



Description and Validation of a new 20-year global wave ensemble reforecast data

Ricardo M Campos¹, Ali Abdolali², Jose-Henrique Alves³, Matthew Masarik⁴, Jessica Meixner⁵, Avichal Mehra⁵, Darin Figurskey⁶

1. Cooperative Institute For Marine And Atmospheric Studies (CIMAS); University of Miami, NOAA/AOML. ricardo.campos@noaa.gov
2. US Army Corps of Engineers, Engineer Research and Development Center.
3. Weather Program Office, National Oceanic and Atmospheric Administration.
4. Lynker at Environmental Modeling Center, National Centers for Environmental Prediction, National Weather Service, NOAA.
5. Environmental Modeling Center, National Centers for Environmental Prediction, National Weather Service, NOAA.
6. Ocean Prediction Center, National Centers for Environmental Prediction, National Weather Service, NOAA.

Motivation

- There is no current capability for maritime hazard information for the two-week period and beyond.
- The science challenge is that we do not know what the predictive skill is for lead times beyond a few days for relevant wind and wave fields available from operational ensemble modeling systems.
- OAR/NWSSLA Project “Extending Maritime Hazard Information to Week Two and Beyond”.

Main goal:

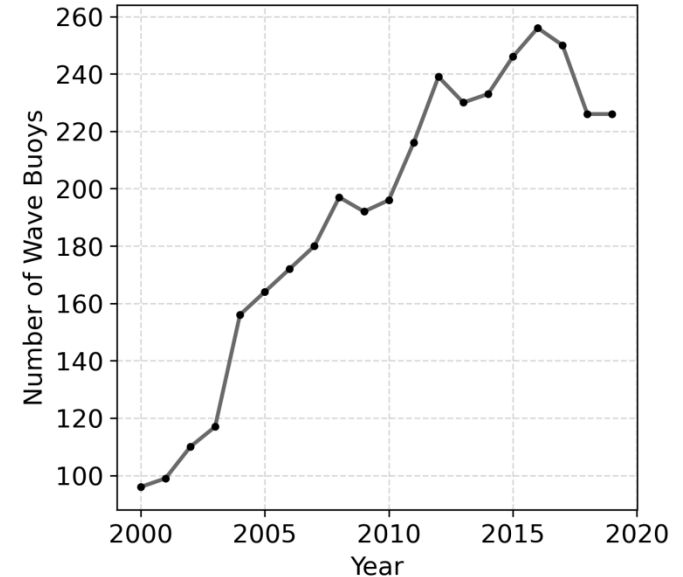
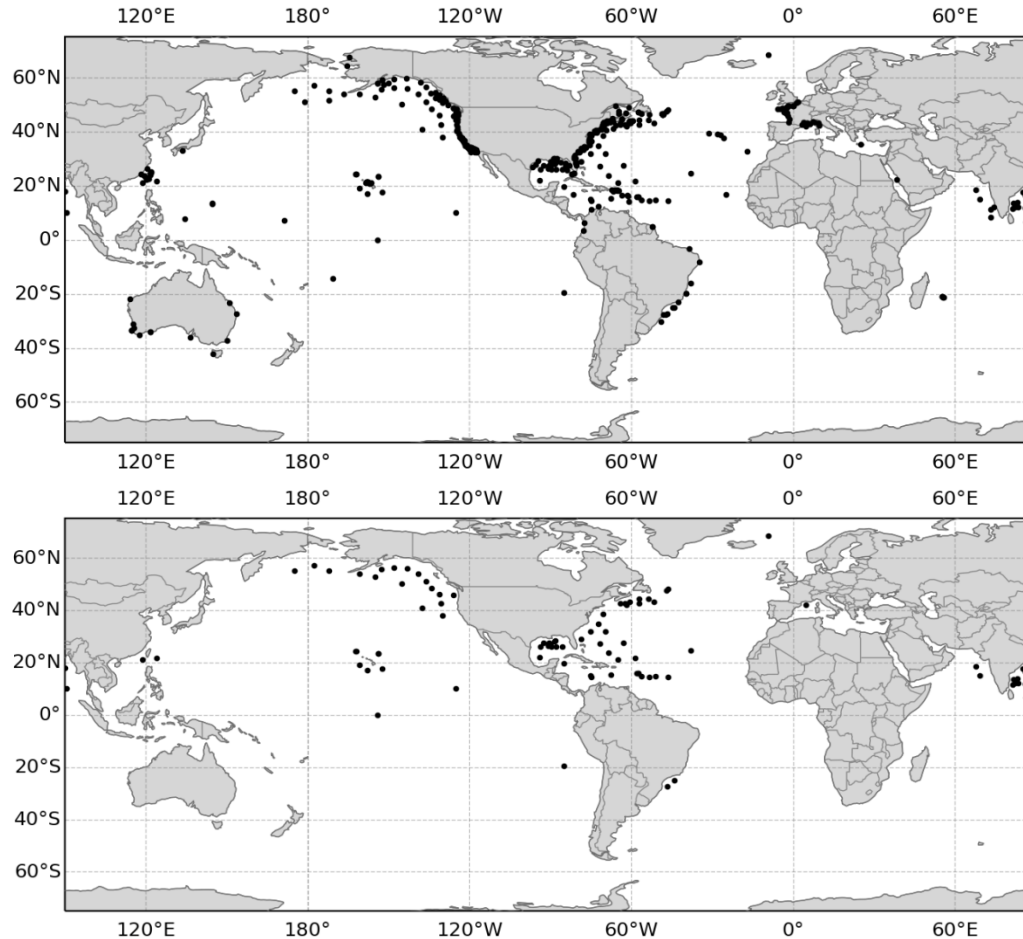
- To develop an oceanic hazards outlook containing delineations of where winds and waves are expected to have the potential of posing a hazard to either life or property for vessels at sea.
- *To conduct this study, a large dataset with the same configuration as the currently operational Global Ensemble Forecast System (GEFSv12) is crucial.*

Global Ensemble Forecast System - Reforecast

- 20 years (2000 to 2019);
- Wave Model WAVEWATCH III (v7.12): input/dissipation source term ST4, nonlinear interactions DIA, and third-order propagation scheme (UQ) with GSE alleviation (PR3).
- Forced by GEFSv12 Reforecast Winds: spatial resolution of 0.25° in the first 10 days and 0.5° for days 11 to 35:
<https://noaa-gefs-retrospective.s3.amazonaws.com/index.html>
- Wave modeling using 3 grids: Polar Grids 20 arc-min, Global Grid 15 arc-min. Output temporal resolution: 3 hours.
- 1 cycle per day (03Z).
- 5 ensemble members (c00 to p04). Once a week (Wednesday) 11 members (+ p05 to p10).
- https://github.com/NOAA-EMC/gefswaves_reforecast/tree/main/ww3_reforecast_scripts

GEFS-reforecast validation against buoy data

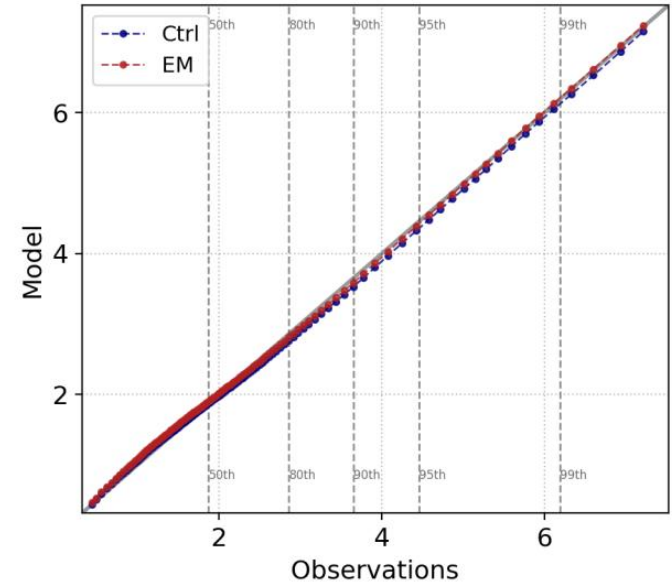
- Validation against buoy and altimeter data.
- Buoys: NDBC and Copernicus. Total of 427 buoys, 96 in deep waters.



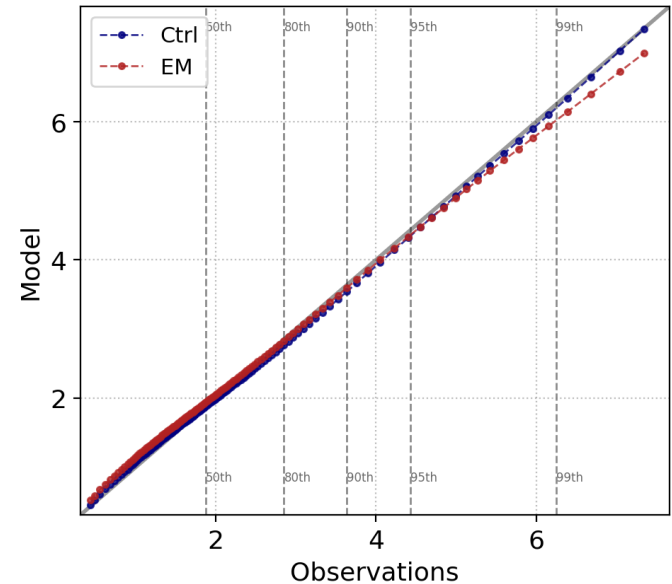
GEFS-reforecast validation against buoy data

- Results for deep waters. Hs (m)

	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
Week1	Control	0.00	0.62	0.26	0.86
	EnsMean	0.05	0.57	0.23	0.88
Week2	Control	0.03	1.09	0.45	0.57
	EnsMean	0.10	0.87	0.36	0.70
Week3	Control	0.02	1.23	0.51	0.45
	EnsMean	0.10	0.94	0.39	0.62
Week4	Control	0.02	1.25	0.52	0.44
	EnsMean	0.10	0.95	0.40	0.61
Week5	Control	0.04	1.26	0.53	0.42
	EnsMean	0.11	0.96	0.40	0.60



