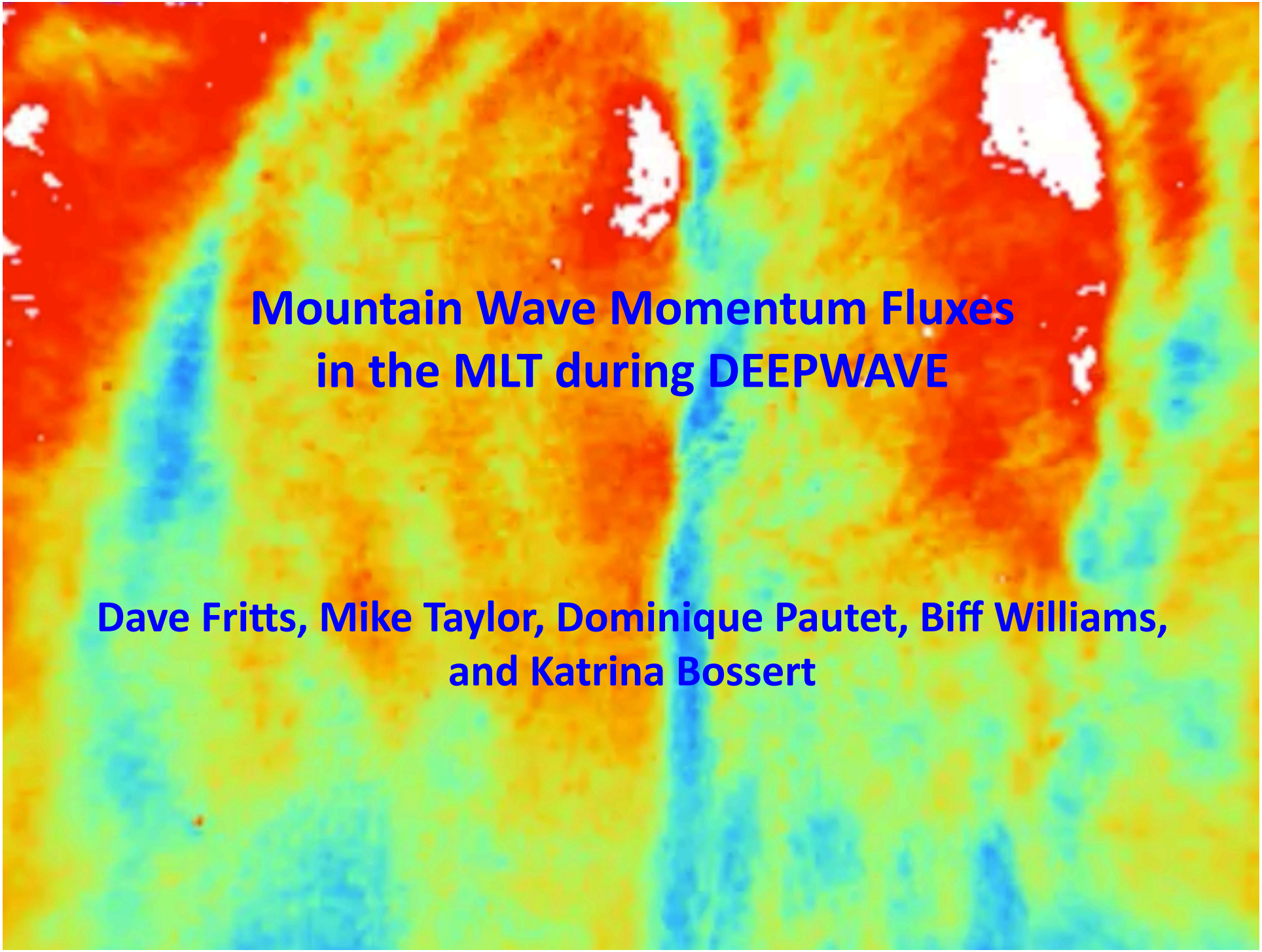


Mountain Wave Momentum Fluxes in the MLT during DEEPWAVE

Dave Fritts, Mike Taylor, Dominique Pautet, Biff Williams, and Katrina Bossert

Quantification of GW momentum fluxes employing the AMTM

Dispersion relation for deep GWs (neglecting U_z and U_{zz})

$$m^2 = k^2 \, (N^2/\omega_i^2 - 1) - 1/4H^2$$

for anelastic GWs

$$T'/T_0 = \theta'/\theta_0 + (\theta'/\theta_0 + \rho'/\rho_0)(1 - H_p/H)$$

H_p ~ H =>

$$T'/T_0 \sim (\theta'/\theta_0) = - \, i(Nu'/g) \, (1 - \omega_i^2/N^2)^{-1/2}$$

simplified polarization relations, assuming $\lambda_z^2 << (4\pi H)^2$ (λ_z < 30 km) =>

