Wind Speed Inversion from HF Radar Backscatter Signal

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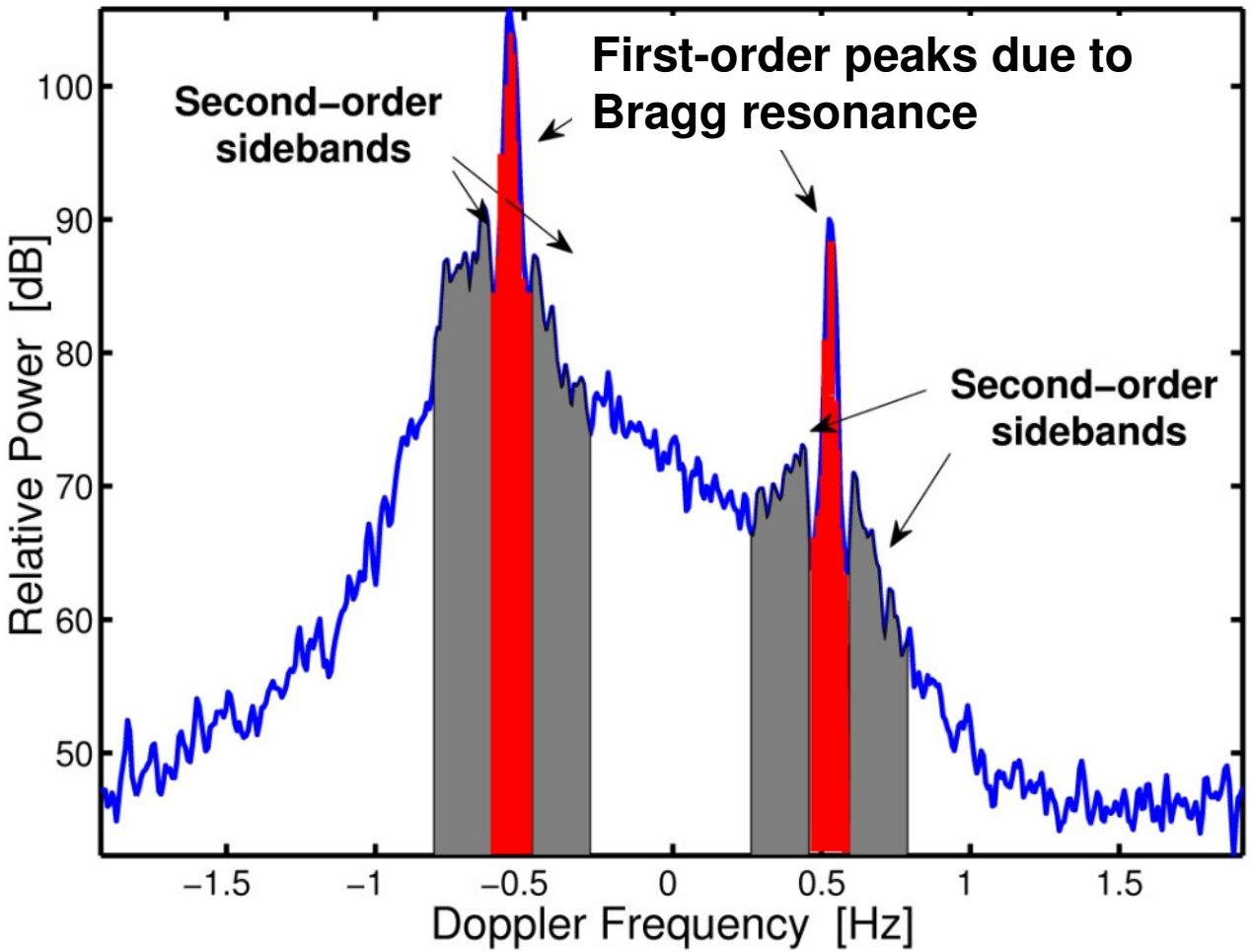
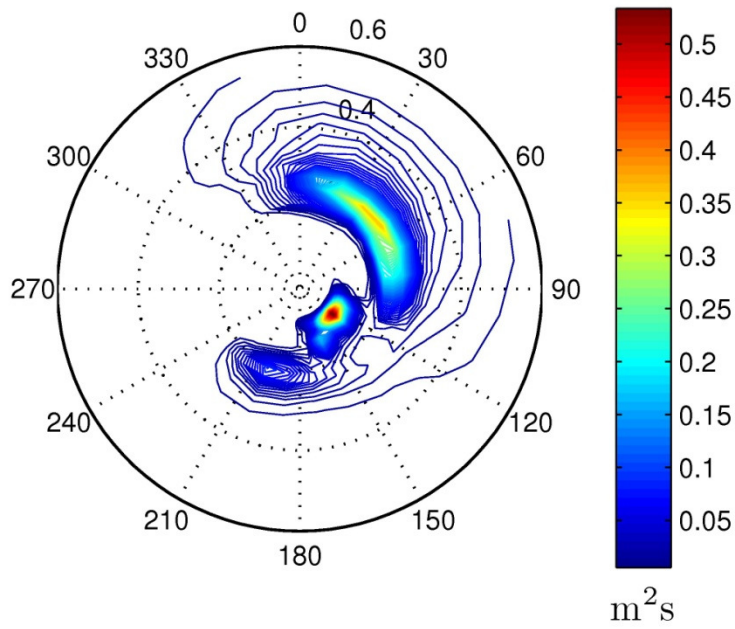
Features in HF radar backscatter Doppler spectra



HIPOCAS WAM data:

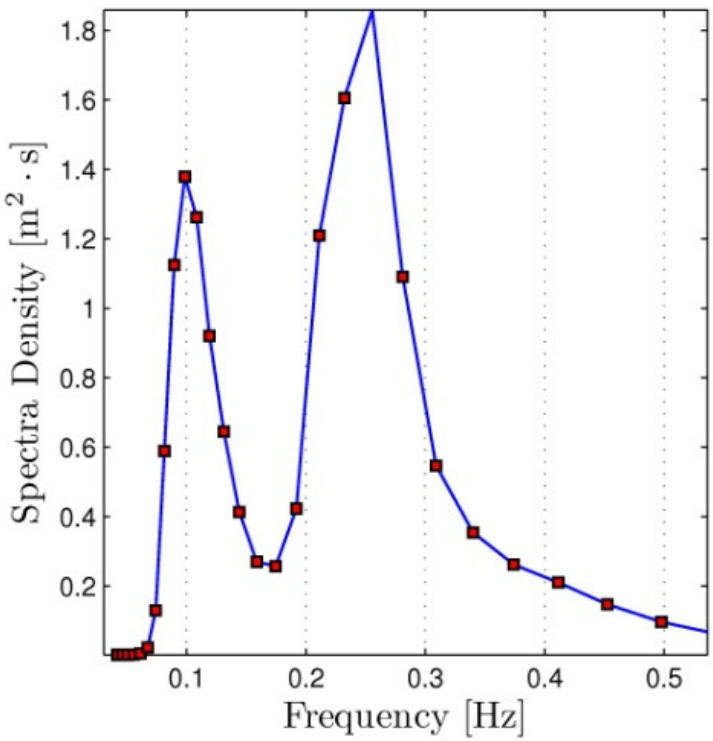
One year of 3-hourly wave directional spectra for the North Sea [2004]

