Monitoring Metop ASCAT backscatter stability over tropical rainforests

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Detecting ASCAT sensor drift

- **ASCAT**: microwave radar instrument on Metop satellites, designed for wind speed and direction over open ocean. Also capable for observing sea ice extent and surface soil moisture changes.

- Regular calibration campaigns using active transponders provide ongoing quality monitoring, but infrequently due to requirements to halt data collection during calibration passes over the transponders.

- Natural targets like tropical rainforests have been used for calibration campaigns that don't rely on active transponders.

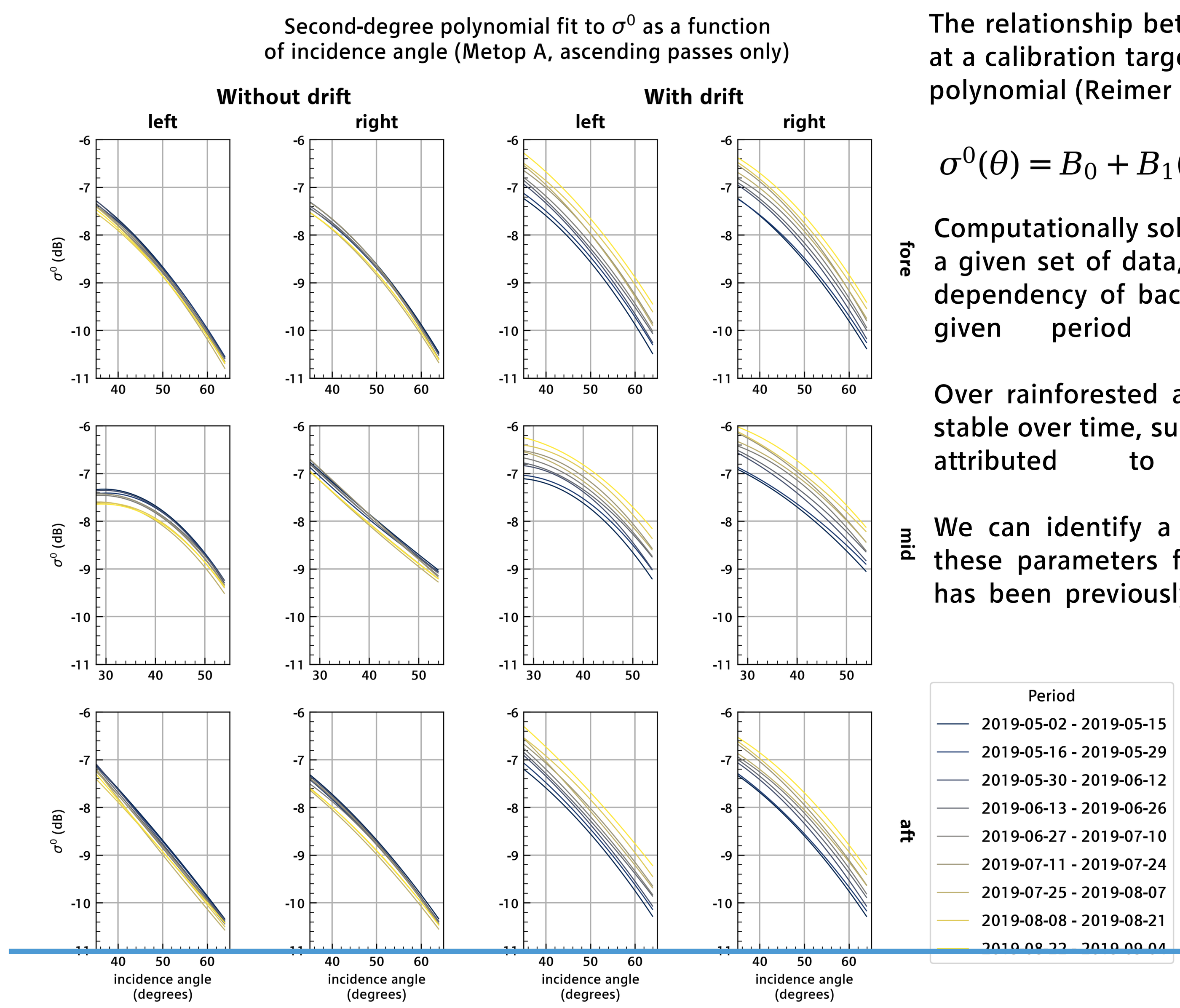
- Upcoming EUMETSAT H SAF ASCAT Surface Soil Moisture (SSM) products categorized as Climate Data Record (CDR), Intermediate CDR (ICDR), and Near Real-Time (NRT).

