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# WAVERYS

## A CMEMS global wave reanalysis during the altimetry period

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# Outline

- Motivation
- Description of WAVERYS
- Coastal validation with buoys
- Open ocean validation with HY2-A altimeter
- Illustration of swell dissipation and currents-waves interactions

Comparison against ERA5 waves

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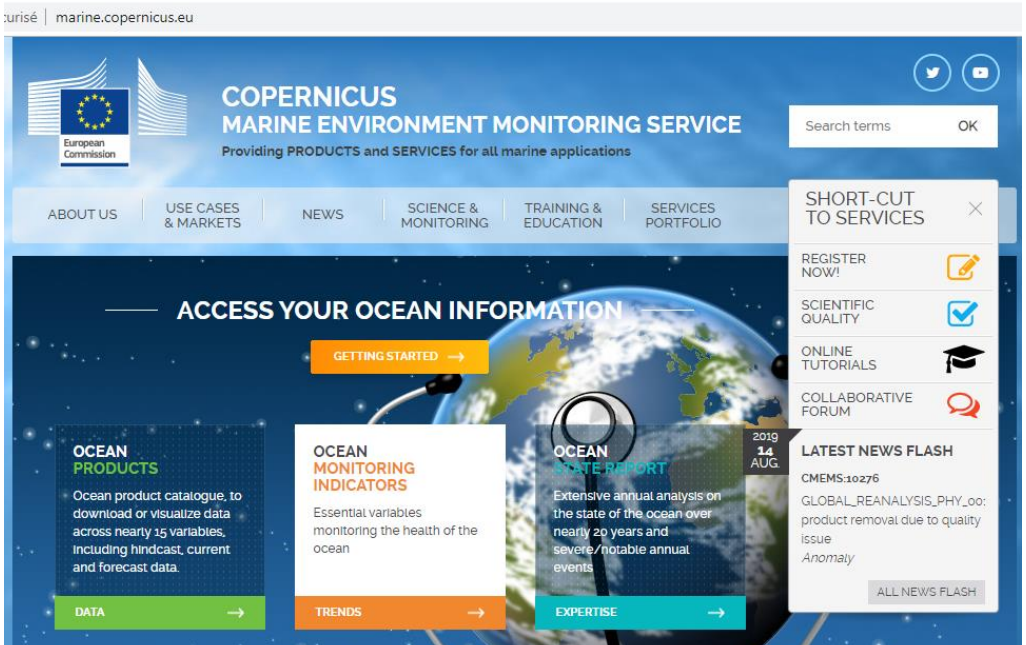
# Copernicus marine service (CMEMS)

- **EU programme**, core reference information on the state of the physical oceans and regional seas

→ *Satellite and in-situ observations, reanalysis and forecast from models, monitoring indicators, scientific reports, etc.*

**http://marine.copernicus.eu/**

- ***Integrated service***
- ***Open and free***
- ***Single catalogue of service***
- ***Reliable and sustainable***



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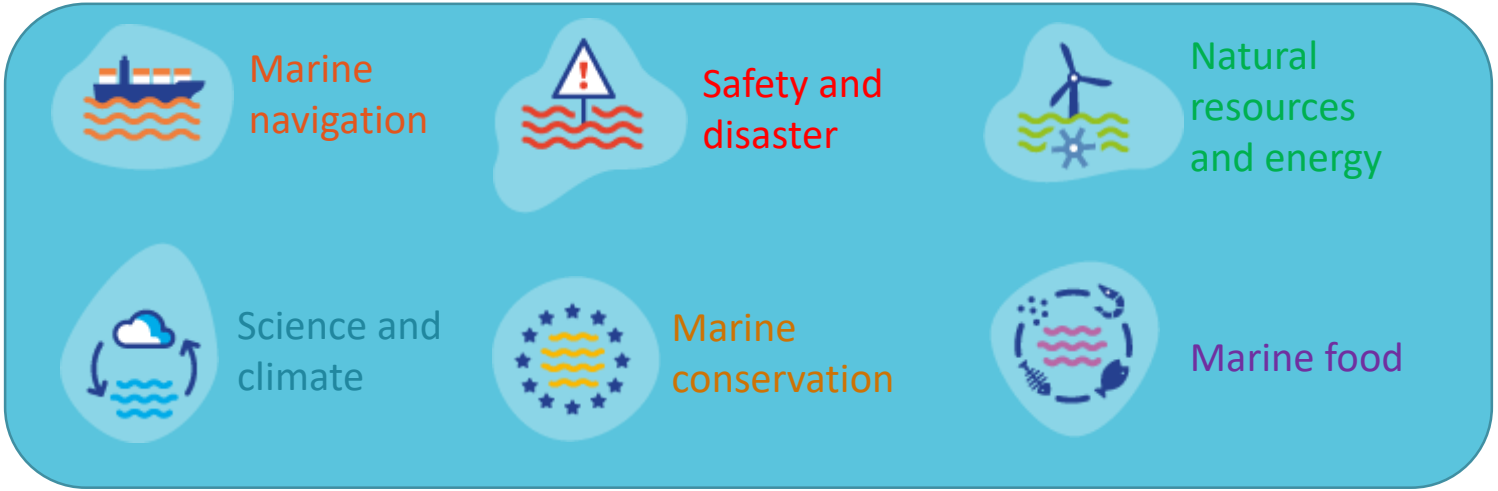
# Motivation

- CMEMS markets/applications that require waves :




→ With 25 years of coverage in the past (1993-2018), WAVERYS (**WAVE R**eanal**Y**si**S**) provides accurate sea state description in need of wave climate studies

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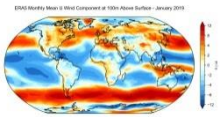
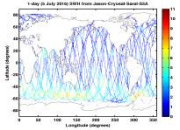
# System description

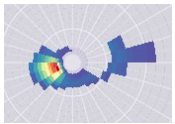
3h ERA5 atmospheric forcing
(winds and sea ice fraction)



