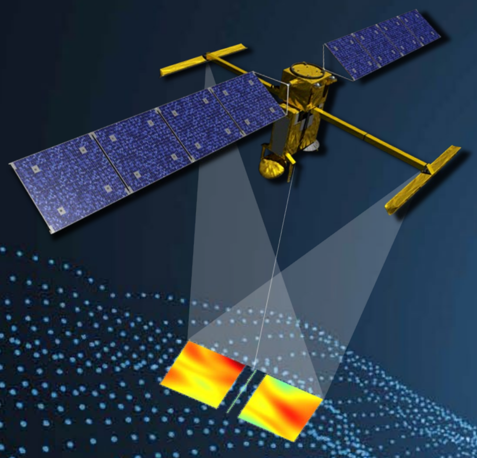
Experimental Mapping of Ocean Surface Topography using SWOT Altimetry: Ongoing and Future Studies



Ballarotta, M., Ubelmann, C., Meda, G., Tréboutte, A., Metref, S., Faugere, Y., Dibarboure, G., Fablet, R.

SWOT-ST – Toulouse 2023

Introduction & Context

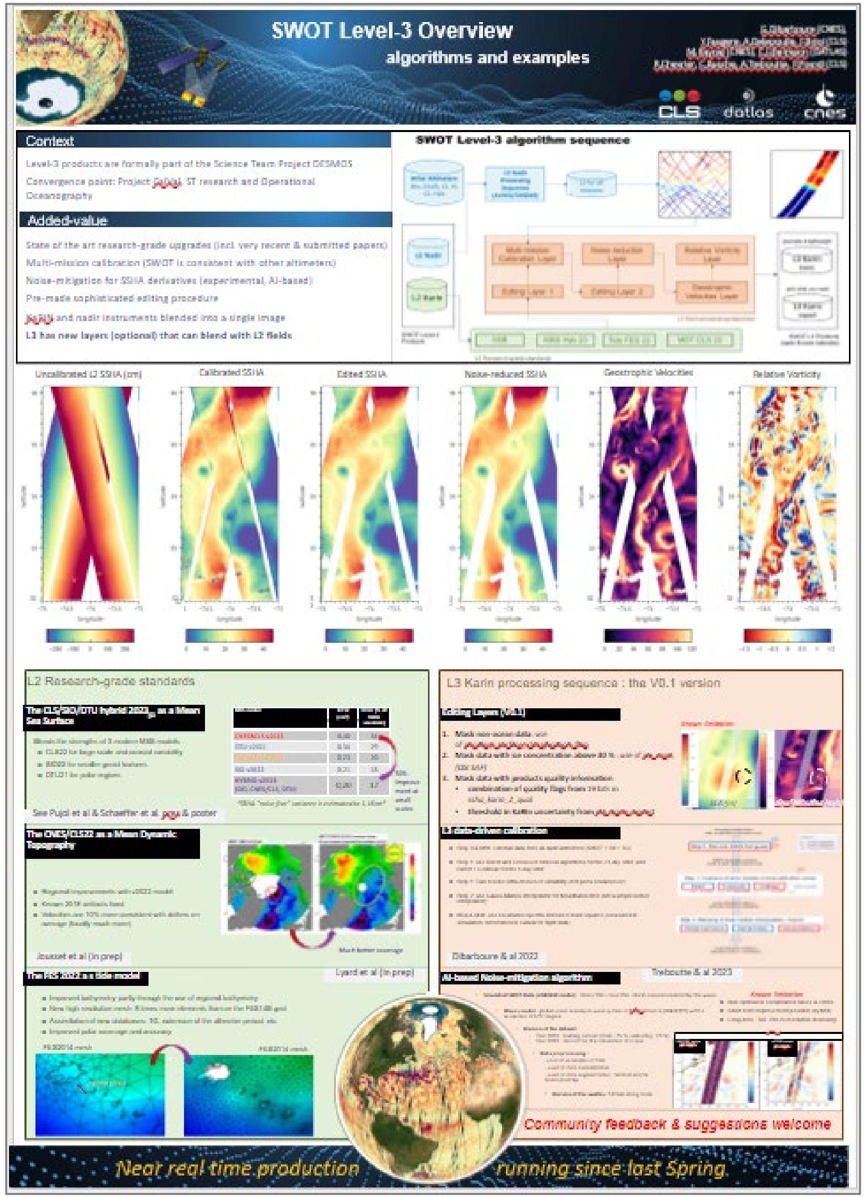
- **3 month** of Level-3 SWOT Karin data during **1-Day repeat** orbit have been processed in the L3-DUACS system (*see SWOT L3 Overview poster & Gerald's presentation*)

