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ECMWF

Linear trends of wind speed and wave height based on ERA-Interim at different forecast range – 1979-2012

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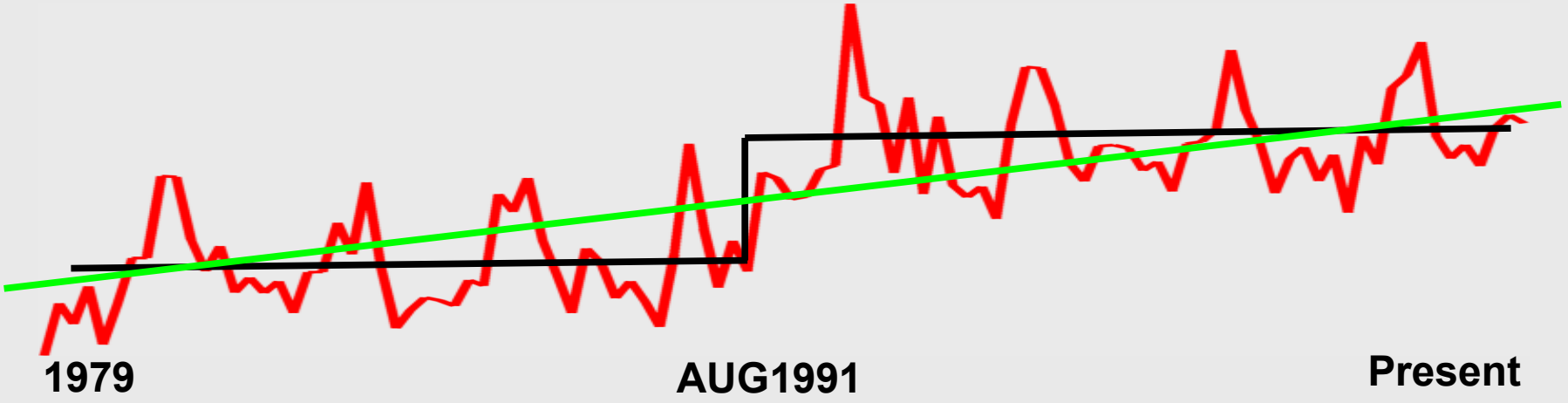
31.10.13

Main issues

- Does the increasing number of assimilated observations 1979-2012 create spurious trends in ERA-Interim?
- Can the effect of wave altimetry be separated - first introduced in Aug 1991?
- Are better trend estimates of wave height and wind speed obtained from ERA-Interim at increasing lead times - being less influenced by the assimilation?



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Methodology

- Sort data into montly values, means and maxima

$$Y_i = (y_{i1}, y_{i2}, y_{i3}, \cdots y_{im})$$ for month *i* and year *m*

- Trends are based on the median of: (**Kendall's tau**):

$$a_{ijk} = \frac{y_{ij} - y_{ik}}{t_{ij} - t_{ik}}, 1 \le k \le j \le m$$

- **Sesonal Mann Kendall test** – test of randomness against trend

$$S_i = \sum_{k=1}^{m_i - 1} \sum_{j=k+1}^{m_i} sgn(y_{ij} - y_{ik}) \quad S' = \sum_{i=1}^{12} S_i$$ has zero mean and variance:

$$V^2_{S'} = \sum_{i=1}^{12} V^2_{S_i} + \sum_{i=1}^{12} \sum_{\substack{l=1 \\ l \neq i}}^{12} cov(S_i S_l) \qquad V^2_{S_i} = n(n-1)(2n+5)/18$$

$$Z' = [S' - sgn(S')]/V_{S'}$$ Two-sided Z-test

when |Z'|<1.96 (alpha=0.05) -> H_0 is accepted (no trend)

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Conclusions

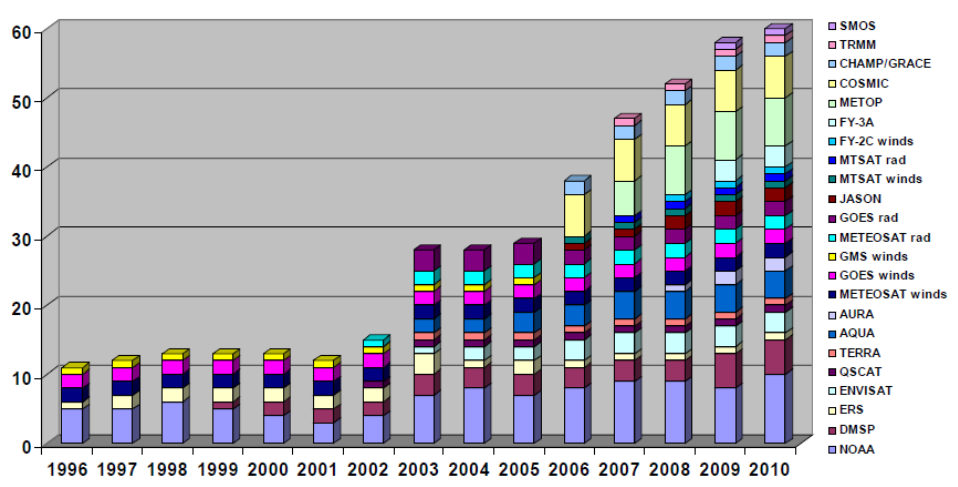
- Discontinuity in ERA-Interim at ANA are detected due to the assimilation of SWH altimeter observations from Aug 1991
- Intrinsic spurious trends in the SWH are highly likely to be present in the ERA-Interim at ANA
- Preliminary results suggest that lead times FC24 to FC48 yield more realistic trends in ERA-Interim

Data

- ERA-Interim: 1979-2012
  - ANA, FC24, FC48, FC72, FC96 at 00/12 UTC
    - Monthly means - SWH/WINDS
    - Monthly maxima - SWH/WINDS
- WAM forced by ERAI WINDS w/wo altimeter assimilation: 1992-2011
    - Monthly means - SWH
    - Monthly maxima - SWH
- ENVISAT(superobs) collocated with ERA-Interim Oct 2002 – Nov 2010
    - Monthly means - WINDS
- Buoy data at 24 locations in the N-Pacific/N-Atlantic
    - Monthly means - SWH

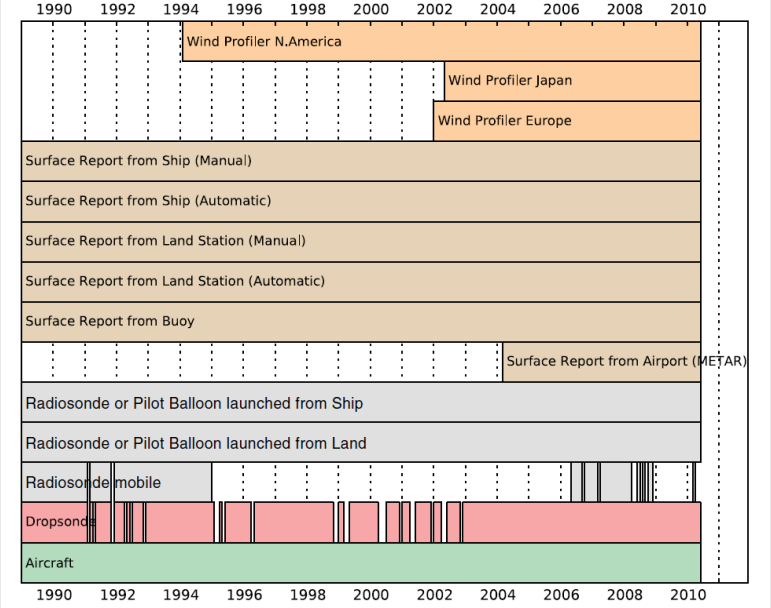
A non-uniform number of assimilations in ERA-Interim over time

Number of satellite-borne instruments providing data



http://people.sca.uqam.ca/~gauthier/WGNE24-montreal/WGNE-BiospherePDF/26_ECMWF_ERA.pdf

Timeline of conventional observations ass.



Dee et al: Q. J. R. Meteorol. Soc. 137: 553–597, April 2011 A

Assimilation of SWH altimeter

- ERS-1: 01 Aug 1991 to 03 Jun 1996
- ERS-2: 03 May 1995 to 21 Jul 2003
- ENVISAT: 21 Jul 2003 to April 2012
- Jason-1: 20 Oct 2003 to 3 July 2013
- Jason-2: 01 Feb 2010 to present

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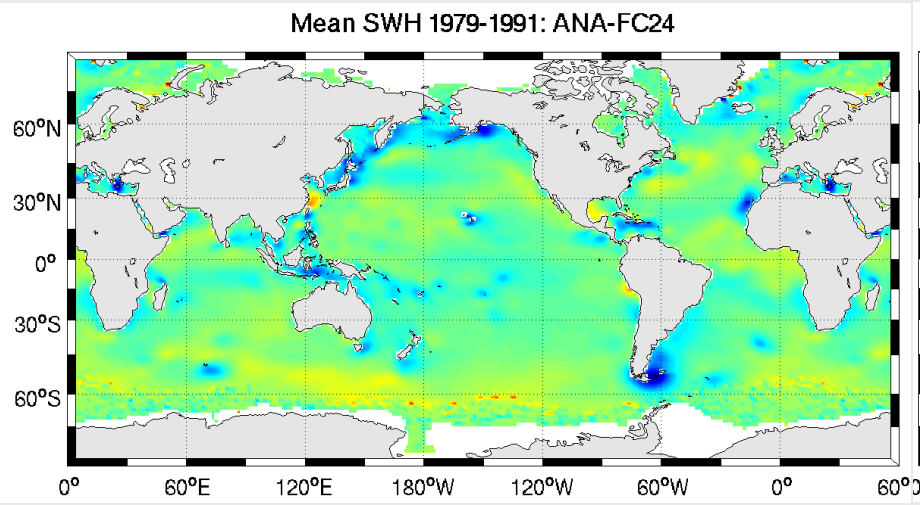
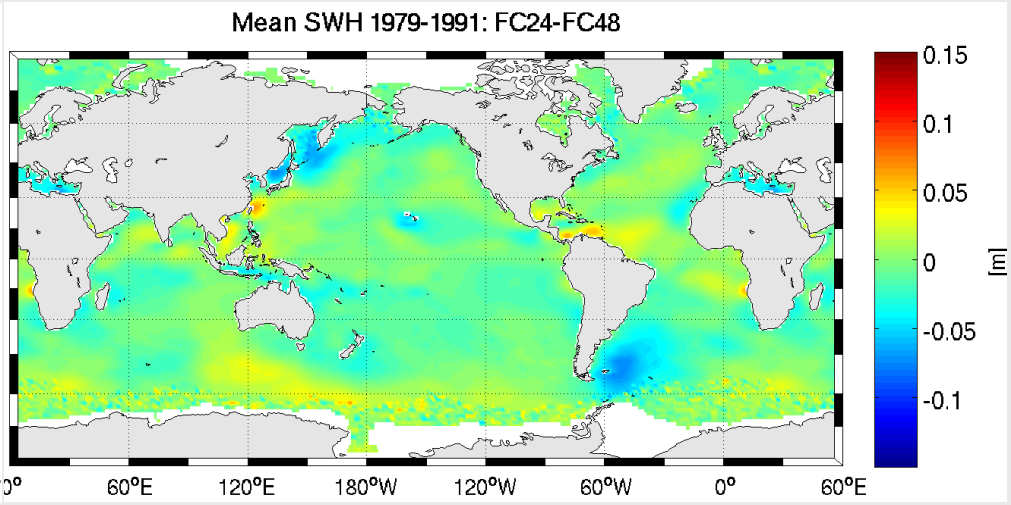
Bias in monthly mean SWH/WINDS wo/altimeter assimilation: 1979-1991

