An event of „Parametric Rolling“ onboard RV “Polarstern”

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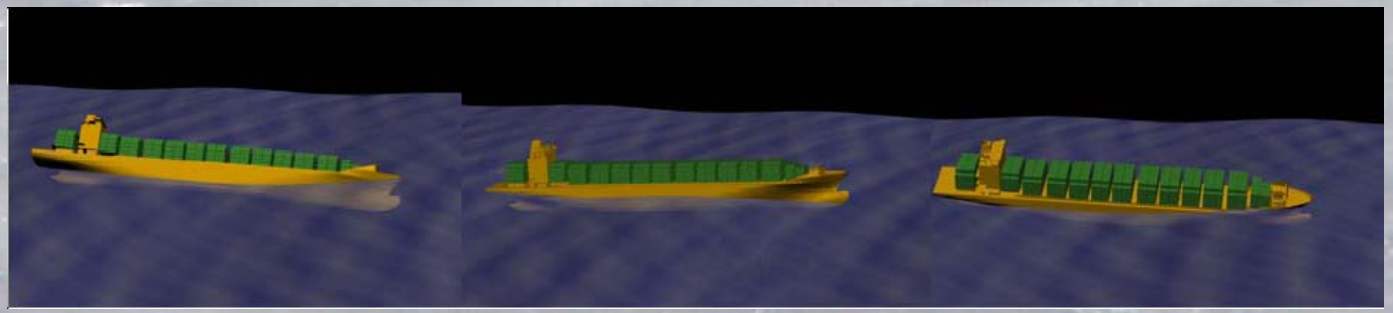
Motivation (1)

„Parametric Rolling”

- **A serious problem for large container ships**
- **Is it possible to set up a warning system based on remote sensing and wave forecasts?**



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Motivation (2)

Project **„PaRol“**

(GMES-DeMarine Security)

GMES = *Global Monitoring for Environment and Security*

Application of Remote Sensing Technology for Ship Damage Prevention

- lead by German Aerospace Center, Oberpfaffenhofen
- GAUSS mbH, Bremen
- OHB-System AG, Bremen
- Deutscher Wetterdienst, Hamburg
- Federal Waterways Engineering and Research Institute, Hamburg

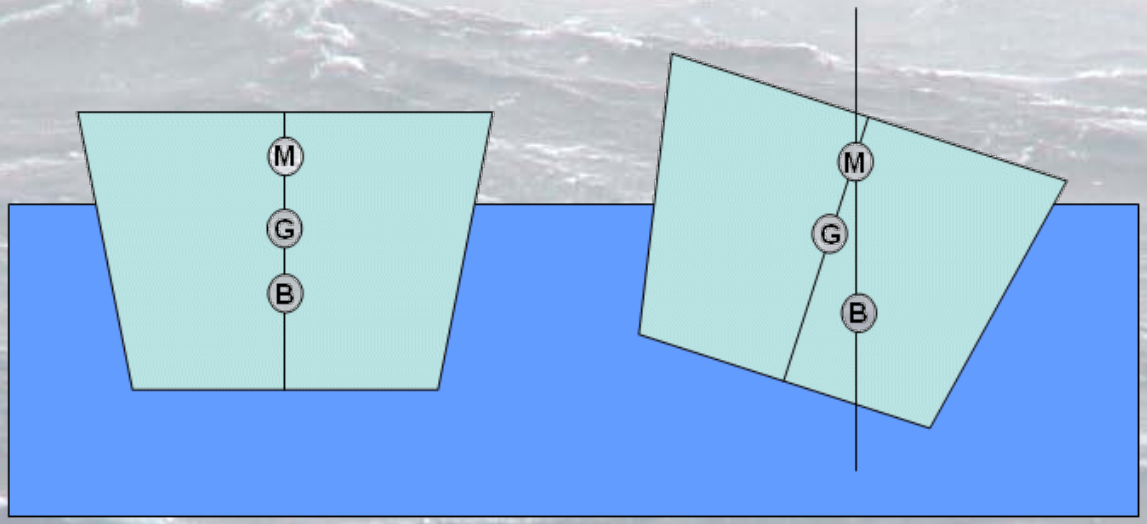
Methodology

- **Installation of a „WaMoS“ Wave Radar System onboard RV„Polarstern“**
- **Antarctic Expedition Oct 2008 – May 2009**
- **Wave Observations from Space**
- **„Parametric Rolling“ occured by accident**

Conclusions (1)

- **RV„Polarstern“ experienced „Parametric Rolling“ on March 7th, 2009**
- **A Cross Sea was observed by Wave Radar and from Satellite and forecast by Wave Models.**
- **Forecasting Rolling Events seems to be possible**

Lateral Stability of a Ship



Eigenperiod of Rolling : $T_R = \frac{f\ B}{(GM_0)^{1/2}}$

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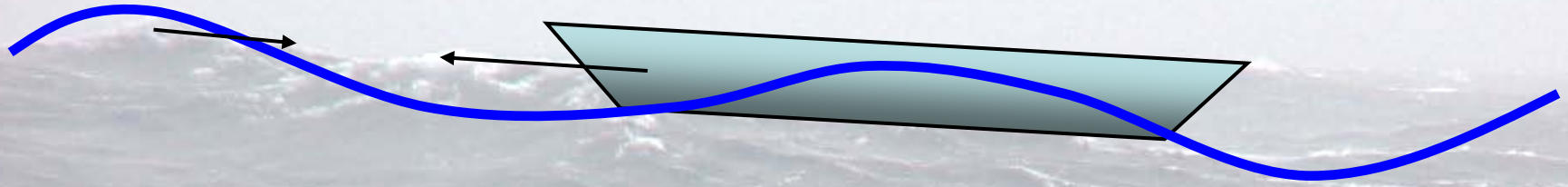
Parametric Rolling

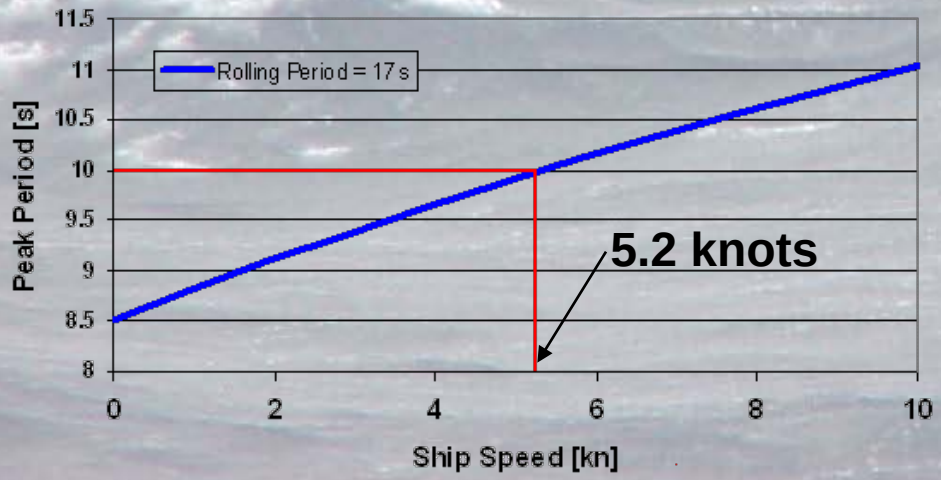
occurs due to

Periodic Loss and Gain of Lateral Stability



- ✓ **Waves must be high enough to cause heavy pitching**
- ✓ **Wave length must be of the order of one to two ship lengths**
- ✓ **Period of Encounter = multiple of half the Rolling Period**

$$T_E = (1 / T_p - V_s \cos(\mu) / L_p)^{-1} \quad \stackrel{!}{=} n/2\ T_R$$



Resonance Condition

in a Heading Sea (μ=180 , n=1)

