NOVELTIS
Innovating to protect our World's Life

DTU Space
National Space Institute

TU Delft

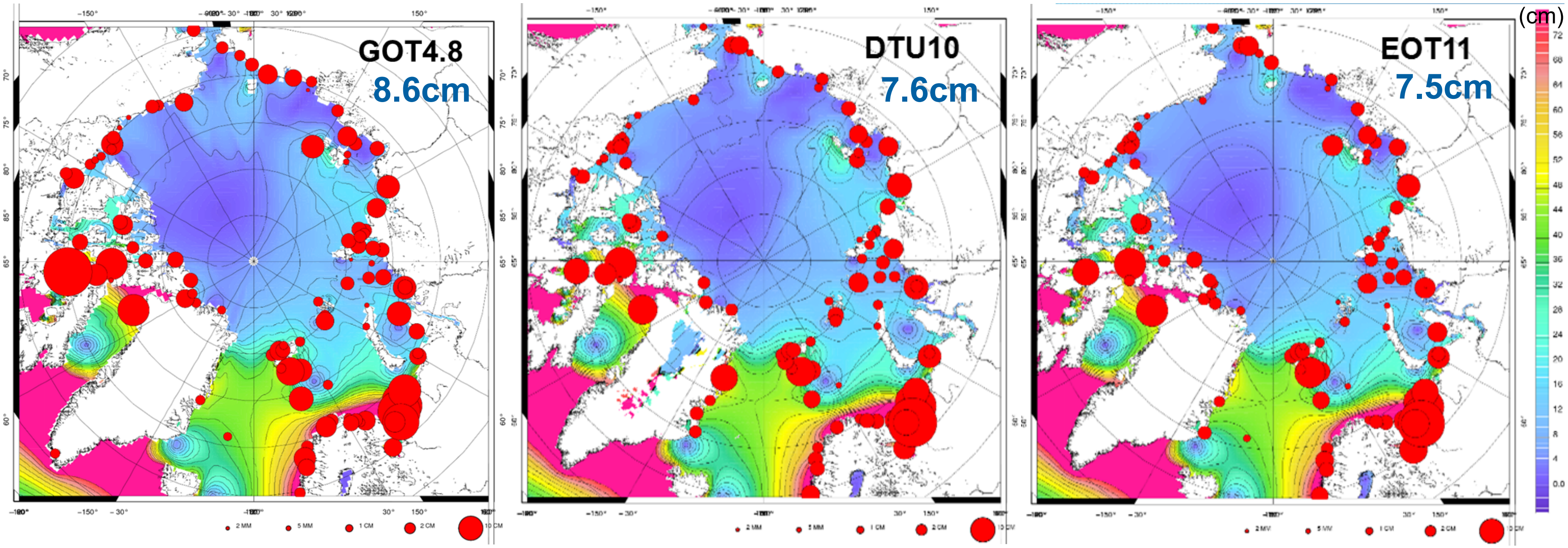
LEGOS

CP4O CCN Final Review

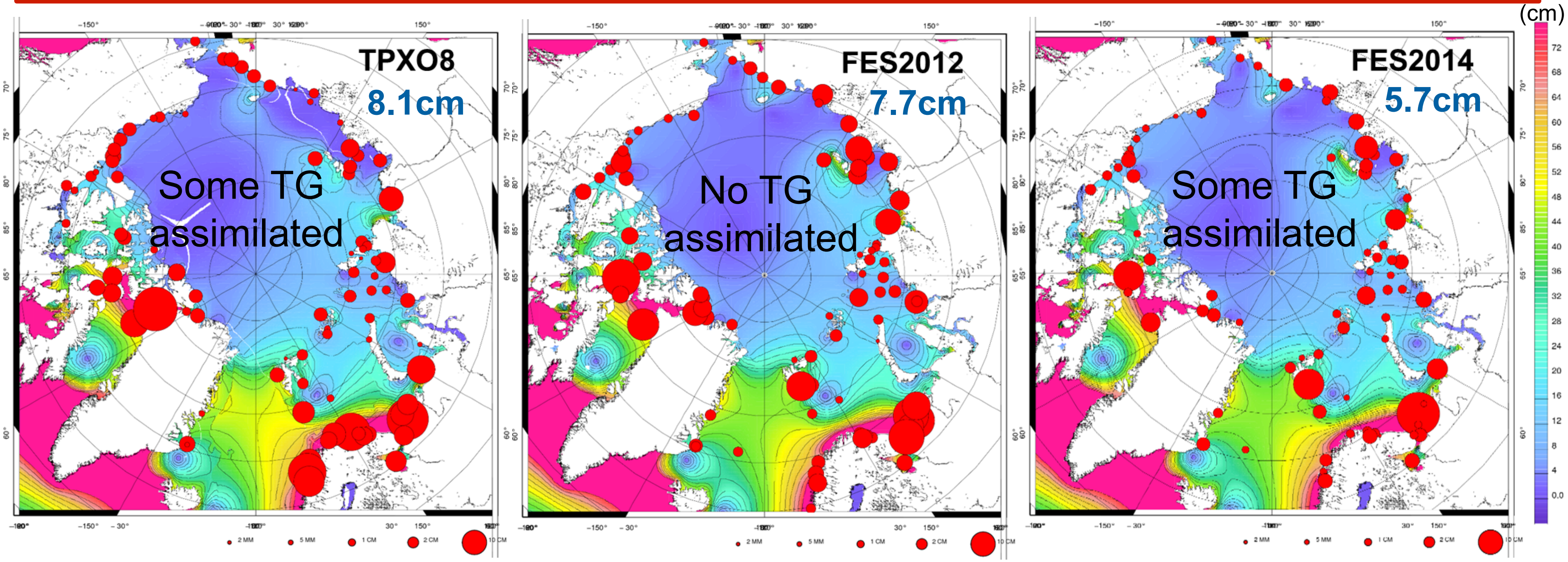
WP2000

Regional tidal atlas in the Arctic Ocean

10/12/2015



Global models vs tide gauges → large errors on shelves in the Arctic Ocean



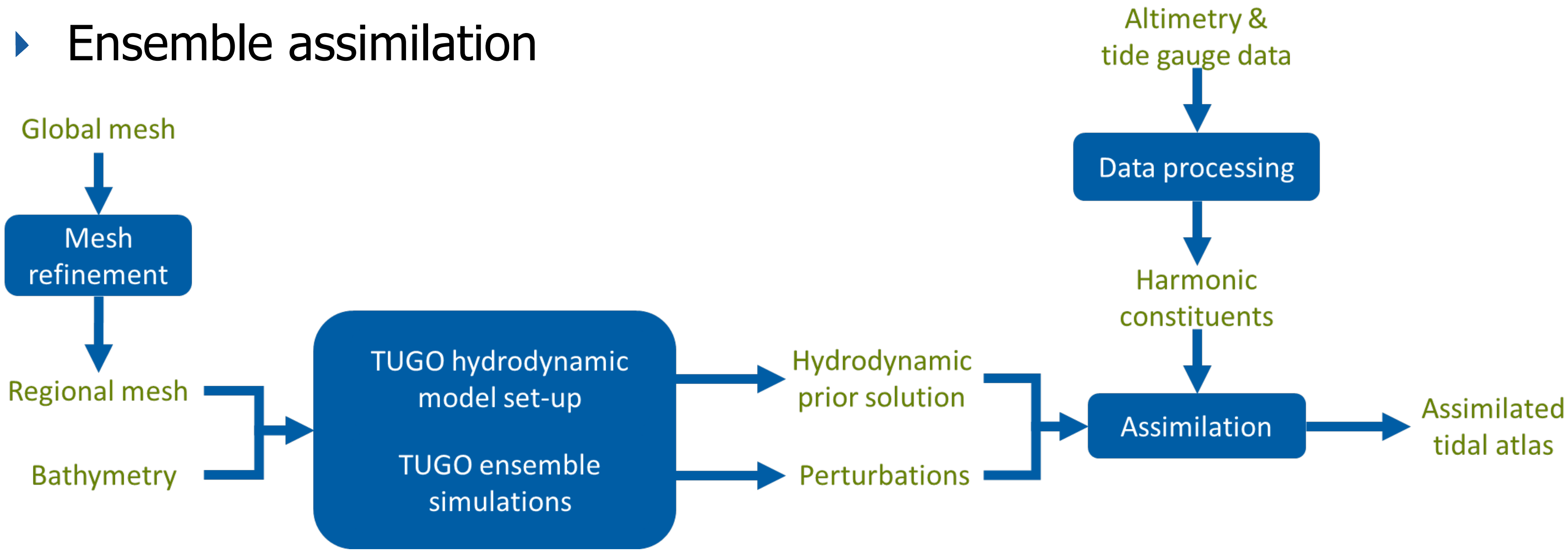
Context and objectives

- Lack of accuracy of the global tidal models in the Arctic Ocean
  - Low mesh resolution
  - Bathymetry:
    - Huge work to check the whole bathymetry in detail in a global model
    - Difficult to have access to the data in the Arctic Ocean
  - Validation / Assimilation:
    - Scarce tide gauge observations
    - Altimetry limited in latitude
    - Not much confidence in the available datasets

➔Regional tidal modeling

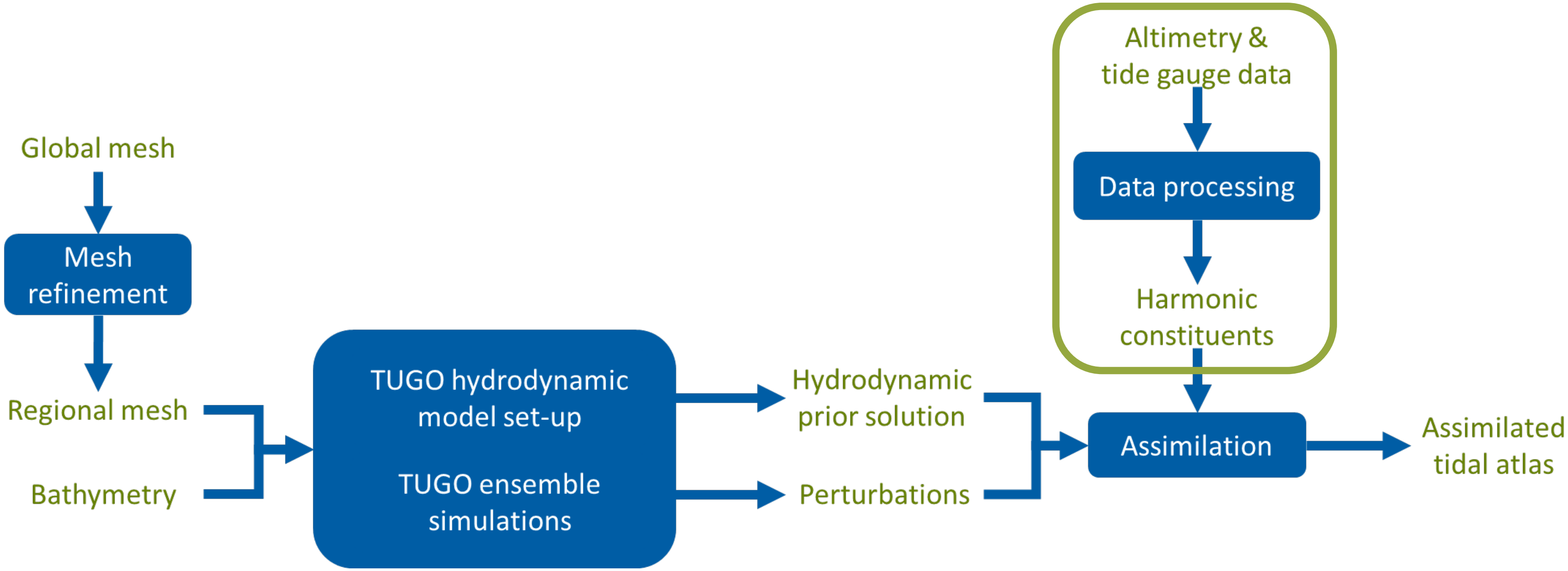
Context and objectives

- Regional tidal modeling in the Arctic Ocean
  - Same method as FES2012 / FES2014 / COMAPI *(CLS/NOVELTIS/LEGOS and NOVELTIS/LEGOS projects, funded by CNES)*
  - Hydrodynamic modeling
  - Ensemble assimilation



Data processing

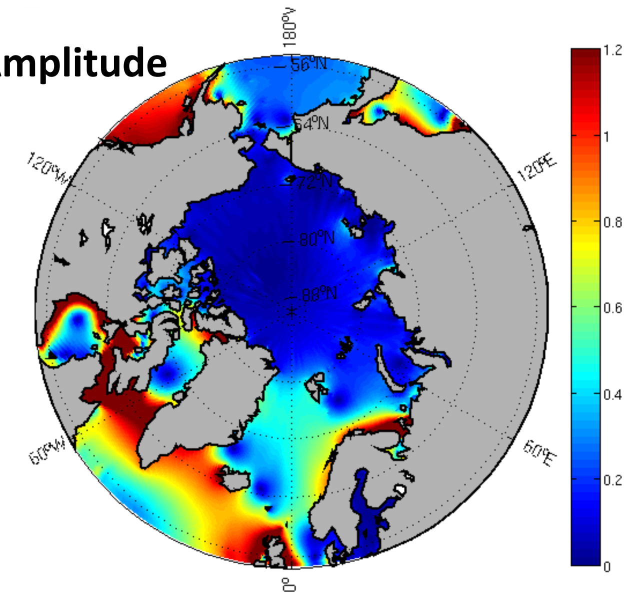
- Computation of the altimeter tidal harmonic constituents
  - Data processed by DTU Space and delivered to NOVELTIS
    (26/06/2015 – 22/09/2015)



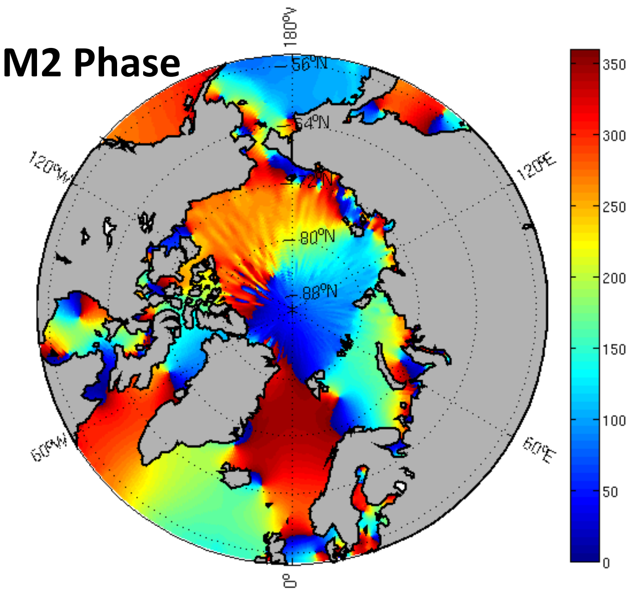
Data processing

- Computation of the altimeter tidal harmonic constituents
  - Remove/restore methodology: FES2004 is removed prior to tidal prediction and then restored to obtain the final tidal signal
  - Altimetry data in boxes of 1°x 3°down to 55°N
    - CryoSat-2 data in LRM and SAR mode (2010-2014)
    - Envisat data (2002-2010)
    - C2 LRM+ENVISAT from RADS, SAR retracked using primary peak retracker