3h ASSIMILATION



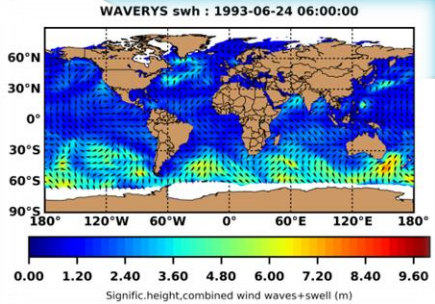
Altimeters Hs (ESA/IFREMER Globwave Data base)



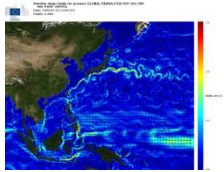
SAR wave spectra from Sentinel-1 (2016-onwards)

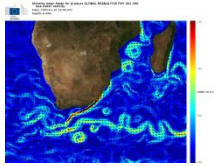
## WAVERYS

- **20 km global** grid (ETOPO2), **3 h inputs/outputs**
- IFS-38R2 computing code (WAM) with
  - Dissipation source terms from ST4 physics + MFWAM 2018
  - Correction of high freq. with Phillips's analytic spectrum (1958)




3h GLORYS12 Surface currents
(refraction)





*3-hourly outputs of 20 wave parameters (including wind-wave and swell partitions)*

# Preliminary experiments

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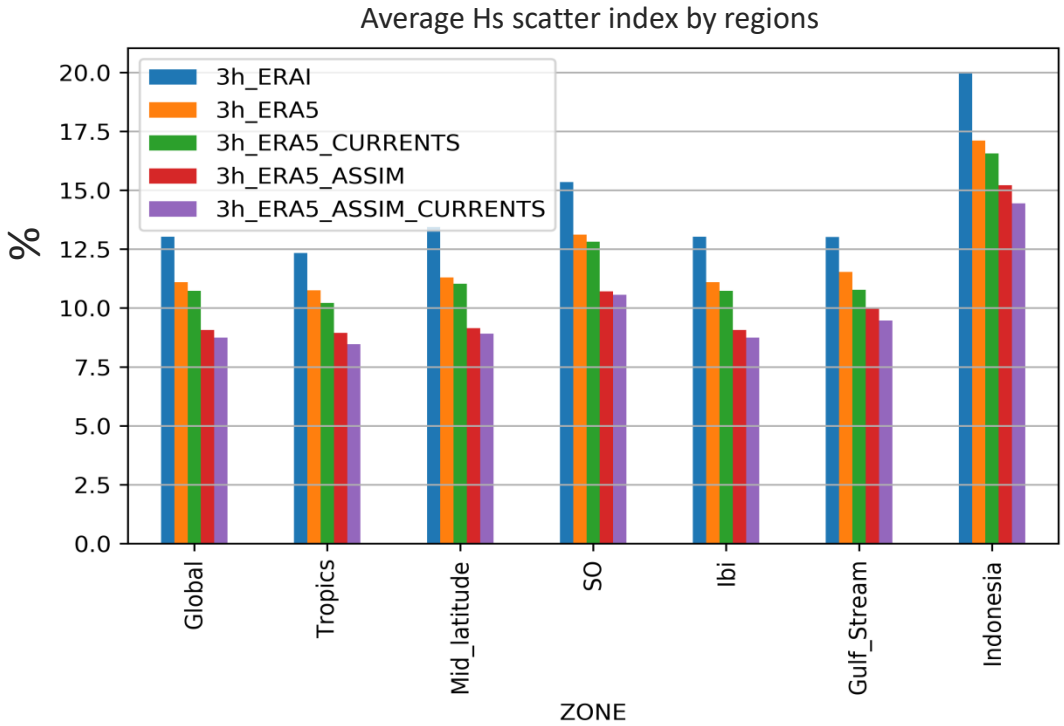
- Testing impact of winds, currents and assim. over the year 2010
- Jason 2 as validation data

$$SI = \frac{RMSD}{E[Obs(t)^2]}$$




| Global SI reduction | |
|---|---|
| ERAI vs ERA5 (winds) | -14.5% |
| Glorys12 (currents)<br>*…but -25% Hs bias for Gulf Stream* | -2.3% |
| Envisat+Jason1 (assim) | -20.4% |
| Currents+assim | -22.7% |

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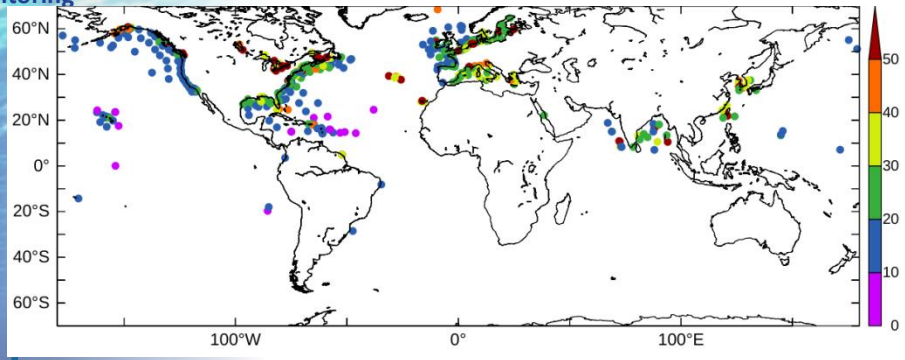
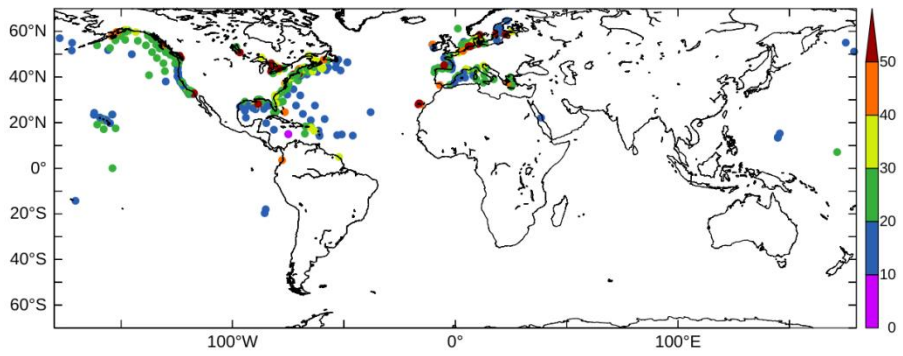
# 1993-2018 validation with CMEMS buoys (3h)

