IMPROVING OPERATIONAL WAVE MODELLING FROM SATELLITE MEASUREMENTS

Jean-Michel Lefevre[1], Lotfi Aouf[1], Pierre Le Roy[1], Pierre Queffeulou[2], Abderrahim Bentamy[2], Yves Quilfen[2]

[1]Meteo-France, Toulouse, France, [2]IFREMER, Plouzané, France

ABSTRACT

Modelling and forecasting sea-state is of great importance for many issues related to the safety of people and goods. Global Numerical Sea State Prediction (NSSP) models are operational in many National Weather Services (NWS) to provide sea state forecasts and analyses. Altimeters offer the opportunity to sample wave height measurements over the whole ocean surface with high accuracy and coverage. At global scale, it is therefore possible to map wave height model errors in order to identify specific geographical areas of these errors. At regional scale, modelling of hurricane winds by national weather services has greatly improved since the availability of satellite wind measurements such as provided by scatterometers and micro wave radiometers. The purpose of this study is to assess the performances of some operational wind and wave models at global scale first, then at regional scale in areas of occurrence of tropical cyclones, using all appropriate surface data from satellite sensors. Winds from several Numerical Weather Prediction models are evaluated and compared with satellite wind measurements (scatterometers, radiometers), and blended winds, merging model and scatterometer wind fields. For instance, the atmospheric models tend to underestimate winds, especially for high wind conditions, compared to the remotely sensed data. Such underestimation may exceed 5m/s. Because winds from tropical cyclones are very strong (above 63 kts) the drag formulation has been also revised. The case of GAMEDE, a tropical cyclone in the Indian Ocean in February 2007 has been carefully documented and analyzed.

MOTIVATIONS

- Meteo-France is currently implementing a global 3rd generation (3G) model (MF-WAM), derived from ECWAM (ECMWF WAM model) and is testing new parametrisations under development for the dissipation term (Ardhuin 2008, personnal communication).
- A hurricane wave model was implemented in overseas French territories a few years ago, based on the 2nd generation (2G) wave model VAG driven by analytical hurricane winds using information from NHC/TPC advisories. However, some strong limitations were found mainly due a too poor wind description, lake of boundaries conditions, wind drag formulation…
- A limited area model was implemented at la Reunion in 2006 with hurricane bogusing and has been recently improved with the introduction of a 3D wind vortex based on hurricane advisories issued by la Reunion Hurricane Centre.

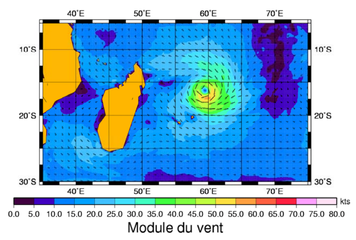
QUESTIONS

- Can winds from NWP models be used to forecast waves for Hurricane conditions (ECMWF, ARPEGE, ALADIN), instead of analytical models and Can global wave model catch hurricane sea-states?
- Are 3rd generation wave models more adapted to such conditions, in comparison to 2nd generation ones?
- Is the wind drag formulation important at high wind speed?

EXPERIMENTAL SET UP

MF-WAM and WW3-SHOM have been implemented at global scale and run for the full 2007 year. Regional versions of MF-WAM and VAG implemented over the Indian ocean and run a tropical cyclone event (GAMEDE) using several wind sources. High resolution wind fields are provided by ALADIN-Reunion NWP model, described hereafter:

Domain



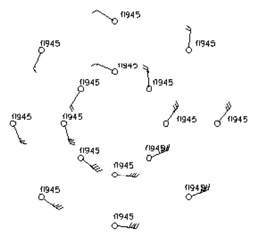
- **Operational since nov. 2006**
- **10km** horizontal résolution
- **3D Var** assimilation scheme over a 6h window (4/day)
- 60 vertical levels
- **2-day leadtime** forecast (at 00 and 12h UTC).

Boundary conditions are from ARPEGE model.

Observation dataset

- SYNOP/SHIP/BUOY, Radiosondes, Profilers, Aircrafts
- Cloud winds (METEOSAT 7, 9)
- Scatterometer winds (QuickScat, ERS-2 and METOP-A
- ATOVS HIRS, AMSU-A, AMSU-B (NOAA 15,16,17,18 AQUA ; METOP-A), AIRS (AQUA)
- SSMI in clear-sky conditions (DMSP F13, F14)
- Satellite GPS

Because of the lack of observations at the vicinity of the hurricane core, syntetic observations are used from vor winds as defined by Holland or Rankine



- One global domain and one limited area domain over the Indian Ocean (–6N –30S 35E 75E)
- Wave Model resolutions:
  - -0.5°x0.5° for global
  - -0.25°x0.25° for limited area
- Wave models :
  - -VAG , MF-WAM,
  - -VAG_MOD (MODified for the DRAG) MF-WAM_MOD
  - -WW3_337 and WW3_441 (SHOM model, Courtesy F. Arduin)
- Wind forcing (6h or 3h) from NWP models
  - -CEP (ECMWF) 0.25
  - -ARPTRO 0.5 (Global model)
  - -ALADIN (2007 version)
  - -ALADIN HOLLAND (2008 version)
  - -ALADIN RANKINE (Experimental)
- Data from ENVISAT, JASON-1 and GFO Satellites

- Hurricane analytical wind models:

-Characteristics of hurricanes from the DVORAK method can feed cyclone analytical models.

