Scatterometer winds

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www.knmi.nl/scatterometer

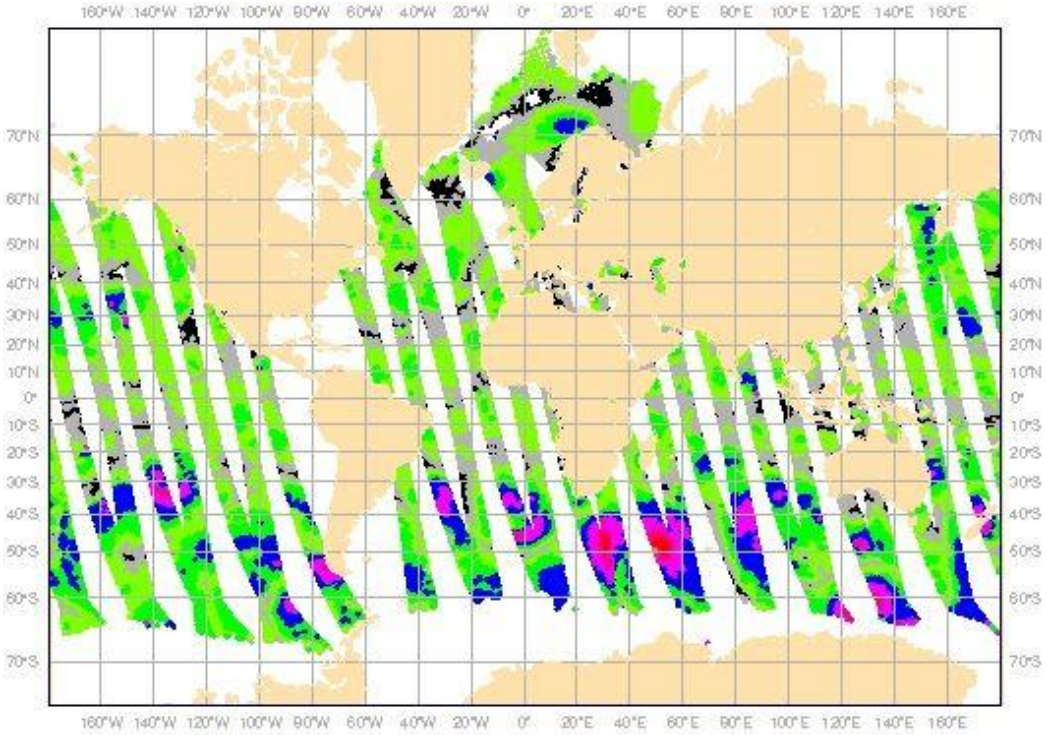
Updated @ 2013-11-04 13:03 utc

OSI SAF ASCAT Coastal product viewer

ASCAT12+, status: pre-operational

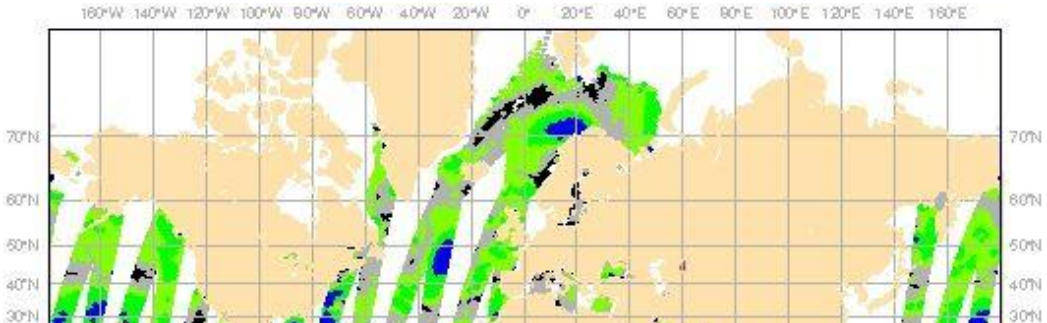
Ascending passes

Click in the map to zoom in



Descending passes

Click in the map to zoom in



Select view
- Monitoring information
- Buoy validations
- Ice maps
- Data from previous day

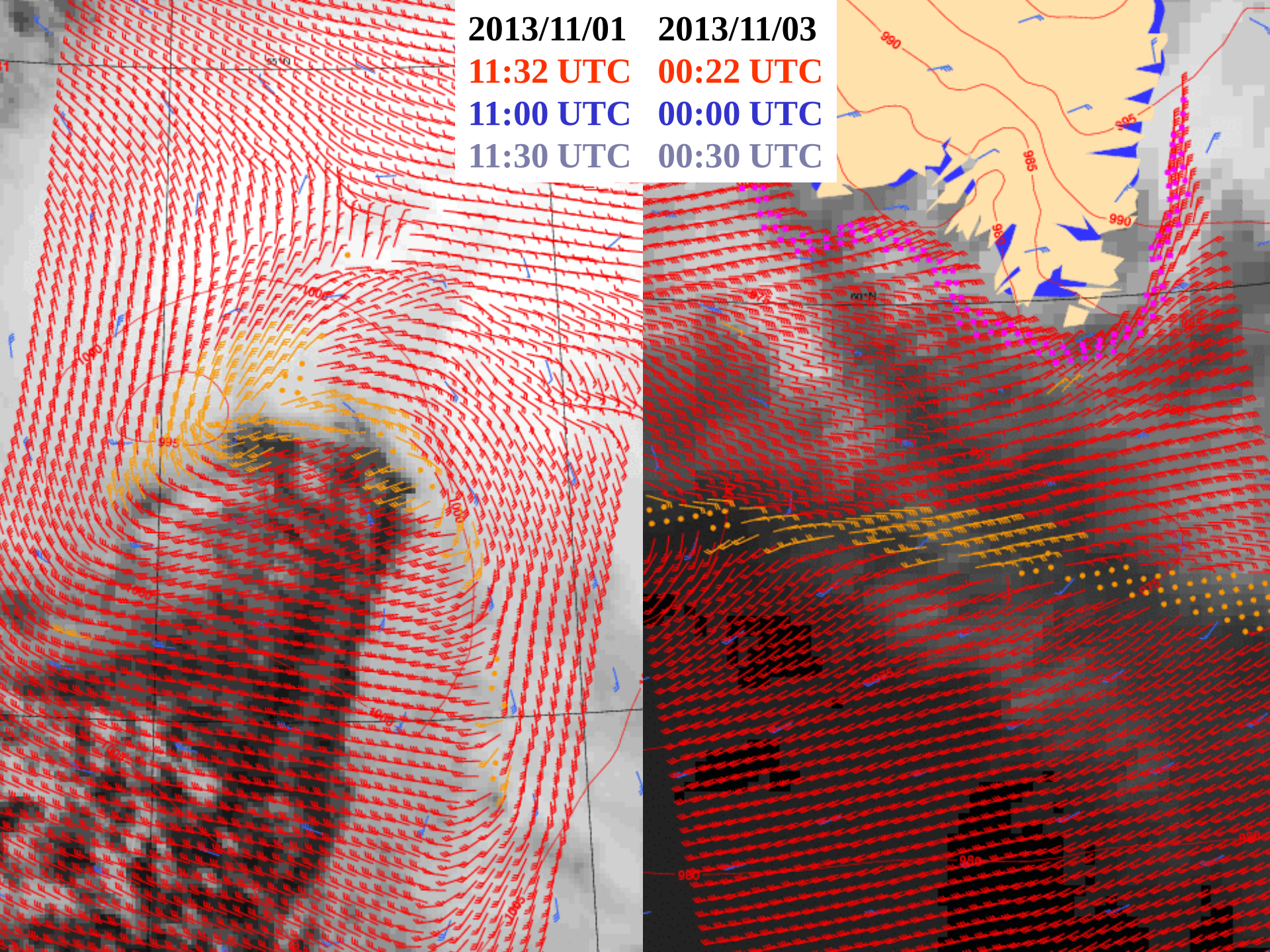
Background information
- Modifications/anomalies
- Description of plots
- Access to products
- Acknowledgements
- ASCAT Product User Manual
- ASCAT Coastal Validation report
- Home OSI SAF Wind Centre

OSI SAF Wind Products
- ASCAT-A 25-km winds
  Operational status
- ASCAT-A 12.5-km winds
  Operational status
- ASCAT-B 25-km winds
  Operational status
- ASCAT-B coastal winds
  Operational status
- Oceansat-2 50-km winds
  Operational status
- QuikSCAT winds
  Discontinued status
- Wind Products Processing Status
- Archived Wind and Stress Product

Other Wind Services at KNMI
- ASCAT 25-km winds (EARS)
  Operational status
- ASCAT 12.5-km winds (EARS)
  Operational status
- ERS-2 winds (EARS)
  Discontinued status
- Scatterometer work at KNMI

Software
- BUFR reader

Related links
- EUMETSAT
- Ocean and Sea Ice SAF
- EUMETSAT EARS system
- Numerical Weather Prediction SA
- Description of ASCAT instrument a
- ASCAT archived data at the EUMET
- ASCAT archived NetCDF data at P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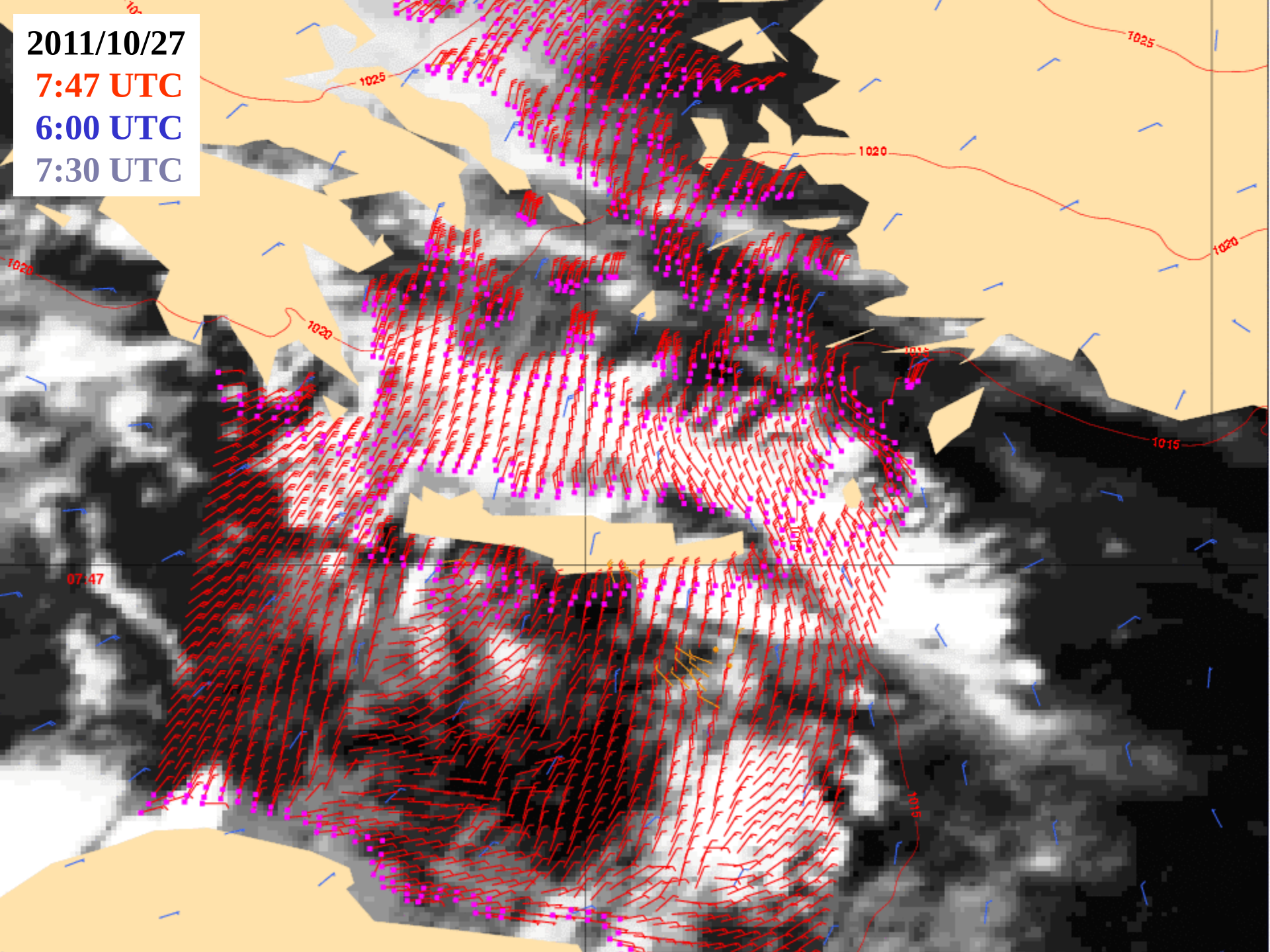
11:00 UTC
11:30 UTC
2013/11/03
00:22 UTC
00:00 UTC
00:30 UTC


2011/10/27
7:47 UTC
6:00 UTC
7:30 UTC
1025
1020
1015
07:47

Overview

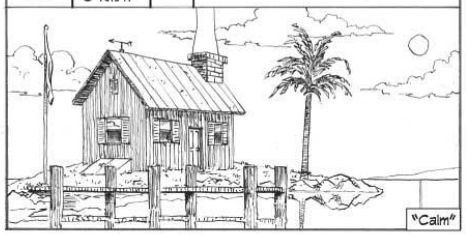
- σ^0 or Normalised Radar Cross Section
- Geophysics, GMF
- Swath geometry, orbit (ASCAT example)
- Accuracy, resolution
- Some limitations
- Applications

The Beaufort Scale

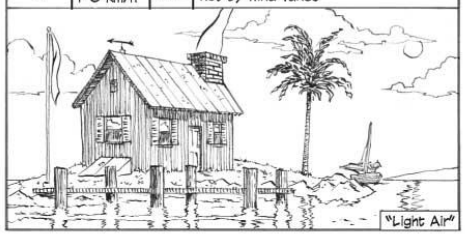
"Over thousands of years sailors have learnt to estimate the speed of the wind just by looking about. This technique matured into what we now call the Beaufort scale. The universe tells you everything you need to know about it as long as you are prepared to watch, to listen, to smell, in short to observe"

.....Howtoons 2006

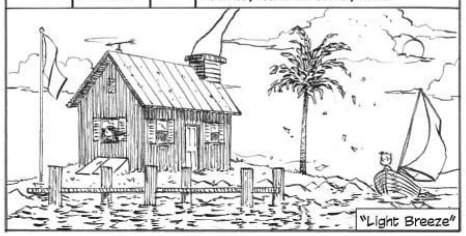
FORCE	SPEED		
0	0 Knots 0 mph 0 km/h	SEA	Sea like a mirror
		LAND	Smoke rises vertically



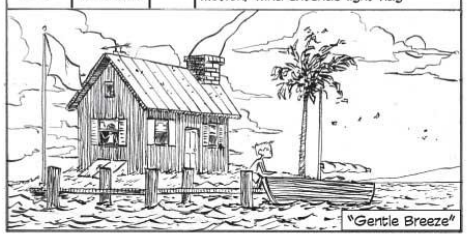
FORCE	SPEED		
1	1-3 Knots 1-3 mph 1-6 km/h	SEA	Ripples with the appearance of scales are formed, but without foam crests
		LAND	Direction of wind shown by smoke but not by wind vanes



FORCE	SPEED		
2	4-6 Knots 4-7 mph 7-11 km/h	SEA	Small wavelets. Crests have a glassy appearance and do not break
		LAND	Wind felt on face; leaves rustle; ordinary vane moved by wind



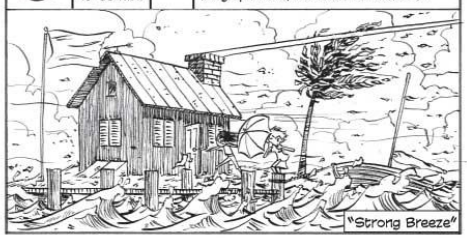
FORCE	SPEED		
3	7-10 Knots 8-12 mph 12-19 km/h	SEA	Large wavelets. Crests begin to break. Foam of glassy appearance.
		LAND	Leaves and small twigs in constant motion; wind extends light flag



FORCE	SPEED		
4	11-16 Knots 13-18 mph 20-29 km/h	SEA	Small waves, becoming longer, fairly frequent white horses
		LAND	Raises dust and loose paper; small branches are moved

FORCE	SPEED		
5	17-21 Knots 19-24 mph 30-39 km/h	SEA	Moderate waves, taking a more pronounced long form; many white horses are formed.
		LAND	Small trees in leaf begin to sway; wavelets form on inland waters

FORCE	SPEED		
6	22-27 Knots 25-31 mph 40-50 km/h	SEA	Large waves begin to form; the white foam crests are more extensive everywhere.
		LAND	Large branches in motion; whistling heard in telegraph wires; umbrellas use difficult.

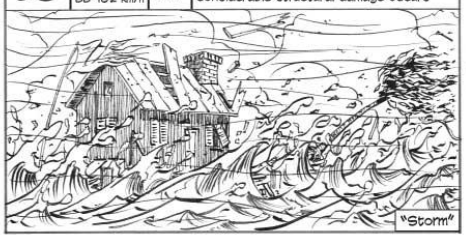


FORCE	SPEED		
7	28-33 Knots 32-38 mph 51-62 km/h	SEA	Sea heaps up and white foam from breaking waves starts to blow in streaks with wind.
		LAND	Whole trees in motion; umbrellas discarded; inconvenience felt when walking

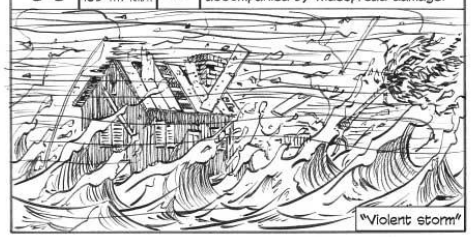
FORCE	SPEED		
8	34-40 Knots 39-46 mph 63-75 km/h	SEA	Moderate high waves of greater length; edges of crests begin to break into spindrift.
		LAND	Breaks twigs off trees; generally impedes progress

FORCE	SPEED		
9	41-47 Knots 47-54 mph 76-87 km/h	SEA	High waves. Crests of waves begin to tumble and roll over. Spray may affect visibility
		LAND	Slight structural damage occurs; chimney pots and slates removed

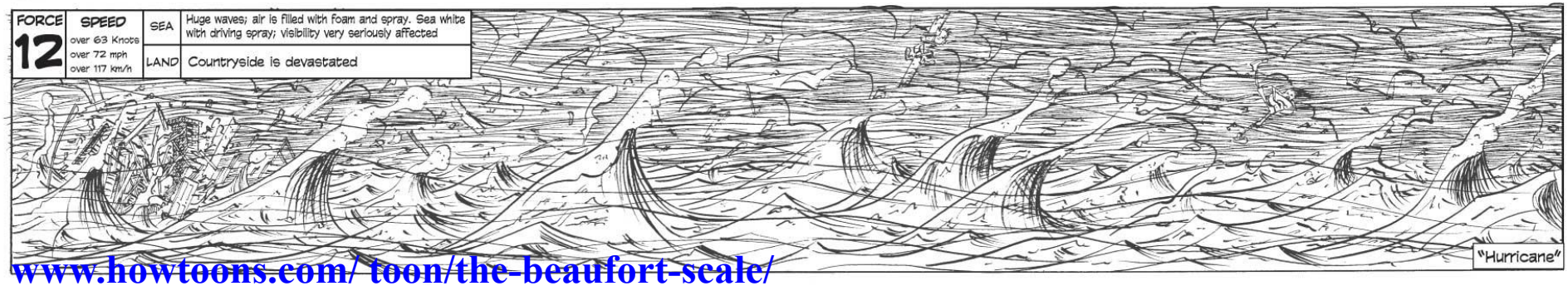
FORCE	SPEED		
10	48-55 Knots 55-63 mph 88-102 km/h	SEA	Very high waves. Surface of the sea takes on a white appearance. Visibility affected
		LAND	Seldom experienced inland; trees uprooted; considerable structural damage occurs



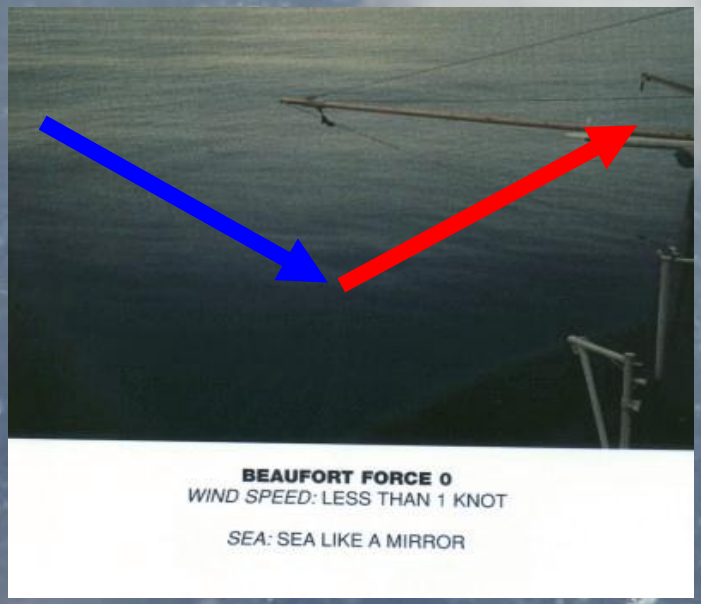
FORCE	SPEED		
11	56-63 Knots 64-72 mph 103-1117 km/h	SEA	Exceptionally high waves. The sea is covered with long white patches of foam.
		LAND	Very rarely experienced on land; accompanied by widespread damage.