- ICDR products introduced to maintain consistency between historic data and NRT products, which may be subject to intentional or unintentional changes.

- This study presents a strategy to monitor ASCAT Level 1b backscatter stability over tropical rainforests and discusses its implementation as an early-warning system for the ASCAT SSM ICDR product.

- Discovering problems that undermine coherence between CDR and ICDR products is critical for applications like drought monitoring and climate studies, which rely on consistent time series data.

Monitoring changes in σ^0 incidence angle dependence



The relationship between incidence angle and backscatter at a calibration target can be modeled by a second-degree polynomial (Reimer et al., 2014):

$$\sigma^0(\theta) = B_0 + B_1(\theta - 40) + B_2(\theta - 40)^2$$

Computationally solving for parameters B_0, B_1, and B_2 with a given set of data, we can describe the incidence angle dependency of backscatter over a location or area for a given period of time.

Over rainforested areas, these parameters remain quite stable over time, such that any significant variation can be attributed to calibration/instrument errors.

We can identify a period as anomalous by checking if these parameters fall outside an acceptable range that has been previously established by well-calibrated data.

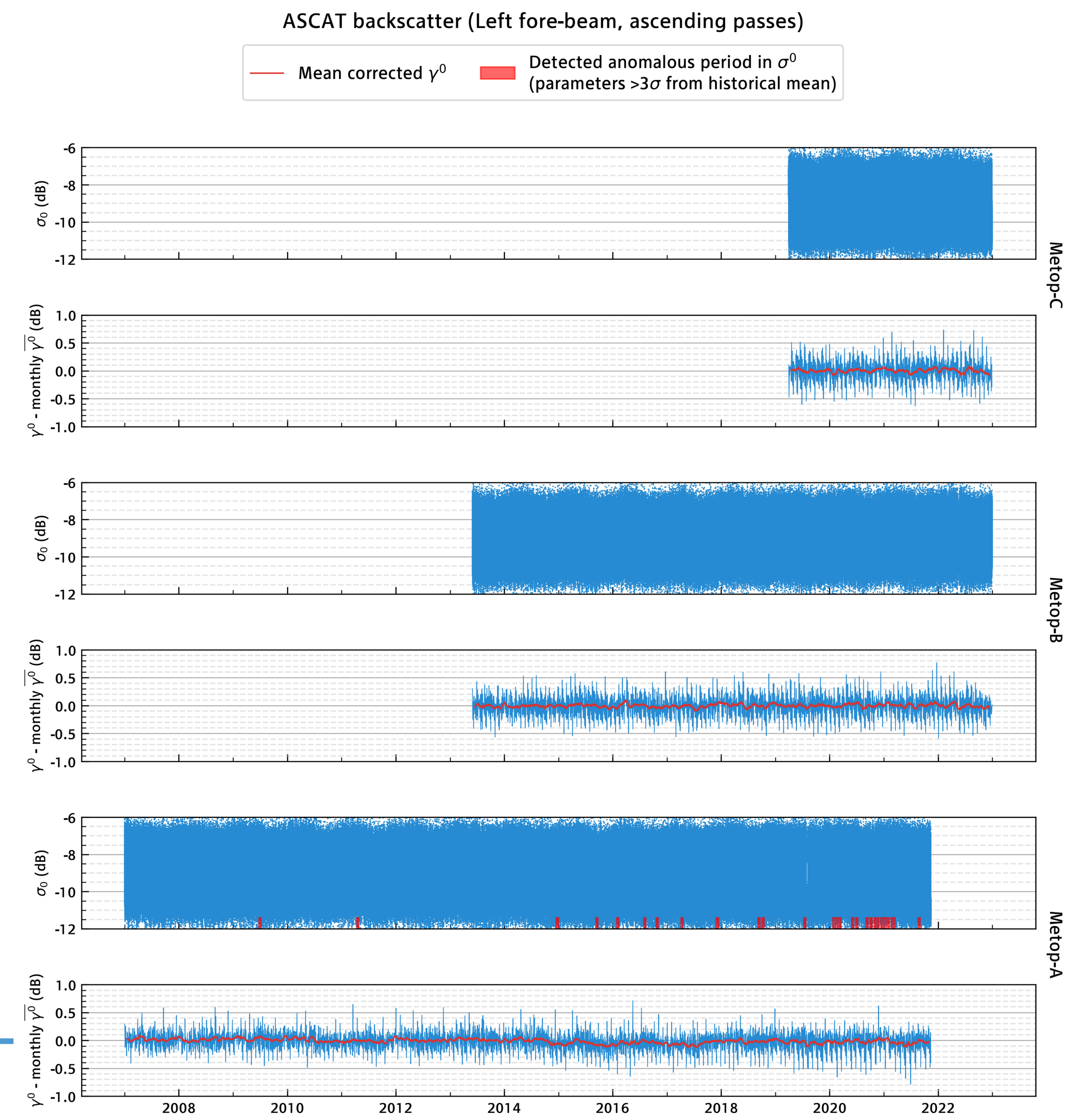
In this experiment, the mean and standard deviation of parameters B_0, B_1, and B_2 were calculated for each satellite over a reference period split into two-week-long chunks. The acceptable range for each satellite was defined as three standard deviations from its mean.