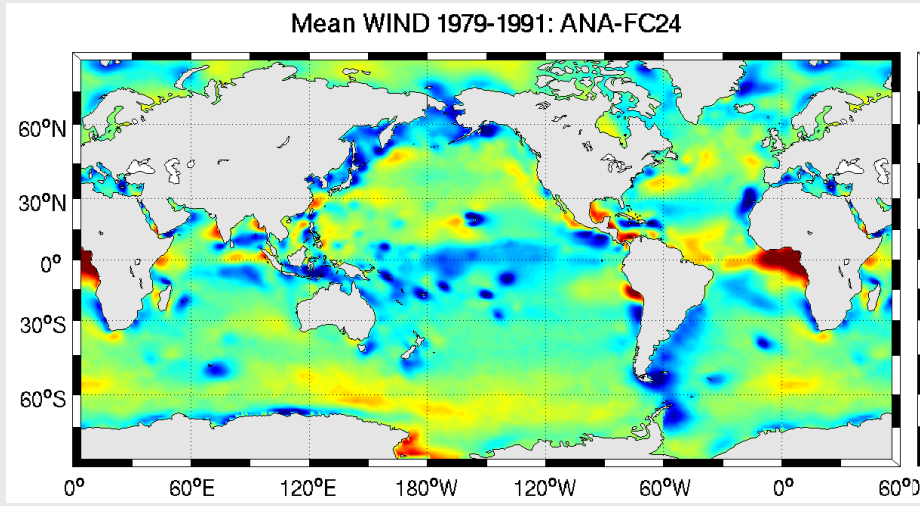
ANA-FC24/SWH



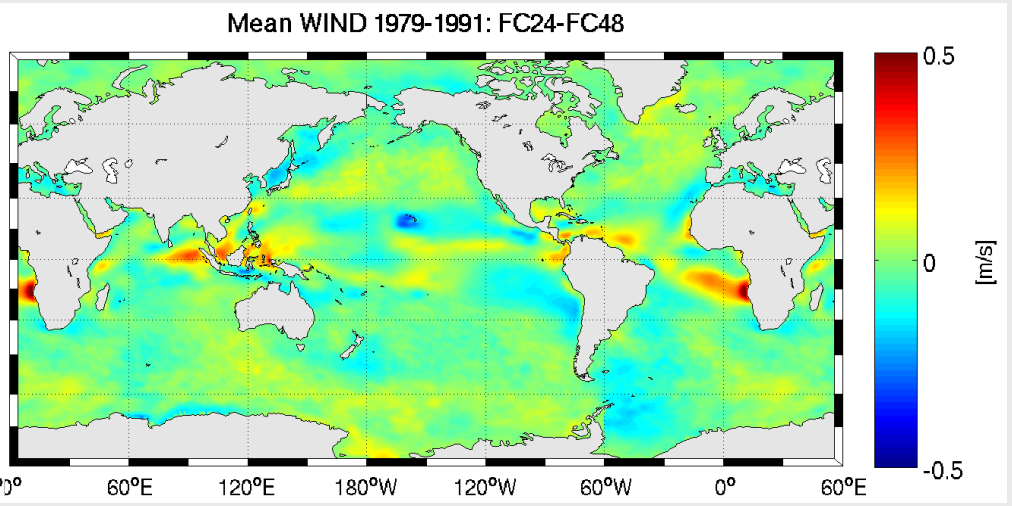
FC24-FC48/SWH



ANA-FC24/WINDS

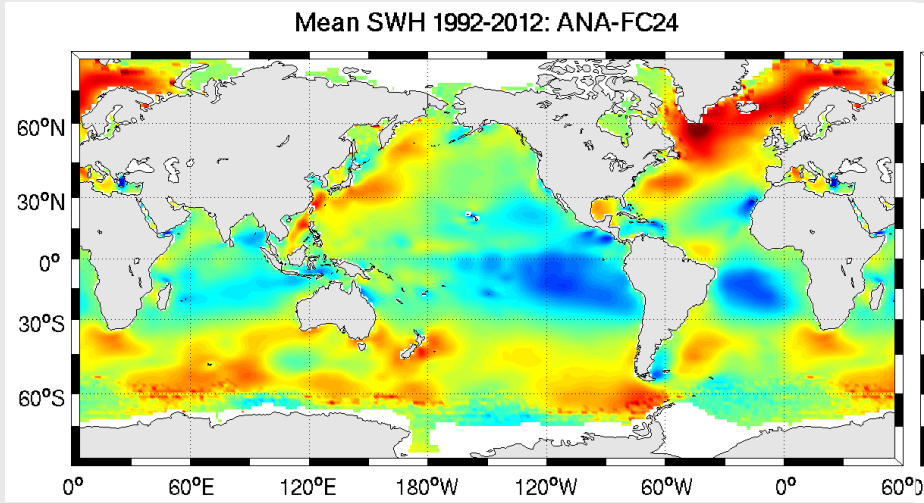


FC24-FC48/WINDS

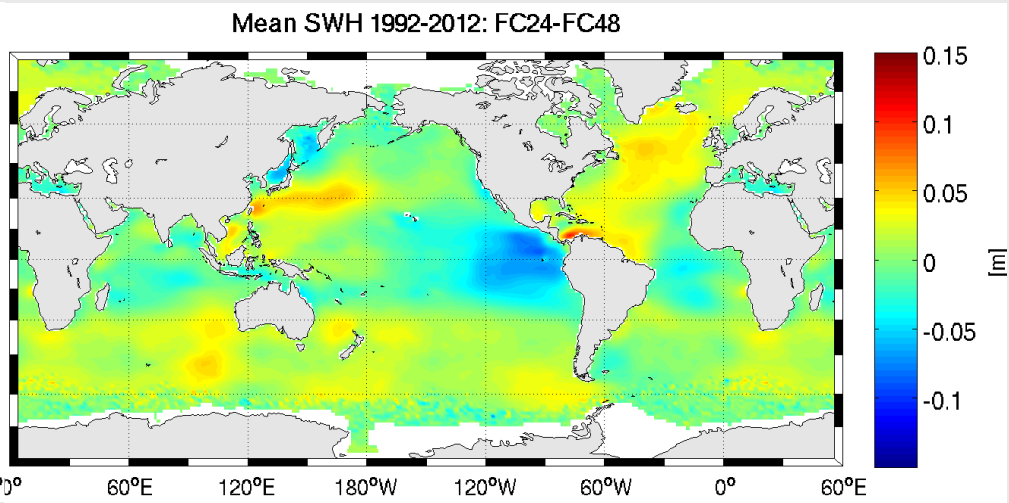


Bias in monthly mean SWH/WINDS w/altimeter assimilation: 1992-2012

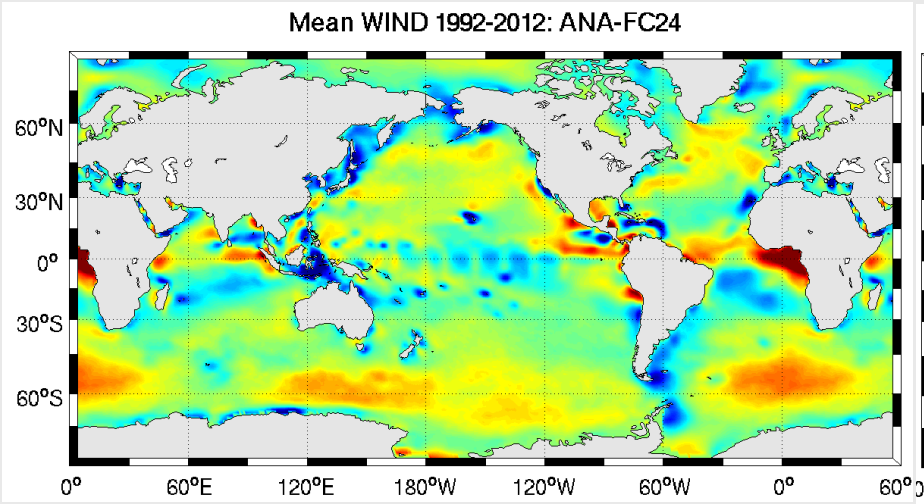
ANA-FC24/SWH



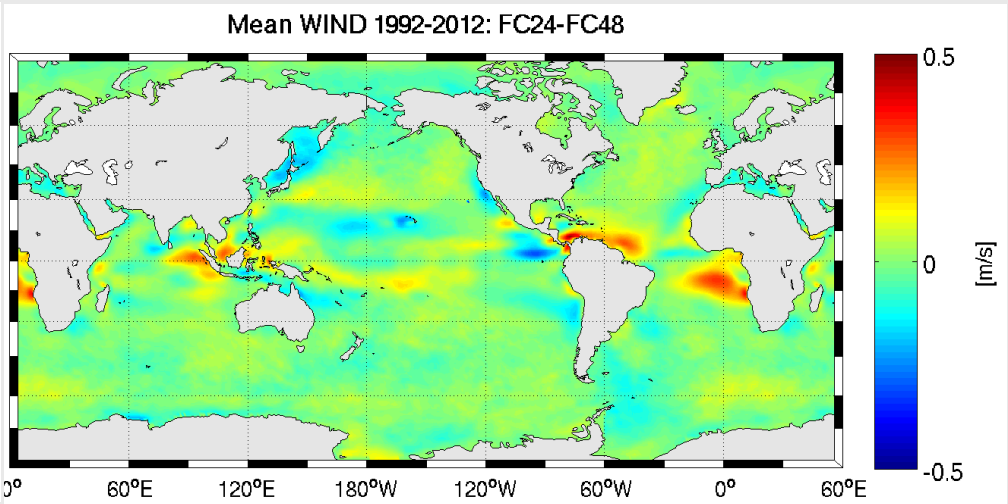
FC24-FC48/SWH



ANA-FC24/WINDS

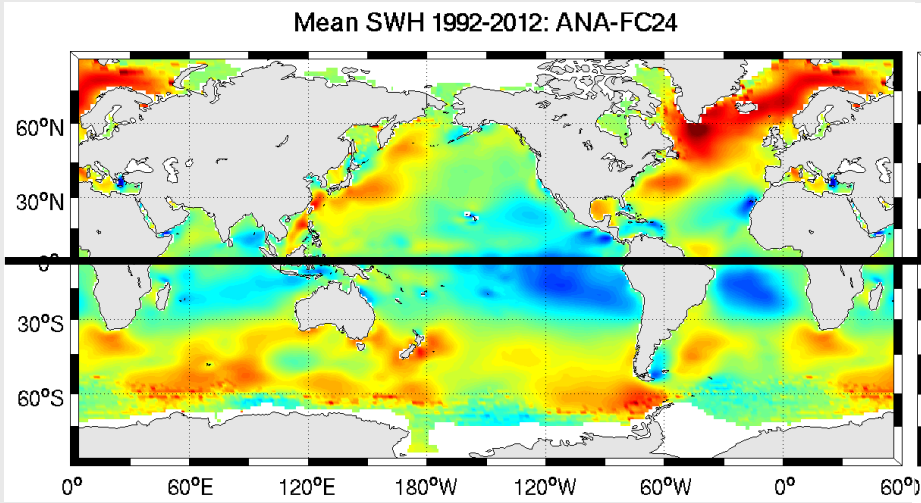


