NATIONAL WEATHER SERVICE

The Wave Component of the Global Ensemble Forecasting System

Ensembles Workshop - August 23, 2023

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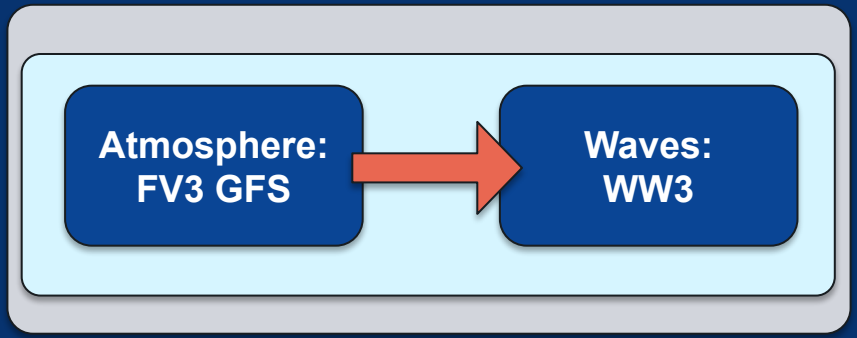
Acknowledgements

- **GEFSv12 and GEFSv13 T20 Teams**
- **Coupled model development efforts at EMC & within UFS**
- **WW3 Developer Community**
- **Previous EMC affiliated wave team members:**
  - Henrique Alves
  - Deanna Spindler
  - Todd Spindler
  - Roberto Padilla
  - Ali Abdolali
  - Visiting Researcher: Richard Gorman

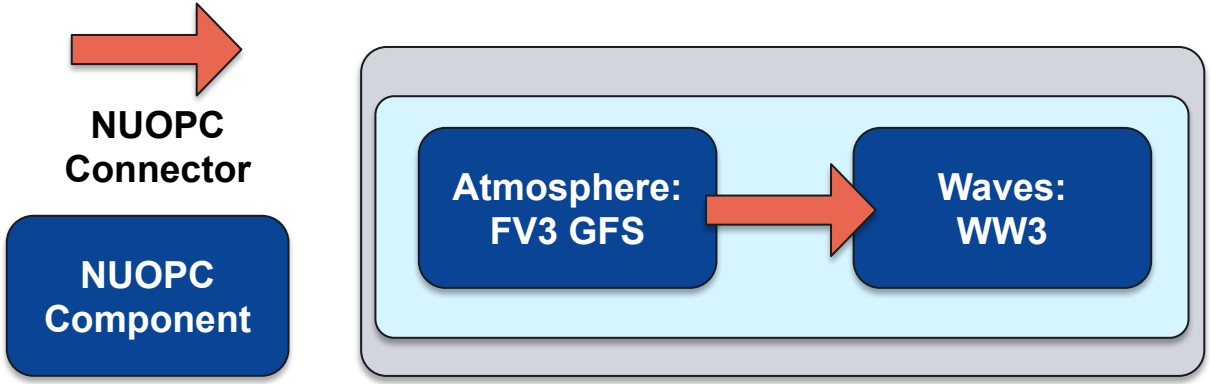
Outline

- Overview of GEFSv12 wave component
- GEFSv12 based wave reforecast
- Looking forward to GEFSv13

Overview of GEFSv12 Wave Component



GWES unified with GEFSv12



- **The atmospheric model is one-way coupled to the wave model**
  - 10m winds (**u**, **v**) are sent every hour to WW3
- **Increased spherical grid resolution: ½° to ¼° global**
  - Three computational grids: Arctic, global core, Southern Ocean
- **Objective optimization for wave source terms***

*Gorman, R. M. and Oliver, H. J.: Automated model optimisation using the Cylc workflow engine (Cyclops v1.0), Geosci. Model Dev., 11, 2153–2173, https://doi.org/10.5194/gmd-11-2153-2018, 2018.

GEFSv12-Wave Configuration

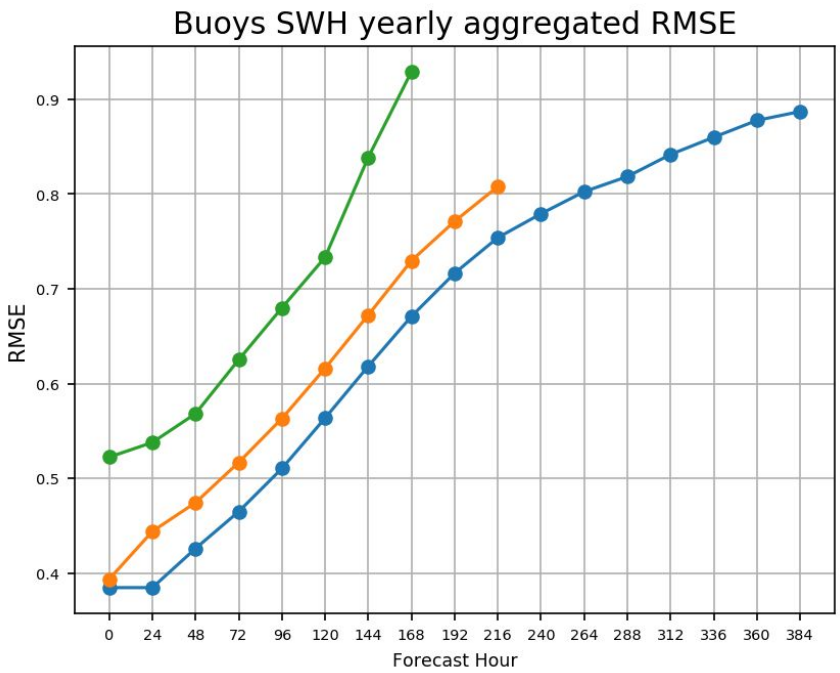
Components	GWESv3.0	GEFSv12
WAVEWATCH III	WW3v4.15	**WW3v7.00**
Physics	Ardhuin et al (2010) + DIA	Ardhuin et al (2010) + DIA
Initialization	24h Hindcast	Previous cycle 6h
Wind Forcing	GEFS grib2 3h	**Coupled 1h**
Ice Forcing	NCEP/EMC daily 1/12^{o} analysis	NCEP/EMC daily 1/12^{o} analysis
Daily frequency	00, 06, 12 and 18 UTC	00, 06, 12 and 18 UTC
Forecast length	10 days	**16 days**
Members	Control + 20 pert members	**Control + 30 pert members**
Output resolution	0.5^{o} x 0.5^{o}	**0.25^{o} x 0.25^{o}**
Output frequency	3h the first 8 days; 6h the rest	3h the first 10 days; 6h the rest
Implementation	December 2, 2015	September 23, 2020

Objective optimization for wave source terms was conducted for GEFSv12 based on Gorman et al 2018.

