HIATUS IN GLOBAL MEAN TEMPERATURE: TREND PATTERNS INSPECTED WITH MSU/AMSU AND GNSS-RO SATELLITE DATA

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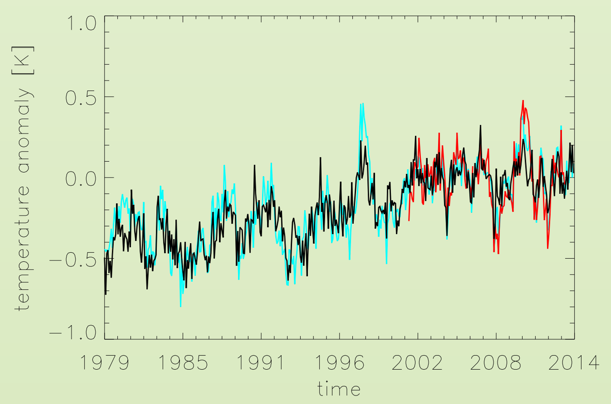
Motivation

Tropospheric temperatures are hard to access in polar regions. In situ measurements are sparse and Microwave Sounding (MSU) measurements have known limitations at polar latitudes. GPS Radio Occultations provides a new independent data set with very good coverage, which is free of calibration issues and independent of model background data. The question is, how can we employ this relatively short data set in climate research?



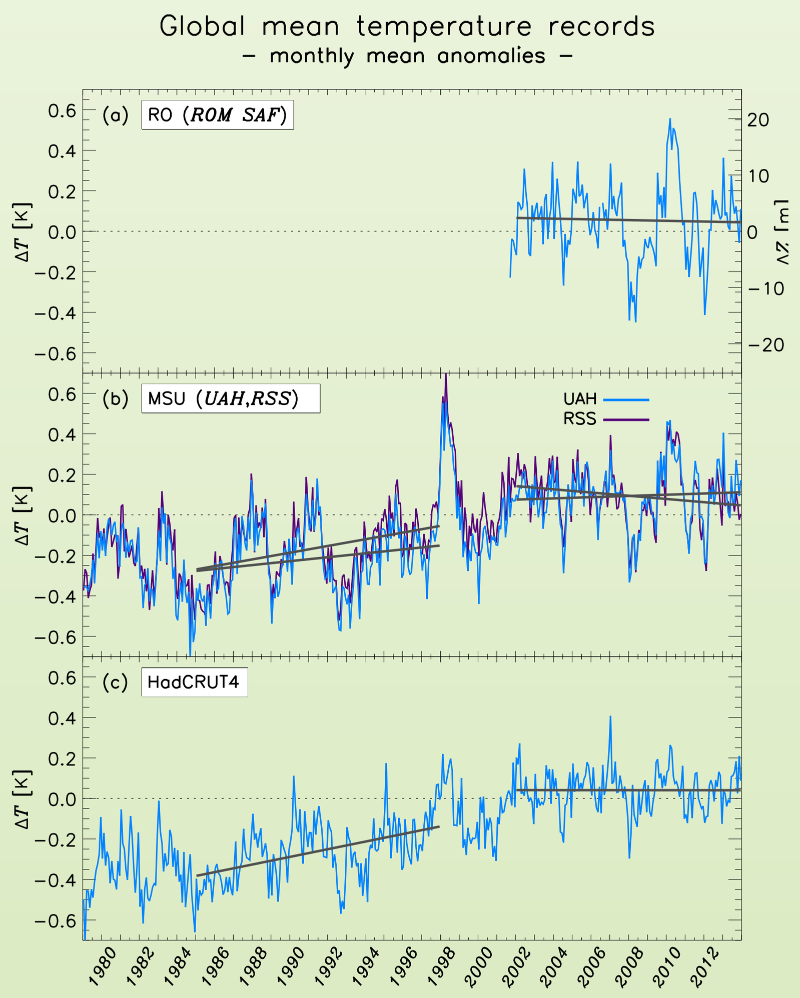
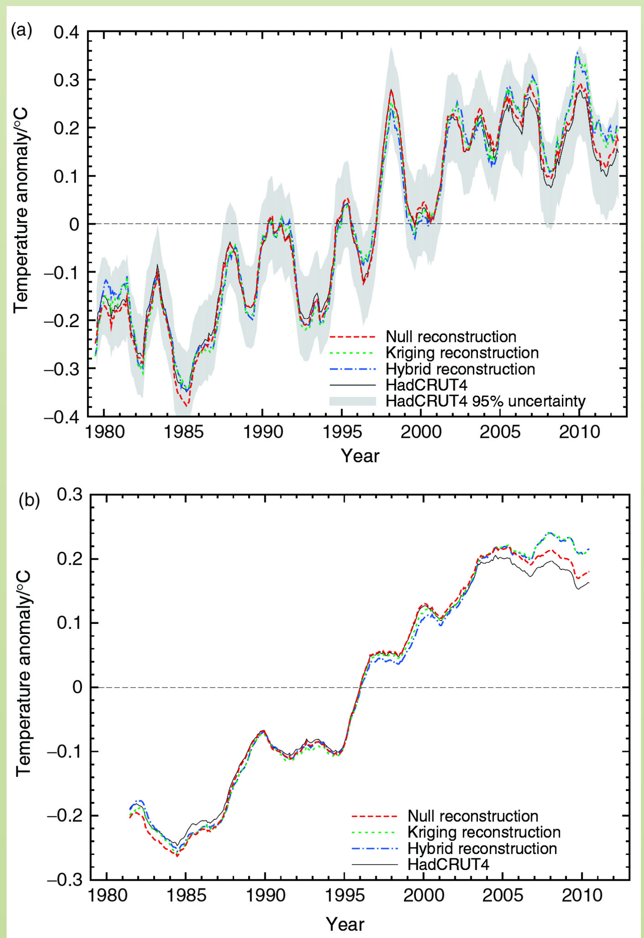


