A US NOPP project to stimulate wave research

Focus on operations and deep water

Hendrik L. Tolman
Chief, Marine Modeling and Analysis Branch
NOAA / NWS / NCEP / EMC

Hendrik.Tolman@NOAA.gov
“The National Oceanographic Partnership Program (NOPP) is a collaboration of federal agencies to provide leadership and coordination of national oceanographic research and education initiatives. “

- http://www.nopp.org/about-nopp/
Motivation

NOPP project: Improving Wind Wave Predictions; Global and Regional Scales

- Considering progress in understanding of wave model physics, particularly dissipation and economical interaction approximations, Linwood, Don and Hendrik started pushing for this project after the 2008 Ocean Sciences meeting.
- Buy-in from:
  - ONR, BOEM (was MMS) with funding.
  - NOAA, USACE, NRL with in-kind contributions.
- Focus on operational modeling, basin and shelf scale.
  - Several “surf-zone” proposals also funded.
Outline of paper:

- NOPP teams
- Validation data.
- Validation techniques.
- 30 year hindcast.
- Code management.
- Outlook.
<table>
<thead>
<tr>
<th>PI-s</th>
<th>Topics</th>
<th>Focus areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ardhuin</td>
<td>in+ds</td>
<td>Dissipation (breaking, swell, bottom) Unstructured grids in WW III.</td>
</tr>
<tr>
<td>Babanin</td>
<td>in+ds</td>
<td>Observations based + swell diss.</td>
</tr>
<tr>
<td>Banner</td>
<td>in+ds</td>
<td>Extreme conditions, explicit breaking prediction, fluxes including sea spray</td>
</tr>
<tr>
<td>Perrie</td>
<td>nl</td>
<td>Two-Scale Approximation.</td>
</tr>
<tr>
<td>Tim Janssen</td>
<td>nl (shal)</td>
<td>Combine quads &amp; triads, field data sets.</td>
</tr>
<tr>
<td>Zakharov / Pushkarev</td>
<td>nl+in+ds</td>
<td>Advanced statistical and dynamical nonlinear models + input and dissipation</td>
</tr>
<tr>
<td>Kaihatu / Sheremet</td>
<td>shal</td>
<td>Traditional mud and vegetation models Two-layer Boussinesq mod. Field data.</td>
</tr>
<tr>
<td>Van Vledder</td>
<td>shal</td>
<td>Shallow water models and obs., including surf beats.</td>
</tr>
<tr>
<td>Hanson</td>
<td>shal</td>
<td>Duck data sets, spatial partitioning.</td>
</tr>
<tr>
<td>Organization</td>
<td>PIs</td>
<td>In-kind contributions</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>USACE</td>
<td>Resio Smith</td>
<td>FRF + Currituck Sound data. New source terms / studies (in+nl+ds) IMEDS + Additional model metrics WAM/STWAVE + ADCIRC coupling Partitioning + tracking (with NCEP)</td>
</tr>
</tbody>
</table>
Validation data

Two type of validation / data important for operational wave models.

- Model needs to work all the time:
  - Bulk long term validation / development against routine observations.
    - In-situ, altimeter, SAR (?).

- Model needs to make physical sense.
  - Directed measurement campaigns focused on specific physics of waves.
    - Individual campaigns.
    - Data mining of routine observations.

- Select data set types and conditions, rather than campaigns.
<table>
<thead>
<tr>
<th>Conditions</th>
<th>Data sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long term validation</td>
<td>In-situ, altimeters, SAR.</td>
</tr>
<tr>
<td>Wind Sea and Swell</td>
<td>“JONSWAP”, Great Lakes, Lake George, SAR, Tehuantepec, Duck. Spectral</td>
</tr>
<tr>
<td></td>
<td>partitioning of buoy data.</td>
</tr>
<tr>
<td>Non-Aligned winds</td>
<td>Slanting fetch, Tropical cyclones (Duck, SRA, WSRA).</td>
</tr>
<tr>
<td>Extreme conditions</td>
<td>TCs, data mining.</td>
</tr>
<tr>
<td>Diminishing winds</td>
<td>FAIRs, data mining, tradewind and monsoon data (INCOIS, …)</td>
</tr>
<tr>
<td>Shallow water</td>
<td>Data sets provided by teams, older bottom friction data sets.</td>
</tr>
</tbody>
</table>
Validation techniques

Going beyond the traditional validation techniques used for wave models.

