ESA–MOST Dragon Cooperation

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SAR Image Cross-spectral Analysis of Intermediate Radial Waves: Directional Properties

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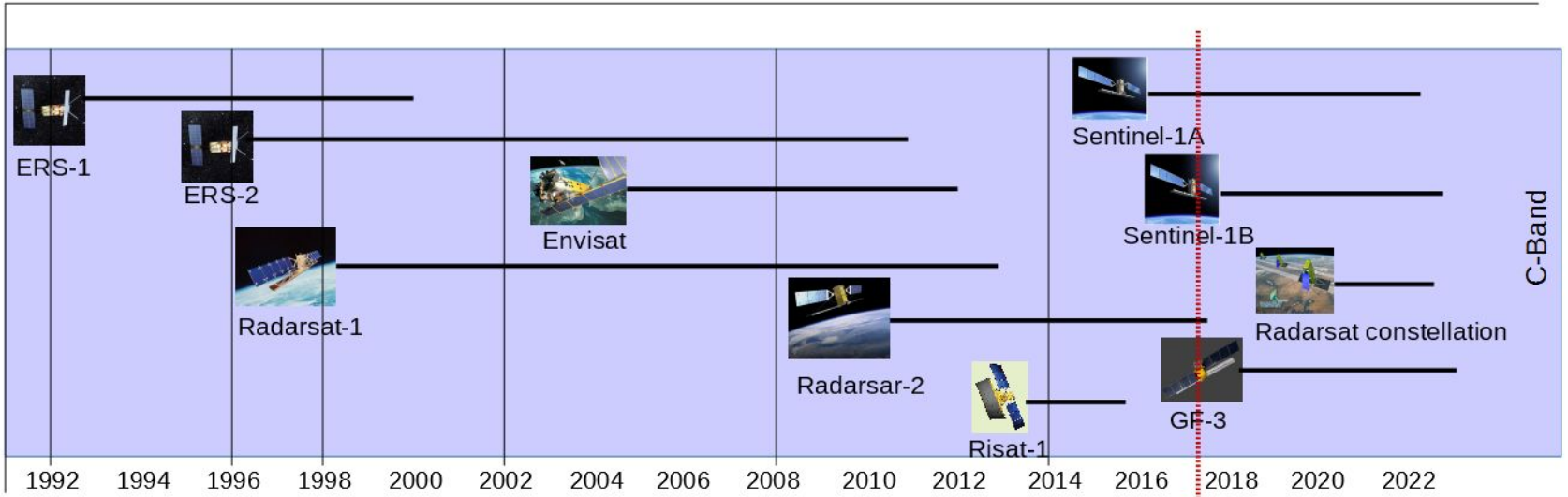
Outlines

1. Introduction
2. Data source and method
3. Data analysis
4. Summary

Introduction: new info from Sentinel-1

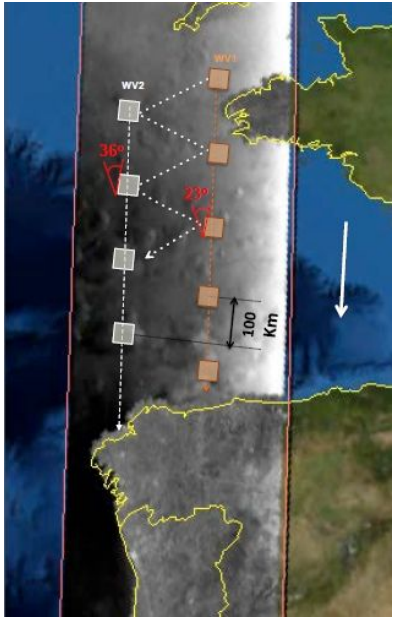


Finest Resolution:

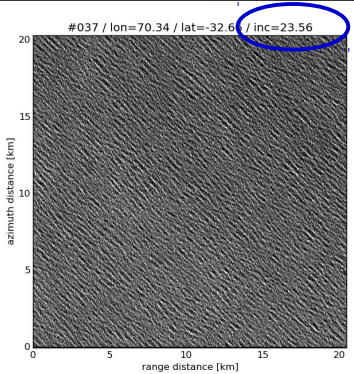
~30m ~10m ~30m ~5m ~5m

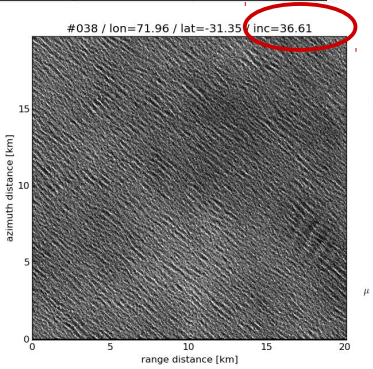
New info?