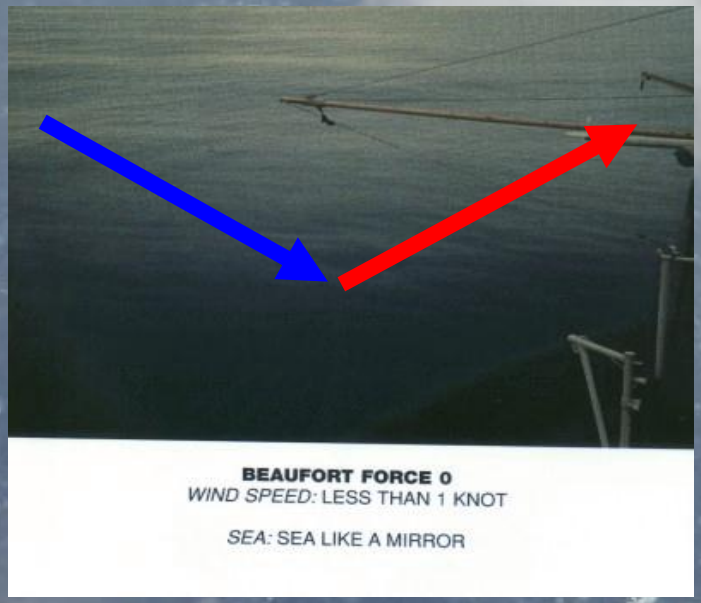
FORCE	SPEED		
12	over 63 Knots over 72 mph over 117 km/h	SEA	Huge waves; air is filled with foam and spray. Sea white with driving spray; visibility very seriously affected
		LAND	Countryside is devastated



Backscatter modulation by surface roughness

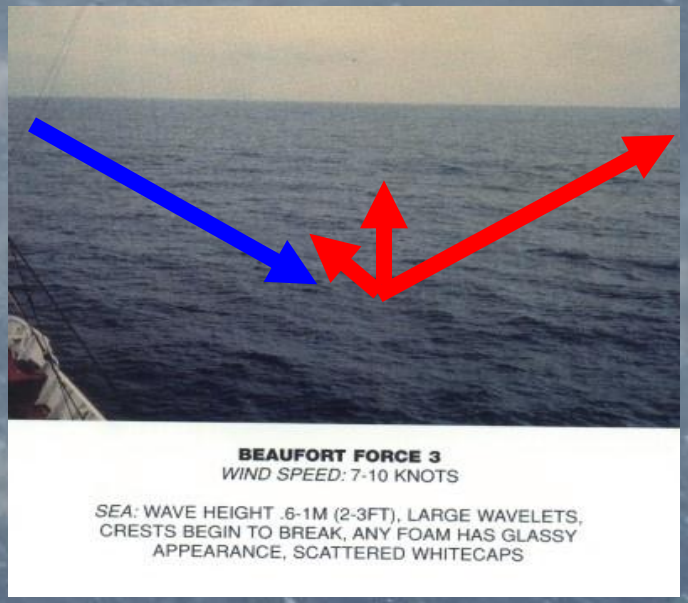


Backscatter modulation by surface roughness



BEAUFORT FORCE 0
WIND SPEED: LESS THAN 1 KNOT

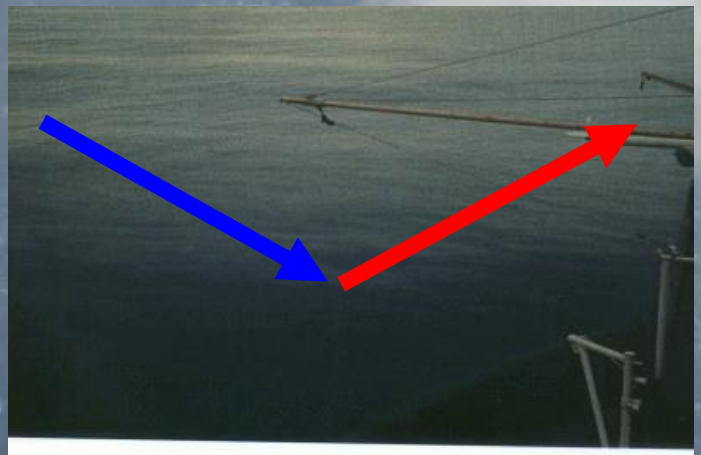
SEA: SEA LIKE A MIRROR



BEAUFORT FORCE 3
WIND SPEED: 7-10 KNOTS

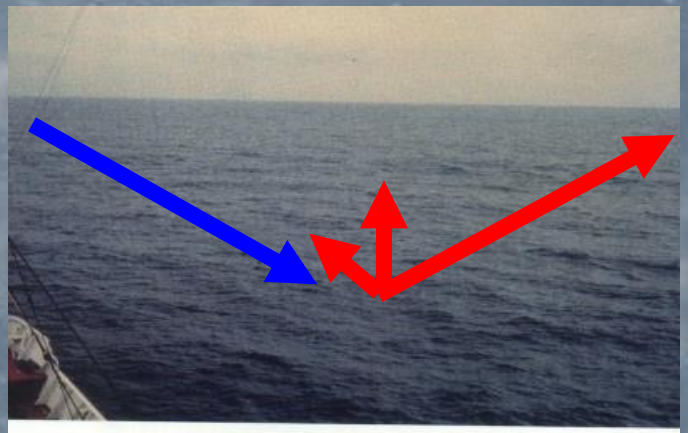
SEA: WAVE HEIGHT .6-1M (2-3FT), LARGE WAVELETS, CRESTS BEGIN TO BREAK, ANY FOAM HAS GLASSY APPEARANCE, SCATTERED WHITECAPS

Backscatter modulation by surface roughness



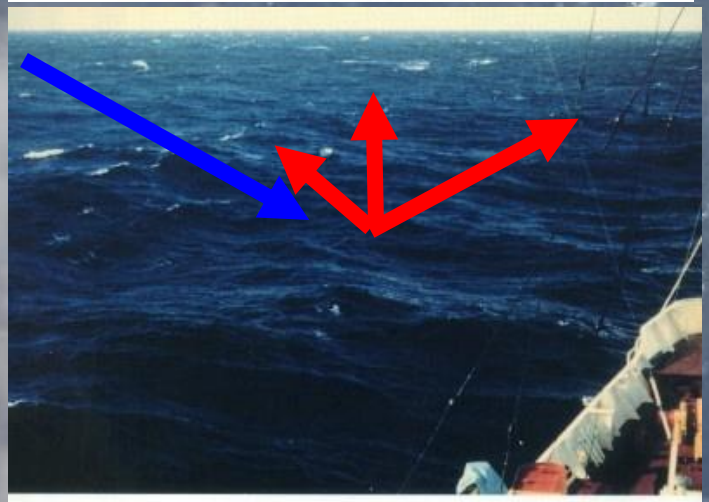
BEAUFORT FORCE 0
WIND SPEED: LESS THAN 1 KNOT

SEA: SEA LIKE A MIRROR



BEAUFORT FORCE 3
WIND SPEED: 7-10 KNOTS

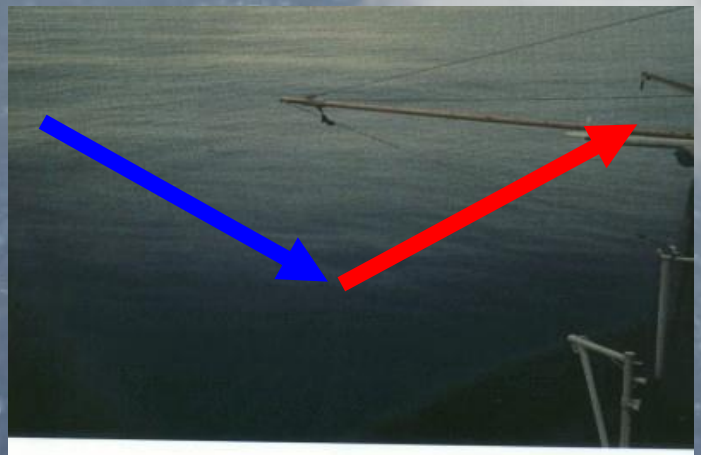
SEA: WAVE HEIGHT .6-1M (2-3FT), LARGE WAVELETS, CRESTS BEGIN TO BREAK, ANY FOAM HAS GLASSY APPEARANCE, SCATTERED WHITECAPS



BEAUFORT FORCE 6
WIND SPEED: 22-27 KNOTS

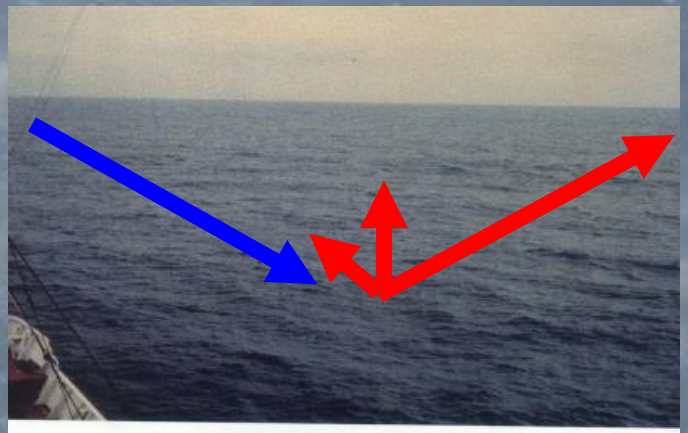
SEA: WAVE HEIGHT 3-4M (9.5-13 FT), LARGER WAVES BEGIN TO FORM, SPRAY IS PRESENT, WHITE FOAM CRESTS ARE EVERYWHERE

Backscatter modulation by surface roughness



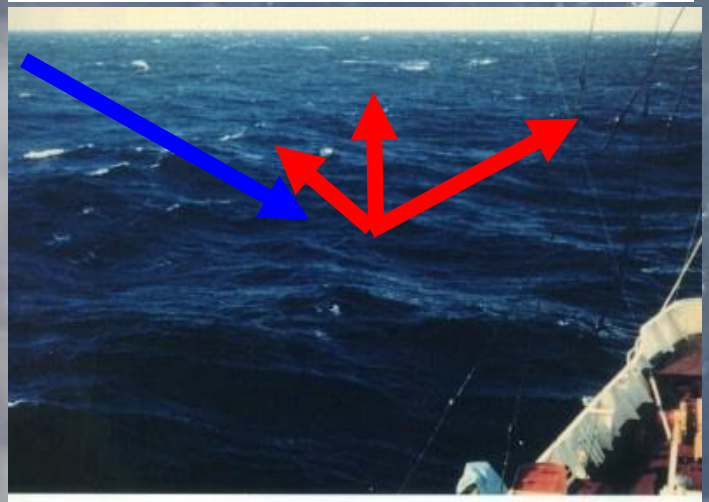
BEAUFORT FORCE 0
WIND SPEED: LESS THAN 1 KNOT

SEA: SEA LIKE A MIRROR



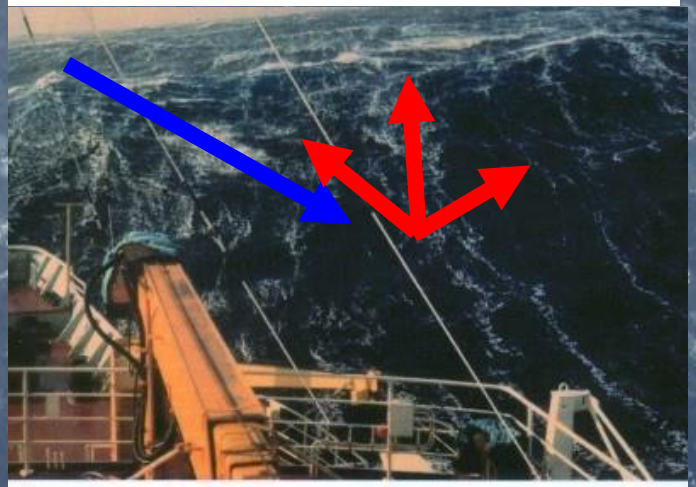
BEAUFORT FORCE 3
WIND SPEED: 7-10 KNOTS

SEA: WAVE HEIGHT .6-1M (2-3FT), LARGE WAVELETS, CRESTS BEGIN TO BREAK, ANY FOAM HAS GLASSY APPEARANCE, SCATTERED WHITECAPS



BEAUFORT FORCE 6
WIND SPEED: 22-27 KNOTS

SEA: WAVE HEIGHT 3-4M (9.5-13 FT), LARGER WAVES BEGIN TO FORM, SPRAY IS PRESENT, WHITE FOAM CRESTS ARE EVERYWHERE

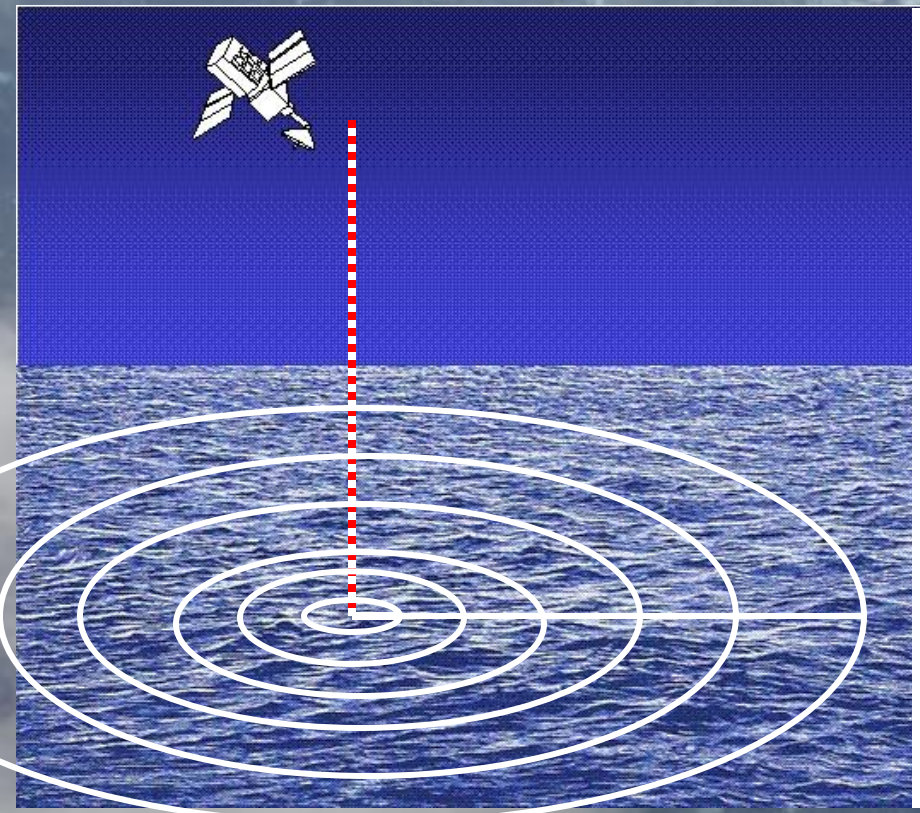


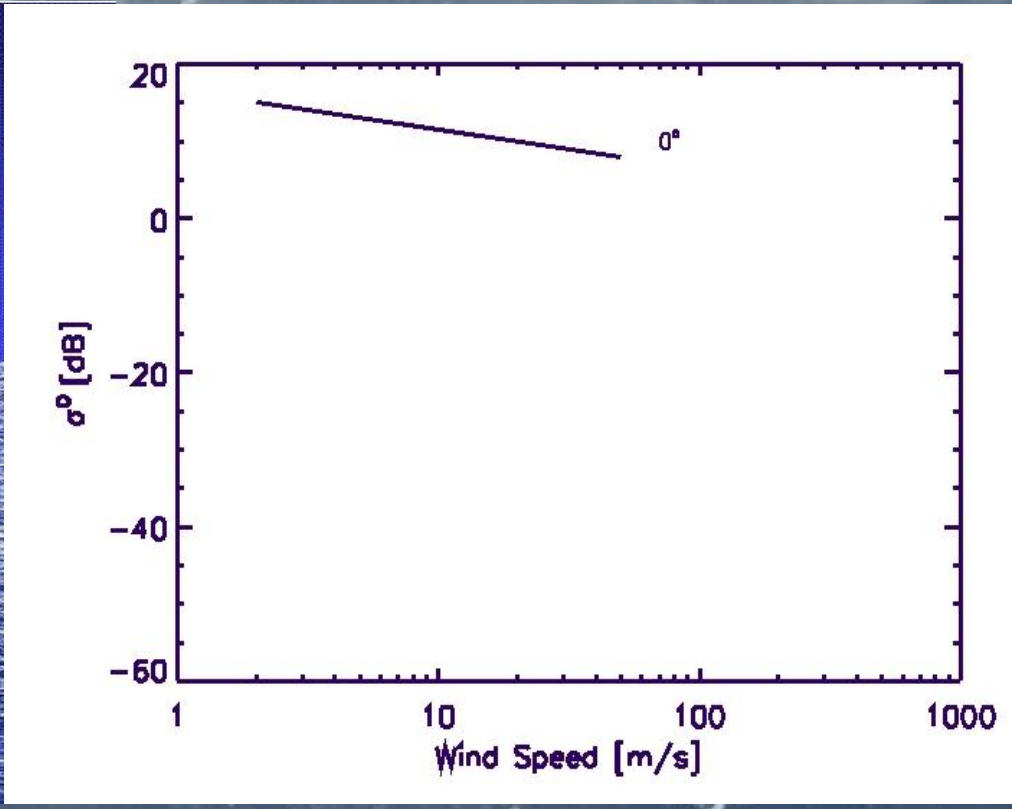
BEAUFORT FORCE 9
WIND SPEED: 41-47 KNOTS

SEA: WAVE HEIGHT 7-10M (23-32FT), HIGH WAVES, DENSE STREAKS OF FOAM ALONG DIRECTION OF THE WIND, WAVE CRESTS BEGIN TO TOPPLE, TUMBLE, AND ROLL OVER. SPRAY MAY AFFECT VISIBILITY.

Backscatter as a Function of Wind Speed and Incidence Angle

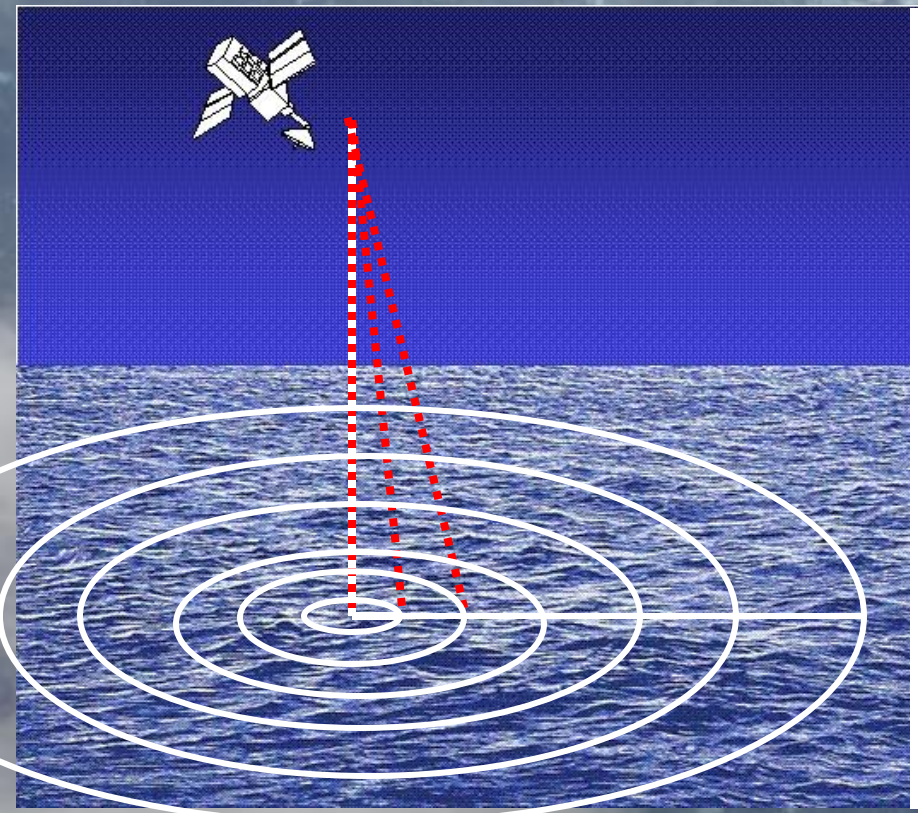
At incidence angles of 0° backscatter decreases with wind

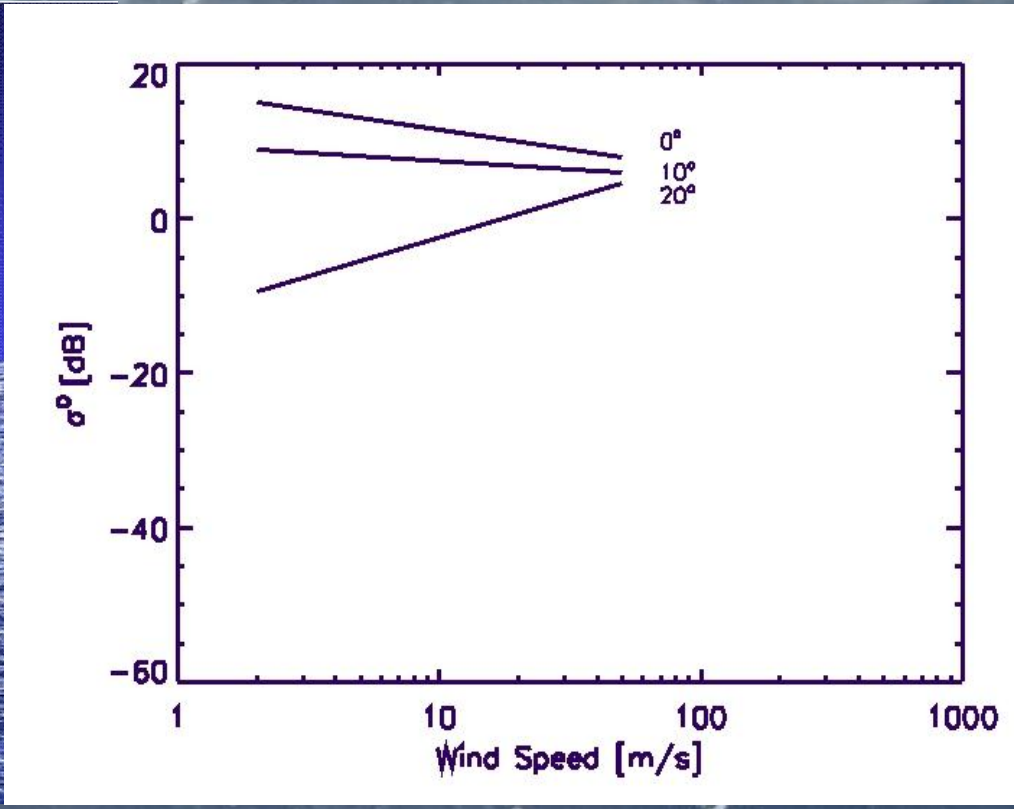




Backscatter as a Function of Wind Speed and Incidence Angle

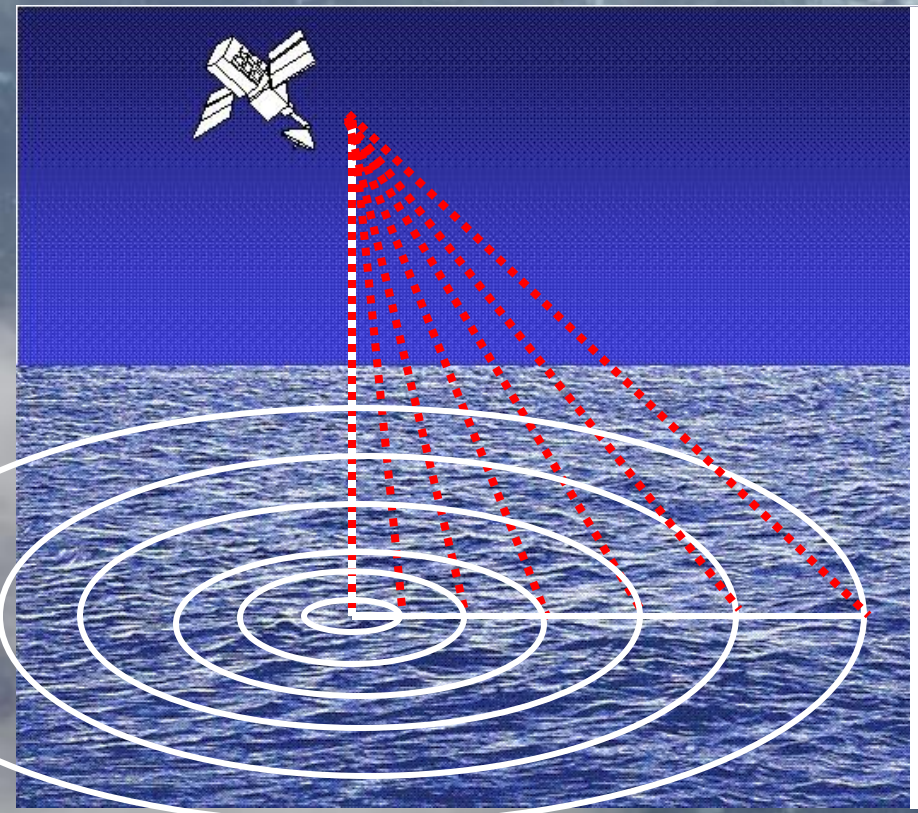
At incidence angles of 20° backscatter increases with wind

