TQ3. Water Use and Availability

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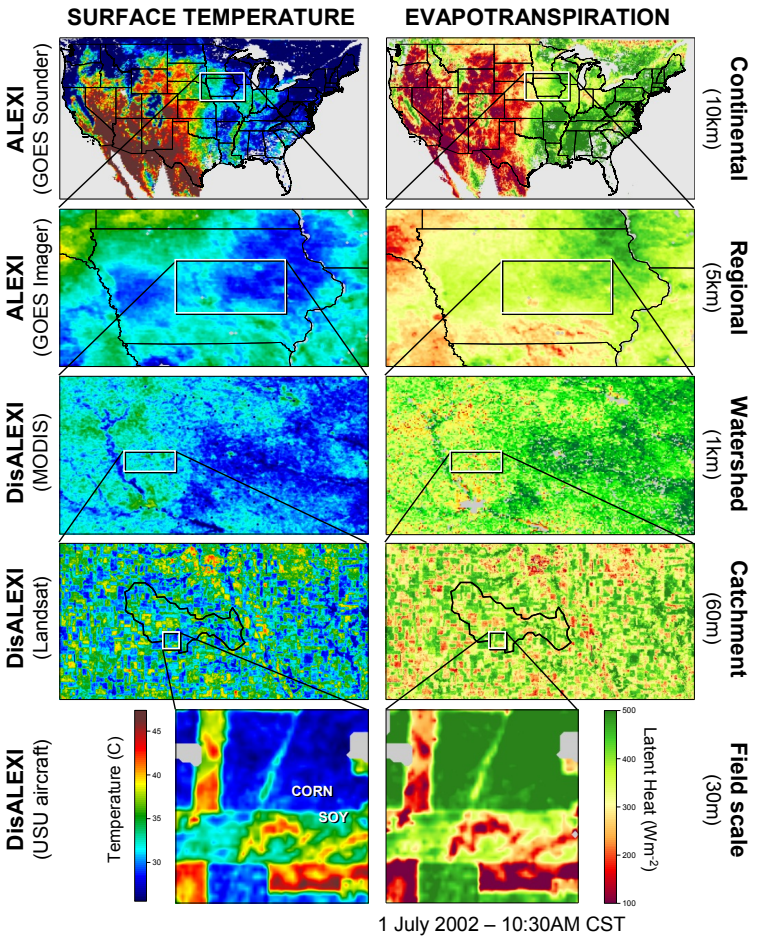


Multi-scale ET maps for 1 July 2002 produced using surface temperature data from aircraft (30-m resolution), Landsat-7 ETM+ (60-m), Terra MODIS (1-km), and GOES Imager (5-km) instruments (Anderson and Kustas (2008), Eos, 89, 233-234)

Science Issue:

• Evapotranspiration (ET) is a measure of water loss to the atmosphere through soil evaporation and plant transpiration, and is a major component of the land-surface hydrologic cycle. With satellite-derived maps quantifying the magnitude and variability of ET over natural and managed landscapes we can estimate the rate at which freshwater resources are being consumed. Particularly useful are maps at $\leq$100m resolution, resolving natural and anthropogenic land-cover features important to local and regional water management: individual fields and irrigation pivots, canals and riverbeds, reservoirs, and other human-made hydrologic structures. Land-surface temperature, retrieved from observations in the thermal wavebands, can be used to evaluate the subsurface moisture status and is a critical input to most satellite-based ET mapping algorithms.

