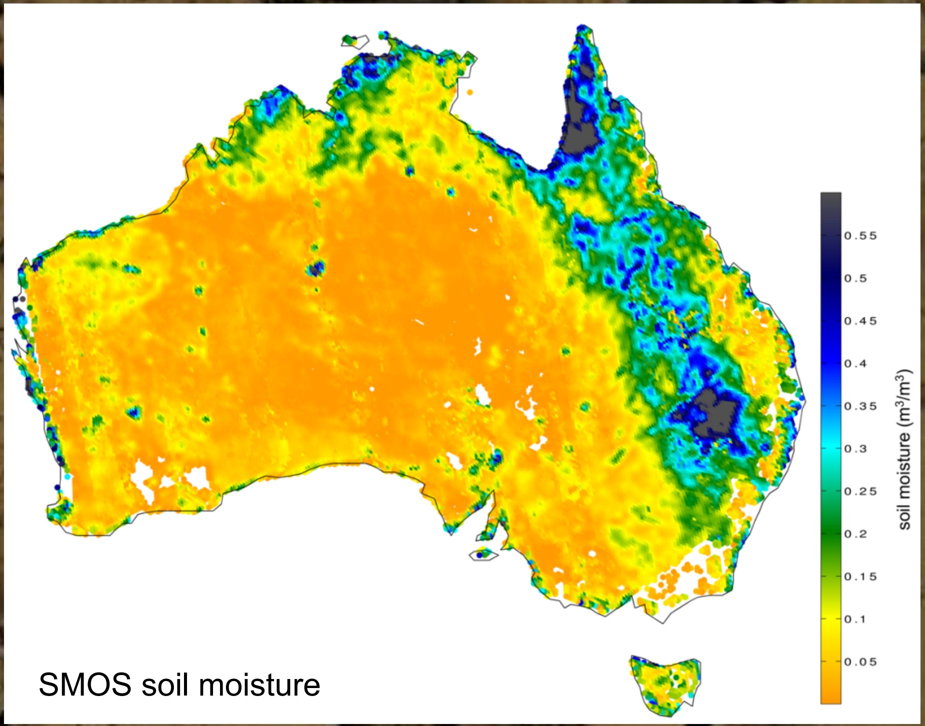
Can HyspIRI-like thermophysical data be used for calibration/validation of SMAP surface soil moisture measurements?



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2014 HyspIRI Science & Applications Workshop

Pasadena, CA (14 – 16 Oct 2014)

Outline

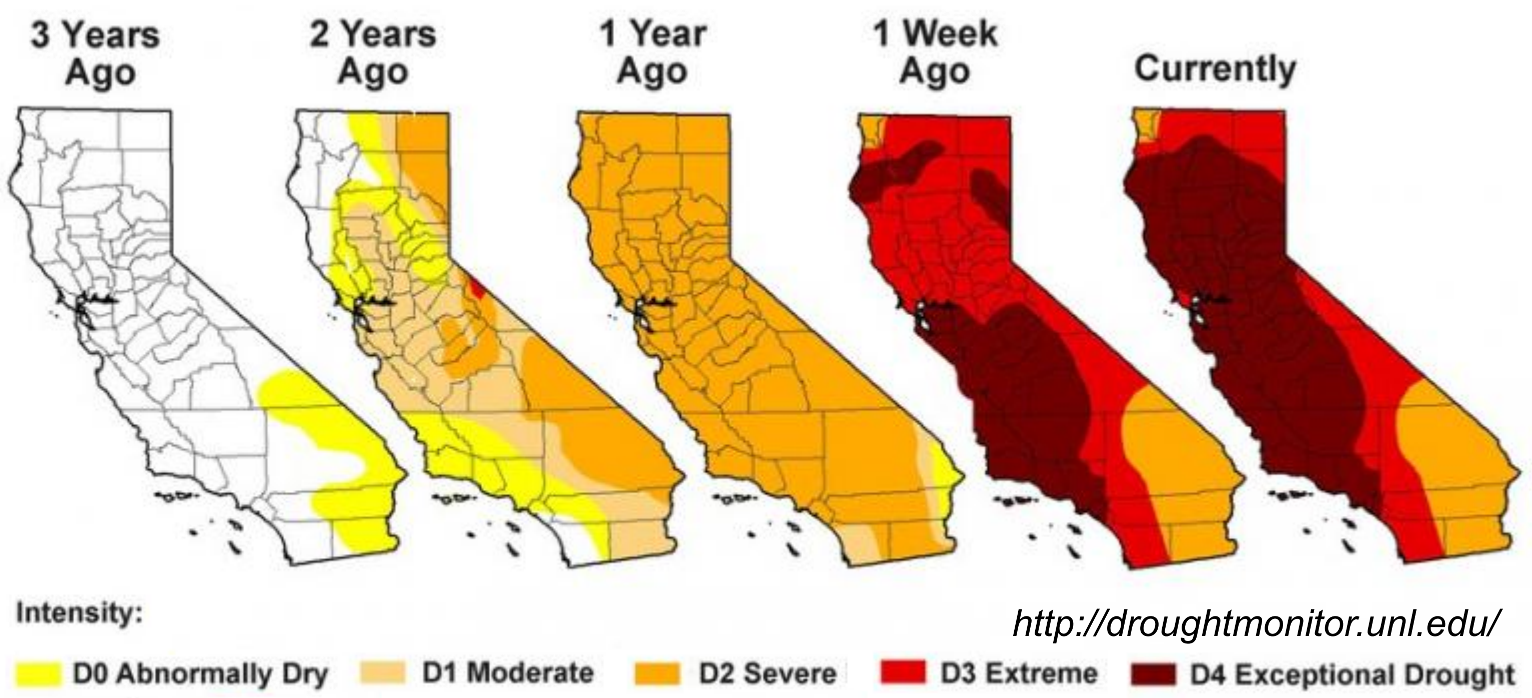
- **Background**
  - soil moisture relevance
  - measurement approaches
  - what is TI/ATI and how is it measured?
    - examples