FC24-FC48/WINDS

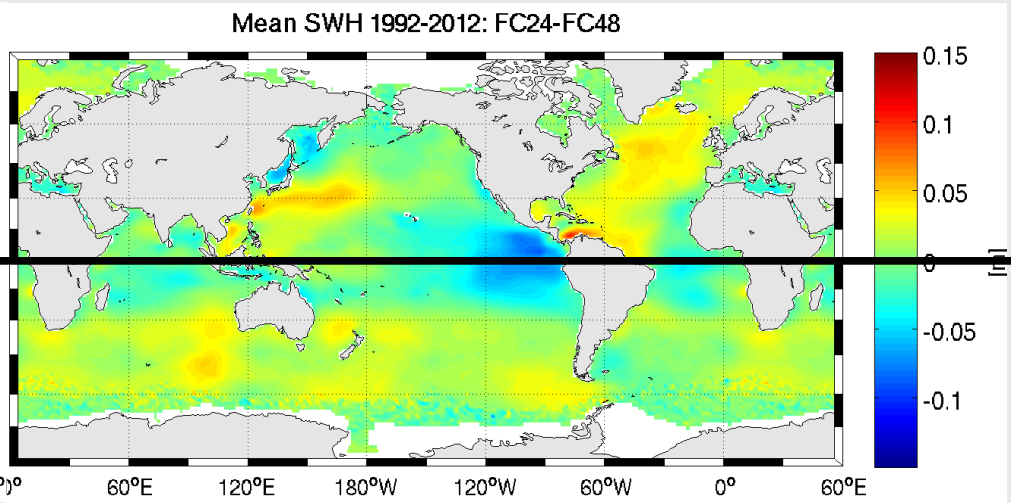


Bias in monthly mean SWH/WINDS w/altimeter assimilation: 1992-2012

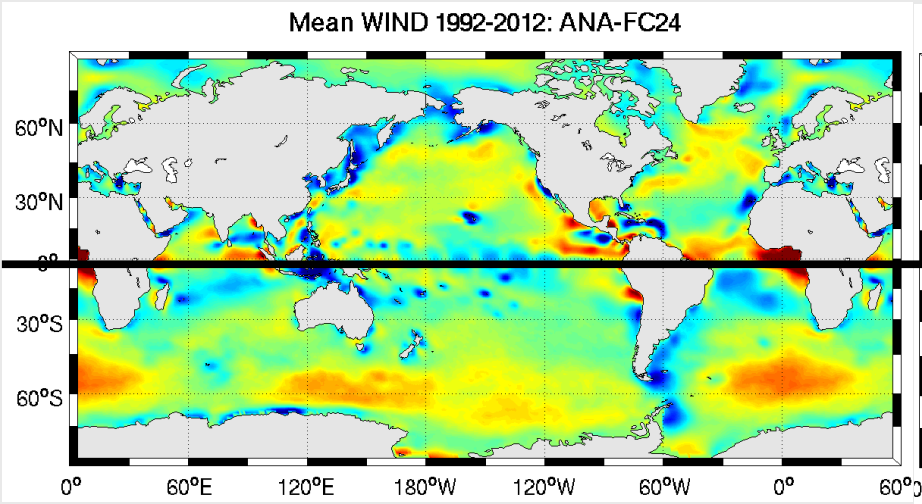
ANA-FC24/SWH



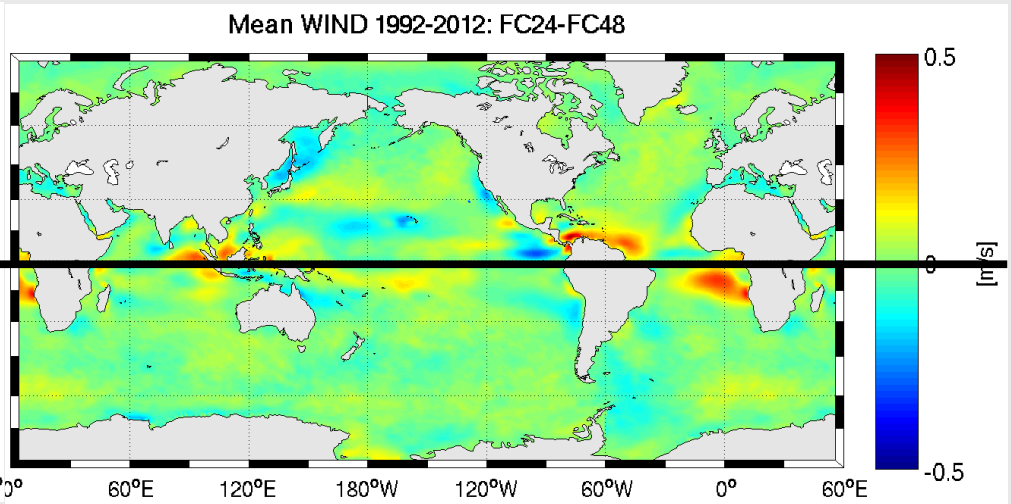
FC24-FC48/SWH



ANA-FC24/WINDS

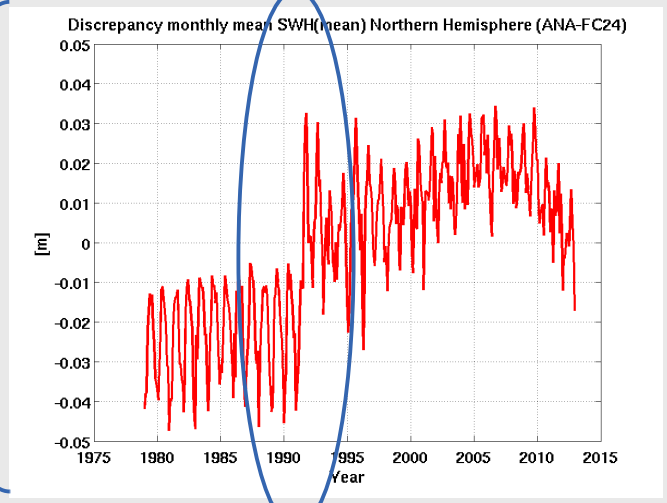


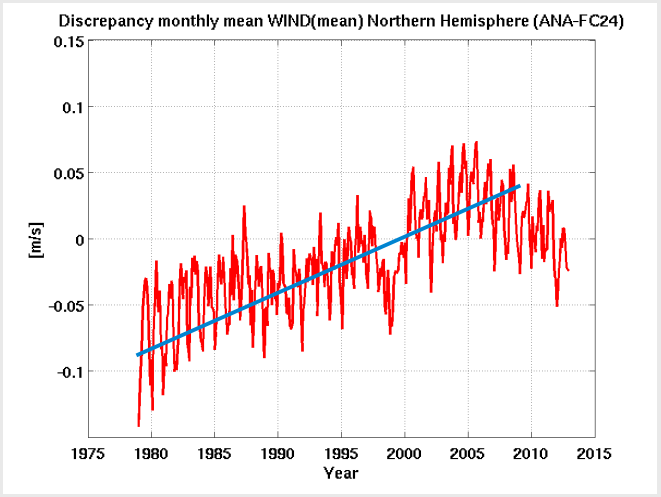
FC24-FC48/WINDS



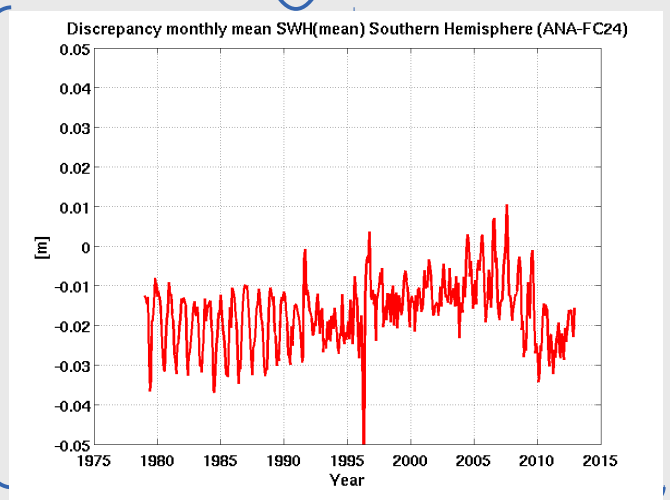
Discrepancy monthly mean SWH and WINDS for N/S-Hemisphere (ANA-FC24)

