Application of the dual-beam width method to a narrow beam MF radar for estimation of spectral width

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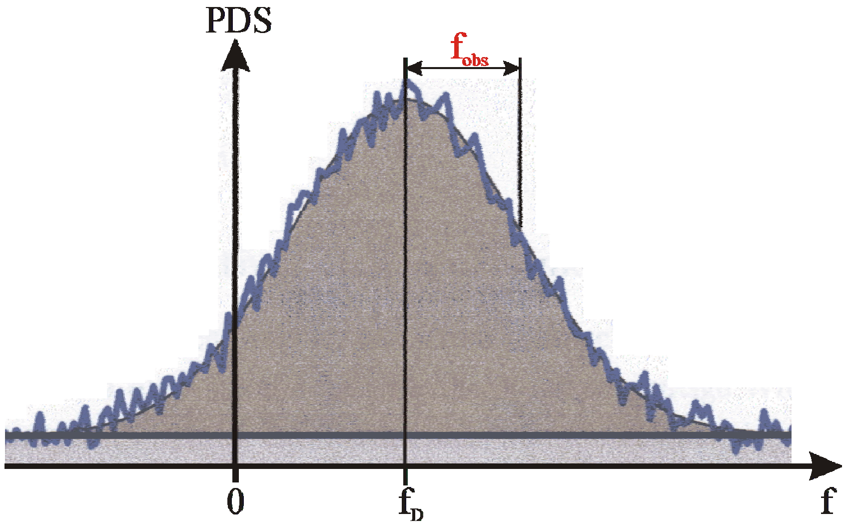
Outline

- Energy dissipation rate from spectral width
- Spectral width and beam broadening effects
- Dual-beamwidth method for estimation of turbulent spectral width
- Experiment configuration of Saura MF radar
- First results
- Outlook

Turbulent kinetic energy dissipation rate



Observed spectral width

$$\sigma_{obs}^2 = \left(\frac{\lambda}{2}\right)^2 f_{obs}^2$$

$$\sigma_{obs}^2 = \sigma_{turb}^2 + \sigma_{beam+shear}^2 + \sigma_{wave}^2$$

Mean turbulent velocity

$$v_{RMS}^2 = \frac{\sigma_{turb}^2}{2 \cdot \ln(2)}$$

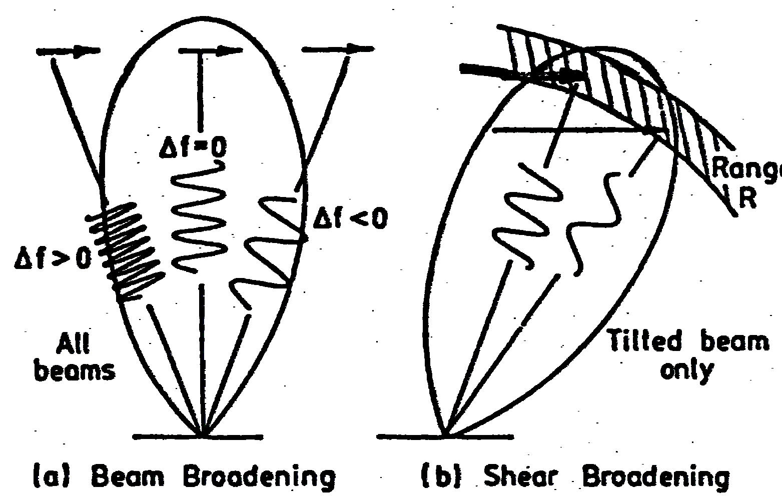
Turbulent kinetic energy dissipation rate $\qquad \varepsilon_{turb} \approx c \cdot v_{RMS}^2 \cdot \omega_B \qquad (c \approx 0.4)$

- Observations without Fresnel scatter/reflection
- Determination of σ^2_{turb} from the observed spectral width

Spectral width and beam broadening effects

$$\sigma_{obs}^2 = \sigma_{turb}^2 + \sigma_{beam+shear}^2 + \sigma_{wave}^2$$

$$\sigma_{obs}^2 = \sigma_{turb}^2 + \sigma_{corr}^2$$



Hocking, *JATP*, 1983

Correction for beam broadening

<u>vertical beam</u>

$$\sigma_{corr}^2 = \frac{\theta^2}{3}\left(U^2 + V^2\right)$$

<u>off-vertical beams</u>

$$\sigma_{corr}^2 = \frac{\theta^2}{3}\left[\left(\cos^2\alpha U^2 + V^2\right) - 2\cos\alpha\sin^2\alpha U\left(u_z R\right) + \sin^4\alpha\left(u_z R\right)^2\right]$$

