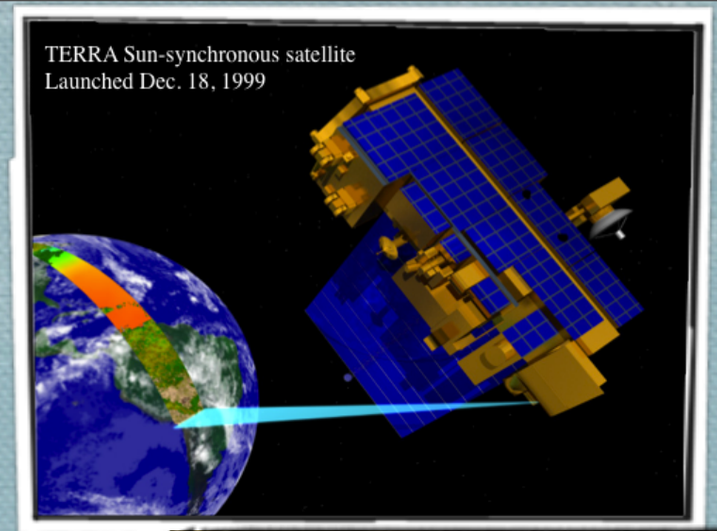
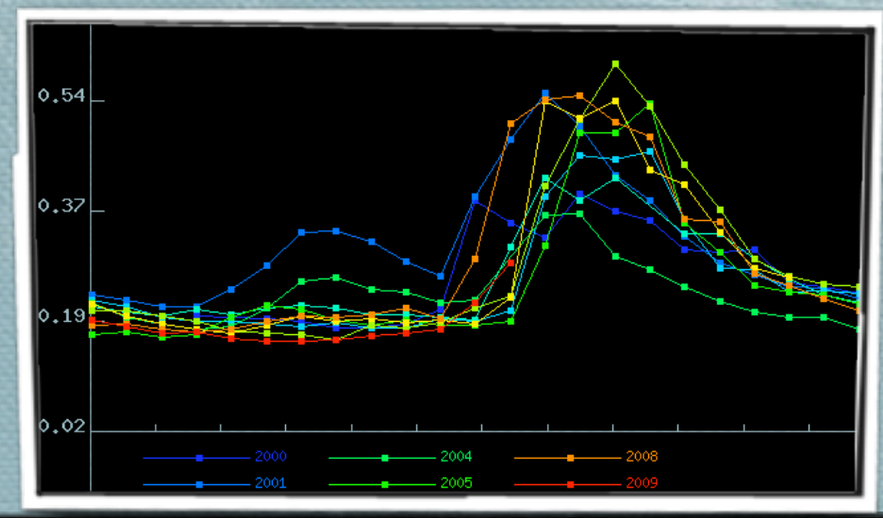
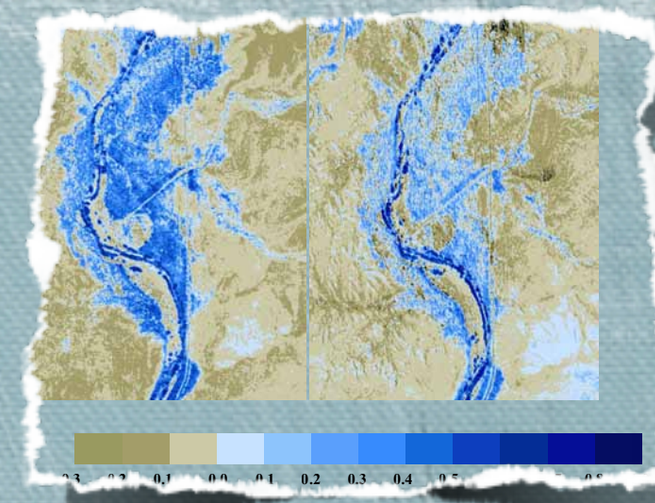
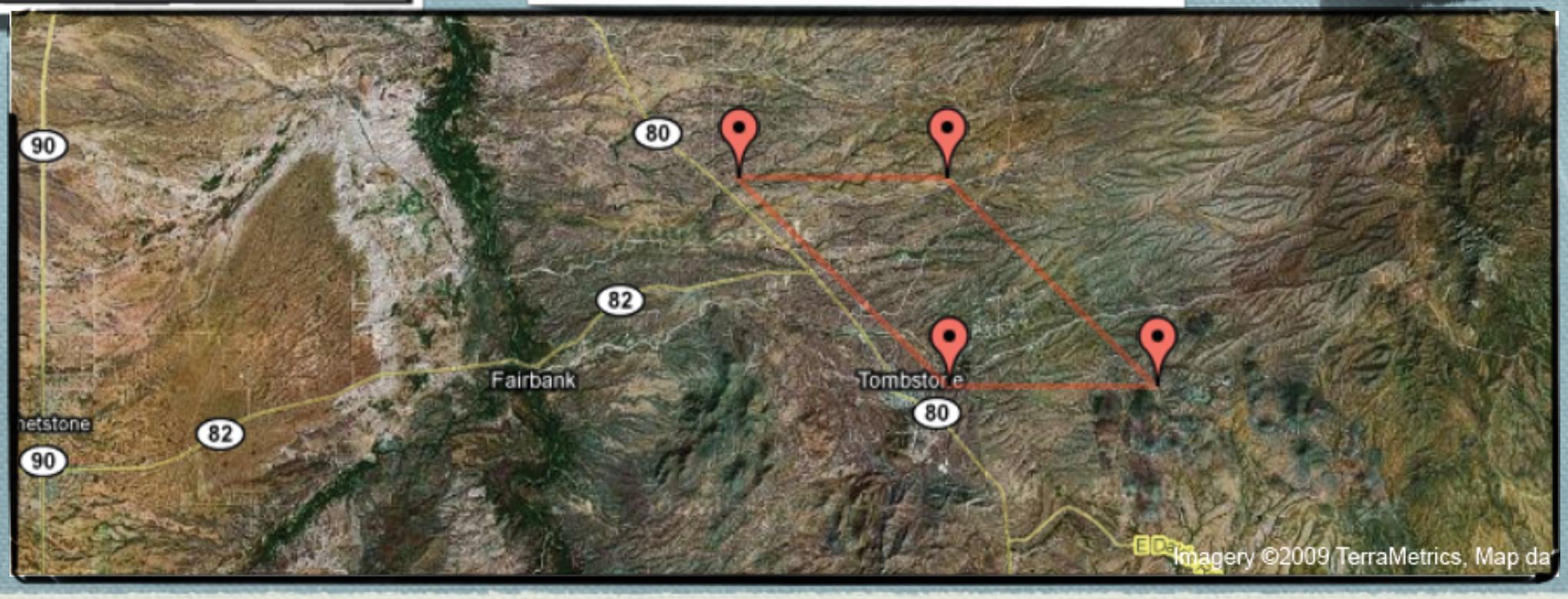








Satellite-observed shifts in biome seasonality and vegetation -rainfall relationships in the Southwest

Alfredo Huete and Guillermo Ponce

Dept. Soil, Water & Environmental Science, University of Arizona

Research Insights in Semiarid Ecosystems (RISE) Symposium will be held at the University of Arizona on Saturday, 3 October 2009

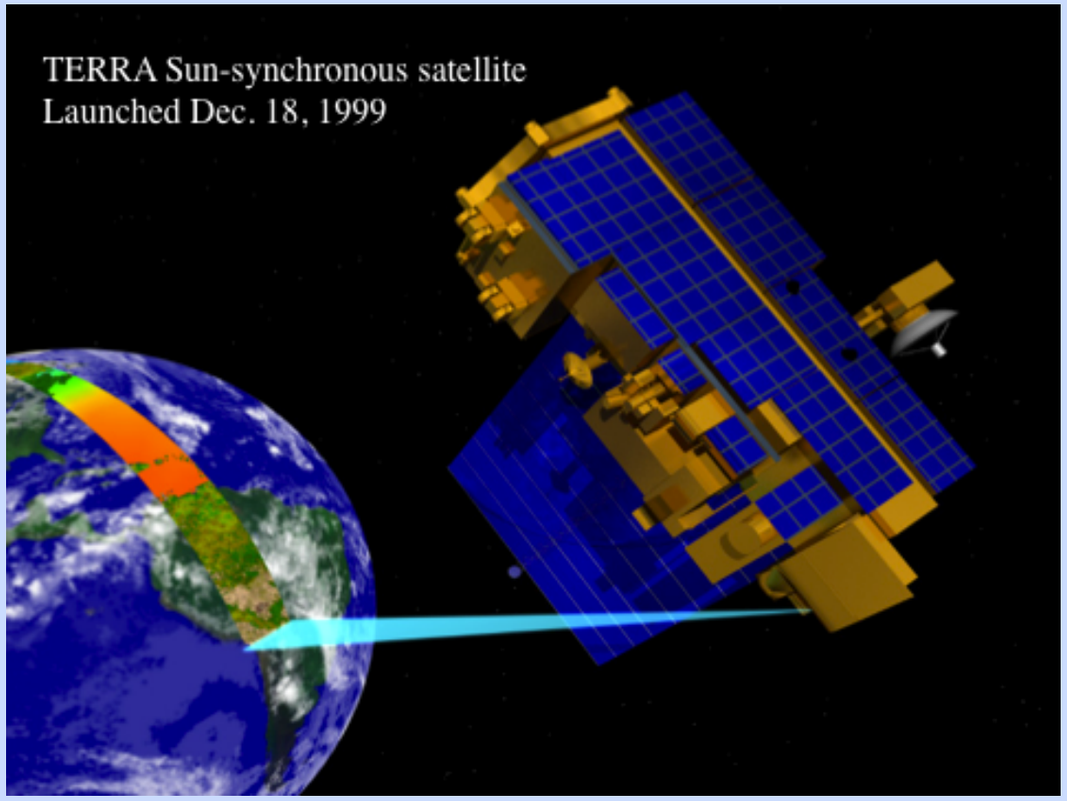
Research questions

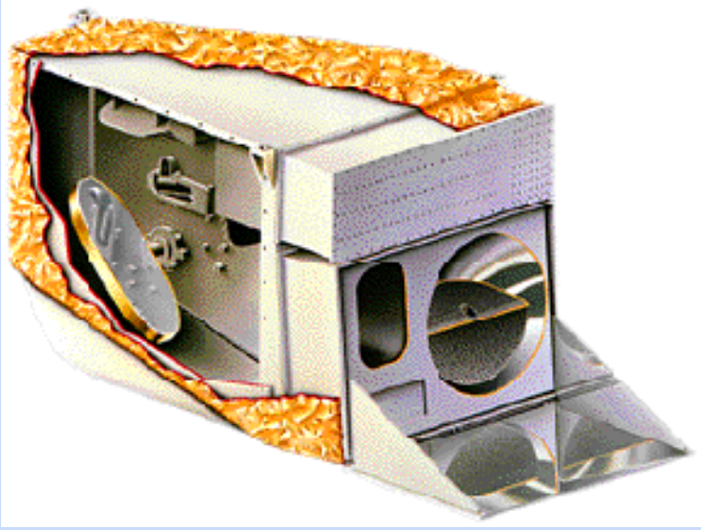
- Can satellite remote sensing datasets be used to detect ecosystem changes and responses to drought?
- How do we couple and validate satellite data with ecosystem processes/properties (*photosynthesis, transpiration, phenology, and land cover change*)
- What are the controls and drivers of biome seasonality?
- *What is the role of climate change and human impacts on seasonal biome shifts (start of and length of growing season; disrupted seasonal cycles)?*
- What are the *resilience* properties of biomes to climate variability?
- Are there thresholds to abrupt changes in seasonality? (extreme events)

Satellite Sensors & Data

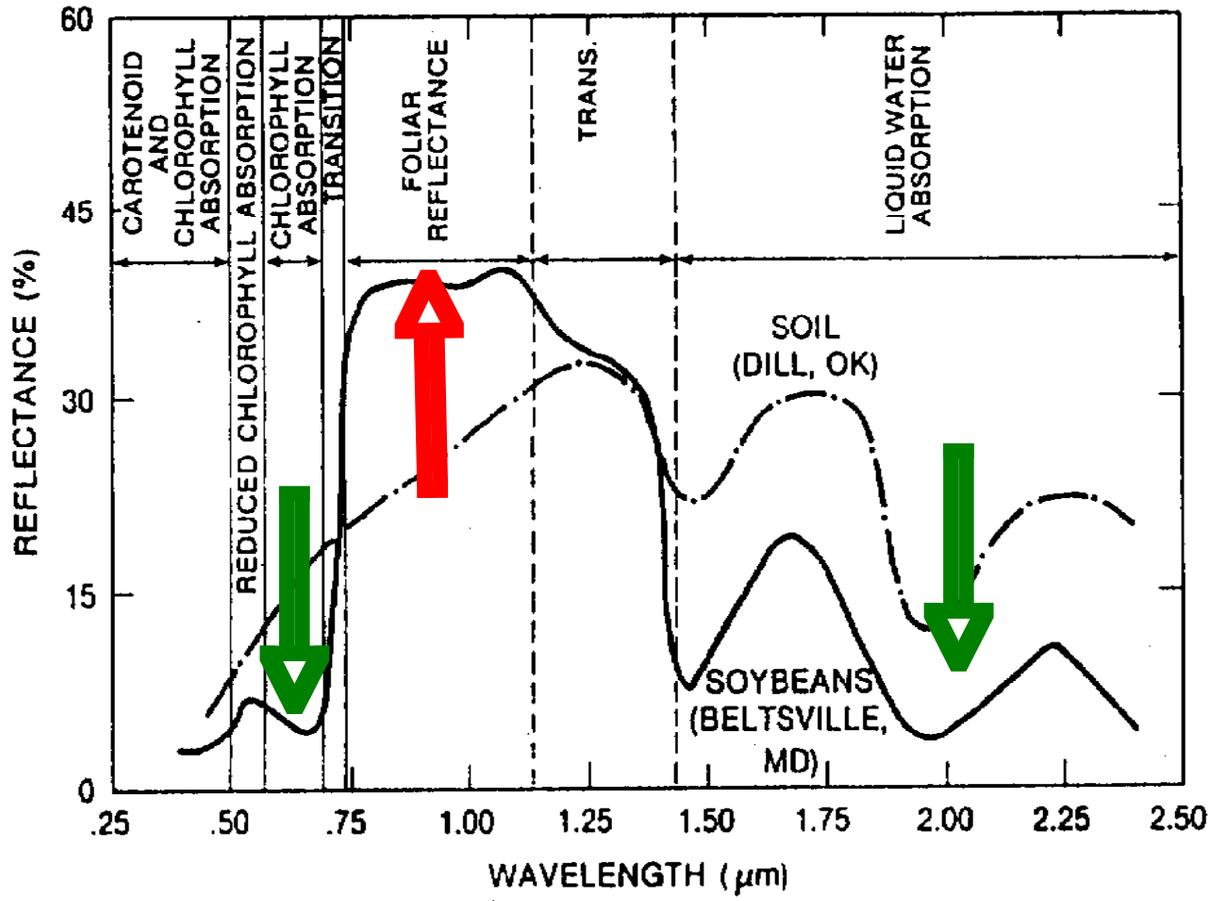
MODerate-resolution Imaging Spectroradiometer (MODIS)

- **NASA, EOS TERRA & AQUA series**
  - **705 km polar orbits, alternating descending & ascending (10:30 a.m. & 1:30 p.m.)**
- **Sensor Characteristics**
  - **36 spectral bands ranging from 0.41 to 14.385 µm**
  - **cross-track scan mirror with 2,330 km swath width**
  - **Highly calibrated (moon, sun, deep space)**
  - **Spatial resolutions:**
    - » **250 m (bands 1 - 2)**
    - » **500 m (bands 3 - 7)**
    - » **1000 m (bands 8 - 36)**





*Provides ‘near-daily view of entire Earth in morning and afternoon



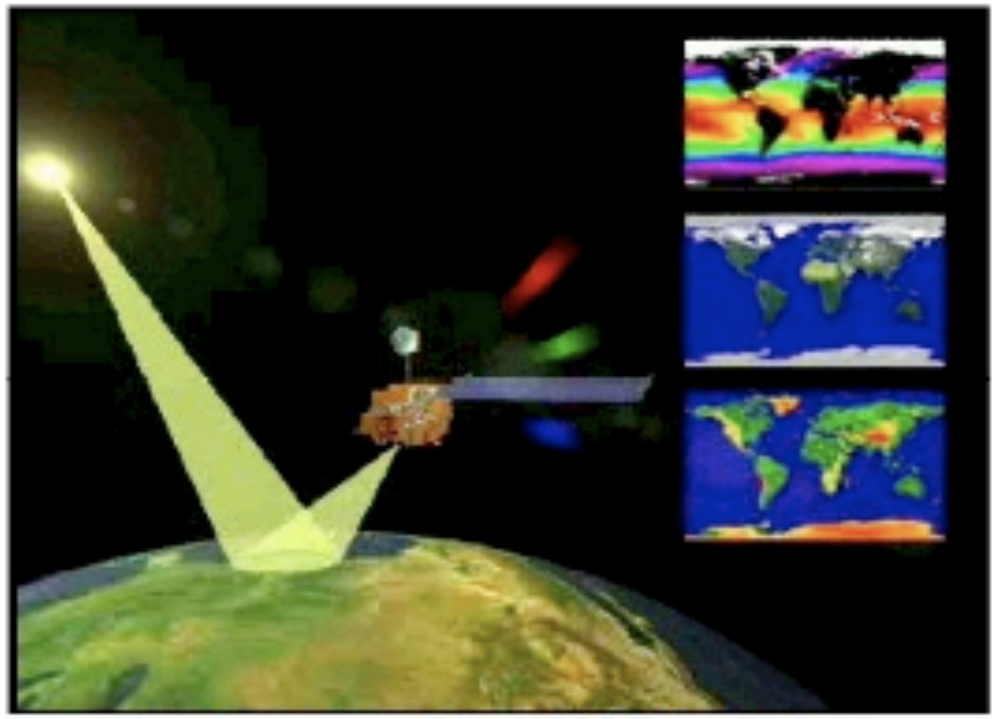


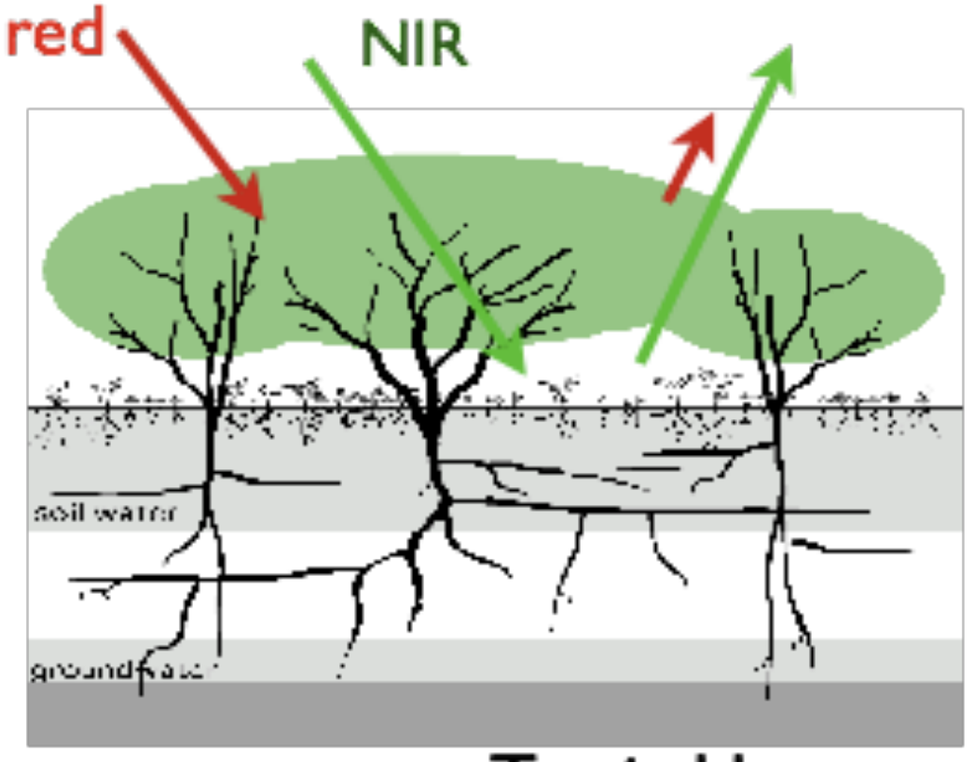
Image courtesy of the NASA Terra Project

The derivation of thematic data from Earth observing satellites.

$$EVI = G \times \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + C_1 \times \rho_{red} - C_2 \times \rho_{blue} + L}$$

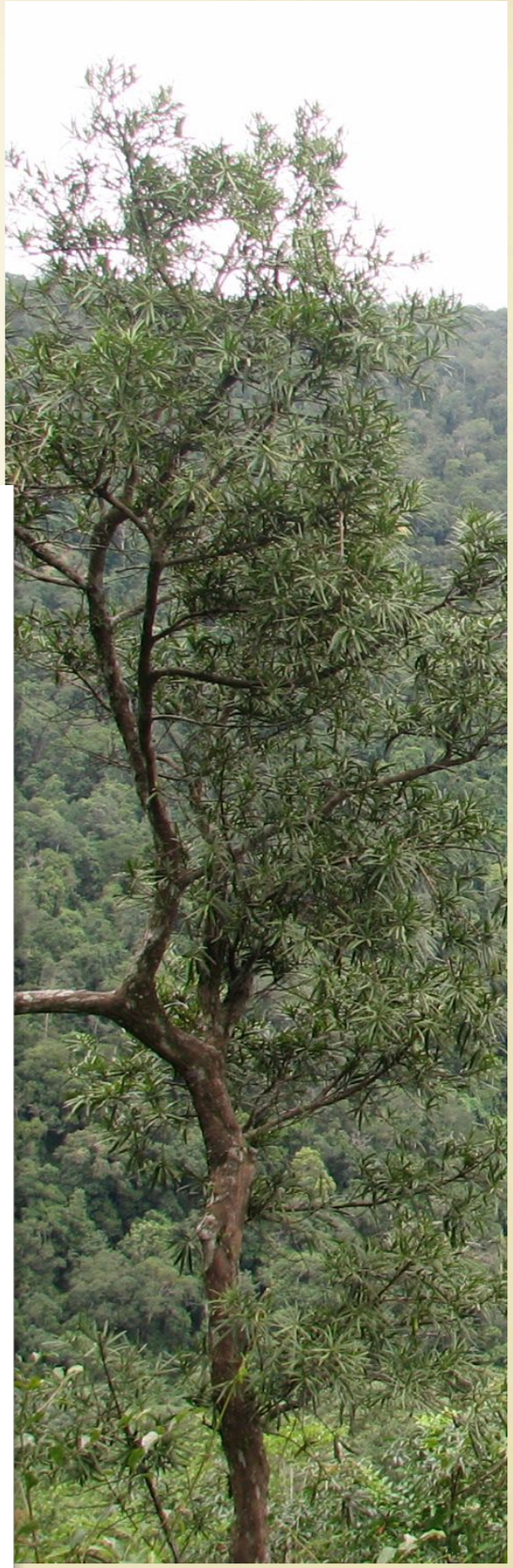
VI's are optical measures of vegetation canopy '***greenness***', which is a composite property of leaf chlorophyll content, leaf area, canopy cover, and structure (seamless and robust).