Data source: Sentinel-1



Mode	Incidence Angle (°)	Resolution (RA*AZ)	Swath Width	Polarization
Stripmap	20-45	5×5 m	80 km	HH/VV/HV/VH
Interferometric Wide Swath	29-46	5×20 m	250 km	HH/VV/HV/VH
Extra Wide Swath	19-47	20×40 m	400 km	HH/VV/HV/VH
Wave	22-25 35-38	5×5 m	20×20 km	HH,VV





S1A/B images + ECMWF wind → Collocated data

Number of collocated dataset

	S1A-VV	S1B-HH
WV1	58162	49608
WV2	58650	50008

After Sentinel-1 Introduction by ESA.

Method: Observations of intermediate waves

- **Intermediate waves: λ~20m**

  in equilibrium range

  modulating short waves and modulated by long waves

- **Sub-resolution waves for ERS-1/2, Envisat/ASAR**

  cannot be resolved by SAR

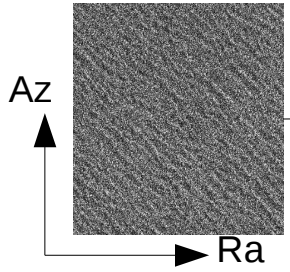
  is described statistically

- **For S1A/B:**

  three times longer than S1A/B spatial resolution

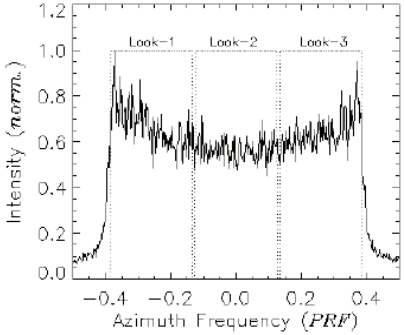
  fully resolved by SAR

Method: Definition of MACS

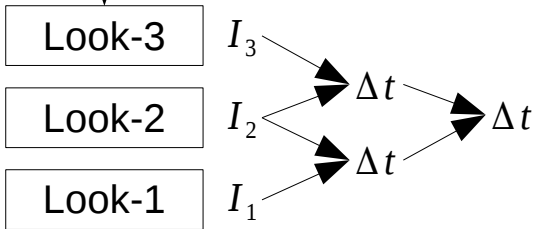


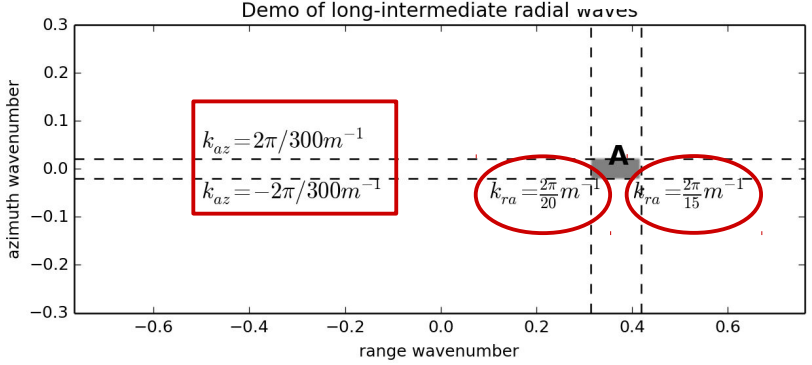
FT in azimuth

After H. Johnsen and F. Collard.



Inverse FT for each segment





$$P_s^{(m,n)}(\vec{k},t)=I_{(m)}(\vec{k},t)I_{(n)}^*(\vec{k},t),m,n\in[1,2,3]$$

$I_{(m)}(\vec{k},t)$ is FT of *mth* look intensity image.

t is the separation time.

