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.
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

Monthly Means Removed, Lowess Line Fit Superimposed

Weatherhead Fri Nov 2 11:48:50 2001
GSFC Predictions - without climate change

GSFC Predictions with SBUV Lowess Residuals
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
Spatial Coherence

Data from Paris correlates well with much of Europe. Does this define the spatial scale of temperature in the upper troposphere? What might this mean for spatial planning of networks?
Network Representation - GRUAN

Maximum Correlation in the Upper Troposphere for the Nine Certified GRUAN Stations
Possible Network Expansion

Maximum Correlation in Upper Troposphere for 24 GRUAN Stations
But What About Redundancy?

Insurance in Upper Troposphere for Full Network of 24 Stations
Long-term changes are often longer than the lifetime of satellites.

- Possible solutions:
  - 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

- 12 radiosonde stations
- Six thoughtful methods (NCDC, UKMET, GFDL-1, GFDL-2, UAH, Texas A&M)
- High confidence
- Blind Intercomparison
- 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-SIM 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 = \(<\text{satellite 1}> \) - \(<\text{satellite 2}> \)
    - With appropriate adjustments for match-up

- **Inverting:**
  - \( S.E_{\text{mean}} = \frac{\sigma}{\sqrt{n-1}} \sqrt{\frac{1+\varphi}{1-\varphi}} \)

- Note that the time needed to understand an offset is independent of the size of the offset.
Understanding uncertainty in estimating number of years.

Length of Satellite Overlap Needed For Detection of Drift

- Detectable Drift vs Years of Overlap
  - Data points are scattered with a peak around 2.0 years of overlap.

Length of Satellite Overlap Needed For Detection of Drift

- Detectable Drift vs Years of Overlap
  - Data points are scattered with a trend indicating lower detectable drift with longer overlap.

Graphs show the relationship between years of overlap and detectable drift, highlighting the uncertainty in estimating the number of years required for detection.
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.
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.