Optimizing Climate Observations for Targeted Results

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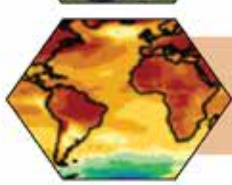
World Climate Research Programme's Grand Challenges

1. Clouds, circulation, climate sensitivity
2. Melting ice and global consequences
3. Carbon feedbacks in the climate system
4. Weather and climate extremes
5. Water for the foodbaskets of the world
6. Regional sea level change and coastal impacts
7. Near term climate prediction

Climate Change Questions

- Trends
  - Many parameters have changed and are expected to change.
  - Trends are fundamental to observing systems for climate.
  - Attribution of change is fundamentally important.
- Processes
  - Specific processes are key to understanding.
  - Interconnections, Drivers/Response
  - Attribution and scenario development are important
- Projections
  - Understanding which parameters are going to make the biggest influence on future climate.

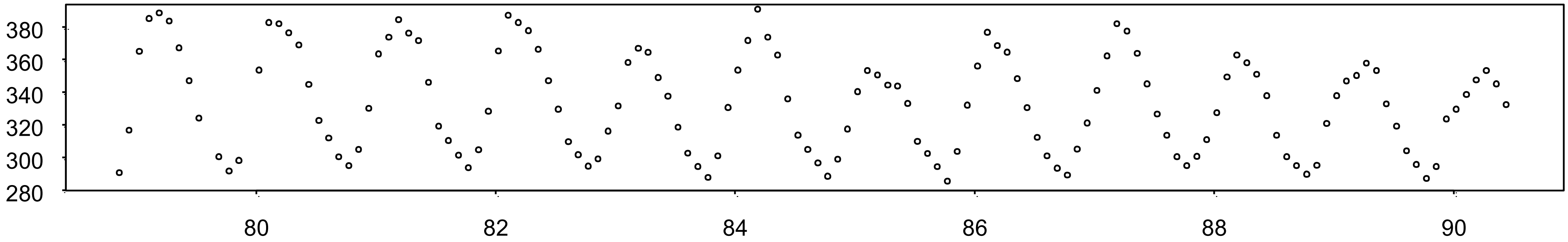
Future Climate Observing System Design

WCRP Grand Challenges	Monitor Earth	Understand Processes	Improve Predictions
 Clouds, Circulation, and Climate Sensitivity	Changes in jet stream, expansion of tropics, aerosols, . . .	Impact of stratus clouds, water vapor into stratosphere, . . .	Survey of cloud properties, . . .
 Melting Ice and Global Consequences	Ice volume, ocean salinity and temperatures, . . .	Sub-ice ocean temperatures, ocean salinity, . . .	Polynya lifecycle, . . .
 Understanding and Predicting Weather Extremes	Droughts, floods, hurricane tracks, . . .	Rapid river run-off, ocean's role in droughts, . . .	Convective initiation, sub-ice ocean temperatures, . . .
 Regional Sea Level Change and Coastal Impacts	Coastal monitoring, winds, local currents, . . .	Tidal impacts, erosion protection efforts, . . .	Inland glaciers, fragile coasts. . .
 Water for the Food Baskets of the World	Soil moisture, inland El Niño impacts, . . .	El Niño impacts to heavy precipitation, ocean's role in droughts, . . .	Seasonal drought forecasts, storm forecasts, . . .
 Carbon Feedbacks in the Climate System	Global methane monitoring, ocean uptake, . . .	Wetland emissions of carbon, . . .	Identification of vulnerable coasts, deep ocean convection & currents, . . .
 Near-term Climate Prediction	Sub-surface ocean temperature, upper air winds, . . .	Ocean heat content anomalies, seasonal precipitation, . . .	Seasonal precipitation forecasts, river monitoring, . . .

Trends

SBUV OZONE TOTAL COLUMN OZONE - 40N

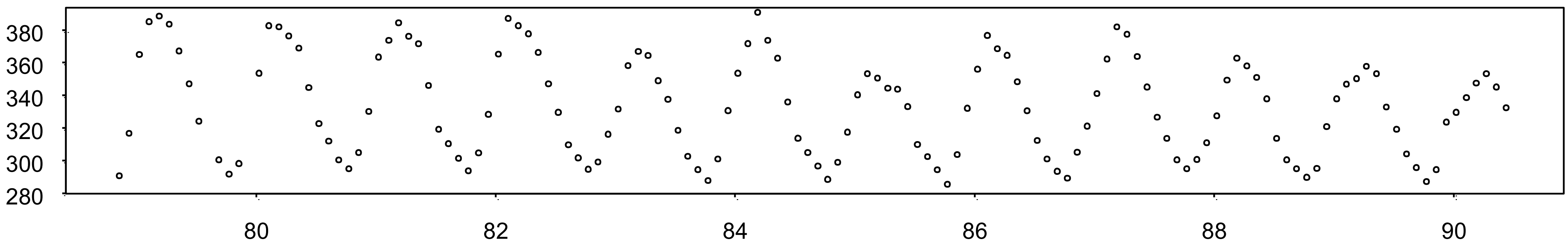
Original Monthly Averaged Data



Weatherhead Fri Nov 2 11:38:10 2001

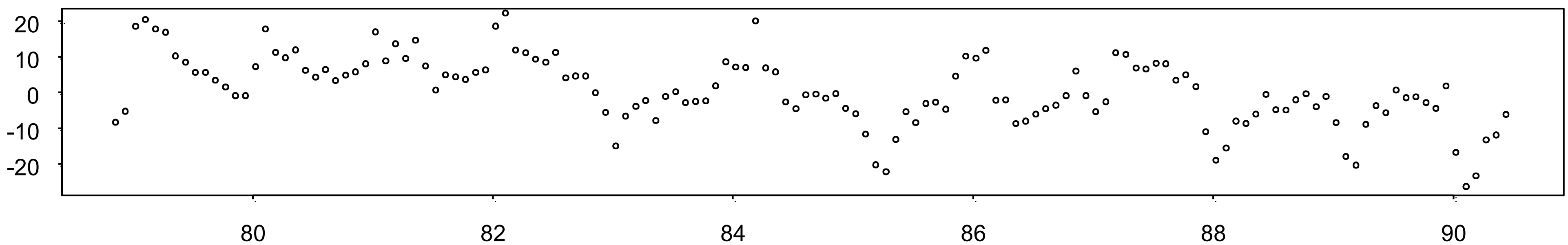
SBUV OZONE TOTAL COLUMN OZONE - 40N

Original Monthly Averaged Data



Weatherhead Fri Nov 2 11:48:50 2001

Monthly Means Removed, Lowess Line Fit Superimposed



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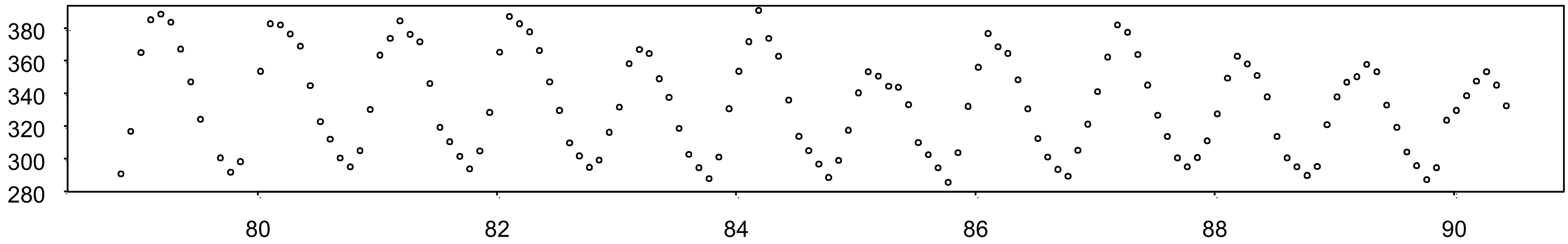
Original Monthly Averaged Data



Weatherhead Fri Nov 2 11:48:50 2001

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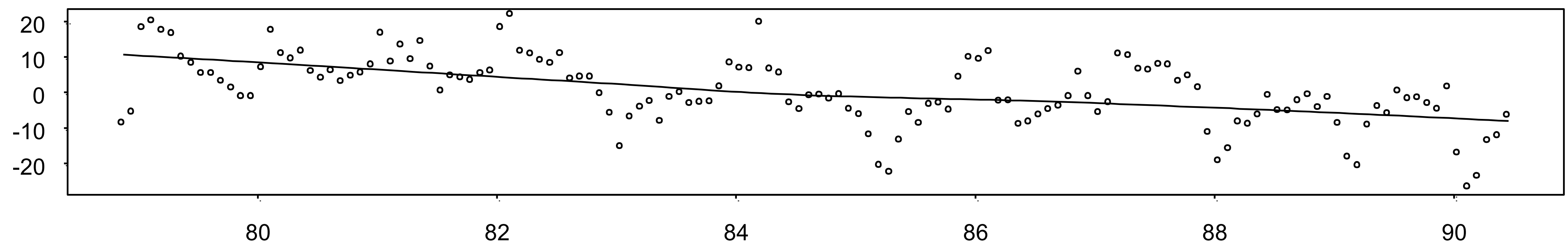

SBUV OZONE TOTAL COLUMN OZONE - 40N

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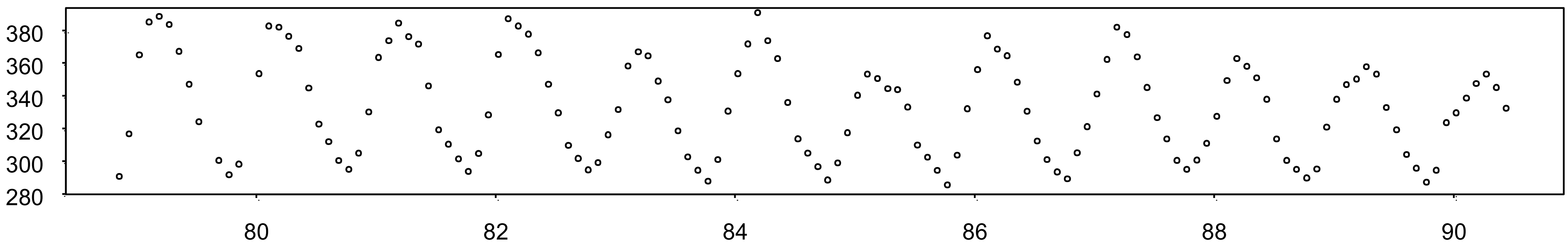
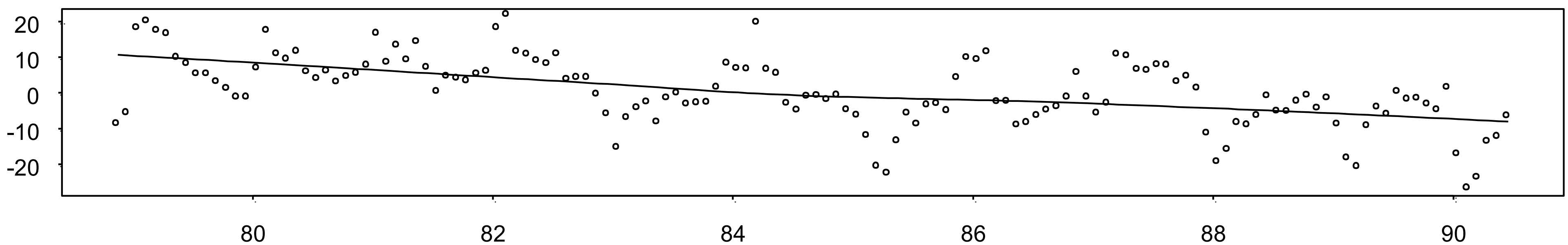
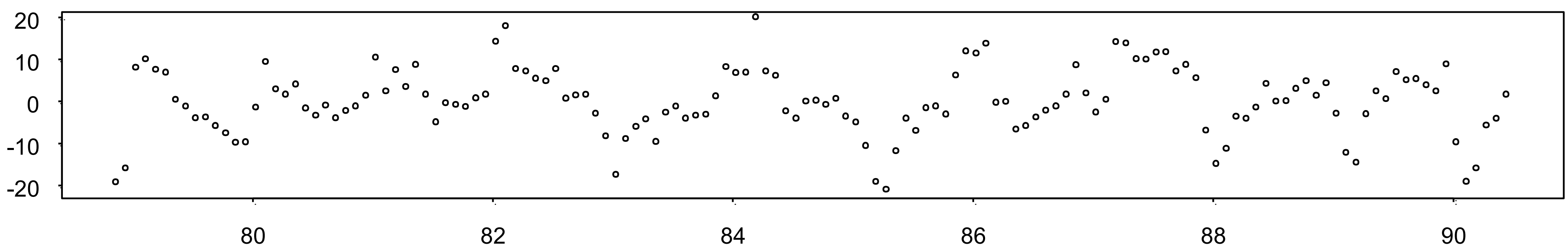


