Sentinel-1 Radial Velocity (RVL) Assessment

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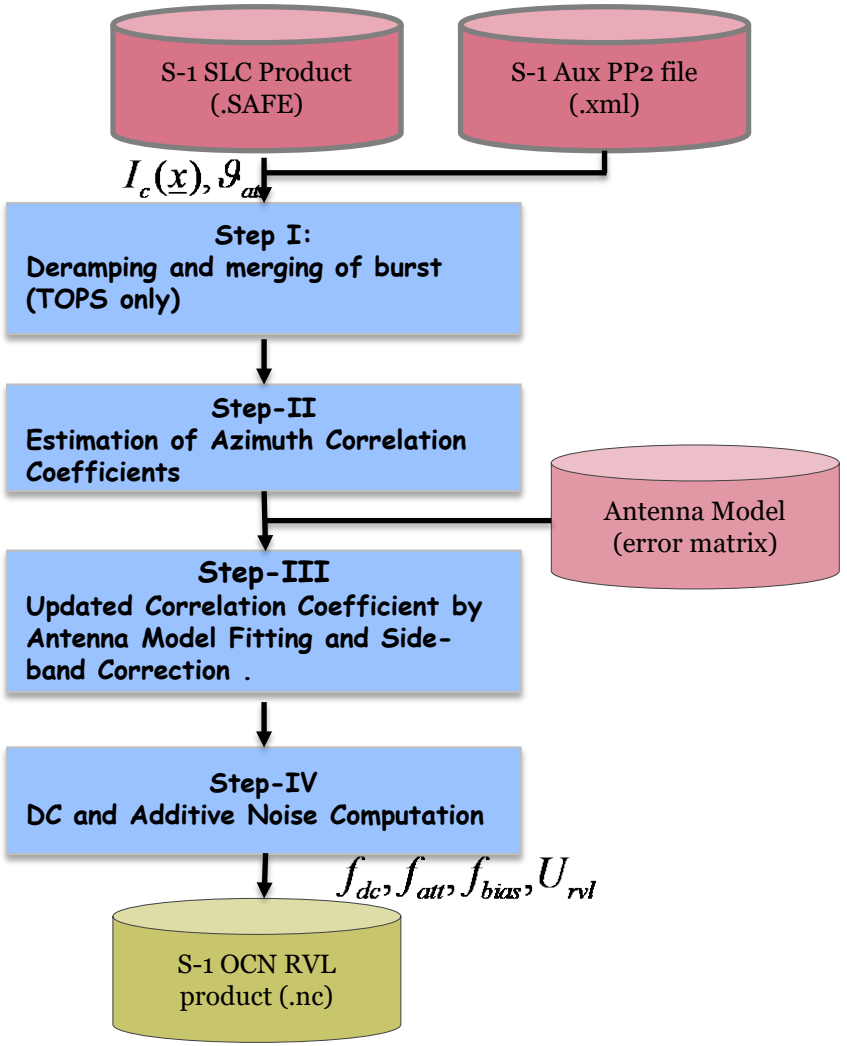
S1 Level 2 Doppler History

- ✓ "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 methodology (ATBD)
- ✓ "Copernicus S-1 RVL Assessment – CCN1 (2020-2021)", ESA/ESRIN contract, PI: OceanDataLab Ltd
  - ✓ Semi-operationalization and test data set generation

