On dual-polarized SAR imaging of ocean surface

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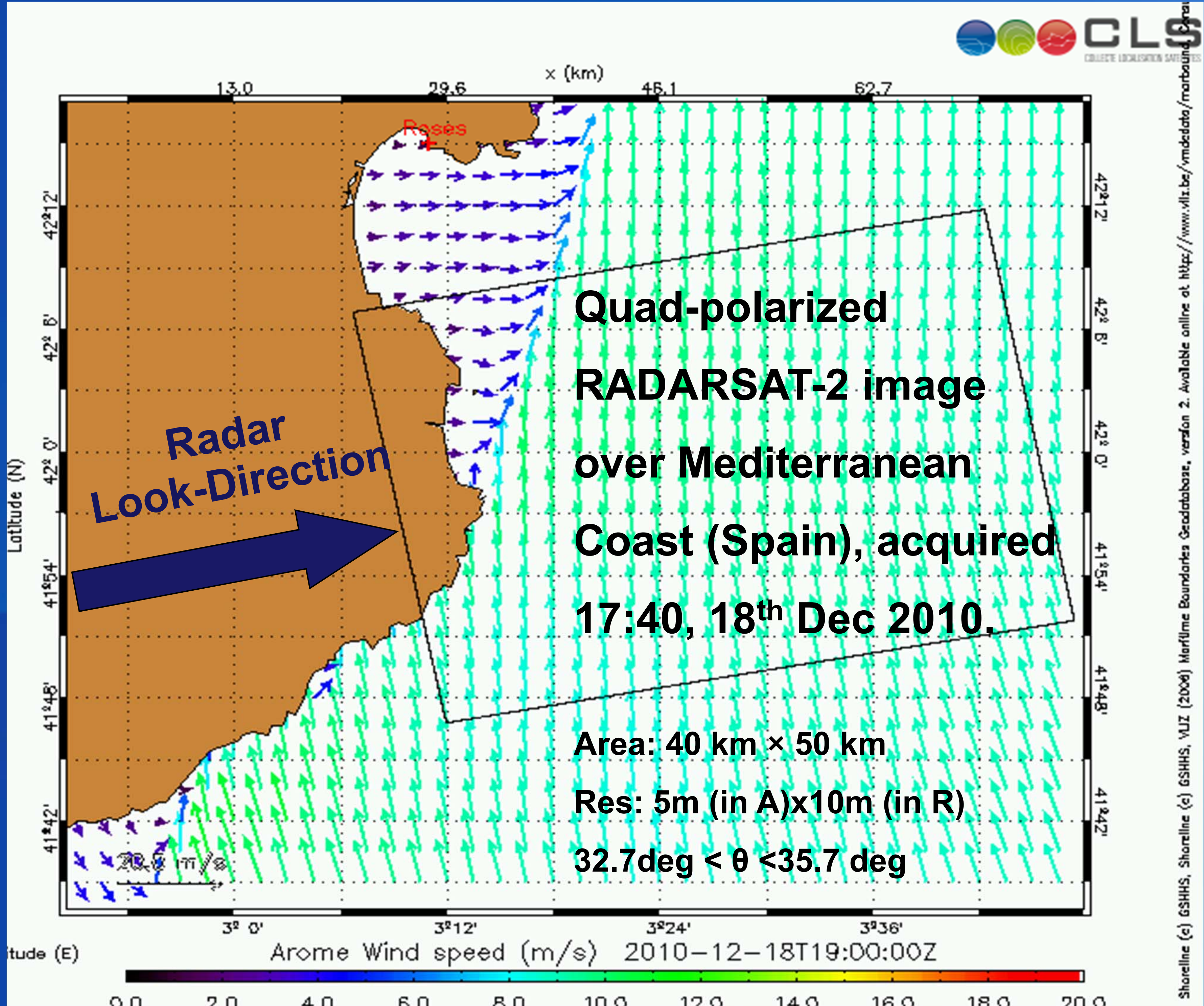
SeaSAR 2012 Workshop

Main Goal

To promote an effective and simple methodology using SAR polarized information to interpret and quantitatively assess role of the different scattering mechanism in surface manifestation of

- Oceanic currents
- Slicks
- Wind field features



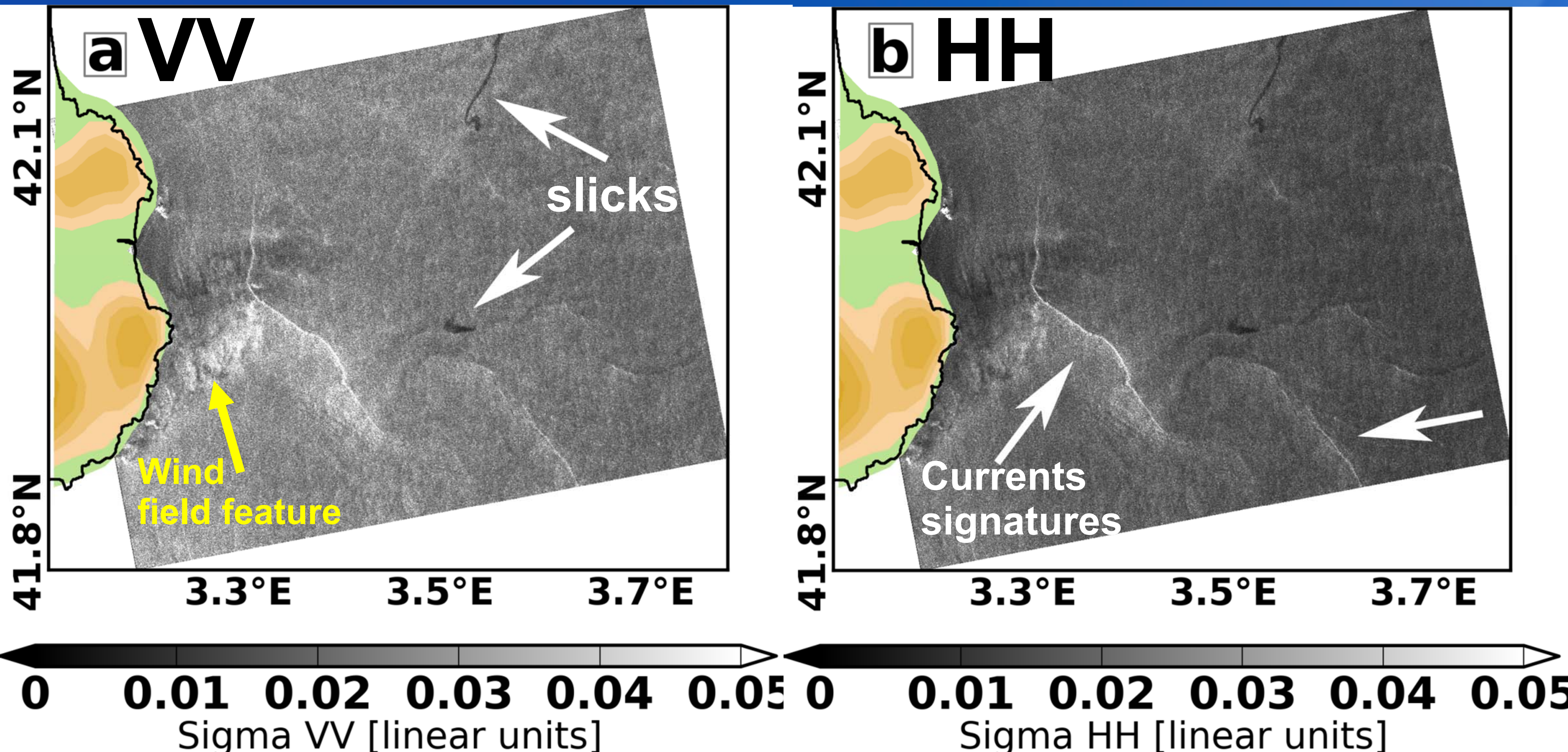
Quad-polarized RADARSAT-2 image over Mediterranean Coast (Spain), acquired 17:40, 18th Dec 2010.

