GEO EVAPOTRANSPIRATION ACTIVITY

David Toll
NASA/GSFC
David.l.toll@nasa.gov

Martha Anderson & William Kustas - USDA
USDA/ARS
Richard Allen - U Idaho
Justin Huntington – DRI
Eric Wood – Princeton U.
Chris Hain – NOAA
Robert Su & Yijian Zeng – U. Twente
Quiaozhen Mu - U. Montana
Forrest Melton - NASA Ames/SGE

ET Task OVERVIEW

By 2015 Improve ET Products for Comprehension and Coordinated Products at Multiple Scales for Decision Support Systems towards Sustainable Water Resources Management.

Metrics demonstrated by Operational and Sustainable Global Network of Earth Observation Data

•The use of Landsat and MODIS for computing Evapotranspiration provides robust solutions **now** for water and ecological management needs

- ✓ METRIC/SEBAL approach using Landsat and MODIS IR being used operationally by many (most) western US state governments (J. Huntington/DRI and R. Allen/U. Idaho)
- ✓ Regional to continental estimates of 'ALEXI' ET has made significant progress (North America, Africa, etc.) and has recently been extended globally at 25 km with capability to run and extract at 1 km grids (USDA/ARS and NOAA)
- ✓ The NASA ET Product (#16) implemented globally has been optimized for the Nile Basin to provide basin wide water balance estimates (Q. Mu)
- ✓ The Vegetation Index ET approach has been implemented with the California Department of Water Resources (DWR) to potentially providing very significant savings (F. Melton/NASA Ames)
- ✓ Assisted with a NASA 'ARSET' ET Training Course Overview (A. Prados/NASA GSFC)

•Development of Continental and Global Water Balance & ET Data (E. Wood/Princeton U.)

- ✓ Developed a 1979-2010 Evapotranspiration global maps using satellite, modeling and reanalysis.
- ✓ Validated globally at flux towers and river basing

•Operational and Sustainable Network of In Situ Data

- ✓ Significant *in situ* capabilities remain but much more ET data is needed in developing countries of the world.
- ✓ ET can also be dramatically improved by increasing the number of 'weather stations' globally. Weather stations are useful in potential ET and temporal interpolations between satellites.

ET: WATER ACCOUNTING AND FOOD SECURITY

- Improved accounting for water diversions/sinks
- Monitoring and managing agricultural water use and distribution within irrigation districts
- Improved hydrologic monitoring (flood, drought, runoff)
- Early detection of crop stress/failure
- Improved crop modeling and yield estimation

We can't manage what we can't measure …

Why is mapping Evapotranspiration (ET) at the field scale important?

- Water **consumption** varies widely at the field scale in irrigated agriculture
- Historical and Current Consumption is often tied to the field scale in:
  - administration and management of water rights
  - marketing of water rights
  - transfer of water
- "Injury" is often assessed at the field scale

R. Allen/ U. Idaho

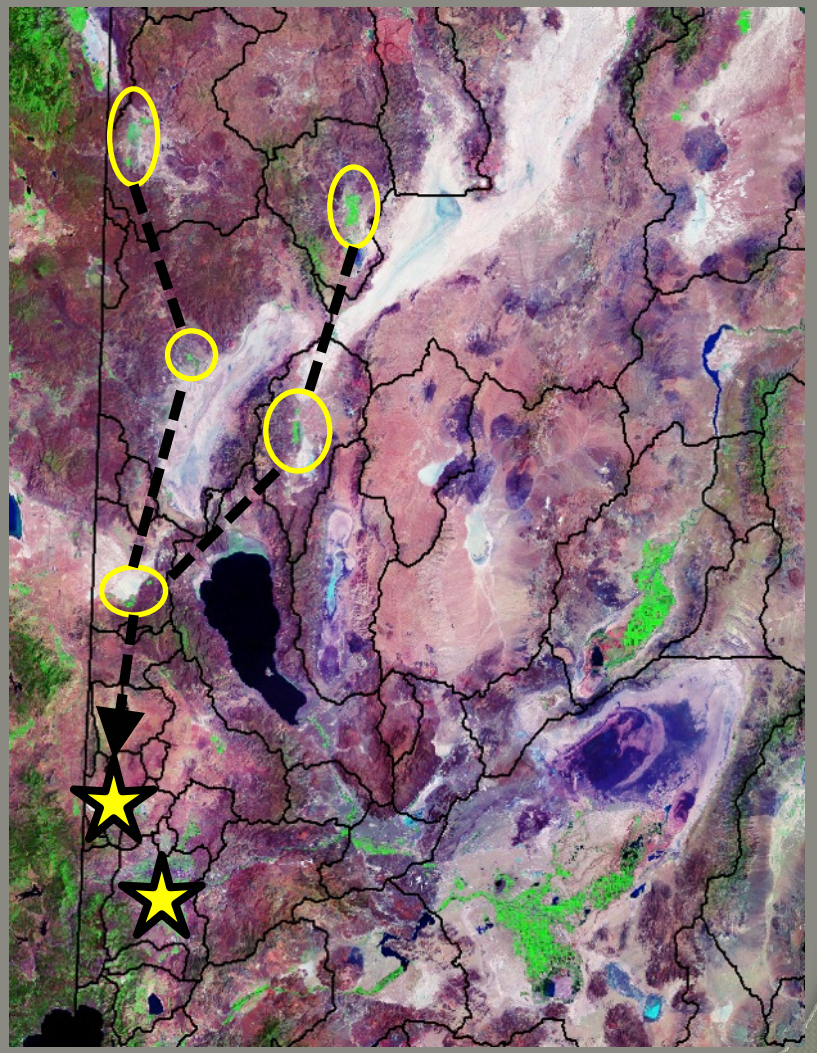
Example of Nevada Water Transfer

- Nevada water law allows for existing water rights to be transferred to a new location and/or use
  - Example: Export groundwater irrigation water rights out of a basin and use it for municipal purposes in a basin needing the water