- Traditional: bulk error measures:
  - Mean, std, SI, $r^2$, scatter/pdf, sometimes qq …
- Event-based statistics:
  - Peak values, timing, shape of signal.
- Spectral wave model validation:
  - Ridge plots identifying individual swell events.
  - IMEDS analysis using spectral partitioning.
- For forecasting, hit-miss statistics are very important, but rarely used in scientific papers.
- Use additional relevant physical parameters, mss, peakedness, etc ….
Validation techniques

Using more concise presentations.

- Taylor diagram.
  - Variance
  - Correlation
  - Error

- Target plot
  - Bias
  - Error

Wind speed during January 2010 based on 75 buoys
The Climate Forecast System (CFS) reanalysis and re-forecasting project (CFSRR) provides a 30+ year high resolution wind field

- 0.5° hourly wind and temperature fields.
- Associated 0.5° daily ice analyses.

This data set appears ideal to be the basis of a wave reanalysis over the same 30+ year period.

- There is insufficient data in any period to obtain a data-dominated analysis, therefore
- It makes more sense to do a hindcast without assimilation, and use data possibly later for bias corrections of the hindcast only.
- Ideal as basis for long-term validation in NOPP project.

http://cfs.ncep.noaa.gov/cfsr
30 year hindcast

NH biases
High wind speed issues with CFSR in SH

NH

SH
30 year hindcast

Annual mean biases against altimeter data

2008, Jason 1

2002, Envisat

Annual signal, After 2005

Persistent signal, Seasonal (djf)
WAVEWATCH III community modeling
code management environment

- Traditionally code distributed as “tarball”, code delivered back to NCEP the same way.
- Does not work with many teams working on same code
  - Subversion (svn) server for version control.
  - Each team has code manager with access to server and latest developmental model versions thereon.
  - Code managers at NCEP merge individual contribution into “trunk” version of code.

- Best practices guide for community model development of WAVEWATCH III as deliverable for NOPP project. NCEP intends to maintain this environment after project is finished.
WAVEWATCH III added capabilities:

- Curvilinear and unstructured grids.
- Quasi-stationary model version.
- New source terms:
  - GMD and nonlinear filter.
  - Two moveable bed bottom friction terms.
  - Ifremer physics packages.
- Massively expanded output options (coupling).
- Wave system tracking.
- Post-processing tools:
  - Re-gridding.
  - NetCDF output.
- Coupling interfaces:
  - ESMF.
  - PALM.
Wave height and relative error(%)
Spectral parameters 100km behind eye (minimal wave height errors)

(a) spectrum (2D)
(b) spectrum (1D)
(c) steepness
(d) direction
(e) dir. spread
(f) Snl

green: WRT  dashed green: G35d   blue: G13d    red G11d

Tolman (2011, 2013)
Wave system tracking

**raw partitioning**

**wave system tracking**

Van der Westhuysen, Hanson and Devaliere (2013)

Tolman, 6/25/2012

ECMWF Workshop on Ocean Waves, 19/26
Outlook

In the pipeline:

- Spatial and temporal tracking of wave fields:
  - Porting internal partitioning to SWAN.
  - Space-time tracking (external / internal).

- NCEP planning first physics upgrade in operational wave models based on NOPP project in 2012 (following slides).

- NCEP planning NOPP “consensus” upgrade in 2014/5.
  - Replacing DIA and other “deep” source terms.
  - New products for SOLAS, specifically wave breaking.
  - Full polar coverage (tri-polar / curvilinear Artic grid).
  - Unstructured coastal grids (2-3 km resolution)
  - Upgrades shelf physics.

- Multiple well performing physics packages …
  - Multi-physics ensembles.
  - Estimate of uncertainty in wave model physics.
NCEP physics upgrade based on Ifremer results, tested with NCEP global and Great Lakes winds.

Outlook

biases Dec. 2009 – Feb 2010

old

new
Monthly global errors 2009

Bias (m)

SI

RMS (m)

$R^2$

Outlook
Great Lakes buoy 45007, 2009 old physics

$H_s$ Total (m), Measurements vs. st2default

Measured $H_s$ (m)

WW3 $H_s$ (m)
Great Lakes buoy 45007, 2009 new physics

Hs Total (m), Measurements vs. st4t500

Outlook
Taylor diagram and alternative version for several GL buoys for 2009

GLERL-Donelan (1-G)
WW III Tolman and Chalikov (1996)
WW III Ardhuin et al. (2010)
Conclusion:

- Making great progress toward improved operational models.
- Laying ground work for community model development and modeling environment.