Gravity Wave Coupling and MLT Measurements

Observations from the DEEPWAVE campaign on 4 July 2014

Katrina Bossert

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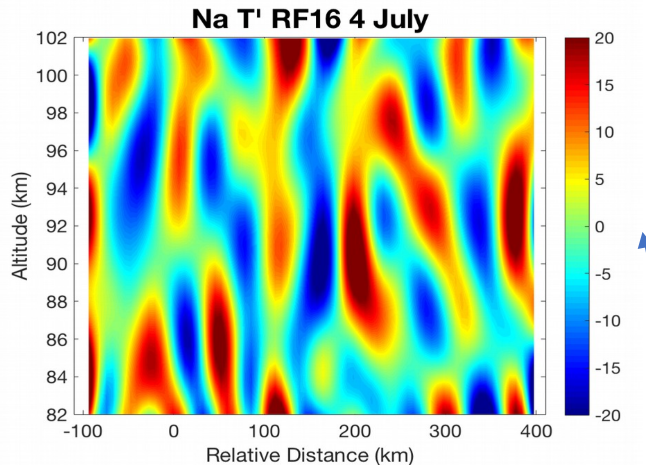
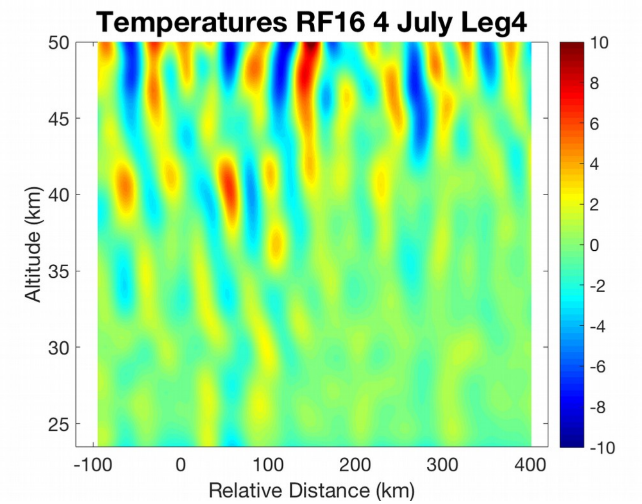
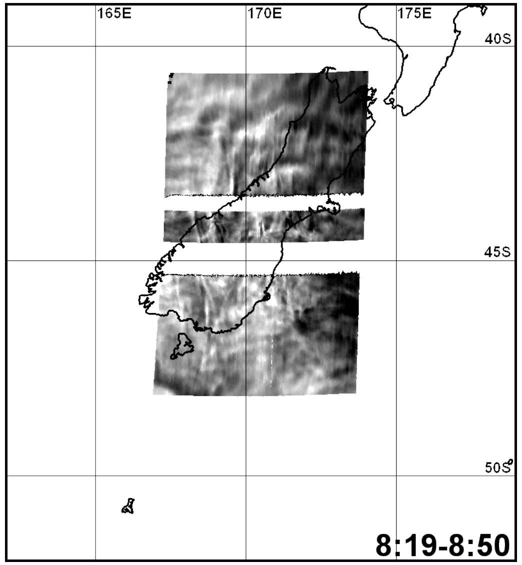
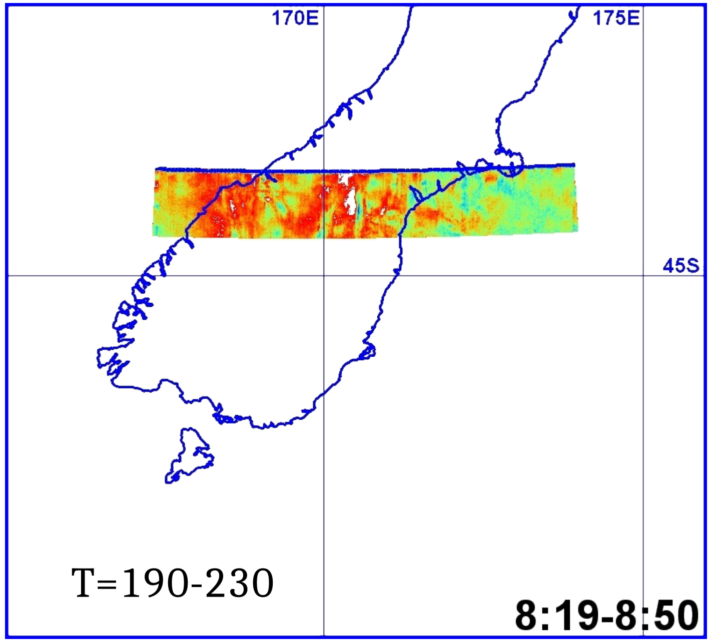
GWs from the Stratosphere to MLT







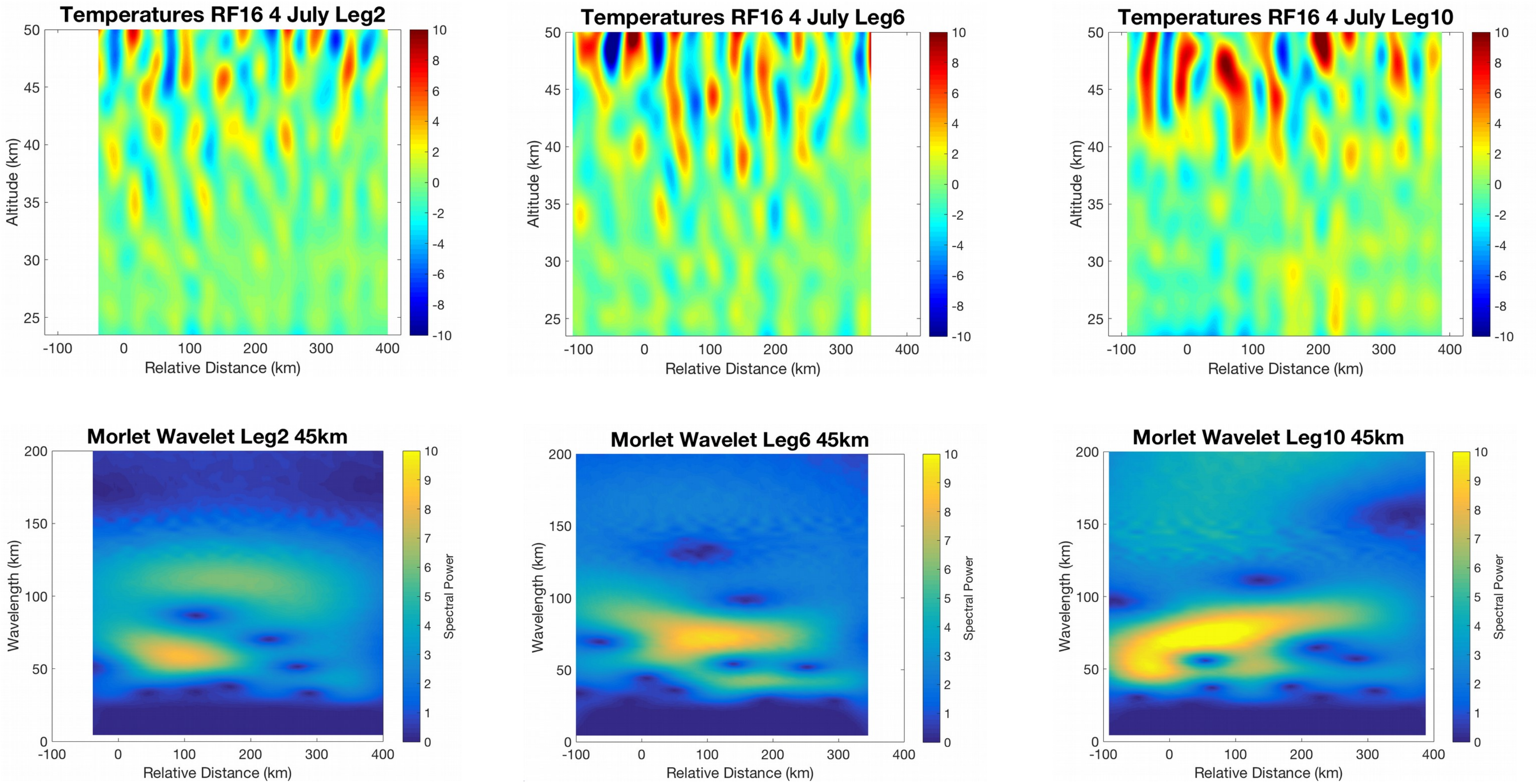
OH airglow observations demonstrate strong stationary perturbations as well as moving perturbations



AMTM temperatures averaged over the airglow layer demonstrate significant temperature perturbations

GWs were observed in both the MLT and the stratosphere from Na and Rayleigh Lidar Respectively

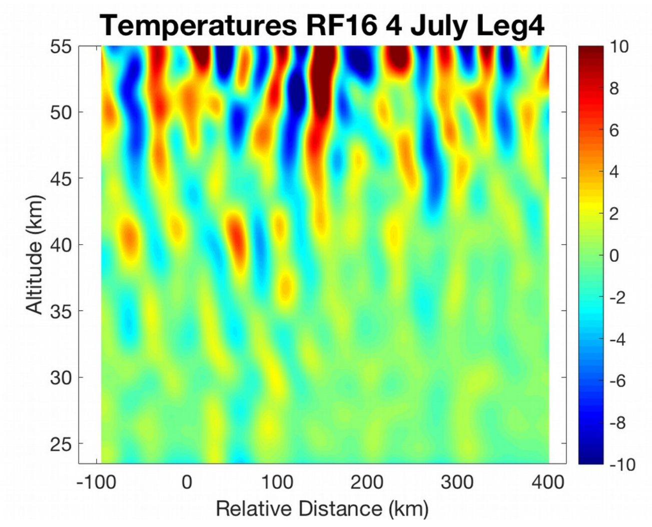
Stratospheric Observations



- Apparent MWs observed during all passes
- Horizontal Wavelength Spectra ~ 40-90km
- (120km present during first pass)
- Some variation in wavelength with time and location may be dependent on mountain terrain and wind speed/direction

