Radar altimetry backscattering signatures at Ka, Ku, C and S bands over the ocean

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Introduction

It is well known that near-surface wind speed is a first-order geophysical parameter that can be retrieved from backscatter observations. But the sea surface roughness also often deviates from simple local wind forcing behavior. The final objective of this study is to gain some insight on the ocean processes other than wind and wave that may produce sea state perturbations observed by altimeter backscatter measurements (i.e. surface currents, eddies, ...). Global statistics will be used to identify regional study cases for field studies that will be performed in a second time.

In this study, we present global maps of the mean and standard deviation of the along-track backscatter coefficients (from ocean retracker) over the ocean at :

- Ku band using ERS-2, ENVISAT, and Jason-2 data
- S band using ENVISAT data
- C band using Jason-2 data
- Ka band using SARAL data

The resulting maps have been obtained from a original method developed to compute any statistics along the pass.

Datasets

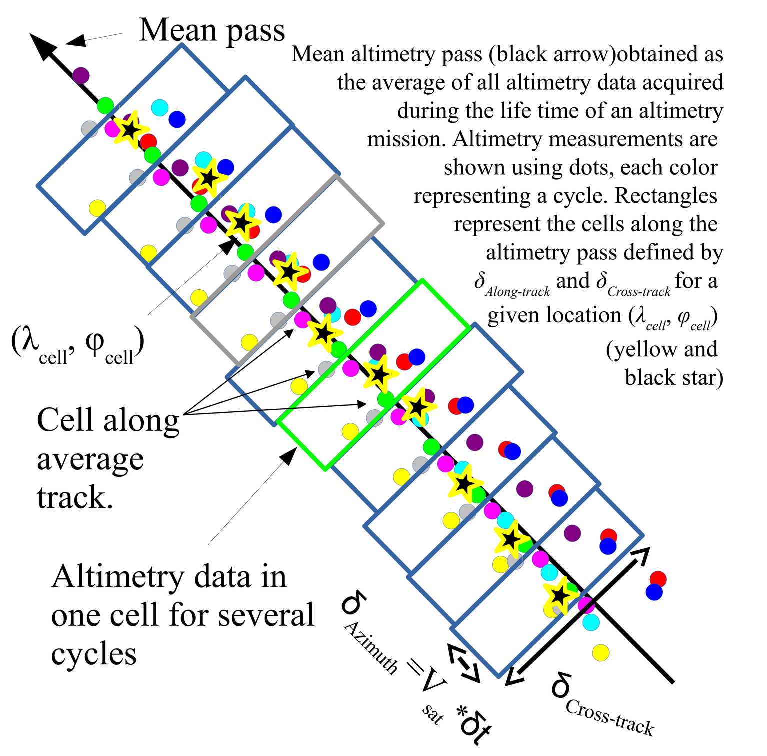
- ERS-2: REAPER data product, release [1]. Data are available from May 1995 to June 2003 (cycles 1 to 84).
- ENVISAT v2.1 : REAPER data product, release [1]. 35-day repeat orbit characteristics are the same as for ERS-2. Data are available from May 2002 to October 2010 (cycles 7 to 93).
- JASON-2 mission: AVISO data product. 10-day orbit is different. Data used are from August 2008 to June 2016 (cycles 0 to 288).
- SARAL: AVISO data product release [2]. Placed in the same orbit as ENVISAT. Data are available from March 2013 to June 2016 (cycles 1 to 33).

Mission	Cycles	Band	Mean (dB)	Std (dB)
ers2.r	1 to 84	ku	10.36	0.84
envisat.v21	7 to 93	ku	11.09	1.80
	7 to 64	s	11.26	1.57
		s-ku	-3.61	4.08
jason2d	0 to 288	ku	13.46	0.66
		c	15.29	0.64
		c-ku	10.58	0.41
saral.s	0 to 33	ka	11.10	1.23

Table :mean and standard deviation of the backscatter coefficient over ocean for each mission and band (Open ocean defined at 200 km from the coast and between 60° N & S).