Ocean wave directional spectrum

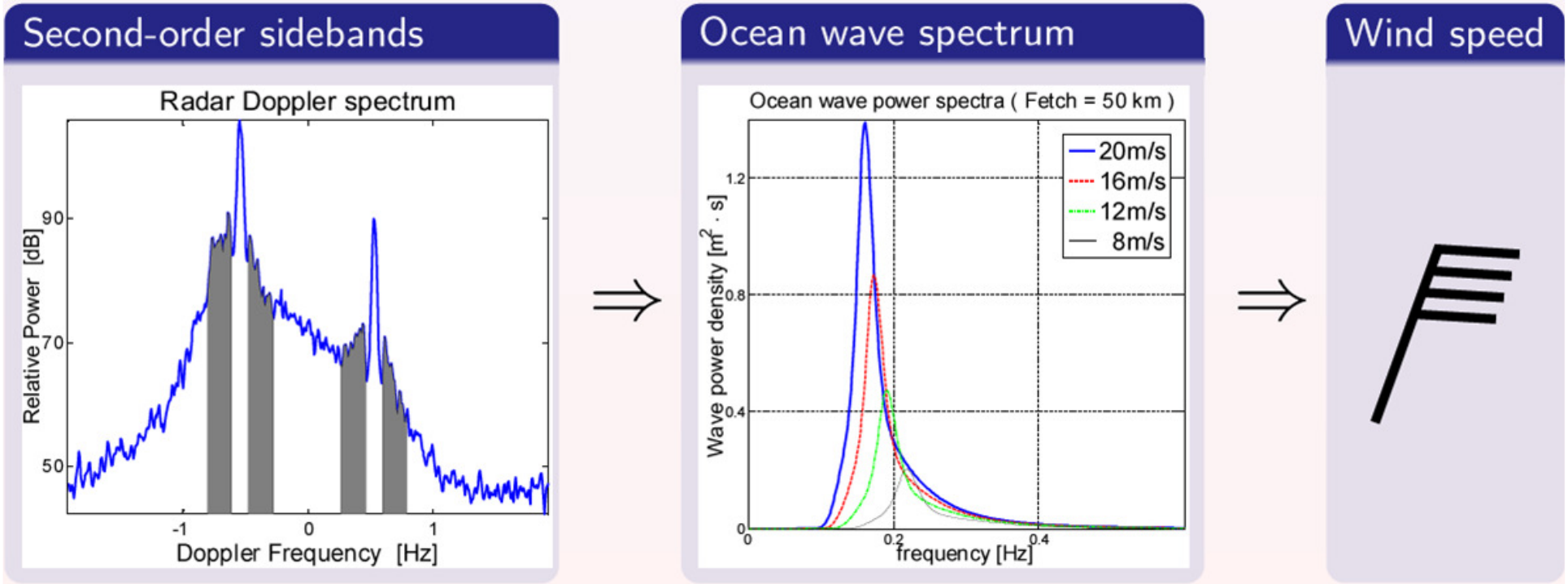


(provided by Heinz Günther, HZG)