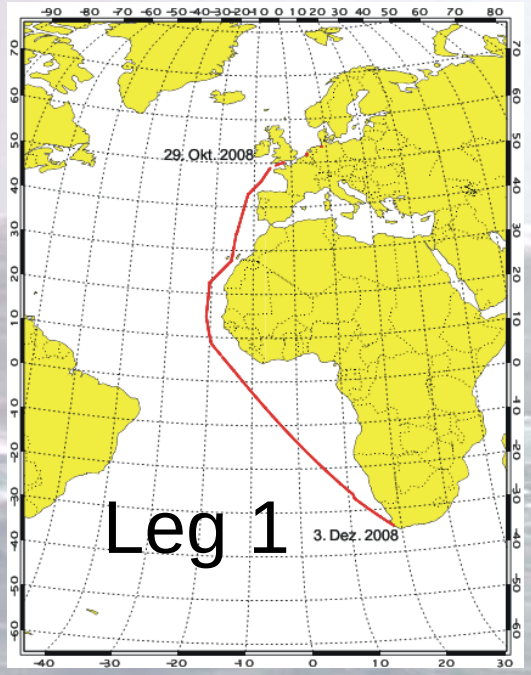
$$T_R = 17\ s$$

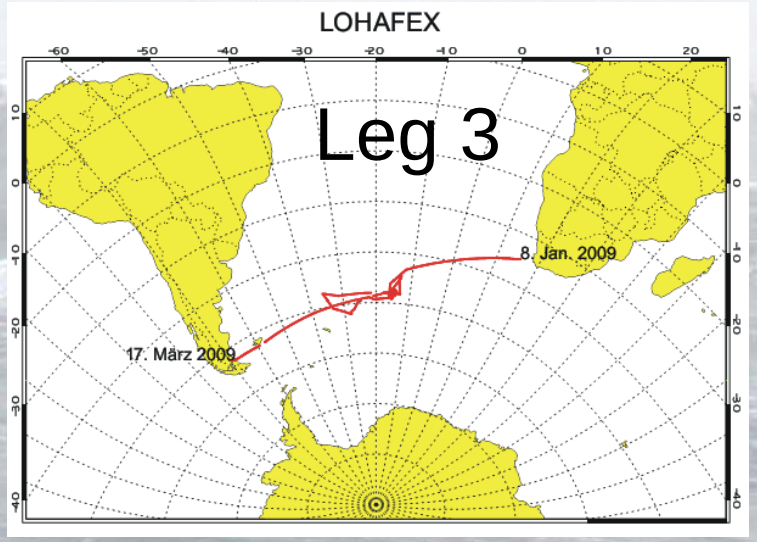
$$T_E = 8.5\ s$$

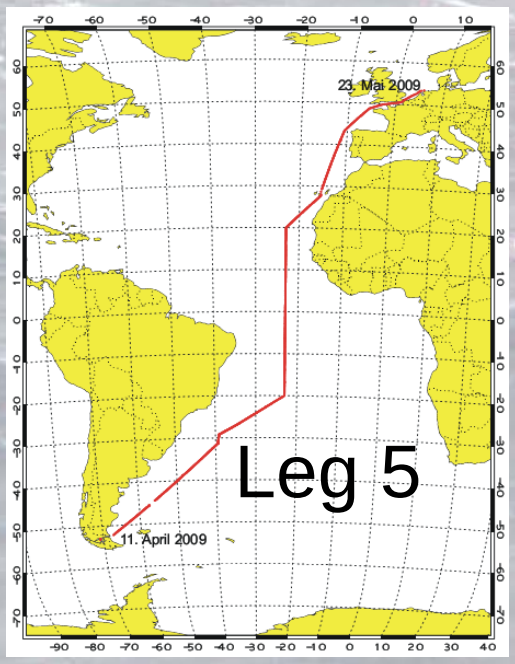
The ship must pitch twice for every roll

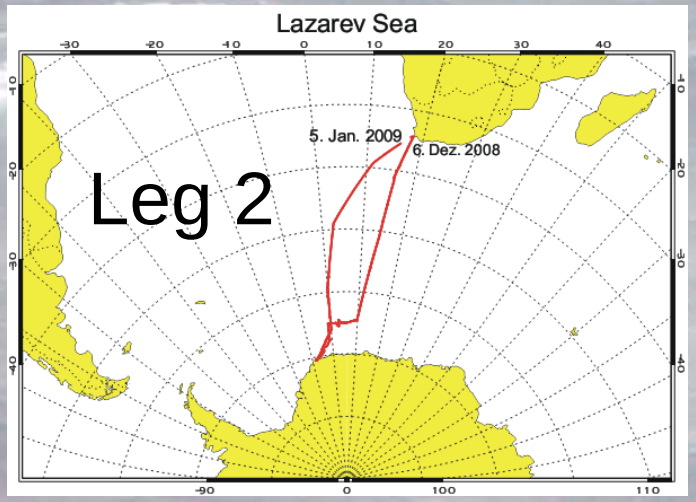
Radar Antenna
POLARSTERN
Hs: 2.1 m
Tp: 8.9 s
λp: 124 m
Θp: 105 °

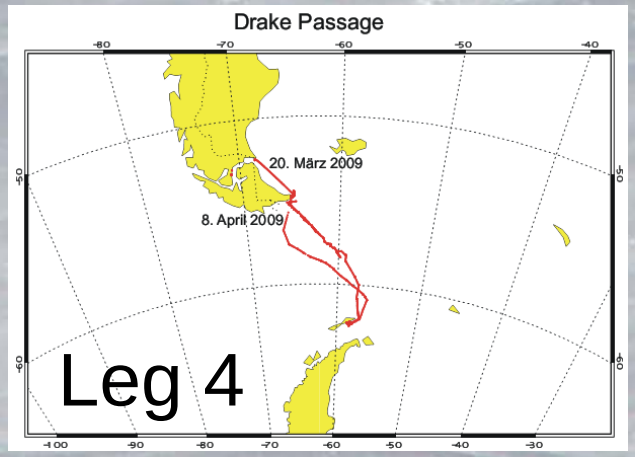
„Polarstern“ Expedition ANT-XXV 2008/2009











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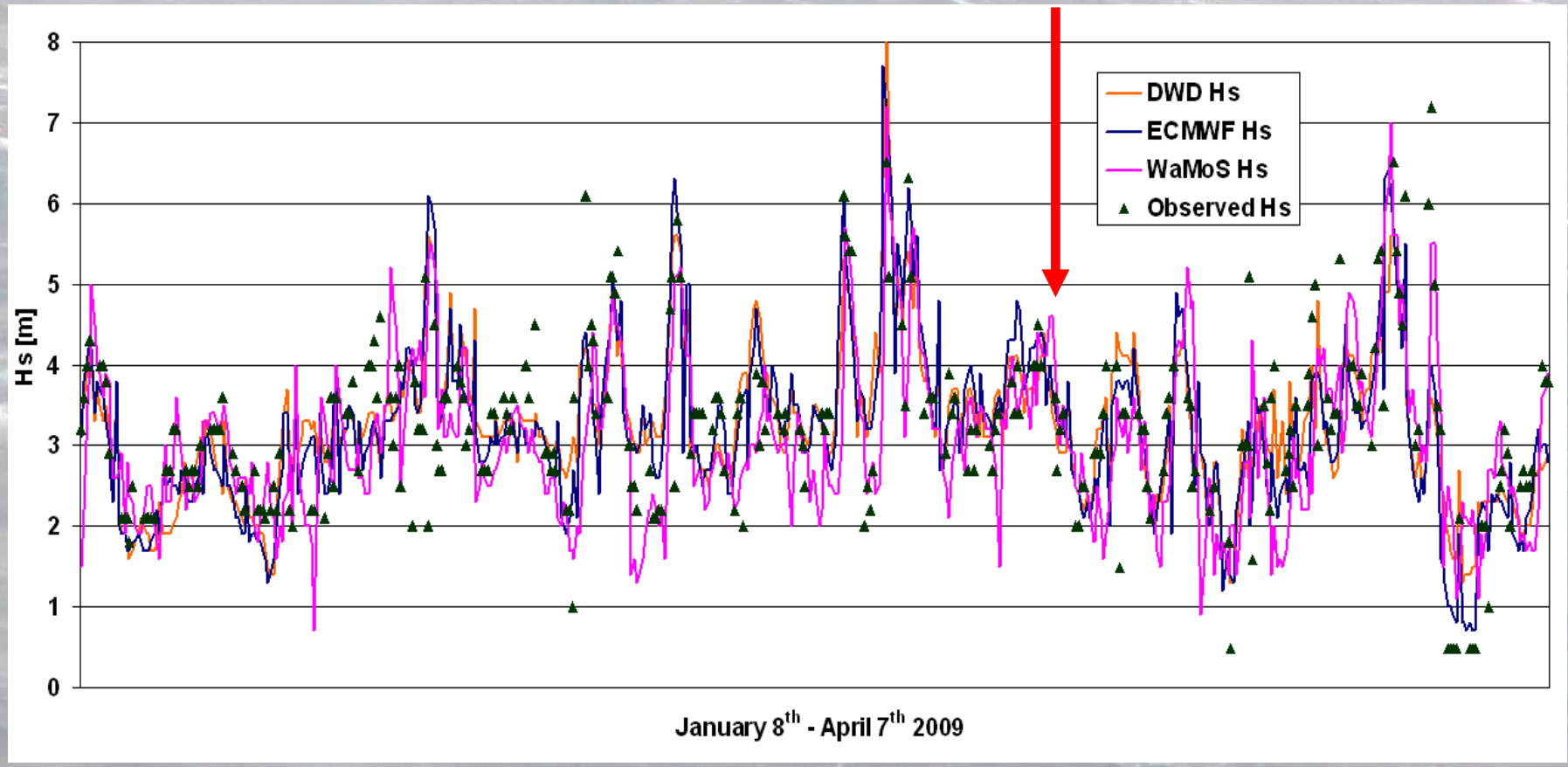
Significant Wave Height
Comparison between
Wave Models, WaMoS and Visual Observations

