Mountain wave excitation under extreme forcing conditions and propagation into the middle atmosphere

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State College

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Introduction

- Kaifler et al. (2015): deep vertical propagation of mountain waves is likely to be observed under two conditions

  1) weak to moderate forcing conditions and

  2) sufficiently strong stratospheric winds

- Dunkerton (1984), Sato (2009):
  GW are refracted/focused into the middle atmospheric jets due to meridional shear of the zonal wind

➔Examine the case during Deepwave with the largest stratospheric gravity wave activity, but only little wave activity in the mesosphere (31.7. – 1.8.2014)

➔What governs the vertical propagation:

Instabilities? Refraction?

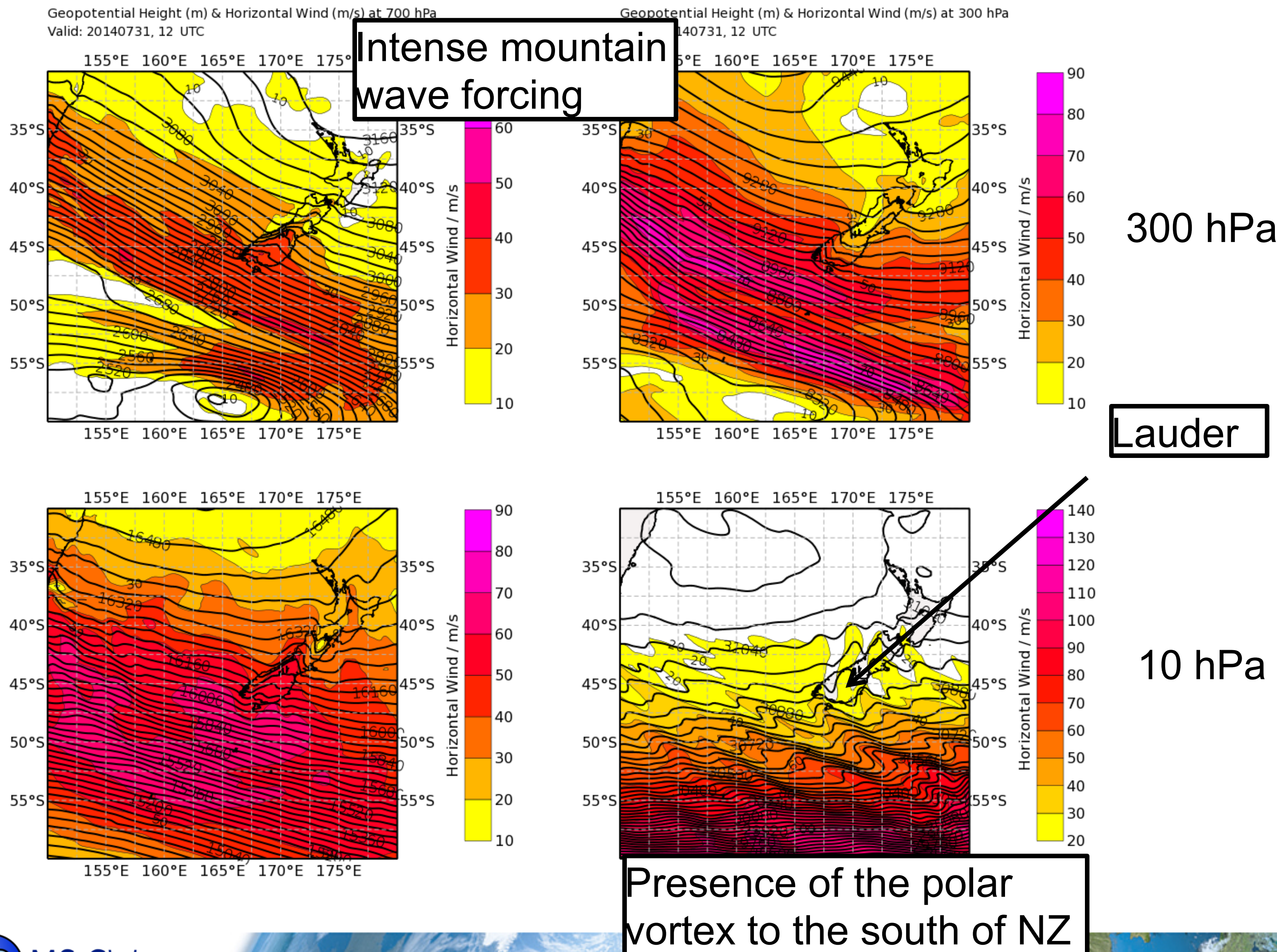
ECMWF hor. wind and geopotential on 31 July 2014