Integrated ocean wave spectrum



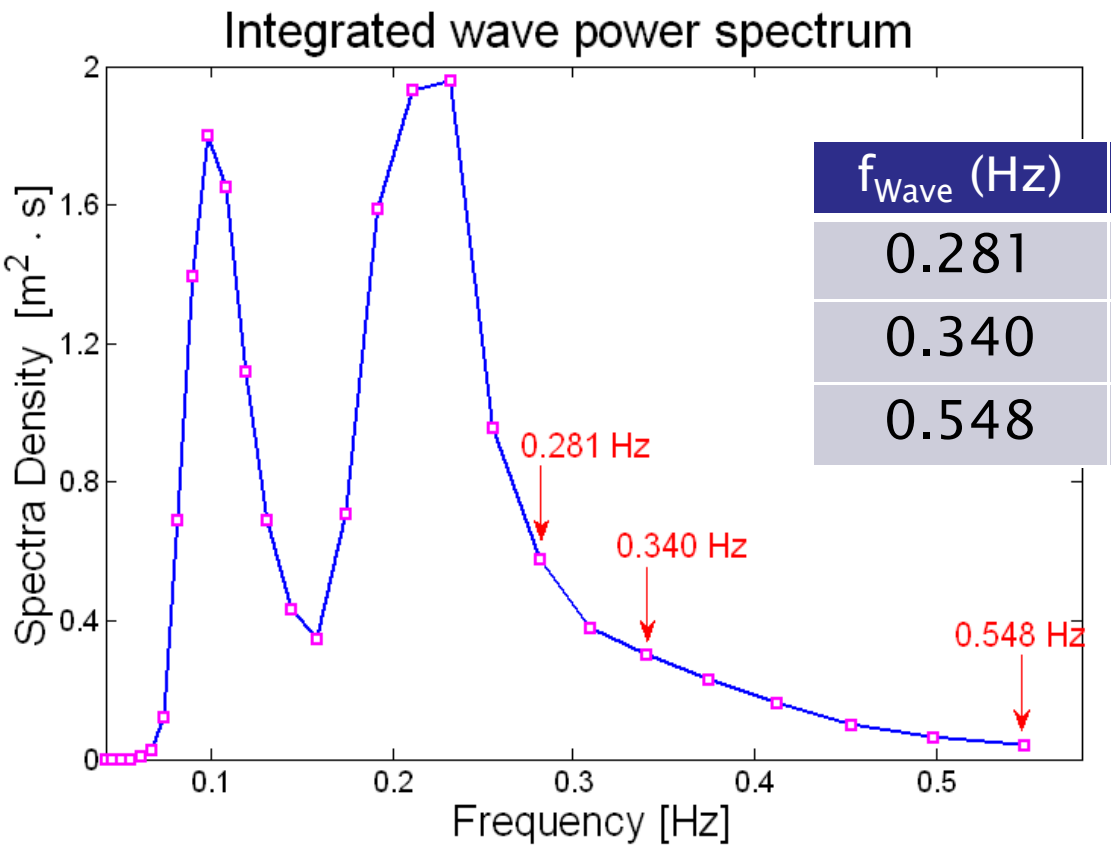
Wind speed from 2nd-order sidebands



Inversion technique **Dexter et al. 1982**

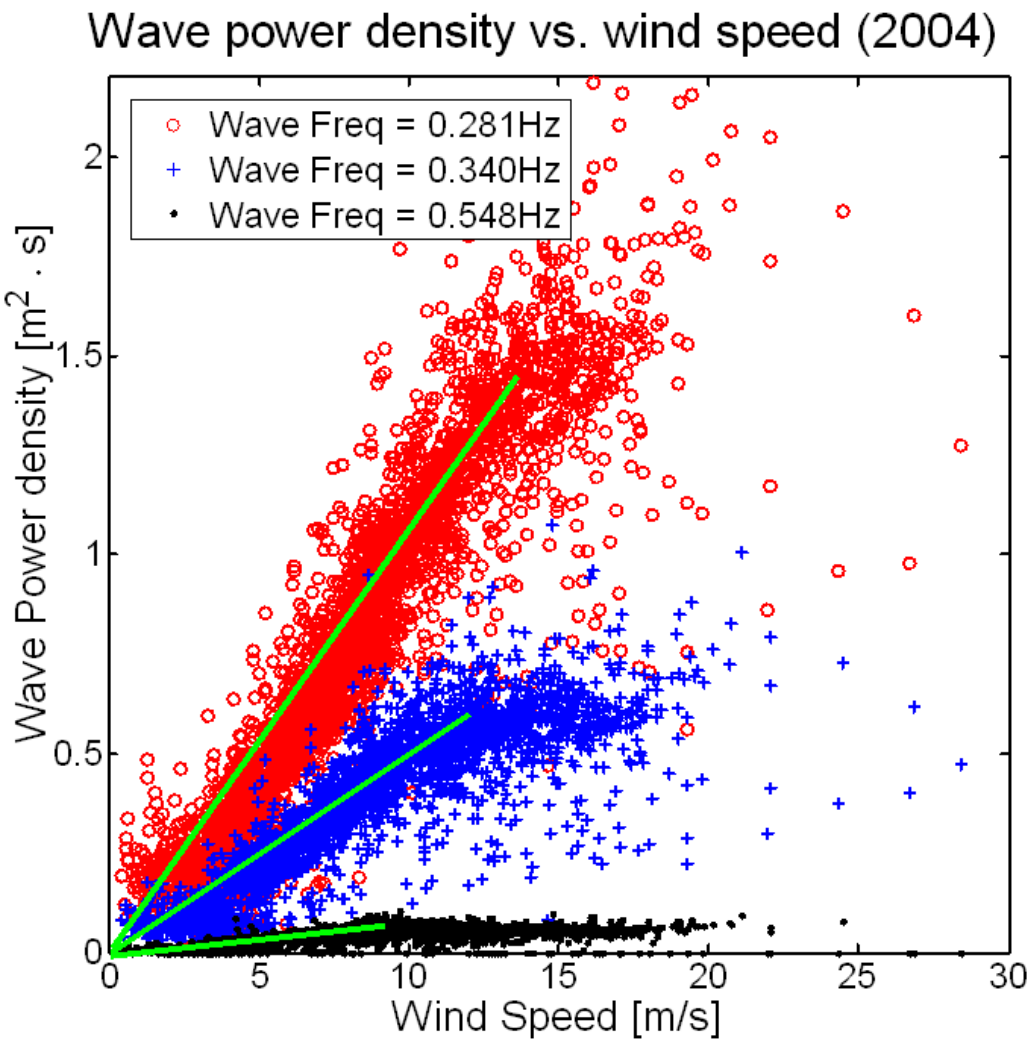
Wind speed inversion using first-order Bragg peaks?

Bragg resonant ocean waves vs. Radar frequency



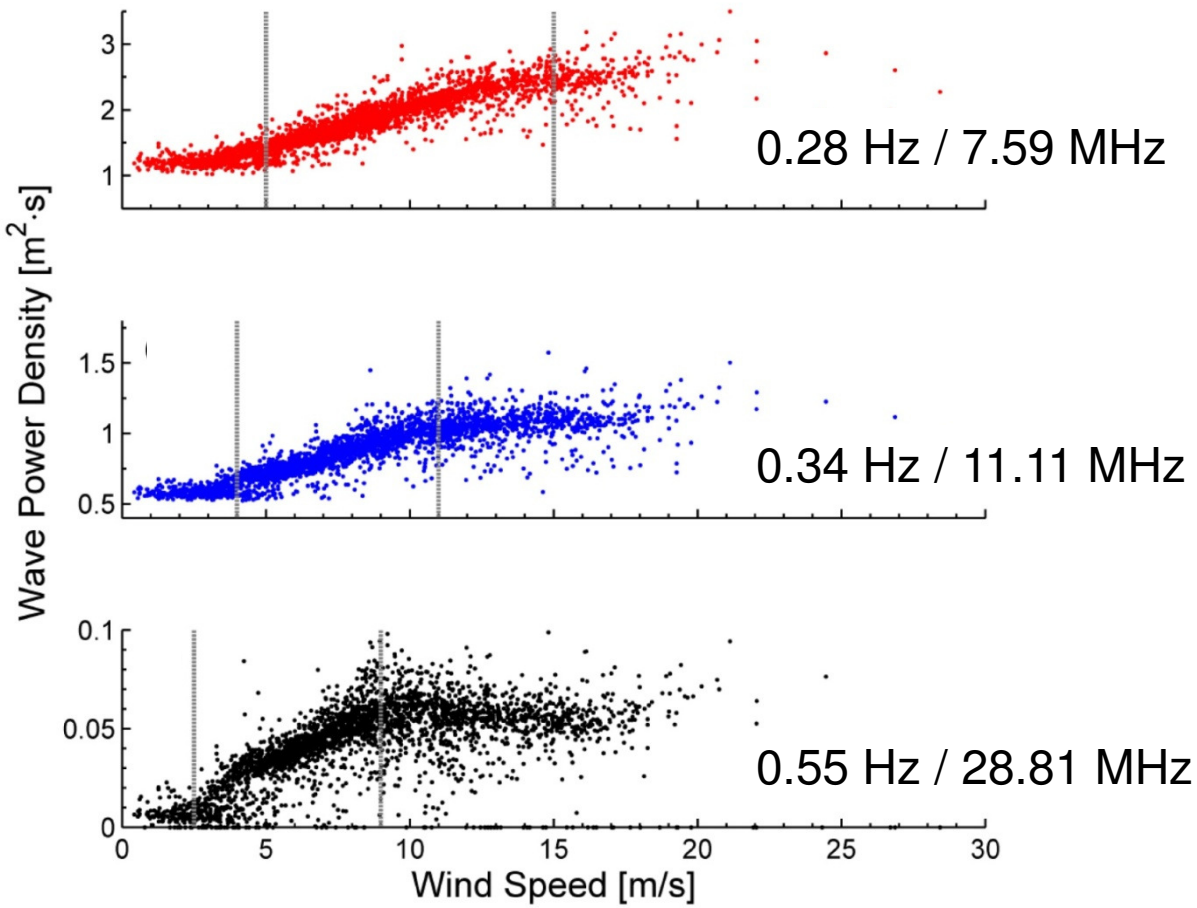
f_{Wave} (Hz)	f_{Radar}(MHz)
0.281	7.586
0.340	11.11
0.548	28.81