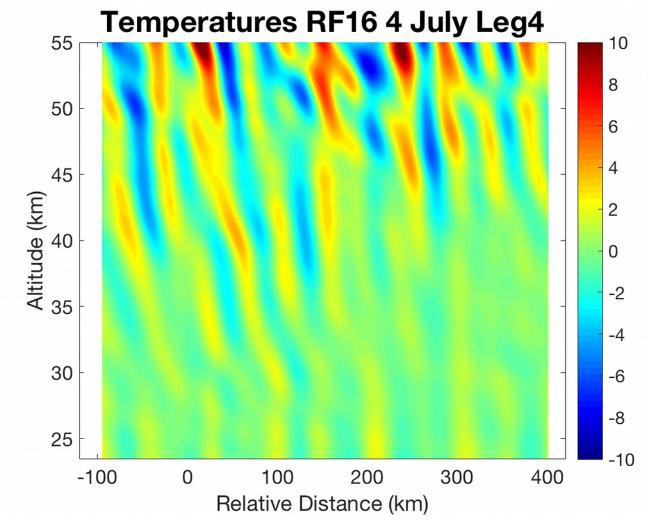
Bramberger et al., 2017

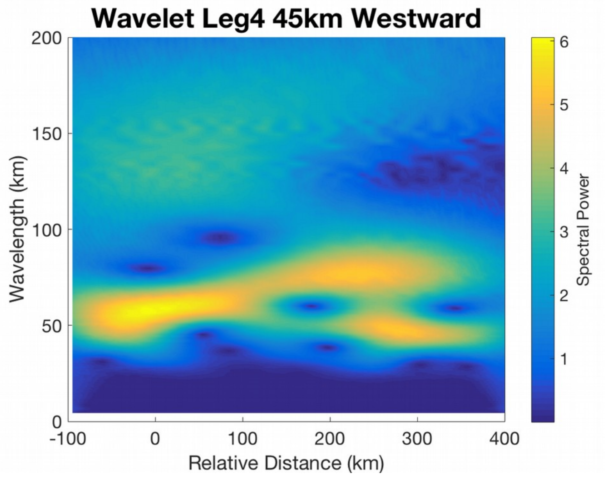
Propagation Direction

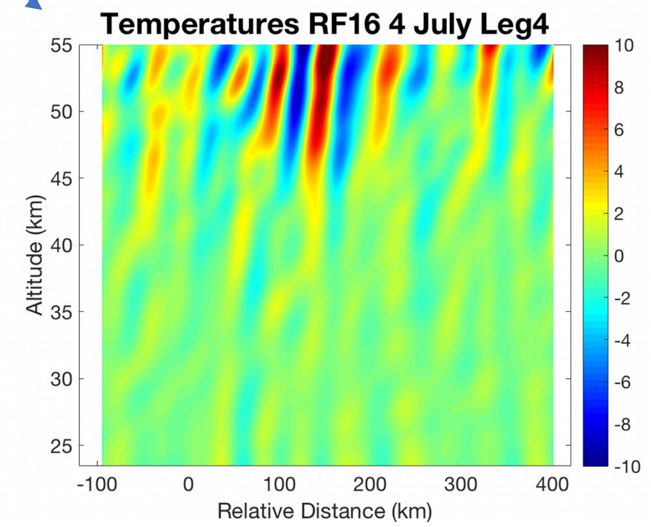


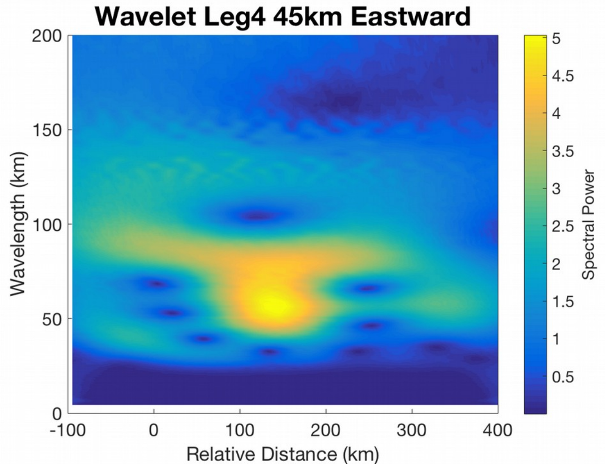
Westward Phase

Eastward Phase









- Each flight pass observed a superposition of both eastward and westward oriented GWs.
- Wavelet analysis demonstrates a range of 40-90km horizontal wavelengths
- MWs are expected to have a westward propagation

Distinguishing MWs

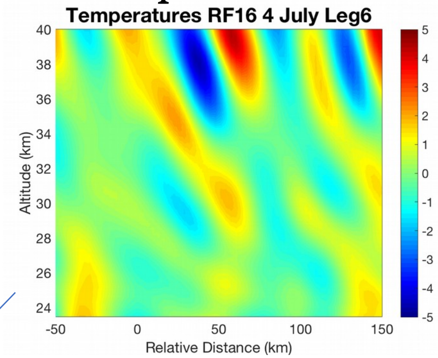
Correlations Between Passes

Weaker correlations between passes indicate phase movement over time

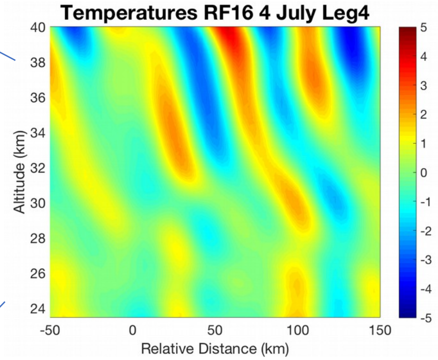
MWs should have stronger correlations between passes (zero or close to zero phase speed)

Despite similar wavelengths, eastward versus westward orientations show significant differences between passes

