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Uncertainty estimates of altimetric Global Mean Sea Level timeseries

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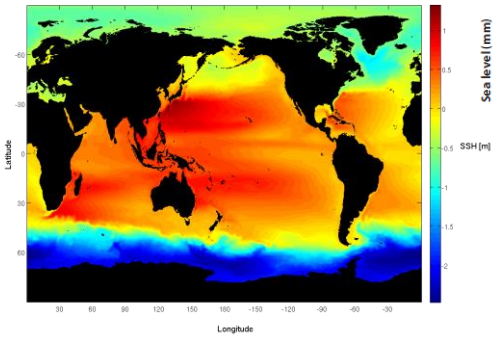
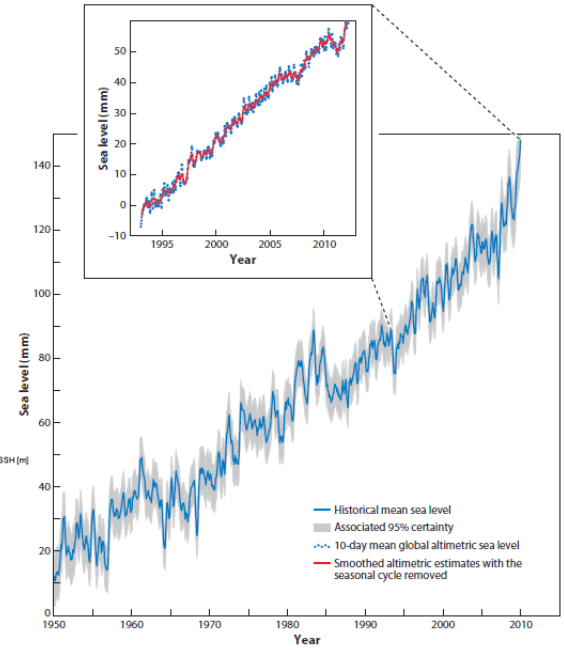
INDTRODUCTION

- 1.2 billion people live at or near the coast [Church, 2010]
- GMSL is predicted to rise between 0.26 an 0.98m within 2100 [Stoecker, 2013, 5th AR of IPCC]
- GMSL increased by ~1.8 mm/yr (tide gauge era) and 3.2 mm/yr (satellite era)

  [Stammer et al., 2013, Fig]

- Therefore, understanding possible Sea Level effects on a regional and global scale is key for future strategies to cope with Sea Level rise
- SL rise of last century mainly due to
  - Increase of ocean heat (steric)
  - Increased ocean mass (eustatic)

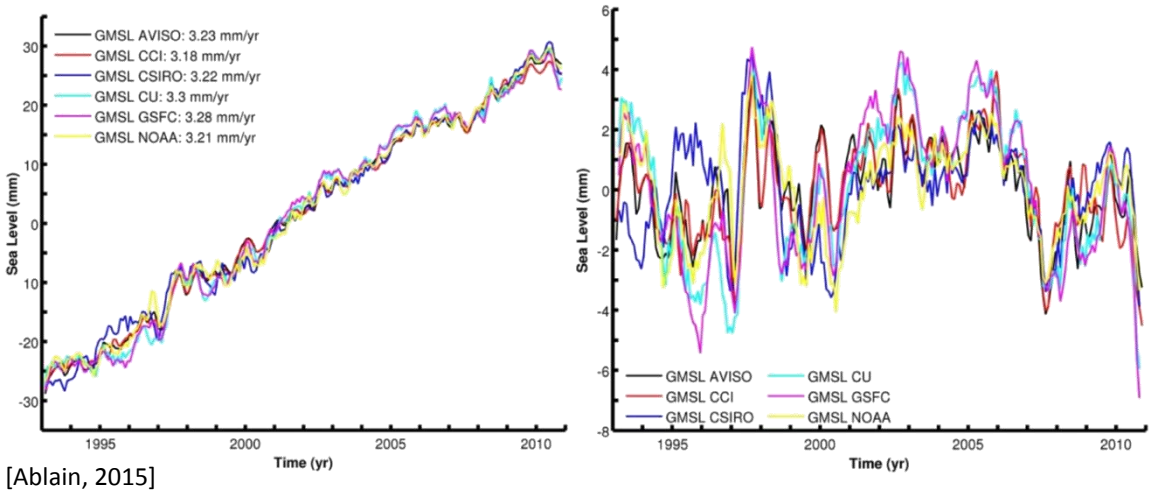




MOTIVATION

A range of GMSL estimates exist as result of different data processing techniques

[Ablain, 2009]



[Ablain, 2015]

The different estimates create uncertainty and it is importatant to reduce doubt about the current GMSL estimate [Masters et al., 2012; Henry et al., 2013]

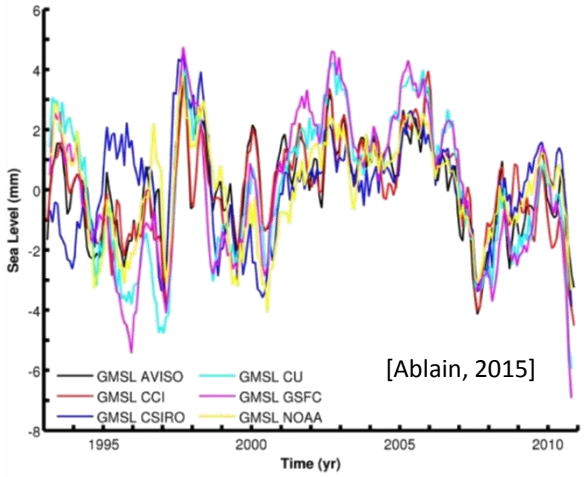
- With this study we investigate the impact different approaches can have on the estimate of GMSL, as it is important to understand the differences in the current GMSL estimates and thier real uncertainties. [for Jason-1 period only: Henry et al., 2013]

GMSL estimates

5 working groups:

CU	University of Colorado
AVISO	Archiving, Validation and Interpretation of Satellite Oceanographic data
GSFC	NASAs Goddard Space Flight Center
NOAA	National Oceanic and Atmospheric Administration
CSIRO	Commonwealth Scientific and Industrial Research Organisation

use different cycle ranges, orbits and corrections



[Ablain, 2015]