Area: 40 km × 50 km

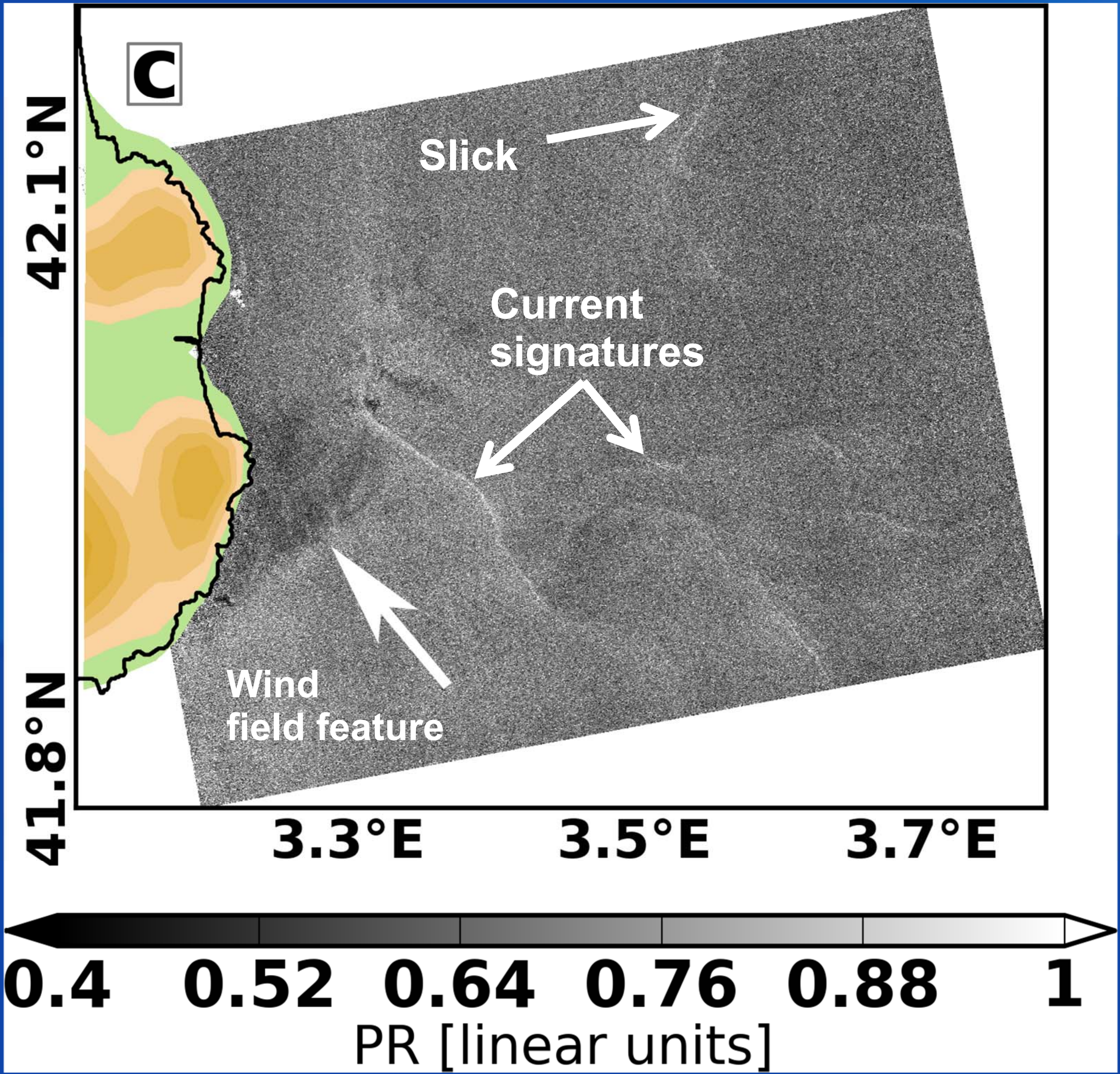
Res: 5m (in A)x10m (in R)

32.7deg < θ <35.7 deg

Original VV and HH RS-2 SAR images



Polarization Ratio HH/VV



The mean PR is - 1.5 dB … - 2 dB except coastal area, PR= - 2.5 dB that close to 2-scale Bragg model predictions.

PR attains PR=1 in “bright” current signatures.

OUTCOME: Impact of non-polarized scattering associated with wave breaking is important

Basis: Scattering decomposition

Chapron et al., 1997; Quilfen et., 1999; Kudryavtsev et al., 2003

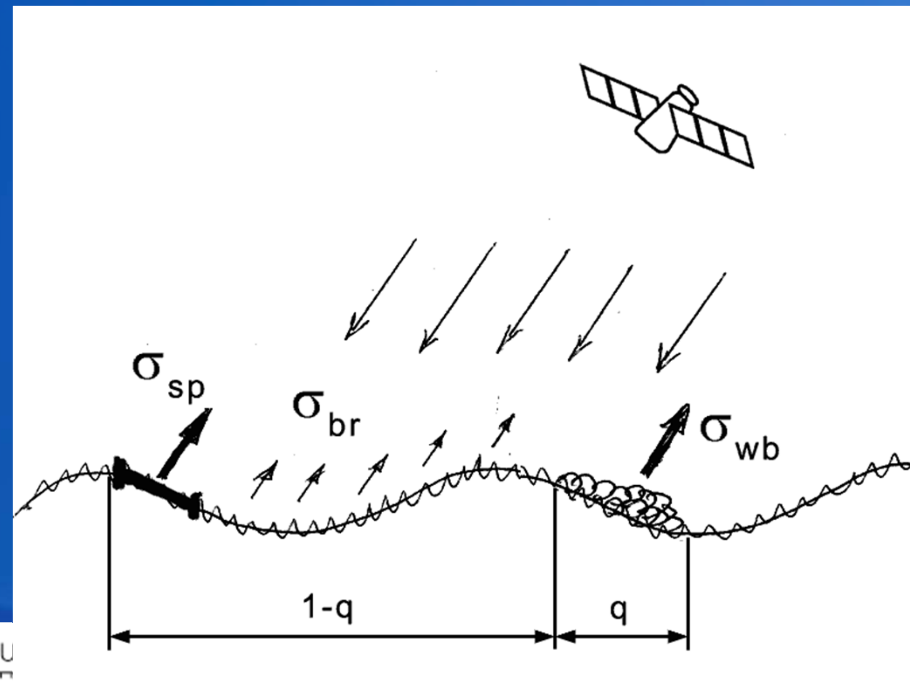
Scattering model :

