Gravity Waves in the Upper Mesosphere at King Sejong Station, Antarctica (62.22°S, 58.78°W) and Their Correlation with the Jet Stream

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Introduction

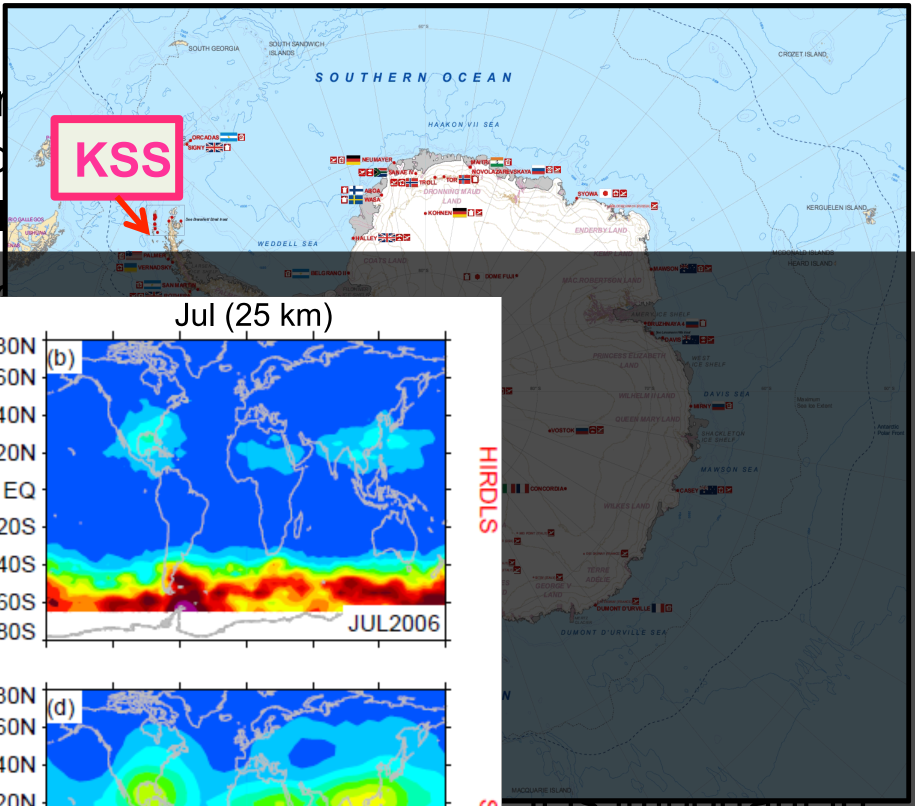
- Gravity wave momentum flux (GWMF) i
temperature perturbation using satellite d
Antarctic Peninsula in wintertime (Jia et al

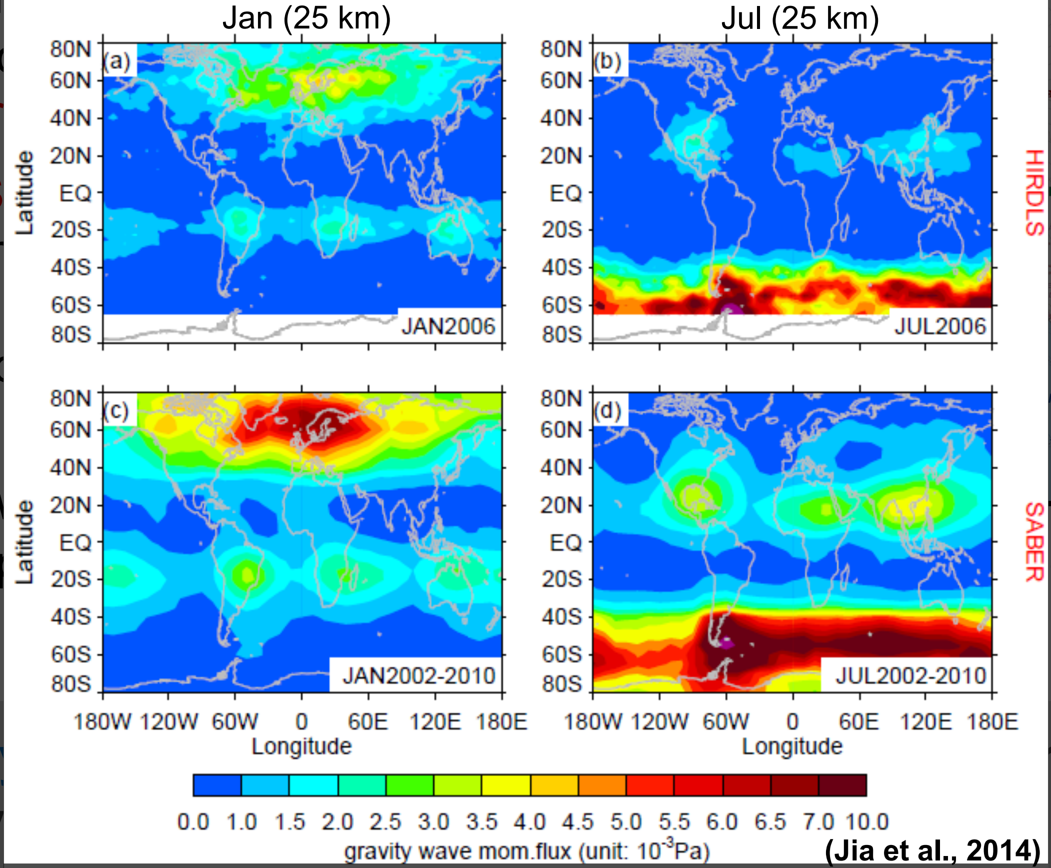
- To understand contributions of GWs to l
where climate c
sources and pr

- King Sejong S
activity occur i
has been obse
gravity wave a
et al., 2013).

- Because the w , it is important to
analyze the im esospheric GWs
variability.

In this stud **mesosphere**
observed by the jet stream
in the troposphere and stratosphere.





(Jia et al., 2014)

Data and Methodology

❖ Meteor radar data at KSS

Meteor radar at KSS		
Variables		U, V, U variance, V variance
Period		Mar. 2007—Dec. 2014
Resolution	Temporal	1 hour (sampling: every 2 min)
	Vertical	2 km (80—100km, 11 levels)

- **[Assumption]** Large-scale motions are homogeneous within a 1 hour
  ➔ Wind variances are induced by small-scale GWs

❖ Total observation days of meteor radar

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
2007			31	**30**	**31**	4	-	-	-	-	**24**	**31**
2008	10	-	-	-	**16**	7	**17**	**31**	**30**	**31**	**30**	**19**
2009	**19**	**28**	**31**	**30**	**31**	**30**	**31**	31	**30**	**29**	3	-
2010	-	13	**19**	2	3	**18**	**31**	**27**	**22**	**31**	**30**	**24**
2011	**31**	**28**	**19**	**30**	**31**	**30**	**31**	**30**	**30**	**31**	**29**	**31**
2012	**31**	**29**	**29**	**30**	**31**	**30**	**31**	**31**	**30**	**31**	**30**	**31**
2013	**26**	**28**	**31**	**30**	**31**	**30**	**31**	**31**	**30**	**31**	**30**	**31**
2014	**31**	**28**	**31**	**30**	**31**	**30**	**31**	**31**	**30**	**31**	**30**	**31**

Data and Methodology

❖ High-resolution analysis and reanalysis

Data set		High-res. ECMWF-YOTC analysis	ERA-Interim reanalysis
Period		May 2008—April 2010 (2 years)	1980—2014 (35 years)
Variables used in this study		u, v, ω	u, v, ω, T, Φ
Resolution	**Temporal**	6 hours	6 hours
	Horizontal	0.25° x 0.25°	1.5° x 1.5°
	Vertical (Model top)	25 levels (1 hPa)	37 levels (1 hPa)

❖ GWMF estimated from high-resolution analysis data

- $\left(\rho_0\overline{u'w'}, \rho_0\overline{v'w'}\right)$, where ρ_0 is density of standard atmosphere (Kim et al. 2009; Kim et al. 2012)
- Background ($\overline{\psi}$) : 21 × 21-grid running average / GW perturbation : $\psi' = \psi - \overline{\psi}$
- $|GWMF| = \sqrt{(\rho_0 \overline{u' w'})^2 + (\rho_0 \overline{v' w'})^2}$

❖ Diagnostics of GWs associated with the jet stream

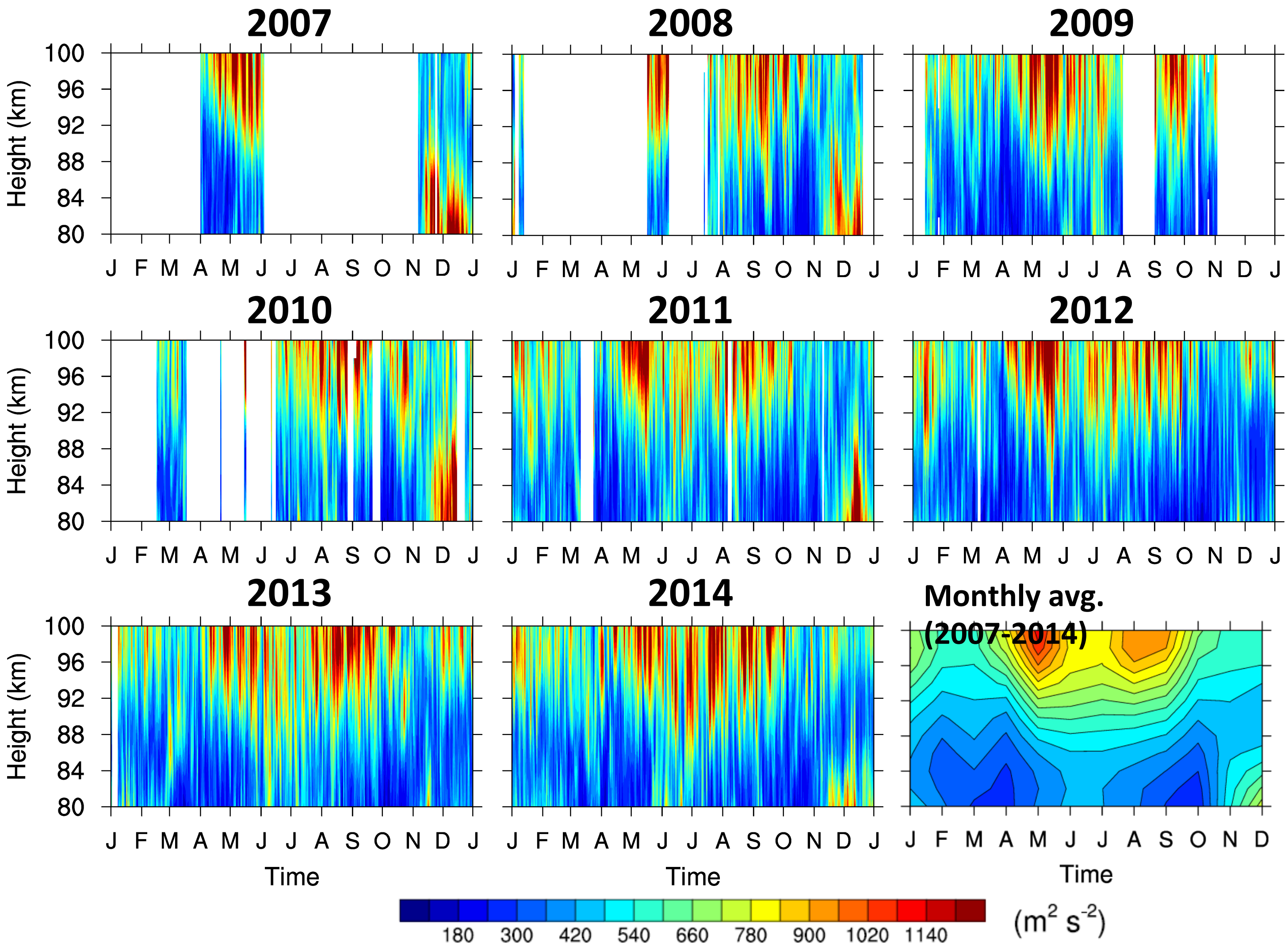
ΔNBE (residual of nonlinear balance equation, Zhang 2004; Chun et al. 2013)

$$\Delta NBE = f\zeta - \nabla^2 \Phi + 2J(u,v) - \beta u + X - (\nabla \cdot V)^2 - \partial V/\partial p \cdot \nabla \omega$$

$$X = (u^2 + v^2)\tan^2\phi/a^2 - (u^2 + v^2)/a^2\cos^2\phi - 2\tan\phi/a^2 \left(u\partial u/\partial\phi + v\partial v/\partial\phi\right)$$

Horizontal wind variance in the upper mesosphere at KSS

Data : Meteor radar at KSS



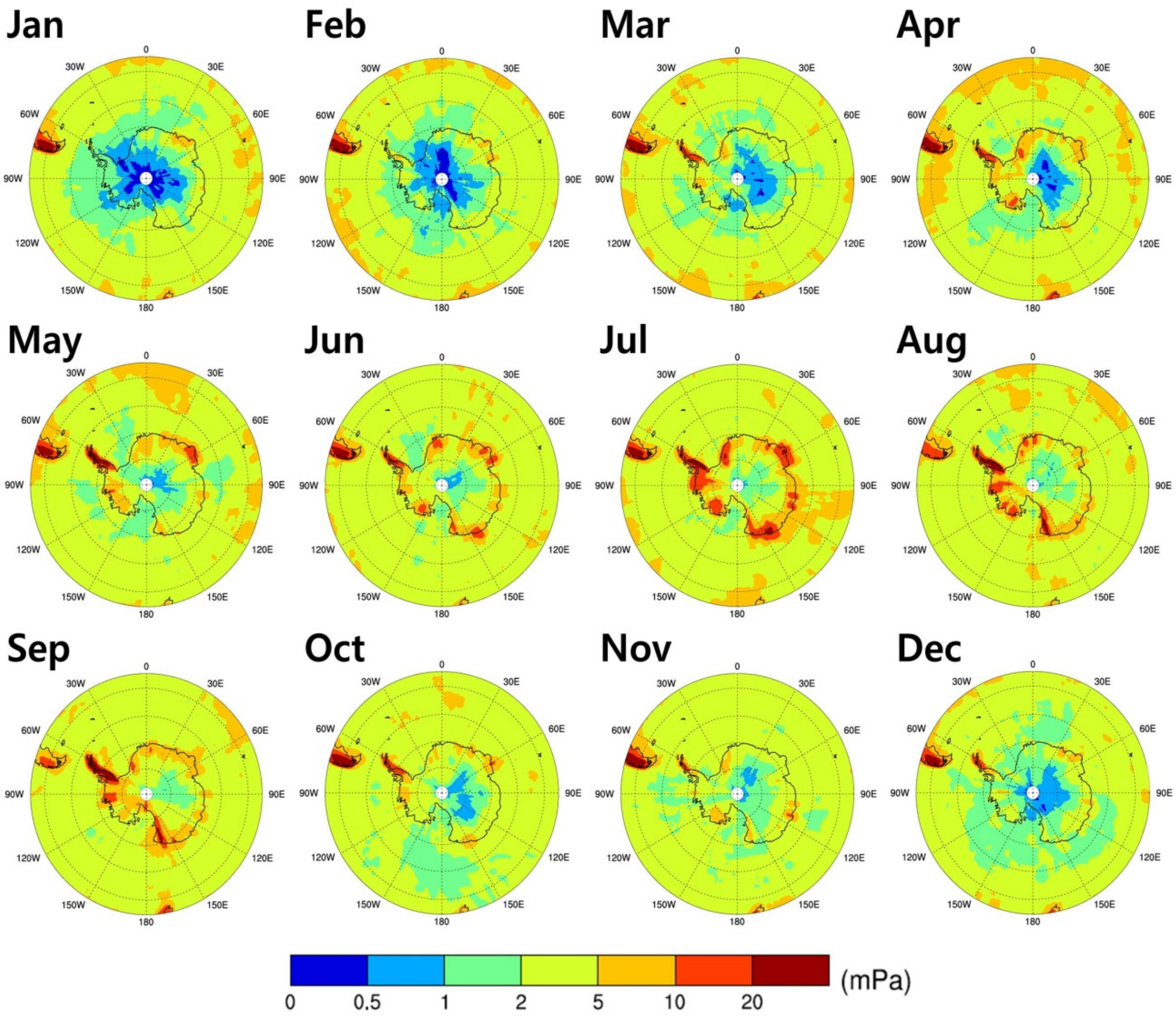
- Maximum in April—May and August—September

➔ sudden increase of GW activities at the lower atmosphere near KSS

➔ formation and breakdown of Antarctic vortex may partially contribute to the enhancement of GW activities (Yoshiki et al., 2004)

Monthly mean |GWMF| at 300 hPa in the SH (May 2008–Apr. 2010)