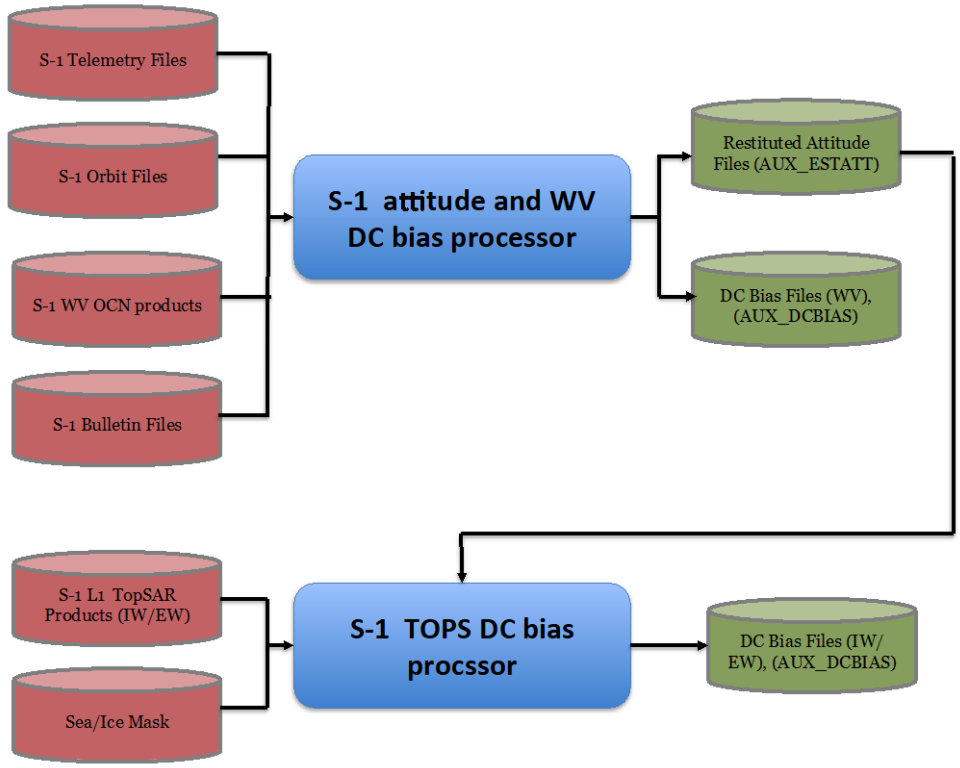
S-1 L2 Doppler Estimation Strategy

- 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

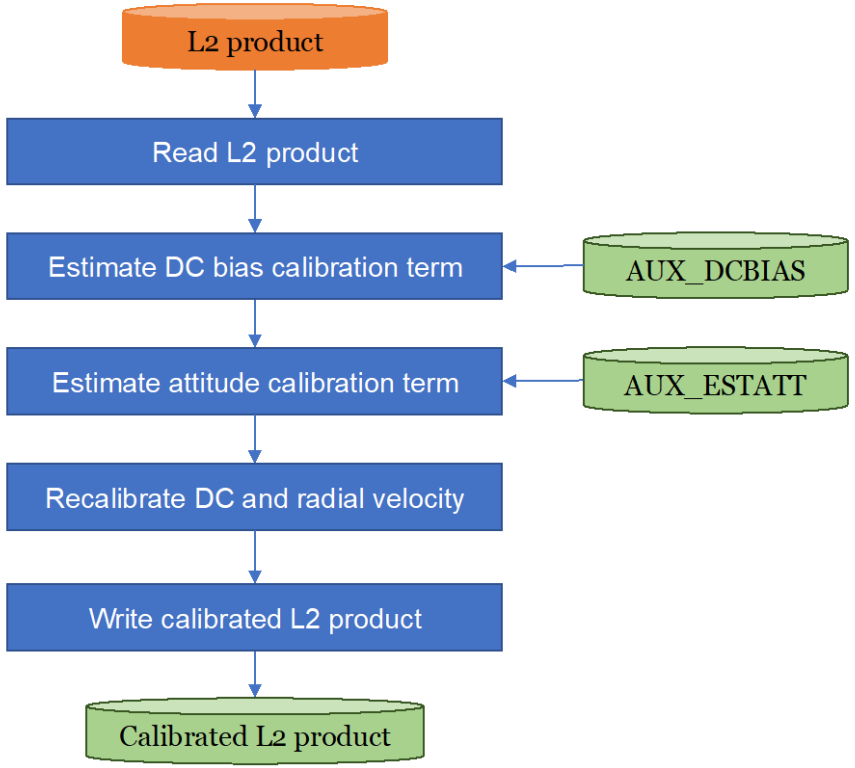
Δf_{bias} = Residual DC bias

f_{dca} = Geophysical Doppler (rvlDcObsCal)

t = time along orbit

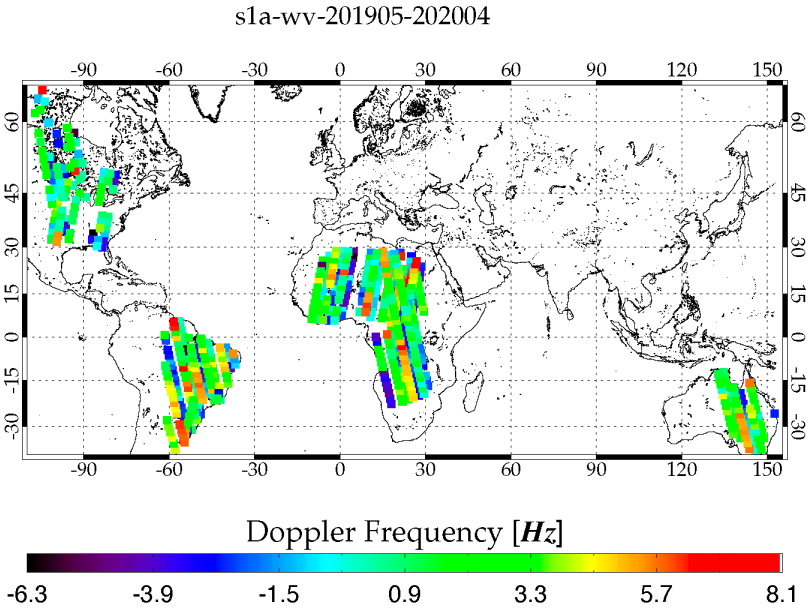
β = boresight angle

$\Delta\theta_{att}$ = 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, Mediterranean Sea)

S-1a WV (orbit segments over land)



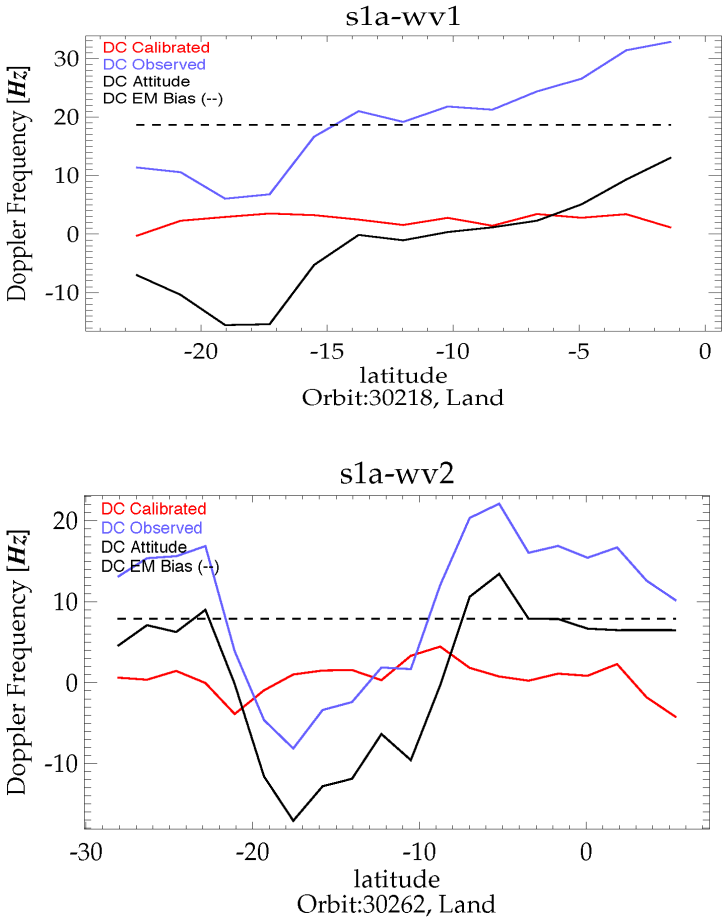


Figure: S-1a WV mean dcObsCal from land acquisitions (left), and examples of S-1a WV DCs (dcObs, dcObsCal, dcAtt, dcBias) along orbit segment acquired over land areas (Australia) (right).

