Vegetation Indices Climate Signals and Error Bars & Transition to VIIRS

Kamel Didan[1], Armando Barreto[1], Compton Tucker[2], Jorge Pinzon[3]

Divergent Responses of Vegetation Cover to Dry and Wet Years at Different Elevations

Kamel Didan[1], Stefanie Herrmann[1], Armando Barreto[1], Michael Crimmins[1]

[1]University of Arizona, [2]Goddard Space Flight Center, [3]SSAI/GSFC

Outline

- Topic I
  - The VI Time Series
  - Global (climate) Signals and Differences
  - Implications and Opportunities
- Topic II
  - US Southwest and 15 years of droughts
  - Montane vegetation cover responses

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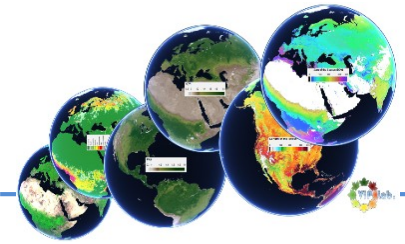
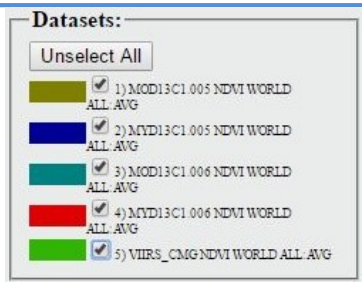


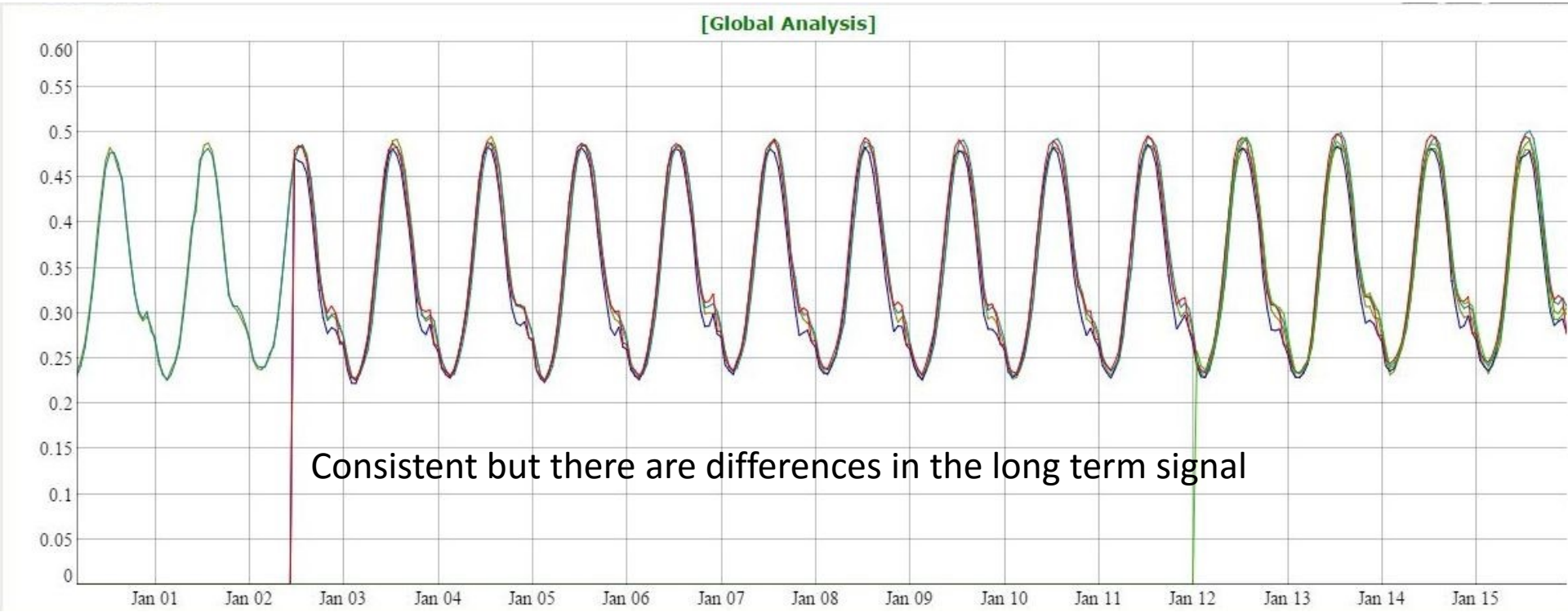
The 35+ years Time Series

- **VIs constitute one of the longest '<u>consistently</u>' generated data record (RS based)**
  - Multi-sensor VI Records (AVHRR, MODIS T/A, and now VIIRS, + others but not same rigor and/or consistency)
    - Potential to go another 25-30 years with VIIRS (S-NPP, JPSS, 2038)
  - Highly valuable, unique, and simple with absolutely no assumptions about anything, long term VI data record (NDVI, EVI/EVI2)
  - Supports one of the largest multidisciplinary science user communities (ranchers to modelers)
  - Many interesting 'science findings'
- **AVHRR Time Series (35+ yrs) : Longest + Least standard + Multiple sources + Lack of consistent correction**
  - **Issues with Atm. Correction, Cloud, Snow, Geolocation, and Spatial Resolution**
- **MODIS Time Series (16+ yrs) : Most standard + Single source + 'Consistent' processing**
  - **Atm. Correction, Cloud, Snow, Geolocation**
  - **However there are contentious and challenging issues**
    - **Full atmosphere correction, but questionable over the Tropics and other biomes (few high end publications)**
    - **No BRDF correction (few high end pubs)**
- **VIIRs Time Series (4+ yrs)**
  - **Cloud & Snow/Ice issues**
  - **Same MODIS Atm. Correction and BRDF challenges**
- **With this wealth of data the question becomes**
  - **At the large Global/Biome scale : How do the Climate Signals look like and are they consistent?**
  - **What is the Global Error Bar and implications**
- **Continuity**
  - **AVHRR – MODIS T-A – VIIRS – J2 – J3 J4**

Terra/Aqua/VIIRS Global Time Series (Earth/Climate Signal)

