GEOPOTENTIAL HEIGHTS AND MEAN TROPOSPHERIC TEMPERATURES

Hans Gleisner

Danish Meteorological Institute

Tropospheric temperature measurements

– current techniques –

Measurement techniques:

- radiosondes
- microwave sounding (MSU/AMSU/ATMS)
- infrared sounding
- GNSS radio occultation

RO mean tropospheric temperatures

Hydrostatic equilibrium

$$\frac{dp}{dz} = -\frac{pg_0}{RT}$$

Integration from pressure *p* down to surface:

$$z(p) - z_s = \int_p^{p_s} \frac{RT(p')}{g_0} d\ln p'$$

The gas constant, *R*, changes slightly with water vapour. Rewriting in terms of universal gas constant (*R**) and molar mass (μ_d) gives

$$z(p) - z_s = \frac{R^*}{\mu_d g_0} \int_p^{p_s} \frac{T(p')}{(1 - \frac{e}{p}(1-\epsilon)} dlnp'$$

Conclusion: geopotential height measures mean (virtual) temperature from the surface up to the given pressure level, approximately volume-weighted.

RO mean tropospheric temperatures

Geopotential height and mean temperature :

$$z(p)-z_s = -R^* T_v / \mu_d g_0 \cdot \ln p/p_s \qquad T_v = \int_{p_s}^{p} T_v(p)\, d\ln p \;/$$

where

For standard values of the constants, and at standard surface pressure, a
1 degree mean temperature increase of the atmospheric column raises the
100, 200, and 300 hPa pressure surfaces by 68, 47, and 36 meters, respectively.

Issues to consider:

- is the atmosphere “dry” down to the selected isobar: difference between p and p_{dry}
- surface pressure variability (1 hPa in surf. Pressure => 7 meter in geopot. height)
- use of virtual temperature instead of physical temperature

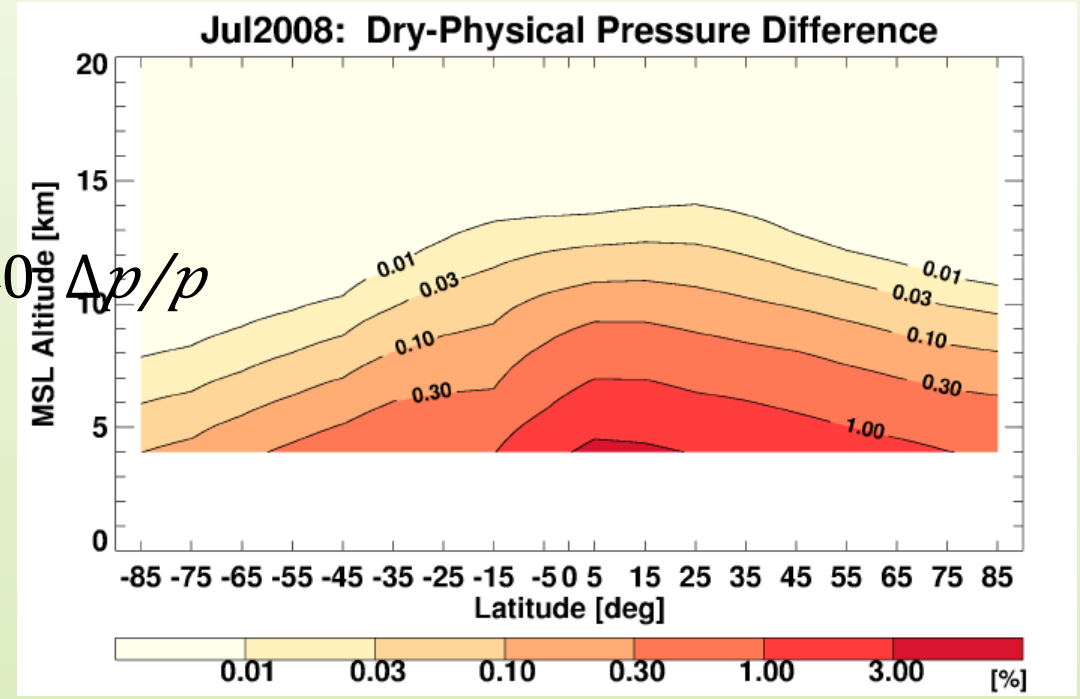
RO mean tropospheric temperatures

– pressure vs. dry pressure –

Differentiation gives:

$$\Delta z = -R\uparrow * T\downarrow v / \mu\downarrow d \, g\downarrow 0 \, \Delta p/p$$

$$T\downarrow v = 250 \text{ K}$$



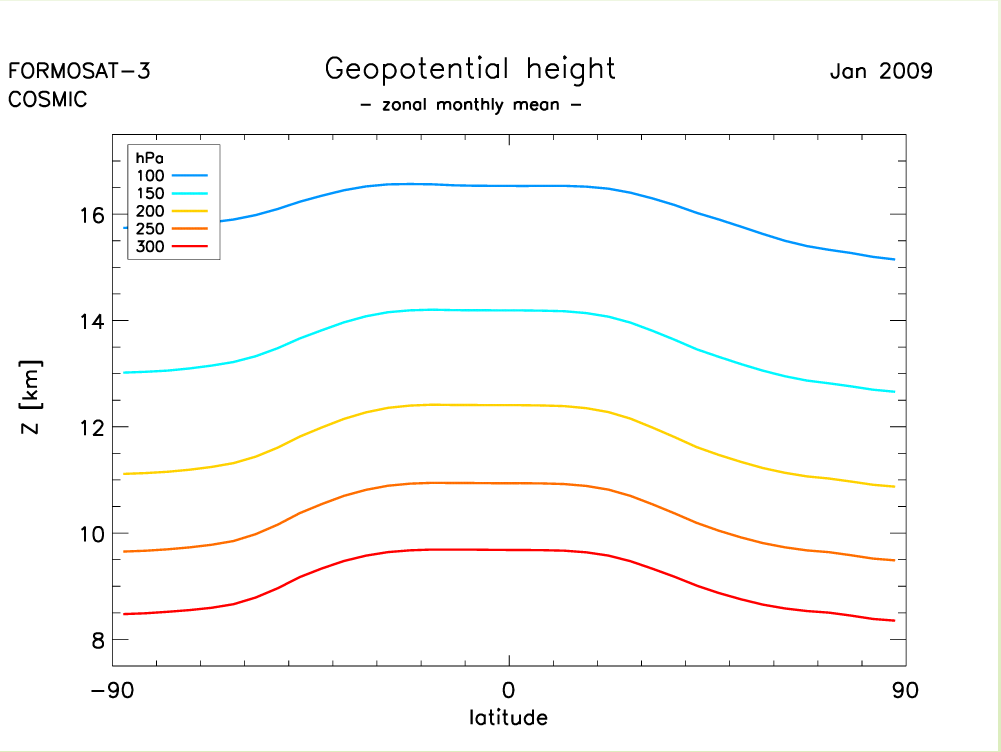
From *Scherllin-Pirscher et al., AMT, 2011.*

