

USACE CODS WAVE INFORMATION STUDY (WIS)

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WAVE INFORMATION STUDY (WIS)



Outline:

1. WIS Description and Purpose
2. WIS Historical Perspective
3. WIS Operations
4. WIS Evaluations
5. WIS Applications and Projects
6. WIS Product Sources
7. WIS Portal Walkthrough
8. WIS Future: NuWIS

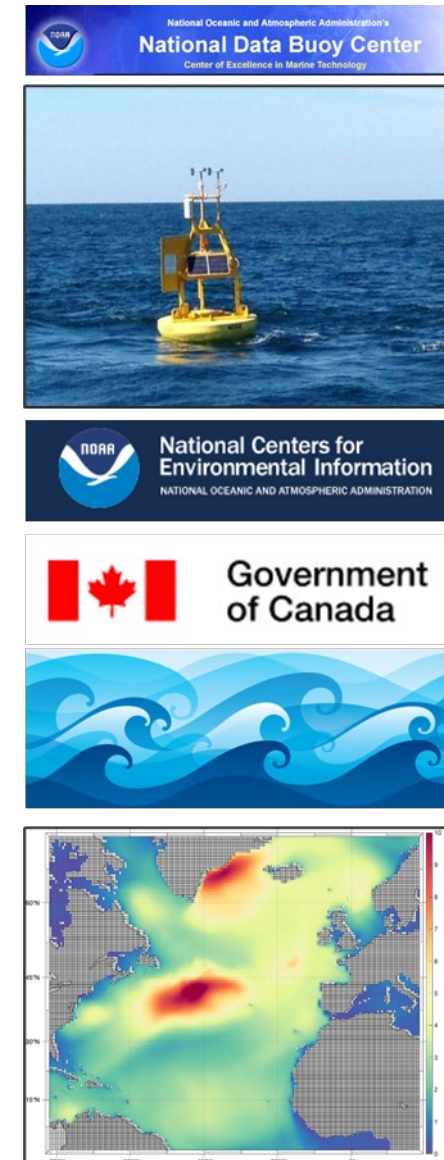




WIS DESCRIPTION AND PURPOSE



- **The Wave Information Study, or WIS, provides a national resource of long-term wave climatologies for all U.S. coastal waters.**
- Stems from the need for wave climatology estimates – observations too expensive, so WIS fills in the spatial gaps
- WIS provides long-term (1980-2024) wave estimates along all US coasts, including the Great Lakes, for pre-selected output locations
- **Hindcast wave estimates (height, wave period, and direction) and directional spectral estimates**
- WIS uses high-resolution wind and ice concentration fields, and third generation phase average wave modeling technologies.
- WIS estimates evaluated to point-source measurements, drifter buoys, and satellite-based altimetry, to ensure that we provide high quality wave estimates.
- **Ultimately, the multi-decade hindcasts and storm event archives are generated to meet tomorrow's coastal engineering needs today.**





WIS HISTORICAL PERSPECTIVE BEFORE 2010



- Started in early 1970's Great Lakes (Resio and Vincent)
- Migrated to the Atlantic Coast (New England District and SA-Division)
- Established Work Unit (~1979) under the CFDCP
- ~ CDIP was established under USACE funding
- Moved to new program Coastal Ocean Data System in 2010

PROBLEM

- Site-specific background and cumulative extreme event wave conditions are essential for USACE coastal planning, design, construction, and maintenance.
- Buoy measurements are too expensive to maintain an exhaustive network, so the **USACE Wave Information Study (WIS)** provides an network of historical background and extreme event wave model hindcast estimates to fill in the gaps.

SOLUTION

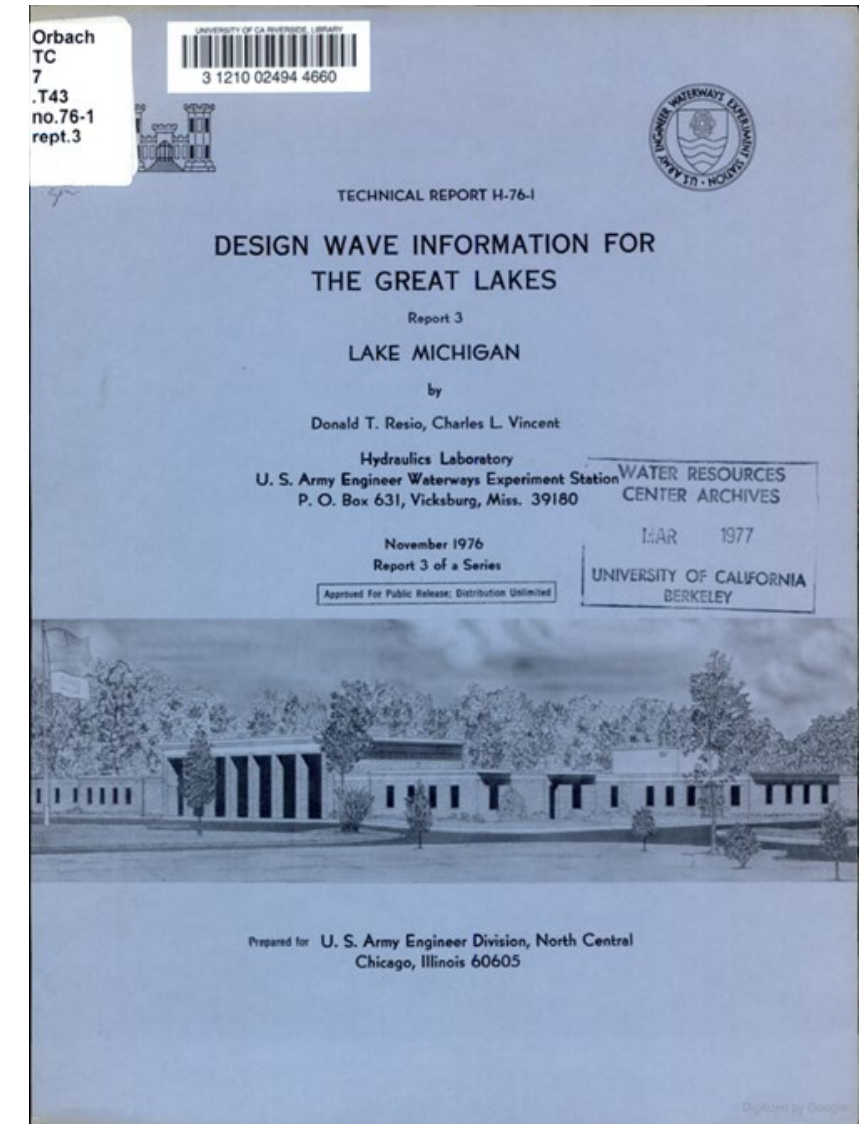
- **WIS** provides historical hindcasts of wave conditions at ~4000 sites along all U.S. coastlines, including the Great Lakes.
- **WIS** estimates are extensively evaluated to point-source measurements and satellite-based altimetry providing high quality wave estimates.
- Easy access to WIS estimates and tailored, interactive products via the **WIS Data Portal**: <https://wisportal.erdc.dren.mil/>
- **WIS Program Website**: <https://wis.erdc.dren.mil/>
- **Contact the WIS Team**: WISinfo@erdc.dren.mil

IMPACT

- Fully automated forty+ year hindcast of wave climatologies for all U.S. coastal waters, including the Great Lakes.
- **FY24 WIS Return on Investment per District Domain: 31,117 %**
- Applications anywhere reliable hindcast wave climate information is needed for **coastal risk management, civil works operations and planning, and coastal research**
- These multi-decade hindcasts and storm event archives are generated to meet tomorrow's coastal engineering needs today.

USACE Wave Information Study (WIS)

April 2024



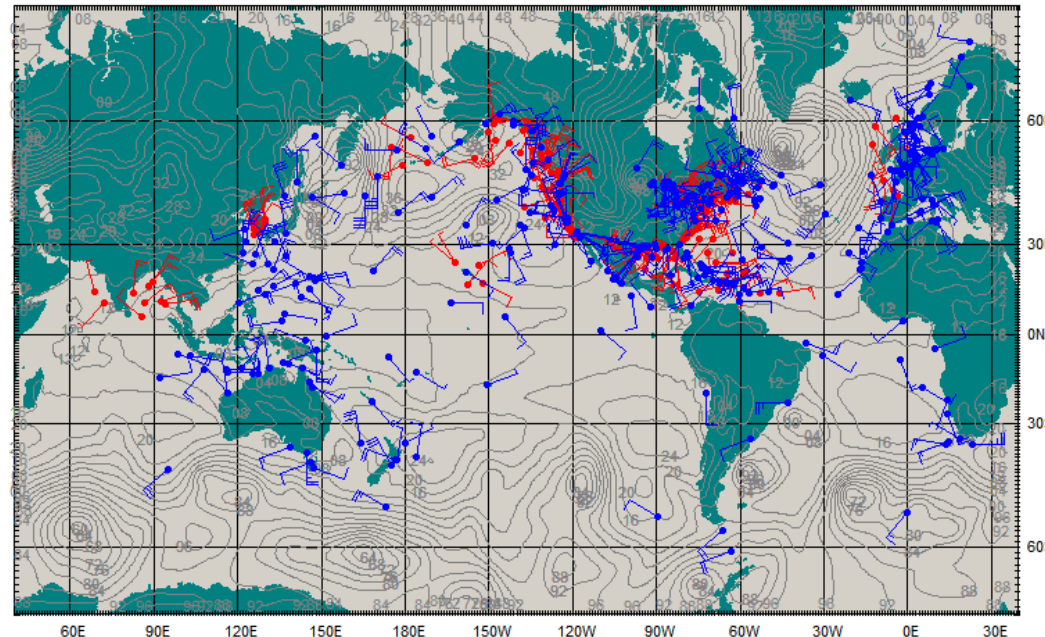


WIS HISTORICAL PERSPECTIVE 2010 - 2020



WIND FIELD SPECIFICATION

- Interpolated from land-based meteorological stations (Great Lakes)
- Generated winds from digital surface pressure archives (Atlantic)
- Used Numerical Weather Prediction wind fields (NCEP / FNMOC)
- OWI: AES-40 / MSC-50 (Atlantic)
- OWI: NCEP/NCAR Re-Analysis 1 + Scatterometer + tropical cyclones (Pacific)
- CFSR: Great Lakes
- ERA5: starting 2020





WIS NUMERICAL MODELS



WIS WAVE MODEL TECHNOLOGIES: Phase Average Models

- 2nd Generation Deepwater Wave Model (Resio and Vincent, 1978)
- Added shallow-water mechanisms to original 2nd Generation model (~mid-1980's)
- Added wave transformation method to carry waves into coastal waters (10m)
- 3rd Generation Wave Models (WAM, WAVEWATCH III and SWAN) (1990's)

They all solve the **Energy (or Action) Balance Equation** for the time rate change in a two-dimensional wave spectrum given by $F(f, \theta, x, y, t)$

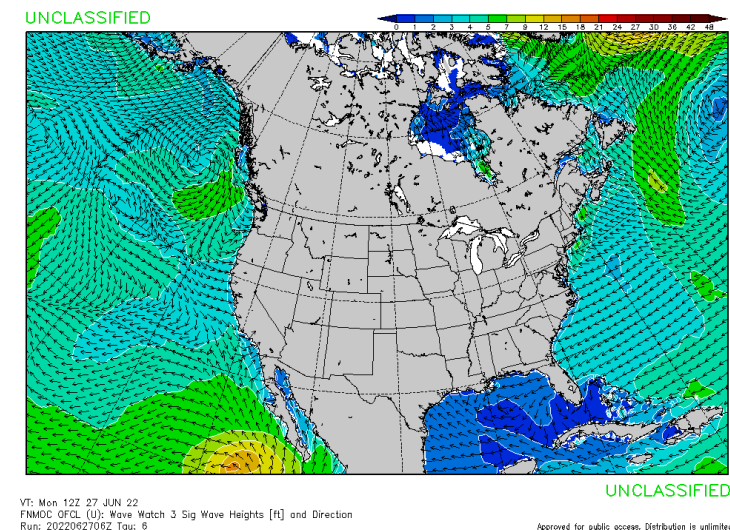
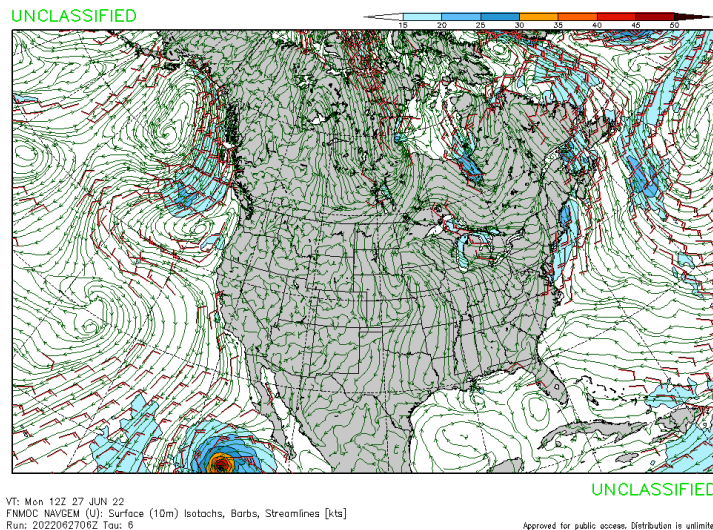
$$\underbrace{\frac{\partial F}{\partial t} + \vec{C}_g \cdot \nabla F}_{\text{Advection}} = \sum_{i=1}^n S_i = S_{TOT} = \underbrace{S_{in} + S_{ds} + S_{nl} + S_{w-b} + S_{br} + \sum_{j=1}^m S_j}_{\text{Source Terms}}$$



WIS INPUTS



- Source and Sink terms
 - *Any mechanism that is time dependent and acts on the spectrum:*
 - S_{in} : *Atmospheric Input*
 - S_{ds} : *Dissipation (White-Capping)*
 - S_{nl} : *Nonlinear Wave-Wave Interaction (Discrete Interaction Approximation)*
 - S_{w-b} : *Wave-Bottom Interaction (Bottom Friction)*
 - S_{br} : *Depth Induced Wave Breaking*
 - S_j : *Triad Interactions, Wave-Ice Interactions*

