National Oceanography Centre

Investigating sea state trends and variability with new climate-quality satellite altimeter products

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Outline

- The ESA Sea State CCI+ project
- CCI+ Sea State products
- Assessment
  - Consistency checks
    - Global climatologies, seasonal variations, inter-comparisons with other products
  - Comparisons with in situ data and other sea state products
    - Hs time series at key instrumented sites
  - Sea State ECV: long-term trends
    - Global maps of Hs trends in CCI and other products
- Summary & Conclusions

The ESA Sea State CCI+ project

- Funded by the European Space Agency Climate Change Initiative program (CCI)
- 36 months project for Sea State
  - Science lead: Fabrice Ardhuin (LOPS/Ifremer)
  - Large international team
- Objectives
  - To produce climate-quality satellite products for Essential Climate Variables (ECV) for Sea State
  - consistent approach across ~ 30 projects for other ECVs e.g. Aerosols, Soil moisture, Sea Level, Sea Surface Temperature, etc.

See presentation by Guillaume Dodet et al., The Sea State Climate Change Initiative project Friday 11:40 (S4)

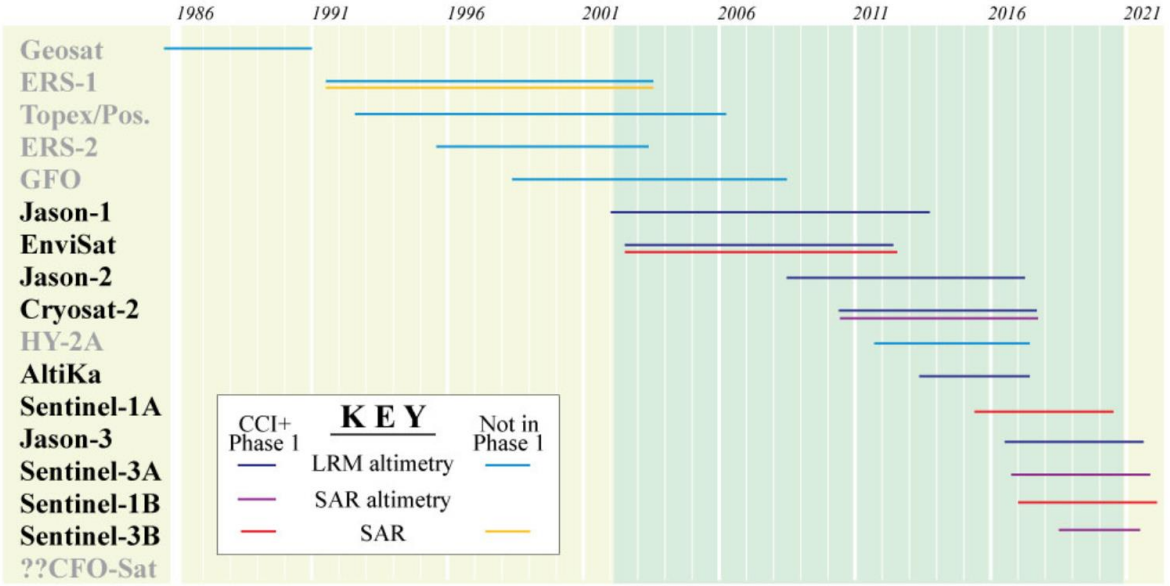
Sea state ECV

- ECV defined by WMO Global Climate Observing System (GCOS)
- GCOS formal requirement for Sea State

Product	Frequency	Resolution	Required uncertainty	Required Stability (per decade)
Hs	3-hourly	25 km	10 cm	5 cm

CCI+ Sea State products

- Satellite altimeters and Synthetic Aperture Radars (SAR)
  - Altimeter: Hs and Sigma0 (mss)
  - SAR: Hs, mean period, mean direction, 2D spectra
  - 1992-2018
- Strong heritage from GlobWave



- CCI+ Sea State Version 1 products available since July 2019
  - Altimeter Hs
  - https://forms.ifremer.fr/lops-siam/access-to-esa-cci-sea-state-data/
    - Level 2P: along-track products separated per mission and pass (7km)
    - Level 3: edited multi-mission daily products
    - Level 4: multi-mission monthly gridded 1° resolution

sea state cci

CCI+ Sea State v1 altimeter products assessment

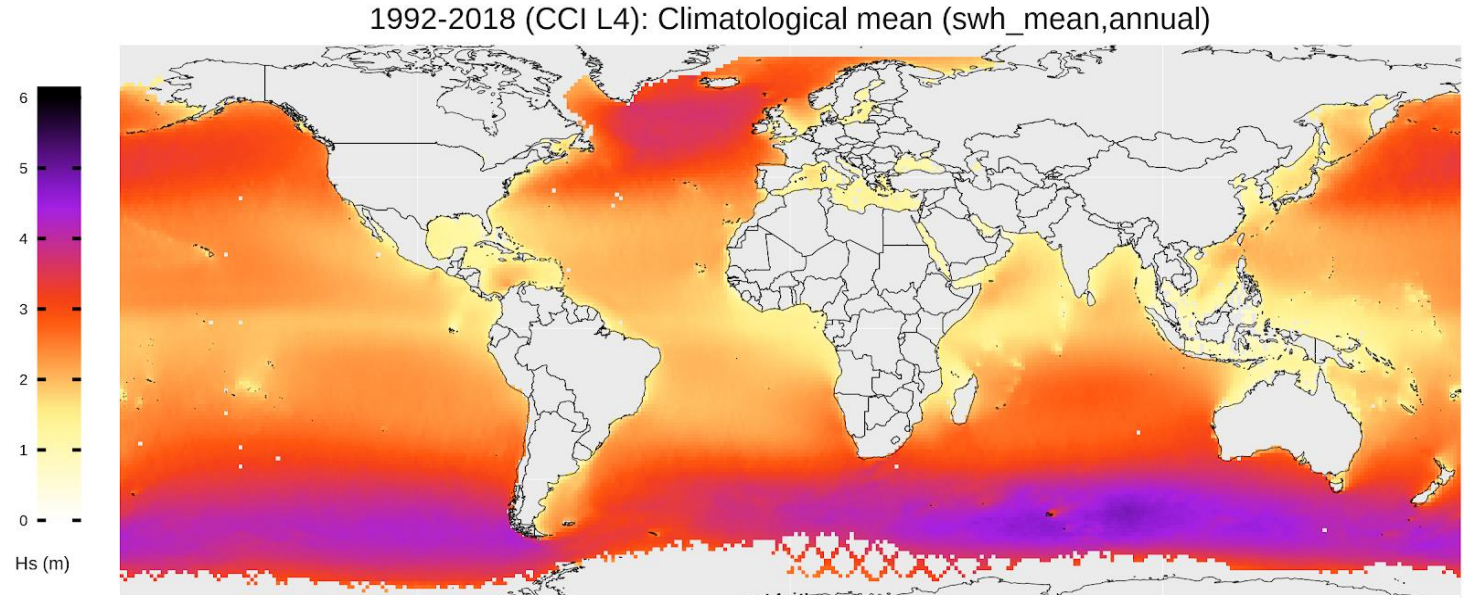
- Datasets

CCI+ Sea State v1.1 L4 altimeter Hs	ERA5 reanalysis
Buoys: NDBC wave buoys (long-term deployment)	ECMWF WAM hindcast (courtesy Jean Bidlot)
Ribal & Young, 2019: multi-mission altimeter (Hs, U10)	+ other global hindcasts (NOC WW3, IH Cantabria)