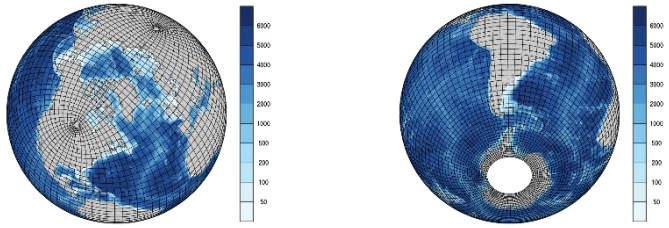
	CU	AVISO	GSFC	NOAA	CSIRO
Min. depth	120 m	0 m	120 m	0 m	0 m
SSH outlier	> 2 m			> 1 m	
Ave. method	along track	Grid	along track	grid	grid
Resolution		3°x 1°		3°x 1°	1°x 1°
Averaging time	per cycle	per cycle	per cycle	per cycle	monthly
Weighting	inclination	area	inclination	area	area

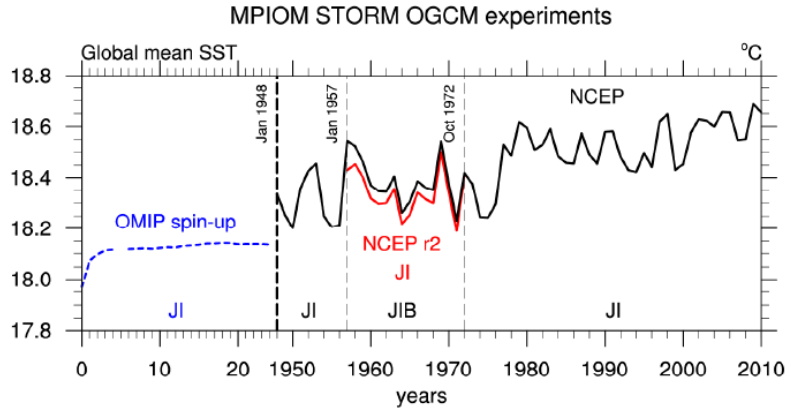
STORM / NCEP

We make use of the STORM/NCEP model [von Storch et al. 2012] as synthetic truth to test the effects of applying different averaging methods.

- Eddy-resolving coupled high resolution simulation with hydrostatic approximation
- tripolar grid for isotropic horizontal resolution with ~0.1° at the equator, two poles north and geographical grid grid south at 0.1**cos(φ)* (5 km resolution at 60°S)
- coupled with: sea ice model with growth and melt of sea ice and sea ice cirulation
- Global mean SL is removed at any timestep, i.e. the global mean model truth is zero.
- spin up for 25 years using daily OMIP forcing German Ocean Model Intercomparison
- 1948-2010 forcing switched to 6 hourly NCEP NCAR reanalysis

(Shown just exemplarily for Global Mean SST)





DATA

STORM/NCEP	grid	90°N-S	daily	model truth	StRegGrFc90
STORM/NCEP	grid	66°N-S	daily		StRegGrFc66
STORM/NCEP	along track	66°N-S	daily		StAtFc
STORM/NCEP	along track	66°N-S	10 day		StAtSubCom
STORM/NCEP	along track	66°N-S	10 day	missing values	StAtSubMiss
TPJJ	along track	66°N-S	10 day	satellite prod.	TPJJ
STORM/NCEP	grid	66°N-S	10 day	2°x 2°, 3°x 1°, 1°x 1°,	3°x 3°
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STORM/NCEP	al tr / grid	66°N-S	10 day	outlier	StAtSubMissSyn
STORM/NCEP	along track	66°N-S	10 day	sea ice	StAtSubMissIce

- 4 month moving average, annual, seimannual harmonic removed from all timeseries

UNCERTAINTIES

STORM/NCEP	grid	90°N-S	daily	model truth	StRegGrFc90
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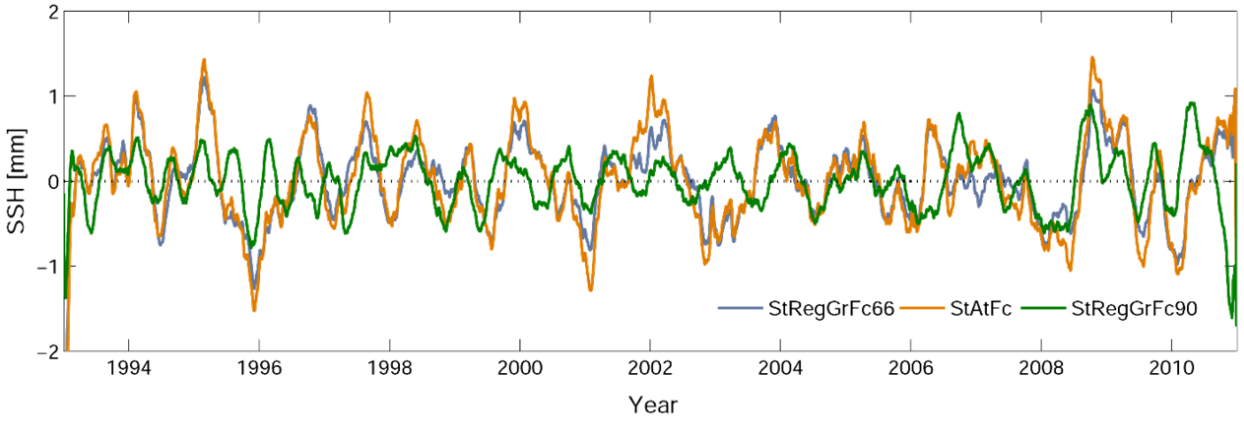
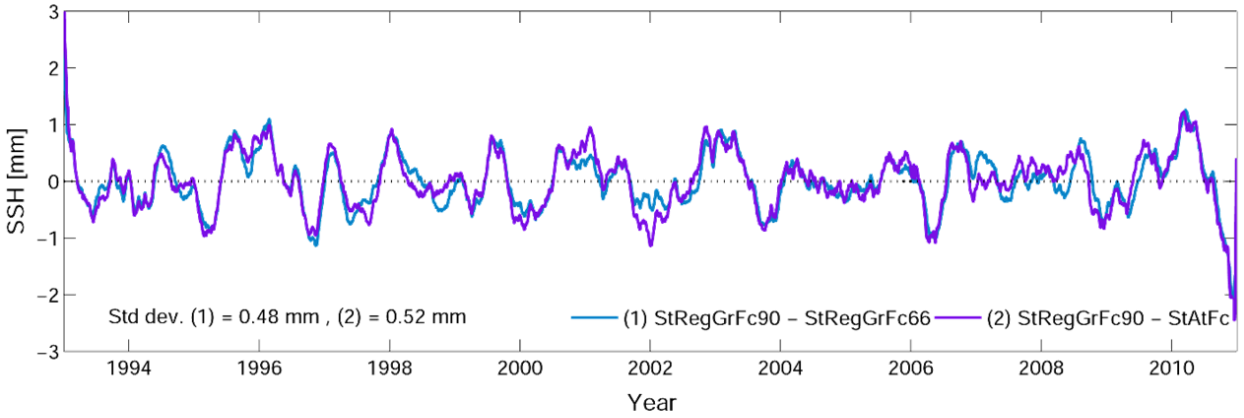
Latitudinal coverage

