

Evaluating the sea ice volume solution in a high-resolution climate models

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RGMA meeting,
October 14th 2020



Meridionally Integrated Sea Ice Area and Volume

Approach

- Meridionally integrated measures defined as a function of longitude.
- Regular longitudinal grid with bins of chosen resolution (1deg, 0.5deg, etc.)
- Accumulation of the native grid sea ice variables (sea ice area, sea ice volume) within the meridional sectors.

Impacts

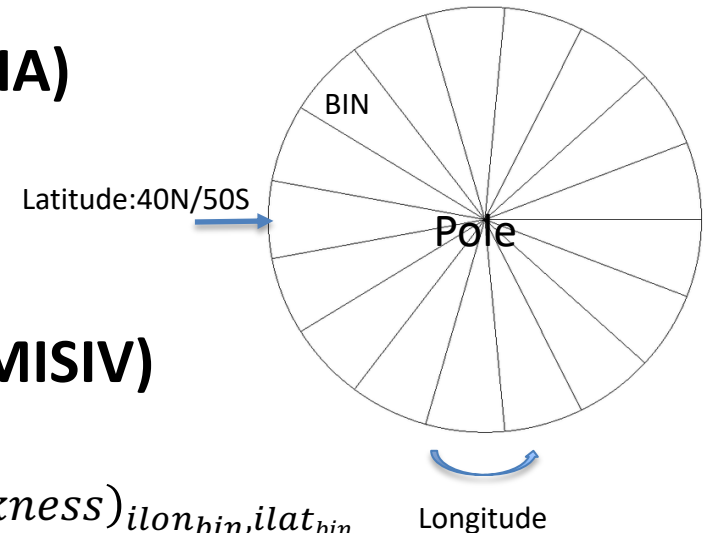
- Simple metric for multi-model and observational data sets comparison that:
- Avoids re-interpolation errors typical when comparing maps.
 - Reduces uncertainty due to compensation errors compared to total hemispheric cumulative quantities.
 - Besides direct evaluation of sea ice area and volume model performance these metrics can be used for model ranking by error compensation in hemispheric total sea ice area and volume estimates.

Meridionally integrated sea ice area (MISIA)

$$MISIA = \sum_{Lat\ 40N/50S}^{90N/S} grid\ cell\ area_{ilon_{bin}, ilat_{bin}}$$

Meridionally integrated sea ice volume (MISIV)

$$MISIV = \sum_{Lat\ 40N/50S}^{90N/S} (grid\ cell\ area * grid\ cell\ thickness)_{ilon_{bin}, ilat_{bin}}$$



Observations & Models

Observations:

CryoSat-2/Cryosat2-SMOS multiple products: ESA SAR Interferometric Radar Altimeter. In orbit since 2010 (Oct-Apr); Grid: Ease 25x25km. (Kurtz et al, 2014, Ricker et al., 2017)

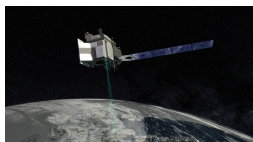
ICESat/ICESat-2: (NASA Ice, Cloud, and land Elevation Satellite) ICESat Period: 2003-2008 (Oct-Apr); ICESat-2 launched in 2018; Grid: Ease 25x25km. (Kwok et al, 2019)

GIOMAS Reanalysis: - Polar Science Center (APL-UW) Global Ice-Ocean Modeling and Assimilation System, POP/TED (Zhang&Rothrock, 2001); Assimilates SSM/I ice concentration. Period: 1979-2020. Grid:360x276;

Models:

E3SMv0 HiLAT UH8to2 : Ultra-high COREll forced POP2/CICE5, 1986-1993. Integration ongoing at NERSC.

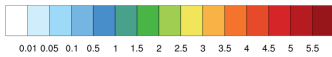
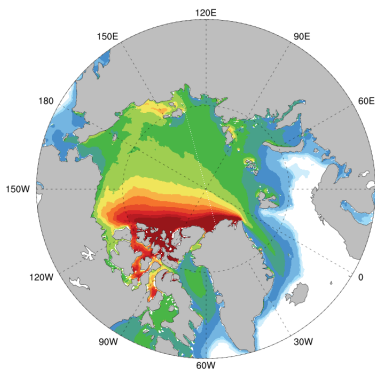
E3SMv1 18to6km: (Caldwell et al, 2019) fully coupled E3SMv1 (Atmospheric component with Spectral element dynamical core (~25km resolution); MPAS ocean/MPAS ice (~0.1deg resolution); 1950-control: time-invariant 1950 forcing following HighResMIP protocol, using 26-55y.



