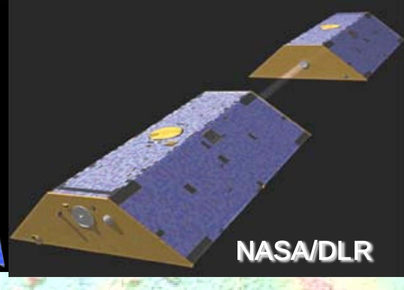
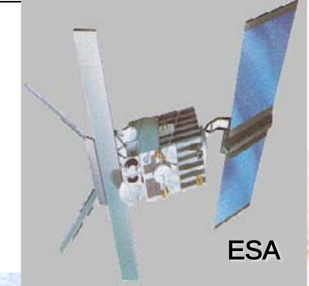




ESA ENVISAT

ESA CRYOSAT 2




# Arctic Ocean Sea-Level Rise

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**Ocean Surface Topography Science Team Meeting**

**Venice-Lido, Italy**

**27–28 September 2012**

UT DALLAS The University of Texas at Dallas


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# Sea-Level Rise in the Arctic Ocean



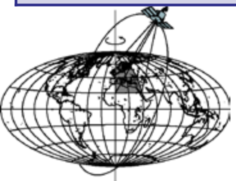
Arctic Ocean sea-level rise is an **important indicator** of the rapid environmental and ecological changes in the Arctic region, **<u>but it is not well observed</u>:**

**Contemporary Arctic sea-level* studies**

| | | |
|---|---|---|
| Prandi et al. [2012] | Reprocessed Duacs | 3.6 mm/yr |
| Cheng et al., *in review* [2012] | AVISO Duacs v3.0 | 1.8 mm/yr |
| | MyOcean V2p | 3.7 mm/yr |
| | RADS | 0.9 mm/yr |
| | SODA | 0.4 mm/yr |

- The most accurate altimetry do not completely cover the Arctic Ocean
- Seasonal or permanent sea-ice coverage degrades Arctic altimetry SSH accuracy
- Fidelity of mean sea surface model used for altimetry repeat-track analysis

- **Analysis of updated multi-satellite altimetry (ERS-1, ERS-2, Envisat, GFO, Cryosat-2, mostly from RADS), tide gauges, and other data (e.g., GIA models, GRACE) to estimate Arctic sea-level trend**
- **Propose <u>adaptive radar altimeter retracking techniques</u> [e.g., *Tseng et al.,* 2012] for possible improvement of Arctic altimetry SSH accuracy**



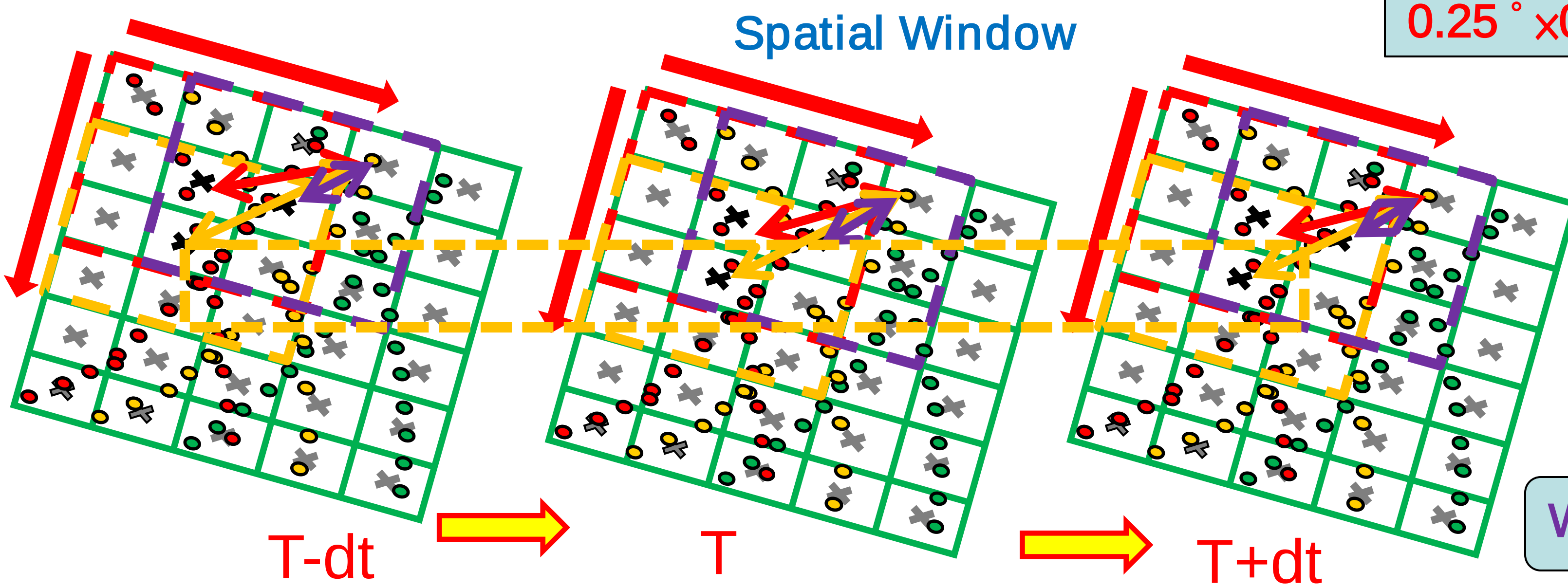
**Other Arctic sea-level studies:**
–2+ mm/yr, ERS-2 [Scharroo et al. 2006]
1.1 to 2.7 mm/yr, multi-altimetry [*Kuo,* 2006; per. com]

*Averaged ~$66–82^0$N

# Arctic Ocean Sea-Level Gridding Based on Spatio-temporal Weighting of Multi-Altimetry Data



0.25°×0.25°




Weekly

Along-track data     Time Window     Gridded point

**Moving-window averaging method based on spatial-temporal Weighting**

$$wgt(r,dt)_{ji} = \frac{1}{\delta^2_{sat_j}} \exp(-3.34\frac{r_{ji}}{L}) \exp(-\frac{dt^2_{ji}}{T^2}) \cos(\phi_j)$$

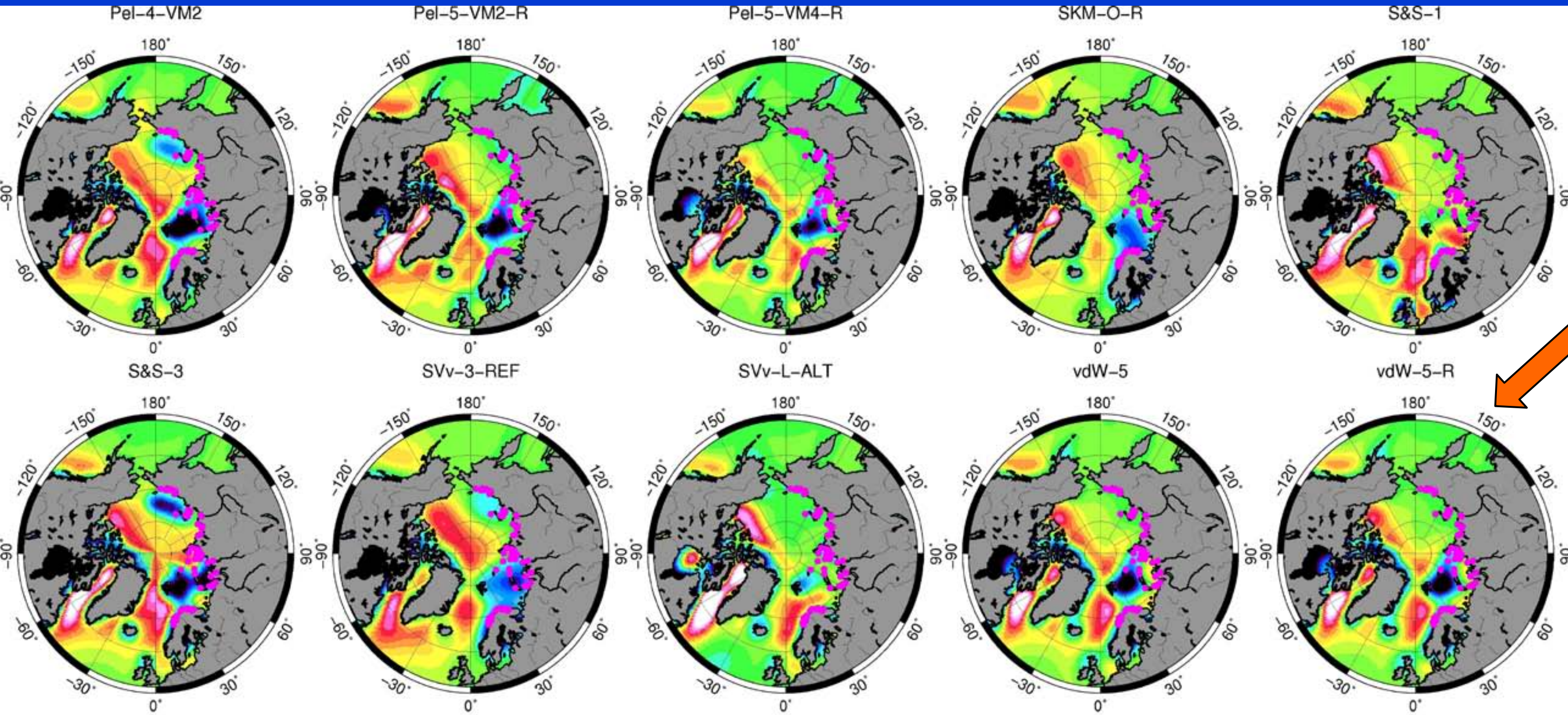
r: distance     dt: time difference     L: distance scale