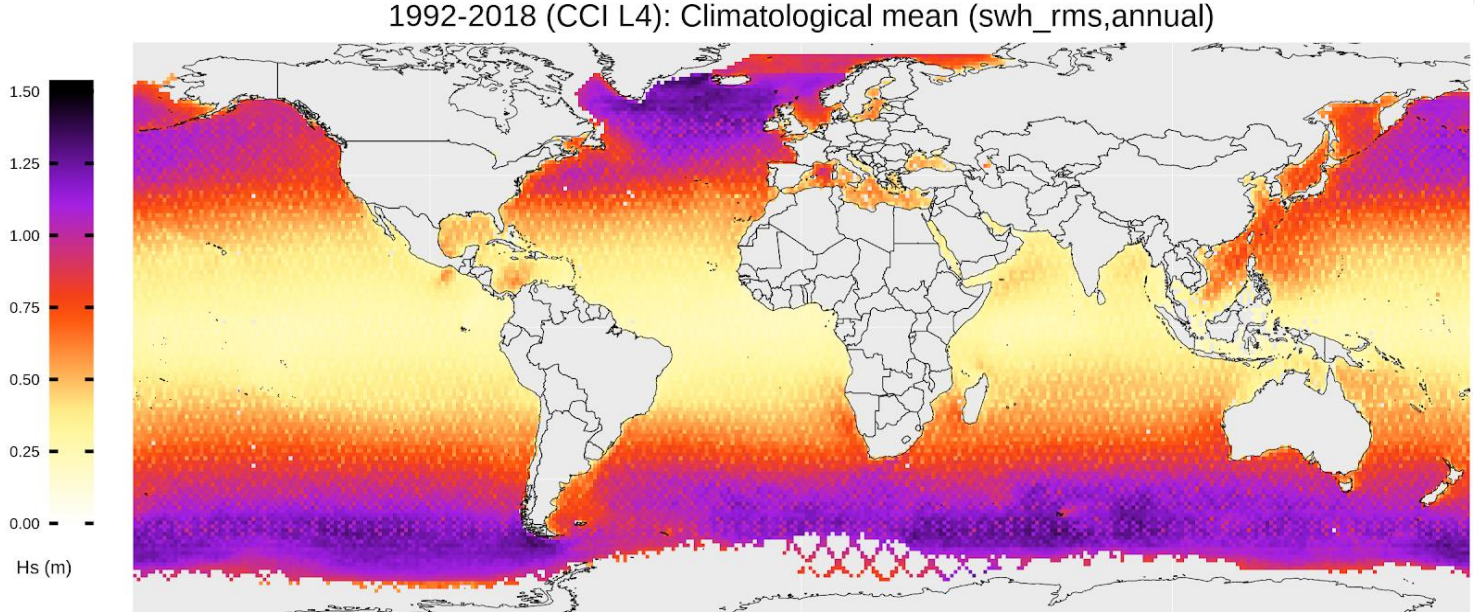
Consistency checks: Hs climatology

- 1992-2018, 1 deg

Mean Hs



Mean RMS

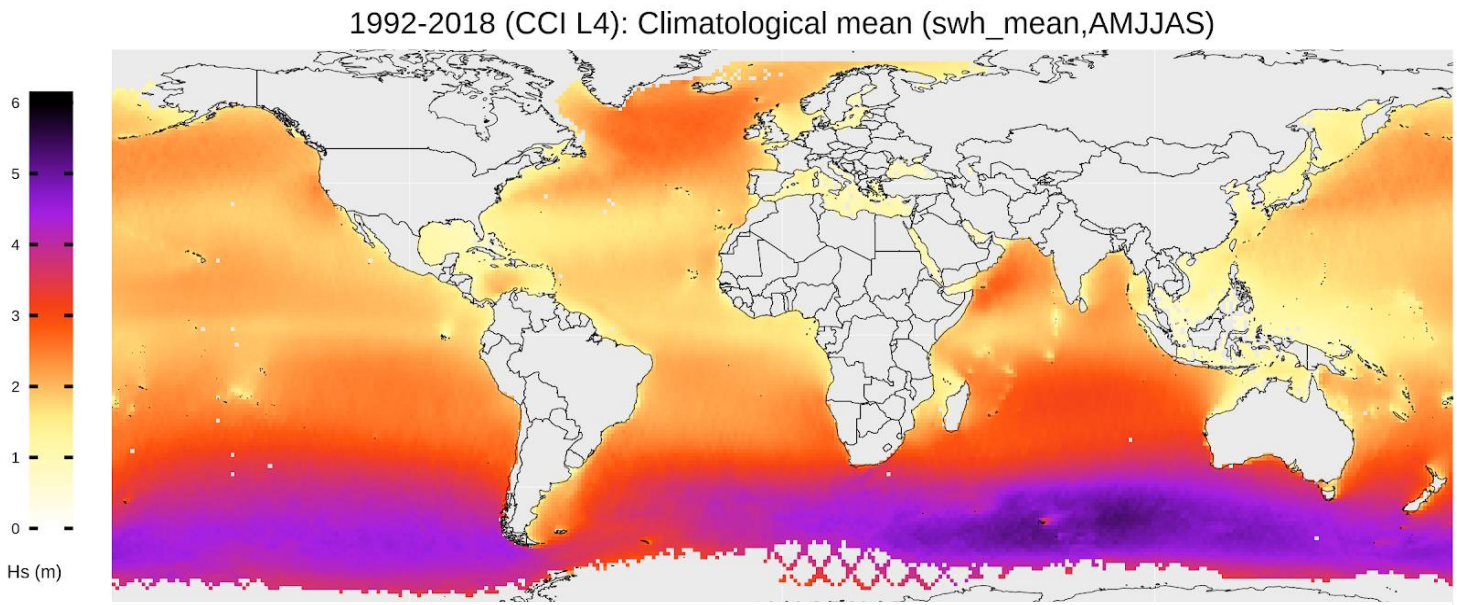


Consistency checks: seasonal cycle

- 1992-2018, 1 deg