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}}$$



Travis Huxman

Satellite Phenology & Biome Seasonality

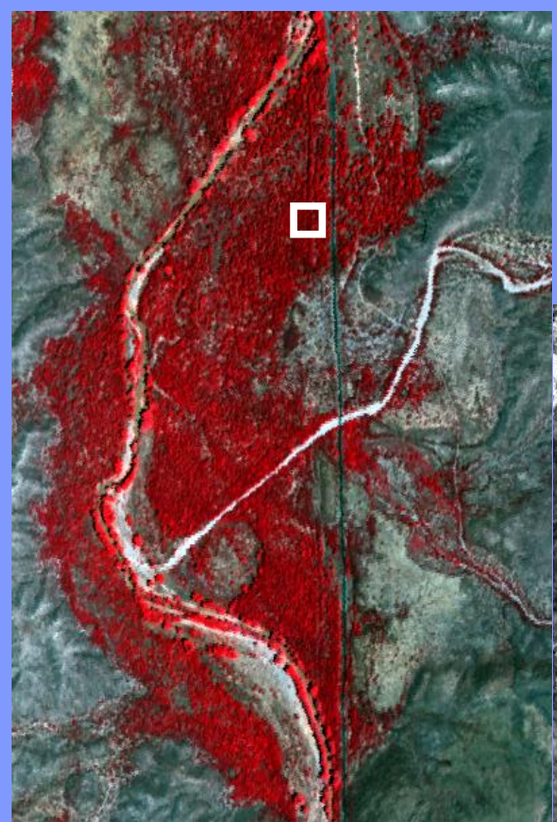


- Phenology "reflects" the interactions (responses, feedbacks) of organisms with their environment,
- Phenologic variations depict a canopies' integrated response to environmental change and influence local biogeochemical processes, photosynthesis, water cycling, soil moisture depletion, and canopy physiology,
- Phenology is an important indicator of climate change, global change, and disturbance (anthropogenic signal),
- Phenological data and models are used in drought monitoring, wildfire risk assessment, archaeology, and treatment of pollen allergies.

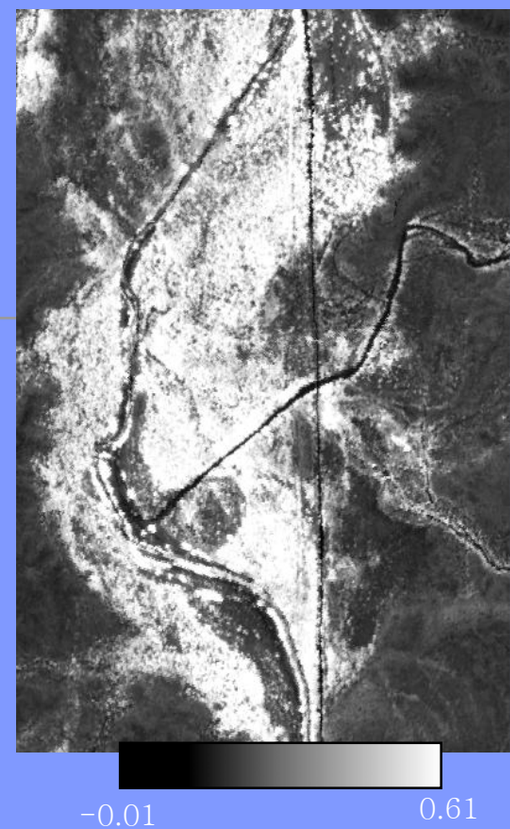
CM site

San Pedro Valley, AZ

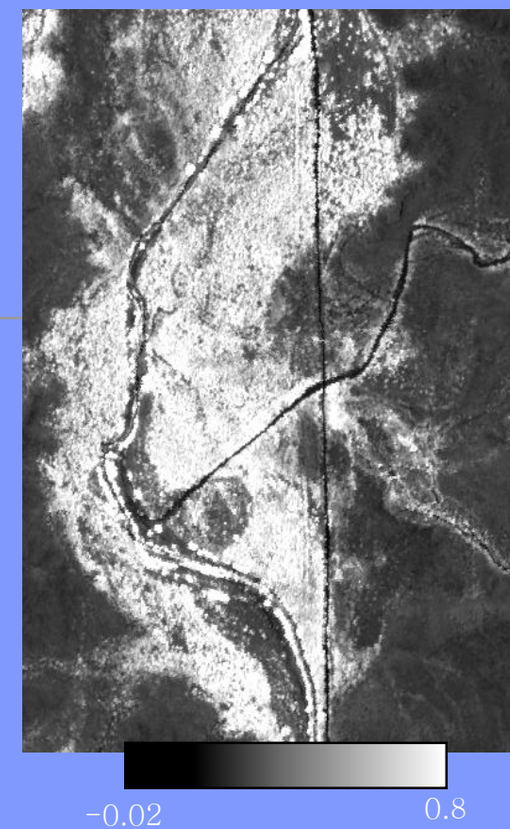
R-855nm,
G-645nm,
B-557nm



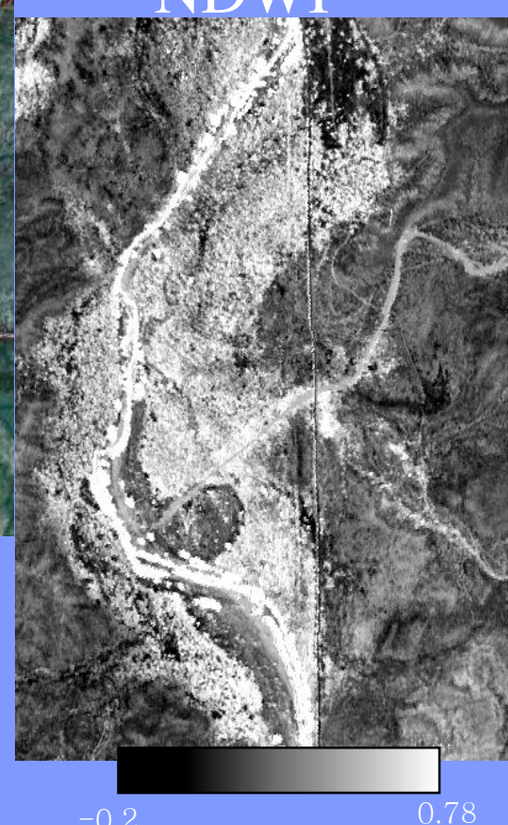
NDVI



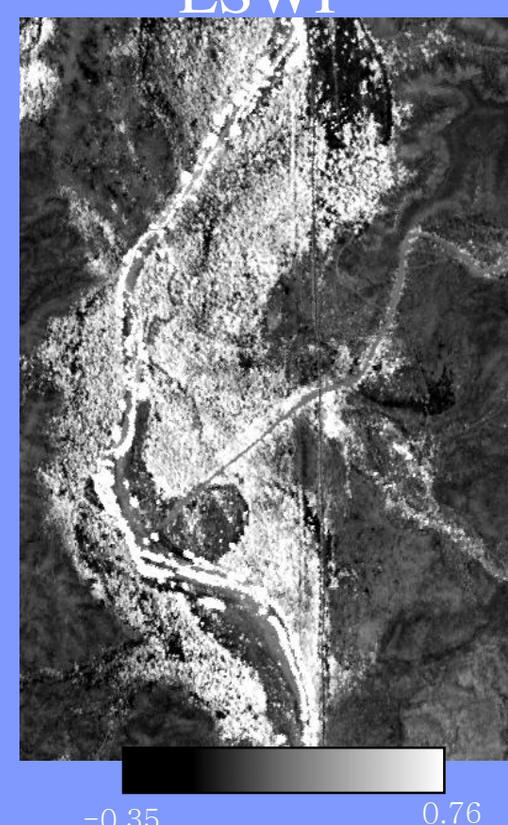
EVI



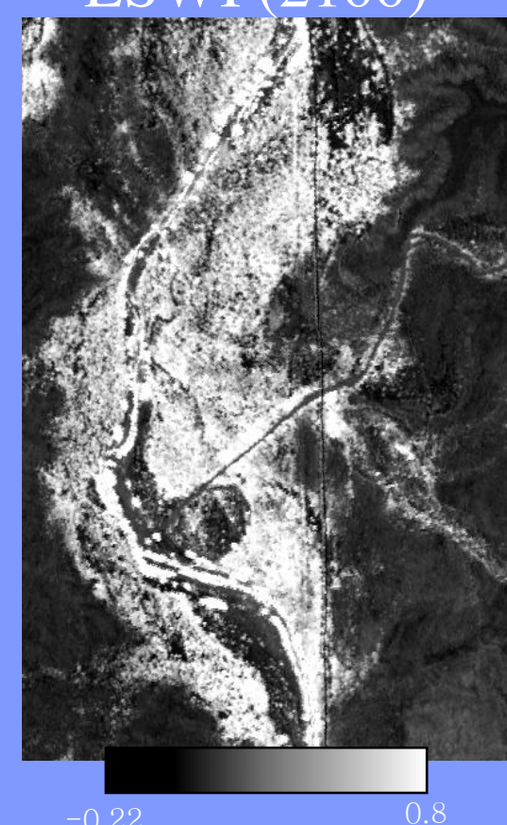
NDWI



LSWI



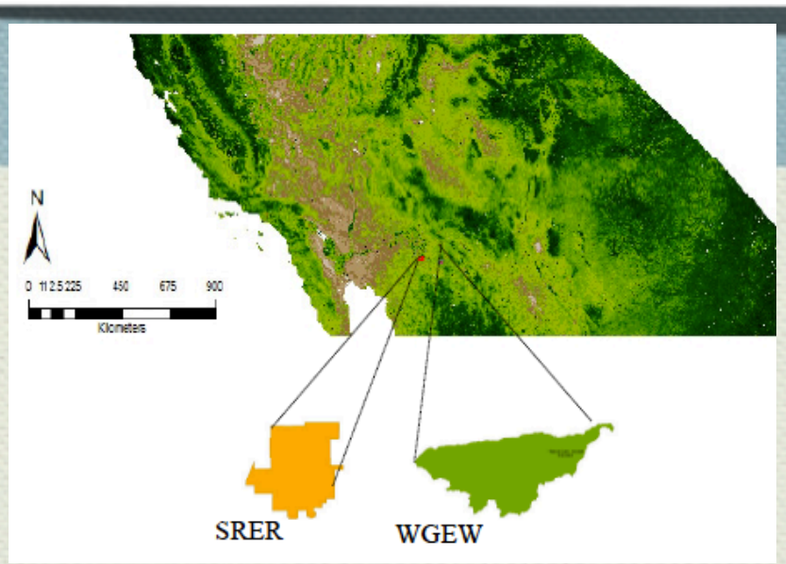
LSWI (2100)



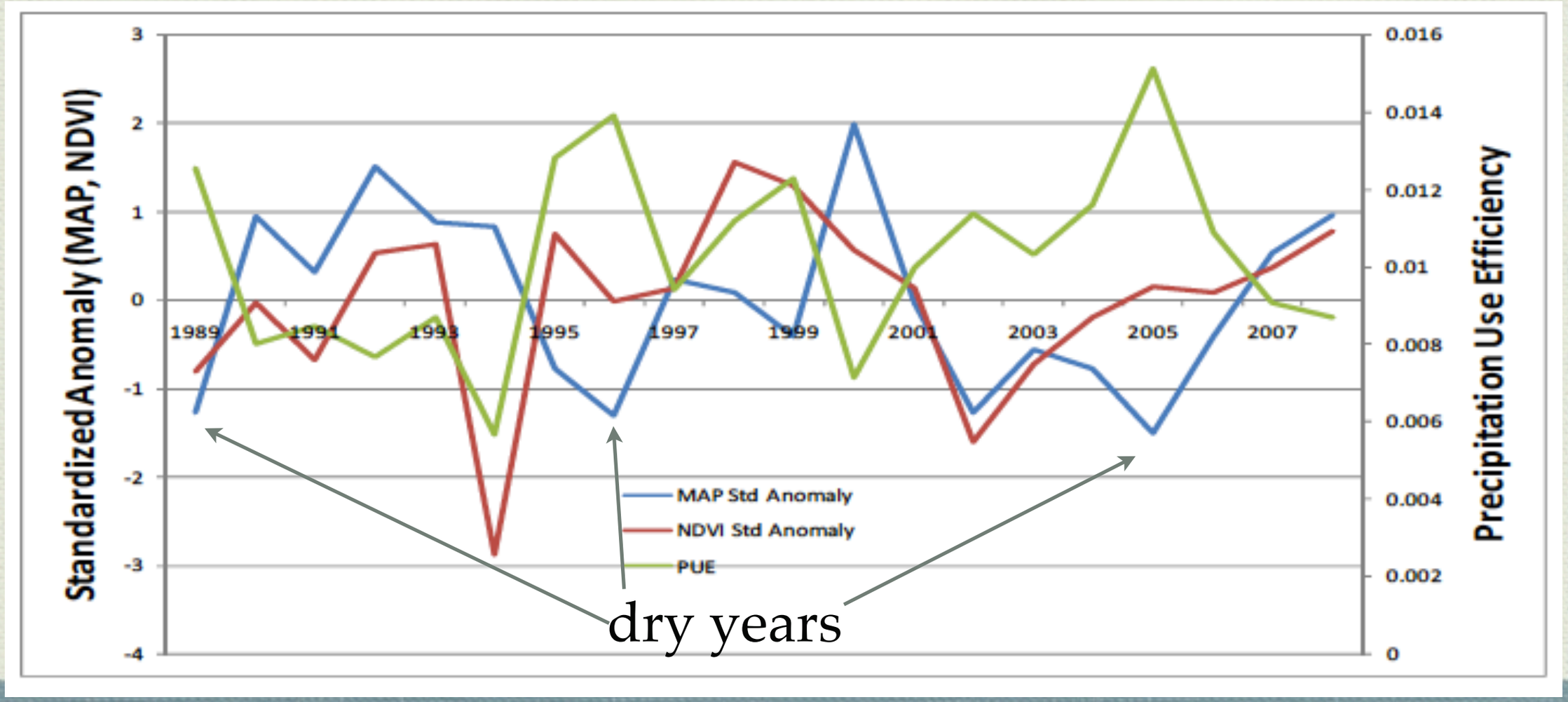
Objectives

- Analyze spatio-temporal vegetation responses, sensitivities, and seasonal shifts to precipitation patterns in the Southwest with time series satellite data (*integrative measures of vegetation responses to environment*).
- Assess vegetation-hydrologic linkages through the analysis of Precipitation Use Efficiencies (PUE) across continuous temporal- spatial scales from 1989 to ~2009.
- Combine spatially distributed rainfall data with satellite-based measures of photosynthetic activity and productivity to derive and analyze PUE dynamics across wet and dry years and across land cover types. (*Are there differential sensitivities associated with land cover type?)*
- Establish relationships of standardized anomalies (PUE, MAP, NDVI).

Previous 20 year analysis with AVHRR



PUE relationships with precipitation standard anomalies



Methods

In this work, we addressed both local site and regional vegetation responses to rainfall over a 150 x 40 km study area, using

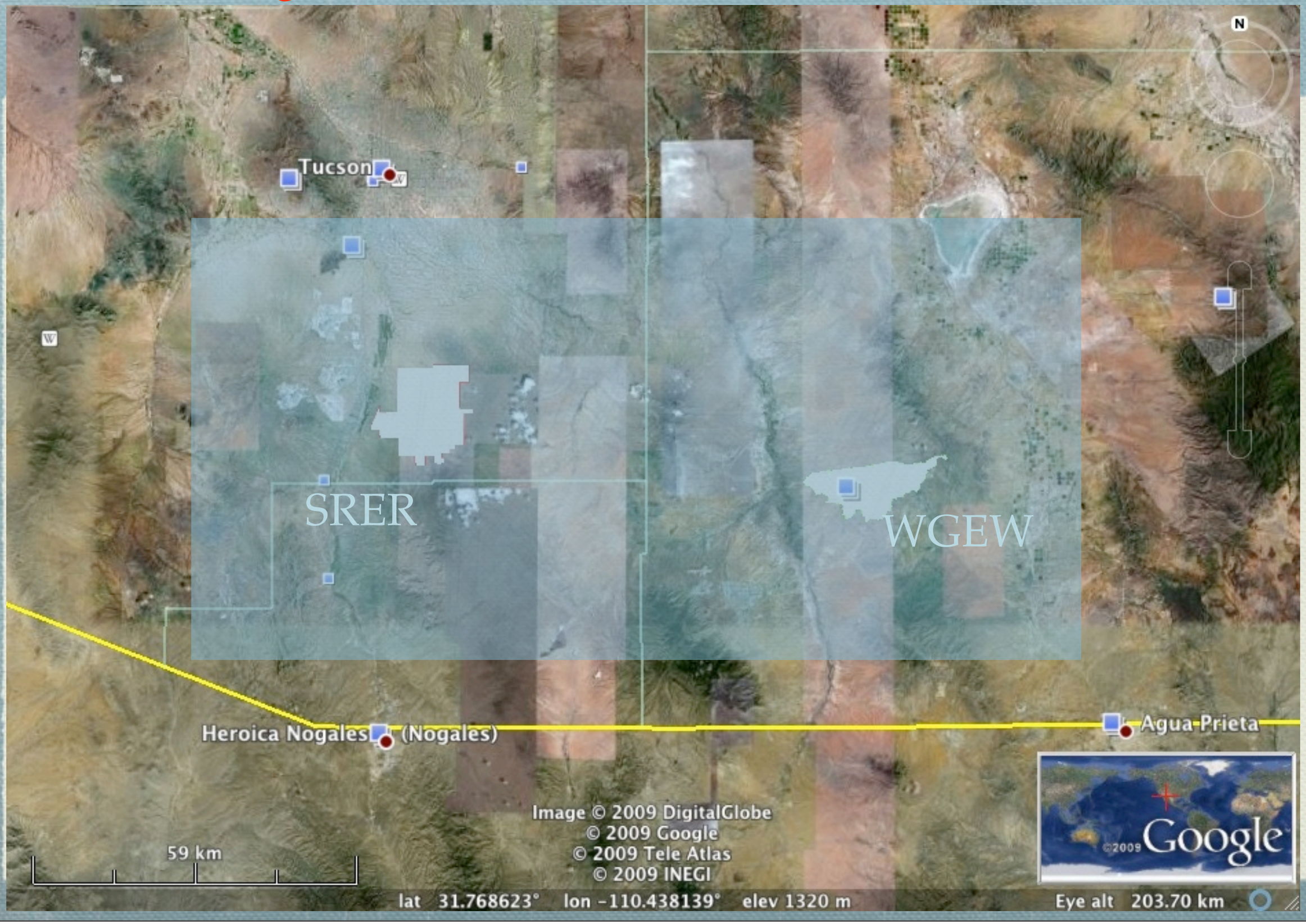
- MODIS (MOD13A3 monthly 1km satellite time series data of vegetation photosynthetic activity 2000- 2008 (re-sampled to 4km through QA-based averaging);
- Precipitation data from PRISM datasets at 4km resolution and spatially registered to MODIS data.
- We used the South West Regional GAP (SWRGap) land cover data, resampled from 30m to 4 km for this initial work.
- Precipitation Use Efficiency (PUE) computed on a pixel basis: Precipitation Use Efficiency (PUE) model on a puxel by pixel basis over a regional window.

