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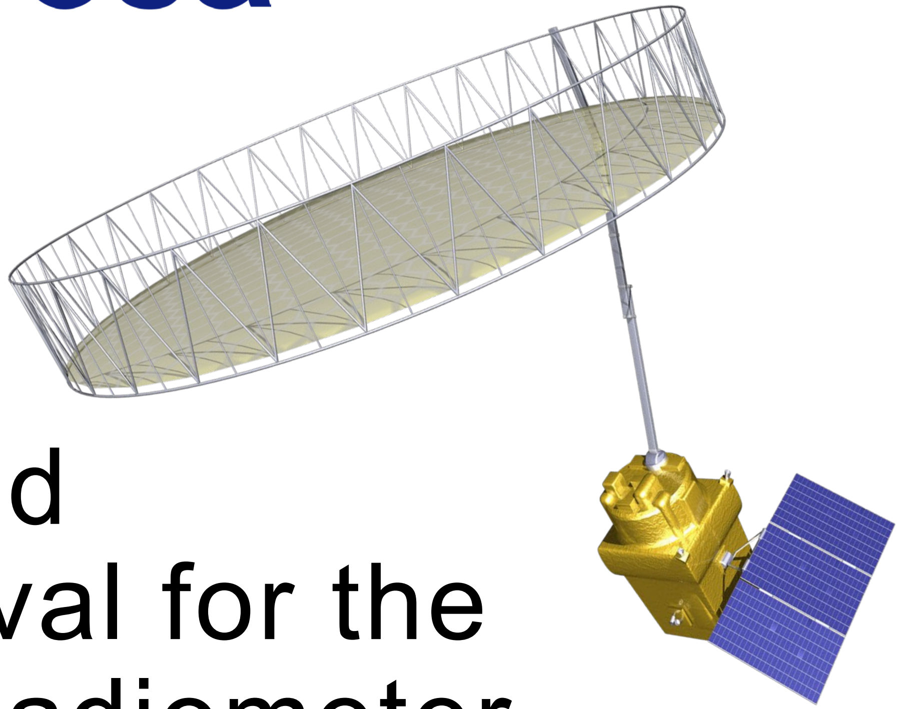
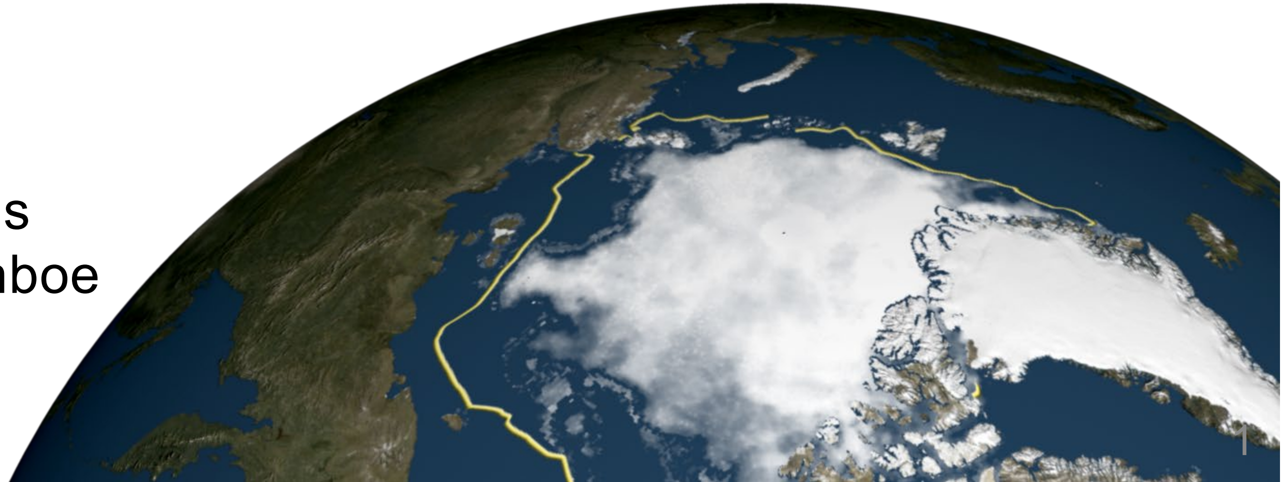


Multi-parameter Sea Ice, Ocean, and Atmosphere Retrieval for the CIMR Microwave Radiometer Satellite Mission

<u>Gunnar Spreen</u>, Janna Rückert, Marcus Huntemann, Raul Scarlat, Rasmus Tonboe