## Hs SI (%)




## Wave mean period (WMP) SI (%)




| DOMAIN | Bias (cm) | SI (%) |
|---|---|---|
| Global | -6 | 22.2 |
| High latitudes | -3 | 24.9 |
| Intermediate | -7 | 21.2 |
| **Tropics** | **-3** | **17.8** |

| DOMAIN | Bias (s) | SI (%) |
|---|---|---|
| Global | -0.4 | 14.9 |
| High latitudes | -0.33 | 14 |
| Intermediate | -0.42 | 15.3 |
| **Tropics** | **-0.39** | **11.3** |

- Global average SI at coasts ~ 20% for Hs and ~ 15% for WMP
- Best results for Tropics (swells and trade waves)

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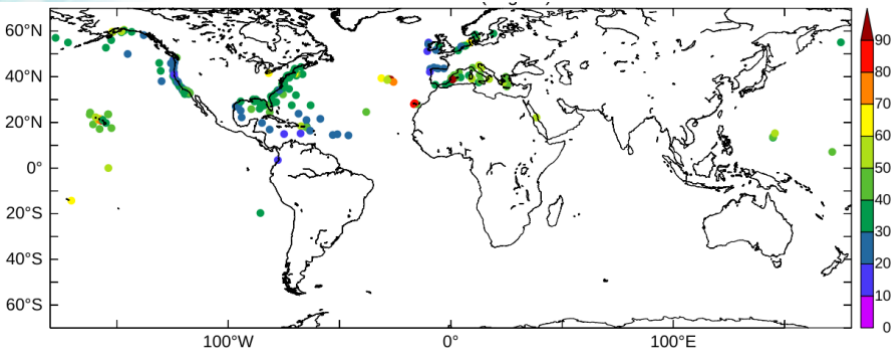
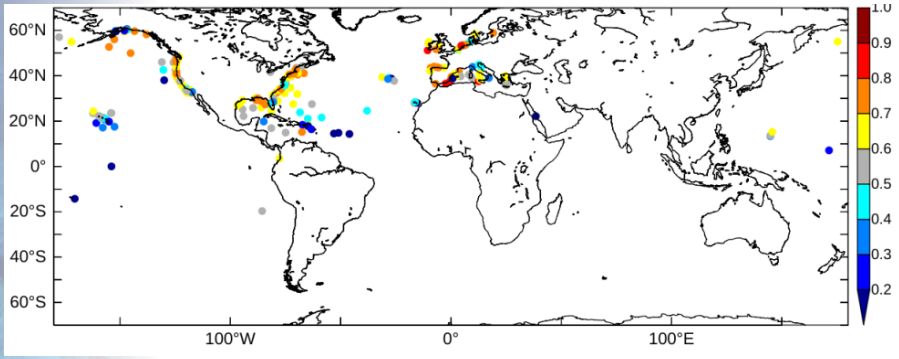
# 1993-2018 validation with CMEMS buoys (3h)

## Mean wave direction RMSD (°)




## Mean wave direction correlation




- Low bias in direction < 5 ° on global average (not shown)
- RMSD in direction are local wave system dependent :
  - 15° Bay of Biscay, Caribbean sea, Western US
  - 35° Eastern US, Med, Hawaii
- Correlation with observations are good in extra-tropics, less significant in tropics

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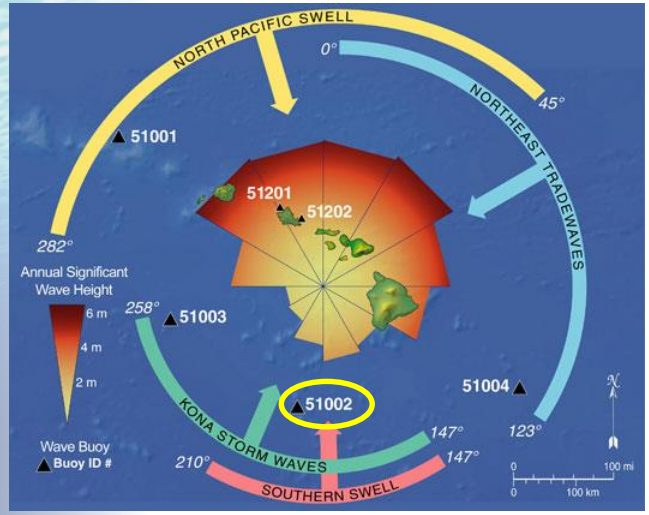
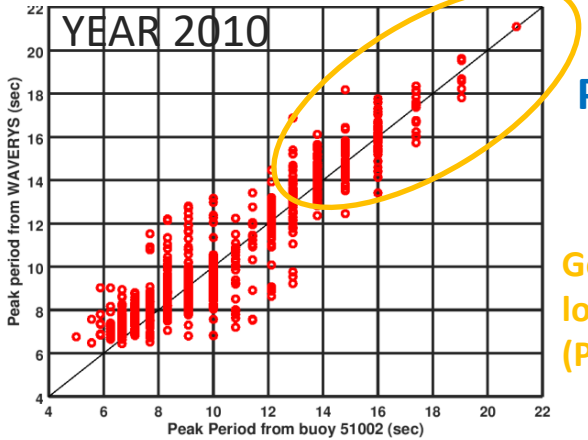
# Zoom on Hawaii NDBC/NOAA buoys: 51002

From Vitousek & Fletcher (2008)





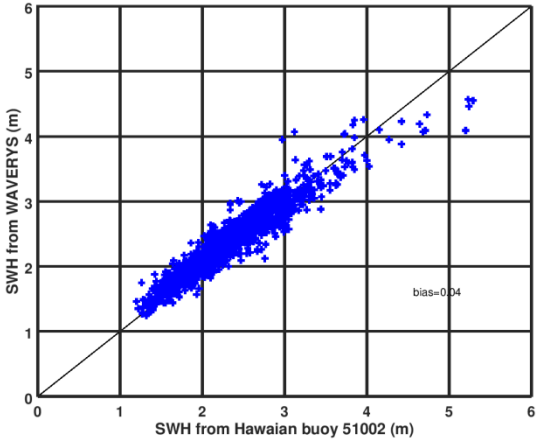
## Peak wave period (PWP)