S-1a,b WV RVL Statistics

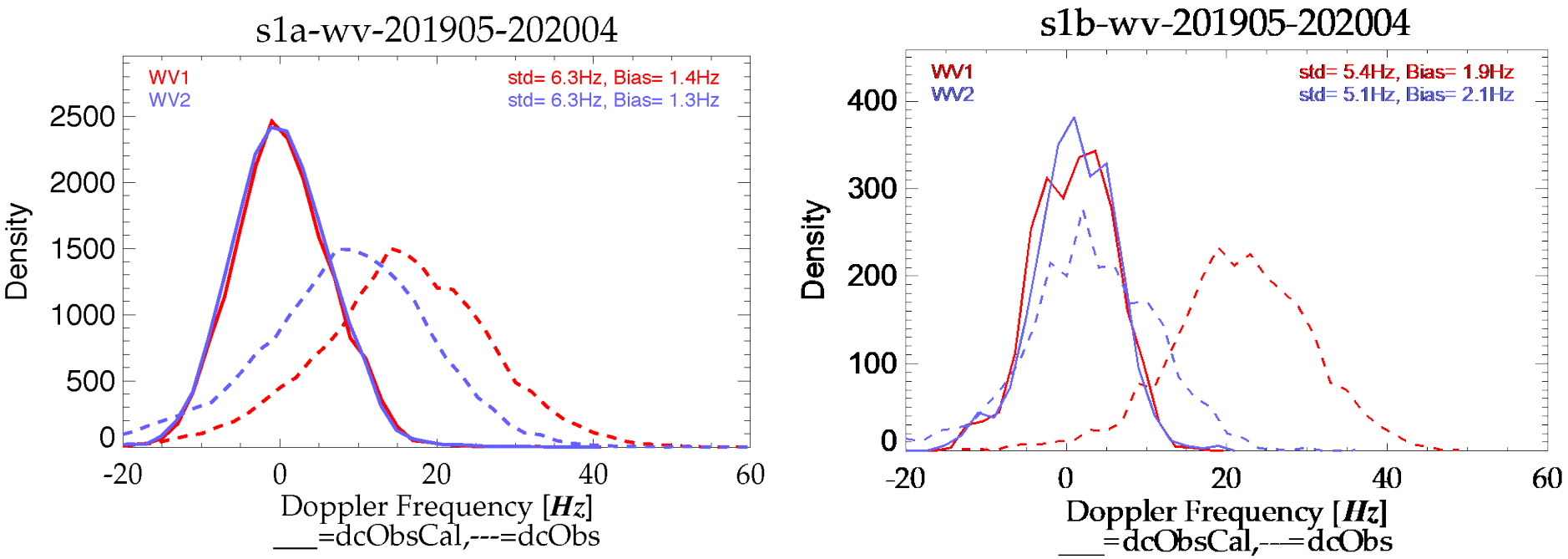
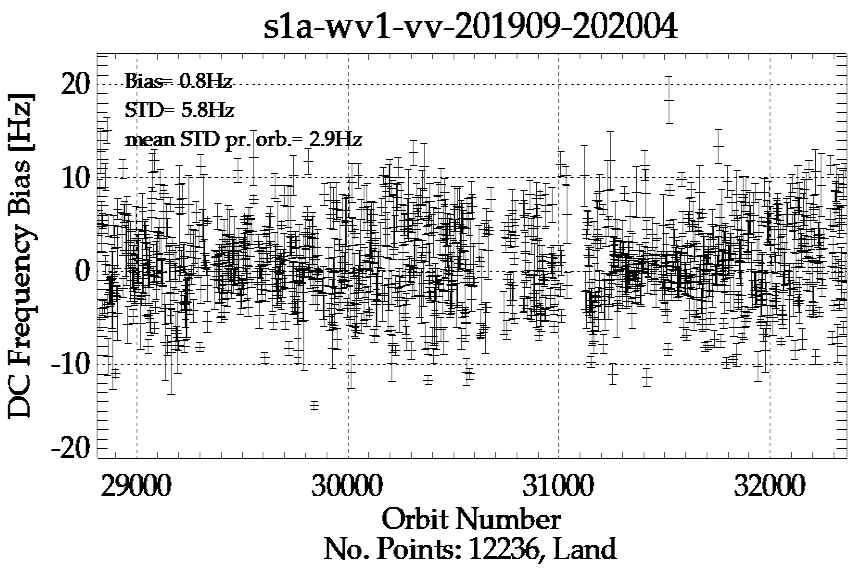


Figure: Histograms of S-1a (left) and S-1b (right) WV OCN RVL DC frequency before (---) and after (___) calibration. The data was acquired between 1st May 2019 and 30th April 2020 over global land areas.



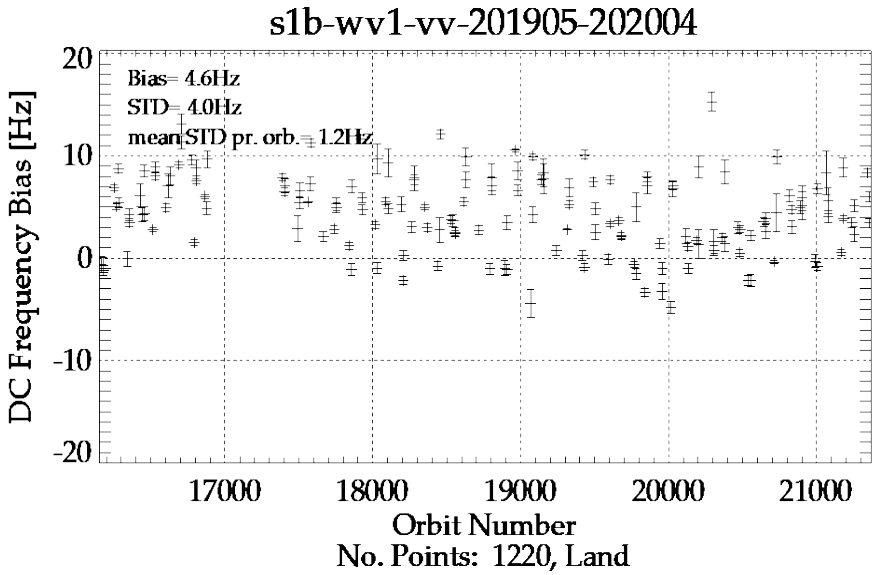


Figure : Examples of S-1a (a) and S-1b (b) WV mean calibrated DC pr. orbit segments over land areas. The vertical bars indicate the standard deviation over the orbit segment.

