Sub-grid scale thermal variability in the UTLS from radio occultation

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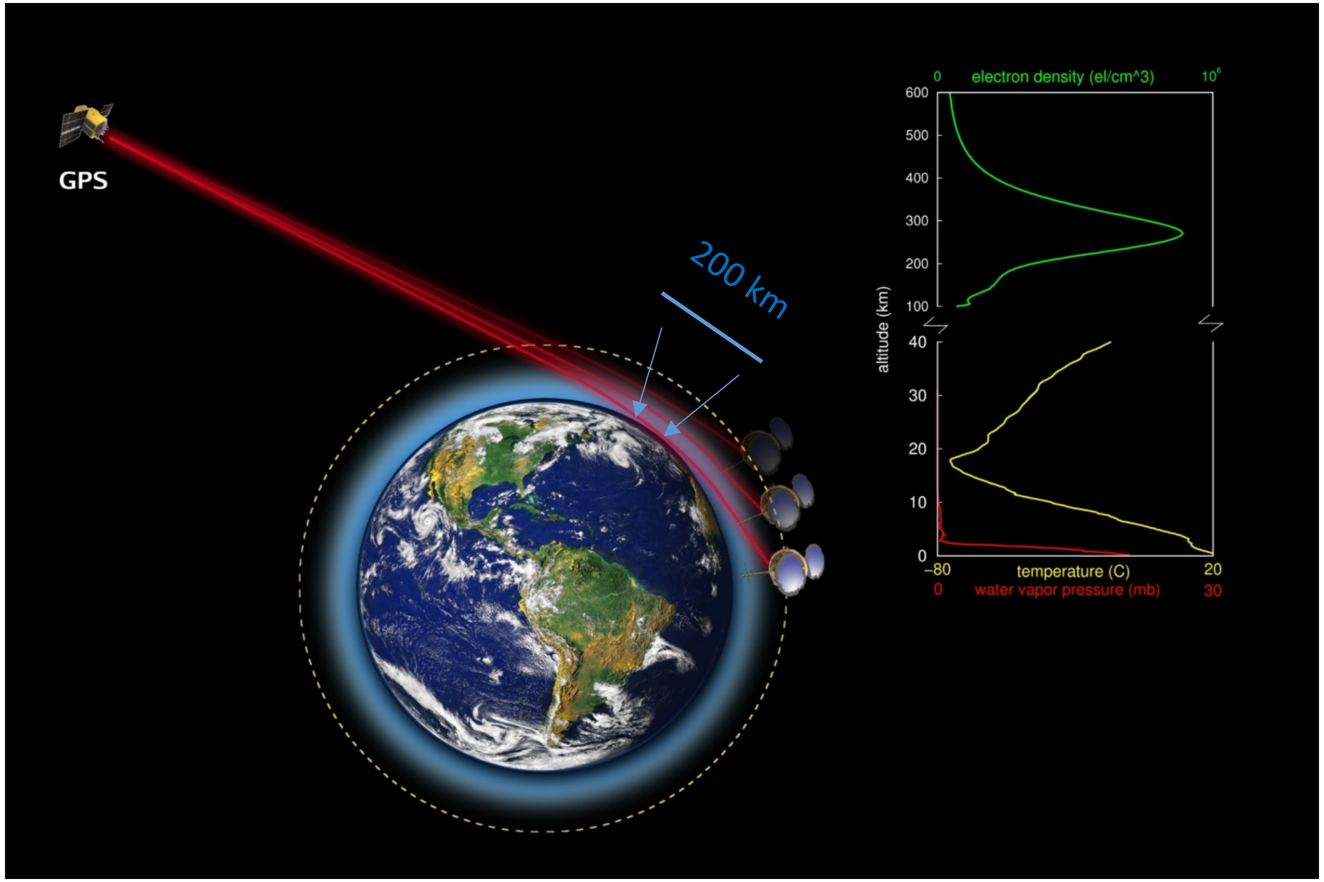
Thanks to: Fei Wu, Jon Starr, Aurelien Podglajen, Rei Ueyama, COSMIC colleagues

Overview

- Objective: quantify UTLS thermal variability in dense RO measurements;
  understand the information content of RO data
- Background, defining ‘sub-grid scales’
- Observations from COSMIC-2 – low latitude seasonal variability;
  links to convection, winds and stability
- Combining COSMIC-2 + SPIRE to study extratropics
- Gravity waves and jet streams

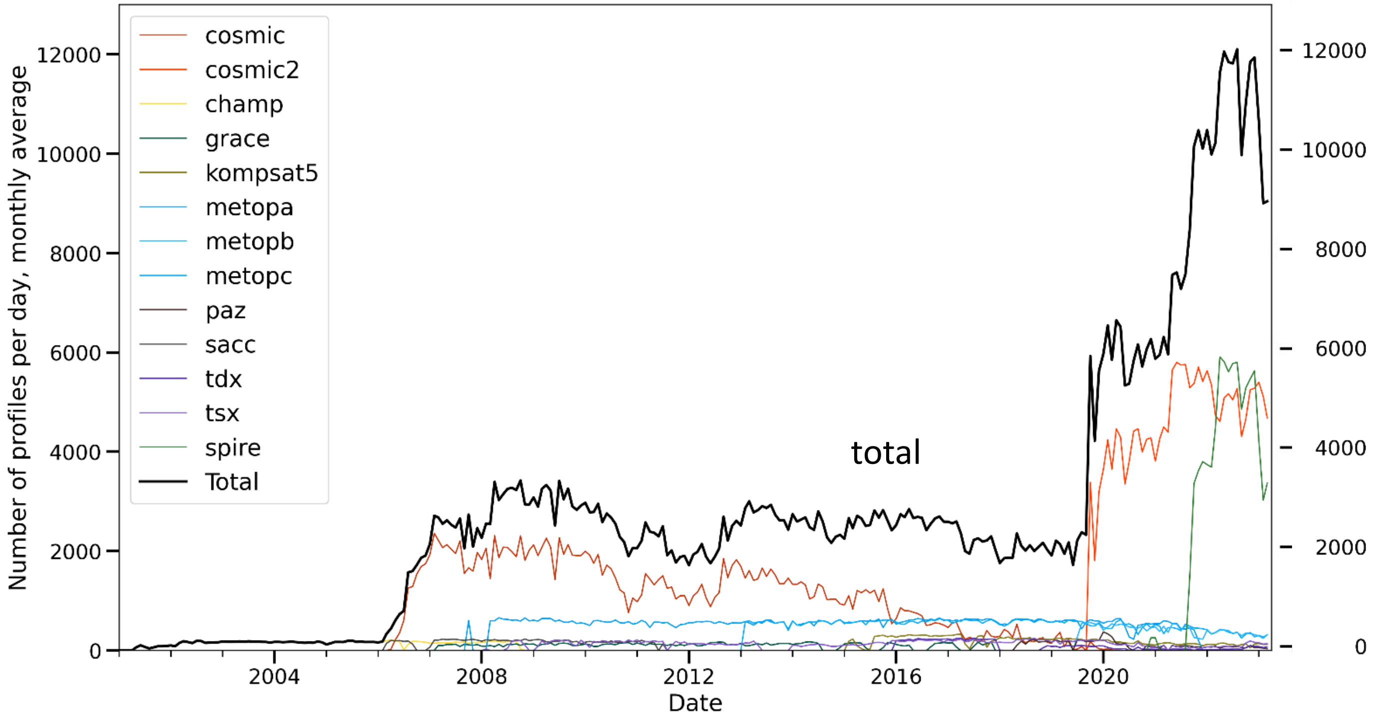
Basic principle of radio occultation:
measure bending angle and derive atmospheric refractivity (N)



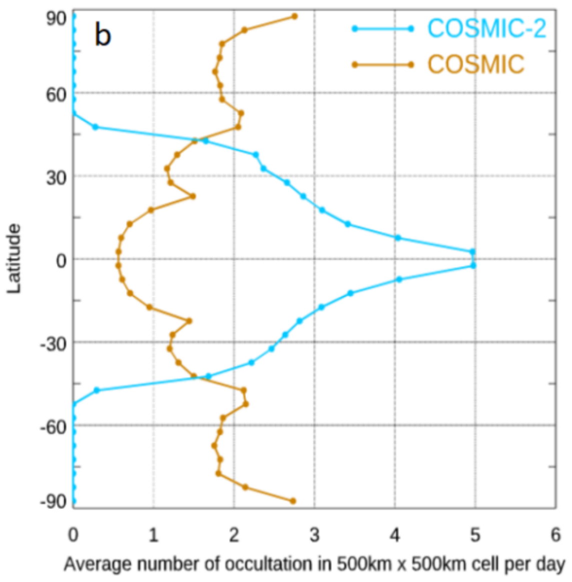
High quality measurements:

- long-term stability, all weather
- Retrieve temperature ~10-35 km; (also H_2O ~0-8 km)
- high vertical resolution (~1 km); ~200 km integral along ray path
- 'most accurate and precise thermometer from space'

Number of radio occultation measurements over time



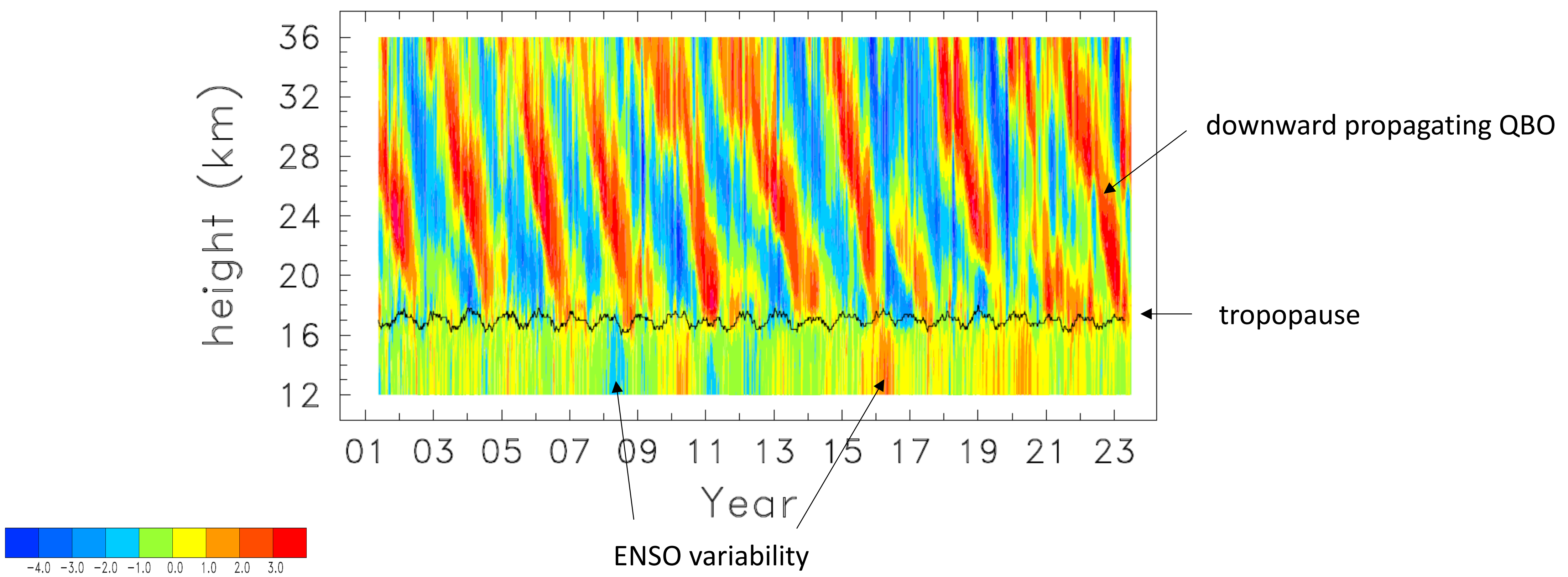
COSMIC-2 focused over 40° N-S



Soon: Radio Occultation Modeling Experiment (ROMEX) - > 30,000 occultations/day

Example of climate data record from radio occultation:

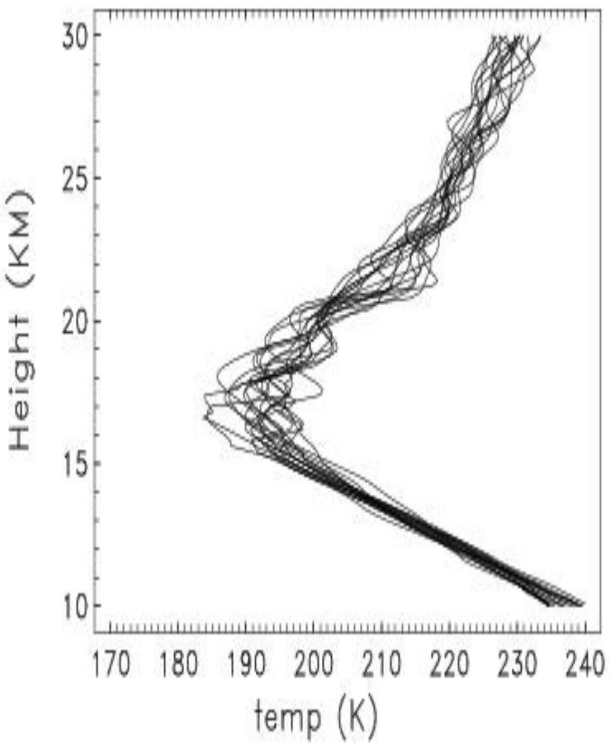
Deseasonalized temperature anomalies over 10° N-S



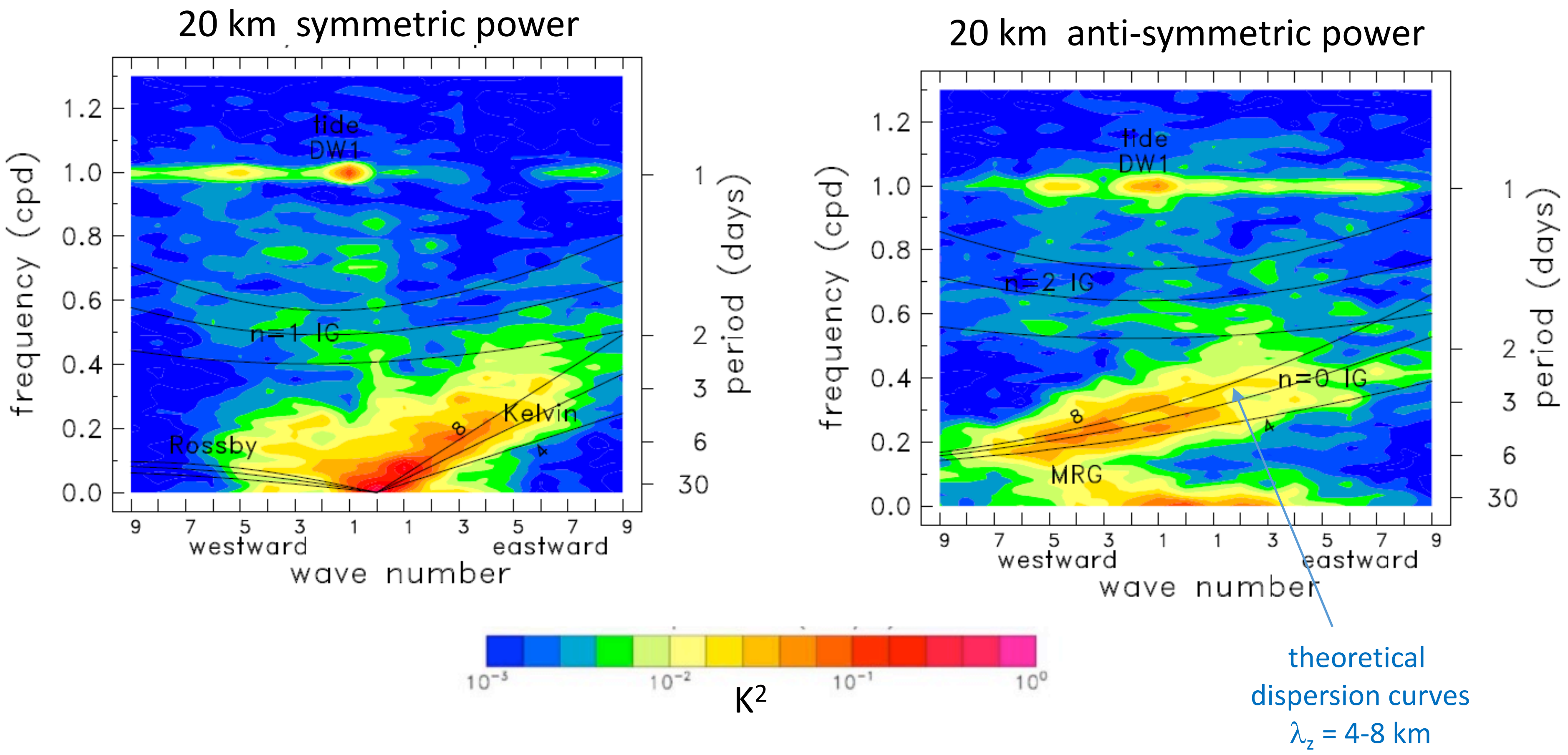
<u>Waves in the tropical UTLS from RO data</u>

- RO data from CDACC retrievals - ‘dry temperature’ for 10-30 km
- Derive gridded data: 4^o x 10^o lat x long x *6-hour resolution*
- Space-time spectrum analysis: equatorial waves and tides
- <u>Sub-grid scale ‘residuals’ – gravity waves</u>

example profiles



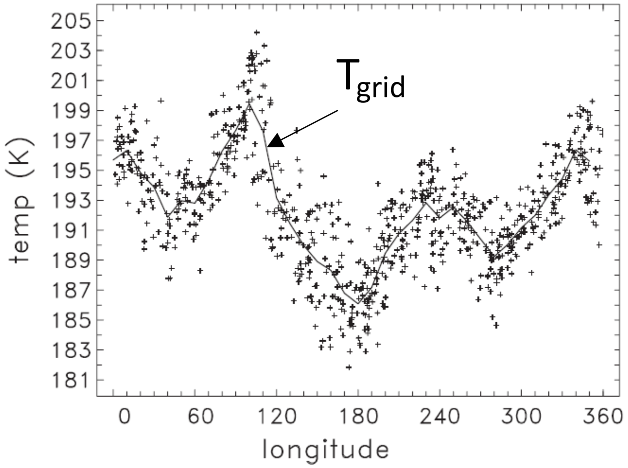
Equatorial waves identified in wavenumber-frequency spectra



Sub-grid scale variance: difference between RO measurements and gridded fields

Example gridding for one day

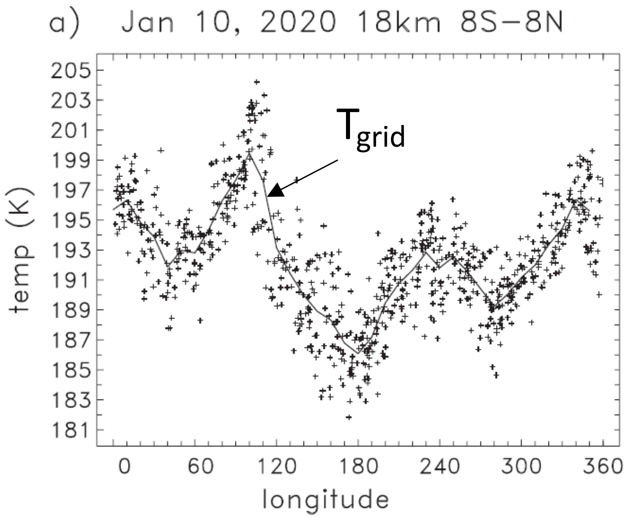
a) Jan 10, 2020 18km 8S–8N



$T_{res}' = T_i - T_{grid}$

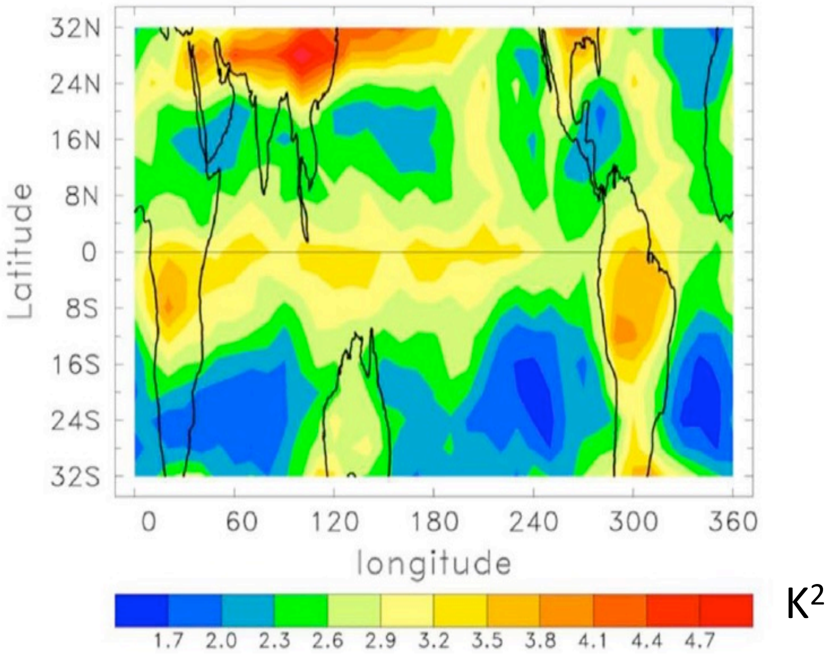
Sub-grid scale variance: difference between RO measurements and gridded fields

Example gridding for one day



$T_{res}' = T_i - T_{grid}$

18-20 km DJF 2019-20 time average $T_{res}'^2$



Sub-grid scale variance: difference between RO measurements and gridded fields

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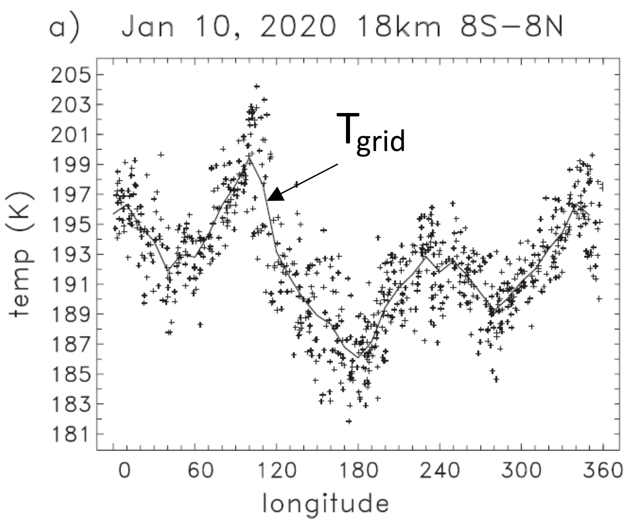

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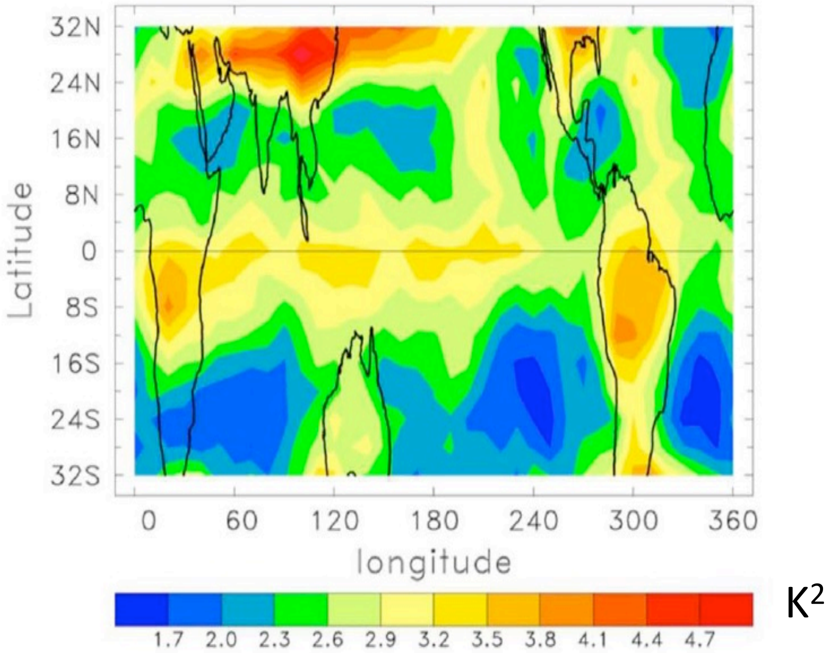
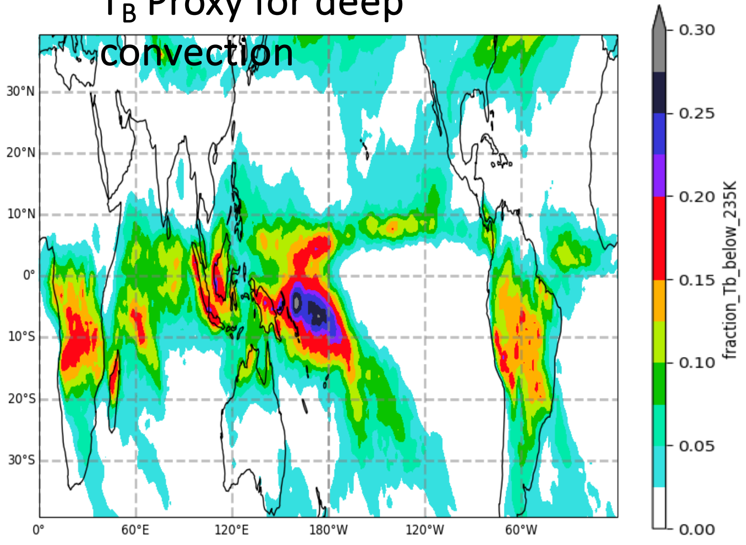