Day 1

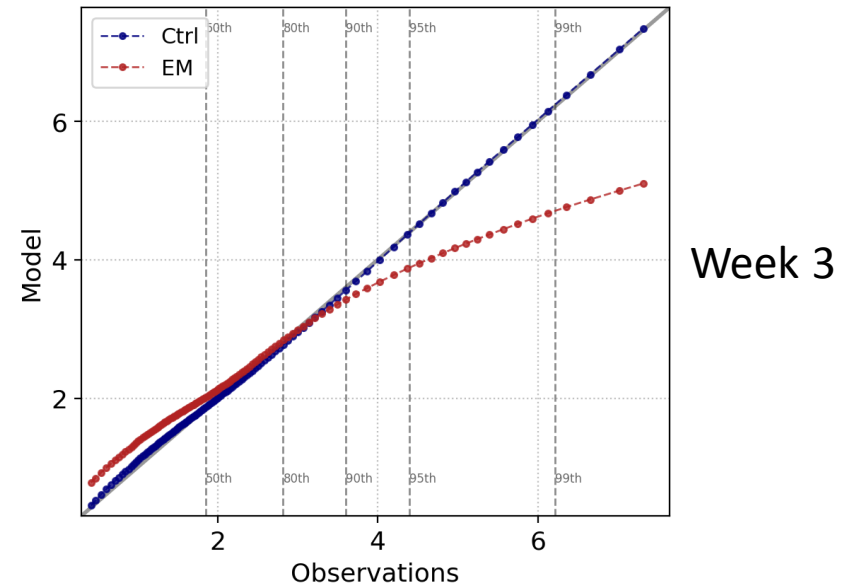
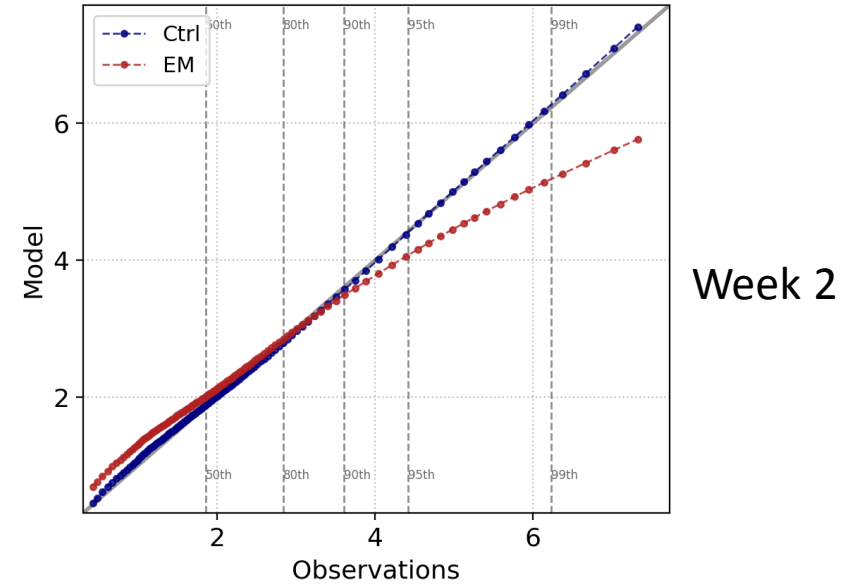


Week 1

GEFS-reforecast validation against buoy data

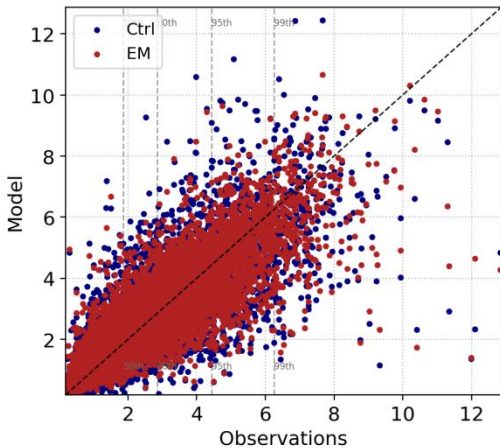
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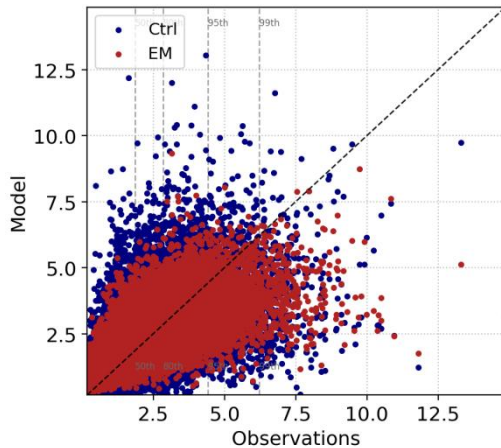


GEFS-reforecast validation against buoy data

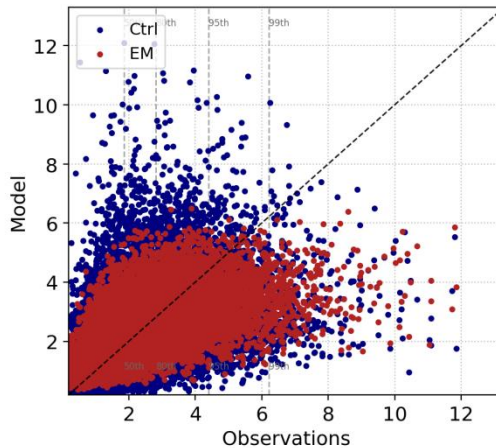
Week 1



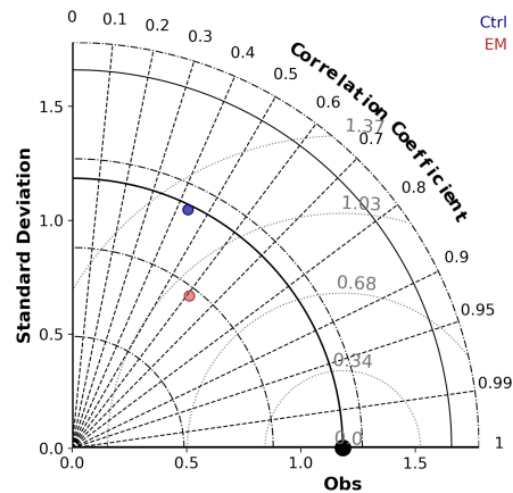
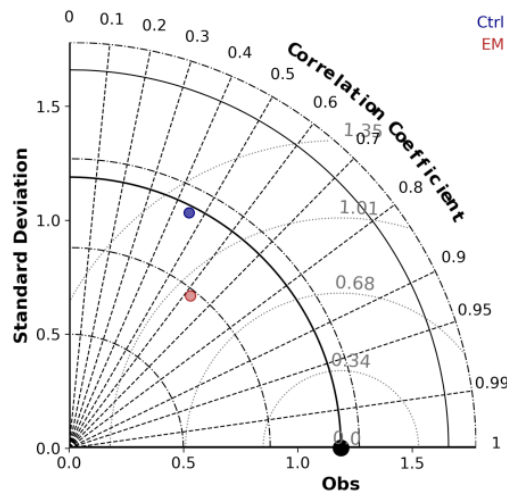
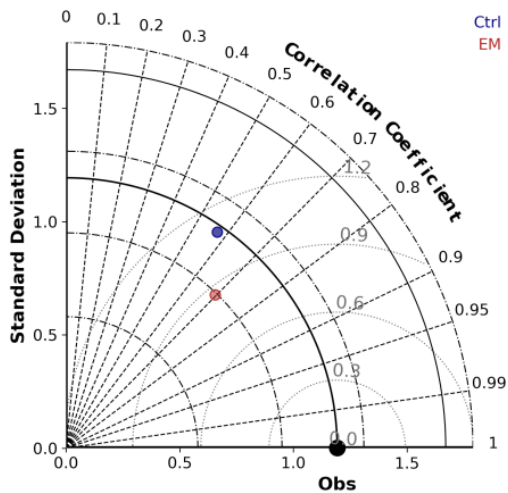
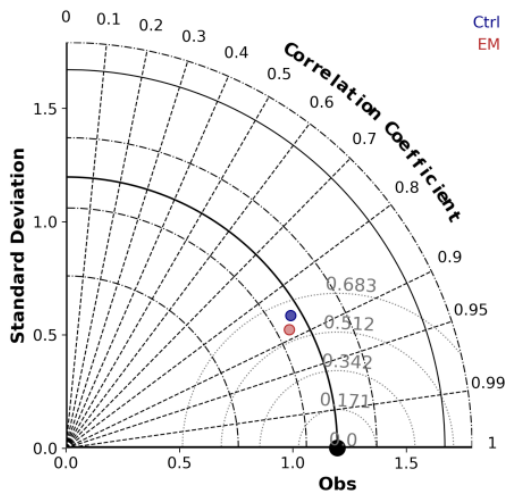
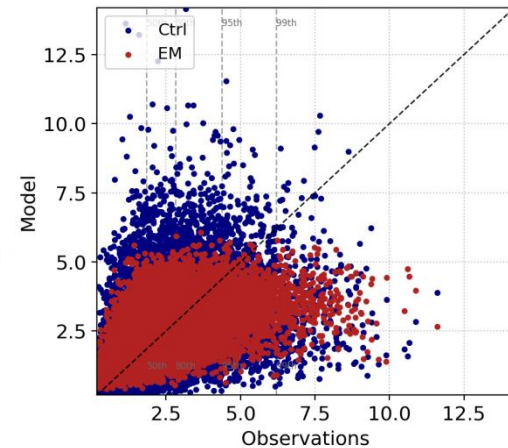
Week 2



Week 3

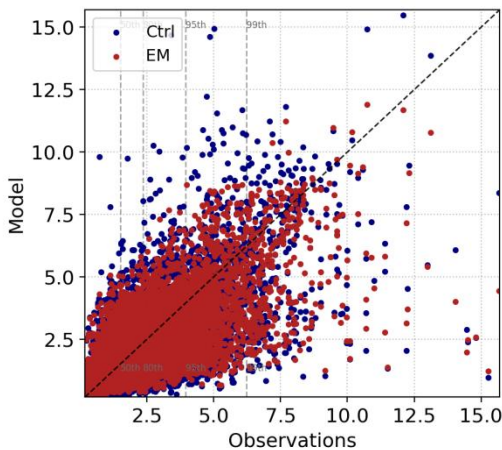


Week 4

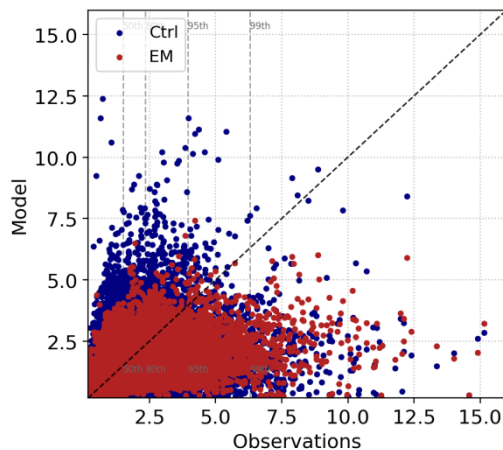


GEFS-reforecast validation against buoy data. Cyclonic conditions:

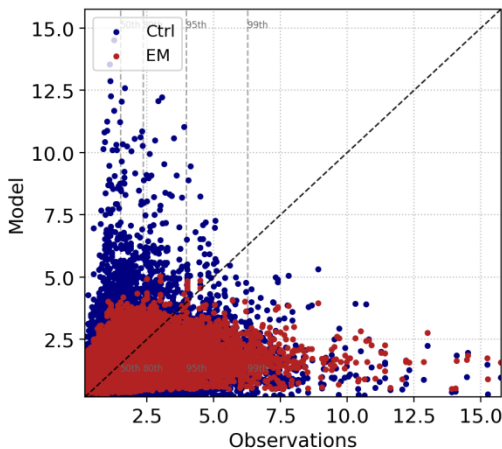
Week 1



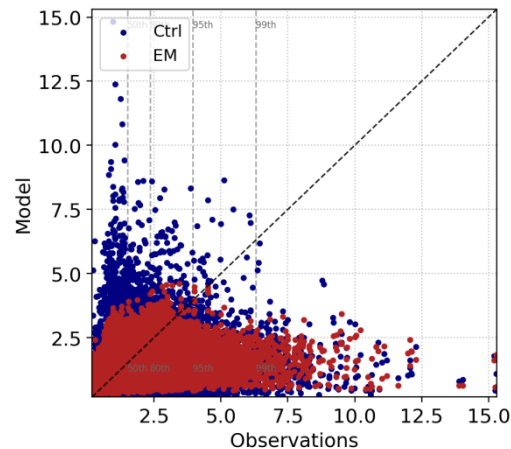
Week 2



Week 3



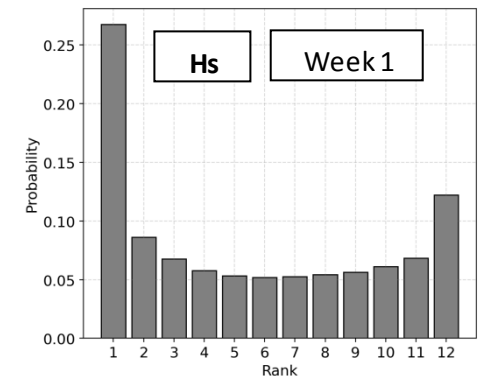
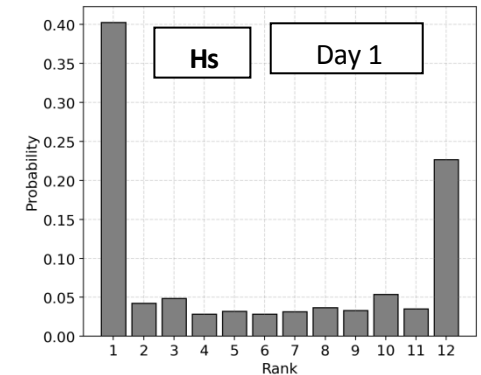
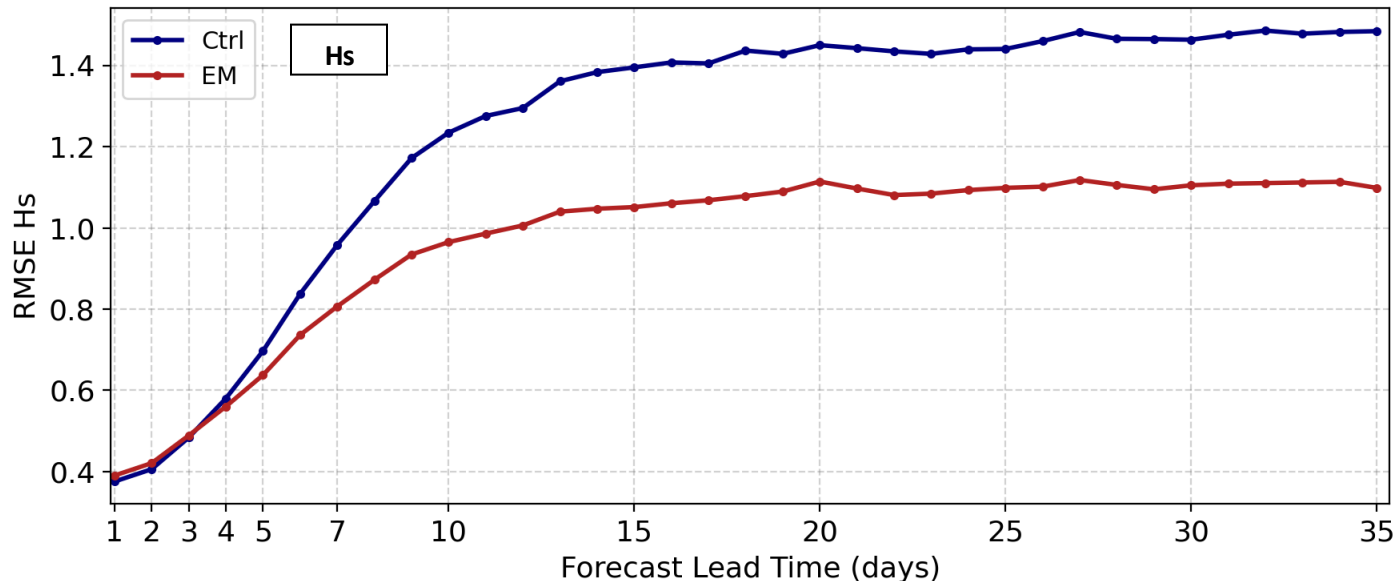
Week 4



	Hs	bias	RMSE	SI	CC
Day 1	Control	0.06	0.46	0.22	0.92
	EnsMean	0.08	0.46	0.21	0.92
Week1	Control	-0.04	0.79	0.38	0.75
	EnsMean	0.00	0.73	0.34	0.78
Week2	Control	-0.18	1.28	0.60	0.30
	EnsMean	-0.15	1.08	0.51	0.41
Week3	Control	-0.24	1.39	0.64	0.17
	EnsMean	-0.21	1.15	0.53	0.29
Week4	Control	-0.30	1.36	0.62	0.15
	EnsMean	-0.24	1.17	0.54	0.25
Week5	Control	-0.31	1.32	0.60	0.19
	EnsMean	-0.25	1.16	0.53	0.27

GEFS-reforecast validation against satellite data

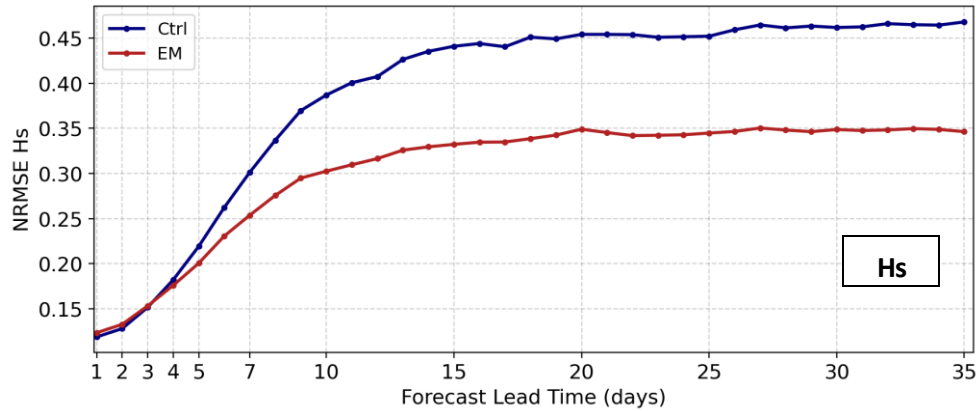
- Australian Ocean Data Network: quality controlled, calibrated, organized.
<https://thredds.aodn.org.au/thredds/catalog/IMOS/SRS/Surface-Waves/Wave-Wind-Altometry-DM00/catalog.html>
- 15 altimeter missions: JASON1, JASON2, JASON3, CRYOSAT2, HY2, SARAL, SENTINEL3A, SENTINEL3B, ENVISAT, ERS1, ERS2, GEOSAT, GFO, TOPEX, CFOSAT
- General similar results to the validation against buoy data.
- Benefits of validation using altimeter data: large volume of data, spatial information with global coverage, 10-m wind speed together with Hs.