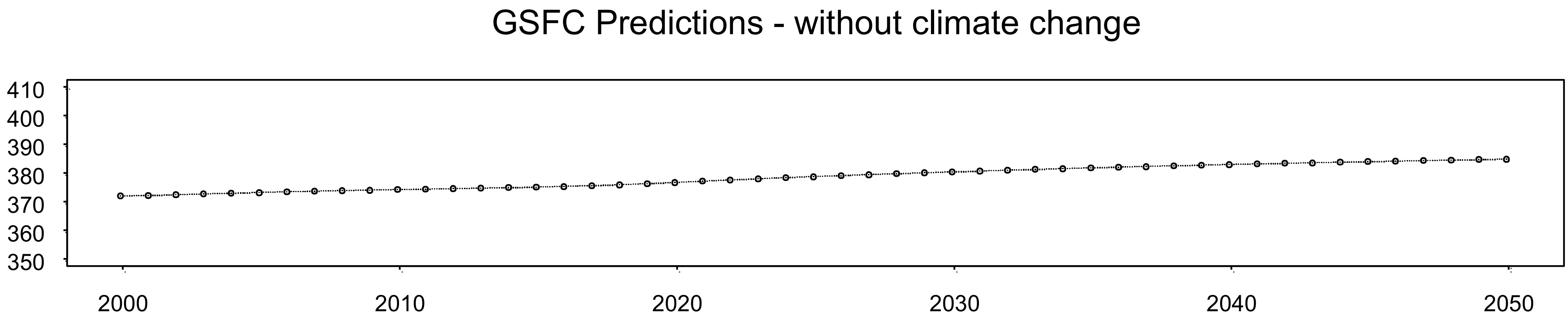
Weatherhead Fri Nov 2 11:48:50 2001

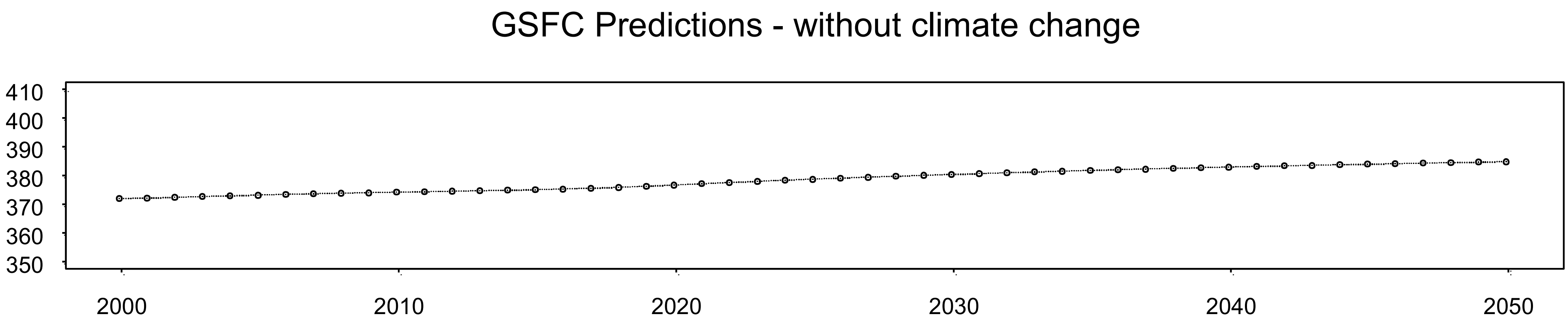
Monthly Means Removed, Lowess Line Fit Superimposed



Residuals From Lowess Line Fit




GSFC Predictions - without climate change
410
400
390
380
370
360
350
2000
2010
2020
2030
2040
2050


GSFC Predictions - without climate change
410
400
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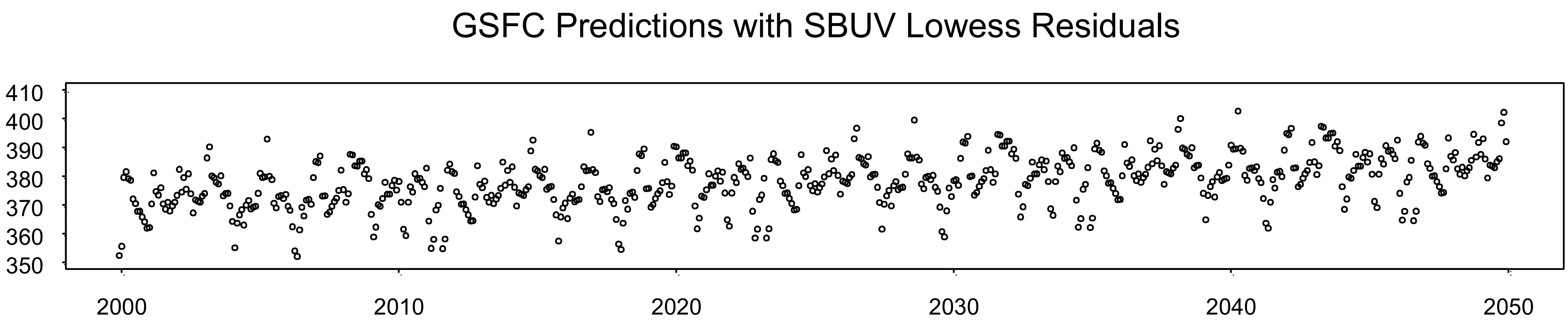
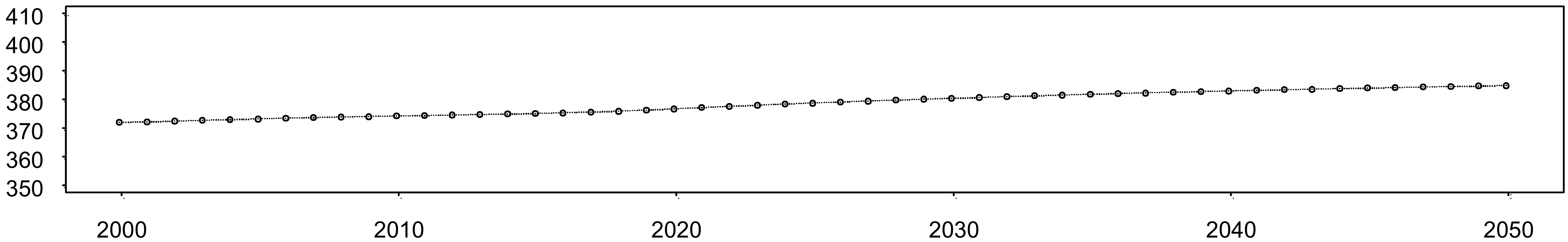
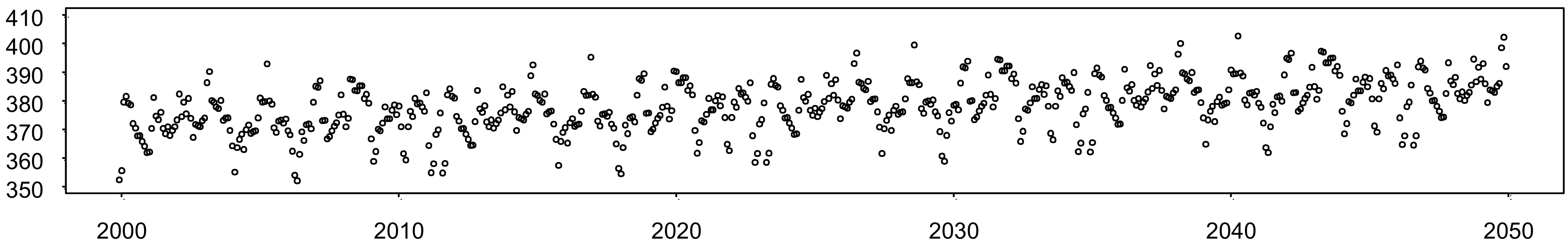

GSFC Predictions with SBUV Lowess Residuals
410
400
390
380
370
360
350
2000
2010
2020
2030
2040
2050

GSFC 2d Predictions with SBUV Residuals of Total Col. Ozone (d.u.) 40N

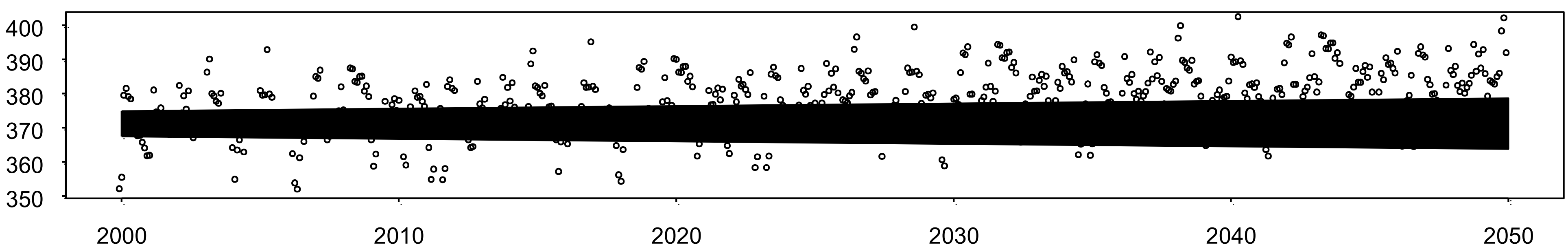
GSFC Predictions - without climate change



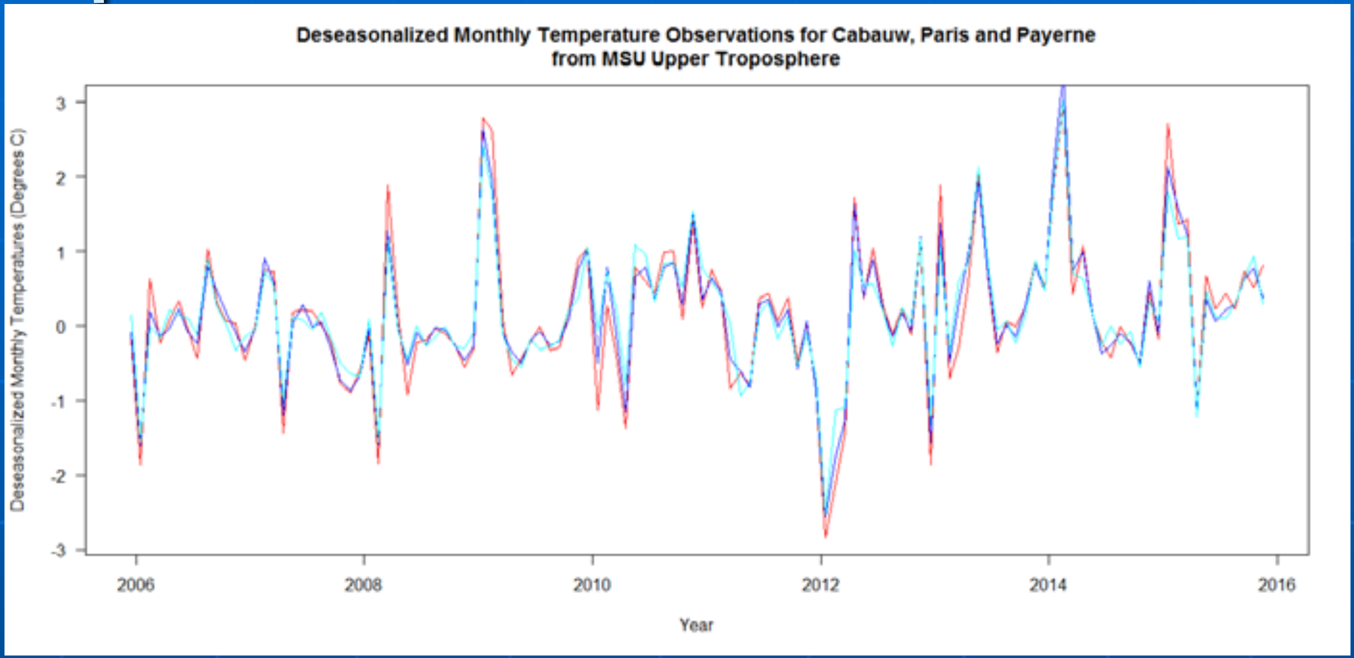
GSFC Predictions with SBUV Lowess Residuals



