Satellite Observations of Ocean Winds and Waves

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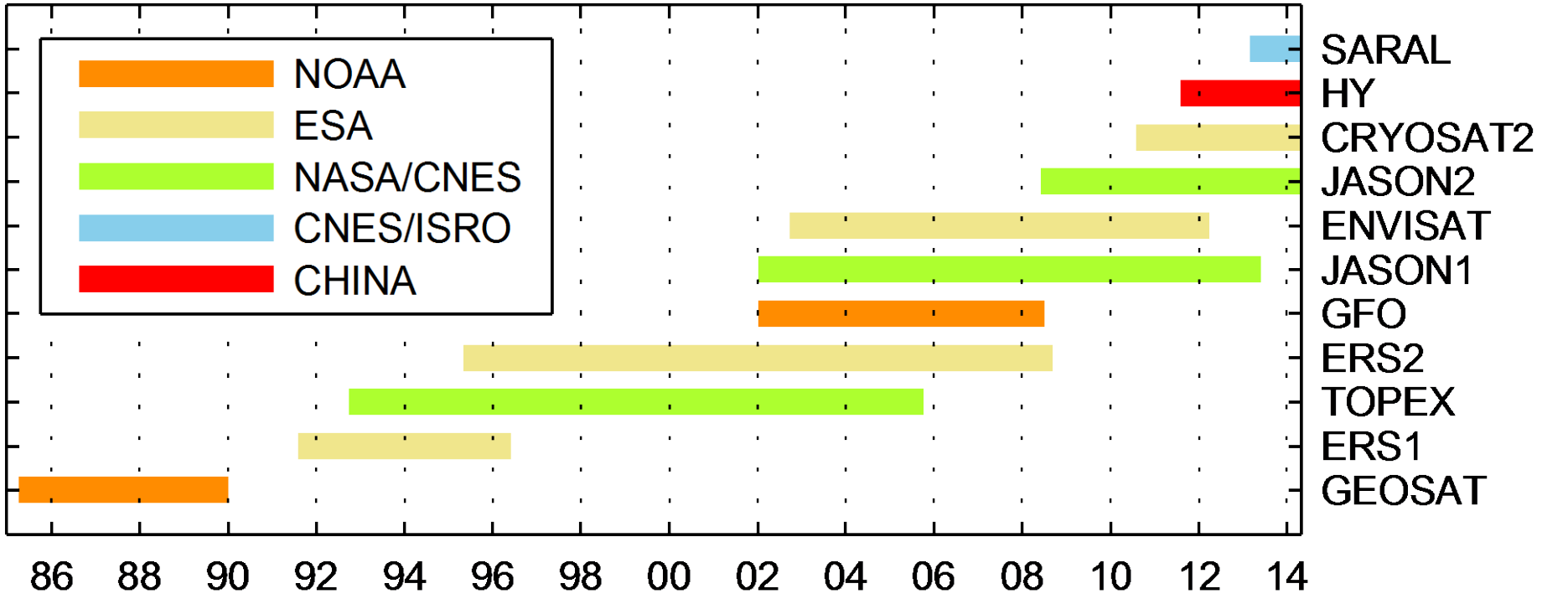
Motivation

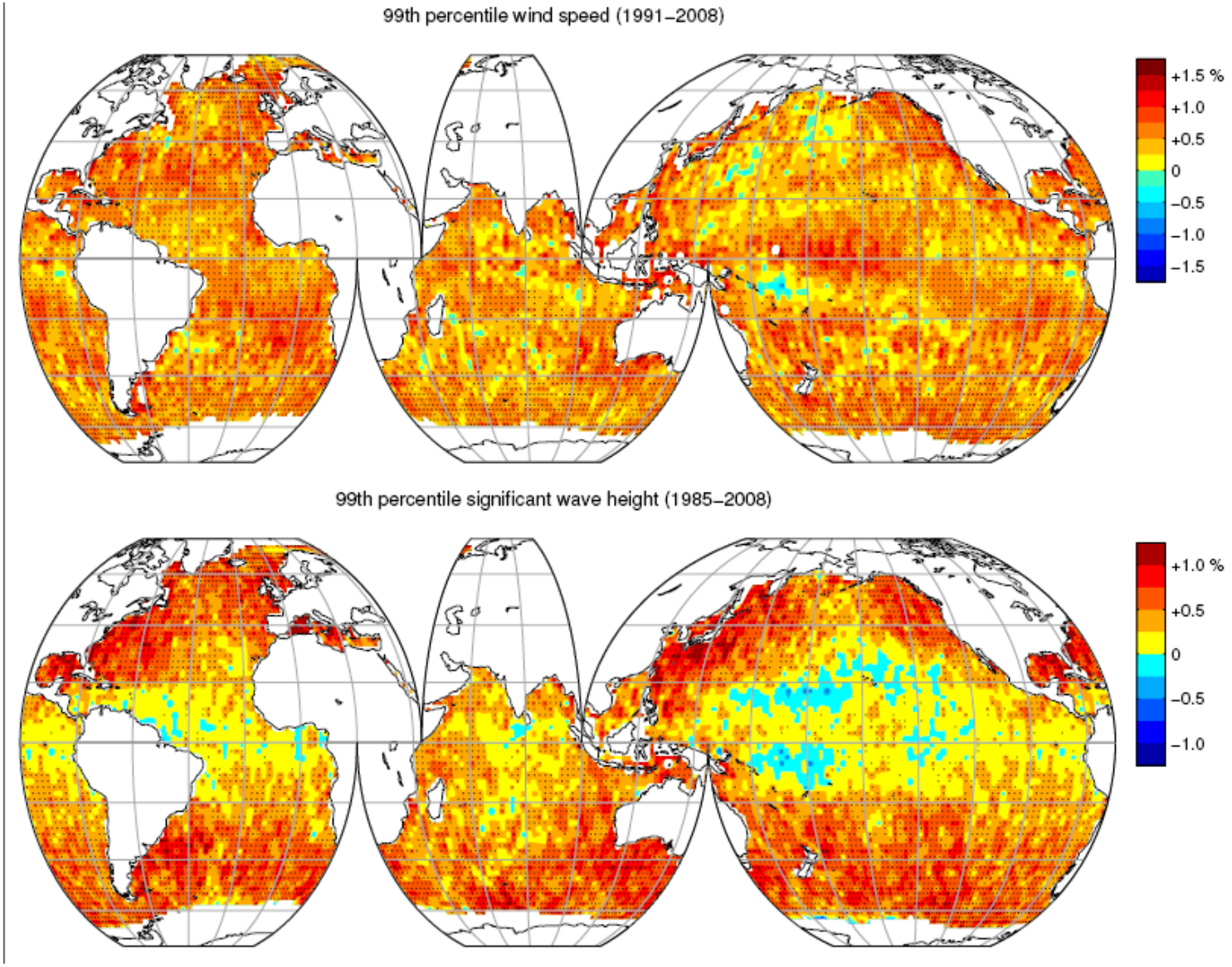
- Satellite-borne devices can measure the global wind, wave, ice and other air-sea interaction properties with global coverage and accuracy comparable to buoy observations
- They have been flown for decades and allow to investigate trends and long-term oscillations
- Waves, ocean winds, sea ice can serve as climate proxies, their means and extremes change
- *Problems:* invalid measurements must be removed first – land, rain, ice

Young, I.R., Babanin, A.V., “A global satellite altimeter database for ocean engineering applications”, ARC Linkage and RPS MetOcean (WA)

Altimeter Data

- Continuous coverage for 22 years
- ERS1 , ERS2 and ENVISAT cover up to 82^{o} latitude
- GEOSAT and GFO cover up to 72^{o} latitude
- JASON and TOPEX reach 66^{o} latitude
- CRYOSAT2 covers areas up to 88^{o}
- HY-2 covers areas up to 80^{o}
- SARAL covers areas up to 81^{o}