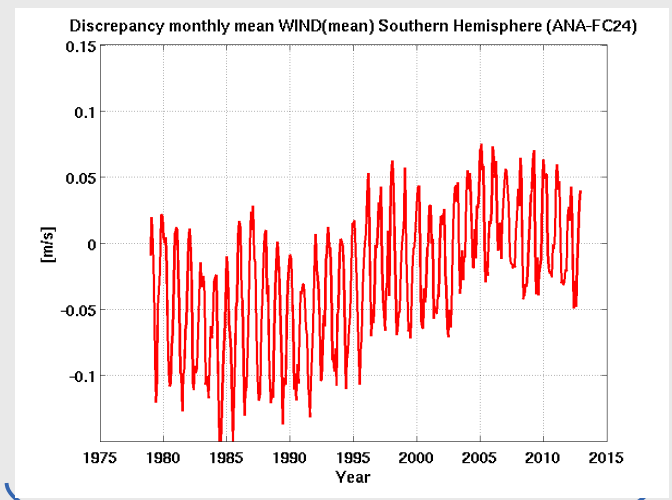
N





S





SWH **WINDS**

- Area weighted averages
- All ice covered areas have been removed for the SWH

Main findings:

- Jump in SWH bias in Aug 1991 in N-Hem. ~4 cm
- Less apparent in the S-Hem.
- Gradual strengthening of WINDS ANA compared to FC

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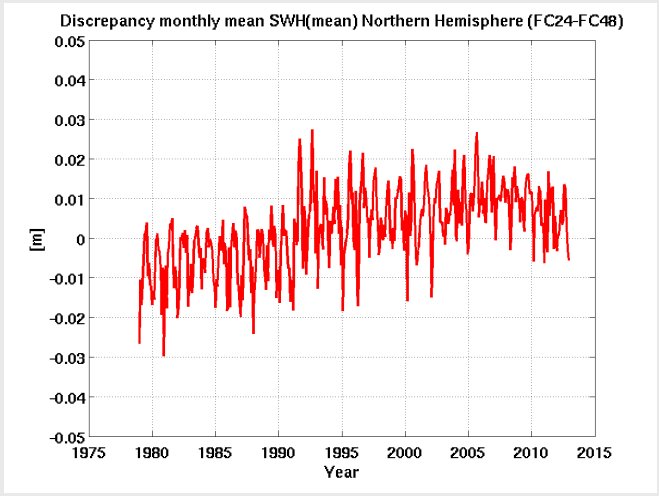
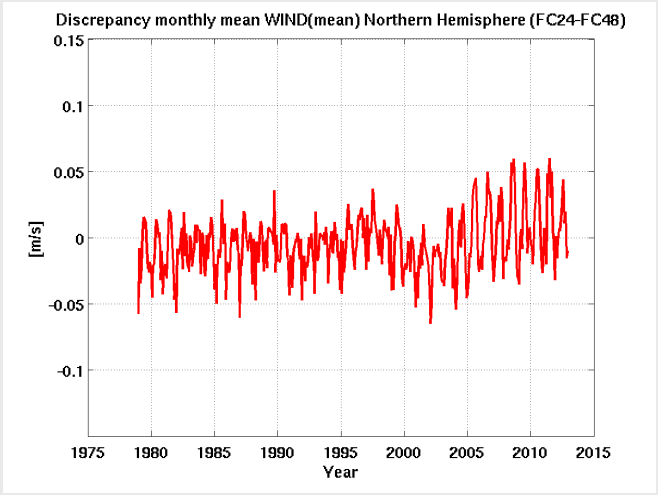
Discrepancy monthly mean SWH and WINDS for N/S-Hemisphere (FC24-FC48)

N





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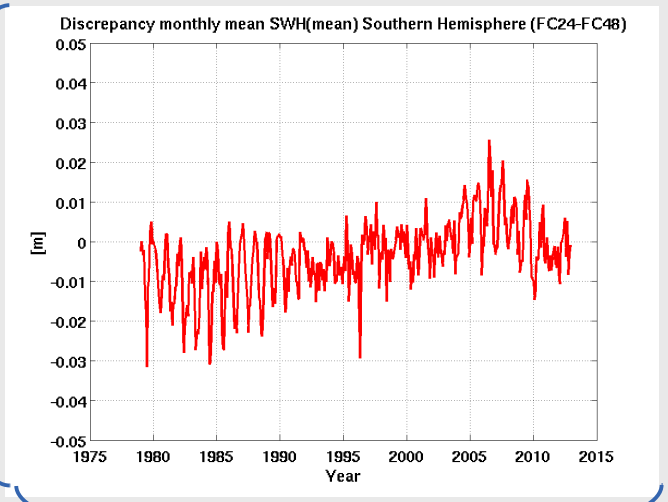

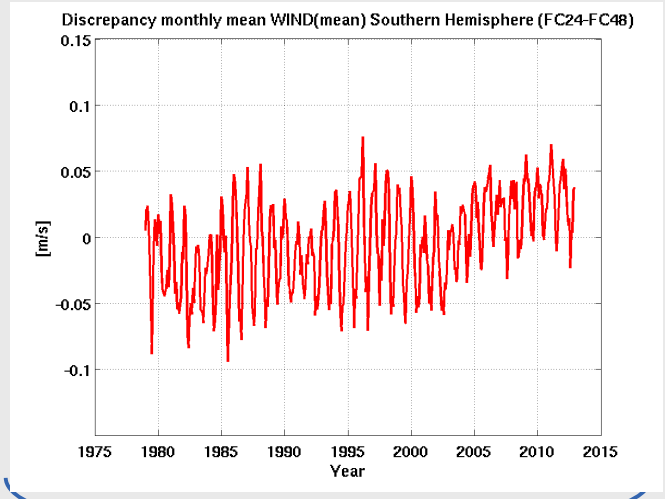

SWH

WINDS

- Area weighted averages
- All ice covered areas have been removed for the SWH

Main findings:

- Smaller jump in SWH (FC24-FC48) N-Hem. ~1 cm
- Smaller bias in WINDS

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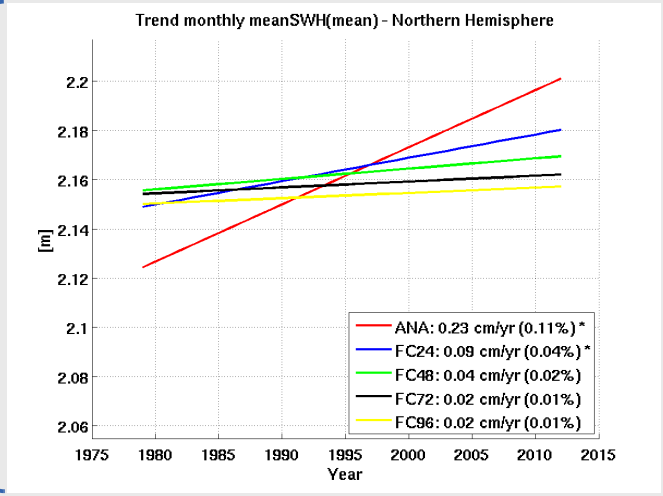
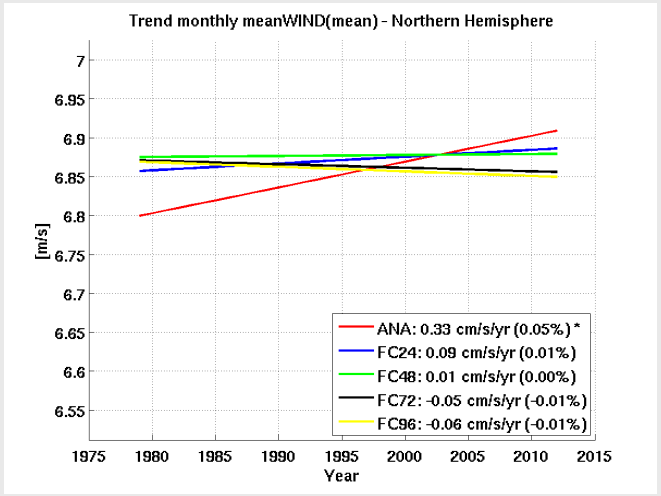
Linear trends in monthly mean SWH and WINDS for N/S-Hemisphere 1979-2012

N





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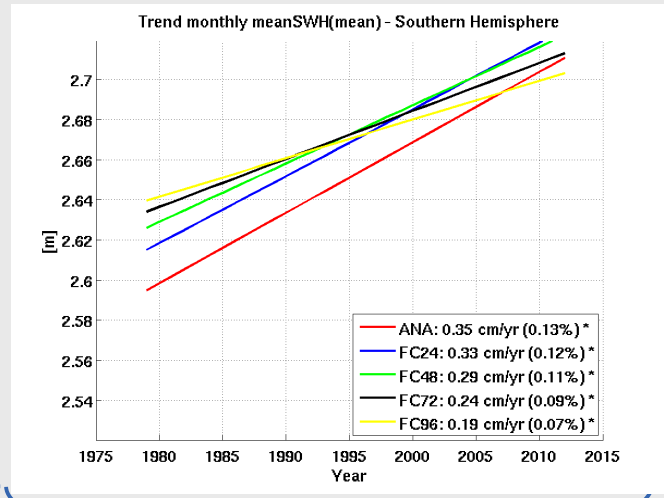

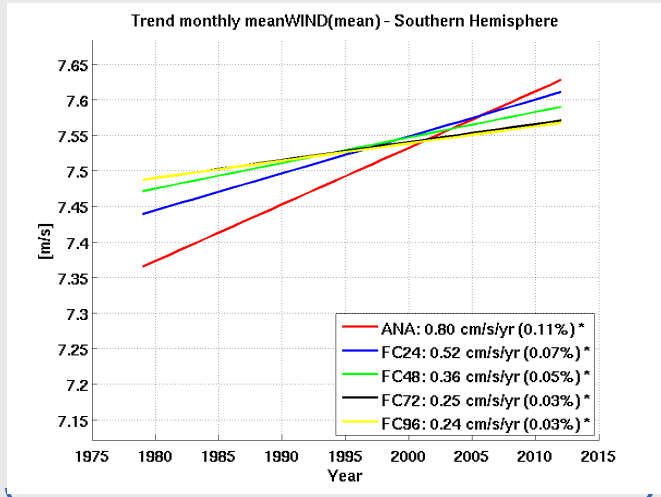

SWH **WIND**

- Area weighted averages
- All ice covered areas have been removed for the SWH

Main findings:

- Trends in SWH/WINDS at ANA clearly deviates from FC, especially in N-Hem.
- FC are less influenced by ass.

