DEEPWAVE Workshop

Steve Eckermann (and many others)

Naval Research Laboratory, Washington, DC,
stephen.eckermann@nrl.navy.mil

Jun Ma, Dave Broutman

Computational Physics, Inc., Springfield, VA

TOPICS

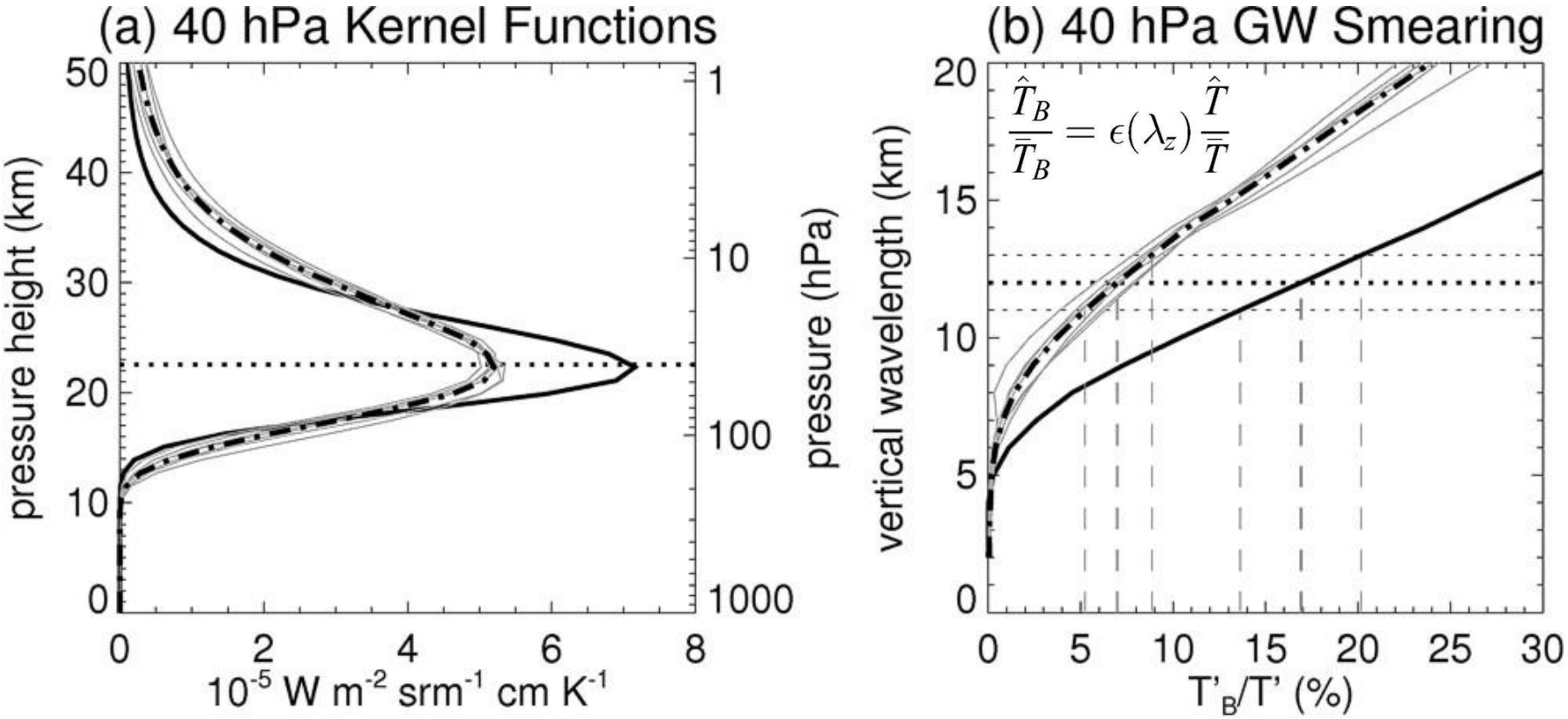
- AIRS Gravity-Wave Observations
- NAVGEM Reanalysis Experiments
- Plans

AIRS DEEPWAVE Gravity-Wave Product

- GWs isolated as small horizontal scale perturbations in Level-1b swath-scanned thermal nadir radiances
- Channel averaging to reduce noise floors and increase S/N thresholds for GW detection
- For DEEPWAVE, provided “nowcast” AIRS GW product based on near-realtime (NRT) radiances
- Post DEEPWAVE, reprocessed 2014 data from 1 April to present using research-quality radiances

Eckermann and Wu, GRL, 2012
Gong, Wu and Eckermann, ACP, 2012

AIRS 40 hPa Radiance Channels



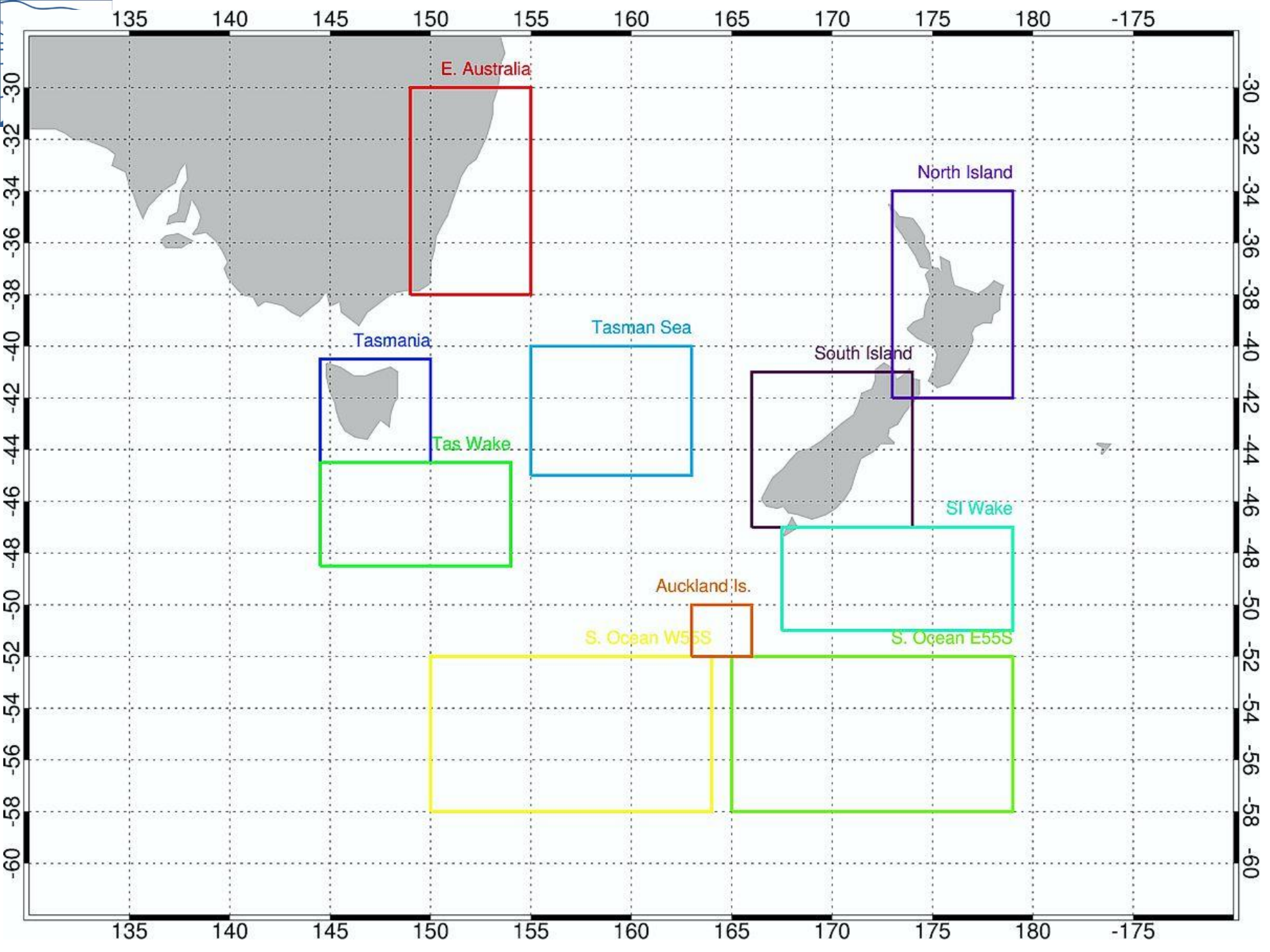
AIRS channels 64, 88, 90, 94, 100, 106 & 118 (665.015–678.839 cm^{-1})

Individual Channel Radiances 64,…,118

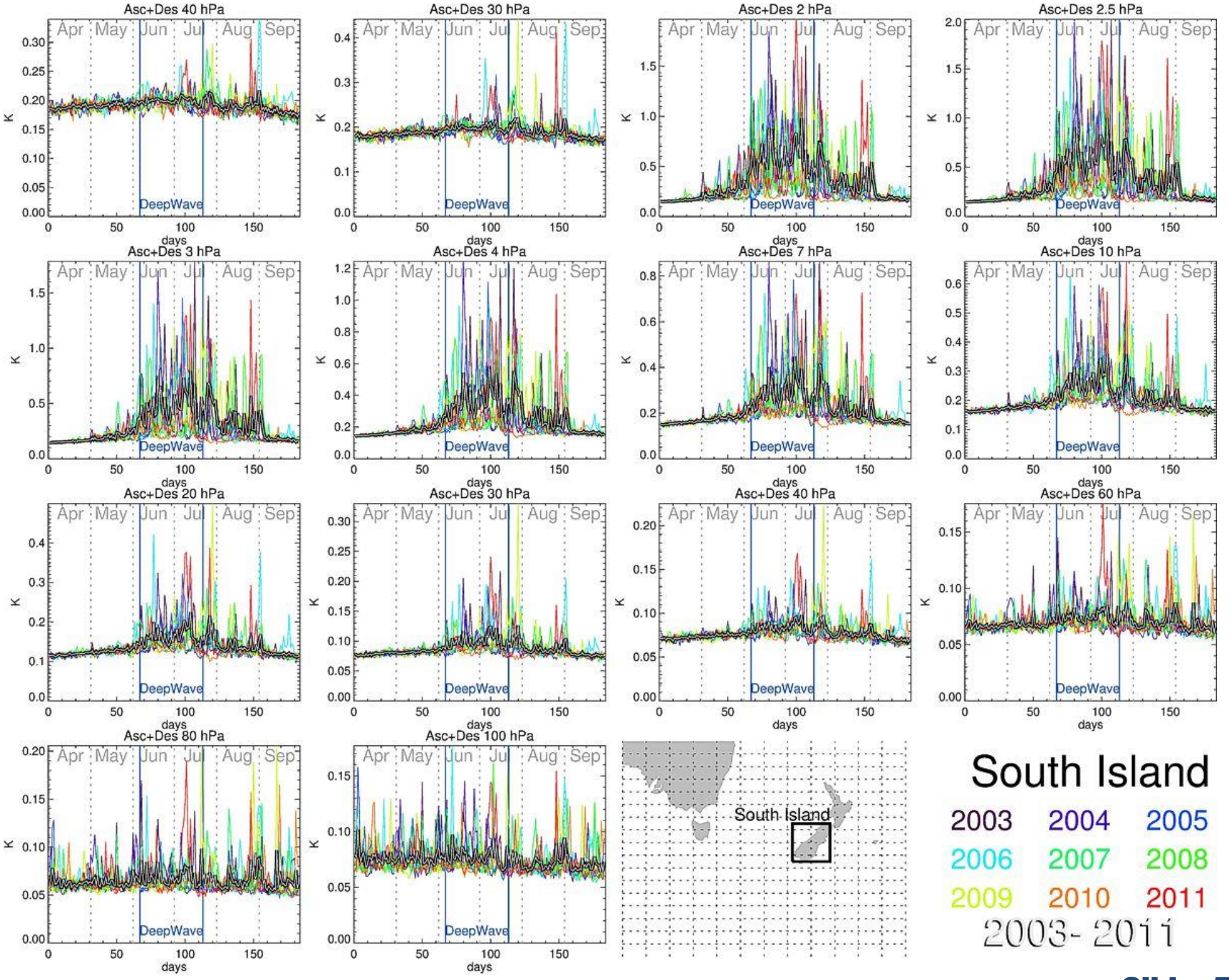
Mean Channel Radiance 64,..,118

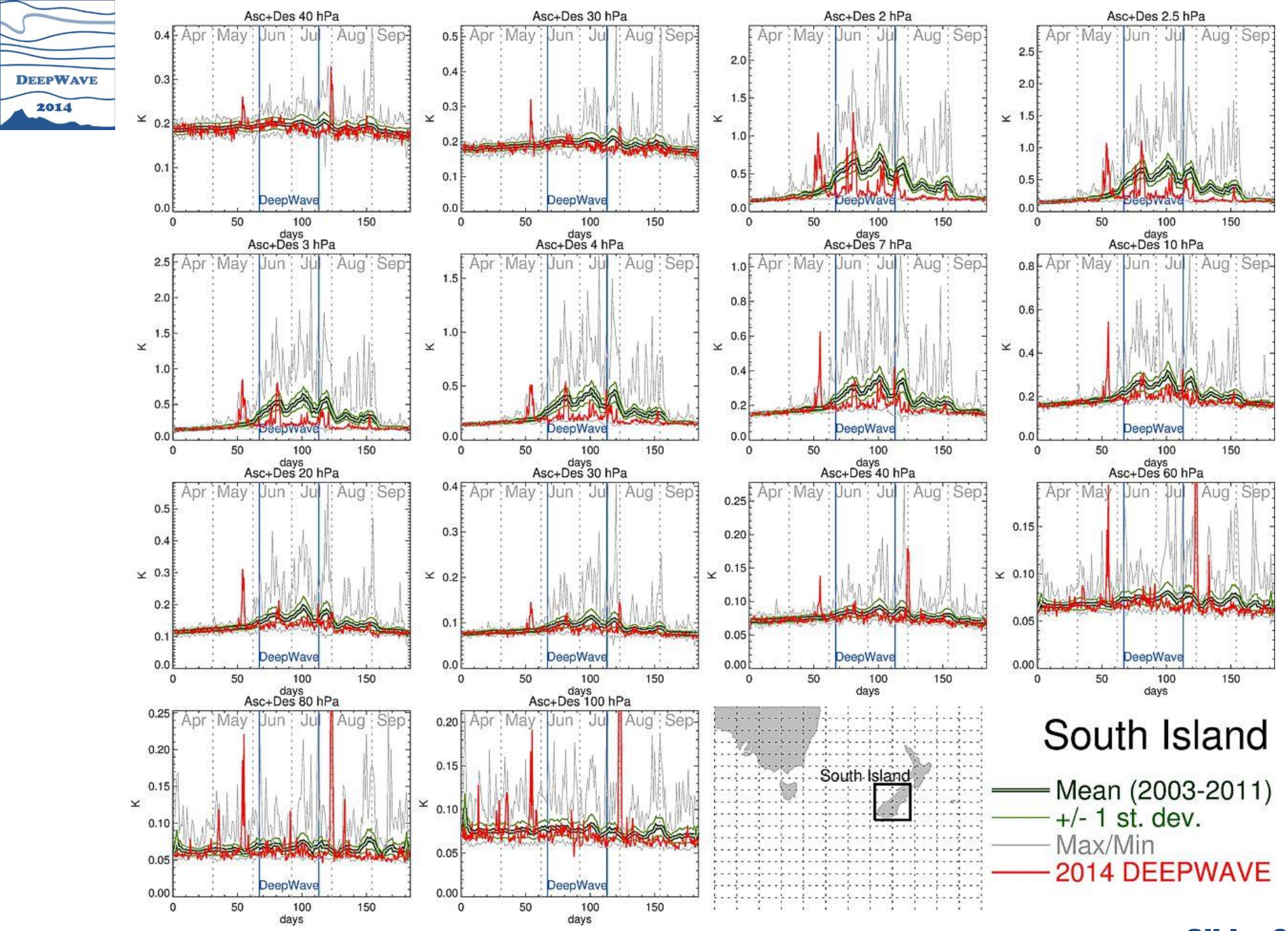
AIRS channel 71 (666.773 cm^{-1}).

