Towards the Direct Assimilation of Scatterometer Backscatter Triplet

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Use of ML for Scatterometer Backscatter over Oceans

Objective:

- The direct assimilation of scatterometer backscatter triplet in ECMWF IFS.

This involves

- Developing ANN SCATT backscatter (sigma_0) forward operator,
- Flexibility in adding new parameters in the forward operator,
- Developing the tangent linear and the adjoint.

SCAT Data Assimilation

Current approach

σ^0_{fore}, σ^0_{mid}, σ^0_{aft}

θ_{fore}, θ_{mid}, θ_{aft}, ϕ

→ U_{10N}, V_{10N} → IFS/4DVar

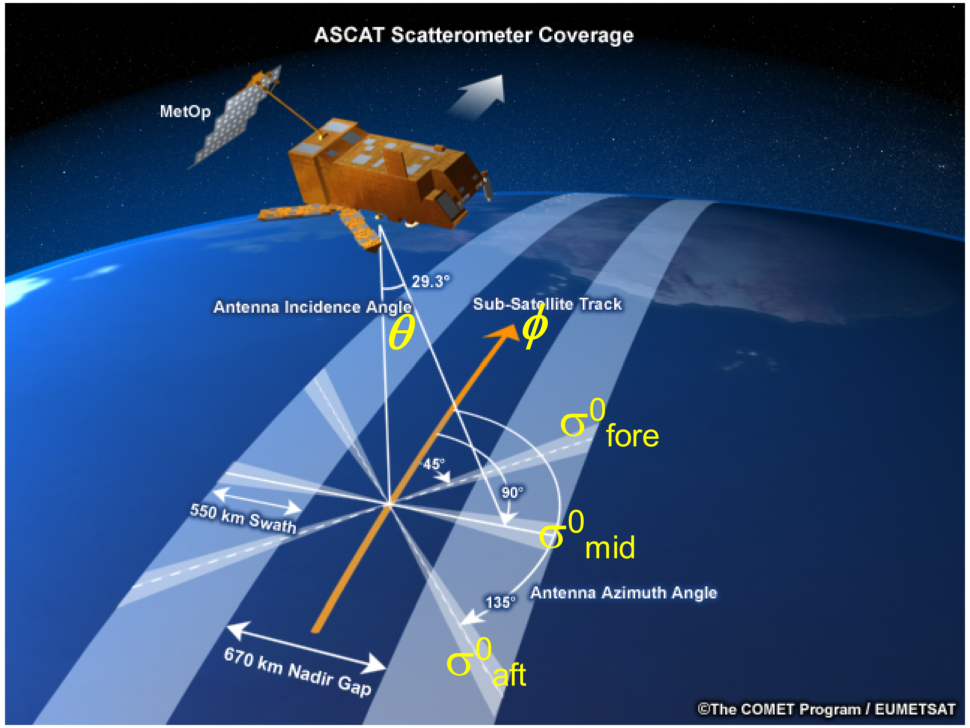
Plan

σ^0_{fore}, σ^0_{mid}, σ^0_{aft}

θ_{fore}, θ_{mid}, θ_{aft}, ϕ

- air density,
- ocean currents,
- precipitation,
- … etc.

→ ML → IFS/4DVar



Relation between backscatter & surface wind vector (speed & direction)

Measurements sensitive to the **ocean-surface roughness** due to capillary gravity waves generated by local wind conditions (**surface stress**)

- ✓ The relationship is determined empirically
  - Ideally collocate with *surface stress* observations
  - In practice with buoy and 10m model winds

$$\sigma_0 = GMF(U_{10N}, \phi, \theta, p, \lambda, \ldots)$$

U_{10N}: equivalent neutral wind speed
ϕ : wind direction w.r.t. beam pointing
θ : incidence angle
p : radar beam polarization
λ : microwave wavelength

"…" can be:
- Air density
- Surface currents
- Rain

- ✓ Geophysical model functions (GMF) families
  - C-band: CMOD (currently CMOD5.N)
  - Ku-band: NSCAT, QSCAT

To assimilate SCATT backscatter (σ^0_{fore} , σ^0_{mid} , σ^0_{aft}), we need:

- Forward modelling
  - Geophysical model function (GMF)
  - Empirical GMF's available but not flexible to include additional parameters
- Tangent Linear
  - Not readily available → to be developed.
- Adjoint
  - Not readily available → to be developed.
- Attractive solution: **ML**

We were able to show that:

- ANN can be used as a GMF for forward modelling (offline training using Tensorflow/Keras):
    - Starting from background wind, we can compute the corresponding σ^0 values (for the given geometry).

- We can add other parameters easily (once we find the data):
    - We were able to add air density (from the model)

- We are now preparing to use:
    - Rain
    - Ocean surface currents
    - Sea state

Introduction to Tests Carried Out So Far

- Data from ASCAT-B for January-March 2021. Only good used data (QC, thinning).