T: time scale     $\varphi_j$ : latitude of data

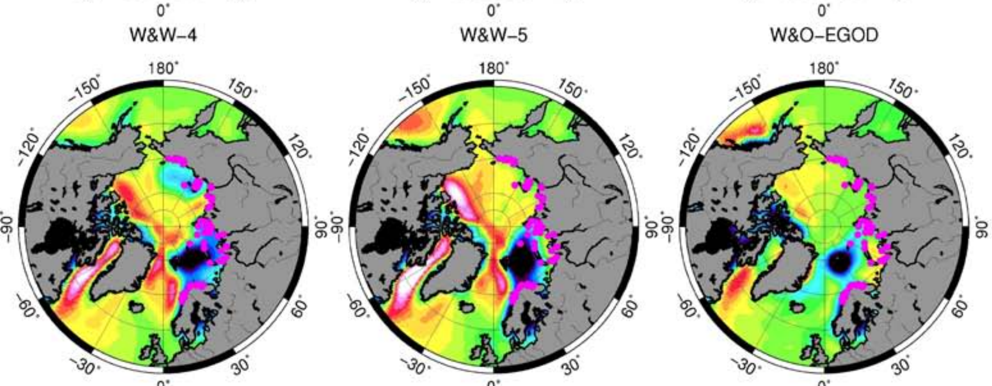
$\delta_{sat_j}$ : Standard deviation of SSHA for each mission

# Effects of Glacial Isostatic Adjustment on Arctic Sea-Level Trend Estimates

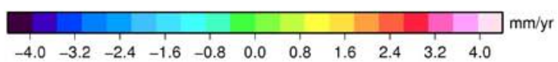





Van der Wal model used [per. com]




Guo et al. [2012], Huang et al., *in-press*, [2012]

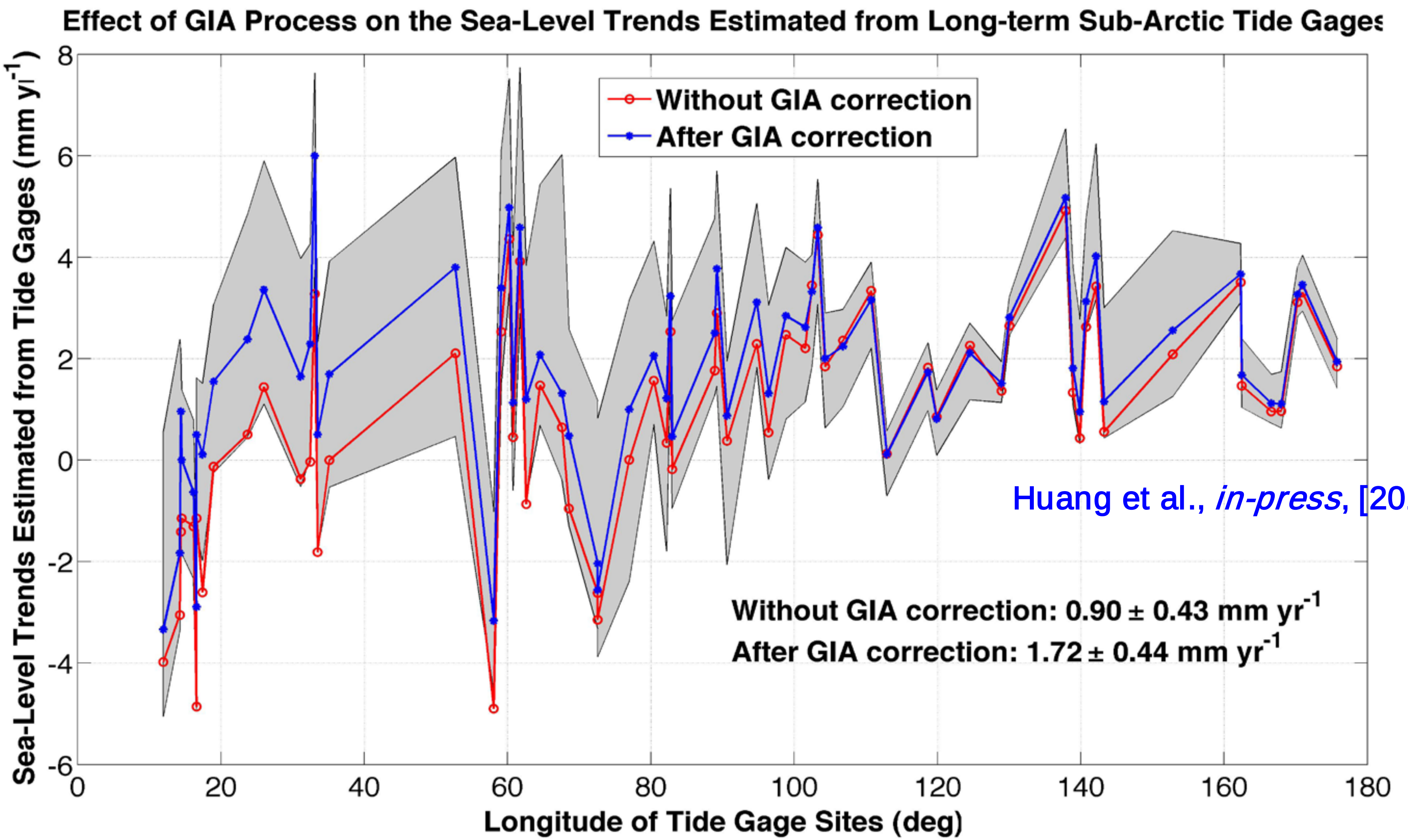



GIA predicted geoid-rate differences (used for altimetry correction) small

Ensembles of 13 GIA model predicted Relative Sea Level (RSL), tide gauge locations in red-dots

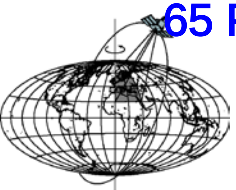
# Effects of Glacial Isostatic Adjustment on Arctic Sea-Level Trend Estimates






Huang et al., *in-press*, [2012]

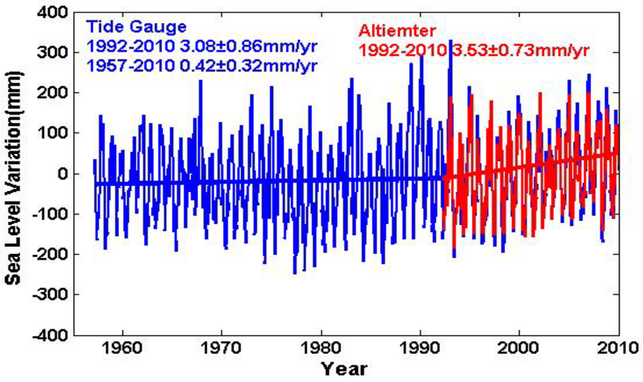
65 PSMSL Arctic/subarctic tide gauges & ensemble of 13 GIA models used