Westward phase orientation

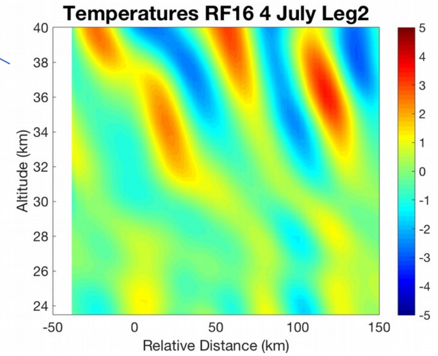


R=.66



Stronger correlation

R=.51

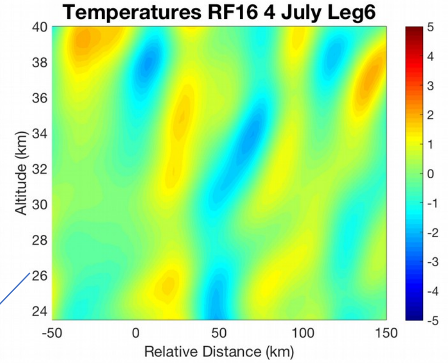


9:53-10:24 UT

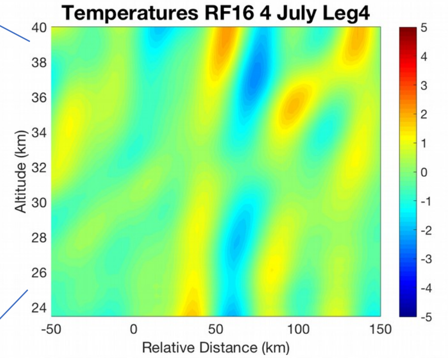
8:19-8:50 UT

6:46-7:13 UT

Eastward phase orientation

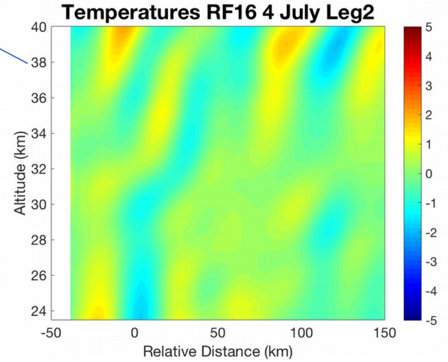


R=.23



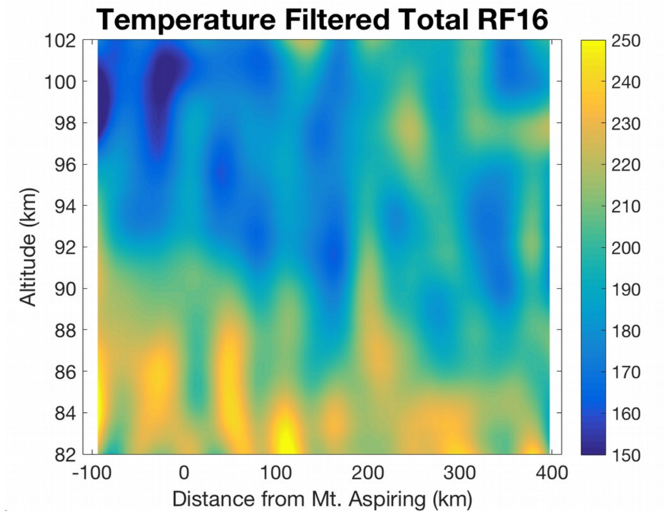
Weaker correlation

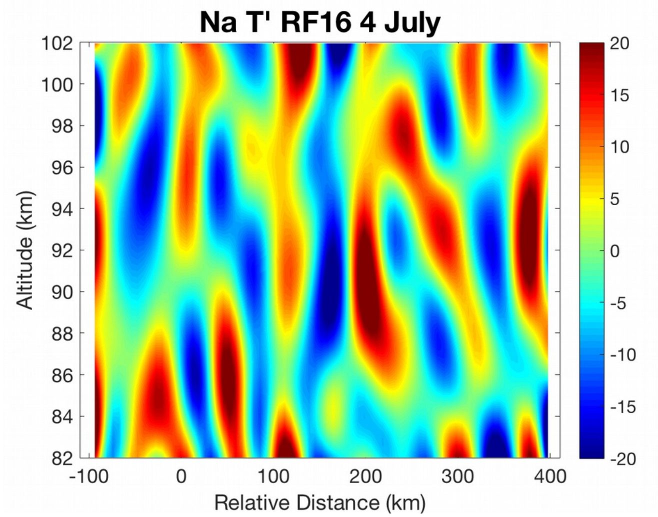
R=-.17

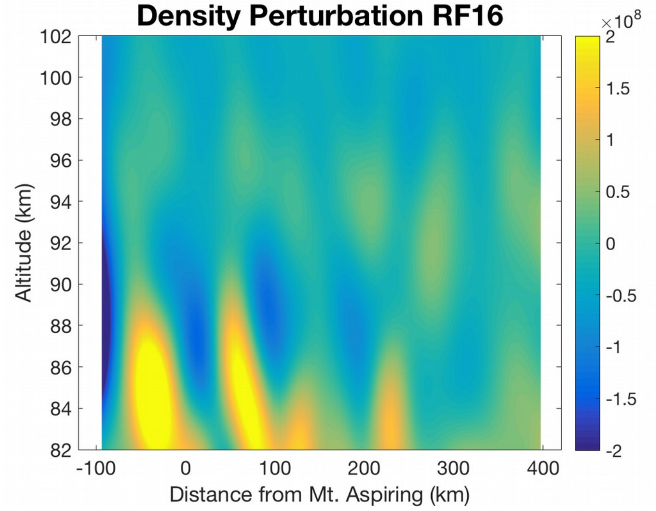


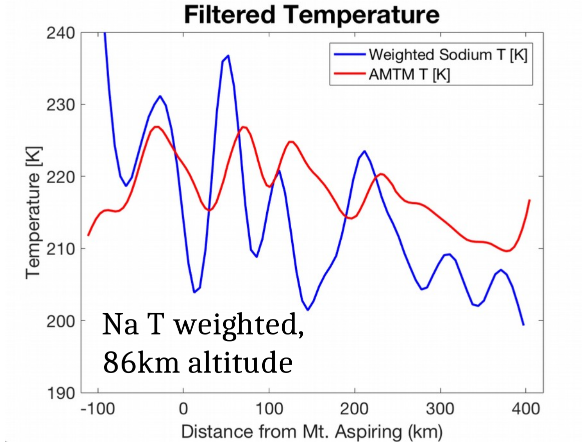
Propagation to the MLT

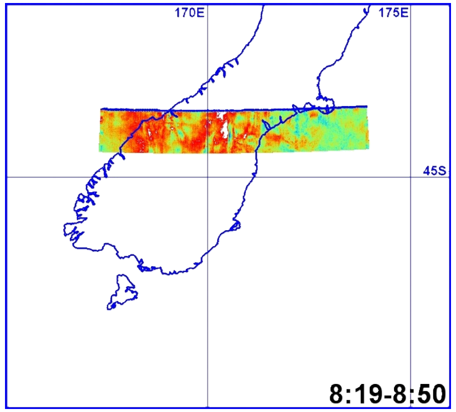
Leg 4 8:19-8:50 UT

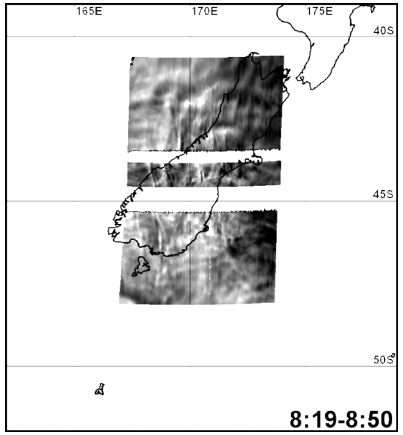






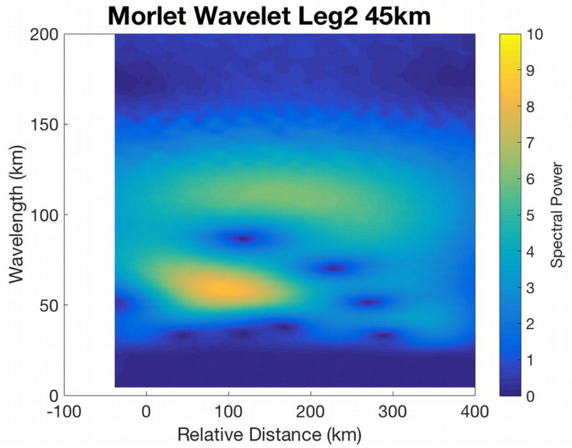




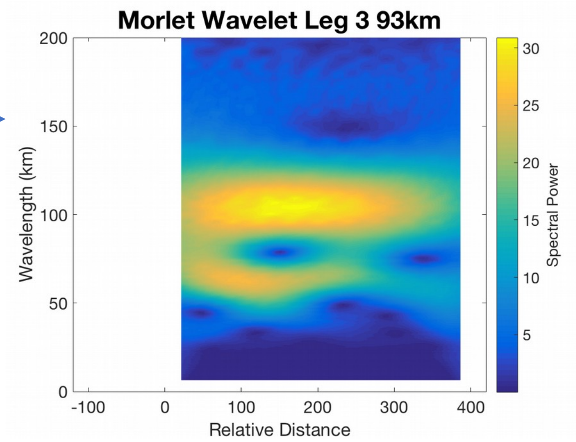


Propagation to the MLT

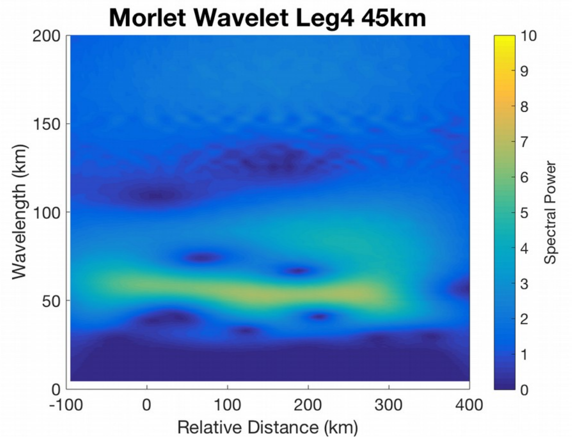
6:46-7:13 UT



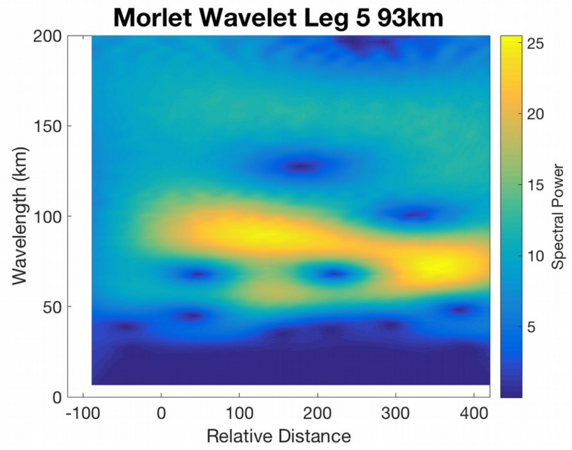
7:22-8:09 UT



8:19-8:50 UT



8:59-9:44 UT

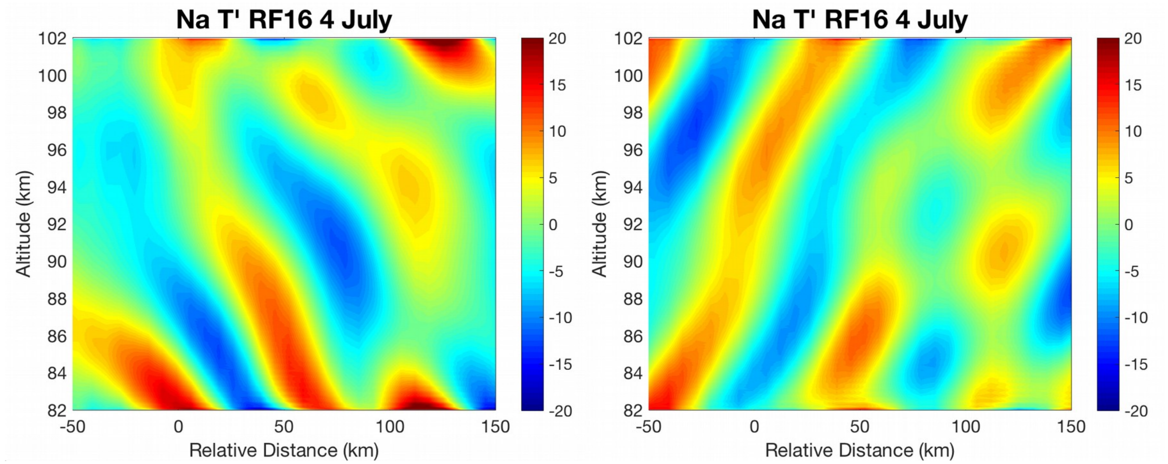


Propagation time from 40 km- 90km is ~30-60 minutes.

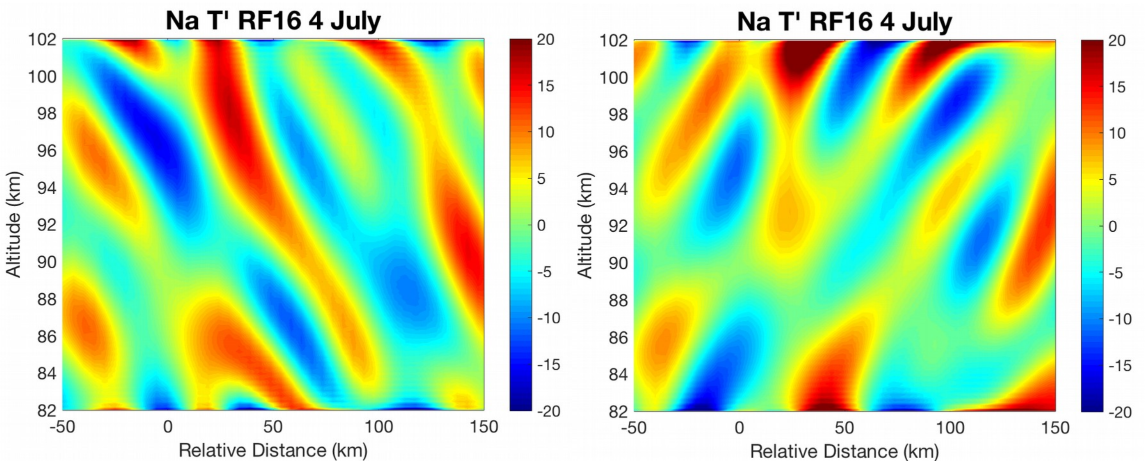
$$c_{gz} = \frac{Nkm}{(k^2 + m^2)^{3/2}}$$

Comparison of successive legs accounts for the propagation time offset and demonstrates similar spectra.

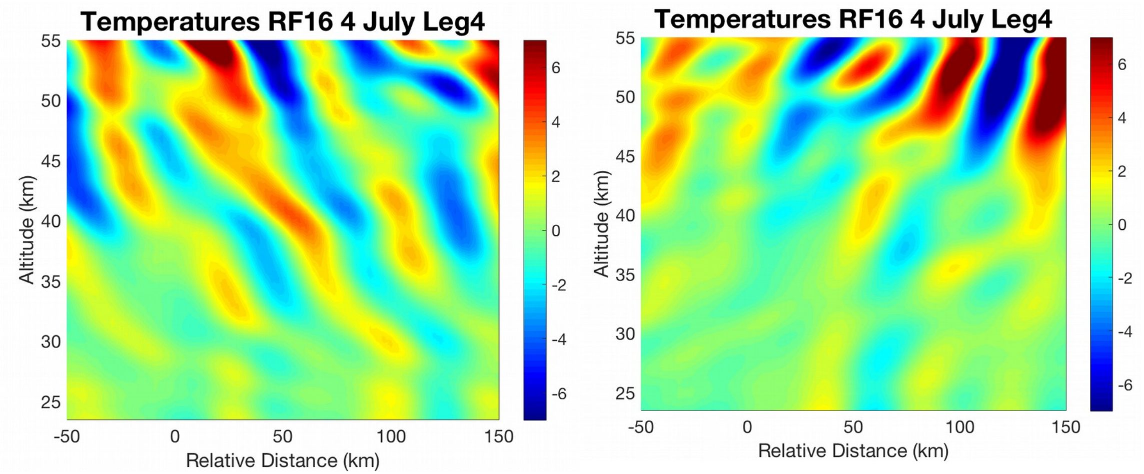
Propagation direction



Leg 4 8:19-8:50 UT



Leg 5 8:59-9:44 UT

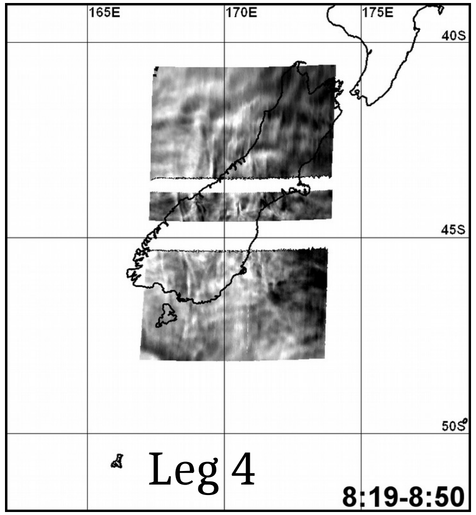


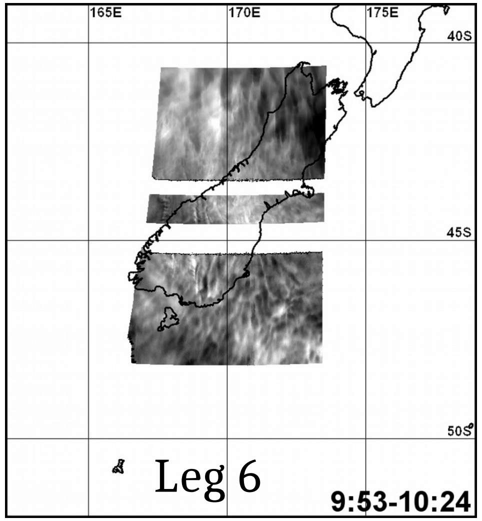
Both eastward and westward GWs were visible throughout the flight in both the stratosphere and MLT.

