METROLOGY FOR CLIMATE ACTION
26–30 SEPTEMBER 2022

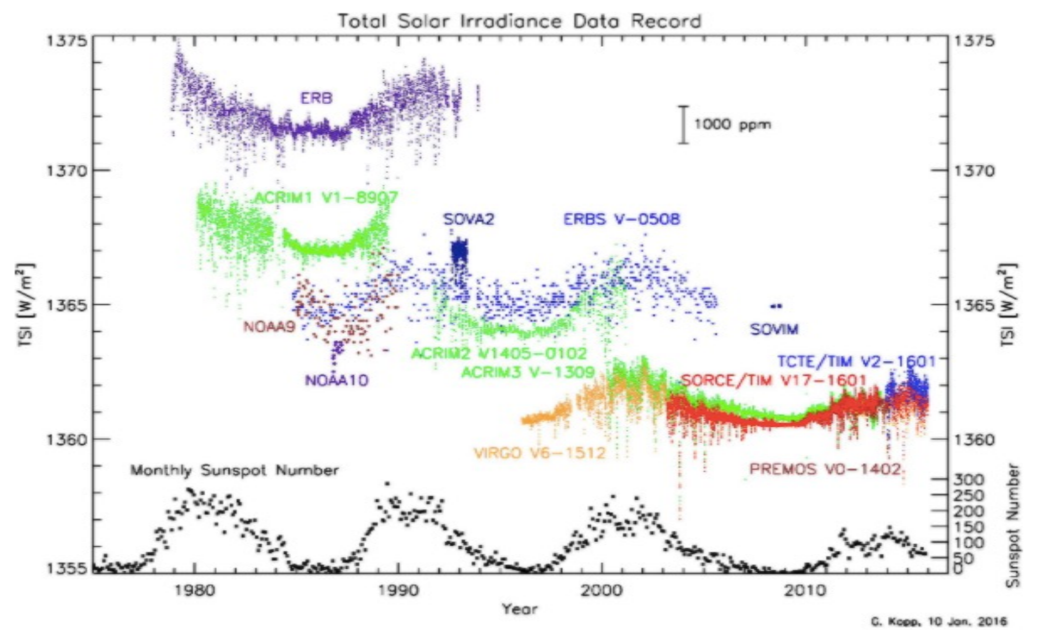
Continuity Challenges with Satellite Overlap

Critical Issues in maintaining global climate records

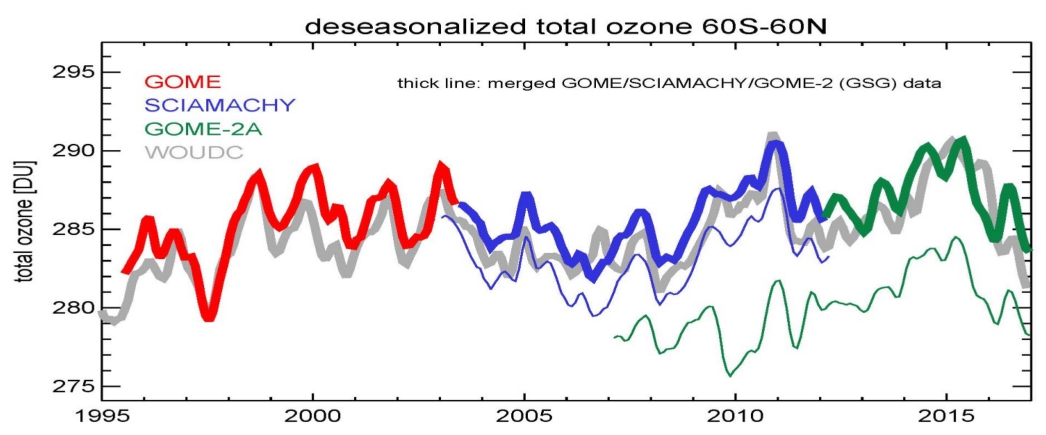
Eduardo Araujo-Pradere[1]

Miami Dade College

The Need: Long-term global records of climate variables are a critical tool for understanding how the Earth's System is changing.



Individual satellites inherently have finite lifetimes. The merging of records from sequential and overlapping satellites is a non-trivial problem which is best addressed with careful planning of the observing systems and multiple paths of verification of merged results.



Stratospheric ozone should be recovering, however the signal is small and the observational uncertainty is large.
Ozone satellite data show notable differences which change over time. Appropriate merging determines the scientific conclusions on recovery or continued loss..

