Danish Meteorological Institute

Passive Microwave Sensing of Polar SST and Retrieval Algorithm for CIMR

Emy Alerskans, Jacob L. Høyer, Pia Nielsen-Englyst & Ioanna Karagali
Danish Meteorological Institute

Norwegian Meteorological Institute

University of Bremen

Ifremer

Universitat de València

DMI Vejr, klima og hav

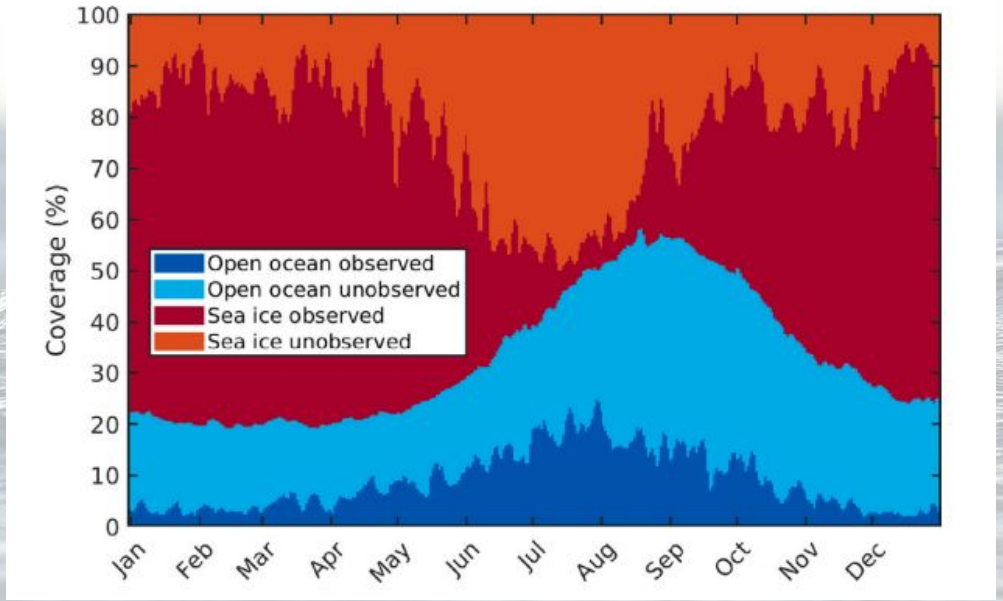
Finnish Meteorological Institute

Introduction

- Sea surface temperature (SST) is an essential climate variable.
- The extreme environment and the poor accessibility make in situ observations challenging and sparse in the Arctic.
- Satellite observations are an important tool for monitoring the Arctic due to their high spatial and temporal coverage.
- There are several global satellite-based gap-free SST products, however, these usually show large uncertainties in the Arctic.
- Improving the Arctic SST data has been identified as being of *high priority* for future SST research and developments.

Infrared (IR) SST observations

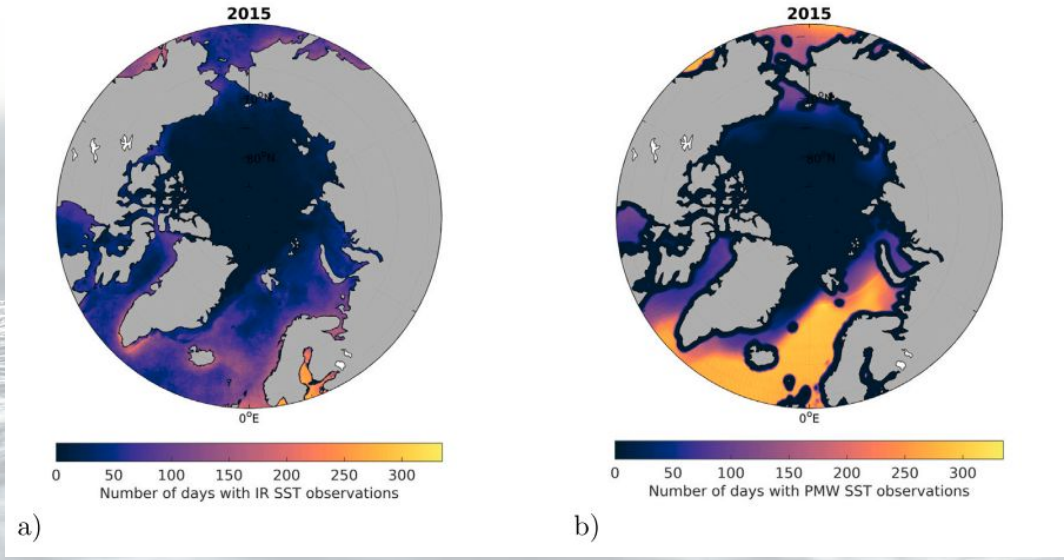
- IR SSTs have a spatial resolution of about 1-4 km and uncertainties of 0.2-0.4 ℃.
- IR retrievals are affected by clouds and atmospheric aerosols.
- On average, only 21.7% of the open ocean is covered by IR satellite observations.
- During winter, only ~10% of the open ocean is covered
- Maximum coverage is reached in summer with ~35%.



Example of the coverage (%) of the open ocean and sea ice, which are satellite-observed and unobserved, respectively, for each day during one year (2015). (*Nielsen-Englyst, et al. 2024*)