- So far, only **OSSEs** have been used to assess the impact of Karin data in Level-4 gridded products.
- These assessments were based on various mapping algorithms, such as:
  - **DUACS** (*Le Traon et al., 1998*),
  - **MIOST** (*Ubelmann et al., 2021*),
  - **DYMOST** (*Ubelmann et al., 2015*),
  - **BFN-QG** (*Le Guillou et al., 2021*), and
  - **4Dvarnet** (*Fablet et al., 2021*)
  - + other Deep learning based method or assimilated OGCM

=> See for example ocean data challenge **2020a_SSH_mapping_NATL60**
=> And presentation by V. Bellemin-Laponnaz @ 2022 SWOT-ST meeting

Today, we present early mapping analysis based on real SWOT Karin observations with the MIOST and 4Dvarnet methods

- The objectives of these studies were:
  - To **verify** the systems behaviour with real SWOT karin observations
  - To **assess** the performance of mapping systems with real SWOT data (in particular the impact on fine scale ocean structures)
  - To **quantify** the contribution of SWOT Karin during the calval phase in mapping systems

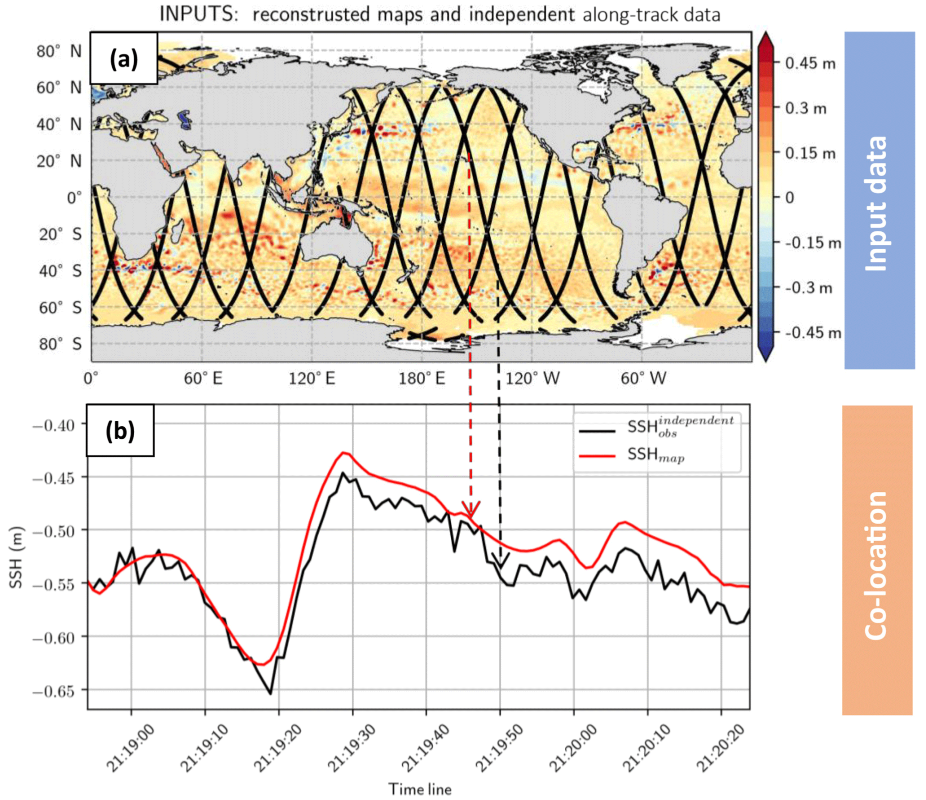


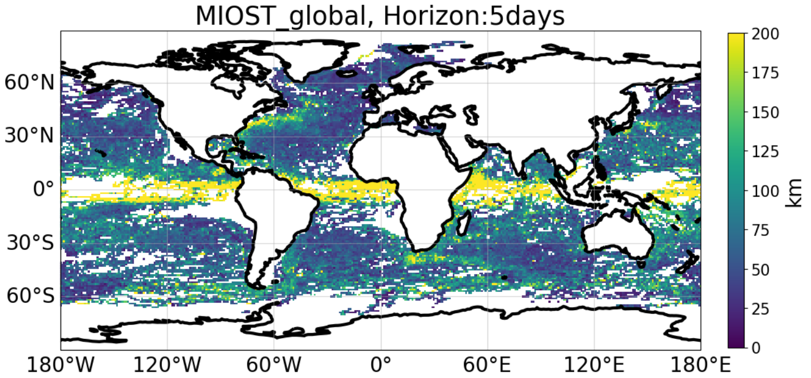
Methodology for mapping error estimation

