Sentinel-1 Radial Velocity (RVL) Assessment

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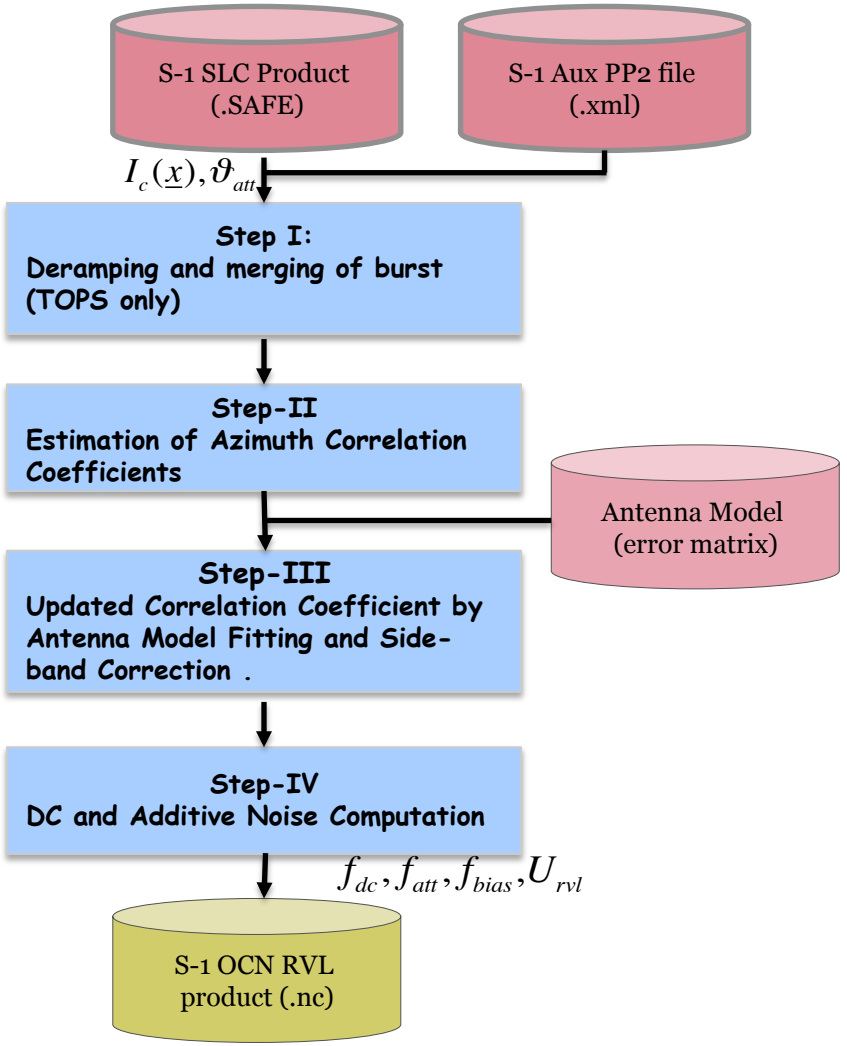
Related Projects

- "S-1 Instrument Processing Facility (IPF) Development" , ESA/ESTEC contract (2009-2012), PI: MDA Ltd
  - Developing the S-1 L2 RVL estimator
- "S-1 Mission Performance Center - Expert Support Laboratory", ESA/ESRIN Contract (2013 -2021),PI: CLS
  - Validation of S-1 L2 RVL products
- "S-1 radial velocity (RVL) assessment ", (2018-2019), ESA/ESRIN Contract, PI: OceanDataLab Ltd
  - Developing and prototyping the DC calibration
- "Copernicus S-1 RVL Assessment – CCN1 (2020-2021)", ESA/ESRIN contract, PI: OceanDataLab Ltd
  - Semi-operationalization and test data set generation

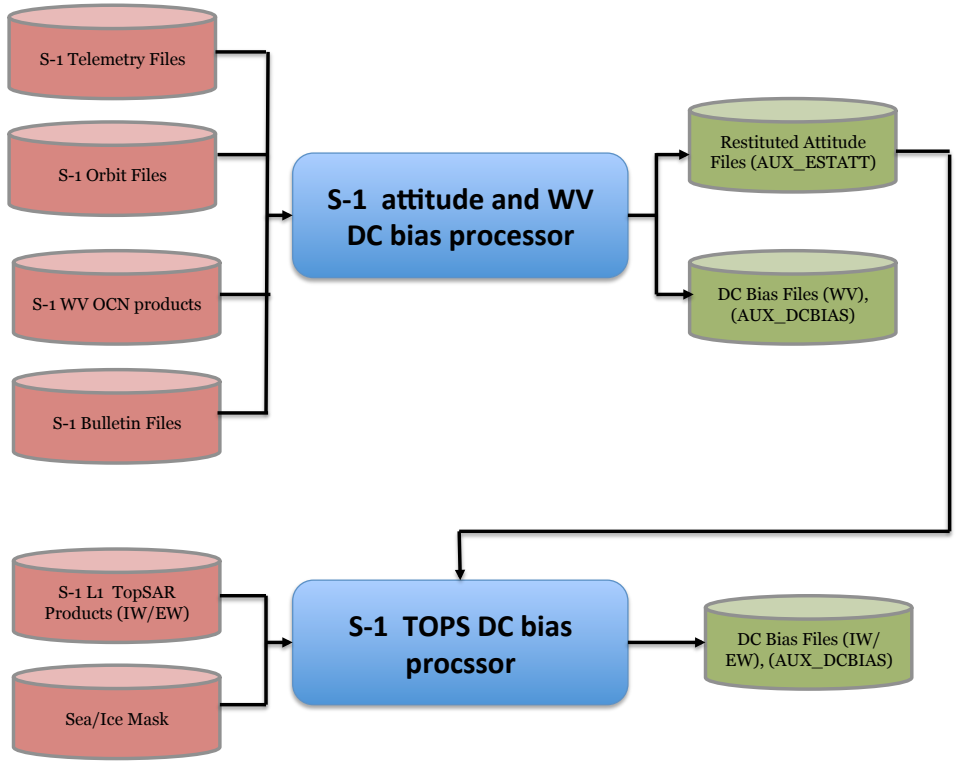
S-1 Doppler Estimation Strategy

- Overall requirements:
  - DC precision ≈ 5Hz (0.2-0.3 m/s)
  - DC accuracy ≈ 0 Hz
- Spatial requirements:
  - WV mode ≈ 20km
  - IW mode ≈ 3 km
  - EW mode ≈ 5 km
- Key inputs:
  - Internal SLC (SL2) as input
  - Attitude DC from quaternions
  - Antenna model (dynamic error matrix)