ESA Living Planet Symposium
Bonn, 26.05.2022



CIMR: Copernicus Imaging Microwave Radiometer

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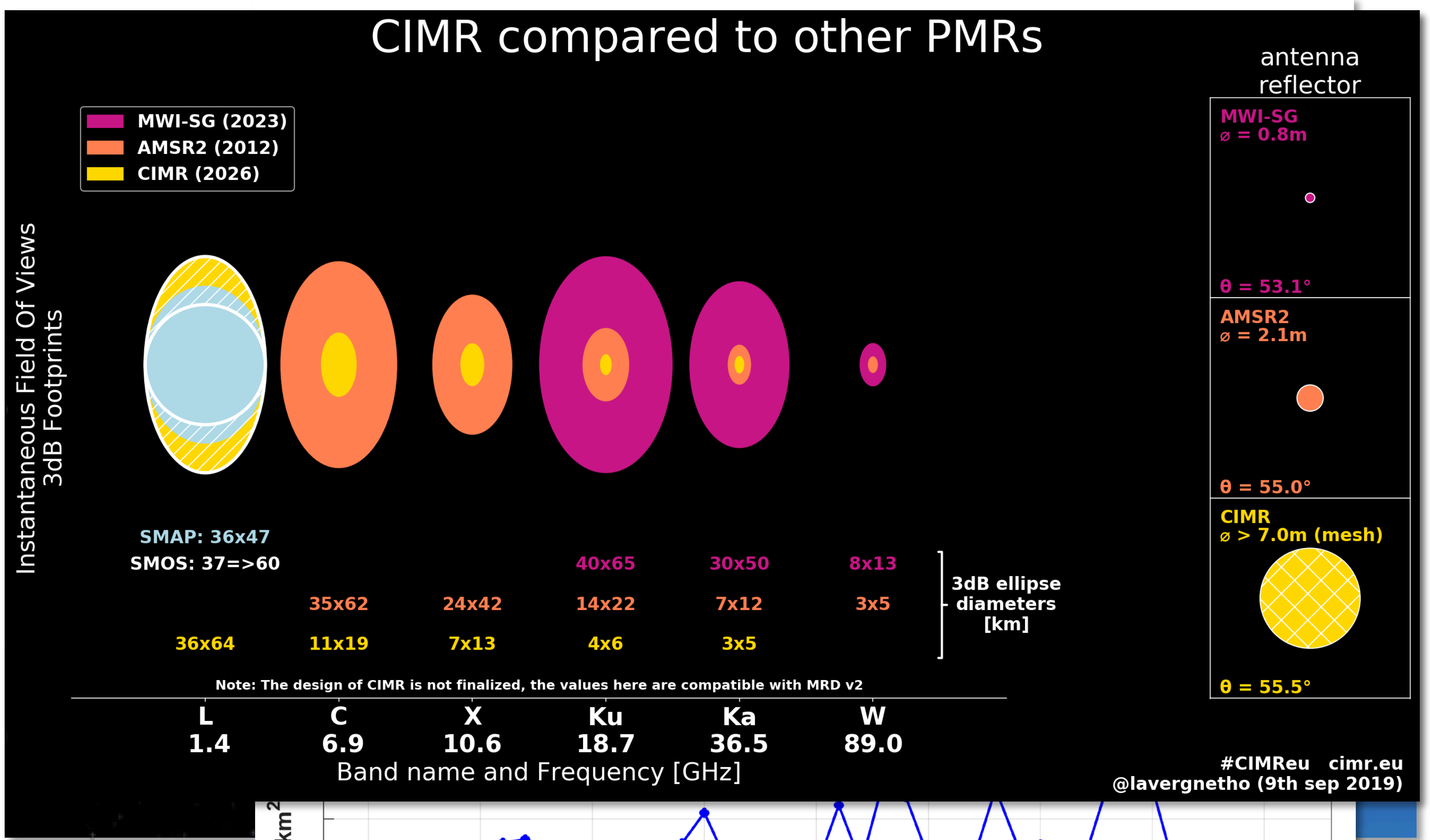
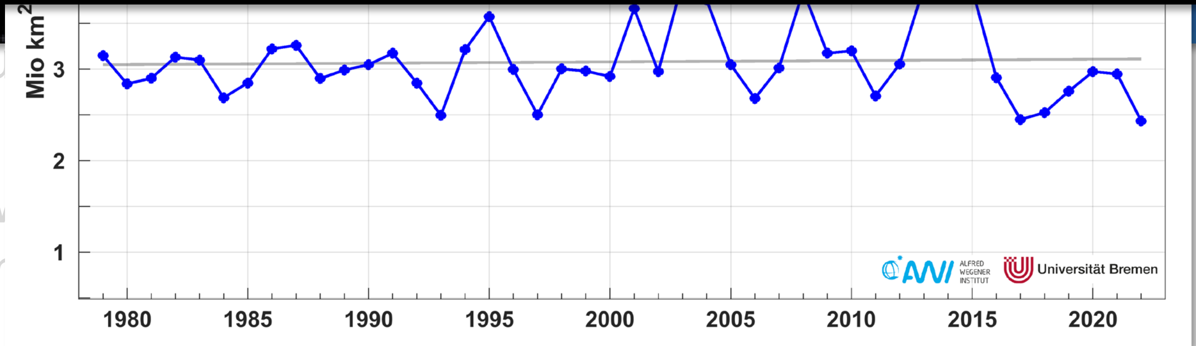
- → Satellite microwave radiometer long time series since 1970s
- → Important climate parameters like sea ice area but low spatial resolution
- → Copernicus Imaging Microwave Radiometer – CIMR
- → Large deployable antenna (>7 m)
- → Will add higher spatial resolution and better radiometric accuracy
- → Adds 1.4 GHz (like SMOS / SMAP) channel: 1.4 – 37 GHz
- → Launch 2028
- → Higher accuracy sea ice concentration and sea su
- → More parameters: ocean winds, surface salinity sea ice drift, thin ice thickness, sea ice type, snow soil moisture, snow water equivalent (land), and m