- Large differences [1.2 mm]
  - Regular gridded 90°N-S
  - Regular gridded 66°N-S
- Small differences [0.5 mm]
  - Regular gridded 66°N-S
  - Along track 66°N-S

→ Norhtern latitudes are crucial for the under-standing of GMSL

→ Along track sampling alters the GMSL estimate





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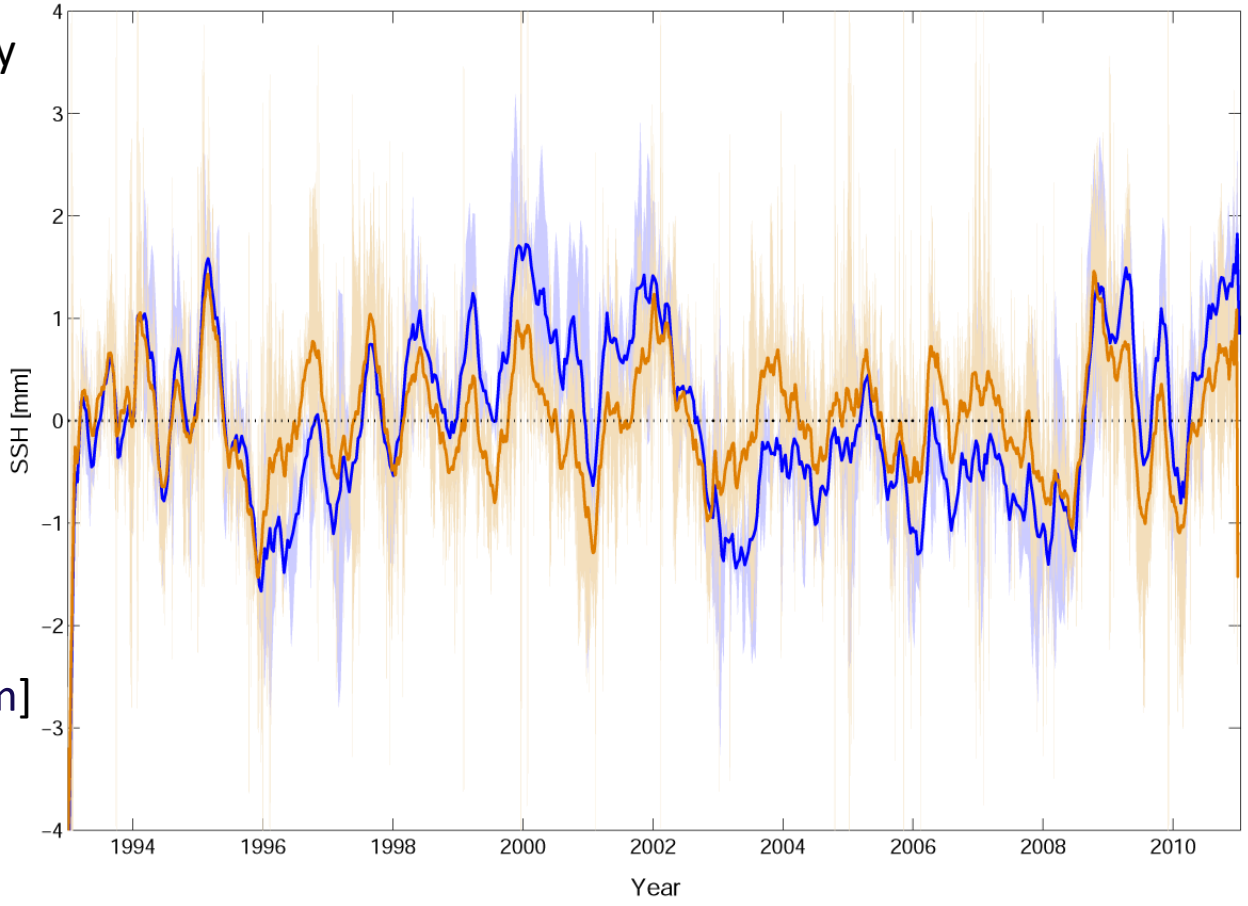
STORM/NCEP	along track	66°N-S	10 day	sea ice	StAtSubMissIce

Temporal coverage

- Subsampling the global daily STORM/NCEP data as seen by T/P gives a nominal global 10 day resolution:
  Along track 66°N-S daily res.
  Along track 66°N-S 10 day res

→ The sparse 10 day satellite coverage has a clear influence on GMSL [1.0 mm]

→ A daily global SL coverage adds plenty of information



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STORM/NCEP	along track	66°N-S	10 day	sea ice	StAtSubMissIce