* significant

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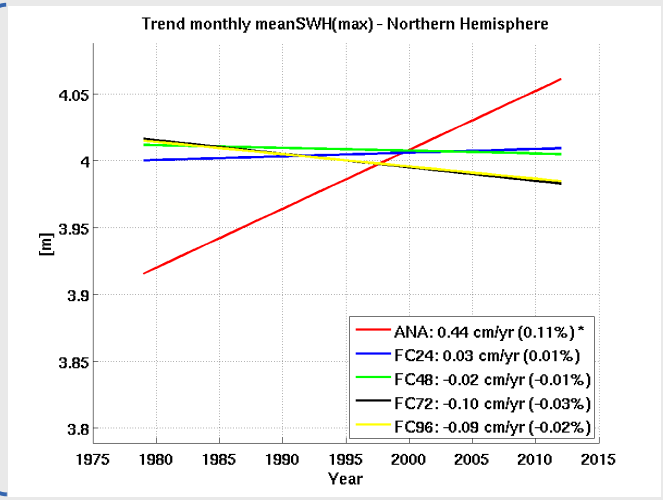
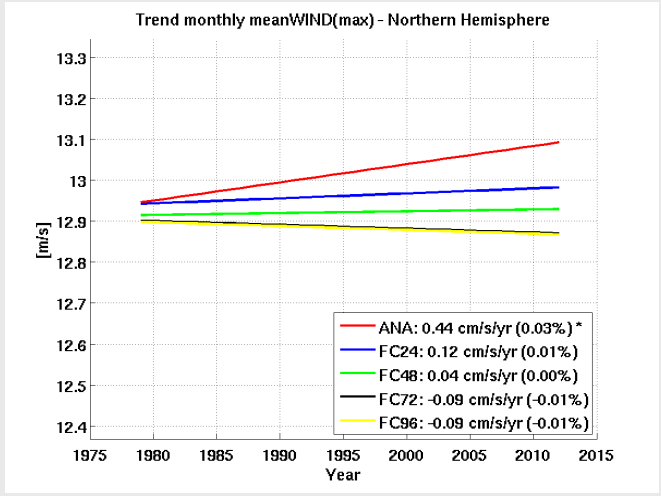
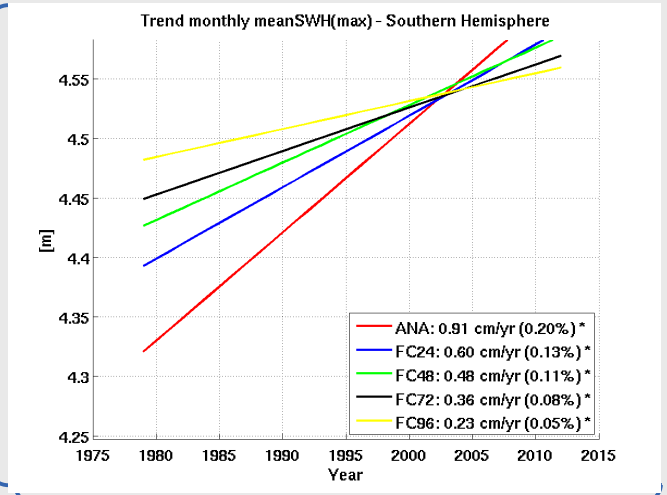
Linear trends in mean monthly max SWH and WINDS for N/S-Hemisphere 1979-2012

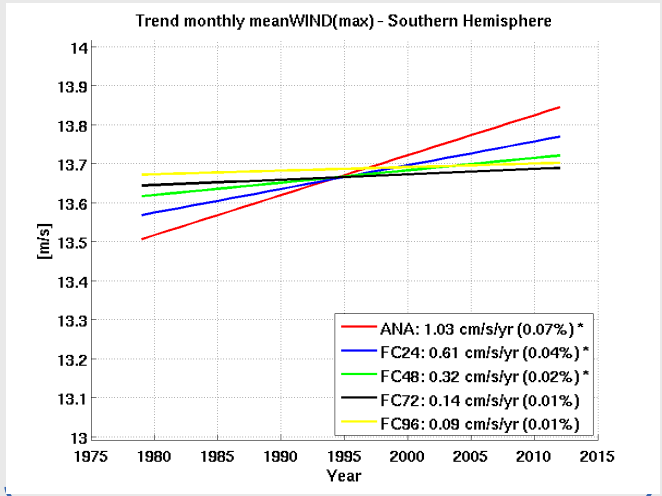
N





S





- Area weighted averages
- All ice covered areas have been removed for the SWH

Main findings:

- Same as for mean values, but enhanced

* significant

SWH **WIND**

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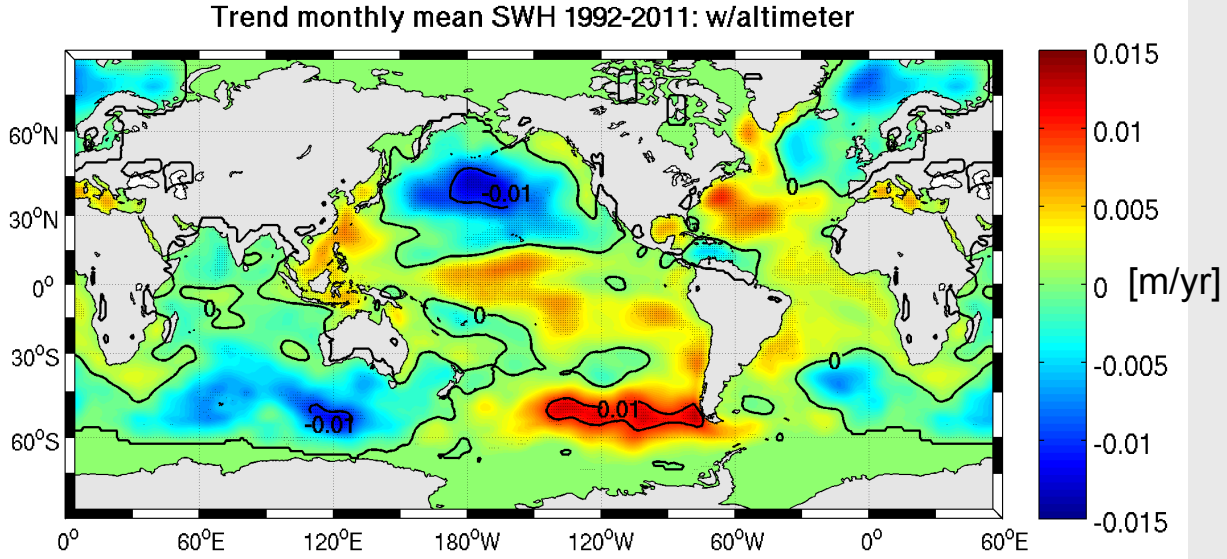
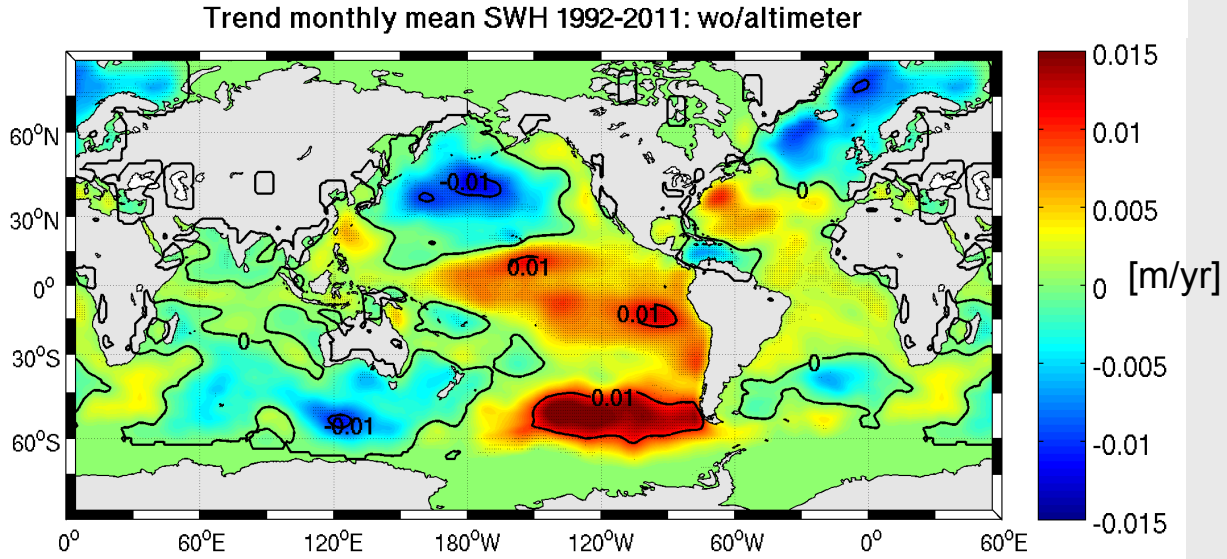
Trends from two seperate WAM runs (ERAI winds ANA) w/ and wo/ wave altimetry assimilation - 1992-2011