Figure: 1
Left: GissTEMP (black), TLT (UAH) (cyan), and GPS Tropospheric Temperature (red). Annual cycle subtracted. Annual cycle calculated from 1981-2010 (both inclusive) for surface and TLT and 2002-2012 for GPS. All datasets centered to zero in 2002-2012.
Right: Global monthly mean temperature records from 1979 to 2013, with linear fits to the two periods 1985–1997 and 2002-2013.
(**a**) GNSS-RO 300 hPa geopotential heights from the ROM SAF, (**b**) MSU/AMSU global mean lower troposphere temperature from Remote Sensing Systems (UAH,RSS), and (**c**) HadCRUT4 combined land and sea surface data, The first series is shown converted to an approximate mean-tropospheric temperature.

The influence of data gaps on global temperature trends.

In [Cowtan and Way,] the hiatus was investigated in the perspective of data gaps. The study suggests that the HadCRUT4 data underestimates the global temperature trend in the 21st century. When missing data areas (mainly polar) are included through use of MASU/MSU the hiatus is less pronounced. Both the pure kriging and hybrid method which includes MSU data seems to boost the temperature of the polar region in the hiatus period. A trend of 0.119 K/decade from 1997 to 2012 is obtained with filling data gaps as opposed to 0.046 K/decade in the original HadCRUT4 data.



