Observing fine-scale ocean structures in the NW Mediterranean Sea from altimetry, gliders and HF radar

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The NW Mediterranean Sea has distinct ocean dynamics, with relatively strong boundary currents and moderate eddy energy, but with variations at small Rossby radius which are difficult to detect with conventional satellite altimetry. In this study, we analyse the observability of the ocean processes using 3 different altimeter missions and measurement systems, and then compare their observation from colocalised glider and HF radar observations.

Mesoscale observability from Jason-2 Ku band, SARAL Ka-Band & Cryosat-2 SAR mode

Mediterranean Sea : fine-scale dynamics

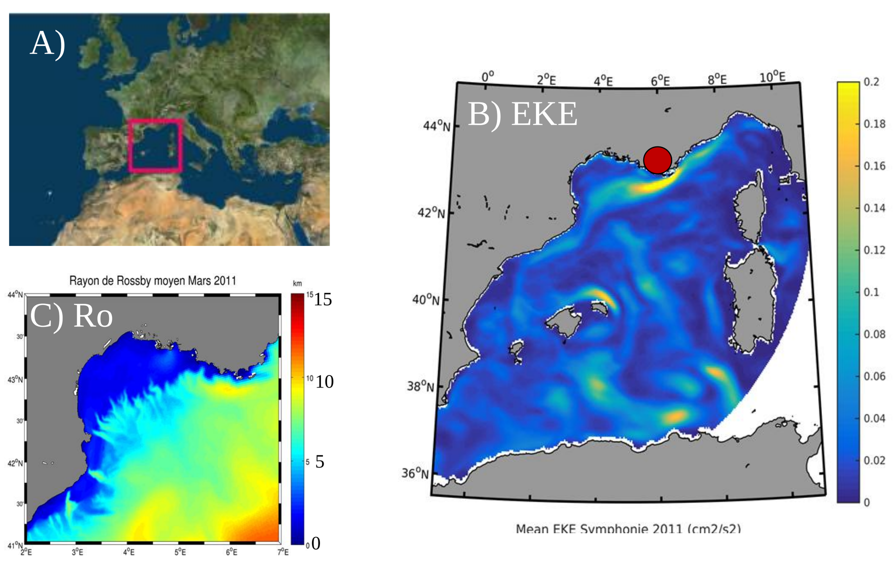
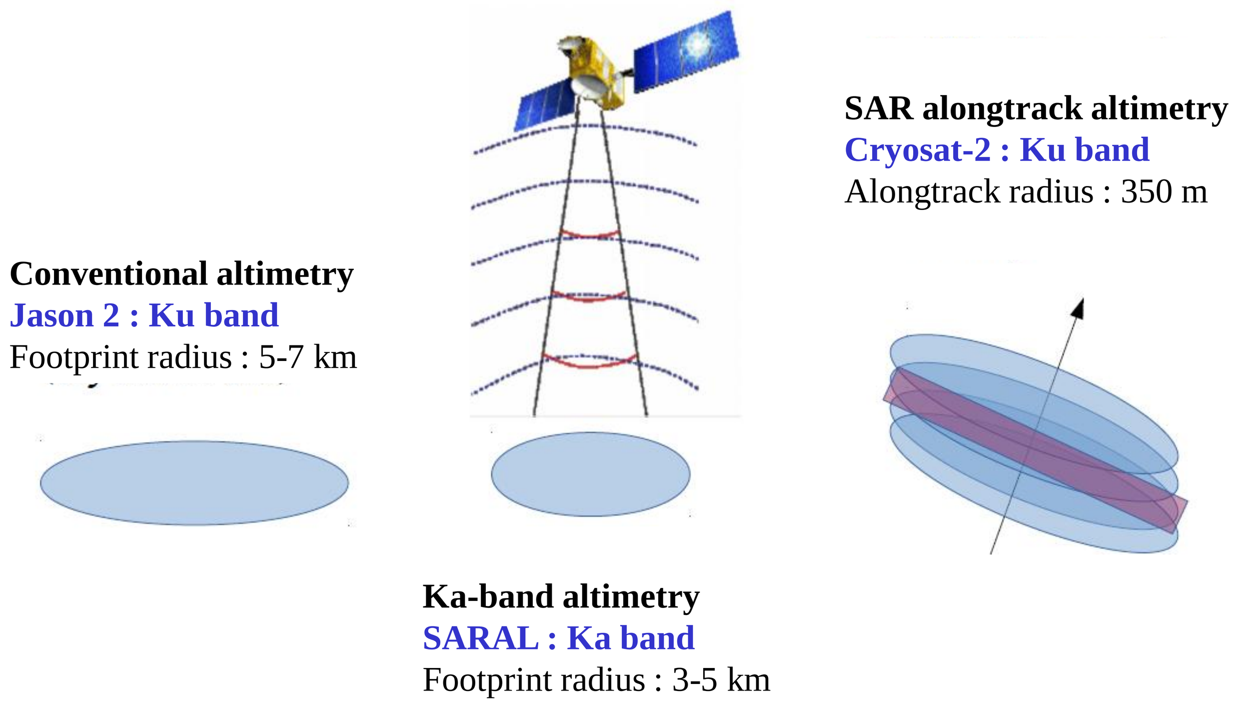
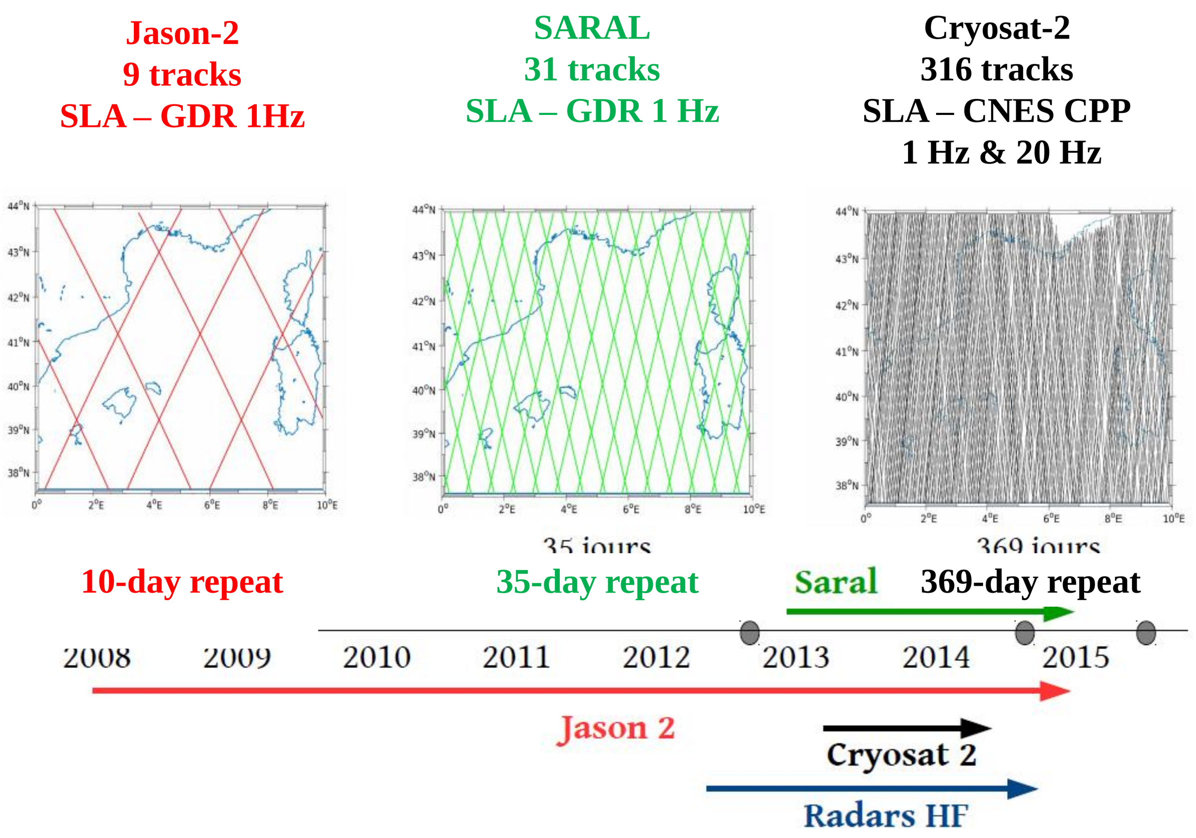


