Differences in trends and anomalies of upper-air observations from GPS RO, radiosondes, and AMSU

Florian Ladstädter Hallgeir Wilhelmsen Barbara Angerer
Andrea K. Steiner

Wegener Center and IGAM/Institute of Physics,
University of Graz, Austria
florian.ladstaedter@uni-graz.at

EGU (April 26, 2017)

Overview

GPS RO, RS, and (A)MSU data

Comparing GPS RO, RS, and (A)MSU

Trends

Datasets—(A)MSU, RS, and GPS RO

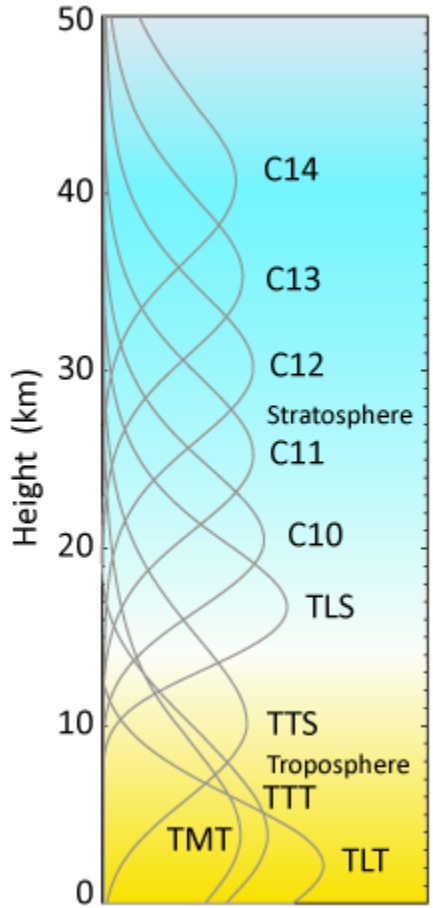
- (A)MSU: Microwave nadir sounder:
  + Long time series, good spatial coverage
  − need sophisticated calibration, low vertical resolution
- Radiosondes: In-situ balloons:
  + Long time series, high vertical resolution
  − sparse spatial coverage, lots of changes in instrumentation
- GPS Radio Occultation: Limb sounder:
  + Good global coverage, high vertical resolution, no inter-mission calibration
  − Short time series (2001–ongoing), influenced by background fields in low and high altitudes

GPS RO in the UTLS

- GPS RO temperatures are best within 8 – 25 km
- RO good for validations of lower stratosphere (LS) temperature products and for LS trend analyses (but: short time period. . .)
- Use WEGC RO OPSv5.6 temperatures to compare to radiosonde and models, and to AMSU TLS channel (MSU channel 4)
- For radiosondes, use Vaisala RS80/90/92/41 from the ERA-I archive
- For AMSU, use calibrated, gridded monthly data from RSS, STAR, UAH

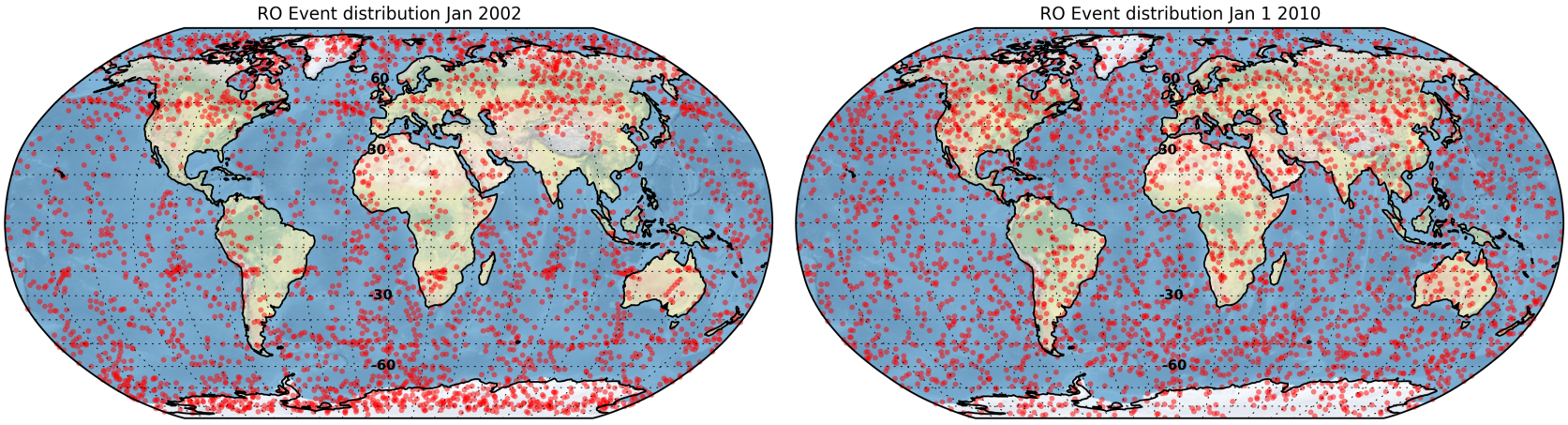
Methods—Climatologies, Sampling Error, MSU-equivalent temperatures

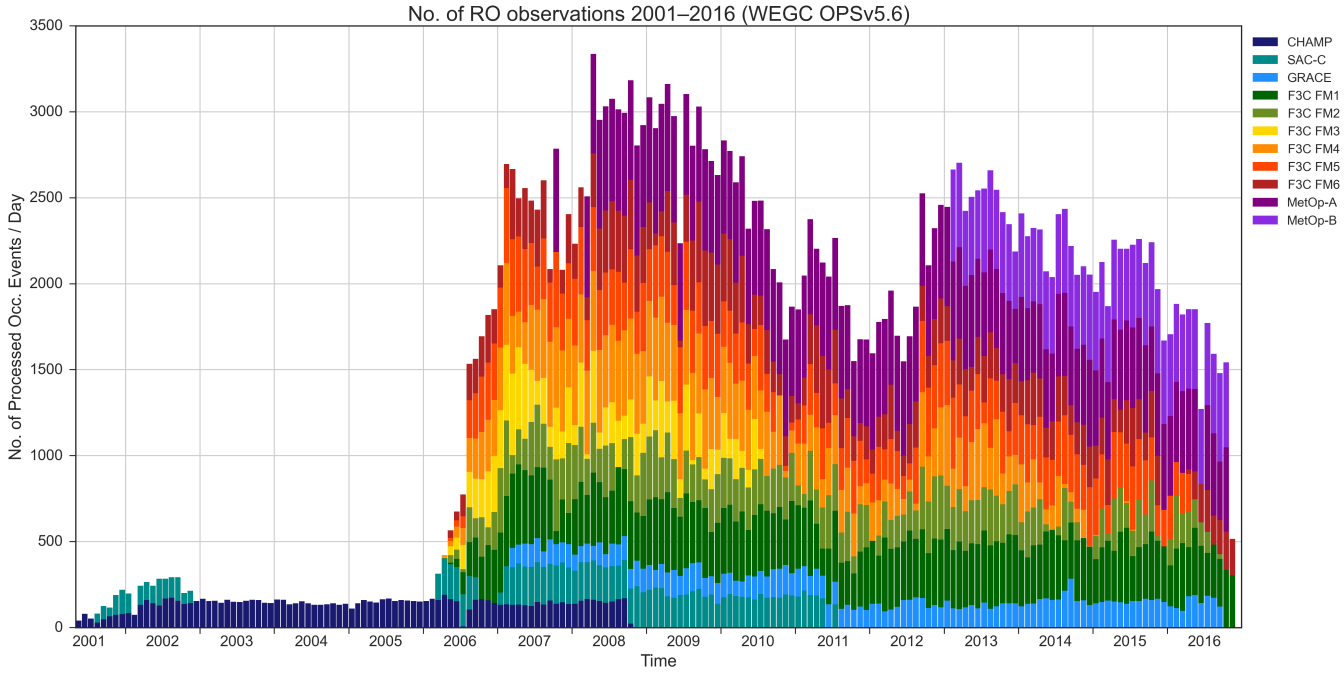
- Use radiative transfer model (RTTOV) on single profiles to retrieve MSU-equivalent brightness temperatures
- Do this for RO and RS, only if profile sufficiently covers range for channel 4 weighting function ($\approx 8 - 30$ km)
- Calculate gridded RO climatologies for multi-satellites, and correct for sampling error
- Do the same for RS, and also correct for sampling error



MSU weighting function (from RSS)