Kernel Change Detection in γ^0 time series

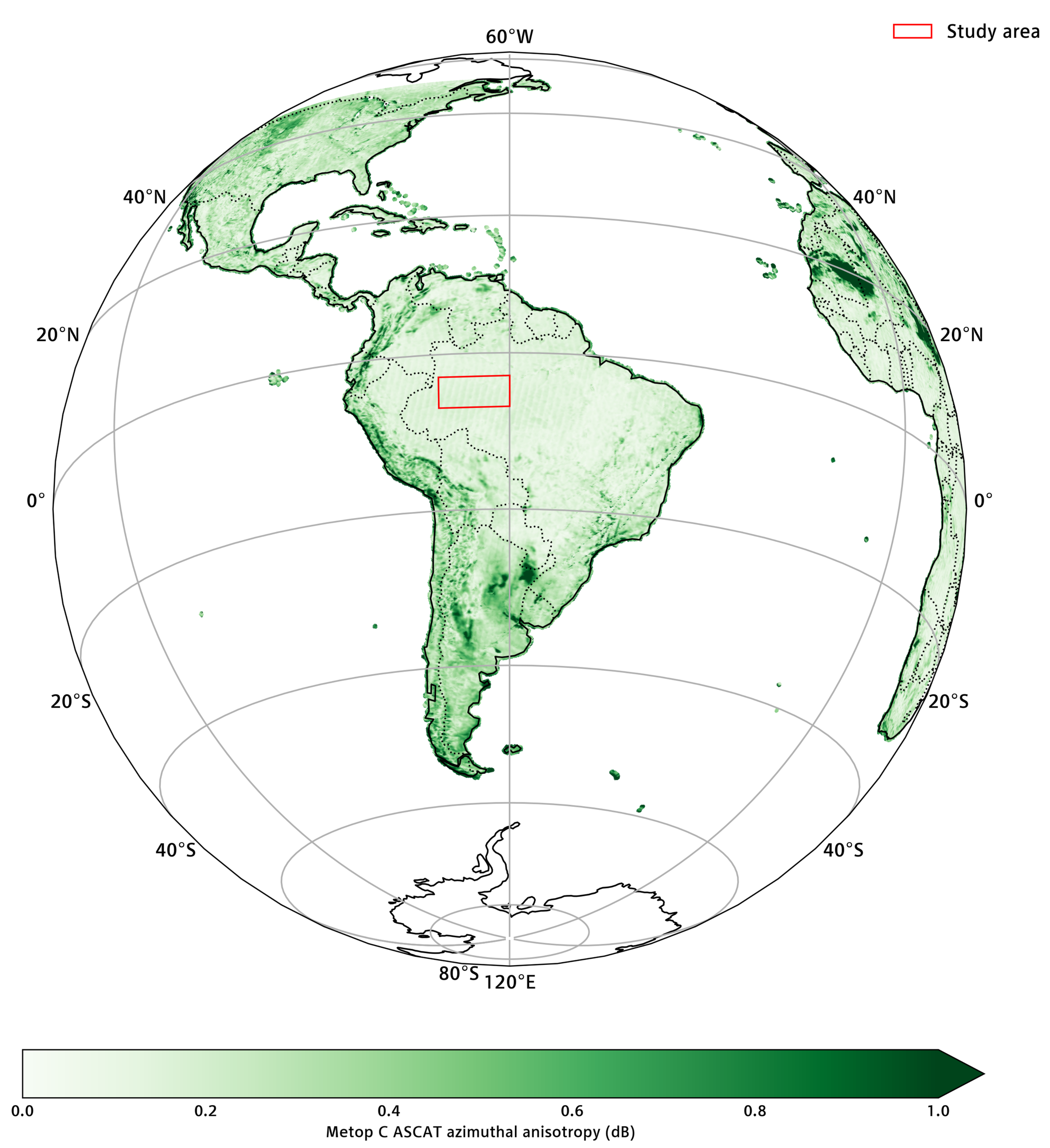
Gamma nought (γ^0) is calculated by dividing sigma nought (σ^0) (in the linear scale) by the cosine of the incidence angle of the observations, normalizing the short-term time-domain effects of this dependence.