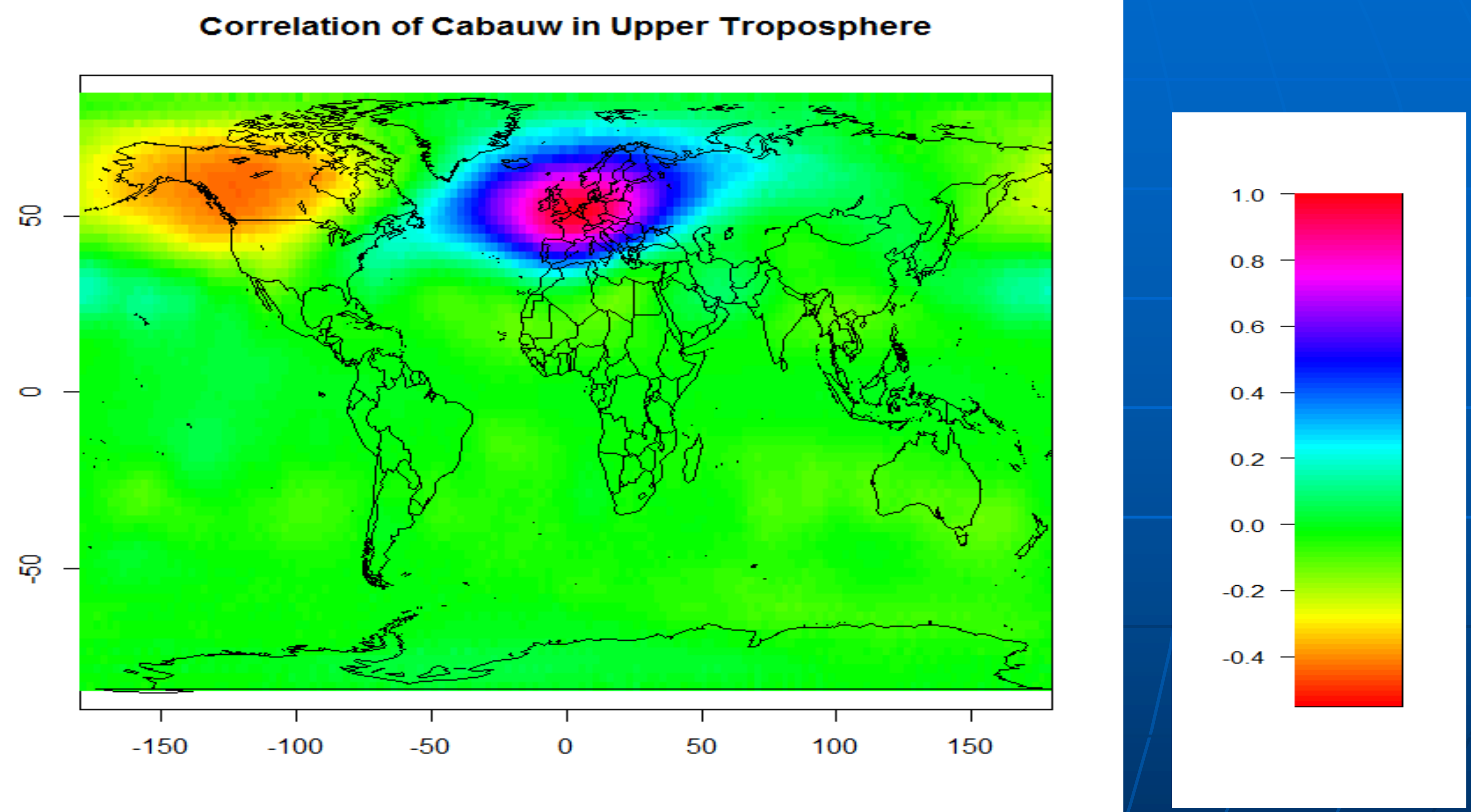
with +-1% error plus +-1% drift



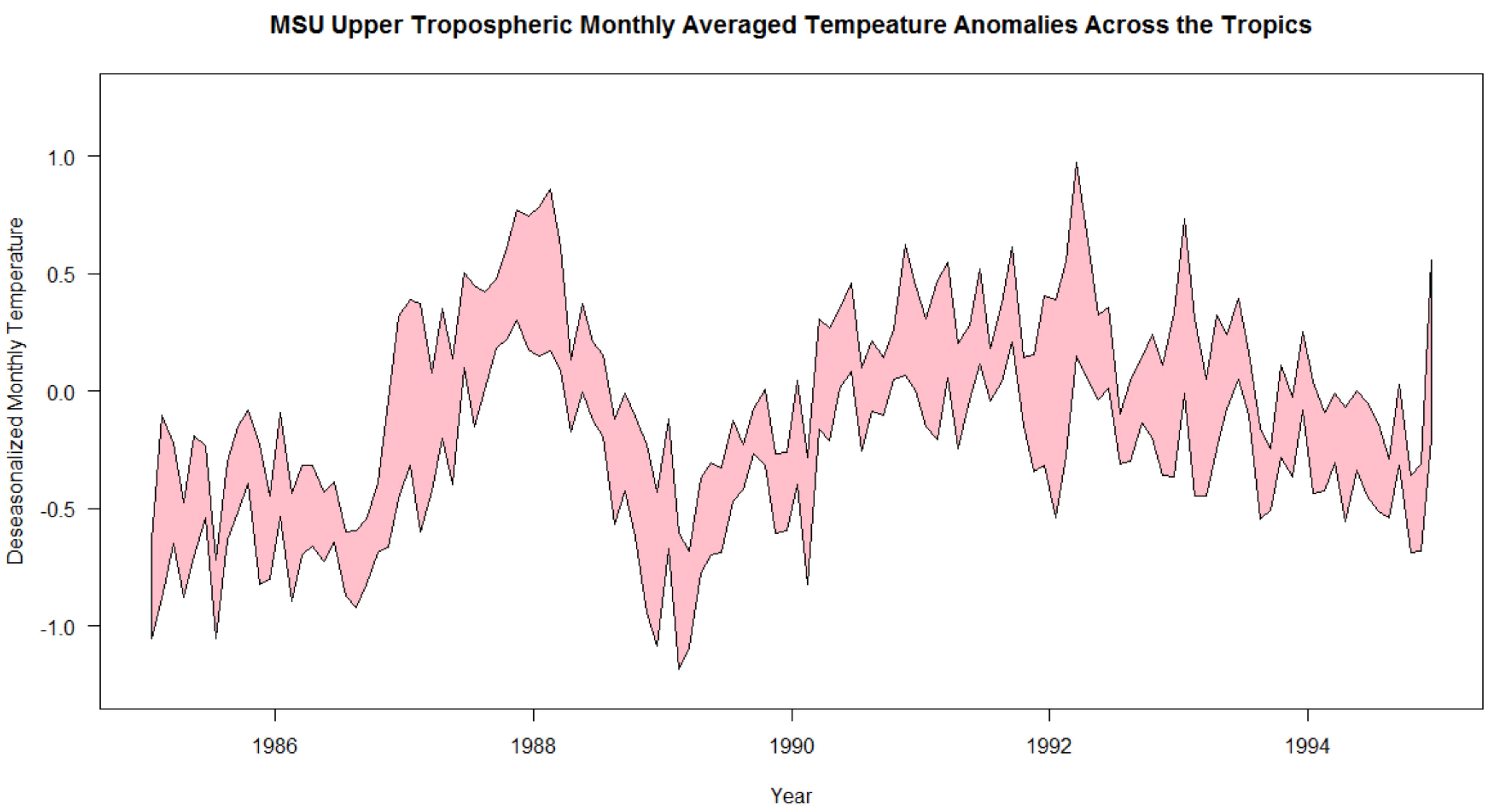
Redundancy of Tropospheric Temperature Records in Europe



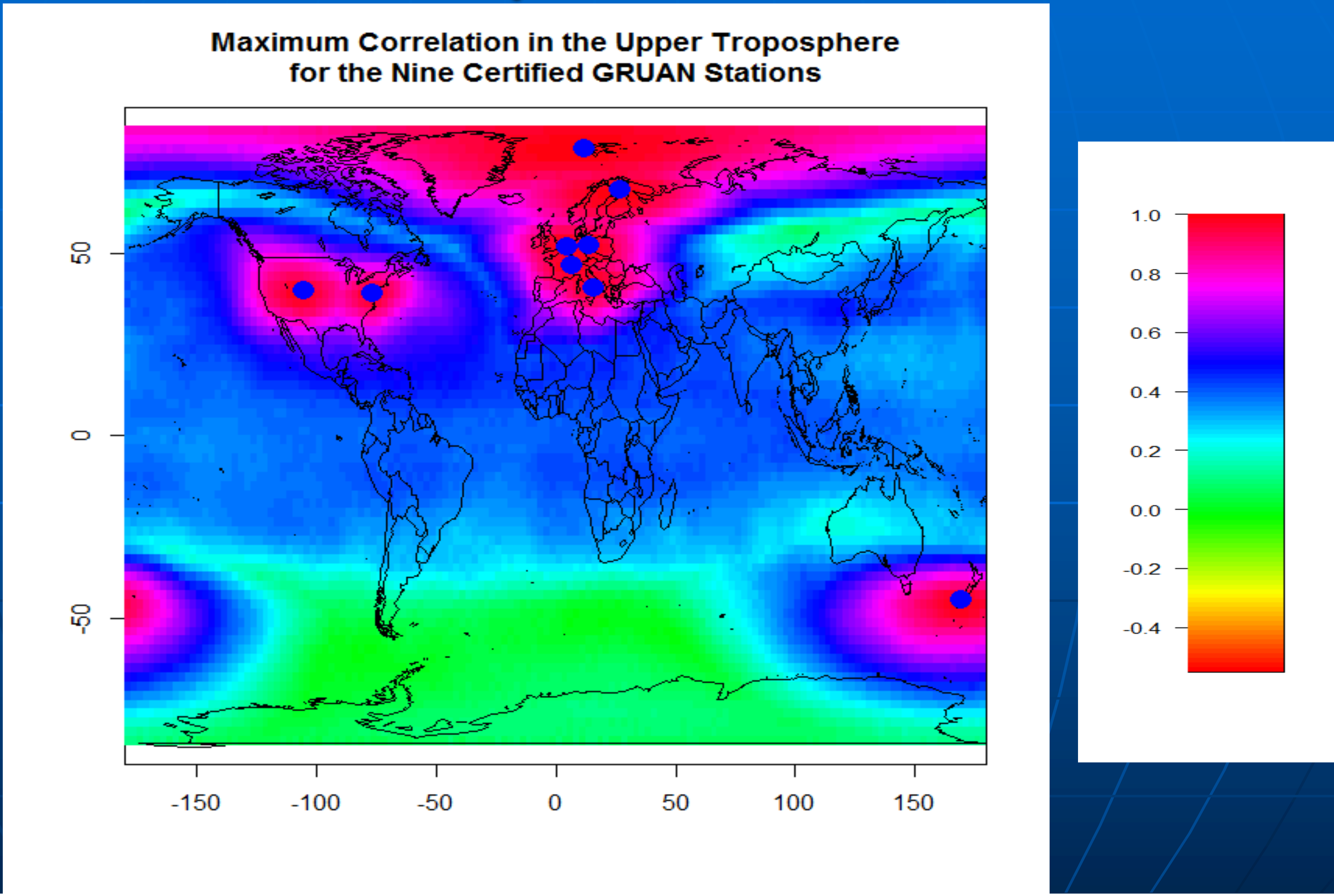
- Cabauw, Paris and Payerne show similar information when we examine deseasonalized temperature records.
- How close is too close?