Method

Along-track altimetry data were first sorted using a normalized pass [3, 4] in order to merge the data measurements into cells regularly organized along the track. The mean pass is then defined by four parameters: the mean longitude and latitude of each cell along the mean pass, and the size of its dimensions - alongtrack ($\delta_{Along\text{-}track}$) and cross track ($\delta_{Cross\text{-}track}$). $\delta_{Cross\text{-}track}$ is chosen as 2 km - the distance of the maximum cross-track variations along the orbit of ERS-2, ENVISAT, SARAL and Jason-2 missions), $\delta_{Along\text{-}track}$ is given by : $\delta_{Along\text{-}track} = V_{sat}\ \delta t$ where V_{sat} is the velocity of the satellite along the orbit (i.e. 7.45 km.s^{-1}) and δt is equal to 1 second. That means that every cell contains a maximum of 20 measurements for each cycle for 20Hz along track mission. For Saral mission at 40hz, it is a maximum of 40 measurements for each cycle. Note that these parameters defining and/or identifying the reference ground track and altimeter points have been integrated into the GDR products distributed by the CTOH.

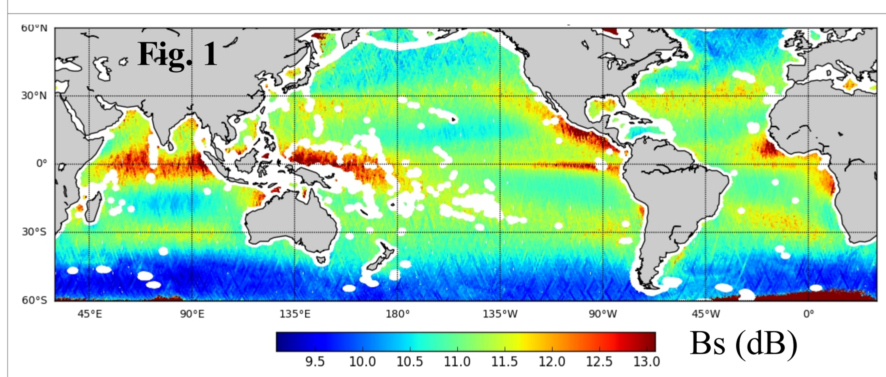


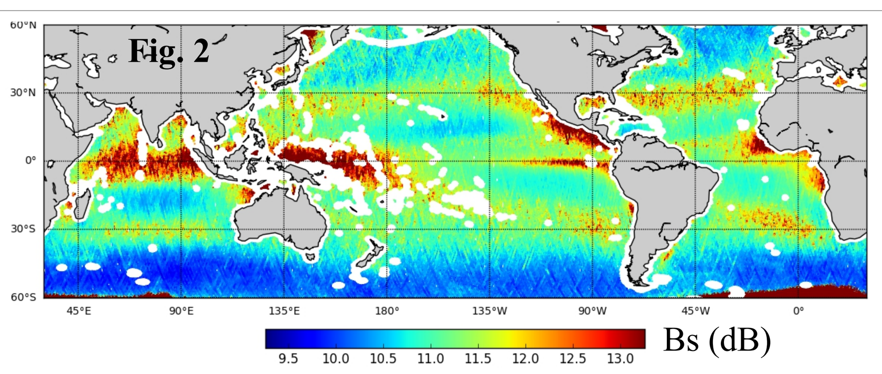
ENVISAT.v21

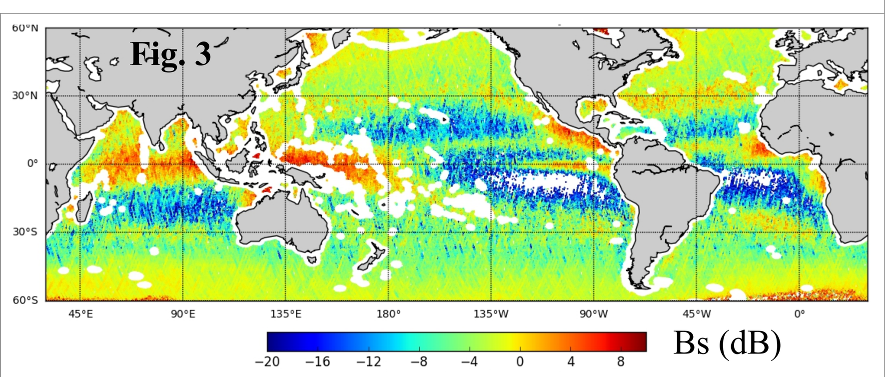
Ku band (13.575 GHz)

