



Climatological temperature trends from Radio Occultation and Radiosondes

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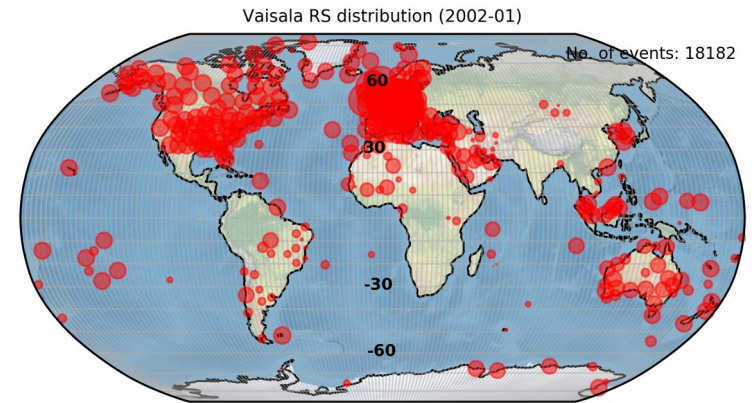
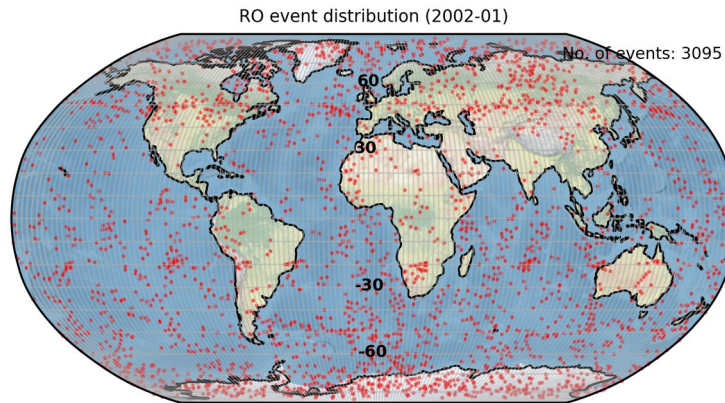
- ▶ Can we determine vertically resolved, robust trends from Radio Occultation?
- ▶ And how does it compare to high-quality radiosondes and reanalysis?

Distribution of events/sampling

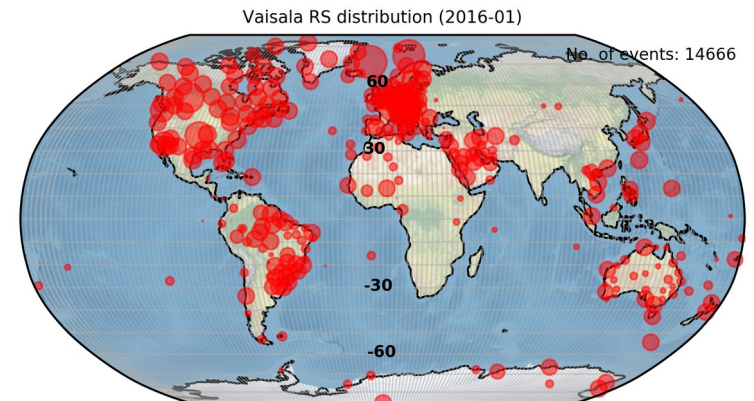
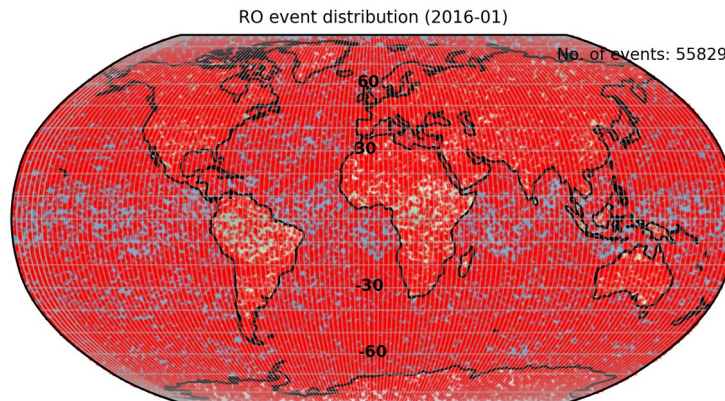
Radio Occultation

Vaisala Radiosondes

Jan 2002



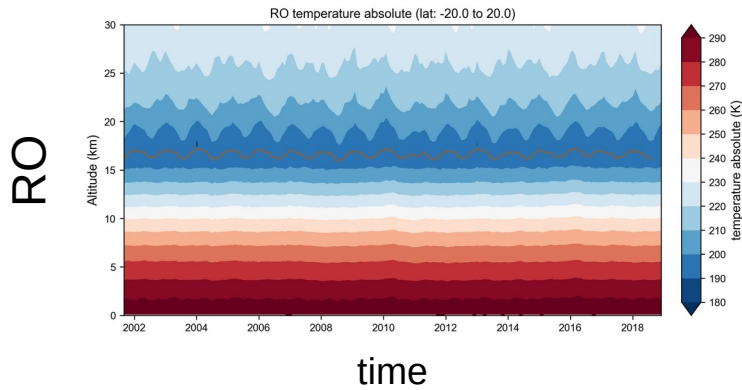
Jan 2016



RO filling the observational distribution gaps

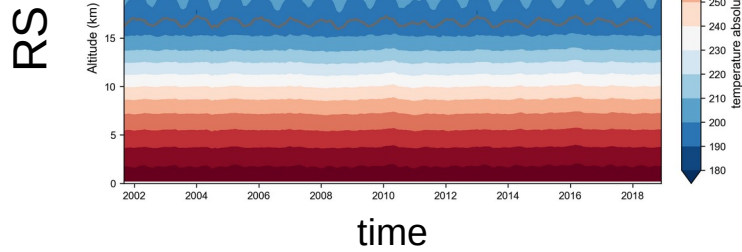
Temperature variability–seasonality

Tropics



30°N to 70°N

70°N to 90°N



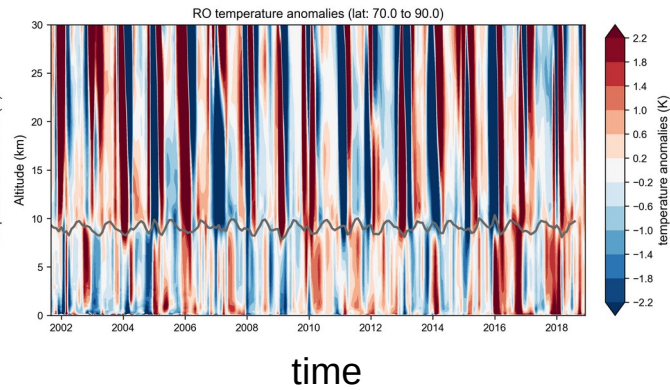
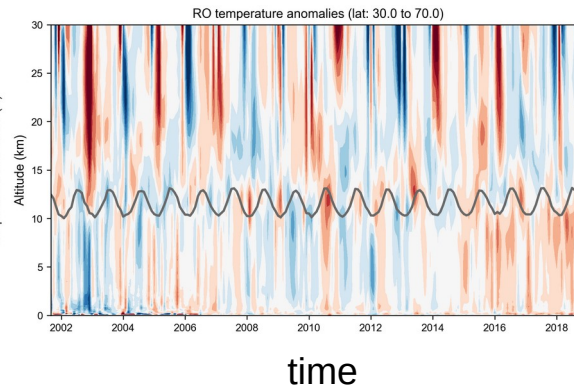
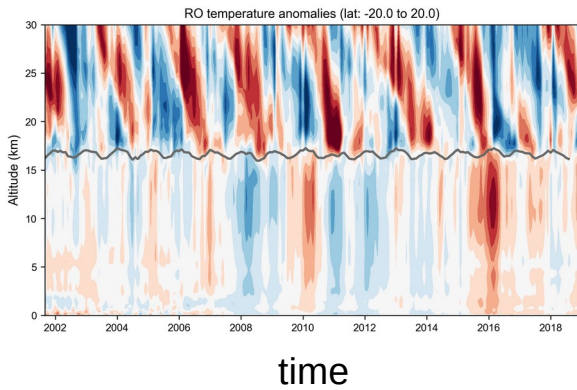
Temperature variability–seasonality removed