M2 Amplitude

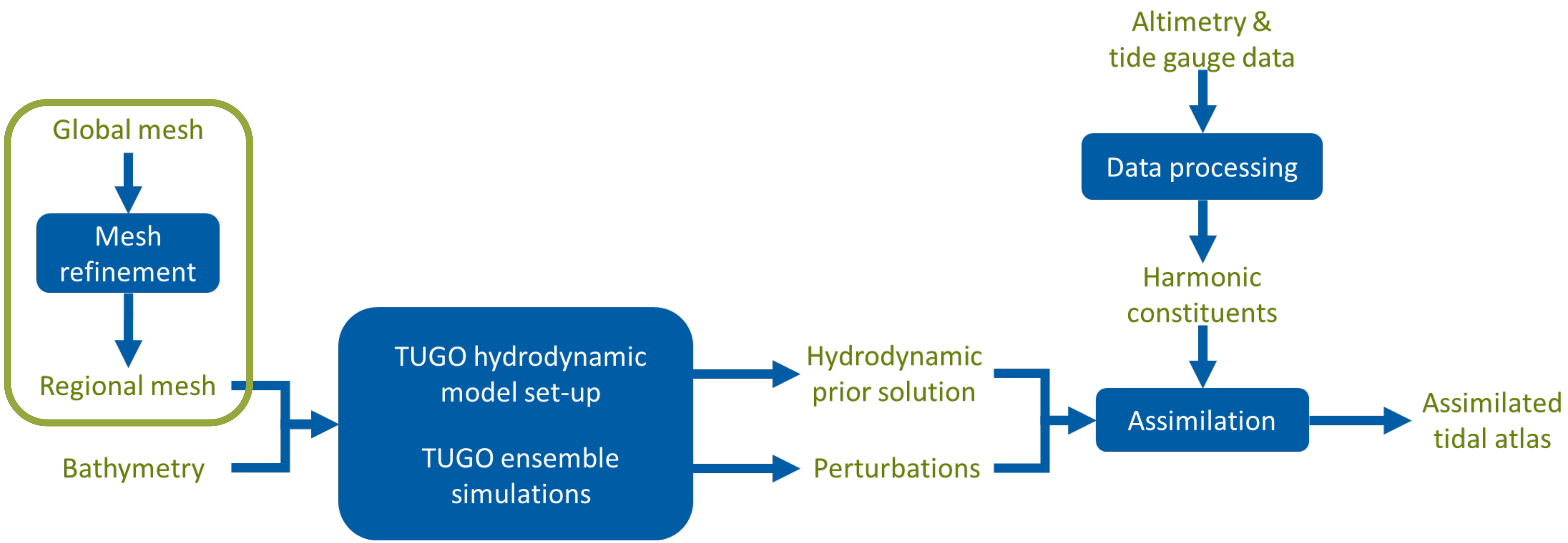


M2 Phase



Mesh refinement

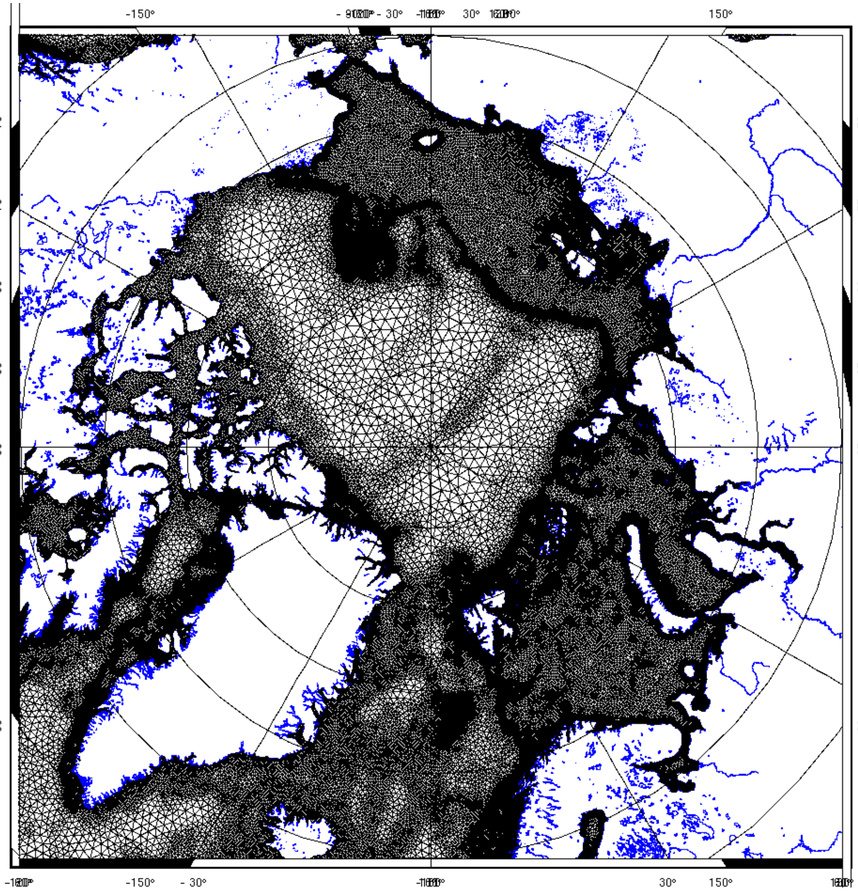
- Start with a global mesh (FES2014 +)



Mesh refinement

- Start with a global mesh (FES2014 +)

  → consistent for patching the regional solution in a global one



Mesh refinement

- Start with a global mesh (FES2014 +)

  → consistent for patching the regional solution in a global one

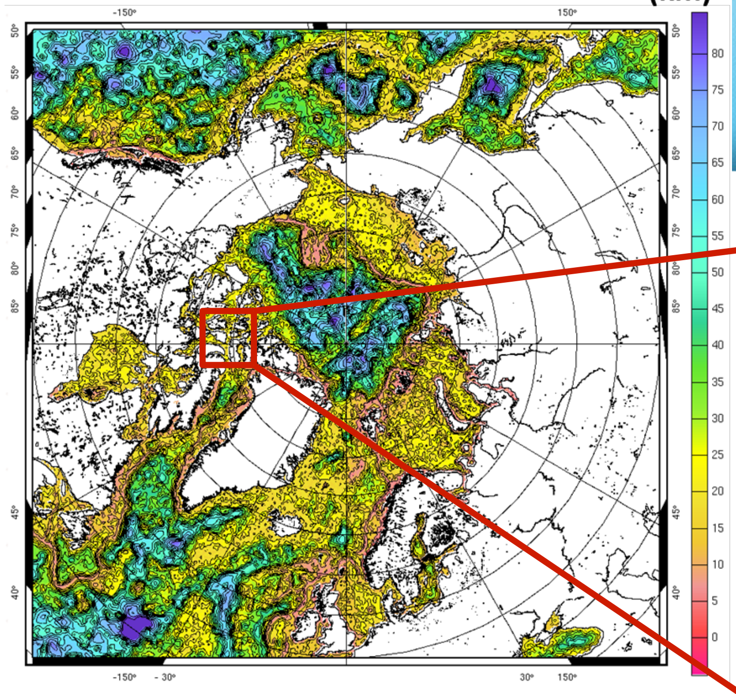
- Locally refine the resolution
  - Greenland East coast
  - Northwest Passage
  - North Pole…

  → Automatization of the mesh generation tools

Mesh refinement

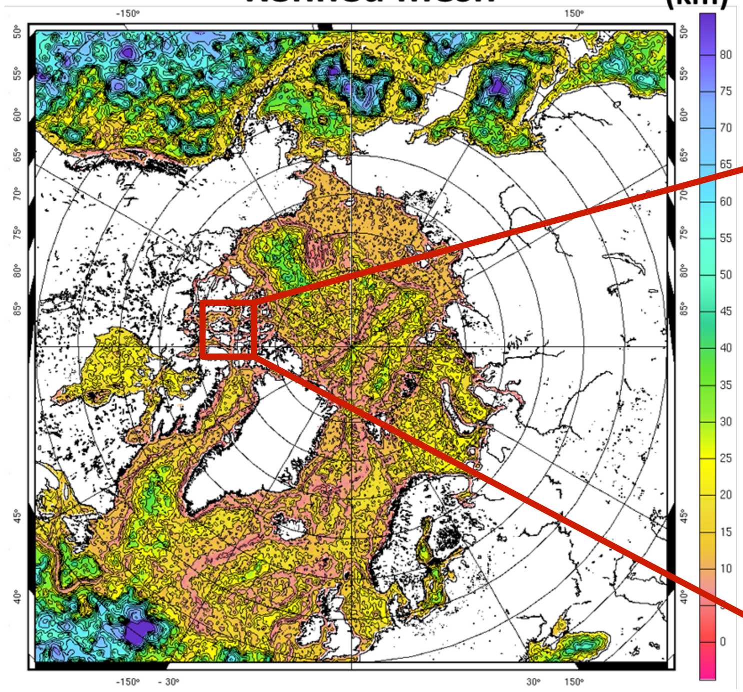
Initial mesh

(km)

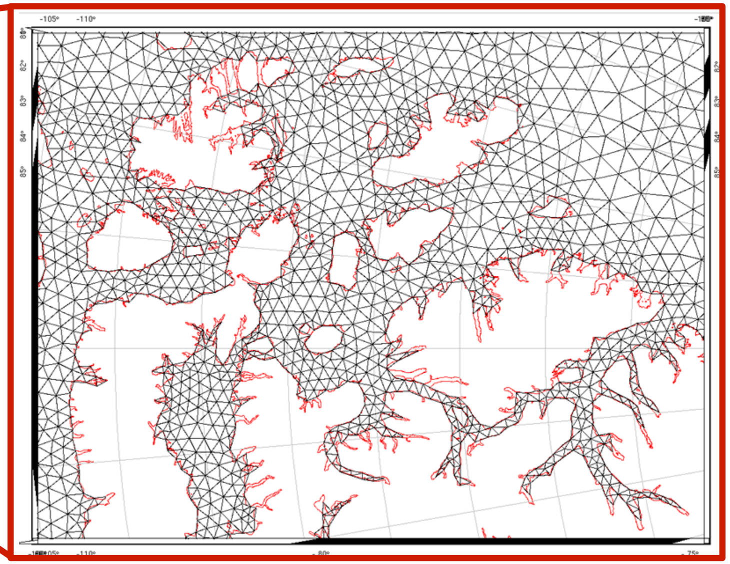


Refined mesh

(km)



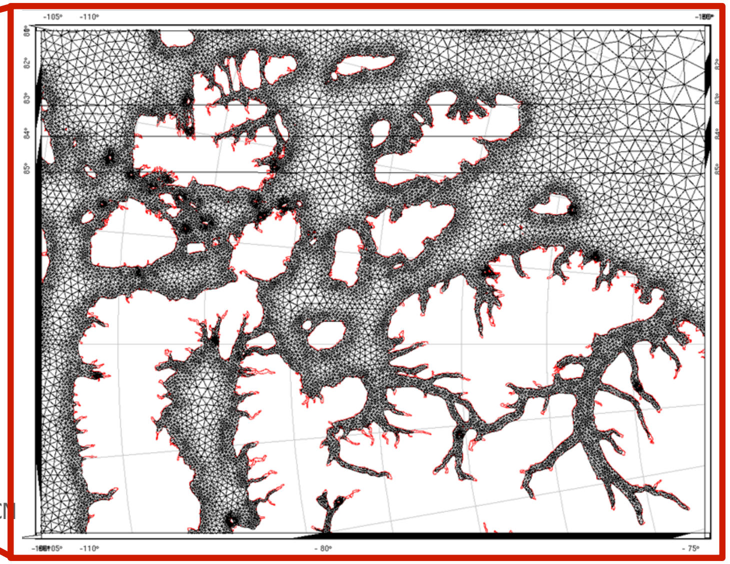
Initial mesh



Coast: 15 km

Offshore: ~25 km

Refined mesh



Coast: 4 km

Offshore: ~8 km

Mesh refinement

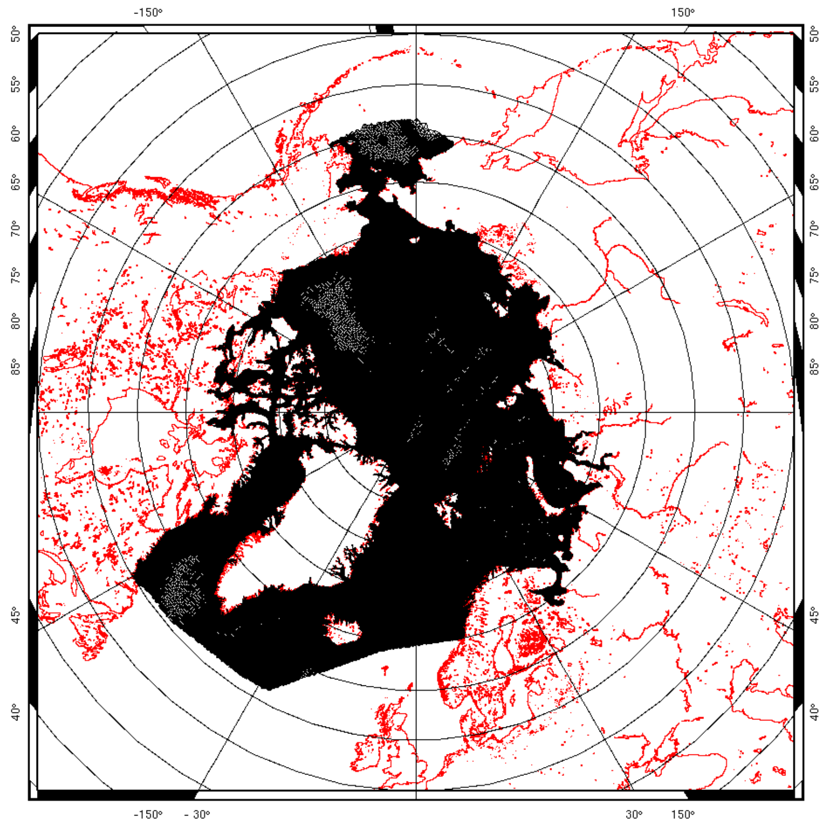
- Start with a global mesh (FES2014 +)

  → consistent for patching the regional solution in a global one

- Locally refine the resolution
  - Greenland East coast
  - Northwest Passage
  - North Pole…

  → Automatization of the mesh generation

- Define and extract the Arctic mesh



Number of vertices over the Arctic:

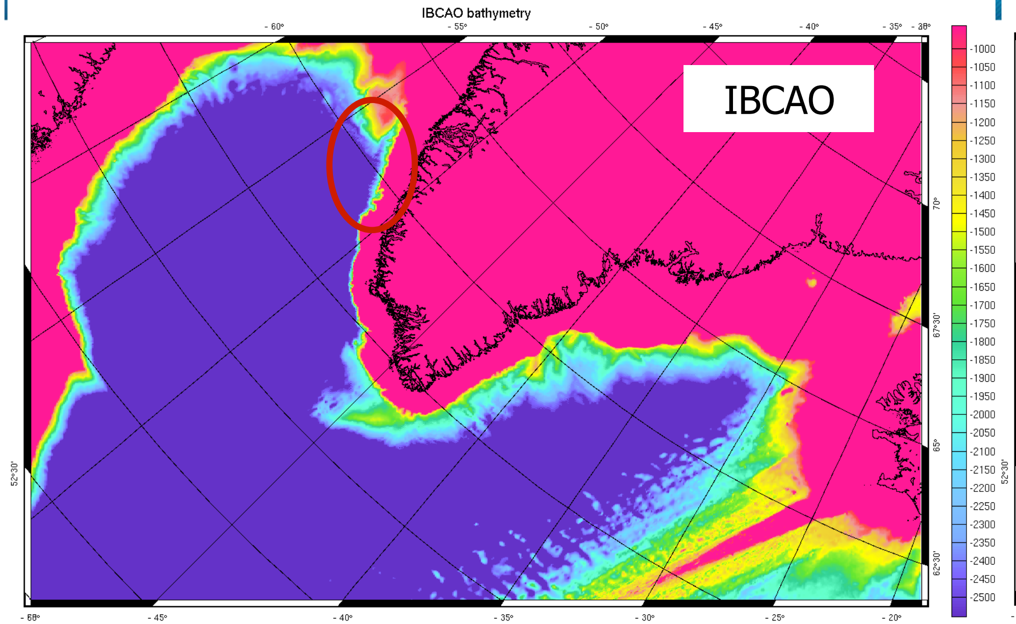
Final refined mesh: 267 980

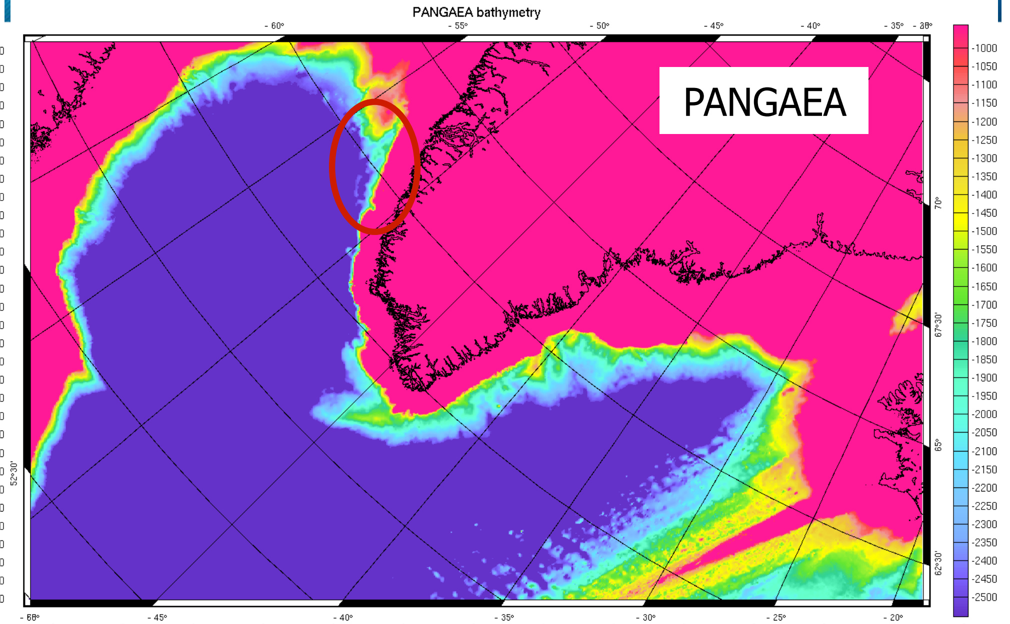
FES2014: 88 271 *(total: 797 366)*

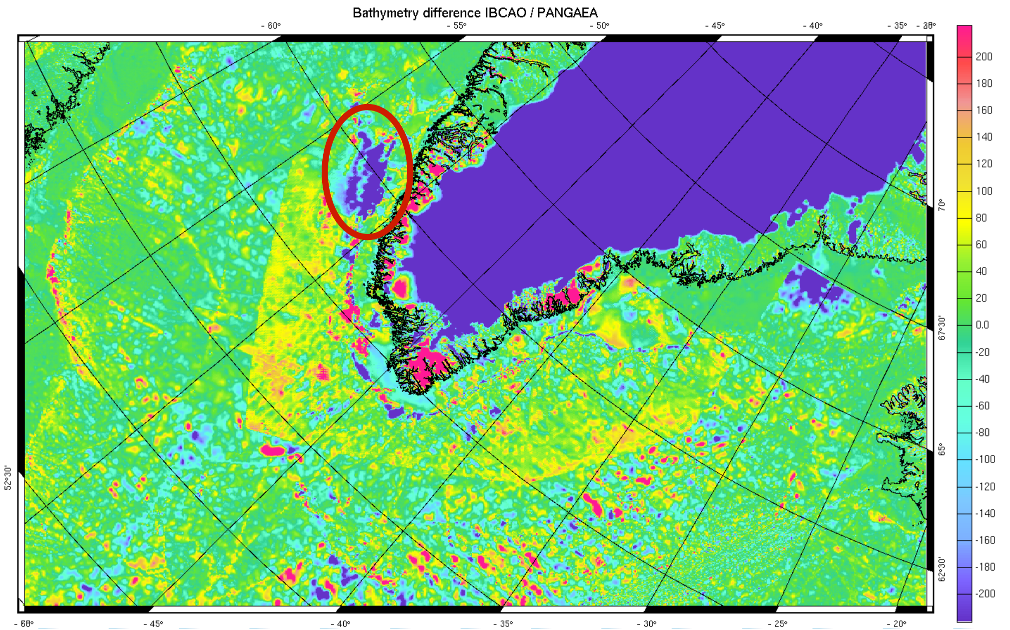
Bathymetry

- One of the most challenging aspects in tidal modeling…
  - Basis: IBCAO
  - Test: PANGAEA global bathymetry from Timmerman et al

Bathymetry


IBCAO bathymetry
IBCAO


PANGAEA bathymetry
PANGAEA


Bathymetry difference IBCAO / PANGAEA

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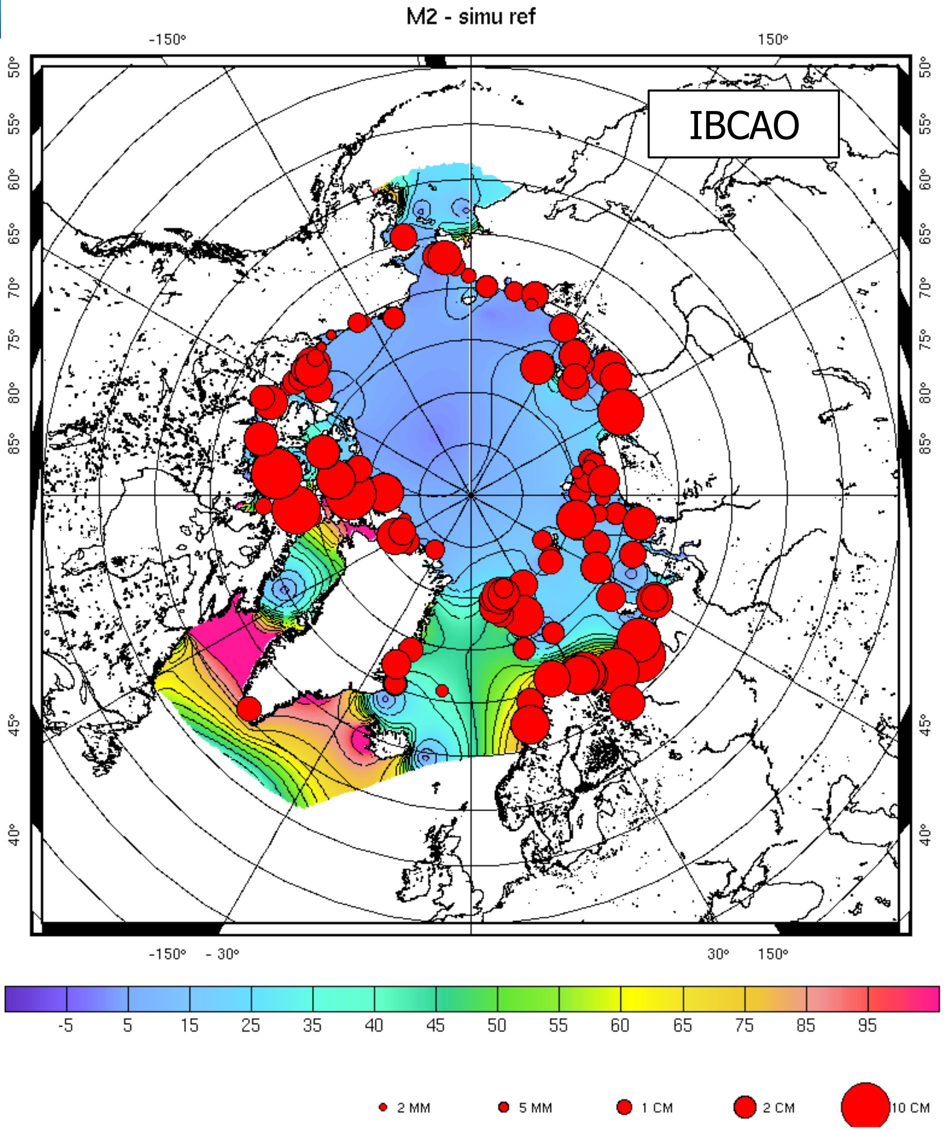
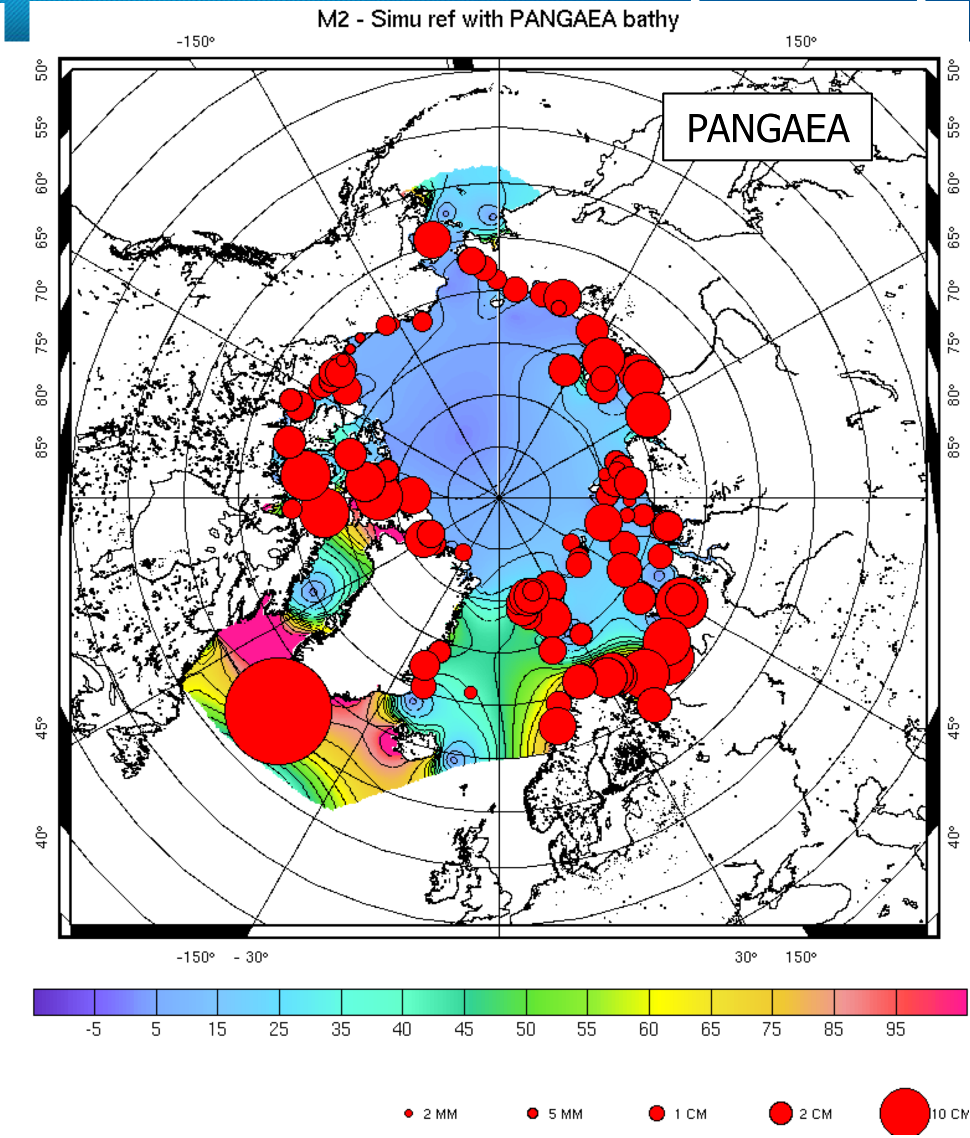
Bathymetry