HIPOCAS WAM data

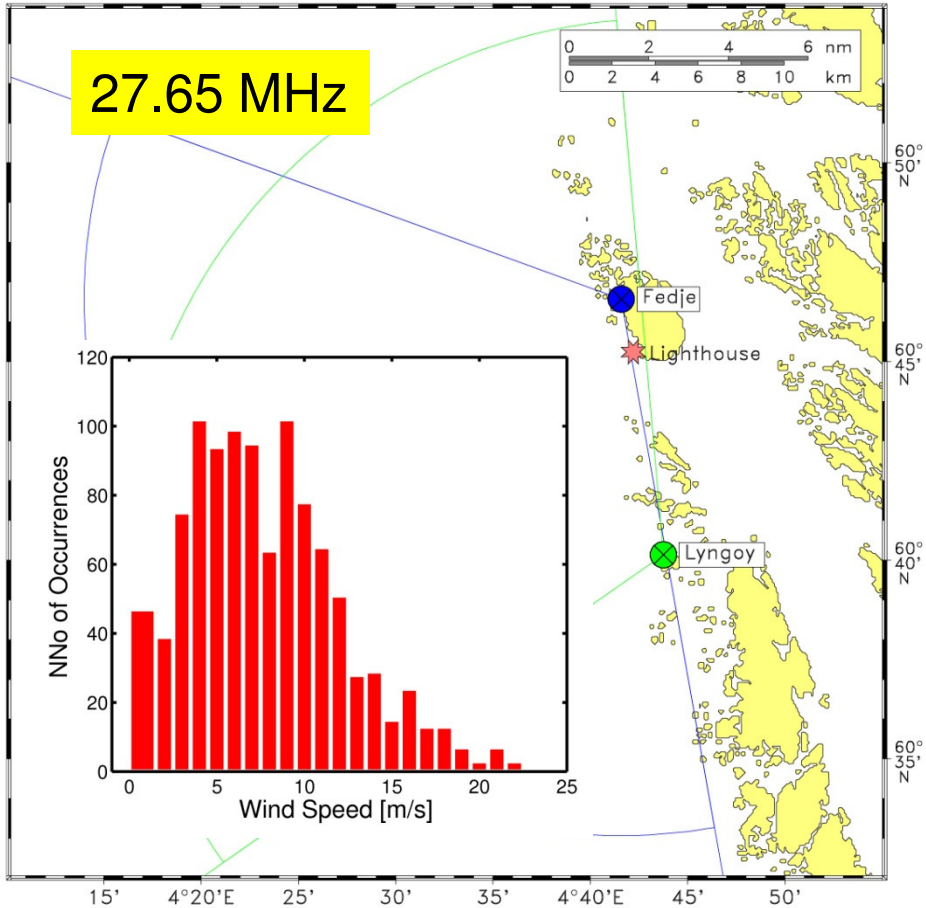


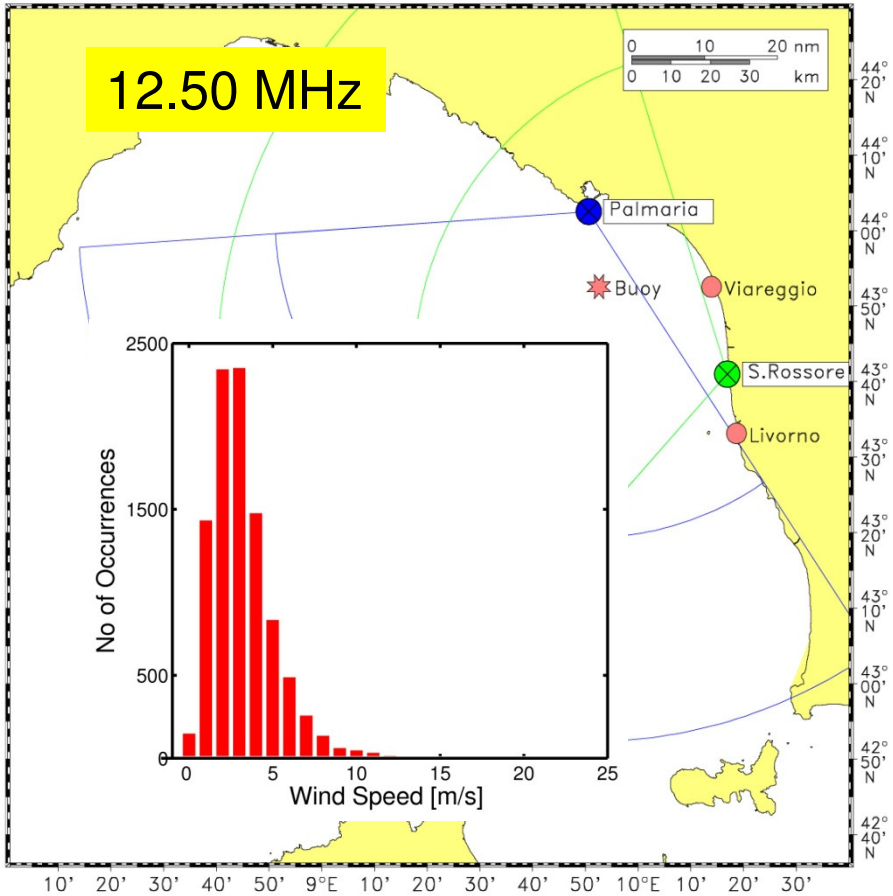
Lower limit: wind speed > wave phase speed

Upper limit: wave saturation



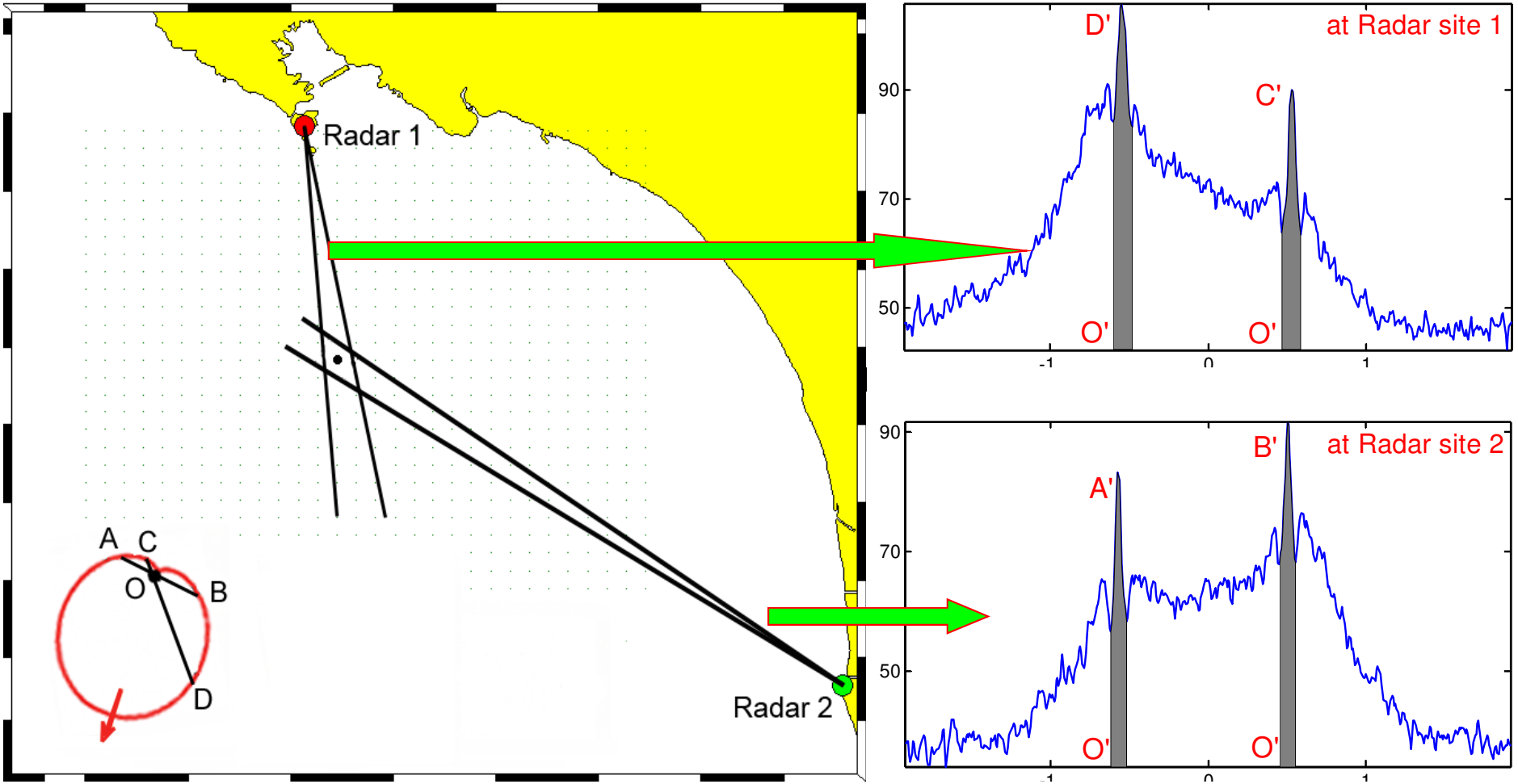
Data sets used for wind inversion based on first-order Bragg peaks





