Equatorial waves, diurnal tides and small-scale thermal variability in the tropical lower stratosphere from COSMIC-2

Bill Randel

NCAR ACOM and COSMIC

Thanks to: Fei Wu, Aurelien Podglajen, Rolando Garcia, Janet Zeng

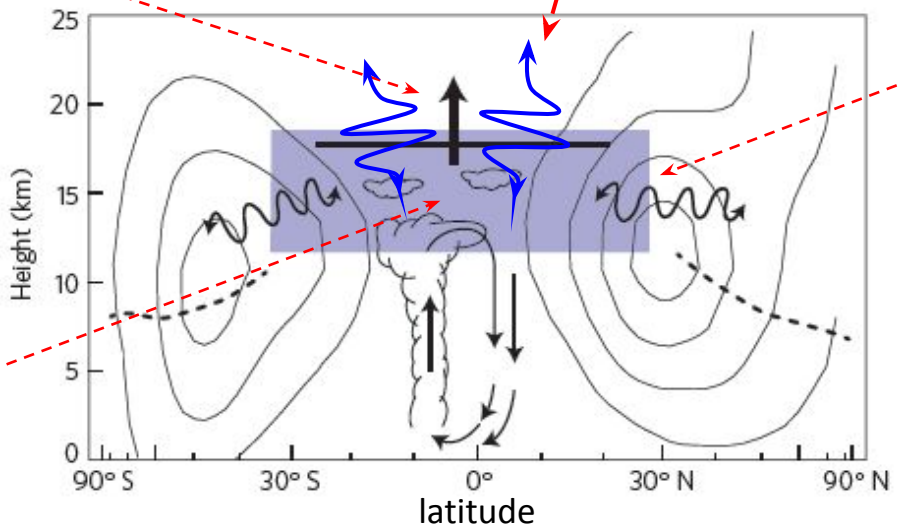
Motivation: Circulation and transport near the tropical tropopause layer (TTL)

lots of waves, mainly forced by deep convection
important for clouds and dehydration
source of forcing for the QBO, SAO

transport to the stratosphere;
water vapor control by
tropopause temperature

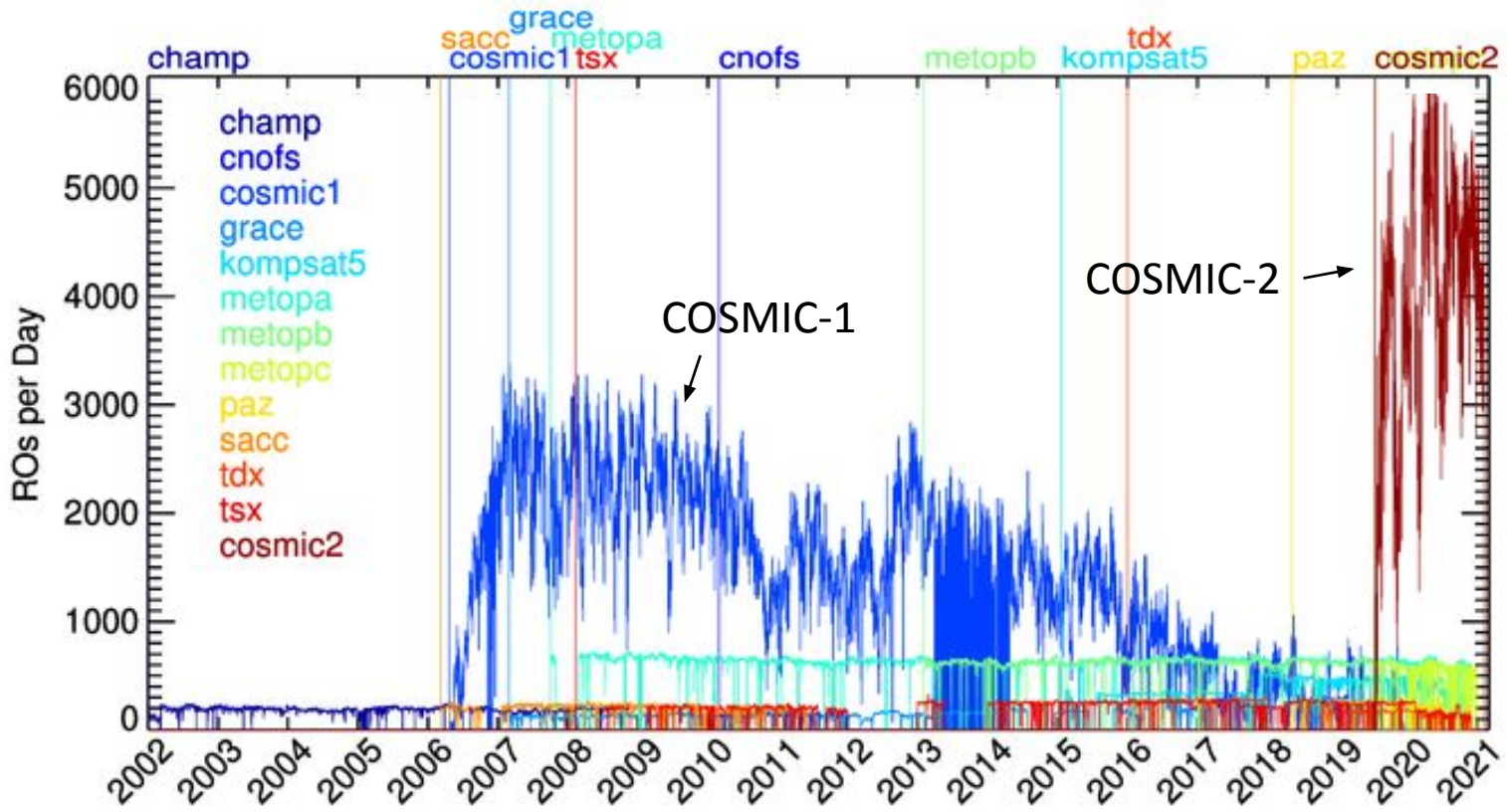
mixing with extratropics
from baroclinic waves
and monsoons