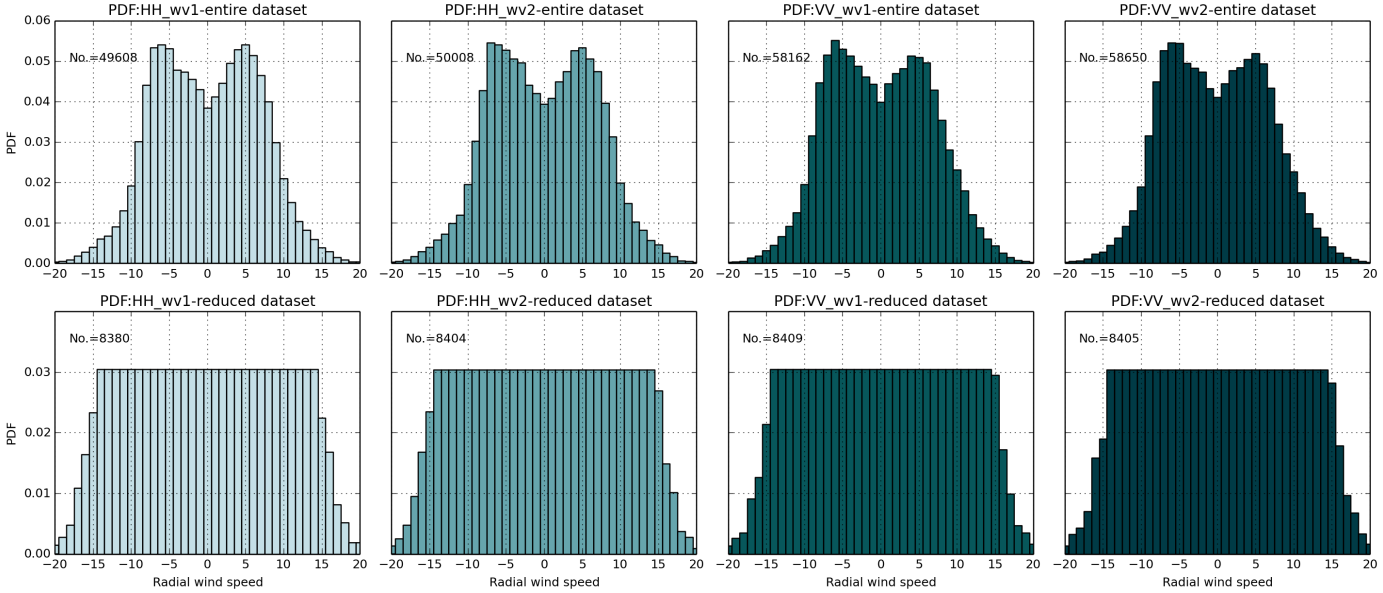
Data analysis w.r.t radial wind-- data equalization

Equalization method:

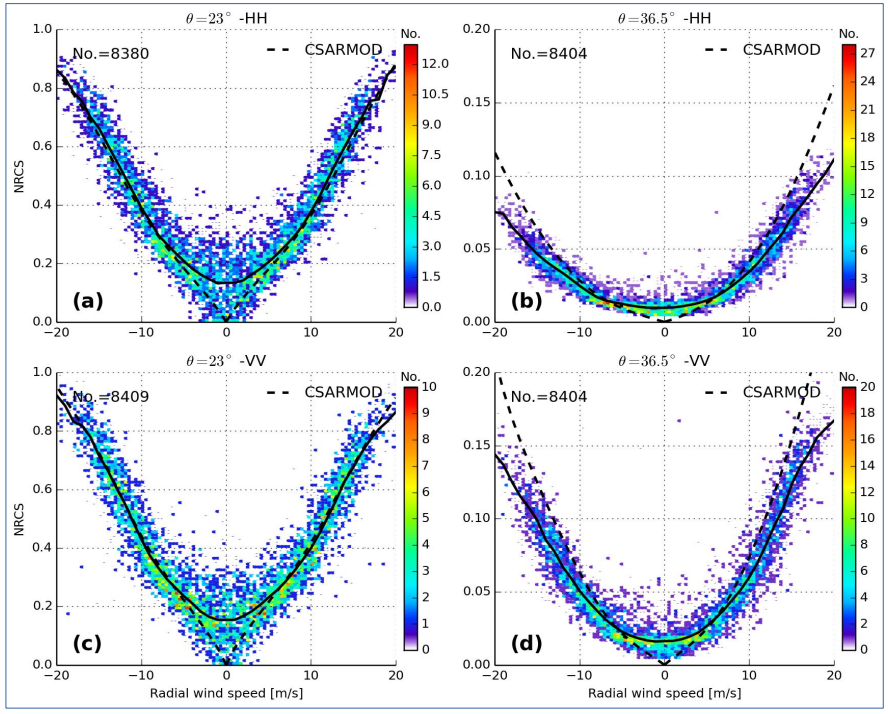
- Valid radial wind speed:

  [-20m/s, 20m/s]

- Bin size of radial wind: 1m/s
- Number of each bin: 255

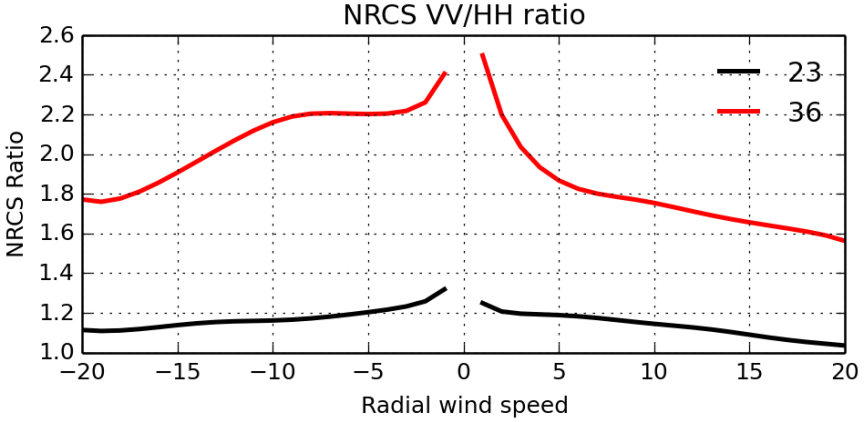


Data analysis w.r.t radial wind-- NRCS

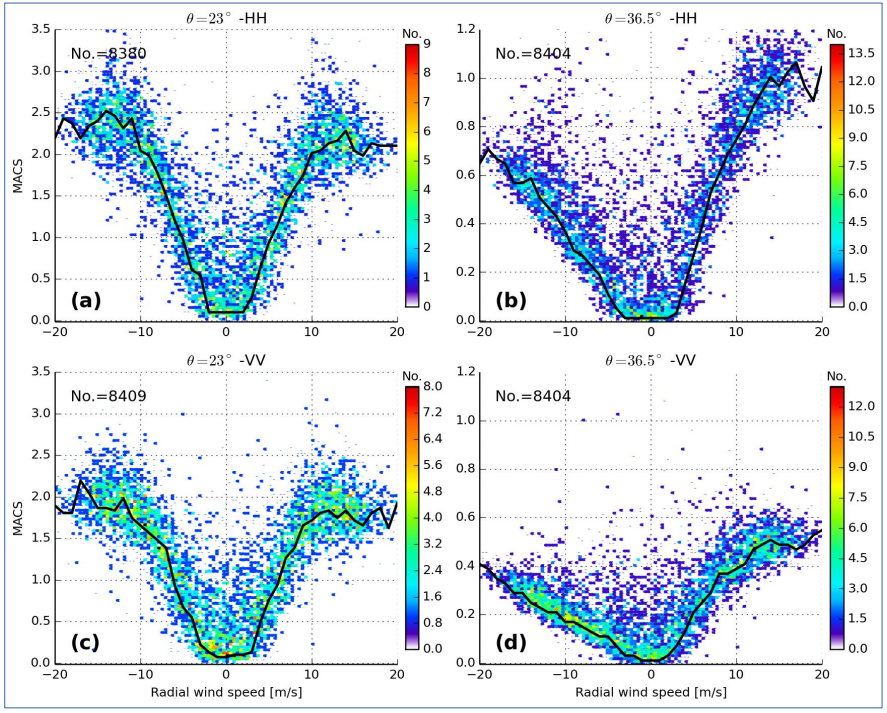


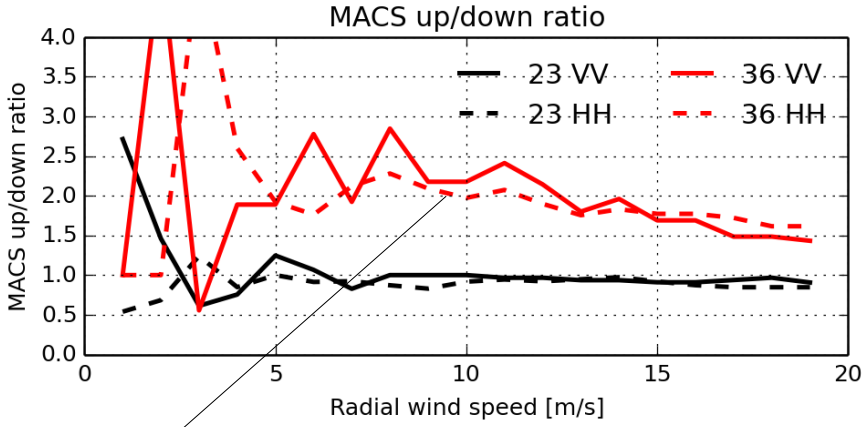
$$\sigma_0 = \sigma_0^p + \sigma_0^{np}$$

- Polarization ratio VV/HH:
  ~1: non-polarized scattering
  ~2: polarized resonant scattering



