Updates to WAM Cycle 4.5+

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MOTIVATION

• WAM Cycle 4 has undergone modifications over the last release under the WAM umbrella
• These modifications have been performed mainly in an isolated mode
• Generally not publicized
  – (Internal Reports, Conference Presentations, Journal Articles)
• Better inform the modeling community of these changes
• Summary of work over the past 3-years
• Portions are from WISE-2007
• Portions are from work at ECMWF and USACE
Outline

- Introduction
- What is new
- What is different
- Some results
- Where to go next
- Summary
Introduction: Historical Perspective

• Pre-1983: Computers: slow / little memory
• The WAM Group’s Challenges:
  – Use state-of-the-art physics
  – Build an operational global wave model
  – Combine data assimilation system (ERS-1)
  – Include time invariant shallow water mechanisms

WAM-Cycle4
The WAM Wave Model

\[
\frac{\partial F}{\partial t} + (\cos \phi)^{-1} \frac{\partial}{\partial \phi} \left( \phi \cos \phi F \right) + \frac{\partial}{\partial \lambda} \left( \phi F \right) + \sigma \frac{\partial}{\partial \sigma} \left( \frac{\phi F}{\sigma} \right) + \frac{\partial}{\partial \theta} \left( \phi F \right) = S
\]

Where

\( F(\lambda, \phi, \sigma, \theta, t) \) wave energy density spectrum

\( (\lambda, \phi) \) longitude, latitude

\( (\sigma, \theta) \) intrinsic frequency, wave direction

\[
\phi = \left( c_g \cos \theta + u_{\text{North}} \right) / R
\]

\[
\lambda = \left( c_g \sin \theta + u_{\text{East}} \right) / \left( R \cos \phi \right)
\]

\[
\phi = c_g \sin \theta \tan \phi / R + \phi_D + \phi_C
\]

\[
\phi = \phi_C
\]
Leap to the Present

- Wind field quality improvements
- Computer’s speed/memory increased
  - Higher resolution global implementation
  - Local applications
- Basic studies on wave physics / numerics
- Reliable directional wave measurements?
- Data assimilation techniques developed / implemented
- New demands for wave modeling
  - Shallow water
  - New group of users
- Programming paradigm and platforms have made significant progress
Model Users

- **Met-Ocean Forecast Centers**
  - Global to local
  - Degrees to minutes
  - Deep to shallow water

- **Research Institutes**
  - Modifying, testing, implementing
  - All temporal and spatial domains
  - Multi-nesting
  - Coupling with ocean / atmospheric processes and interaction mechanisms
WAM Cycle 4.5.1

- Standard FORTRAN 95
- Free format code
- Modular rather than common blocks
- Dynamic allocation arrays
- Application of intrinsic functions
- IMPLICT none
- INTERFACE Blocks
- USE module, ONLY

ONE EXECUTABLE FOR ALL APPLICATIONS
Source Functions

- Integration method is fully implicit
  \[ F_{n+1} = F_n + \frac{\Delta t S}{1 - \Delta t G} \]
- Growth limited as given by Hersbach and Janssen, (1999)
- Diagnostic tail is defined by Cycle 4
  \[ \text{Max}\{2.5 f_{\text{mean}}; 4 f_{PM}\} \]
- Optional wave breaking source function defined by Battijes and Janssen (1978)
New Options

• Spectral direction modifications
• Sea Ice
• Multiple sub-nest domain
• Time interpolation of BC spectra included in main routine
  – Significant reduction of I/O
• Blocked grid computation removed
• Cold-start removed

REDUCTION IN PARTS and SYSTEM I/O
Research Activities

• High winds and the $C_D$:
  – Original tests on Camille
  – Extended tests
    • Dennis, Ivan, Katrina, Lili and Rita
  – Limited the drag based on these tests
    • IS TO SOME EXTENT A LEAP IN THE DARK
  – Tests also included WAM 4.5.2 modification of $S_{ds}$ (Bidlot et al., 2006)
• Pseudo-linear coupling with high-resolution winds (Janssen, 1991)
  – Influence on $C_d$ from wave induced stress term
  – At high winds $C_d$ increases
  – The profile remains time invariant based on PBL

• Pure coupling at the Air-Sea Interface at ECMWF
  – Increasing wave heights
  – Increase in drag
  – Alters the wind profile
  – Decrease the wind speed

• There are differences of these approaches
Data Assimilation

• WAM Model Performance
  – Reduction in the bias, RMSE, SI,…
  – Improved physics
  – Improved Winds

• Data Assimilation (ECMWF)
  – Incorporate altimeter data
  – Incorporates SAR
Data Assimilation (ECMWF)
Summary and Outlook

- Let the atmospheric modeling do all the work
- Model Physics: Source terms
  - Wind input
    - Fully coupled to the atmosphere vs pseudo linear coupling
  - DIA replacement
    - It is coming DTR
  - Dissipation
    - Bidlot et al. (2007) solution have significant merits
  - Depth limited spectral breaking
  - Still needs work
Summary and Outlook

• Data Assimilation is the key
• Operational:
  – Parallel Programming paradigms
    • OpenMP
    • MPI
  – Factors of 10 to 100 decrease run time
    • 8 times faster  →  Doubling the resolution
QUESTIONS