temperature and wind measurement in the middle atmosphere during GWLcycle

Gerd Baumgarten

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GW-LCYCLE

Investigation of the life cycle of gravity waves

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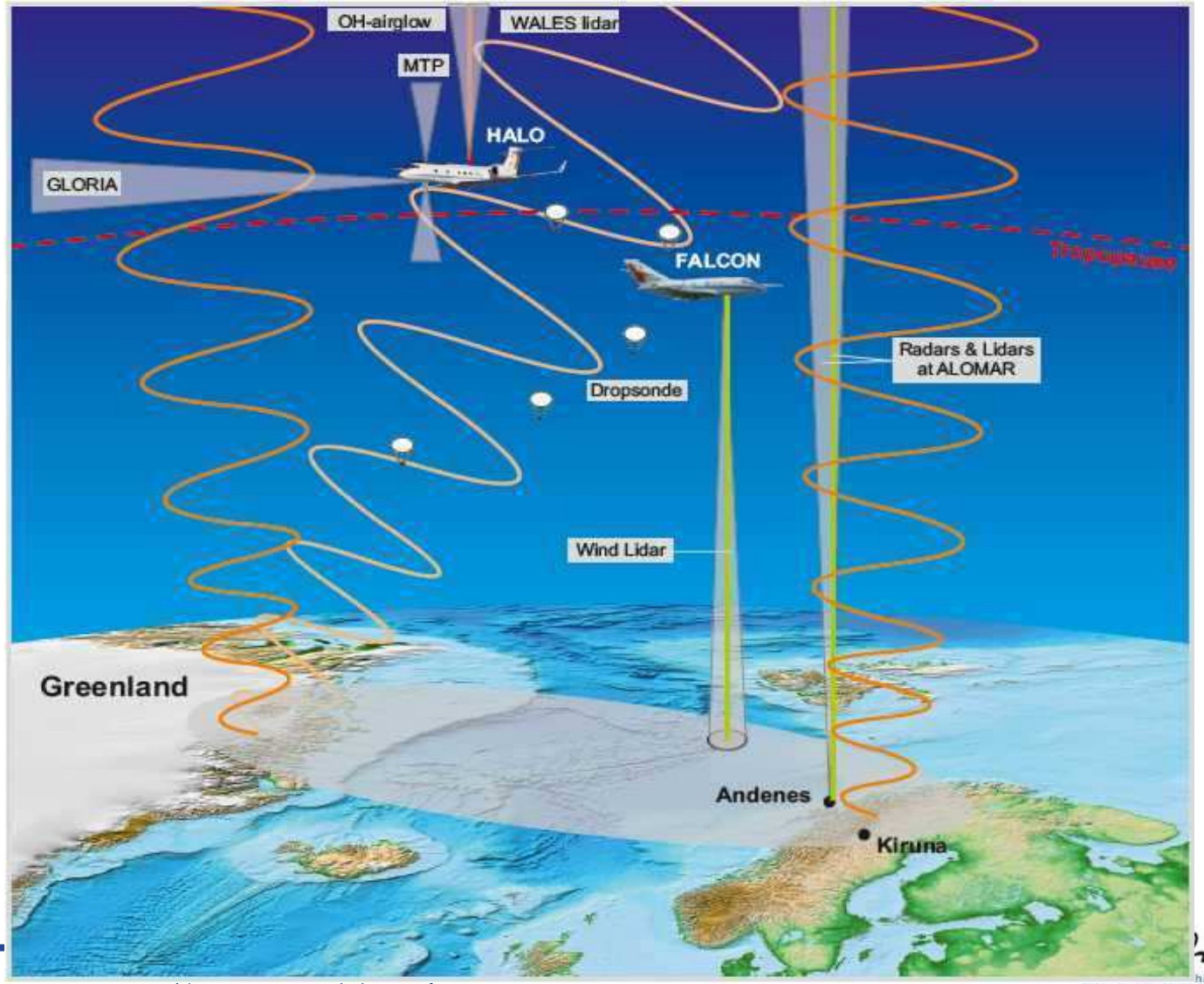
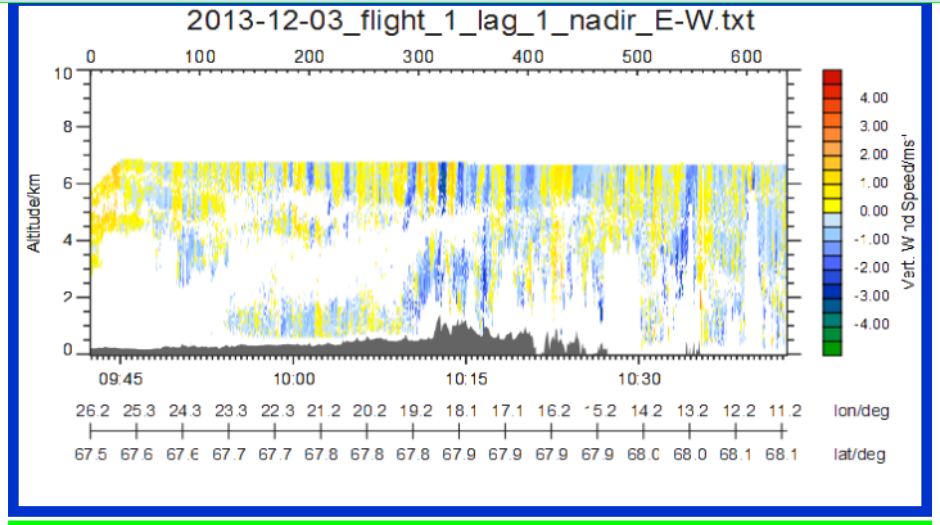
BMBF Research Initiative: ROMIC (Role of the Middle atmosphere In Climate)

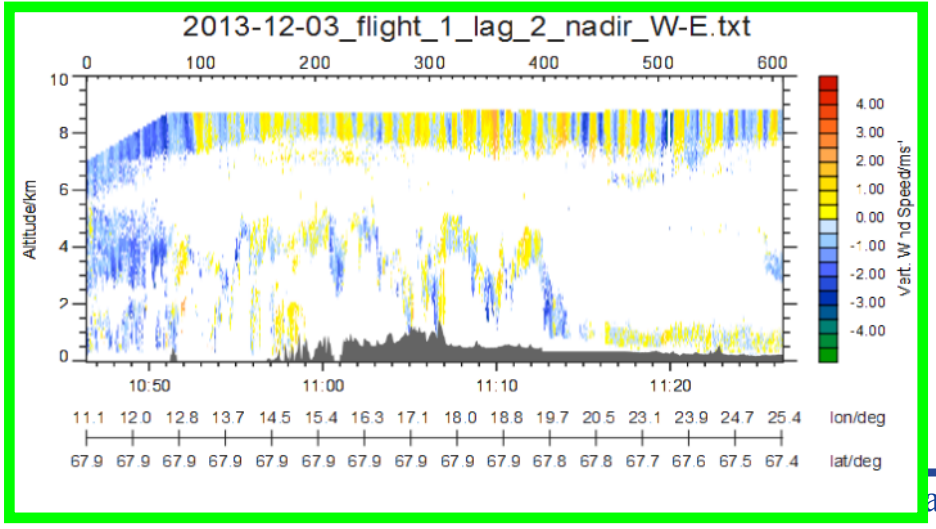
Campaign 1
December 2013

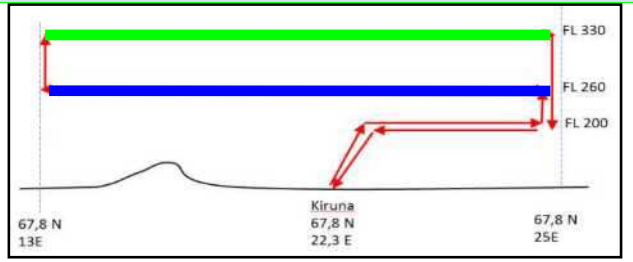
Campaign 2
January 2016

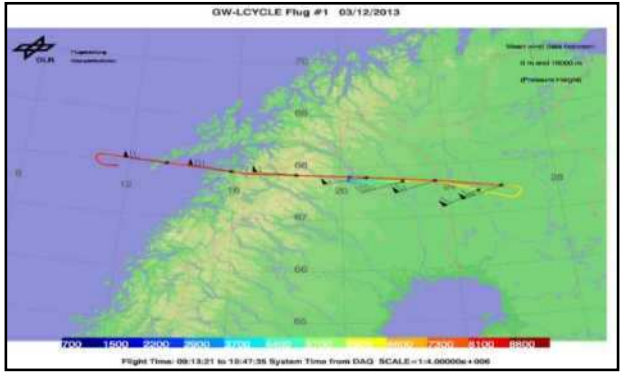


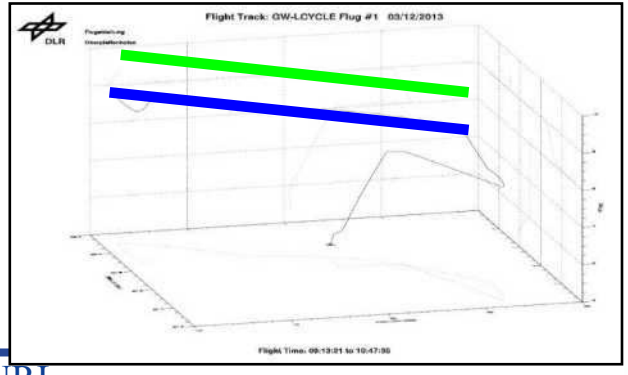
Falcon Doppler Wind Lidar IOP 1 - 3 Dec 2013







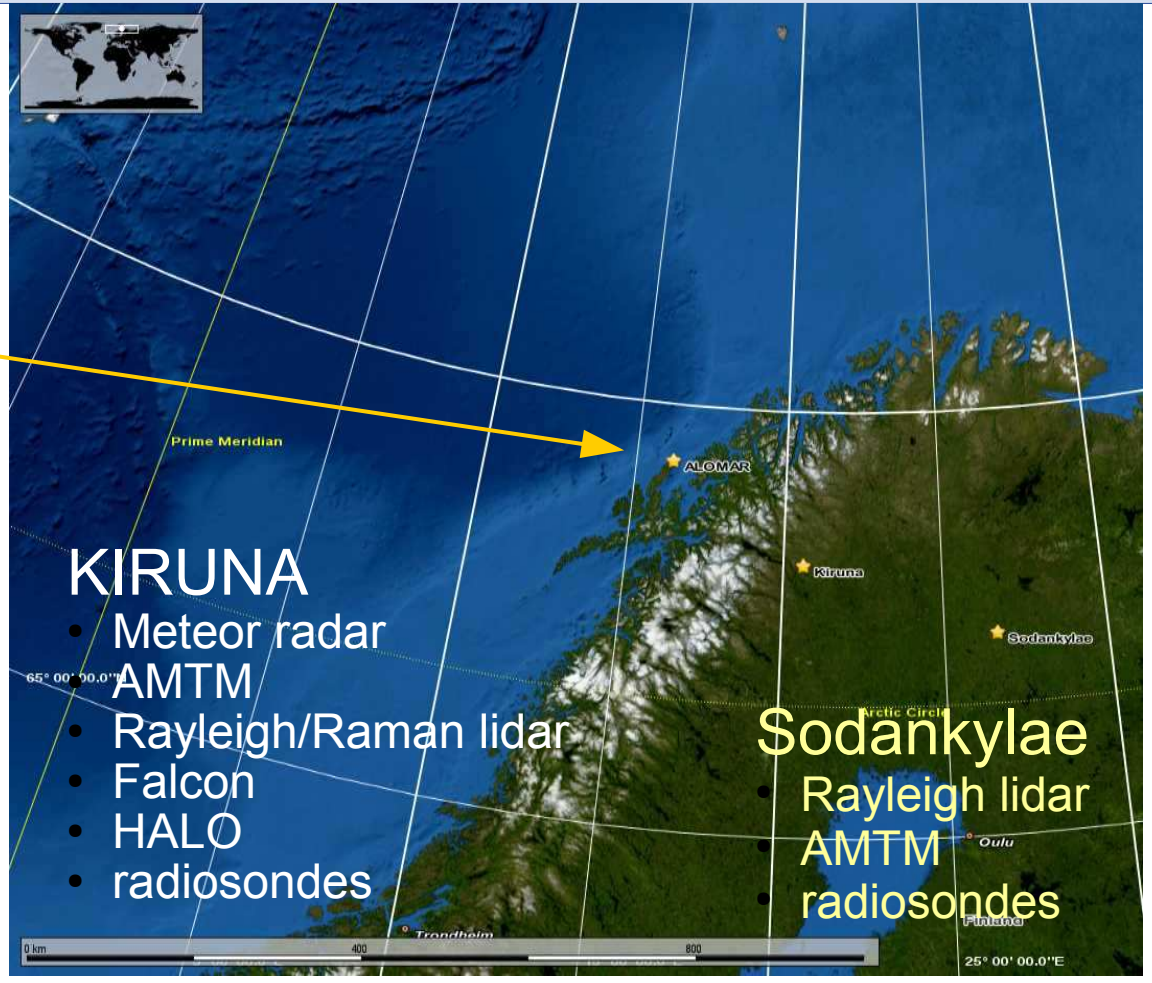




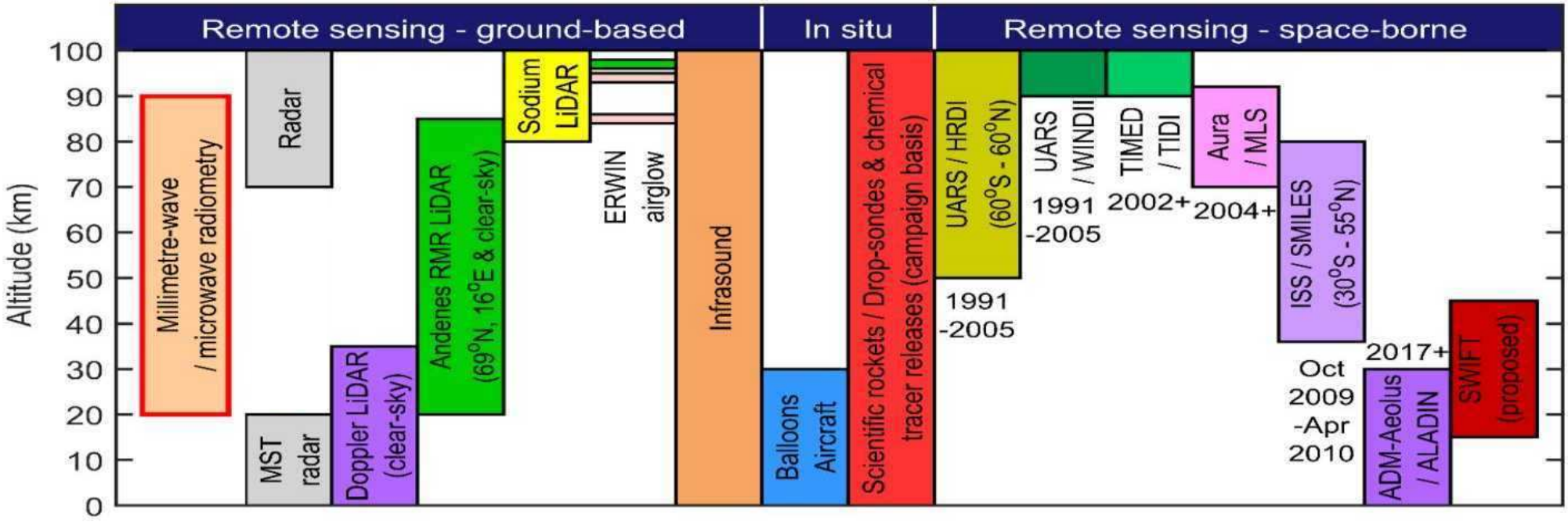
GWLCYCLE core campaign January 12 – February 3

ALOMAR

- MST radar
- MF radar
- Meteor radar
- Rayleigh/Raman/ Doppler wind lidar
- Fe-Lidar
- (Na-Lidar)
- AMTM
- GRIPS
- radiosondes
- LITOS balloon