Rolling Event
on March 7th, 2009



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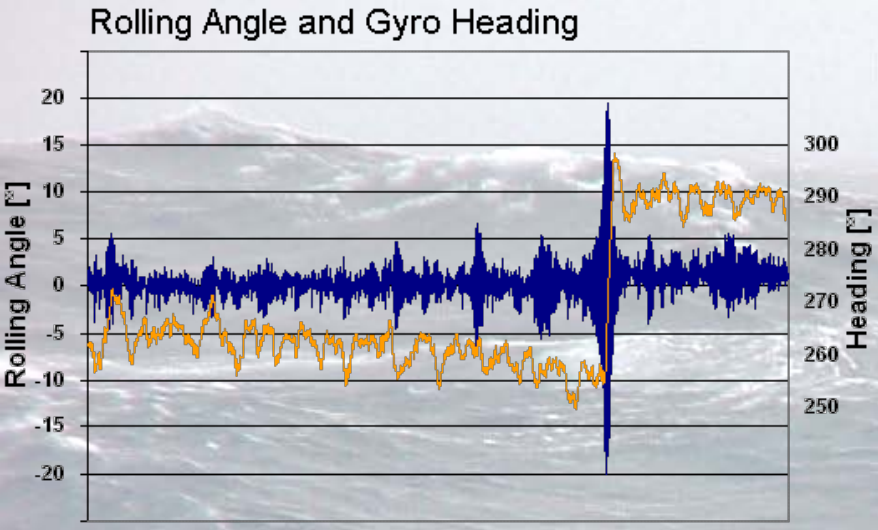
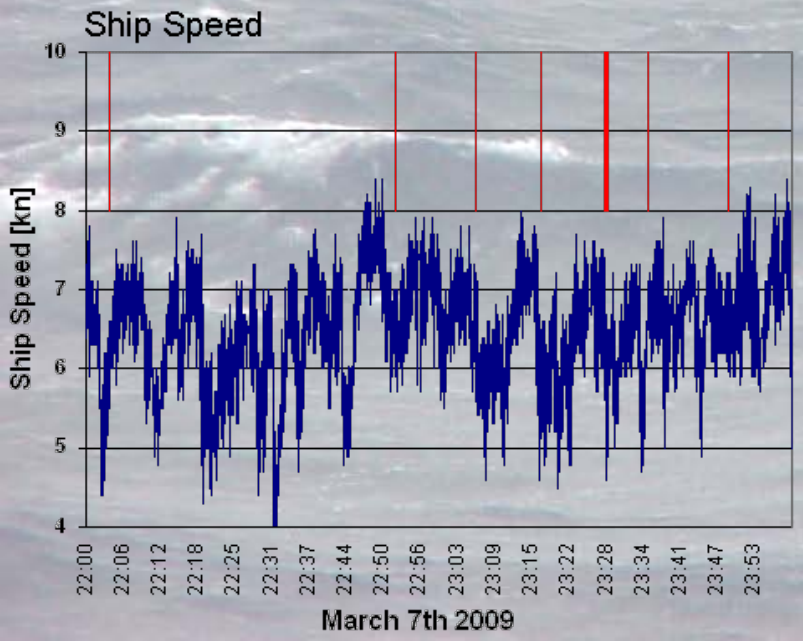
The Rolling Event