$$<u'w'> = (g^2 \omega_i/2N^3) \, (1 - \omega_i^2/N^2)^{1/2} (T'/T_0)^2$$

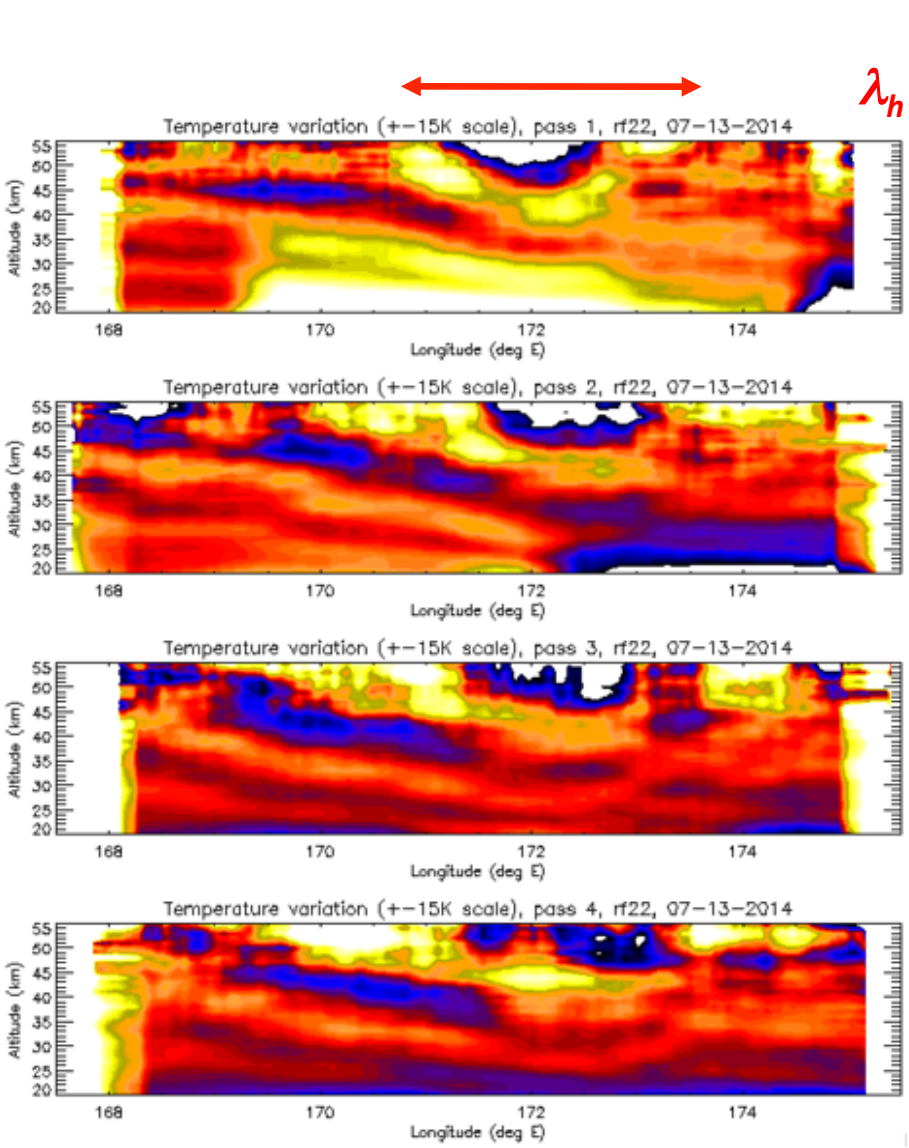
the "cancellation" (phase averaging) factor for z_{FWHM} = 7 km is

$$C = <T'>/T'(z_0) = \exp(-\pi^2 \, z_{FWHM}^2/4ln2 \, \lambda_z^2) = \exp(-1.78 \, z_{FWHM}^2/\lambda_z^2)$$