effects of deep convection;
tropopause-level cirrus
and aerosols

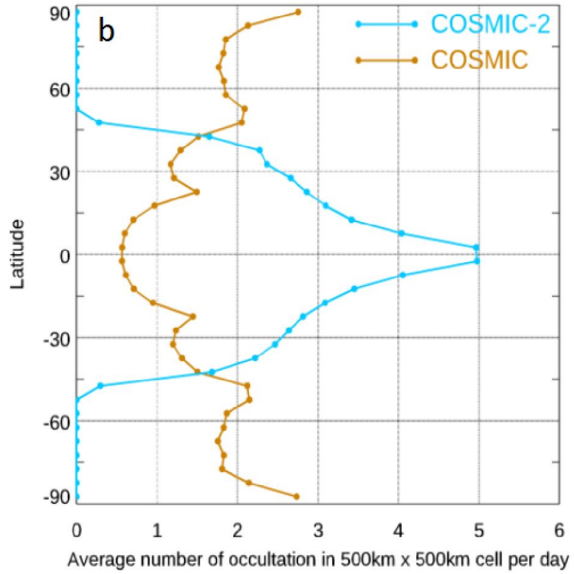


Objective here: analysis of TTL thermal variability using COSMIC-2

Number of radio occultation measurements over time



COSMIC-2 focused over 40^{o} N-S

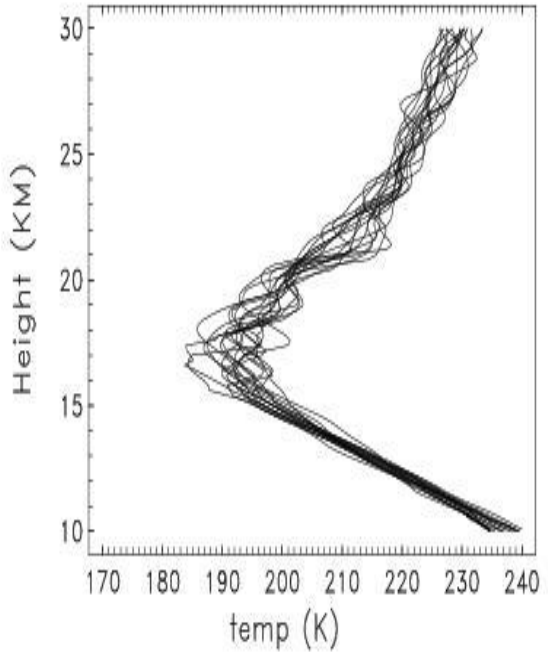


Ho et al, 2020

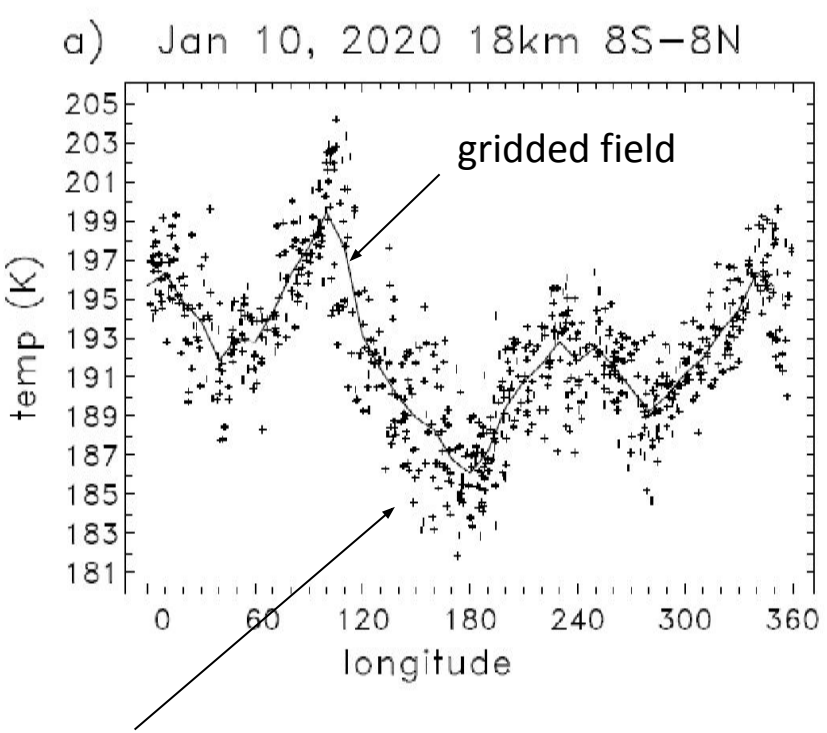
Analyses of early COSMIC-2 data applied to the TTL

