TO BLEND OR NOT TO BLEND
In the Pursuit of Finding an Operational Way to Give hurricane characteristics to the CMC Forecast Wind Field

Serge Desjardins[2]
Roop Lalbeharry[1]
Allan MacAfee[2]
Hal Ritchie[3]
Garry Pearson[2]

Environment Canada
1: Science and Technology Branch
2: Meteorological Service of Canada
3 : Recherche en Prévision Numérique

National Lab for Marine and Coastal Meteorology

Halifax, Nova Scotia

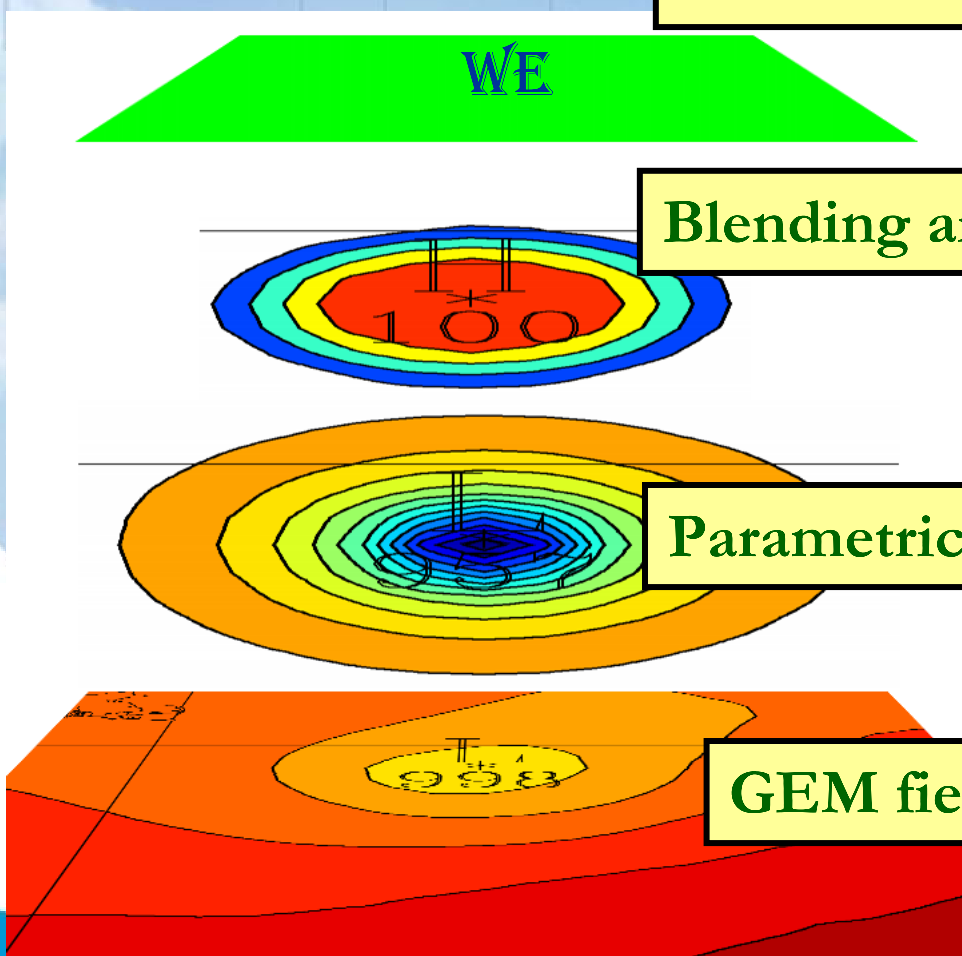
Environment Canada Environnement Canada

Canada

Towards an operational hurricane surge/wave forecast system

- In the longer term, improvements in observations, data assimilation and NWP forecast systems should produce more accurate hurricane and extratropical transition (ET) forecasts.
- In search of practical improvements in the shorter term, we propose to blend parametric hurricane wind and pressure fields based on Canadian Hurricane Centre trajectory forecasts into the operational surface fields used as input for the ocean wave model and storm surge model.
- Because of the unpredictable nature of hurricanes, a human intervention tool is needed. The Canadian Hurricane Centre forecast trajectory becomes the official and final hurricane forecast (track and intensity) for various users.
- HURSWIM has been developed to supply wave and storm surge forecast guidance for forecasters when hurricanes or tropical cyclones affect the Canadian waters of responsibility.

A glimpse at the Blending Methodology



Environment Weight $= f\left(\left\langle \zeta_c^f \middle| \zeta_c^h \right\rangle\right)$

Blending area $= f\left(\zeta_c, \left\langle P_0^f \middle| P_0^h \right\rangle, \left\langle UV_{max}^f \middle| UV_{max}^h \right\rangle\right)$

Parametric fields:

hurricane_Δx : resolution = 0.1 deg

Model2_Δx : resolution = 0.5 deg

Δt_blending : 1 hour

GEM fields:

Model1_Δx : resolution = 24km(Juan)
= 15km(Wilma)

CONCLUSIONS

- **BLENDING methods are applied as <u>an artificial way to merge together</u> valuable information from different sources.**
  - **One should not expect to simulate reality perfectly.**
  - **Blending methods can vary and adopt personal characteristics.**

- **Insertion of a Hurricane wind field into the Regional GEM forecast gives a more realistic wind forecast reflecting the presence of an intense and compact wind system.**

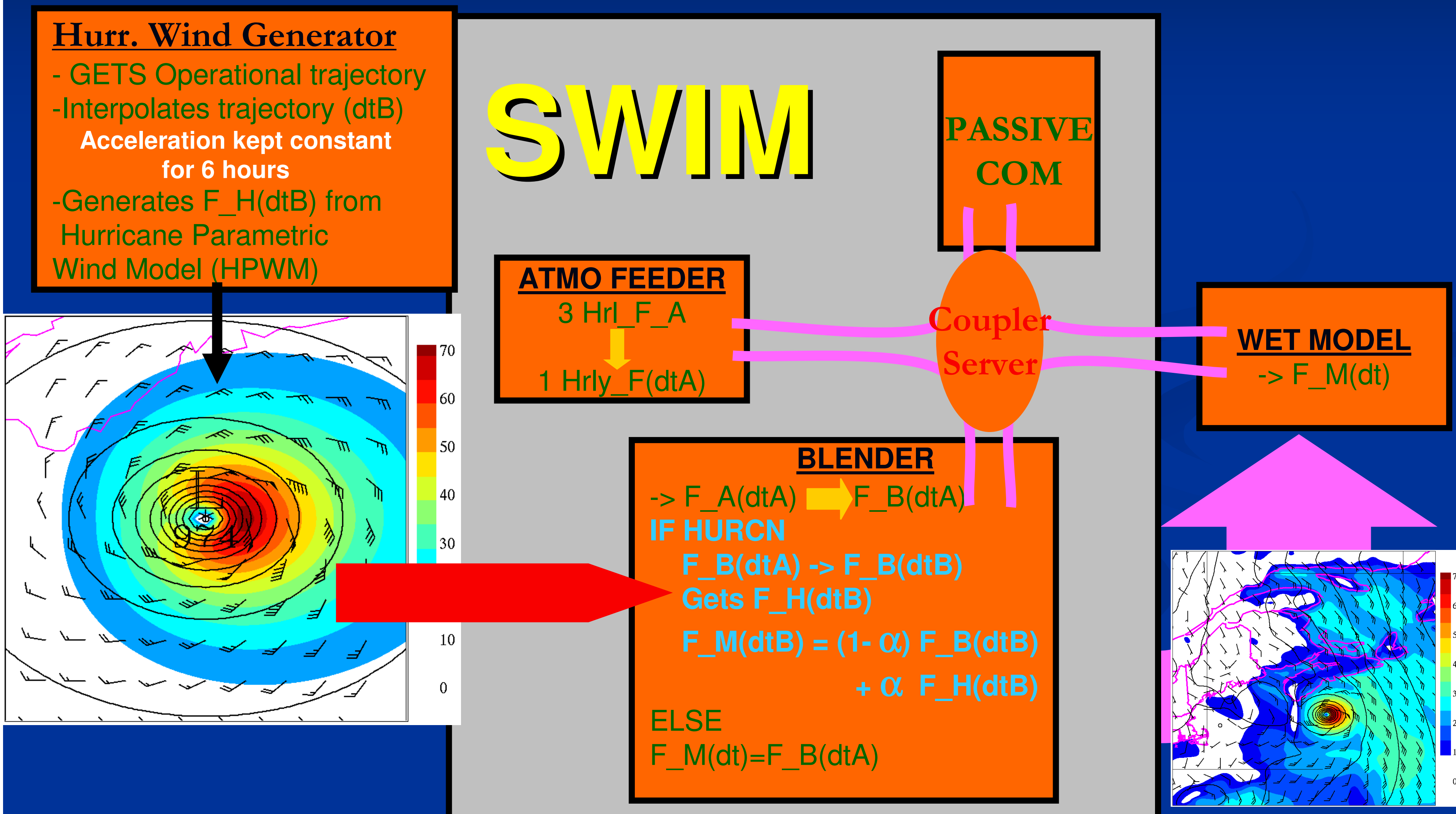
- **Consequently, improves the wave field.**