Wind Speed Inversion from HF Radar Backscatter Signal

Presented by Klaus-Werner Gurgel



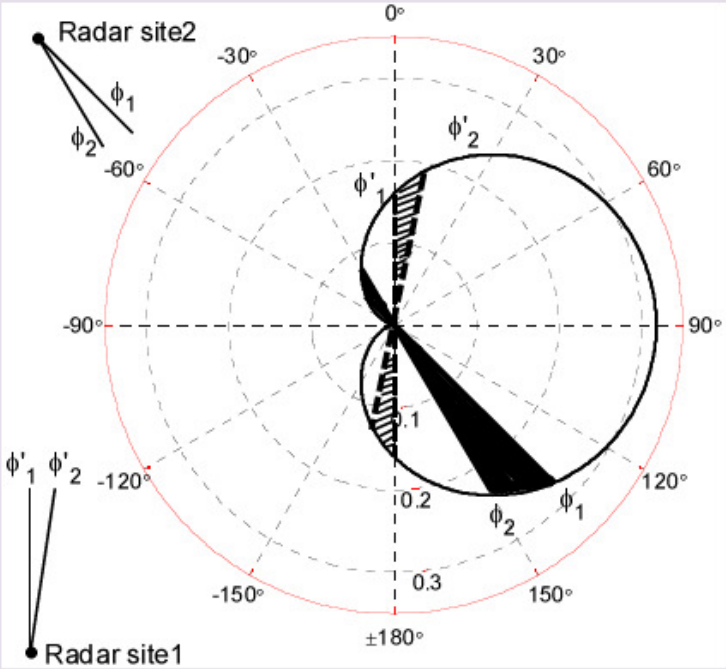
Wind Speed Inversion from HF Radar Backscatter Signal

Presented by Klaus-Werner Gurgel

$\sigma_1(\pm f_B)$

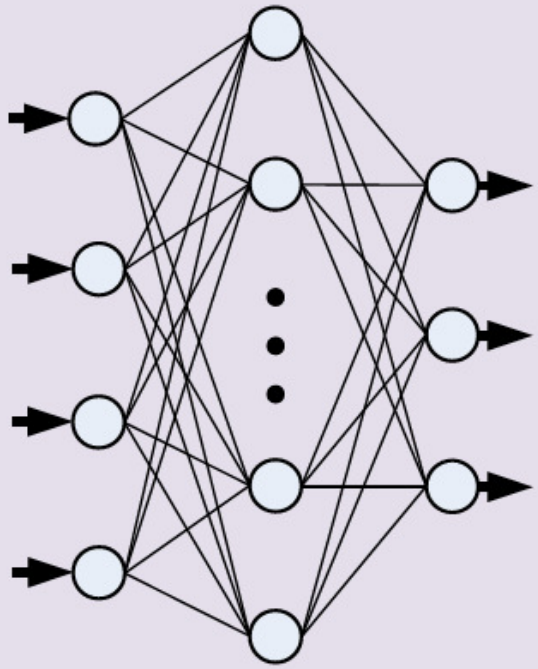
1. **Fixed radar range** **(buoy location)**
2. **Fixed radio beam direction (ϕ)** **(buoy location)**
3. **Local wind condition (U, θ)**

Input data set



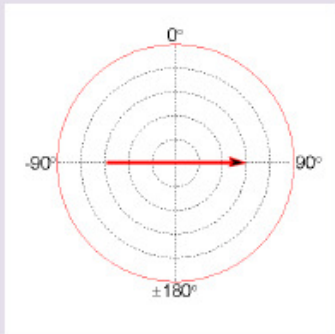
$\sigma_1(\pm f_{\mathrm{Bragg}})$ and $\sigma_1'(\pm f_{\mathrm{Bragg}})$

Neural Network (BP)



4-N-3 (3-layer network)