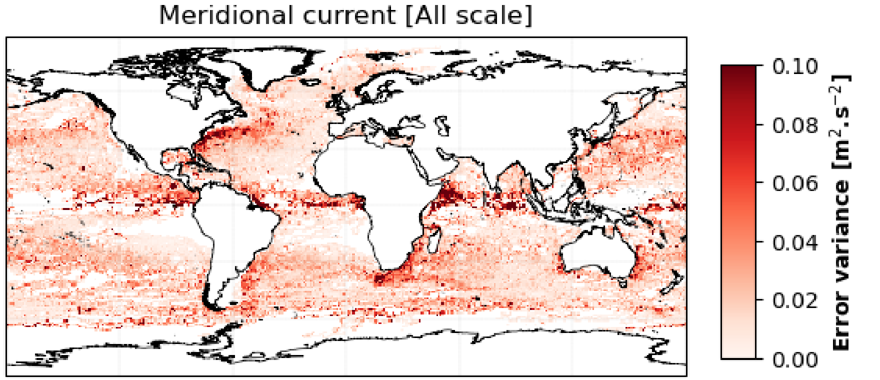
- **Validation** based on the **SSHA comparison** between gridded reconstruction and independent **altimeter** data
    - Apply various along-track filter to isolate the signal of interest
    - Perform spectral analysis
    - Metrics: RMSE, explained variance score, effective resolution

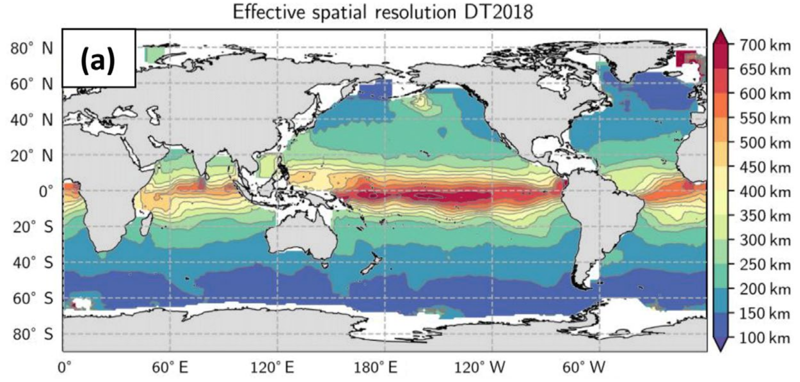
- **Validation** based on sea surface **current comparison** between gridded reconstruction and independent **drifters** data: => *on going work undertaken in the CMEMS Service Evolution SLICING project*

- **Validation** based on Lagrangian method: dispersion at specific time horizons => *on going work undertaken in the CMEMS Service Evolution SLICING project*