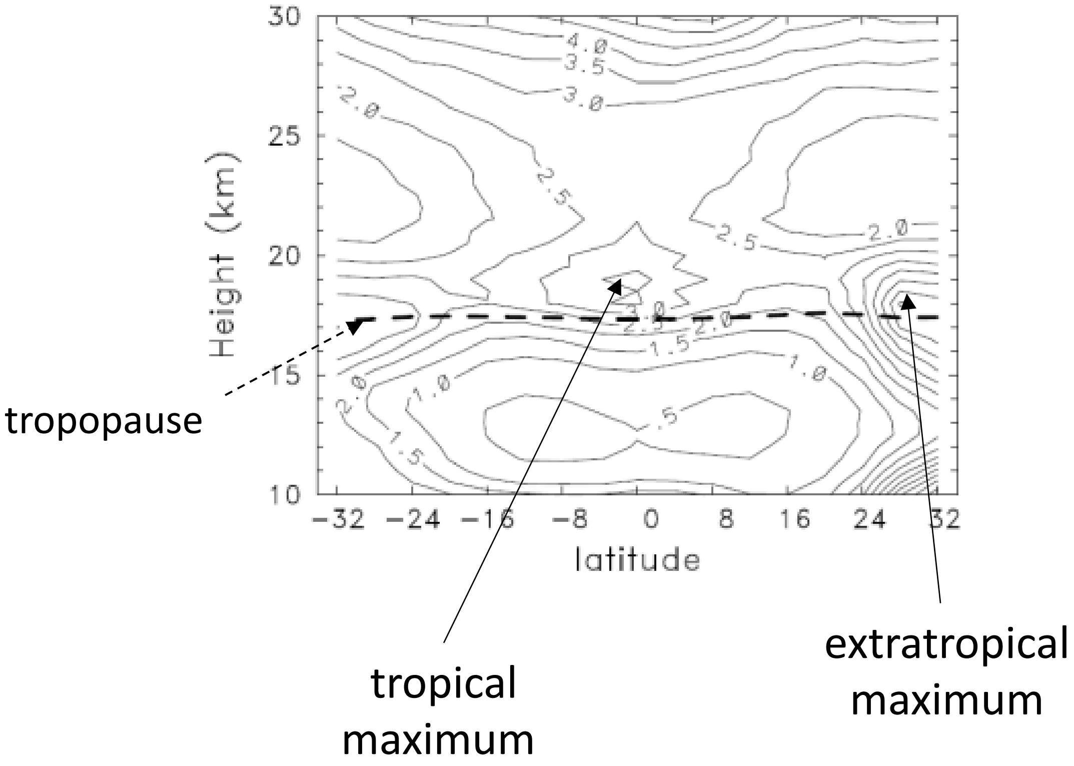
T_B Proxy for deep convection



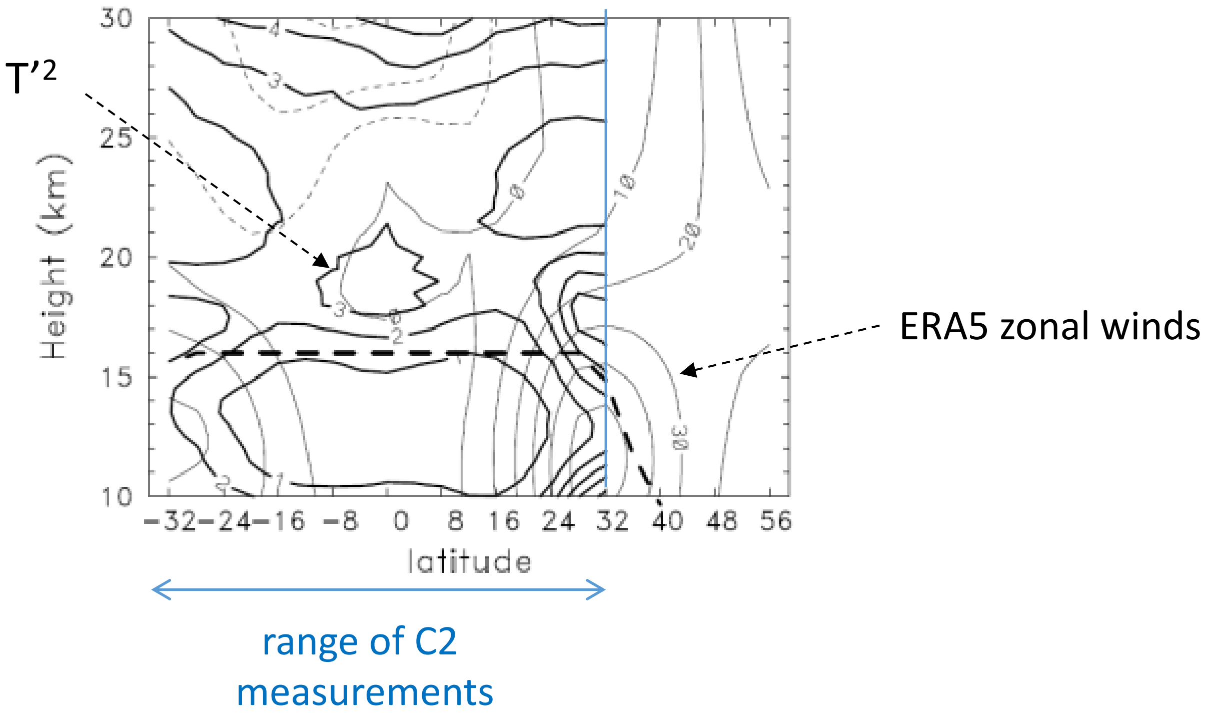
coherent space-time structure suggestive of gravity waves