R - Range

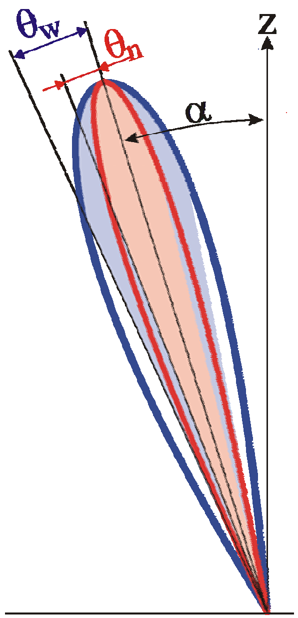
U, V - Horizontal wind components

$u_z \equiv dU/dz$

- Problems, if U and V or u_z are large !

The dual-beamwitdh method

- The dominant terms in $\sigma^2_{beam+shear}$ are proportional to θ^2
- σ^2_{corr} is also approximately proportional to θ^2
- σ^2_{obs} is measured simultaneously in nested volumes with a narrow beamwidth θ_n and a wide beamwidth θ_w that for both beamwidths the same fraction of the pulse volume is filled with turbulence

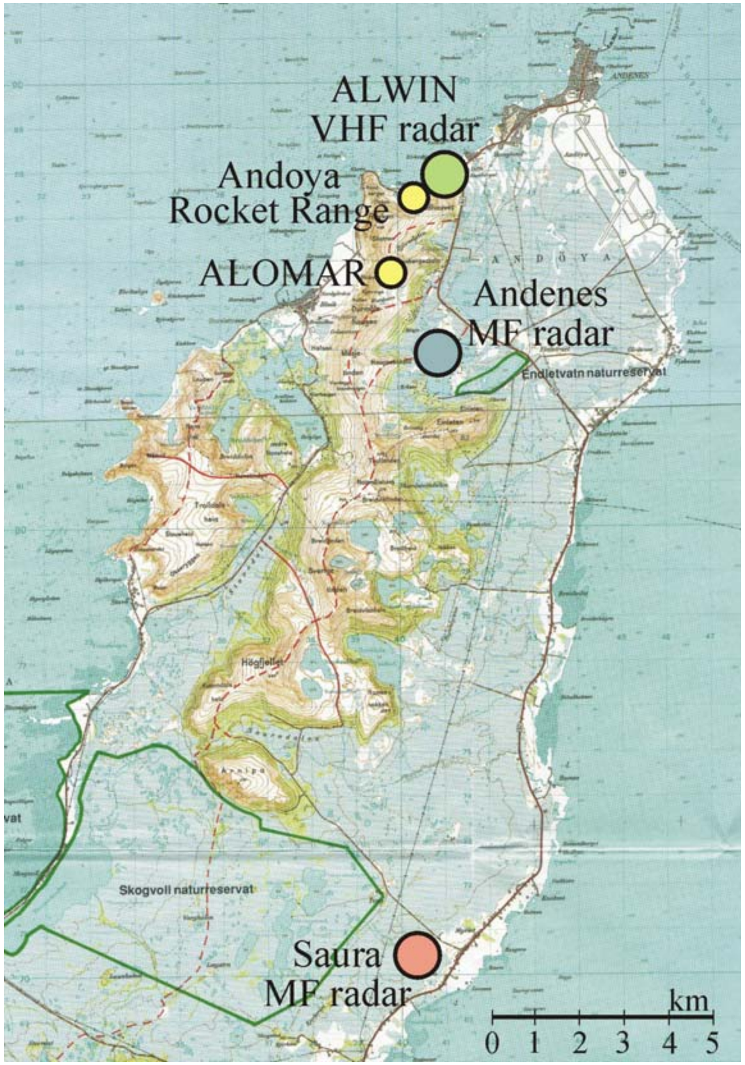


$$\sigma^2_{turb} = \frac{\theta_w^2 \cdot \sigma^2_{obs,n} - \theta_n^2 \cdot \sigma^2_{obs,w}}{\theta_w^2 - \theta_n^2}$$

$$\sigma^2_{corr,n} = \theta_n^2 \left[\frac{\sigma^2_{obs,w} - \sigma^2_{obs,n}}{\theta_w^2 - \theta_n^2} \right] \qquad \sigma^2_{corr,w} = \left(\frac{\theta_w^2}{\theta_n^2} \right) \cdot \sigma^2_{corr,n}$$

