Update on Satellite GW Products and Forward Model for DEEPWAVE Science

Steve Eckermann

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

OUTLINE:

Analysis of AIRS and CrIS GW Products Continues

Meaningful Model/Data Comparisons Requires a Forward Model to Connect Model Fields to Data

Forward Models for DEEPWAVE Science

- Representative vertical weighting functions
- Full 3D forward model capability

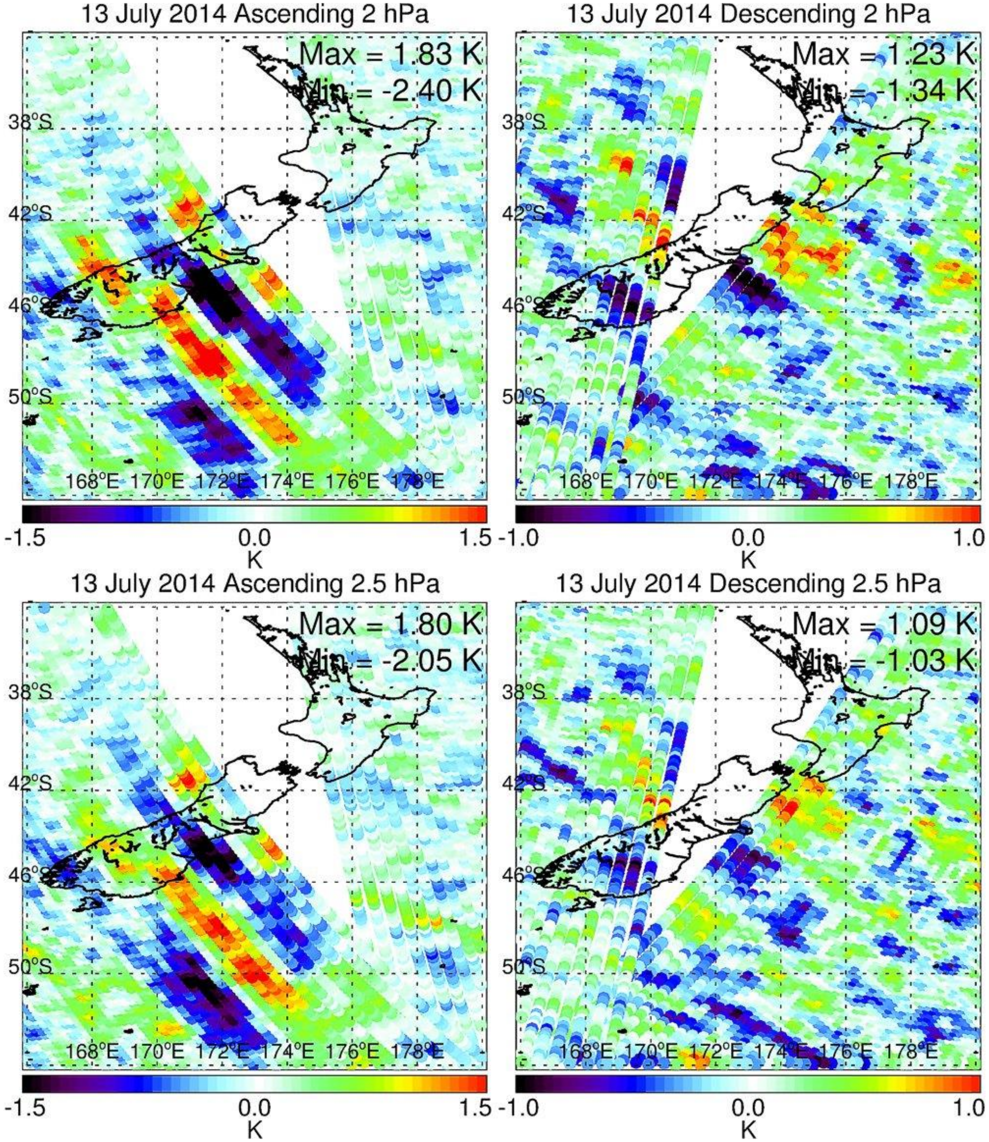
Acknowledgements

NRL's DEEPWAVE research and support is/was supported by:

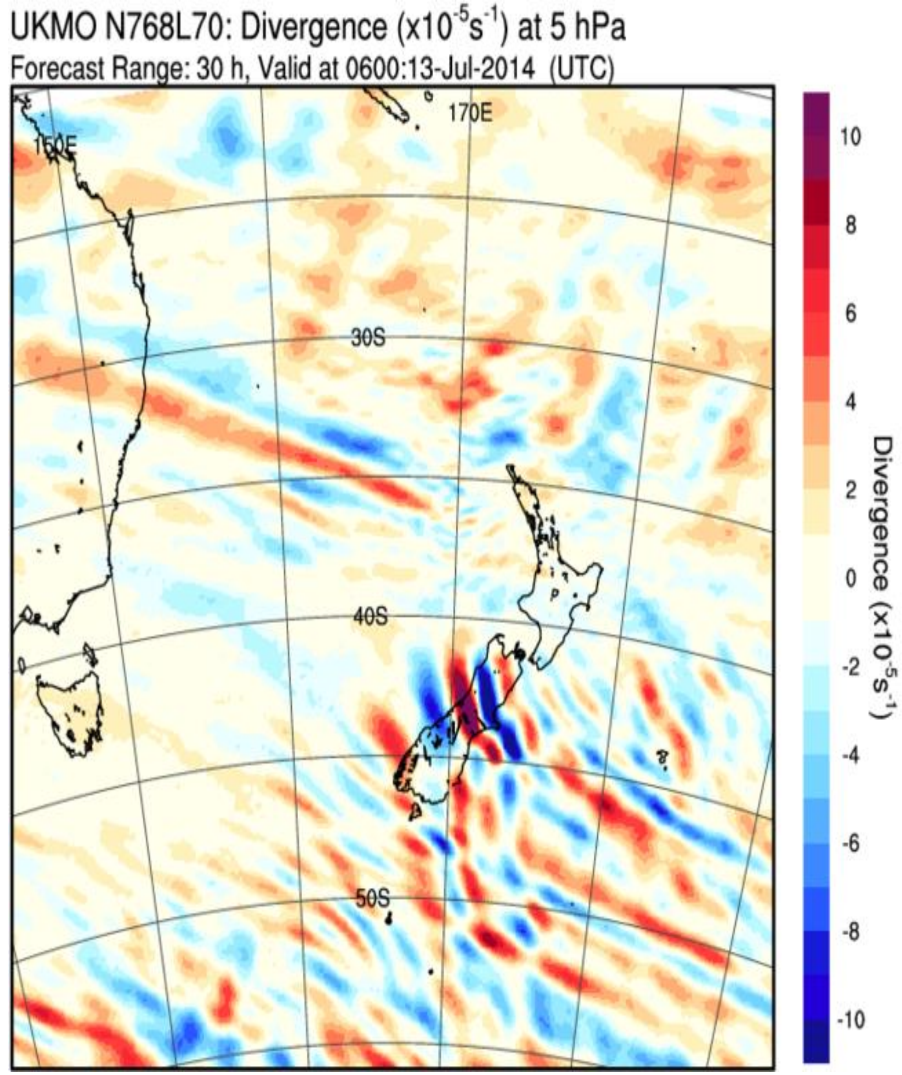
- The Chief of Naval Research (CNR) through the NRL base 6.1 and 6.2 research program
- The Office of Naval Research (ONR) Departmental Research Initiative (DRI)"Predictability of Seasonal and Intraseasonal Oscillations."
- The National Science Foundation
- The Oceanographer of the Navy through PMW-120/SPAWAR 6.4 transition contracts
- NASA through the Heliophysics Division SR&T and GI programs.

The Model/Data Comparison Issue

Channel Brightness Temperature $T'_B(x_S, y_S)$



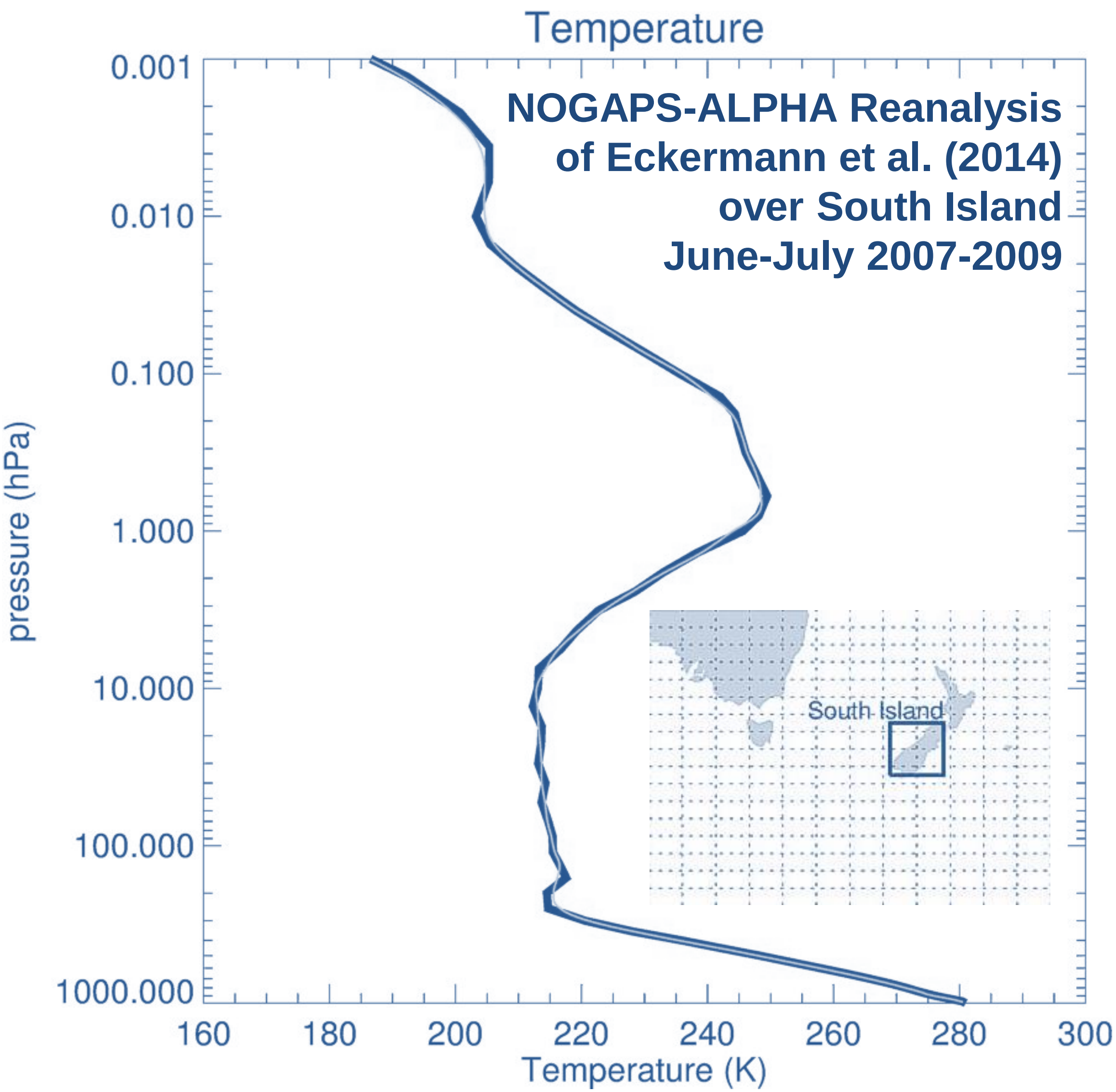
Divergence $D(x,y,p,t)$ p=5 hPa t=0600Z

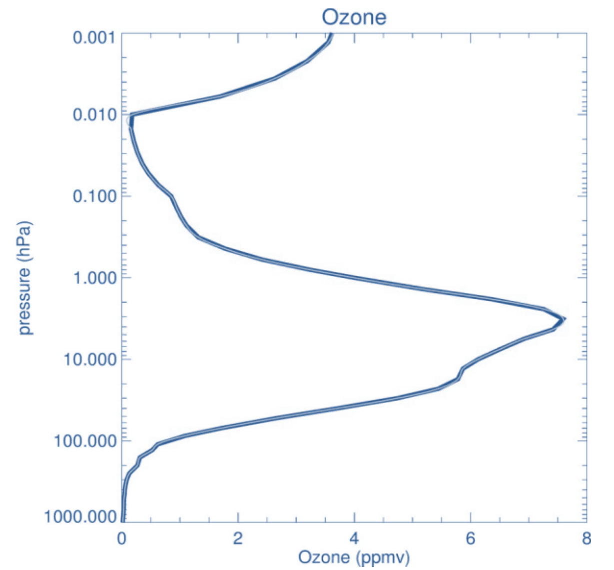


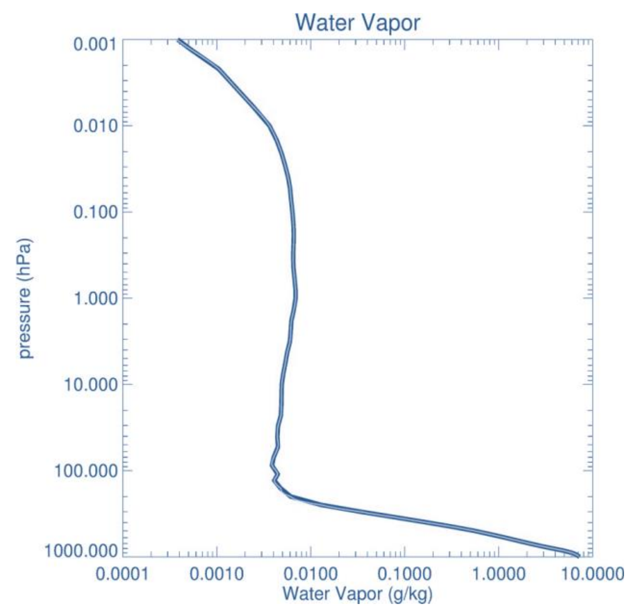
Community Radiative Transfer Model v2.1.3 (CRTM)

- State-of-the-art operational radiative transfer (RT) model supported by Joint Center for Satellite Data Assimilation and used for radiance assimilation by US operational centers (e.g. NAVGEM)
- Updates AIRS and CrIS transmittance coefficients for all IR channel bands
- V2.1 includes non-LTE IR physics for upper altitudes (Chen et al. JOAT 2013)
- Includes Zeeman splitting of high-altitude microwave radiances.
- Allows user-specified channel subsets