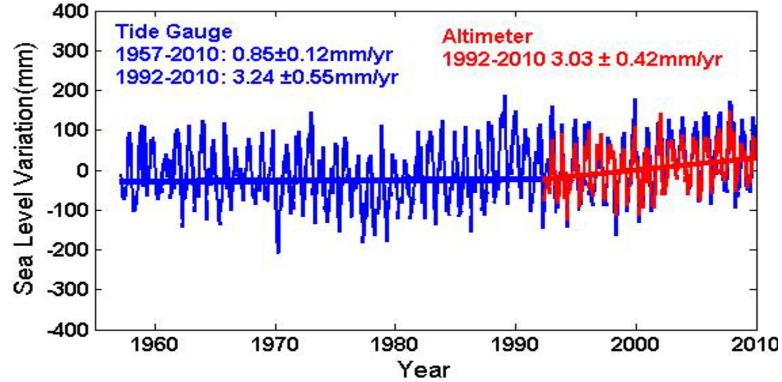
Effect of GIA significant in the Arctic Ocean for sea-level

# Altimetry VS tide gauge time series

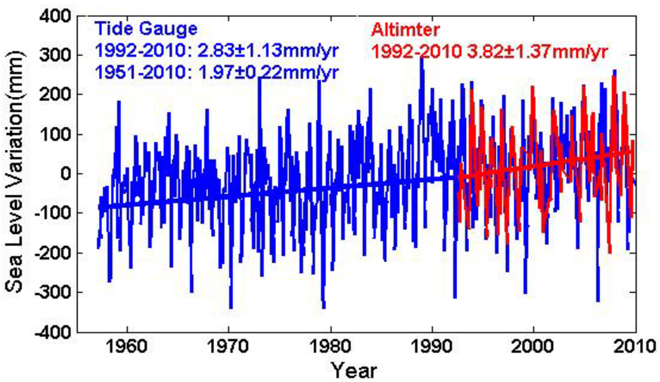




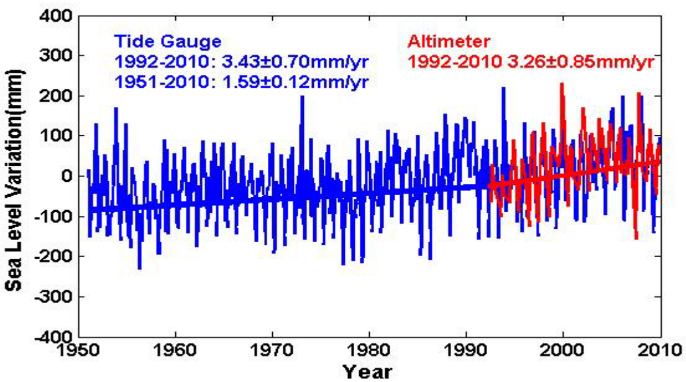

Averaged time series without IB in Nordic Sea



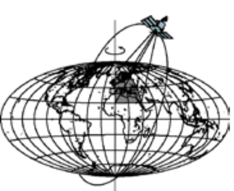

Averaged time series with IB in Nordic Sea

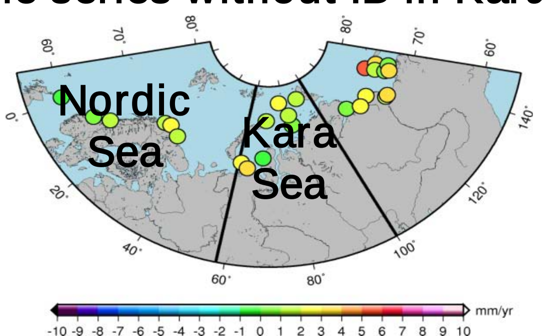



Averaged time series without IB in Kara Sea




Averaged time series with IB in Kara Sea






Averaged time series of long-term tide gauge record and decadal costal altimetry for Nordic Sea (upper panel) and Kara Sea (down panel)

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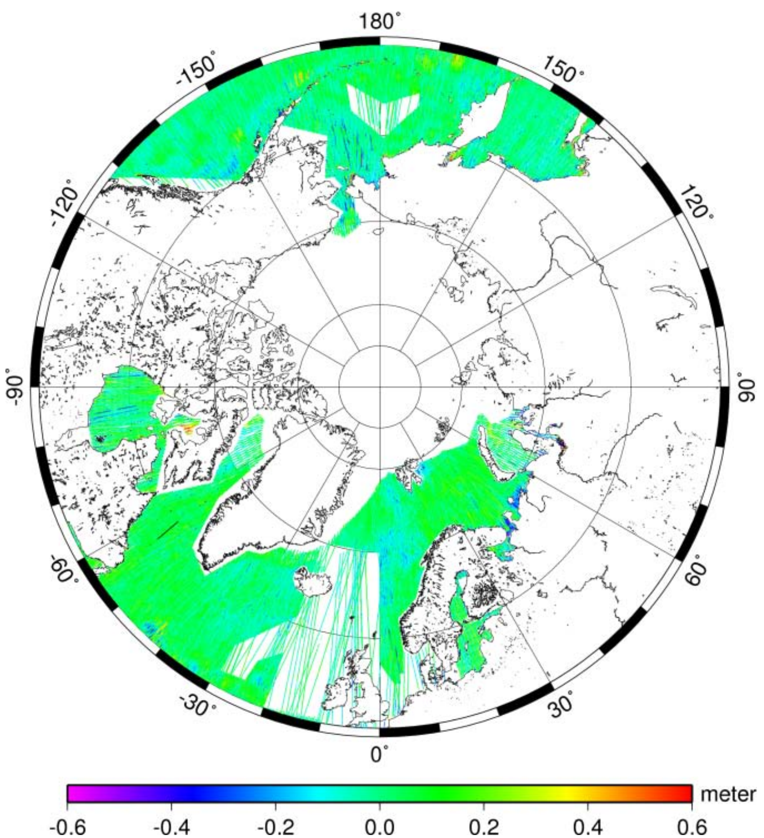
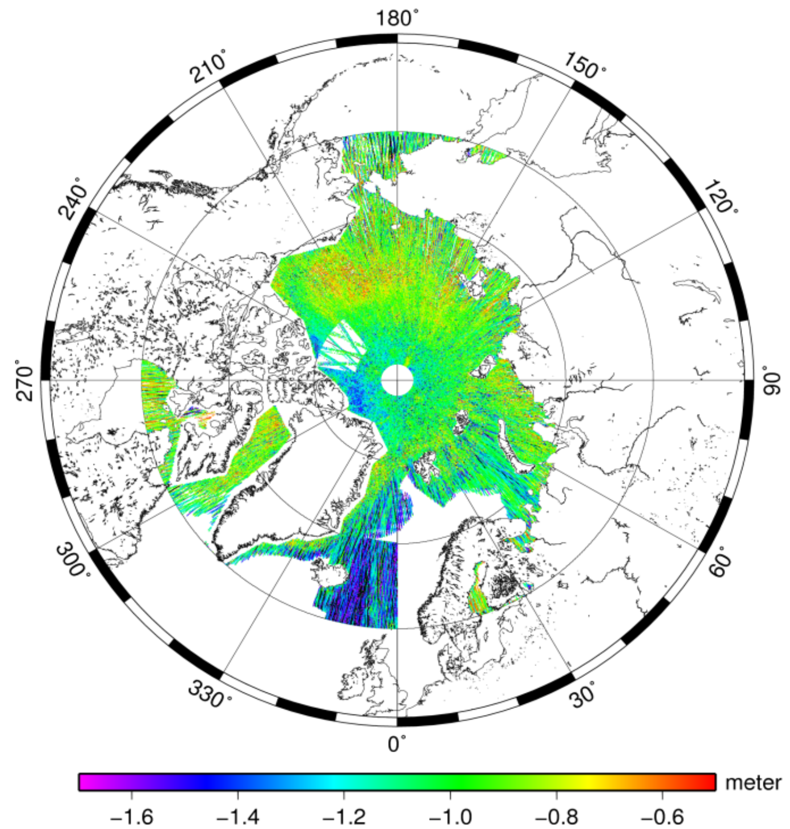
# CryoSat-2 LRM and SAR Data Processing