Tropics

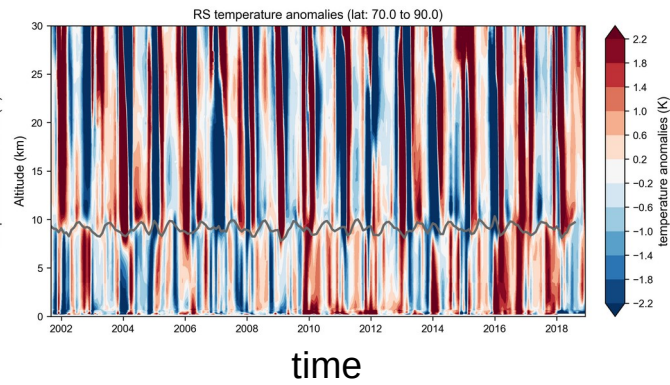
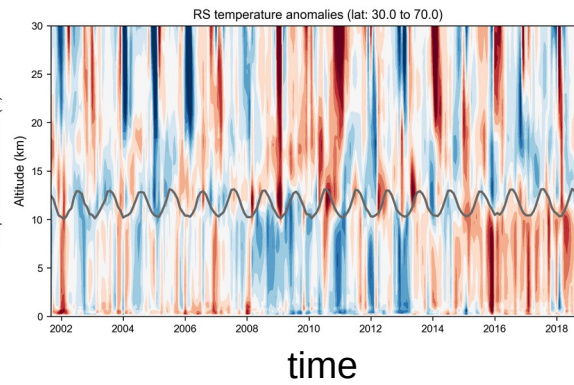
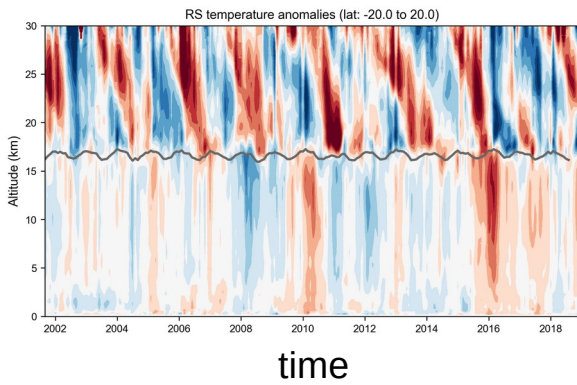
30°N to 70°N

70°N to 90°N

RO



RS



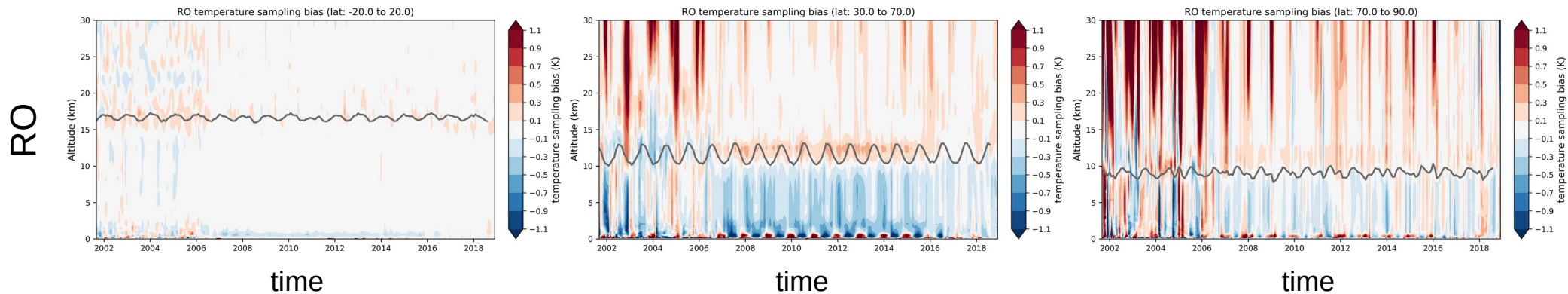
Sampling bias adjustments

Estimate sampling bias using e.g. ERA5 (interpolated to observations minus full field)

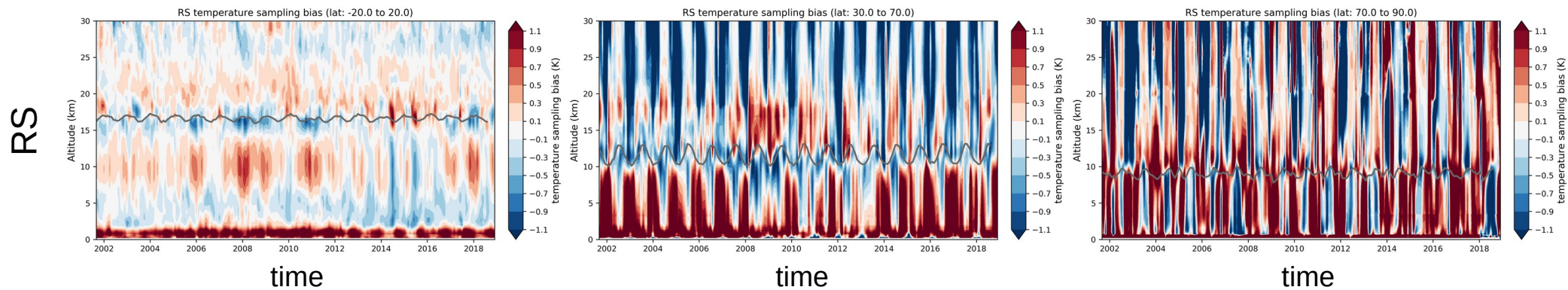
Tropics

30°N to 70°N

70°N to 90°N



RO has small, but time-dependent sampling bias



RS struggling with catching the atmospheric variability, especially at high latitudes

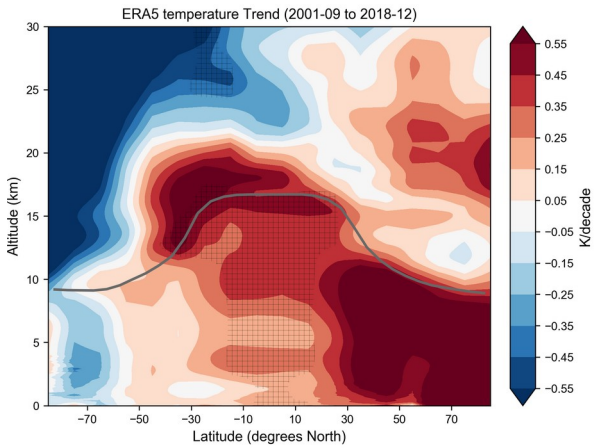
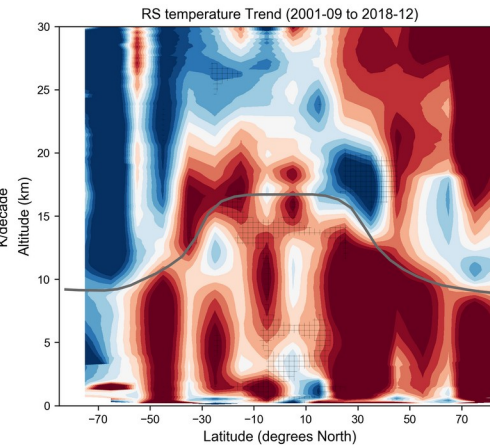
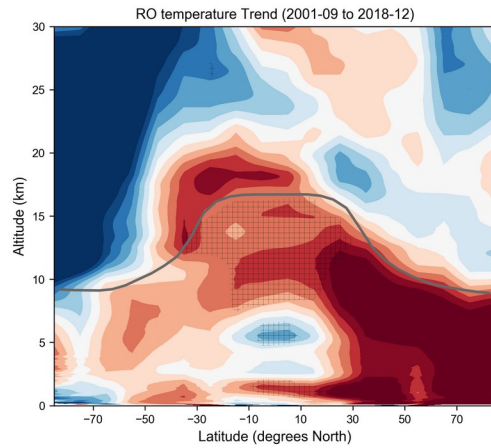
Trends of absolute temperature

RO

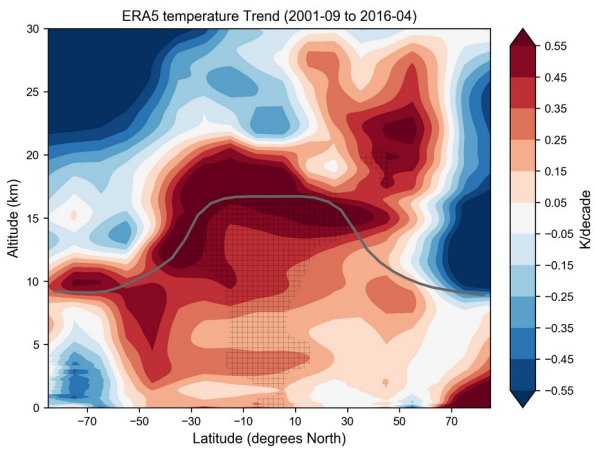
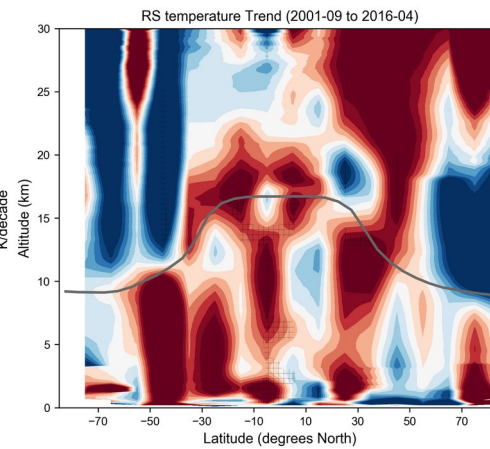
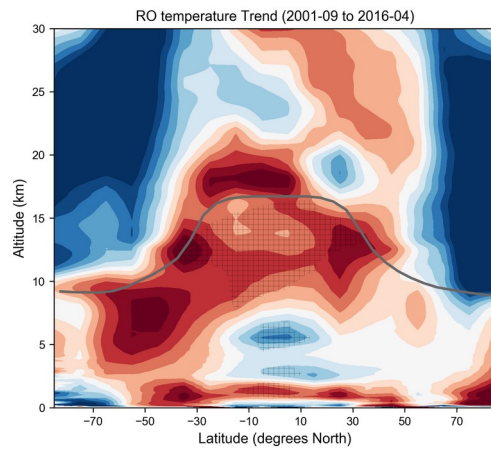
RS