$$PUE = \frac{ANPP}{MAP}$$

*where **ANPP** is Aboveground Net Primary Productivity and **MAP** is Mean Annual Precipitation.*

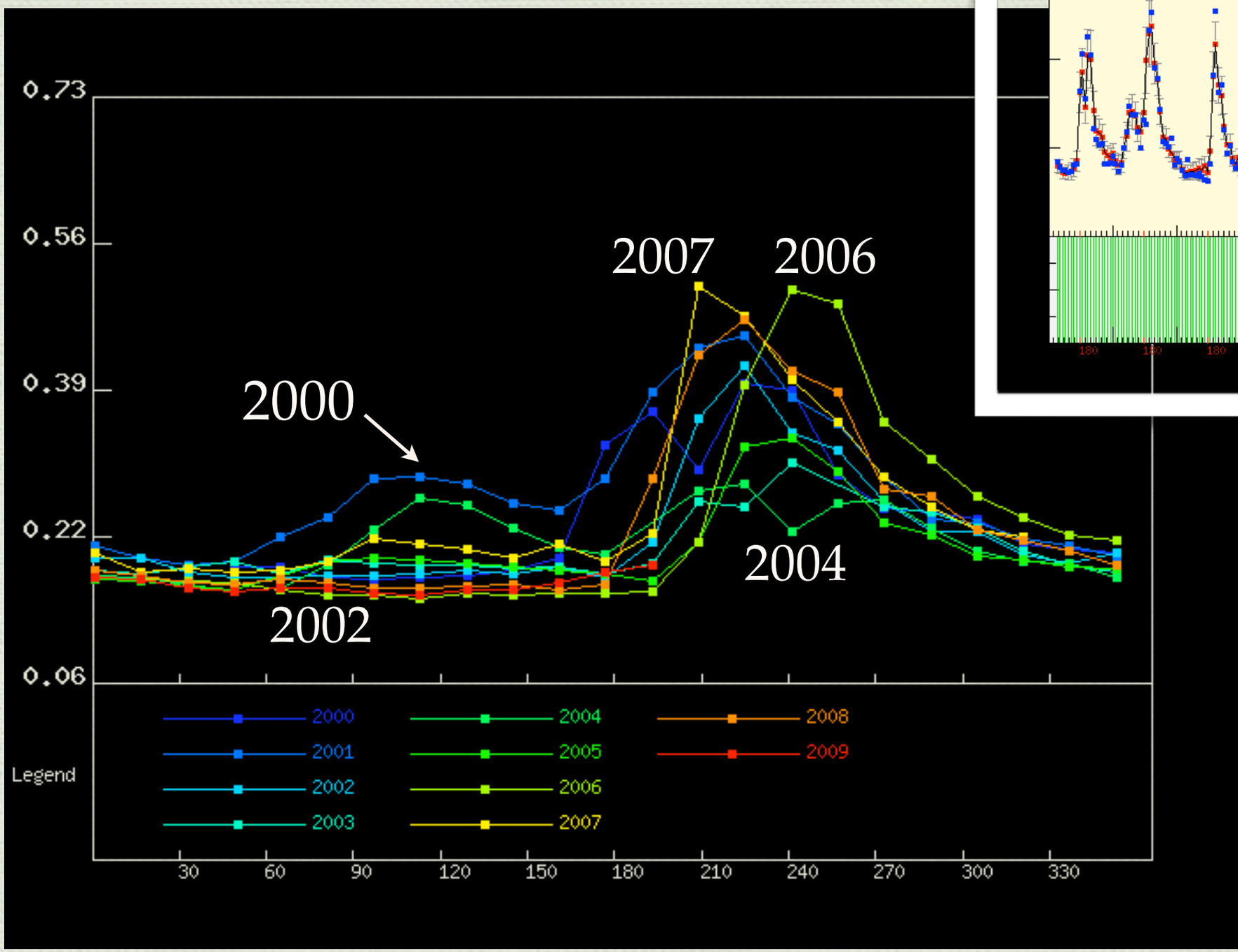
- Compute climatologic and standard anomaly values for MAP, NDVI, and PUE.

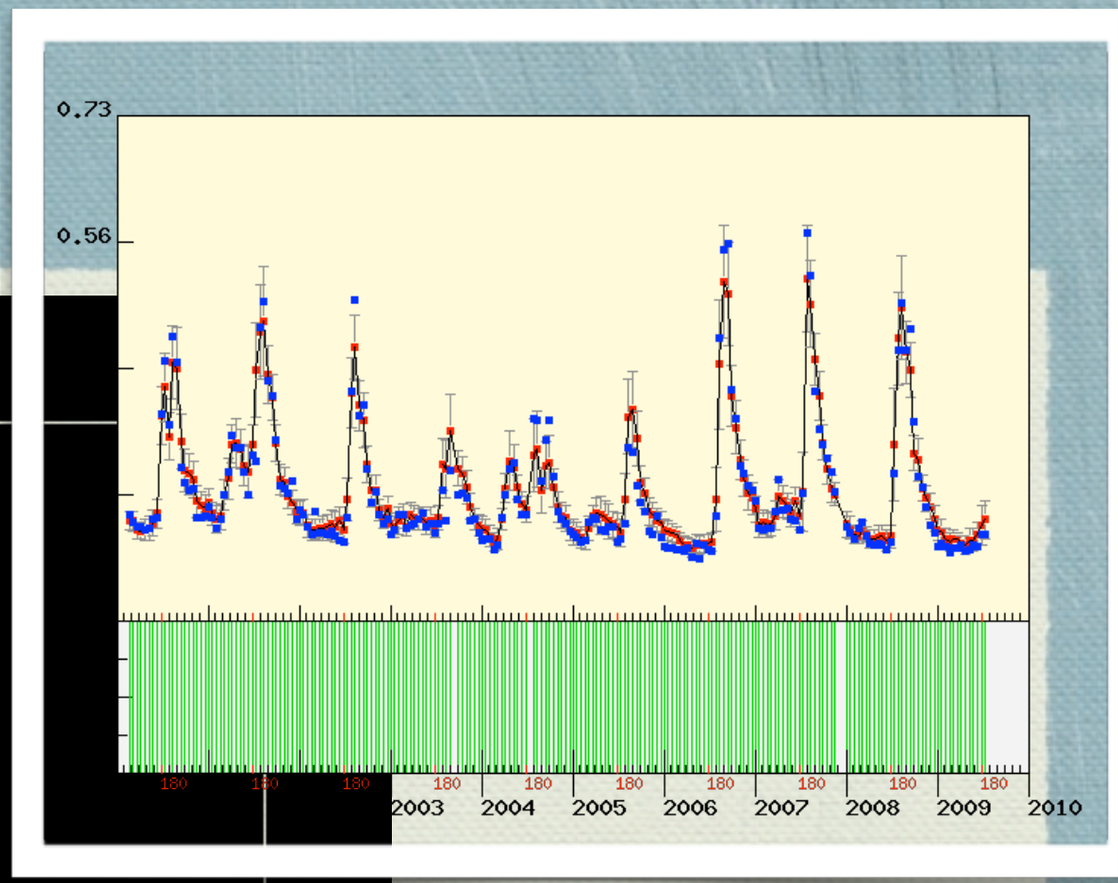
Study Area


Tucson
SRER
WGEW
Heroica Nogales (Nogales)
Agua Prieta
Image © 2009 DigitalGlobe
© 2009 Google
© 2009 Tele Atlas
© 2009 INEGI
59 km
lat 31.768623° lon -110.438139° elev 1320 m
Eye alt 203.70 km
Google

Site: Walnut Gulch Kendall Grassland site, NDVI extract 7x7 km from 2000- 2009

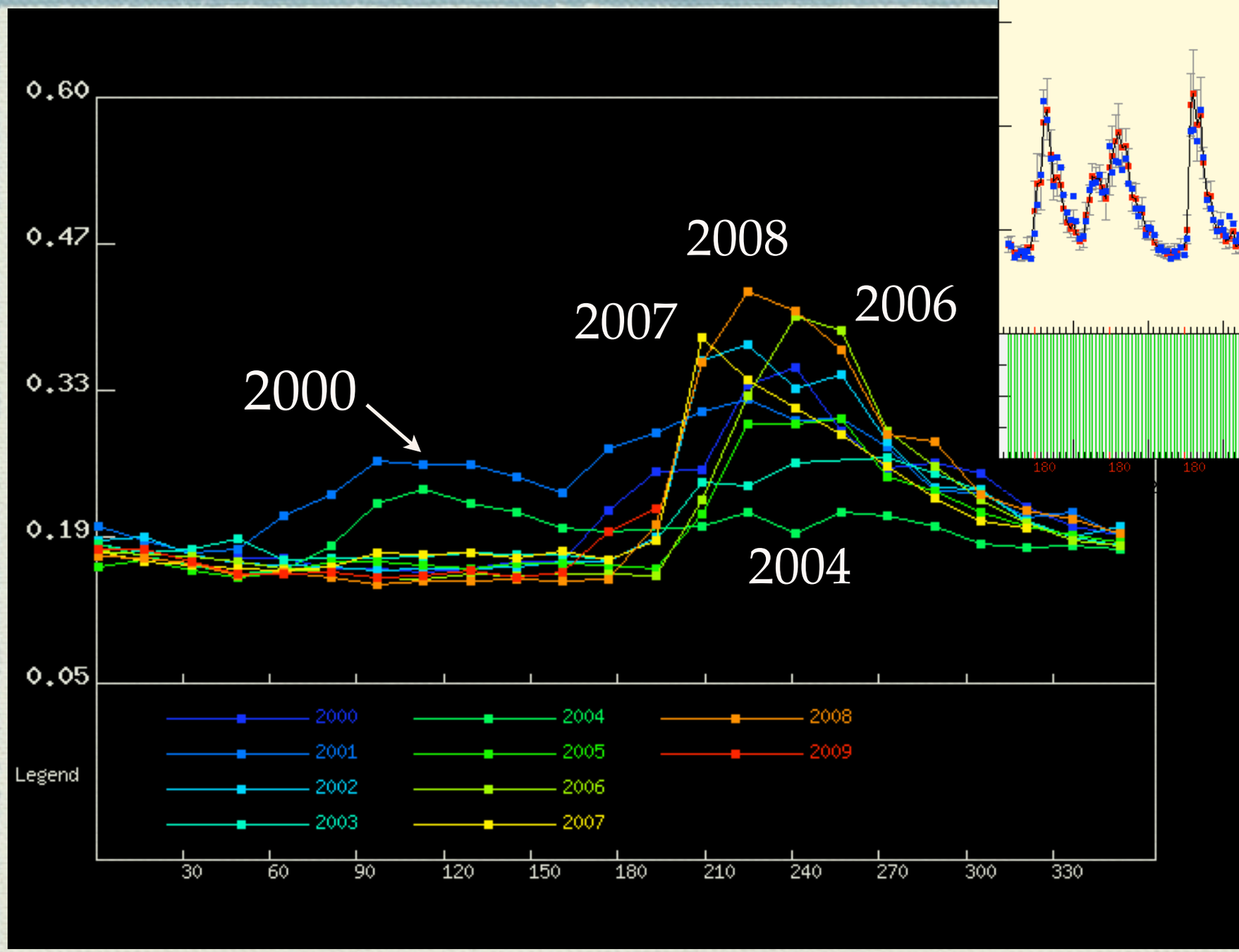
[Lat:31.736527,Lon:-109.94188]

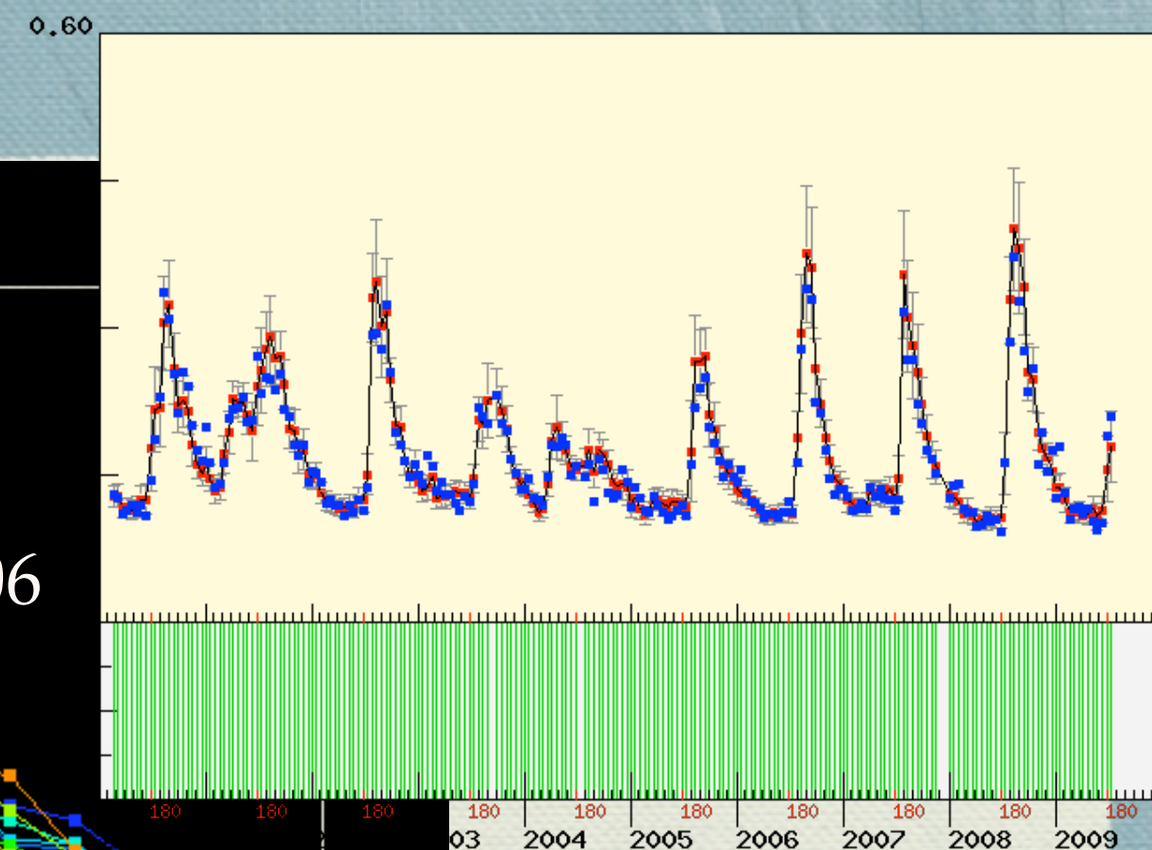




Site: Walnut Gulch Lucky Hills Shrub site, NDVI extract 7x7 km from 2000- 2009

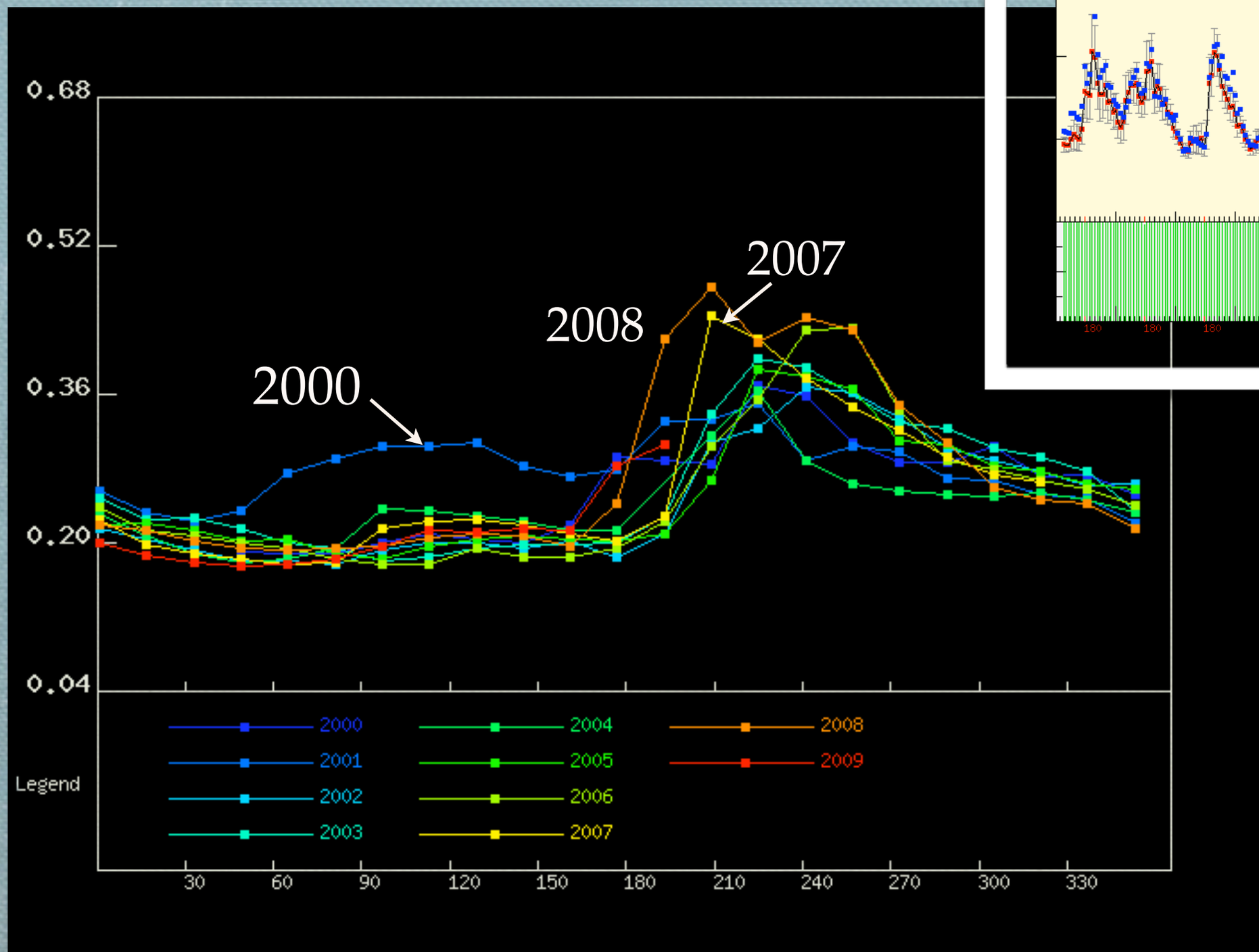
[Lat:31.743833,Lon:-110.052222]