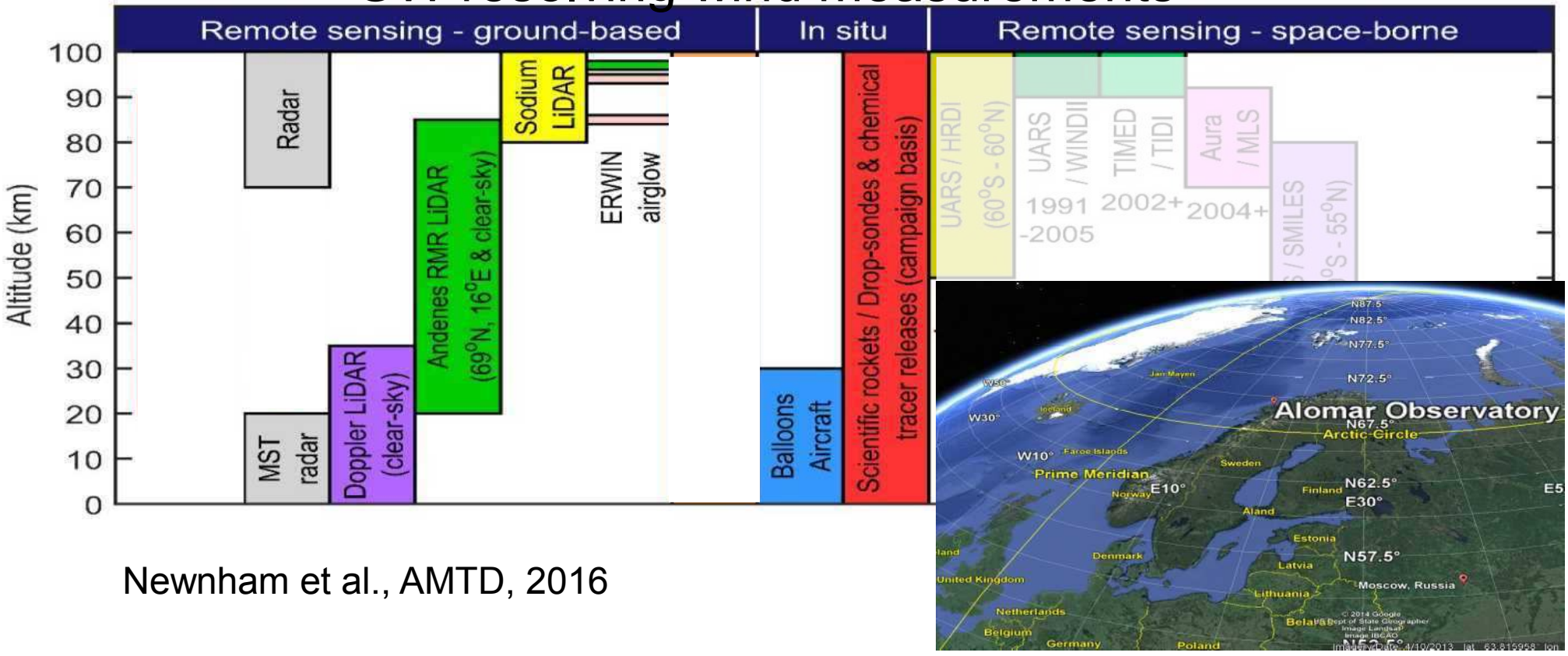
Wind measuremenst (global)



Newnham et al., AMTD, 2016

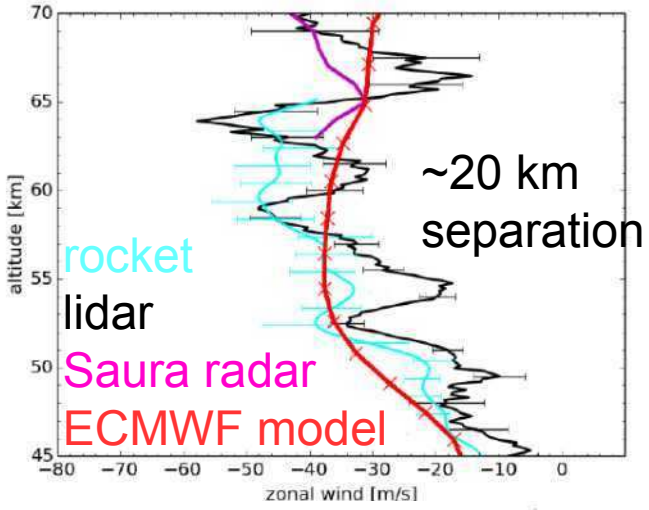
Wind measurements (global)

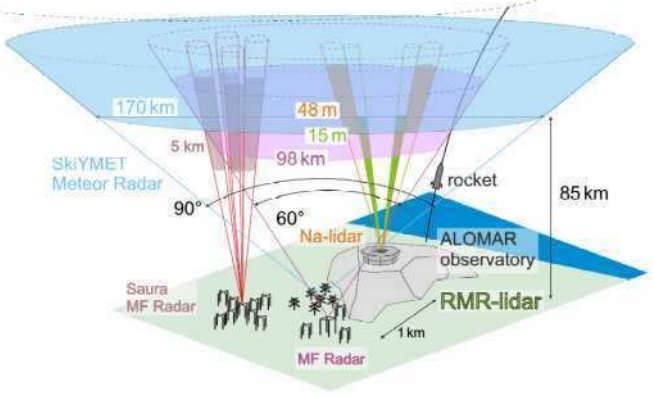
GW resolving wind measurements



Newnham et al., AMTD, 2016

DoRIS day validation: lidar vs. rocket



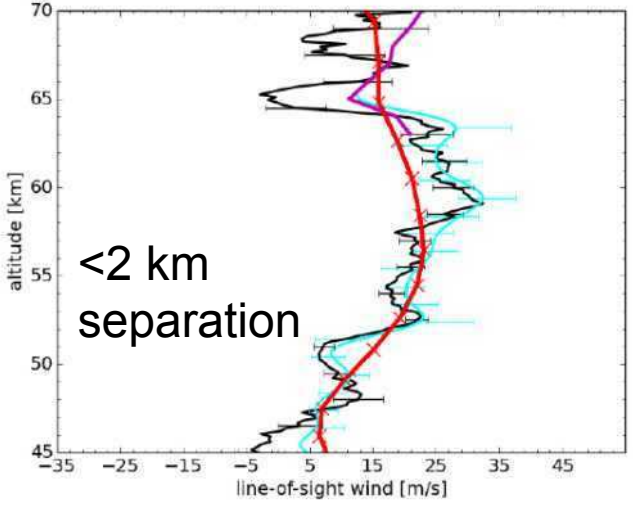


WADIS Campaign, June, 2013

….

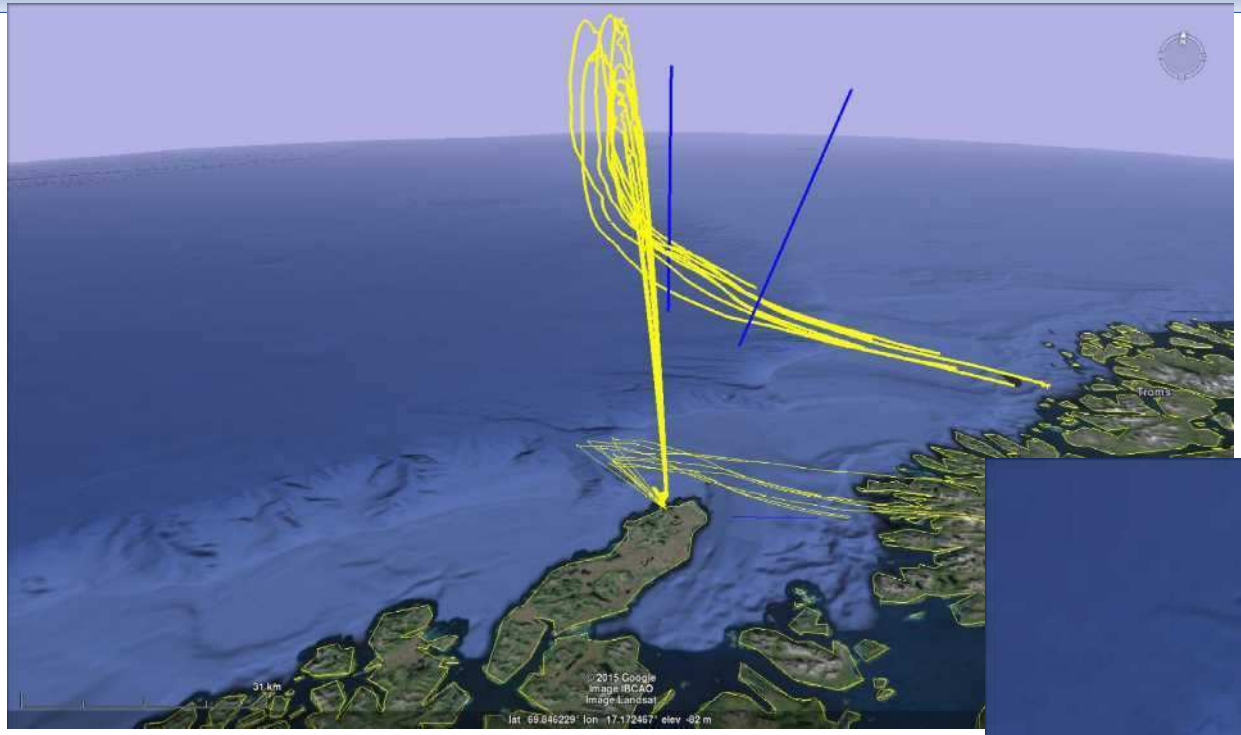
11 Superloki / Starutes

Daytime!

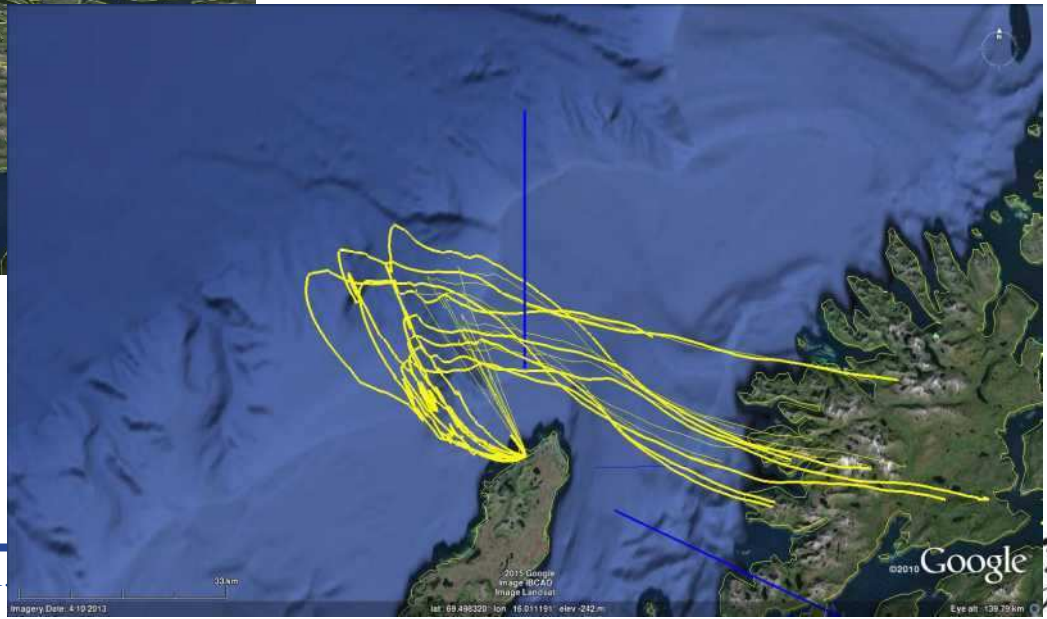


Staney, Diploma, 2014

How to make sure we have a common volume?