Overall, HURSWIM could help the forecaster by supplying products where the forecast wind field, used by a wet model, has a hurricane or tropical cyclone in it.

- **The New Environment Weight parameter :**
  - **Minimizes the impact of blending in developed synoptic system**
  - **Allow blending of various tropical system (TS, Hurricane, ET)**

- **The New Blending Radius parameter :**
  - **Edge of the positive surface geostrophic vorticity seems to define well the blending zone.**

SWIM
Surface Wind Interpolator and Modifier



Hurricane Parametric Wind Model (HPWM)

SLOSH Model (Jelesnianski et al. 1992)

Empirical: Curve Fitting method

$$V = V_m \frac{2RR_m}{(R_m^2 + R^2)}$$

$$V_T = V_{Storm} \frac{RR_m}{(R_m^2 + R^2)}$$

Adjustments of modelled winds

- corresponds to mean boundary layer or gradient wind above the surface

-Adjusted to 10-m elevation with

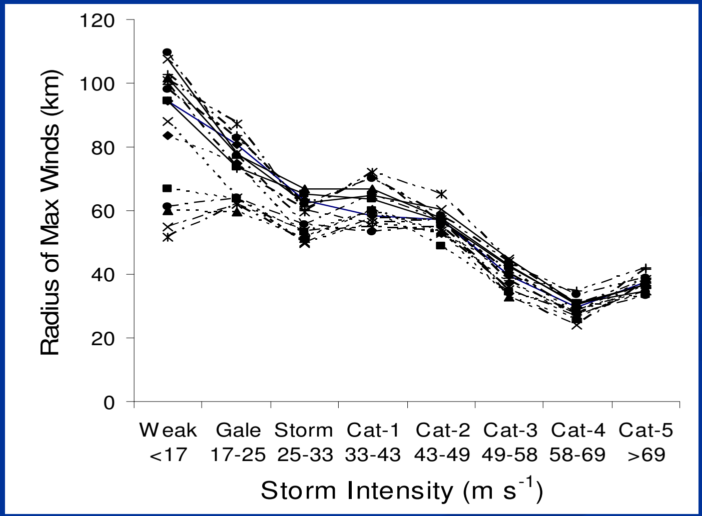
$$V_{10} = K_m V$$

Km -> [70-85] %

In our case Km = 75%

Atlantic HPWM particularity

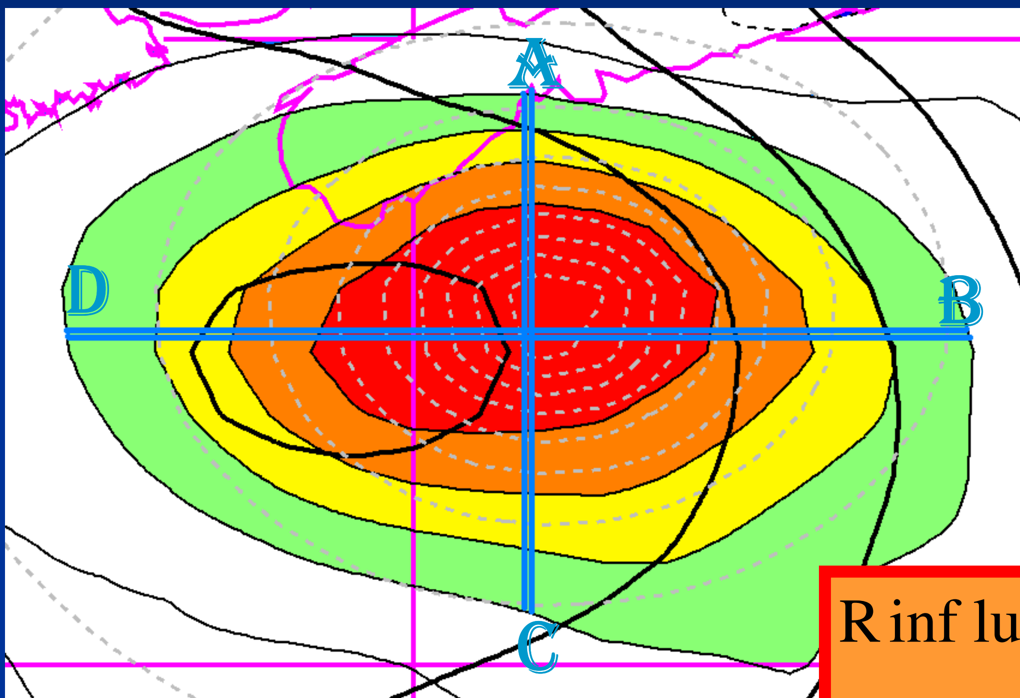
(Allan MacAfee's work)



- Radii of maximum wind (R_m) curves, extracted along radial profiles from the storm centre at 22.5° intervals, for different classes of storm intensity. (Storm data: HRD gridded winds for 389 storms from 1998–2003).

- Vary with latitude

Blending Zone : Geostrophic vorticity edge
(ζ_{min} = 1*10^{-6} sec^{-1})
Rinflu : Radius of Influence



Color : Forecasted Geo. Vorticity (10^{-6} s^{-1})
Black : Forecasted Isobars (4 hPa)
Gray : Inserted Hurricane Isobars (4 hPa)

LAPLACIAN COMPUTATION

$$\Delta x = \sim 100\,\mathrm{km}$$

$$\nabla^2 = 0.5 * \left(\nabla^2_{+} + \nabla^2_{x}\right)$$

$$R\inf lu = \zeta_c / \overline{\nabla}$$

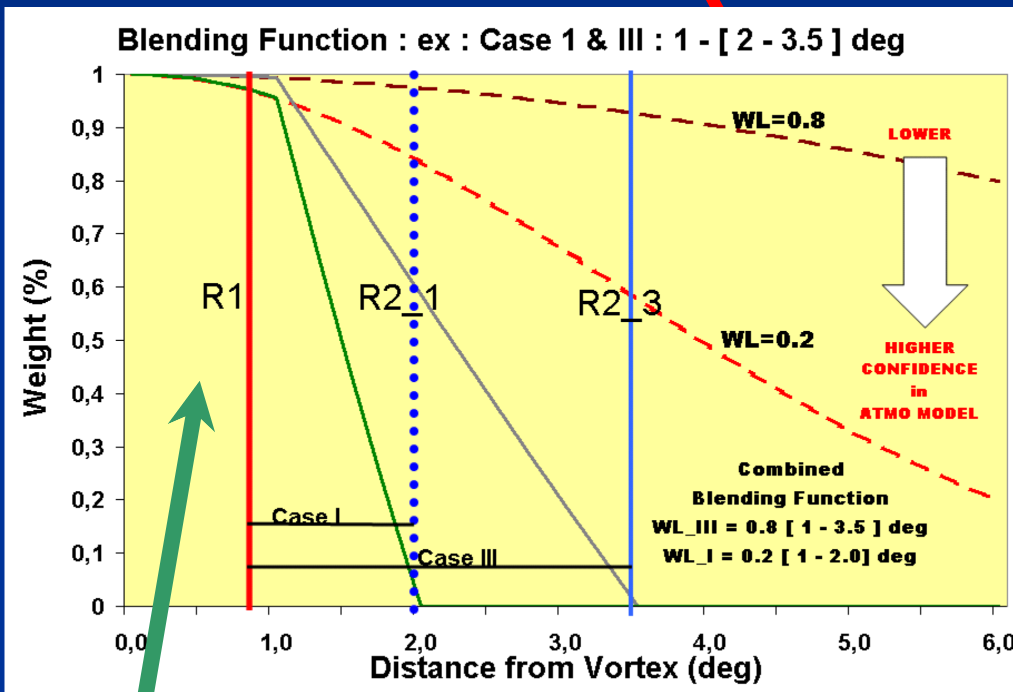
$$\text{where } \overline{\nabla} = AVG\left[\frac{\zeta_c - \zeta_{min}}{R_i}\right]$$

