

Numerical wave modelling today & tomorrow

from Hs to broadband spectra, \rightarrow mss ...

from global to (sub)-kilometer scales... ...from spectra to other parameters? through fluxes?

Fabrice Ardhuin, Pedro Guimaraes, Justin Stopa, Mickael Accensi, Charles Peureux, Lucia Pineau-Guillou ...

+ the WAVEWATCH III developping team (Alves, Rogers, Chawla ...) Version 5 coming out in October







Air-sea gas flux: progress and future prospects, Brest, 2016



From navigation safety to Earth system science



Waves in the Earth System : towards a broader thematic range

Where? ... waves are important interfaces between

- atmosphere and ocean





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Wave scales : towards a « broadband view »





Wave models results are determined by

- Forcing fields (winds, currents, water levels, sea ice param., icebergs ...)
- Parameterizations of "source terms"
 - wind input (Janssen vs Makin …)
 - dissipation due to breaking: Komen & al. vs Phillips Banner
 - swell dissipation (Ardhuin et al. 2009, Zieger et al. 2015)
- Numerical methods
 - Splitting (Yanenko: WAM, WW3...) vs interative method (patankar: SWAN)
 - High order (WW3) vs low order (WAM) advection
 - Adaptative time step (WW3) vs fixed time step (WAM)
 - Different types of grids ...

WAVEWATCH III is a « framework » : can be run in many many ways.

Here (ftp://ftp.ifremer.fr/ftp/ww3) :

- WW3 3rd order on reg. Grids, 1st order on triangle meshes
- forced by ECMWF or CFSR winds, SSM/I ice, Ifremer icebergs
- Rascle & Ardhuin (OM 2013) and Roland & Ardhuin (OD 2014) parameterizations with minor updates + new wave-ice parameterizations



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Where we are today: Wave heights





Errors in free model runs using ECWAM (top) and WW3 (bottom) for free runs, Year 2009

→ large errors at short fetch possibly due to weak wave-age dependence in wind stress

→ wave-currents

→ wave -ice ...

THIS IS ONLY HS !!!

Where we are today: Surface Stokes drift



The surface Stokes drift (and the mss) strongly depends on the inertial range : not well done in ECMWF WAM (-20% off U.S. West coast).



Where we are today: mean square slope



The surface Stokes drift (and the mss) strongly depends on the inertial range : not well done in ECMWF WAM



Where we are today: **Energy flux**





Recent steps: Ice cubes

Icebergs needed in Southern Ocean wave models

(Ardhuin et al. Ocean Modelling, 2011)

Using iceberg data from altimeter (Tournadre & al. JGR 2009)

-150

-100

-50

0

Longitude

50

No icebergs



with icebergs



100

150

-150 -100

50 100 150

0

Longitude

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Getting into sea ice

ww.umr-lops.fr

Ardhuin, Sutherland, Doble, Wadhams

Ocean waves across the Arctic: Attenuation due to dissipation dominates over scattering for periods longer than 19 s

ົທີ S 3500 **GRL (2016)** m30 -3000 \mathbf{m} a 25 ŝ Swell wave height in cm 28 Model: scattering 2500 \sim 20 - Model: dissipation \sim ⊢ Observed (my) 2000 O 15 Hs (mm, 19 \sim 1°08 10 ഹ 1500 5 Greenland 10 0 1000 01 03 05 07 09 11 13 15 17 19 21 23 Days (February 2007) Numerical ഹ model new parameterization : ice break-up and creep 500 Validation :S1 data in the Southern Ocean 2500 5000 3000 3500 4000 4500 \frown x (km)

Days (February 2007)

14

13

15 16

data

14

17

20

25

33

wave period T

40

(seconds)

relative energy (dB)

-20

-30

-40 -50

-60

-70 -80

-90

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See also Stopa et al. (The Cryosphere 2016).

Getting into sea ice: Hindcasts & forecasts for FP7 project « SWARP

Ice thickness from TOPAZ



Maximum floe diameter (WW3)





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Small-scale currents: Not just the mss, Hs also varies





Example of local validation of current effects (Ardhuin et al. JPO 2012):





"Pierres Noires" buoy, WMO number 62069



Ongoing work at smaller scales... using drifting wave buoys

f (Hz)

w.um





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Short waves, spectrum & fluxes





Wave evolution should be the result of



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Another reason to split S is to be able to compute fluxes :

 $S = S_{ln} + S_{in} + S_{nl} + S_{ds} + S_{bot} + S_{db} + S_{tr} + S_{sc} + S_{ice} + S_{ref}$







Inertial range seemed OK with « TEST451 » (e.g. Thomson & al. JGR 2013) ... compared to Datawell buoy.







At higher frequencies... no good balance... → TEST471 update + ongoing work







Using stereo-video as reference data (Leckler et al. JPO 2015)







Attempts at whitecap parameters (Leckler et al. 2013):

- little variability of WCC ... missing currents ? Other ?







Attempts at whitecap parameters (Leckler et al. 2013):

More variability of foam thickness (based on modelled lambda + Reul & Chapron 2003)







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- Different forcing & parameterizations \rightarrow different results
 - Rapid improvements in wave-ice interactions
 - Small scale variability requires realistic currents
 - Hence EE9 proposal « SKIM »: measuring waves + currents https://www.facebook.com/SKIM4EE9
 - Slow progress on spectrum tail: new techniques (stereo, polarimetry ...) are great
 - Connecting to fluxes (see poster by Lucia) and whitecap parameters :

more validation work needed

Tons of model output at ftp://ftp.ifremer.fr/ww3/HINDCAST