Model:

- Newer model cycle than ERAI
- Higher hor. res.
- One-way coupling

- Significant trends are detected in the Pacific and central Atlantic
- Only minor geographical diff. between runs w/wo alt. ass
- Does not indicate any spurios trends in SWH due to altimetry updates

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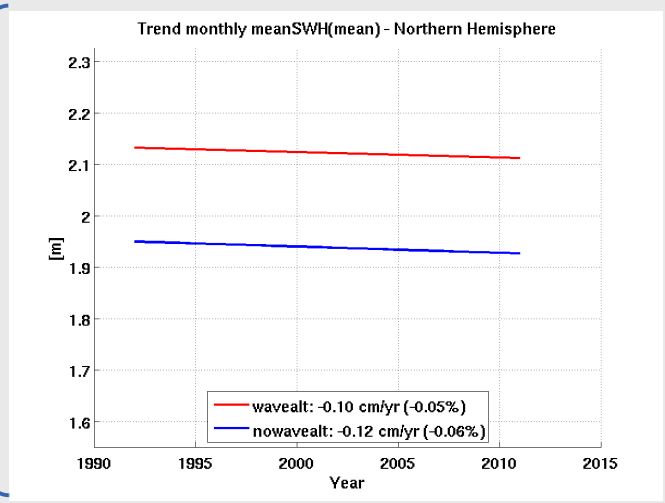
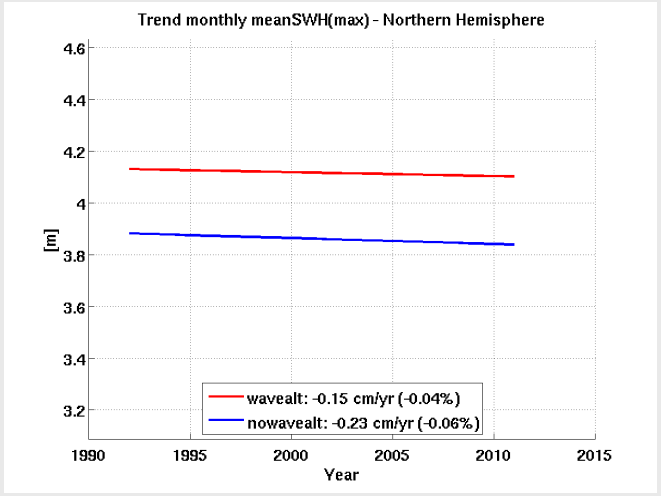
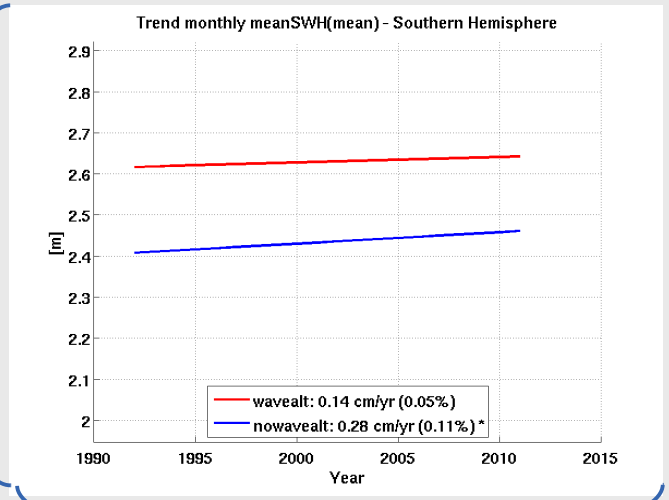
Linear trends in monthly mean/max SWH w/wo alt. ass N/S-Hemisphere 1992-2011

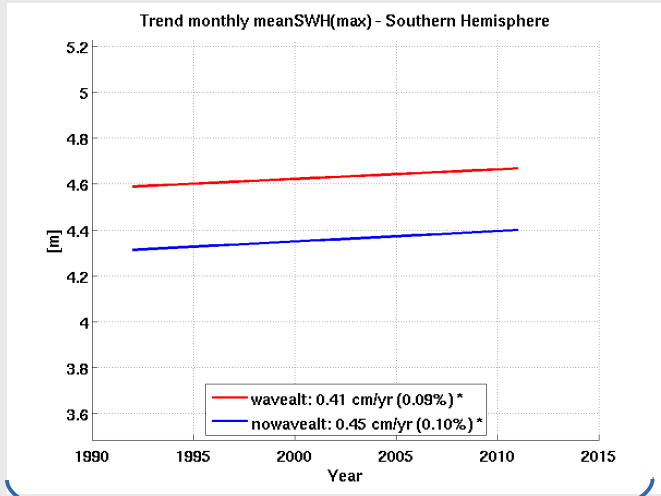
N





S





- Very large bias: ~7-10%
- Model biased low wo/alt ass.
- However, trends are mainly pointing in the same direction

N-Hemisphere:
- Negative
- Non-significant

S-Hemisphere:
- Positive
- Significant

* significant

Mean SWH **Max SWH**

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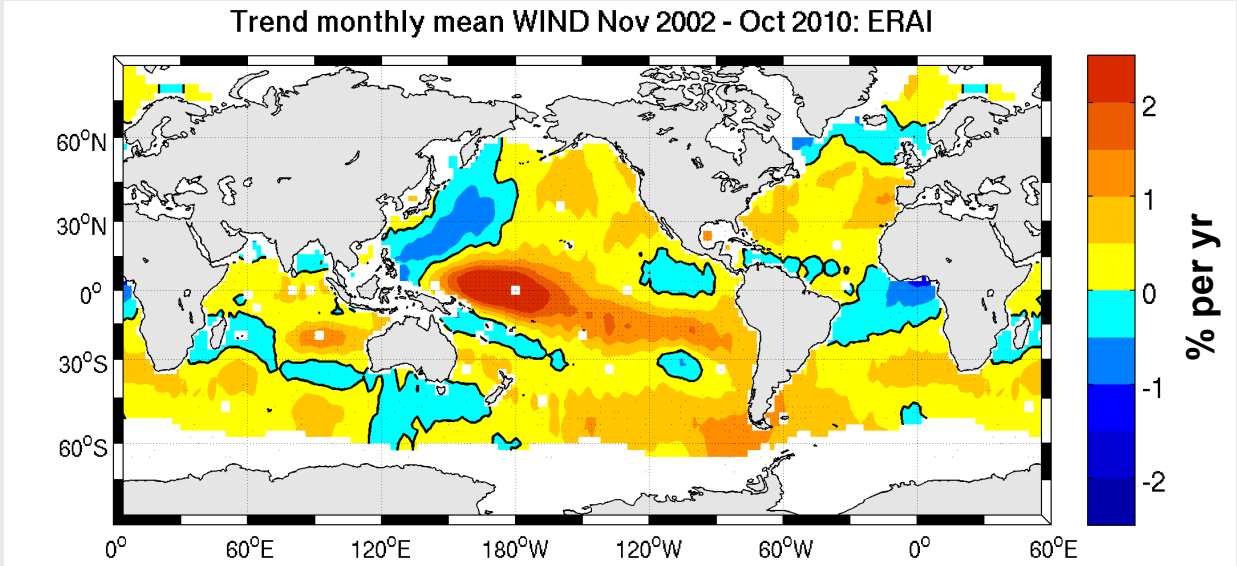
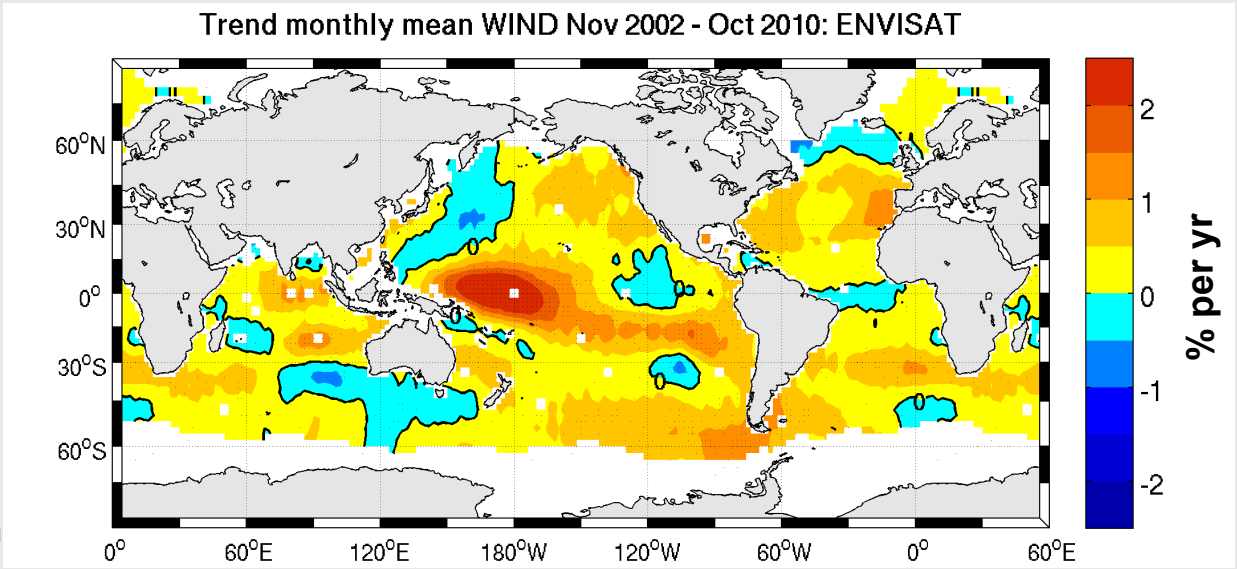
Linear trends of mean WINDS from ERAI(ANA) and ENVISAT - 2002-2010