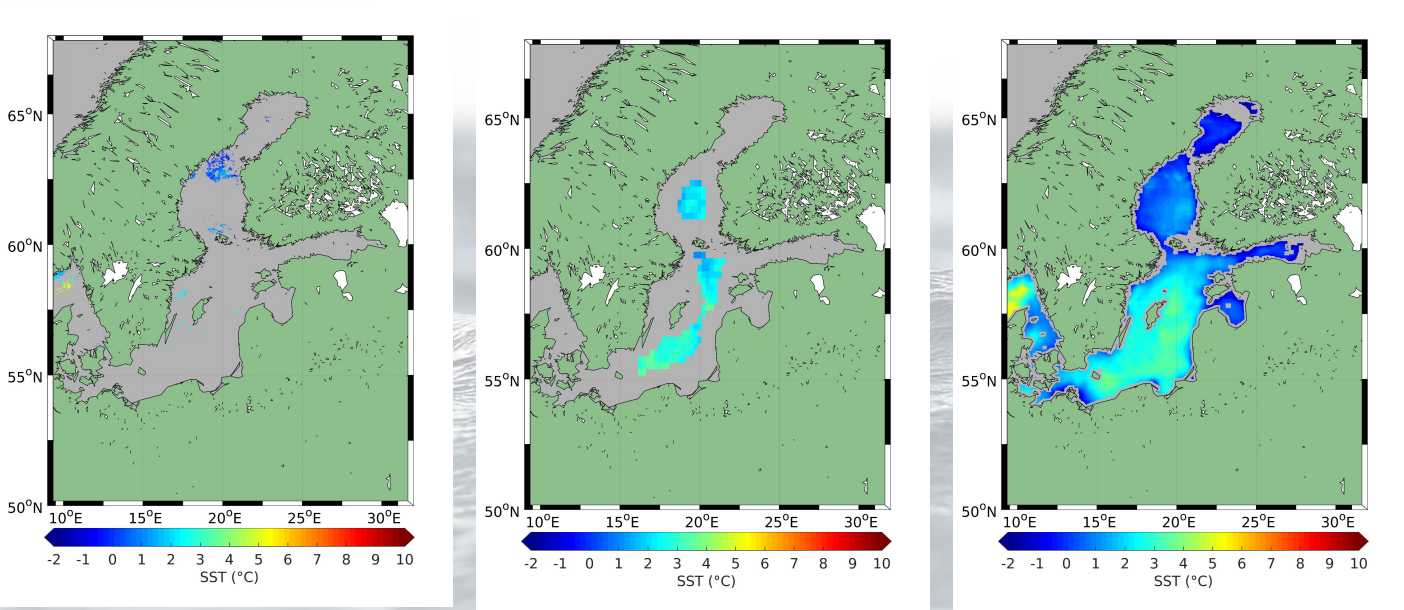
IR vs PMW total number of days with SST observations

- IR observations of the surface are limited by clouds in many regions for more than half of the year.
- PMW SST observations show better coverage compared to the IR SST retrievals.
- Potential for improved SST mapping of the Arctic through combining IR and PMW observations.
- PMW SST observations have a coarse spatial resolution.



Total number of days with SST observations during 2015 from (a) IR and (b) PMW sensors. (*Nielsen-Englyst et al., 2024*)

SST coverage in the Baltic Sea



Sea surface temperature in the Baltic Sea for February 20, 2017 for a) IR L3S SST product; b) RSS AMSR2 SST product; and c) simulated CIMR SSTs. Grey areas indicate regions of missing data. (*Høyer et al., 2019*)

SST observations from CIMR

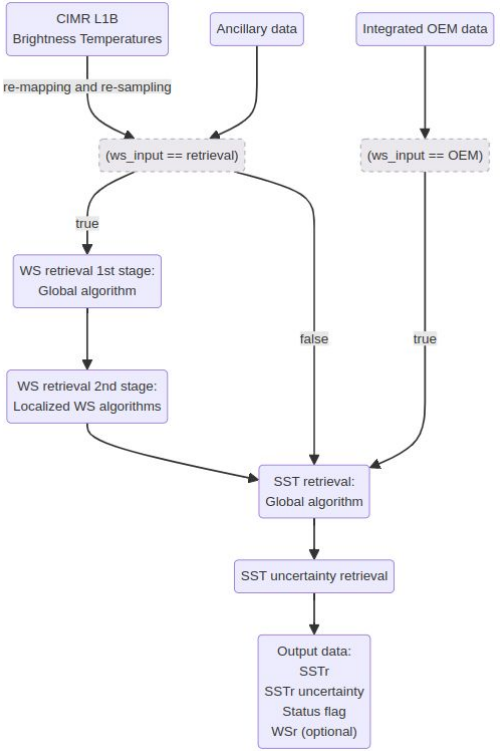
- The Copernicus Imaging Microwave Radiometer (CIMR) is one of the Copernicus Expansion missions.
- CIMR addresses several policies and Copernicus services, with a focus on the Arctic and the polar regions.
- “A dream come true” : cutting-edge European technologies to allow low noise and unprecedented spatial resolution for an imaging microwave radiometer.
- Measure SST in non-precipitating atmospheres at an effective spatial resolution of ≤15 km, with a total standard uncertainty of ≤0.3 K with a focus on sub-daily coverage of Polar Regions and daily coverage of Adjacent Seas.

Credit: ESA/mlabspace

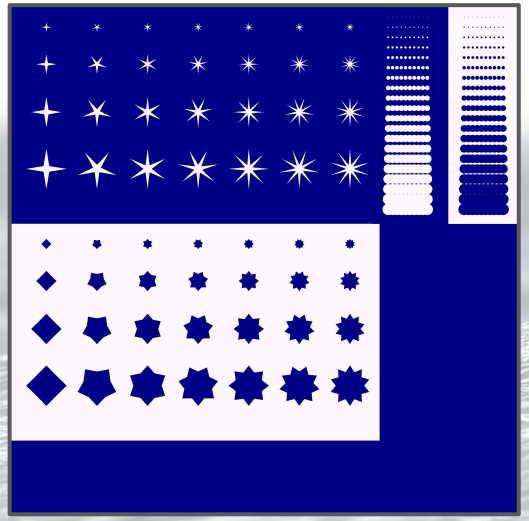
DEVALGO - Prototype SST retrieval algorithm for CIMR

Statistically-based SST retrieval algorithm:

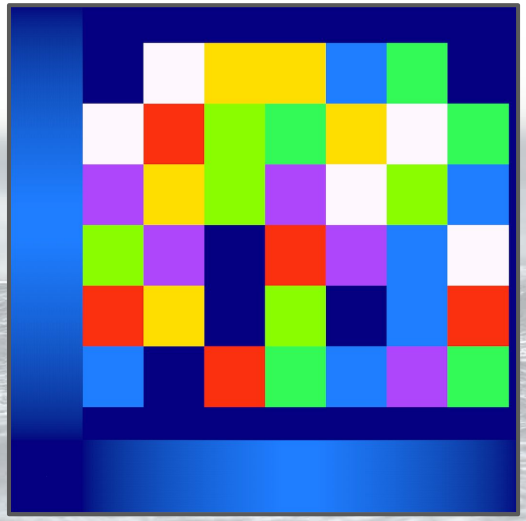
- Re-sampling of CIMR Level-1b data
- Two-stage WS retrieval algorithm based on multiple linear regression
  - The 1st stage retrieval algorithm provides an initial estimate of WS.
  - In the 2nd stage retrieval algorithm WS is obtained through localised algorithms based on fixed WS intervals.
- SST retrieval algorithm based on multiple linear regression with global regression coefficients