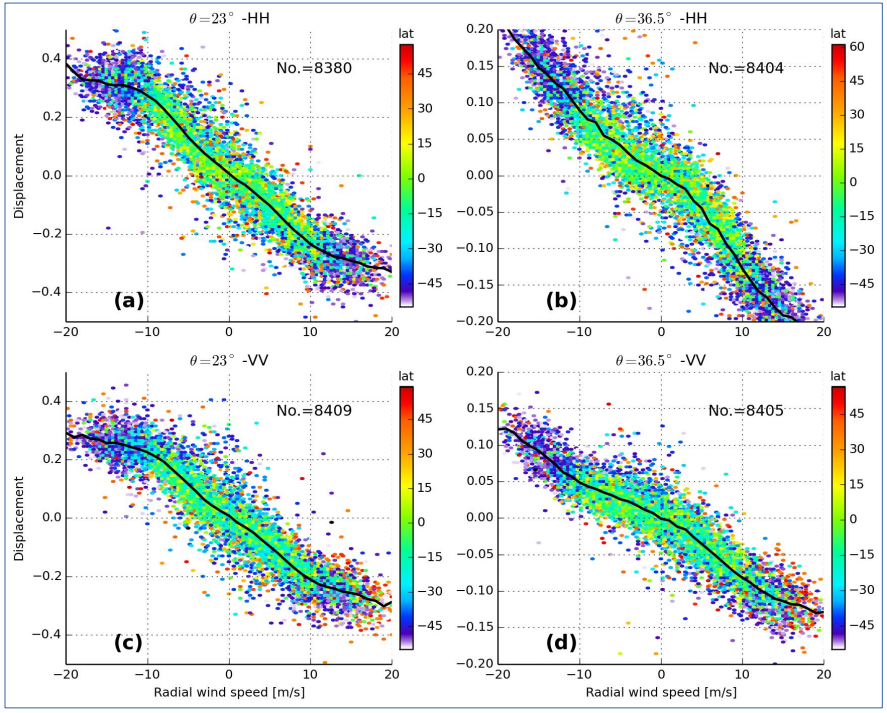
Data analysis w.r.t radial wind-- MMACS

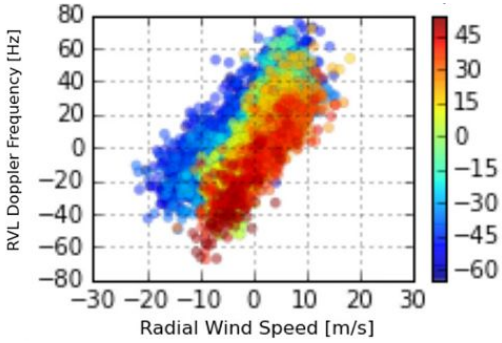


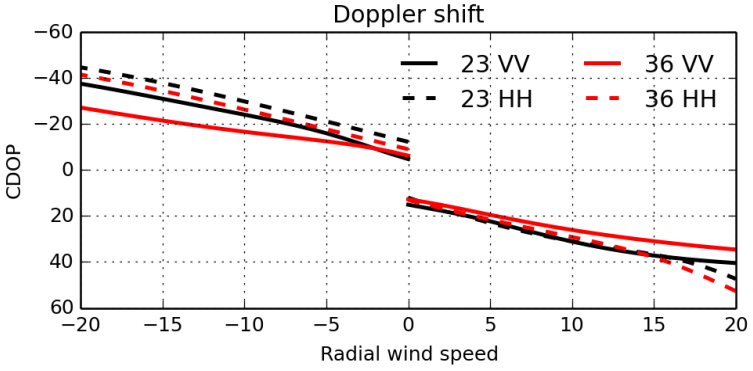


- Up-to-downwind asymmetry:
  - hydrodynamic modulation
  - nonpolarized scattering at upwind

Data analysis w.r.t radial wind-- IMACS







Preliminary interpretation:

- Local NRCS can be written relative to surface slope up to second order, with η surface elevation:

$$\sigma^0(\theta+\Delta\theta)=\sigma^0(\theta)+\Delta\theta\frac{\partial\eta}{\partial\theta}+\frac{\Delta\theta^2}{2}\frac{\partial^2\eta}{\partial\theta^2}$$

- SAR NRCS observations:

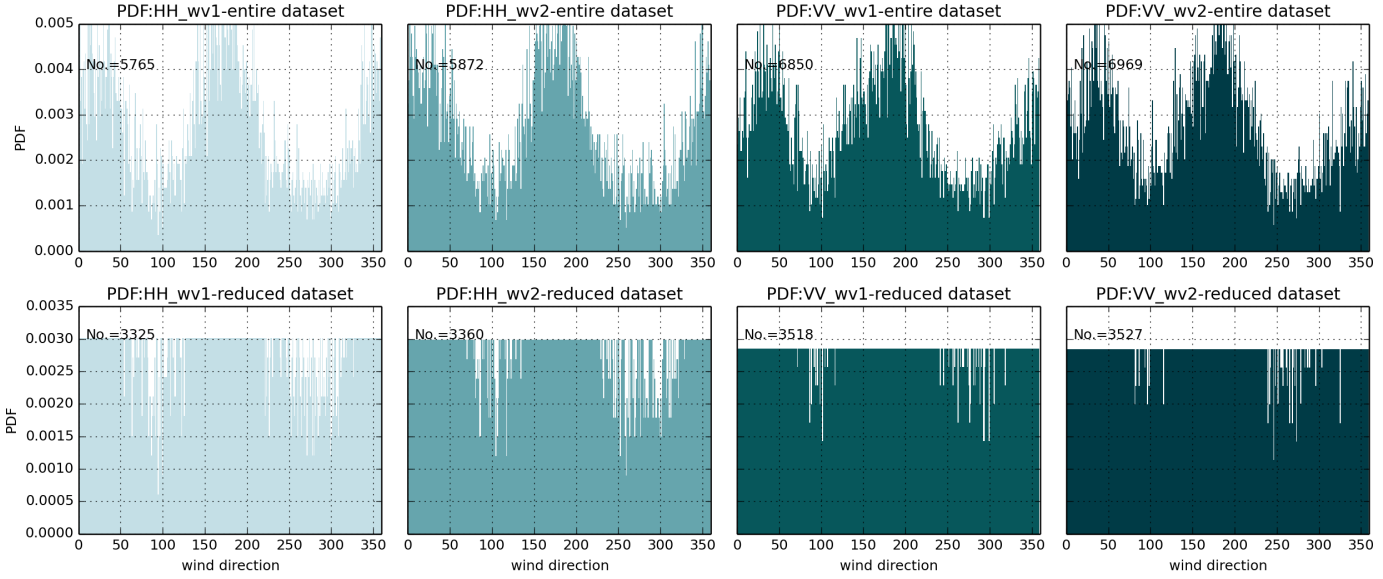
$$\left\langle\sigma^0(\theta)\right\rangle=\overline{\sigma^0(\theta)}+\overline{\frac{1}{2}\left(\frac{\partial\eta}{\partial x}\right)^2\frac{\partial^2\sigma}{\partial\theta^2}}$$