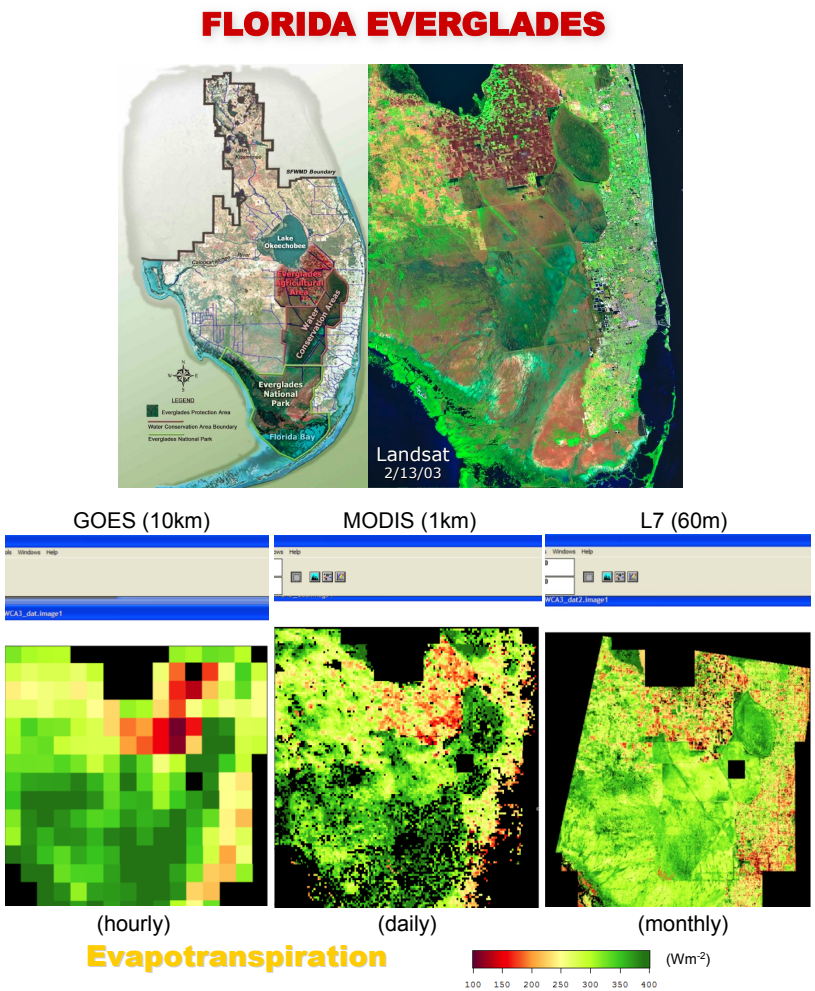
Tools:

• HyspIRI TIR observations of surface brightness temperature at <100m resolution and ~weekly revisit intervals.
• Robust and well-validated thermal-based ET mapping algorithms.
• Gridded information on land-use/landcover and precipitation.
• Hydrologic decision support tools.

Approach:

• Integrate remotely sensed ET maps into hydrologic modeling tools to estimate consumptive water use and groundwater recharge associated with specific land uses.

TQ3a: How is climate variability impacting the evaporative component of the global water cycle over natural and managed landscapes? (DS 166, 196, 203, 257, 368; WGA)



Multi-scale ET maps for 13 February 2003 over the Florida Everglades – a hydrologically sensitive ecosystem that is responding to a suite of natural (climatic) and anthropogenic stressors (urban encroachment, agricultural runoff, altered drainage patterns). The sub-100m scale map is critical for connecting ET patterns to specific land-uses.

Science Issue:

- Based on principles of surface energy balance, the land-surface temperature signal conveys valuable information about the evaporative component of the hydrologic cycle and its response to varying climatic drivers. If we can accurately monitor this response in relationship to land-use and land-cover conditions, we will improve our ability to forecast water consumption and demand and to develop effective climate adaptation strategies for our water systems.

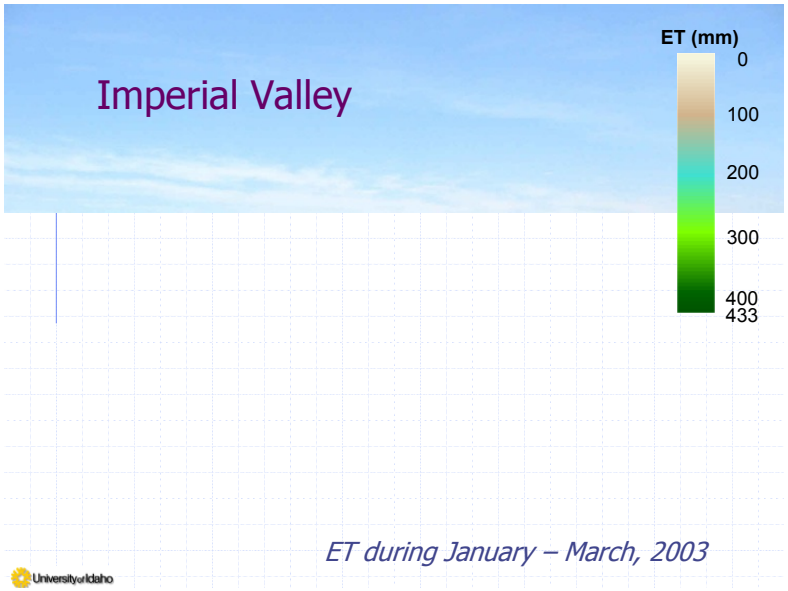
Tools:

- HyspIRI TIR observations of surface brightness temperature at <100m resolution to resolve field-scale land use, preferably with 3+ bands in the 8-12μm region for atmospheric and emissivity corrections. The weekly revisit of HyspIRI will improve accuracy of seasonally integrated ET estimates.
- Collocated/contemporaneous maps of vegetation index and landuse.
- Insolation data to estimate net radiation.
- Regional scale ET maps using coarser resolution TIR imagery from geostationary satellites and MODIS/VIIRS provide spatial context for local assessments.

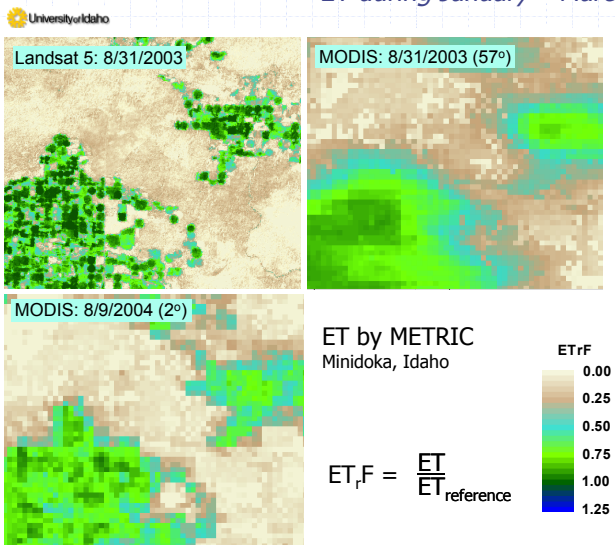
Approach:

- Periodic maps of instantaneous clear-sky ET from a TIR-based surface energy balance algorithm can be used to produce daily ET maps by incorporating time-continuous observations of reference ET or available energy from met stations or geostationary satellites.
- Record of daily ET at scales resolving major land use patterns can be analyzed in conjunction with gridded climate data.

TQ3b: How can information about evapotranspiration and its relationship to land-use/land-cover be used to facilitate better management of freshwater resources? (DS 196, 203, 368; WGA)



ET during January – March, 2003



Science Issue:

- Accurate high-spatial resolution ET information from satellites will improve our ability to wisely manage increasingly scarce freshwater resources around the globe. Maps of ET at scales resolving irrigation systems can be used to monitor groundwater extractions by individual users, while estimates of ET from canals, reservoirs and riparian vegetation along stream and river channels facilitate dam and basin management.

Tools:

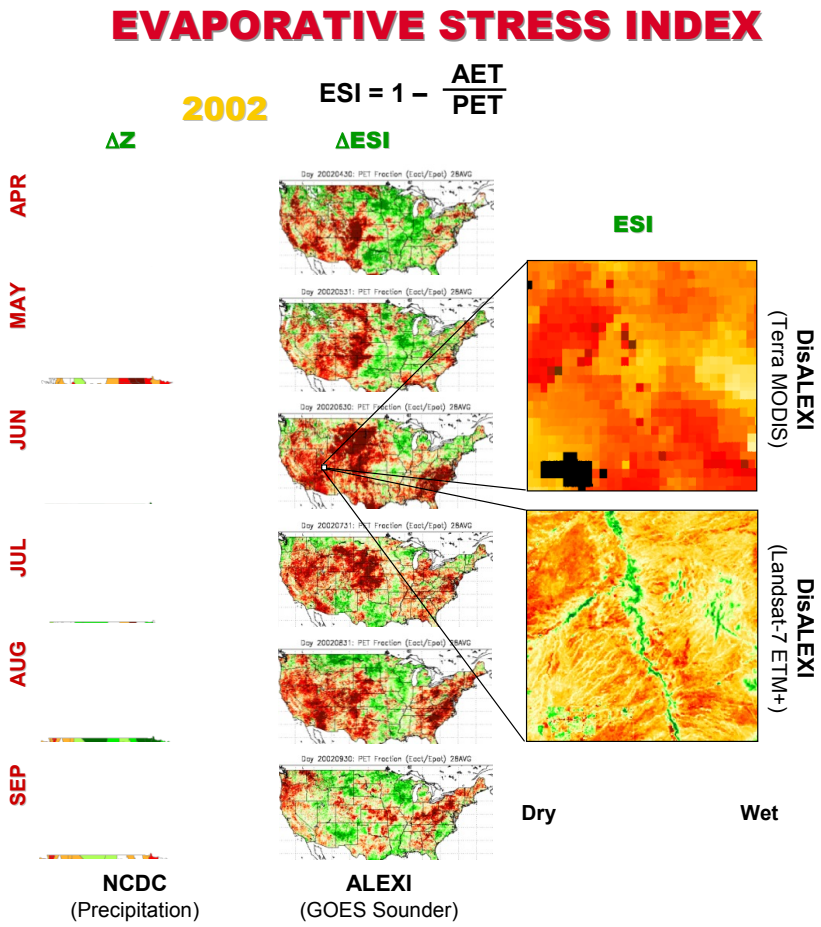
- High spatial and temporal resolution ET maps using TIR imagery from HyspIRI, resolving land-surface features related to water management.
- Water management decision support tools that can ingest spatially explicit ET information.

Approach:

- For consumptive use monitoring, maps of seasonal ET can be aggregated over water rights polygons and compared to allowed pumpage rates. Estimates of ET losses from irrigation districts, canals, riverways and reservoirs are critical inputs to decision support tools used by water managers in the Bureau of Reclamation.

MODIS TIR at 1-km is unable to provide unambiguous estimates of ET and consumptive water use associated with individual center pivot irrigation systems for water rights monitoring (Allen et al. (2007), *J. Irrig. Drainage Eng.*, doi:10.1061/(ASCE)0733-9437(2007)1133:1064(1395)).

TQ3c: How can we improve early detection, mitigation, and impact assessment of droughts at local to global scales? (DS 166, 196, 203, 368; WGA)



Monthly anomalies in a GOES-based Evaporative Stress Index (ESI=1-ET/PET) and in the Palmer Z index (Z), a precipitation-based metric of short-term meteorological drought, computed with respect to 4-year (2002-2005) mean monthly conditions. Also shown are ESI values over the San Pedro River basin in Arizona using TIR data from MODIS (1-km resolution) and Landsat 8 (60-m). (Anderson et al.(2007) J. Geophys. Res, 112, D11112, doi:11110.11029/12006JD007507.)

Science Issue:

• Drought information is being requested at increasingly high spatial resolution to assist in yield forecasting, drought mitigation and crop loss compensation efforts. The ratio of actual to potential ET (ET/PET) is a valuable indicator of soil moisture deficiency that can be mapped efficiently at multiple spatial scales using TIR-band satellite data. Unlike standard meteorologically-based drought indices, TIR-based indices do not require ancillary information about rainfall or soil moisture holding capacity and are therefore well-suited for application in areas lacking extensive precipitation monitoring networks and surface characterization.