Correlations Between Sodium Flight Legs

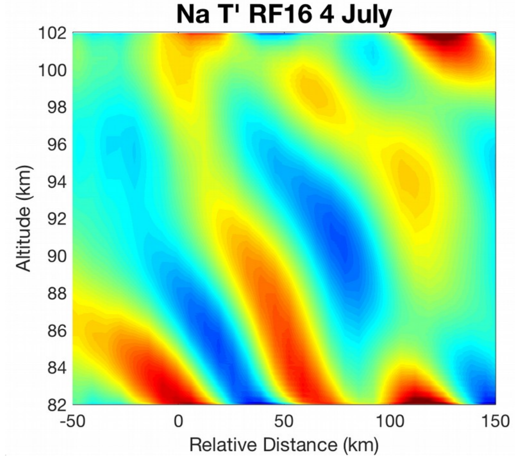
MWs present in airglow, but not clearly defined on every pass.

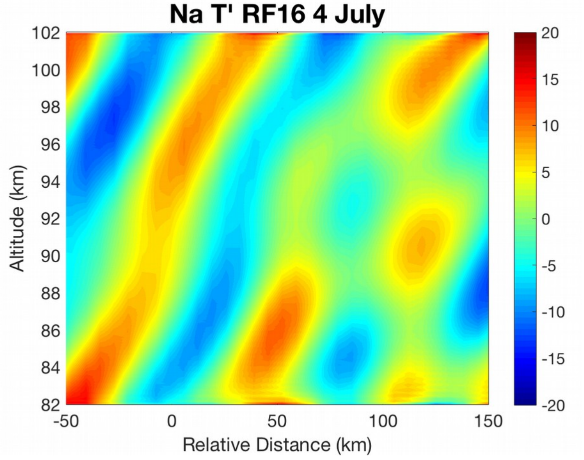
Many waves are present in the airglow, making correlations between MWs in the lidar less effective.