ERA5

2001-09 to
2018-12

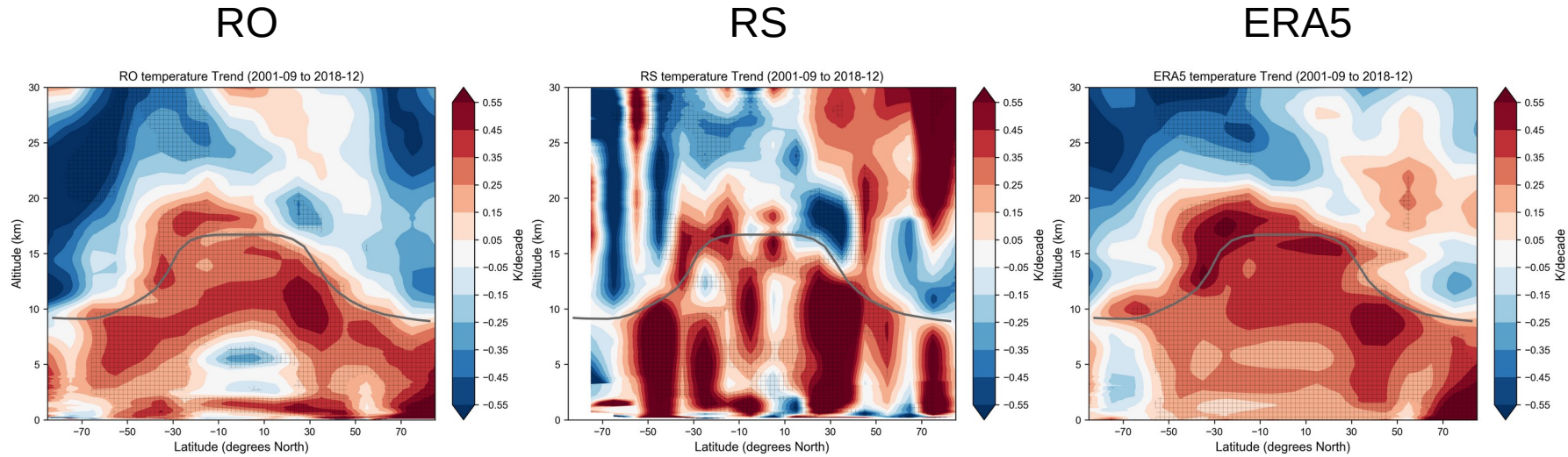


2001-09 to
2016-04

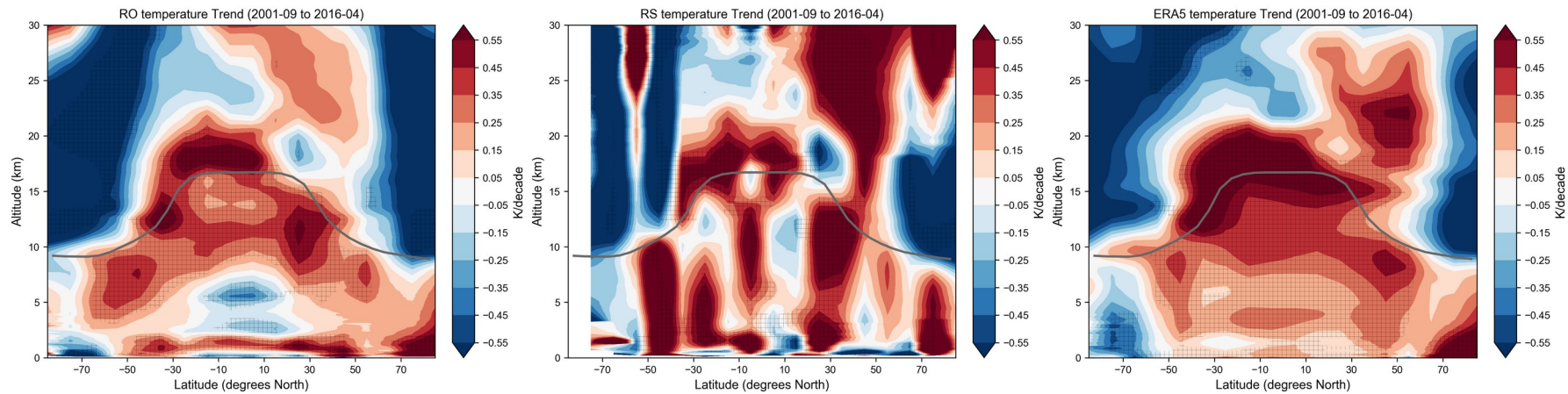


Trends of temperature anomalies

2001-09 to
2018-12

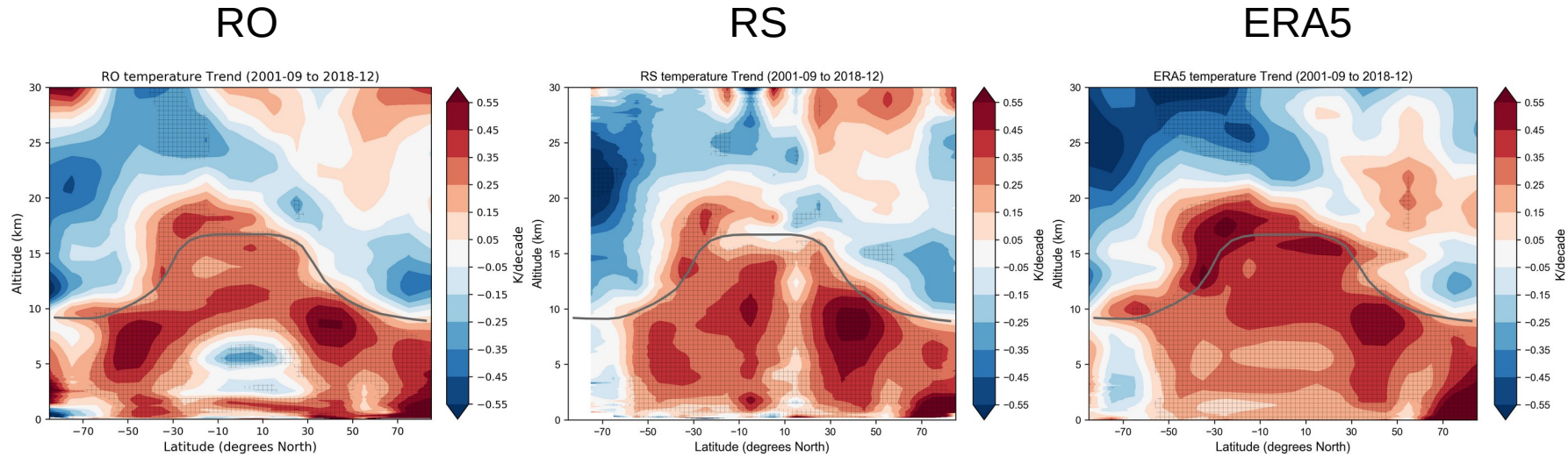


2001-09 to
2016-04

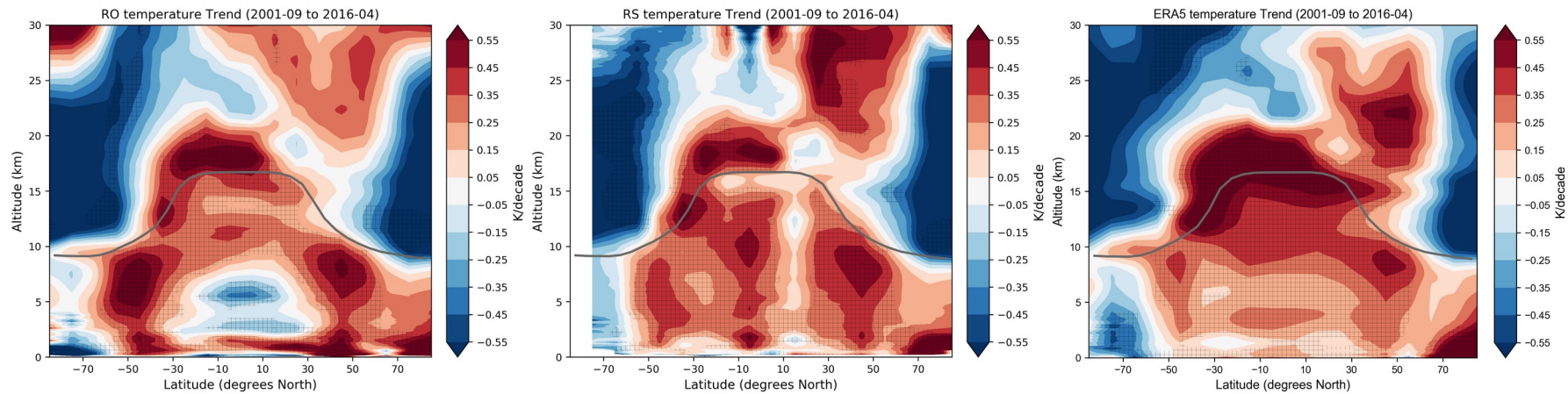


Trends of temp anomalies, sampling corrected

2001-09 to
2018-12



2001-09 to
2016-04

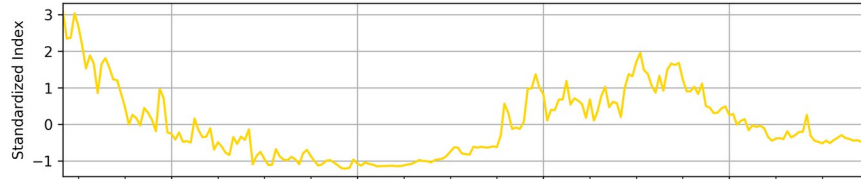


Multiple linear regression

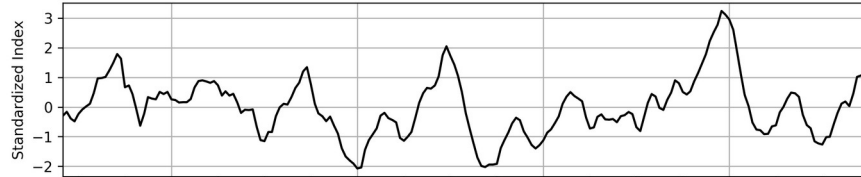
“Conventional” indices:
Singapore winds,
ENSO34 index, solar flux