Figure. A) Position of NW Mediterranean Study. B) EKE from Symphonie 1 km model in W Mediterranean (Estournel et al., 2014). ● Position of HF radar at Toulon C) Zoom on Rossby radius scales in winter in NW Med (5-15 km)

Different altimetric technologies



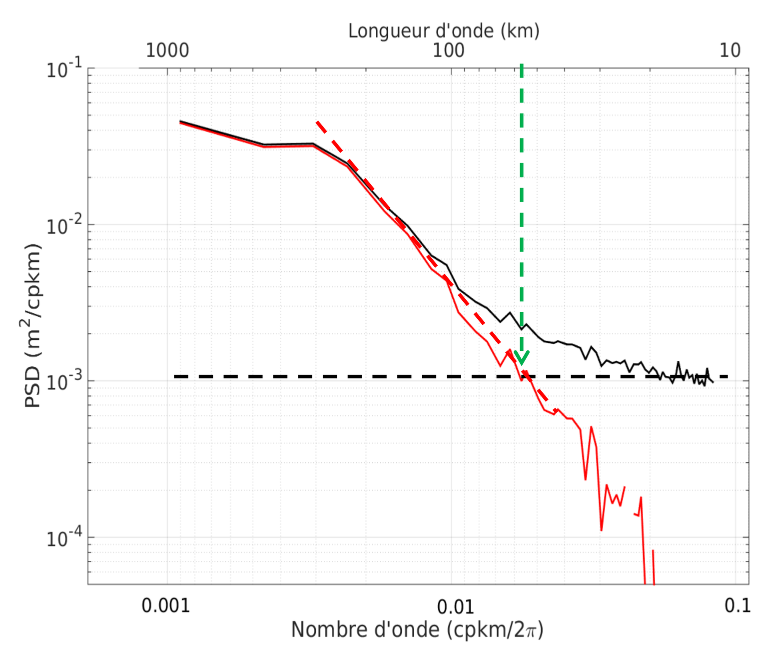
Different space-time coverage in NW Med



Spectral analysis – signal and noise estimates

Calculate average spectra PSD for each mission
(following *Xu & Fu, 2012; Dufau et al., 2015*)

1) Mean spectral PSD calculated for all tracks: data > 50 km from coast
2) Noise estimated by horizontal fit to mean PSD between 12 – 25 km ------
3) Noise level removed from original PSD
4) Estimate spectral slope (between 50-280 km) -------
5) Mesoscale observability scale estimated at the point of intersection ----->



Mean spectral results in NW Med

Mean spectral SSH PSD were calculated over the commun 13 month period *1 Apr 2013 – 30 Apr 2014*.
The **original spectra** have similar slopes down to ~100 km wavelength. Different noise levels for each mission then impact the smaller scales.
After noise removal, the 3 missions are observing similar spectral energy down to 50-60 km wavelength.