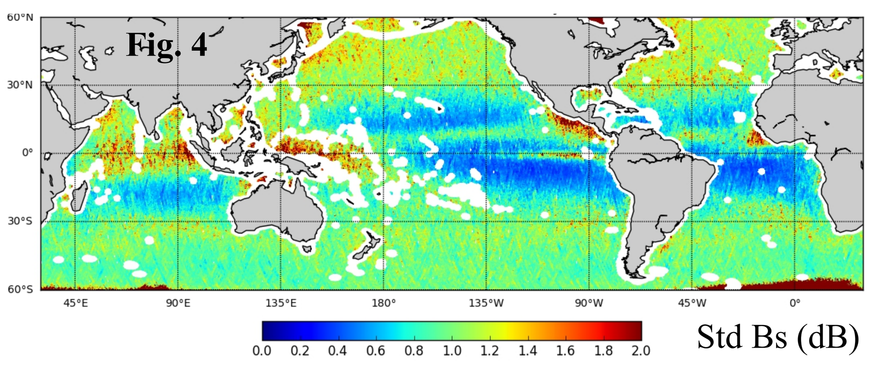
S band (3.2 GHz)

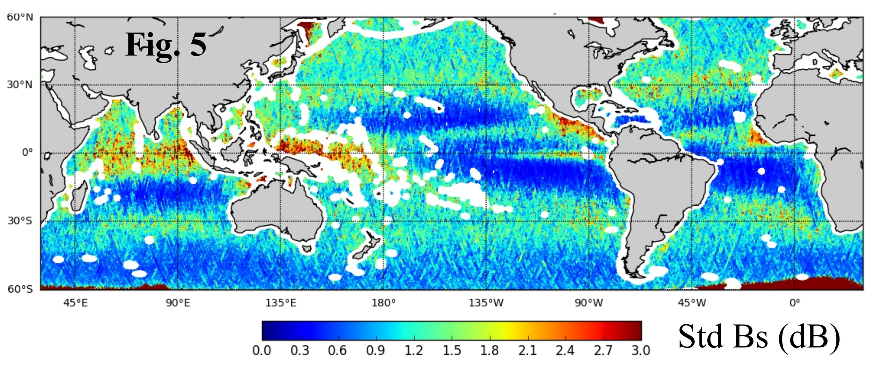
S-Ku Band difference

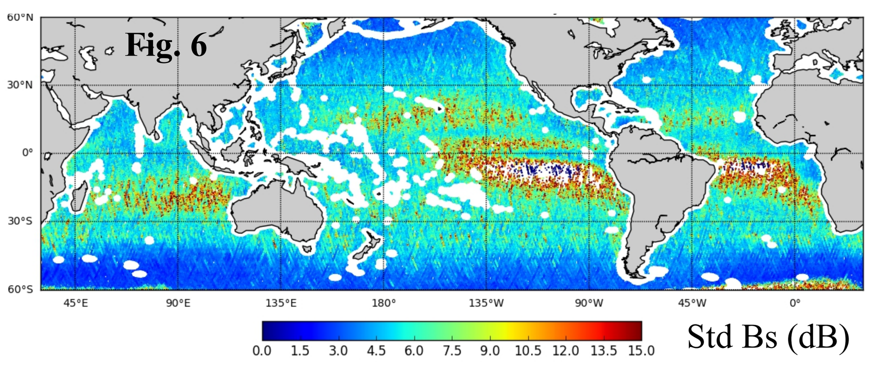