Multi-parameter Retrieval

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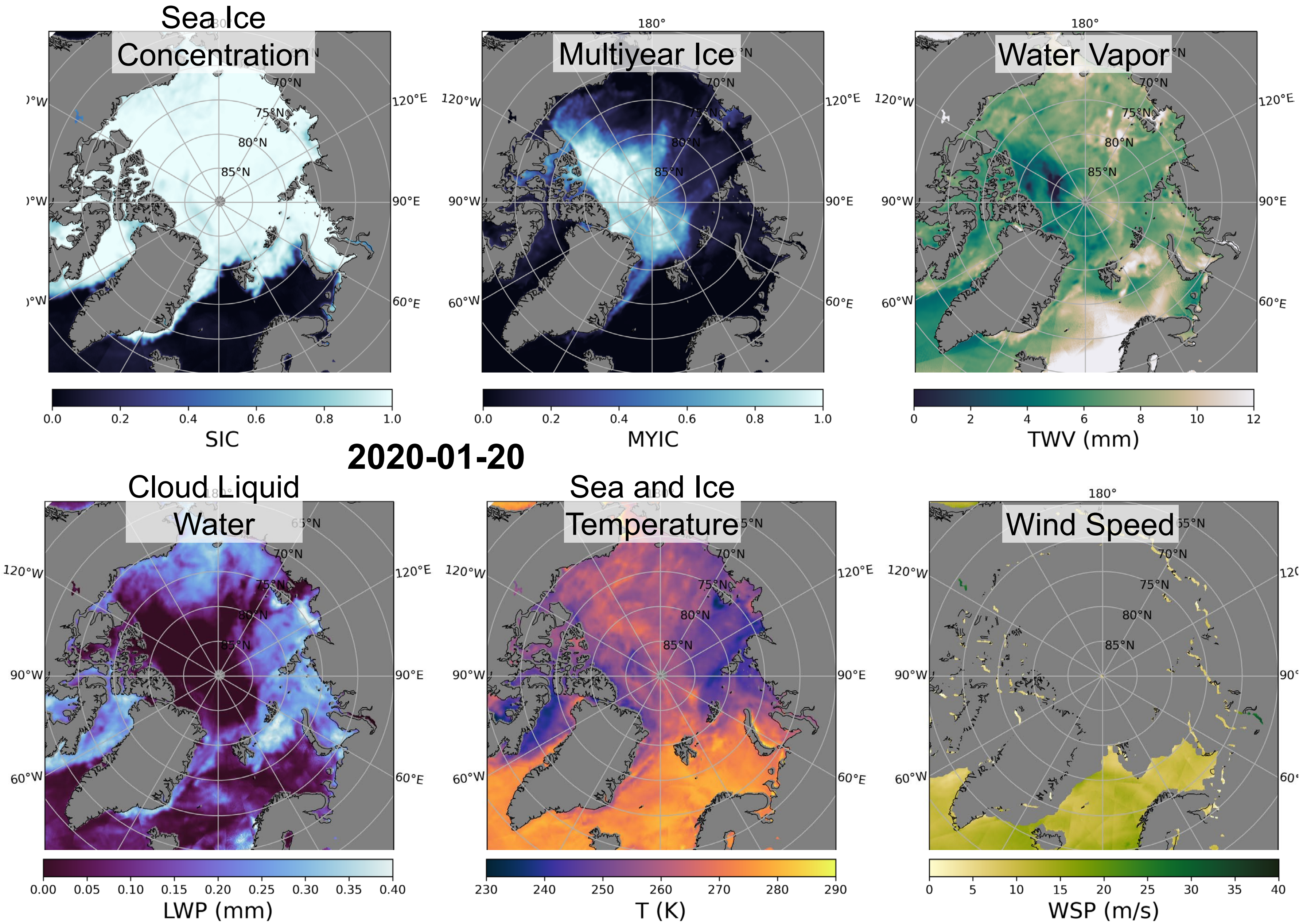
- → Simultaneous retrieval of surface and atmosphere properties using optimal estimation (OE)
- → Using all available channels
- → Physically consistent for all variables
- → Adaptive surface emissivity allows better retrieval of atmospheric properties over sea ice
- → Here shown for JAXA's AMSR2 MW radiometer (7 – 89 GHz)
- → Existing AMSR2 OE retrieval now adapted for CIMR



Scarlat et al., JGR, 2020

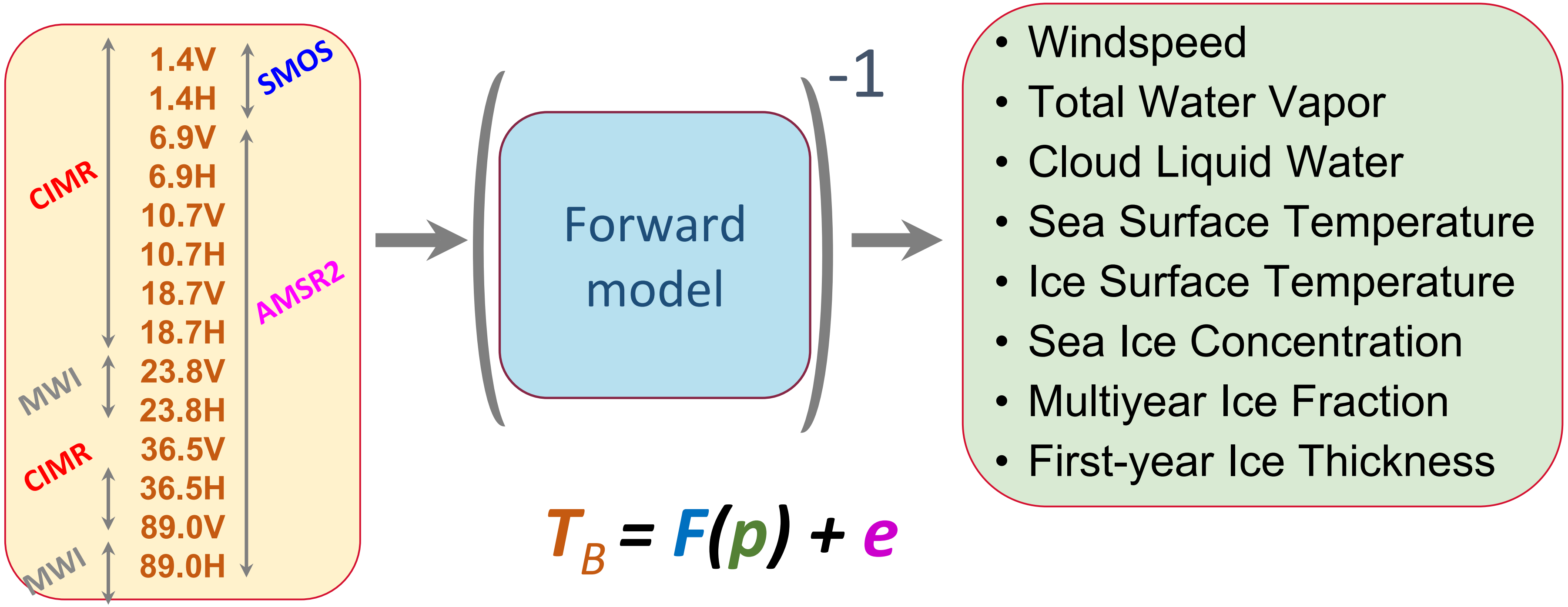
Adaptation to CIMR

- CIMR has 5 frequencies: 1.4, 6.9, 10.7, 18.7, 36.5 GHz
- Use AMSR2 without 7.3, 23.8, 89 GHz channels
  - ➢ less atmospheric sensitivity
- Add SMOS for 1.4 GHz