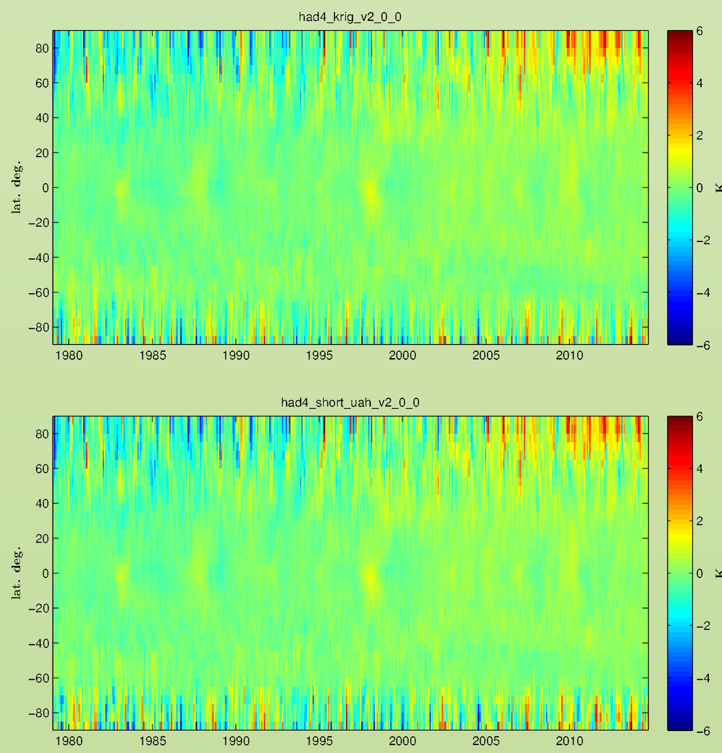


Figure: 2
Left Global temperature anomaly from [Cowtan and Way,]: "Comparison of null, kriging and hybrid [ed. i.e. including surface temperatures based on model using MSU data as input] reconstructions of the HadCRUT4 data over the period January 1979–December 2012. The data are shown with (a) a 12 month moving average and (b) a 60 month moving average. The original HadCRUT4 record before re-baselining of the map series (but offset to match the other series) is also shown, including uncertainty bounds in the upper figure."
Right Latitude/time plots Kriging and hybrid reconstructions downloaded from Cowtan and Ways webpage:
http://www-users.york.ac.uk/ kdc3/papers/coverage2013/series.html

The hiatus phenomenon

Since the large El Nino in 1997-1998 the land and sea surface temperatures, compiled in the HadCRUT4 and GISS data sets, have remained constant or at least only increased moderately. The stagnation of measured surface temperatures in the 21'st century has been widely referred to as a "hiatus period" or just "the hiatus" e.g. [Trenberth and Fasullo,]. The hiatus has been attributed to several causes in recent studies, including decrease in stratospheric water vapor content [Solomon et al.,], ocean uptake of energy not represented in the models and [Balmaseda et al.,],surface winds in the Pacific which drive overturning mixing, being incorrectly added to the models. Recently the hiatus phenomenon has been analysed in the light of data-coverage gaps [Cowtan and Way,]. Gaps have an impact when regions that are rapidly warming (or cooling) are omitted from the observed data, see figure 2.