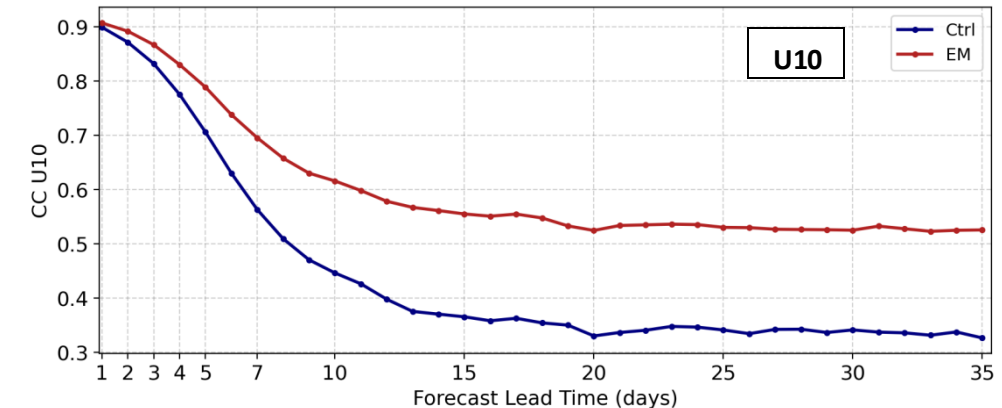
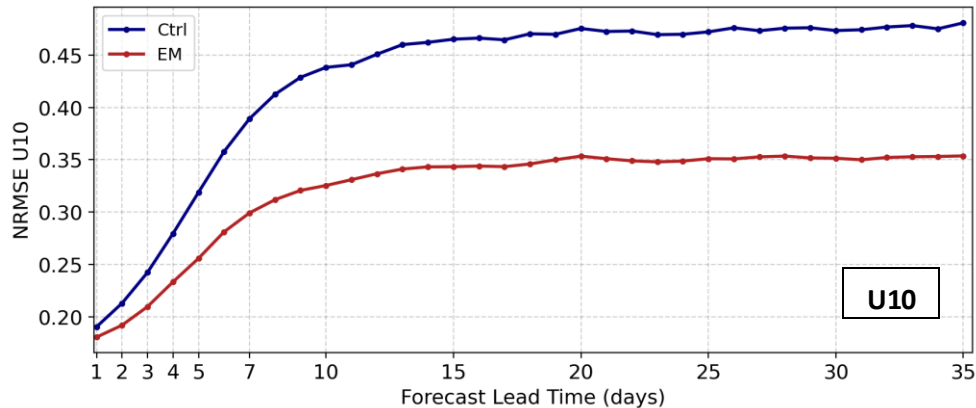
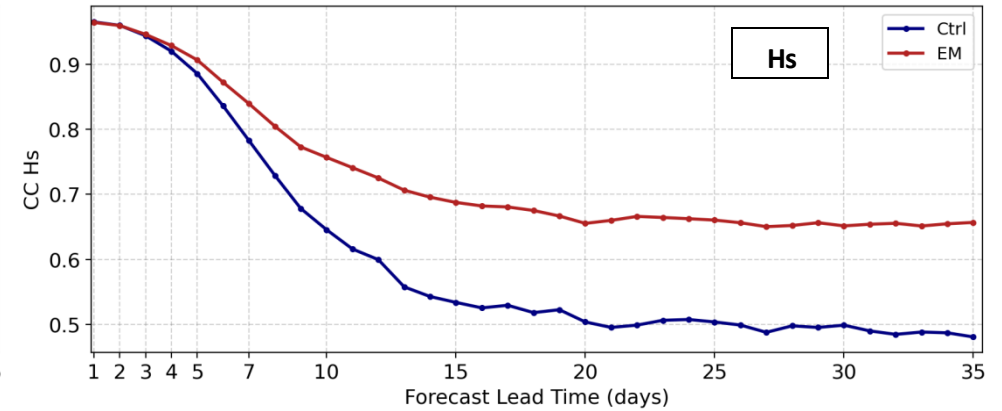
GEFS-reforecast validation against satellite data

- Comparison of Hs and U10

Normalized RMSE



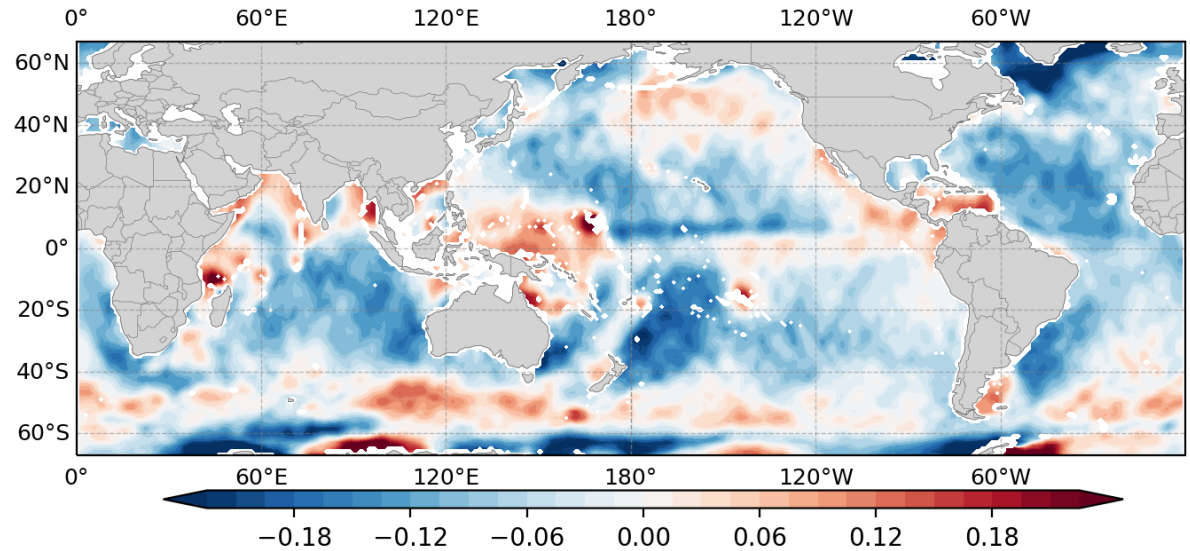
Correlation Coefficient



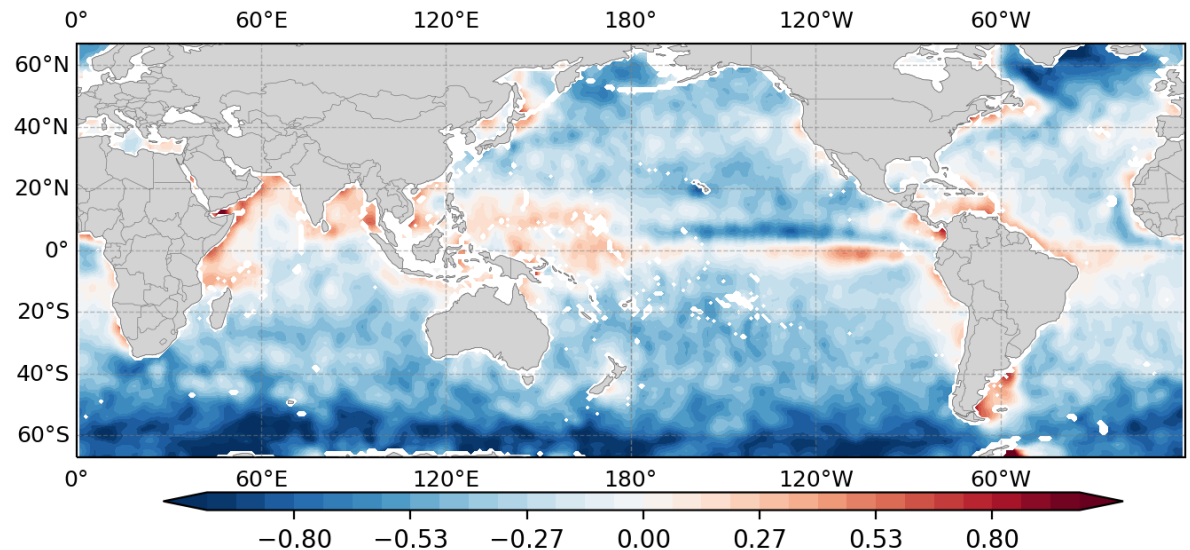
GEFS-reforecast validation against satellite data. Global maps.

- Assessment results
 - Day 1 (0-24h)
 - Control member
- Bias (model-obs):

Hs (m)



U10 (m/s)

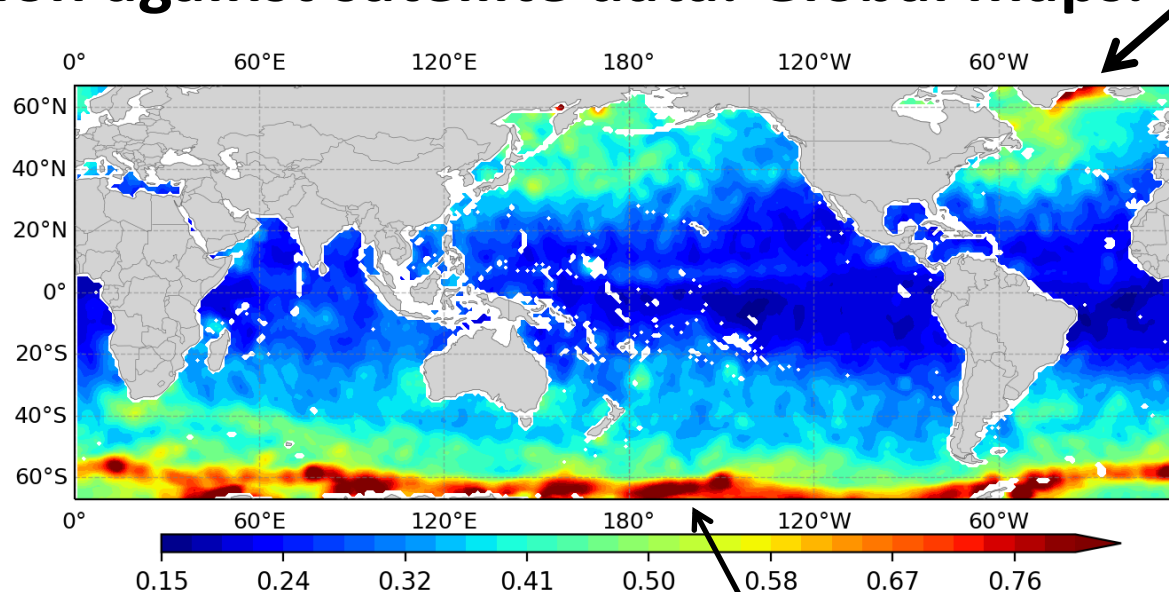


GEFS-reforecast validation against satellite data. Global maps.

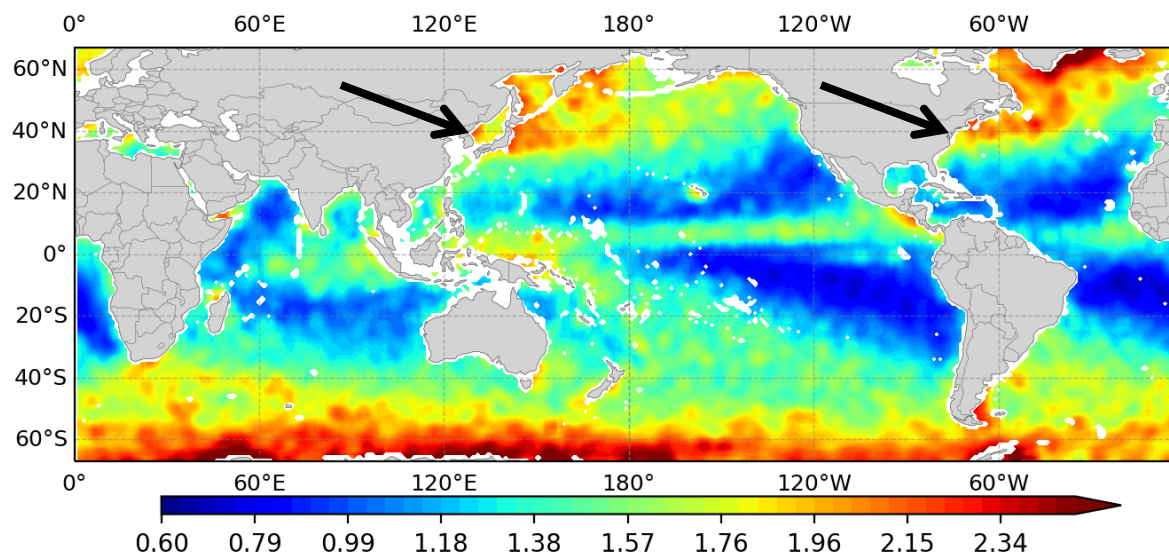
- Assessment results
- Day 1 (0-24h)
- Control member