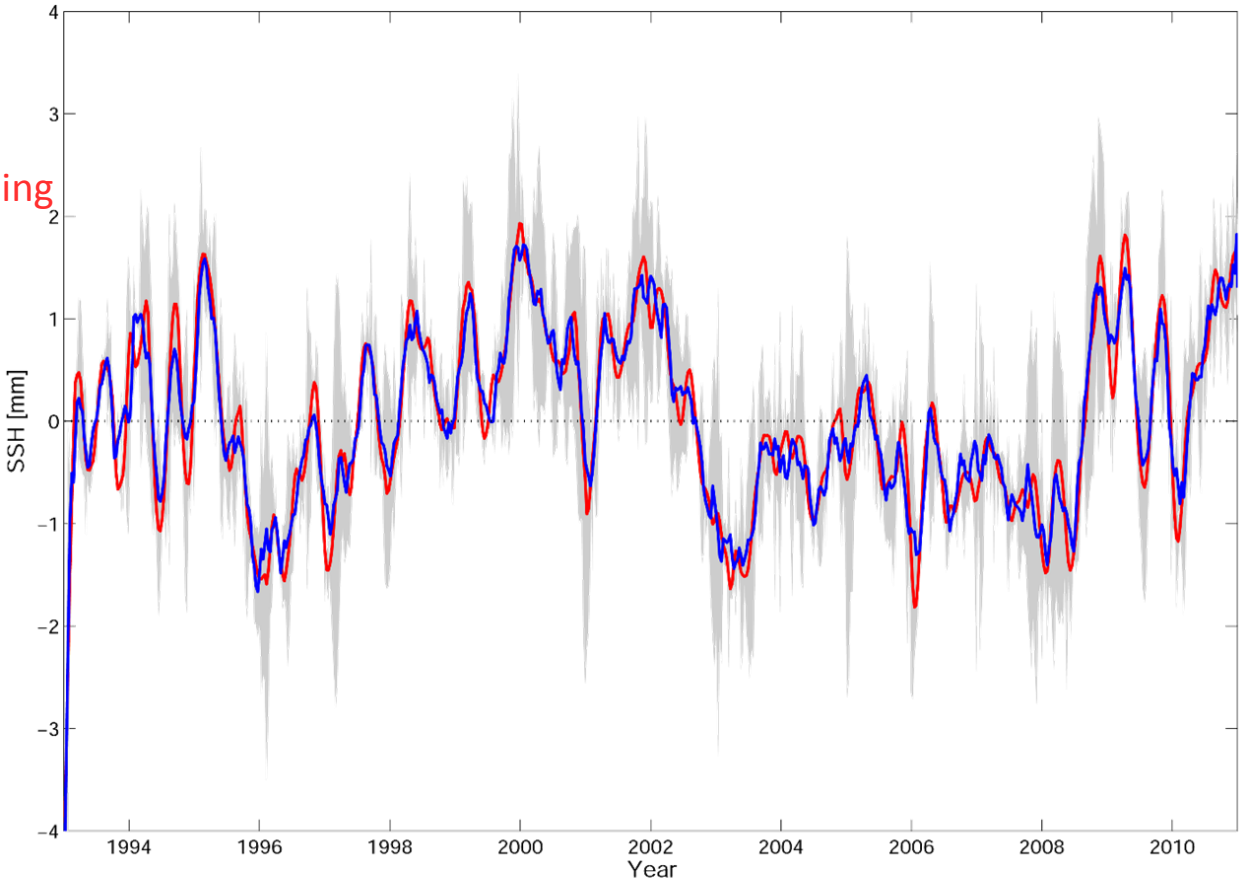
Missing values due to retrieval errors

- in the data flags

  Along track 66°N-S 10 day

  Along track 66°N-S 10 day Missing

→ have a moderate but not negligible influence on GMSL estimates [0.4 mm]



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Variability of synthetic truth of STORM/NCEP

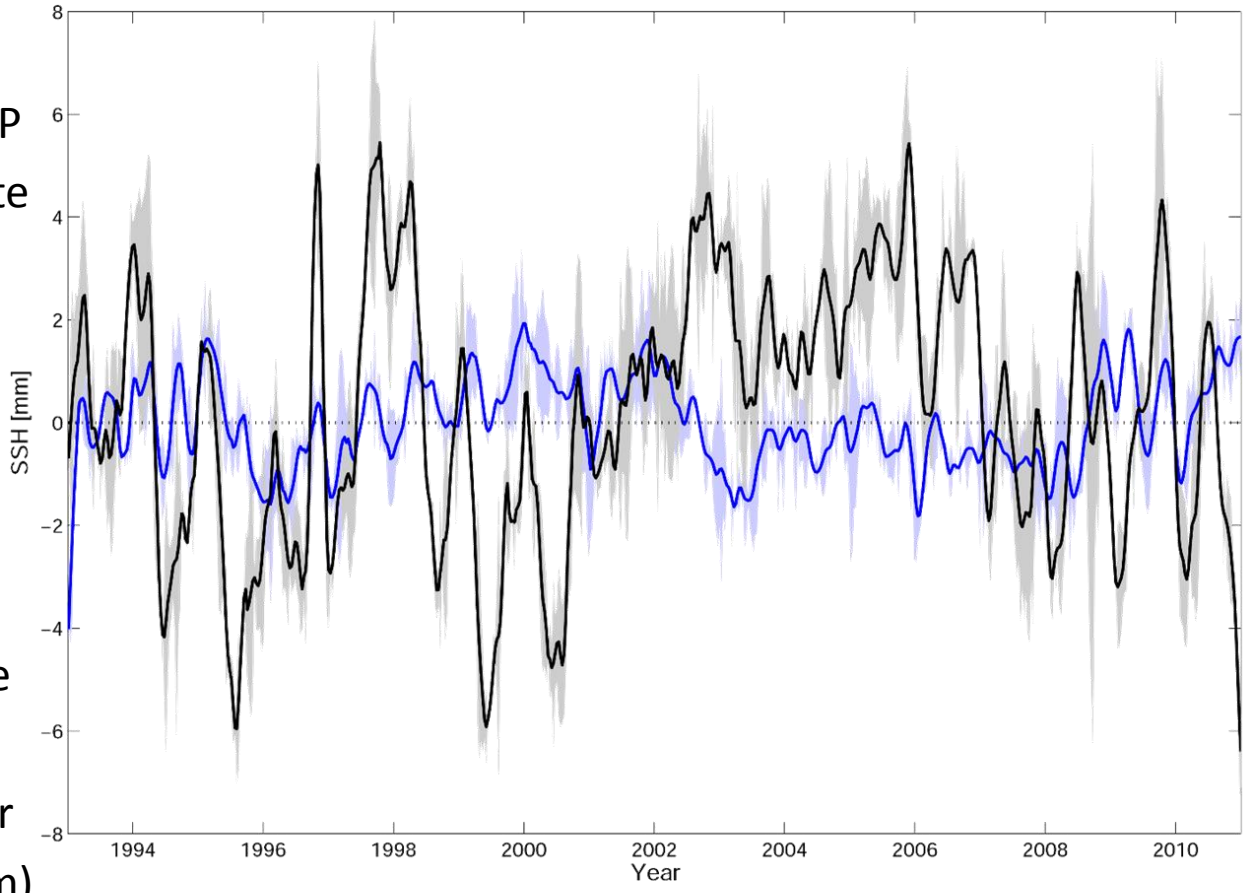
- Comparing the synthetic model truth of STORM/NCEP to the to the real T/P satellite series

  Along track 66°N-S 10 day

  Along track TPJJ

→ Majority of maxima and minima peaks of STORM agree with the TPJJ satellite series

→ STD of both series is similar (TPJJ 23.8 mm and 21.2 mm)



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Along track / gridded GMSL estimates

- Gridding the along track data as well as a different grid resolution have a strong impact on the GMSL estimate.