- MACS: spectral analysis highlights first-order tilt modulation
- CDOP: $\dfrac{\overline{(usin\theta_I-wcos\theta_I)\sigma^0(\theta+\Delta\theta)}}{\overline{\sigma^0(\theta+\Delta\theta)}}$

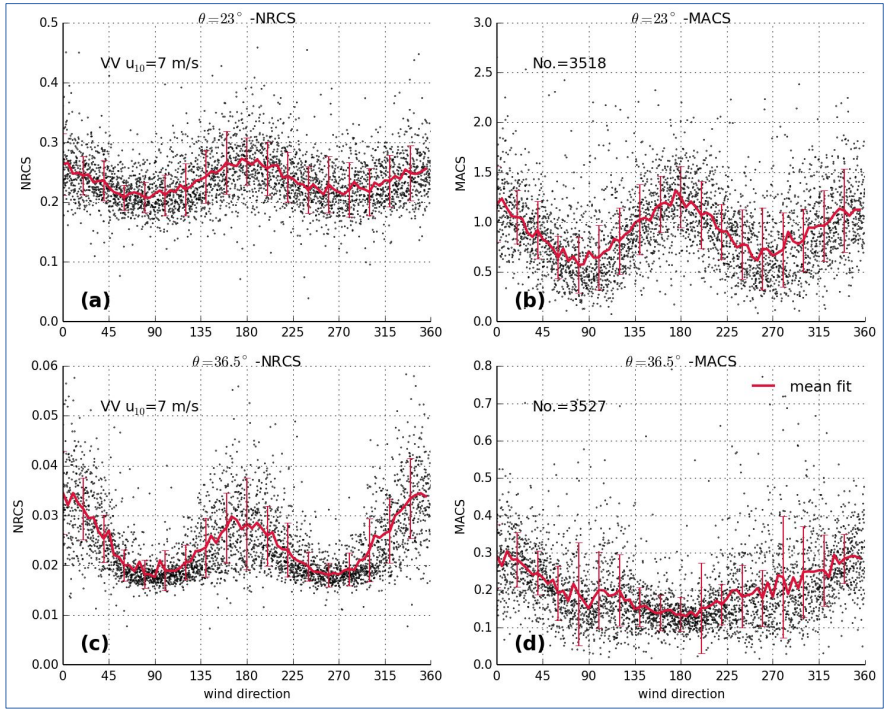
Data analysis w.r.t wind direction-- data equalization at 7m/s

Equalization method:

- Valid direction: [0°, 360°]
- Bin size of direction: 1°
- Number of each bin: 10



Data analysis w.r.t wind direction-- VV NRCS & MMACS



Regression fit:

$$P = a_0 + a_1\cos(\phi) + a_2\cos(2\phi)$$

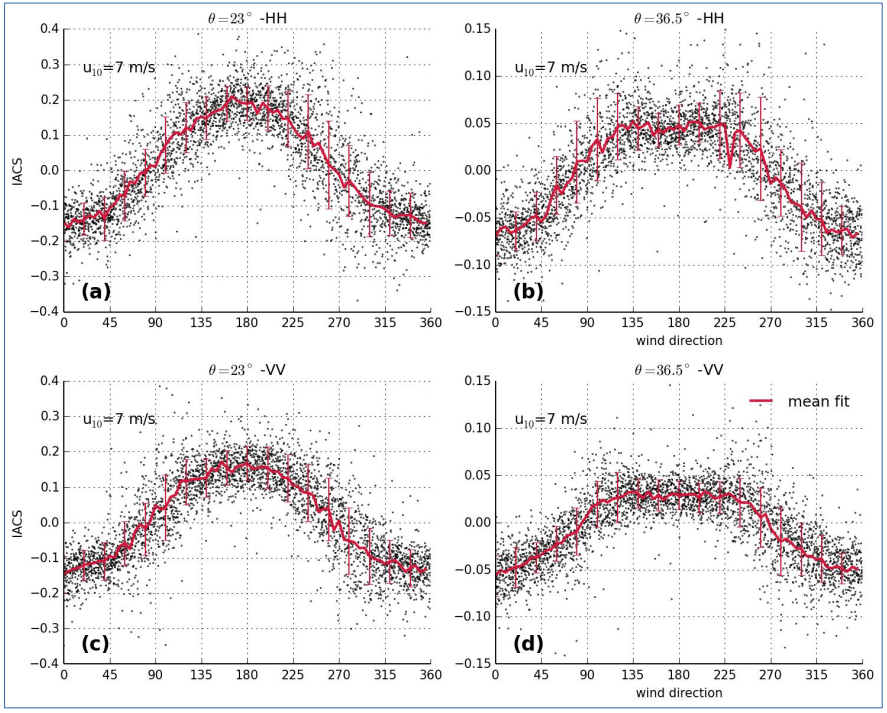
$$UCA = \frac{a_0 + a_2}{a_0 - a_2} - 1$$

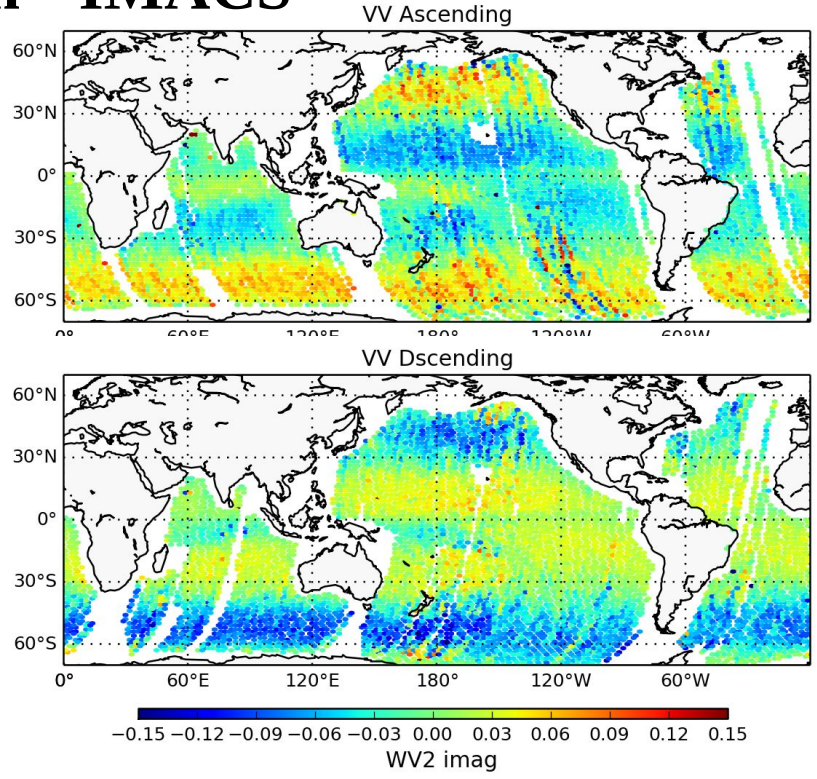
0.2446	0.8884
0.7694	0.0872

$$UDA = \frac{a_1}{a_0}$$

-0.0275	-0.0249
0.0967	0.3146

Data analysis w.r.t wind direction-- IMACS





Summary

- **Sentinel-1 can provide new information on intermediate waves;**

  Shorter waves (~20m)

- **SAR image cross-spectra over range intermediate waves:**

  modulation of short-scale waves

  effectiveness of polarized resonant scattering

- **Analysis of MACS relative to surface winds:**

  independent of latitude

  potential in accurate wind direction retrieval

Thank you a lot !

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