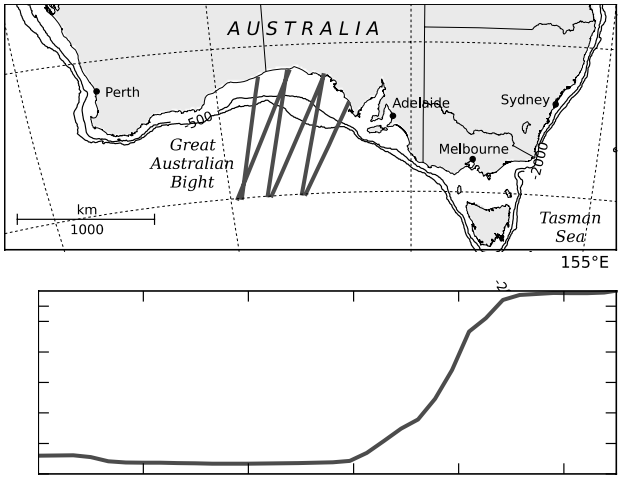


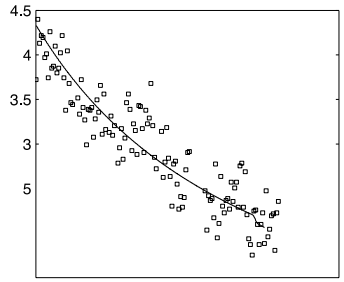


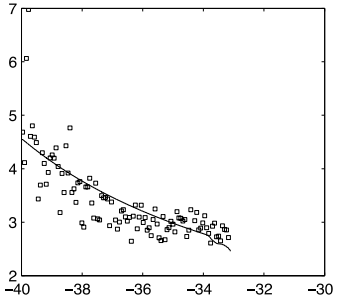
Young, Zieger, Babanin, 2011, *Science*

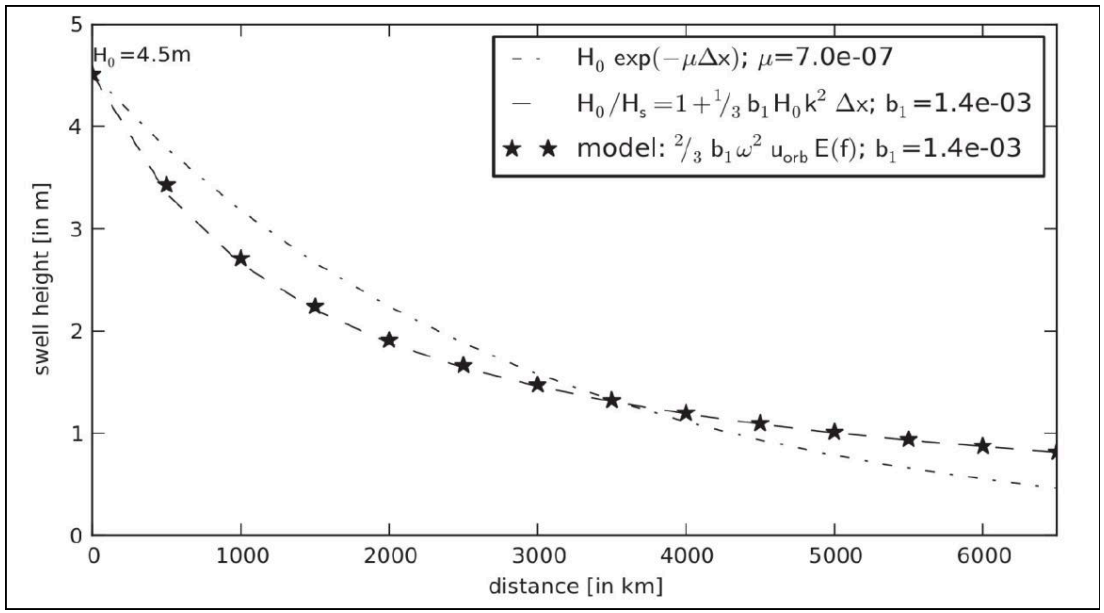
Young, Babanin, Zieger, 2013, *JPO*

Swell attenuation

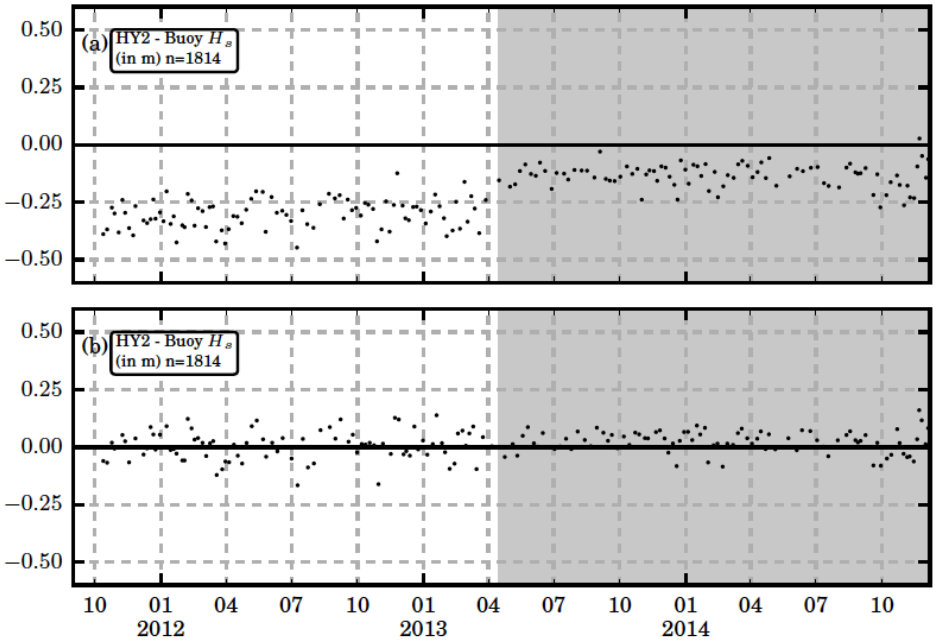


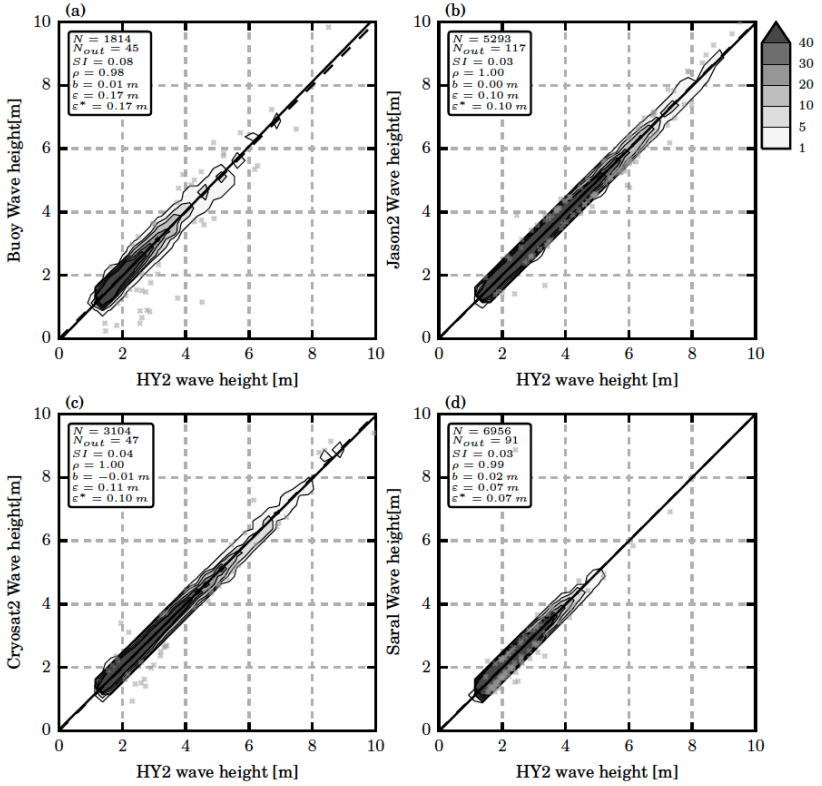






HY-2





- Calibrated against buoys and other altimeters
- Needs additional correction for Hs > 6m
- Jump in Hs in April 2013 due to switch to backup sensors and software

Liu, Babanin, Guan, Zieger, Sun and Jia, *submitted*

Young, I.R., Babanin, A.V., Hemer, M.A. (CSIRO), Aster, R.C. (New Mexico Institute of Mining and Technology, USA), “Global trends in oceanic wind speed and wave height”, ARC Discovery DP130100215

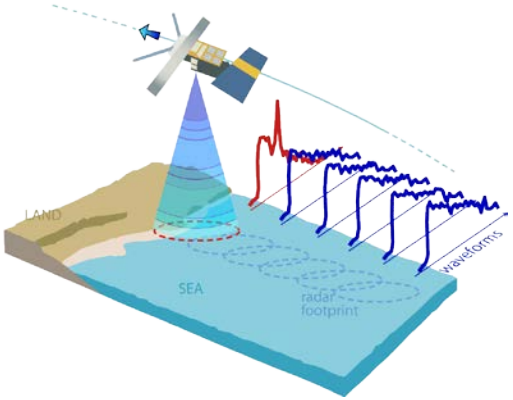
Aims:

- Compile global database from all platforms
- Wind and wave conditions
- Fully calibrated and independently validated
- Cross-validated between platforms

Uses

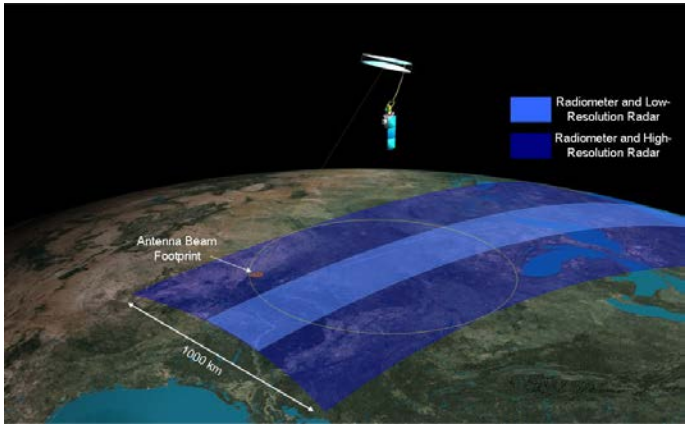
- Global climatology
- Long terms trends (30 years)
- Extreme value estimation (1:100 year estimates)
- Trends in extremes?