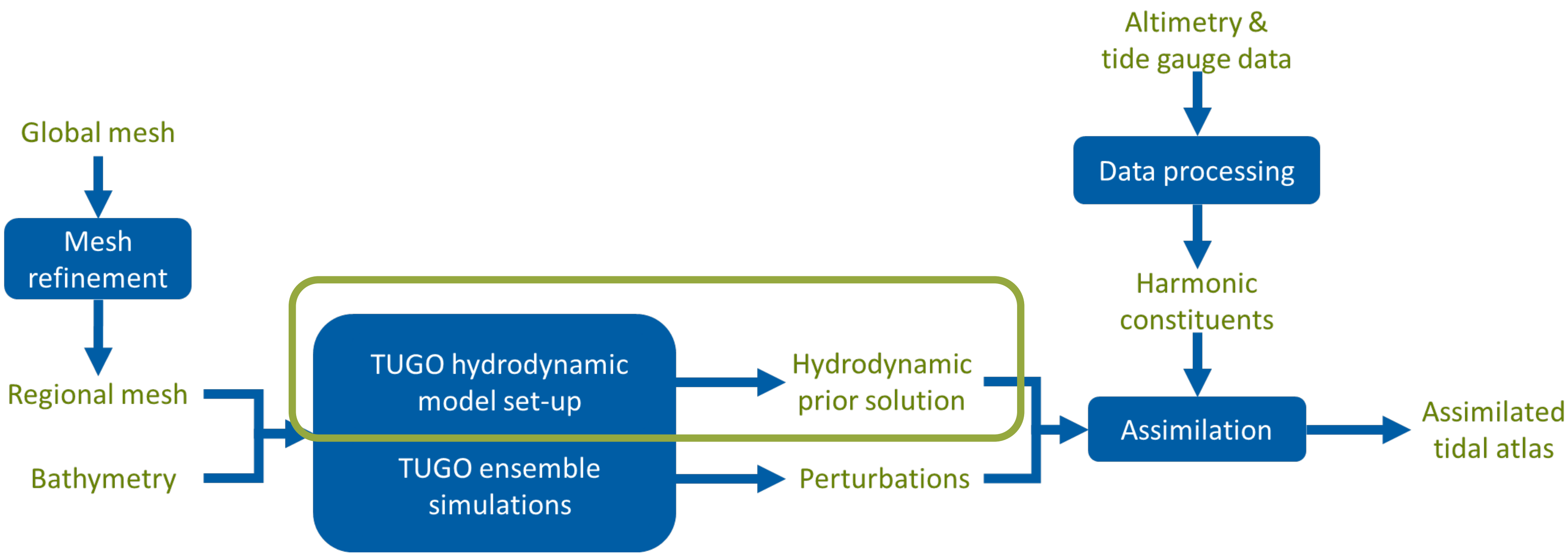




→ Large impact of the bathymetry differences at the South of Greenland

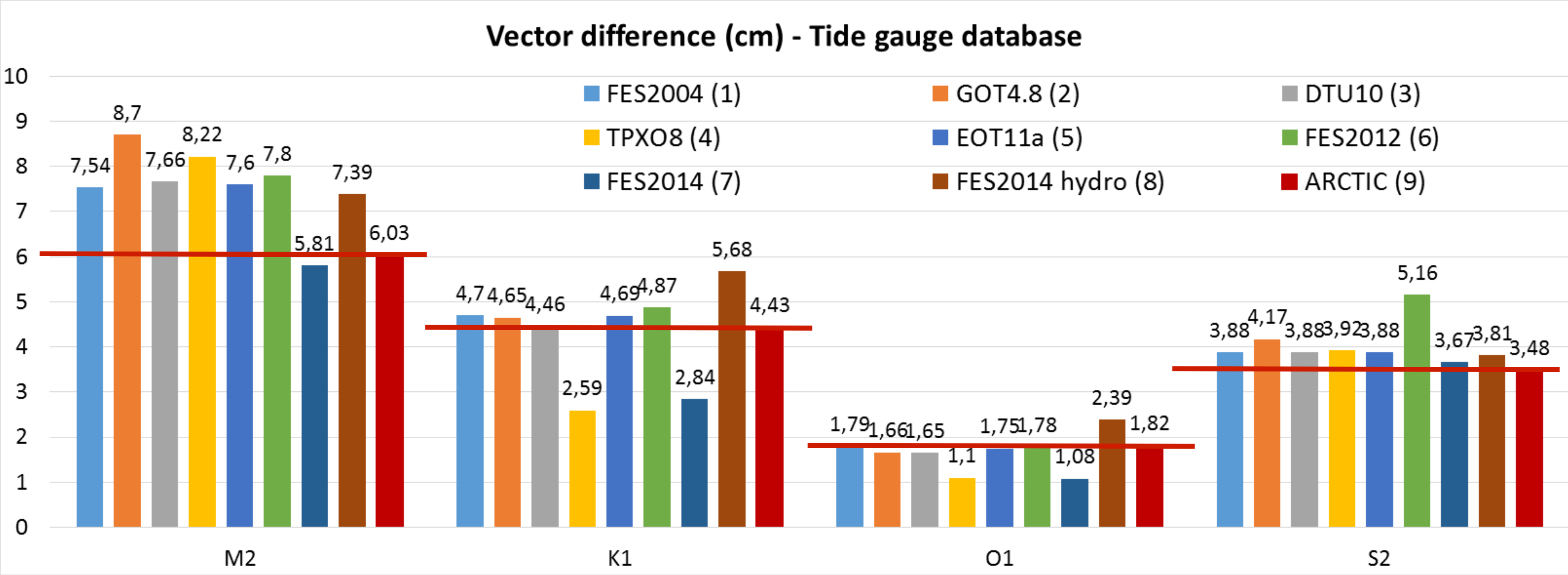
Hydrodynamic model set-up

- TUGO hydrodynamic model from LEGOS



Hydrodynamic model set-up

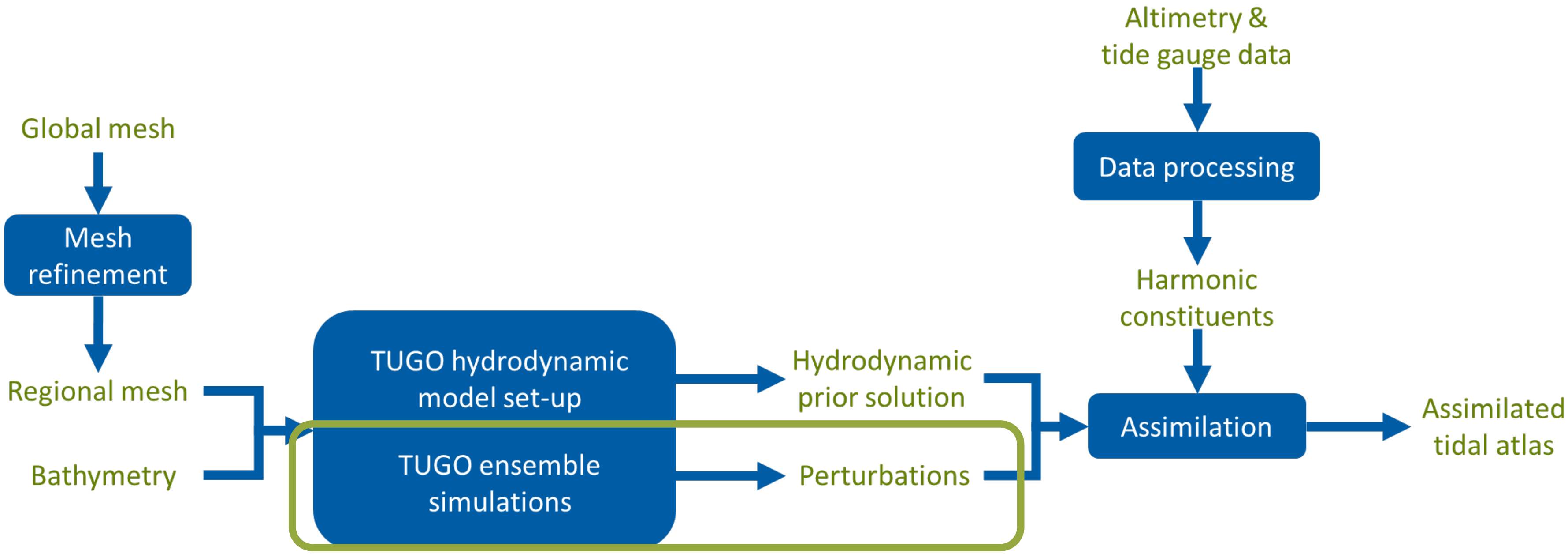
- TUGO hydrodynamic model from LEGOS
  - Tuning of the bottom friction coefficient



→ The best regional hydrodynamic (non-assimilated) solution obtained with bottom friction tuning has equivalent performances to the assimilated global models.

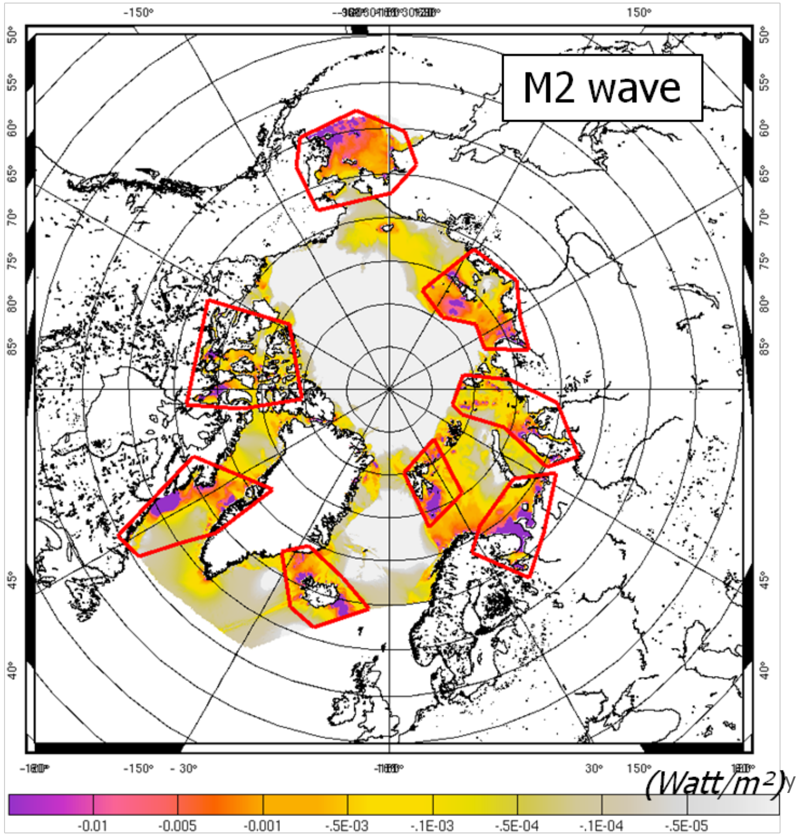
Ensemble simulation

- Generation of perturbations



Ensemble simulation

- Local perturbations of the bottom friction coefficient
  - 8 regions
  - Global coefficient: 5.10^{-3} m
  - Local coefficient: 13 values between 10^{-4} m and 0.1 m

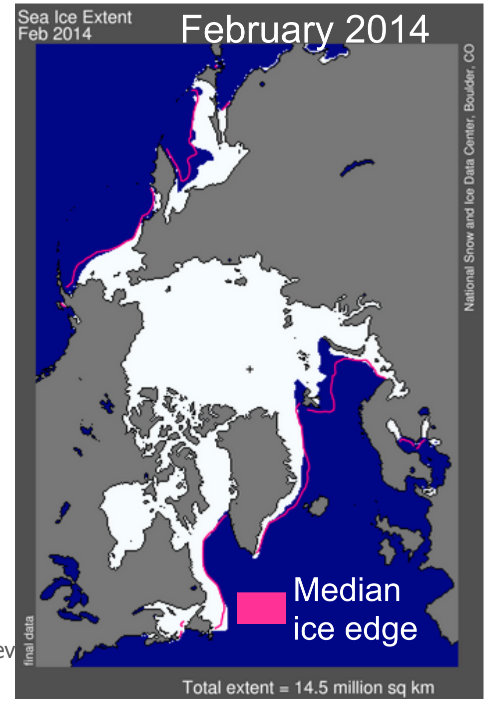


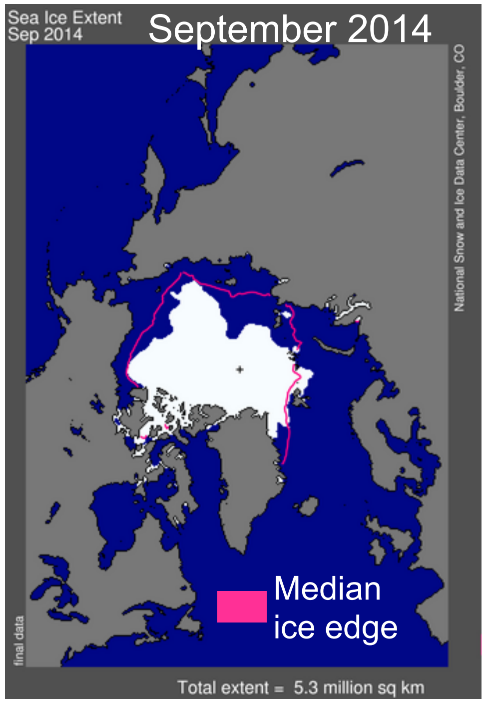
Regions of bottom friction perturbations based on the energy dissipation

Ensemble simulation

- Local perturbations of the bottom friction coefficient
  - 8 regions
  - Global coefficient: 5.10^{-3} m
  - Local coefficient: 13 values between 10^{-4} m and 0.1 m
- Same thing when considering the sea ice extent: double the bottom friction under the ice
  - Median Summer extent
  - Median Winter extent