Problems in data:

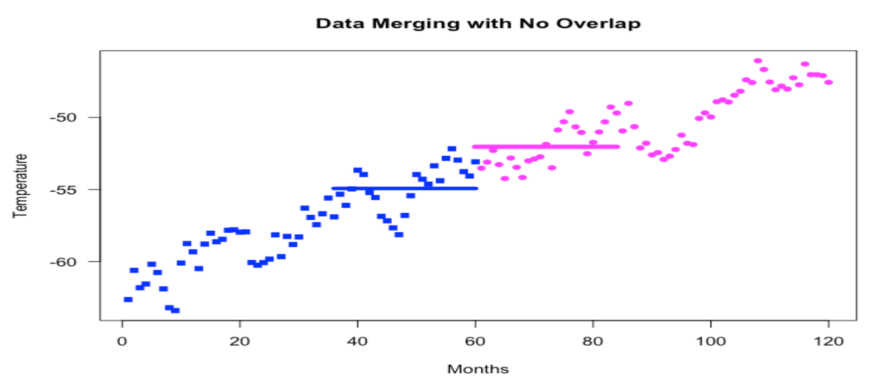
Free, Melissa, et al. "Creating climate reference datasets: CARDS workshop on adjusting radiosonde temperature data for climate monitoring." *Bulletin of the American Meteorological Society* 83, no. 6 (2002): 891-900.

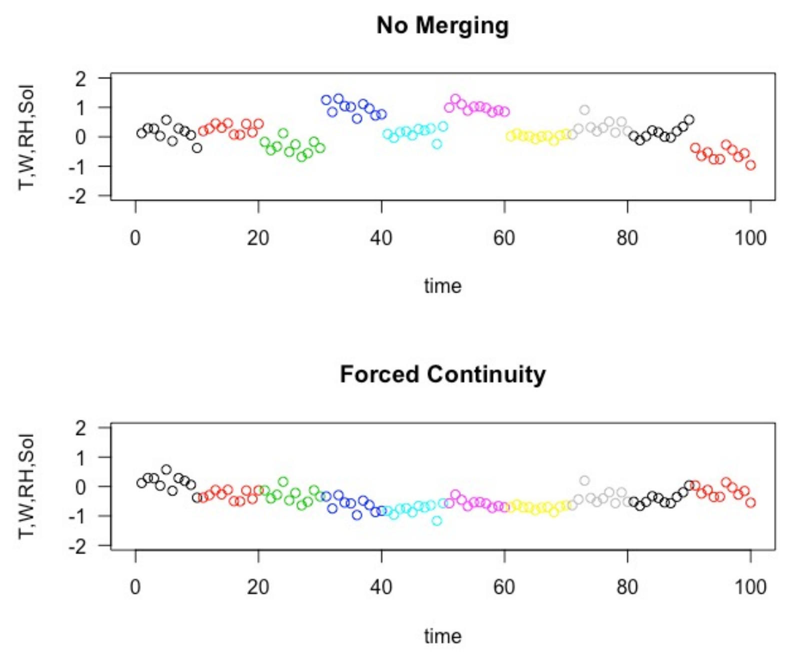
Wang, Ruonan, and Yuanbo Liu. "Recent declines in global water vapor from MODIS products: Artifact or real trend?." *Remote Sensing of Environment* 247 (2020): 111896.

Need for fundamental metrology

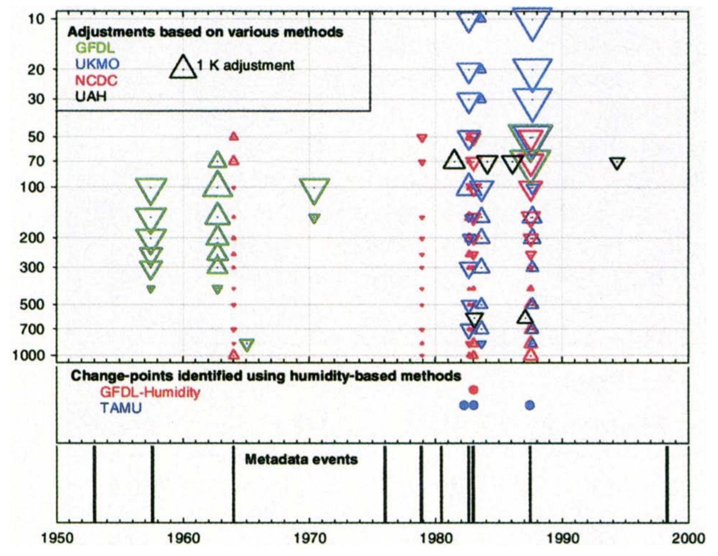
Ohring, George, Bruce Wielicki, Roy Spencer, et al. . "Satellite instrument calibration for measuring global climate change: Report of a workshop." *Bulletin of the American Meteorological Society* 86, no. 9 (2005): 1303-1314.