Leg 4

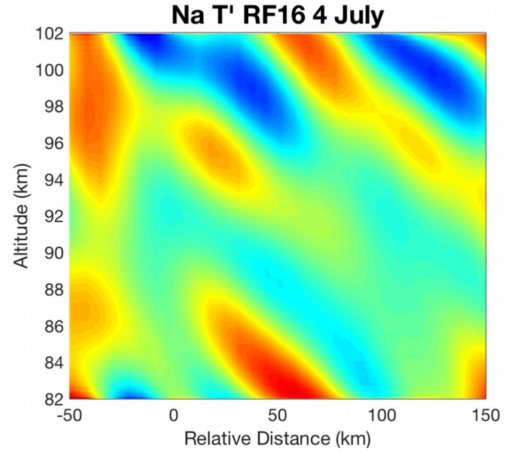


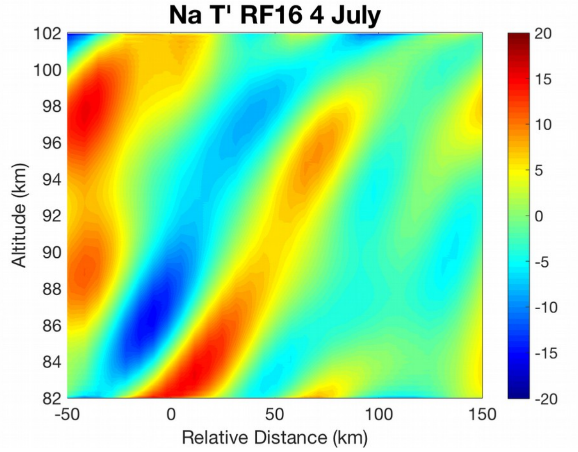


R=-.17

Leg 6

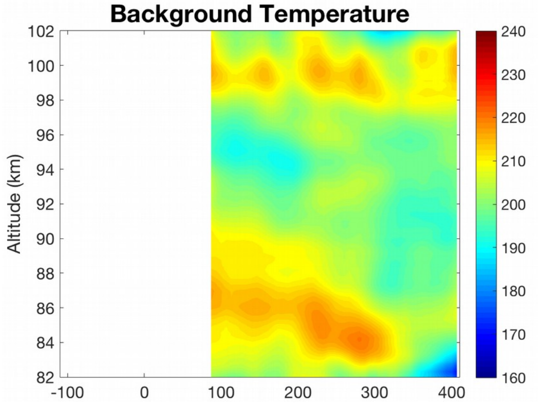
R=-.10



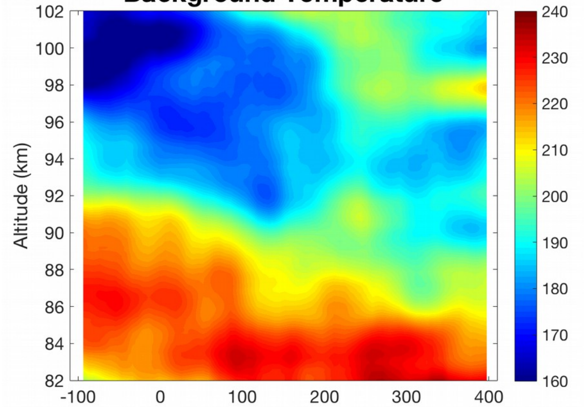


Changing Background Environment

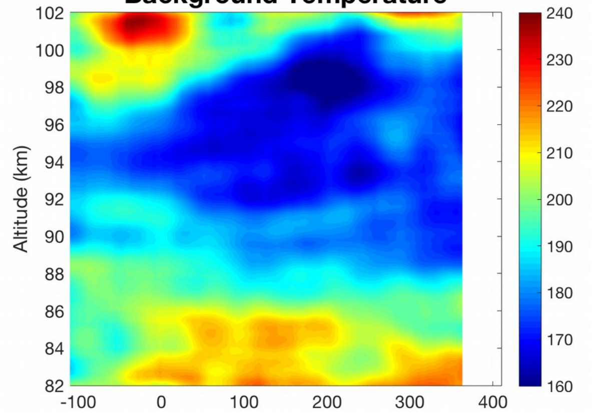
Leg 2



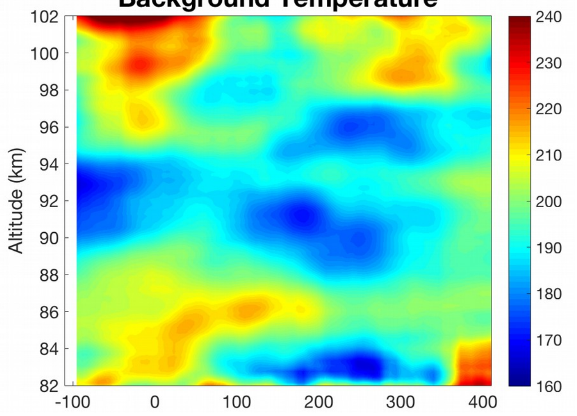
Leg 4

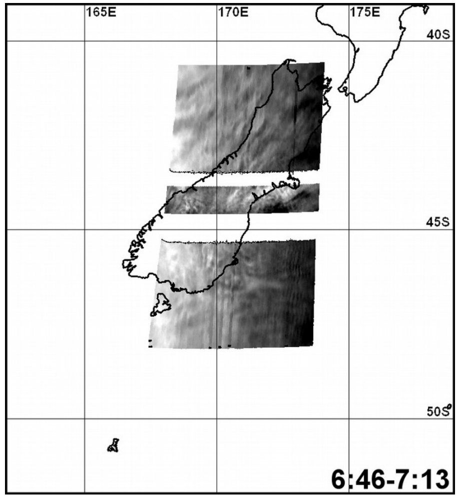


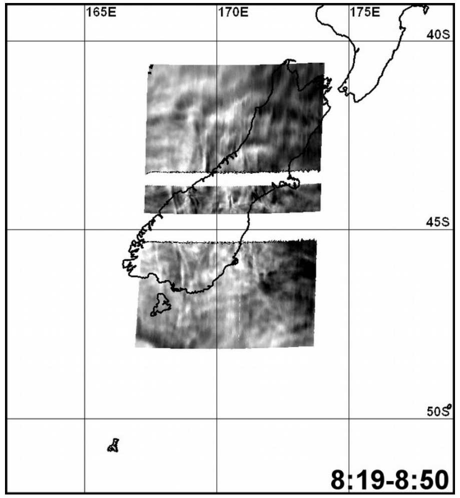
Leg 6

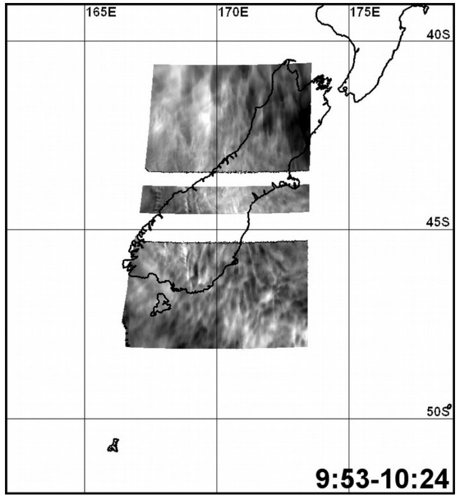


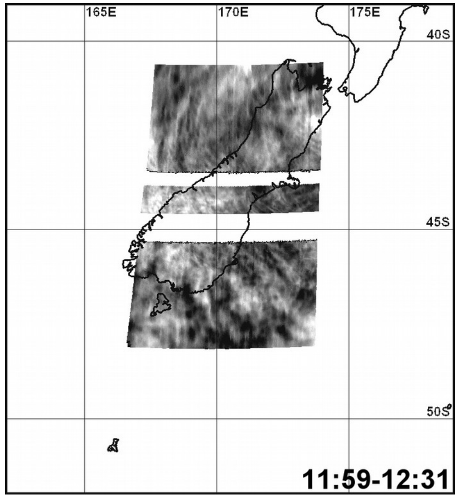
Leg 10





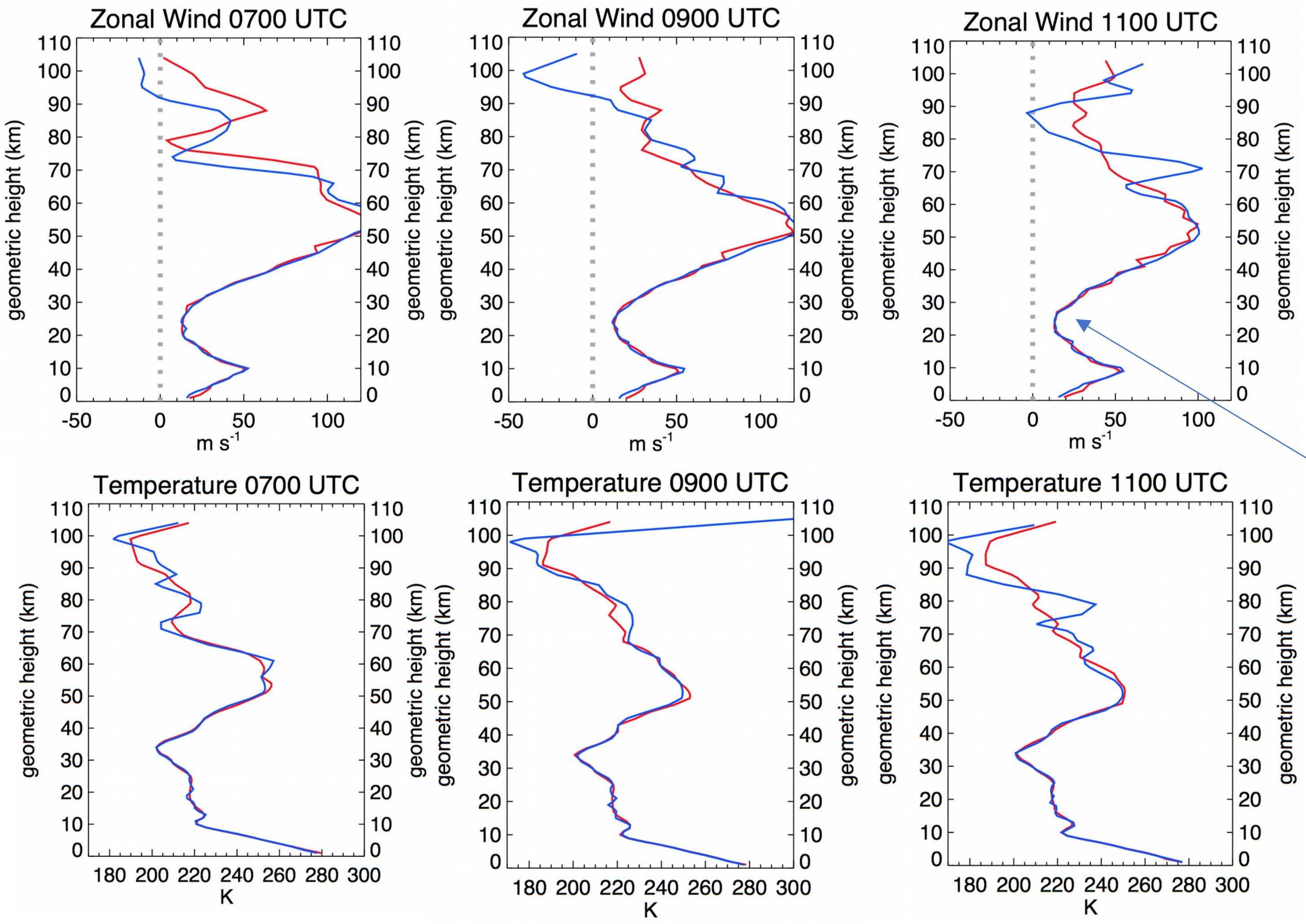




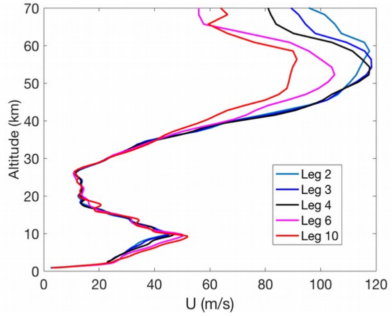


Propagation Environment

NAVGEM Winds and Temperatures



ECMWF Winds



Each pass, winds near 50km decrease

MW "valve layer" present

$$|u'_H| \leq |c_H - \bar{U}_H|$$

Effects of saturation lead to dissipation

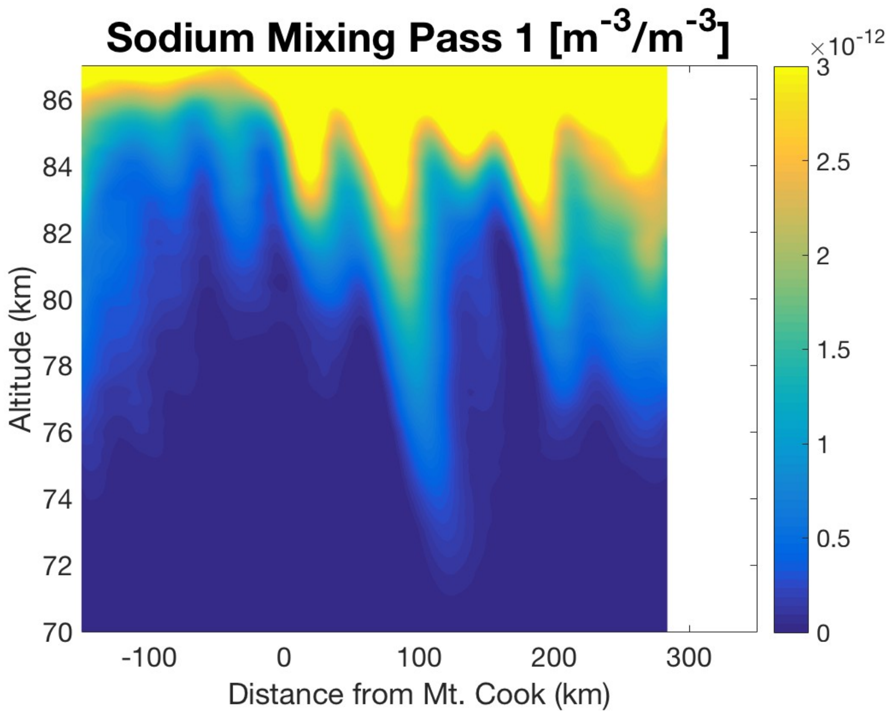
Conclusions

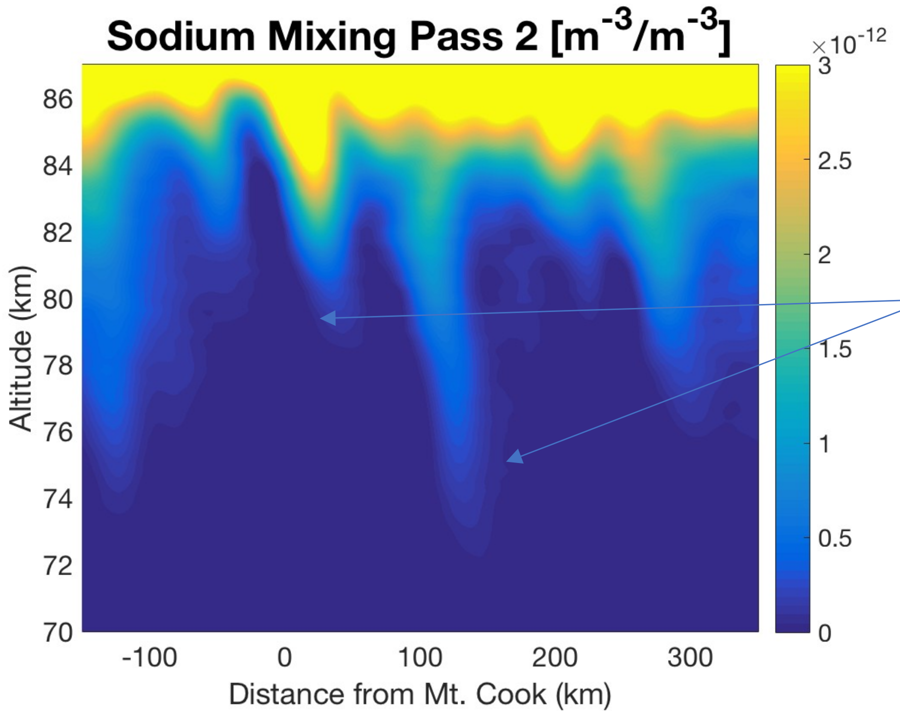
- GWs with similar spectra are observed in both the stratosphere and MLT regions during a high forcing event
- Both westward and eastward GWs are observed in the stratosphere-MLT on all passes
- Westward propagating waves in the stratosphere have a stronger correlation between passes, but this changes in the MLT region
- GWs observations in the MLT may vary more due to changing background environment

Spectral Momentum Flux in the MLT

Momentum Flux from MW Events

RF 22 Mixing Ratios



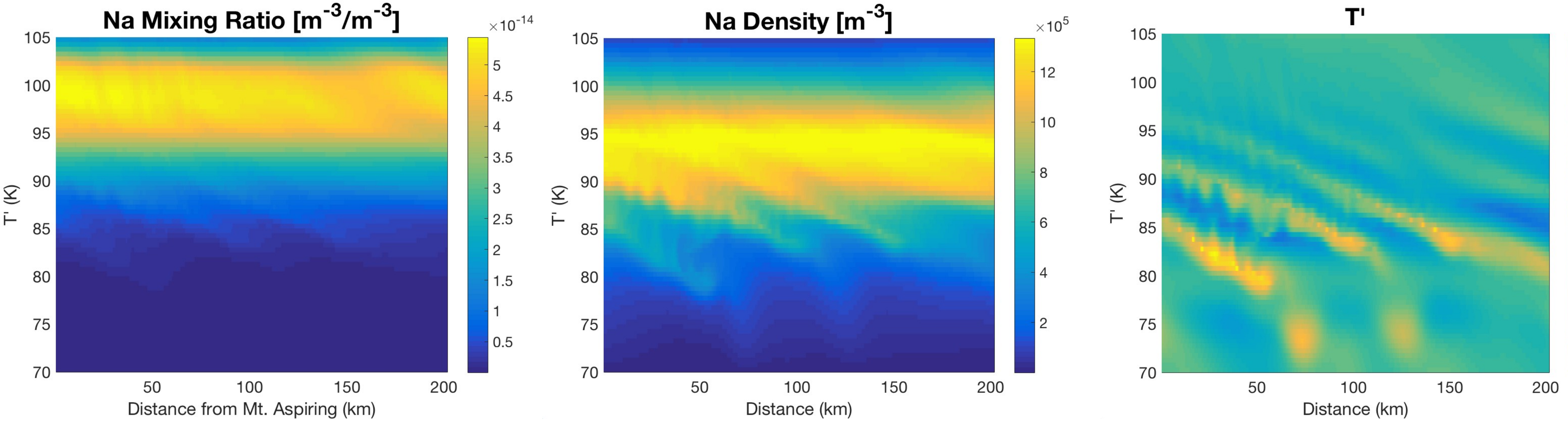


Difficult to calculate temperature due to:
-high resolution mode/no temperatures available
OR
-low sodium densities on bottom side of layer
OR
-discontinuous sodium across a given altitude

LPF data:
Stopband 12km
Passband 24km

-Multiple horizontal scales present in addition to ~240 km MW
-MW harmonics present

Modeled Data



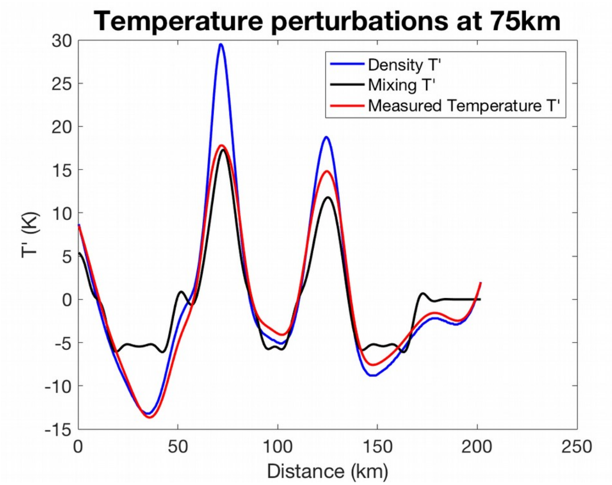
Model Output from Heale et al., 2017

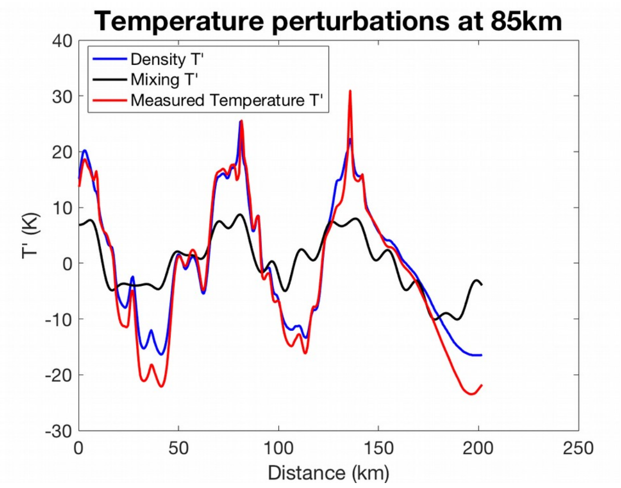
Temperatures can be calculated from the single frequency density measurements via the following methods:

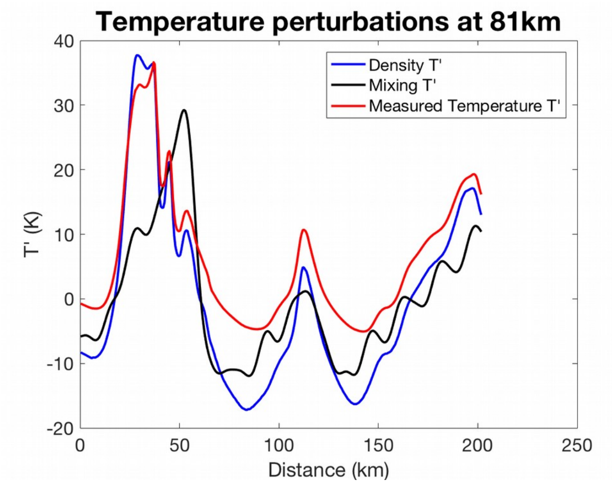
-Density perturbation amplitude

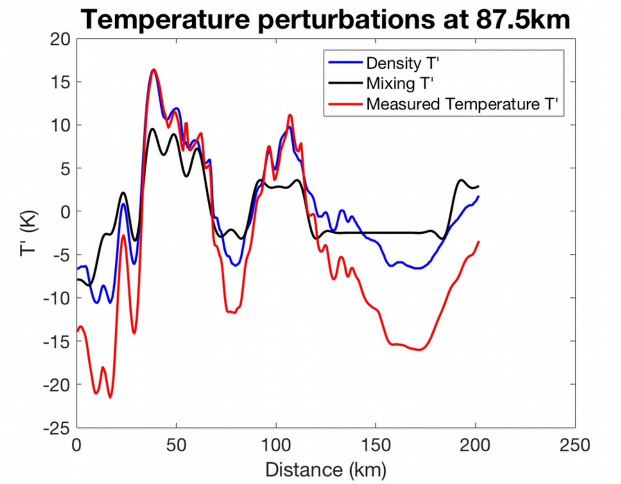
-Mixing ratio

Modeled Methodology and Validation









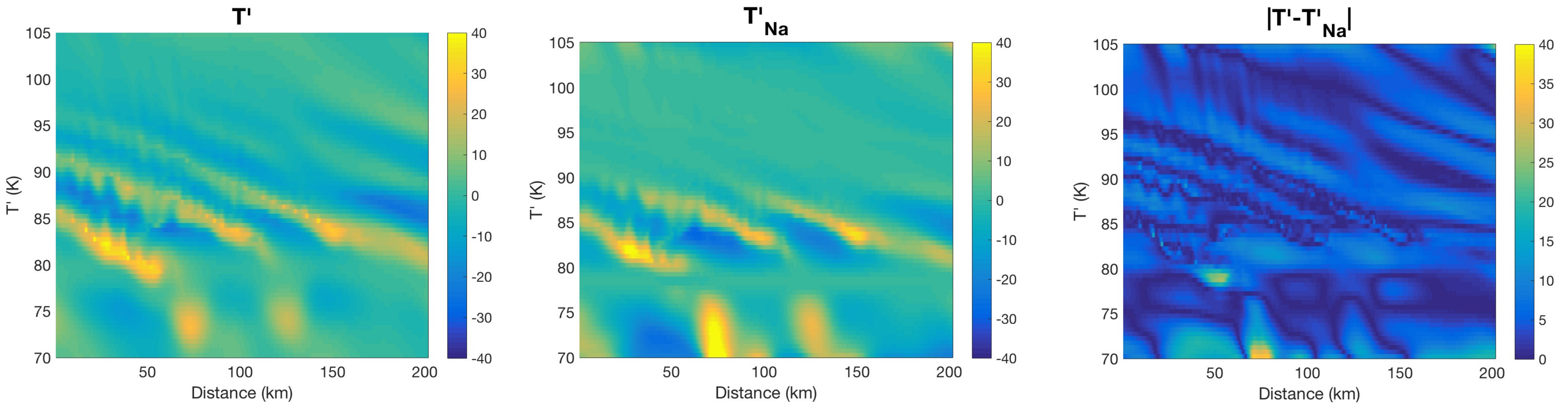
Density perturbation method uses perturbation amplitude with respect to background density gradient

$$\rho_s' e^{-i\omega t} = \left[\left(\frac{g}{N^2}\frac{T'}{\bar{T}}\right)\left[\frac{\bar{\rho}_s}{H}+\frac{\partial\bar{\rho}_s}{\partial z}\right]-\bar{\rho}_s\frac{T'}{\bar{T}}\right]e^{-i\omega t}$$

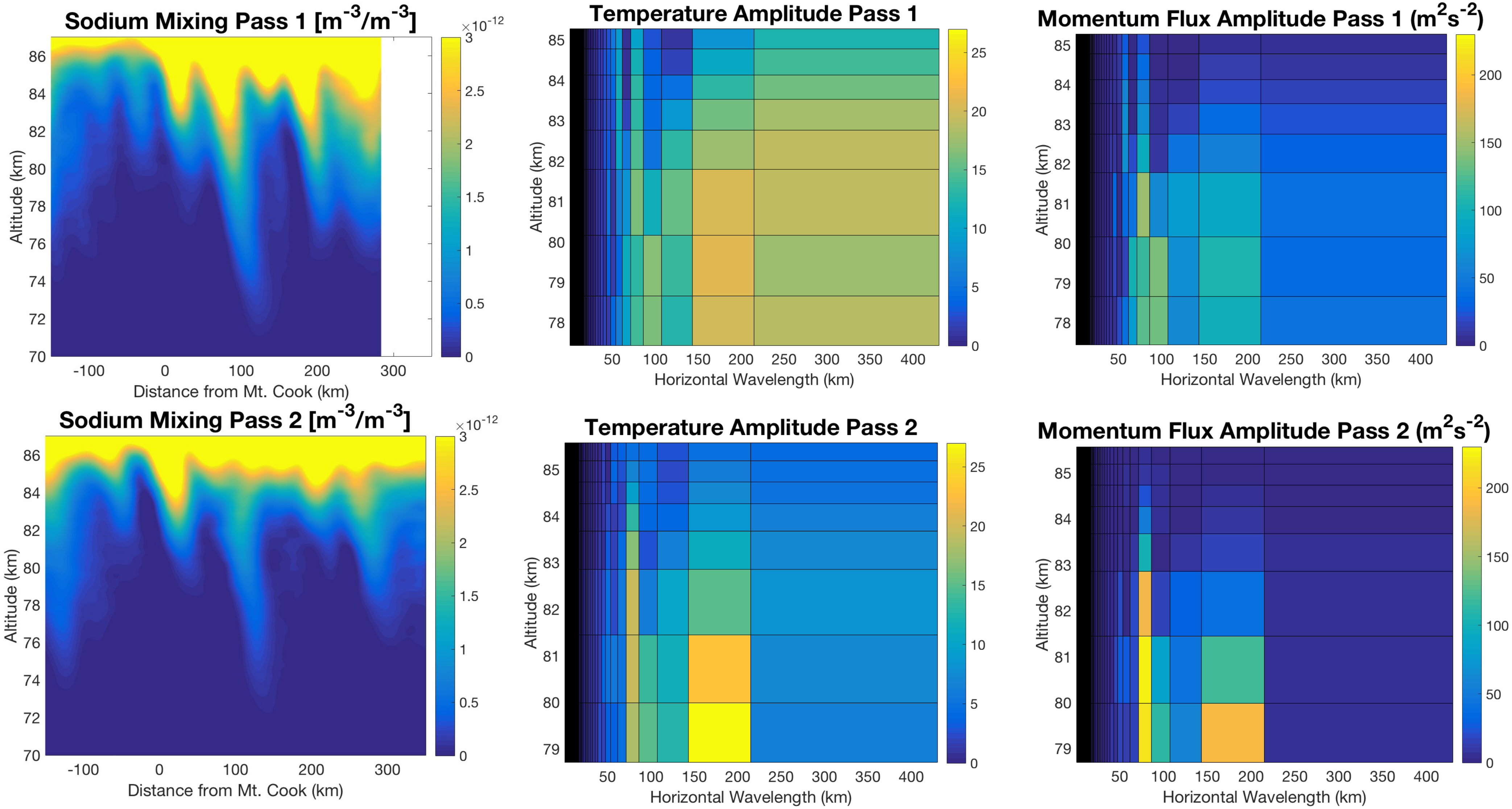
Mixing ratio uses displacement distance dz with respect to a mean altitude to calculate T' based on background temperature gradient and adiabatic lapse rate

-Mixing ratio T' better estimate for large deviations from Na layer
-Density amplitude T' better estimate for perturbations within the layer

Sodium Density Temperature Perturbation



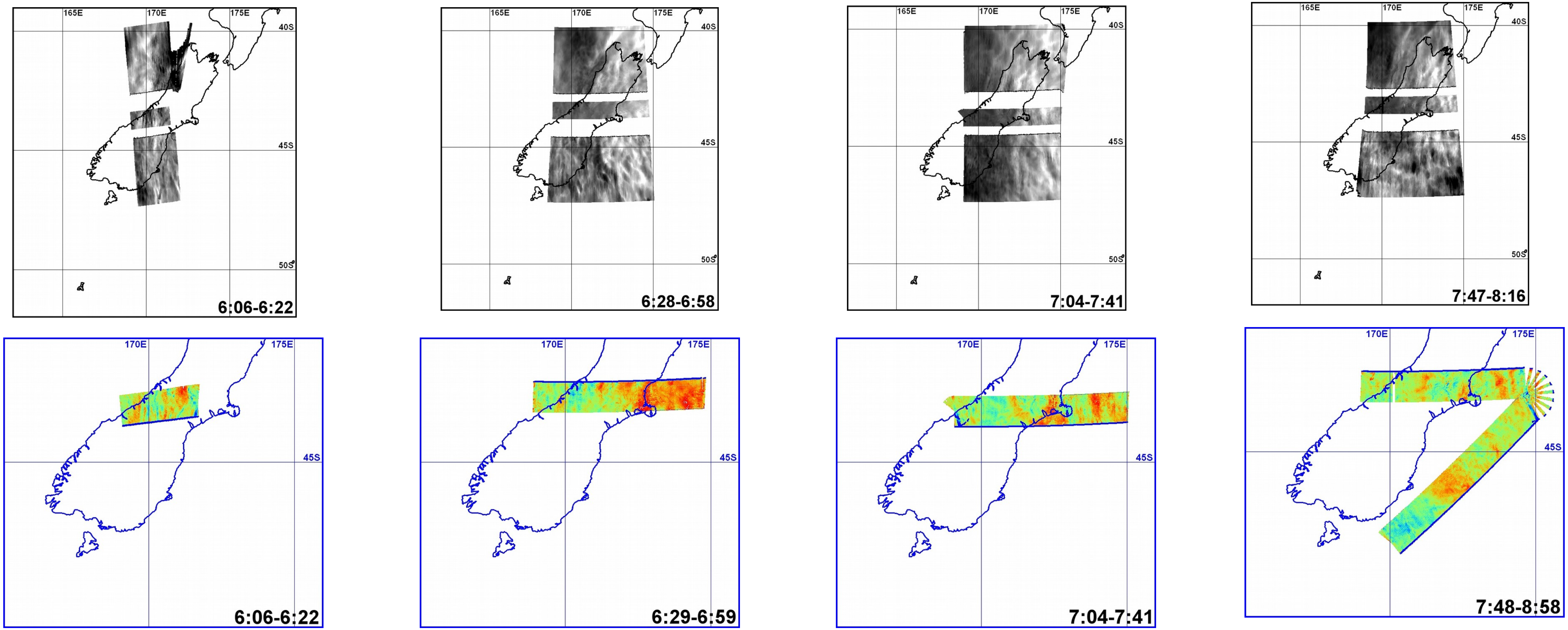
Calculations for RF22 (mixing ratio T')