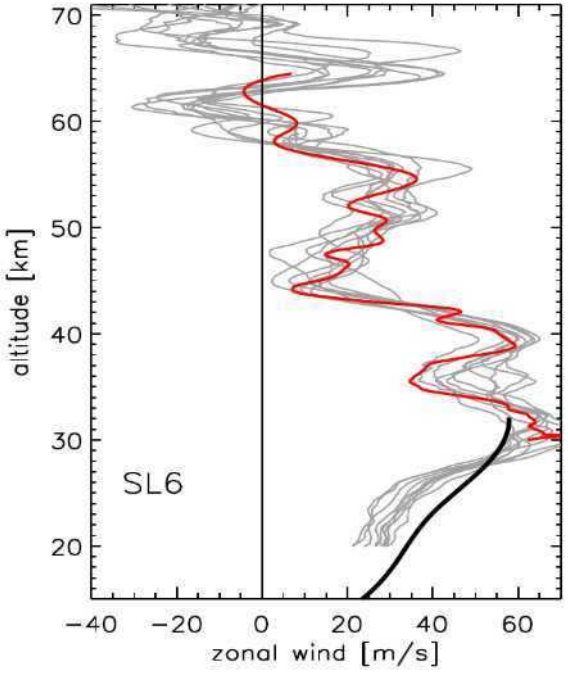


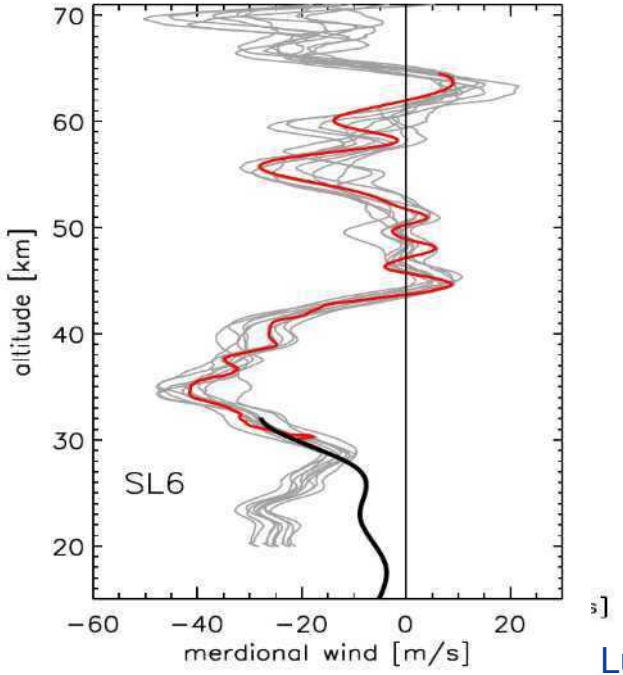
WADIS-2 Starute trajectories



DoRIS validation: lidar vs. rocket

WADIS Campaign, March, 2015





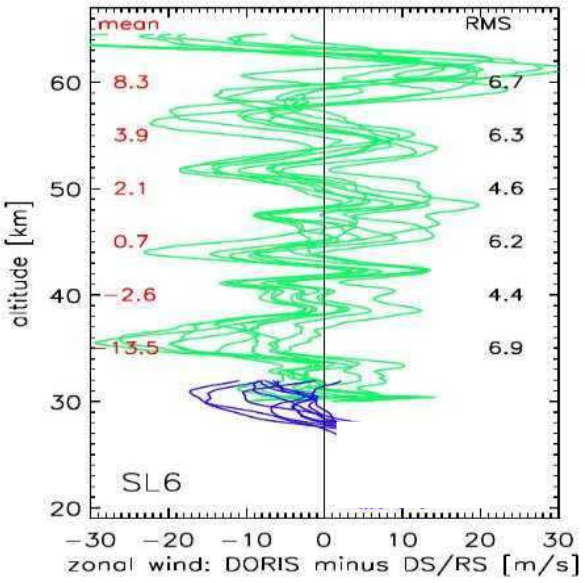
example March 14, 2015
20:36 UT

lidar
rocket

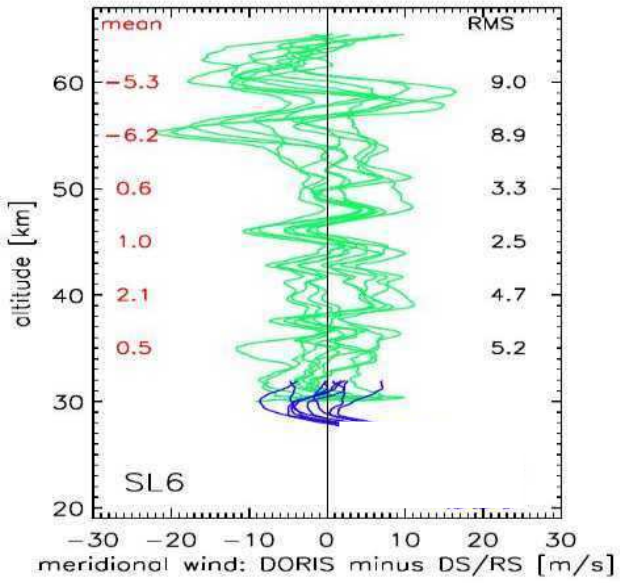
Lübken et al., AMTD, 2016

DoRIS validation: lidar vs. rocket

WADIS Campaign, March, 2015



closer to lidar beam



example March 14, 2015
20:36 UT

Lübken et al., AMTD, 2016

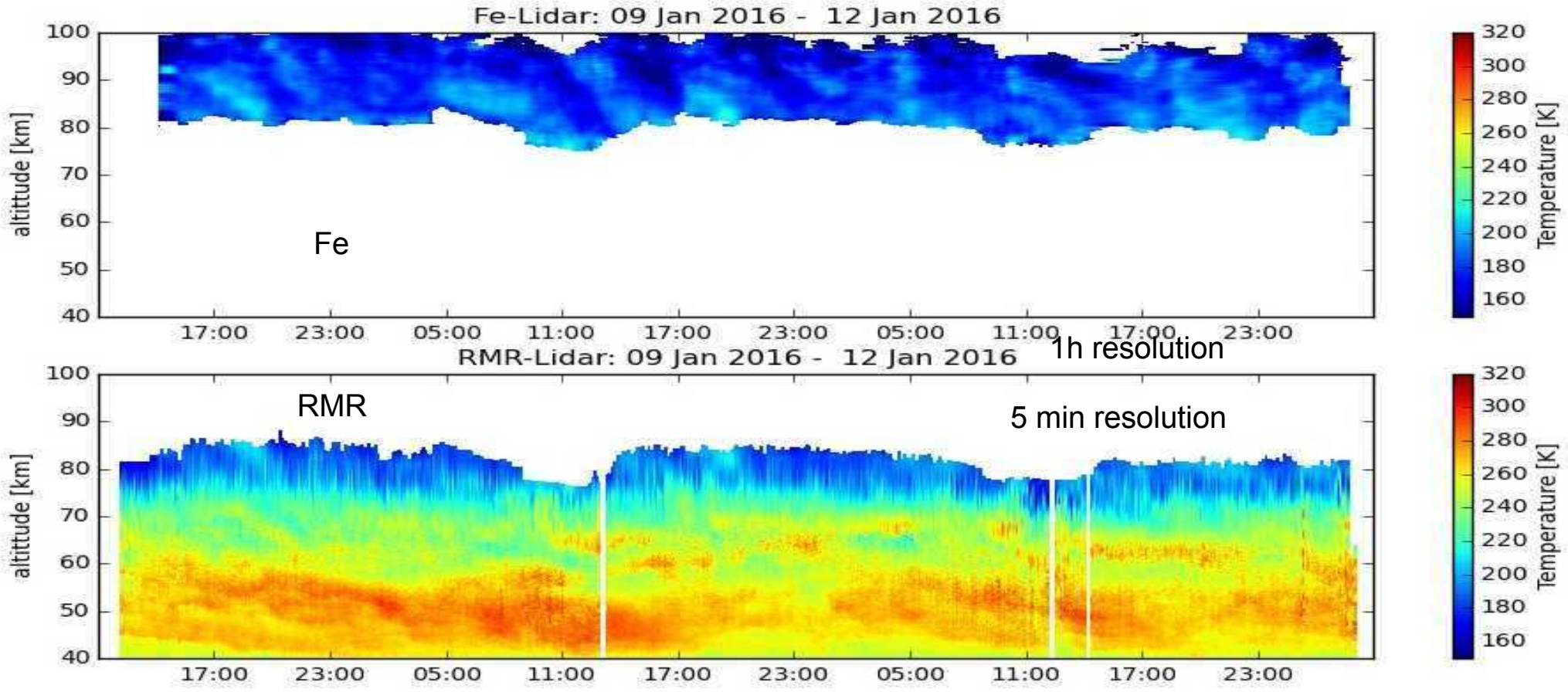
RMR Measurement statistics

Maximum Break 2.5 h

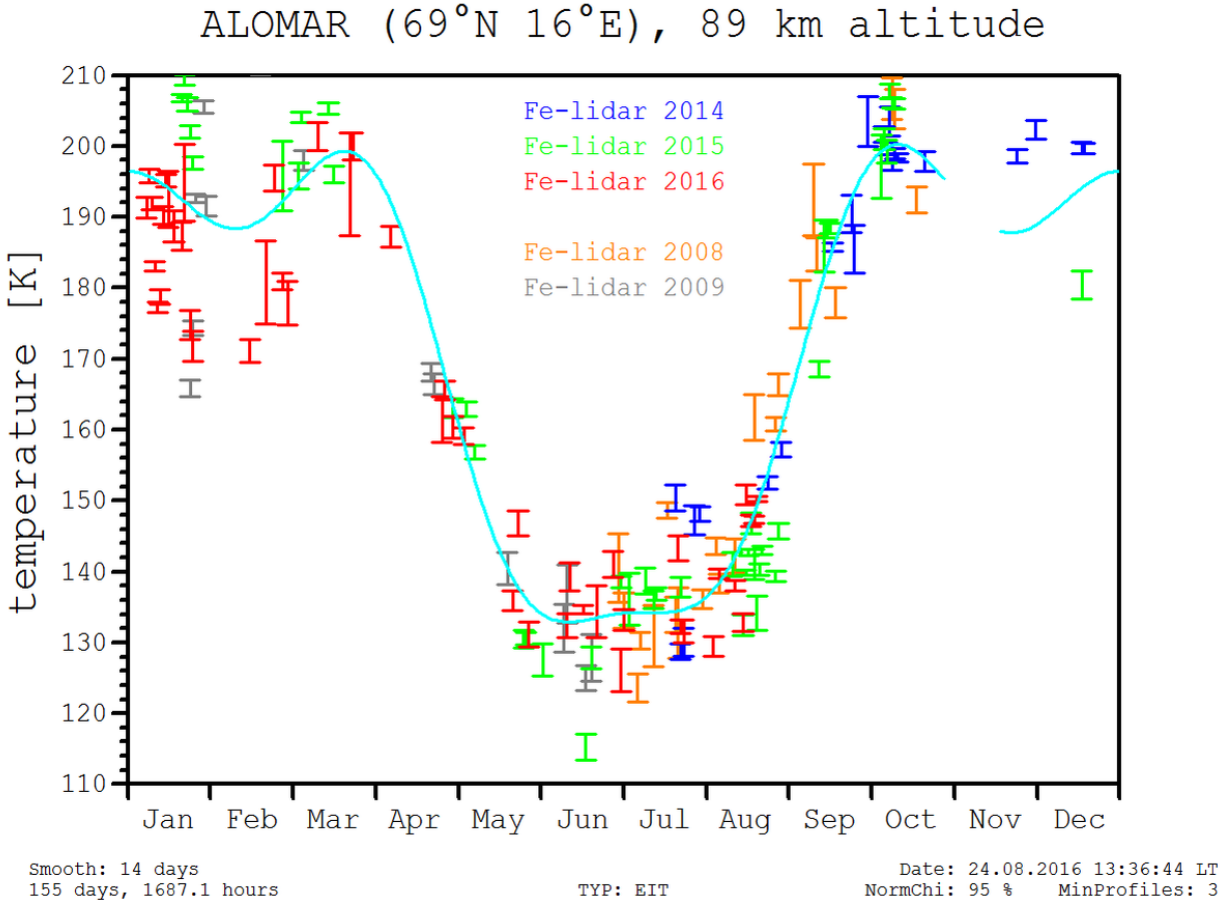
DoRIS Wind

	shots [1E6]	total time [h]	unique time [h]	< 6h	6h--12h	12--24h	24h--48h	> 48h	max duration [h]
2016	152.6	1410.0	706.2	35	22	12	2	4	64.3
2015	160.1	1482.5	745.5	36	13	8	4	5	96.4
2014	229.7	2126.6	1068.0	47	22	18	8	4	131.6
2013	166.1	1536.7	849.7	64	20	20	9	0	41.9
2012	102.2	946.3	494.0	33	15	9	3	1	58.8
2011	84.2	780.0	651.0	47	15	10	2	3	107.3
2010	156.1	1445.9	726.3	60	33	16	5	0	31.5
2009	187.8	1738.6	931.3	86	29	18	4	2	90.8
2008	138.1	1279.3	704.0	35	27	16	5	0	42.9
2007	118.2	1095.1	632.4	36	12	12	5	3	58.9
2006	56.7	519.6	343.7	43	10	8	2	0	31.6
2005	120.7	1106.6	756.4	64	24	5	4	3	158.8
2004	108.3	996.3	774.0	73	9	13	3	3	102.7
2003	106.6	982.8	851.1	92	14	13	9	1	78.9
2002	114.3	1054.5	921.8	98	35	19	4	1	59.6
2001	45.6	420.9	385.4	65	21	4	0	1	62.1
2000	56.7	522.8	375.8	80	10	6	3	0	39.8
1999	59.5	549.0	493.9	87	14	9	2	1	56.7
1998	69.1	637.4	591.7	99	22	7	4	1	64.8
1997	49.0	451.7	451.5	74	20	14	0	0	21.3
1996	71.2	656.6	656.6	122	35	14	0	0	17.1

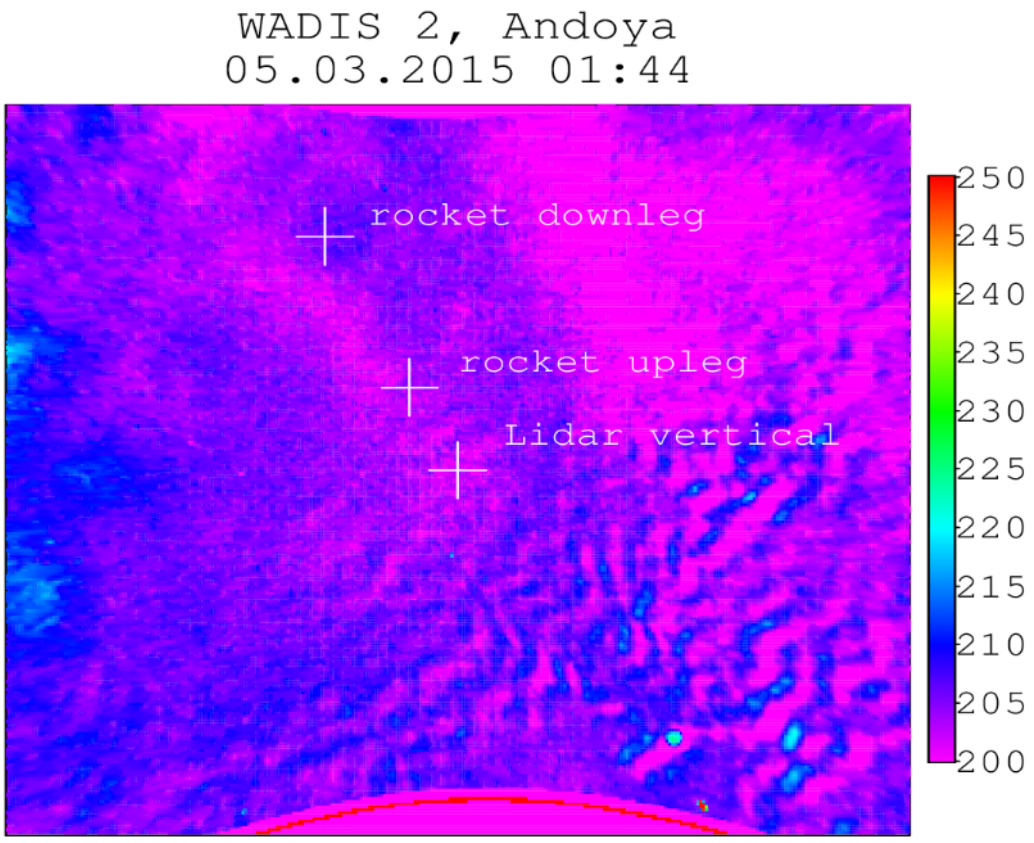
Combining T-Measurements of Fe and RMR lidar

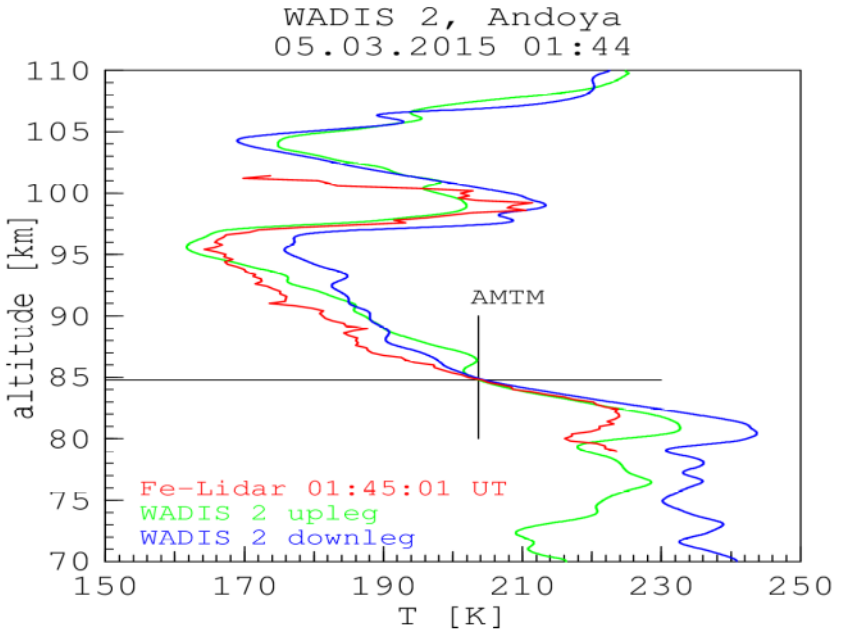


Fe-Lidar Temperatures 2008/2009/2014/2015/2016

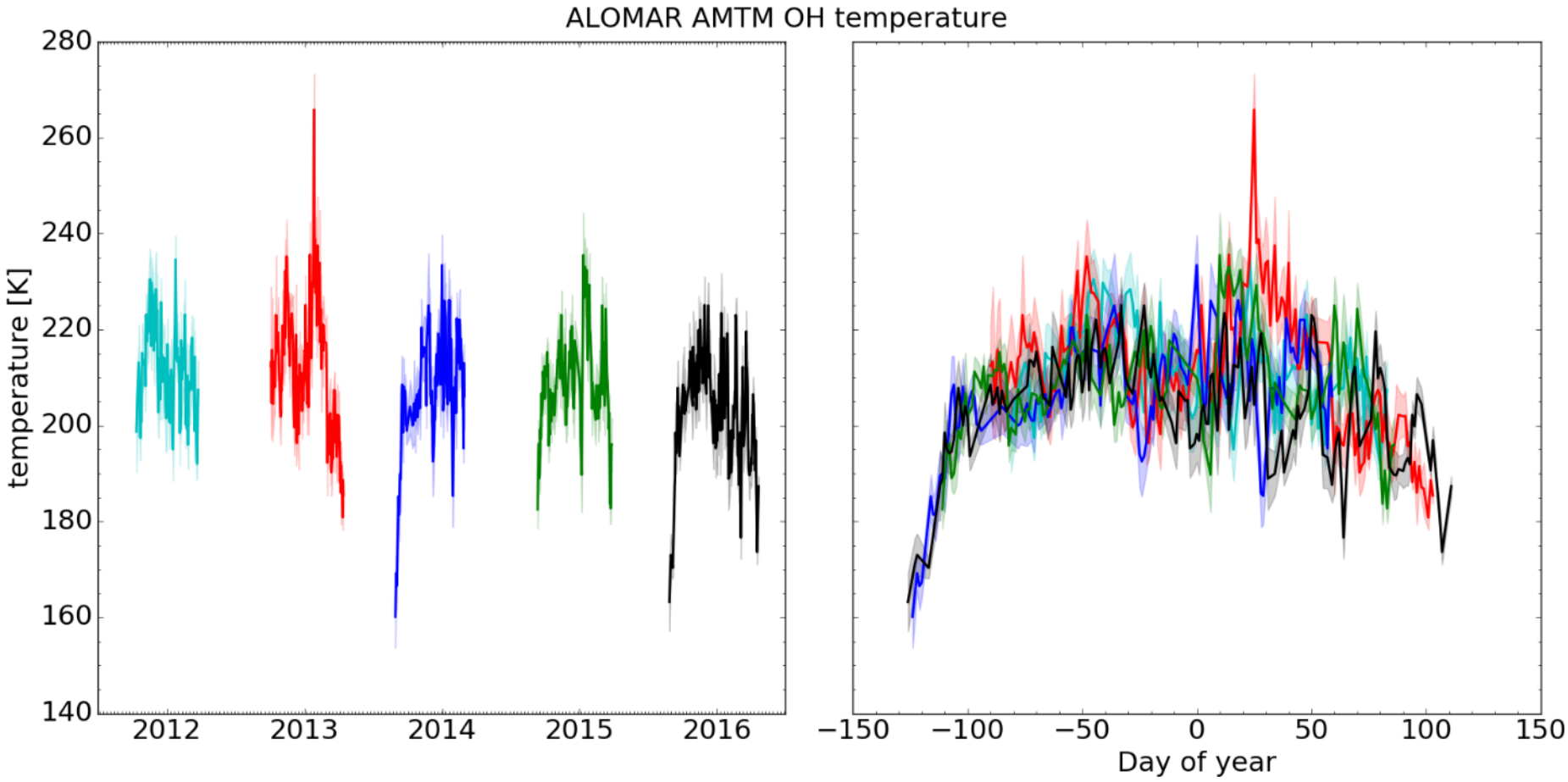


Comparison of Lidar, rocket and OH Temperature mapper (WADIS-2)

