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Satellites and sea ice

esa

→ COPERNICUS DAYS ROME

Polar View

Satellite monitoring of Arctic sea ice

Leif Toudal Pedersen, Danish Meteorological Institute

My Ocean 2

myOcean

DMI Vejr, klima og hav

DTU Technical University of Denmark

EUMETSAT

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- Operational monitoring – Ice charts
- Copernicus operational oceanography - CMEMS
  - Sentinel-1 (og 2 og 3)
- Downstream Services – PolarView/PolarIce
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- ESA's Climate Change Initiative
- FP7 ICE-ARC & H2020 SPICES

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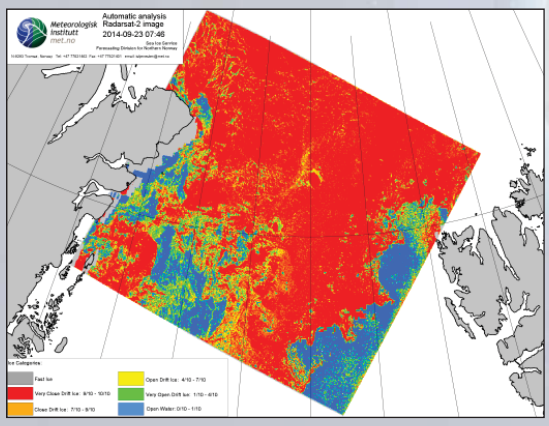
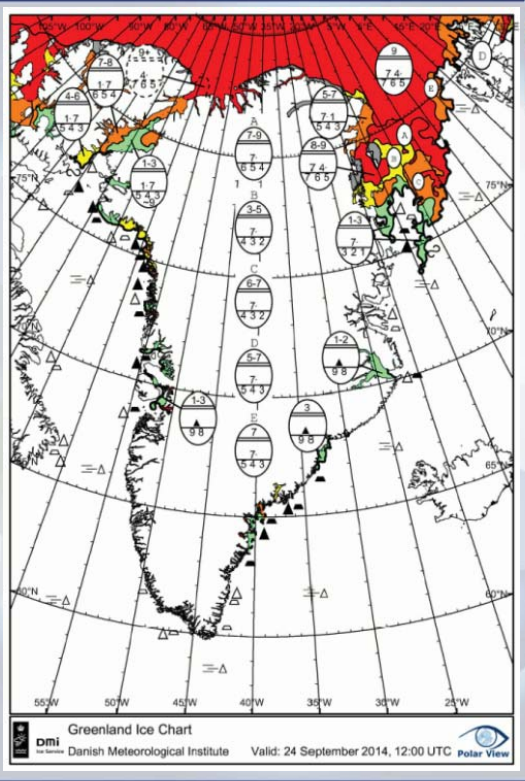
Satellites and sea ice

- Today we derive ice information from SAR data by manual interpretation
- With the large number of SAR scenes we get from Sentinel-1 we need further automatic methods
- Not easy - SAR data are very noisy
- However, potential for much higher resolution, and faster delivery





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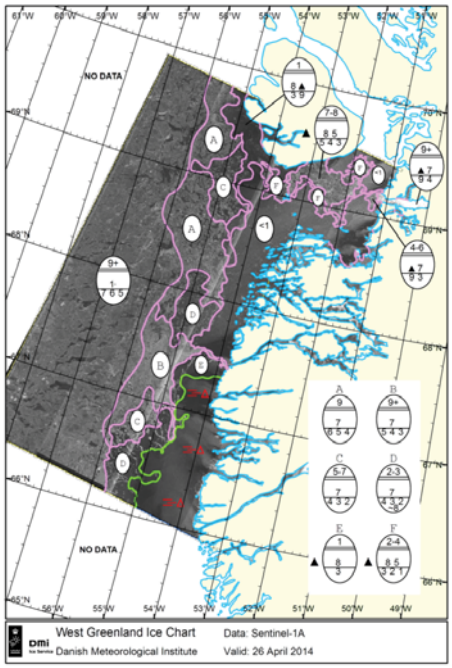
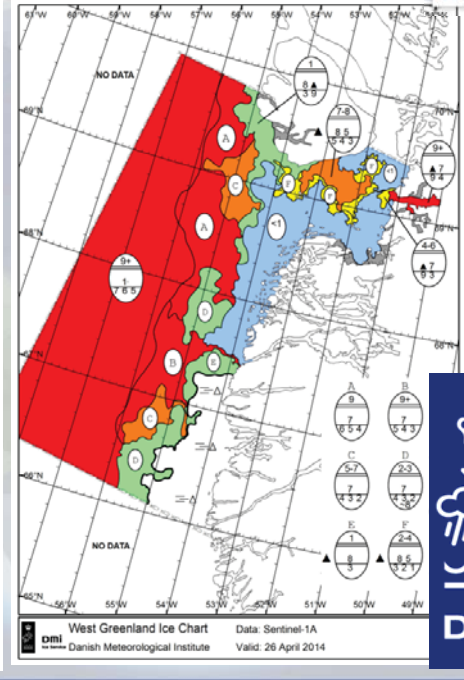
First ice charts from Sentinel-1A

The first Sentinel-1 sea-ice chart





S1A image20140426 10:10 UTC, EWS, HH

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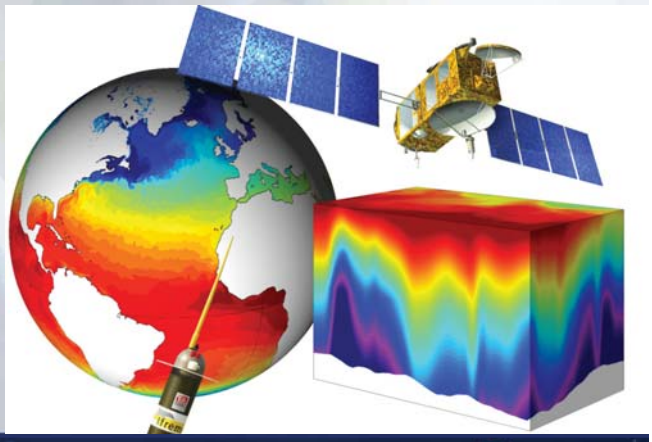
Satellites and sea ice

myOcean

Mission: « **improving the value of and the access to core information on the ocean** »

- **Space** data, **In Situ** Data and **Models** : an integrated approach
- Based on **existing** capacities: the European network
- Focus on the **European value**
- **Open and free** information



Information: *ocean currents, temperature, salinity, sea level, primary ecosystems, **ice** coverage and thickness …*

