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Studying Gravity Waves using Mesoscale-Resolving Whole Atmosphere Community Climate Model

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NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

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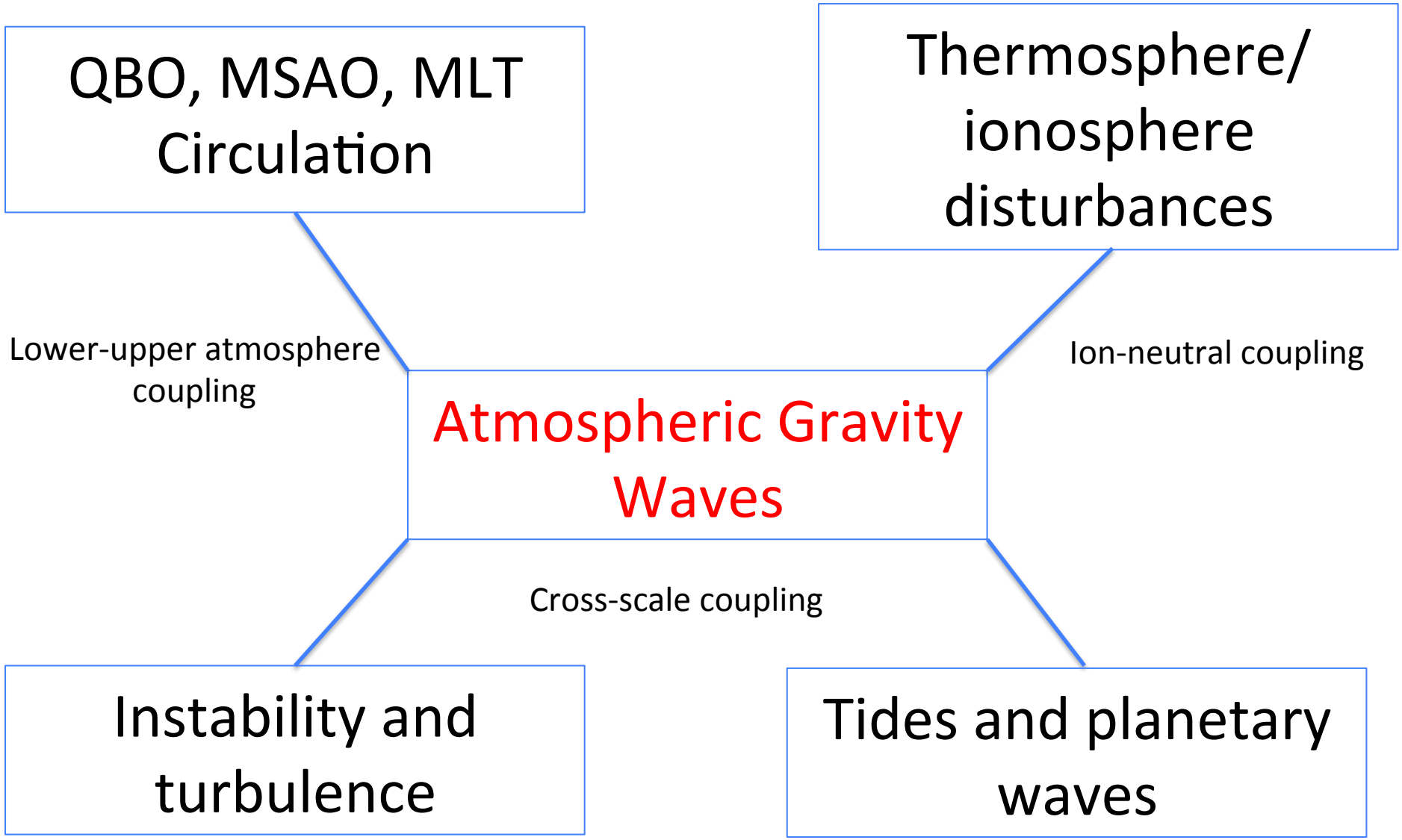
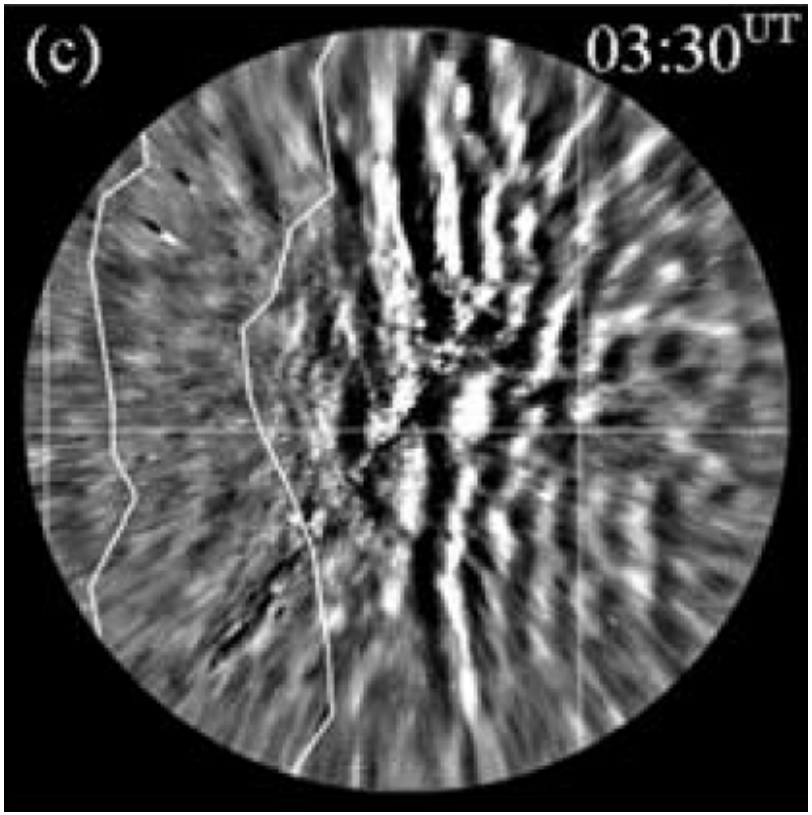
NSF

Motivations: A Central Theme for CEDAR Research

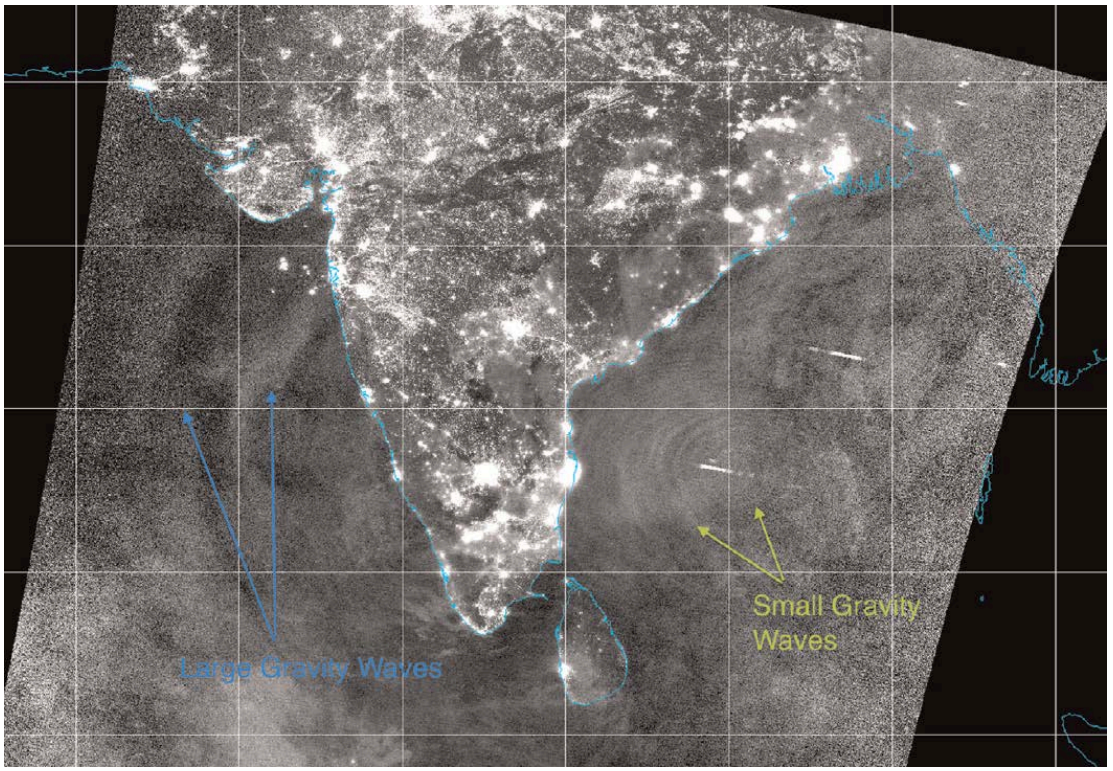


Challenge: From wave sources to their impacts in a global context.