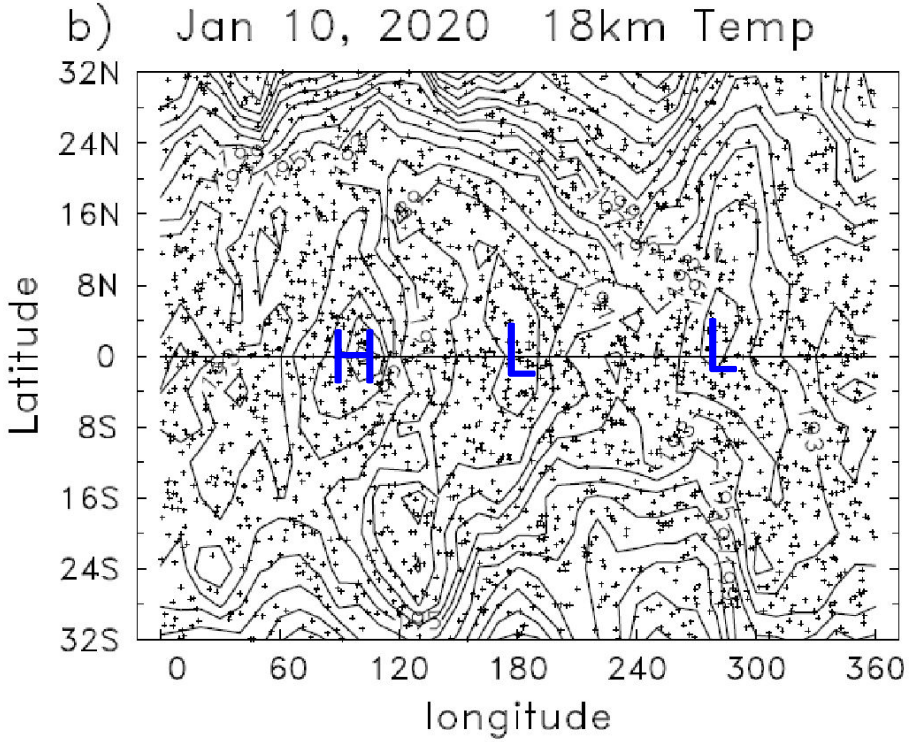
- Data for October 2019 – April 2020 (4,000 – 5,000 per day)
- Derive a gridded data set: 4^{o} x 10^{o} lat x long x *6-hour resolution*
- Space-time spectrum analysis: equatorial waves and tides
- Small-scale ‘residuals’ – gravity waves

example profiles



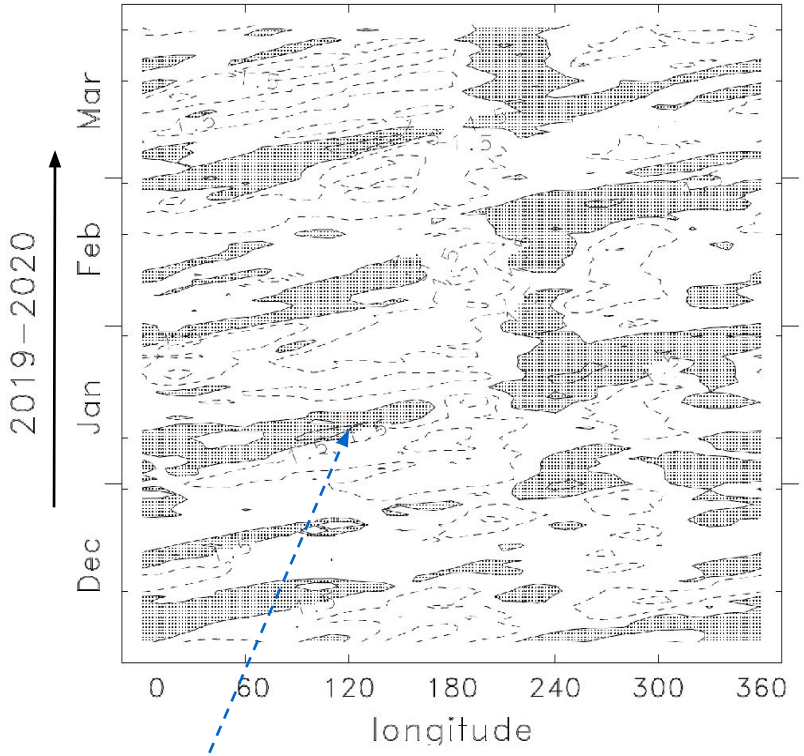
Example COSMIC-2 gridding for one day





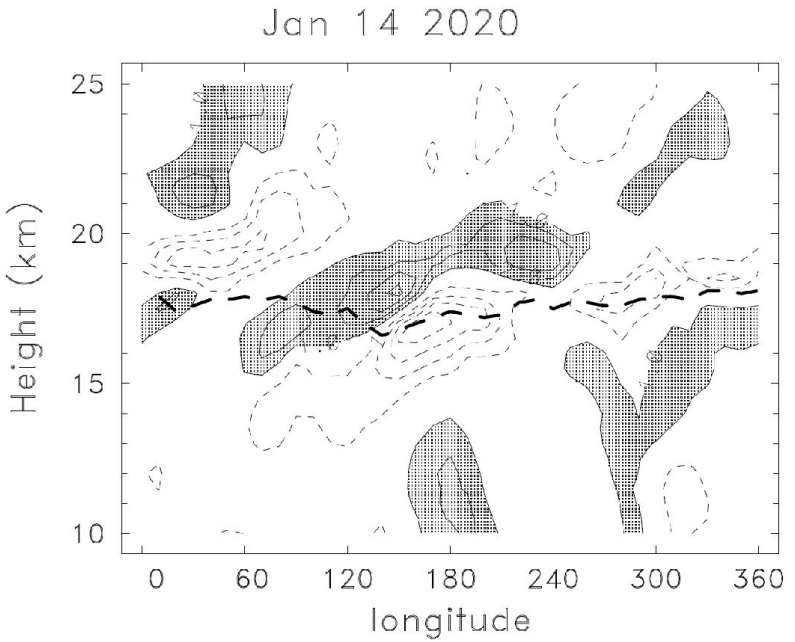
'residual' = difference between C2 measurements and gridded field