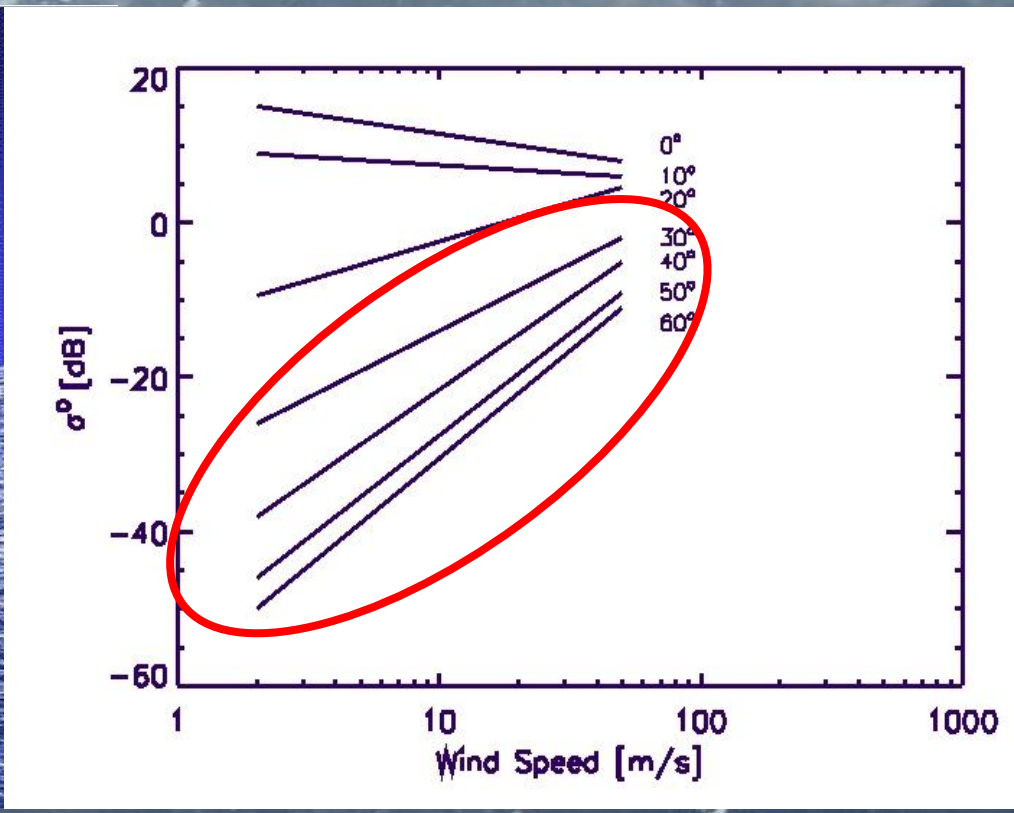




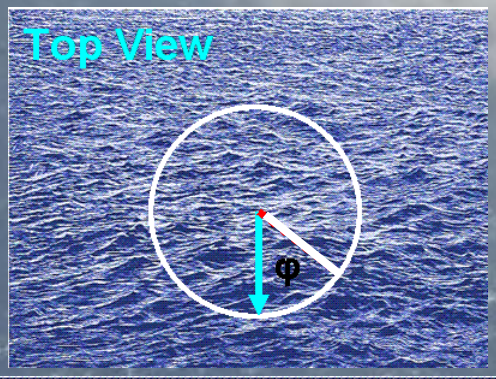
Backscatter as a Function of Wind Speed and Incidence Angle

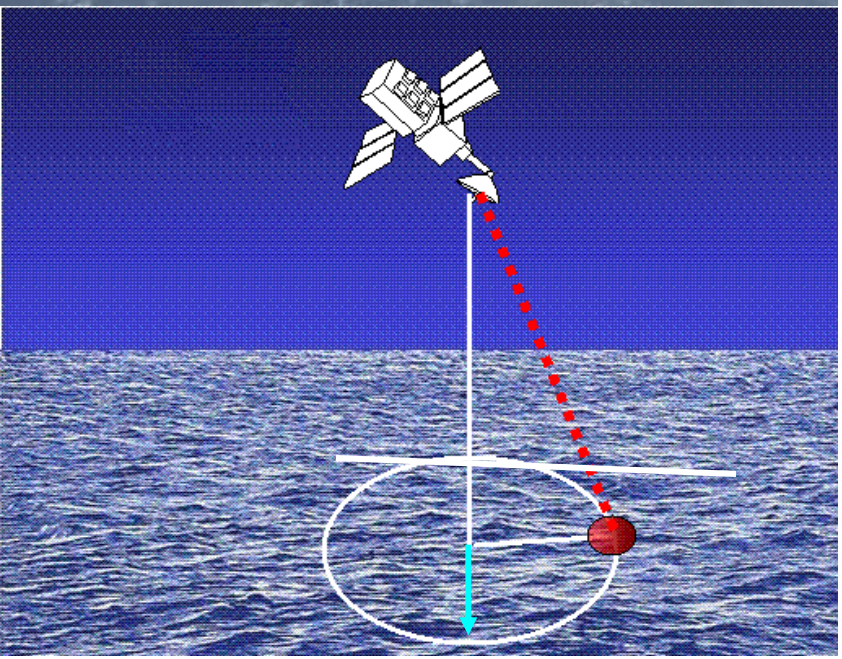
Most sensitivity to wind at moderate incidence angles 30°-60°

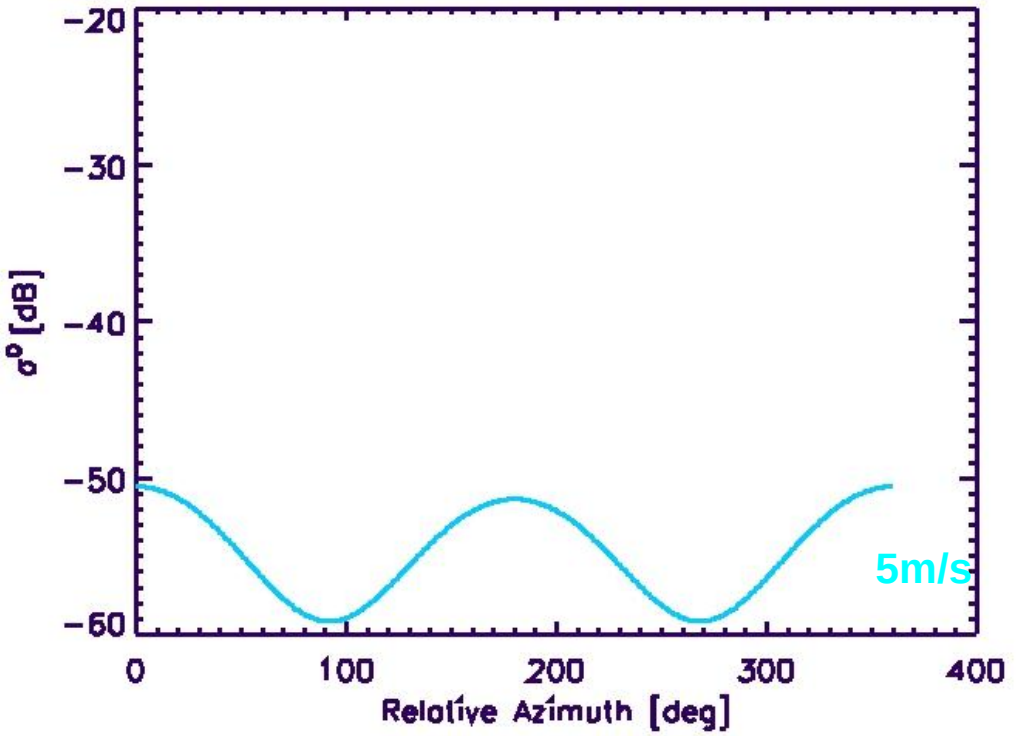




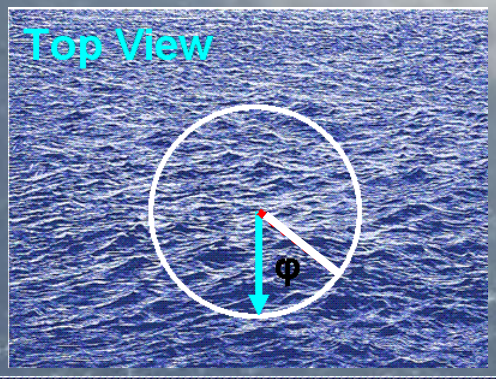
Backscatter Sensitivity to Wind Direction

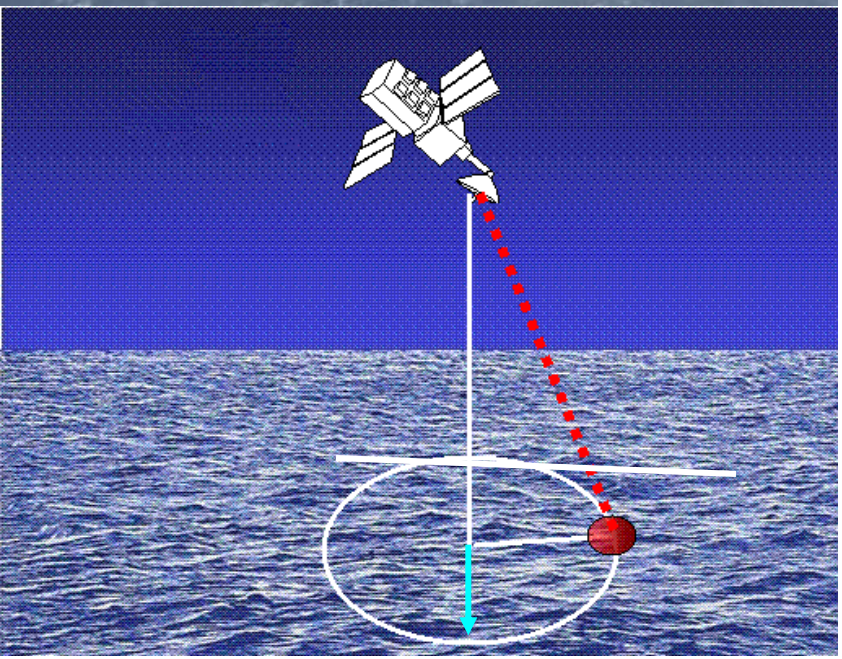


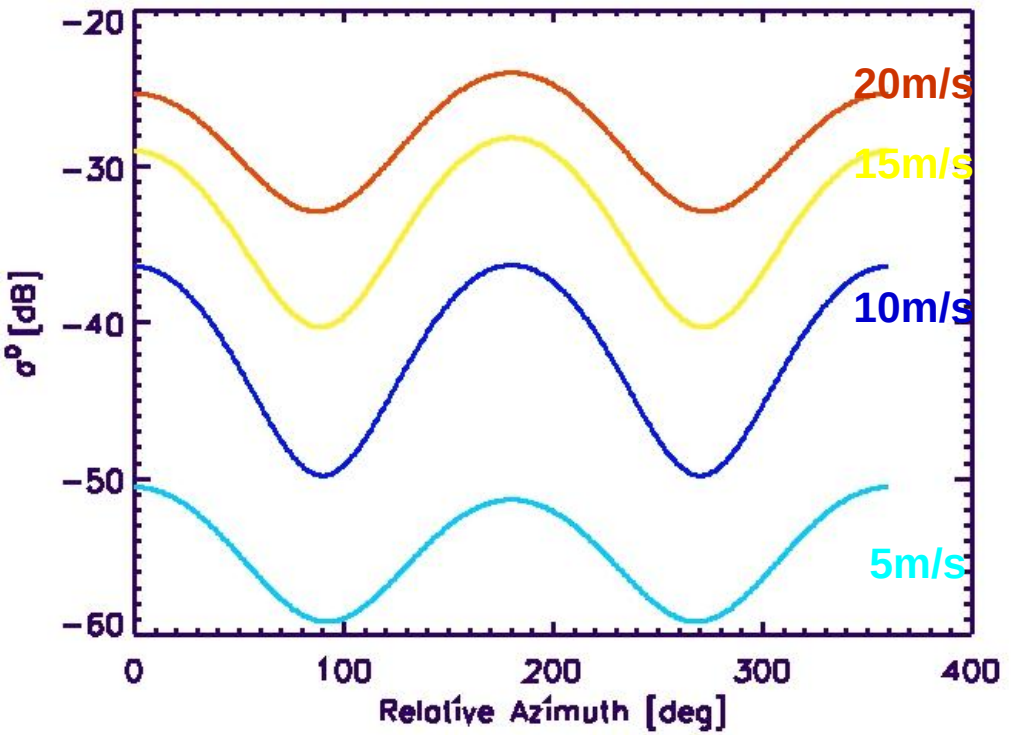




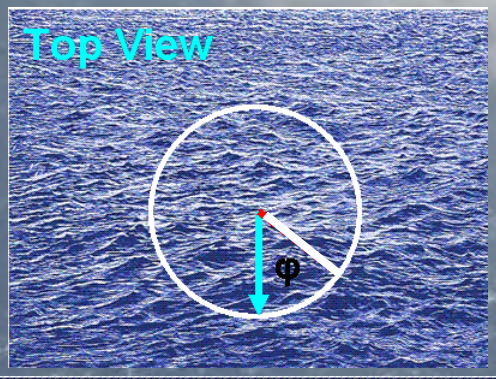
Backscatter Sensitivity to Wind Direction

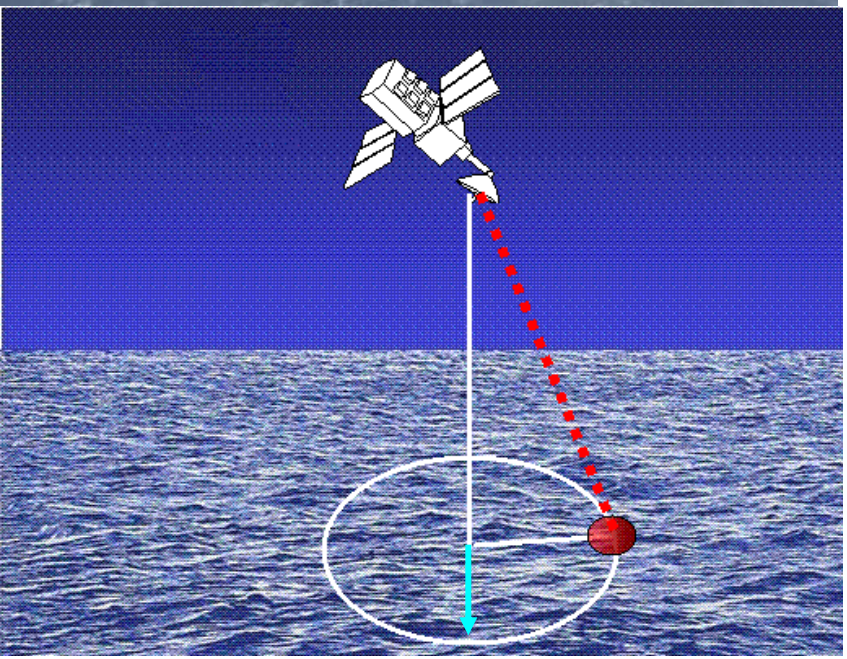


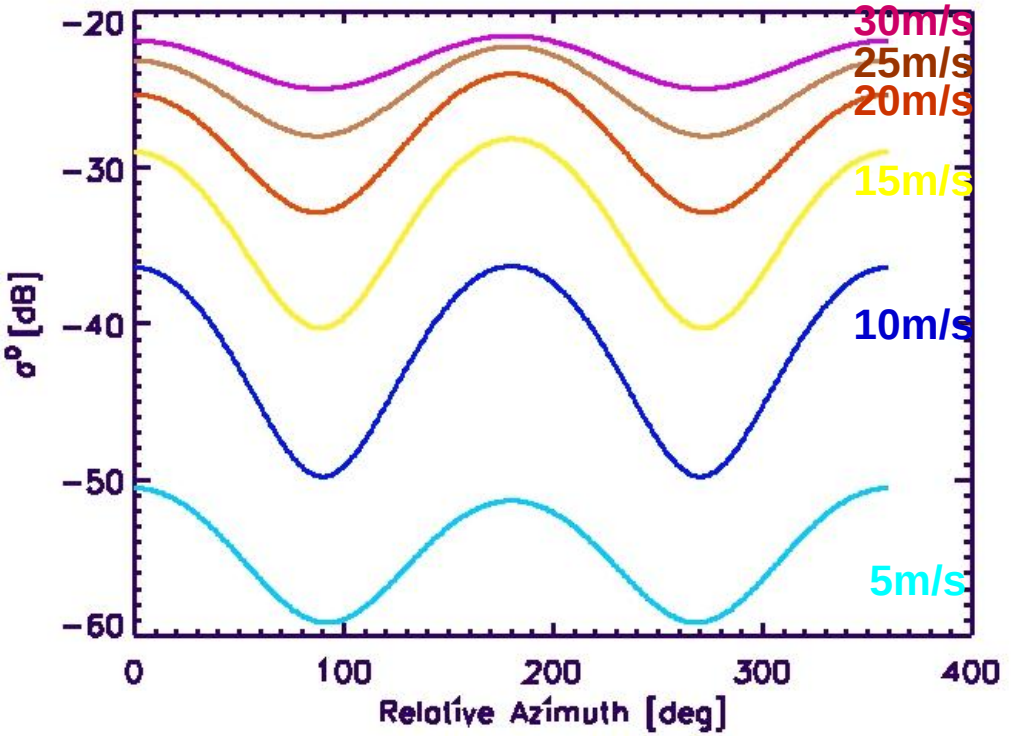




Backscatter Sensitivity to Wind Direction







® Z.Jelenak

Back Scattering Theory

- Bragg scattering
  - Incoming microwave radiation in resonance with short waves (dominant for $30^\circ < \theta < 70^\circ$)

$$\lambda_B = \lambda/(2\sin(\theta))$$

- Specular reflection
  - Ocean facets normal to incident radiation (non-negligible for $\theta < 30^\circ$)

- Accuracy of theoretical models ~1 dB and not adequate

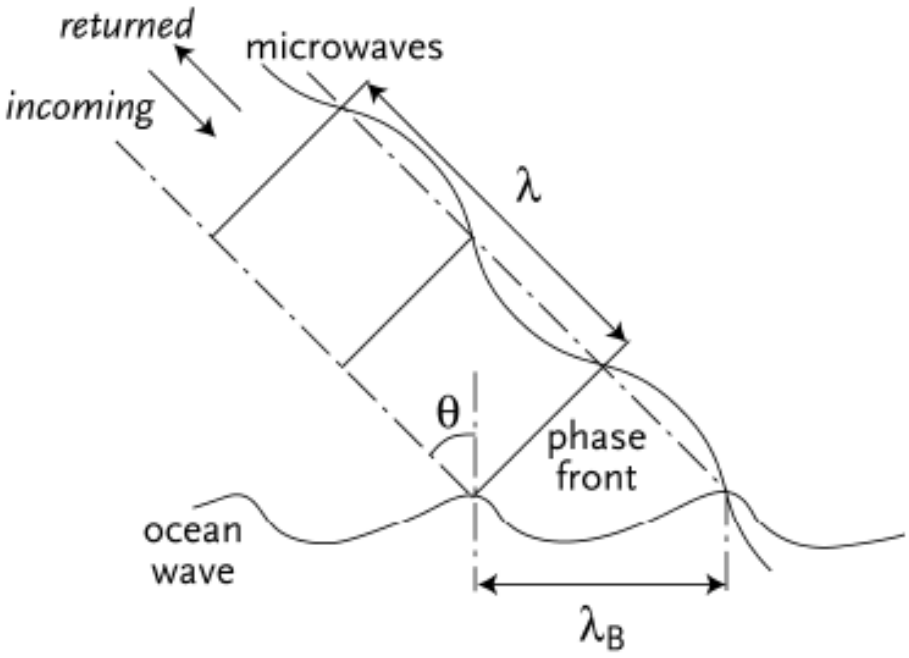


Figure 11. Bragg scattering: A plan-parallel radar beam with wavelength λ hits the rough ocean surface at incidence angle θ, where capillary gravity waves with Bragg wavelength λ_B will cause microwave resonance.

λ ~ 2cm (Ku-band) ; λ ~ 5cm (C-band)

Geophysical Model Function

- An empirical geophysical model function (GMF) relates ocean surface wind speed and direction to the backscatter cross section measurements.

$$\sigma_o^{\text{model}} = GMF(U_{10N}, \phi, \theta, p, \lambda)$$

U_{10N}: equivalent neutral wind speed
ϕ : wind direction w.r.t. beam pointing
θ : incidence angle
p : radar beam polarization
λ : microwave wavelength

Equivalent neutral wind U_{10N}

$$U_{10} = \frac{u_* \left[\ln(10/z_0) - \psi(10/L) \right]}{k} + U_S$$

$$z_0 = \frac{0.11 \cdot \nu}{u_*} + \frac{\alpha \cdot u_*^2}{g}$$

$$U_{10N} = \frac{u_* \ln(10/z_0)}{k}$$

- U_{10} depends on air stability ψ while σ^0 is a sea property
- Surface roughness z_0 relates to σ^0 and depends on friction velocity u_* and thus on stress
- U_{10N} is computed from u_* by setting $\psi = 0$ and is available from NWP models and buoys
- GMF fits σ^0 and collocated U_{10N}
- So, σ^0 = GMF (U_{10N}, ϕ, θ, p, λ)
- NWP models usually ignore current (U_s = 0), but a scatterometer does measure relative to ocean motion

Portabella & Stoffelen, 2009

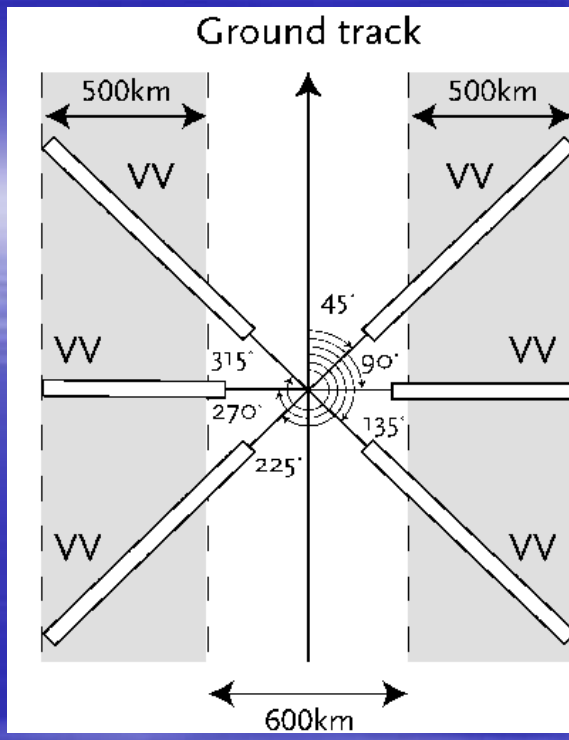
Current scatterometer instruments

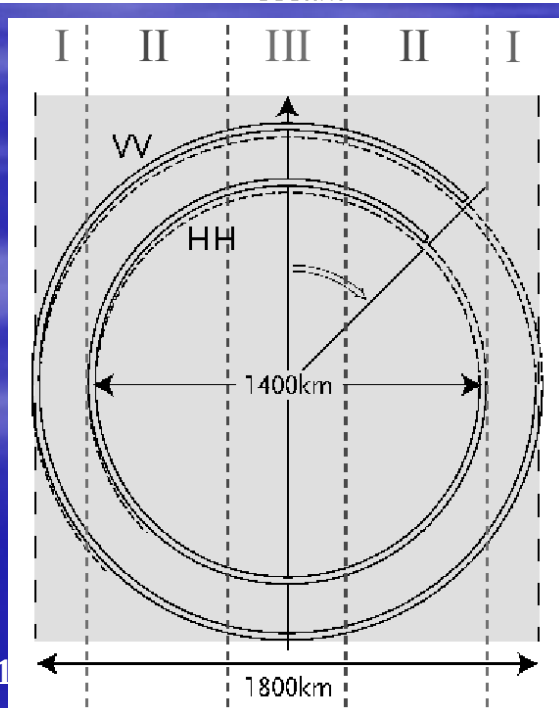
Fixed fan beam

- C-band (5 cm)
- VV-pol
- Sampling 12.5-25 km
- Static geometry
- ASCAT, double swath
- ERS2, single swath