Randel et al 2021 JGR

T'^{2} structure   DJF 2019-20

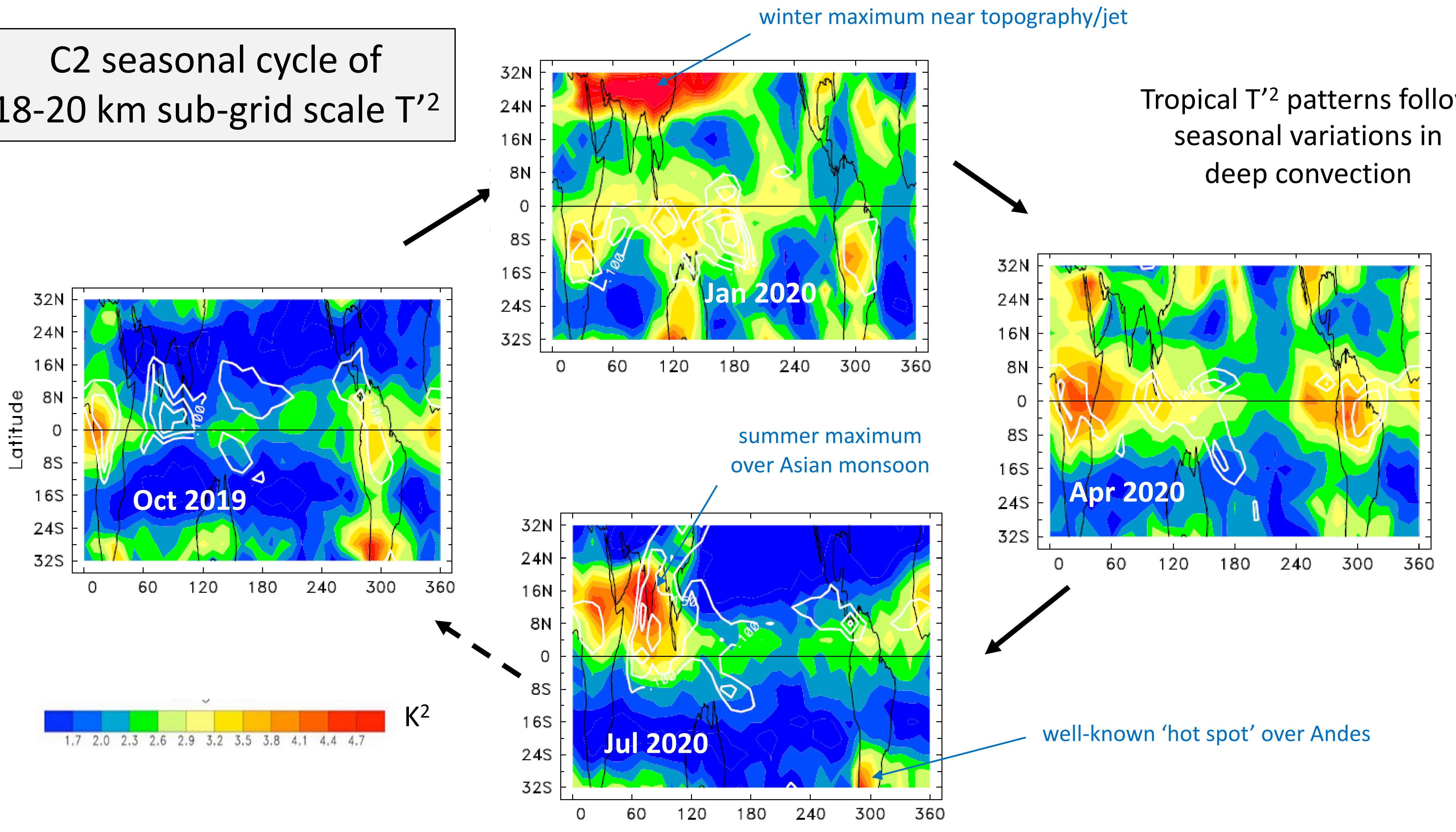


T'^{2} with background zonal winds

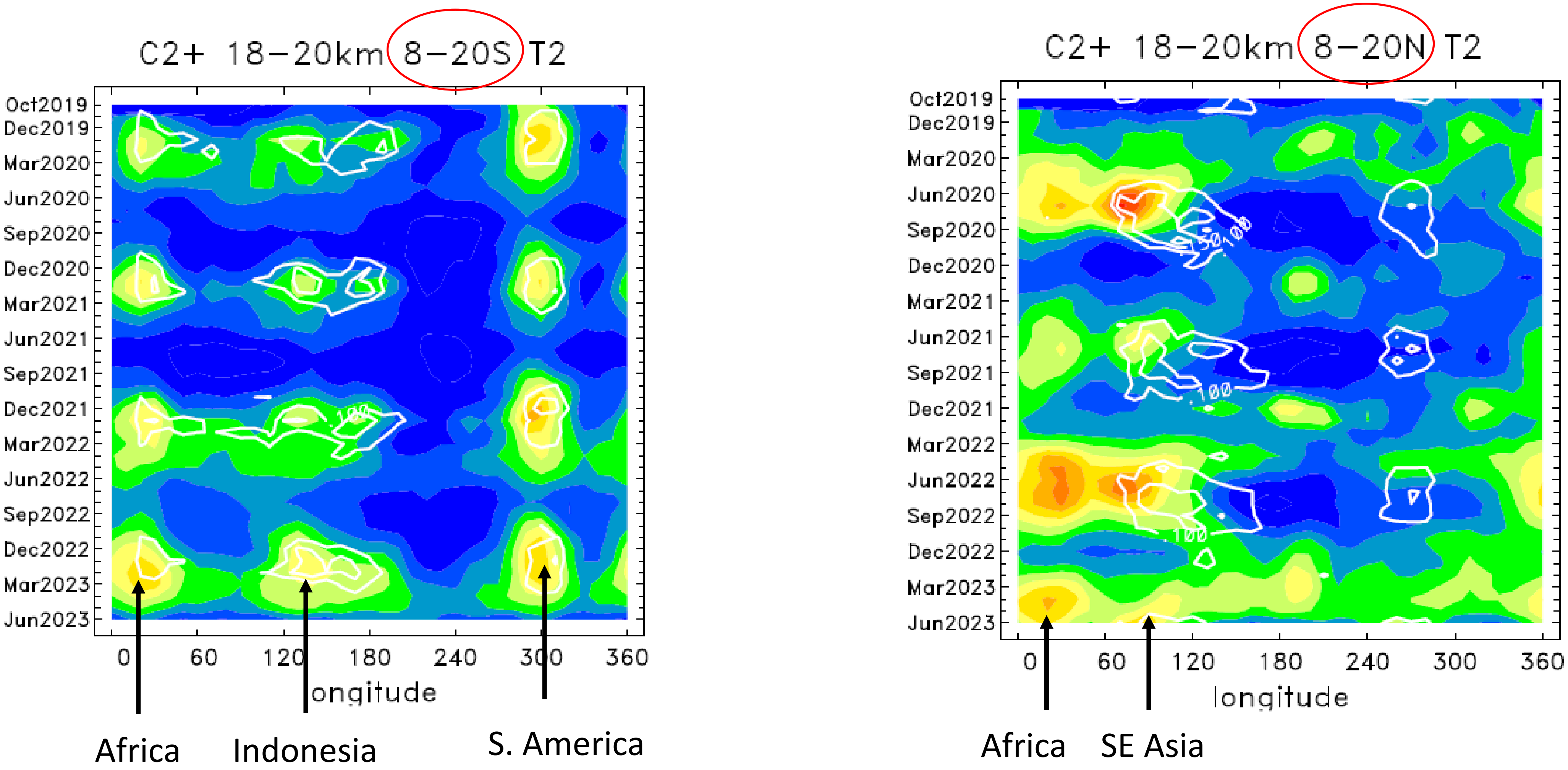


C2 seasonal cycle of 18-20 km sub-grid scale T'^2

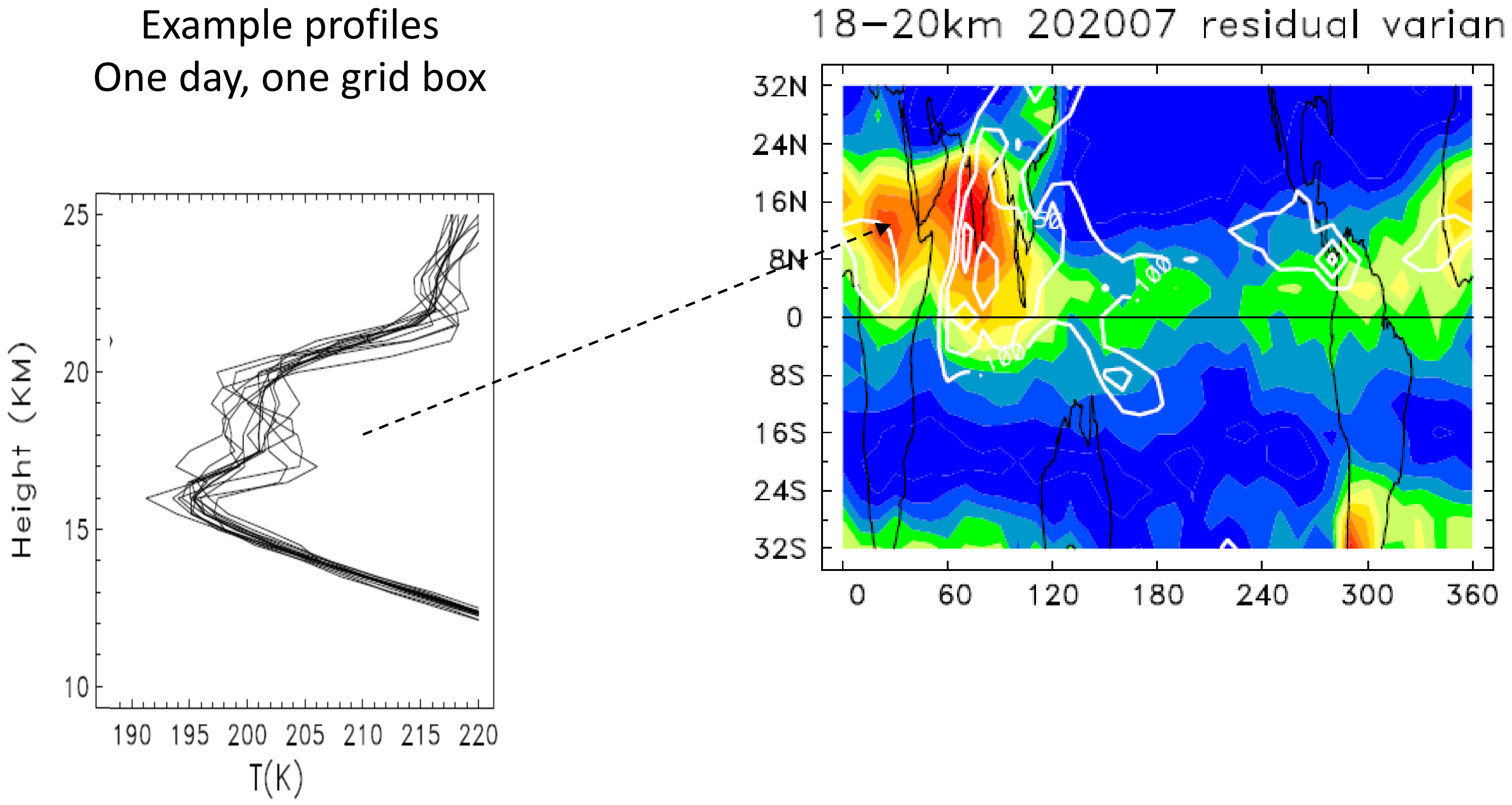
Tropical T'^2 patterns follow seasonal variations in deep convection



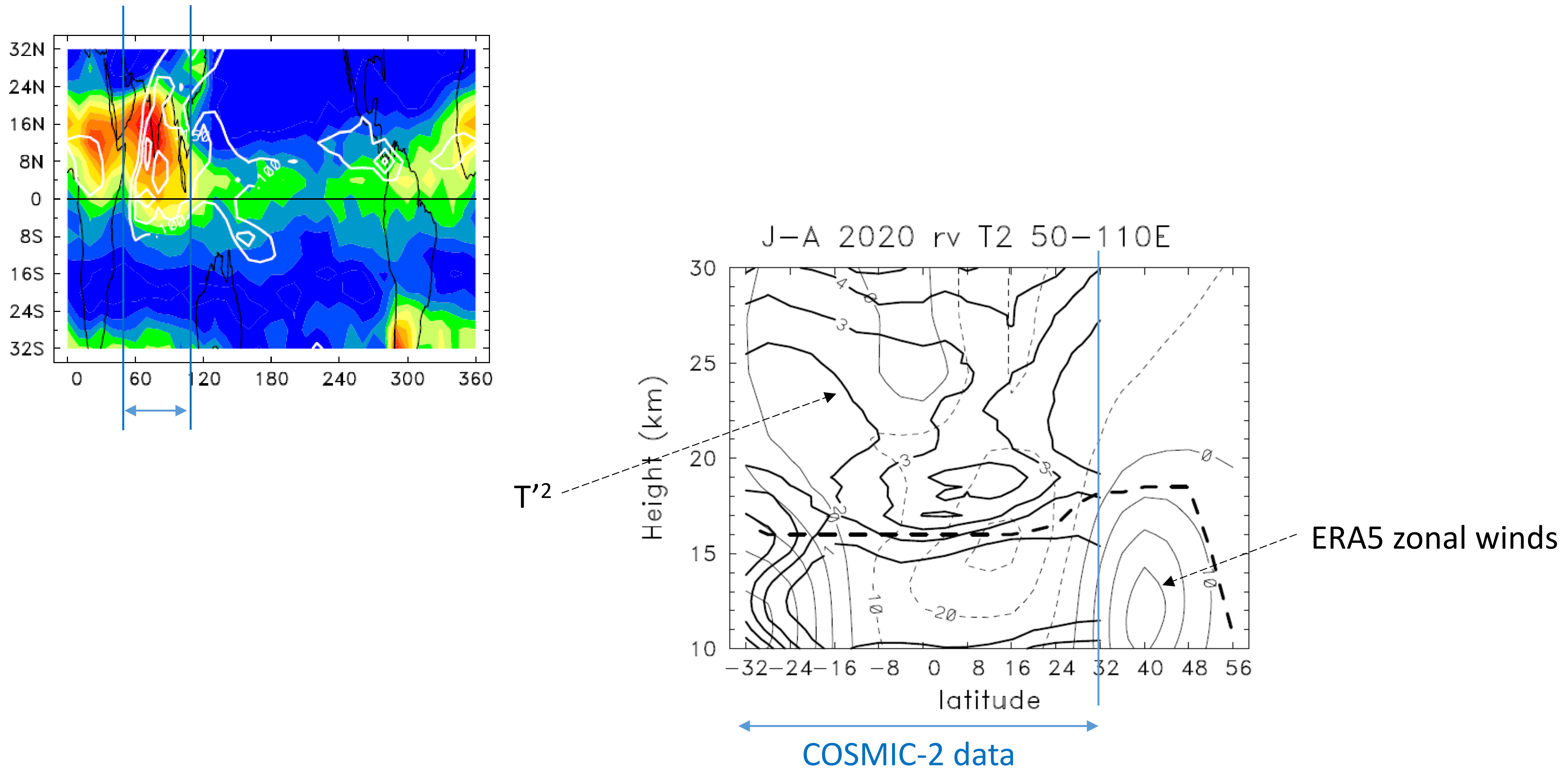
4 years from COSMIC-2



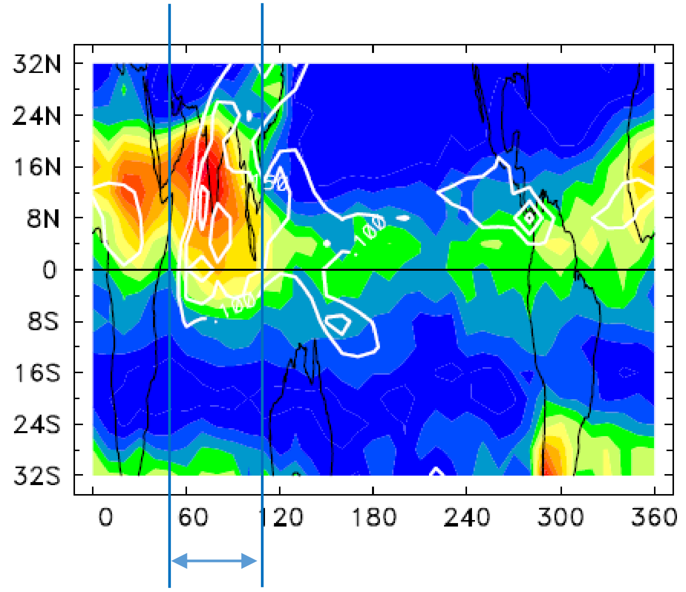
Example profiles
One day, one grid box



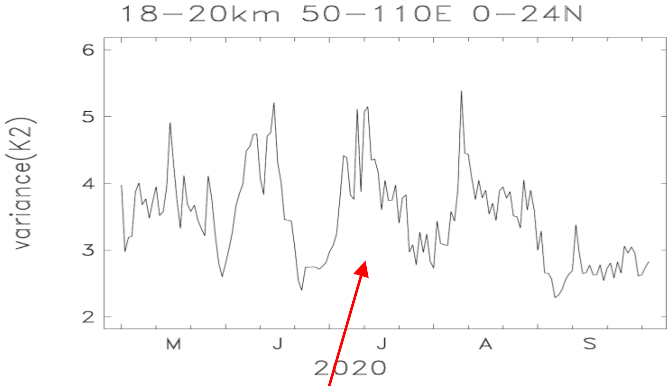
T'^2 in UTLS Asian monsoon



T'^2 in UTLS Asian monsoon

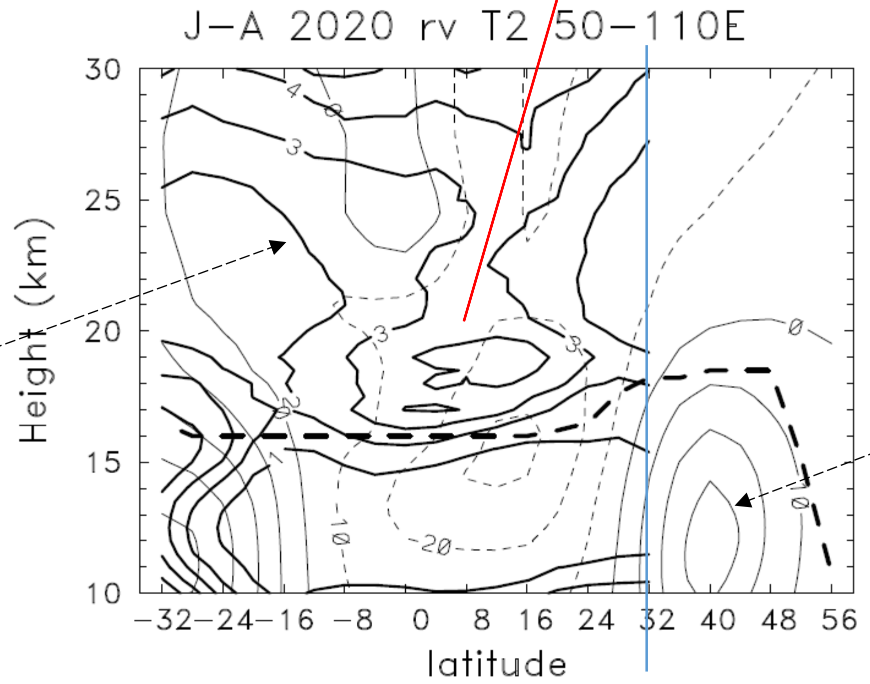


daily T'^2 variability



- Geophysical?
- Not simply related to underlying convection
- Linked to easterly jet?