Altimeter



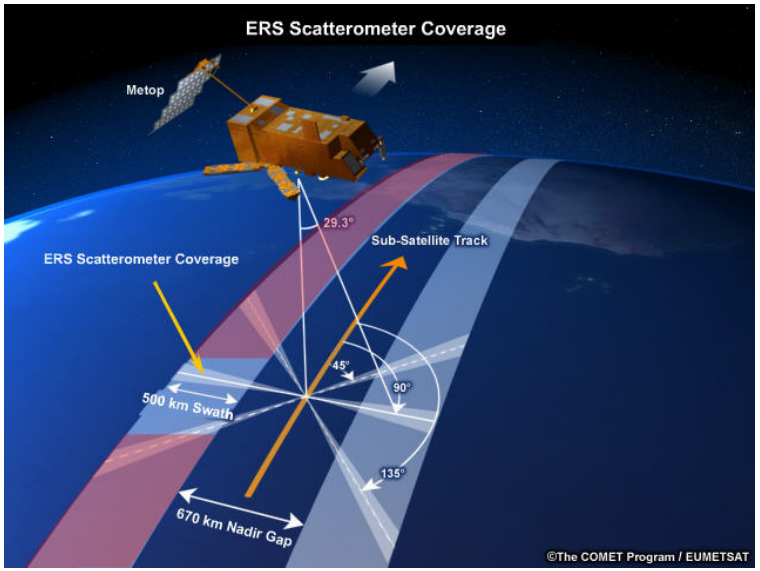
- Nadir looking
- H_s and U_{10} from waveform

Radiometer



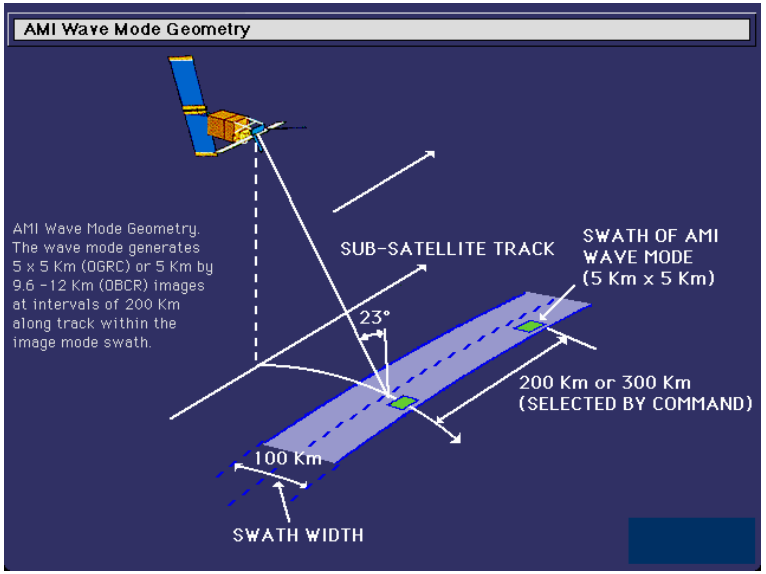
- U_{10} from brightness temp
- 1000 km swath at 25 km resolution

Scatterometer



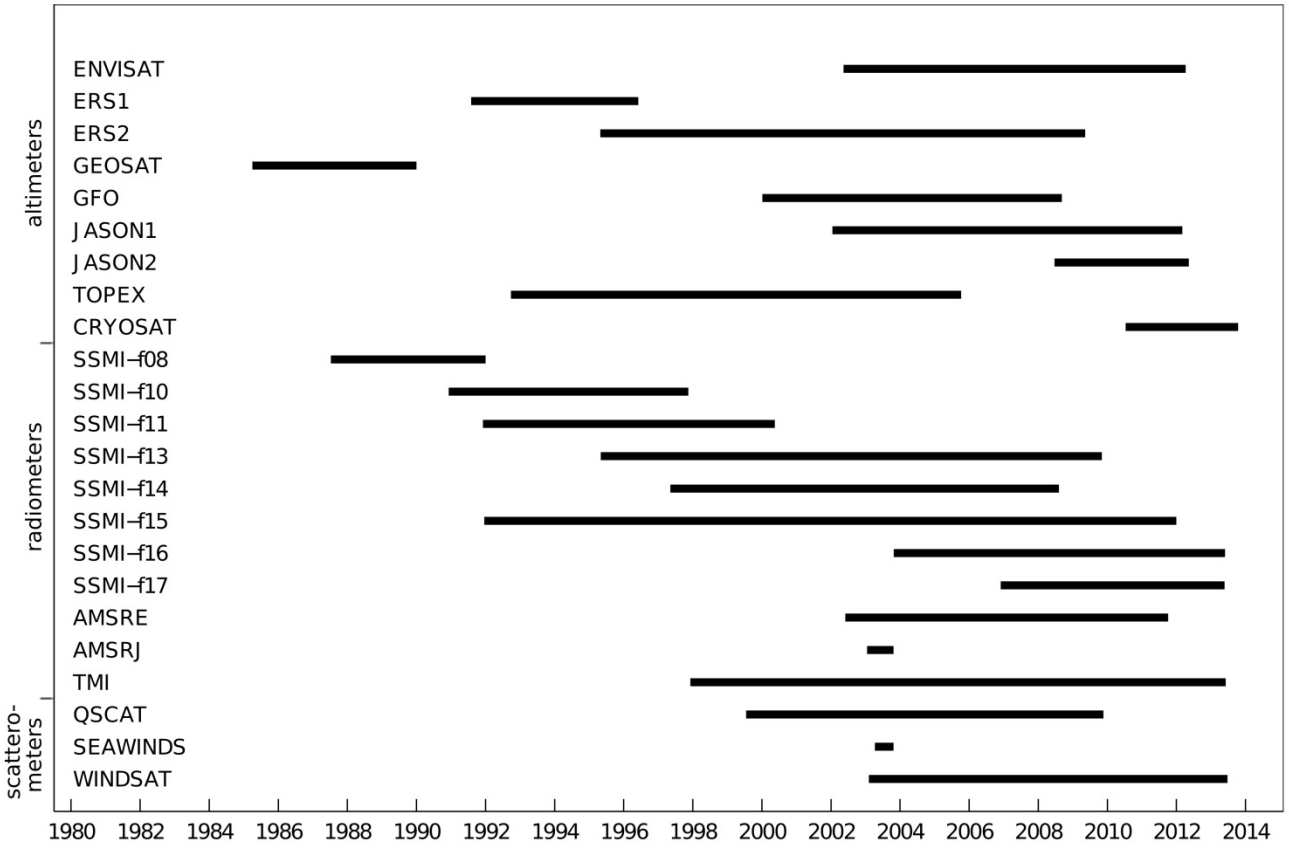
- U_{10} direction from multiple looks
- 1000km swath at 25km resolution