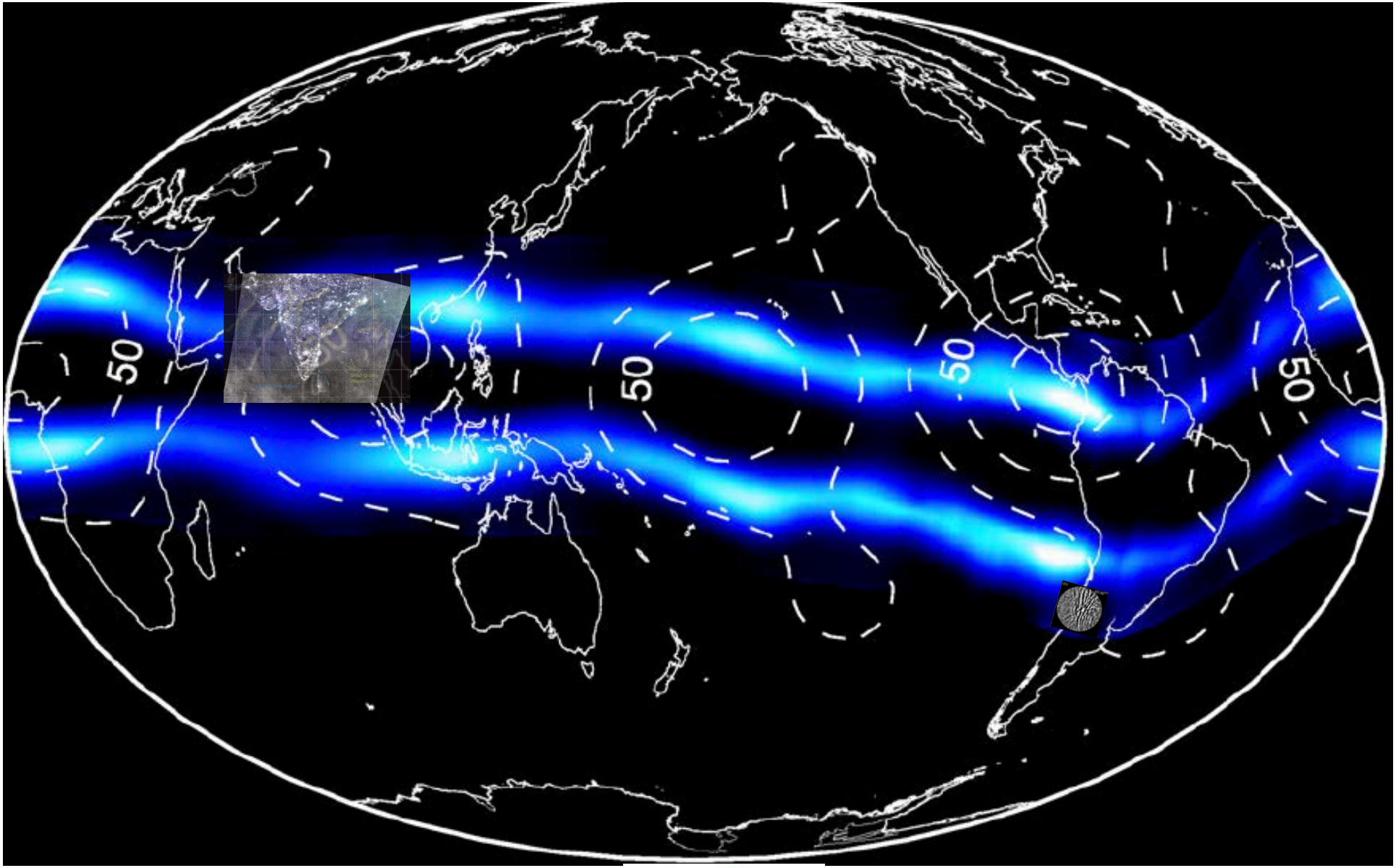
MLT Gravity Wave Observations



Smith et al., 2009



Yue et al, 2014

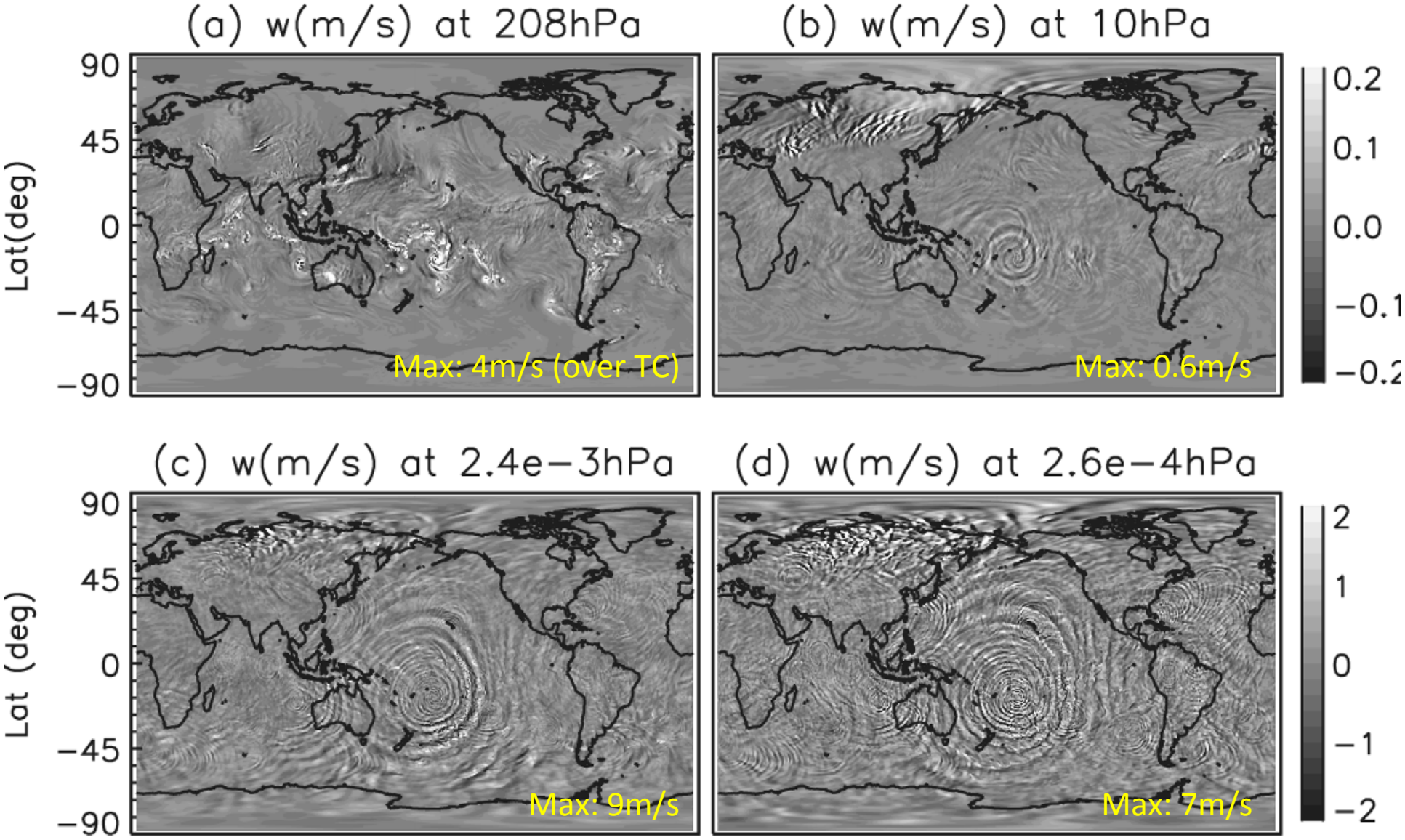


Immel et al., 2006

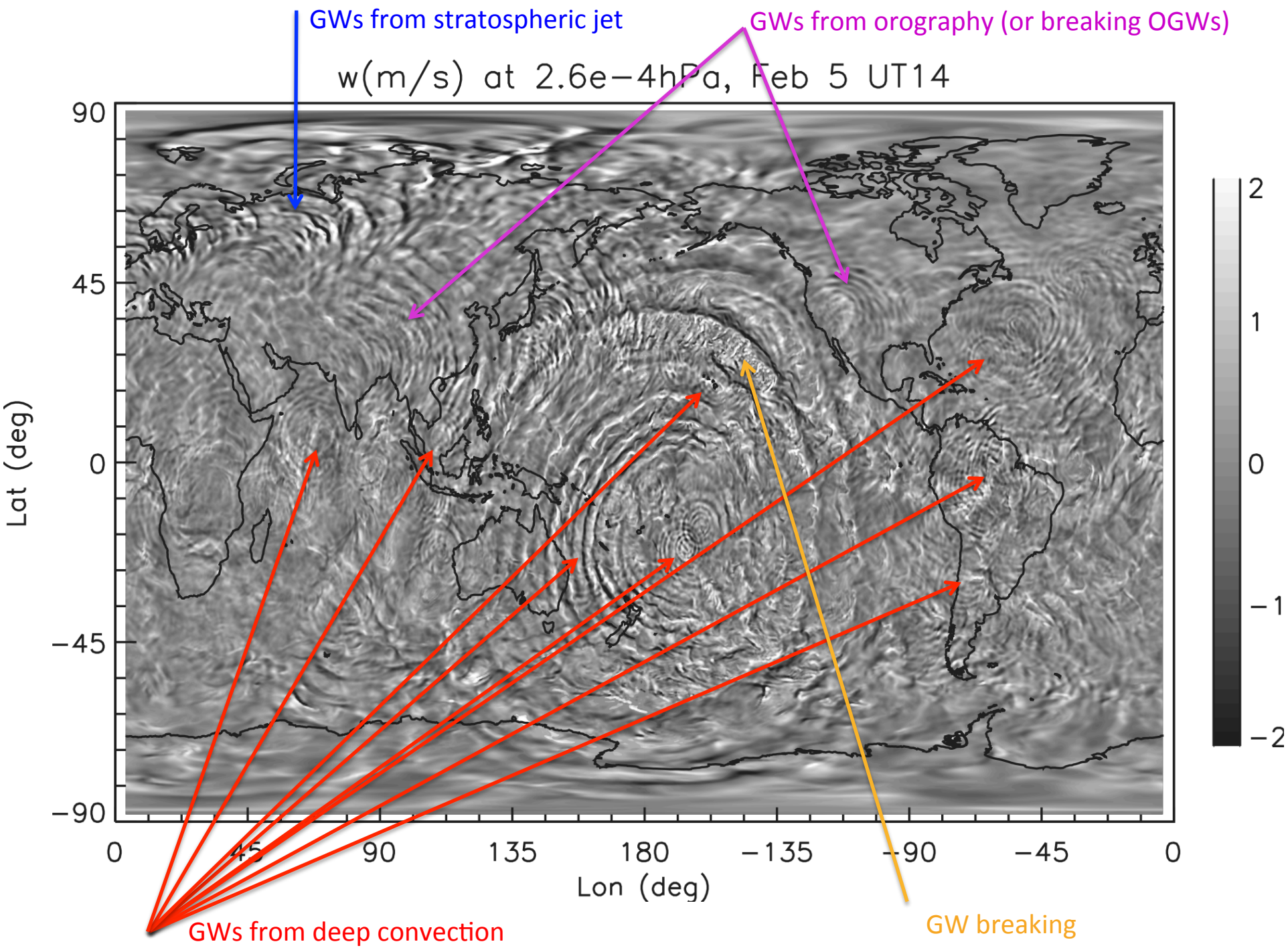
Resolving Mesoscales Globally: WACCM

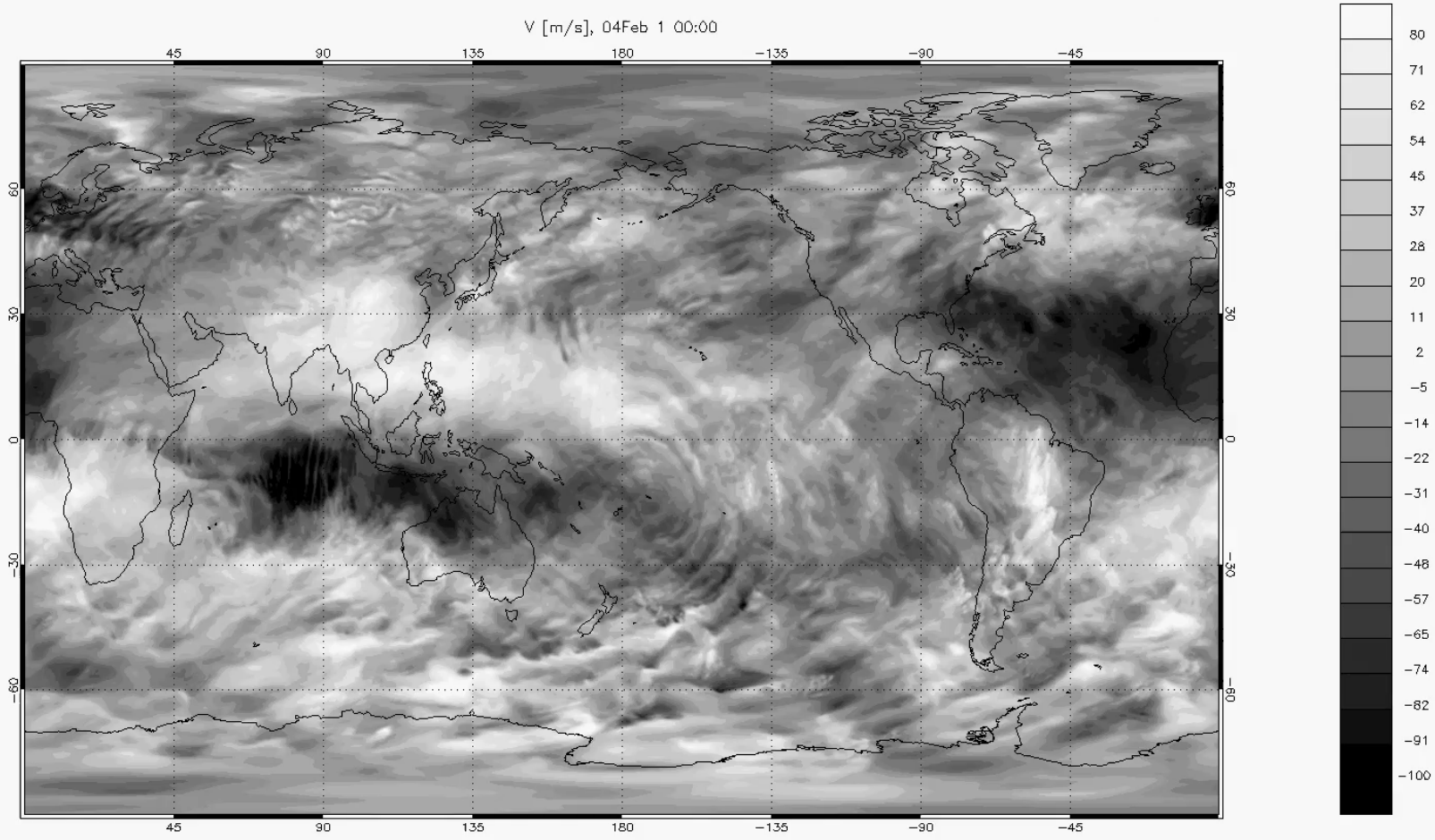
- NCAR Whole Atmosphere Community Climate Model (WACCM)
  - Continuous Galerkin spectral finite element dynamical core
  - Solved on cubed-sphere—no polar singularity.
  - Resolution: ~0.25^{o}(25km) horizontal; 0.1 scale height (500-700m) vertical (WACCM NE120NP4/L209).
  - Scalable up to 10000+ cores on NSF NWSC/Yellowstone.
- GW parameterization turned off: to evaluate resolved waves.
- Completed 1.5 model year simulation.