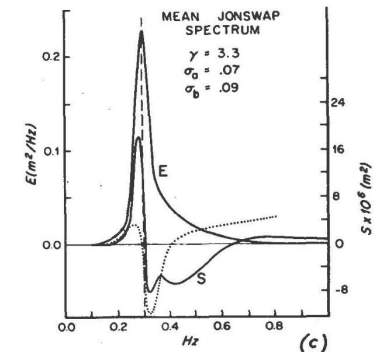




WIS WAVE MODEL



- 2nd Generation wave models use parametric formulations for source terms
 - Requires tuning (for different wind field specification)
 - Sets limit on the spectral shape
- 3rd Generation wave models use full 2-D spectra for the source terms
 - No a priori limit to spectral shape
 - Allows the spectrum evolve based on the source terms
- 3rd Generation wave modeling technology was developed based on
 - Sea-Wave Modeling Project (SWAMP)
 - 2nd Generation Models were run based on a series of *Academic Tests*
 - Models reported wide range of results
- EU provided \$10M for 10-years to develop a community wave model to be used operationally at the European Centre for Medium Range Weather Forecasts (ECMWF)



OUTCOME WAS WAM

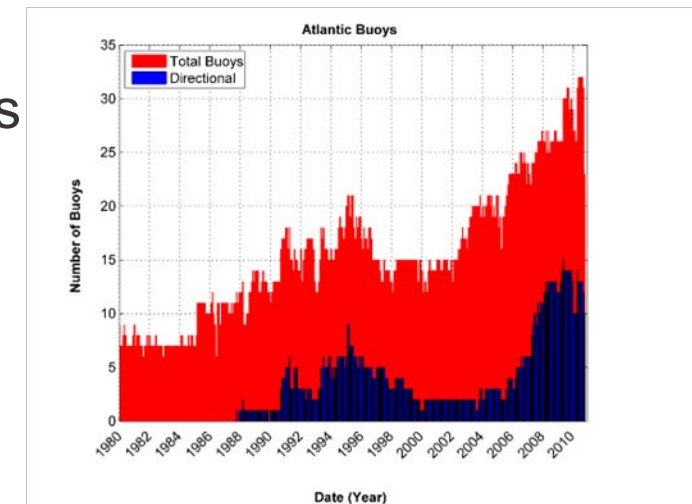
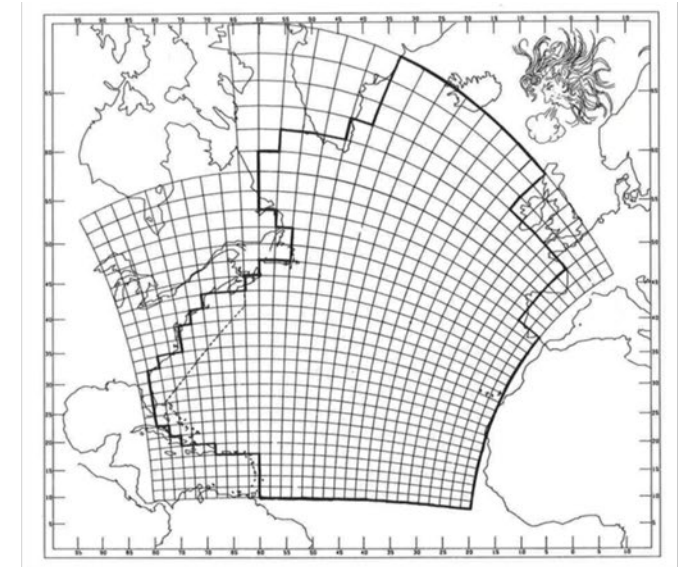


WIS COMPUTATION



COMPUTATIONAL PLATFORMS AND OPERATIONS

- Computer platforms limited in the 1970's – 1990's
 - Memory bounded
 - No Internet / IO-magnetic tapes
- Labor intensive
- Expensive data reports
- From the 1990's
 - Computer resources improved
 - Increased the number of WIS output stations
 - Internet established the first WIS website based on static products
 - Operations became semi-automated hindcasts (yearly updates)
 - When measurement availability increased added evaluations





WIS TECHNOLOGICAL ADVANCEMENTS



- The WIS Hindcast aims for temporal consistency
 - Wind field specification does not change over the period of record
 - Wave model technology does not change over the period of record
 - Grids and all other factors associated with the hindcast do not change
- Replacement of the WIS Hindcast Archive
 - Aware of technological advancements occurring in the Waves community
 - Parallel testing and evaluations of new winds and/or new wave model technology
 - Metrics to determine the net impact of these advancements
- If improvements are found:
 - The entire hindcast is re-run replacing the entire archive
 - Use of version control of the final archived set of estimates

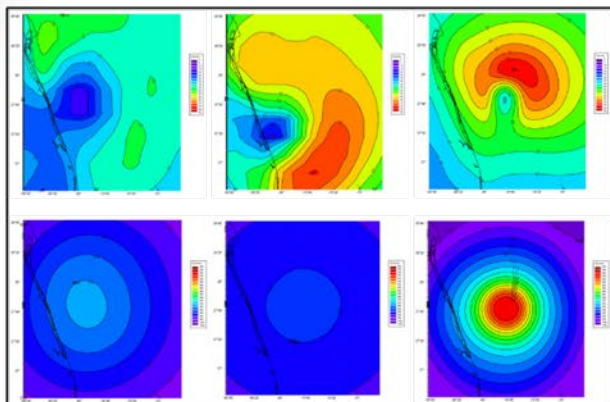
REPLACEMENT PERFORMED IN 2011 FOR ALL WIS DOMAINS



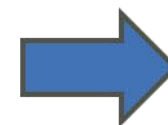
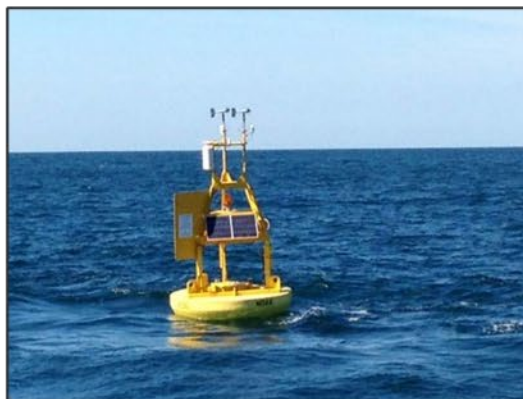
WIS OPERATIONS



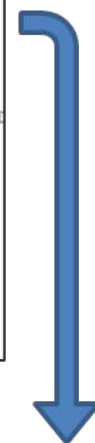
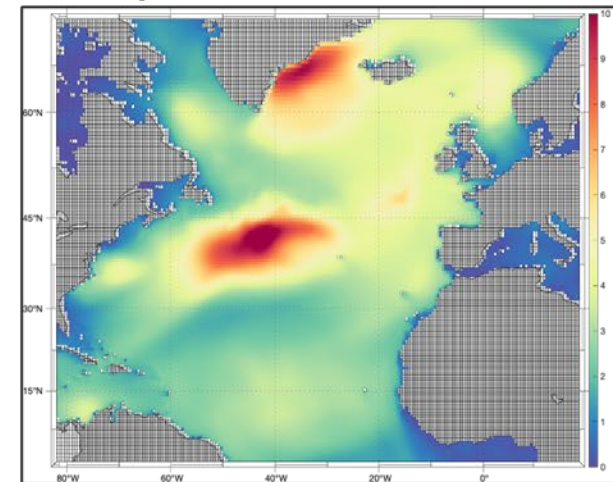
Get wind and ice fields



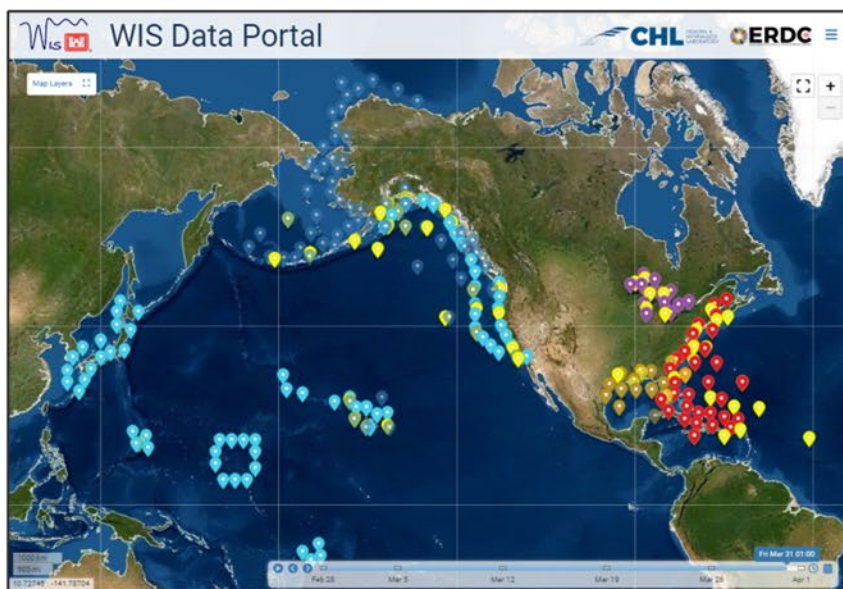
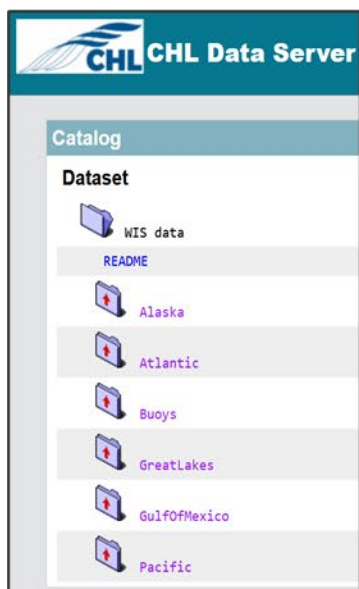
Update buoy locations
for annual run



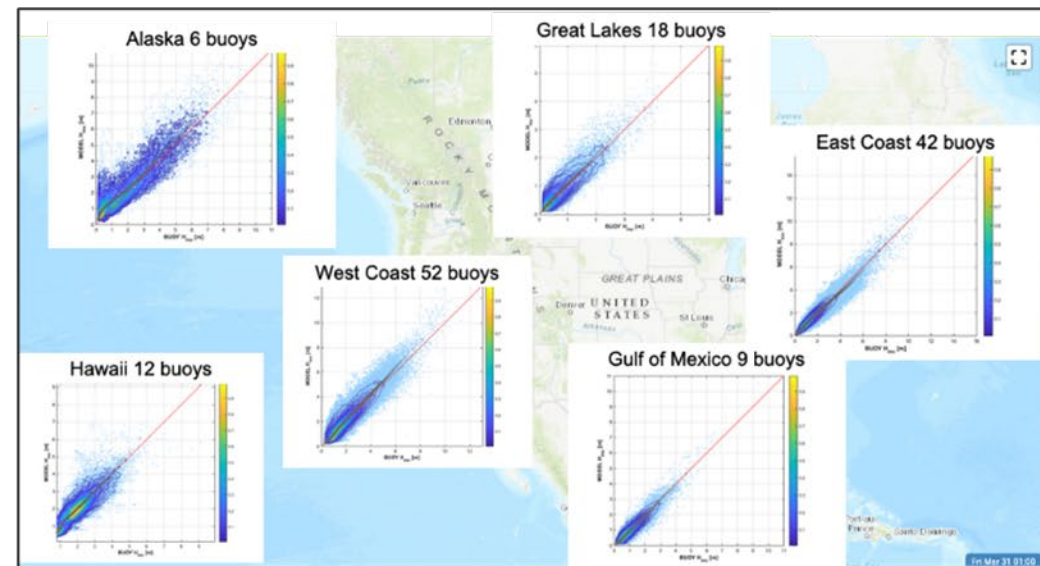
Setup and run WW3 and WAM



Update Server and Generate Products



Evaluate results





WIS CURRENT OPERATIONS



WAVE MODELING TECHNOLOGY:

- WAVEWATCH III: Atlantic and Pacific
- WAM: Gulf of Mexico / Western Alaska / Great Lakes

Why Two Models?

- Model evaluations were performed for each domain (3-yr POR)
Model selected based on comparisons to measurements
- At the time only WAM had ice field implementation (Western Alaska and Great Lakes)

Similarities / Differences

- WAM is a wave model - No tuning parameters
- WAVEWATCH III is a wave model system
 - More options for variants in source term specification/more tuning parameters

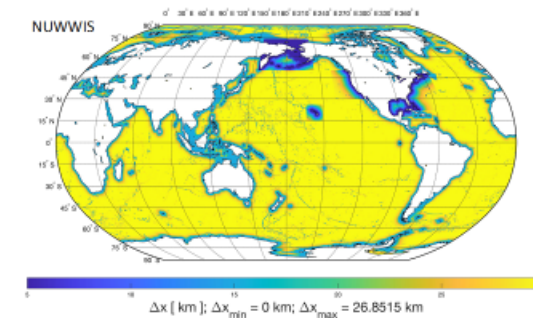
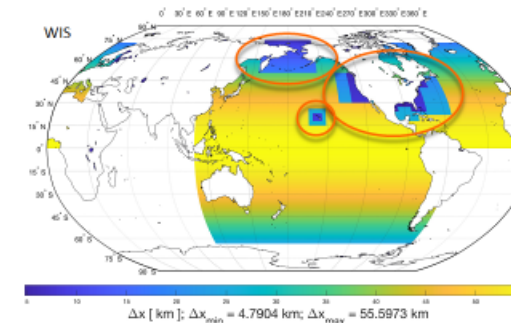
Current R&D effort is looking into the use of a global unstructured WAVEWATCH III domain



USACE WAVE INFORMATION STUDY (WIS)