The Metrological Challenge: Data from different sensors and platforms must be understood well enough to quantify the systematic uncertainty as is relevant for long-term trends.





Without overlap, forced continuity can dominate trend results, depending on the fundamental uncertainty in the observations.



Reasonable, thoughtful approaches for merging can results in very different time series and resultant trends.

TABLE 2. Linear temperature trends from adjusted and unadjusted time series for 1979–97 and their differences (adjusted minus unadjusted), in K decade⁻¹, for GFDL, NCDC, Met Office, and UAH at Darwin, Australia. UAH trends are for MSU4 equivalent temperatures calculated from Darwin radiosonde data. Uncertainty is at the 95% confidence level. Uncertainty in the differences is calculated as twice the square root of the sum of the squares of the standard errors of the individual time series.

	GFDL	NCDC	Met Office	UAH
Unadjusted				
50 hPa	–2.58 ± 1.30	–2.44 ± 1.24	–2.41 ± 1.12	–0.89 ± 0.74
850 hPa	–0.12 ± 0.24	–0.07 ± 0.20	–0.07 ± 0.20	
Adjusted				
50 hPa	–0.62 ± 0.96	–1.60 ± 1.04	–0.47 ± 0.86	–0.24 ± 0.48
850 hPa	–0.10 ± 0.22	–0.27 ± 0.22	–0.09 ± 0.20	
Difference				
50 hPa	1.96 ± 1.61	0.83 ± 1.62	1.94 ± 1.41	0.65 ± 0.88
850 hPa	0.02 ± 0.32	–0.20 ± 0.30	–0.02 ± 0.28	

Note that all observations are within measurement uncertainties for the respective instruments..

Merging Techniques:

Madonna, Fabio, et al. "The new Radiosounding HARMonization (RHARM) dataset of homogenized radiosounding temperature, humidity and wind profiles with uncertainties. Part II: comparisons with reanalysis, satellite data and validation of uncertainties." (2021).Satellite

Weatherhead, Elizabeth C., Jerald Harder, Eduardo A. Araujo-Pradere, Greg Bodeker, Jason M. English, Lawrence E. Flynn, Stacey M. Frith et al. "How long do satellites need to overlap? Evaluation of climate data stability from overlapping satellite records." *Atmospheric Chemistry and Physics* 17, no. 24 (2017): 15069-15093.

Madonna, Fabio, et al. "Radiosounding HARMonization (RHARM): a new homogenized dataset of radiosounding temperature, humidity and wind profiles with uncertainty." *Earth System Science Data Discussions* (2020): 1-38.

New approaches to metrology

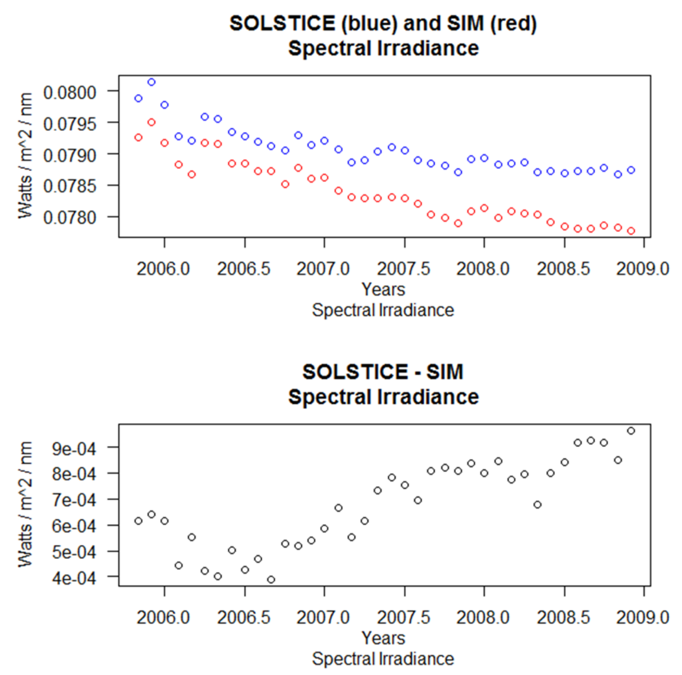
Wielicki, Bruce A., D. F. Young, M. G. Mlynczak, K. J. Thome, S. Leroy, J. Corliss, J. G. Anderson et al. "Achieving climate change absolute accuracy in orbit." *Bulletin of the American Meteorological Society* 94, no. 10 (2013): 1519-1539.