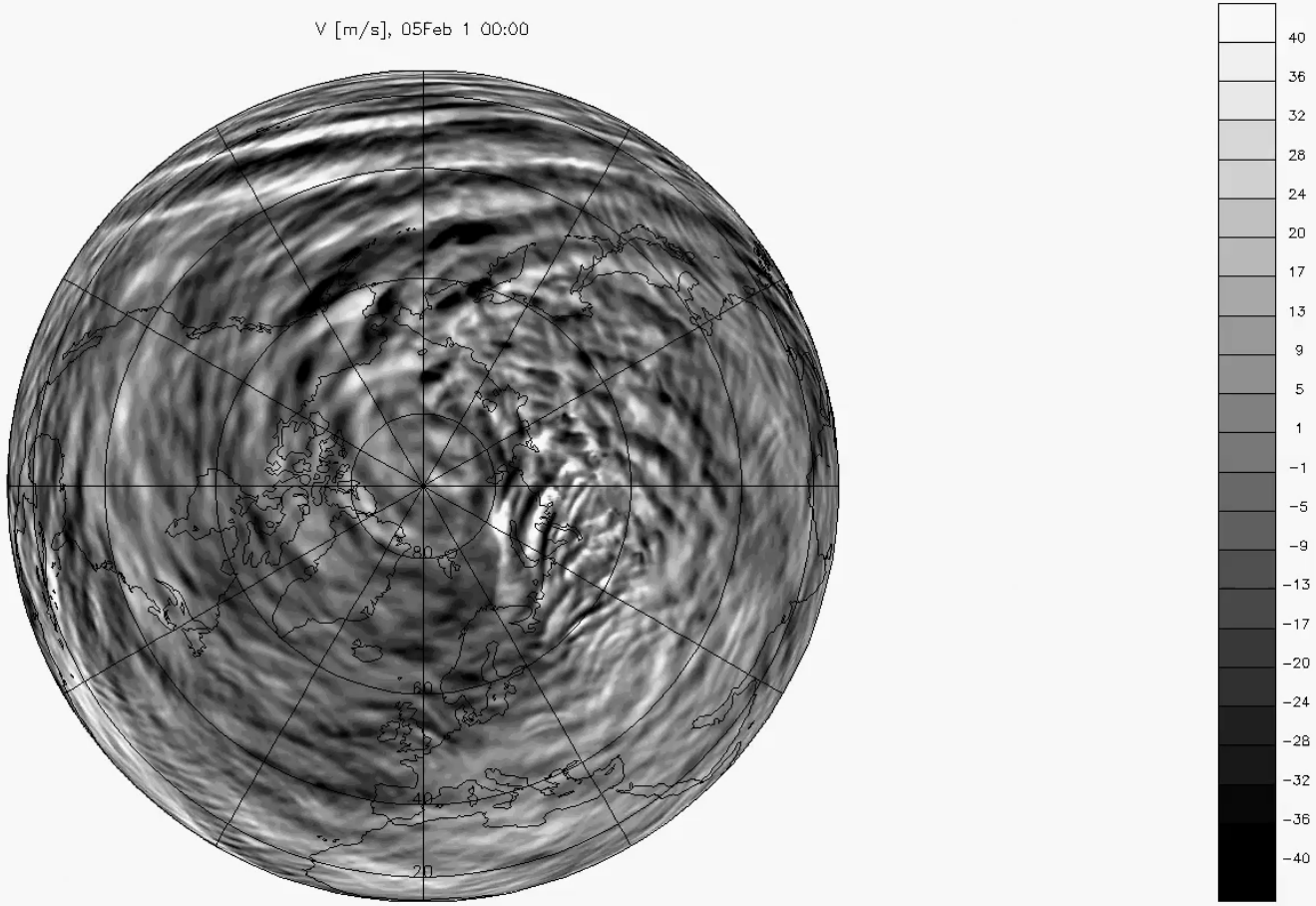
Vertical winds: tropopause to lower thermosphere



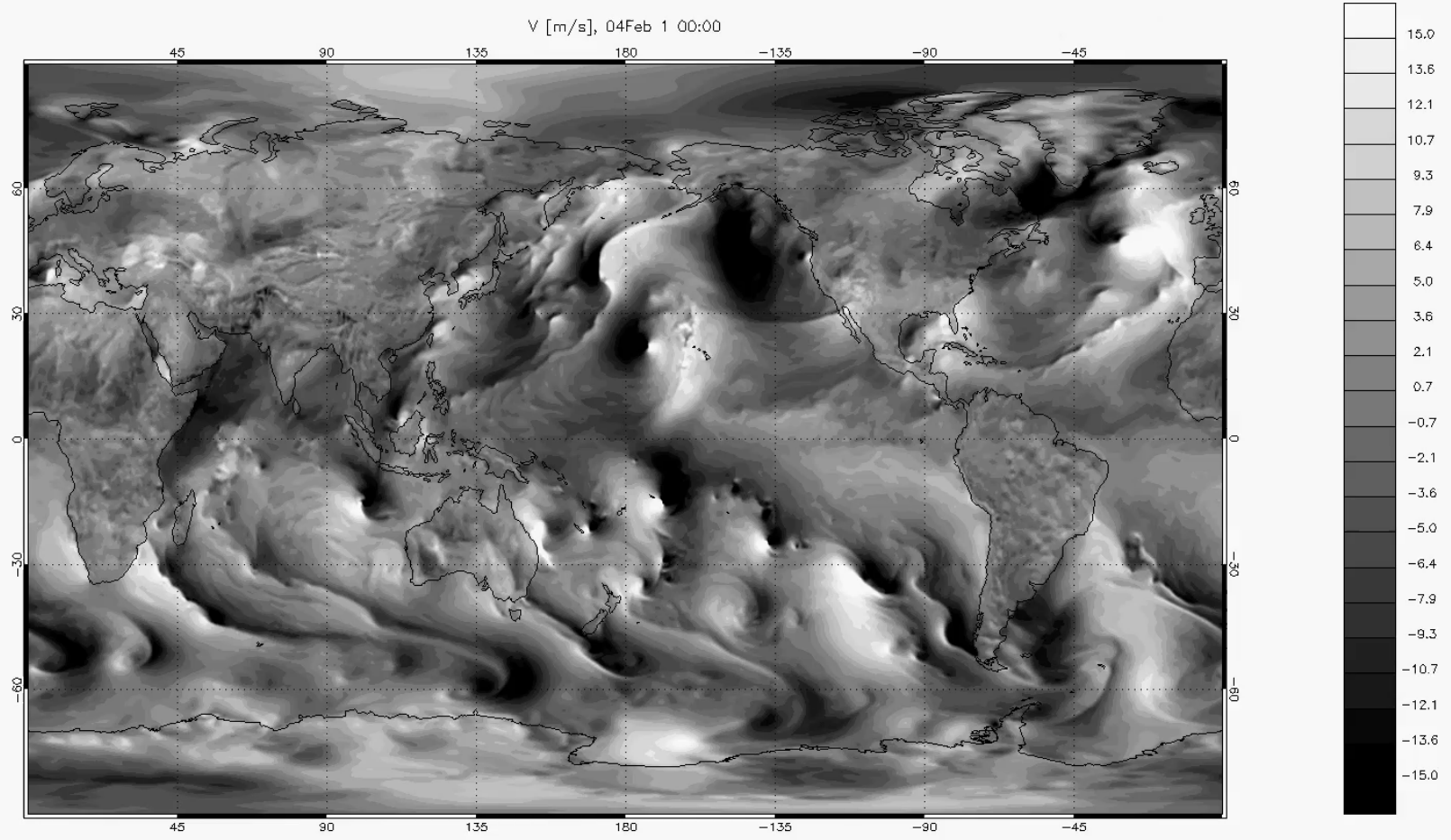
Liu et al., 2014


GWs from stratospheric jet
GWs from orography (or breaking OGWs)
w(m/s) at 2.6e−4hPa, Feb 5 UT14
90
45
0
−45
−90
Lat (deg)
0
45
90
135
180
−135
−90
−45
0
Lon (deg)
2
1
0
−1
−2
GWs from deep convection
GW breaking

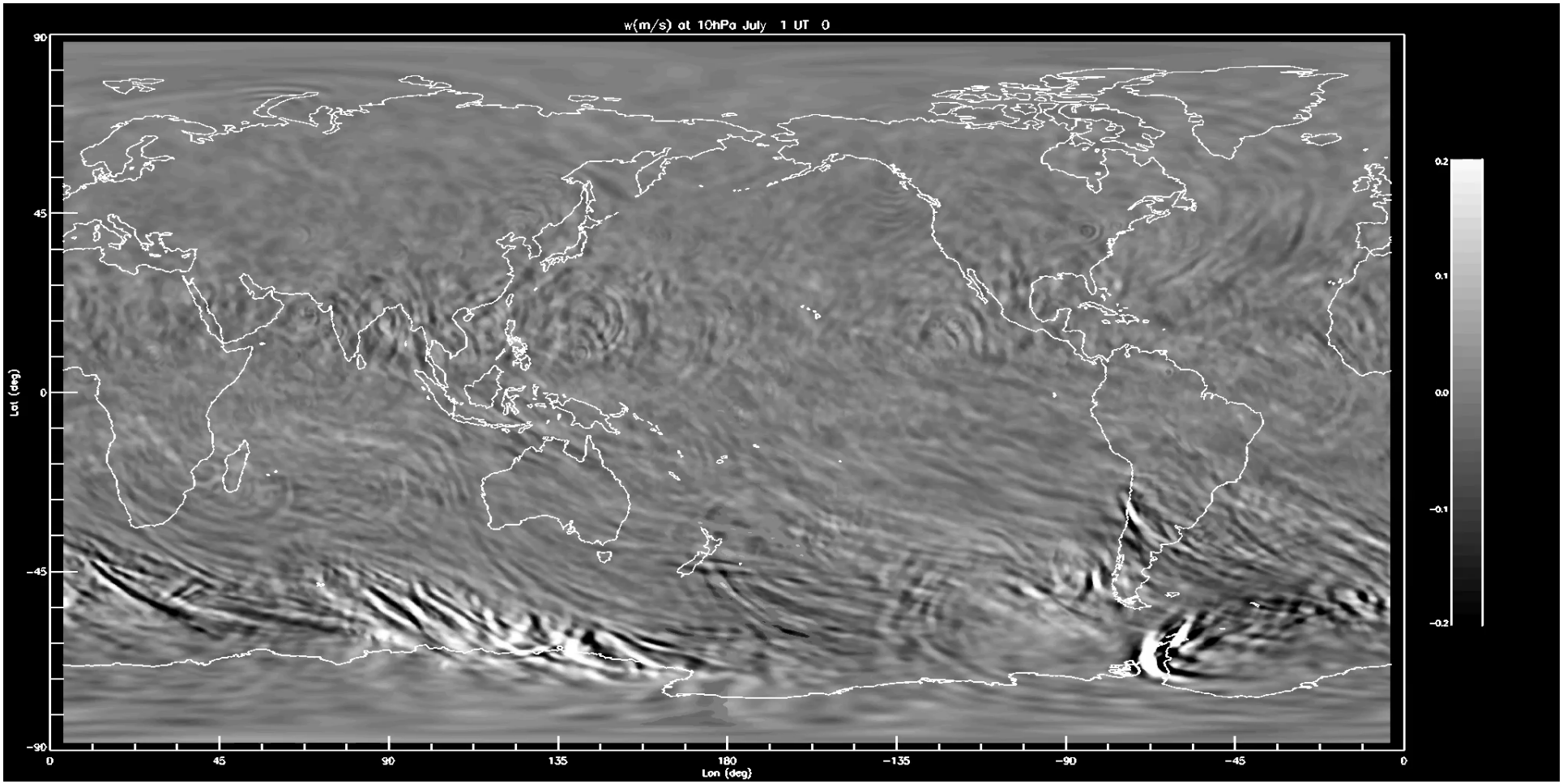

V [m/s], 04Feb 1 00:00
45
90
135
180
−135
−90
−45
60
30
0
−30
−60
80
71
62
54
45
37
28
20
11
2
−5
−14
−22
−31
−40
−48
−57
−65
−74
−82
−91
−100