700 hPa

300 hPa

100 hPa

10 hPa



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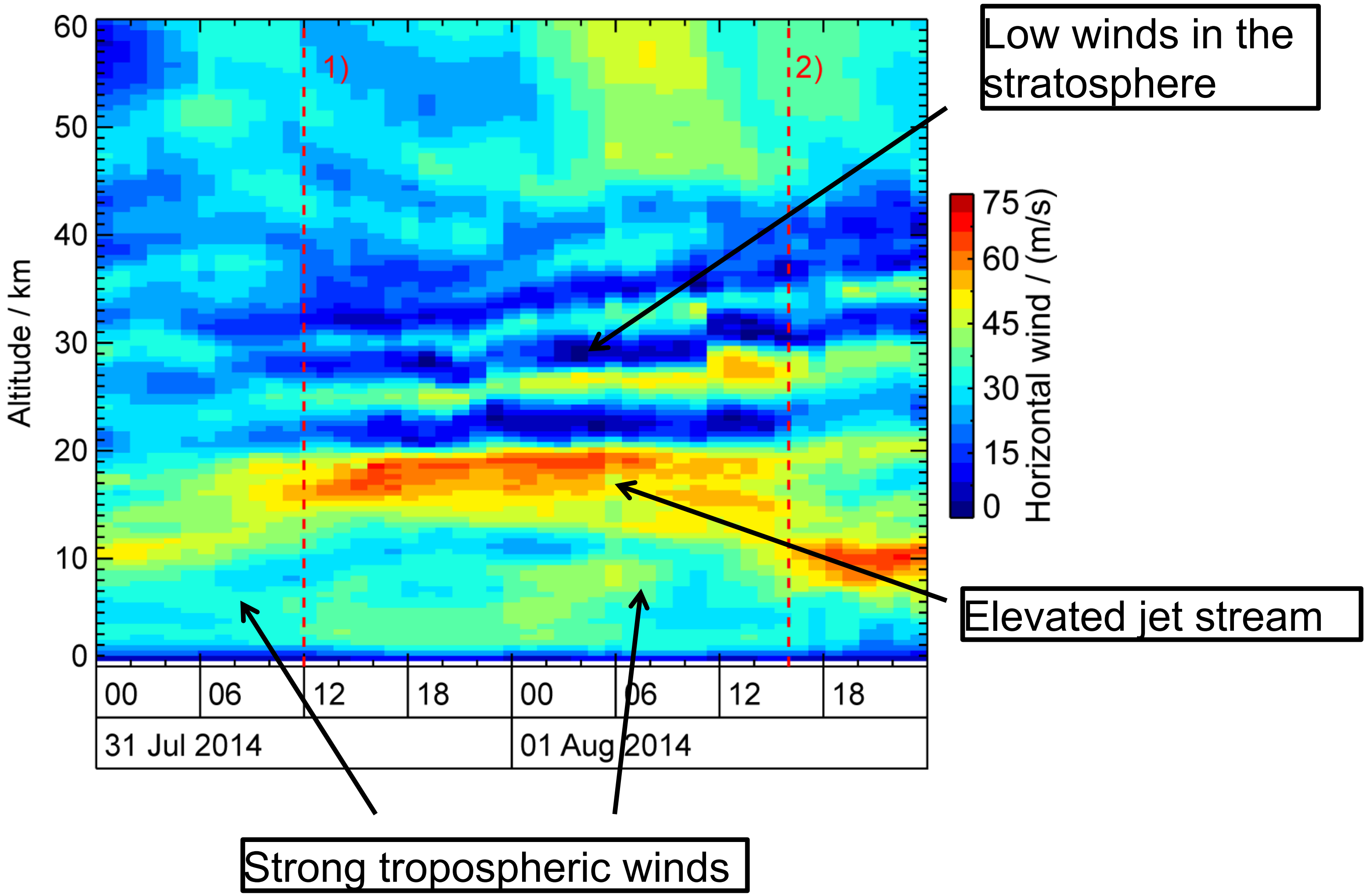
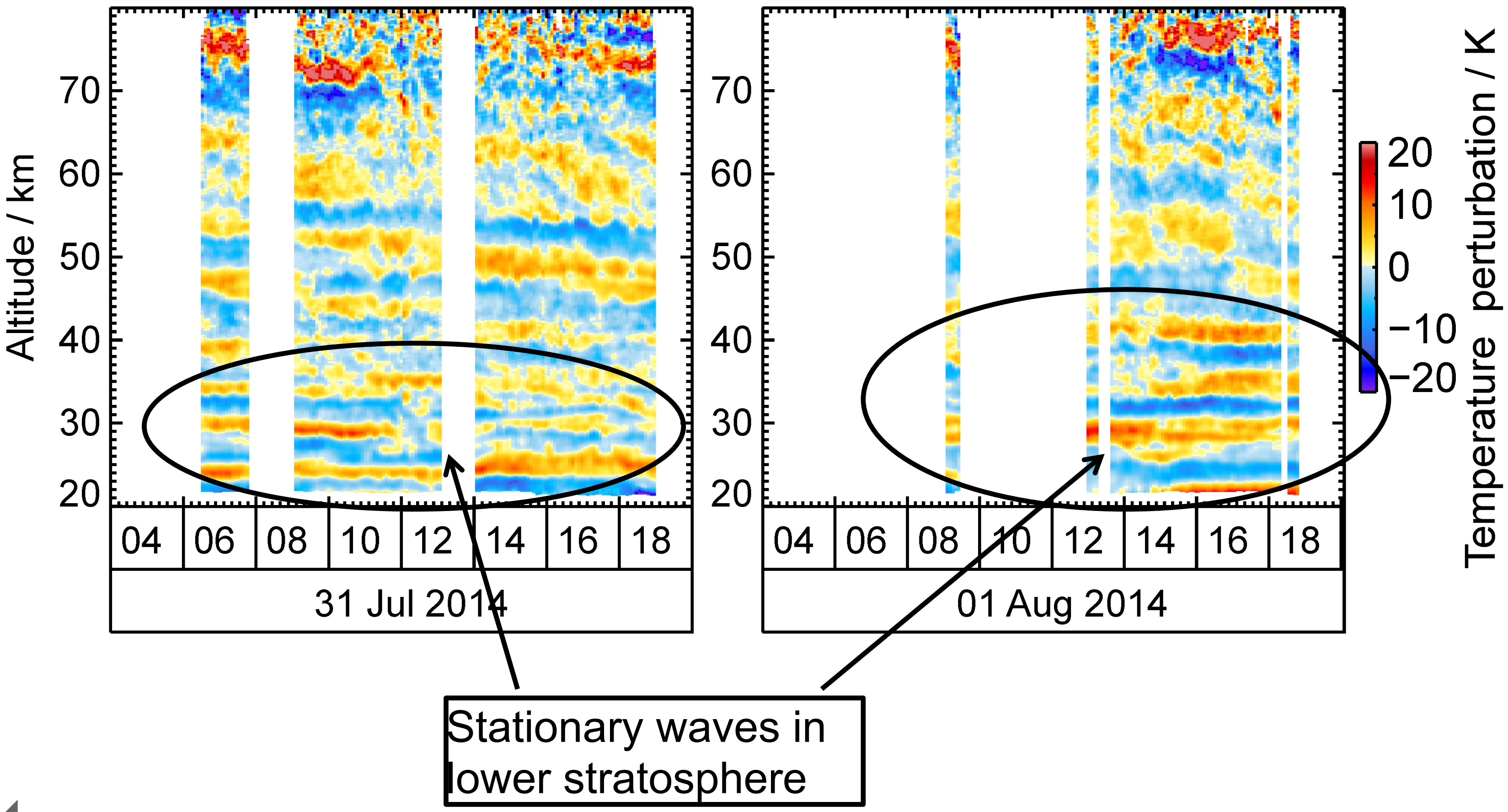
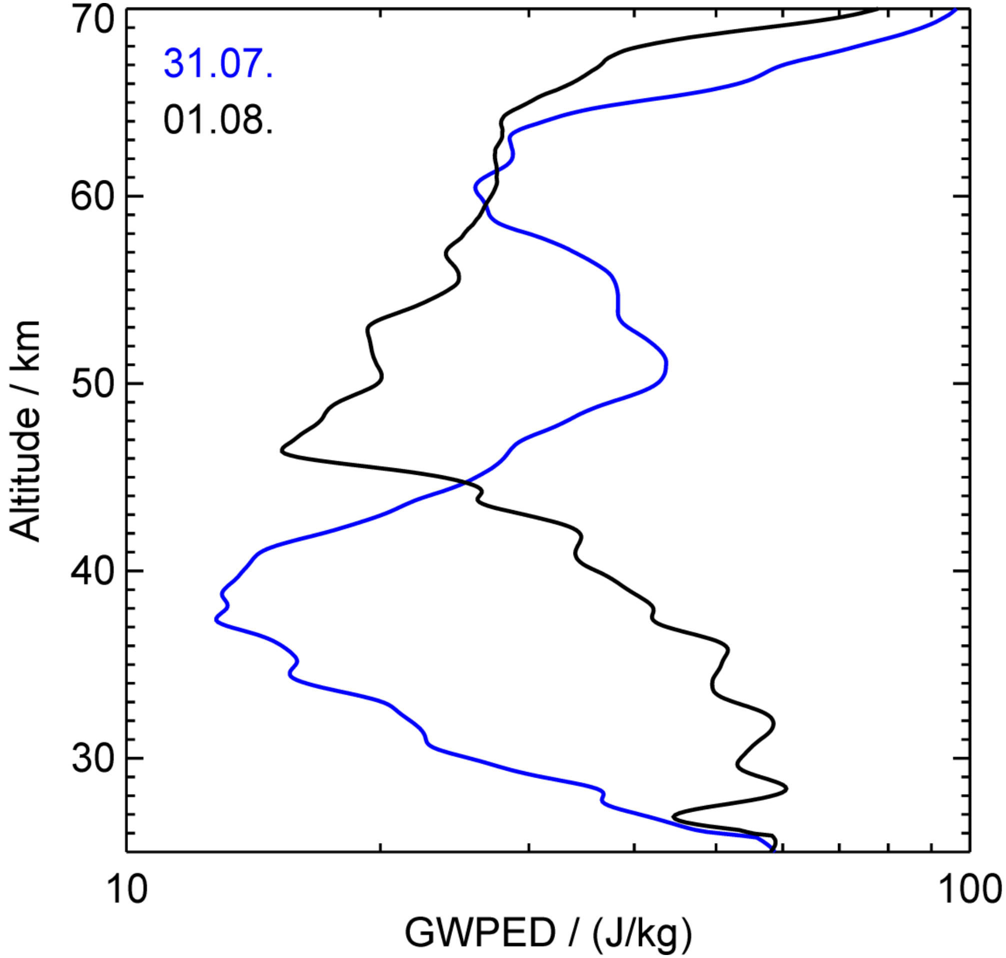
Horizontal wind speed above Lauder from ECMWF



Lidar measurements at Lauder around 1 August 2014



Gravity wave potential energy density (GWPED) from Lidar measurements at Lauder



$E_p = 1/2\; g^2 / N^2 \;\; (T' / T$

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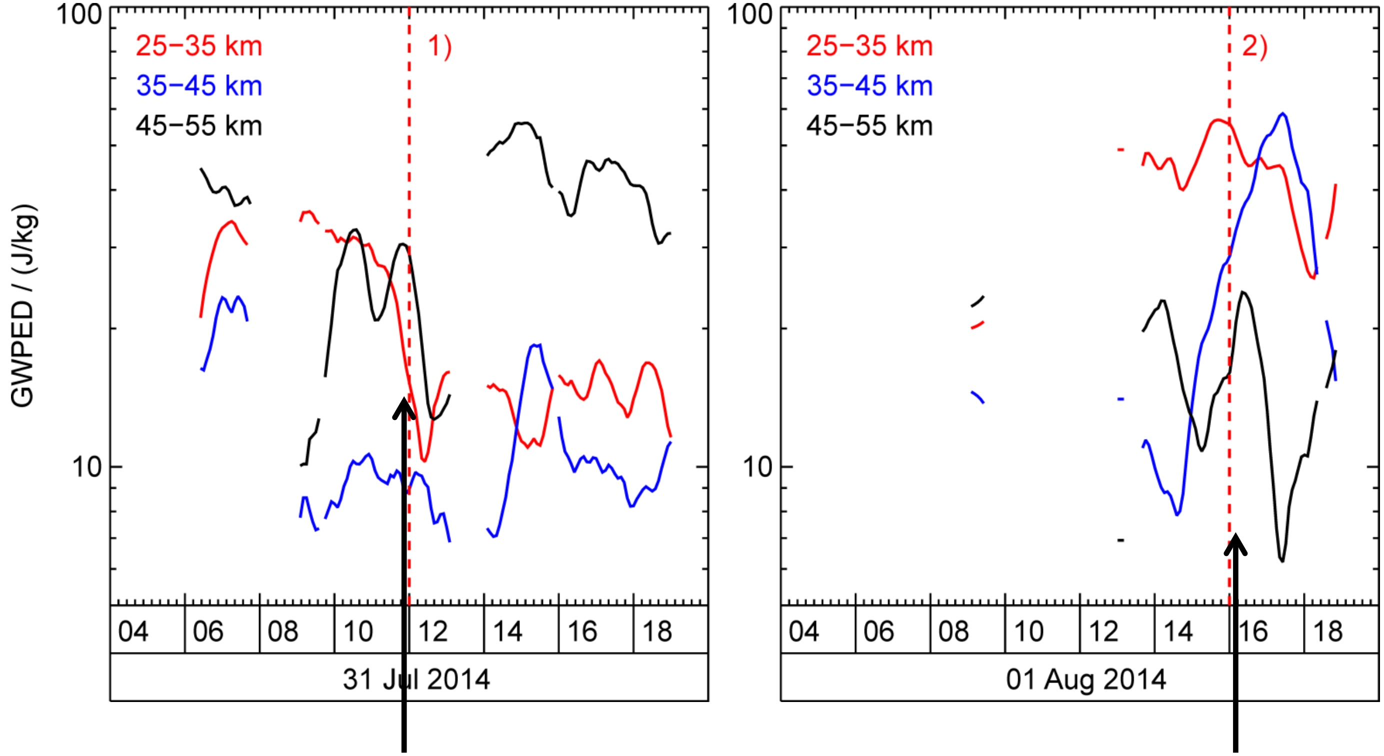
Gravity wave potential energy density (GWPED) from Lidar measurements at Lauder