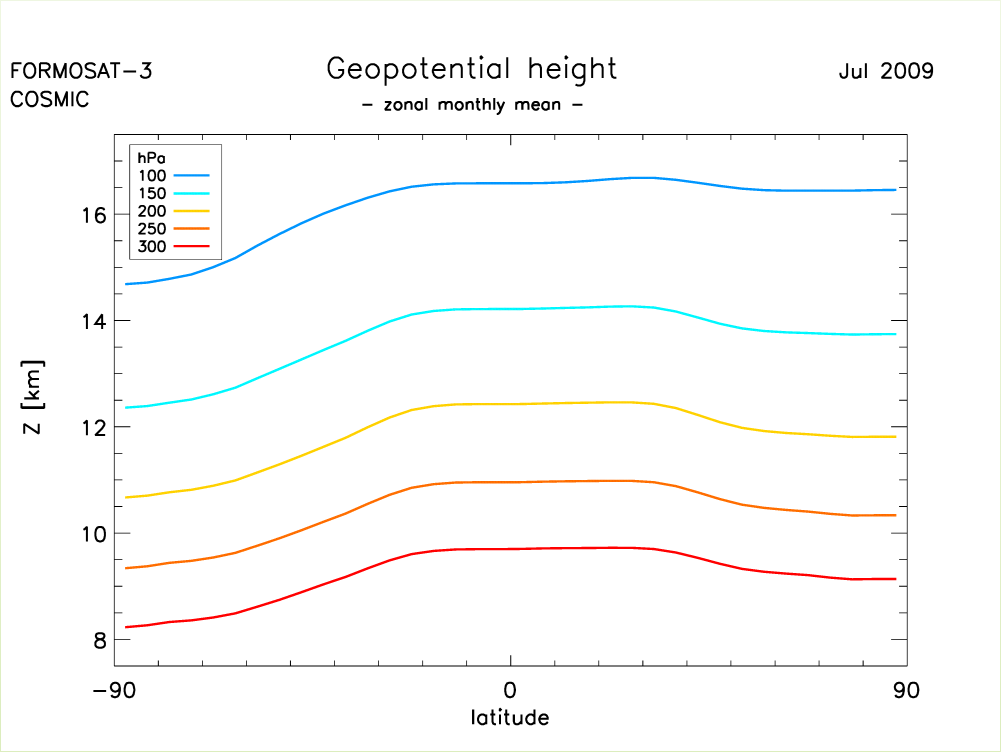
A 0.1% difference p-p_{dry} corresponds roughly to 7 meters.

This difference is found at 10 km in the tropics, and at 4-8 km near the poles.

Geopotential height of isobars

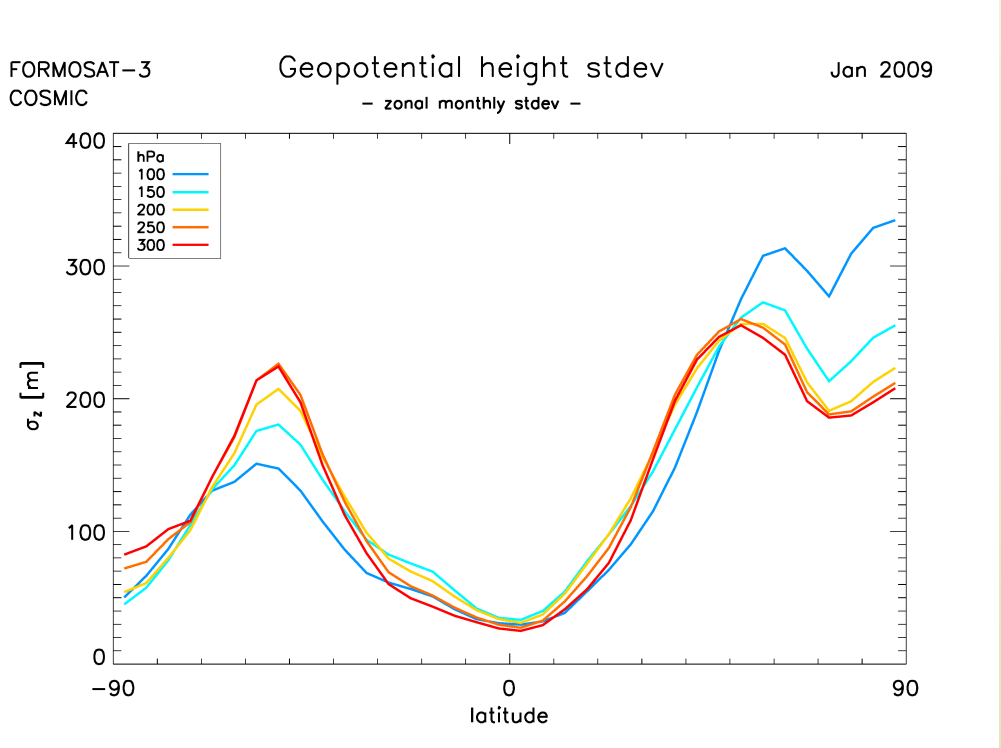
– zonal monthly means –

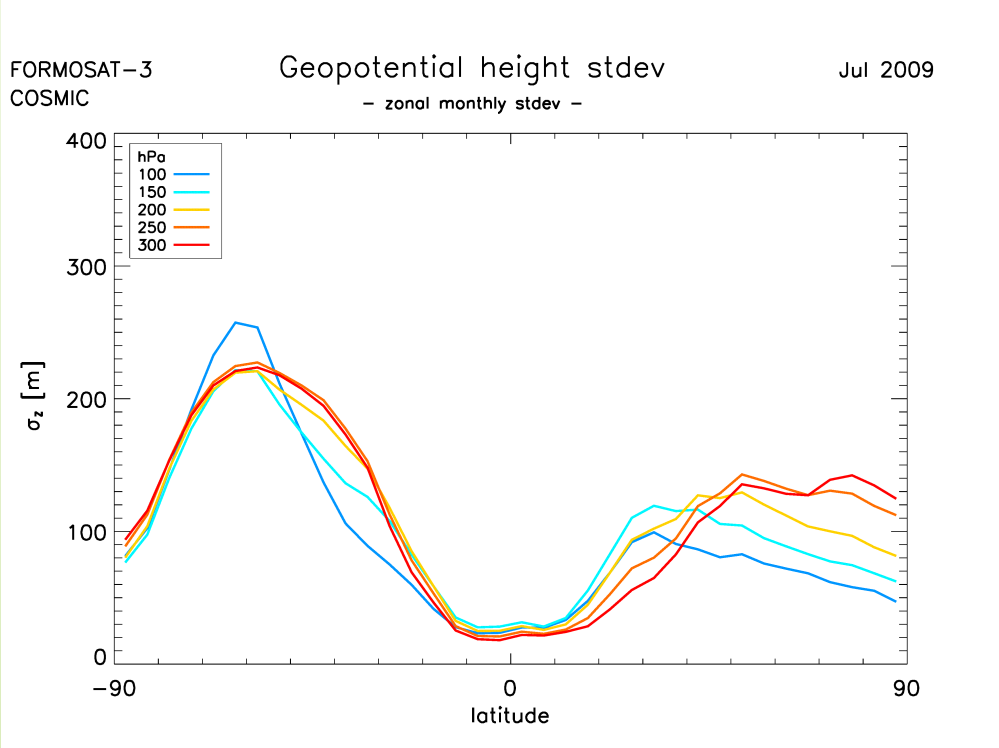




300 hPa isobar: around ~9.5 km at low latitudes and ~8-9 km at high latitudes.
Differences p-p_{dry} at 300 hPa around 0.1% near equator and 0.01% near poles, corresponds to geopotential height errors of 5-10 meter and 1 meter, respectively.

