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Update in US Navy Global Wave Model Forecasting

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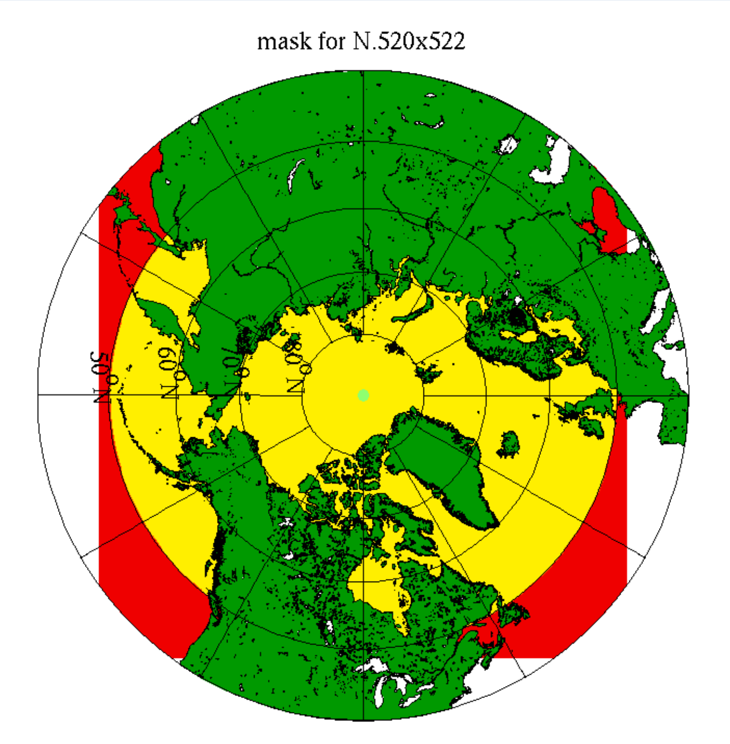
Background

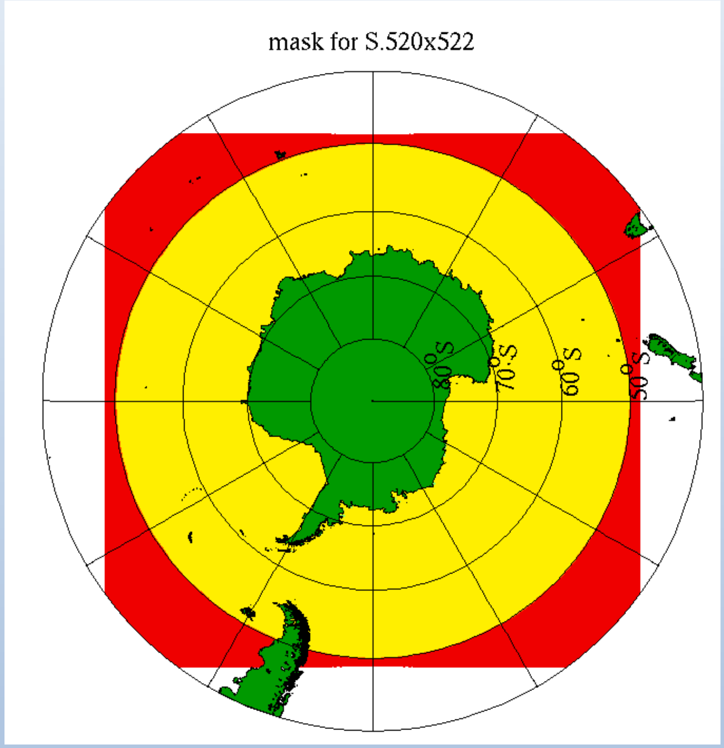
- Circa 1990 FNMOC started running WAM for regional and eventually global products.
- Circa 1995 NAVOCEANO started running WAM to apply BCs for smaller domain wave models, WAM and later SWAN.
- In 2000 FNMOC went to multi-processor mode requiring switch over to WAVEWATCH III. Meanwhile NAVOCEANO stayed with WAM the code of which was adapted to multi-processor machines.
- Also, WAM attained “relocatability”.
- Transition in 2014 upgraded NAVOCEANO and FNMOC with latest technology with WAVEWATCH III, versions 4.18 and 5.03.
- In process, FNMOC (both Stennis and Monterey) will be updated to version 5.16, streamlined multi-grid set-up, new ice processing and improved data assimilation.