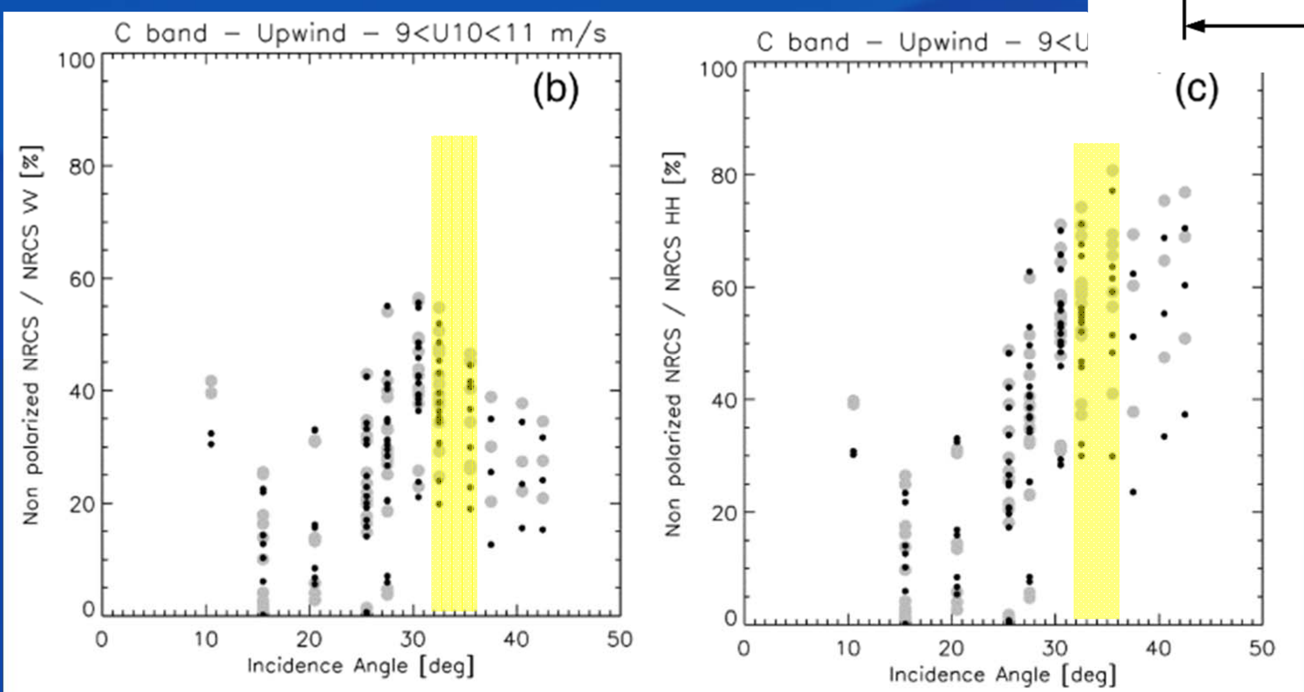
$$\sigma_0^{pp} = \sigma_{0B}^{pp} + \sigma_{wb}$$

where

σ_{0B}^{pp} is 2-scale Bragg scattering

σ_{wb} is impact of breaking waves



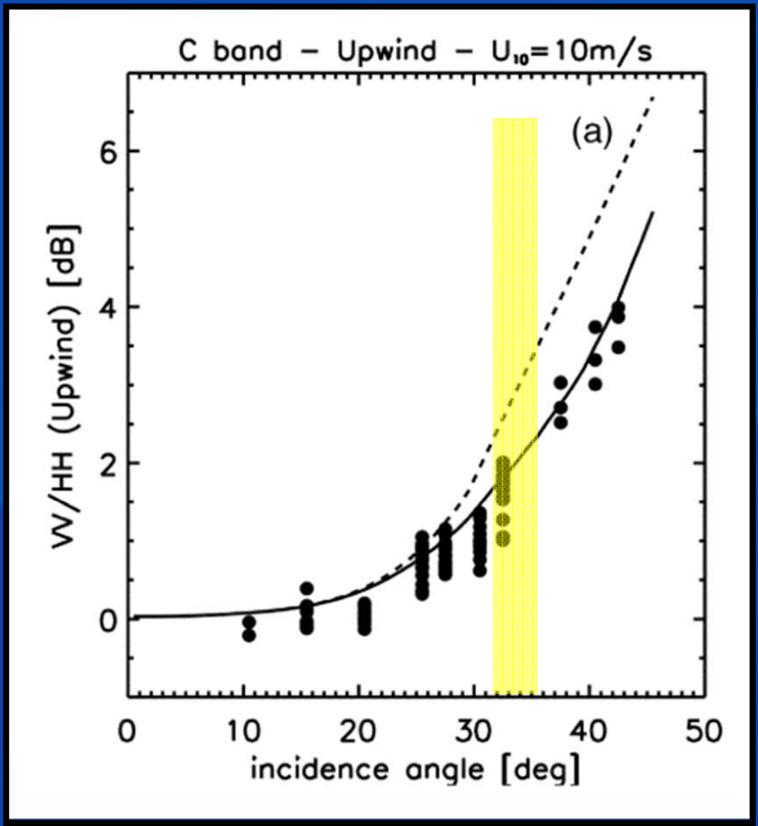


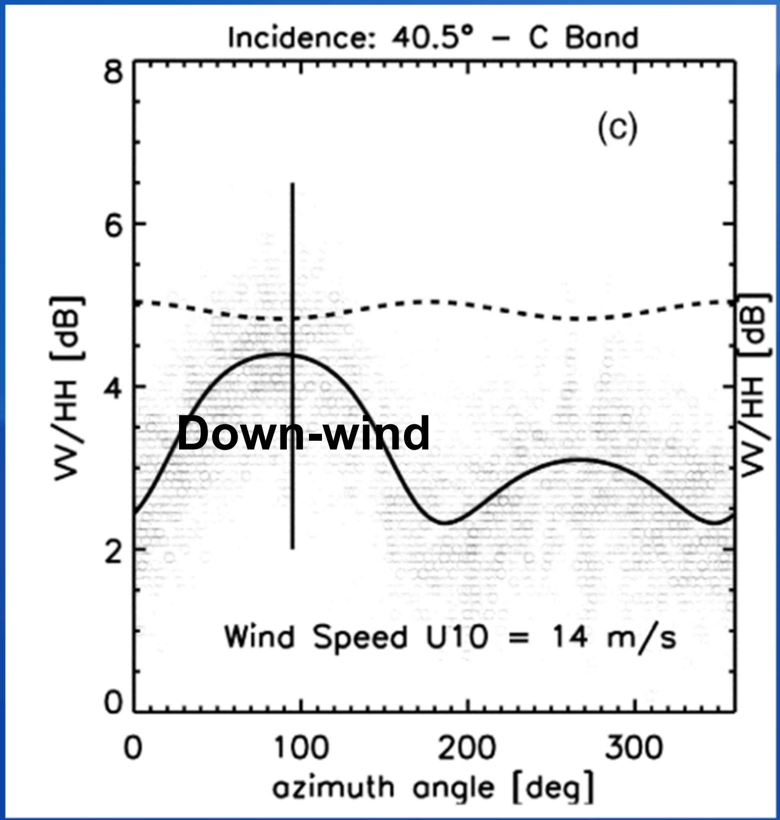
Contribution of wave breaking to NRCS at θ=30 deg is about 30% for VV and 60% for HH (e.g. see air-born C-band Du-Pol obs. by Mouche et al. 2006)

Polarization Ratio

$$P = \frac{\sigma_0^{hh}}{\sigma_0^{vv}} = \frac{\sigma_{0B}^{hh} + \sigma_{wb}}{\sigma_{0B}^{vv} + \sigma_{wb}}$$