$$\text{where } i \text{ indicates Points } \langle A, B, C, D \rangle$$

Blending Weight : Ω

WL = Confidence Indices

W_edge (uv,p) = WL = 40 % W(Δuv) + 60 % W(Δp)



Vortex max speed difference

if $uv_{mdl} > 15$ knots

$$W(\Delta uv) = \frac{|uv_{hur} - uv_{mdl}|}{uv_{mdl}} \leq 1. \quad \text{else} \quad 1.0$$

Vortex pressure difference

$$W(\Delta p) = \frac{|p_{hur} - p_{anl}|}{\Delta p_{Lim}} \quad \Delta p < \Delta p_{Lim} = 30hPa$$

$$= 1.0 \quad \Delta p \geq \Delta p_{Lim}$$

$$B = \begin{cases} = \Omega & r \leq R_1 \\ = \Omega * \dfrac{R_2 - r}{R_2 - R_1} & r \in [R_1 , R_2] \\ = 0.0 & r \geq R_2 \end{cases}$$

$$\Omega(r, R_2, WL) = \exp(\ln(WL) * Z^2) \quad | \quad Z = \frac{r}{R_{max} (= 6 \text{ deg})}$$

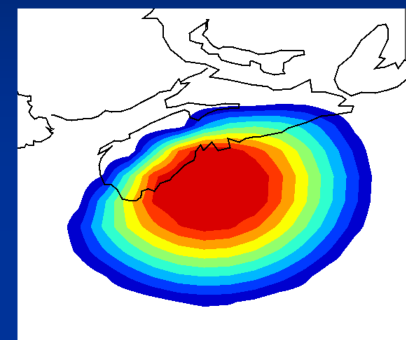
Blending : Track Dependency

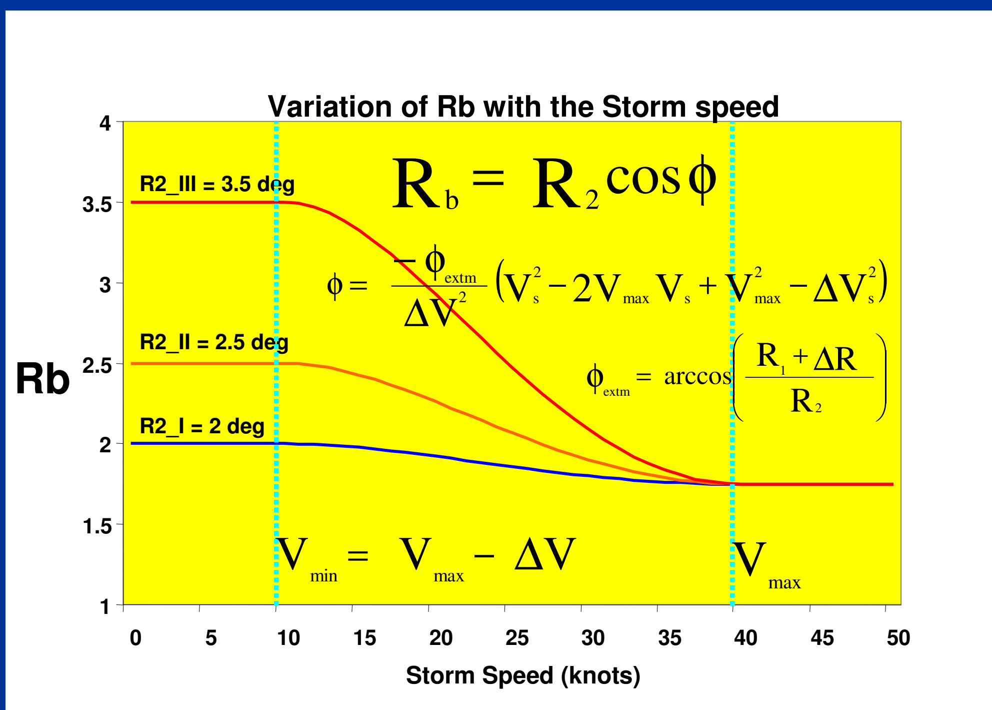
LEFT OF TRACK : ELLIPTIC BLENDING ZONE

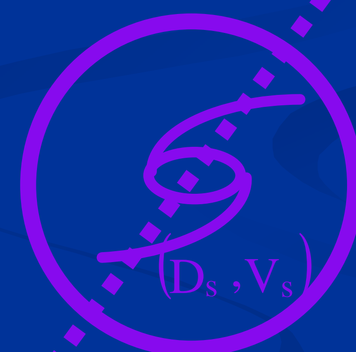
$$
B = \begin{cases} 1.0 & r \le R_1 \\ \Omega * \dfrac{R_{2\_ellp} - r}{R_{2\_ellp} - R_1} & r \in [R_1 , R_{2\_ellp}] \\ 0.0 & r \ge R_{2\_ellp} \end{cases}
$$

$$
R_{2\_ellp} = \frac{R_2^2 R_b^2}{R_2^2 \sin^2(\theta - \phi) + R_b^2 \cos^2(\theta - D_s)}
$$

D_s : Storm direction

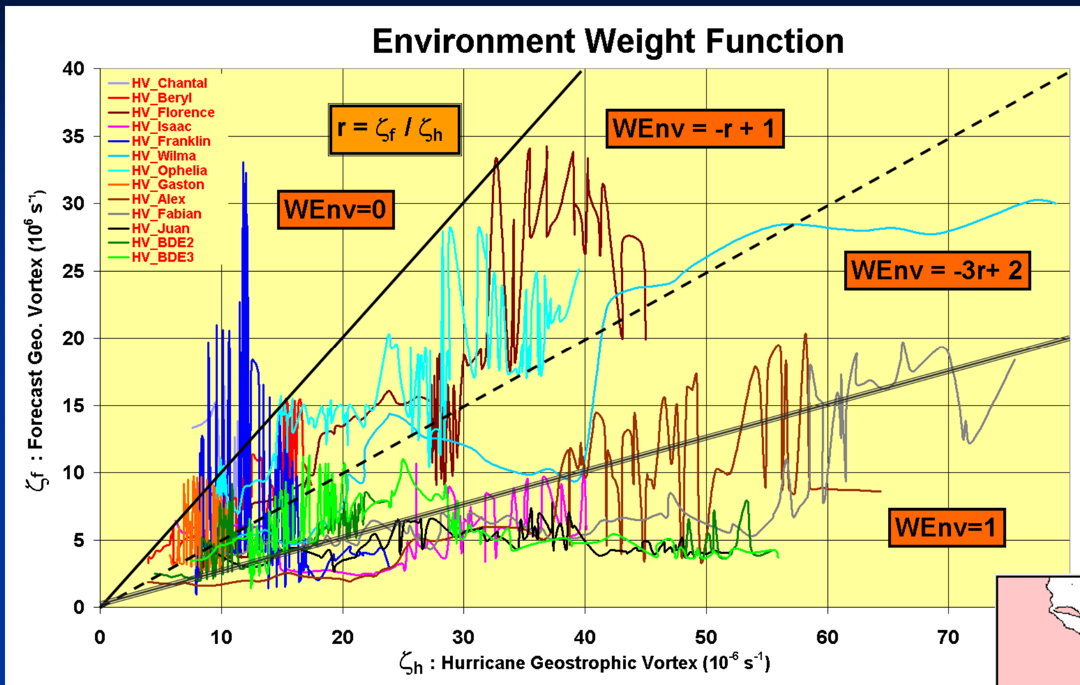






$$
B = \begin{cases} 1.0 & r \le R_1 \\ \Omega * \dfrac{R_2 - r}{R_2 - R_1} & r \in [R_1 , R_2] \\ 0.0 & r \ge R_2 \end{cases}
$$