Gridded equatorial temp anomalies at 18 km
zonal average removed



eastward traveling Kelvin waves
phase speed ~ 20 m/s

'snapshot' of Kelvin wave structure



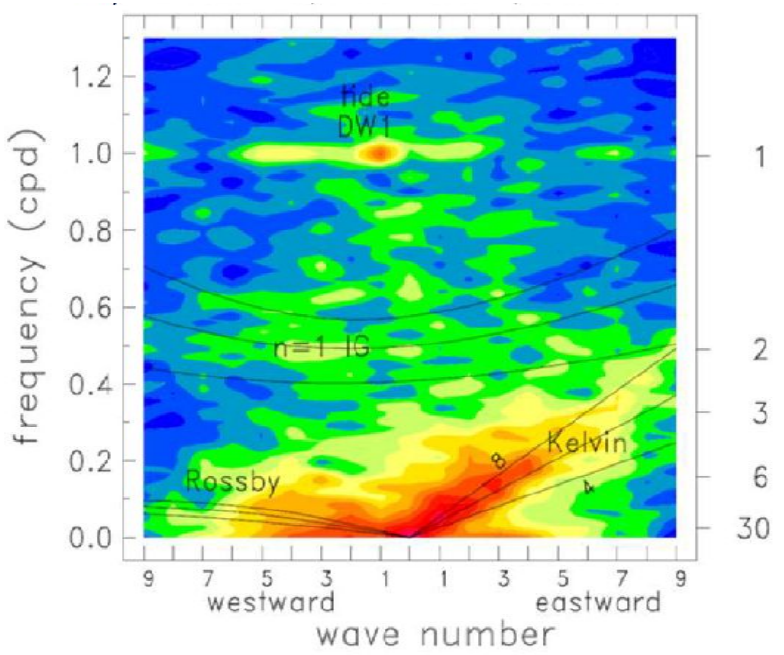
tropopause

eastward phase tilt with height
vertical wavelength ~ 6 km

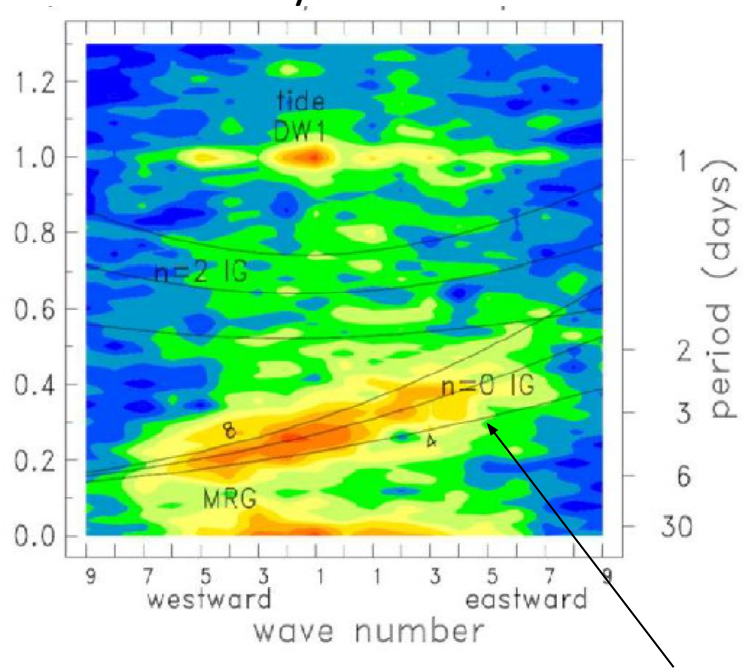
Space-time spectrum analysis of gridded C2 temperatures

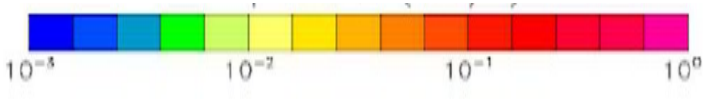
Wavenumber-frequency spectra at 20 km: planetary-scale equatorial waves