Aggregate every land pixel = An NDVI 'Keeling Curve' of sort

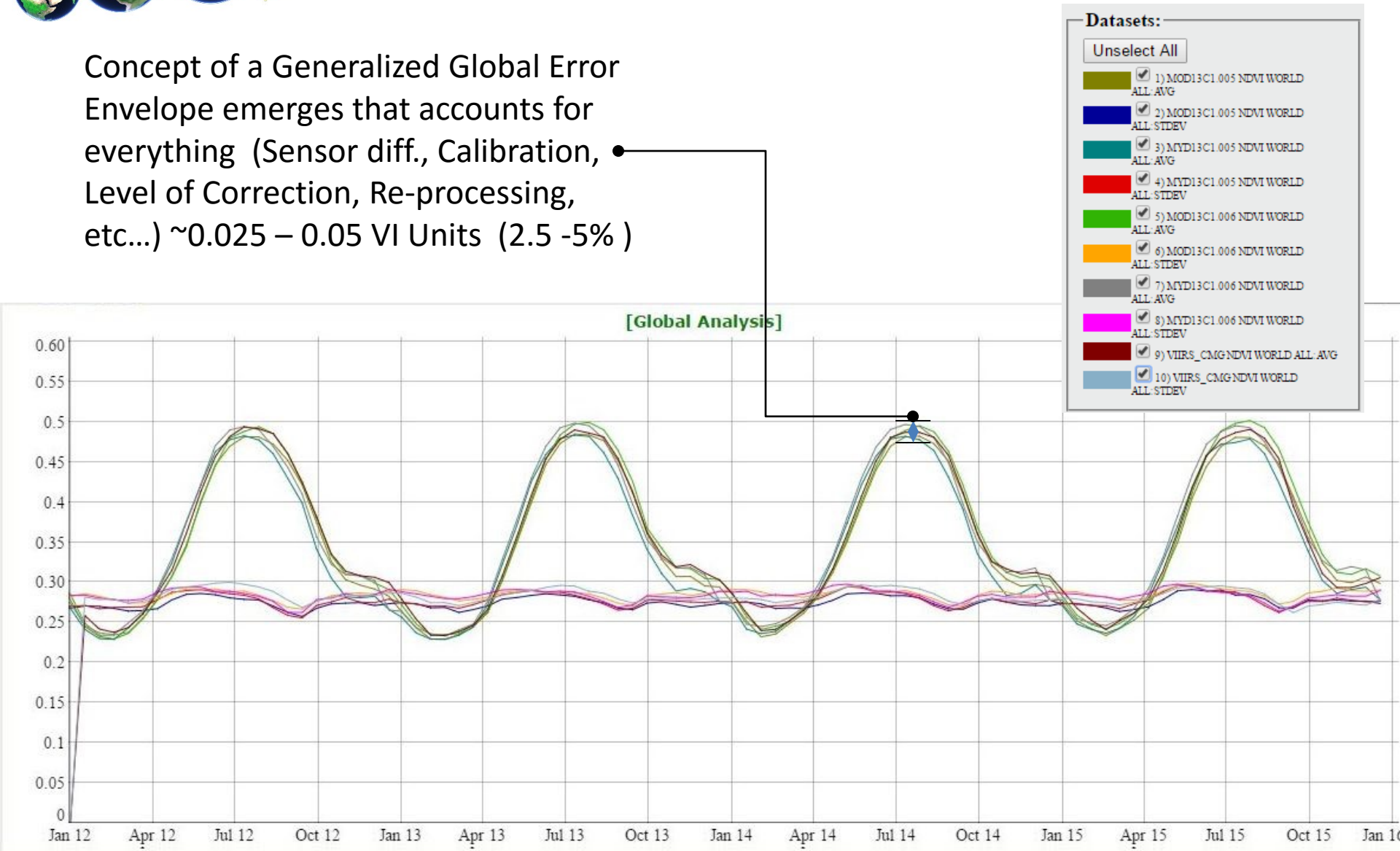




Consistent but there are differences in the long term signal

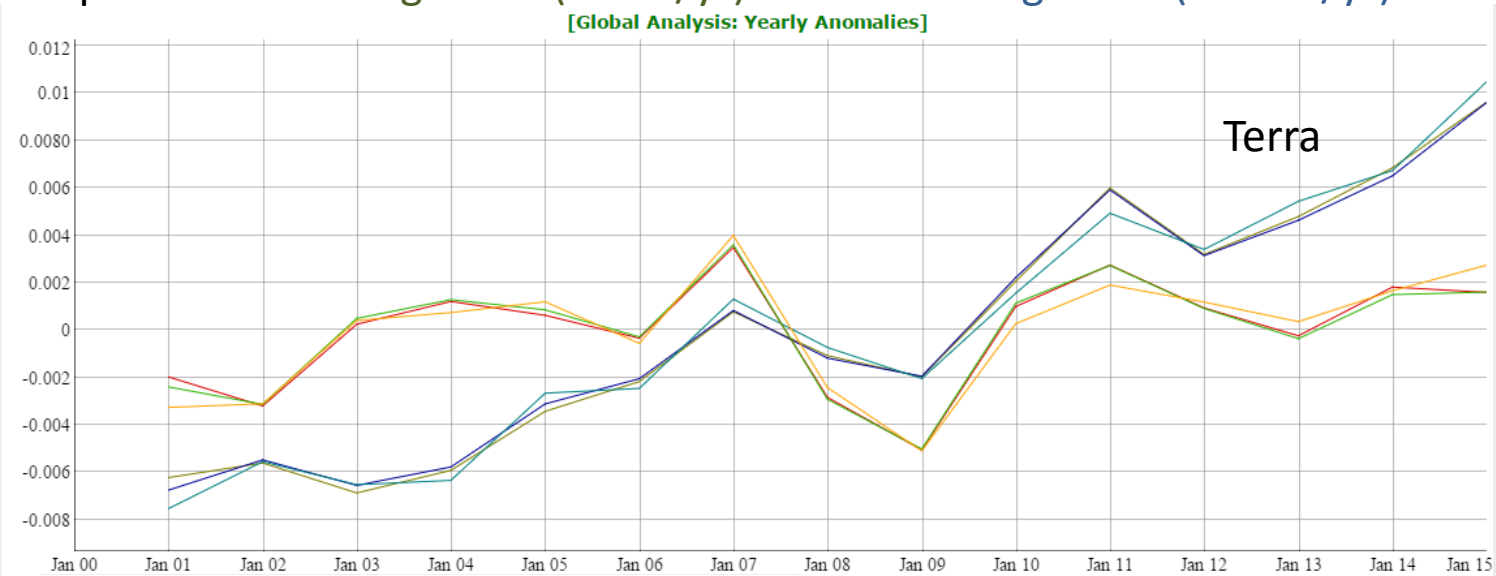
Terra-Aqua-VIIRS Overlap period

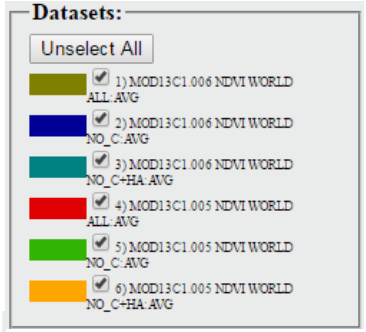
Concept of a Generalized Global Error Envelope emerges that accounts for everything (Sensor diff., Calibration, Level of Correction, Re-processing, etc…) ~0.025 – 0.05 VI Units (2.5 -5%)

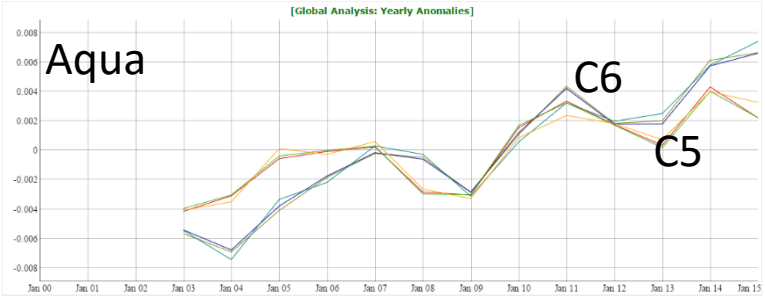


Global Anomalies/Trends

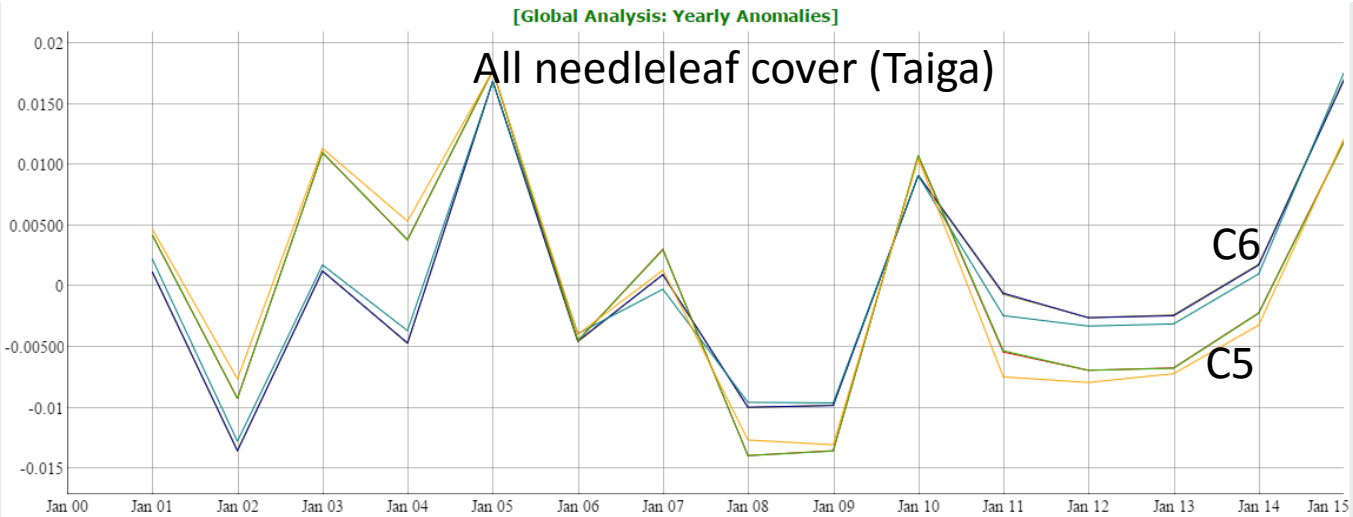
Aggregate every land pixel and compute annual anomaly (Trend)
Consistent across all data filtering approaches
Major differences between the two collections
Terra C6 : Greening trend (0.00133/yr) , C5 : Stable trend
Aqua C6 : Greening trend (0.001/yr) C5 : Greening trend (0.0006/yr)