[Sosnowski, 2012]

- **Possibilities with HyspIRI-like Data**
  - relevant science questions and what's realistic?
  - limitations/synergies with other sensors (e.g., SMAP, Landsat, …) and modeling approaches

Relevance

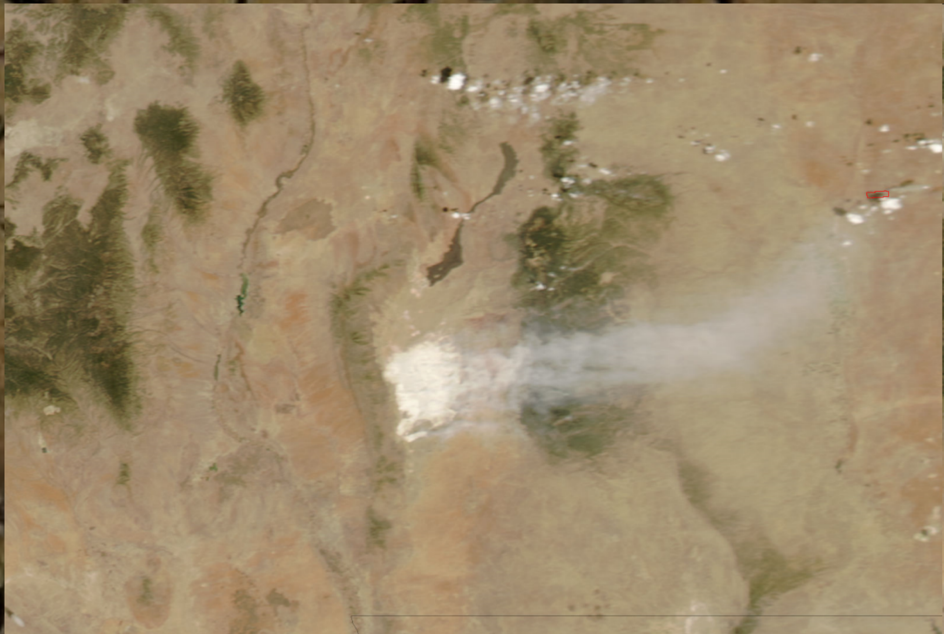
- **California Drought 2014: "Exceptional" Drought Levels Now Cover More Than Half The State; Soil Water Levels 'Nearly Depleted'**
  - International Business Times *[31 July 2014]*



- D4 *(58% of the state)*
- D2 *(95%)*
- rangeland: *(poor to v. poor – 70%)*
- est. cost: $2.2 billion

Soil Moisture Content (SMC)

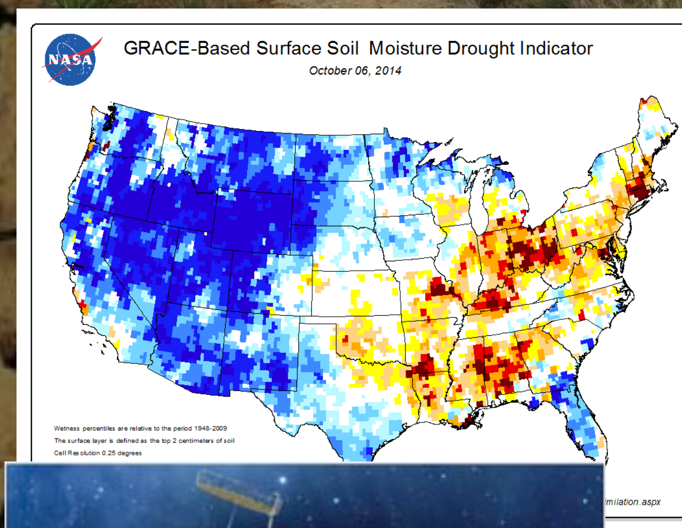
- **Importance in a Changing Climate**
  - soil moisture only represents ~0.05% of the global water budget
    - however, it has a disproportionate influence to its volume
    - fundamentally affects a variety of global climatic conditions
      - e.g., vegetation, ET, soil organic matter, aridity

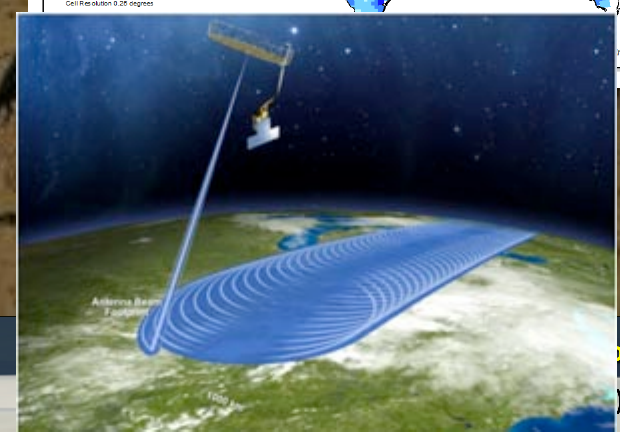

MODIS: 14 March 2008

    - in semi-arid landscapes soil moisture changes can alter the mobilization and entrainment of dust, for example