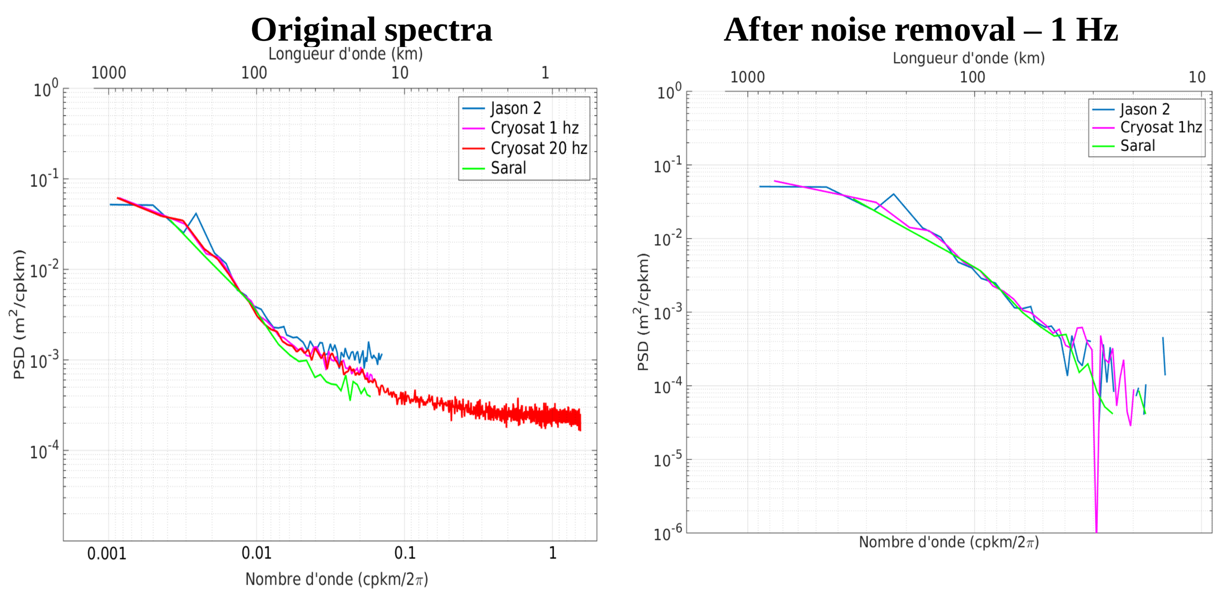
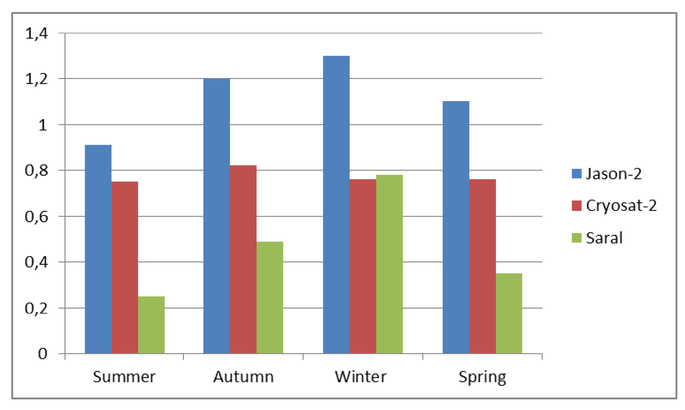


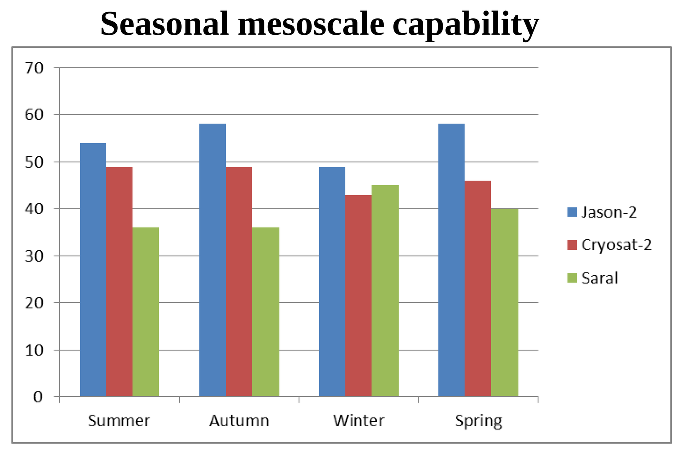
Figure. (Left) Mean spectral PSD for all altimeter tracks in NW Med for the common period. Jason-2 and SARAL 1 Hz data analysed. CNES-CPP processing of CR2 SAR mode data is used, for CR2 20 Hz and CR2 1 Hz. (right) 1 Hz spectra after noise removal.