Then, seasonal effects in γ^0 are corrected by normalizing the entire time series by monthly mean values, creating a stable time series that can be analyzed for breakpoints.

Breakpoints in the time series are identified using Kernel Change Detection with a Gaussian kernel, as implemented in the Python package "Ruptures" (Truong et al., 2020), with no prespecified number of breakpoints and a penalty value of 20.

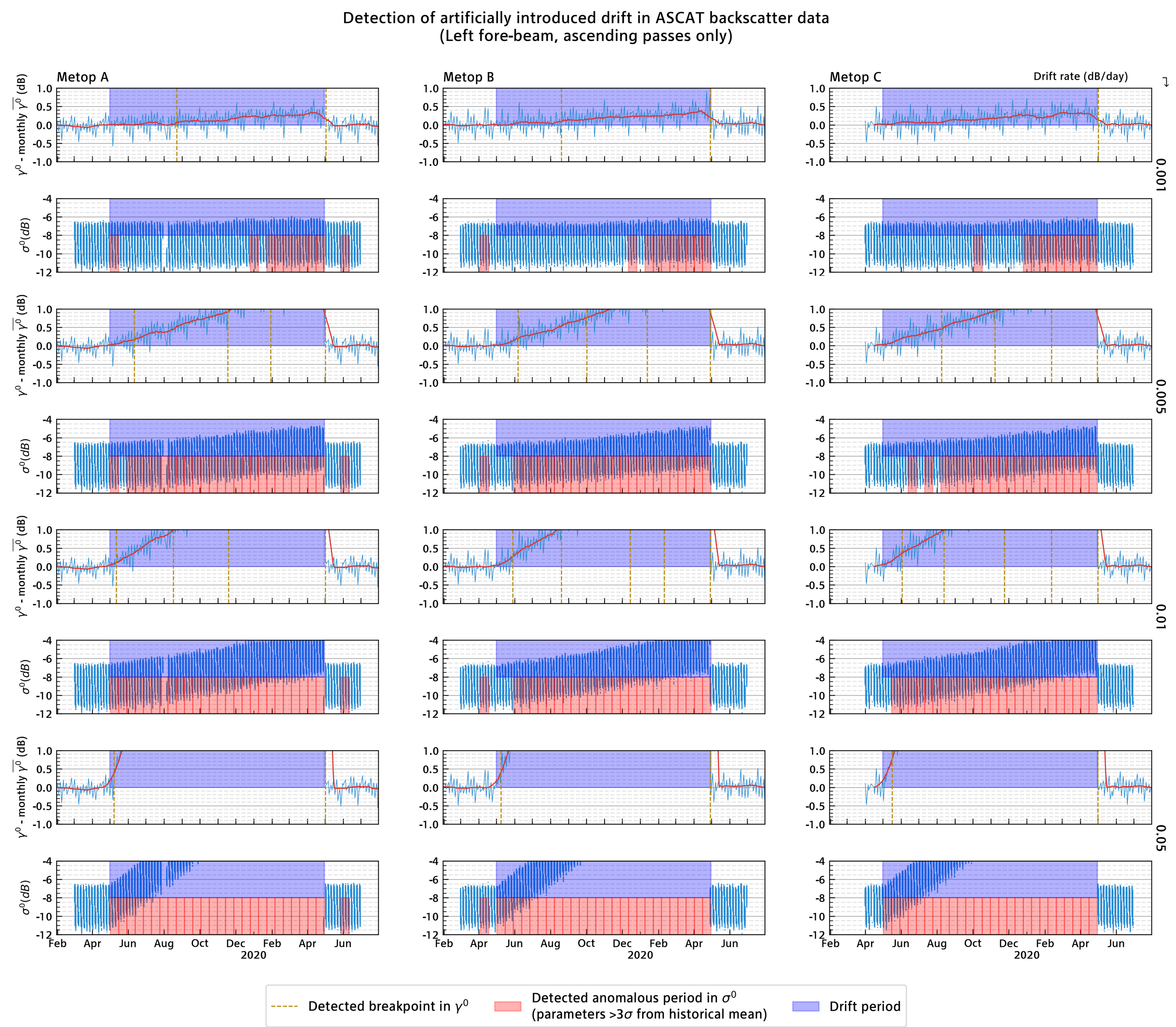


Rainforests as stable calibration targets



- ASCAT backscatter shows low azimuthal anisotropy and spatio-temporal variability in rainforested regions.
- Stable relationship between backscatter measurements and incidence angles.
- Stable γ^0 backscatter signal after correcting for seasonal effects.
- Study area was selected from a region of the Amazon which exemplifies these properties.

Comparison



- Artificial drift was introduced to the ASCAT backscatter product at several different rates (0.001, 0.005, 0.01, and 0.05 dB/day).

- Both detection methods were applied to the resulting timeseries data.

- The time each method took to detect the drift at each rate was recorded.

- The Kernel Change Detection method usually detected the drift earlier than the incidence-angle-dependence method, especially at lower (and more realistic) drift rates, except on Metop C data.

- Both methods were also applied to the entire unaltered timeseries of all three backscatter products.