Irregular-Regular-Irregular

- Dubbed ¼-degree IRI system
- Global latitude-longitude grid - Spherical
  - 55^{o}S to 55^{o}N
  - ¼-degree resolution Before: ½-degree
- Polar Stereographic grids North (South) - Curvilinear
  - Starting 50^{o}N(S) to nearly the poles (overlaps global grid)
  - 18-km resolution at 70^{o}N(S)
- Spectral bins
  - 36 directional bins (10^o resolution), [5, 15, 25, …]
  - 25 frequency bins, with logarithmic spacing from 0.0418 to 0.7294 Hz (increment factor = 1.1)
- Bathymetry from ETOPO1, but deepest is 999 metres
- Obstruction grids identify sub-resolution features
- Time steps: 3600 s maximum global, 720 s maximum CFL time step for x-y

Curvilinear Grids at Poles





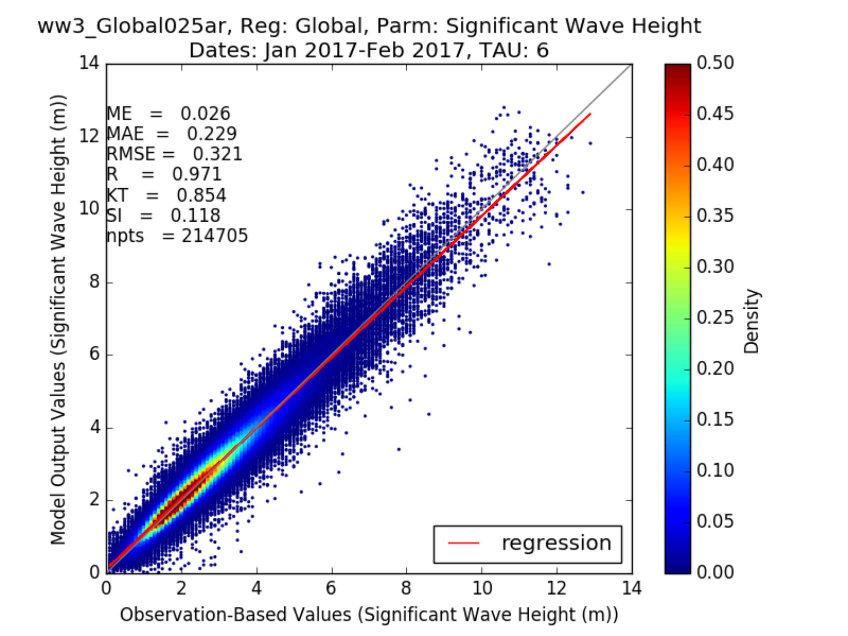
Computational points in the model region are depicted in yellow. Although a square grid is "draped" over the poles, the corners are "trimmed" off by using a mask depicted in red. Land is depicted in green.

Data Assimilation

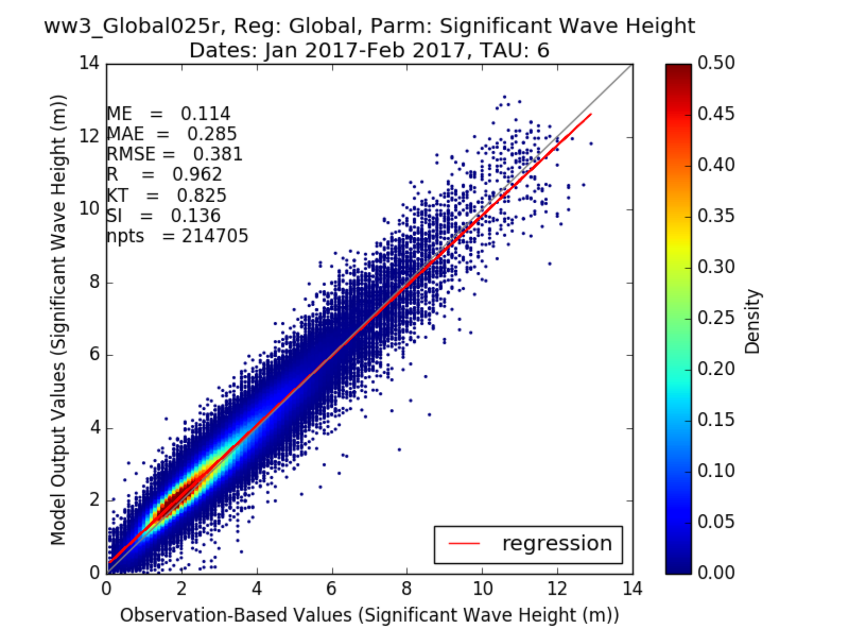
- A version functioning at FNMOC for global grid.
- NCODA 4.1 incorporates WAVEWATCH III modules to read any type grid.
  - Generalized approach allows for using curvilinear/irregular grids.
  - Infrastructure sets stage for later developments, e.g. 4DVar.
- Differences in observed SWH and modelled fields determines overall adjustment of spectra with no regard to frequency and direction.
- Restart files are adjusted with DA every 6 hours.
- Observations from OCNQC (also available on USGODAE) are used, window of 3 hours on either side.
- Six-hour roll-back will no longer be used.
- An advantage is that spin-up from cold-start can be shortened.