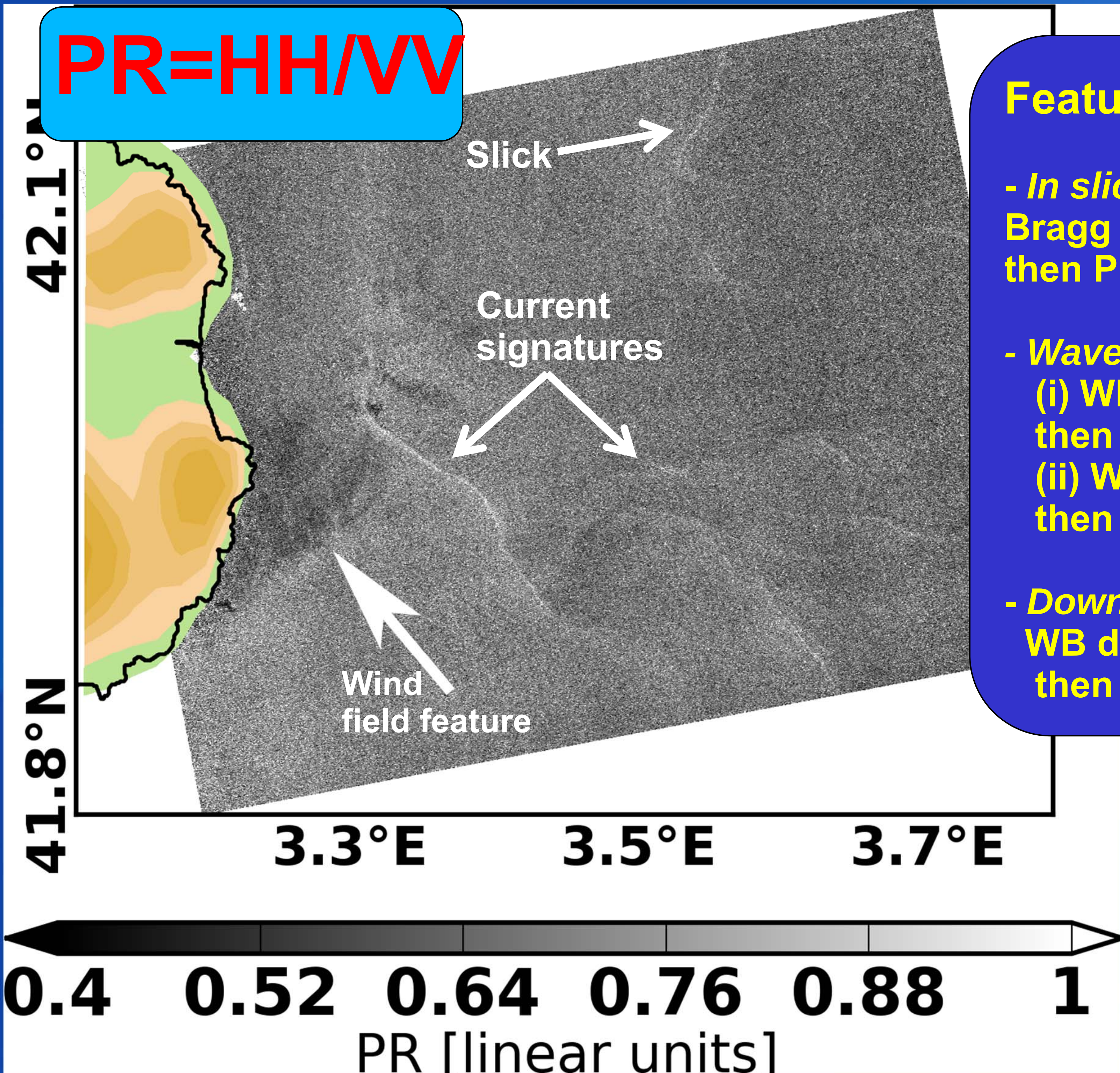
Some C-band PR properties from Mouche et al. 2006.





- PR = HH/VV significantly deviates from PR_Bragg for analyzed images, This justifies that radar returns from breaking waves (WB) play important role.
- When PR->1, role of wave breaking is dominant.
- and when role of wave breaking is weak, PR -> PR_Bragg

PR=HH/VV



Features:

- ***In slicks:***
  Bragg waves are killed, then PR -> 1

- ***Wave-current interact.:***
  (i) WB enhanced then PR -> 1
  (ii) WB suppressed then PR -> PR_Bragg

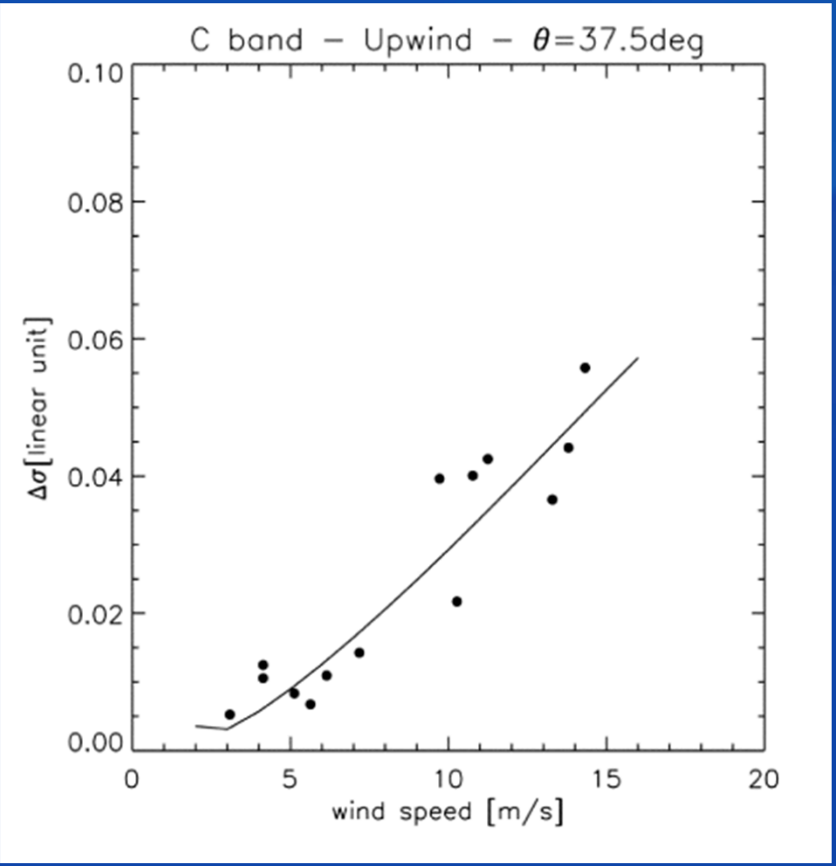
- ***Down-wind condition***
  WB do not scatter then PR -> PR_Bragg

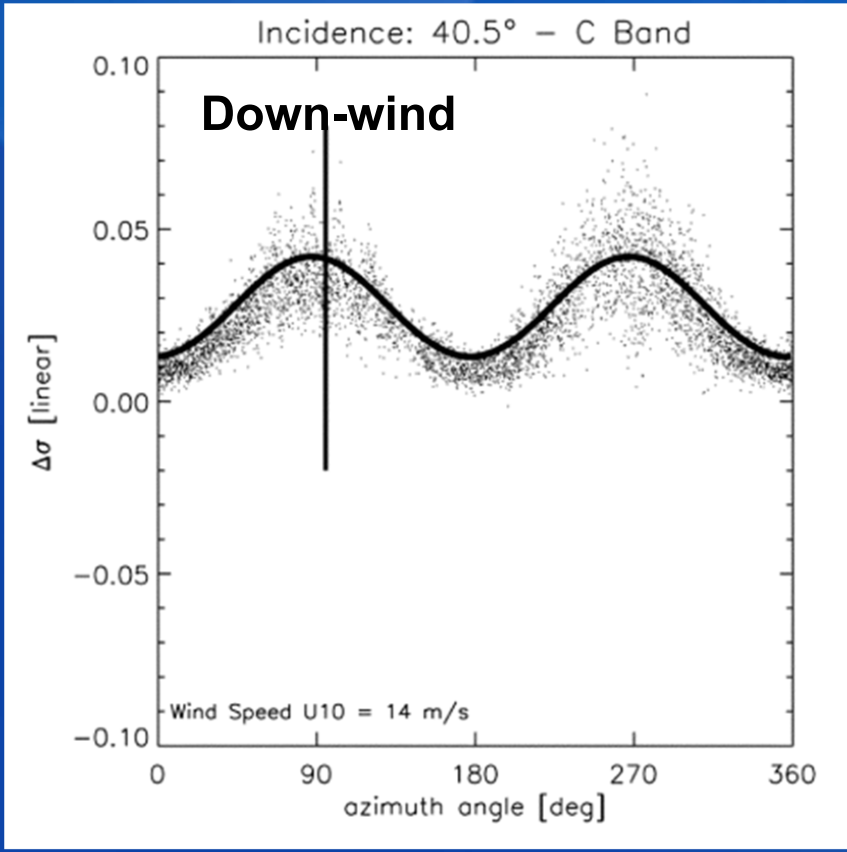
Polarization Difference VV-HH (PD)