- Number of records (excluding headers):
  - Training: 1,126,239 samples (01-31 January 2021)

    Training: 754,580 samples (67%),

    Testing: 371,659 samples (33%)
  - Independent Validation: 1,487,973 samples (08 January – 20 March 2021)

- Input (features): (total: 8 features)
  - IFS (background) wind vector → 2 features
  - Incidence angles (fore, mid and aft) → 3 features
  - Direction of look (fore, mid and aft) → 3 features
- Output (targets): (total: 3 targets)
  - Backscatter (fore, mid and aft) → 3 targets

← Other features can be easily added.
Examples:
- Air density
- Ocean currents
- Precipitation
- … etc.

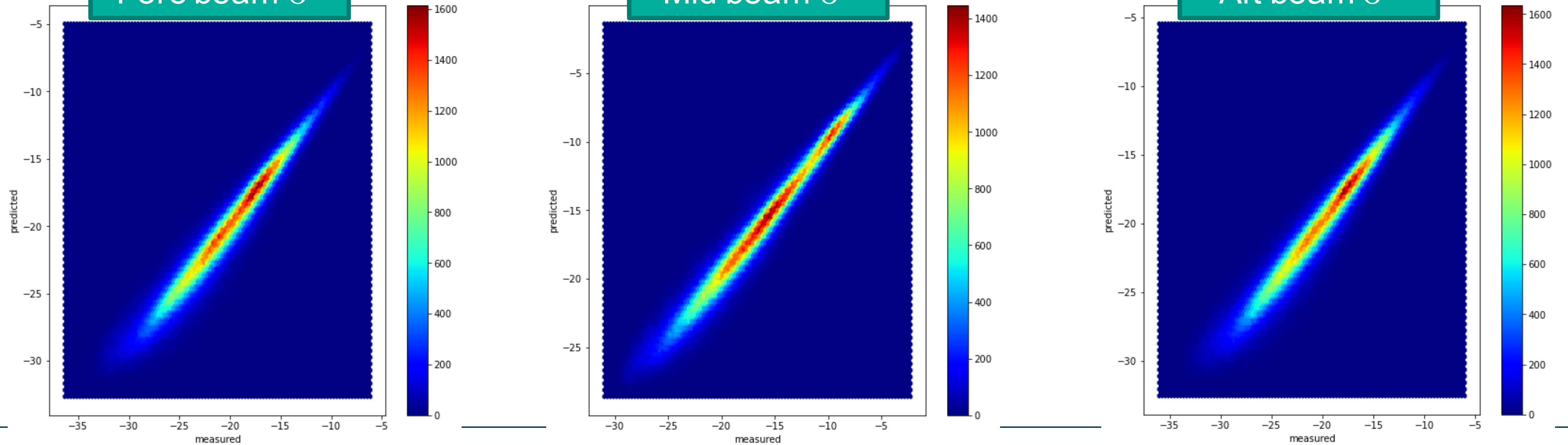
Results: Predictions from ECMWF Model Background

- Statistics (predicted vs measured) for two trainings:

(SDD: Standard deviation of the difference ~ proxy to the random error)

Beam	Correlation	Bias (dB)	SDD (dB)
Fore	0.9585 (0.9584)	0.126 (0.109)	1.347 (1.351)
Mid	0.9746 (0.9745)	0.172 (0.071)	1.156 (1.159)
Aft	0.9583 (0.9585)	0.143 (0.127)	1.350 (1.346)

Fore beam σ^0 | Mid beam σ^0 | Aft beam σ^0



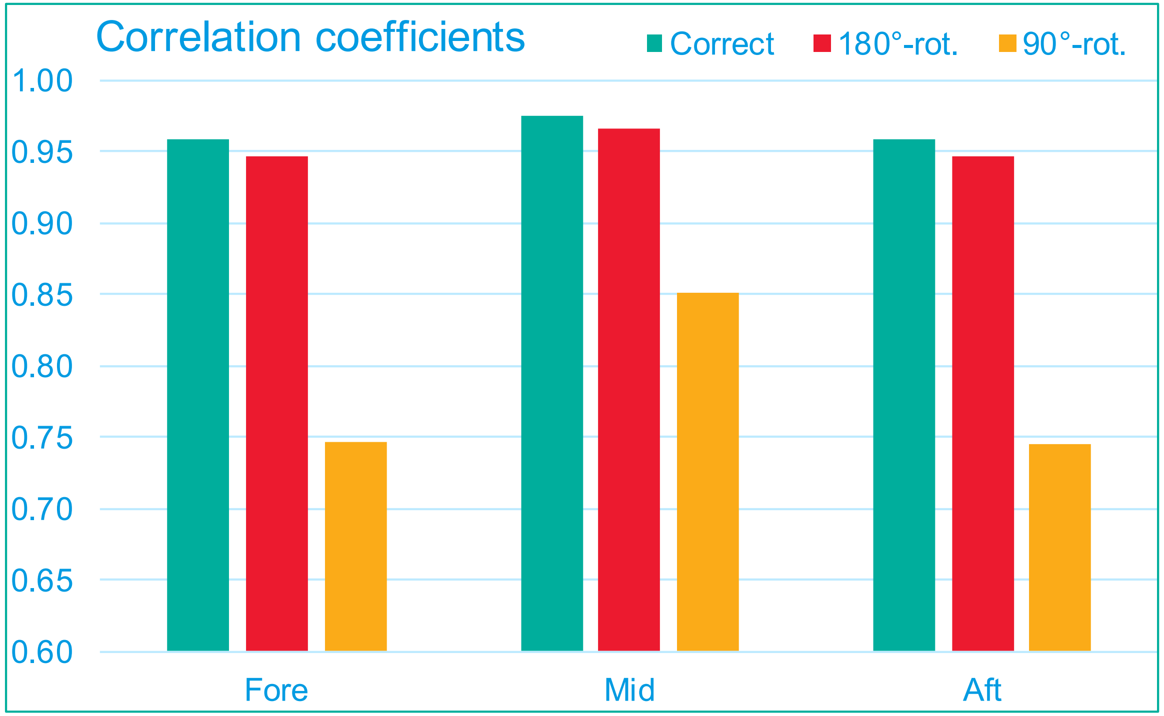
Sensitivity to wind direction in sigma_0 forward model (1/2)