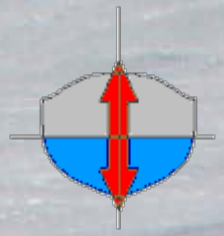




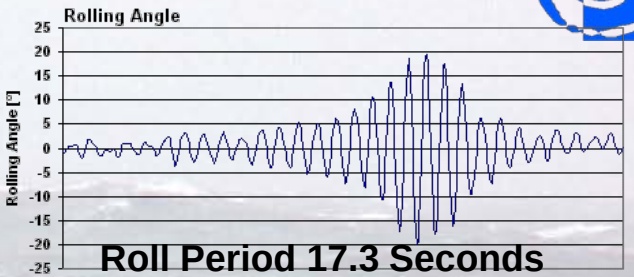
Roll

Speed

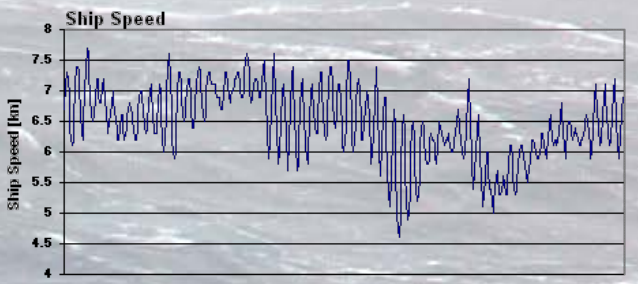
Pitch

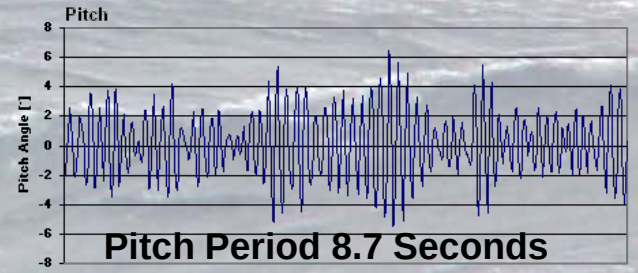


Heave

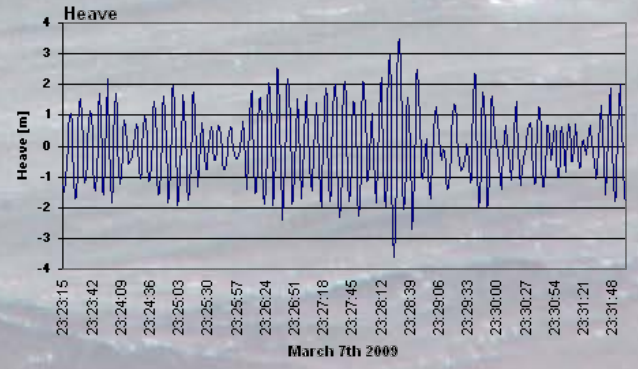


Roll Period 17.3 Seconds





Pitch Period 8.7 Seconds



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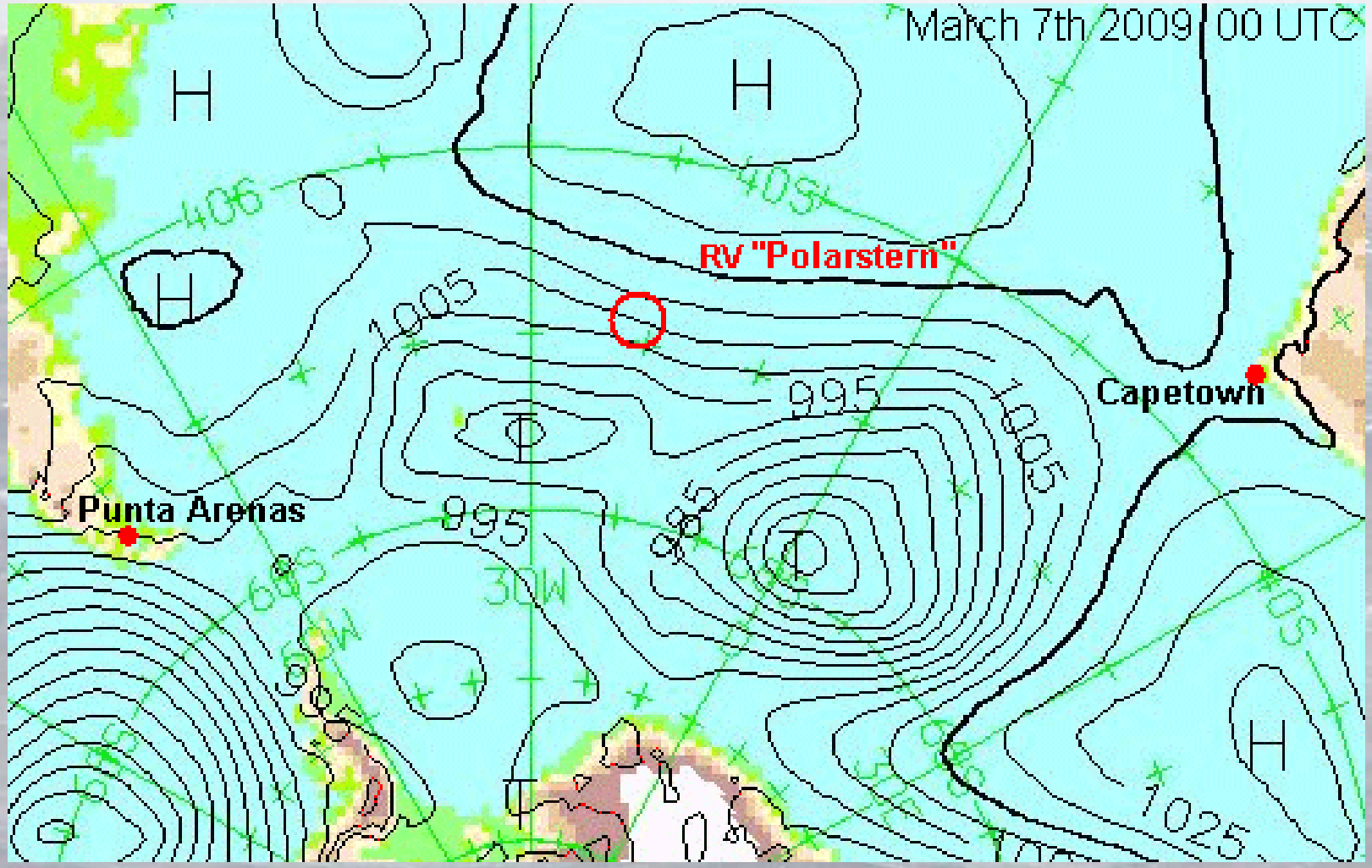
Synoptic Situation on March 7th, 2009



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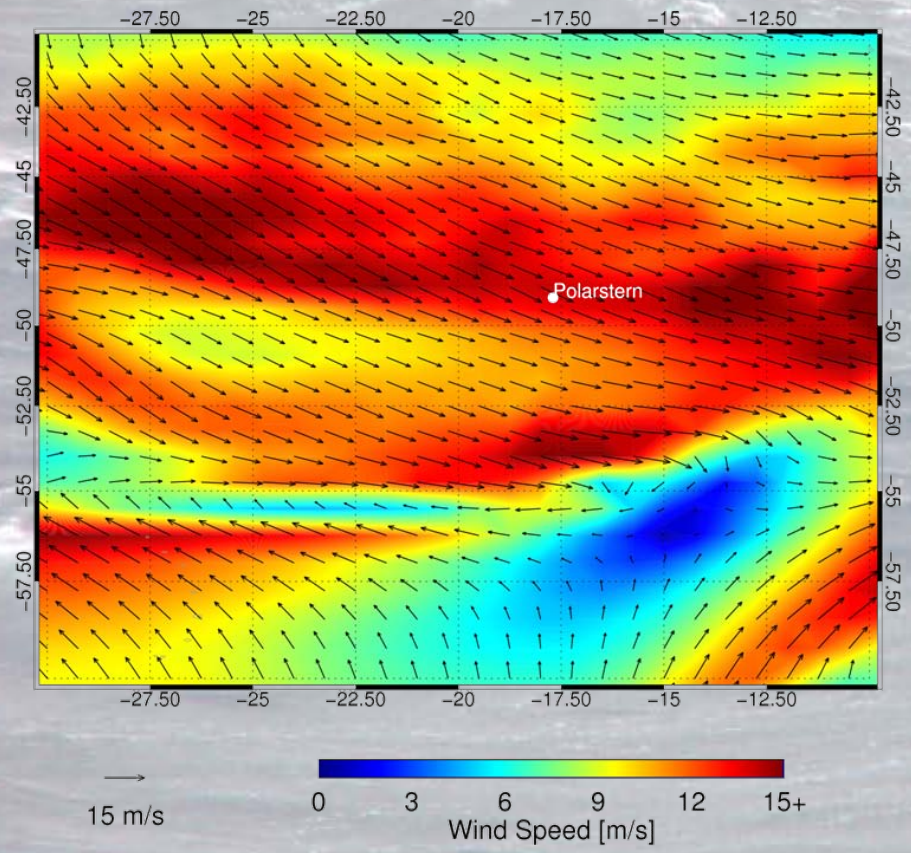
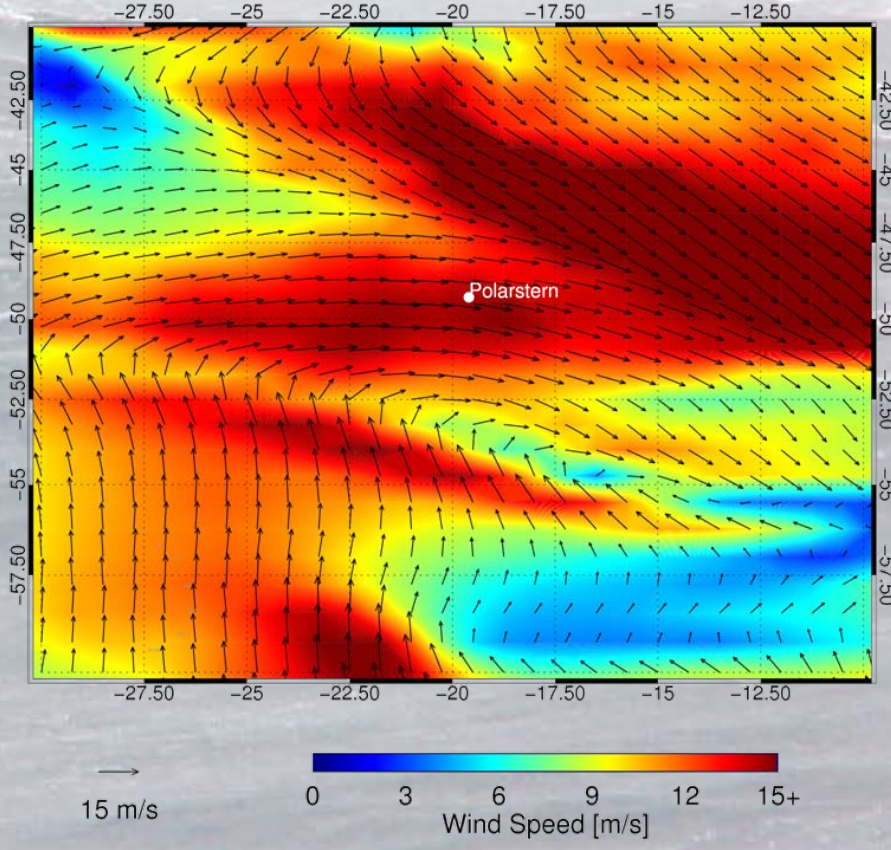
Wind Field of DWD Global Wave Model on March 7th , 2009