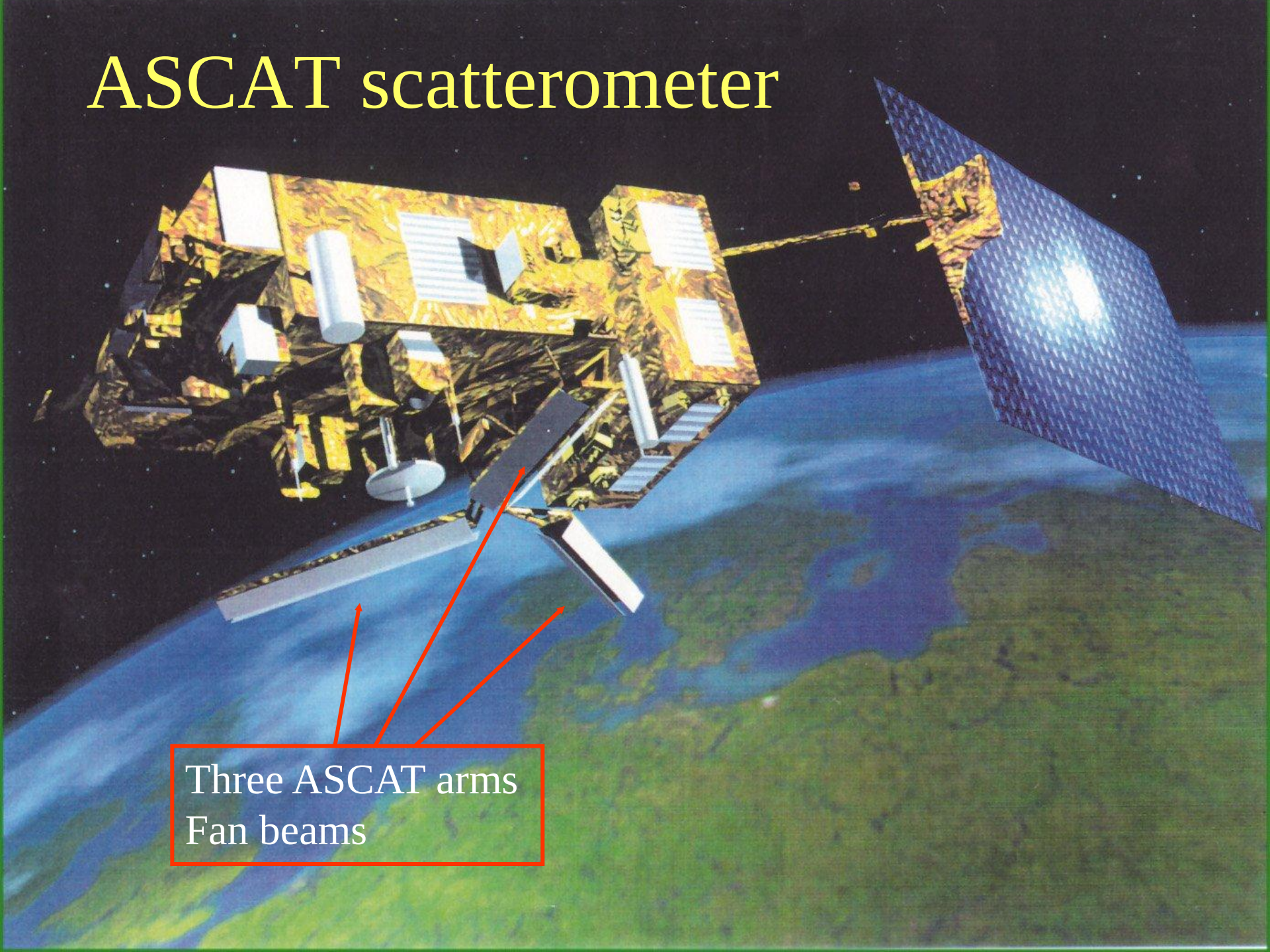
Rotating pencil beam

- Ku-band (2 cm)
- Dual polarization
- Sampling 25 km, 50 km
- Rotating antenna
- OSCAT, QuikScat, HY2A
- RAIN

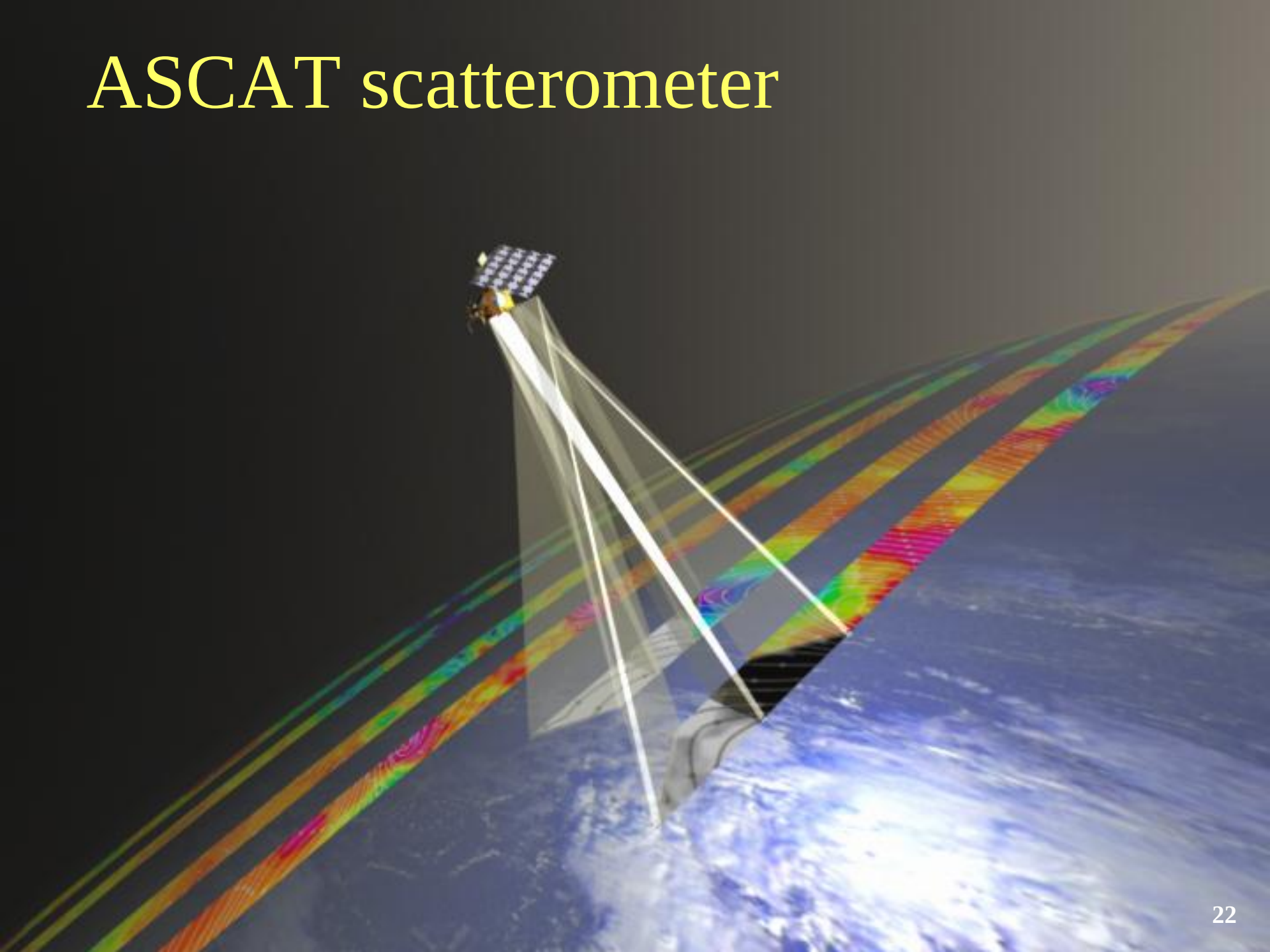




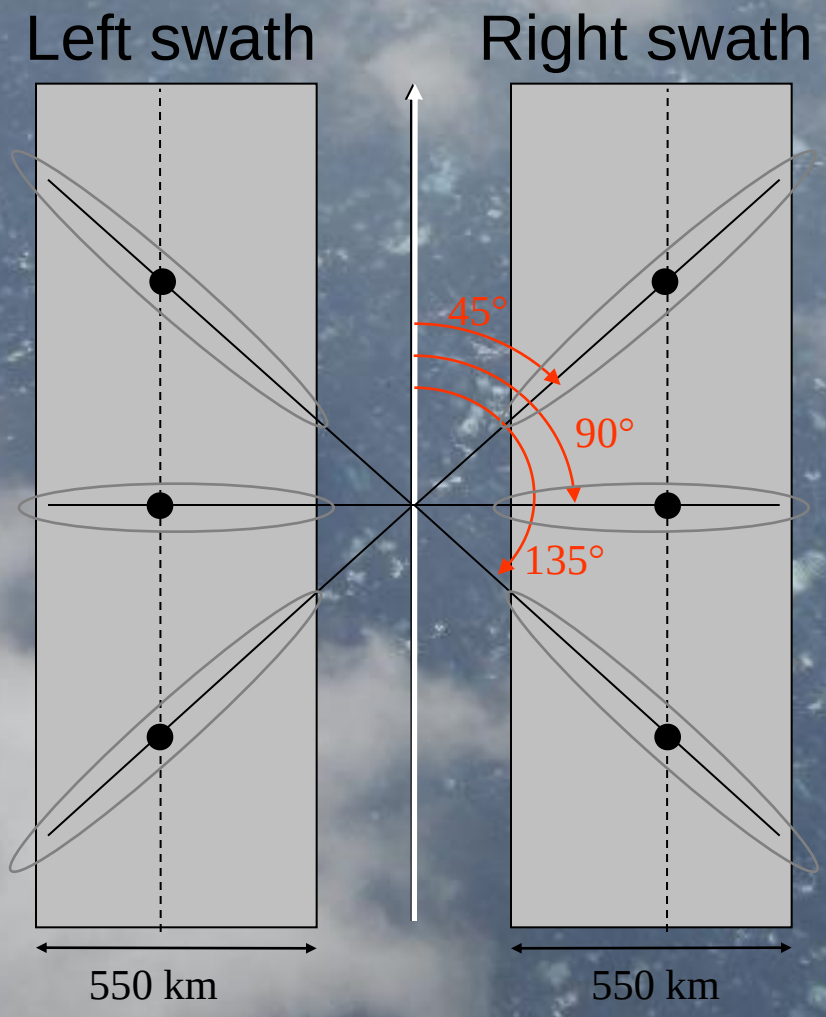
ASCAT scatterometer



ASCAT scatterometer

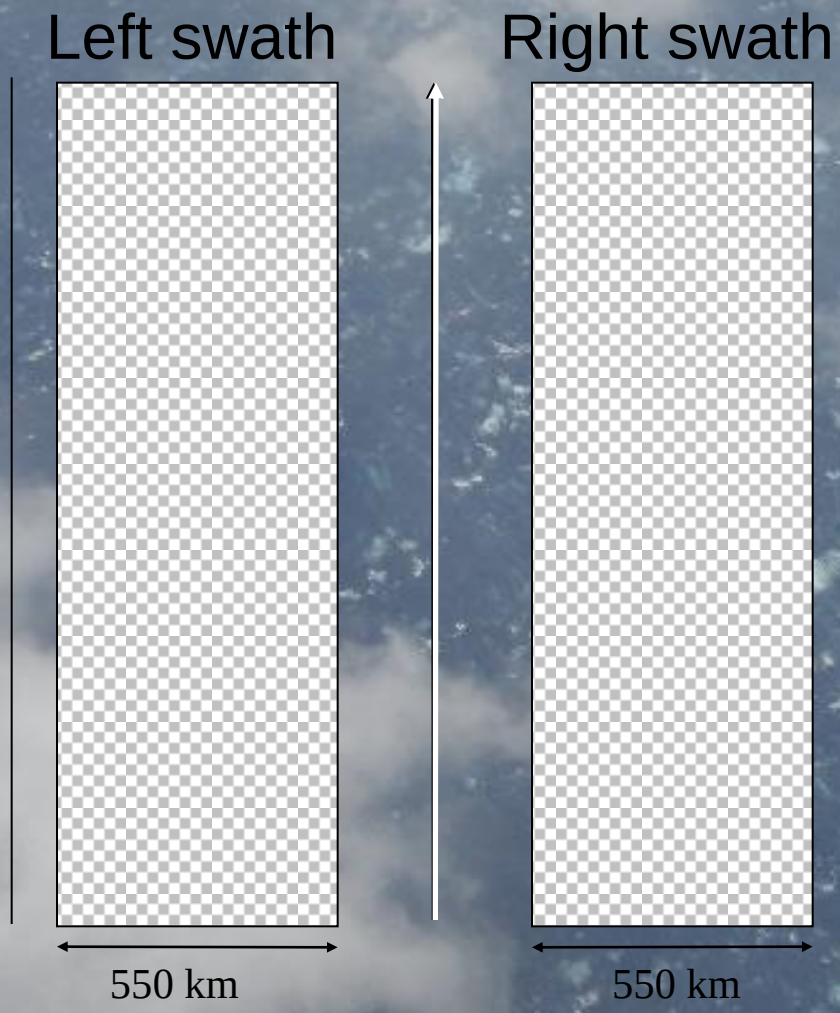


ASCAT observation geometry



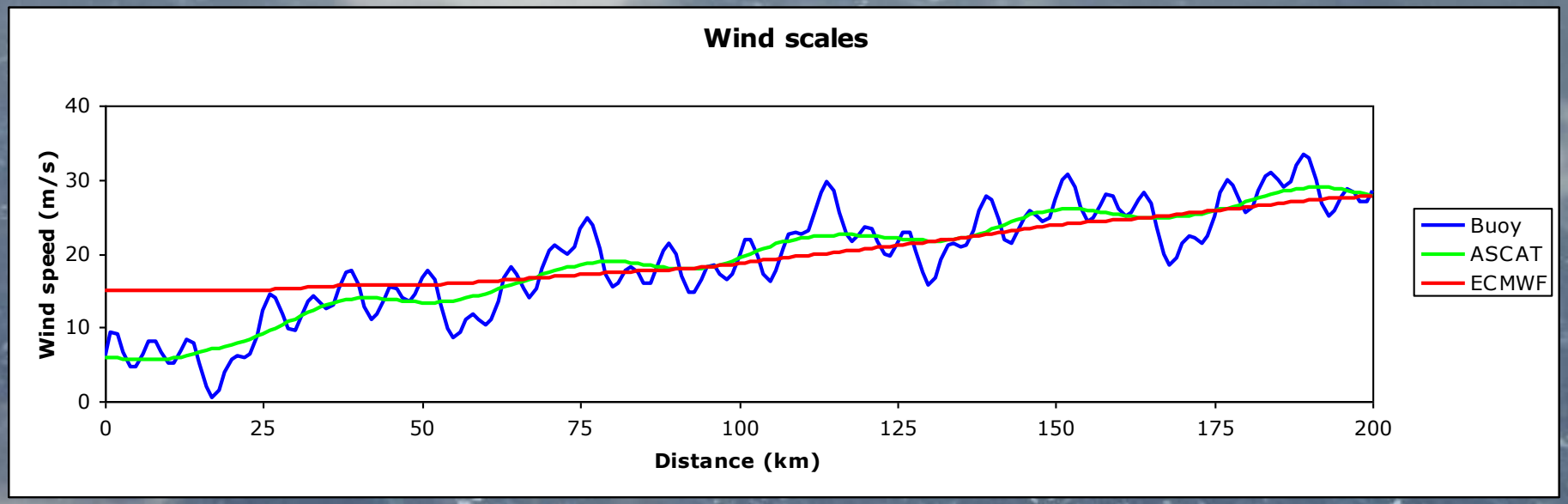
- Real aperture radar, 5.255 GHz (C-band), VV polarisation
- All weather measuring capability
- Measuring geometry: 3 fan-beam antennas, double swath, incidence angles between 25 and 65 deg
- Measurement: normalised radar cross-section (NRCS, backscatter, $\sigma 0$)
- Swath gridded into nodes (25 km and 12.5 km spacing), one triplet of averaged backscatter measurements per node

ASCAT observation geometry



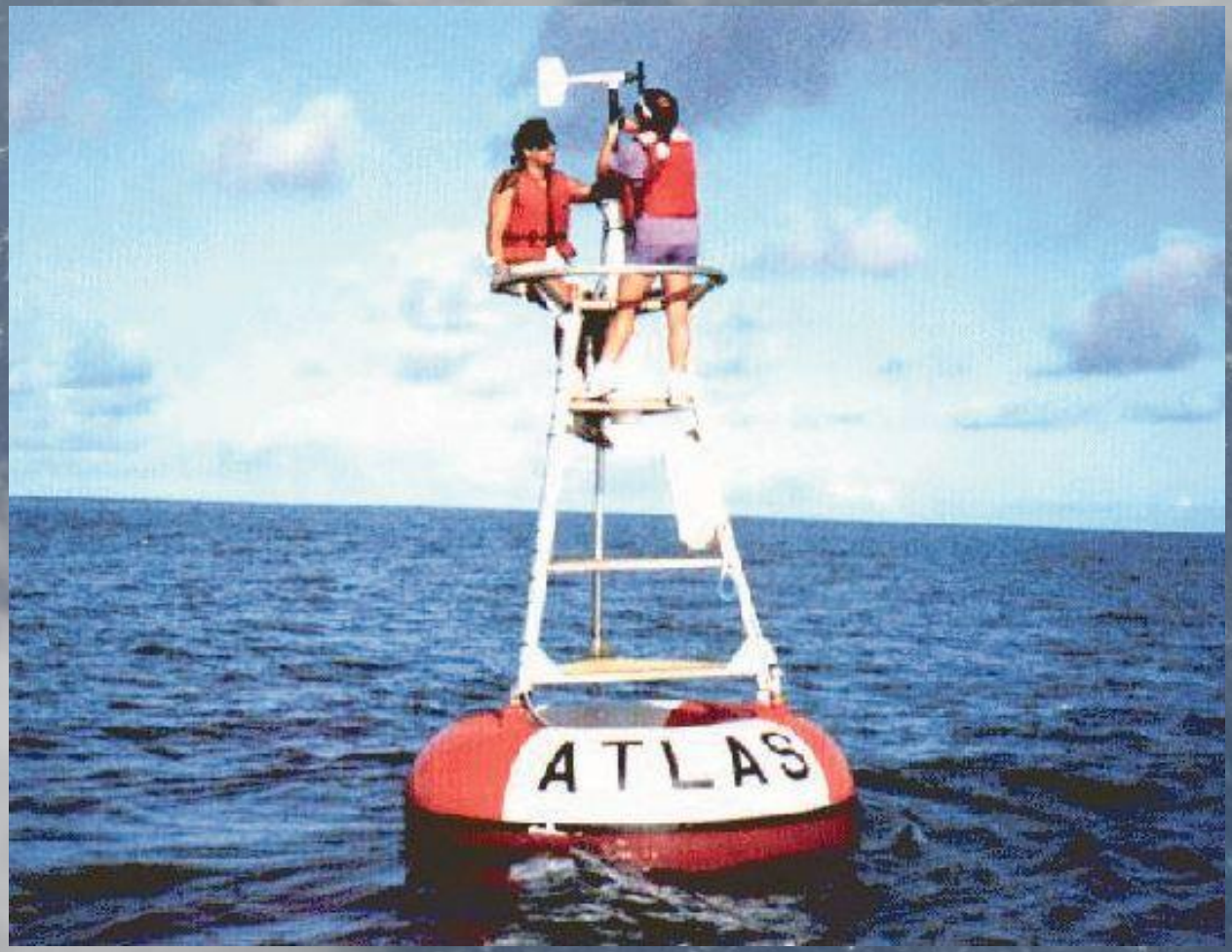
- Each swath is divided into 21 Wind Vector Cells (WVCs) for the 25 km product
- For the 12.5-km product 43 WVCs exist on each side

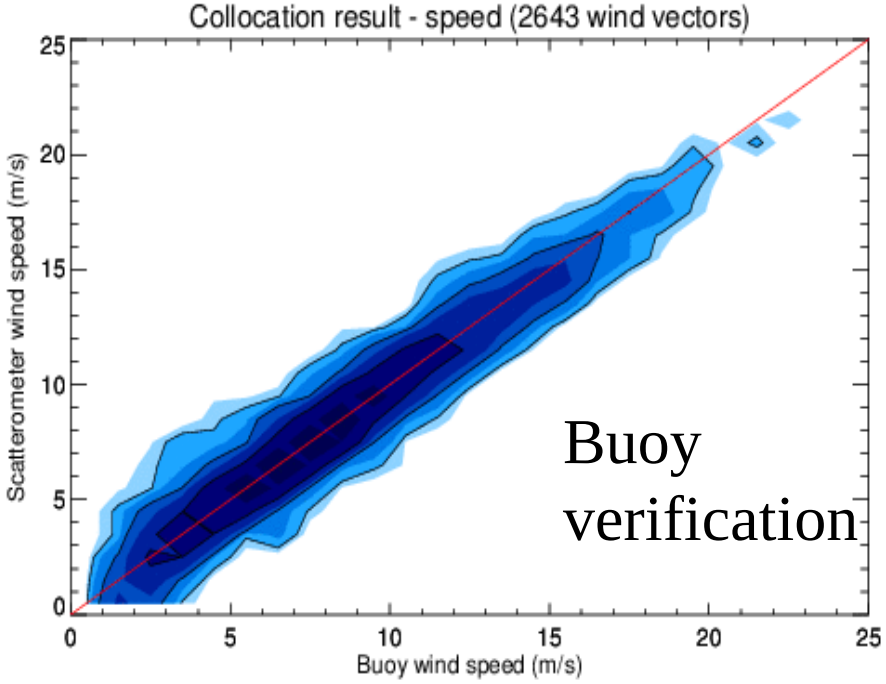
Spatial representation



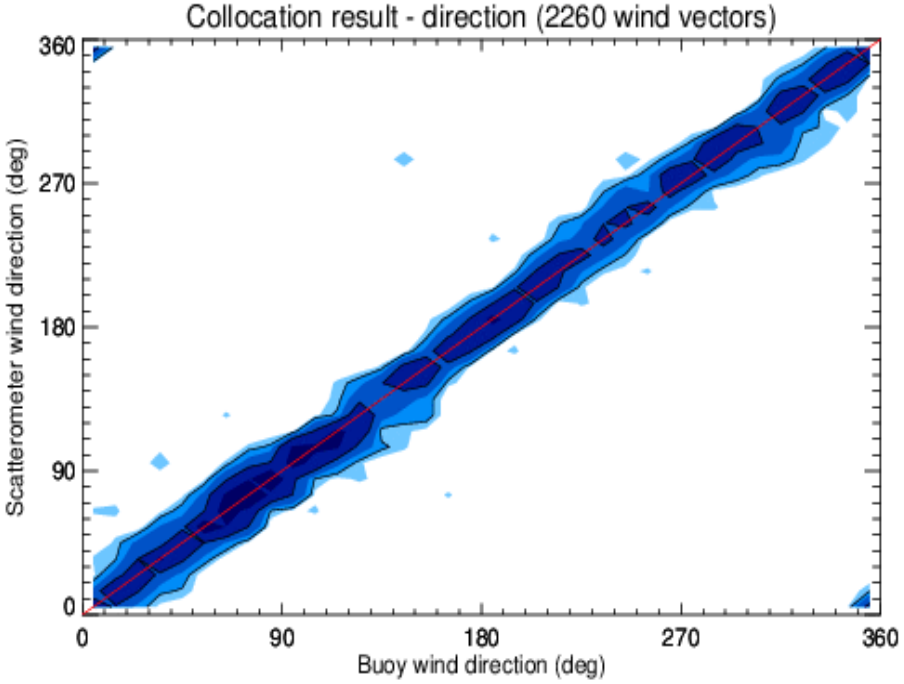
- We estimate area-mean (WVC) winds using the empirical GMFs
- 25-km areal winds are less extreme than 10-minute sustained in situ winds (e.g., from buoys)
- So, extreme buoy winds should be higher than extreme scatterometer winds (allow for gustiness factor)
- Extreme NWP winds are again somewhat lower due to lacking resolution

