A US NOPP project to stimulate wave research*

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ABSTRACT

The National Oceanographic Partnership Program (NOPP) recently started a project focused on improving operational wind wave forecasting. The main focus is on deep water and continental shelf physics, but some projects focusing on extremely shallow water are also included. Note that a more extensive description of this program has already been published. The present manuscript, therefore, provides only a brief description, relying on previous publications for a more in-depth description.

1 Introduction

The National Oceanographic Partnership Program (NOPP) is "*a collaboration of federal agencies in the United States of America to provide leadership and coordination of national oceanographic research and education initiatives*"[1]. NOPP projects are always sponsored by more than one federal agency, and thus projects are initiated based on joint interests of various agencies.

In this context, the Office of Naval Research (ONR), the US Army Corps of Engineers (USACE), the National Oceanic and Atmospheric Administration / National Weather Service (NOAA / NWS) and the Bureau of Ocean Energy Management (BOEM, formally MMS) have joined forces to sponsor a five-year project entitled "Improving Wind Wave Predictions: Global to Regional Scales"[2]. The project intends to focus mainly on wave physics for deep and intermediate water depths, with an emphasis on development of methods sufficiently economical to be used in operational wave forecasting. As the purpose of this NOPP project and its setup are already described in some detail in literature (Tolman et al., 2011, 2013, henceforth denoted a TBK), the present presentation will be short, and for more details, reference is made to TBK.

As project sponsors, ONR and BOEM provide funding for research groups, and USACE, NCEP and the Naval Research Laboratory (NRL-Stennis) are providing in-kind support, and leverage this NOPP project with other separately funded projects. The latter three partners also are direct recipients of wave model improvements developed in the project. The project funds nine research teams (see TBK for details). Four teams focus on input and dissipation in deep water, three teams focus on nonlinear interactions (two teams for deep water, one for arbitrary depth), and three teams focus on shallow water physics.

An essential part of the project requirements is that new approaches must be presented to the community at large for general use. Most teams have chosen to work with the WAVEWATCH III® wave modeling framework (Tolman et al., 2002; Tolman, 2008), and to distribute their new approaches with this model to the public. WAM (WAMDIG, 1988; Komen et al., 1994), SWAN (Booij et al., 1999; Ris et al., 1999)

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[1] Definition copied from http://www.nopp.org/about-nopp/
[2] http://www.nopp.org/funded-projects/fy2009-projects-funded-under-nopp/topic 1.

and STWAVE (Massey et al., 2011) are also used in the project, and can be used as distribution vehicles for new approaches.

Special attention is also given to wave model validation. This project does not fund new observations. Existing data sets are used to assess specific model behavior, such as long term validation, separate wind sea and swell behavior, and behavior in extreme conditions. Attention is also given to validation techniques, considering presentation of model errors using for instance, Taylor and target diagrams (e.g., Taylor, 2001; Boer and Lambert, 2001; Jolliff et al., 2009), validation of individual wave systems (e.g., Hanson et al., 2009), and analysis of individual (extreme) events.

Several ancillary projects and products are associated with this project. In particular, a set of 30 year wave hindcasts based on forcing from the Climate Forecast System Reanalysis (CFSR, Saha et al., 2010) are produced. Whereas this project is separately funded, it will be used extensively for validating old and new source term approaches. An early description of the hindcasts can be found in Chawla et al. (2011). Special attention is also given to developing a community modeling, and shared model development environment for WAVEWATCH III.

Some early results and an outlook will be presented in the following sections.

2 Early results

Although the project is only at its midway point, many early results have already been reported in a special session of the 12$^{\text{th}}$ International Workshop on Wave Hindcasting and Forecasting and 3$^{\text{rd}}$ Coastal Hazards Symposium[3], held at the Hilton Waikoloa Village resort in Hawai'i, in November 2011. Four specific results will be described here briefly; i) development of the collaboration environment for WAVEWATCH III, ii) model improvements in community models, iii) new operational wave model implementations at NCEP, and iv) completion of phase I of the 30 year wave hindcast.

NCEP has set up subversion server (Collins-Sussmann et al., 2004) to perform code management for all its operational models. On this server, the publicly distributed version of WAVEWATCH III is now also maintained. Selected co-developers of this model have been given access to the server, including most of the NOPP teams, and other collaborators like Delft University, and the Met Office. A best practices guide is in development, based on close collaboration between, and previous experiences of NCEP and NRL-Stennis. As a consequence of this focus, many improvements for WAVEWATCH III are already available to the NOPP team. These improvements include curvilinear and unstructured grid approaches within the two-way nested mosaic approach of Tolman (2008), many new output parameters, particularly focusing on model coupling, and various new source term packages and pre- and post-processing tools (see TBK for morel details). Not all NOPP development is done with or for this model, and as part of this project, partitioning approaches implemented in WAVEWATCH III are ported to the SWAN model.