Data Assimilation

With DA



Without DA



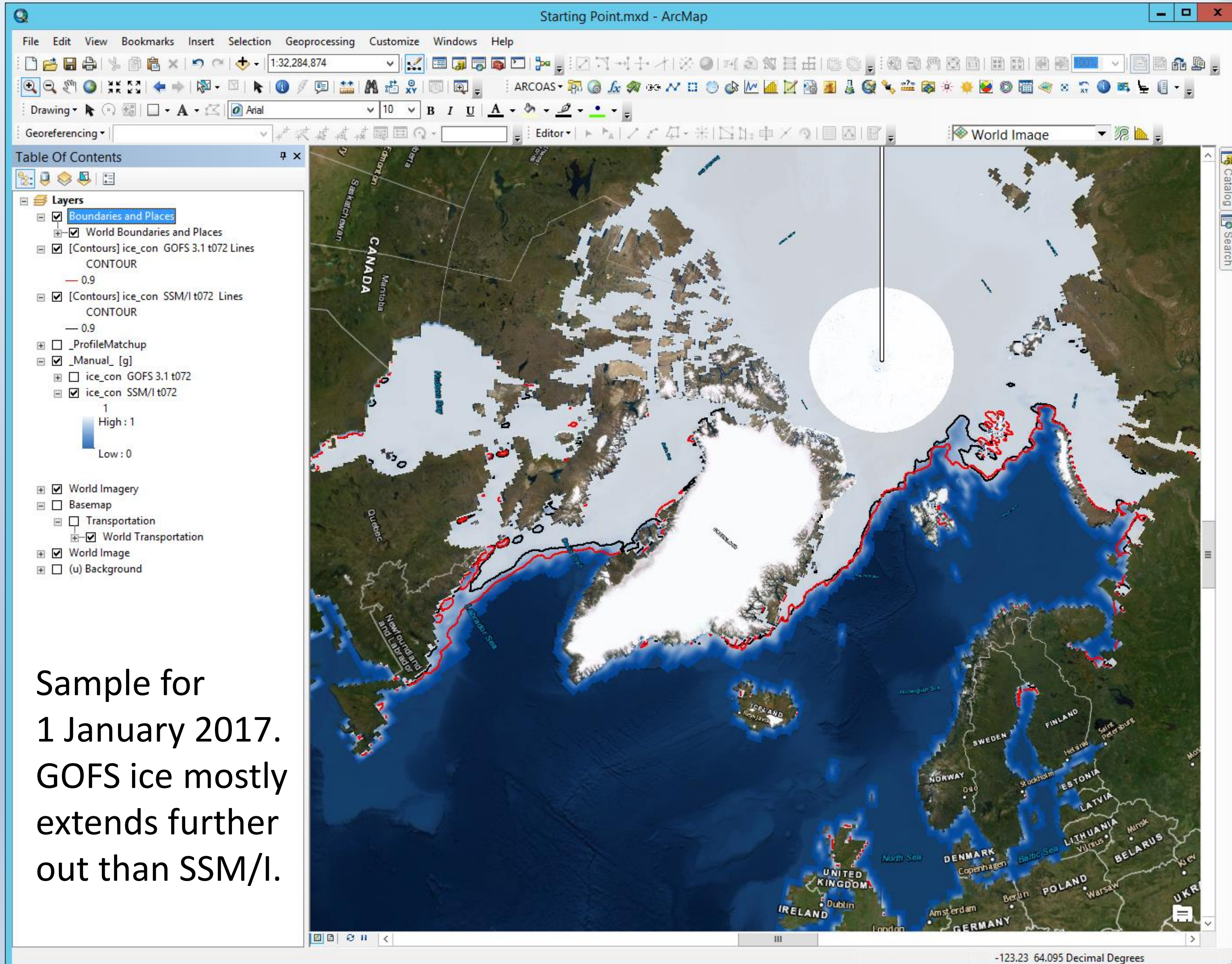
Altimeter-based SWH measurements (in OCNQC files from USGODAE) are compared to model output at TAU 6 with a 1.5 hour window on either side.