S-1 WV Ocean Doppler

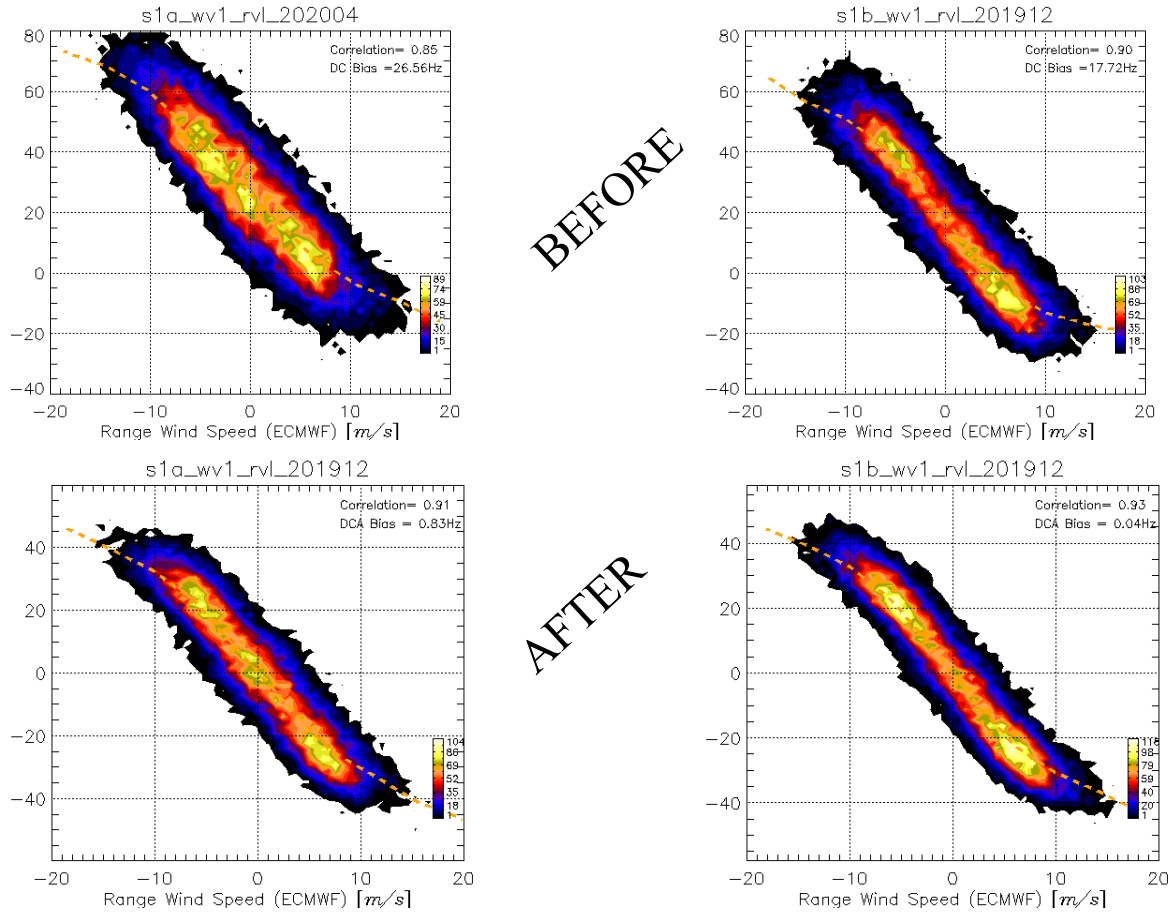


Figure : S-1a (left) and S-1b (right) WV Doppler frequency before (upper) and after (lower) calibration versus range wind speed (ECMWF). Ocean data.

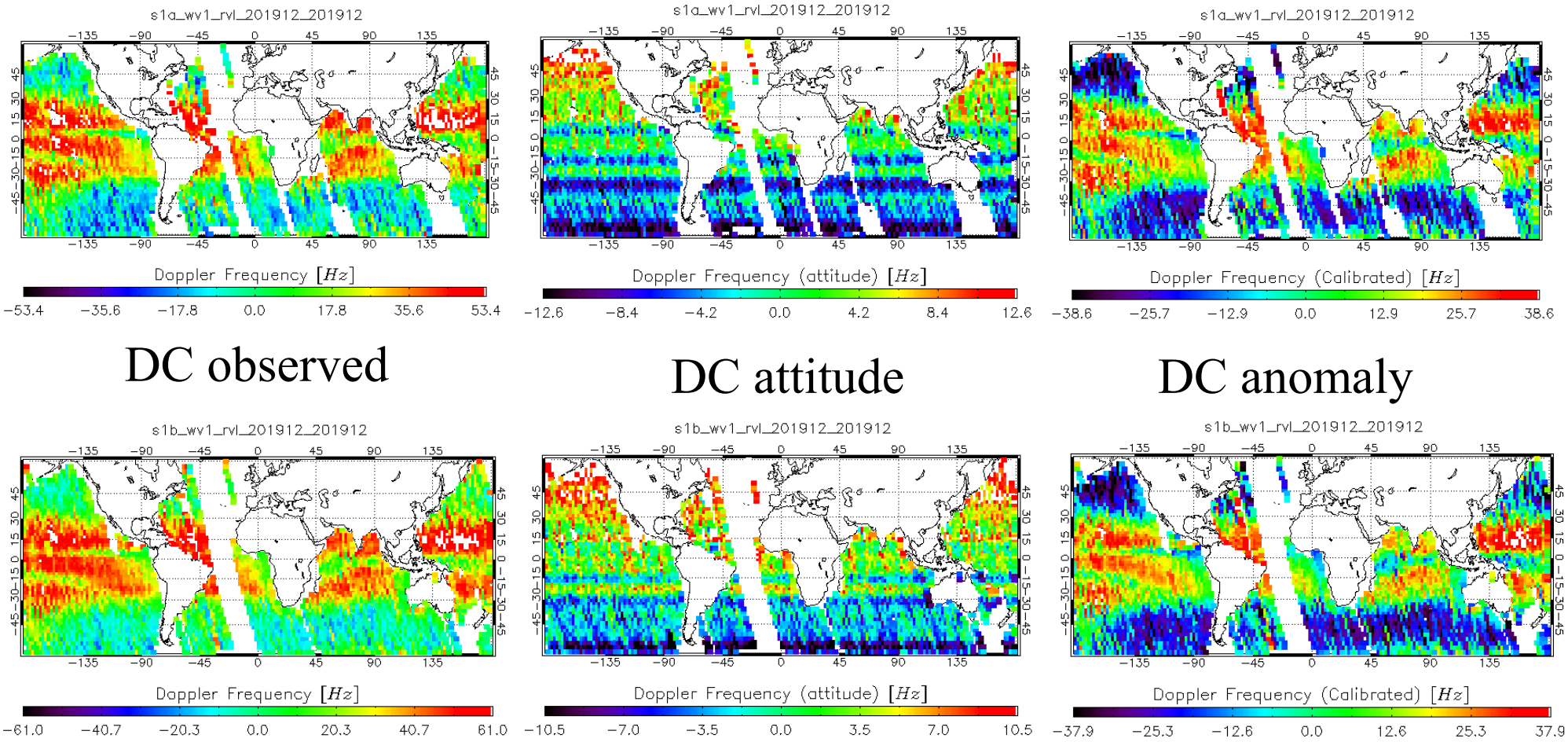


Figure : S-1a (upper) and S-1b (lower) WV DC observed (left), DC attitude (middle) and DC anomaly (right).