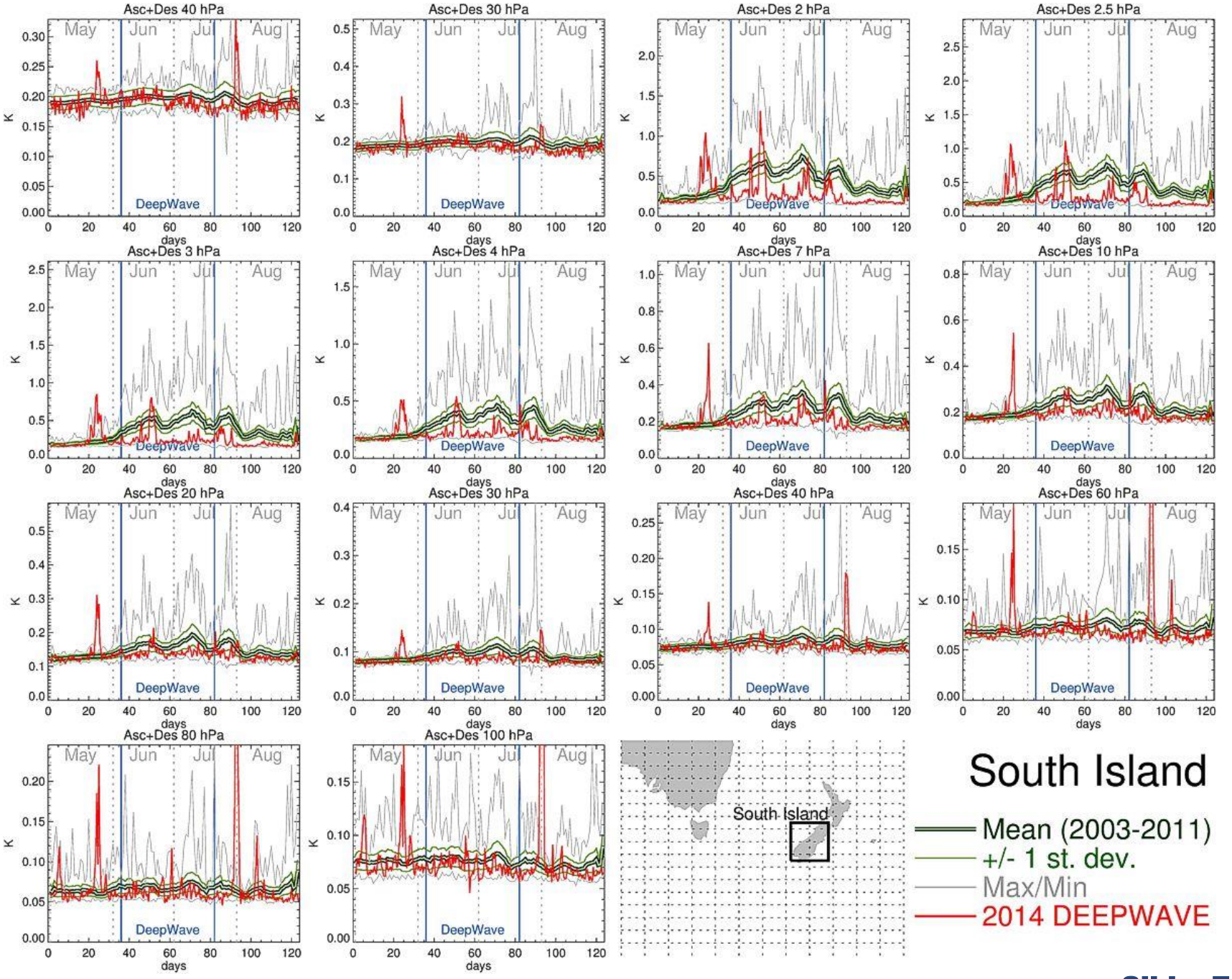
see Hoffmann and Alexander (JGR, 2009)
Eckermann et al. (GRL 2009)

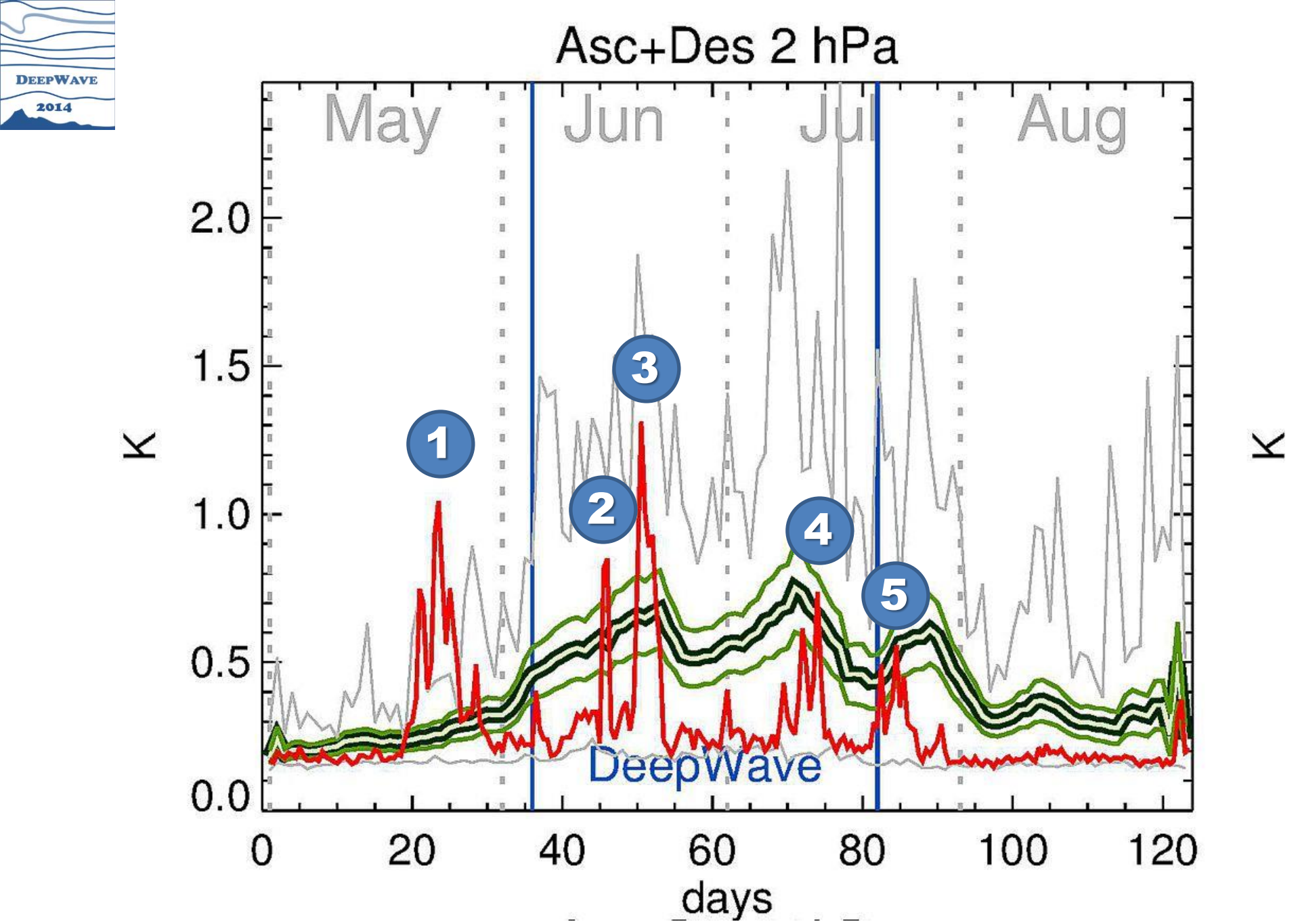

135
140
145
150
155
160
165
170
175
180
-175
-30
-32
-34
-36
-38
-40
-42
-44
-46
-48
-50
-52
-54
-56
-58
-60
E. Australia
North Island
Tasman Sea
Tasmania
South Island
Tas Wake
SI Wake
Auckland Is.
S. Ocean W55S
S. Ocean E55S

DEEPWAVE 2014




Asc+Des 40 hPa
Asc+Des 30 hPa
Asc+Des 2 hPa
Asc+Des 2.5 hPa
Asc+Des 3 hPa
Asc+Des 4 hPa
Asc+Des 7 hPa
Asc+Des 10 hPa
Asc+Des 20 hPa
Asc+Des 30 hPa
Asc+Des 40 hPa
Asc+Des 60 hPa
Asc+Des 80 hPa
Asc+Des 100 hPa
Apr May Jun Jul Aug Sep
K
days
DeepWave
South Island
Mean (2003-2011)
+/- 1 st. dev.
Max/Min
2014 DEEPWAVE

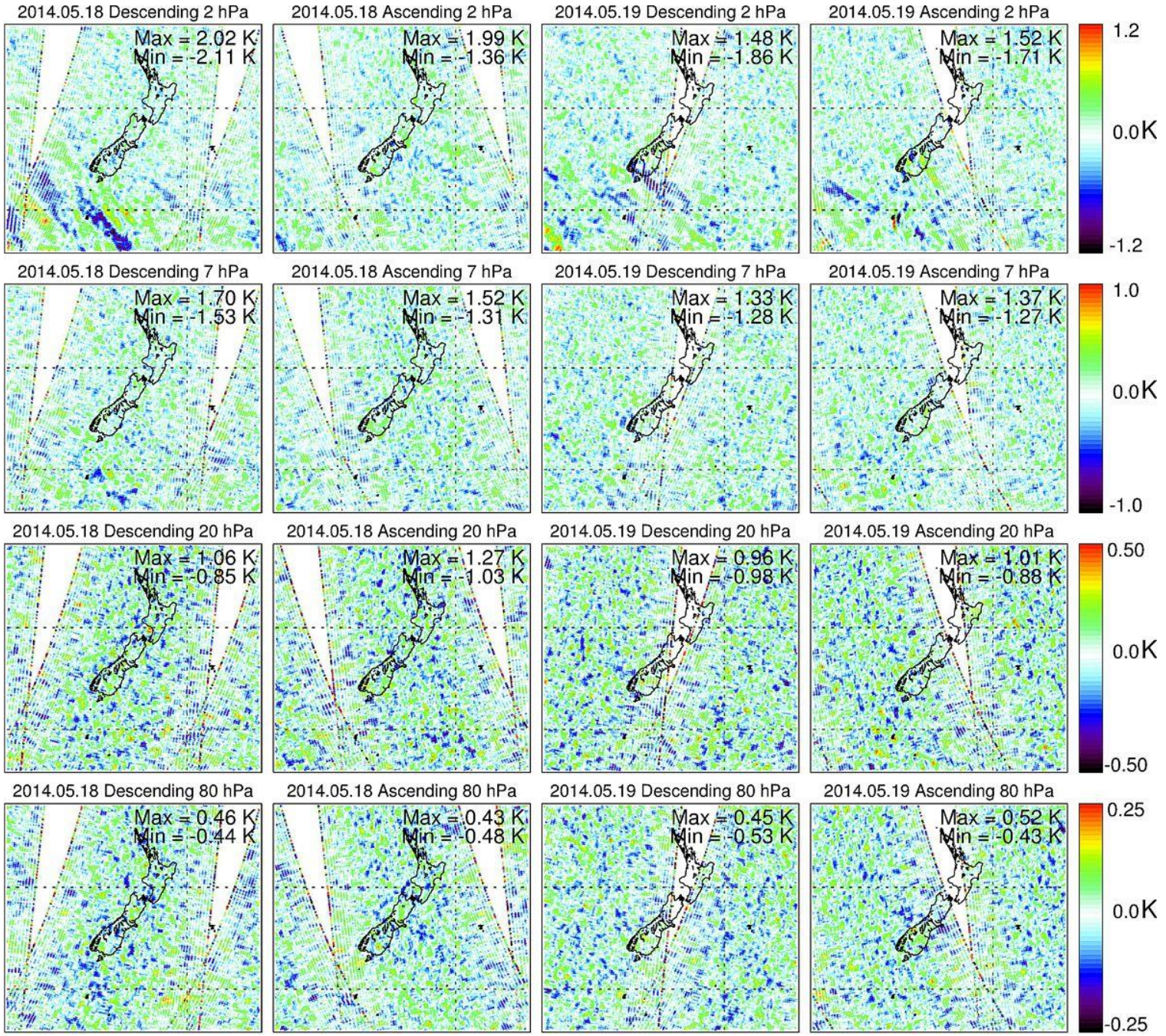

Asc+Des 40 hPa
Asc+Des 30 hPa
Asc+Des 2 hPa
Asc+Des 2.5 hPa
Asc+Des 3 hPa
Asc+Des 4 hPa
Asc+Des 7 hPa
Asc+Des 10 hPa
Asc+Des 20 hPa
Asc+Des 30 hPa
Asc+Des 40 hPa
Asc+Des 60 hPa
Asc+Des 80 hPa
Asc+Des 100 hPa
May
Jun
Jul
Aug
K
days
DeepWave
South Island
Mean (2003-2011)
+/- 1 st. dev.
Max/Min
2014 DEEPWAVE


Asc+Des 2 hPa
May
Jun
Jul
Aug
2.0
1.5
1.0
0.5
0.0
K
K
1
2
3
4
5
DeepWave
0
20
40
60
80
100
120
days