  Along track 66° 10d Miss

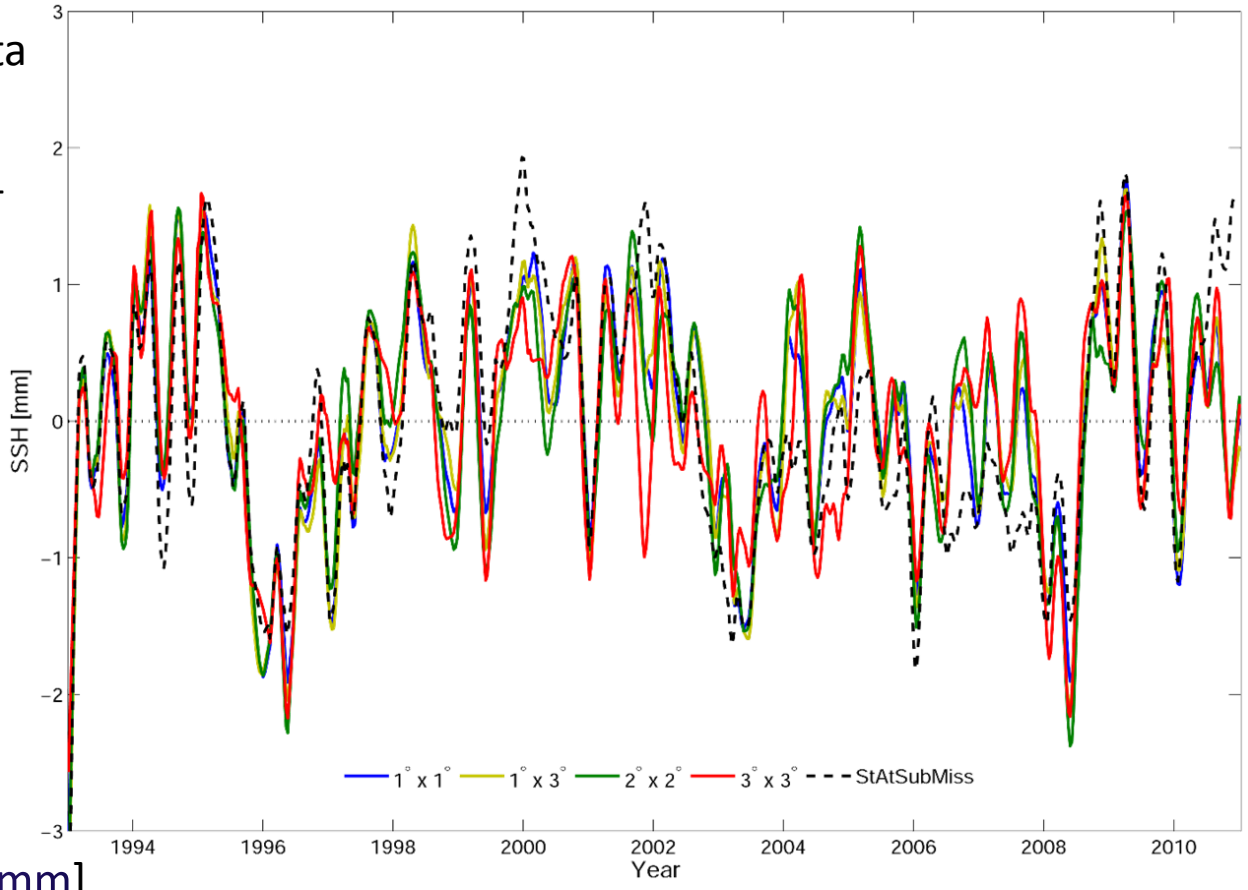
  1°x 1° CSIRO

  3°x 1° NOAA, AVISO

  2°x 2° previous AVISO

  3°x 3°

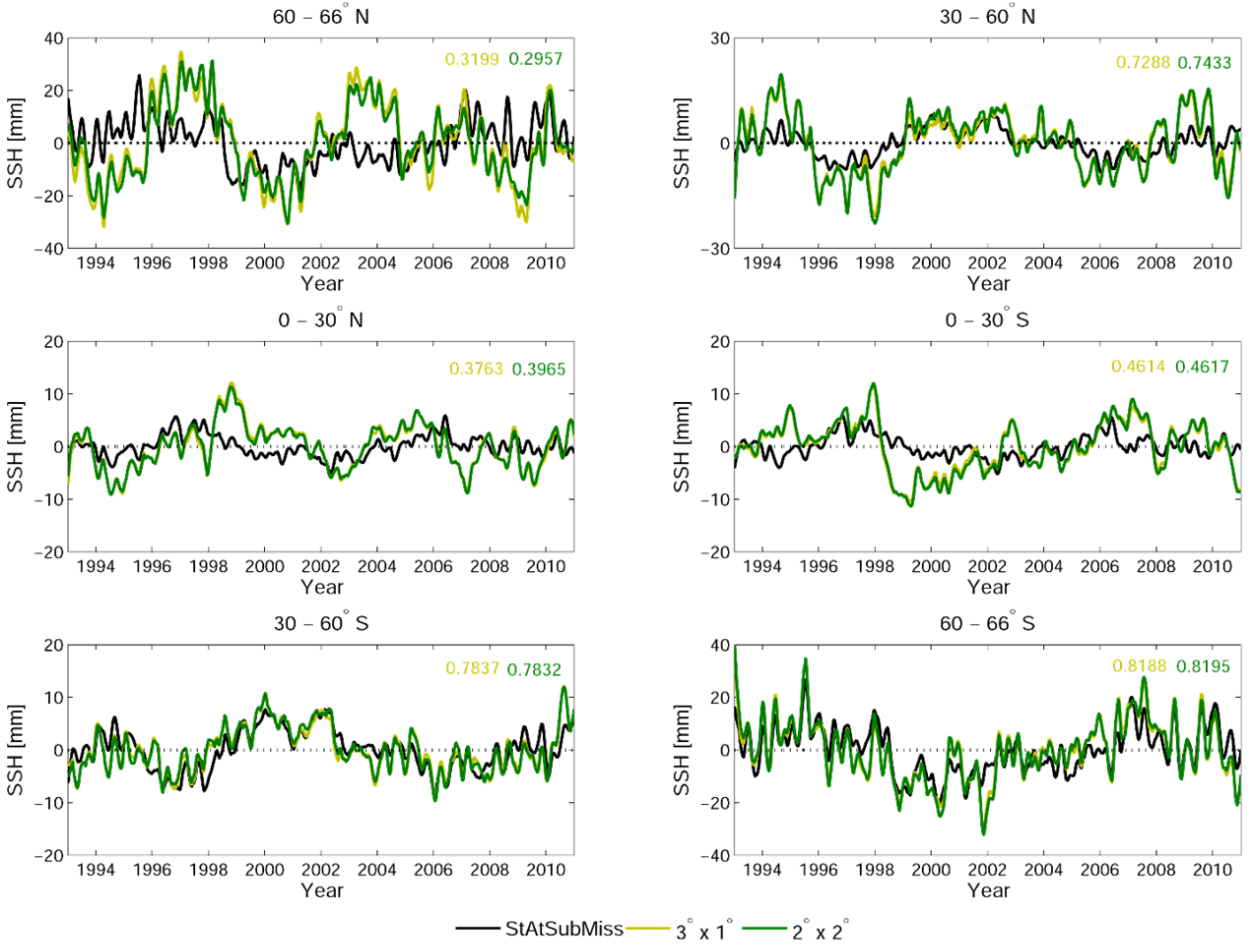
→ A finer the grid resolution, results in a closer GMSL gridded estimate [1.0/1.5 mm]