Algorithm Performance Assessment - Picasso scenes



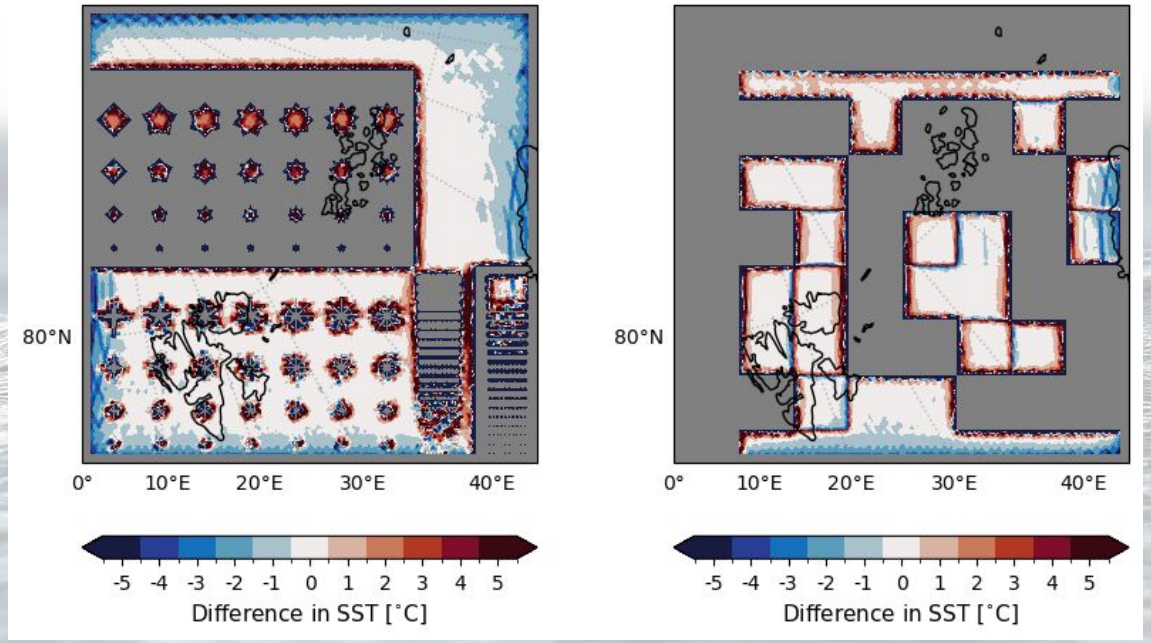
Geometric reference scenario scene. This Picasso scene consists of a high-contrast brightness temperature pattern.



Radiometric reference scenario scene. This Picasso scene consists of 8 different surface types (2 sea ice, 2 land, 4 ocean) adjacent to each other, and sea ice concentration sub-resolution gradients

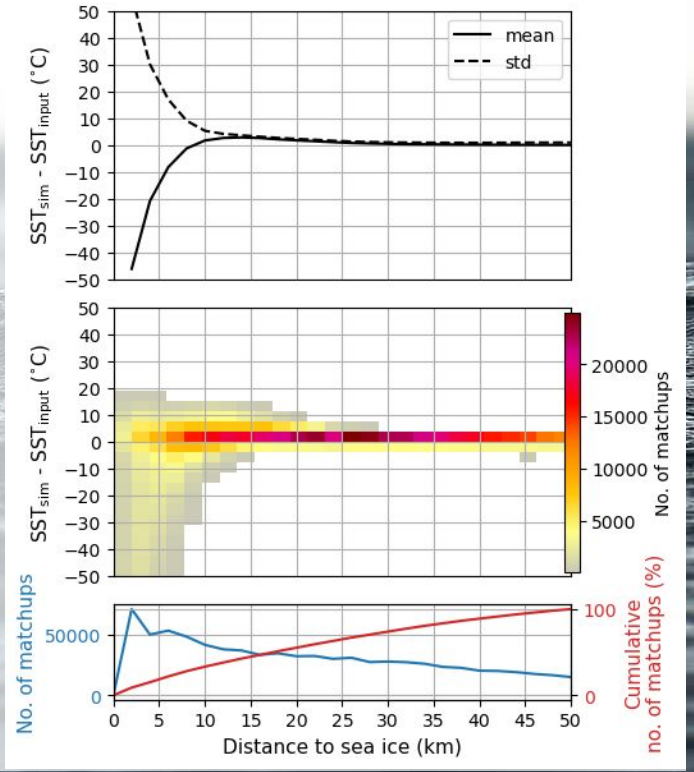
Algorithm Performance Assessment

- Artificially induced errors along the outer borders.
- All surface types other than *'ocean'* have been masked.
- Large differences when close to other surface types (transitions from sea ice/land to ocean).



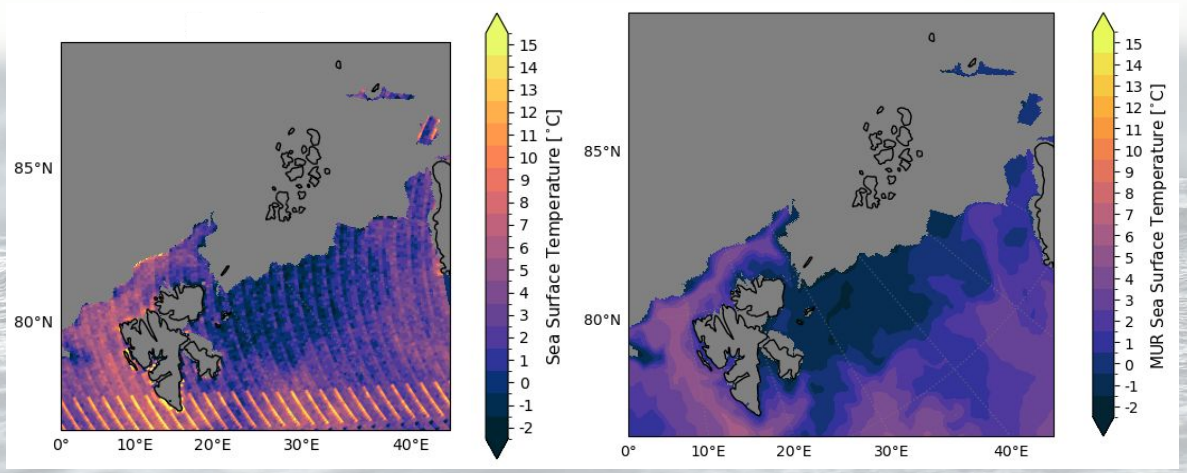
Algorithm Performance Assessment - Distance to sea ice

- Calculated distance between ocean and sea ice surface types.
- Evaluate the performance as a function of distance to sea ice.
- SST difference decreases with increasing distance to sea ice.
- Sea ice contamination is negligible at a distance of 15 km from closes sea ice pixel.
- Similar results obtained for distance to land.