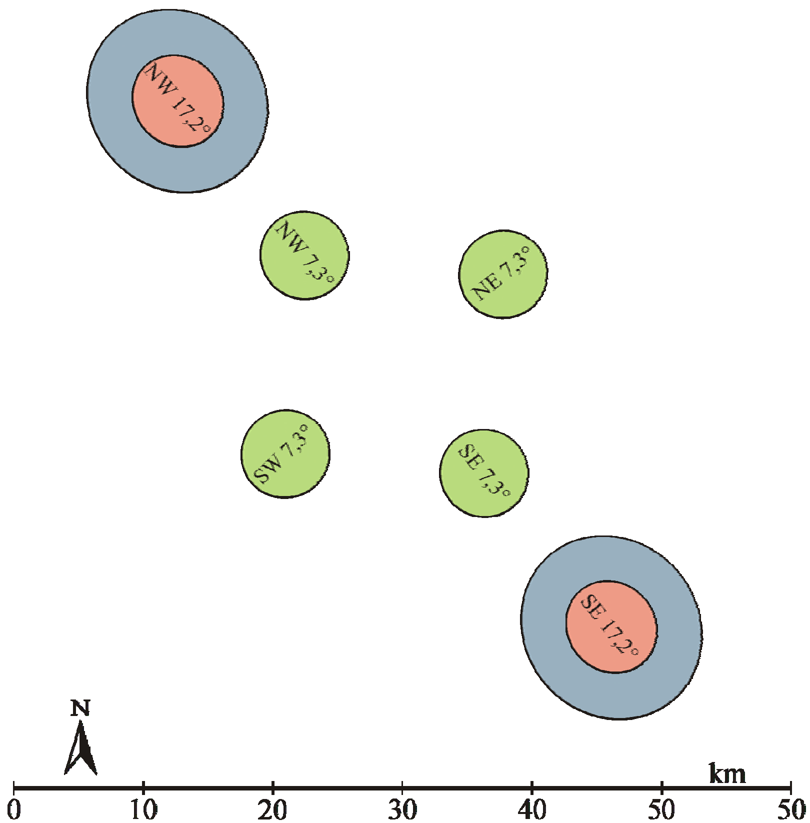
VanZandt,T.E., G.D.Nastrom, J. Furumoto, T. Tsuda, and W.L. Clark, A dual-beamwidth radar method for measuring atmospheric turbulent kinetic energy, *Geophys. Res. Lett.*, Vol. 29, No. 12, 13-1 - 13-3, 2002

Saura MF radar



Radar frequency	3.17 MHz
Peak power	116 kW
Mean power (0.2% dc)	230 W
Pulse form	Gauss
Pulse width	> 7 μs
Range resolution	1000m
Antenna	29 crossed dipoles
Half power beam width	6.4°
Beam directions	Vertical, 8 off-zenith