V [m/s], 05Feb 1 00:00
80
60
40
20
40
36
32
28
24
20
17
13
9
5
1
-1
-5
-9
-13
-17
-20
-24
-28
-32
-36
-40

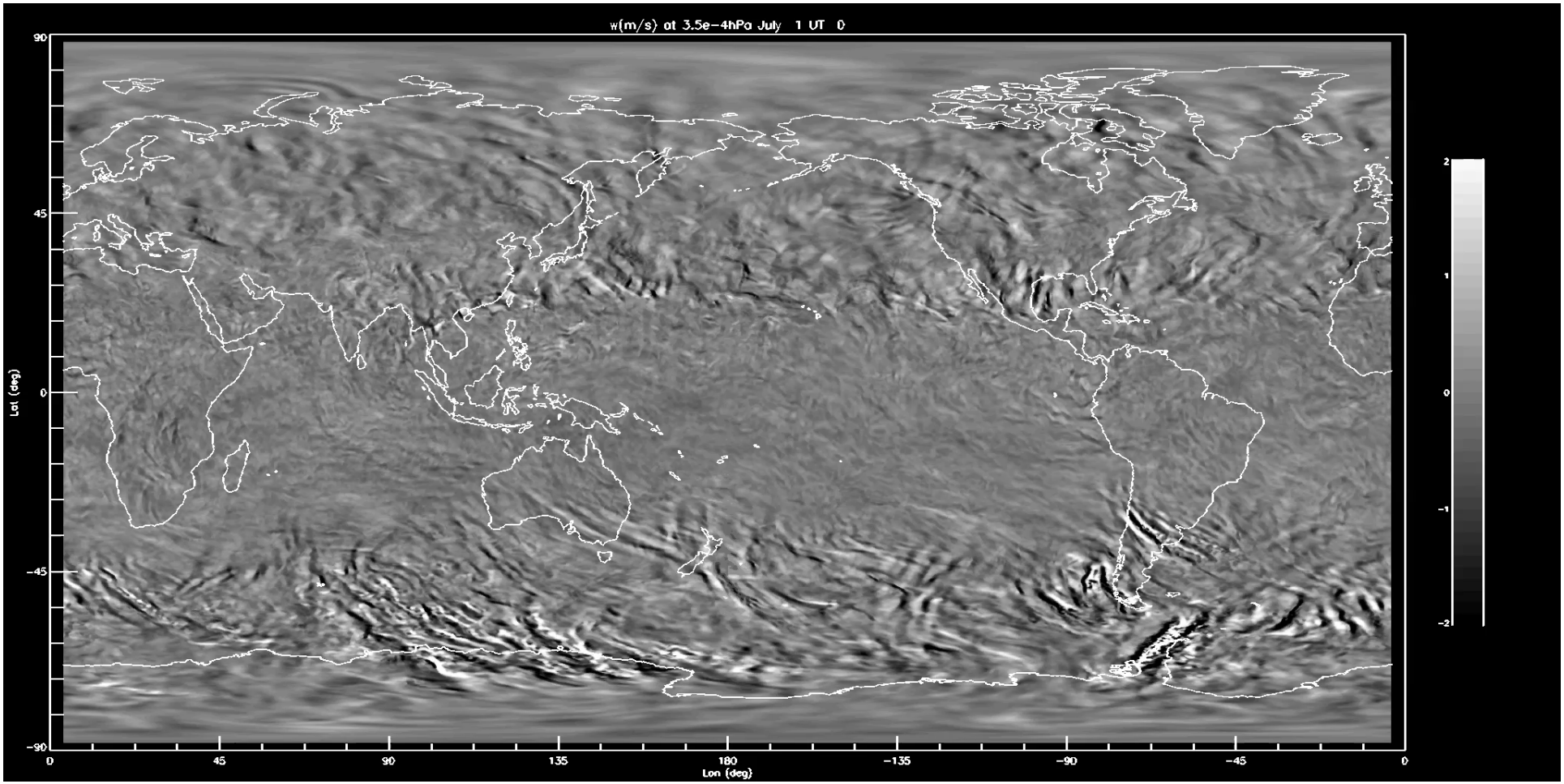
Altitude Dependence of Temporal/Spatial Scales