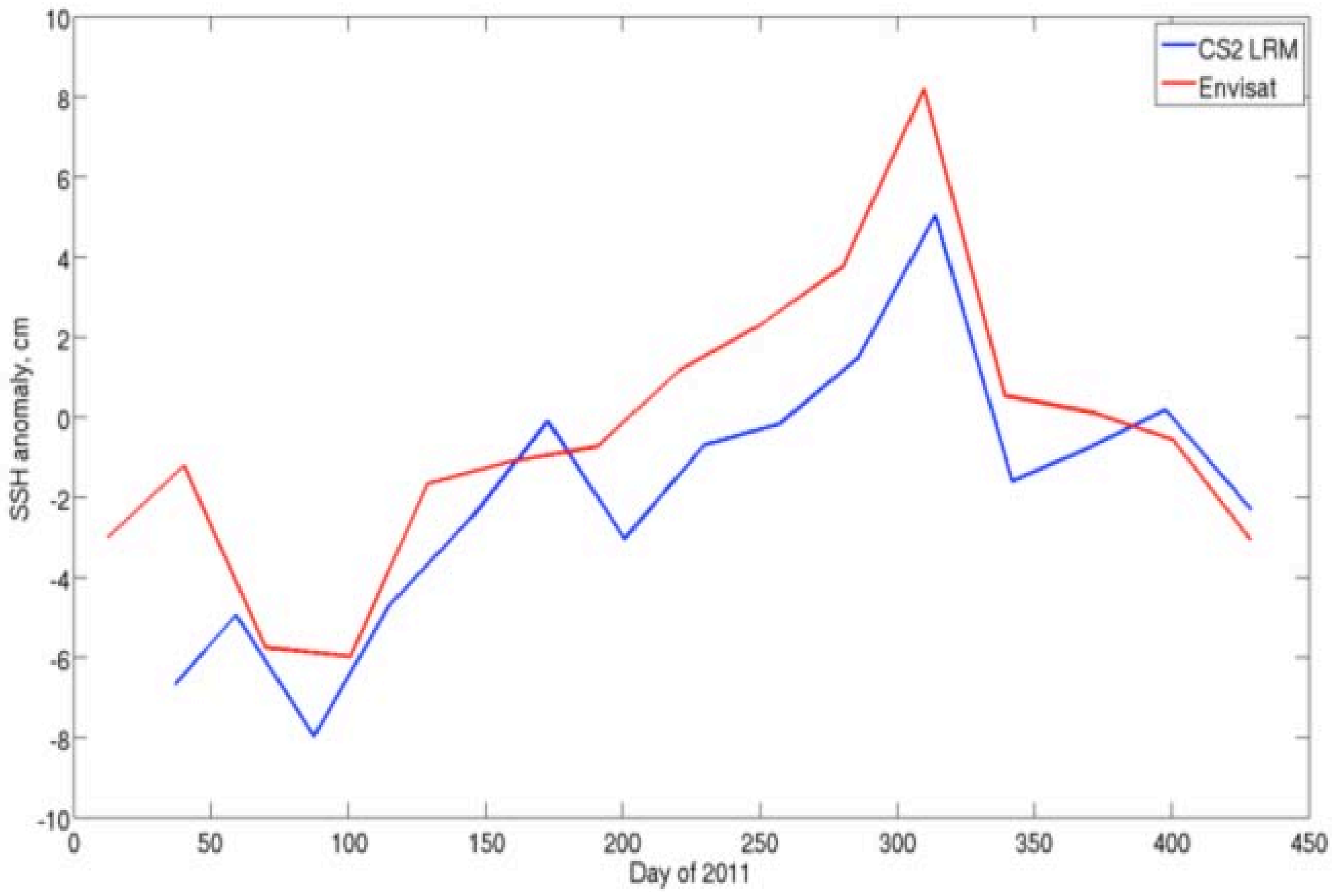

Sea surface height (SSH) anomaly of the CS2 retracked LRM 1-Hz data (RADS).