Fox, Nigel, Andrea Kaiser-Weiss, Werner Schmutz, Kurtis Thome, Dave Young, Bruce Wielicki, Rainer Winkler, and Emma Woolliams. "Accurate radiometry from space: an essential tool for climate studies."*Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 369, no. 1953 (2011): 4028-4063.

Proposed Actions: A variety of analytical techniques need to merge metrological information, observations from different sensors and analytical approaches to estimate uncertainty on long-term climate records.

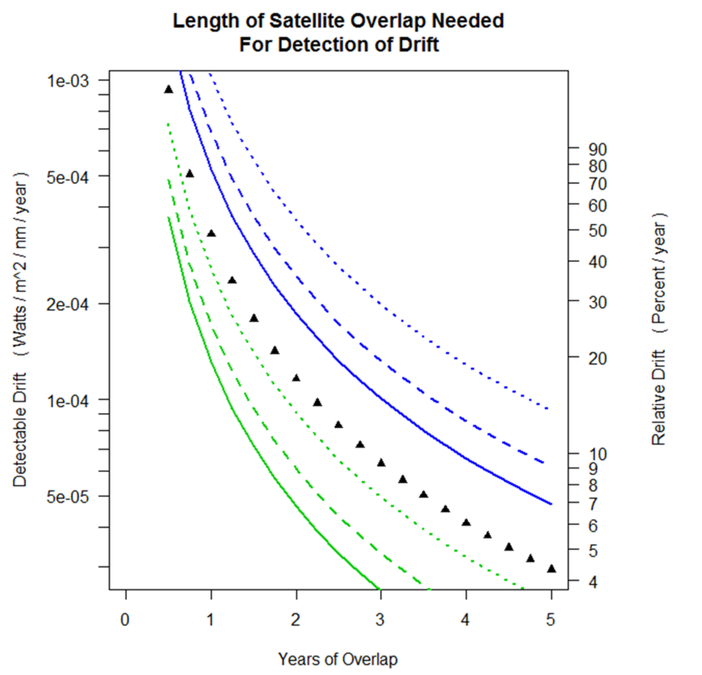
Adjusting for offsets:

- $mean_{differences} = \frac{<sat.1>}{<sat.2>}$
- $SE_{mean} \cong \sigma/\sqrt{n}\ \frac{\sqrt{1+\varphi}}{\sqrt{1-\varphi}}$
- Inverting:
- $Years\ to\ Estimate\ an\ Offset \cong 12 * 1.96^2\ \sigma^2/{Offset\ Limit}^2\ \frac{1+\varphi}{1-\varphi}$
- Note that the time needed to understand an offset is independent of the size of the offset.



Adjusting for drifts:

- $mean_{differences} = \frac{<sat.1>}{<sat.2>}$
- $SE_{mean} \cong \sigma/\sqrt{n}\ \frac{\sqrt{1+\varphi}}{\sqrt{1-\varphi}}$
- Inverting:
- $Years\ to\ Estimate\ a\ Drift \cong 12 * \left[1.96\ \frac{\sigma}{|drift|} * \sqrt{\frac{1+\varphi}{1-\varphi}}\right]^{2/3}$



The fundamental traceability of measurement uncertainty is critically important for reducing observational differences.

Referencing / Anchoring techniques:

Leontiev, A. and Reuveni, Y.: Combining Meteosat-10 satellite image data with GPS tropospheric path delays to estimate regional integrated water vapor (IWV) distribution, Atmos. Meas. Tech., 10, 537–548, https://doi.org/10.5194/amt-10-537-2017, 2017.

Dirksen, R. J., et al.. "Reference quality upper-air measurements: GRUAN data processing for the Vaisala RS92 radiosonde." *Atmospheric Measurement Techniques* 7, no. 12 (2014): 4463-4490.

Diamond, Howard J., et al. "US Climate Reference Network after one decade of operations: Status and assessment." *Bulletin of the American Meteorological Society* 94, no. 4 (2013): 485-498.

Aceves-Bueno, Eréndira, et al.. "The accuracy of citizen science data: a quantitative review." *Bulletin of the Ecological Society of America* 98, no. 4 (2017): 278-290.

Steiner, Andrea K., et al. "Consistency and structural uncertainty of multi-mission GPS radio occultation records." *Atmospheric Measurement Techniques* 13, no. 5 (2020): 2547-2575.

[1] Miami-Dade College