The new S-1 DC calibration strategy

- Estimate restituted attitude DC , $f_{att}(t)$:
  - Orbit data, Telemetry data (Gyro), Star Tracker info
  - SAR WV OCN data
- Estimate mean DC profiles over swaths, $f_{bias}(\beta)$:
  - S-1 L1 TOPS data
  - Sea/Ice Mask
- Use $f_{att}(t)$ and $f_{bias}(\beta)$ to recalibrate S-1 OCN RVL products



Recalibration of S-1 OCN RVL products

- S-1 OCN RVL recalibration process:

$$f_{dca} = f_{dc} - (f_{bias}(\beta) + f_{att}(\beta, \Delta\theta_{att}(t)) + \Delta f_{bias}(t))$$

f_{dc} = Estimated DC from SLC (rvldcObs)

f_{bias} = Daily mean DC bias computed over land areas

f_{att} = Attitude Dc along orbit

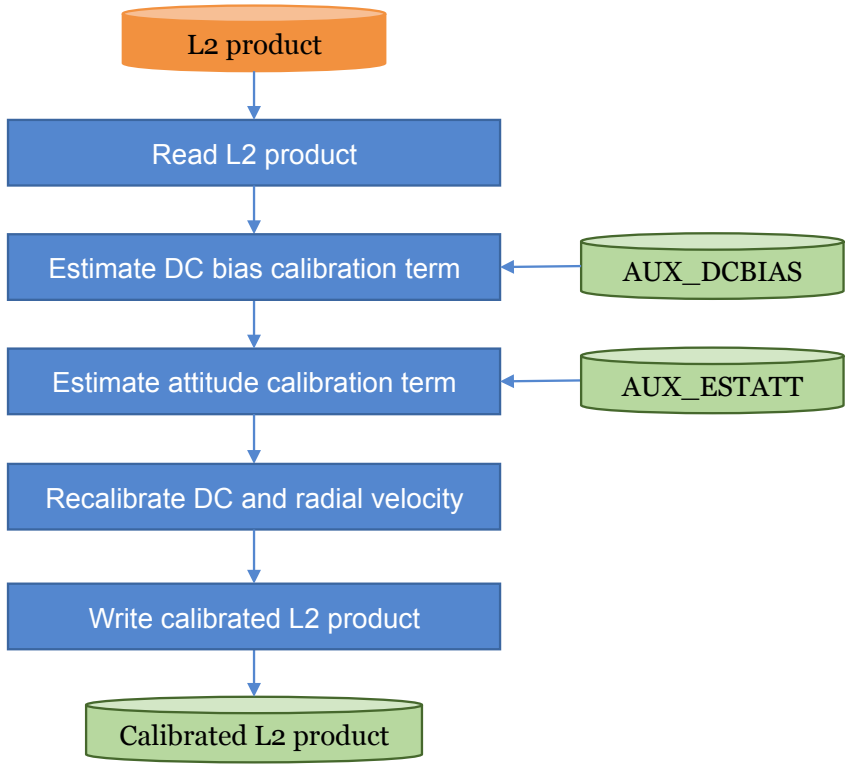
Δf_{bias} = Residual DC bias

f_{dca} = Geophysical Doppler (rvlDcObsCal)

t = time along orbit

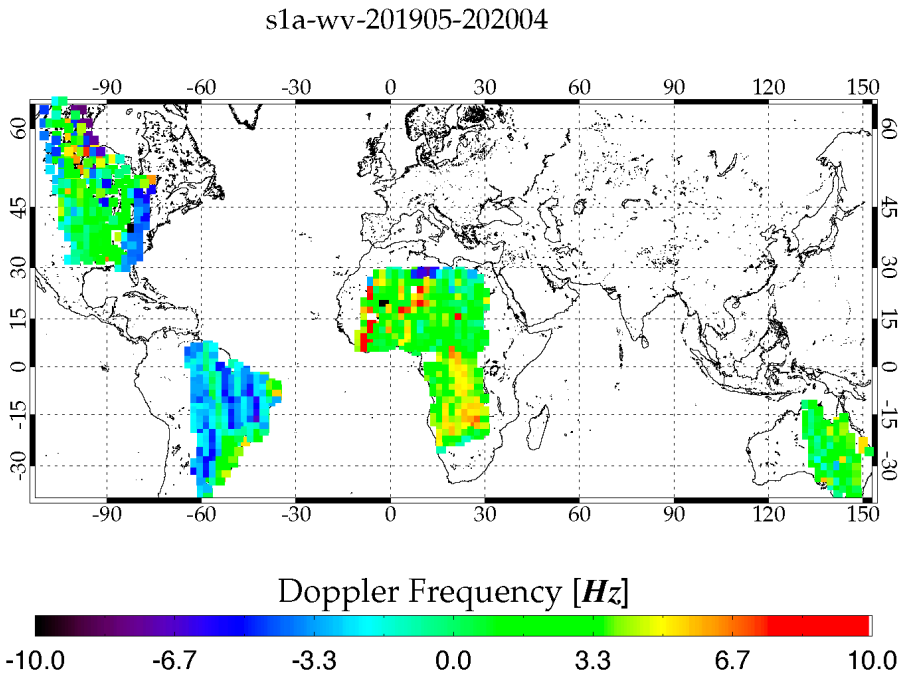
β= boresight angle

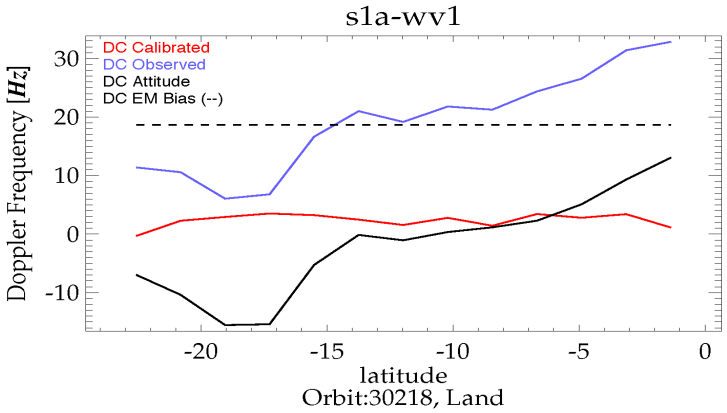
$\Delta\theta_{att}$ = attitude error $(\Delta\theta_r, \Delta\theta_p, \Delta\theta_y,)$