Trends distributed on latitude

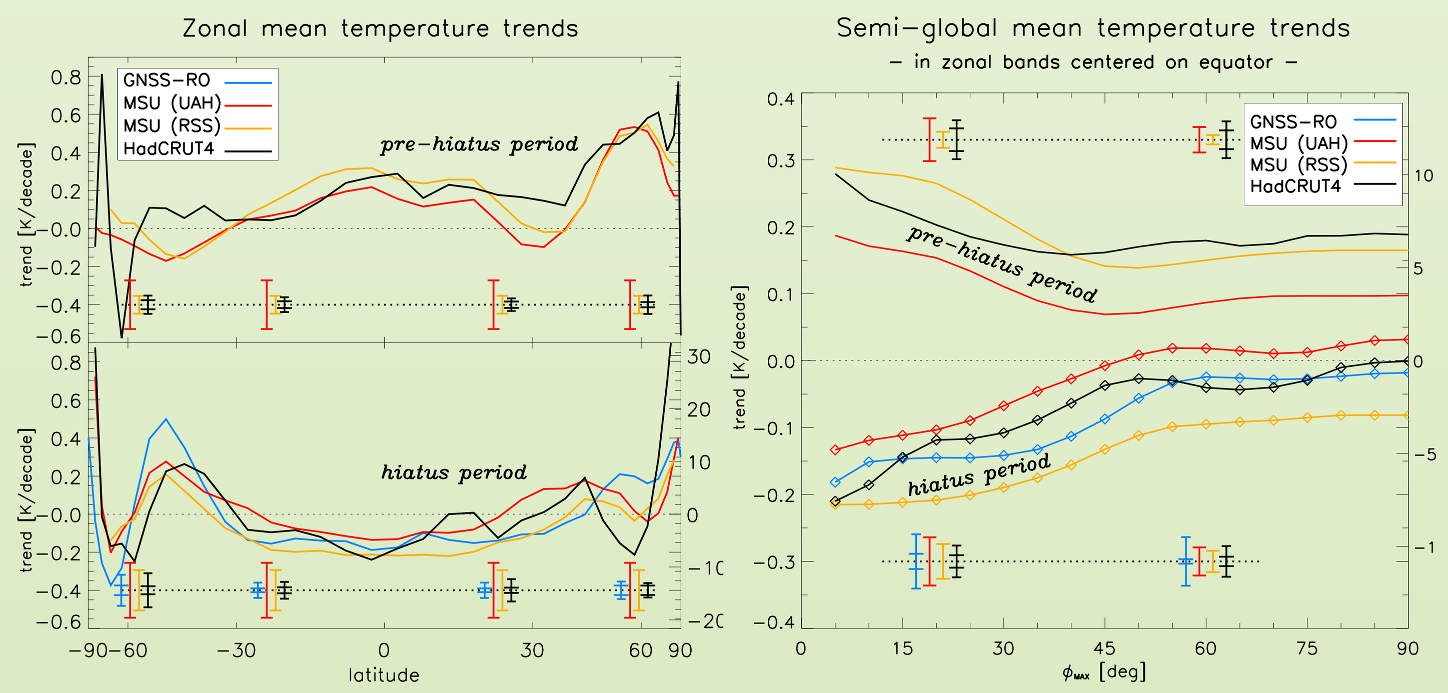


Figure: 3
Left: Decadal trends of lower tropospheric temperature in 5-degree latitude bands for the pre-hiatus period 1985–1997 and the hiatus period 2002–2013.
Right: Satellite-based tropospheric temperature trends as function of the width, $2\lambda_{max}$, of a latitude band (centered at the Equator), during pre-hiatus (1985-1997) and hiatus (markers;2002-2013) time periods. Inner error bars indicate the $\pm 1\sigma$ uncertainty estimates for the slopes, based on the uncertainty of the measurements (sampling and calibration uncertainty), outer error bars also include structural uncertainty (difference between various data centers and algorithms).

Use of ROM SAF gridded climate data

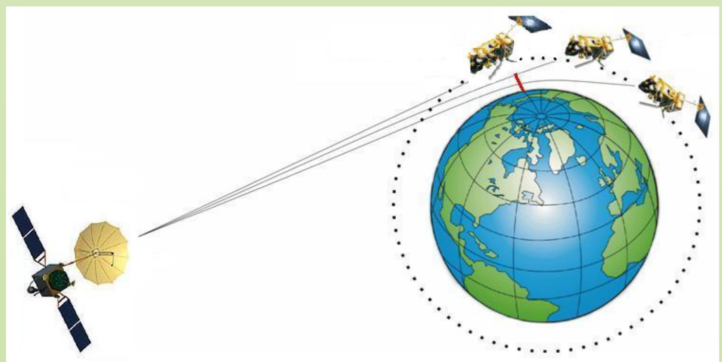


Figure: 4 GPS RO heuristics.

The geopotential height of a stratospheric pressure level can be retrieved with high accuracy from Radio Occultations measurements. The measured RO *bending angle* is converted to a *refractivity* profile, $N(h)$, near the tangent point of the occultation. The geometric height h is related to the geopotential height through the relation $z(h) = \phi(h)/g$. Assuming the gas-law and hydrostatic equilibrium, one can calculate the pressure at a given stratospheric height

$$p(h) = \int_h^\infty \frac{Ng}{k_1 R} dh \tag{1}$$

where R is the universal gas constant and $k_1 = N\frac{T}{p}$ is a known constant relating refractivity to density of dry air.

Relating geopotential height to mean tropospheric temperature

Under rather general assumptions, it is found that

$$z(p) = z_s + \frac{R}{\mu_d g} \int_p^{p_s} T_v(p') d\ln p' \tag{2}$$

where T_v is the virtual temperature

$$T_v = \frac{T}{1 - \frac{e}{p}(1 - \frac{\mu_w}{\mu_d})} \tag{3}$$

R is the universal gas constant, $\mu_{w/d}$ is the molar mass of water/dry air, and e is the partial pressure of water vapour. I.e. the geopotential height of a pressure surface is proportional to the mean T_v of the atmospheric layer beneath it. We use this 'gas-thermometer' concept to estimate tropospheric temperature trends since 2002. The data were obtained from EUMETSAT's ROM SAF as gridded zonal monthly means.

Conclusions

The temperature calculated from GPS-RO geopotential height matches the MSU tropospheric temperature time series and trends in the hiatus period, and therefore our analysis strengthens the case for using MSU/AMSU TLT in polar regions. However, when partitioning the trends of all 4 data sets into different latitude bands we do not observe an impact of omitting polar data (Figure 3 right panel). We find that the main reason for the absence of global warming in 21'st century must be found in the tropics. This is not contradicting Cowtan and Way, who analysed a more extended hiatus time interval from 1997-2012.