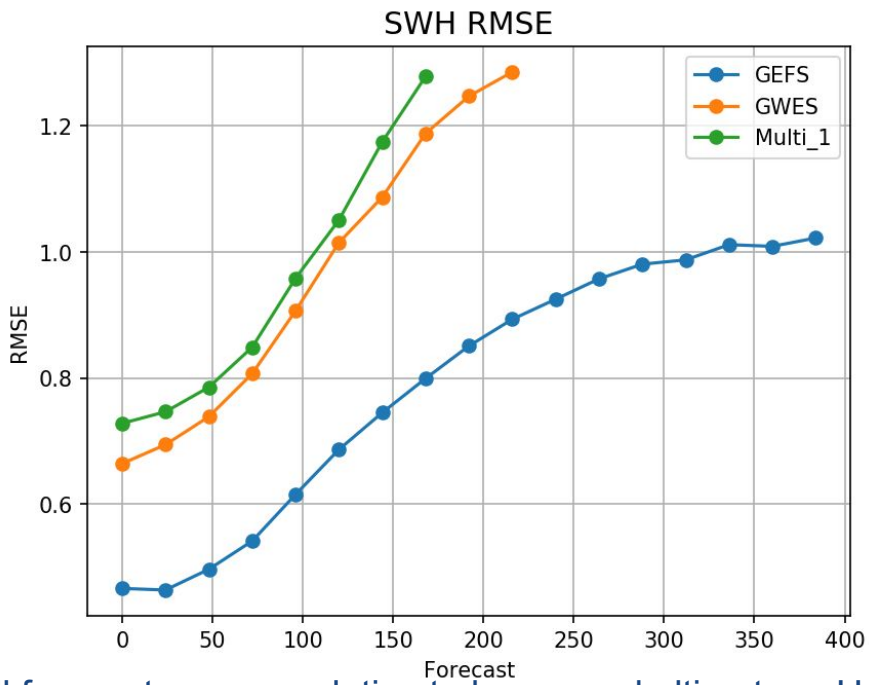
Hs Statistics Entire v12 Retrospective by Forecast Range

GEFS
GWES
multi_1

NDBC Buoys



Jason-3/SARAL Altimeters



Data from the entire validation period confirms: in all forecast ranges, relative to buoys and altimeters, Hs from upgrade significantly reduces Hs error. Note that extended forecast range provides skillful forecast. New model 10-day forecast is equivalent in skill to 5-day current operational, 16-day, equivalent to 10-day.

GEFSv12 Based Wave Reforecast

Data is available on AWS at
https://noaa-nws-gefswaves-reforecast-pds.s3.amazonaws.com/index.html

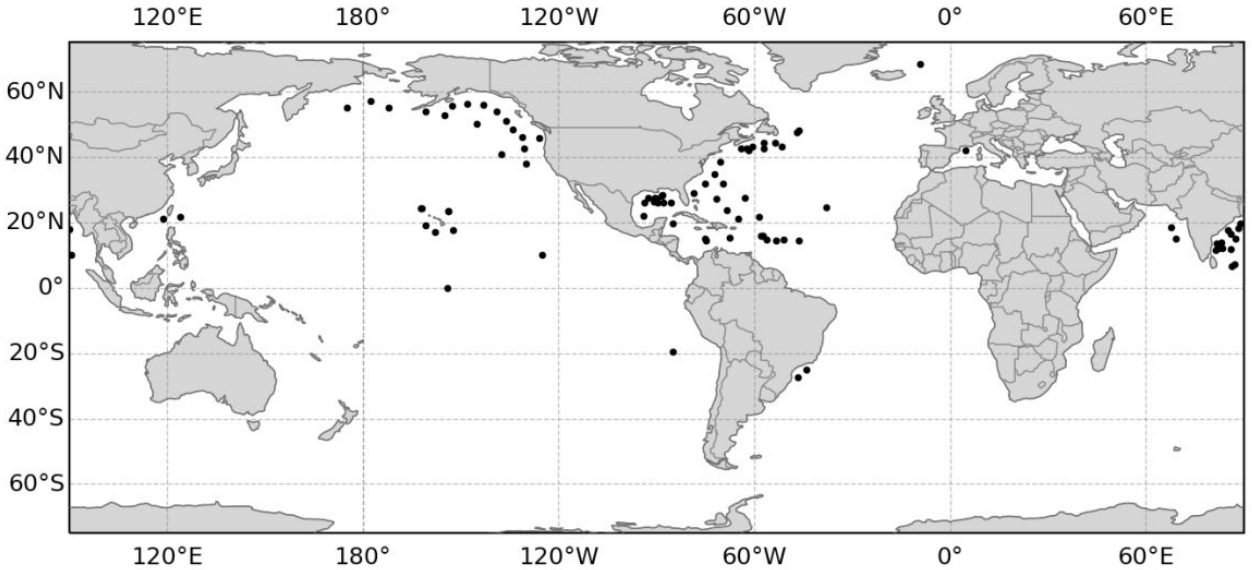
POC: Ricardo Campos (Ricardo.Campos@noaa.gov)

GEFSv12 Based Reforecast

- **Standalone wave reforecast forced by GEFSv12 Reforecast**
  - Forcing:
    - Can be found on AWS https://noaa-gefs-retrospective.s3.amazonaws.com/index.html
    - Winds
      - 0.25° through day 10, 0.5° after
    - Ice analysis
  - Details:
    - 20 years 2000 to 2019
    - Generated once per day, 5 members
      - 11 members every Wednesday
- **Wave model configuration**
  - GEFSv12 grids and model settings
  - Updated WW3 code