Along track / gridded GMSL estimates - latitudinal

- Clear latitudinal differences exist between the along track and the gridded GMSL products
  - Along track 66° 10d Miss
  - 3°x 1° NOAA, AVISO
  - 2°x 2° previous AVISO

→ Largest differences in northern latitudes and close to the equator (correlation coefficients)



UNCERTAINTIES

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STORM/NCEP	along track	66°N-S	10 day	50, 100, 300, 500 m	StAtSubMissDep
STORM/NCEP	al tr / grid	66°N-S	10 day	outlier	StAtSubMissSyn
STORM/NCEP	along track	66°N-S	10 day	sea ice	StAtSubMissIce

Depth criteria

- Removing data close to land alters the GMSL estimates
- In contrast to satellite data, STORM is free of errors close to land. Differences represent effect of missing data points

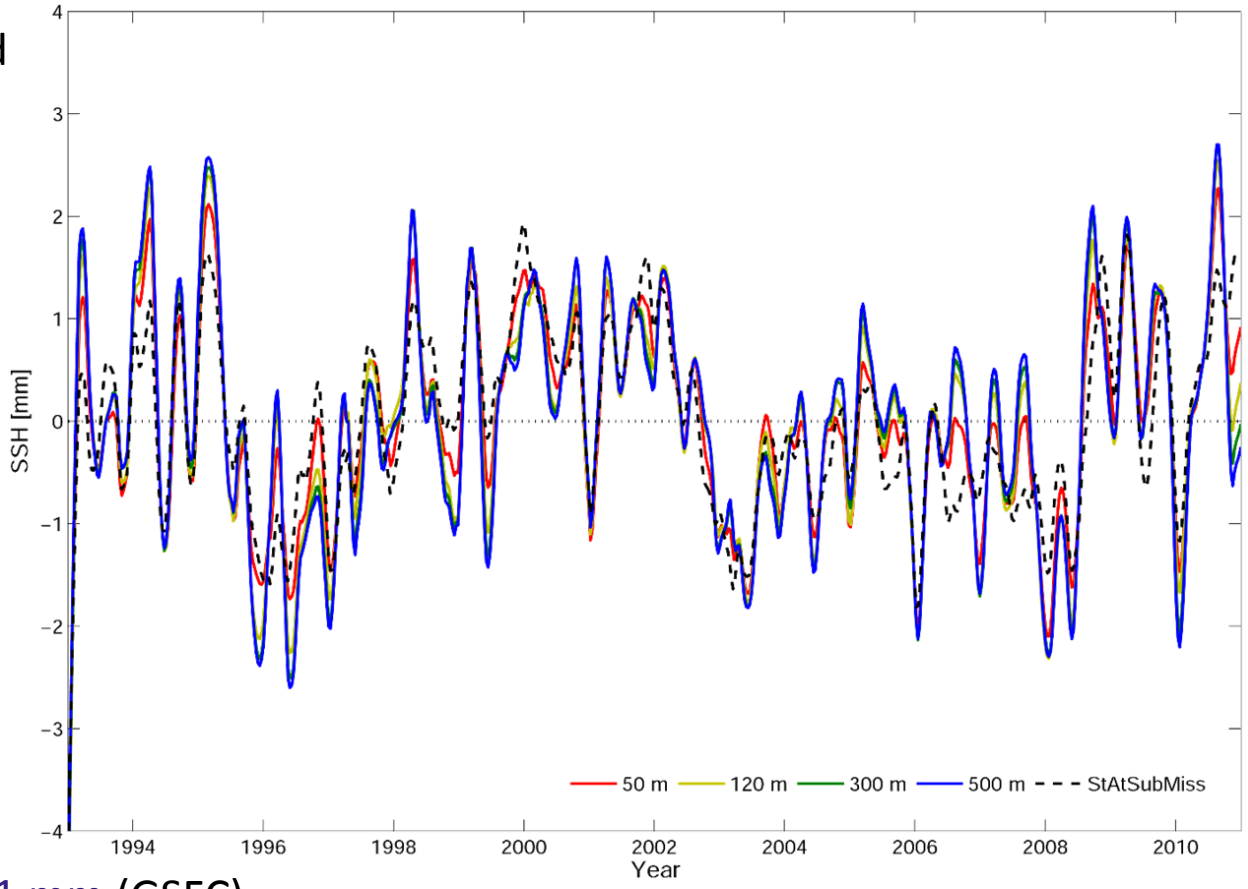
Along track 66° 10d Miss

50 m

120 m (CU, GSFC)

300 m

500 m



→ Differences: 0.3 mm (CU), 1 mm (GSFC)