Nearshore Unstructured Worldwide
Wave Information Study



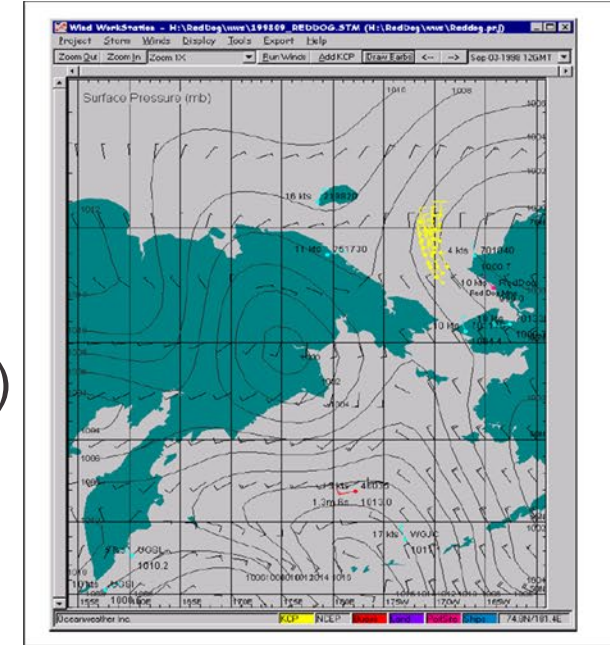
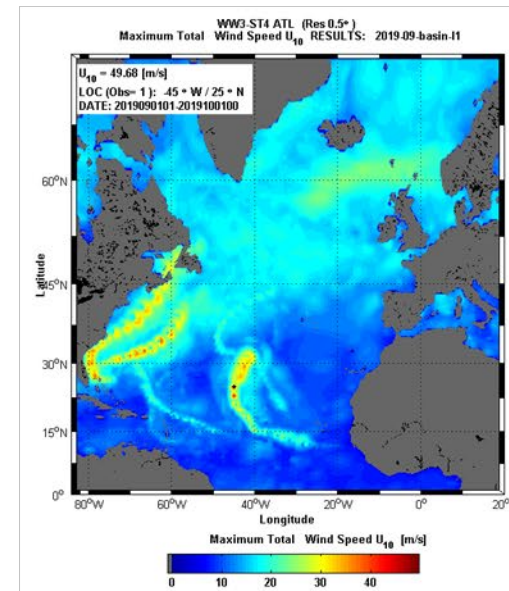
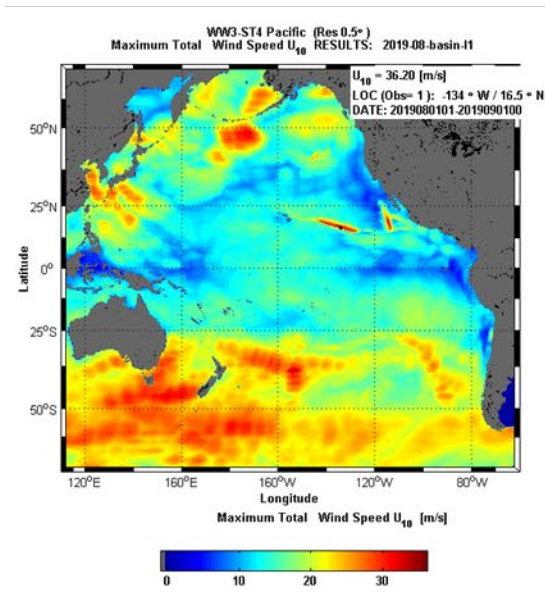


WIS WIND FIELDS (ATL, PAC, GOM, AK)



WIND FIELD SPECIFICATION (CONTRACTED)

- Adapted from NCEP/NCAR Re-Analysis-1 (pre-2020) and ERA5 (post-2020) fields
- *Value Added*
 - Scatterometer (QUIKSCAT) adjustments (pre-2020/NCEP/NCAR)
 - Embedded tropical cyclones
 - Kinematic analysis of major storm events (~10/domain)





WIS WIND FIELDS (GREAT LAKES)



WIND FIELD SPECIFICATION

- Climate Forecast System Reanalysis: CFSR
- Interpolated to the wave model grid
- Retained the Land/Sea Mask: Terrain-Marine Interface
- Found to be spatial coherent
 - Orographic Effects
 - Steering by land masses

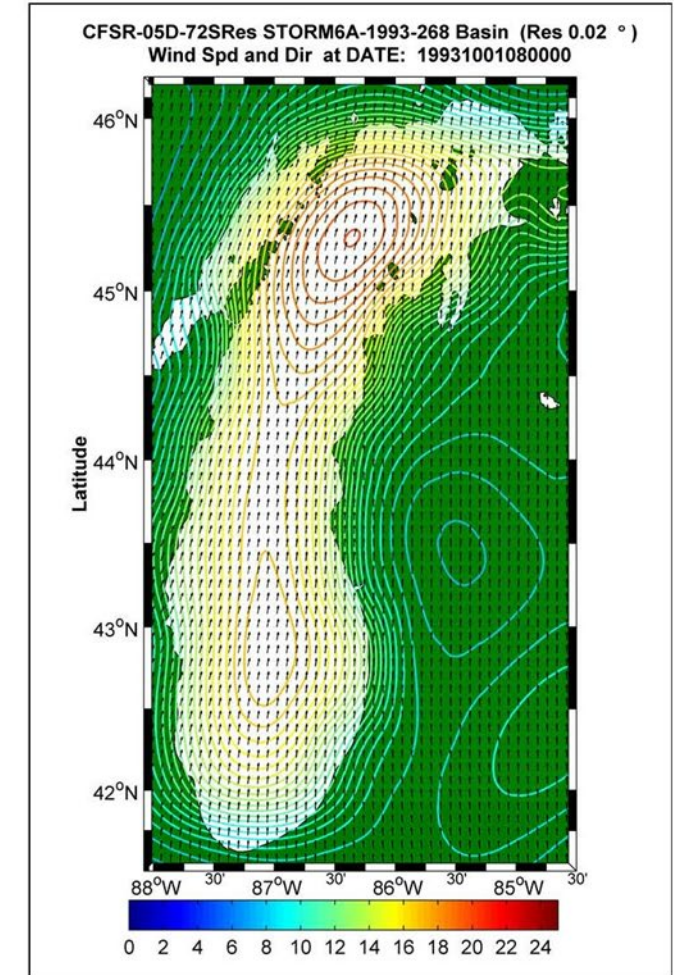
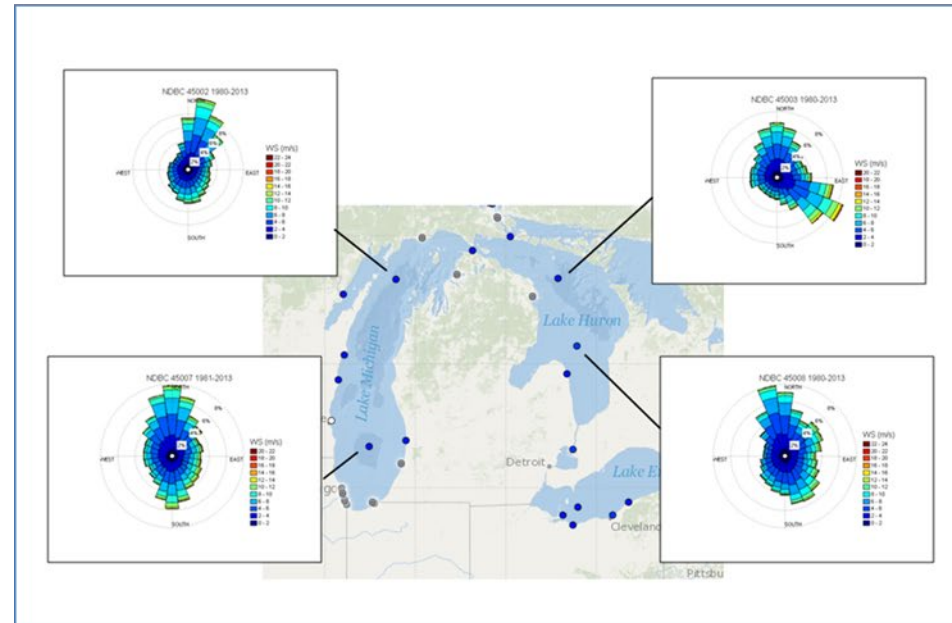


Figure 1-11. Snapshot of wind speed isotach color contour (m/sec) and wind directions (arrows) using the CFSR for Storm 6W.

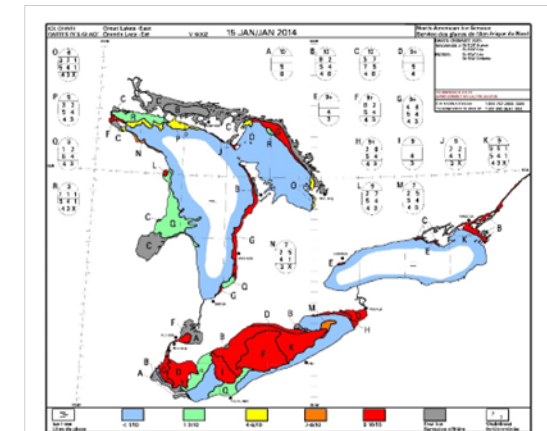
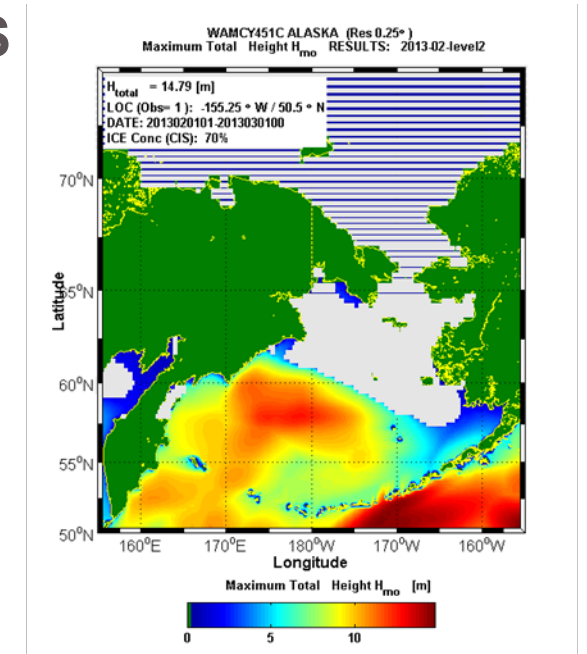
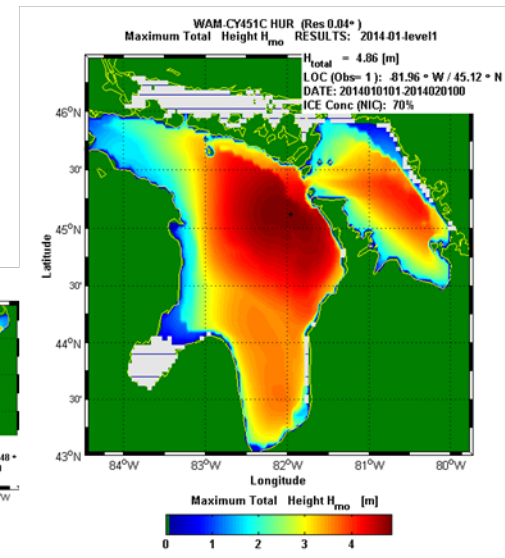
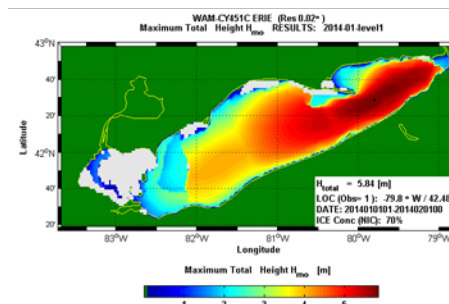


WIS ICE CONSIDERATION



ICE CONCENTRATION FIELDS: WESTERN ALASKA / GREAT LAKES

- Western Alaska
 - Ice Product- Climate Forecast System Reanalysis (pre2020)
 - Ice Product- ERA5 (post2020)
 - Gridded ice concentration fields
- Great Lakes
 - National Snow & Ice Data Center (NSIDC) ice product
 - Images (verification / digital)
- Set ice concentration threshold value (70%)
 - If met or exceeded set water to land



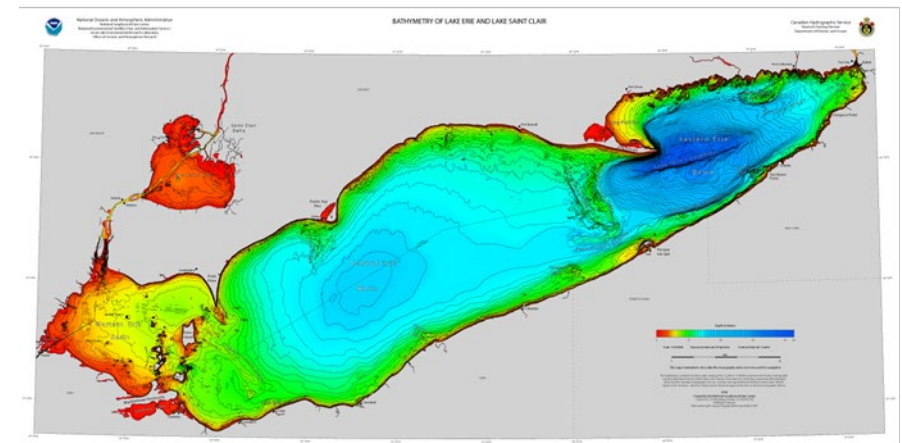
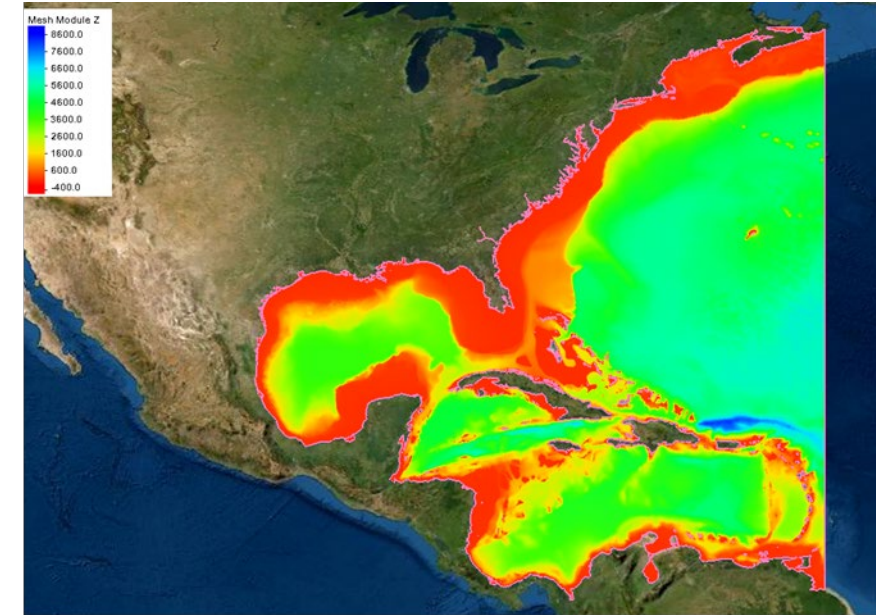


WIS BATHYMETRY



WAVE MODEL BATHMETRY AND GRIDS

- Atlantic, Gulf of Mexico and Pacific
 - General Bathymetric Chart of the Oceans: GEBCO
 - Providing elevation data on a 15 arc-second interval grid
 - Data are an average of multiple surveys
 - Near coastal areas: GEOphysical DAta System: GEODAS
- Great Lakes
 - NOAA-GLERL (available at NOAA/NCEI)
- Resolution Selection
 - Based on processes modeled
 - Based on input wind fields