S-1 IW RVL (Skagerak/Norway)

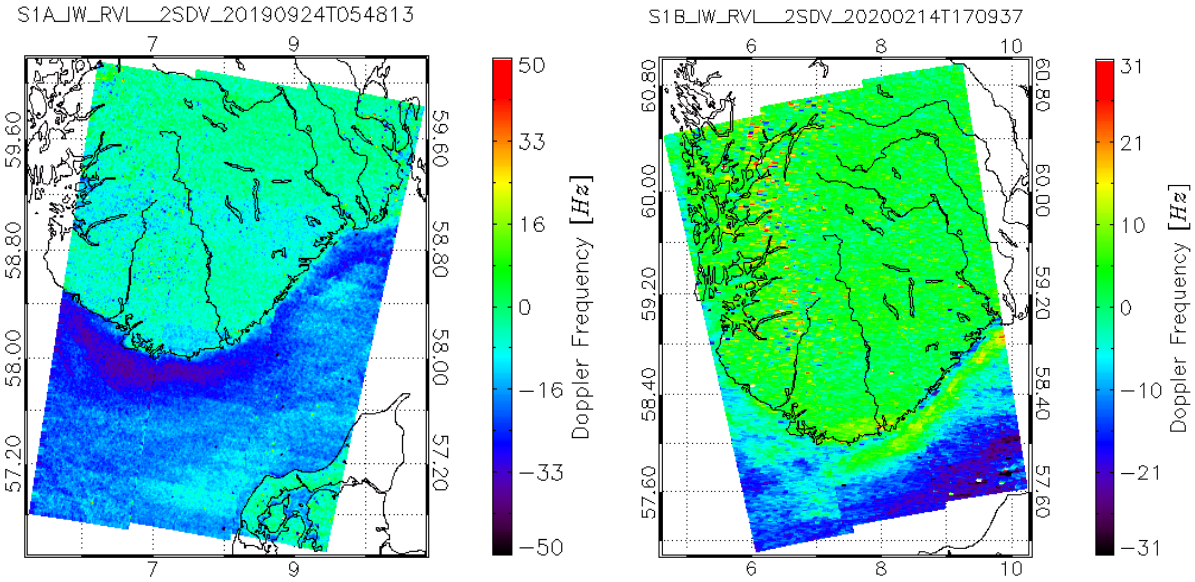


Figure: S-1a (left) and S-1b (right) IW calibrated Doppler frequency acquired over Skagerak area.

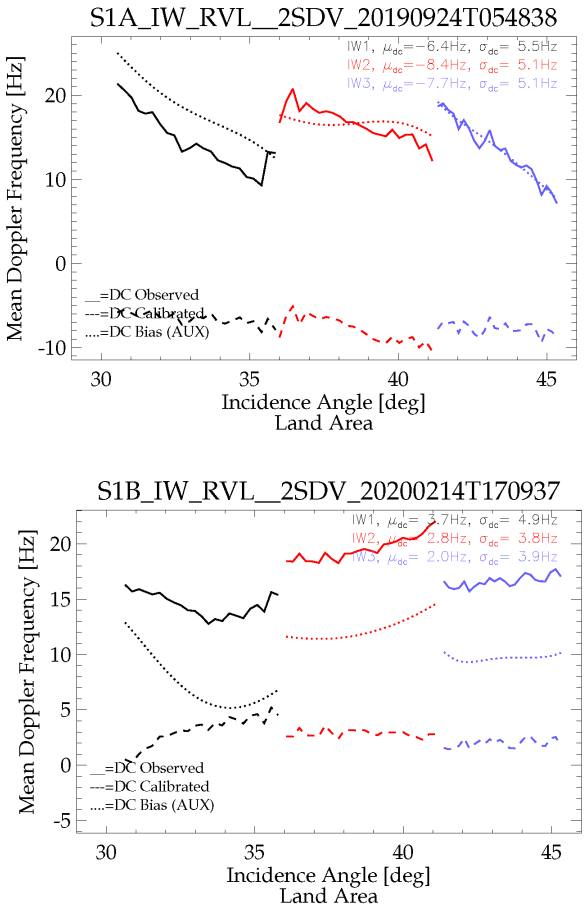


Figure: Mean DC profiles over swath (dcObs, dcObsCal, dcBias).