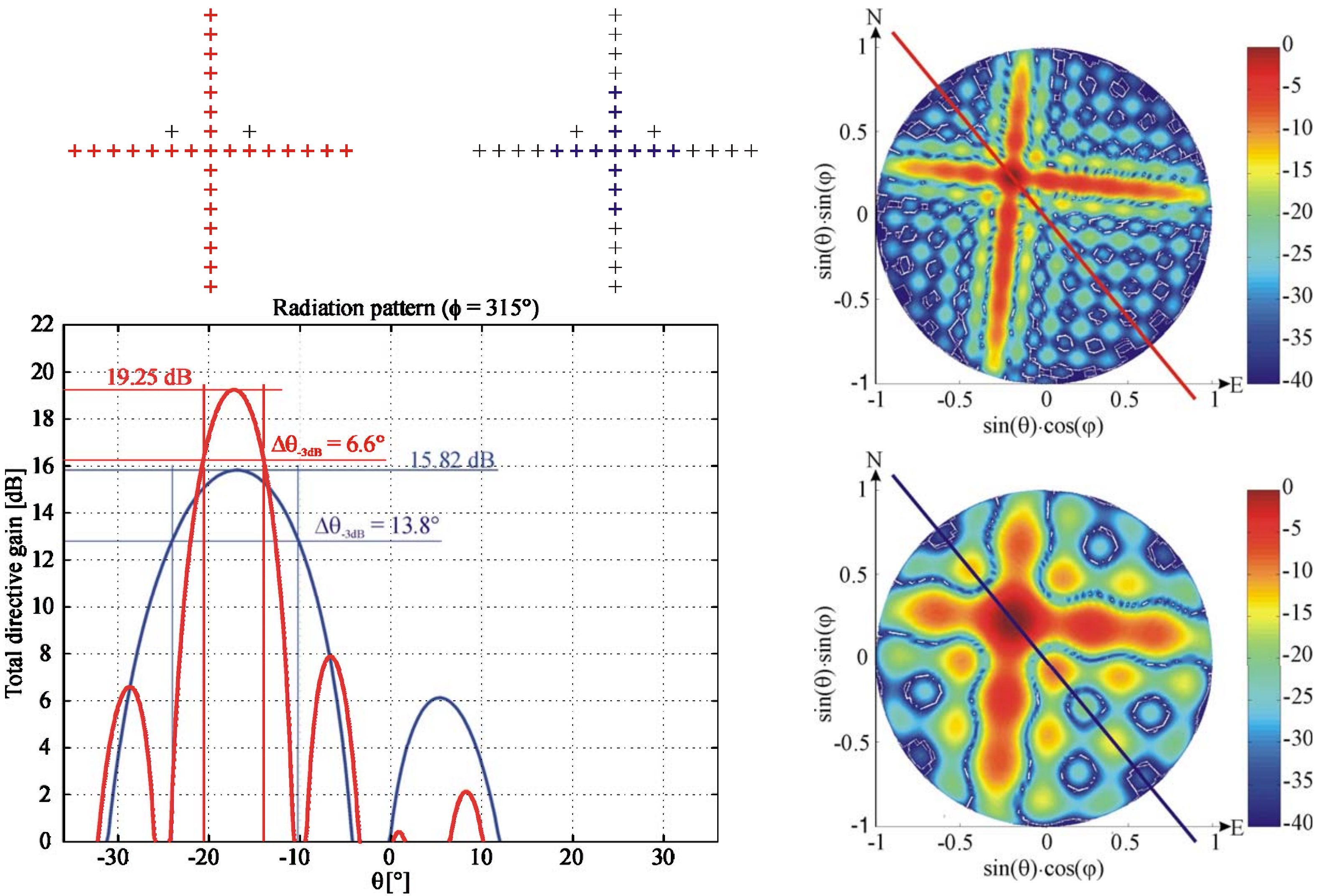
Experiment configuration



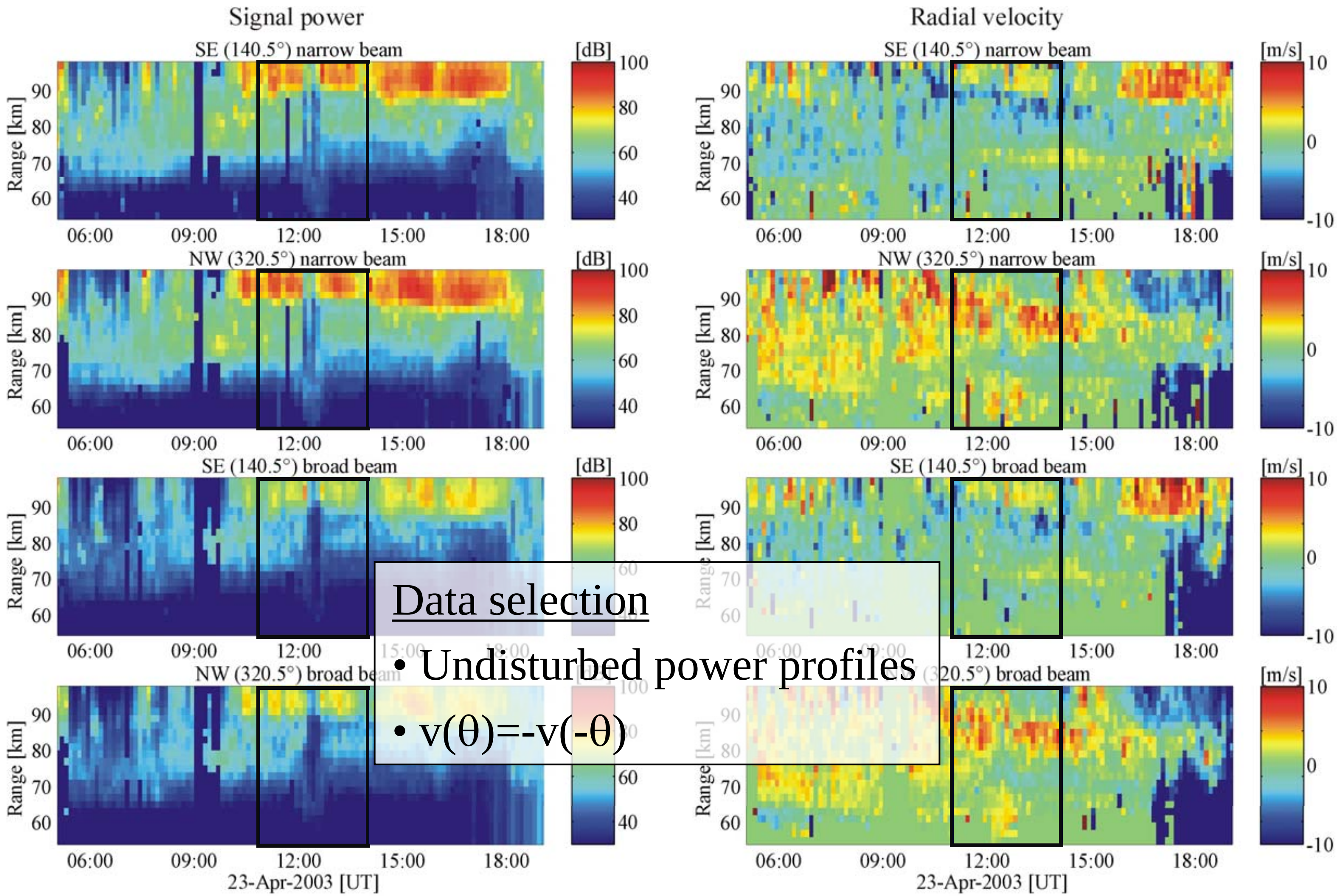
Illuminated areas in 85km

	Broad beam	**Narrow beam**	**DBS wind**
$\Delta\theta_{3db}$ (HPFW)	13.8°	6.6°	6.6°
PRF [Hz]	150	150	150
Coherent integrations	16	16	8
Data points	512	512	800
Range [km]	50 – 98	50 – 98	50 – 98
Sampling res. [m]	2000	2000	2000
Pulse width [μs]	13.3	13.3	13.3
Beam directions [°]	NW/17.2 SE/17.2	NW/17.2 SE/17.2	NW/7.3 NE/7.3 SE/7.3 SW/7.3
Δt [ms]	213.33	213.33	213.33
Exp. run time [s]	109.23	109.23	170.67