Seasonal variations

Noise levels vary seasonally for **Jason-2** & **Saral** – higher noise in autumn/winter due to higher sea-state roughness (wind-waves). **CR2 noise** is relatively stable. **Saral** has the lowest noise levels. (*Unit : 10^{-3} m2/cpkm*)

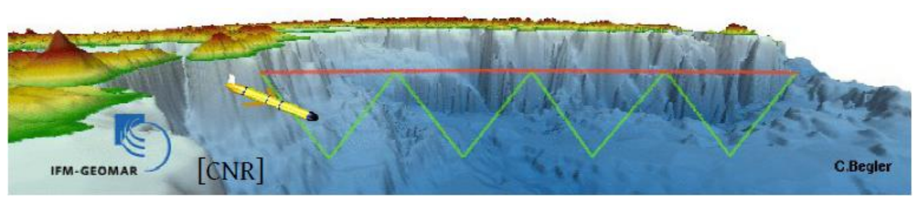


Mesoscale capability shows the observable ocean scales above the noise. **In winter**, when submesoscales are more energetic but the altimetric noise is higher, all missions are detecting ocean scales > 45-50 km. **In summer**, when submesoscales are weaker, Saral can detect ocean scales down to 35 km, whereas the higher noise of Jason-2 & Cryosat-2 blocks our observation of scales < 50-55 km wavelength.

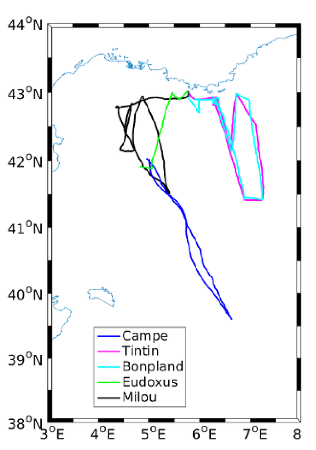


Altimetry vs in-situ observations of SSH and currents

Gliders in NW Mediterranean Sea



Many gliders are available in NW Mediterranean Sea from the MOOSE program but only 5 campaigns are colocalised in space and time with altimetric tracks :



- **Campe** : 23/09/2012 – 23/10/2012 → Jason 2
- **Eudoxus** : 23/10/2014 – 29/10/2014 → Saral
- **Milou** : 27/10/2014 – 13/11/2014 → Saral
- **Tintin** : 17/04/2015 – 13/05/2015 → Cryosat 2 & Saral
- **Bonpland** : 13/04/2015 – 01/05/2015 → Cryosat 2 & Saral

Large (slow) Mesoscale structures

Oct 2012, the Campe glider followed a Jason-2 track and intersected a large mesoscale structure (~100 km) with 20 cm/s currents. **Good comparison** between altimetry and gliders.

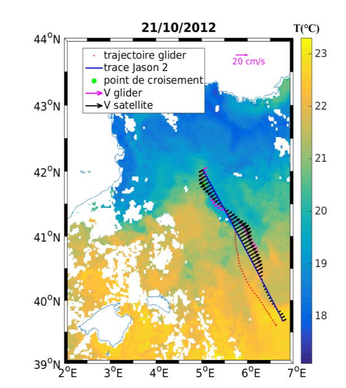


*Figure. SST on 21 Oct 2012 with **Jason-2 currents** and 2 glider tracks and currents*

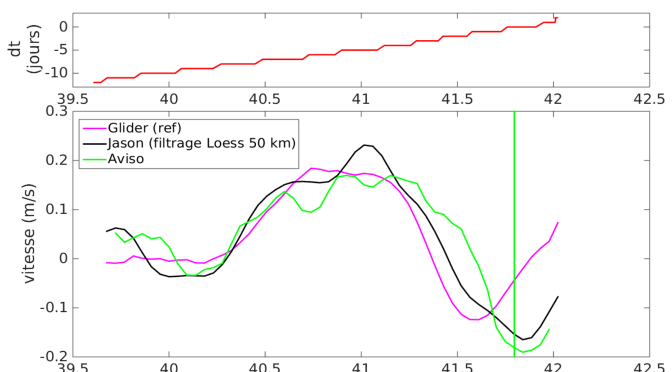


*Figure. Upper: Time difference of Jason-2 and glider along the track from 0-10 days Lower. Geostrophic currents from glider, **alongtrack Jason-2** filtered at 50 km, and gridded AVISO data.*