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

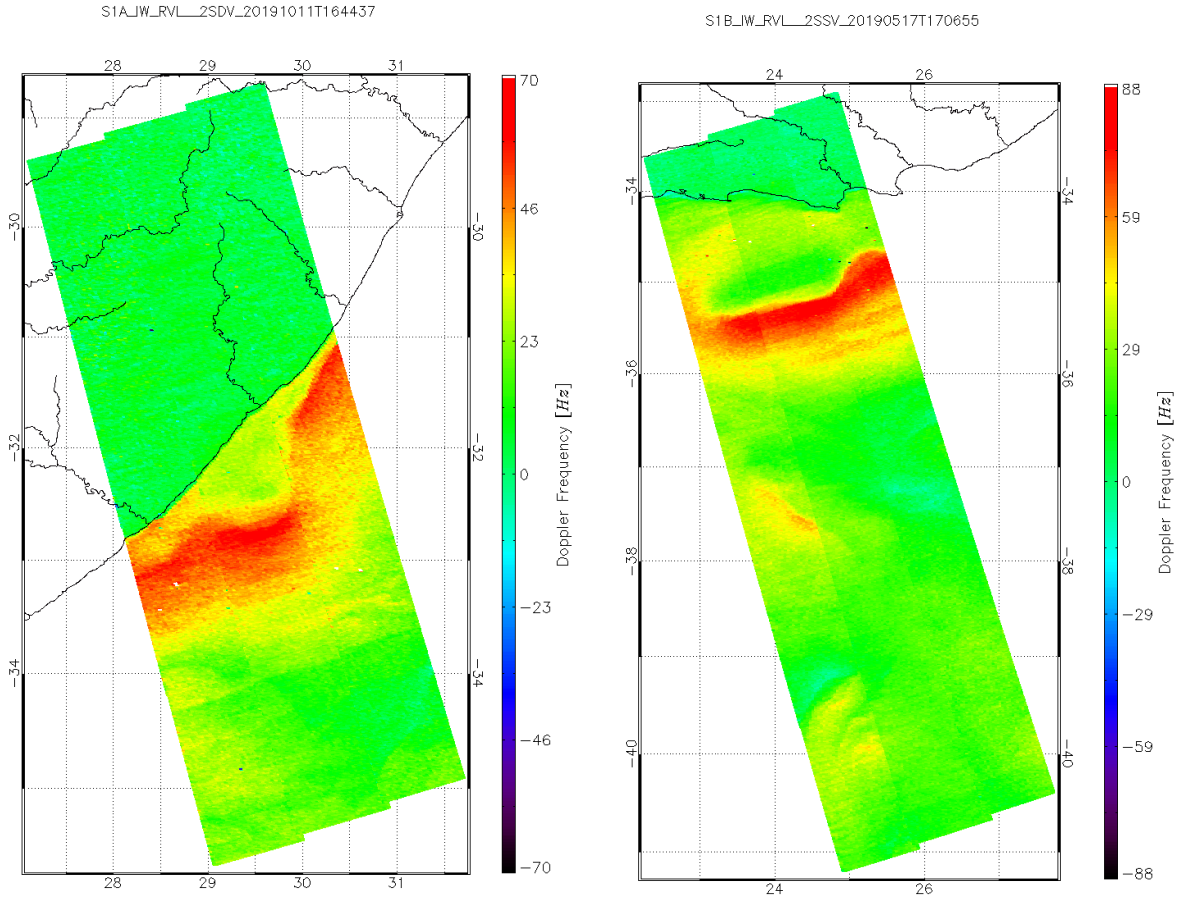


Figure: S-1a (left) and b (right) IW calibrate Doppler frequency acquired over Agulhas

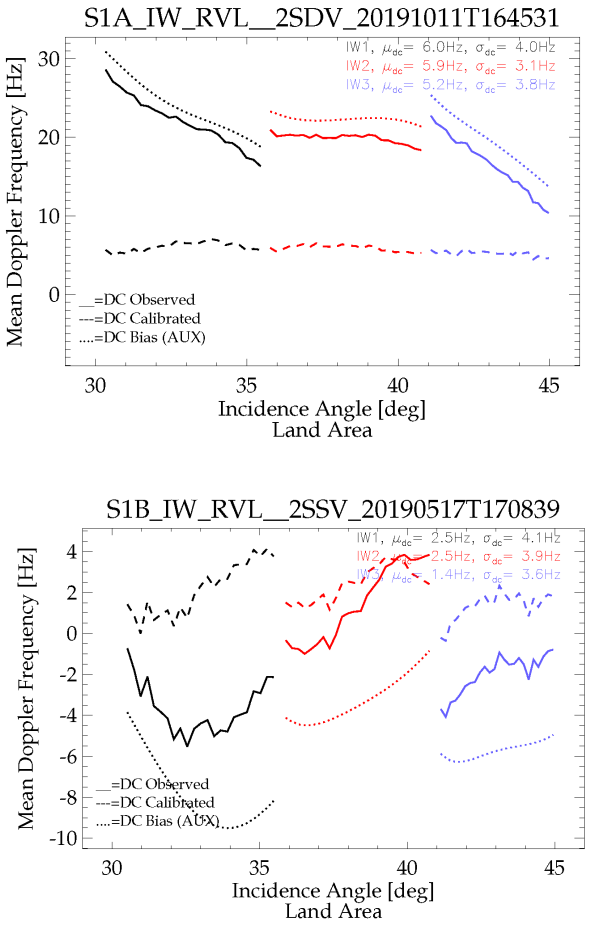


Figure: Mean DC profiles over swath (dcObs, dcObsCal, dcBias).