GPS RO sampling

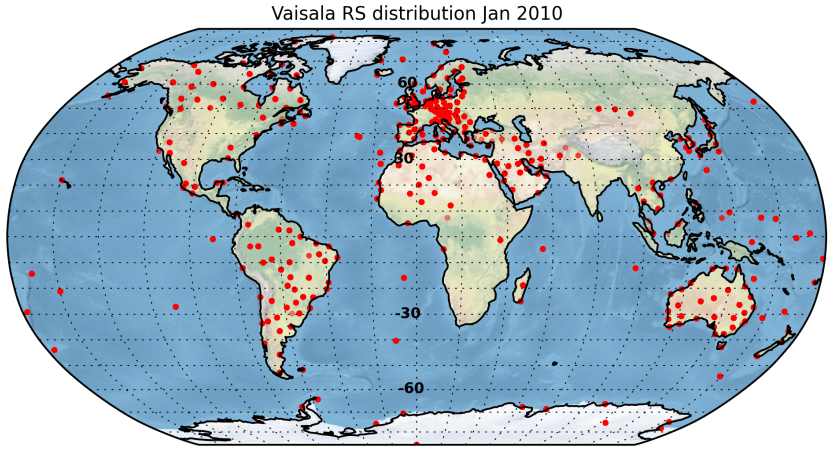


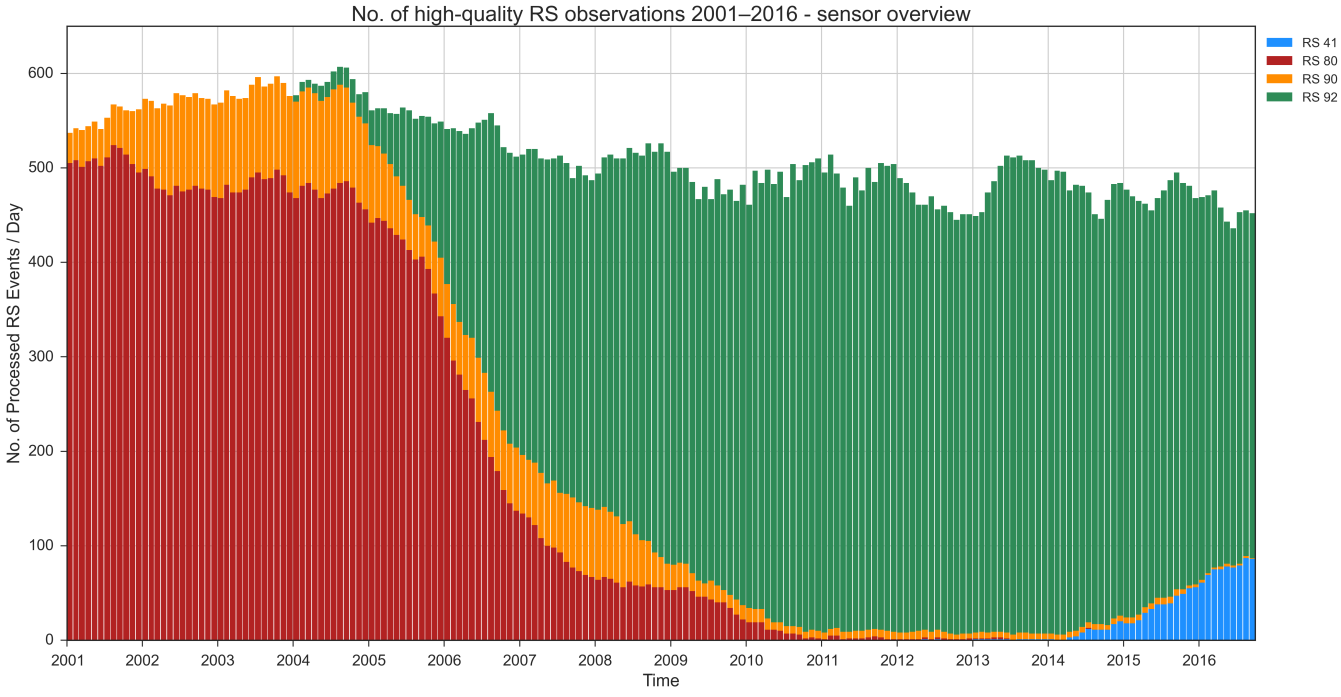


Good spatial coverage of RO. But needs to take care when doing trend analysis, because of CHAMP period.

Wegener Center
www.wegcenter.at
UNI GRAZ

Radiosonde sampling—only Vaisala

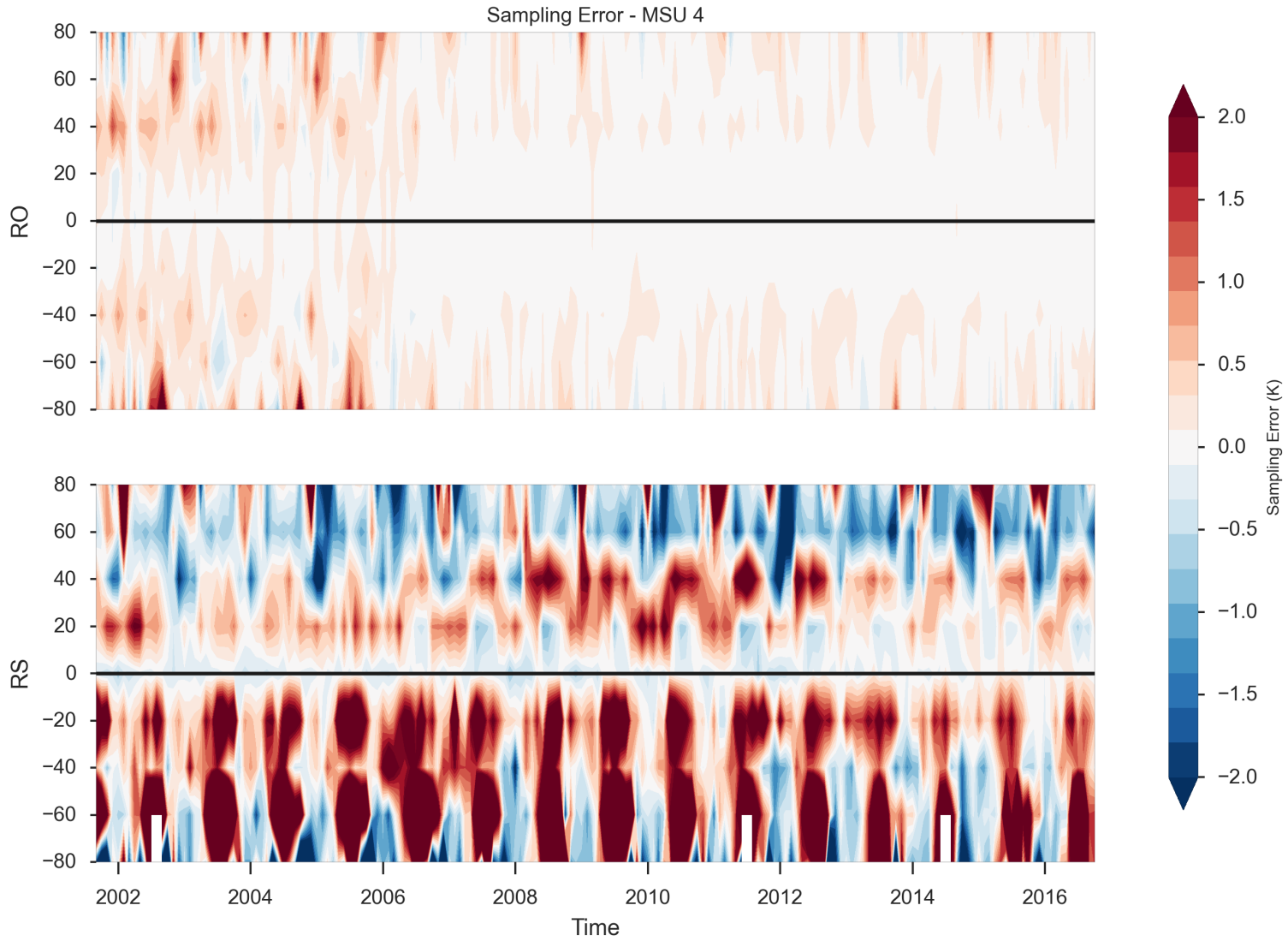




Sparse spatial sampling; constant number of measurements during this time period, but changes in instrumentation for Vaisala sondes.

Wegener Center
www.wegcenter.at
UNI GRAZ

Sampling Error



Transition from CHAMP to COSMIC period is not a big issue.

