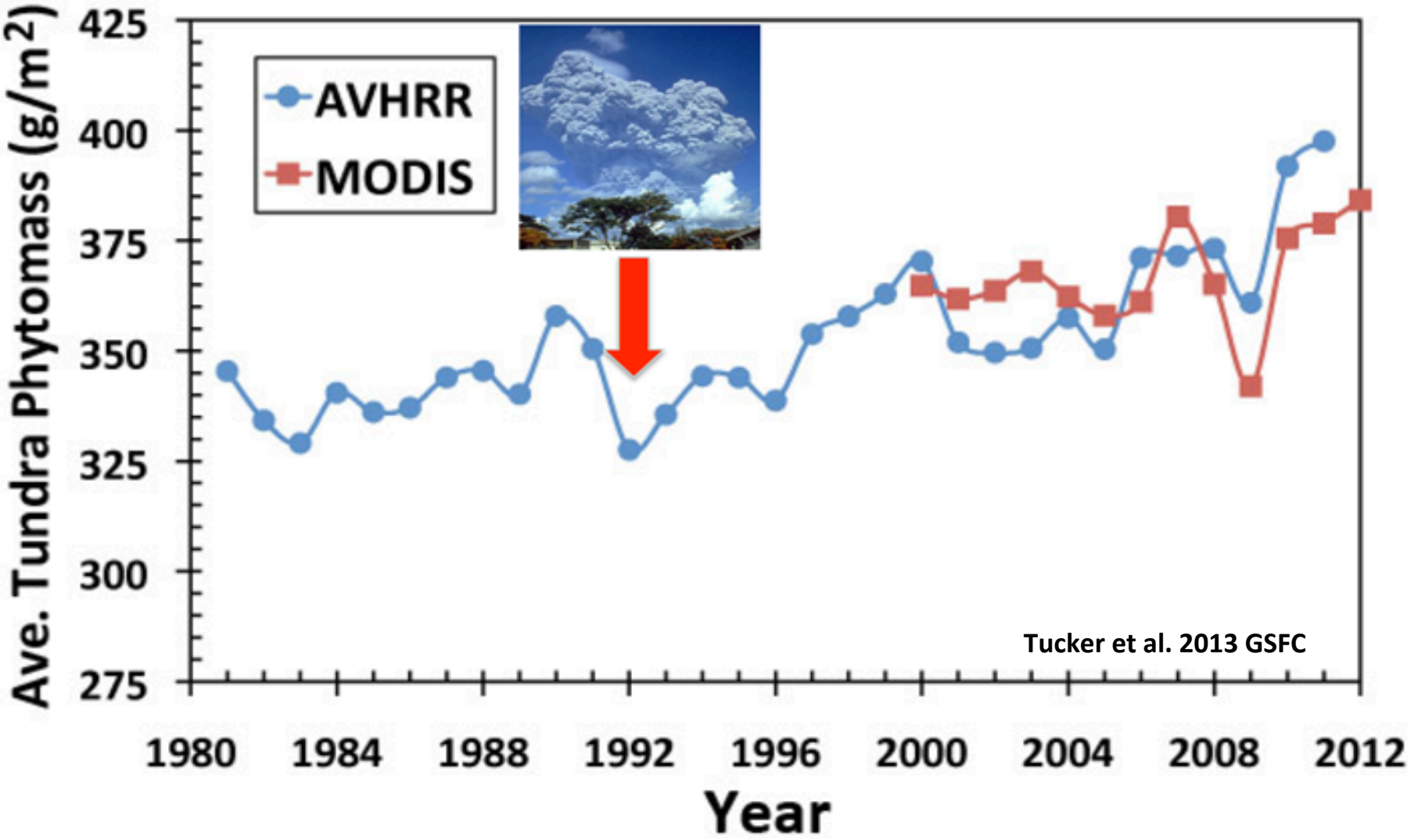
Satellite Climate Observations and 'Research to Operations'--has it worked?

Compton Tucker NASA/GSFC

- **Climate research requires continuous, well-characterized/well-calibrated satellite, & backward compatible observations over multi-decadal time periods.**
- **Algorithm consistency is as important as instrument consistency.**

How many years are enough to detect trends in climate data?