SAR

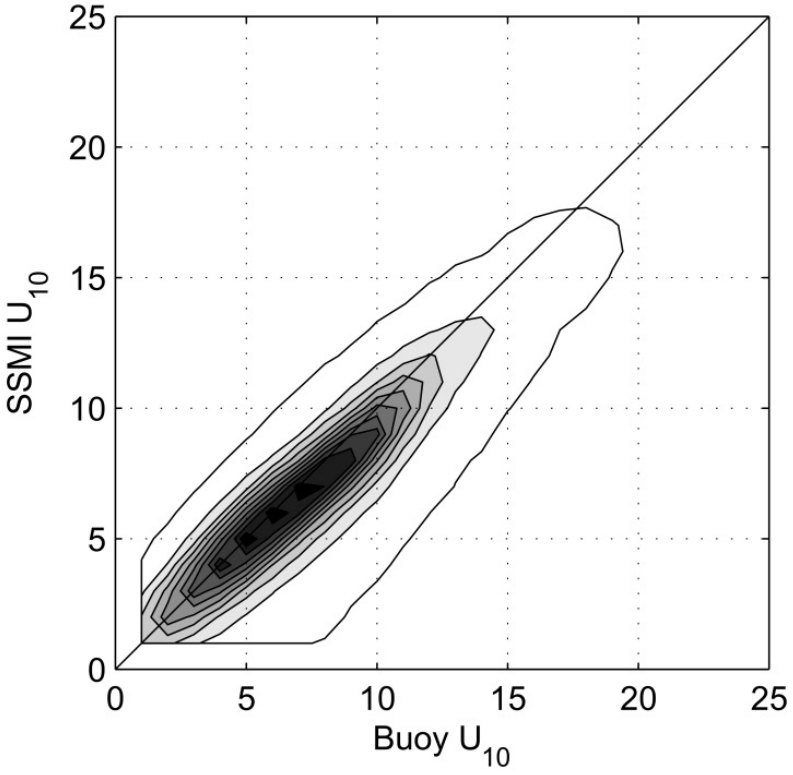


- Imaging radar
- Full spectrum at 200km spacing

Satellite data set over 30 years

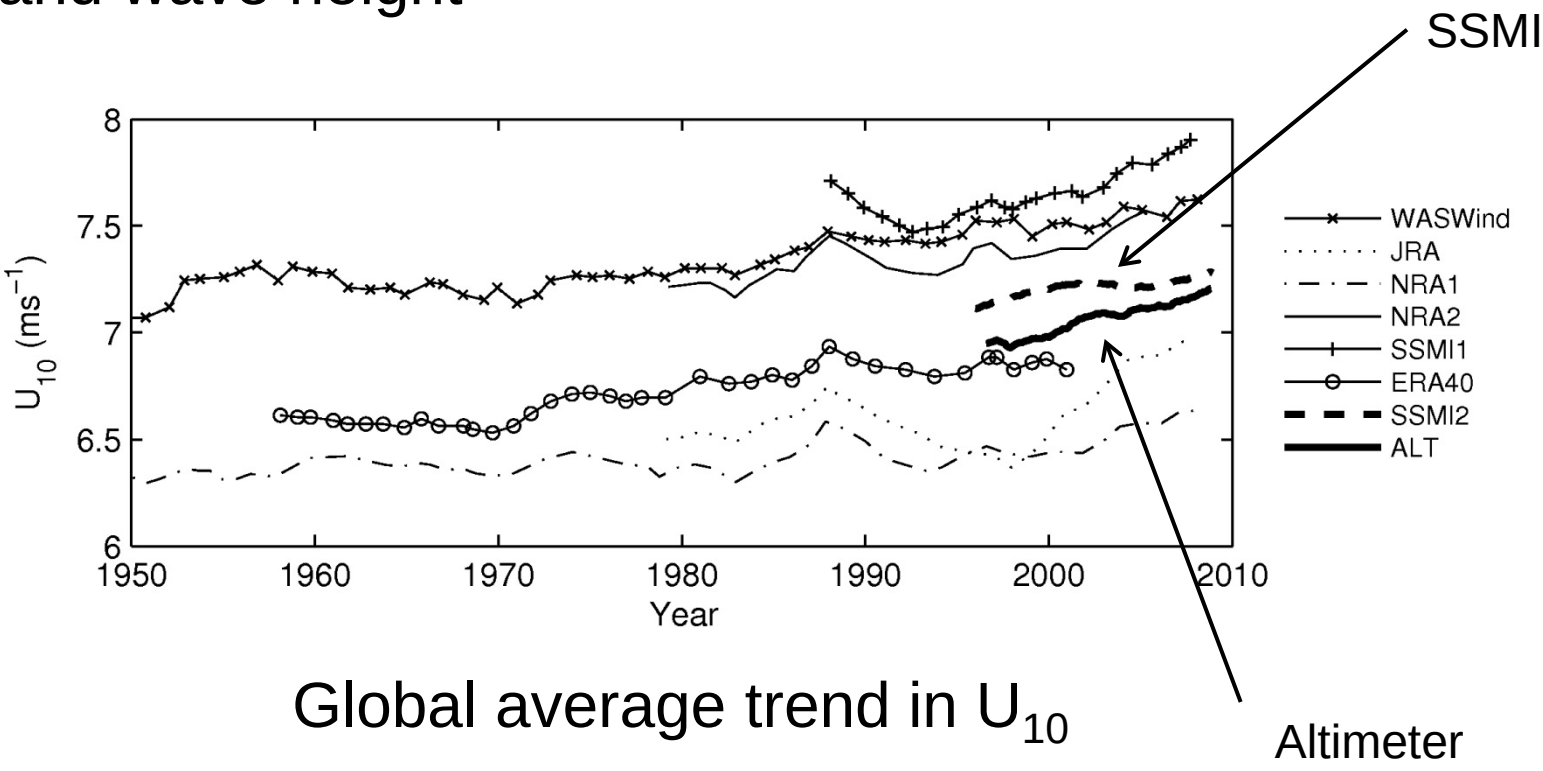


Radiometer Calibration



vs. buoys

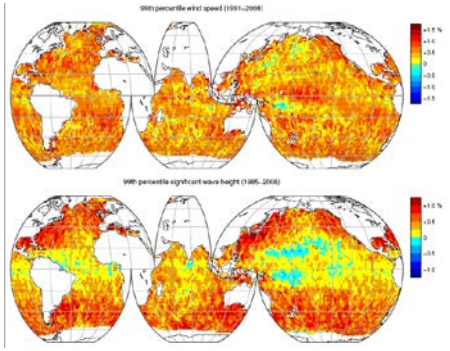
Other evidence of a global increase in wind speed and wave height

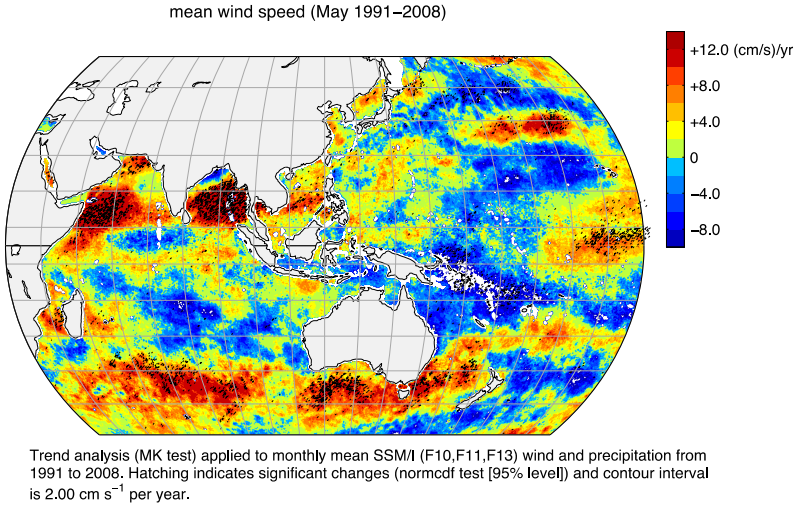


Global average trend in U_{10}

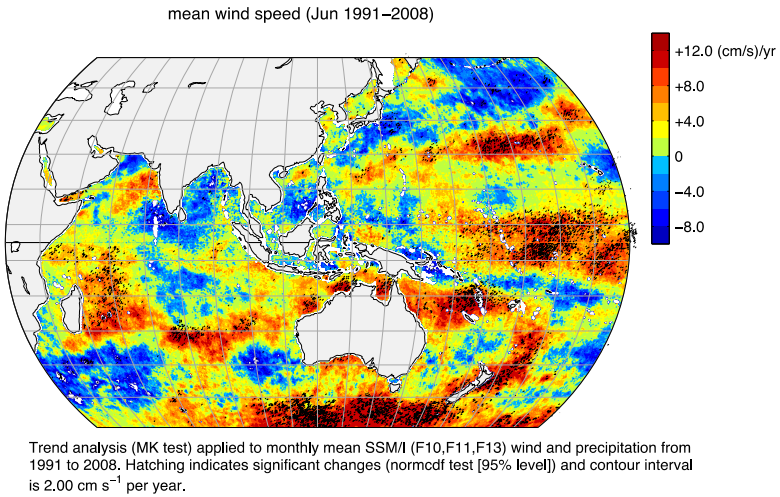
Young, Babanin, Zieger, 2011, *Science*

Wind Trends, by month (SSM/I)



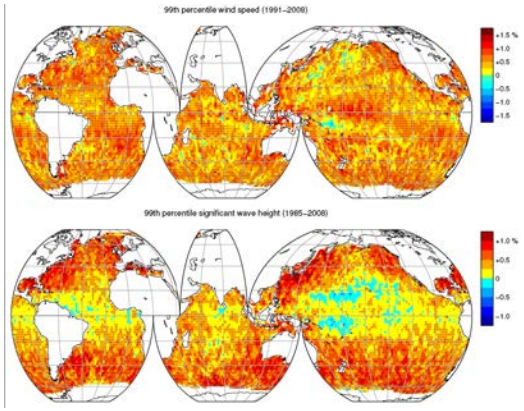


Trend analysis (MK test) applied to monthly mean SSM/I (F10,F11,F13) wind and precipitation from 1991 to 2008. Hatching indicates significant changes (normcdf test [95% level]) and contour interval is 2.00 cm s^{-1} per year.



Trend analysis (MK test) applied to monthly mean SSM/I (F10,F11,F13) wind and precipitation from 1991 to 2008. Hatching indicates significant changes (normcdf test [95% level]) and contour interval is 2.00 cm s^{-1} per year.