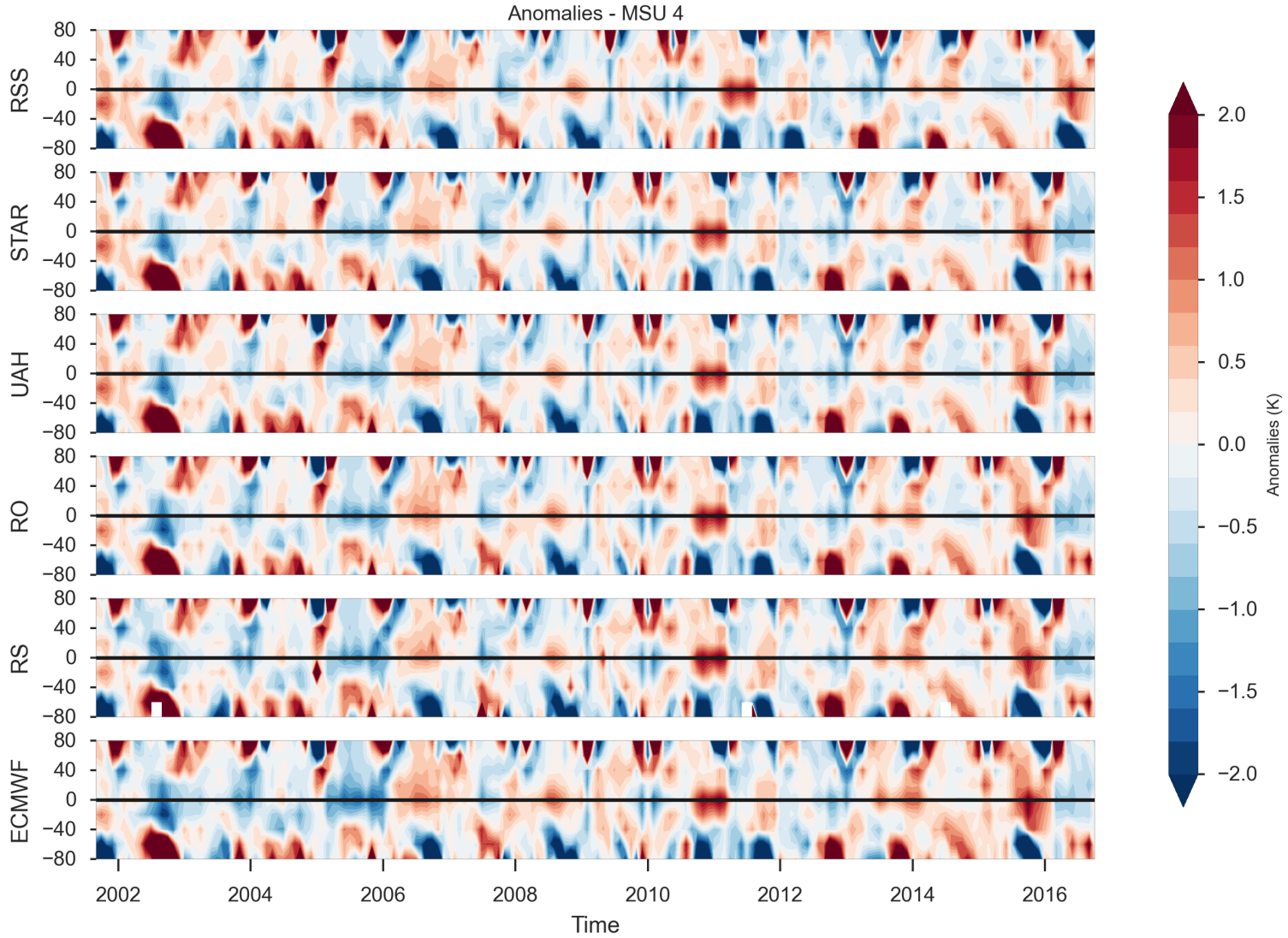
Overview

GPS RO, RS, and (A)MSU data

Comparing GPS RO, RS, and (A)MSU

Trends

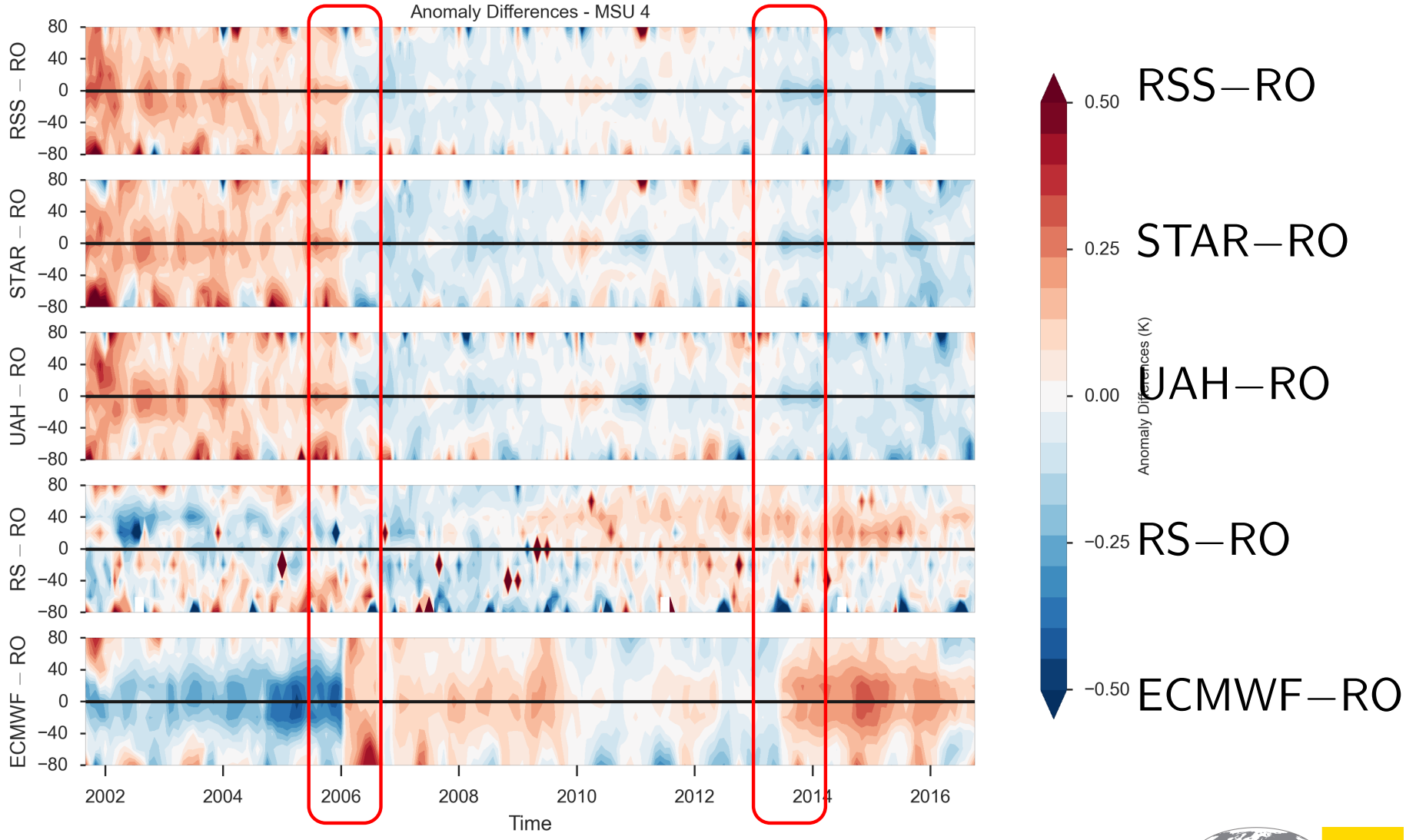
MSU TLS Anomalies



All datasets look very similar, but looking at the differences. . .

Wegener Center
www.wegcenter.at
UNI GRAZ

MSU TLS Anomaly Differences to GPS RO

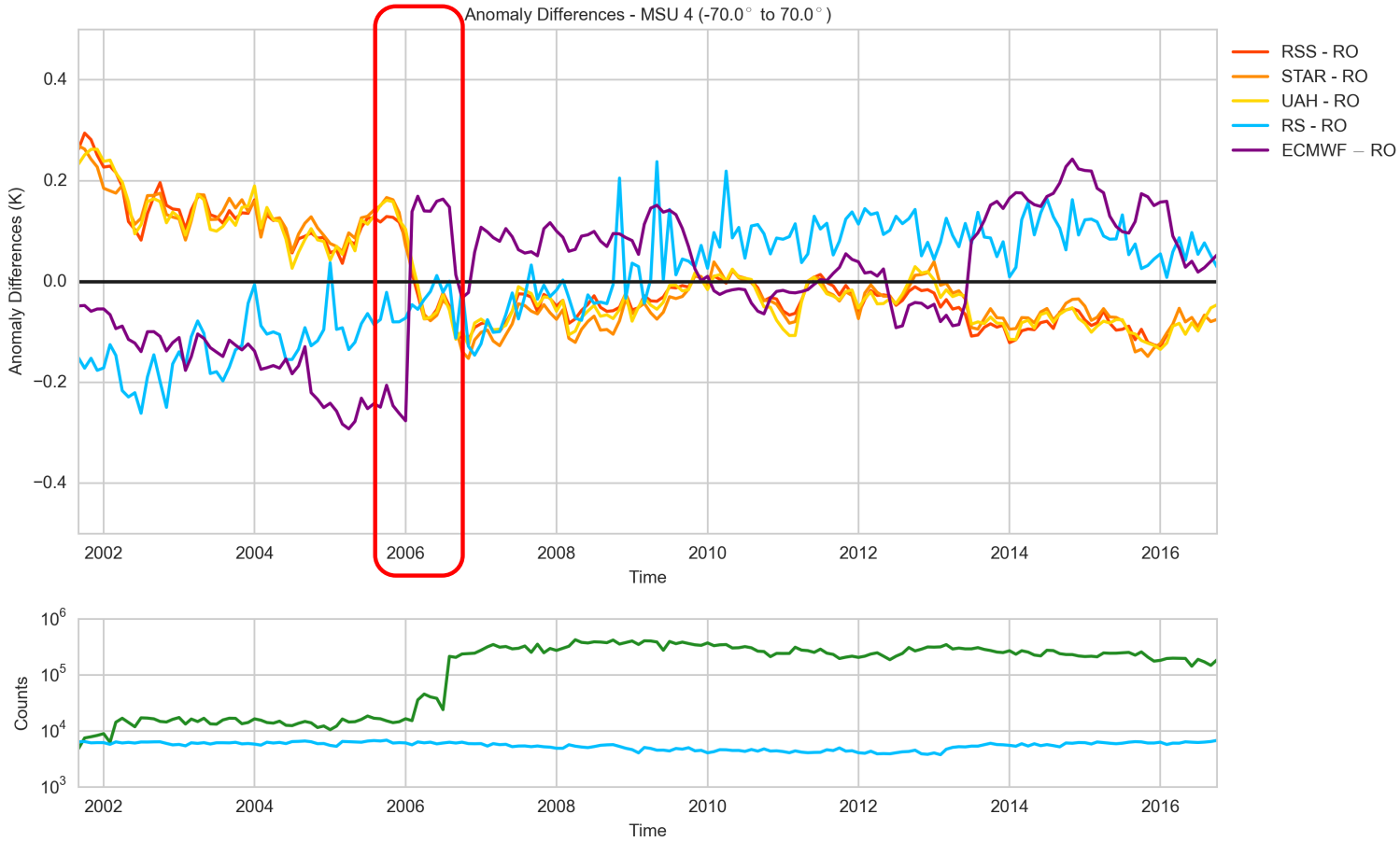


Jumps coincide with changes in ECMWF model; interestingly not for RS?