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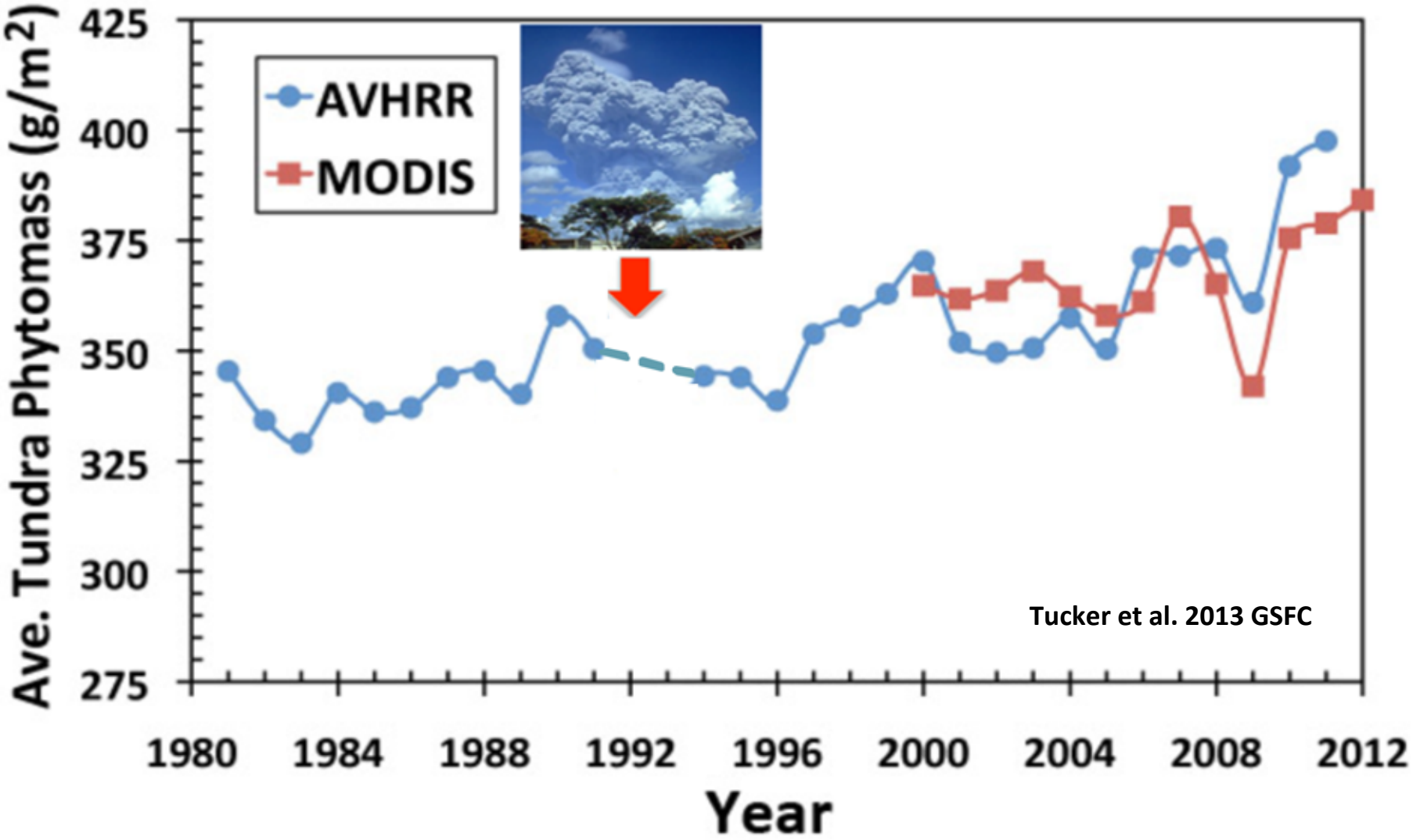
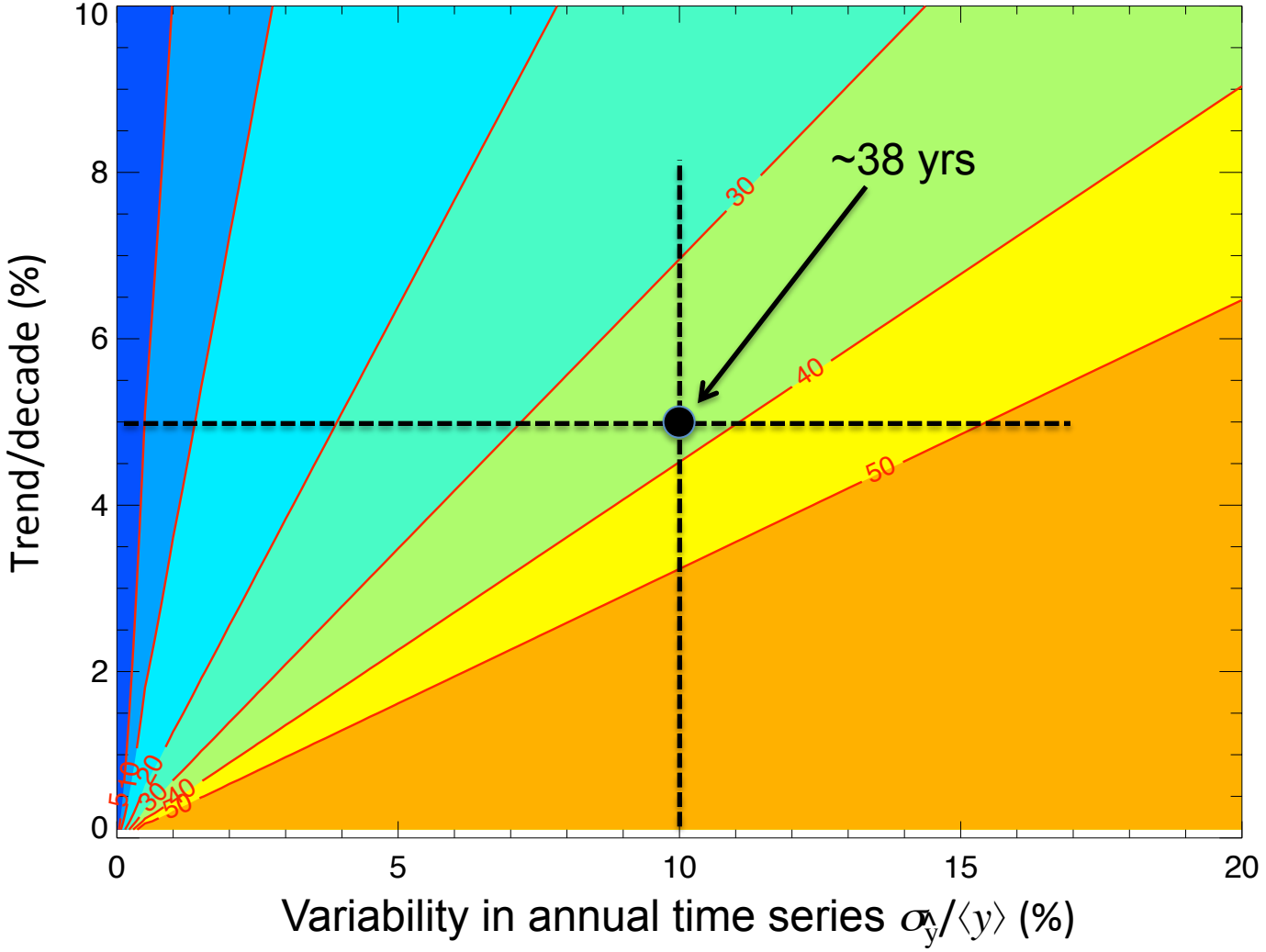