Zieger, Babanin, Young, 2014*, DSR1*



Babanin, A.V., Young. I.R., Zieger, S., “Wave climate in the marginal ice zones of Arctic Seas, observations and modelling”, Office of Naval Research Grant Number N00014-13-1-0278, USA

Motivation

- Sea ice has been retreating in summer months in the Arctic (since 2006?)
- Waves become an issue: navigation, air-sea interactions, coastal erosion etc.
- Wave climate and trends unknown
- Wave modelling is problematic
- Notably, ice cover is extending in Antarctic
- At high latitudes, winds have been shifting polarwards

Jeffries et al., 2013, Physics Today

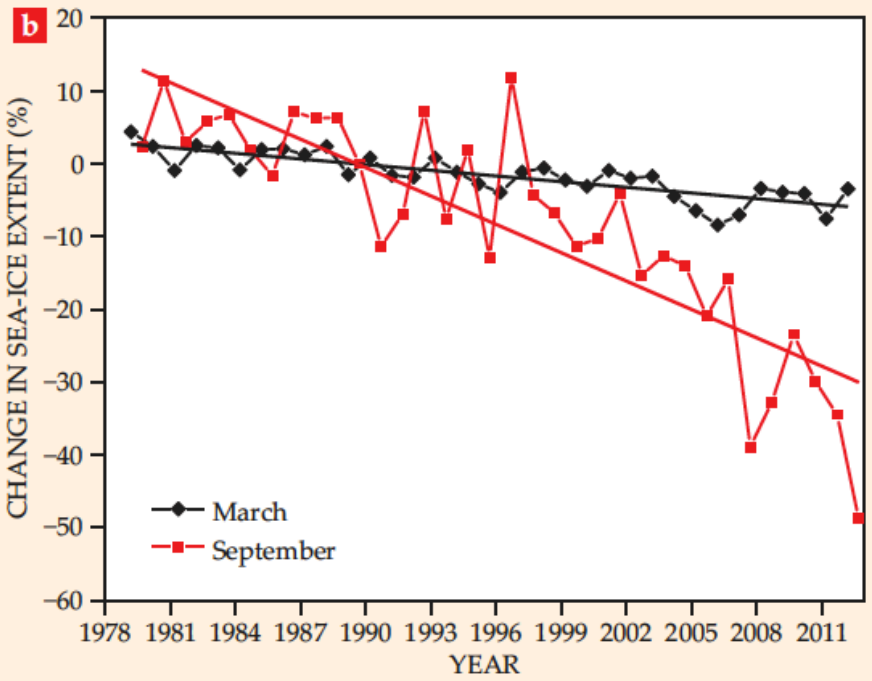


Figure 2. The decline in areal extent of Arctic sea ice has been mapped daily since 1979 by satellites using passive microwave sensors. **(a)** Between September 1980, when the summer minimum was 7.5 million square kilometers, and September 2012, when there were 3.4 million square kilometers of ice, the end of summer ice extent has shrunk by 55%. **(b)** Minimum (September) and maximum (March) ice-extent anomalies for each year are plotted beginning in 1979, when satellite observations began. Each data point represents the departure of the measured ice extent in March and September each year from the average of those months over the reference period 1979–2012. (Data are from the Sea Ice Index, National Snow and Ice Data Center; see http://nsidc.org/data/seaice_index. Walt Meier provided the plot.)

The Arctic

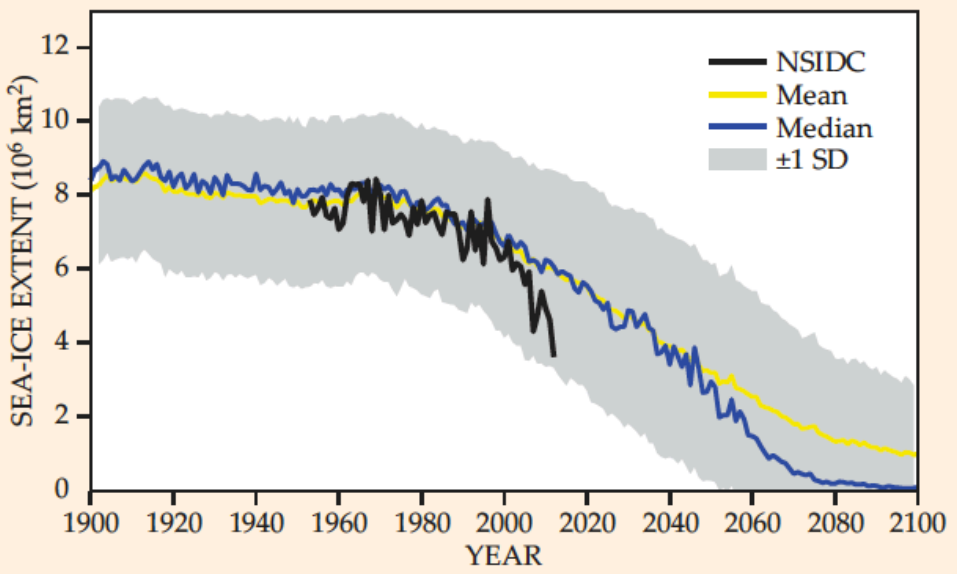
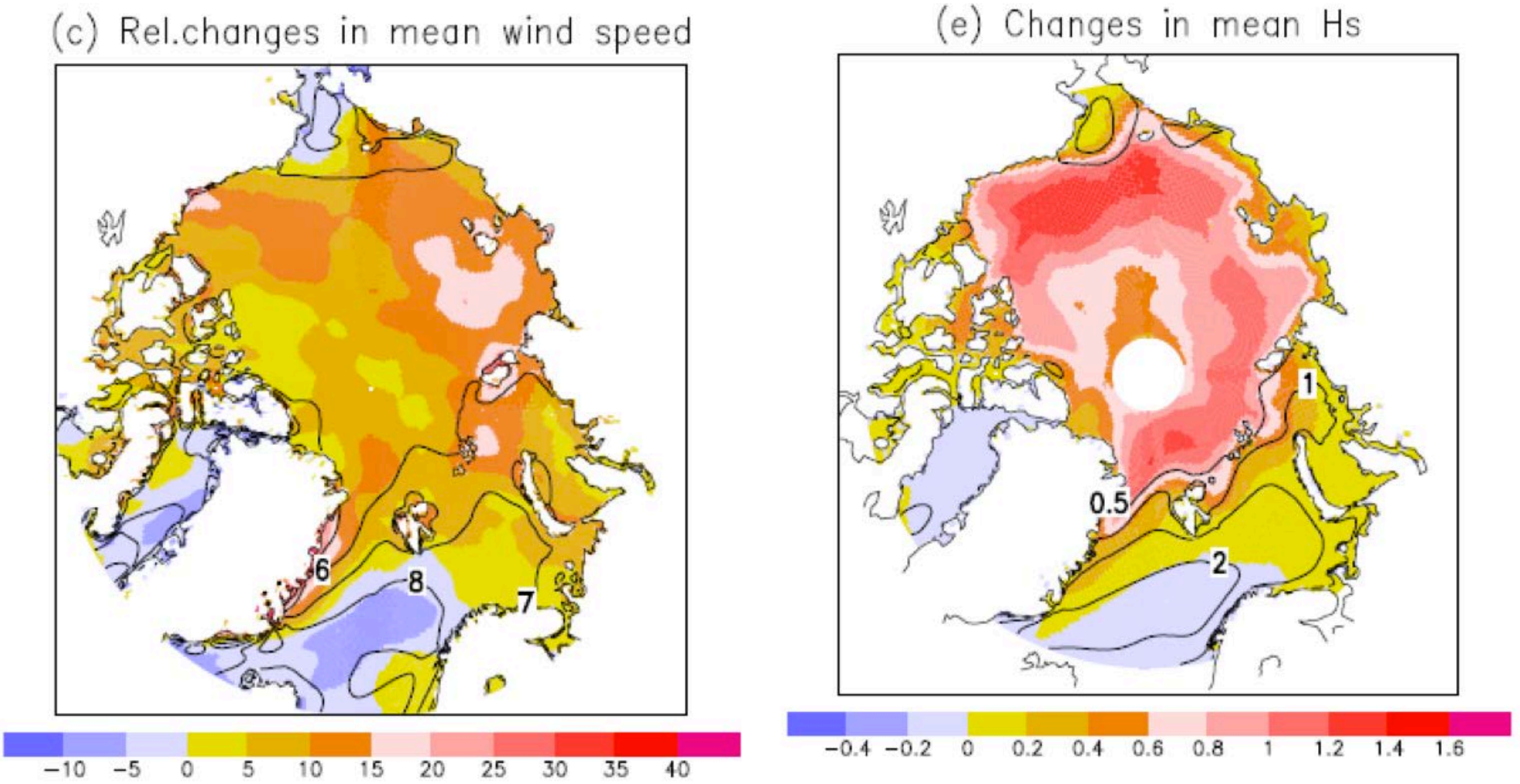


Figure 6. Sea-ice extent is declining faster than models predict. The large spread of ±1 standard deviation (SD; gray) in 84 predictions of ice extent from 36 different current models underscores the uncertainty about the future state of the ice cover and the need to improve our understanding of air-ice-ocean processes and their representation in the models. These and similar results form the basis for the fifth assessment report of the Intergovernmental Panel on Climate Change. The black curve plots observational data dating back to 1953 from the National Snow and Ice Data Center (NSIDC). The yellow and blue curves are the mean and median of the model results, respectively. (Adapted from ref. 13.)