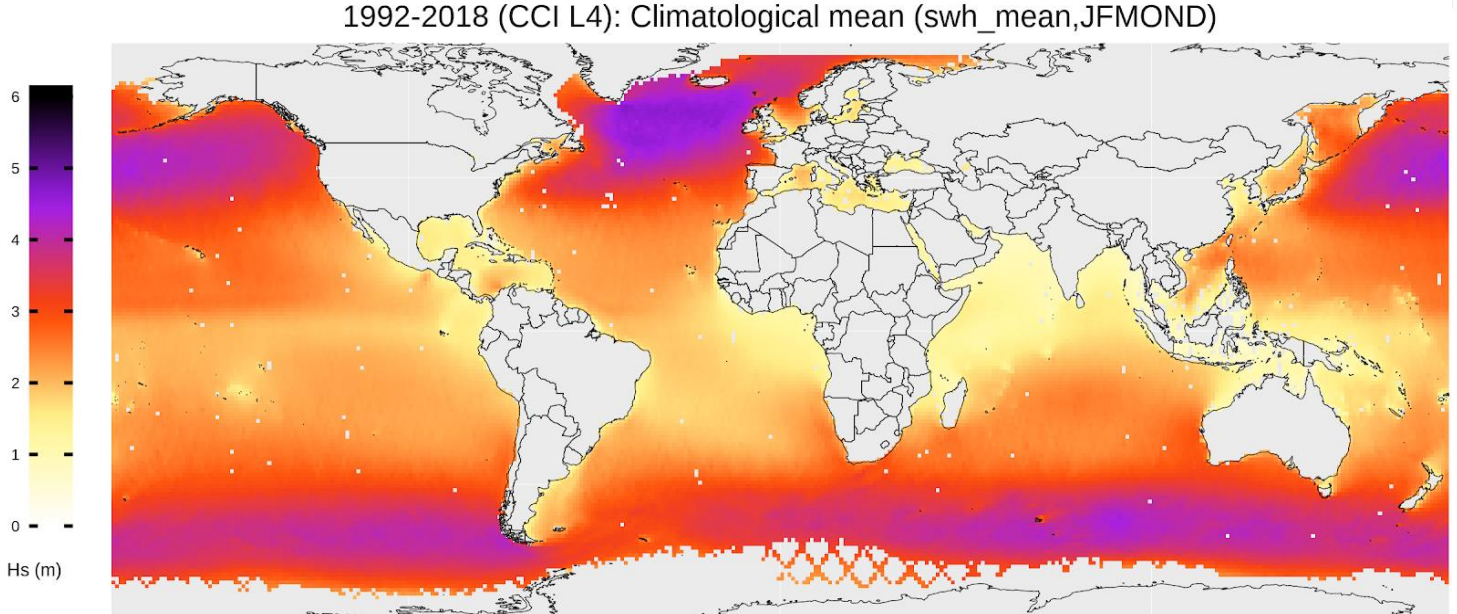
SH Winter

April-Sept



SH Summer

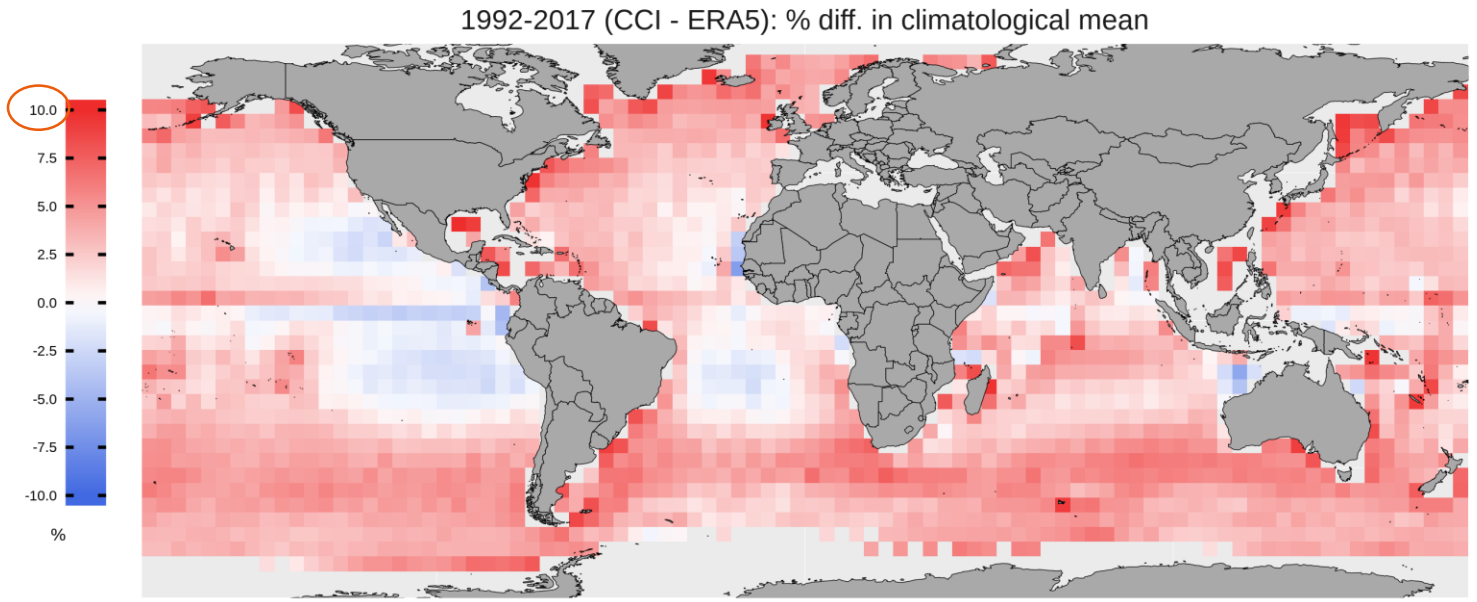
Oct-March



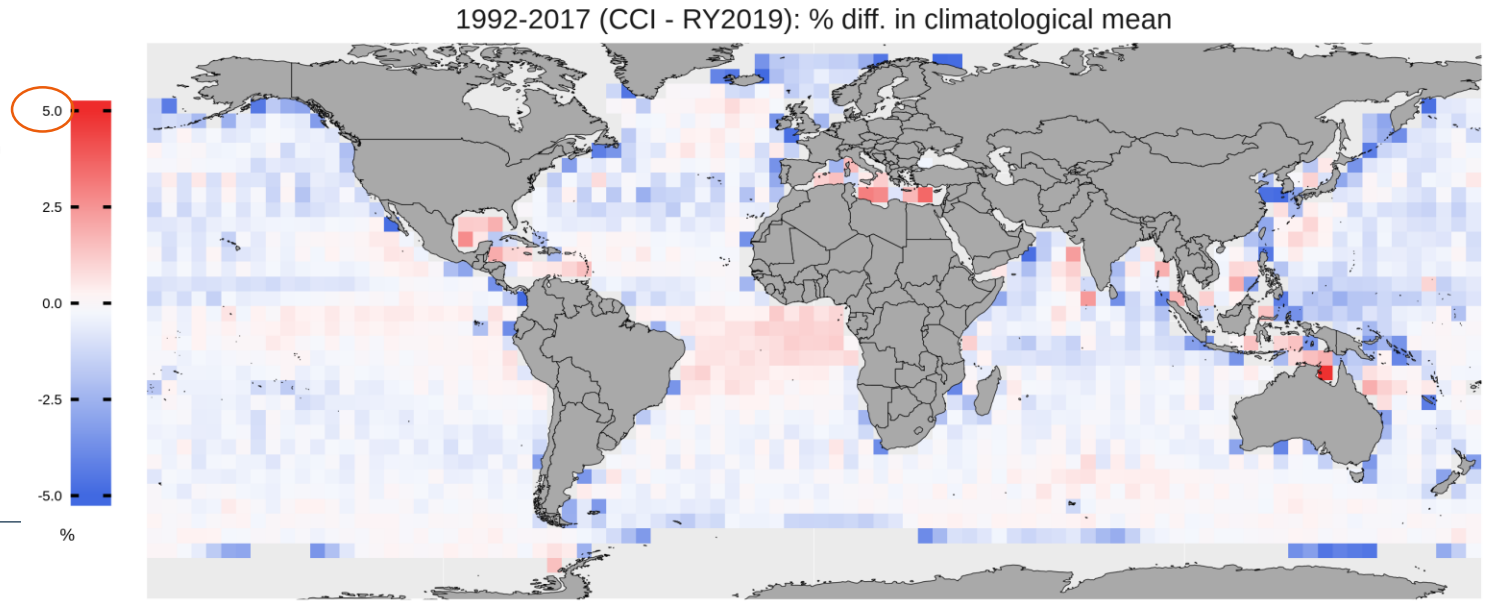
Consistency checks: inter-comparisons

- 1993-2017, 4 deg