Wegener Center
www.wegcenter.at
UNI GRAZ

MSU TLS Anomaly Differences to GPS RO

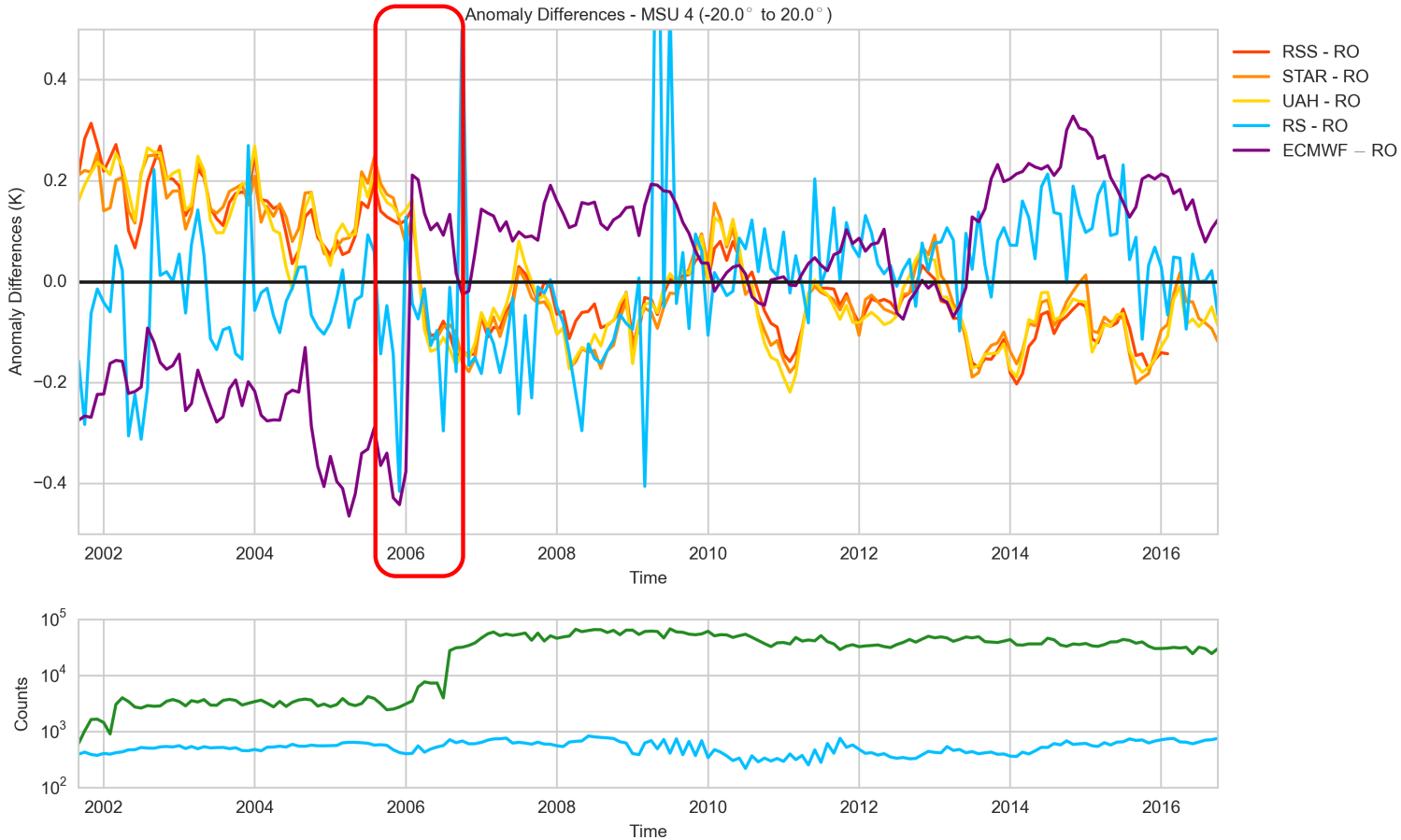
global $(-70° - 70°)$



Jump clearly visible; also trend in anomaly difference for RS vs. RO

MSU TLS Anomaly Differences to GPS RO

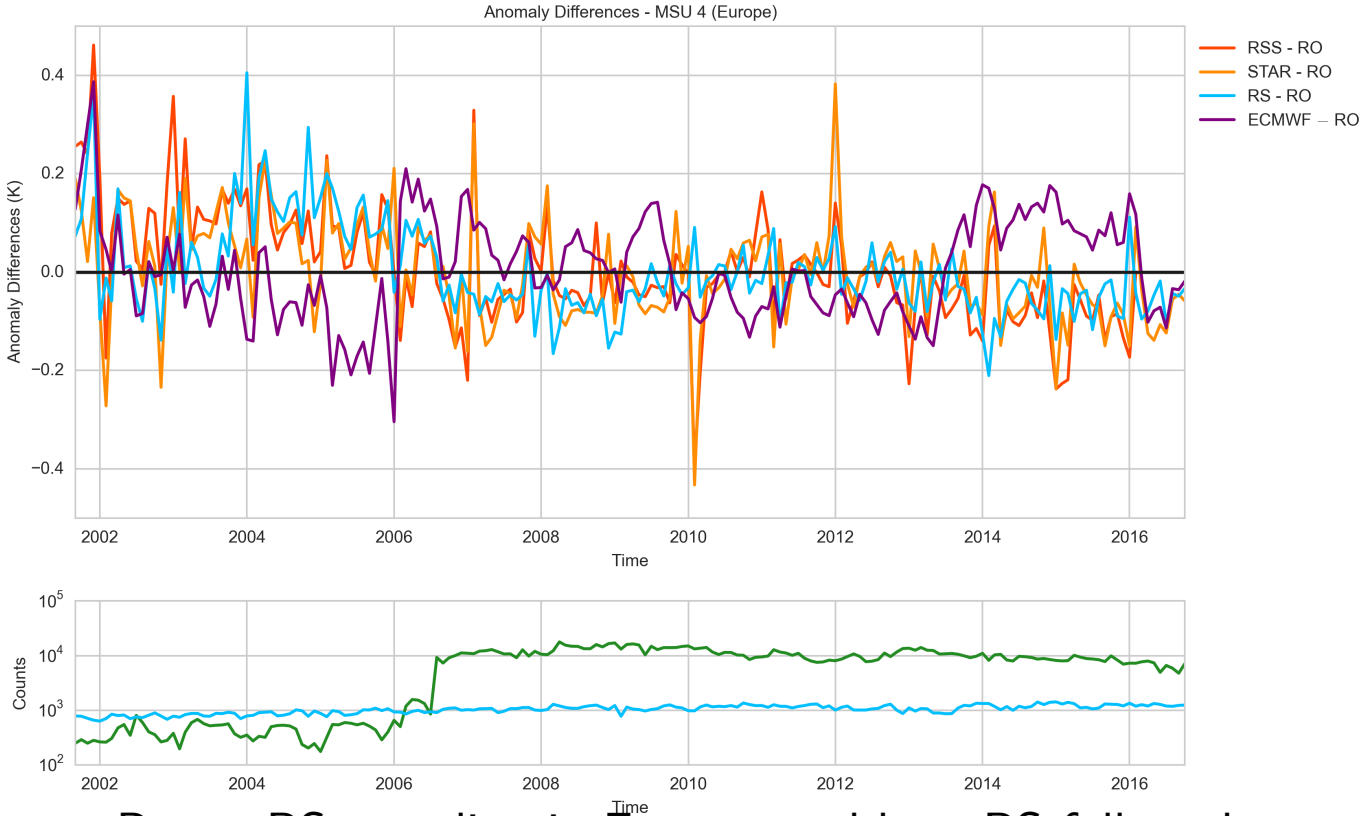
tropics $(-20° - 20°)$

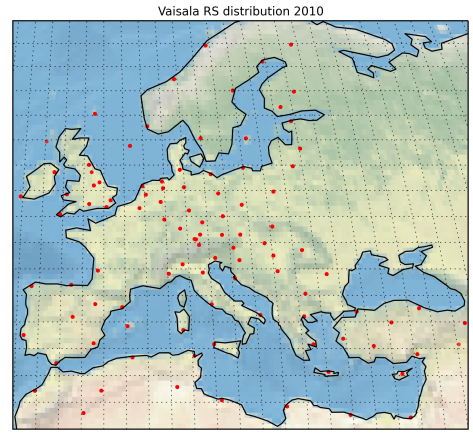


Also in the tropics

MSU TLS Anomaly Differences to GPS RO

Europe





Better RS sampling in Europe, and here RS follows better the AMSU characteristics

Overview

GPS RO, RS, and (A)MSU data

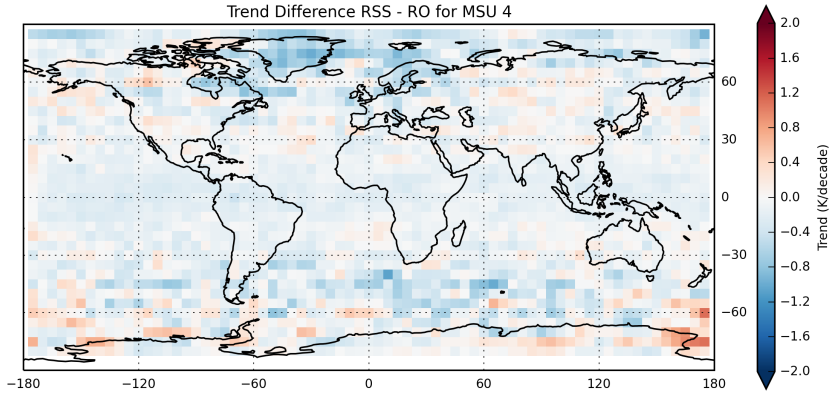
Comparing GPS RO, RS, and (A)MSU

Trends

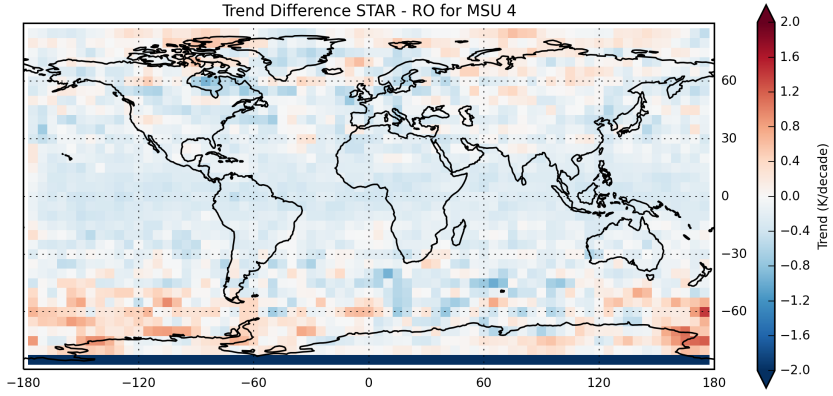
Trends method

- Use multiple linear regression
- QBO indices from PCA analysis over RO temperatures
- ENSO3.4 and solar flux indices
- Time period September 2001 to October 2016
- See poster X5.335 from Hallgeir about retrieving variability indices from RO temperatures

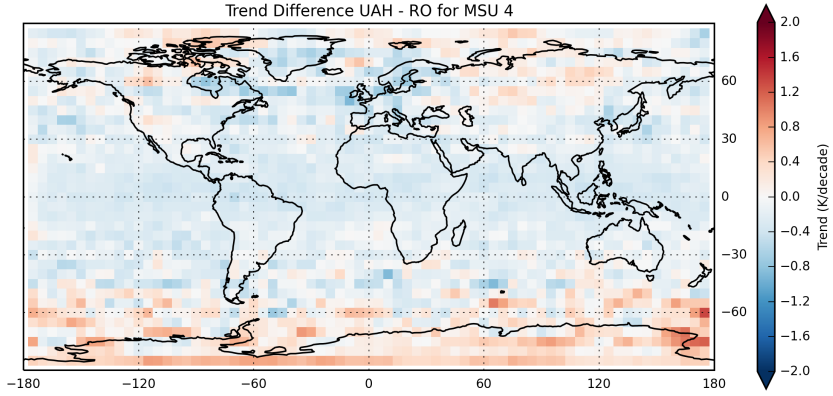
Trend differences for AMSU datasets to GPS RO



RSS−RO



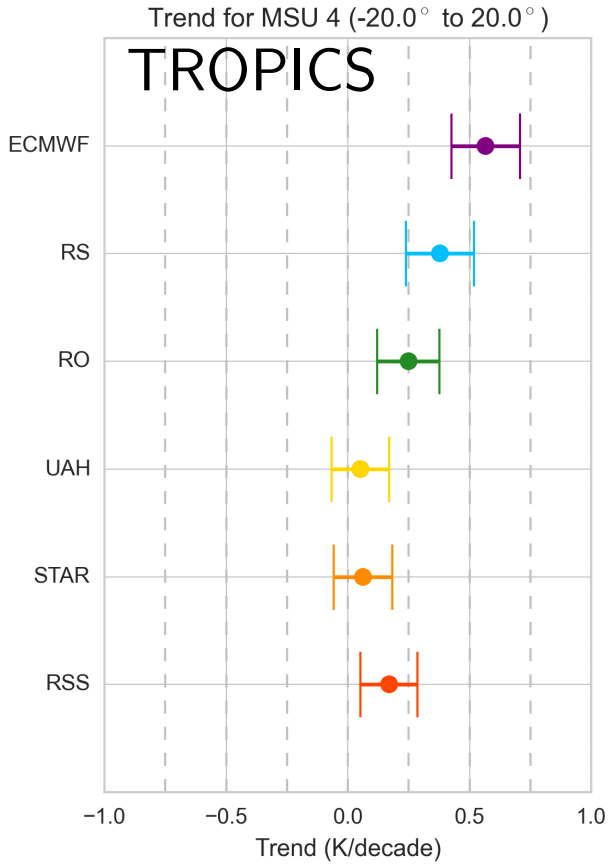
STAR−RO



UAH−RO

RO shows more warming (consistent with anomaly differences)