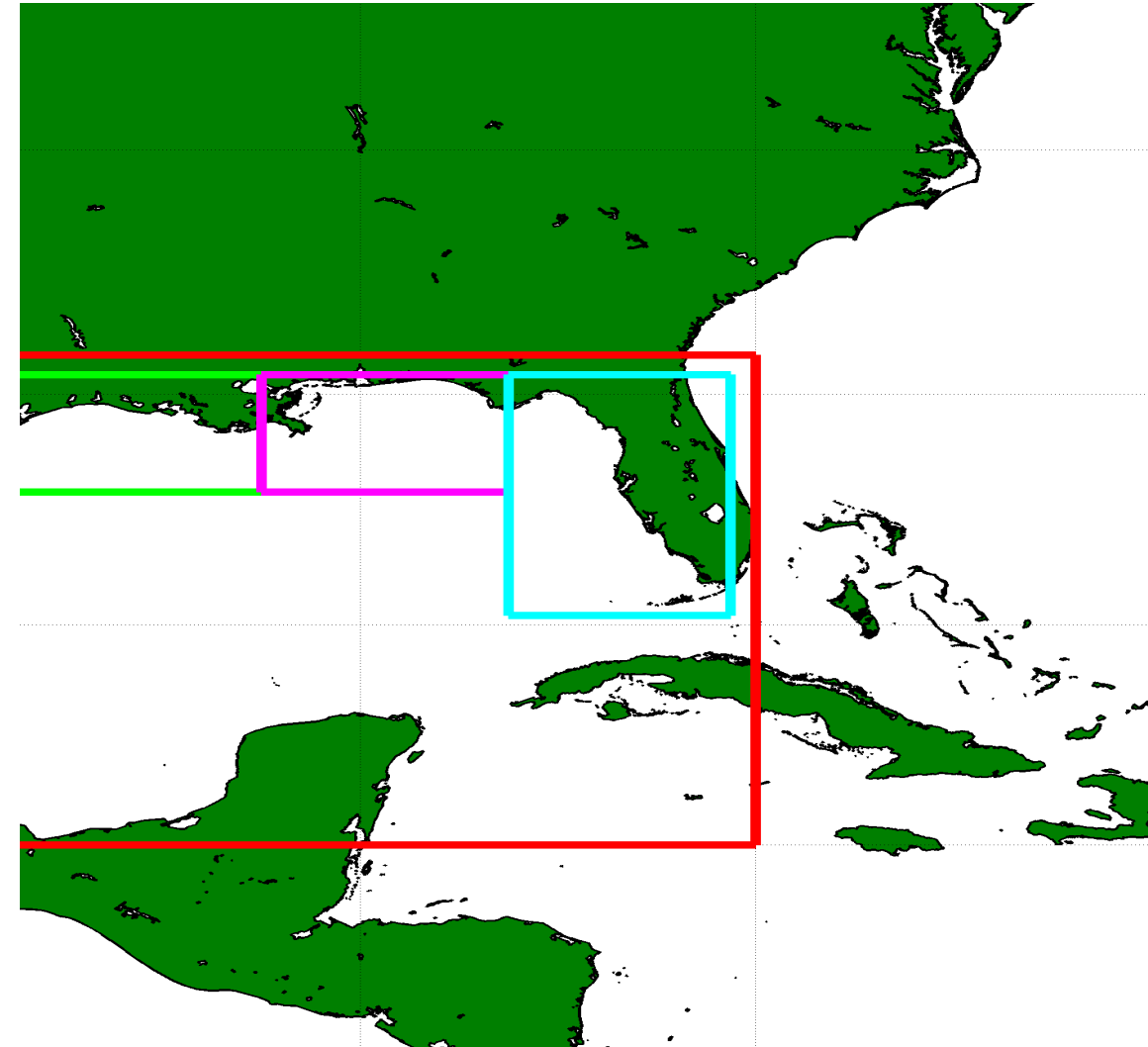




WIS GRID RESOLUTION AND NESTING



- Spherical / Cartesian Grids
 - Grid nesting minimizes computational load running wave model
 - Higher resolution coastal areas (where needed)
- Requires 2D spectra
 - Generation of output Boundary Condition
 - Acceptance of input Boundary Condition
- Model Differences
 - WAM: one way nesting
 - WAVEWATCH III: two-way nesting





WIS HINDCAST SCRIPTING



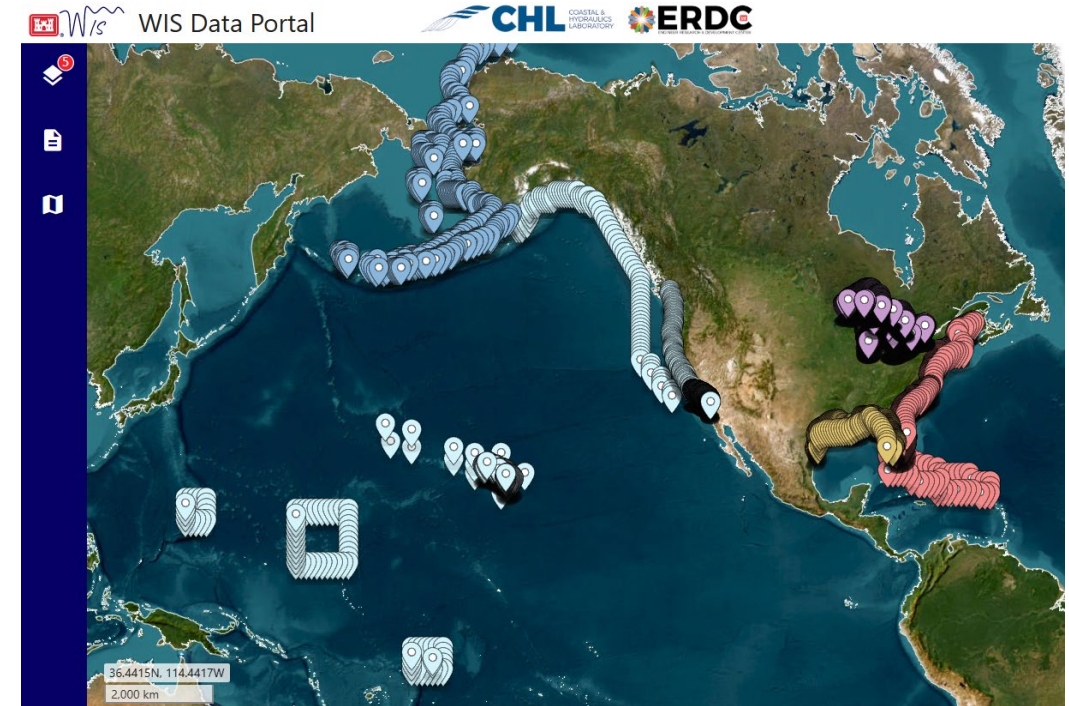
- Despite the differences between WAM and WW3, the Standard Operation Procedure is **IDENTICAL**
 - Upload files to HPC platform
 - Shell Scripts
 - Restart, Boundary Condition Files from previous yearly update
 - Preprocessing (e.g. geographical information) file
 - New wind and ice fields
 - Corrected evaluation sites in input file
 - Fully automated: Controller Shell Script
 - Works off of a wind list (by month)
 - Generates shell to
 - ❖ Preprocess wind field
 - ❖ Run Wave Model
 - ❖ Post-Process: Output file generation
 - ❖ File Transfer (to HPC Archive and download for local processing)



WIS EVALUATION SITES



- WIS Station Points
 - Defined by Basin/Level/Station Number
 - Will not change over POR
 - Threshold of water depths ~10m
 - Why 10m and so far from the coast?



- No universal consensus for finite depth mechanisms (e.g. S_{w-b} , S_{br} , etc).
- Temporal changes in water depth not defined (e.g. tides and surge)
- Local effects not appropriately modeled to spatial grid resolution
- Increase in computational requirements



WIS EVALUATION SITES, 2



- Point source measurements (e.g., buoys)
 - NOAA National Data Buoy Center (NDBC)
 - Coastal Data Information Program (CDIP)
 - Meteorological Service of Canada (MEDS)
 - Partner sites (e.g., Federal, State, Local and Universities)
- Critical to have
 - Metadata describing the data set
 - At a minimum frequency spectra

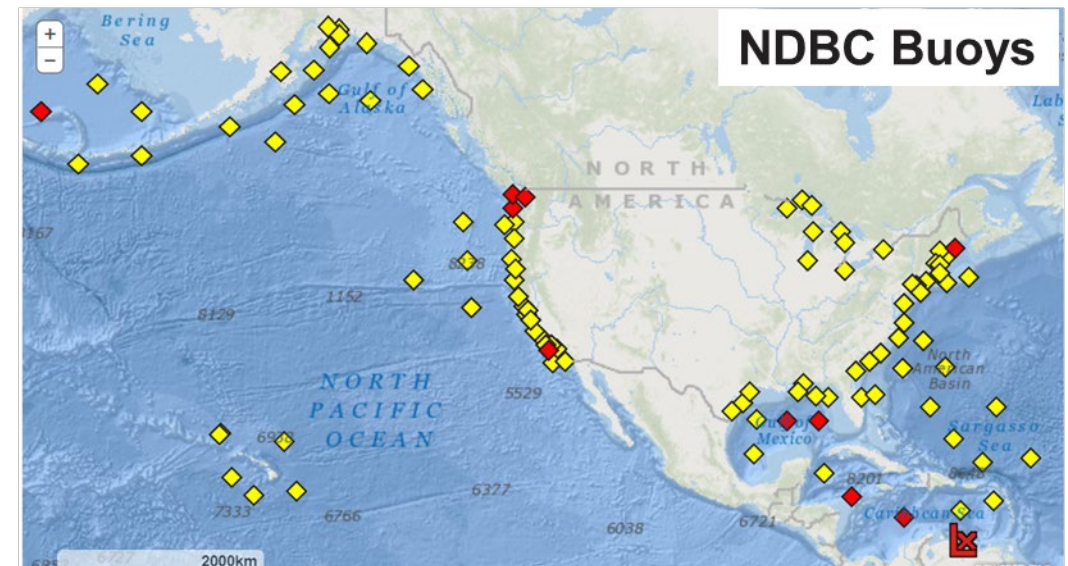
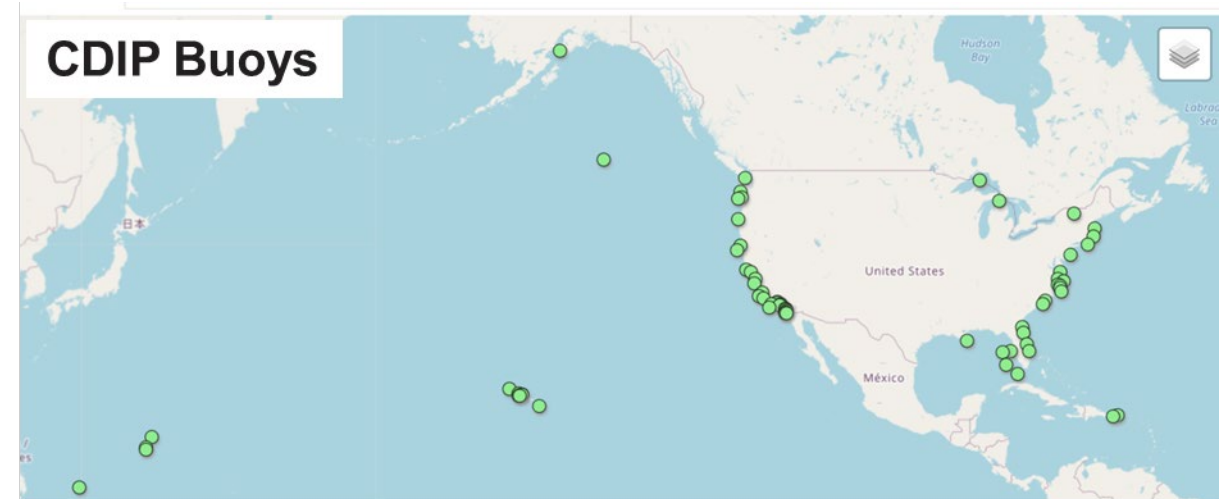




WIS EVALUATION SITES, 3



- Buoys move location over time from re-deployments
 - Could move greater than the grid resolution dimension
 - Need to update the evaluation site list on a yearly/monthly basis
 - Minimize the errors associated with differences in positions