- One year of S1a,b data, 01.05.2019-30.04.2020
- WV global, IW regional (Agulhas, Skagerak)

S-1a WV (orbit segments over land)





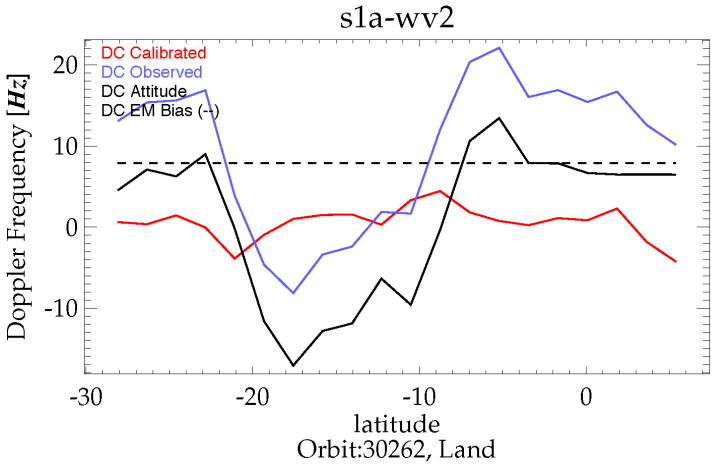


Figure: S-1a WV mean dcObsCal from land acquisitions (left), and examples of DCs (dcObs, dcObsCal, dcAtt, dcBias) along orbit segment acquired over land areas (right).

S-1a,b WV RVL Statistics

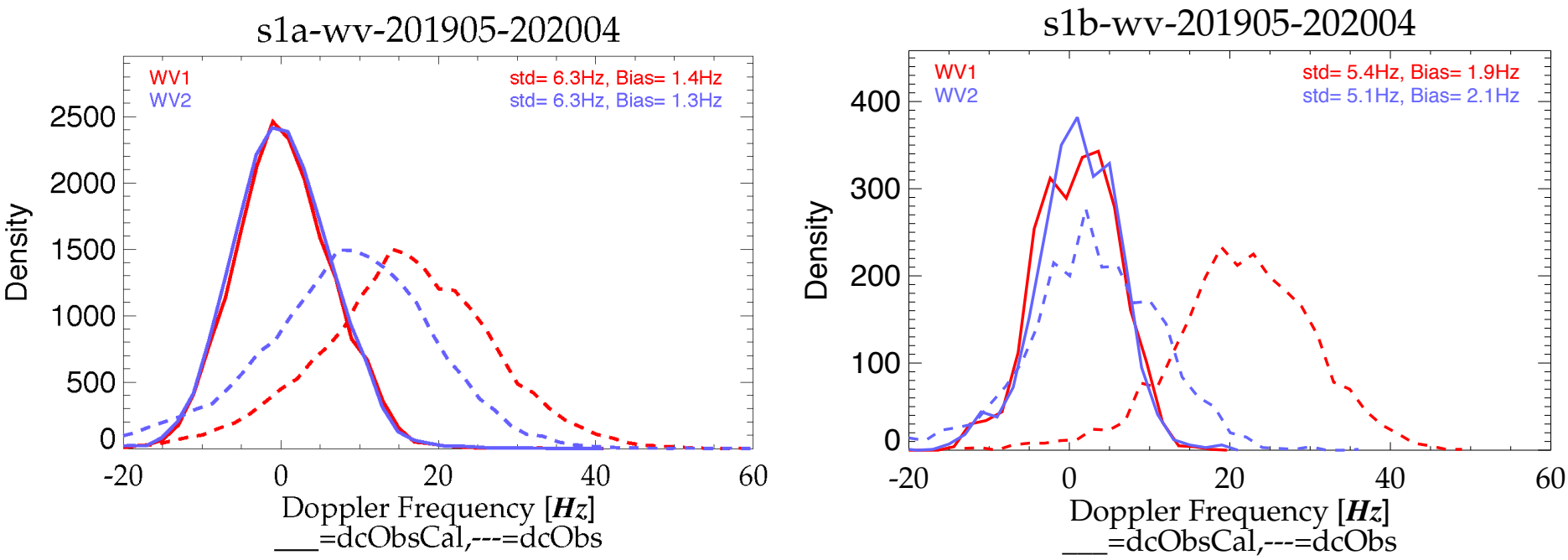
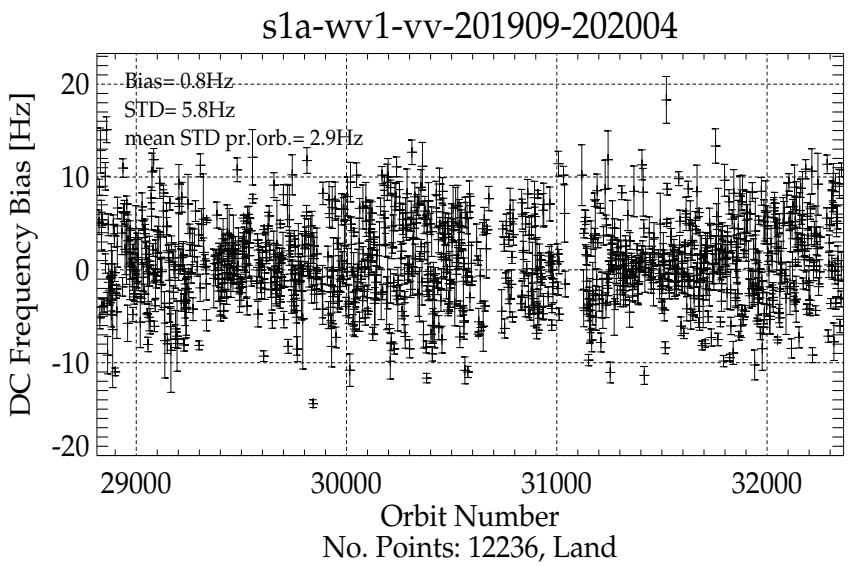


Figure: Histograms of S-1a (left) and S-1b (right) WV OCN RVL DC frequency before (---) and after (___) calibration. The data was acquired between 1st May 2019 and 30th April 2020 over global land areas.