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

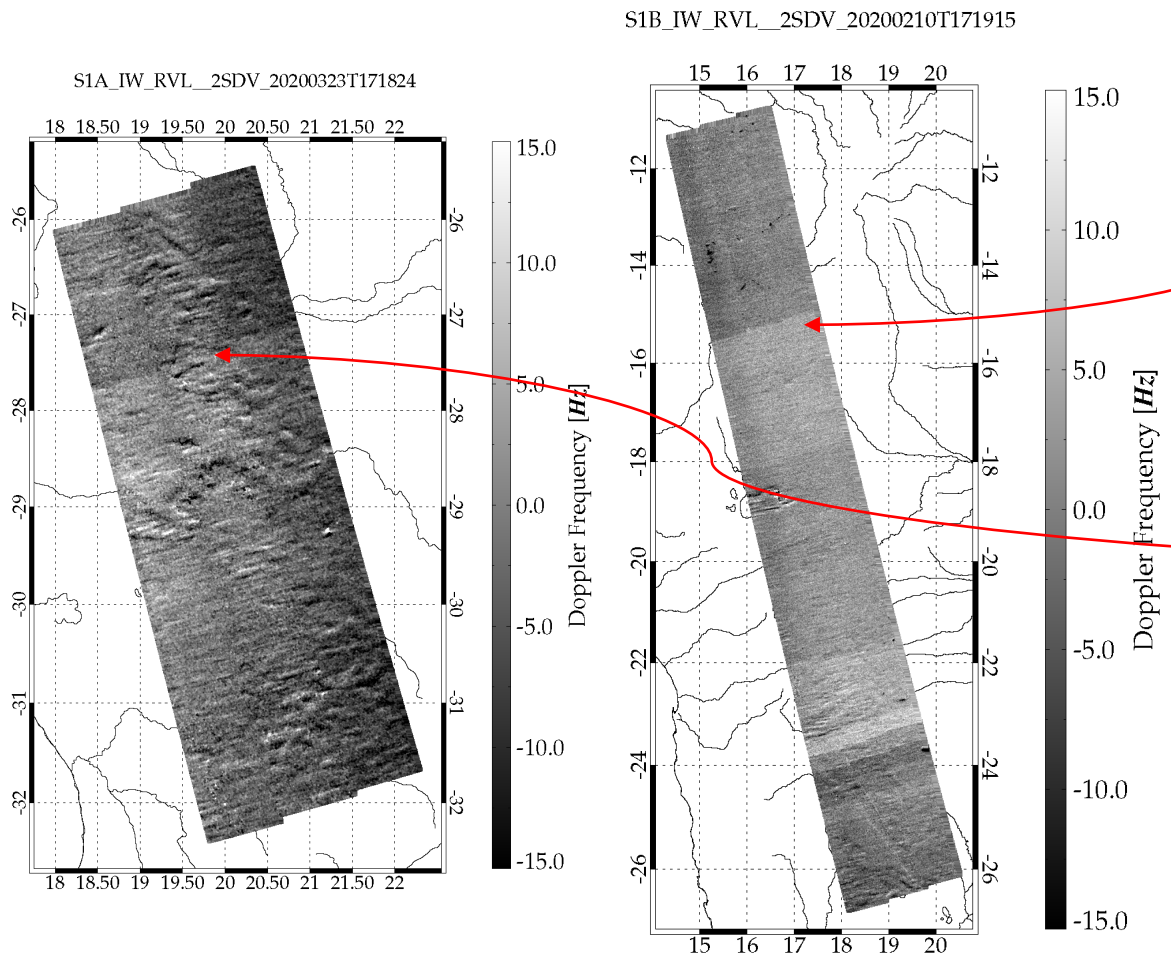


Figure: S-1a (left) and b (right) IW calibrate Doppler frequency acquired over Africa

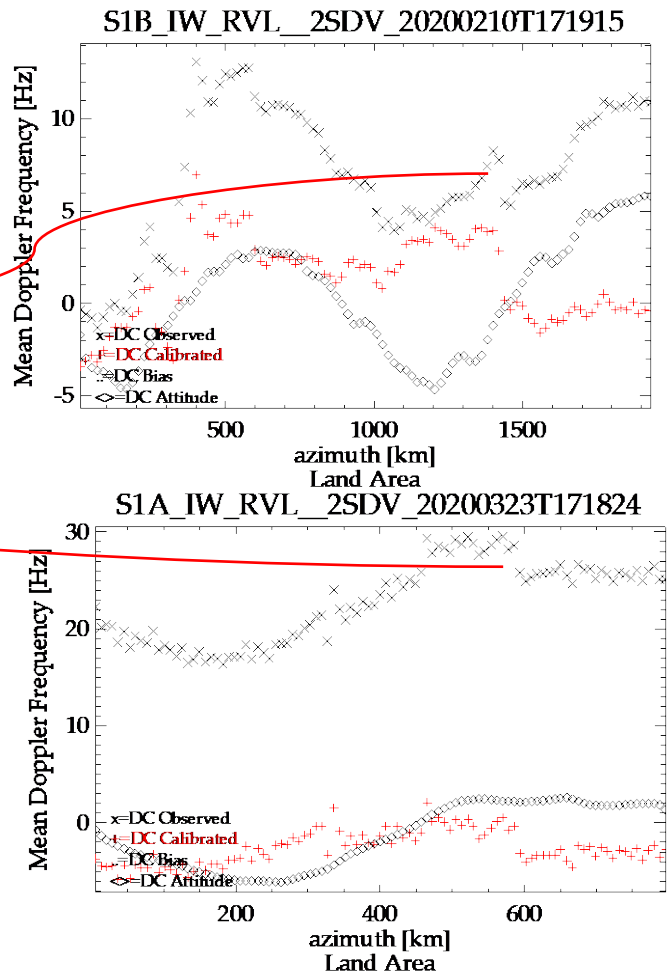


Figure: Mean DC profiles (dcObs, dcObsCal, dcAtt) along track.

S-1 IW RVL Statistics (South-Africa)

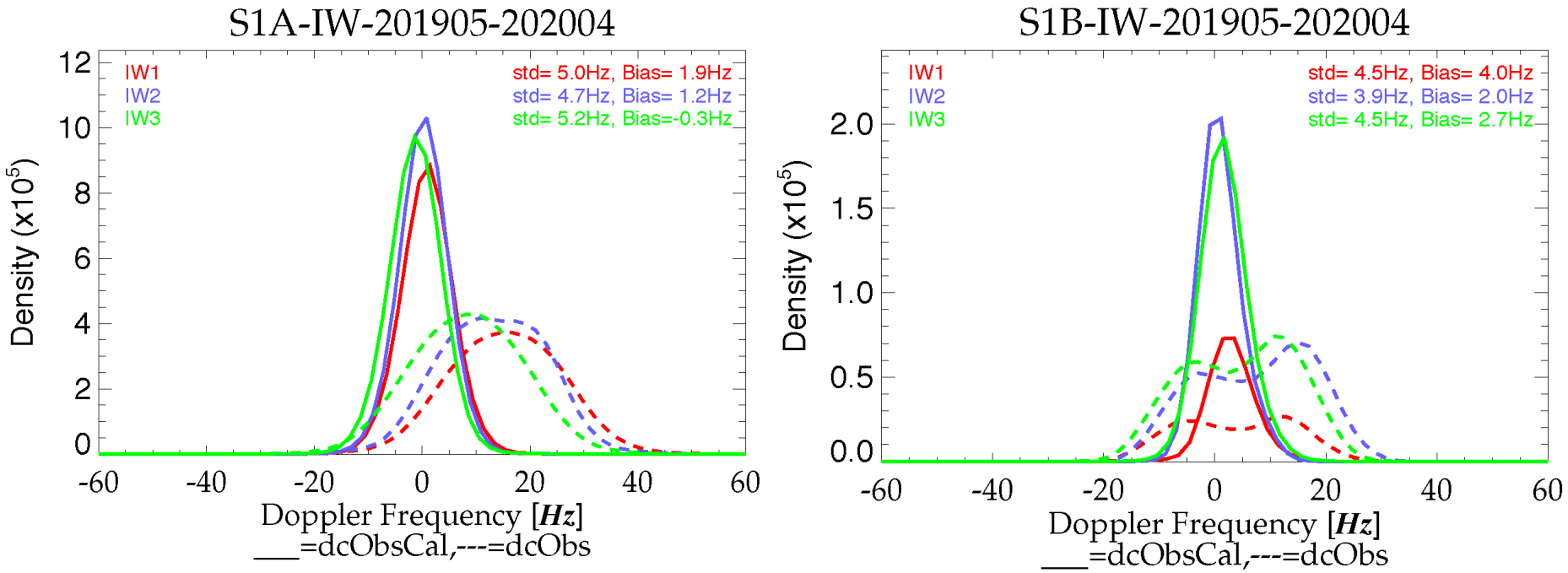


Figure: Histogram of S-1a (left) and S-1b (right) IW DC before (---) and after (___) calibration. Data from South-Africa area in the period 01.05.2019 to 30.04.2020. Data over land areas.