Measurement Approaches

- **Ground-Based**
  - DOE-ARM sites, USCRN sites
- **Orbital**
  - SMOS *(ESA)*
    - L-band, 50km spatial, 1-2m depth, every 3 days
  - GRACE *(NASA+DLR)*
    - gravity, 100's km spatial, vertically-integrated ground water, seasonal
  - SMAP *(NASA)*
    - L-band active/passive, 10 km spatial, 5cm depth, every 3 days





Integrative Possibilities

- **Microwave Sensors**
  - upcoming Soil Moisture Active Passive (SMAP)
    - SMC maps at 10 km up to every 3 days
      - excluding regions of snow and ice, frozen ground, mountainous topography, open water, urban areas, and vegetation with water content greater than 5 kg/m2
      - will not resolve small-scale features
        - *1 SMAP pixel is approximately 27,000 HyspIRI pixels*
    - a unique synergy exists between microwave and TIR based measurements of SMC
      - TIR data captures different scales of measurements both spatially and vertically
      - sensitive to different hydrologic conditions

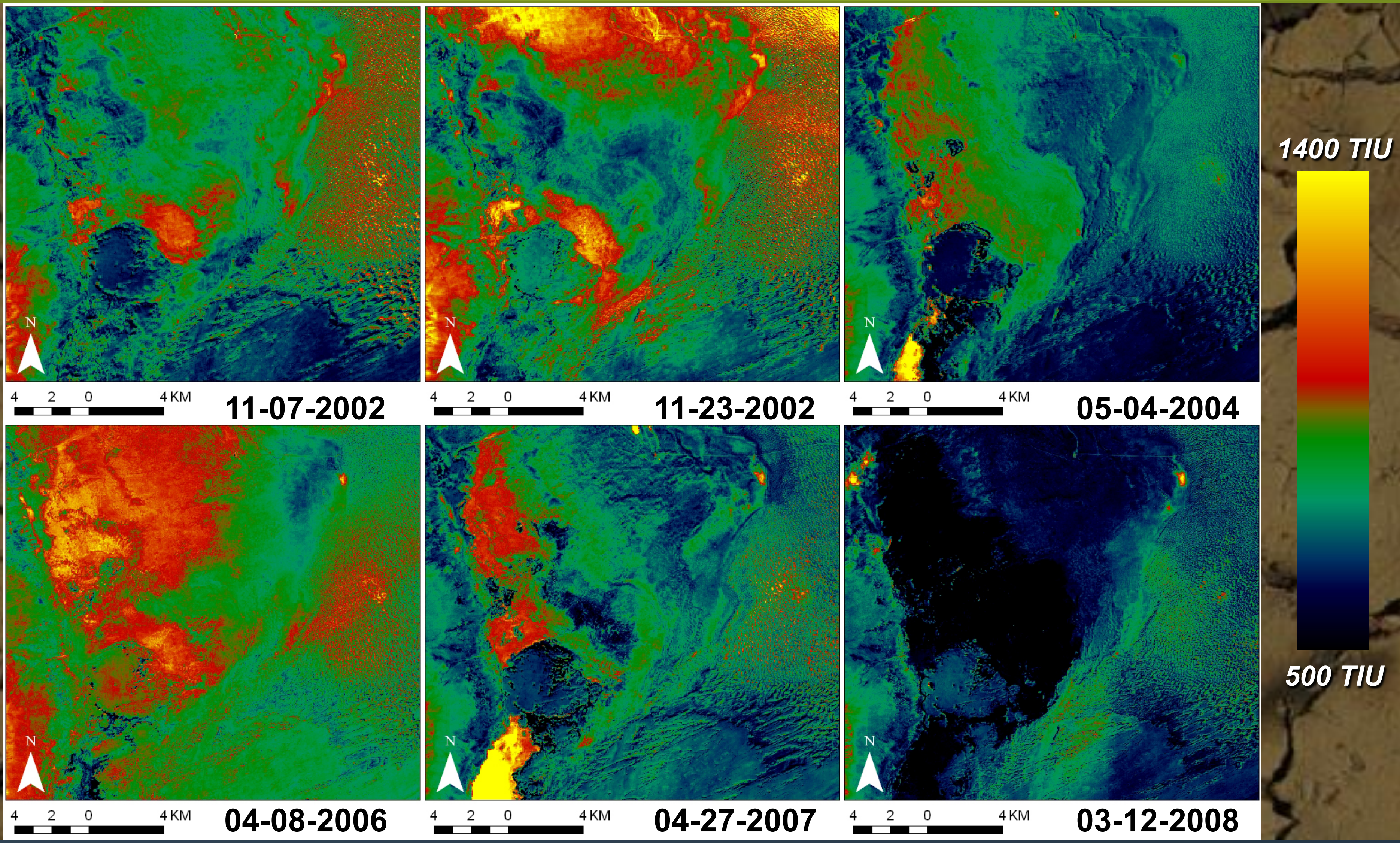
What is Missing?