- % difference in climatological mean

Against ERA5

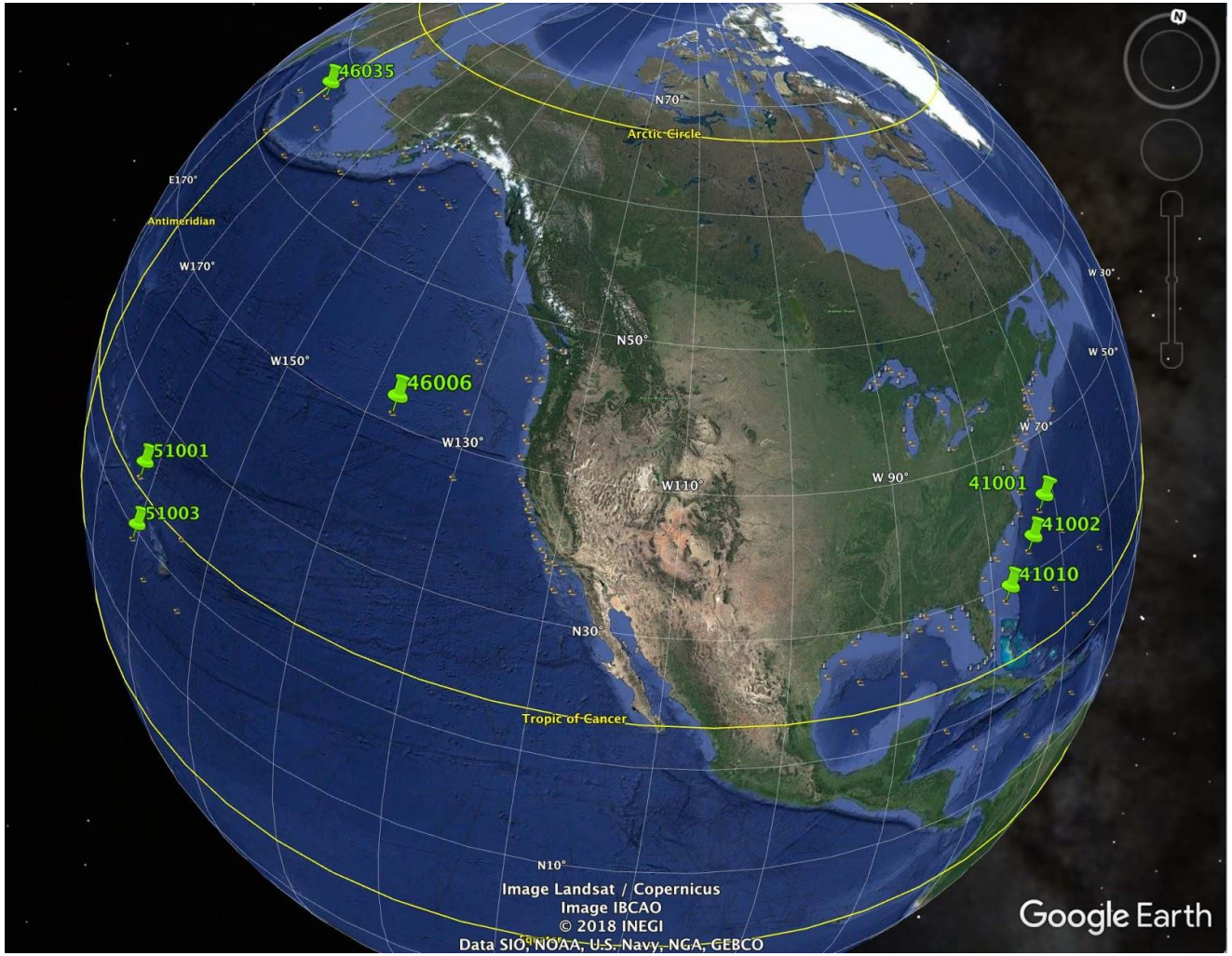


Against RY2019



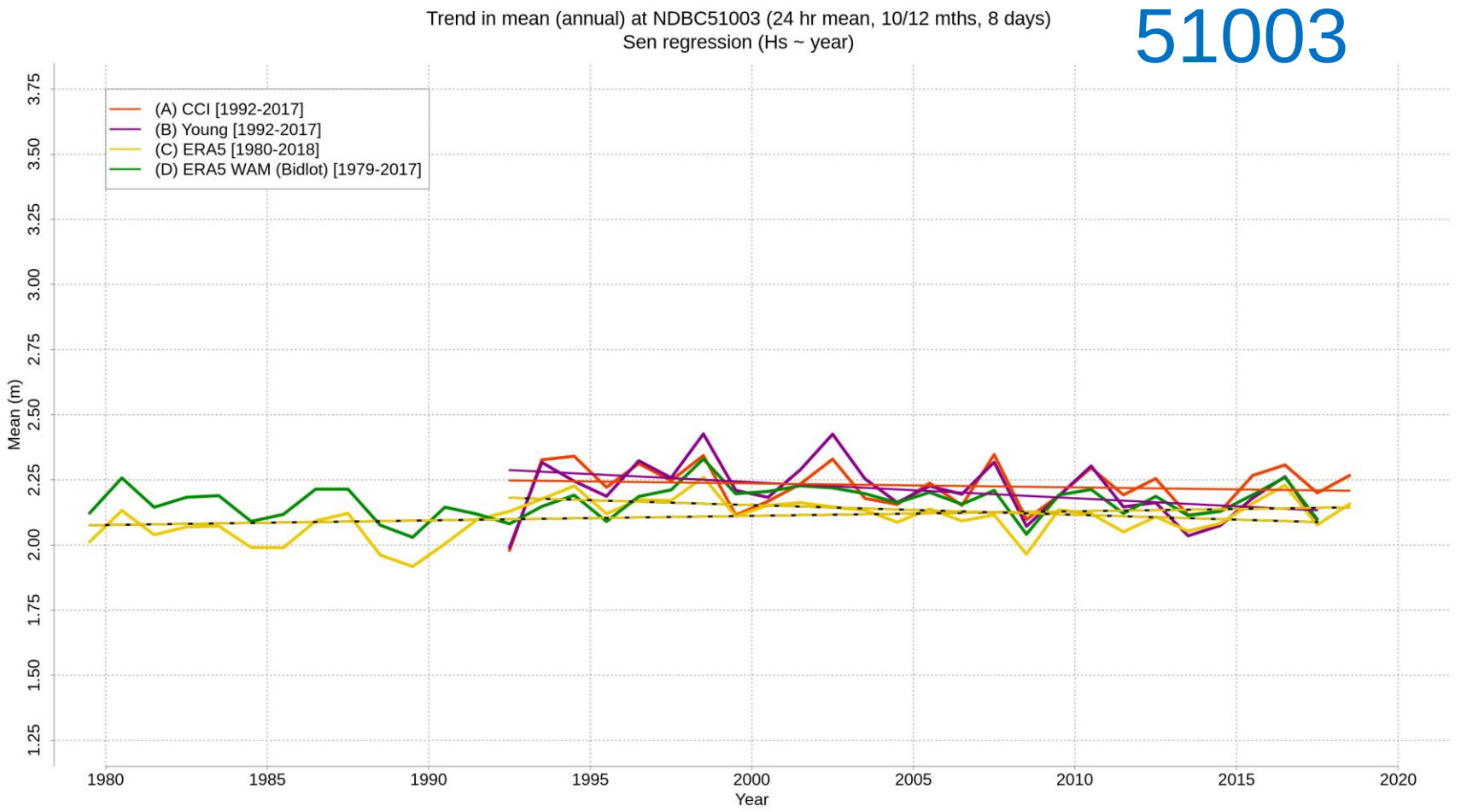
Comparison with in situ data and other sea state products