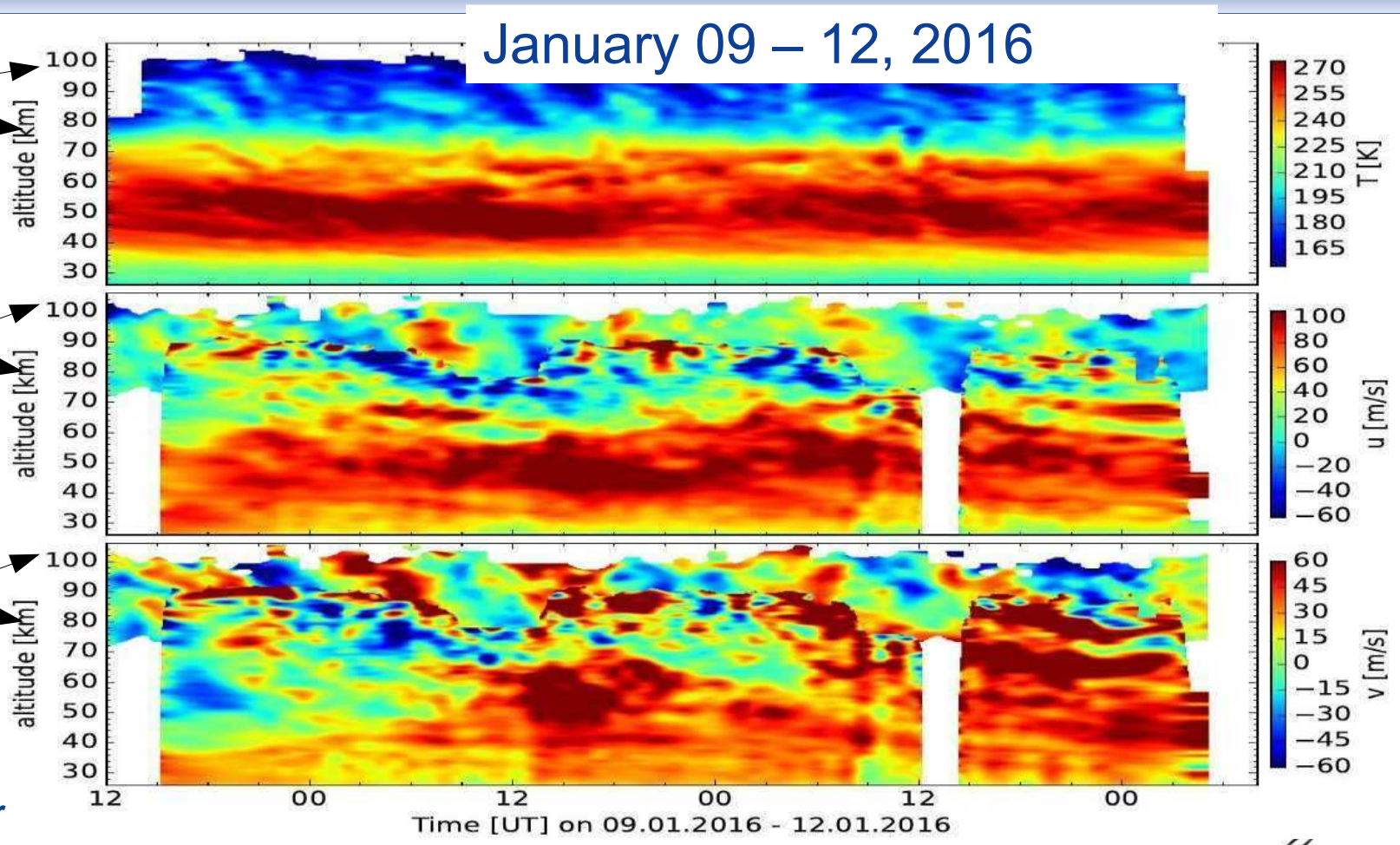




Combining T from Fe, RMR and OH: To be done



Combinig multiple instuments at ALOMAR



Fe-data: **J. Höffner**
Meteor data: **G. Stober**

Combinig multiple instuments at ALOMAR

Fe Lidar

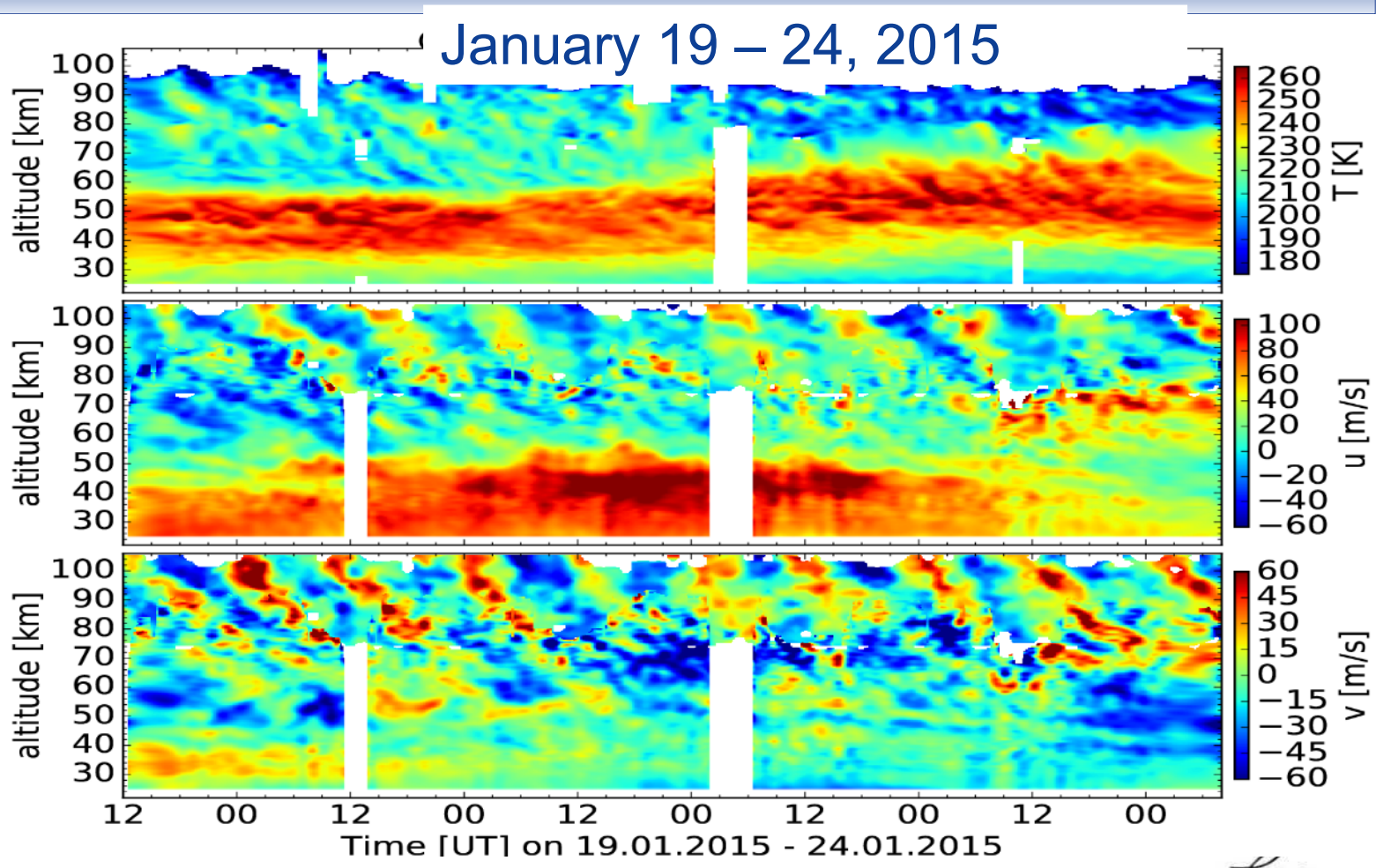
RMR Lidar

Meteor Radar

RMR Lidar

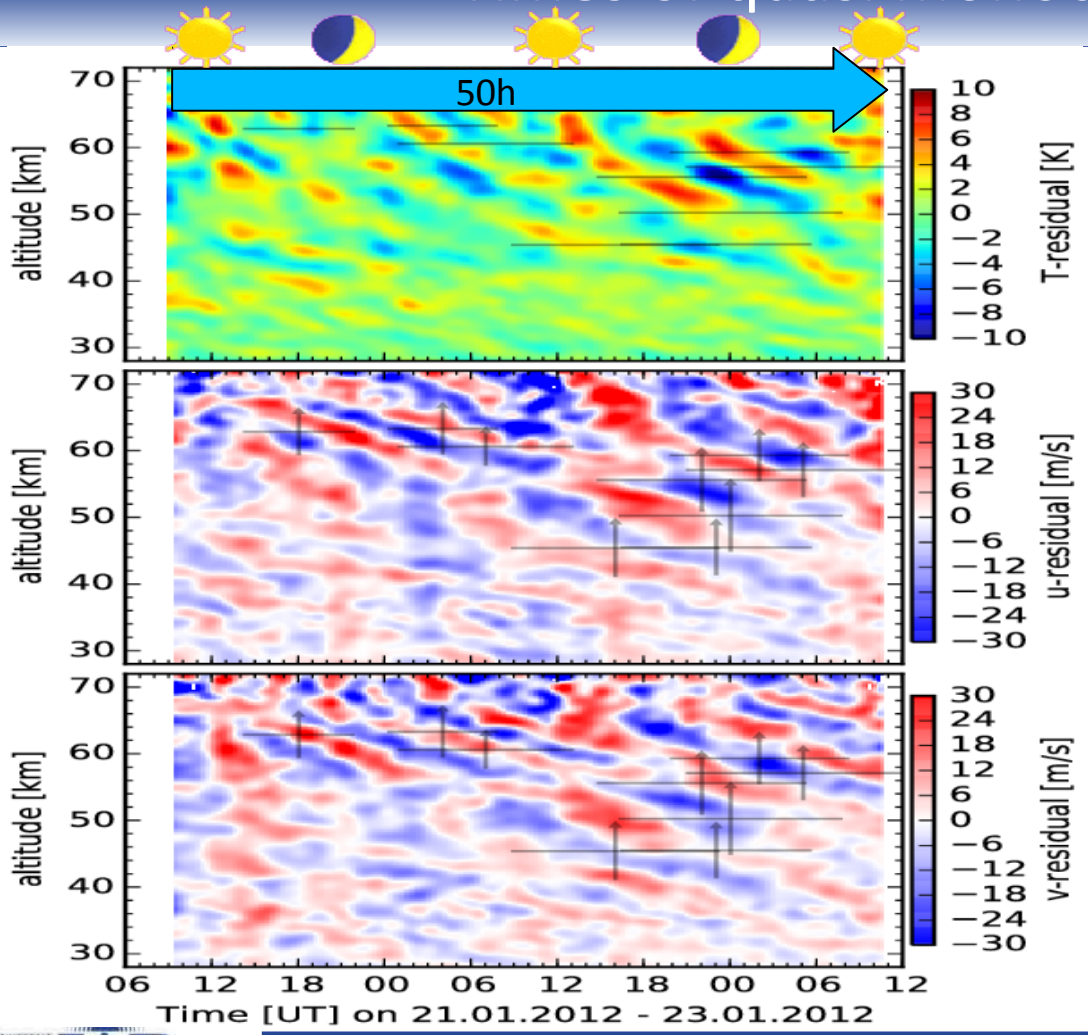
Meteor Radar

RMR Lidar



Fe-data: **J. Höffner**
Meteor data: **G. Stober**

Times of quasi monochromatic GW



How do GW show up in different quantities?

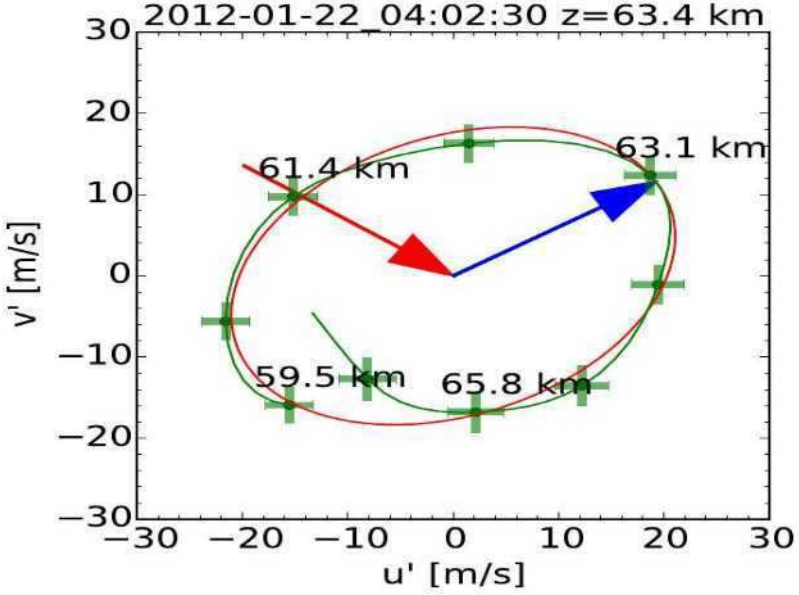
$$T' = i\frac{N^2}{g\hat{\omega}}\frac{\lambda_z}{\lambda_h}u'_l$$

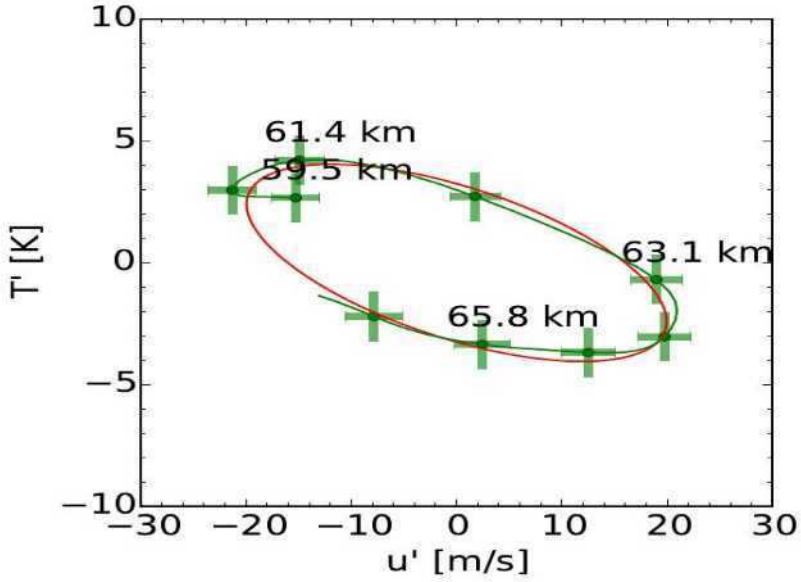
$$u'_r = -i\frac{f}{\hat{\omega}}u'_l$$

u'_l parallel and

u'_r perpendicular to GW direction

hodograph analysis / example





- combining *u'* and *v'* wind perturbations
  - vertical wavelength: 7.4 km /propagation: upward
  - horizontal propagation: northeastward (or southwestward)
  - intrinsic period: 9.4 h
- combining *u'* and *T'*: northeastward

Table of GW properties

background

gravity wave

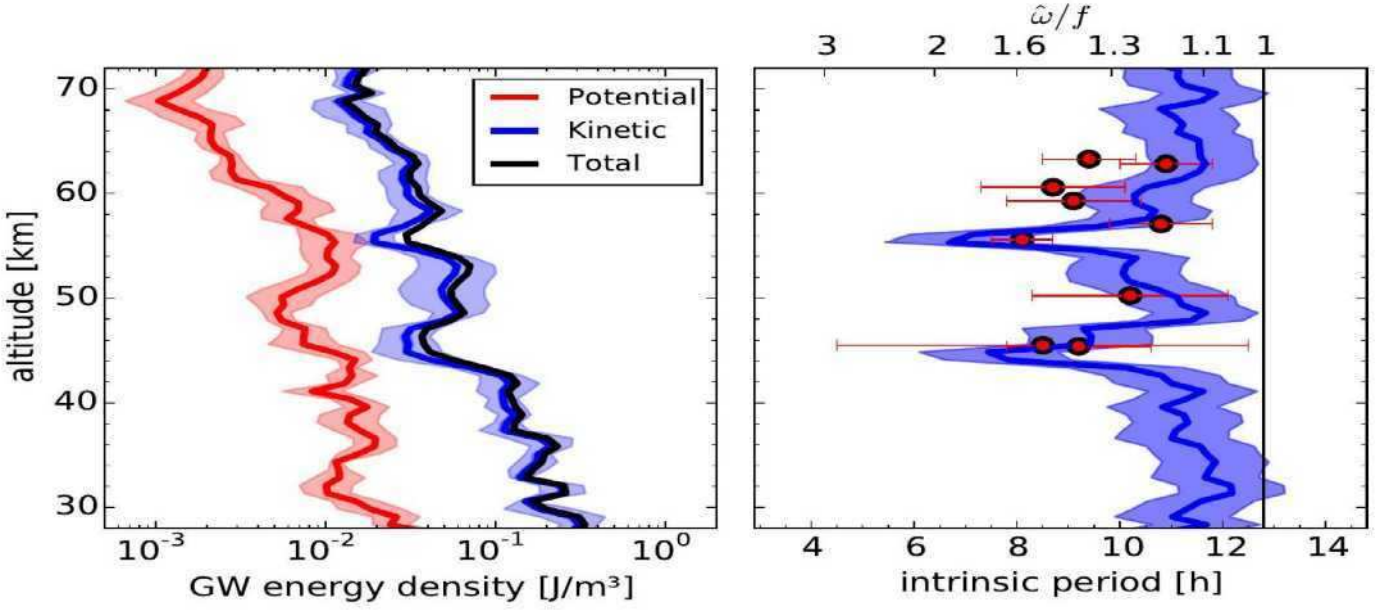
stability | **direction** | **phase speed**

time	altitude range		T	N^2	background wind				λ_z	λ_h	ϕ	amplitude			AR	$\hat{P}$	P	c_z	c_h	$\overline{u'w'}$
					u	v	u_l	u_r				T'	u'_l	u'_r						
UT	km	km	K	10^{-4}s^{-2}	m/s	m/s	m/s	m/s	km	km	°	K	m/s	m/s		h	h	m/s	m/s	m^2/s^2
2012-01-21 18:02	59.5	66.2	218.7	3.48	13.9	-12.1	4.9	17.8	6.7	1490	26	2.4	24.1	24.3	1.18	10.9	7.5	0.17	38.0	3.1
2012-01-22 04:02	59.6	67.0	218.0	3.58	20.0	-13.7	9.5	-22.3	7.4	1110	237	4.0	21.1	16.8	1.36	9.4	7.4	0.22	32.8	3.3
2012-01-22 07:02	57.9	63.3	222.7	3.31	22.0	-2.1	-13.1	17.8	5.4	670	42	2.1	18.3	19.9	1.47	8.7	12.0	0.17	21.3	4.2
2012-01-22 16:02	41.2	49.6	248.3	3.43	27.6	27.5	-30.5	24.2	8.4	1180	7	1.4	11.7	16.3	1.39	9.2	14.2	0.25	35.6	1.8
2012-01-22 22:02	51.0	60.2	232.5	3.29	14.9	12.2	-19.2	1.9	9.2	1000	45	7.2	21.9	21.3	1.58	8.1	14.3	0.32	34.3	5.9
2012-01-22 23:02	41.5	49.5	247.3	3.44	18.1	18.9	-15.2	21.3	8.0	970	349	2.5	5.4	8.3	1.51	8.5	13.0	0.26	31.6	0.5
2012-01-23 00:02	45.0	55.5	241.0	3.27	11.3	24.8	-17.5	20.9	10.5	1840	335	5.7	14.2	15.1	1.25	10.2	15.3	0.29	50.1	1.3
2012-01-23 02:02	55.6	63.0	225.8	3.56	21.2	-0.6	-10.5	18.4	7.4	1040	31	4.5	21.8	26.1	1.41	9.1	12.2	0.23	31.6	4.5
2012-01-23 05:05	53.2	61.0	227.8	3.47	6.7	14.9	-14.8	6.9	7.8	1680	359	6.1	21.2	15.2	1.18	10.8	16.0	0.20	43.2	1.8

$$\overline{u'w'} = \frac{\hat{\omega}}{N} u_l'^2 \sqrt{\left(1 - f^2/\hat{\omega}^2\right) / \left(1 - \hat{\omega}^2/N^2\right)}$$