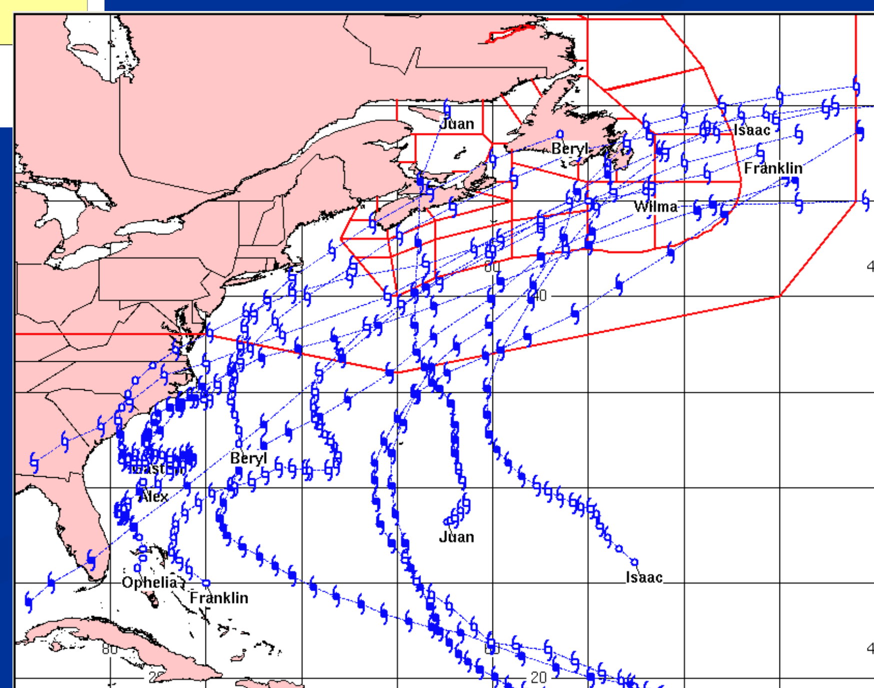
Blending : Environment Weight



HURRICANE CASES

CASE	PERIOD	INTENSITY
Chantal_2007	Jul. 29 - Aug. 02	TP
Beryl_2206	Jul. 18 - Jul. 23	TS
Florence_2206	Sep. 09 - Sep. 15	TS-SS1-TS
Isaac_2006	Sep.27 - Oct. 03	TS-SS1-TS
Franklin_2005	Jul. 21 - Jul. 31	TS
Ophelia_2005	Sep. 09 - Sep. 19	TS/SS1-TS
Wilma_2005	Oct. 24 - Oct. 28	SS2-SS3-TS
Alex_2004	Jul. 31 - Aug. 06	TS-SS1/2-TS
Fabian_2003	Sep. 04 - Sep. 08	SS4-SS1
Juan_2003	Sep. 25 - Sep. 30.	TS-SS1
BDE_1998	Aug. 31 - Sep. 09	SS1-TS / TS

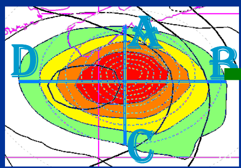
HURRICANE TRAJECTORIES



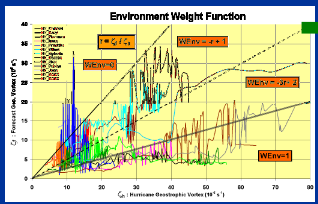
Blending : Vortex Distance Dependency
FINAL ADJUSTMENT on R2 and WE