UNCERTAINTIES

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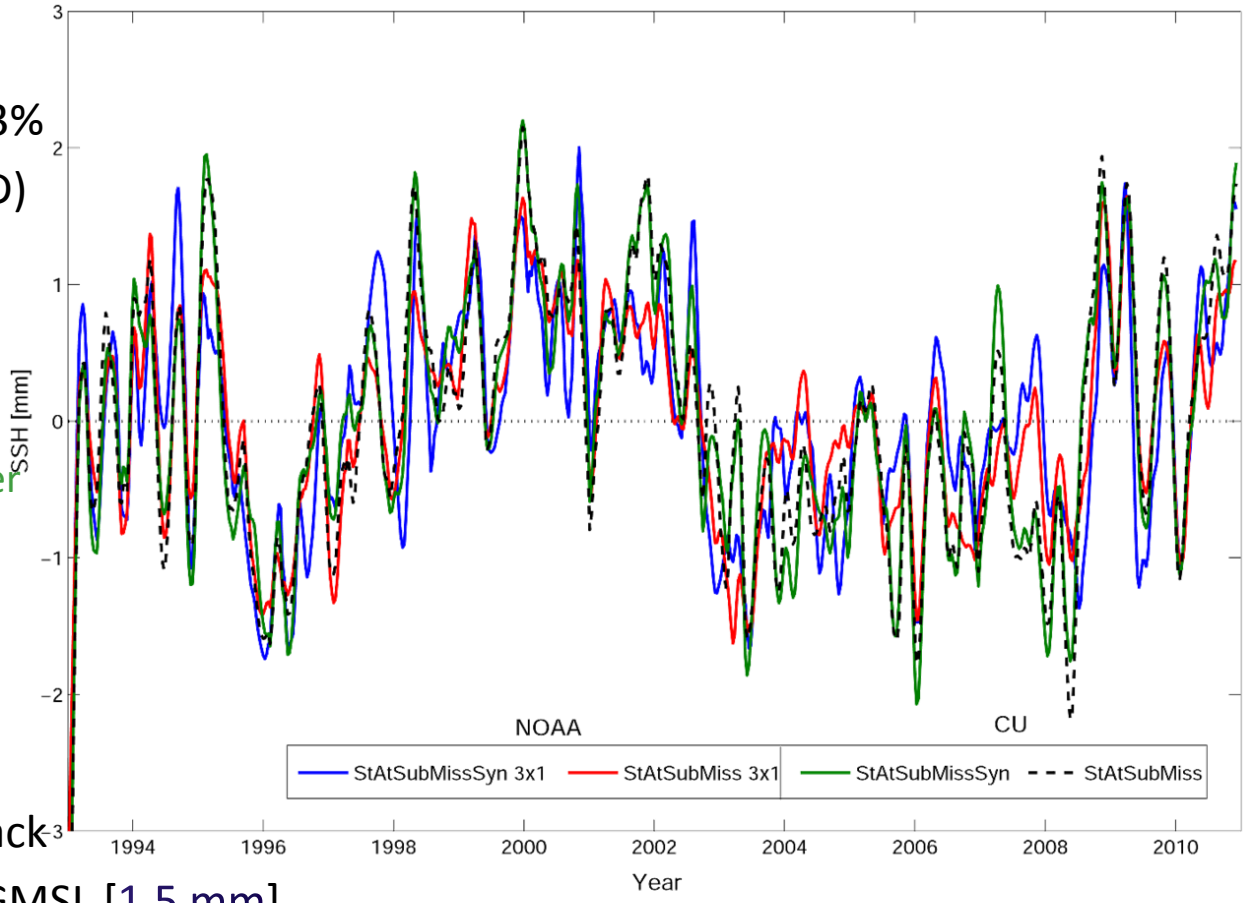
STORM/NCEP	along track	66°N-S	10 day	sea ice	StAtSubMissIce

Outlier removal

- Same percentage of outlier as in the satellite series 0.13% (3 times greater as their STD) randomly added (2-3m) to:
- CU along track
  - Along track 66° 10d Miss
  - Along track 66° 10d Miss outlier
- NOAA 3°x 1° grid
  - Grid 66°N-S 3°x 1° Miss
  - Grid 66°N-S 3°x 1° Miss outlier



→Smaller impact on along track [0.5 mm] than on gridded GMSL [1.5 mm]

UNCERTAINTIES

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STORM/NCEP	along track	66°N-S	daily		StAtFc
STORM/NCEP	along track	66°N-S	10 day		StAtSubCom
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STORM/NCEP	along track	66°N-S	10 day	50, 100, 300, 500 m	StAtSubMissDep
STORM/NCEP	al tr / grid	66°N-S	10 day	outlier	StAtSubMissSyn
STORM/NCEP	along track	66°N-S	10 day	sea ice	StAtSubMissIce