Gravity wave energy density

January 21/23, 2012:



$$\hat{\omega}^2 = N^2 \cdot \lambda_z^2/\lambda_h^2 \cdot + f^2$$

$$\hat{\omega} = \omega - 2\pi/\lambda_h \cdot u_l$$

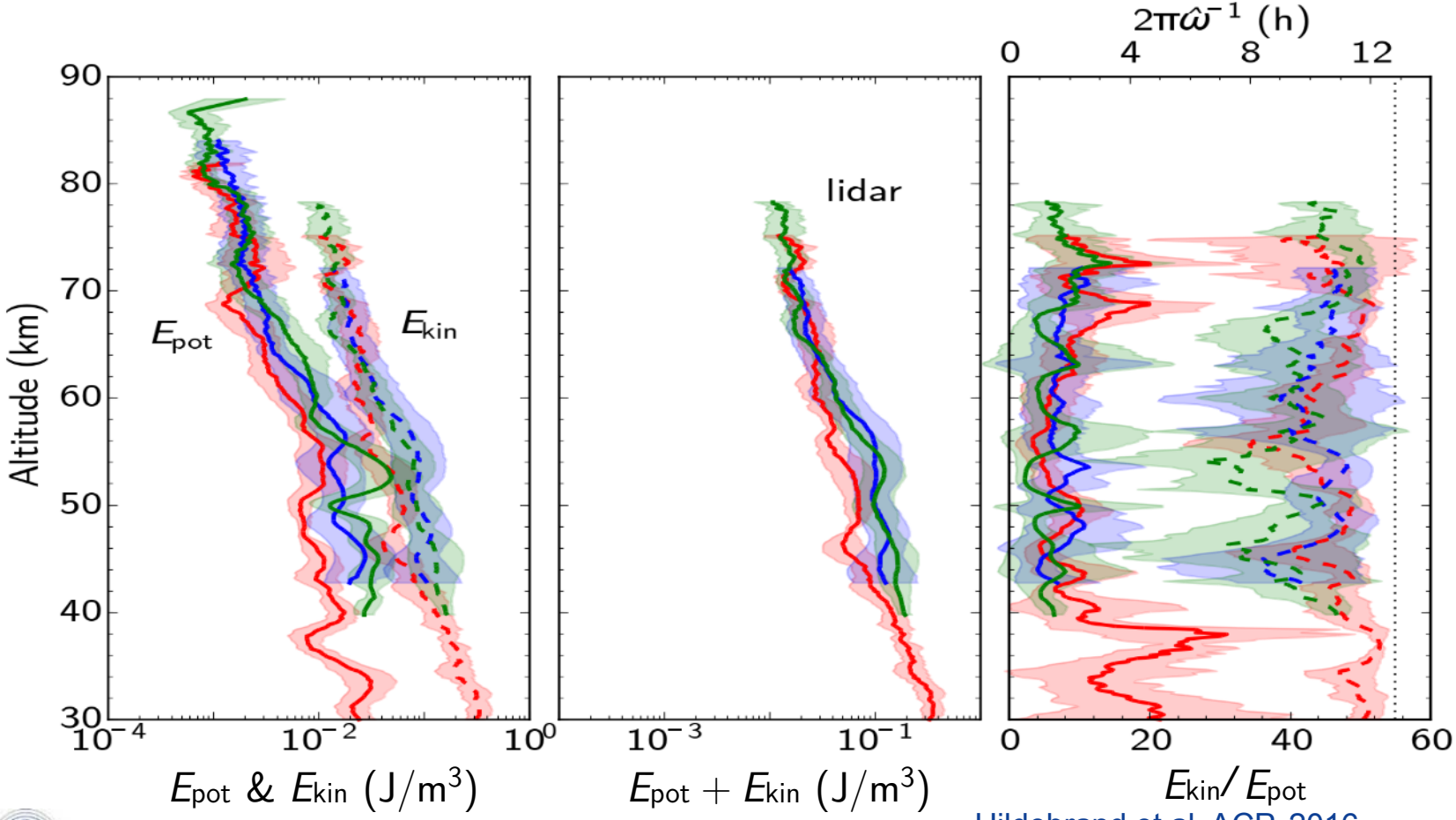
$P_{Coriolis}$= 12.8 h (69°N)

$$\hat{\omega} = \pm f \sqrt{\frac{E_{kin}/E_{pot} + 1}{E_{kin}/E_{pot} - 1}},$$

Geller&Gong,2010

- energy density decreases: waves transfer momentum to mean flow
- at lower altitudes more energy in larger scales