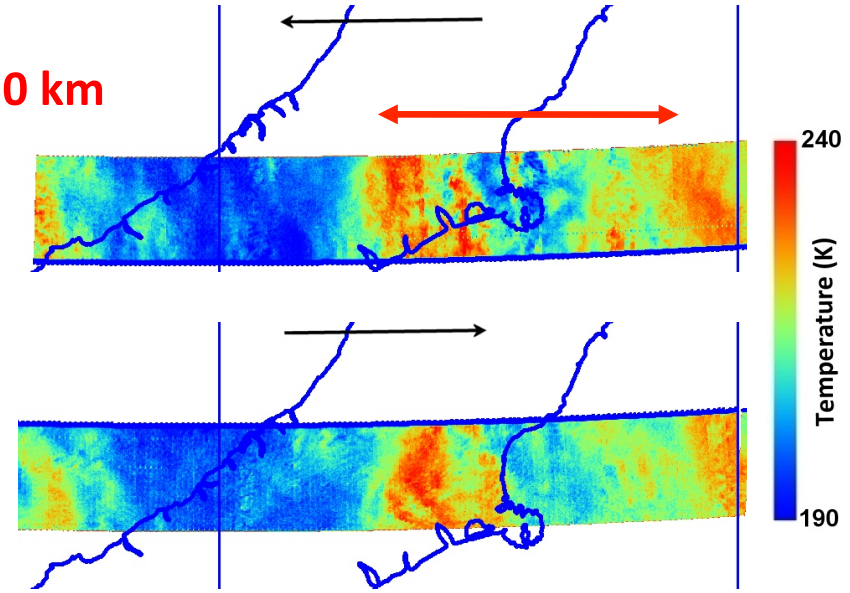
and the GW MF is given by

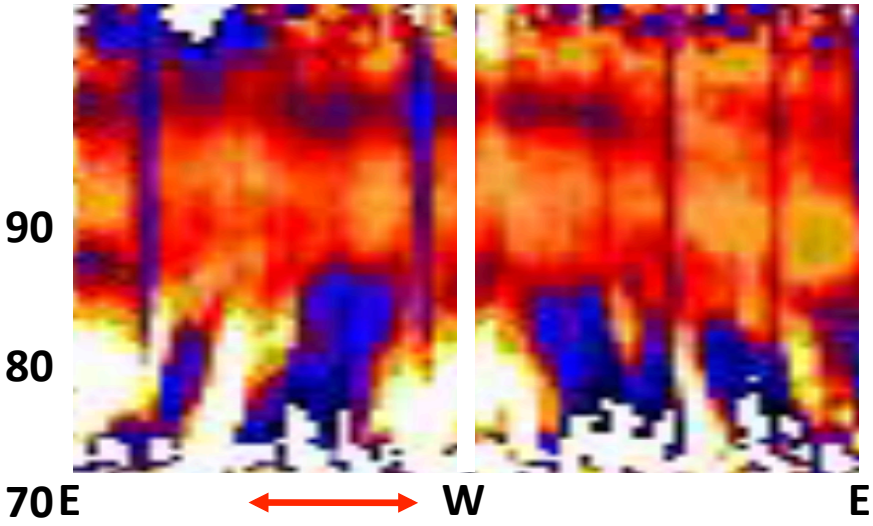
$$\boxed{<u_h'w'> = (g^2 \omega_i/2N^3)(1 - \omega_i^2/N^2)^{1/2} (<T'>/T_0)^2/C^2}$$

MWs on RF22 (13 July)
large-amplitude MW events superposed
1. large-scale MW at 20-55 and ~85 km



λ_h ~250 km





MWs on RF22 (13 July)
large-amplitude MW events superposed
1. large-scale MW at 20-55 and ~85 km

Observed parameters: λ_h ~250 km

at 55 km:

Rayleigh lidar: λ_z ~25 km, T' ~15-20 K,

=> <u'w'> ~ 100 m^2/s^2 at 55 km

at ~87 km:

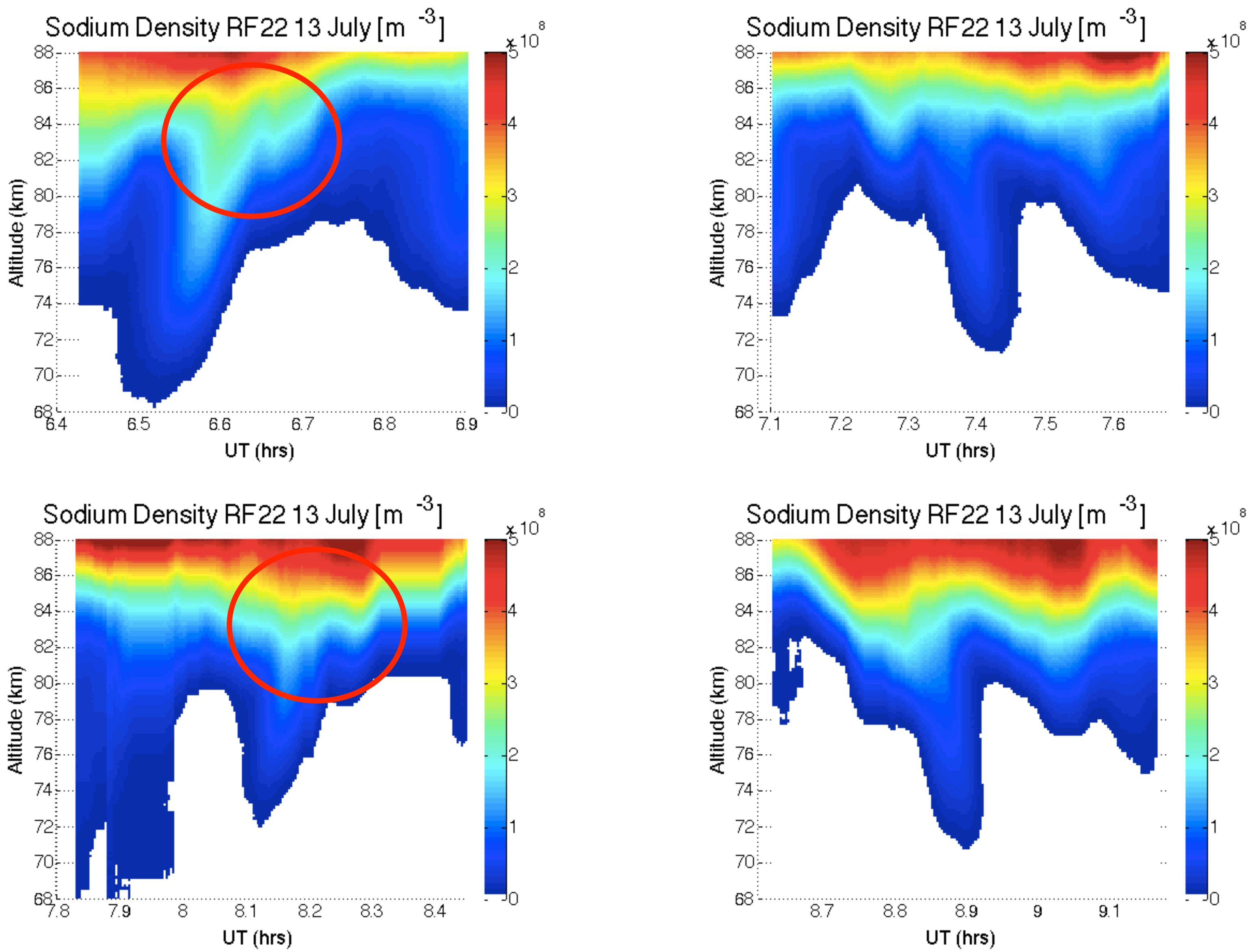
AMTM T' ~20K variations,

Na lidar λ_z ~25 km, δz ~3-5 km, possible overturning (needs refinement)

=> T' ~20-40 K

=> <u'w'> ~ 300-1000 m^2/s^2 at 85 km

MWs on RF22 (13 July)
large-amplitude MW events superposed
2. smaller-scale MWs at 20-55 and ~85 km



MWs on RF22 (13 July)
large-amplitude MW events superposed
2. smaller-scale MWs at 20-55 and ~85 km

Observed parameters: λ_h ~60-80 km

at 85 km:

AMTM T' ~10K variations,

Na lidar λ_z ~25 km, dz ~1-2 km

=> T' ~10-15 K (evidence of overturning would increase this)