Algorithm Performance Assessment - Polar Scene

- Typical winter polar case in the area around Svalbard and the Barents Sea.
- The retrieval algorithm captures the main features of the reference SST field.
- Problematic areas.

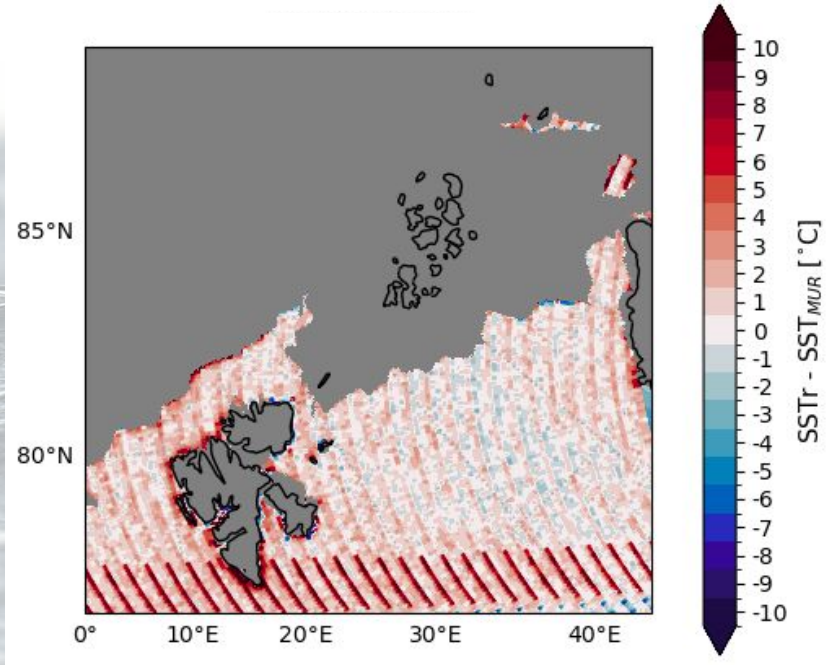


Retrieved SST.

MUR SST reference field.

Algorithm Performance Assessment - Polar Scene

- Unmasked sea ice and land contamination
- Large differences at “edges” of the swath + “striped” look
  → Observation Zenith Angle (OZA) variations
- Difference in OZA between C/X and K/Ka bands → Differences up to 1 K
  → OZA adjustment
- Promising results but the algorithm includes several simplifications.



Retrieved SST minus reference SST

Outlook

- Use of a 2-stage SST retrieval with localized algorithms
- OZA adjustment of brightness temperatures
- Application of additional retrieval algorithms
    - Physical-based algorithms - Optimal estimation (OE)
    - Machine Learning algorithms

Danish Meteorological Institute

esa

Thank you!