RMSE:

Hs (m)



U10 (m/s)

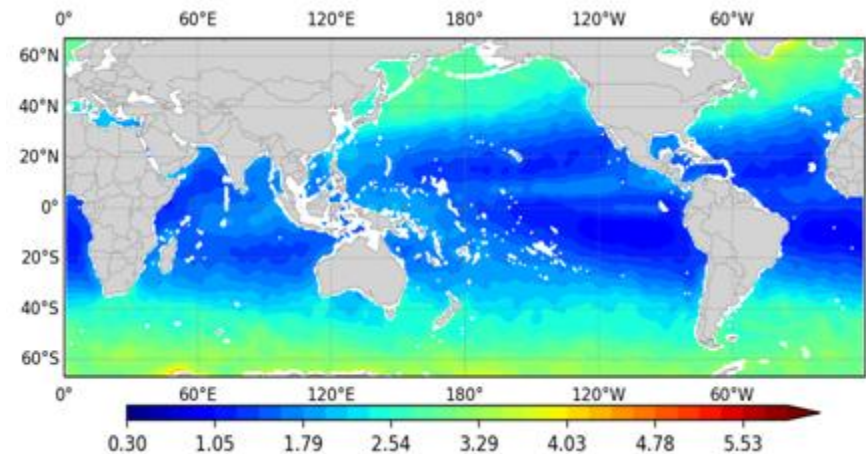
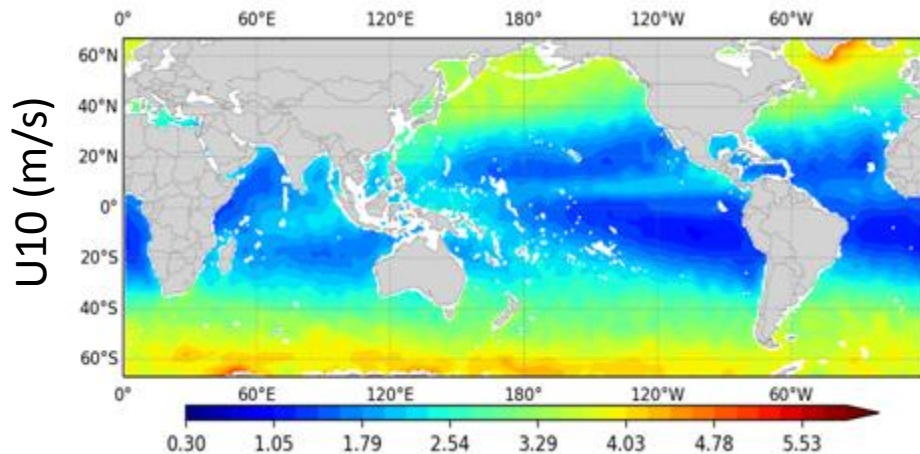
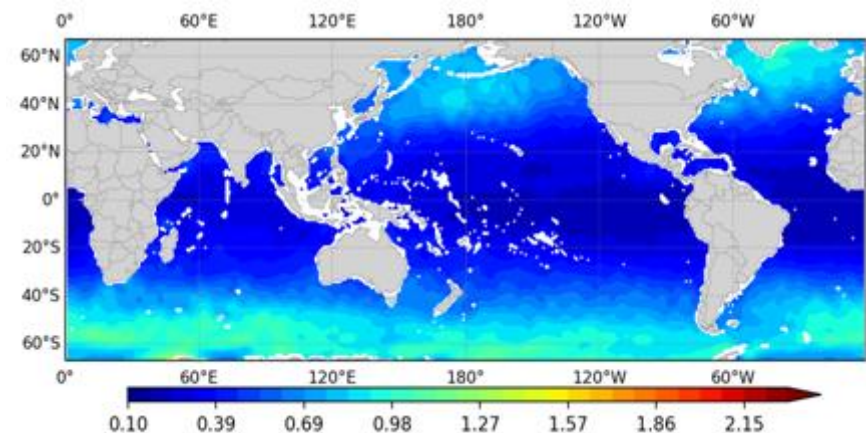
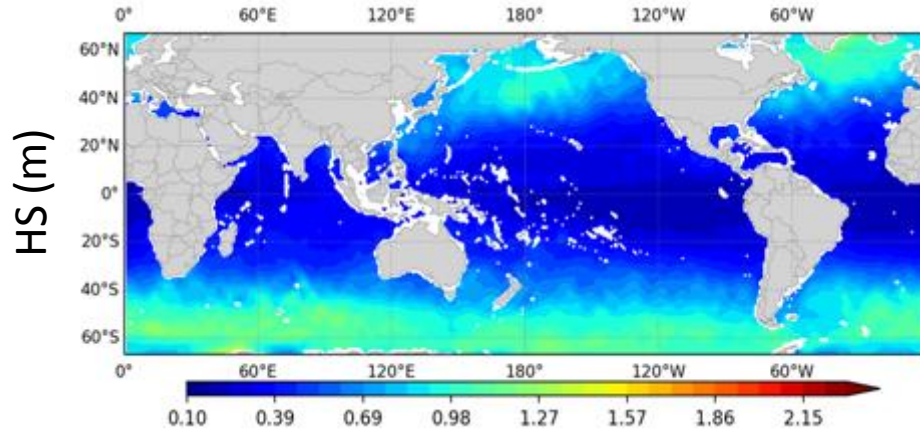


GEFS-reforecast validation against satellite data. Global maps.

- RMSE – Week 1

Control Member

Ensemble Mean

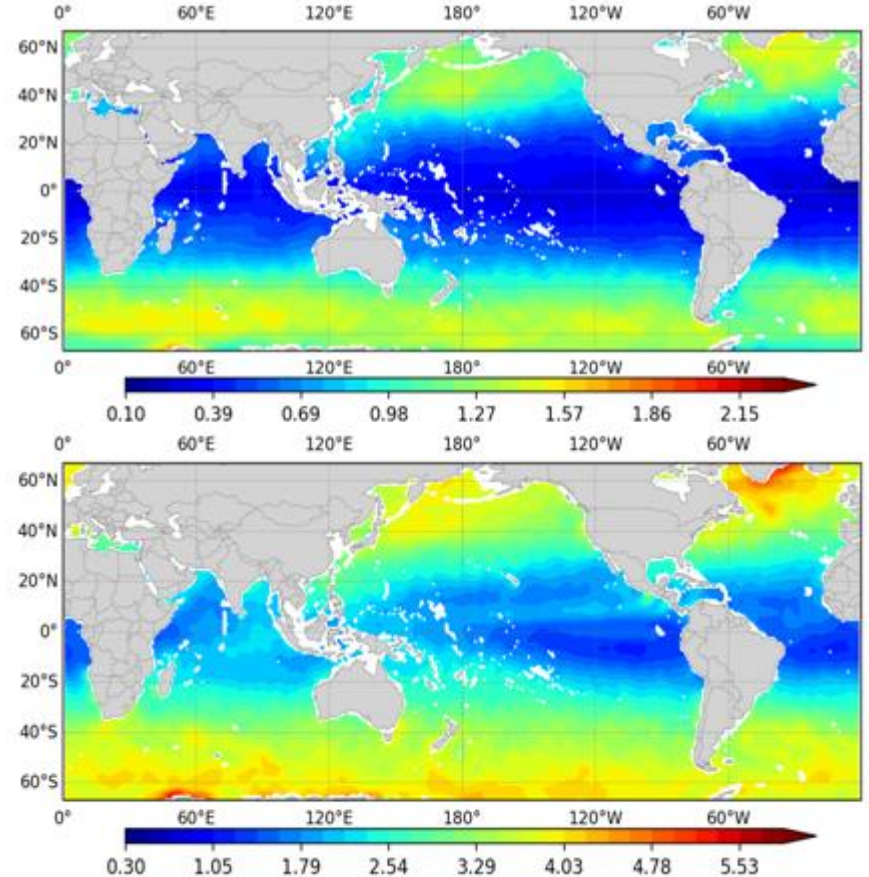
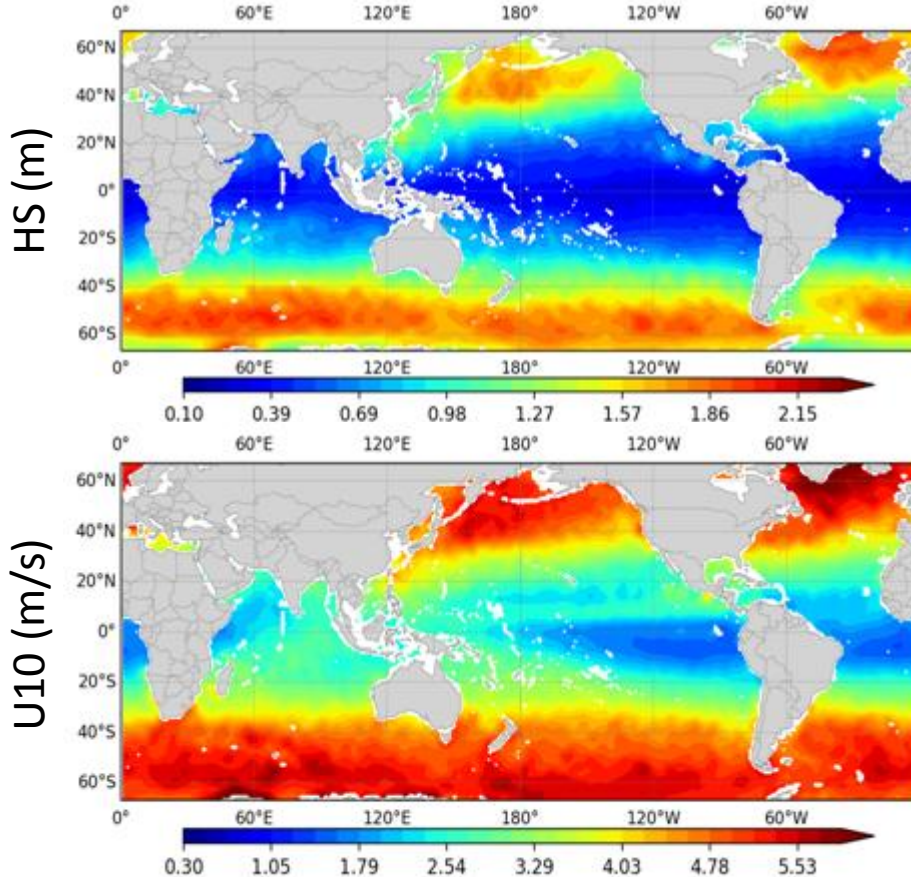


GEFS-reforecast validation against satellite data. Global maps.

