An experimental 2D-Var retrieval using AMSR2

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1. Introduction

Overlapping passive microwave field of view (FOV) information is usually discarded in data assimilation systems and standalone retrievals. But at low frequencies this is very significant information loss and a concern for MetOp-SG sensors MWI and ICI with heavily overlapping scan strategies. In this study we build and test a two-dimensional variational retrieval that accounts for overlapping beams and full antenna patterns in the forward model. It is applied to the Advanced Microwave Scanning Radiometer 2 (AMSR2) to retrieve surface parameters. The goal is to resolve patterns smaller than passive microwave FOVs by leveraging this overlapping information content.

2. Forward model and method

The forward model and variational solver are contained in Atmospheric Radiative Transfer Simulator (ARTS) v2.3 using FASTEM-6. The AMSR2 sensor geometry is from JAXA L1R data and all channels are used at their native resolution.

Antenna patterns are modelled as a 2D Gaussian in angular space with measurements sampled by a grid of “pencil beam” calculations.

The 2-Var solver returns grids of SST and wind speed (WSP). Observation error is a diagonal matrix of sensor noise, while state vector error is non-diagonal with a defined decorrelation length.

Method

- Test 2-Var on synthetic scene to determine optimal grid spacing and achievable resolution
- Assess achieved spatial resolution via averaging kernel rows
- Attempt 2-Var retrievals with observed data from AMSR2

3. Synthetic scene results

To ensure posterior errors and averaging kernels are exactly correct, background fields are constructed to have exact spatial decorrelations and standard deviations from a flat prior. The measurement vector is created by running the forward model and then noise is added equivalent to published NEDT.

- Larger spatial structures in SST, WSP are resolved
- Retrieved SST is a smoother field due to FOV size
- Grid spacing of 0.05º
- Posterior errors are dominated by smoothing error
- 2D-Var outperforms a 1D-Var-type retrieval that lacks antenna patterns and spatial correlations

4. Achieved resolution

From synthetic scene, we judge achieved spatial resolution by the HPBW of the averaging kernel. This “measurement response” is compared to FOVs of co-located AMSR2 channels

Achieved spatial resolutions:
- ~30km for SST (about 10GHz FOV)
- ~10km for WSP (about 36GHz FOV)

All points within area of dense observations show that sum of measurement response is 1.0, indicating retrieval is fully constrained by measurements

5. Observed scene from AMSR2

A test scene near Canary Islands
- Clear-sky, strong SST gradient
- ERA5 used for a priori but with large assumed errors
- Excellent fit to AMSR2 T, despite some FASTEM-6 and calibration biases
- 2D-Var resolves stronger and tighter gradients in SST and WSP
- Note no sensitivity outside ‘observation area’ shown by FOVs
- Good agreement with RSS despite different methodologies
- T° fits show remarkably low noise, less than NEDT

Summary

- 2D-Var permits greatest use of total information content from microwave sensors—targets are retrieved at the highest possible spatial resolution, driven by the channels’ sensitivities
- Spatial oversampling can mitigate need for larger antennas in the push for higher spatial resolution of future sensors
- All AMSR2 channels can be simulated within near NEDT values for observed clear-sky ocean scenes
- This method could be applied to imagers or sounders and expanded to 3D-Var to retrieve cloud fields, temperature, and humidity

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