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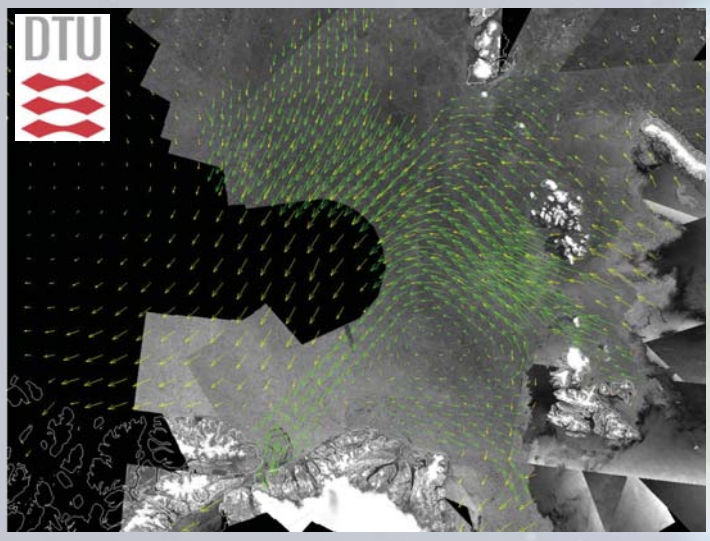
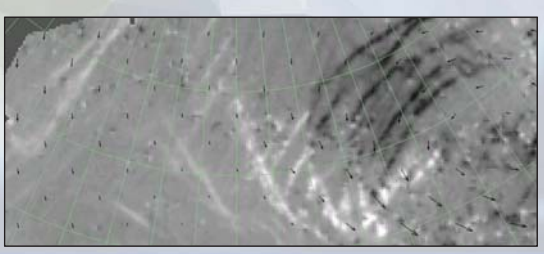
SAR mosaic from Sentinel-1a w MyOcean data



Ice drift predicted by MyOcean (yellow)
Ice drift observed by S1A (green)
January 7-8 2015

- Mosaic of SAR data from Sentinel-1 on the very first day of operational delivery (October 4, 2014)
- Excellent Arctic coverage at this early stage of the ramp up phase
- This capability of S1A(+B) will provide the data background for development of next generation ice drift modules in Climate- and sea ice models.
- Efforts are underway in France, Belgium and Norway.



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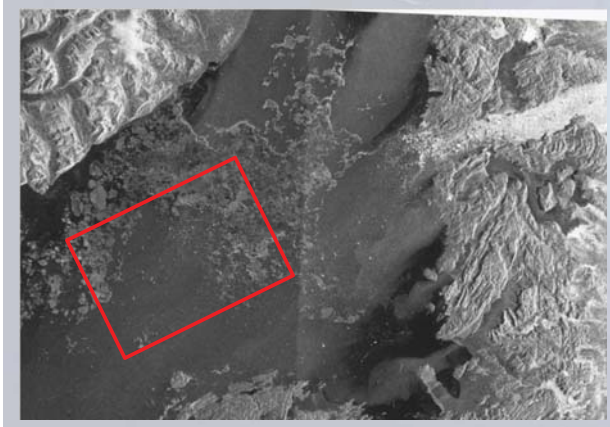
Iceberg detection in Disko Bay

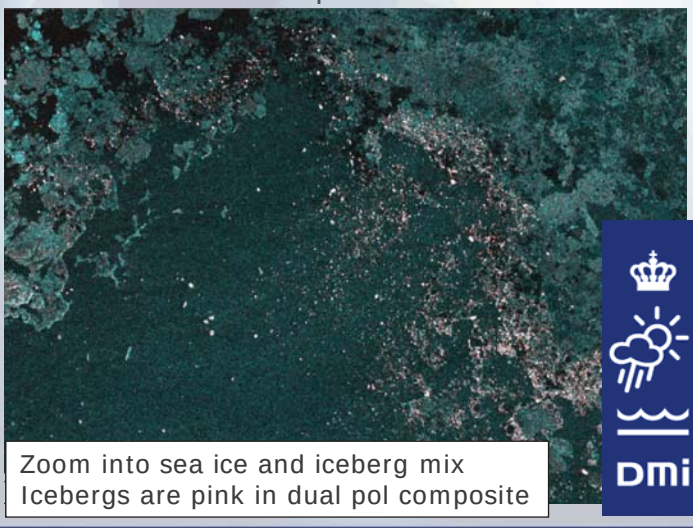
Icebergs in Disko Bay, Sentinel 1A, 20140426 10:10 UTC, EWS, HH+HV
Icebergs show up pink, sea-ice in bluish colors when using dual polarisation

Single pol HH



Jakobshavn glacier pouring icebergs into Disko Bay

Dual pol HH+HV



Zoom into sea ice and iceberg mix
Icebergs are pink in dual pol composite

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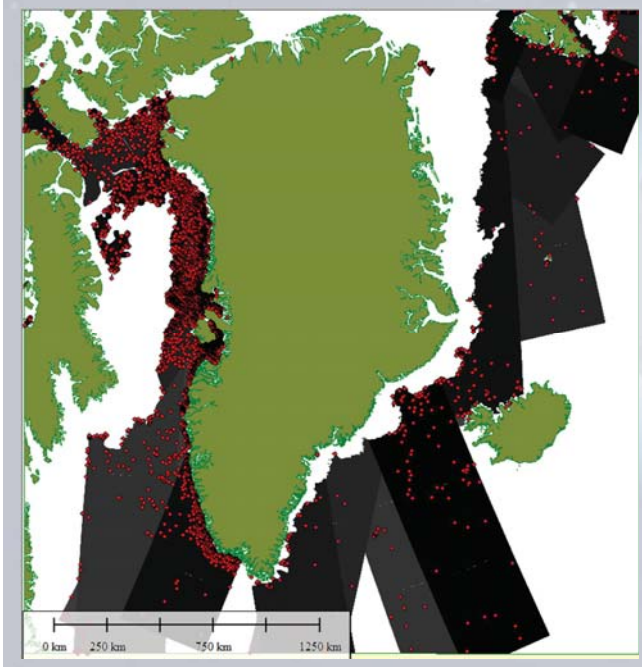
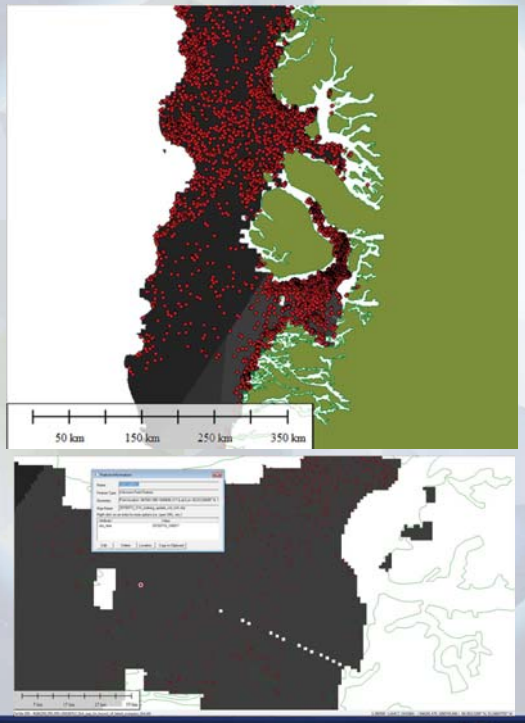
Towards daily iceberg maps of Greenland