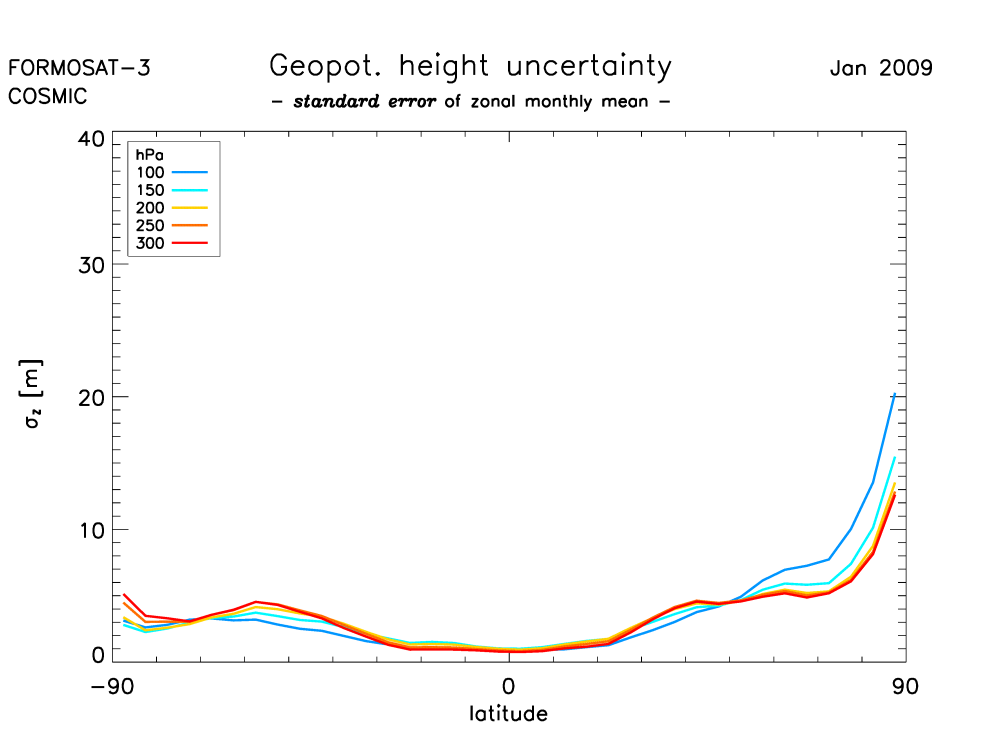
Geopotential height of isobars
– zonal monthly stdev –

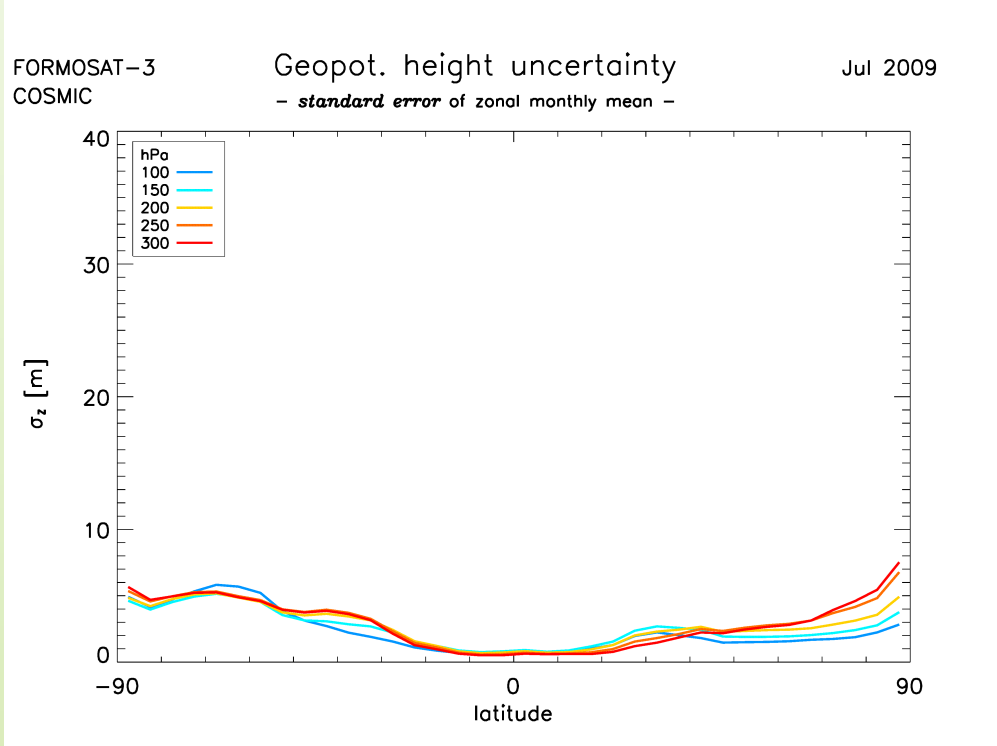




Geopotential height of isobars

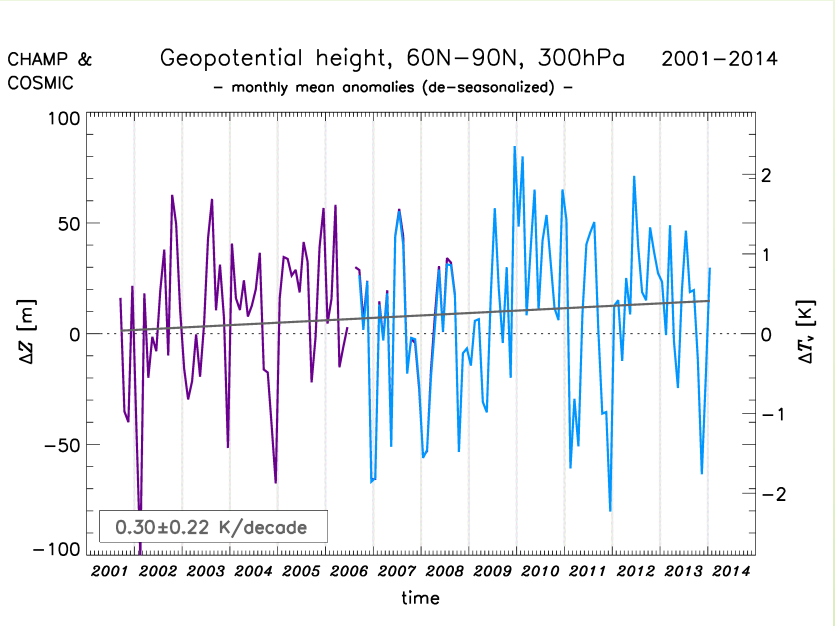
– standard error of zonal monthly means –