~$10K per ac-ft
~$70,000 per ac-ft in 2007

One 125 acre center pivot @ 4ac-ft/acre

= $5,000,000 !! per center pivot
= 35,000,000 !! per center pivot



Existing Remote Sensing Based ET Tools (Examples)

METRIC - Mapping Evapotranspiration at High Resolution and Internal Calibration (U of Idaho)

SEBAL – Surface Energy Balance Algorithm for Land (WaterWatch International)

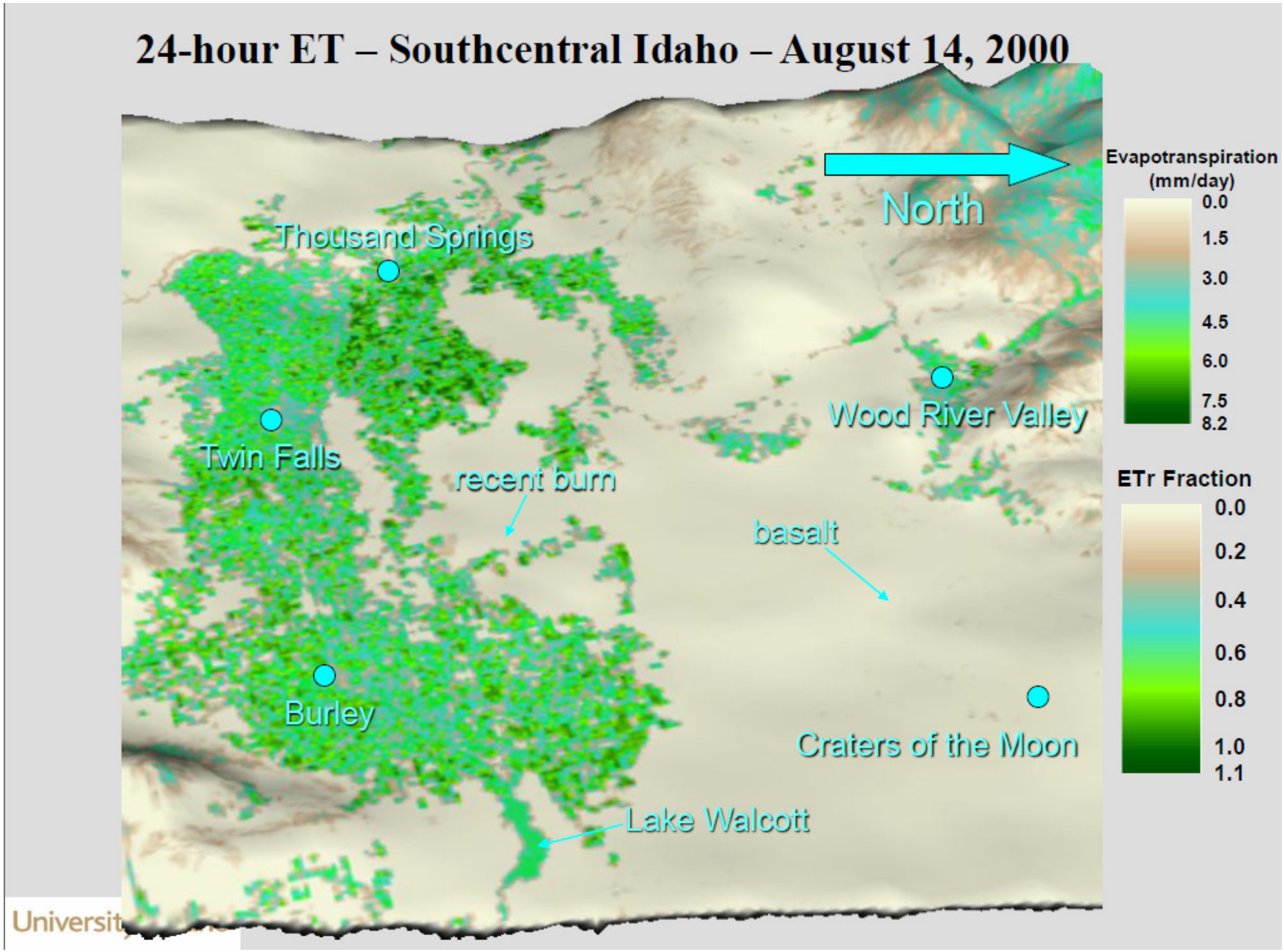
ALEXI – The Atmosphere-Land Exchange Inverse (USDA – ARS)

MODIS-ET – MODIS Global ET Project (U of Montana)

MODIS-ET SEBS – Surface Energy Balance System (Princeton U.)