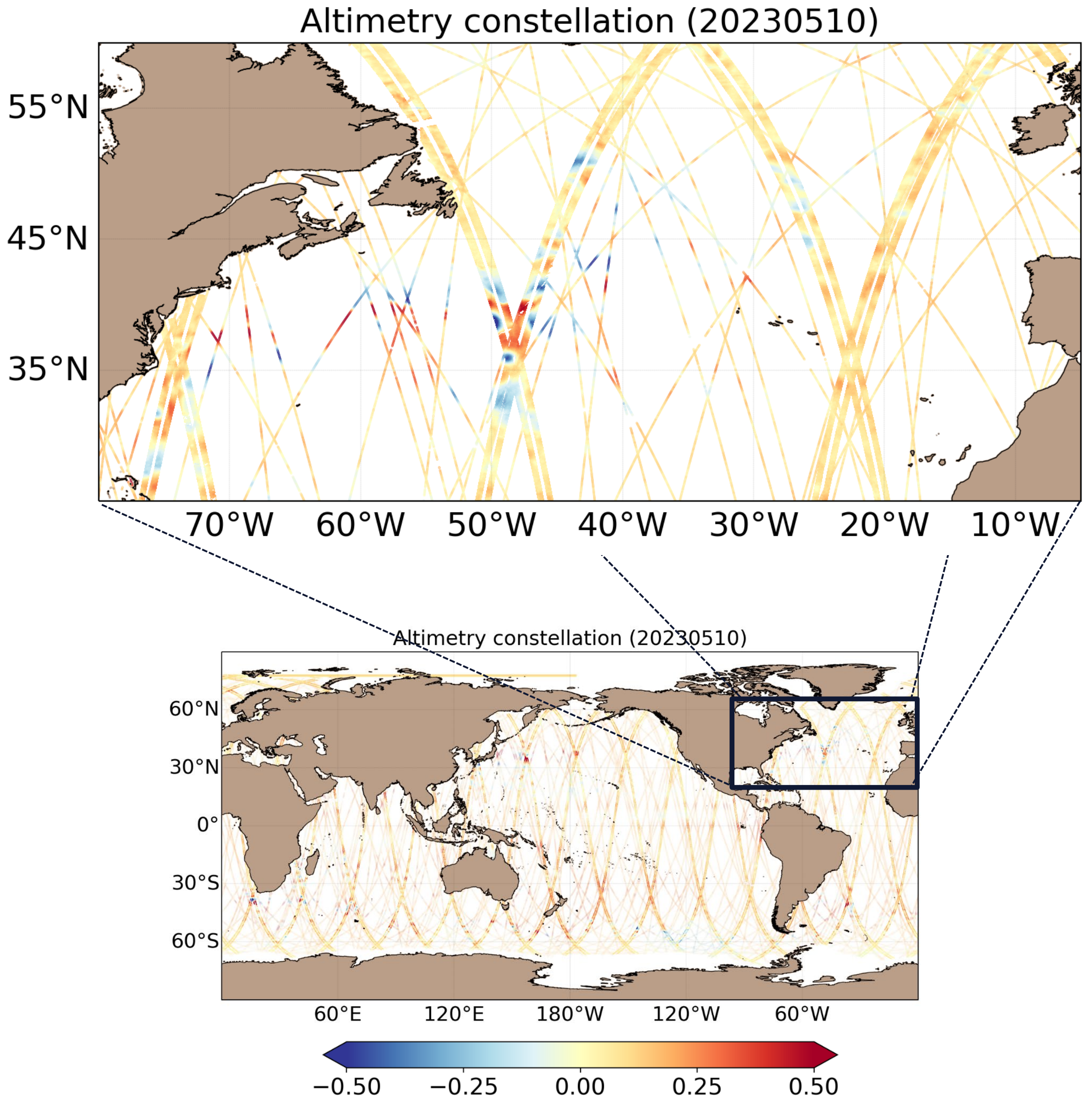
Experimental design

- With MIOST:
  - **Global** mapping conducted for the period from 2023-05-01 to 2023-07-01.
- With 4Dvarnet:
  - **North Atlantic** mapping conducted for the period from 2023-05-01 to 2023-07-01.

- Experiments carried out in Delayed-Time mode (DT: past & future observations):
  - **EXP#1**: Cryosat-2, HaiYang-2B, Sentinel-3A, Sentinel-3B, Sentinel-6, Jason-3: => **nadirs only reference exp.**
  - **EXP#2**: Cryosat-2, HaiYang-2B, Sentinel-3A, Sentinel-3B, Sentinel-6, Jason-3 + **SWOT Karin: to quantify the contribution of Karin**

- SARAL/Altika kept aside for validation

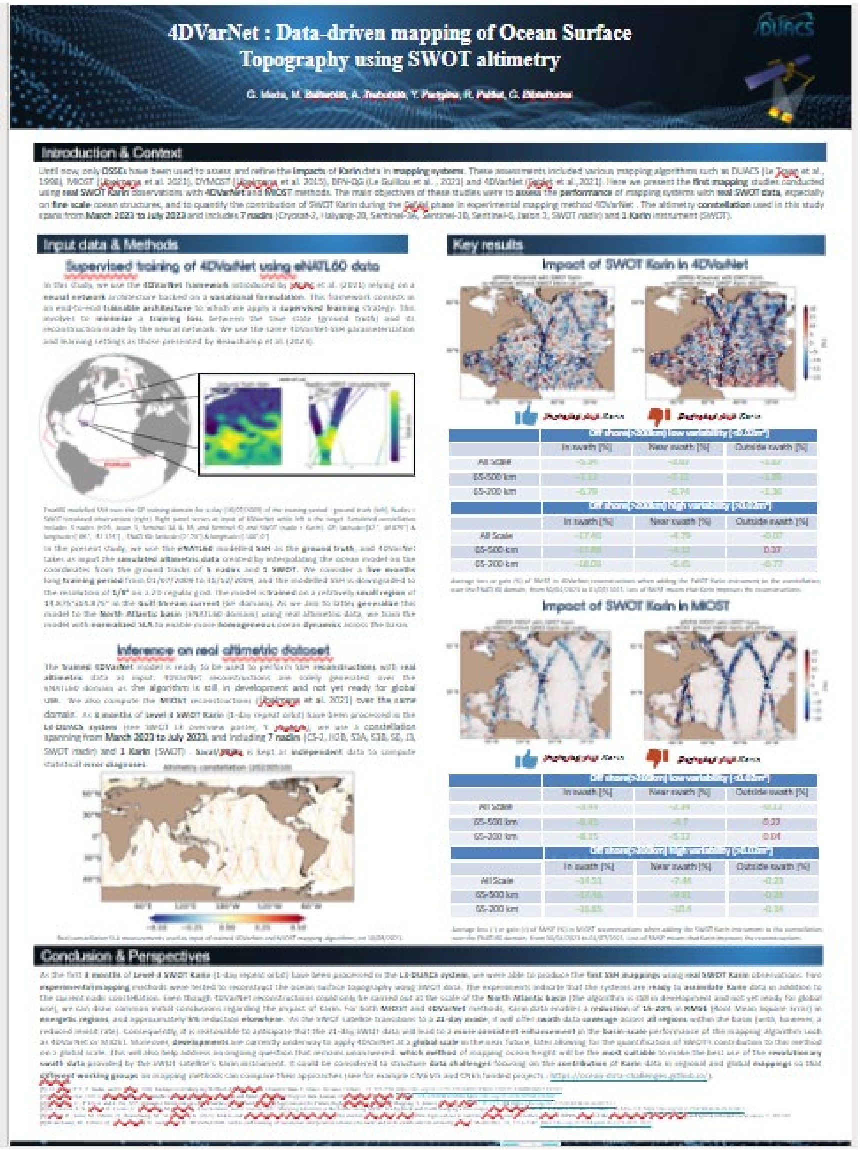
- **Resources**: Mapping & Validations are undertaken on the CNES Computing Center (see Cyril presentation on CNES computing facilities)