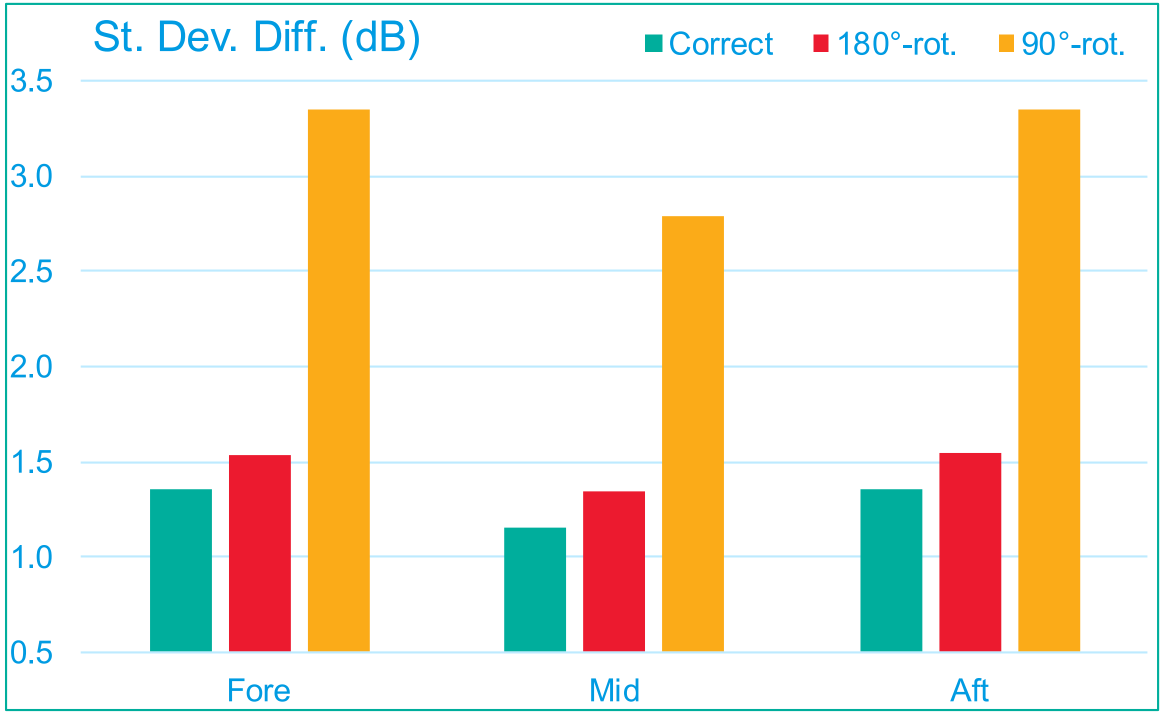
- Data volume:
  - Training: 1-31 Jan. 2021 (754,580 obs.)
  - Validation: 08-20 Mar. 2021 (1,487,973 obs.)

- Statistics of sigma_0 differences (predicted - measured) when:
  - training is done using **correct** wind, while
  - validation is done based on **rotated** wind.

- ➔ Sensitive to wind direction:
  - Significant sensitivity for rotation of 90°
  - Less sensitive for rotation of 180°

Sensitivity to wind direction in sigma_0 forward model (2/2)





Summary

- Work towards direct assimilation of scatterometer backscatter triplet into IFS:
  - Forward operator ← we are still here!
  - Tangent linear
  - Adjoint

- Development of SCATT sigma_0 operator. Very promising results
  - In particular, the sensitivity of the simulated sigma_0 to perturbations in wind speed and direction

- Work in progress….