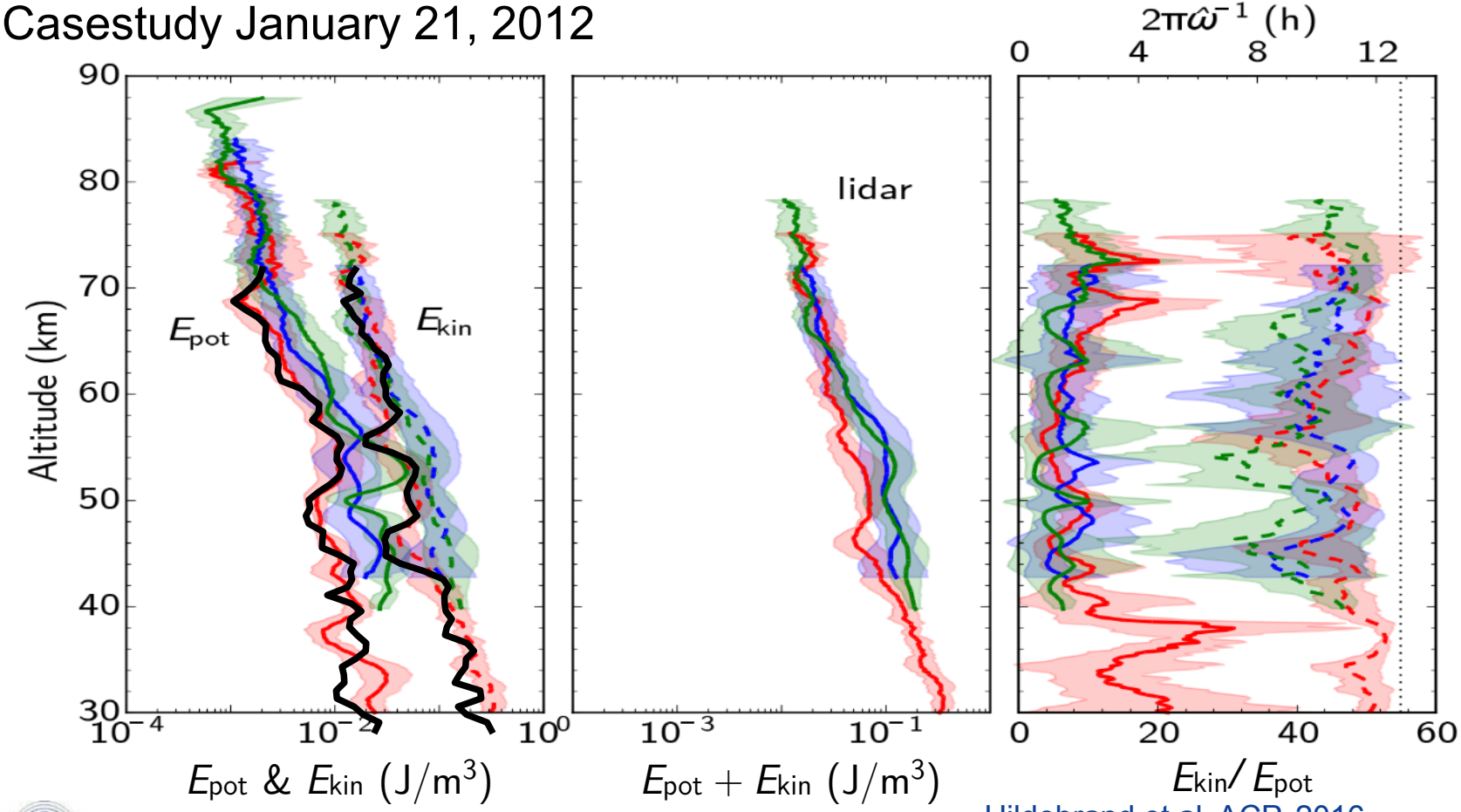
GW energy – January 2012,2014,2015



Hildebrand et al. ACP, 2016

GW energy – January 2012,2014,2015

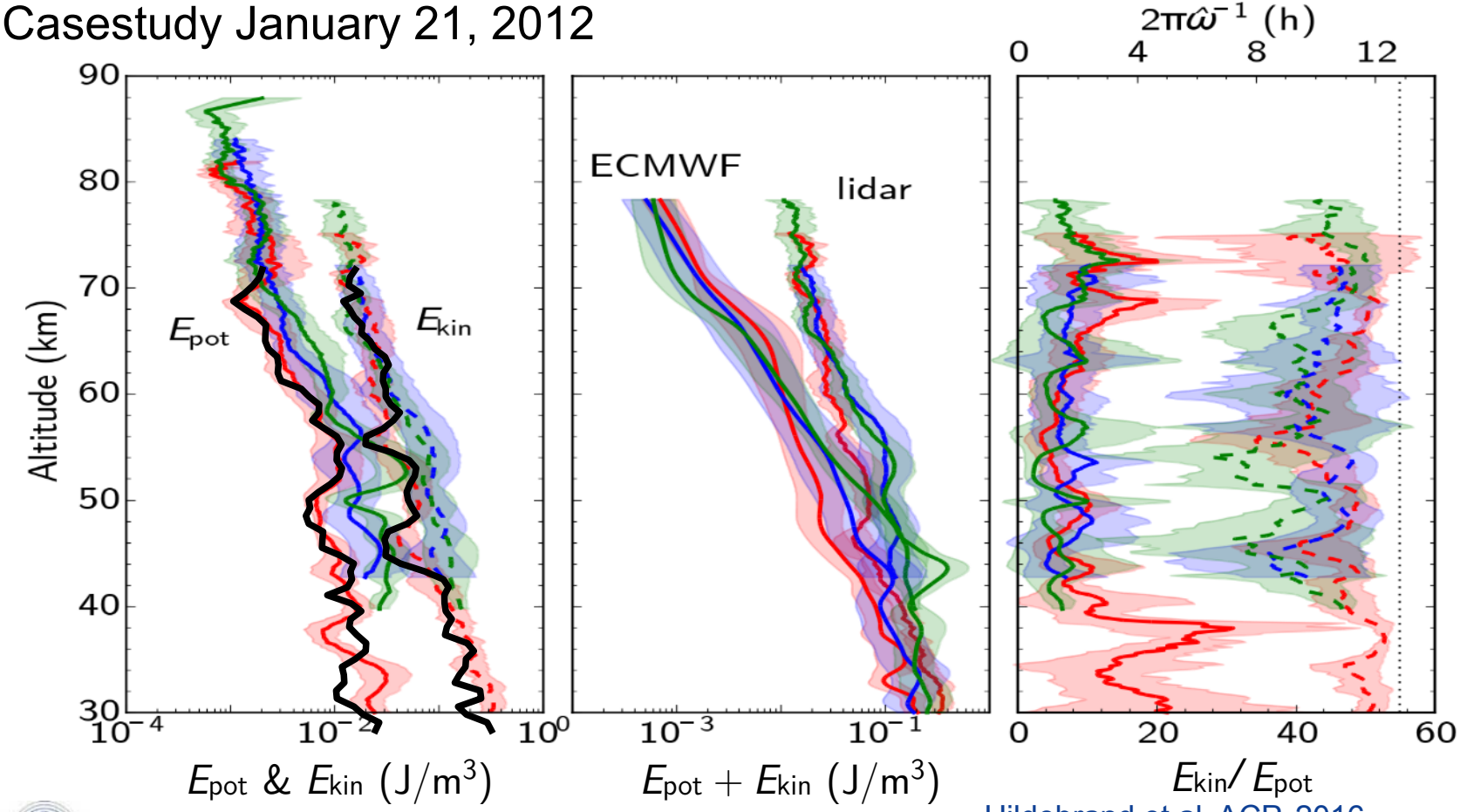
Casestudy January 21, 2012



Hildebrand et al. ACP, 2016

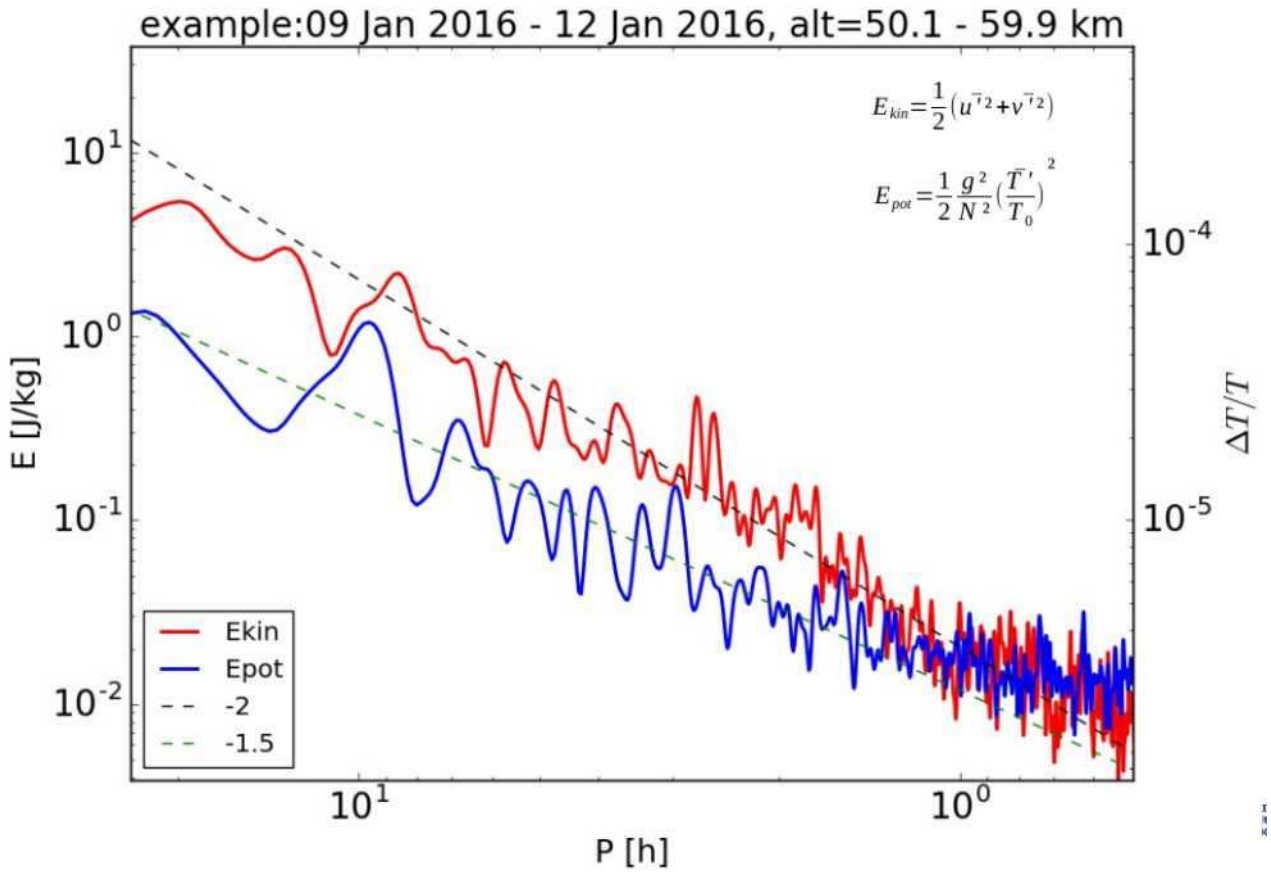
GW energy – January 2012,2014,2015

Casestudy January 21, 2012



Hildebrand et al. ACP, 2016

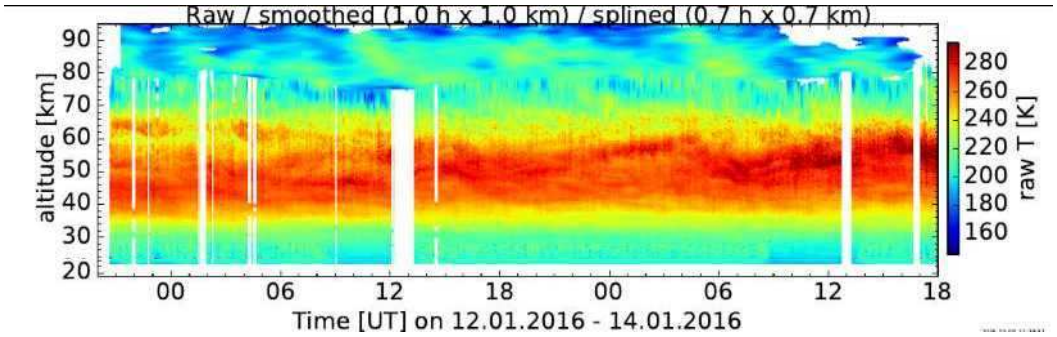
Kinetic and potential energy spectra

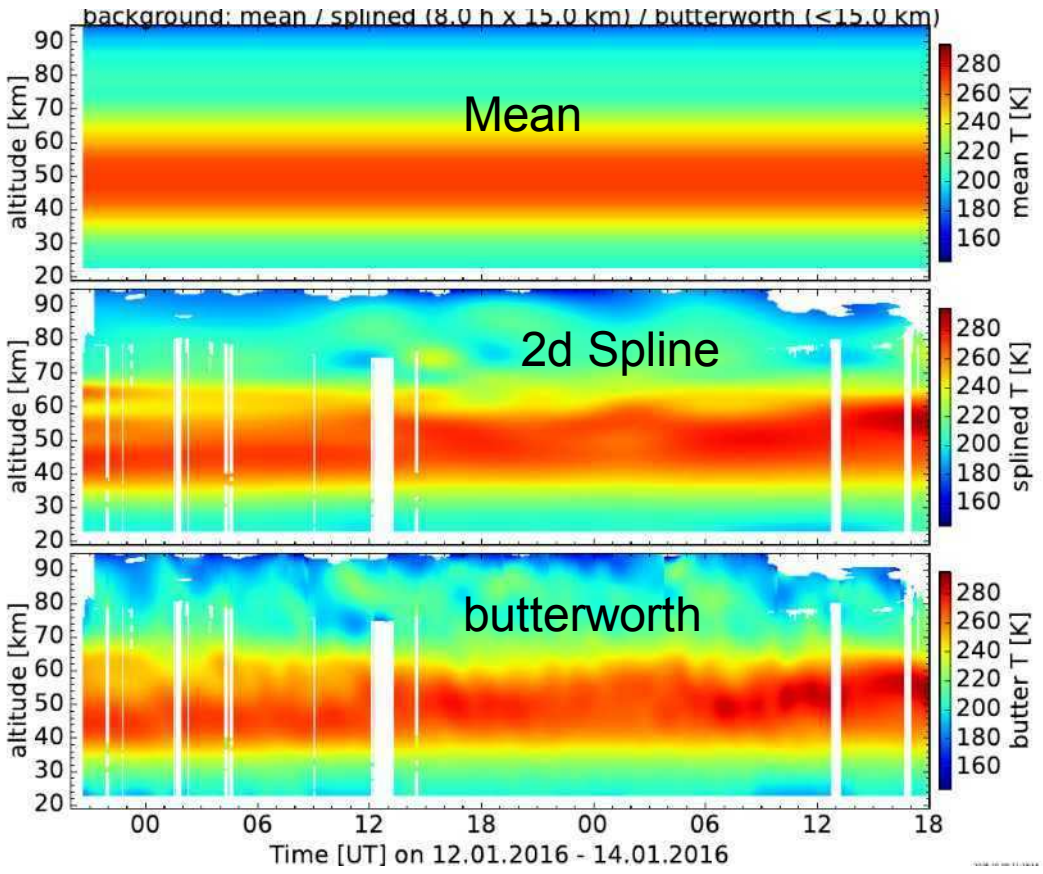


although RMR Doppler lidar wind measurements are technical challenging:

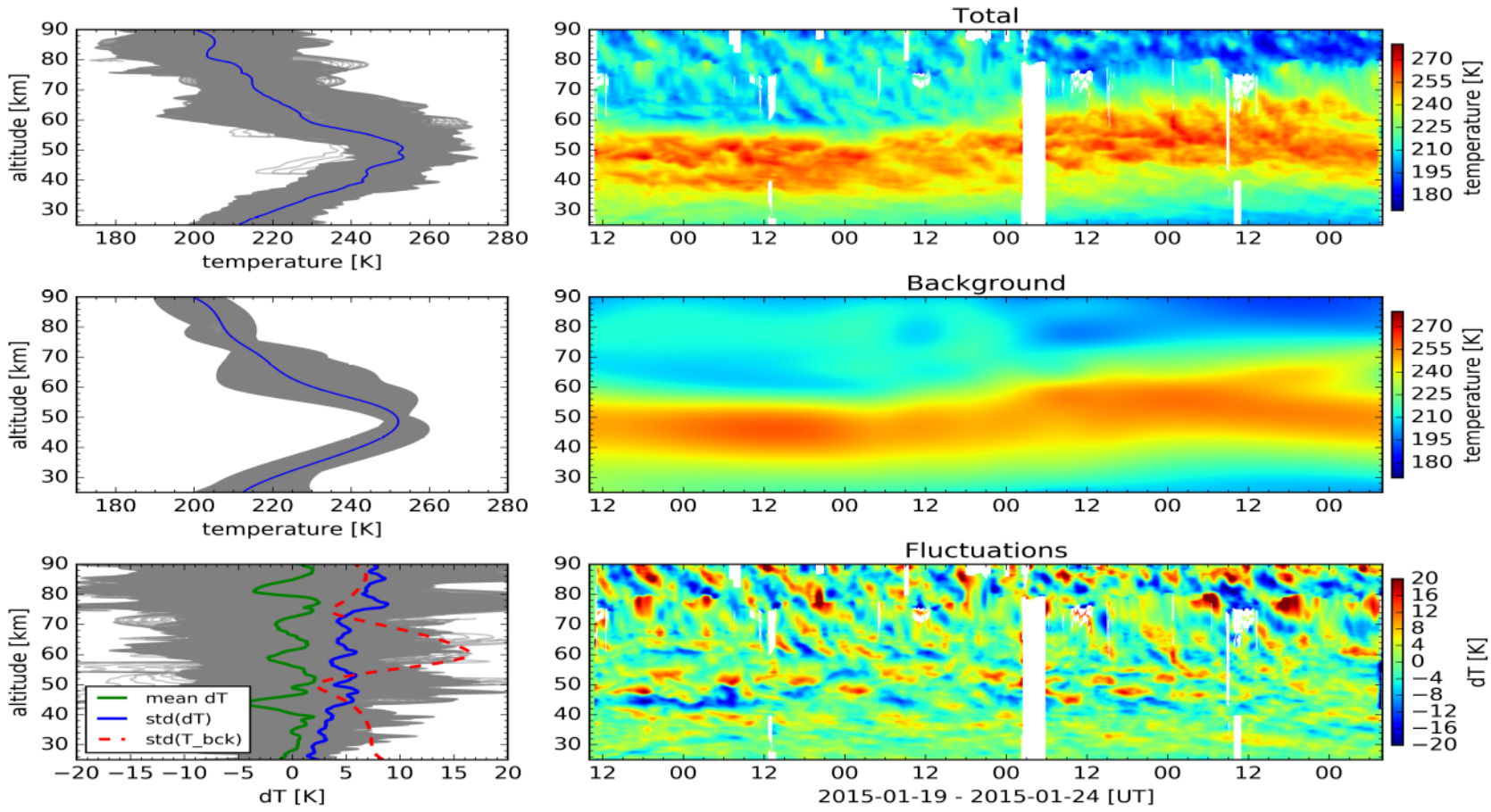
GW might be easier to identify in wind measurements

How to estimate the Background

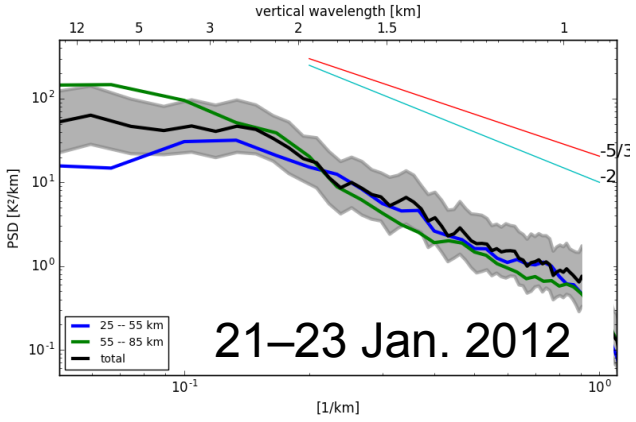


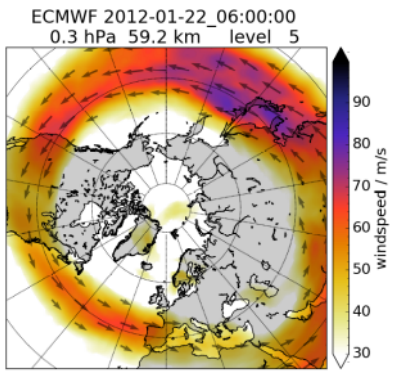


GW and variable background

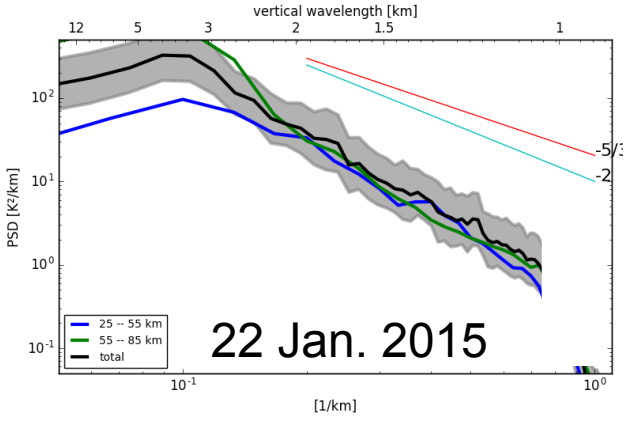


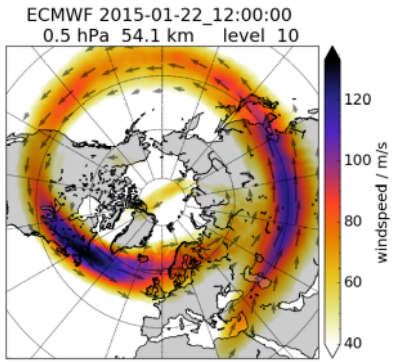
Vertical wavelength spectra / Vortex location



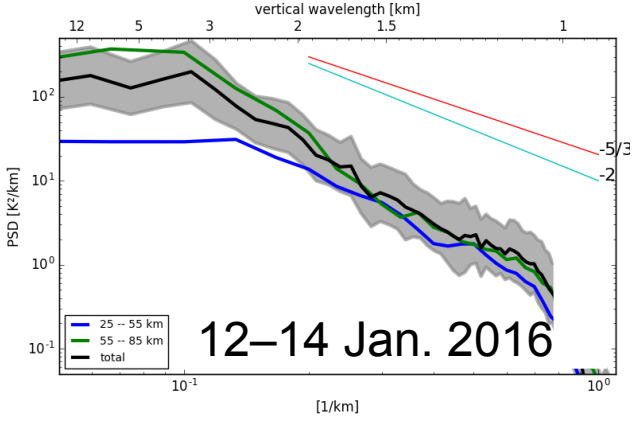


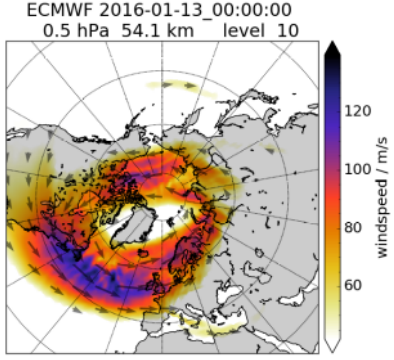
21–23 Jan. 2012



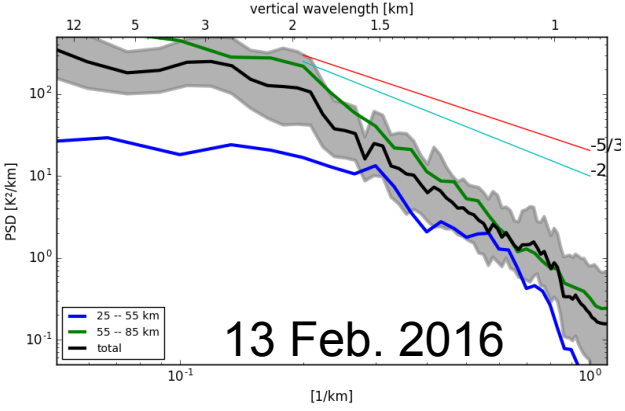


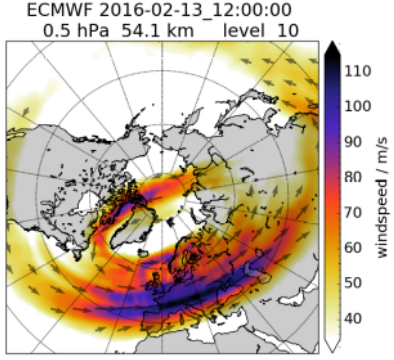
22 Jan. 2015





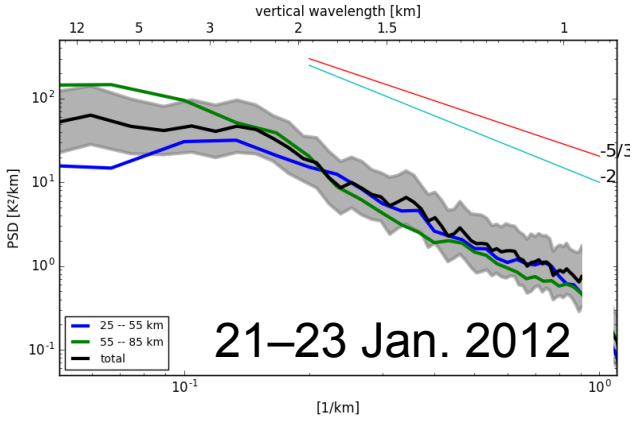
12–14 Jan. 2016

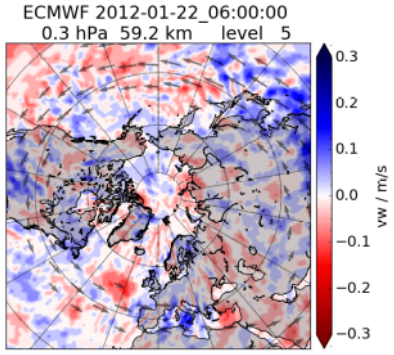


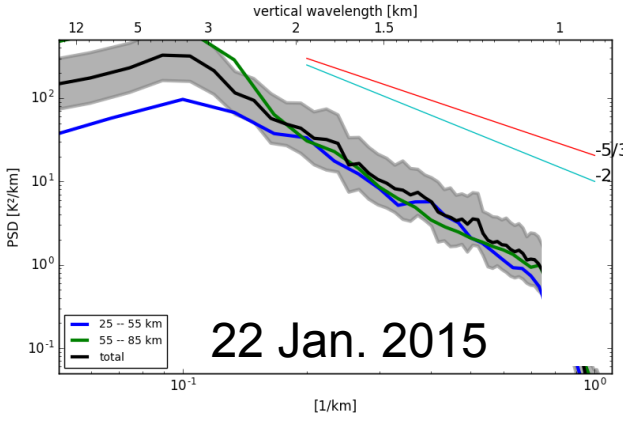


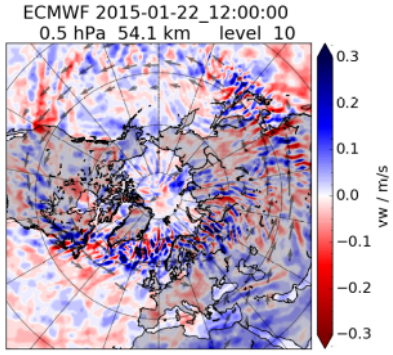
13 Feb. 2016

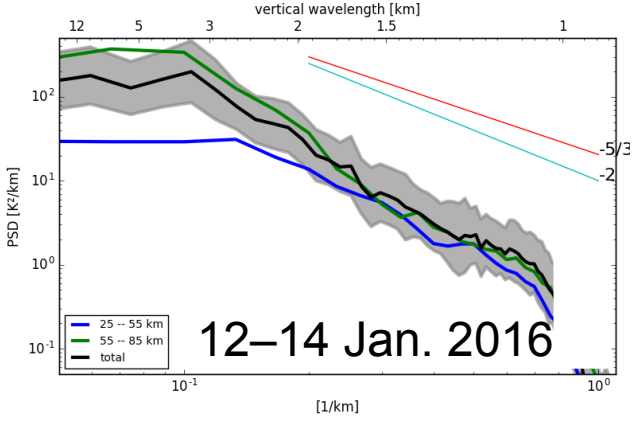
Vertical wavelength spectra / ECMWF vertical wind