Reforecast: Validation Against Buoy Data

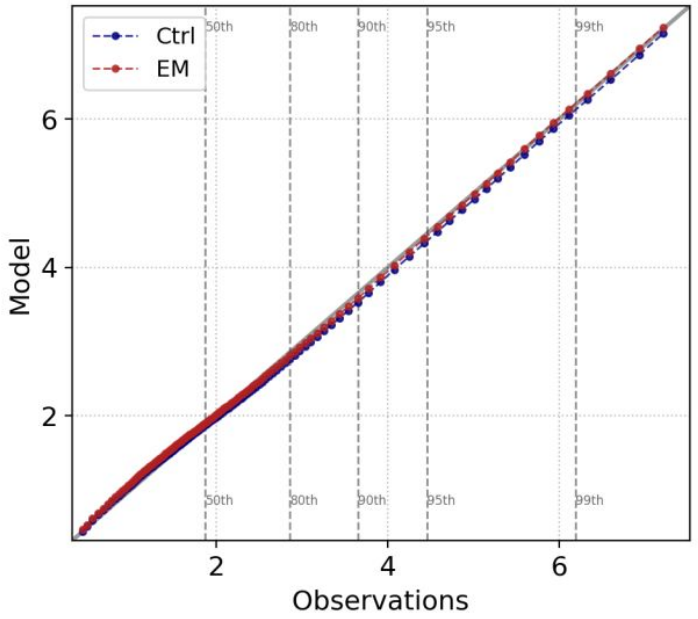
NDBC & Copernicus: Deep Water Buoys



Reforecast: Validation Against Buoy Data

Results for Deep Water

Hs		bias	RMSE	SI	CC
Day 1	Control	-0.01	0.37	0.15	0.95
	EnsMean	0.03	0.37	0.15	0.95
Week 1	Control	0.00	0.62	0.26	0.86
	EnsMean	0.05	0.57	0.23	0.88
Week 2	Control	0.03	1.09	0.45	0.57
	EnsMean	0.10	0.87	0.36	0.70
Week 3	Control	0.02	1.23	0.51	0.45
	EnsMean	0.10	0.94	0.39	0.62
Week 4	Control	0.02	1.25	0.52	0.44
	EnsMean	0.10	0.95	0.40	0.61
Week 5	Control	0.04	1.26	0.53	0.42
	EnsMean	0.11	0.96	0.40	0.60

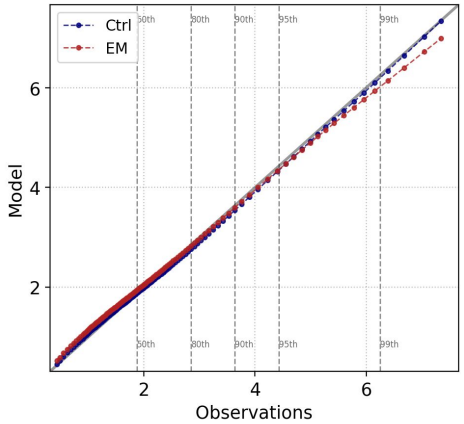


Day 1

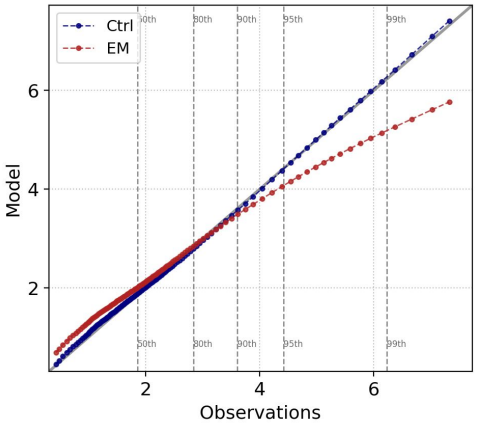
Reforecast: Validation Against Buoy Data