**PWP SI = 9.7%**

Good capturing of long swell (Pwp >12 s)

## Sig. wave height (Hs)




**Hs SI = 7.5%**

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# Zoom on Hawaii NDBC/NOAA buoys: 51202

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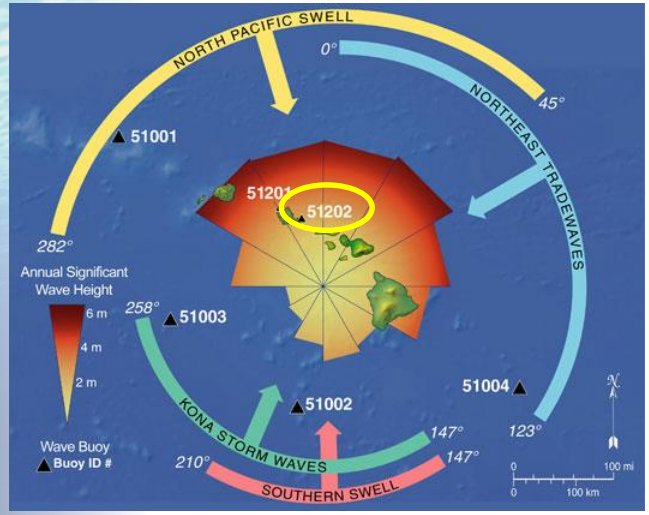
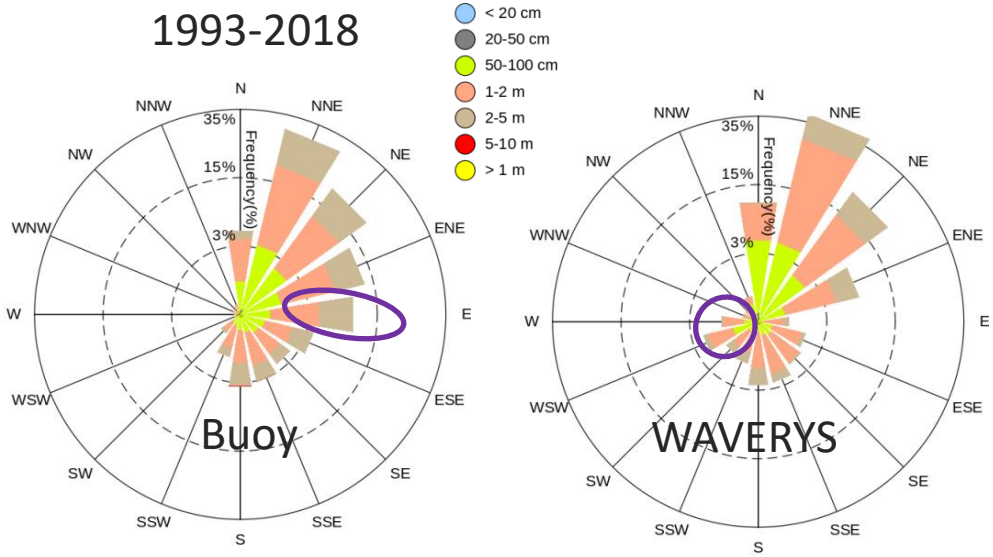
From Vitousek & Fletcher (2008)




1993-2018





- Very good accuracy for the north-northeast trade regime (~ 70 % of occurrence) and southern swell
- but… some misses

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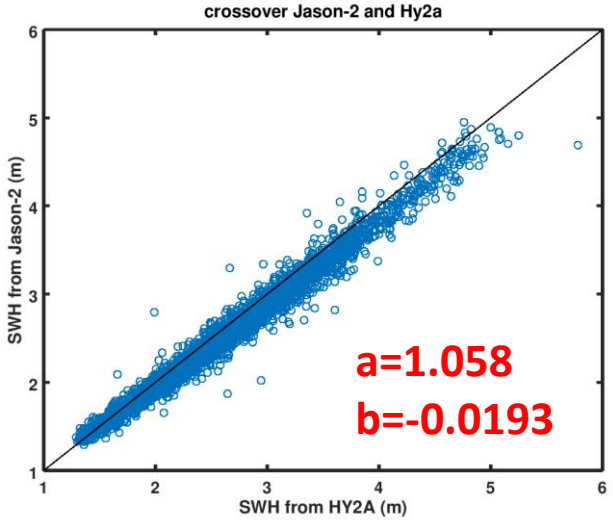
# Open ocean validation with HY2A

- HY2A altimeter (2011, China) is an independent validation data for WAVERYS *(Courtesy of CNES)*
- Hs from HY2A has been calibrated with Jason-2 following a regression relation (Y=a*X+b)
- ➢ **Open-ocean validation** = Colocation of HY2A with WAVERYS model grid points over 2012-2018
- ERA5 wave dataset was tested as well for comparison




| | Physics for source terms | Coupling with atmosphere model | Current refraction | Horizontal resolution |
|---|---|---|---|---|
| **ERA5 wave** | ECWAM-IFS 41R2 | in: air density, 10 m wind and surface roughness<br><br>out: Charnock parameter | NO | 0.5° |
| **WAVERYS** | MFWAM 2018 | NO | 3h GLORYS12V1 currents | 0.2° |