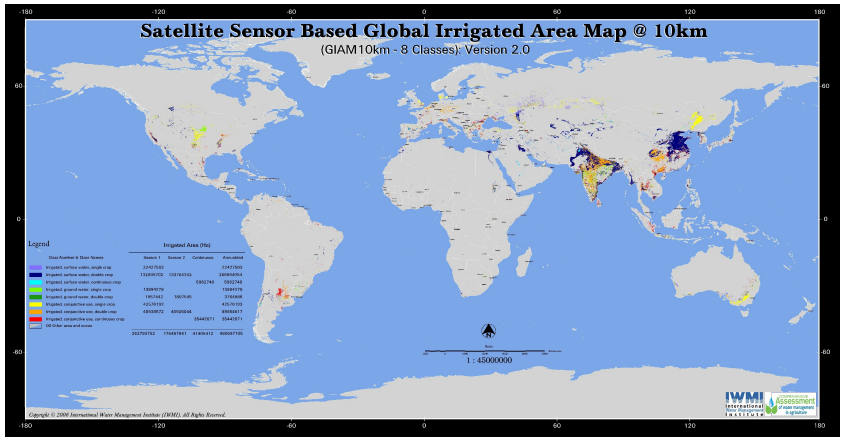
Tools:

• High spatial resolution ET and PET using TIR imagery from HyspIRI, with global coverage and frequent revisit.
• Coarse resolution daily ET/PET from MODIS/VIIRS or geostationary satellites.

Approach:

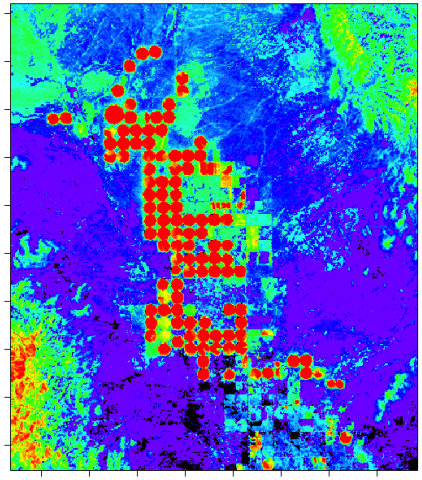
• Coarse resolution daily ET/PET maps (e.g. from geostationary satellite data) used to screen globally for drought-affected areas.
• Higher resolution assessments using HyspIRI can be generated in targeted regions where detailed spatial information is required.

TQ3d: What is the current global irrigated acreage, how is it changing with time, and are these changes in a sustainable balance with regional water availability? (DS 196, 368)

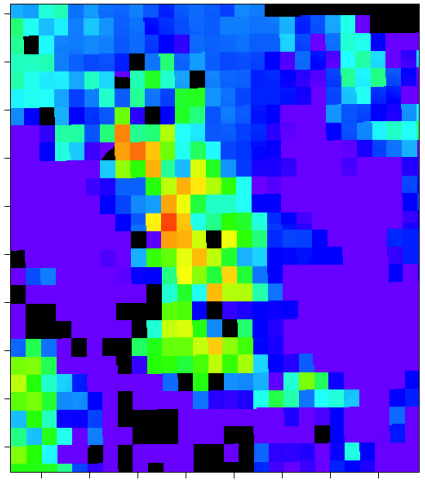


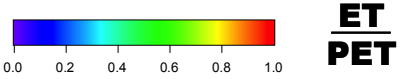
Current irrigation maps are based on primarily on observations of radiation, precipitation, landcover class, and shortwave reflectance.

Landsat 7 – 60m



MODIS – 1km





Science Issue:

• Accurate knowledge of irrigated land area, both in the U.S. and globally, and how it is changing with time is critical for water resource management and assessment of global food security. Irrigation consumes nearly 80% of all the global surface water currently used by humans, and in many parts of the world current groundwater over drafts are unsustainable, causing concern for future food production.

Tools:

• TIR imagery and derived ET datasets resolving individual irrigation systems.

• Additional data layers including climatic data (e.g., insolation and precipitation) to screen for areas of potential for irrigation, a landcover classification for identifying cropland, and shortwave band satellite data to define time series of NDVI or indices related to stress or chlorophyll content.

• Classification algorithm (e.g., decision tree).