- ENVISAT WINDS are not ass. into ERAI
- Period is short
- Trends are mainly not significant
- No significant diff. are detected
- It is plausibel that the increasing number of ass. is not affecting the trends in WINDS over the period

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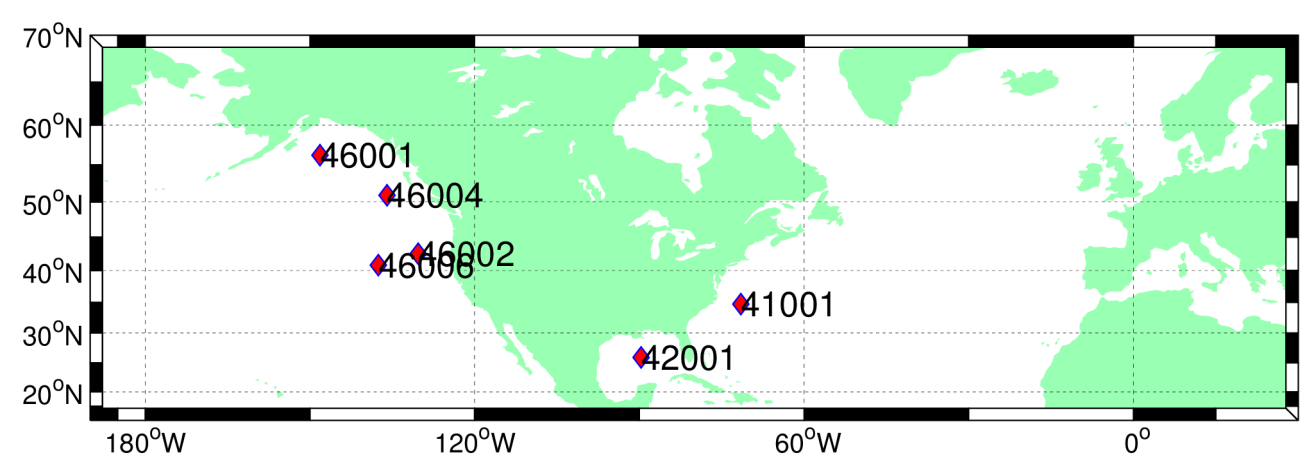
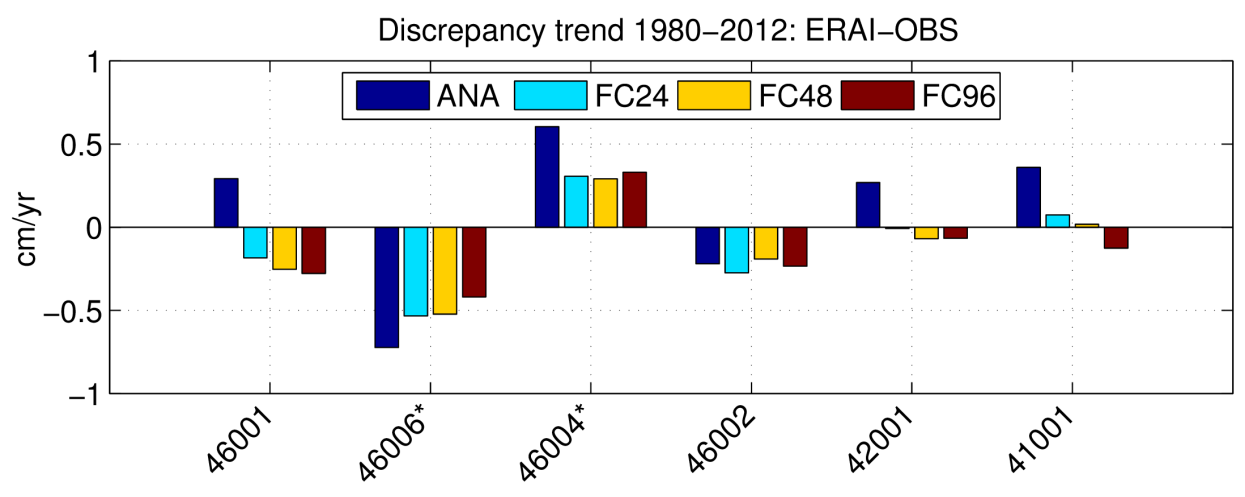
Discrepancy in trend from monthly mean SWH 1980-2012: ERAI-OBS(buoy)





- Obs have not been corrected for any discontinuities
- Months with 50% data coverage are included
- Only two pos. show significant trends
- ANA shows largest bias
- FC24 and FC48 show equal performance

* OBS significant

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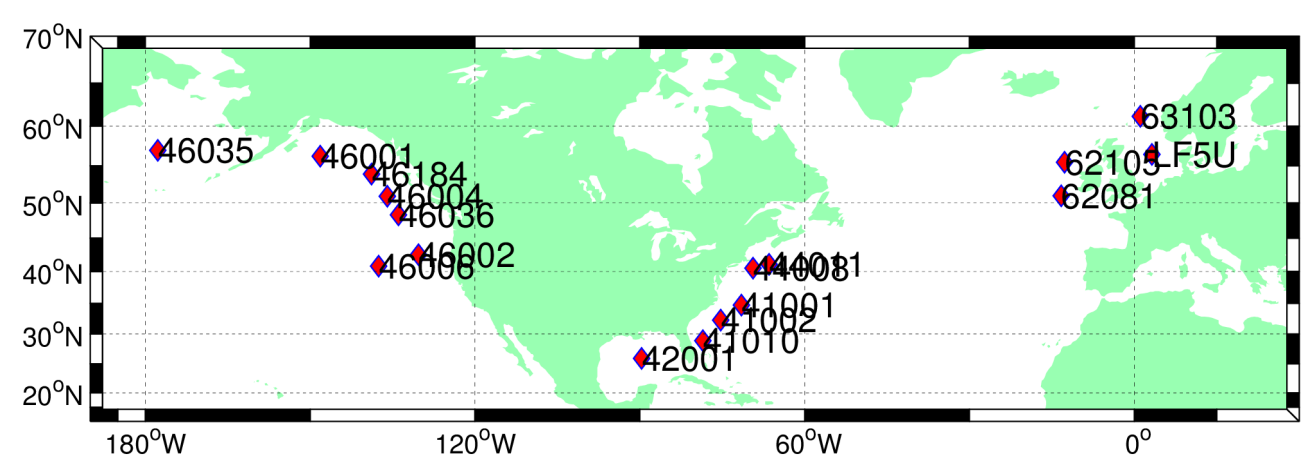
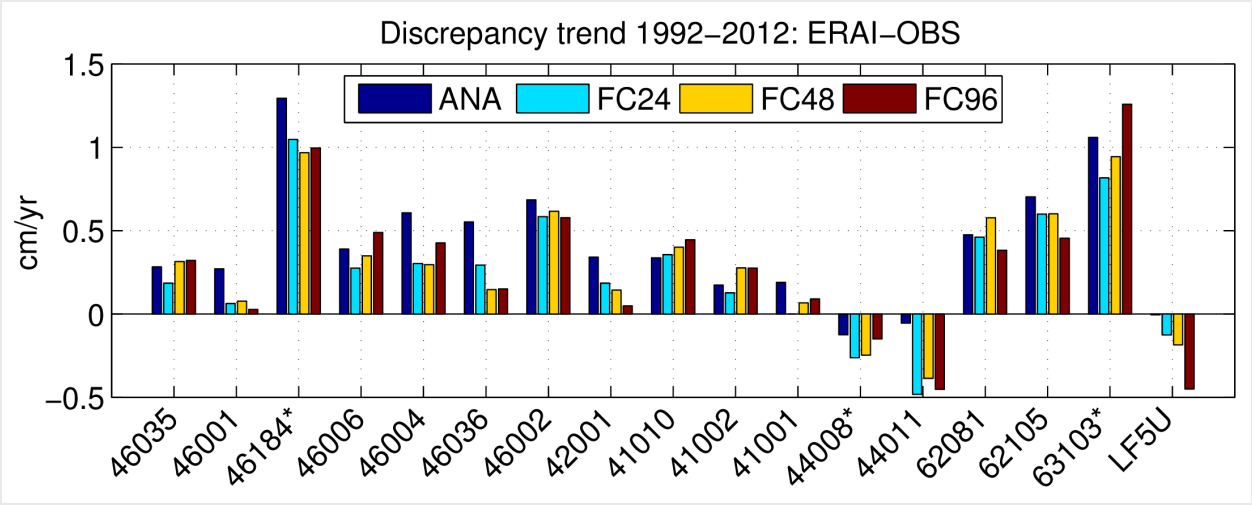
Discrepancy in trend from monthly mean SWH 1992-2012: ERAI-OBS(buoy)





- Corresponds to period w/alt. ass.
- ERAI (ANA to FC96) shows larger trends than obs
- Only three pos. show significant trends
- Again - FC24 and FC48 come closer to obs compared to ANA