- Hs time series at selected buoys
  - NDBC
  - long-term buoy deployments
  - various wave climates
- Inter-comparisons with altimeter, in situ and model products
- 51003 (Hawaii)
- 41002 (W Atlantic)
- 46006 (E Pacific)



Comparison with in situ data and other sea state products

- Hawaii (51003)
- Satellite products show similar variability, occasional biases (± 0.1 m) & negative trends
  - Stronger negative Hs trend in RY2019
- Models biased low, with weaker interannual variability
- Note the impact of chosen period on estimated Hs trends
  - Trend is opposite over longer period



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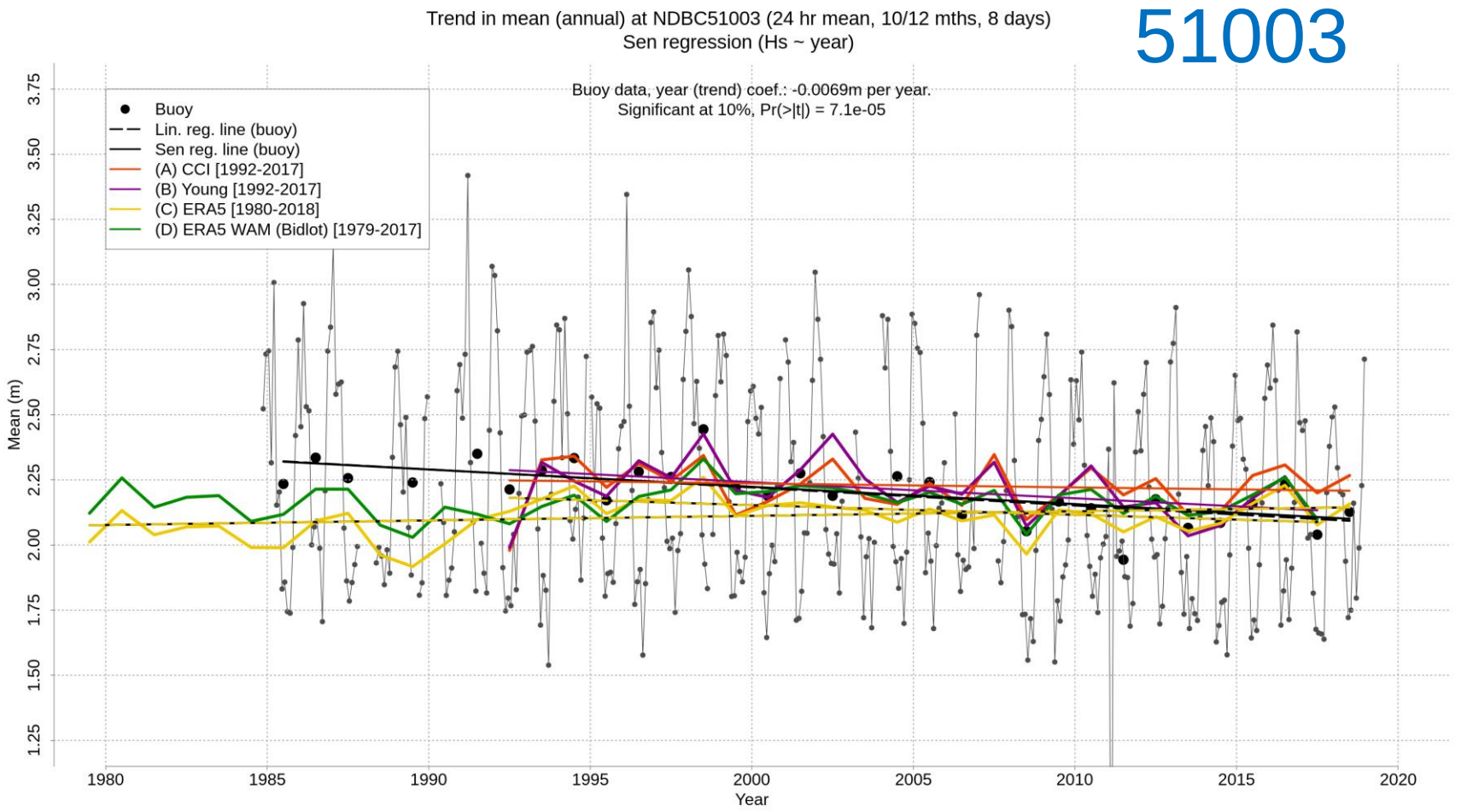
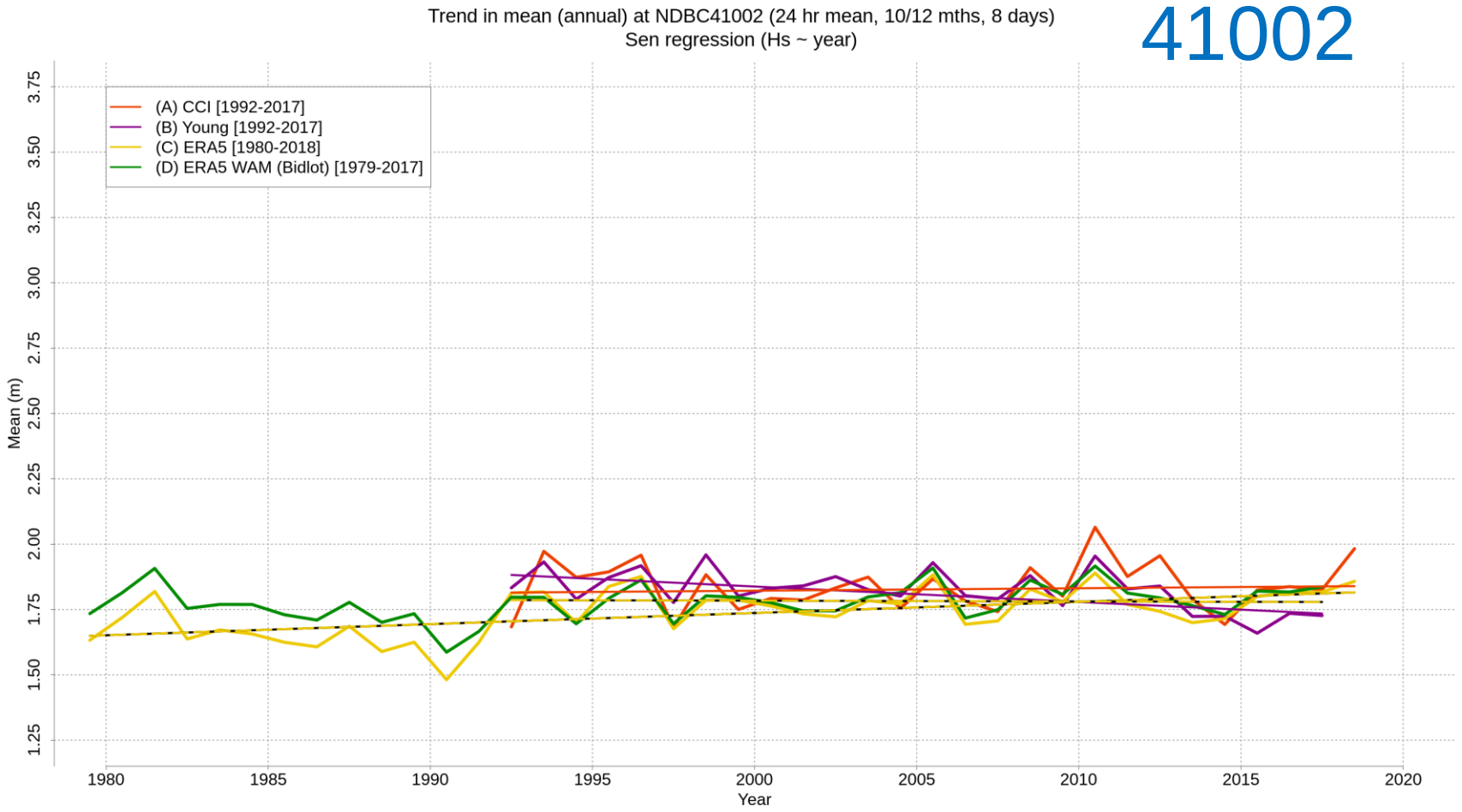