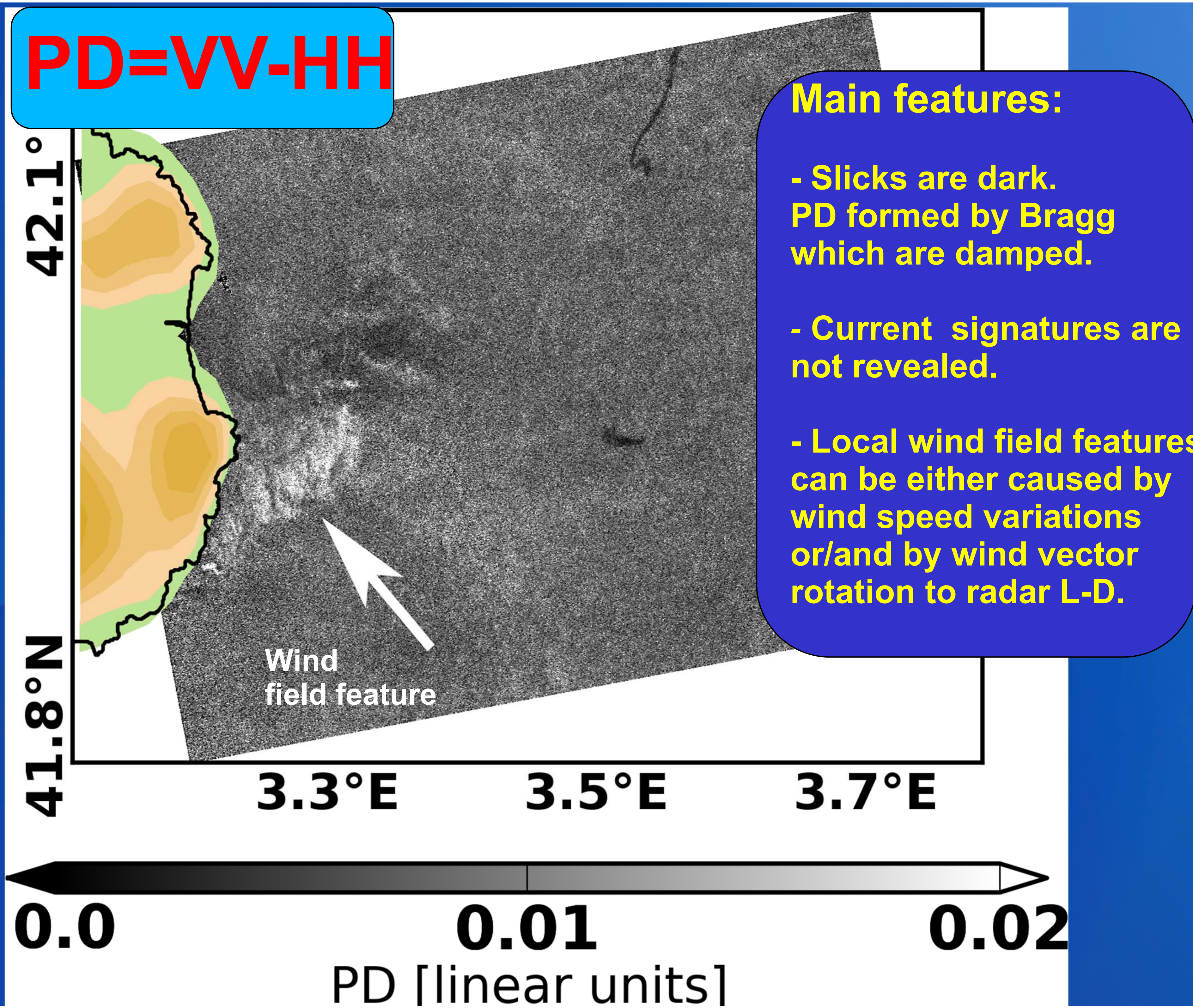
$$\Delta\sigma_0 \equiv \sigma_0^{vv} - \sigma_0^{hh} = \sigma_{0B}^{vv} - \sigma_{0B}^{hh}$$

PD is mostly controlled by short wind waves around the Bragg wavenumber. In C-band these waves have "quick-response" to surface wind (~10m relaxation scale). PD-image should reflect wind field variability and presence of slicks

Some PD-properties in C-band from Mouche et al., 2006






PD=VV-HH
Main features:
- Slicks are dark.
PD formed by Bragg
which are damped.
- Current signatures are
not revealed.
- Local wind field features
can be either caused by
wind speed variations
or/and by wind vector
rotation to radar L-D.
Wind
field feature
42.1°
41.8°N
3.3°E
3.5°E
3.7°E
0.0
0.01
0.02
PD [linear units]

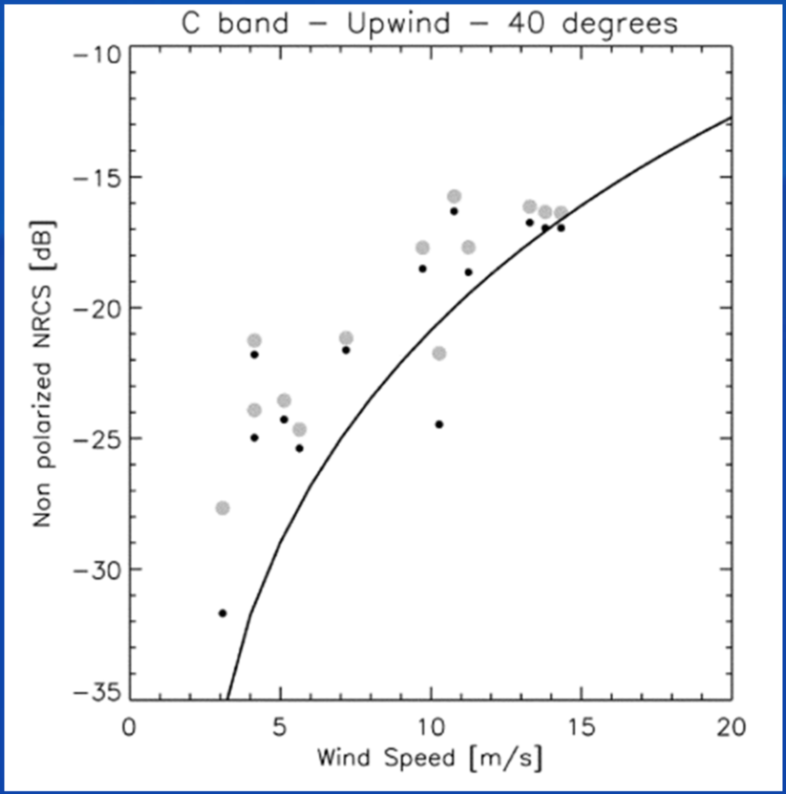
Non-polarized contribution from breaking waves (NP)

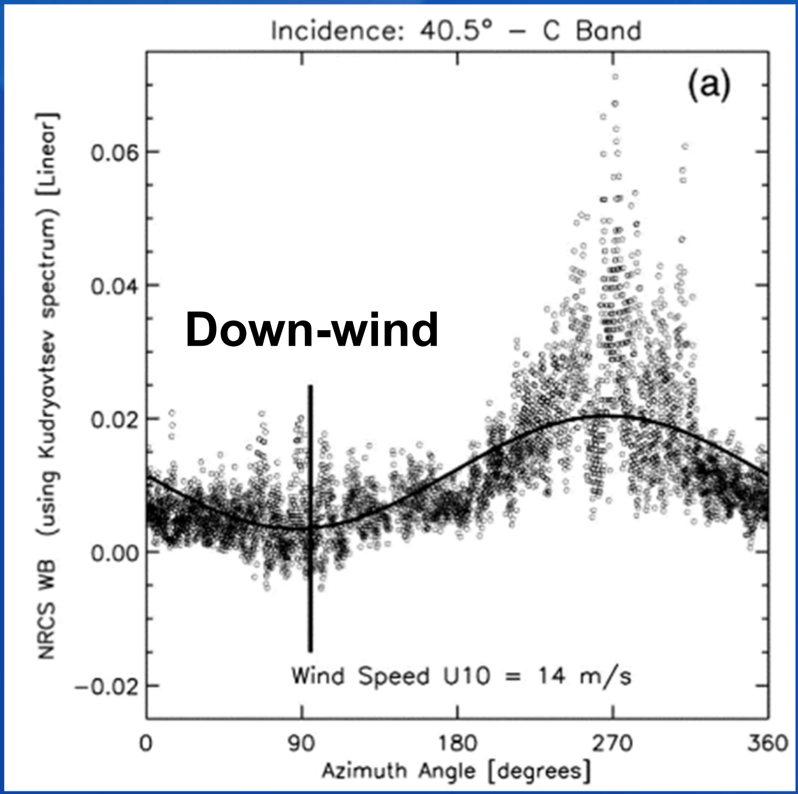
$$\sigma_{wb} = \sigma_0^{vv} - \Delta\sigma_0 / (1 - p_B),$$