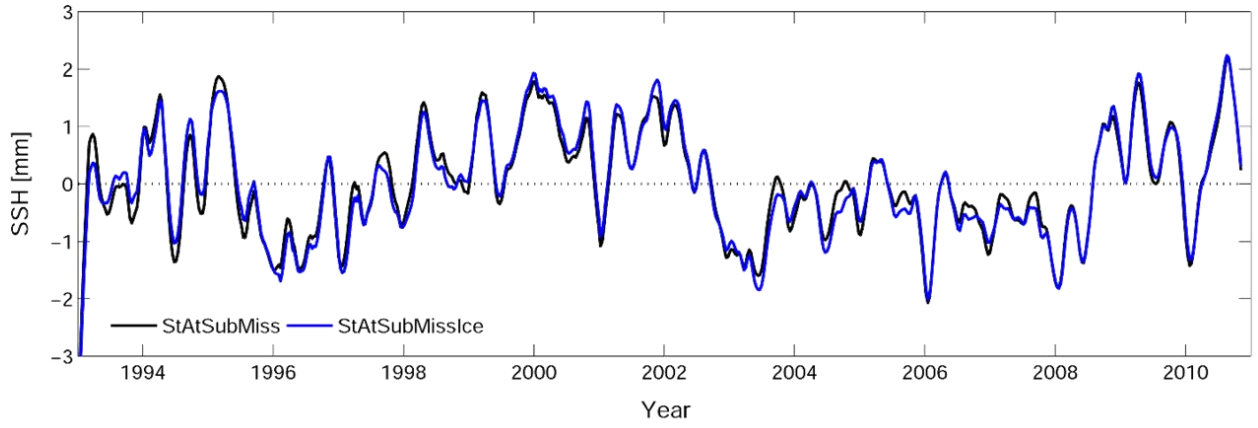
Sea Ice Cover

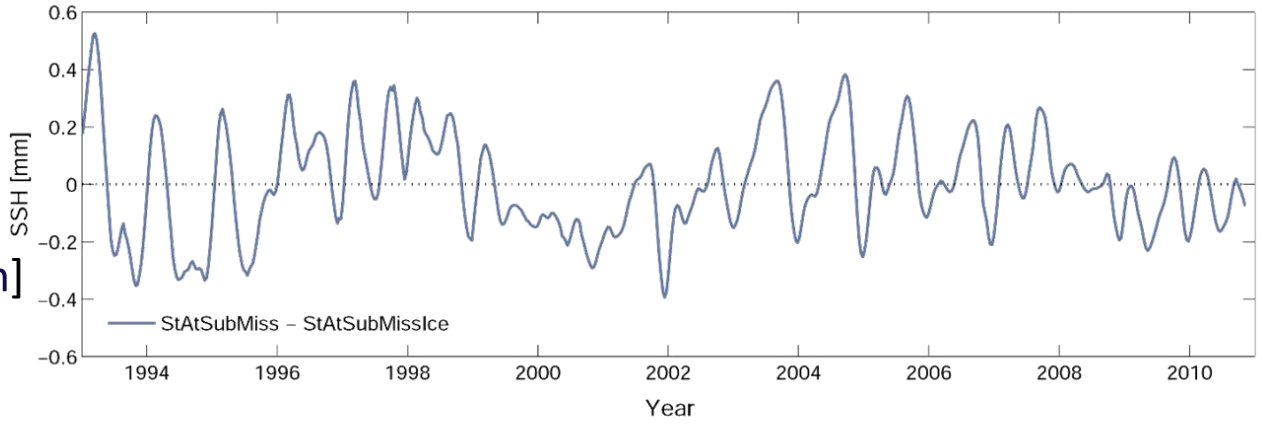
- diminishes the amount of possible SL measurments
- Use ECMWF ERA interim sea ice cover

  Along track 66° 10d Miss

  Along track 66° 10d Miss+Ice

→ As for the missing values and the outliers, sea ice missing SL data alters the estimate of GMSL [0.5 mm]





CONCLUSIONS

uncertainties

	grid	90°N-S	daily	model truth	StRegGrFc90
1.2 mm	grid	66°N-S	daily		StRegGrFc66
0.5 mm	along track	66°N-S	daily		StAtFc
1.0 mm	along track	66°N-S	10 day		StAtSubCom
0.4 mm	along track	66°N-S	10 day	missing values	StAtSubMiss
	along track	66°N-S	10 day	satellite prod.	TPJJ
1.0-1.5 mm	grid	66°N-S	10 day	2°x 2°, 3°x 1°, 1°x 1°,	3°x 3°
0.3-1.0 mm	along track	66°N-S	10 day	50, 100, 300, 500 m	StAtSubMissDep
0.5 / 1.5 mm	al tr / grid	66°N-S	10 day	outlier	StAtSubMissSyn
0.5 mm	along track	66°N-S	10 day	sea ice	StAtSubMissIce

CONCLUSIONS

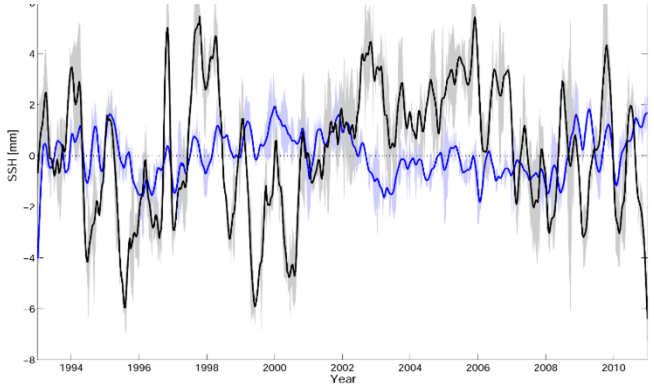
uncertainties for STORM

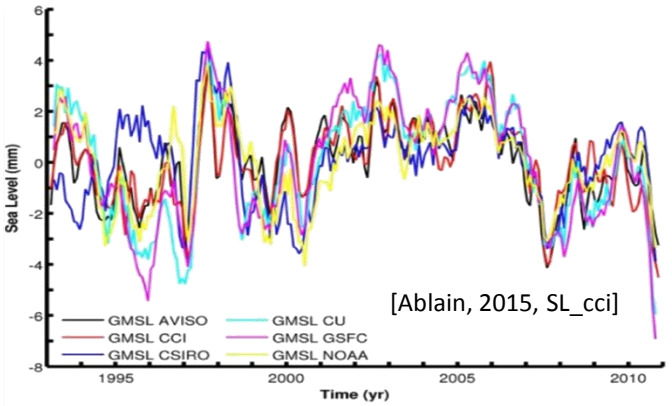
1.2 mm

0.5 mm

1.0 mm

0.4 mm





[Ablain, 2015, SL_cci]

- Due to the smaller variablity in STORM as compared to satellite data the uncertainties for GMSL estimates serve as a lower bound
- Exemplarily for the 5 working groups the error budged for SL_cci (multi mission) is given as GMSL (>10 yrs) 0.5 mm/yr
  GMSL (< 5 yrs) 2.0 mm/yr

1.0-1.5 mm

0.3-1.0 mm

0.5 / 1.5 mm

0.5 mm

→ depending on the method used, the uncertainties of the GMSL estimates needs to be considered larger by up to +6 mm

CONCLUSIONS

cen

uncertainties

					CU	AVISO	GSFC	NOAA	CSIRO
	grid	90°N-S	daily	mm	+3.9	+6.6	+5.1	+5.1	+6.1
1.2 mm	grid	66°N-S	daily		X	X	X	X	x
0.5 mm	along track	66°N-S	daily		X	X	X	X	X
1.0 mm	along track	66°N-S	10 day		X	X	X	X	X
0.4 mm	along track	66°N-S	10 day	miss	X	X	X	X	X
	along track	66°N-S	10 day						
1.0-1.5 mm	grid	66°N-S	10 day			1.5		1.5	1.0
0.3-1.0 mm	along track	66°N-S	10 day	depth	0.3		1.0		
0.5 / 1.5 mm	al tr / grid	66°N-S	10 day	outlier		1.5	0.5		1.5
0.5 mm	along track	66°N-S	10 day	sea ice	X	X	X	X	X

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