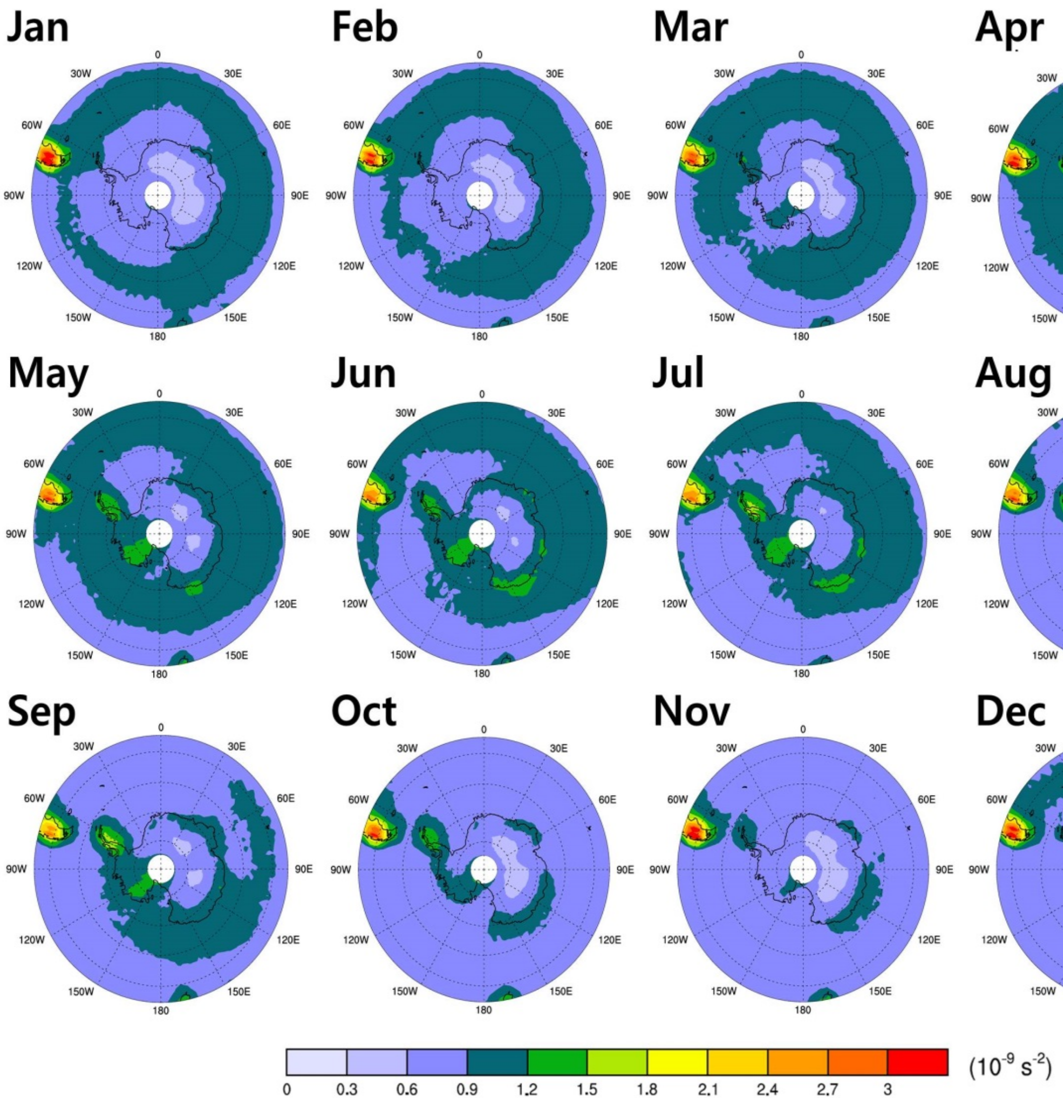
Data :
Hi-res. ECMWF-YOTC analysis



- Strong in May—September
- Local maxima at Antarctic peninsula, Tip of the Andes, and Antarctic coastline

Monthly mean |△NBE| at 350 hPa in the SH (1980–2014)

Data :
ERA-Interim reanalysis



- Persistent maxima in Tip of the Andes and Antarctic peninsula
- Large value in the Antarctic peninsula : winter > summer

△NBE at different altitudes

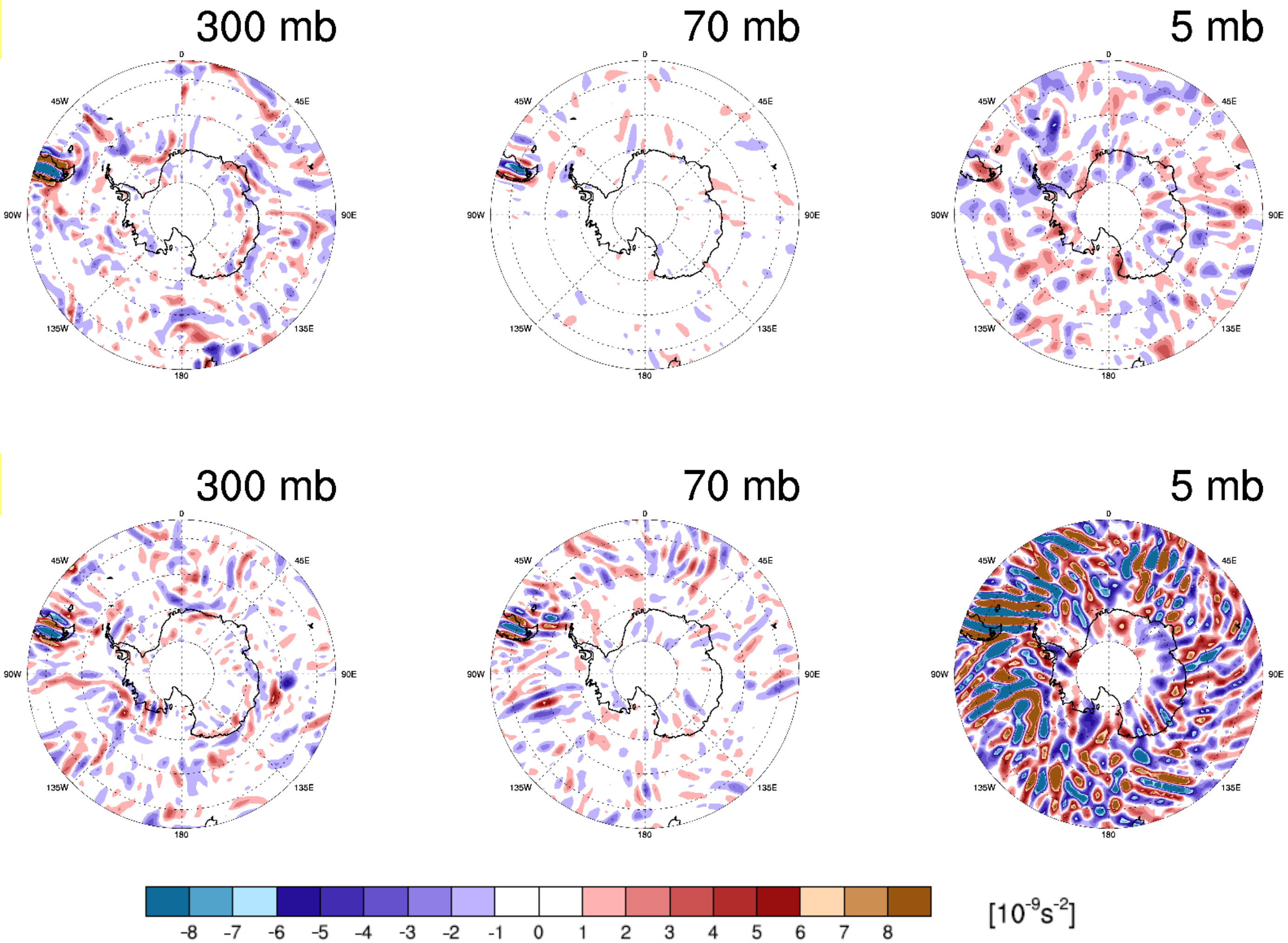
300 hPa

70 hPa

5 hPa

00Z 16 Jan. 2009

00Z 16 Jul. 2009

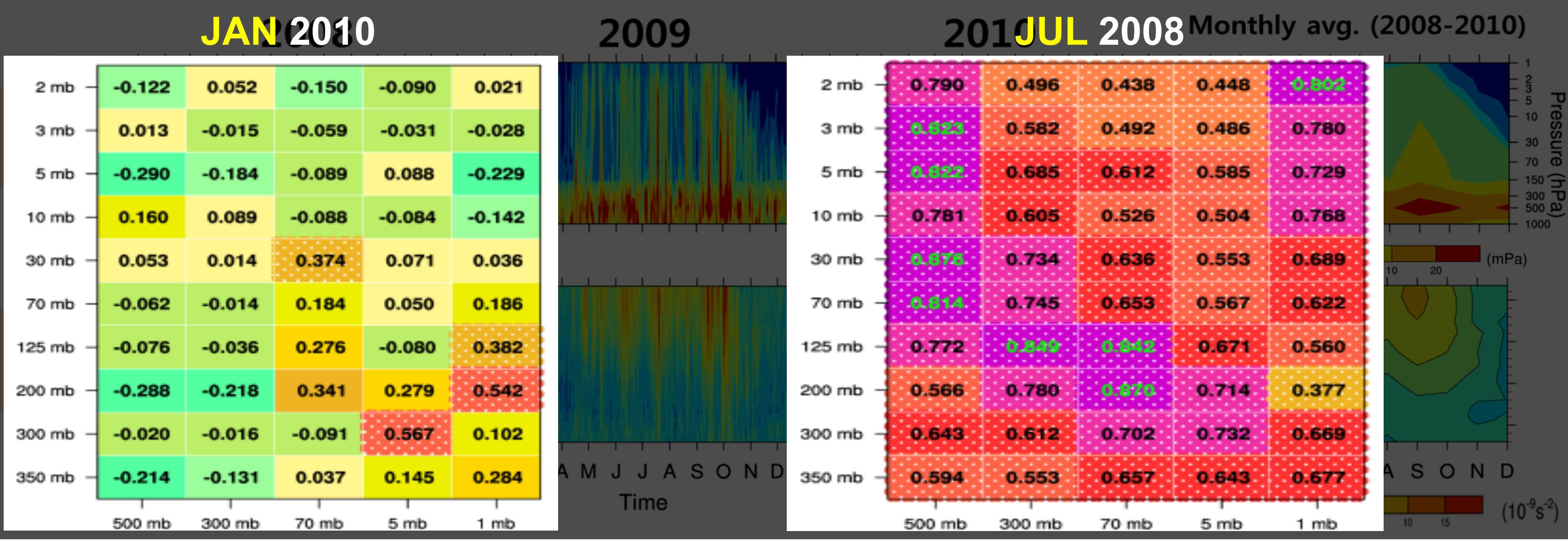


- GWs not only from the tropospheric jet, but also from the stratospheric jet
- Stratospheric vortex in winter-time is important

|GWMF| and |△NBE| near KSS

|GWMF| (H-ECMWF)

|△NBE| (ERA-I)



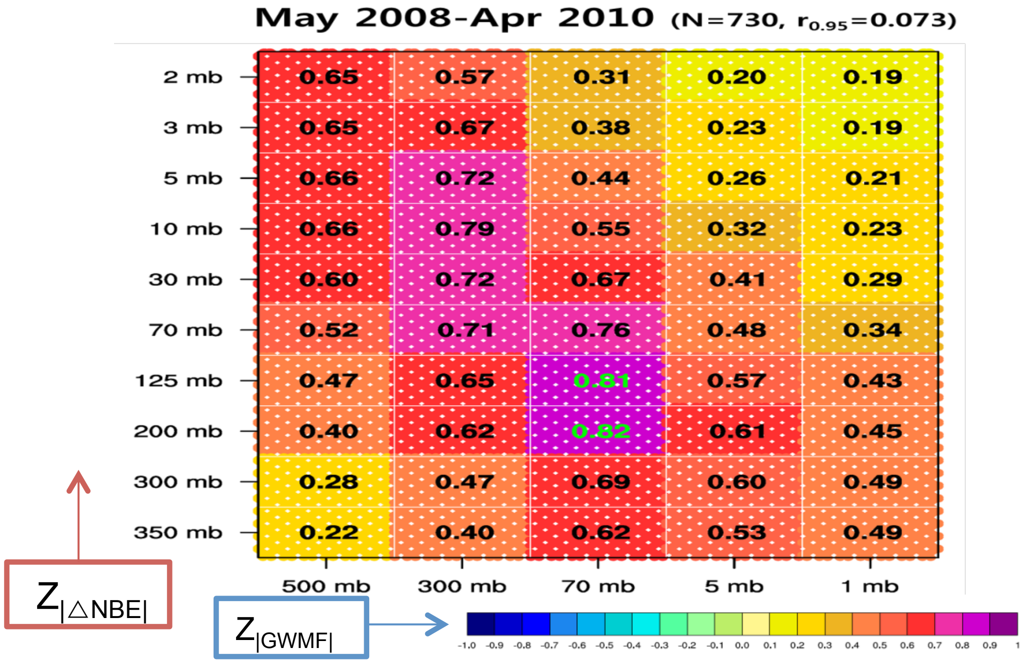
JAN 2010

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	-0.122	0.052	-0.150	-0.090	0.021
3 mb	0.013	-0.015	-0.059	-0.031	-0.028
5 mb	-0.290	-0.184	-0.089	0.088	-0.229
10 mb	0.160	0.089	-0.088	-0.084	-0.142
30 mb	0.053	0.014	0.374	0.071	0.036
70 mb	-0.062	-0.014	0.184	0.050	0.186
125 mb	-0.076	-0.036	0.276	-0.080	0.382
200 mb	-0.288	-0.218	0.341	0.279	0.542
300 mb	-0.020	-0.016	-0.091	0.567	0.102
350 mb	-0.214	-0.131	0.037	0.145	0.284

JUL 2008

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	0.790	0.496	0.438	0.448	0.802
3 mb	0.823	0.582	0.492	0.486	0.780
5 mb	0.822	0.685	0.612	0.585	0.729
10 mb	0.781	0.605	0.526	0.504	0.768
30 mb	0.876	0.734	0.636	0.553	0.689
70 mb	0.814	0.745	0.653	0.567	0.622
125 mb	0.772	0.849	0.842	0.671	0.560
200 mb	0.566	0.780	0.870	0.714	0.377
300 mb	0.643	0.612	0.702	0.732	0.669
350 mb	0.594	0.553	0.657	0.643	0.677

❖ Correlation between |GWMF| and |△NBE|

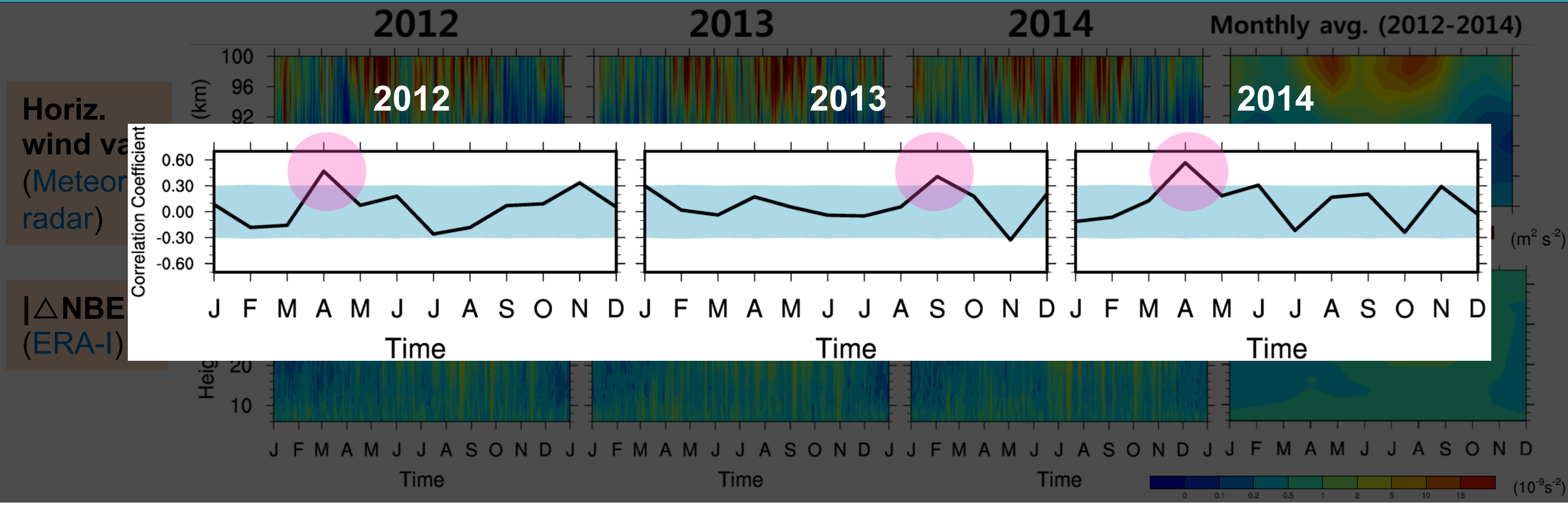


May 2008-Apr 2010 (N=730, $r_{0.95}$=0.073)