Results for Deep Water

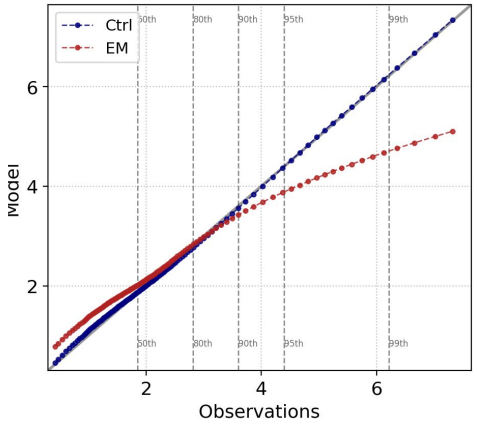
Week 1



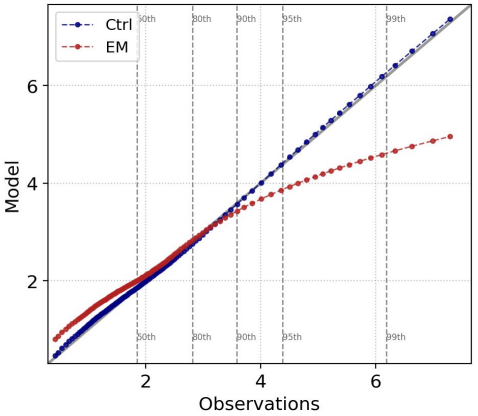
Week 2



Week 3

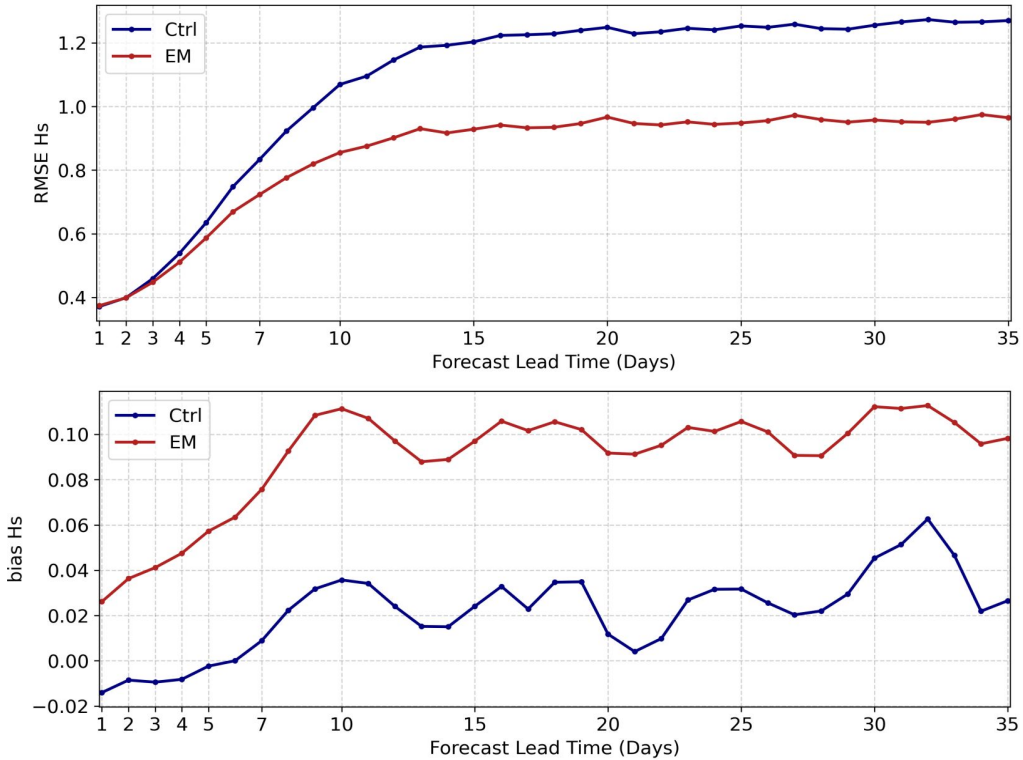


Week 4



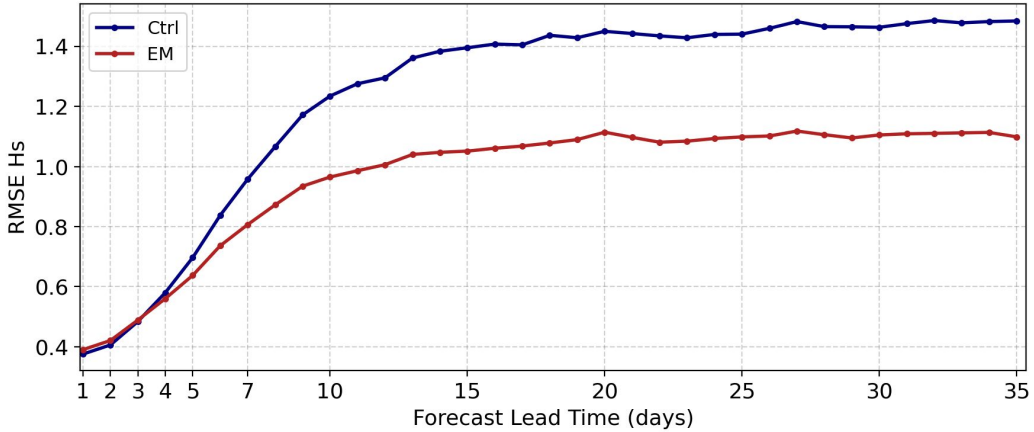
Reforecast: Validation Against Buoy Data

Results for Deep Water



Reforecast: Validation Against Satellite Data

- Australian Ocean Data Network: https://thredds.aodn.org.au/thredds/catalog/IMOS/SRS/Surface-Waves/Wave-Wind-Altimetry-DM00/catalog.html
- 15 altimeter missions: JASON1, JASON2, JASON3, CRYOSAT2, HY2, SARAL, SENTINEL3A, SENTINEL3B, ENVISAT, ERS1, ERS2, GEOSAT, GFO, TOPEX, CFOSAT
- Generally similar results to the validation against buoy data

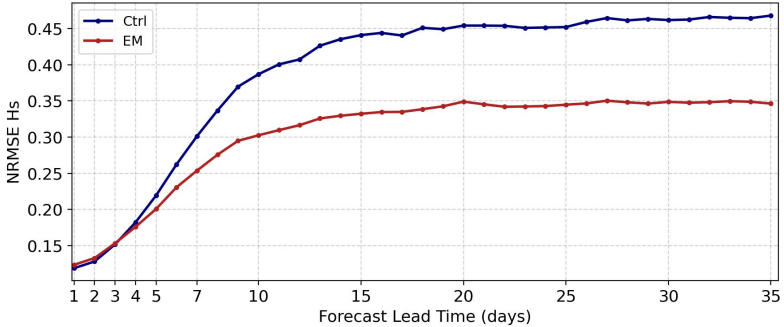


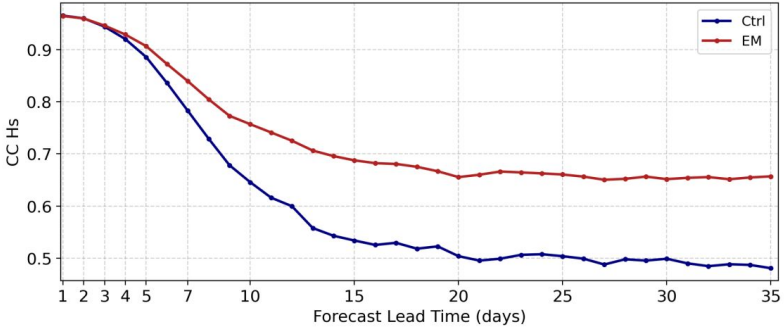
Reforecast: Validation Against Satellite Data