DEEPWAVE 2014

1

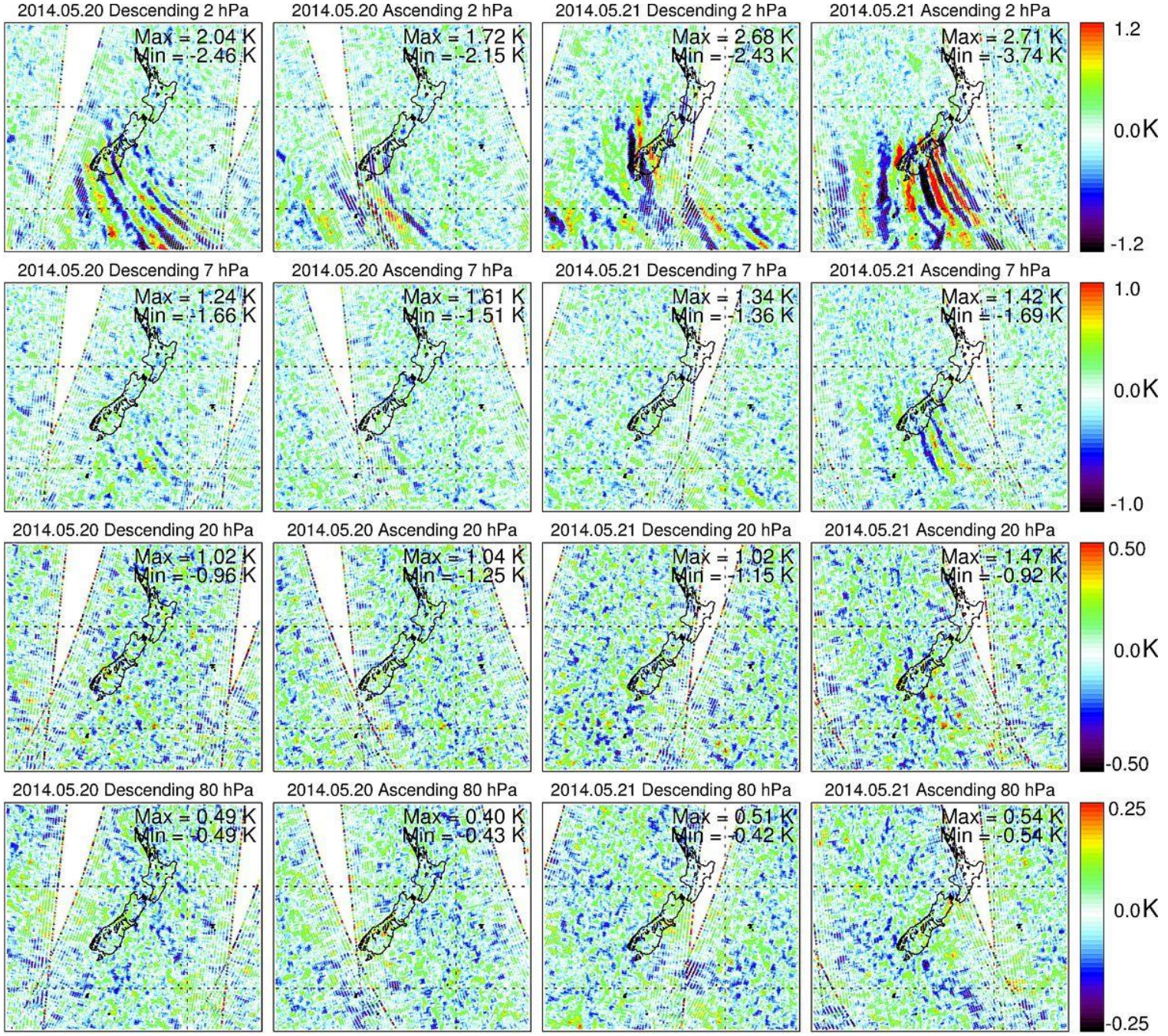
18-28 May



DEEPWAVE 2014

1

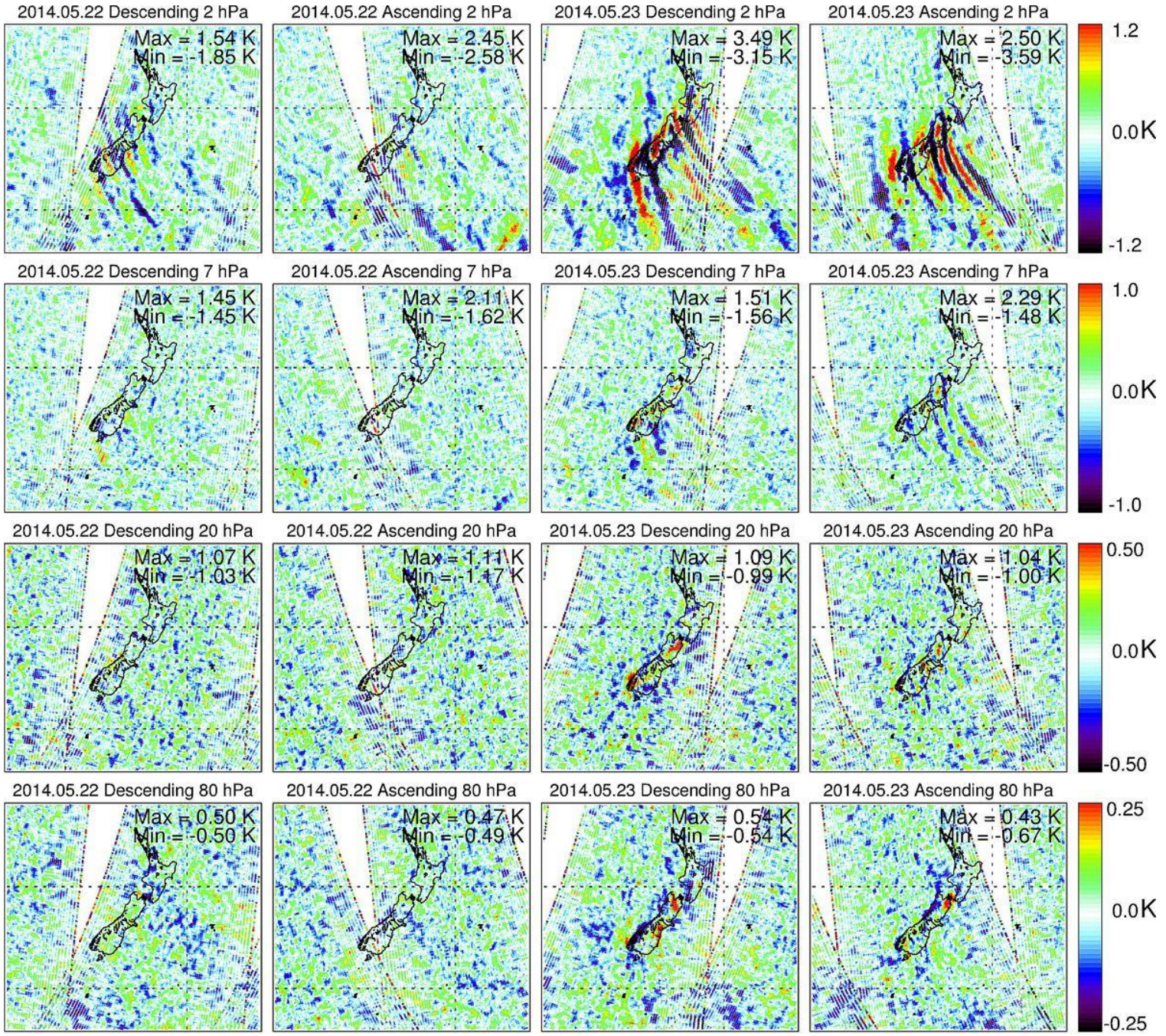
18-28 May



DEEPWAVE 2014

1

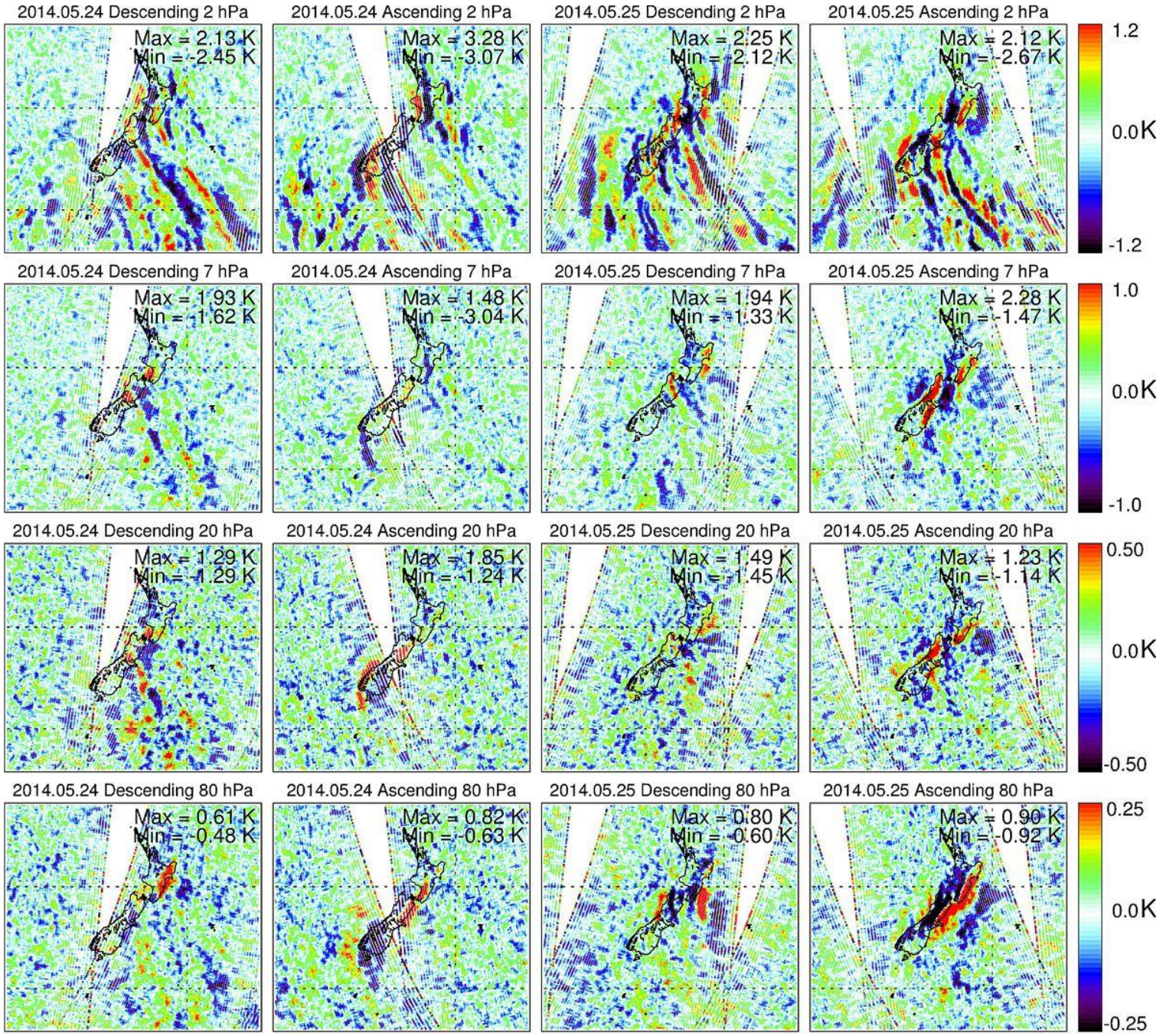
18-28 May



DEEPWAVE 2014

1

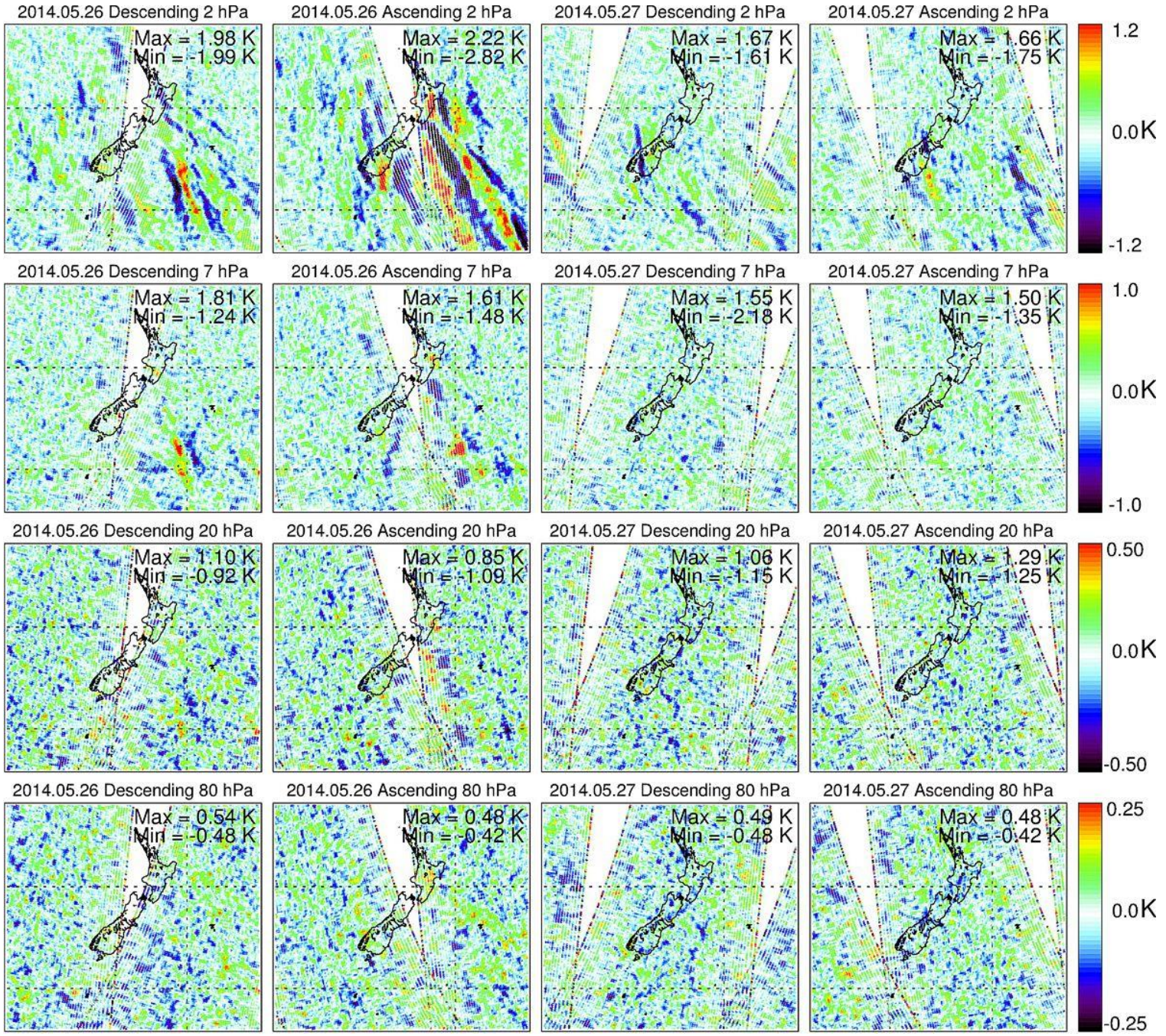
18-28 May



DEEPWAVE 2014

1

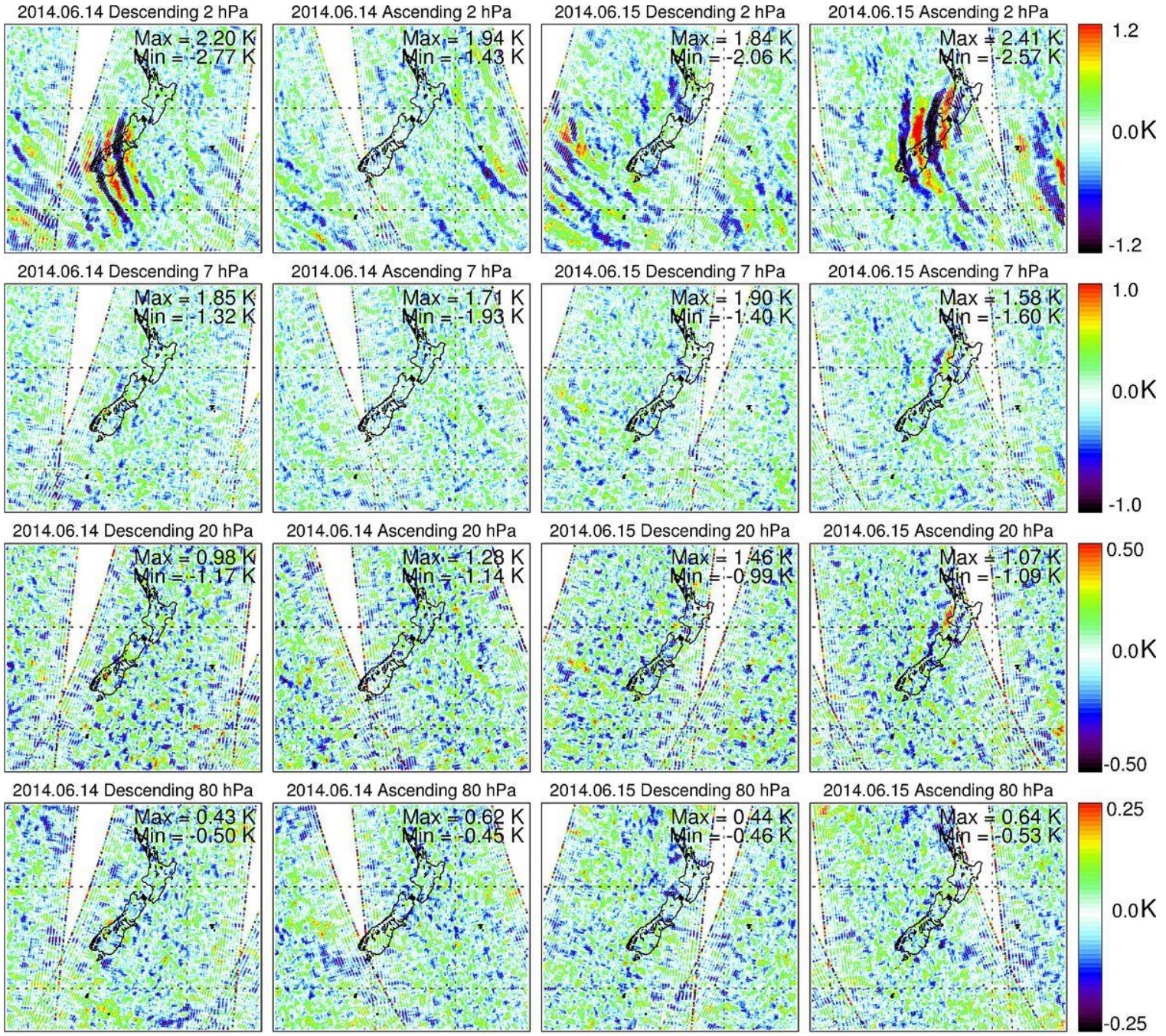
18-28 May



DEEPWAVE 2014

2

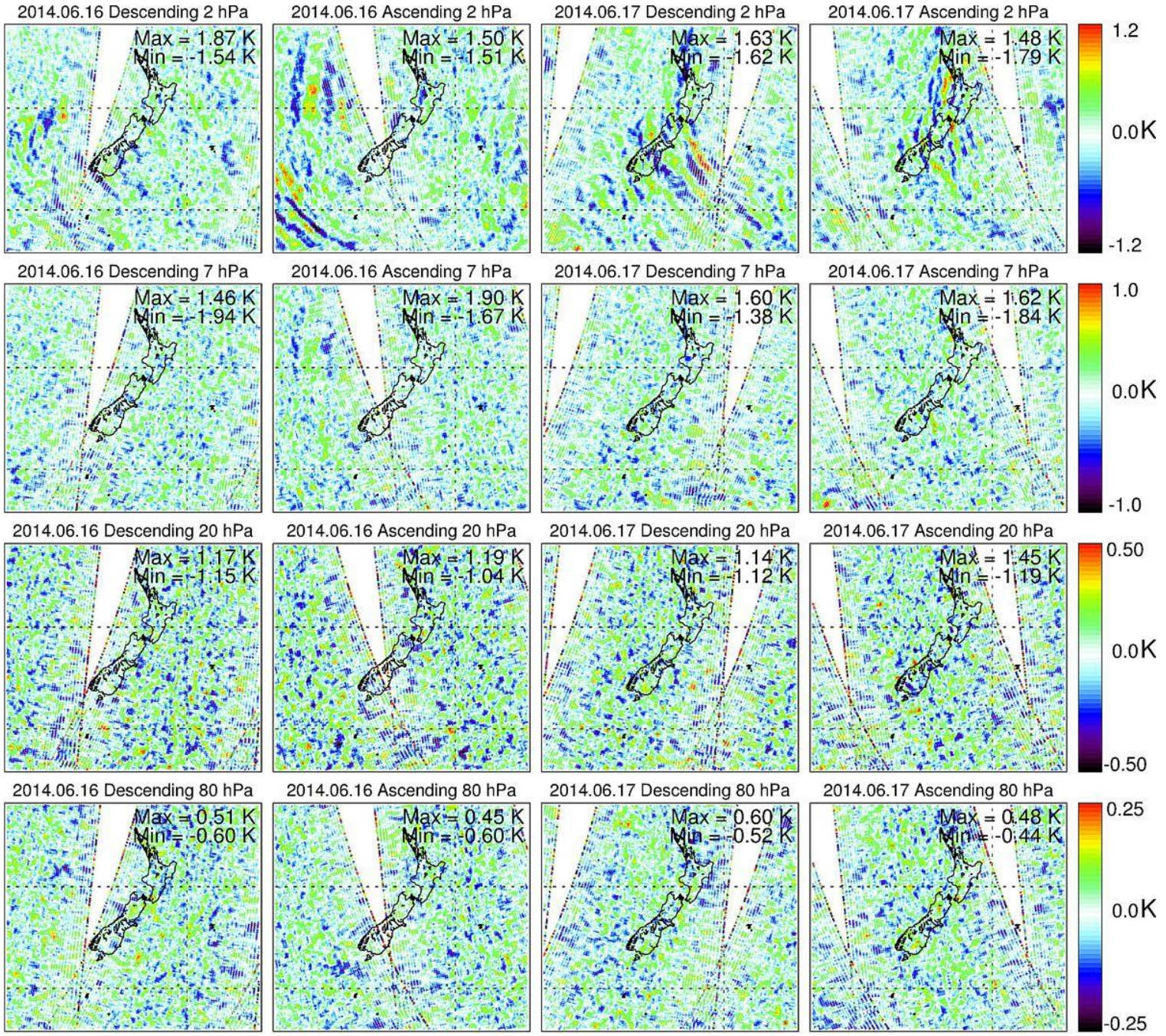
15-16 June



DEEPWAVE 2014

2

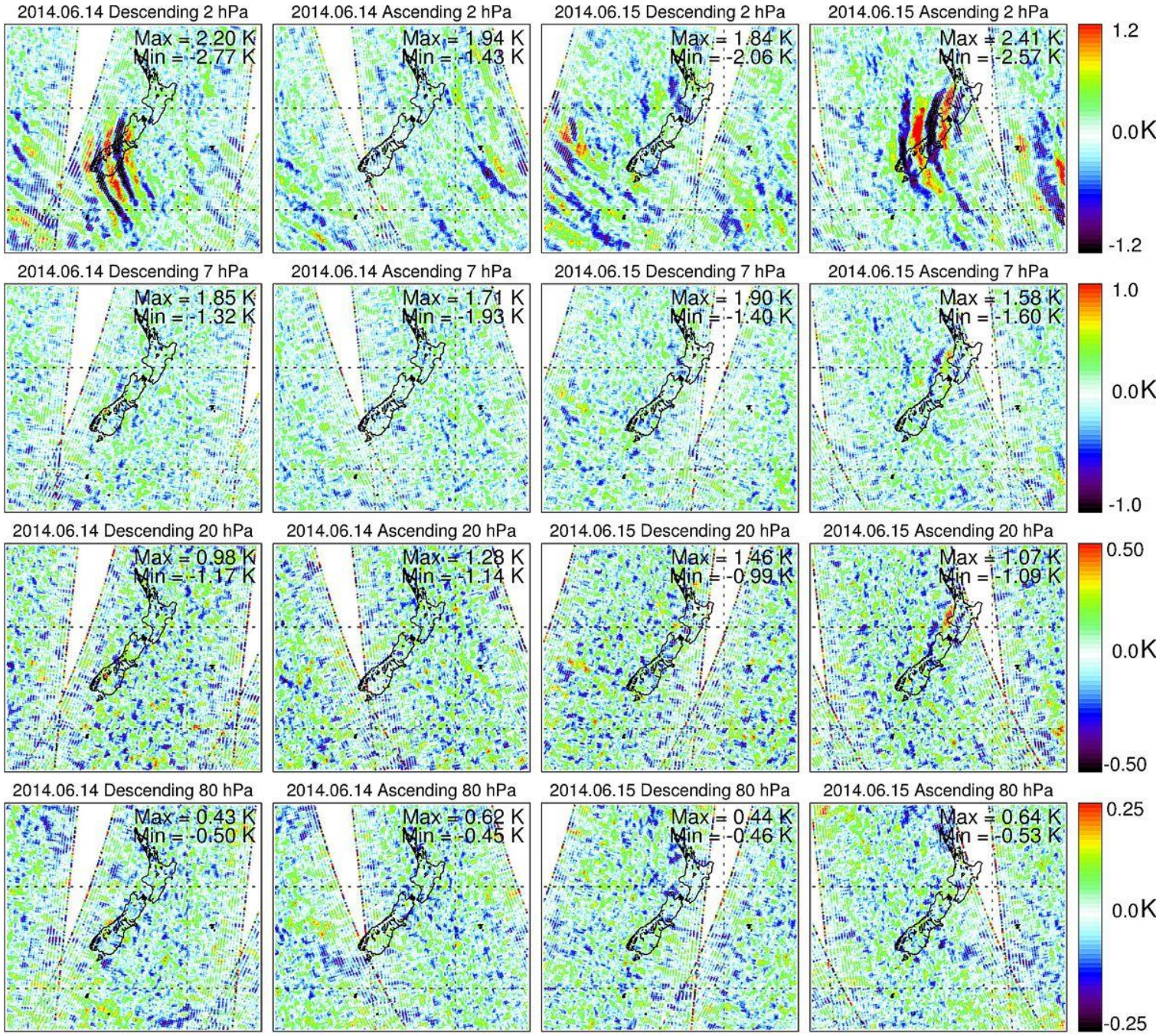
15-16 June



DEEPWAVE 2014

3

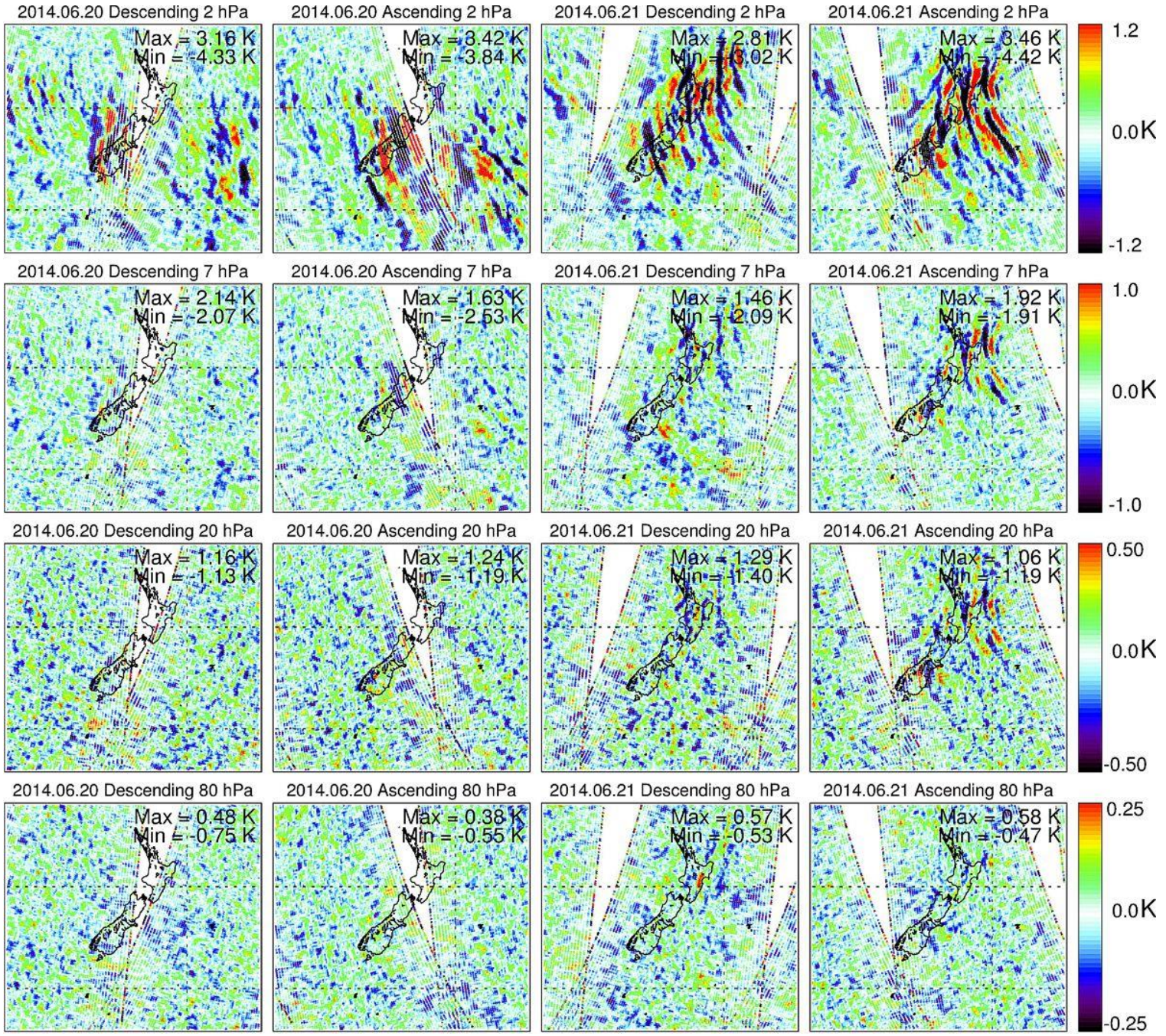
19-24 June



DEEPWAVE 2014

3

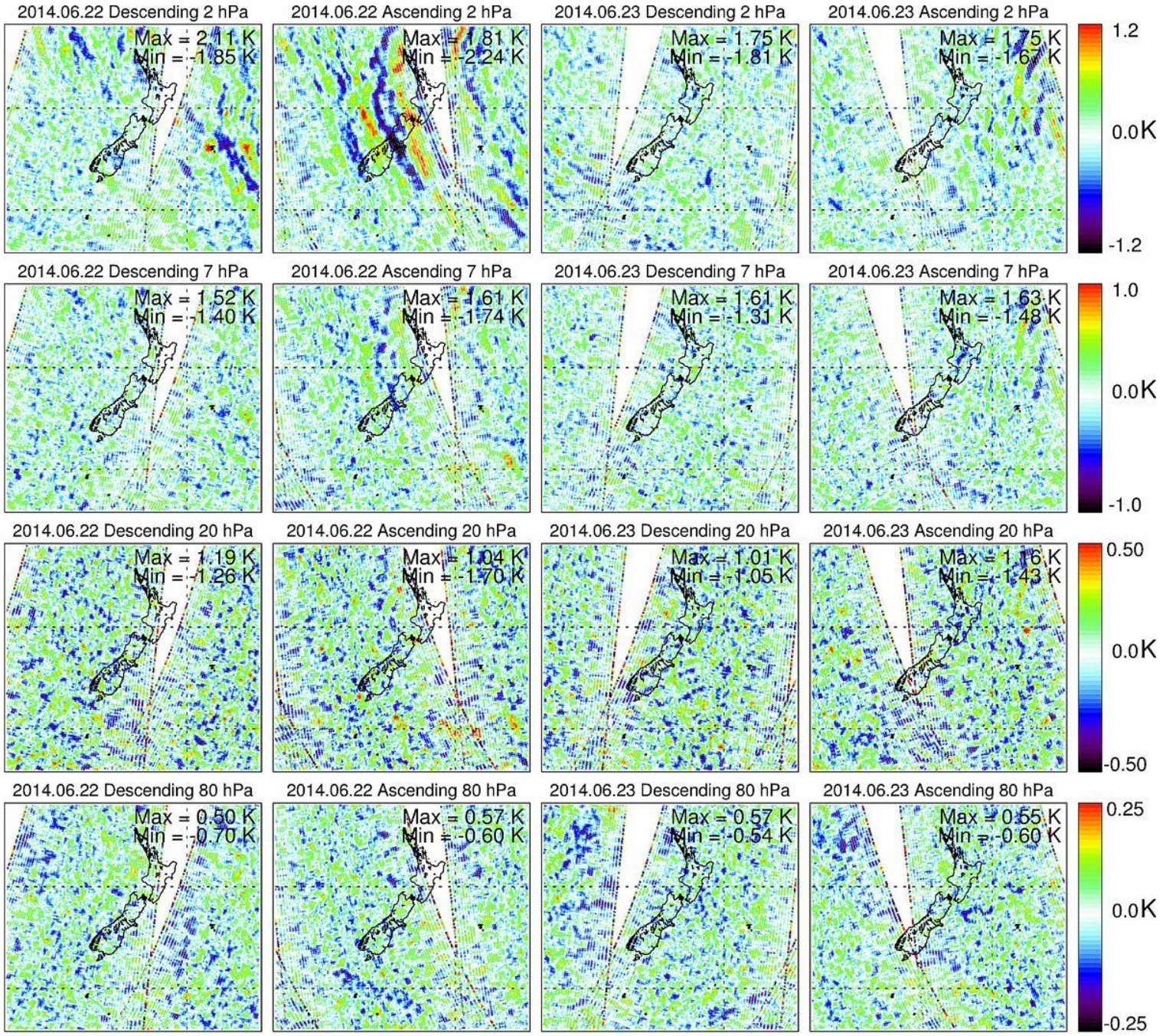
19-24 June

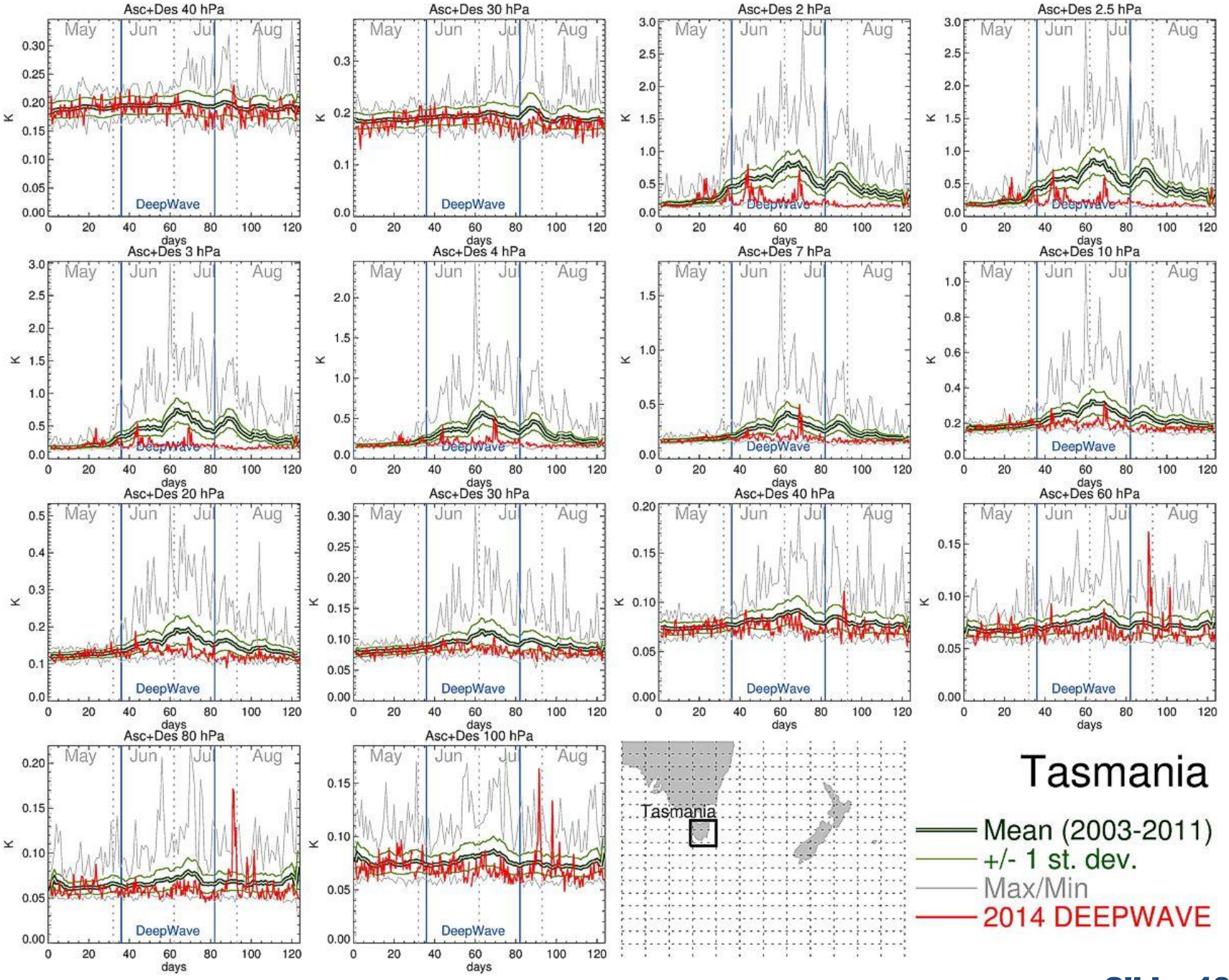


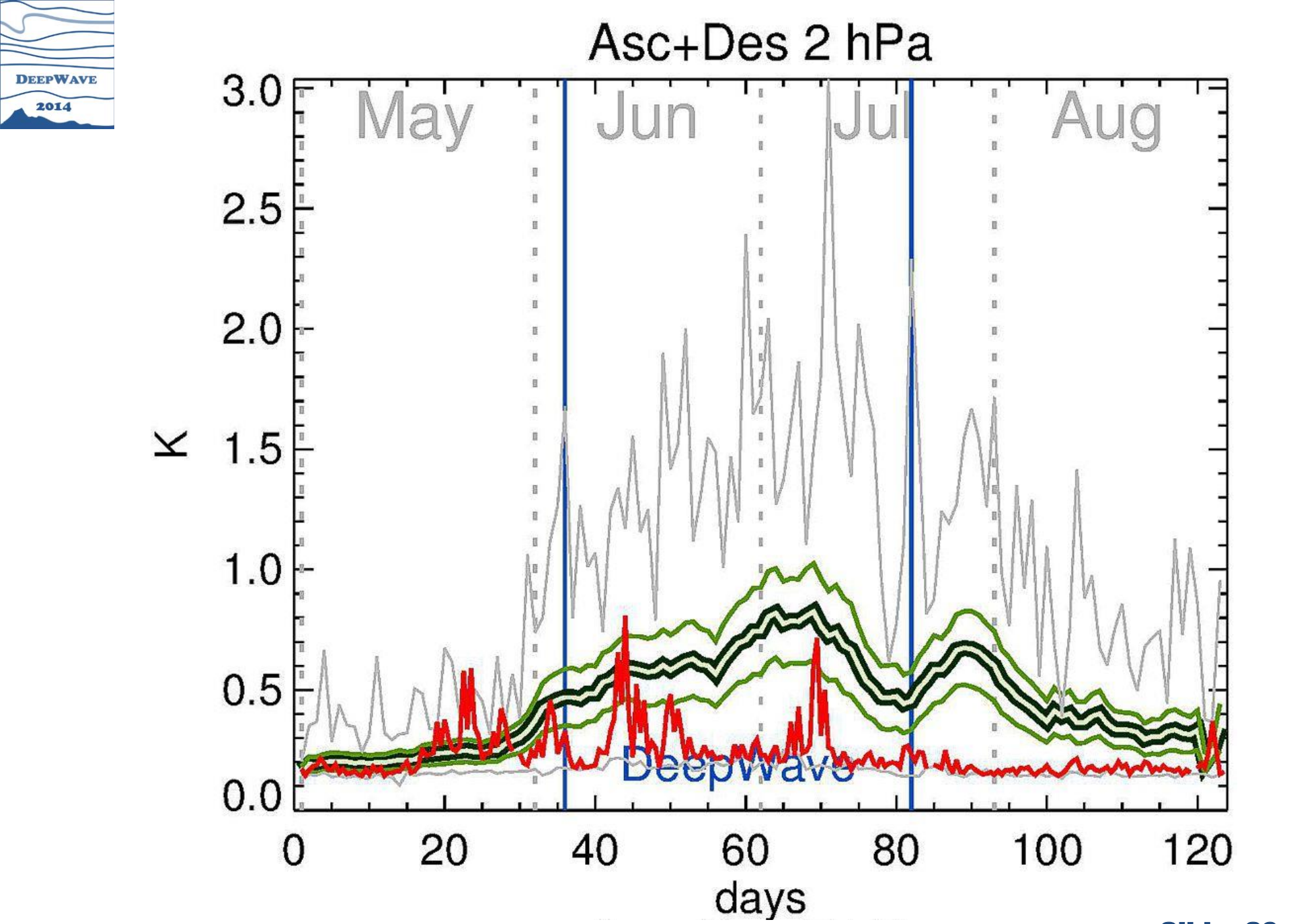
DEEPWAVE 2014

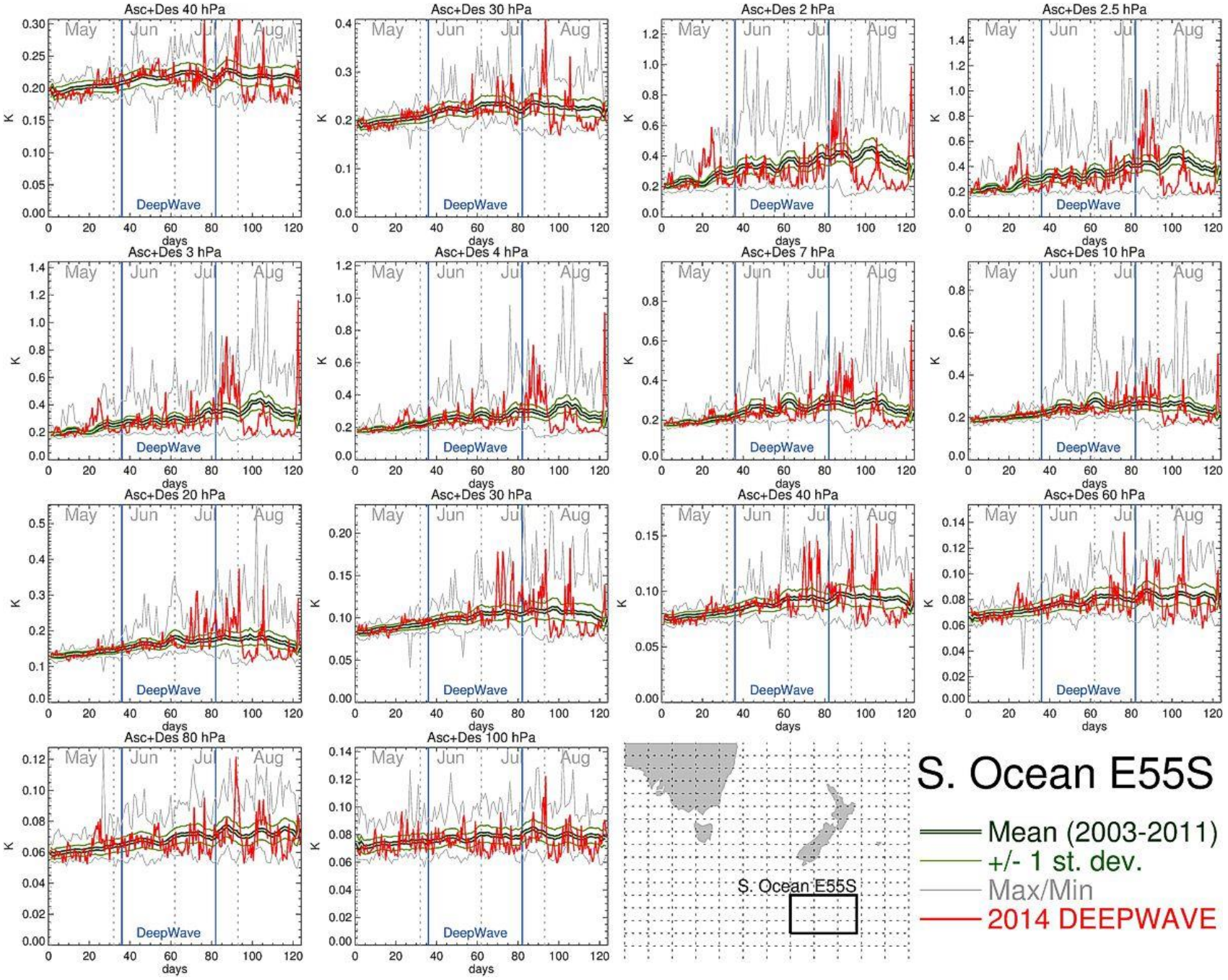
3

19-24 June




Asc+Des 40 hPa