- **Thermophysical Properties**
  - function of diurnal temperature differences & albedo
  - able to interpret daily to seasonal processes at various scales
    - soil moisture content (SMC)
    - soil erosion potential, consolidation, and density/cohesion
    - thermal inertia: resistance of a material to change in temperature, $I = (\kappa \rho c)^{1/2}$
    - ATI: apparent thermal inertia, $ATI = NC(1-A)/(T_d - T_n)$
      - a measure of the magnitude of the daily thermal curve moderated by albedo (A) and changes in solar flux with latitude and solar declination (N and C)
    - *modeling → ATI to TI to SMC (to soil-specific properties)*

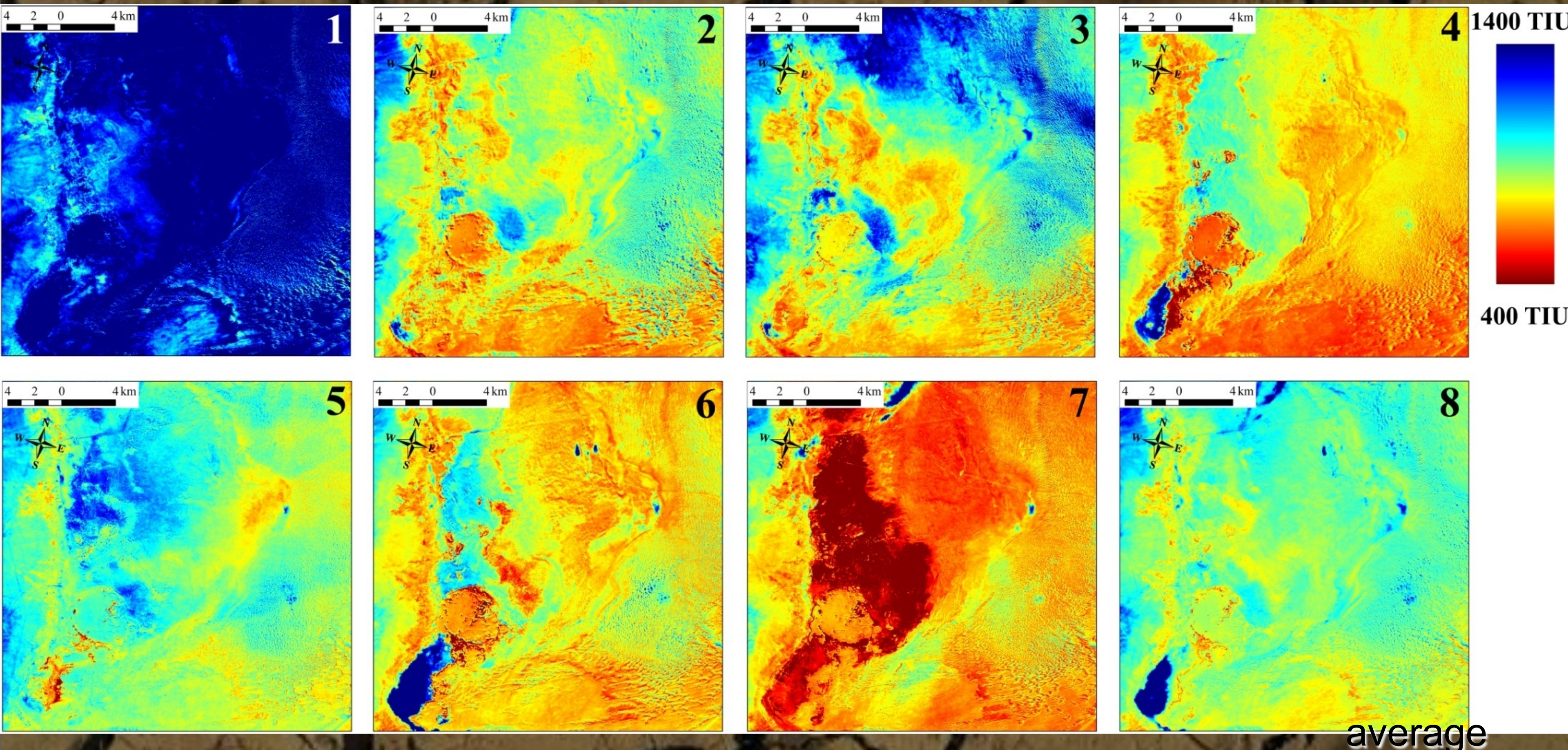
Prior Example

- **SMC and Sediment Mobility at White Sands, NM**
  - calculated over 8 years using ASTER ATI
  - to understand the relationship between
    - ATI ↔ TI ↔ SMC ↔ sediment availability
    - how are the differences in ATI over time explained for the same geographic area?
    - what are the errors in a vegetation-limited system?
    - can this approach determine SMC & sediment mobility?