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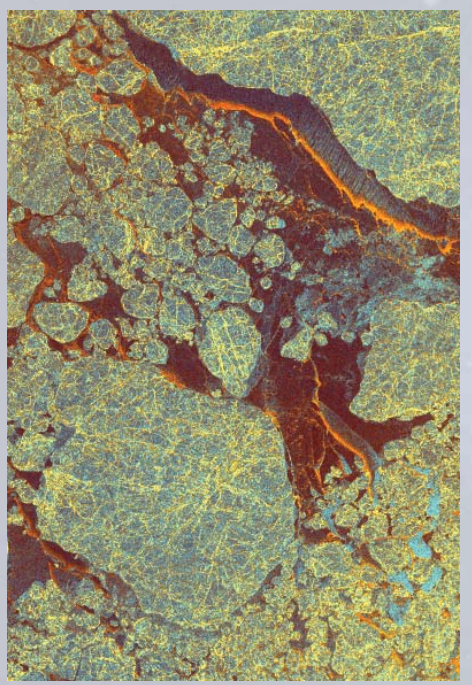
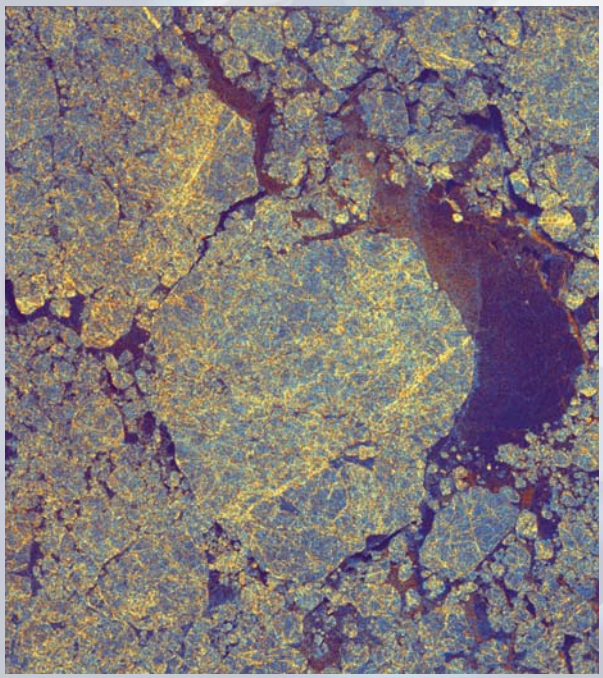
Sentinel-1A dual polarisation SAR for ice charting





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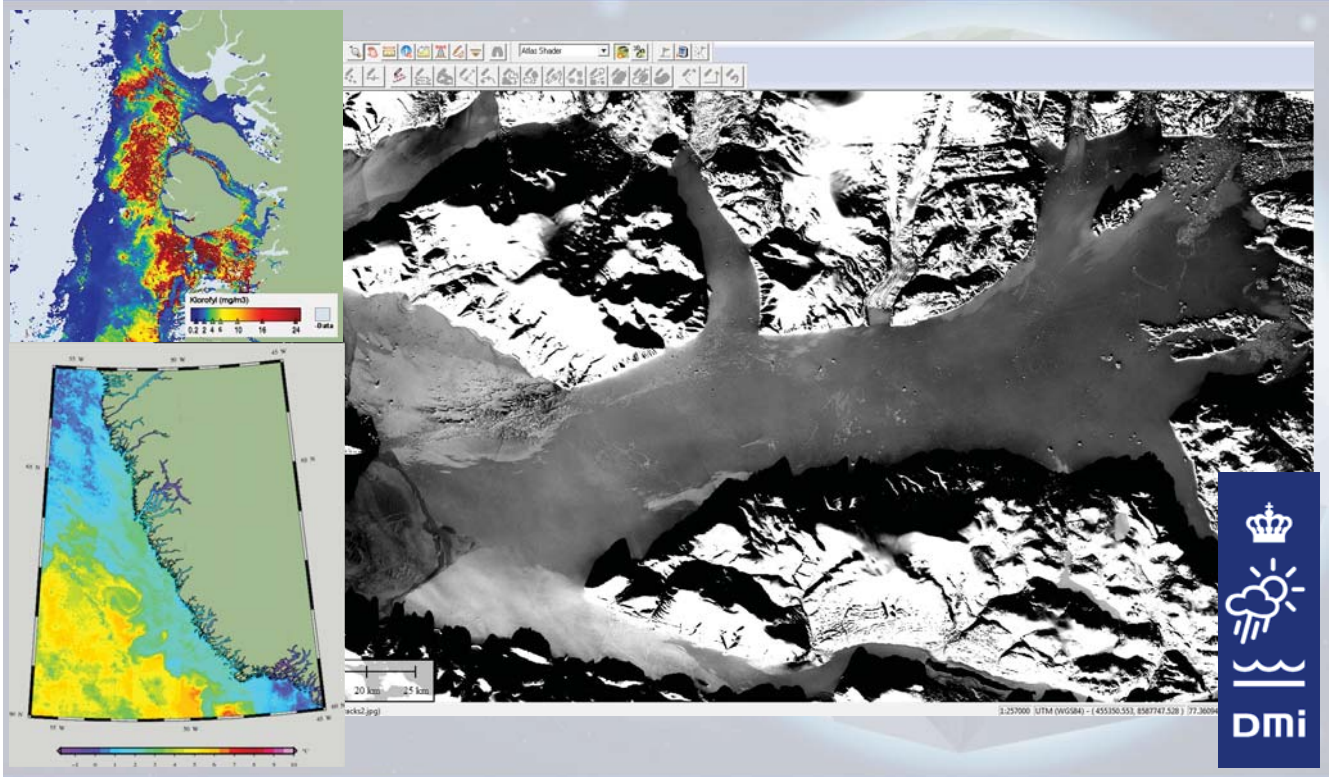
Sentinel-2 og Sentinel-3