Zonal means

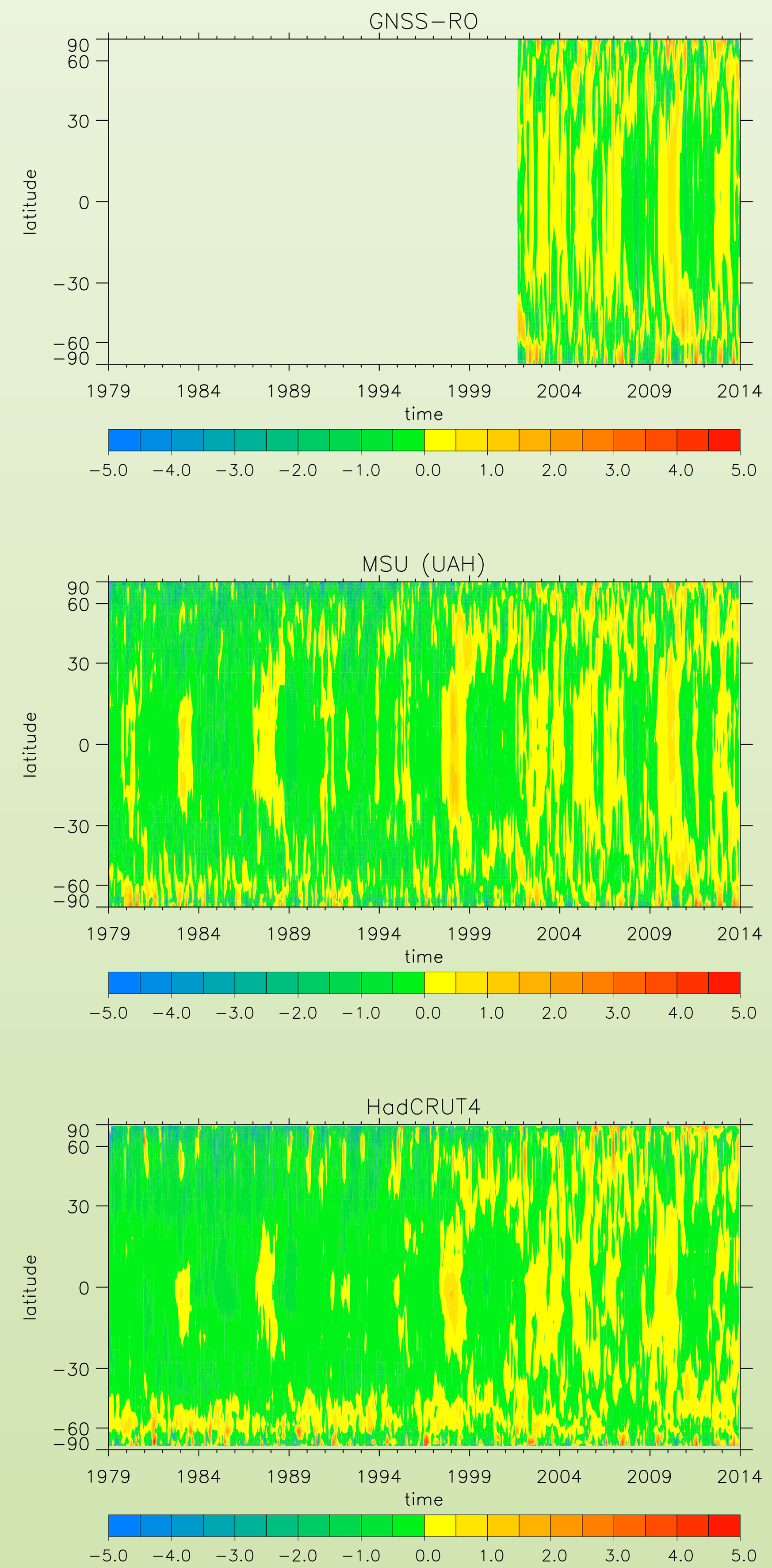


Figure: 4
Zonal mean temperature anomaly as function of time and latitude from GPS RO, MSU (UAH) TLT and HadCRUT4. Annual cycle subtracted. Annual cycle calculated from 1981-2010 (both inclusive) for surface and TLT and 2002-2012 for GPS. All datasets centered to zero in 2002-2012. Latitudes scaled to preserve area.

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  40(9):1754–1759.
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The EUMETSAT Network of Satellite Application Facilities
ROM SAF Radio Occultation Meteorology
dmi