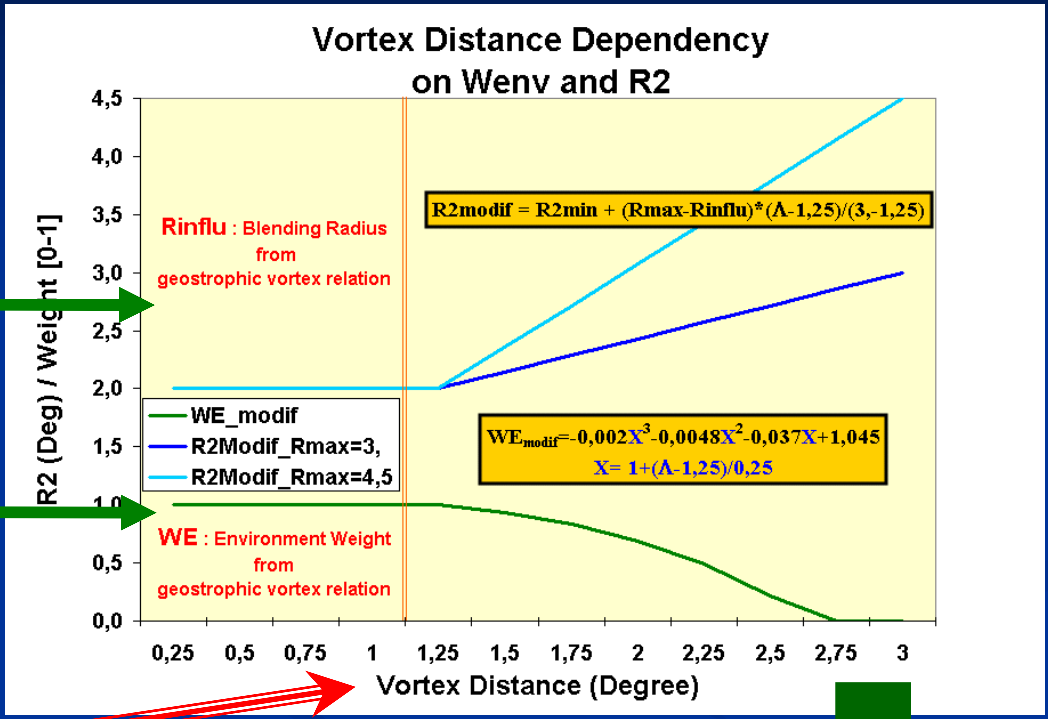
BLENDING PARAMETERS

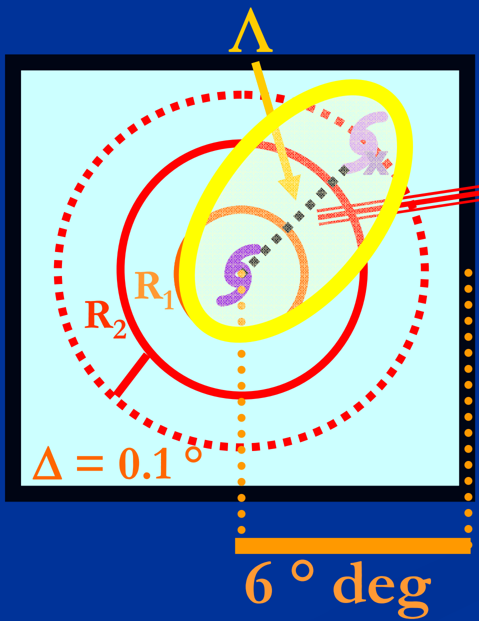
Rinflu



WE







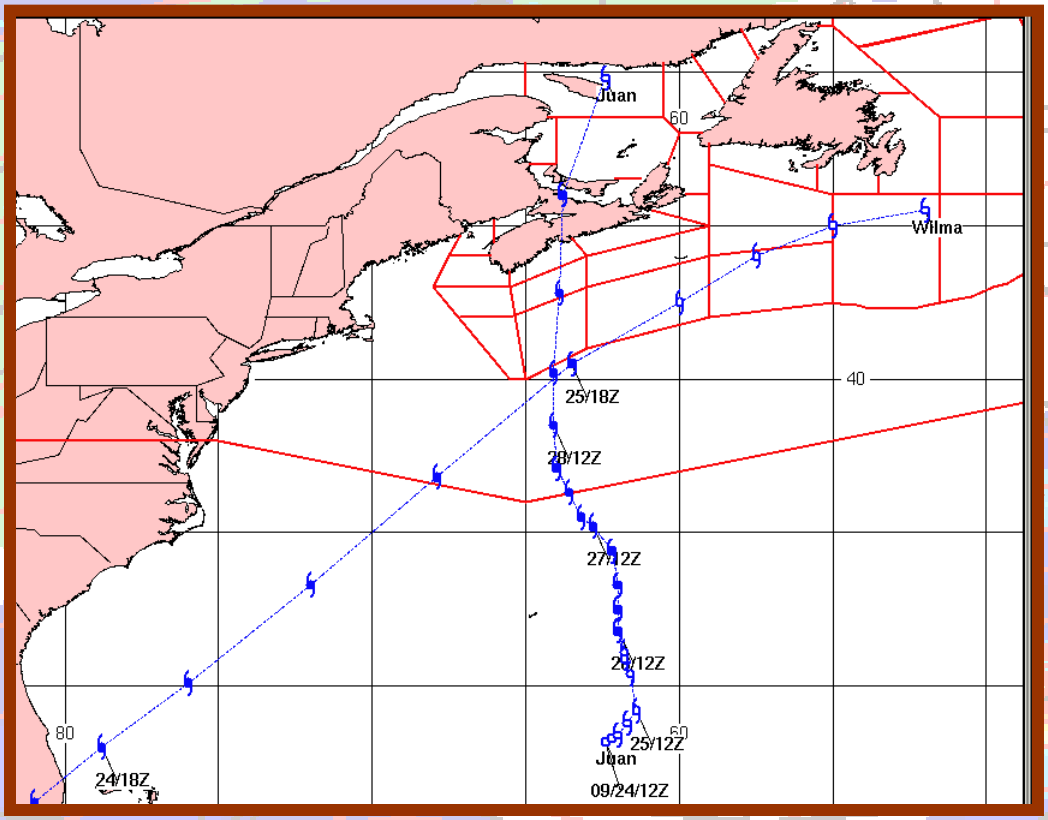
$$
B = \begin{cases} WE & r \le R_1 \\ WE * \Omega * \dfrac{R_2^M - r}{R_2^M - R_1} & r \in [R_1, R_2^M] \\ 0.0 & r \ge R_2^M \end{cases}
$$