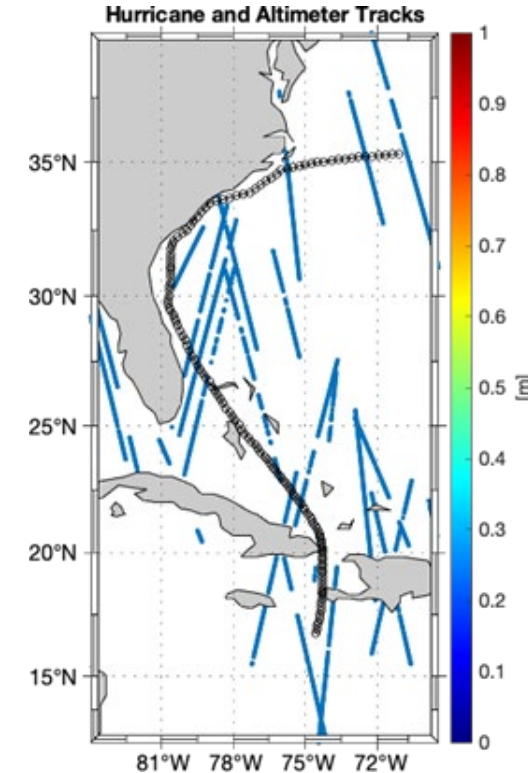




WIS EVALUATION ALTIMETRY: FAR FIELD

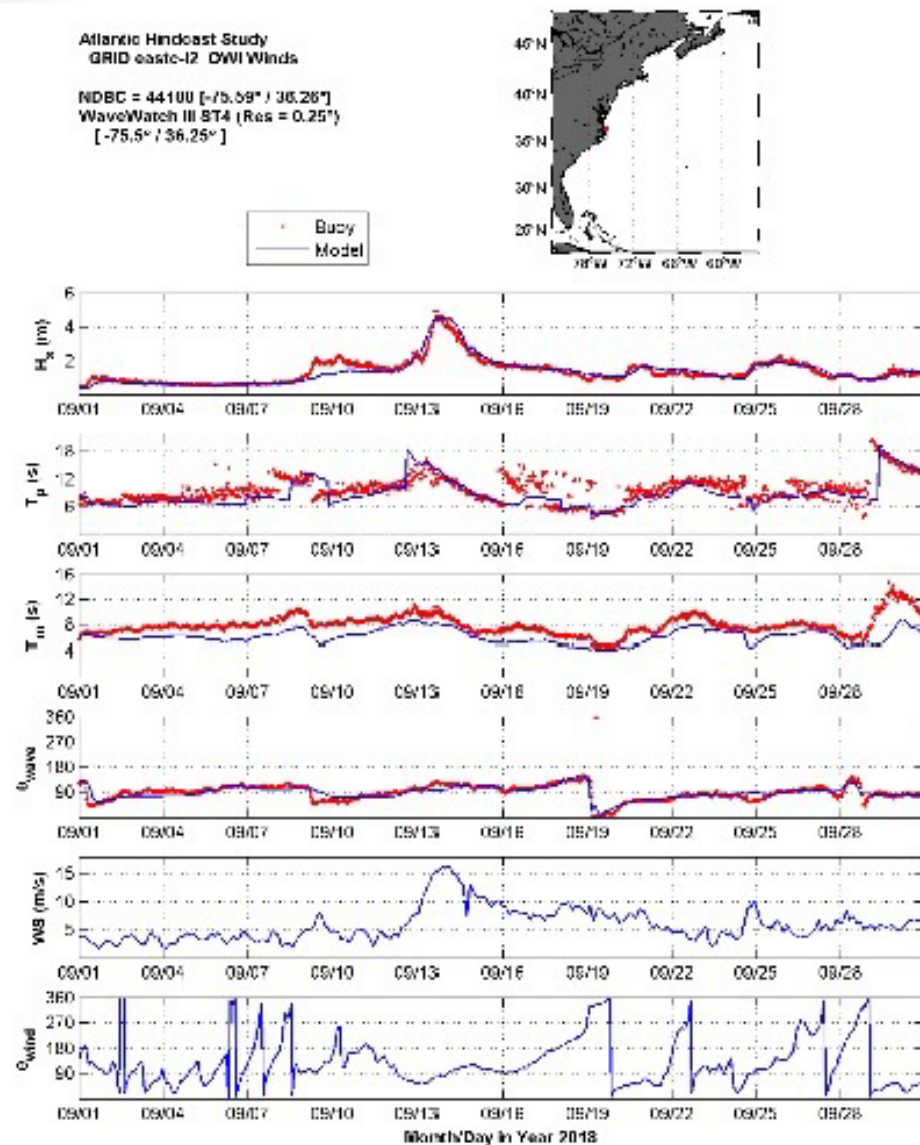
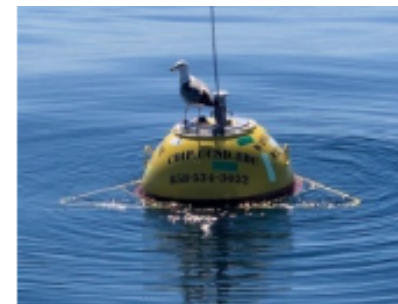


- Satellite-based Altimetry
 - Estimates Significant Wave Height
 - Excellent spatial coverage
 - With multiple satellites more coverage
 - Limited in time based on return cycle
 - Cover areas where no buoy data exist
- Wave Measurements from drifting buoys
 - SIO-E. Terrill
 - Coverage in far-field / Currents
 - Returns frequency spectra / Four Directional Moments
 - Cover areas where no moored buoys exist





WIS VALIDATION AND VERIFICATION: POINT

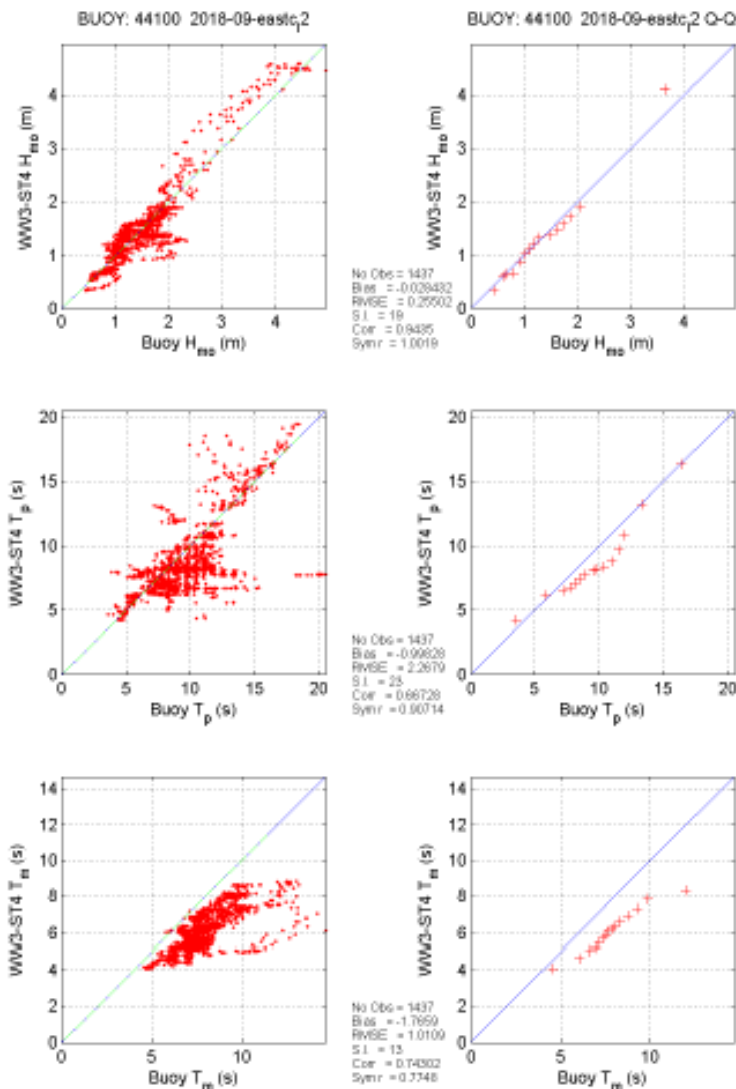


Time series (TS) analyses:

- Shows how variables change over time - shows how the data adjusts over the course of the data points as well as the final results.
- Usually requires a large number of data points to ensure consistency and reliability, ensuring a representative sample size and that analysis can cut through noisy data.
- Highlights trends or patterns, isolates outliers and can account for seasonal variance.
- Time series data can be used for forecasting—predicting future data based on historical data.



WIS V&V: POINT SOURCE



Validation Statistics:

- n – number of comparable observations and model estimates.
- Mean – the average of a data set (average wind speed).
- Bias – anything that leads to a systematic difference between the true observations and the model estimates. Basically highlights flaws in the model process, which generates results that don't accurately represent the population.
 - 1 – 1 plot to compare means
 - Quantile-quantile (Q-Q) plot to test quantiles against each other
- Root Mean Square Error (RMSE) – the differences between values predicted by a model and the observations.
- Correlation coefficient – the strength of the linear association between two variables. Always a value between -1 and 1.

r = correlation coefficient

x_i = values of the observations

$\bar{x}$ = mean of the observations

y_i = values of the model estimates

$\bar{y}$ = mean of the model estimates

$$\text{Bias} = \text{Mean} - \text{True value}$$

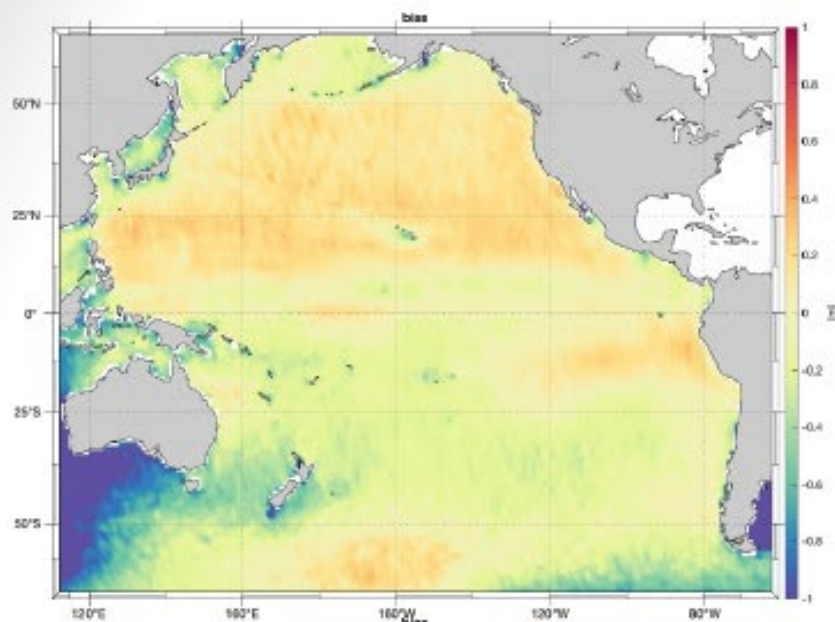
$$\% \text{Bias} = \frac{\text{Mean} - \text{True value}}{\text{True value}}$$

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^N (\text{Predicted}_i - \text{Actual}_i)^2}{N}}$$

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$



WIS V&V: FAR FIELD CASE STUDY

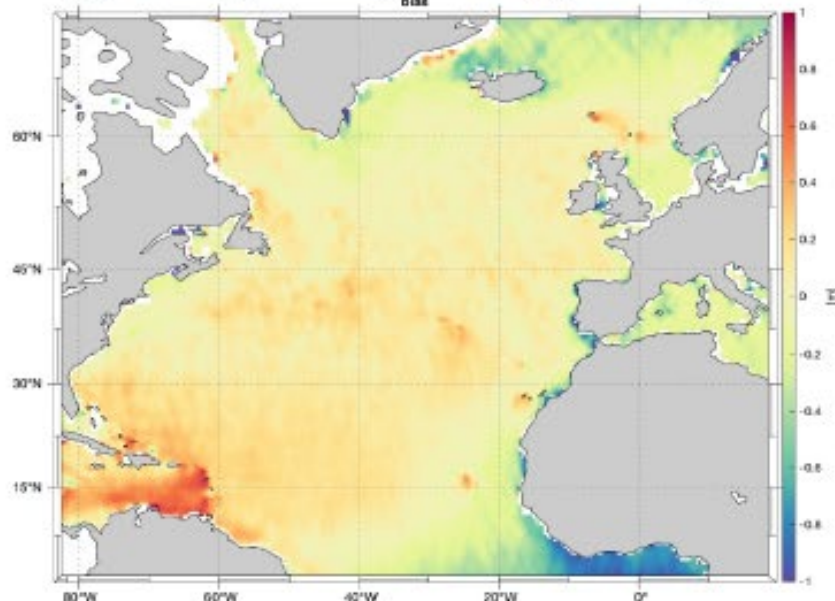


Altimeter validation

Bias: difference between observations and model
RMSE: highlights the differences

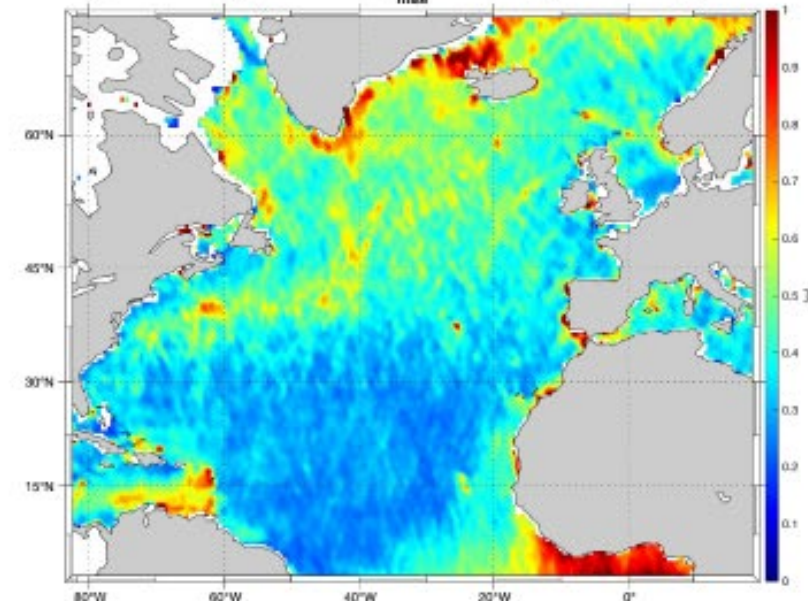
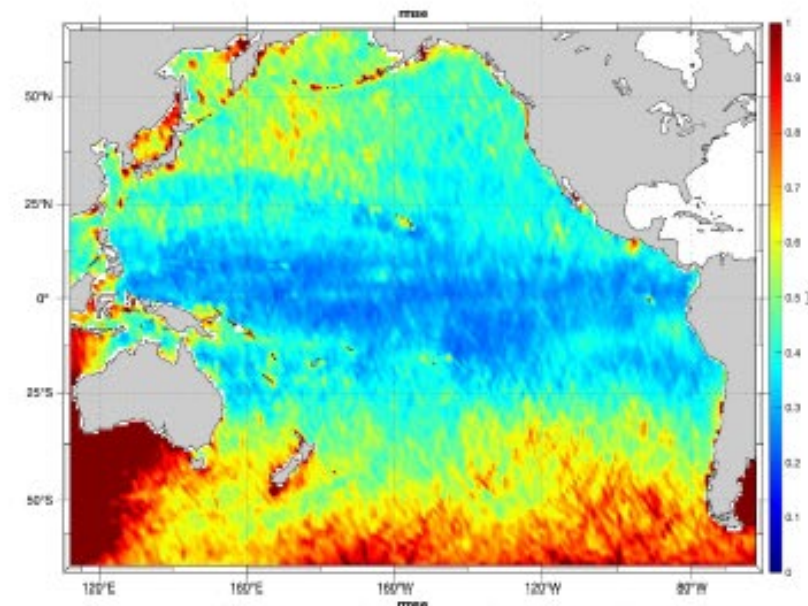
Pacific Basin

- Positive bias for most of the north Pacific
- RMSE of 0.4 or less for most of the US West Coast = good



Atlantic Basin

- Positive bias in Caribbean region - could be due to land effects
- Higher RMSE and bias where gulf stream tracks in N. Atlantic.





USACE QCC MEASUREMENT ARCHIVE



Question: How accurate are the wave measurement data that are used for USACE WIS validation, wave related R&D and wave model improvements?

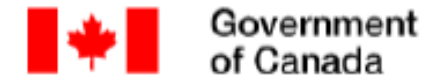


Goal: Clean Data for Assimilation / Uncertainty Quantifications (UQ) – USACE wave applications and climate trend analyses



Observational data storage errors – develop a clean, quality controlled measurement archive.