Trends in MSU TLS



ECMWF

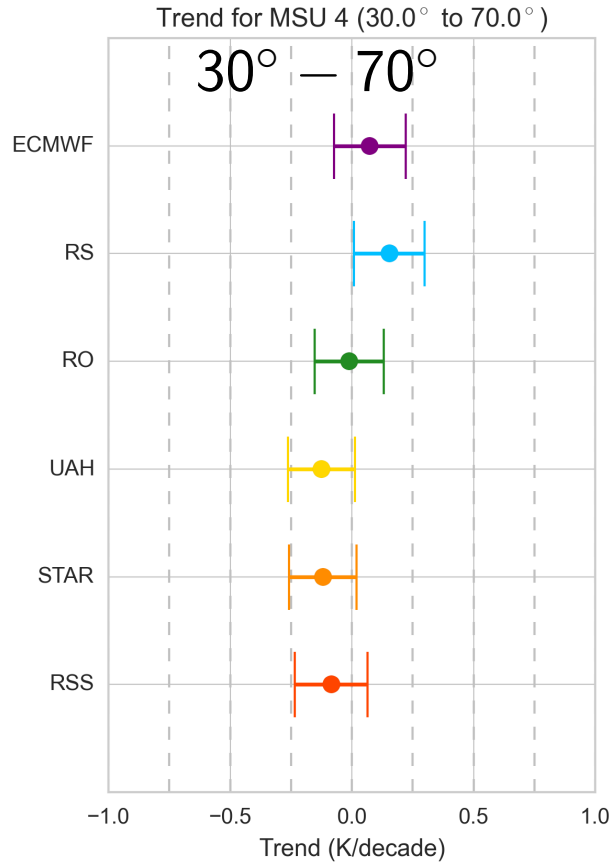
RS

RO

UAH

STAR

RSS

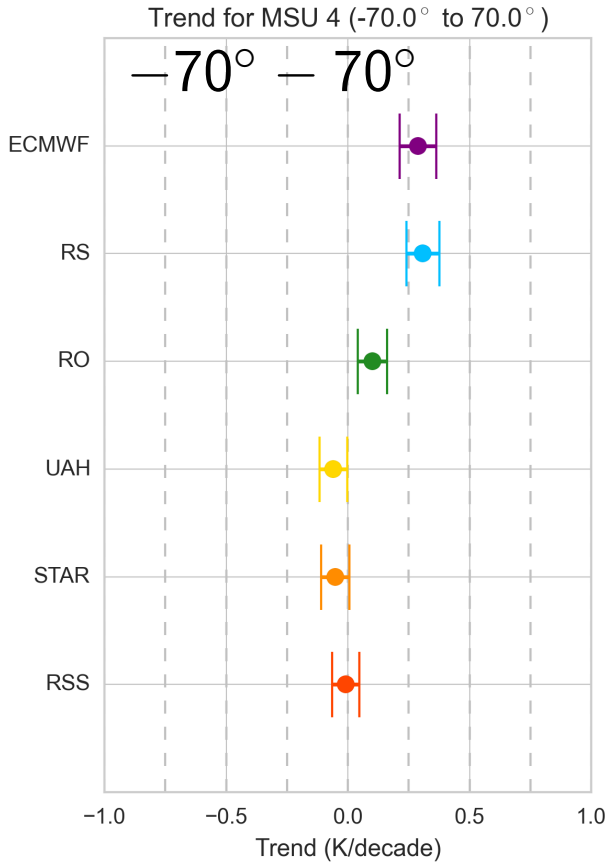


- Largest trend from ECMWF
- RS close to ECMWF
- RO at around 0.25 K/decade
- Trends positive; but contributions from UT in the tropics

- Slightly negative trends, except for RS

Wegener Center
www.wegcenter.at
UNI GRAZ

Trends in MSU TLS



ECMWF

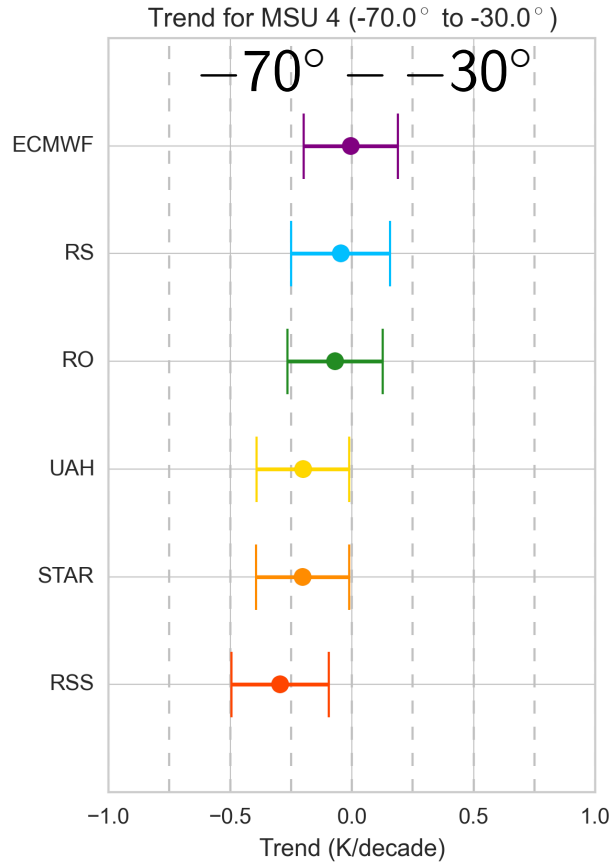
RS

RO

UAH

STAR

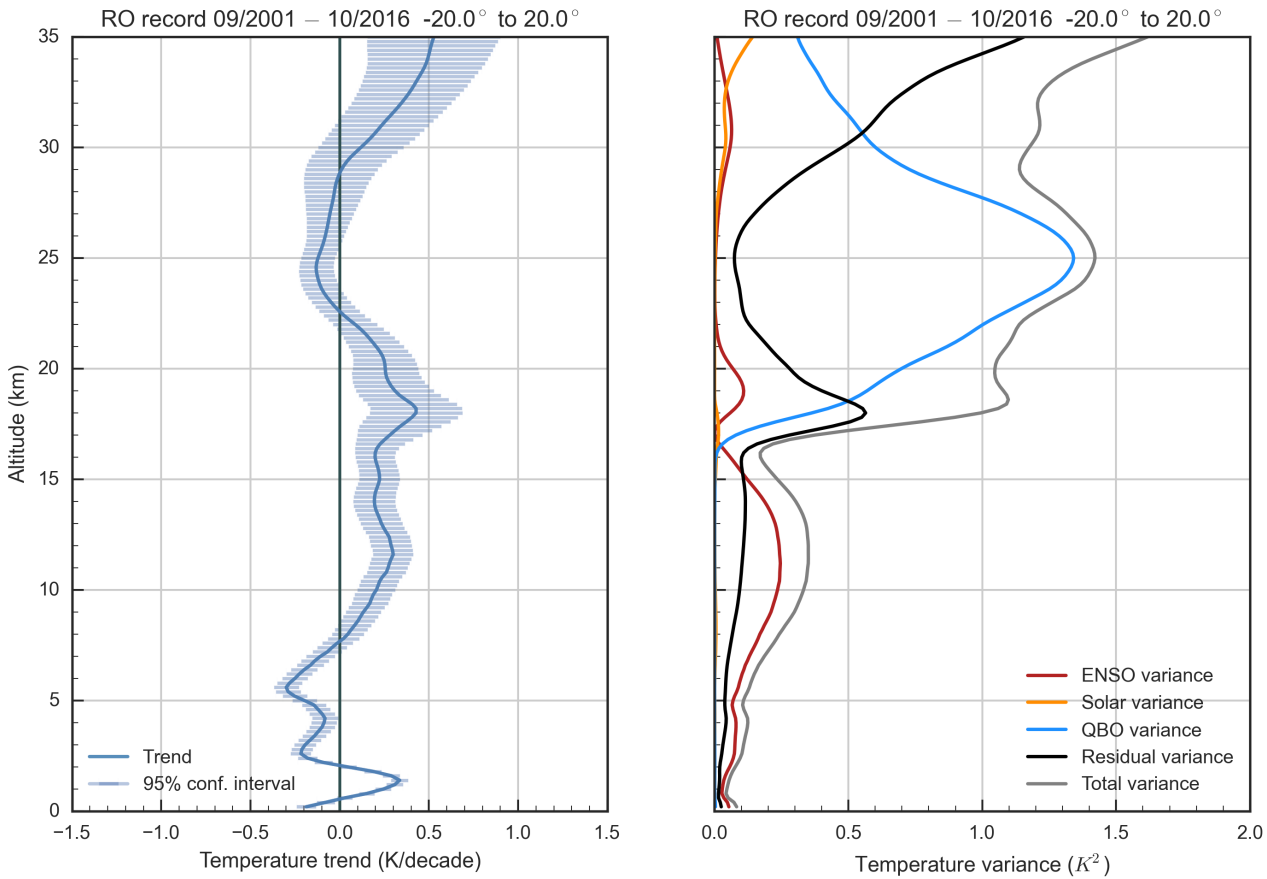
RSS



- AMSU datasets and RO/RS not in good agreement globally, but differences are small
- Negative trends for AMSU datasets