Buoy data from 1985, confirm stronger negative trend seen in RY2019

Comparison with in situ data and other sea state products

- 41002 (W Atlantic)
- No significant trend in CCI and models
  - negative Hs trend in RY2019
- Models show positive trend over longer period

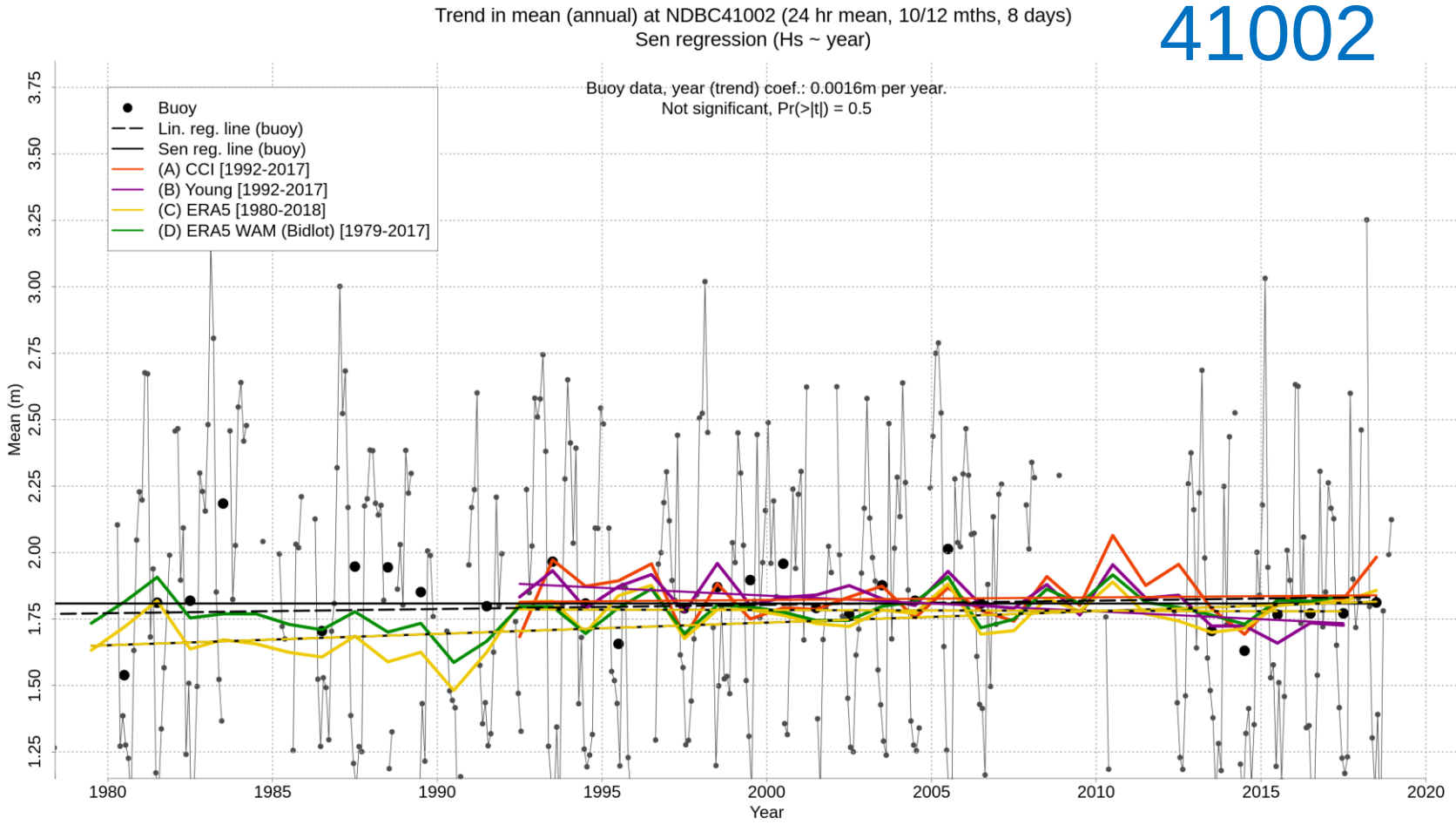
41002



Comparison with in situ data and other sea state products

- 41002 (W Atlantic)
- No significant trend in CCI and models
  - negative Hs trend in RY2019
- Models show positive trend over longer period
- All products show discrepancies with buoy Hs in magnitude and variability