SSH anomaly of CS2 GDR SAR mode data

# CryoSat-2 LRM and SAR Data Processing



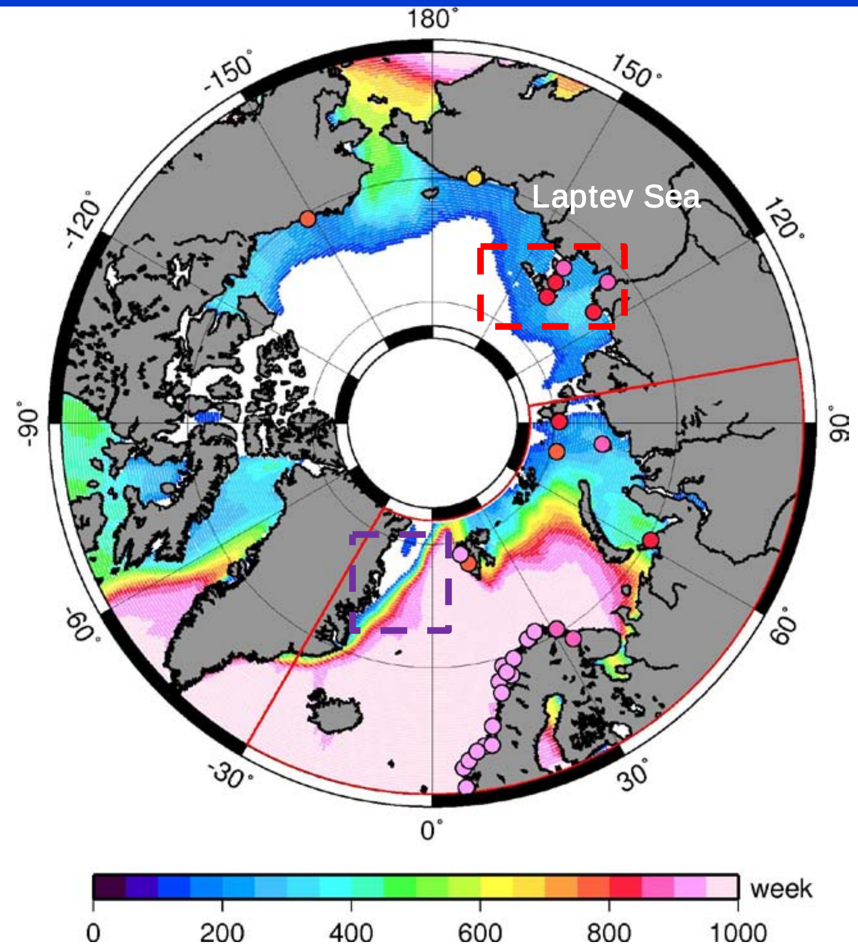



**Averaging results of SSH of CS2 LRM and that of ENVISAT over a box area , (0˚–30˚ E/70˚ N–80 ˚ N)**

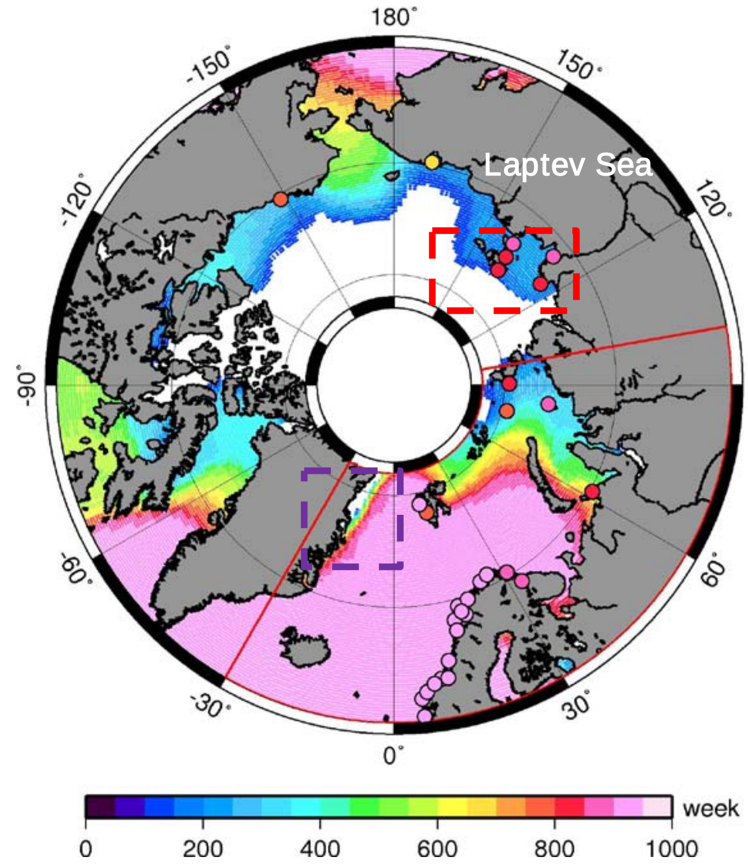
Only 1 Hz LRM data are provided in RADS

# Multi-mission Altimetry Data Coverage 1992–2010

- ✓ Introduction
- ✓ Preliminary result
- Technique approach
- Conclusion




This study

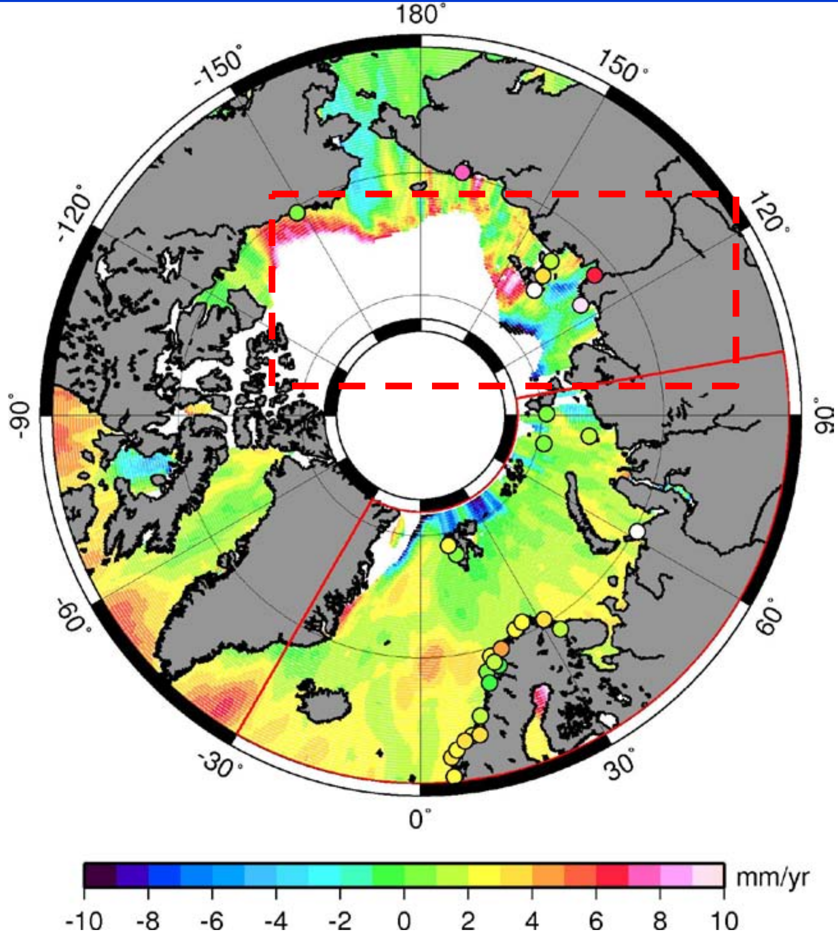



Duacs V3.0

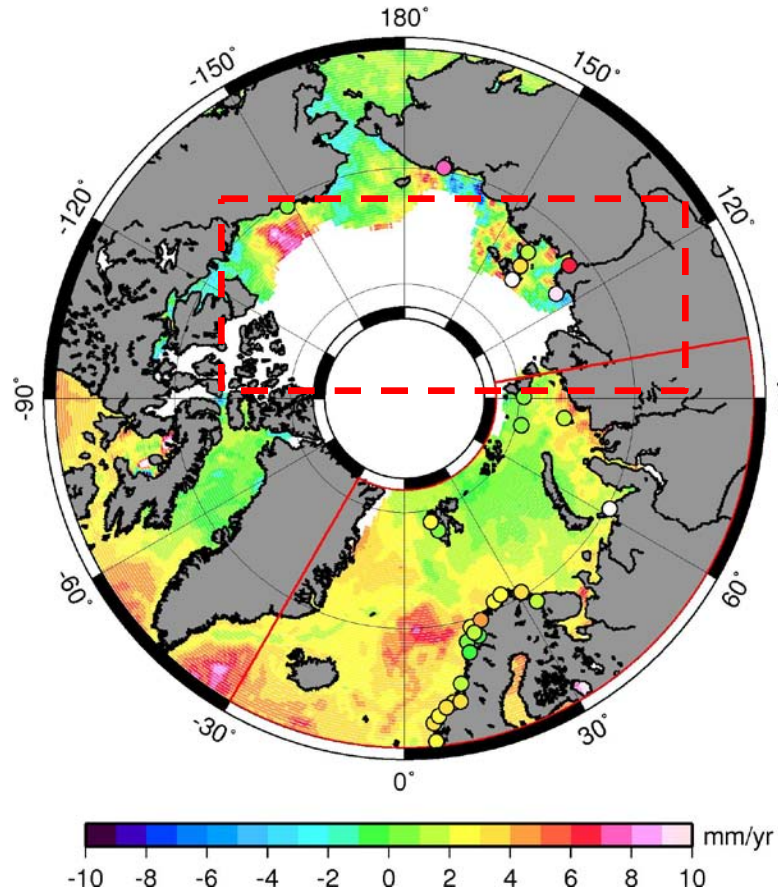
Color-coded coverage maps for altimetry (background) and tide gauge (color-coded circles). Data edited if <100 weeks

# Sea-Level Trends Over the Arctic Ocean 1992–2010 (Preliminary)






This Study




Duacs v3.0

1.1 mm/yr, 66~82$^{0}$N
(2.3 mm/yr, 60N~82N, 30W~100E)

1.5 mm/yr, ~66–82$^{0}$N

Spatial variation of sea level trend estimates using multi-mission altimetry (background) and tide gauges (color-coded circles)