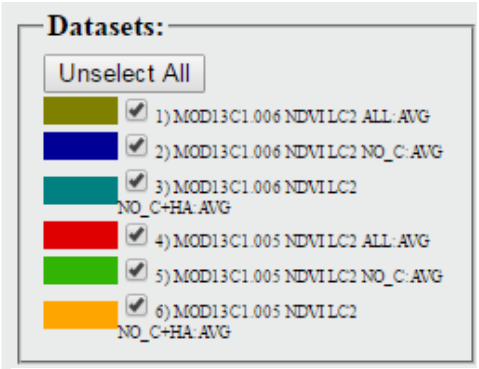


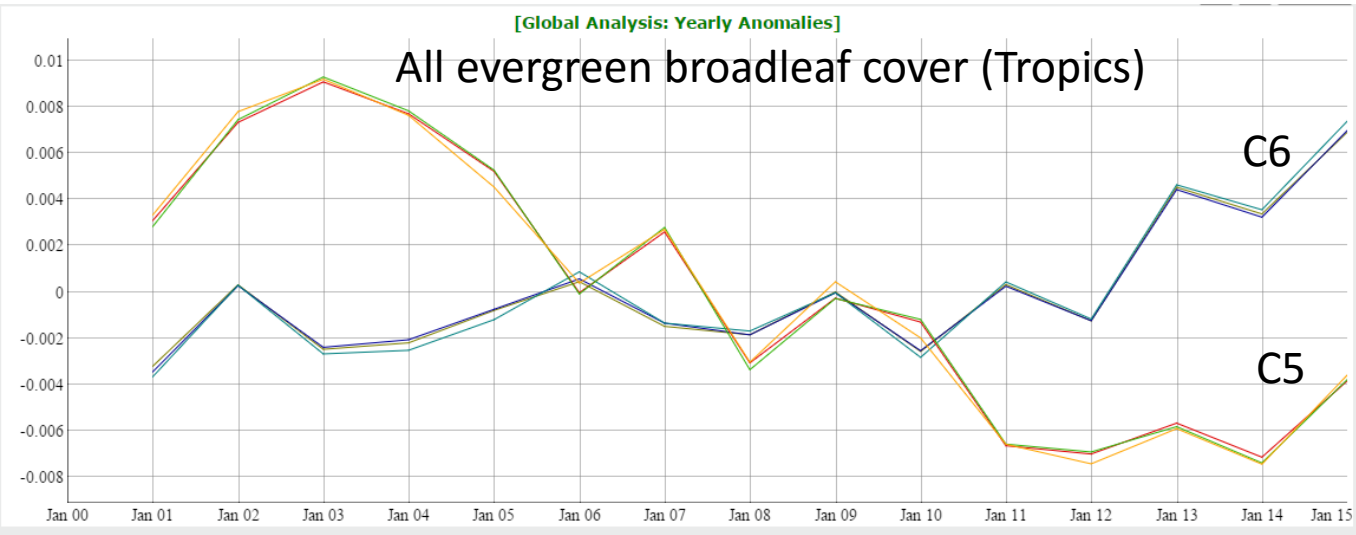




Specific Biomes Signal Anomalies/Trends



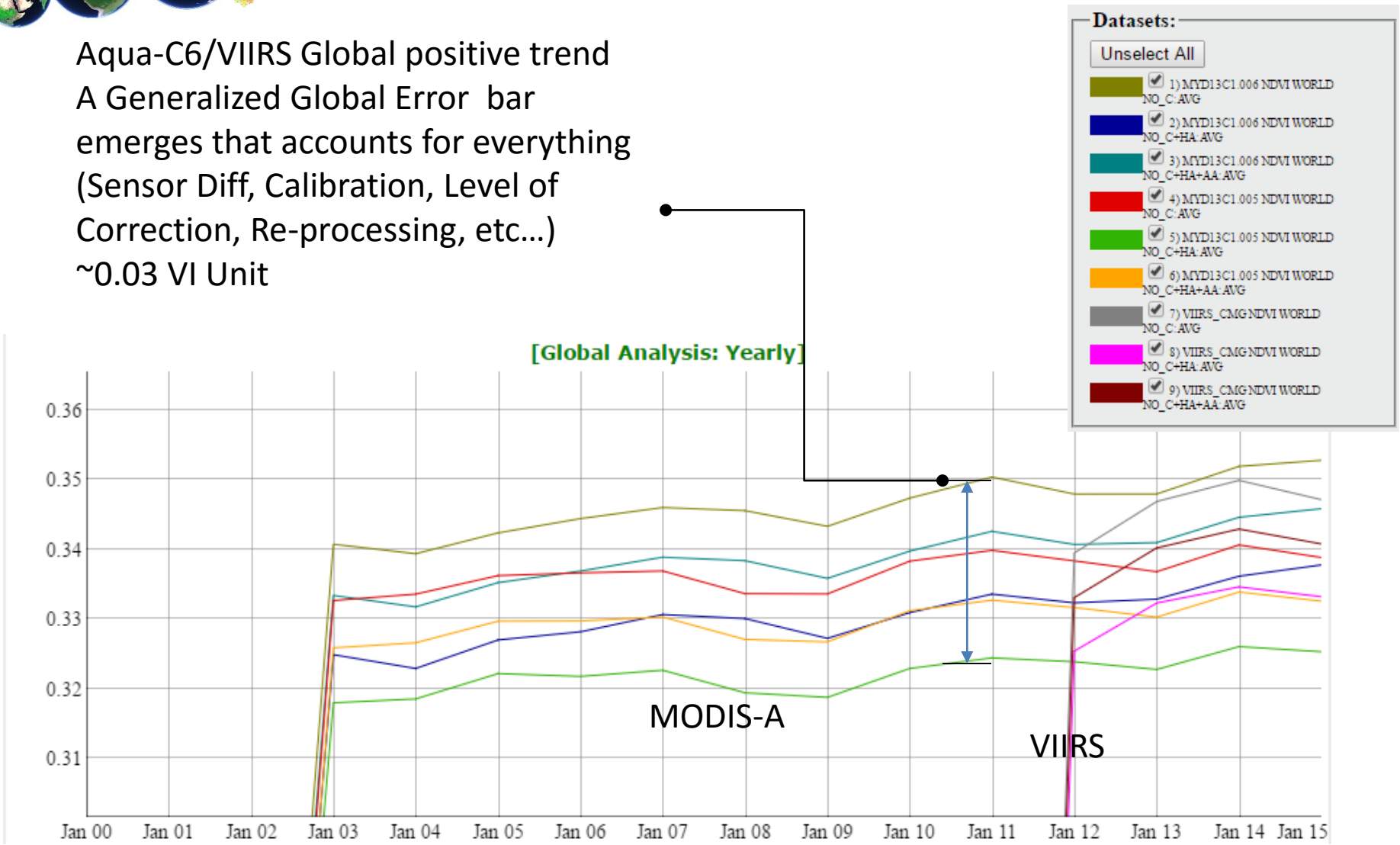




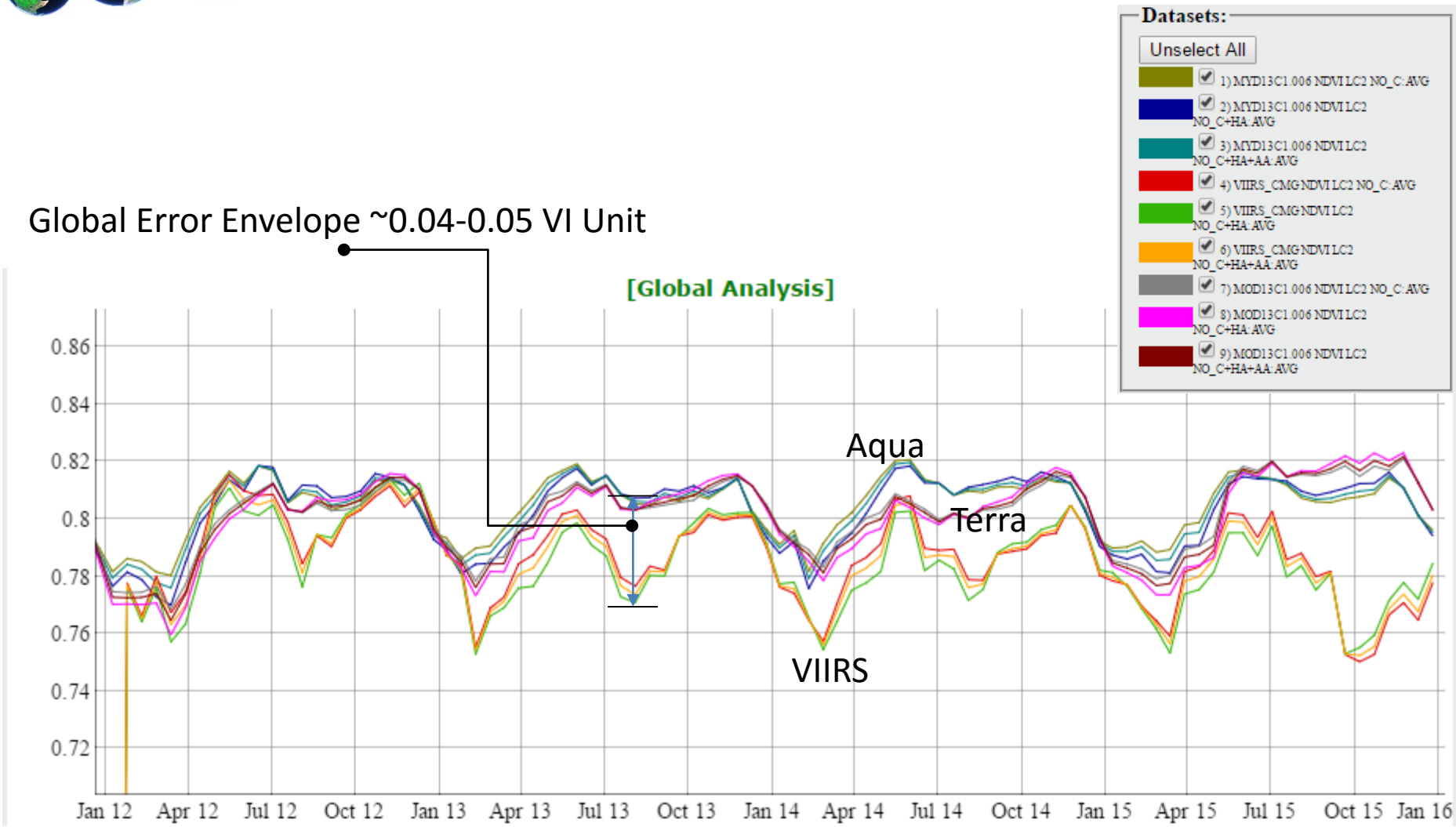
Consistent across all data filtering approaches.
Major differences between the two collections
Taiga:
C6 ~ C5 : no clear trend
Tropics
C6 : Greening
C5 : Browning