➔ 312 hydrodynamic simulations

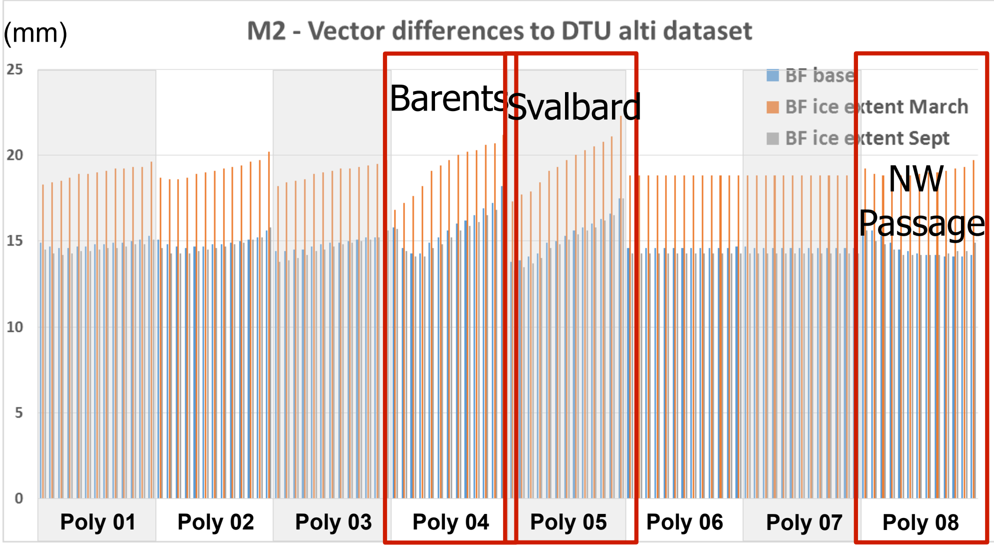


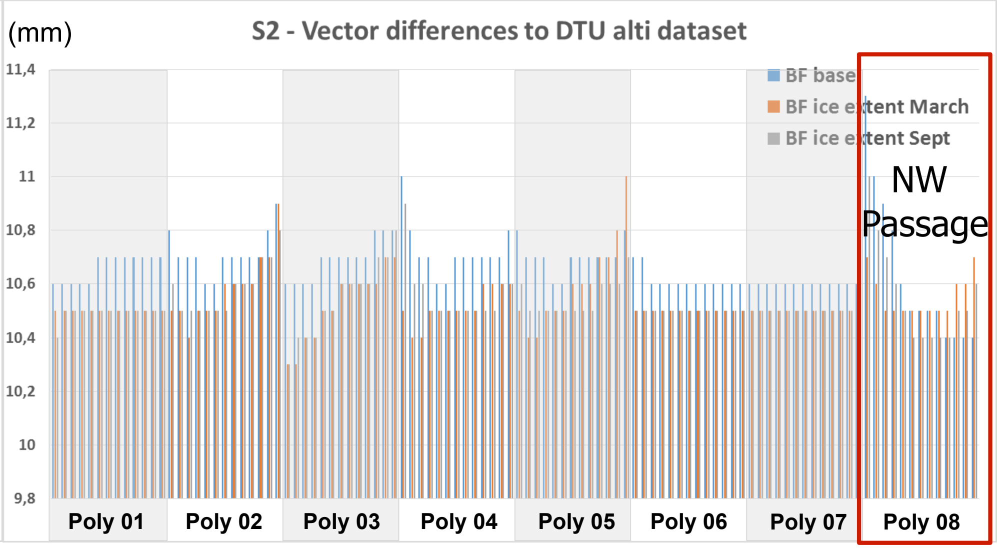


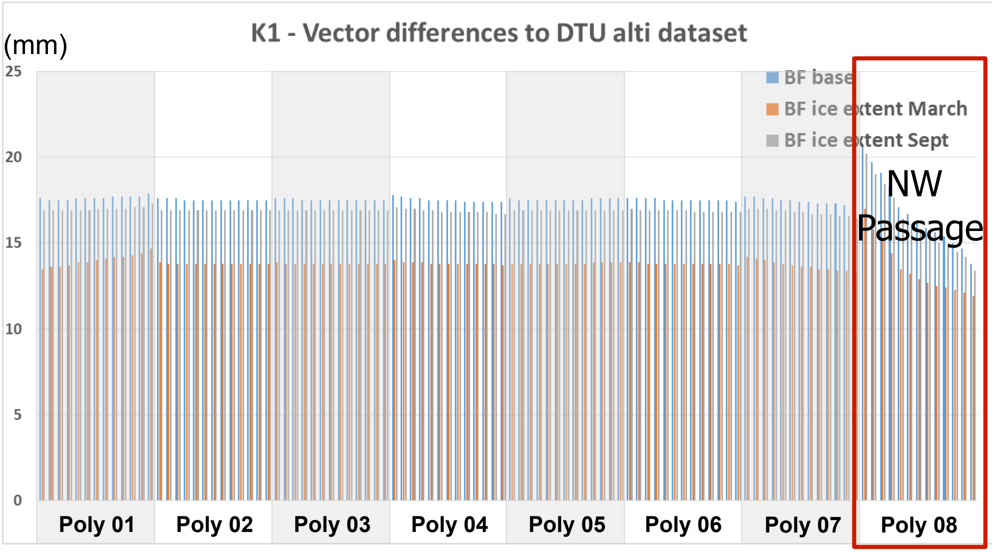
Maps and shapefiles from NSIDC

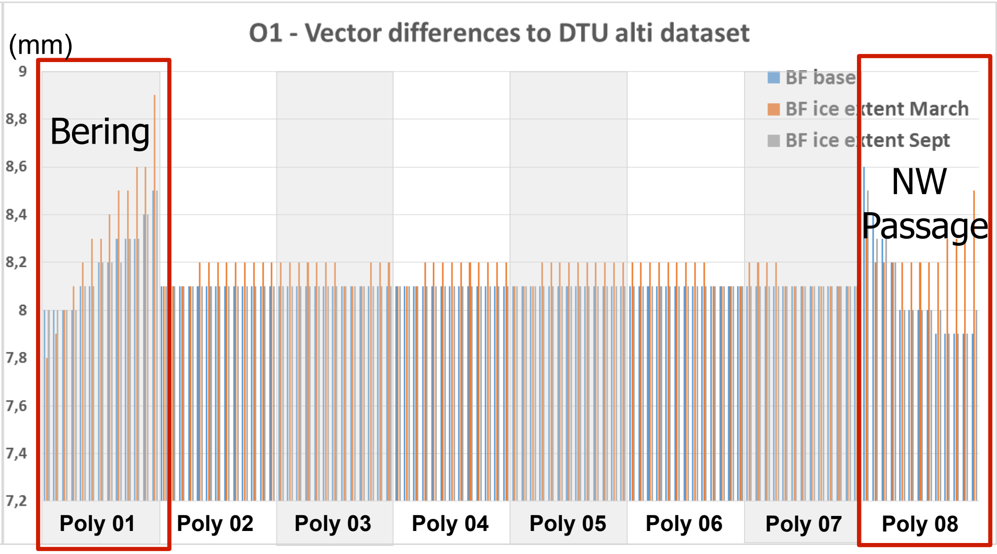
Ensemble simulation

- Local perturbations of the bottom friction coefficient

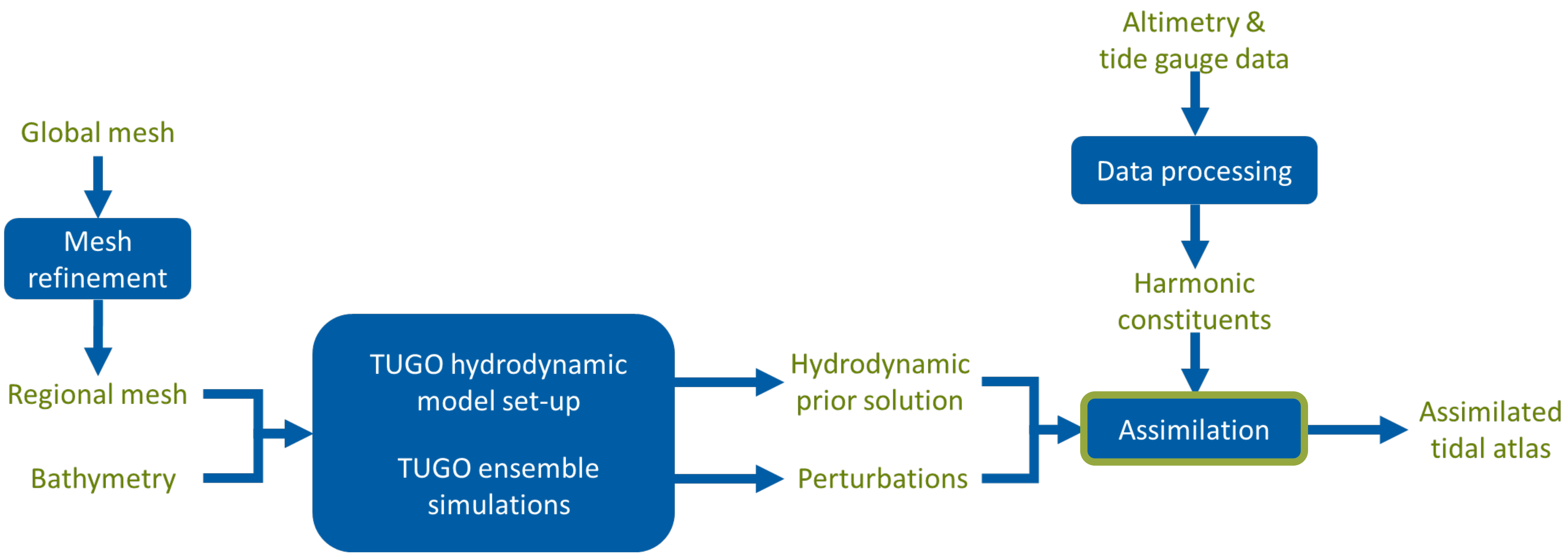








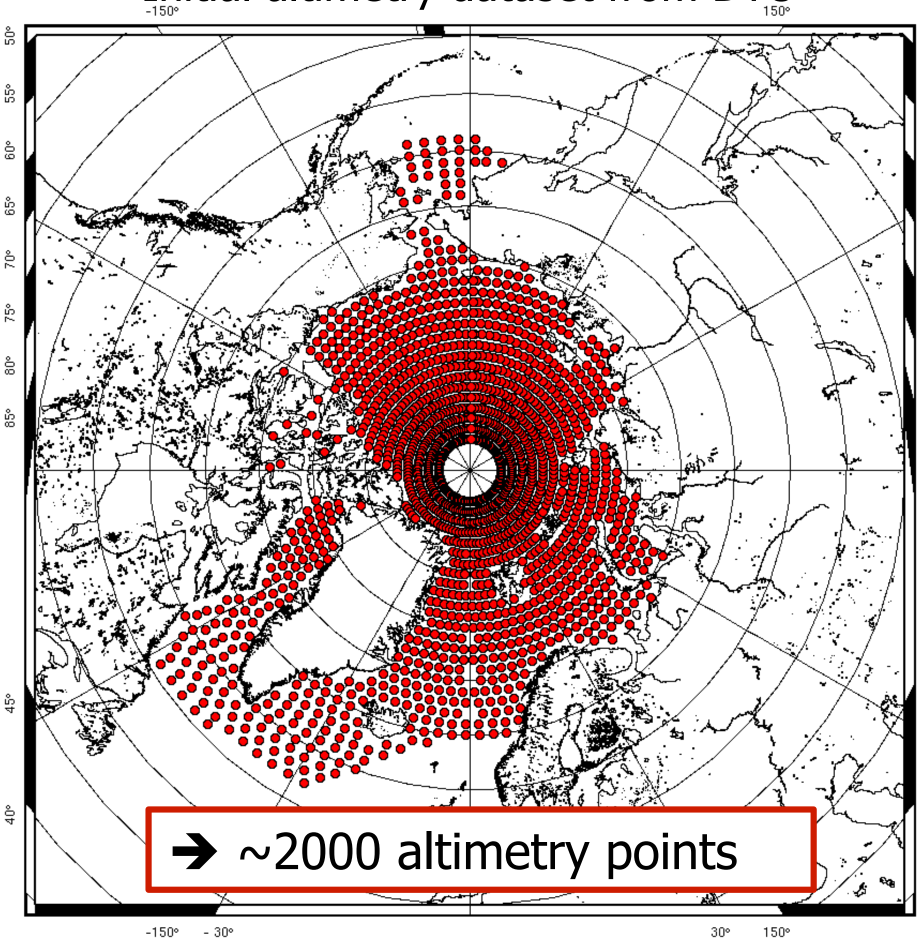
Assimilation



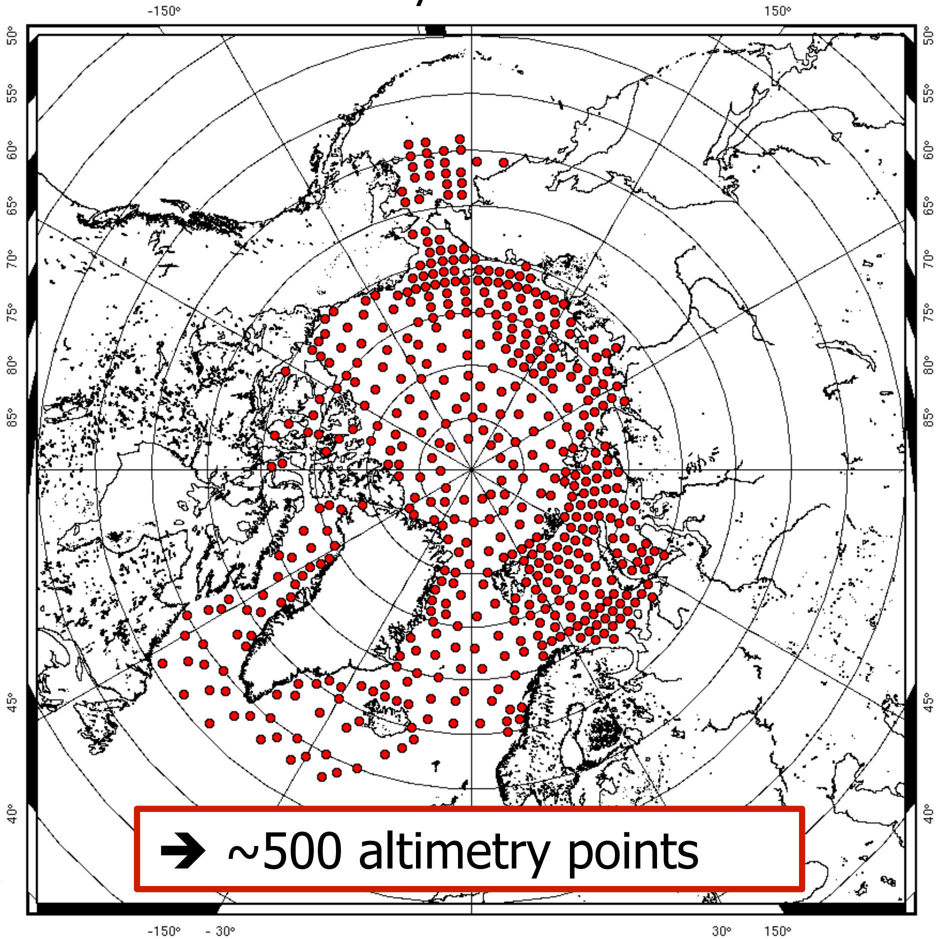
Assimilation

- Selection of the altimetry and tide gauge data
  - Decimation of the altimetry data: 200 km offshore, 100 km on the shelves

Initial altimetry dataset from DTU



Decimated altimetry dataset for assimilation



- Selection of the altimetry and tide gauge data
  - Selection of the tide gauge data:
    - Not much confidence in the available data: old datasets, sometimes only a few tidal components, elevation time series not available, Russian tide gauges from the 1980s, etc…
    - Strict editing performed by LEGOS and NOVELTIS over the years (ex: detection of clock problems)

    ➔Starting with about 400 stations, the dataset now contains ~120 stations

Selection of the altimetry and tide gauge data

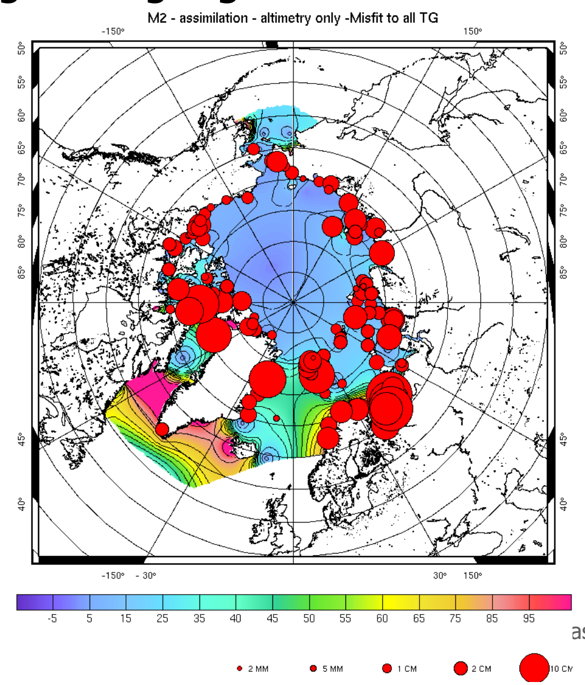
Selection of the tide gauge data:

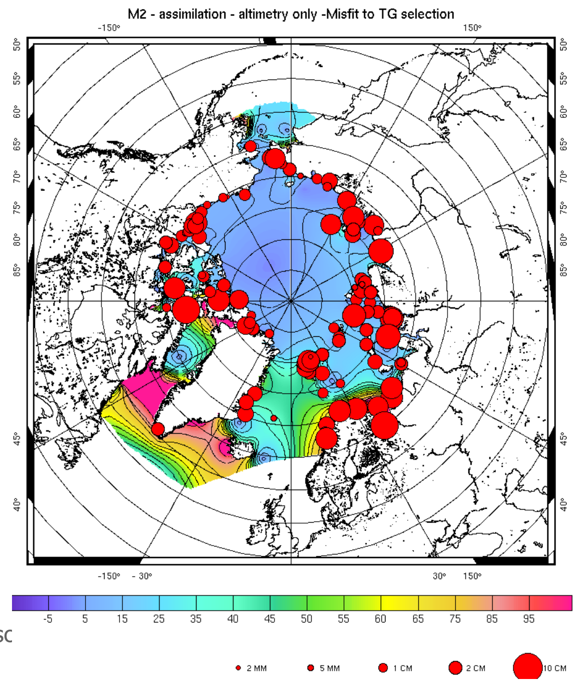
- Editing strategy:

1/ Assimilate only altimetry in the M2 component (most reliable)

2/ Remove the tide gauge stations with large misfit to the M2 solution computed at 1/

➔The remaining tide gauge stations are considered as the most reliable and are assimilated.





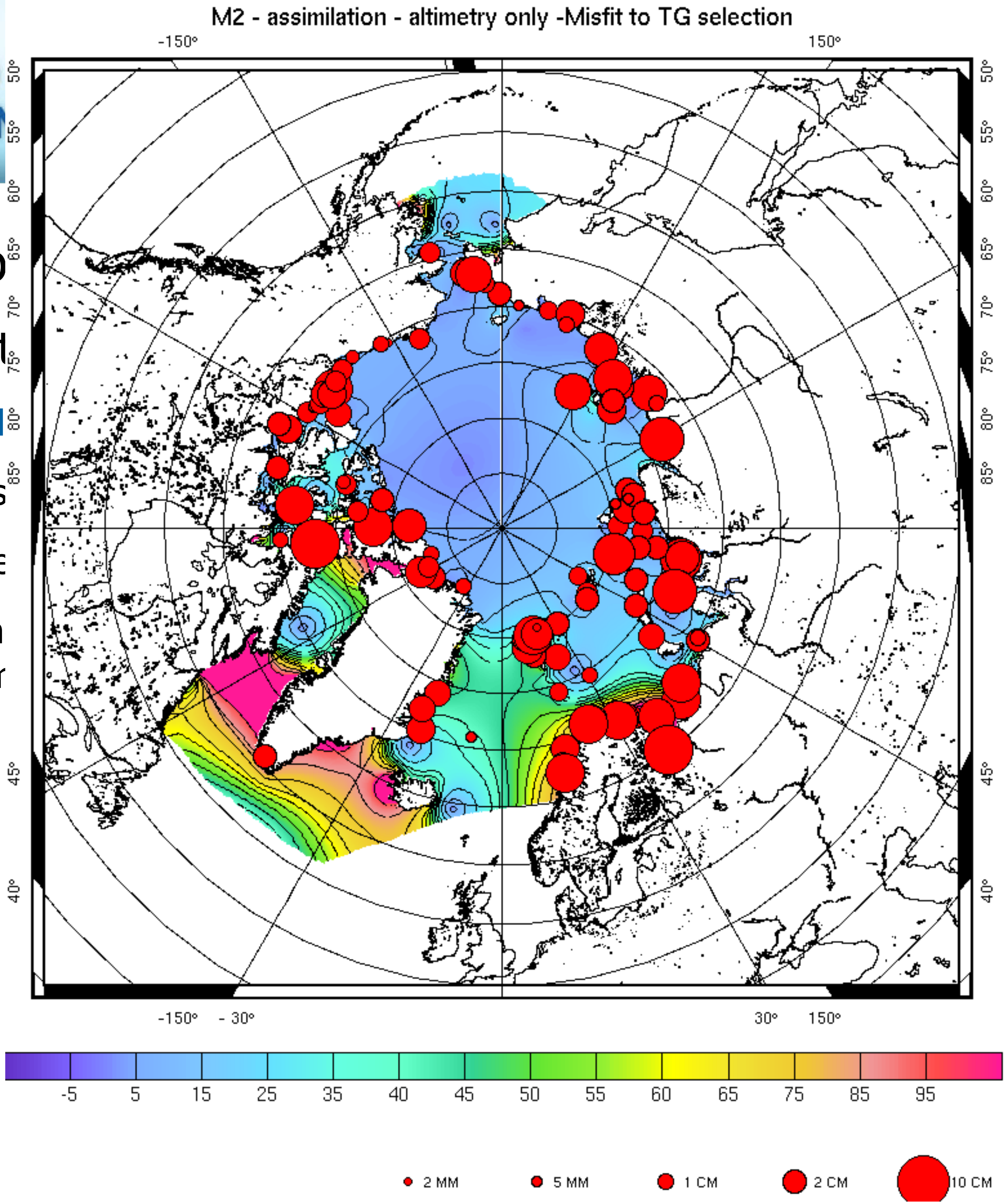
...similation

- Selectio...
  - Select...
    - Ed...

1/ As...

2/ Re... ...n computed at 1/

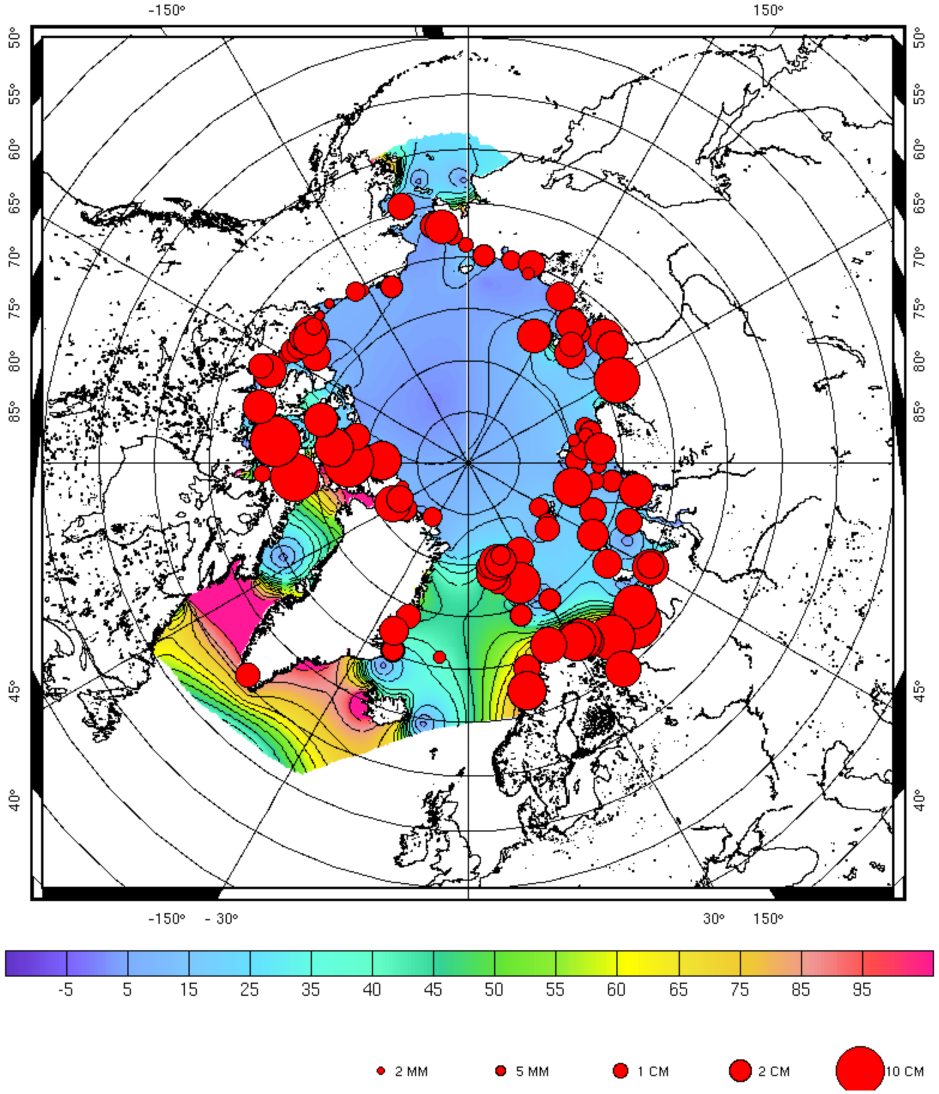
➔Th... ...t reliable and are assim...