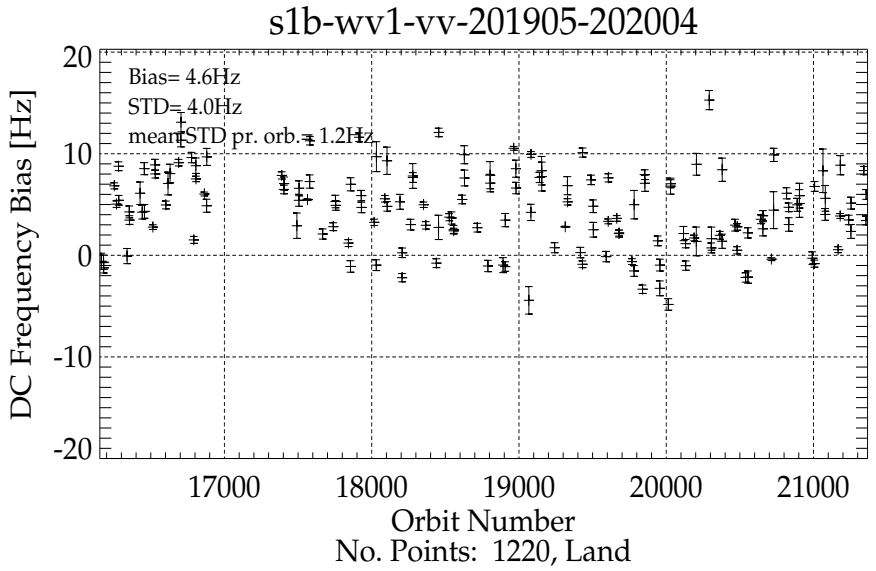


Figure : Examples of S-1a (a) and S-1b (b) WV mean calibrated DC pr. orbit segments over land areas. The vertical bars indicate the standard deviation over the orbit segment.

S-1 WV Doppler versus Range Wind Speed

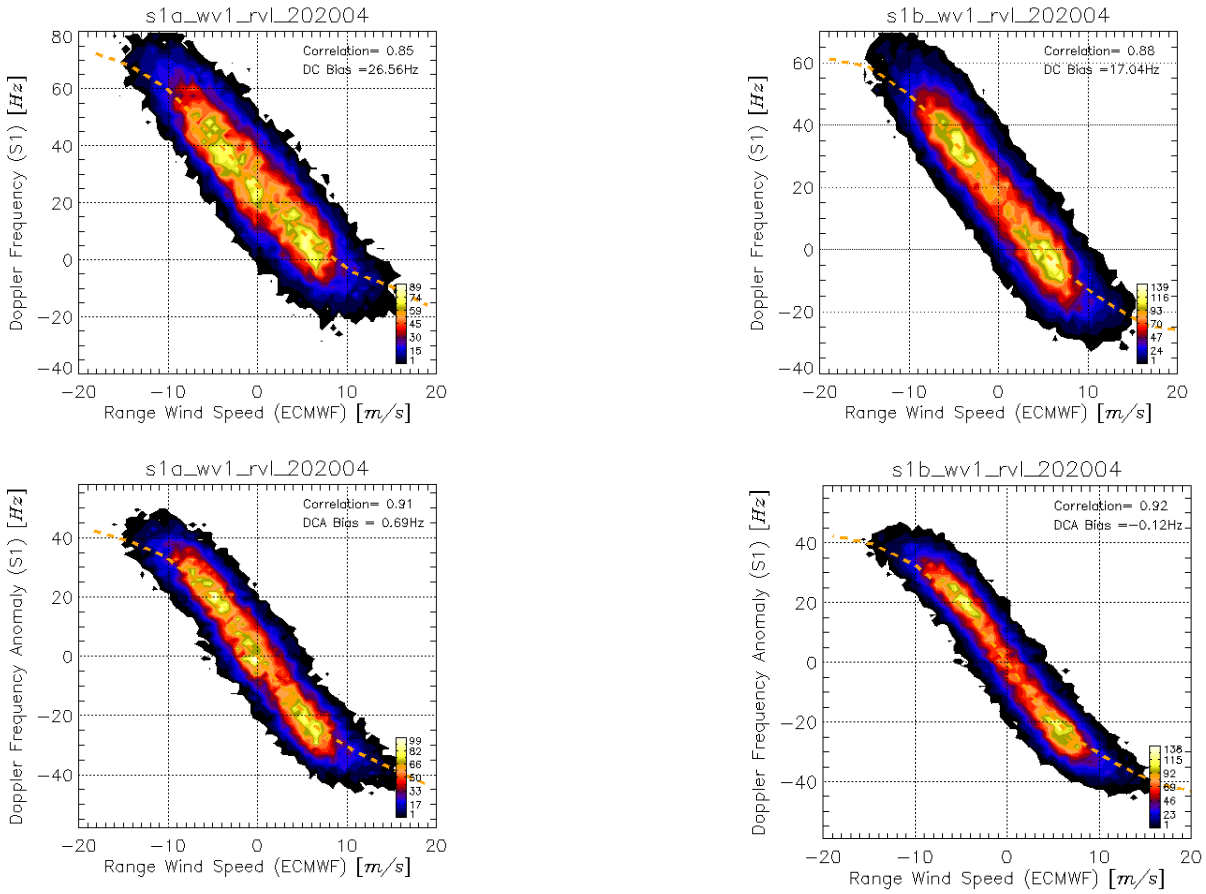


Figure : S-1a (left) and S-1b (right) WV Doppler frequency before (upper) and after (lower) calibration versus range wind speed (ECMWF).