06:00 UTC



18:00 UTC



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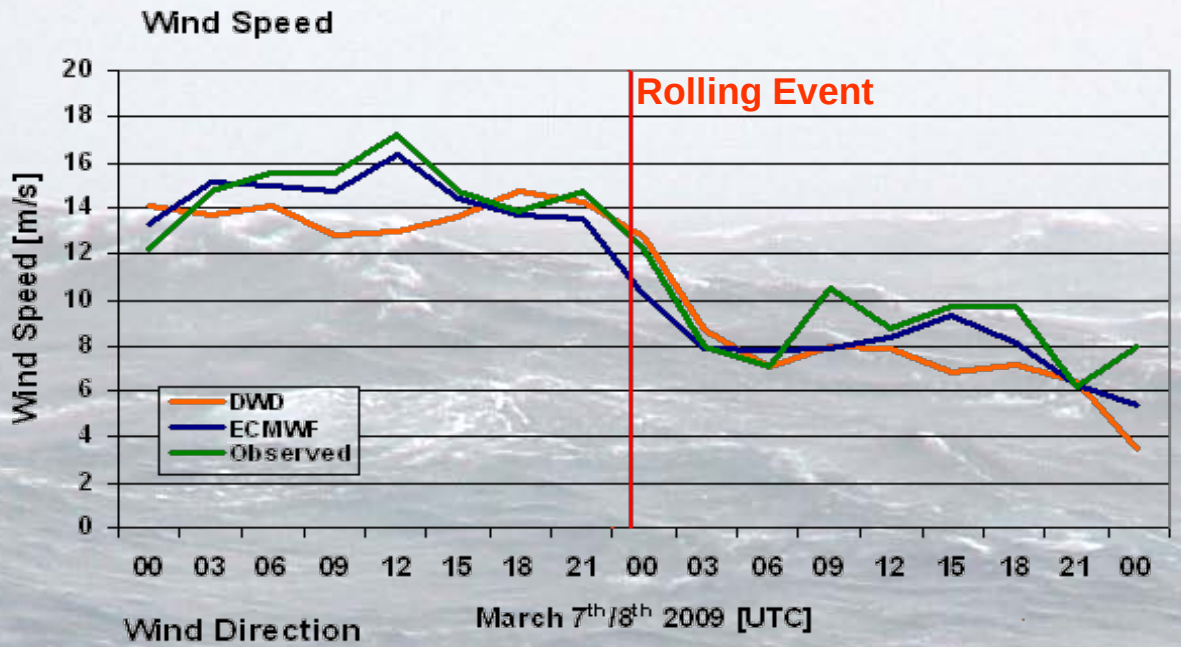
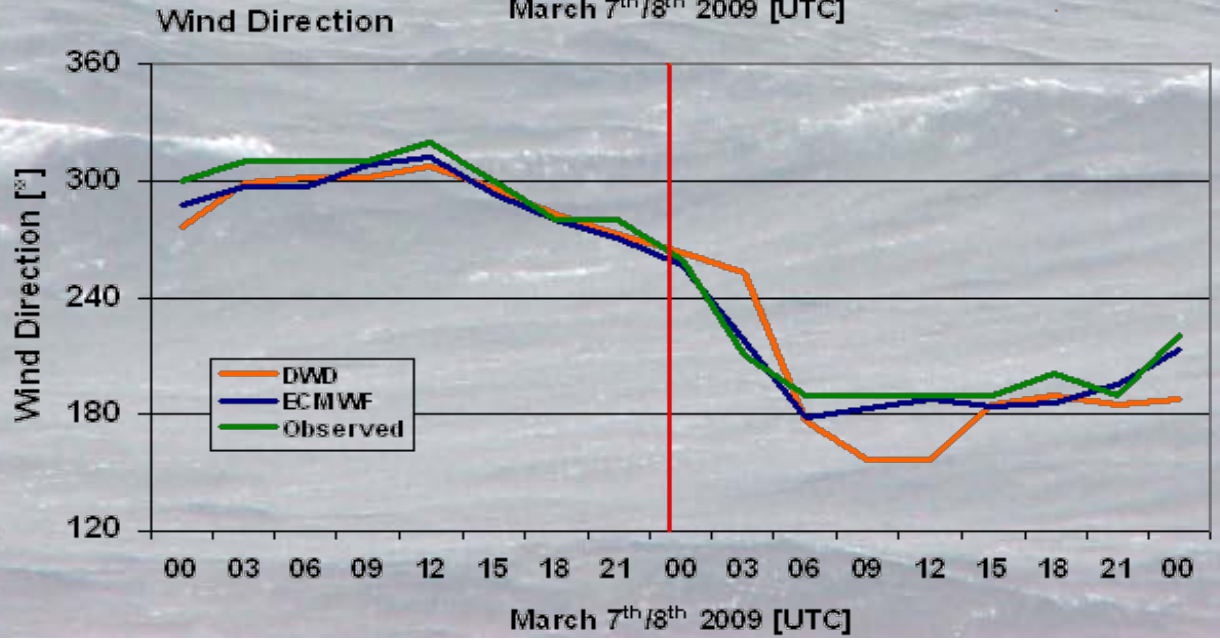
Wind observed and forecast





DWD

ECMWF

Anemometer

(reduced to 10m)

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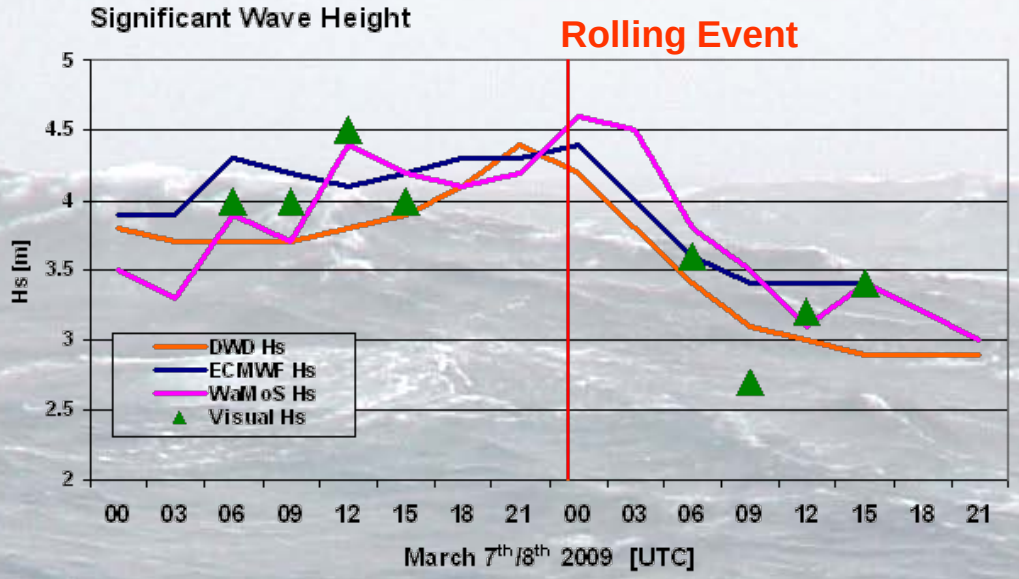
Waves observed and forecast