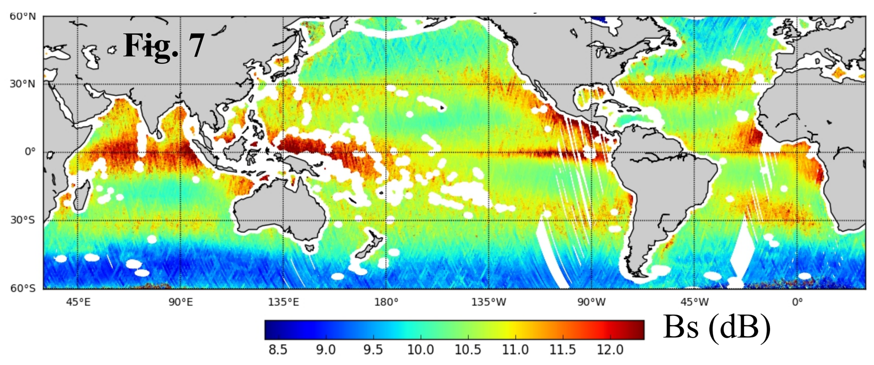


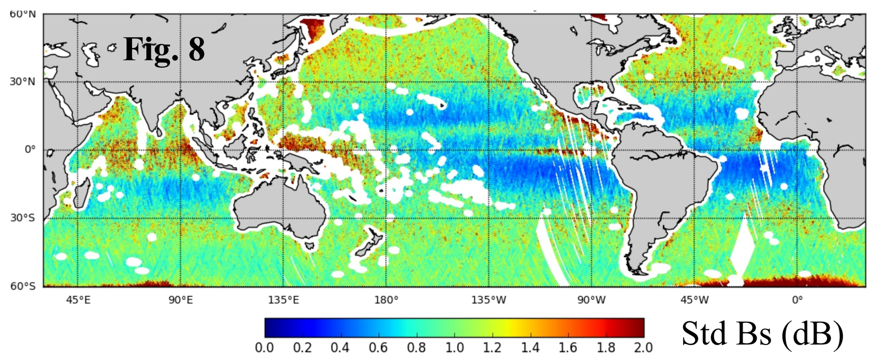




ERS-2 reaper

Ku Band (13.8 GHz)