Juan

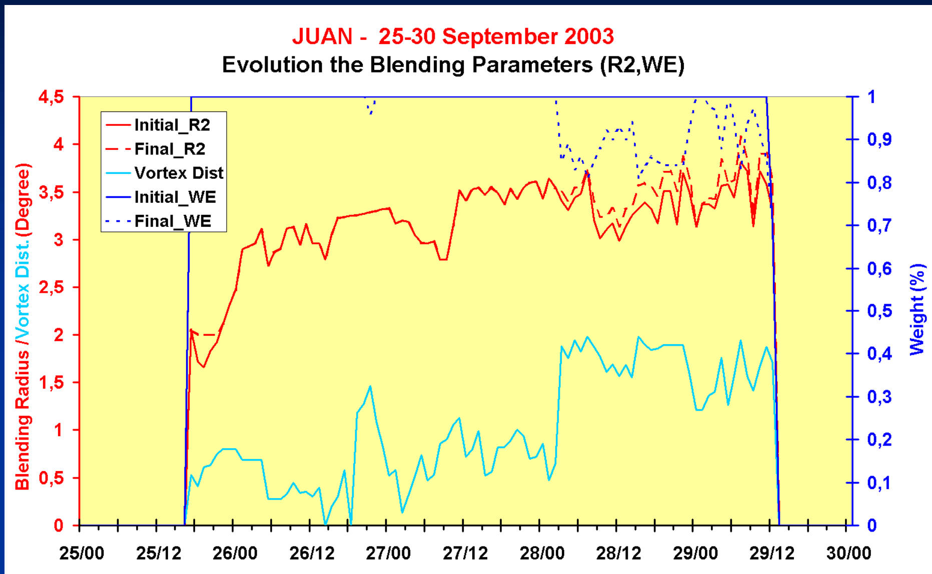
2003 : Sep 25/00z - 30/00z

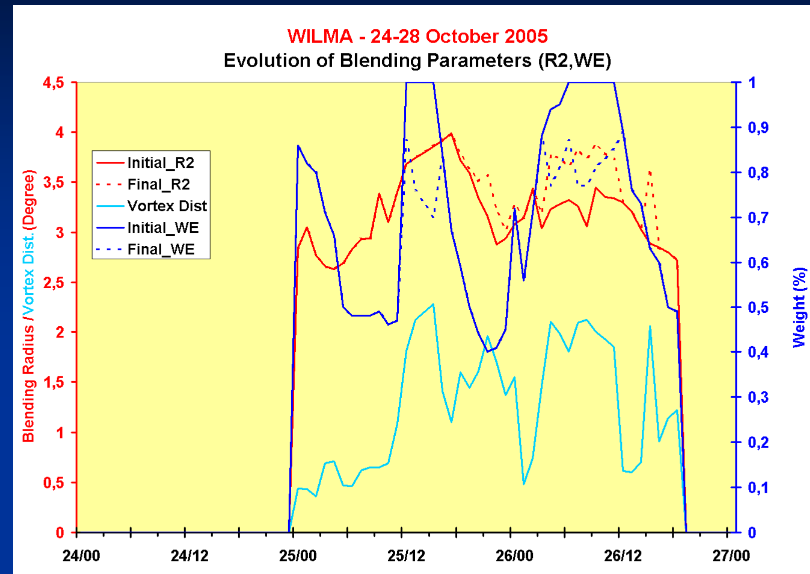
Wilma

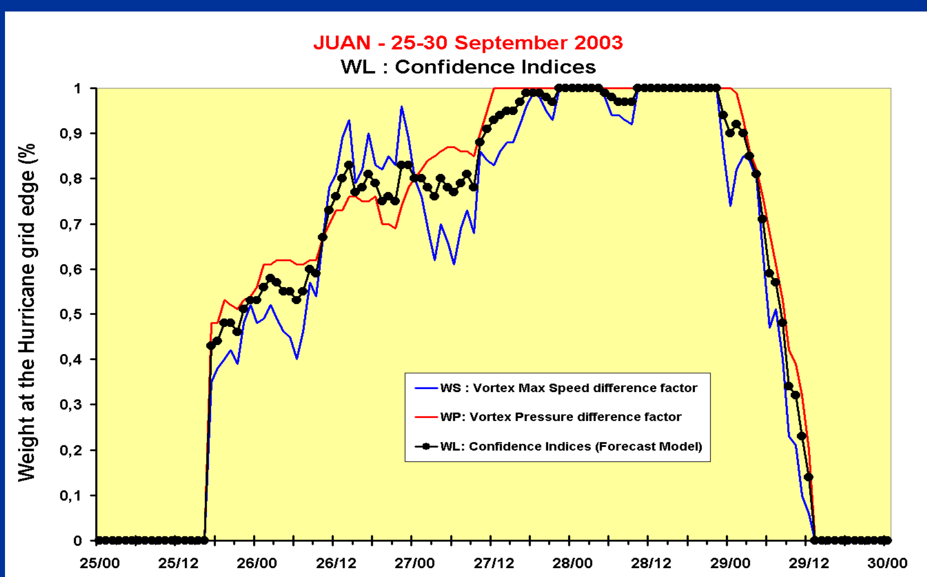
2005 : Oct 24/00z – Oct 28/00z

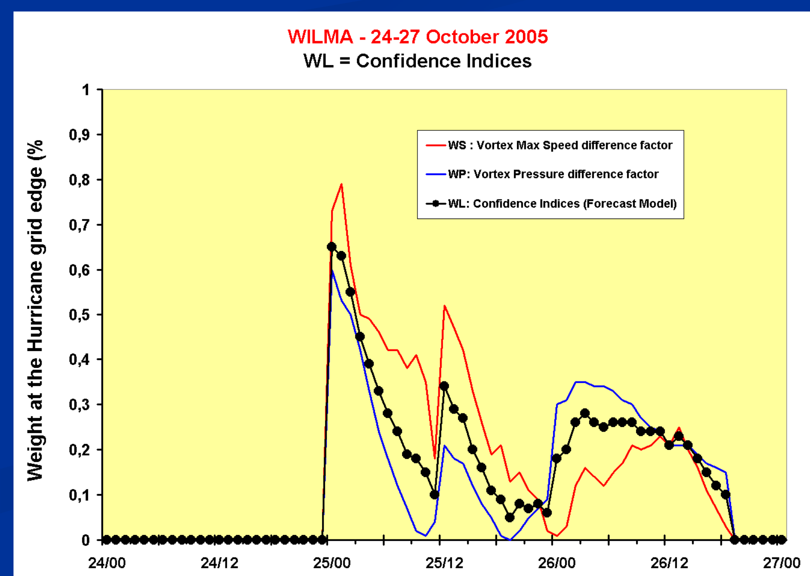


Blending : Parameter Evolution



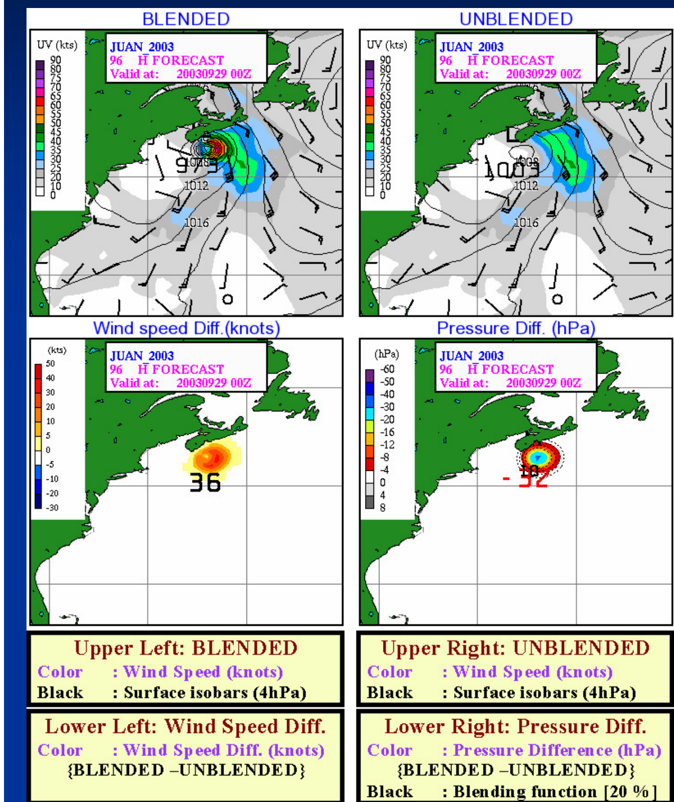




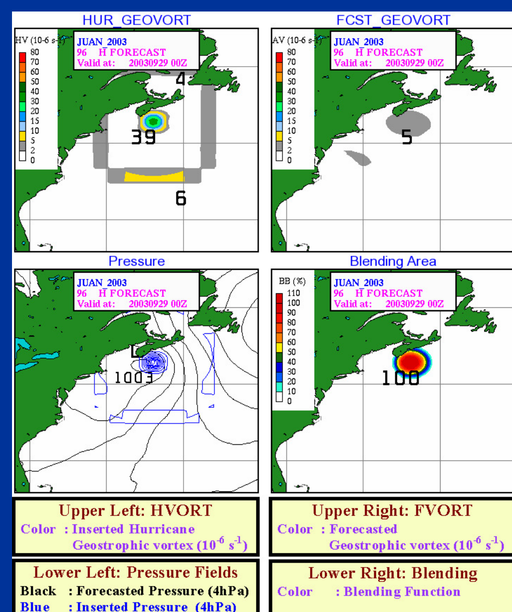


Blended Fields : Juan : Sep 25-30 2003

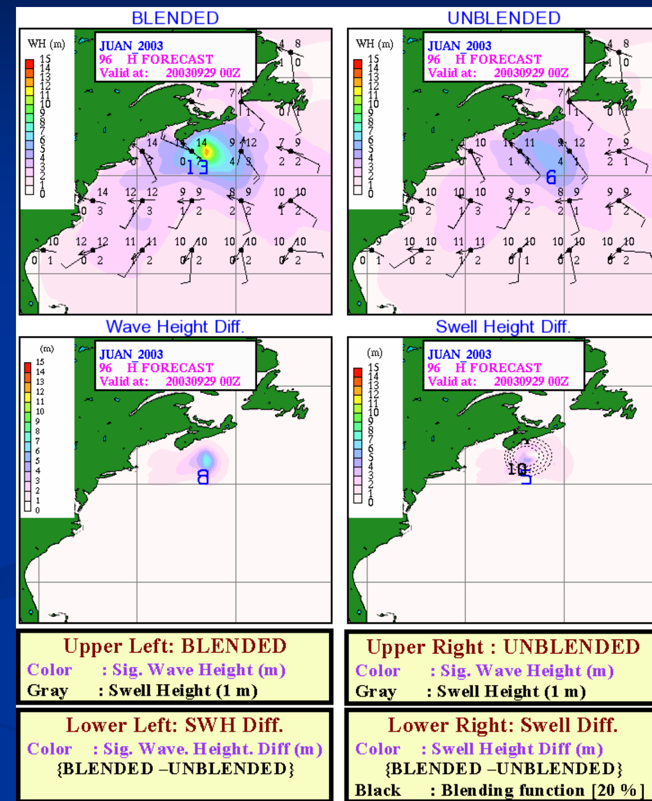
PRESSURE AND WIND

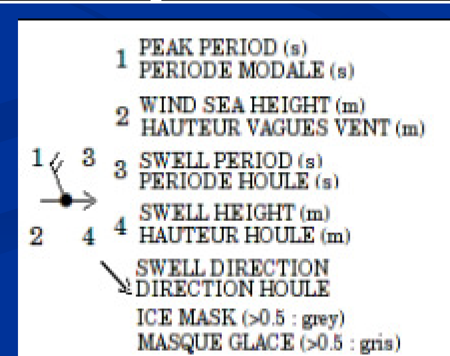


VORTICITY