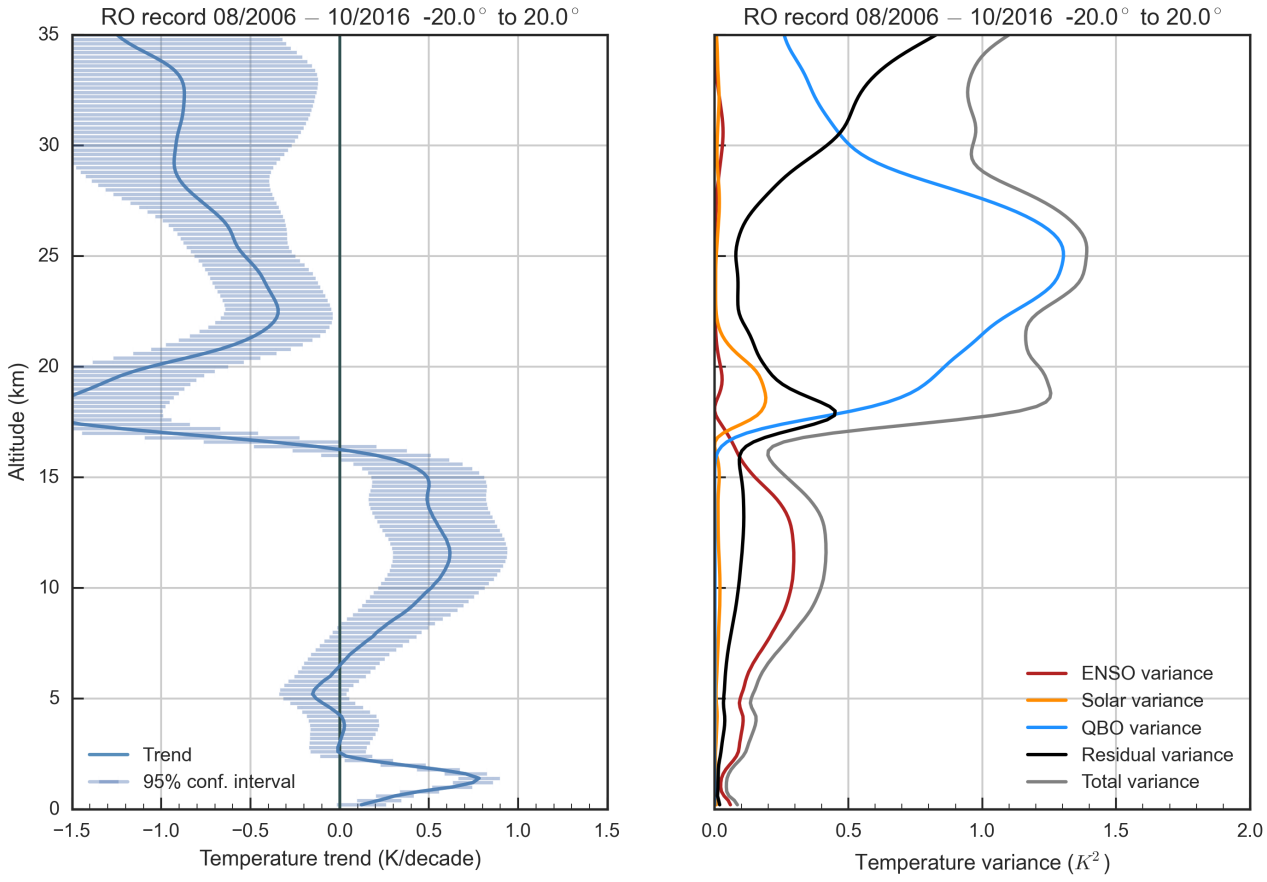
Wegener Center
www.wegcenter.at
UNI GRAZ

Vertically resolved trends RO—Tropics



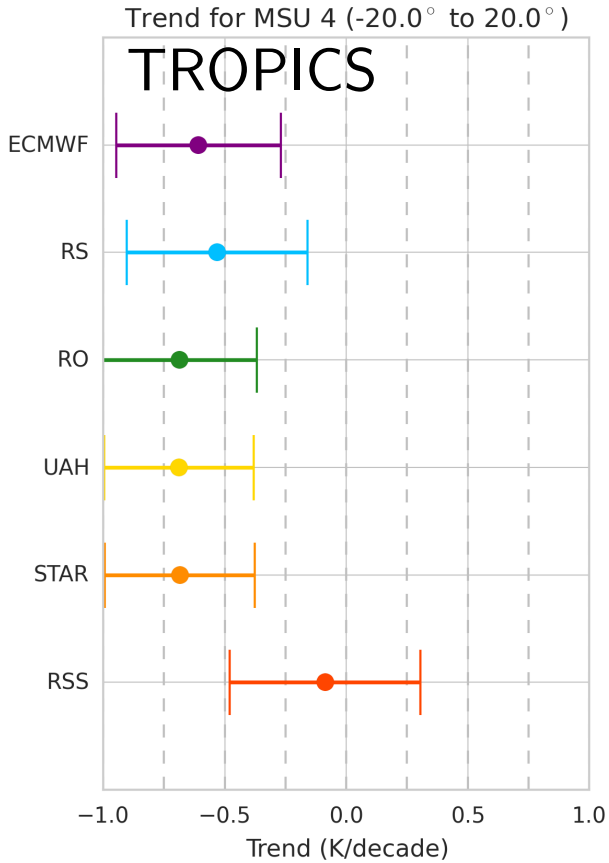
Positive trends in lowermost stratosphere; effects of initialization visible above 30 km and of moist air retrieval below 8 km

Trends robust? (10-yrs trend)



Limit to COSMIC period, only 10 years: very different in the stratosphere (but: short-term trends are not robust)

Trends robust? (10-yrs trend)



ECMWF

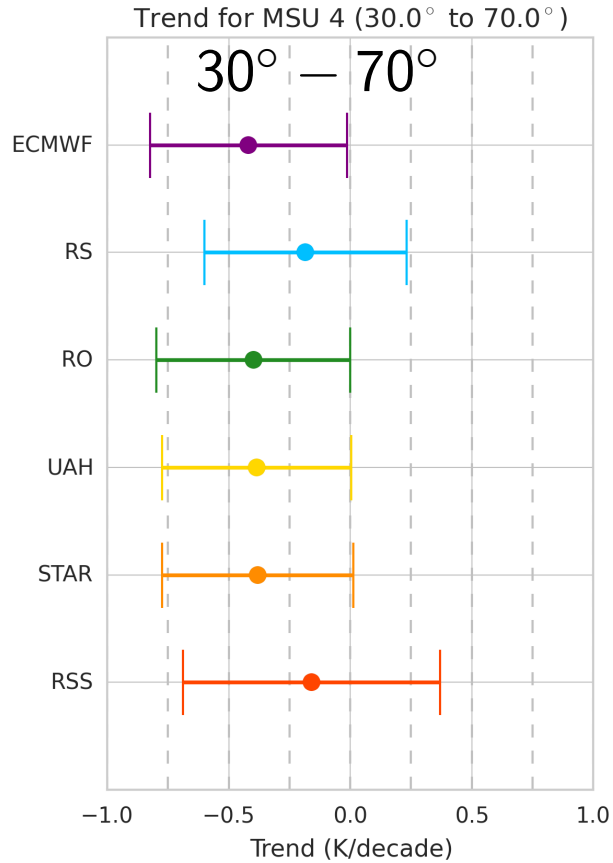
RS

RO

UAH

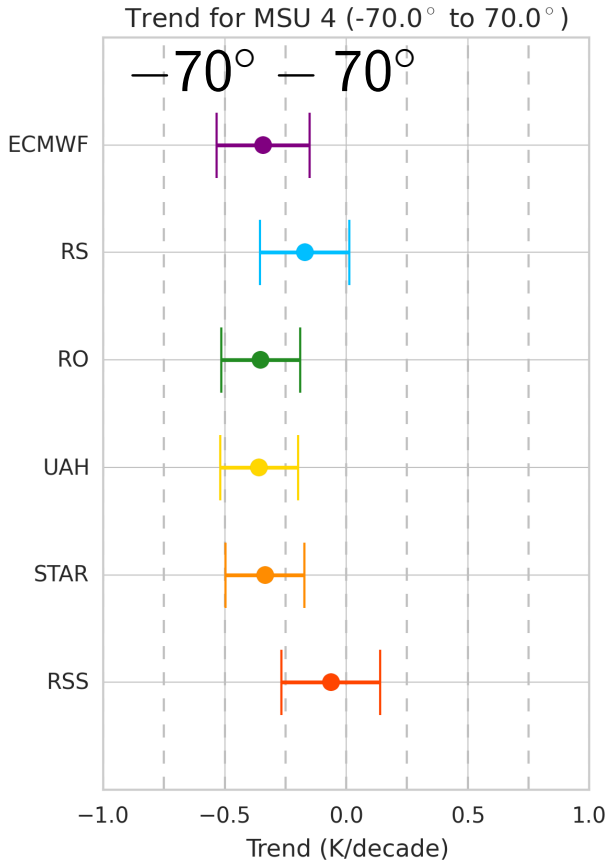
STAR

RSS



Wegener Center
www.wegcenter.at
UNI GRAZ

Trends robust? (10-yrs trend)