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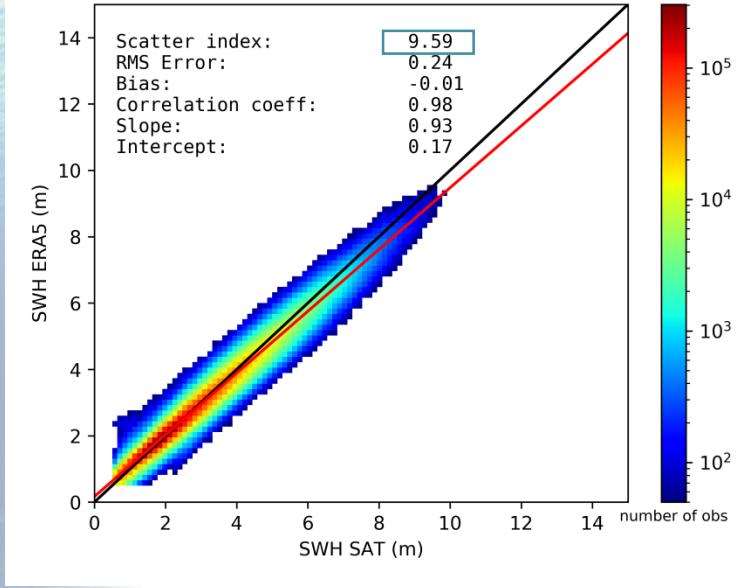
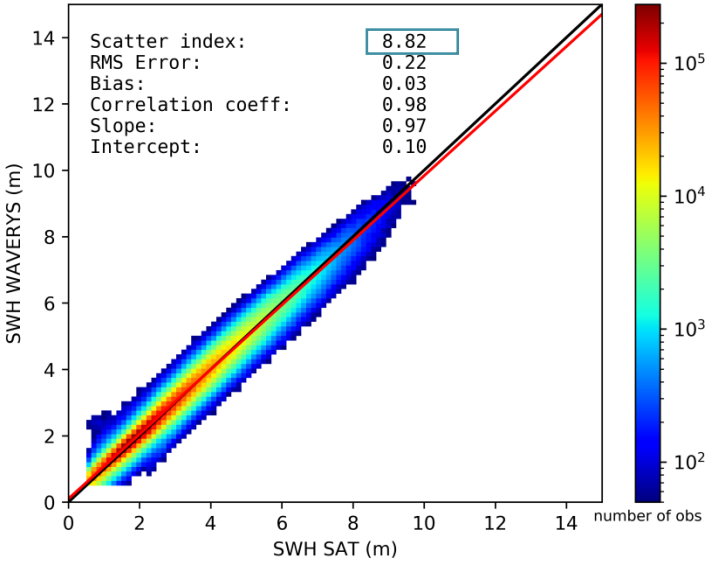
# Validation with HY2A(2012-2018): scatter plots

## ERA5




## WAVERYS




- WAVERYS is better of roughly 8% for Hs SI compared to ERA5
- Underestimation of highest waves for ERA5 (Southern Ocean)

# Validation with HY2A (2012-2018): biases

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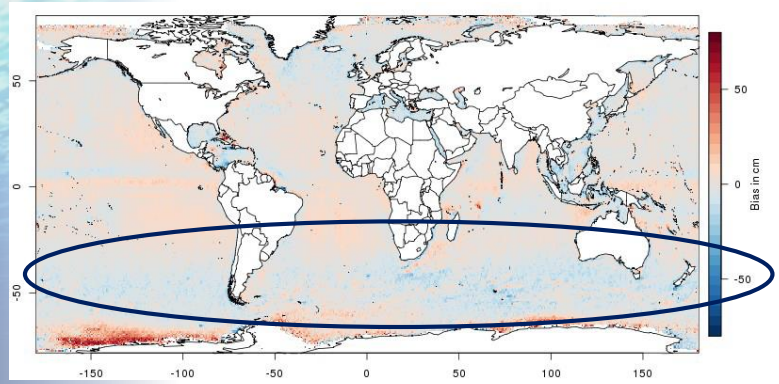
Hs bias (0.5° mapping) ERA5

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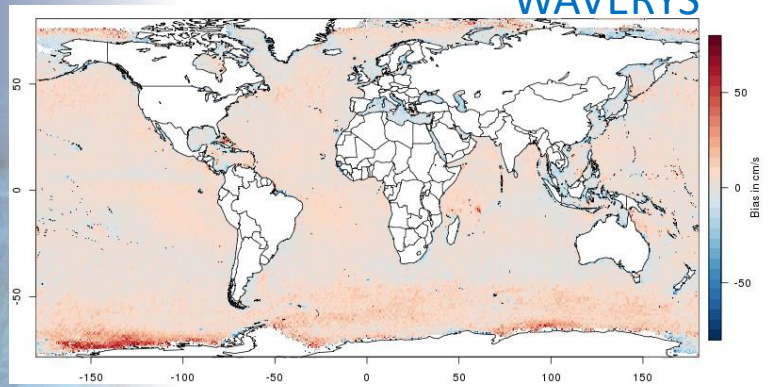


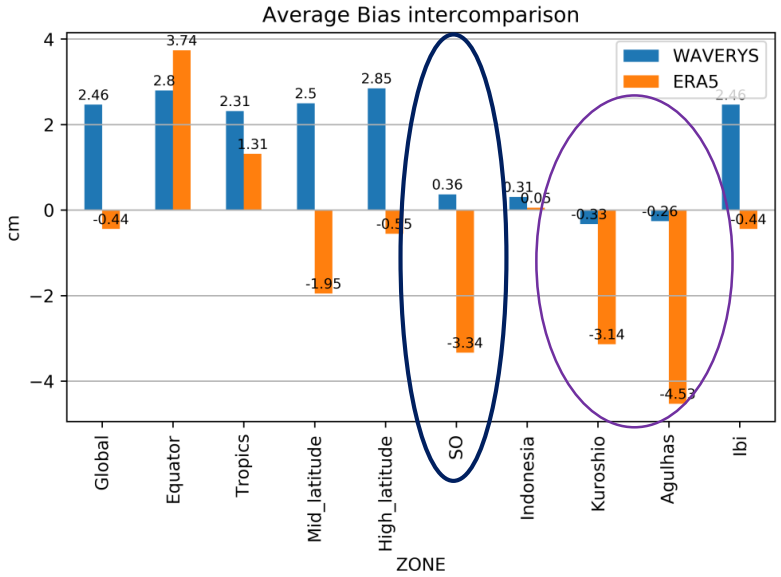


- Biases of a few cms for WAVERYS and ERA5
- Nearly zero bias in strong currents for WAVERYS, underestimation for ERA5