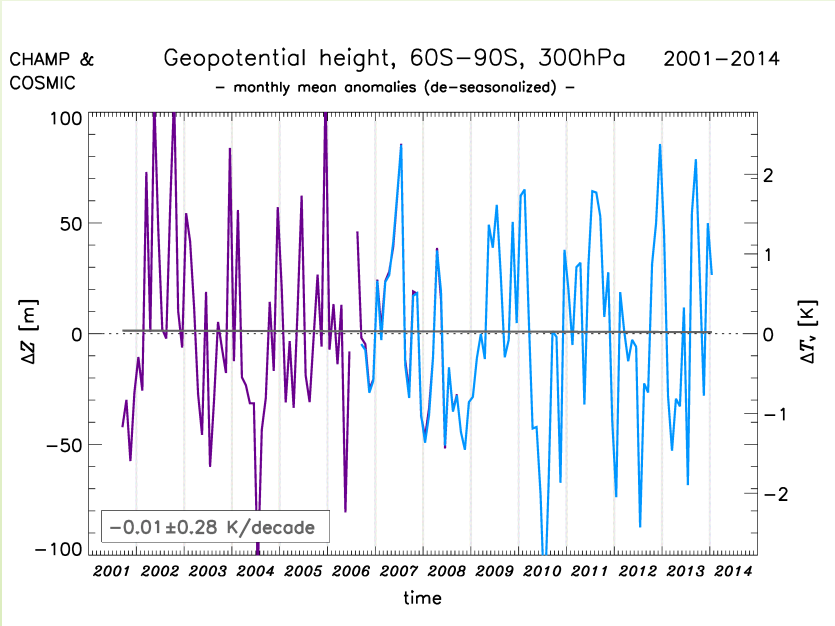




Geopotential height of 300 hPa

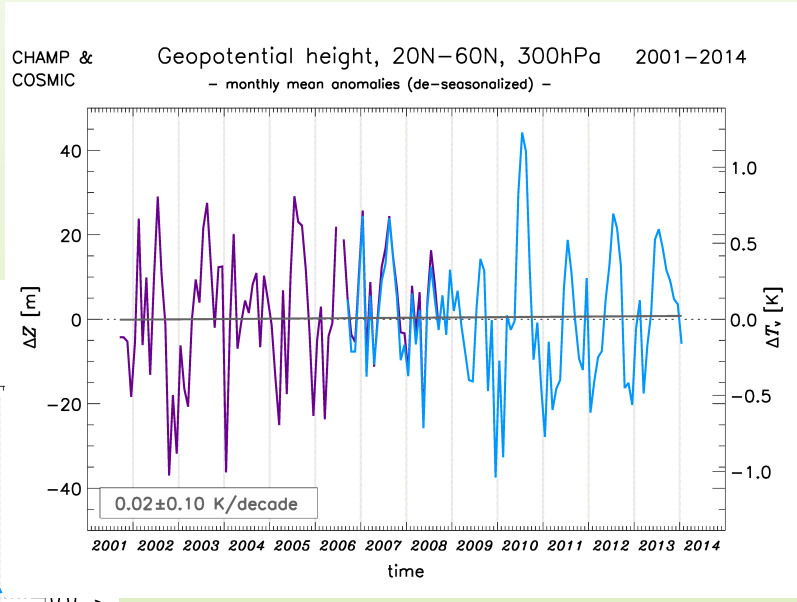
– CHAMP & COSMIC, high latitudes –

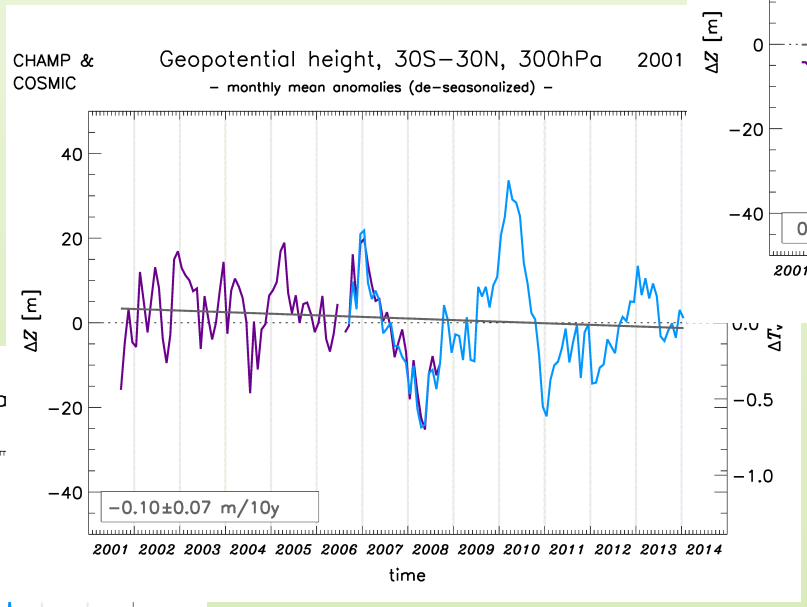


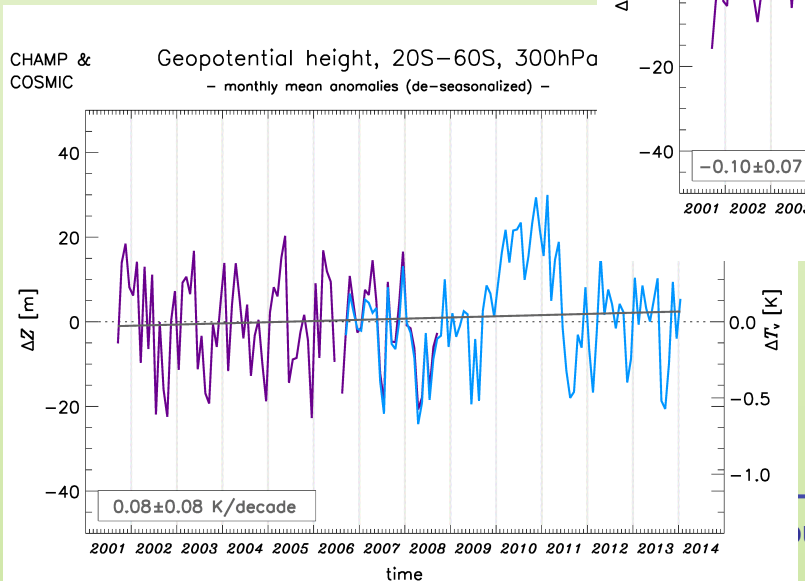


Geopotential height of 300 hPa

– CHAMP & COSMIC, equatorial & mid-lats –

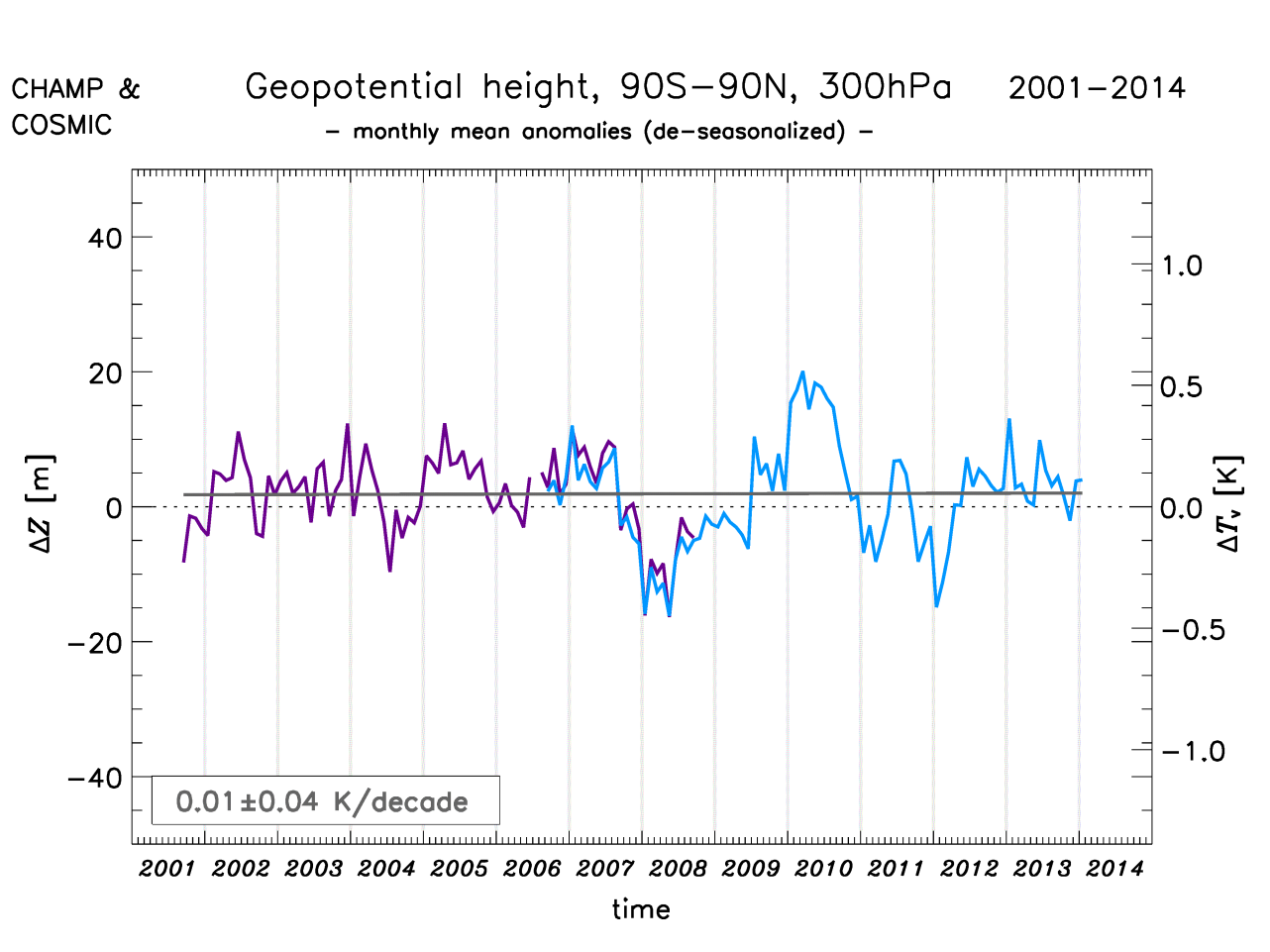