Number of Years Required to Detect a Trend

(90% prob. of detecting a trend to a 0.05 statistical level, no autocorrelation)



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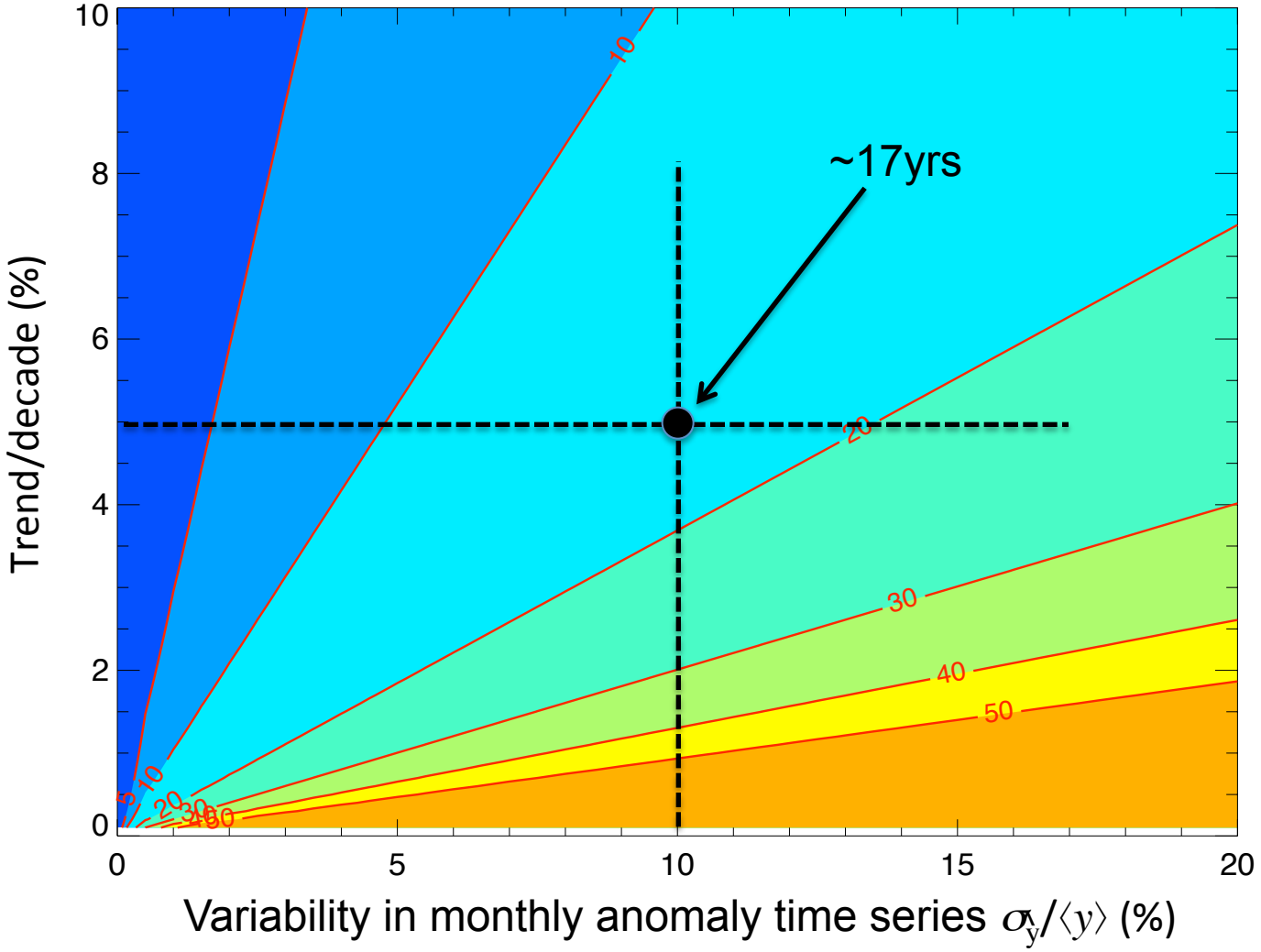
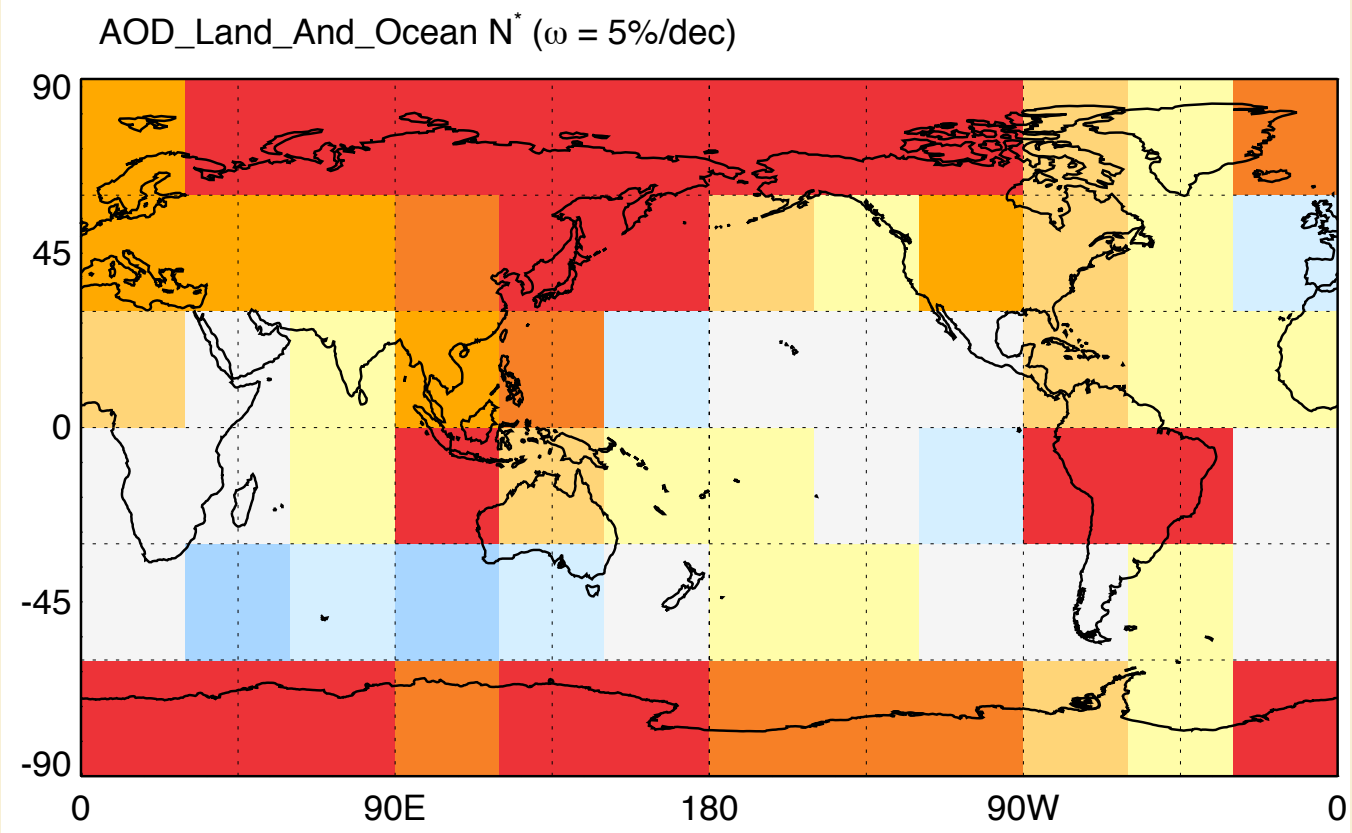