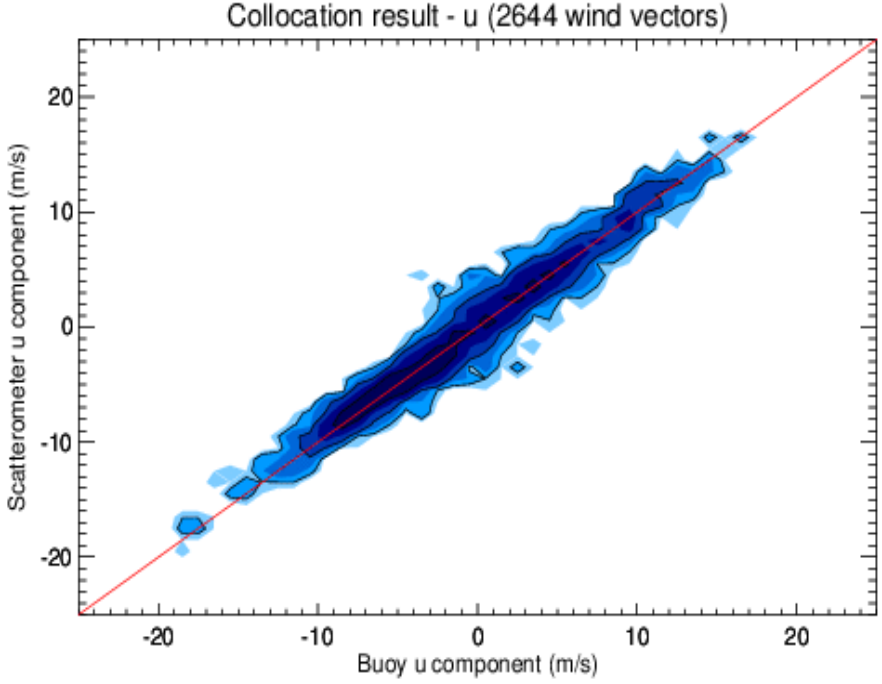
Buoy Verification

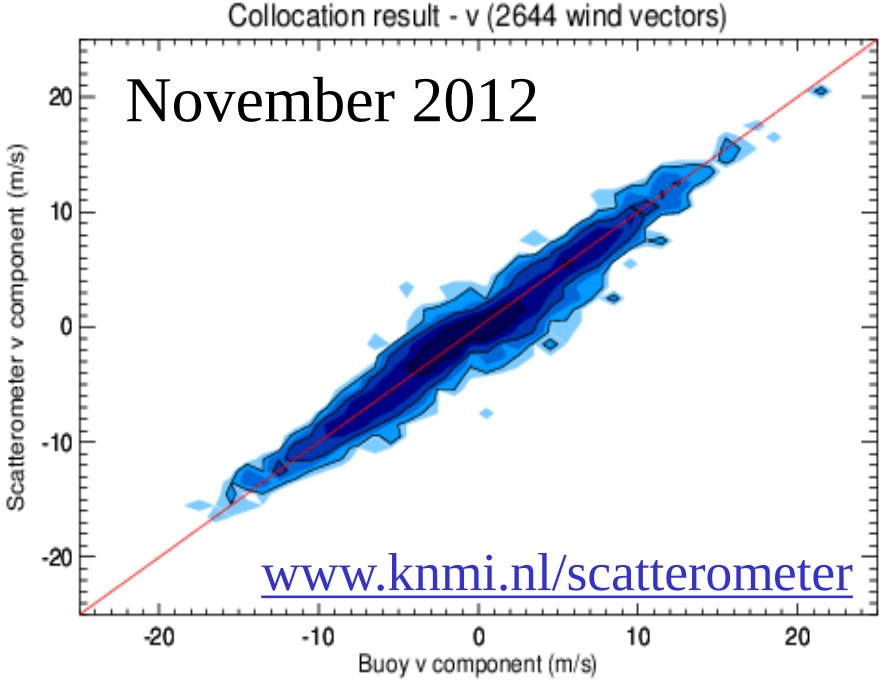




Buoy verification



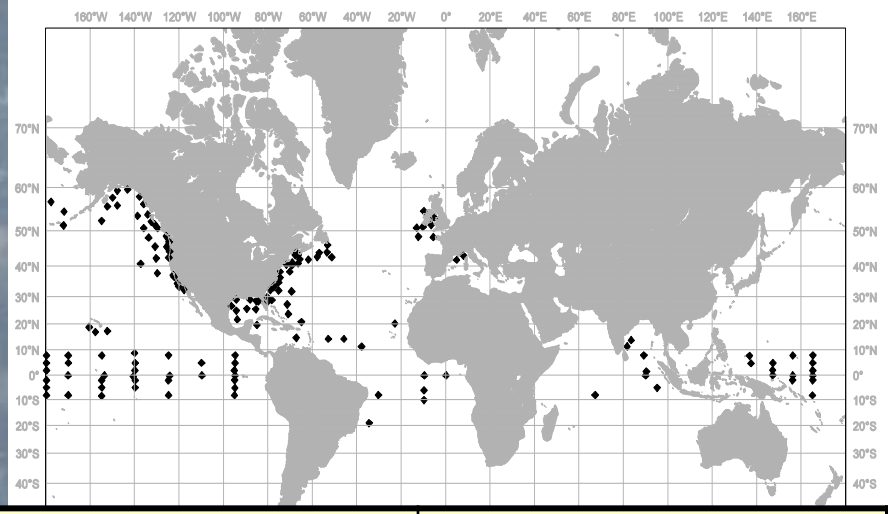




November 2012

www.knmi.nl/scatterometer

Buoy verification



ASCAT 12.5		ASCAT 25		SeaWinds 25 KNMI		SeaWinds 25 USA	
σ_u [m/s]	σ_v [m/s]	σ_u [m/s]	σ_v [m/s]	σ_u [m/s]	σ_v [m/s]	σ_u [m/s]	σ_v [m/s]
1.67	1.65	1.70	1.64	1.76	1.83	2.19	1.99

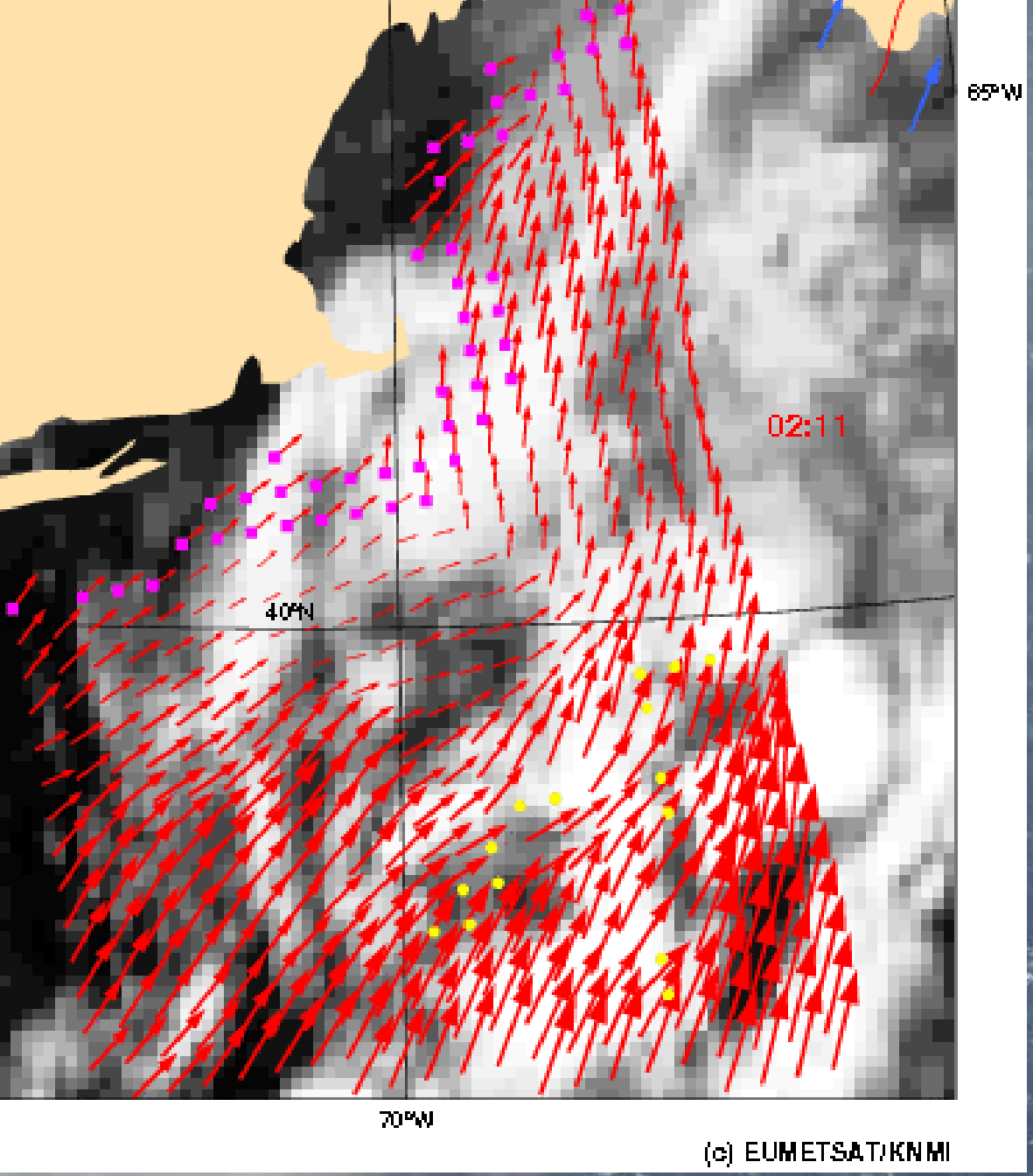
- ASCAT @ 12.5 compares best to buoys
- SeaWinds @25 is slightly noisier than ASCAT @12.5 and @25

Triple collocation result

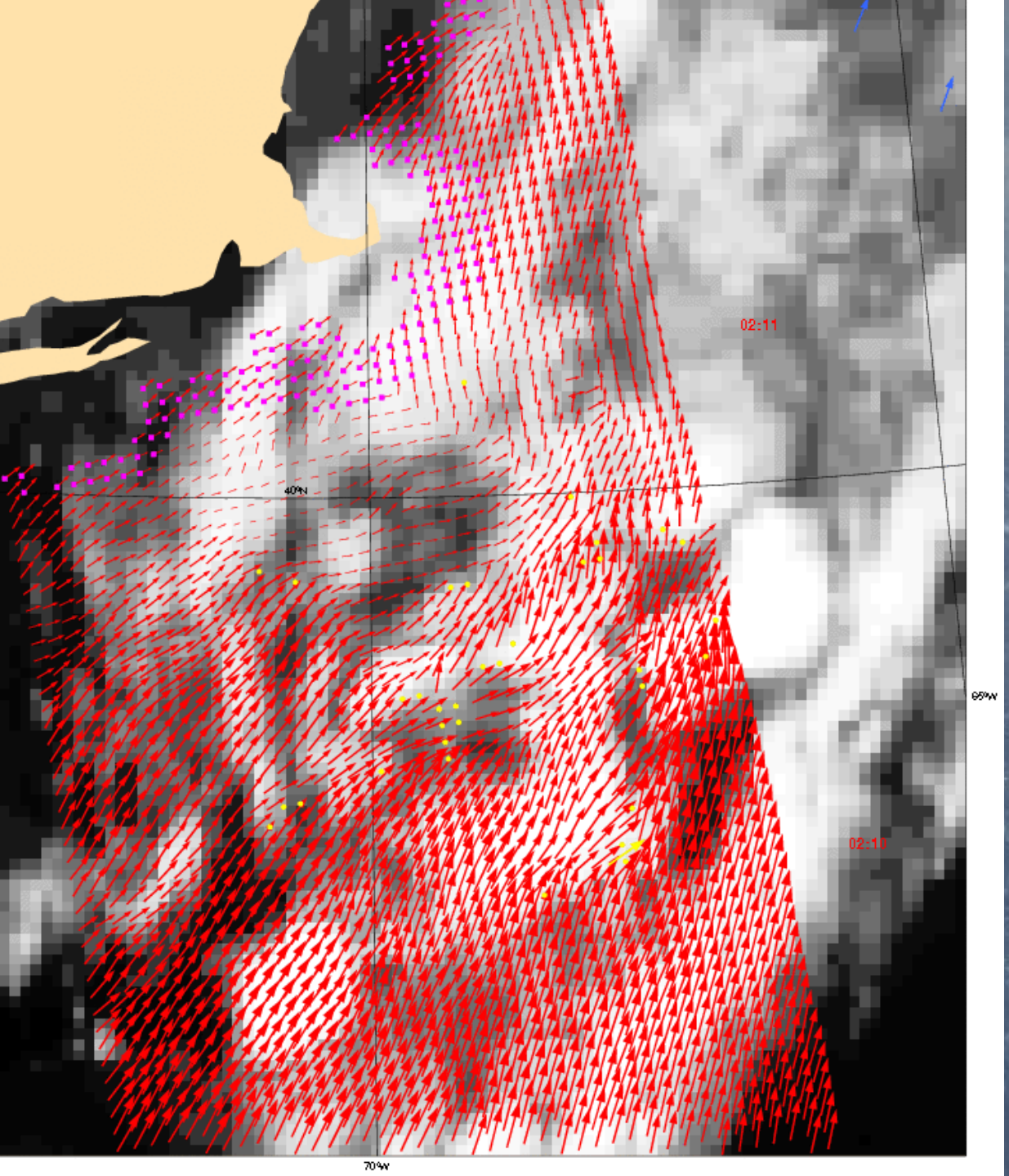
12.5 km coastal product	*u*	*v*
Bias ASCAT (m/s)	0.15	-0.02
Bias ECMWF (m/s)	0.28	0.08
Trend ASCAT	1.01	1.01
Trend ECMWF	1.03	1.04
σ ASCAT (m/s)	0.69	0.81
σ ECMWF (m/s)	1.50	1.52
σ buoy (m/s)	1.21	1.23

- On scatterometer scale (25 km)
- OSI SAF NRT req. 2 m/s, WMO in speed/dir.

See also Vogelzang et al., JGR, 2011

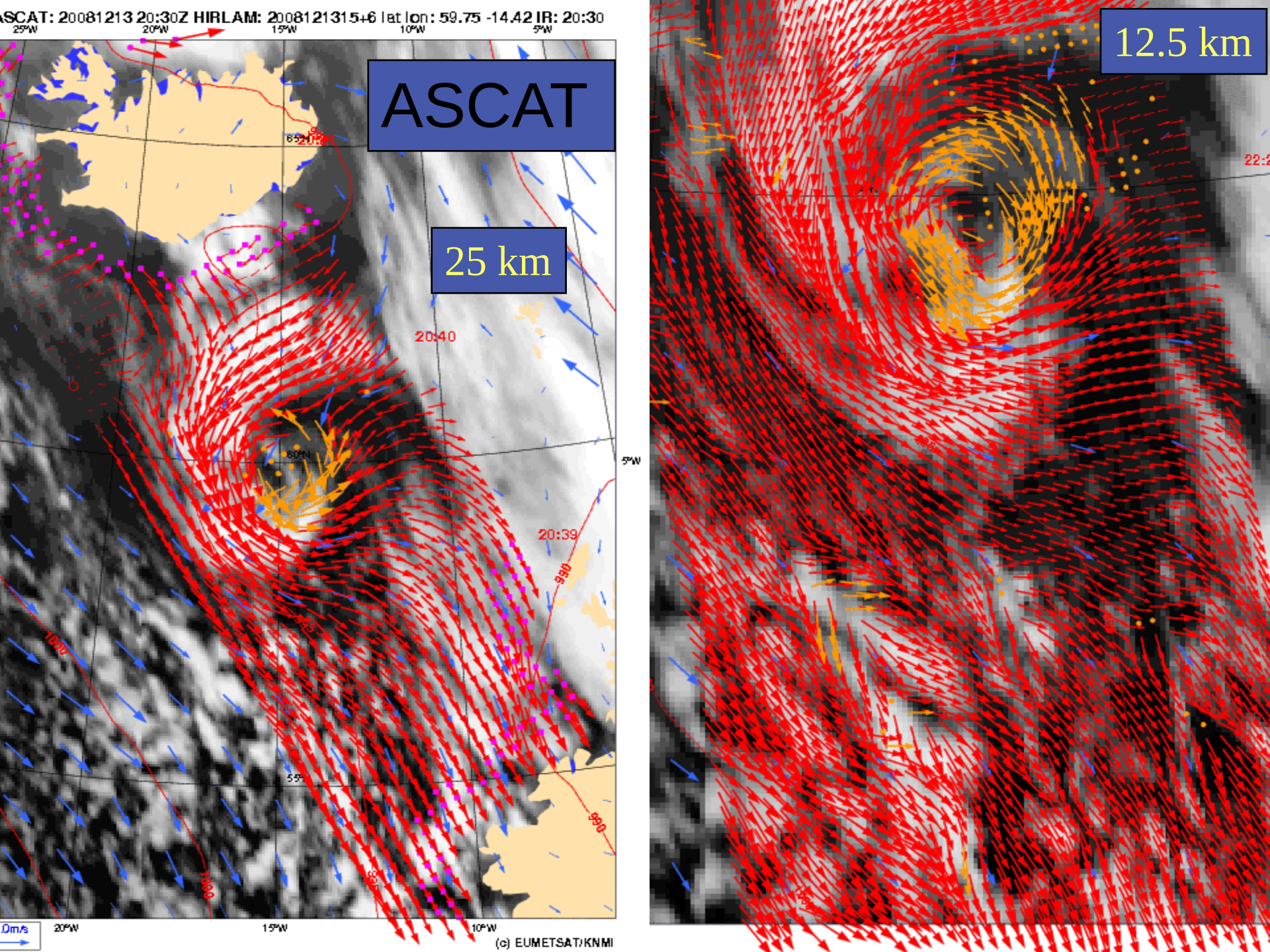


Operational 25 - km product



Operational 12.5-km product

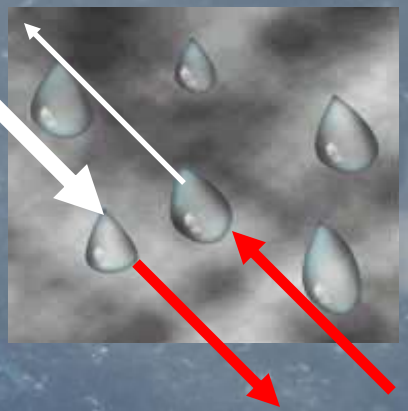
- Convective systems
- SST
- Currents


ASCAT: 20081213 20:30Z HIRLAM: 2008121315+6 lat lon: 59.75 -14.42 IR: 20:30
ASCAT
25 km
12.5 km
20:40
20:39
(c) EUMETSAT/KNMI

Quality Control (QC)

- Scatterometers provide good quality sea surface winds except for:
  - Sea ice or land contamination
  - Large spatial wind variability (e.g., vicinity of fronts and low-pressure centres, downbursts)
  - Rain (especially in Ku-band systems, e.g.,OceanSat-2)

Rain Effects



- The radar signal is attenuated by the rain as it travels to and from the Earth's surface → σ_0 ↓
  - Retrieved wind speed ↓

- The radar signal is scattered by the raindrops. Some of this scattered energy returns to the instrument → σ_0 ↑
  - Retrieved wind speed ↑ (to ~ 15 m/s)
  - Directional information can be lost

Rain Effects

- The radar signal is attenuated by the rain as it travels to and from the Earth's surface → σ_0 ↓
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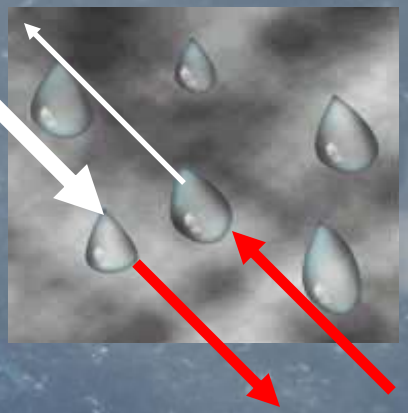
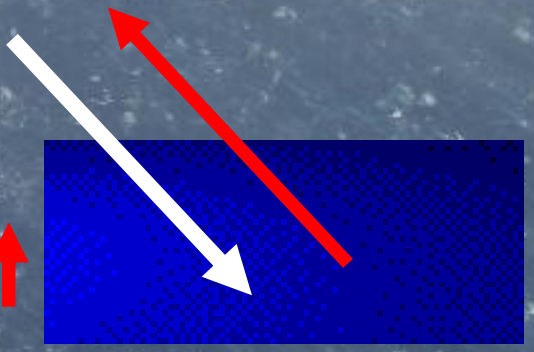
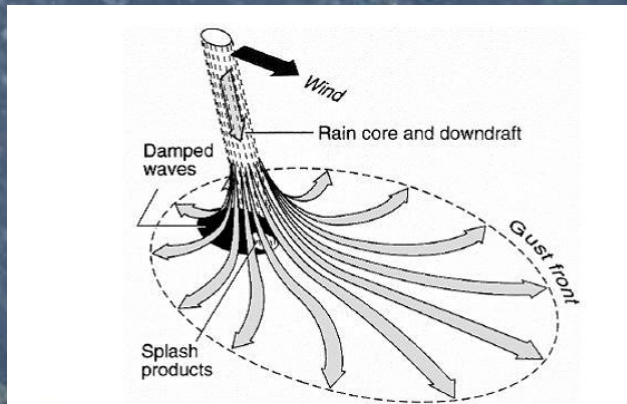


- The radar signal is scattered by the raindrops. Some of this scattered energy returns to the instrument → σ_0 ↑
  - Retrieved wind speed ↑ (to ~ 15 m/s)
  - Directional information can be lost

