15D.5

SENSITIVITY OF A COUPLED TROPICAL CYCLONE/OCEAN WAVE SIMULATION TO DIFFERENT ENERGY TRANSFER SCHEMES

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1. ATMOSPHERIC MODEL COUPLING USING "WAVE AGE" RELATIONSHIPS

A major component of next-generation operational models will include coupling between meteorology and wave models. The achievement of this goal requires improved coupling relationships, physically-based forcing terms in the spectral density transport equation of wave models, and software which facilitates computationally fast and ease of use in the development of coupled models.

Currently, most atmospheric models implicitly include crude ocean feedback using the well-known Charnock relationship. However, it is only valid for well-developed ("old") seas in the swell regime, characterized by waves in equilibrium with the wind, with peak energy in the lower frequencies. Under these conditions, roughness length z_0 will be proportional to wind stress $z_0 = a u_*^2 / g$ where u_*, a, and g are the friction velocity, Charnock constant, and gravity, respectively. On the other hand, "young seas," associated with sudden wind speed increases or changes in wind directions, have a large steepness in the high frequency range, creating an additional "wave-induced stress" which slows down the wind more than in well-developed seas. z_0 values can be up to 5 times larger than given by Charnock's equation, although 2-3 times is more common. For accurate atmosphere-ocean coupling, two-way interaction for young seas is required.

To account for both classes, several z_0 relationships using wave age have been proposed (Nordeng 1991; Donelan et al. 1993; Janssen et al. 1989). Wave age can be quantified by the ratio C_p / u_*, where C_p is the wave phase of the wave with the peak frequency. This ratio is typically small for a young sea (<10), sometimes called slow moving waves, while it is large for the swell regime (>20), sometimes called fast moving waves. [As an alternative, sometimes the 10-m wind speed C_p / u_{10} is used instead.] In addition, information regarding the chaotic nature of the young sea is required. This is quantified by the root mean square wave height s . These relationships typically take the form $z_0 = a u_*^2 / g \times f(u_*, C_p, s)$. Modeling studies have shown that the structure and intensity of cyclones and fronts are sensitive to wave age (Doyle 1995; Powers and Stoelinga 2000).

An obvious candidate for atmosphere-wave model coupling is the tropical cyclone. In this study, a "weak" hurricane (Gordon 2000) is being investigated since the applicability of current wave parameterizations to strong hurricane conditions is questionable. The atmospheric model being used in this study is COAMPS (Hodur 1997), and the wave model is WaveWatch (Tolman 1999). Examples of both for Hurricane Gordon are shown in Figs. 1 and 2. At the conference, two-way coupling of this event will be presented by exchanging u_* and $z_0(u_*, C_p, s)$ between both models.

2. THE MODEL COUPLING EXECUTABLE LIBRARY (MCEL)

The coupling will be facilitated by new software called the Model Coupling Executable Library (MCEL). MCEL uses a data flow approach to model coupling where the communication is handled via the Common Object Request Broker Architecture (CORBA). In this approach, a central server is responsible for storing and passing information. The numerical models, or clients, are responsible for storing data into the server. Once a request is made for a set of data, the data flows from the server through a series of filters and to the client. These filters modify the data into a form that can be used by the clients, such as performing interpolation between the two different model grids or computing physical terms such as

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$z_0(u_*, C_p, s)$. In this manner, little modification of the model source code is required other than including filter subroutines, and both models can be synchronized for their respective time steps.