Norwegian Meteorological Institute

University of Bremen

Ifremer

VNIVERSITAT DE VALÈNCIA

DMI Vejr, klima og hav

FINNISH METEOROLOGICAL INSTITUTE

Danish Meteorological Institute

esa

Extra slides

Norwegian Meteorological Institute

University of Bremen

Ifremer

VNIVERSITAT DE VALÈNCIA

DMI Vejr, klima og hav

FINNISH METEOROLOGICAL INSTITUTE

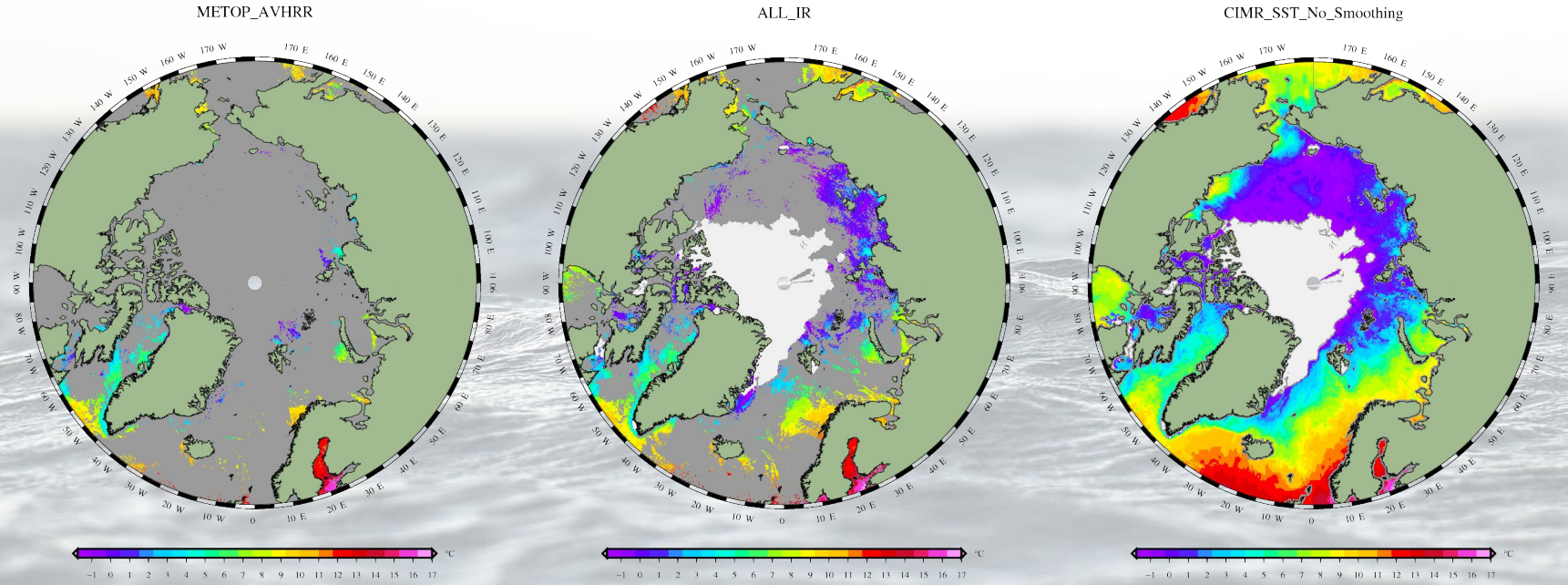
Summary & conclusions

- The coverage of IR SST observations in the Arctic is very sparse due to persistent cloud covers.
- PMW SST observations show better coverage as they are not affected by non-precipitating clouds.
- The resolution of current microwave imagers is not enough to capture subscale to mesoscale variability + suffers from sea ice and land contamination.
- CIMR will measure SST in non-precipitating atmospheres at an effective spatial resolution of ≤15 km with a focus on sub-daily coverage of Polar Regions.
- A prototype SST retrieval algorithm has been developed in the CIMR DEVALGO project with promising results.
- Sea ice and land contamination become negligible at distance of 15 km
- Retrieval of SST for a realistic scenes show promising results but also issues that needs to be addressed (OZA adjustment).

References

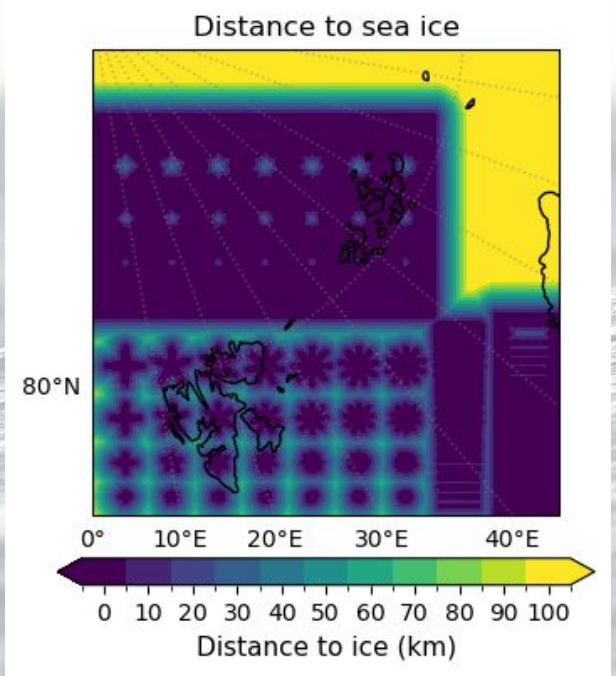
- Nielsen-Englyst, P., Høyer, J. L., Karagali, I., Kolbe, W. M., Tonboe, R. T., & Pedersen, L. T. (2024). Impact of microwave observations on the estimation of Arctic sea surface temperatures. Remote Sensing of Environment, 301, 113949.
- Høyer, J. L., Ribegaard, M. H., & Alerskans E. (2019). Impact of CIMR microwave observations om the CMEMS SST product in the North Sea/Baltic Sea. Technical Report.
- Høyer, J. L. (2018). IR versus PMW SST coverage in the Arctic, September 2012.URL: https://figshare.com/articles/dataset/IR_versus_PMW_SST_coverage_in_the_Arctic_September_2012/6969422, doi:10.6084/m9.figshare.6969422.v1.

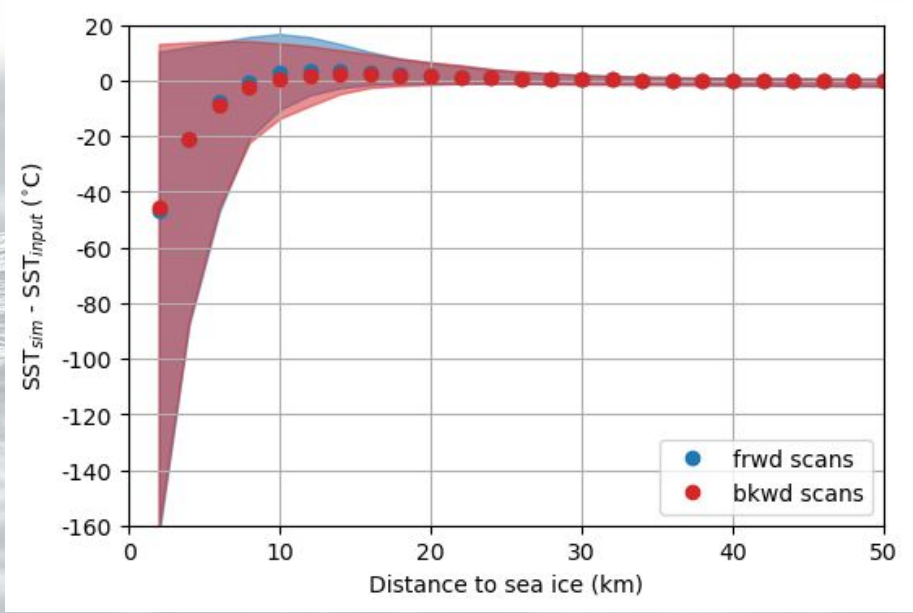
IR versus PMW SST coverage in the Arctic