ECMWF

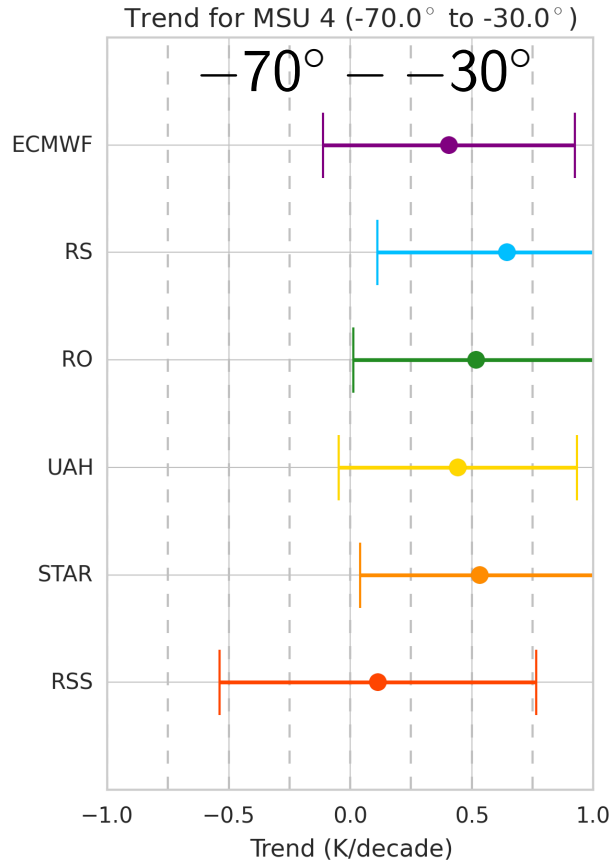
RS

RO

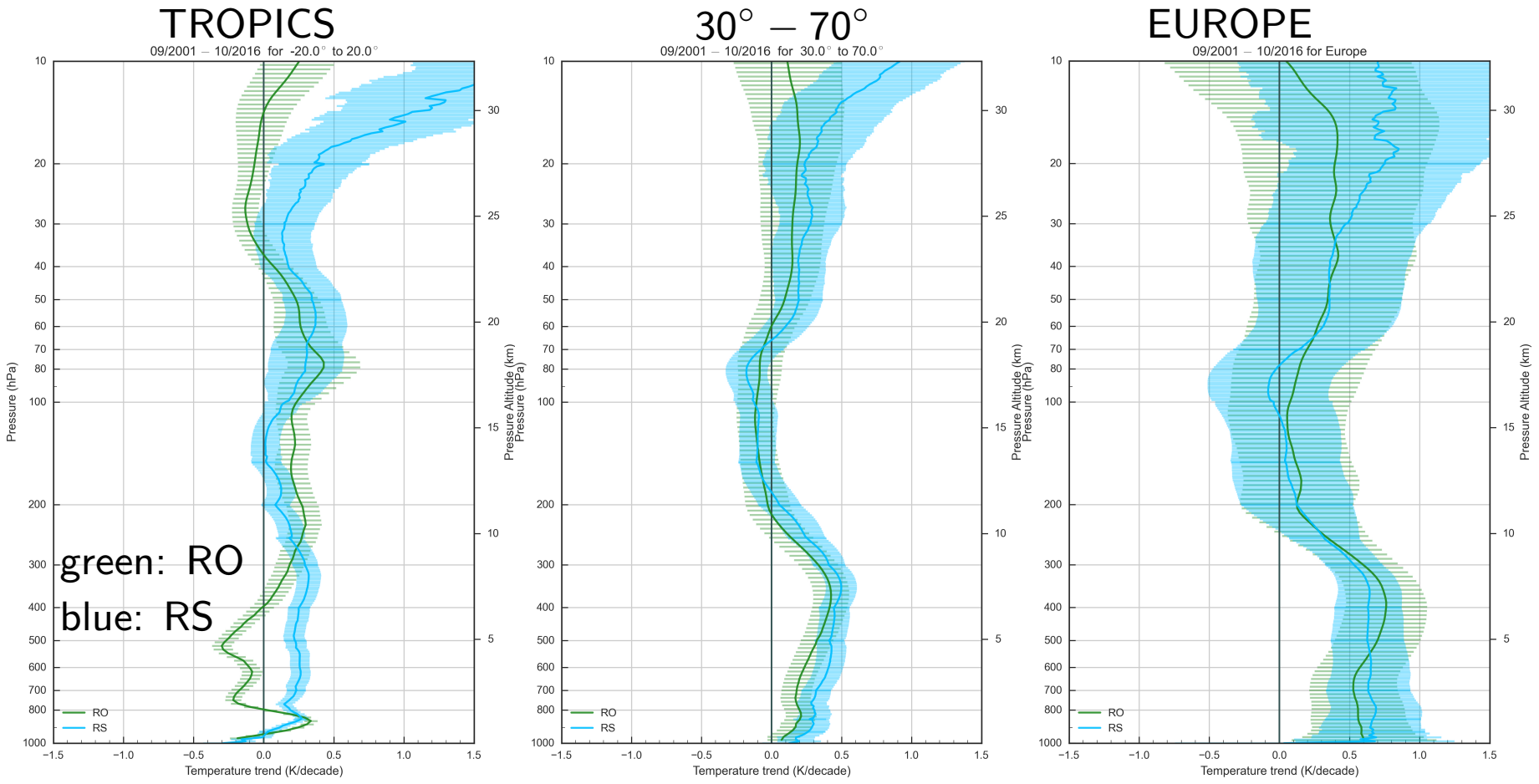
UAH

STAR

RSS



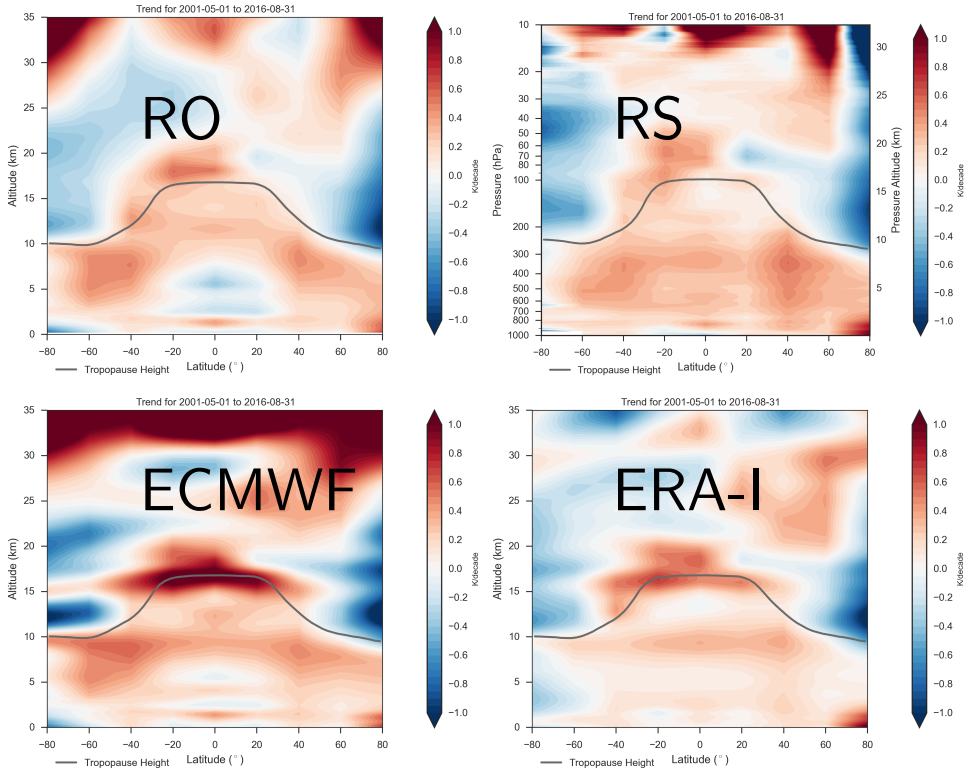
Vertically resolved trends RO and RS



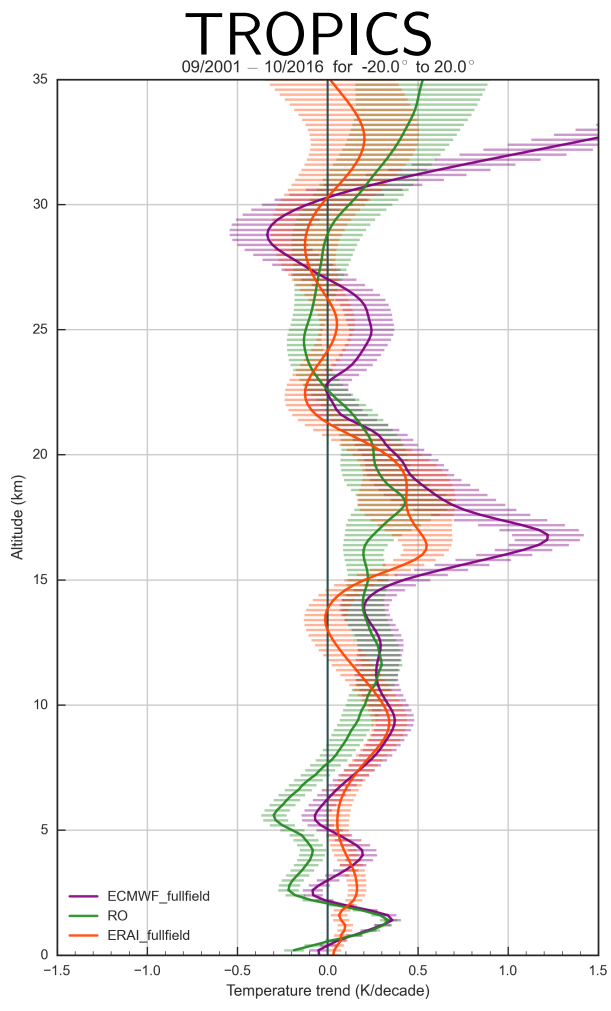
RS shows positive trend in lower troposphere in tropics, in UTLS consistent with RO; for mid-latitudes RO and RS highly consistent

Wegener Center
www.wegcenter.at
UNI GRAZ

Vertically resolved trends RO, RS, models



RO: warming above tropopause; RS: consistent with RO (SE corrected); ECMWF too large warming, due to model changes; ERA-I and ECMWF wave-like structures, ERA-I missing warming in upper troposphere?



green: RO
orange: ERA-I
purple: ECMWF

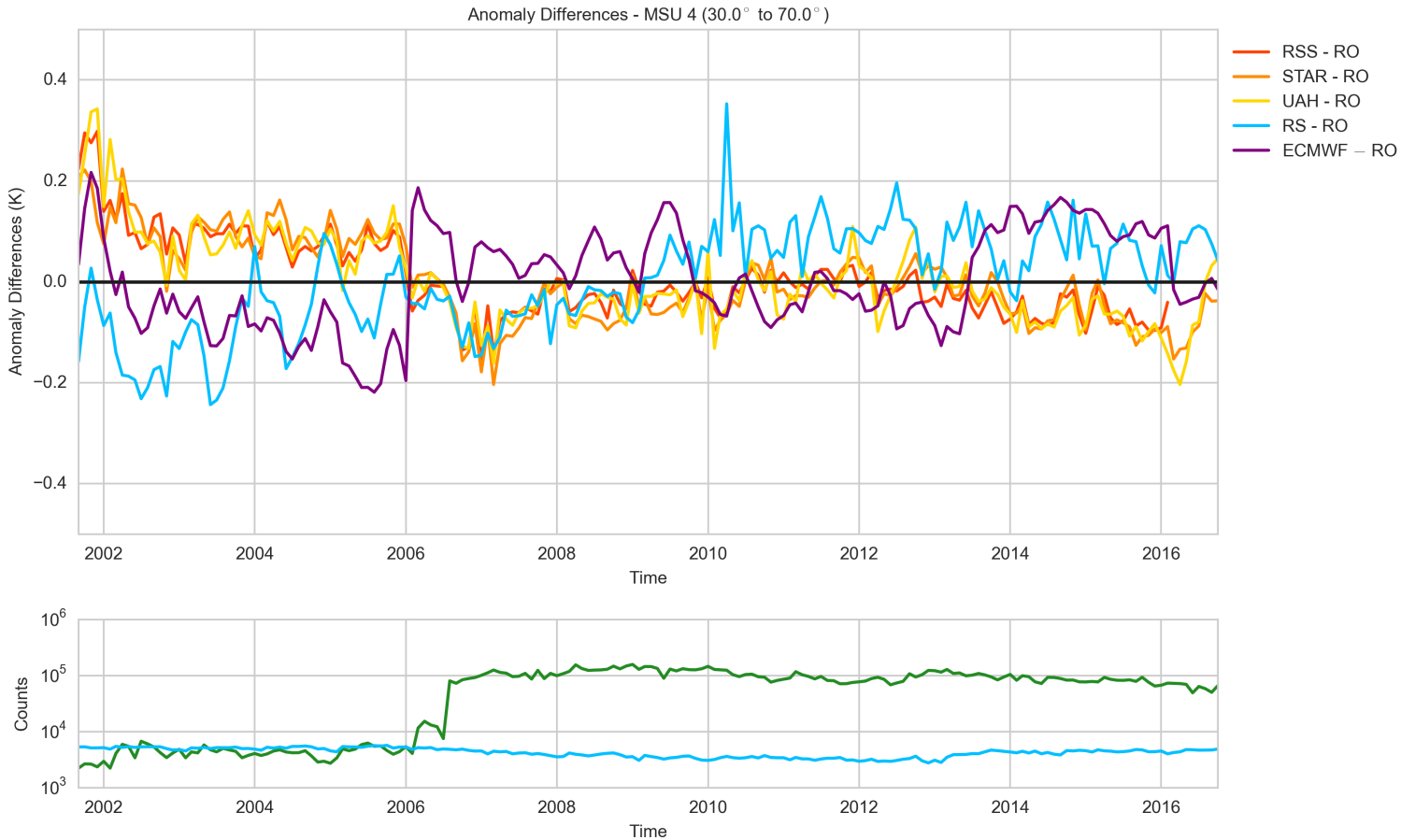
Wegener Center
www.wegcenter.at
UNI GRAZ