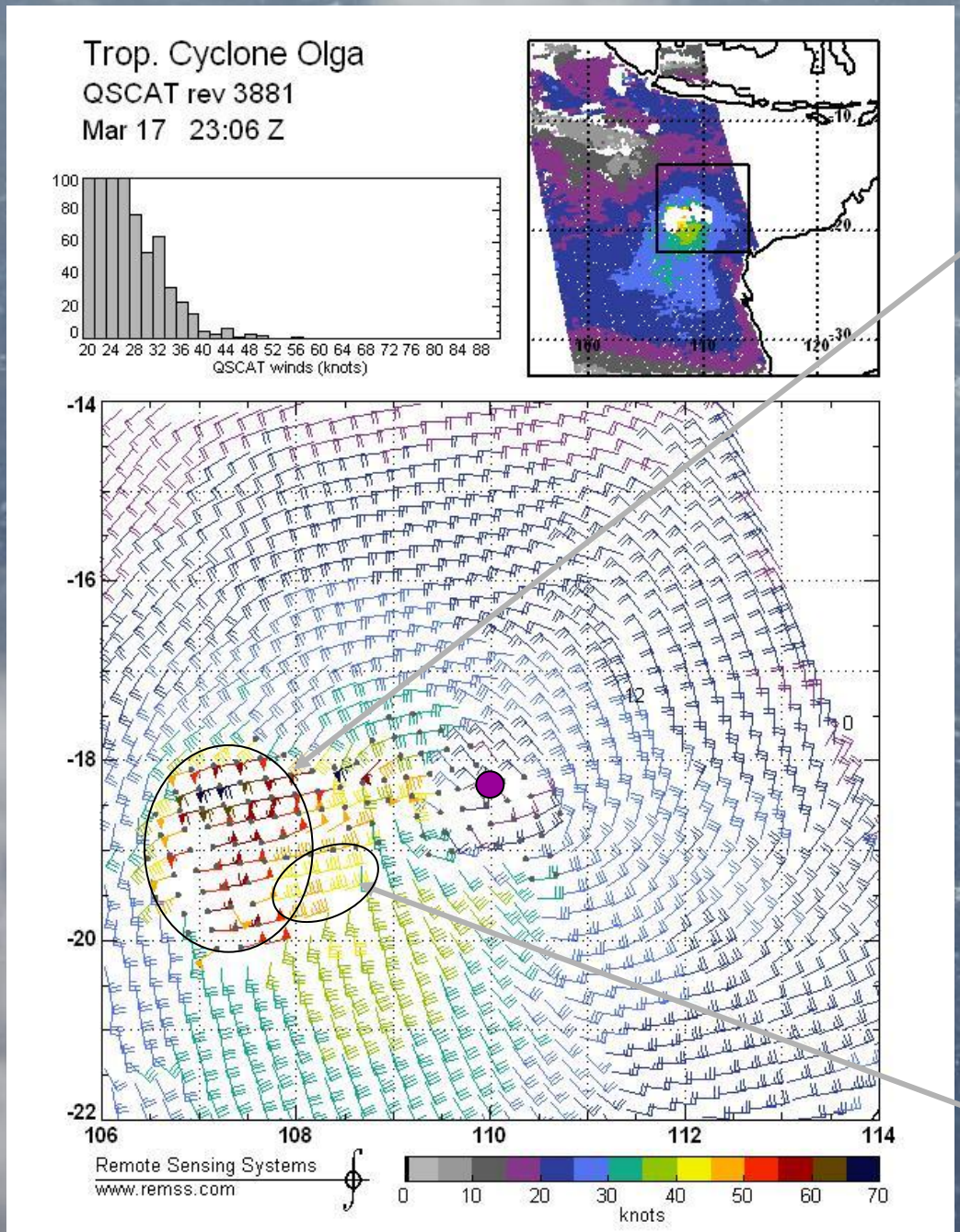


- The roughness of the sea surface is increased because of the splashing due to raindrops → σ_0 ↑
  - Retrieved wind speed (at low winds)
  - Directional information can be lost

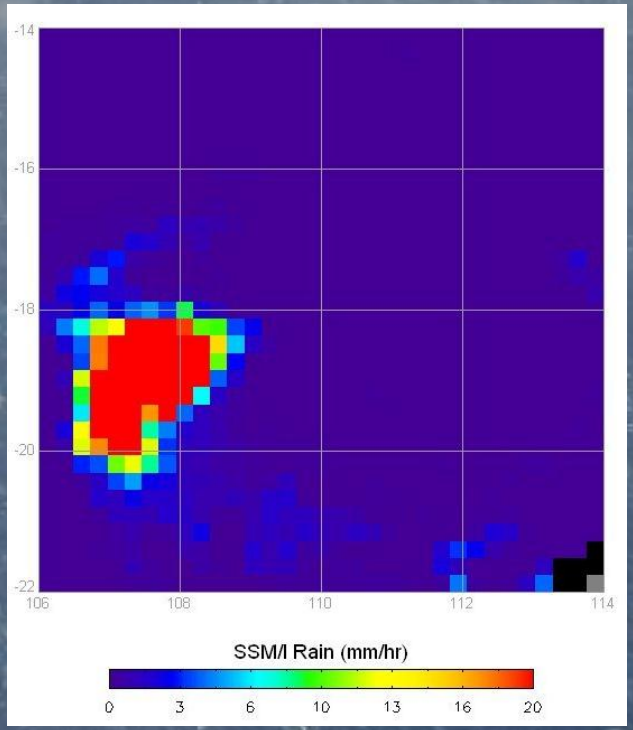
- Variable roughness due to wind downbursts
  - Confused sea state, speed/direction unclear



Typical Rain Patterns



Rain effects:
Cross swath vectors
Higher wind speeds

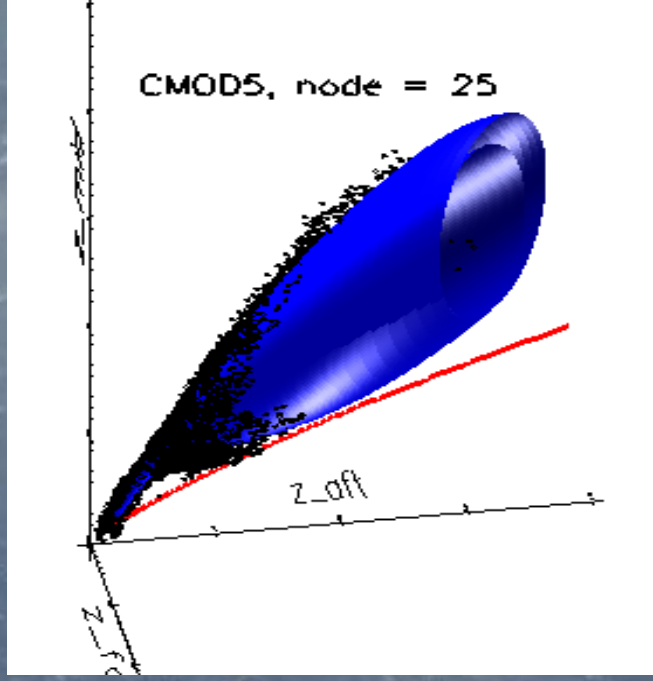


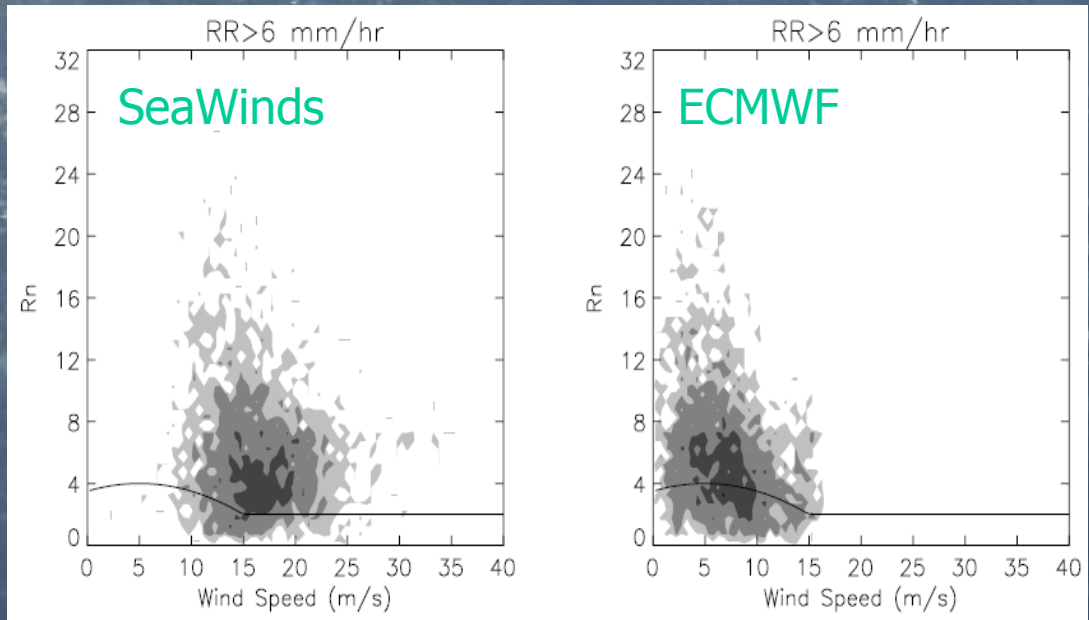
Some intense rain not flagged by RSS

® RSS slide

Quality Control

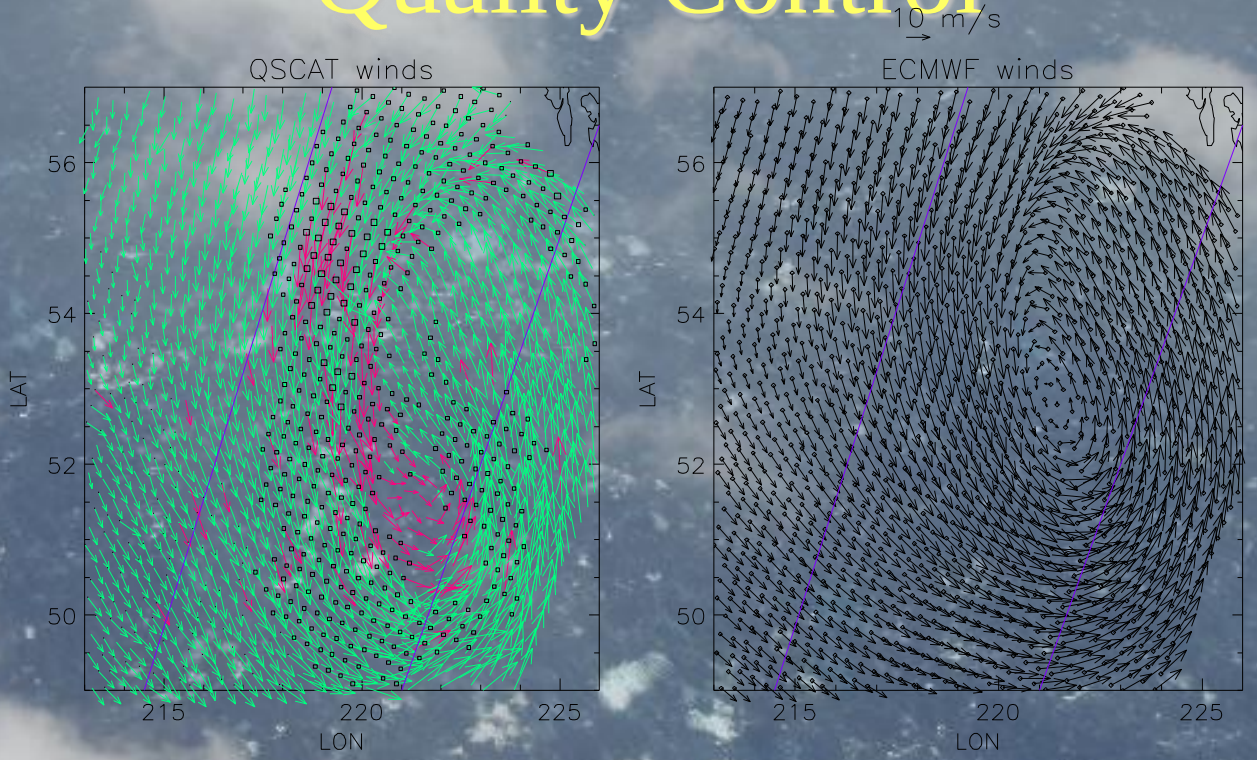
- Inversion residual value (MLE)
  - low = good quality wind
  - high = low quality wind
- A uniform metric is derived (Rn)
- A Rn threshold is derived to optimize
  - rejection of low quality
  - accept good quality





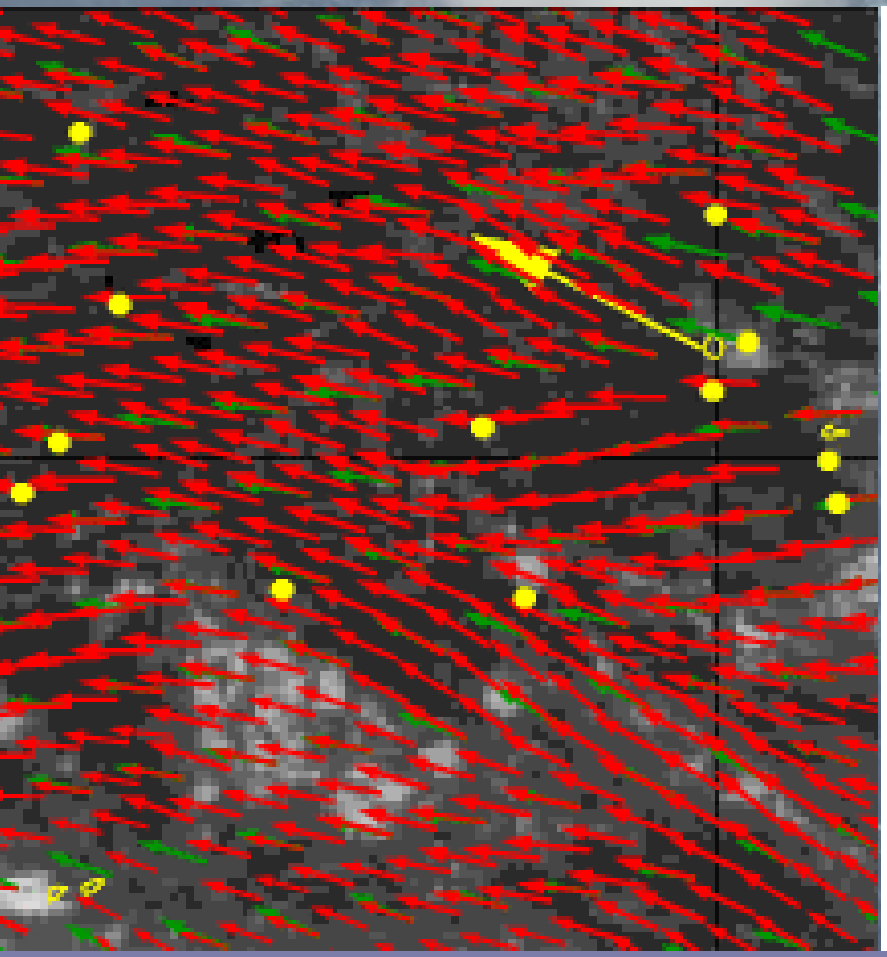
Portabella and Stoffelen, 2001

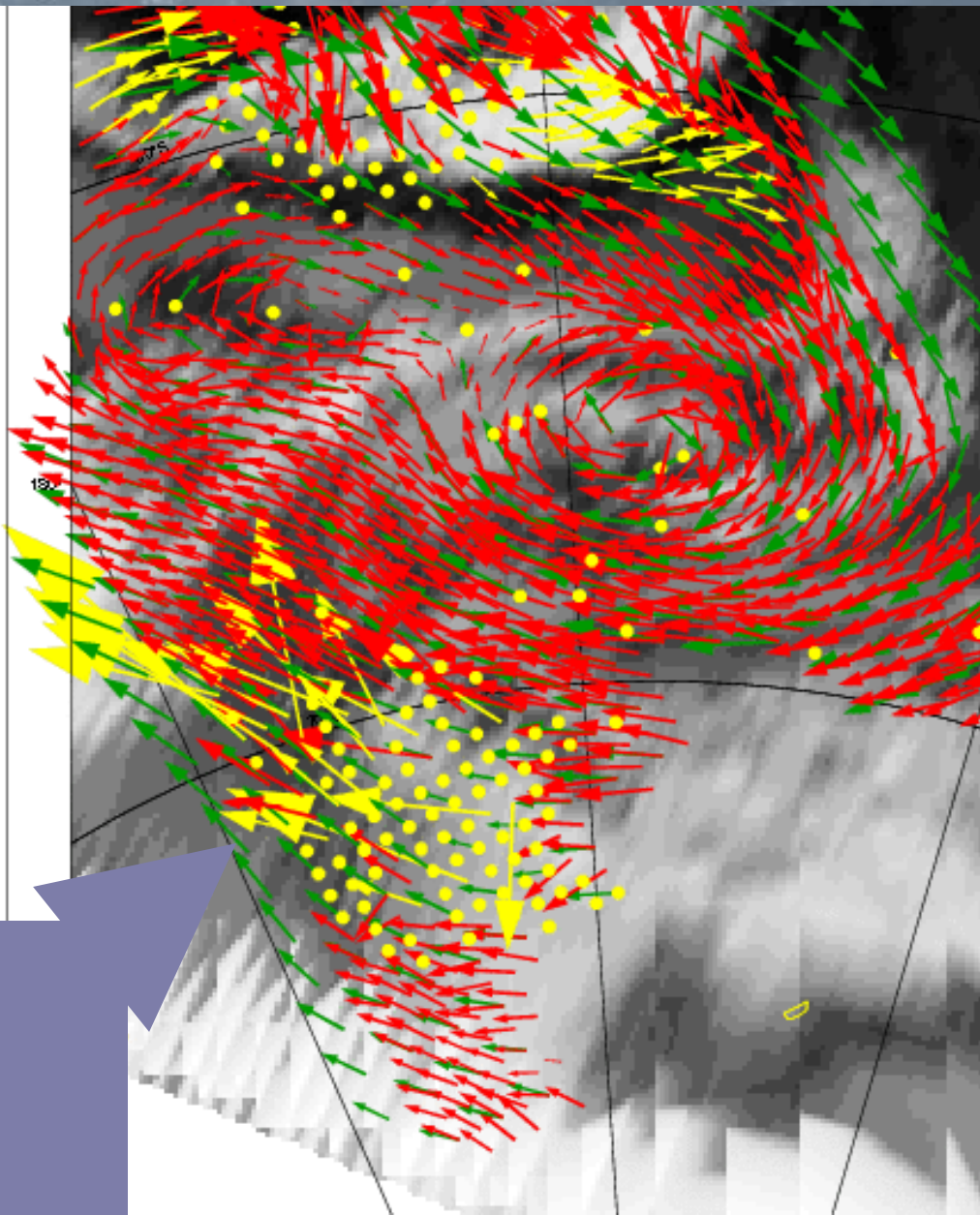
Quality Control



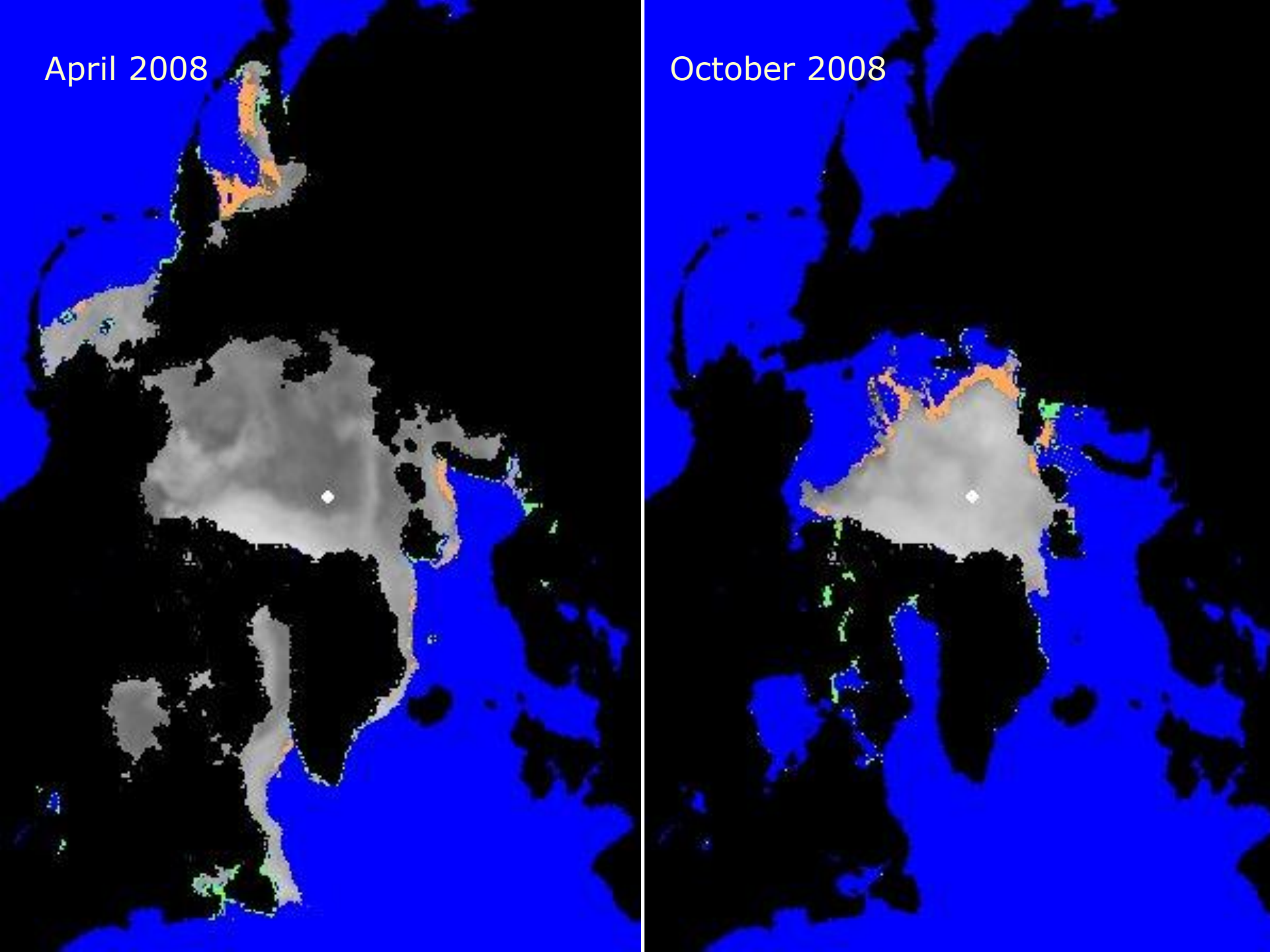
- Areas with significant Rain (large squares) effectively detected
- Frontal and low-pressure centre areas effectively removed
- Vast majority of spatially consitent winds are accepted (green arrows)