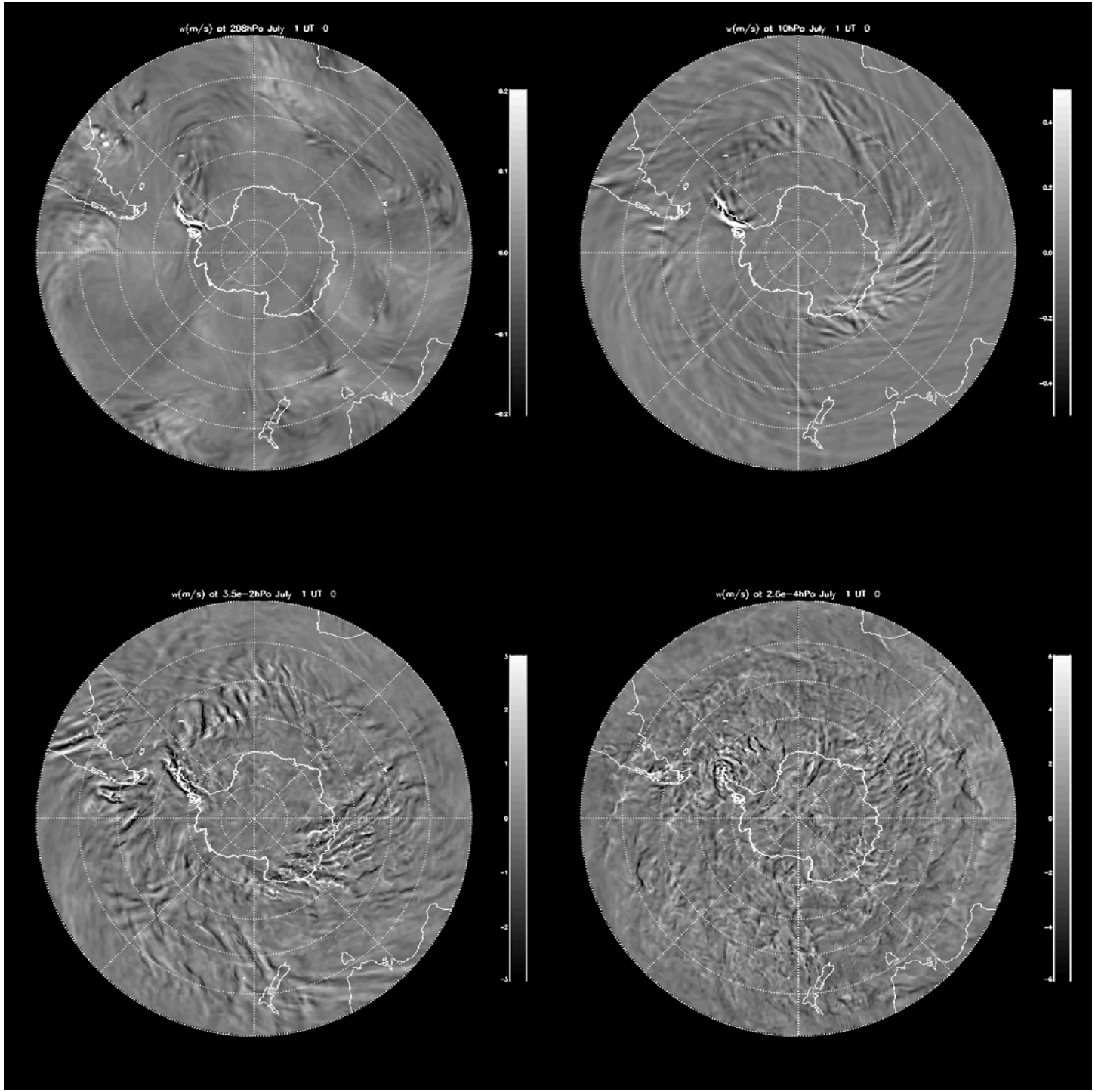


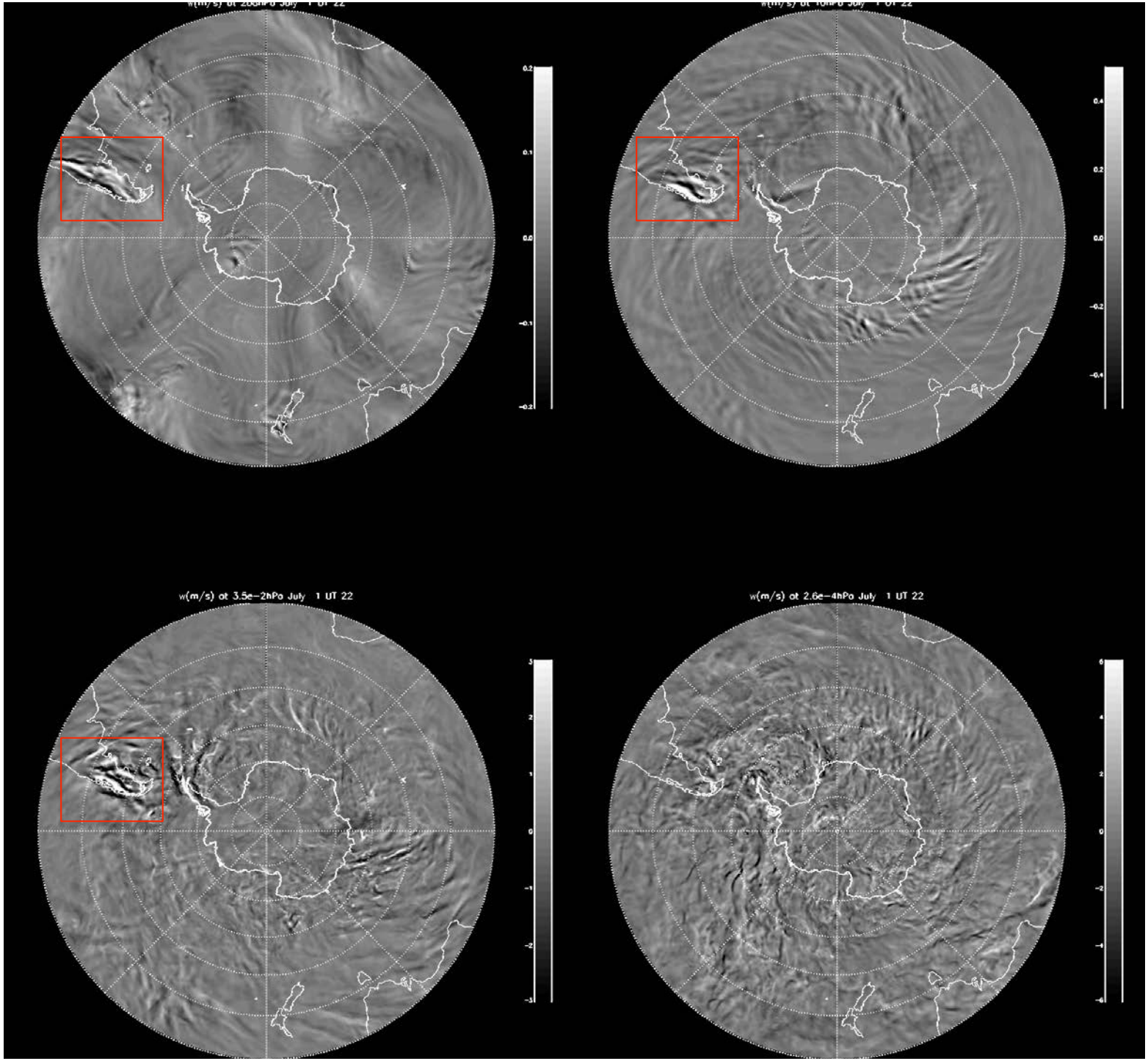
Vertical wind at 10hPa: July

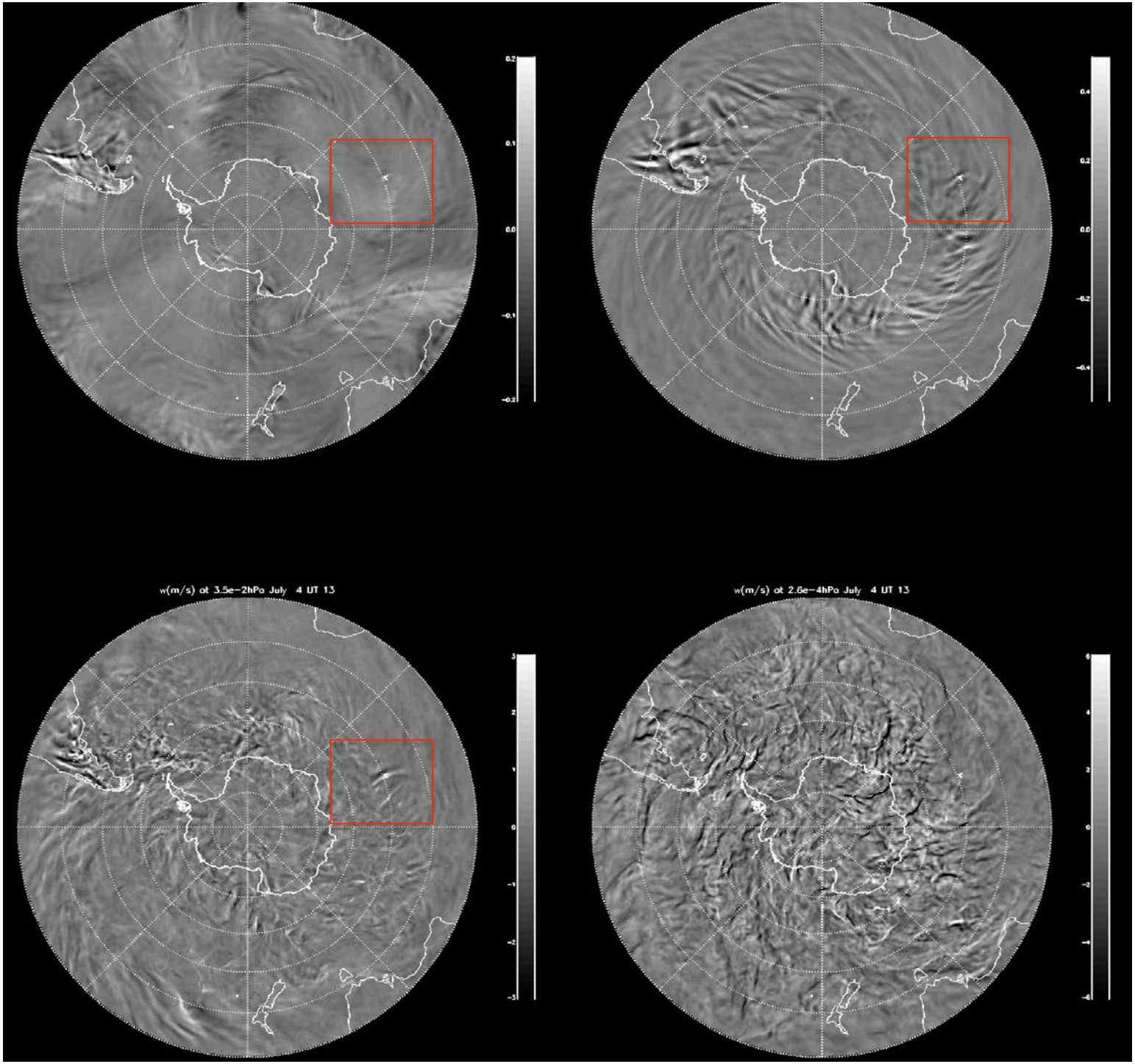


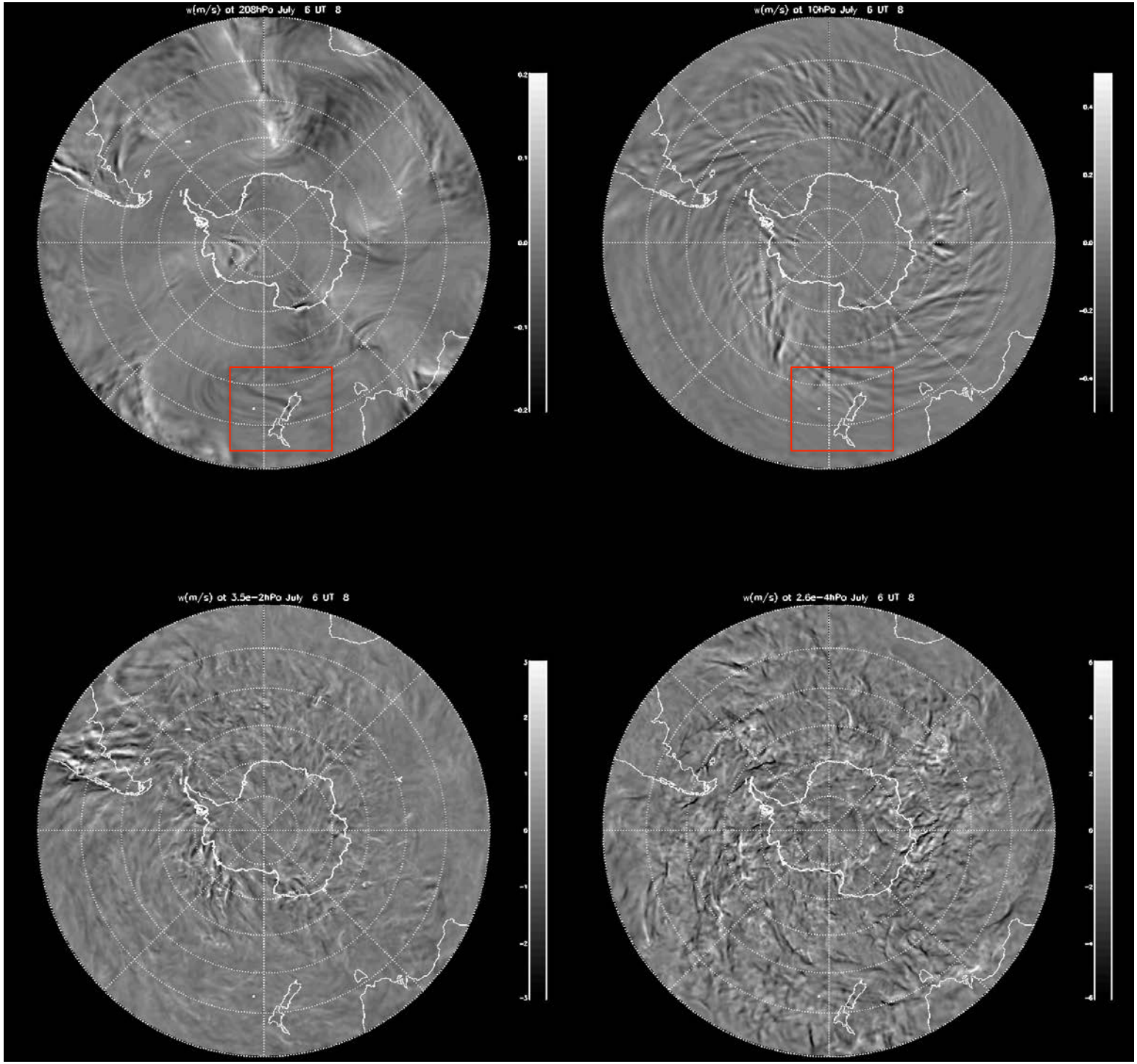
Vertical wind at 3.5e-2hPa: July

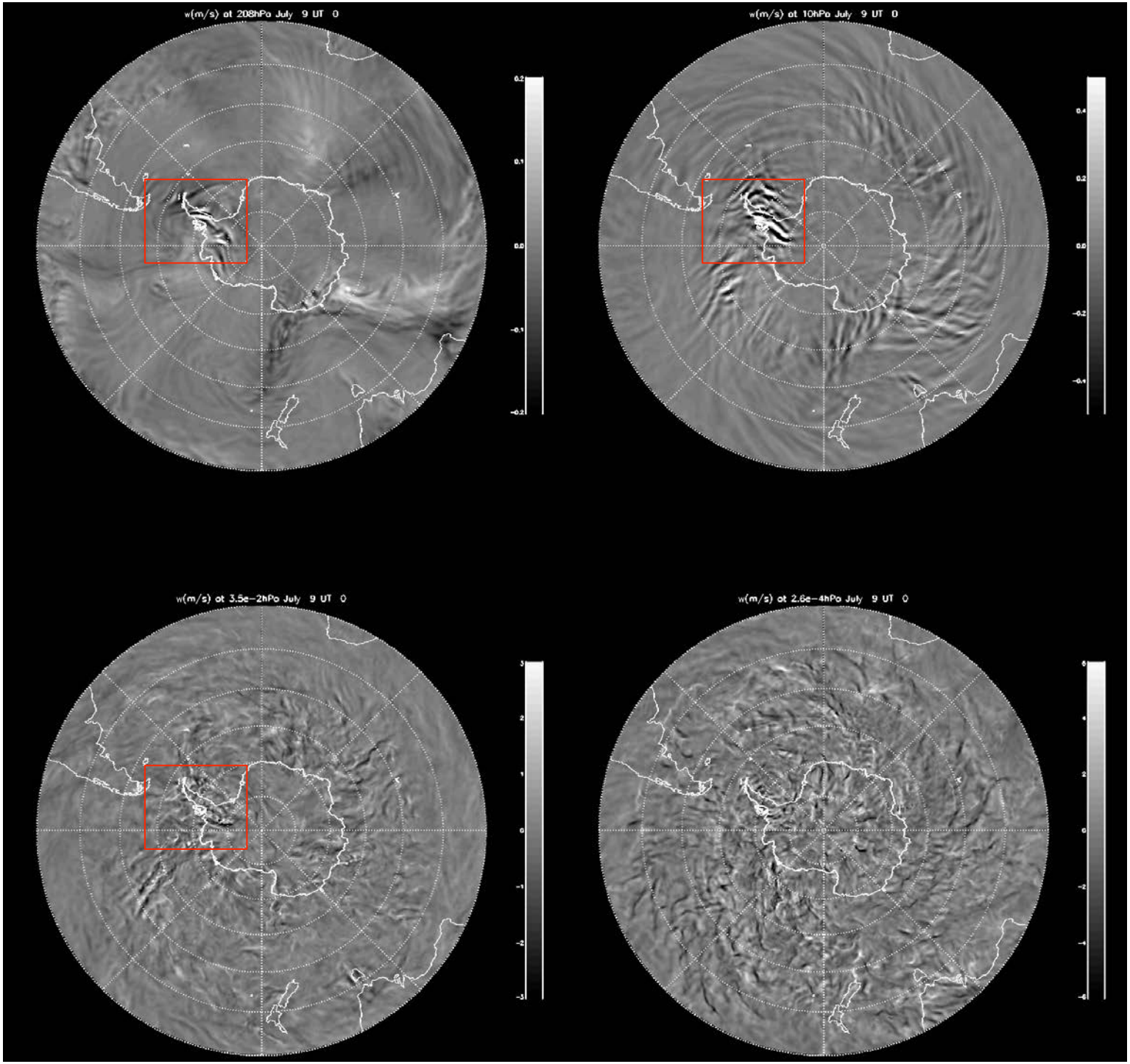



w(m/s) at 208hPa July 1 UT 0
w(m/s) at 10hPa July 1 UT 0
w(m/s) at 3.5e-2hPa July 1 UT 0
w(m/s) at 2.6e-4hPa July 1 UT 0