# Validation with HY2A(2012-2018):SI

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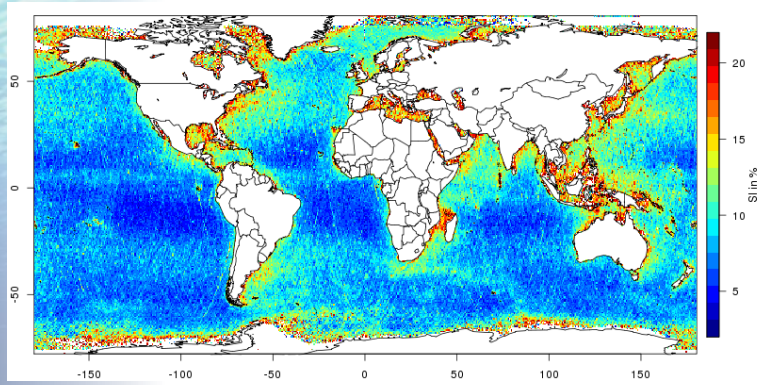
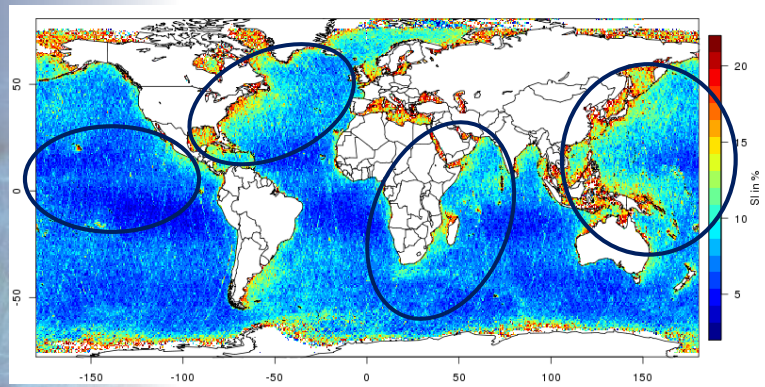
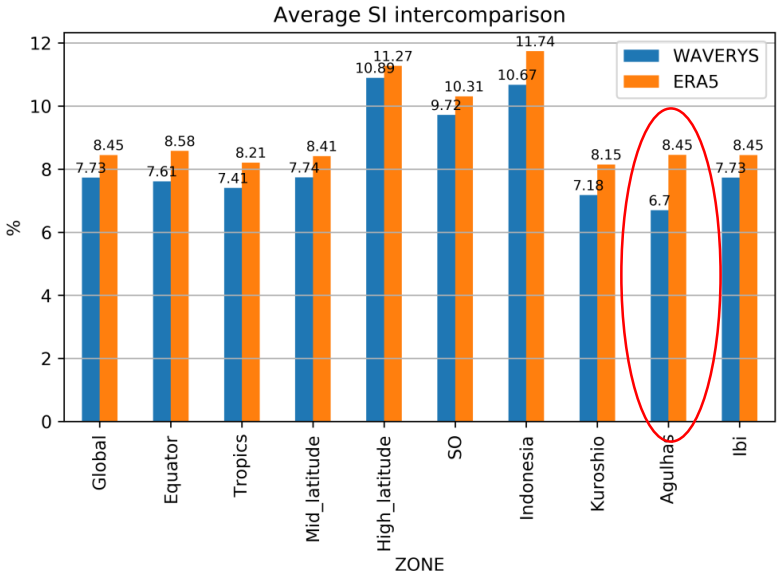
Hs SI (0.5° mapping)

ERA5




WAVERYS




- WAVERYS is always better than ERA5 in terms of SI
- Improvement in SI for Agulhas = 20.7% compared to ERA5

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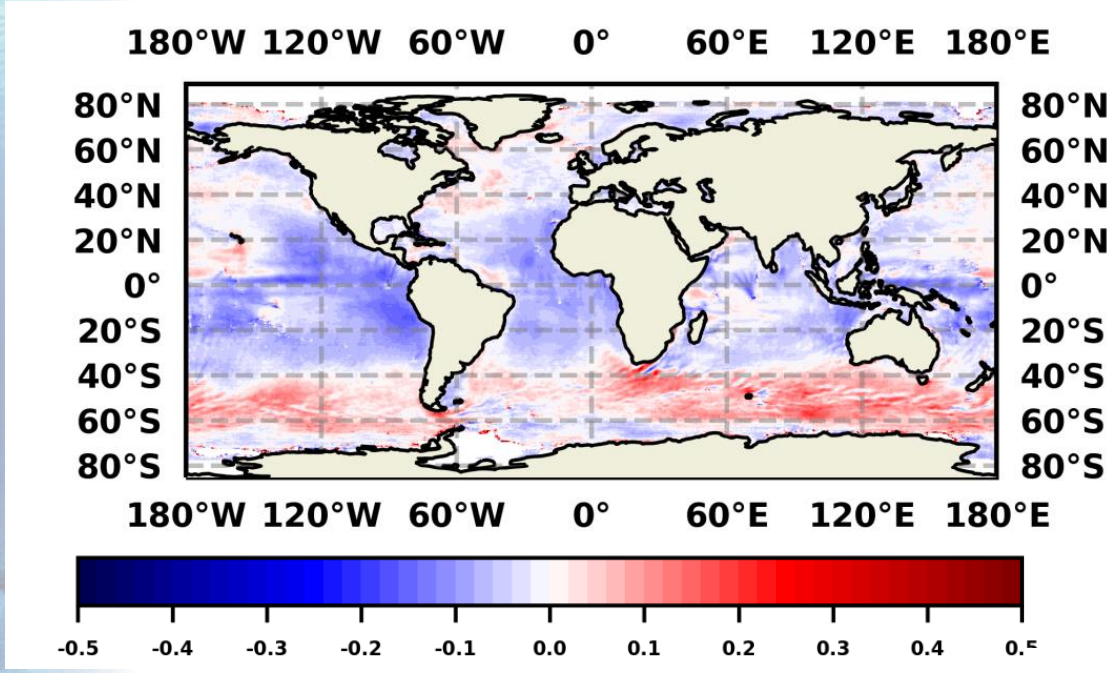
# WAVERYS-ERA5 swell physics comparison (2010)