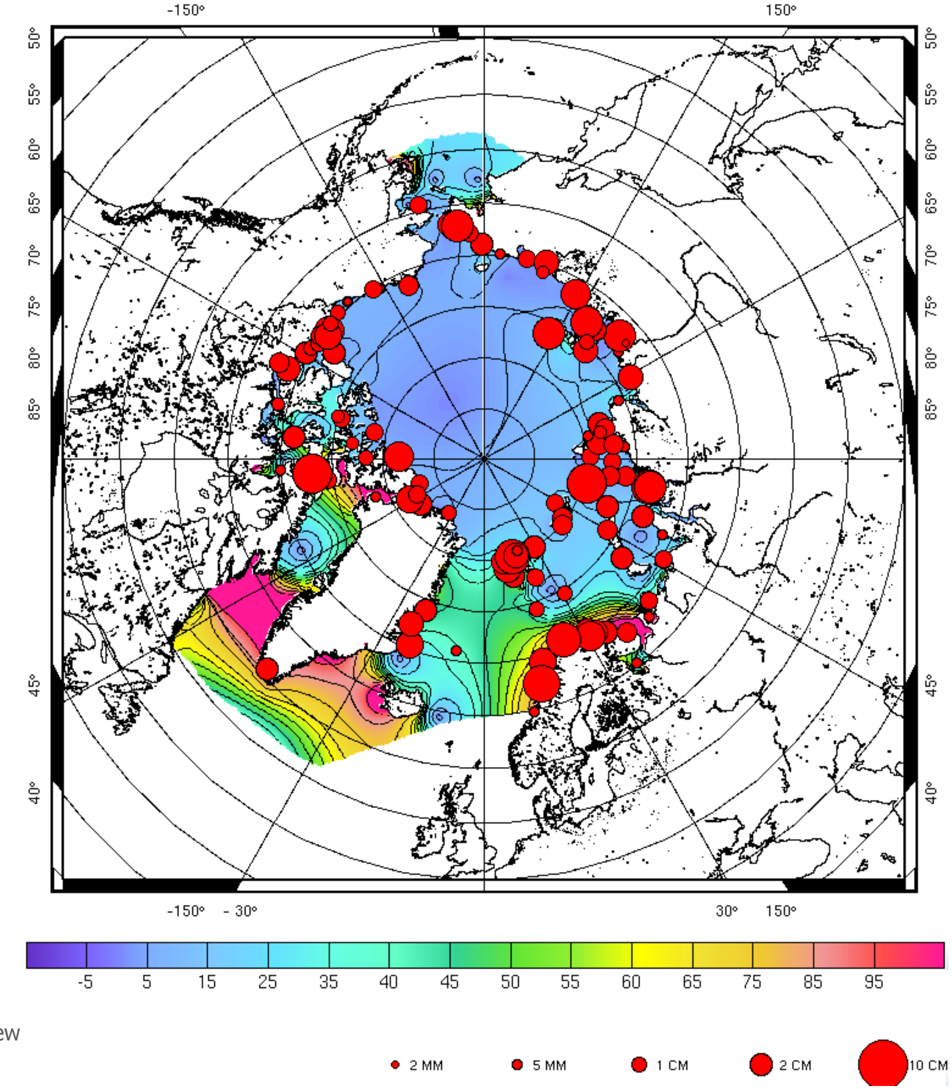
Assimilation (on-going work)

- Assimilation experiments: M2 tidal component

M2 - simu ref



M2 - Assimilation



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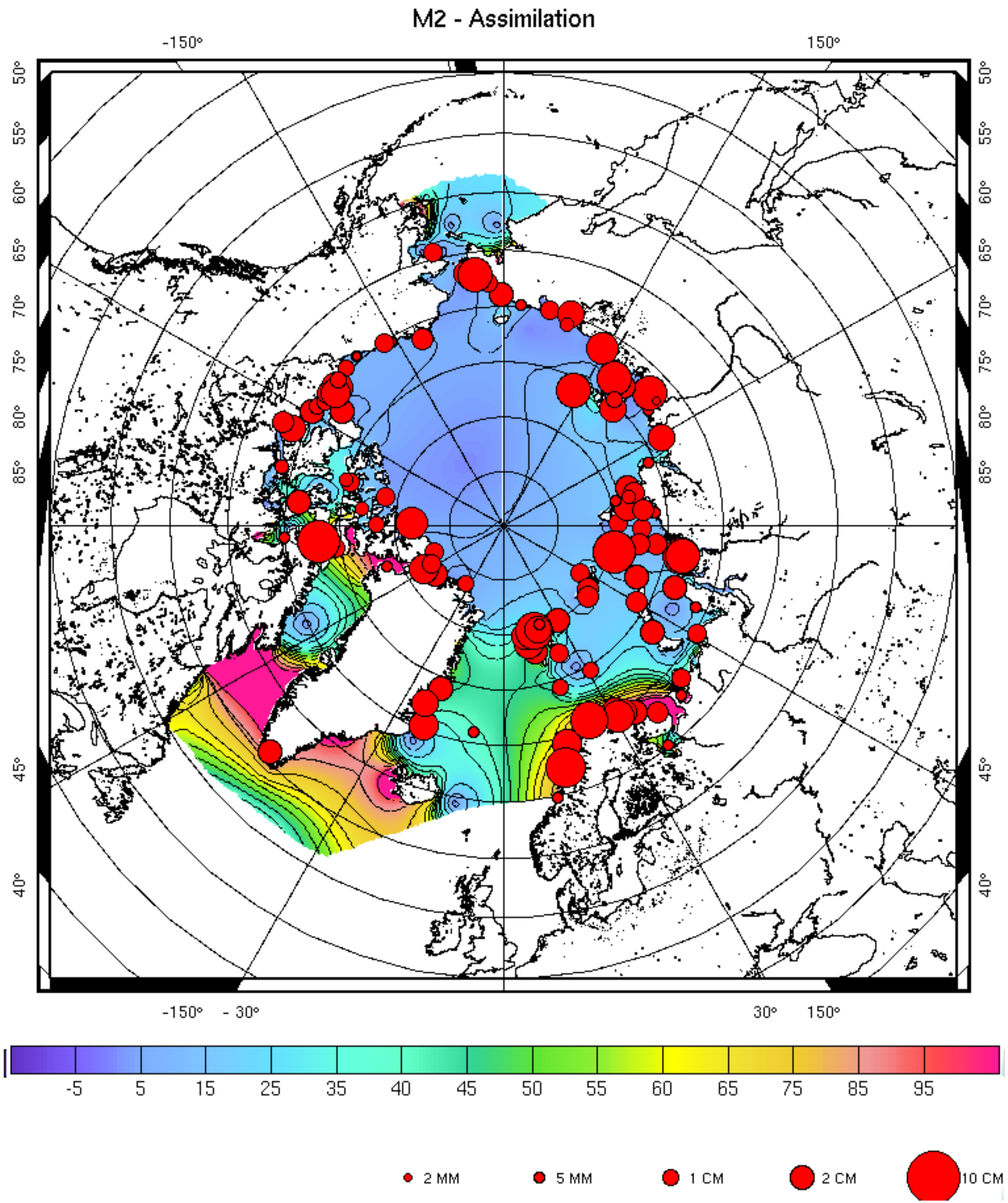
- Assimilat...



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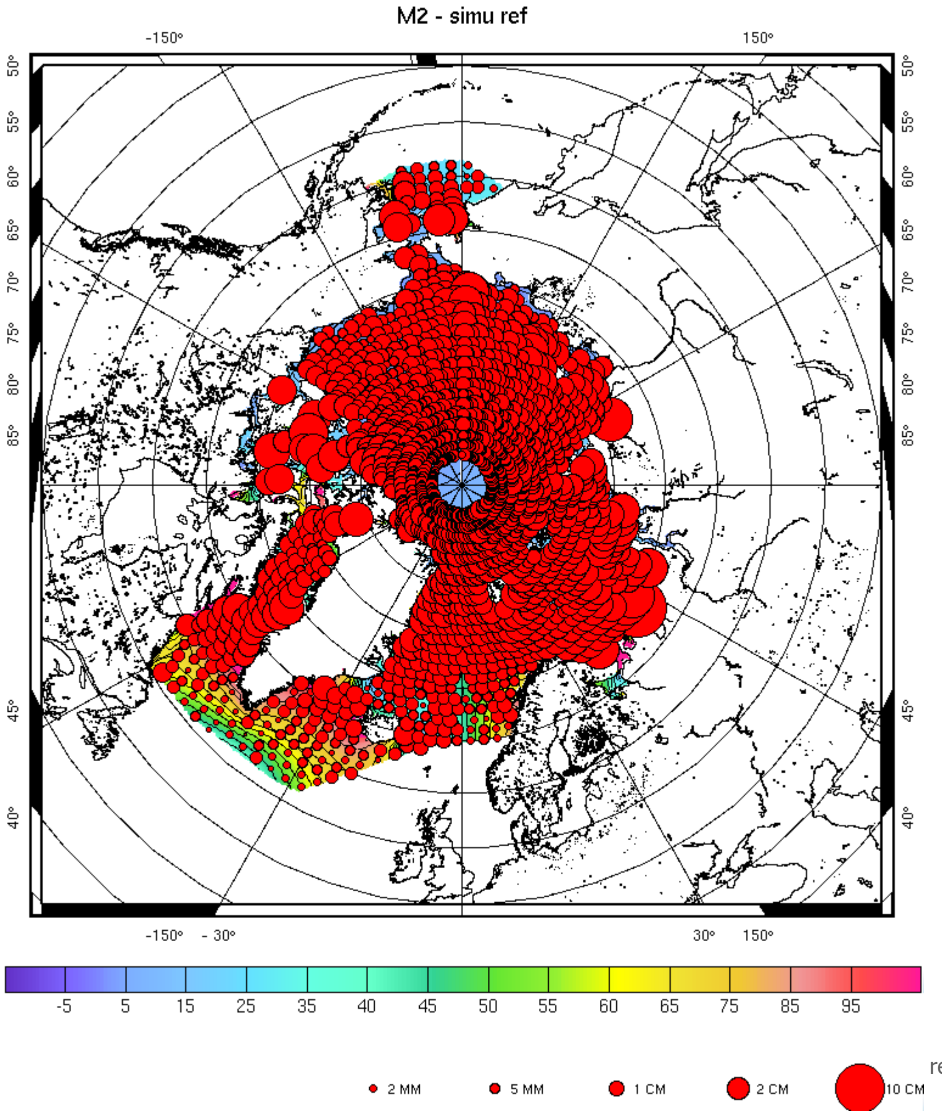