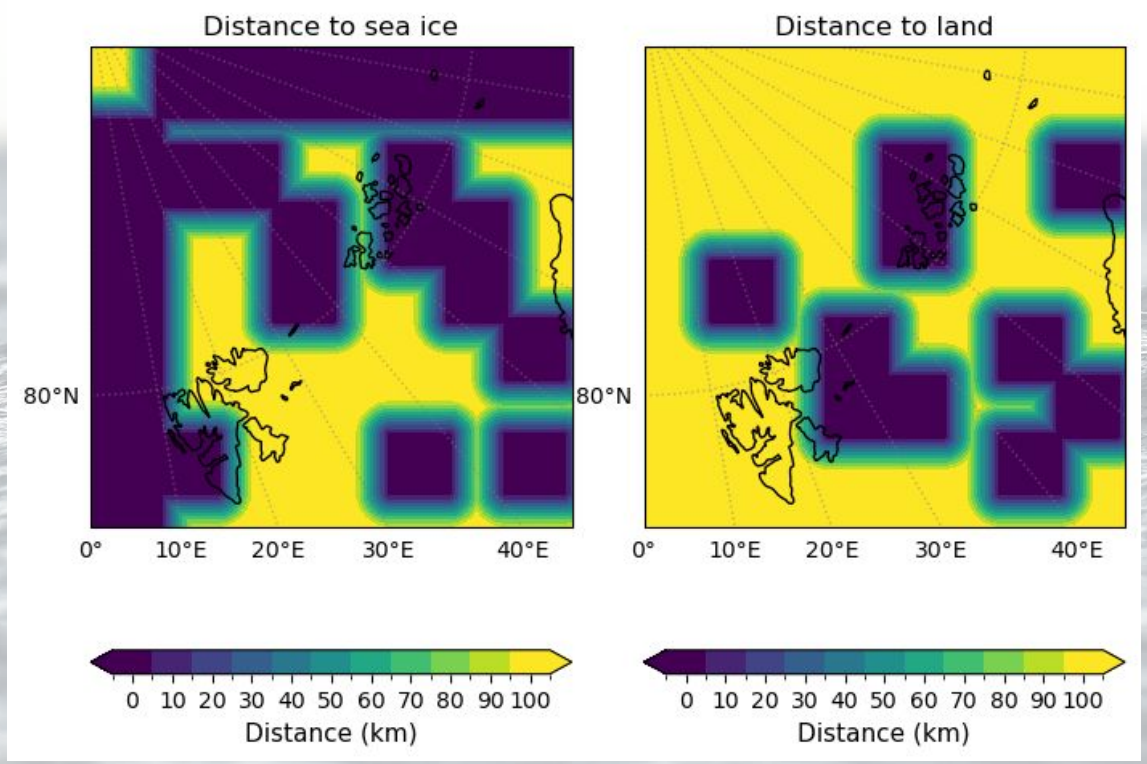
Comparison of IR satellite SST (taken from Copernicus Marine Environment Monitoring Service (CMEMS) data production) and microwave radiometer SST in the Arctic, September 2012. (left) SST from one (MetOp-A) satellite, (centre) SST from all available IR satellites and (right) simulated CIMR SST during the sea ice minimum in September 2012 (Høyer, 2018)