Mean Profiles for Austral Winter







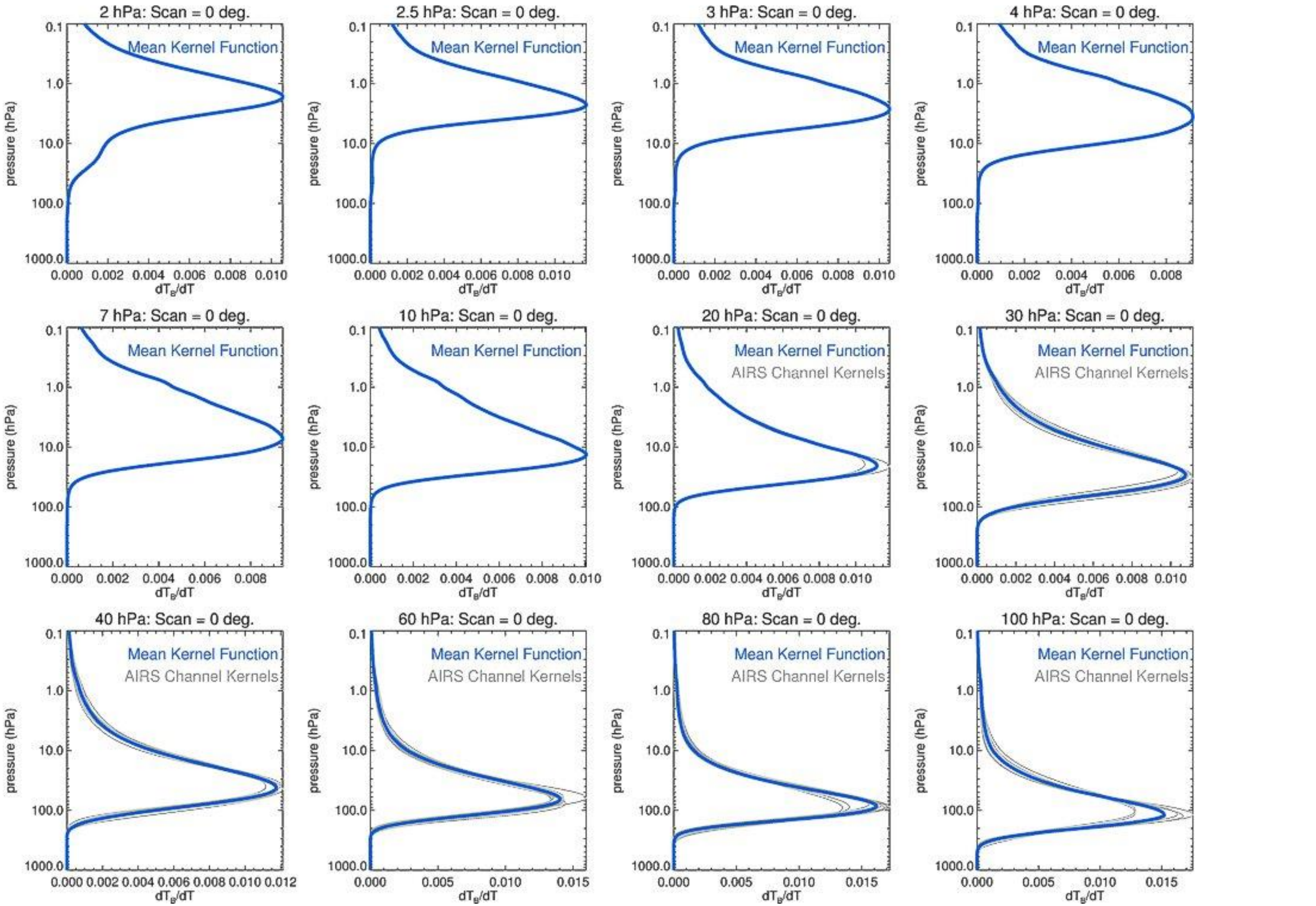
AIRS Channel Averaging

50 raw channels → 12 net channels

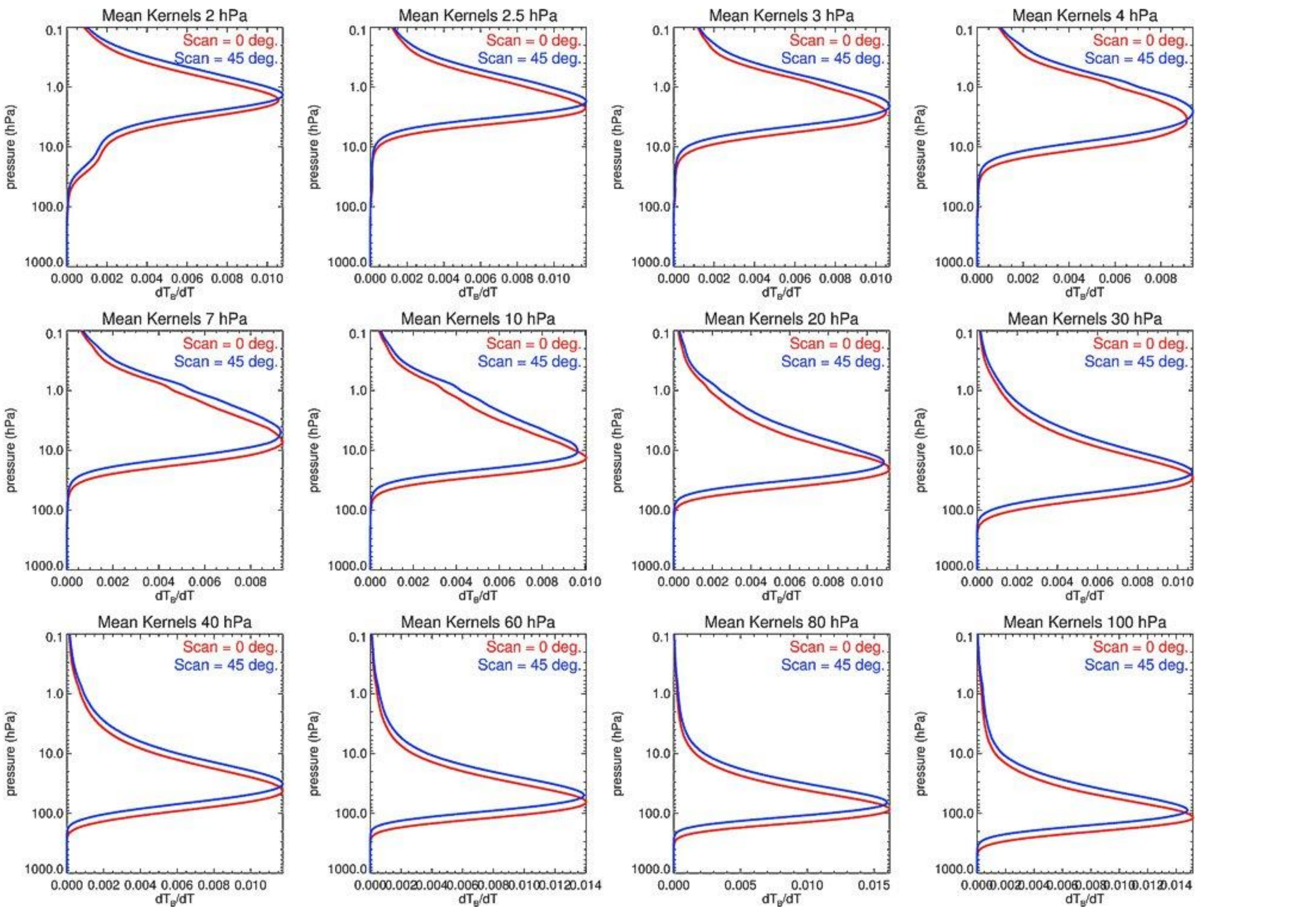
Gong Wu & Eckermann (Atmos. Chem. Phys., 12, 1701-1720, 2012)

				Min. detectable GW var. ($\times 10^{-3}$ K^2)	
Pressure (hPa)	Channel numbers	Noise (K^2)	NEdT (K^2)	Zonal mean	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

AIRS Vertical Weighting Functions



AIRS WF Variation with Scan Angle



Two Options for DEEPWAVE Model/AIRS GW Comparisons

Comparing model GWs to AIRS GWs requires a forward model to convert 3D model $T'(x,y,z)$ fields into a $T'_B(x,y)$ fields along measurement swaths

Option 1 (Simple): $W(z,\alpha)$ can now be sent to modelers

$$T_B(x_S,y_S) = \int_0^{z_S} W(z,\alpha) T(x,y,z,t)\,dz$$

$$T'_B(x_S,y_S) = T_B(x_S,y_S) - \overline{T_B}(x_S,y_S)$$

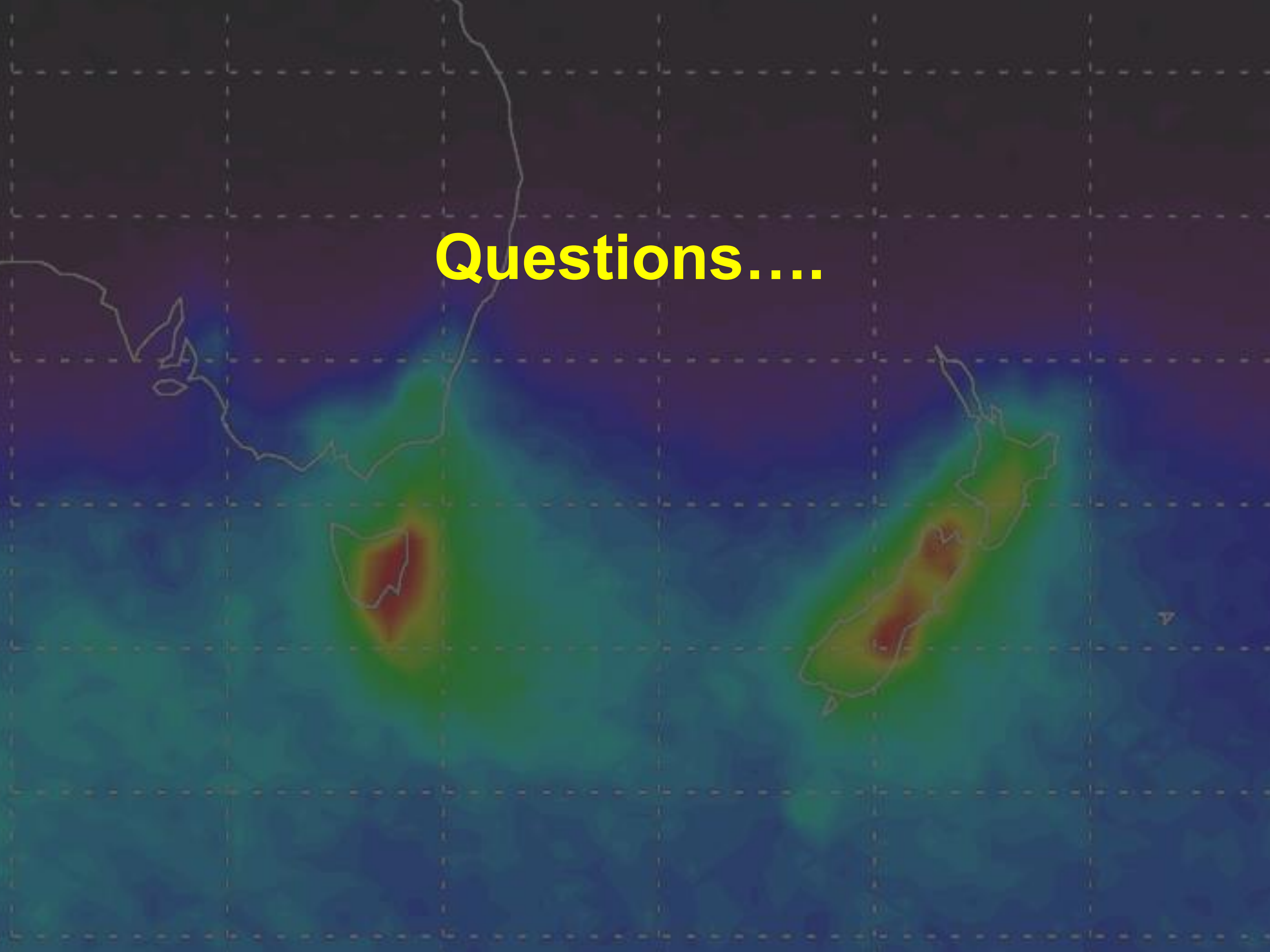
or

$$T'(x,y,z) = T(x,y,z) - \bar{T}(x,y,z)$$

$$T'_B(x_S,y_S) = \int_0^{z_S} W(z,\alpha) T'(x,y,z,t)\,dz$$

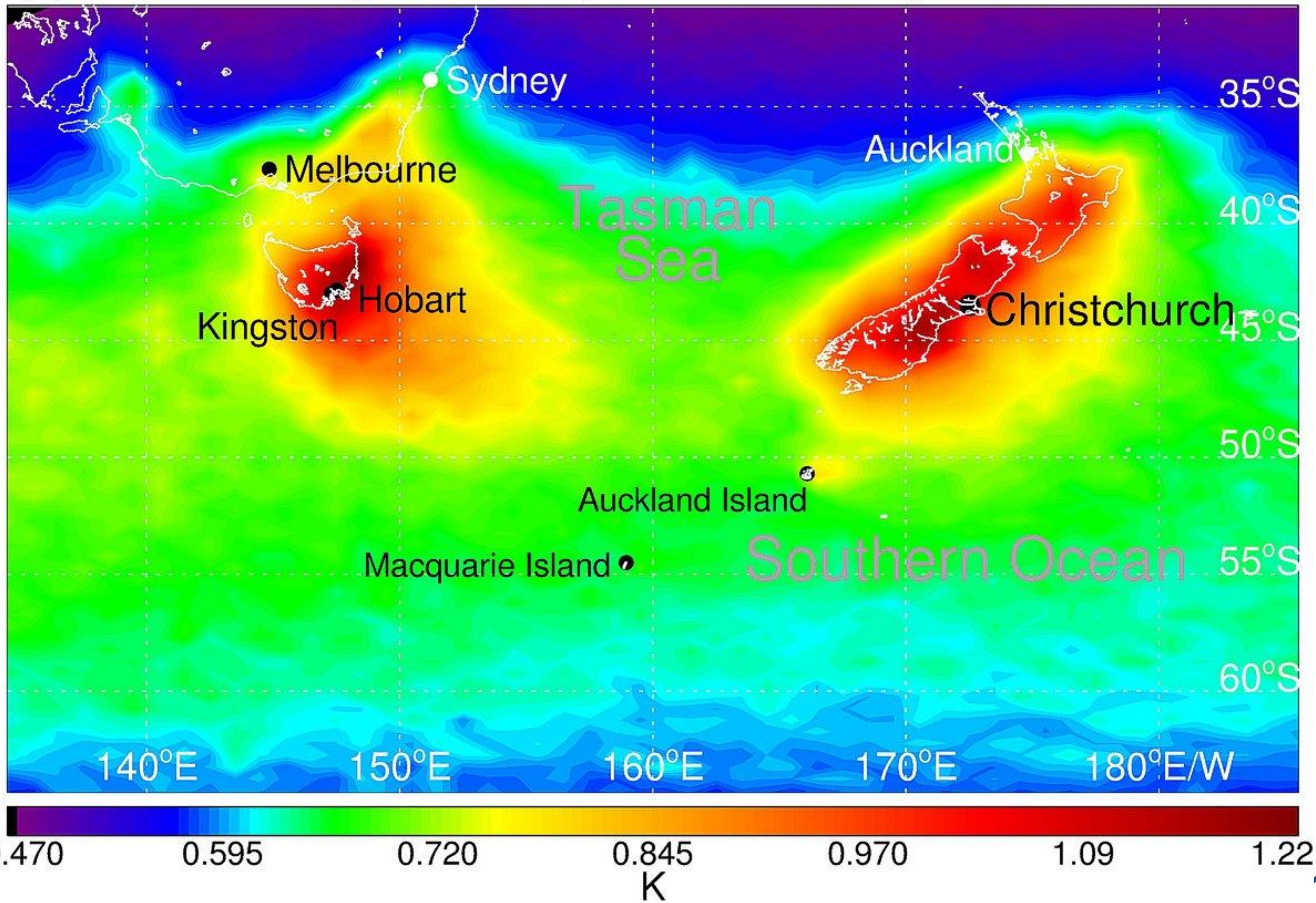
Option 2 (Brute Force): Working at NRLDC, not readily distributable as yet

Questions….