Aqua vs. VIIRS - Global Trends

Aqua-C6/VIIRS Global positive trend
A Generalized Global Error bar emerges that accounts for everything (Sensor Diff, Calibration, Level of Correction, Re-processing, etc…)
~0.03 VI Unit

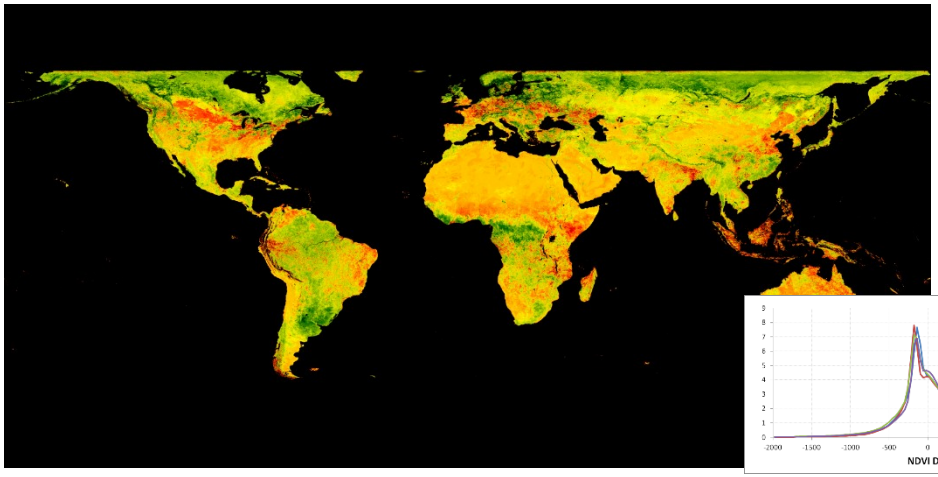


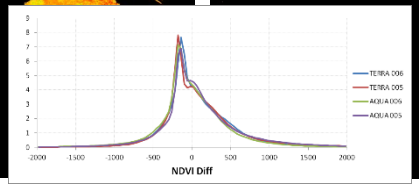
Terra-Aqua-VIIRS (Tropics)