- Combining NDBC website (no metadata – QA/QC)
- National Centers for Environmental Information (NCEI) website (low QA/QC, real-time feed)
- CDIP – direct link to website
- Canadian wave data: Marine Environmental Data Section Archive (MEDS)





OBSERVATIONAL DATA STORAGE ERRORS



USACE Quality Controlled, Consistent Archive

Objective: to archive best available measurement data – meteorological, spectral and integral wave measurements

Hall, C. & R.E. Jensen.
2021. Utilizing Data from the NOAA National Data Buoy Center. ERDC/CHL CHETN-I-100

:: Both re-published within the UNESCO / IOC Ocean Best Practices Repository: <http://dx.doi.org/10.25607/OBP-1087>



US Army Corps of Engineers

Utilizing Data from the NOAA National Data Buoy Center

By Candice Hall and Robert E. Jensen

PURPOSE: This Coastal and Hydraulics Engineering Technical Note (CHETN) guides users through the quality control (QC) and processing steps that are necessary when using archived U.S. National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center (NDBC) wave and meteorological data. This CHETN summarizes methodologies to geographically clean and QC NDBC measurement data for use by the U.S. Army Corps of Engineers (USACE) user community.

INTRODUCTION: The USACE acknowledges that “Estimates of wave conditions are needed in almost all coastal engineering studies” (USACE 2002, II-1-1). The expense to monitor waves along all U.S. coasts can become cost prohibitive; however, the importance of wave measurements is real. The USACE has adopted a paradigm of strategically positioning wave measurement sites to maximize their effectiveness and filling in the gaps with model estimates. To satisfy this requirement, in the 1970s, the USACE developed the Wave Information Studies (WIS) that computes long-term (over 4 decades), hourly wave estimates along all U.S. coastlines, including the Great Lakes and U.S. island territories (USACE 2020).

The WIS wave estimates require in situ buoy wave data for validation and calibration similar to that of Ortiz-Royero and Mercado-Irizarry (2008); Reguero et al. (2012); Rusu and Guedes Soares (2012); Van Nieuwkoop et al. (2013); Stopa and Cheung (2014); Stopa and Mouche (2016). One source of WIS validation data is the NDBC network of meteorological and wave measurement buoys.

NDBC has deployed buoys with wave measurement capabilities around the U.S. coastline and the Great Lakes since the 1970s. Long-term time series data from a single buoy site have experienced multiple instrumentation modifications and data archival upgrades with advances in technology. Between 1970 and 2020, NDBC has deployed at least eight directional wave measurement systems for operational or experimental use (e.g., Steele et al. 1985; NDBC 1996; NDBC 2003; Teng et al. 2007; Crout et al. 2008; Teng et al. 2009; Riley et al. 2011; Hall et al. 2018a; Riley et al. 2019).

While NDBC has worked hard to minimize the effects of the modifications on its data (e.g., Teng and Timpe 1995; Teng et al. 2007; Riley and Bouchard 2015; Hall et al. 2018a), different versions of these data are archived in multiple online locations, each with their own set of storage protocols. If these data are used without prior knowledge of these archival idiosyncrasies, use of the measured data in wave-related research activities may be compromised. This CHETN summarizes the steps required to achieve the best available time-series datasets for all buoy data collected by NDBC since the 1970s.

ERDC/CHL CHETN-I-100
MONTH 2021

Utilizing Data from the NOAA National Data Buoy Center

By Candice Hall and Robert E. Jensen

PURPOSE: This Coastal and Hydraulics Engineering Technical Note (CHETN) guides users through the quality control (QC) and processing steps that are necessary when using archived U.S. National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center (NDBC) wave and meteorological data. This CHETN summarizes methodologies to geographically clean and QC NDBC measurement data for use by the U.S. Army Corps of Engineers (USACE) user community.

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Hall, C. & R.E. Jensen. 2022. USACE Coastal and Hydraulics Laboratory Quality Controlled, Consistent Measurement Archive. *Scientific Data* 9:248. <https://doi.org/10.1038/s41597-022-01344-z>

scientific data

OPEN

DATA DESCRIPTOR

USACE Coastal and Hydraulics Laboratory Quality Controlled, Consistent Measurement Archive

Candice Hall^{1,2} & Robert E. Jensen¹

The US Army Corps of Engineers (USACE) utilizes the National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center (NDBC) buoy measurements for validation of their wave models and within coastal applications. However, NDBC data are accessible via multiple avenues, each with their own source-specific storage, metadata, and quality control protocols, which result in inconsistencies in the accessible data. Therefore, USACE has developed an independent, quality controlled, consistent (QCC) Measurement Archive that captures the best available NDBC observations with verified metadata. This work details the methodology behind this USACE QCC Measurement Archive; showcasing improvements in data quality via geographical location and wave parameter examples. Note that this methodology only removes known erroneous data; it does not verify data quality from all alternate sources. This self-describing, USACE QCC Measurement Archive therefore provides a database of consistently stored, geographically QA/QC'd NDBC data and metadata.

Background & Summary

One of the US Army Corps of Engineers (USACE) missions is to oversee operations and maintenance activities in the coastal waters of the U.S. These activities include sediment transport, hardened structures, harbor navigability, climate resilience and coastal protection, all of which require knowledge and assessment of the wave climate. For practical assessments, USACE wave-related technologies require accurate and homogeneous wave measurements from in situ observational platforms.

To that end, USACE sponsored an investigation into uncertainty errors in the wave measurement systems that are used for evaluating products such as their Wave Information Study (WIS), a wave forecast effort that serves as the basis for resolving the U.S. wave climate. Of particular interest are measurement errors that compromise wave model evaluations. These errors may be indistinguishable from wind forcing or wave model deficiencies, and may transfer into other USACE wave and coastal applications.

One source of validation data is the National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center (NDBC) on its buoy meteorological and wave measurements. As of 2022, NDBC publishes their data via two different streams: real time and historical. The real time data feed undergoes internal, automated QA/QC protocols to meet emergency management and forecasting agency requirements that require swift publication to the Global Telecommunications System (GTS). These “Real Time Data” files are also published within individual station pages on the NDBC website as tabular files that are continually updated and cover the last forty-five days (e.g. https://www.ndbc.noaa.gov/station_realtime.php?station=43009).

Once latency constraints are met, NDBC manually QA/QC's their data and stores them within station specific “Historical Data” text files on their website on a monthly basis (e.g. https://www.ndbc.noaa.gov/station_historical.php?station=43009). As per NOAA requirements, NDBC archives their data on a monthly basis in the official NOAA archives, which are found at the National Center for Environmental Information (NCEI) (<https://www.ncei.noaa.gov/access/marine-environmental-buoy-database/>). NDBC collates their website data annually and copy these data, in a Universal Network Common Data Form (netCDF) format, for storage on the NDBC Distributed Oceanographic Data Systems framework (DOOS) (<https://doos.ndbc.noaa.gov/thread/curling/distributing.html>). Essentially, the NDBC website and the DOOS may be considered as a single source of NDBC historical data that are stored in different formats.

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WIS PUBLIC AVAILABILITY AND UPDATES



WIS OPERATIONS WIS WEBSITE AND WIS PORTAL (URLs listed on WIS Sources slide)

- Archive on CHL Data (Thredds) Server
 - Reduction of time required for yearly updates
- Standard WIS Portal Products
 - Updated automatically when hindcast completed
- Update of the QCC Wave Measurements Archive



WIS Project Mission

Wave Information Studies provides a national resource of long-term wave climatologies for all U.S. coastal waters using high-resolution wind fields, mean daily ice concentration fields (where appropriate), third generation phase average wave modeling technologies, that are extensively evaluated to point-source measurements and satellite-based altimetry providing high quality wave estimates. The multi-decade hindcasts and storm event archives are generated to meet tomorrow's coastal engineering needs today.

Problem

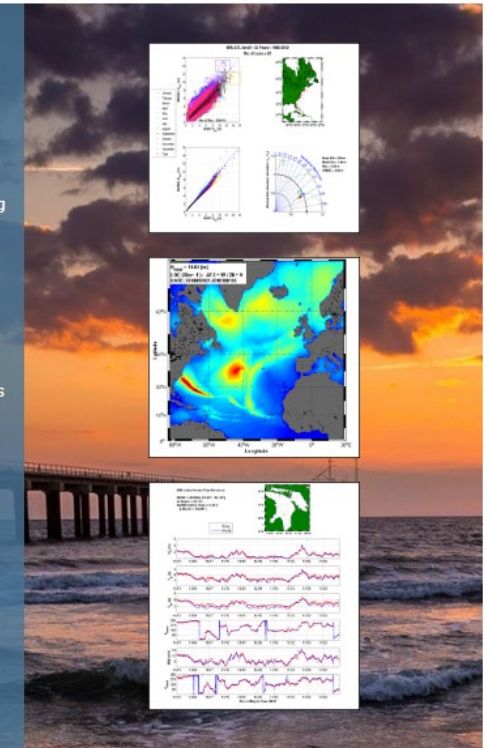
- Knowledge of the wave climatology is required for planning, design, construction, and maintenance of USACE projects in the coastal zone
- Information is scarce due to the lack of measurements at locations over timescales long enough to be statistically significant
- This lack of information is a critical problem for USACE operations, and project maintenance near the coast

Solution

- Generation of long-term coastal wave estimates using spectral wave models forced by high quality wind fields, to retain continuity
- Validate the model estimates to measurements
- Provide easy access to the estimates and tailored products specific to project needs

Impact

- Fully automated hindcast system with limited manual intervention
- Model simulations cost-effective compared measurements
- Timely web site updates with new wave estimates

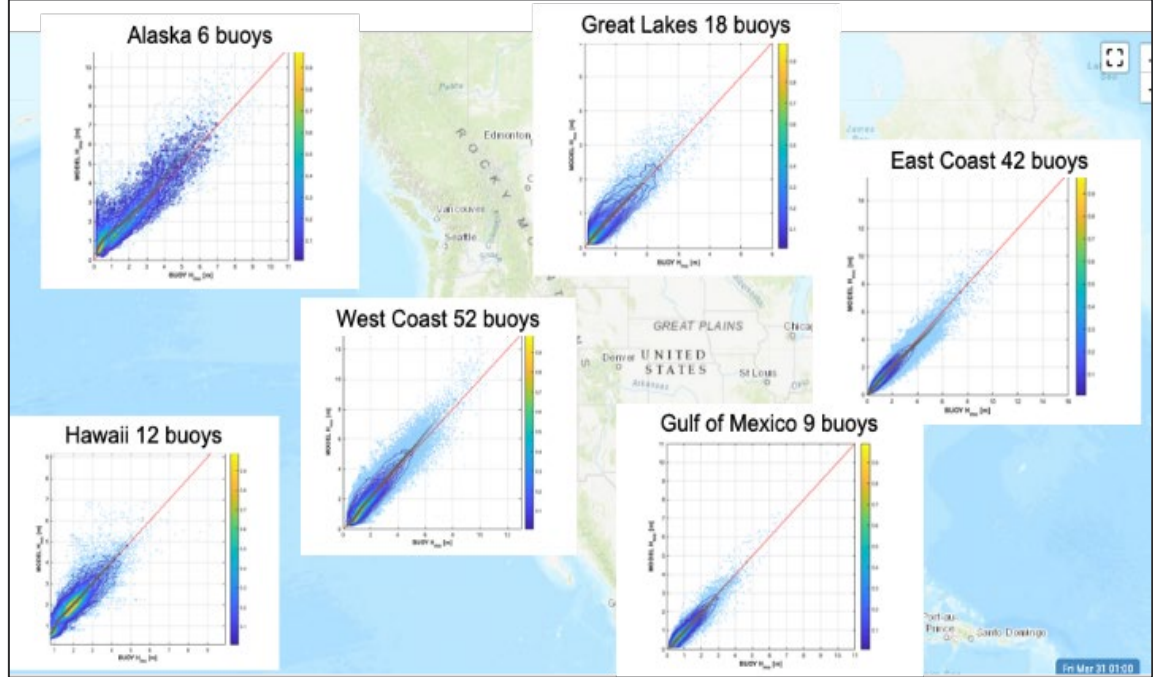




WIS APPLICATIONS



Applications: Anywhere reliable hindcast wave climate information is needed for coastal risk management, civil works operations and planning, and coastal research studies.

- **Forcing** for numerical nearshore wave modeling, e.g. STWAVE
 - Communicate **wave climate** for a given area to the public
 - To produce seaway statistics for use in **ship motion models**
 - To produce summary statistics for **wave climate** at a given project
 - Investigate design wave conditions for **design of coastal structures** at design phase and feasibility phases
 - Nearshore extreme wave heights and periods for **revetment design**
 - Investigate wave conditions for rapid estimates of potential **coastal flooding** at higher water levels for Emergency Management
 - Investigate offshore wave conditions for **wave run-up simulations**
 - Correlation of offshore WIS data to nearshore wave data, particularly looking at **rip currents**
 - As part of a **geomorphic vulnerability index**, WIS provided wave climate information to help identify vulnerable locations around Lake Michigan.
 - Offshore wave information used for both **extreme analysis and typical conditions**. Determination of a representative **storm hydrograph**. Creation of wave/period roses.
 - Transformed the WIS hindcasts to the nearshore and estimate the **sediment transport capability** of a site for the beneficial use of dredged sediment.
- 
- Used to define deep water boundary conditions for wave modeling to determine design wave heights and evaluate **harbor performance** - estimate durations of time waters adjacent to the project site were calm enough for different classes of vessels to operate to support economic analysis of the harbors.



