Evaluation of ocean surface currents derived from Sentinel-1A IW Doppler shift by comparison with HF-radar and ocean surface drifters observations

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Abstract: Doppler frequency shift acquired by SAR can be used to retrieve ocean surface current velocity in look-on-side (range) direction (RVL). The Doppler shift observations from Sentinel-1 A/B IW mode available on regular basis (up to twice per day) for coastal areas. Therefore, SAR derived surface currents can be used for filling a white space in observations in areas discriminated by in-situ and land-based remote sensing measurements and eventually can be assimilated into ocean models. Careful validation of SAR RVL observations through systematical collocation with other remote sensing and in-situ datasets is required. This poster presents preliminary results of evaluation of the surface currents derived from Sentinel-1A IW VV with a comparison to High-Frequency (CODAR SeaSonde) radar and ocean surface drifters (iSLDMB) observations.

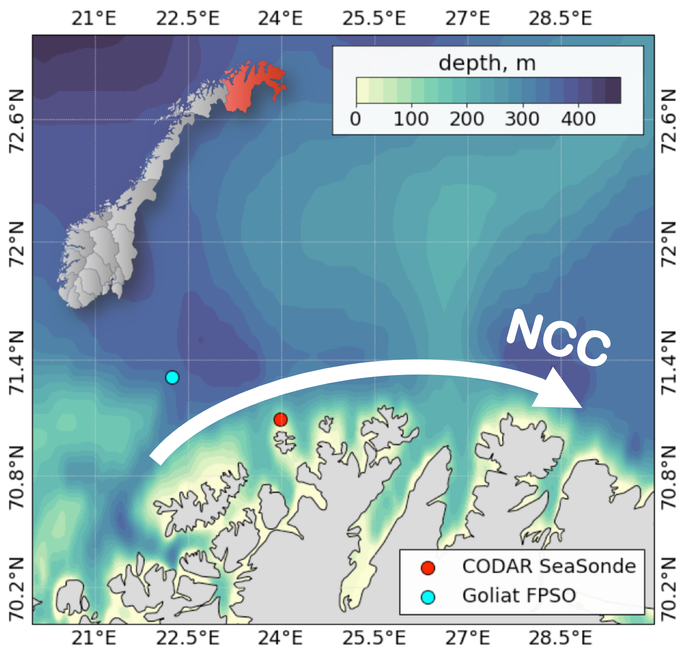


Figure 1. Region of the study where color is depth, m, from ETOPO1, white arrow is schematic location Norwegian Coastal Current (NCC)

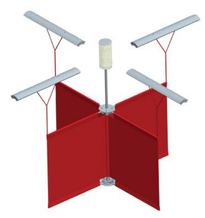
Region of study

The region (fig. 1) is located near the northern coast of Norway (Finnmark) and was chosen due to several reasons:

- An intensive Norwegian Coastal Current (NCC), with a typical current speed about 50 cm/s (up to 1 m/s) propagates eastwards along the coast;
- The domain overlaps with a domain of currently operating High-Frequency radar (HFR) system (Fruholmen island);
- Sentinel-1 A/B orbit over the region is located in favor to acquiring observations over land required for the Doppler shift calibration;
- SAR look direction (especially in ascending pass, fig.3 top right) is directed along the expected current jet;
- In-situ wind observations (both over land and sea) are available for validation of model-simulated near-surface wind fields.

Datasets

- **Sentinel - 1A:**
  - Parameter: Doppler shift
  - Sensing mode: IW
  - Polarization: VV
  - Pixel size: 1 x 1 km
- **AROME-Arctic:**
  - Parameter: Near-surface wind speed and dir.
  - Pixel size: 2.5 km
  - Time resolution: 1 hour
- **CODAR SeaSonde HFR:**
  - Parameter: Radial velocity
  - Beam range: 175 km
  - Range resolution: 5 km
  - Time step: 1 hour
- **Meteostations:**
  - Parameter: Near-surface wind speed and direction
  - Goliat FPSO
  - Fruholmen fyr
- **iSLDMB (CODE) surface drifters:**
  - Parameter: Eulerian surface currents
  - Time step: 5 min



The Doppler anomaly, f_{phys}, (i. e. Doppler shift after removing of all non geophysical parameters) contains information of the near-surface wind field (U_{10}), sea state and ocean surface current (OSC). The contribution from wind/wave inducted motion, f_{ww}, should be carefully estimated and removed in order to retrieve the surface current. This can be done using CDOP [Mouche A., et al. 2012] and U_{10}, extracted from a model (AROME-Arctic). Thus, the Doppler shift due to OSC is:

$$f_{osc} = f_{phys} - f_{ww}$$

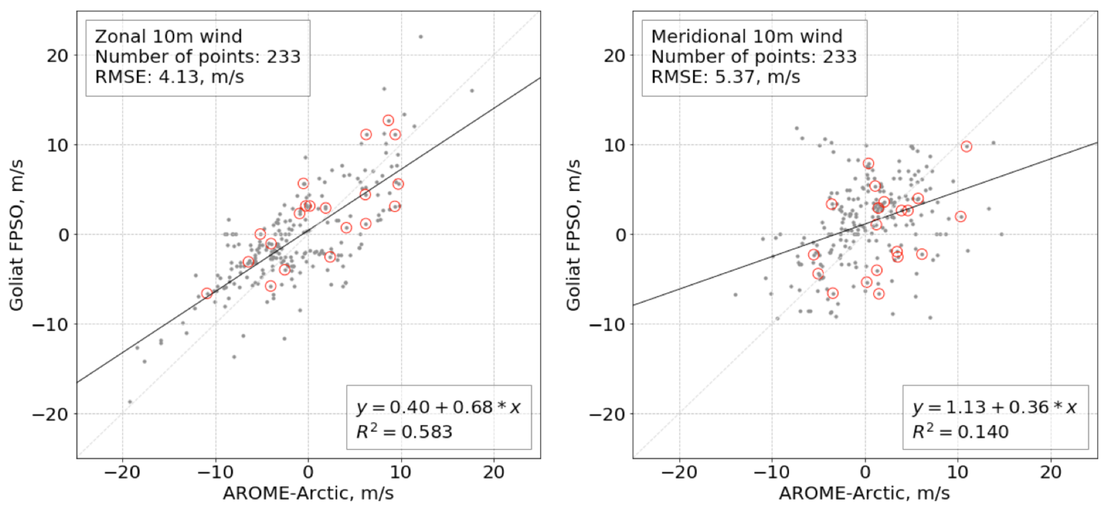


Figure 2. Collocation of zonal (left) and meridional (right) components of near-surface wind speed from AROME-Arctic model and observations at Goliat FPSO platform. Red circles point to measurements collocated in time with available Sentinel-1 acquisitions

Near-surface wind field from the AROME-Arctic model (required for estimation of wind contribution to registered Doppler shift) was validated versus in-situ observations at the coast (Fruholmen fyr., not presented) and at sea (Goliat FPSO platform, fig 2.). RMSE for zonal / meridional components 2.93 / 2.87 [m/s] for the coastal station, and 4.13 / 5.37 [m/s] for the sea station.