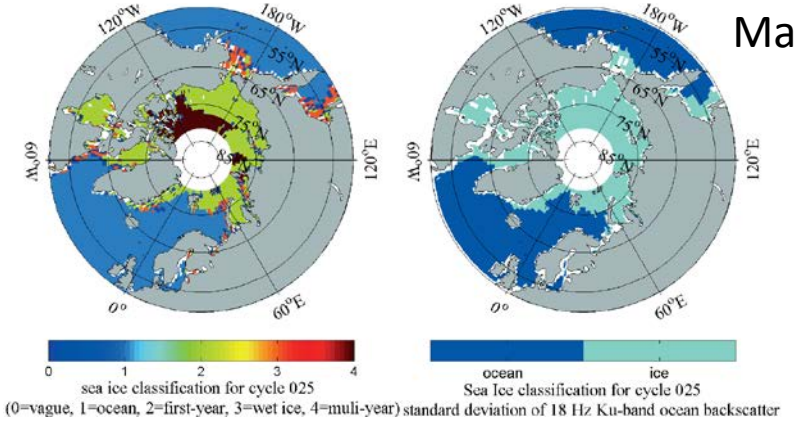
Khon, Mokhov, Pogarskiy, Babanin, Dethloff, Rinke, Matthes, 2013, *GRL*



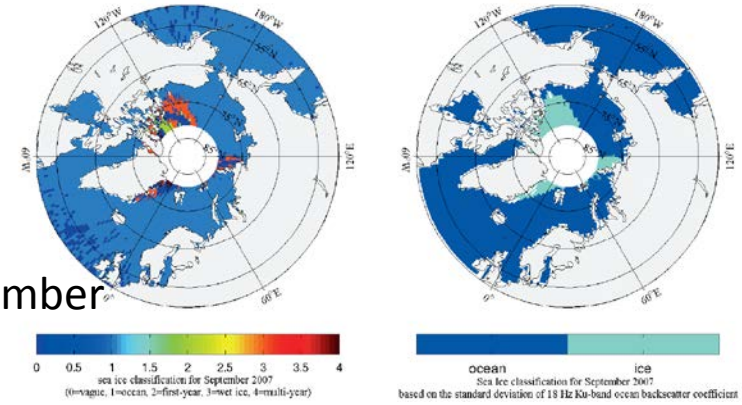
September. Simulated relative changes (%) in mean wind speed at 10 m height (normalized to mean climatological for 1980-1999) and (m) in significant wave height , for the period 2046-2065 with respect to reference period 1980-1999. Contours indicate mean climatological values of for 1980-1999. **Coupled climate, ice and wave models**

Sea/Ice Classification

- needs to be based on altimeter measurements
- Tran et al. 2009 suggested a three-parameter cluster algorithm to brightness temperature data and backscatter data
- brightness data are not always available
- Laxon (1990) and Rinne and Skourup (2012) is approach is a one-parameter classification algorithm