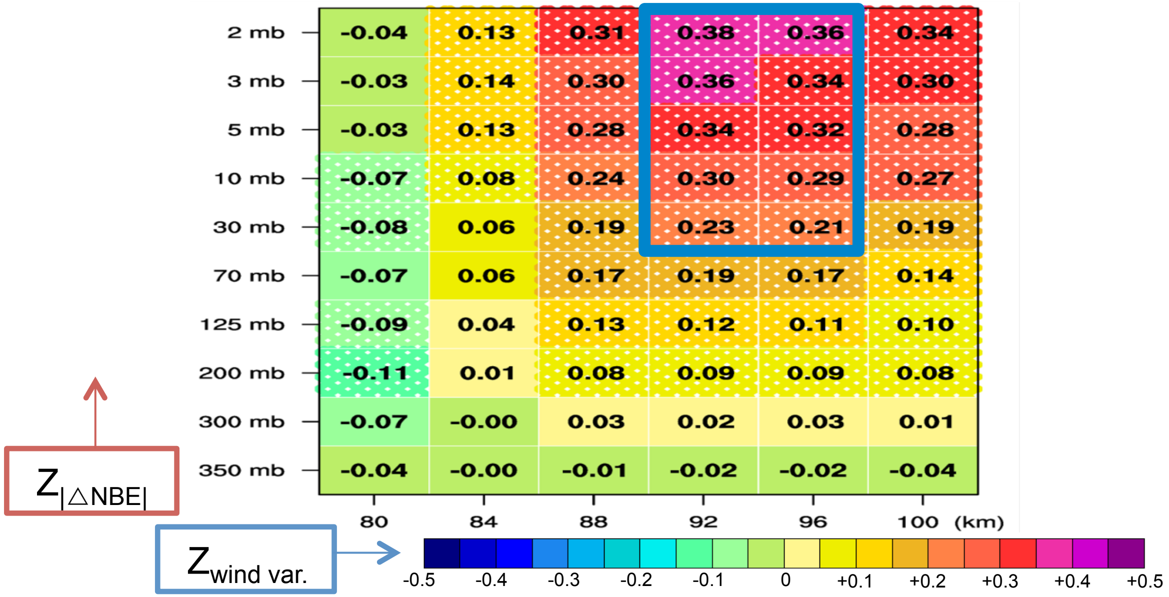
	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	0.65	0.57	0.31	0.20	0.19
3 mb	0.65	0.67	0.38	0.23	0.19
5 mb	0.66	0.72	0.44	0.26	0.21
10 mb	0.66	0.79	0.55	0.32	0.23
30 mb	0.60	0.72	0.67	0.41	0.29
70 mb	0.52	0.71	0.76	0.48	0.34
125 mb	0.47	0.65	0.81	0.57	0.43
200 mb	0.40	0.62	0.82	0.61	0.45
300 mb	0.28	0.47	0.69	0.60	0.49
350 mb	0.22	0.40	0.62	0.53	0.49

- Statistically significant positive correlations exist at whole layers
- Jet stream in the troposphere and stratosphere is a dominant source of GWs in the troposphere and stratosphere near KSS especially in winter to early spring

Horizontal wind variance and |△NBE| near KSS



❖ Correlation between wind variance and |△NBE|



Jan 2012-Dec 2014 (N=730, $r_{0.95}$=0.073)

	80	84	88	92	96	100 (km)
2 mb	-0.04	0.13	0.31	0.38	0.36	0.34
3 mb	-0.03	0.14	0.30	0.36	0.34	0.30
5 mb	-0.03	0.13	0.28	0.34	0.32	0.28
10 mb	-0.07	0.08	0.24	0.30	0.29	0.27
30 mb	-0.08	0.06	0.19	0.23	0.21	0.19
70 mb	-0.07	0.06	0.17	0.19	0.17	0.14
125 mb	-0.09	0.04	0.13	0.12	0.11	0.10
200 mb	-0.11	0.01	0.08	0.09	0.09	0.08
300 mb	-0.07	-0.00	0.03	0.02	0.03	0.01
350 mb	-0.04	-0.00	-0.01	-0.02	-0.02	-0.04

- Positive correlation between the |△NBE| in the upper stratosphere and wind variance in the upper mesosphere, especially in April and September
- Strong mesospheric GW activities observed in Spring and Autumn seem to be related to the jet stream in the upper stratosphere

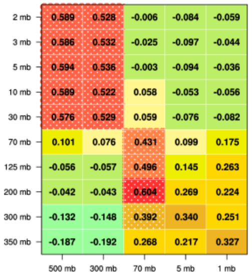
Summary

- Seasonal variations in GW activities in the upper mesosphere revealed two peaks in April–May and August–September, with a larger value in April–September from the 8-year (2007-2014) means, although interannual variations are considerable.
- GWMF estimated from the high-resolution ECMWF analysis was enhanced during May–September, and have local maxima at Antarctic peninsula, Tip of the Andes, and Antarctic coastline.
- Large value of △NBE exists near the Tip of the Andes and Antarctic Peninsula in the troposphere and along polar vortex in the stratosphere.
- Significant positive correlation between △NBE and GWMF implies that △NBE is a good diagnostics of GWs associated with jet stream in the troposphere and stratosphere, and GWMF at a particular altitude include not only GWs propagated from the lower layers but also GWs generated from in-situ source or GWs propagated downward from the upper layers.
- △NBE in the upper stratosphere is correlated well with the observed GWs in the upper mesosphere, especially in April and September.
- Sources of the GWs that observed in the upper mesosphere are being examined by backward integration of a 3-dimentional GW ray-tracing model, with wave characteristics observed from the meteor radar and airglow all-sky camera at KSS.

THANK YOU.

Monthly correlation between |GWMF| and |△NBE| near KSS

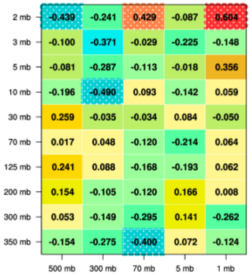
01/2009



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	0.589	0.528	-0.006	-0.084	-0.059
3 mb	0.586	0.532	-0.025	-0.097	-0.044
5 mb	0.594	0.536	-0.003	-0.094	-0.036
10 mb	0.589	0.522	0.058	-0.053	-0.056
30 mb	0.576	0.529	0.059	-0.076	-0.082
70 mb	0.101	0.076	0.431	0.099	0.175
125 mb	-0.056	-0.057	0.496	0.145	0.263
200 mb	-0.042	-0.043	0.604	0.269	0.224
300 mb	-0.132	-0.148	0.392	0.340	0.251
350 mb	-0.187	-0.192	0.268	0.217	0.327

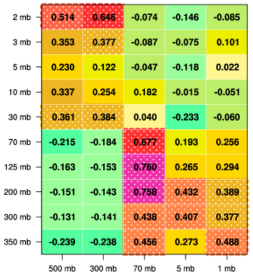
02/2009



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	-0.439	-0.241	0.429	-0.087	0.604
3 mb	-0.100	-0.371	-0.029	-0.225	-0.148
5 mb	-0.081	-0.287	-0.113	-0.018	0.356
10 mb	-0.196	-0.490	0.093	-0.142	0.059
30 mb	0.259	-0.035	-0.034	0.084	-0.050
70 mb	0.017	0.048	-0.120	-0.214	0.064
125 mb	0.241	0.088	-0.168	-0.193	0.062
200 mb	0.154	-0.105	-0.120	0.166	0.008
300 mb	0.053	-0.149	-0.295	0.141	-0.262
350 mb	-0.154	-0.275	-0.400	0.072	-0.124

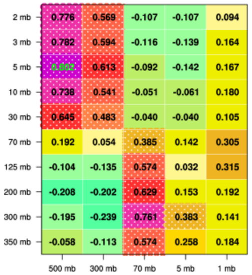
03/2009



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	0.514	0.646	-0.074	-0.146	-0.085
3 mb	0.353	0.377	-0.087	-0.075	0.101
5 mb	0.230	0.122	-0.047	-0.118	0.022
10 mb	0.337	0.254	0.182	-0.015	-0.051
30 mb	0.361	0.384	0.040	-0.233	-0.060
70 mb	-0.215	-0.184	0.677	0.193	0.256
125 mb	-0.163	-0.153	0.760	0.265	0.294
200 mb	-0.151	-0.143	0.758	0.432	0.389
300 mb	-0.131	-0.141	0.438	0.407	0.377
350 mb	-0.239	-0.238	0.456	0.273	0.488

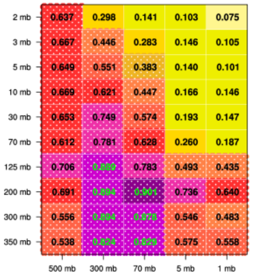
04/2009



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	0.776	0.569	-0.107	-0.107	0.094
3 mb	0.782	0.594	-0.116	-0.139	0.164
5 mb	0.802	0.613	-0.092	-0.142	0.167
10 mb	0.738	0.541	-0.051	-0.061	0.180
30 mb	0.645	0.483	-0.040	-0.040	0.105
70 mb	0.192	0.054	0.385	0.142	0.305
125 mb	-0.104	-0.135	0.574	0.032	0.315
200 mb	-0.208	-0.202	0.629	0.153	0.192
300 mb	-0.195	-0.239	0.761	0.383	0.141
350 mb	-0.058	-0.113	0.574	0.258	0.184

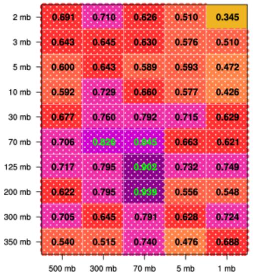
05/2008



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	0.637	0.298	0.141	0.103	0.075
3 mb	0.667	0.446	0.283	0.146	0.105
5 mb	0.649	0.551	0.383	0.140	0.101
10 mb	0.669	0.621	0.447	0.166	0.146
30 mb	0.653	0.749	0.574	0.193	0.147
70 mb	0.612	0.781	0.628	0.260	0.187
125 mb	0.706	0.889	0.783	0.493	0.435
200 mb	0.691	0.894	0.901	0.736	0.640
300 mb	0.556	0.894	0.878	0.546	0.483
350 mb	0.538	0.824	0.829	0.575	0.558

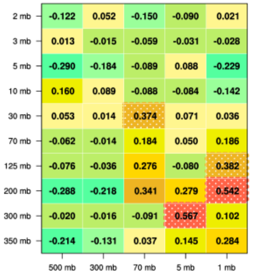
06/2008



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	0.691	0.710	0.626	0.510	0.345
3 mb	0.643	0.645	0.630	0.576	0.510
5 mb	0.600	0.643	0.589	0.593	0.472
10 mb	0.592	0.729	0.660	0.577	0.426
30 mb	0.677	0.760	0.792	0.715	0.629
70 mb	0.706	0.826	0.845	0.663	0.621
125 mb	0.717	0.795	0.902	0.732	0.749
200 mb	0.622	0.795	0.939	0.556	0.548
300 mb	0.705	0.645	0.791	0.628	0.724
350 mb	0.540	0.515	0.740	0.476	0.688

01/2010



Correlation (abs. GWMF. vs abs. dNBE)

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2 mb	-0.122	0.052	-0.150	-0.090	0.021
3 mb	0.013	-0.015	-0.059	-0.031	-0.028
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10 mb	0.160	0.089	-0.088	-0.084	-0.142
30 mb	0.053	0.014	0.374	0.071	0.036
70 mb	-0.062	-0.014	0.184	0.050	0.186
125 mb	-0.076	-0.036	0.276	-0.080	0.382
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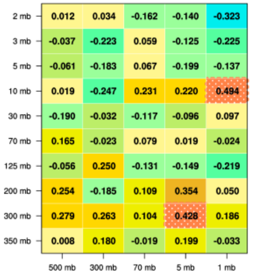
300 mb	-0.020	-0.016	-0.091	0.567	0.102
350 mb	-0.214	-0.131	0.037	0.145	0.284

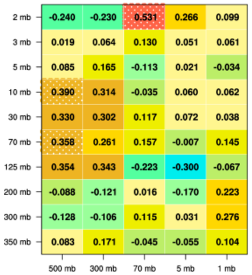
02/2010



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	0.012	0.034	-0.162	-0.140	-0.323
3 mb	-0.037	-0.223	0.059	-0.125	-0.225
5 mb	-0.061	-0.183	0.067	-0.199	-0.137
10 mb	0.019	-0.247	0.231	0.220	0.494
30 mb	-0.190	-0.032	-0.117	-0.096	0.097
70 mb	0.165	-0.023	0.079	0.019	-0.024
125 mb	-0.056	0.250	-0.131	-0.149	-0.219
200 mb	0.254	-0.185	0.109	0.354	0.050
300 mb	0.279	0.263	0.104	0.428	0.186
350 mb	0.008	0.180	-0.019	0.199	-0.033

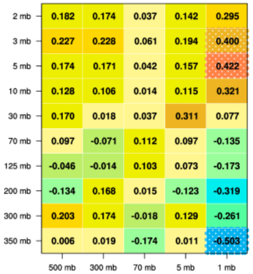
03/2010



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	-0.240	-0.230	0.531	0.266	0.099
3 mb	0.019	0.064	0.130	0.051	0.061
5 mb	0.085	0.165	-0.113	0.021	-0.034
10 mb	0.390	0.314	-0.035	0.060	0.062
30 mb	0.330	0.302	0.117	0.072	0.038
70 mb	0.358	0.261	0.157	-0.007	0.145
125 mb	0.354	0.343	-0.223	-0.300	-0.067
200 mb	-0.088	-0.121	0.016	-0.170	0.223
300 mb	-0.128	-0.106	0.115	0.031	0.276
350 mb	0.083	0.171	-0.045	-0.055	0.104

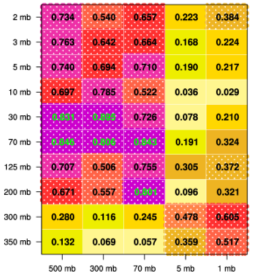
04/2010



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	0.182	0.174	0.037	0.142	0.295
3 mb	0.227	0.228	0.061	0.194	0.400
5 mb	0.174	0.171	0.042	0.157	0.422
10 mb	0.128	0.106	0.014	0.115	0.321
30 mb	0.170	0.018	0.037	0.311	0.077
70 mb	0.097	-0.071	0.112	0.097	-0.135
125 mb	-0.046	-0.014	0.103	0.073	-0.173
200 mb	-0.134	0.168	0.015	-0.123	-0.319
300 mb	0.203	0.174	-0.018	0.129	-0.261
350 mb	0.006	0.019	-0.174	0.011	-0.503

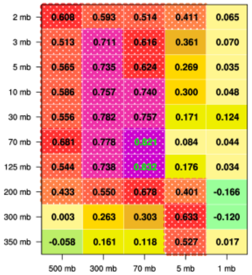
05/2009



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	0.734	0.540	0.657	0.223	0.384
3 mb	0.763	0.642	0.664	0.168	0.224
5 mb	0.740	0.694	0.710	0.190	0.217
10 mb	0.697	0.785	0.522	0.036	0.029
30 mb	0.831	0.895	0.726	0.078	0.210
70 mb	0.846	0.806	0.843	0.191	0.324
125 mb	0.707	0.506	0.755	0.305	0.372
200 mb	0.671	0.557	0.801	0.096	0.321
300 mb	0.280	0.116	0.245	0.478	0.605
350 mb	0.132	0.069	0.057	0.359	0.517

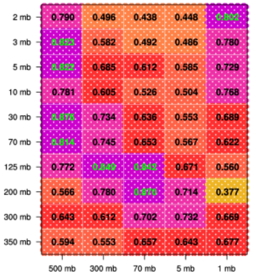
06/2009



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	0.608	0.593	0.514	0.411	0.065
3 mb	0.513	0.711	0.616	0.361	0.070
5 mb	0.565	0.735	0.624	0.269	0.035
10 mb	0.586	0.757	0.740	0.300	0.048
30 mb	0.556	0.782	0.757	0.171	0.124
70 mb	0.681	0.778	0.821	0.084	0.044
125 mb	0.544	0.738	0.832	0.176	0.034
200 mb	0.433	0.550	0.678	0.401	-0.166
300 mb	0.003	0.263	0.303	0.633	-0.120
350 mb	-0.058	0.161	0.118	0.527	0.017

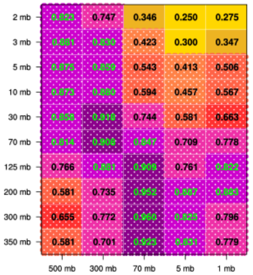
07/2008



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	0.790	0.496	0.438	0.448	0.802
3 mb	0.823	0.582	0.492	0.486	0.780
5 mb	0.822	0.685	0.612	0.585	0.729
10 mb	0.781	0.605	0.526	0.504	0.768
30 mb	0.876	0.734	0.636	0.553	0.689
70 mb	0.814	0.745	0.653	0.567	0.622
125 mb	0.772	0.849	0.842	0.671	0.560
200 mb	0.566	0.780	0.870	0.714	0.377
300 mb	0.643	0.612	0.702	0.732	0.669
350 mb	0.594	0.553	0.657	0.643	0.677