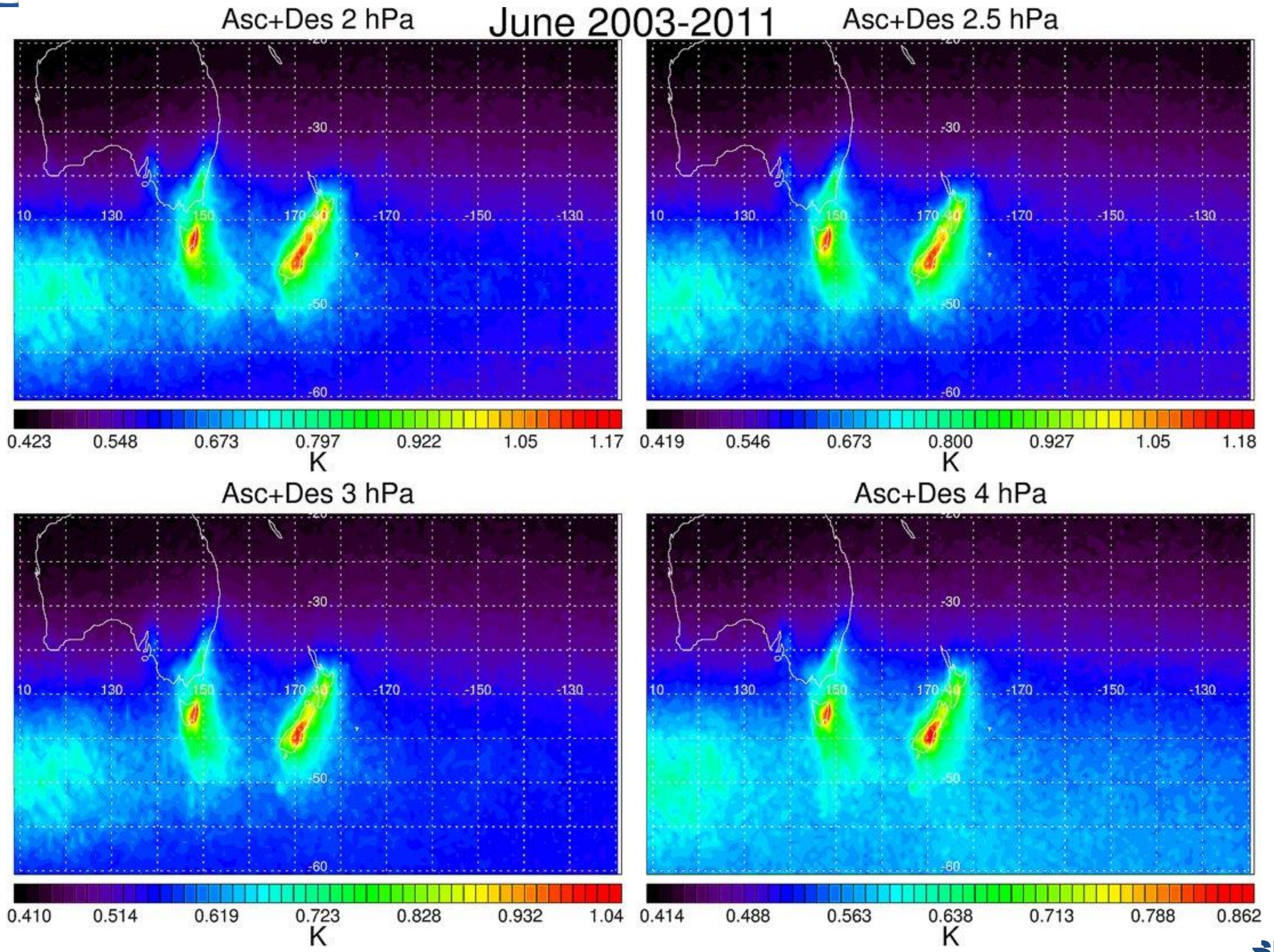


AIRS Premission Climatology

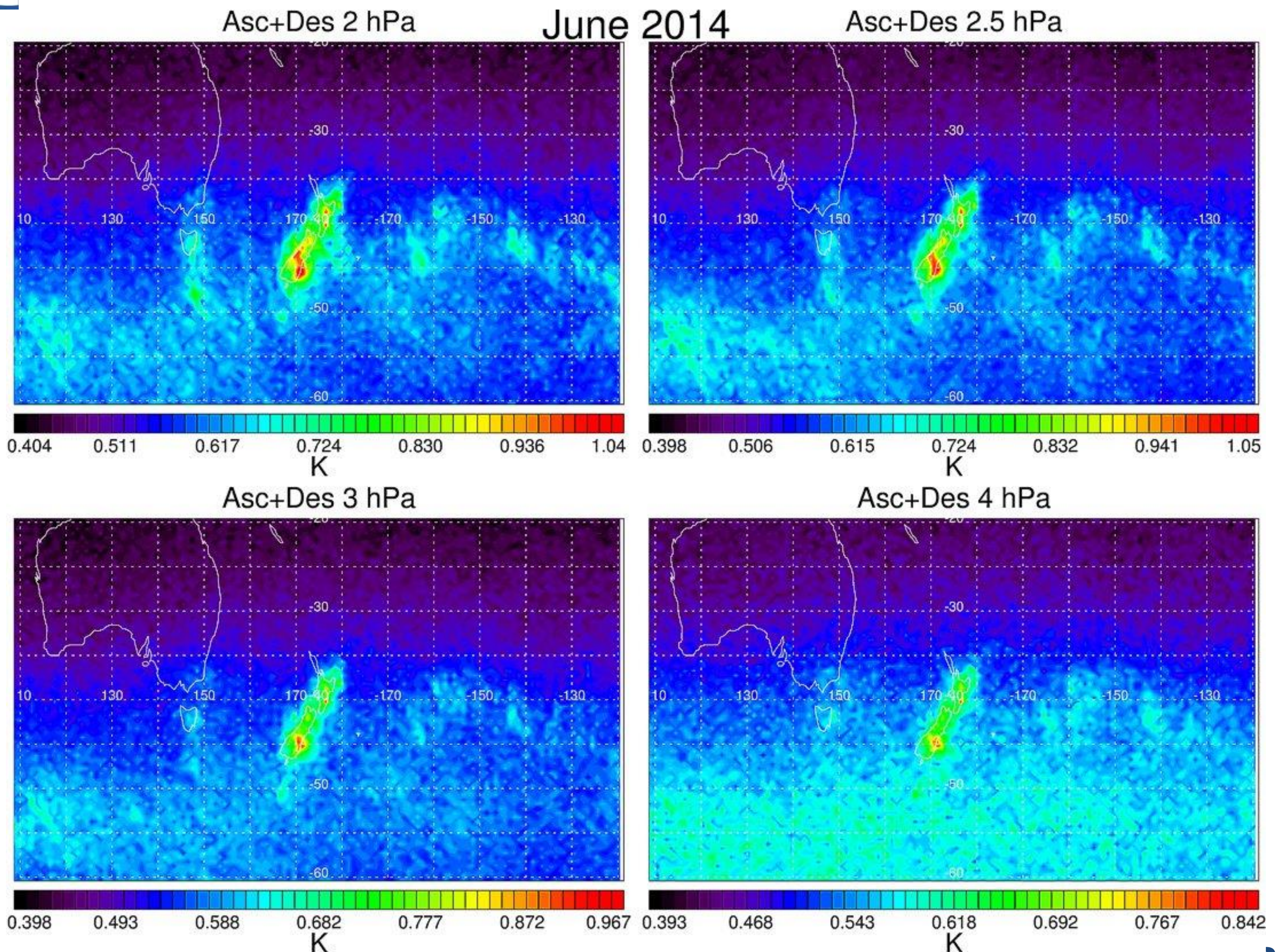
(a) RMS AIRS Brightness Temperature: June-July 2003-2011 2.5 hPa