S-1 IW RVL (Skagerak/Norway)

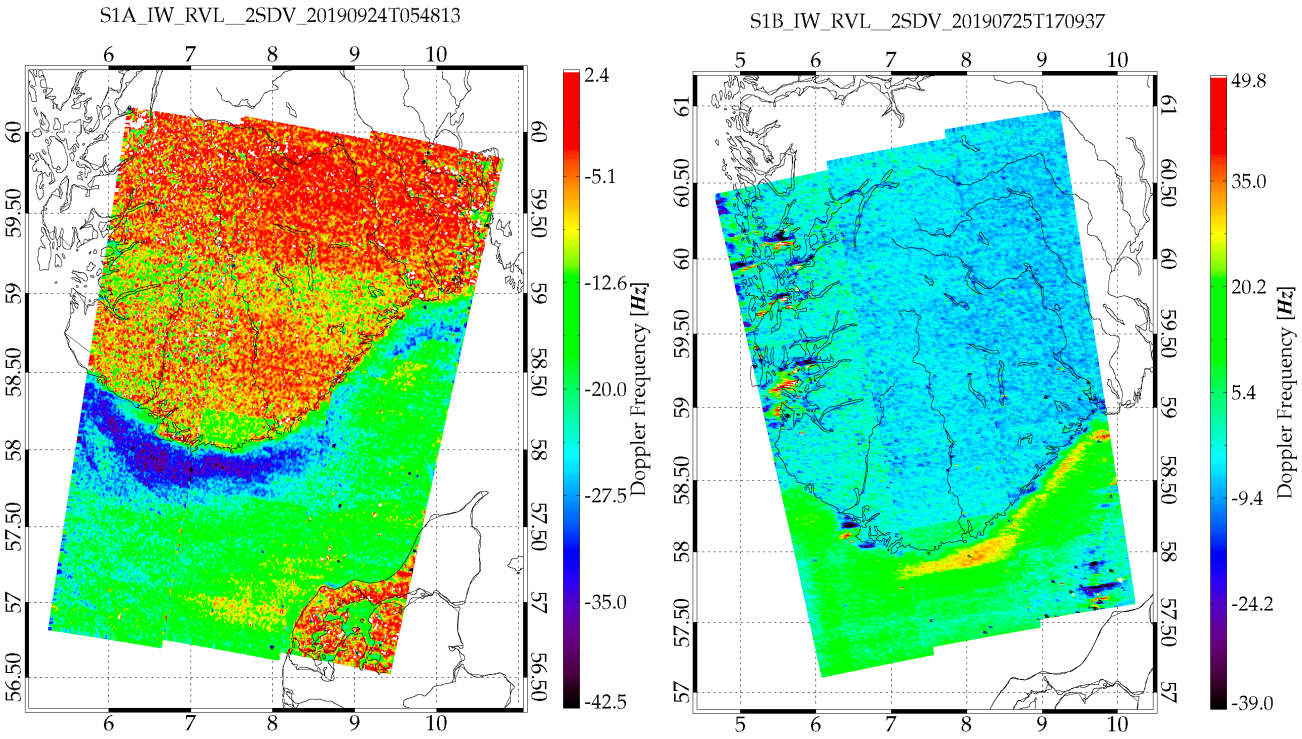


Figure: S-1a (left) and S-1b (right) IW calibrated Doppler frequency acquired over Skagerak area.

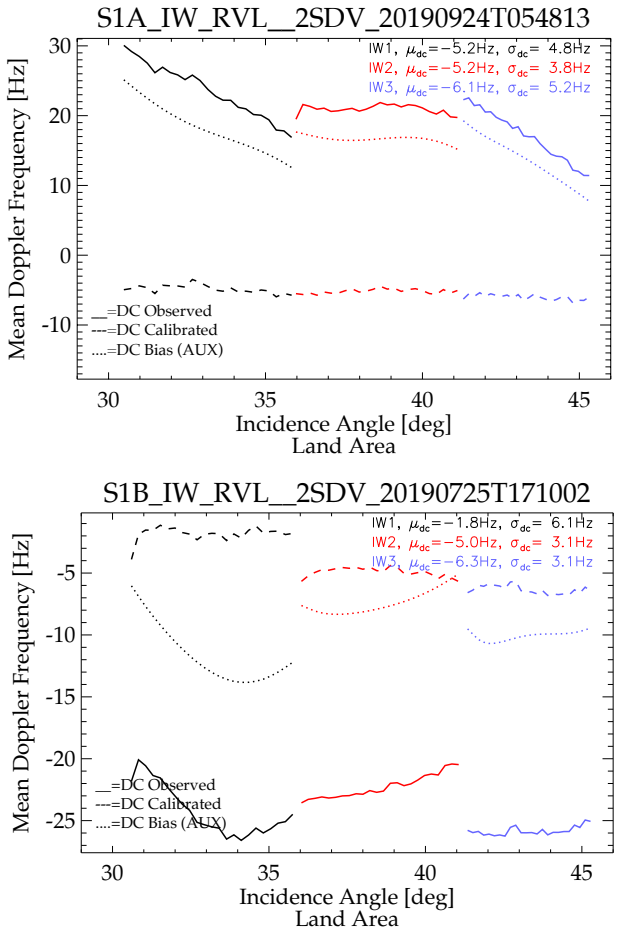


Figure: Mean DC profiles over swath (dcObs, dcObsCal, dcBias).

S-1 IW RVL (Agulhas, South-Africa)