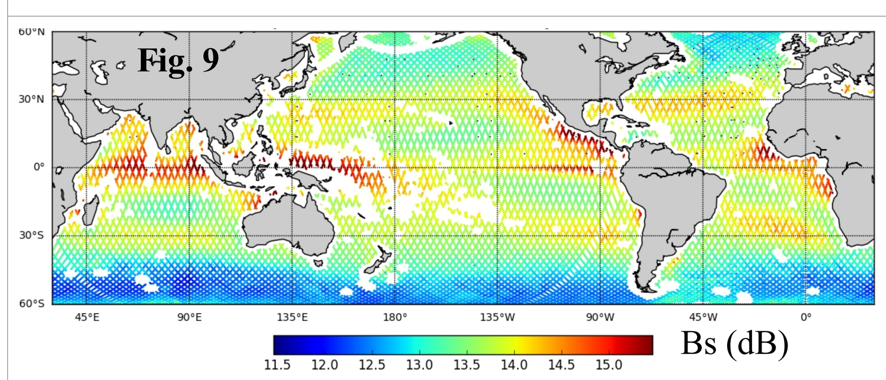


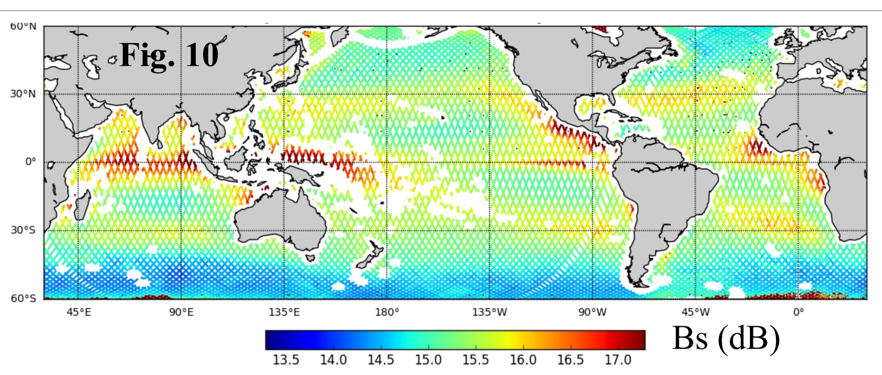
JASON 2

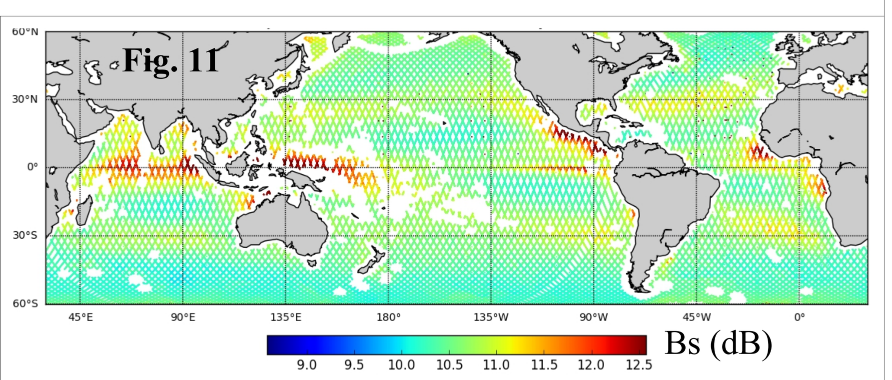
Ku band (13.575 GHz)

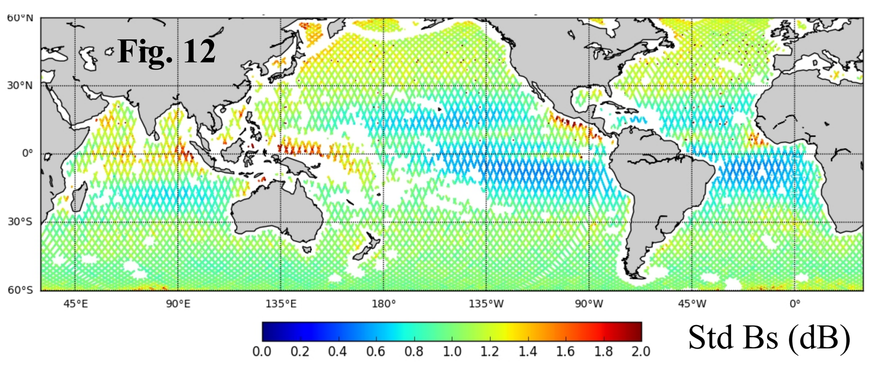
C band (5.4 GHz)