Symmetric



Antisymmetric



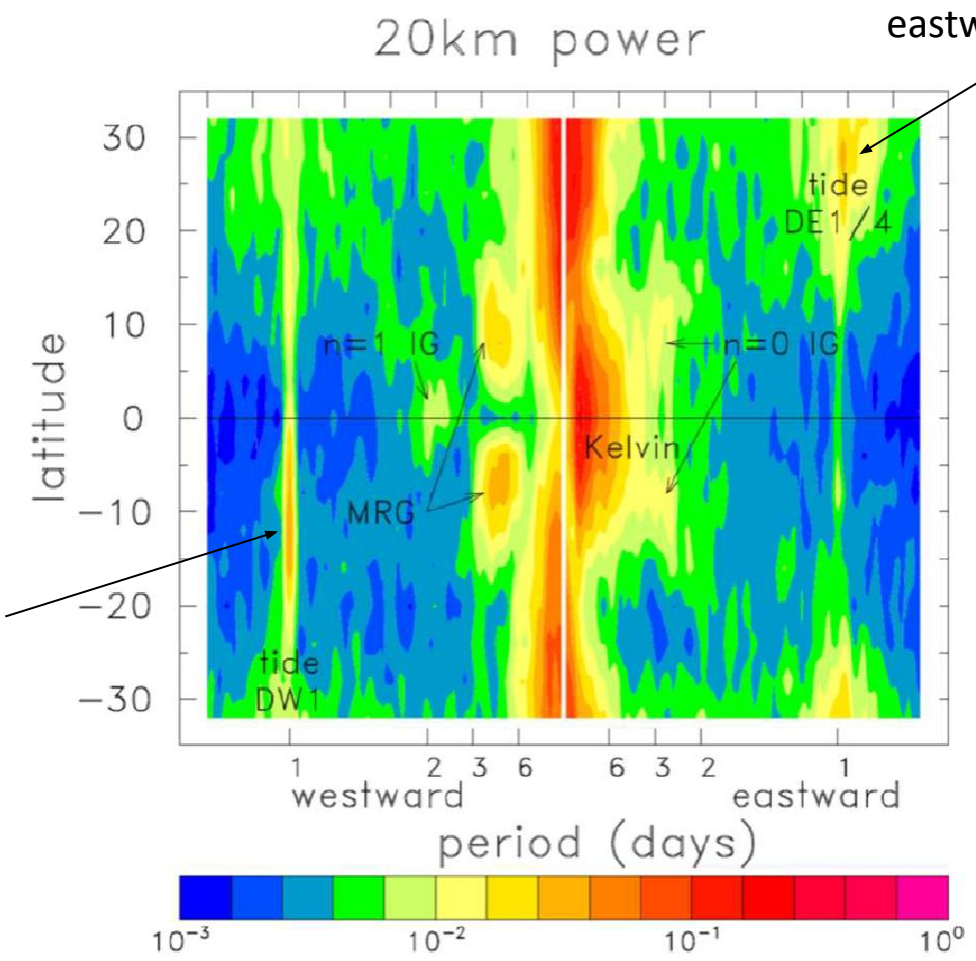


equatorial wave dispersion curves

IG = Inertia-Gravity
MRG = mixed Rossby-gravity
DW1 = diurnal westward wave 1

Latitude vs. frequency

summed for zonal waves 1-6



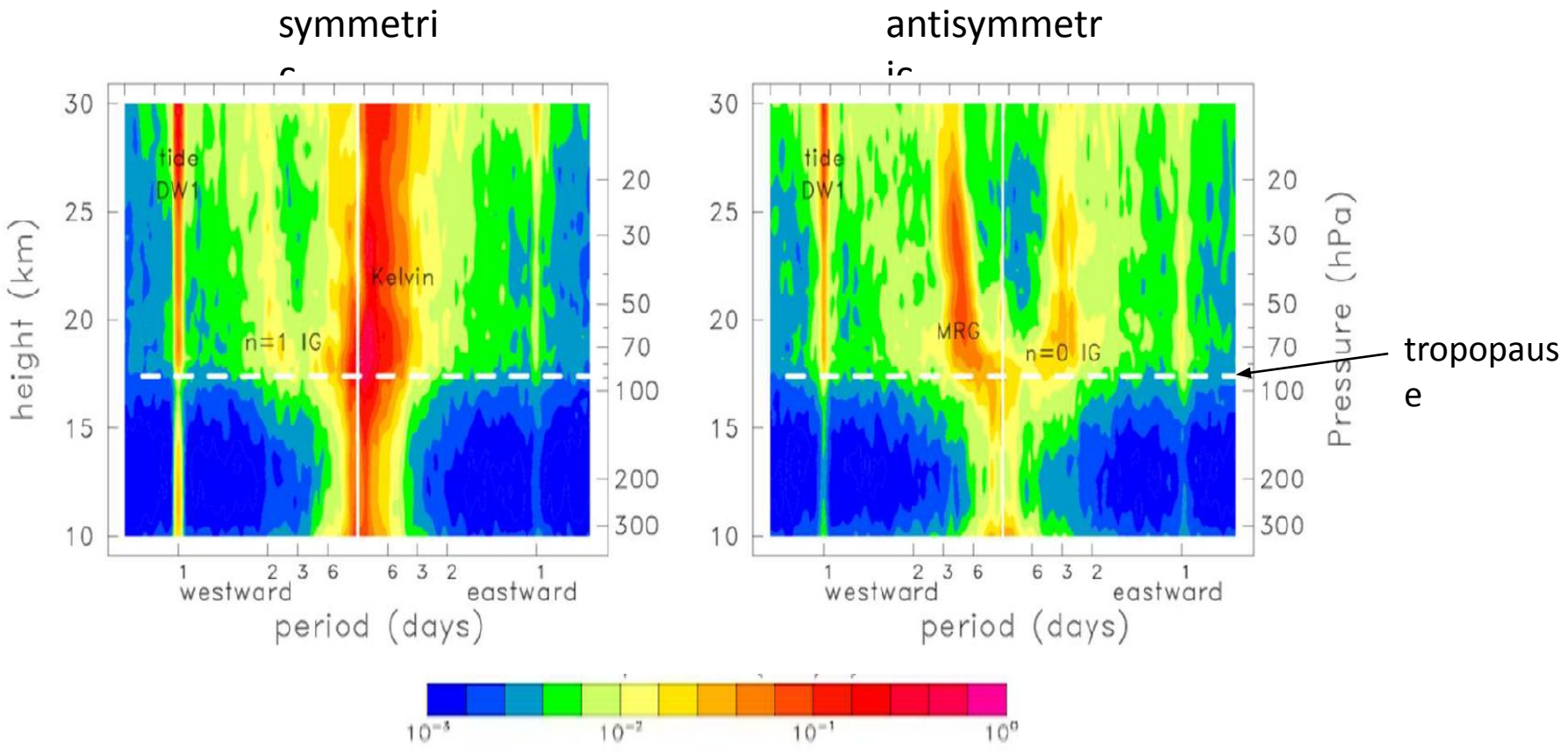
eastward non-migrating tide

westward migrating tide

labels indicate equatorial wave modes

Vertical structure

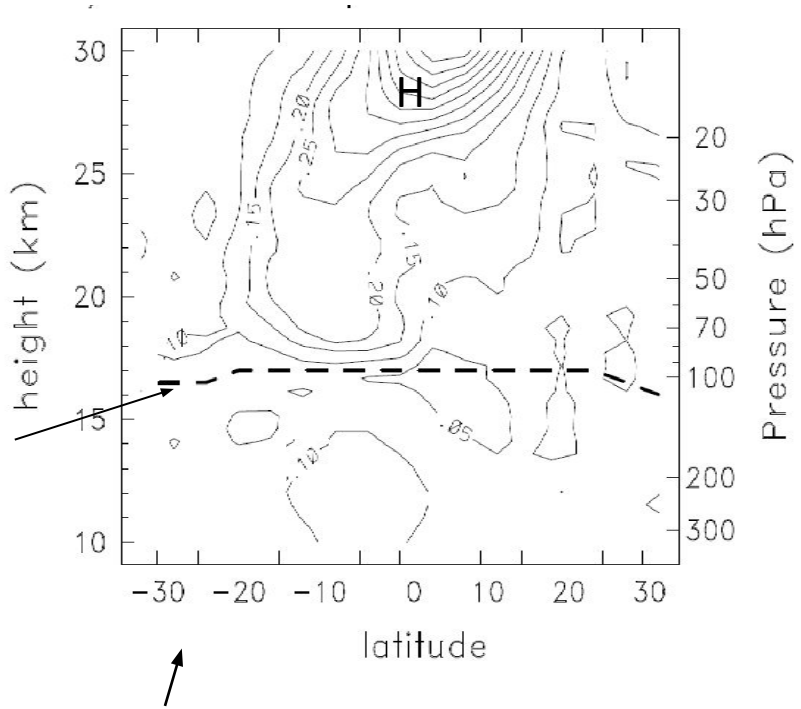
summed for zonal waves 1-6



Propagating diurnal tides

temperature amplitude (K)