SIG WAVE AND SWELL

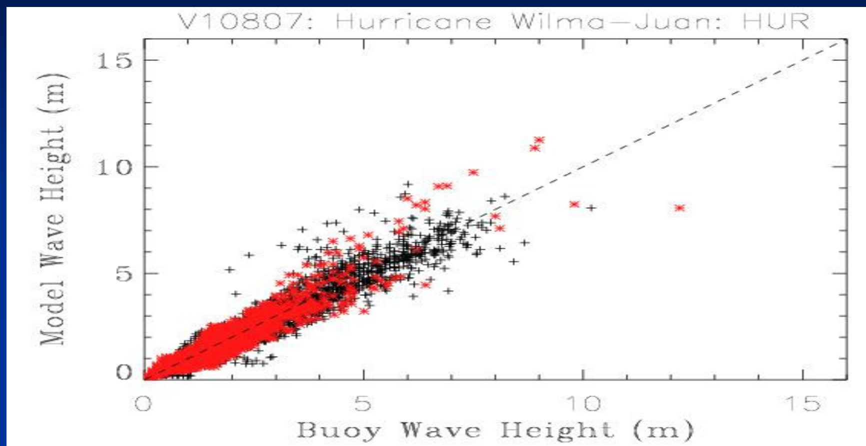


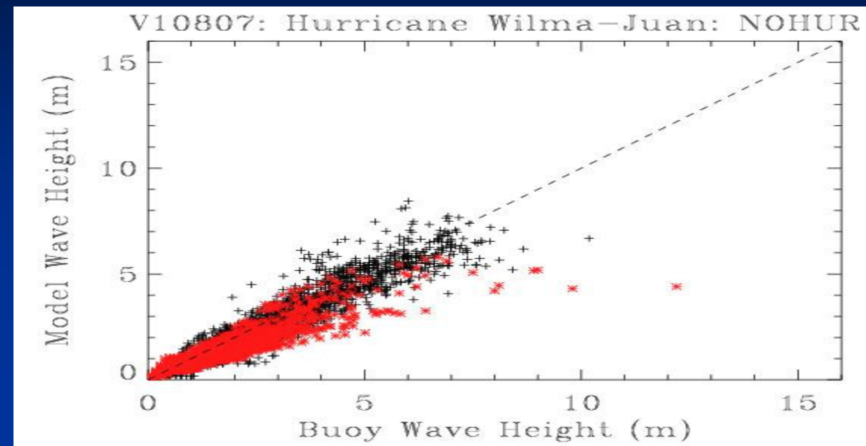


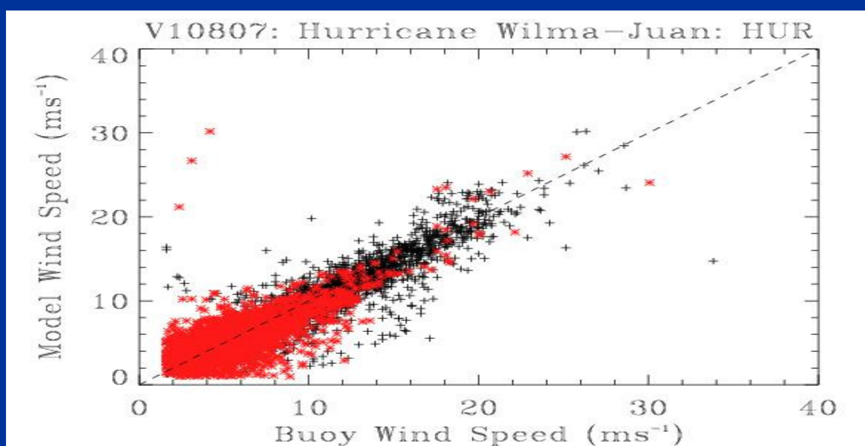
IF INTERESTED

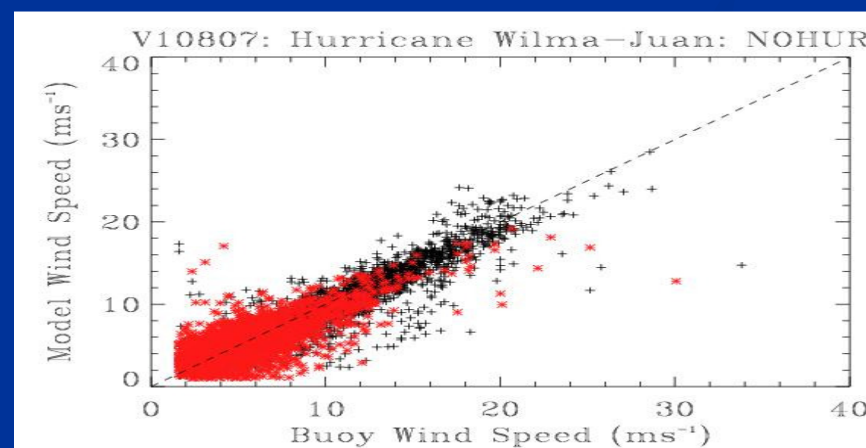
I HAVE ANIMATIONS FOR ALL CASES

Scatter Plots for Juan and Wilma









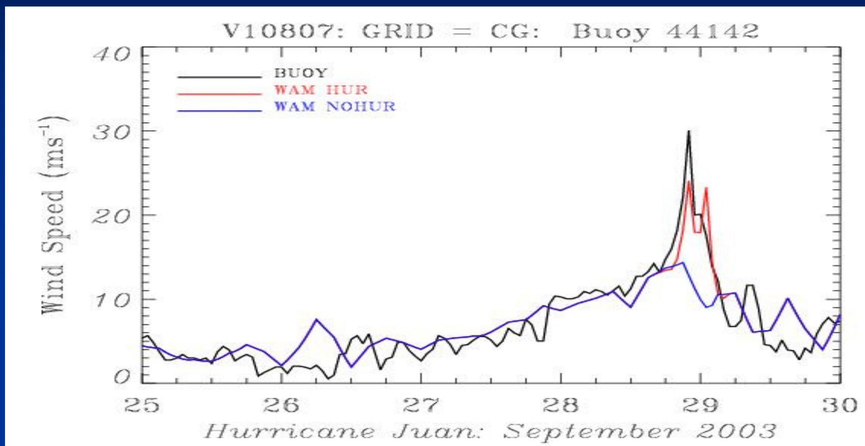
Wilma (black) and Juan (red) ***SWH and Wind Speeds Scatter Plots***

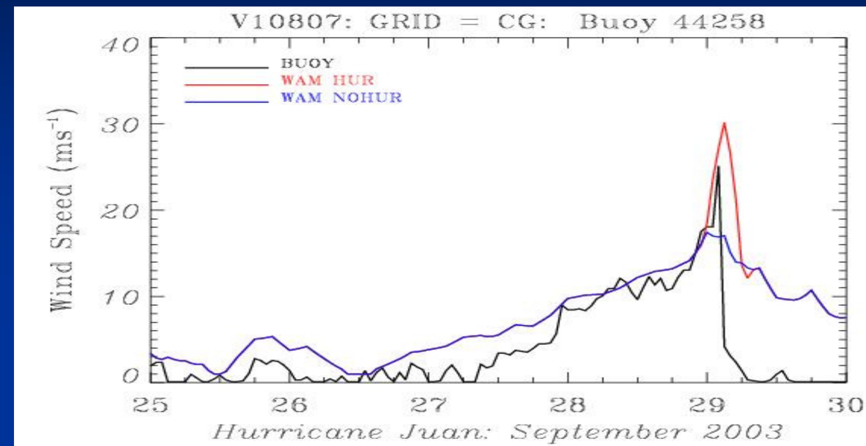
Legend: HUR = Hurricane blending
NOHUR = No hurricane blending
CG = Coarse grid (0.5° res.)