Discrimination of land, water and ice



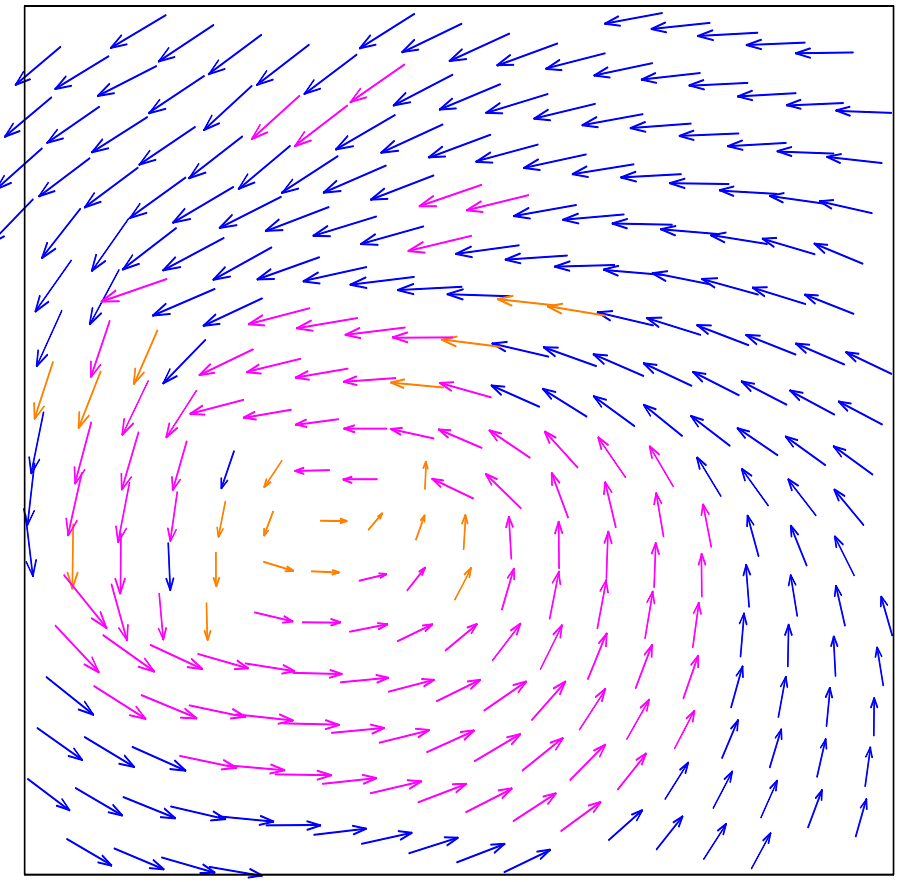


Detached sea ice field of
400kmx400km at South Pole

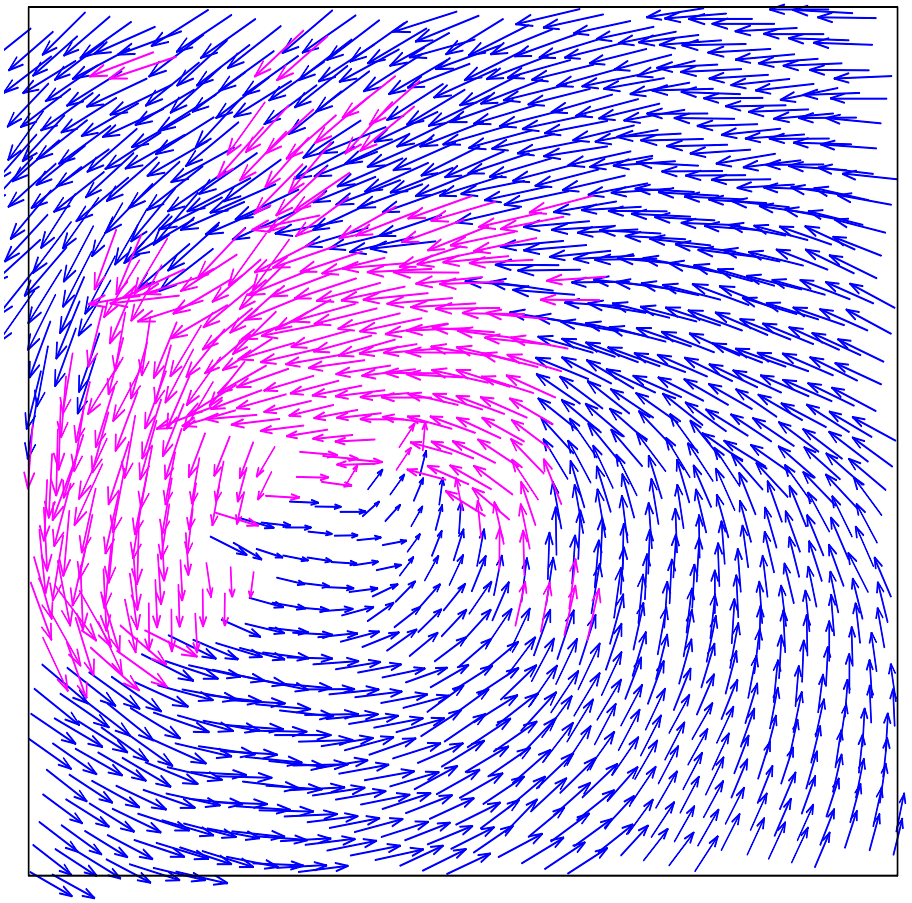

April 2008
October 2008

6 km σ^0 grid

12.5 km grid size

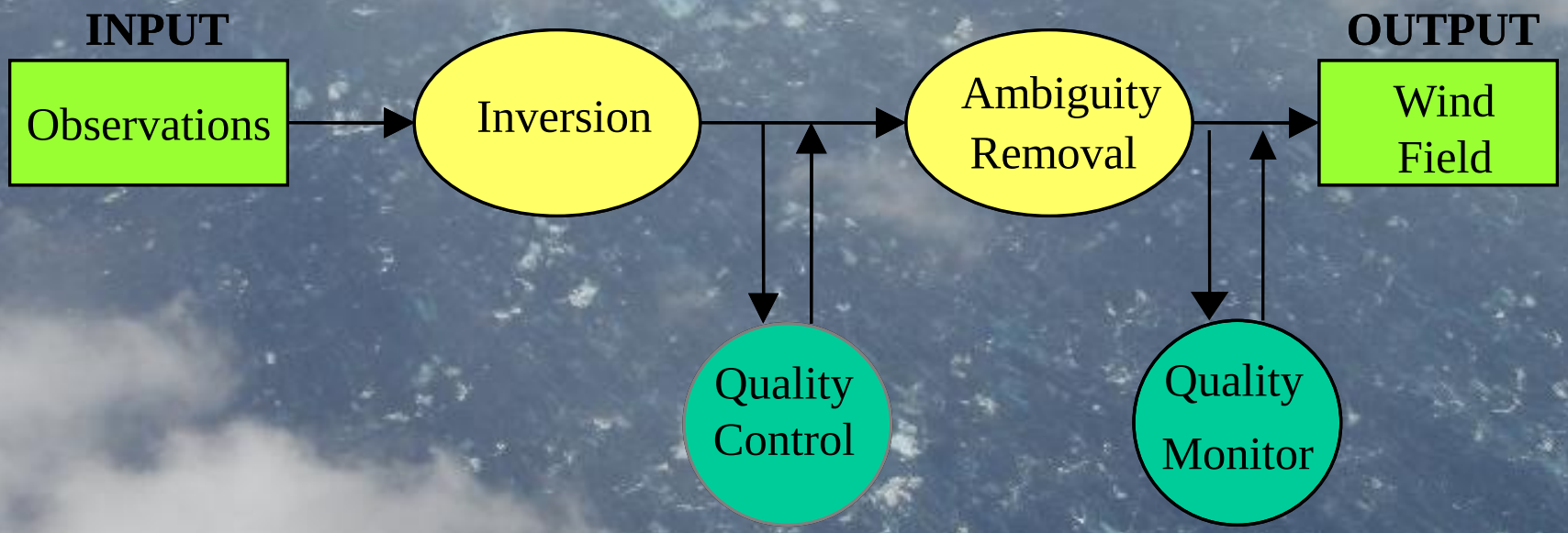


6.25 km grid size



- **In development**

Generic Scatterometer Data Processor



AWDP: ASCAT Wind Data Processor, also ERS

SDP: SeaWinds Data Processor

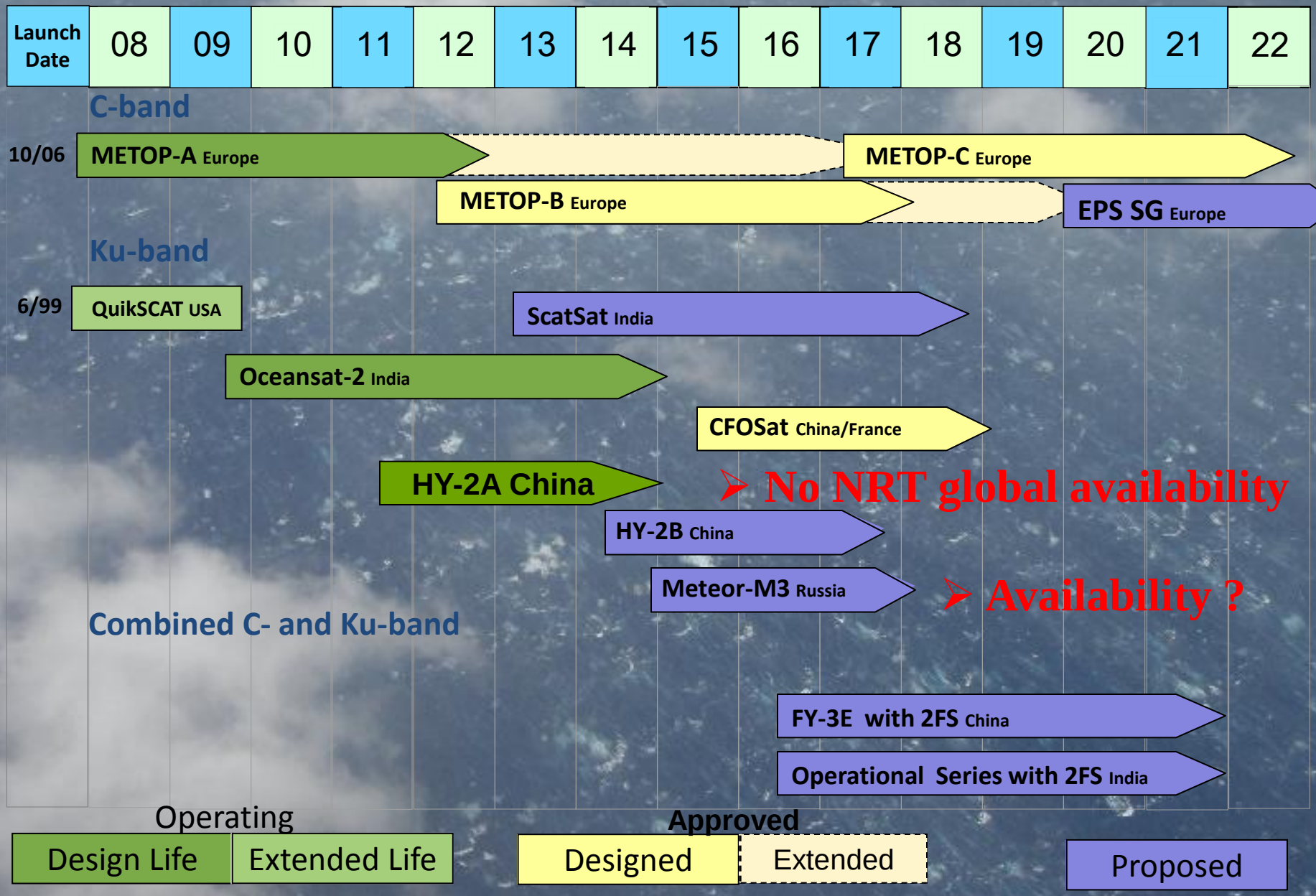
OWDP: OSCAT Wind Data Processor, also HY2A

Scatterometer winds

- Represent the mean WVC wind
- Are provided as equivalent neutral winds
- Verify very well with NWP model
- Verify very well with buoys
- Show spectra close to that expected for 3D turbulence for scales < 500 km
- Spatial plots show small-scale features in line with these three features

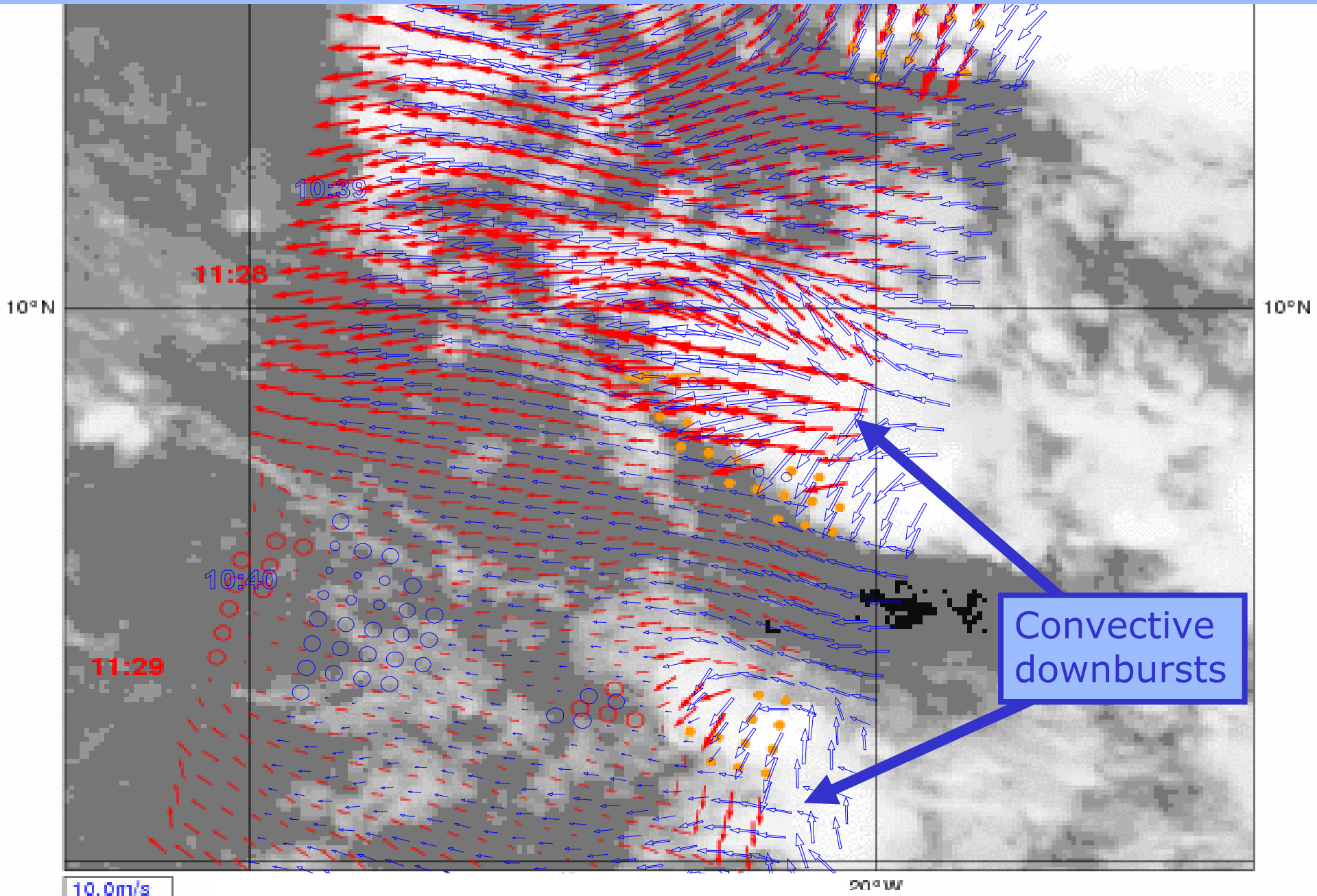
- Can be contaminated by land, sea ice and rain
- Winds > 30 m/s are difficult to measure/calibrate
- Are ambiguous

GLOBAL SCATTEROMETER MISSIONS (CEOS VC)



sw 24feb11

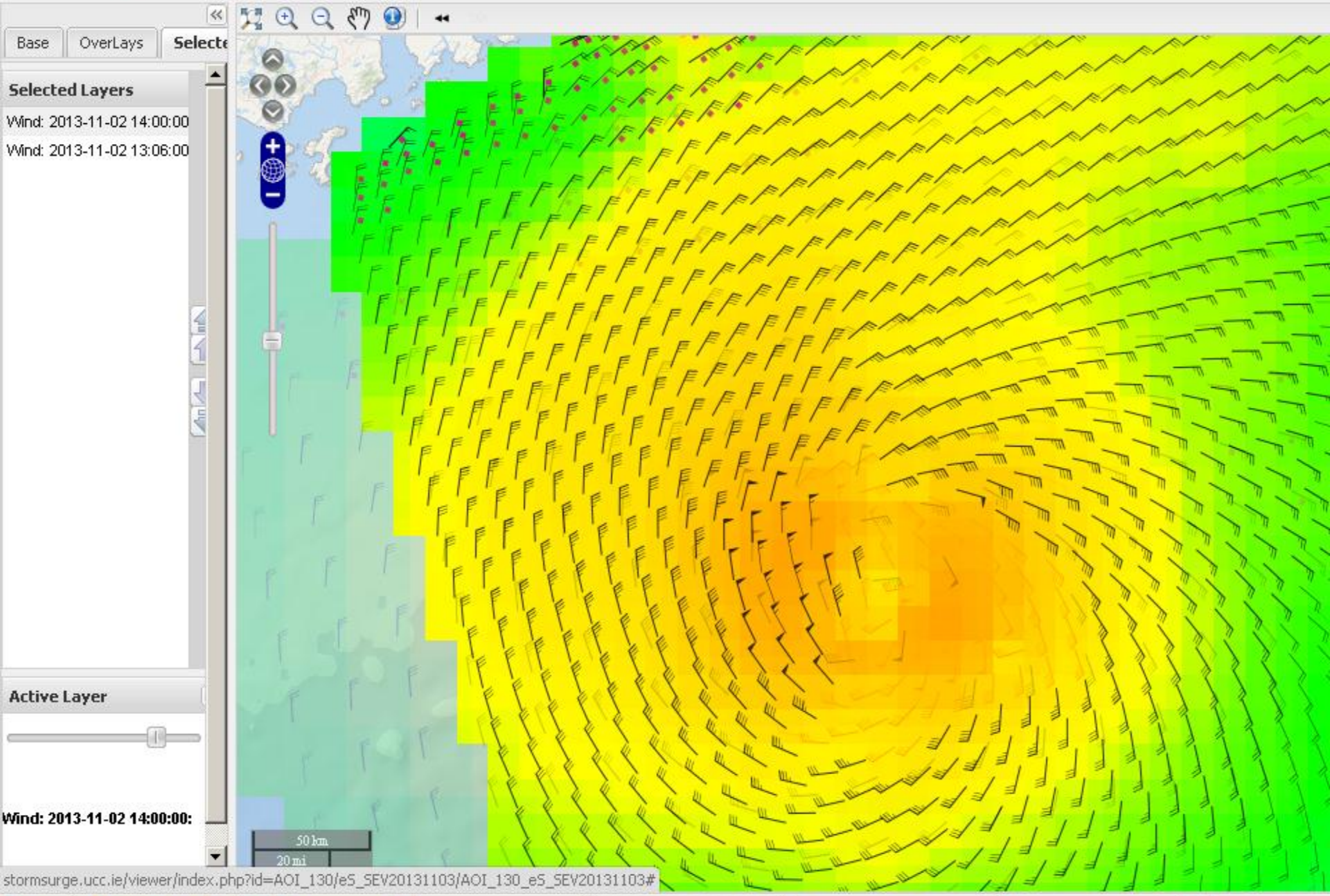
ASCAT-A and ASCAT-B come together



➢Lin et al. manuscripts on rain and wind variability effects on ASCAT

eSurge *eSurge Data Viewer*

Yellow and South China Seas - Cyclone Krosa (3 Nov 2013)

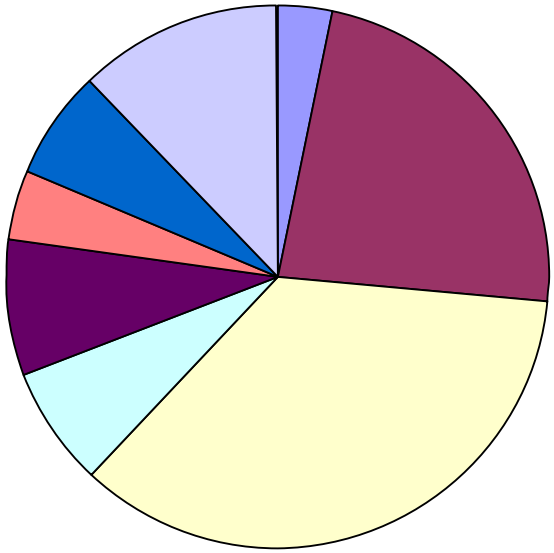


stormsurge.ucc.ie/viewer/index.php?id=AOI_130/eS_SEV20131103/AOI_130_eS_SEV20131103#

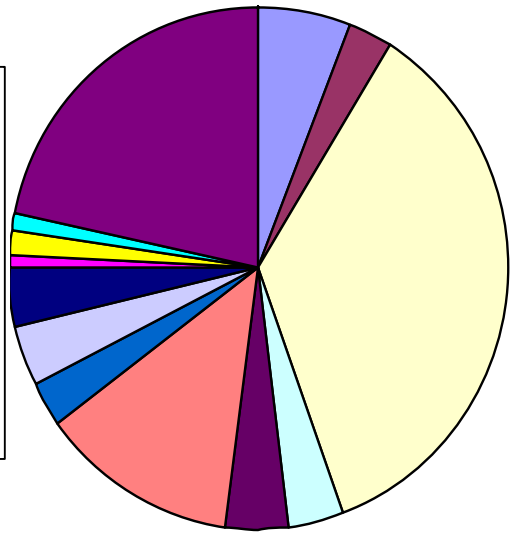
Global constellation users

- KNMI products are used at all major NWP centres (e.g., ECMWF, NCEP, BoM, JMA, NRL, UKMet, DWD, MF, ..), nowcasting centres (e.g., NHC, ..), marine services, wind energy branche, universities, …
- All EUMETSAT SAF wind product service messages are popular world wide (service messages also through EUMETCAST and JPL PODAAC)
- Both data products and wind processing software are popular