Forming of narrow and broad beams for 17.2° ZA



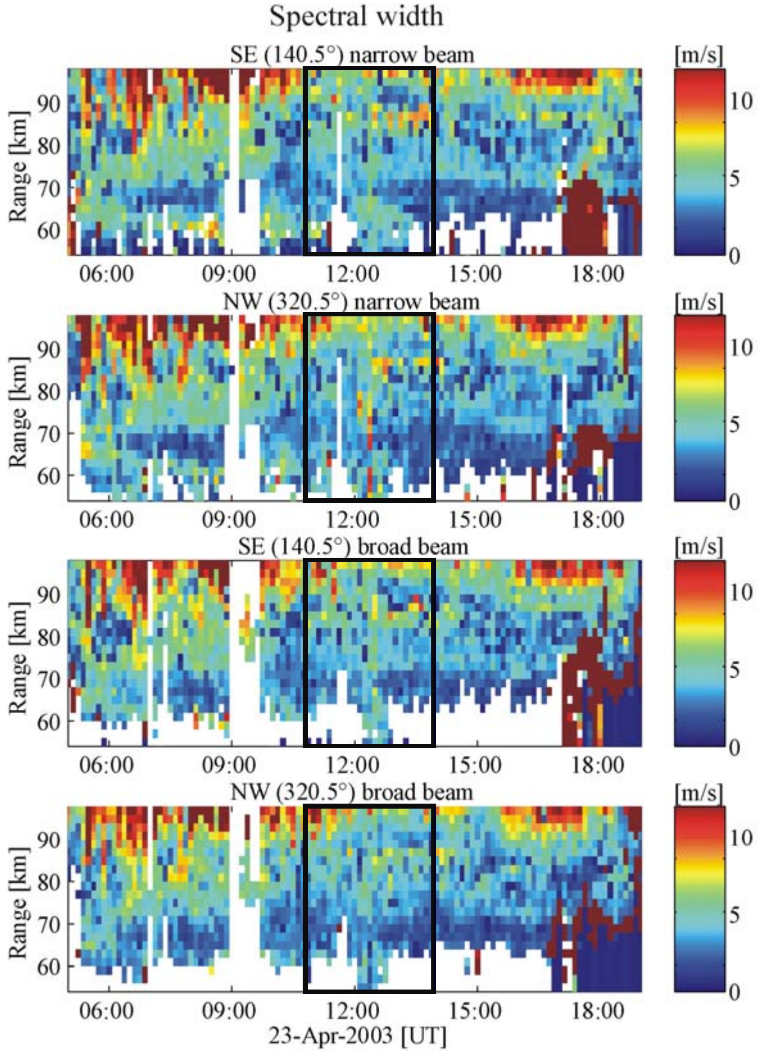
Signal power and radial velocity