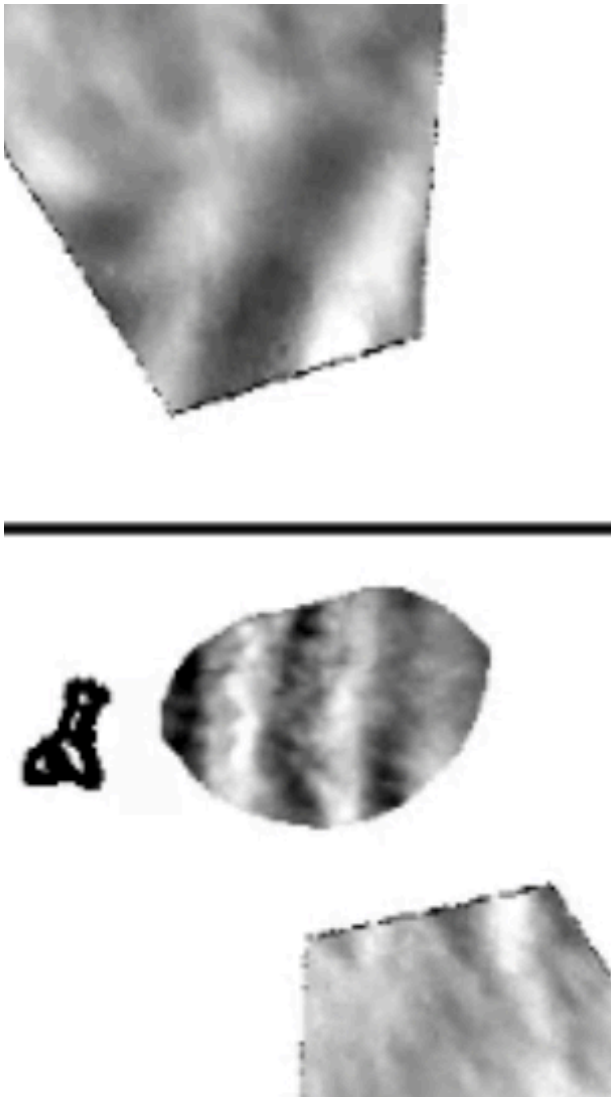
=> <u'w'> ~ 600-1000 m^2/s^2 at 85 km

note that <u'w'> ~1000 m^2/s^2

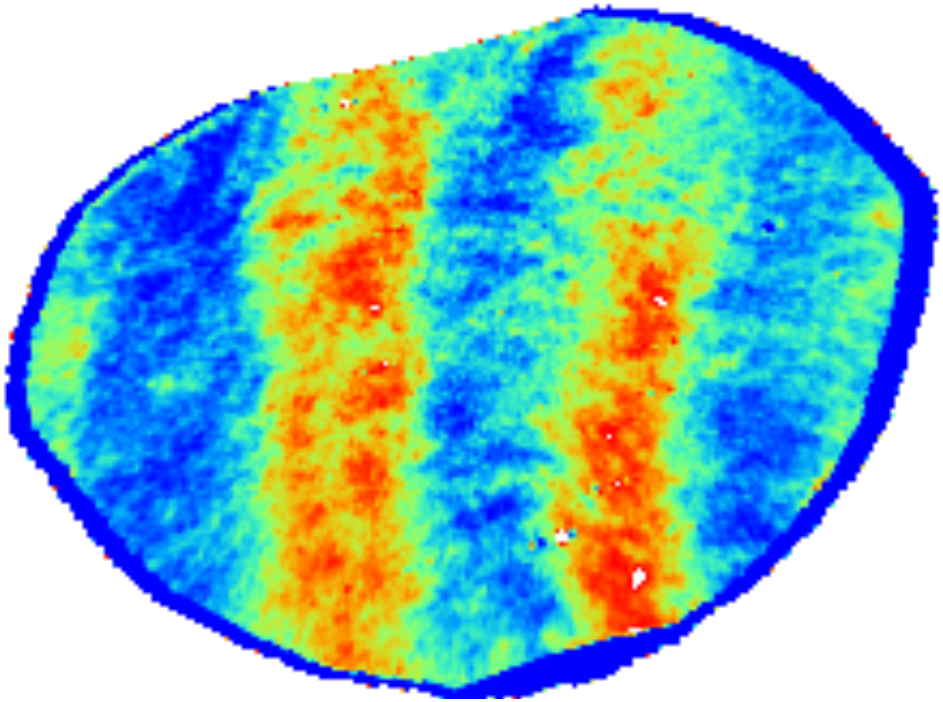
=> local acceleration of ~30 m/s/hr, rapid local wind reductions, and possible explanation for strong temporal modulation

Aukland Island MWs on RF23 (14 July)