Time Required for Detection of 5%/decade Trend

(90% prob. of detecting a 0.05 statistical level,
based on yr-to-yr variability from July 2000 – June 2010, various binning)



What are the key climate observations?

- **Total & Spectral Solar Irradiance – SORCE/TIM etc...**
- **Sea Level – Jason2 etc...**
- **Ice sheets – GRACE, IceSat2, & SAR...**
- **Clouds – MODIS, MISR, AIRS, CloudSat, CALIPSO**
- **Aerosols – MODIS, GLORY, MISR**
- **Carbon Cycle – MODIS, VIIRS (land, ocean), Landsat (forests), OCO & laser sounders (CO_2), etc.**
- **Freeze-thaw/permafrost – SAR & passive microwave**

- **Atmospheric Sounding – AIRS/AMSU etc.**

Let's compare MODIS & VIIRS

- **VIIRS is inferior to MODIS for cloud studies (missing key CO2 bands) & possibly/possibly not in other regards (NPP Science Teams Assessment Reports will be out shortly on this)**
- **VIIRS isn't backward compatible with MODIS**
- **MODIS has proven to be an excellent instrument & the two operating are still going (13 years... & 11 years...)**
- **VIIRS has cost 800 M$ for two instruments, while MODIS copies, circa 1998-1999 would have cost 100 M$ each -- pay more, waste time, & get less = stupidity**
- **No guarantee that JPSS-2 will fly a VIIRS instrument; Unbelievably the AVHRR has been proposed for JPSS-2 instead of VIIRS to save $$$$**
- **We've lost our morning imager in the JPSS-era. We only have MetOps' AVHRR instruments… (3 AVHRR instruments were given to MetOps)**

Why might USGS & NOAA have problems with research to operations handoffs?

- **NASA's Earth & Space science missions result in an abundance of engineering and project management talent—it takes both Earth & Space missions to have a critical mass of experienced talent**

- **NPOESS/Joint Polar-orbiting Satellite System is a good example what happens when experienced civilian agency space engineers & project managers aren't in charge**

What about the Decadal Survey?