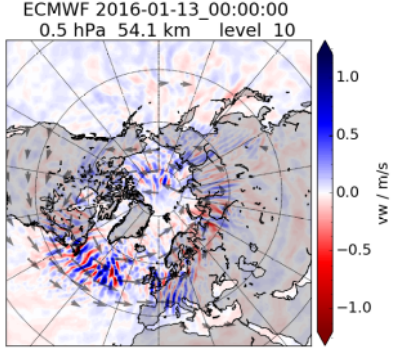


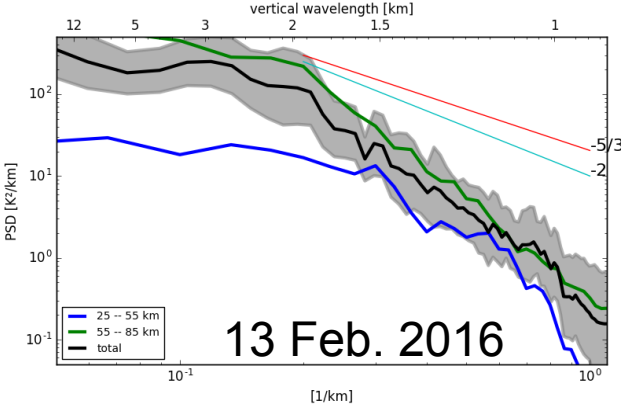


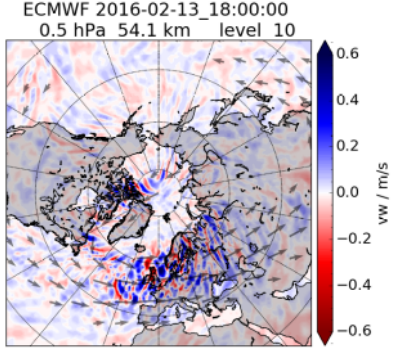








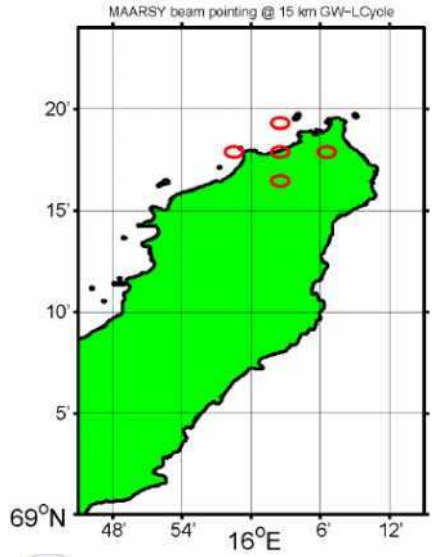


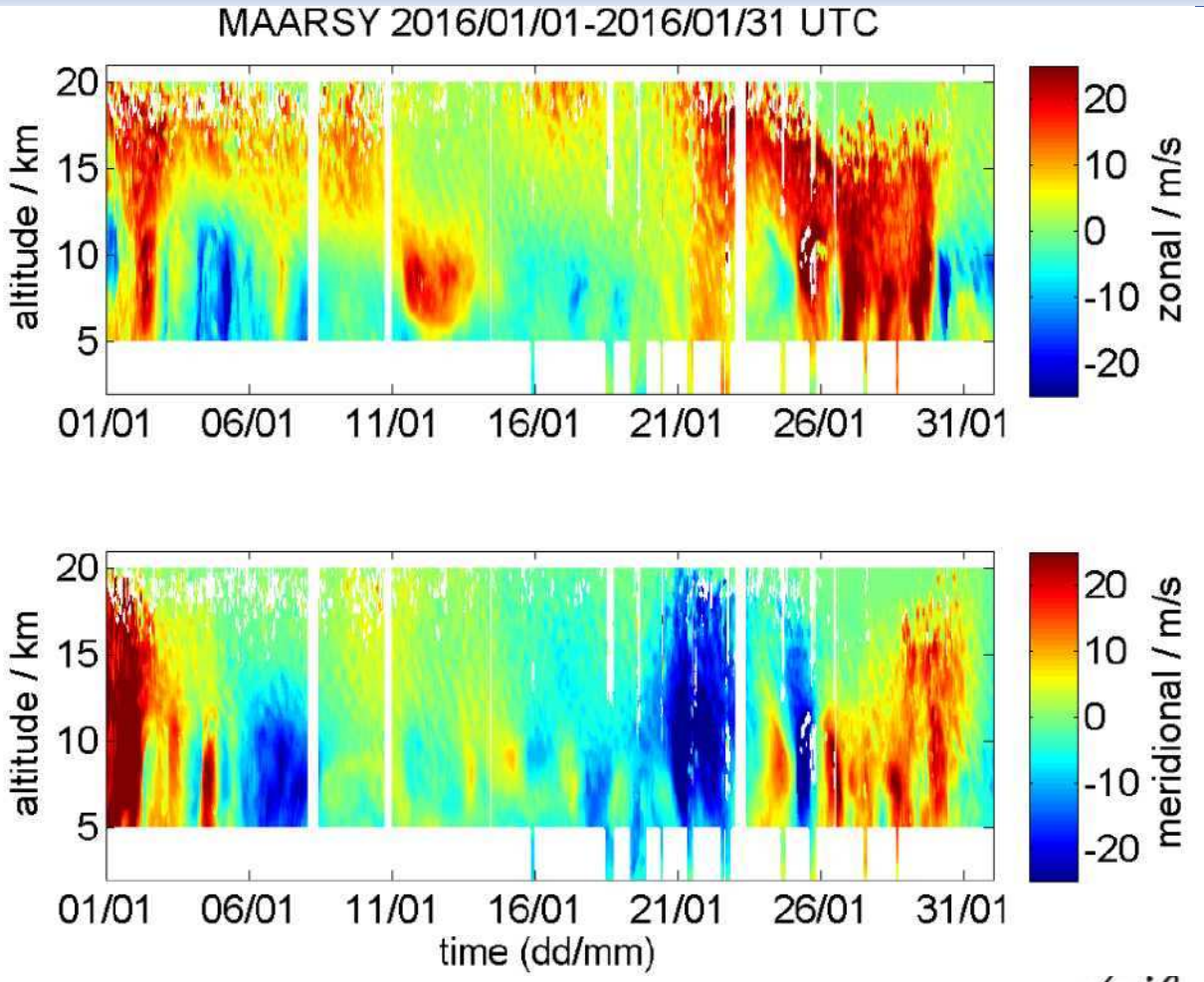


Radar results

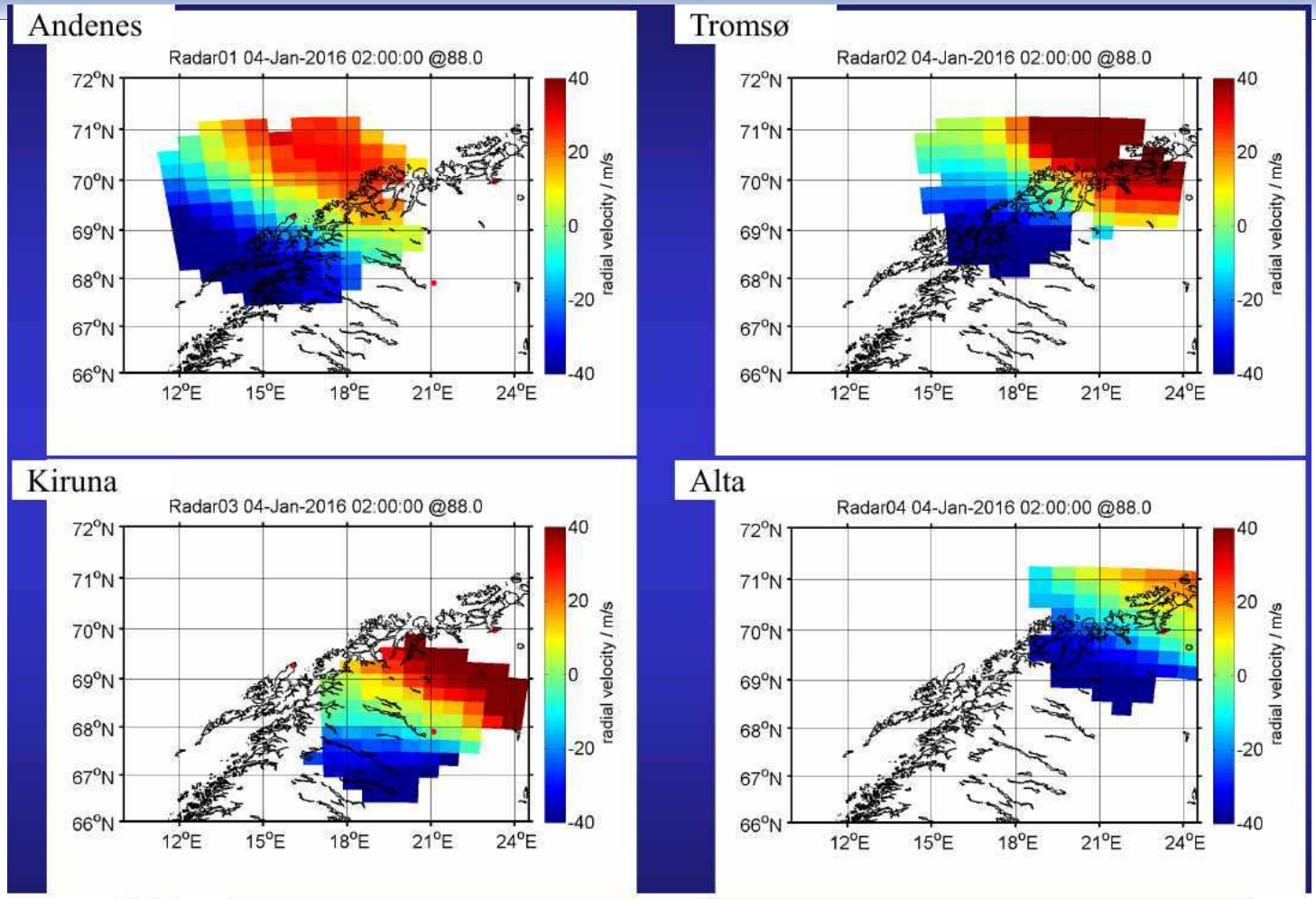
MST radar @ ALOMAR

parameter	tropo009m	tropo010m
range resolution	300 m	75 m
pulse code	coco	mono
altitude coverage	5-18/22 km	2-8 km
sampling time	approx. 1 min 45 sec 2048 points	approx. 1 min 45 sec 2048 points
3D winds time resolution	single profiles / 1 hour	5-10 min average