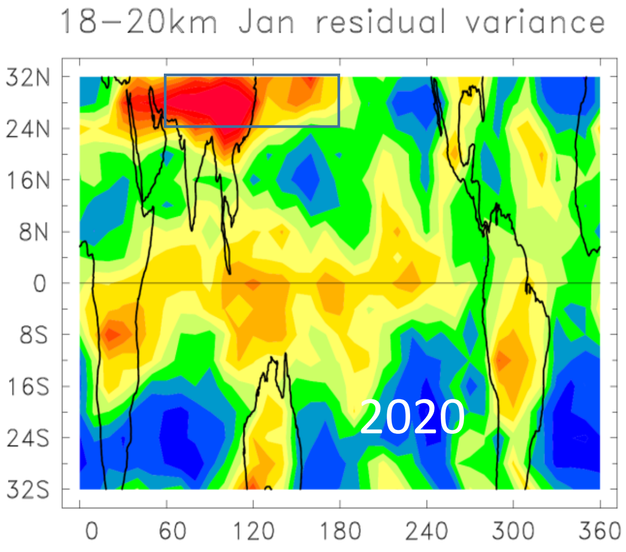
T'^2

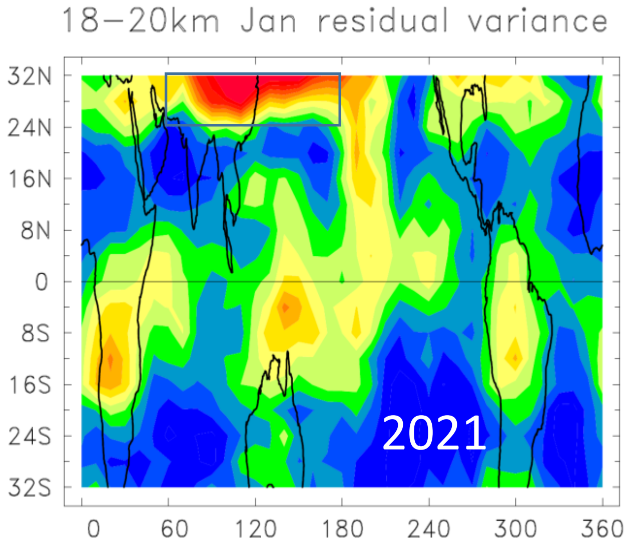


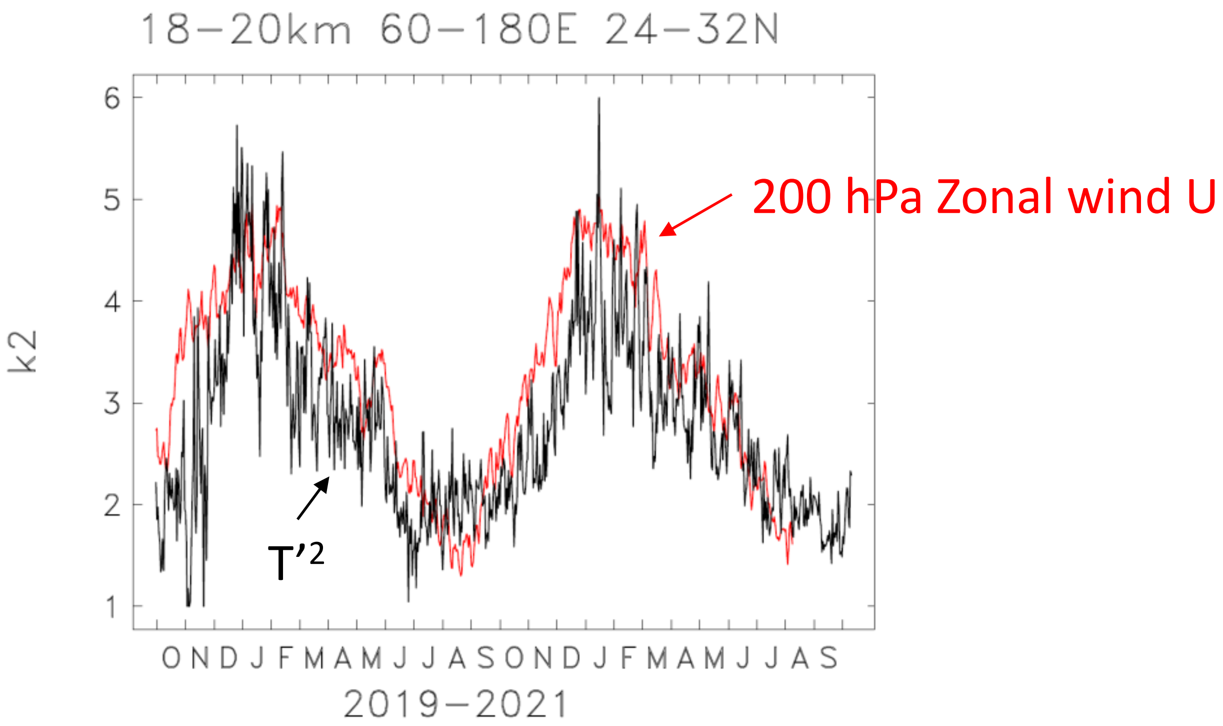
ERA5 zonal winds

COSMIC-2 data

T'^2 maxima near the boreal wintertime extratropical jet





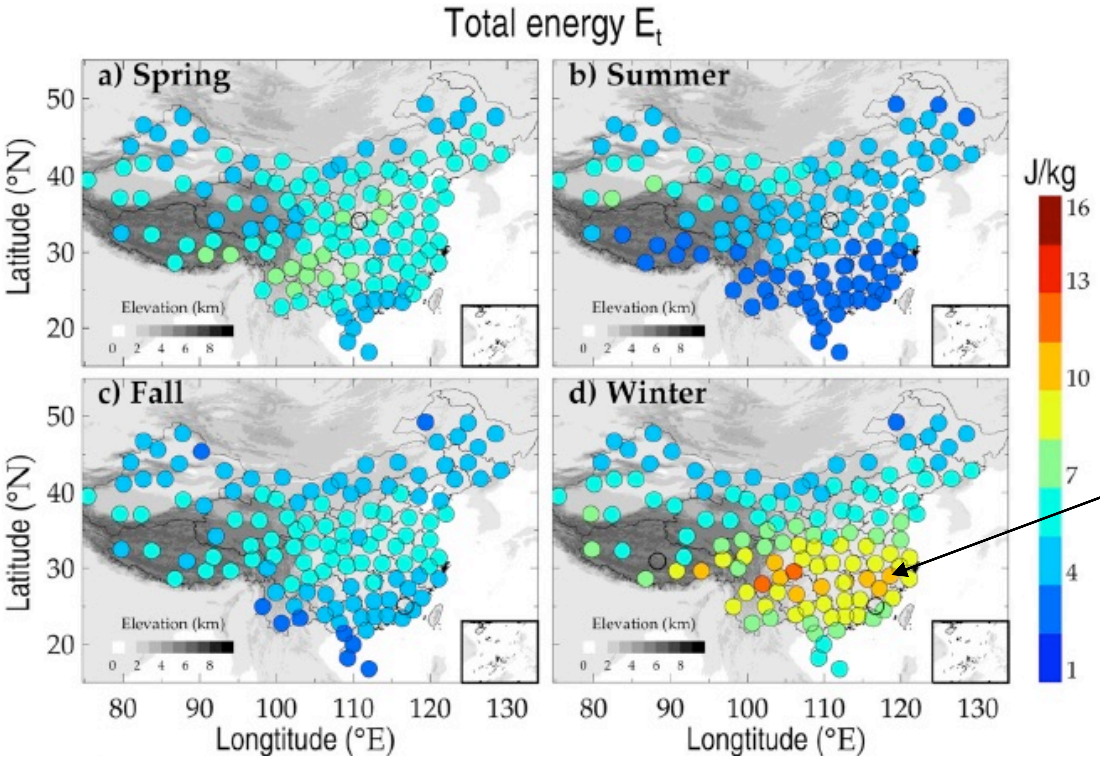


Tropospheric Gravity Waves as Observed by the High-Resolution China Radiosonde Network and Their Potential Sources

JGR 2022

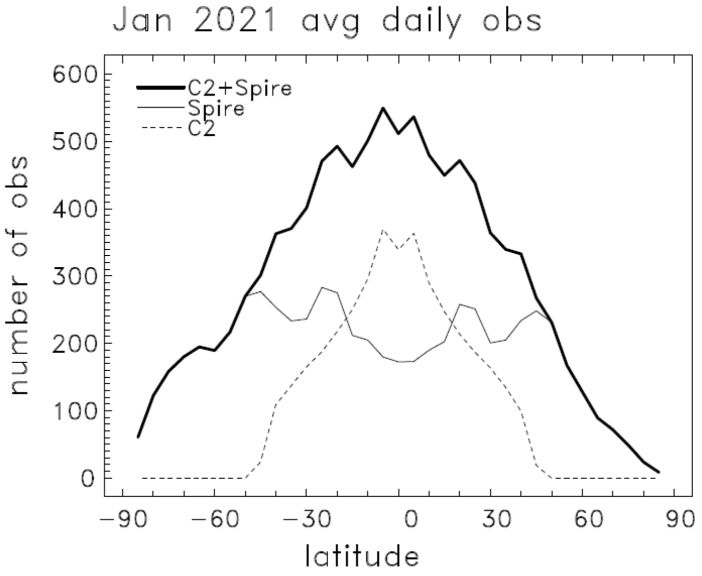
Jian Zhang[1], Jianping Guo[2], Haile Xue[2], Shaodong Zhang[3], Kaiming Huang[3], Wenjun Dong[4], Jia Shao[5], Ming Yi[6], and Yehui Zhang[7]