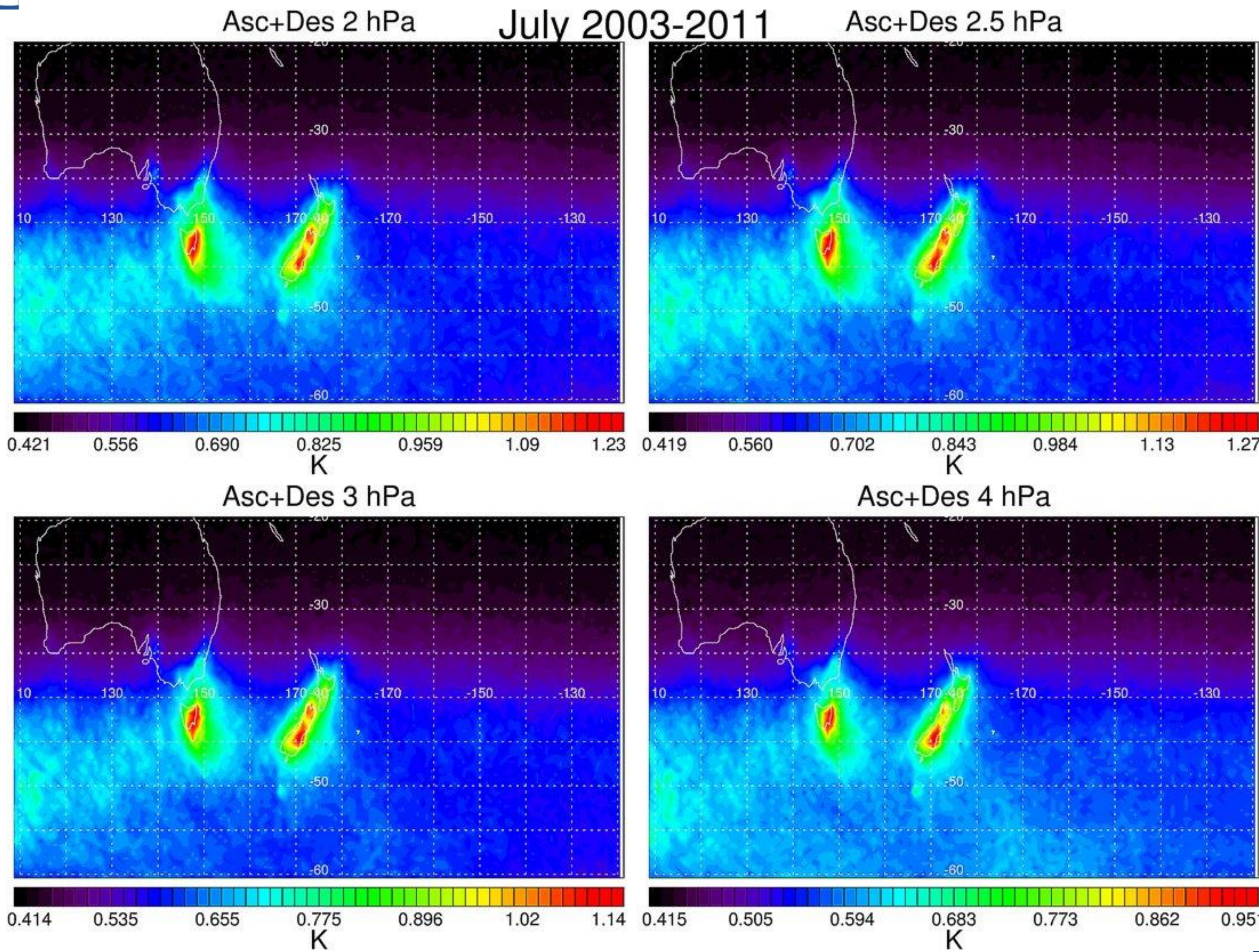
AIRS GWs: 2-4 hPa June 2003-2011



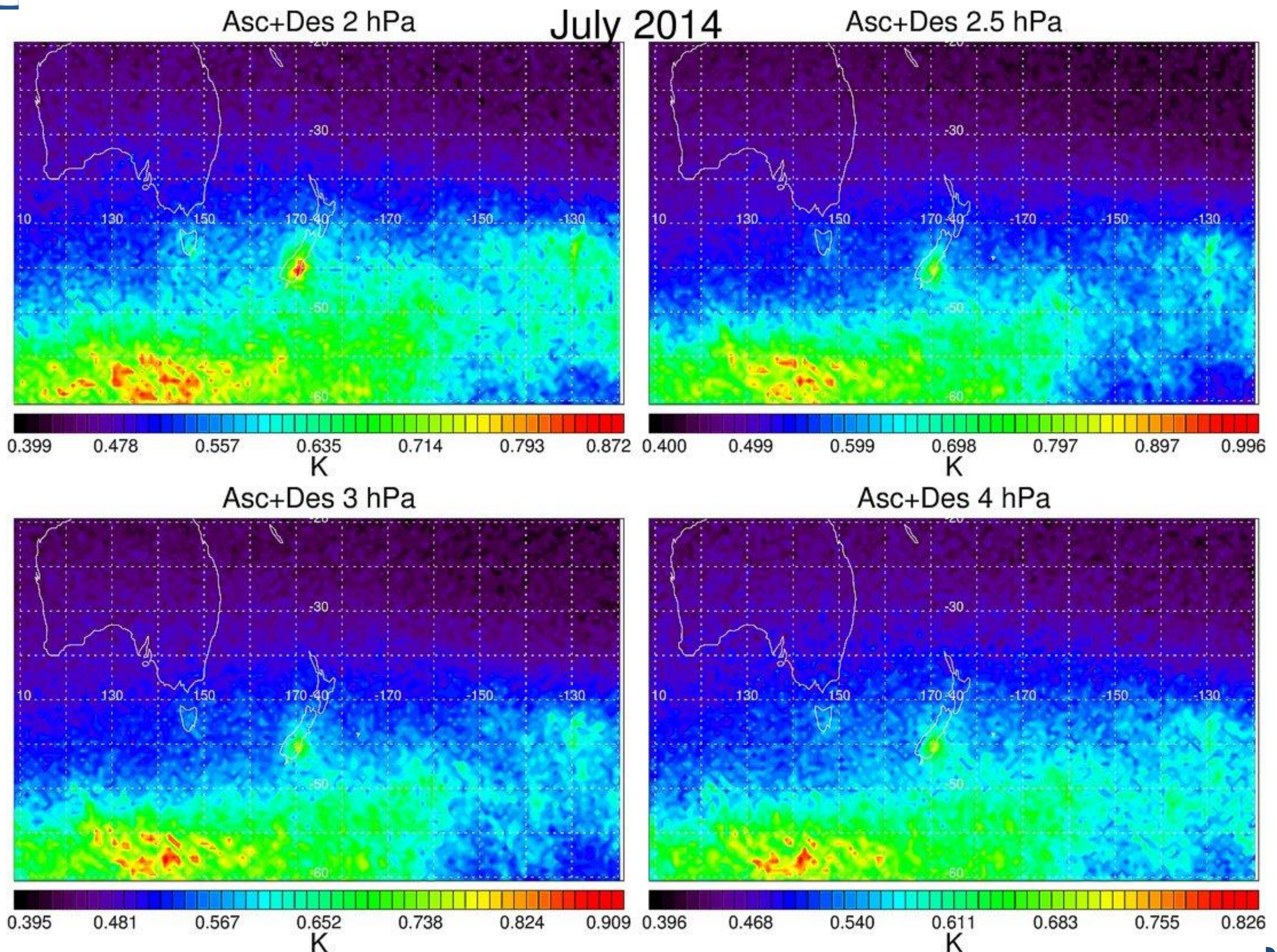
AIRS GWs: 2-4 hPa June 2014



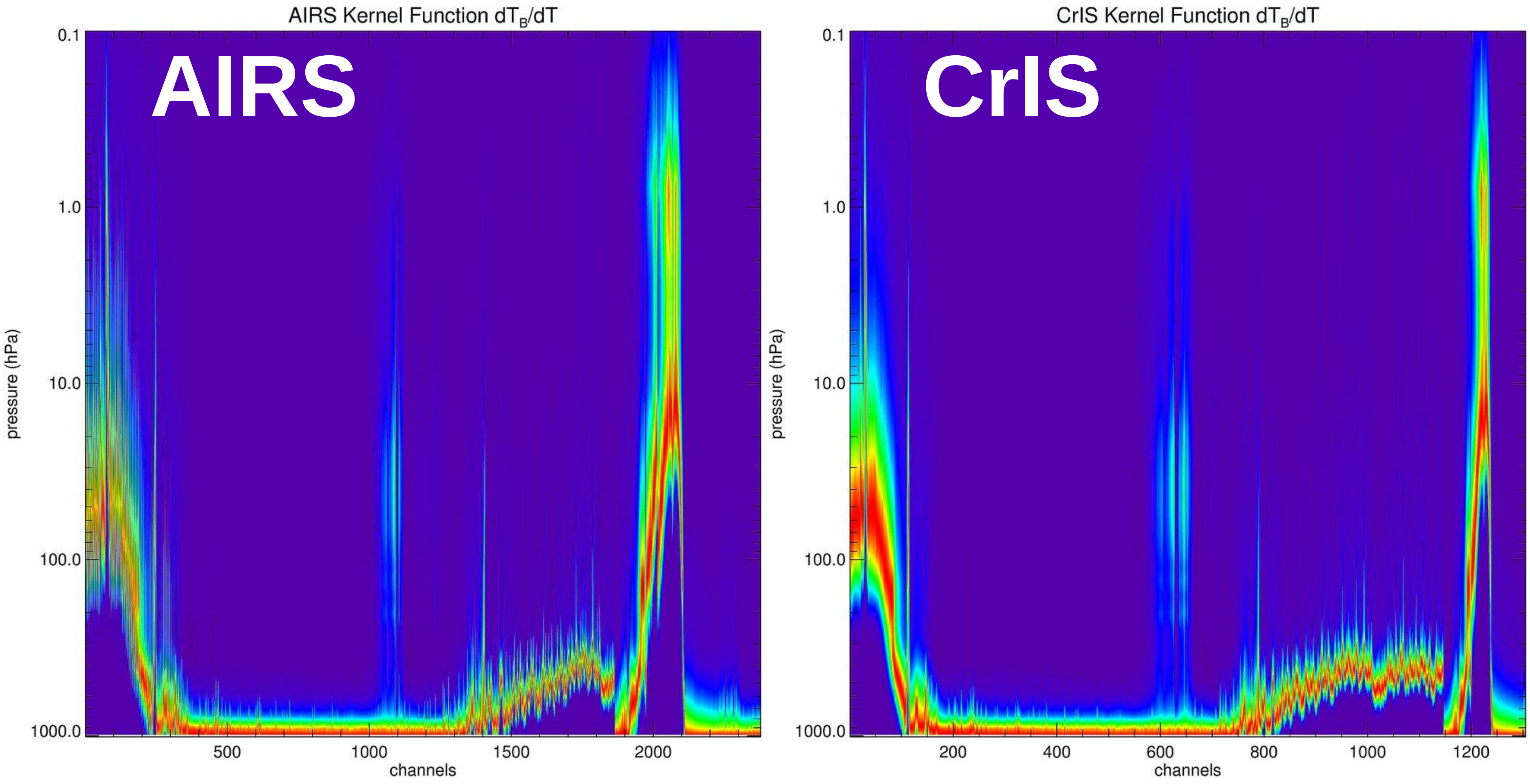
AIRS GWs: 2-4 hPa July 2003-2011



AIRS GWs: 2-4 hPa July 2014



Reproduction of WFs for Every AIRS & CrIS Channel Using CRTM



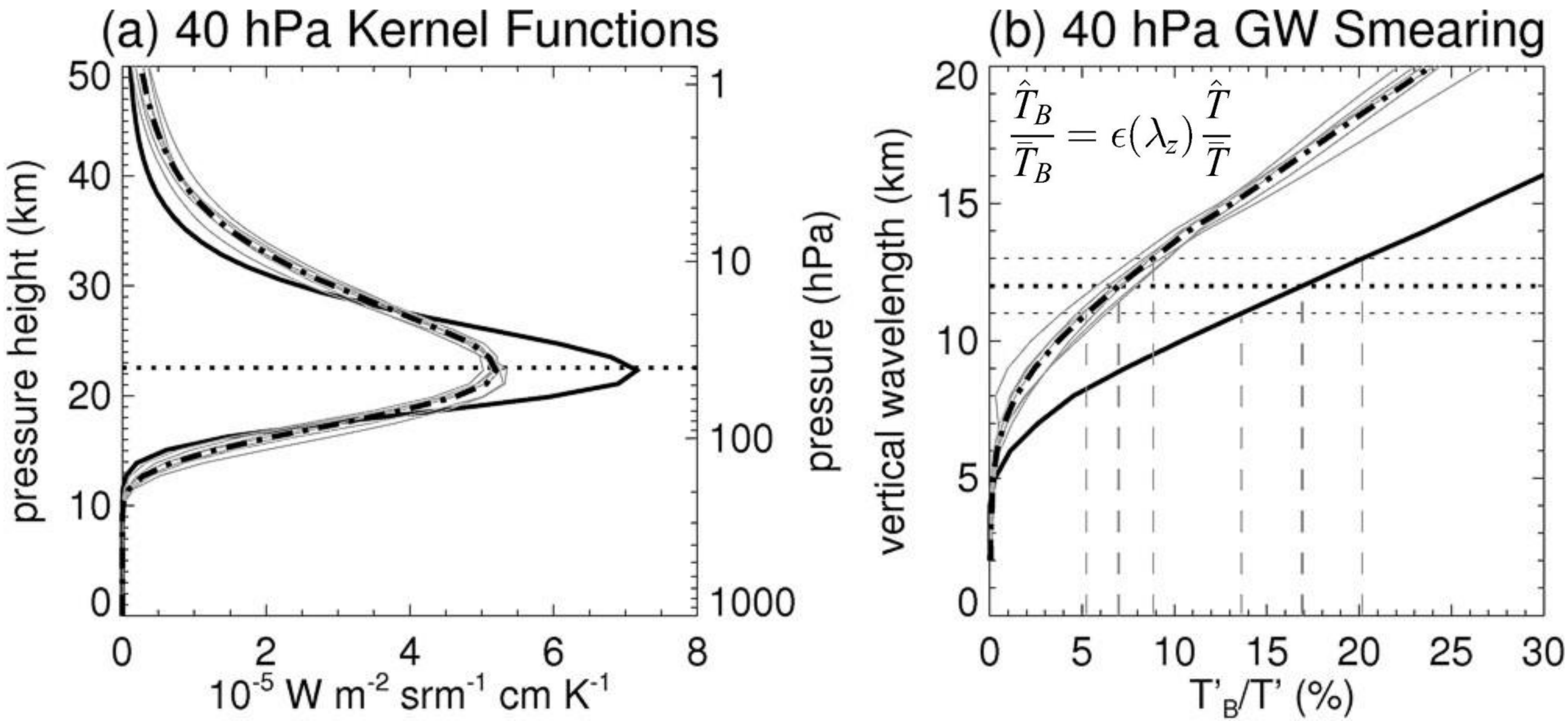
AIRS DEEPWAVE Gravity-Wave Product

- 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

BACKUP SLIDES

AIRS 40 hPa Radiance Channels



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

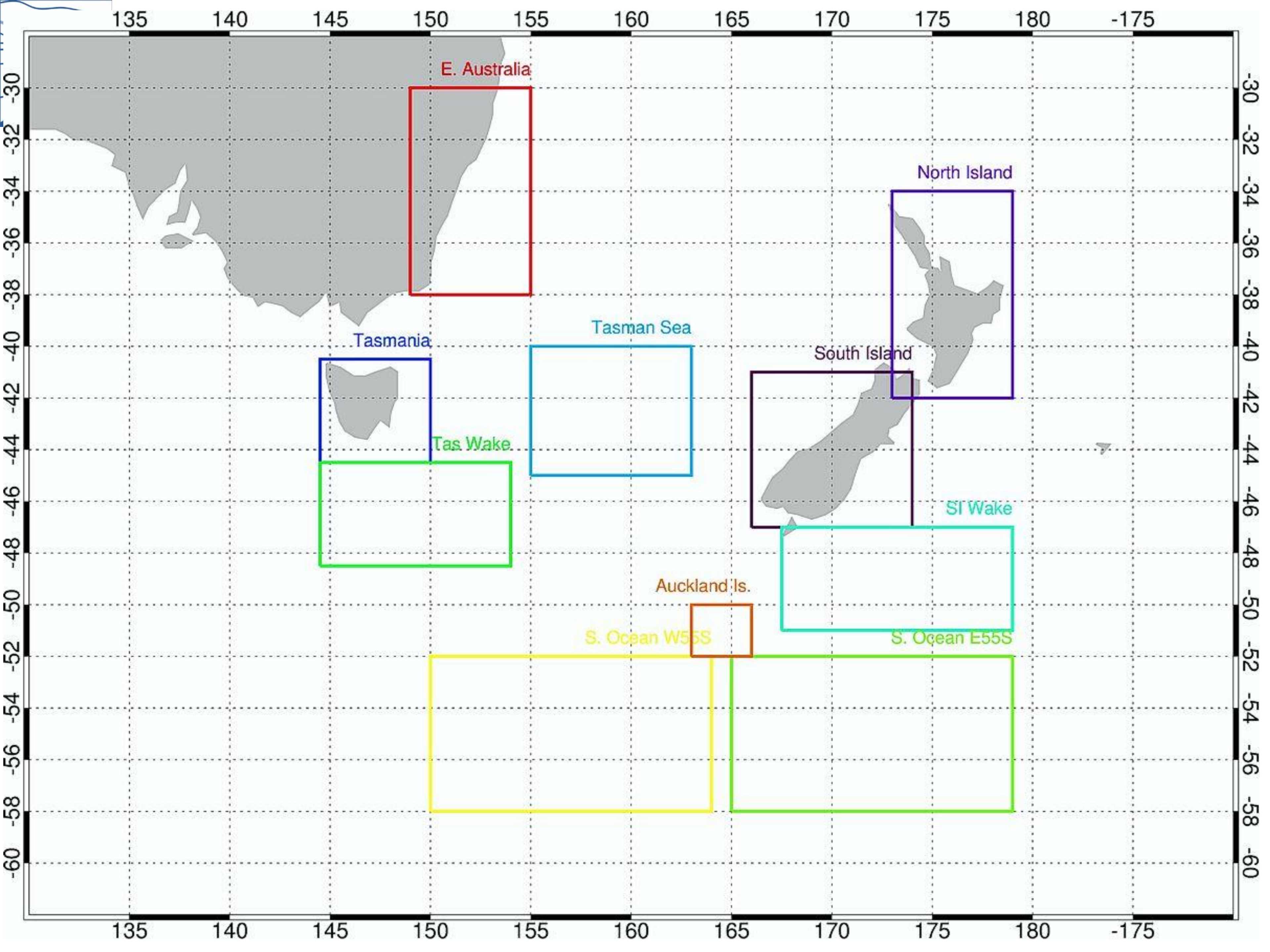
——— Individual Channel Radiances 64,…,118

— · — · Mean Channel Radiance 64,..,118

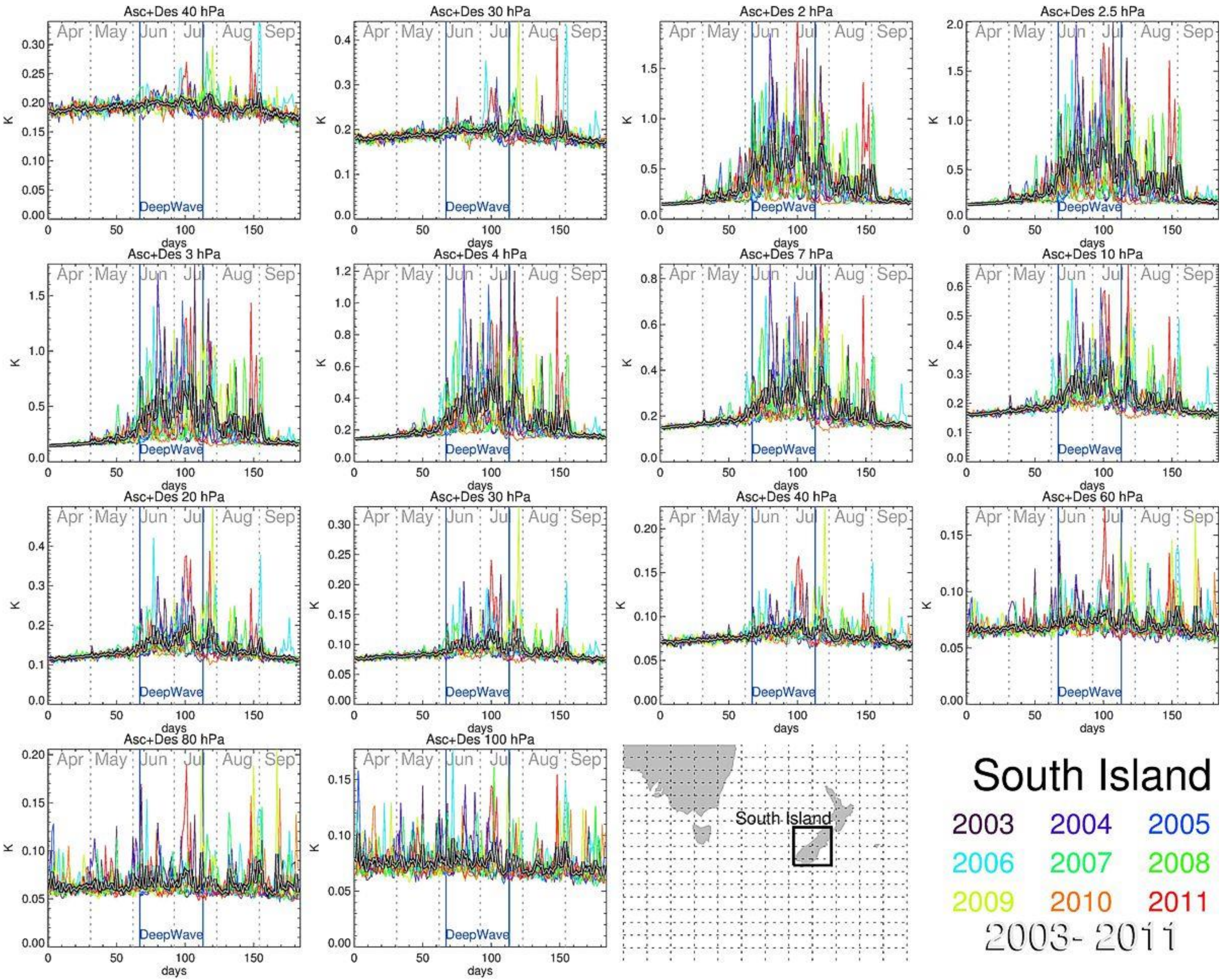
AIRS channel 71 (666.773 cm^{-1}).

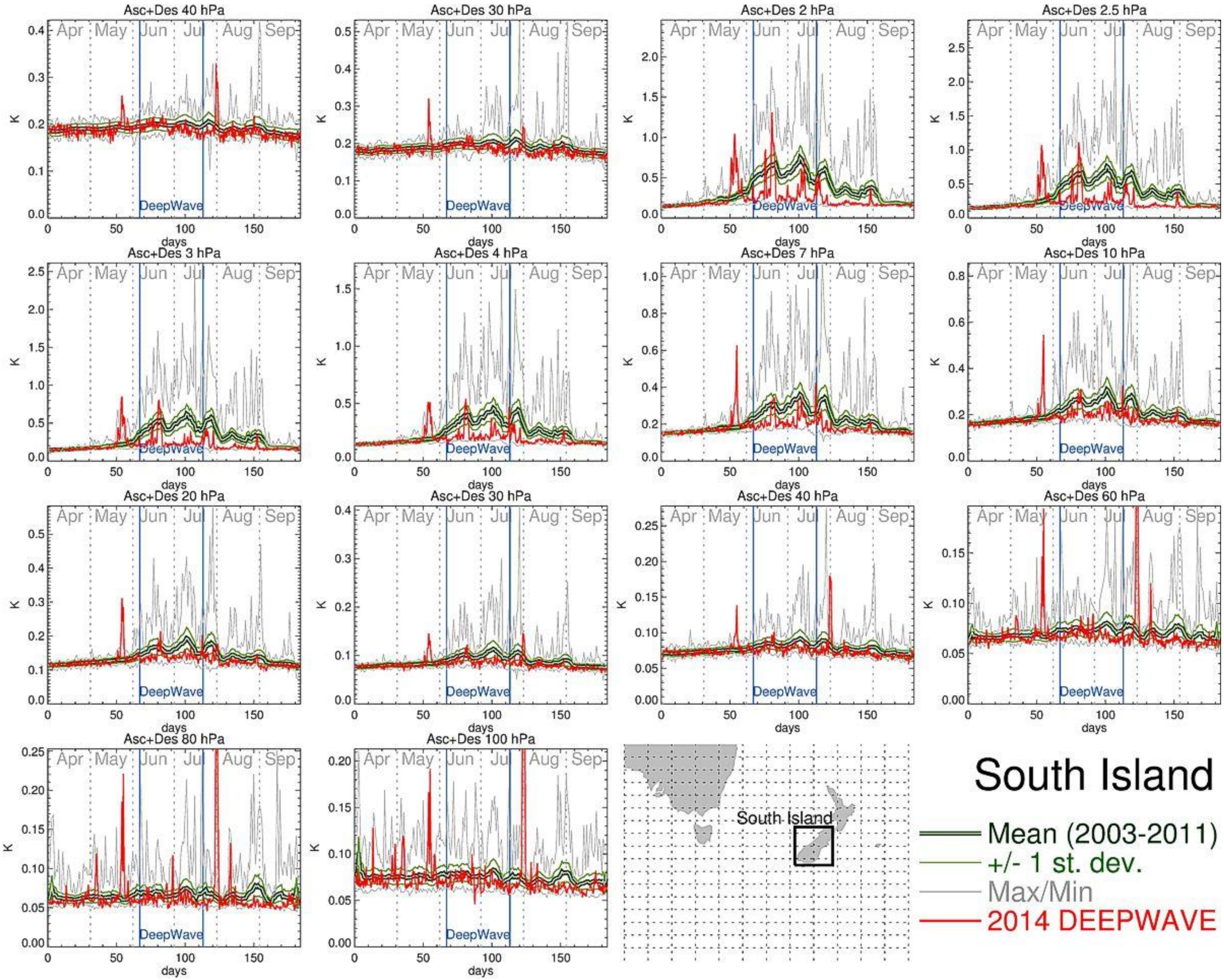
———

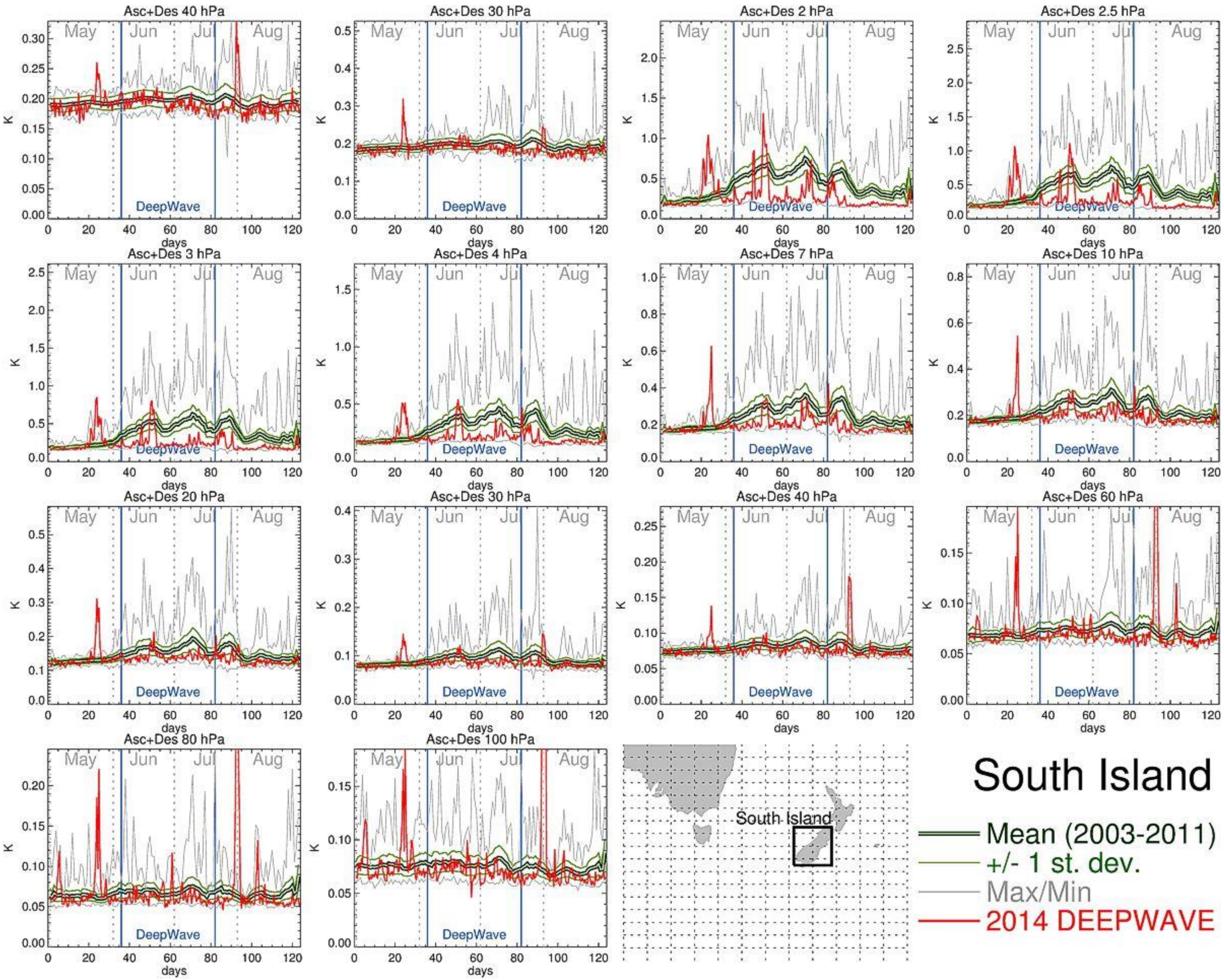
see Hoffmann and Alexander (JGR, 2009)
Eckermann et al. (GRL 2009)