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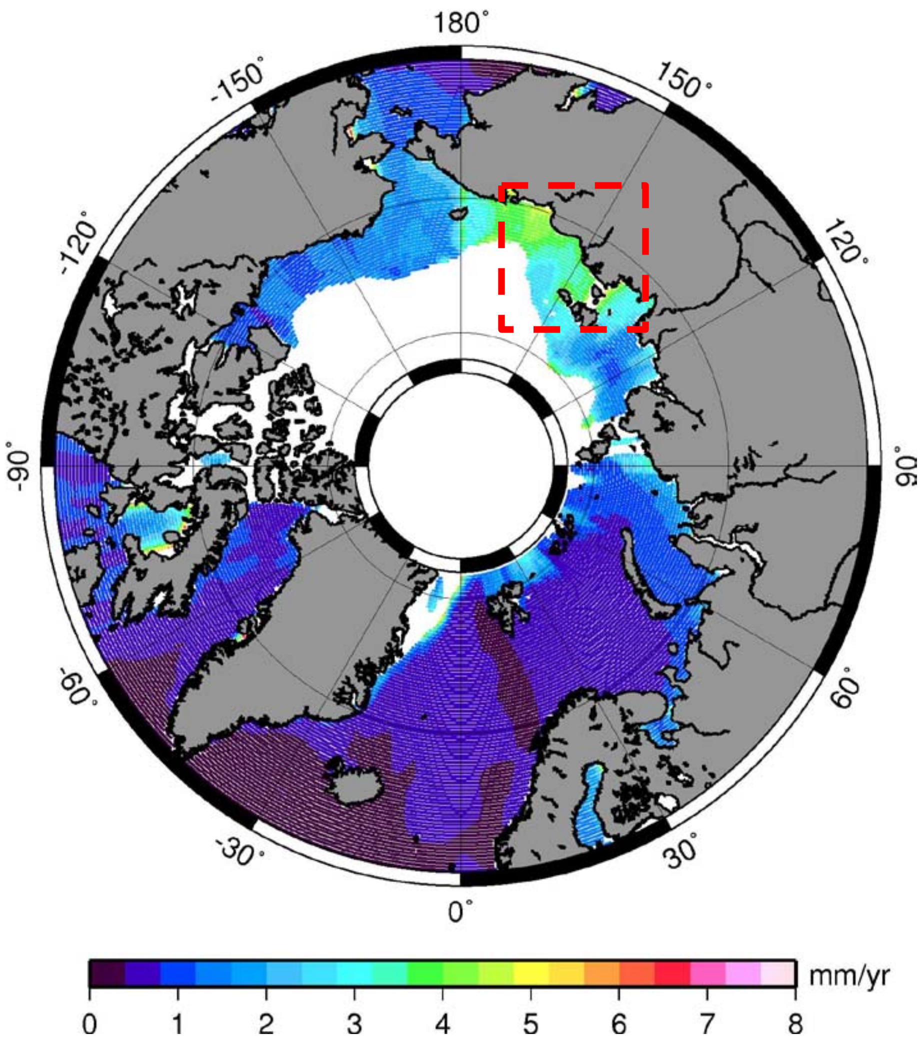
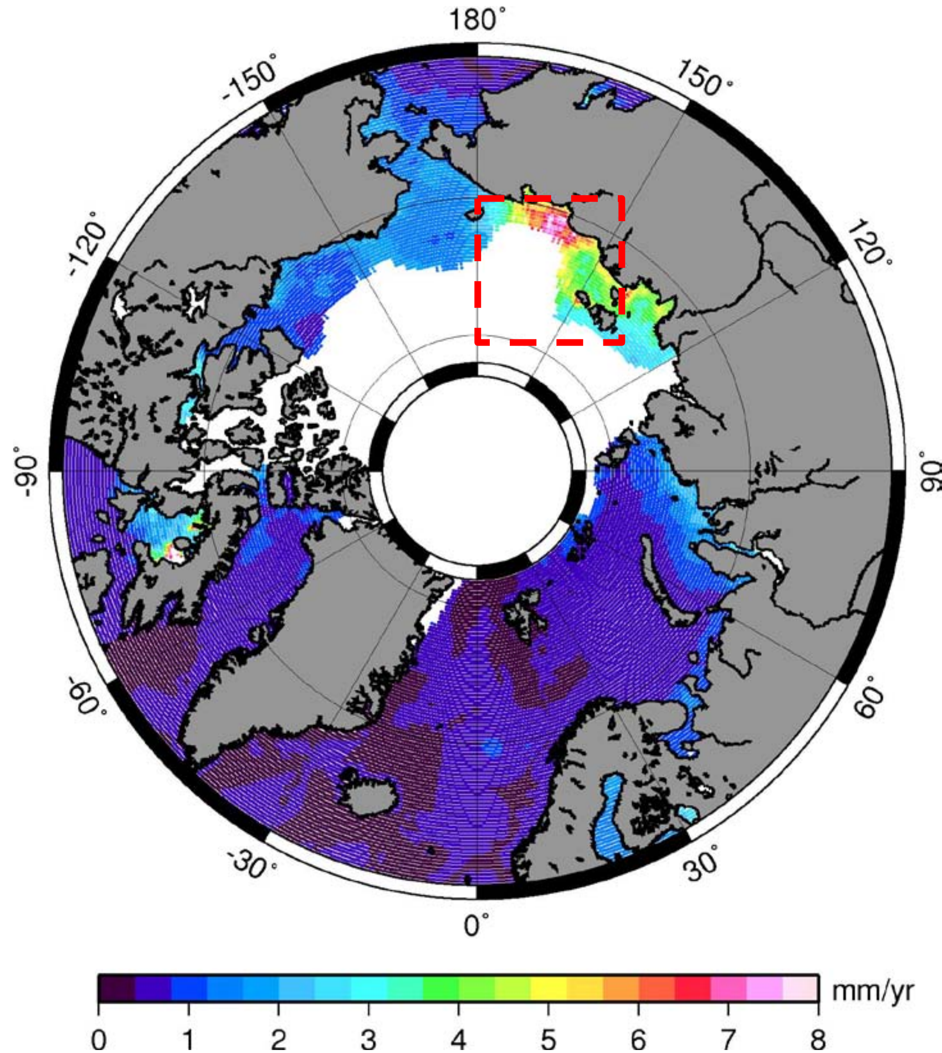
# Sea-Level Trend Uncertainties Over the Arctic Ocean, 1992–2010 (Preliminary)





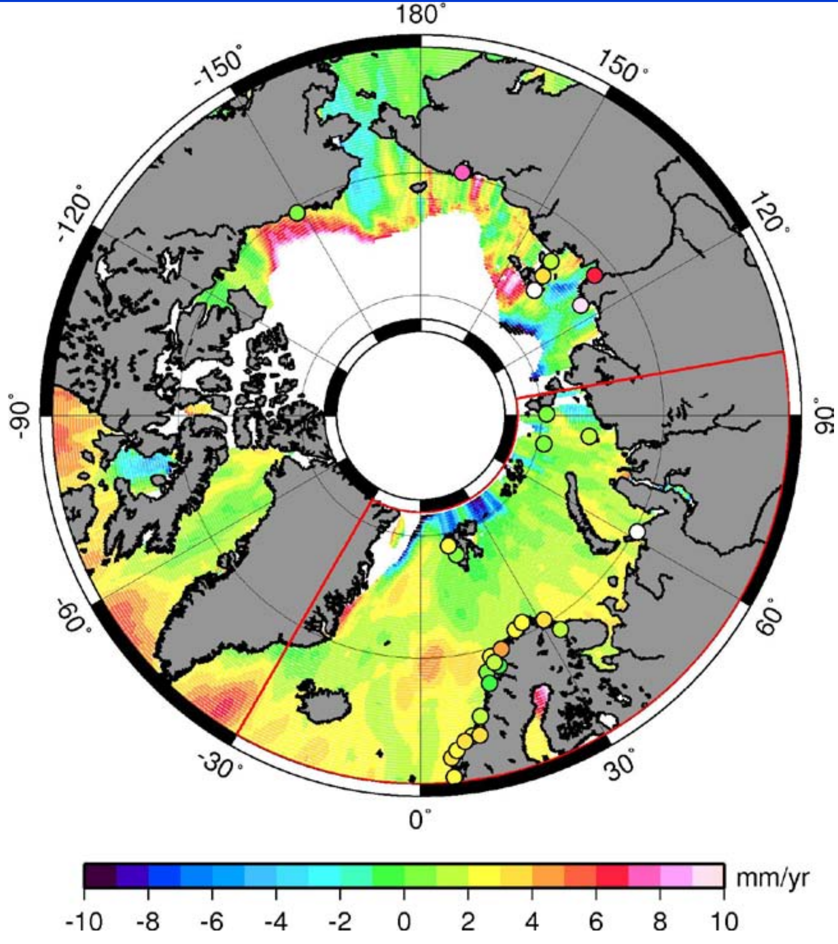

This study

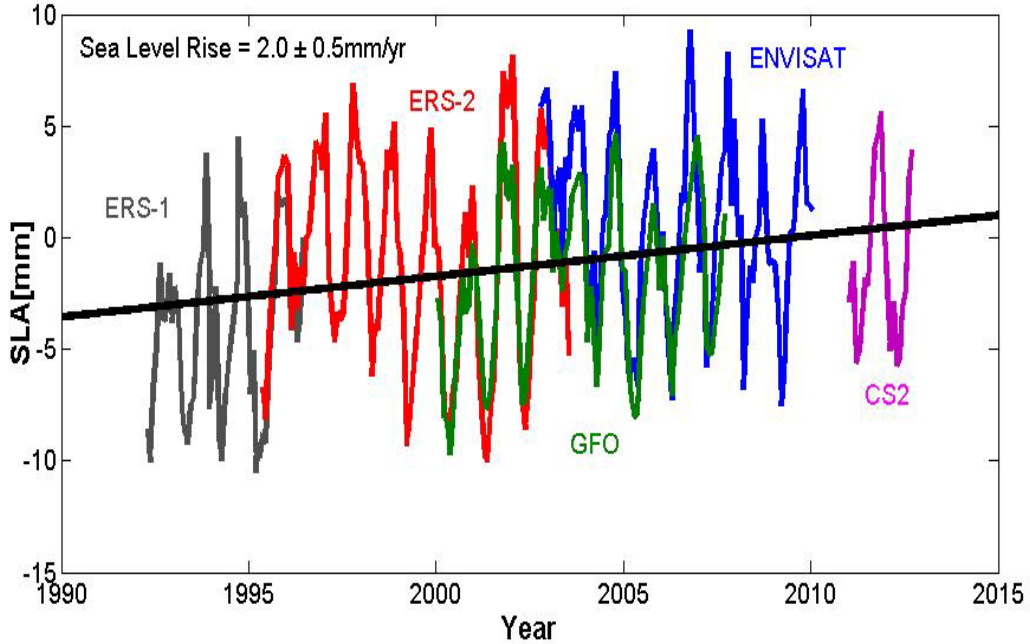



Duacs v3.0

# Estimated Sea-Level Trend in the Arctic Ocean 1992–2010

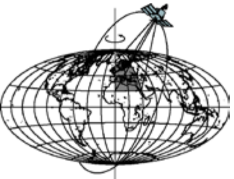
- ✓ Introduction
- ✓ Preliminary result
- Technique approach
- Conclusion