Asc+Des 30 hPa
Asc+Des 2 hPa
Asc+Des 2.5 hPa
Asc+Des 3 hPa
Asc+Des 4 hPa
Asc+Des 7 hPa
Asc+Des 10 hPa
Asc+Des 20 hPa
Asc+Des 30 hPa
Asc+Des 40 hPa
Asc+Des 60 hPa
Asc+Des 80 hPa
Asc+Des 100 hPa
May
Jun
Jul
Aug
K
days
DeepWave
Tasmania
Mean (2003-2011)
+/- 1 st. dev.
Max/Min
2014 DEEPWAVE


Asc+Des 2 hPa
May
Jun
Jul
Aug
3.0
2.5
2.0
1.5
1.0
0.5
0.0
K
0
20
40
60
80
100
120
days
Deepwave


Asc+Des 40 hPa
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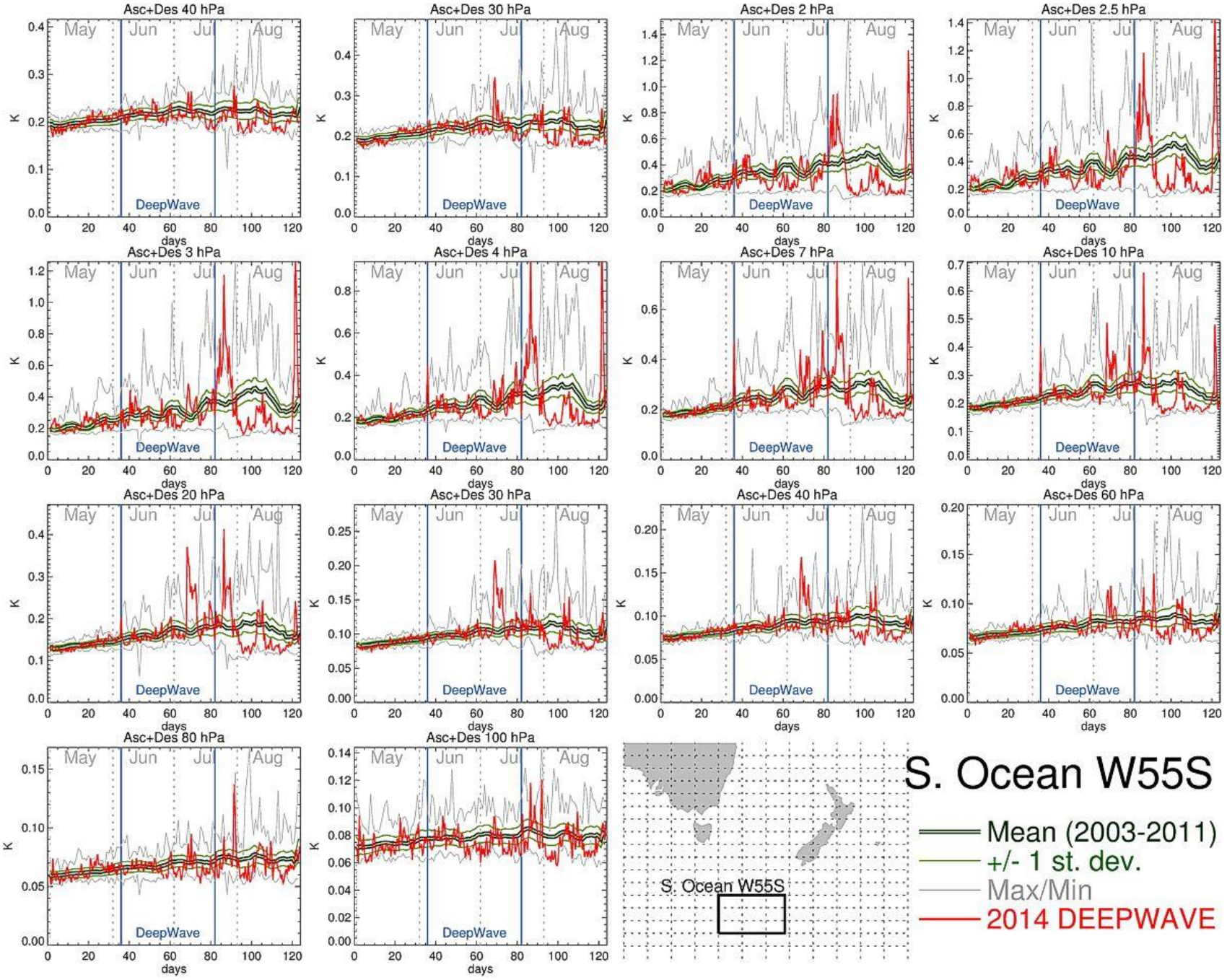
Asc+Des 3 hPa
Asc+Des 4 hPa
Asc+Des 7 hPa
Asc+Des 10 hPa
Asc+Des 20 hPa
Asc+Des 30 hPa
Asc+Des 40 hPa
Asc+Des 60 hPa
Asc+Des 80 hPa
Asc+Des 100 hPa
May
Jun
Jul
Aug
K
days
DeepWave
S. Ocean E55S
Mean (2003-2011)
+/- 1 st. dev.
Max/Min
2014 DEEPWAVE

DEEPWAVE 2014



DEEPWAVE Workshop

Steve Eckermann