- Kernel Change Detection picked up some known anomalies in the historical Metop-A timeseries (e.g. in October 2014).

- The incidence-angle-dependence method did not pick up on any known anomalies in unaltered historical data, and flagged many false positives in Metop A data.

Number of days until drift detected

Drift rate (dB/day)	Metop A γ^0 breakpoints	Metop A σ^0 polynomials	Metop B γ^0 breakpoints	Metop B σ^0 polynomials	Metop C γ^0 breakpoints	Metop C σ^0 polynomials
0.05	*7*	15	*8*	15	16	*15*
0.01	*11*	15	*28*	43	33	*29*
0.005	42	*15*	*37*	43	100	*57*
0.001	*114*	253	*111*	239	N/A	*253*

Takeaways

Detection of anomalies by measuring variance from historical data is highly sensitive to the data used to calculate the historical mean and standard deviation and the properties of that data.

Kernel Change Detection shows promise for live detection of instrument miscalibration in Metop/ASCAT, although analysis of incidence angle dependence could also serve this purpose well with further parameter tuning.

Moving forward

Time-series stability should be increased by analyzing only specific grid locations where azimuthal anisotropy and spatio-temporal variability are historically low.

One or both methods will be implemented in a process that runs weekly on live data.

Results from live monitoring should be evaluated after the system has been in place for a period of time.

Acknowledgements

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References

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