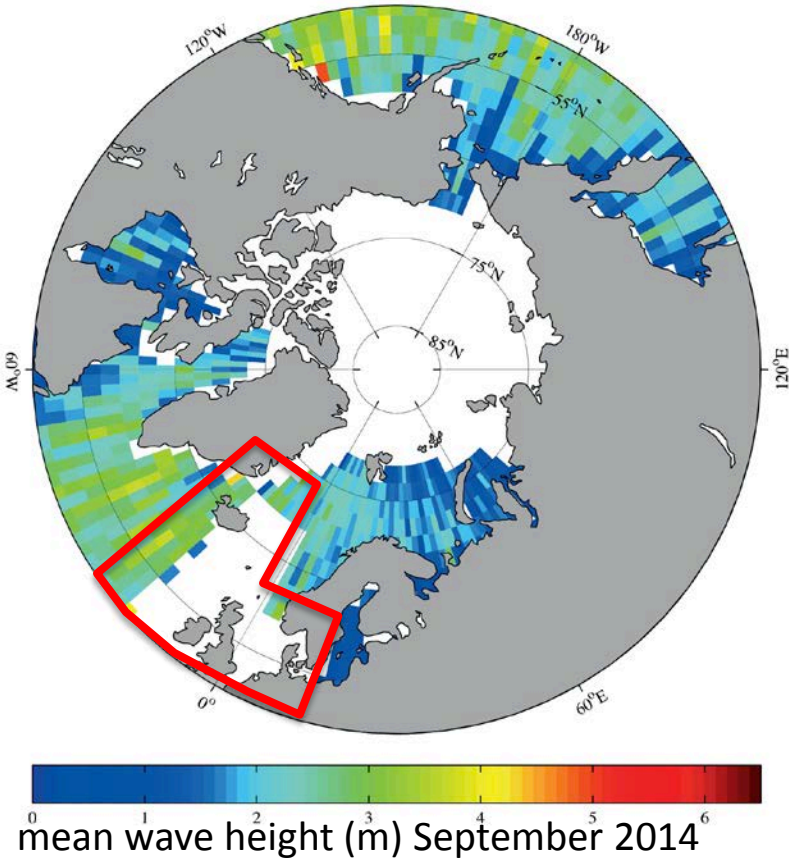


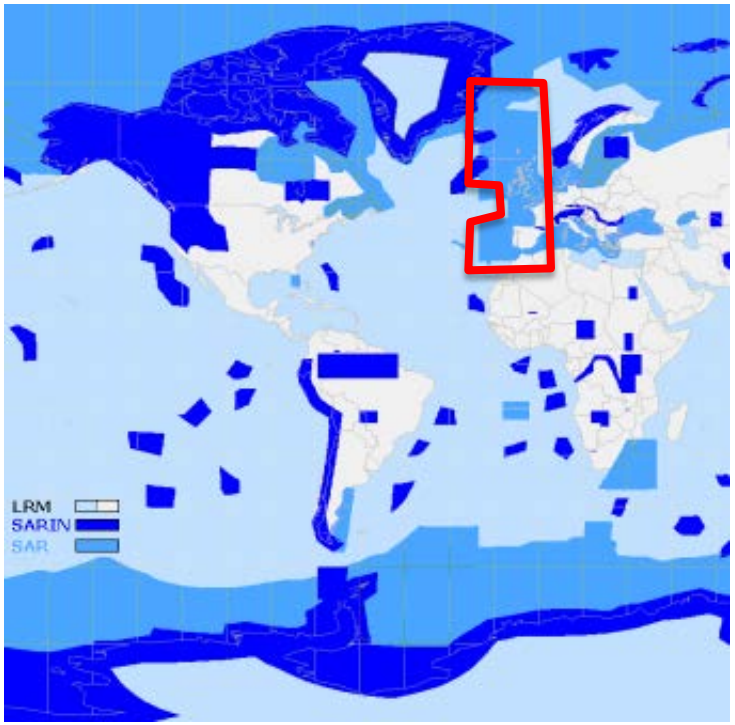
March 2004



September 2007

CRYOSAT2

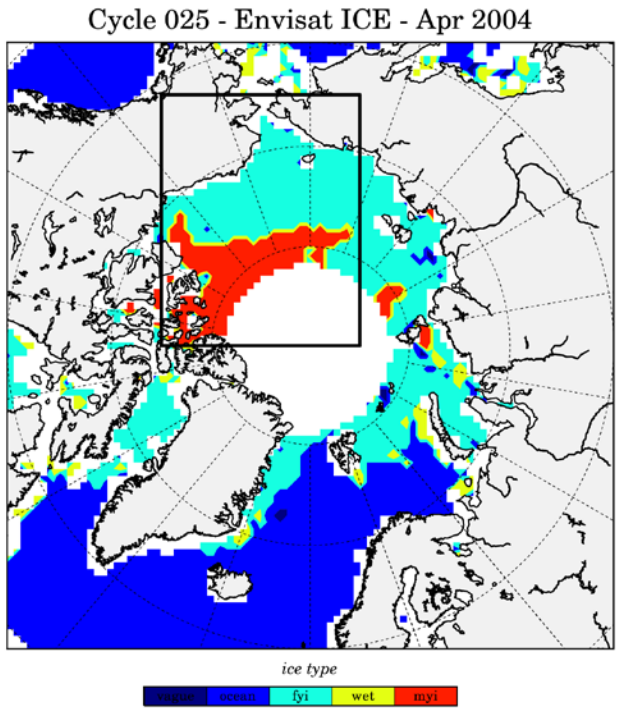


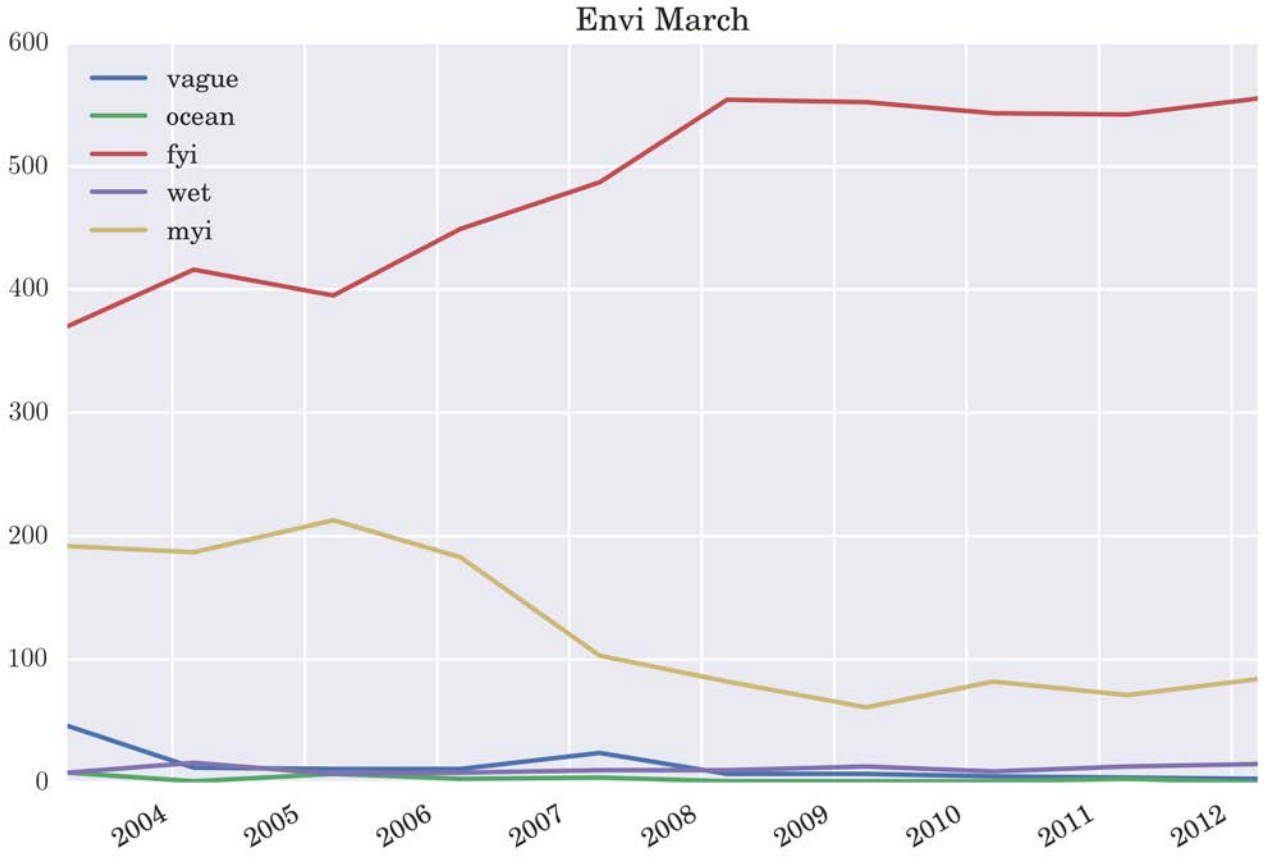


CRYOSAT2 modes: LRM (low rate mode, or conventional altimeter mode), SAR (synthetic aperture radar), and SARIN (SAR interferometry)

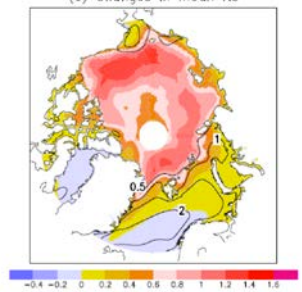
- CRYOSAT2 L2 product contains no wave height when altimeter in SAR/SARIN mode
- Use waveform retracking from L1b FDM products

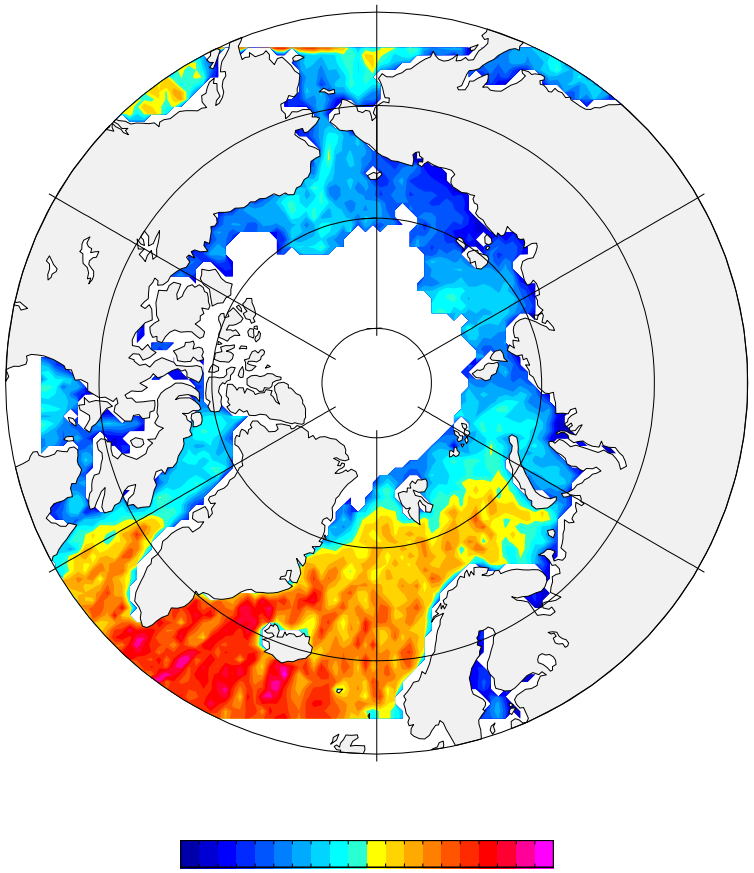
Ice trends

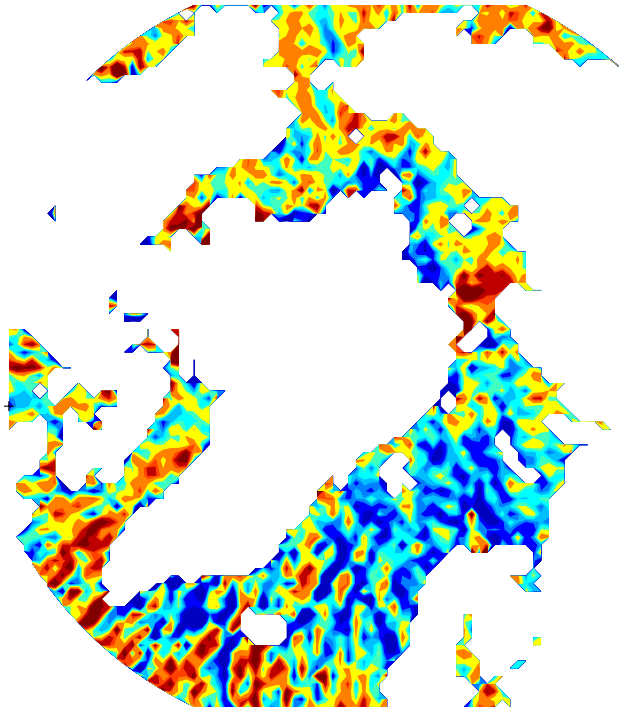

Cycle 025 - Envisat ICE - Apr 2004
ice type
vague
ocean
fyi
wet
myi


Envi March
vague
ocean
fyi
wet
myi
600
500
400
300
200
100
0
2004
2005
2006
2007
2008
2009
2010
2011
2012

Waves, 99th, 2002-2014







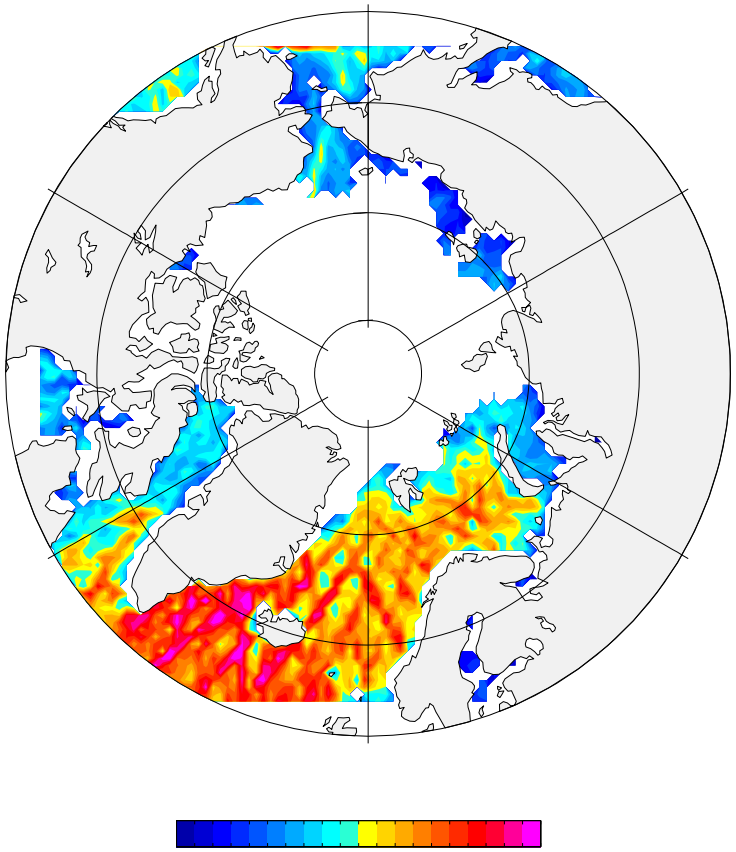
n conditions

significant wave height (m decade^{-1})