Difference in Hs (m) for 1st swell




More balanced swell dissipation in Tropics

More energetic swells in storm track zone

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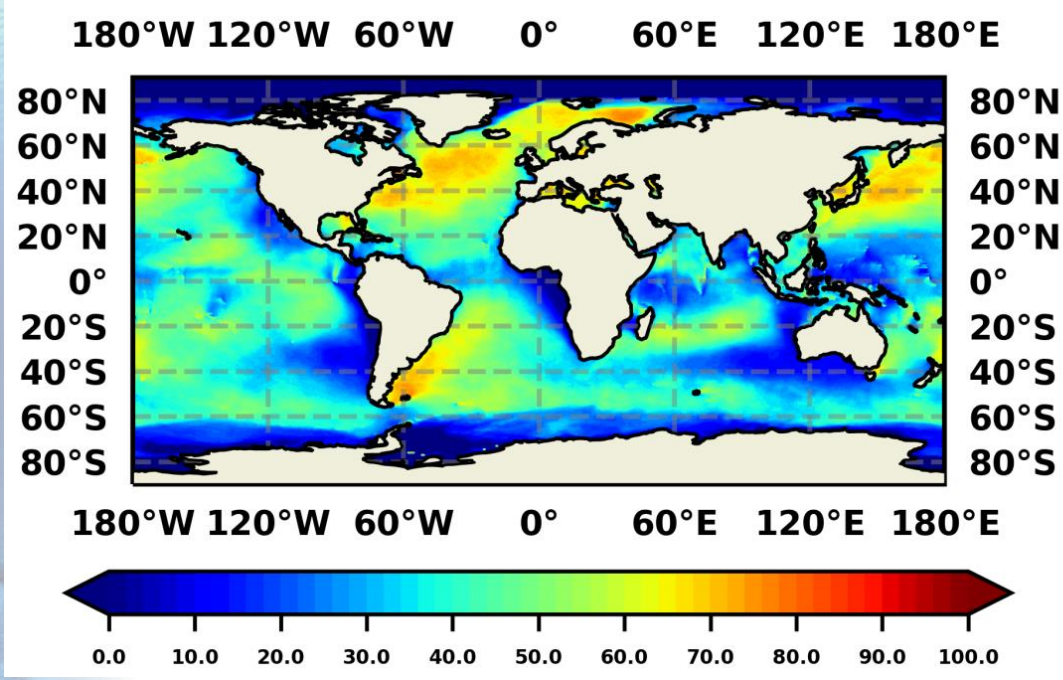
# WAVERYS-ERA5 swell physics comparison (2010)

Occurrence map (%) when first swell between WAVERYS and ERA5 is deviated than more than 45°




- Frequent deviation of 1st swell in western boundary currents (>70% occurrence)
- Rare deviation of 1st swell in eastern boundary currents

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# Conclusion

- **WAVERYS** is a CMEMS global wave reanalysis at 20 km (1993-2018) that is **particularly efficient** **for regions dominated by ocean currents and long swells**

- **Very good results** : ~8% SI on global average (8% better that ERA5 w.r.t HY2A altimeter) and a few cm of bias

❖ WAVERYS will be released on **3rd December 2019** on *marine.copernicus.eu* product name : ***GLOBAL_REANALYSIS_WAV_001_032***

➢ *Monthly (degraded) and biannual (optimal) time series extension planned*

➢ *New 1/10° version planned for 2020*

➢ *Additional information in product's quality information document (QUID)*

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Thanks for your attention !

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# Known issues: 1/2

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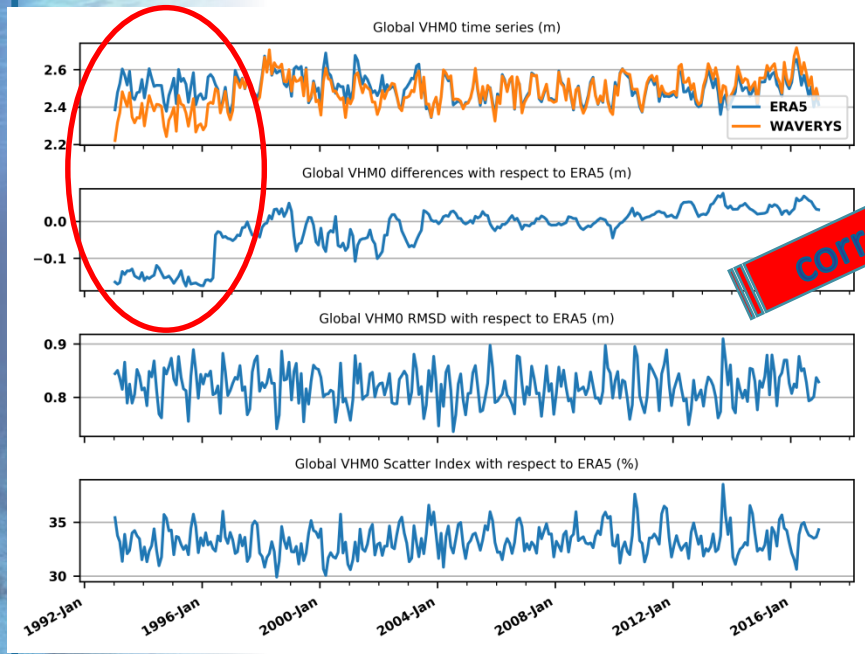
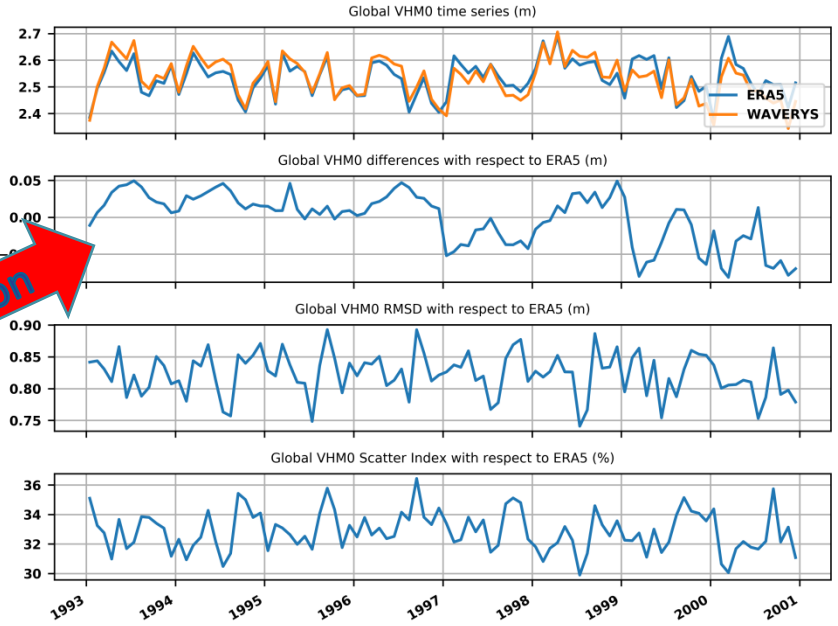
V1.0 : Bias of 15 cm in Hs compared to ERA5 over 1993-1997