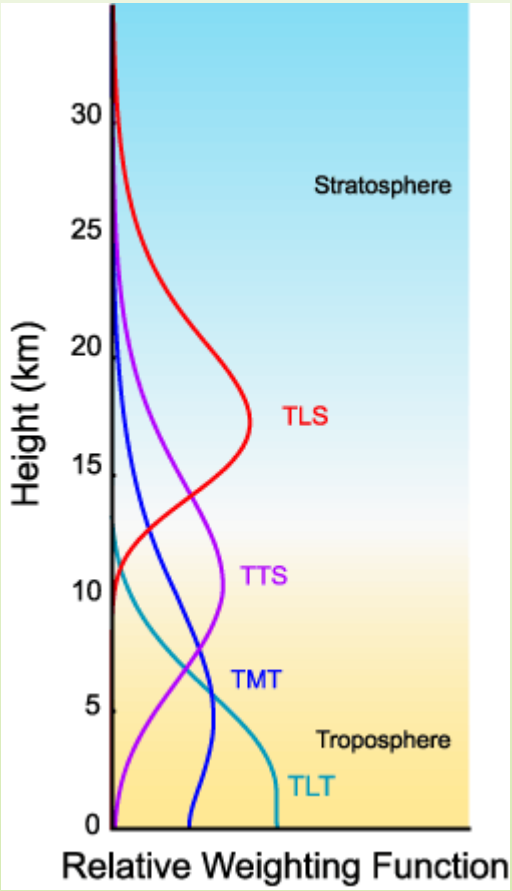
Geopotential height of 300 hPa

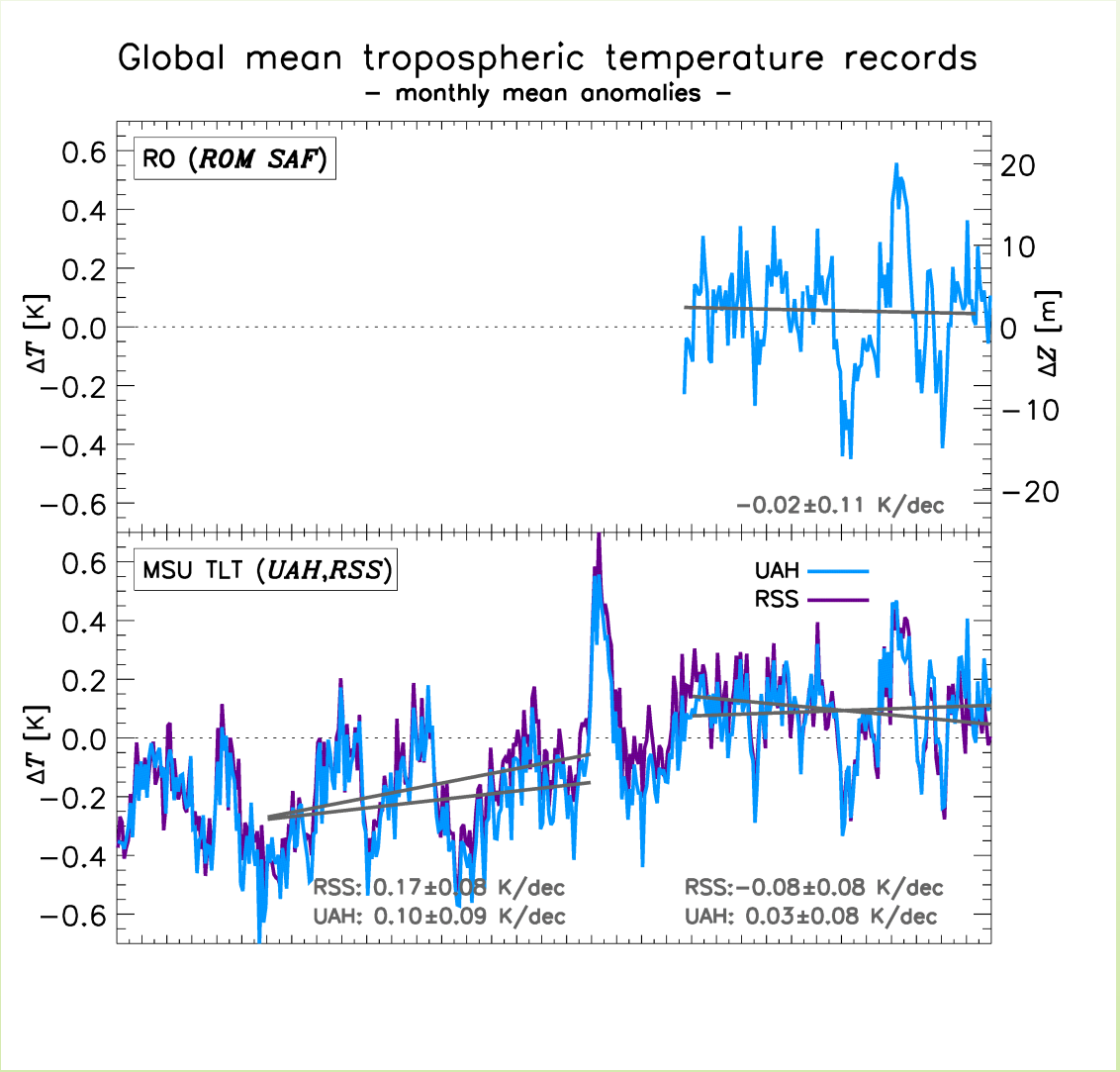
– CHAMP & COSMIC, global –



RO and MSU/AMSU

– bulk tropospheric temperatures –

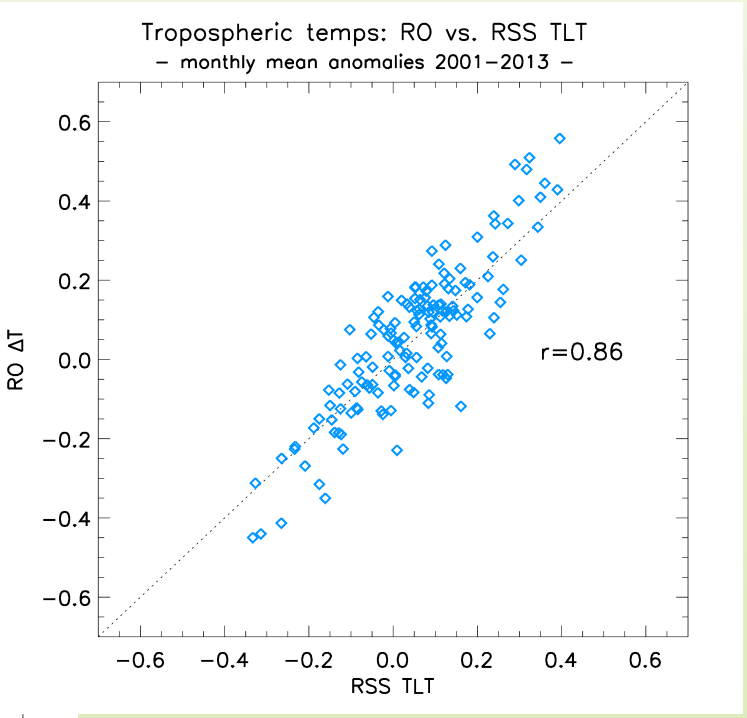




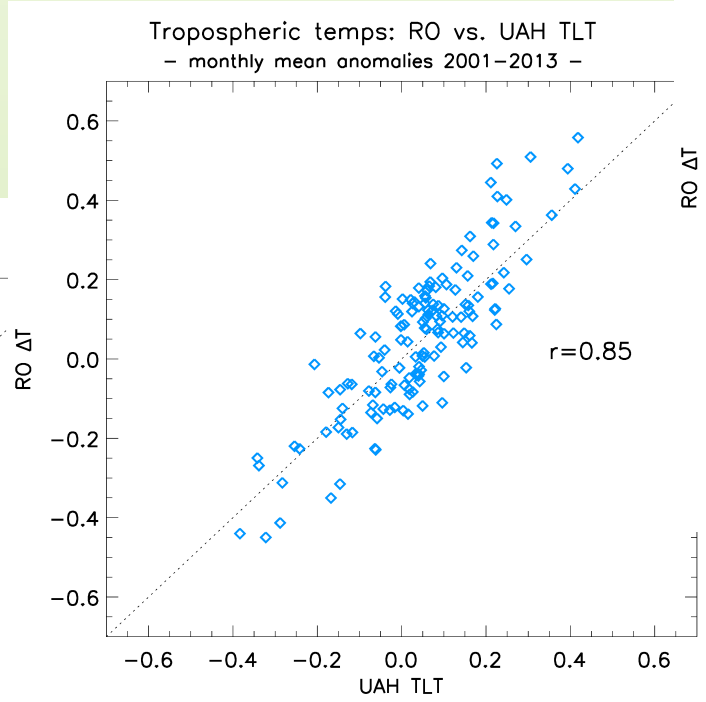
RO and MSU/AMSU

– bulk tropospheric temperatures –