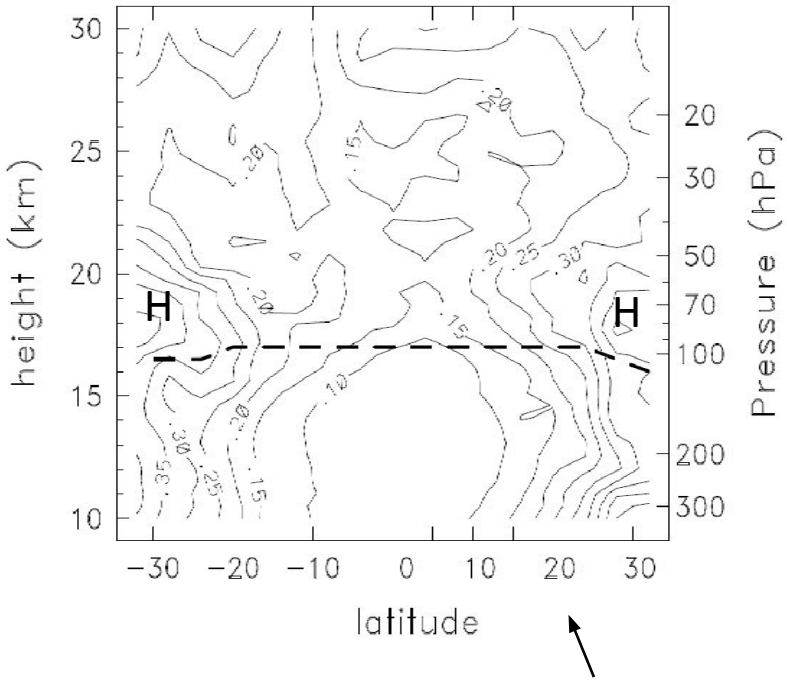
westward wave 1 (DW1)



tropopause

well-known from previous RO analyses
Zeng et al (2008), Xie et al (2010), Pirscher et al (2010)

eastward waves 1-4 (DE1-4)



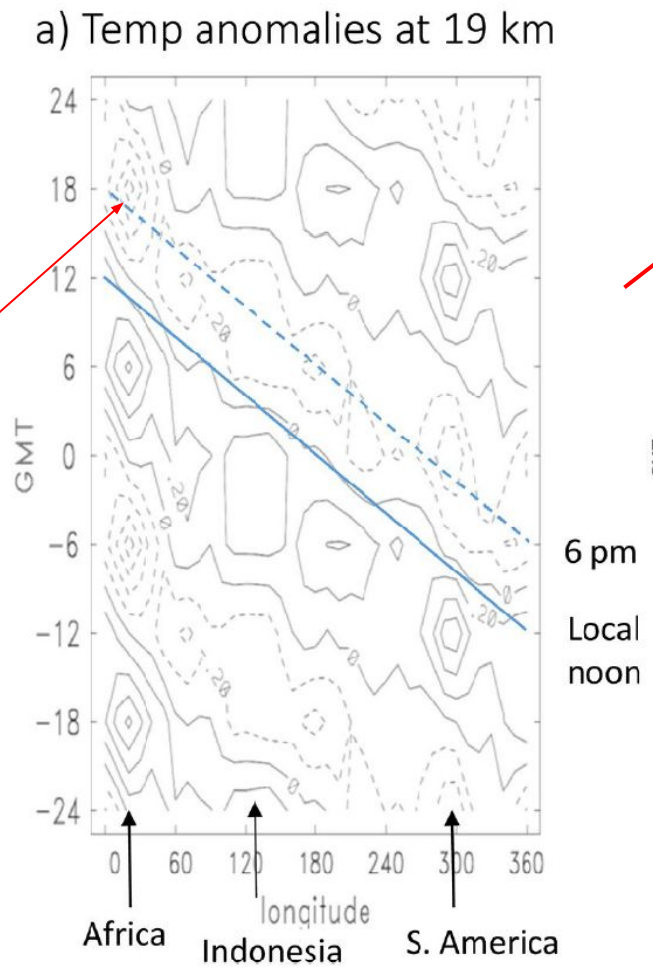
not well understood

Local structure, and links with diurnal cycle in convection

C2 diurnal temperature anomalies near tropopause 0-16° S

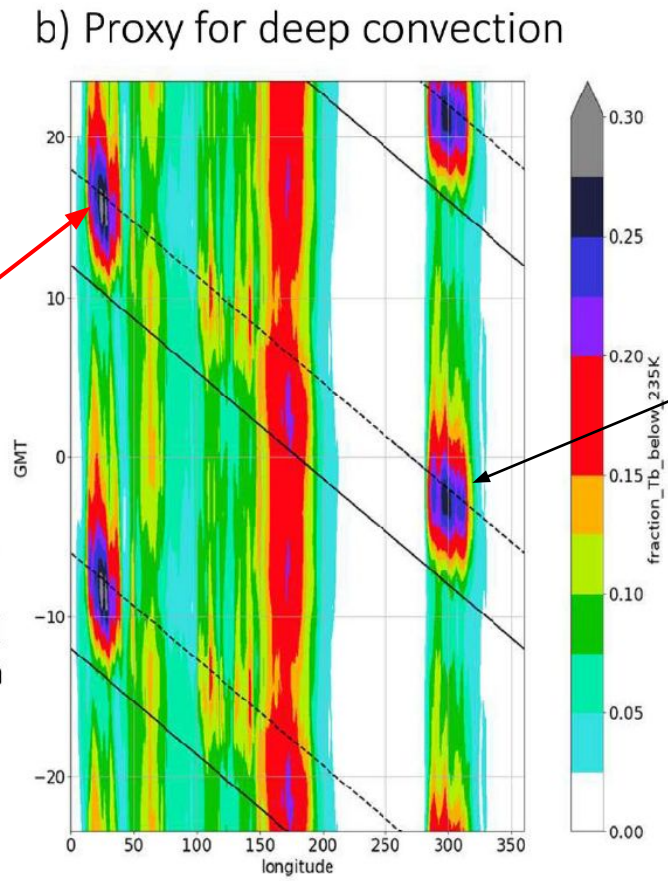
lower stratosphere cooling tied to diurnal convection