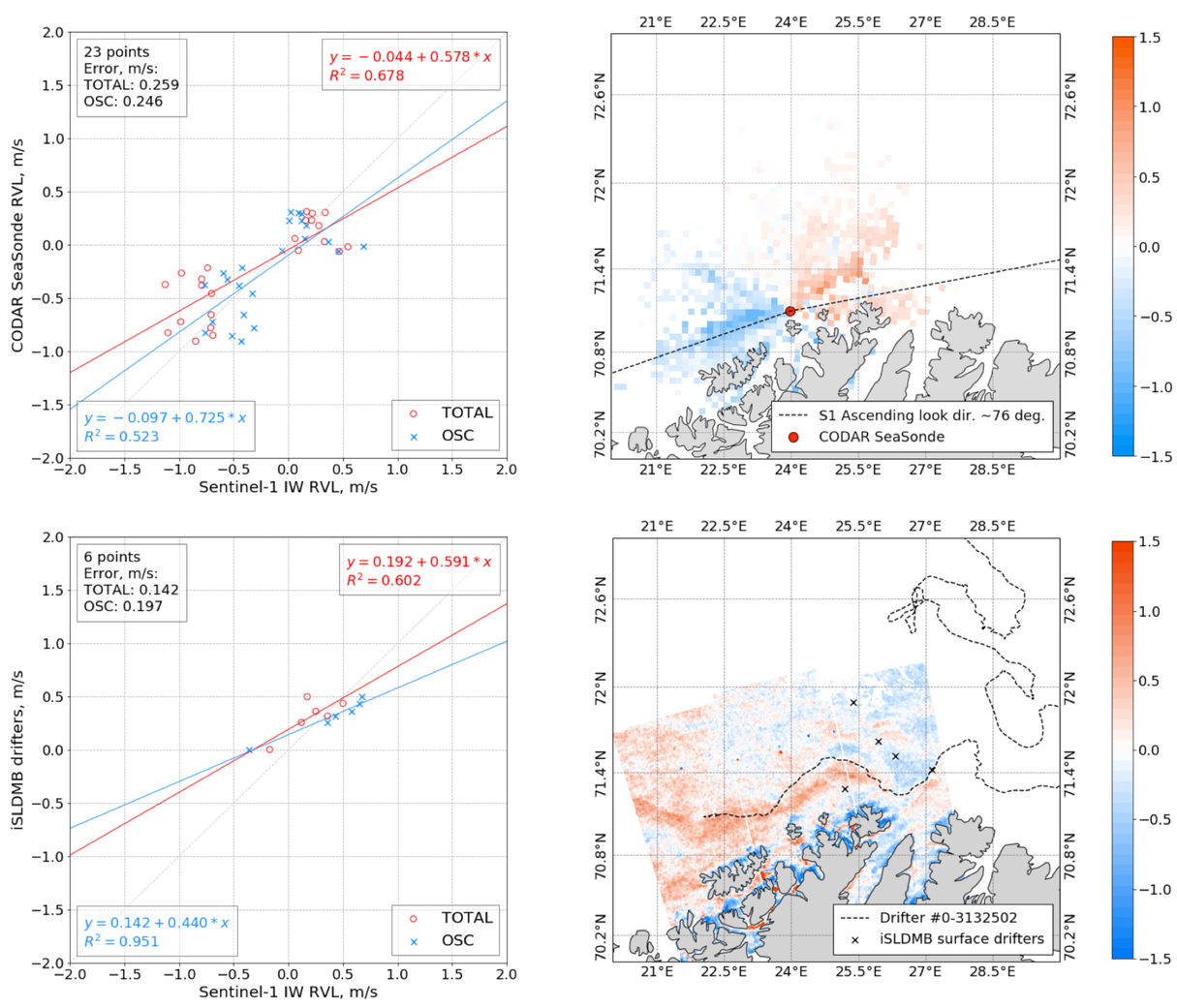


Figure 3. Collocation of Sentinel-1A IW VV radial velocities [m/s] from 26 October 2017 at 15:43:31 with iSLDMB (CODE) surface drifters **(bottom)** and CODAR SeaSonde radial velocities [m/s] **(top)**, and. Red (o) and blue (x) and markers on scatter plots represents collocation for SAR RVL with include and exclude wind contribution representatively

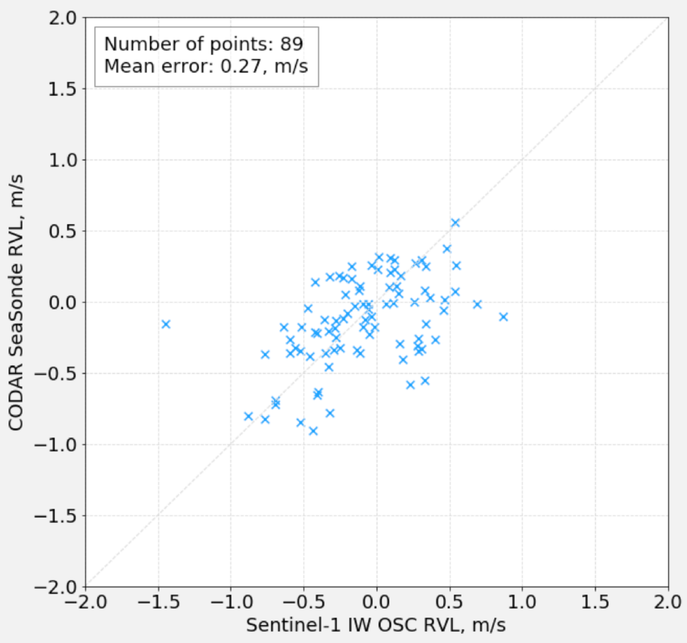


Figure 4. Collocation of Sentinel-1A IW VV radial velocities from 8 acquisitions in October – November with HFR radial velocities

Results

- Sentinel-1A IW VV Level 2 products from October-November 2017 were collocated with HF-radar (located at Fruholmen isl.) and ocean surface drifters observations near the coast of northern Norway (Finnmark);
- Residual bias in Doppler frequency shift was corrected with using signal acquired over land areas within a scene [Johnsen H. et al 2016]. Mean residual error over the land after all calibrations is 0.74 Hz (0.04 m/s). Wind contribution to the Doppler frequency shift was estimated with CDOP and AROME-Arctic simulated near-surface wind speed.
- Comparison of SAR derived radial velocities with HFR observations shows significant correlation with mean absolute error about 0.27 m/s (fig 3 top, fig. 4)
- Collocation of SAR RVL's with ocean surface velocities obtained from drifters shows good correlation only for single SAR acquisitions (fig 3. bottom), while on average the mean error is about 0.48 m/s (figure not presented on the poster).
- Signatures of the Norwegian Coastal Current can be observed in dominant part of investigated SAR acquisitions in both ascending (e.g. fig. 3, bottom right) and descending pass. Accurate retrieving of absolute value from a single pixel still has limitations due to residual bias in Doppler centroid calibration and uncertainty due to wind contribution to the acquired signal.
- Significant contribution to the error in SAR Radial Velocities could be introduced during wind bias estimation. The error can appear due to incorrect simulation (e.g. fig. 2) of wind speed and direction by model (AROME-Arctic). The most significant error can appear in case of azimuthal wind direction while incorrect wind direction can yield change of sign (direction) of wind inducted Doppler shift.

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References:

Johnsen, H., Nilsen, V., Engen, G., Mouche, A., Collard, F. 2016 . Ocean doppler anomaly and ocean surface current from Sentinel 1 tops mode. 3993-3996. 10.1109/IGARSS.2016.7730038.

Mouche, A., Collard, F., Chapron, B., el al. 2012. On the Use of Doppler Shift for Sea Surface Wind Retrieval From SAR. IEEE Transactions on Geoscience and Remote Sensing. 1. 10.1109/TGRS.2011.2174998.