SSEB – Simplified Surface Energy Balance (USGS)

Vegetation Indices – Landsat and MODIS (NASA Ames)



Allen/U. Idaho

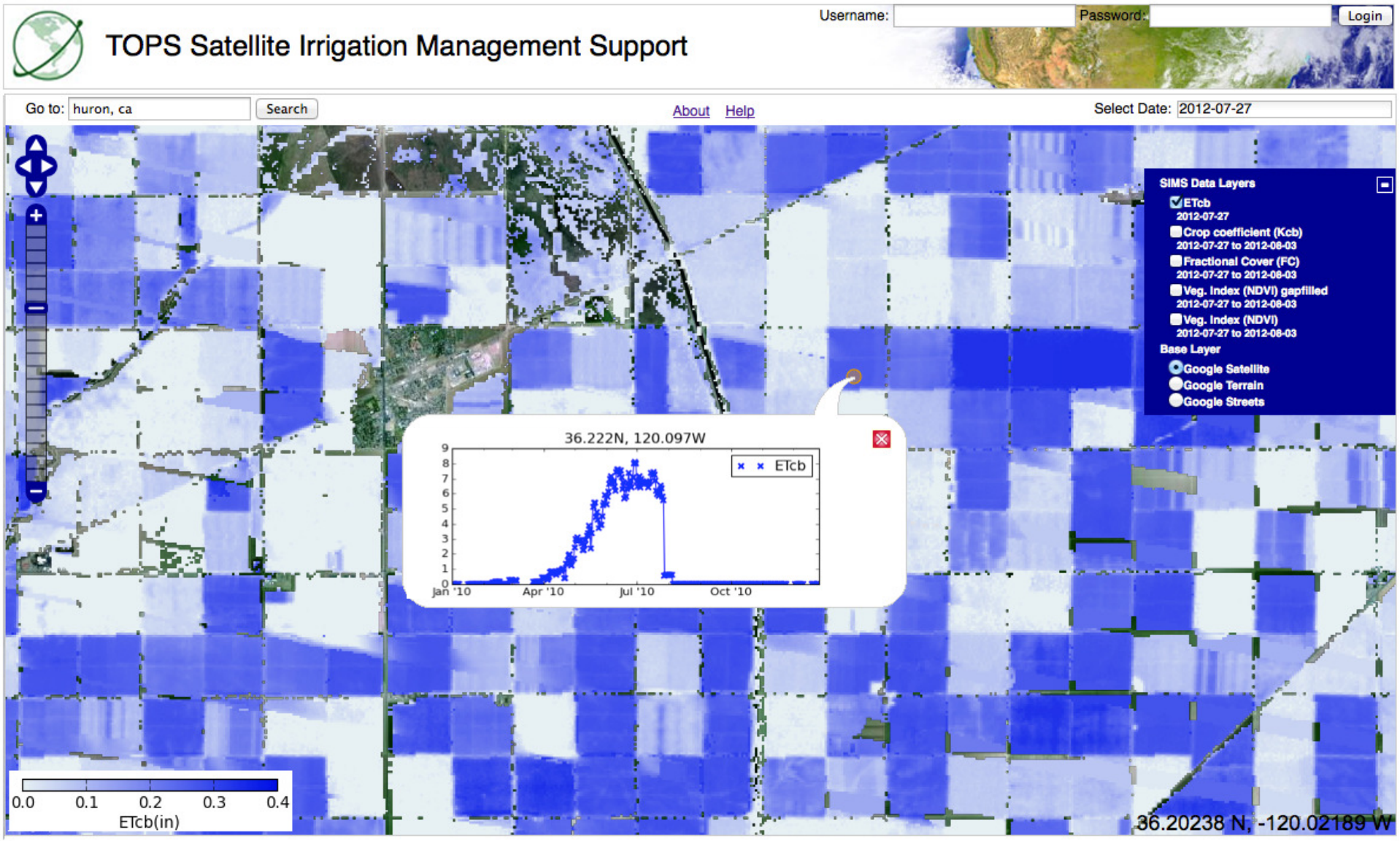
METRIC ET Summary and Recommendations

- Field scale (30-60m) resolution ET mapping is, and will become, more and more critical for water accounting as supplies decline and demands increase
- The use of Landsat and MODIS for computing EB and VI derived ET separately, and in combination, provide robust solutions *now* for water and ecological management needs
- Currently assessing the use of remote sensing ET in court
- Many western US states are using METRIC ET operationally
- Automation of EB and VI based ET estimates, improved time integration, cloud, and gap filling
- Representative weather station data for computing reference ET (not nearly enough quality weather station data to use)
- Gridded reference ET and potential consumptive use estimates at < 1Km resolution to provide consistent estimates across all Western States
- Buoy weather station network for estimating open water evaporation
- Need multiple Landsat's and not just one due to cloud cover and accuracy.