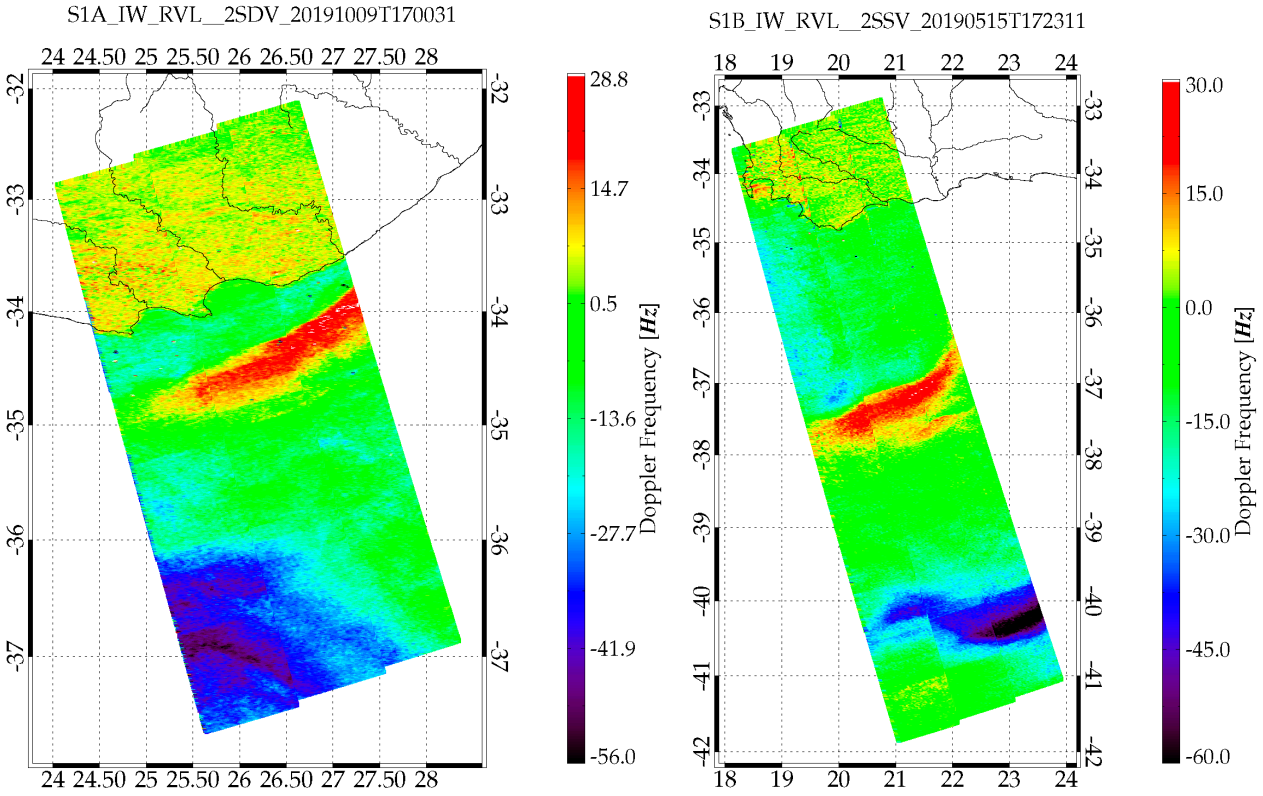


Figure: S-1a (left) and b (right) IW calibrate Doppler frequency acquired over Agulhas

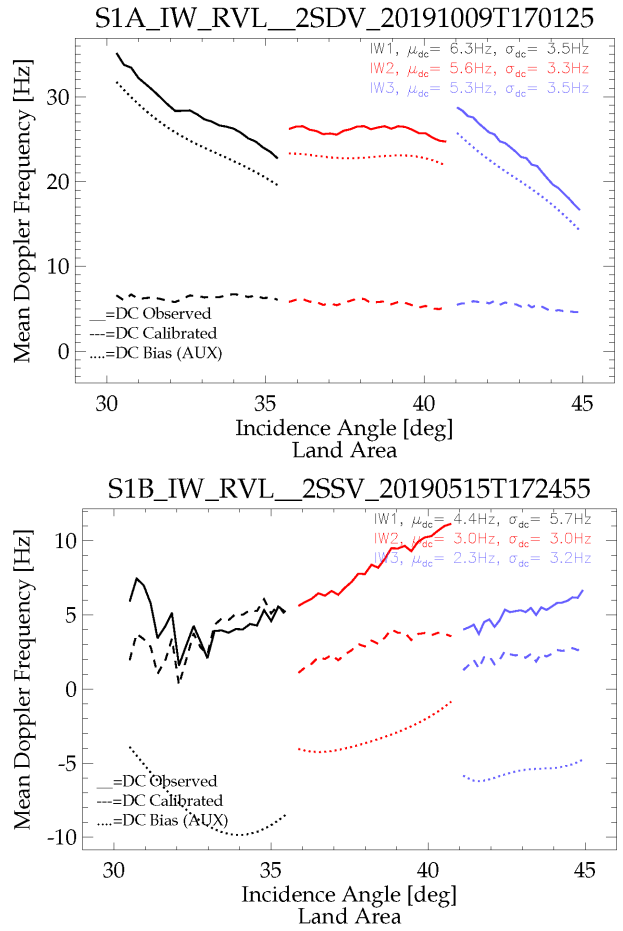


Figure: Mean DC profiles over swath (dcObs, dcObsCal, dcBias).

S-1 IW RVL (IW long data takes over land)