Global domain for these plots extends from the 80^{o}S to 90^{o}N . All statistical indicators the model with DA.

Ice in the Model

- IC4: wave attenuation, several empirical schemes for highly parameterized wave-ice interaction physics, most of them frequency dependent, Using method 6, 10 steps.
- Not just on or off. Low, energy can exist throughout the ice extent.
- Ice concentration input
- SSM/I originally, delivered through NAVGEM fields
- Start using ice fields from HYCOM-CICE from GOFS 3.1

Ice in the Model



Sample for 1 January 2017. GOFS ice mostly extends further out than SSM/I.

Model Runs

- Restarts are adjusted by data assimilation.
- GOFS 3.1 ice and NAVGEM winds are processed. Before: SSM/I ice.
- Model run cycles every six hours. Before: every 12.
- Uses one node of 48 cores. Before: 256 cores were occupied, 128 were actually used.
- 6-hour run completes in < 3.5 mins. 72-hour in ~30 mins. Before: 21 mins with more cores and coarser overall.
- Three domains are integrated as one. Before: 10 domains.
- netCDF files are produced with standard products.
- Selected output points are processed.
- Results are archived.
- Navy DSRC will be primary, Monterey machines secondary.

Model Performance of Significant Wave Height

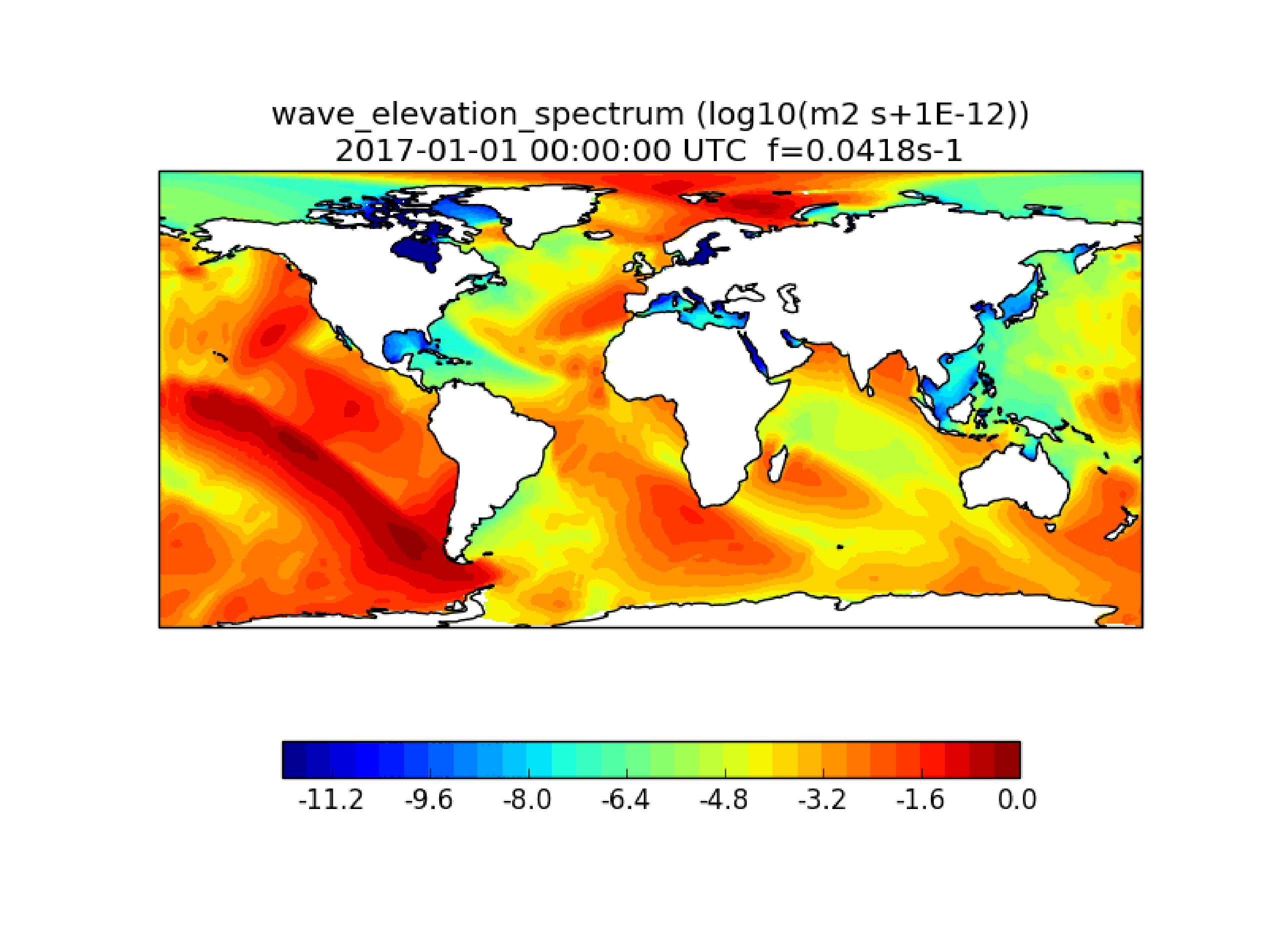
	ME (m)	MAE (m)	RMSE (m)	CorCoef / R	SI	# points
January	0.167	0.294	0.388	0.957	0.150	60413
February	0.170	0.298	0.397	0.959	0.148	55264