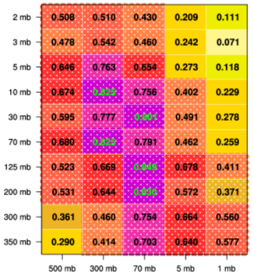
08/2008



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	0.823	0.747	0.346	0.250	0.275
3 mb	0.881	0.830	0.423	0.300	0.347
5 mb	0.875	0.859	0.543	0.413	0.506
10 mb	0.873	0.880	0.594	0.457	0.567
30 mb	0.858	0.918	0.744	0.581	0.663
70 mb	0.814	0.908	0.847	0.709	0.778
125 mb	0.766	0.881	0.909	0.761	0.822
200 mb	0.581	0.735	0.952	0.887	0.883
300 mb	0.655	0.772	0.960	0.825	0.796
350 mb	0.581	0.701	0.923	0.831	0.779

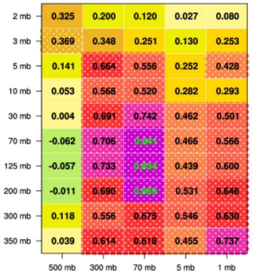
09/2008



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	0.508	0.510	0.430	0.209	0.111
3 mb	0.478	0.542	0.460	0.242	0.071
5 mb	0.646	0.763	0.654	0.273	0.118
10 mb	0.674	0.825	0.756	0.402	0.229
30 mb	0.595	0.777	0.801	0.491	0.278
70 mb	0.680	0.825	0.791	0.462	0.259
125 mb	0.523	0.669	0.849	0.678	0.411
200 mb	0.531	0.644	0.830	0.572	0.371
300 mb	0.361	0.460	0.754	0.664	0.560
350 mb	0.290	0.414	0.703	0.640	0.577

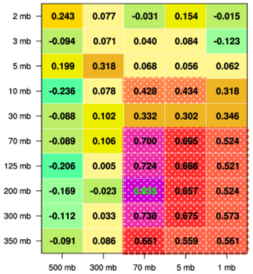
10/2008



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	0.325	0.200	0.120	0.027	0.080
3 mb	0.369	0.348	0.251	0.130	0.253
5 mb	0.141	0.664	0.556	0.252	0.428
10 mb	0.053	0.568	0.520	0.282	0.293
30 mb	0.004	0.691	0.742	0.462	0.501
70 mb	-0.062	0.706	0.841	0.466	0.566
125 mb	-0.057	0.733	0.834	0.439	0.600
200 mb	-0.011	0.690	0.869	0.531	0.646
300 mb	0.118	0.556	0.675	0.546	0.630
350 mb	0.039	0.614	0.618	0.455	0.737

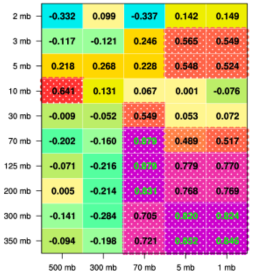
11/2008



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	0.243	0.077	-0.031	0.154	-0.015
3 mb	-0.094	0.071	0.040	0.084	-0.123
5 mb	0.199	0.318	0.068	0.056	0.062
10 mb	-0.236	0.078	0.428	0.434	0.318
30 mb	-0.088	0.102	0.332	0.302	0.346
70 mb	-0.089	0.106	0.700	0.695	0.524
125 mb	-0.206	0.005	0.724	0.688	0.521
200 mb	-0.169	-0.023	0.835	0.657	0.524
300 mb	-0.112	0.033	0.738	0.675	0.573
350 mb	-0.091	0.086	0.661	0.559	0.561

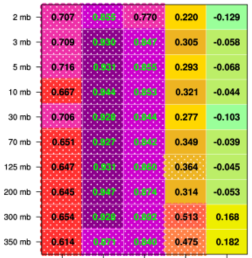
12/2008



Correlation (abs. GWMF. vs abs. dNBE)

	500 mb	300 mb	70 mb	5 mb	1 mb
2 mb	-0.332	0.099	-0.337	0.142	0.149
3 mb	-0.117	-0.121	0.246	0.565	0.549
5 mb	0.218	0.268	0.228	0.548	0.524
10 mb	0.641	0.131	0.067	0.001	-0.076
30 mb	-0.009	-0.052	0.549	0.053	0.072
70 mb	-0.202	-0.160	0.879	0.489	0.517
125 mb	-0.071	-0.216	0.879	0.779	0.770
200 mb	0.005	-0.214	0.831	0.768	0.769
300 mb	-0.141	-0.284	0.705	0.820	0.824
350 mb	-0.094	-0.198	0.721	0.852	0.846

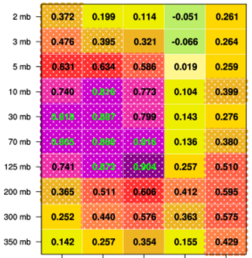
07/2009



Correlation (abs. GWMF. vs abs. dNBE)

2 mb	0.707	0.855	0.770	0.220	-0.129
3 mb	0.709	0.930	0.847	0.305	-0.058
5 mb	0.716	0.931	0.855	0.293	-0.068
10 mb	0.667	0.944	0.853	0.321	-0.044
30 mb	0.706	0.928	0.844	0.277	-0.103
70 mb	0.651	0.927	0.842	0.349	-0.039
125 mb	0.647	0.931	0.860	0.364	-0.045
200 mb	0.645	0.947	0.874	0.314	-0.053
300 mb	0.654	0.928	0.892	0.513	0.168
350 mb	0.614	0.871	0.840	0.475	0.182

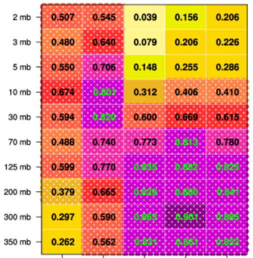
08/2009



Correlation (abs. GWMF. vs abs. dNBE)

2 mb	0.372	0.199	0.114	-0.051	0.261
3 mb	0.476	0.395	0.321	-0.066	0.264
5 mb	0.631	0.634	0.586	0.019	0.259
10 mb	0.740	0.816	0.773	0.104	0.399
30 mb	0.819	0.887	0.799	0.143	0.276
70 mb	0.805	0.868	0.816	0.136	0.380
125 mb	0.741	0.873	0.904	0.257	0.510
200 mb	0.365	0.511	0.606	0.412	0.595
300 mb	0.252	0.440	0.576	0.363	0.575
350 mb	0.142	0.257	0.354	0.155	0.429

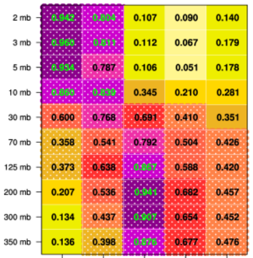
09/2009



Correlation (abs. GWMF. vs abs. dNBE)

2 mb	0.507	0.545	0.039	0.156	0.206
3 mb	0.480	0.640	0.079	0.206	0.226
5 mb	0.550	0.706	0.148	0.255	0.286
10 mb	0.674	0.801	0.312	0.406	0.410
30 mb	0.594	0.820	0.600	0.669	0.615
70 mb	0.488	0.740	0.773	0.813	0.780
125 mb	0.599	0.770	0.835	0.882	0.825
200 mb	0.379	0.665	0.829	0.880	0.841
300 mb	0.297	0.590	0.863	0.901	0.865
350 mb	0.262	0.562	0.831	0.861	0.852

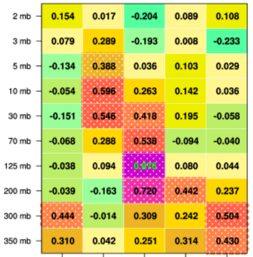
10/2009



Correlation (abs. GWMF. vs abs. dNBE)

2 mb	0.942	0.804	0.107	0.090	0.140
3 mb	0.960	0.811	0.112	0.067	0.179
5 mb	0.934	0.787	0.106	0.051	0.178
10 mb	0.860	0.839	0.345	0.210	0.281
30 mb	0.600	0.768	0.691	0.410	0.351
70 mb	0.358	0.541	0.792	0.504	0.426
125 mb	0.373	0.638	0.867	0.588	0.420
200 mb	0.207	0.536	0.941	0.682	0.457
300 mb	0.134	0.437	0.907	0.654	0.452
350 mb	0.136	0.398	0.876	0.677	0.476

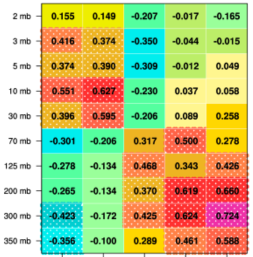
11/2009



Correlation (abs. GWMF. vs abs. dNBE)

2 mb	0.154	0.017	-0.204	0.089	0.108
3 mb	0.079	0.289	-0.193	0.008	-0.233
5 mb	-0.134	0.388	0.036	0.103	0.029
10 mb	-0.054	0.596	0.263	0.142	0.036
30 mb	-0.151	0.546	0.418	0.195	-0.058
70 mb	-0.068	0.288	0.538	-0.094	-0.040
125 mb	-0.038	0.094	0.876	0.080	0.044
200 mb	-0.039	-0.163	0.720	0.442	0.237
300 mb	0.444	-0.014	0.309	0.242	0.504
350 mb	0.310	0.042	0.251	0.314	0.430

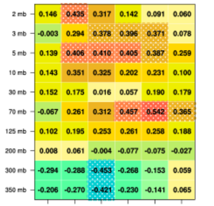
12/2009



Correlation (abs. GWMF. vs abs. dNBE)

2 mb	0.155	0.149	-0.207	-0.017	-0.165
3 mb	0.416	0.374	-0.350	-0.044	-0.015
5 mb	0.374	0.390	-0.309	-0.012	0.049
10 mb	0.551	0.627	-0.230	0.037	0.058
30 mb	0.396	0.595	-0.206	0.089	0.258
70 mb	-0.301	-0.206	0.317	0.500	0.278
125 mb	-0.278	-0.134	0.468	0.343	0.426
200 mb	-0.265	-0.134	0.370	0.619	0.660
300 mb	-0.423	-0.172	0.425	0.624	0.724
350 mb	-0.356	-0.100	0.289	0.461	0.588

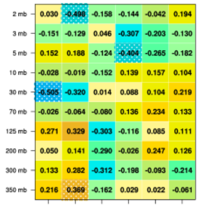
01/2012



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	0.146	0.435	0.317	0.142	0.091	0.060
3 mb	-0.003	0.294	0.378	0.396	0.371	0.078
5 mb	0.139	0.406	0.410	0.405	0.387	0.259
10 mb	0.143	0.351	0.325	0.202	0.231	0.100
30 mb	0.152	0.175	0.016	0.057	0.190	0.179
70 mb	-0.067	0.261	0.312	0.457	0.542	0.365
125 mb	0.102	0.195	0.253	0.261	0.258	0.188
200 mb	0.008	0.061	-0.004	-0.077	-0.075	-0.027
300 mb	-0.294	-0.288	-0.453	-0.268	-0.153	0.059
350 mb	-0.206	-0.270	-0.421	-0.230	-0.141	0.065

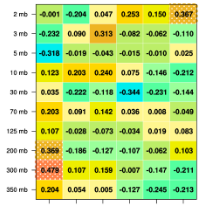
02/2012



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	0.030	-0.498	-0.158	-0.144	-0.042	0.194
3 mb	-0.151	-0.129	0.046	-0.307	-0.203	-0.130
5 mb	0.152	0.188	-0.124	-0.404	-0.265	-0.182
10 mb	-0.028	-0.019	-0.152	0.139	0.157	0.104
30 mb	-0.505	-0.320	0.014	0.088	0.104	0.219
70 mb	-0.026	-0.064	-0.080	0.136	0.234	0.133
125 mb	0.271	0.329	-0.303	-0.116	0.085	0.111
200 mb	0.050	0.141	-0.290	-0.026	0.247	0.126
300 mb	0.133	0.282	-0.312	-0.198	-0.093	-0.214
350 mb	0.216	0.369	-0.162	0.029	0.022	-0.061

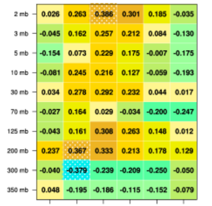
03/2012



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.001	-0.204	0.047	0.253	0.150	0.367
3 mb	-0.232	0.090	0.313	-0.082	-0.062	-0.110
5 mb	-0.318	-0.019	-0.043	-0.015	-0.010	0.025
10 mb	0.123	0.203	0.240	0.075	-0.146	-0.212
30 mb	0.035	-0.222	-0.118	-0.344	-0.231	-0.144
70 mb	0.203	0.091	0.142	0.036	0.008	-0.049
125 mb	0.107	-0.028	-0.073	-0.034	0.019	0.083
200 mb	0.369	-0.186	-0.127	-0.107	-0.062	0.103
300 mb	0.479	0.107	0.159	-0.007	-0.147	-0.211
350 mb	0.204	0.054	0.005	-0.127	-0.245	-0.213

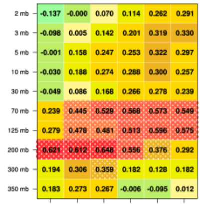
04/2012



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	0.026	0.263	0.386	0.301	0.185	-0.035
3 mb	-0.045	0.162	0.257	0.212	0.084	-0.130
5 mb	-0.154	0.073	0.229	0.175	-0.007	-0.175
10 mb	-0.081	0.245	0.216	0.127	-0.059	-0.193
30 mb	0.034	0.278	0.292	0.232	0.044	0.017
70 mb	-0.027	0.164	0.029	-0.034	-0.200	-0.247
125 mb	-0.043	0.161	0.308	0.263	0.148	0.012
200 mb	0.237	0.367	0.333	0.213	0.178	0.129
300 mb	-0.040	-0.379	-0.239	-0.209	-0.250	-0.050
350 mb	0.048	-0.195	-0.186	-0.115	-0.152	-0.079

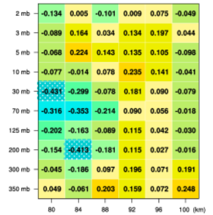
05/2012



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.137	-0.000	0.070	0.114	0.262	0.291
3 mb	-0.098	0.005	0.142	0.201	0.319	0.330
5 mb	-0.001	0.158	0.247	0.253	0.322	0.297
10 mb	-0.030	0.188	0.274	0.288	0.300	0.257
30 mb	-0.049	0.086	0.168	0.266	0.278	0.239
70 mb	0.239	0.445	0.529	0.568	0.573	0.549
125 mb	0.279	0.478	0.481	0.513	0.596	0.575
200 mb	0.621	0.612	0.648	0.556	0.376	0.292
300 mb	0.194	0.306	0.359	0.182	0.128	0.182
350 mb	0.183	0.273	0.267	-0.006	-0.095	0.012

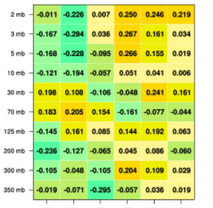
06/2012



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.134	0.005	-0.101	0.009	0.075	-0.049
3 mb	-0.089	0.164	0.034	0.134	0.197	0.044
5 mb	-0.068	0.224	0.143	0.135	0.105	-0.098
10 mb	-0.077	-0.014	0.078	0.235	0.141	-0.041
30 mb	-0.431	-0.299	-0.078	0.181	0.090	-0.079
70 mb	-0.316	-0.353	-0.214	0.090	0.056	-0.018
125 mb	-0.202	-0.163	-0.089	0.115	0.042	-0.030
200 mb	-0.154	-0.413	-0.181	0.115	0.027	-0.016
300 mb	-0.045	-0.186	0.097	0.196	0.071	0.191
350 mb	0.049	-0.061	0.203	0.159	0.072	0.248

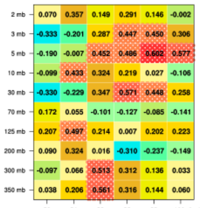
01/2013



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.011	-0.226	0.007	0.250	0.246	0.219
3 mb	-0.167	-0.294	0.036	0.267	0.161	0.034
5 mb	-0.168	-0.228	-0.095	0.266	0.155	0.019
10 mb	-0.121	-0.194	-0.057	0.051	0.041	0.006
30 mb	0.198	0.108	-0.106	-0.048	0.241	0.161
70 mb	0.183	0.205	0.154	-0.161	-0.077	-0.044
125 mb	-0.145	0.161	0.085	0.144	0.192	0.063
200 mb	-0.236	-0.127	-0.065	0.045	0.086	-0.060
300 mb	-0.105	-0.048	-0.105	0.204	0.109	0.029
350 mb	-0.019	-0.071	-0.295	-0.057	0.036	0.019