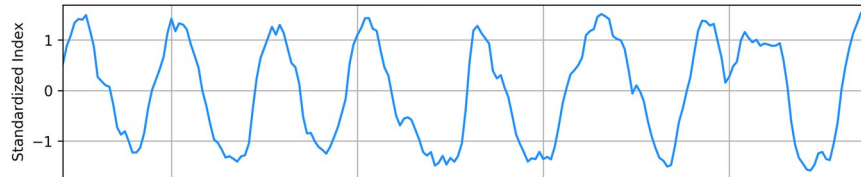
Solar Index



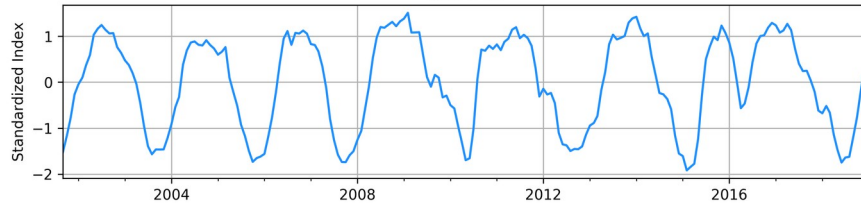
ENSO 3.4 Index



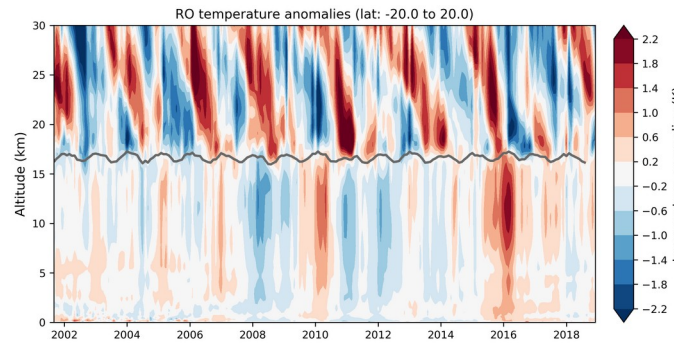
QBO PC1



QBO PC2



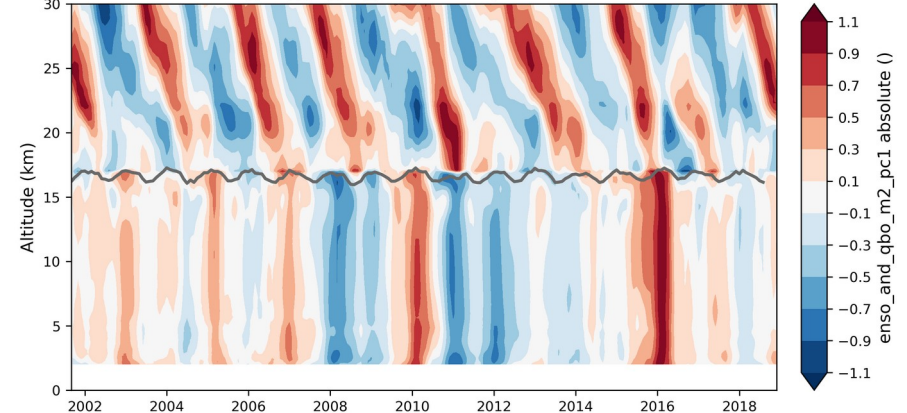
Sep 20, 2019



Height-resolved indices:
PCA over gridded RO
temperature field
(also lat-resolved!)

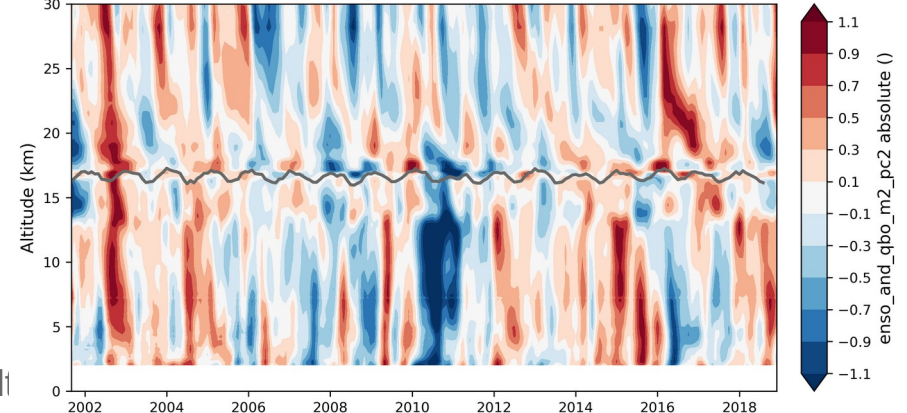


enso_and_qbo_m2_pc1 absolute (lat: -20.0 to 20.0)



PC1

enso_and_qbo_m2_pc2 absolute (lat: -20.0 to 20.0)

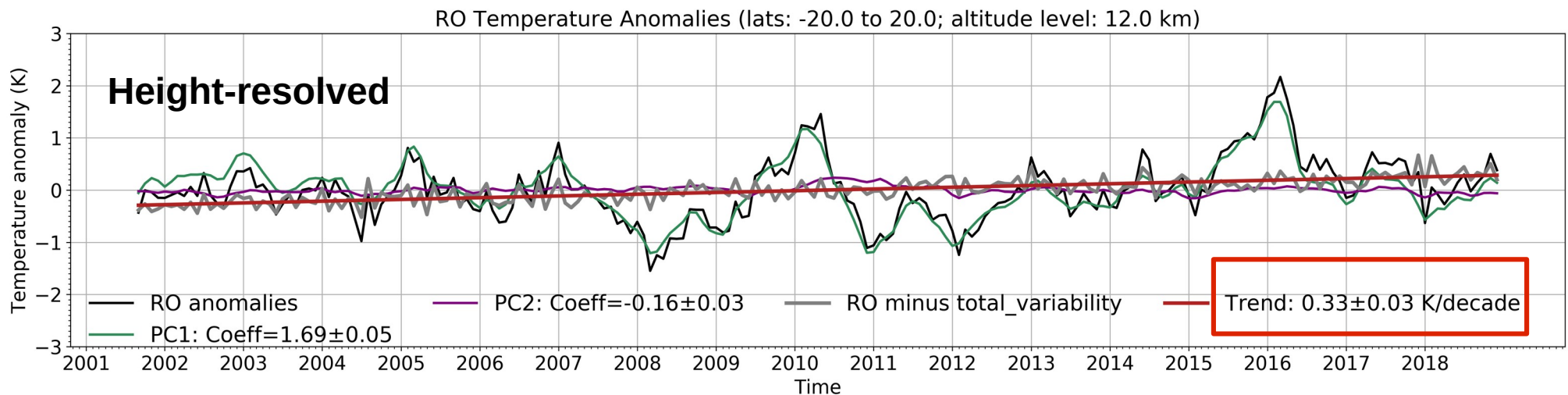
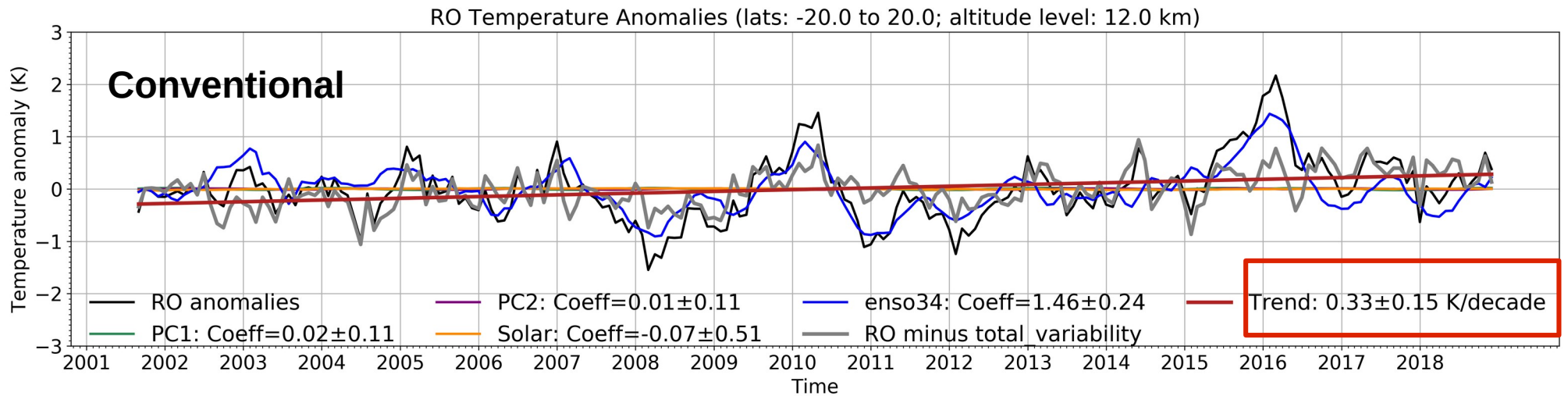