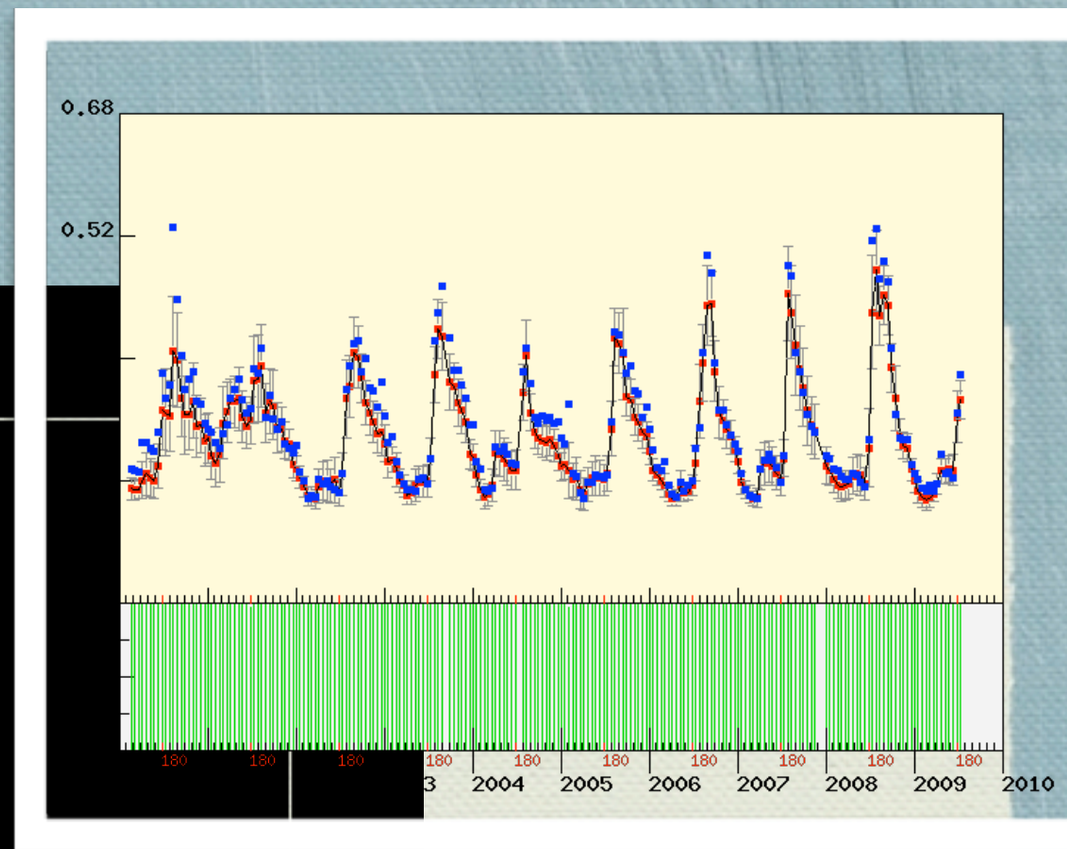




Site: Santa Rita site, NDVI extract 7x7 km from 2000- 2009

[Lat:31.82143,Lon:-110.86611]





Site: Lewis Springs Mesquite site, NDVI extract 7x7 km from 2000- 2009

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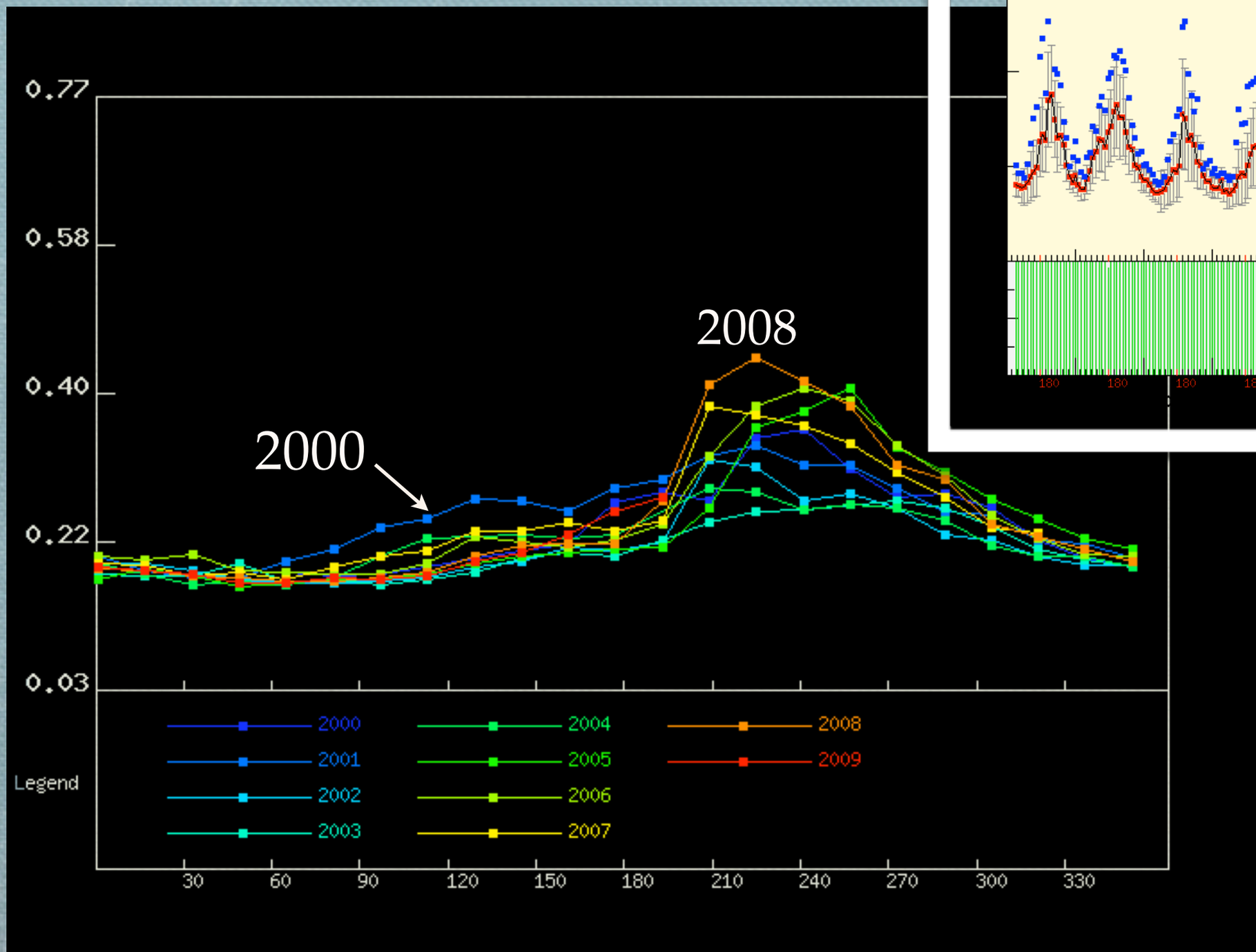

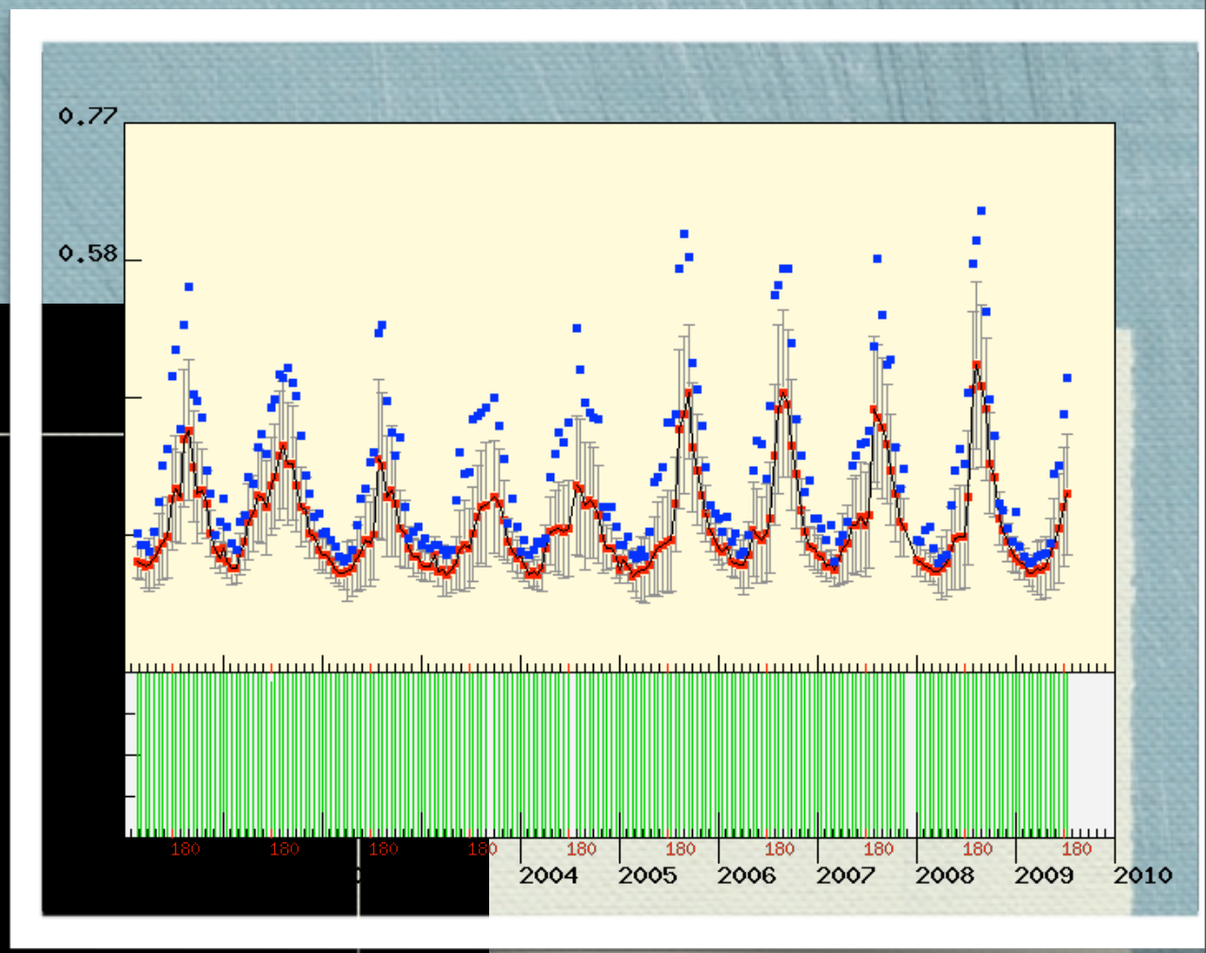

Site: Audubon Research Ranch site, NDVI extract 7x7 km from 2000- 2009

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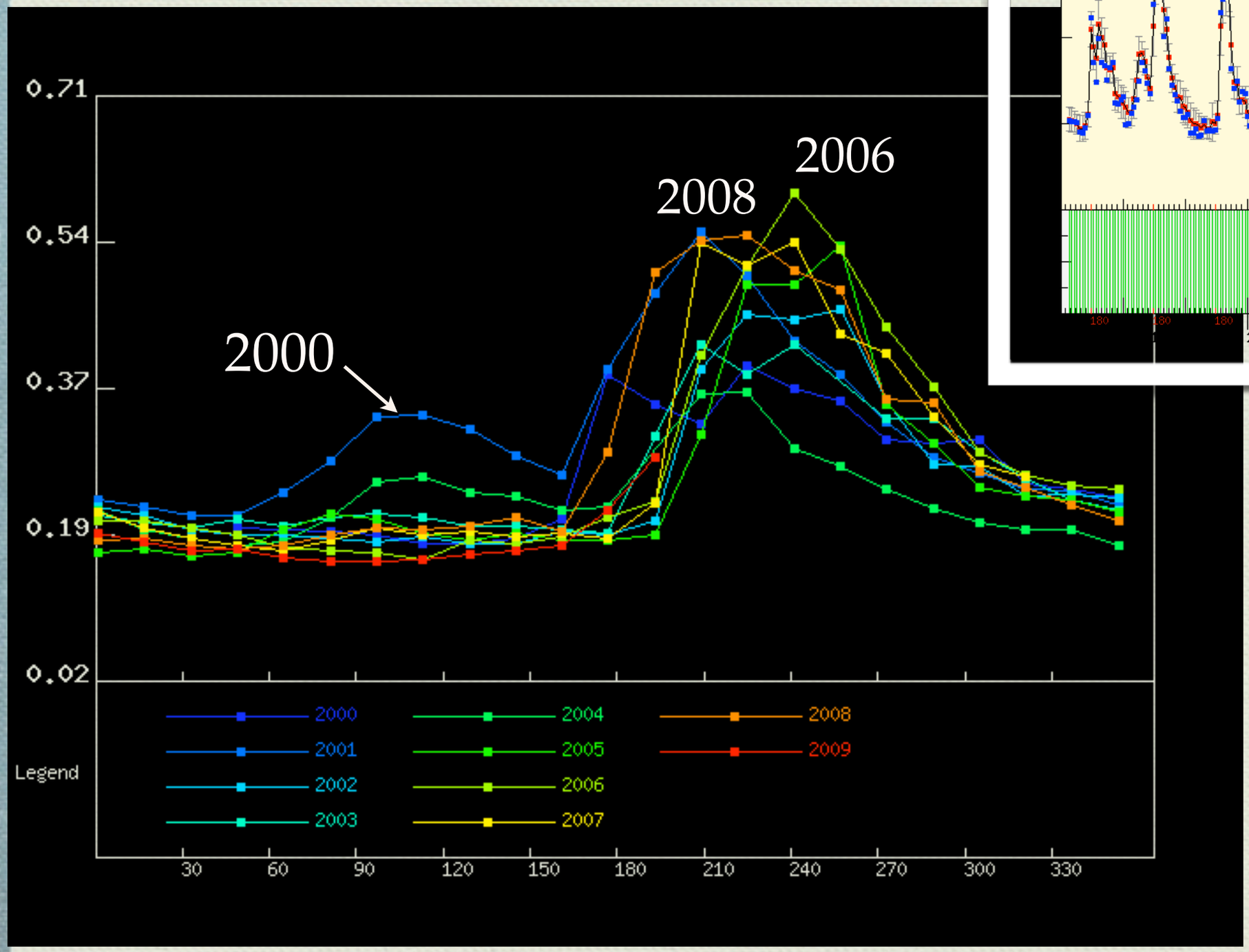
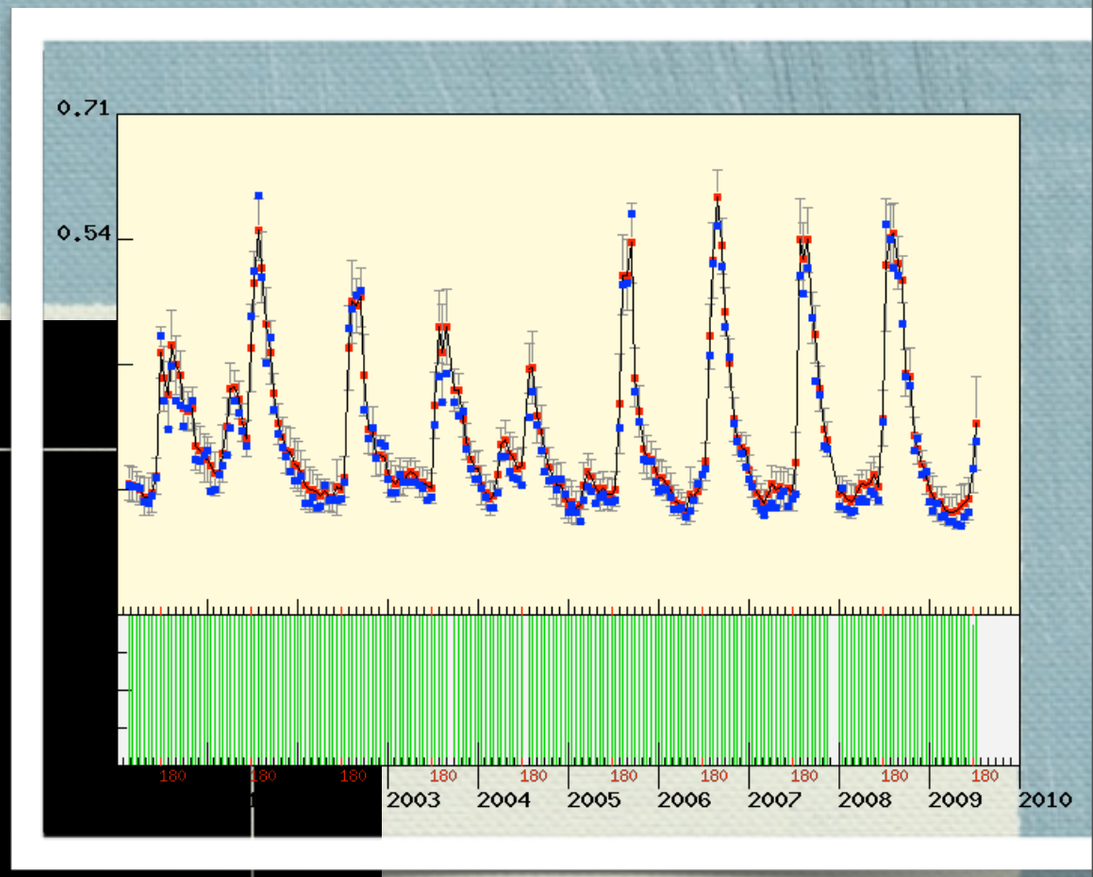
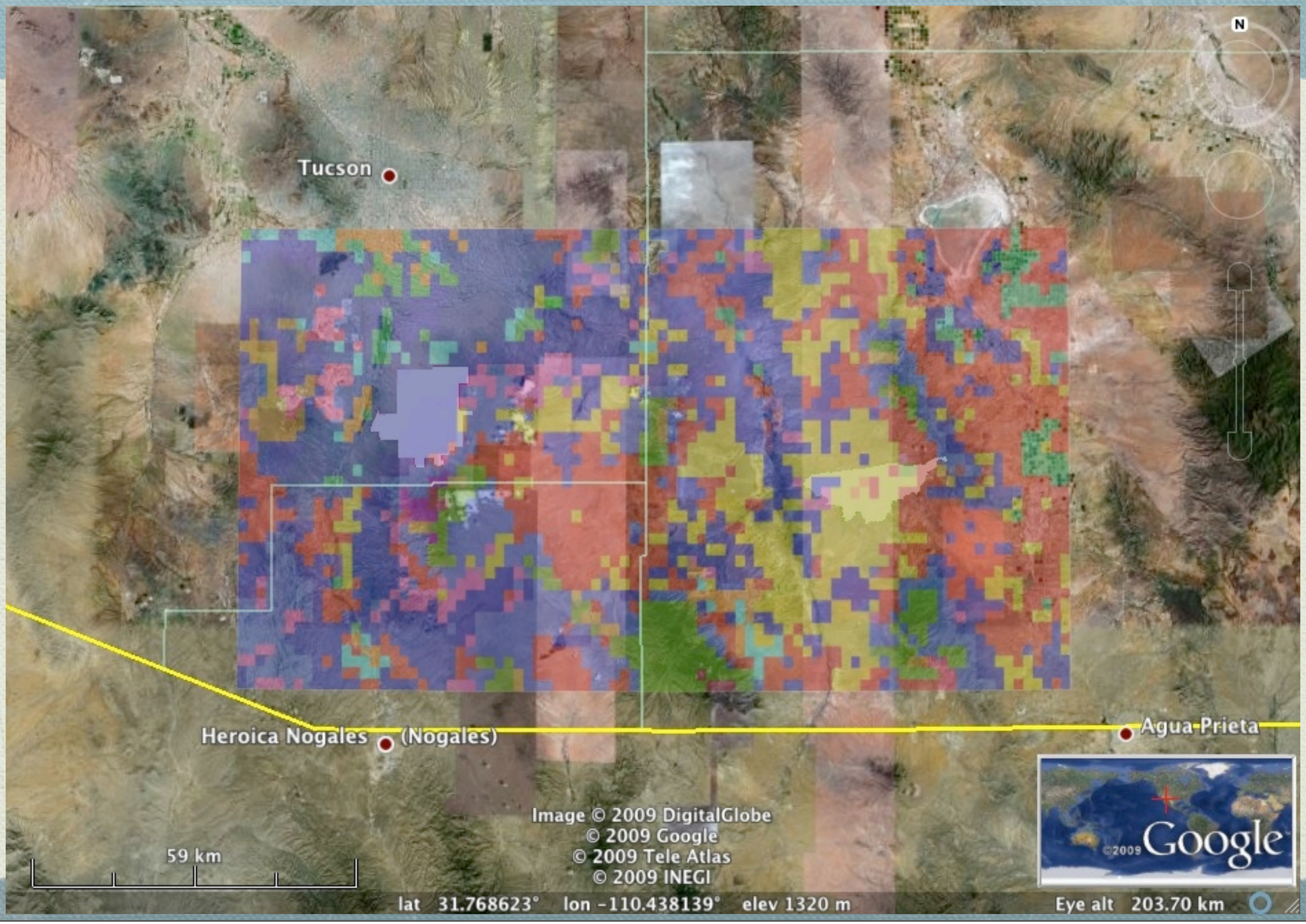
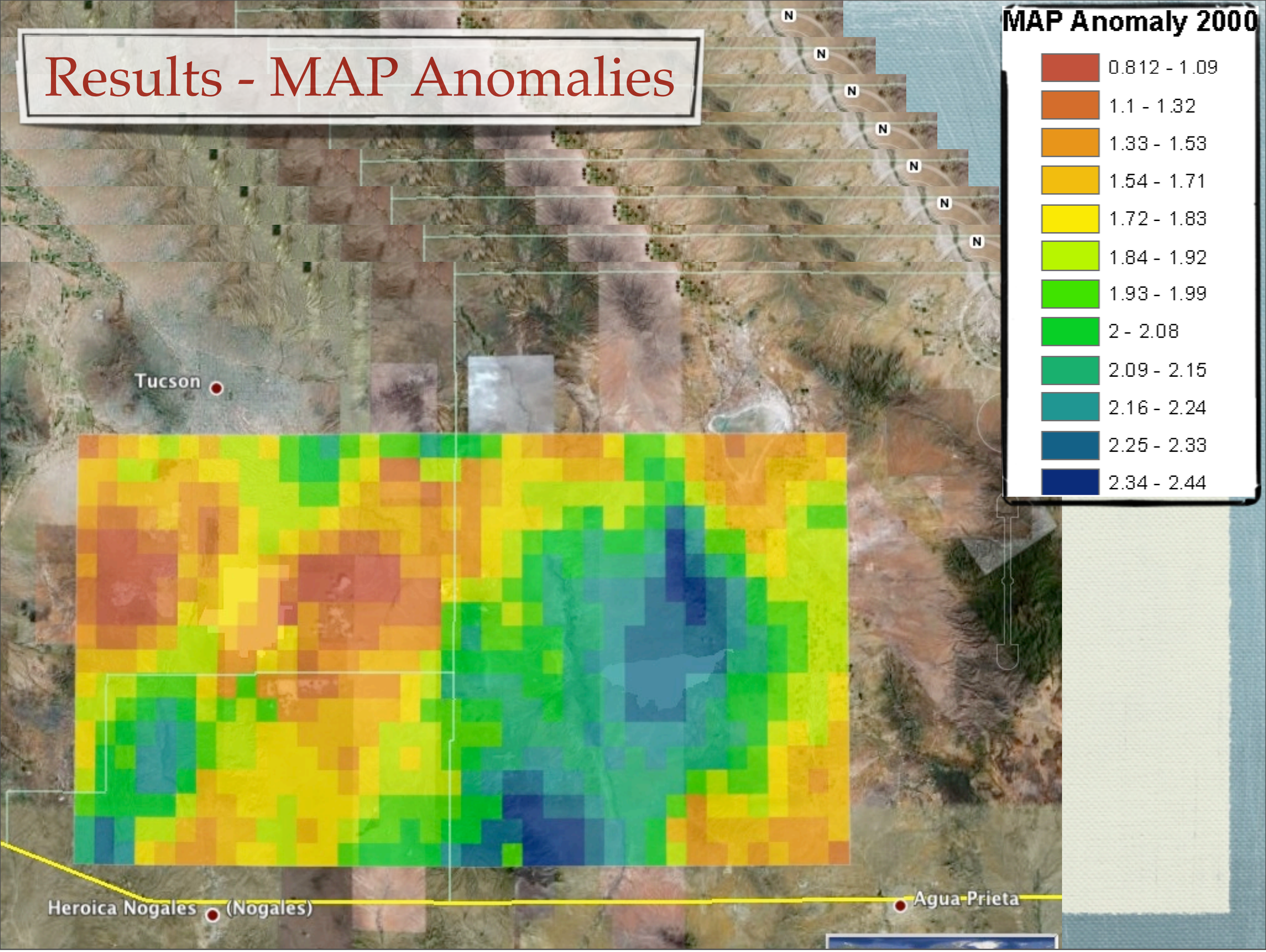