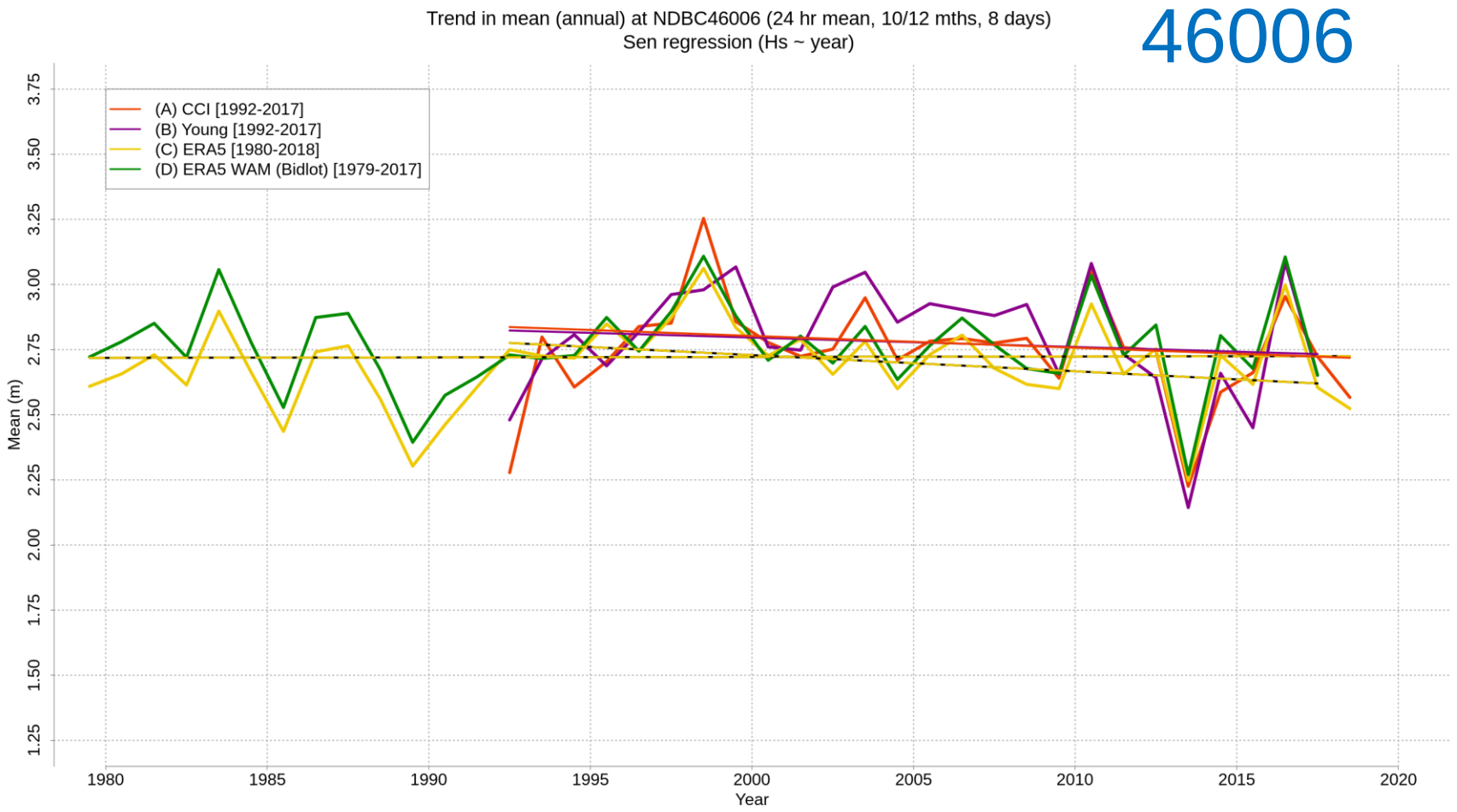
41002



Buoy data from 1980, confirms small Hs trend seen in CCI

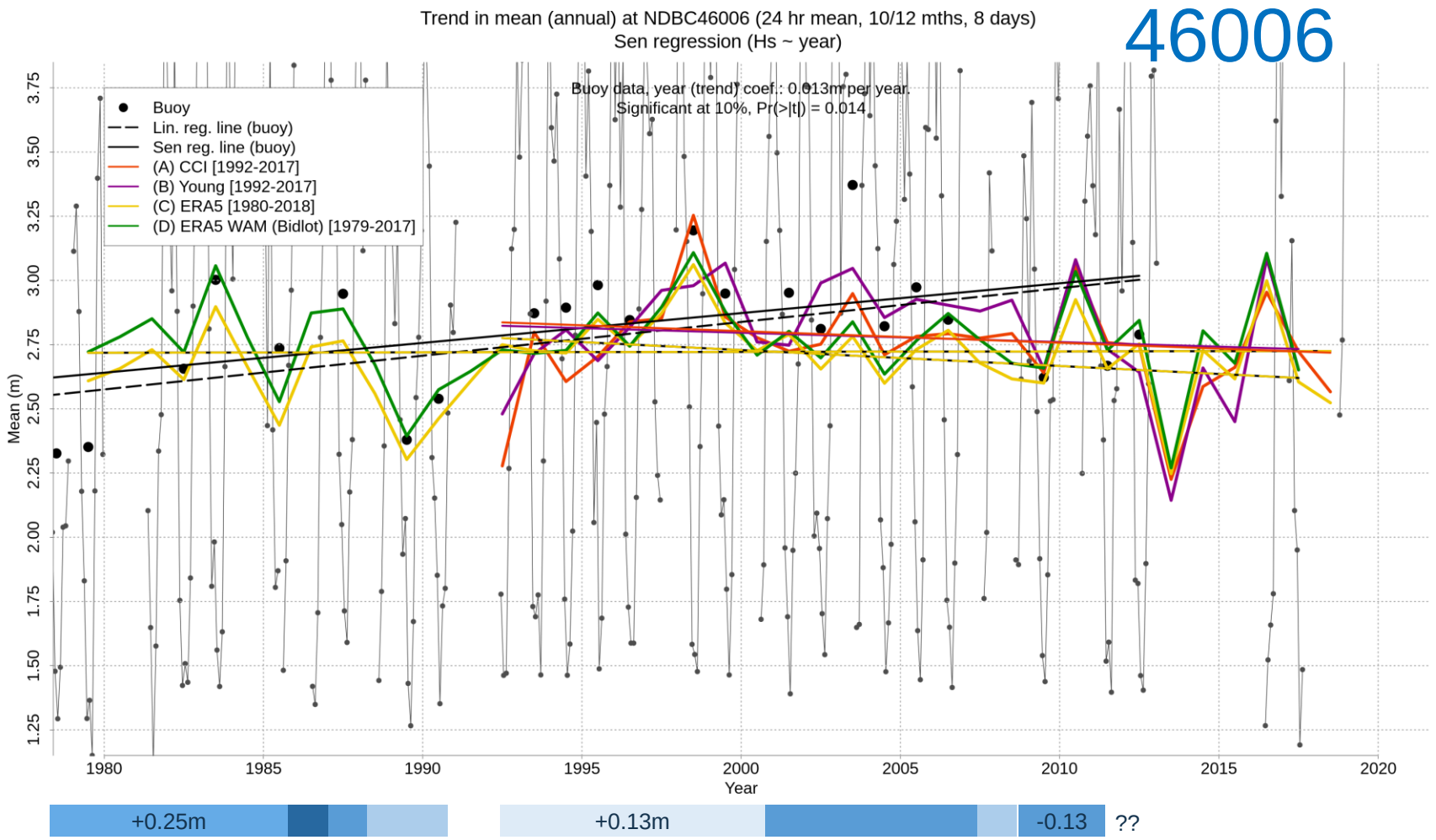
Comparison with in situ data and other sea state products

- North Pacific (46006)
- Better agreement between products, particularly towards end of the altimeter era
- Trends broadly consistent between satellite and models