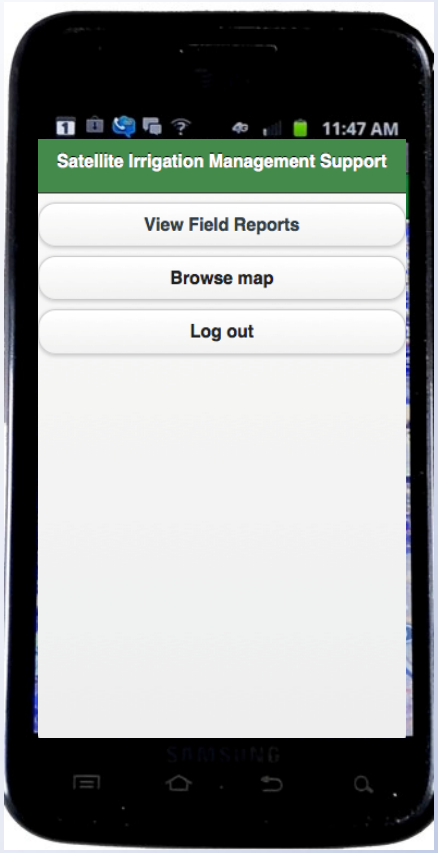
Huntington/DRI, mod by Toll

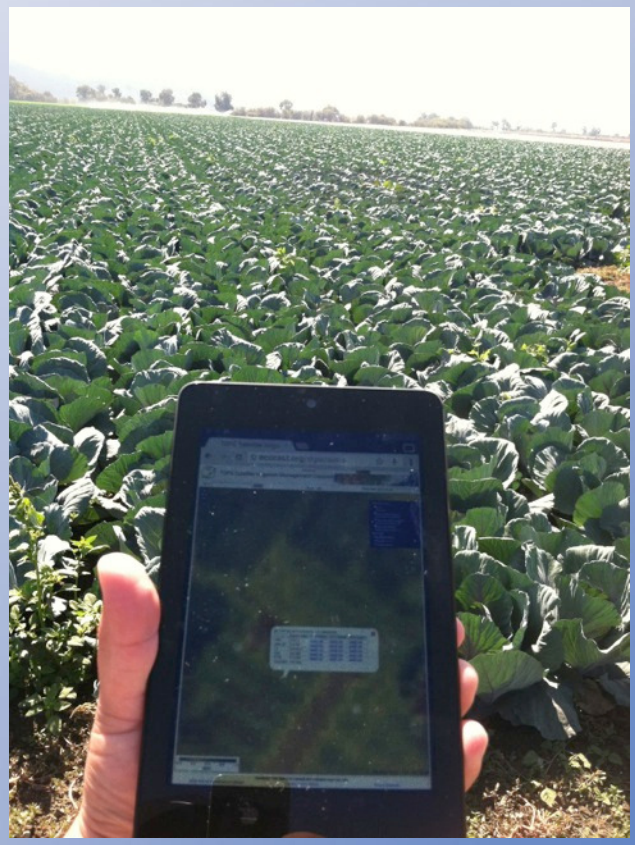
F. Melton/NASA Ames

Satellite Irrigation Management Support (SIMS) Framework



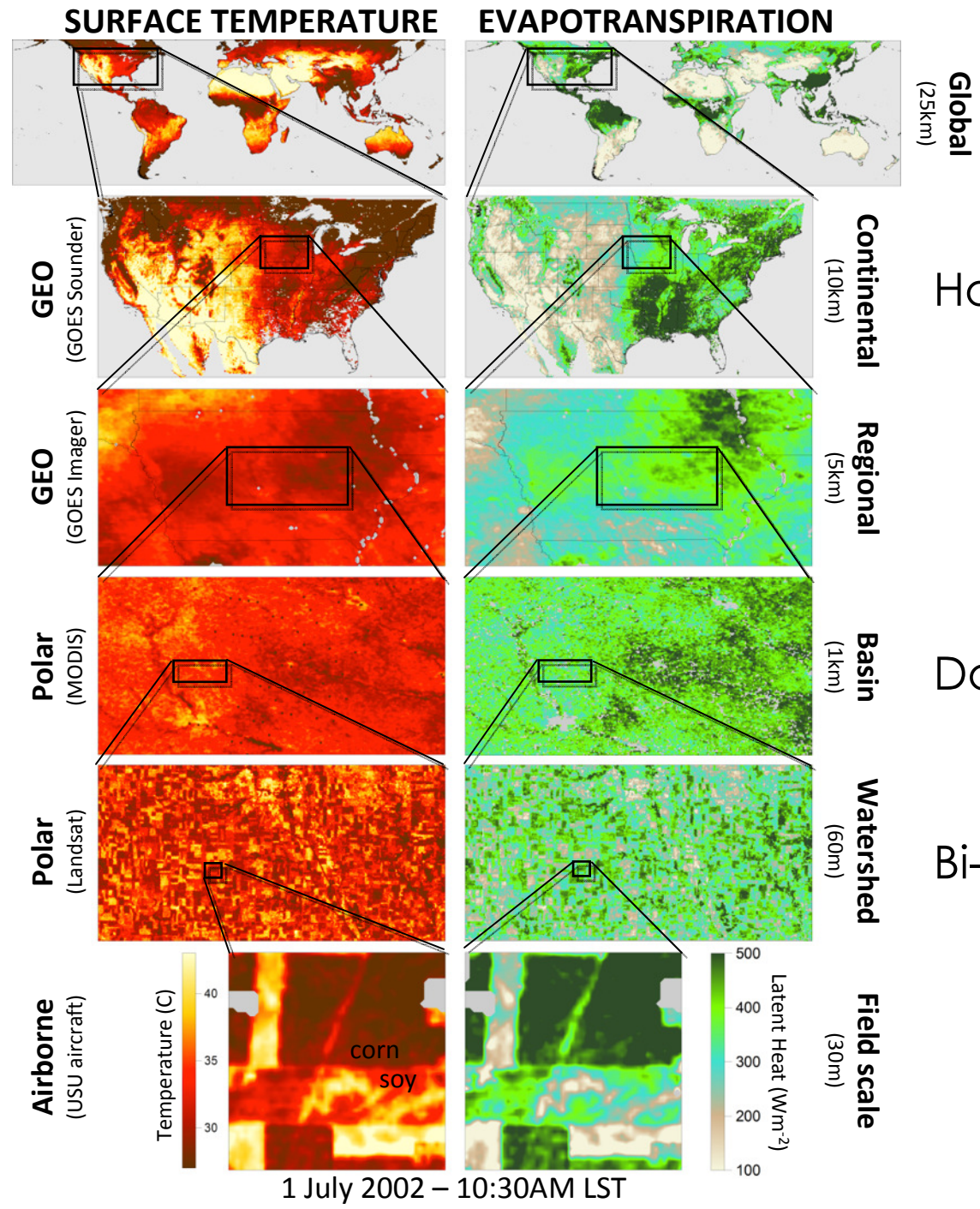
Delivering Data to the Field: Mobile Interfaces