Conclusions

- RO and RS consistent in upper-troposphere/lower stratosphere (when RS sampling is properly accounted for)
- Knowledge about data characteristics essential for proper comparisons of variability and trends
- Especially the spatial sampling plays a major role
- Differences of AMSU and RO is still an unresolved issue and needs further work
- See also: poster on RO trend analysis (Andrea Steiner et. al, X5.338)
- See also: poster on variability indices from RO (Hallgeir Wilhelmsen et. al, X5.335)
- See also: poster on WEGC RO data record quality and influence of ECMWF jumps (Barbara Angerer et. al, X3.154 on Thursday evening)

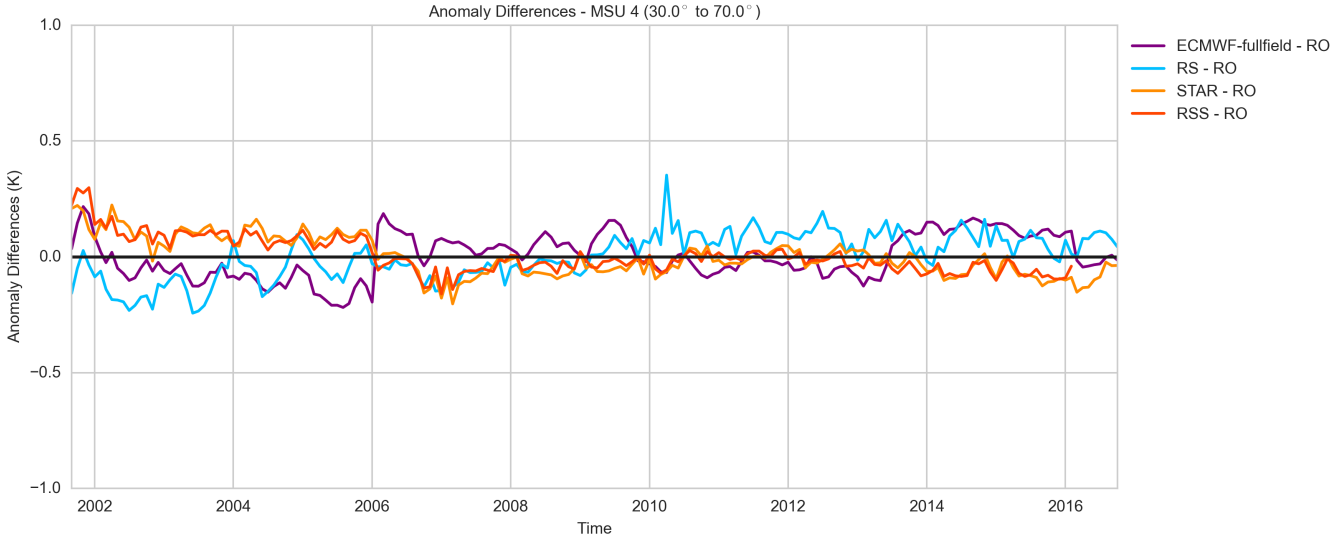
Wegener Center
www.wegcenter.at
UNI GRAZ

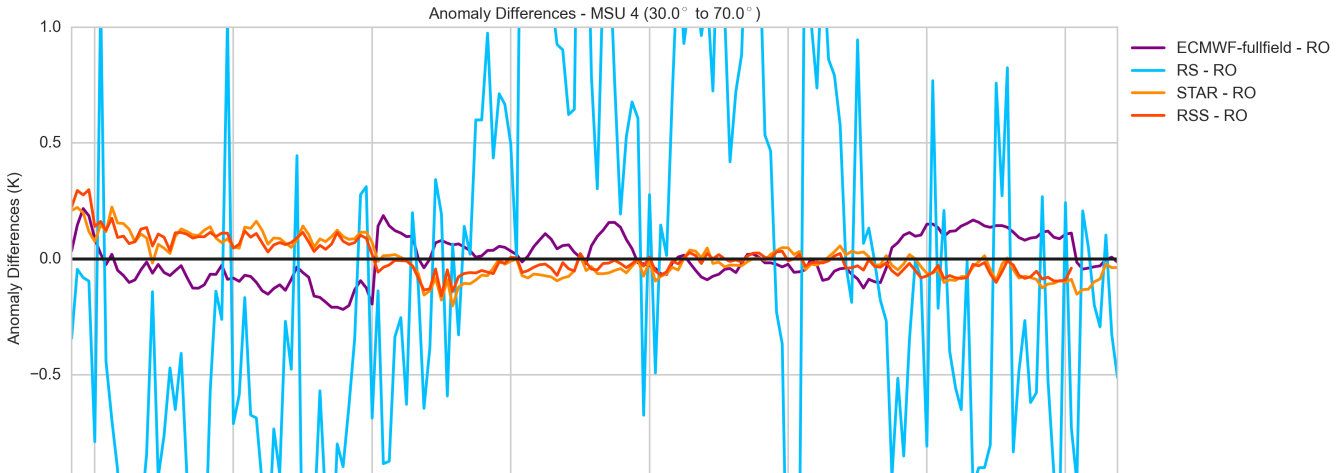
MSU TLS Anomaly Differences to GPS RO



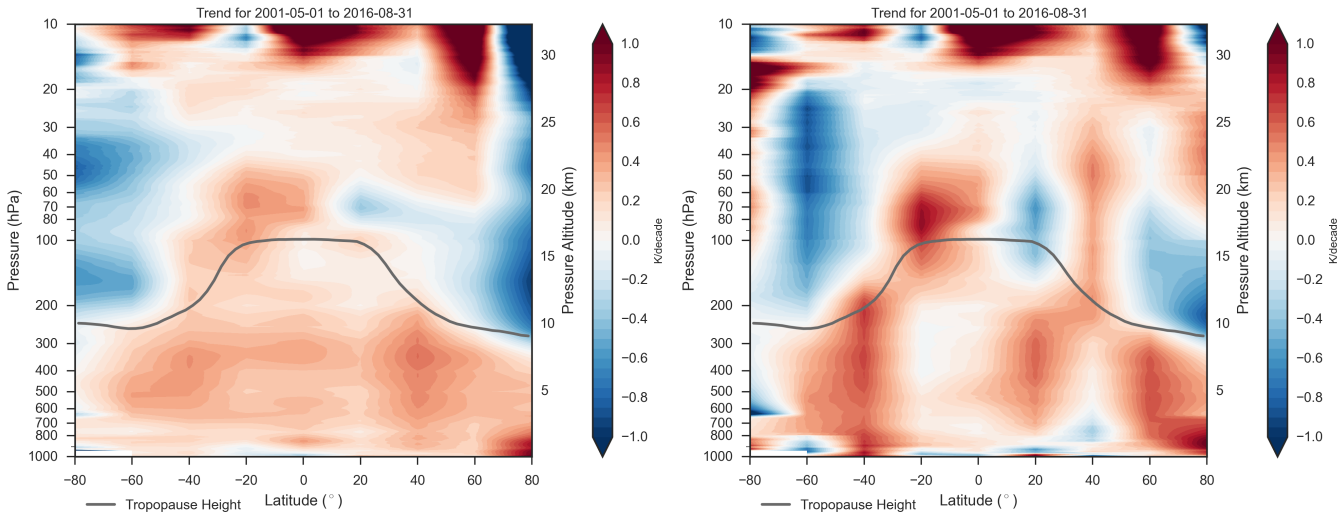
Wegener Center
www.wegcenter.at
UNI GRAZ

Influence of sampling error correction on TLS anomaly differences from RS



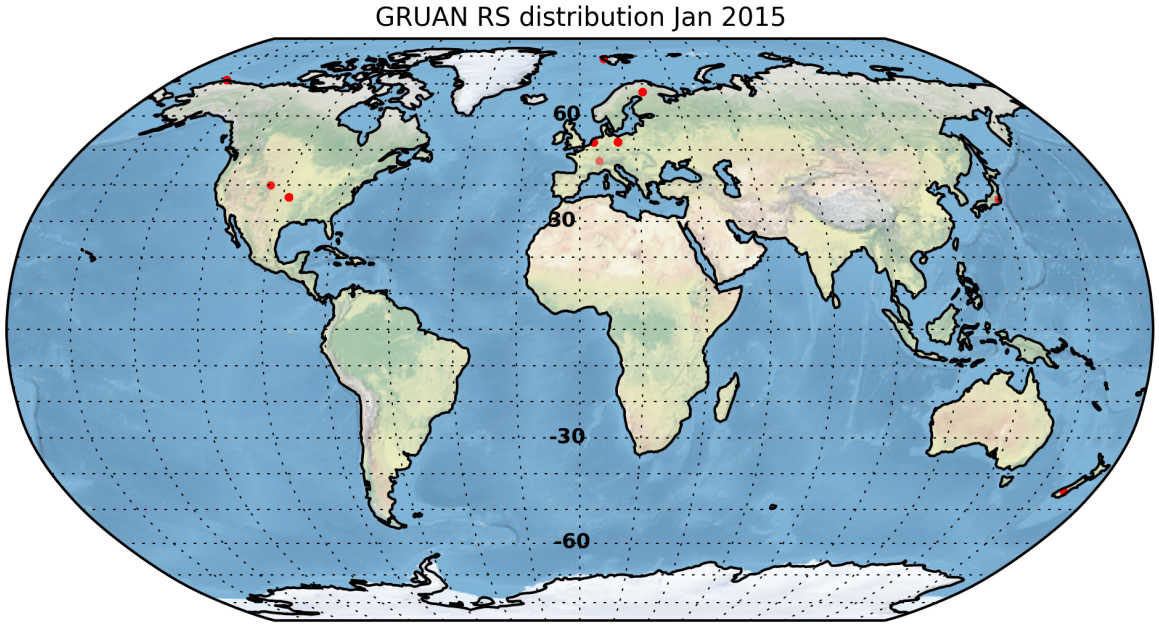


Influence of sampling error correction on radiosonde trends



Large improvement due to sampling error correction

GRUAN



RS Sampling in Europe