March	0.098	0.275	0.372	0.963	0.136	55016
April	0.154	0.286	0.378	0.964	0.130	58518
May	0.128	0.287	0.386	0.972	0.126	48508
June	0.113	0.278	0.369	0.974	0.120	35258
July	0.091	0.280	0.378	0.976	0.127	35894
August	0.078	0.260	0.344	0.970	0.126	50035
September	0.073	0.264	0.352	0.974	0.125	43553
October	0.113	0.273	0.363	0.971	0.125	51667
November	0.106	0.265	0.354	0.967	0.136	53123
December	0.119	0.269	0.356	0.958	0.135	54990

Statistics of global model performance against altimeter measurement for each month in 2017. Altimeter points were subsampled for every 30 km.

Preserving Directional Spectra Using Fourier Series Coefficients

- $E(f)$, $\theta_1(f)$, $\sigma_1(f)$, $\theta_2(f)$, and $\sigma_2(f)$ based on $F(\sigma, \theta)$, $a_1(f)$, $b_1(f)$, $a_2(f)$, $b_2(f)$
- Fixed error in model code for $\theta_2(f)$ and $\sigma_2(f)$)
- For all computational points in domain
- Can be integrated easily into that one large global domain from pole to pole
- Easily processed into netCDF, conveniently readily available
- Occupies 1/10 the space of full spectra
  - 3029 Mbytes for one snapshot of restart files
  - 299 Mbytes for one snapshot of reduced spectra files
- Can be reconstructed to the approximated full spectrum using MLM and MEM
- Preliminary tests demonstrate suitability as boundary conditions for SWAN
- Will be incorporated into the Spritzer, a newly developed WAVEWATCH III application