Normalized RMSE

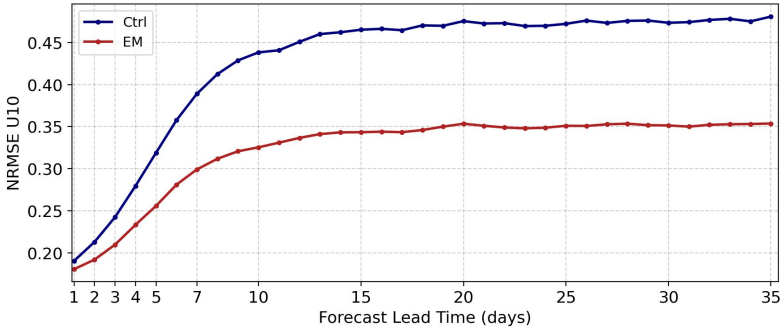
Correlation Coefficient

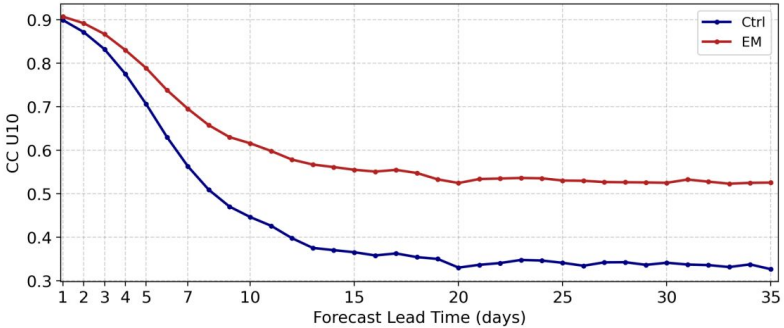
HS (m)





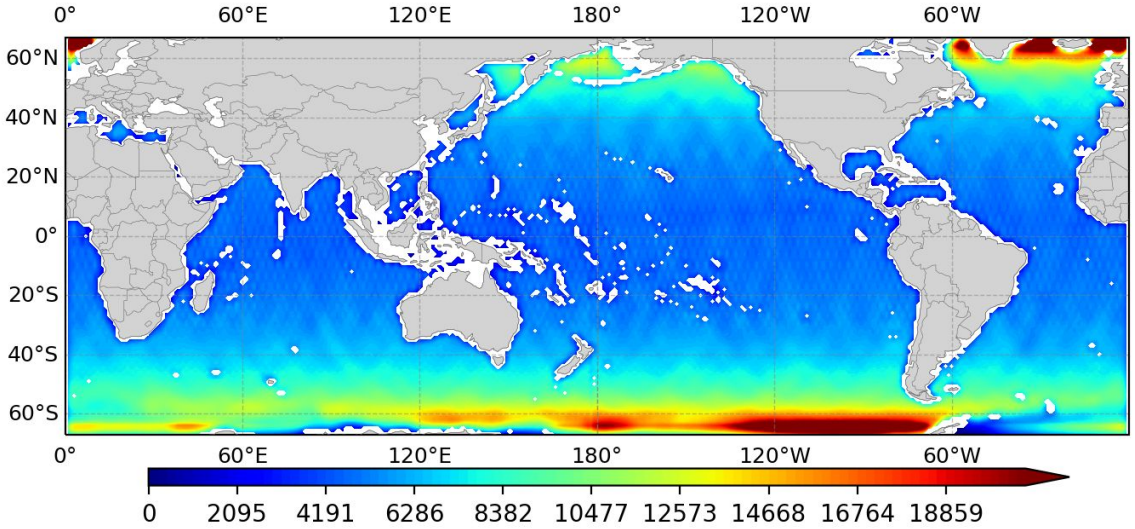
U10 (m/s)





Reforecast: Validation Against Satellite Data

- Satellite missions with more homogeneous spatial distribution of tracks, combined with high accuracy: JASON1, JASON2, JASON3
- Statistics computed at 1°X1° bins.
- Amount of observation records per bin:



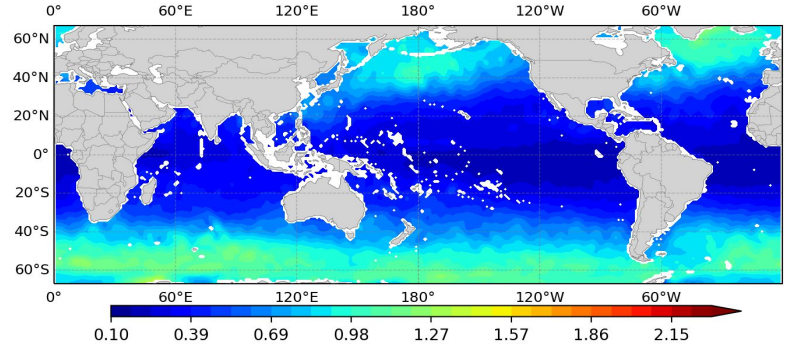
Reforecast: Validation Against Satellite Data