PC2

F. Ladstädt

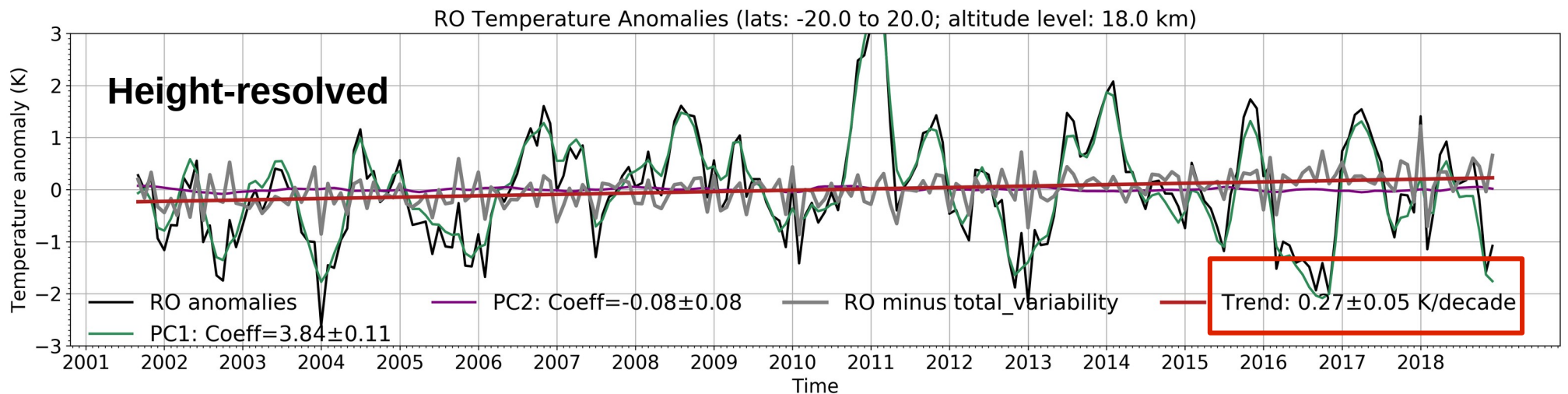
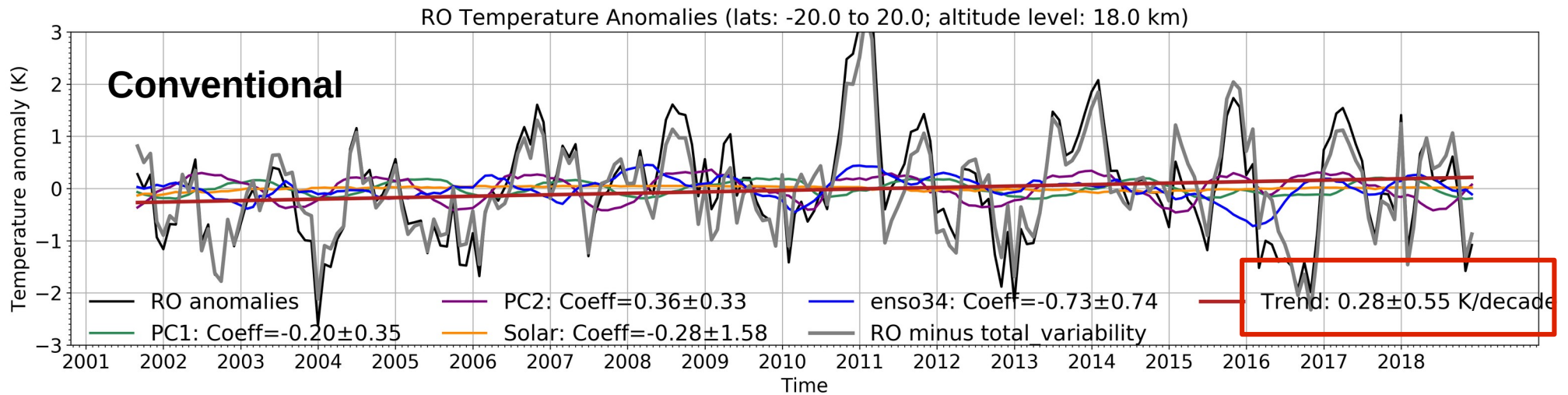
Multiple linear regression@12 km, tropics

How much of the total variability do the indices resolve?



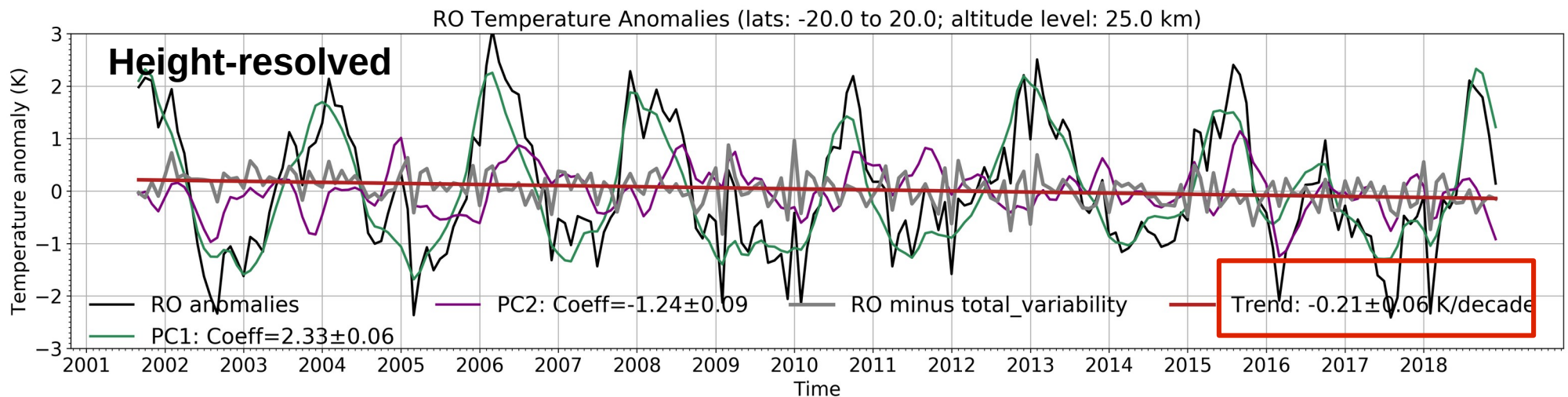
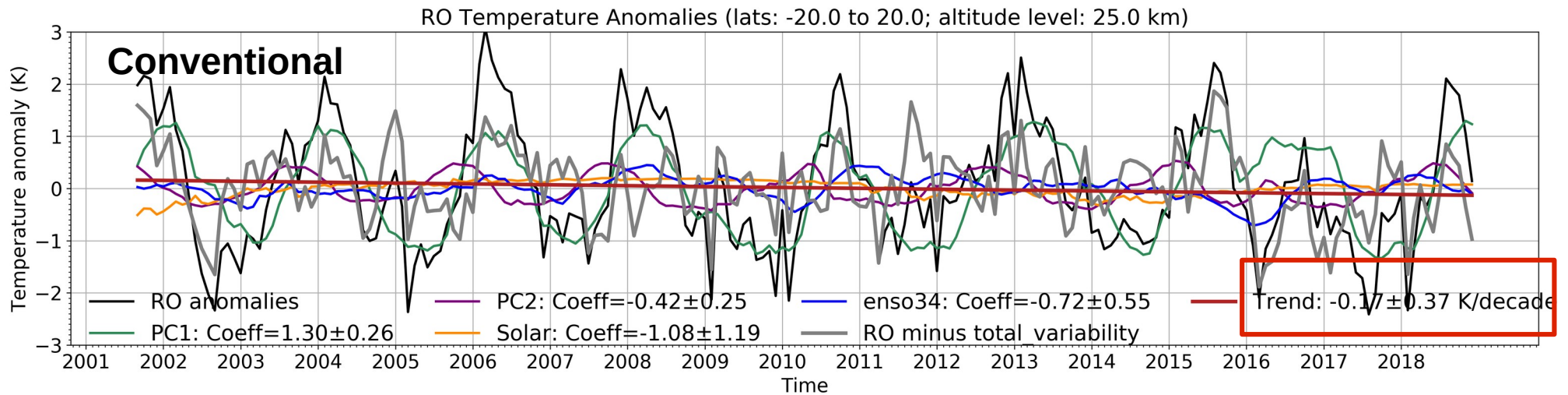
Multiple linear regression@18 km, tropics

How much of the total variability do the indices resolve?