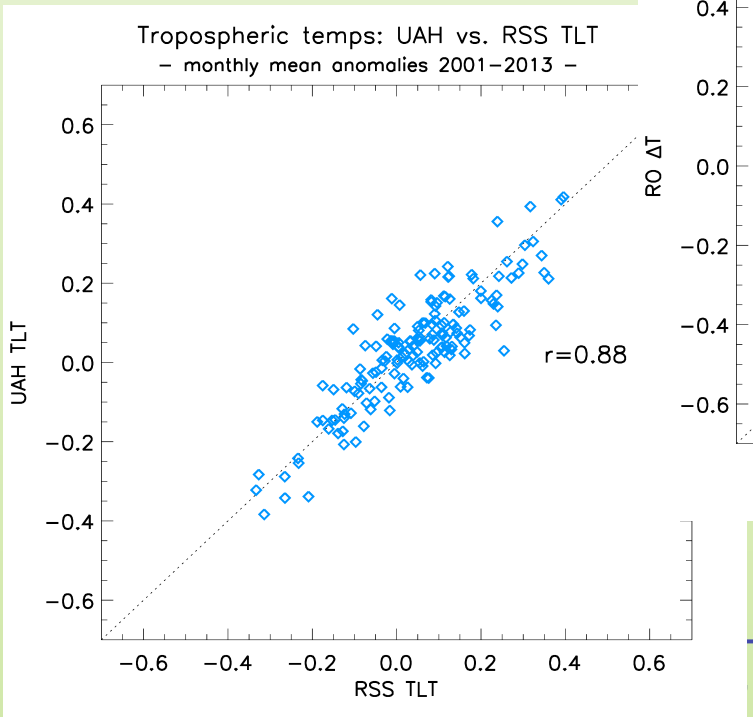
RO vs RSS TLT



RO vs UAH TLT



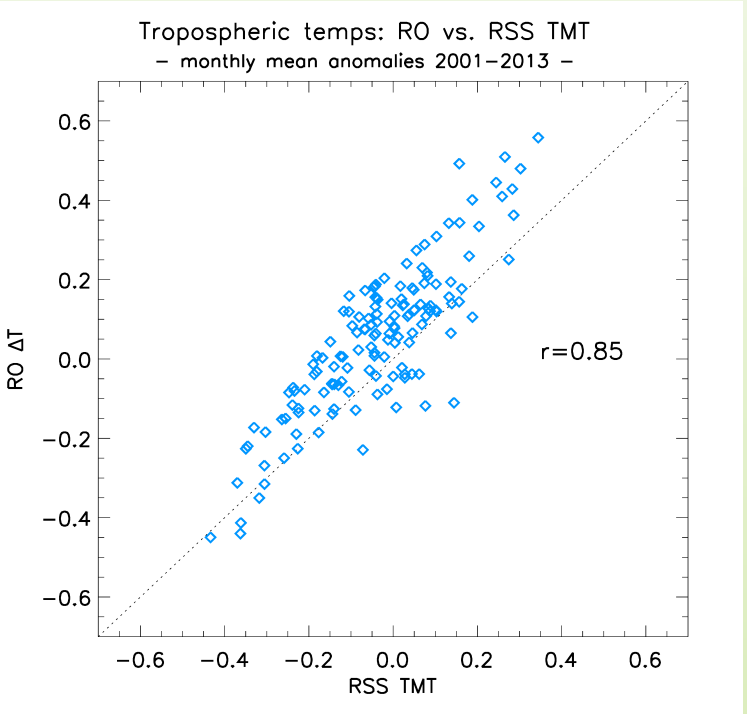
UAH vs RSS TLT



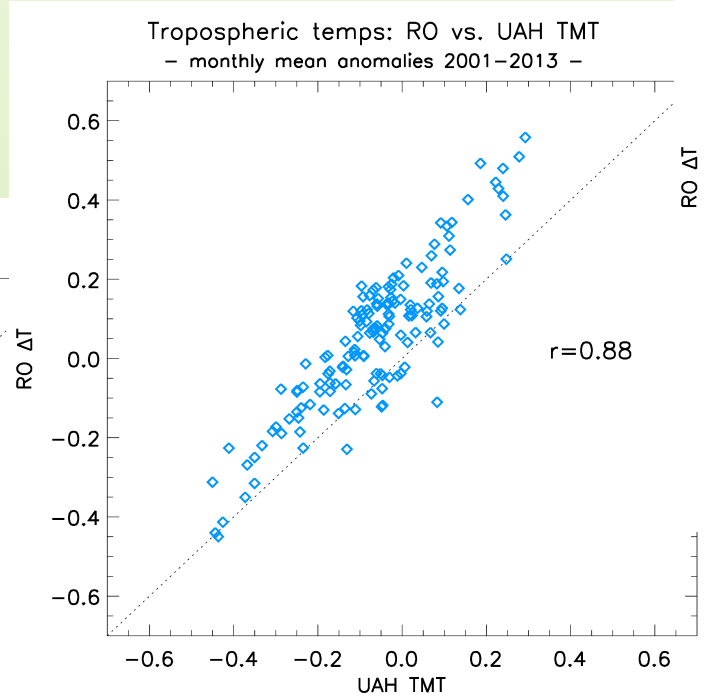
RO and MSU/AMSU

– bulk tropospheric temperatures –

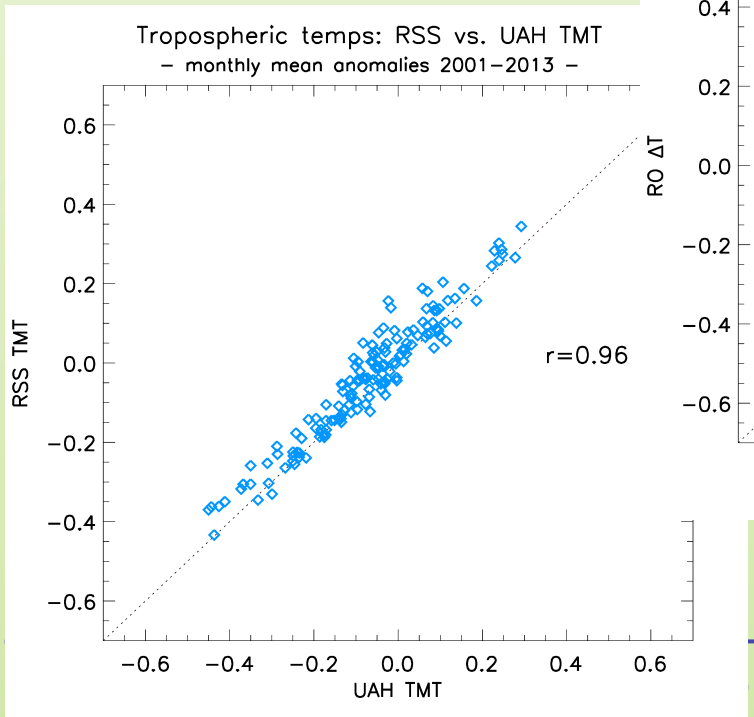
RO vs RSS TMT



RO vs UAH TMT

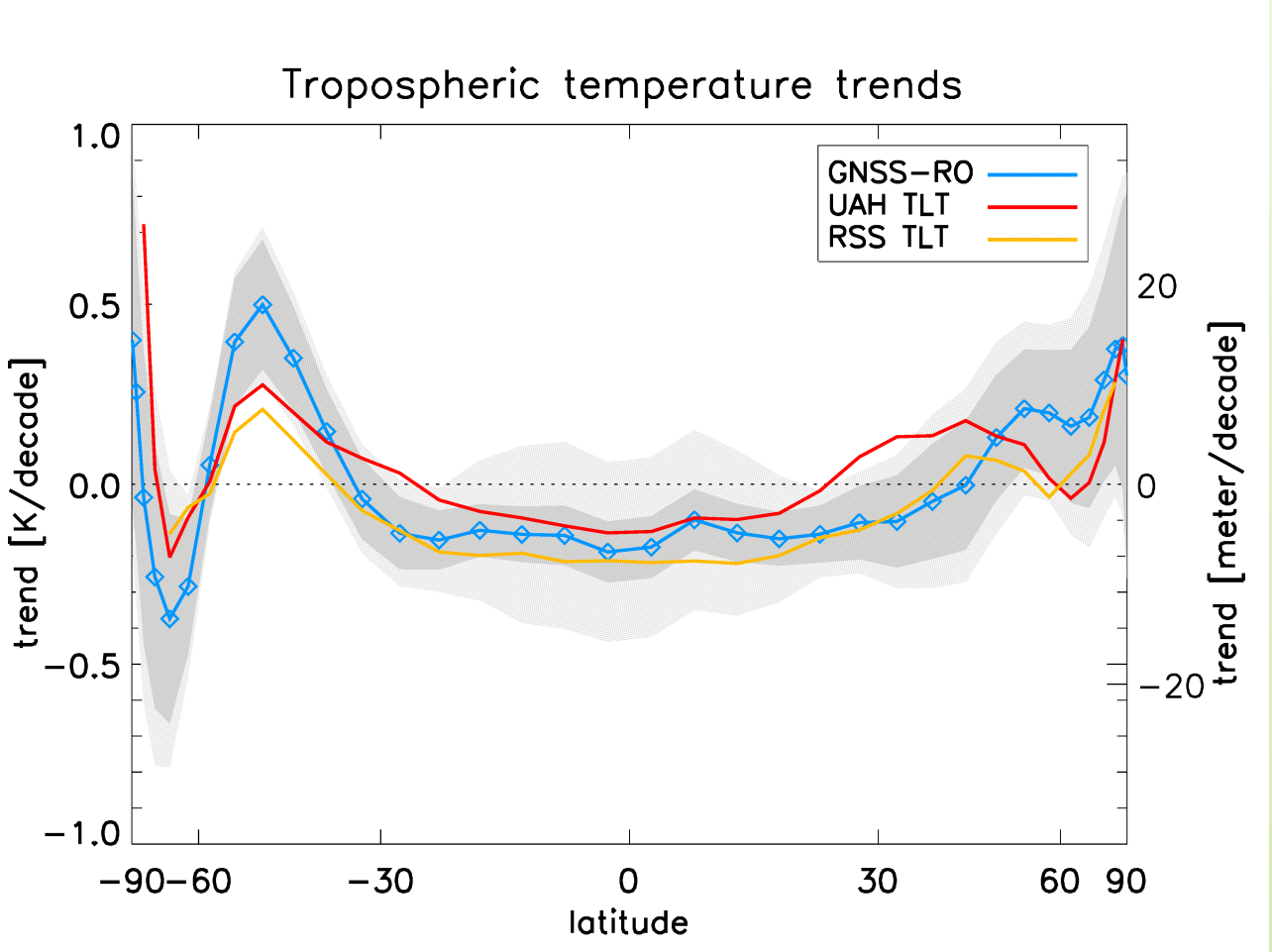