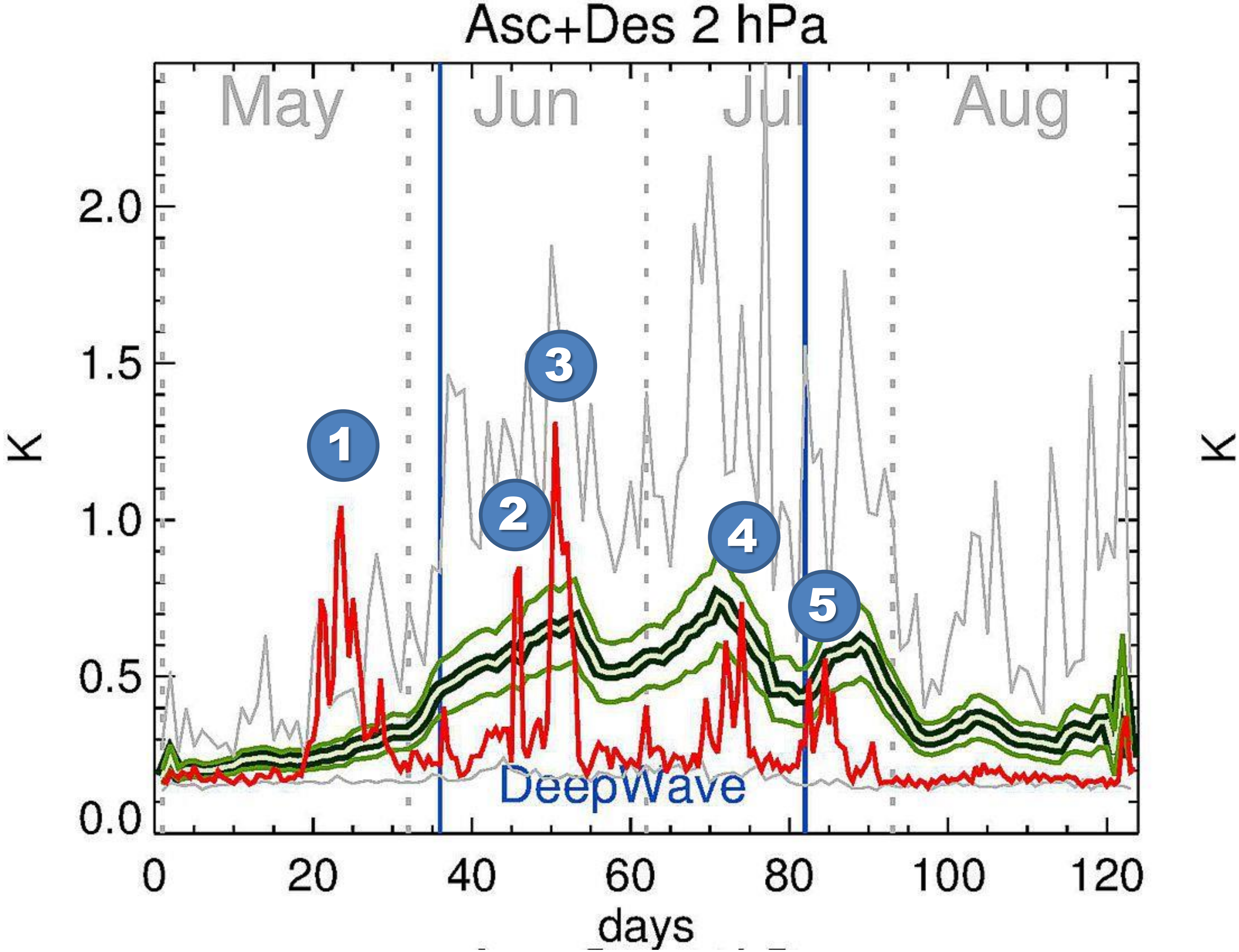
E. Australia
North Island
Tasman Sea
Tasmania
South Island
Tas Wake
SI Wake
Auckland Is.
S. Ocean W55S
S. Ocean E55S
135 140 145 150 155 160 165 170 175 180 -175
-30 -32 -34 -36 -38 -40 -42 -44 -46 -48 -50 -52 -54 -56 -58 -60


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
DeepWave
K
days
South Island
South Island
2003 2004 2005
2006 2007 2008
2009 2010 2011
2003- 2011


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
DeepWave
K
days
South Island
South Island
Mean (2003-2011)
+/- 1 st. dev.
Max/Min
2014 DEEPWAVE

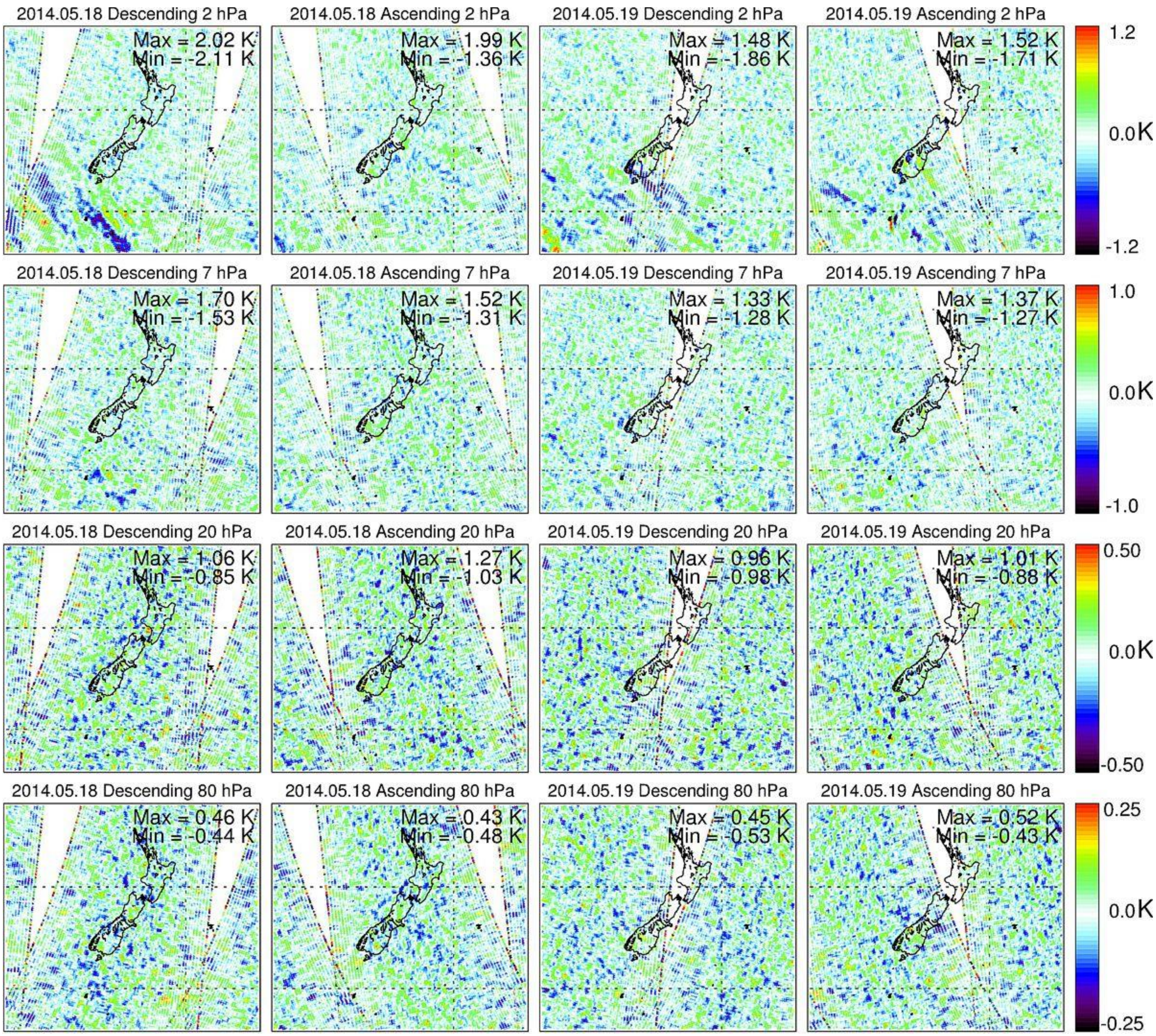


Asc+Des 40 hPa
Asc+Des 30 hPa
Asc+Des 2 hPa
Asc+Des 2.5 hPa
Asc+Des 3 hPa
Asc+Des 4 hPa
Asc+Des 7 hPa
Asc+Des 10 hPa
Asc+Des 20 hPa
Asc+Des 30 hPa
Asc+Des 40 hPa
Asc+Des 60 hPa
Asc+Des 80 hPa
Asc+Des 100 hPa
May
Jun
Jul
Aug
DeepWave
K
days
South Island
South Island
Mean (2003-2011)
+/- 1 st. dev.
Max/Min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

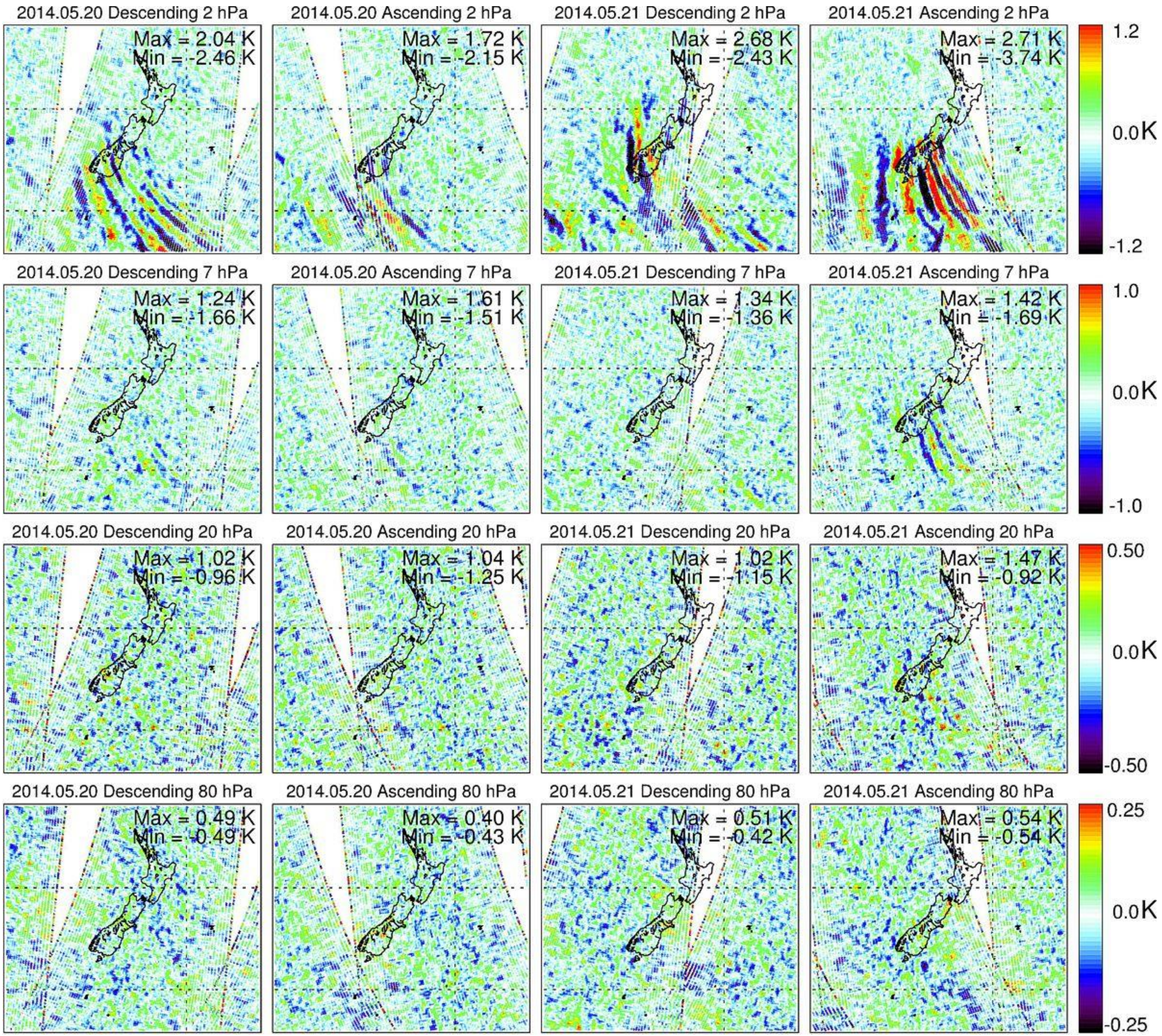
1

18-28 May


2014.05.18 Descending 2 hPa
Max = 2.02 K
Min = -2.11 K
2014.05.18 Ascending 2 hPa
Max = 1.99 K
Min = -1.36 K
2014.05.19 Descending 2 hPa
Max = 1.48 K
Min = -1.86 K
2014.05.19 Ascending 2 hPa
Max = 1.52 K
Min = -1.71 K
1.2
0.0K
-1.2
2014.05.18 Descending 7 hPa
Max = 1.70 K
Min = -1.53 K
2014.05.18 Ascending 7 hPa
Max = 1.52 K
Min = -1.31 K
2014.05.19 Descending 7 hPa
Max = 1.33 K
Min = -1.28 K
2014.05.19 Ascending 7 hPa
Max = 1.37 K
Min = -1.27 K
1.0
0.0K
-1.0
2014.05.18 Descending 20 hPa
Max = 1.06 K
Min = -0.85 K
2014.05.18 Ascending 20 hPa
Max = 1.27 K
Min = -1.03 K
2014.05.19 Descending 20 hPa
Max = 0.96 K
Min = -0.98 K
2014.05.19 Ascending 20 hPa
Max = 1.01 K
Min = -0.88 K
0.50
0.0K
-0.50
2014.05.18 Descending 80 hPa
Max = 0.46 K
Min = -0.44 K
2014.05.18 Ascending 80 hPa
Max = 0.43 K
Min = -0.48 K
2014.05.19 Descending 80 hPa
Max = 0.45 K
Min = -0.53 K
2014.05.19 Ascending 80 hPa
Max = 0.52 K
Min = -0.43 K
0.25
0.0K
-0.25

1

18-28 May

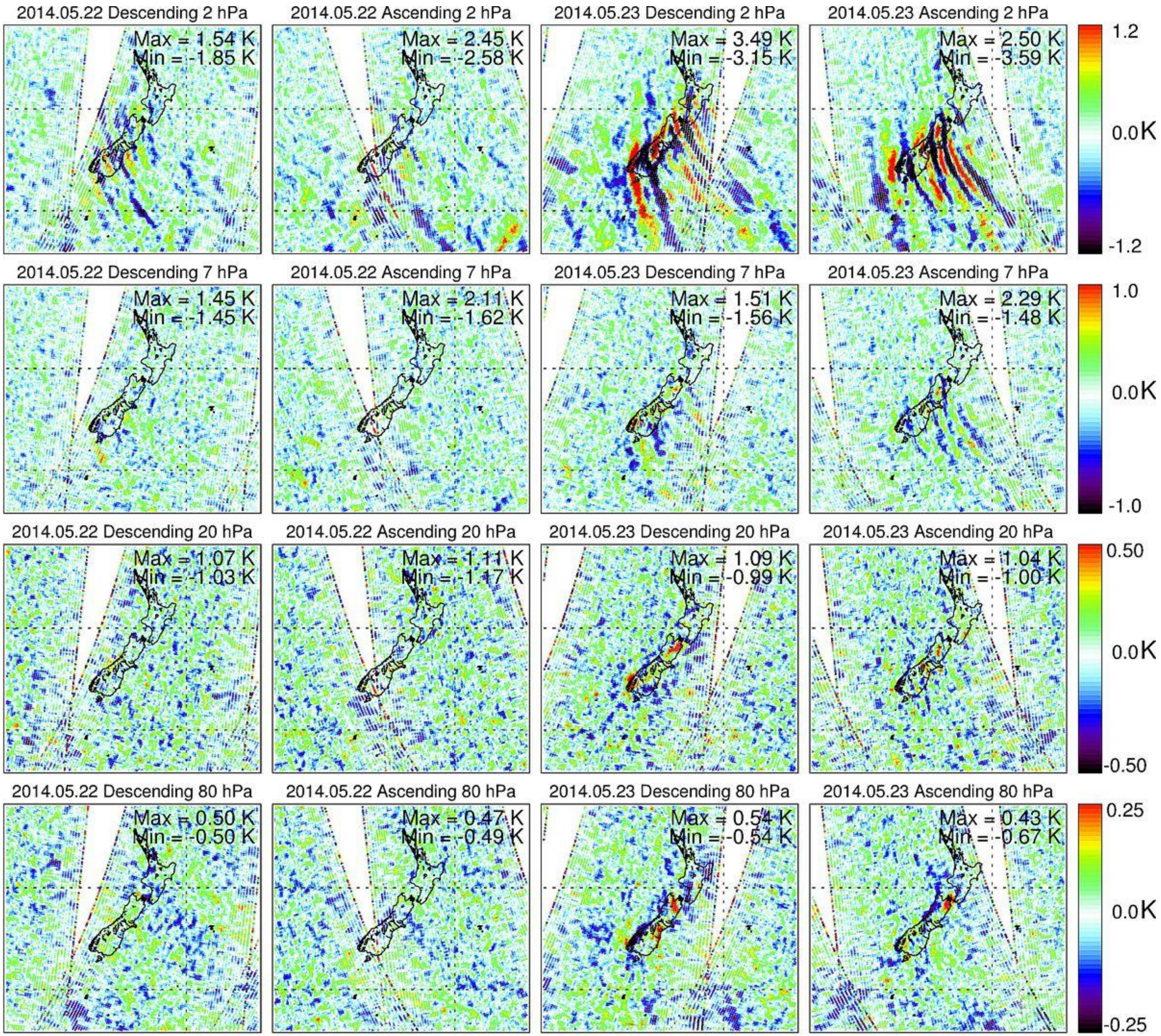


2014.05.20 Descending 2 hPa
Max = 2.04 K
Min = -2.46 K
2014.05.20 Ascending 2 hPa
Max = 1.72 K
Min = -2.15 K
2014.05.21 Descending 2 hPa
Max = 2.68 K
Min = -2.43 K
2014.05.21 Ascending 2 hPa
Max = 2.71 K
Min = -3.74 K
1.2
0.0K
-1.2
2014.05.20 Descending 7 hPa
Max = 1.24 K
Min = -1.66 K
2014.05.20 Ascending 7 hPa
Max = 1.61 K
Min = -1.51 K
2014.05.21 Descending 7 hPa
Max = 1.34 K
Min = -1.36 K
2014.05.21 Ascending 7 hPa
Max = 1.42 K
Min = -1.69 K
1.0
0.0K
-1.0
2014.05.20 Descending 20 hPa
Max = 1.02 K
Min = -0.96 K
2014.05.20 Ascending 20 hPa
Max = 1.04 K
Min = -1.25 K
2014.05.21 Descending 20 hPa
Max = 1.02 K
Min = -1.15 K
2014.05.21 Ascending 20 hPa
Max = 1.47 K
Min = -0.92 K
0.50
0.0K
-0.50
2014.05.20 Descending 80 hPa
Max = 0.49 K
Min = -0.49 K
2014.05.20 Ascending 80 hPa
Max = 0.40 K
Min = -0.43 K
2014.05.21 Descending 80 hPa
Max = 0.51 K
Min = -0.42 K
2014.05.21 Ascending 80 hPa
Max = 0.54 K
Min = -0.54 K
0.25
0.0K
-0.25