This NOPP project is used at NCEP as a focal point for upgrades of its operational wave models. In this context, the physics packages of (Tolman and Chalikov, 1996) is being replaced with a package developed by (Ardhuin et al., 2010). This represents the first major physics upgrade at NCEP in more than a decade. NCEP's global wave model was upgraded in May 2012, and the Great Lakes models are tentatively scheduled for upgrades later this year. The hurricane and ensemble models are tentatively scheduled for the corresponding physics upgrade in 2013. These upgrades are focusing on removing major deficiencies from previous operational models at NCEP as briefly illustrated below.

A major deficiency of the older Tolman and Chalikov (1996) physics package for global applications has been a persistent winter time positive swell bias in the North Pacific Ocean (e.g., Hanson et al., 2009), and a systematic positive swell bias in the Southern Oceans. Whereas the former bias has existed

[3] http://www.waveworkshop.org/

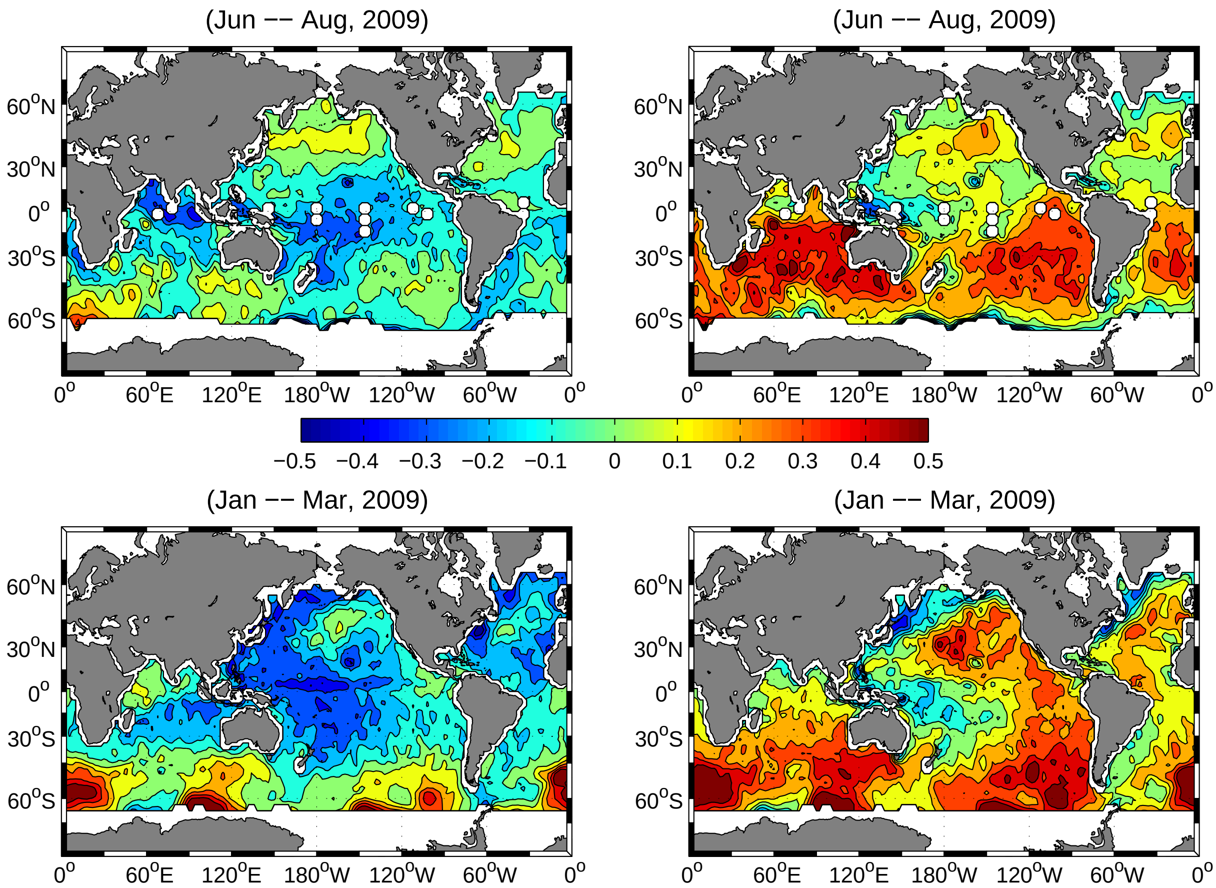

Figure 1: Wave height biases against Jason-1 altimeter data for old physics package (Tolman and Chalikov, 1996, right panels) and new physics package (Ardhuin et al., 2010, left panels), for June through August 2009 (top panels) and (January through March 2009 (bottom panels).'

since the implementation of this model, the latter developed in 2006, and appears related to a systematic change in extreme winds (95, 99 and higher percentile winds) in the southern ocean in the NCEP global weather models (see Spindler et al., 2011; Chawla et al., 2011). This behavior is illustrated in the right panels of Fig. 1. Introduction of the Ardhuin et al. (2010) input and dissipation parameterizations removes most of these deficiencies, as is illustrated in the left panels of Fig. 1.