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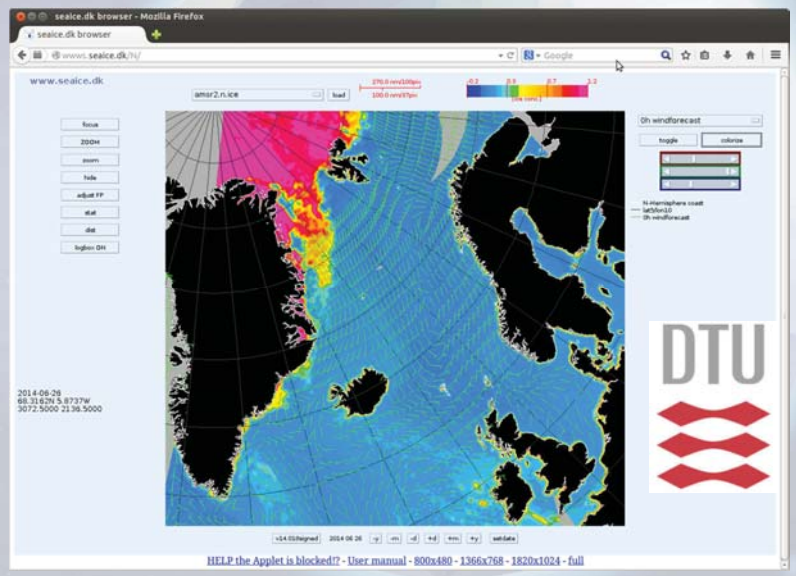
Satellites and sea ice

Polar View

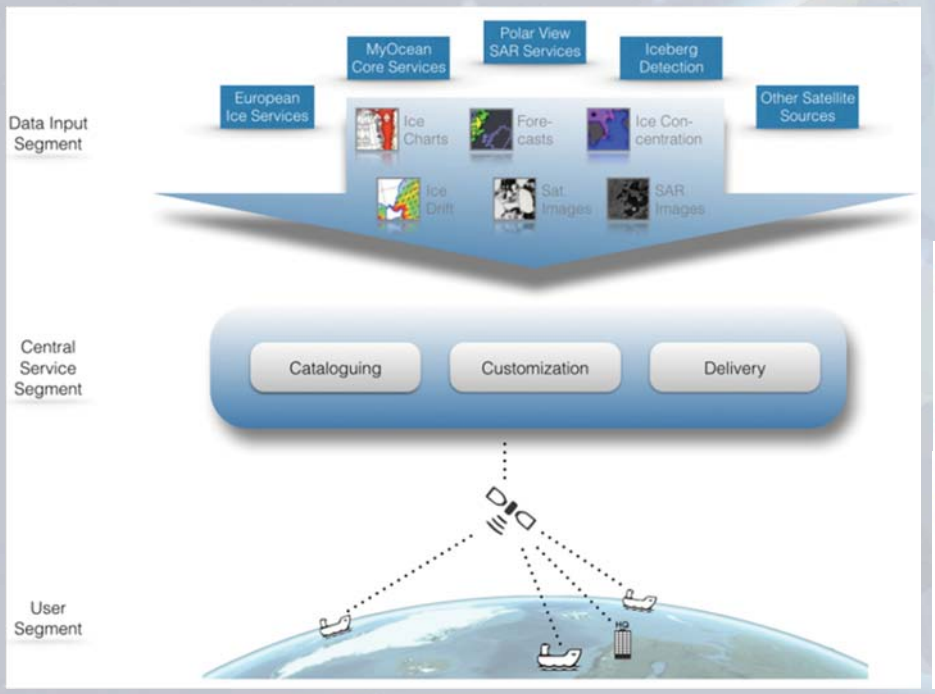
- Many research results were matured and brought to users
- Additional downstream services were invented
- Products were later adopted by
  - MyOcean/Copernicus
  - National agencies
  - Commercial customers
- A spin-off company "PolarView Earth Observation Ltd (PVEO)" was founded



PolarICE

SEVENTH FRAMEWORK PROGRAMME

Downstream project under FP7

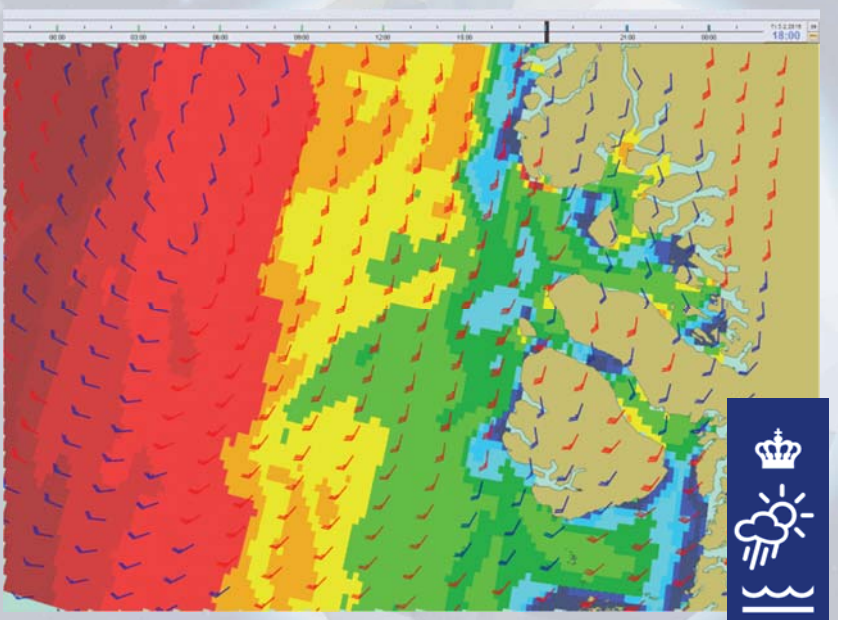


POLAR ICE

eOsphere · British Antarctic Survey · FMI · VTT · NR · DTU · Universität Bremen · KONGSBERG · DMI · Polar View · Meteorologisk Institutt · SMHI · C-CORE · Hickling Arthurs Low