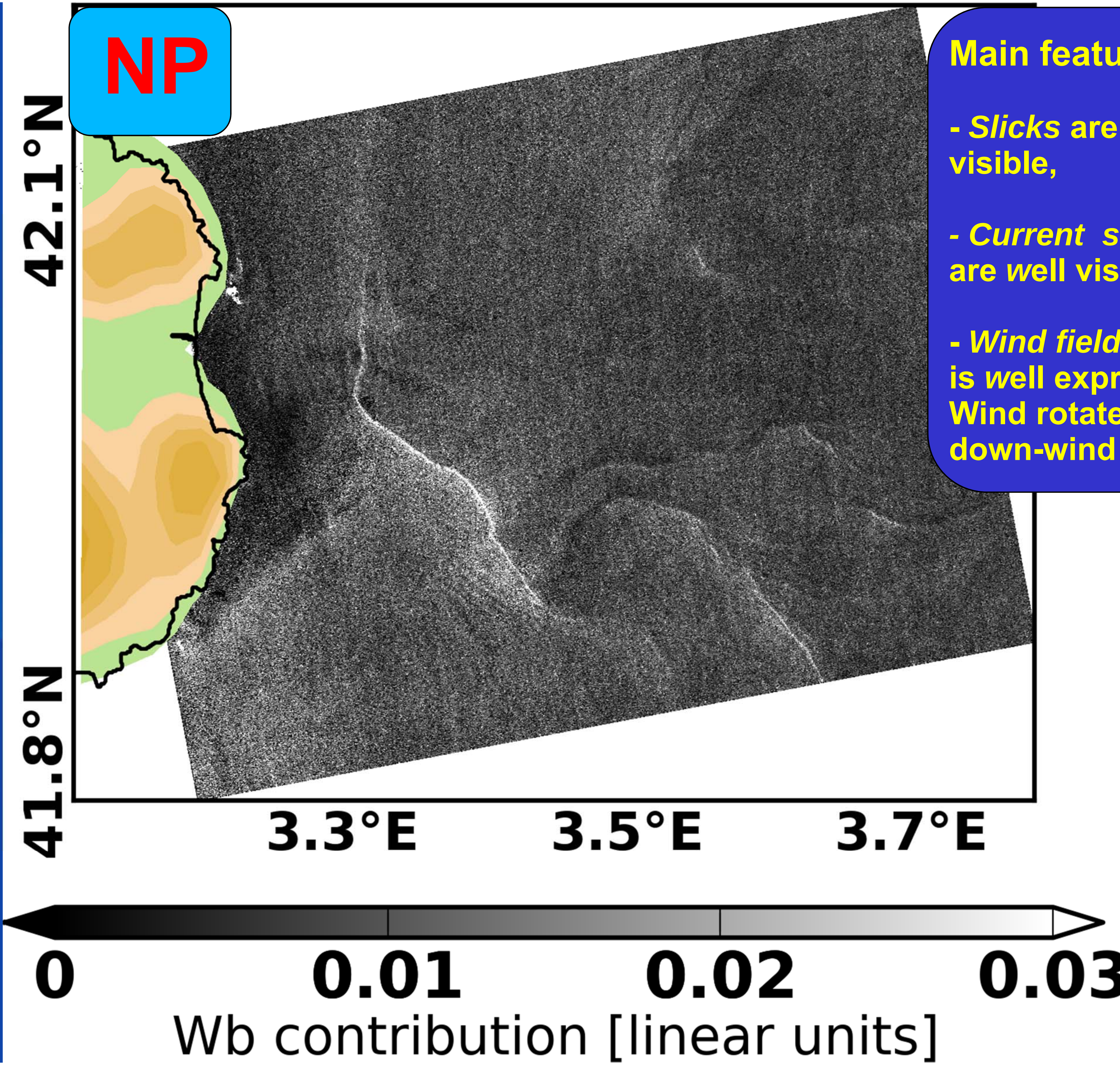
where $p_B = \sigma_{0B}^{hh} / \sigma_{0B}^{vv}$ is PR for Bragg scattering

Bragg PR is function of θ only, and since $\Delta\sigma_0$ reflects wind field variability, the NP-image should mainly reflect variations in wave breaking field associated with wave-current interaction

Some properties of wave breaking NRCS according to Mouche et al., 2006





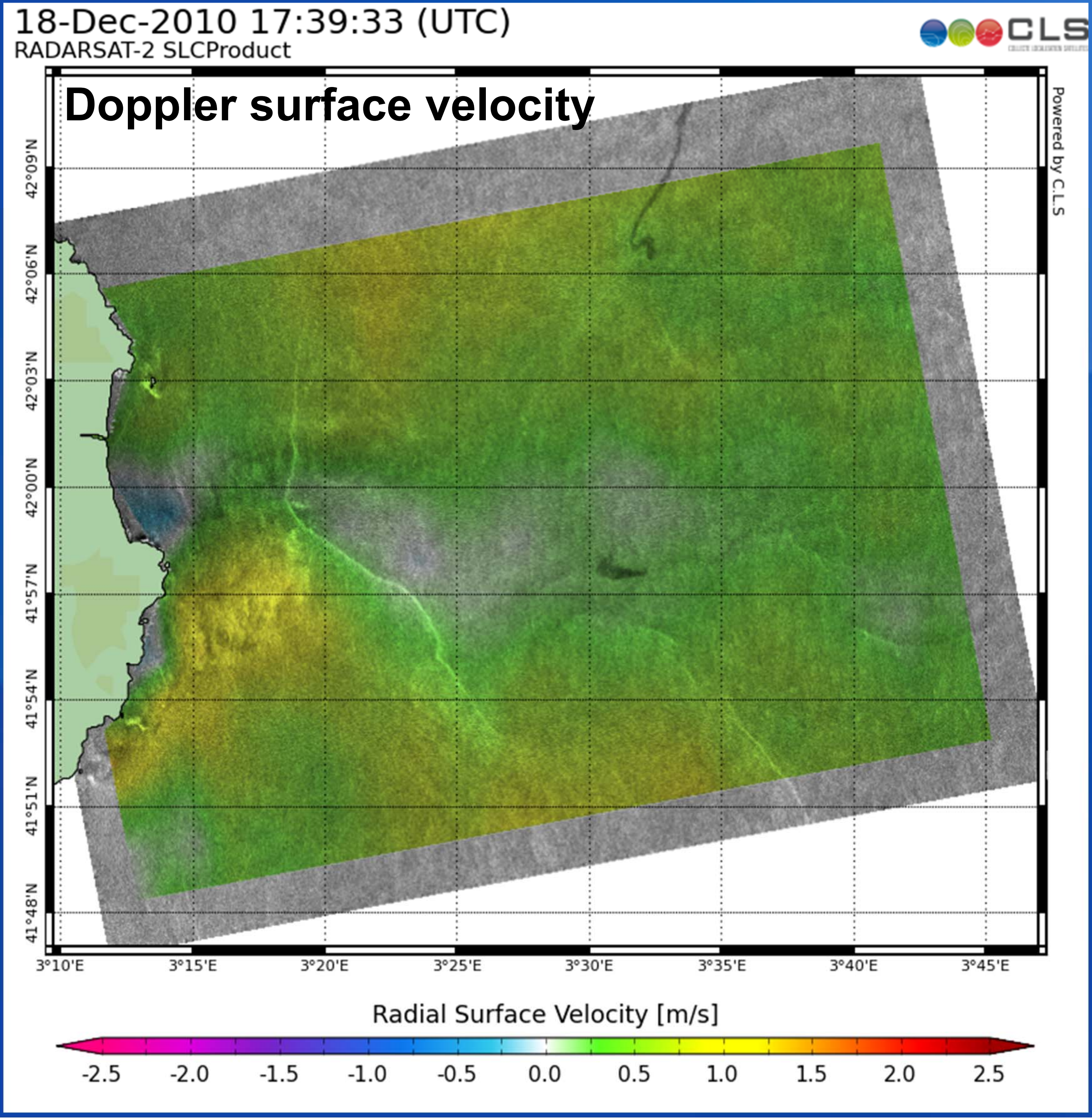


Main features:

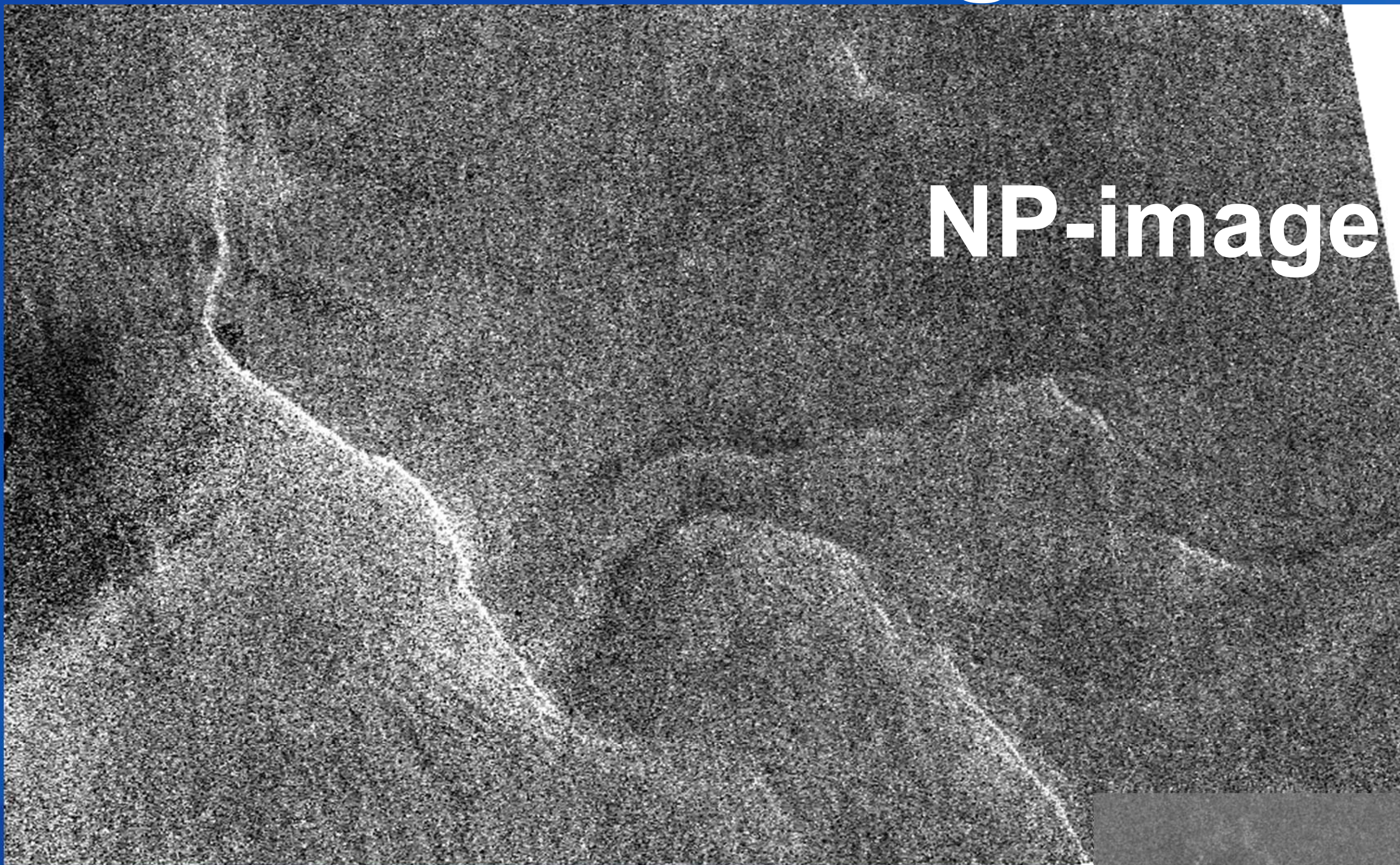
- ***Slicks*** **are not visible,**

- ***Current signatures*** **are well visible.**

- ***Wind field feature*** **is well expressed. Wind rotates to down-wind SAR L-D**


18-Dec-2010 17:39:33 (UTC)
RADARSAT-2 SLCProduct
CLS
Doppler surface velocity
Powered by C.L.S
42°09'N
42°06'N
42°03'N
42°00'N
41°57'N
41°54'N
41°51'N
41°48'N
3°10'E
3°15'E
3°20'E
3°25'E
3°30'E
3°35'E
3°40'E
3°45'E
Radial Surface Velocity [m/s]
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5