Space Science Division, Naval Research Laboratory, Washington, DC, stephen.eckermann@nrl.navy.mil

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TOPICS

- AIRS Gravity-Wave Observations
- **NAVGEM Reanalysis Experiments**
- Plans

Goals of NAVGEM Reanalysis

- Analysis fields for DEEPWAVE MLT science above ECMWF and NIWA/UKMO upper boundaries at ~70-80 km.
- Lateral boundary conditions for COAMPS up to 90-100 km
- Backgrounds for ray models
- Platform for studying and tuning orographic and nonorographic gravity-wave drag parameterizations for DEEPWAVE

NAVGEM

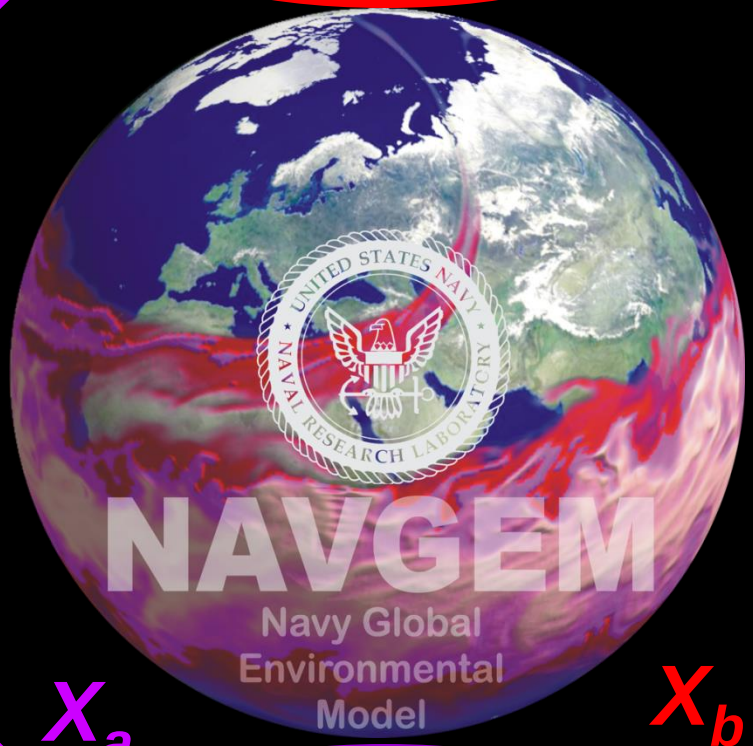
Navy Global Environmental Model

Global SLSI Forecast Model

0-10 Day Forecasts

0-9 Hour Forecasts

Global observations over next 0-6 hours



X_a

X_b

y

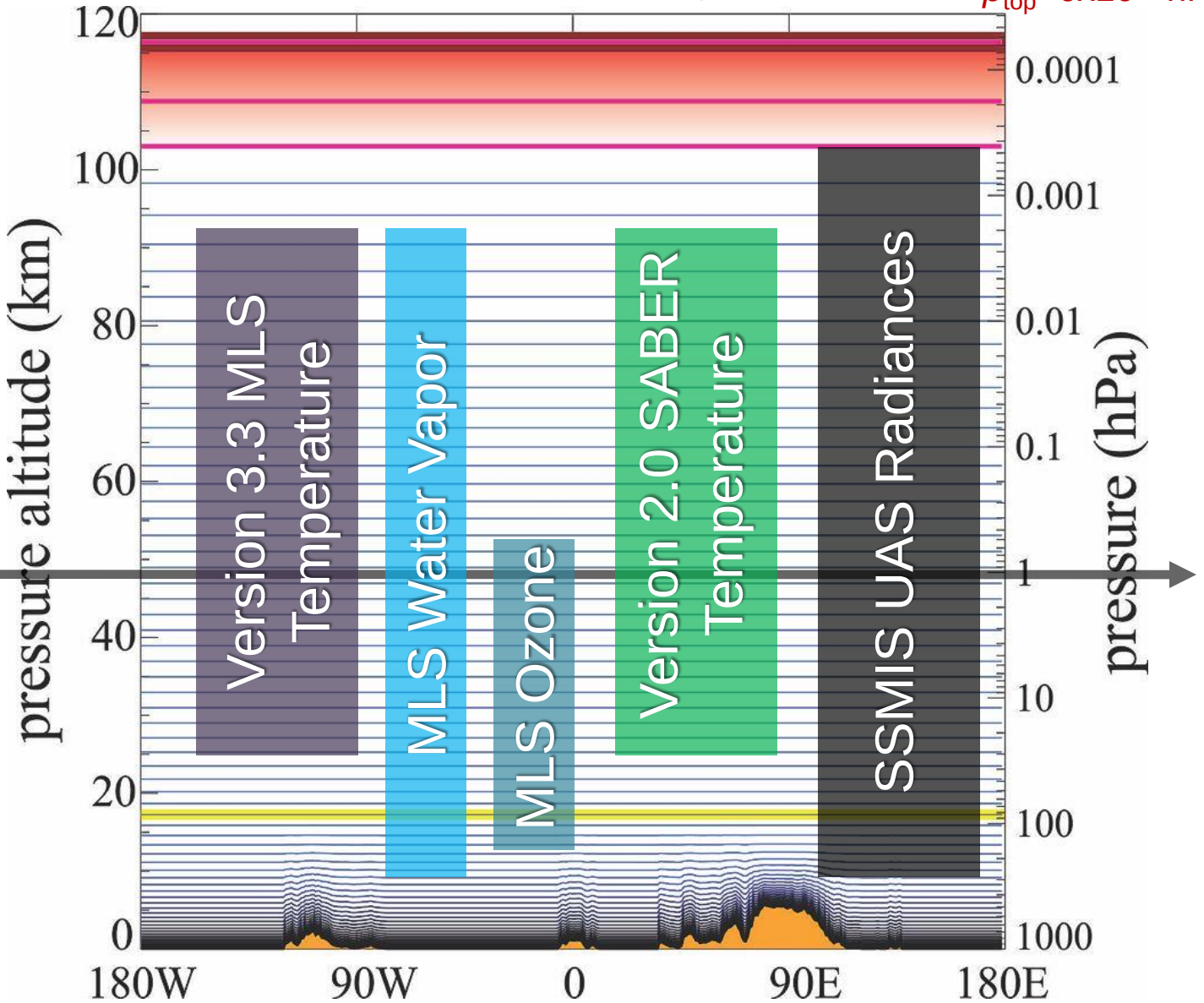
Data Assimilation System
NAVDAS-AR 4DVAR