Distance to sea ice

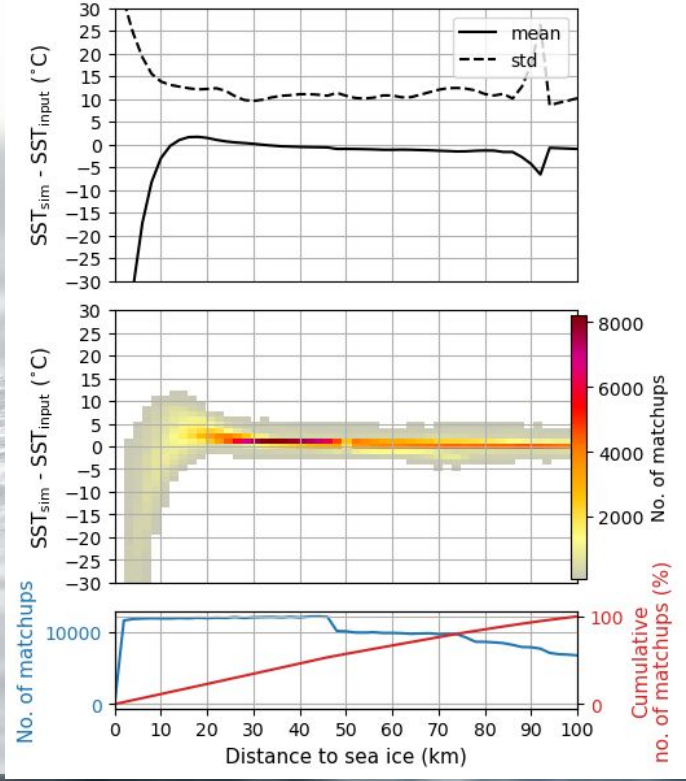


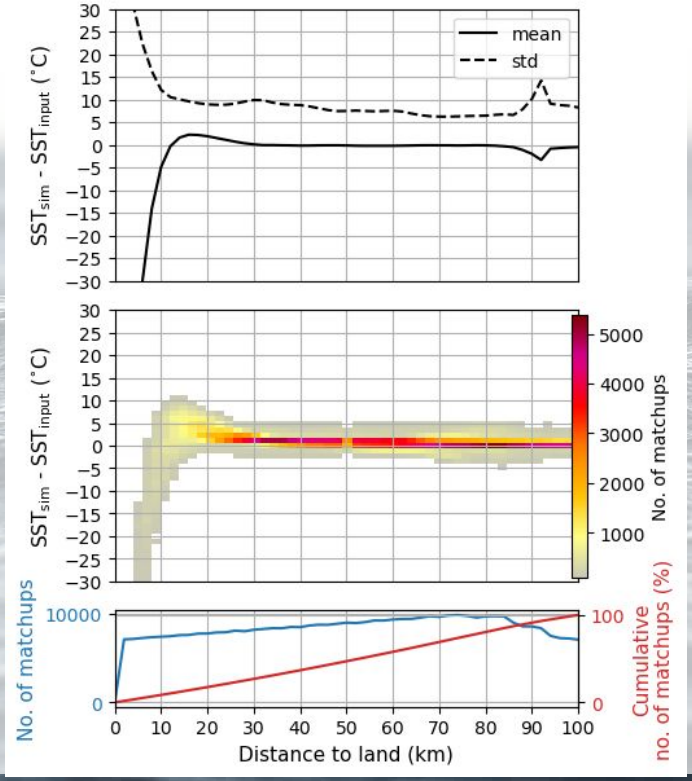


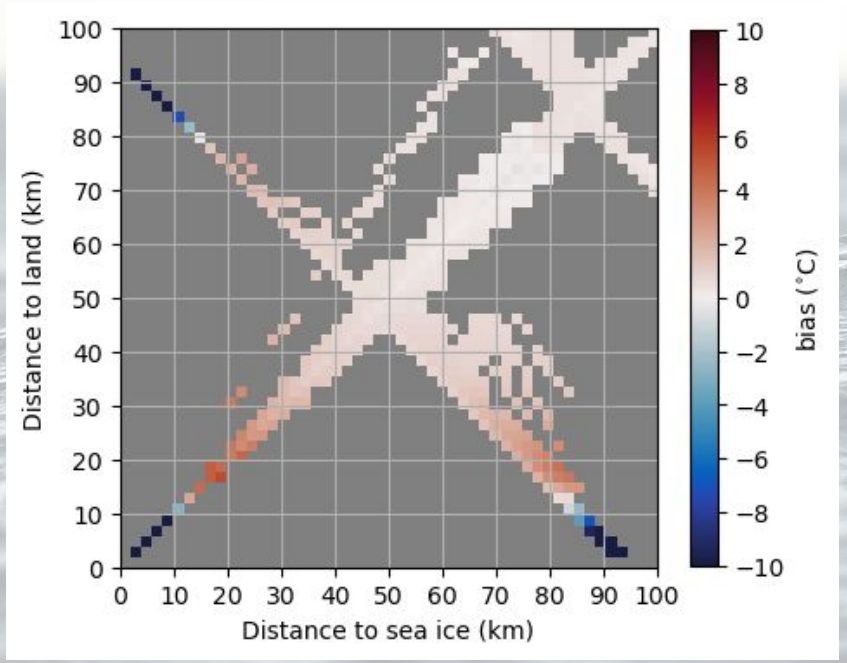
Distance to land and sea ice

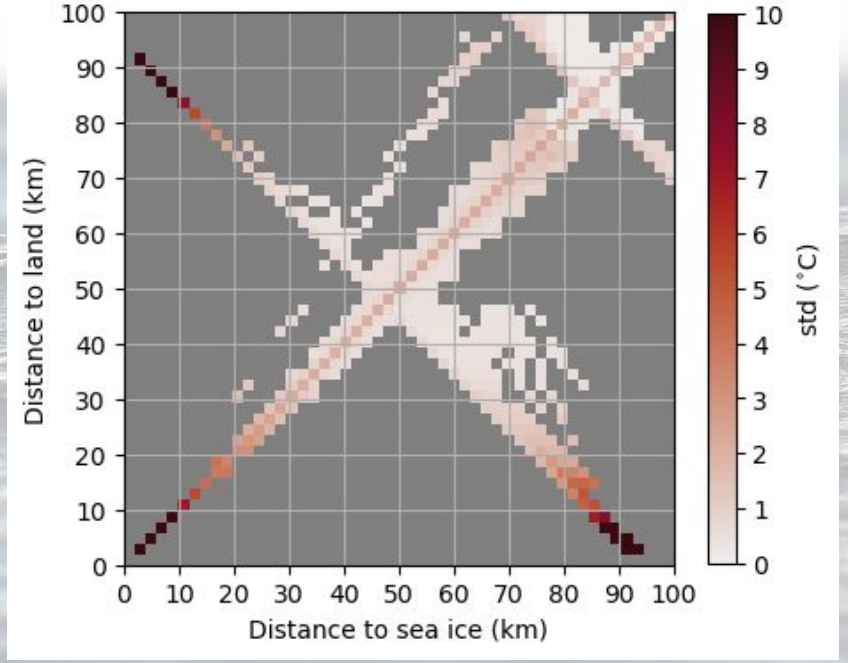


Distance to sea ice and land

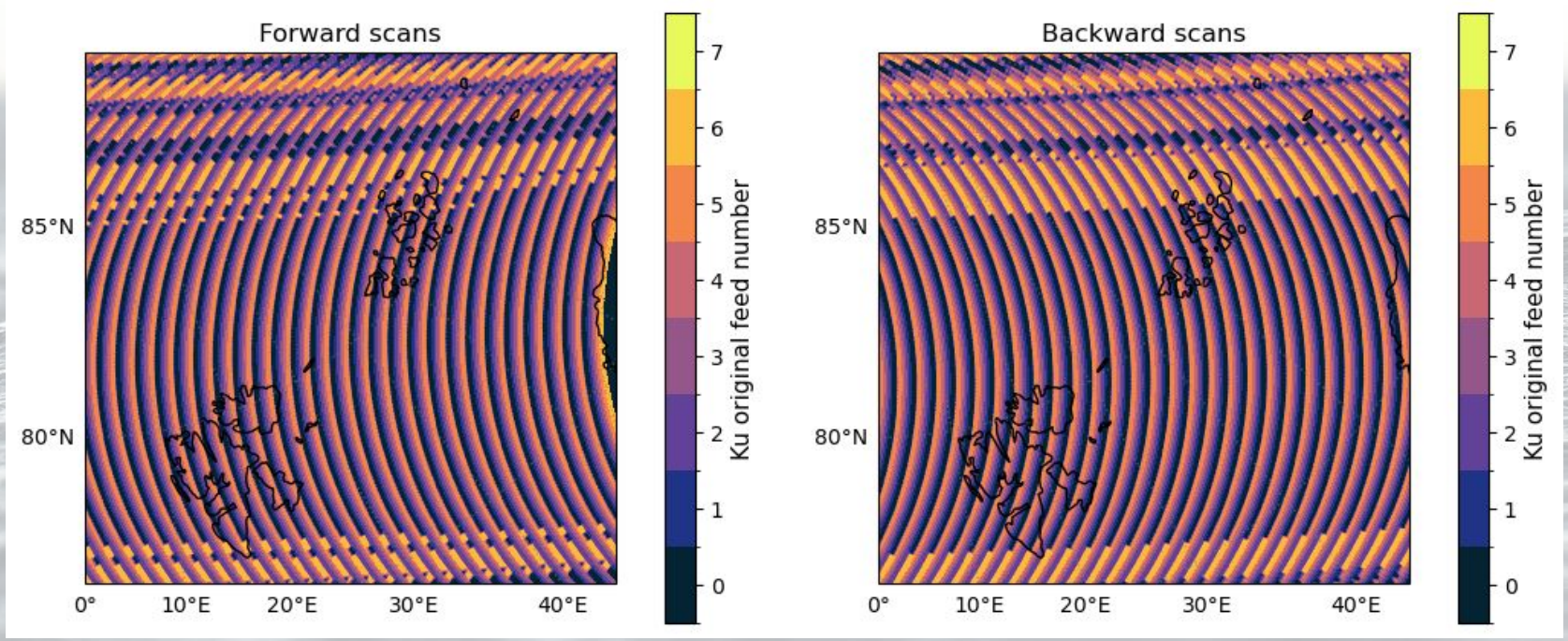




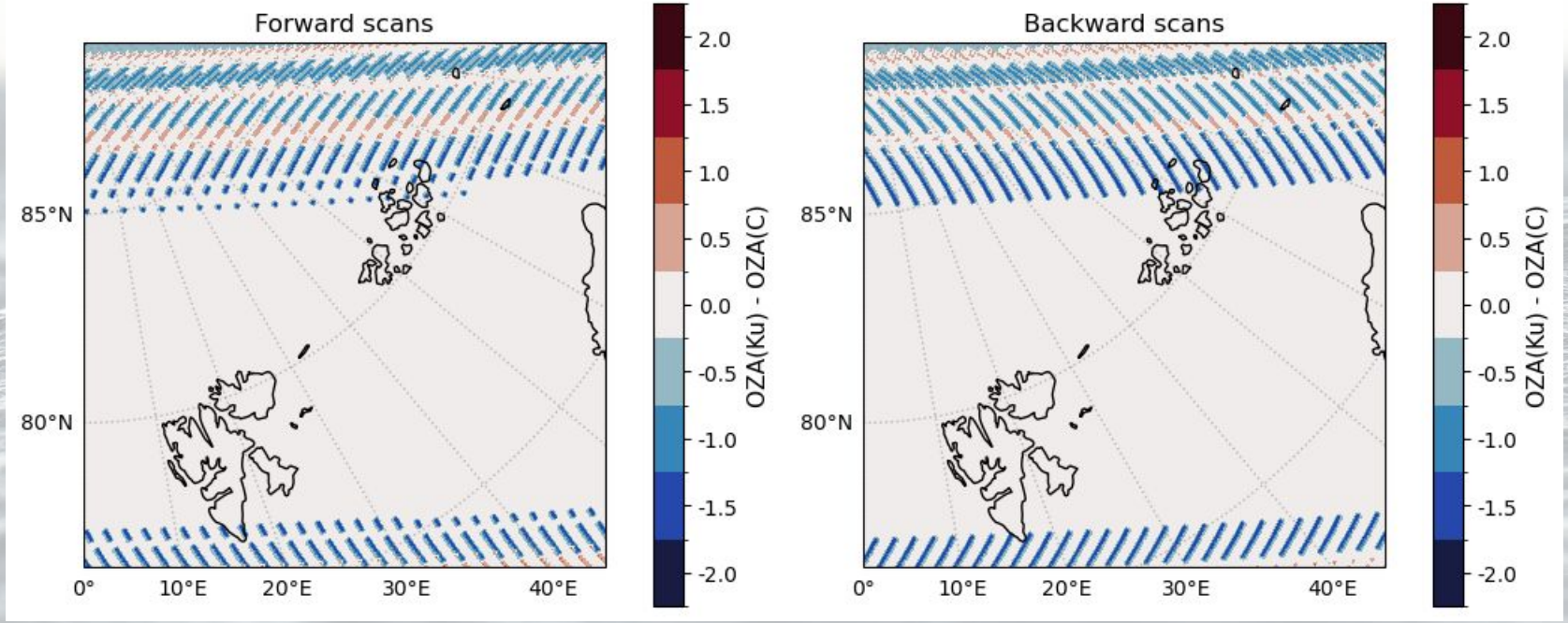

Distance to land (km)