Mobile-based interfaces important for enhancing access to data

F. Melton/NASA Ames



DATA FUSION:
daily ET at
field scale

Hourly

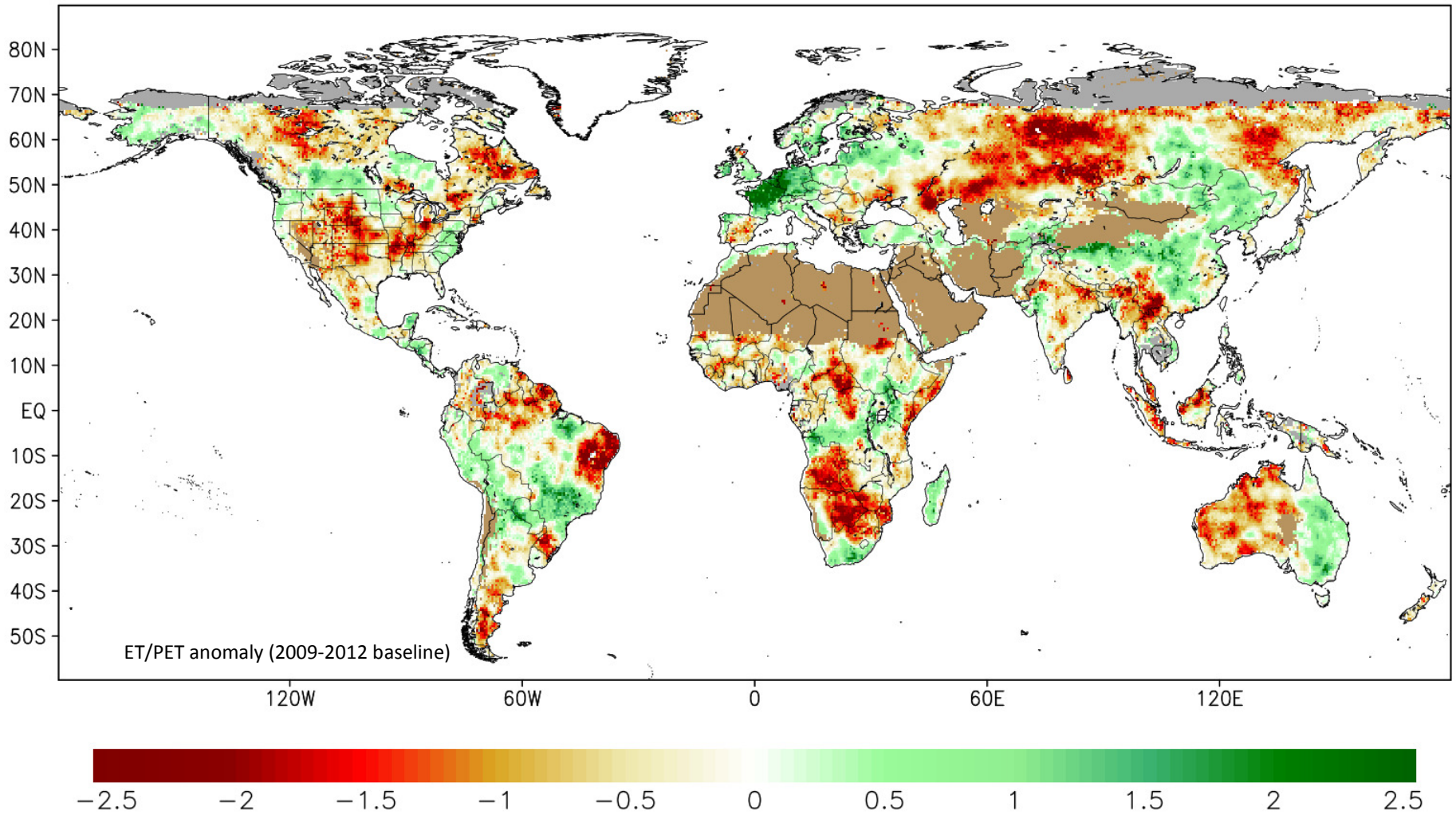
Daily

Bi-weekly

Anderson/USDA

M. Anderson/USDA & C. Hain/NOAA. New 'ALEXI' MODIS Based Evapotranspiration Gridded at 25 km with 1 km Capabilities

JUNE 2012 - 12-week composite

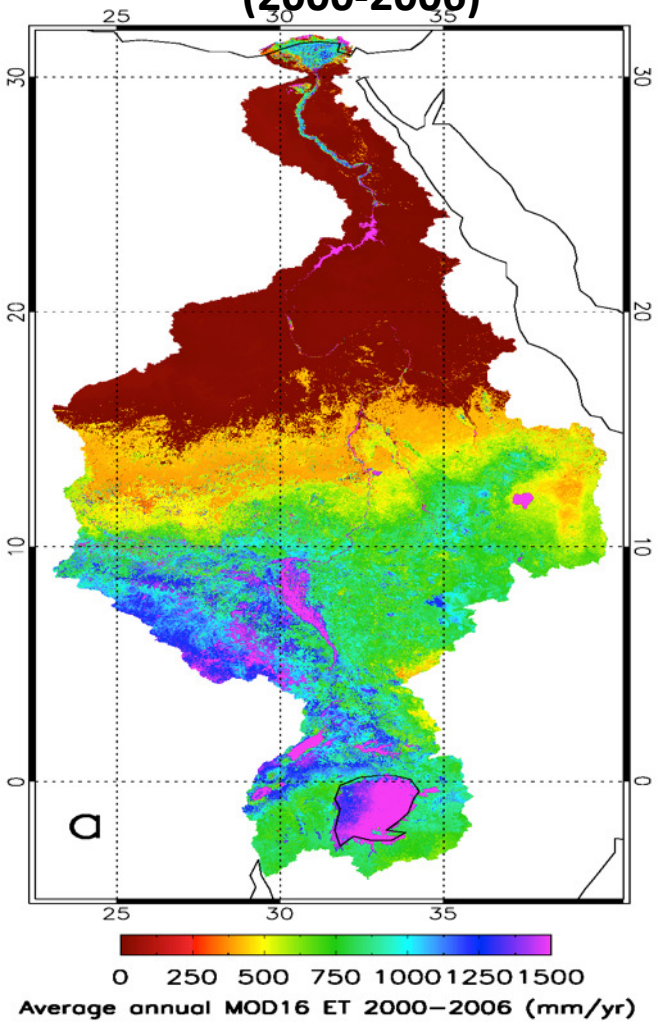


C. Hain/NOAA and M. Anderson/USDA

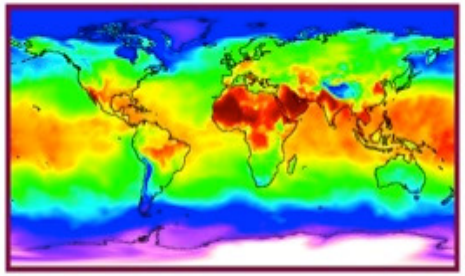
MODIS ET (16) Product – U. Mont & Q. Mu

Q. Mu in 2013 and 2014 optimized the NASA ET Product for the Nile Basin providing basin wide water balance. ET estimates are 576 mm/yr, precipitation at 618 mm/yr with estimated runoff at 42 mm/yr.

Nile Basin Evapotranspiration (2000-2006)



Input MODIS data (RS)
(Albedo, FPAR/LAI, Land cover)



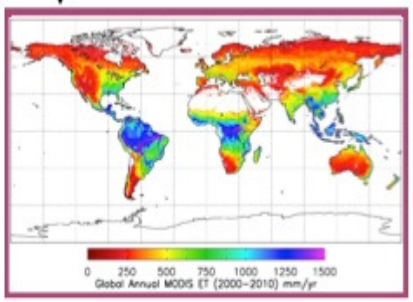
Daily Meteorological data (MET)
(S↓ , VPD, Temperature. No Prcp!)

Penman-Monteith equation

$$\lambda E = \frac{\Delta \cdot R_a \cdot (R_n - G) + \rho \cdot C_p \cdot VPD}{R_a \cdot (\gamma + \Delta) + \gamma \cdot R_S}$$

MODIS ET: soil evaporation, evaporation from intercepted water by canopy and plant transpiration.