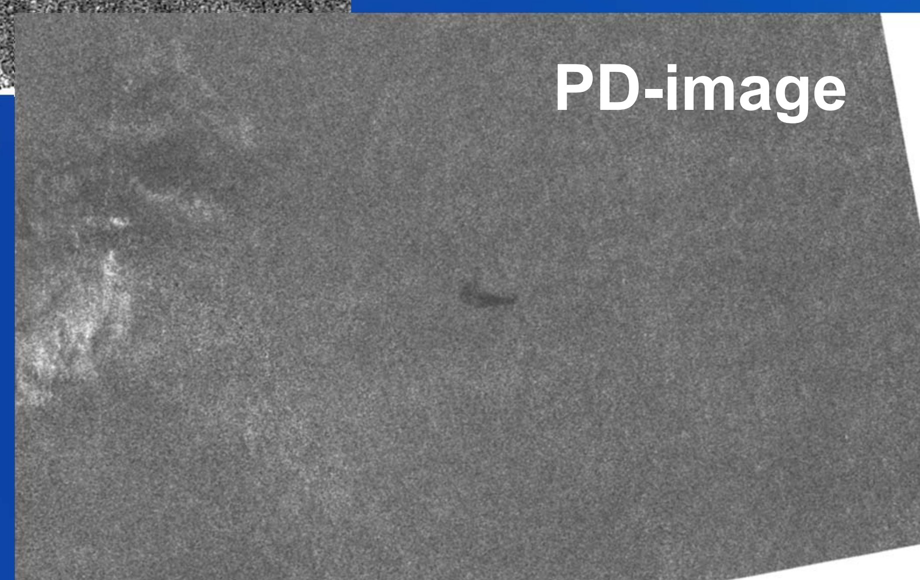
Current signature



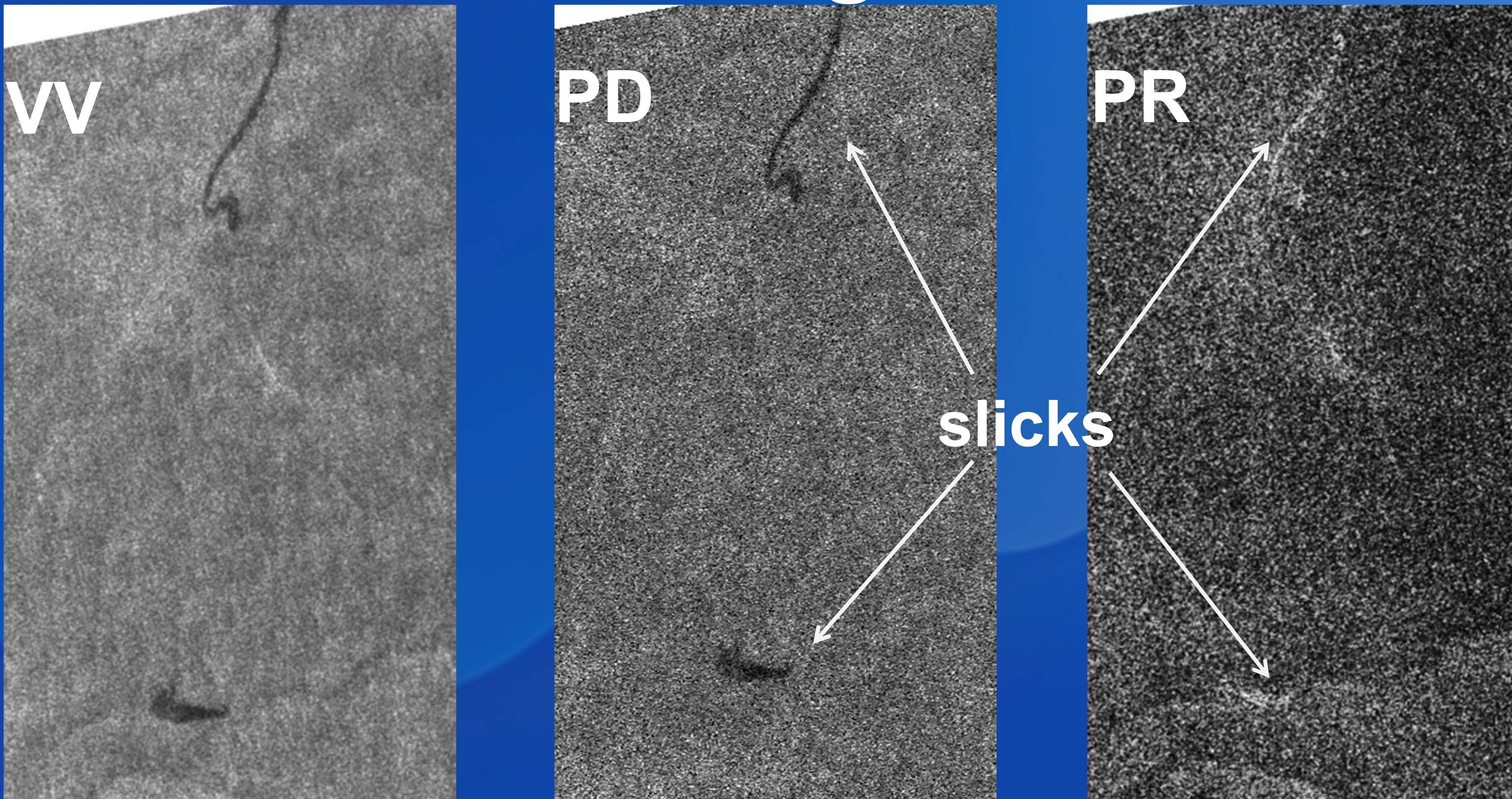
NP-image anomalies trace surface current convergence and divergence

Current signatures are well detected in NP-image (as well as in PR-image), and *invisible* in PD –mage.

This justify that origin of SAR signatures is enhancement/suppression of wave breaking due to wave-current interaction. Role of Bragg waves transformation is negligible

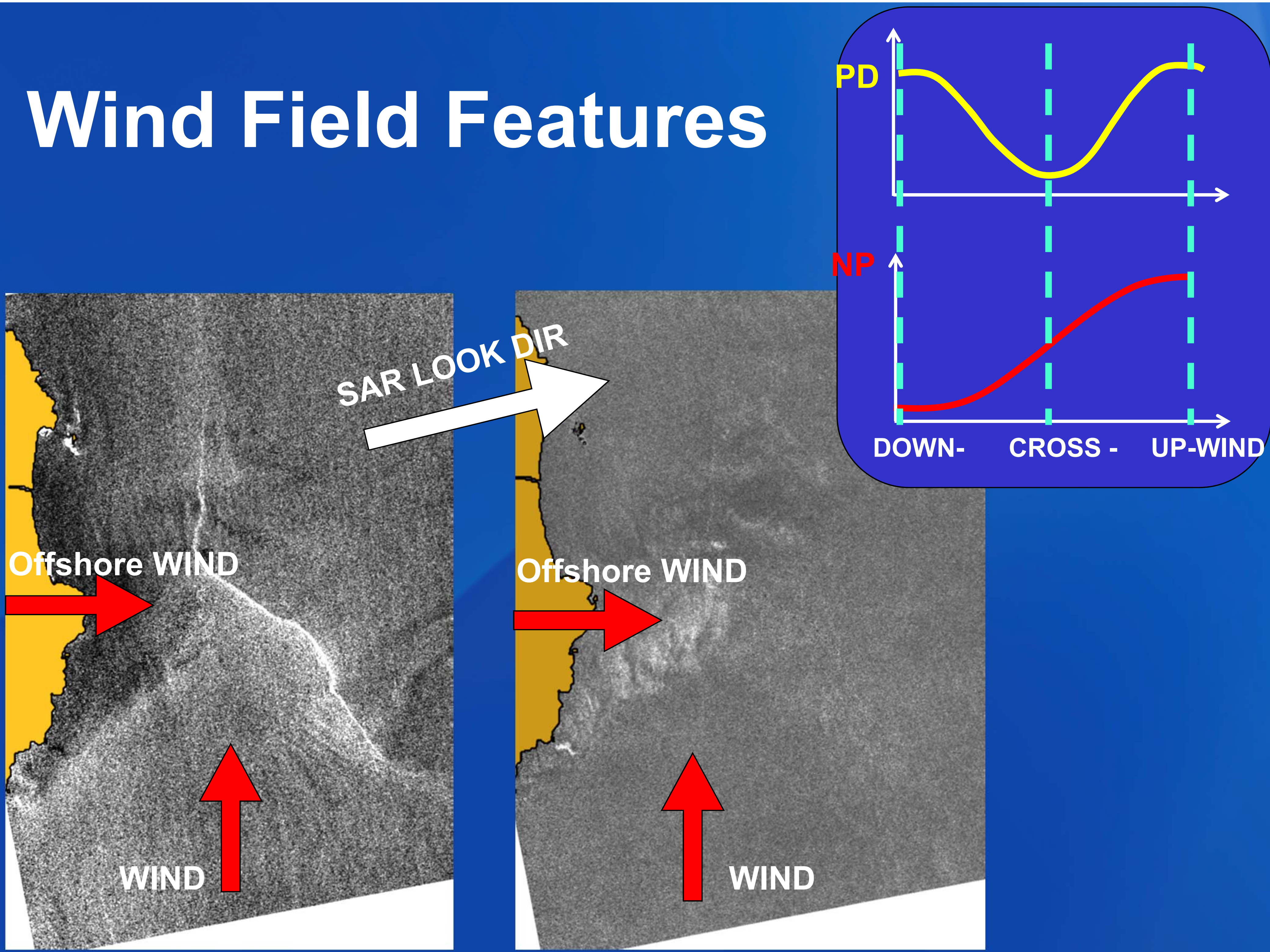


Oil slicks signatures



- Oil slicks are well detected in PD-image (in VV and HH-image) as dark areas. In PR-image they are visible as a bright against ambient values .
- Mechanism: Bragg waves are damped but longer waves and wave breaking – not. Therefore PR in slicks area attains PR=1. This gives a possibility to discriminate slicks from look-alikes.

Wind Field Features



Summary

We suggested an effective and simple approach for analysis of dual-polarized VV and HH images. These images can be transformed in two new images:

- PD-image (Polarization Difference VV-HH), and
- NP-image (Non-Polarized contribution to NRCS).

PD-image is linked to resonant scattering mechanism, and since Bragg waves are fast-response waves, this image carries information about wind field variability and slicks.

NP-image is linked to “scalar” radar returns provided by breaking waves. Since wave breaking are sensitive to surface current, NP-image reflects manifestation sub- and meso-scale ocean current features.

Use of PD- and NP-images *per se* or in combination with original VV-, HH-images or/and PR-image can become a powerful tool for detection and discrimination of various ocean phenomena, e.g.:

- Detection of surface ocean current features and discrimination from wind field variability
- Detection of oil slicks and discrimination from look-alikes (calm area and current features)
- Detection of large-scale variability in wind vector field.