DEEPWAVE 2014

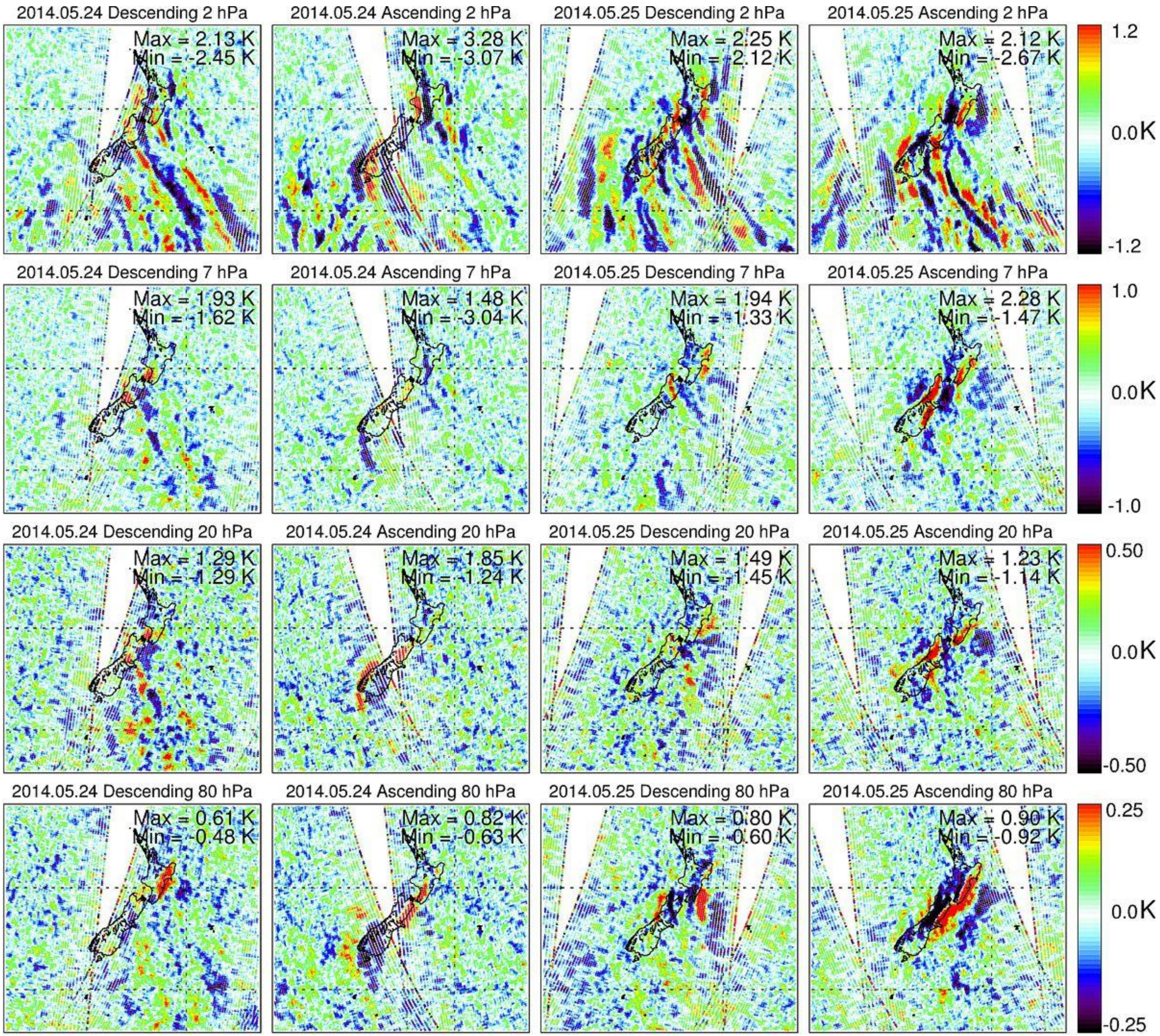
1

18-28 May



1

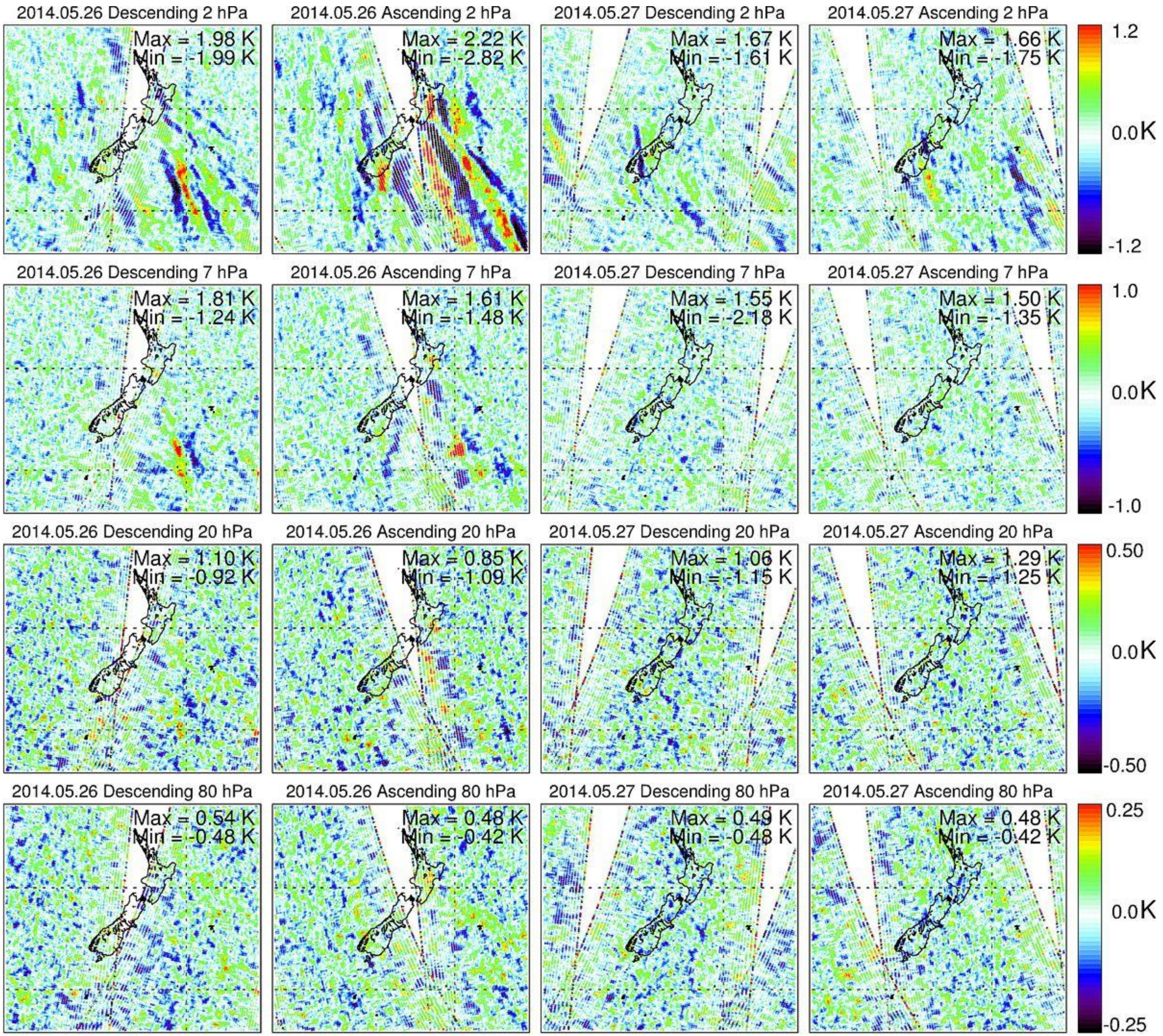
18-28 May


2014.05.24 Descending 2 hPa
Max = 2.13 K
Min = -2.45 K
2014.05.24 Ascending 2 hPa
Max = 3.28 K
Min = -3.07 K
2014.05.25 Descending 2 hPa
Max = 2.25 K
Min = -2.12 K
2014.05.25 Ascending 2 hPa
Max = 2.12 K
Min = -2.67 K
1.2
0.0K
-1.2
2014.05.24 Descending 7 hPa
Max = 1.93 K
Min = -1.62 K
2014.05.24 Ascending 7 hPa
Max = 1.48 K
Min = -3.04 K
2014.05.25 Descending 7 hPa
Max = 1.94 K
Min = -1.33 K
2014.05.25 Ascending 7 hPa
Max = 2.28 K
Min = -1.47 K
1.0
0.0K
-1.0
2014.05.24 Descending 20 hPa
Max = 1.29 K
Min = -1.29 K
2014.05.24 Ascending 20 hPa
Max = 1.85 K
Min = -1.24 K
2014.05.25 Descending 20 hPa
Max = 1.49 K
Min = -1.45 K
2014.05.25 Ascending 20 hPa
Max = 1.23 K
Min = -1.14 K
0.50
0.0K
-0.50
2014.05.24 Descending 80 hPa
Max = 0.61 K
Min = -0.48 K
2014.05.24 Ascending 80 hPa
Max = 0.82 K
Min = -0.63 K
2014.05.25 Descending 80 hPa
Max = 0.80 K
Min = -0.60 K
2014.05.25 Ascending 80 hPa
Max = 0.90 K
Min = -0.92 K
0.25
0.0K
-0.25