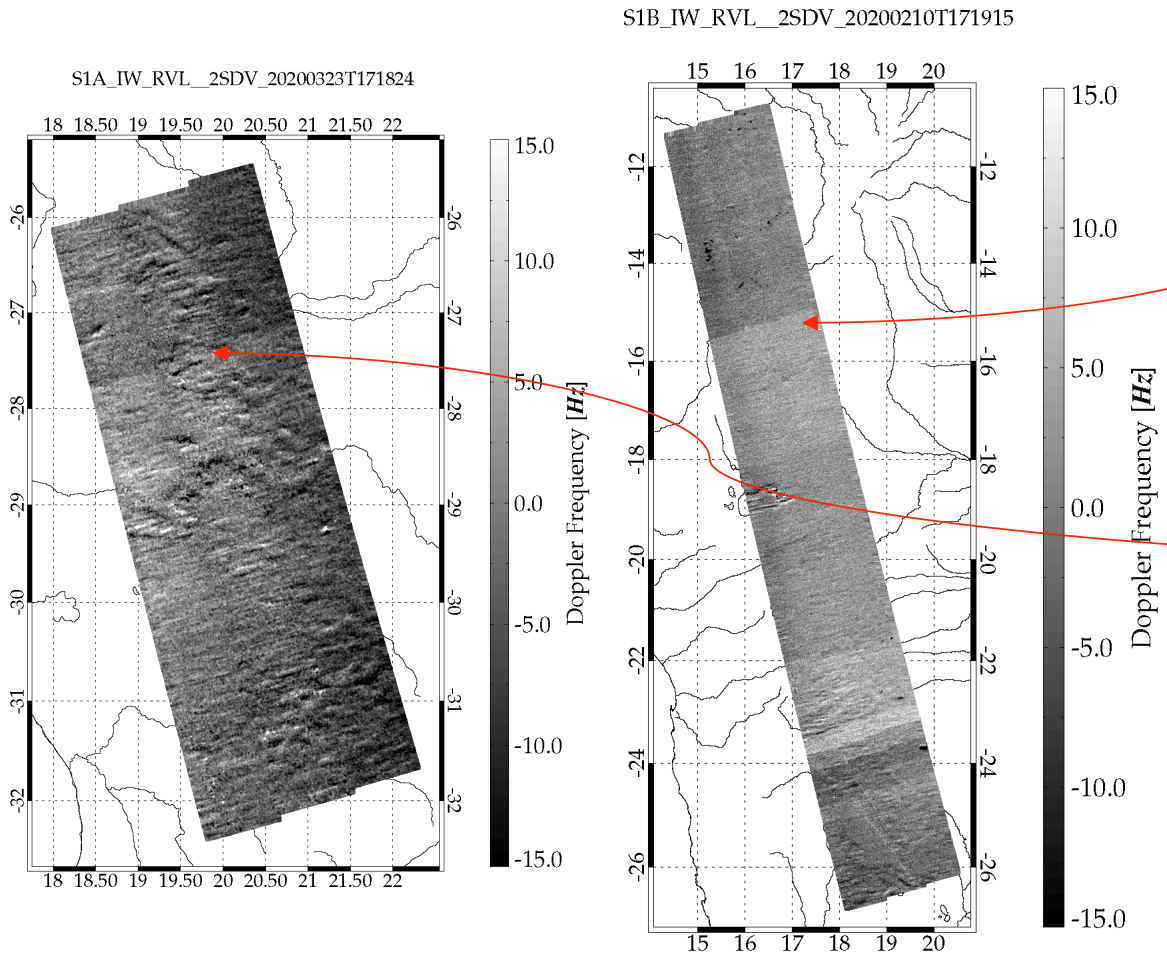


Figure: S-1a (left) and b (right) IW calibrate Doppler frequency acquired over Africa

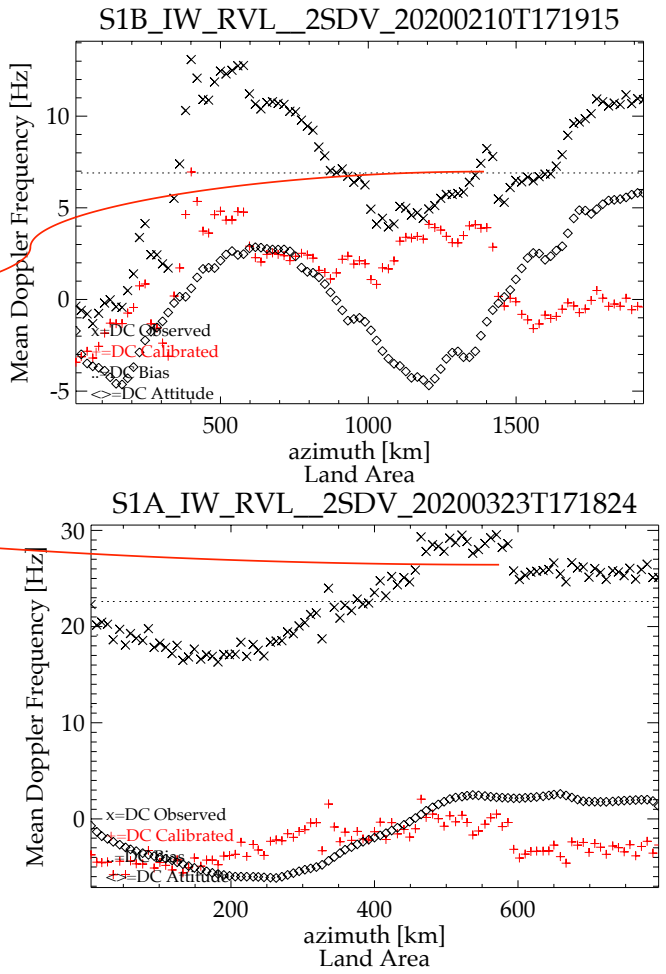


Figure: Mean DC profiles (dcObs, dcObsCal, dcAtt) along track.

S-1 IW RVL Statistics (South-Africa)