Correlation of Cabauw in Upper Troposphere
50
0
-50
-150
-100
-50
0
50
100
150
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4

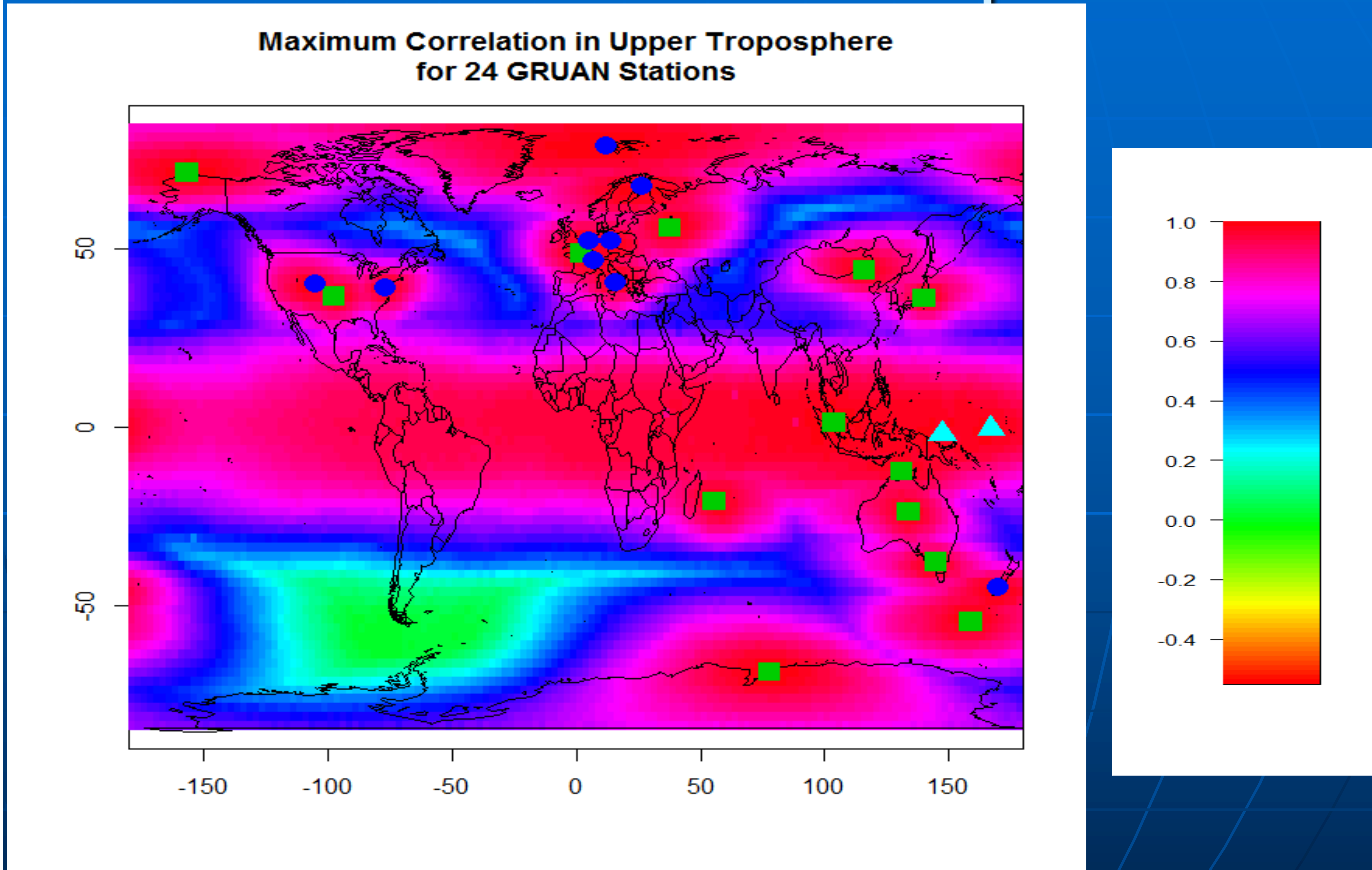
Spatial Coherence



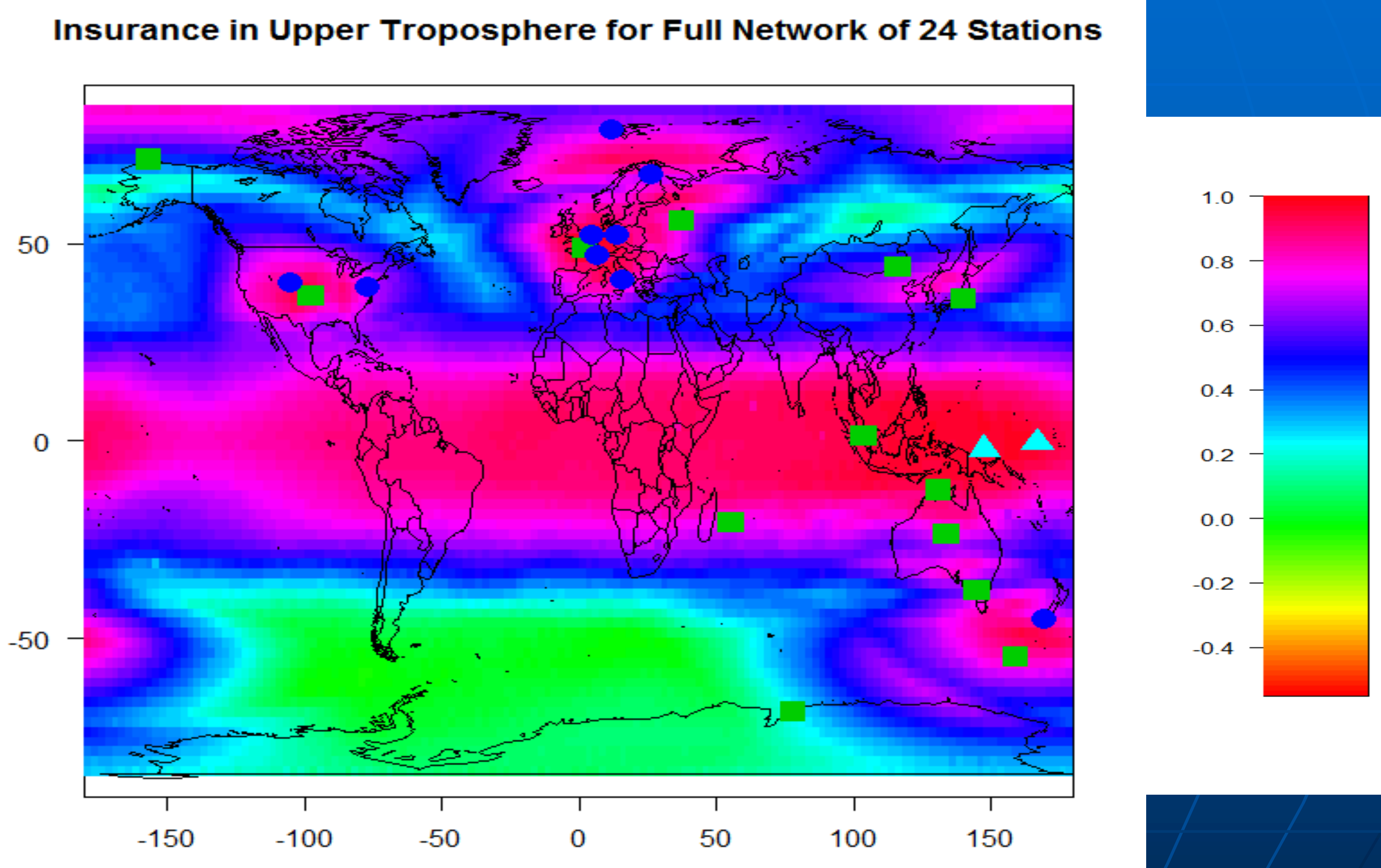
Network Representation - GRUAN



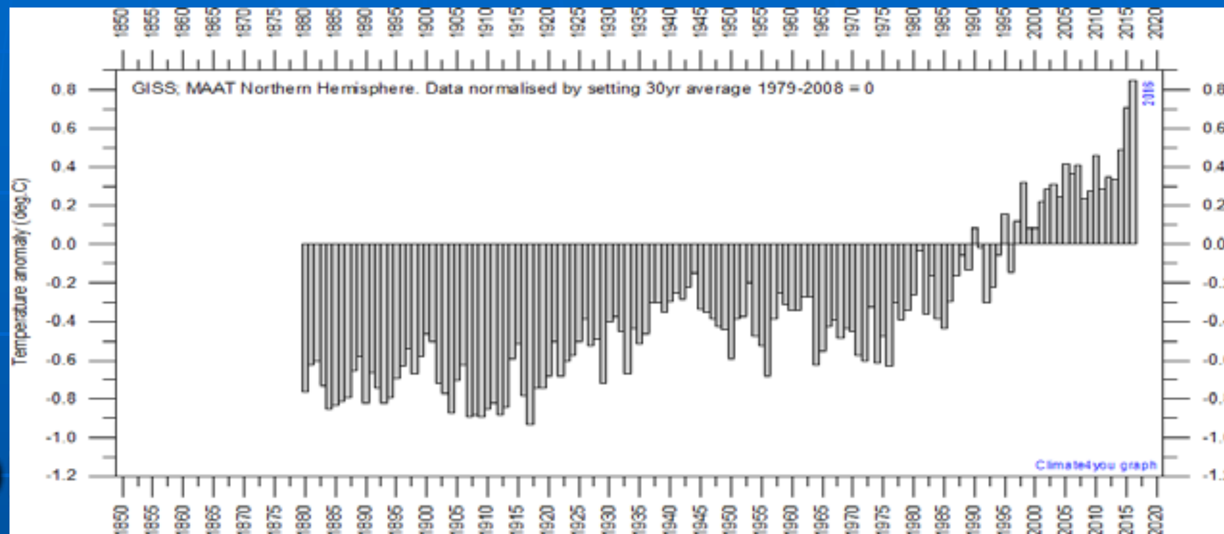
Possible Network Expansion



But What About Redundancy?

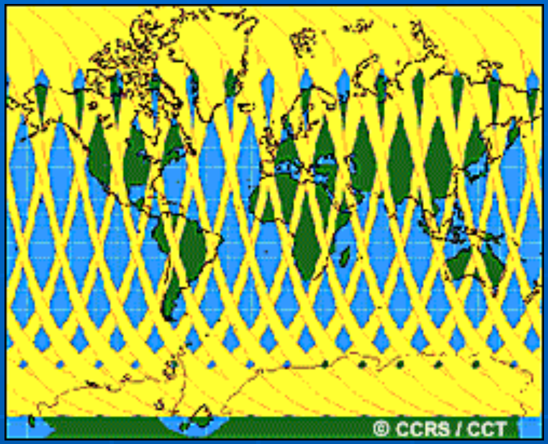


Long-term changes are often longer than the lifetime of satellites.

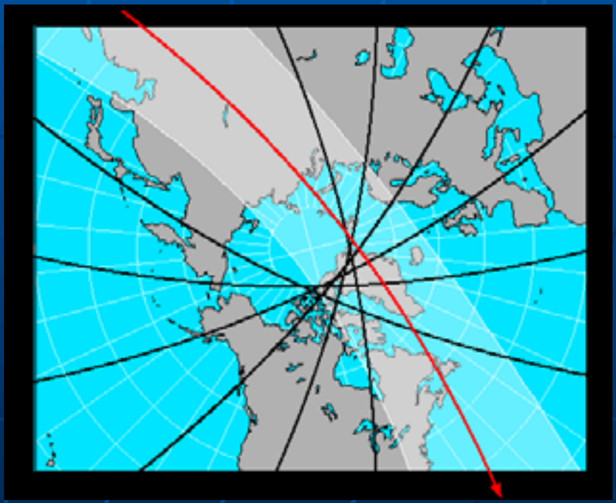


- Possible solutio
  - Anchoring observations from non-satellite observations (e.g. GRUAN, USCRN, etc.)
  - Often spatially and temporally limited
  - Sometimes not available
  - Reference standards can change (improve)
  - Satellite overlap

Challenges with Satellite Overlap



- Not always possible
- Changes in technology
- Changes in footprints
- Temporal matching, including diurnal biases
- Not true calibration
- Marginally expensive for lengthy overlap

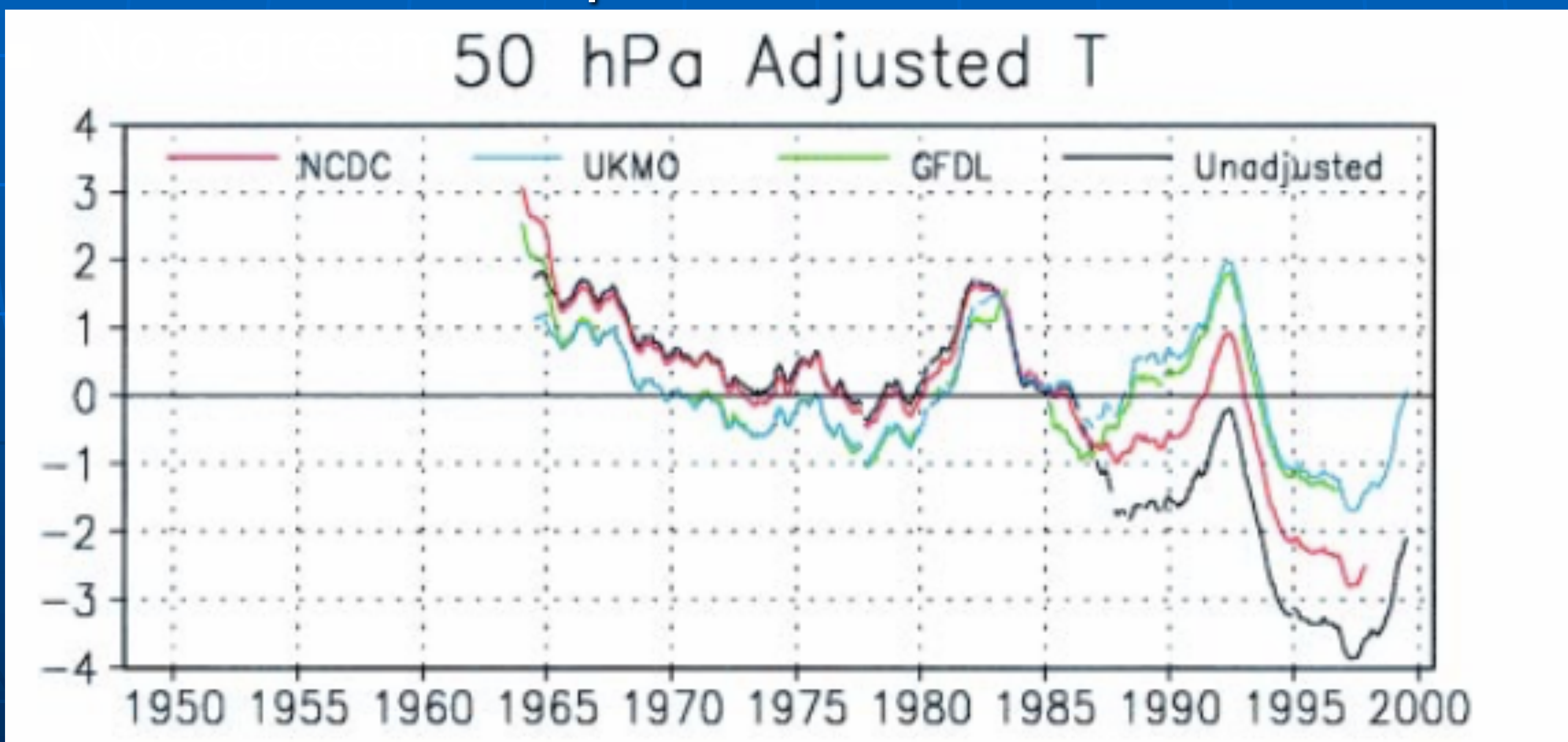


Worst Case Scenario: No Overlap

- Our new measurements are sooo good.
- We can analyze this.
- We can statistically solve for the gap.
- We can use other data to help us bridge the gap.
- Free et al. (2002) compared approaches where there was no overlap.