➢ Combined AMSR2 and SMOS in Optimal Estimation retrieval

- Will be readily applicable to CIMR after launch
- AMSR + SMOS can provide a long-term consistent multi-parameter time series back to 2010, however, with reduced resolution compared to CIMR

Basic OEM setup with AMSR2+SMOS and CIMR brightness temperatures



$$T_B = F(p) + e$$

- **MWI** - MircoWave Imager (Metop-SG)
- **SMOS** - Soil Moisture & Ocean Salinity
- AMSR2 - **Advanced Microwave Scanning Radiometer 2**

Where

- T_B – *measured* brightness temperatures
- ***e*** – effective *error of the* T_B
- ***F*** – forward model (details in Scarlat et al., 2017), including thickness dependency from thin ice RRDP (Scarlat et al., 2020)
- ***p*** – geophysical parameters

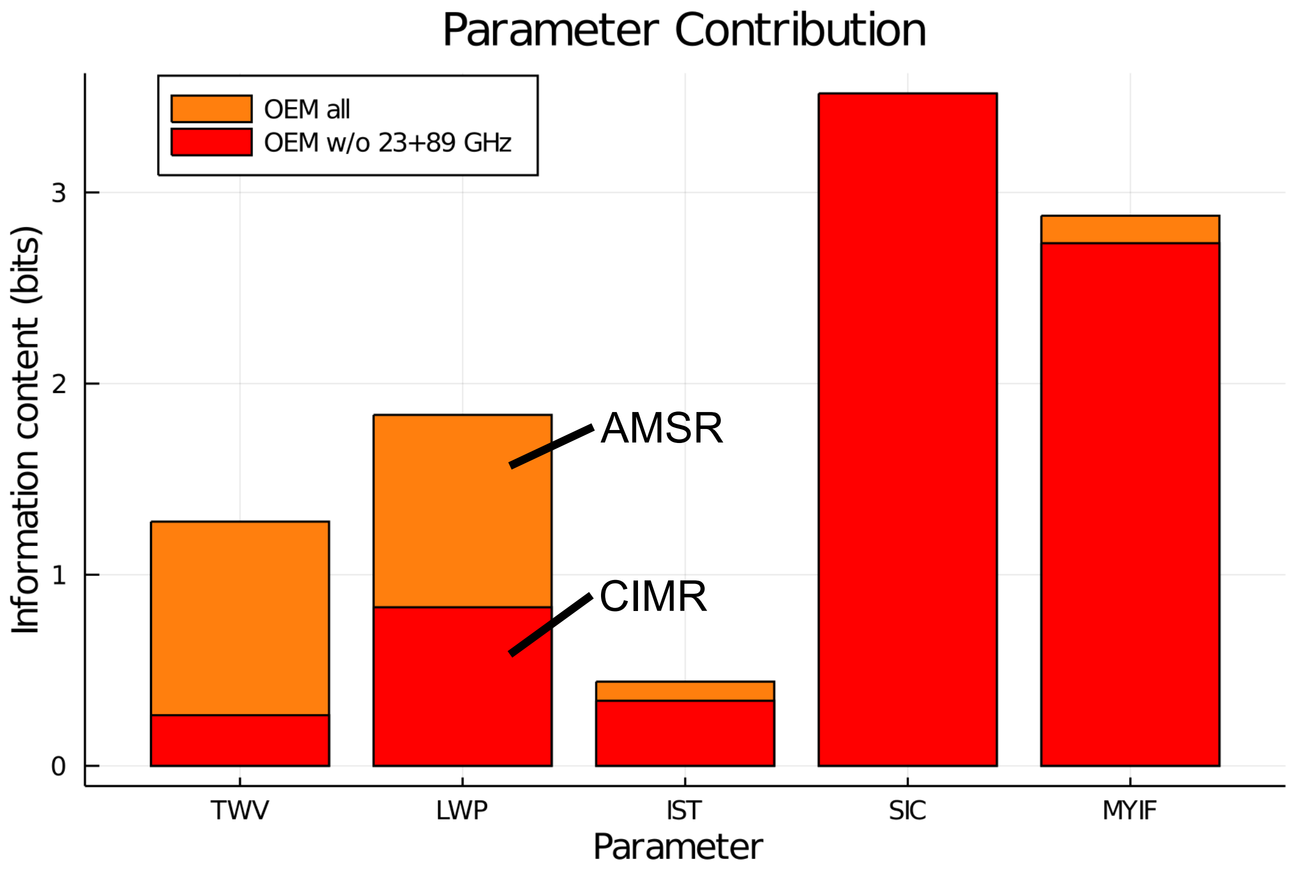
Inversion through Optimal Estimation Method (OEM)

- inverts a **forward model** and retrieves that **set of parameters** for which the forward model simulations best match the measured **brightness temperatures**
- takes advantage multi-channel radiometer, **a priori** data and known uncertainties to obtain a consistent set of parameters

A priori
(used as background data with low weights)
From ERA5 reanalysis data: (WSP, TWV, CLW, TSK, T2M)
From T_B itself:

- Nasa Team: SIC, MYF
- Empirical relation (T_B1.4H): FYSIT

Information content AMSR2-OEM for CIMR (over 100% SIC (MOSAiC))



Lower frequencies:

- Sensitive to **surface** parameter

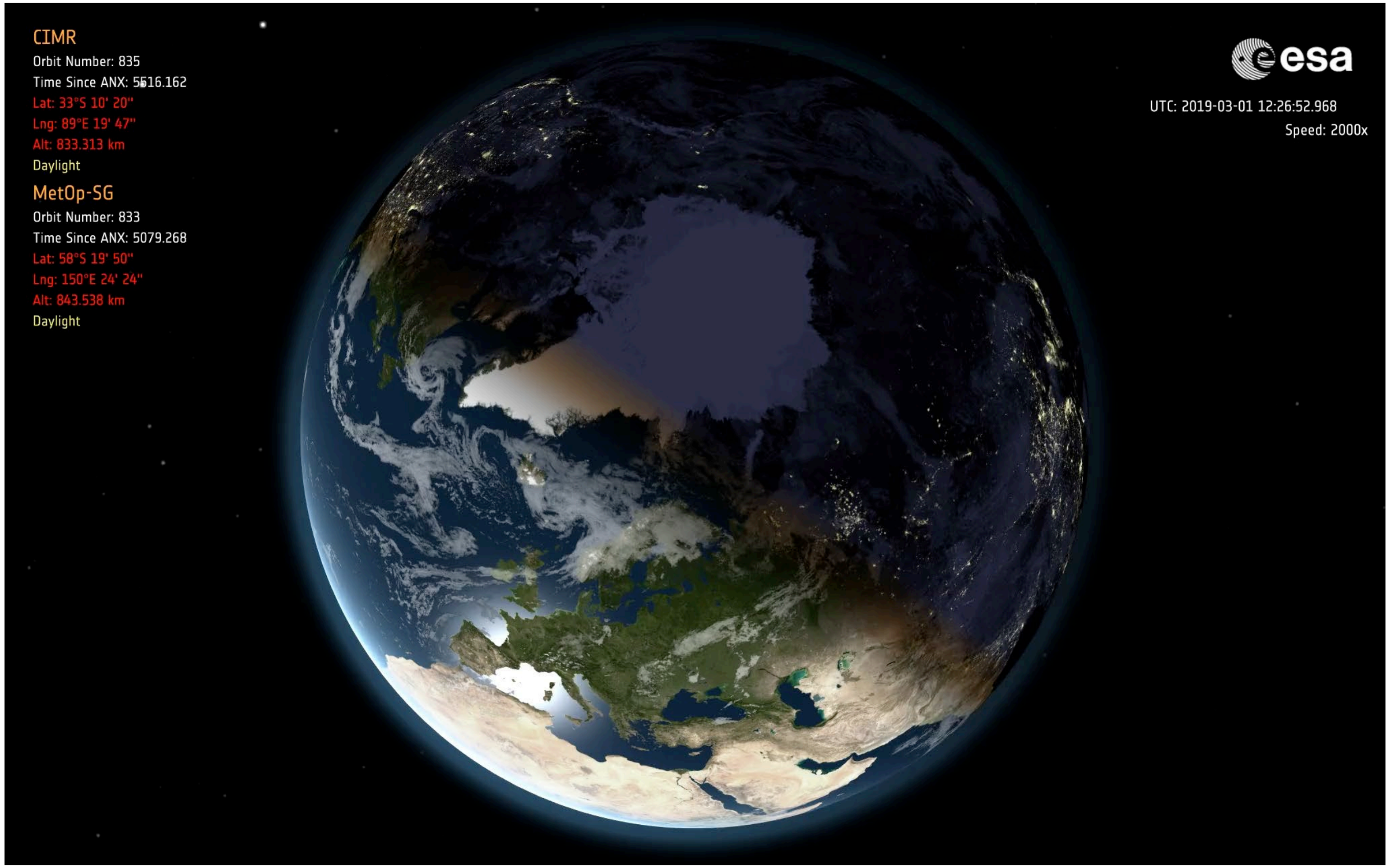
23/89 GHz:

- Sensitive to **atmospheric** parameter

- CIMR similar sensitivity to ocean and ice parameters
- Reduced atmospheric sensitivity ➜ combine with MWI

TWV: total water vapor, LWP: liquid water path, IST: ice surface temperature, SIC: sea ice concentration, MYIF: multi-year ice fraction

MWI – MicroWave Imager on EPS MetOp-SG

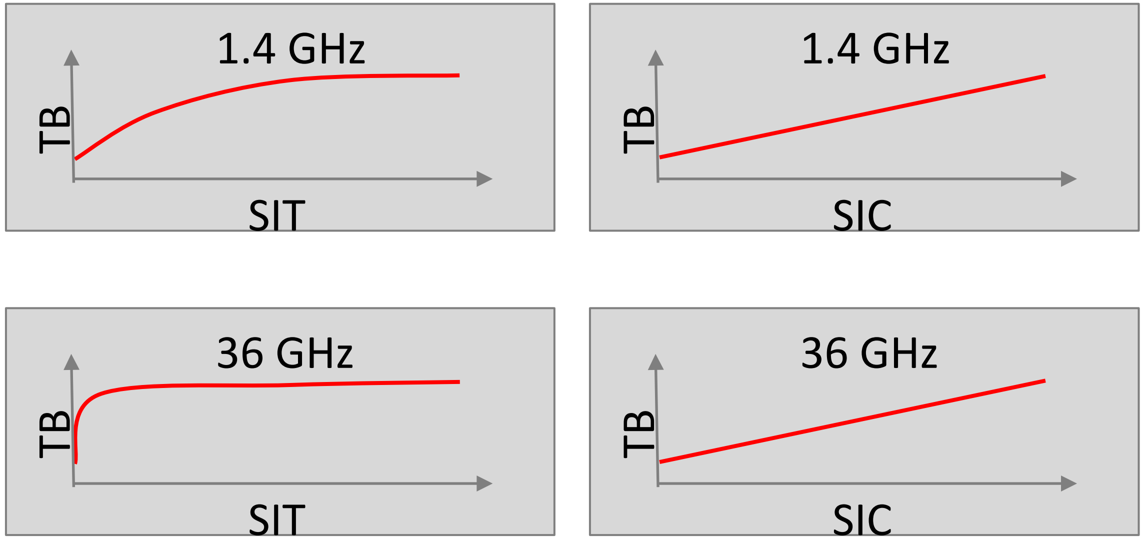


- Launch 2025
- Will fly in close constellation (Δt <10 minutes) with CIMR in polar regions
- Will allow to combine MWI atmosphere channels (23, 56, 89, 118, 183 GHz) with CIMR
- Has also SCA scatterometer

Adding Thin Ice Thickness to the OE Multi-parameter Retrieval for CIMR

– An idealized example –

Ice Thickness (SIT) | Ice Concentration (SIC)



Unfortunate situation:

- TB related to SIT and also SIC
- Need more information on SIC

Fortunate situation:

TB related more to SIC than to SIT

✓ can retrieve SIC alone

✓ can be used to correct for SIC in an 1.4GHz SIT retrieval

… But in reality: 36GHz is influenced by many surface and atmospheric parameters.