For the Great Lakes wave models at NCEP, the major deficiency of the Tolman and Chalikov (1996) physics package is that it systematically underestimates wave heights in extreme events. This is illustrated in Fig. 2 with two of the most extreme events in the Great Lakes that occurred in 2009. The winds used here (upper panel of Fig. 2) are from the wind field analysis provided by the Great Lakes Environmental Research Laboratory (GLERL) as described in Schwab and Morton (1984). The lower panel in the figure represents the corresponding significant wave heights. The blue line represent the older GLERL-Donelan model (Schwab et al., 1984), that is still used at many Weather Forecast Offices (WFOs) in the Great Lakes region. It gives an excellent description of the extreme events. The green line represents the results of WAVEWATCH III with the Tolman and Chalikov (1996) physics package (denote as GLW model in caption). Whereas this model in terms of bulk error statistics is as accurate as the GLERL model, it is obviously inferior with respect to the representation of extreme events. The planned implementation of the Ardhuin et al. (2010) physics package (red line in figure) will result in a model that describes extreme events as accurate as the old GLERL model, while reducing bulk errors by 20 - 30%. More details on the model comparison for the Great Lakes can be found in Alves et al.

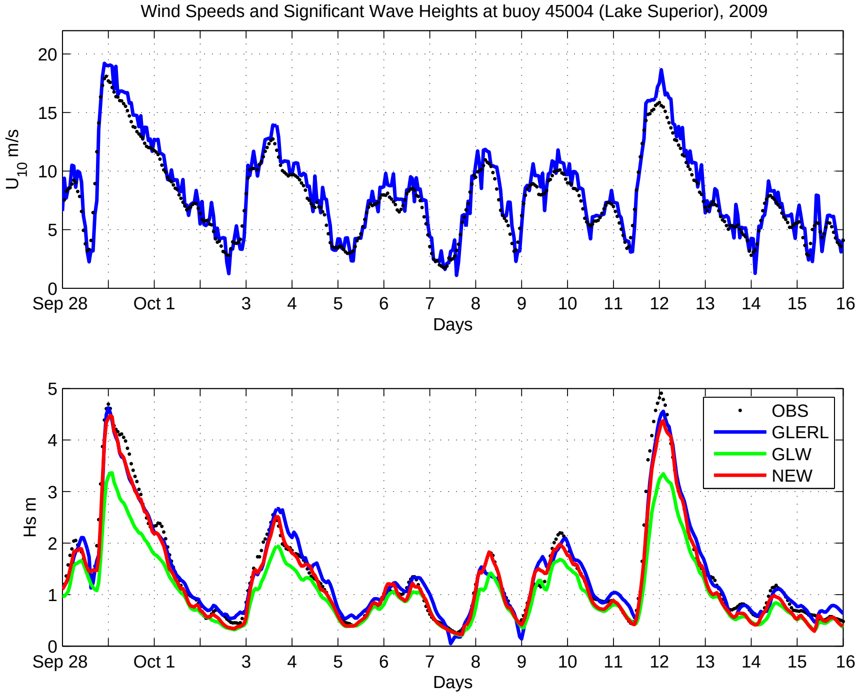

Figure 2: Wind speeds (panel a) and wave height H_s for buoy 45004 in the Great Lakes for parts of September and October 2009.

(2011, 2012).

Finally, the first phase of the 30 year wave hindcast project based on CFSR winds has been finished, and the results will be made public in the summer of 2012. The first phase uses 16 grids with resolutions ranging from 58 to 7.5km and uses the raw CFSR winds and the Tolman and Chalikov (1996) physics. Results are presented in Chawla et al. (2011, 2013).

3 Outlook

It is expected that this NOPP project will result in either a consensus set of best physics parameterizations for deep water, or in several sets of physics parameterizations with similar statistical error characteristics. In the latter case, a multi-physics ensemble can be constructed to estimate the underlying uncertainty in operational wave modeling associated with the physics parameterizations. It is expected that improvements or alternatives for all major source terms will result from this project, including for the nonlinear interactions (Tolman, 2011). Note that the nonlinear interactions in operational wave models have essentially been unchanged since the development of the first third-generation wave model (Hasselmann et al., 1985; WAMDIG, 1988). It is also expected that the comprehensive validation data sets and techniques gathered and developed as part of this project will be the basis for future model validation and intercomparison studies.

Phase II of the 30 year wave hindcast is presently being designed, and is intended to be performed in late 2012 and early 2013. Tentatively, this phase will introduce a bias correction for high-percentile winds in the southern hemisphere for winds before 2006, in order to get a climatically consistent 30 year record. Grids will be expanded to cover most of the Arctic Ocean using curvilinear grids, and possible higher-resolution grids will be used in selected coastal areas. Tentatively, phase II will use the physics package of Ardhuin et al. (2010), consistent with the operational global wave model upgrades at NCEP.

This NOPP project already has given us a wealth of experience with respect to code management in the context of a community model development effort. NCEP intends to maintain the development environment for WAVEWATCH III well beyond the time frame of this project.

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[4] Updated versions available online at http://subversion.tigris.org/.

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