- RMSE – Week 2

Control Member

Ensemble Mean

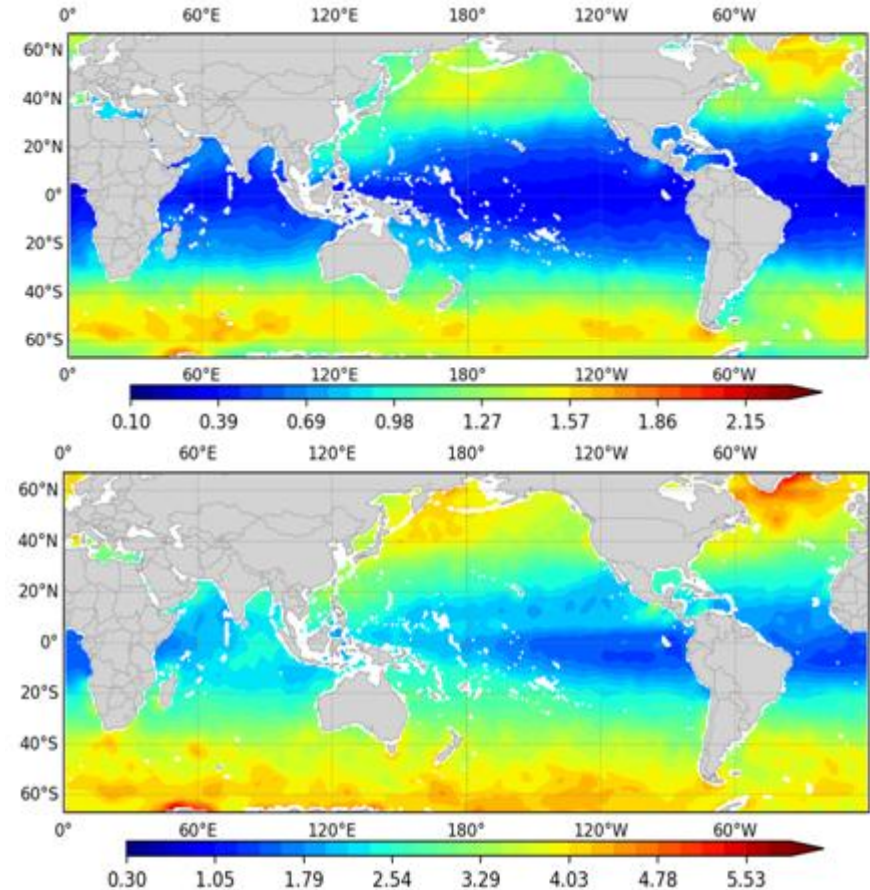
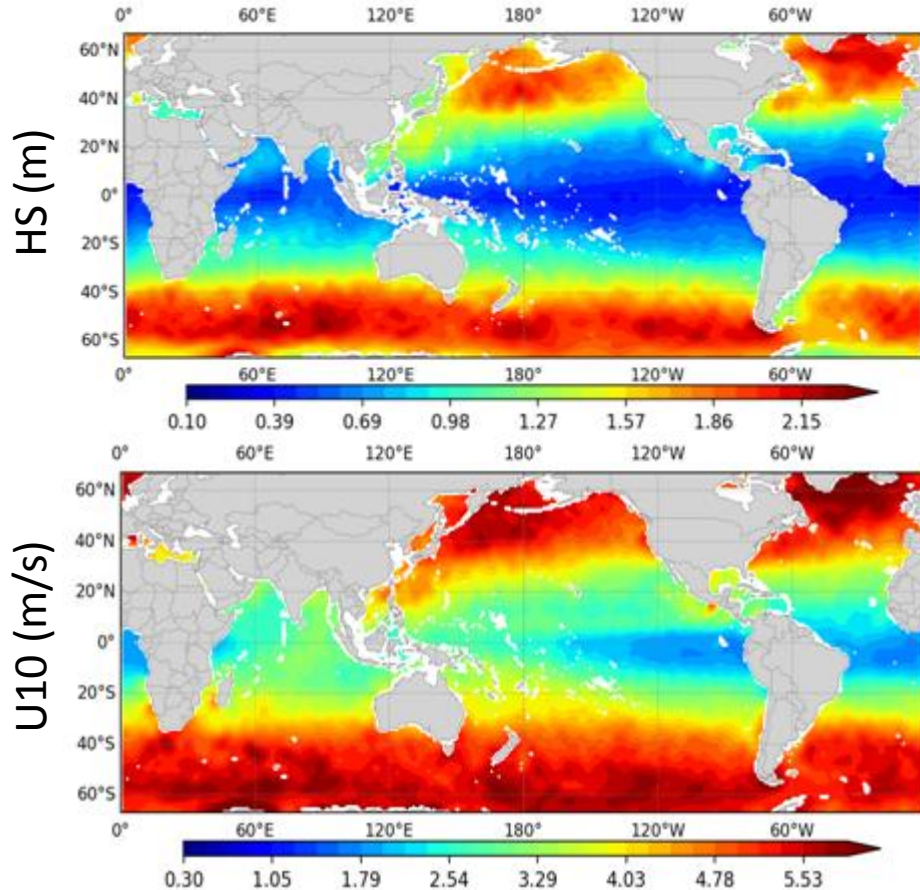


GEFS-reforecast validation against satellite data. Global maps.

- RMSE – Week 4

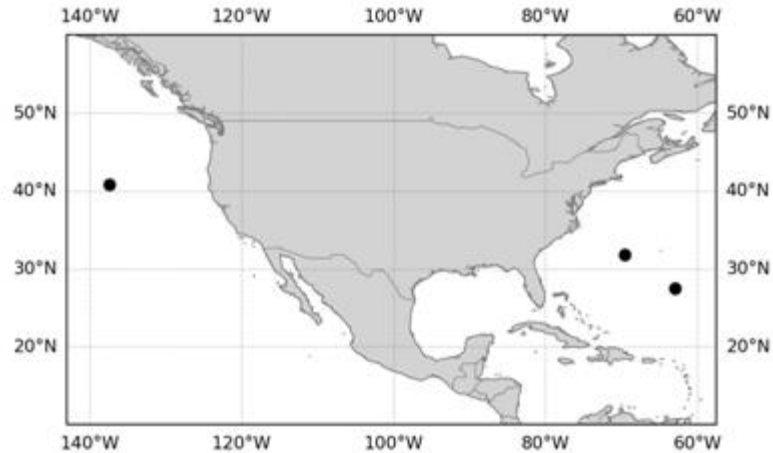
Control Member

Ensemble Mean



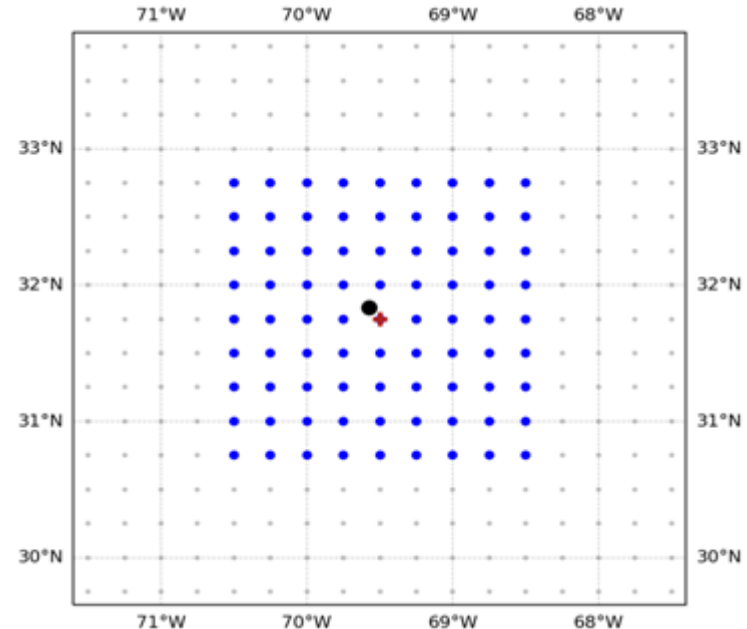
Fuzzy Verification and Probability Maps. Week 2 and beyond

Importance of a probabilistic product and validation. Space-time analysis.



GEFS reforecast;
GEFS reanalysis (appended segments of 24-hr forecasts);
GDAS;
NDBC buoy data (41048, 41049, 46006).