**Averaged trend: 2.3 mm/yr**

**2.0 mm/yr including CS2**

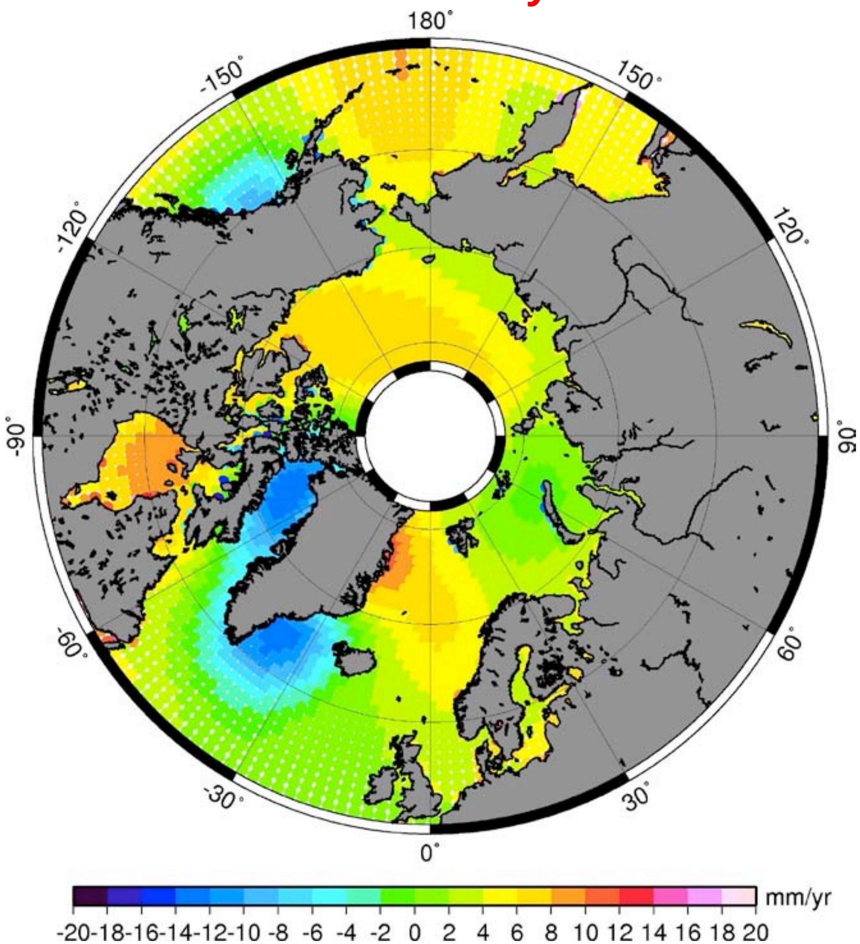


**Multi-satellite altimetry (ERS-1, ERS-2, Envisat, GFO, Cryosat-2) for Arctic Region (60N~82N, 30W~100E )**

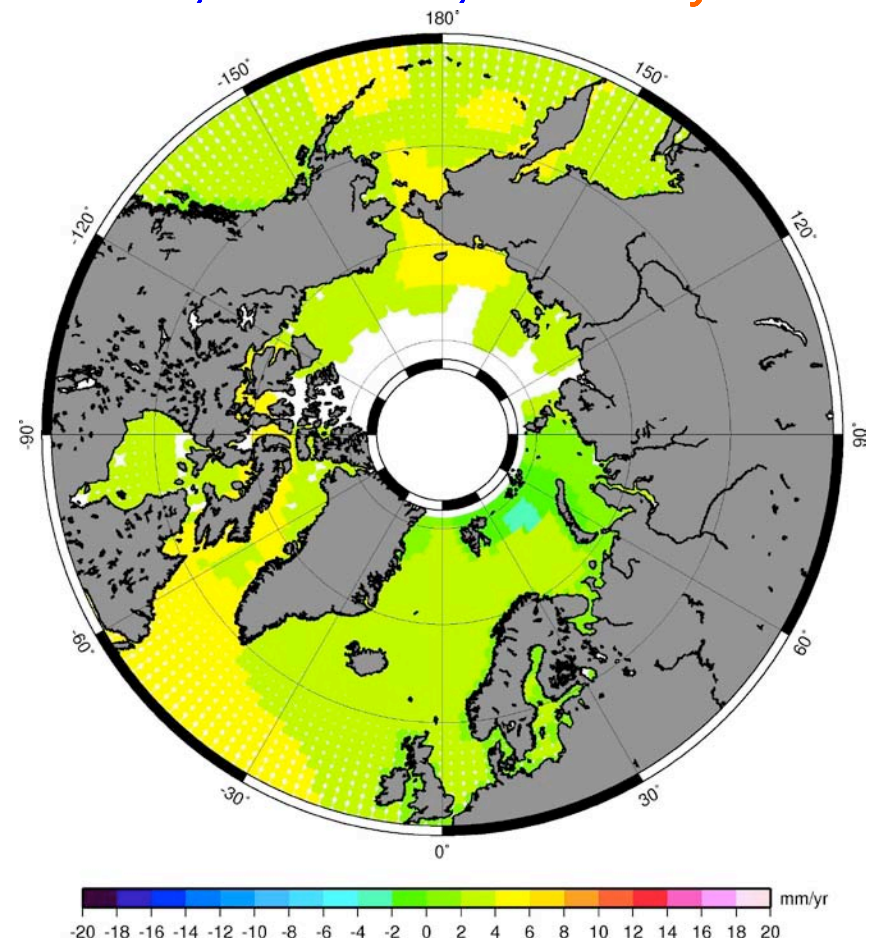
# Observed Arctic Ocean Mass Variations (Trend)

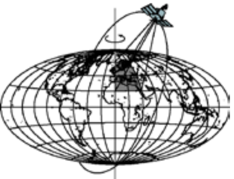


**GRACE OBP Trend, 2002–2011**
**1.14 mm $yr^{-1}$**




**Steric-corrected multi-altimetry sea-level trend, 2002–2011, 0.98 mm $yr^{-1}$**



Both data set filtered with a 400 km radius. GRACE data set (RL04) desctriped, corrected using van der Wal GIA model and SLR geocenter