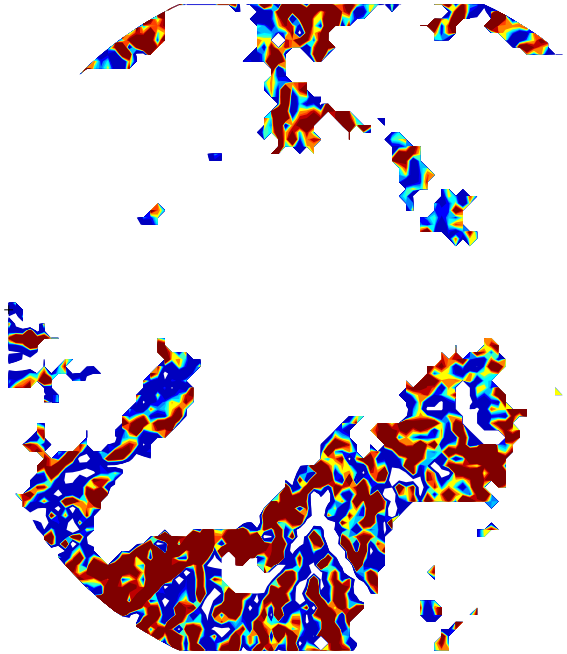
−1.2 −.8 −.4 0 +.4 +.8 +1.2

npStereoClimAltiAUGSEP2002−2014.nc alpha=0.10

Waves, 99th, 2002-2006

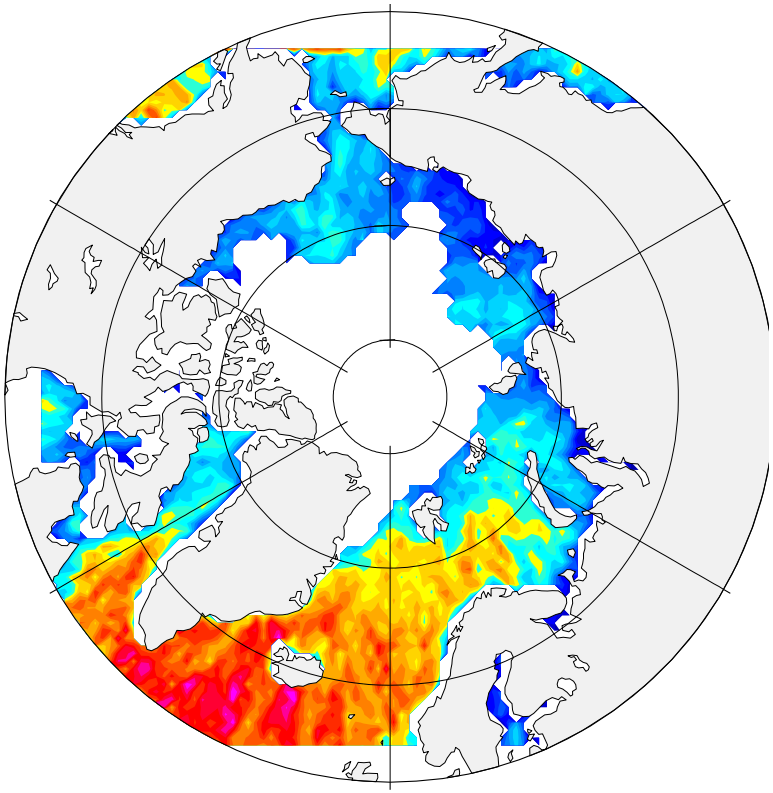


limAltiAUGSEP2002–2006.nc mean conditions

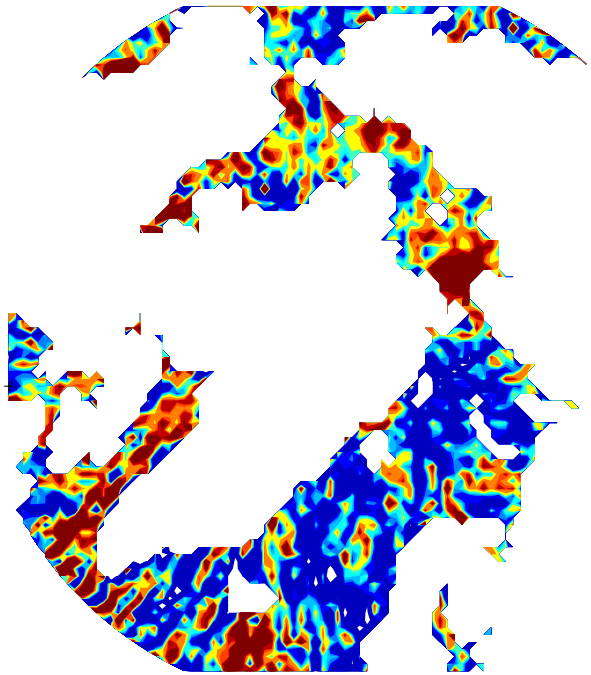


reoClimAltiAUGSEP2002–2006.nc alpha=0.10

Waves, 99th, 2006-2014



SEP2007–2014.nc mean conditions



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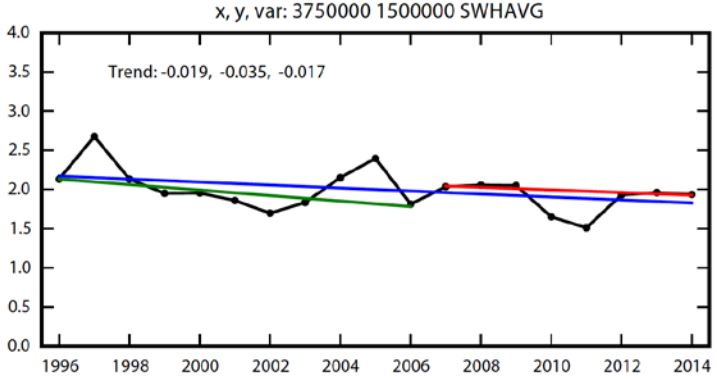
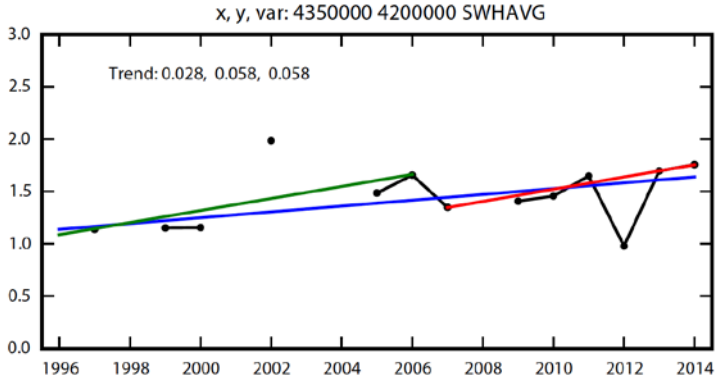
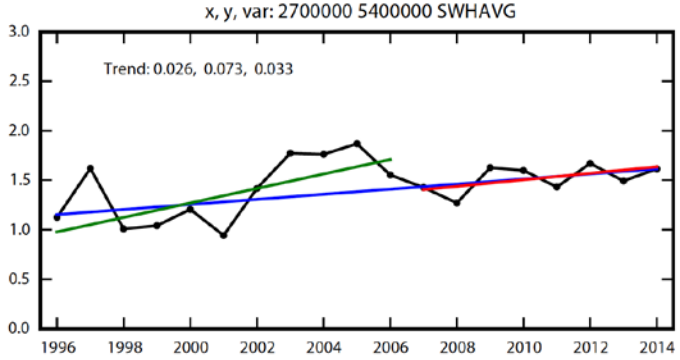
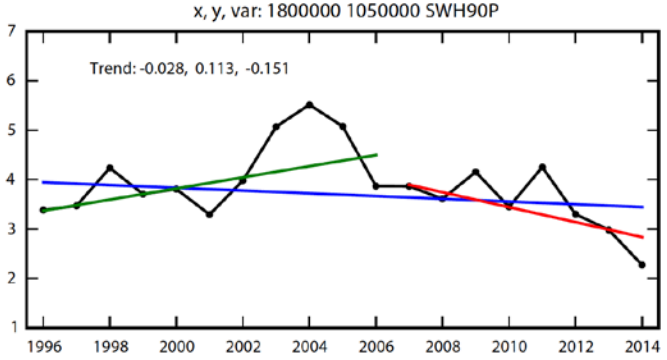

x, y, var: 3750000 1500000 SWHAVG
Trend: -0.019, -0.035, -0.017
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


x, y, var: 4350000 4200000 SWHAVG
Trend: 0.028, 0.058, 0.058
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


x, y, var: 2700000 5400000 SWHAVG
Trend: 0.026, 0.073, 0.033
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


x, y, var: 1800000 1050000 SWH90P
Trend: -0.028, 0.113, -0.151
7
6
5
4
3
2
1
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

Conclusions

- Satellite data can clearly give global
  - Climatology
  - Trends
  - Extremes

- This is for wind speed, wave height, ice cover and various related metocean properties