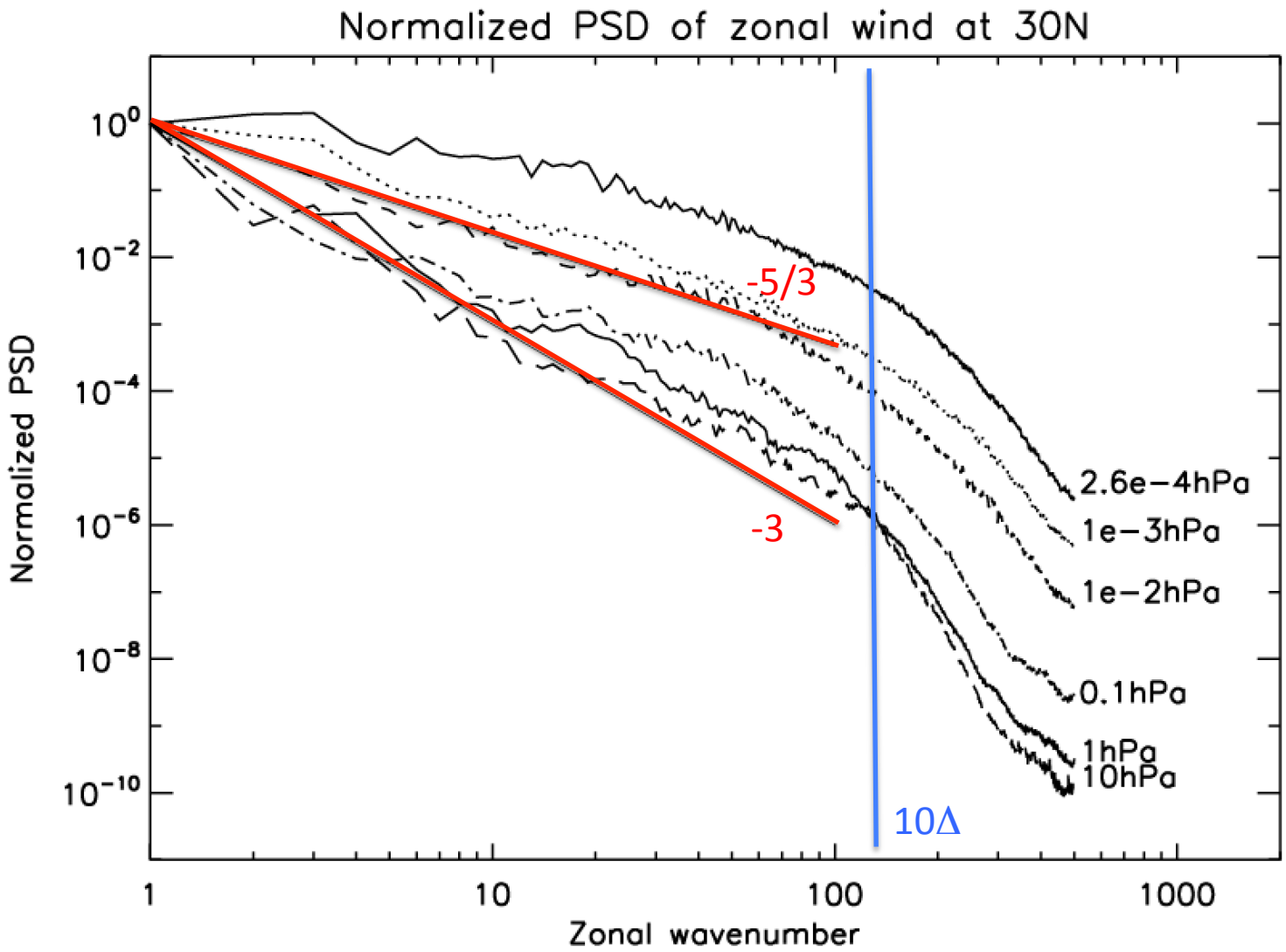

w(m/s) at 3.5e−2hPa July 1 UT 22
w(m/s) at 2.6e−4hPa July 1 UT 22


w(m/s) at 3.5e−2hPa July 4 UT 13
w(m/s) at 2.6e−4hPa July 4 UT 13

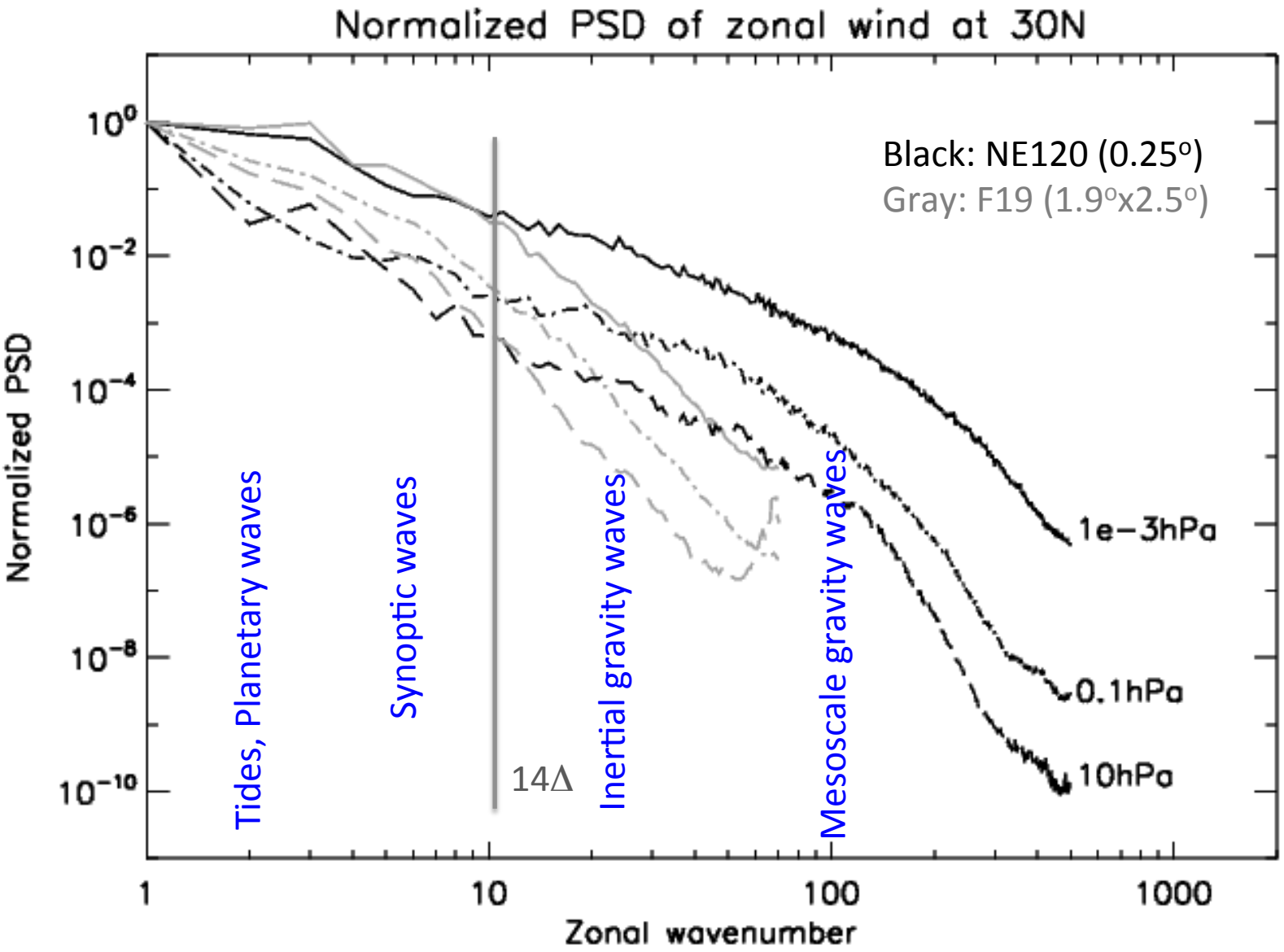

w(m/s) at 208hPa July 6 UT 8
w(m/s) at 10hPa July 6 UT 8
w(m/s) at 3.5e-2hPa July 6 UT 8
w(m/s) at 2.6e-4hPa July 6 UT 8

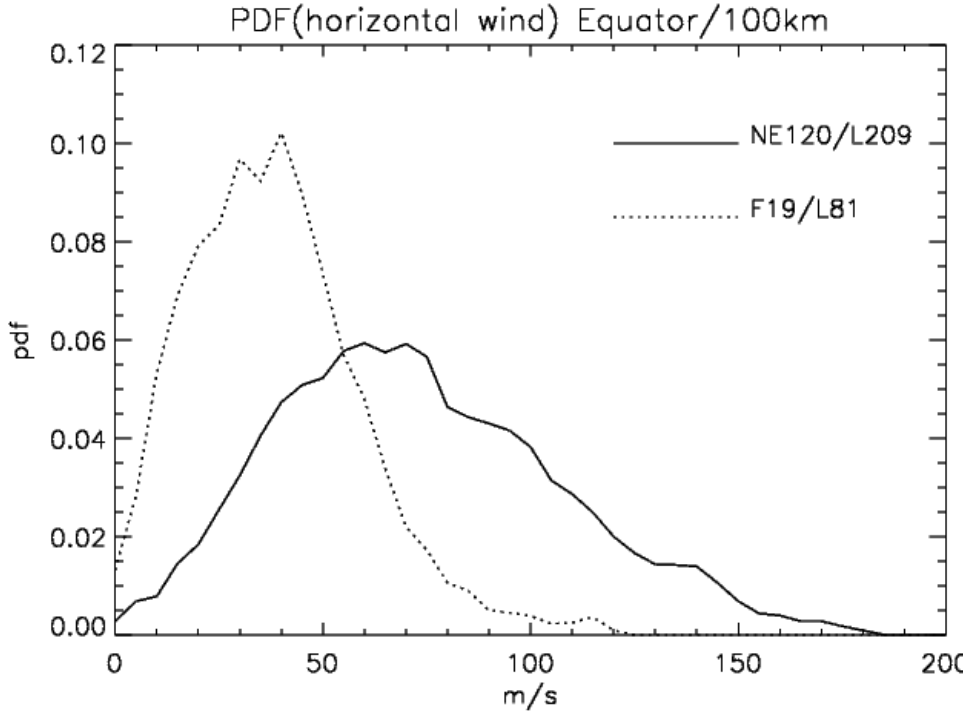

w(m/s) at 208hPa July 9 UT 0
w(m/s) at 10hPa July 9 UT 0
w(m/s) at 3.5e-2hPa July 9 UT 0
w(m/s) at 2.6e-4hPa July 9 UT 0