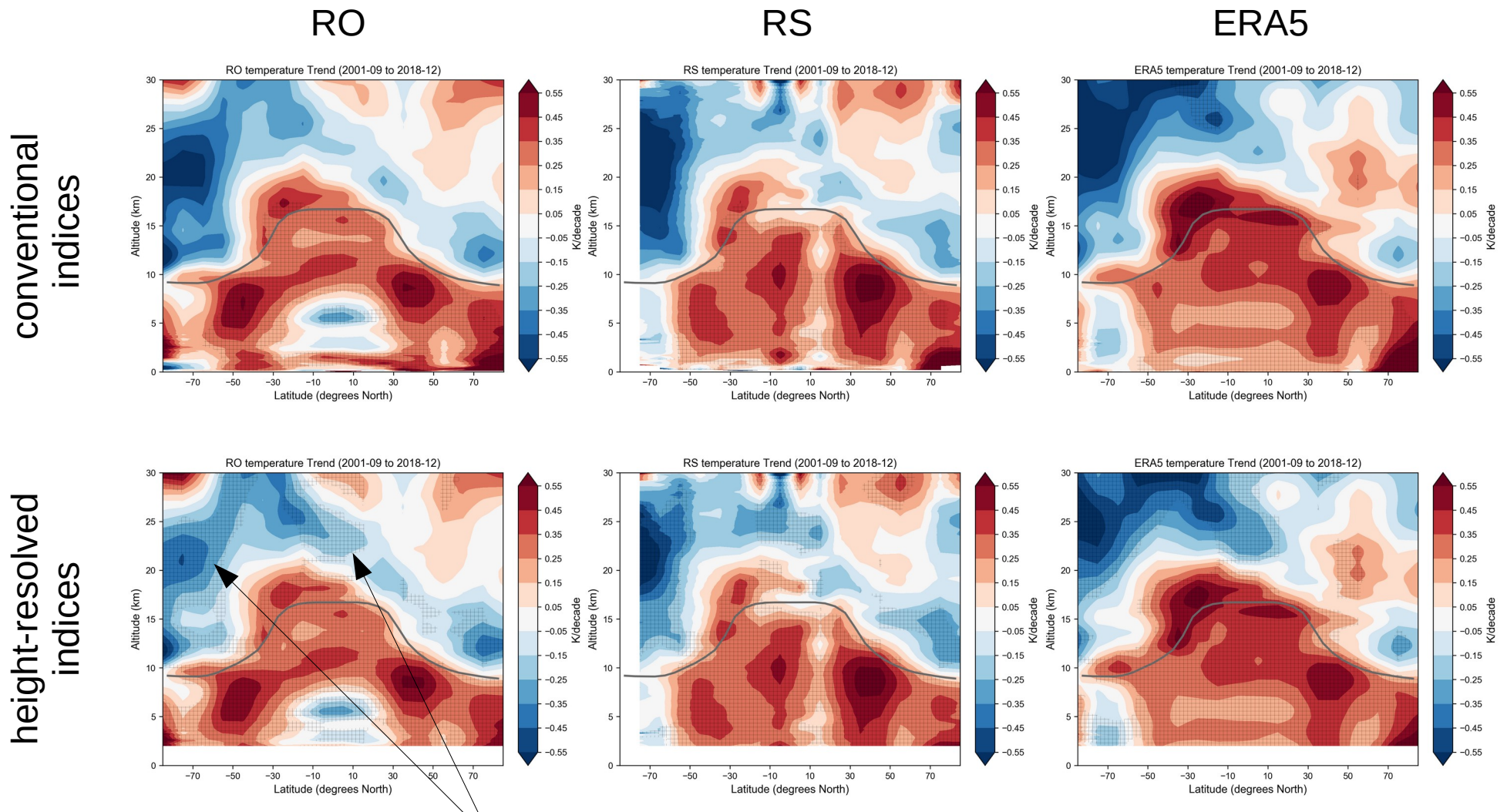


Multiple linear regression@25 km, tropics

How much of the total variability do the indices resolve?



Temperature trends, multiple linear regression



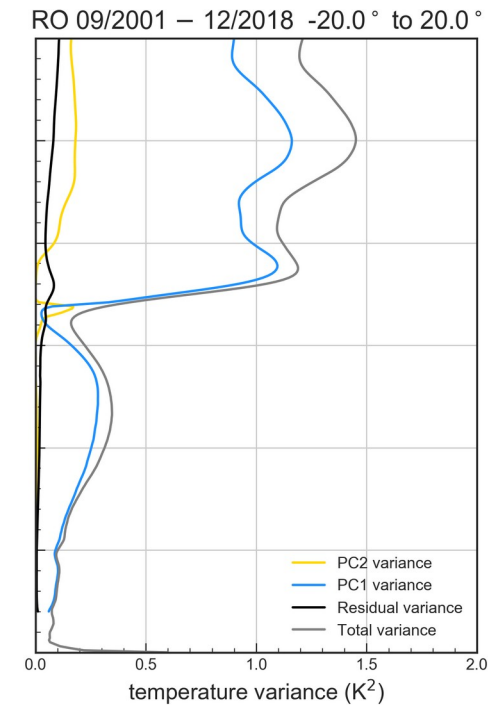
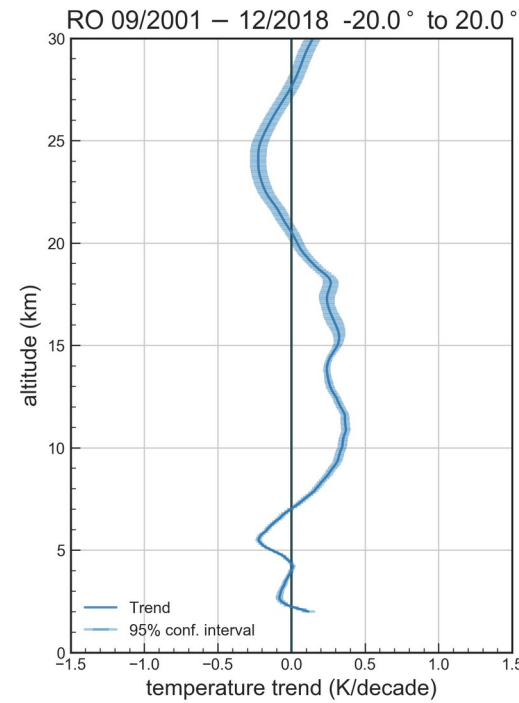
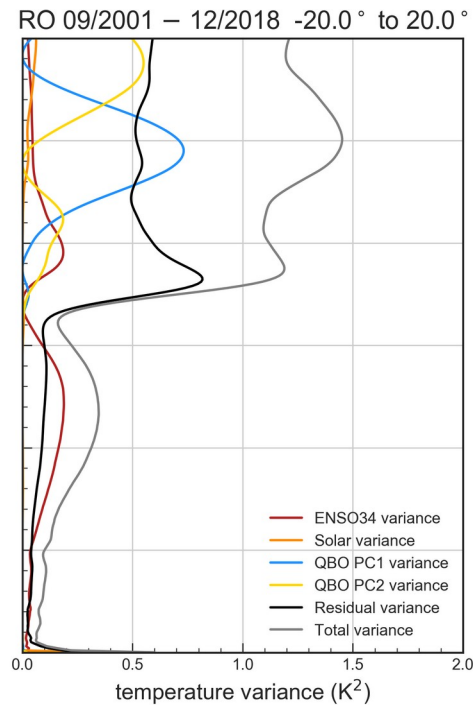
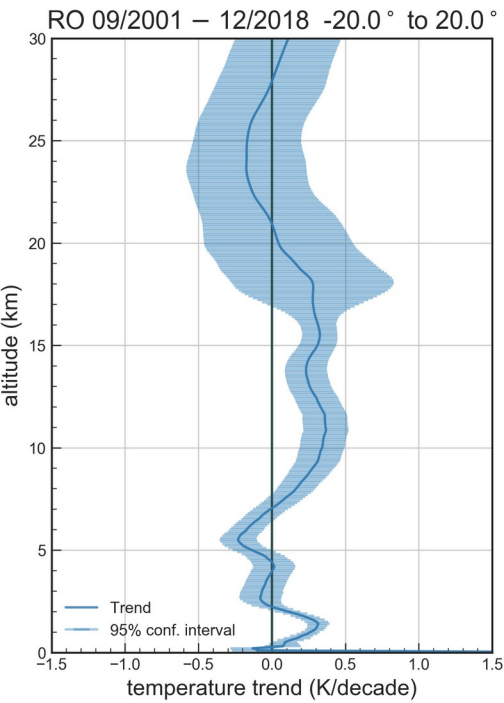
Robust trends, but: With height-resolved indices, also stratospheric trends become statistically significant (95%)

Multiple linear regression, explained variance

What is the advantage of the height-resolved indices? Here, e.g., tropics:

conventional indices

height-resolved indices



trend with 95% conf.int.