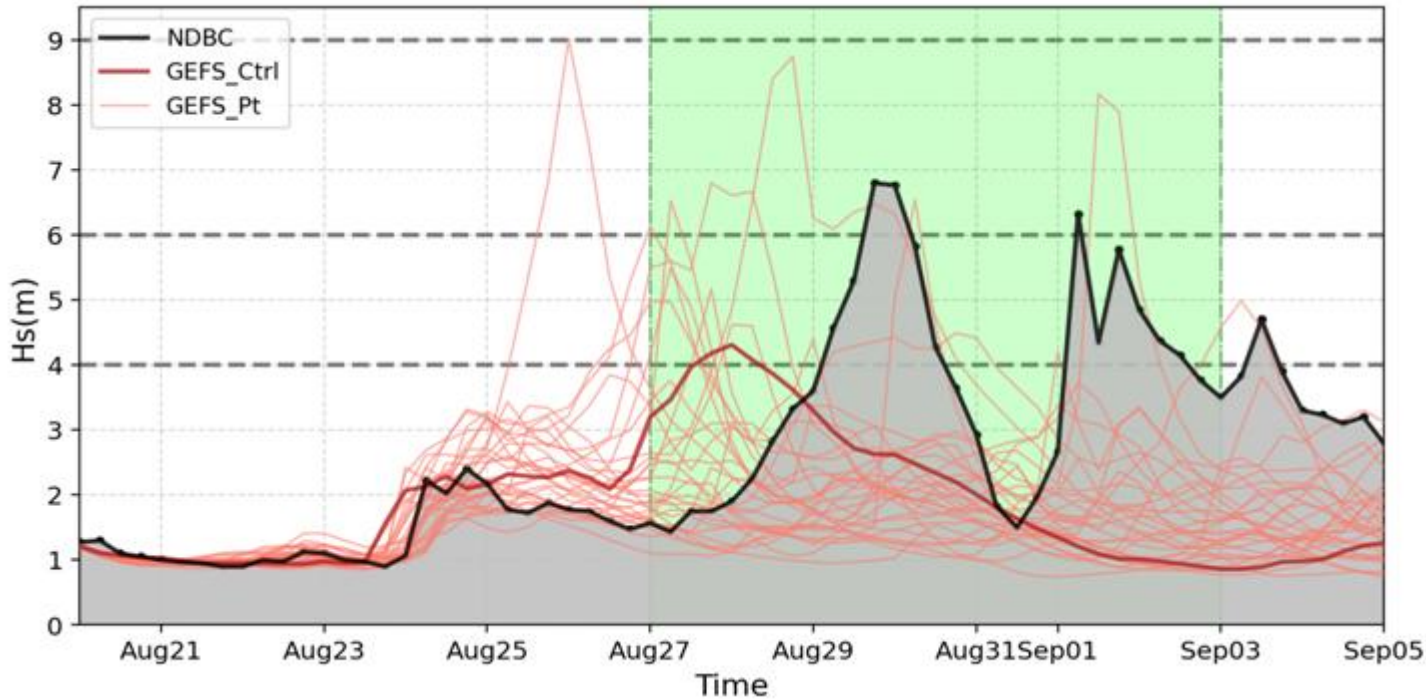
Fuzzy Verification
Probability Maps and fine tuning of parameters



“Fuzzy” verification rewards closeness by relaxing the requirement for exact matches between forecasts and observations. **Spatial window and neighborhood surrounding the observed point.**

Fuzzy Verification and Probability Maps. Week 2 and beyond

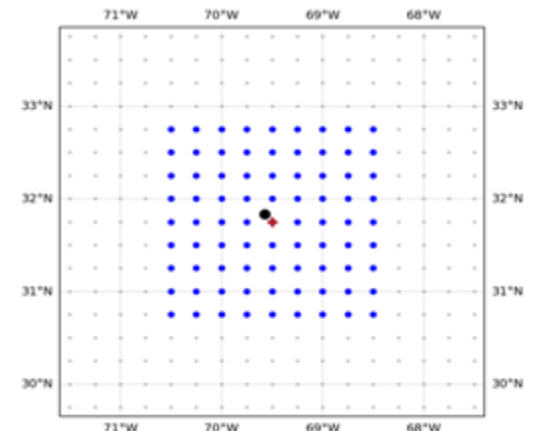
Importance of a probabilistic product and validation. Space-time analysis.
Example Hurricane Franklin, Aug 20 – Sep 1, 2023. NDBC 41048



Week 2 in light green.

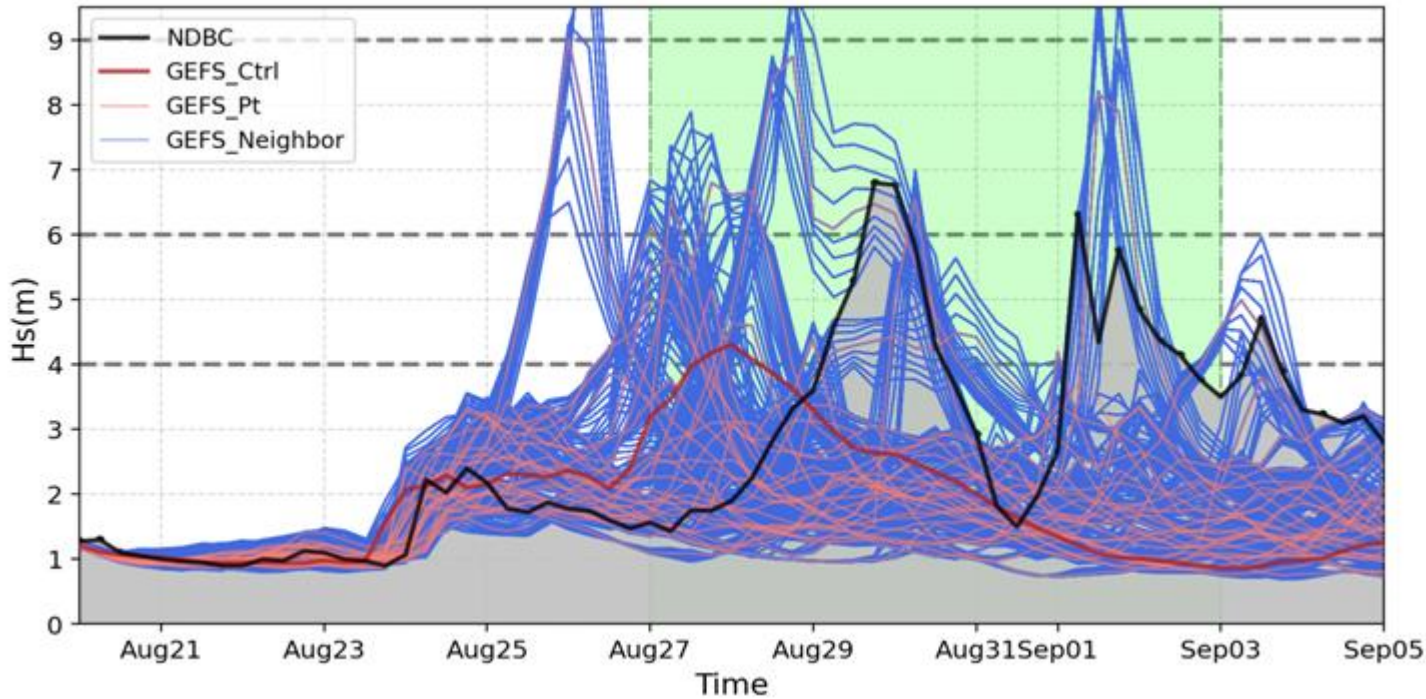
Levels: 4, 6 and 9 meters

GEFS: 30+1 members (same point)



Fuzzy Verification and Probability Maps. Week 2 and beyond

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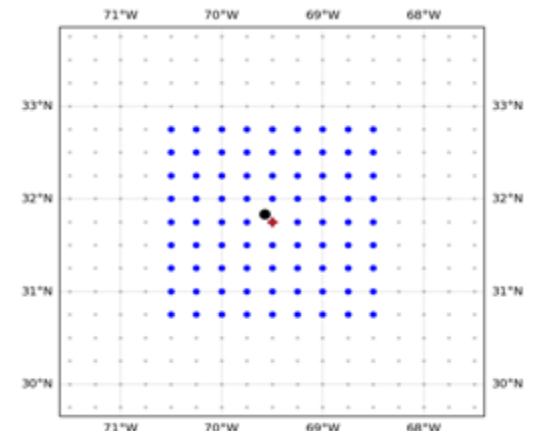
Levels: 4, 6 and 9 meters

GEFS: 30+1 members (same point)

GEFS: 30+1 members, 2°X2° neighbors (64 points).

Total of 1984 predictions.

Brier score, ROC curve, CRPS, reliability diagrams.



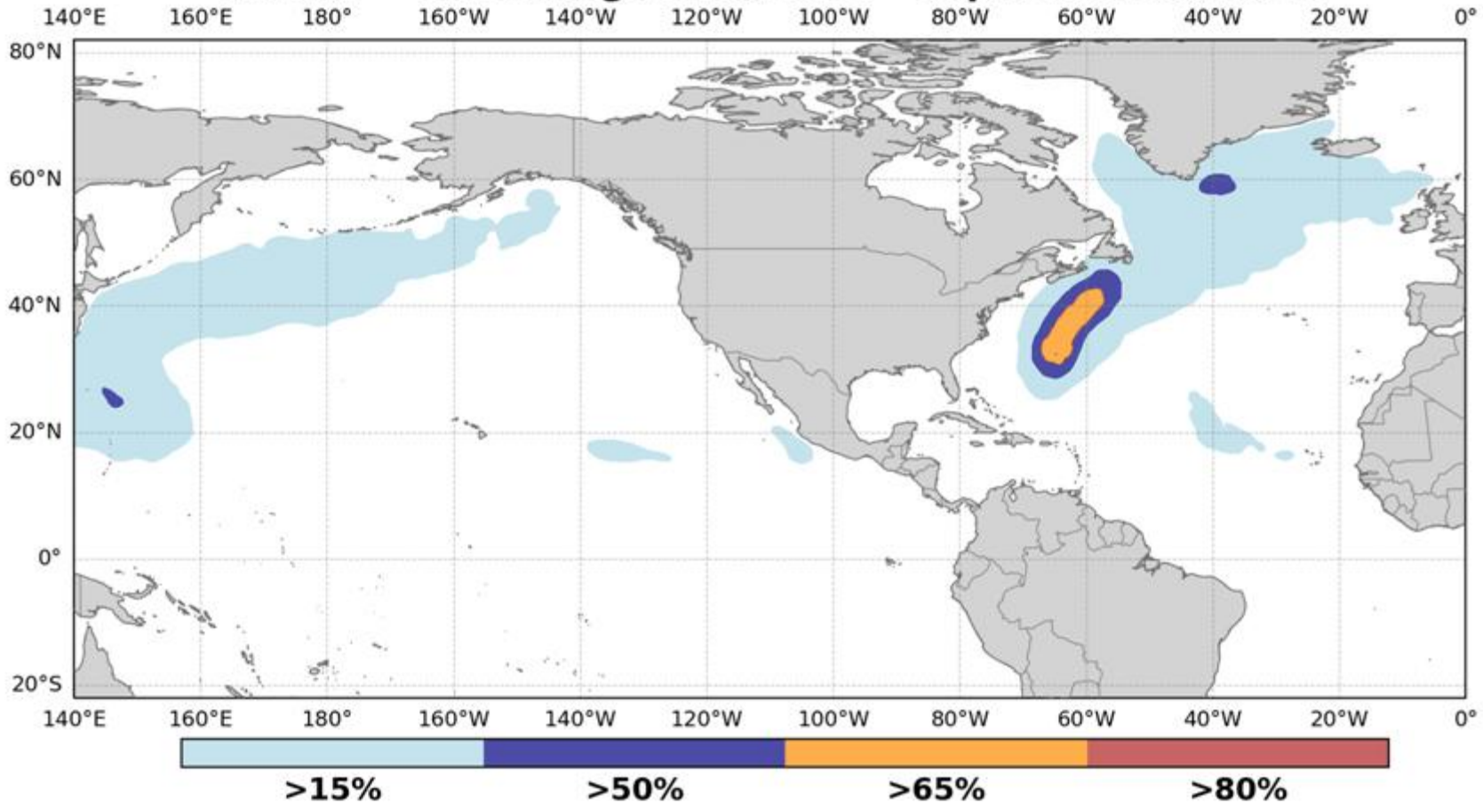
Probability Maps. Example

Hurricane Franklin (C4), peak Aug 28 and 29.