6 hourly global analysis fields

NAVGEM T119L74

DEEPWAVE Reanalysis Runs

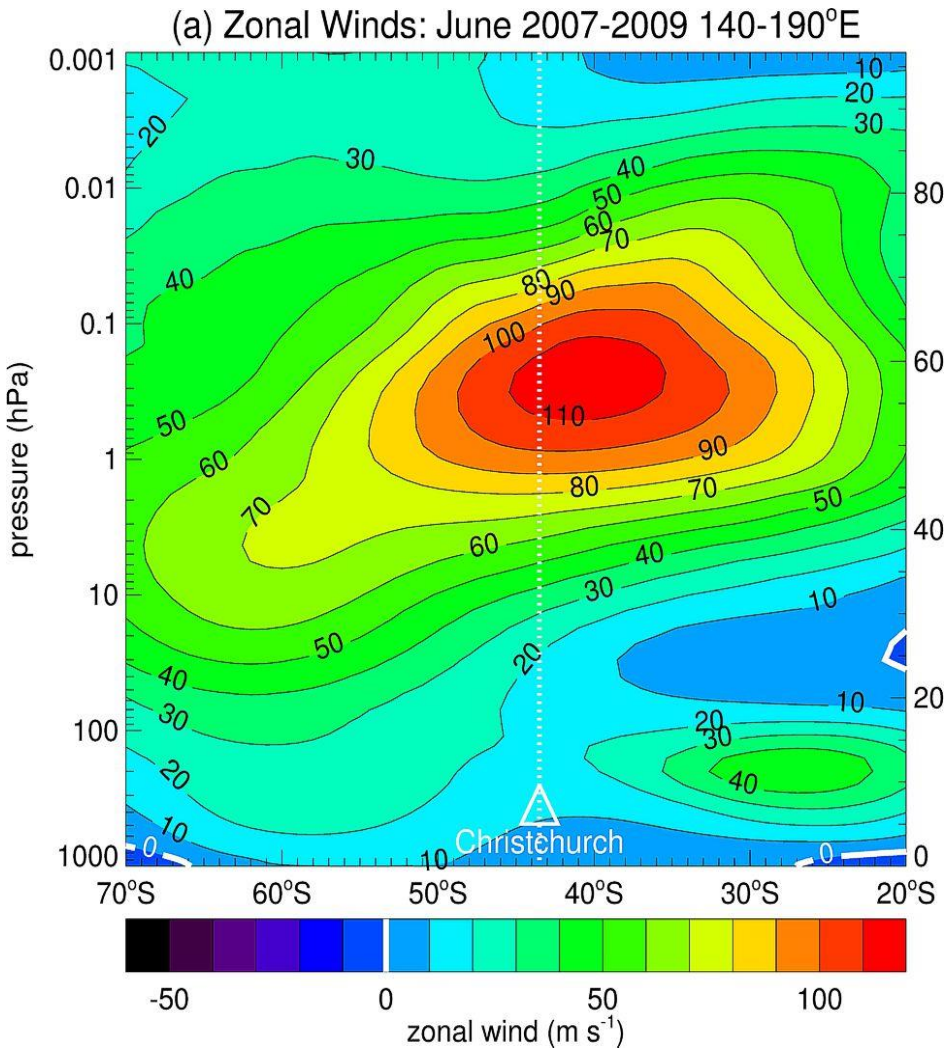
p_{top}=6x10^{-5} hPa



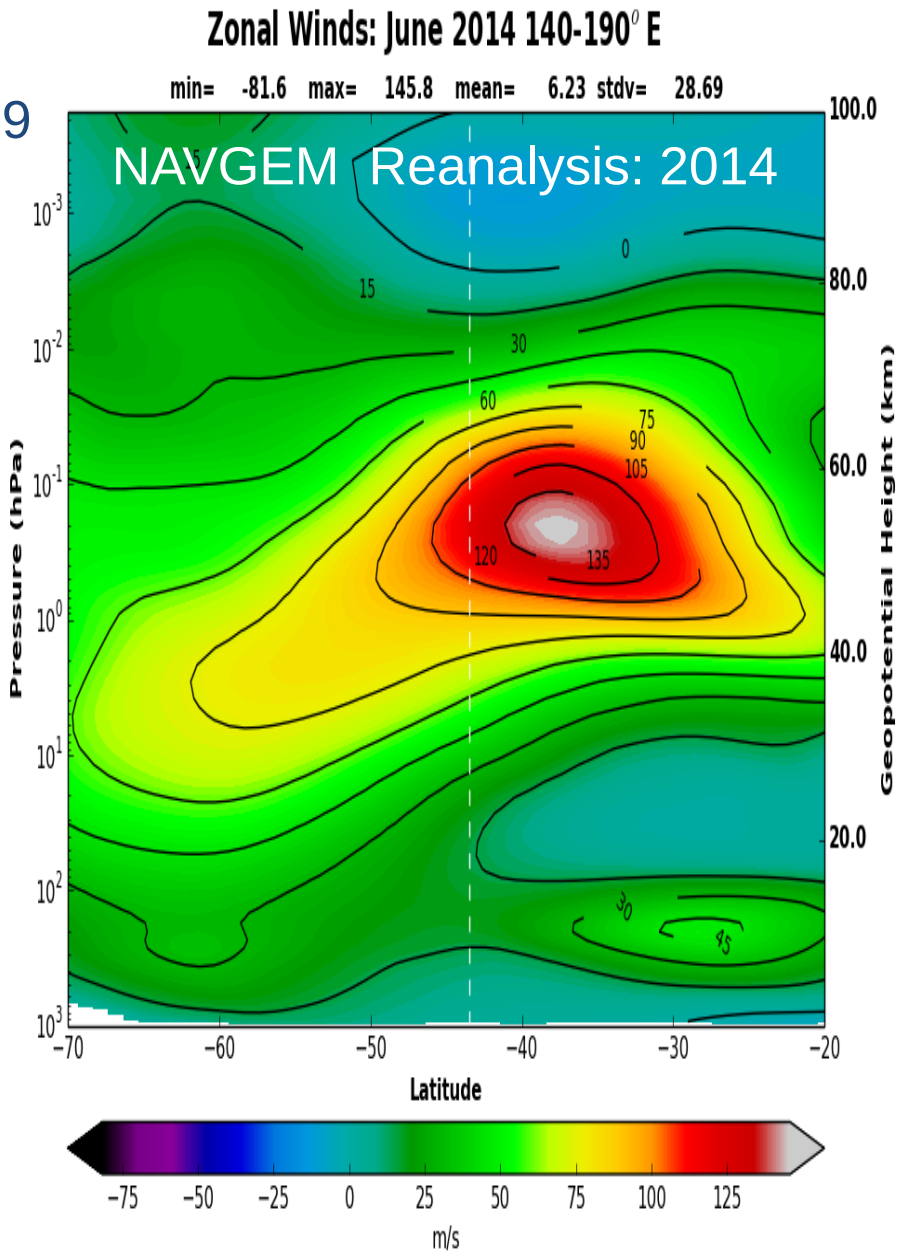
Top Data Insertion Operationally

Zonal Mean Winds for June

NOGAPS-ALPHA Reanalysis: 2007-2009

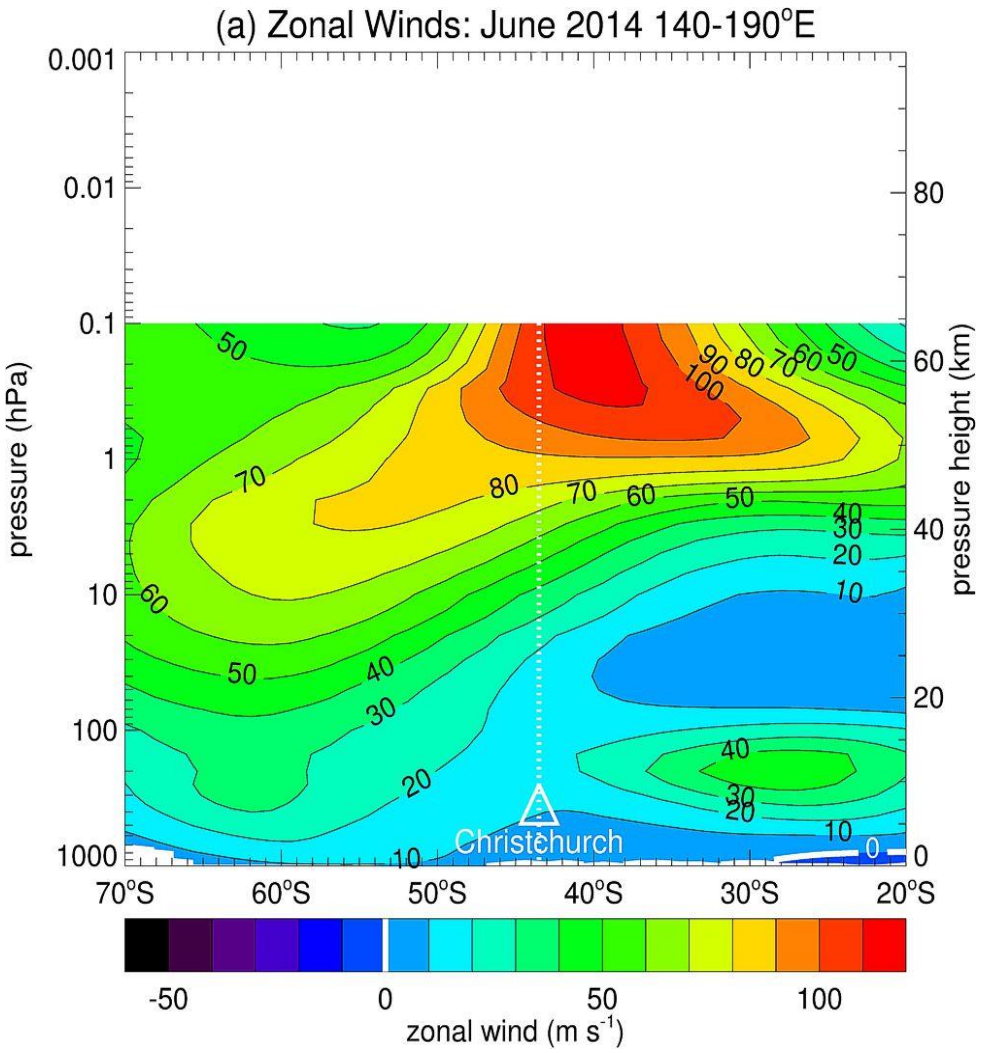


NAVGEM Reanalysis: 2014

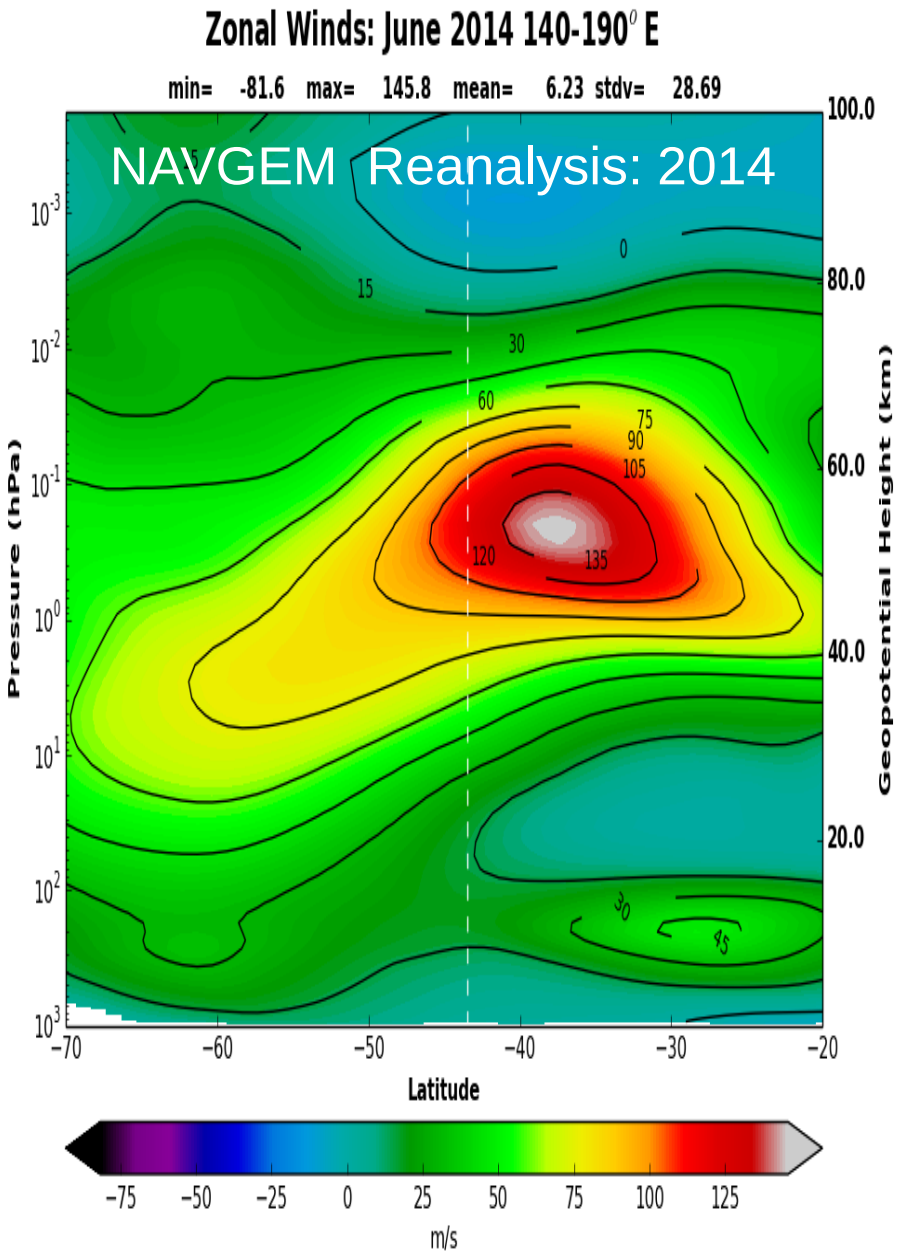


Zonal Mean Winds for June

NASA MERRA Reanalysis: 2014

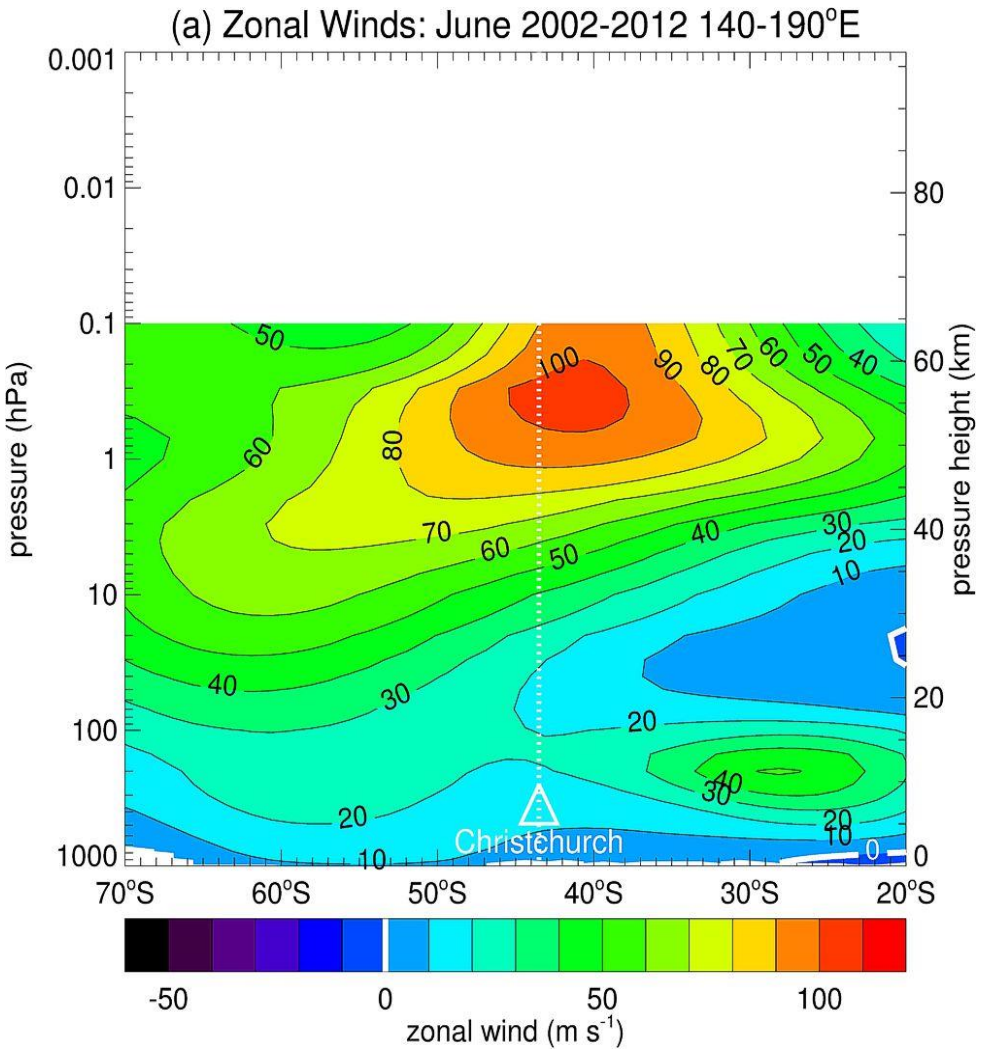


NAVGEM Reanalysis: 2014

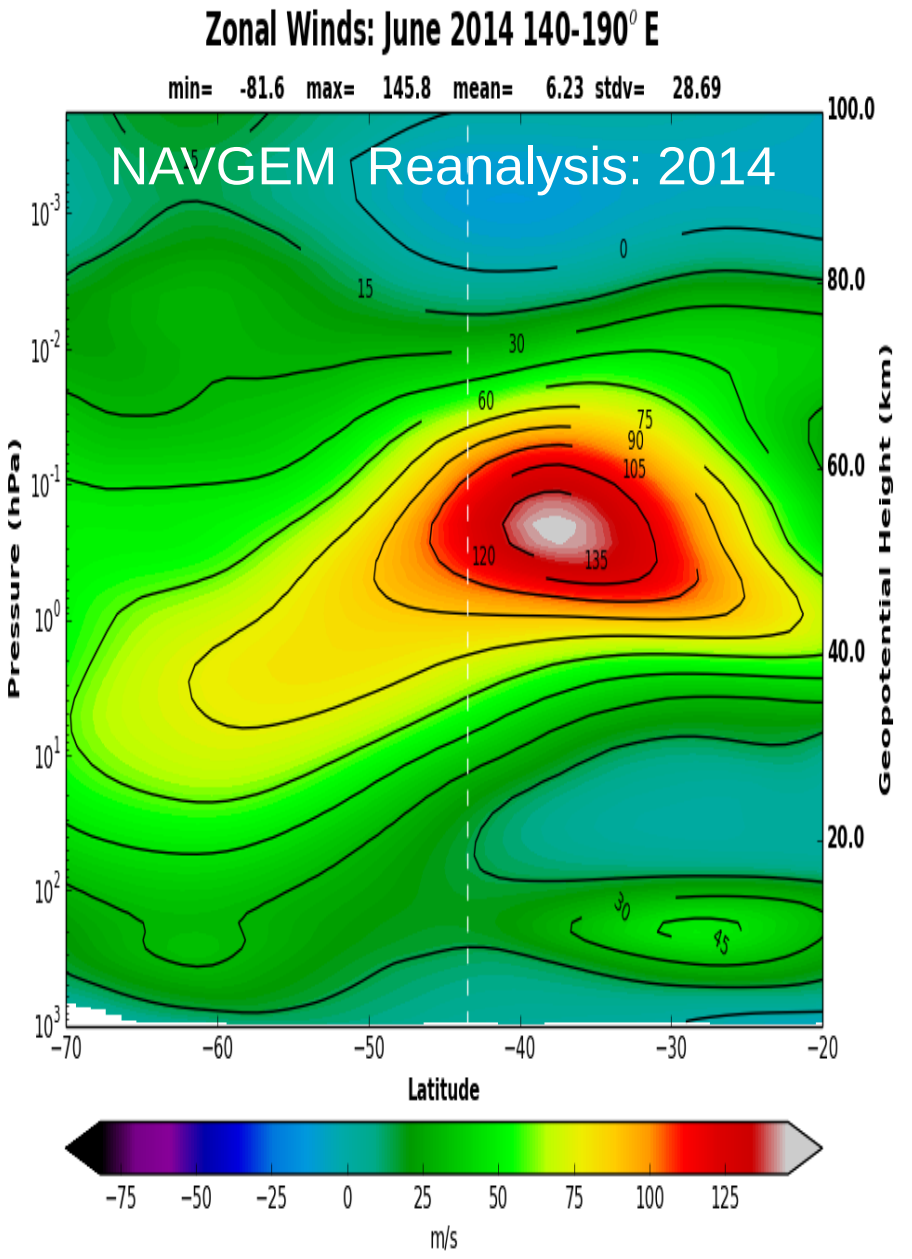


Zonal Mean Winds for June

NASA MERRA Reanalysis: 2002-2012

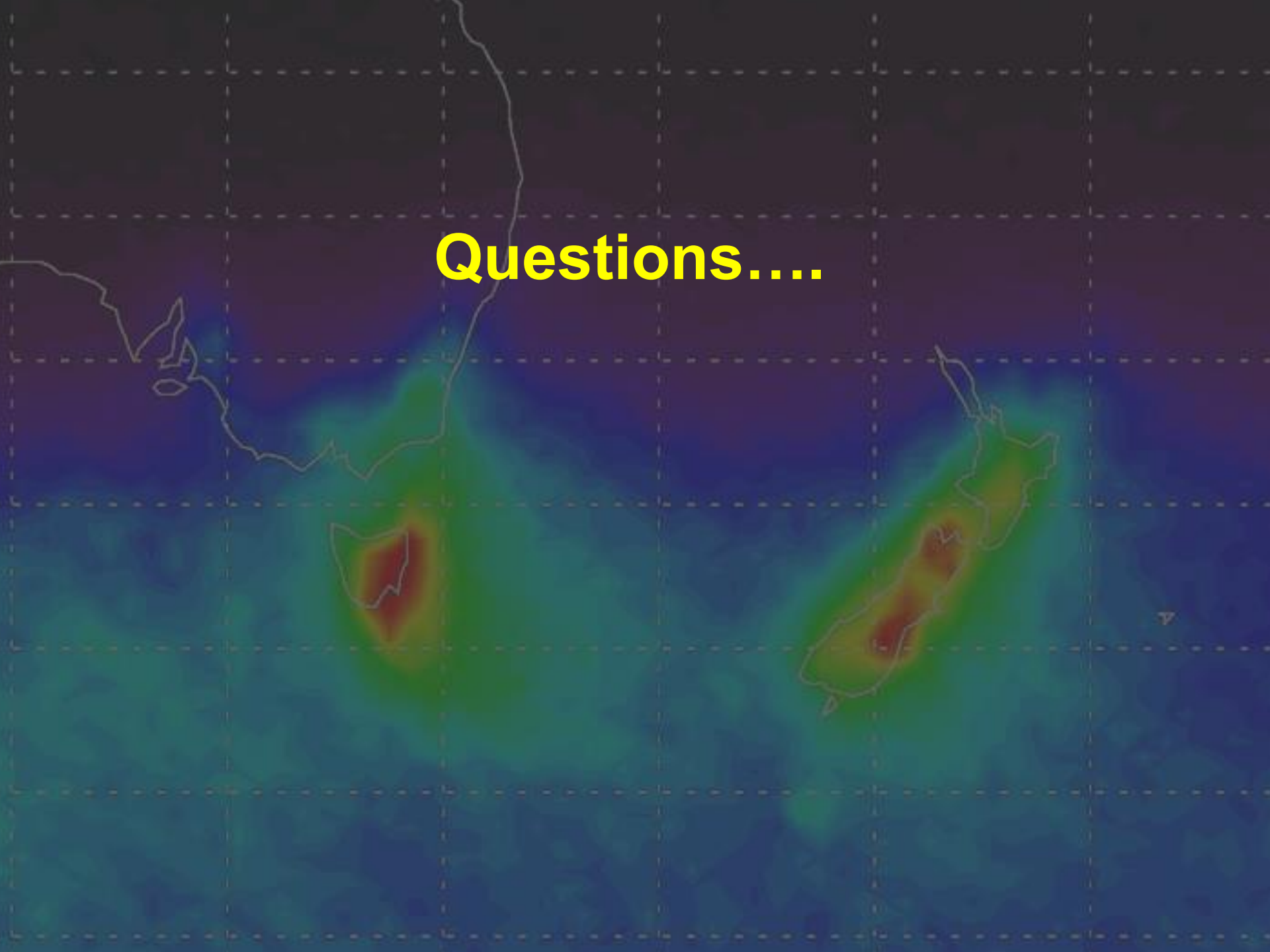


NAVGEM Reanalysis: 2014



Summary/Plans

- Not sure yet which events to focus on with which tools (workshop priority – action items and collabs)