Key scientific points

- Two mapping methods (MIOST (OI based) & 4Dvarnet (data-driven)) were tested to reconstruct the ocean surface topography using Level-3 SWOT Karin data and nadirs observations.
- The experiments indicate that the **systems behave well for assimilating Karin** data in addition to the current **nadir constellations**.
- Currently, the key message regarding the **contribution of Karin in mapping** is a **reduction of 15-20% in RMSE** (Root Mean Square Error) in energetic regions, and approximately **8% reduction elsewhere**.

=> Science results presented in Guillaume’s Poster:
4DvarNet: Data-driven mapping of Ocean Surface Topography using SWOT altimetry



What's next…

- **Data sharing**: experimental L3 & L4 datasets presented here may be distributed (e.g., AVISO+, CNES HPC ?)
- **Sharing Validation method**: structuring data challenge for Global/Regional mapping focused on Karin's contribution, so that different mapping groups can intercompare their mapping and validation methods

  => Ongoing work through CMEMS Service Evolution SLICING project, as well as CNES funded projects

  https://ocean-data-challenges.github.io/

- **Improved mapping & validation plans**:
  – Towards a globalization of the 4dvarnet method
  – Result consolidation: Validation and refinement of mapping for SWOT **Science orbit** with MIOST & 4Dvarnet
  – Test mapping with **dynamical methods** such as BFN-QG, DYMOST, and 4Dvar-QG (F. Le Guillou), etc.. at the regional scale => Next presentation & posters
  – **Validation** with independent data (along-track and in-situ) => Possible synergy with fields campaign (validation with insitu data)

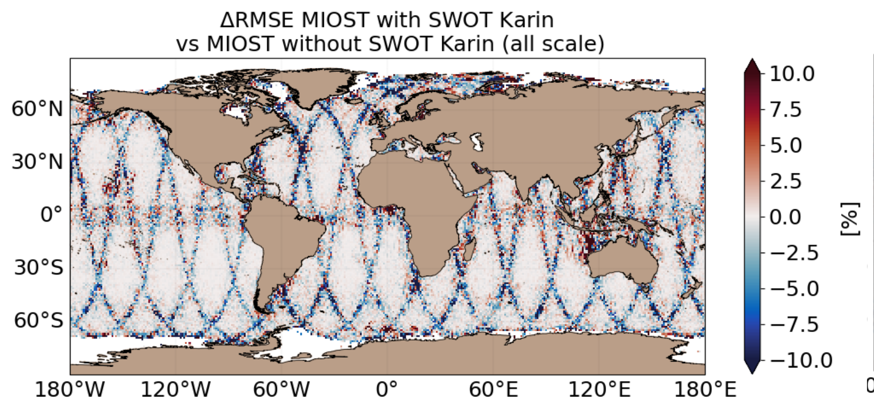
THANK YOU !!!