Small (fast) mesoscale structures

Oct 2014, the Milou glider followed a SARAL track and intersected a rapidly evolving small meander (~30 km) at 42.5°N with 30 cm/s currents on 12 Nov, which was not observed by the glider at that location on 10 Nov. Glider and alongtrack altimetry are filtered to remove HF noise. **Poor comparison** between altimetry and gliders.

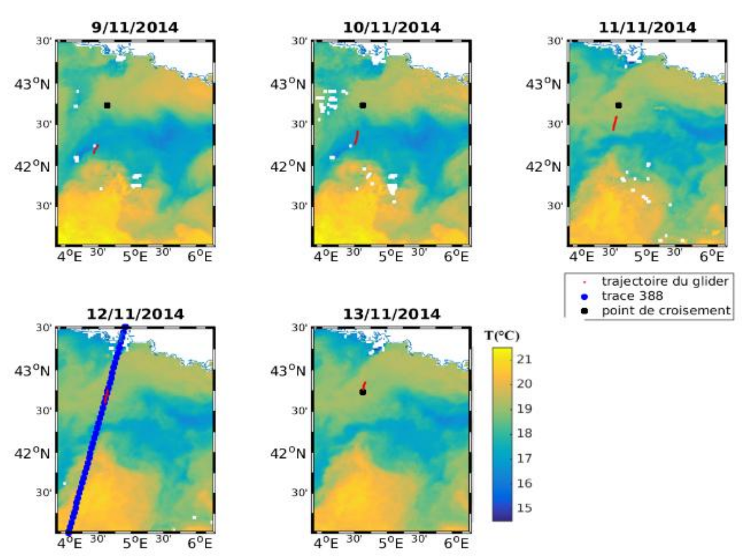


*Figure. SST from 9-13 Oct 2014 with **SARAL** track and position of glider. Dot shows their intersection*

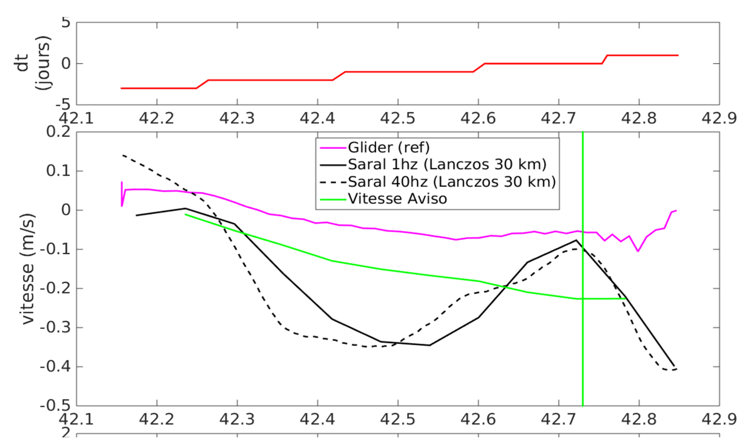
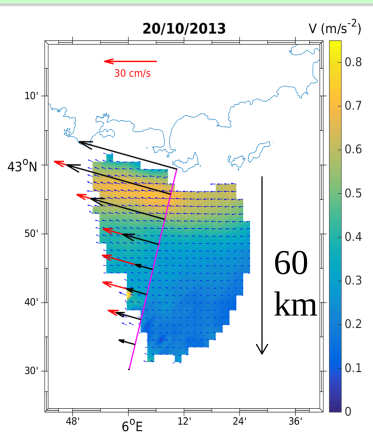


