m)
 0.72                      : Jason-2 Bias adjustment (m)

Column 1: satellite mission name
Column 2: satellite repeat cycle
Column 3: year,month,day of along track observations traversing lake
Column 4: hour of day at mid point of along track pass traversing lake
Column 5: minutes of hour at mid point of along track pass traversing lake
Column 6: lake height variation with respect to TOPEX/POSEIDON 9  year mean le
Column 7: estimated error of lake height variation with respect to TOPEX/POSEI
mean level (meters)
Column 8: mean along track K-band backscatter coefficient (decibels)
Column 9: wet troposheric correction applied to range observation (TMR=radiome
FMO=ECMWF model)
```

```
OSTM  240 20150114  12  0   0.06  0.045  22.06 AMR
OSTM  241 20150124   9 59   0.07  0.046  20.14 AMR
OSTM  242 20150203   7 57  -0.04  0.046  19.06 AMR
OSTM  243 20150213   5 56  -0.12  0.047  17.04 AMR
OSTM  244 20150223   3 54  -0.19  0.047  16.67 AMR
OSTM  245 20150305   1 53  -0.14  0.048  16.28 AMR
OSTM  246 99999999  99 99 999.99 99.999 999.99 N/A
OSTM  247 20150324  21 50   0.18  0.046  18.68 AMR
OSTM  248 20150403  19 48   0.18  0.045  16.17 MIX
OSTM  249 20150413  17 47   0.36  0.044  35.11 AMR
OSTM  250 20150423  15 45   0.26  0.044  17.55 MIX
OSTM  251 20150503  13 44   0.20  0.044  21.49 MIX
OSTM  252 20150513  11 42   0.19  0.046  33.32 AMR
OSTM  253 20150523   9 41   0.05  0.047  25.41 AMR
OSTM  254 20150602   7 39   0.14  0.044  14.34 AMR
OSTM  255 20150612   5 38   0.09  0.045  18.08 AMR
OSTM  256 20150622   3 37   0.14  0.044  14.16 AMR
OSTM  257 20150702   1 35   0.10  0.046  26.71 AMR
OSTM  258 20150711  23 34   0.15  0.046  21.52 AMR
OSTM  259 20150721  21 32   0.07  0.048  20.69 AMR
OSTM  260 20150731  19 31   0.16  0.044  13.45 AMR
OSTM  261 20150810  17 29   0.16  0.062  31.25 AMR
OSTM  262 20150820  15 28   0.24  0.044  14.44 AMR
OSTM  263 20150830  13 26   0.22  0.045  13.90 AMR
```

Next Week:

Evapotranspiration Data and Applications

Ground Water Data and Applications

Thank You!

Amita Mehta

email: amita.v.mehta@nasa.gov