BACKUP

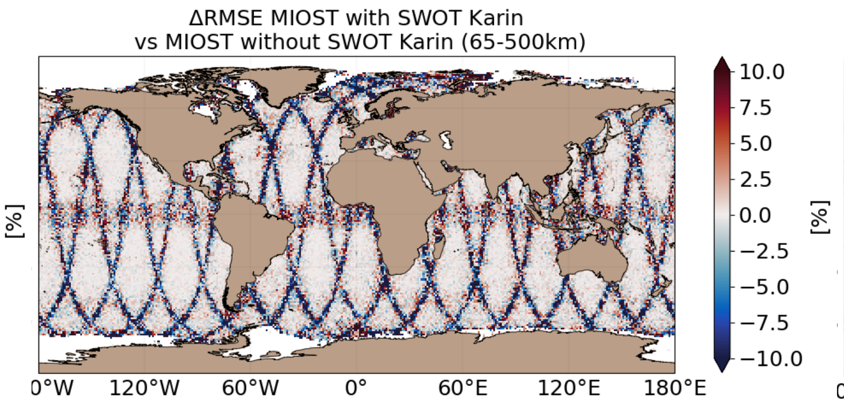
References

- Maxime Ballarotta, Emmanuel Cosme, & Aurélie Albert. (2020). ocean-data-challenges/2020a_SSH_mapping_NATL60: Material for SSH mapping data challenge (Version v1). Zenodo. https://doi.org/10.5281/zenodo.4045400
- Le Traon P.-Y., F. Nadal, N. Ducet, An Improved Mapping Method of Multisatellite Altimeter Data, ?, J. Atmos. Oceanic Technol. 15, 522-534, 1998
- Ubelmann, C., Dibarboure, G., Gaultier, L., Ponte, A., Ardhuin, F., Ballarotta, M., and Faugère, Y.: Reconstructing ocean surface current combining altimetry and future spaceborne Doppler data, J. Geophys. Res.-Oceans, 126, e2020JC016560, https://doi.org/10.1029/2020JC016560, 2021.
- Ubelmann, C., Klein, P., and Fu, L.-L.: Dynamic interpolation of sea surface height and potential applications for future high-resolution altimetry mapping, J. Atmos. Ocean. Tech., 32, 177–184, https://doi.org/10.1175/JTECH-D-14-00152.1, 2015.
- Le Guillou, F., Metref, S., Cosme, E., Ubelmann, C., Ballarotta, M., Le Sommer, J., and Verron, J.: Mapping Altimetry in the Forthcoming SWOT Era by Back-and-Forth Nudging a One-Layer Quasigeostrophic Model, J. Atmos. Ocean. Tech., 38, 697–710, https://doi.org/10.1175/JTECH-D-20-0104.1, 2021.
- Fablet, R., Amar, M., Febvre, Q., Beauchamp, M., & Chapron, B. (2021). End-toend physics-informed representation learning for satellite ocean remote sensing data:Applications to satellite altimetry and sea surface currents. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 3, 295-302.

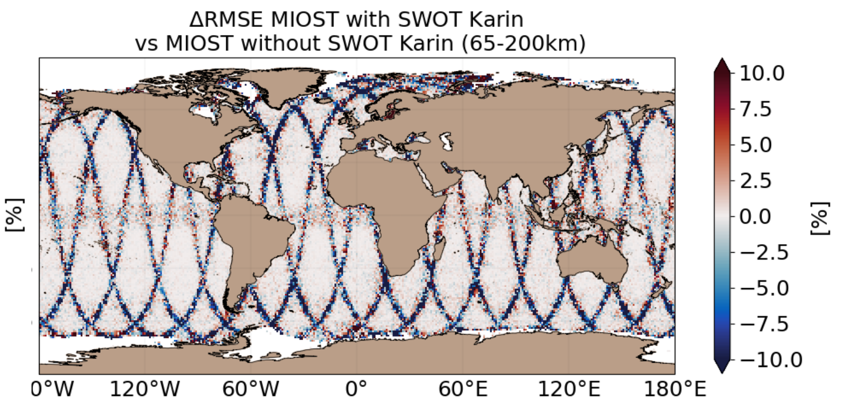
FOR ALL SPATIAL SCALE



FOR SPATIAL SCALE < 500km



FOR SPATIAL SCALE < 200km



Improved with Karin **Degraded with Karin**

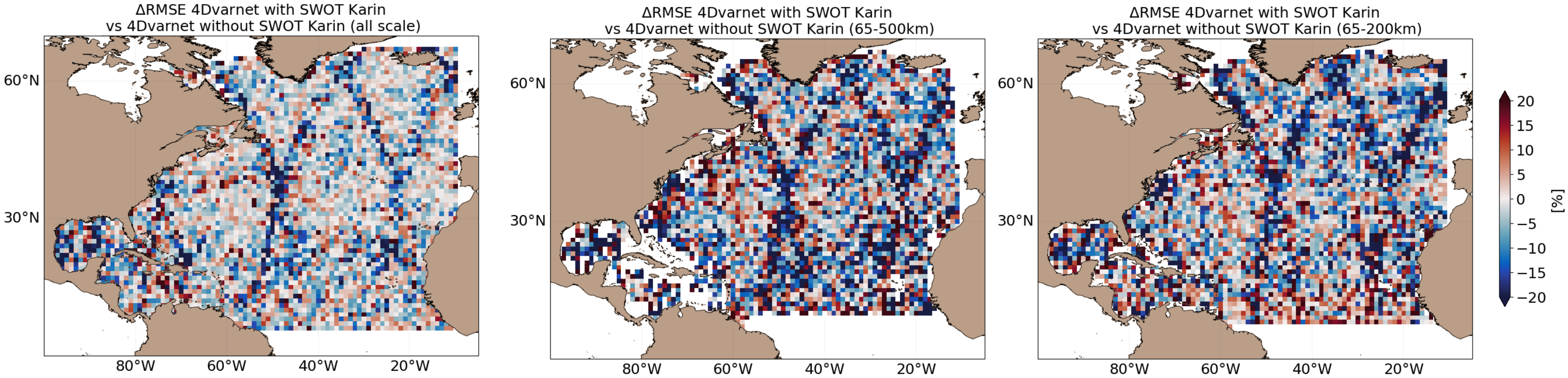
	offshore (>200km) low var (<0.02m2)		
	In swath [%]	Near swath [%]	Outside swath [%]
ALL SCALE	-2.05	-1.03	0.06
65-500km	-5.79	-1.98	0.12
65-200km	-5.97	-2.34	0.06

	offshore (> 200km) high var (> 0.02m2)		
	In swath [%]	Near swath [%]	Outside swath [%]
ALL SCALE	-9.83	-4.03	-0.05
65-500km	-15.91	-6.21	0.03
65-200km	-16.85	-6.89	0.06