Target data

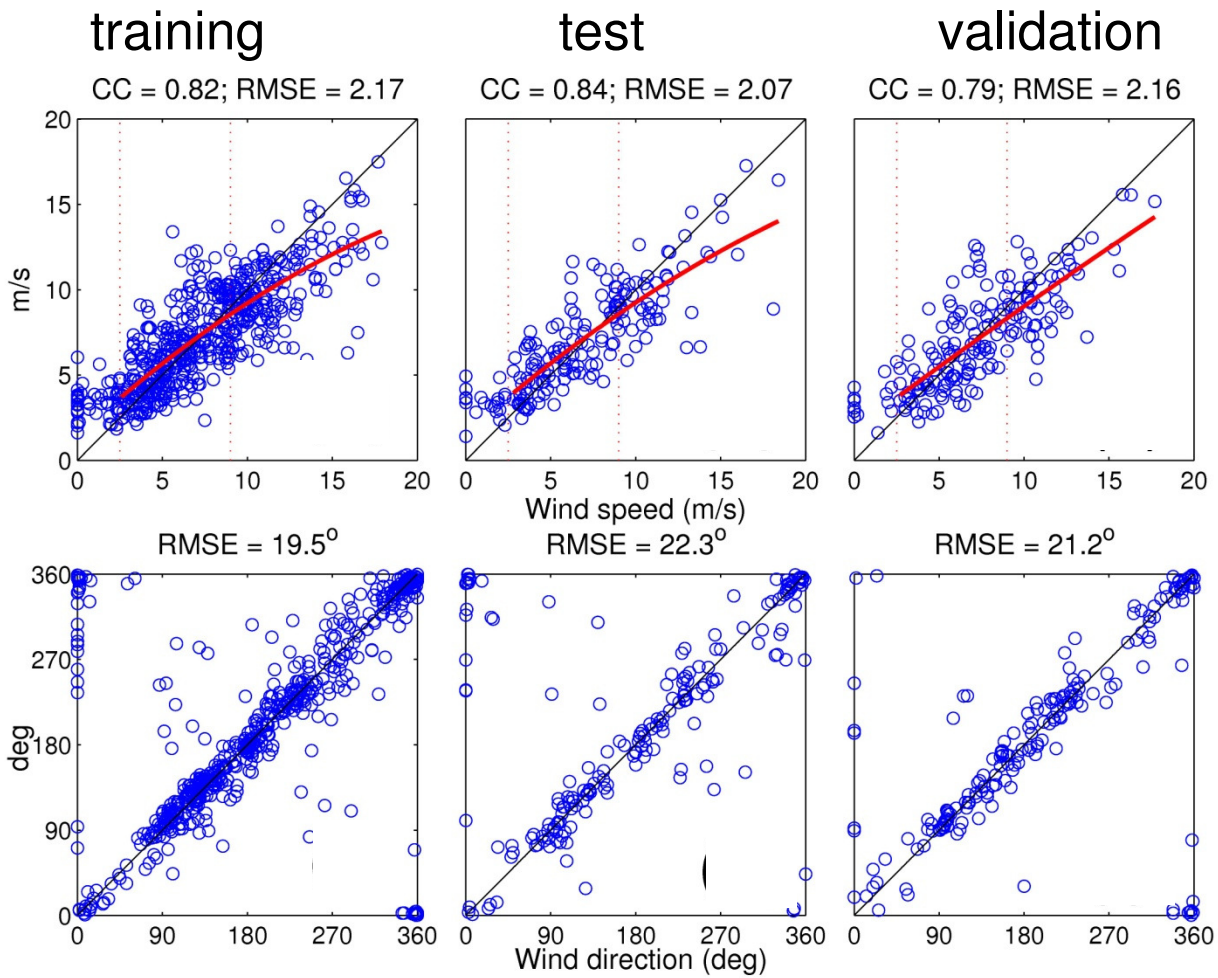


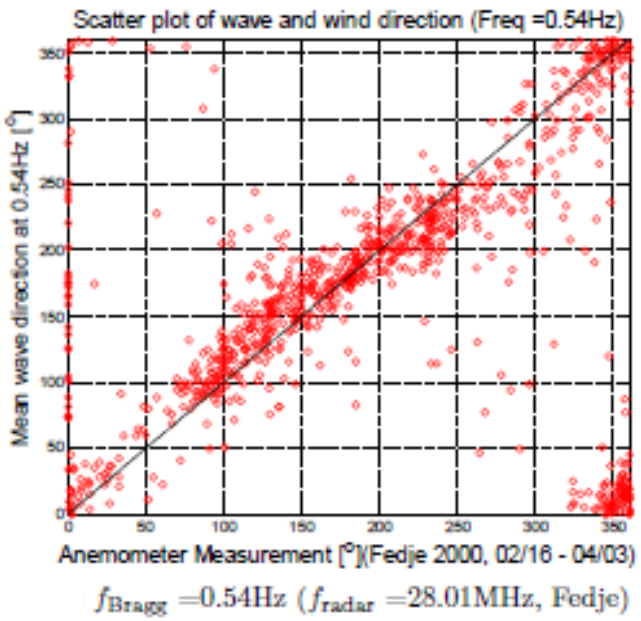
U_{10}

$\cos\theta$

$\sin\theta$

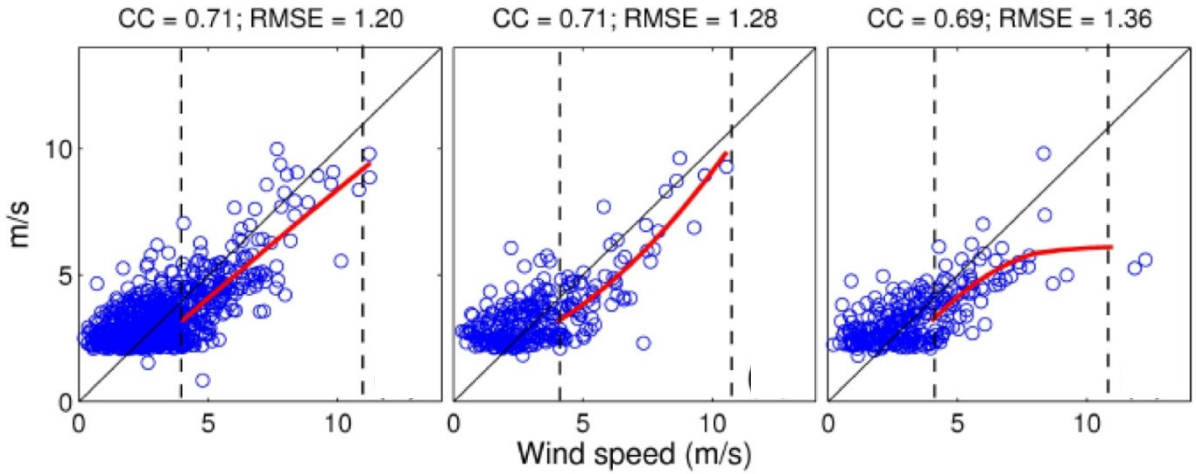
27.65 MHz Norway / Fedje

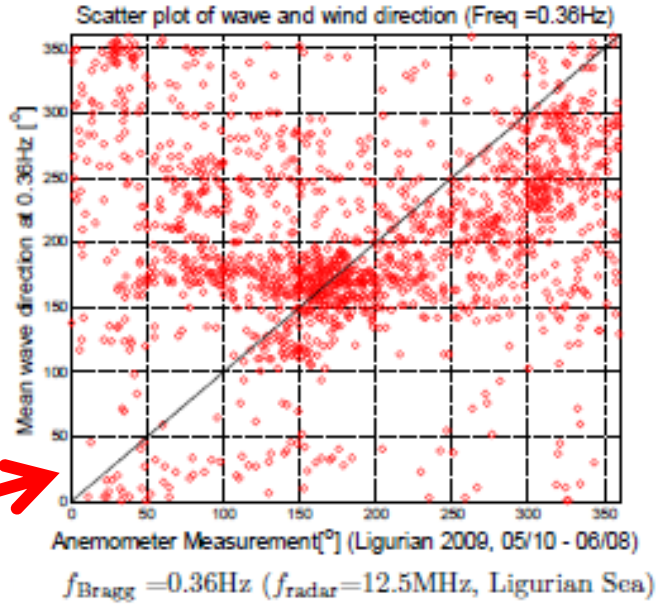




12.50 MHz Ligurian Sea

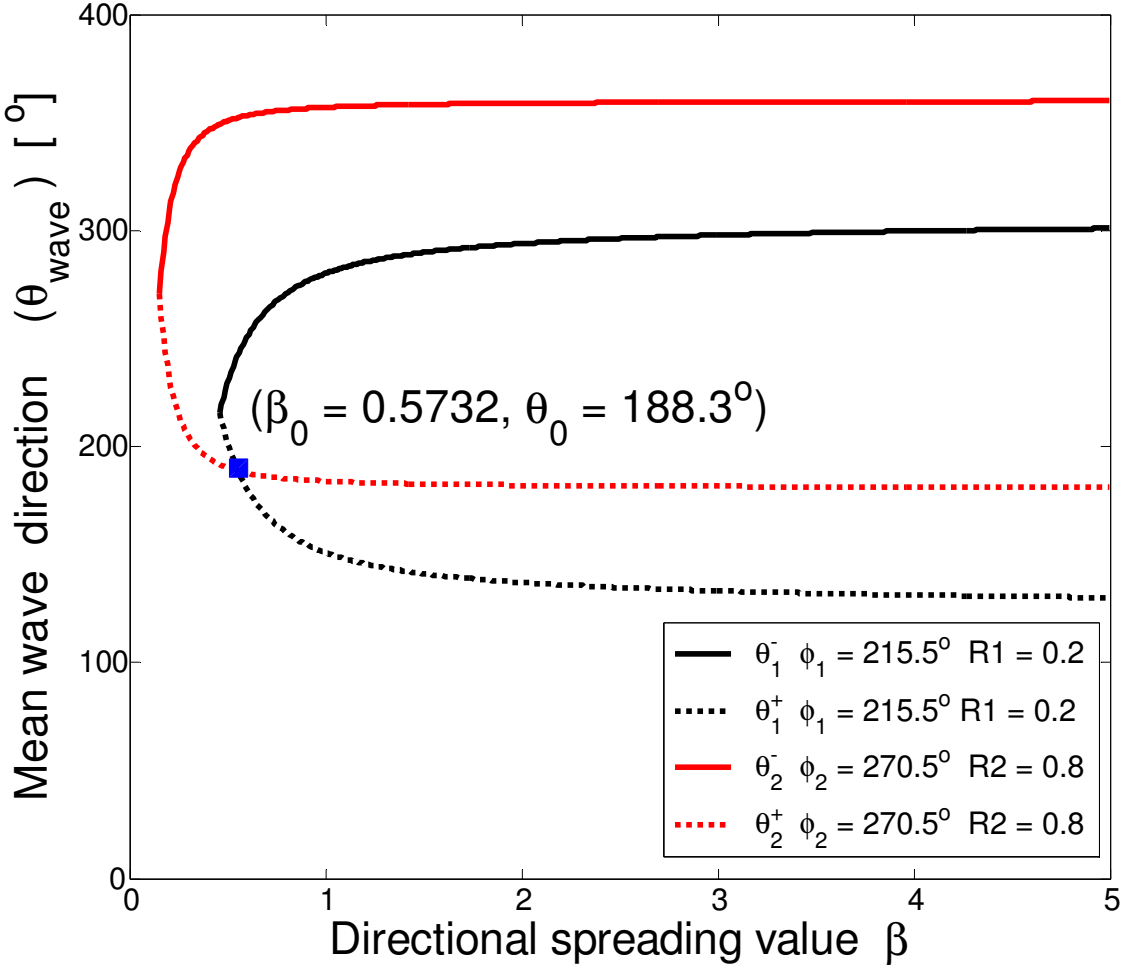
training test validation





No inversion of wind direction possible, because wind direction and Bragg resonant wave direction are not related to eachother.

Mean wave direction as a function of spreading value



Wave direction and spreading from site 1