Adding Thin Ice Thickness for CIMR

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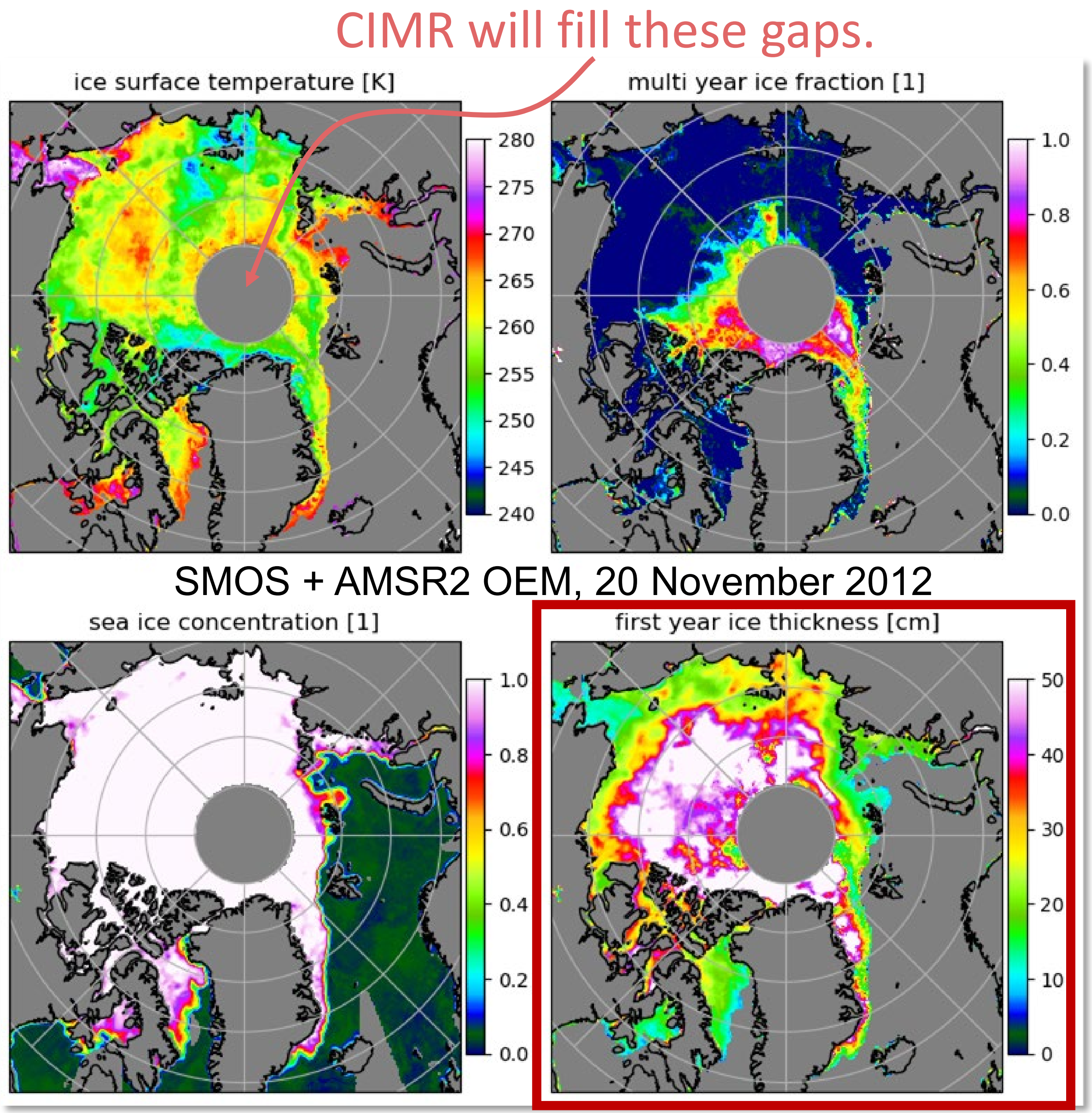
- Use full CIMR frequency range 1.4 – 36.5 GHz
- Shown here for combined AMSR2 + SMOS
  - Reasonable thin ice in the marginal ice zone
  - Some low ice thicknesses in the Central Arctic not corrected for multiyear ice fraction
  - Can retrieve ice concentration, type, and thickness simultaneously (not possible with SMOS/SMAP alone)