- AIRS-focused DEEPWAVE methods and first-results paper [?]
- Forward model Rayleigh lidar and COAMPS/WRF GW temperature fields for detailed comparisons with AIRS observations
- Continue NAVGEM analysis experiments, validate against DEEPWAVE 0-100 km observations, tuned GWD parameterizations
- Detailed GW event studies with ray models and COAMPS/NAVGEM


Questions….

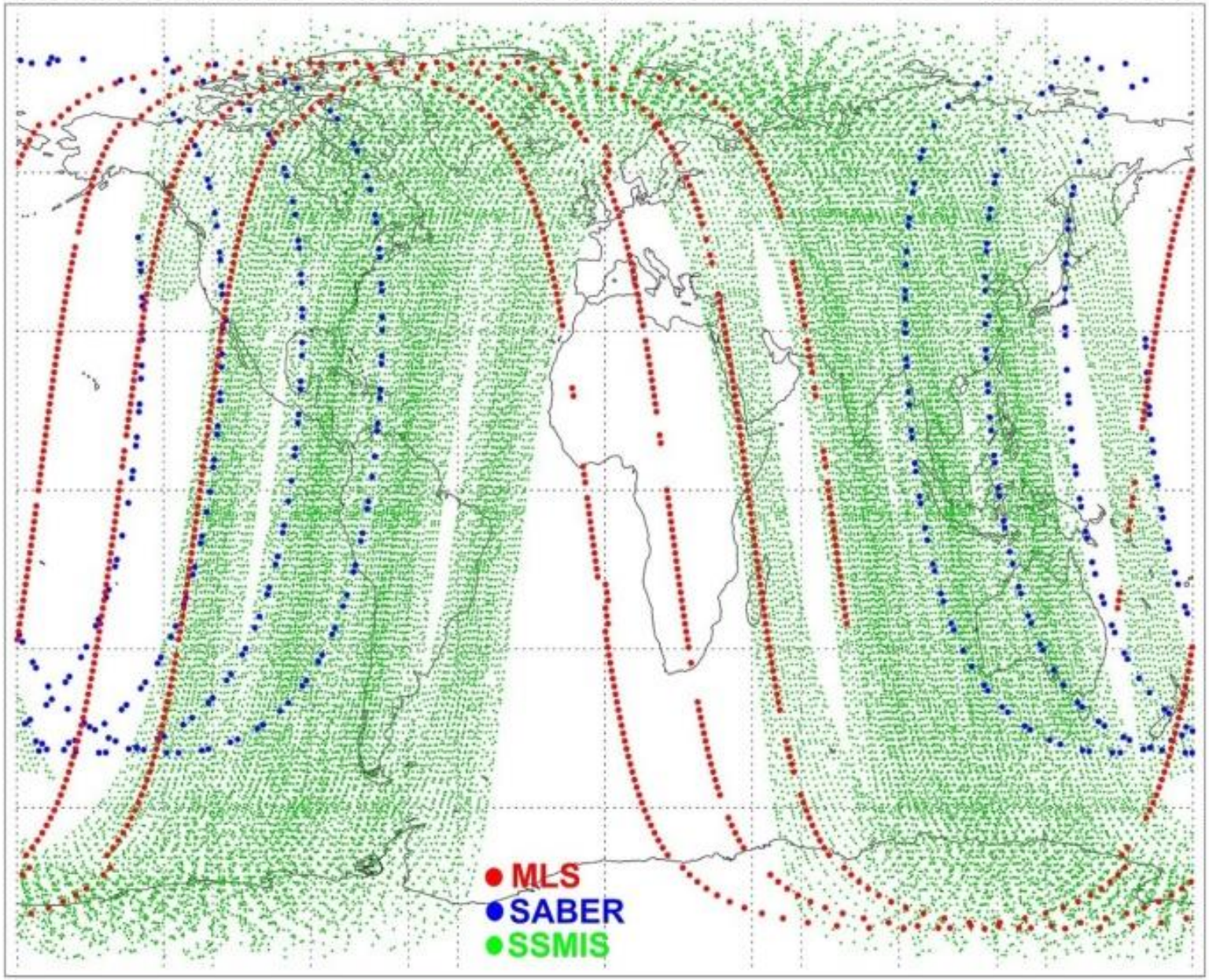
Variation of Gravity-Wave Vertical Wavelength with Winds

$$\lambda_Z = \frac{2\pi\left|c - \bar{U}\cos\left(\phi - \varphi\right)\right|}{N} \propto \bar{U}$$

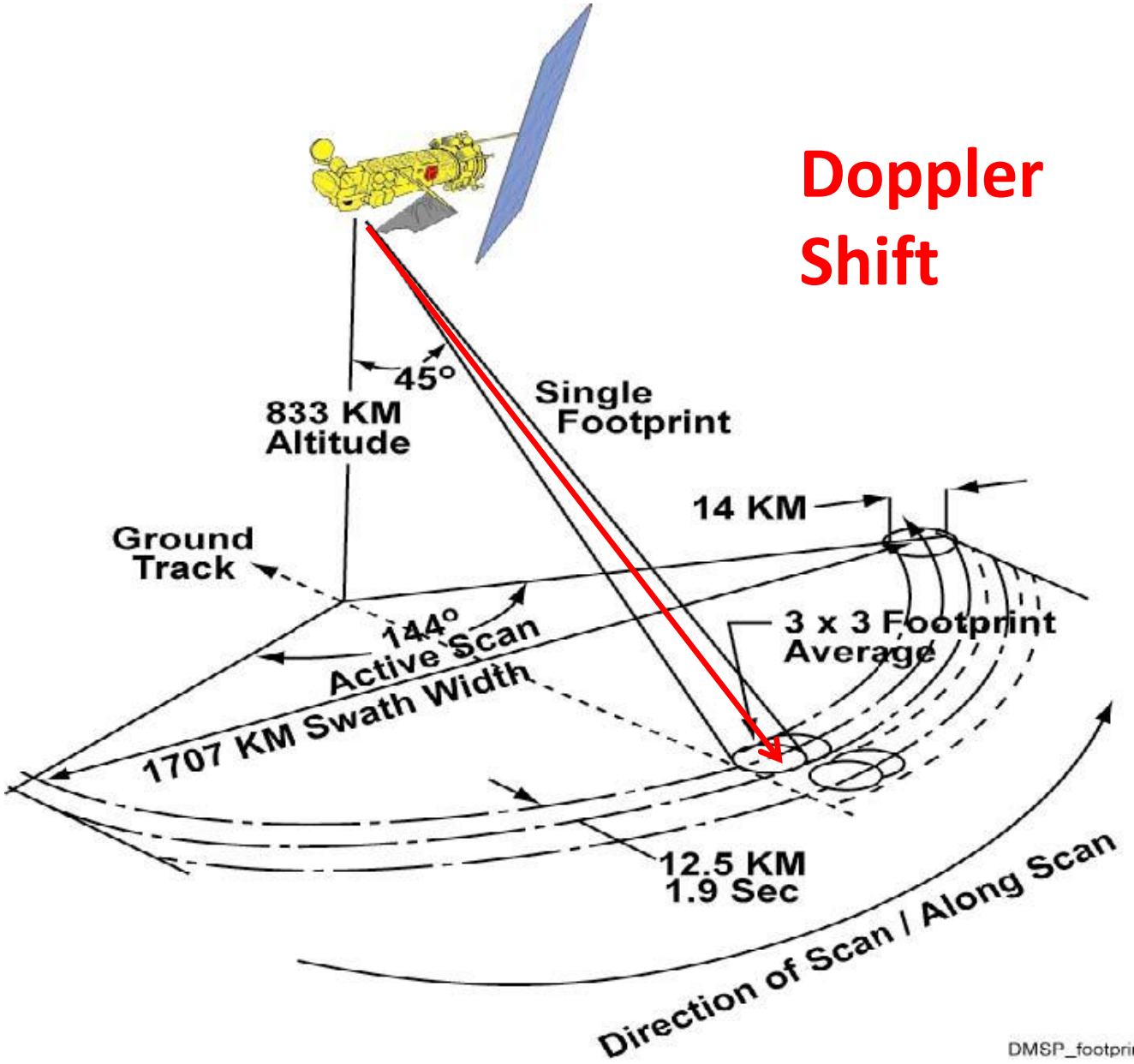
φ	wind vector azimuth
ϕ	wave vector azimuth
λ_Z	gravity-wave vertical wavelength
c	gravity-wave phase velocity ($c \approx 0$)
N	background buoyancy frequency
$\bar{U}$	background wind speed