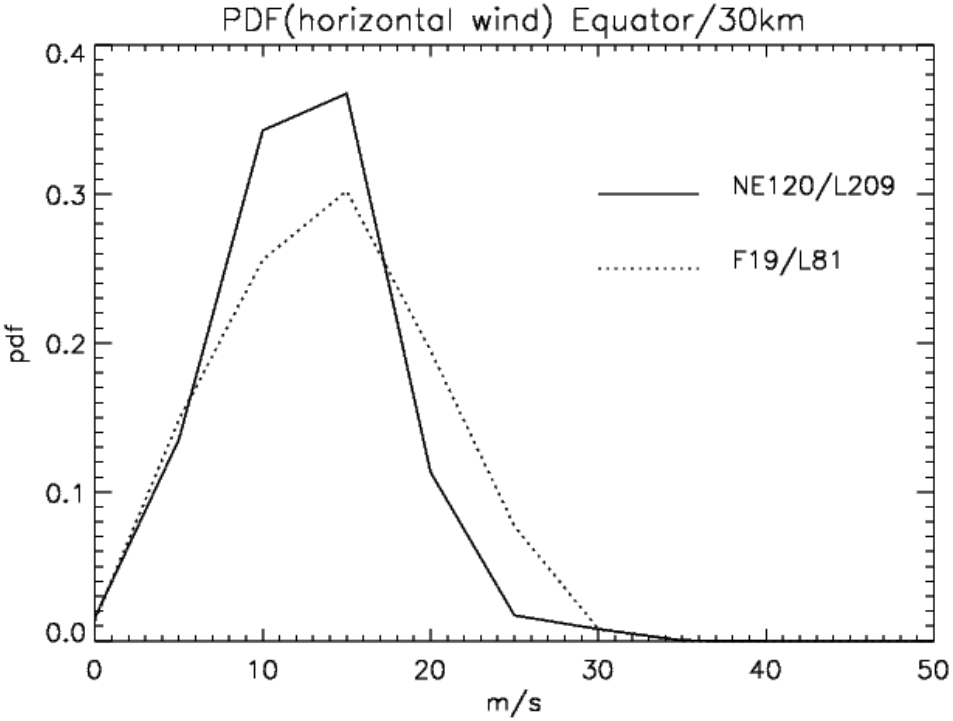
Power Spectrum Density: Altitude Dependence

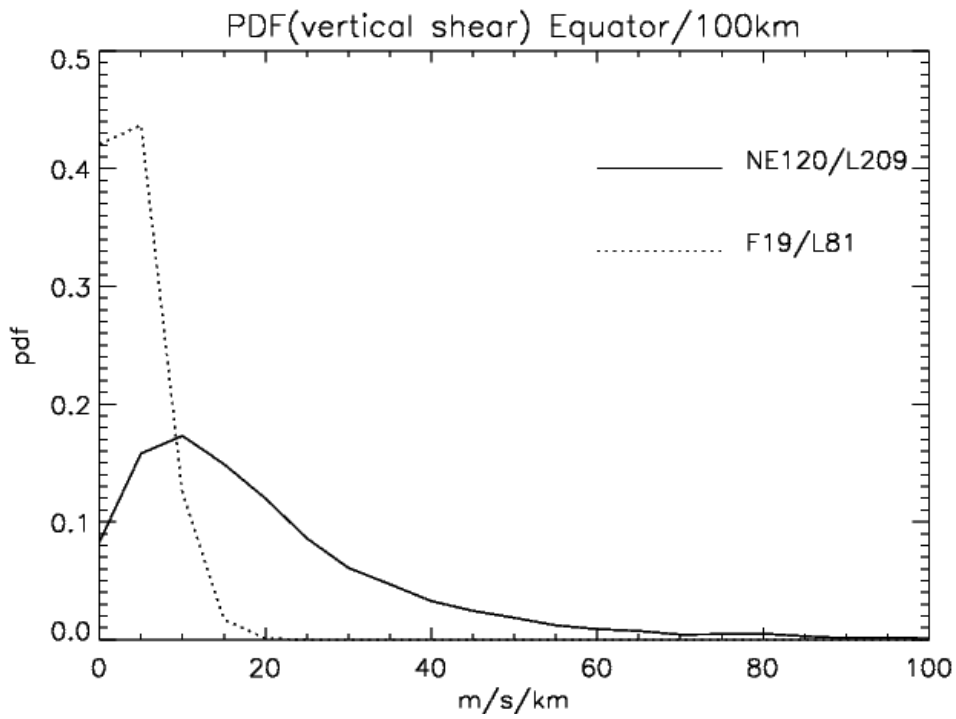


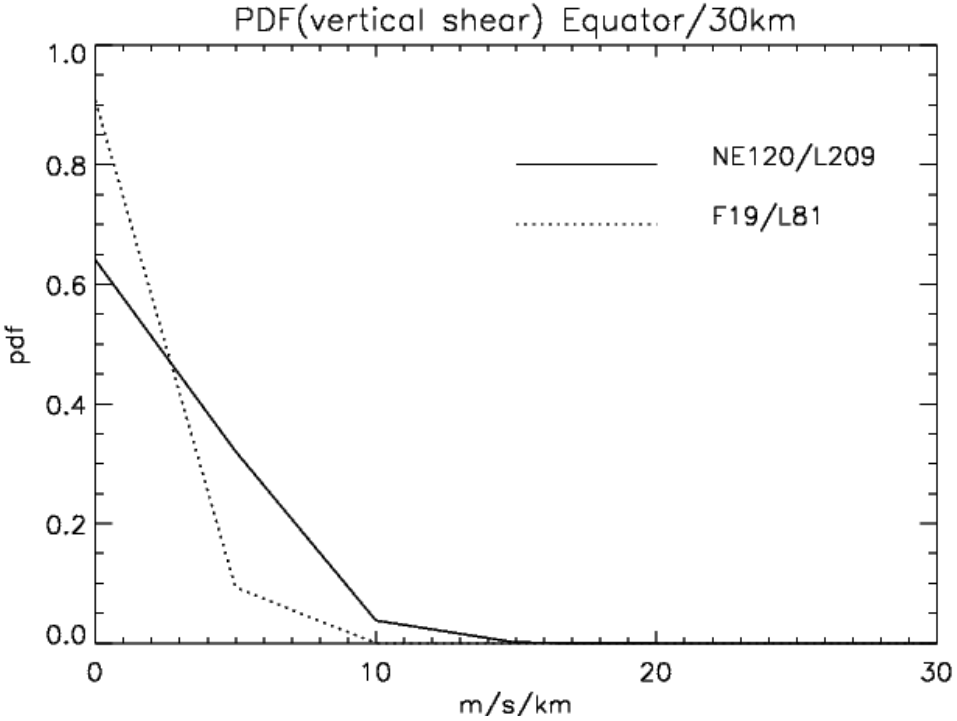
What's Resolved, and What's Not




PDF(horizontal wind) Equator/100km
NE120/L209
F19/L81
pdf
m/s
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
50
100
150
200


PDF(horizontal wind) Equator/30km
NE120/L209
F19/L81
pdf
m/s
0.4
0.3
0.2
0.1
0.0
0
10
20
30
40
50


PDF(vertical shear) Equator/100km
NE120/L209
F19/L81
pdf
m/s/km
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100


PDF(vertical shear) Equator/30km
NE120/L209
F19/L81
pdf
m/s/km
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30

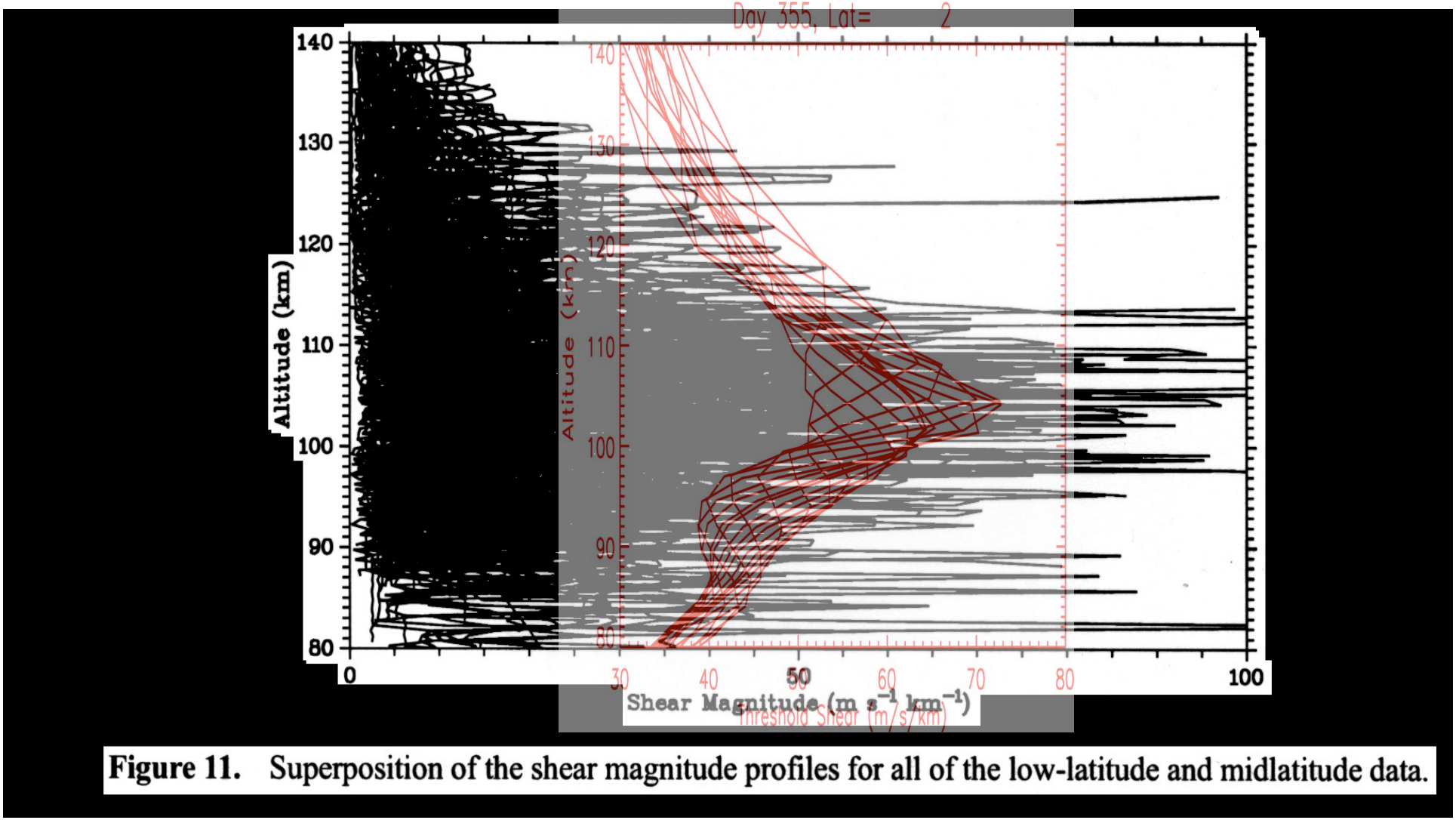
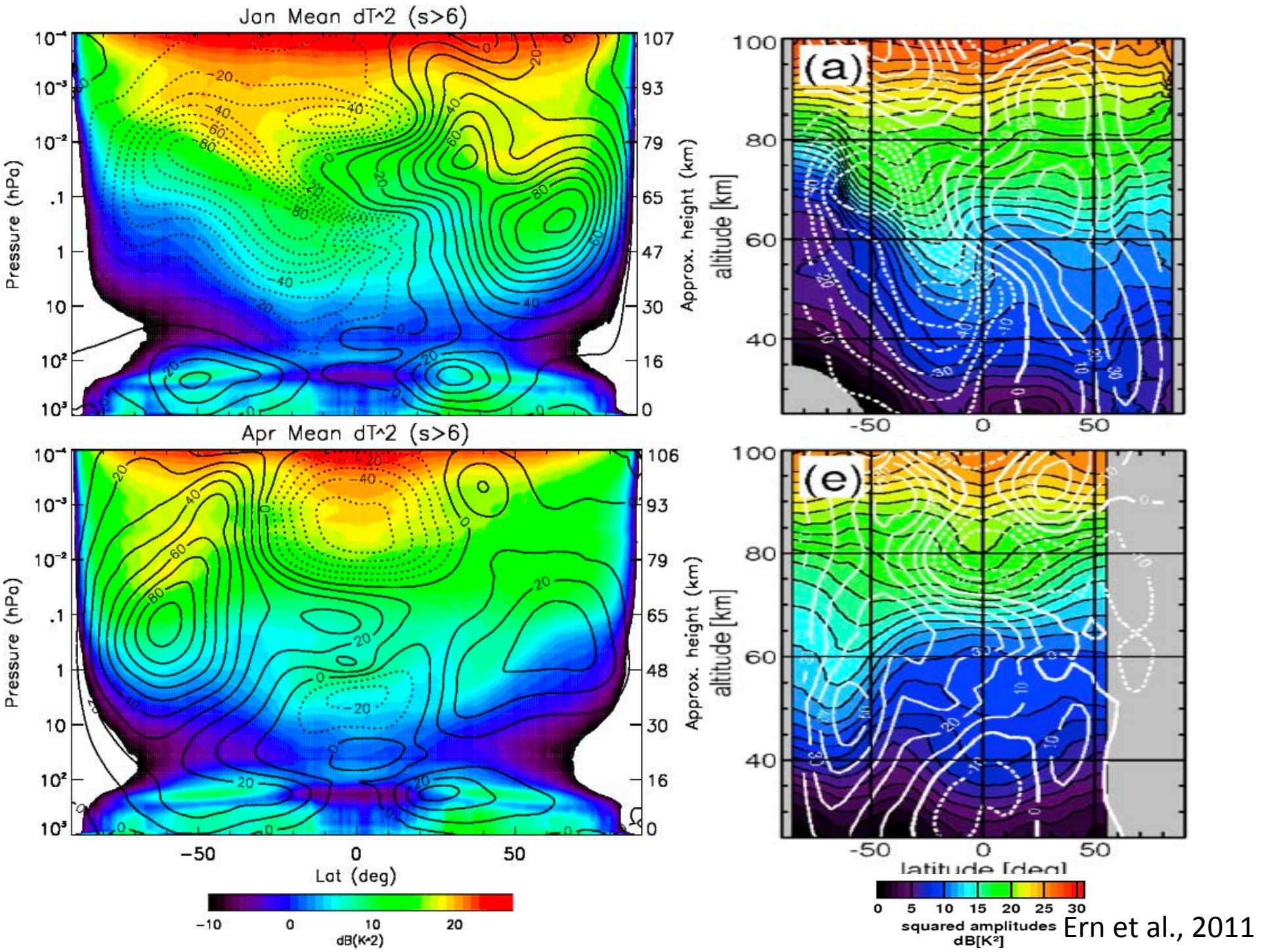