- clear "ship-wave" response at ~87 km



λ_z ~ 40 km, T' ~10 K



Aukland Island MWs on RF23 (14 July)

- clear "ship-wave" response at ~87 km

Observed parameters at ~87 km:

AMTM: λ_h ~40 km, T' ~10 K

=> δz ~1-2 km

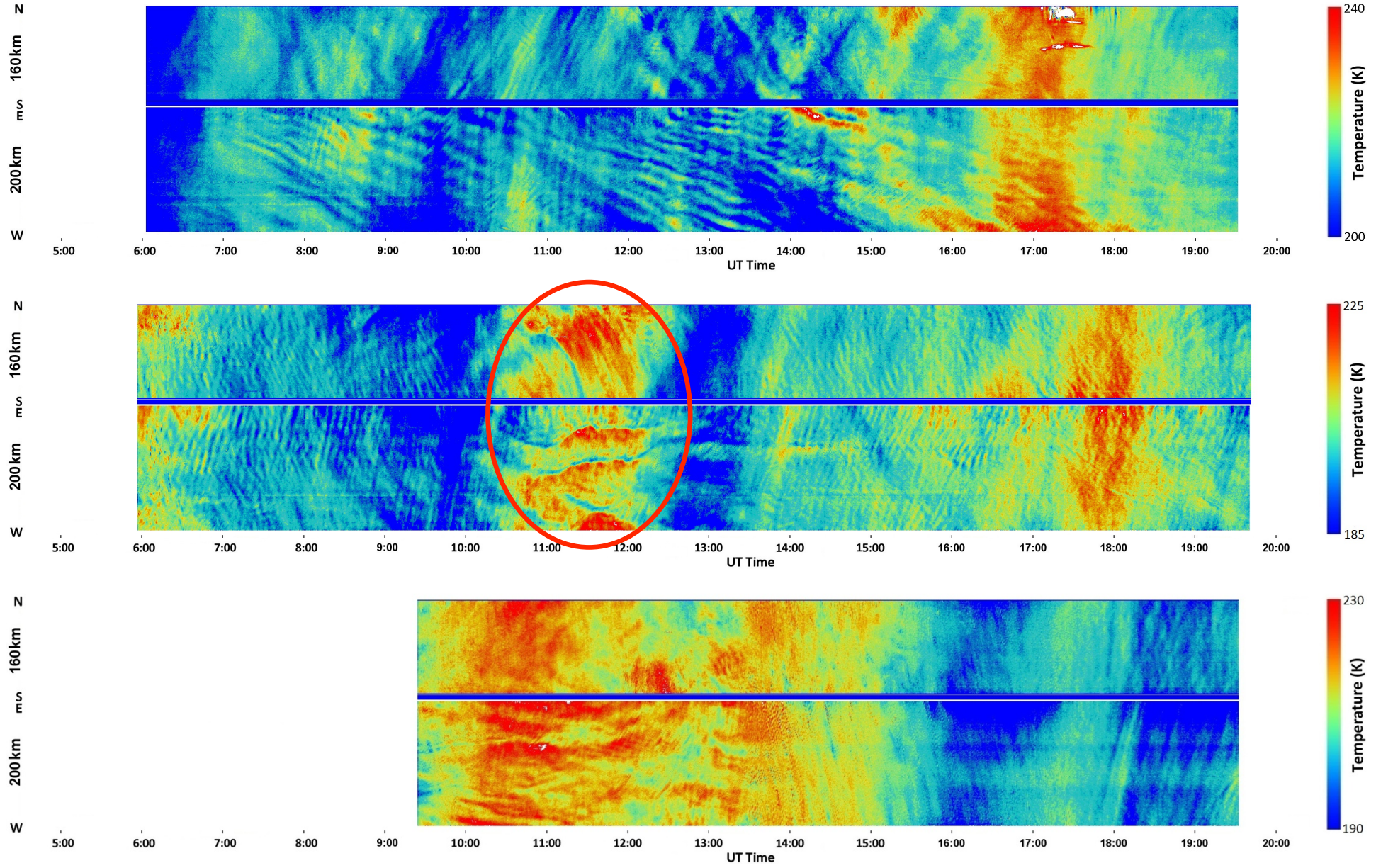
=> $\lambda_z > 2\pi\,\delta z >$ 10 km (larger more likely due OH phase cancellation)