Distance to sea ice (km)
bias (°C)
0
10
20
30
40
50
60
70
80
90
100
10
8
6
4
2
0
−2
−4
−6
−8
−10


Distance to land (km)
Distance to sea ice (km)
std (°C)
0
10
20
30
40
50
60
70
80
90
100
9
8
7
6
5
4
3
2
1

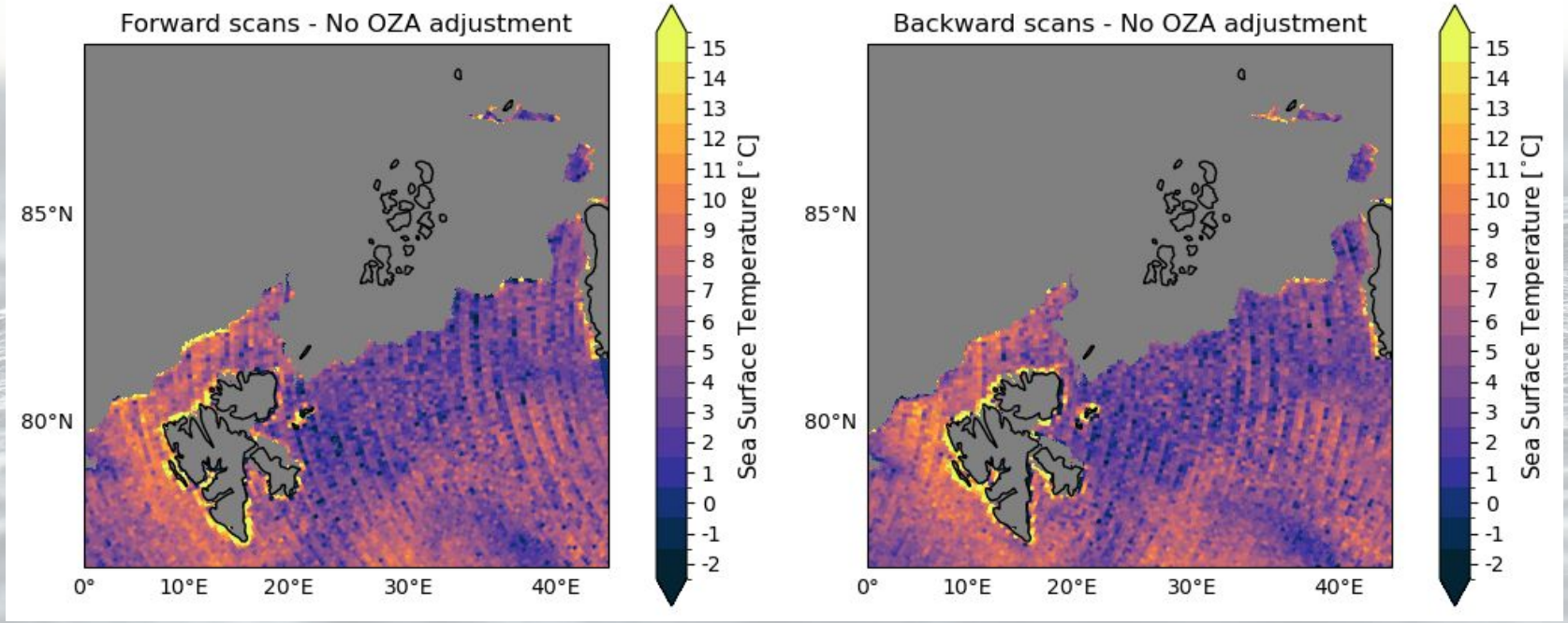
Ku original feed number



Difference in OZA between Ku and C band



No OZA adjustment of TBs



OZA adjusted TBs