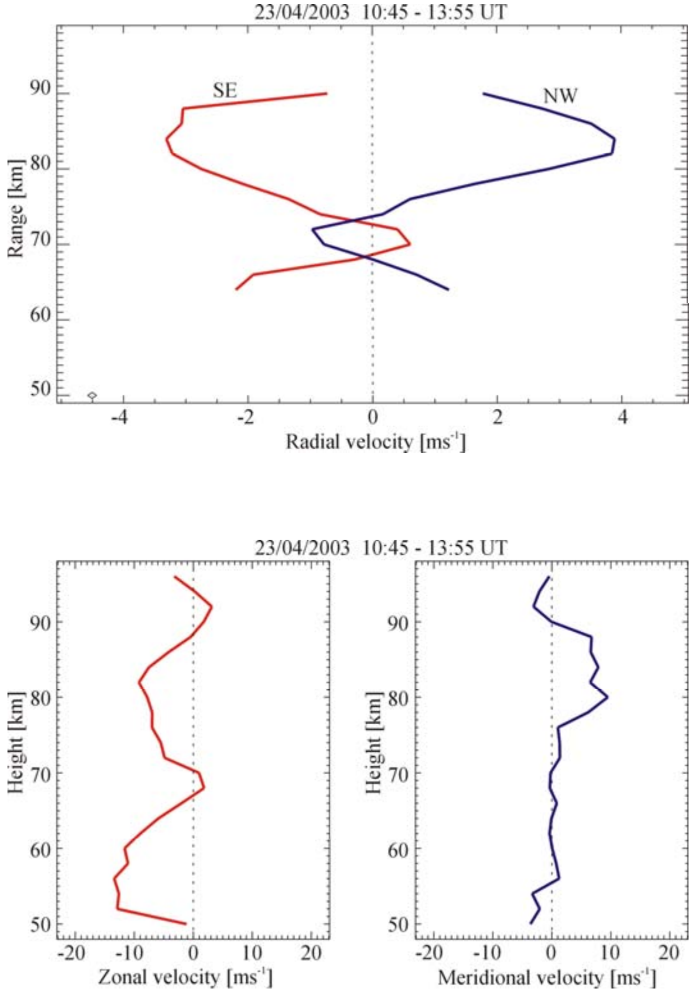


Data selection

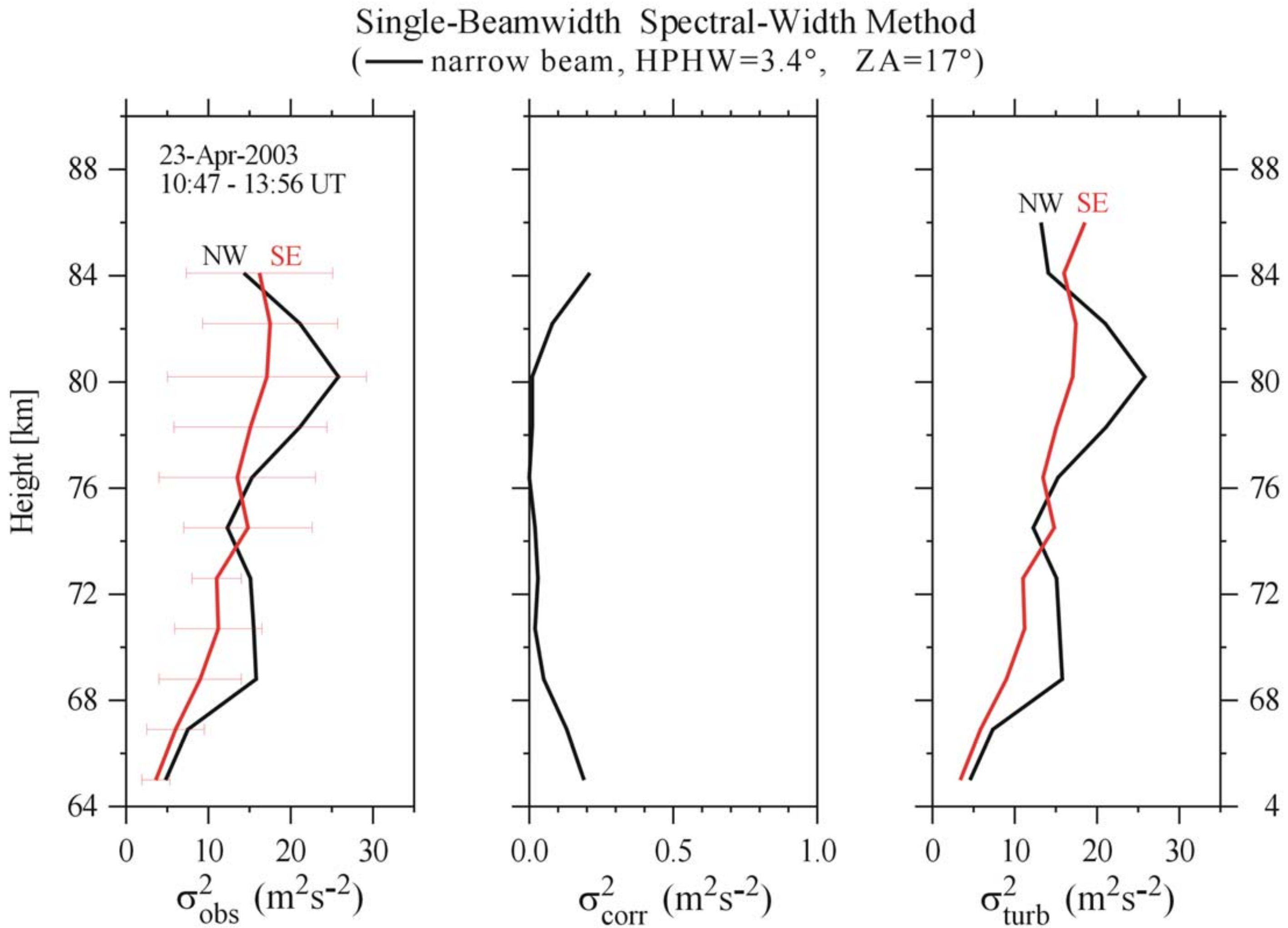
- Undisturbed power profiles
- v(θ)=-v(-θ)