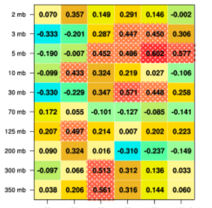
02/2013



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	0.070	0.357	0.149	0.291	0.146	-0.002
3 mb	-0.333	-0.201	0.287	0.447	0.450	0.306
5 mb	-0.190	-0.007	0.452	0.486	0.602	0.577
10 mb	-0.099	0.433	0.324	0.219	0.027	-0.106
30 mb	-0.330	-0.229	0.347	0.571	0.448	0.258
70 mb	0.172	0.055	-0.101	-0.127	-0.085	-0.141
125 mb	0.207	0.497	0.214	0.007	0.202	0.223
200 mb	0.090	0.324	0.016	-0.310	-0.237	-0.149
300 mb	-0.097	0.066	0.513	0.312	0.136	0.033
350 mb	0.038	0.206	0.561	0.316	0.144	0.060

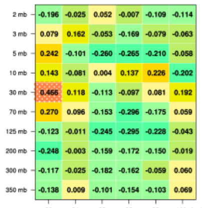
03/2013



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	0.070	0.357	0.149	0.291	0.146	-0.002
3 mb	-0.333	-0.201	0.287	0.447	0.450	0.306
5 mb	-0.190	-0.007	0.452	0.486	0.602	0.577
10 mb	-0.099	0.433	0.324	0.219	0.027	-0.106
30 mb	-0.330	-0.229	0.347	0.571	0.448	0.258
70 mb	0.172	0.055	-0.101	-0.127	-0.085	-0.141
125 mb	0.207	0.497	0.214	0.007	0.202	0.223
200 mb	0.090	0.324	0.016	-0.310	-0.237	-0.149
300 mb	-0.097	0.066	0.513	0.312	0.136	0.033
350 mb	0.038	0.206	0.561	0.316	0.144	0.060

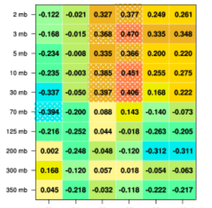
04/2013



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.196	-0.025	0.052	-0.007	-0.109	-0.114
3 mb	0.079	0.162	-0.053	-0.169	-0.079	-0.063
5 mb	0.242	-0.101	-0.260	-0.265	-0.210	-0.058
10 mb	0.143	-0.081	0.004	0.137	0.226	-0.202
30 mb	0.466	0.118	-0.113	-0.097	0.081	0.192
70 mb	0.270	0.096	-0.153	-0.296	-0.175	0.059
125 mb	-0.123	-0.011	-0.245	-0.295	-0.228	-0.043
200 mb	-0.248	-0.003	-0.159	-0.172	-0.150	-0.019
300 mb	-0.117	-0.025	-0.182	-0.162	-0.059	0.060
350 mb	-0.138	0.009	-0.101	-0.154	-0.103	0.069

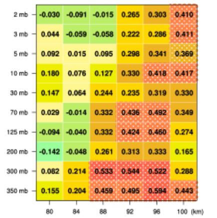
05/2013



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.122	-0.021	0.327	0.377	0.249	0.261
3 mb	-0.168	-0.015	0.368	0.470	0.335	0.348
5 mb	-0.234	-0.008	0.335	0.366	0.200	0.220
10 mb	-0.235	-0.003	0.385	0.451	0.255	0.275
30 mb	-0.337	-0.050	0.397	0.406	0.168	0.222
70 mb	-0.394	-0.200	0.088	0.143	-0.140	-0.073
125 mb	-0.216	-0.252	0.044	-0.018	-0.263	-0.205
200 mb	0.002	-0.248	-0.048	-0.120	-0.312	-0.311
300 mb	0.168	-0.120	0.057	0.018	-0.054	-0.063
350 mb	0.045	-0.218	-0.032	-0.118	-0.222	-0.217

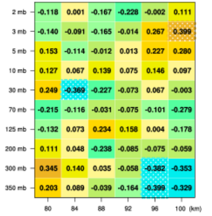
06/2013



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.030	-0.091	-0.015	0.265	0.303	0.410
3 mb	0.044	-0.059	-0.058	0.222	0.286	0.411
5 mb	0.092	0.015	0.095	0.298	0.341	0.369
10 mb	0.180	0.076	0.127	0.330	0.418	0.417
30 mb	0.147	0.064	0.244	0.235	0.319	0.330
70 mb	0.029	-0.014	0.332	0.436	0.492	0.349
125 mb	-0.094	-0.040	0.332	0.424	0.460	0.274
200 mb	-0.142	-0.048	0.261	0.313	0.333	0.165
300 mb	0.082	0.214	0.533	0.544	0.522	0.288
350 mb	0.155	0.204	0.459	0.495	0.594	0.443

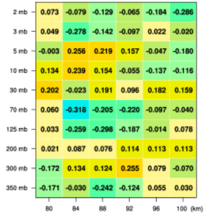
01/2014



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.118	0.001	-0.167	-0.228	-0.002	0.111
3 mb	-0.140	-0.091	-0.165	-0.014	0.267	0.399
5 mb	0.153	-0.114	-0.012	0.013	0.227	0.280
10 mb	0.127	0.067	0.139	0.075	0.146	0.097
30 mb	0.249	-0.369	-0.227	-0.073	0.067	-0.003
70 mb	-0.215	-0.116	-0.031	-0.075	-0.101	-0.279
125 mb	-0.132	0.073	0.234	0.158	0.004	-0.178
200 mb	0.111	0.048	-0.238	-0.085	-0.075	-0.059
300 mb	0.345	0.140	0.035	-0.058	-0.382	-0.353
350 mb	0.203	0.089	-0.039	-0.164	-0.399	-0.329

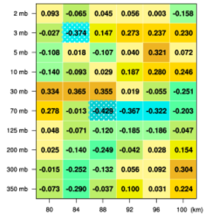
02/2014



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	0.073	-0.079	-0.129	-0.065	-0.184	-0.286
3 mb	0.049	-0.278	-0.142	-0.097	0.022	-0.020
5 mb	-0.003	0.256	0.219	0.157	-0.047	-0.180
10 mb	0.134	0.239	0.154	-0.055	-0.137	-0.116
30 mb	0.202	-0.023	0.191	0.096	0.182	0.159
70 mb	0.060	-0.318	-0.205	-0.220	-0.097	-0.040
125 mb	0.033	-0.259	-0.298	-0.187	-0.014	0.078
200 mb	0.021	0.087	0.076	0.114	0.113	0.113
300 mb	-0.172	0.134	0.124	0.255	0.079	-0.070
350 mb	-0.171	-0.030	-0.242	-0.124	0.055	0.030

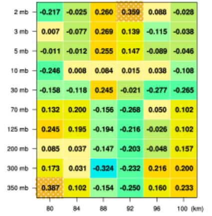
03/2014



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	0.093	-0.065	0.045	0.056	0.003	-0.158
3 mb	-0.027	-0.374	0.147	0.273	0.237	0.230
5 mb	-0.108	0.018	-0.107	0.040	0.321	0.072
10 mb	-0.140	-0.093	0.029	0.187	0.280	0.246
30 mb	0.334	0.365	0.355	0.019	-0.055	-0.251
70 mb	0.278	-0.013	-0.429	-0.367	-0.322	-0.203
125 mb	0.048	-0.071	-0.120	-0.185	-0.186	-0.047
200 mb	0.025	-0.140	-0.249	-0.042	0.028	0.154
300 mb	-0.015	-0.252	-0.132	0.056	0.092	0.304
350 mb	-0.073	-0.290	-0.037	0.100	0.031	0.224

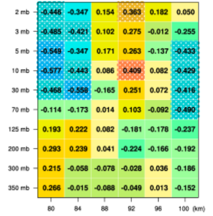
04/2014



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.217	-0.025	0.260	0.359	0.088	-0.028
3 mb	0.007	-0.077	0.269	0.139	-0.115	-0.038
5 mb	-0.011	-0.012	0.255	0.147	-0.089	-0.046
10 mb	-0.246	0.008	0.084	0.015	0.038	-0.108
30 mb	-0.158	-0.118	0.245	-0.021	-0.277	-0.265
70 mb	0.132	0.200	-0.156	-0.268	0.050	0.102
125 mb	0.245	0.195	-0.194	-0.216	-0.026	0.102
200 mb	0.085	0.037	-0.147	-0.203	-0.048	0.157
300 mb	0.173	0.031	-0.324	-0.232	0.216	0.200
350 mb	0.387	0.102	-0.154	-0.250	0.160	0.233

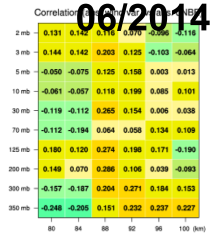
05/2014



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.446	-0.347	0.154	0.363	0.182	0.050
3 mb	-0.485	-0.421	0.102	0.275	-0.012	-0.255
5 mb	-0.549	-0.347	0.171	0.263	-0.137	-0.433
10 mb	-0.577	-0.443	0.086	0.409	0.082	-0.429
30 mb	-0.468	-0.558	-0.165	0.251	0.072	-0.416
70 mb	-0.114	-0.173	0.014	0.103	-0.092	-0.490
125 mb	0.193	0.222	0.082	-0.181	-0.178	-0.237
200 mb	0.293	0.239	0.041	-0.224	-0.166	-0.192
300 mb	0.215	-0.058	-0.078	-0.028	0.036	-0.186
350 mb	0.266	-0.015	-0.088	-0.049	0.013	-0.152

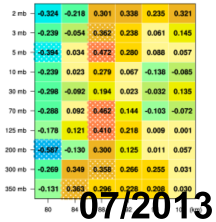
06/2014



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	0.131	0.142	0.116	0.070	-0.096	-0.116
3 mb	0.144	0.142	0.203	0.125	-0.103	-0.064
5 mb	-0.050	-0.075	0.125	0.158	0.003	0.013
10 mb	-0.061	-0.057	0.118	0.199	0.085	0.101
30 mb	-0.119	-0.112	0.265	0.154	0.006	0.038
70 mb	-0.112	-0.194	0.064	0.058	0.134	0.109
125 mb	0.180	0.120	0.274	0.198	0.171	-0.190
200 mb	0.149	0.070	0.286	0.106	0.039	-0.093
300 mb	-0.157	-0.187	0.204	0.271	0.184	0.153
350 mb	-0.248	-0.205	0.151	0.232	0.237	0.227

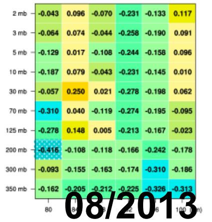
07/2012



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.324	-0.218	0.301	0.338	0.235	0.321
3 mb	-0.239	-0.054	0.362	0.238	0.061	0.145
5 mb	-0.394	0.034	0.472	0.280	0.088	0.057
10 mb	-0.239	0.023	0.279	0.067	-0.138	-0.085
30 mb	-0.298	-0.092	0.194	0.023	-0.032	0.135
70 mb	-0.288	0.092	0.462	0.144	-0.103	-0.072
125 mb	-0.178	0.121	0.410	0.218	0.009	0.001
200 mb	-0.587	-0.130	0.300	0.125	0.011	0.057
300 mb	-0.269	0.349	0.358	0.266	0.255	0.031
350 mb	-0.131	0.363	0.296	0.228	0.208	0.030

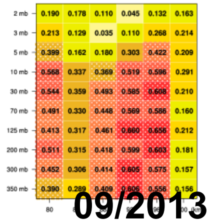
08/2012



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.043	0.096	-0.070	-0.231	-0.133	0.117
3 mb	-0.064	0.074	-0.044	-0.258	-0.190	0.091
5 mb	-0.129	0.017	-0.108	-0.244	-0.158	0.096
10 mb	-0.187	0.079	-0.043	-0.231	-0.145	0.010
30 mb	-0.057	0.250	0.021	-0.278	-0.198	0.062
70 mb	-0.310	0.040	-0.119	-0.274	-0.195	-0.095
125 mb	-0.278	0.148	0.005	-0.213	-0.167	-0.023
200 mb	-0.416	-0.108	-0.118	-0.166	-0.242	-0.178
300 mb	-0.093	-0.155	-0.163	-0.174	-0.310	-0.186
350 mb	-0.162	-0.205	-0.212	-0.225	-0.326	-0.313

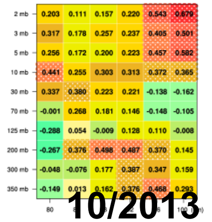
09/2012



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	0.190	0.178	0.110	0.045	0.132	0.163
3 mb	0.213	0.129	0.035	0.110	0.268	0.214
5 mb	0.399	0.162	0.180	0.303	0.422	0.209
10 mb	0.568	0.337	0.369	0.519	0.596	0.291
30 mb	0.544	0.359	0.493	0.585	0.608	0.210
70 mb	0.491	0.330	0.448	0.569	0.586	0.160
125 mb	0.413	0.317	0.461	0.660	0.656	0.212
200 mb	0.511	0.315	0.418	0.599	0.603	0.181
300 mb	0.452	0.306	0.414	0.605	0.575	0.157
350 mb	0.390	0.289	0.409	0.606	0.556	0.156

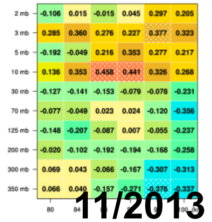
10/2012



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	0.203	0.111	0.157	0.220	0.543	0.679
3 mb	0.317	0.178	0.257	0.237	0.405	0.501
5 mb	0.256	0.172	0.200	0.223	0.457	0.582
10 mb	0.441	0.255	0.303	0.313	0.372	0.365
30 mb	0.337	0.380	0.223	0.221	-0.138	-0.162
70 mb	-0.001	0.268	0.181	0.146	-0.148	-0.105
125 mb	-0.288	0.054	-0.009	0.128	0.110	-0.008
200 mb	-0.267	0.376	0.498	0.487	0.370	0.145
300 mb	-0.048	-0.076	0.177	0.387	0.347	0.159
350 mb	-0.149	0.013	0.162	0.376	0.468	0.293

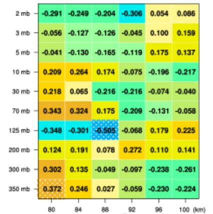
11/2012



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.106	0.015	-0.015	0.045	0.297	0.205
3 mb	0.285	0.360	0.276	0.227	0.377	0.323
5 mb	-0.192	-0.049	0.216	0.353	0.277	0.217
10 mb	0.136	0.353	0.458	0.441	0.326	0.268
30 mb	-0.127	-0.141	-0.153	-0.079	-0.078	-0.231
70 mb	-0.077	-0.049	0.023	0.024	-0.120	-0.356
125 mb	-0.148	-0.207	-0.087	0.007	-0.055	-0.237
200 mb	-0.020	-0.102	-0.192	-0.194	-0.168	-0.258
300 mb	0.069	0.043	-0.066	-0.167	-0.307	-0.313
350 mb	0.066	0.040	-0.157	-0.271	-0.376	-0.337

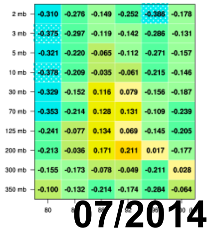
12/2012



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.291	-0.249	-0.204	-0.306	0.054	0.086
3 mb	-0.056	-0.127	-0.126	-0.045	0.100	0.159
5 mb	-0.041	-0.130	-0.165	-0.119	0.175	0.137
10 mb	0.209	0.264	0.174	-0.075	-0.196	-0.217
30 mb	0.218	0.065	-0.216	-0.216	-0.074	-0.040
70 mb	0.343	0.324	0.175	-0.209	-0.131	-0.058
125 mb	-0.348	-0.301	-0.505	-0.068	0.179	0.225
200 mb	0.124	0.191	0.078	0.272	0.110	0.141
300 mb	0.302	0.135	-0.049	-0.097	-0.238	-0.261
350 mb	0.372	0.246	0.027	-0.059	-0.230	-0.224

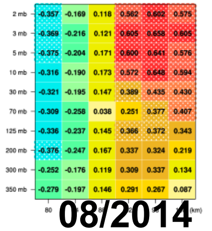
07/2013



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.310	-0.276	-0.149	-0.252	-0.386	-0.178
3 mb	-0.375	-0.297	-0.119	-0.142	-0.286	-0.131
5 mb	-0.321	-0.220	-0.065	-0.112	-0.271	-0.157
10 mb	-0.378	-0.209	-0.035	-0.061	-0.215	-0.146
30 mb	-0.329	-0.152	0.116	0.079	-0.156	-0.187
70 mb	-0.353	-0.214	0.128	0.131	-0.109	-0.239
125 mb	-0.241	-0.077	0.134	0.069	-0.145	-0.205
200 mb	-0.213	-0.036	0.171	0.211	0.017	-0.177
300 mb	-0.155	-0.173	-0.078	-0.049	-0.211	0.028
350 mb	-0.100	-0.132	-0.214	-0.174	-0.284	-0.064