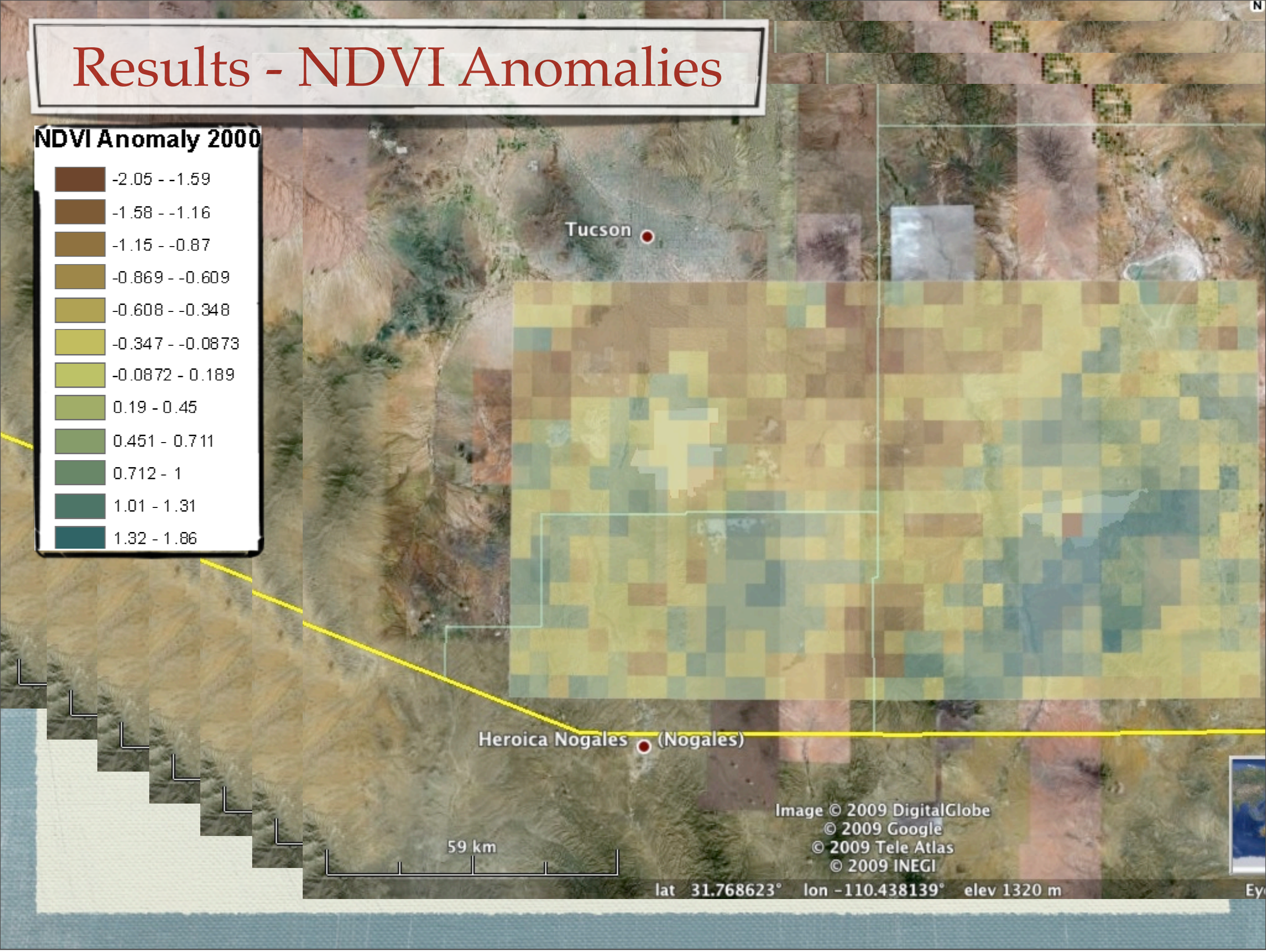
Land Cover Map SW ReGAP



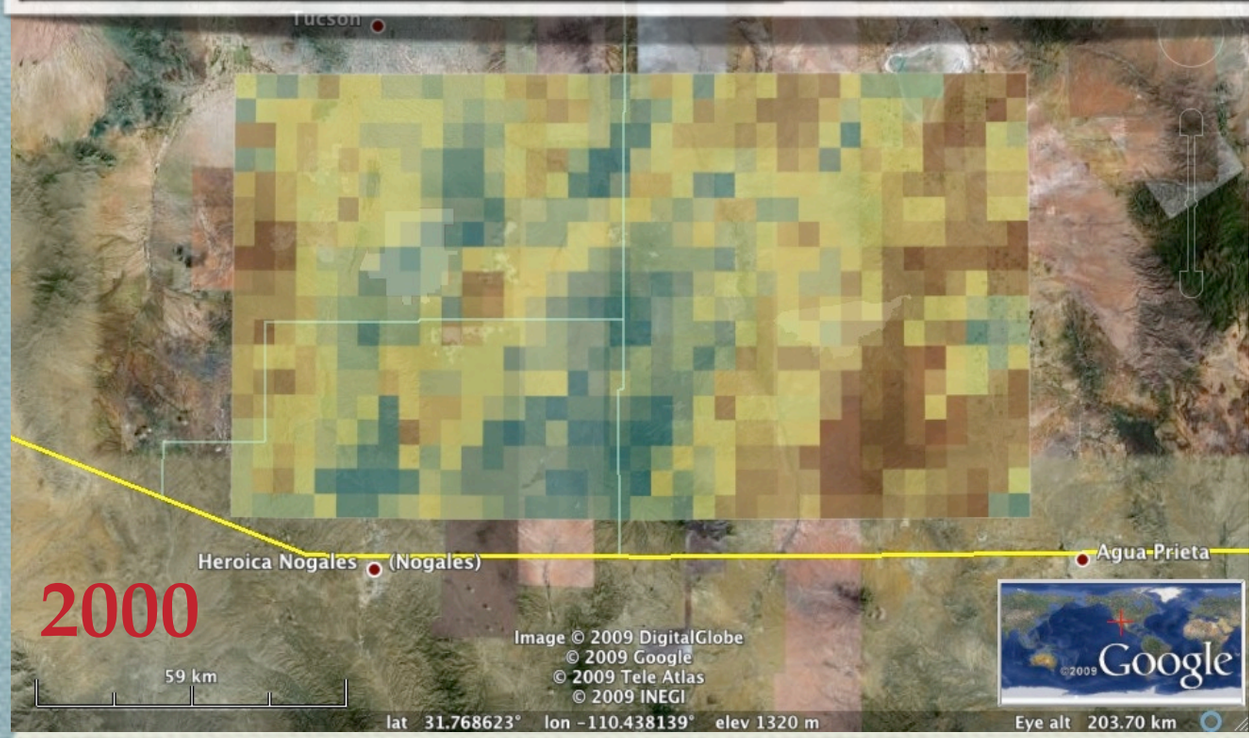
Results - MAP Anomalies

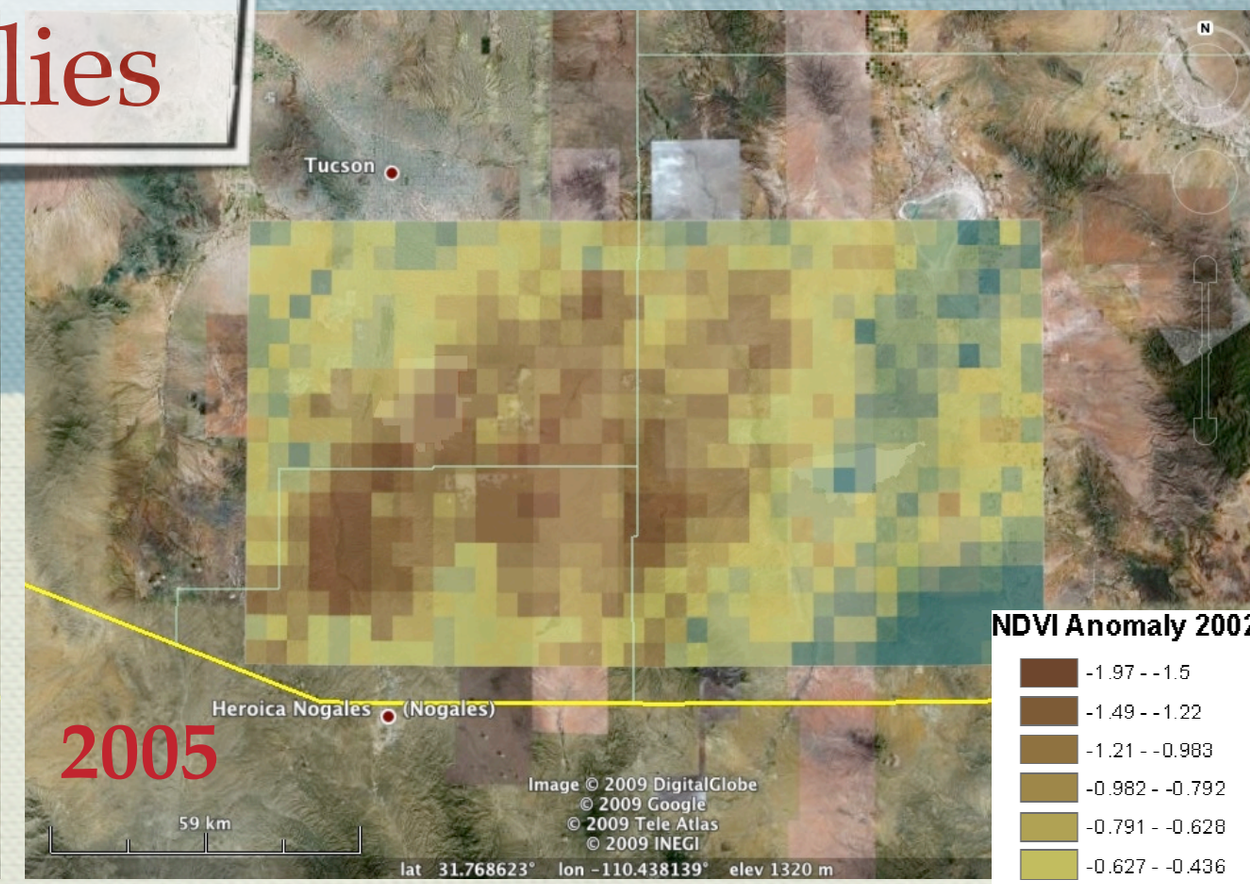


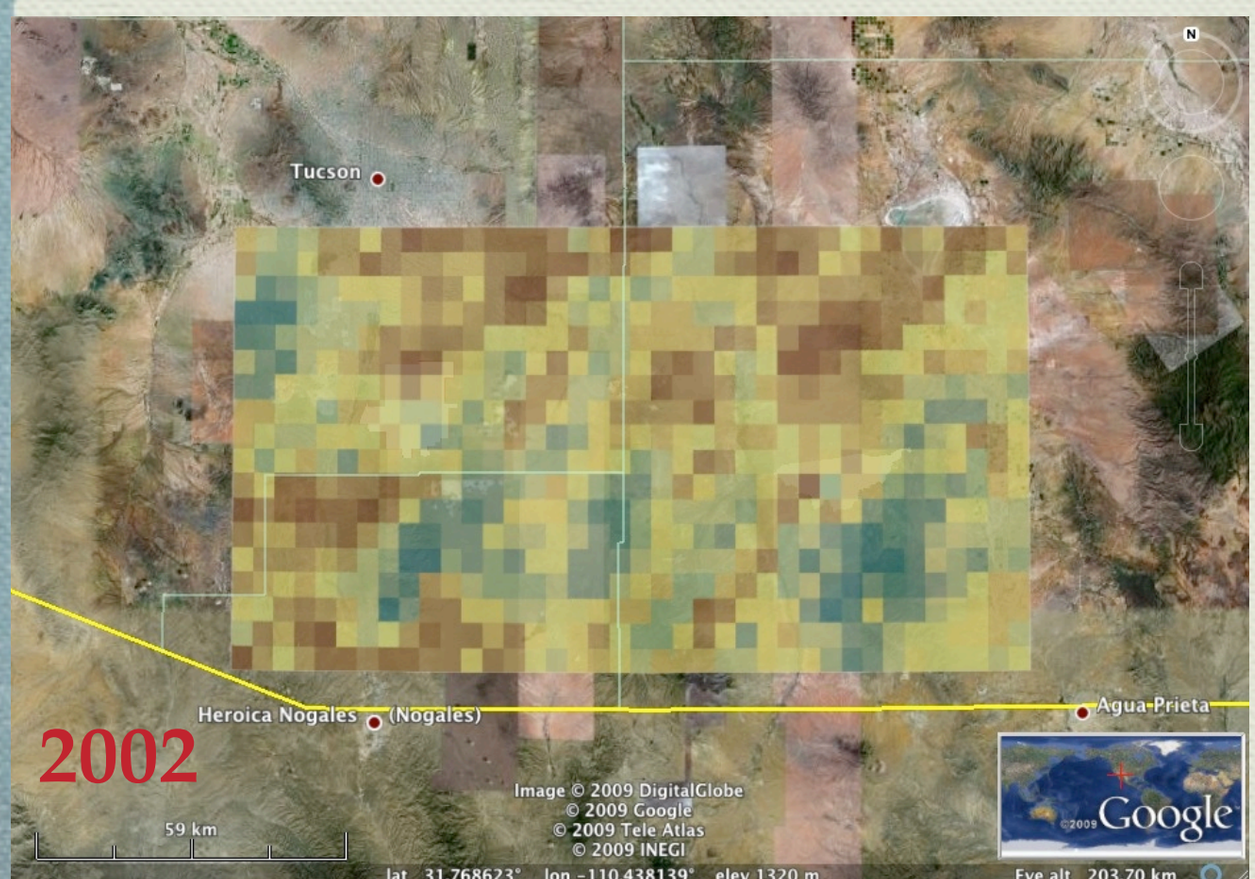
Results - NDVI Anomalies

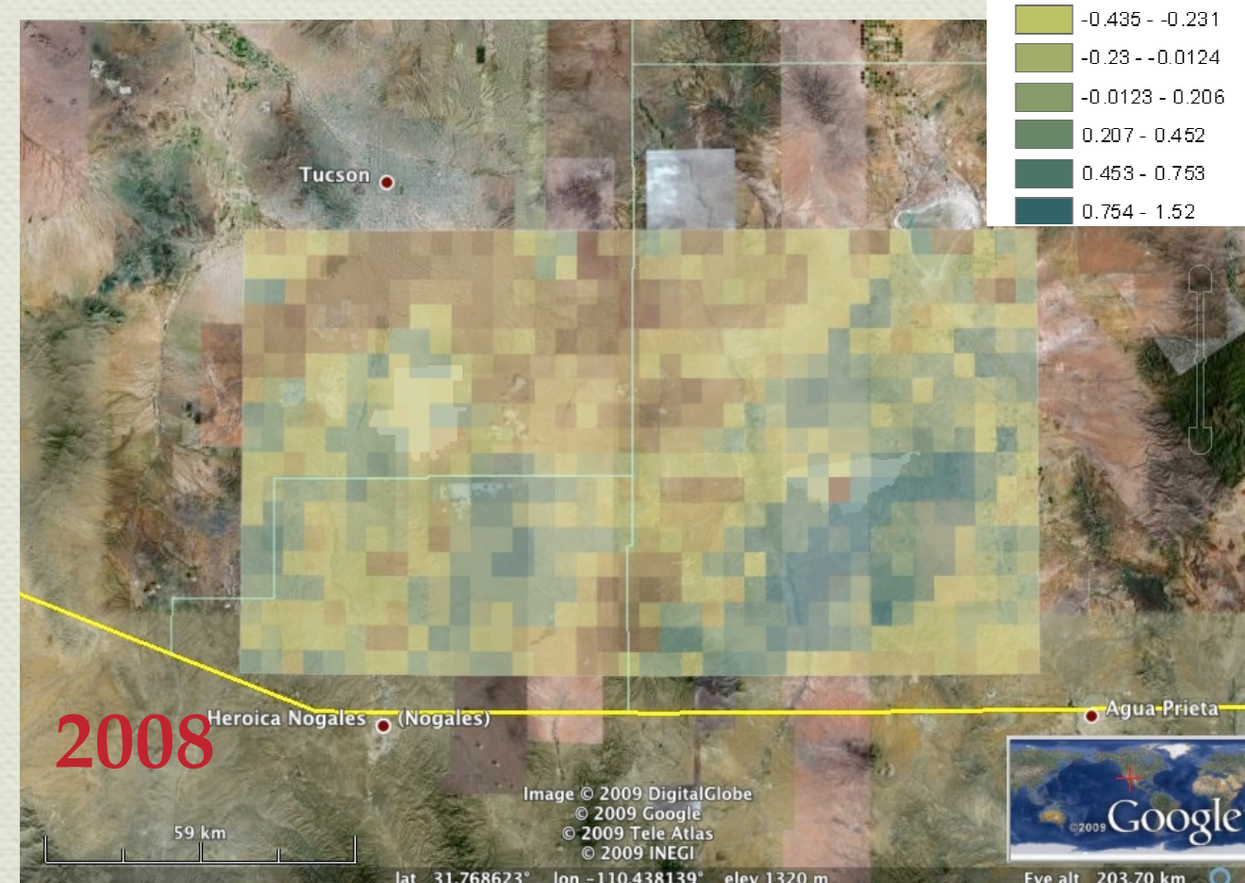


Results - NDVI Anomalies

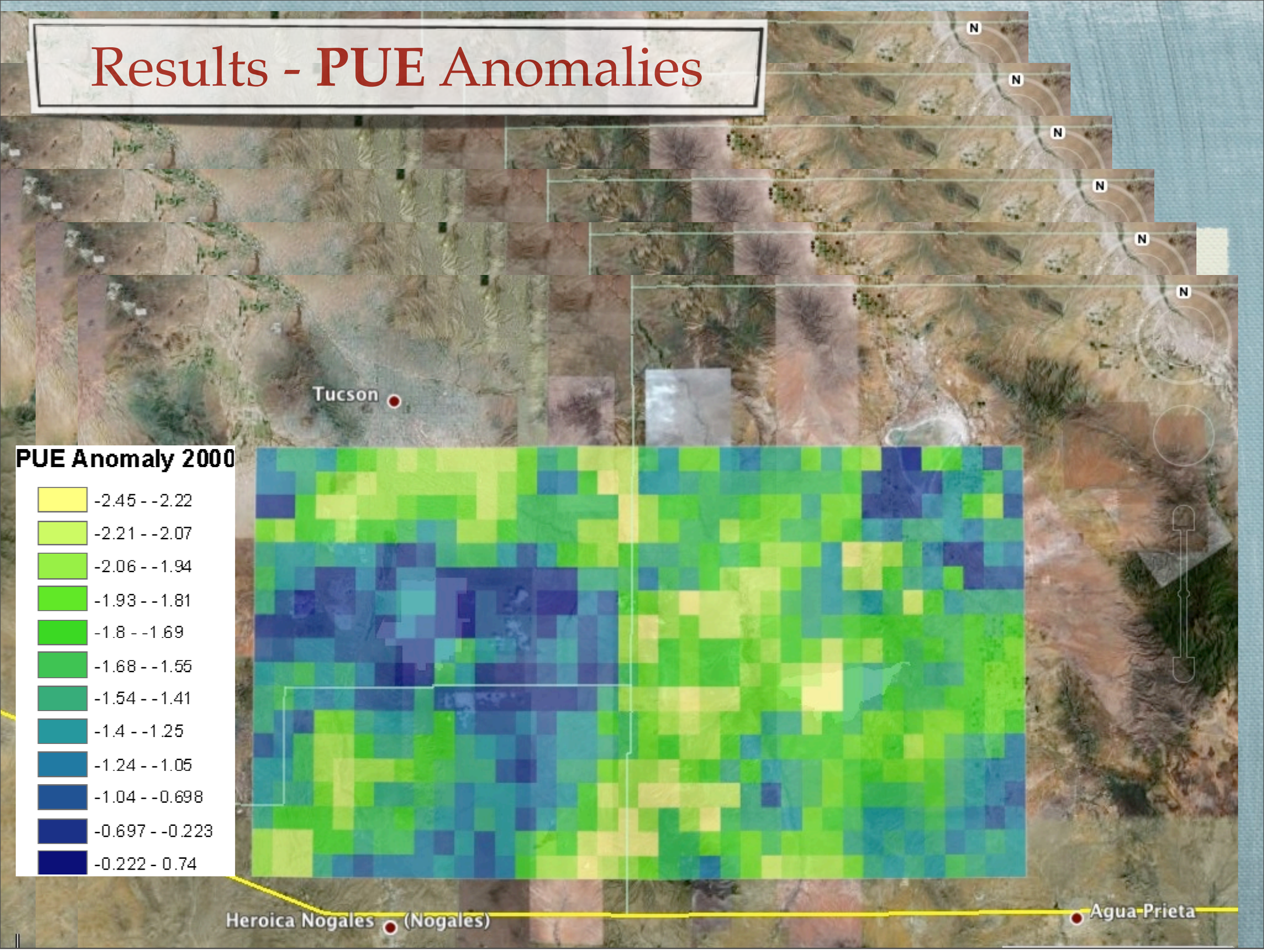




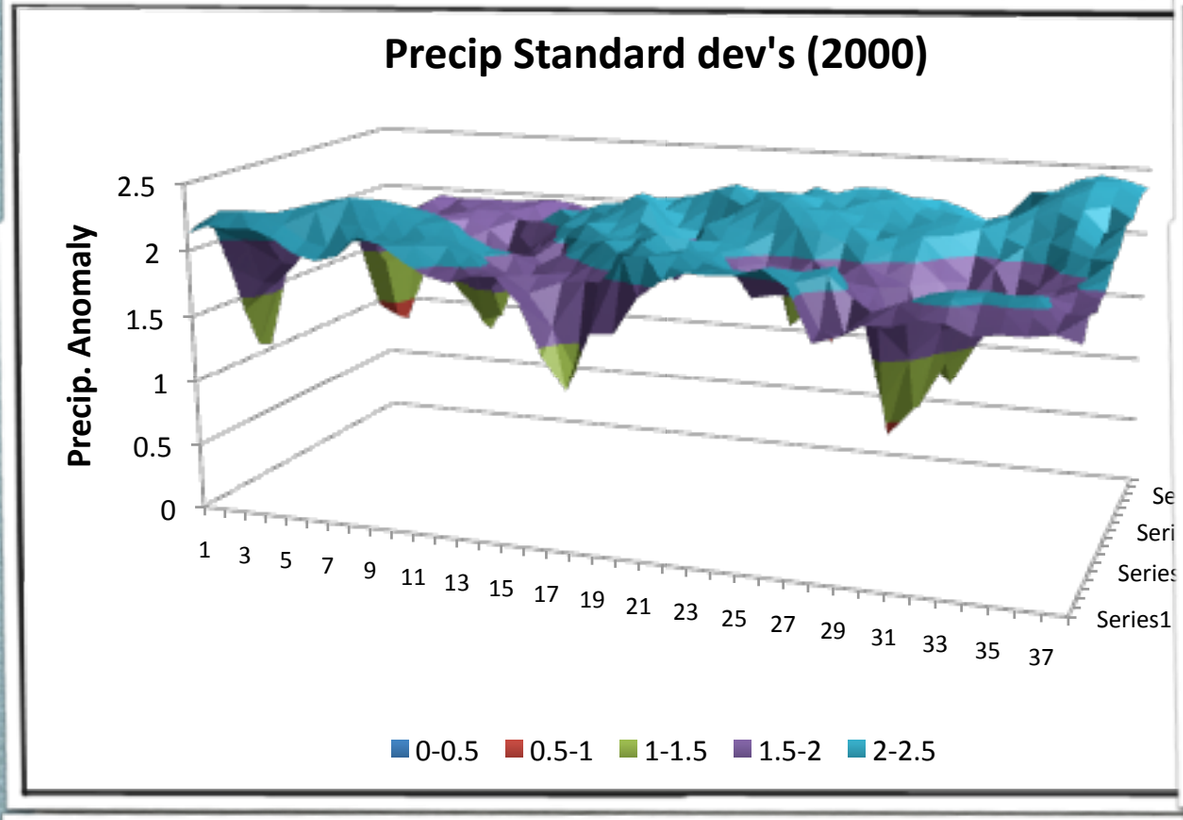