Observed spectral widths

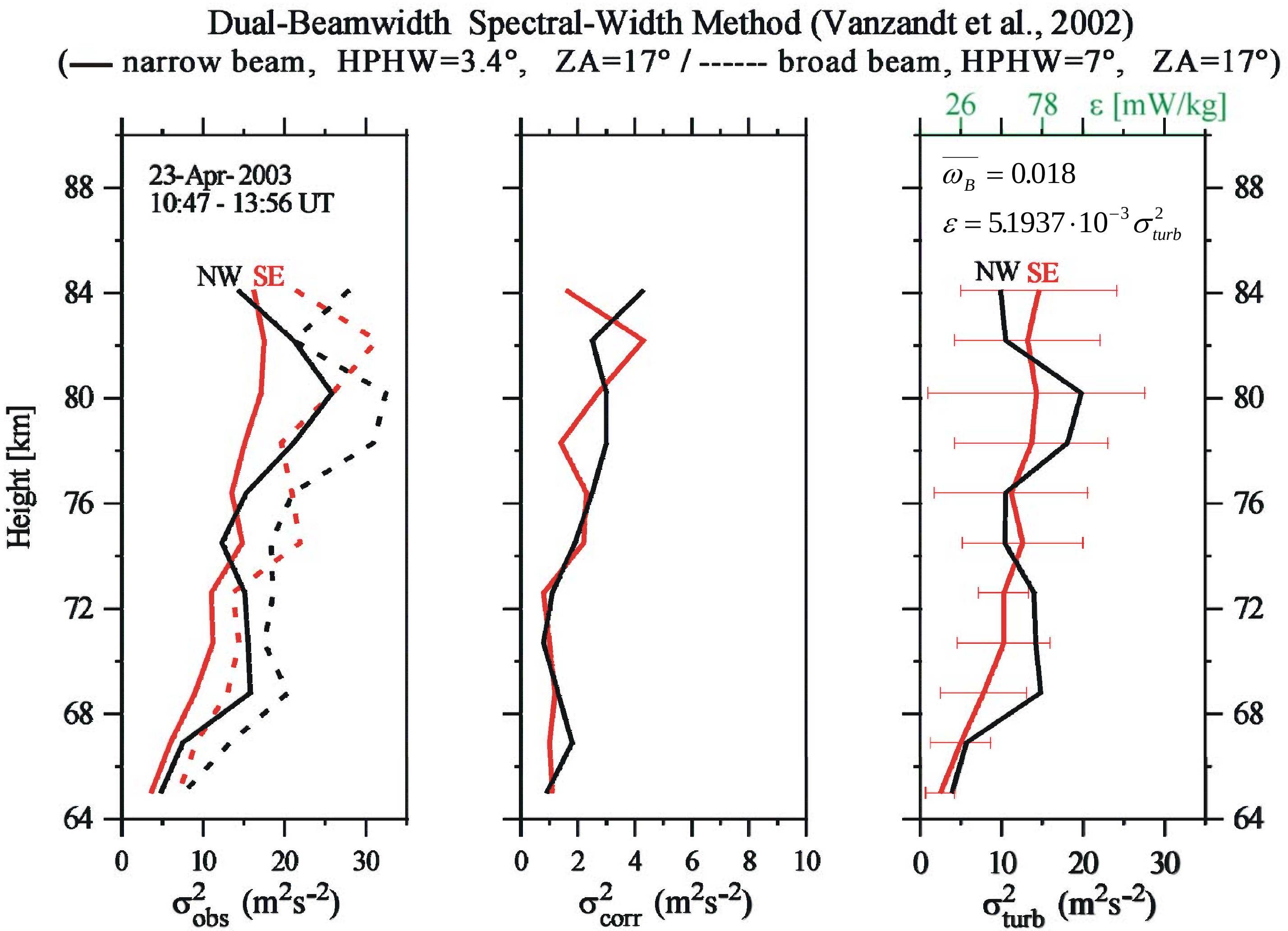




Results obtained from 1BW method



Results obtained from 2BW method



Summary

- New Saura MF radar allows flexible beam steering and beam forming
- Successful test of dual-beamwidth (2BW) method for estimation of turbulent spectral width
- Turbulent spectral widths detected with 2BW and traditional 1BW method are comparable at low wind speeds
- Preliminary energy dissipation rates are in the order of 20 to 60 mW/kg in April

Outlook

- Further test of dual-beamwidth method for high wind speeds during summer mesopause jet
- Common volume observations at mesospheric altitudes with the nearby located ALWIN VHF radar

➢ Comparison of conventional single beamwidth methods and dual beamwidth method (including other new techniques)

Outlook

Method	**Saura MF radar 3.18 MHz**		**ALWIN 53.5 MHz**	
	Beam	*ZA* $(\Delta\theta_{3dB})$	*Beam*	*ZA* $(\Delta\theta_{3dB})$
Dual beam width	Oblique	17.2°		
Dual azimuth	Oblique	17.2° (6,6° 13.8°) 7.2° (6.6°)	Oblique	7° (6°) 14° (6°)
Traditional	Vertical Oblique	 17.2° (6.6°) 7.2° (6.6°)	Vertical Oblique	 7° (6°) 14° (6°)
Full deconvolution	October 2003			