U estimated from Kingston meteor radar

N^2 estimated from Lauder Rayleigh Lidar and SABER (Bossert et al, 2015)

RF 14 MW event



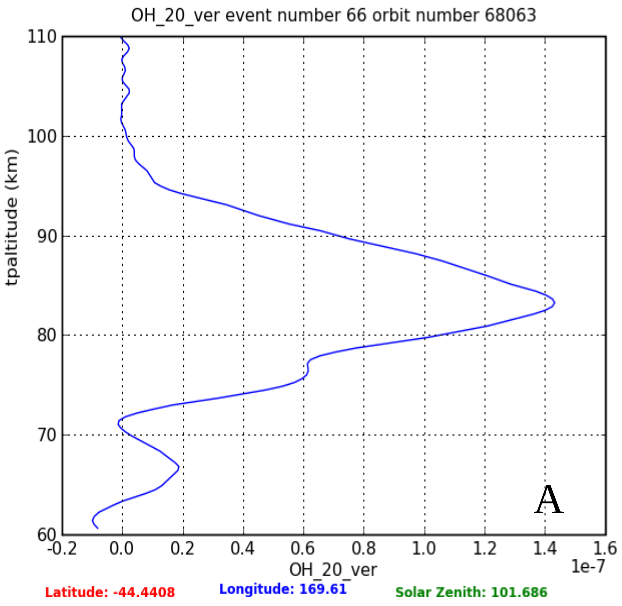
Leg 1

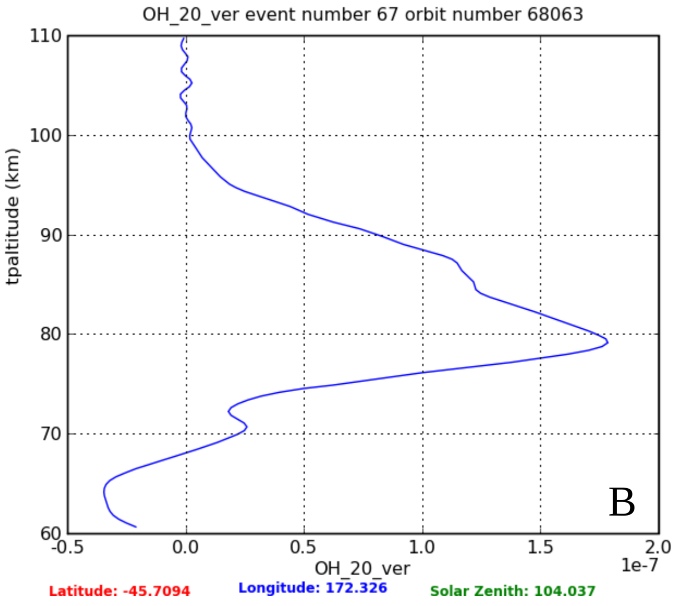
Leg 2

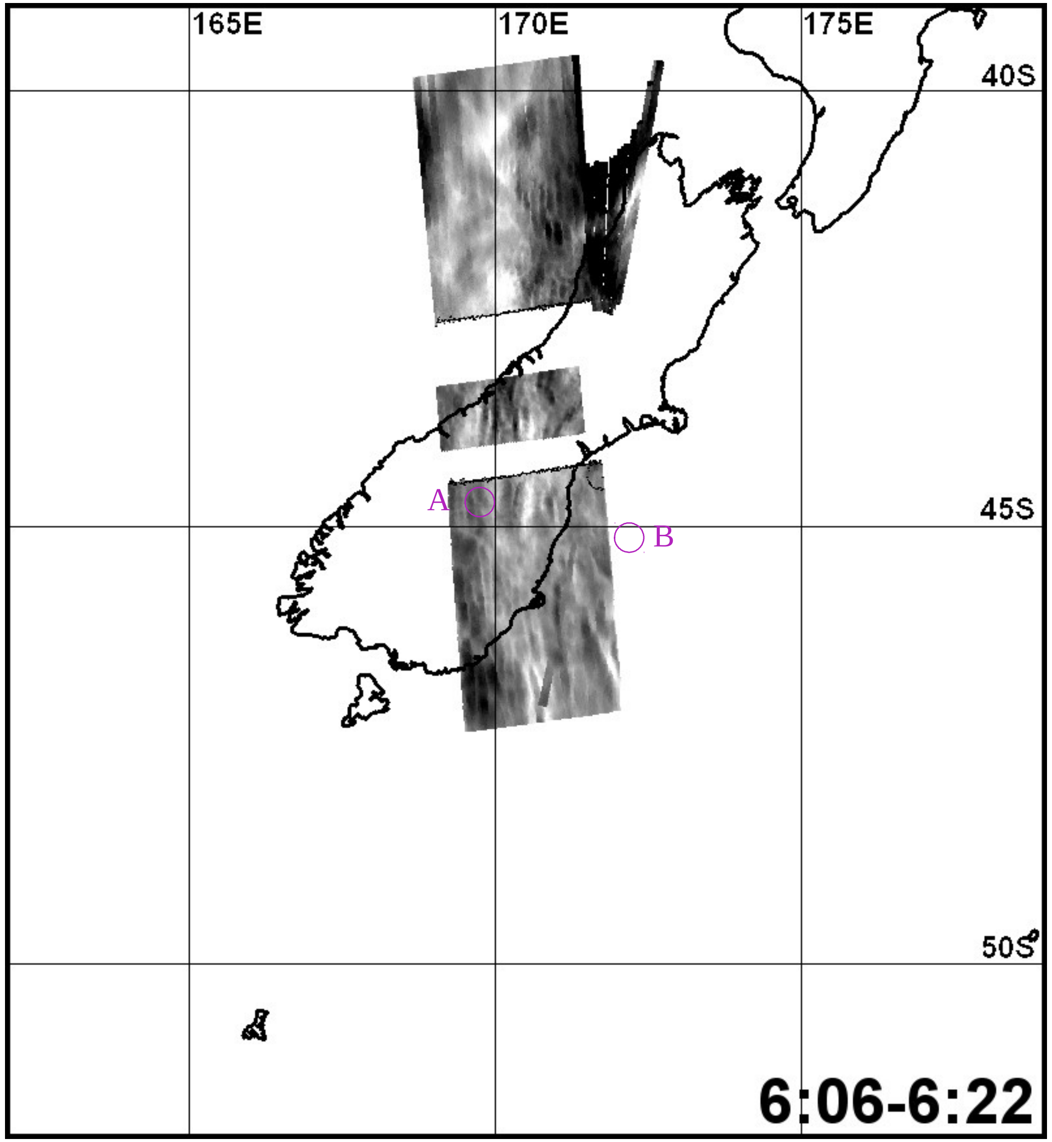
Leg 3

Leg 4

OH Layer displacement (RF14)



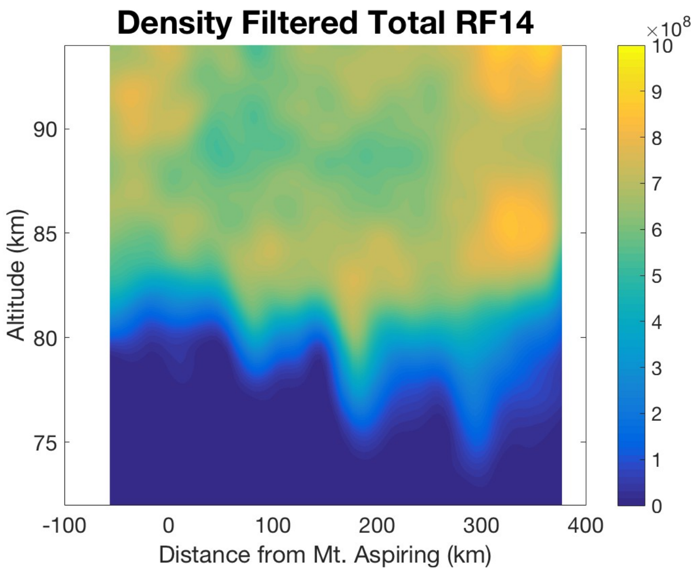


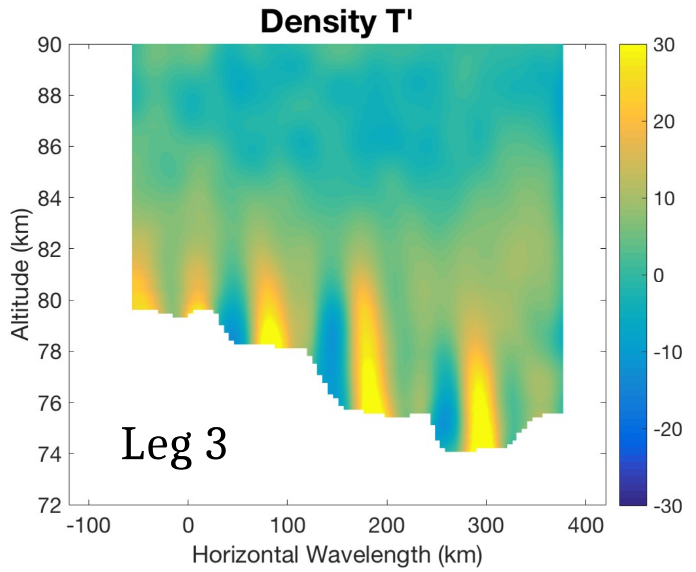


-First pass, ~80km wave apparent in OH intensity (no sodium data available

-Observed wave may possibly perturb OH layer (SABER observation at same time as OH observations. At location B, the OH layer is displaced to 79km)