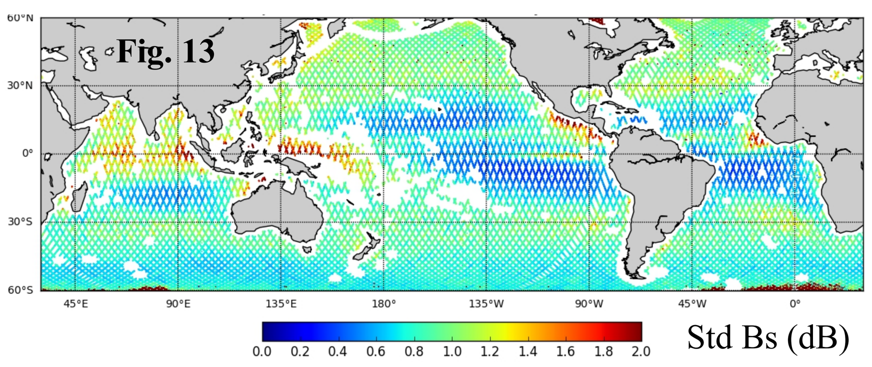
C-Ku Band difference

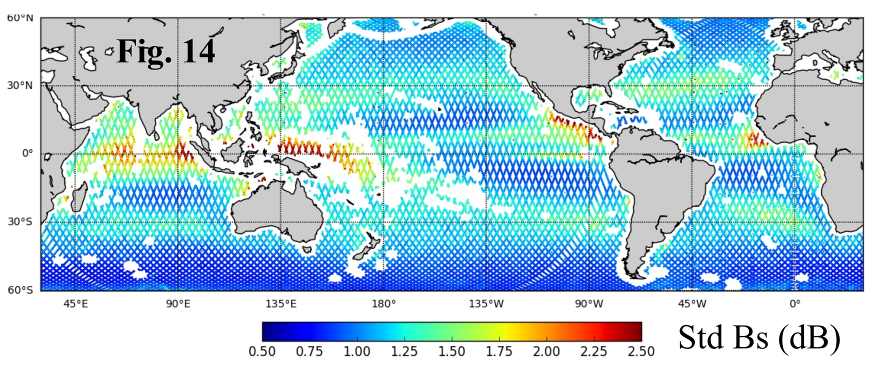






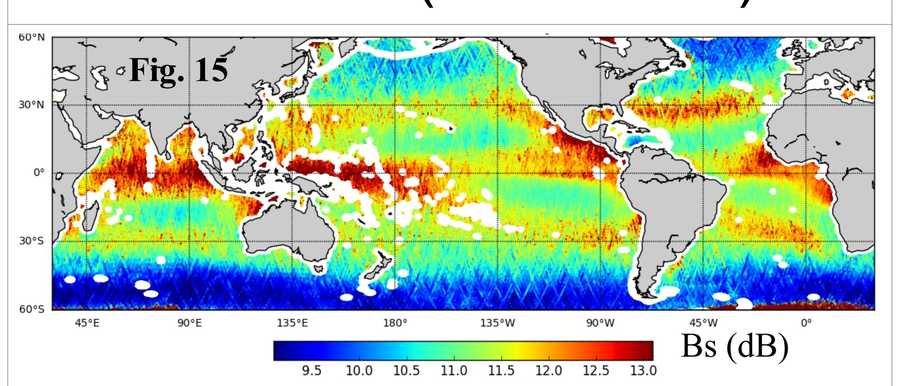


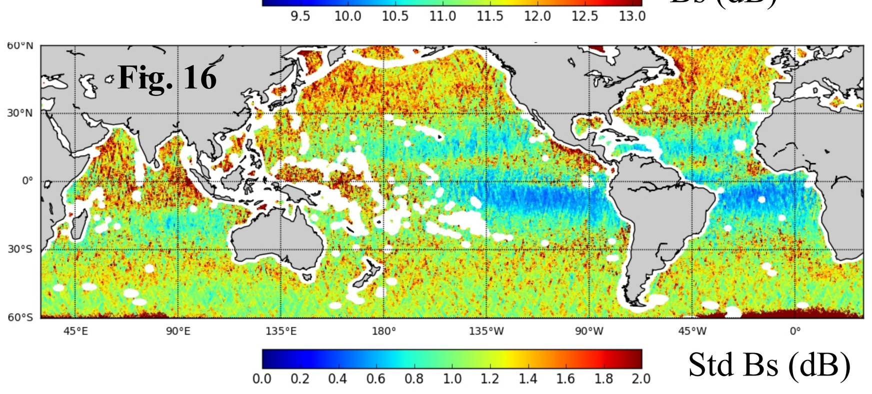




Saral

Ka Band (35.75 GHz)