3. NEW ENERGY TRANSFER SCHEMES

Most current wave models use empirically-based parameterizations which often lead to inaccurate solutions. For example, underestimation of wave growth due to wind-wave interaction is a well-known problem in current wave models, and attempts to address this problem are often crude. In recent years, Sajjadi et al. (1997, 1999) and Sajjadi (1998, 2001a,b, 2002) have identified that the underestimation in wave models is due to the neglect of turbulent interaction between the atmosphere and ocean, a lack of consideration for all ranges of C_p, and nonlinearity in surface wave profiles. Most models follow the original critical-layer contribution made by Miles (1957) which only accounts for wave growth due to inviscid shear-flow instability, and assumes an old windsea. An example of an improved parameterization for the energy wind-wave exchange parameter (b) using Sajjadi's Rapid Distortion Theory (1998, 2001, 2002) based on dynamics is shown in Fig. 3. Also shown are other parameterization schemes largely derived from empiricism. This algorithm, along with other parameterizations, will be incorporated into WaveWatch and presented at the conference.

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References

References available upon request.

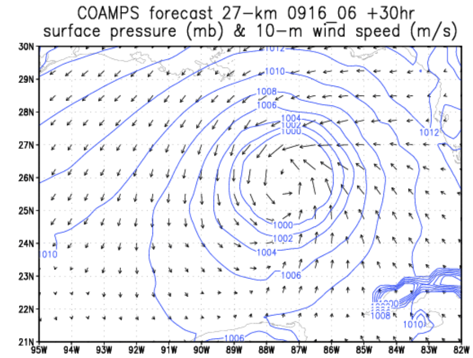

Figure 1. 30-h COAMPS simulation of Hurricane Gordon (2000) valid 12Z 17 Sep. 2000, initialized by NOGAPS data.

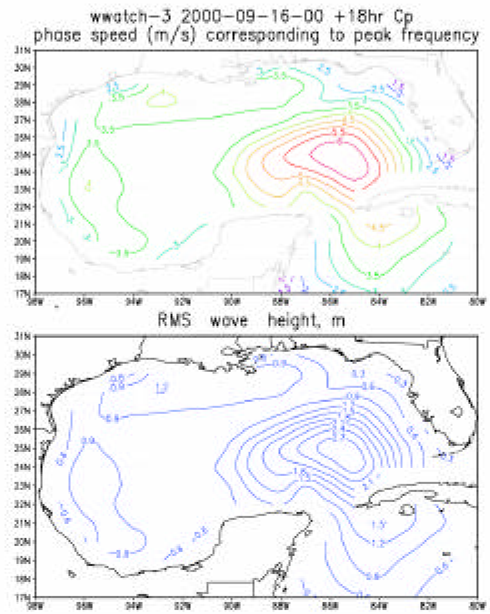

Figure 2. C_p at peak frequency (top) and rms wave height (bottom) from WaveWatch at 18Z 16 Sep 2000 initialized by NOGAPS. "Young waves" will be generated near Gordon (small values of C_p / u_*), giving z_0 values exceeding Charnock's.

Plot of energy transfer parameter b (y-axis) vs. C_p / u_* (x-axis)

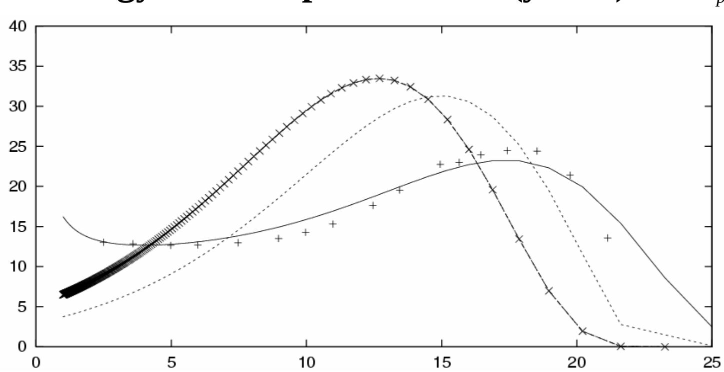

Figure 3. Energy transfer parameter b versus wave age C_p / u_*. xxxx., Jansen's WAM formulation (1991); dashed line, Miles' critical layer mechanism (1957); solid line, Sajjadi's rapid distortion theory (2001); ++++, experimental "observations" from numerical solutions of turbulent wind simulation over Stokes wave (Sajjadi 2002).