Wave direction and spreading from site 2

$$\theta^{\pm}_{\mathrm{wave},i} = \phi_i \pm \frac{1}{2\beta} \ln \left| \frac{1 - R_i^{1/2} e^{-\beta \cdot \pi}}{R_i^{1/2} e^{\beta \cdot \pi} - 1} \right| \; (i = 1, 2)$$

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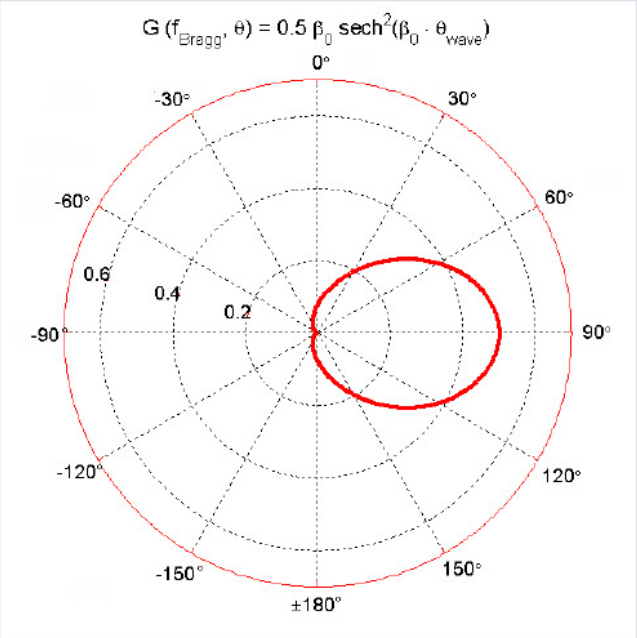
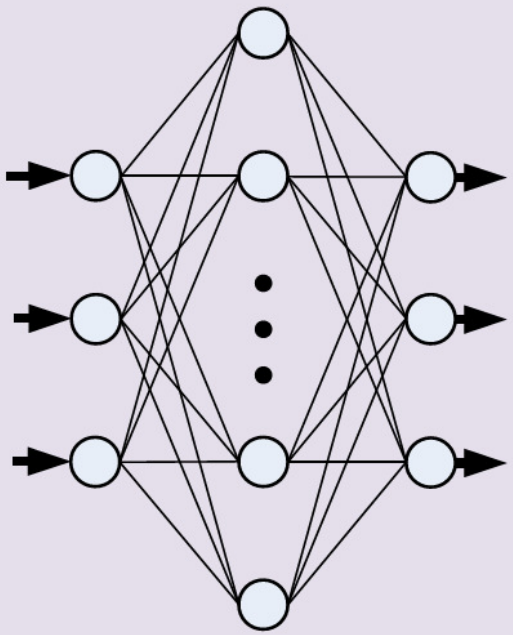
Spreading of Bragg waves



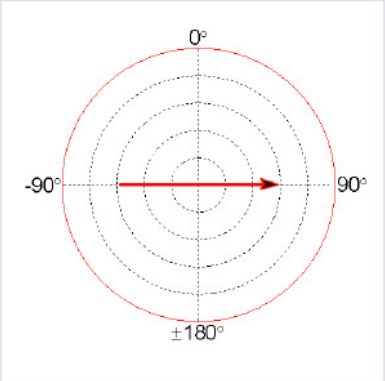
β_0, $\cos\theta_{\text{wave}}$, $\sin\theta_{\text{wave}}$

Neural network (BP)



3-N-3 (3-layer network)