Also, gw's are strongly correlated with zonal wind intensity



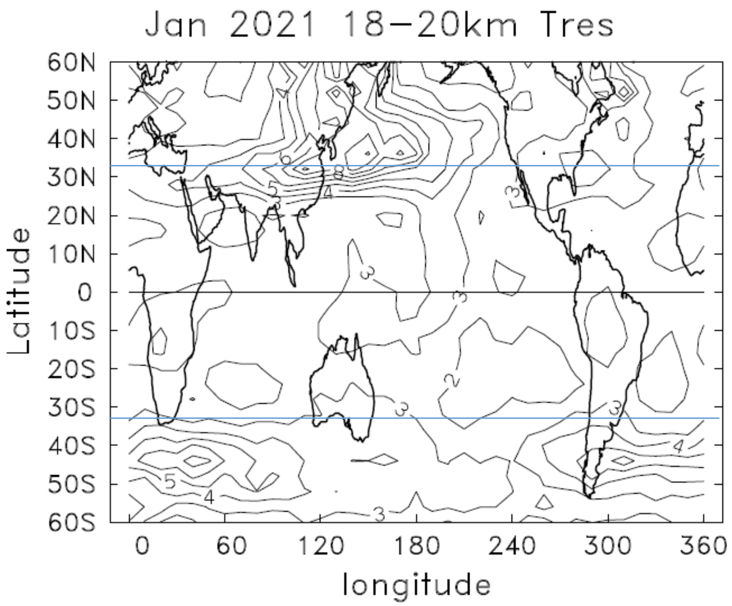
winter maximum

Merged COSMIC-2 and SPIRE-C data to study global behavior

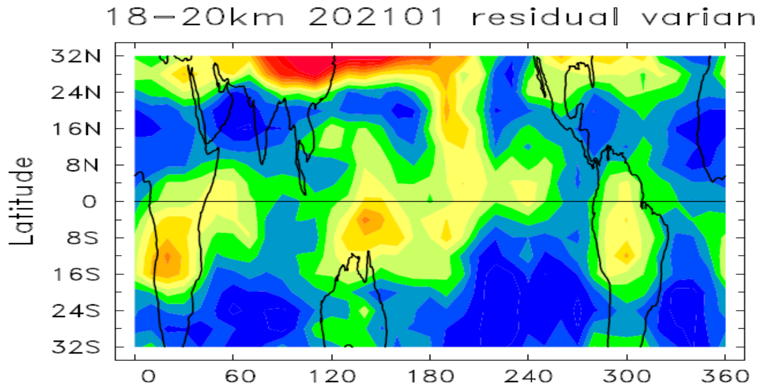


Total: 10,300 occultations/day

T'^2



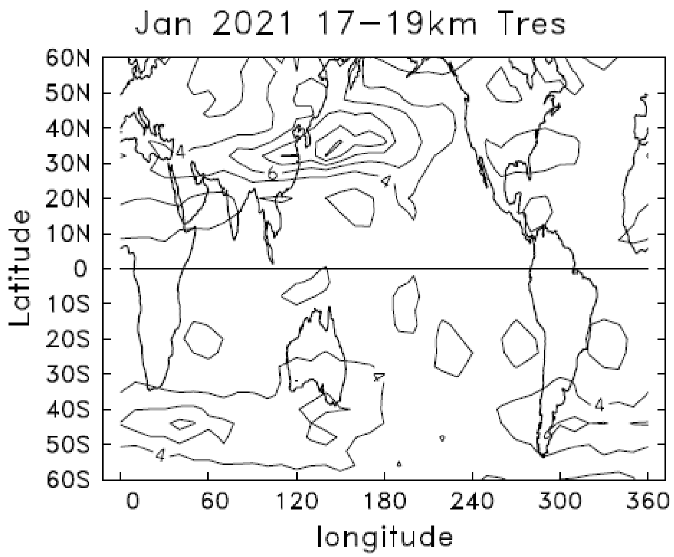
C2 + SPIRE-C



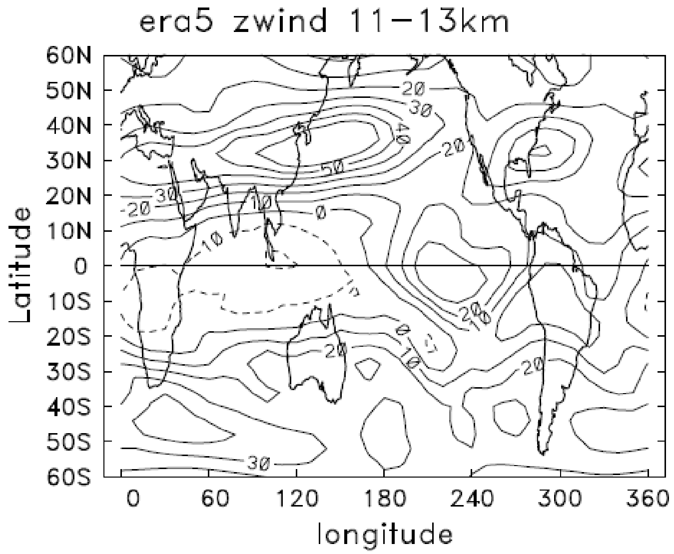
C2 only

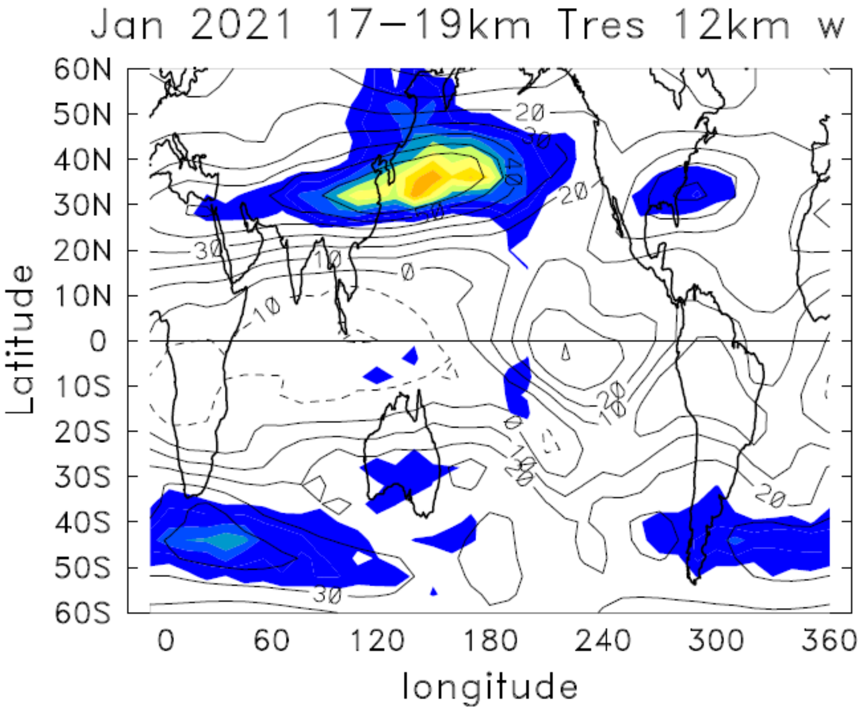
Extratropical T'^2 closely aligned with background jets

T'^2



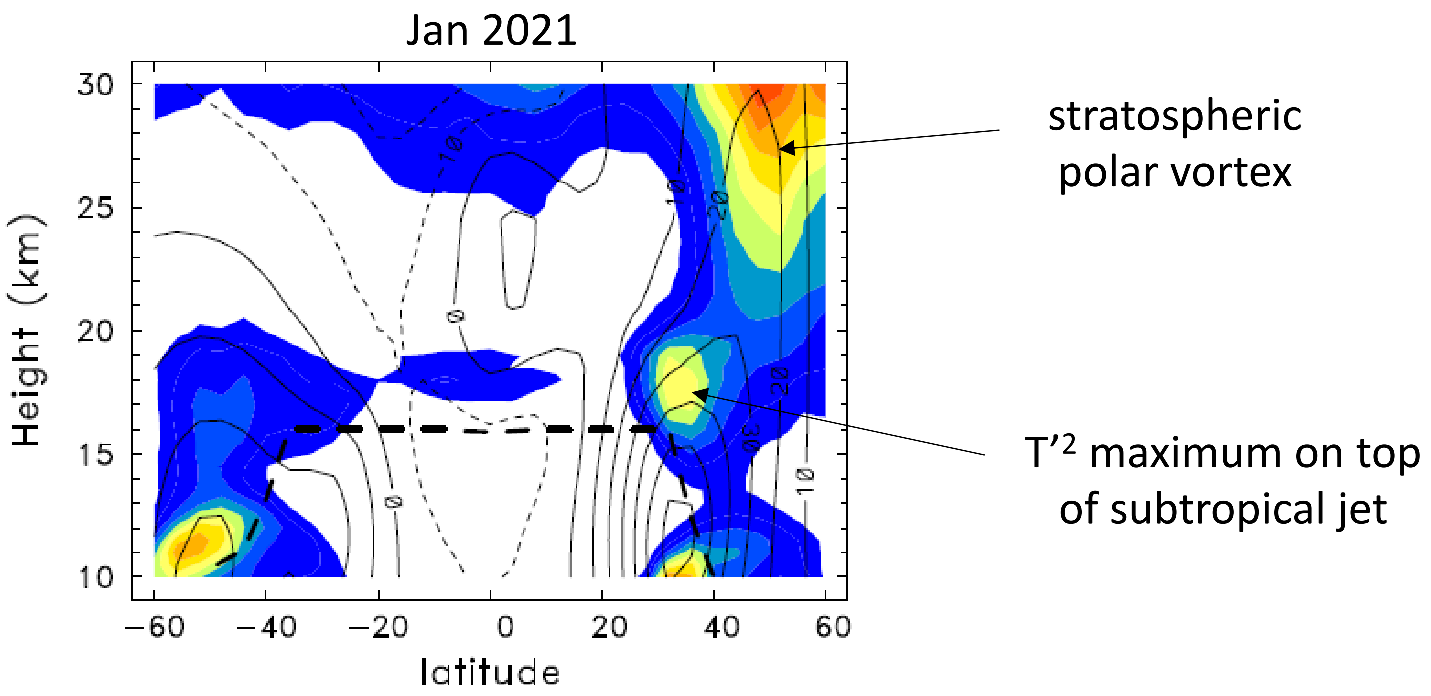
ERA5
zonal wind



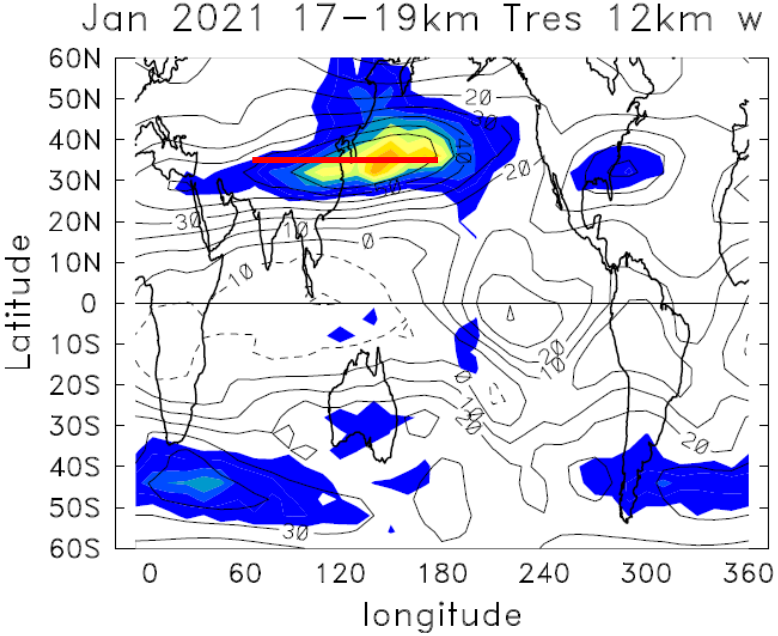


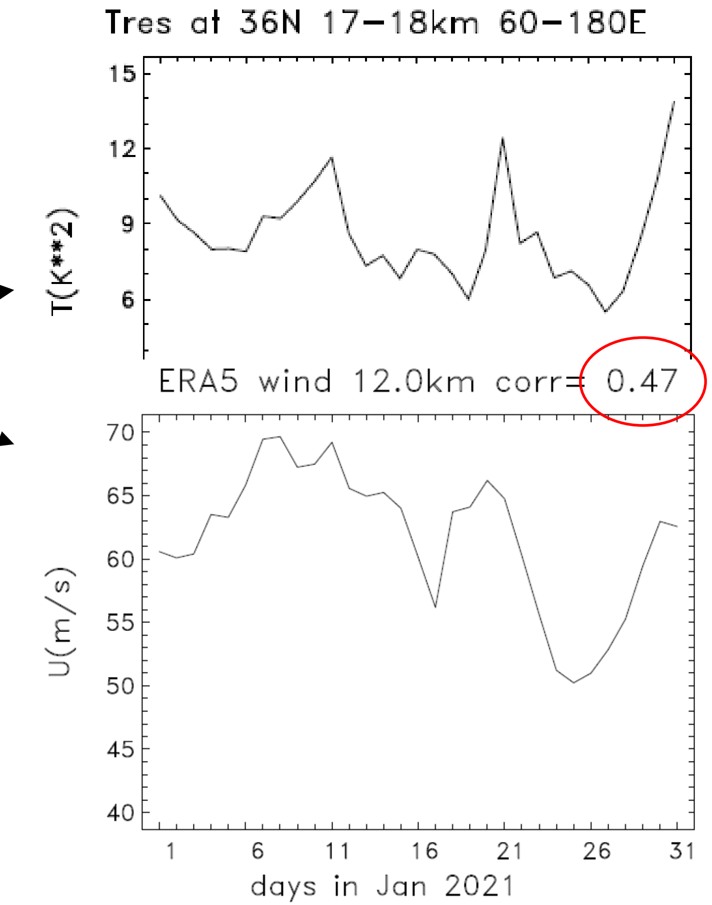
Colors: T'^2

Contours: ERA5 winds



Is temporal variability correlated?