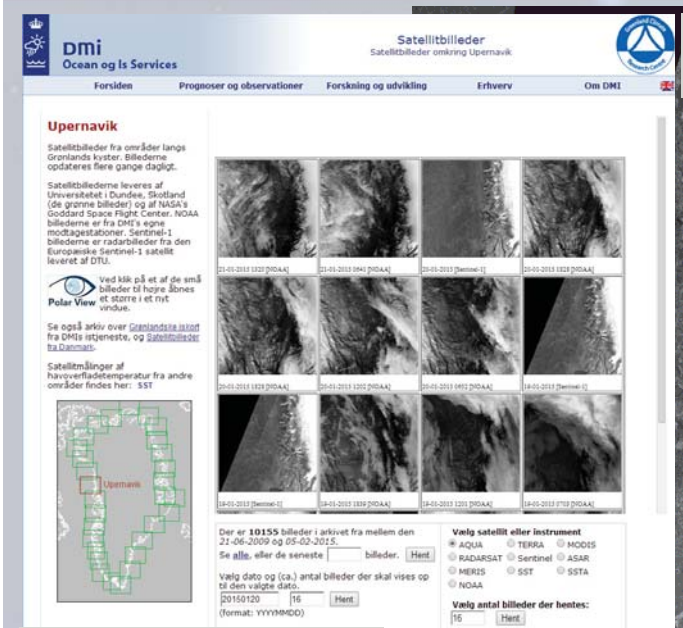
PolarICE

- Combining **satellite** data and **model forecasts** to provide the future of ice service provision
- Use MyOcean data as boundary conditions
- Use **higher resolution** models to provide more details in an operation area



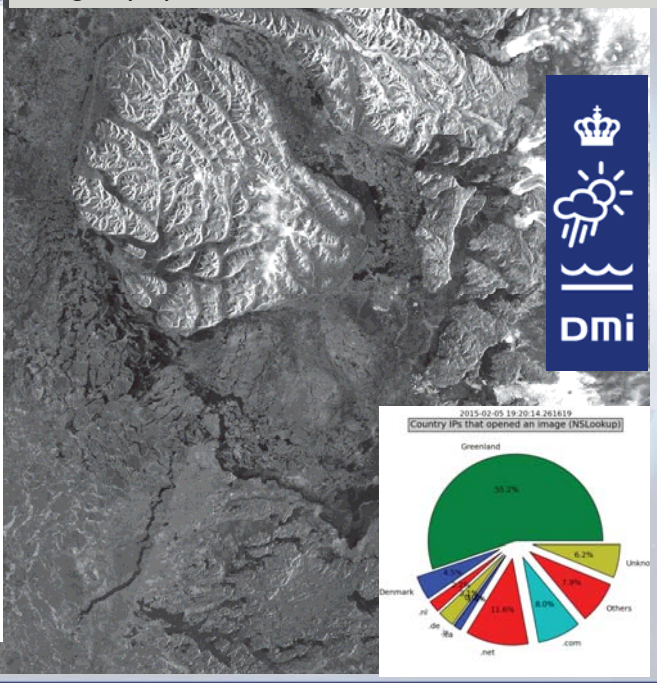
POLAR ICE

Satellites and sea ice



Der hentes mere end 300 billeder om dagen til Grønland

Satellitbilleder, ikke mindst Sentinel-1 er meget populære i Grønland



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PMR ice concentration

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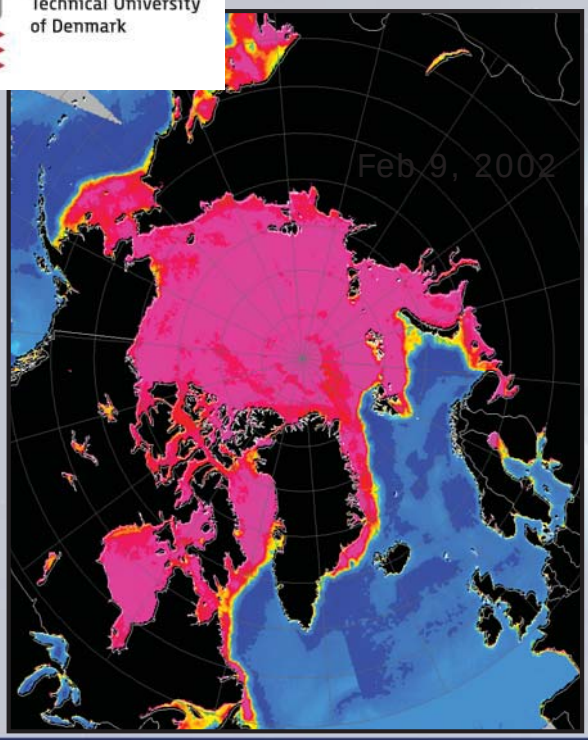