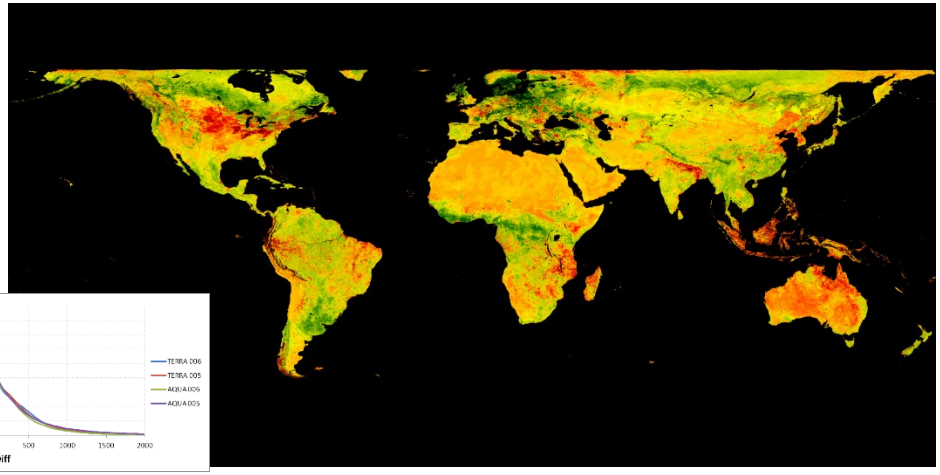


VIIRS - MODIS Differences

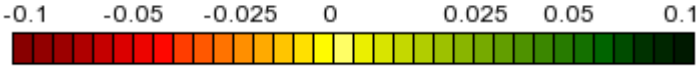
VIIRS –MODIS-T winter VIIRS –MODIS-A

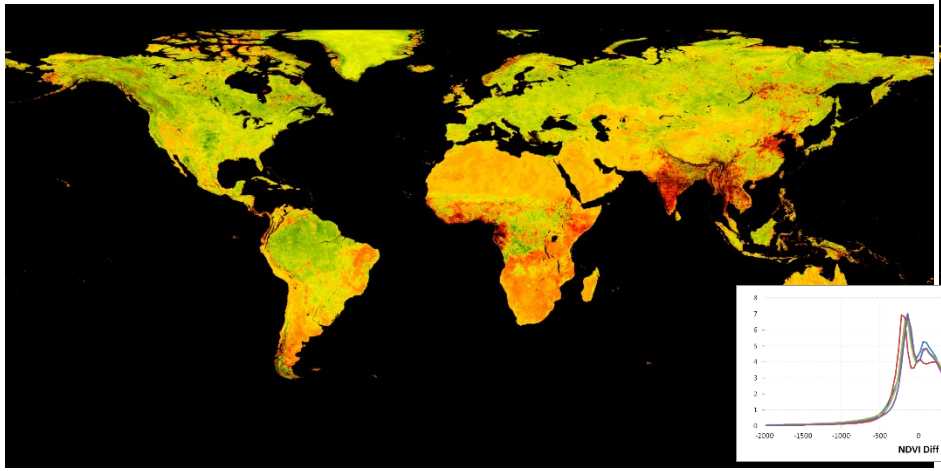


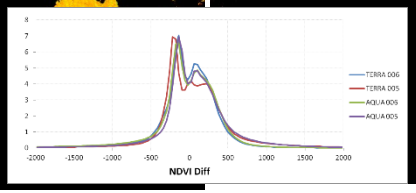


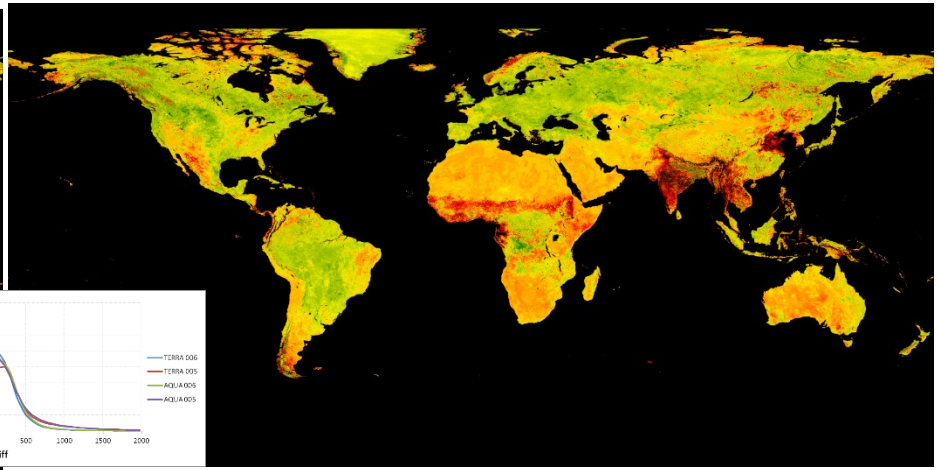


Summer

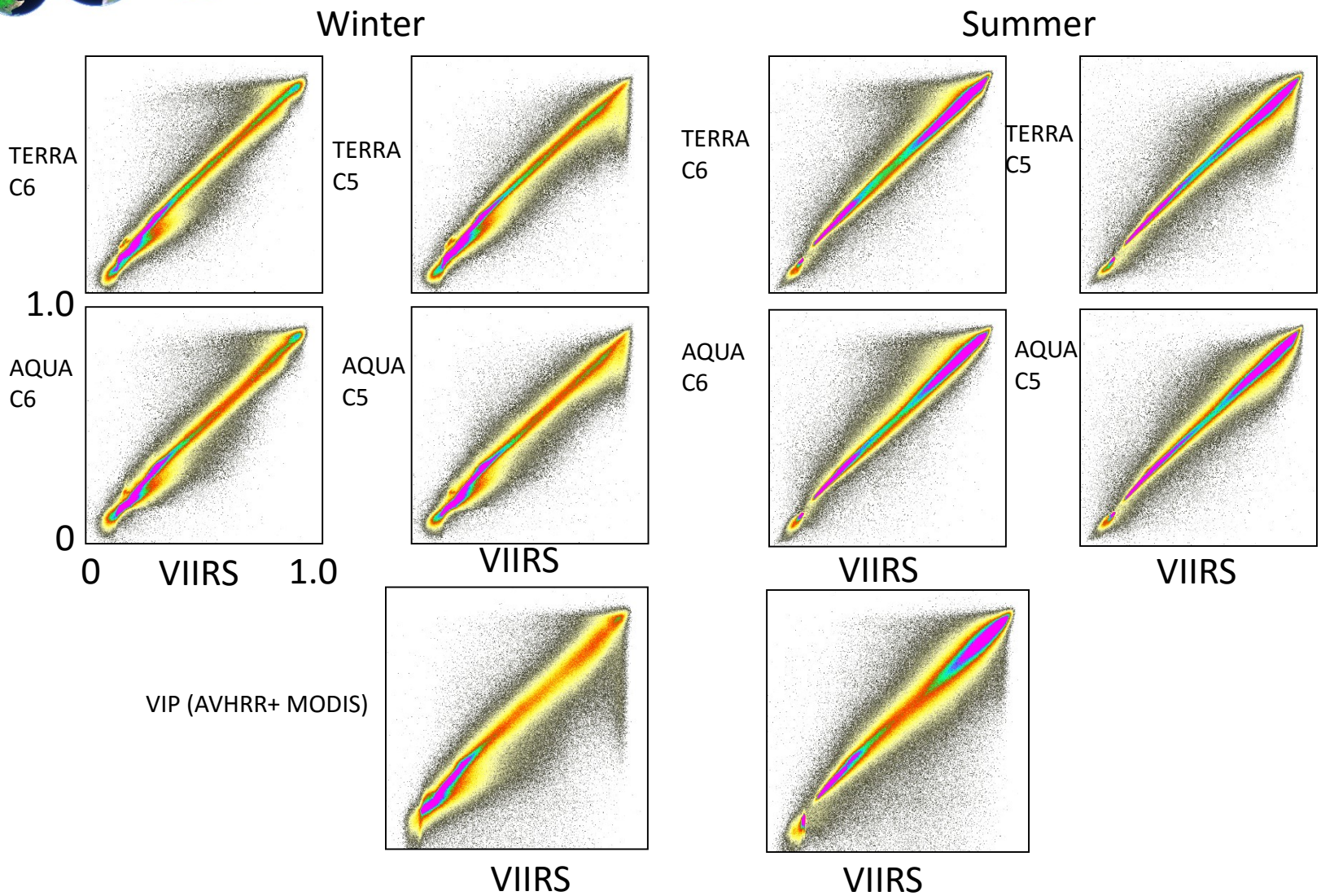




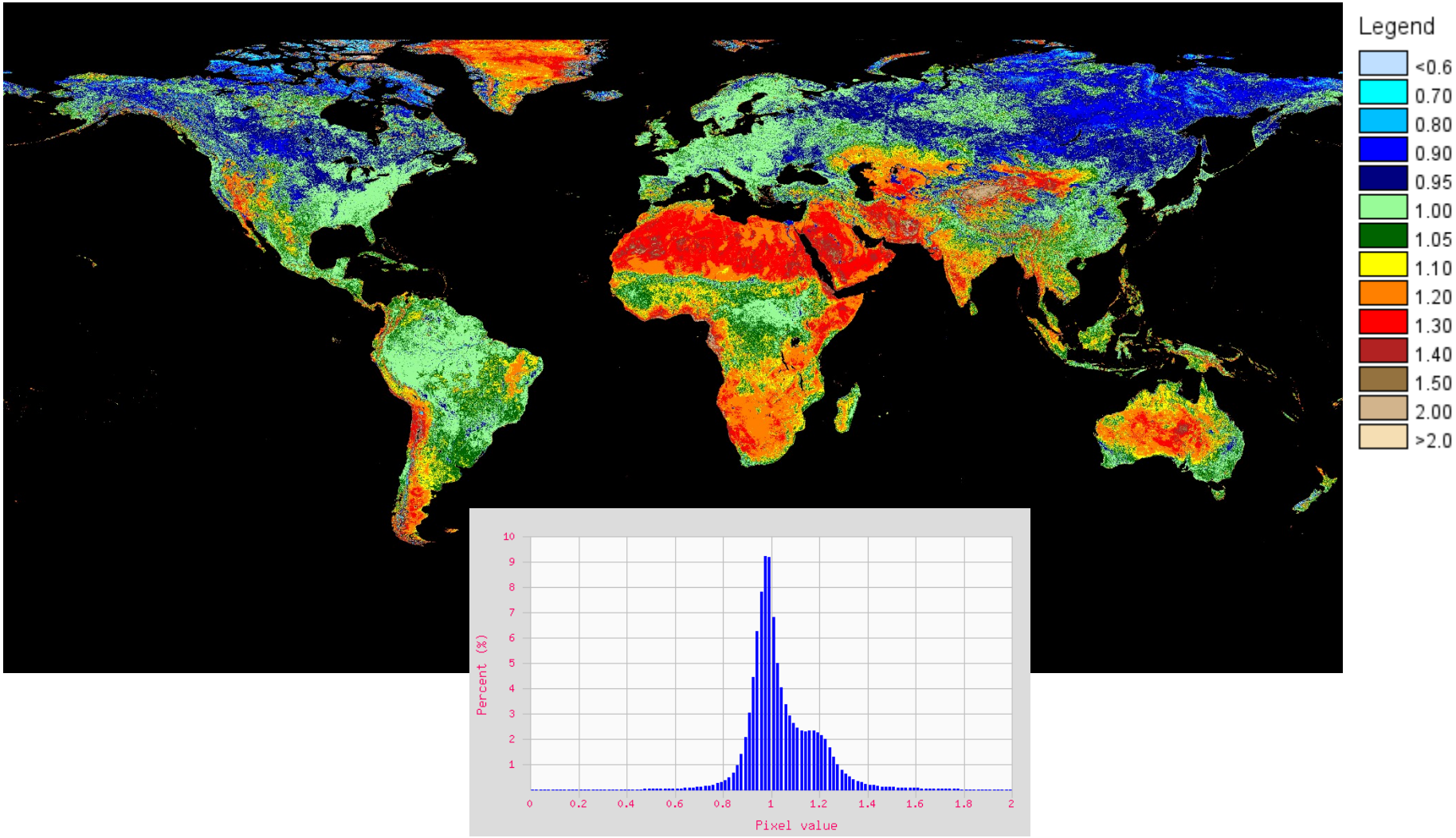




Across sensor continuity



VIIRS(Aqua) = Slope*VIIRS



Conclusions

- **Global climate signal:**
  - C4 to C5 to C6 changes (C7 ?)
  - Change with collection (Terra more pronounced than Aqua)
  - Large Differences Between C5 -C6 (same data and/or filtered the same way)
  - Indicates changes in Correction or Calibration, or?
  - Global Error Bar/Envelope in the (LSR) VI records ~ Around 5%
    - This error bar capture differences in Sensors, Calibration, Residual Clouds, Poor Aerosol correction, QA, BRDF?, Reprocessing, etc..
- **Continuity (LC Dependent, Atm. Quality dependent)**
  - T-A 1:1
  - C6 > C5
  - VIIRS – Aqua 0. 95-1.2 : 1
- **Challenges**
  - Atm .Correction & BRDF correction remain a challenge
  - Better Reprocessing with convergence in mind
  - VIIRS MAIAC could be an option (better correction & BRDF handling)

Divergent Responses of Vegetation Cover to Dry and Wet Years at Different Elevations