RECENT WIS PROJECTS



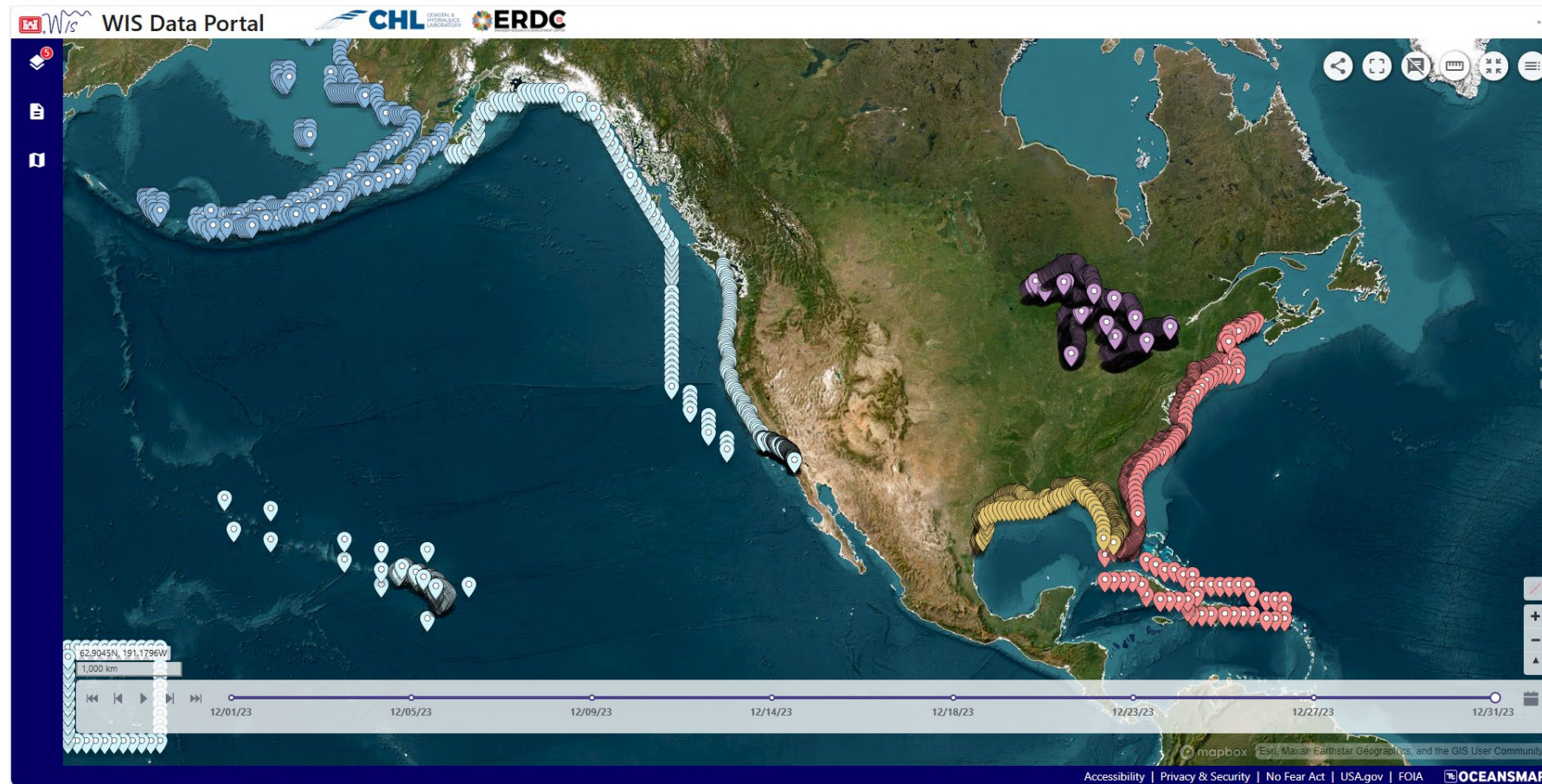
- Port of Nome Modification, Phase 1 design (Alaska District)
- Barrow Coastal Erosion, Phase 1 design (Alaska District)
- Akutan Harbor Tribal Partnership Program Study (Alaska District)
- Dutch Harbor Navigation Channel Feasibility Study (Alaska District)
- Elim Harbor Tribal Partnership Program Feasibility Study (Alaska District)
- St George Harbor GI Feasibility Study (Alaska District)
- Westward Beach Shore Protection Coastal Engineering Study (Los Angeles County Department of Beaches and Harbors)
- Adamson Wall Shore Protection Coastal Engineering Study (Los Angeles County Department of Beaches and Harbors)
- Little Diomed Helipad Improvements (State of Alaska DOT)
- East Hagatna, Guam Section 14 Study (Honolulu District)
- Ofu Airport, Am Samoa Section 14 Study (Honolulu District)
- Agat Mayors Office, Guam Section 14 Study (Honolulu District)
- Agat Bay Regional Shoreline Assessment (Honolulu District)
- American Samoa Climate Change Vulnerability Study (Honolulu District)
- Laupahoehoe Harbor Breakwater Repair Final Design Report, Island of Hawaii (Honolulu District)
- Haleiwa Harbor and Shore Protection Project, RSM and Section 1122 Beneficial Use Studies (Honolulu District)
- Hilo Harbor Breakwater Resiliency Study (Honolulu District)
- St George Breakwater Repairs
(<https://www.hdrinc.com/portfolio/st-george-island-breakwater-and-dredging-improvements>)
- Kodiak Island Airport Runway Extension
- Kwajalein (<https://www.hdrinc.com/portfolio/kwajalein-atoll-shoreline-protection>)
- Monroe County Roadway Vulnerability Assessment
(<https://www.hdrinc.com/portfolio/monroe-county-roadway-vulnerability-study>)
- East San Pedro Ecosystem Restoration Feasibility Study (FS)
- San Diego County Shoreline CSRM FS
- Carpinteria Shoreline CSRM FS
- Saipan, Beach Rd. CSRM FS (for Pacific Ocean Division)
- Bay Mills Feasibility Study (Detroit District)
- Holland Rip Current Study (Detroit District)
- Grand Haven Wave Absorber Design (Detroit District)
- Keweenaw Stamp Sands Feasibility Study (Detroit District)
- Lexington Harbor Planning Assistance to States Study (Detroit District)
- Community fact sheets for outreach events with the State of Michigan (Detroit District)



WIS SOURCES

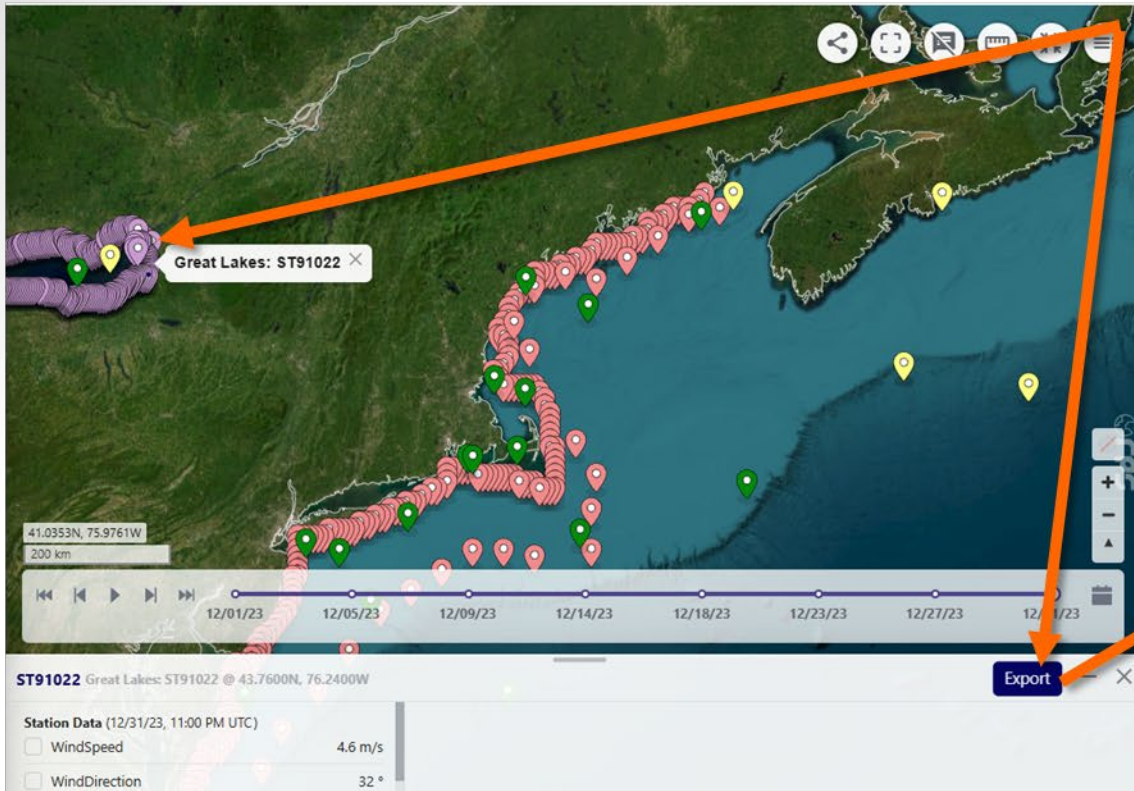
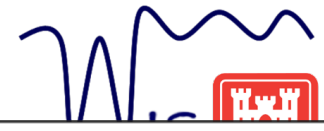


1. WIS Program website: <https://wis.erdcdren.mil>. Informational (no data), link to the WIS Portal.
2. WIS Data Portal: <https://wisportal.erdcdren.mil/>. Interactive, data download.
3. WIS Data Portal API: <https://wisportal.erdcdren.mil/data/apidocs/>
4. CHL Data Server (Thredds): <https://chlthredds.erdcdren.mil/thredds/catalog/catalog.html>





WIS DATA PORTAL



<https://wisportal.erdc.dren.mil/>

WIS Export

ST91022 @ 43.7600N, 76.2400W / 01/01/79, 01:00 AM UTC - 01/01/24, 12:00 AM UTC

- Overview
- Data Export
- Generic Export
- 2D Spectra
- Time Series (ONELINES)
- Mean-Max Summary Table
- Extremes Analysis Table
- Wave Percent Occurrence
- Wind Percent Occurrence
- Plots
- Wave Rose
- Wind Rose
- Mean & Max Wave Height Duration
- Wave Height Duration Distribution
- Yearly Wave Height Time Series
- Extremes Analysis Plot
- Input for Models

Great Lakes Station ST91022

The Wave Information Studies (WIS) is a US Army Corps of Engineers (USACE) sponsored project that generates consistent, hourly, long-term (40+ years) wave climatologies along all US coastlines, including the Great Lakes and US island territories.

Extents Spatial: 43.7600N, 76.2400W

Extents Temporal: 01/01/79, 01:00 AM UTC - 01/01/24, 12:00 AM UTC

Extents Depth: 11.0

Zoom In

For issues/updates, please see the WIS website

ST91022 @ 43.7600N, 76.2400W / 01/01/79, 01:00 AM UTC - 01/01/24, 12:00 AM UTC

- Overview
- Data Export
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- Wind Percent Occurrence
- Plots

Link to file: WIS Online file format (PDF)

Preset Dates Custom Dates

Select Year: 2023

Select Month: All Months

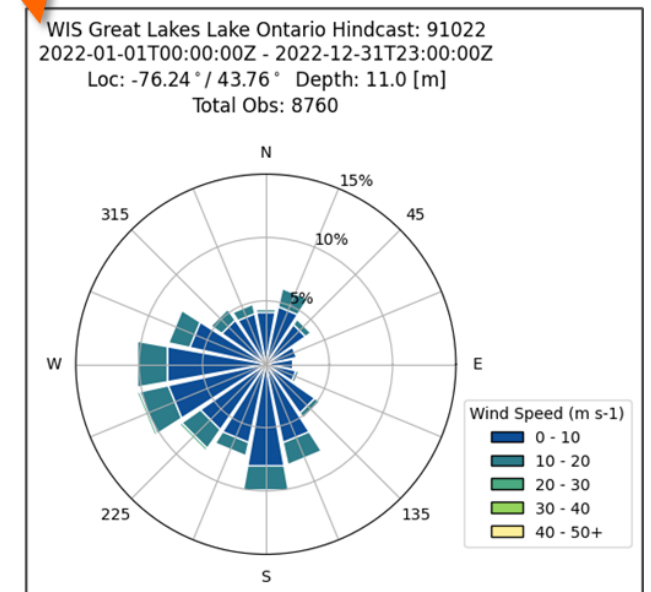
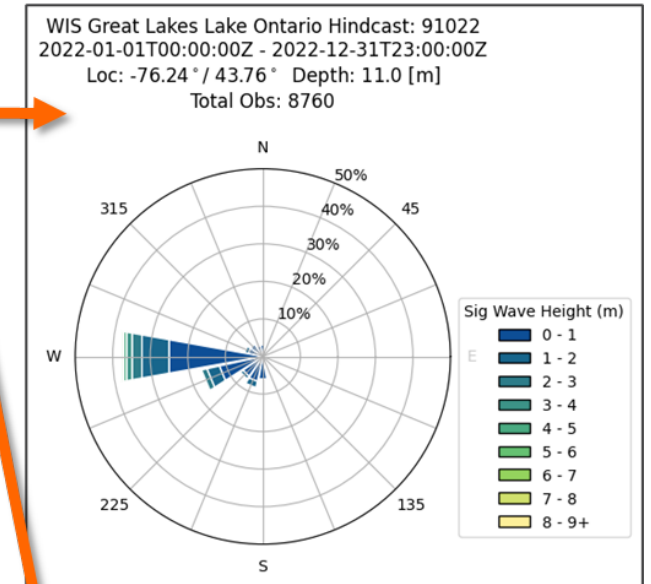
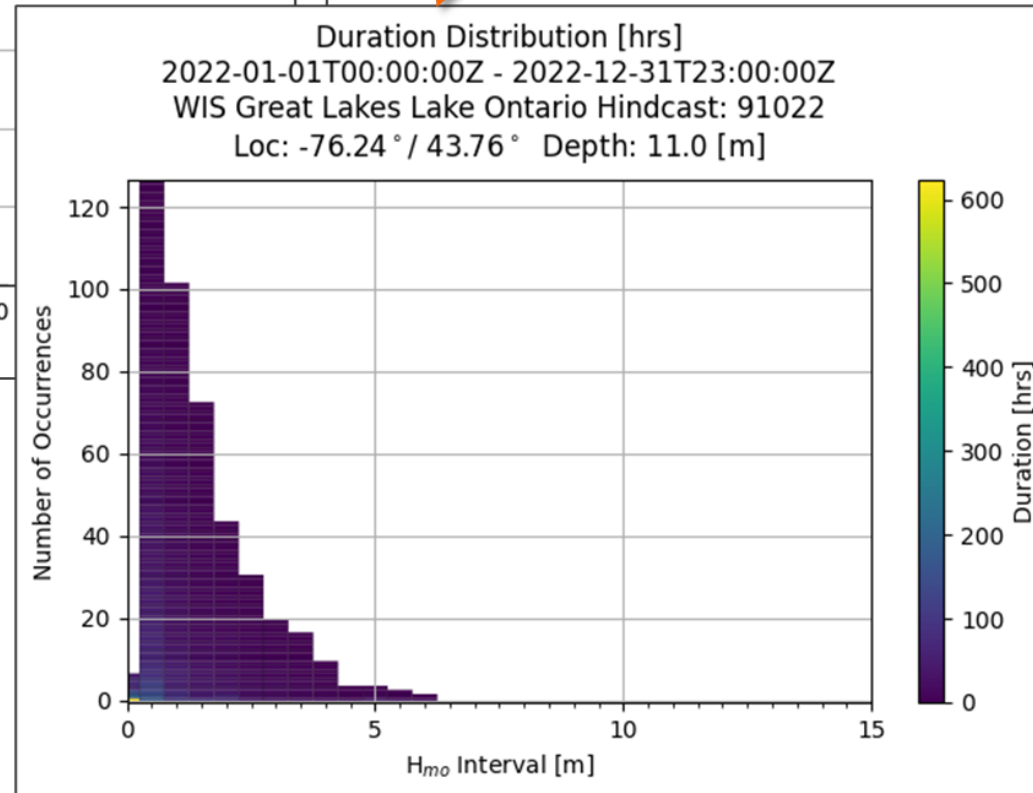
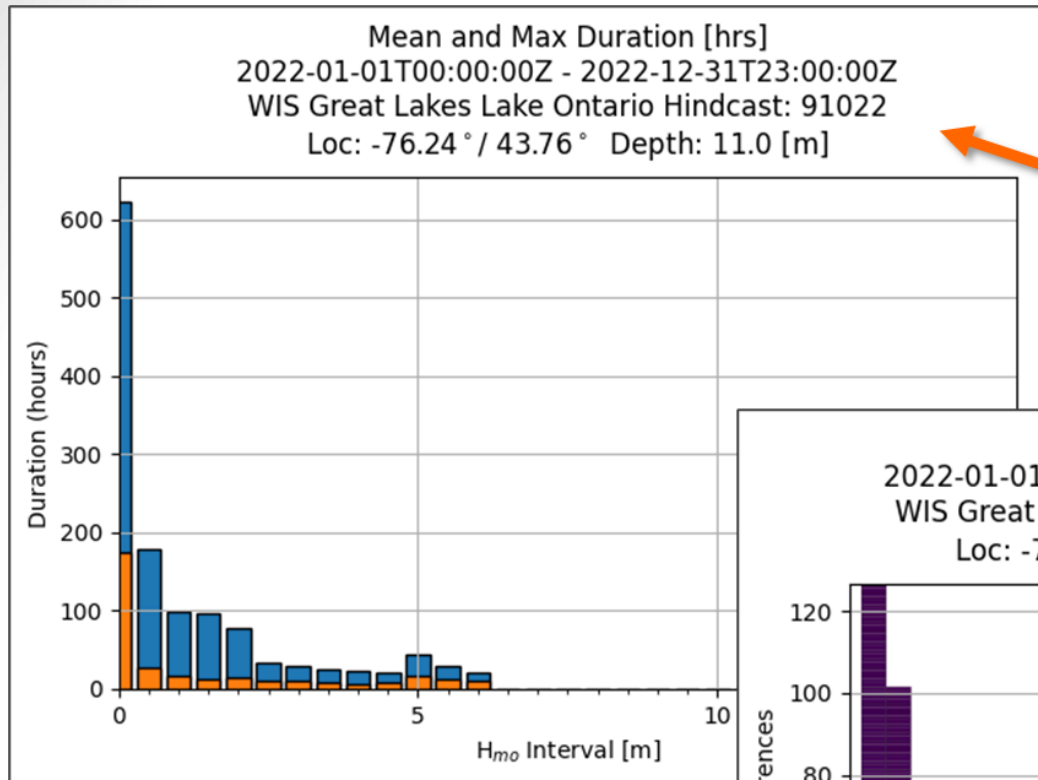
Add to Export Group Download