Free et al., 2002

- 12 radiosonde stations
- Six thoughtful methods (NCDC, UKMET, GFDL-1, GFLD-2, UAH, Texas A&M)
- High confidence
- Blind Intercomparison



Free et al., 2002

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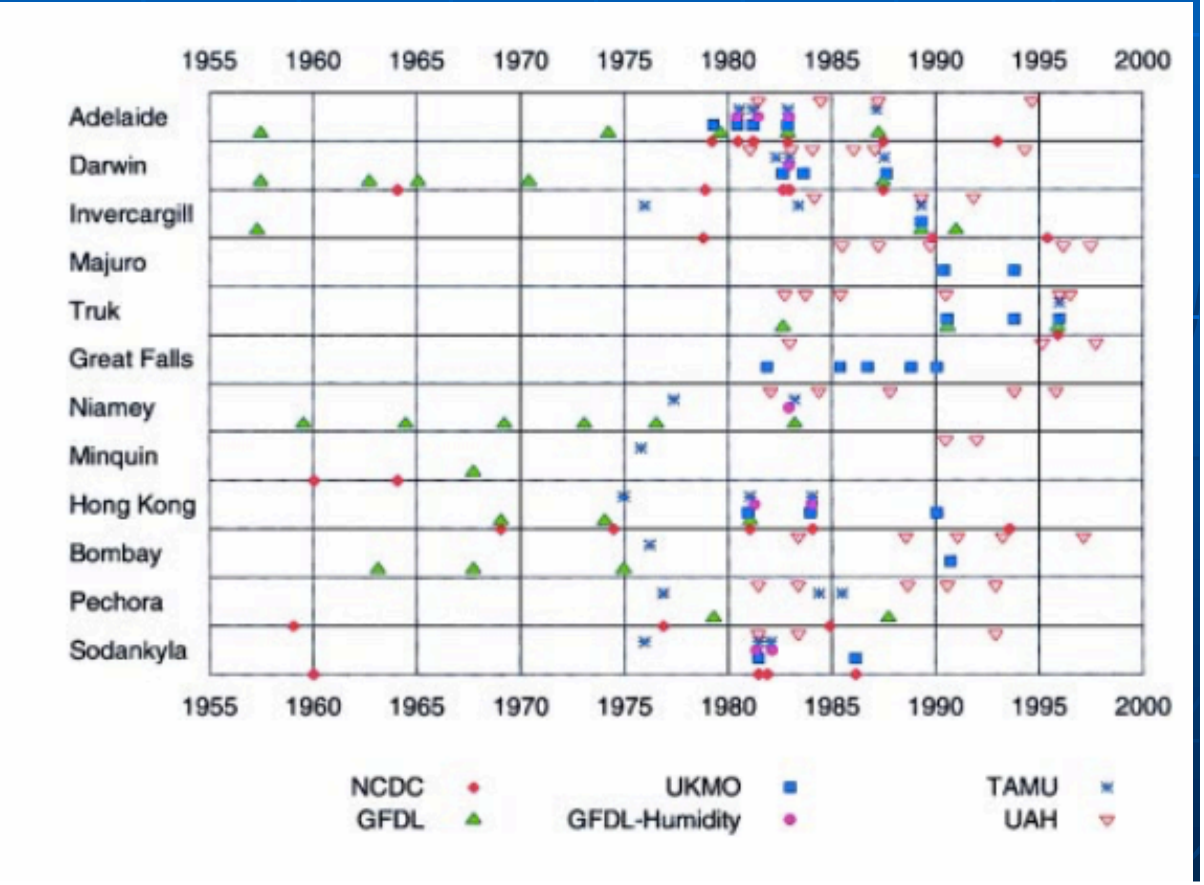
- No agreement

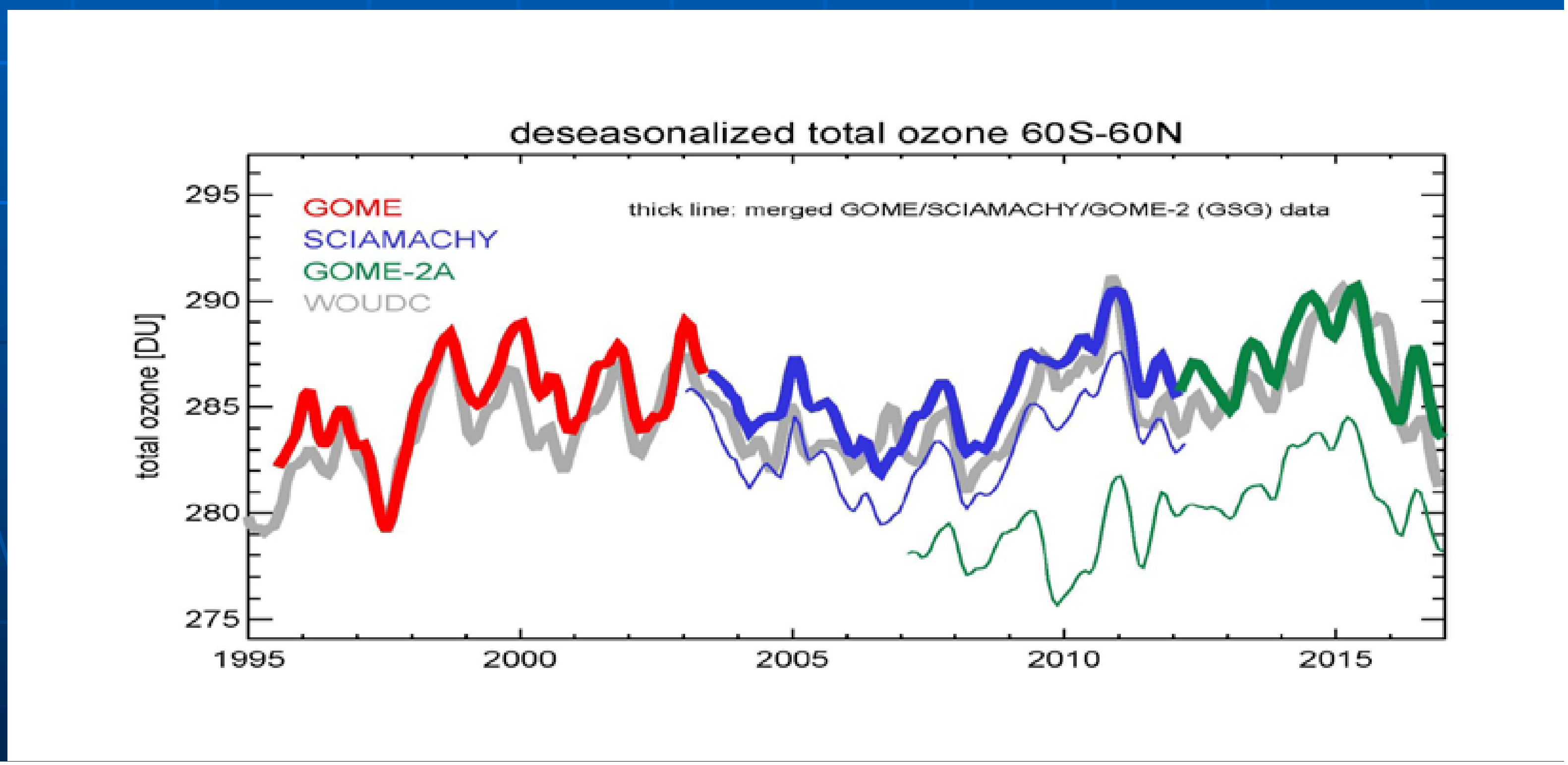


Some common wisdom on satellite overlap

- Overlap for a full year so that the range of values can be observed.
  - This ignores the burn-in time that many satellites require before they stabilize.
  - Not all phenomena display their full range of values in one year.
- More overlap is better
  - This ignores the expense in overlapping which could deny other efforts to quality assure observations such as on-board calibrations, campaigns to verify observations, analysis of the data.
- Don't worry about the overlap because analysis can handle the discontinuities
  - Wishful thinking, but the claim needs to be verified.
  - Multiple examples show that analysis can not always solve quality issues in observations (Free et al.)
- Fundamentally, these issues to do not compare the purpose of the observations to the value of information from the overlap.

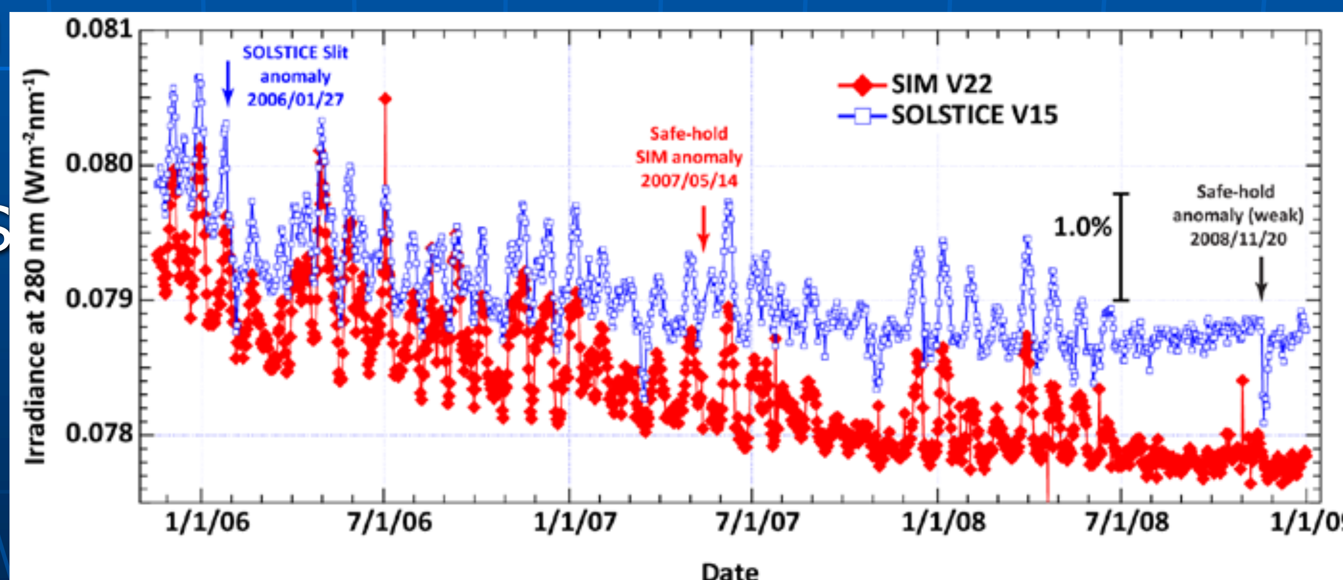
Ozone Satellite Data

- Stratospheric ozone should be recovery, however the signal is small and the observational uncertainty is large.
- Ozone satellite data show notable differences which change over time.
  - Large compared to signal of long-term increases