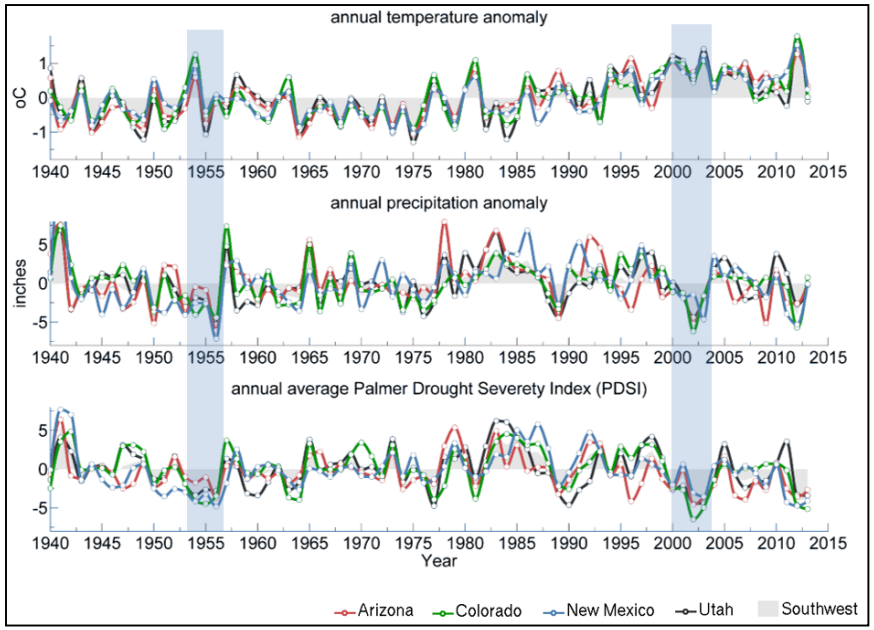
Kamel Didan[1], Stefanie Herrmann[1], Armando Barreto[1], Michael Crimmins[1]

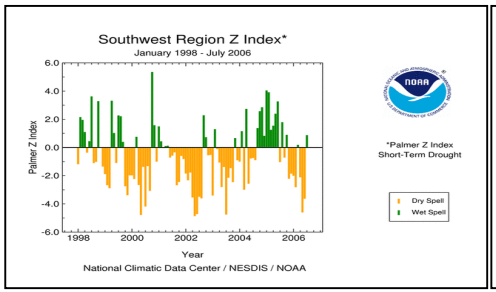
[1]University of Arizona

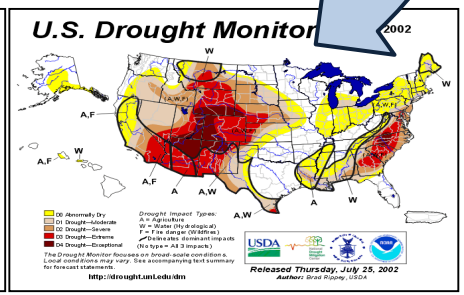
Droughts in the US Southwest

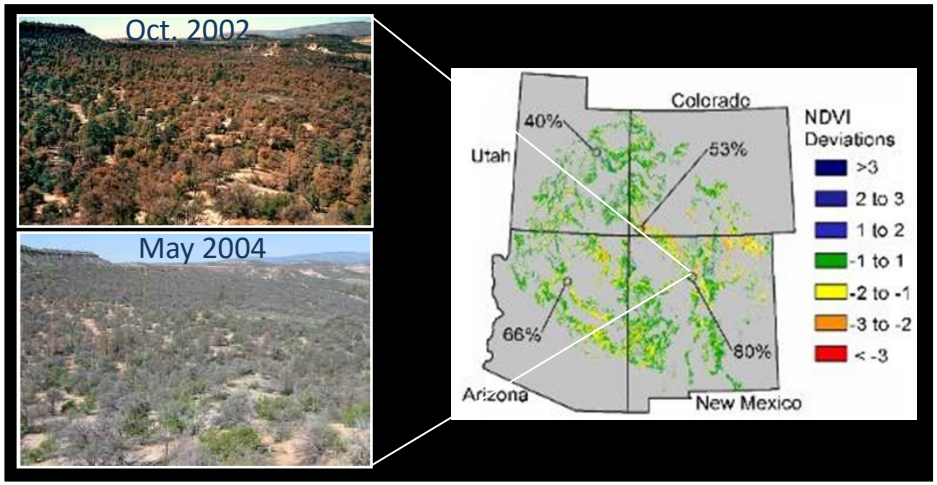
- Based on NOAA National Climate Data Center **2002** was
  - US Southwest's driest year since 1895 & 111rd hottest (out of 120 yr)
  - Leading to an exceptional '*mega*' drought and **"…Massive Pinyon Pine Die-off…"** [Breshears et al., PNAS, '05]

SW-Climate





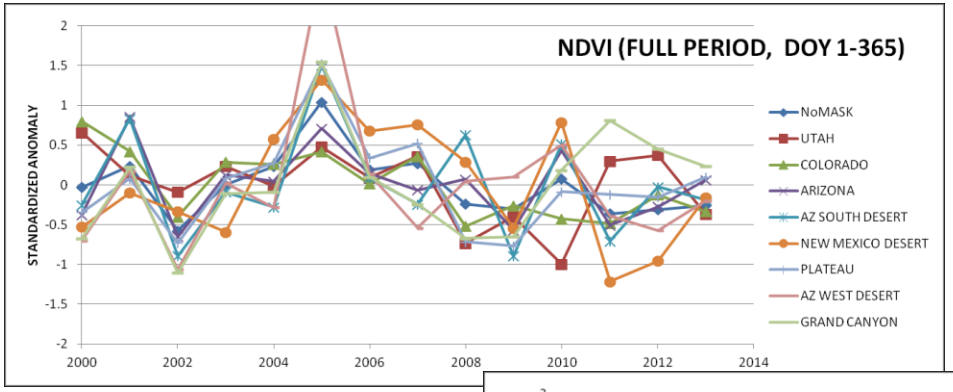




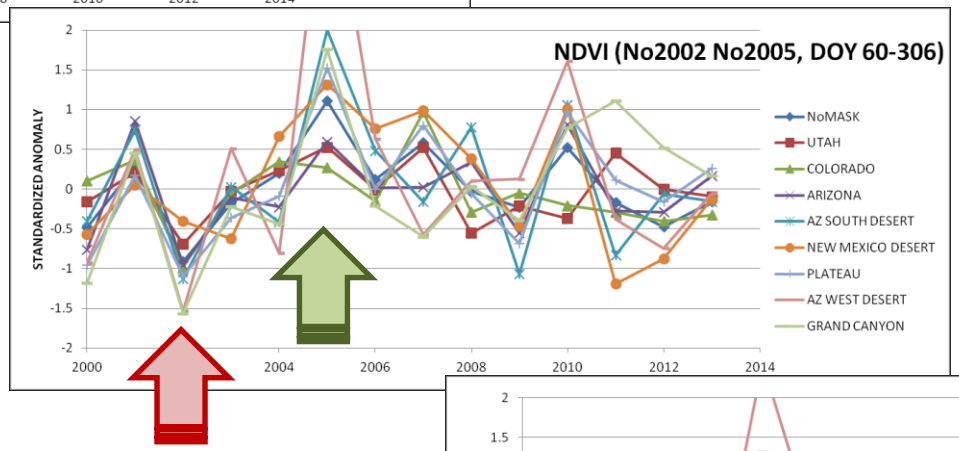
Questions

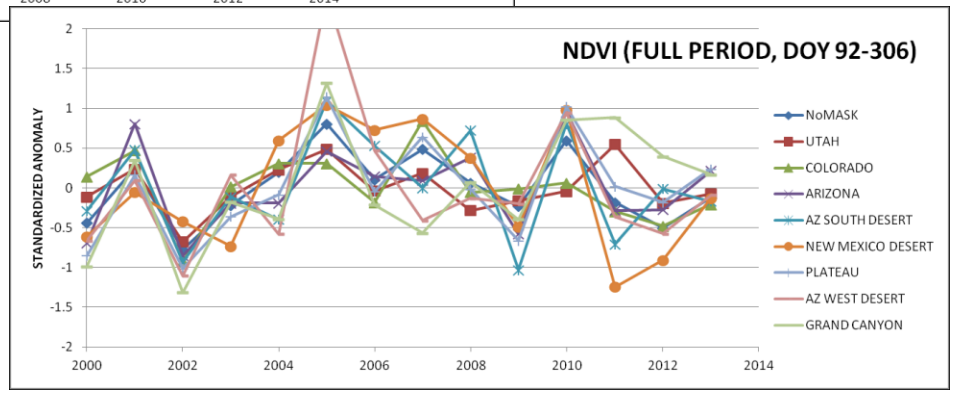
- How did the LC respond (considering wet episodes) to these protracted droughts?
  - **General Answer:**
    - Obvious Response is expected to be (die off) decline/ 'browning'
  - How about **Dry** [2002] vs. **Wet** [2005]?
    - **Answer** : Divergent Response moderated by elevation
  - What is the generalized view/response
    - **Answer**:
      - Positive dependency on precipitation at lower elevation
      - Less dependency and even opposite at higher elevation