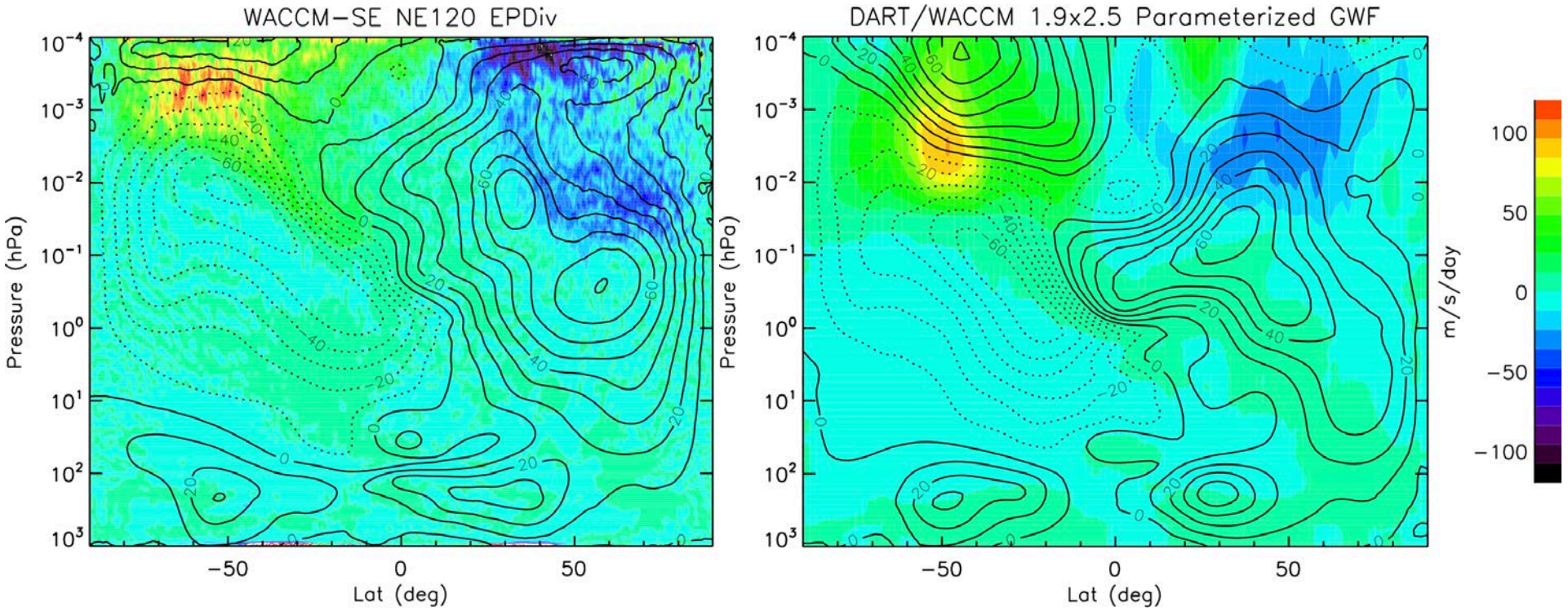
Figure 11. Superposition of the shear magnitude profiles for all of the low-latitude and midlatitude data.

Larsen, 2002 Liu, 2007



Ern et al., 2011

Zonal Wind and GW Forcing



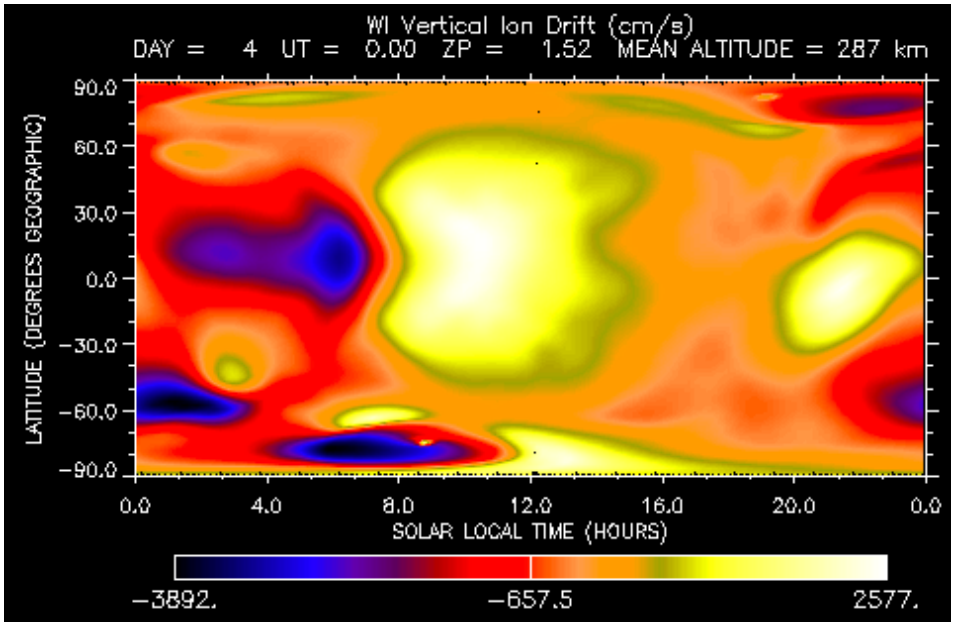
Liu et al., 2014

Summary

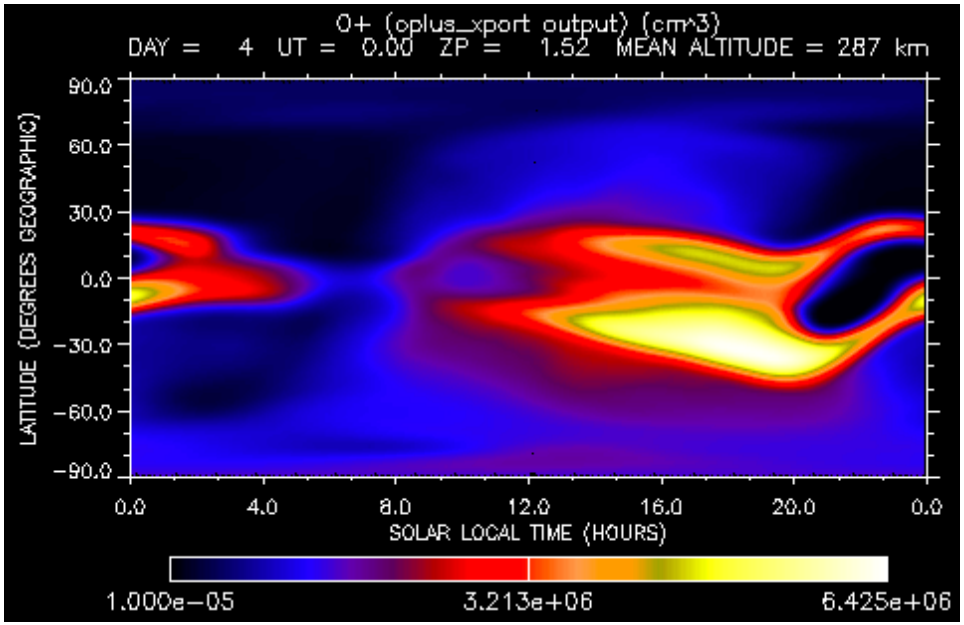
- Mesoscale-resolving WACCM is a valuable tool to gain insights of GW dynamics in the middle/upper atmosphere.
- Gravity waves play an increasingly significant role in the upper atmosphere. They contribute to the large winds and shears in the MLT, and are not accounted for in models where these waves are absent.
- Evaluation of gravity waves
  - Resolved GWs generally agree with satellite observations (distribution and seasonal variation).
  - Resolved GW forcing is not large enough to reverse the winter stratospheric/mesospheric jet.
  - Resolved GW forcing can reverse summer stratospheric/mesospheric jet, but still weak and altitude is too high.
- Impacts of these waves in ionosphere/thermosphere?

WACCM-X Ionosphere: Electrodynamics and Plasma Transport

Vertical Drift



F region O+ Density



Tuesday Poster by McInerney et al.

Acknowledgement

- NCAR CESM and WACCM Team (HAO, ACOM, CGD).
- High resolution WACCM work: Joe McInerney, Sean Santos, Peter Lauritzen, Mark Taylor, and Nick Pedatella.
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- NASA LWS Strategic Capability NNX09AJ83G.
- NCAR Strategic Capability (NSC) award.