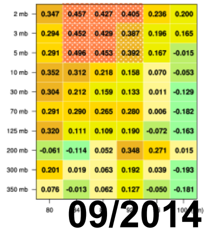
08/2013



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.357	-0.169	0.118	0.562	0.602	0.575
3 mb	-0.369	-0.216	0.121	0.605	0.658	0.605
5 mb	-0.375	-0.204	0.171	0.600	0.641	0.576
10 mb	-0.316	-0.190	0.173	0.572	0.648	0.594
30 mb	-0.321	-0.195	0.147	0.389	0.435	0.430
70 mb	-0.309	-0.258	0.038	0.251	0.377	0.407
125 mb	-0.336	-0.237	0.145	0.366	0.372	0.343
200 mb	-0.376	-0.247	0.167	0.337	0.324	0.219
300 mb	-0.252	-0.176	0.119	0.309	0.337	0.134
350 mb	-0.279	-0.197	0.146	0.291	0.267	0.087

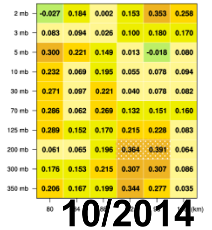
09/2013



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	0.347	0.457	0.427	0.405	0.236	0.200
3 mb	0.294	0.452	0.429	0.387	0.196	0.165
5 mb	0.291	0.496	0.453	0.392	0.167	-0.015
10 mb	0.352	0.312	0.218	0.158	0.070	-0.053
30 mb	0.304	0.212	0.159	0.133	0.011	-0.129
70 mb	0.291	0.290	0.265	0.280	0.006	-0.182
125 mb	0.320	0.111	0.109	0.190	-0.072	-0.163
200 mb	-0.061	-0.114	0.052	0.348	0.271	0.015
300 mb	0.201	0.019	0.063	0.192	0.039	-0.193
350 mb	0.076	-0.013	0.062	0.127	-0.050	-0.181

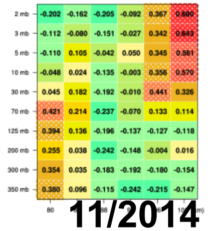
10/2013



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.027	0.184	0.002	0.153	0.353	0.258
3 mb	0.083	0.094	0.026	0.100	0.180	0.170
5 mb	0.300	0.221	0.149	0.013	-0.018	0.080
10 mb	0.232	0.069	0.195	0.055	0.078	0.094
30 mb	0.271	0.097	0.221	0.040	0.078	0.082
70 mb	0.286	0.062	0.269	0.132	0.151	0.160
125 mb	0.289	0.152	0.170	0.215	0.228	0.083
200 mb	0.061	0.065	0.196	0.364	0.391	0.064
300 mb	0.176	0.153	0.215	0.307	0.307	0.086
350 mb	0.206	0.167	0.199	0.344	0.277	0.035

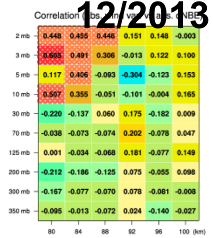
11/2013



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	-0.202	-0.162	-0.205	-0.092	0.367	0.680
3 mb	-0.112	-0.080	-0.151	-0.027	0.342	0.643
5 mb	-0.110	0.105	-0.042	0.050	0.345	0.561
10 mb	-0.048	0.024	-0.135	-0.003	0.356	0.570
30 mb	0.045	0.182	-0.192	-0.010	0.441	0.326
70 mb	0.421	0.214	-0.237	-0.070	0.133	0.114
125 mb	0.394	0.136	-0.196	-0.137	-0.127	-0.118
200 mb	0.255	0.038	-0.242	-0.148	-0.004	0.016
300 mb	0.354	0.035	-0.183	-0.192	-0.180	-0.154
350 mb	0.380	0.096	-0.115	-0.242	-0.215	-0.147

12/2013



Correlation (abs. wind var. vs abs. dNBE)

	80	84	88	92	96	100 (km)
2 mb	0.448	0.455	0.446	0.151	0.148	-0.003
3 mb	0.605	0.491	0.306	-0.013	0.122	0.100
5 mb	0.117	0.406	-0.093	-0.304	-0.123	0.153
10 mb	0.507	0.355	-0.051	-0.101	-0.004	0.165
30 mb	-0.220	-0.137	0.060	0.175	-0.182	0.009
70 mb	-0.038	-0.073	-0.074	0.202	-0.078	0.047
125 mb	0.001	-0.034	-0.068	0.181	-0.077	0.149
200 mb	-0.212	-0.186	-0.125	0.075	-0.055	0.098
300 mb	-0.167	-0.077	-0.070	0.078	-0.081	-0.008
350 mb	-0.095	-0.013	-0.072	0.024	-0.140	-0.027

07/2014

Correlation (abs. wind var. vs abs. dNBE)

2 mb	-0.367	0.175	0.290	0.354	0.542	0.601
3 mb	-0.323	0.120	0.187	0.256	0.451	0.500
5 mb	-0.296	0.104	0.150	0.215	0.405	0.461
10 mb	-0.241	0.088	0.089	0.117	0.285	0.355
30 mb	-0.240	0.008	-0.003	0.018	0.136	0.170
70 mb	-0.235	-0.005	-0.043	-0.009	0.104	0.110

08/2014

Correlation (abs. wind var. vs abs. dNBE)

2 mb	-0.157	-0.019	-0.117	-0.198	-0.157	-0.065
3 mb	-0.102	-0.032	-0.233	-0.388	-0.364	-0.260
5 mb	-0.138	-0.087	-0.265	-0.413	-0.418	-0.338
10 mb	-0.078	0.026	-0.198	-0.333	-0.328	-0.250
30 mb	-0.013	0.048	-0.229	-0.377	-0.365	-0.321
70 mb	0.000	0.059	-0.208	-0.339	-0.347	-0.335

09/2014

Correlation (abs. wind var. vs abs. dNBE)

2 mb	-0.243	-0.106	-0.065	-0.209	-0.226	-0.137
3 mb	-0.224	-0.112	-0.146	-0.190	-0.165	-0.095
5 mb	-0.224	-0.122	-0.116	-0.151	-0.109	-0.030
10 mb	-0.323	-0.207	-0.081	-0.067	0.007	0.126
30 mb	-0.303	-0.096	-0.025	0.044	0.165	0.287
70 mb	-0.264	-0.043	0.011	-0.009	0.119	0.202

10/2014

Correlation (abs. wind var. vs abs. dNBE)

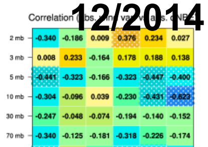
2 mb	-0.259	-0.044	0.110	0.149	0.302	0.549
3 mb	-0.128	-0.008	0.085	0.114	0.240	0.398
5 mb	0.052	0.005	-0.024	0.079	0.228	0.298
10 mb	0.209	0.065	-0.162	-0.026	0.099	0.097
30 mb	0.199	0.139	-0.080	-0.029	0.020	-0.016
70 mb	0.256	0.008	-0.275	-0.126	-0.036	-0.101

11/2014

Correlation (abs. wind var. vs abs. dNBE)

2 mb	0.377	0.191	-0.231	-0.205	-0.079	-0.034
3 mb	0.261	0.201	-0.214	-0.229	-0.049	-0.011
5 mb	0.258	0.240	-0.039	-0.029	0.108	-0.097
10 mb	0.281	0.294	0.017	-0.032	0.123	-0.070
30 mb	0.203	0.245	0.014	-0.001	0.182	-0.010
70 mb	0.224	0.249	-0.166	-0.249	-0.078	0.001

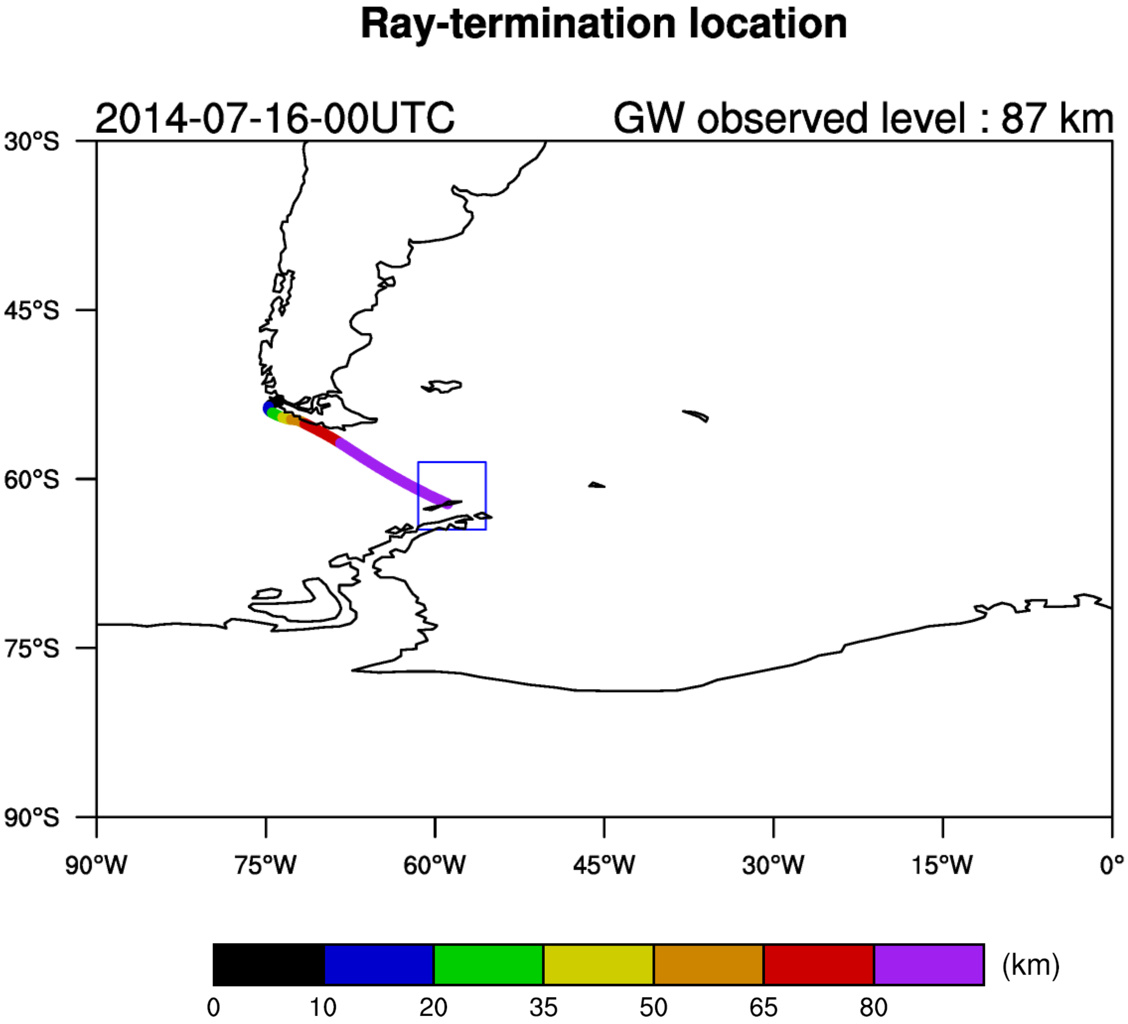
12/2014



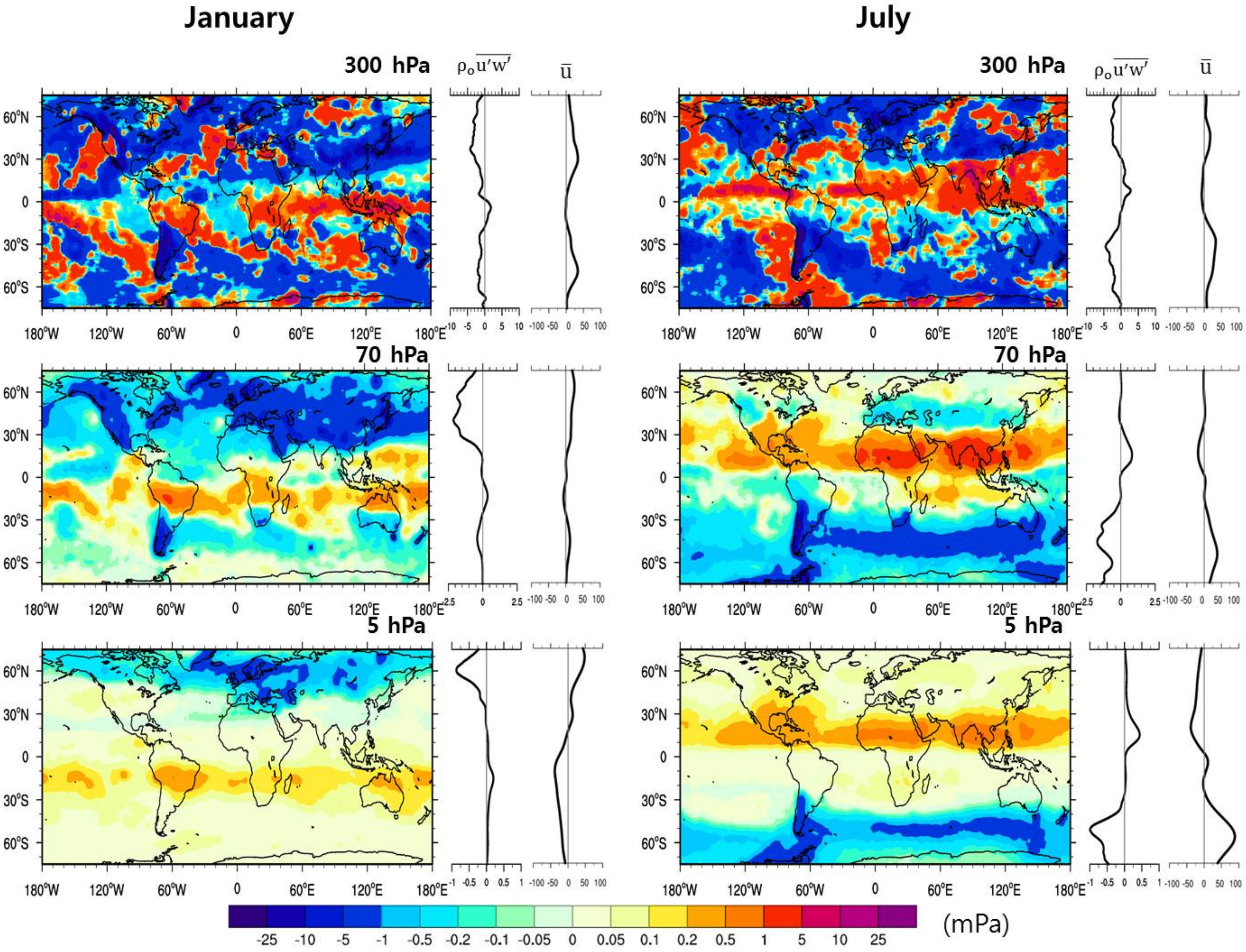
Correlation (abs. wind var. vs abs. dNBE)

2 mb	-0.340	-0.186	0.009	0.376	0.234	0.027
3 mb	0.008	0.233	-0.164	0.178	0.188	0.138
5 mb	-0.441	-0.323	-0.166	-0.323	-0.447	-0.400
10 mb	-0.304	-0.096	0.039	-0.230	-0.431	-0.623
30 mb	-0.247	-0.048	-0.074	-0.194	-0.140	-0.152
70 mb	-0.340	-0.125	-0.181	-0.318	-0.226	-0.174