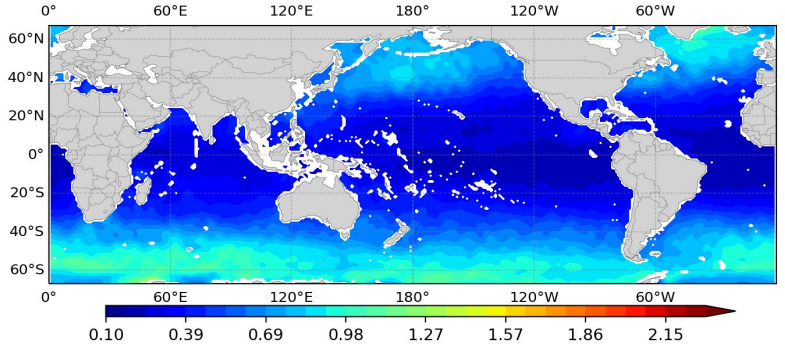
RMSE for Week 1

Control Member

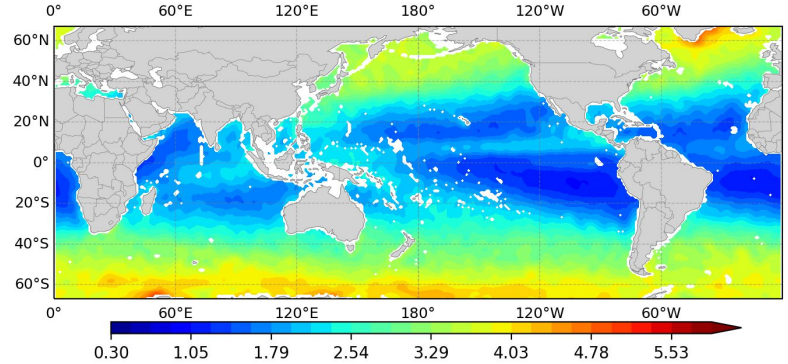
Ensemble Mean

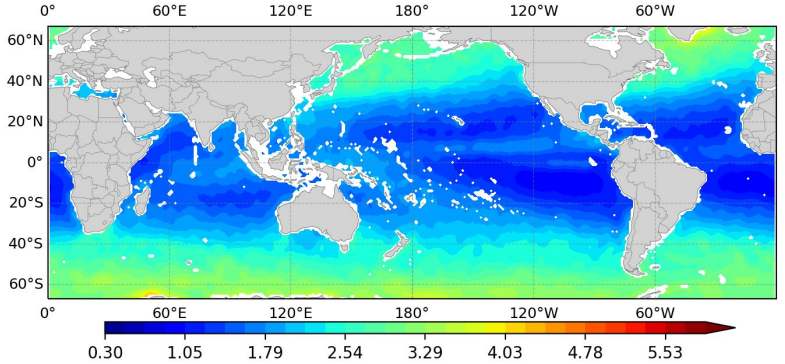
HS (m)





U10 (m/s)





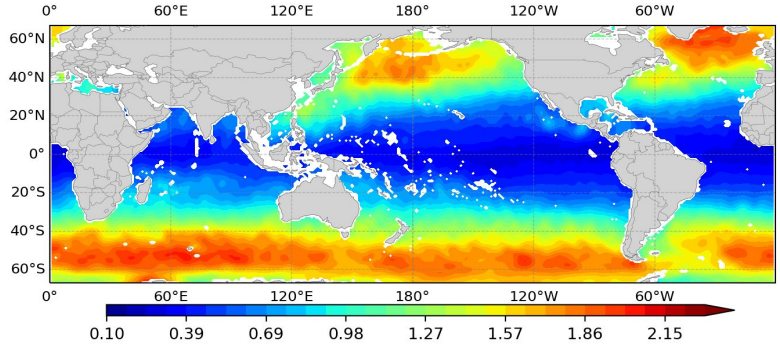
Reforecast: Validation Against Satellite Data

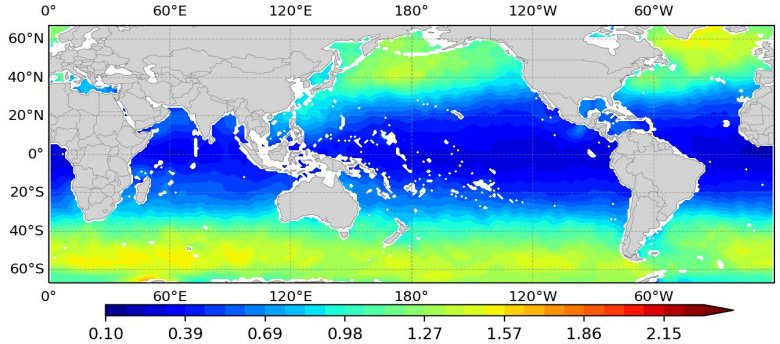
RMSE for Week 2

Control Member

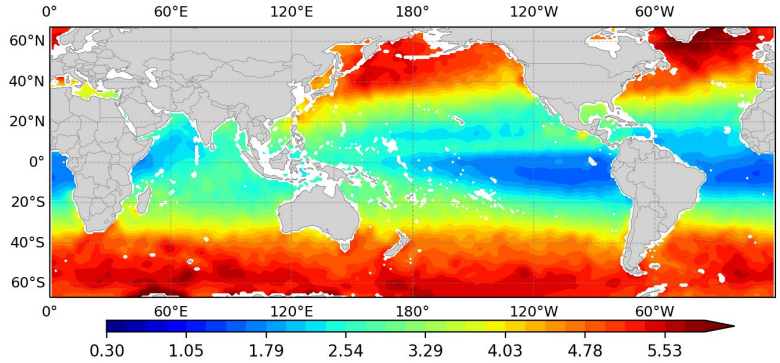
Ensemble Mean

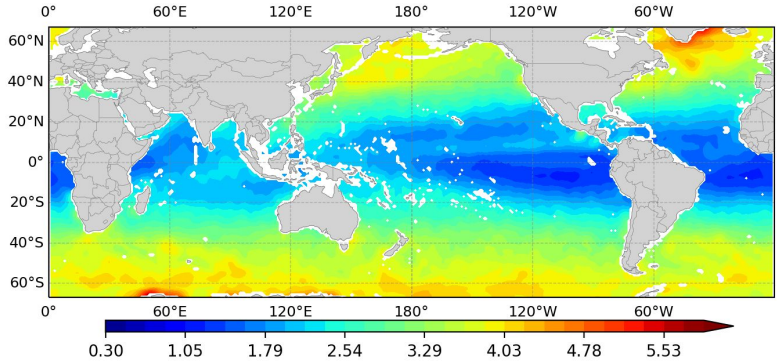
HS (m)





U10 (m/s)





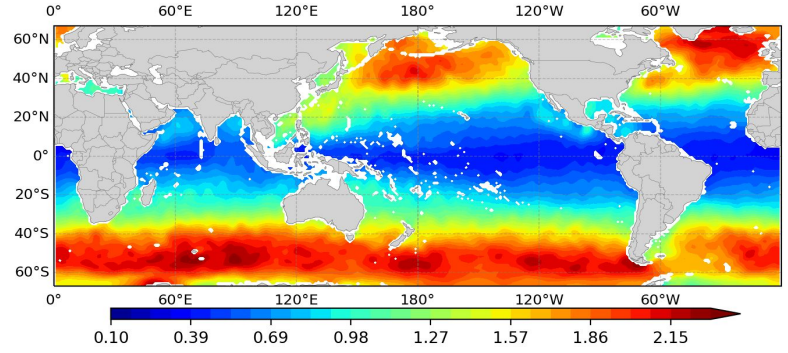
Reforecast: Validation Against Satellite Data