1) Reduction of GWPED @ 25-35 km
35-45 km stays low

2) Increase of GWPED @ 35-45 km
25-35 km stays high

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Convective instability

- convective instabilitiy limit:

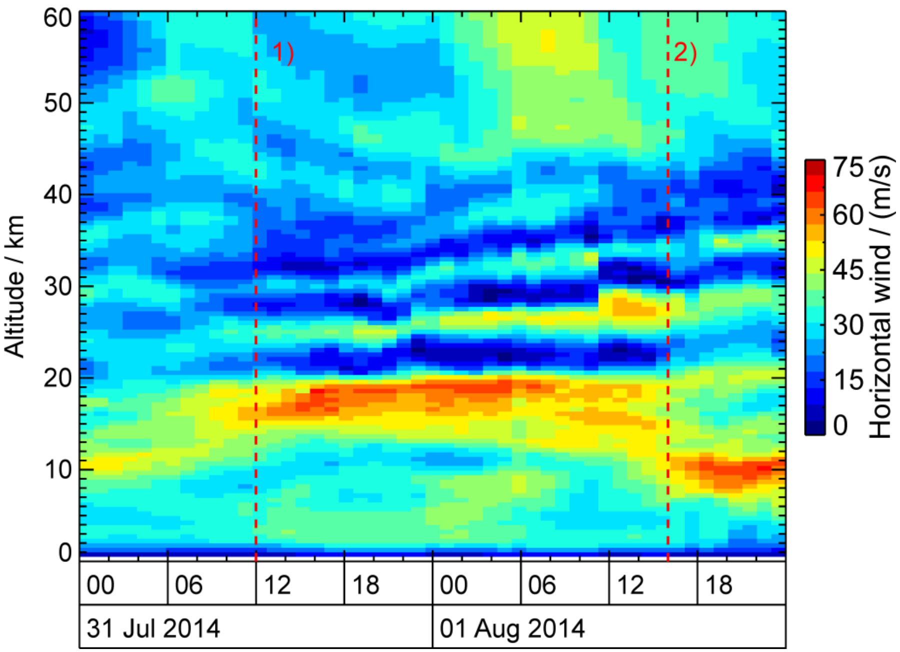
$$a = u' / c - u \geq 1$$

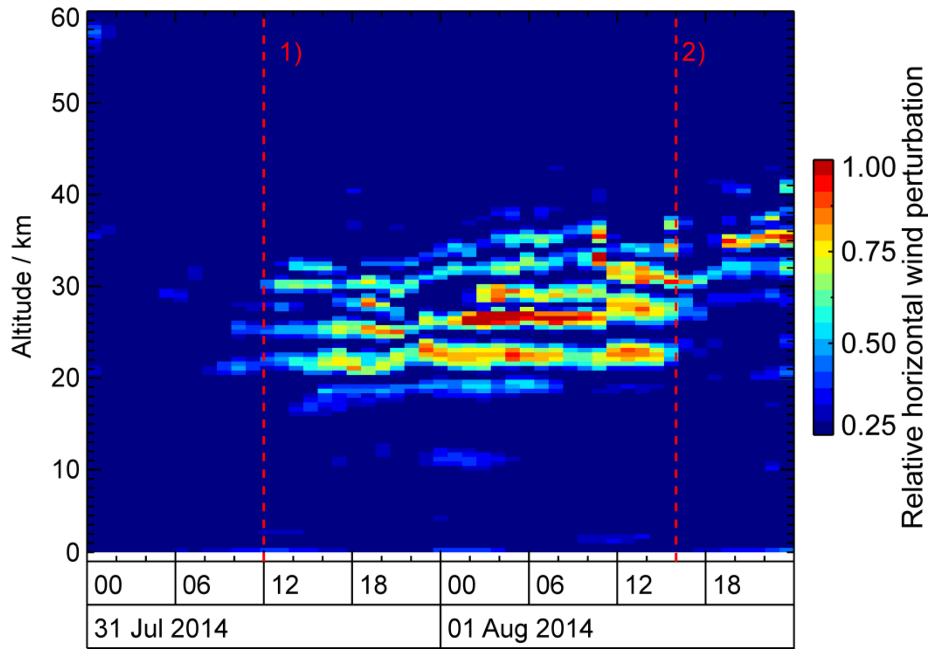
(Fritts and Alexander, 2003 (Eq. 58))

- Mountain waves: c=0

➔ only the relative horizontal wind propagation remains

Horizontal wind speed above Lauder from ECMWF





$|u' / u|$

u

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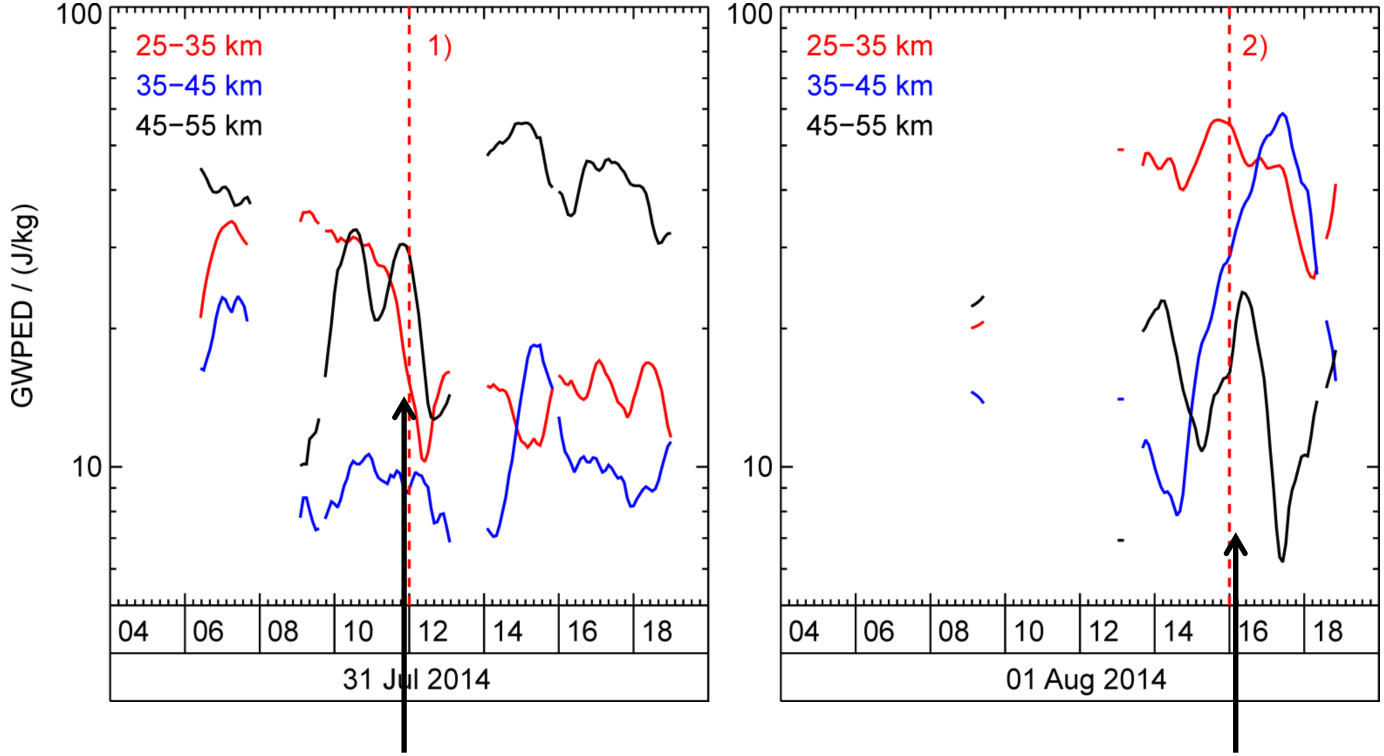
Gravity wave potential energy density (GWPED) from Lidar measurements at Lauder