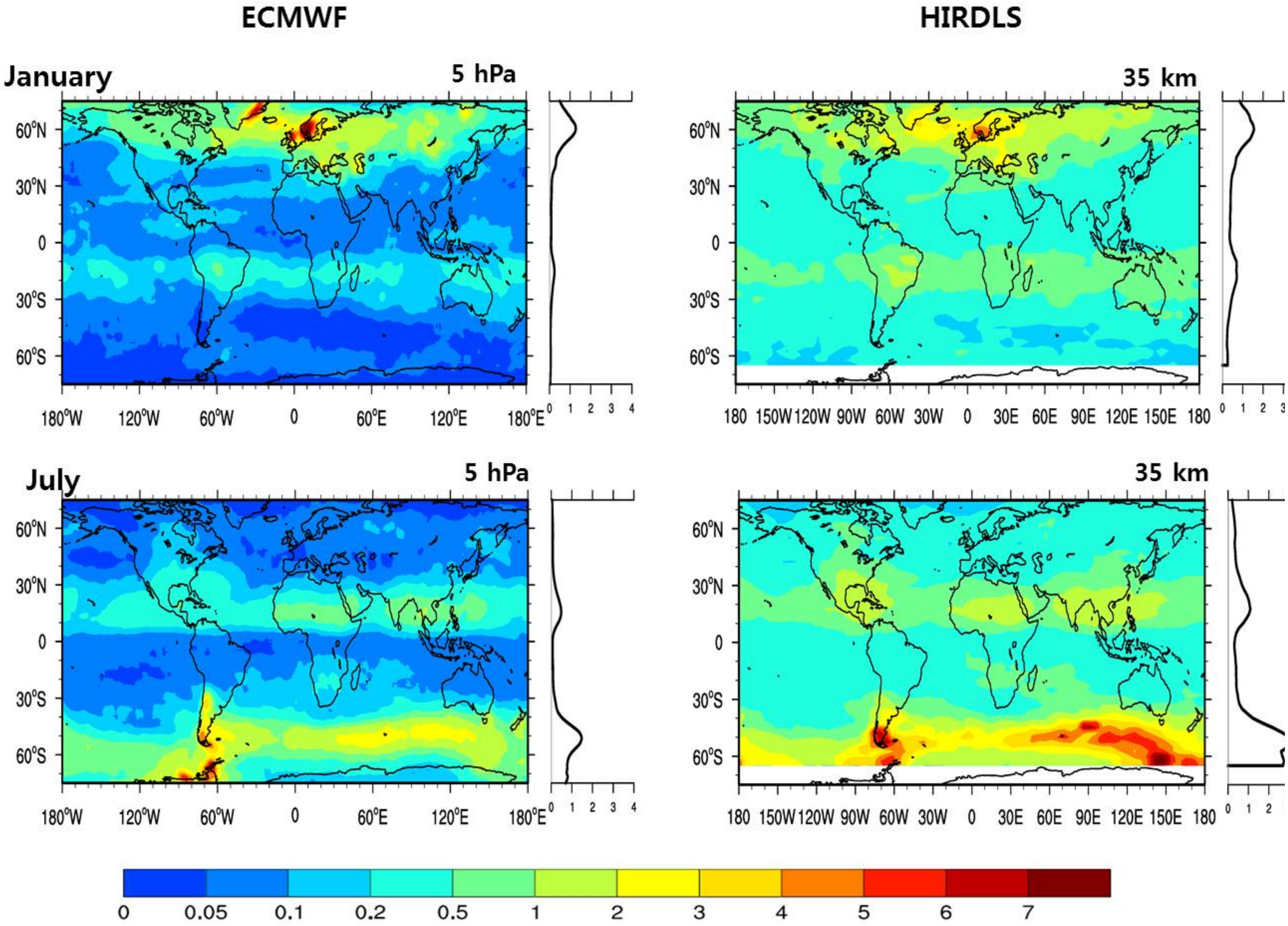
3-D ray-tracing result



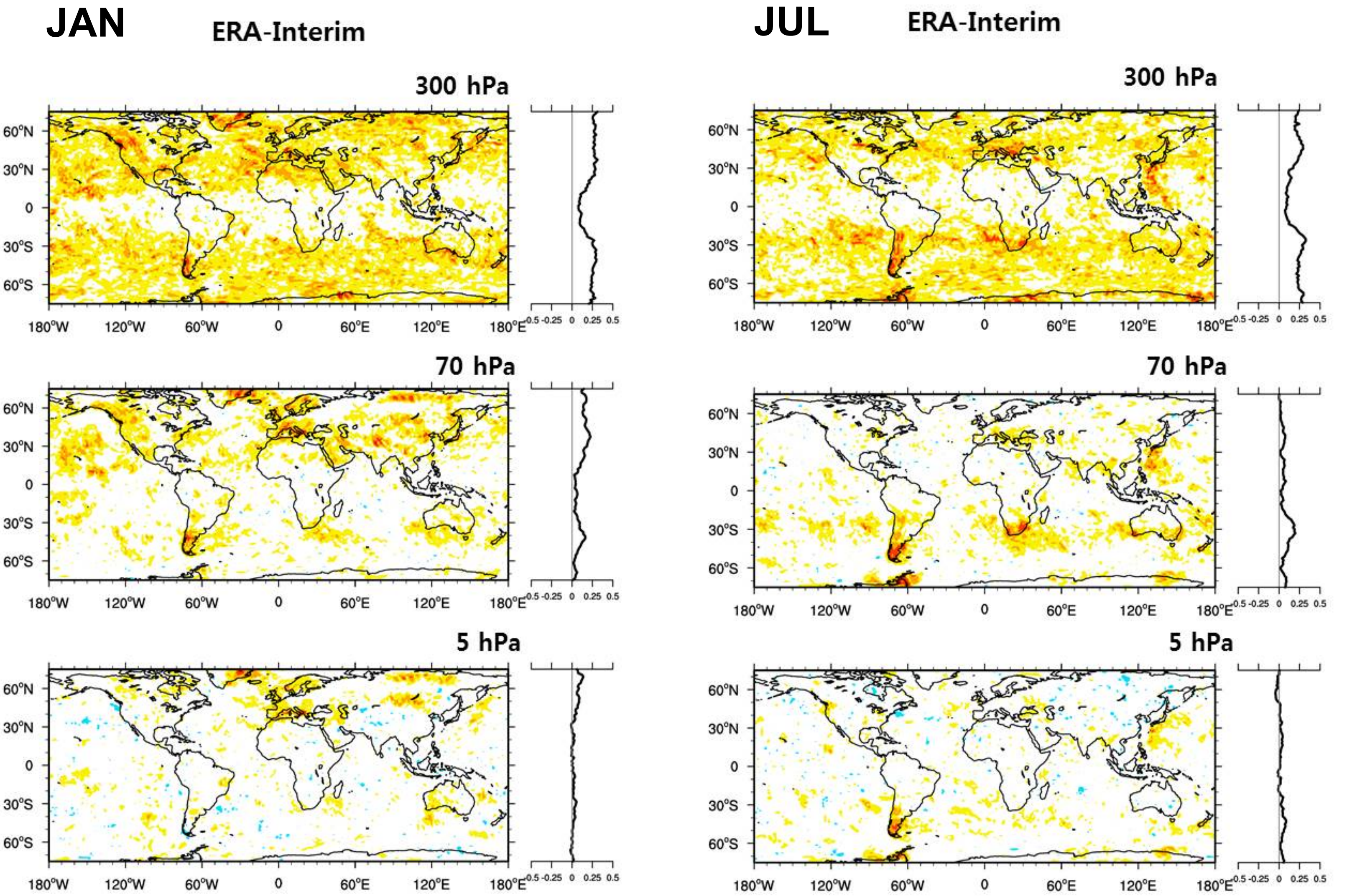
Zonal GWMF at different altitude



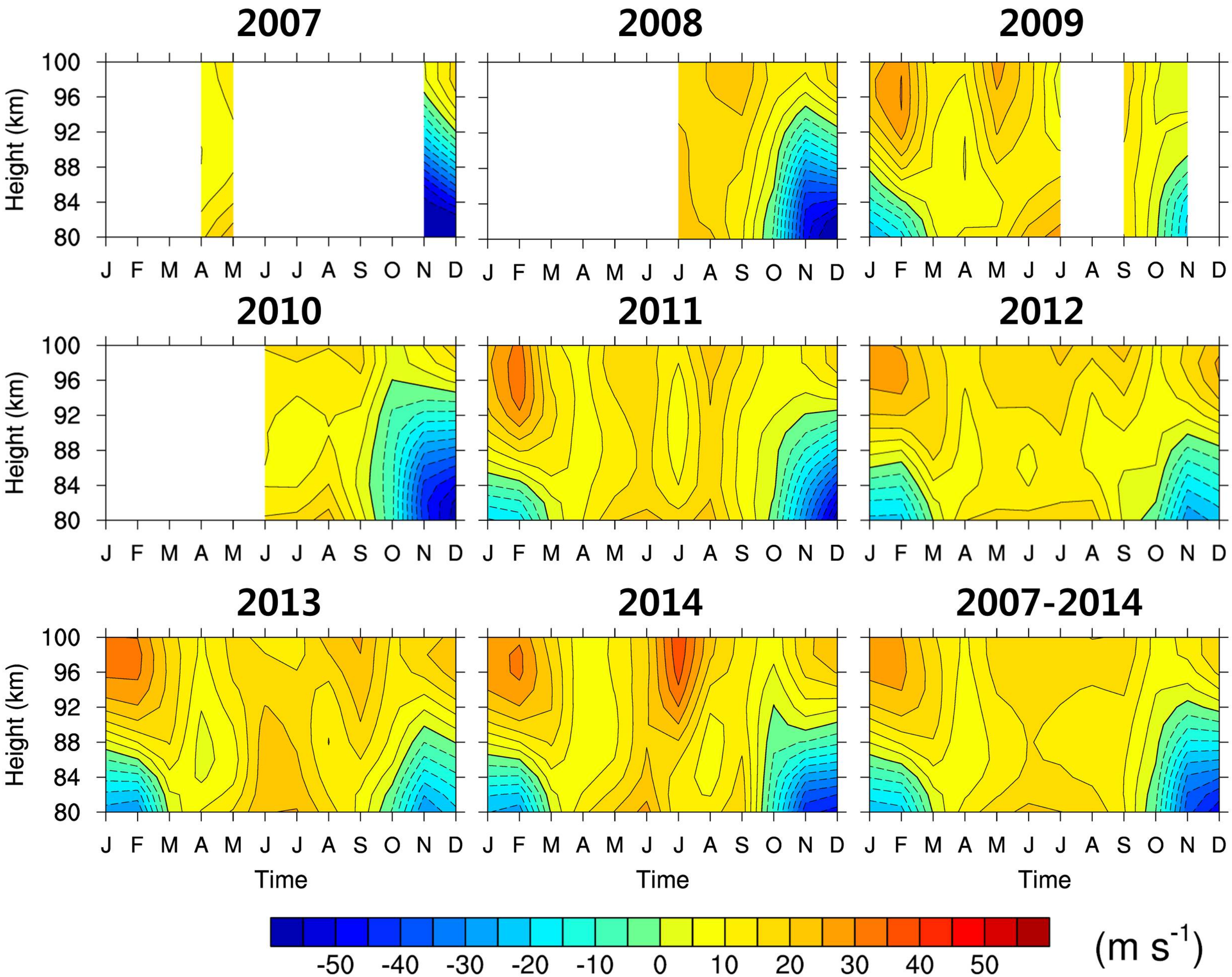
Global distribution of |GWMF| (H-ECMWF vs HIR인)



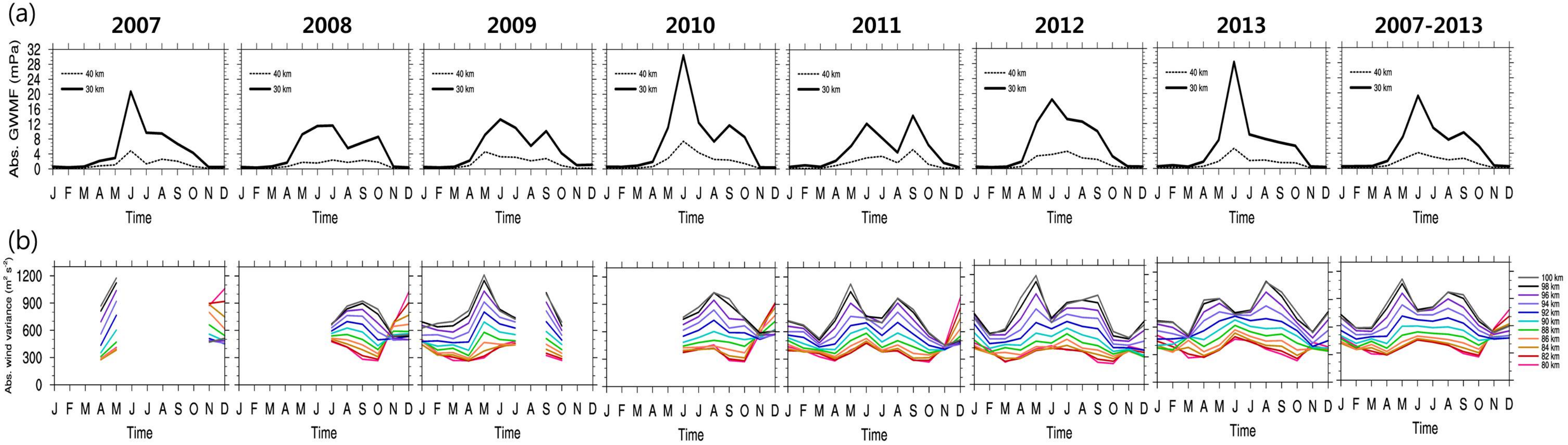
Correlation (zonal GWMF & |△NBE|



Zonal wind observed by meteor radar at KSS

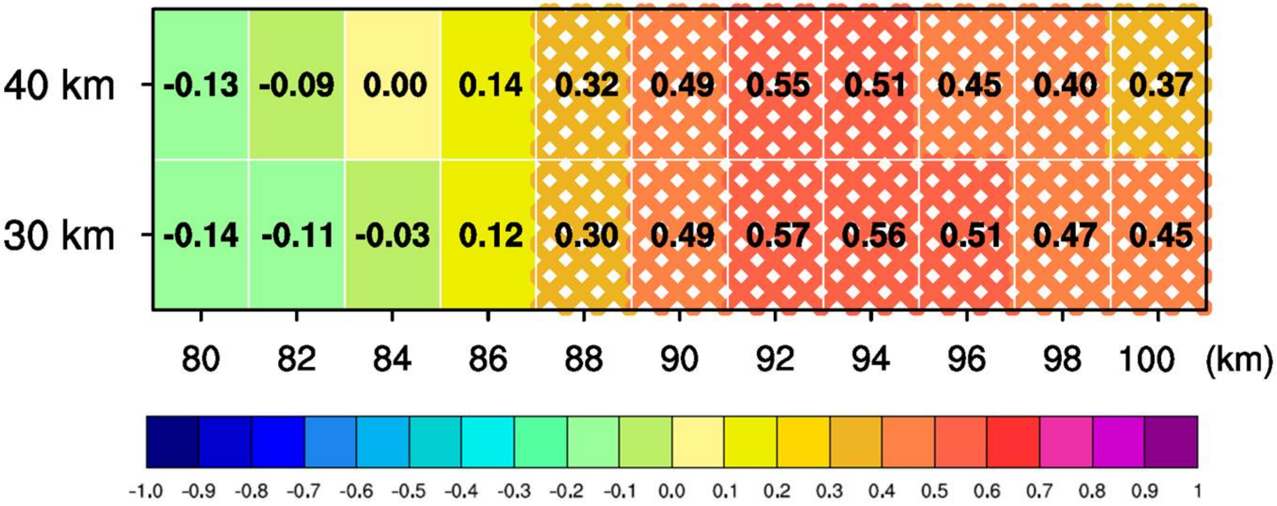


Correlation (|GWMF| from HIRDLS vs horiz. wind var.]



|GWMF| (SABER) vs horizontal wind var.

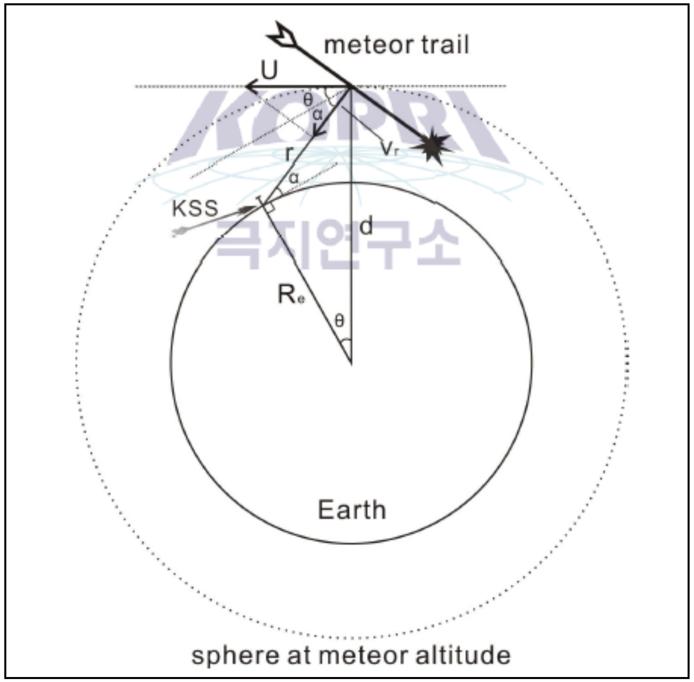
Jun 2010-Dec 2013 (N=43, $r_{0.95}$=0.301)



	80	82	84	86	88	90	92	94	96	98	100 (km)
40 km	-0.13	-0.09	0.00	0.14	0.32	0.49	0.55	0.51	0.45	0.40	0.37
30 km	-0.14	-0.11	-0.03	0.12	0.30	0.49	0.57	0.56	0.51	0.47	0.45

Analysis of meteor radar data

- The horizontal winds are determined from radial velocities of meteor echoes within a height–time sector of 2 km and 1 h from 78 km to 100 km. The radial velocity is determined from at least six echoes in each height–time sector by using the least squares method and the meteor echoes used for this analysis were selected only when the absolute difference between observed and projected radial velocities is less than 25 ms^{-1} (Holdsworth et al., 2004).