Derived Thermal Inertia

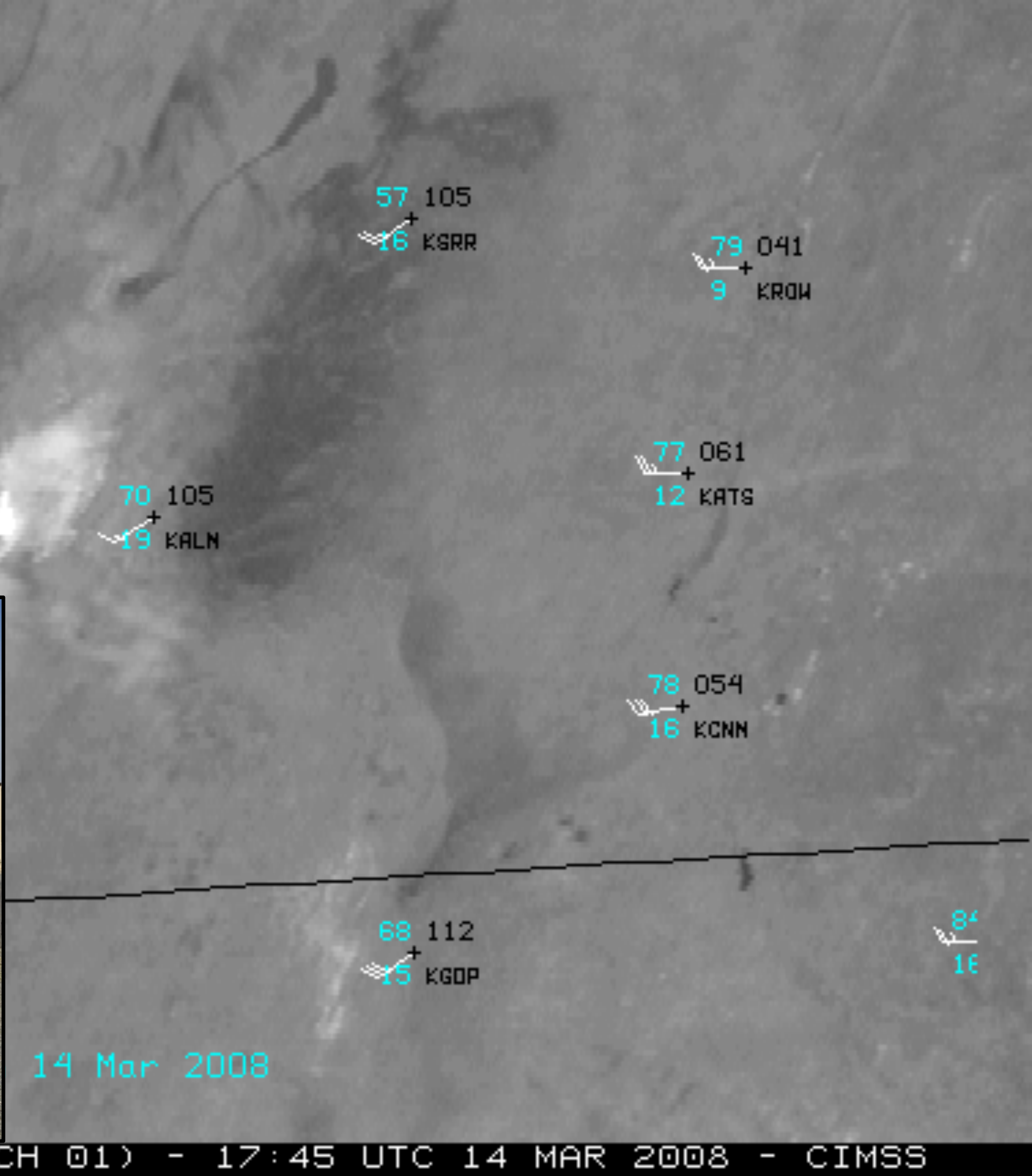


Derived SMC



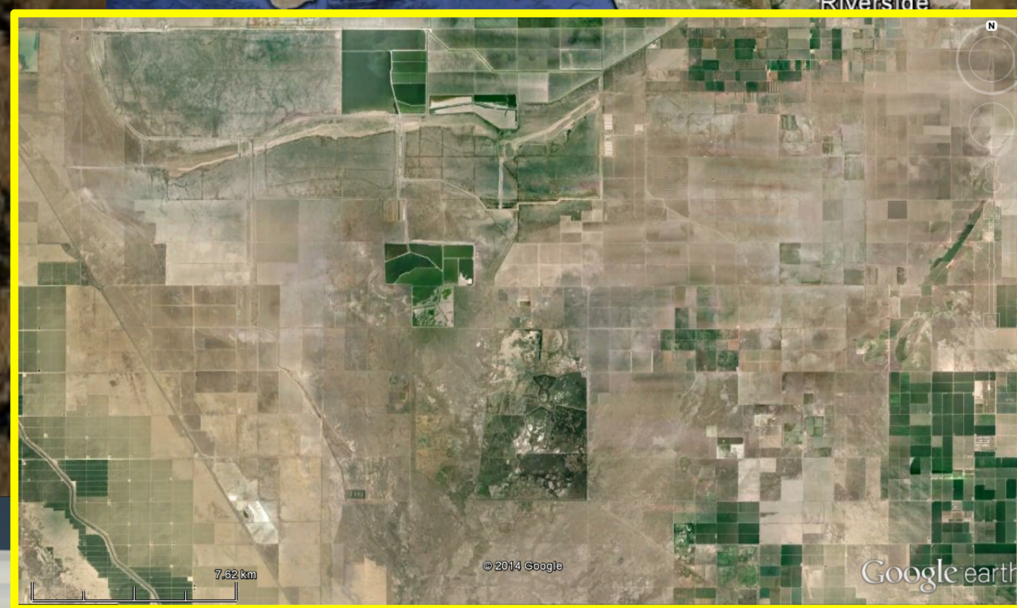
range of soil moisture content (9% - 25%)