note that 2 cycles are repeated



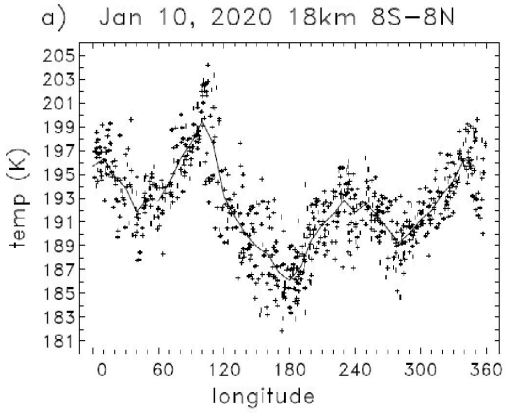
6 pm

Local noon



diurnal convection over S. America

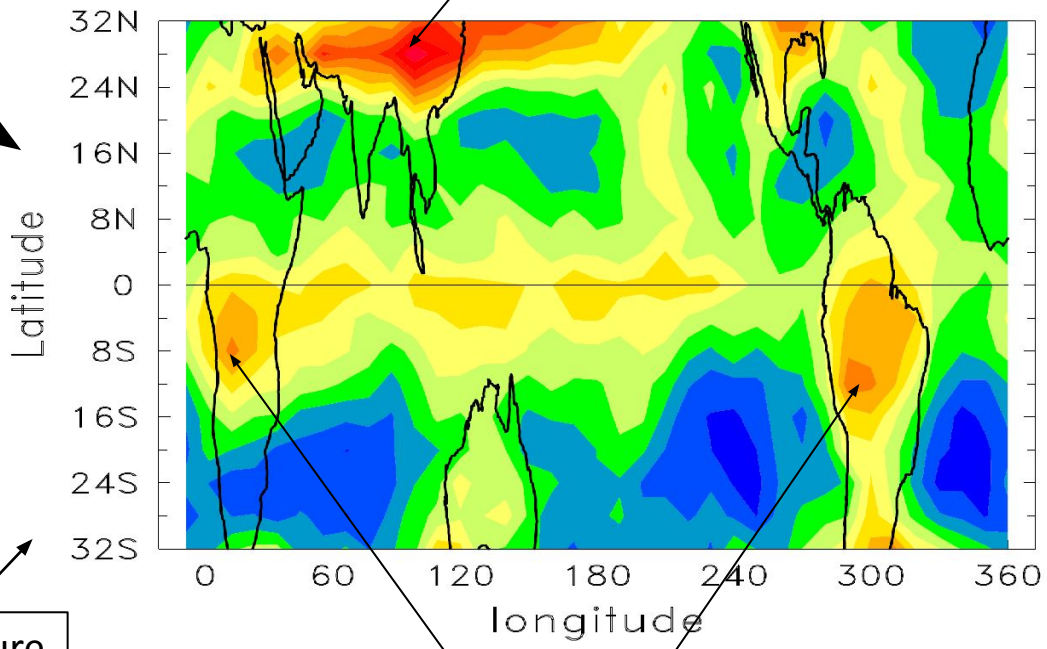
Residual variance: difference between COSMIC-2 measurements and gridded fields