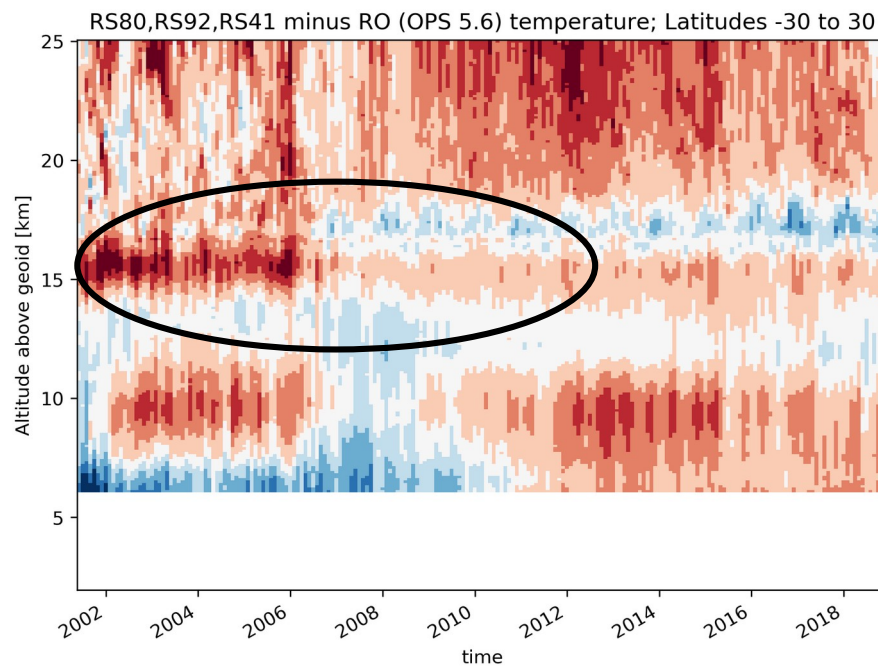
explained variance

trend with 95% conf.int.

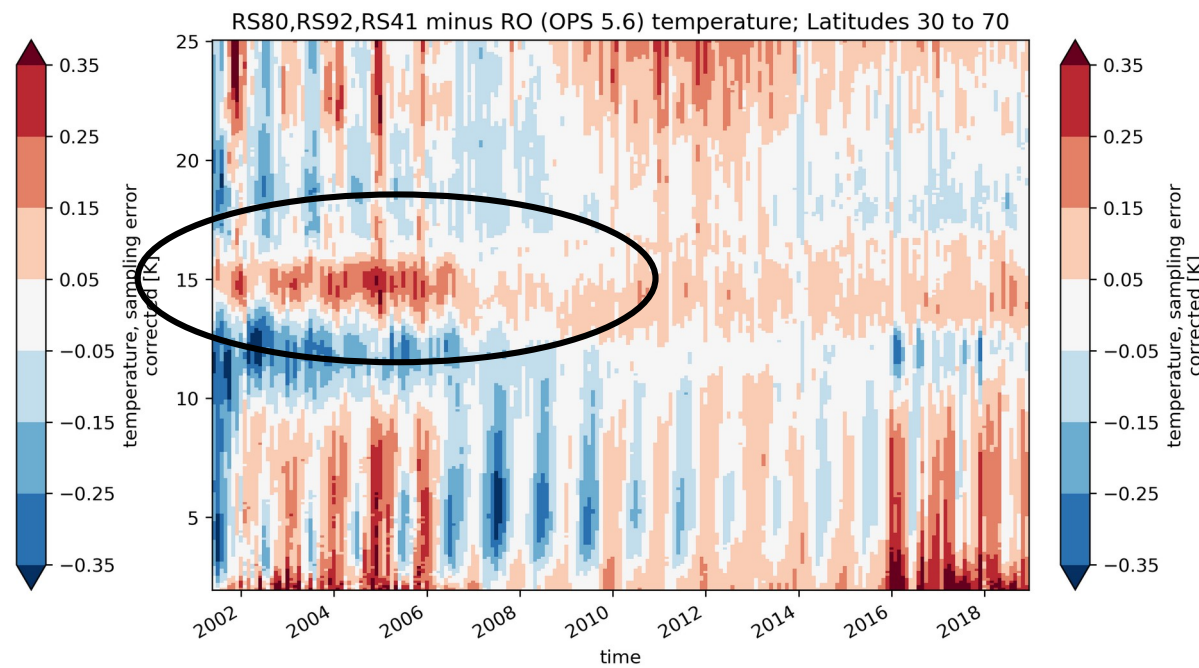
explained variance

Excursion: Differences RO, RS

RS minus RO, tropics



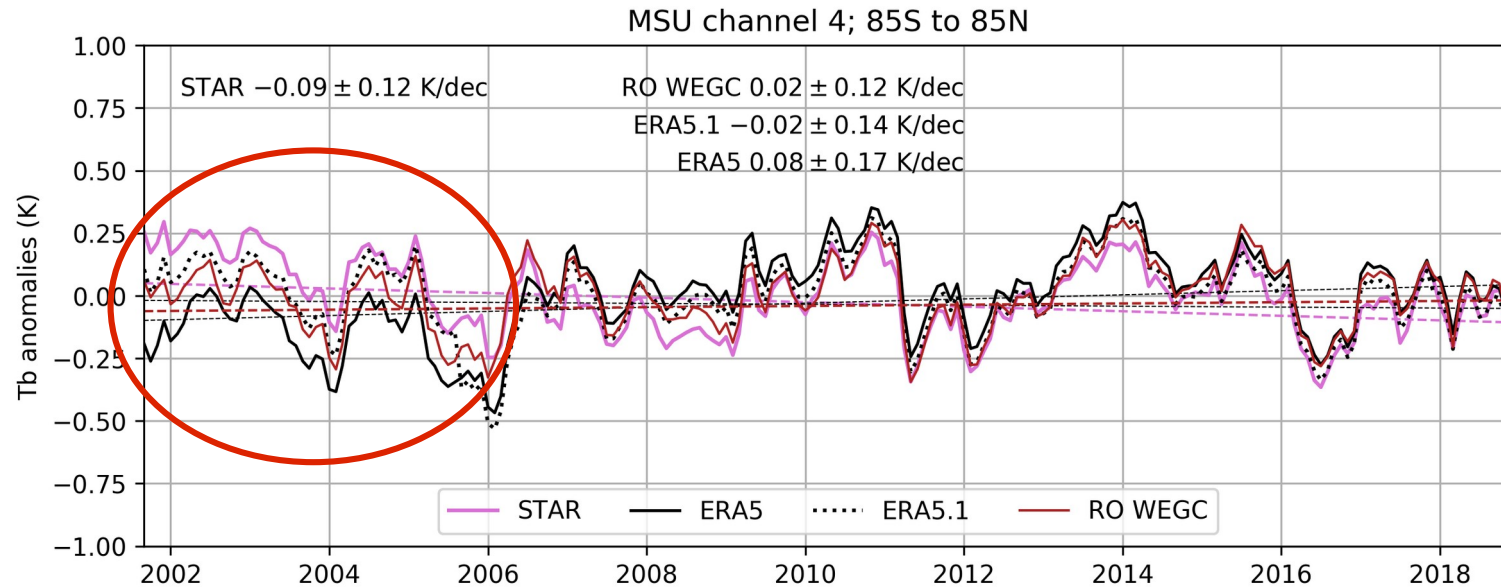
RS minus RO, 30N to 70N



Reason for differences RO-RS in tropopause region could be switch from RS80 to RS92