Zoom capabilities to isolate a WIS or Buoy Site, Measuring Tool available

- Download preset or custom POR – All Years & All Months; Select Year & All months; All Years & Select Month.
- Static and interactive product generation – For all tables and plots
- Export individual or Group products – For tables: .csv or .nc; for plots: .png, .svg, or .pdf.
- Input for Models – CMS-Wave beta testing phase.
- Future: Add more capabilities and wave model inputs.

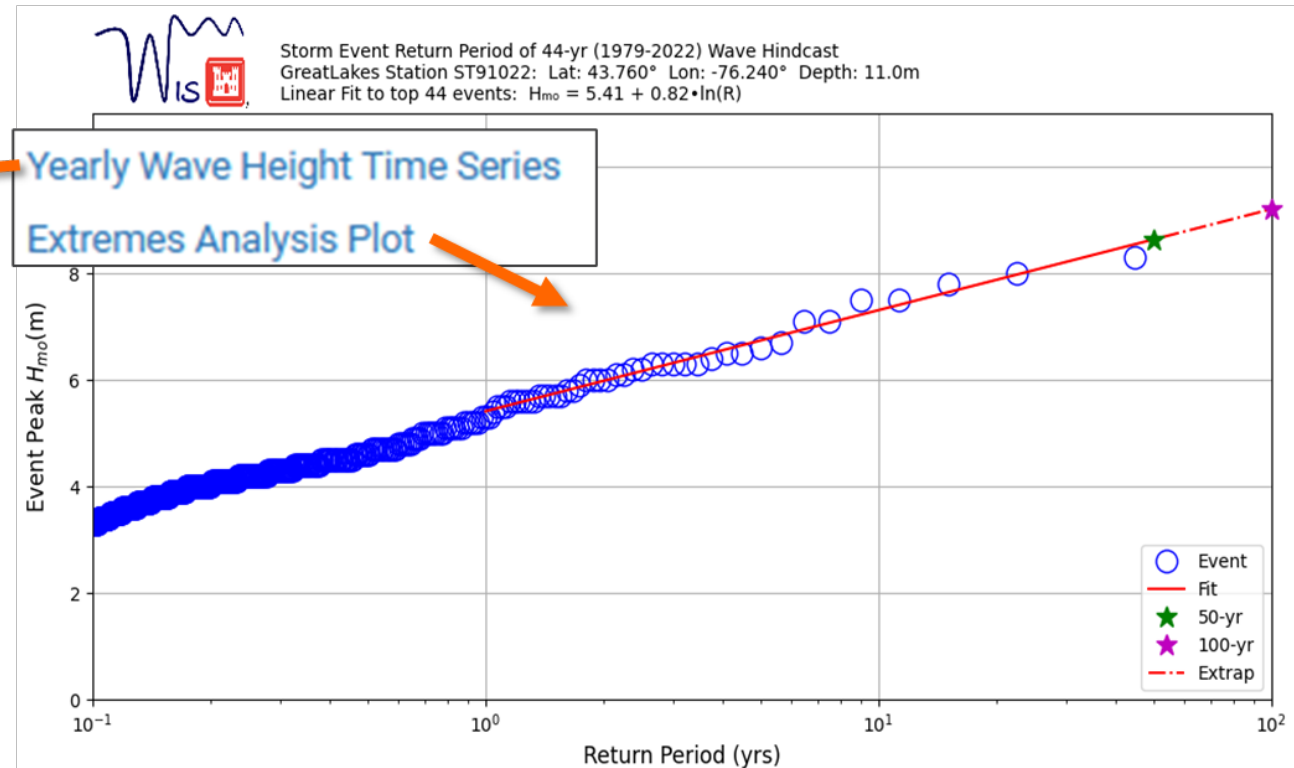
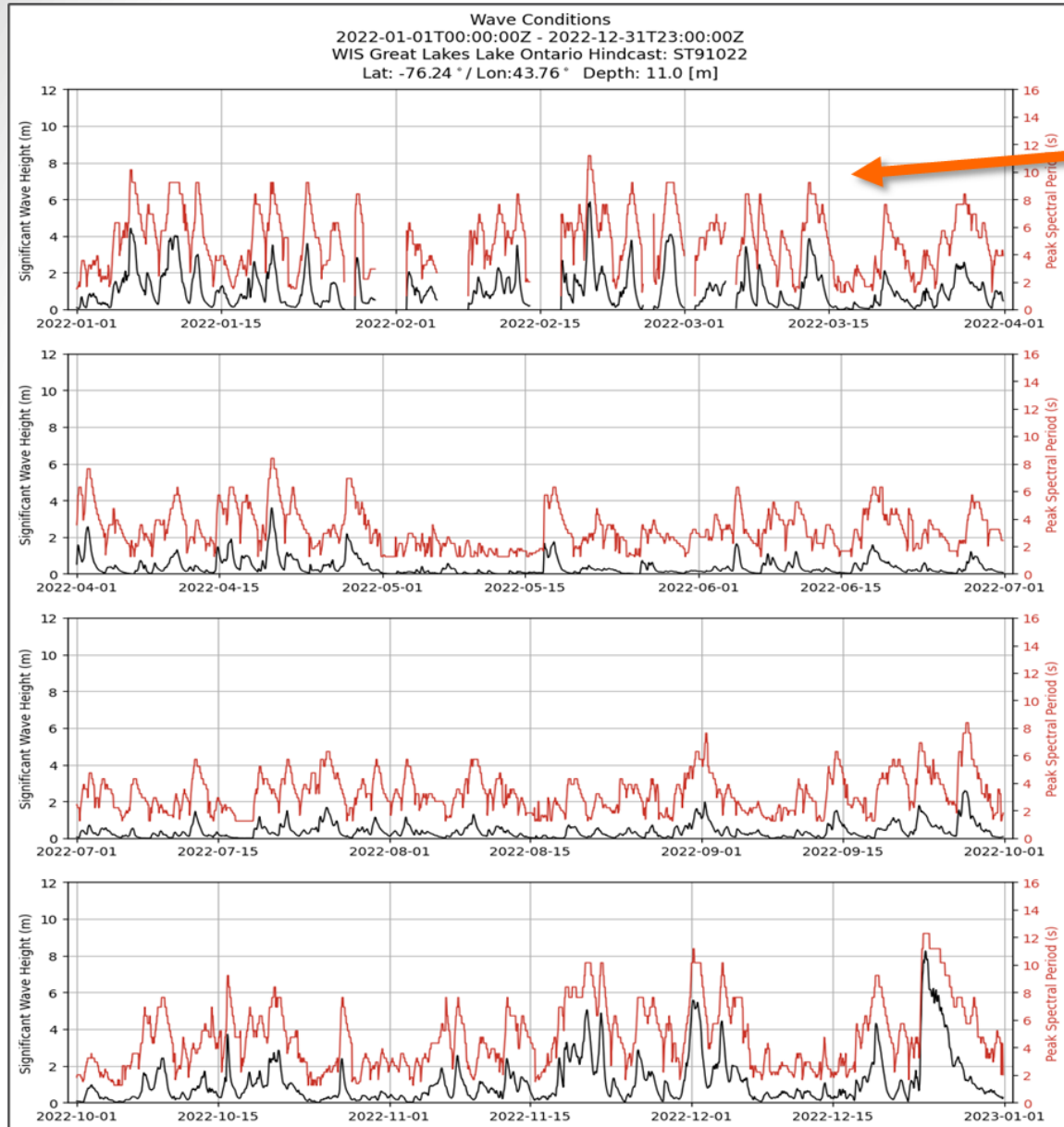


SELECT WIS DATA PORTAL PRODUCTS





ADDITIONAL WIS DATA PORTAL PRODUCTS



Top 10 Events based on Peak H_{mo}

Event	Date/Time(UTC)	H_{mo}	T_p	θ_{mean}	Event	Date/Time(UTC)	H_{mo}	T_p	θ_{mean}
1	2019/11/01 11:00	8.0	12.1	260.0	6	2021/12/12 04:00	7.1	11.8	261.0
2	2019/02/25 12:00	7.8	12.1	260.0	7	2018/04/04 23:00	6.7	11.2	260.0
3	2003/11/13 17:00	7.5	11.9	260.0	8	2013/01/31 16:00	6.6	11.2	260.0
4	1979/04/06 20:00	7.5	11.9	259.0	9	2013/01/20 16:00	6.5	11.1	260.0
5	2000/12/18 07:00	7.1	11.2	259.0	10	2011/10/16 02:00	6.5	11.1	260.0

An event is defined as any period when $H_m > 1.00m$

θ_{mean} is direction that waves are arriving from



WIS FUTURE: NUWWIS



Current WIS Operations:

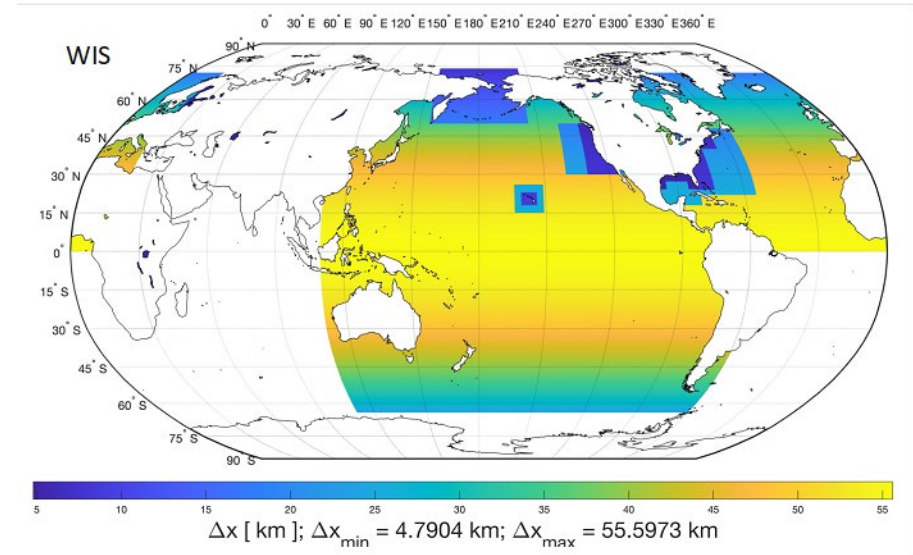
- WW3: Atlantic and Pacific
- WAM: Gulf of Mexico / Western Alaska / Great Lakes

Multiple Objectives (FY23 – 26): *A complete modernization of our hindcast approach to a global product, which centers on newly available unstructured grid capabilities in the latest release of WW3 and forced by the best available input data and validated against in-situ, and remote-sensing datasets.*

1. **Wind forcing:** Transition the OWI-corrected ERA5 wind forcing into operational WIS for all domains besides the Great Lakes.
2. **Model:** Test and transition WIS over to unstructured with implicit solver WW3 for all domains besides the Great Lakes.
 - Reduce the number of individual domains and model technologies.
 - WIS Operations more fiscally and operationally efficient.
 - Align our wave modeling between nearshore and offshore projects - WIS points closer to shore.
 - Simplify wave model developments for both civil and military applications.
3. **Global Product:** Test and transition to a global WIS product
 - Enhanced resolution across the globe.
 - To respond swiftly to future WIS requests in new territories, including polar regions, islands chains (Marshall Islands, Palau etc.), Indian Ocean and Persian Gulf etc.
 - Nearshore wave estimates

“We anticipate future needs as well as advances in model capabilities, computational resources, and emerging observational data sources.”

Current WIS domains



Highest resolution global mesh under consideration – 1557261 nodes