S-1 IW RVL Statistics (Norway)

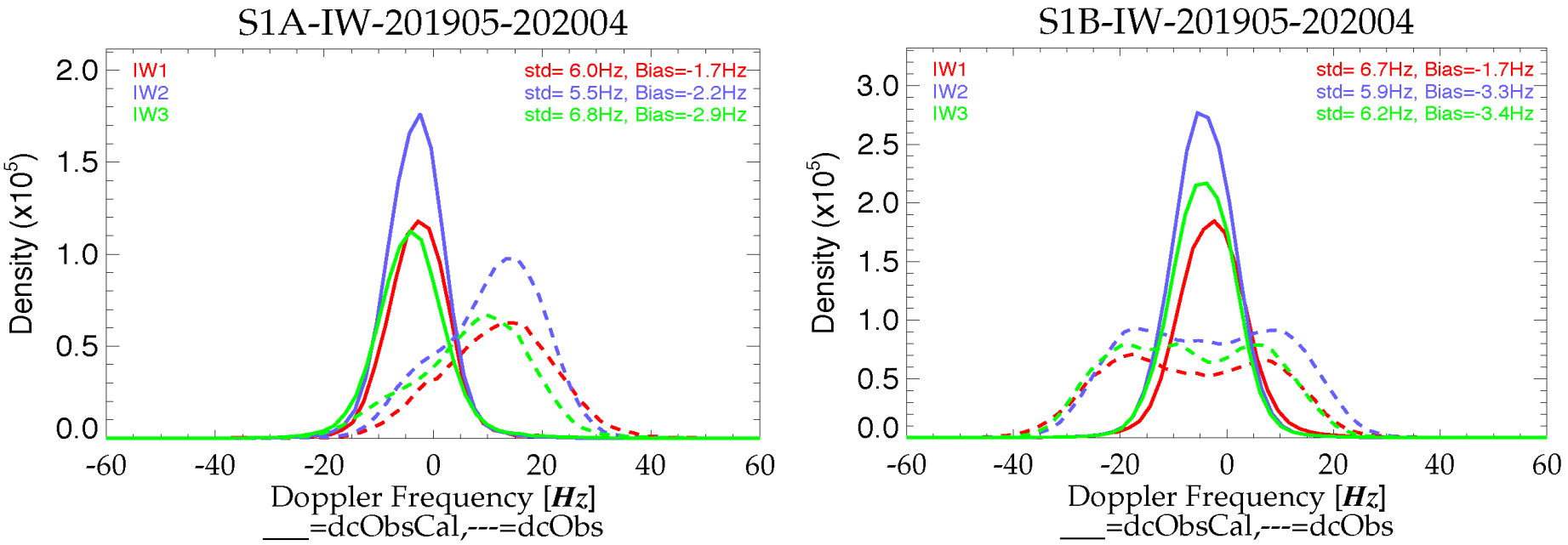
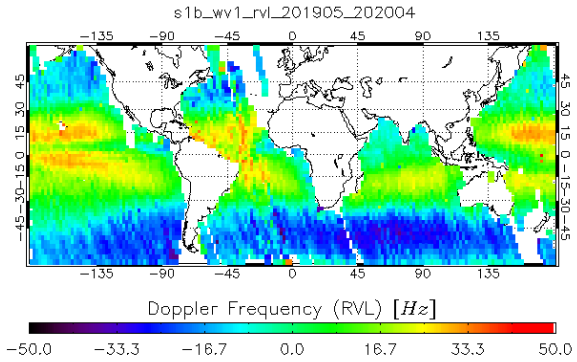
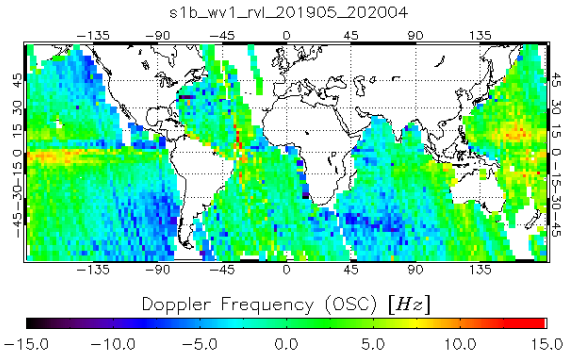


Figure: Histogram of S-1a (left) and S-1b (right) IW DC before (---) and after (___) calibration. Data from South-Norway area in the period 01.05.2019 to 30.04.2020. Data over land areas.

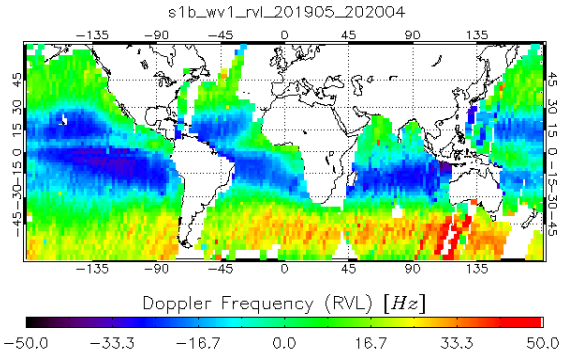
Global OSC - S1 WV



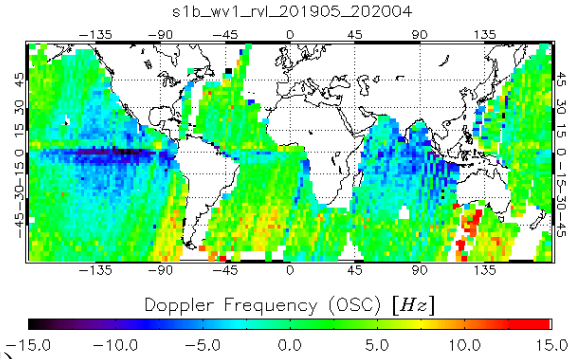
a) DC Anomaly



b) DC OSC



c)



d)

Mean DC of the radial velocity (a),(c) and the mean DC of the radial surface current (b),(d) derived from S1b WV1 between 01.05.2019 and 30.04.2020 in ascending (upper) and descending (lower) passes.

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** from individual scenes.

- Major remaining issues:
  - DC jumps caused by antenna temperature compensation (within the TOPS acquisitions)
  - 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)

Acknowledgement

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  Copernicus Sentinel-1 mission is funded by the EU and ESA.
- The views expressed herein can in no way be taken to reflect the official opinion of the European Space Agency or the European Union.

Some references

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