Target data



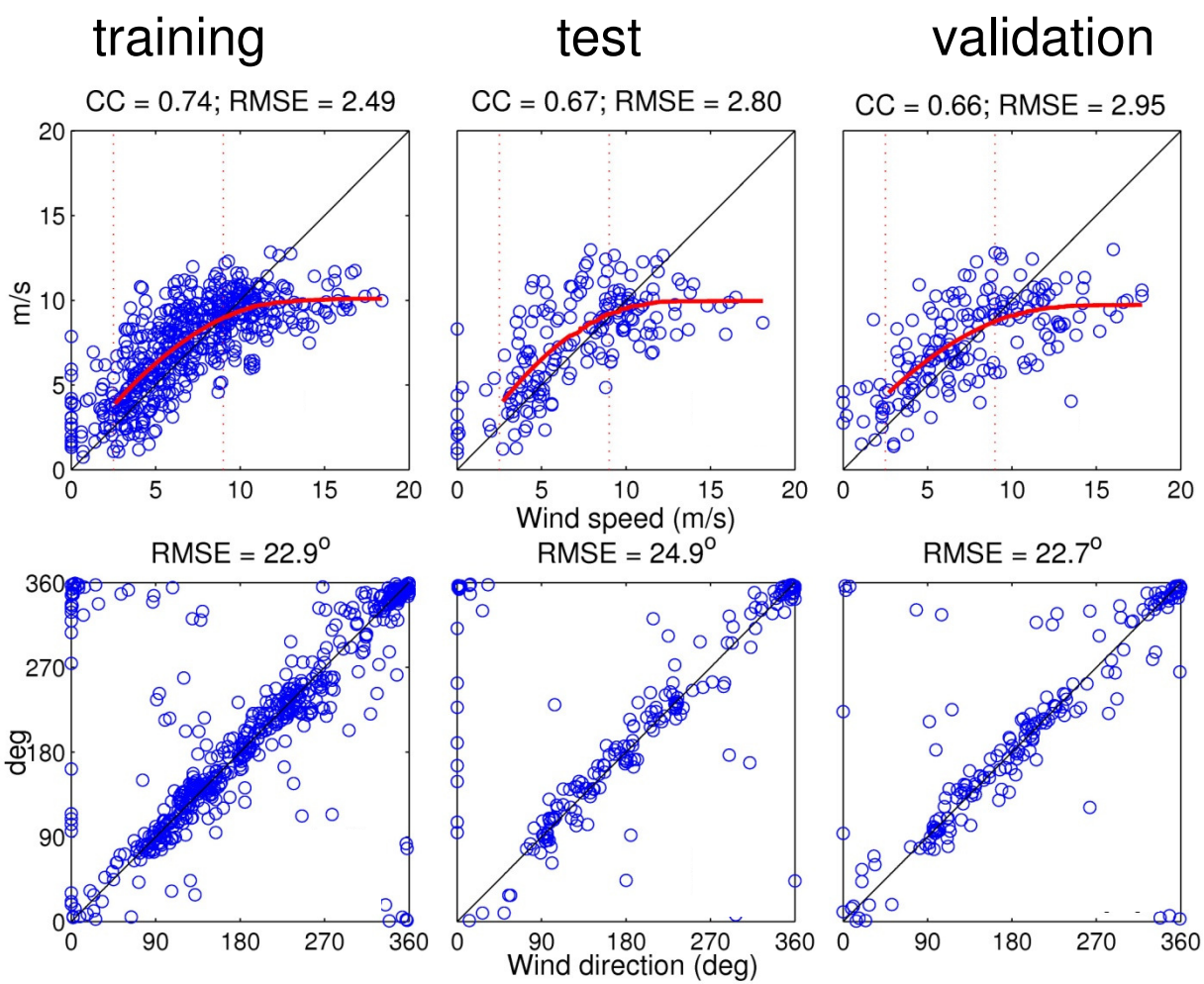
U_{10}

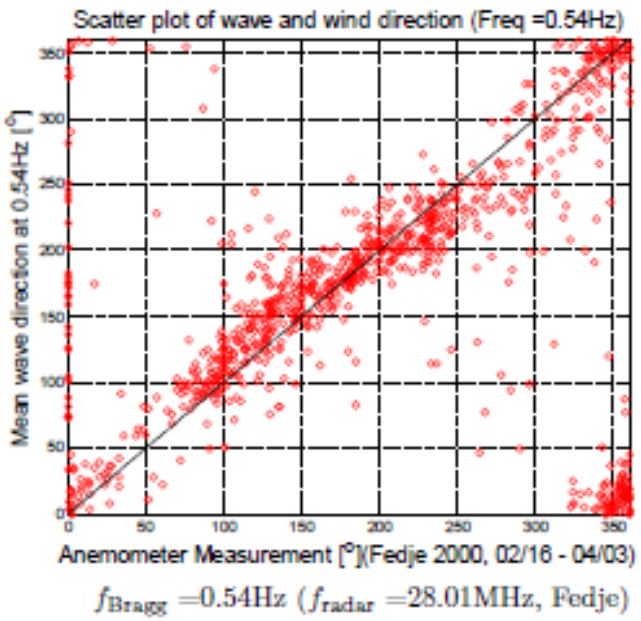
$\cos\theta$

$\sin\theta$

1. Train the ANN with wave speading and wind speed and direction at the buoy location
2. Use the trained ANN to get wind speed and direction at all grid points within the radar coverage

27.65 MHz Norway / Fedje





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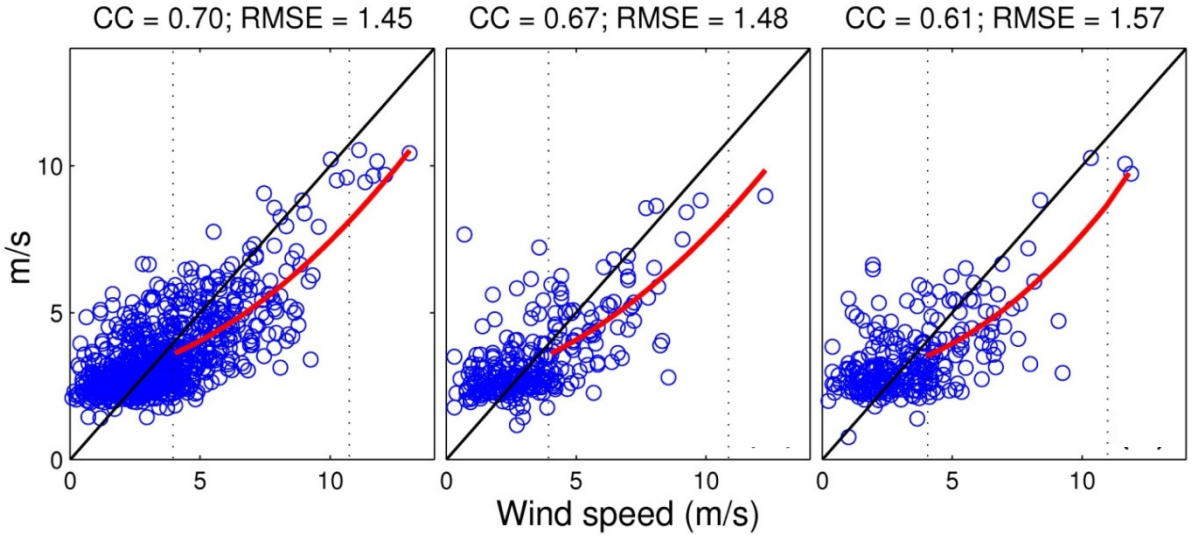

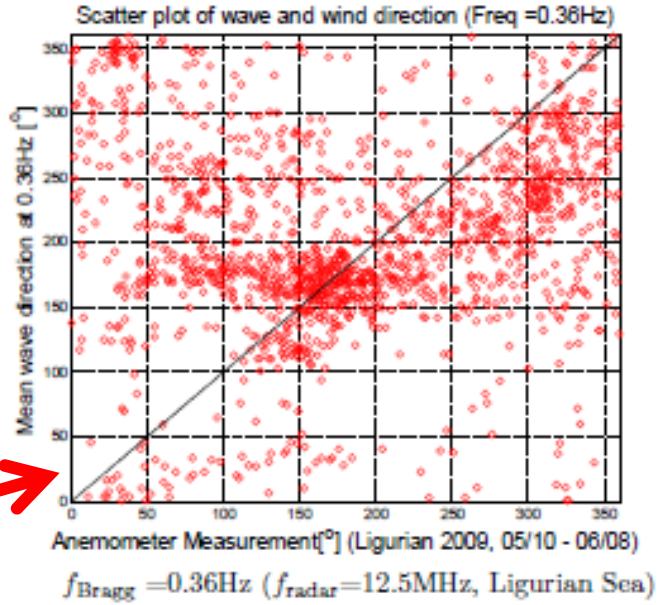

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RMS error using different inversion methods (U>3 m/s)			
Radar experiments	NN1	NN2	2nd-order method
Fedje (27.68 MHz)	1.85	2.45	3.52
Ligurian (12-13 MHz)	1.36	1.47	2.21
NN1 - Inversion from radar first-order peaks NN2 - inversion from directional distribution of Bragg waves			

RMS error is reduced by a factor of 1.5 to 2

Conclusions

- An algorithm to estimate wind speed from first-order HF radar backscatter has been presented.
- In contrast to existing second-order methods the working range is extended.
- There are lower and upper limits of wind speed which depend on radar frequency.
- The first method uses the an ANN trained at the location of the wind measurements. After training, the buoy can be removed.
- The second method makes use of the directional spreading. The ANN trained at the buoy location can be used all over the radar domain where first-order Bragg peaks have been measured from two radars.