$$\vec{U} = u\hat{x} + v\hat{y}$$

$$T(u,v) = \sum_i \left(\vec{U} \cdot \hat{r}_i - V_{ri}\right)^2$$

$$u\sum l_i^2 + v\sum l_i m_i = \sum V_{ri} l_i$$

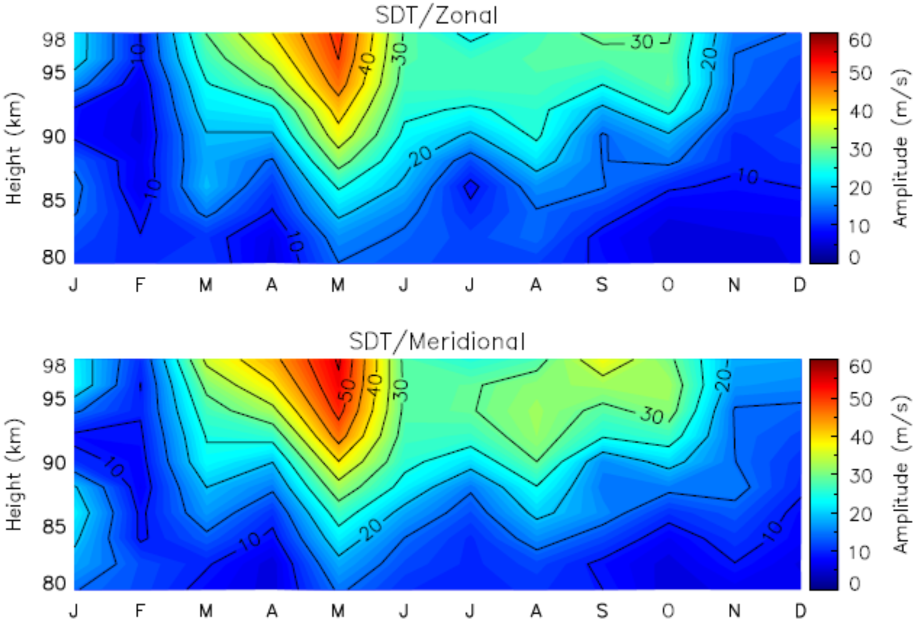
$$u\sum l_i m_i + v\sum m_i^2 = \sum V_{ri} m_i$$

$$\Delta V = \vec{U} \cdot \hat{r}_i - V_{ri}$$

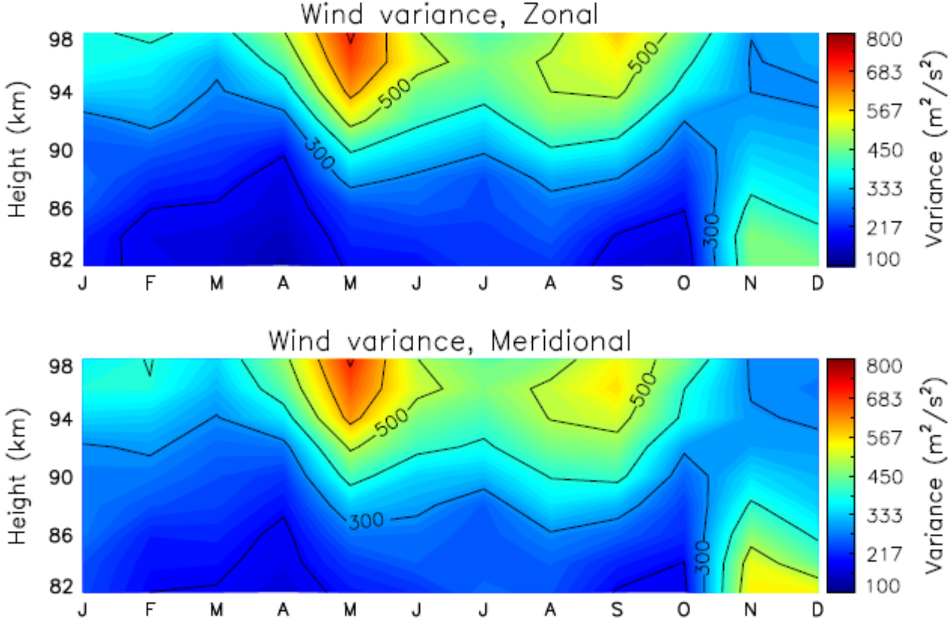
➔ These height–time averaged winds represent only the large-scale atmospheric motions such as tides, planetary waves.

Motivation

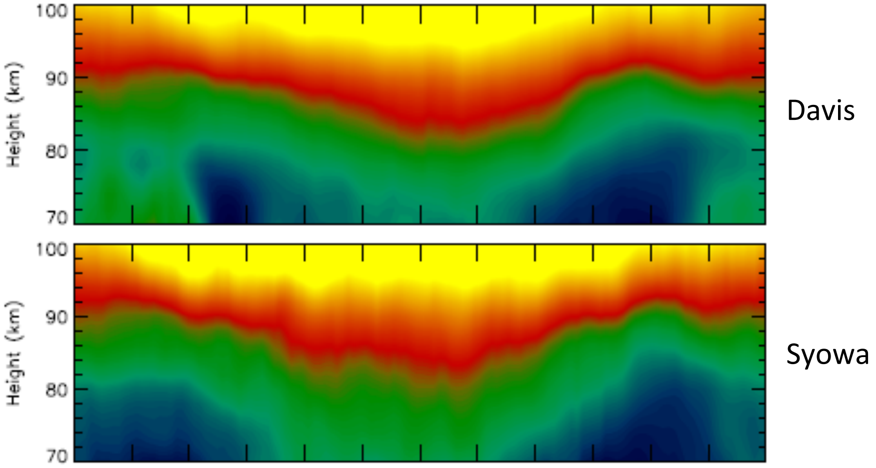
Semi-diurnal tide



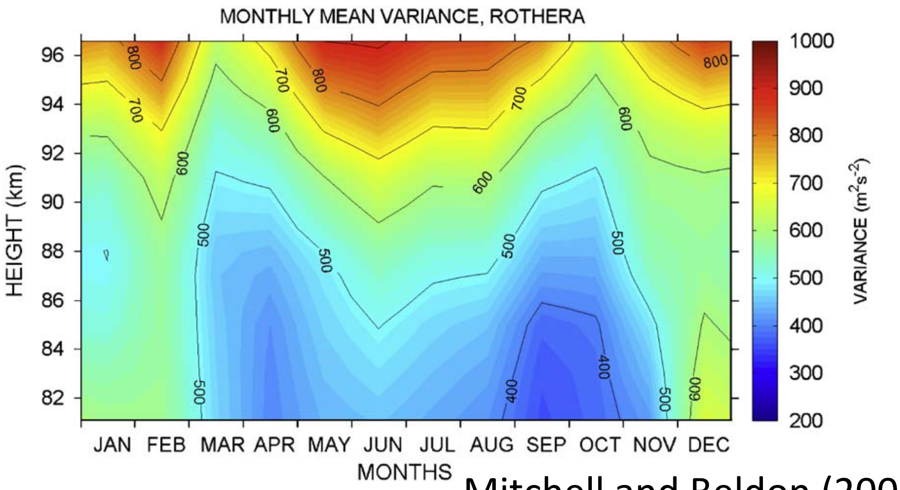
Wind variance (GWs)



Lee et al. (2013)



Dowdy et al. (2007)



Mitchell and Beldon (2009)

SKiYMET meteor radar in Rothera station

- **SKiYMET meteor radar**
  - installed in Rothera, Antarctica (68°S, 68°W) in February 2005
  - using data from February 2005 to December 2008.
  - record the radial drifts of individual meteor trails ➔ large scale winds of the MLT.
  - height and time resolution of ~2 km and 2 hour
  - variance of the horizontal velocities ➔ a proxy for gravity wave activity

    $u'^2 + v'^2$ (horizontal wavelengths of up to ~400 km and periods up to ~3 hours)

Moffat-Griffin et al. (2011, JGR)

- **1. Energy**

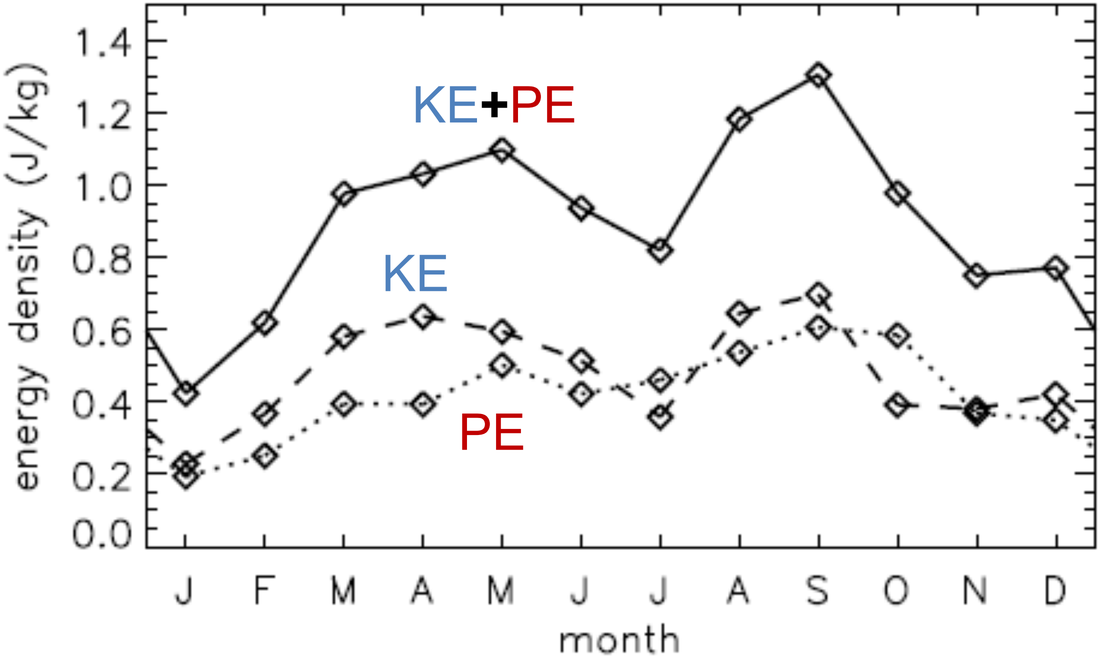


Figure 5. Monthly mean density of kinetic (dashed line) and potential (dotted line) gravity wave energy. Total energy per unit mass (the sum of the kinetic and potential energy density) is shown with a solid line.

- clear seasonal variation
  - KE : 0.22 J/kg in summer
    0.69 J/kg in spring
  - PE : 0.19 J/kg in summer
    0.60 J/kg in spring

➔ peak to a similar value in September, the spring equinox
(consistent with other radiosonde results from other stations)

➔ lower peak in both around April/May
(Yoshiki and Sato [2000] do not show the clear increase in energy after the austral autumn equinox)

Moffat-Griffin et al. (2011, JGR)

2.1. Vertical Propagation Direction

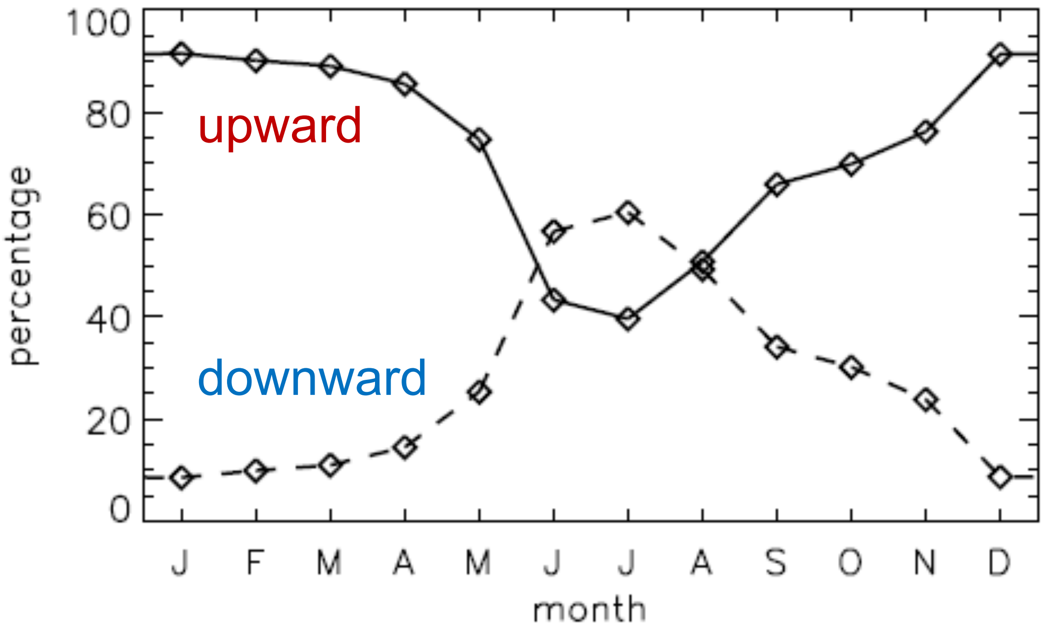


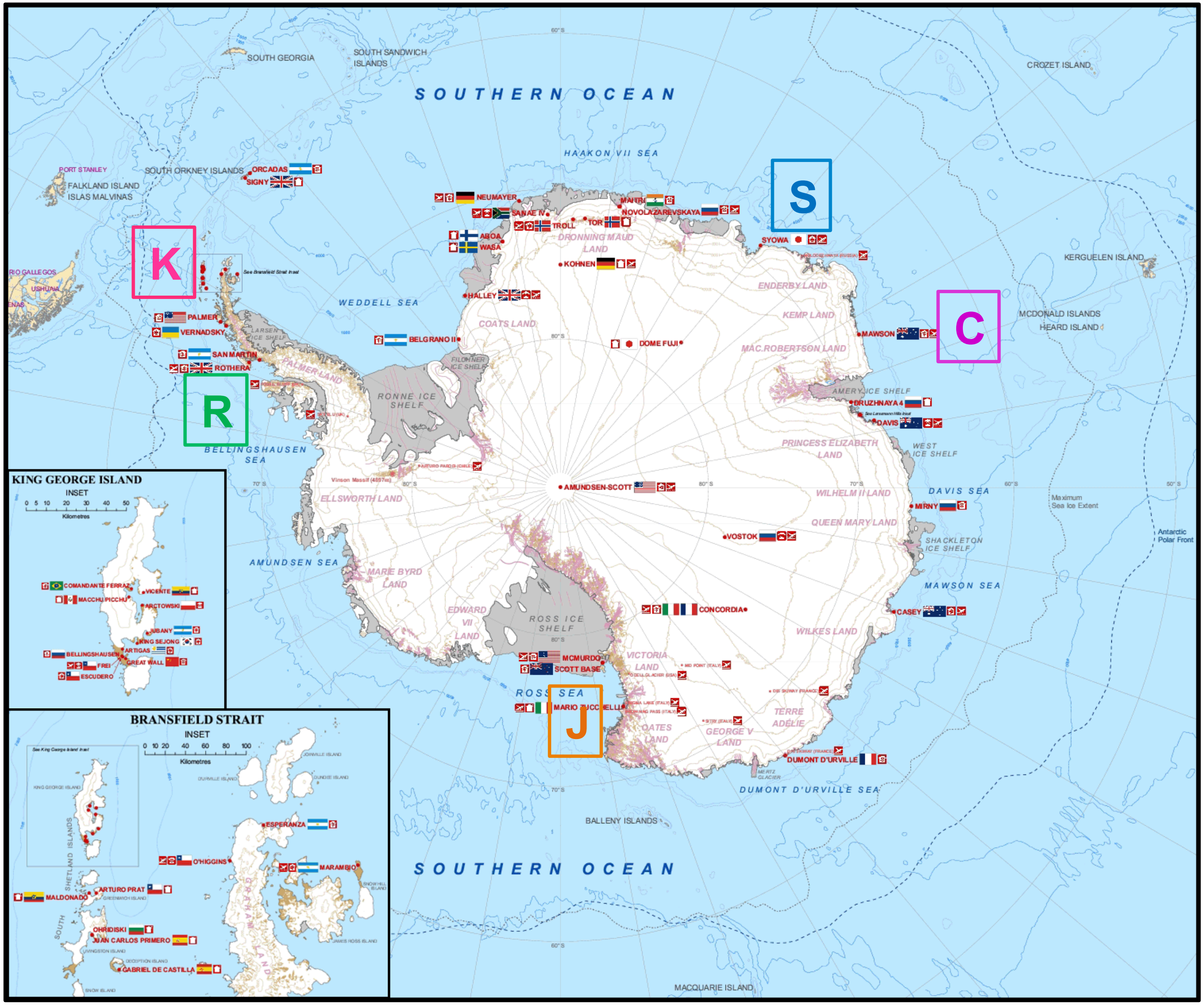
Figure 6. Percentage of upward and downward propagating gravity waves between 15 and 22 km for each month. The upward propagating waves are represented by the solid line; the downward propagating waves are represented by the dashed line.

- strong seasonal variation

- Sep.–May : upward propagation
- winter : downward propagation

- Yoshiki and Sato, [2000] : dominance of upward propagating waves all year round. (downward max. ~40%
  in Jul.–Aug.)

Research station in the Antarctic



Rothera (67˚S, 68˚W)
Syowa (69˚S, 39˚E)
Casey (66˚S, 110˚E)
KSS (62˚S, 58˚W)
JBS (74˚S, 164˚E)