Collocation of AMSR2 and SMOS is problematic

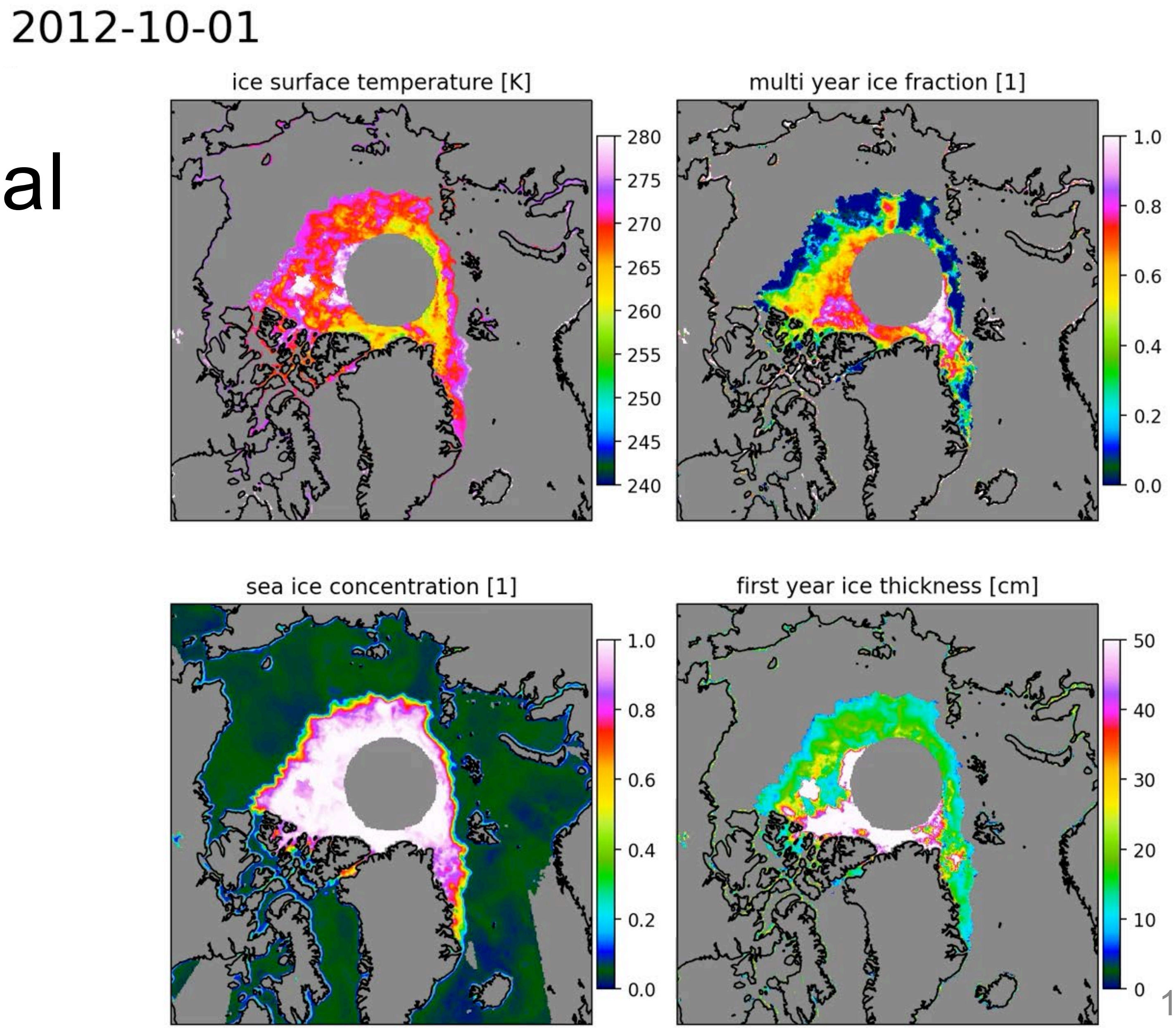
- SMOS 55° incidence angle observations are only in forward direction (large hole at the pole)
- Time differences of observations cause problems (currently daily TB averages are used)
- Solved with CIMR.

Scarlat et al., JGR, 2020



AMSR-2 plus SMOS multi-parameter retrieval

- 2012/2013 winter
- Four sea ice variables
- Ocean and atmosphere not shown
- Ice thickness addition by SMOS