White Sands: 14 March 2008

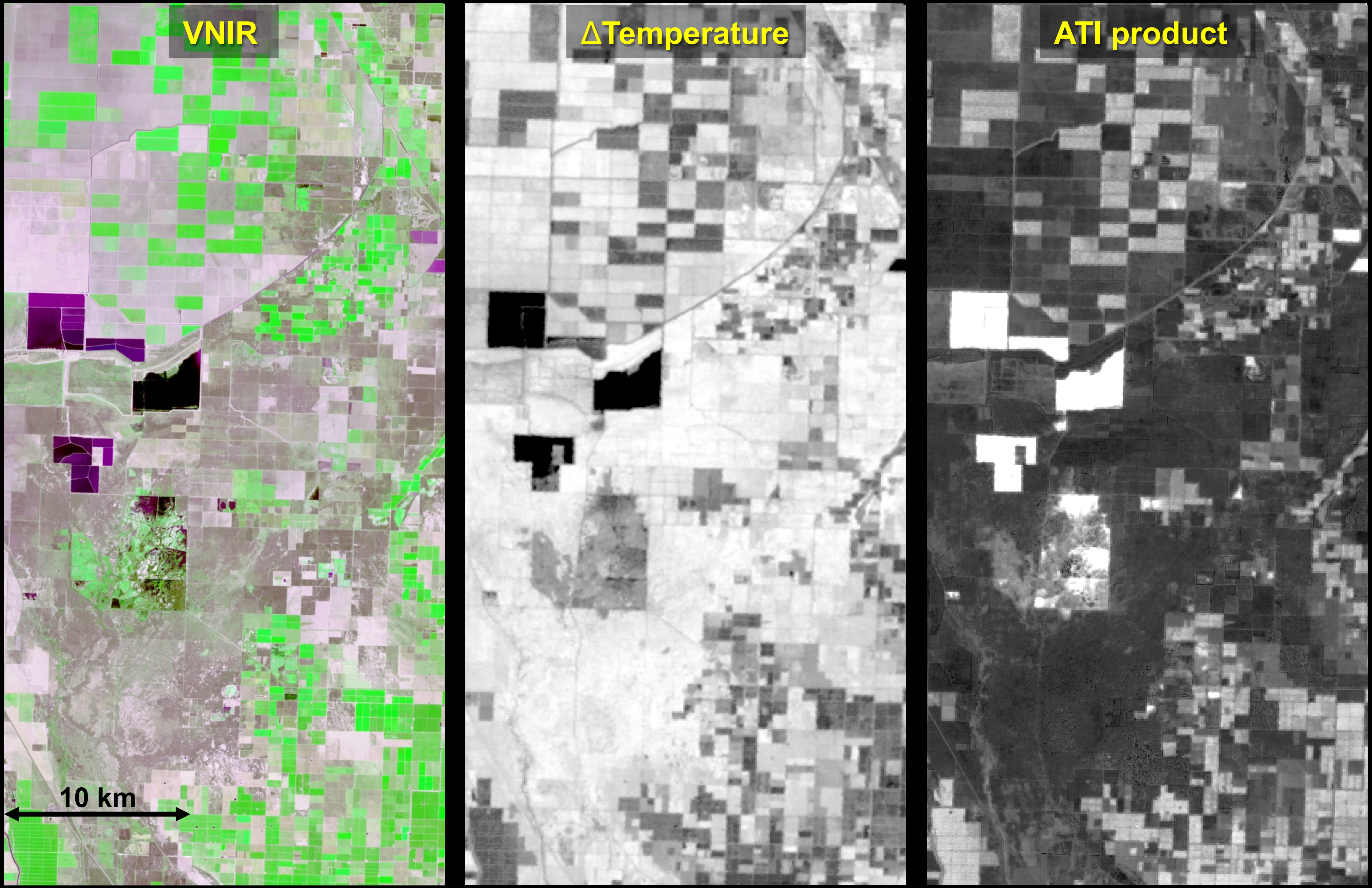


More Recent Example

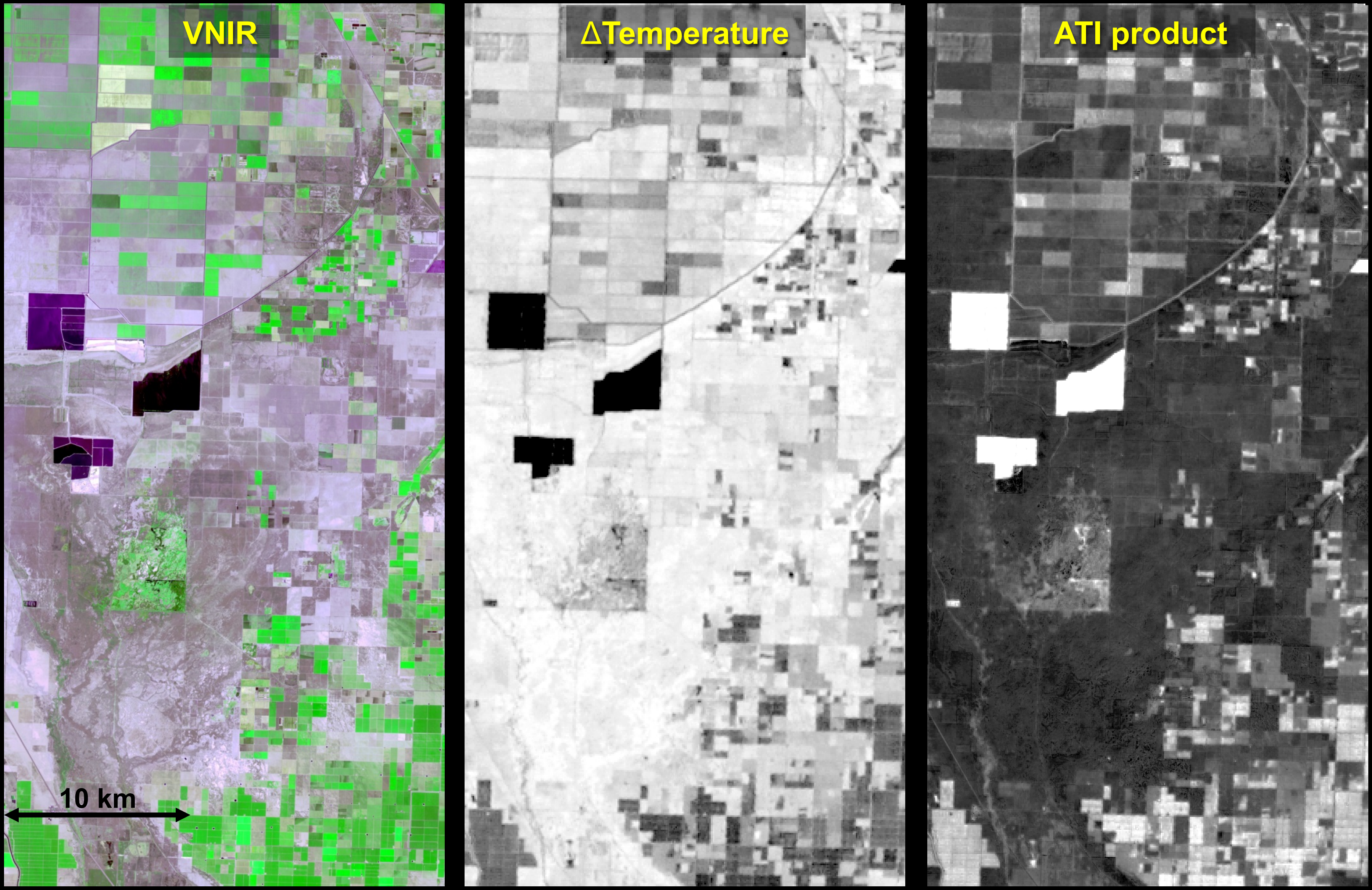
- **Tracking SMC During the Recent CA Drought**
  - examined ASTER ATI from 8-9 May 2012 and 30-31 May 2014 in CA central valley
    - is ATI-derived SMC viable in more agricultural landscapes?
    - are seasonal/yearly SMC changes due to drought detected?