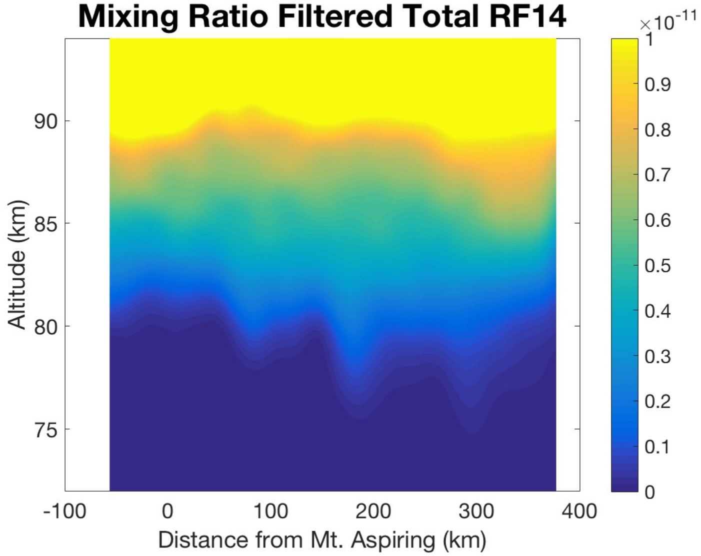
RF 14 Sodium Density Measurements

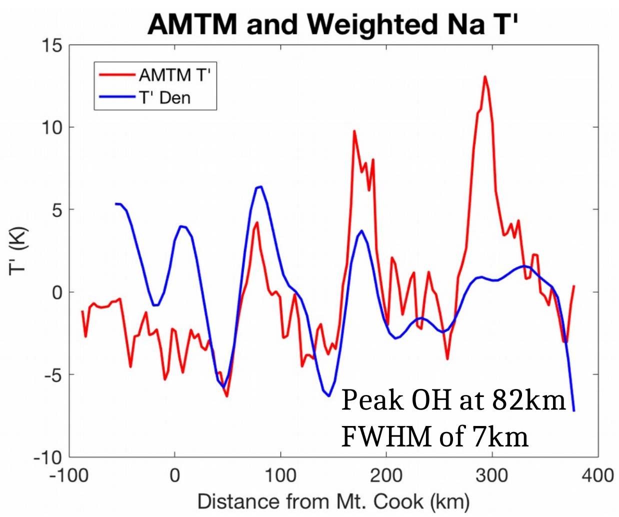


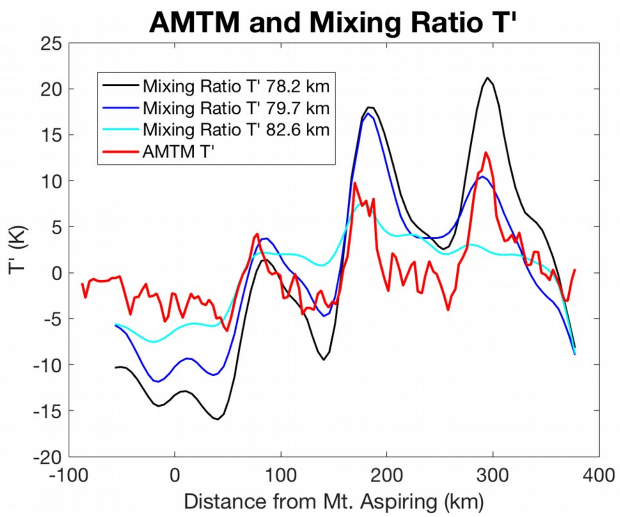


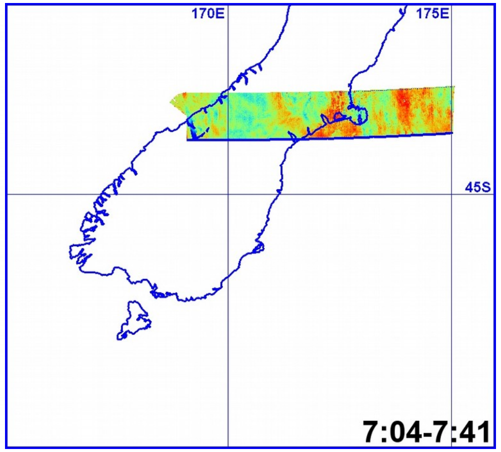
$$\rho_s' e^{-i\omega t} = \left[\left(\frac{g}{N^2}\frac{T'}{\overline{T}}\right)\left[\frac{\overline{\rho}_s}{H}+\frac{\partial \overline{\rho}_s}{\partial z}\right]-\overline{\rho}_s\frac{T'}{\overline{T}}\right]e^{-i\omega t}$$

T' from densities shows similar perturbations as the AMTM

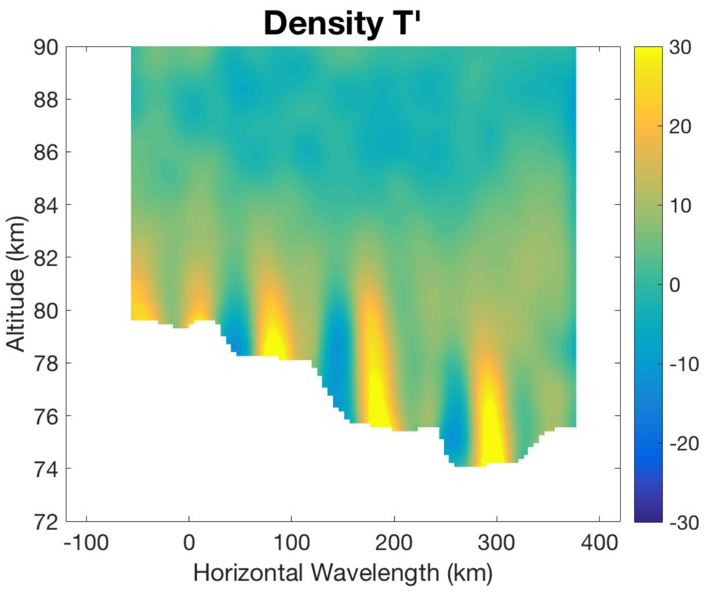


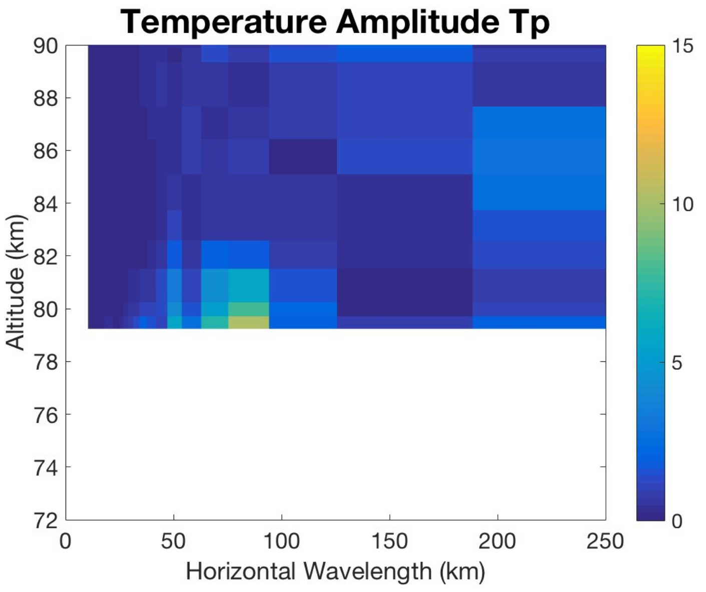


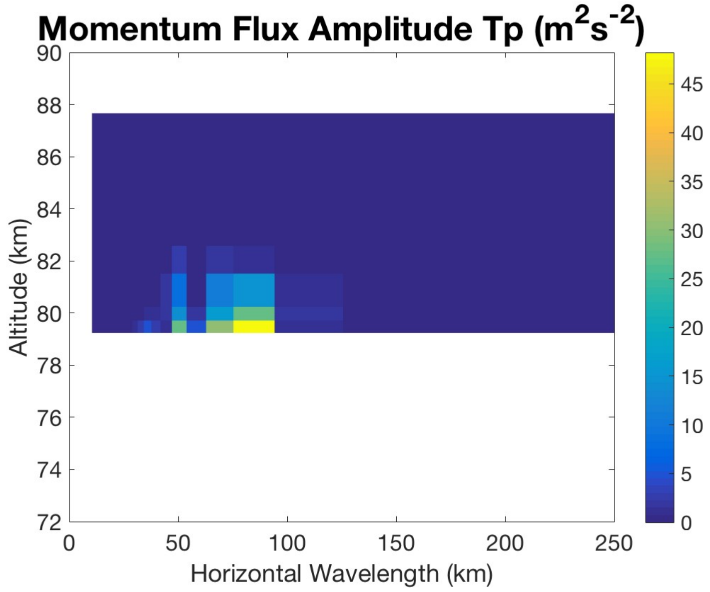


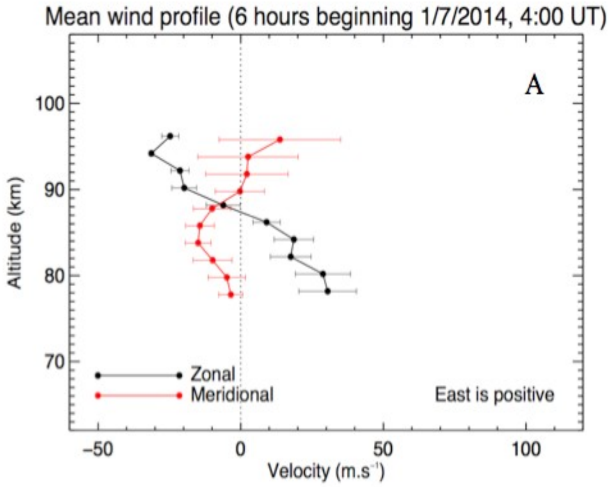


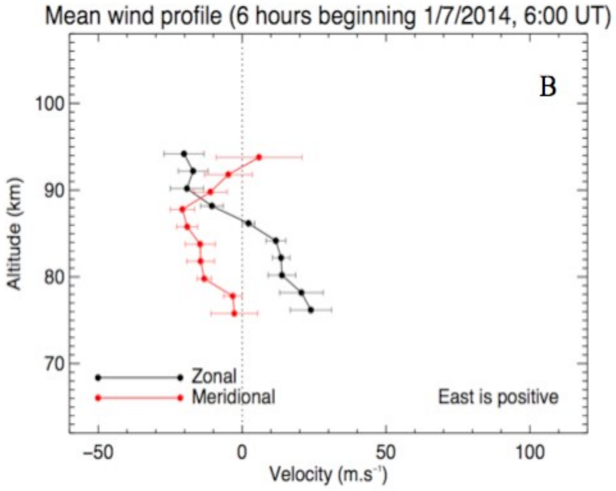
Spectral Momentum Flux

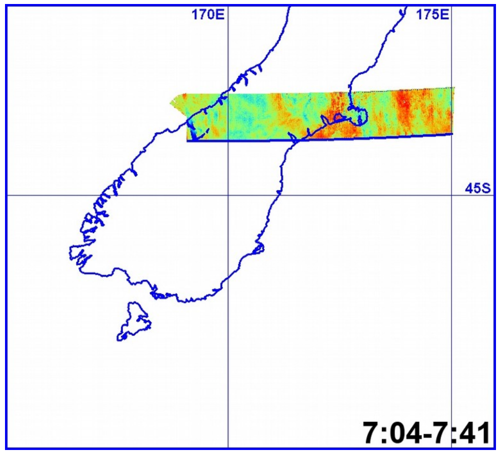












Conclusions

- Temperature perturbations can be extracted from single frequency sodium densities in the following ways:
  - Mixing ratio contour displacement
  - Sodium density perturbation amplitude
- Mixing ratios give a more accurate calculation for large deviations from the layer, and density perturbation amplitudes give a more accurate calculation within the layer
- MWs have a spectra associated with them, resulting in varying MF across the spectra

Questions