1) Reduction of GWPED @ 25-35 km
35-45 km stays low

2) Increase of GWPED @ 35-45 km
25-35 stays high

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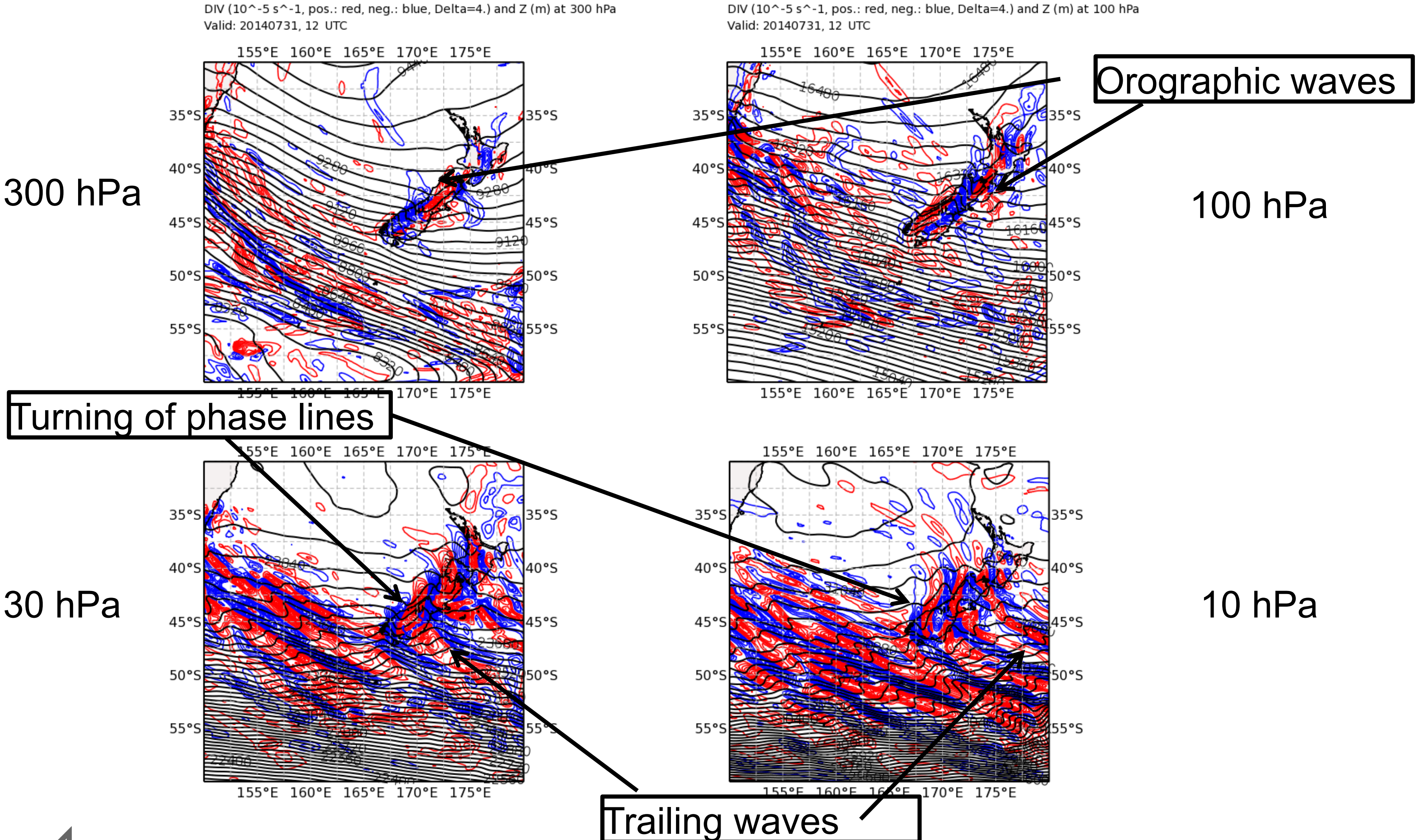
Hor. divergence and geopotential height on 31 July 2014



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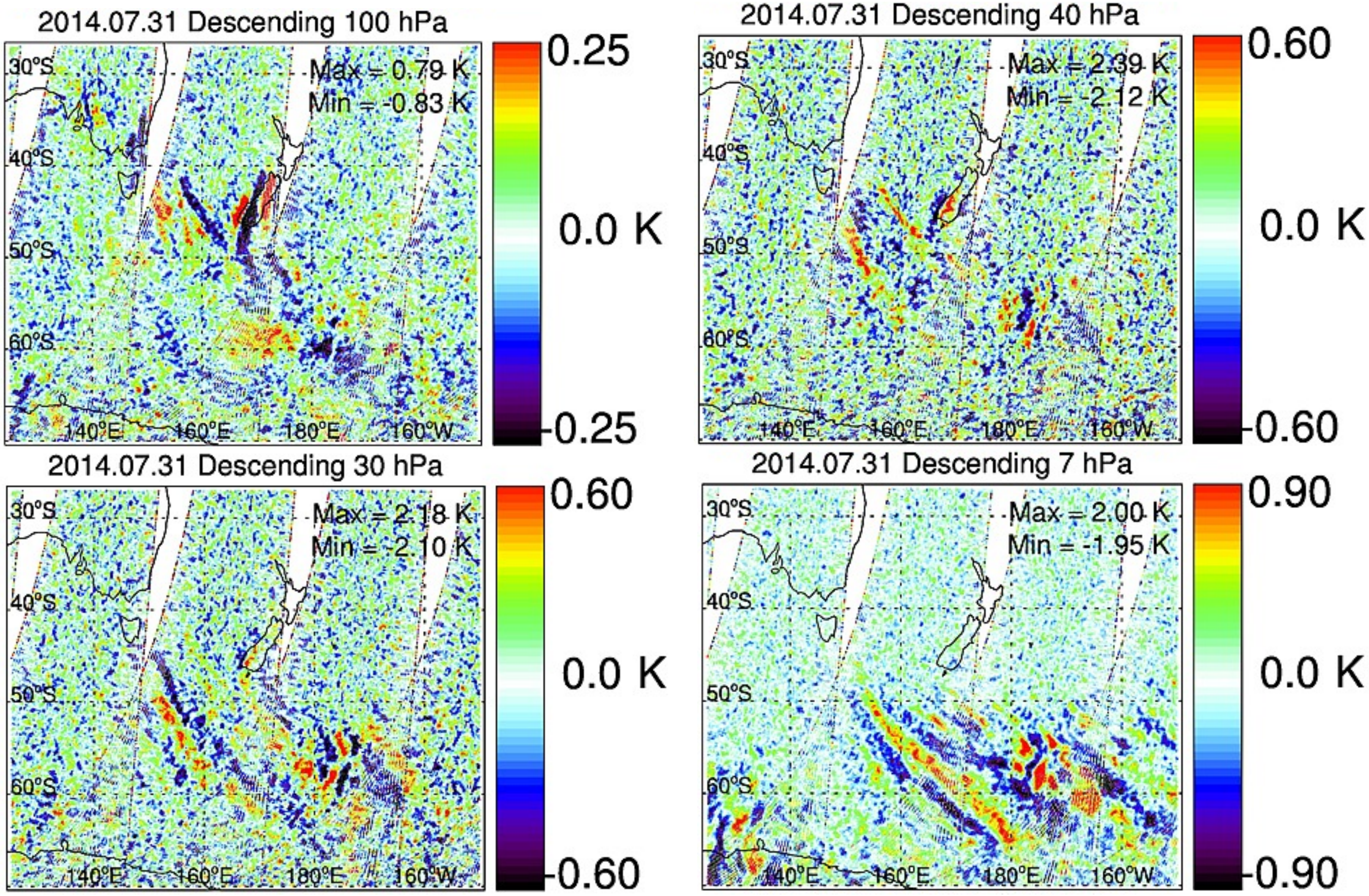
AIRS on 31 July (courtesy of S. Eckermann)



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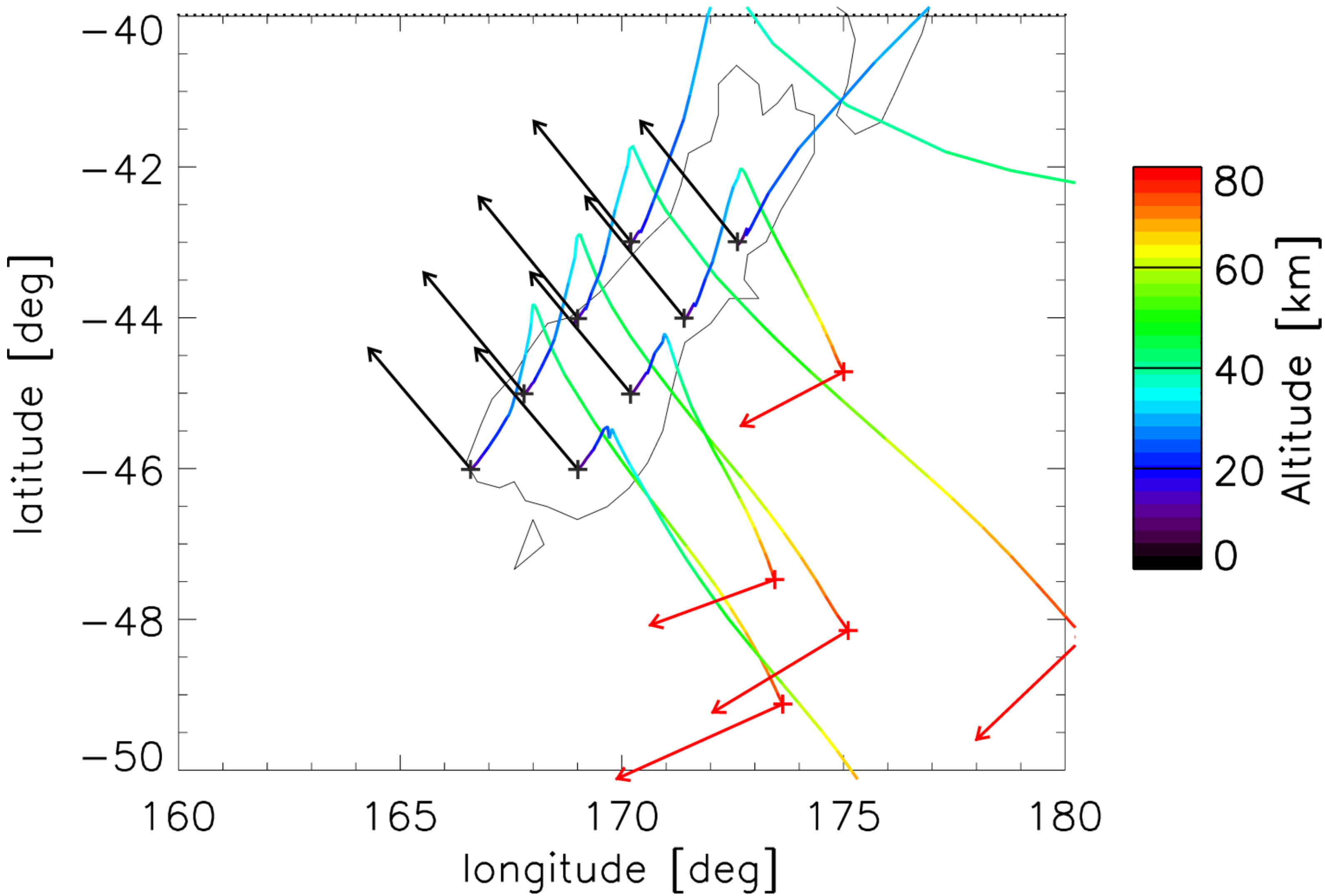
GROGRAT Raytraces on 1 August 2014