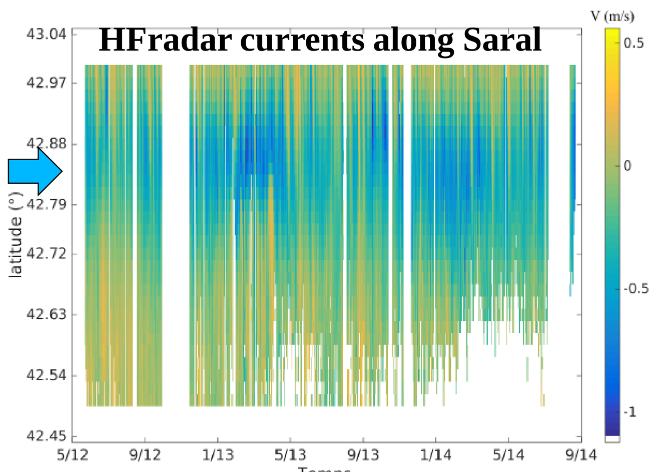
*Figure. Upper: Time difference of Saral and glider along the track over 5 days Lower. Geostrophic currents from glider, **alongtrack SARAL** filtered at 30 km, and gridded AVISO data.*

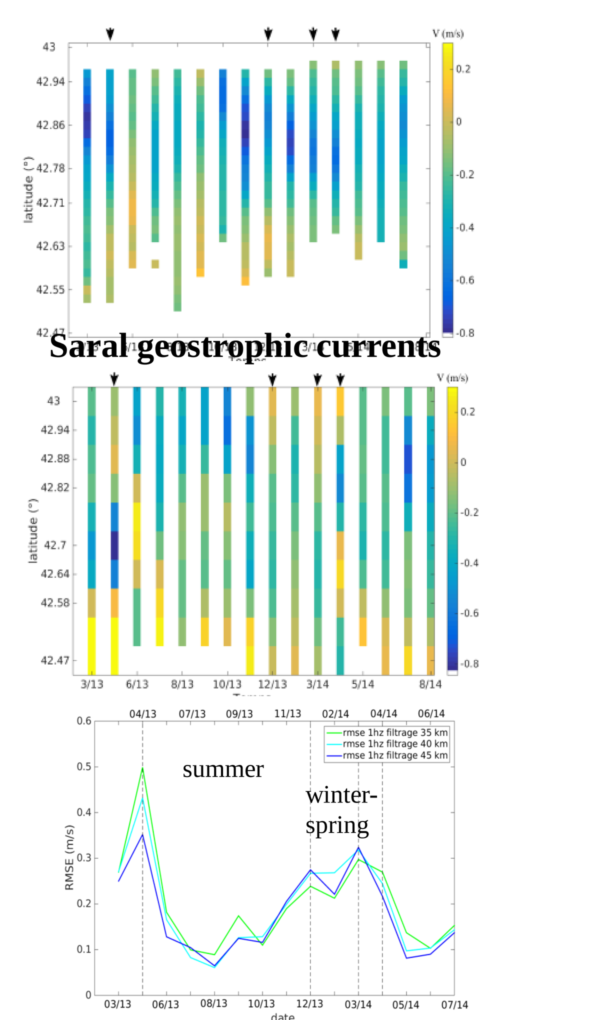
HF Radar comparisons



2 years of **HF radar data** have been collected near Toulon extending 60 km offshore across the Northern Current. A SARAL track crosses this region

HF radar measures **total surface current**, but good correlation shows the Northern Current is **mainly geostrophic**.





*Upper : HF radar current anomalies perpendicular to SARAL track at SARAL dates. Middle. SARAL geostrophic current anomalies. **Bottom**. RMSE of glider-altimeter differences.*

Conclusions

- Strong **seasonal variations in altimetric noise,** linked to higher surface roughness in winter
- Small seasonal variations for CR2 – Why? CPP processing?
- Limit of **observability** of NW Med mesoscale structures is **45-50 km in winter** when submesoscales are energetic; **in summer**, we can observe down to **35 km with SARAL**, and **50 km with Jason-2** (signal & noise both lower)
- Small, rapid mesoscale structures are difficult to observe with **gliders** due to colocalisation issues
- **HF radar is promising** for its good colocalisation in regions where geostrophy dominates.