- Mapping is improved under SWOT Karin

Impact SWOT Karin in 4Dvarnet

FOR ALL SPATIAL SCALE | **FOR SPATIAL SCALE < 500km** | **FOR SPATIAL SCALE < 200km**



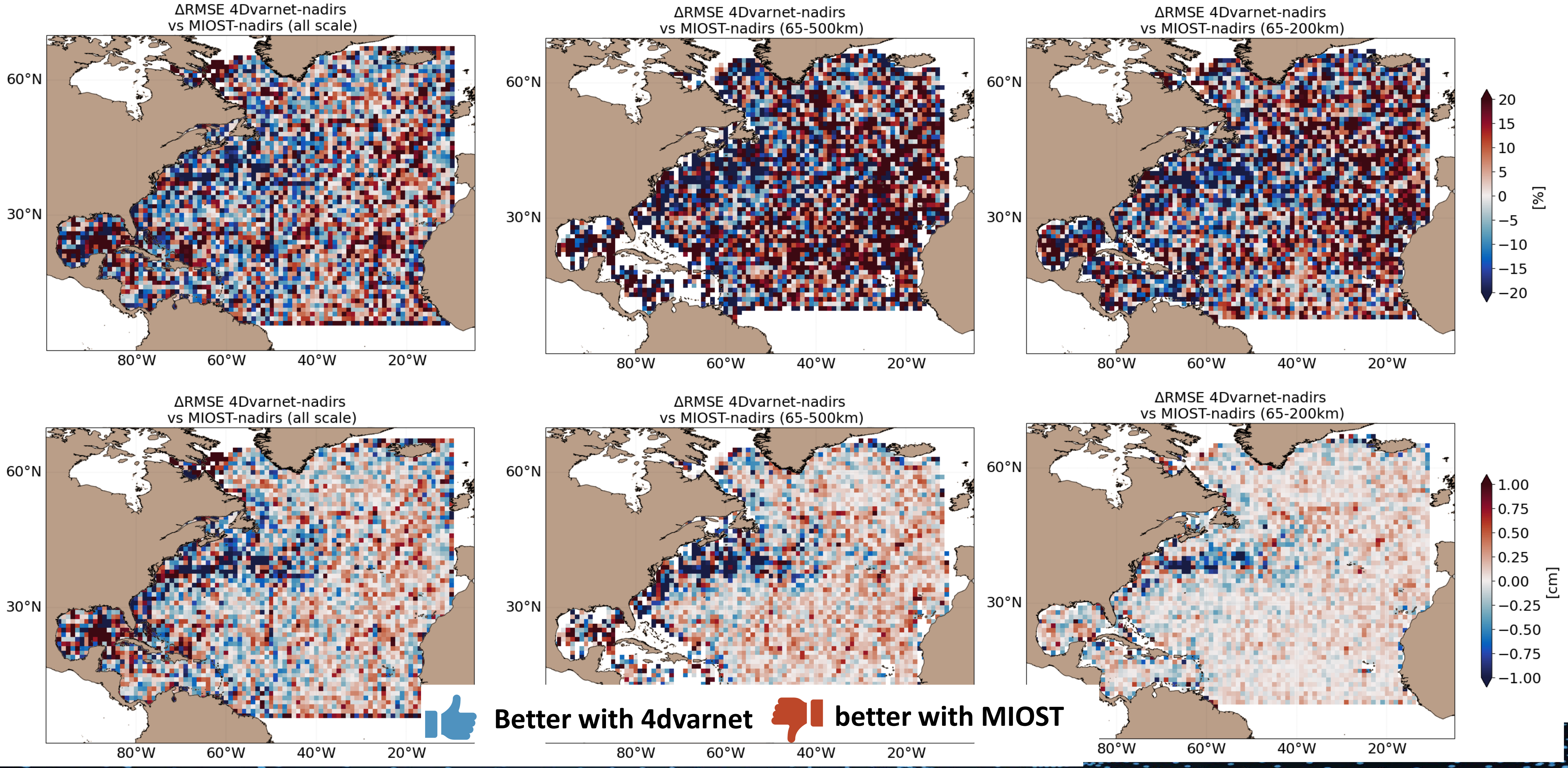
	offshore (>200km) low var (<0.02m2)		
	In swath [%]	Near swath [%]	Outside swath [%]
ALL SCALE	-5.34	-3.92	-1.67
65-500km	-7.13	-7.12	-1.89
65-200km	-6.79	-6.74	-1.36

	offshore (> 200km) high var (> 0.02m2)		
	In swath [%]	Near swath [%]	Outside swath [%]
ALL SCALE	-17.46	-4.79	-0.07
65-500km	-17.88	-3.12	0.37
65-200km	-18.09	-6.45	-0.77