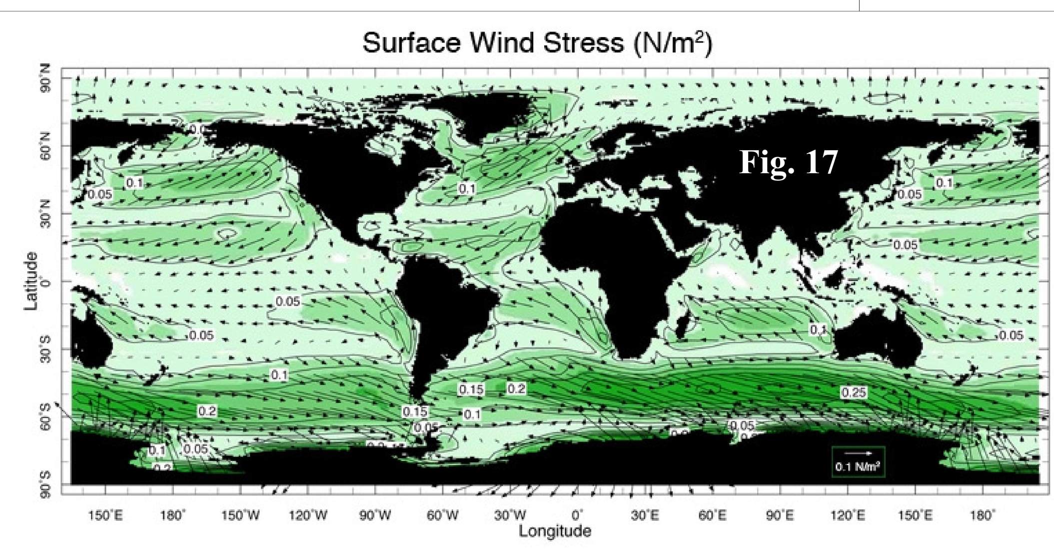
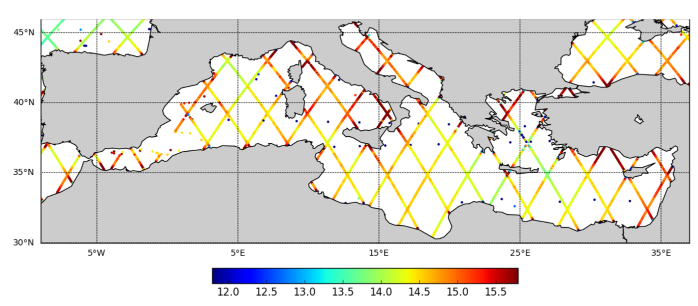


Fig. 17: Annual mean wind stress on the ocean. A contour of 1 represents a wind-stress of magnitude 0.1 Nm−2. Stresses reach values of 0.1 to 0.2 Nm−2 under the middle-latitude westerlies, and are particularly strong in the southern hemisphere. The arrow is a vector of length 0.1 Nm−2. *Marschall et al [5].*

Mean backscatter

- In order to compare the mean backscatter patterns for the different frequency band, the colour scales have been centered on the spatially average backscatter value (see above table); variations in amplitude can reach 4 dB. The maps of mean altimeter backscatter at Ku- (ERS-2 ENVISAT, Jason2d) , S- (Envisat), Ka- (Saral) and C- bands (Jason2d) reflect a wide range of sea state situations over the ocean. Whatever the frequency, they (Fig. 1, 2, 3, 4, 9, 10, 11 and 15) show similar oceanic patterns. Significant differences appear for Saral (Fig. 15): larger differences are observed between the maximum and the minimum backscatter values and wider areas associated to high backscatter value (>13.0 dB) appear. It will be investigated into more details using Envisat Ku-band data as a reference.
- As a first order approximation, the spatial patterns of mean backscatter (Fig. 1, 2, 3, 4, 9, 10, 11 and 15) appear strongly related to the wind stress (Fig.17) and its effect on the sea surface. Higher mean values of altimeter backscatter are observed where the wind stress is lower because for nadir ocean radars, a low/high wave roughness increases/decreases the altimeter backscatter value. But we assume that other second order perturbations have a signature in the radar backscatter variations.
- Not surprisingly, the maps of standard derivation of the backscatter (above the maps of the mean backscatter: Fig. 4, 5, 6, 8, 12, 13, 14 and 16) show that the most important variations are also associated to the wind stress which is know to have important seasonal variations. The next step of this study is to separate and analyze the different spatial and time scales of the backscatter variations in order to study ocean processes other than the local wind forcing which can have a signature on the ocean sea state. In parallel, regional analysis will be done (the Mediterranean Sea is one example)
- The different frequency bands have a net offset, with higher mean backscatter at lower frequencies *Chelton et al., 2001* [7]. Patterns in the backscattering differences result from wind-wave interaction, and rain, etc. .

Results & Conclusion



Mean Backscatter (dB) over Mediterranean Sea for Jason-2

- As a first order approximation, the backscatter distribution and variations over the ocean can be related to the the wind stress.
- As next steps of this work, we plan:
  - To analyze the different spatial and time scales associated to the radar backscatter variations in order to identify and study second order perturbations of the backscatter and the related geophysical parameter
  - To perform regional studies as over the Mediterranean Sea
  - Use higher frequency measurements (20 Hz, 40Hz) in specific coastal areas.

References

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