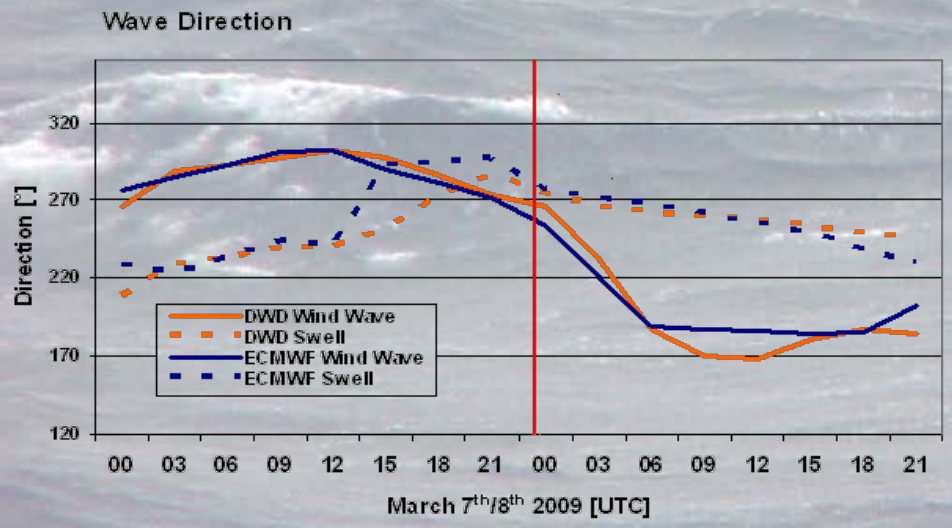


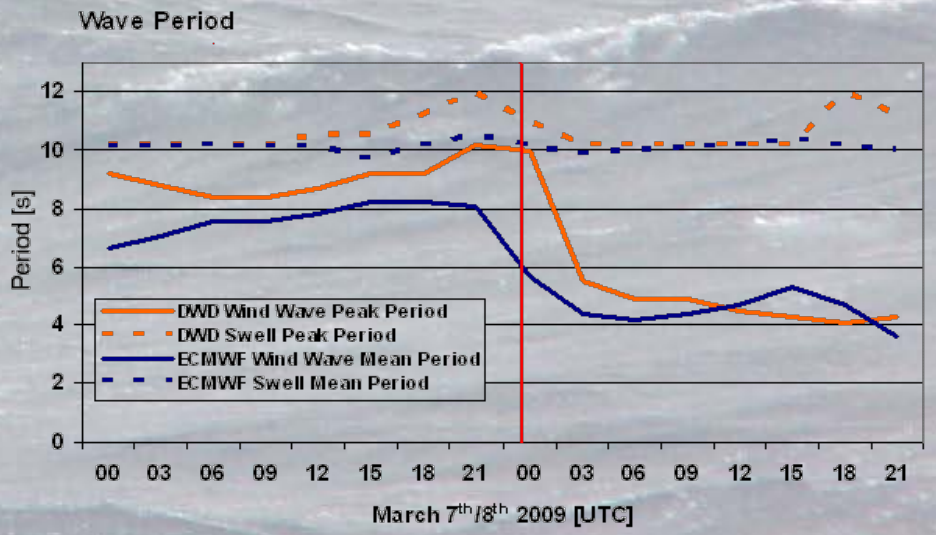
DWD

ECMWF

WaMoS

VISUAL





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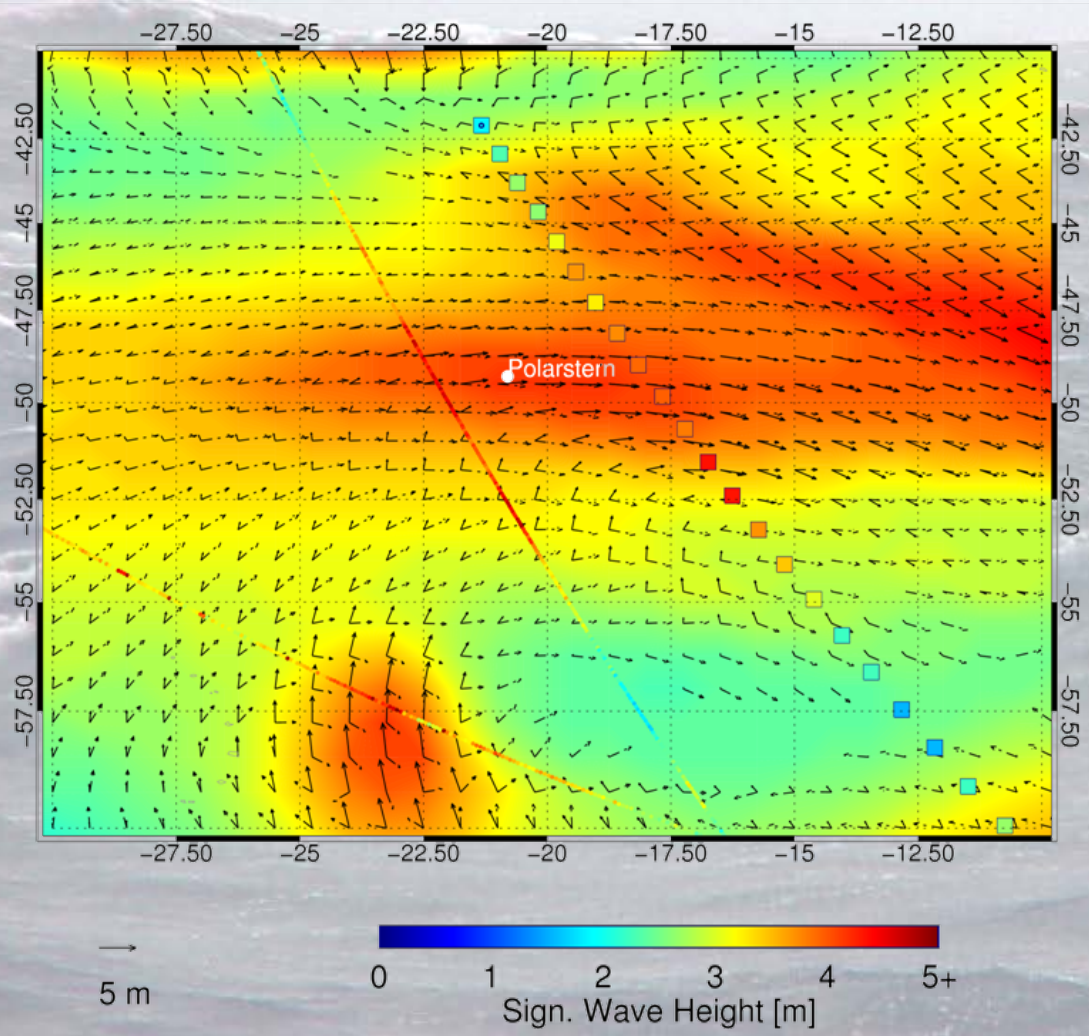
Wave Field of DWD Global Wave Model on March 8, 2009 at 0:00 UTC



Measurements of **SWH** derived from **ENVISAT** Radar Altimeter and ASAR wave mode

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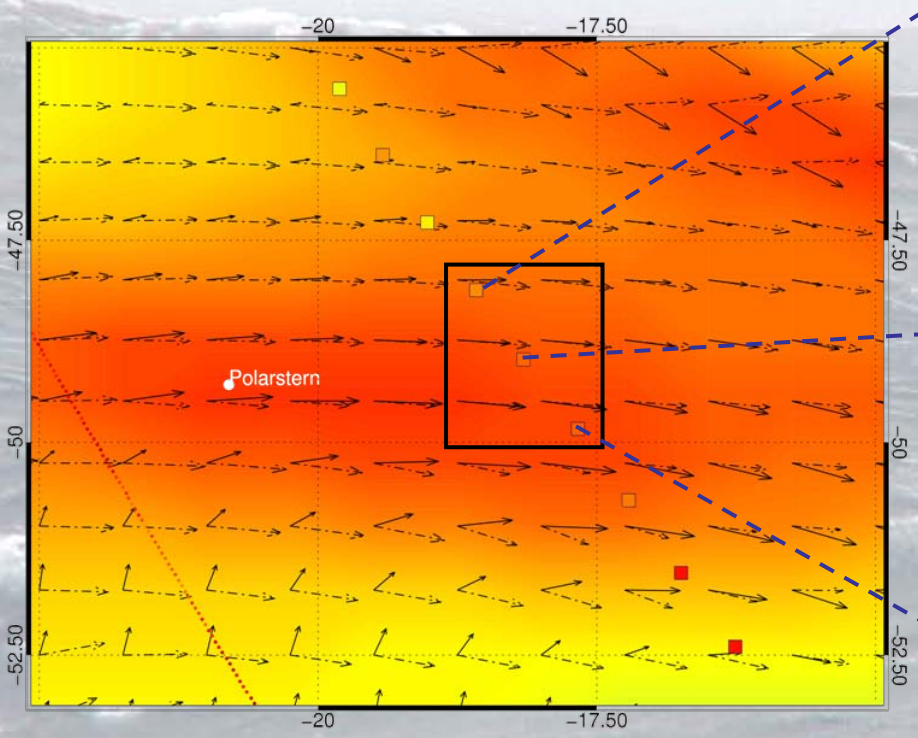
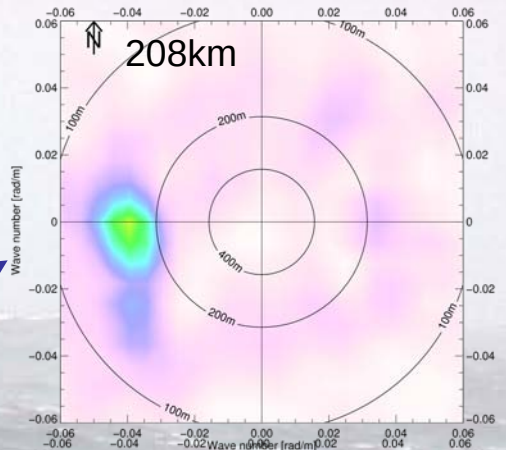
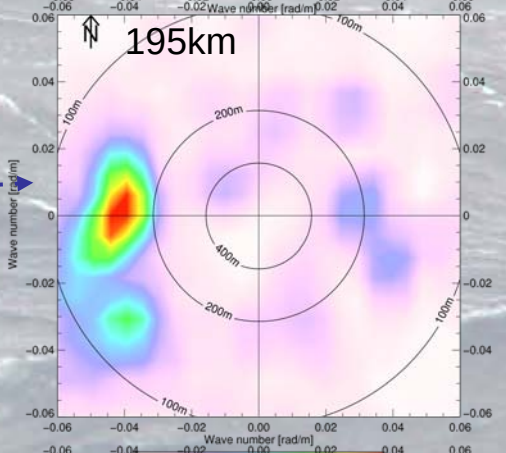
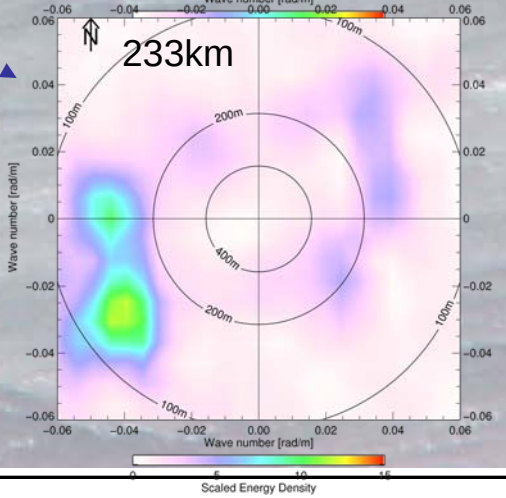
Imaginary parts of ENVISAT ASAR Cross Spectra near to the “Polarstern” shortly after the Rolling Event.