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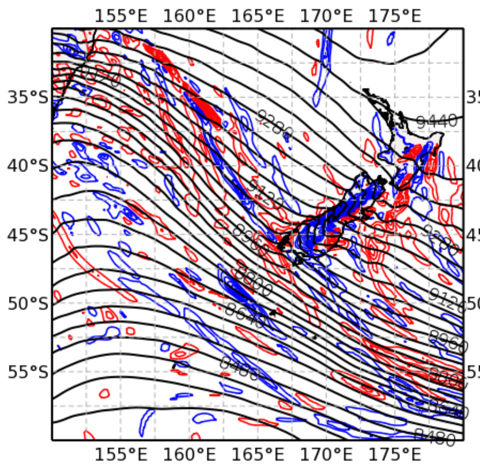
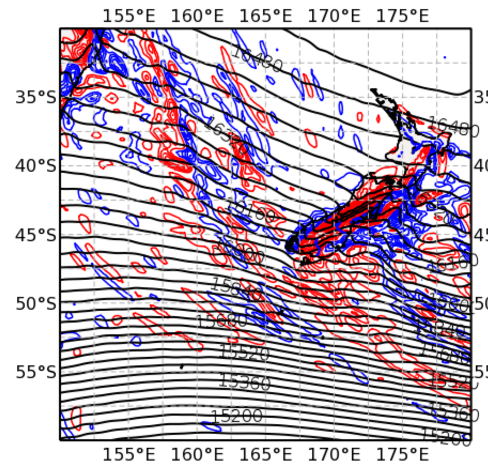
1 August 2014

300 hPa

DIV (10^-5 s^-1, pos.: red, neg.: blue, Delta=4.) and Z (m) at 300 hPa
Valid: 20140801, 12 UTC

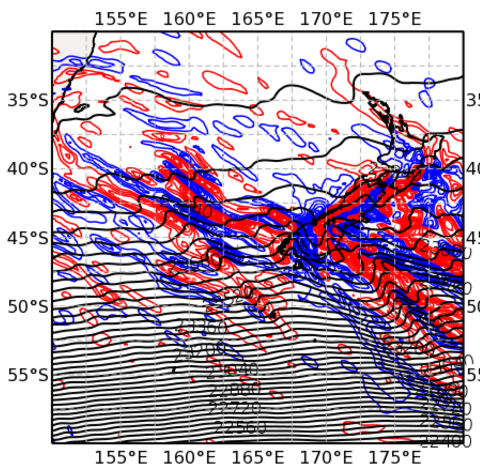


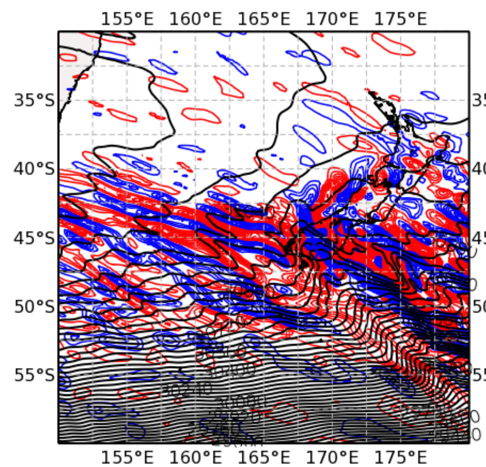
DIV (10^-5 s^-1, pos.: red, neg.: blue, Delta=4.) and Z (m) at 100 hPa
Valid: 20140801, 12 UTC



100 hPa

30 hPa





10 hPa

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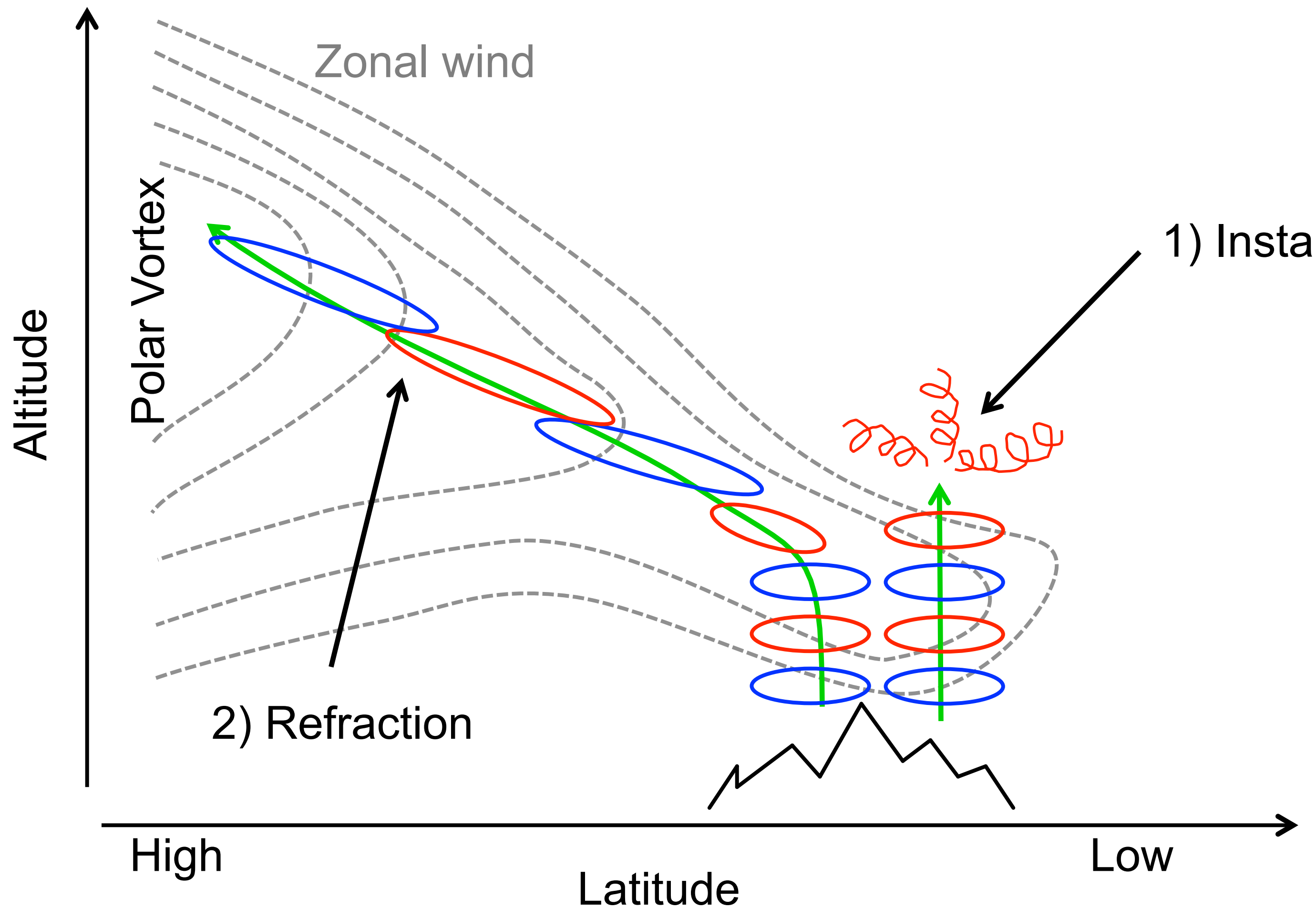
Propagational pathways on 31 July – 1 August 2014