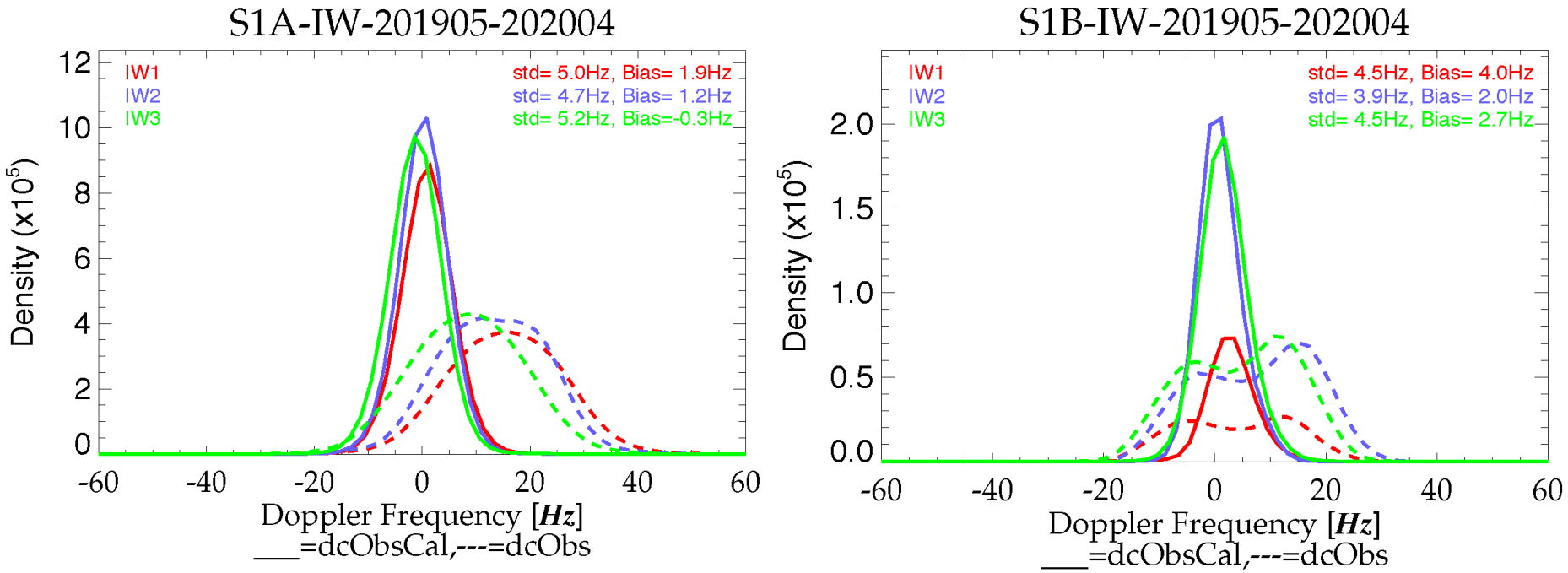


Figure: Histogram of S-1a (left) and S-1b (right) IW DC before (---) and after (___) calibration. Data from South-Africa area in the period 01.05.2019 to 30.04.2020. Data over land areas.

S-1 IW RVL Statistics (Norway)

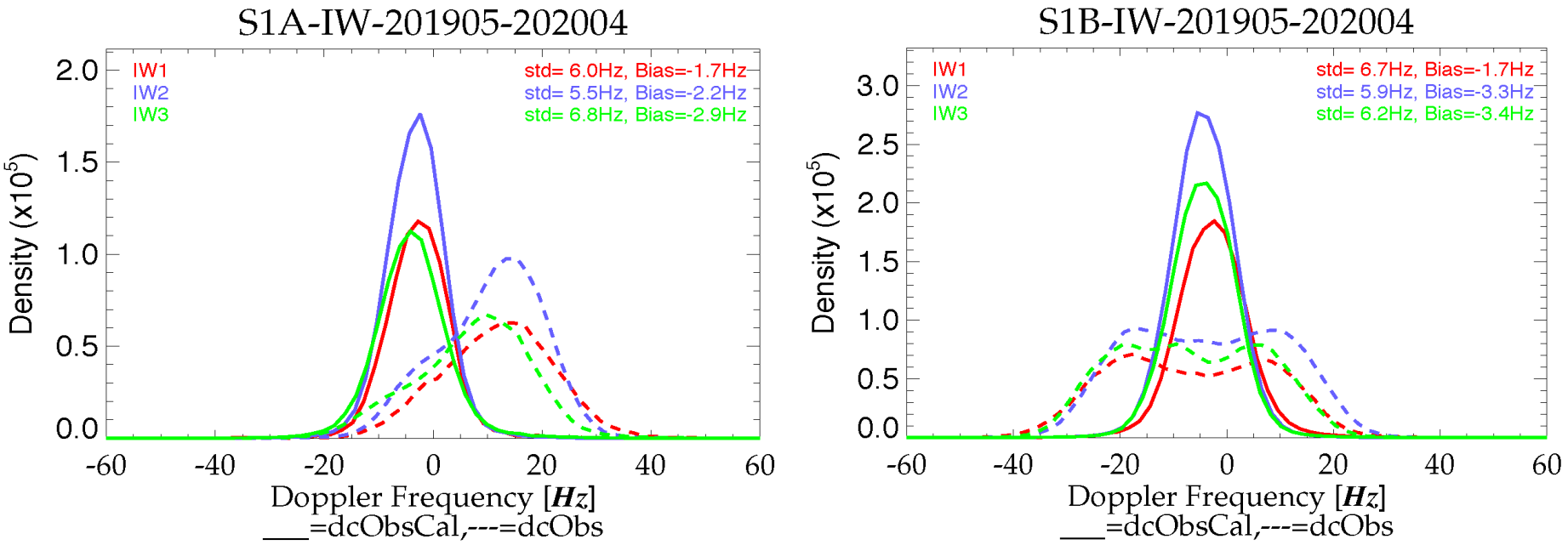


Figure: Histogram of S-1a (left) and S-1b (right) IW DC before (---) and after (___) calibration. Data from South-Norway area in the period 01.05.2019 to 30.04.2020. Data over land areas.

Summary of Assessment

- A recalibration of the S-1 OCN RVL products using restituted attitude and pre-computed DC bias data, shows significant improvements of the accuracy and precision of Doppler Centroid Anomaly.

- The recalibrated S-1 WV OCN RVL performance is within the requirement for climatology mapping of global ocean current?

- The recalibrated S-1 IW OCN RVL products can be used to derived reliable estimates of the radial coastal surface current.

- Major remaining issues:
  - DC jumps caused by antenna temperature compensation
  - Other (thermo elastic effects on the antenna) not capture by the calibration procedure
  - Other issues: SL2 DC estimation (RVL DC) vs Raw data DC (Aux_Dcbias)

Some references

- Engen G., Johnsen H., Larsen Y., "Sentinel-1 geophysical Doppler product – performance and application", Proc. of EUSAR2014, Berlin, 3-5 June 2014

- Moiseev A., Johnsen H., Wergeland Hansen M., Johannessen J. A., "Evaluation of Radial Ocean Surface Currents Derived from Sentinel-1 IW Doppler Shift Using Coastal Radar and Lagrangian Surface Drifter Observations", *Journal of Geophysical Research: Oceans*, *125*, e2019JC015743. https://doi.org/10.1029/2019JC015743

- OceanDataLab. (2019). *S-1 RVL DIL4: Algorithm Description Document.* Esrin/ESA.

- Moiseev, A., Johnsen, H., Johannessen, J. A., Collard, F., & Guitton, G. (2020). "On removal of sea state contribution to Sentinel-1 Doppler shift for retrieving Reliable Ocean surface current". Journal of Geophysical Research: Oceans, 125, e2020JC016288. https://doi.org/ 10.1029/2020JC016288

- S-1A & B Annual Performance Report for 2020, DI-MPC-APR, MPC-0504, Issue 1, 08/02/2021