correction

V1.1 : bias correction of first altimetry missions




**V1.1 will be delivered soon after V1.0**

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# Known issues: 2/2

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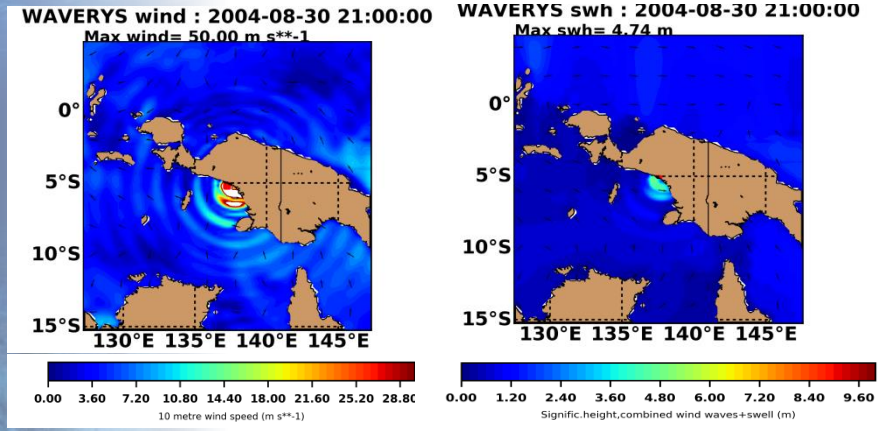
- For the Black Sea and Papua-Guinea, large and erroneous 10 m winds (> 50 m/s) in ERA5 at systematic locations
- All events are referenced in WAVERYS' QUID




| Site : Black Sea, [40.89°N, 39.6°E] | |
|---|---|
| **Time** | Maximum SWH (m) |
| **1995-01-27 21:00** | 4.3 |
| **1997-04-22 21:00** | 5.15 |
| **2001-01-27 09:00** | 6.72 |
| **2005-12-08 09:00** | 3.82 |
| **2006-12-10 09:00** | 2.5 |
| **2010-01-10 21:00** | 4.04 |
| **2011-12-08 00:00** | 4.4 |
| **2013-12-24 09:00** | 5.83 |

| Site : Papua-Guinea, [5.199°S, 137.531°E] | |
|---|---|
| **Time** | Hs max generated value (m) |
| **1996-07-10 21:00** | 5.27 |
| **1997-06-27 00:00** | 4.41 |
| **1997-08-18 00:00** | 4.72 |
| **2003-05-17 00:00** | 3.85 |
| **2004-08-04 00:00** | 4.04 |
| **2004-08-31 00:00** | 7.02 |
| **2005-08-06 00:00** | 5.48 |
| **2006-06-12 21:00** | 6.98 |
| **2012-06-29 21:00** | 4.18 |

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# MEAN PARAMETERS DELIVERED

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Spectral significant wave height (Hm0)
Spectral moments (-1,0) wave period (Tm-10)

Spectral moments (0,2) wave period (Tm02)
Wave period at spectral peak / peak period (Tp)

Mean wave direction from (Mdir)
Wave principal direction at spectral peak
Stokes drift U
Stokes drift V
Spectral significant wind wave height
Spectral moments (0,1) wind wave period
Mean wind wave direction from
Spectral significant primary swell wave height

Spectral moments (0,1) primary swell wave period

Mean primary swell wave direction from
Spectral significant secondary swell wave height

Spectral moments (0,1) secondary swell wave period

Mean secondary swell wave direction from

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# First swell MWP differences

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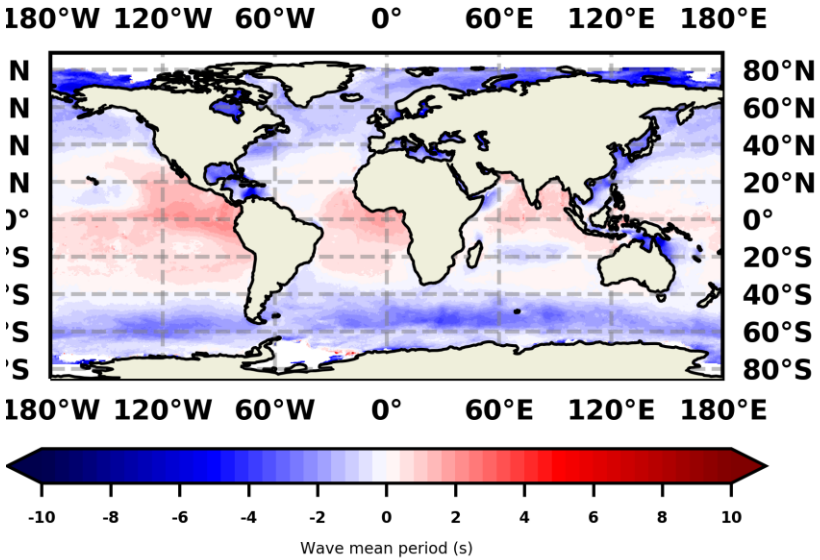
Difference in MWP (s) for 1st swell

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