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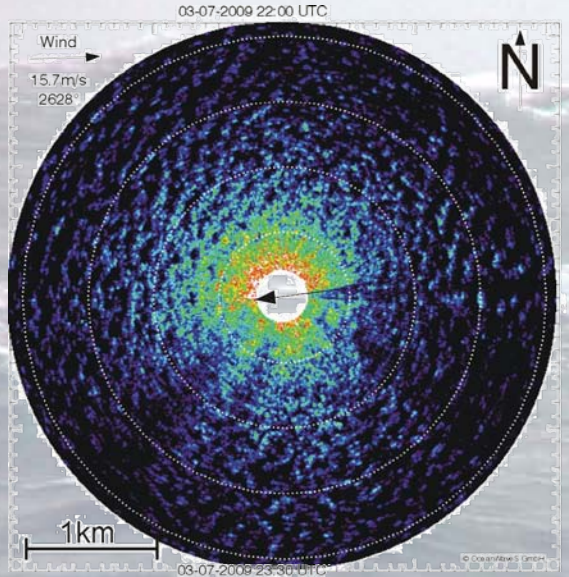
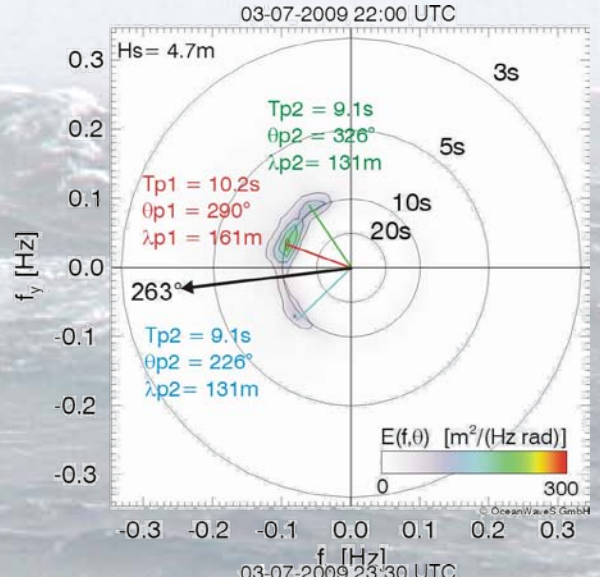
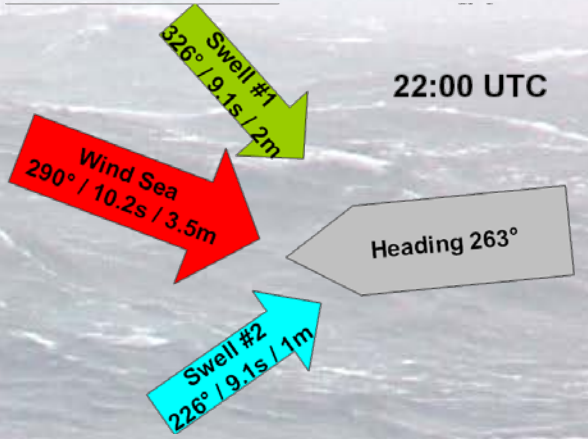
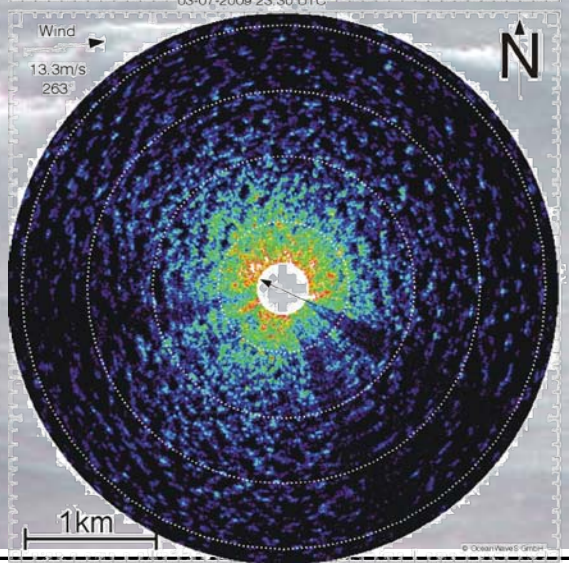
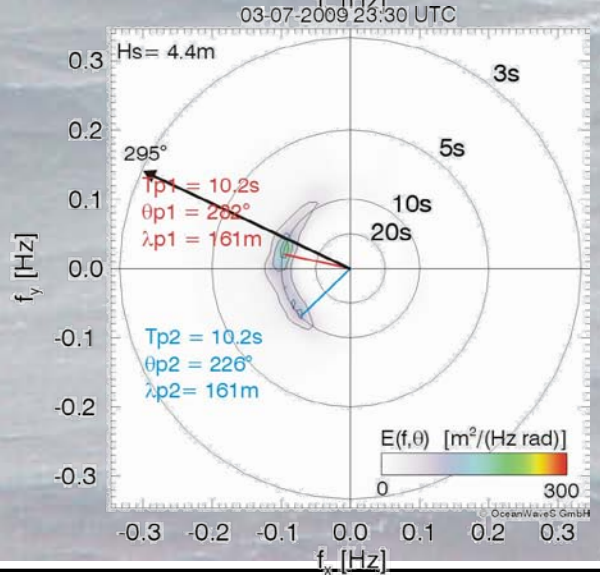
„WaMoS“ Wave Spectra