Comparison with in situ data and other sea state products

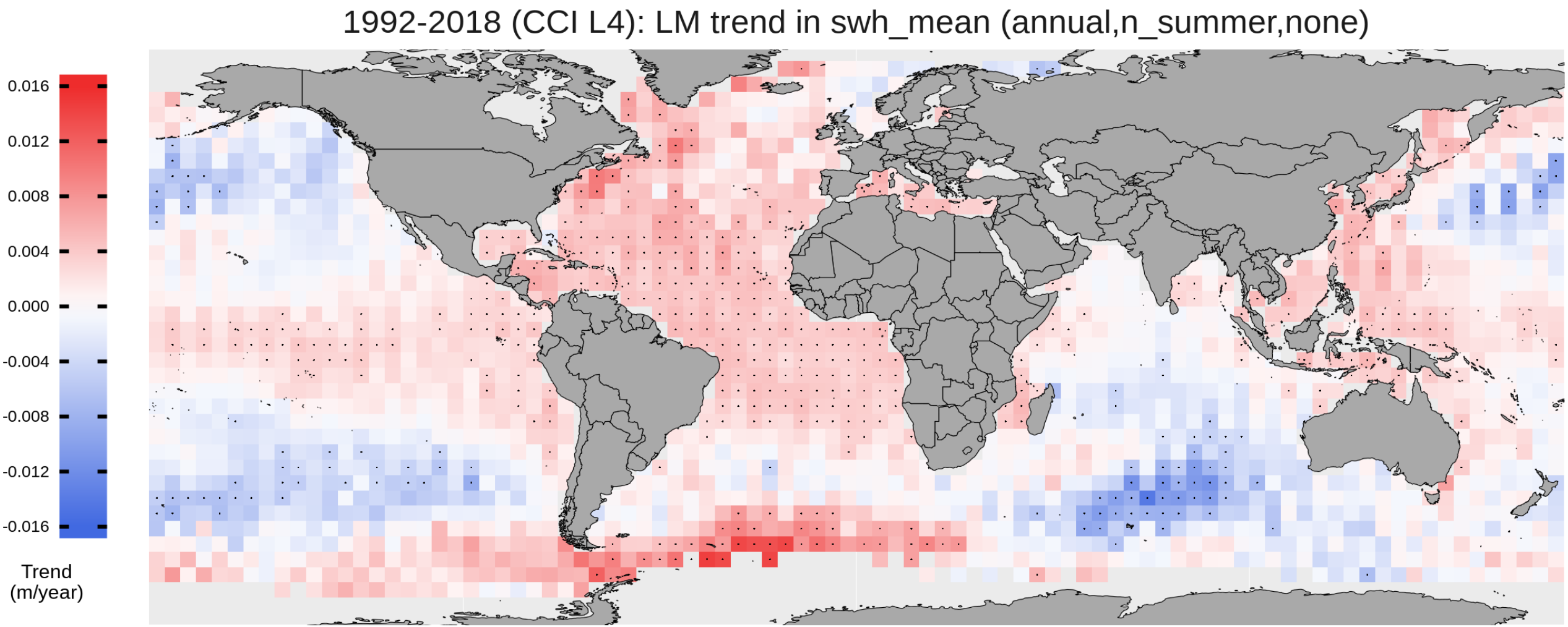
- North Pacific (46006)
- Better agreement between products, particularly towards end of the altimeter era
- Trends broadly consistent between satellite and models
- Large variability in buoy Hs
- Buoy Hs shows opposite (positive) trend



Impact of changes in buoy platform/sensor ? (Gemmrich et al., 2011)

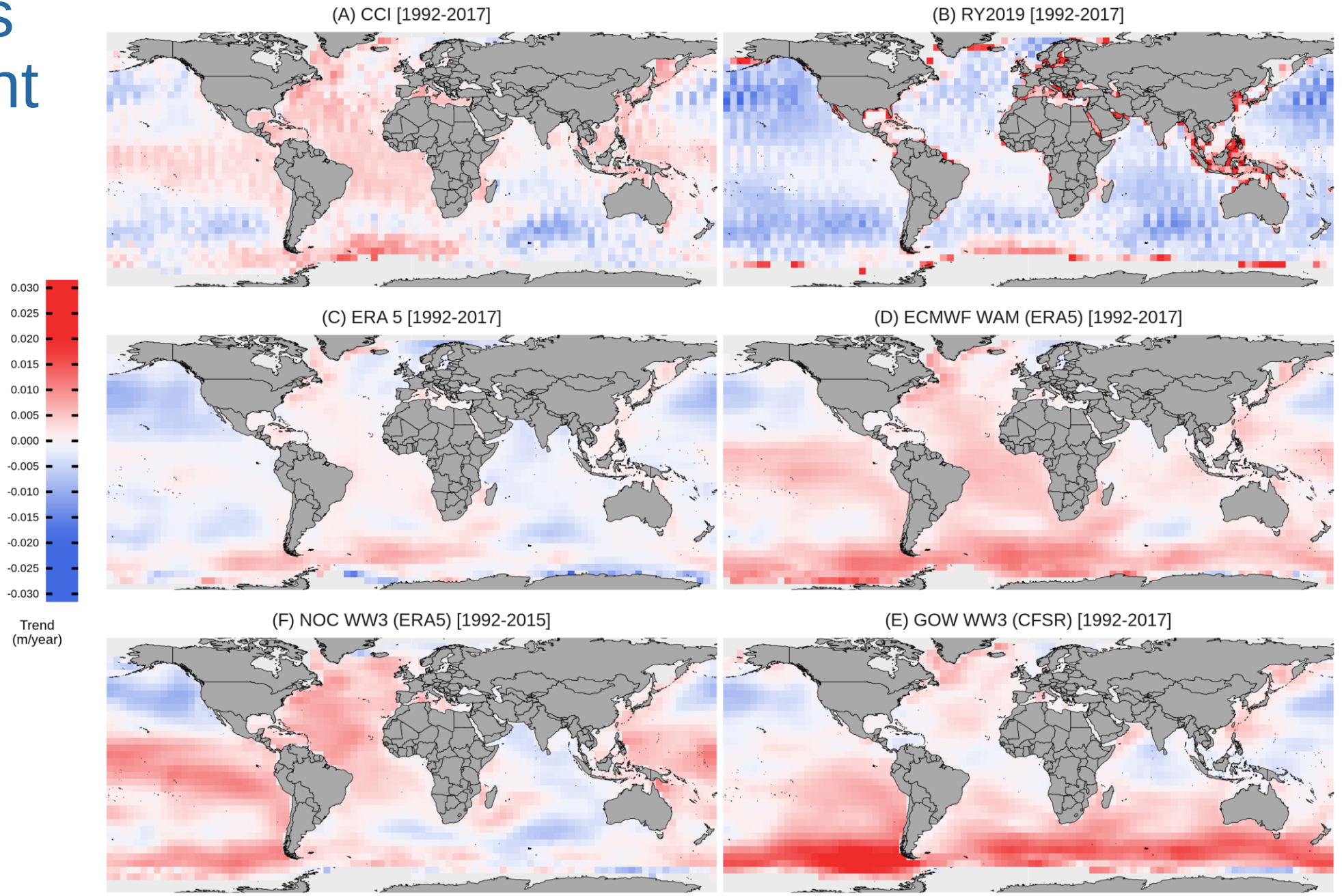
Sea State ECV Assessment: long-term trends

Sea State ECV: global distribution of Hs trends



Strong geographical patterns in CCI Hs trend

Hs trends in different products



Summary & Conclusions

- New satellite altimeter products for Hs now available from the ESA CCI+ Sea State project
  - CCI Level 4 gridded products, 1992-2018
- Good consistency of Hs climatological fields with Ribal & Young (2019)
  - But ERA5 biased low v CCI Hs
- Inter-comparisons at several buoy sites
  - Models biased low with weak variability, and sometimes show opposite trends over long/short periods
  - Buoy Hs time series confirm trends in turn for CCI and Ribal & Young (2019)
    - reliability of buoy Hs for climate applications ?
- Global distribution of Hs trends in CCI show strong geographical patterns
  - E.g. strong positive trends in Atlantic and Southern Ocean, negative trends in Indian Ocean
- Distributions of Hs trends differ markedly between different products
  - Hs trends in Ribal & Young (2019) tend to be more strongly negative, and more strongly positive in reanalyses and hindcasts