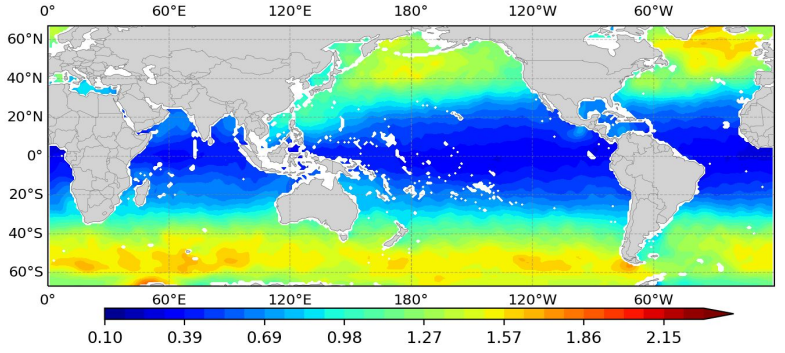
RMSE for Week 4

Control Member

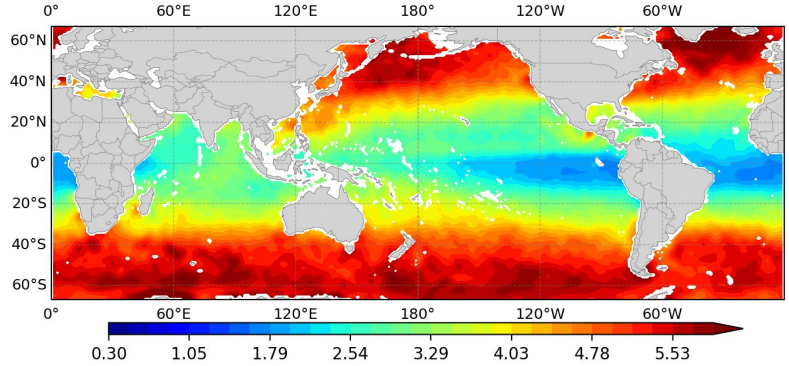
Ensemble Mean

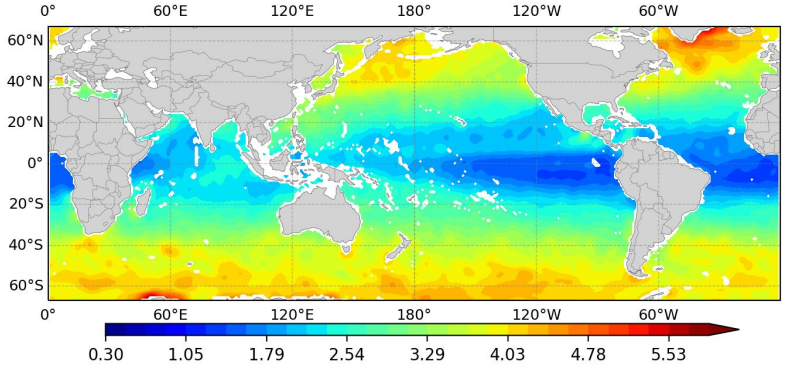
HS (m)



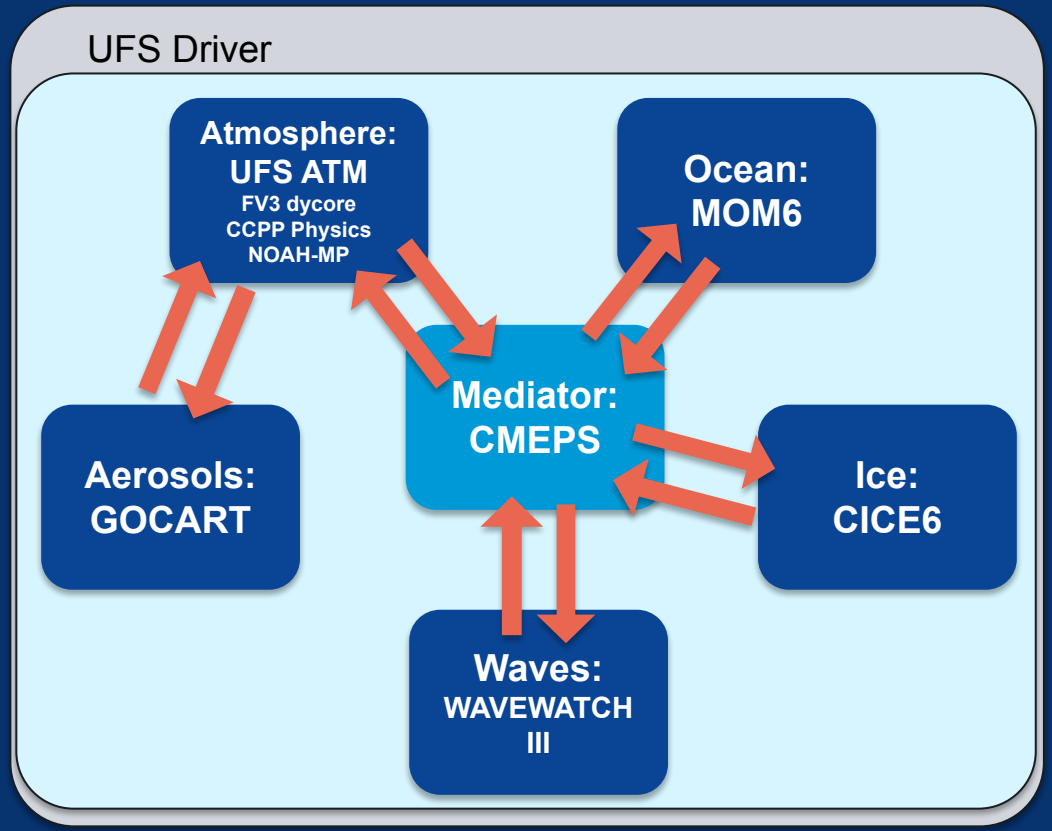


U10 (m/s)