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Conclusions

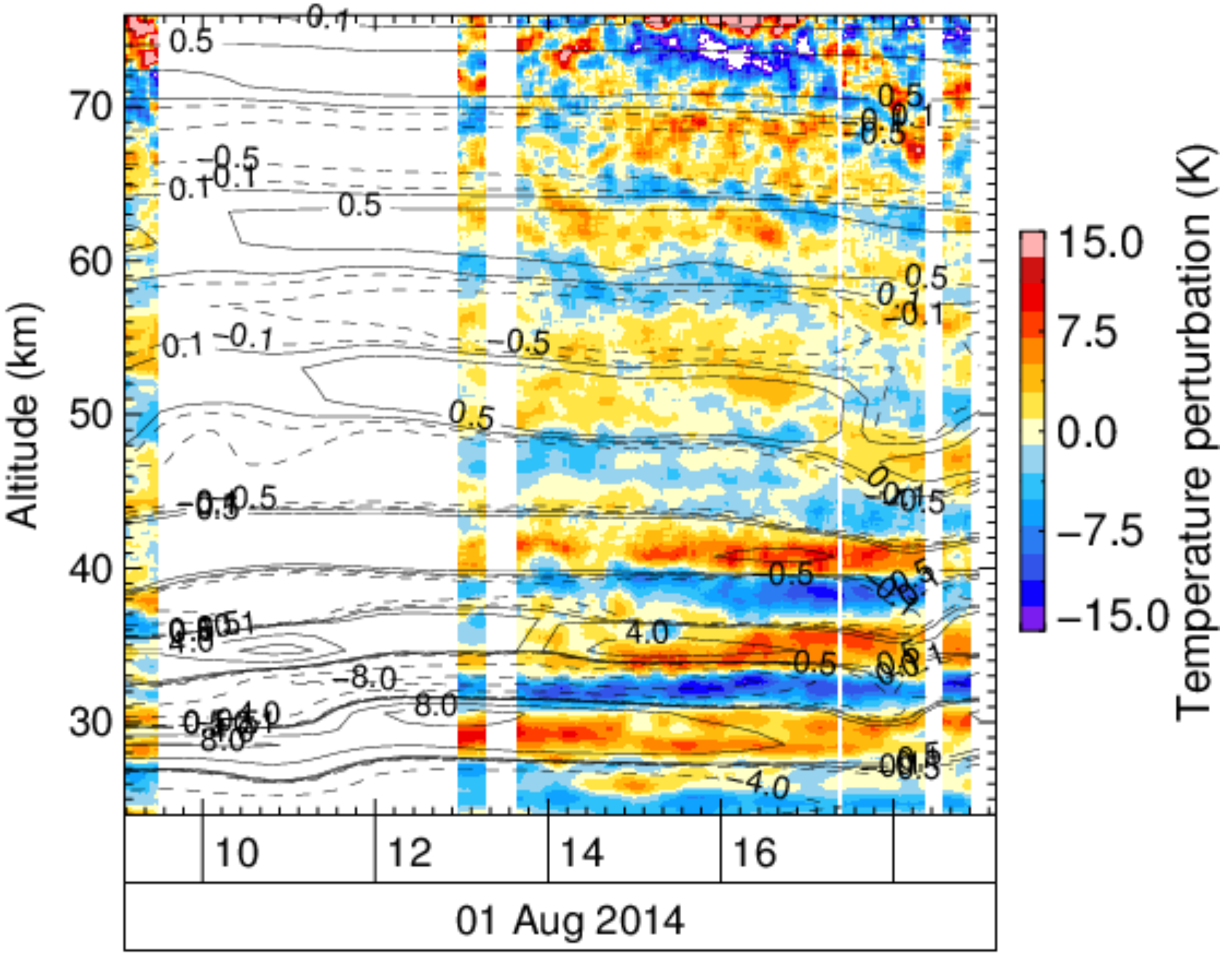
➔Strong influence of the polar vortex edge on the vertical propagation of mountain waves

Even at midlatitudes!

➔Horizontal propagation has to be considered if purely vertical measurements are analyzed

➔Raises questions:
Did we really observe all „deep propagating cases“ during Deepwave?
Or was our volume of observations still too small?

Agreement ECMWF and Lidar



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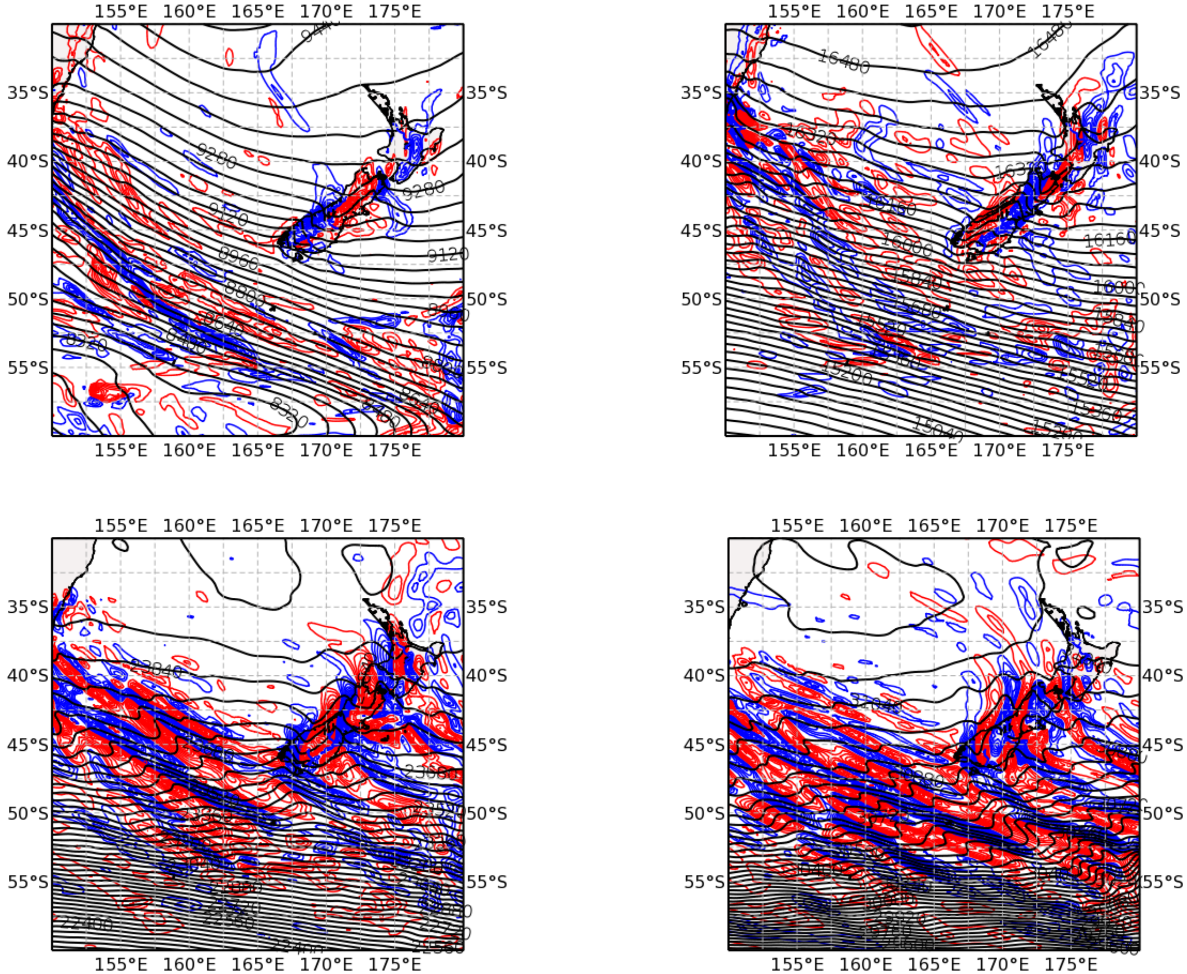
31 July 2014

DIV (10^-5 s^-1, pos.: red, neg.: blue, Delta=4.) and Z (m) at 300 hPa
Valid: 20140731, 12 UTC

DIV (10^-5 s^-1, pos.: red, neg.: blue, Delta=4.) and Z (m) at 100 hPa
Valid: 20140731, 12 UTC