Improved with Karin **Degraded with Karin**

4Dvarnet vs MIOST (7 nadirs: c2n, h2b, s3a, s3b, j3n, s6a_hr, swonc)

FOR ALL SPATIAL SCALE | FOR SPATIAL SCALE < 500km | FOR SPATIAL SCALE < 200km

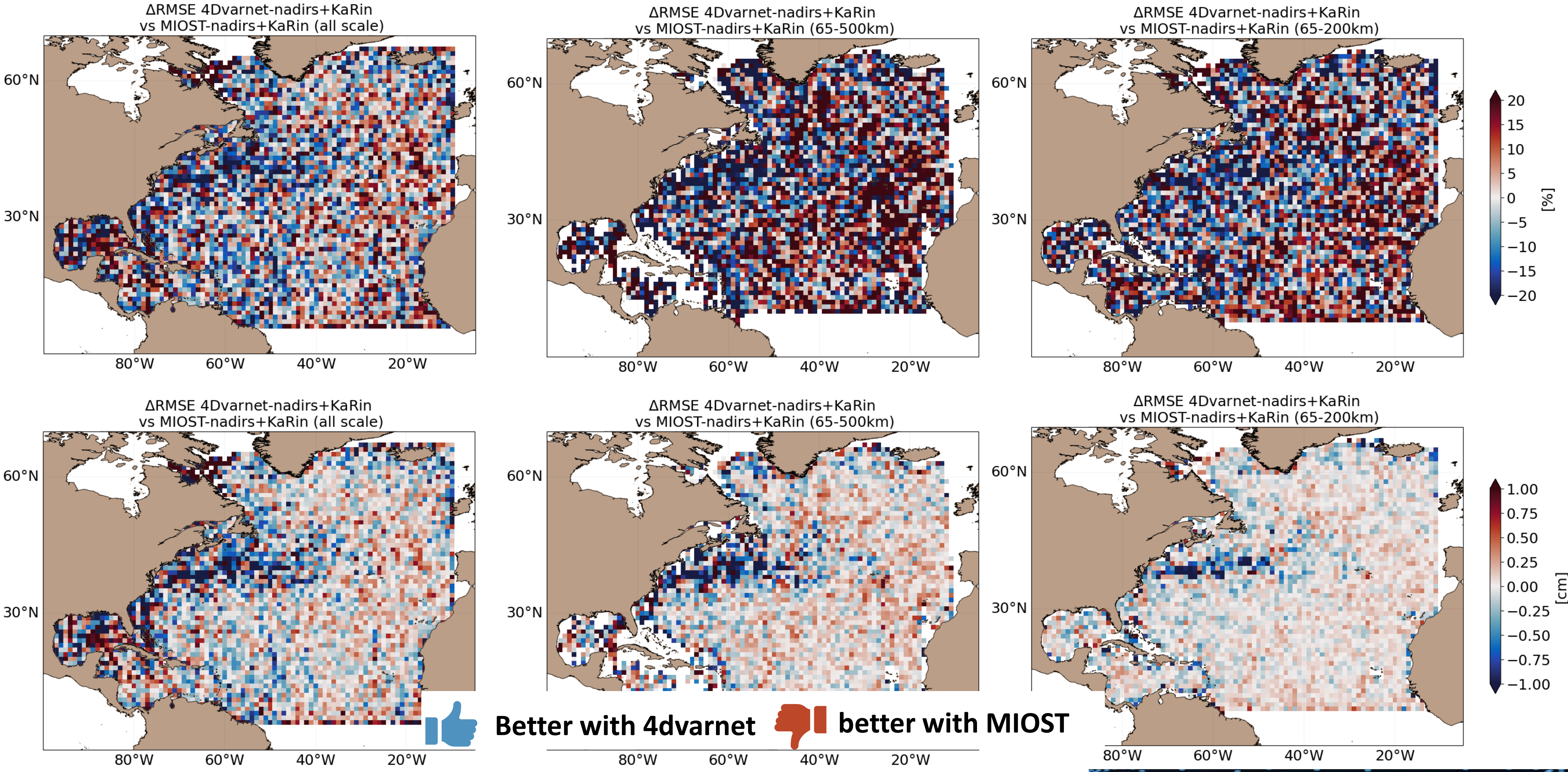


4Dvarnet vs MIOST (7 nadirs: c2n, h2b, s3a, s3b, j3n, s6a_hr, swonc + Karin)

FOR ALL SPATIAL SCALE

FOR SPATIAL SCALE < 500km

FOR SPATIAL SCALE < 200km



Better with 4dvarnet   better with MIOST