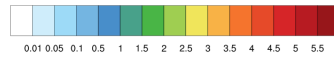
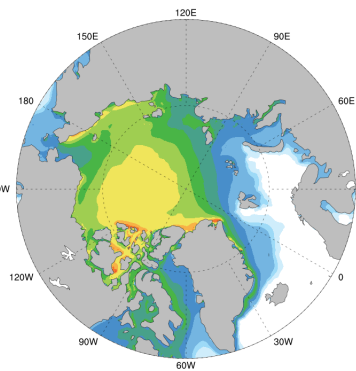
Motivation: Large spread of the Arctic sea ice thickness/volume estimates across models and observations.

Arctic Winter Sea Ice Thickness (m)

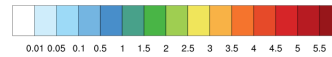
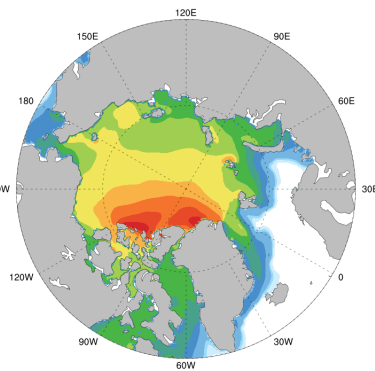
E3SMv0 UH8to2, JFM,1986-1993



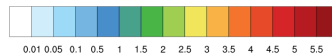
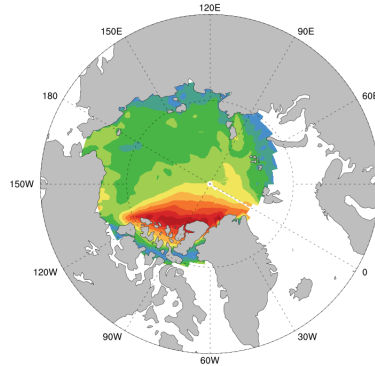
E3SMv1 18to6, JFM 26-55y



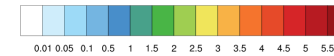
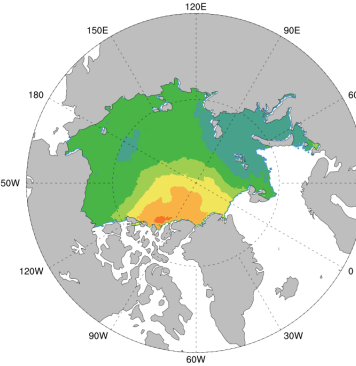
GIOMAS, JFM 1986-1993



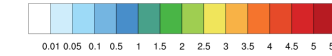
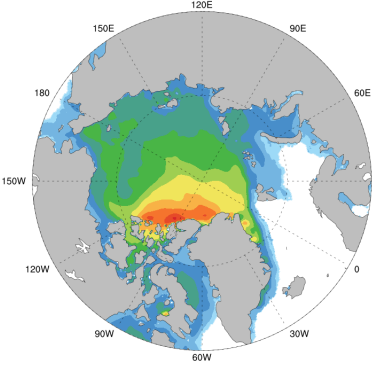
ICESat, FM 2003-2008