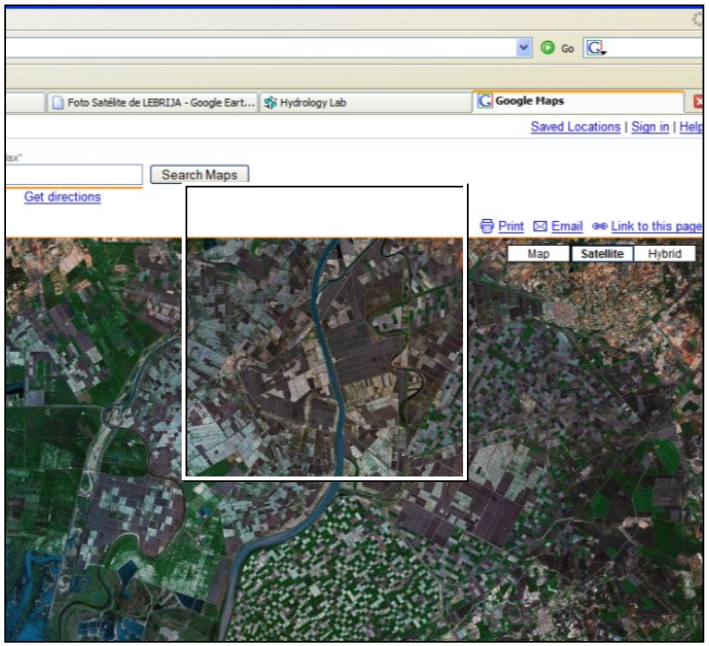
Approach:

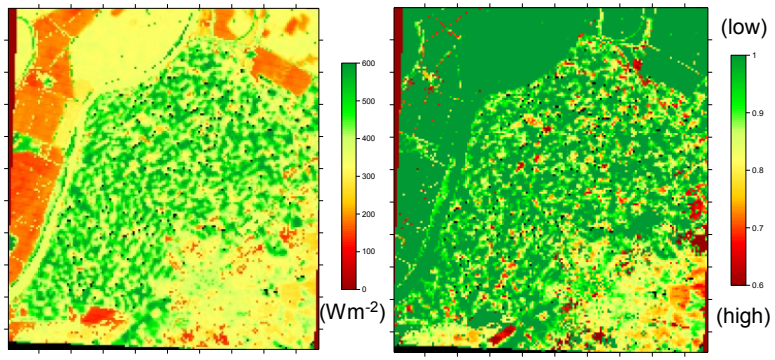
• Pixels exhibiting sustained high levels of ET/PET relative to surroundings suggest a localized source of non-precip related soil moisture addition – either through irrigation or access to shallow groundwater.

TIR maps of ET/PET at scales resolving irrigation systems provide a valuable input layer to irrigation classifiers. To date, TIR data have not been widely exploited in irrigation mapping due to temporal and spatial resolution constraints.

TQ3e: Can we increase food production in water-scarce agricultural regions while improving or sustaining water available for ecosystem function and other human uses? (DS 196, 368; WGA)

Irrigation district in Lebrija, Spain





Evapotranspiration **Evaporative Stress Index**

Landsat 5 (120m)

Science Issue:

• TIR remote sensing can be used to address important questions about global food production and its relationship to sustainable water use. There have been many cases where irrigation efficiency programs have ultimately led to *increased* water consumption, leaving stakeholders at the tail of the water distribution system with less water than before the project was instituted. To implement sustainable and equitable irrigation projects, both biomass production and ET should be monitored at the field scale. In areas of shallow water table, the relationship between soil salinity and irrigation efficiency must also be considered.

Tools:

• High spatiotemporal resolution TIR imagery and derived ET fields resolving individual irrigated parcels, linking water consumption to individual users.

• Yield/biomass and land-use maps at comparable resolution.

• Local hydrogeologic information (e.g., depth to water table, soil salinity, etc.)

Approach:

• Based on daily ET distribution and knowledge of the local hydrologic system, assess case-specific methods for converting non-beneficial ET (e.g., soil and sprinkler evaporation) into beneficial ET (i.e., crop transpiration) and for reducing the non-reusable fraction of the total irrigation diversion (Allen et al., 1996).

Landsat 5 TIR data at 120-m resolution are only marginally able to resolve ET and stress in individual fields in this irrigation district in southern Spain (see additional discussion in http://www.idwr.idaho.gov/gisdata/ET/thermal-band-issues/european-thermal_use.pdf).