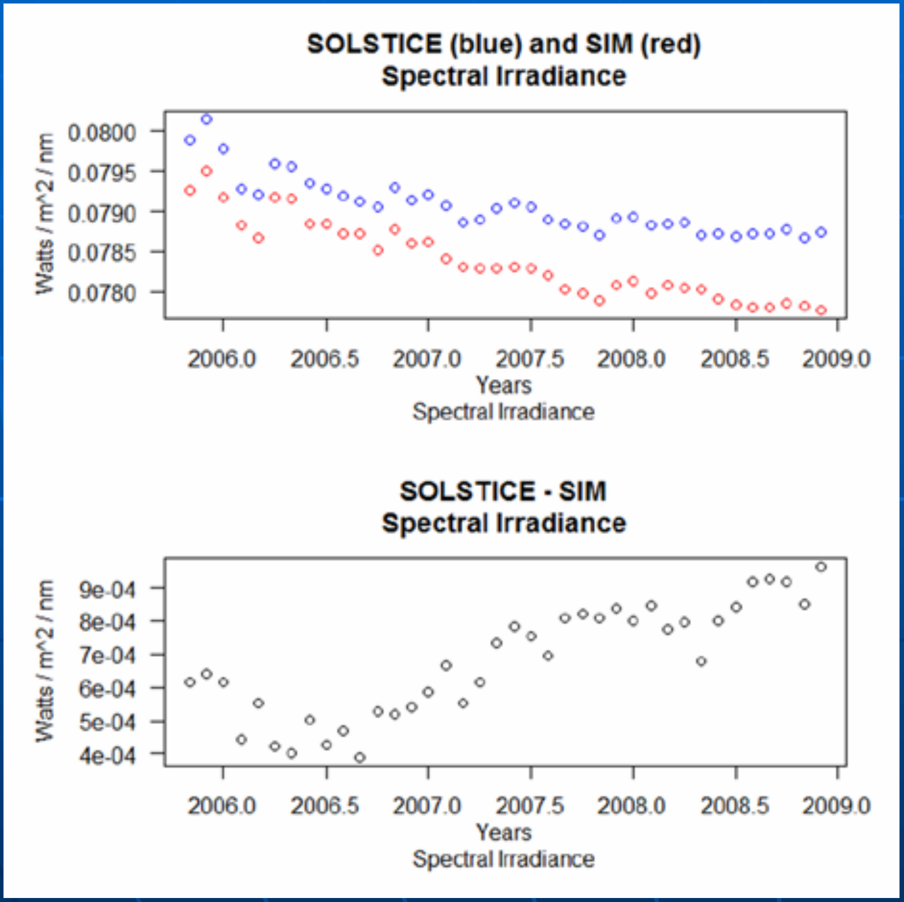


Looking at Offsets in Overlapping Satellites

- Overlapping satellites often show offsets.
- For the period of overlap, the differences can be calculated, often in an ideal region where footprints and time differences are minimized.
- Both the differences and the standard error on the differences can be estimated from the overlap data
- Example:
  - SOLSTICE-S
    Overlap



Exploring overlap impacts using SOLSTICE and SIM data



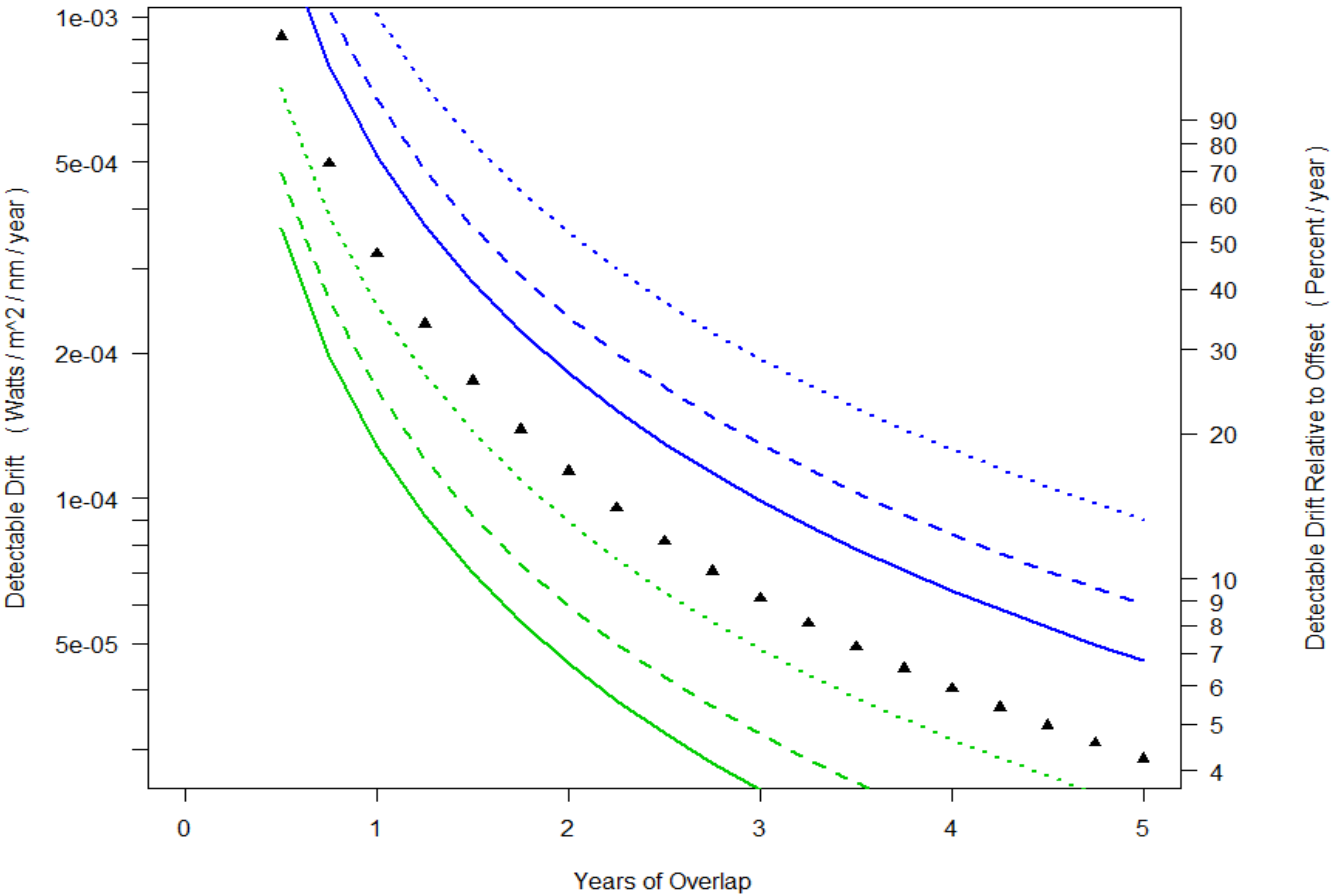
Monthly averaged overlap data

- Looking at one wavelength: Mg (280 nm)
- Offset is clearly observable.
- Drift is also possible.

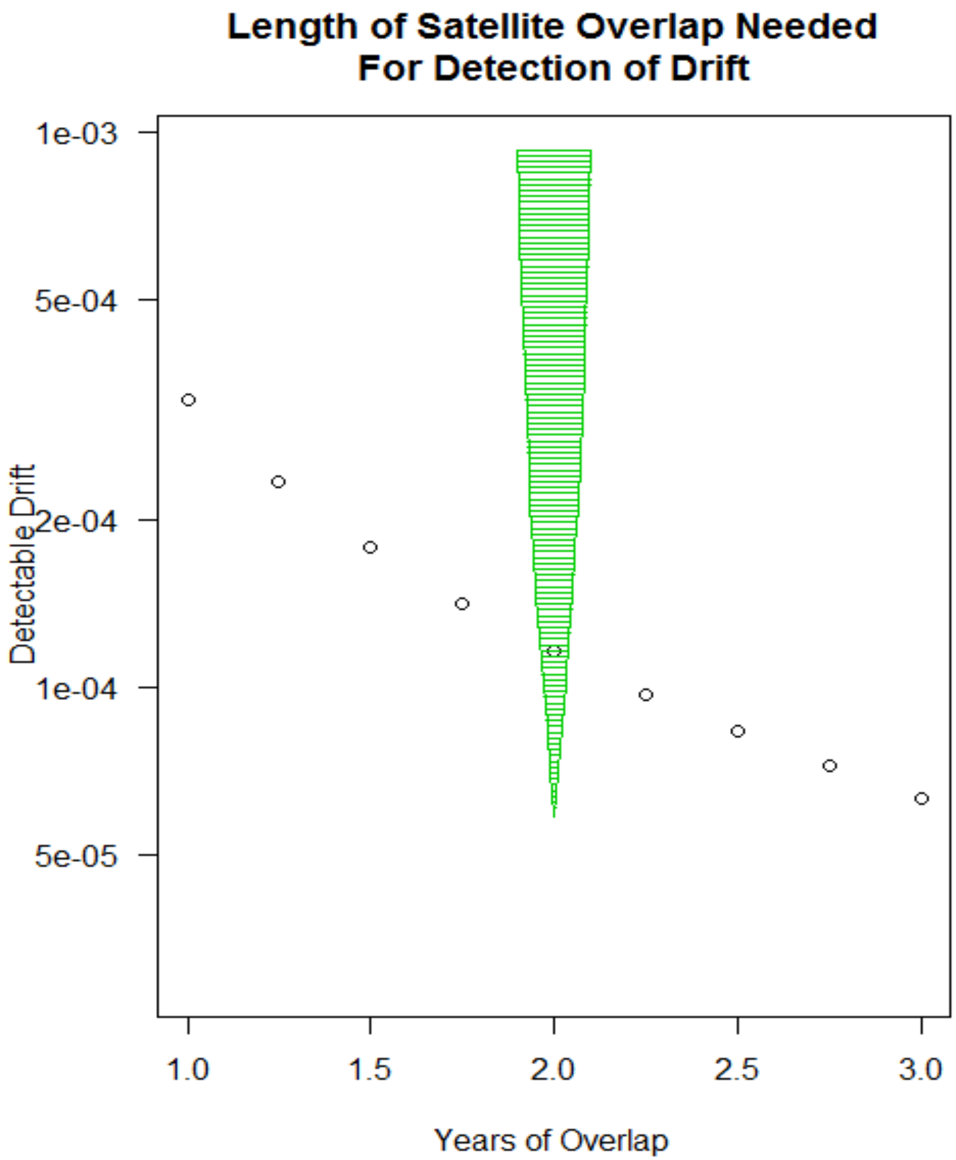
Adjusting for offsets

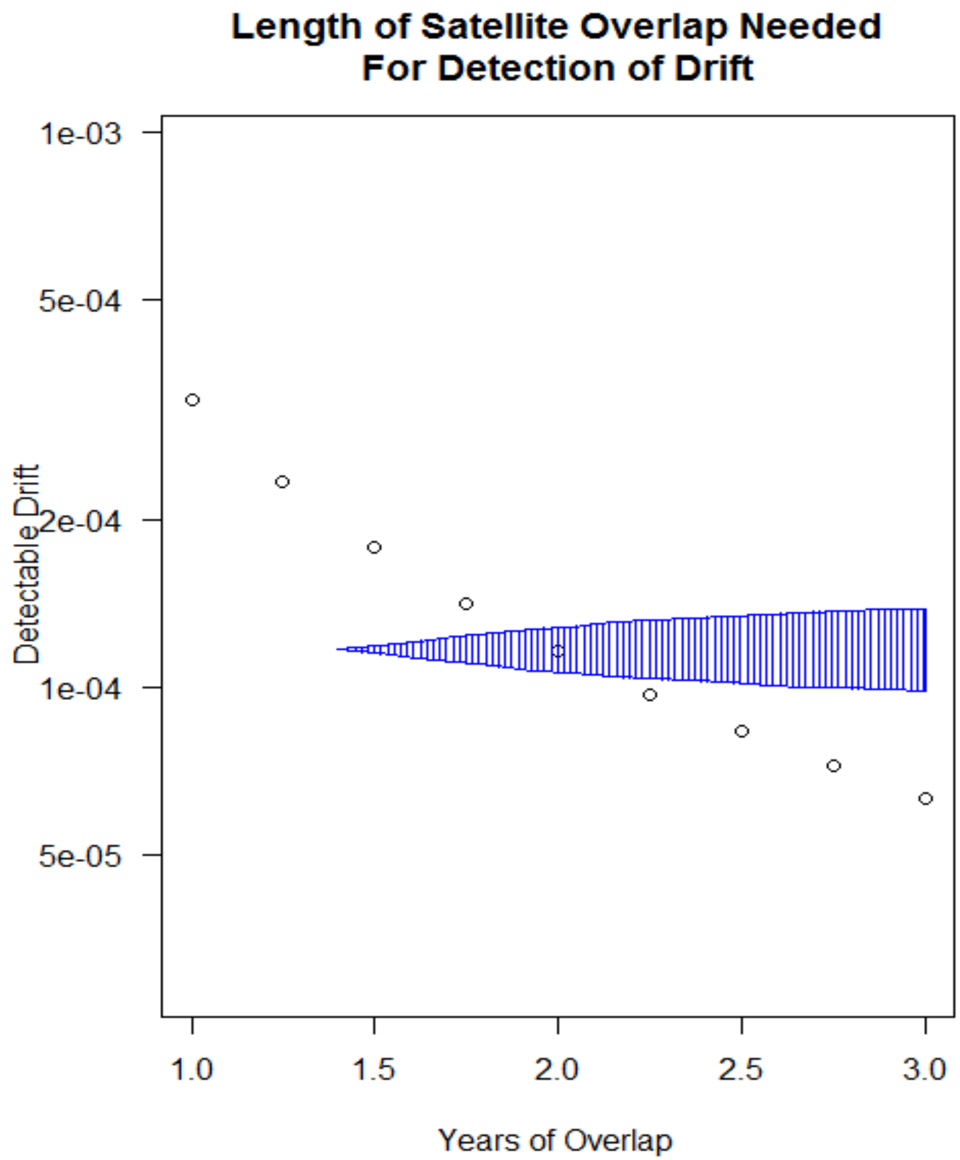
- Adjustments:
- Offset = <satellite 1> - <satellite 2>
  - With appropriate adjustments for match-up
- Inverting:
- $S.E._{mean} = \sigma / sqrt(n-1) \; sqrt(1+\varphi / 1-\varphi)$
- Note that the time needed to understand an offset is independent of the size of the offset.