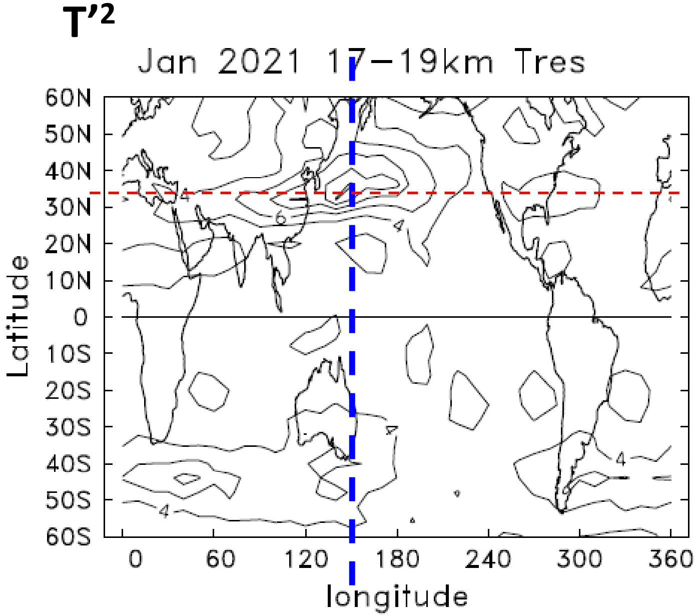




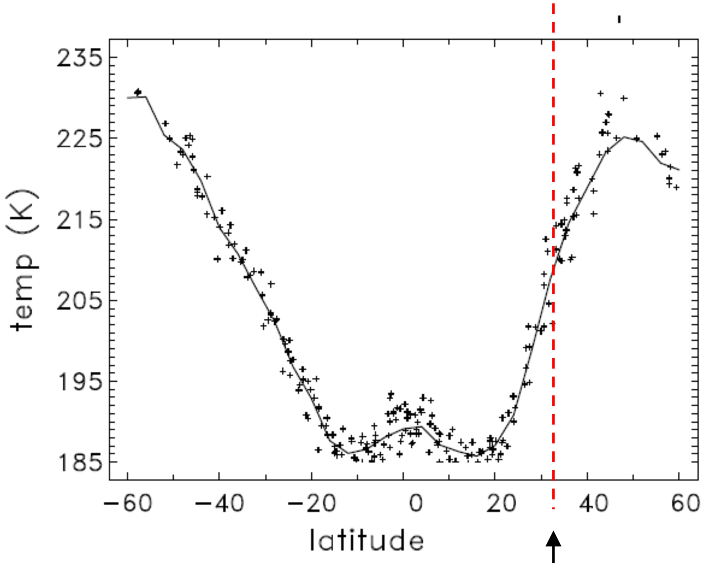
T’^{2}

ERA5 200 hPa zonal wind

Are these gravity waves?



One day
N-S slice at 150° E

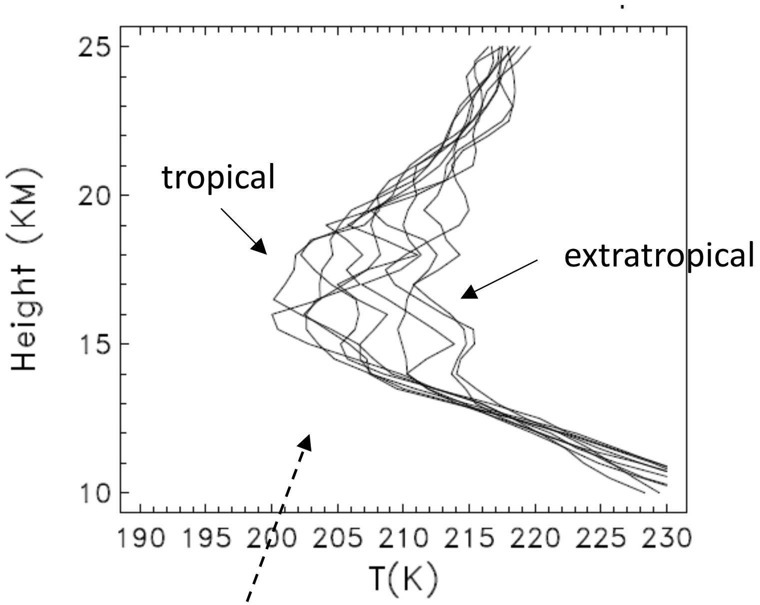


Region of strong background T gradients

Note that background T gradient
is related to jet strength via
thermal wind balance

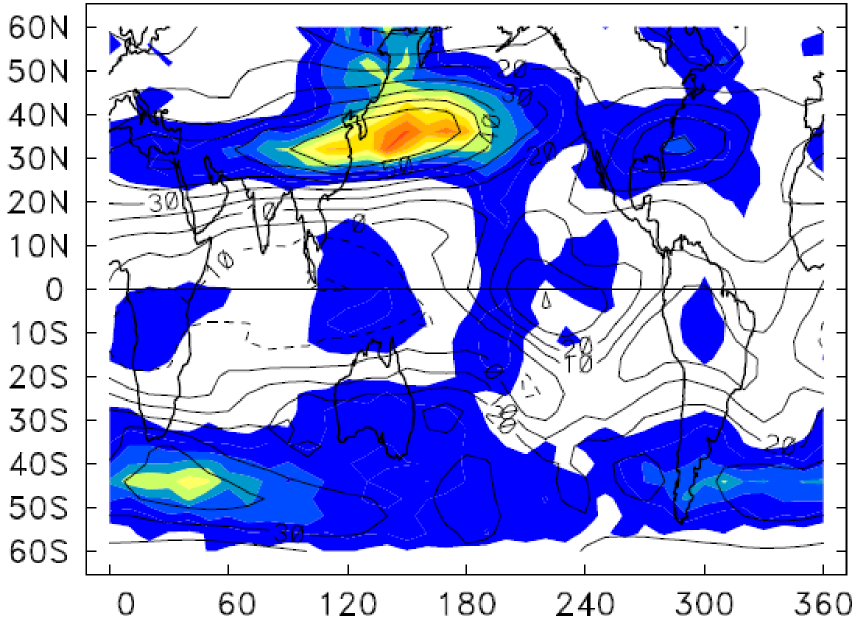
dT/dy ~ dU/dz

T profiles near 150° E, 32° N



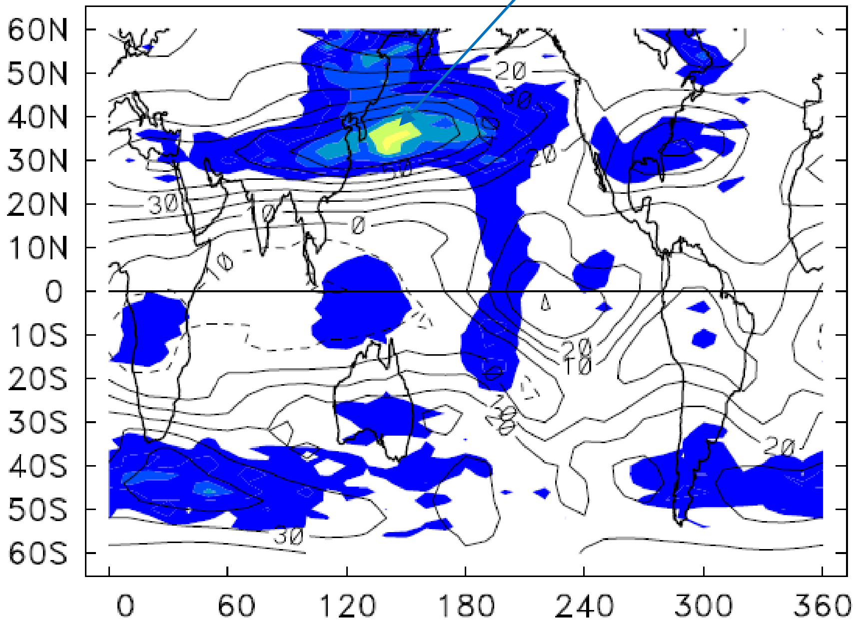
'wavy' structures, but also large variability across transition from tropics to extratropics

T'^2 calculations on 4 degree latitude grid



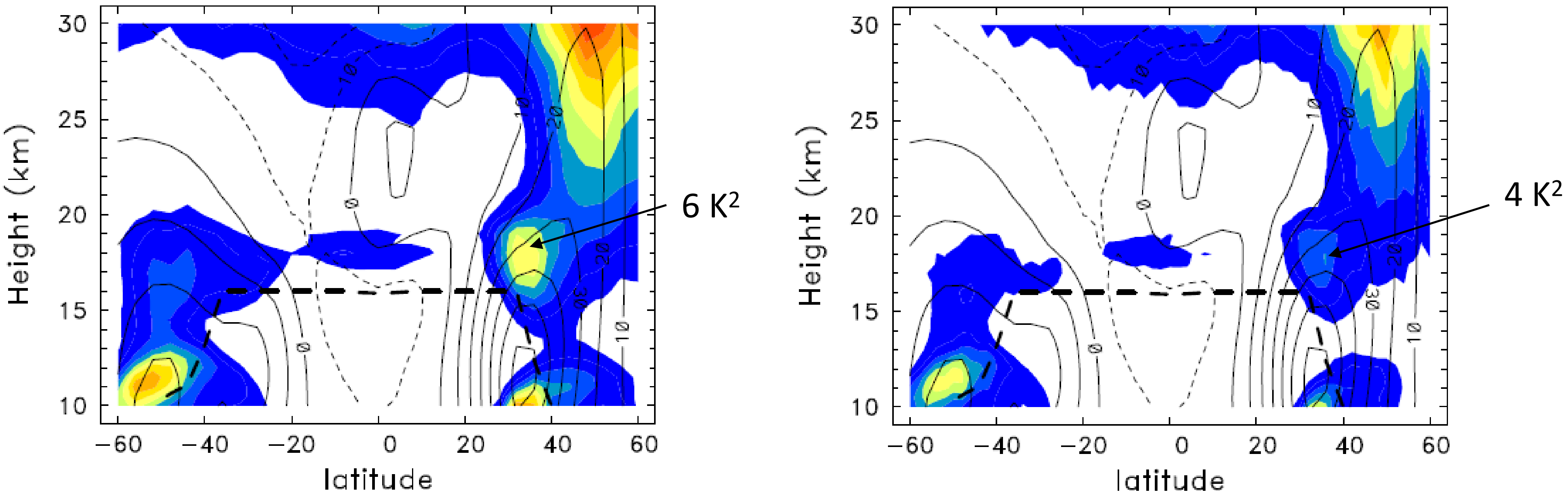
2 degree grid

reduction in T'^2 by ~35%



T'^{2} calculations on 4 degree latitude grid

2 degree grid



Net result: same T'^{2} patterns evident on finer 2 degree latitude grid, but ~1/3 reduced variances above jets

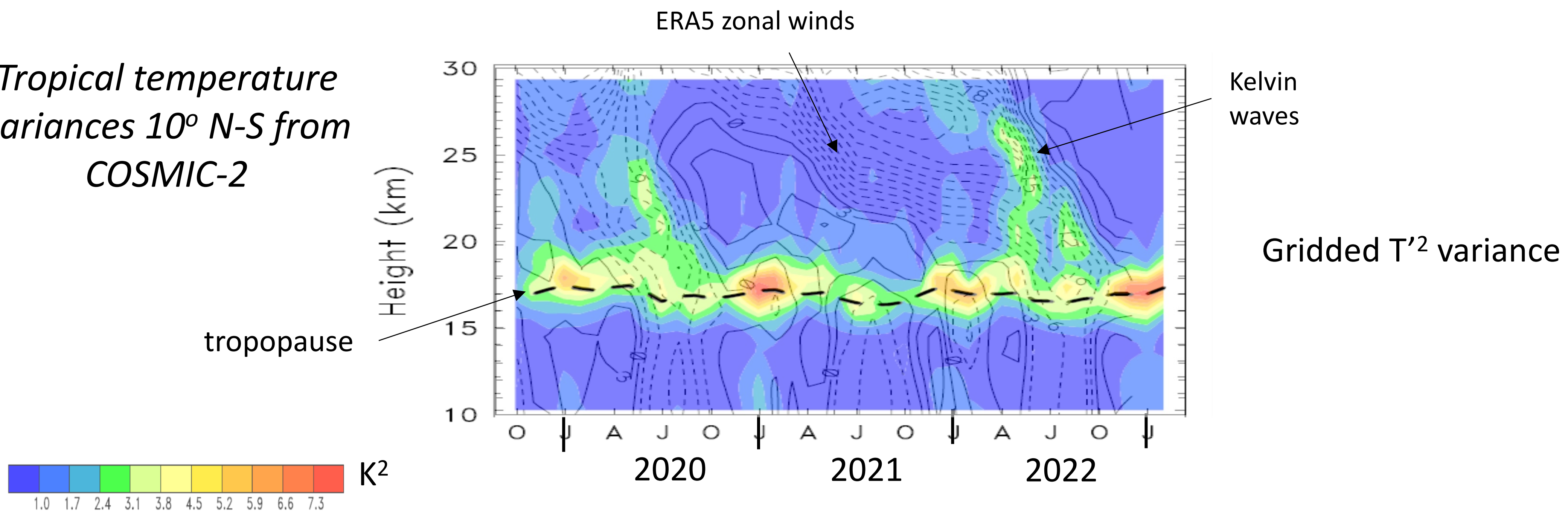
Conclusions and questions

- Tropical lower stratosphere T'^2 follows convection, with strong seasonal and interannual variations. Results look ‘geophysical’. Studying links with convection, background winds and stability.