- **Decadal Survey climate observations – SMAP, IceSat-2, GRACE-2 etc.**
- **The Earth Science Decadal Survey also has promising research missions that can & will be linked with integrated climate observations.**
- **The Earth Science Decadal Survey was based upon the assumption that EOS climate measurements were assured & they are not.**

Algorithm consistency is as important as instrument consistency

David Wark, Bill Smith Phil Rosenkranz Larrabee Strow Catherine Gautier Larry McMillin Alain Chedin

Hank Revercomb Roberto Calheiros Joel Susskind Moustafa Chahine Mitch Goldberg George Aumann

AIRS Science Team

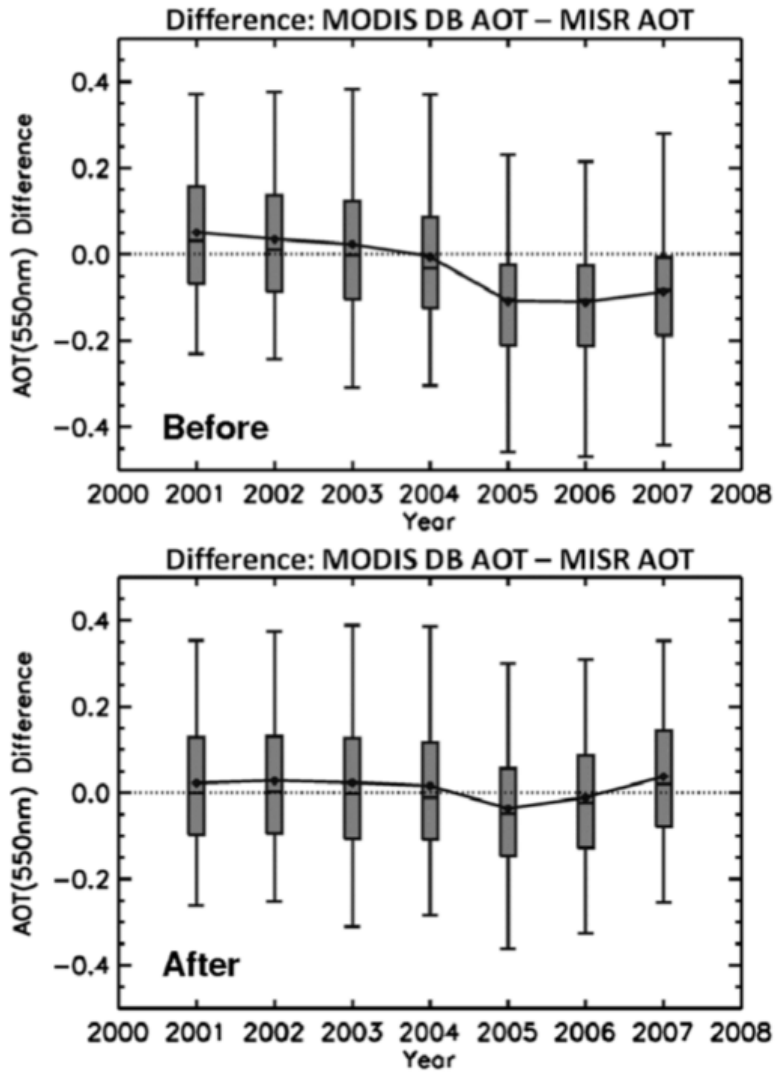
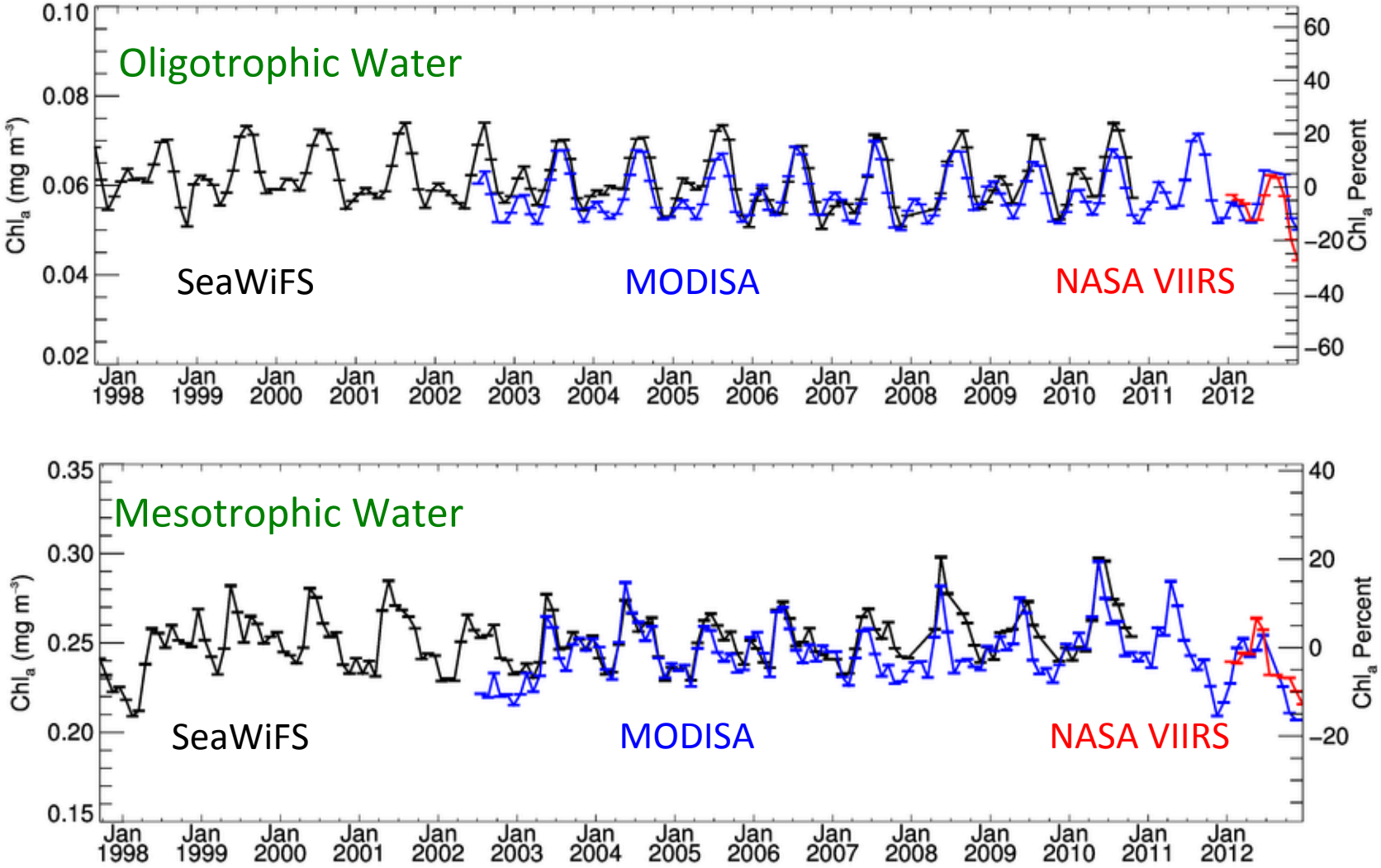