NWP SAF software users

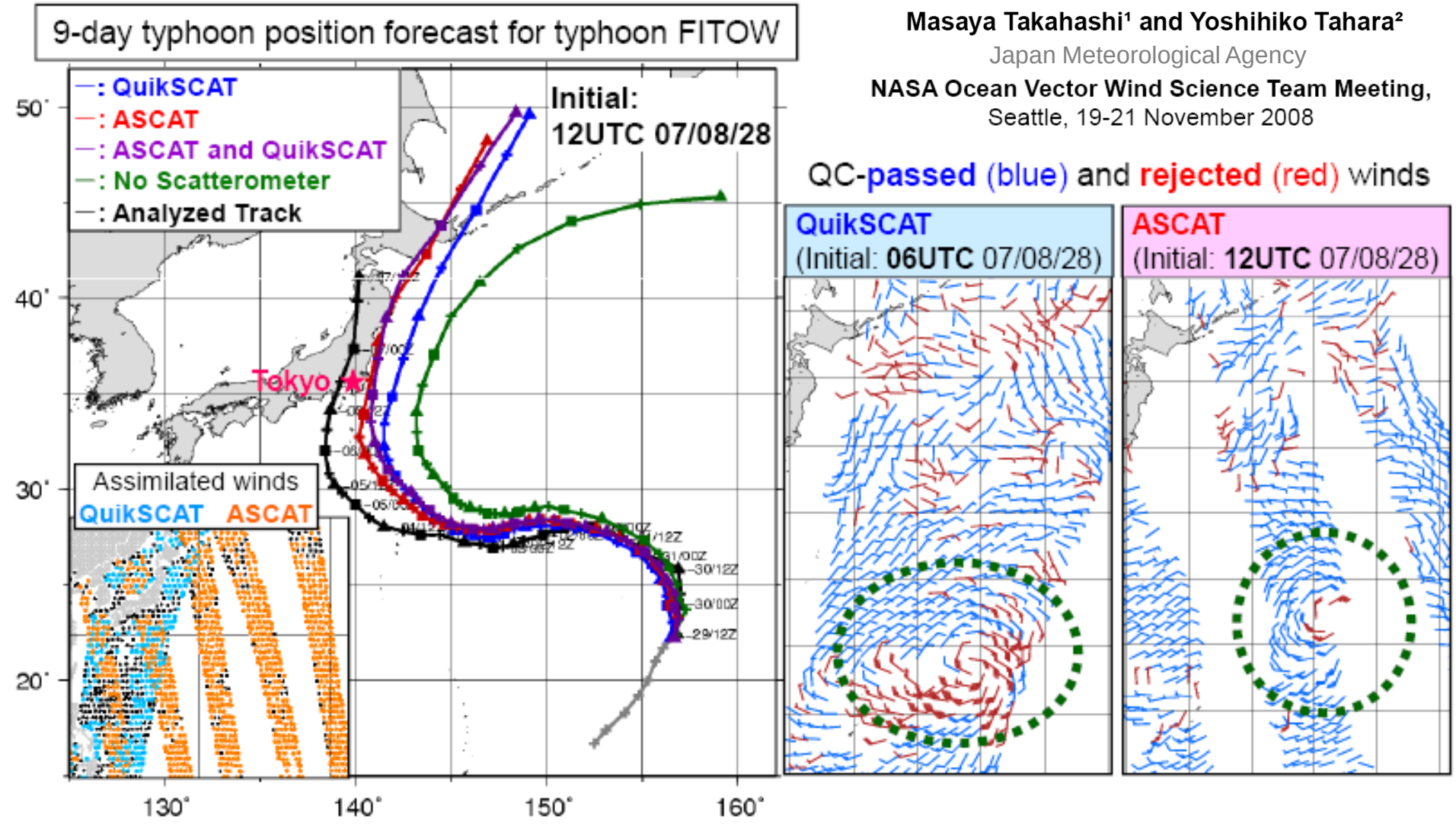


OSI SAF Message List



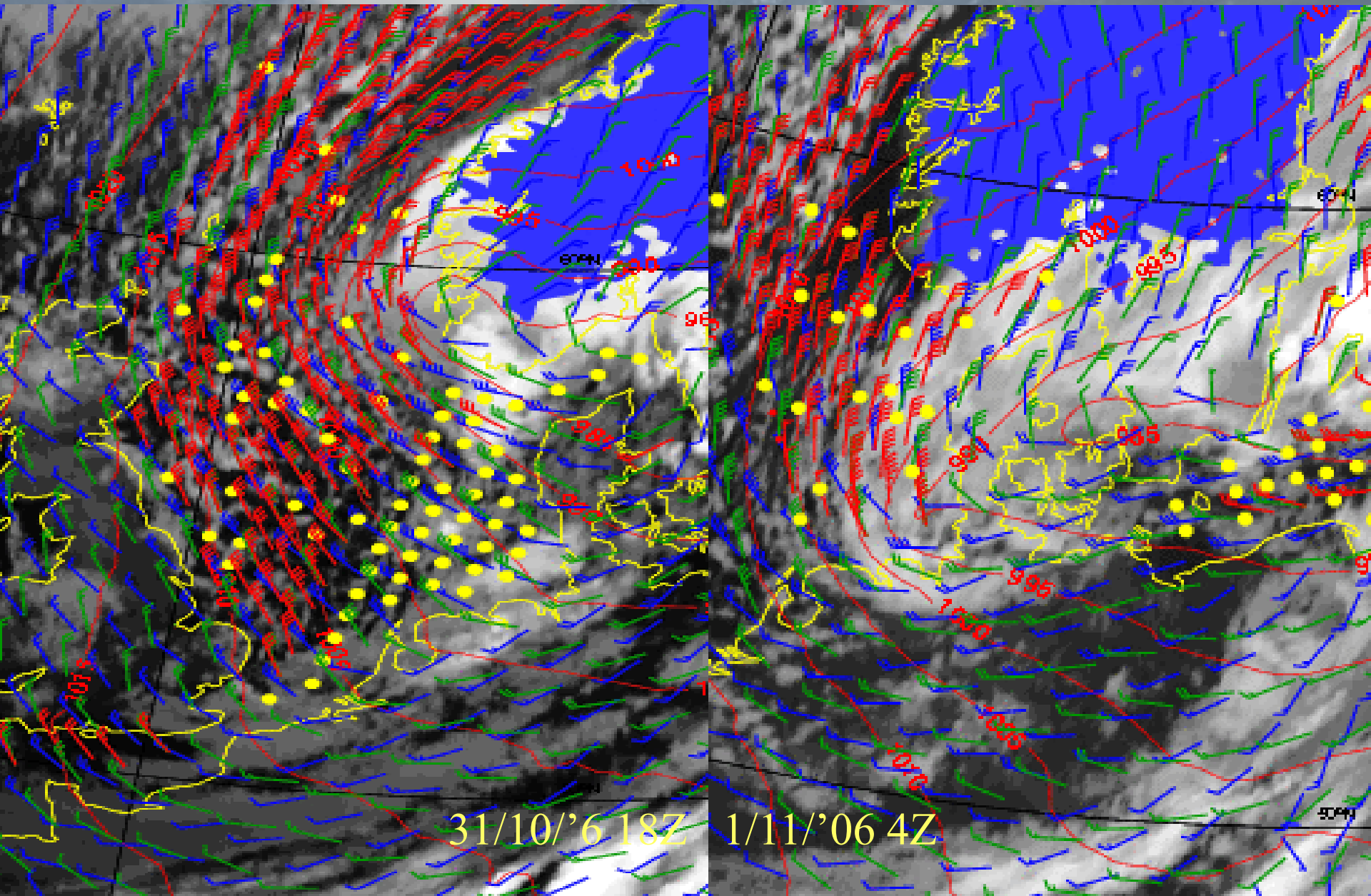
Scatterometer winds for tropical storms

Masaya Takahashi[1] and Yoshihiko Tahara[2]
Japan Meteorological Agency
NASA Ocean Vector Wind Science Team Meeting,
Seattle, 19-21 November 2008



- ASCAT has smaller rain effect; splash remains

Underpredicted surge Delfzijl by 0.5 m



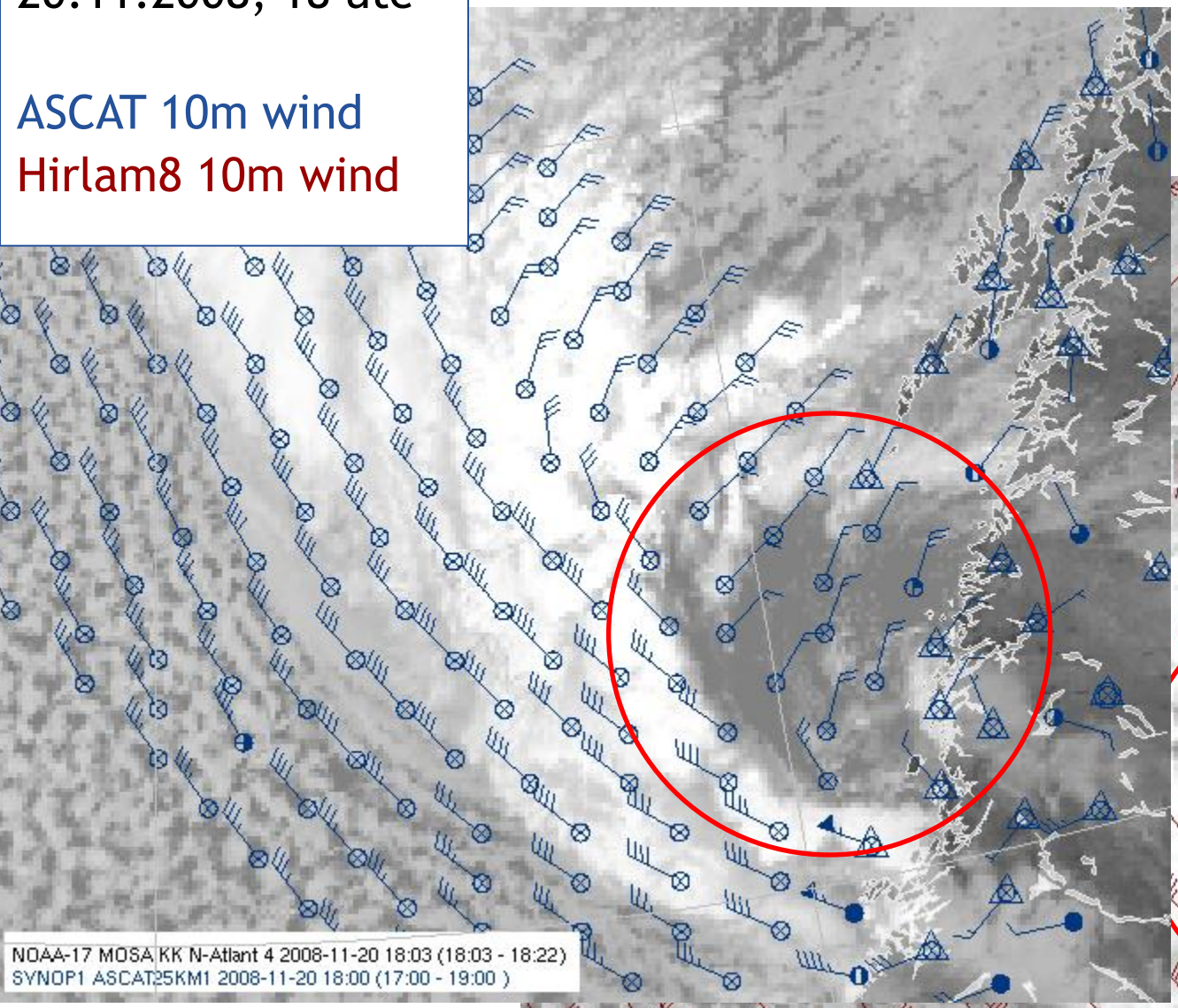
NOAA-17 AVHRR
20.11.2008, 18 utc

ASCAT 10m wind

Hirlam8 10m wind

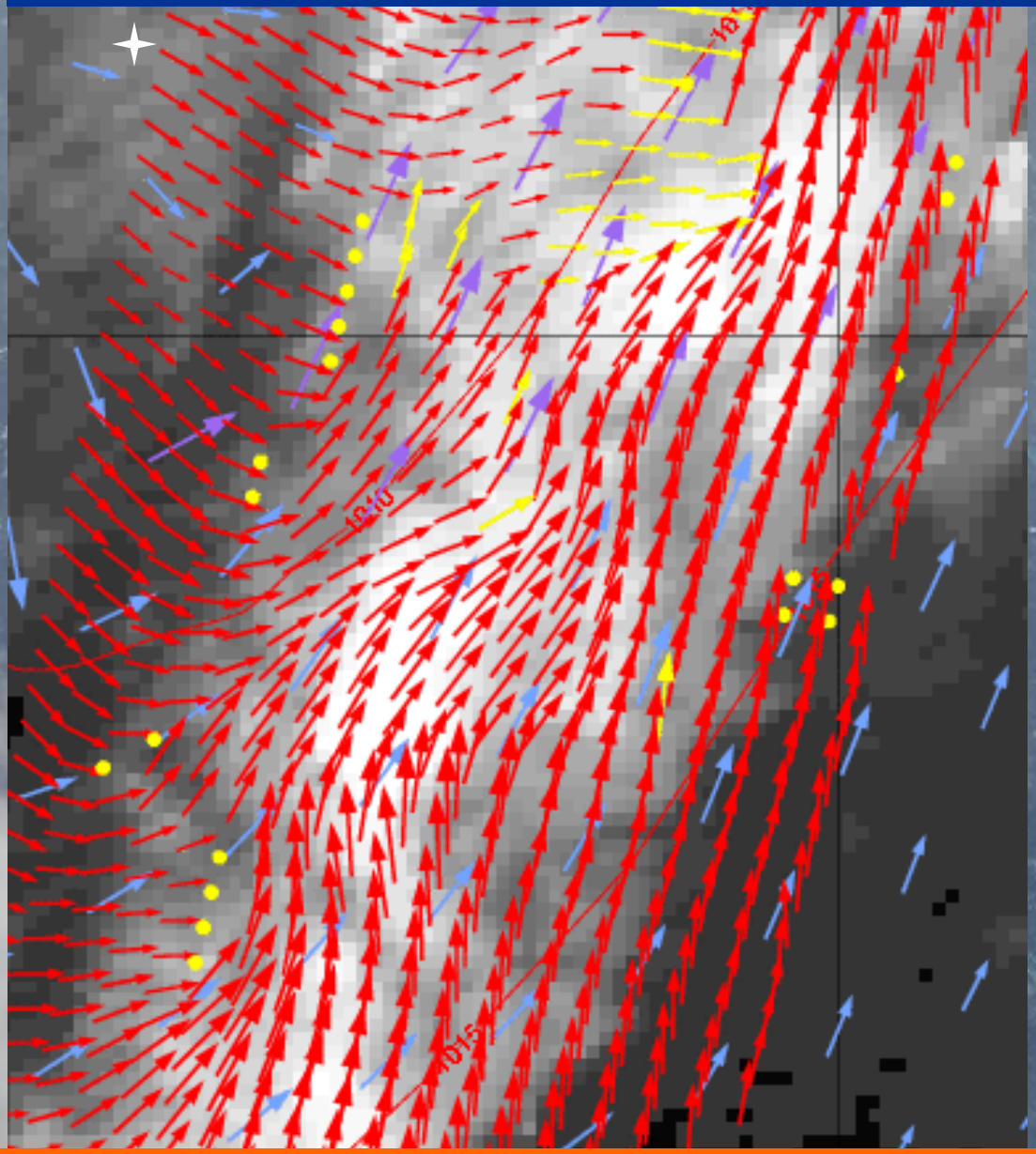
Polar Low

20.11.2008



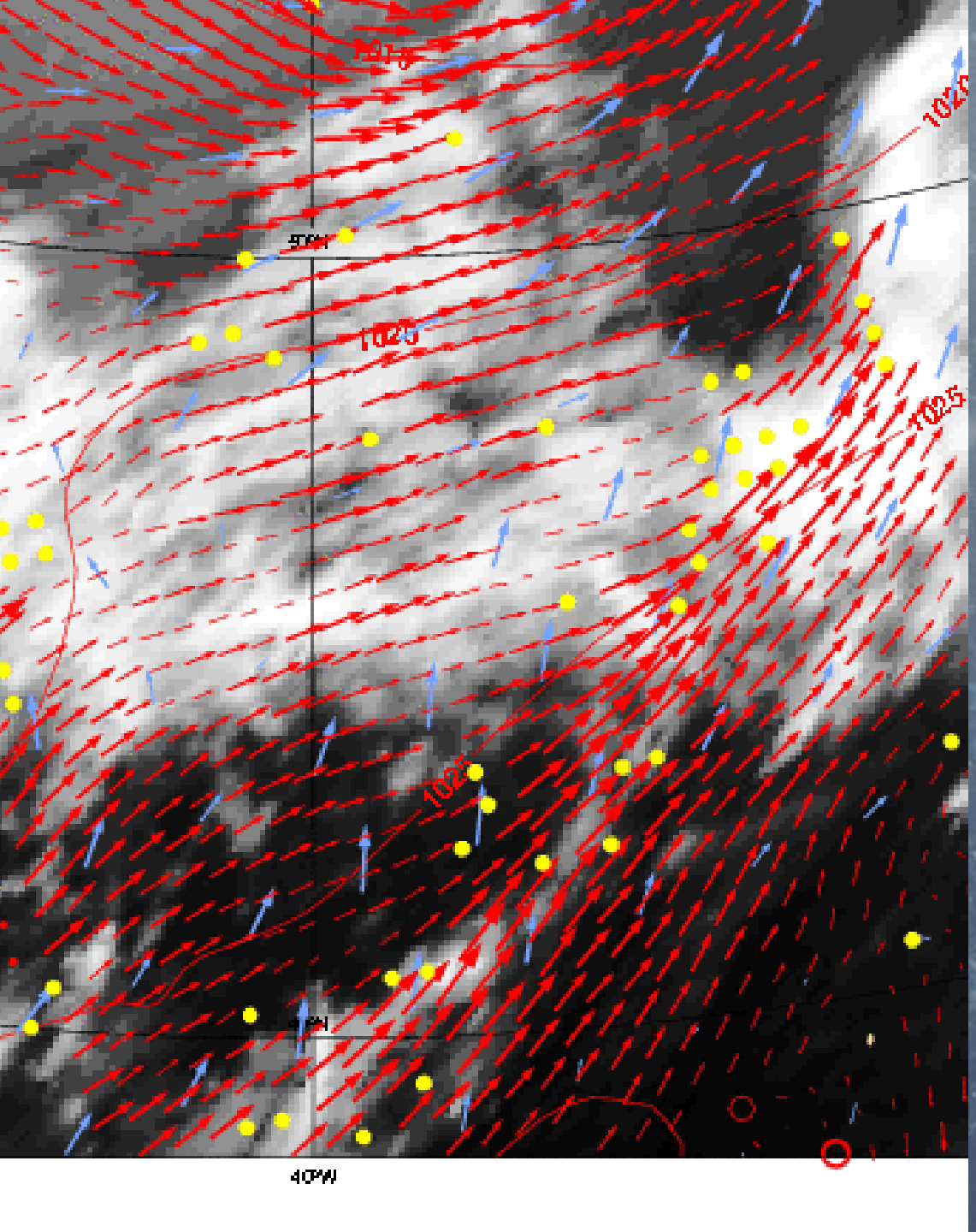
ASCAT 10m wind OK

Wind overestimated



NWP models miss wave; Next day forecast bust

ERS-2 scatterometer wave train; missed by NWP models

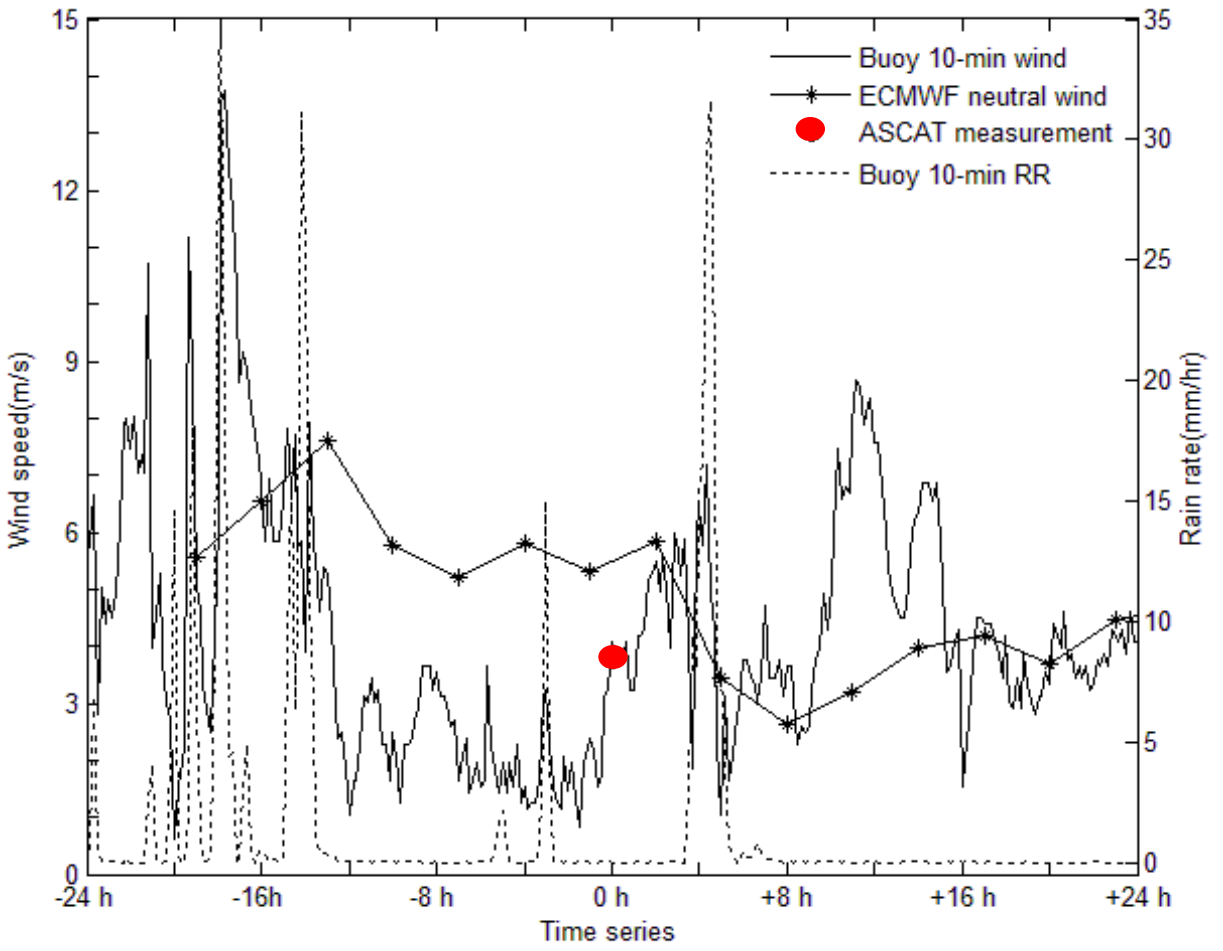


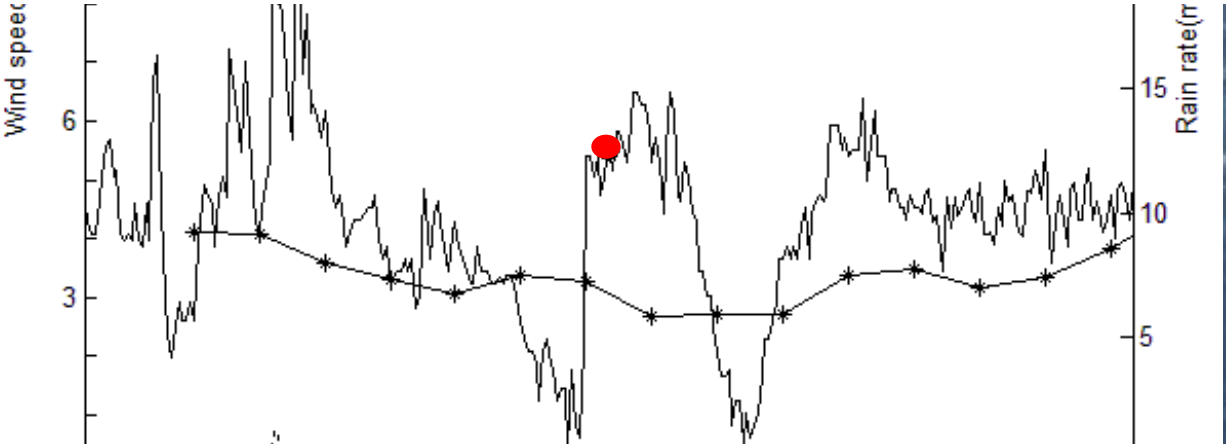
Missed wave train in QuikScat

Tropical variability

1. Dry areas reasonable
2. NWP models lack air-sea interaction in rainy areas
3. ASCAT scatterometer does a good job near rain
4. QuikScat, OSCAT and radiometers are affected by rain droplets

Portabella et al., TGRS, 2012





Further references

- scat@knmi.nl
  - Registration for data, software, service messages
  - Help desk
- EUMETCAST, RMDCN, KNMI FTP
- www.knmi.nl/scatterometer
  - Viewer
  - Status, monitoring, validation
  - User Manual
- EUMETrain, forecasters forum
- NWP SAF monitoring
  www.metoffice.gov.uk/research
  /interproj/nwpsaf/monitoring.html

Ocean references

- MyOcean (Copernicus), www.myocean.eu/
- PODAAC, podaac.jpl.nasa.gov/
- eSurge (ESA), www.storm-surge.info/
- MyWave (EU)
- 2011 scatterometer conference, www.eumetsat.int/Home/Main/Satellites/Metop/index.htm?l=en
- IOVWST meetings, coaps.fsu.edu/scatterometry/meeting/

June 2014, IFREMER, Brest, France


Thanks !