* OBS significant

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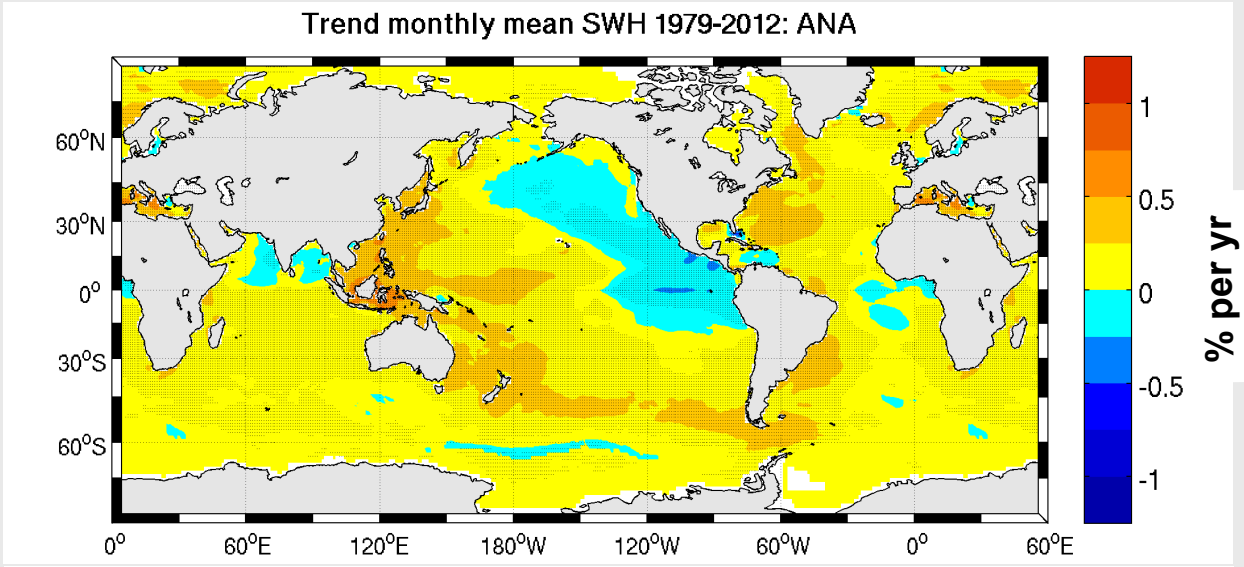
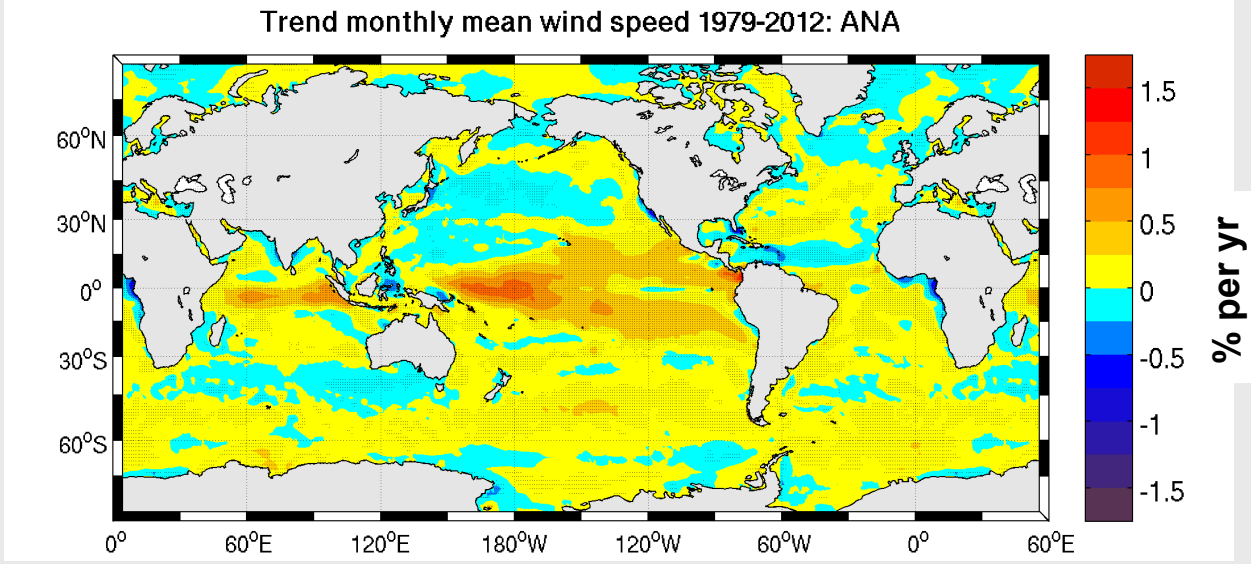
Linear trends of mean SWH and WINDS from ERAI at ANA: 1979-2012





SWH:

- Trends are mainly significant and positive

WINDS

- Geographically less significant than SWH
- Largest trend near equator

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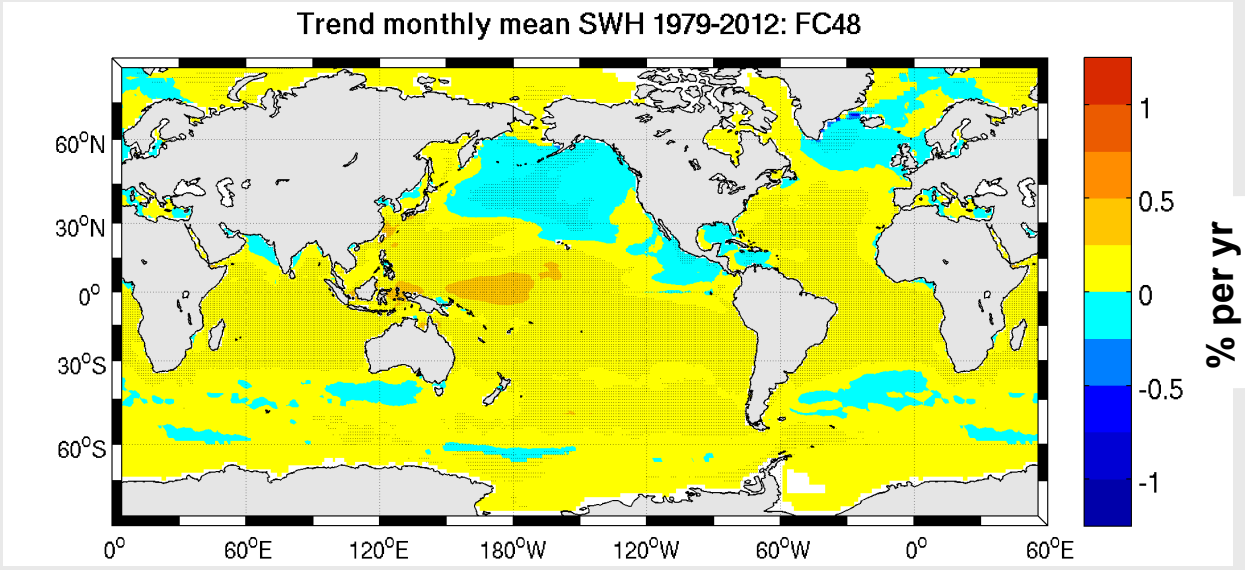
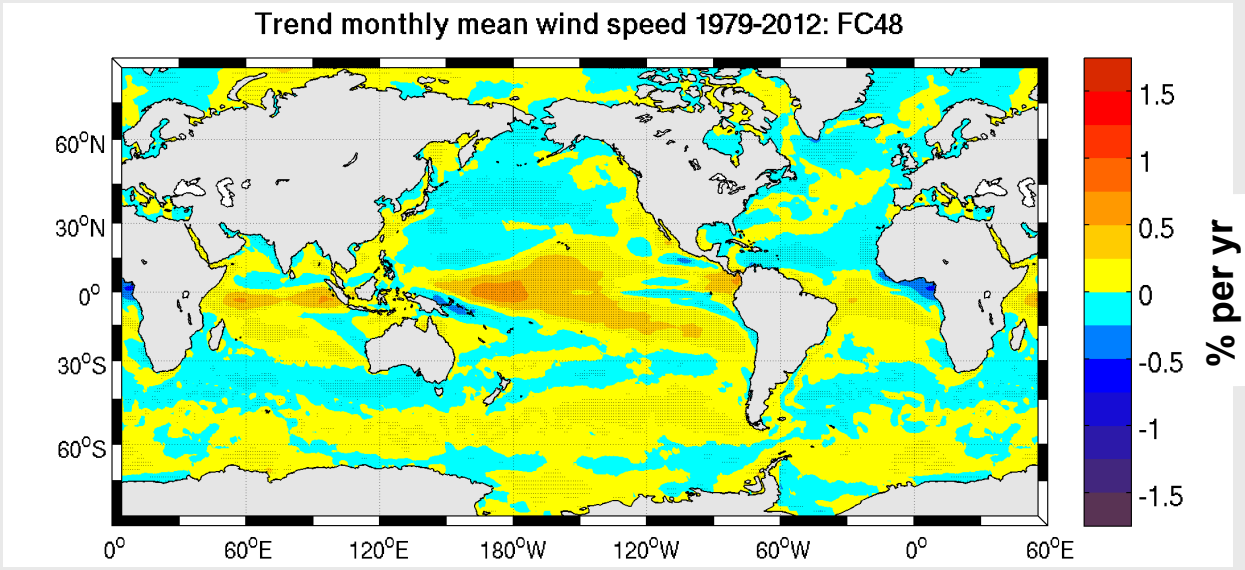
Linear trends of mean SWH and WINDS from ERAI at FC48: 1979-2012



SWH:

- Trends are more moderat the ANA
- Negative trend in N-Pacific shifts towards the North



WINDS

- Trends are more moderat than ANA

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Conclusions

- Discontinuity in ERA-Interim at ANA are detected due to the assimilation of SWH altimeter observations from Aug 1991
- Intrinsic spurious trends in the SWH are highly likely to be present in the ERA-Interim at ANA
- Preliminary results suggest that lead times FC24 to FC48 yield more realistic trends in ERA-Interim

Abstract

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Title:
Linear trends of wind speed and wave height based on ERA-INTERIM at different forecast range – 1979-2011.

Abstract:
The ECMWF ERA-Interim reanalysis (1979 to present) is widely used in studies of the recent past climate. Most studies focus on the analysis time, but the archive also contains ten-day forecasts starting from 00 and 12 UTC each day.

During the ERA-Interim period the total number of assimilated observations has increased dramatically. This is likely to introduce biases and artificial trends, especially near analysis time. At increasing lead times, these adverse side effects are expected to be somewhat suppressed.

In this study we investigate trends of wind speed and wave height, represented by monthly means and monthly maxima, obtained at analysis time and at lead times +24 h, +48 h, +72h and +96 h, with the objective of determining a best estimate of the real trend over the archived period. Special care is taken to investigate the impact of altimeter wave observations (first introduced in 1992).

In order to separate the effect of the introduction of altimeter wave data in 1992 from the steady increase of other meteorological observations assimilated into the ERA-INTERIM, we analyze two stand-alone WAM-model runs spanning the period 1989-2011, both forced with ERA-Interim winds, but only one assimilating altimeter wave data.

We find that the trends vary significantly with forecast lead time. A best estimate of the trends is presented together with a recommended lead time for trend estimates.

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