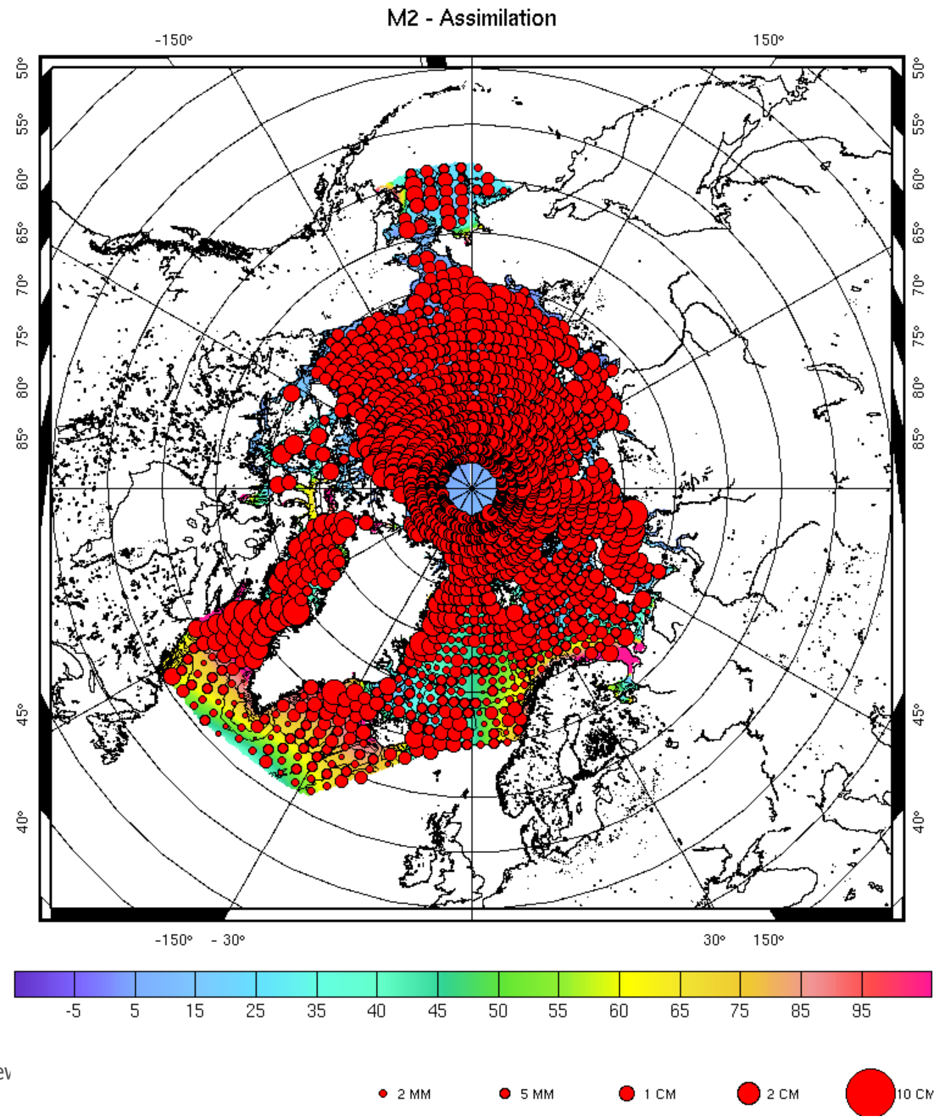

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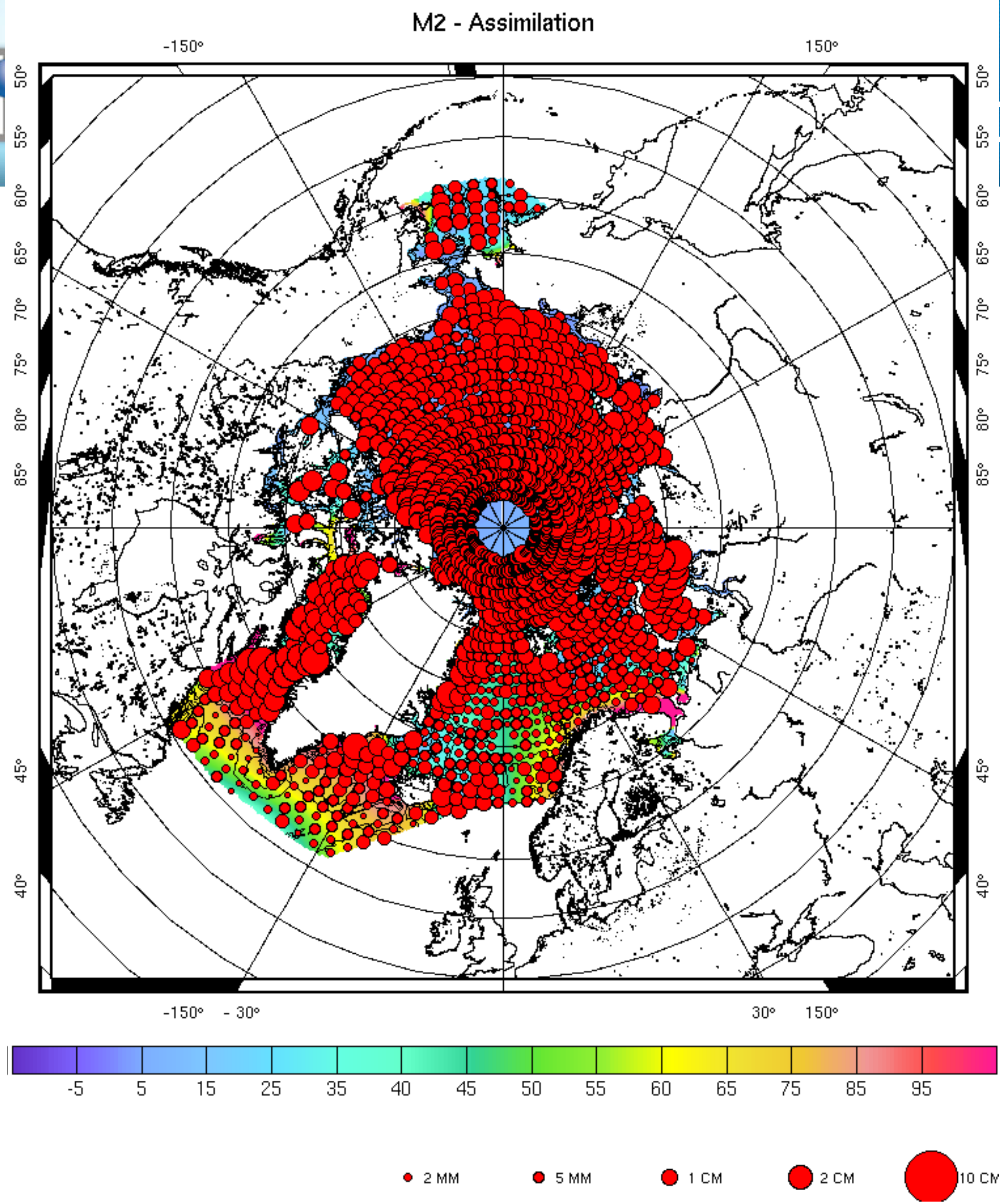
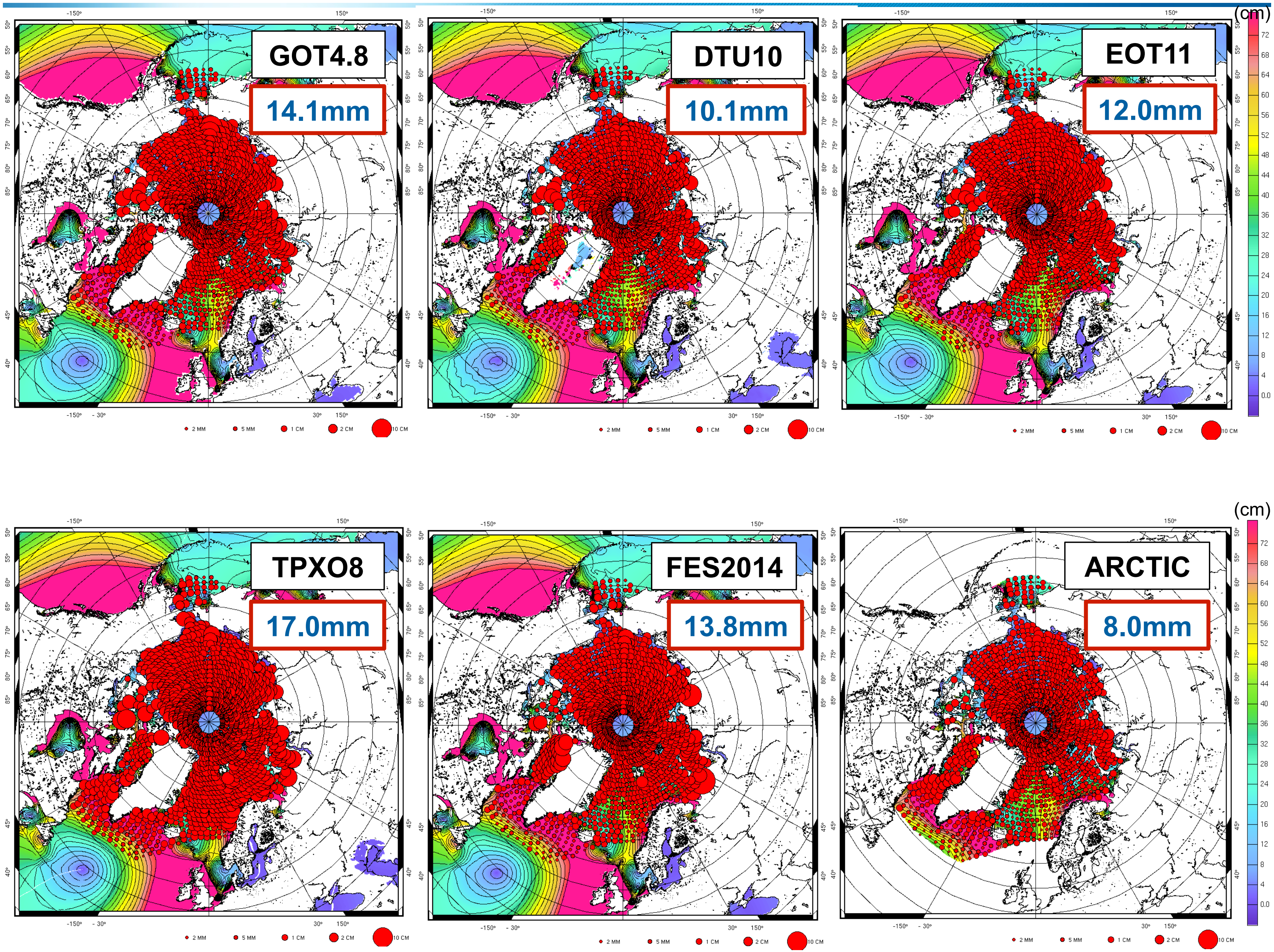
- Assimi




GOT4.8
14.1mm
DTU10
10.1mm
EOT11
12.0mm
TPXO8
17.0mm
FES2014
13.8mm
ARCTIC
8.0mm
(cm)
72
68
64
60
56
52
48
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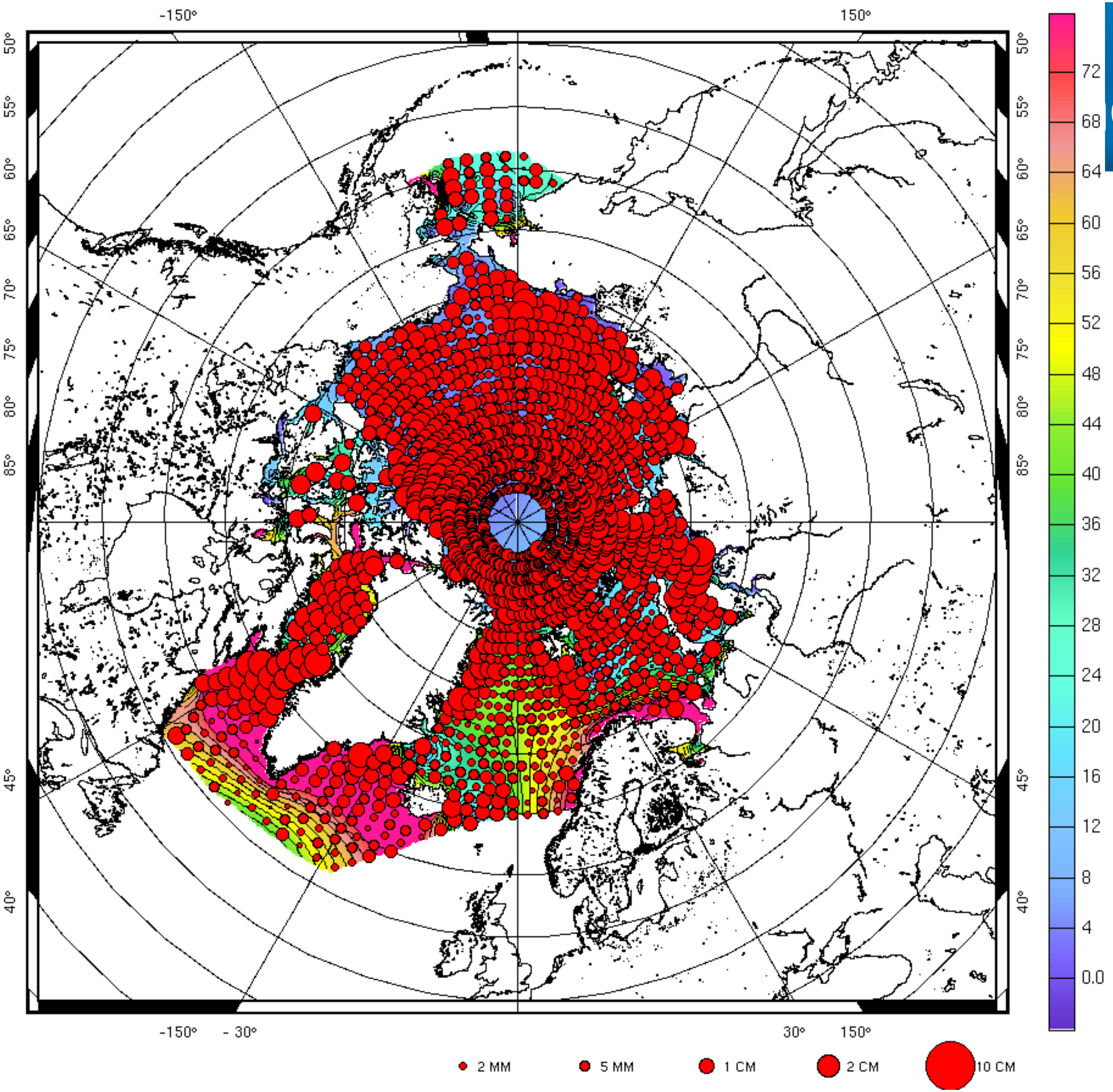

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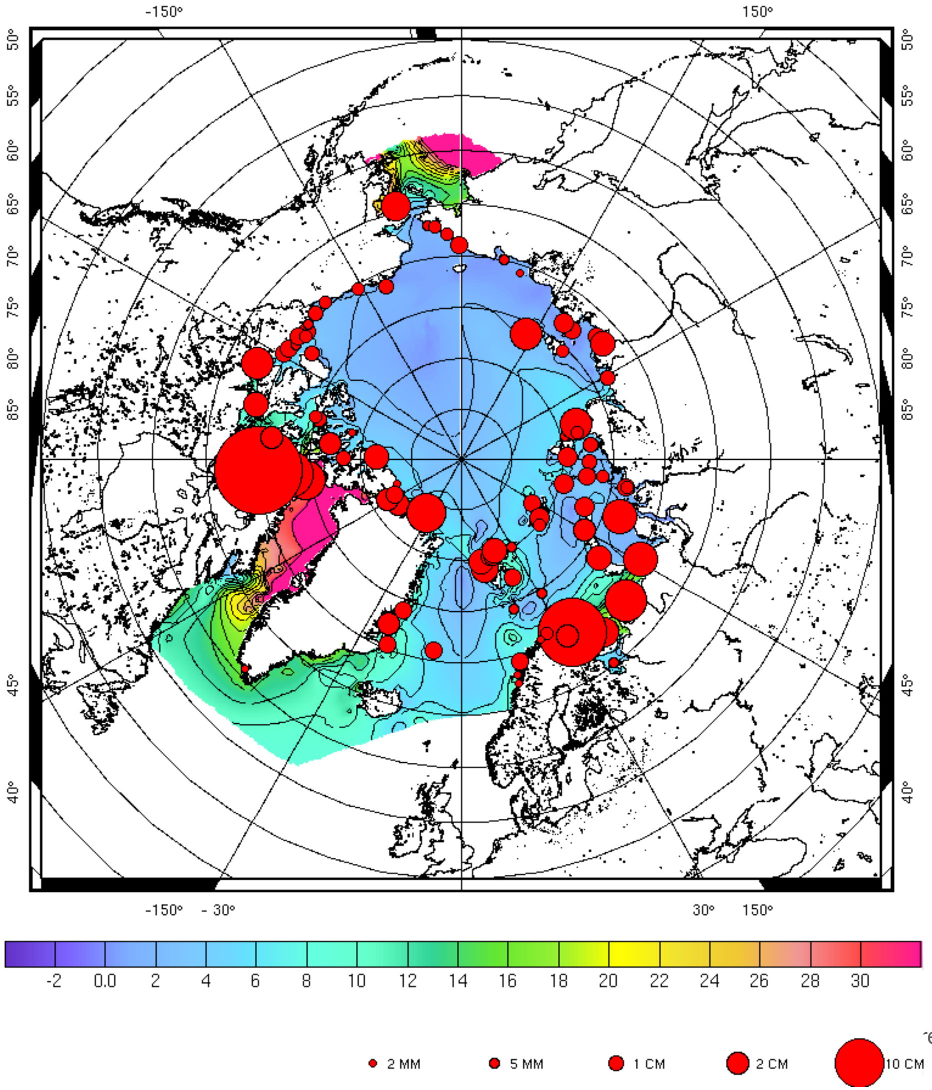
8.0mm

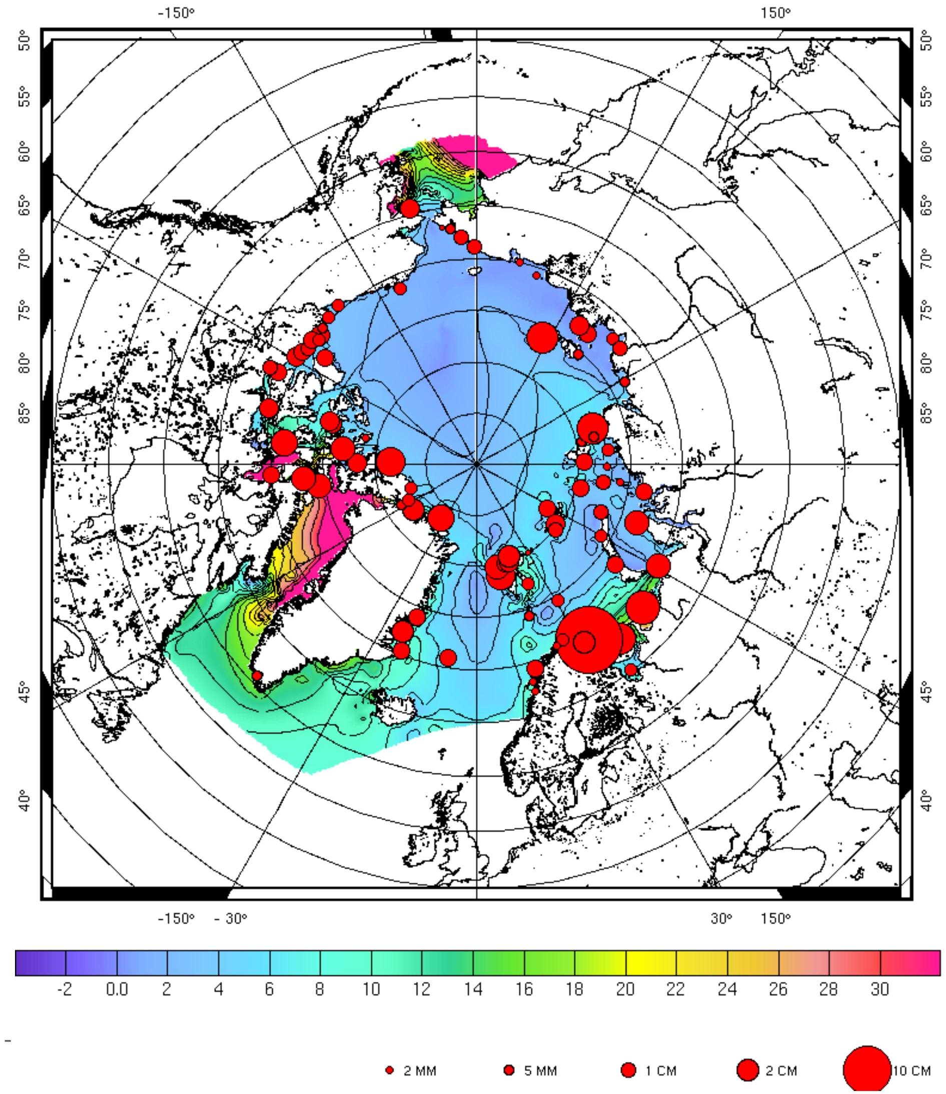
Assimilation (on-going work)