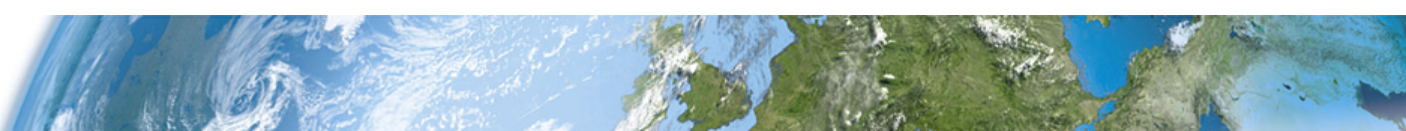
300 hPa

100 hPa



30 hPa

10 hPa



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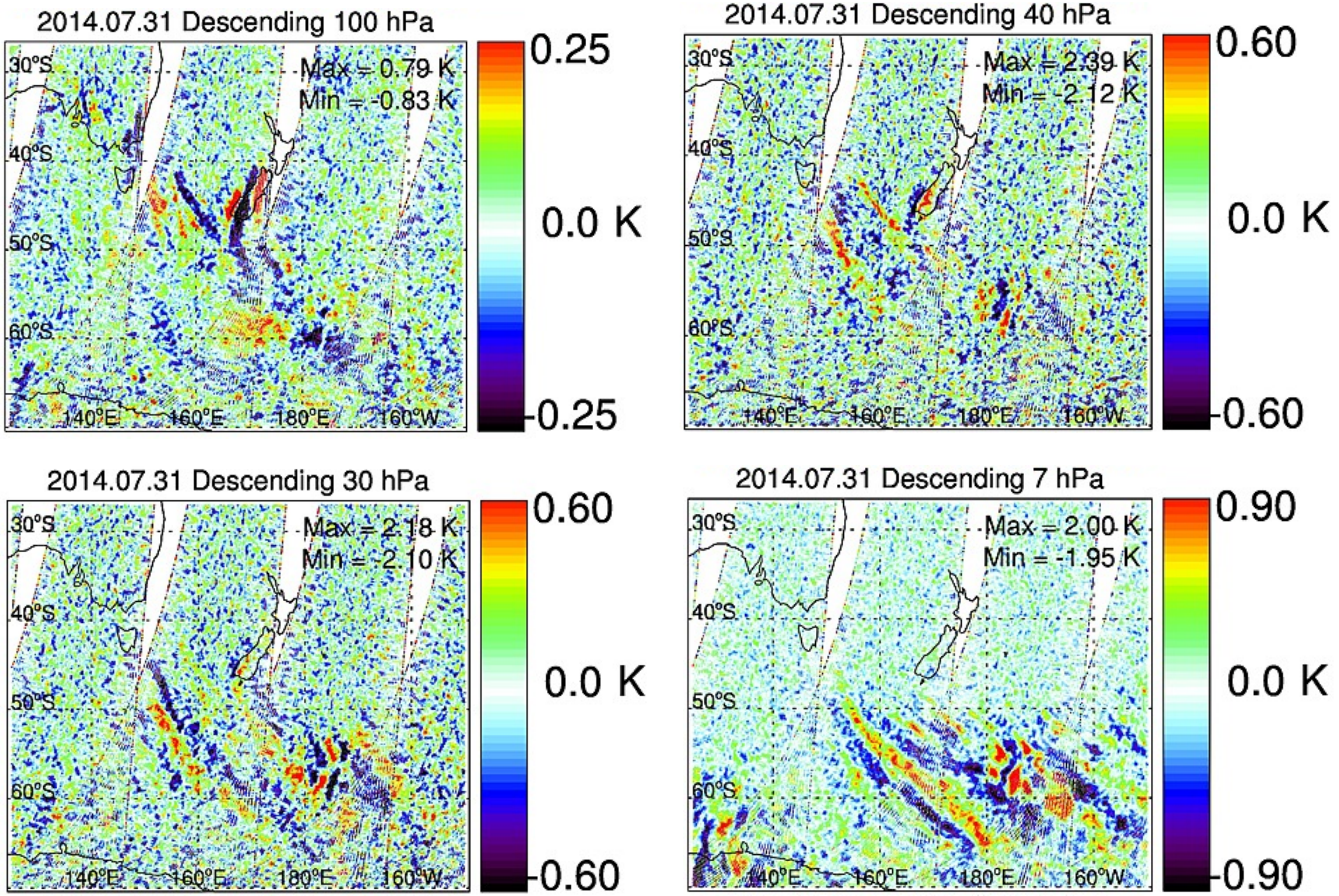
AIRS on 31 July



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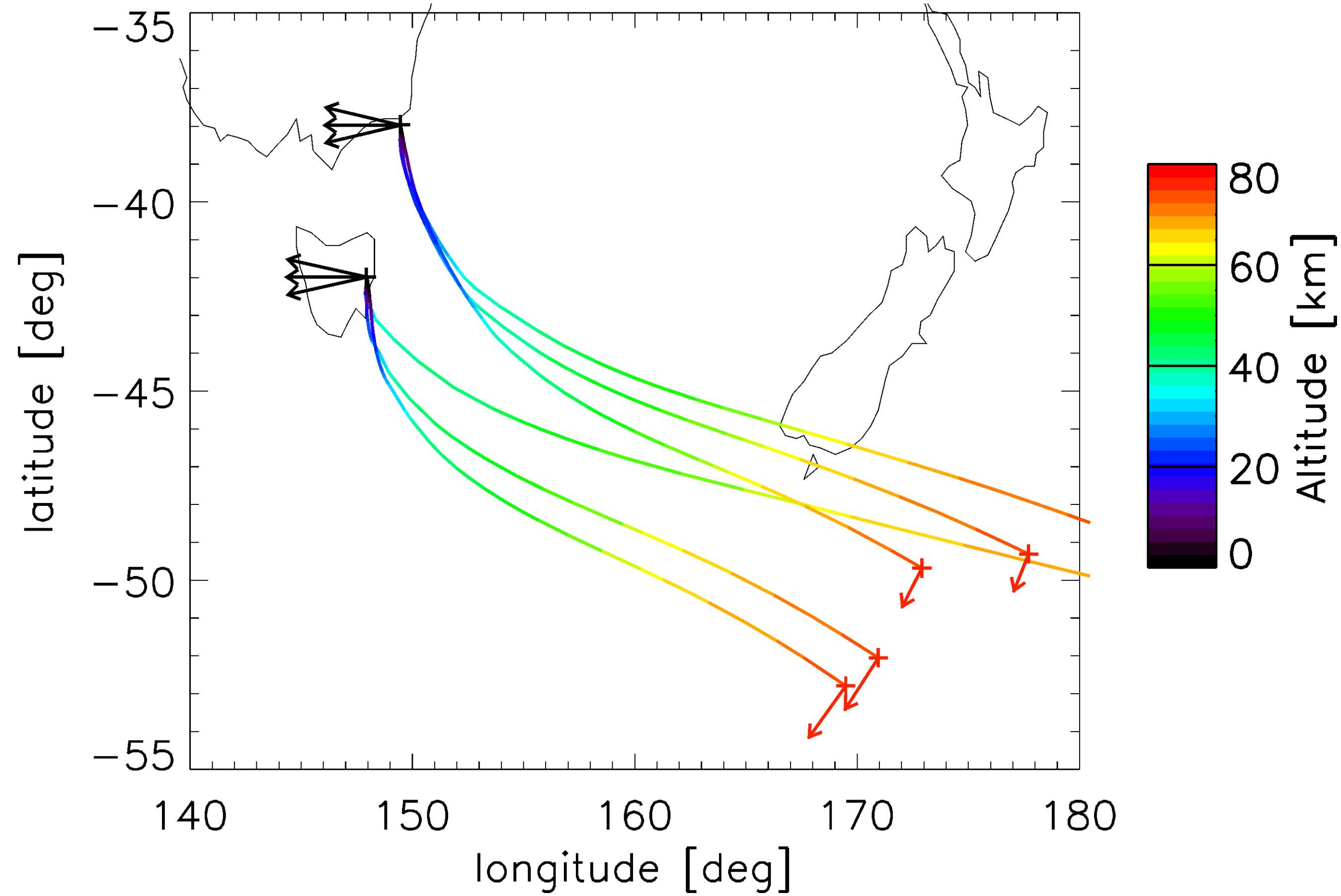
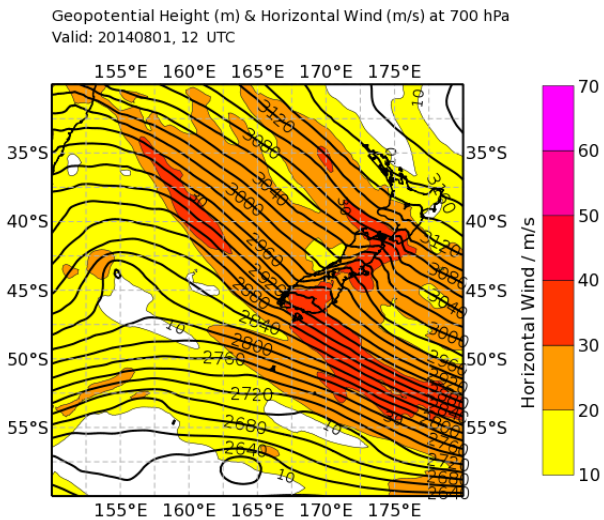
Additional waves from Tasmania/Australia on 31 July