- need large λ_z to yield observed AMTM T'

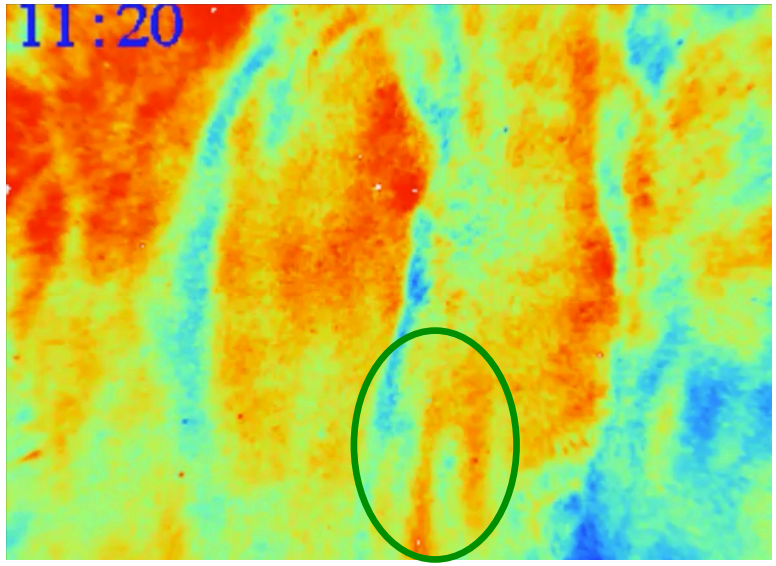
- winds of ~30-50 m/s => λ_z ~14-20 km

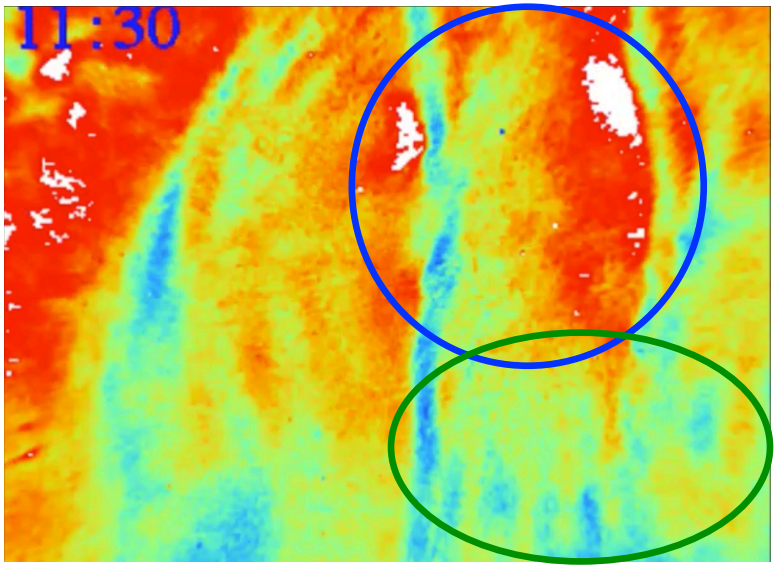
=> <u'w'> ~ 100-300 m^2/s^2 at 87 k

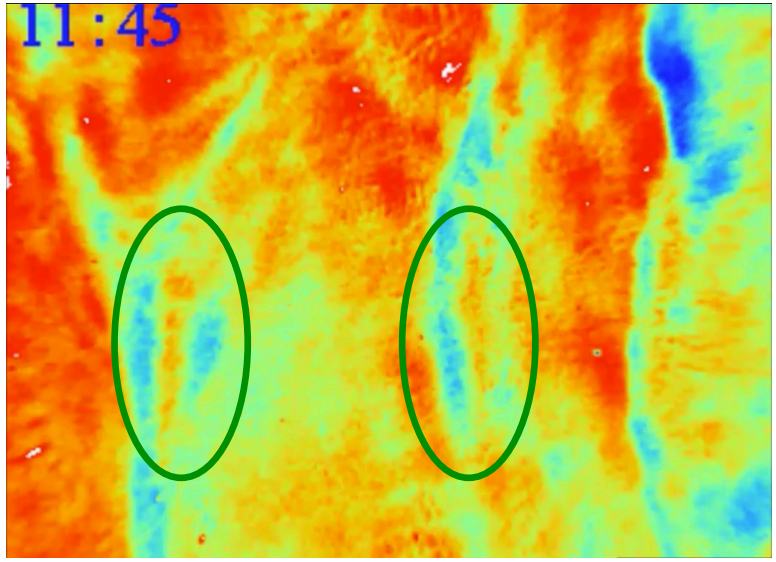
GW momentum fluxes in the MLT during DEEPWAVE
- multiple large-amplitude MW events (during weak forcing)



GWs observed by the Lauder AMTM on 21 June 2014
- several large-amplitude MW events superposed





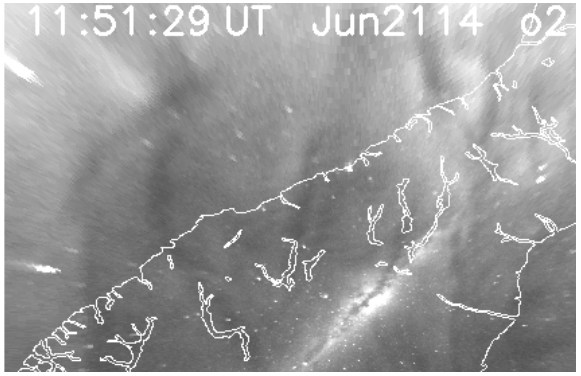


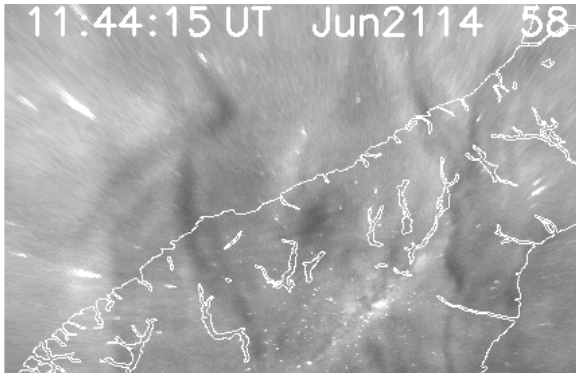
Observed parameters:

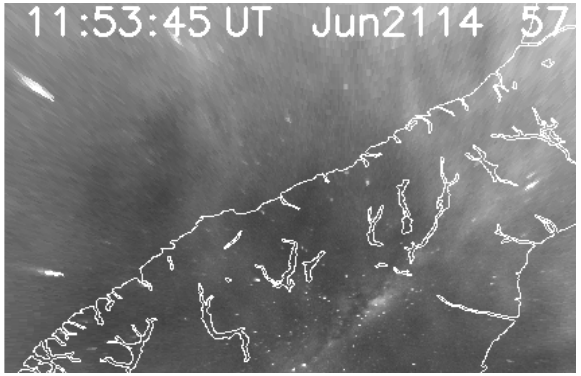
λ_h ~12-15 and ~65 km

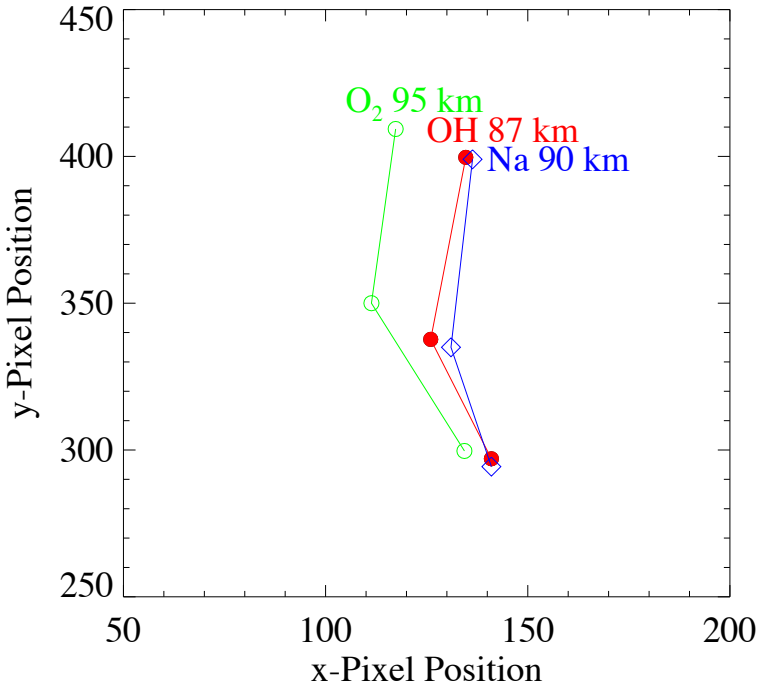
AMTM T' and sawtooth GW T(x) variations
=>
T' ~20 K, T'/T ~0.1 or greater for ~65 km GW
δz ~2 km, overturning
=>
λ_z ~$2\pi\,\delta z$ ~12.5 km or greater

Other estimates or constraints on λ_z
- Mt. John airglow phase differences among OH, Na, and O_2 layers







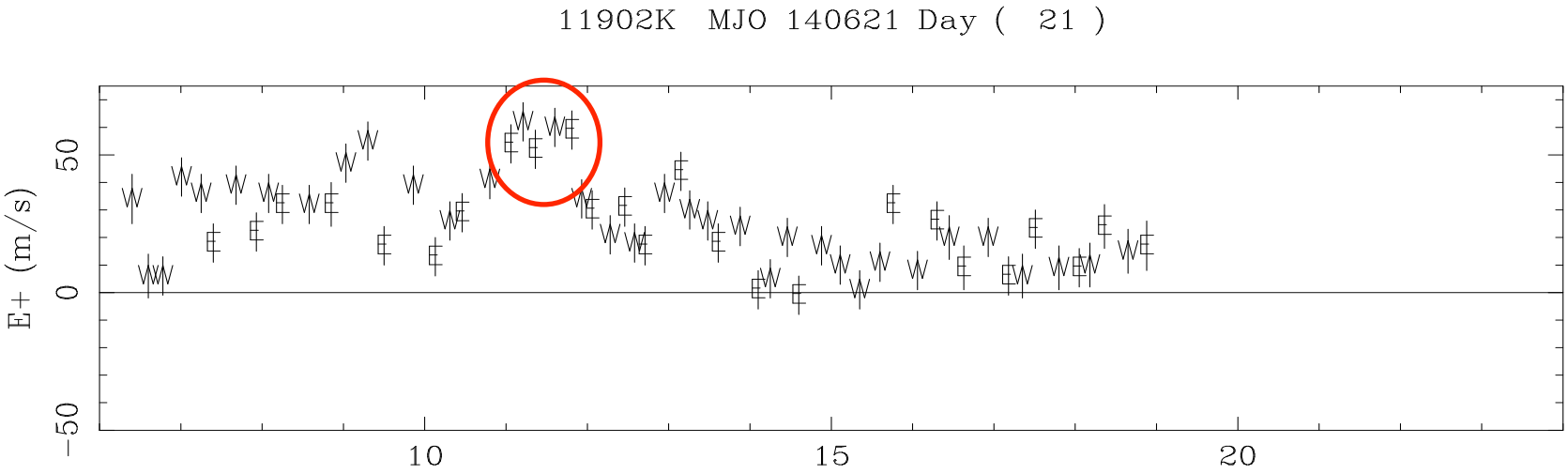


Observed and inferred wavelengths (from Steve Smith)

λ_h ~65 km

λ_z ~33 km (from OH and O_2 airglow)

Other estimates or constraints on λ_z
- Mt. John FPI E-W winds



U ~ 50 m/s during this event

=>

λ_z ~2π U/N ~15 or 30 km for N ~ 0.02 or 0.01 s^{-1}

Summary of options:

λ_z ~33 km => ω'/N ~0.45, <u'w'> ~530 m^2/s^2

λ_z ~15 km => ω'/N ~0.22, <u'w'> ~540 m^2/s^2

λ_h ~15 km, T'/T ~0.03 => ω'/N ~0.71, <u'w'> ~110 m^2/s^2

Summary

- larger MLT momentum fluxes preferentially accompany large-amplitude MWs

- dominant horizontal wavelengths, λ_h ~20-200 km

- largest coherent MWs in the stratosphere and MLT occur for weak tropospheric forcing