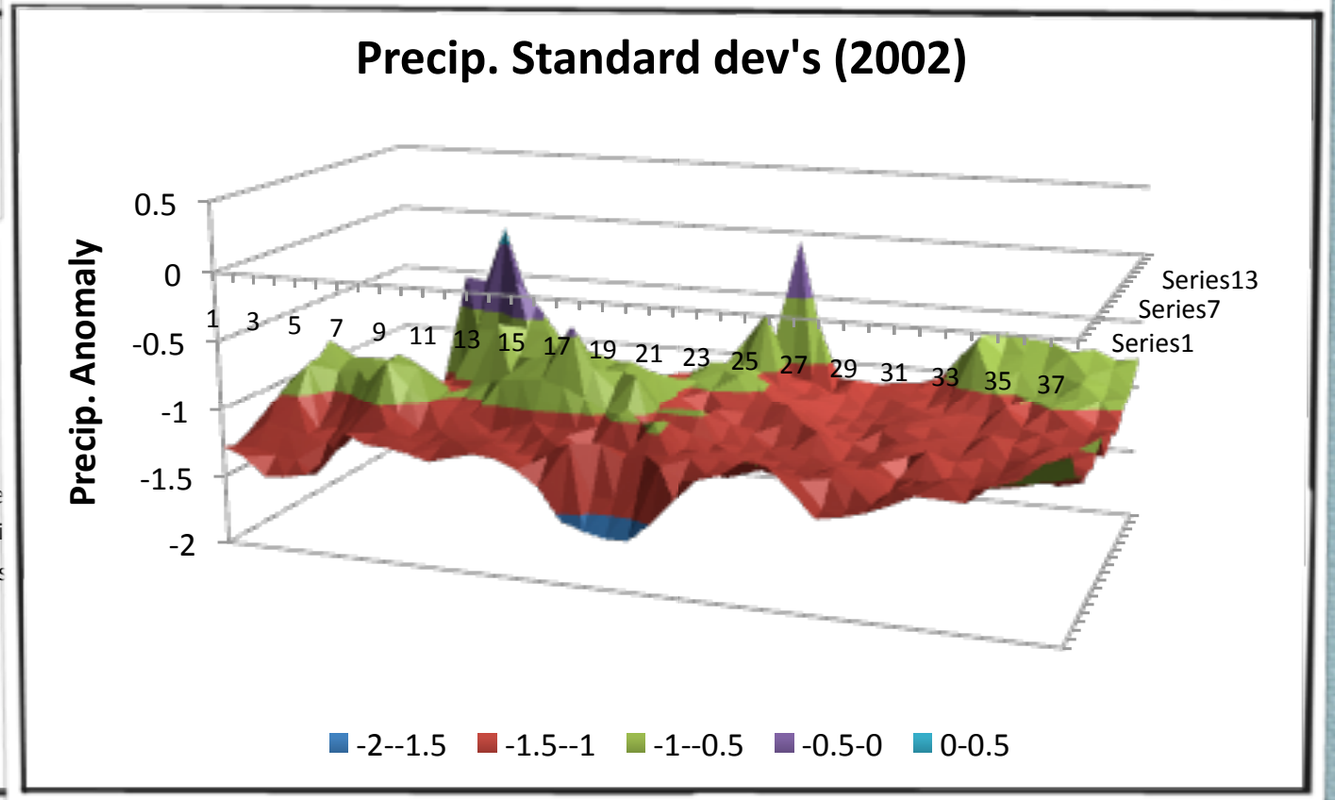


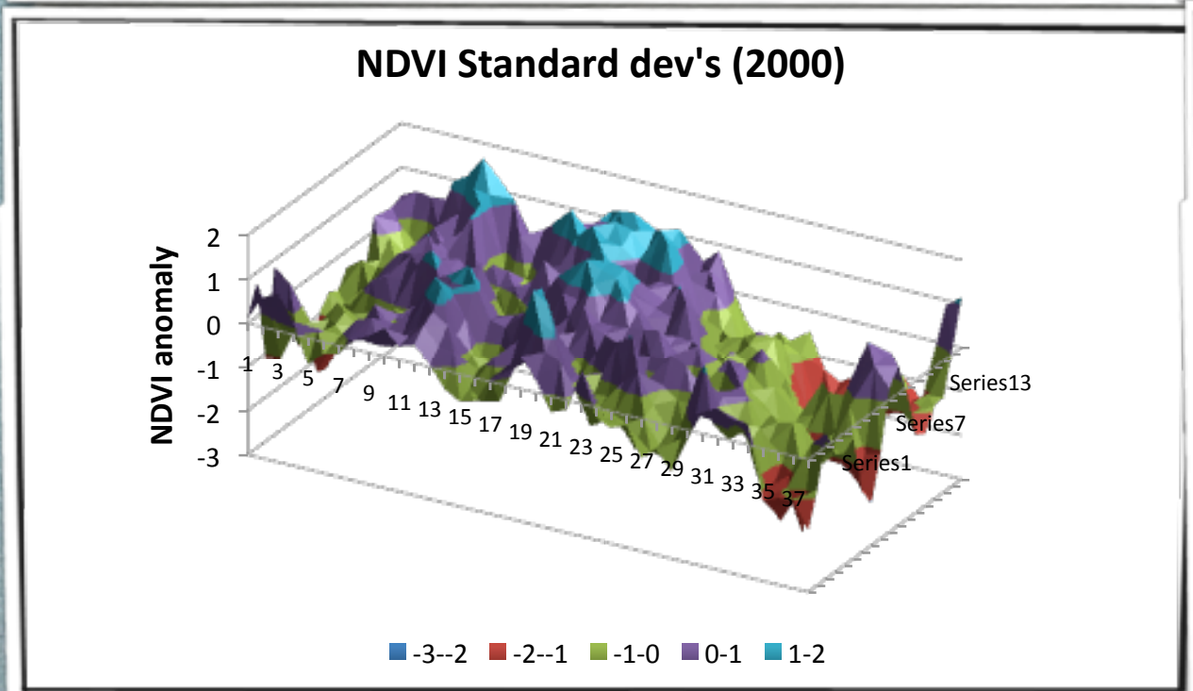
Results - **PUE** Anomalies

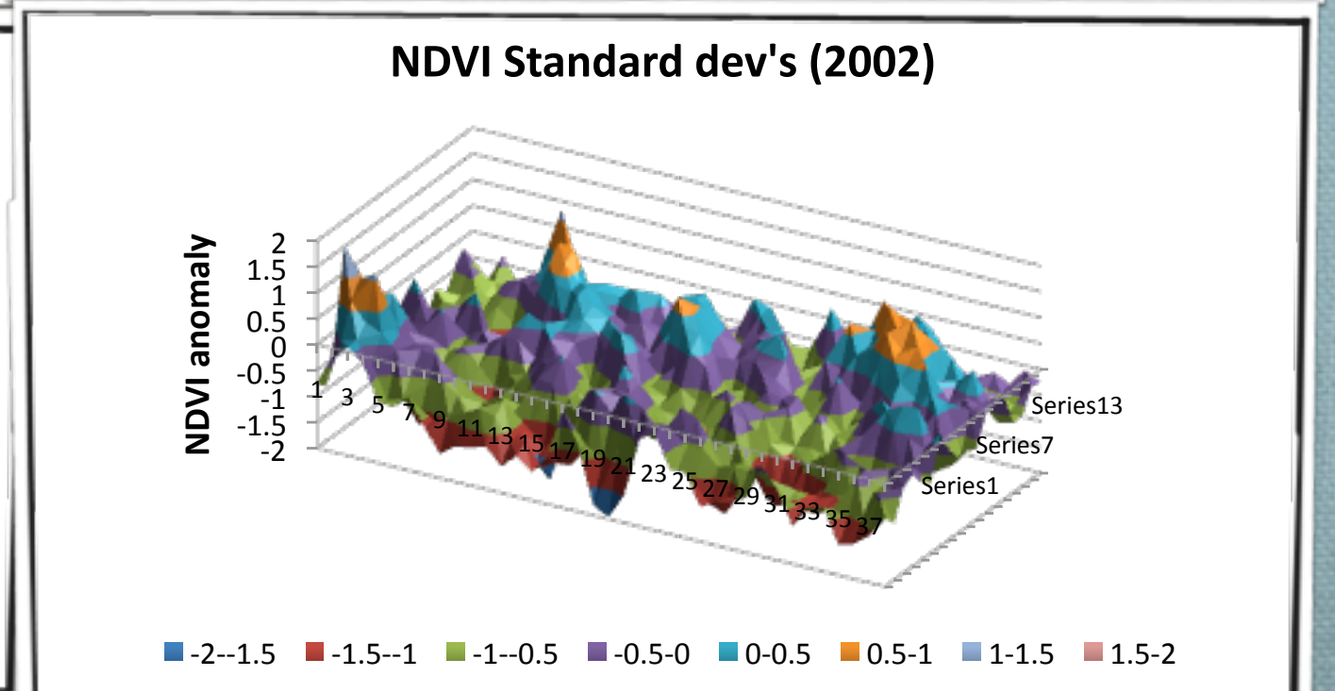


NDVI and Precipitation Standard Anomalies

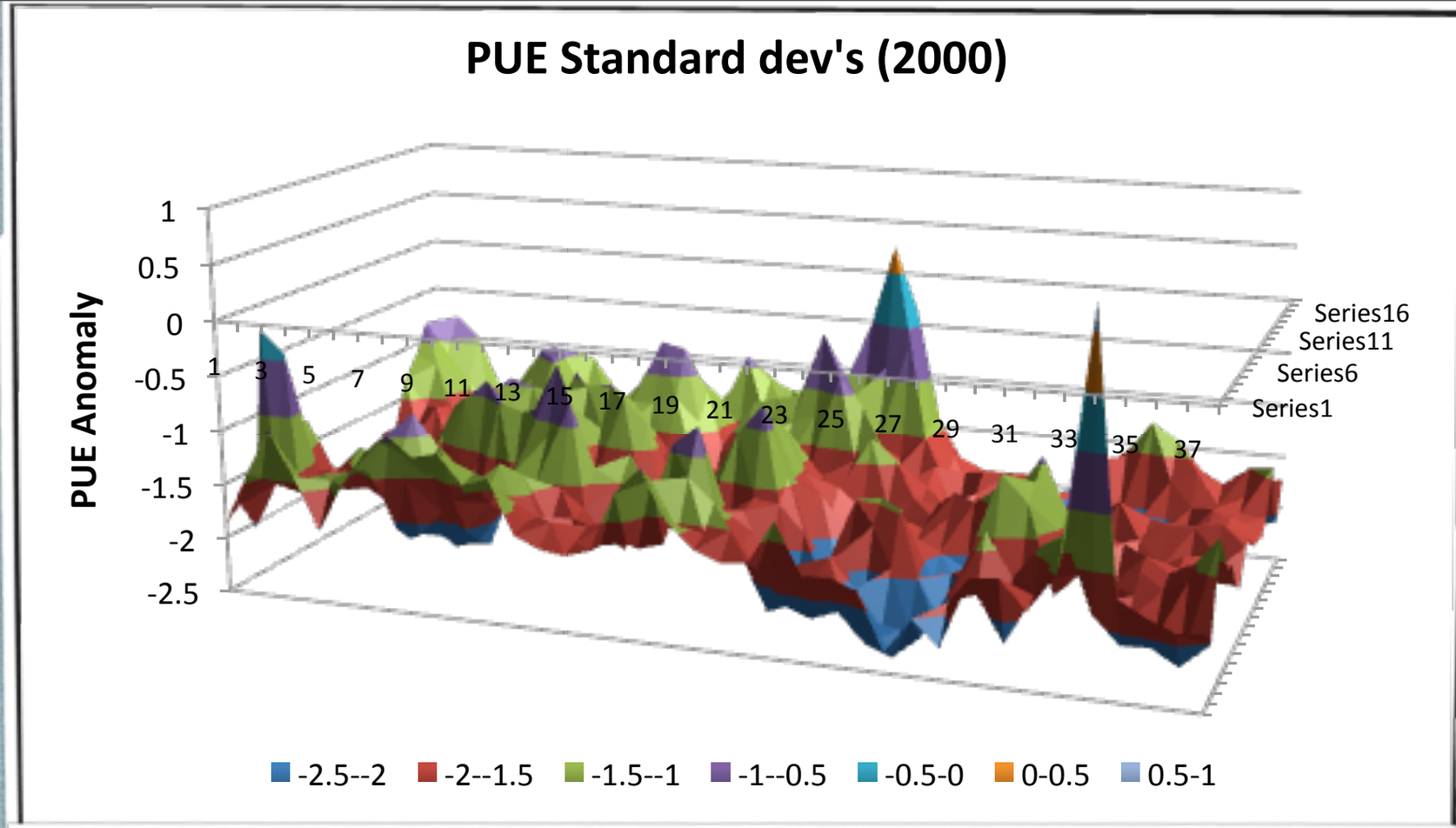


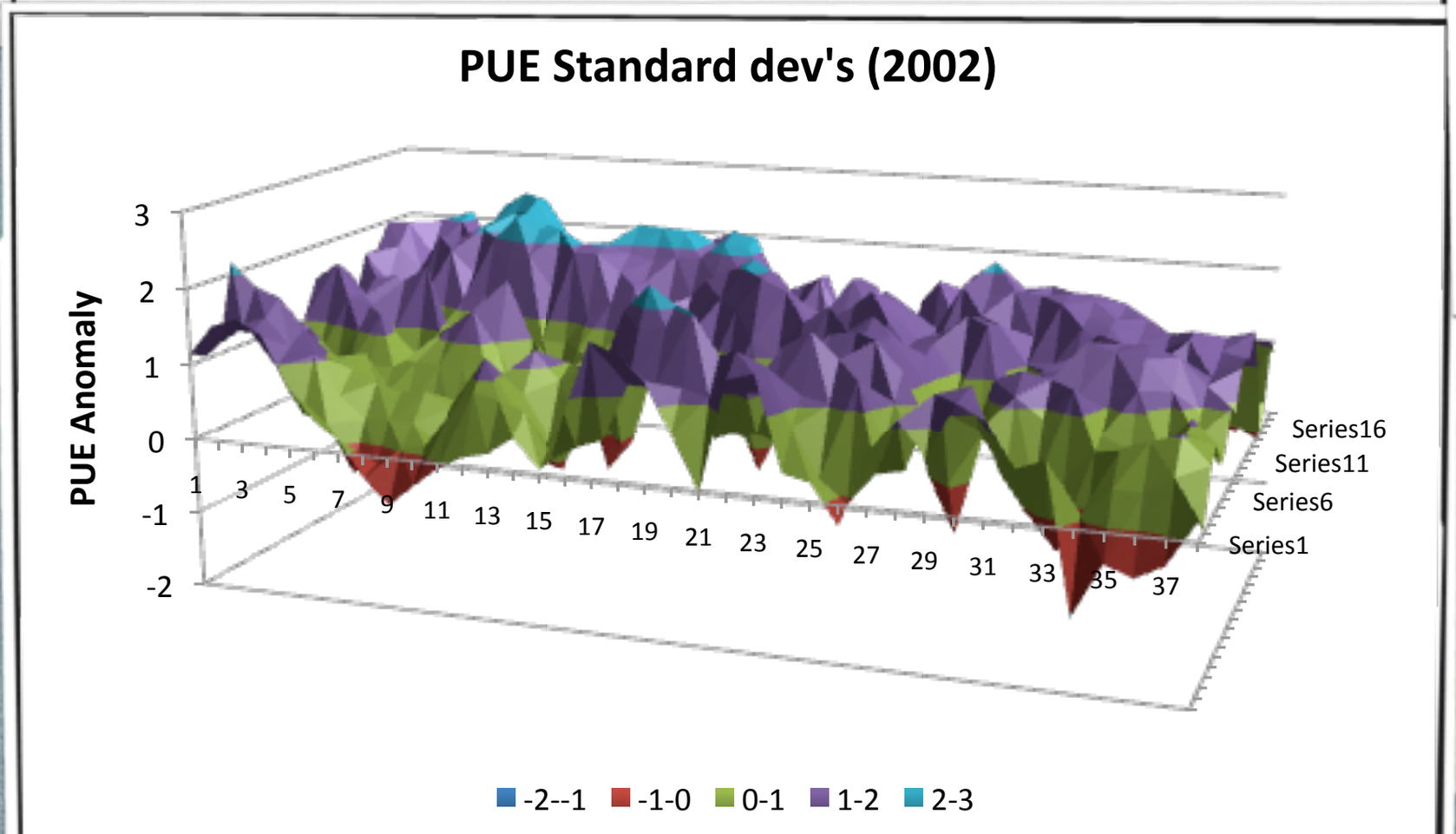




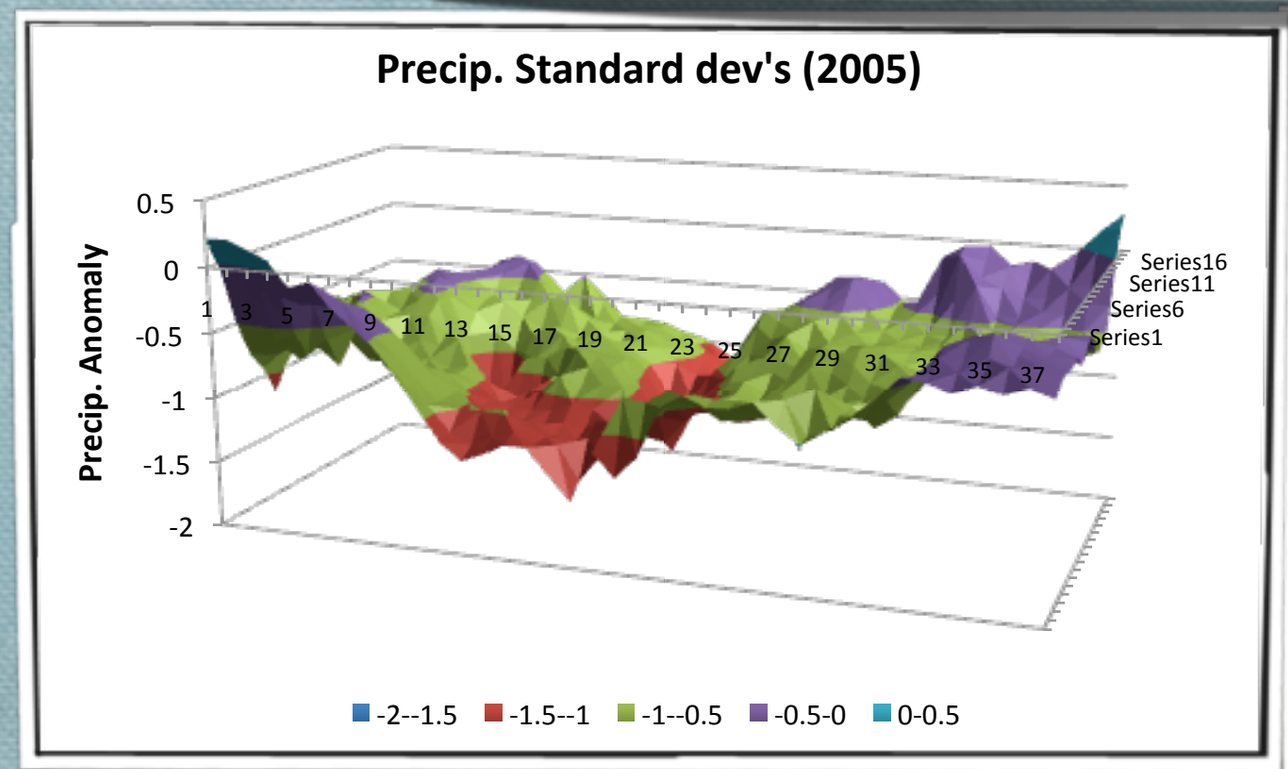


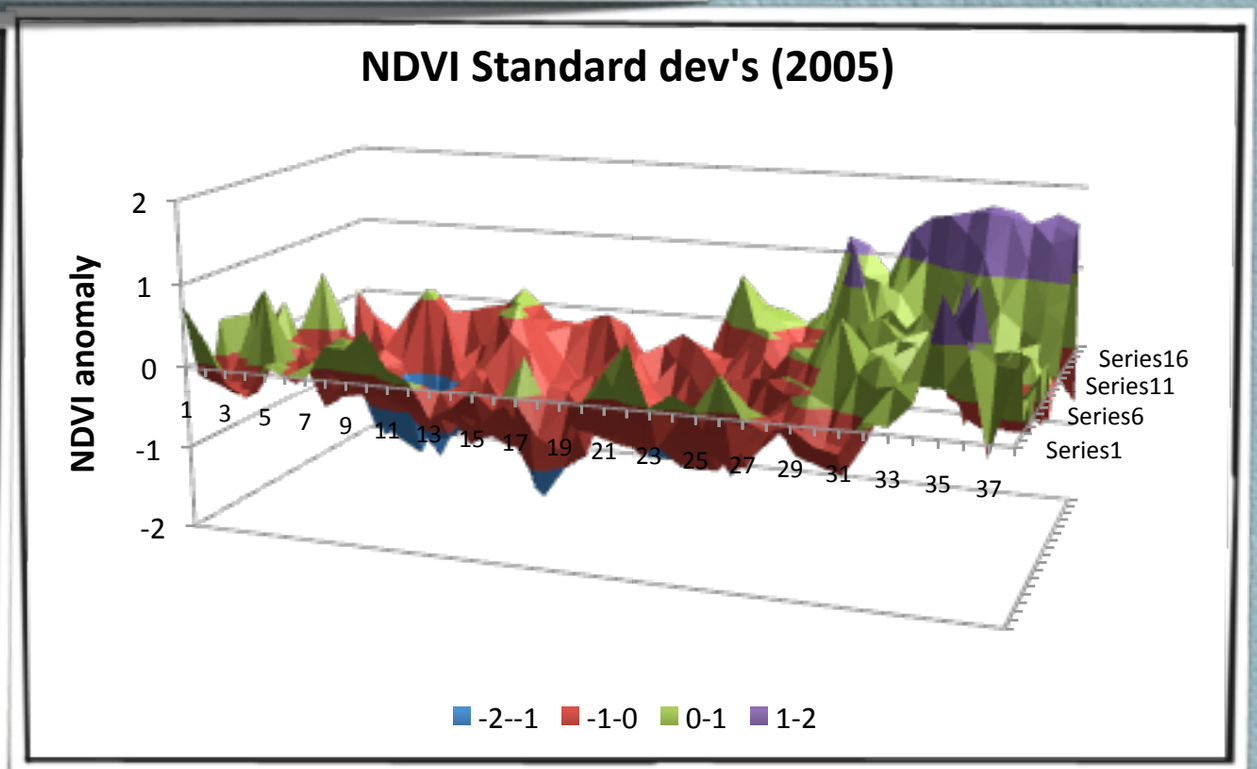
Precipitation Use Efficiency Anomalies for Dry and Wet Years