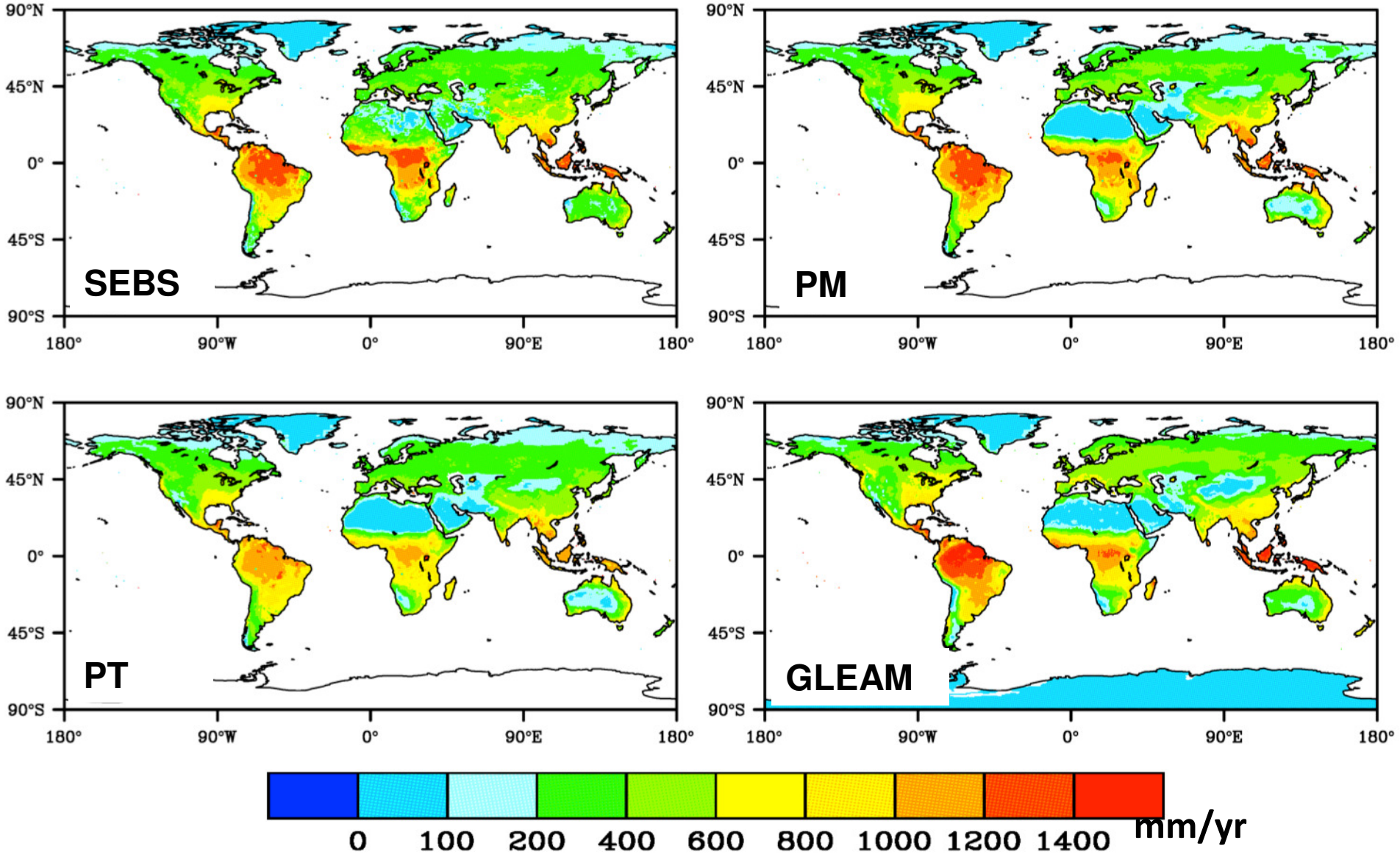
ET = f (RS, MET)



Mu et al., 2007, RSE; Mu et al., 2011. RSE. Mu et al., 2009, WRR

Land Flux – 3 Global ET Approaches with Products
(E. Wood/Princeton U.)

Mean evapotranspiration (1984-2007, units: mm/yr)