Fig. A1. The impact of improved MODIS radiometric calibrations on MODIS Deep Blue (DB) aerosol trend estimates against those from MISR. This figure shows that there were strong temporal trends occurred in AOT differences (MODIS DB AOT – MISR AOT) between Terra/MODIS and MISR over North Africa using the previous MODIS calibration (top panel), which disappear in the new time series after applying the re-calibrated reflectances (bottom panel).

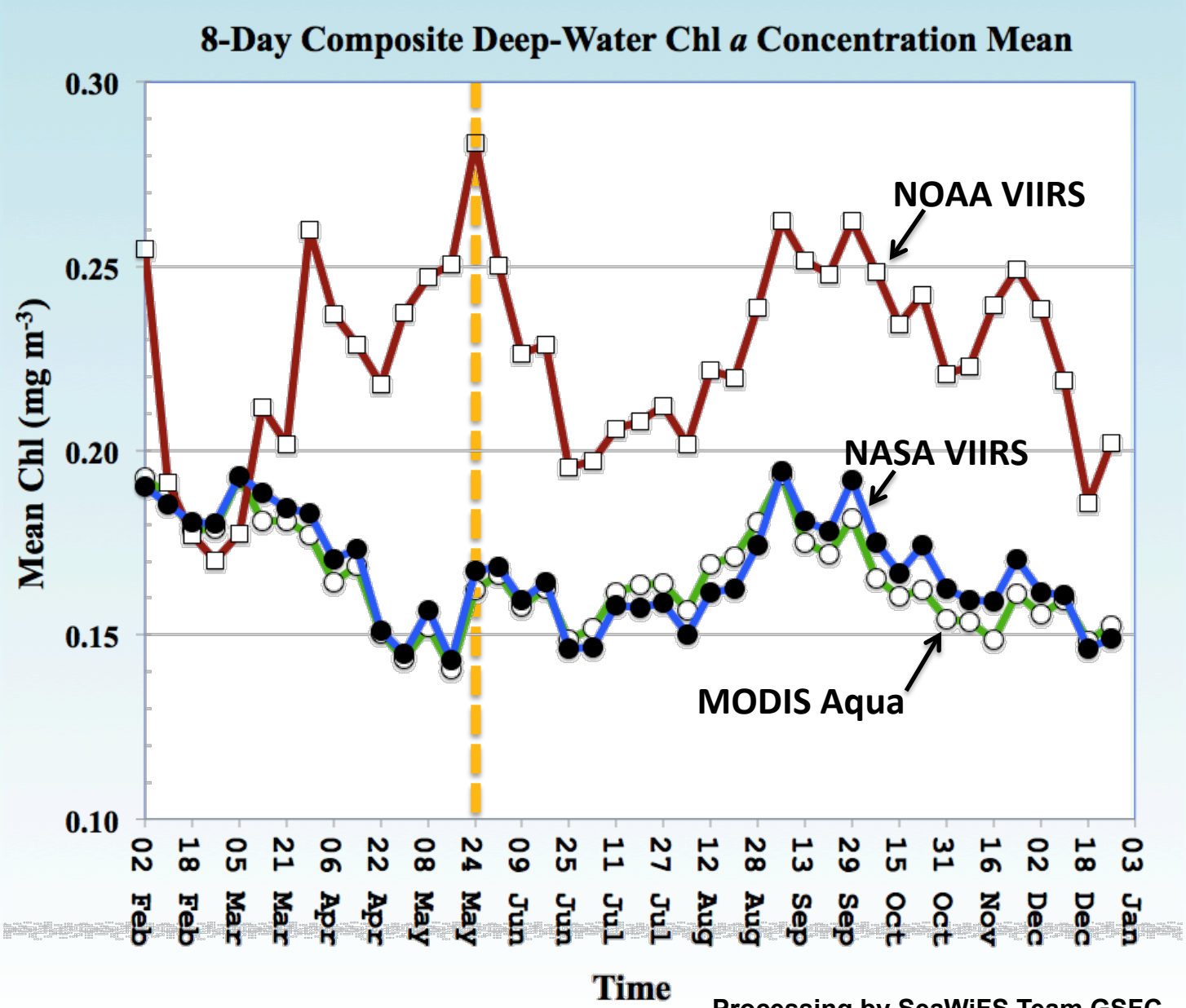
The MODIS record has been reprocessed five times…