General Responses to Dry vs. Wet Years



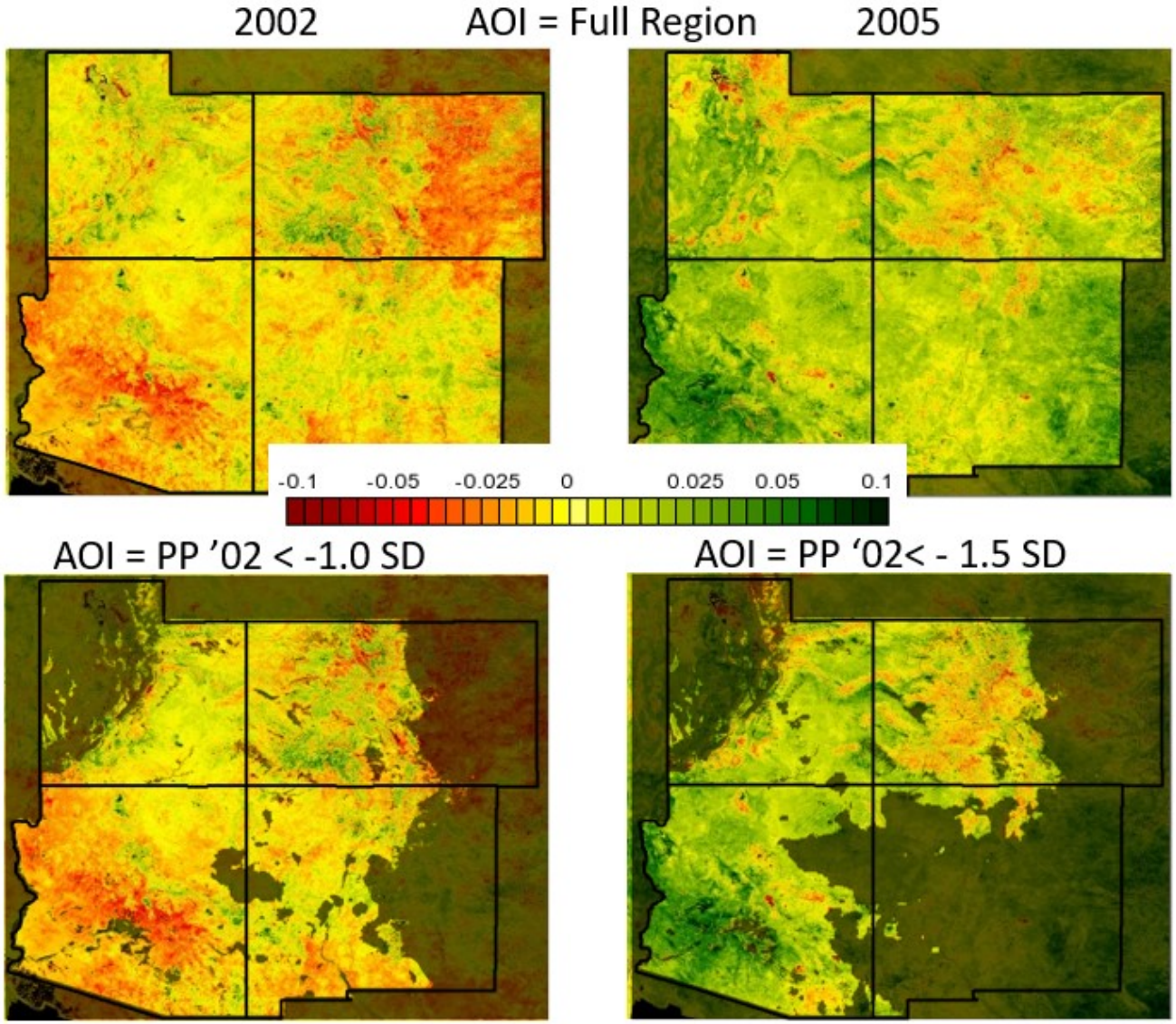
- Snow removed by a considering the growing season to be:
  - DOY 60-306 or 92-306
  - Filtering the rest





- General responses
  - Dry = Browning
  - Wet = Greening

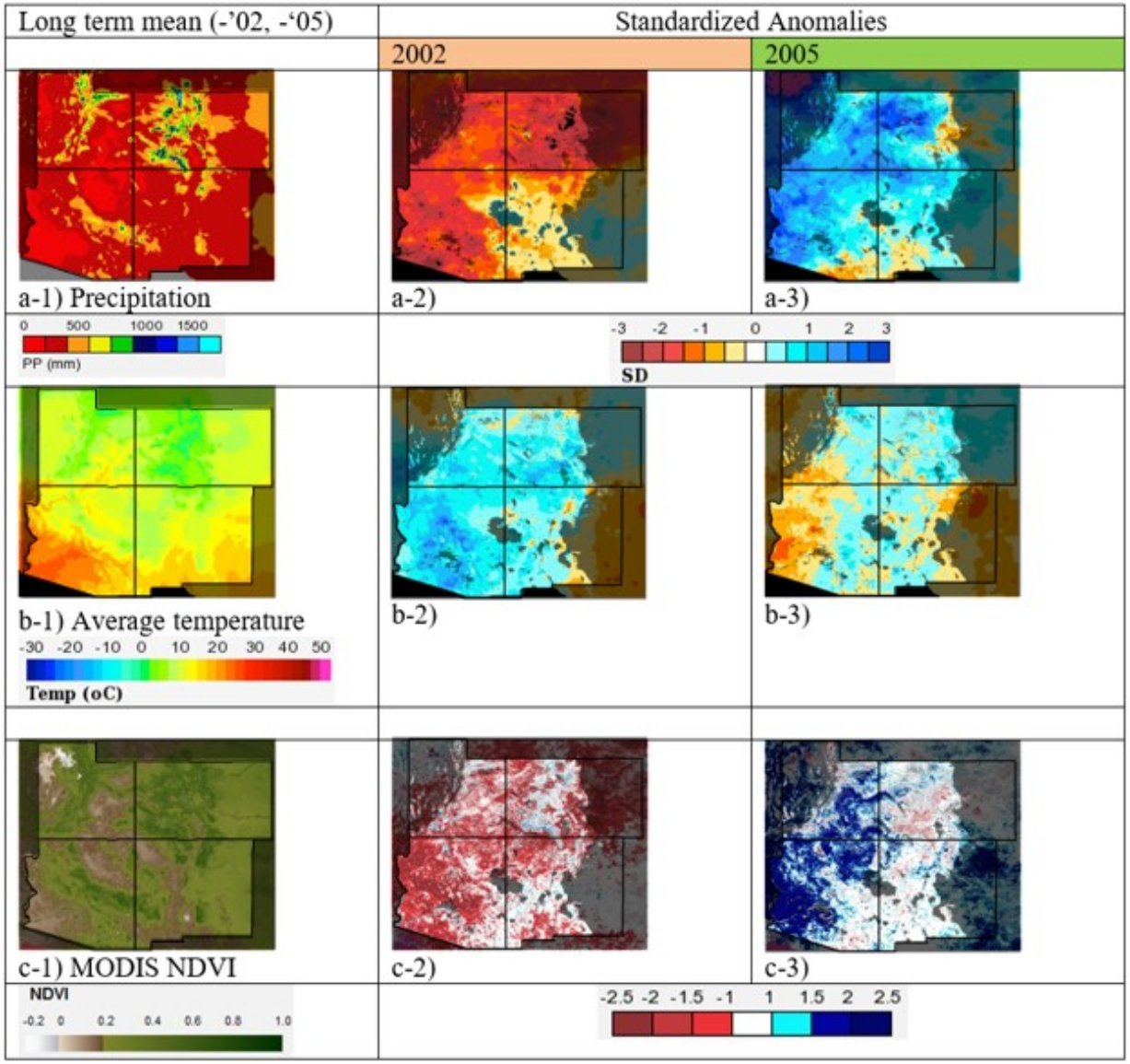
General Spatial Responses to Dry vs. Wet Years