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Sea Ice MW Emission

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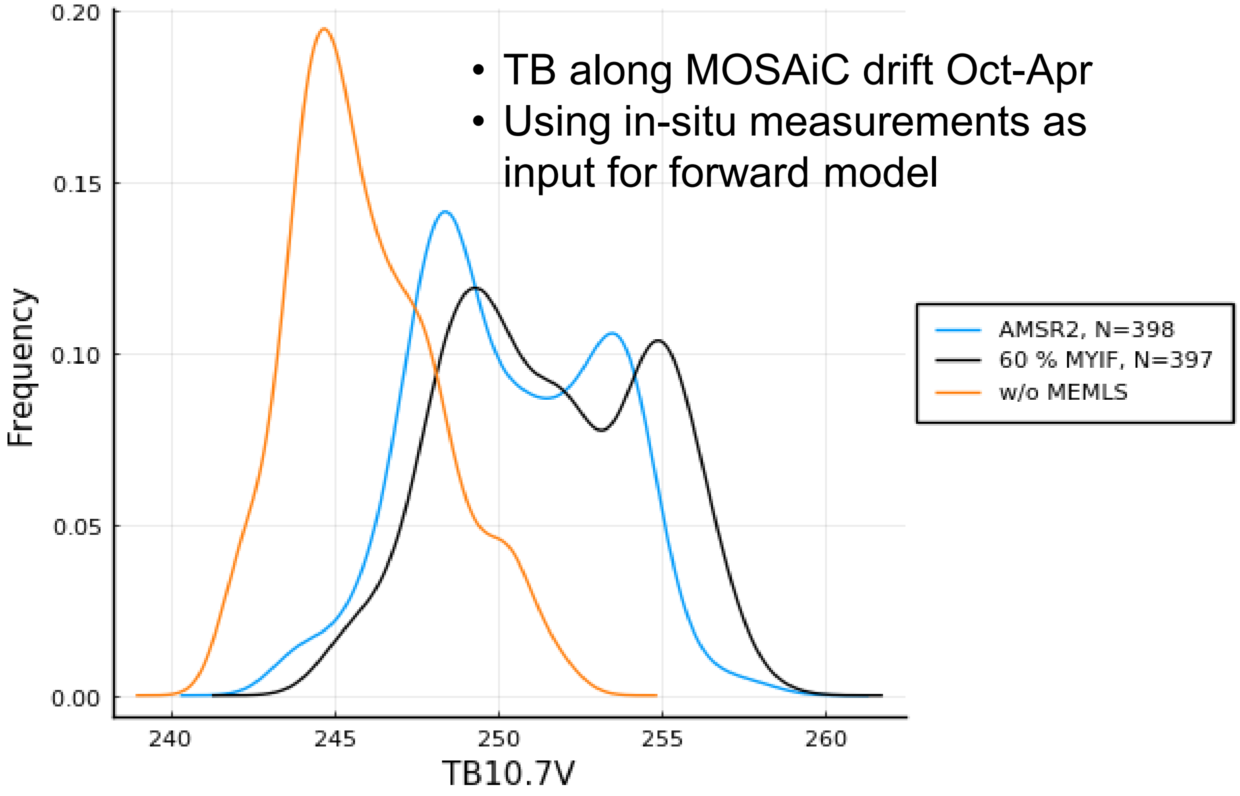
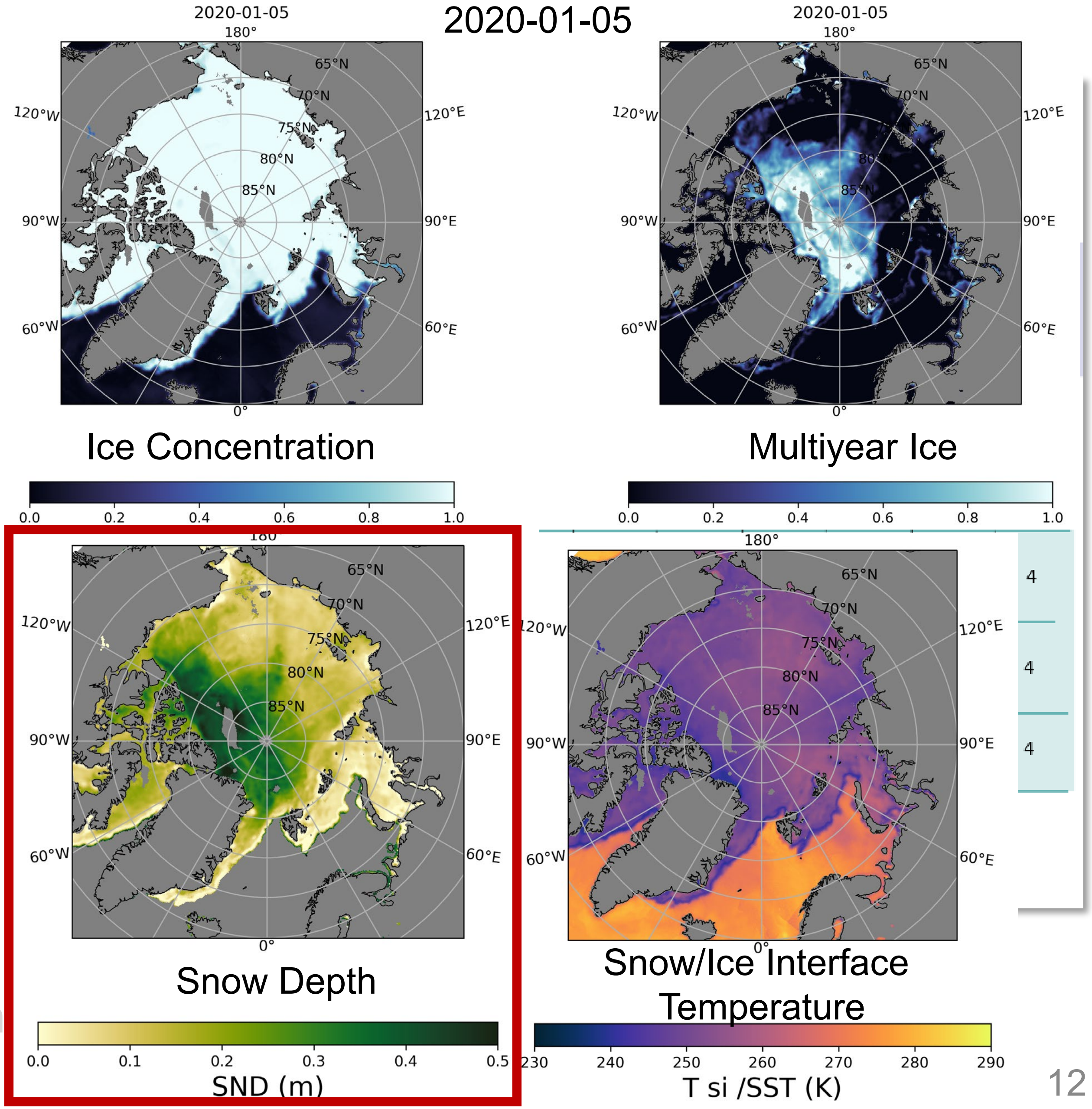
- TB along MOSAiC drift Oct-Apr
- Using in-situ measurements as input for forward model





→ Problem: many MEMLS input parameters like snow density, salinity, or correlation length scale are poorly constrained

→ First, preliminary results are promising:

→ Realistic snow depth and temperature distribution

→ Inclusion of MEMLS allows more realistic ice TB

Conclusions

Thank you!

- Multi-parameter retrieval for sea ice, ocean and atmosphere using optimal estimation can provide physically consistent datasets
  - ➢ single parameter retrieval, e.g. for sea ice concentration, ice type, SST could be inconsistent along ice margins
- Uncertainties are comparable to single parameter retrieval and should meet CIMR requirements
- The CIMR L-band channel, for the first time, will allow to retrieve thin ice thickness and ice concentration simultaneously
- Inclusion of a sea ice microwave emission model will improve all sea ice and atmosphere parameters and allow new parameters like snow depth

Outlook

- Include sea surface salinity in retrieval ➜ ongoing work
- Use consistent multi-parameter retrieval as baseline for more sophisticated single parameter retrievals ➜ will provide physical consistency