- Tangential wind (Rankine, 1901,left panel):

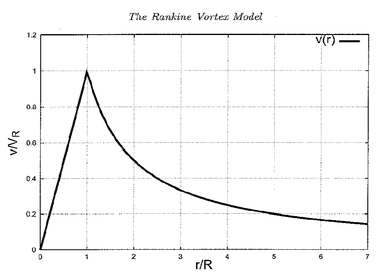
if r<rm vt=vm*(r/rm); if r>rm vt=vm*(rm/r)

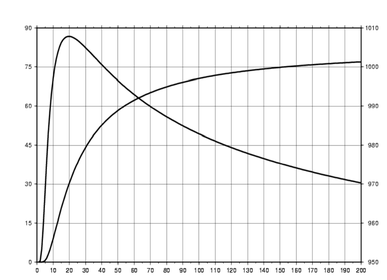
-Tangen equatio $P = P_c + (P_n - P_c).e^{\left[-\left(\frac{r_m}{r}\right)^b\right]}$ id panel)

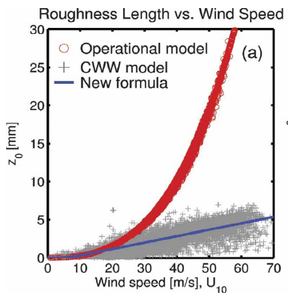
With:

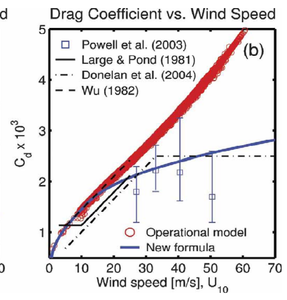
- In MF-WAM, the wind stress is sea-state dependant resulting in a saturation of the drag coefficient at high winds as shown below:

$$z_0 = \frac{\alpha . u_*^2}{g\sqrt{1-\frac{\tau_w}{\tau}}} \qquad u_* = \frac{kU}{\ln\left(10/z_0\right)}$$

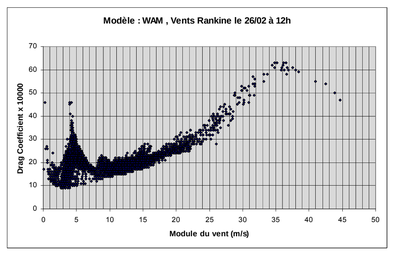


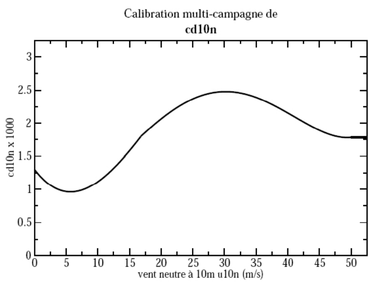






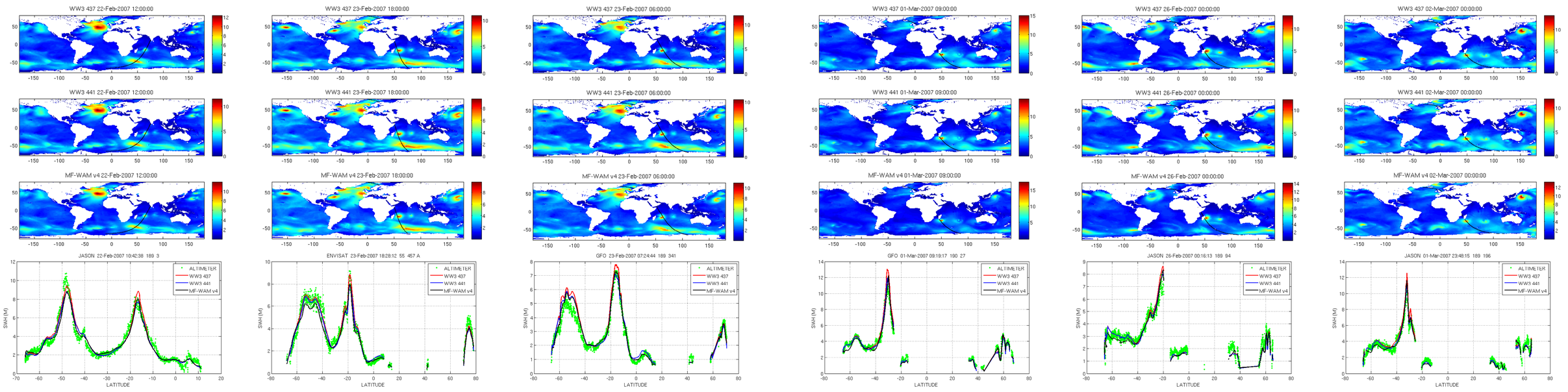
Roughness length and Drag coefficient versus wind speed from different parametrisatin, In Moon et all 2006