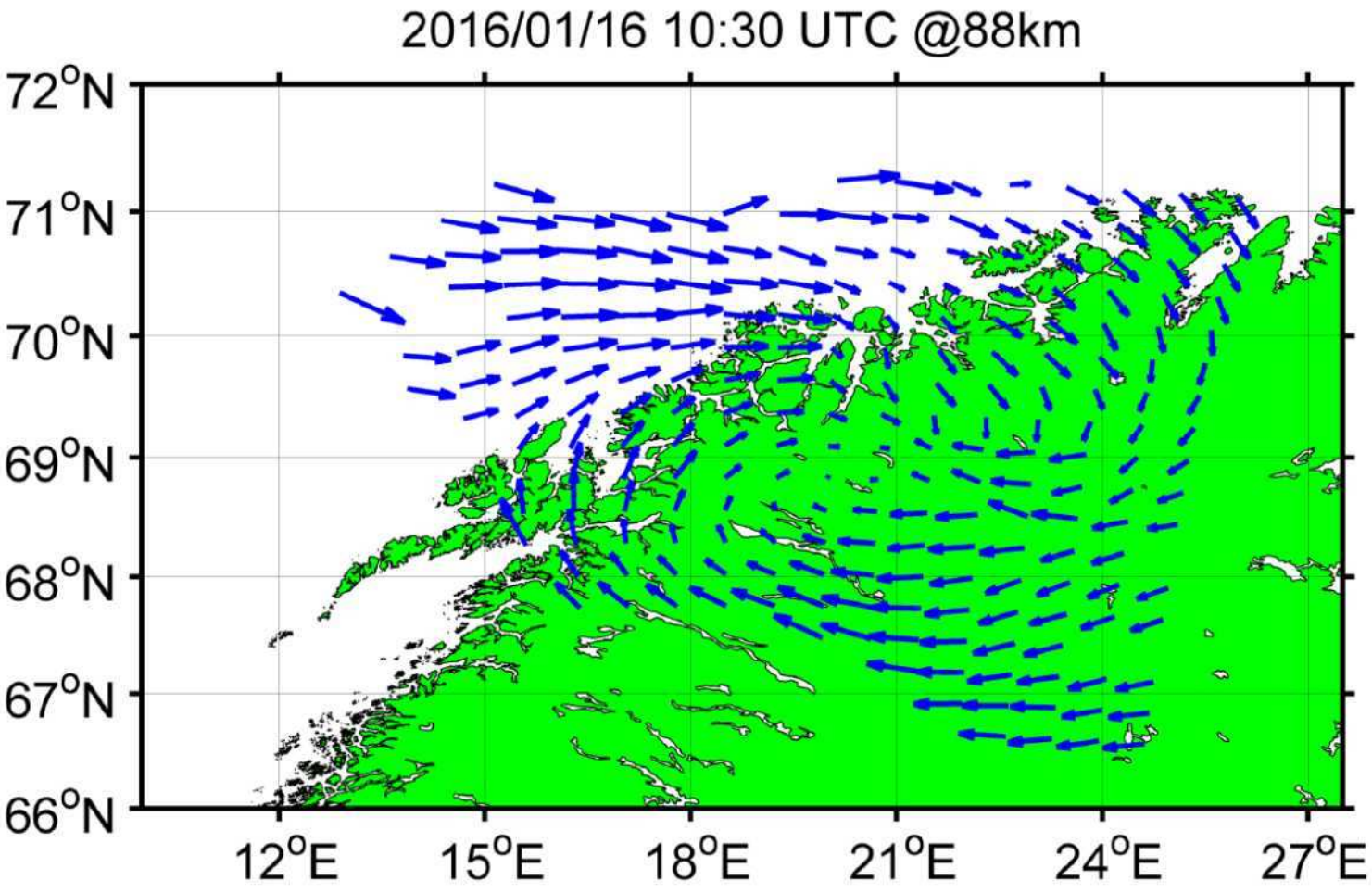


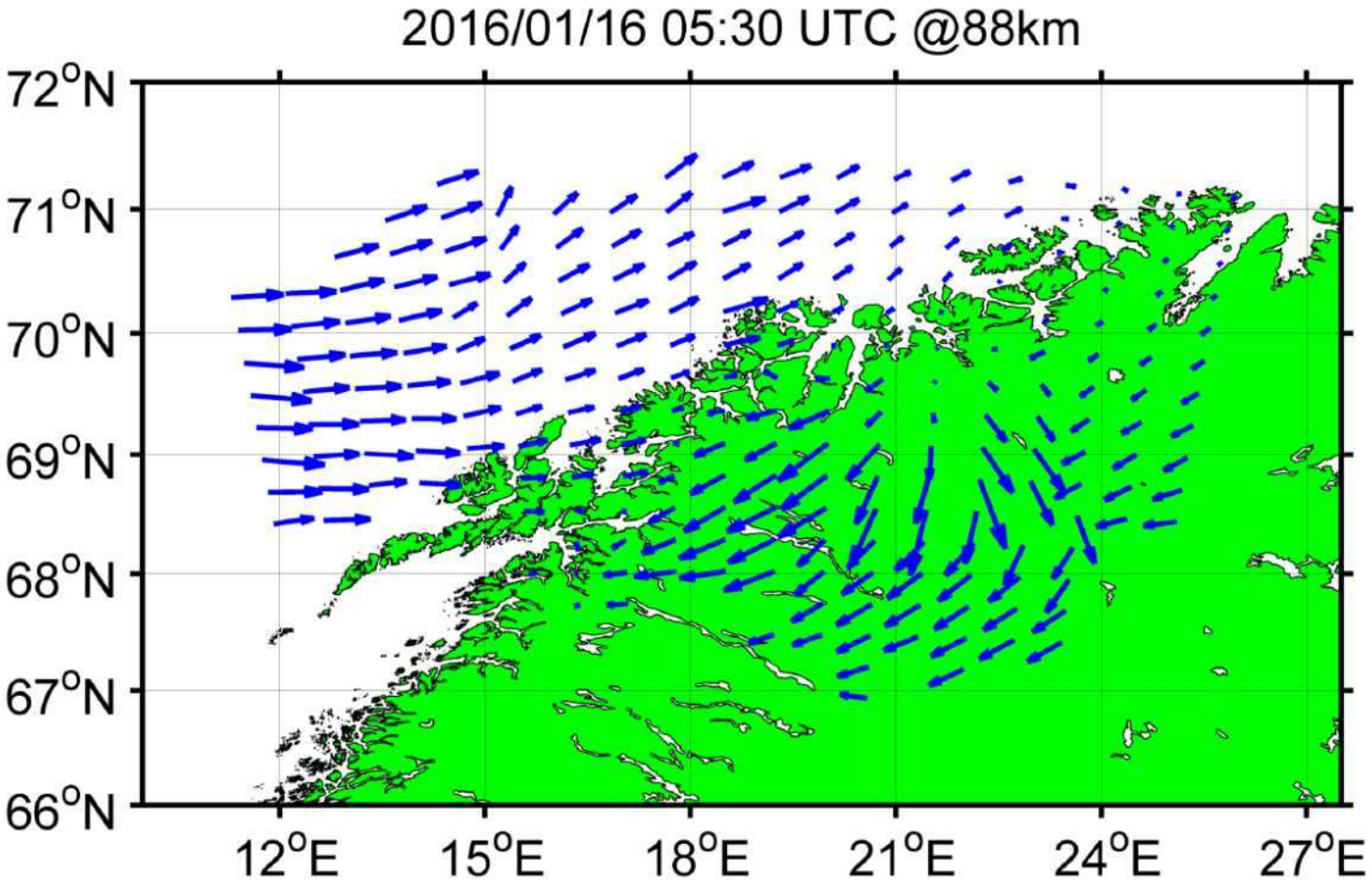


Atmospheric Tomography and multi-static networks

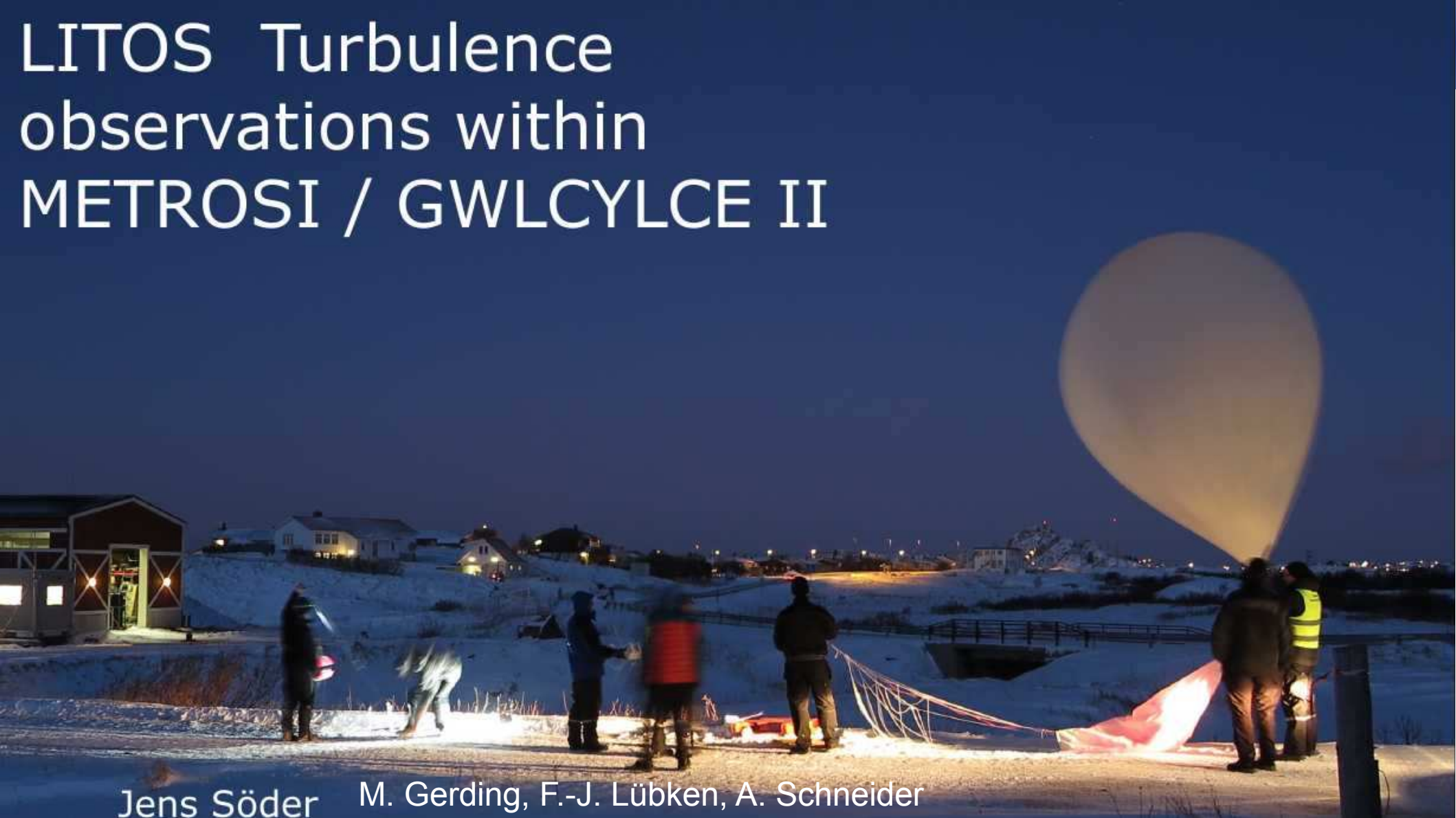


MMaria concept

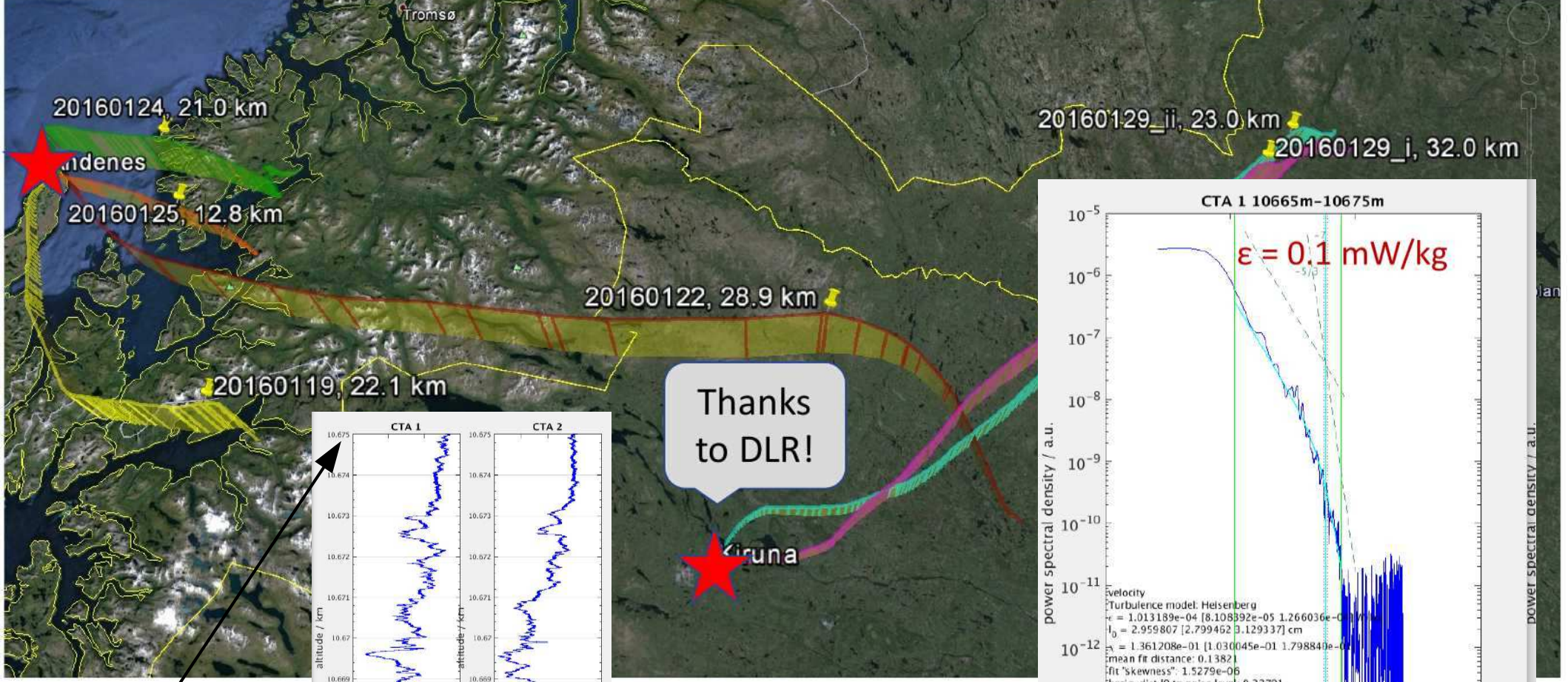



2016/01/16 05:30 UTC @88km
72°N
71°N
70°N
69°N
68°N
67°N
66°N
12°E
15°E
18°E
21°E
24°E
27°E

LITOS Turbulence observations within METROSI / GWLCYLCE II



Jens Söder M. Gerding, F.-J. Lübken, A. Schneider


Tromsø
20160124, 21.0 km
20160125, 12.8 km
20160122, 28.9 km
20160119, 22.1 km
20160129_ii, 23.0 km
20160129_i, 32.0 km
Thanks to DLR!
Kiruna

CTA 1
CTA 2
altitude / km
voltage / V

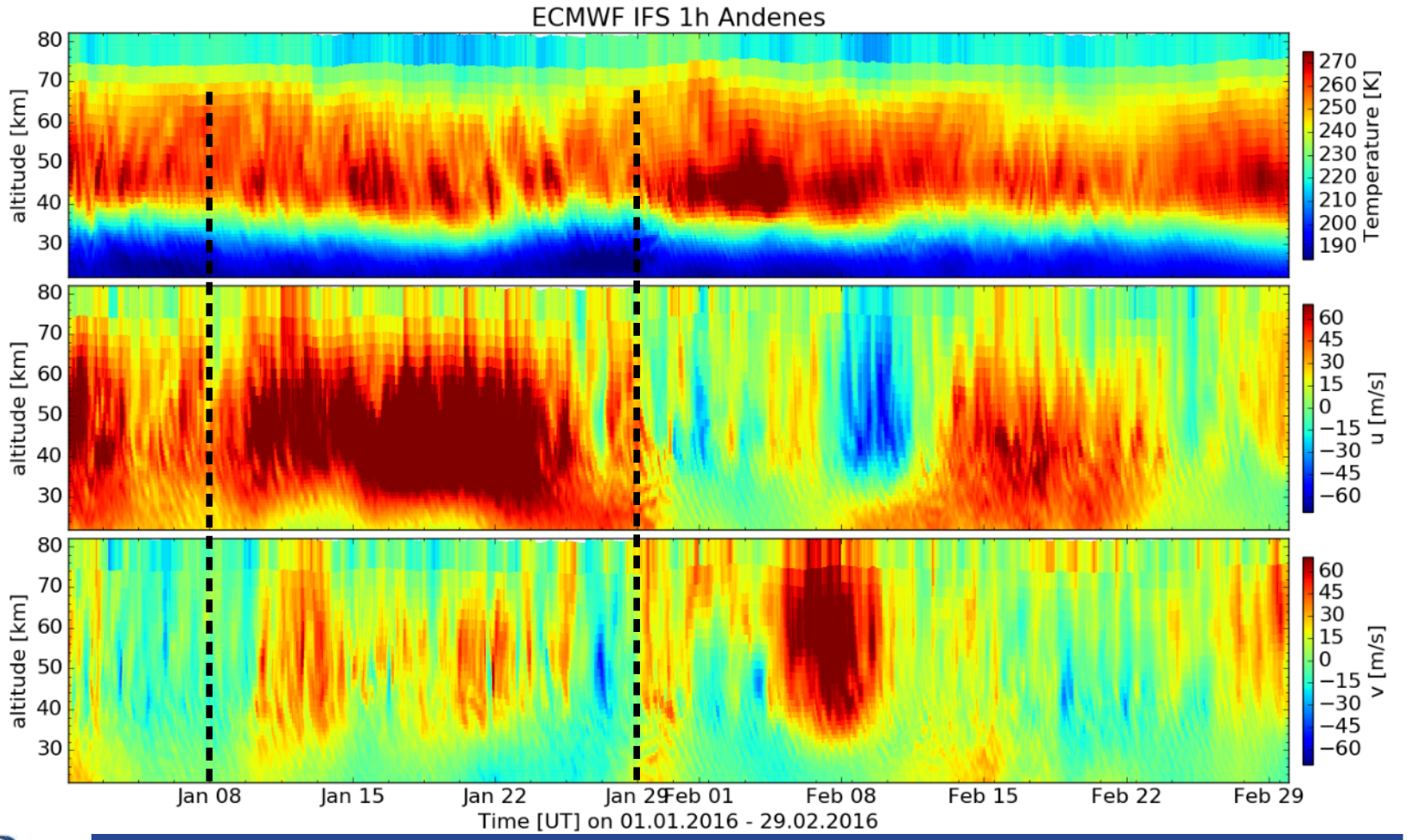
10 m

CTA 1 10665m-10675m
ε = 0.1 mW/kg
power spectral density / a.u.
spatial scales / m
velocity
Turbulence model: Heisenberg

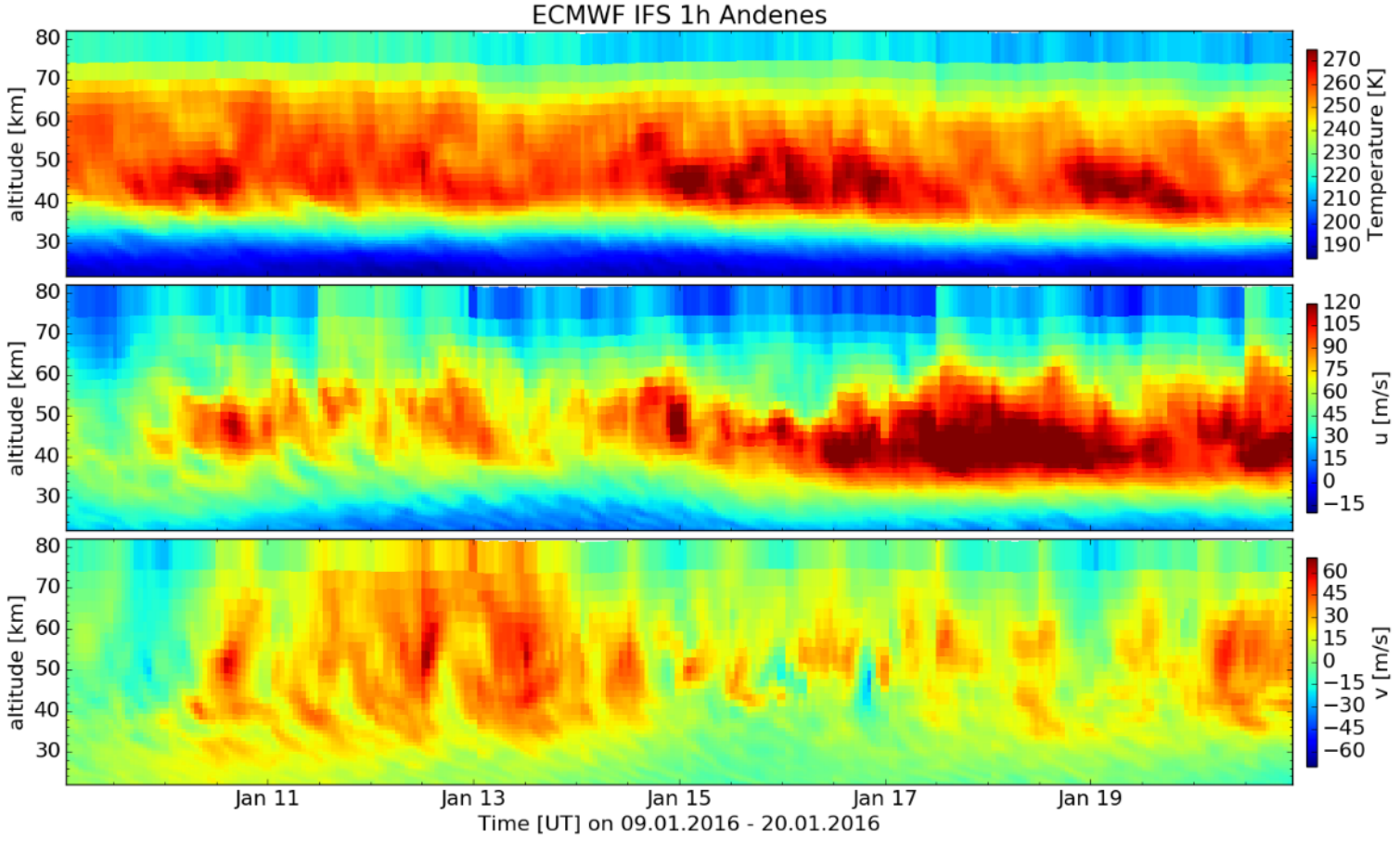
Conclusions

- Data treatment to pull out GW information even on large dataset of single instruments working
- Combined datasets available, but analysis has just begun
- Combination with model data just started

ECMWF High resolution (1h, 7 km x 14 km) – Jan/Feb. 2016 – Andenes



9 – 20 January 2016



9 – 20 January 2015