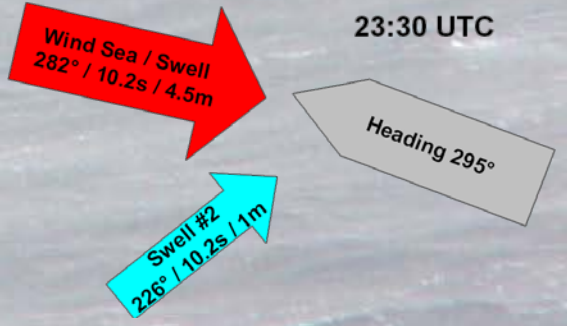












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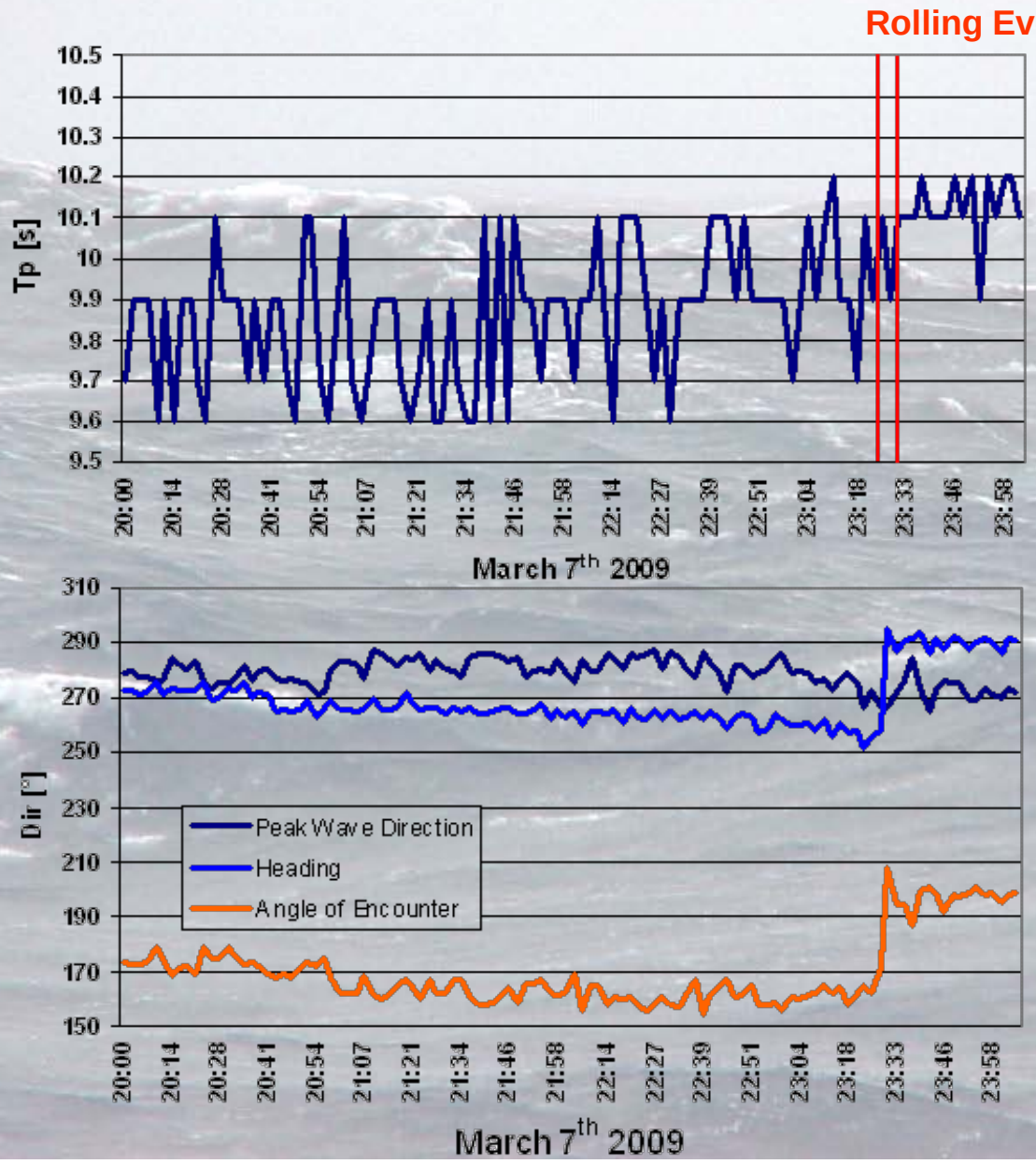
WaMoS 2-min-running mean data



Peak Wave Period

Peak Wave Direction

Heading

Angle of Encounter

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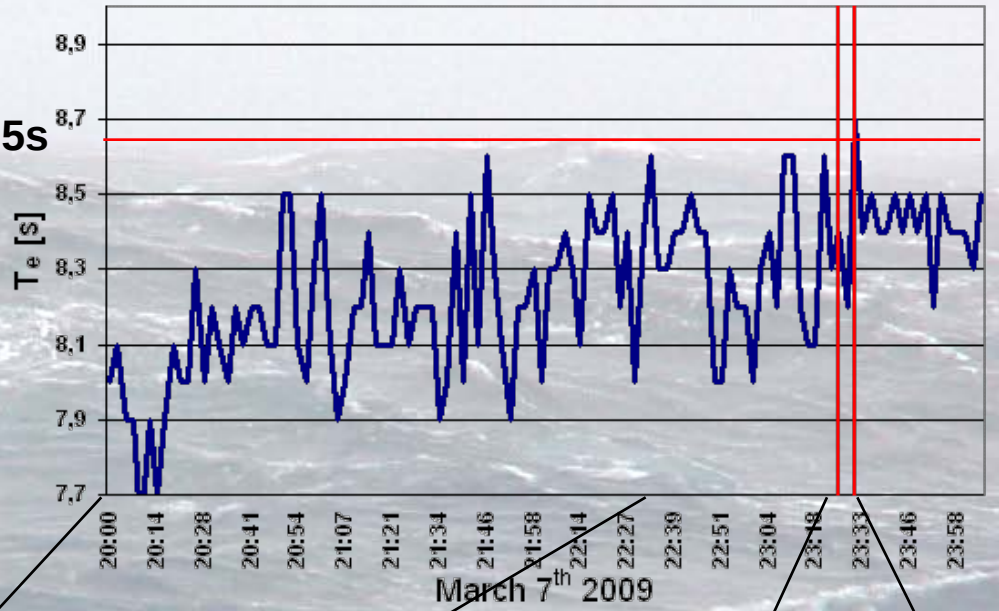
Period of Encounter

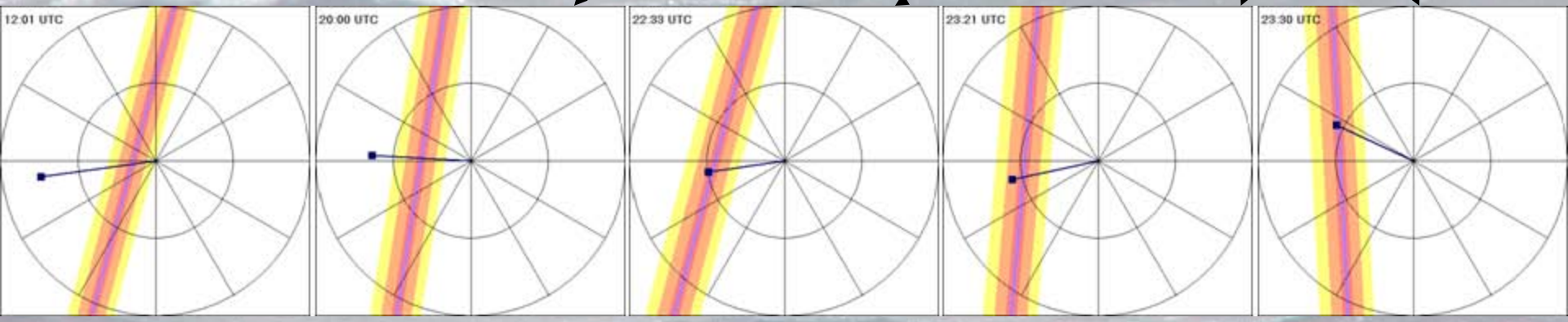
Critical Period 8.65s

Wave Radar

(2-min-running mean)



Resonance Diagrams



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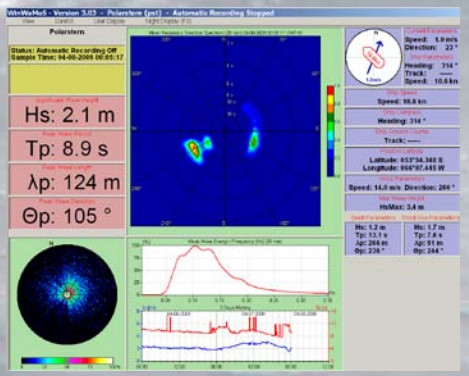
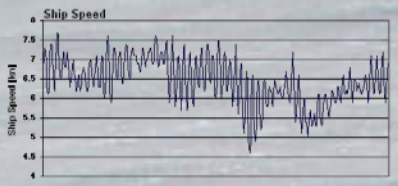
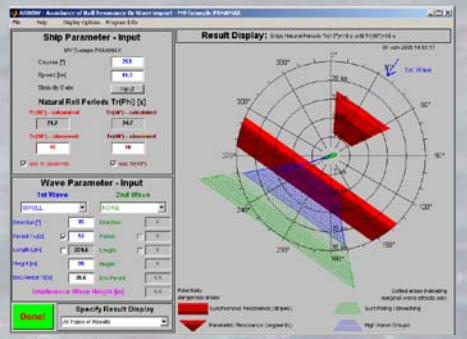
Conclusions (2)

- The Rolling Event was of the „parametric type“
- Parametric Rolling is predictable and avoidable by Monitoring
  - Sea Condition **(Wave Radar + Model Forecasts)**
  - Ship Motion **(Sensors + Accelerators)**
  - Resonance Condition **(Intelligent Software)**







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Thanks for your attention

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