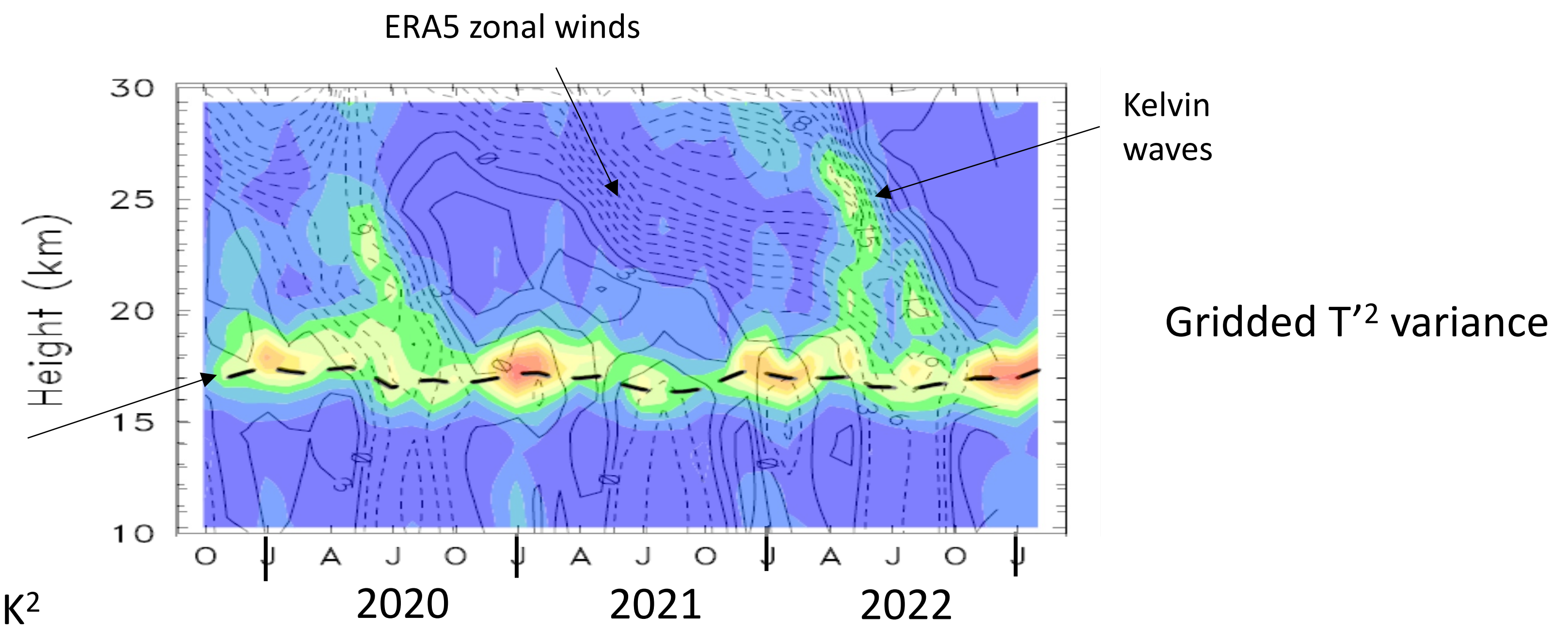
- Extratropical T'^2 follows jet structure (in space and time). Combination of gw’s and/or strong background latitudinal T gradients. *Region above jets is highly dynamic.*

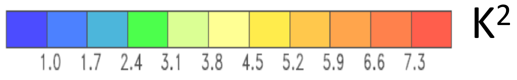
- COSMIC-2, SPIRE and others providing novel high density RO data sets. What will we find with 30,000 occ./day? 100,000!

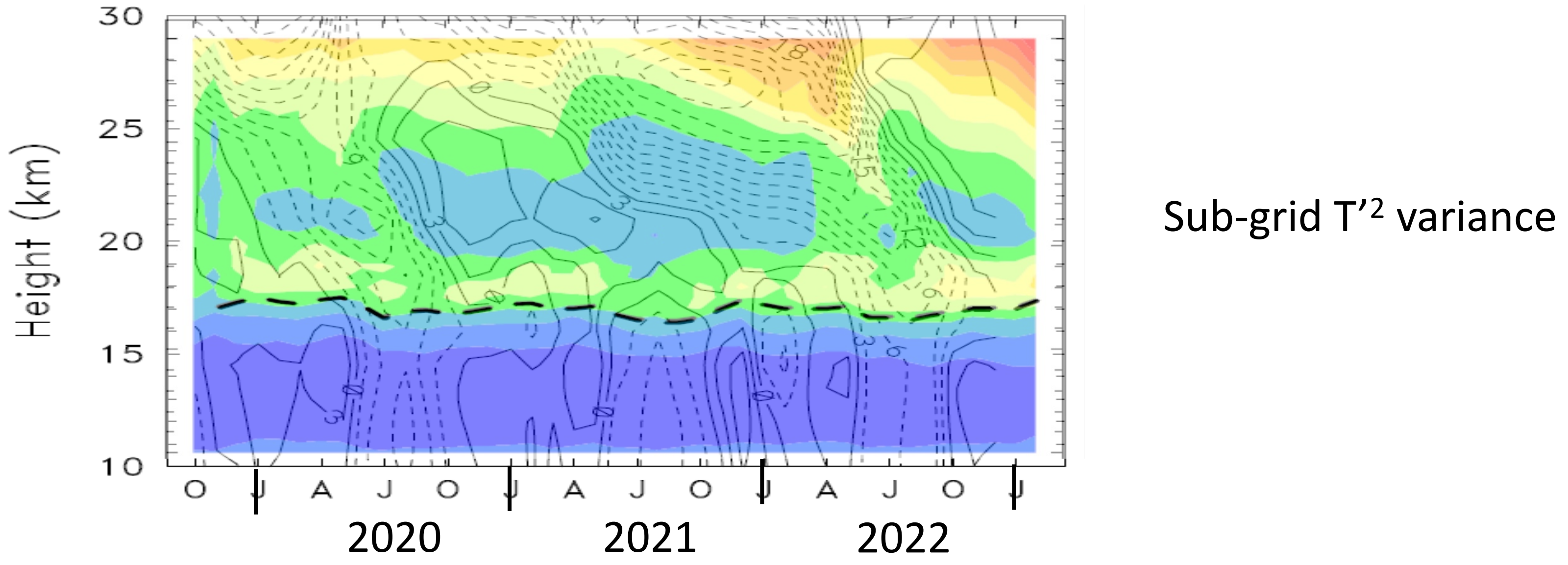
Tropical temperature variances 10° N-S from COSMIC-2



Tropical temperature variances 10º N-S from COSMIC-2

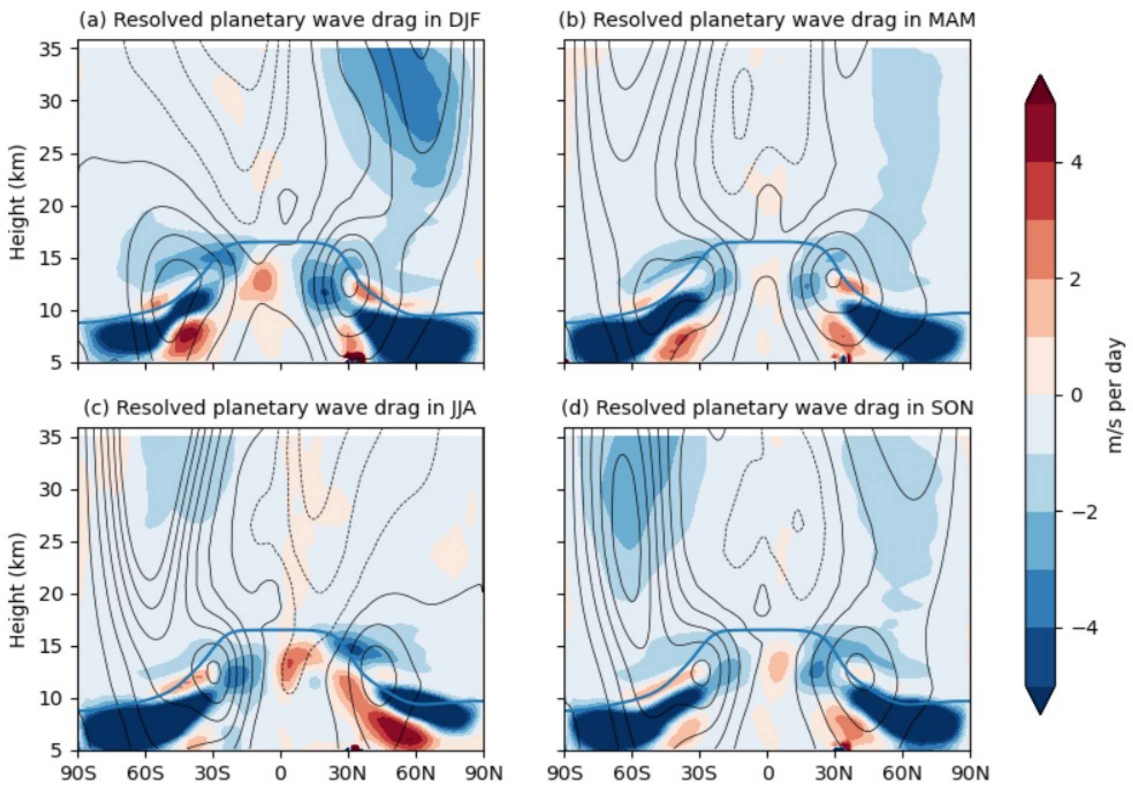




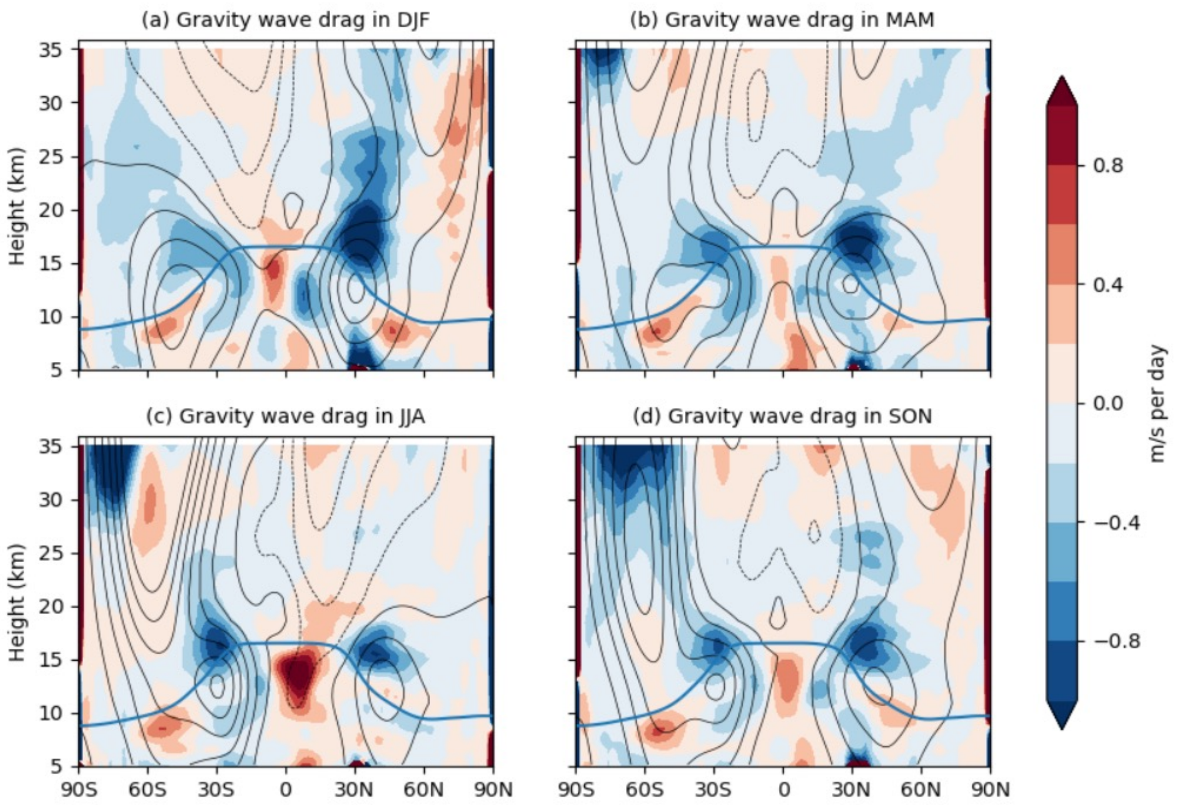


Wave drag (EP flux divergence) derived from ERA5 data

Zonal waves 1-20



Zonal waves 21-180
plus unresolved scales



From: Ern and Diallo (Juelich) via Lan Luan/Paul Staten (Indiana U.)