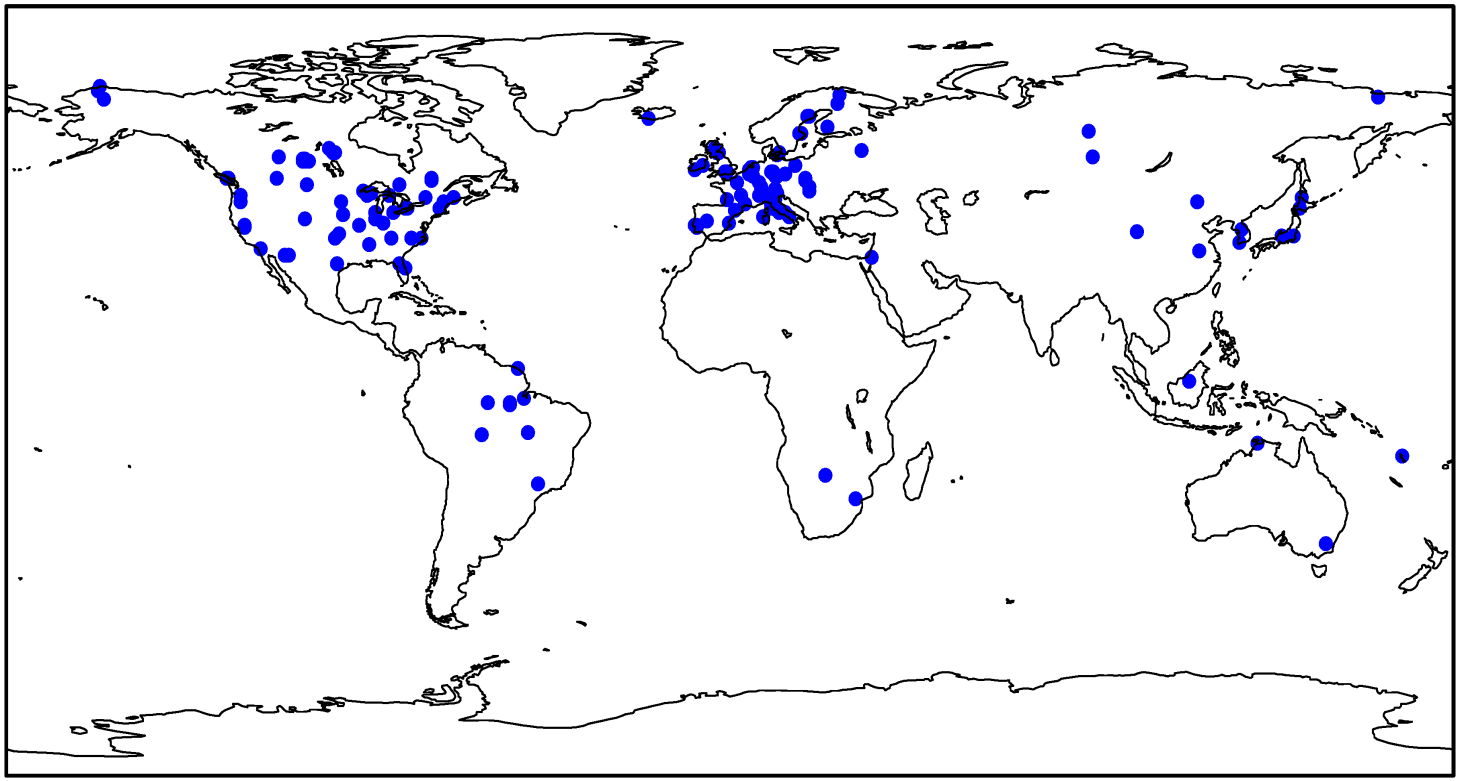


	Convergence		P_{GPCP}-ET				D
(mm/year)	MERRA	ERA-Int	PM	PT	SEBS	GLEAM	VIC
South America	483	526	590	734	686	579	653
North America	249	218	269	306	267	218	316
Africa	90	115	174	174	114	143	147
Eurasia	190	175	257	293	253	194	335
Australia/Oceania	276	92	243	313	390	226	227

Analysis from 1984-2006

Tower Scale: Validation over 143 FluxNet sites

FLUXNET Site locations



2014 LAND FLUX UPDATES

1. The project successfully retrieved, from remote sensing, 1984 – 2006 terrestrial evapotranspiration data products using three alternative algorithms. The current resolution is daily and 1-degree spatially.

2. The data products have been validated using FluxNet tower data and basin-based budget analysis.

3. The data sets are being used to further understand the global water and energy cycle variability and trends, a central scientific focus of NEWS.

4. The project successfully retrieved Land Surface Temperature (LST) data product that is consistent with the HIRS sensor from 1979-2009. The data set ha been validated against available measurements at Baseline Surface Radiation Network (BSRN) stations.

5. The data sets are available to NEWS investigators to use.

National Aeronautics & Space Administration

Water Resources Program

Required Satellite Systems for ET Mapping from Local to Global Scales

Satellite Thermal Imaging Systems

Pixel Scale	Spatial Resolution	Temporal Resolution	Current Sources	Future Sources
Coarse	5-20 km	15 min	AIRS **GOES** MSG	CrIS GOES MSG
Moderate	1 km	2-4 times daily	**MODIS** AVHRR ATSR	VIIRS AVHRR ATSR
Fine	90–120 m	Once every 8-16 days	ASTER **Landsat**	LDCM HyspIRI?

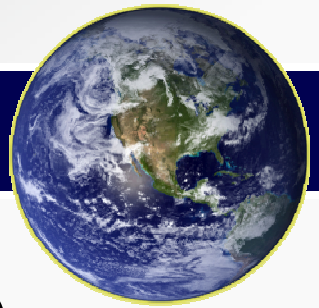
Table from S. Hook

Next Steps

- **Continue the improvement and implementation of ET products across multiple scales globally with an emphasis in developing countries of the world. Also provide in near real-time and with short-term (<10 days) forecasts.**
- **Work with GEO to improve the operational implementation and further development of *In Situ* ET measurements and weather station data.**
- **Expand on the ET training courses to enable capacity and implementation of ET products operationally and in decision support systems**
- **Expand on the Global ET and Western ET Workshops NASA sponsored for an international ET workshop in conjunction with the World Bank**
- **Connect with the USGS Water Census on Water Use & Evapotranspiration to the US for broader and global applications.**
- **Advocate by CEOS and GEO to provided multi-temporal and multi-spatial satellite observations**
- **Integrate better across ET team with the goal to reduce errors and to implement approaches more to benefit society.**
- **Further improve continental scale water balance uncertainties across modeling, satellite derived results and reanalysis data.**
- **Further integrate and develop with land surface modeling ET results**
- **Continue to accelerate by recognition of ET as an 'Essential Climate Variable'**

USGEO Water

Component Status Summary



- 2014 milestones
  - Initial USGEO Meeting (Nov. 20, 2013 Washington DC)
  - AGU USGEO Water Town Hall (December 7, 2013, San Francisco)
  - Geo Ministerial Summit: US GEO &Advanced Water Technologies Side Event (Jan 13, 2014, Geneva)
  - GEOSS Water Strategy Report Released
  - Strategic Workshops
  - Complete Water Strategy and Concept Components
- 2015 milestones: In development.
- Identified risks – not achieving desired Earth Observation capability (including accuracy and accessibility) with end users. Funding. Integrated Water Task strategy.
- Synergy opportunities with other water groups/activities – USG, USWP, PEER Water, Skoll Global Threats Fund, WRI, NOAA NIDIS, GEO GDIS.