Towards GEFSv13



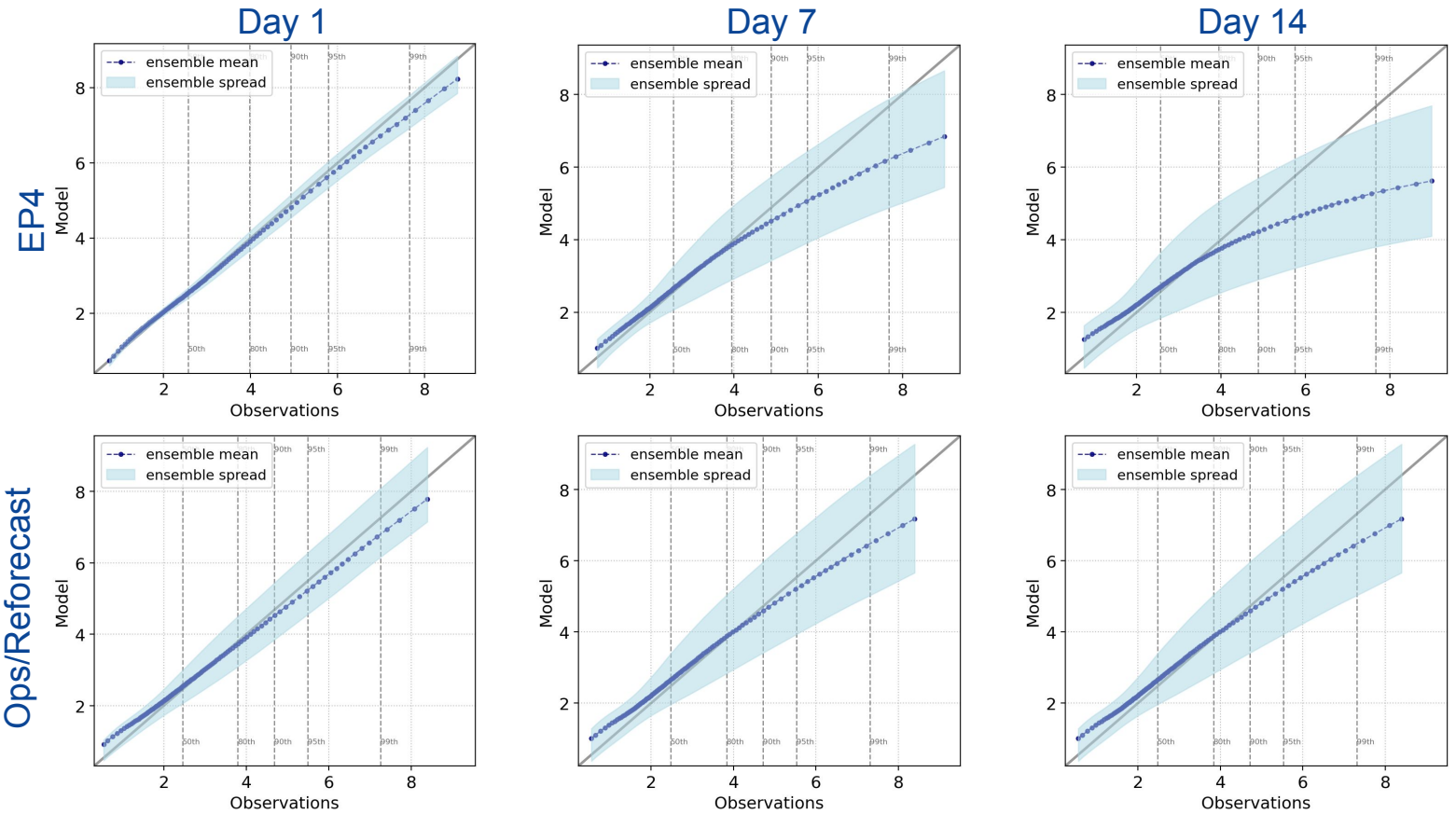
Targeted GEFSv13-Wave Configuration

Components	GEFSv12	GEFSv13
WAVEWATCH III	WW3v7.00	**Updated WW3**
Physics	Ardhuin et al (2010) + DIA	Ardhuin et al (2010) + DIA
Initialization	Previous cycle 6h	Previous cycle 6h
Wind Forcing	Coupled 1h	**Coupled 30 min**
Ice Forcing	NCEP/EMC daily 1/12^{o} analysis	**Coupled input from CICE6**
Current Forcing	N/A	**Coupled input from MOM6**
Daily frequency	00, 06, 12 and 18 UTC	00, 06, 12 and 18 UTC
Forecast length	16 days	**35+ days**
Members	Control + 30 pert members	Control + 30 pert members
Output resolution	0.25^{o} x 0.25^{o}	0.25^{o} x 0.25^{o}
Output frequency	3h the first 10 days; 6h the rest	3h the first 10 days; 6h the rest

EP4 Evaluation

- **Time span covers 3 years**
  - Fall 2017-Summer 2019 + Fall 2020 - Summer 2021
- **Comparison to observations:**
  - Jason 3
  - Buoy observations
  - Note: Observations are filtered to be in minimum water depth of 80m and 50km from the coast
- **Comparison to other model:**
    - “GEFSv12” reforecast (2017-2019) and GEFSv12 operations (2020-2021)

Validation of EP4: QQ Plots HS (m)



Summary

- **GEFSv12**
  - Unified GWES with GEFS
  - Significant wave height has lower RMSE compared to GWES
- **GEFSv12 Based Reforecast**
  - 20 year reforecast for waves was completed
  - Data is available on AWS at https://noaa-nws-gefswaves-reforecast-pds.s3.amazonaws.com/index.html
  - POC: Ricardo Campos (Ricardo.Campos@noaa.gov)
- **Towards GEFSv13**
  - Coupled input of current and ice to wave component
  - Send feedback from wave to atmosphere and ocean
  - POC: Saeideh Banihashemi (Saeideh.Banihashemi@noaa.gov)

Questions

Thank you!