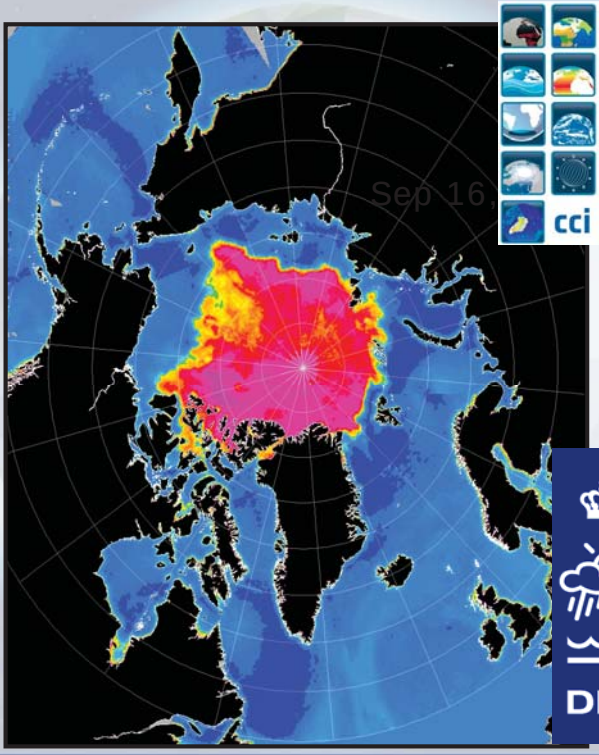

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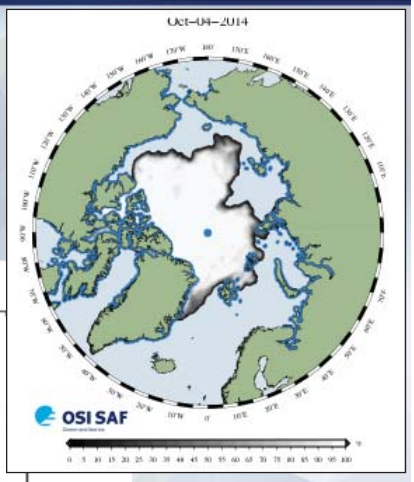
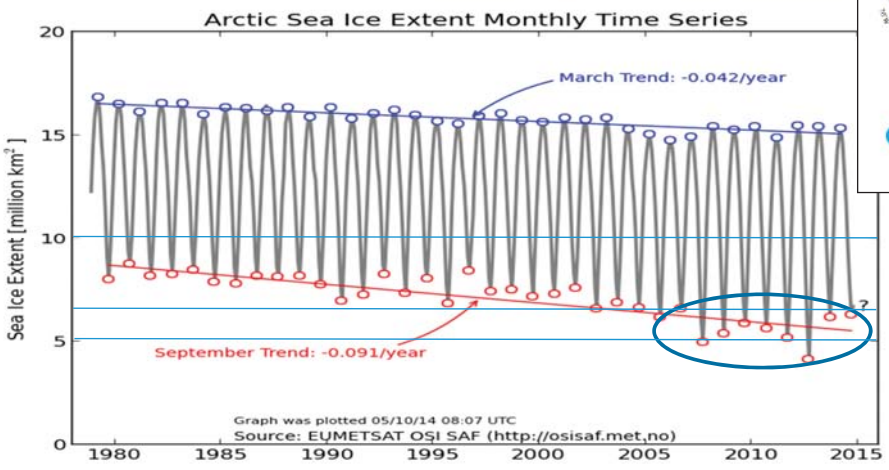
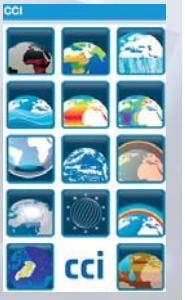
Satellites and sea ice

- Remote areas
- High latitudes (Polar Night)
- 35 years of data







Algorithm comparison, SIC=15%, AMSR

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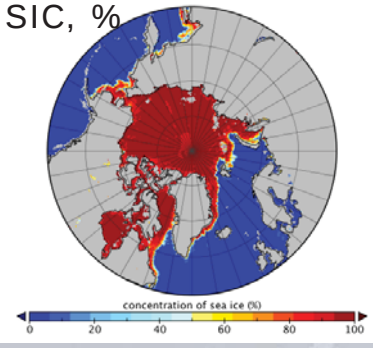
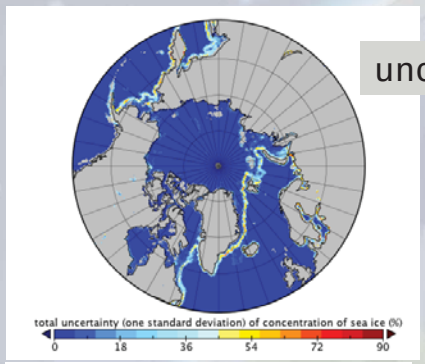
Arctic and Antarctic ice concentrations with uncertainties

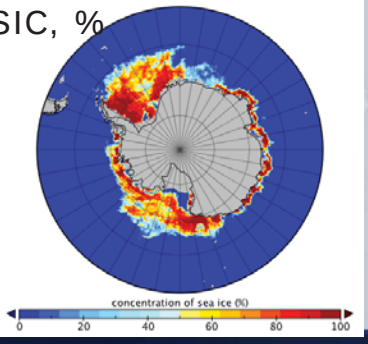
SIC, %

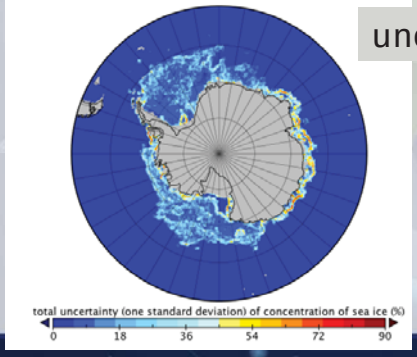




uncertainty, %

SIC, %





uncertainty, %

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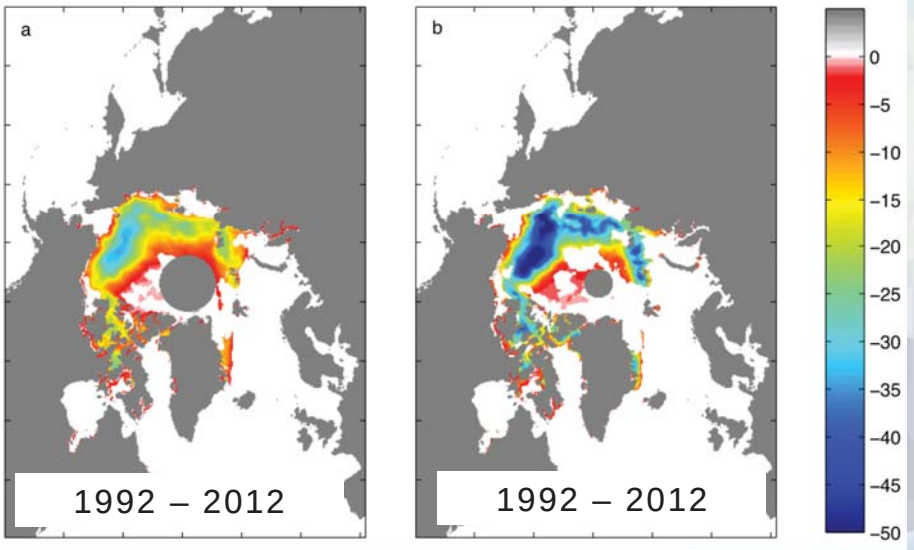
Time Series: Showing Trends