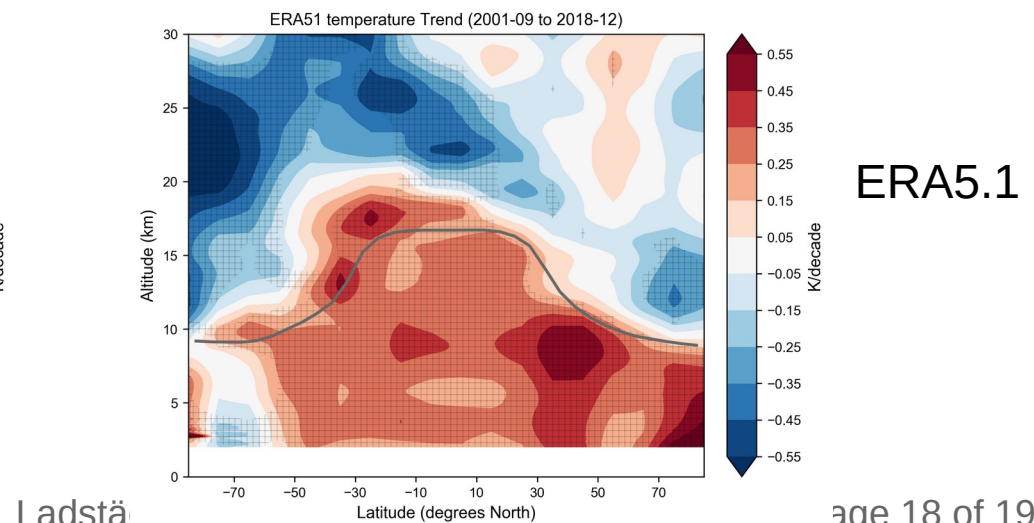
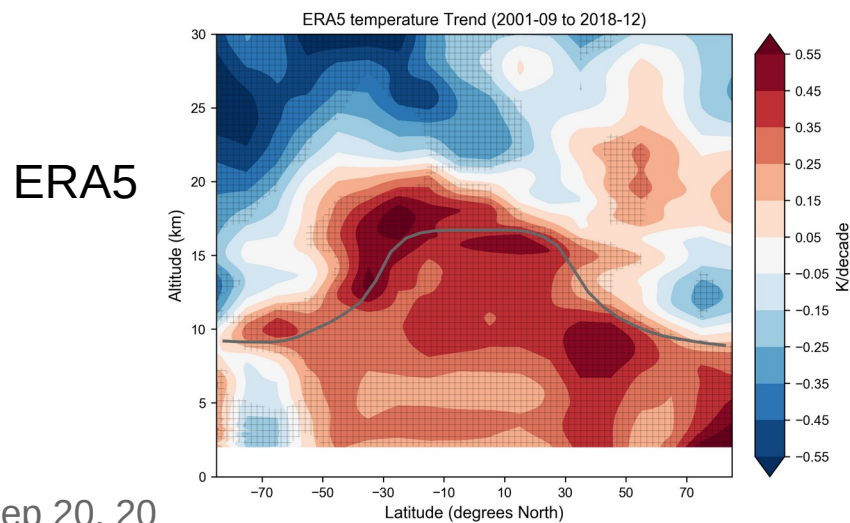
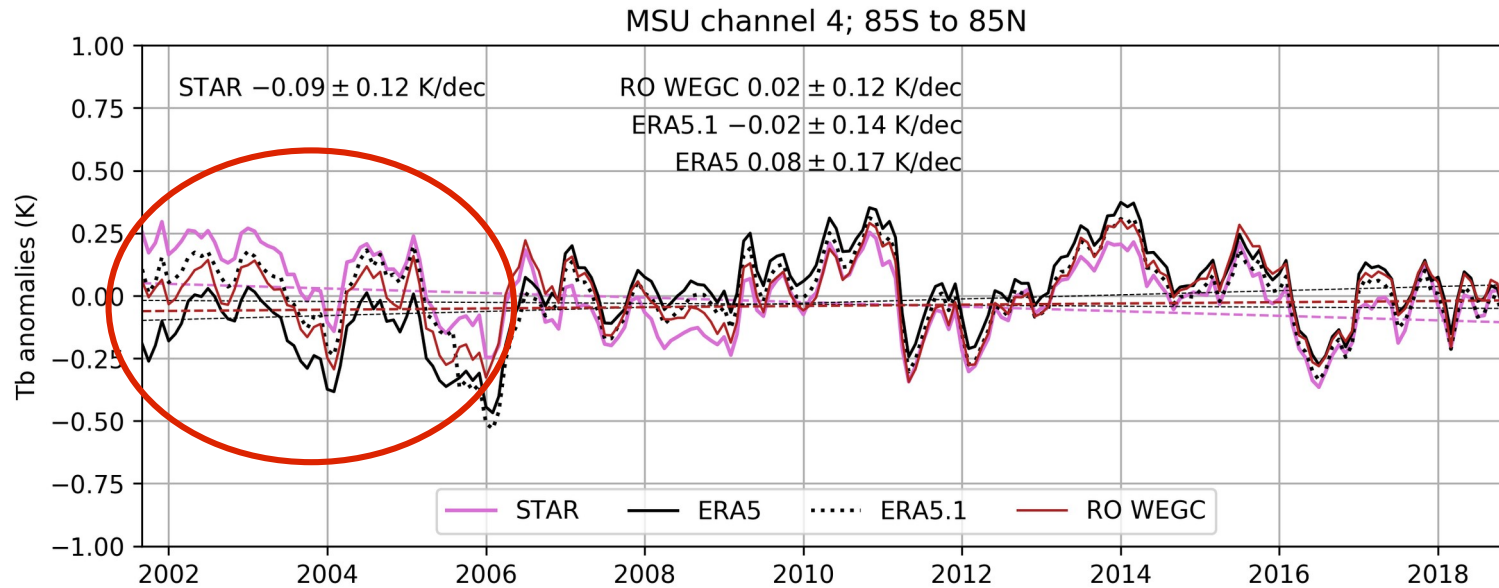
Excursion2: ERA5 2000–2006

ERA5.1 much improved between 2000 and 2006, compared to original ERA5.



Excursion2: ERA5 2000–2006

ERA5.1 much improved between 2000 and 2006, compared to original ERA5.



Conclusions: Trends 2001-09 to 2018-12

RO

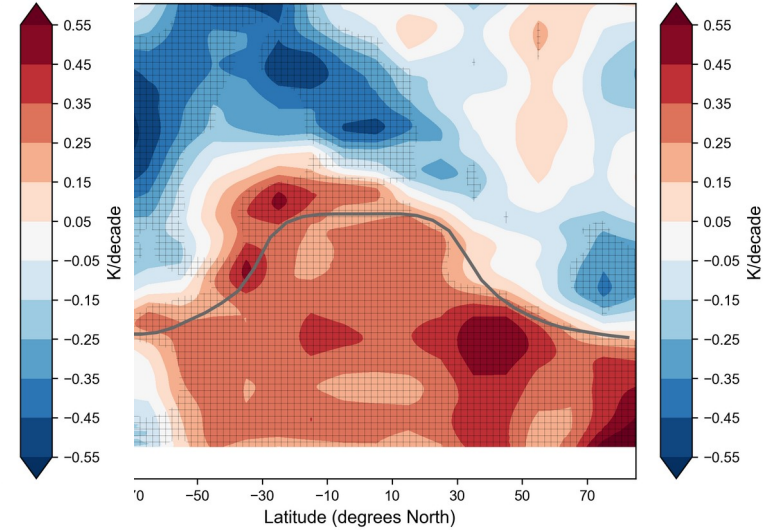
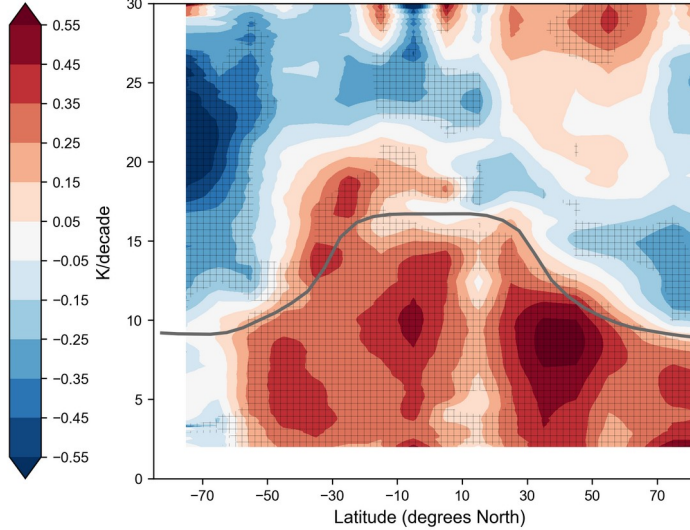
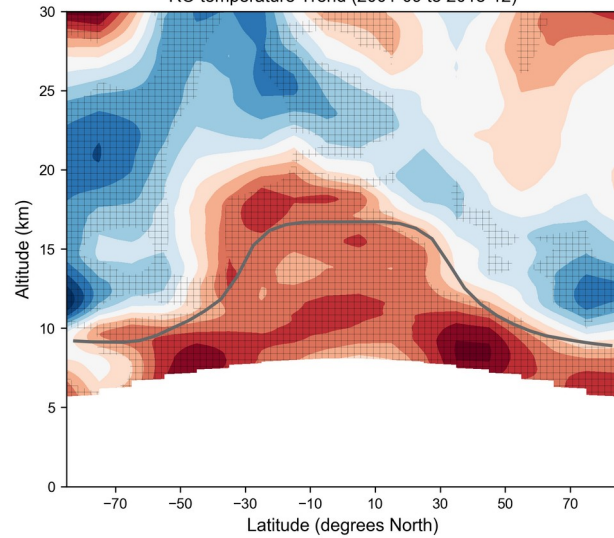
RS

ERA5.1

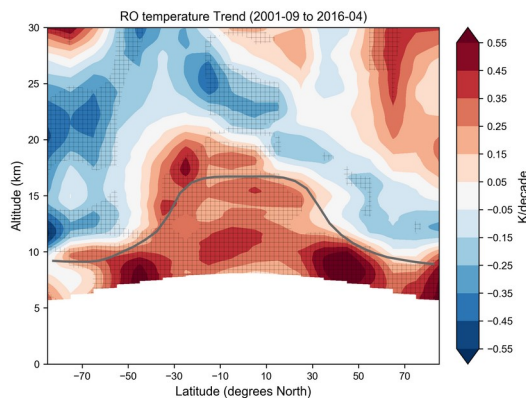
RO temperature Trend (2001-09 to 2018-12)

RS temperature Trend (2001-09 to 2018-12)

ERA51 temperature Trend (2001-09 to 2018-12)



2001-09 to 2016-04
to compare:



Conclusions:

- Careful consideration of variability versus trend signal needed for climate trend detection over short time period.
- RO and RS trends overall consistent, differences to be resolved remain.