A divergent response starts to emerge

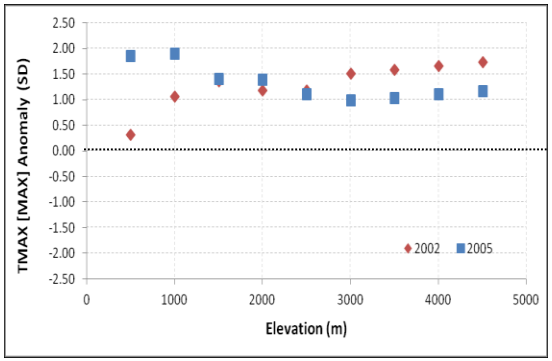
- 2002 mostly decline + pockets of greening
- 2005 mostly recovery + pockets of decline

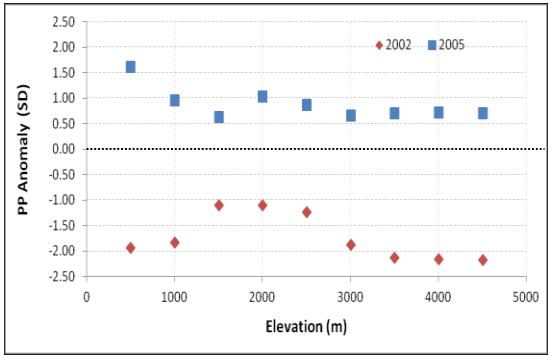
Standardized General Spatial Responses to Dry vs. Wet Years (Only areas with significant '02 PP change)

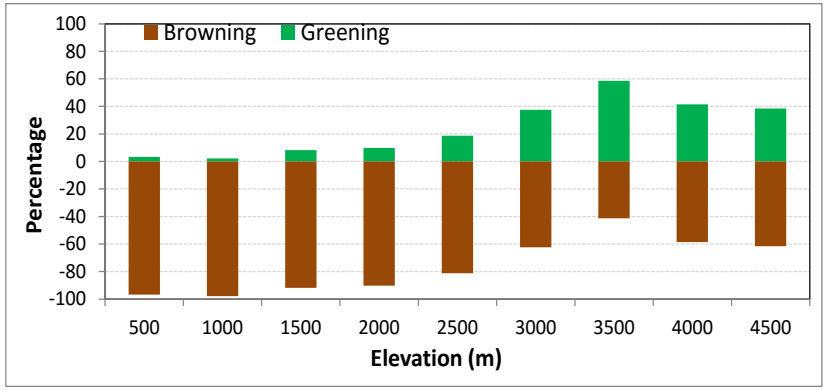


Same divergent response with a strong spatial correlation with P but opposite correlation at higher Elevation

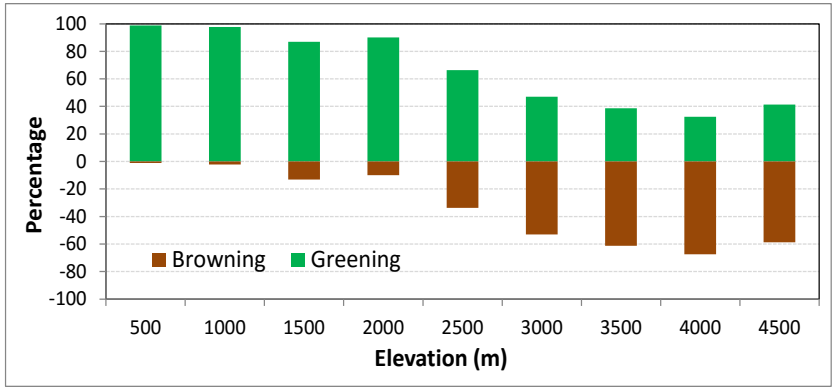
Responses vs. Elevation - Full region







2002



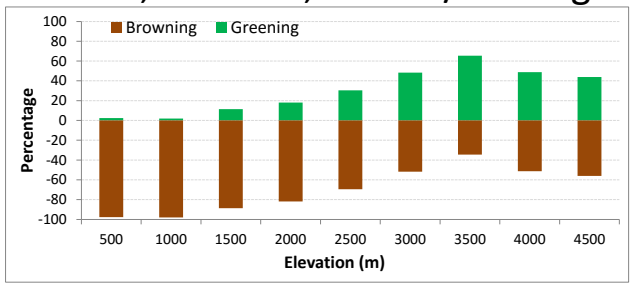
2005

- The same divergent response starts to emerge following an elevation gradient

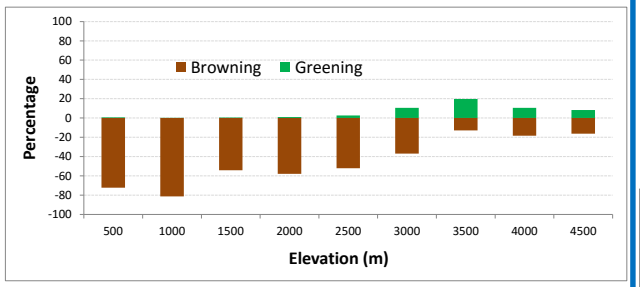
AOI based Sensitivity of Responses per Elevation

2002

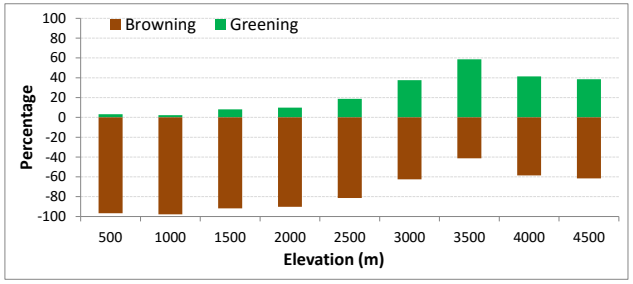
All data, All Years, NDVI +/- Change



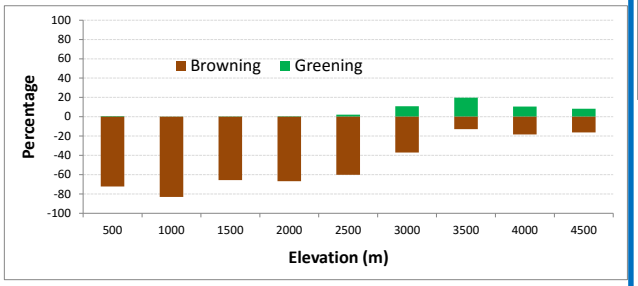
-’02 –’05, DOY = 60-306
PP < 0 & NDVI < -1sd or > 1sd



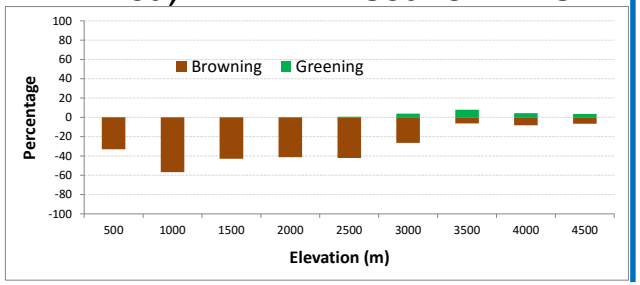
-’02, -’05, DOY= 60-306



PP < 1SD, NDVI < -1sd or > 1sd

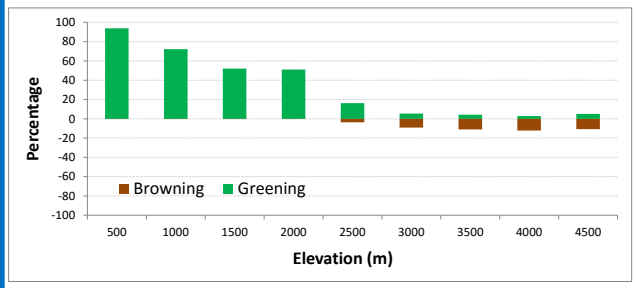


PP < -1sd, NDVI < -1.5sd or > 1.5



2005

-’02 –’05, DOY = 60-306
PP < -1sd, NDVI < -1.5sd or > 1.5



A General picture emerges

- **Clustering the change by 500m elevation classes for the precipitation and temperature anomalies shows a uniform response to the 2002 drought and 2005 wet year. By contrast, the NDVI responses show a divergent pattern between lower (<2,500m) and higher (>2,500m) elevations.**
- ***The Spearman rank correlation coefficient between annual average MODIS NDVI and annual total PRISM precipitation (2000-2014) shows a positive correlation with precipitation at lower elevation (< 2500m) and negative correlation at > 2500m.***

Conclusions

- **General Response**
  - Widespread decline/'browning' – die off
- How about **Dry** [2002] vs. **Wet** [2005]
  - Divergent Response moderated by elevation
- What is the generalized Response
  - Dependency on precipitation at lower elevation
  - Less dependency and even opposite at higher elevation
- While there are droughts precipitation remains favorable at higher elevation
- Temperature may have created favorable conditions
  - Reduction is snow cover means more opportunity for growth