DEEPWAVE 2014

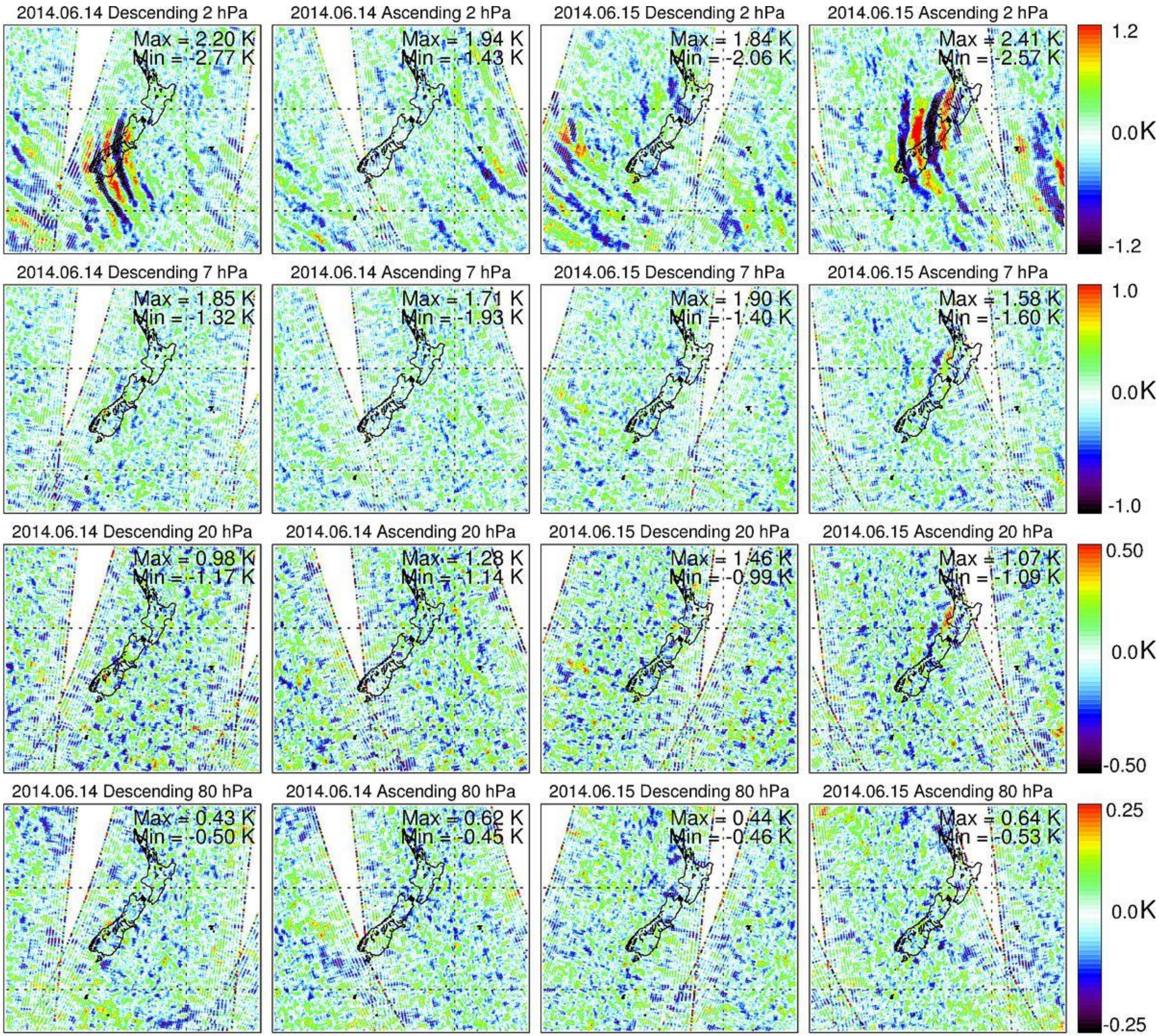
1

18-28 May



2

15-16 June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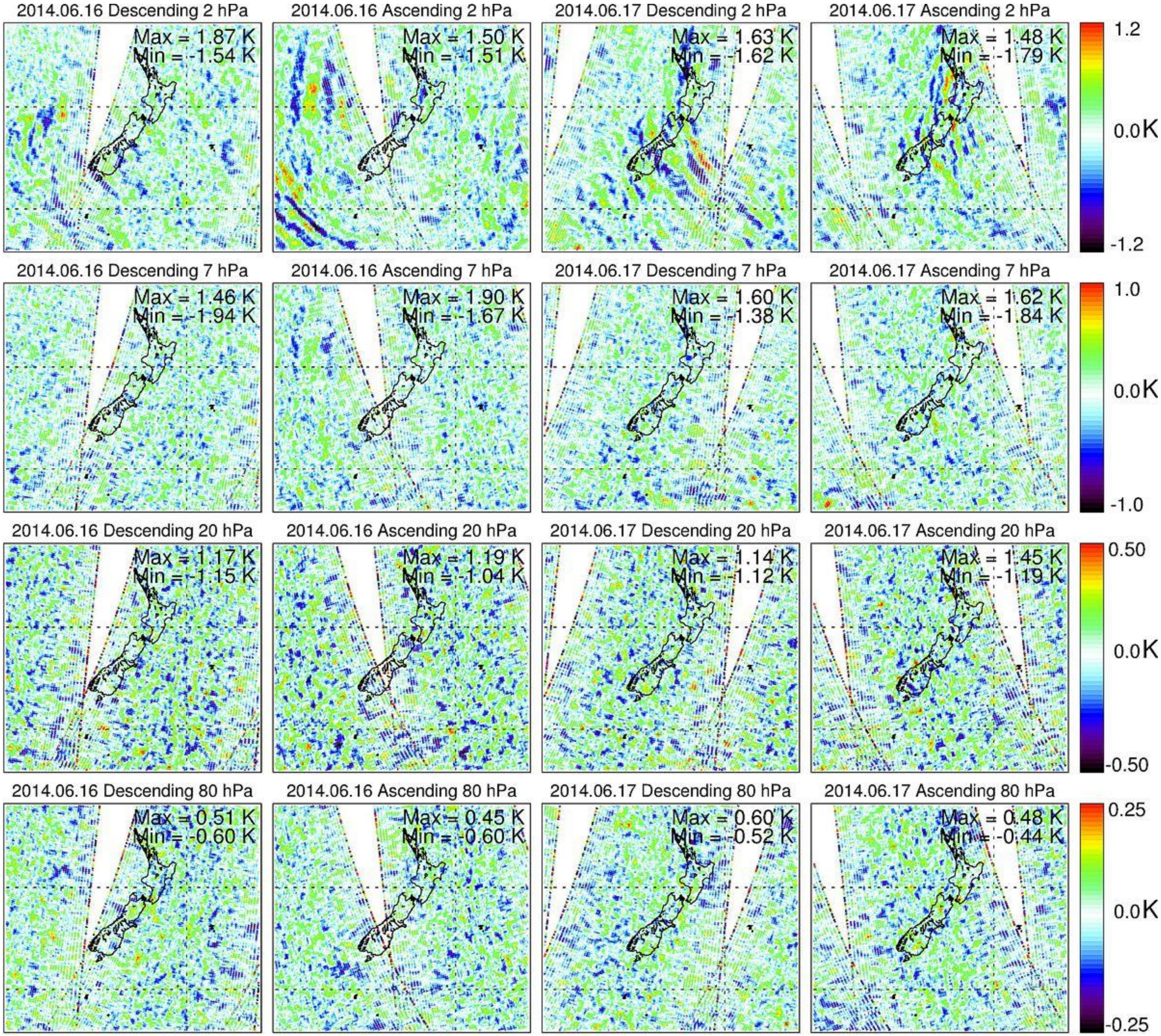
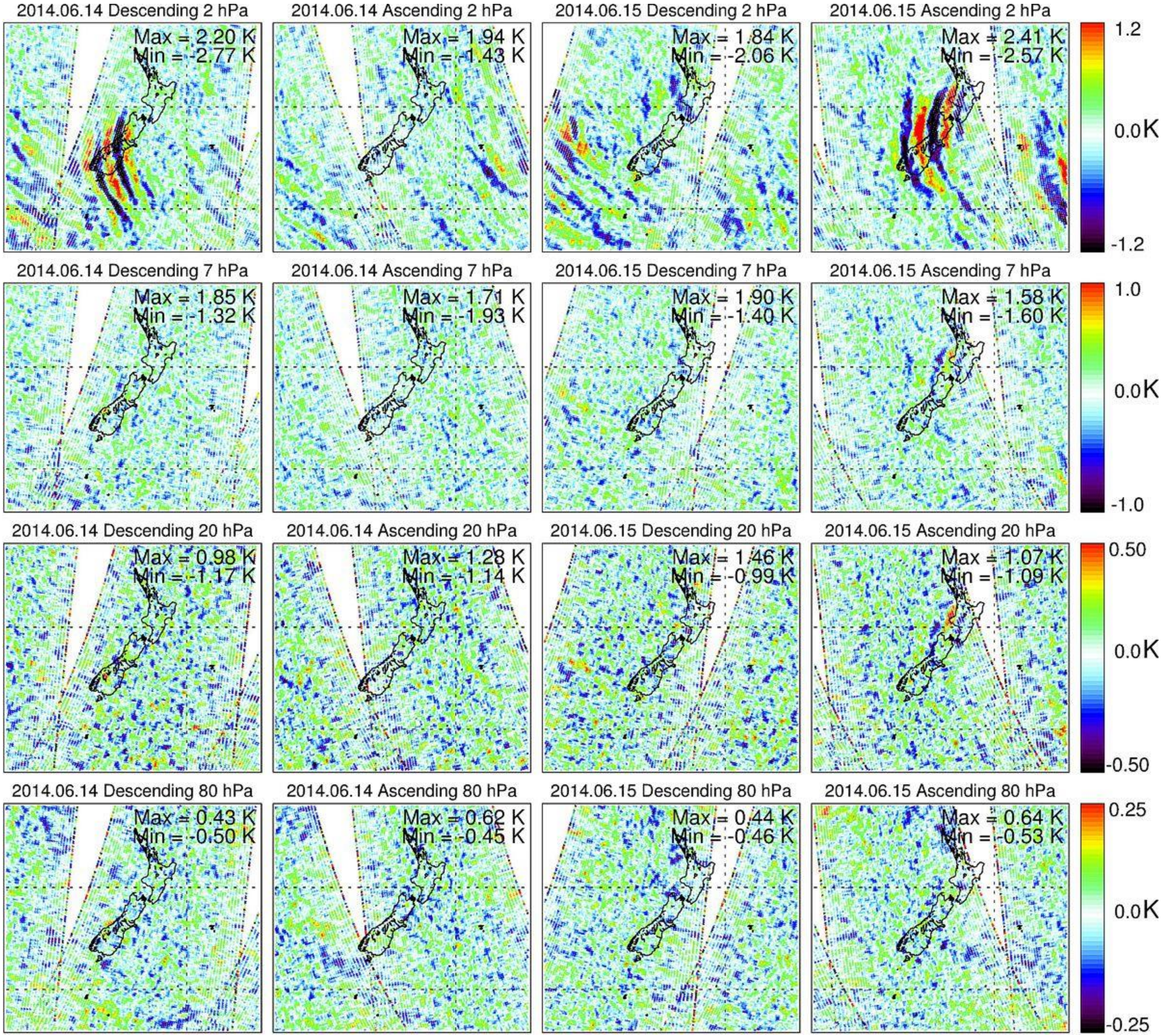
Max = 2.20 K
Min = -2.77 K
2014.06.14 Ascending 2 hPa
Max = 1.94 K
Min = -1.43 K
2014.06.15 Descending 2 hPa
Max = 1.84 K
Min = -2.06 K
2014.06.15 Ascending 2 hPa
Max = 2.41 K
Min = -2.57 K
1.2
0.0K
-1.2
2014.06.14 Descending 7 hPa
Max = 1.85 K
Min = -1.32 K
2014.06.14 Ascending 7 hPa
Max = 1.71 K
Min = -1.93 K
2014.06.15 Descending 7 hPa
Max = 1.90 K
Min = -1.40 K
2014.06.15 Ascending 7 hPa
Max = 1.58 K
Min = -1.60 K
1.0
0.0K
-1.0
2014.06.14 Descending 20 hPa
Max = 0.98 K
Min = -1.17 K
2014.06.14 Ascending 20 hPa
Max = 1.28 K
Min = -1.14 K
2014.06.15 Descending 20 hPa
Max = 1.46 K
Min = -0.99 K
2014.06.15 Ascending 20 hPa
Max = 1.07 K
Min = -1.09 K
0.50
0.0K
-0.50
2014.06.14 Descending 80 hPa
Max = 0.43 K
Min = -0.50 K
2014.06.14 Ascending 80 hPa
Max = 0.62 K
Min = -0.45 K
2014.06.15 Descending 80 hPa
Max = 0.44 K
Min = -0.46 K
2014.06.15 Ascending 80 hPa
Max = 0.64 K
Min = -0.53 K
0.25
0.0K
-0.25

2

15-16 June


2014.06.16 Descending 2 hPa
Max = 1.87 K
Min = -1.54 K
2014.06.16 Ascending 2 hPa
Max = 1.50 K
Min = -1.51 K
2014.06.17 Descending 2 hPa
Max = 1.63 K
Min = -1.62 K
2014.06.17 Ascending 2 hPa
Max = 1.48 K
Min = -1.79 K
1.2
0.0K
-1.2
2014.06.16 Descending 7 hPa
Max = 1.46 K
Min = -1.94 K
2014.06.16 Ascending 7 hPa
Max = 1.90 K
Min = -1.67 K
2014.06.17 Descending 7 hPa
Max = 1.60 K
Min = -1.38 K
2014.06.17 Ascending 7 hPa
Max = 1.62 K
Min = -1.84 K
1.0
0.0K
-1.0
2014.06.16 Descending 20 hPa
Max = 1.17 K
Min = -1.15 K
2014.06.16 Ascending 20 hPa
Max = 1.19 K
Min = -1.04 K
2014.06.17 Descending 20 hPa
Max = 1.14 K
Min = -1.12 K
2014.06.17 Ascending 20 hPa
Max = 1.45 K
Min = -1.19 K
0.50
0.0K
-0.50
2014.06.16 Descending 80 hPa
Max = 0.51 K
Min = -0.60 K
2014.06.16 Ascending 80 hPa
Max = 0.45 K
Min = -0.60 K
2014.06.17 Descending 80 hPa
Max = 0.60 K
Min = -0.52 K
2014.06.17 Ascending 80 hPa
Max = 0.48 K
Min = -0.44 K
0.25
0.0K
-0.25