Consistent Long-Term Time Series



Processing by SeaWiFS Team GSFC

Consistent Approach vs Operational Approach



Core climate measurement continuity is paramount

- **Climate research requires multi-decadal periods of continuous observations, thus "climate research to operations" occurs >30-40 years of observations**

- **Build multiple copies of instruments instead of one or two. Eli Whitney invented inter-changeable parts in the early 19th century.**

- **Algorithm consistency & reprocessing critical.**

- **Lower launch costs—Boy we miss the Delta-II but thank Whomever we have four left!**

- **Essential weather missions should be Class C missions and all other climate missions should be Class D. This would lower the costs of Class D missions by 50%.**

Evaluating Temporal Trends: Overview

Hypothesis: $y = \beta_0 + \beta_1 x$, e.g., y = cloud fraction, x = time (month, season, yr

Linear Fit: $\hat{y} = b_0 + b_1 x$

Measures of significance: F-test, T-test on b_1, Var(b_1), R^2. All four are related for an OLS of this form.

Ignoring temporal autocorrelation:

natural variability (+ retrieval + instrument uncertainty)

$$\mathrm{Var}(b_1) = \frac{\sum (y_i - \hat{y}_i)^2}{n-2} \frac{1}{\sum (x_i - \langle x_i \rangle)^2}$$

degrees of freedom (n =number of pts)

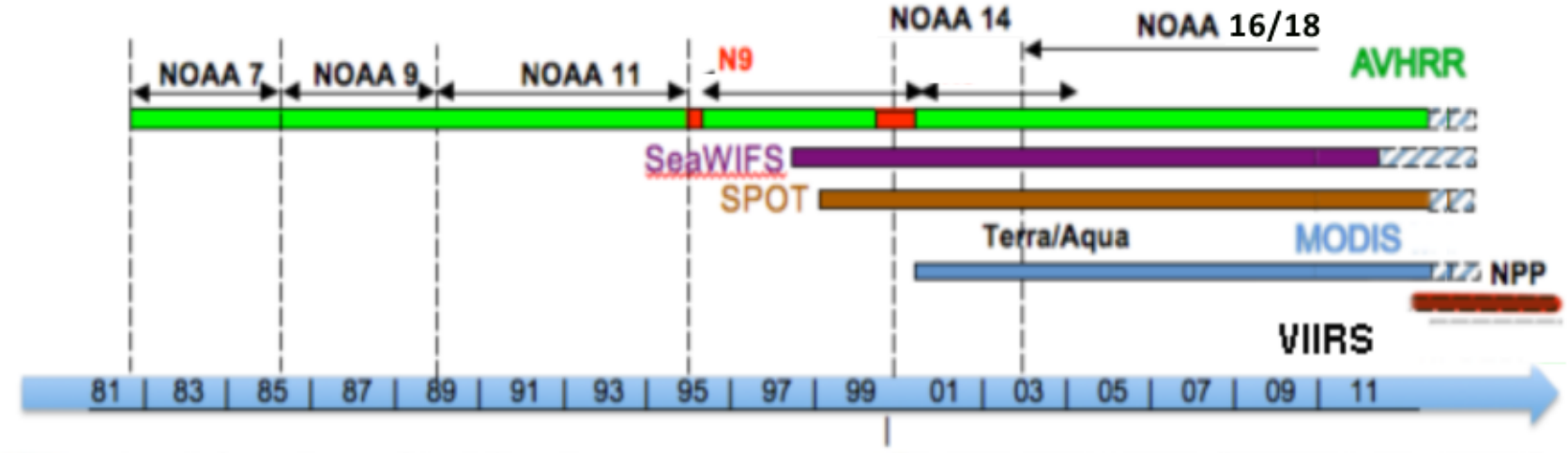
Time record required for 90% probability in detecting a trend at the 0.05 statistical significance level (Tiao et al., 1990; Weatherhead et al., 1998):

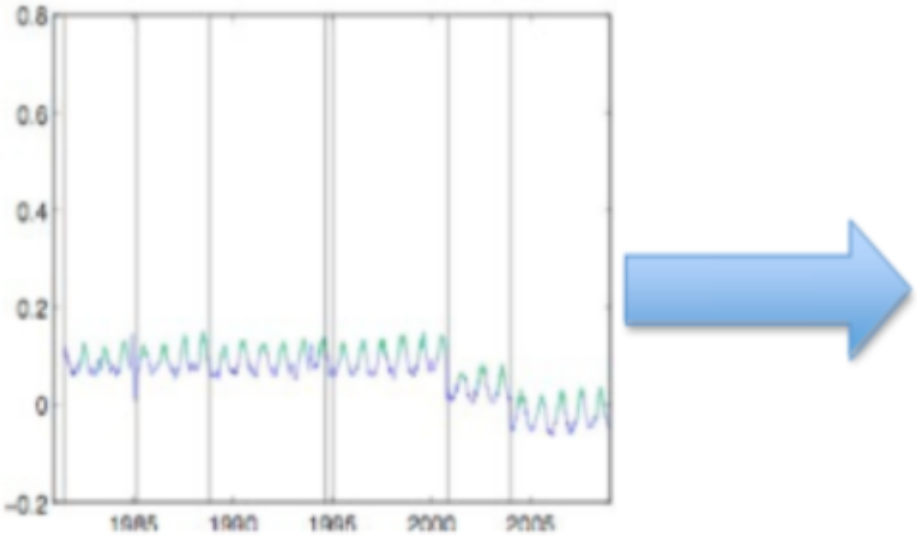
larger variability (uncertainty) => larger n^*