Average September sea ice concentration trends



OSI SAF

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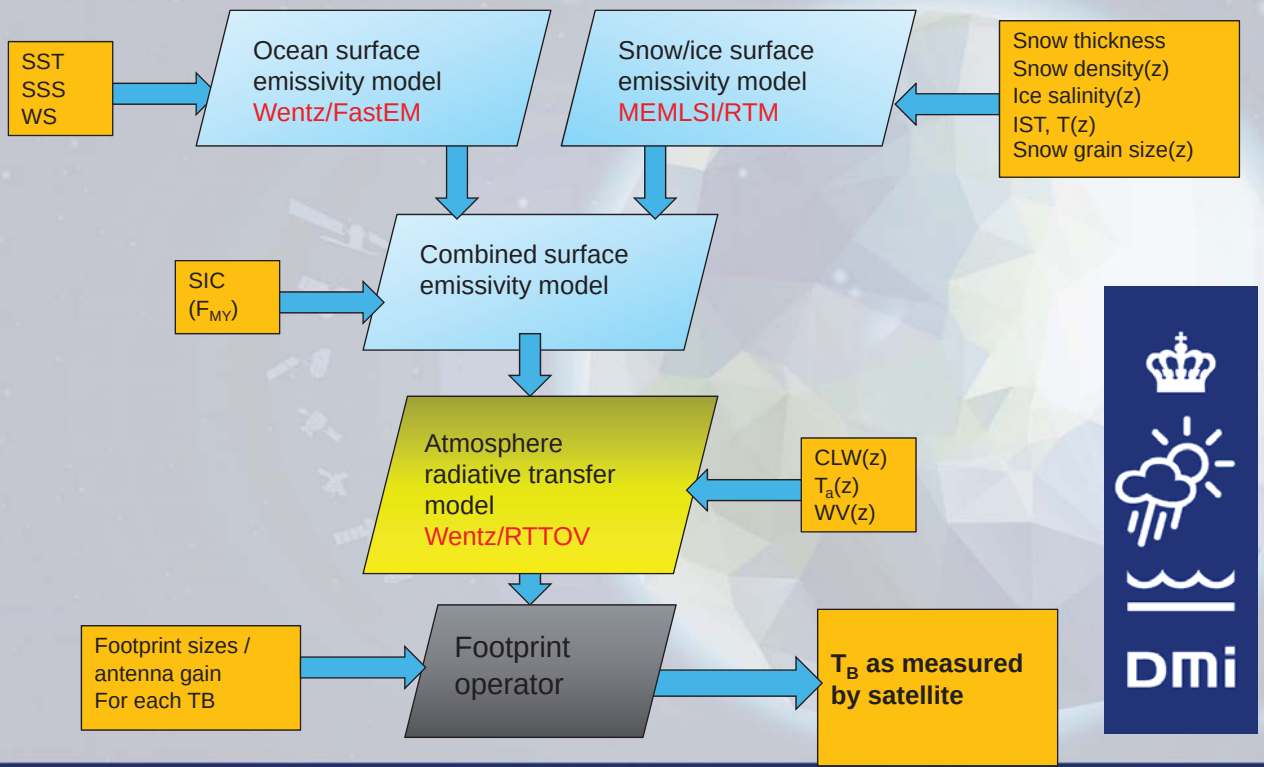
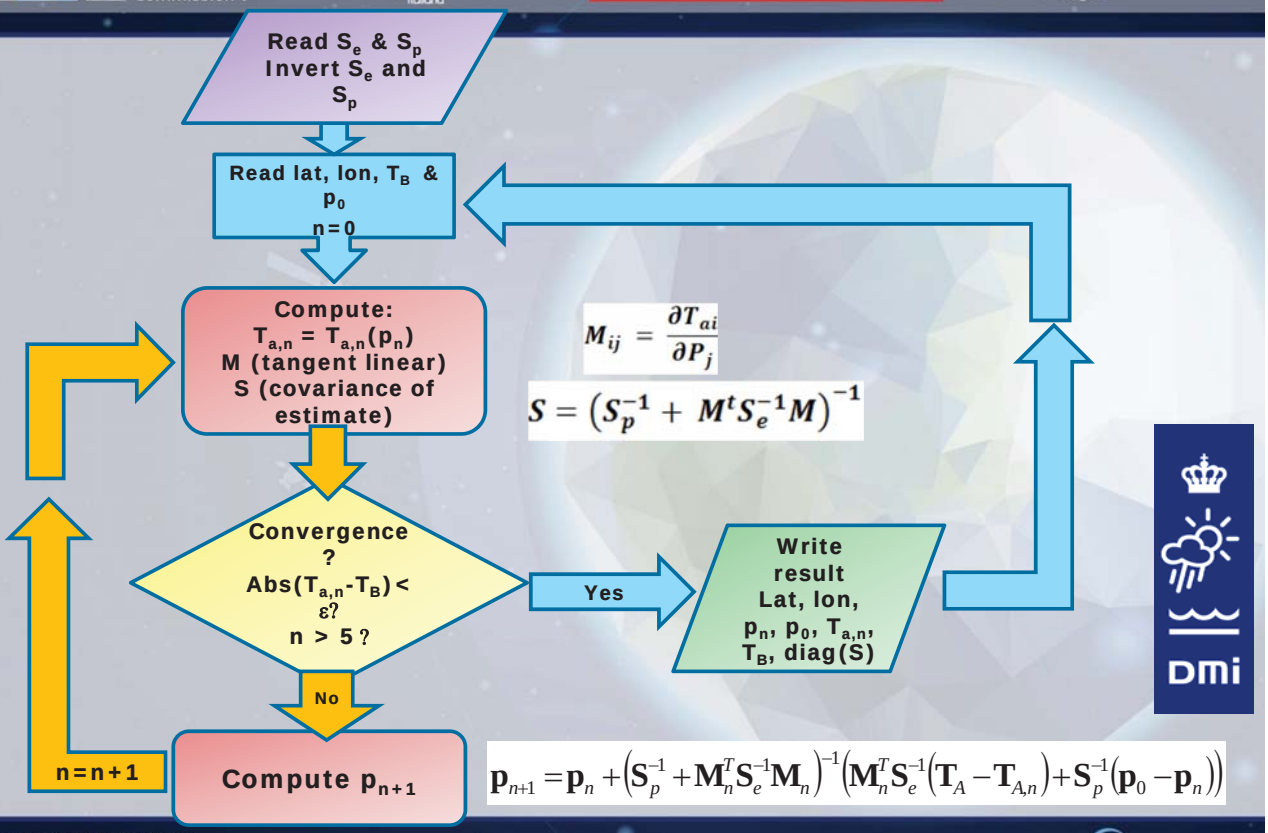
  - What's next