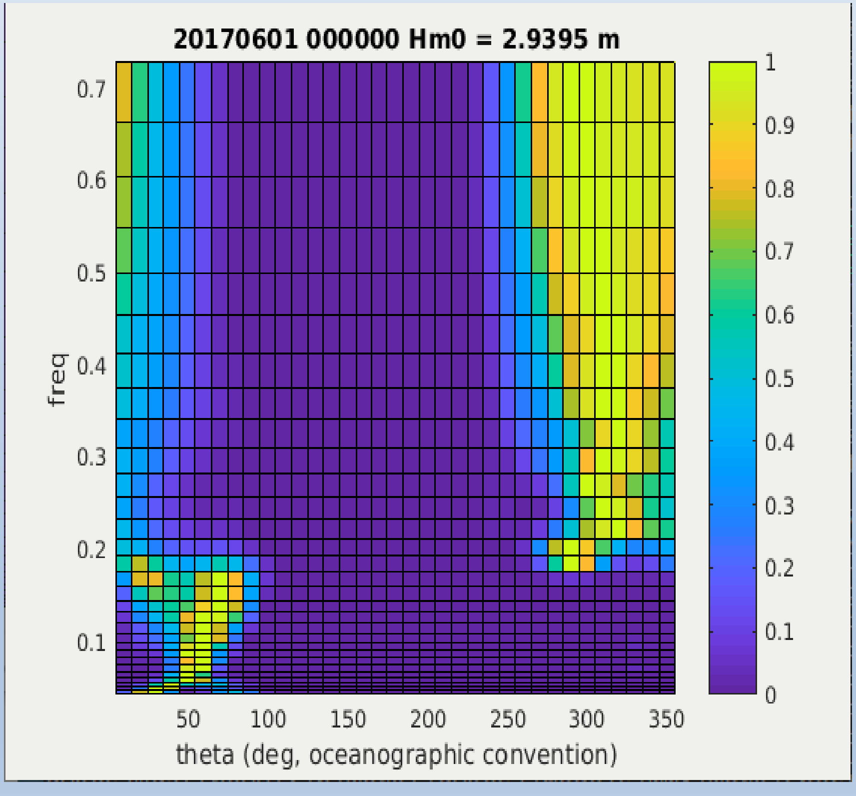
Frequency Spectra



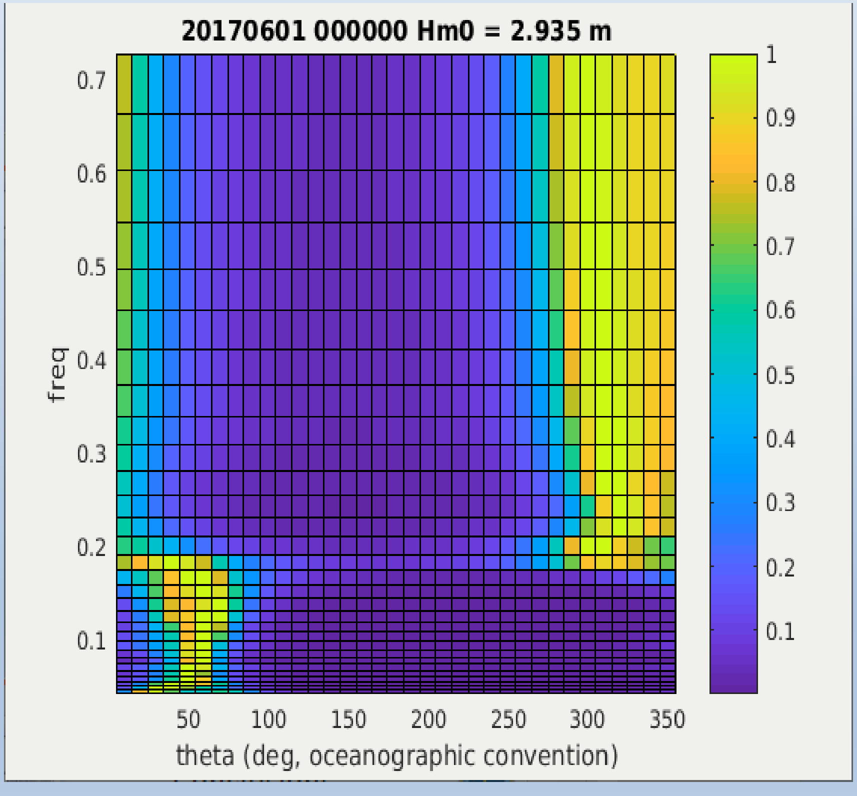
Plotted from netCDF right out of the box, i.e. passing along metadata as-is.

Reconstructed Spectra

Original



Reconstructed



Conclusions

- Global WAVEWATCH III upgraded for FNMOC
  - More streamlined IRI configuration, maintainable
  - DA for all domains, WW3 modules in NCODA 4.1
  - Ice from HYCOM-CICE and IC4
  - Performs more accurately than last version
  - Performs faster in terms of CPU time with higher resolution
- Upcoming features
  - Reconstructed full spectra from reduced form which takes less space
  - Implement in Cylc
  - Rogue wave estimator slated to use output from this model

Acknowledgements

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