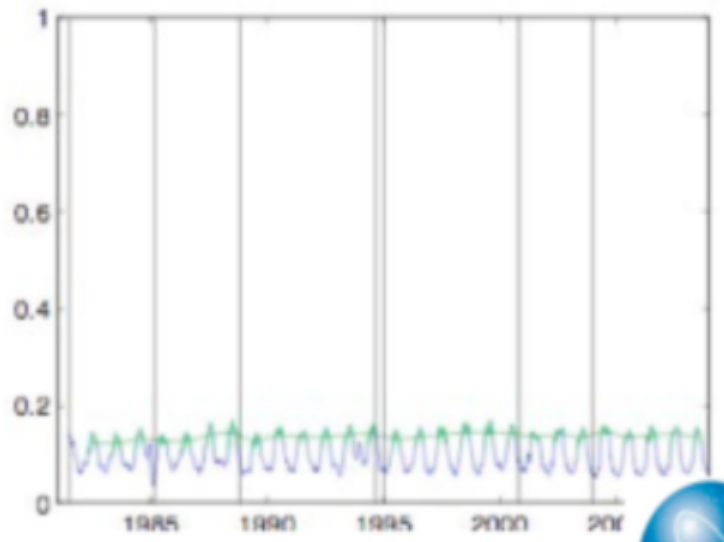
$$n^*(\mathrm{yrs}) \approx \left[\frac{3.3 \; \frac{100\sigma_{\hat{y}}}{\langle y \rangle}}{\mathrm{trend\ (\%/yr)}} \right]^{2/3}$$

larger the trend => smaller n^*

Goal: Produce Accurate Non-stationary NDVI Record from July 1981 →Dec. 2012 ...

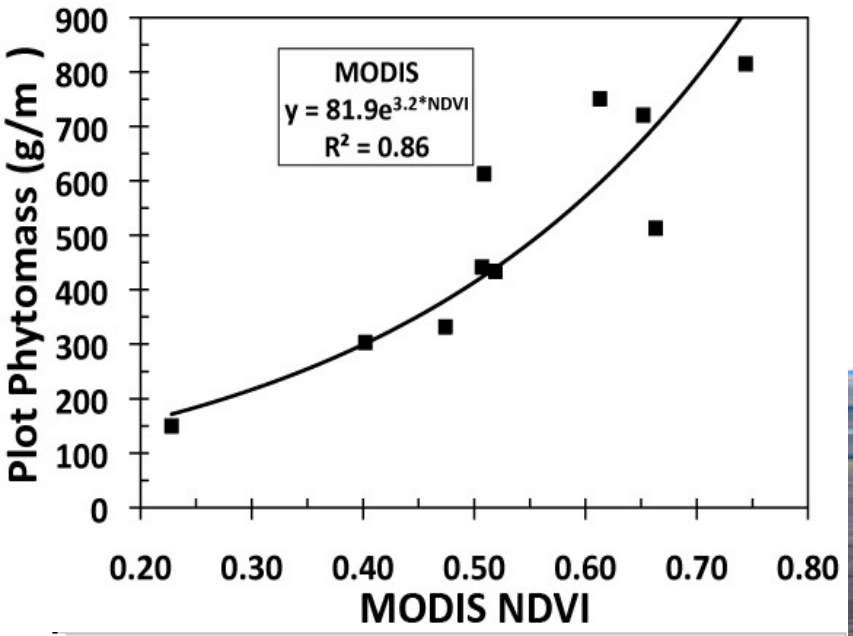


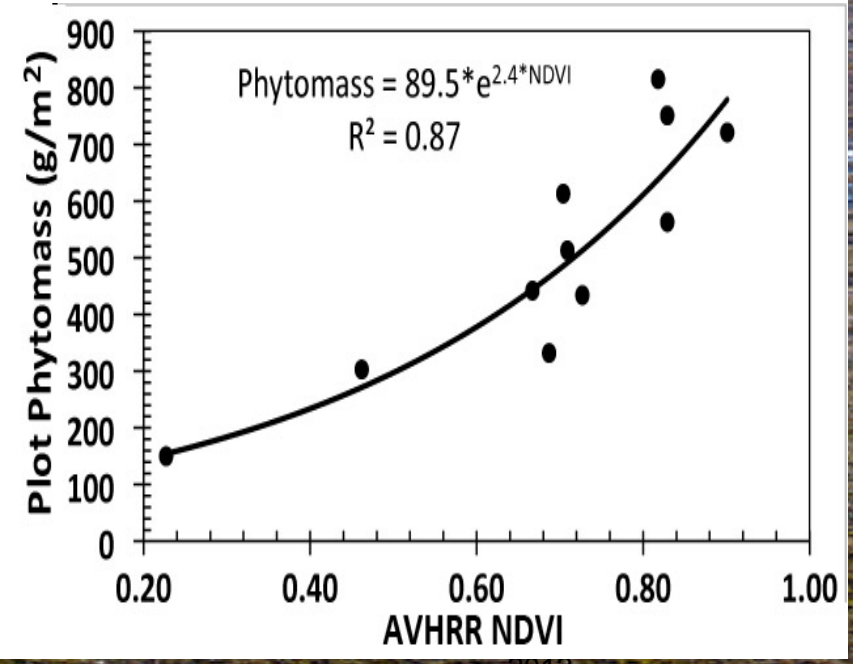




Arctic Tundra Biomass Work: How?

Arctic Tundra Biomass





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