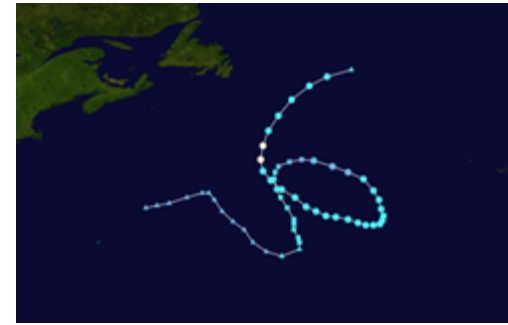
Prob Hs>6.0m, Cycle 20230822 00Z

Week2 – Valid : August29, 2023 – September05, 2023

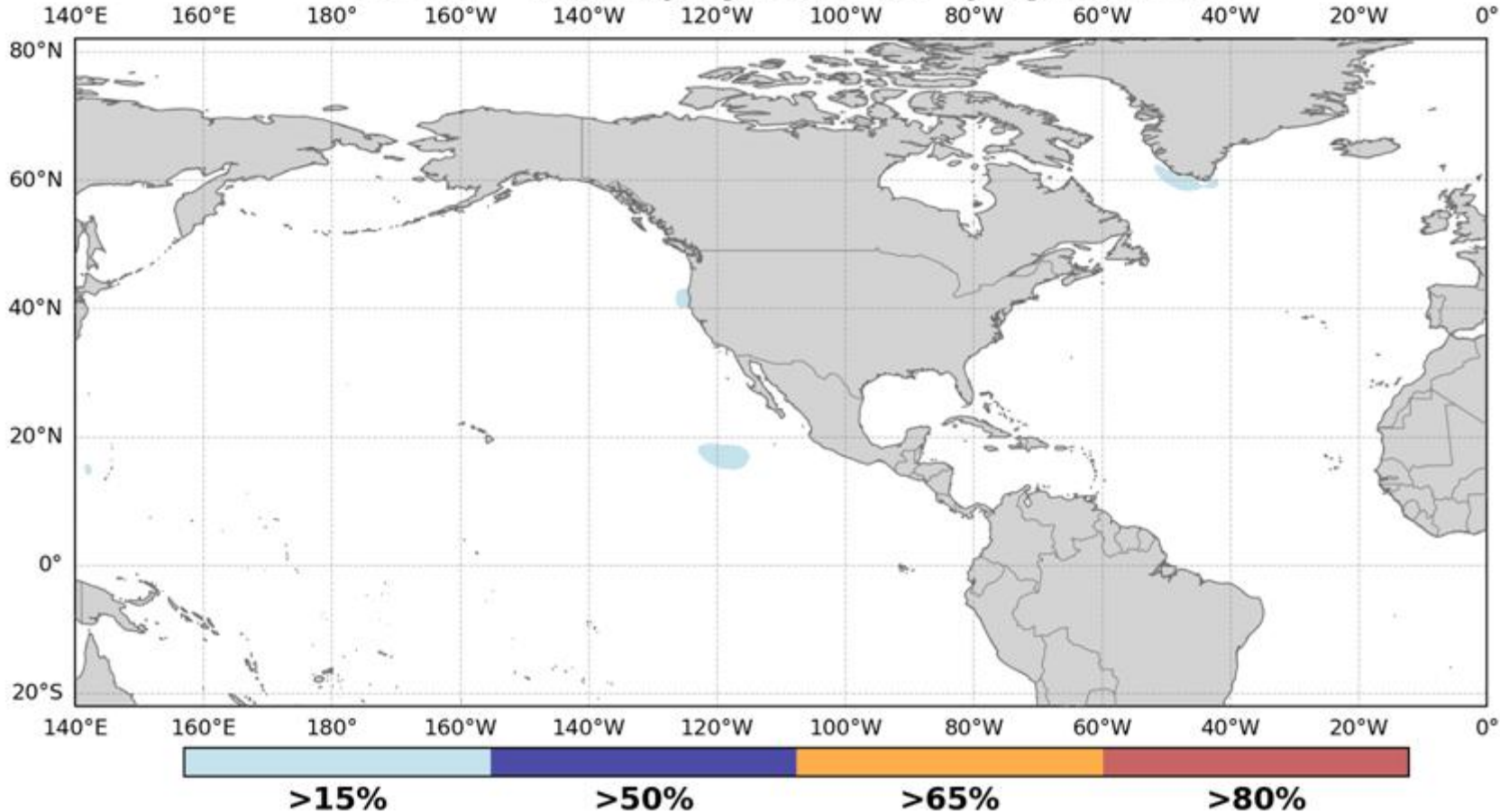


Probability Maps. Example

Hurricane Don (C1), July 14 – 24, 2023.



Prob U10>41.0knots, Cycle 20230715 00Z
Week2 – Valid : July22, 2023 – July29, 2023



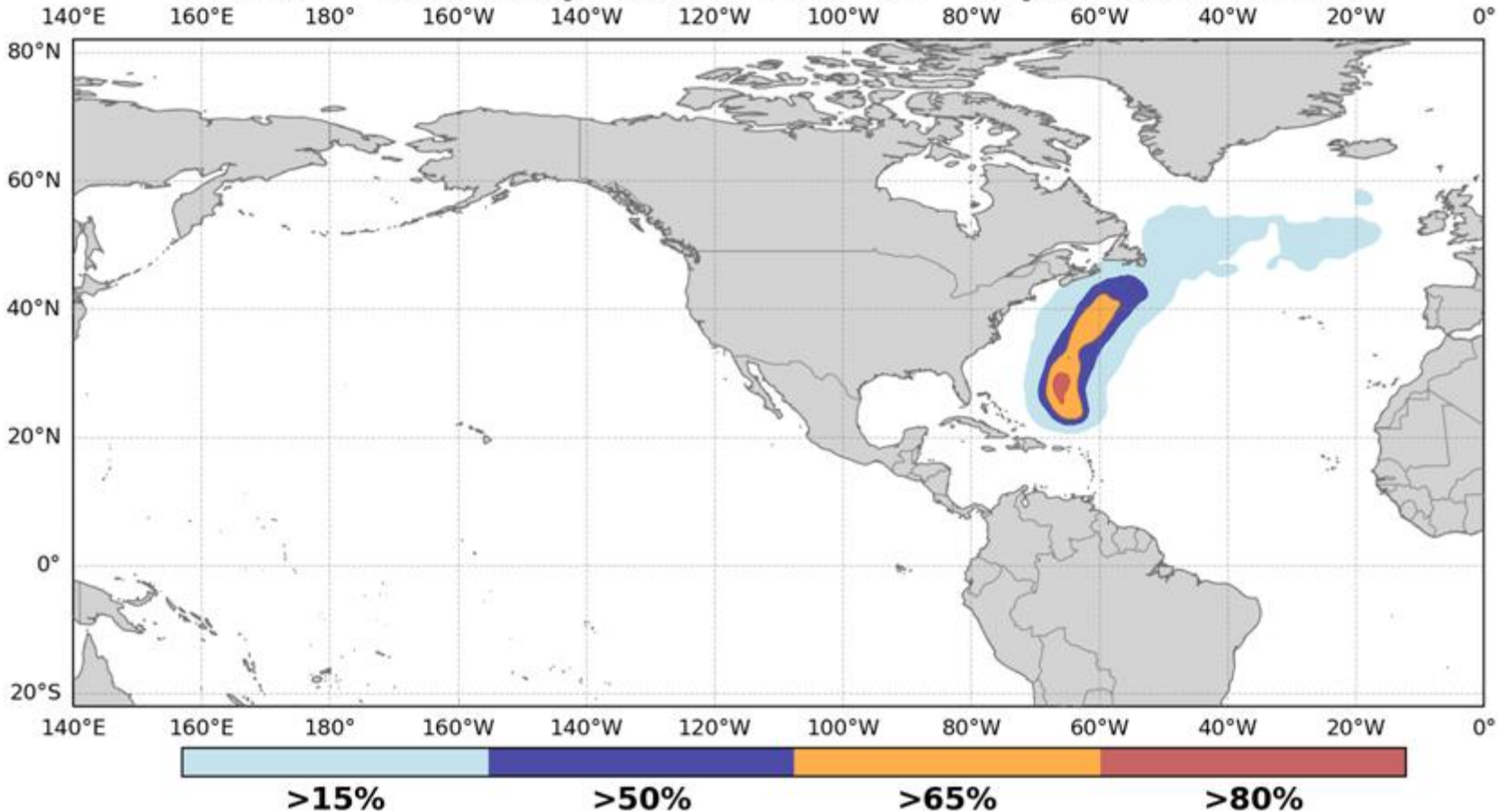
Probability Maps. Example

Hurricane Lee (C5), Sep 5 –16. West of Bermuda on Sep 14



Prob Hs>9.0m, Cycle 20230905 00Z

Week2 – Valid : September12, 2023 – September19, 2023



Conclusions

- The validation of GEFSv12 has demonstrated high performance and low systematic errors for the first five days of the forecast;
- Between day 5 and day 10, there is a rapid increase in scatter errors along with a decrease in correlation coefficients. The error metrics stabilize at 15 days;
- Under cyclonic conditions, quality remains high for the initial forecast days, but deterioration occurs more rapidly, typically within the first week.
- Scatter errors in U10 and Hs are more pronounced in locations with warm currents.
- By relaxing the requirement for exact matchups in time and space, probability maps generated from GEFSv12 show significant potential for week 2.

Thank you

ricardo.campos@noaa.gov

- 20-Year GFSv12 reforecast data:

<https://noaa-nws-gefswaves-reforecast-pds.s3.amazonaws.com/index.html>

- Archives with GFSv12 operational forecast data:

<https://noaa-gefs-pds.s3.amazonaws.com/index.html>

- GFSv12 WAVEWATCH III optimized parameters:

https://github.com/NOAA-EMC/WW3/tree/develop/regtests/ww3_ufs1.3

- Validation tools:

<https://github.com/NOAA-EMC/WW3-tools>