Length of Satellite Overlap Needed For Detection of Drift

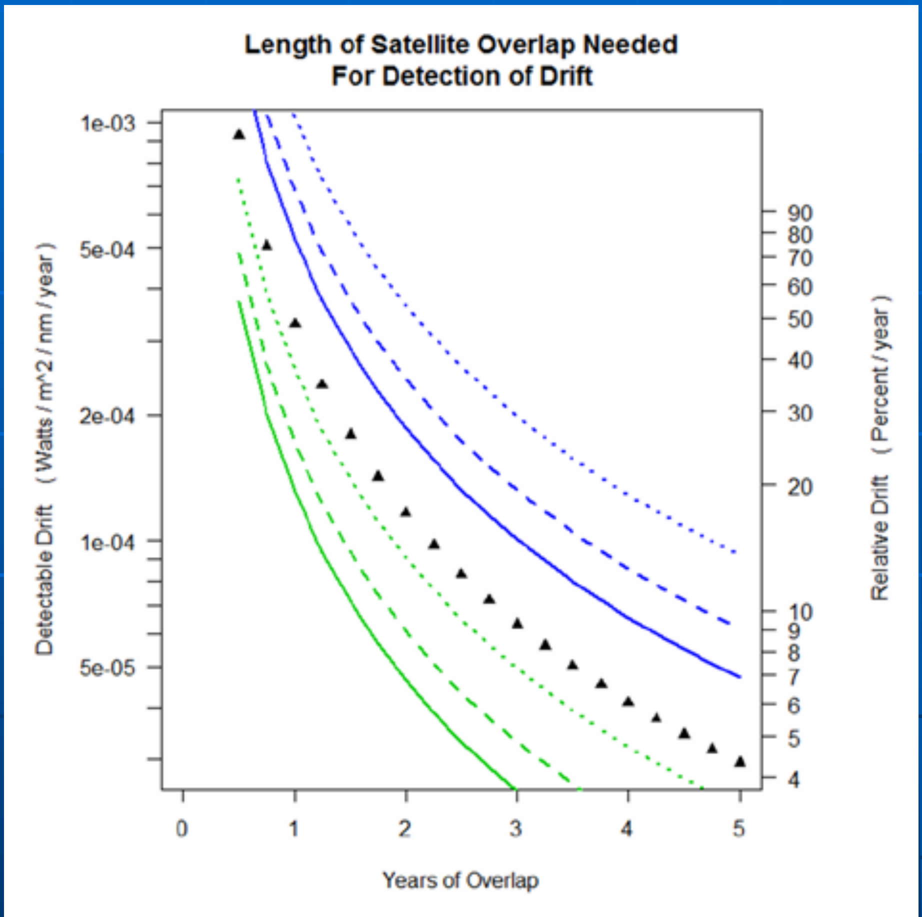


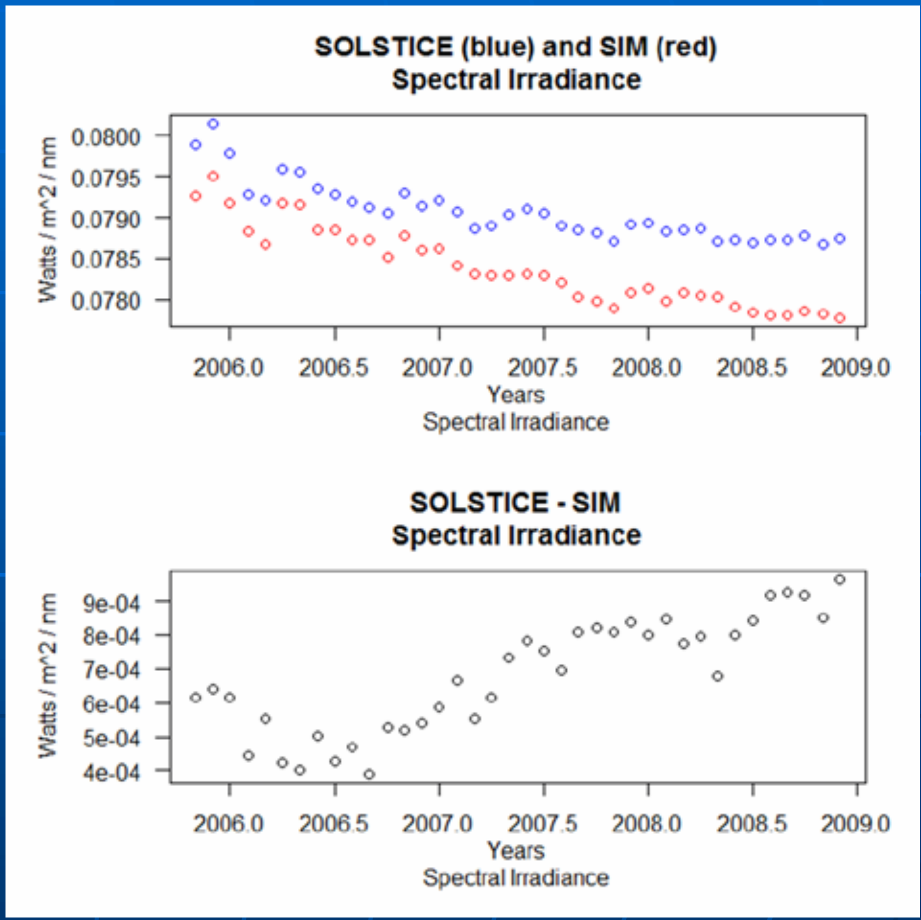
Understanding uncertainty in estimating number of years.





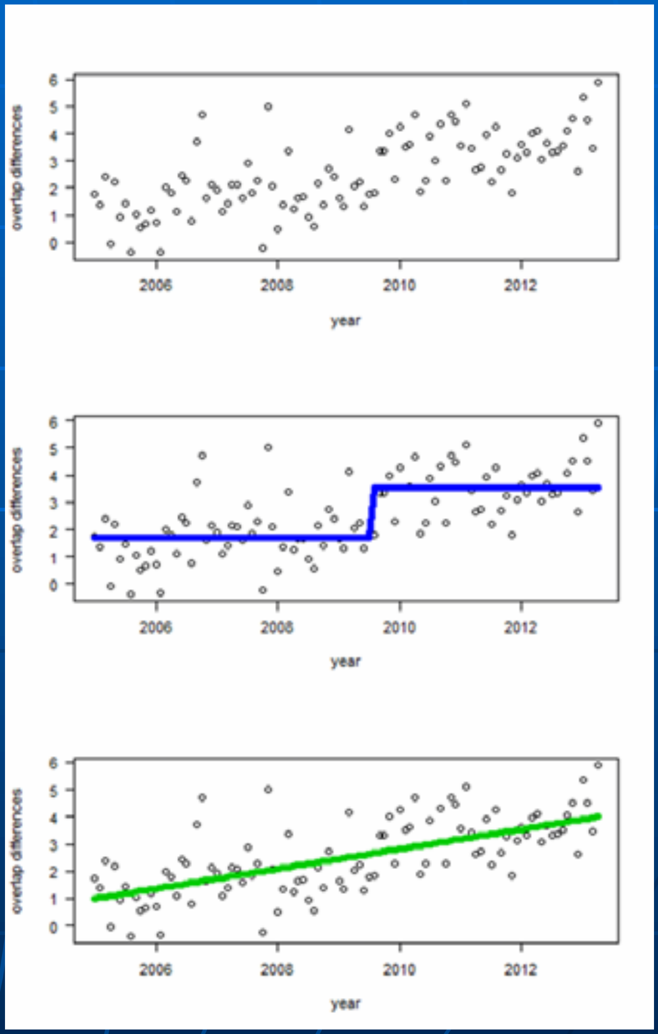
Results are dependent on the character of the overlap data.



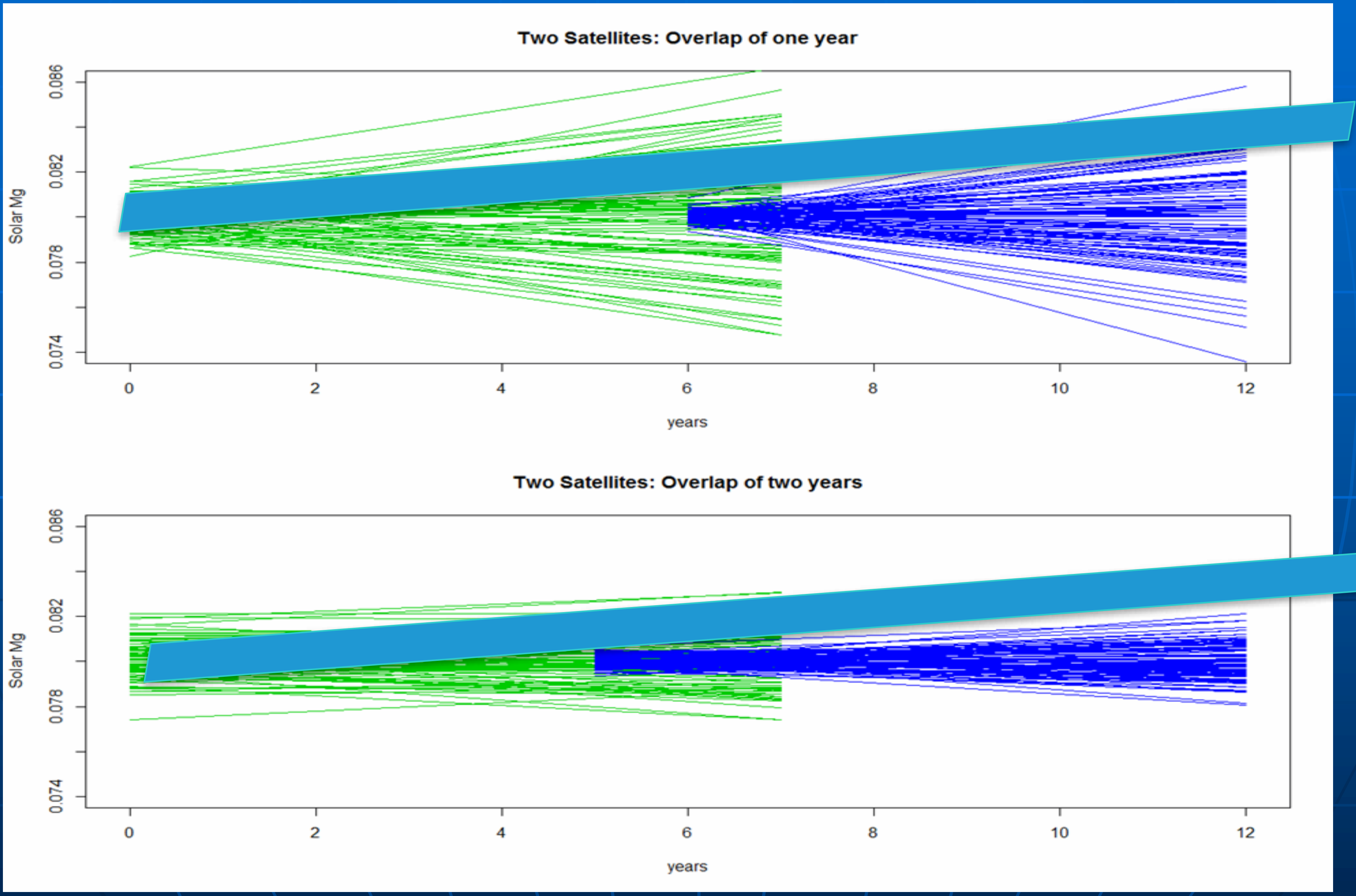


Unfortunately, not all instrument behavior can be assumed to be offsets and drifts.

- Sudden jumps in data can obscure the long-term offsets and drifts.
- Large offsets can be identified, but corrections still introduce uncertainty.



Is this a large or small effect?