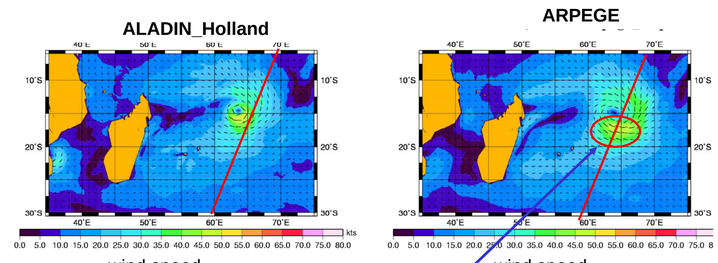




New Drag coefficient) from a multicampain analysis (Belamari, personnal communication. This parametrisation has been tested for wind speed above 30 m/s

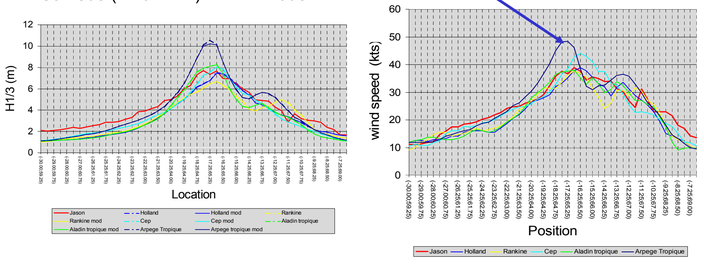
Maps of SWH outputs from WW3_437, WW3_441 and MF-WAM, together with comparisons of SWH values from models and altimeters along the indian ocean satellite track (shown in black on the maps)



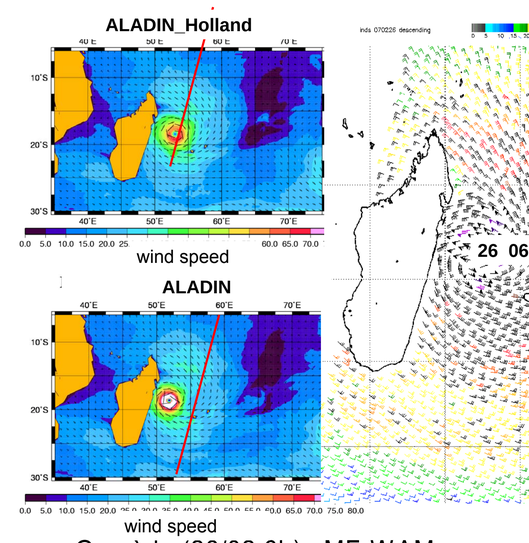


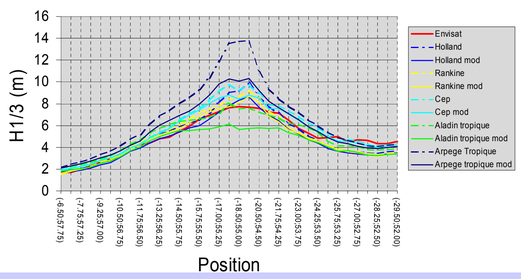
ARPEGE winds are too strong at a certain distance from the storm centre, probably due a too coarse NWP model resolution (0.5°)

Gamède (22/02 12h) : WAM model



On March 23rd at 12h, Gamède is already a Tropical Cyclone and large differences in wind speed spatial structures are found depending on NWP models





The wind structure asymmetry as shown by Quickscat data is not well reproduced by NWP models, resulting in wrong fetch and to an overestimation of the model SWH in the vicinity of la Réunion. According to the scatterometter data, the best location of the Hurricane centre is given by the ALADIN model.

MAIN RESULTS AND PERSPECTIVES

- Quality of the wind forcing is the dominant factor for hurricane sea-state modelling, as expected and the ALADIN-Réunion NWP model (3D Bogusing) is performing better than others NWP models we used. It is also true in the forecast period (Westrelin et al. 2008), however the wind structure asymmetry was not always well represented.
- The drag modification had a week impact in our study (large hurricane case), in particular for MF-WAM since the saturation of the drag already exists at high wind speed unlike for VAG. WAM and VAG provides similar results in the « resonant » quadrant, elsewhere they are significant differences and MF-WM performs better.
- Small hurricane cases have to be investigated in the future and the wave model sensitivity to wind input frequency as well. Because of the quick wind rotation in hurricanes the impact of exact non-linear interactions rather than DIA (Discret Interaction Approximation) has to be investigated as well.

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