CryoSat-2 NASA, JFM 2011-2019



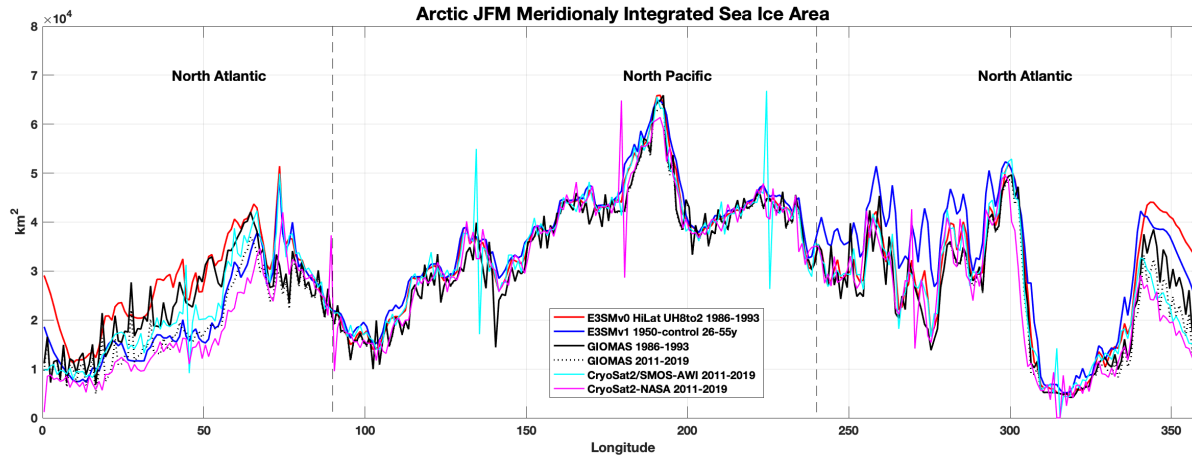
CryoSat-2 /SMOS AWI, JFM 2011-2019



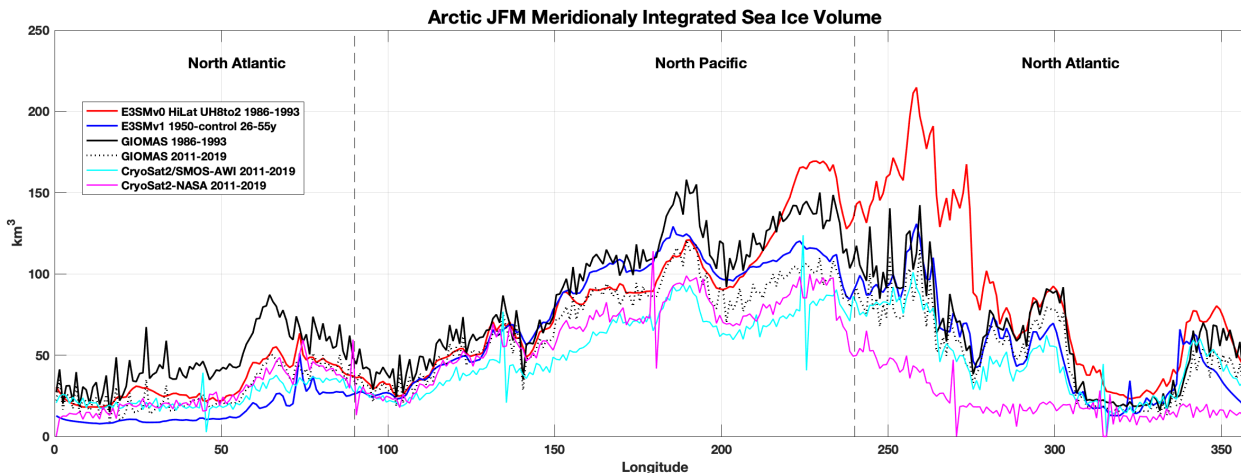
Large differences in the models

Large uncertainty in the NASA/ESA ice thickness/area retrieval algorithms
Need for ensemble of satellite estimates.

Preliminary Results: JFM Arctic MISIA & MISIV



MISIA: Challenging for low resolution models (Ivanova et al., 2016). Biases are reduced with increasing the model resolution.

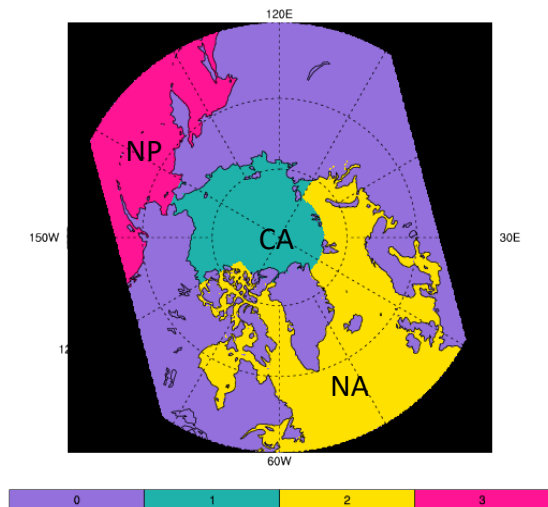


MISIV: Large differences between model-reanalysis-satellite observation estimates.

Ongoing research:

- Similar evaluations for Antarctic
- Uncertainty quantification;
- HighResMIP evaluation.
- Extend to first and multi-year ice.
- Incorporate in PCMDI Metrics package.

Arctic Regions Mask



Ivanova, D. P., P. J. Gleckler, K. E. Taylor, P. J. Durack, and K. D. Marvel, 2016: Moving beyond the Total Sea Ice Extent in Gauging Model Biases. *J. Climate*, **29**, 8965–8987, <https://doi.org/10.1175/JCLI-D-16-0026.1>.