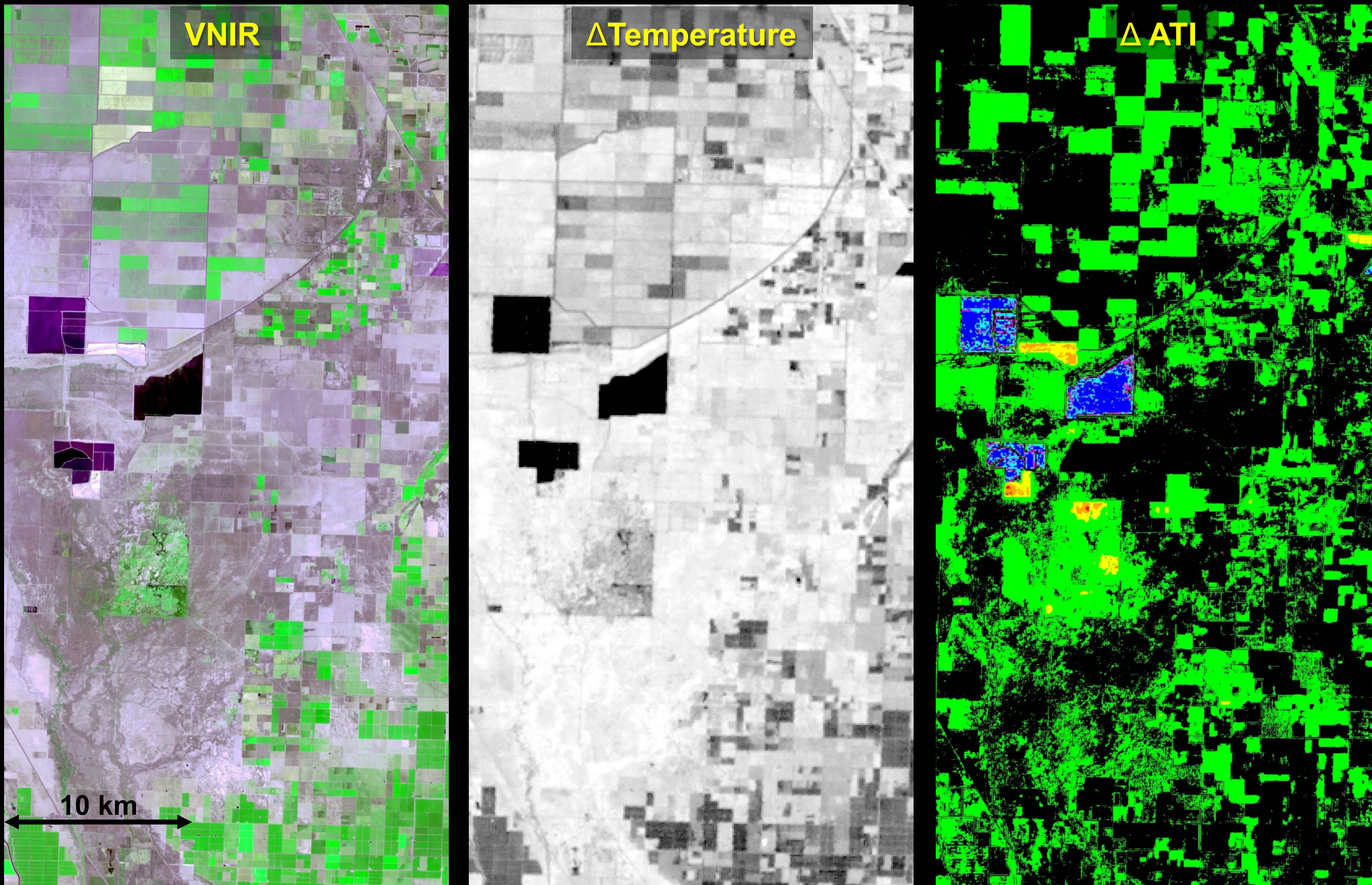
Derived Thermal Inertia *(05-09-12)*



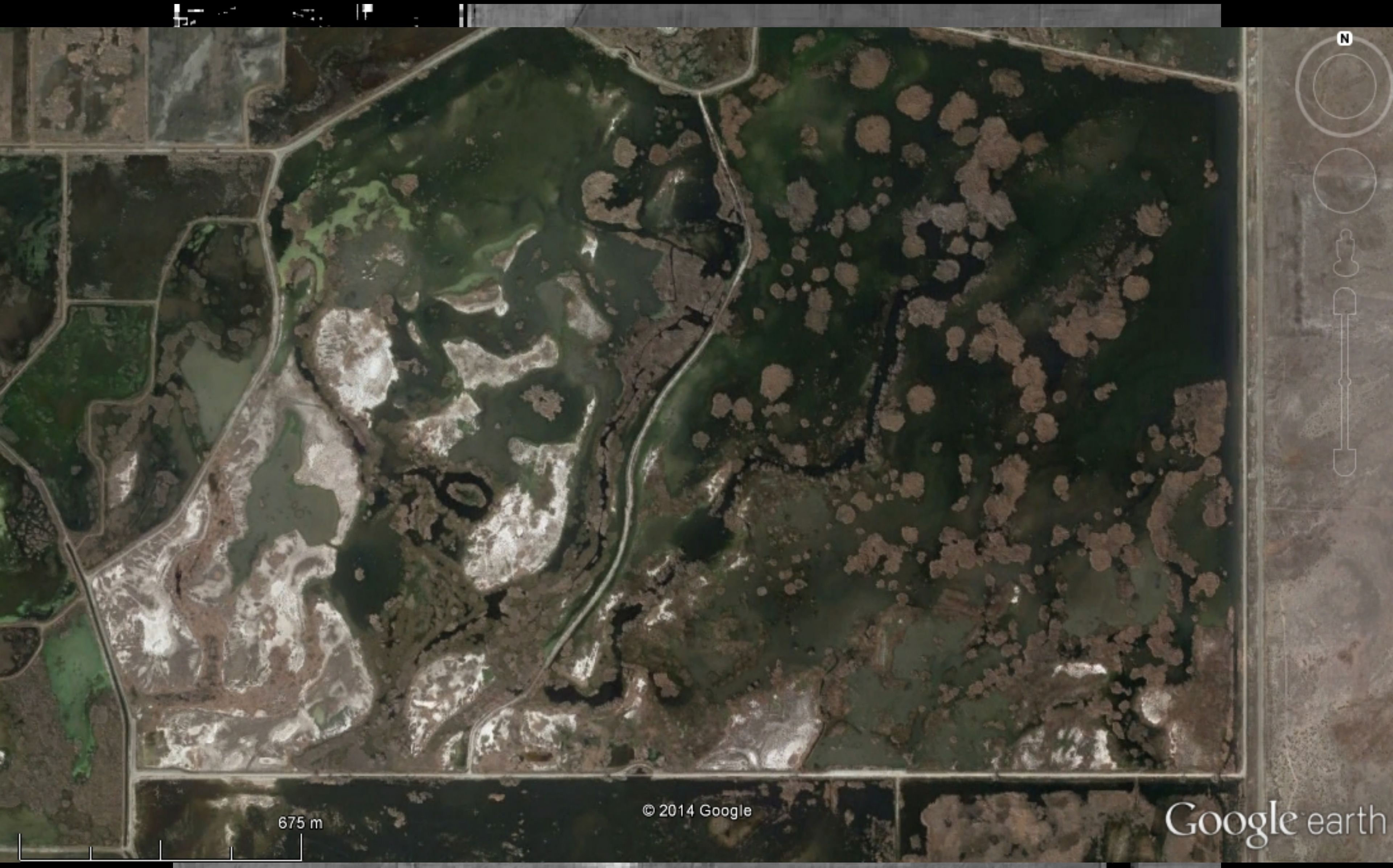
Derived Thermal Inertia *(05-31-14)*



Derived Thermal Inertia *(2014-2012)*



Derived Thermal Inertia



HyspIRI Relevant Science

- **TQ3: Water Use and Availability**
  - *TQ3c:* How can we improve early detection, mitigation, and impact assessment of droughts at local to global scales?
    - as a "TIR question", the description focuses only on ET/PET
- **CQ5: Surface Composition and Change**
  - *CQ5c:* How is the composition of exposed terrestrial surface responding to anthropogenic and non anthropogenic drivers *(e.g., desertification, seasonal/ yearly climate change, weathering, disturbances)*?
    - this "combined question" focuses only on the spectral mapping

Integrative Possibilities?

- **Microwave Sensors**
  - we have proposed cal/val air and ground testing of this TIR approach at SMAP calibration sites *(USCRN sites in the southwestern CONUS)* following launch
    - nominally with ASTER as part of ongoing science activities
    - pending NASA Earth Venture Suborbital-2 proposal entitled the Thermal Inertia Mapping Experiment (TIME)
      - use multispectral MASTER VSWIR + TIR and hyperspectral Mako airborne instruments
      - 5-year campaign at over one dozen well-calibrated fields sites in NM, AZ and CA
      - overarching goal: *conduct a hierarchical analysis of ground, airborne and satellite based SMC measurement to assess spatial/temporal scale-dependent variables and determine the overall accuracy of the thermophysically-derived approach*

Conclusions

- **Able to Retrieve TI, SMC, and Wind Threshold Velocity Using Thermophysical Data**
  - at a high spatial resolution using ASTER
  - *for eolian systems*
    - SMC is the most important parameter for sediment availability
      - general trends over many years appear valid
      - detected a marked decrease in soil moisture in March 2008
        - several days before the largest dust storm at White Sands in over a decade
  - *for agricultural systems*
    - SMC change is detected with worsening drought
    - initial testing appears viable for vegetation-dominated areas
      - model needs further refinement and testing in other regions