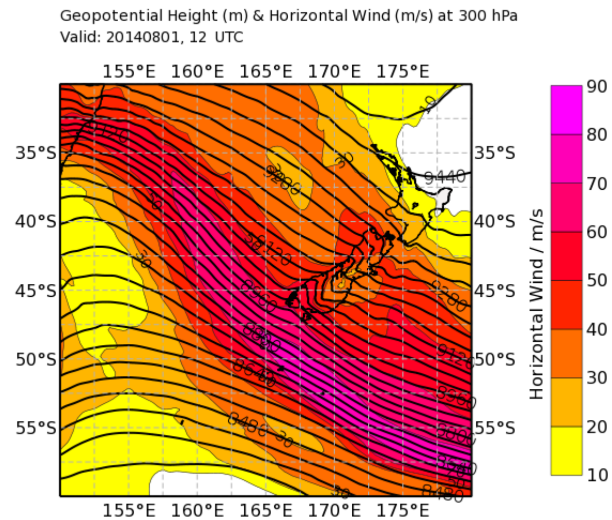


1 August 2014

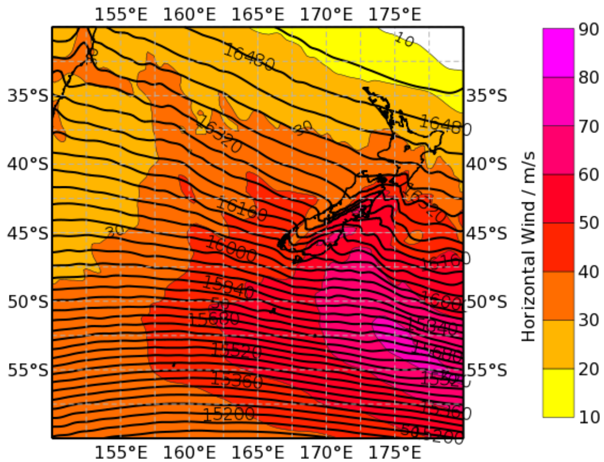
700 hPa



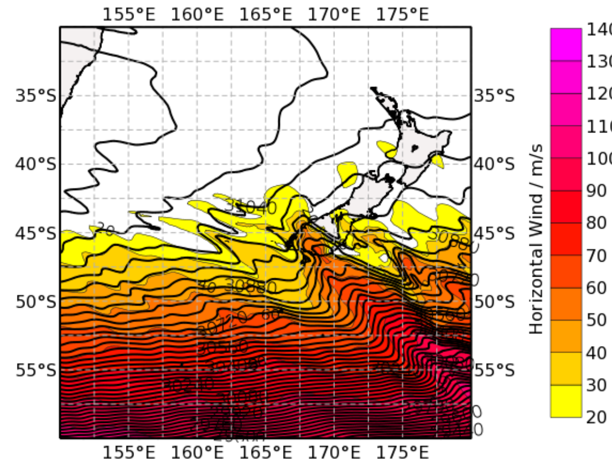
300 hPa



100 hPa



10 hPa



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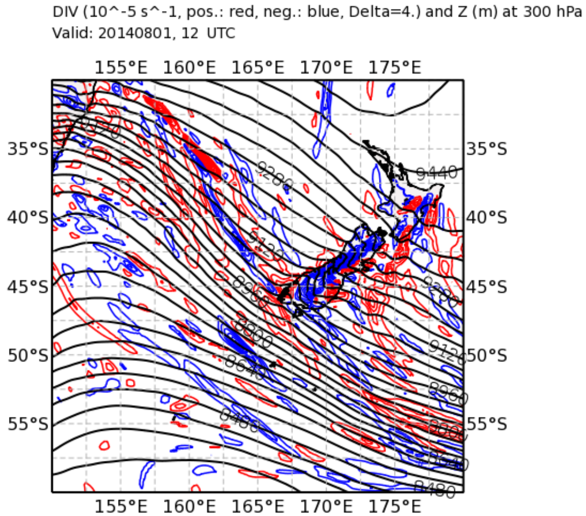
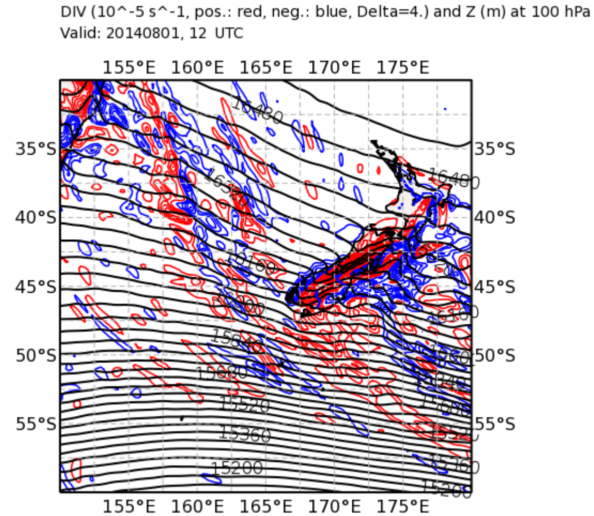
1 August 2014

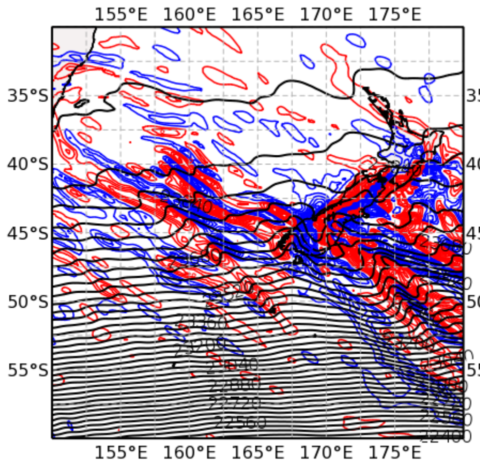
300 hPa



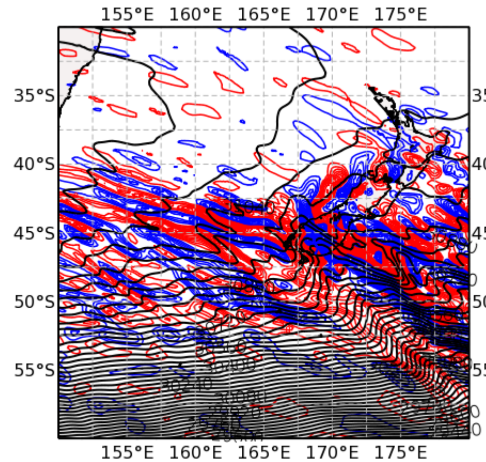
100 hPa



30 hPa



10 hPa



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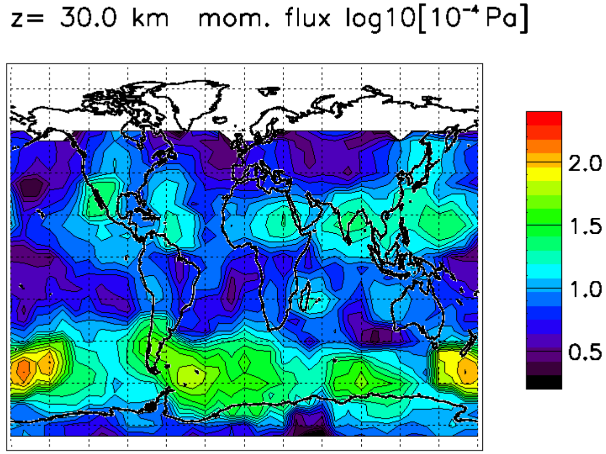
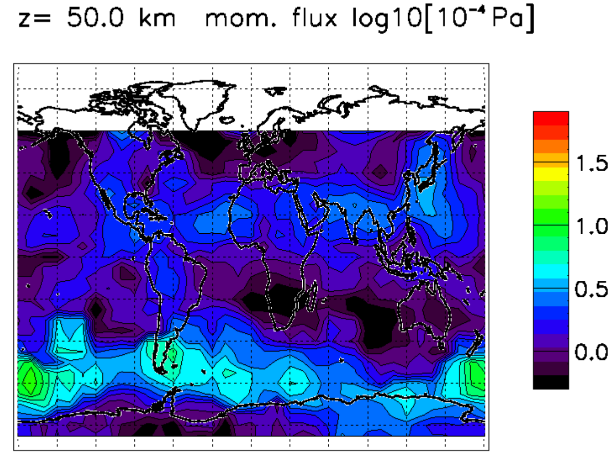
Saber GW Momentum flux (courtesy of M. Ern)

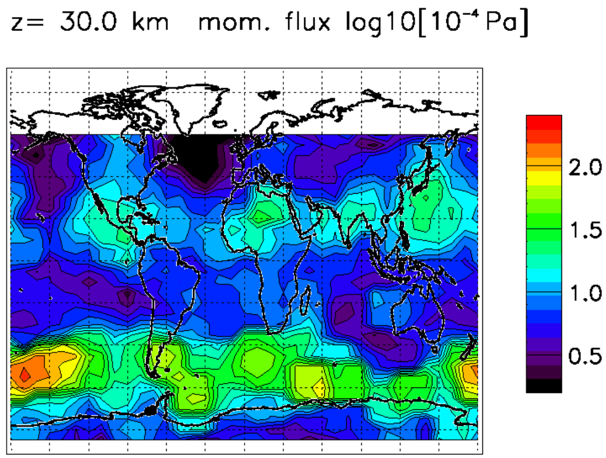
30 km | **50 km**

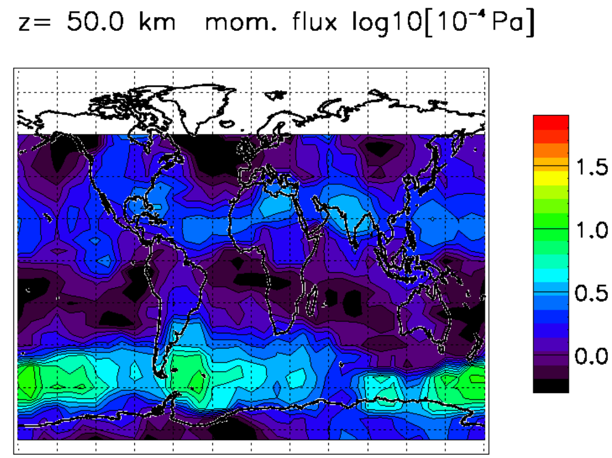
30 Jul - 1 Aug 2014





01-03 Aug 2014





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