- Assimilation experiments: K1 tidal component

K1 - Simu ref



K1 - Assimilation



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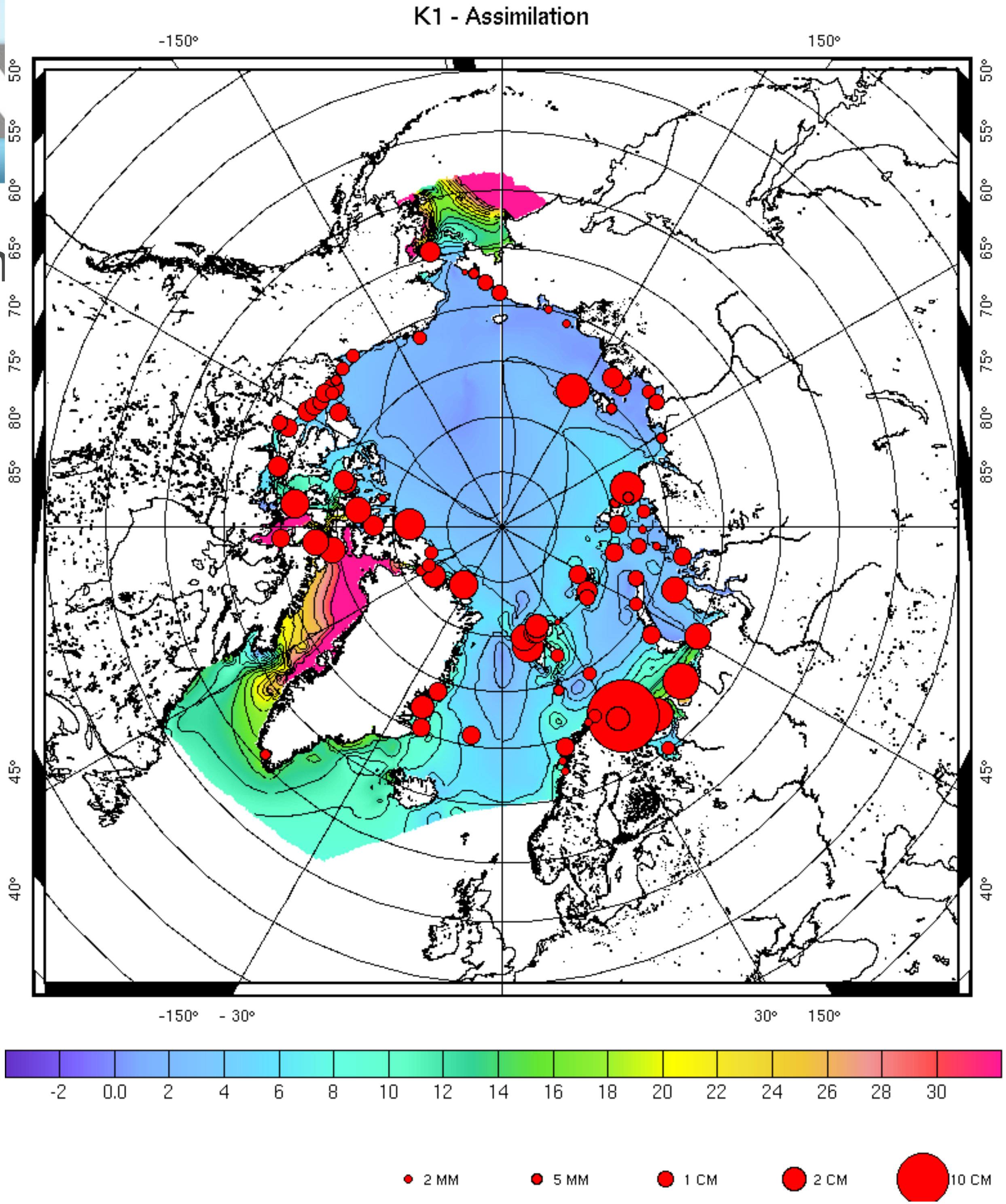
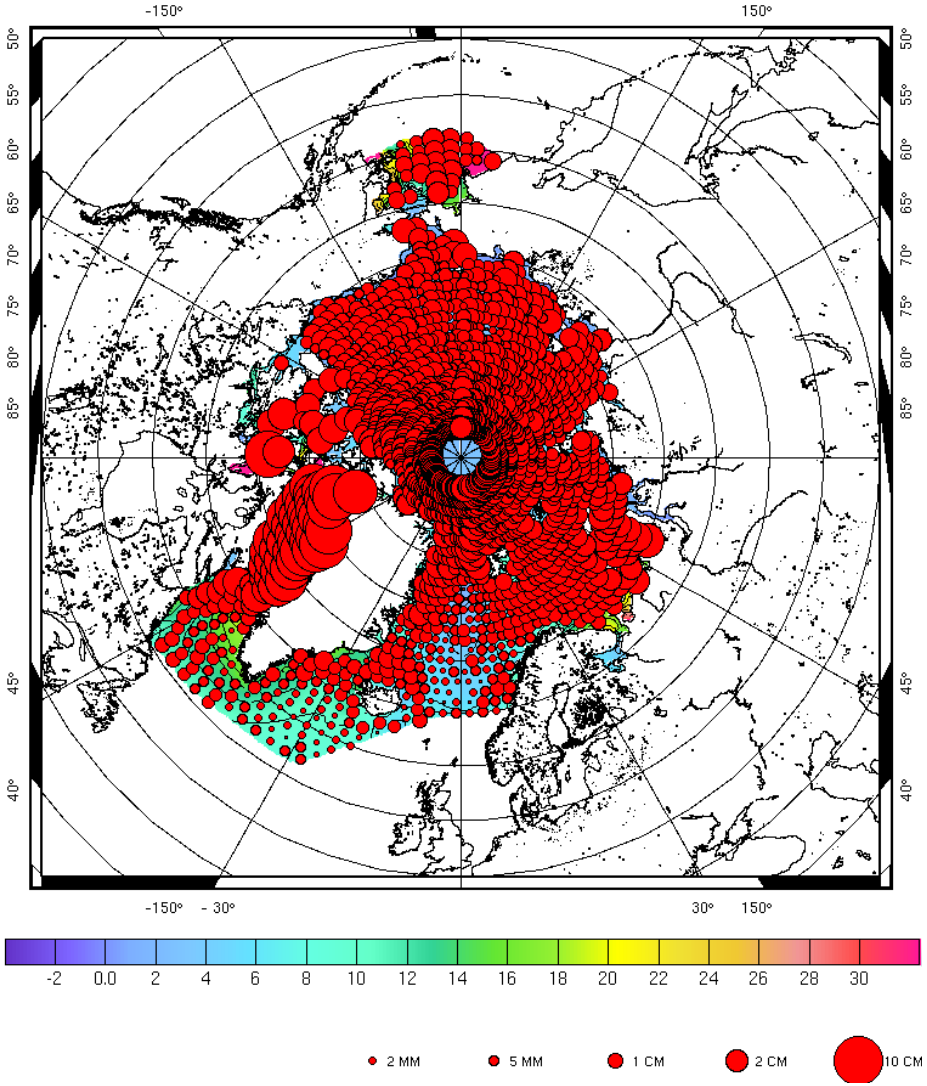


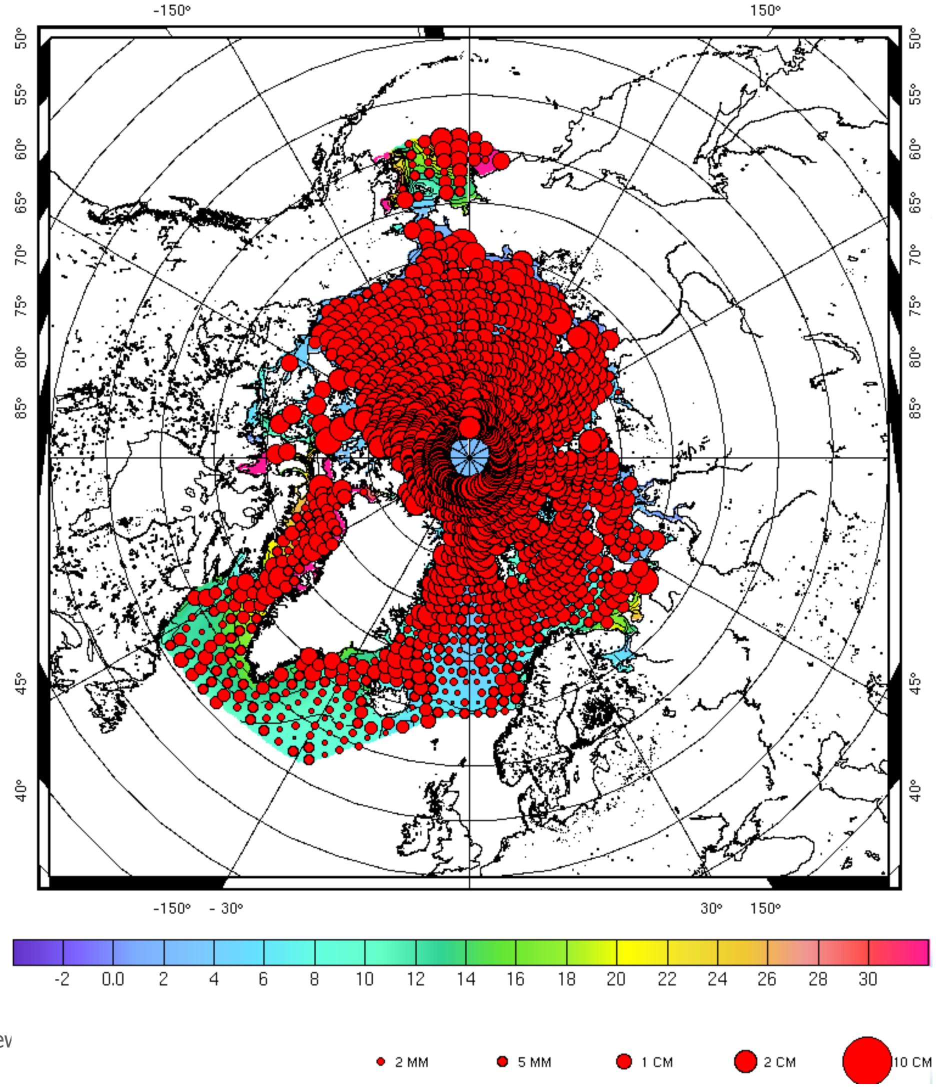
Assimilation (on-going work)

- Assimilation experiments: K1 tidal component

K1 - simu ref



K1 - Assimilation



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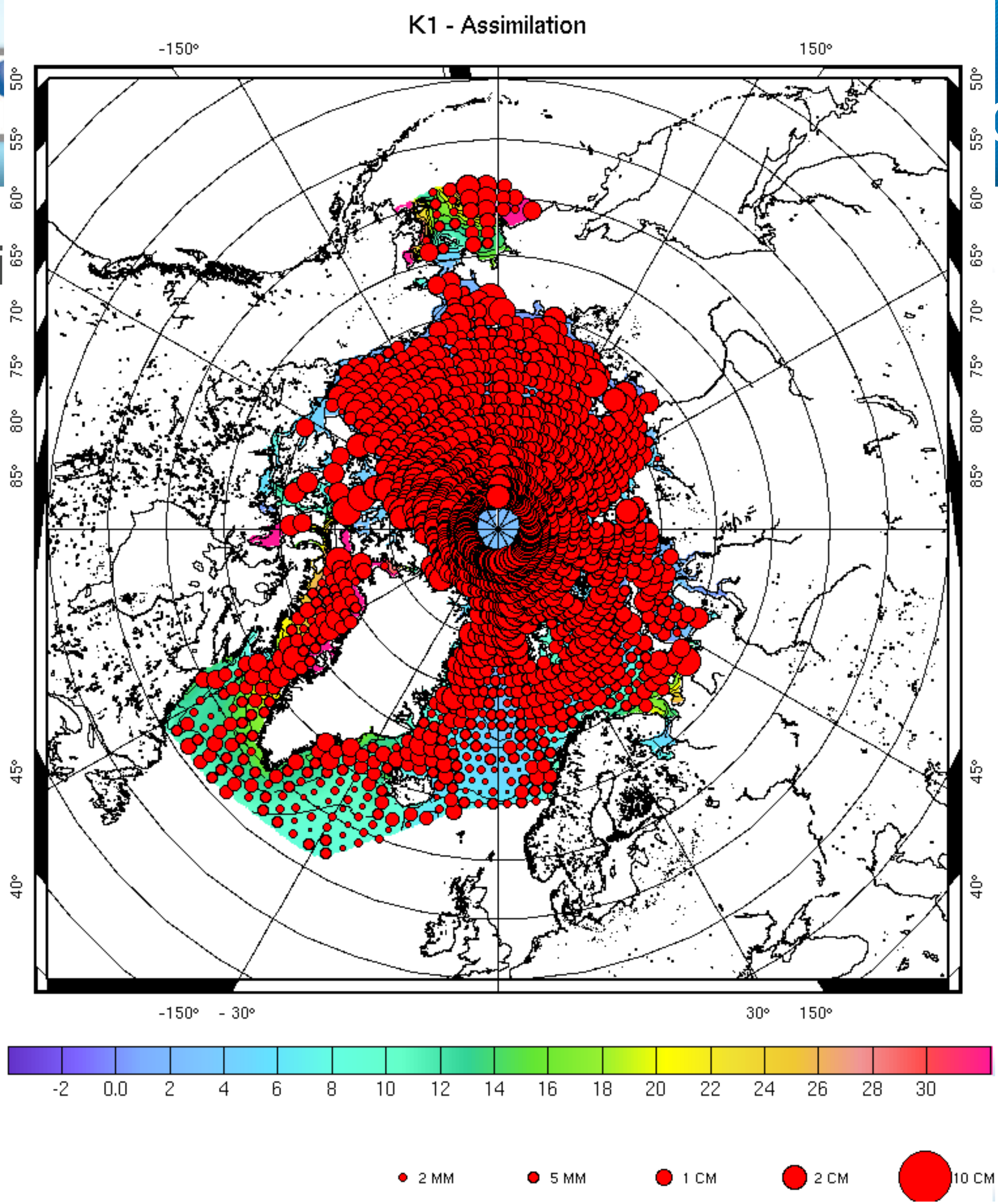
- Assimi…



Conclusions and perspectives

- Conclusions
  - The regional purely hydrodynamic model shows equivalent performances to the global assimilated models, in particular for the semi-diurnal waves (M2 and S2)
  - For the diurnal waves (K1, O1), some further developments needed in the physics of the hydrodynamic model (wave drag)
  - Assimilation improves the model performances
  - Globally, better performances than the global models, but need for independent validation
  - The "hardest part of the work" has been done: mesh refinement, model set-up, data editing.

  → Development of automatic tools for the mesh generation

  → Any further improvement is now cheaper to implement in the configuration

Conclusions and perspectives

- Next steps
  - Assimilation for 6 additional tidal components: S2, O1, K2, N2, P1, Q1
  - Time stepping hydrodynamic simulation to complete the spectrum
  - Independent validation (DTU Space) + any other interested group ?
  - The Arctic tidal atlas will be delivered to ESA in mid-January 2016

Conclusions and perspectives

- Perspectives
  - Exploitation of this new tidal model to improve CRYOSAT-2 altimeter products and prepare CRYOSAT Follow-On (tide correction)
  - Exploitation of this model to improve ocean modeling and forecasting for Arctic studies: ocean circulation, sea-ice drift, …
  - Bathymetry improvement in the Arctic
    - Design of a new bathymetry based on IBCAO and PAGAEA
    - In situ data release ?
    - Inversion of altimetry data
  - Improvement of the altimetry data: remove annual signal (DTU)

  ➔ Could lead to an update of the tidal atlas (cf FES2012 → FES2014)

  - Other strategic regions with a need for high resolution tidal modeling

Thank you !