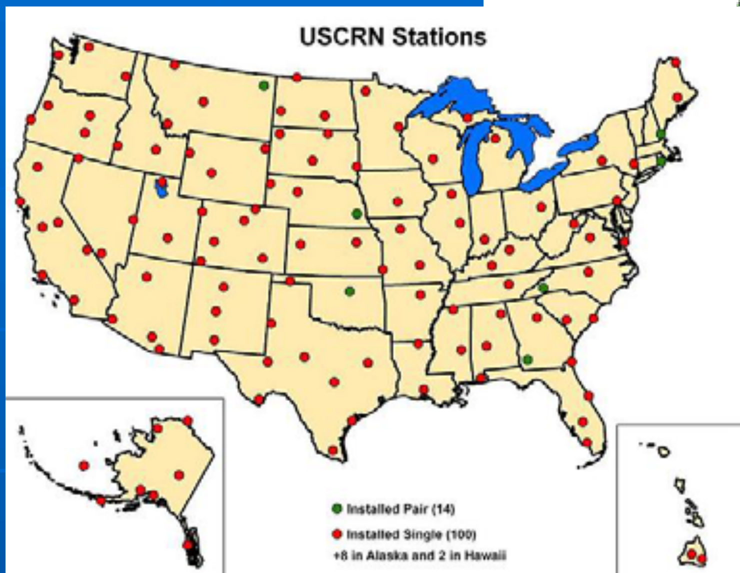
Improve Climate Projections

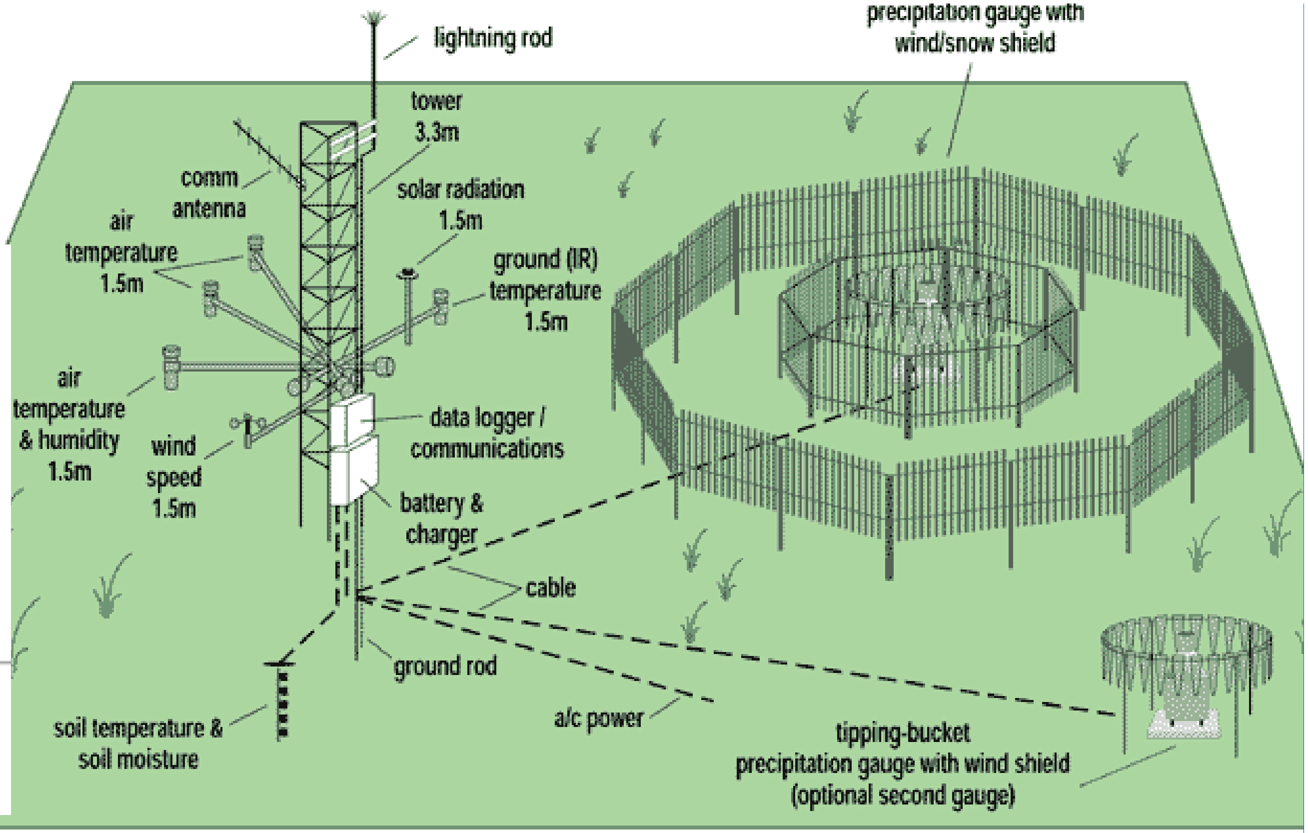
We can control only four aspects of monitoring to address climate observations

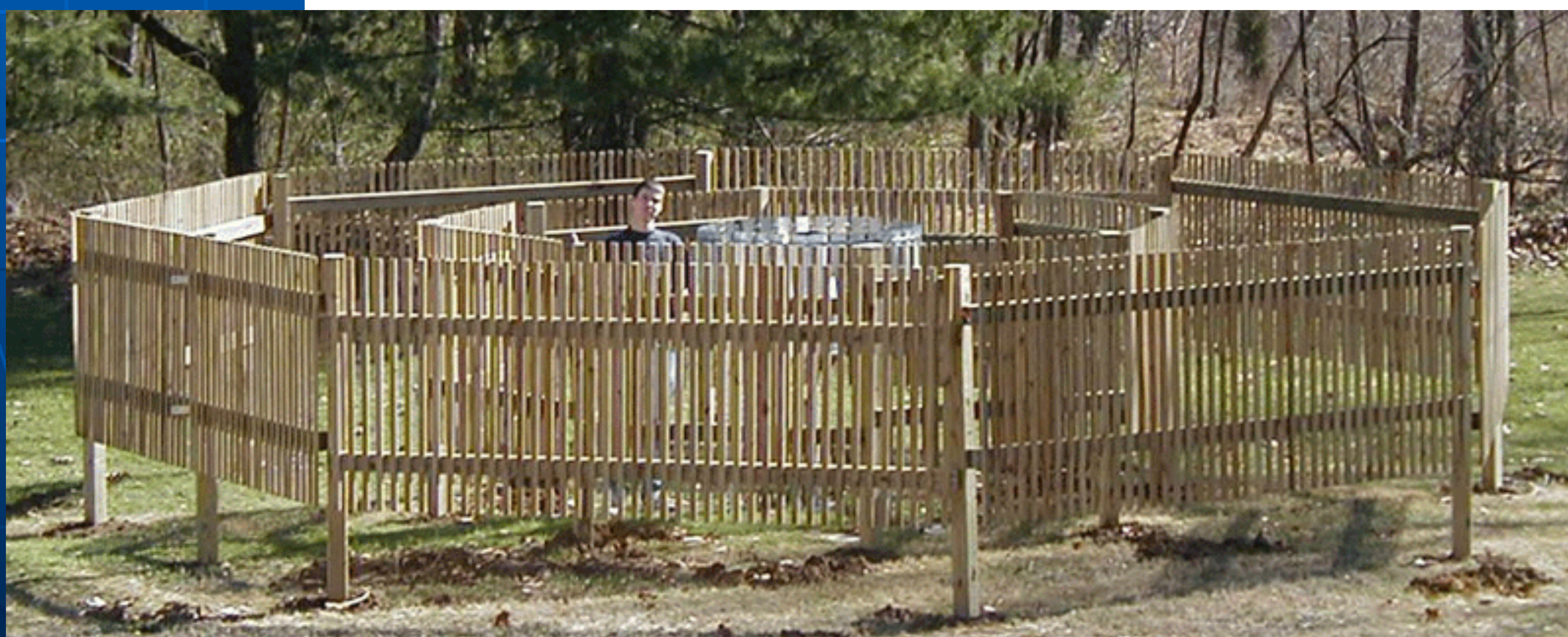
- **Where we monitor**
- **What frequency**
- **What accuracy**
- **What we monitor**

Climate Observing System Simulation Experiments (COSSEs) can evaluate observational choices

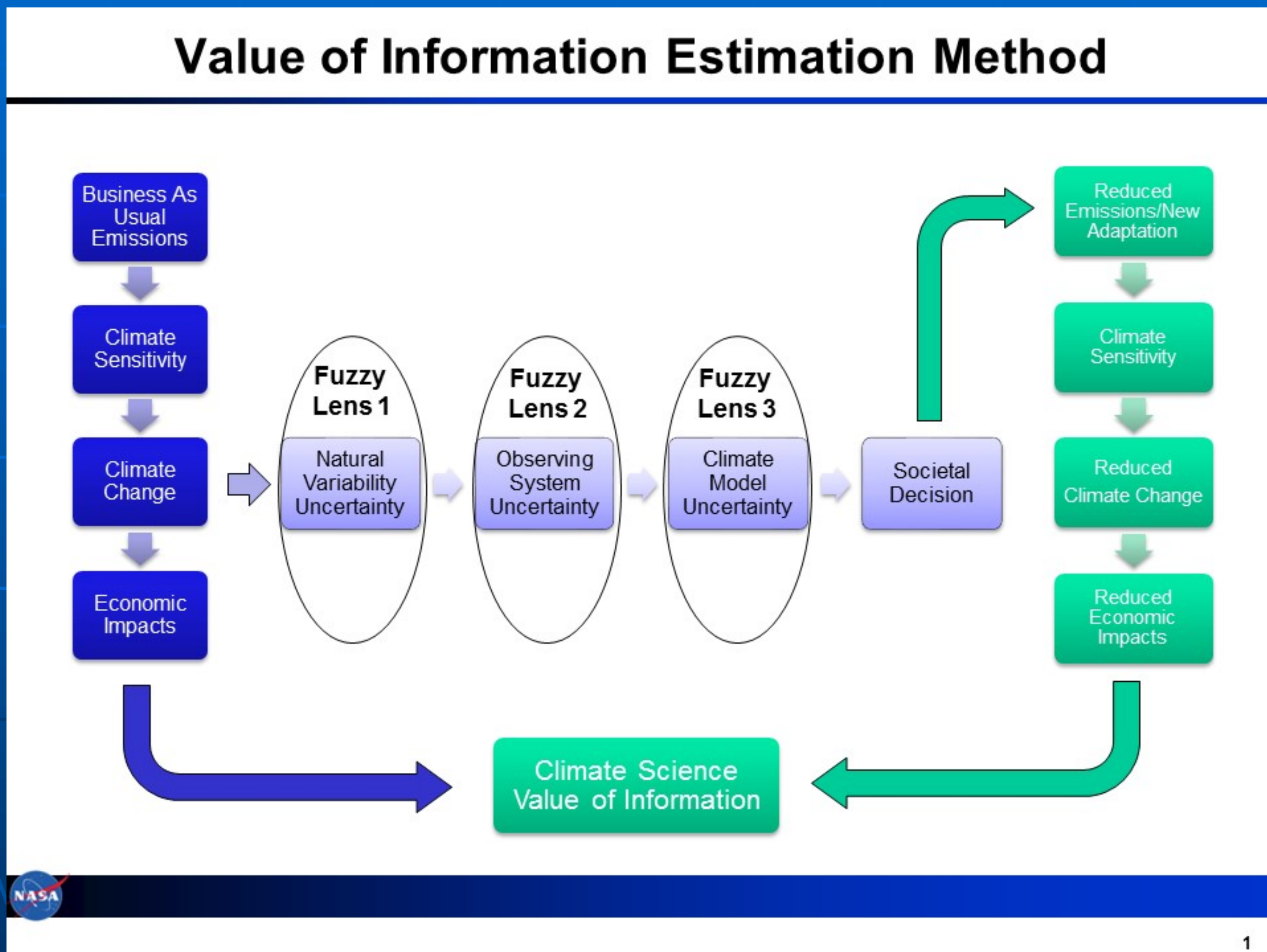
Complementary measurements can allow more confidence in results and attribution.


USCRN Stations
Installed Pair (14)
Installed Single (100)
+8 in Alaska and 2 in Hawaii


lightning rod
precipitation gauge with wind/snow shield
tower 3.3m
comm antenna
solar radiation 1.5m
air temperature 1.5m
ground (IR) temperature 1.5m
air temperature & humidity 1.5m
wind speed 1.5m
data logger / communications
battery & charger
cable
ground rod
a/c power
soil temperature & soil moisture
tipping-bucket precipitation gauge with wind shield (optional second gauge)



Economic Value Revisited



Conclusion

- Focus observations on critical climate questions.
- Decisions about accuracy, overlap, location, temporal sampling need to be made with respect to the science question.
- The best observing system is likely a set of observations.
- Societal decisions mean economic value.