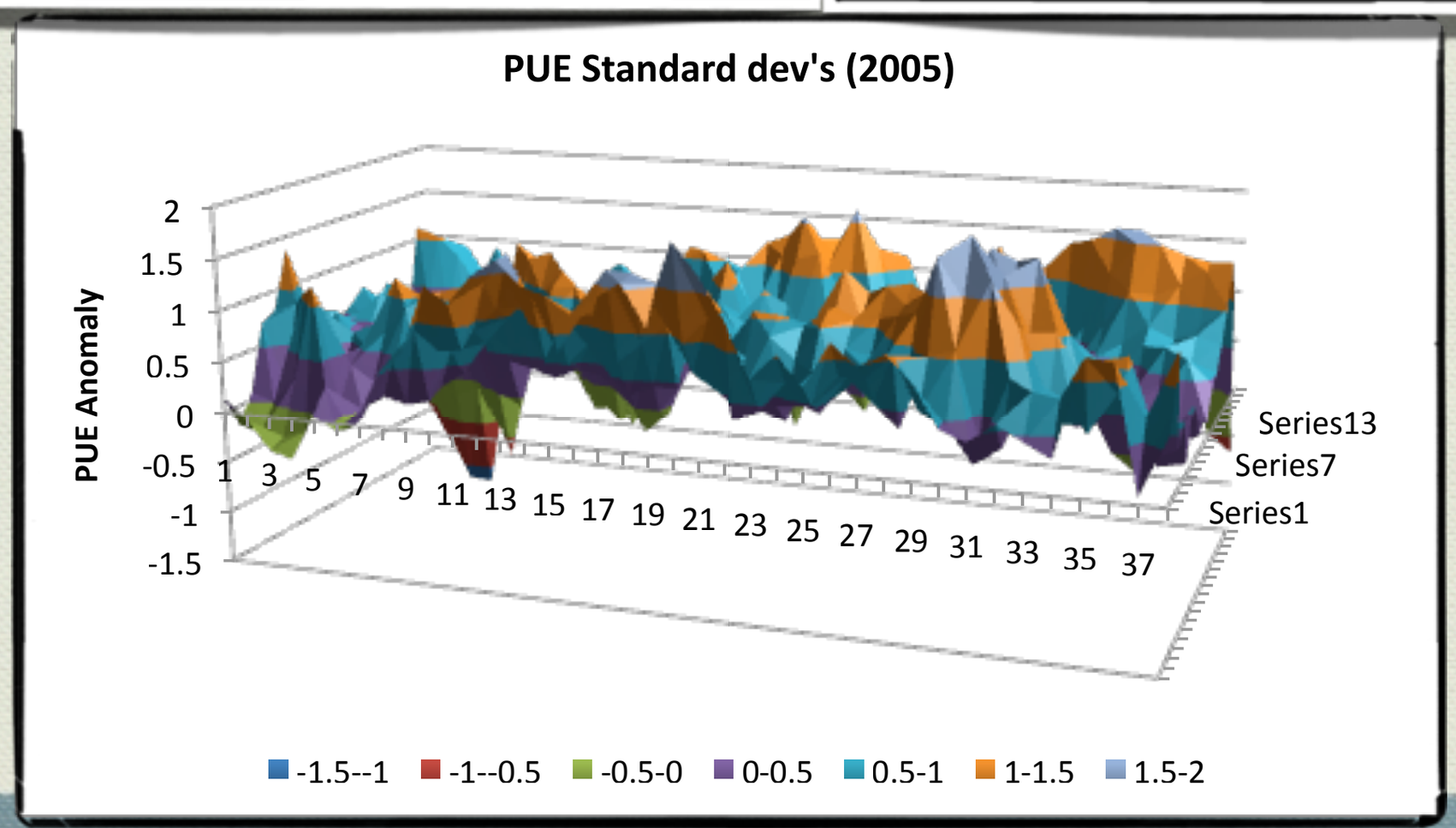




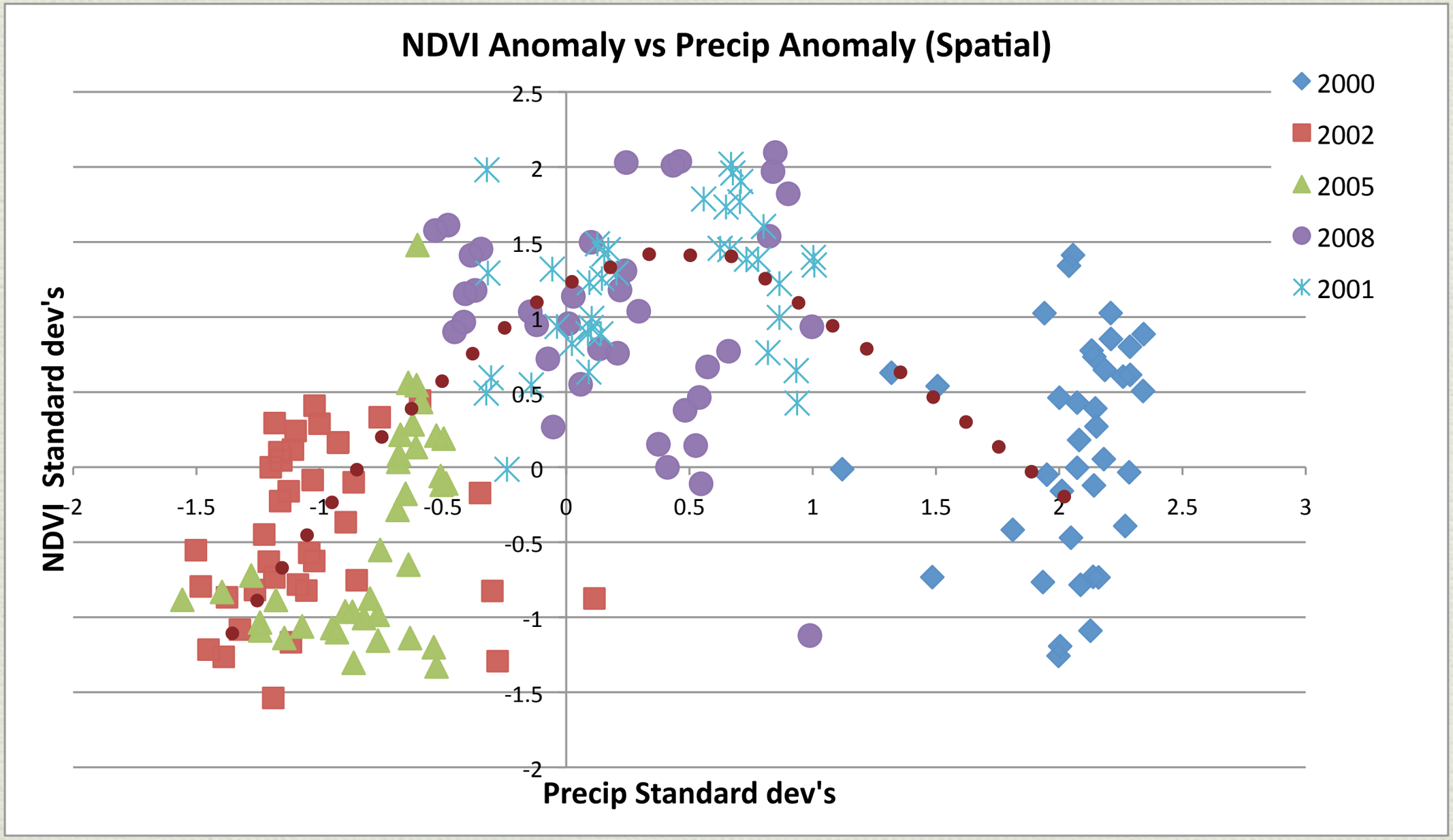
Standard Anomalies in 2005



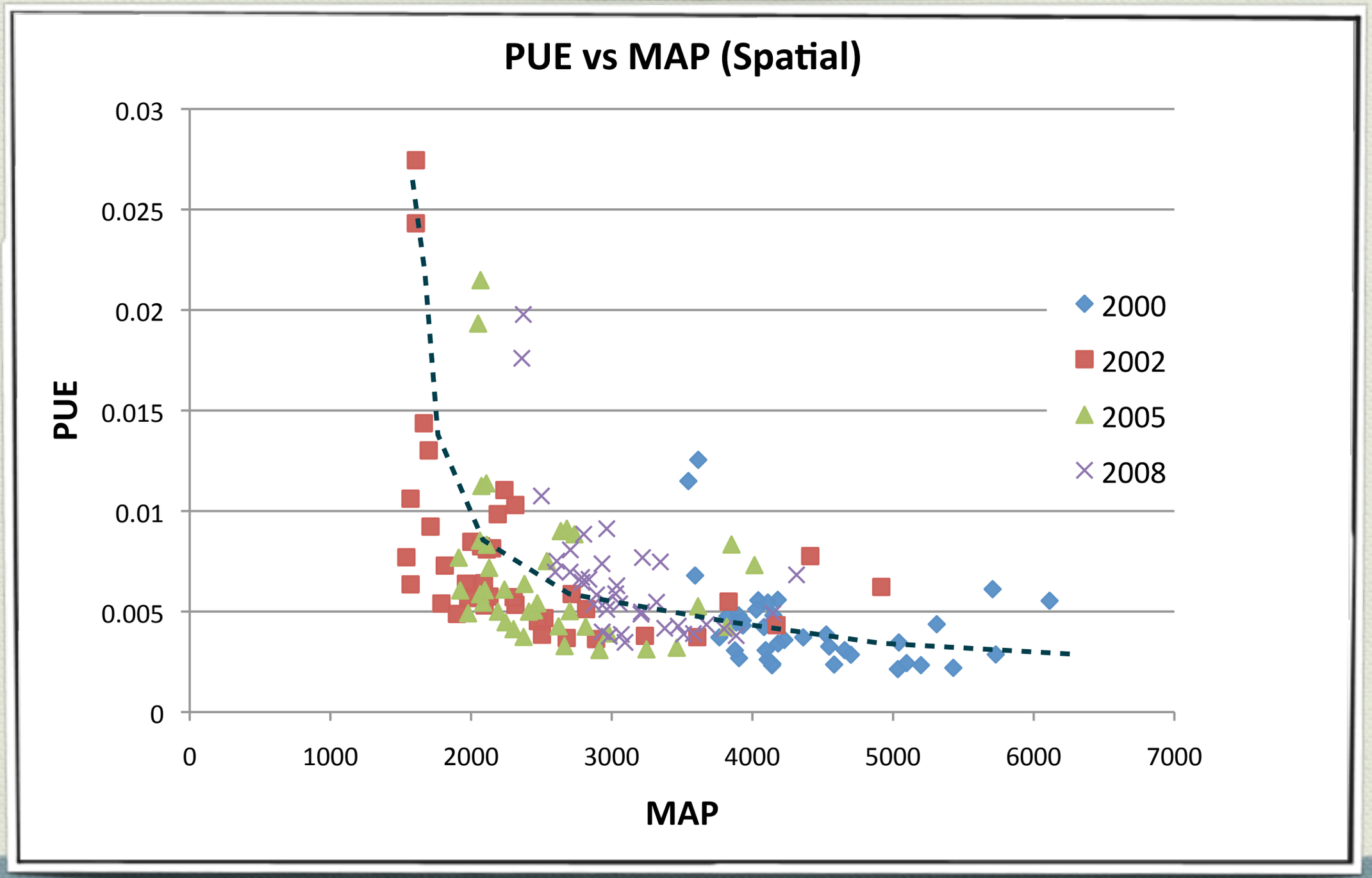




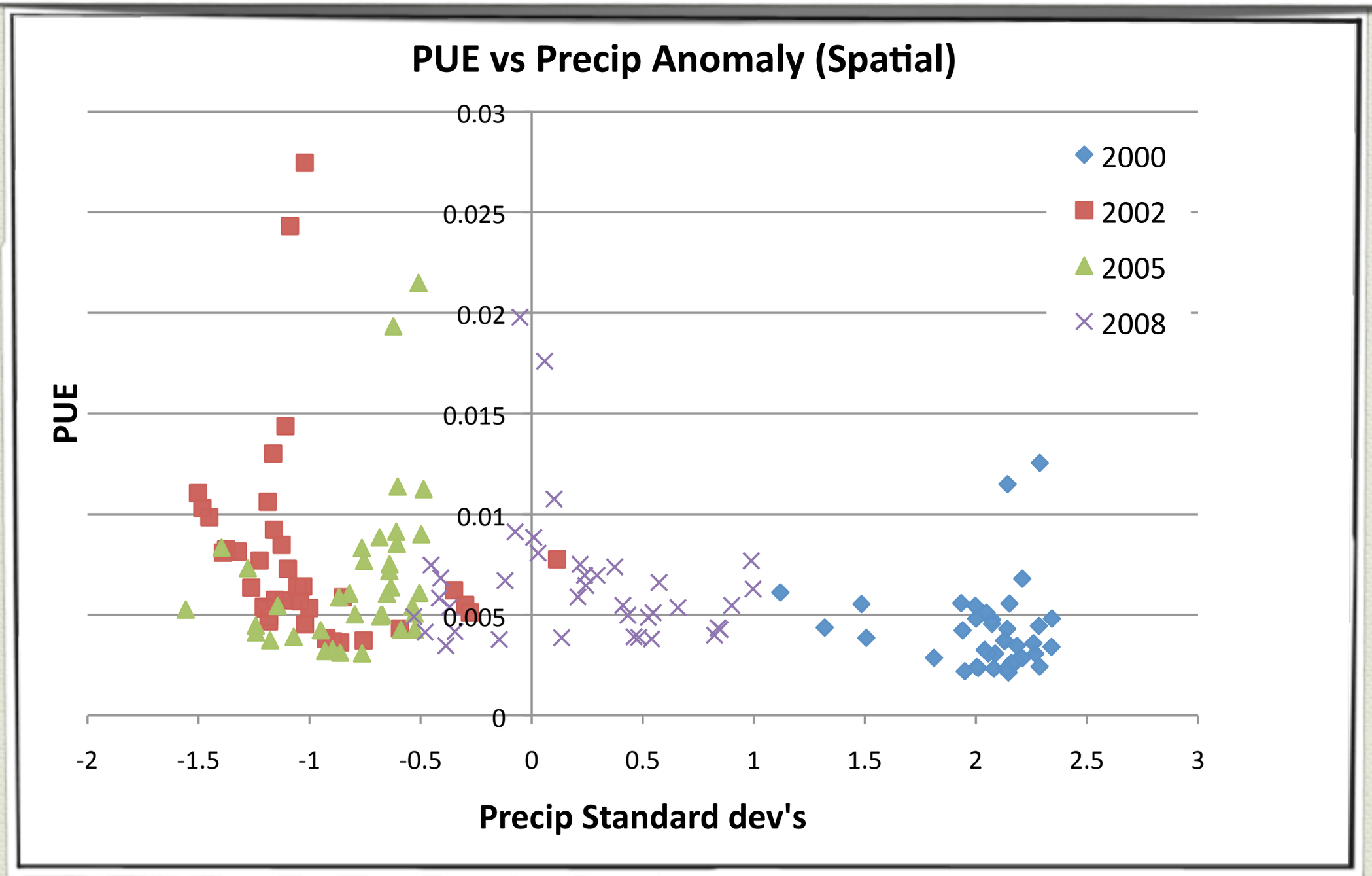
Relationship of NDVI and Precip standard anomalies across land cover types



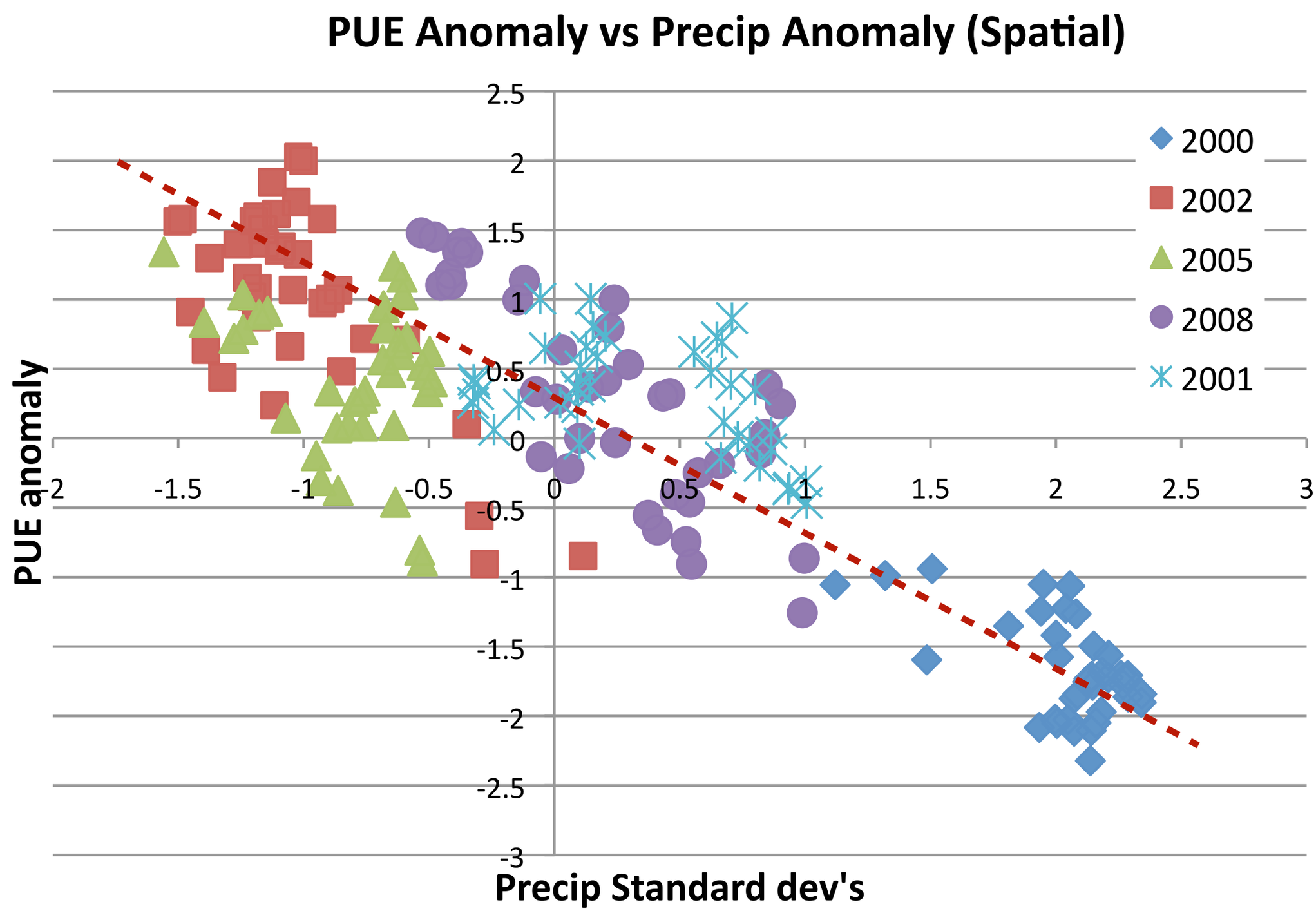
PUE and MAP across land cover types



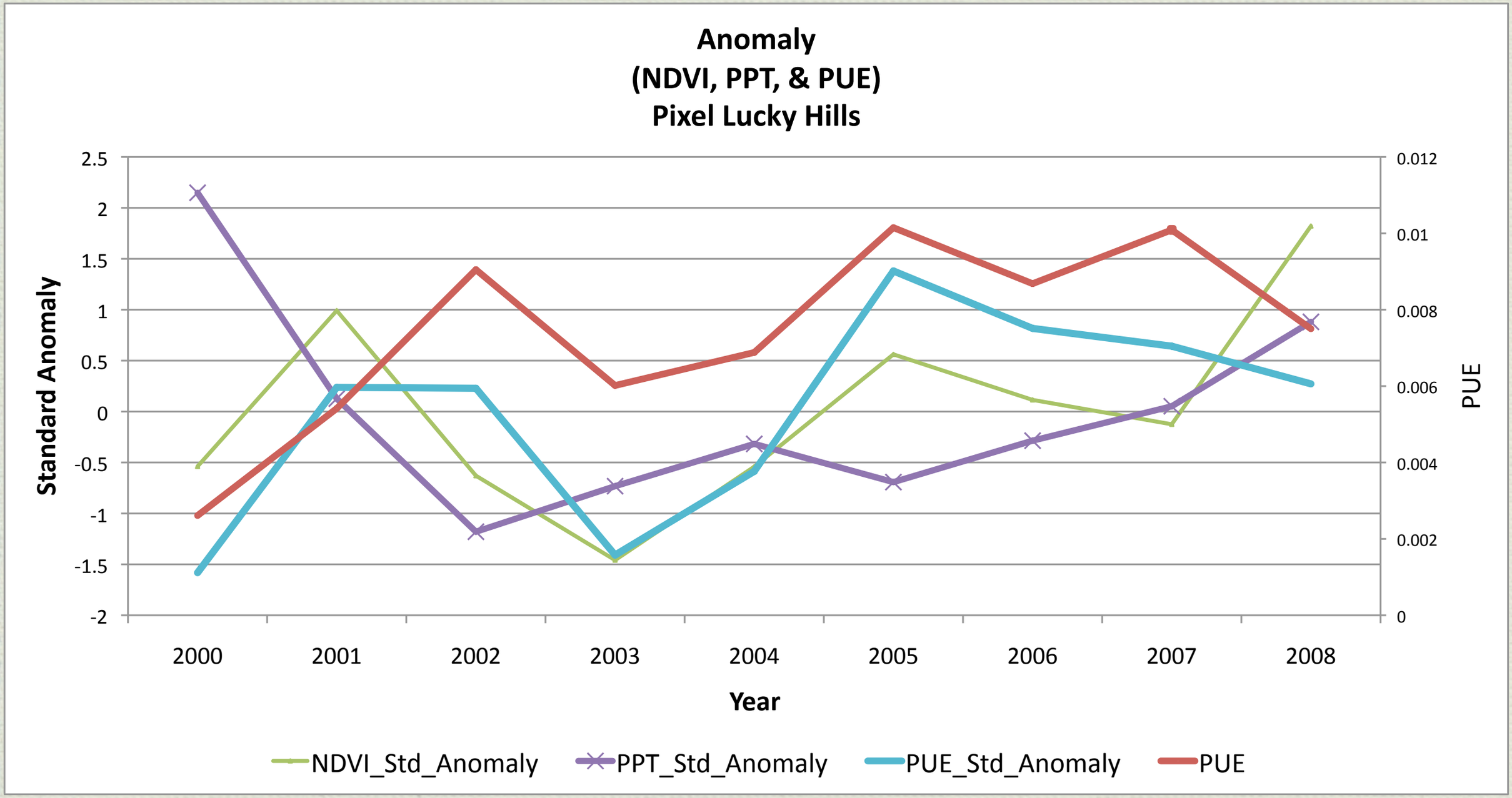
PUE and MAP anomaly across land cover types



PUE vs MAP anomalies - across land cover types

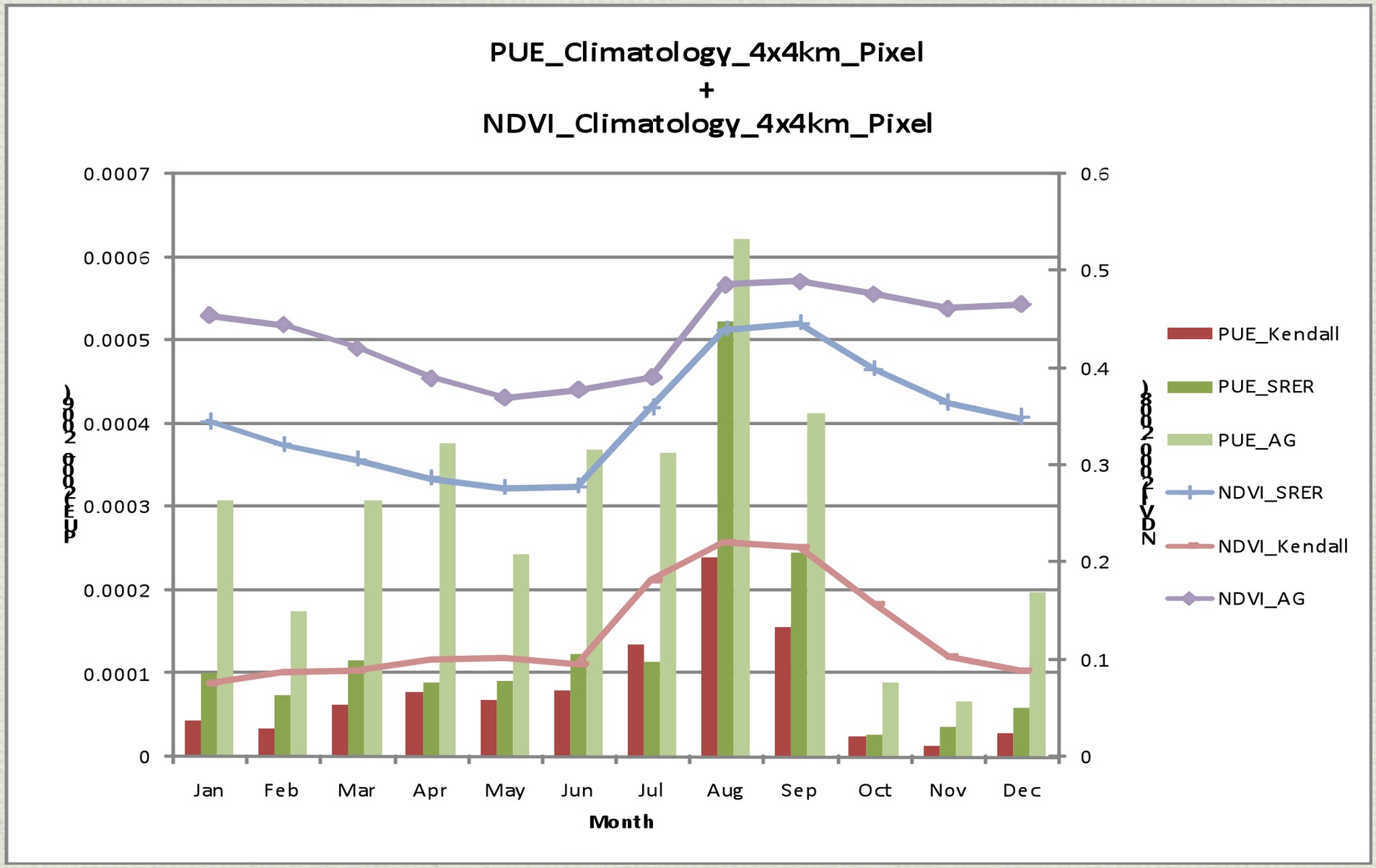


Interannual trends in PUE



G. Ponce Poster

Monthly- seasonal PUE

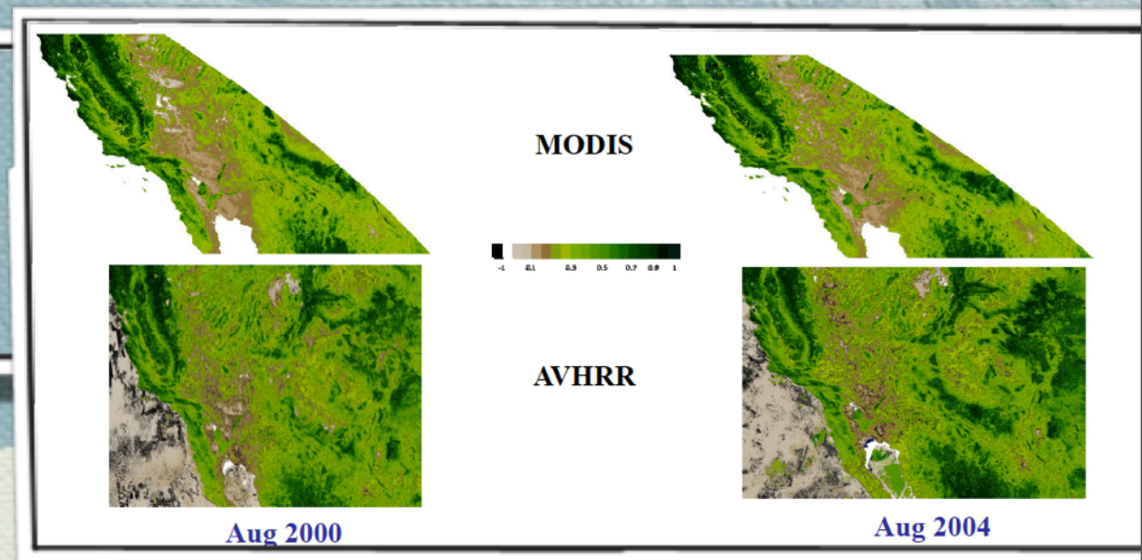


G. Ponce Poster

Summary & Challenges

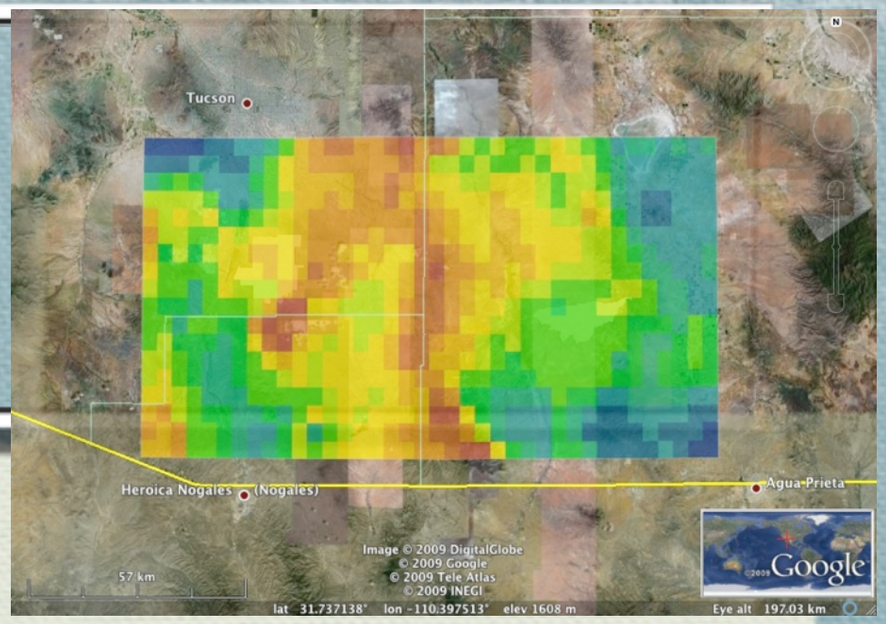
- Our time series and anomaly analyses yielded highly sensitive and strong vegetation response patterns to drought, including land cover dependencies. We found complex ecohydrological relationships in space and time
- What are the interactions of severe drought events with variable ecosystem seasonalities?
- More intense drought periods, combined with land degradation, may stress ecosystems beyond a threshold resulting in the widespread drying.
- Remote sensing products need in situ observations, such as flux towers, to validate and better understand what optical signals are measuring.
- The dynamics and interplay of climate change, land-use activities, and socio-ecologic sustainability will largely determine the fate of many ecological systems.

Future activities



- Scale-down to local meteorology stations and soil moisture
- Scale- up to daily satellite-derived precipitation data (TRMM) over a broader region, including northern Mexico and NAME study areas.
- Merge AVHRR and MODIS satellite data to extend results to 1981.
- Optimize retrievals of ANPP with satellite measurements (calibrate to flux tower sites),
- PUE-vegetation response relationships at monthly, and daily time steps.
- Application of new satellite indices, including the Enhanced Vegetation Index (EVI, EVI2).

Poster



- Regional Vegetation Responses to Drought in the Southwest U.S.A. – A Precipitation Use Efficiency Analysis by combining MODIS satellite products and PRISM/TRMM data
  - Guillermo Ponce and Alfredo Huete