DEEPWAVE 2014

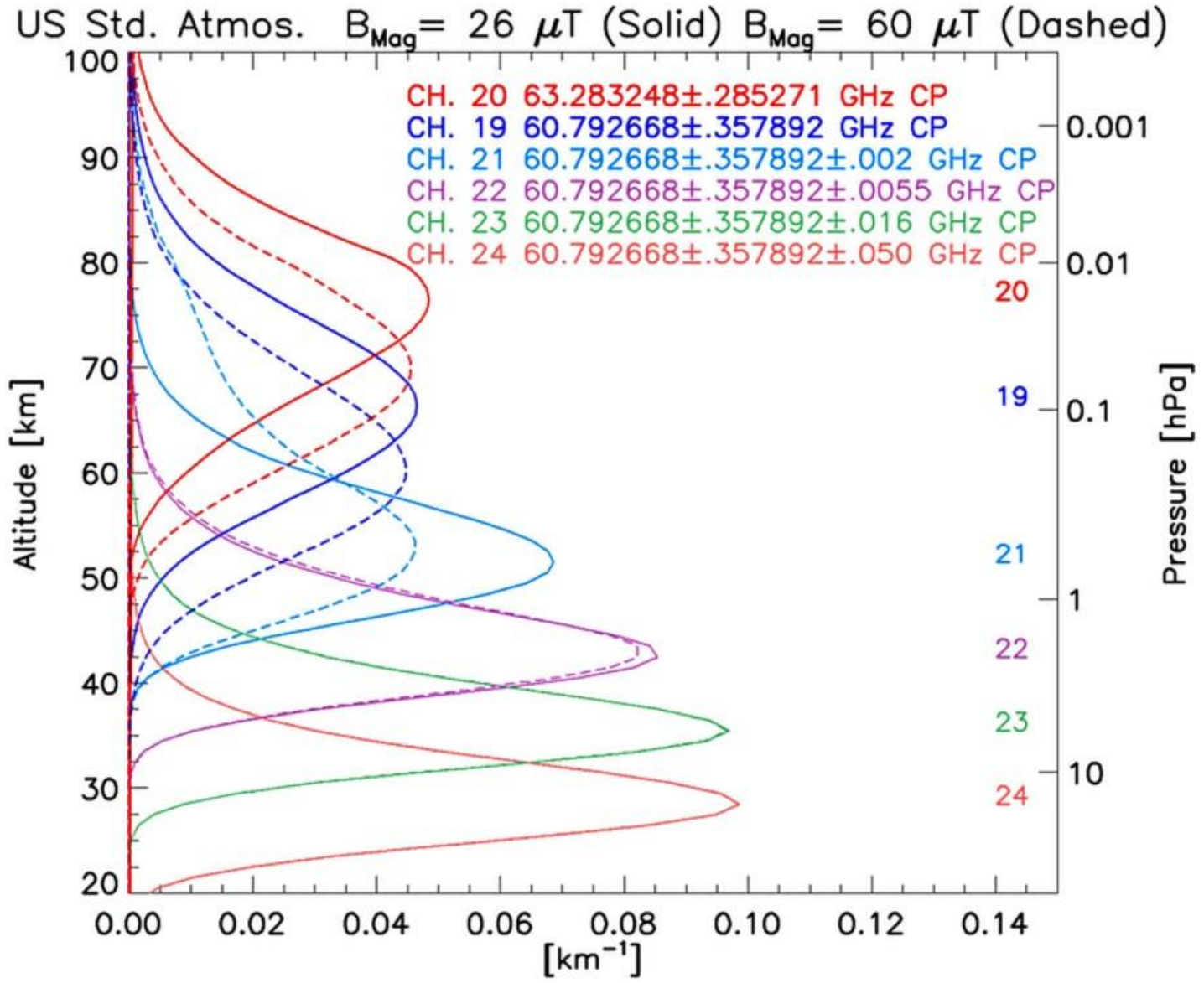
Observation Points: 10 June 2010 0900-1500 UTC



SSMIS on DMSP F16-F19

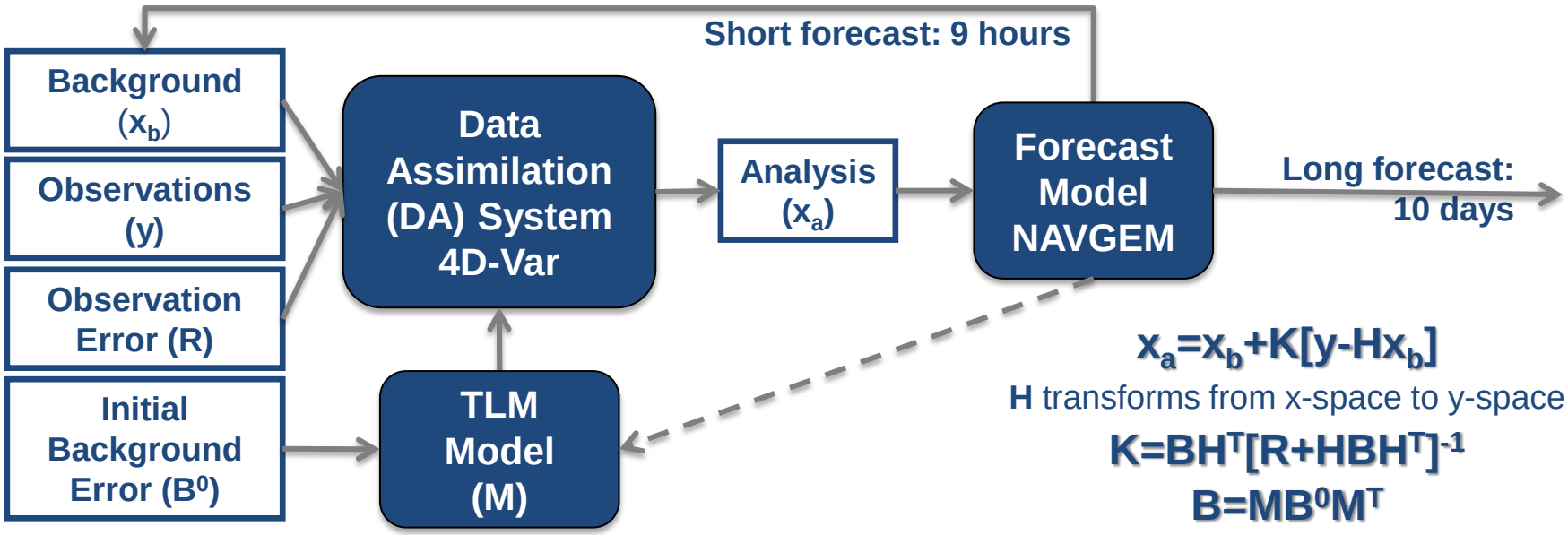


Zeeman Line Splitting by Geomagnetic Fields



NAVDAS-AR

NRL Atmospheric Variational DAS (Accelerated Representer: 4DVAR)



NAVDAS-AR

- Numerically minimize the scalar cost function

$$J(\mathbf{x_a}) = (\mathbf{y} - \mathcal{H}(\mathbf{x_a}))^T \mathbf{R}^{-1} (\mathbf{y} - \mathcal{H}(\mathbf{x_a})) + (\mathbf{x_b} - \mathbf{x_a})^T \mathbf{P_b}^{-1} (\mathbf{x_b} - \mathbf{x_a})$$

observation vector $\mathbf{y}$

obs. error covariance

forward obs. operator

background vector $\mathbf{x_b}$

bgnd. error covariance

analysis vector $\mathbf{x_a}$

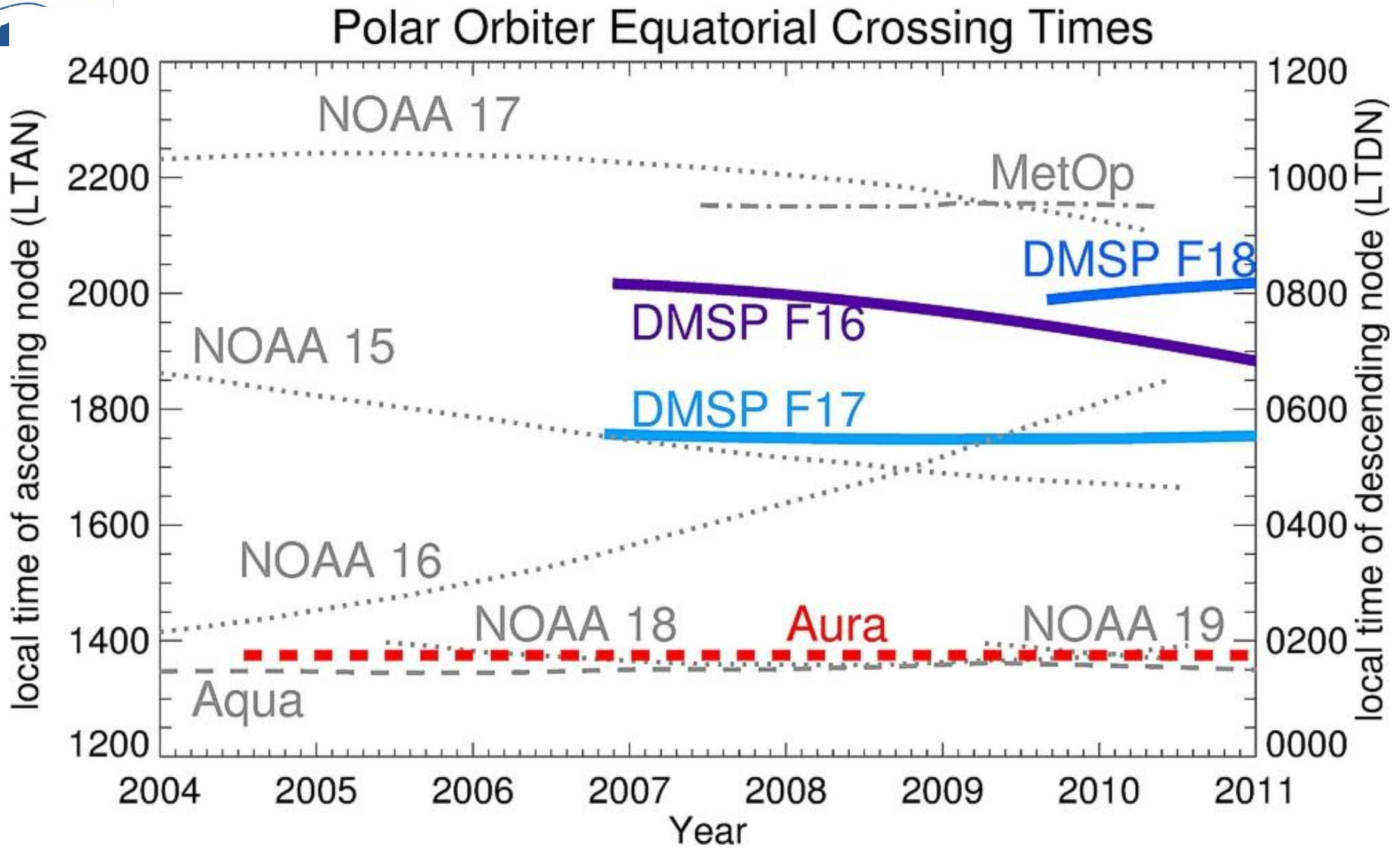
- NAVDAS computes the observation-space solution

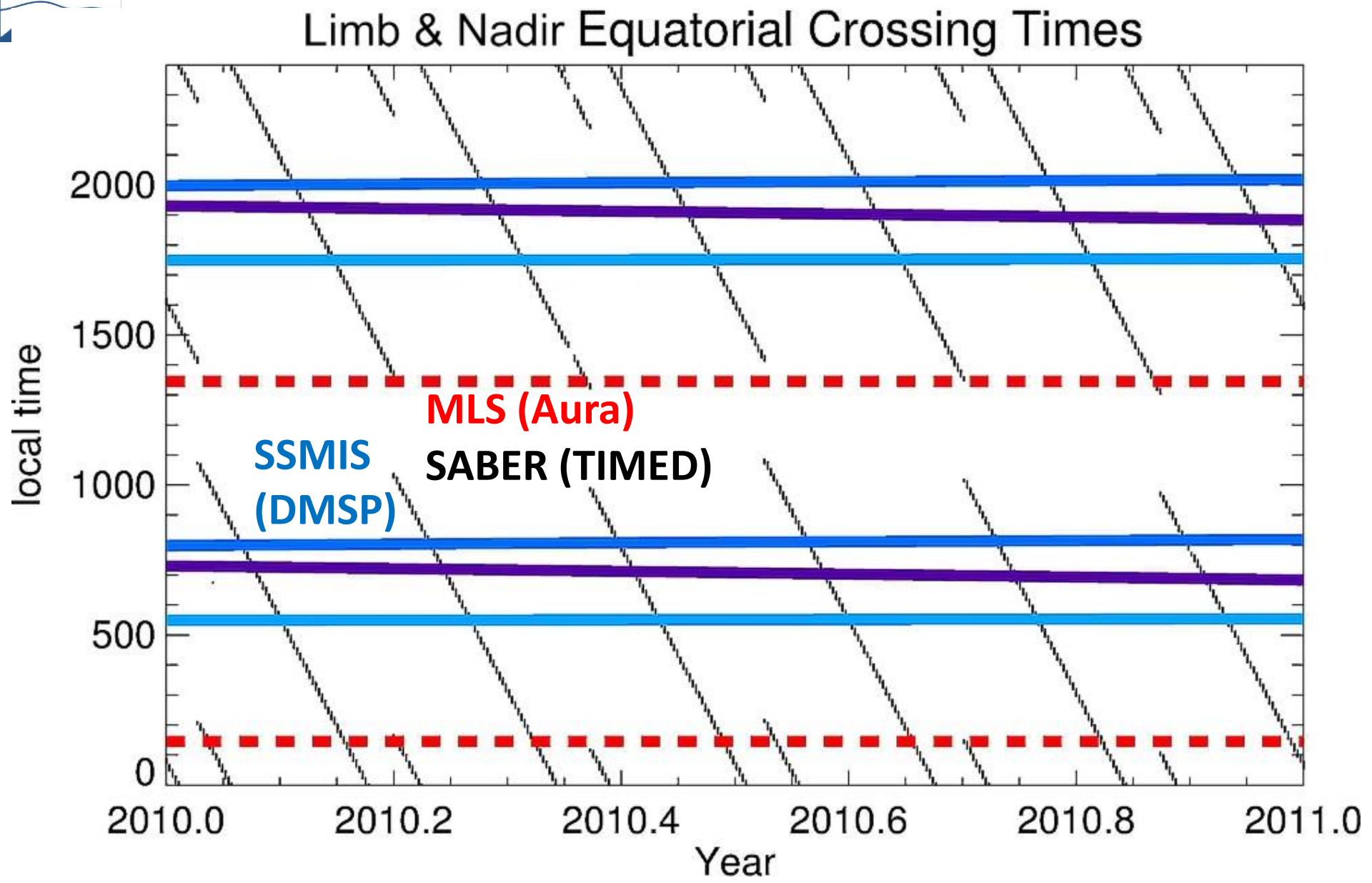
$$\mathbf{x_a} - \mathbf{x_b} = \mathbf{P_b H}^T \left[\mathbf{H P_b H}^T + \mathbf{R}\right]^{-1} [\mathbf{y} - \mathcal{H}(\mathbf{x_b})]$$

corrections

Solution converts ***"innovation" vectors*** in the observation space into ***"correction" or "increment" vectors*** in the model/analysis space.

innovations


Polar Orbiter Equatorial Crossing Times
local time of ascending node (LTAN)
local time of descending node (LTDN)
2400
2200
2000
1800
1600
1400
1200
1200
1000
0800
0600
0400
0200
0000
2004
2005
2006
2007
2008
2009
2010
2011
Year
NOAA 17
MetOp
DMSP F18
DMSP F16
NOAA 15
DMSP F17
NOAA 16
NOAA 18
Aura
NOAA 19
Aqua


Limb & Nadir Equatorial Crossing Times
local time
2000
1500
1000
500
0
MLS (Aura)
SSMIS
(DMSP)
SABER (TIMED)
2010.0
2010.2
2010.4
2010.6
2010.8
2011.0
Year

Channel Averaging to Reduce Noise

- 50 raw stratospheric channel radiances →12 net stratospheric channel radiances
- See Gong, Wu and Eckermann (Atmos. Chem. Phys., 2012) for details

Pressure (hPa)	Channel numbers	Noise (K^2)	NEdT (K^2)	Min. detectable GW var. ($\times 10^{-3}$ K^2) Zonal mean	Min. detectable GW var. ($\times 10^{-3}$ K^2) Map
2	74	0.149	0.165	3.78	26.64
2.5	75	0.147	0.166	3.72	26.22
3	76	0.143	0.161	3.63	25.55
4	77	0.145	0.160	3.66	25.80
7	**78**	0.153	0.162	3.88	27.34
10	**79**	0.182	0.172	4.62	32.53
20	81, 82	0.084	0.078	2.14	15.05
30	**102**, **108**, **114**, **120**, 125, 126	0.039	0.029	0.98	6.88
40	64, 88, 90, **94**, **100**, 106, 118	0.033	0.028	0.83	5.86
60	66, 68, 70, 86, 87, 91, 93, **97**, 130	0.026	0.018	0.66	4.68
80	92, 98, 104, 105, 110, 111, **116**, 117, 122, 123, 128, 129, 134, 140	0.020	0.011	0.50	3.54
100	132, 133, 138, 139, 149, 152	0.026	0.014	0.67	4.73

NOGAPS-*ALPHA*

Navy Operational Global Atmospheric Prediction System –
Advanced Level Physics, High Altitude

Global Eulerian
Spectral Model

0-10 Day Forecasts

6-hourly update cycle

0-9 Hour Forecasts

Global 0-100 km observations over next 0-6 hours

X_a

X_b

Data Assimilation System
NAVDAS 3DVAR

y

6 hourly global 0-100 km analysis fields