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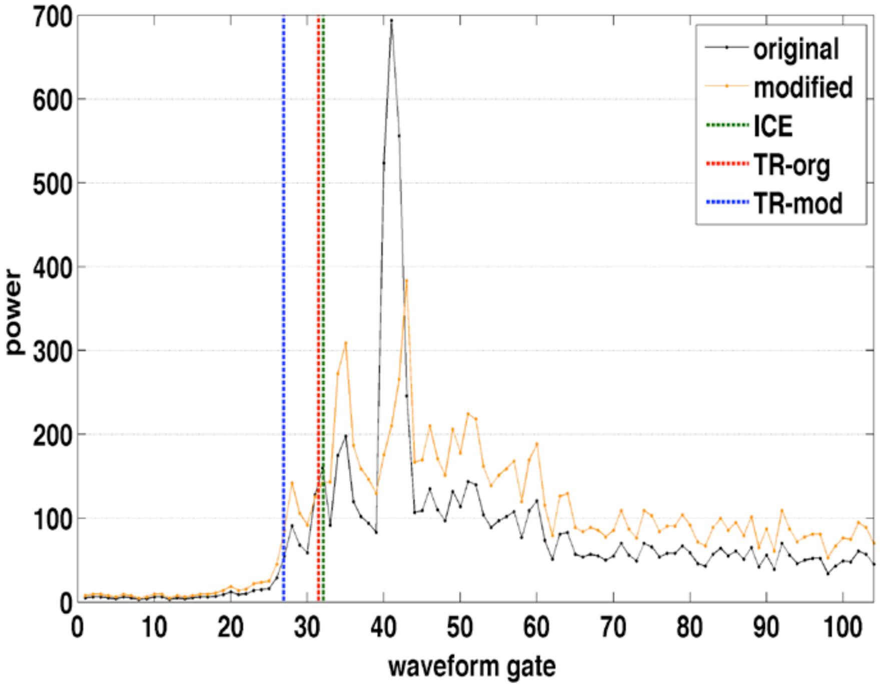
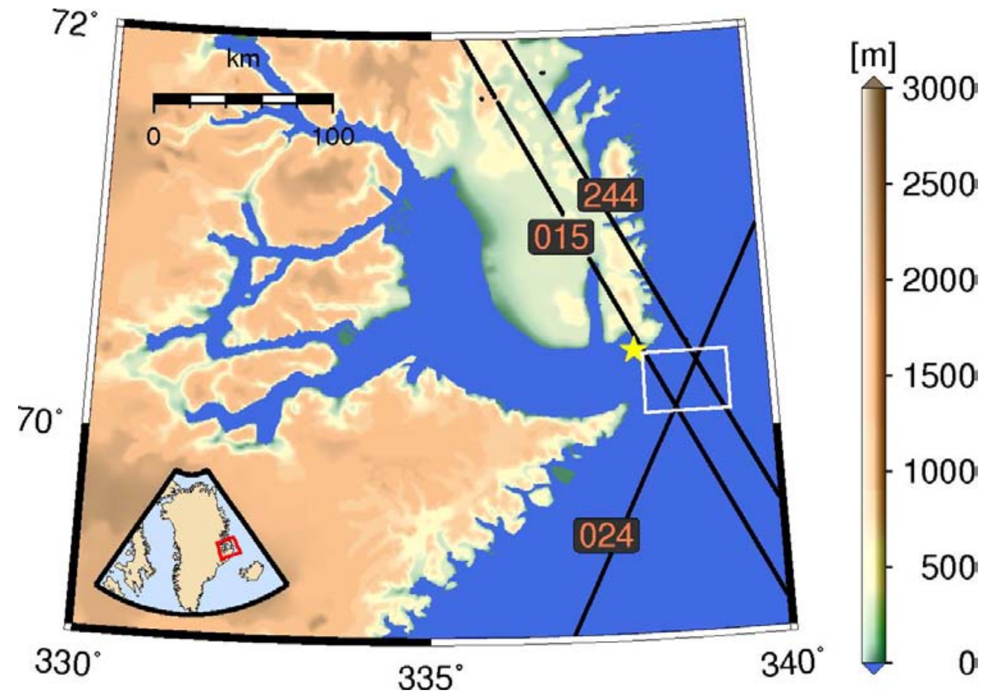
# Retracking: case Study in Greenland






An example of 1D waveform modification for Jason-2 near Los Angles



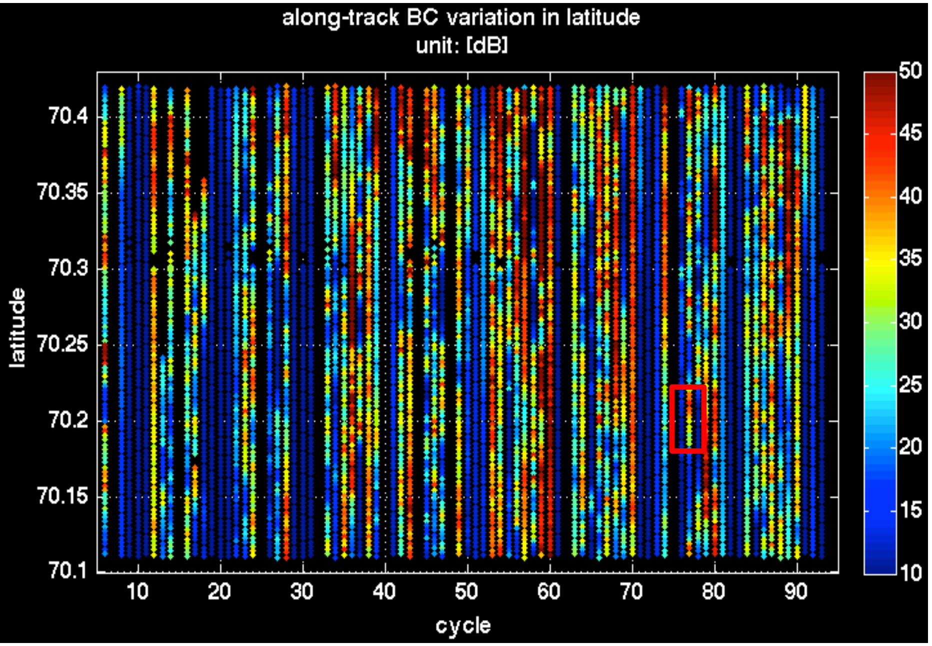

Envisat passes and WOCE gauge site used as ground truth at Greenland east coast

**Hypothesize that waveforms from the ice-covered ocean are similar to coastal ocean**

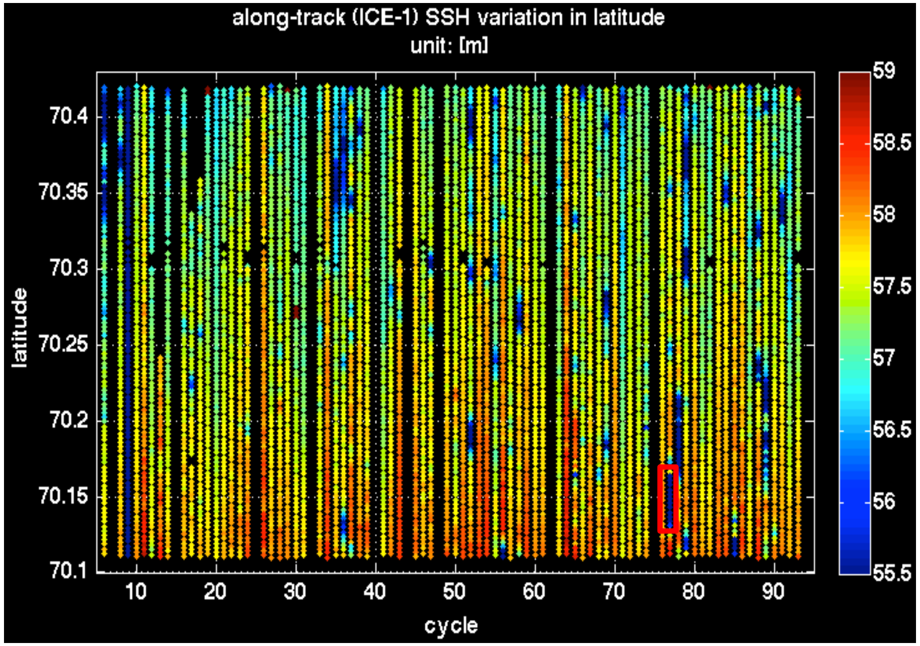
Tseng et al. [2012], Coastal WS, 20 yr RA Symposium

# Retracking: Case Study in Greenland



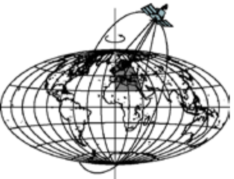



Envisat along-track variation of BC in latitude during each cycle




Envisat along-track variation of height (ICE-1) in latitude during each cycle

The off-nadir sea ice dominates the energy in the return waveform and leads to an **overestimate** of the range.



During **winter-spring** seasons, sudden drops of height measurements are commonly seen on the **edge of sea ice floe**.

Tseng et al. [2012], Coastal WS, 20 yr RA Symposium

# Retracking: Case Study in Greenland



**Table 1. RMS of available pass/cycles over study region against hourly gauge data**

| Cycle | | ICE-1 | OCEAN | SEA ICE | 20%TR | 20% TRmod |
|---|---|---|---|---|---|---|
| 224 | RMS [cm] | 21 | 41 | 42 | 22 | 17 |
| | Correlation | 0.77 | 0.5 | 0.42 | 0.76 | 0.87 |
| | Cycle gap | 0 | 4 | 0 | 0 | 0 |
| 24 | RMS [cm] | 14 | 61 | 34 | 15 | 14 |
| | Correlation | 0.88 | 0.25 | 0.43 | 0.86 | 0.88 |
| | Cycle gap | 0 | 0 | 0 | 0 | 0 |
| 15 | RMS [cm] | 30 | 72 | 62 | 30 | 23 |
| | Correlation | 0.58 | 0.43 | 0.42 | 0.58 | 0.71 |
| | Cycle gap | 0 | 0 | 0 | 0 | 0 |