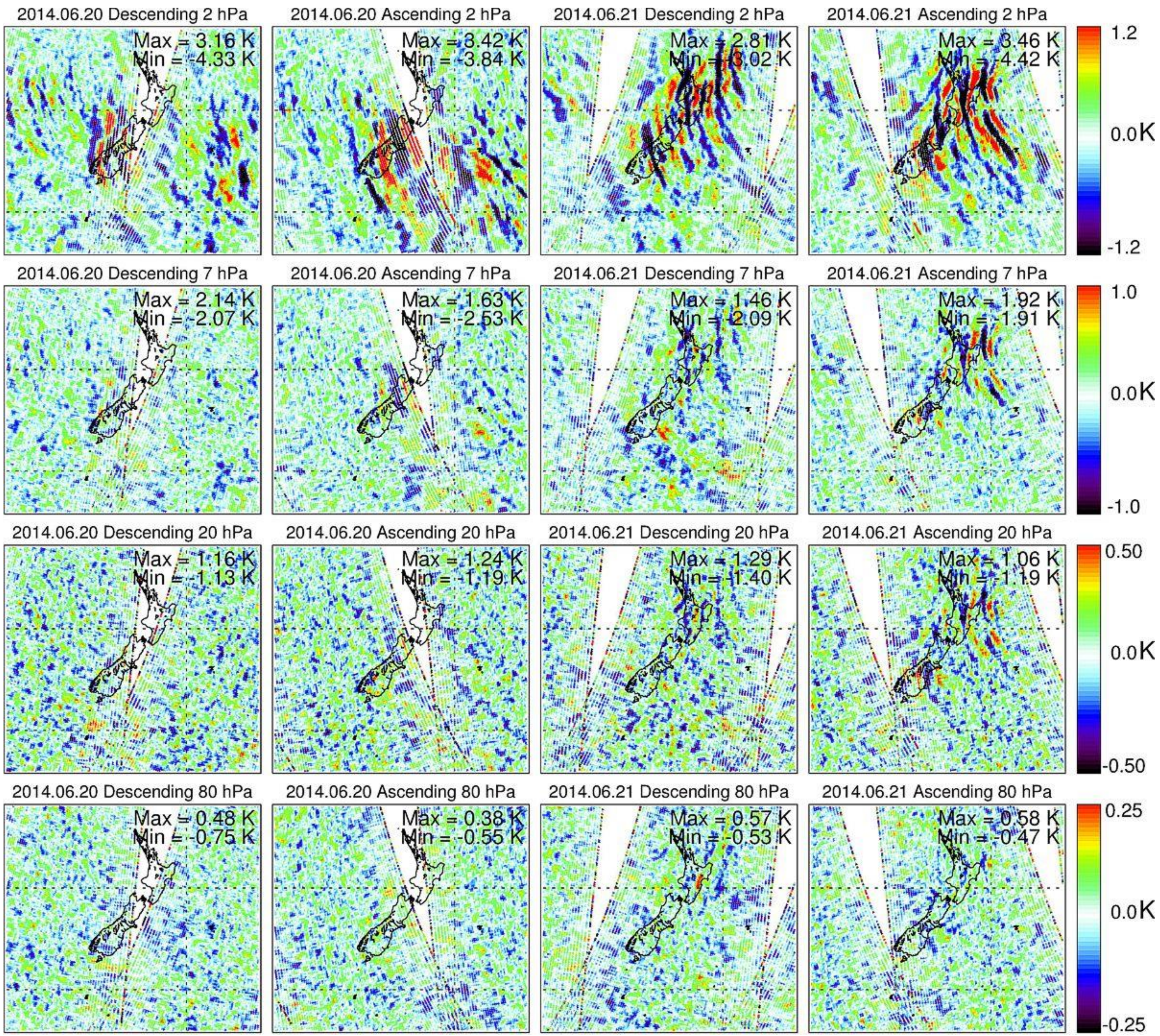
DEEPWAVE 2014

3

19-24 June

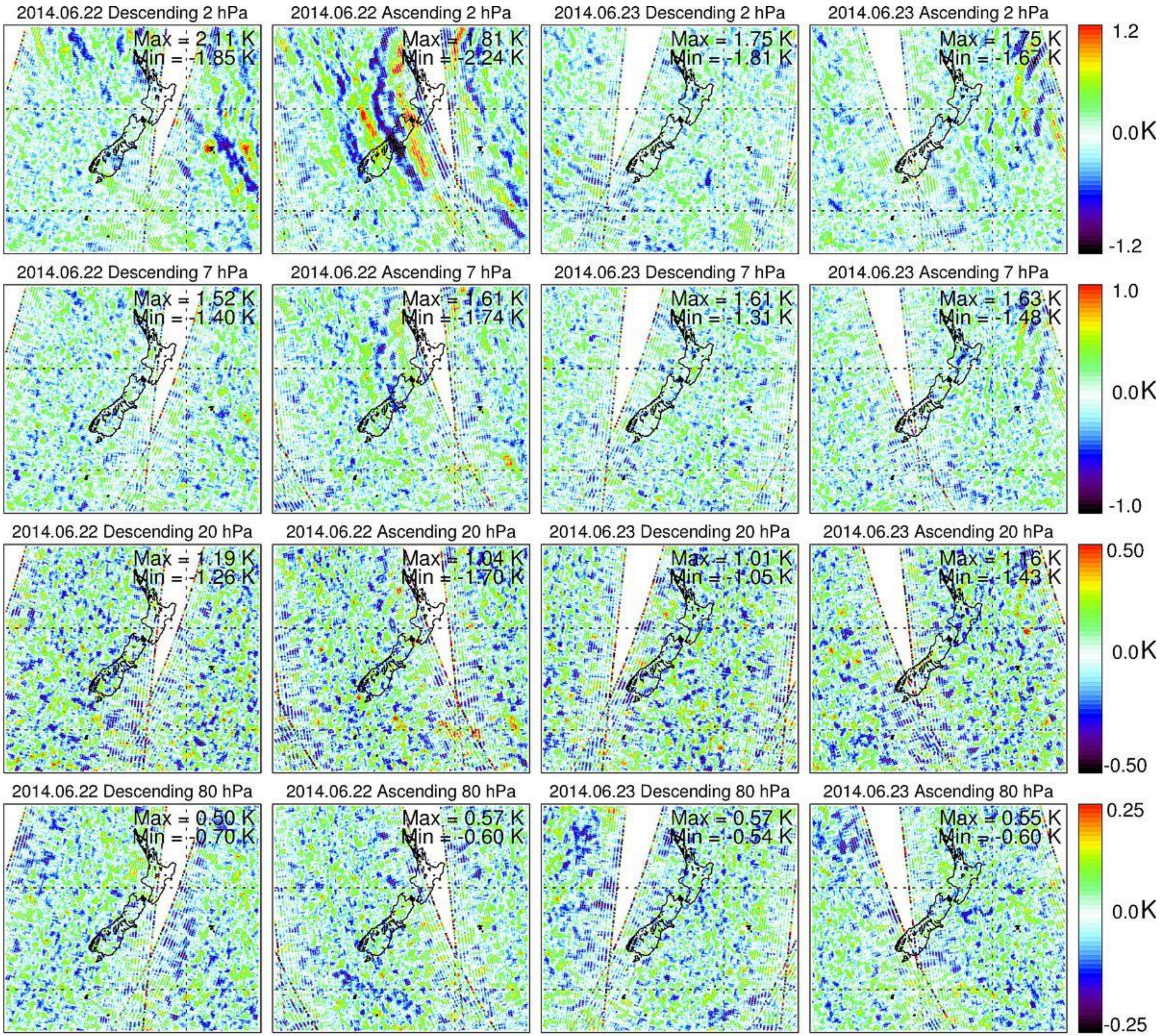
3

19-24 June

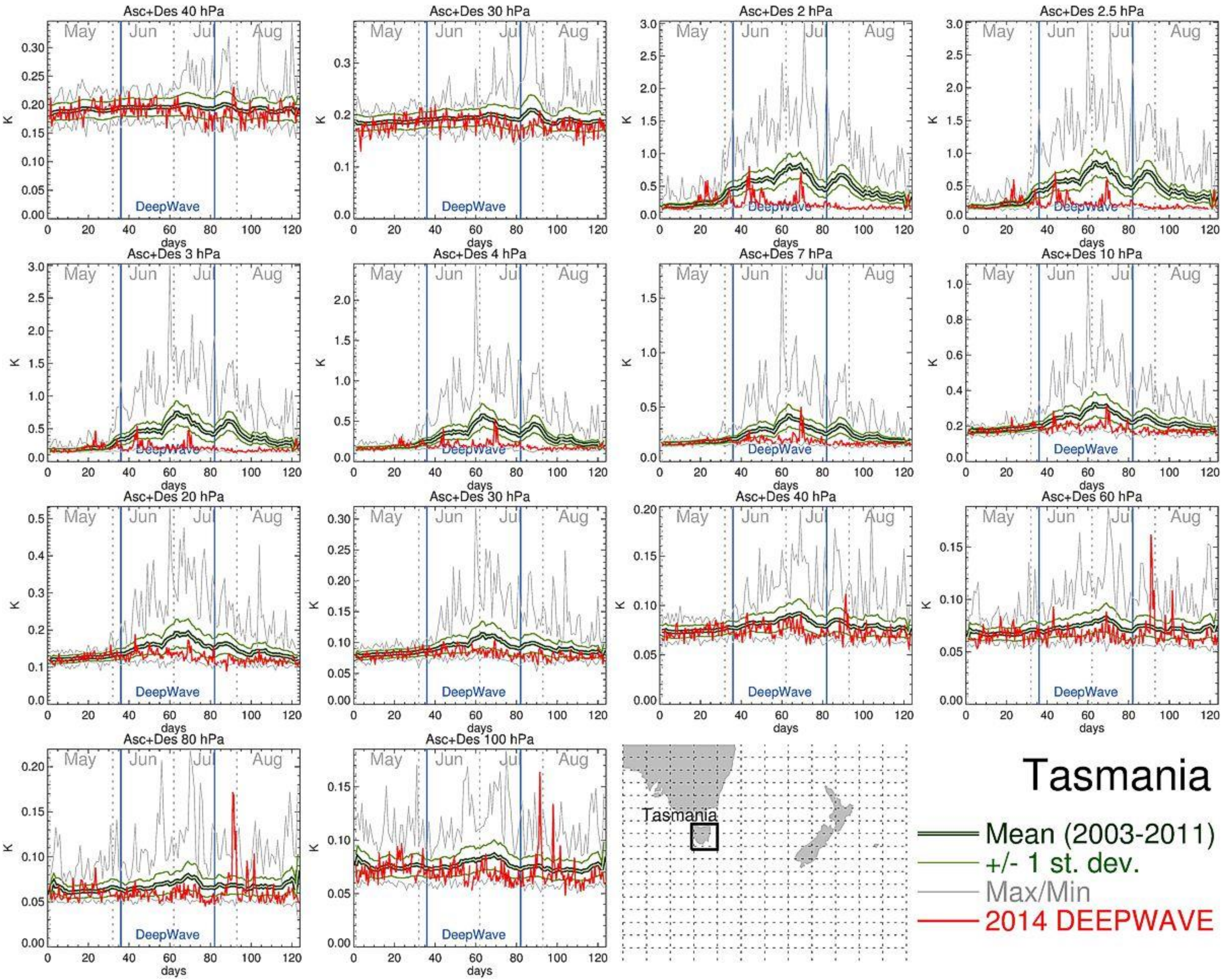

2014.06.20 Descending 2 hPa
Max = 3.16 K
Min = -4.33 K
2014.06.20 Ascending 2 hPa
Max = 3.42 K
Min = -3.84 K
2014.06.21 Descending 2 hPa
Max = 2.81 K
Min = -3.02 K
2014.06.21 Ascending 2 hPa
Max = 3.46 K
Min = -4.42 K
1.2
0.0K
-1.2
2014.06.20 Descending 7 hPa
Max = 2.14 K
Min = -2.07 K
2014.06.20 Ascending 7 hPa
Max = 1.63 K
Min = -2.53 K
2014.06.21 Descending 7 hPa
Max = 1.46 K
Min = -2.09 K
2014.06.21 Ascending 7 hPa
Max = 1.92 K
Min = -1.91 K
1.0
0.0K
-1.0
2014.06.20 Descending 20 hPa
Max = 1.16 K
Min = -1.13 K
2014.06.20 Ascending 20 hPa
Max = 1.24 K
Min = -1.19 K
2014.06.21 Descending 20 hPa
Max = 1.29 K
Min = -1.40 K
2014.06.21 Ascending 20 hPa
Max = 1.06 K
Min = -1.19 K
0.50
0.0K
-0.50
2014.06.20 Descending 80 hPa
Max = 0.48 K
Min = -0.75 K
2014.06.20 Ascending 80 hPa
Max = 0.38 K
Min = -0.55 K
2014.06.21 Descending 80 hPa
Max = 0.57 K
Min = -0.53 K
2014.06.21 Ascending 80 hPa
Max = 0.58 K
Min = -0.47 K
0.25
0.0K
-0.25

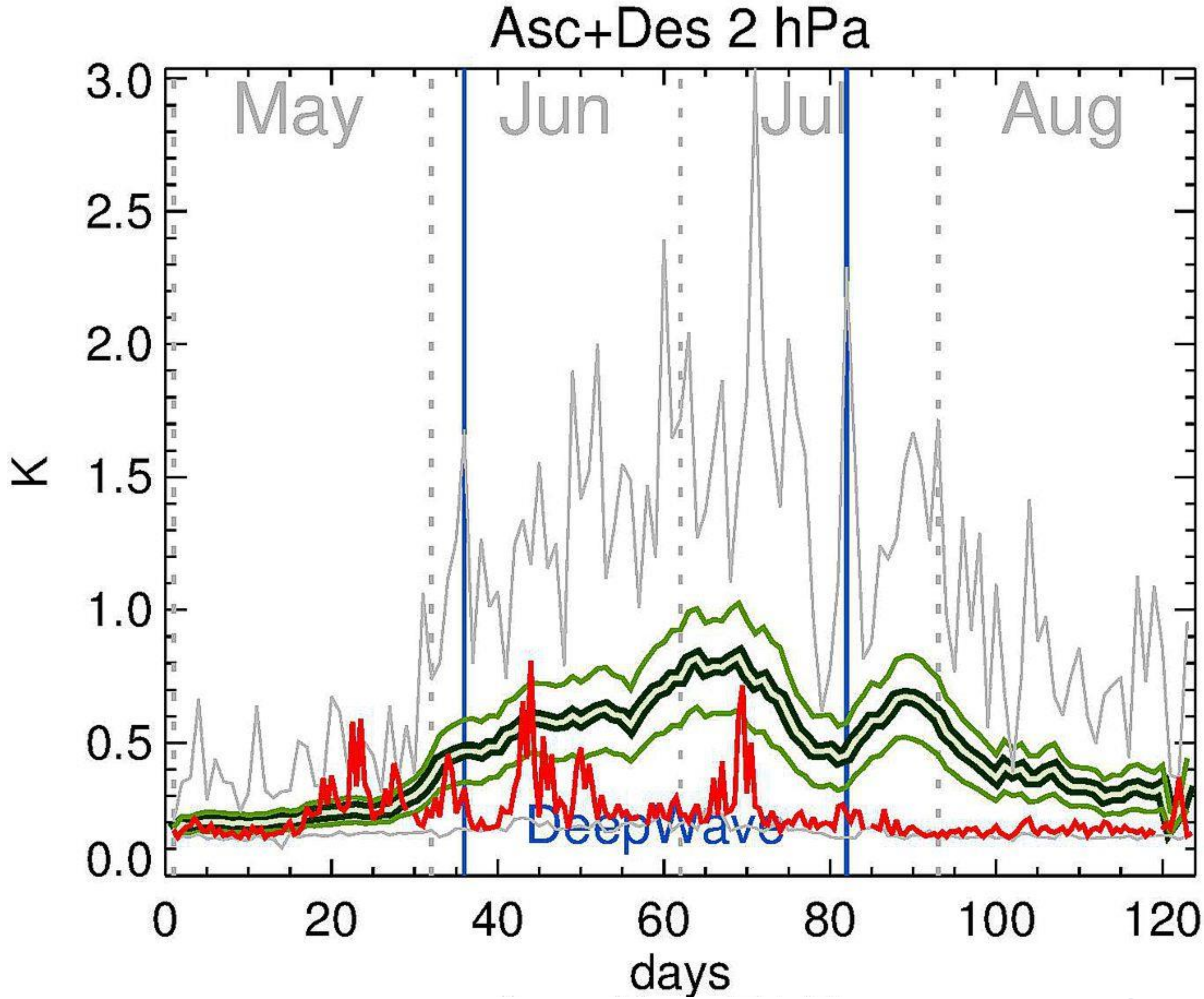
3

19-24 June

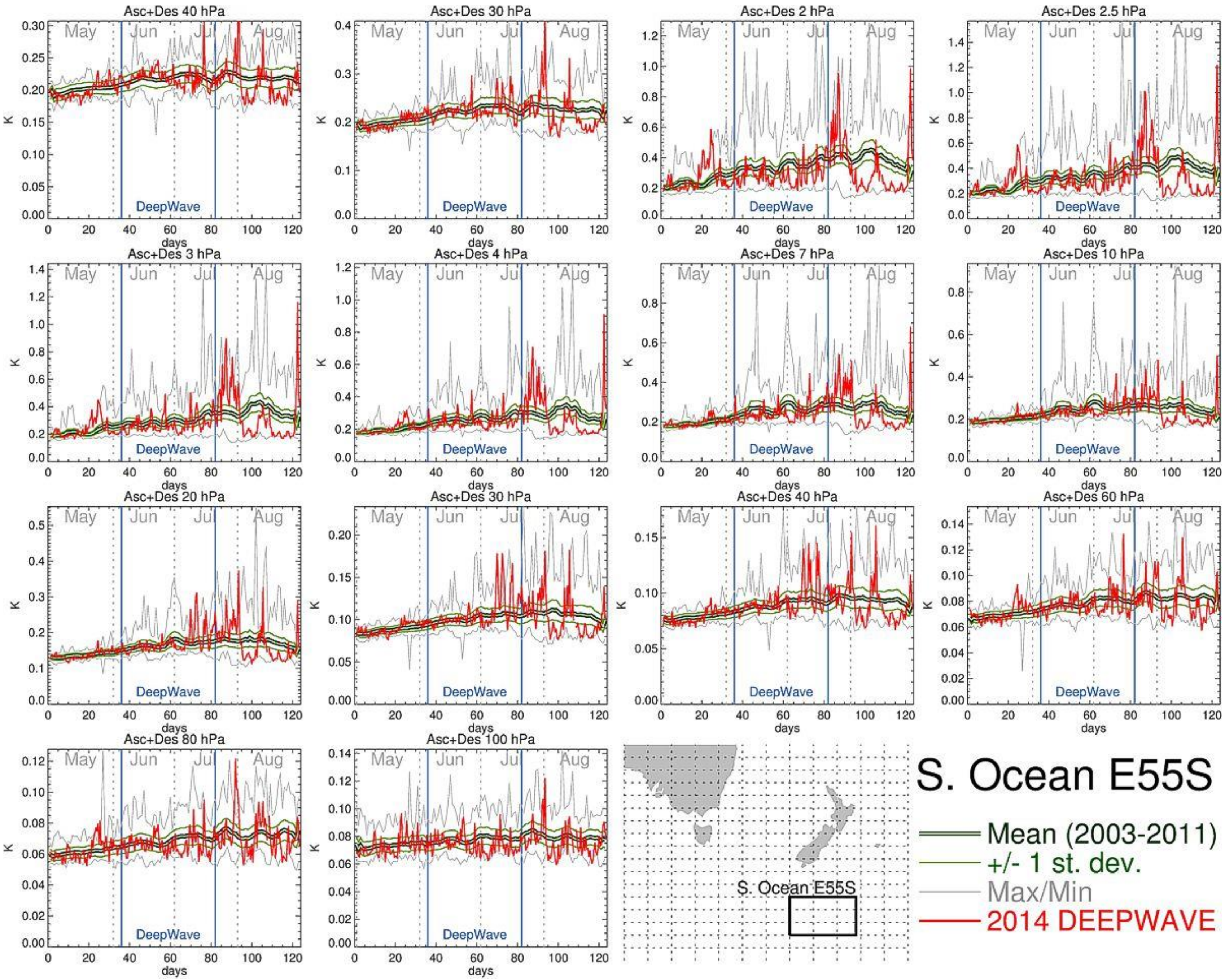


2014.06.22 Descending 2 hPa
Max = 2.11 K
Min = -1.85 K
2014.06.22 Ascending 2 hPa
Max = 1.81 K
Min = -2.24 K
2014.06.23 Descending 2 hPa
Max = 1.75 K
Min = -1.81 K
2014.06.23 Ascending 2 hPa
Max = 1.75 K
Min = -1.67 K
1.2
0.0K
-1.2
2014.06.22 Descending 7 hPa
Max = 1.52 K
Min = -1.40 K
2014.06.22 Ascending 7 hPa
Max = 1.61 K
Min = -1.74 K
2014.06.23 Descending 7 hPa
Max = 1.61 K
Min = -1.31 K
2014.06.23 Ascending 7 hPa
Max = 1.63 K
Min = -1.48 K
1.0
0.0K
-1.0
2014.06.22 Descending 20 hPa
Max = 1.19 K
Min = -1.26 K
2014.06.22 Ascending 20 hPa
Max = 1.04 K
Min = -1.70 K
2014.06.23 Descending 20 hPa
Max = 1.01 K
Min = -1.05 K
2014.06.23 Ascending 20 hPa
Max = 1.16 K
Min = -1.43 K
0.50
0.0K
-0.50
2014.06.22 Descending 80 hPa
Max = 0.50 K
Min = -0.70 K
2014.06.22 Ascending 80 hPa
Max = 0.57 K
Min = -0.60 K
2014.06.23 Descending 80 hPa
Max = 0.57 K
Min = -0.54 K
2014.06.23 Ascending 80 hPa
Max = 0.55 K
Min = -0.60 K
0.25
0.0K
-0.25

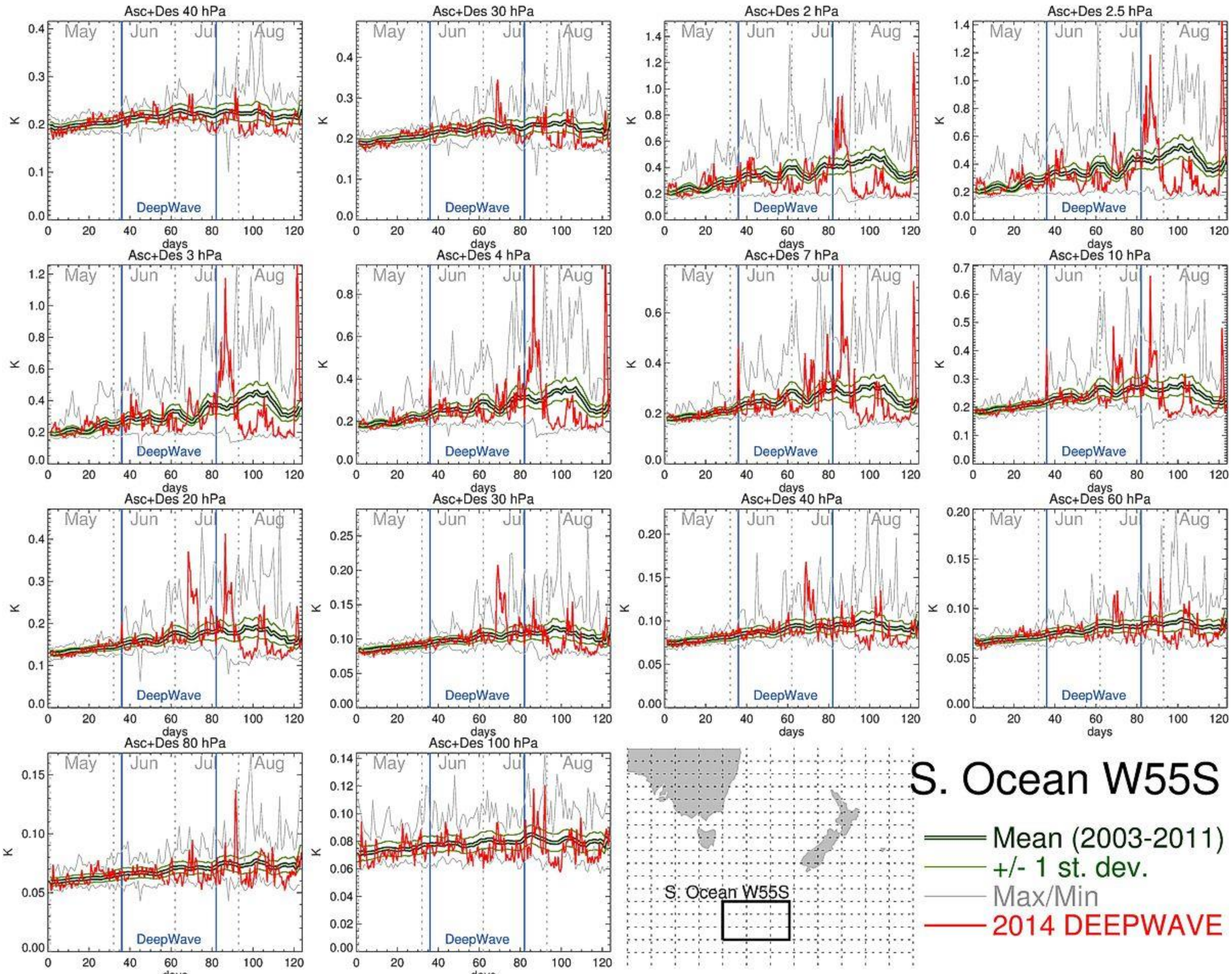

Asc+Des 40 hPa
Asc+Des 30 hPa
Asc+Des 2 hPa
Asc+Des 2.5 hPa
Asc+Des 3 hPa
Asc+Des 4 hPa
Asc+Des 7 hPa
Asc+Des 10 hPa
Asc+Des 20 hPa
Asc+Des 30 hPa
Asc+Des 40 hPa
Asc+Des 60 hPa
Asc+Des 80 hPa
Asc+Des 100 hPa
May
Jun
Jul
Aug
DeepWave
K
days
Tasmania
Tasmania
Mean (2003-2011)
+/- 1 st. dev.
Max/Min
2014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



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



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
DeepWave
days
K
S. Ocean E55S
S. Ocean E55S
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
DeepWave
K
days
S. Ocean W55S
S. Ocean W55S
Mean (2003-2011)
+/- 1 st. dev.
Max/Min
2014 DEEPWAVE