UAH vs RSS TMT



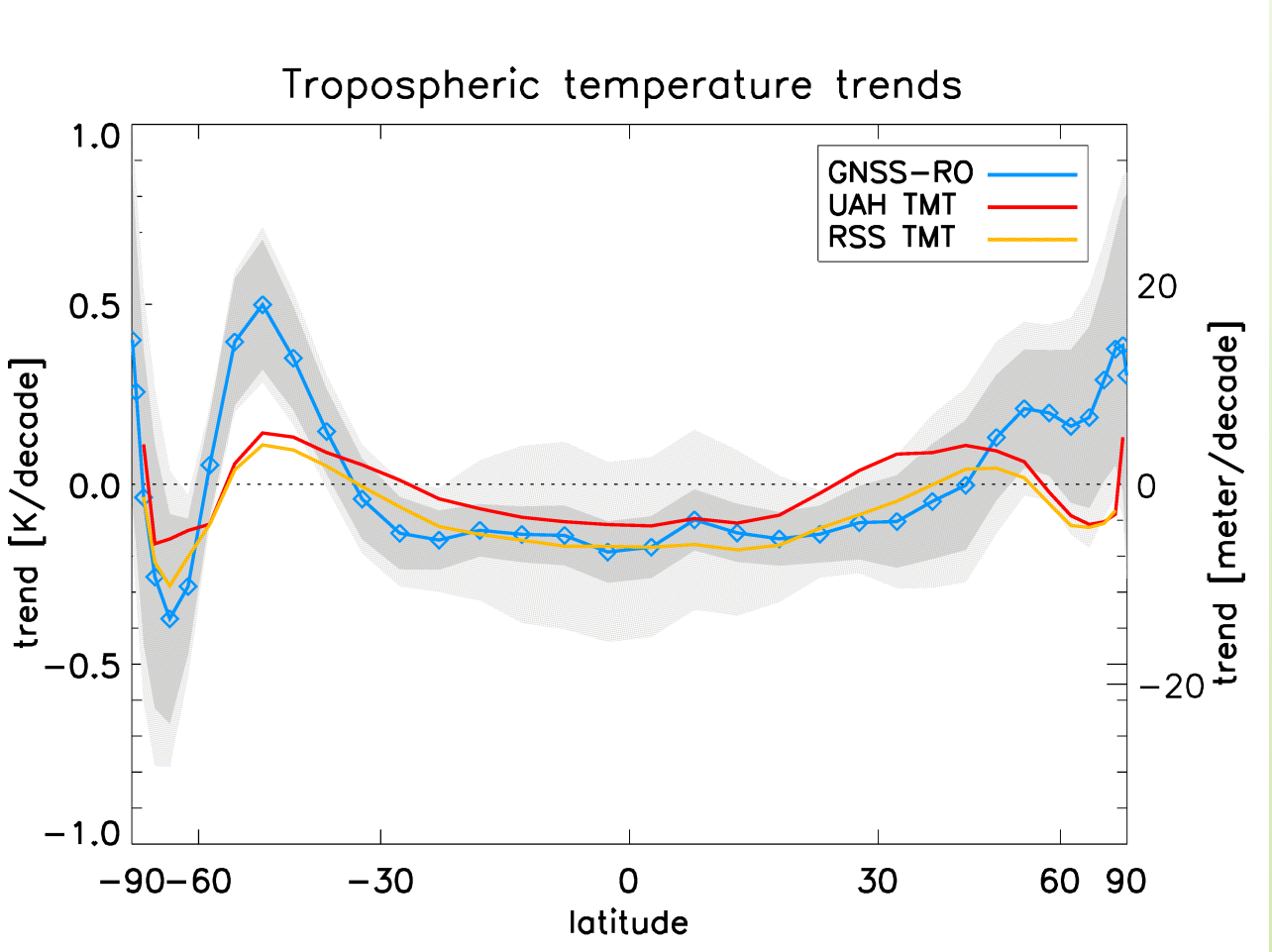
RO and MSU/AMSU

– temperature trend in latitude bands –



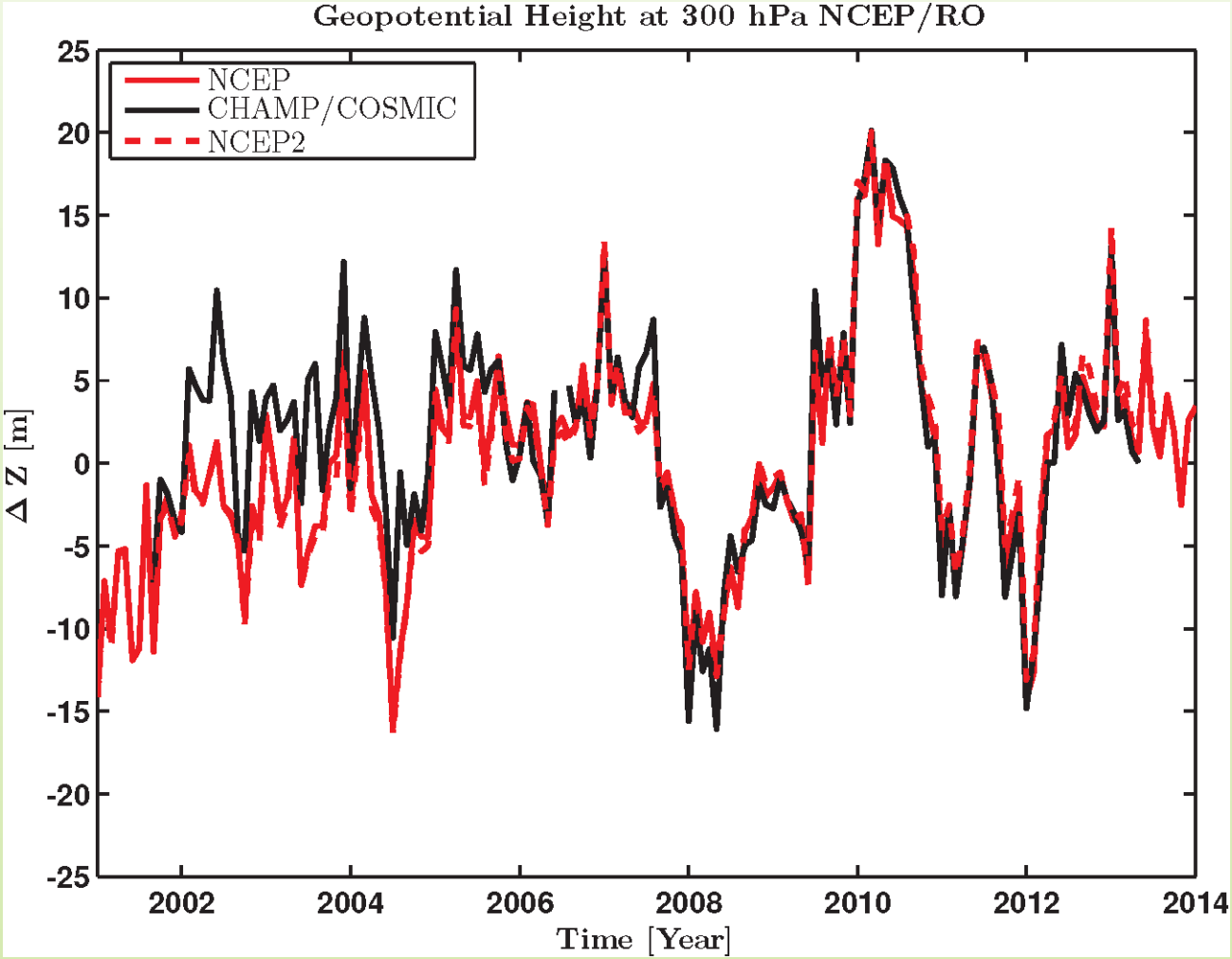
RO and MSU/AMSU

– temperature trend in latitude bands –



Geopotential height of 300 hPa

– CHAMP/COSMIC & NCEP, global –



Some conclusions

- geopot. heights can be used to quantify thermal expansion of troposphere
- systematic error from p-p_{dry} differences: limited to above ~300 hPa
- random error from surface pressure variability
- good agreement with MSU/AMSU TLT and TMT
- qualitative agreement with MSU/AMSU TLT and TMT trends
- excellent agreement between CHAMP and COSMIC during overlap periods