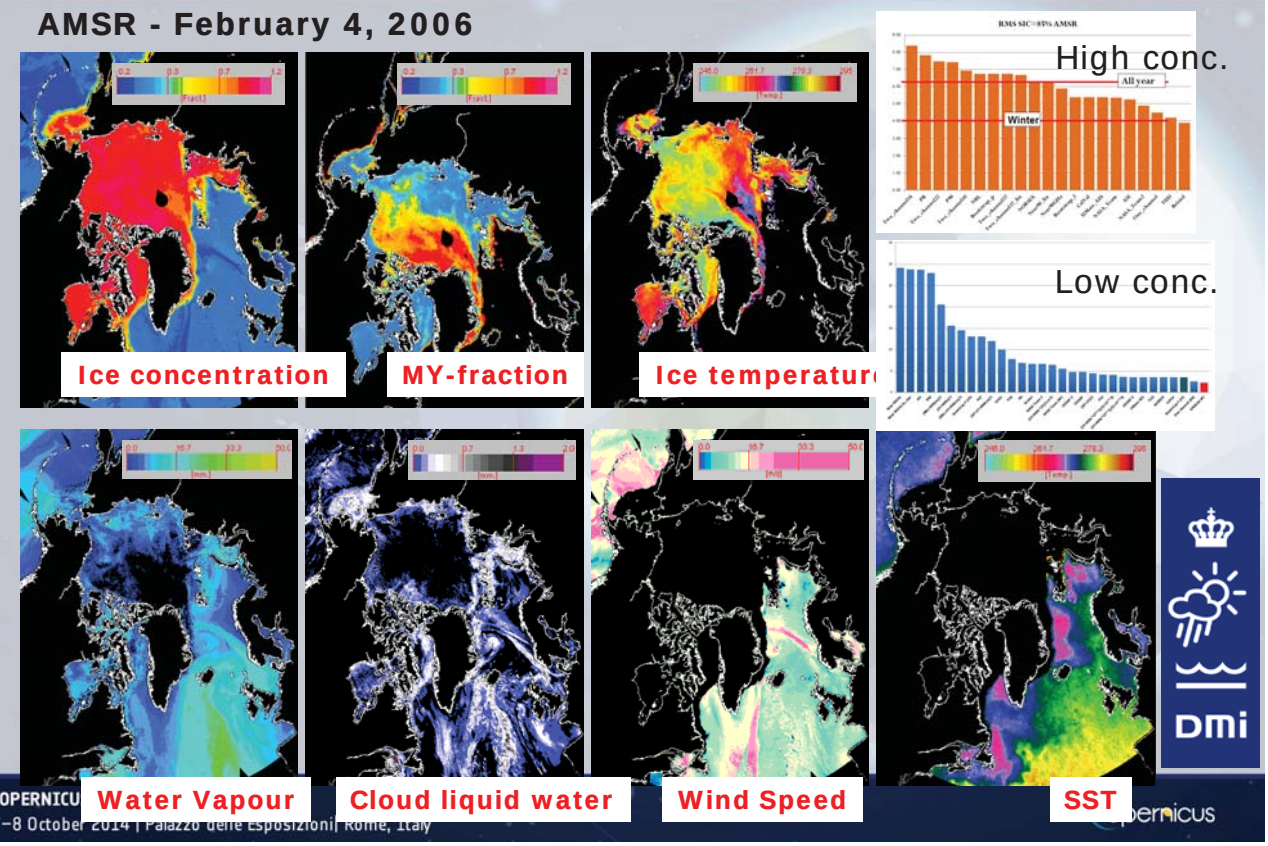
Satellite Simulator



DMI PMR Optimal estimation processor



Inversion example

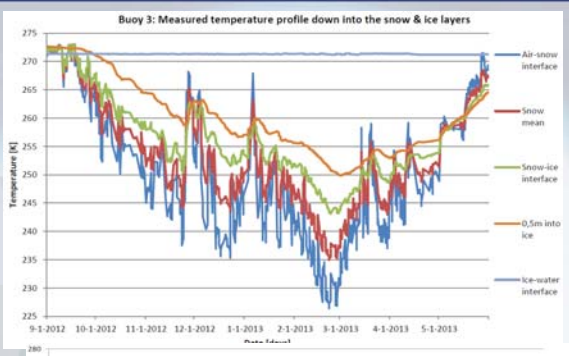


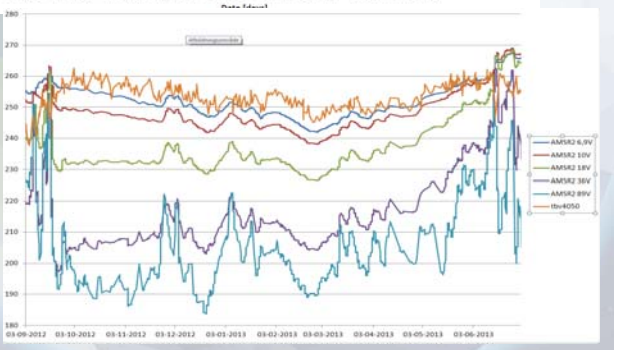
ICE-ARC & SPICES FP7 / H2020

1. Originally we used climatological mean from a dataset of observations at Jan Mayen as p_0
2. We should use NWP data (analysis or short term forecasts)

1. Originally we used covariances of climatology as S_p since p_0 was just climatological mean values.
2. We should be able to compute S_p from differences between NWP and retrievals using reference RRDP dataset

3. Originally we used a diagonal matrix with AMSR T_B measurement errors (independent) as S_e but should include also PMR model errors.
4. We should be able to calculate this from differences in observed and modelled T_Bs after retrieval. Assuming that reamining residuals are due to either AMSR measurement errors or PMR/forward model errors





$$\mathbf{p}_{n+1} = \mathbf{p}_n + \left(\mathbf{S}_p^{-1} + \mathbf{M}_n^T \mathbf{S}_e^{-1} \mathbf{M}_n\right)^{-1} \left(\mathbf{M}_n^T \mathbf{S}_e^{-1} \left(\mathbf{T}_A - \mathbf{T}_{A,n}\right) + \mathbf{S}_p^{-1} \left(\mathbf{p}_0 - \mathbf{p}_n\right)\right)$$

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Conclusions

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Conclusions and perspectives for sea ice applications :

- *Satellites provide the majority of our information about the development of the ice conditions in the Arctic*
- *Most sea ice monitoring is carried out using microwave satellite instruments such as Sentinel-1 SAR and GCOM-W AMSR2, capable of monitoring irrespective of cloud cover and also during the polar night*
- *For operational monitoring, time is critical and data must be made available in near real time (within an hour or less) preferably at least daily. The value of data diminishes with time in a dynamic environment*
- *For climate monitoring, consistency is critical, and data calibration and quality control are improtant*
- *We can measure ice extent, ice drift and ice deformation all year round and monitor icebergs in the sea-ice free season using satellite data.*

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Sentinel-1 A+B and GCOM-W AMSR2 will be the backbone of future ice charting and ice service provision as well as sea ice science development

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