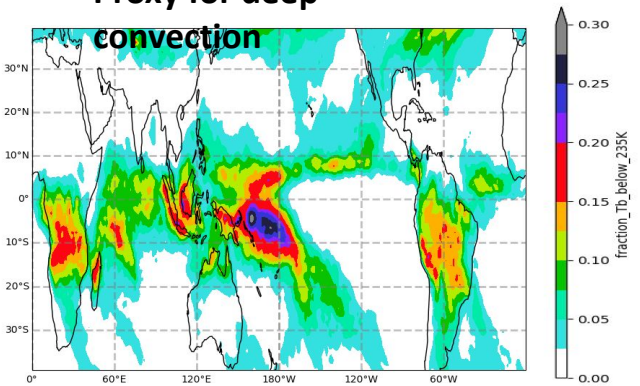
$T_{res}' = T_i - T_{grid}$

max variance over
Asian topography

18-20 km residual variance $T_{res}'^2$



Proxy for deep convection

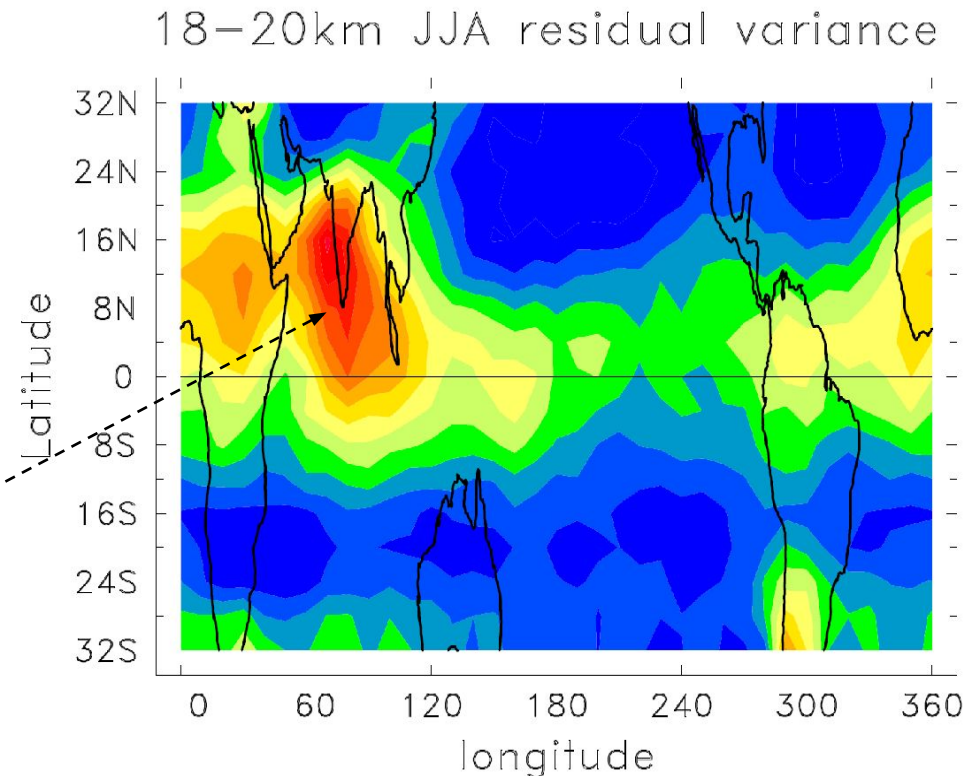


coherent space-time structure
consistent with gravity waves

maxima over
continents/convection

Residual variance $T_{res}'^2$ during boreal summer (June-August 2020)

gravity waves tied to monsoon convection



Key points:

1) COSMIC-2 is providing an excellent, high quality dataset.

2) Novel high resolution space-time spectra: planetary waves and tides

3) Rich information on small scales and gravity waves - work in progress

Paper recently published in JGR-Atmospheres

JGR Atmospheres

RESEARCH ARTICLE
10.1029/2020JD033969

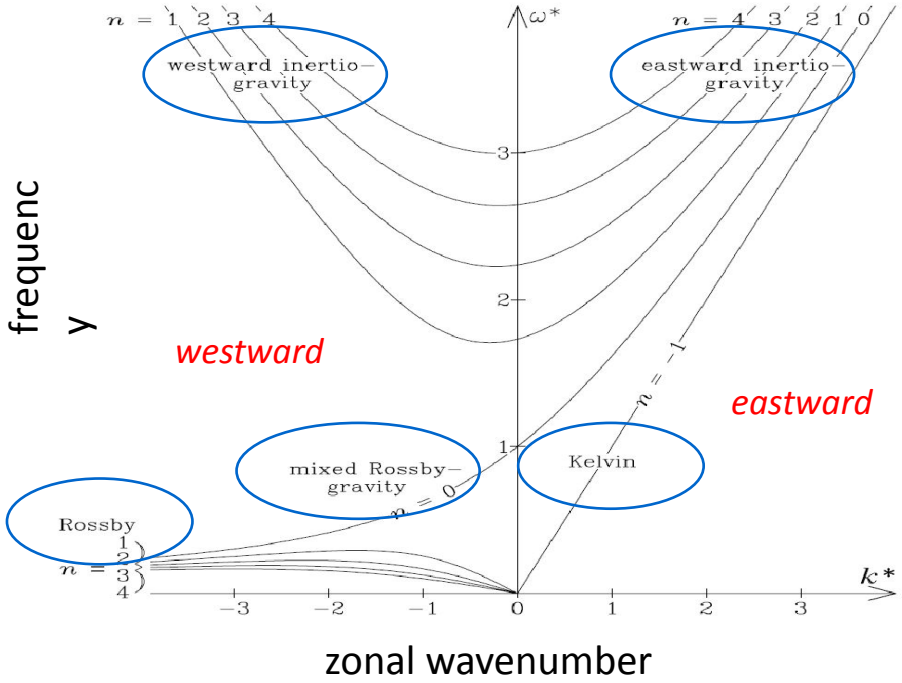
Equatorial Waves, Diurnal Tides and Small-Scale Thermal Variability in the Tropical Lower Stratosphere From COSMIC-2 Radio Occultation

William J. Randel[1,2], Fei Wu[1], and Aurélien Podglajen[3]

Thank you

Matsuno 1966

Dispersion relations for equatorial waves

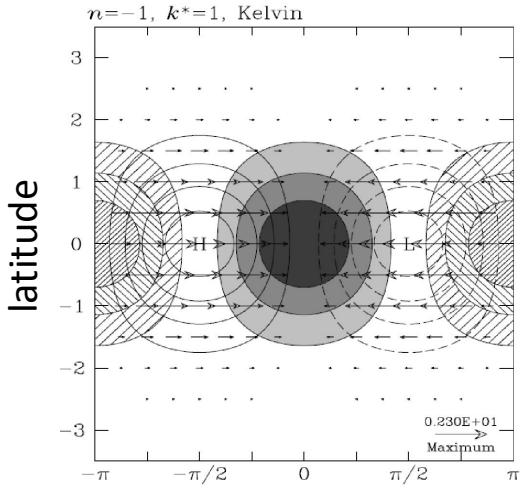


frequency

zonal wavenumber

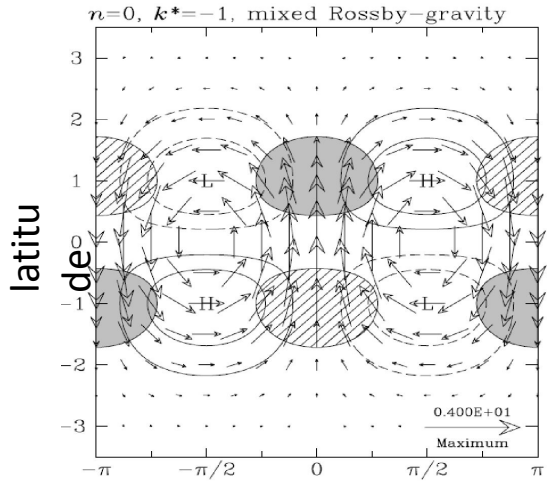
n is the meridional index: n=odd, symmetric about equator

n=even, antisymmetric



latitude

symmetric Kelvin wave



latitude

longitude

antisymmetric mixed Rossby-gravity wave