Wind /Wave time series : Juan

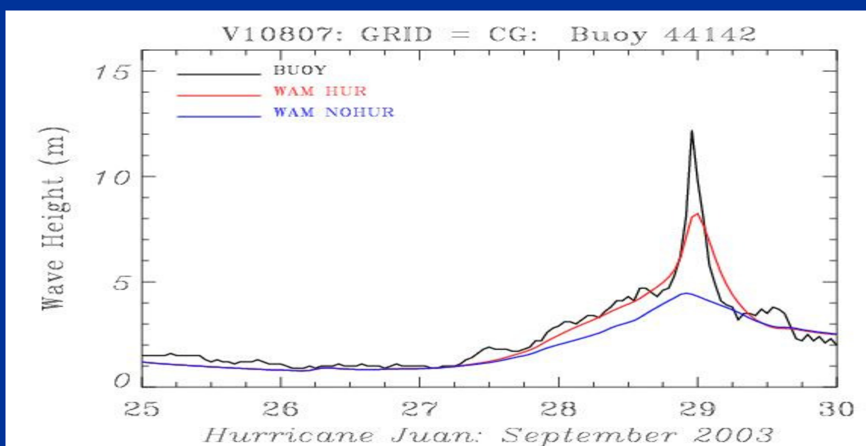
44142

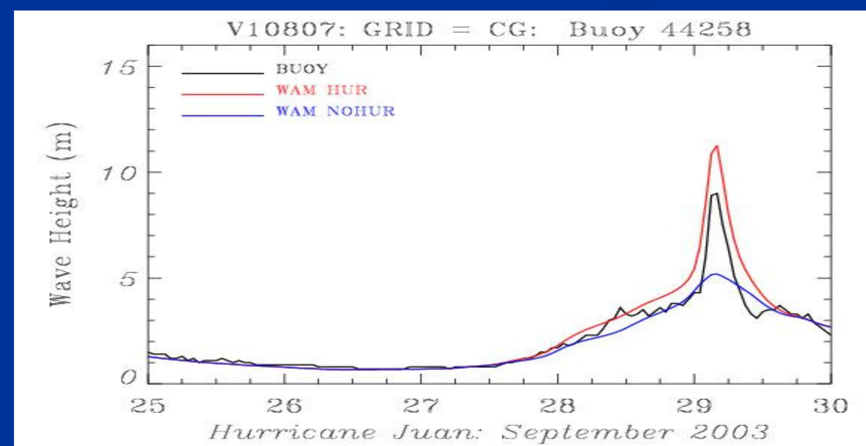
44258





Wind Speed



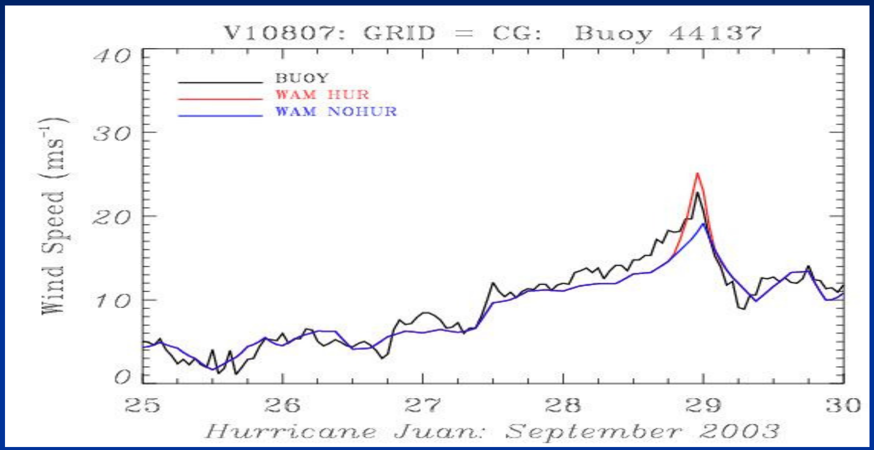


Wave Heigth

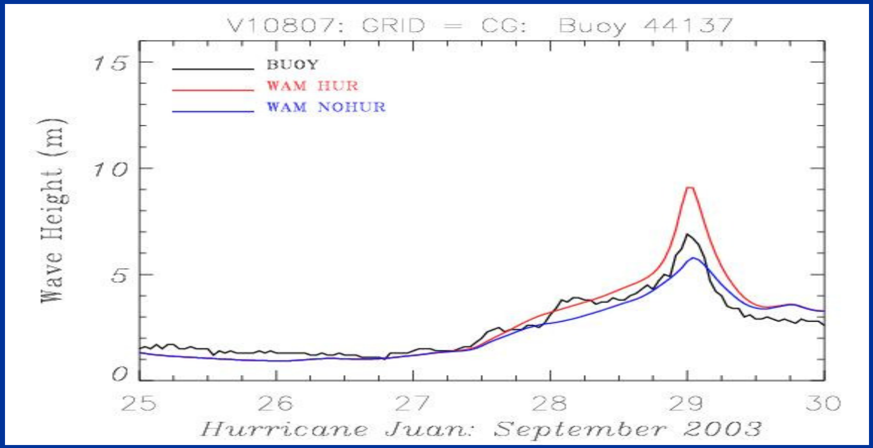
Legend: *HUR = Hurricane blending*
NOHUR = No hurricane blending
CG = Coarse grid (0.5° res.)

Wind /Wave time series : Juan

44137



Wind Speed

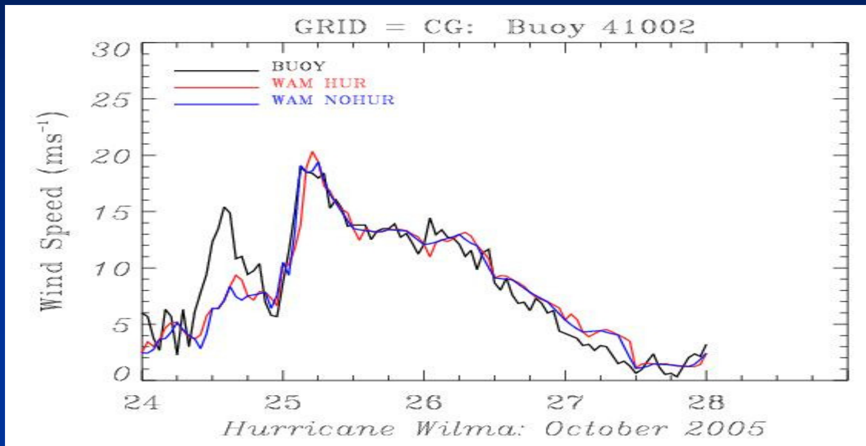


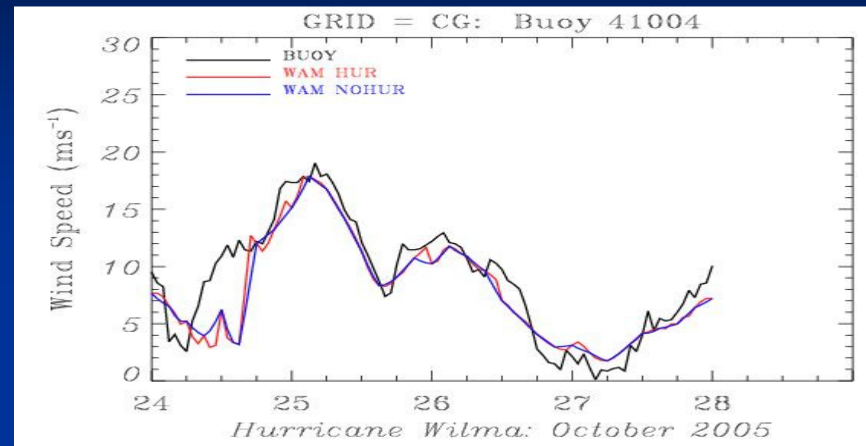
Wave Heigth

Legend: *HUR = Hurricane blending*
NOHUR = No hurricane blending
CG = Coarse grid (0.5° res.)

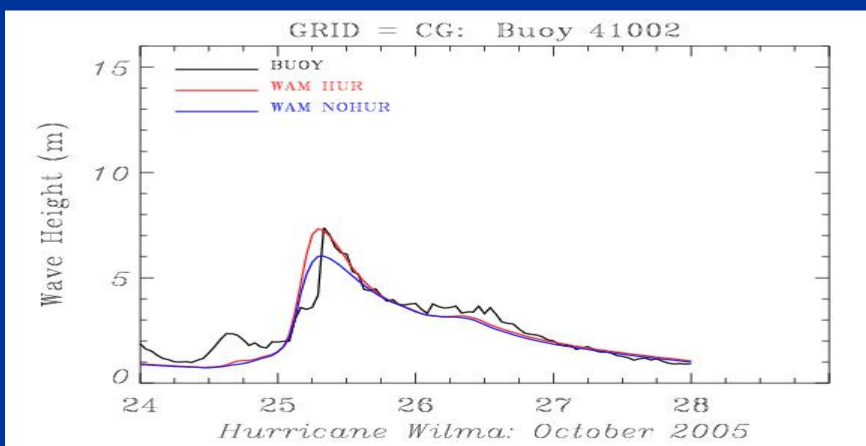
Wind /Wave time series : Wilma

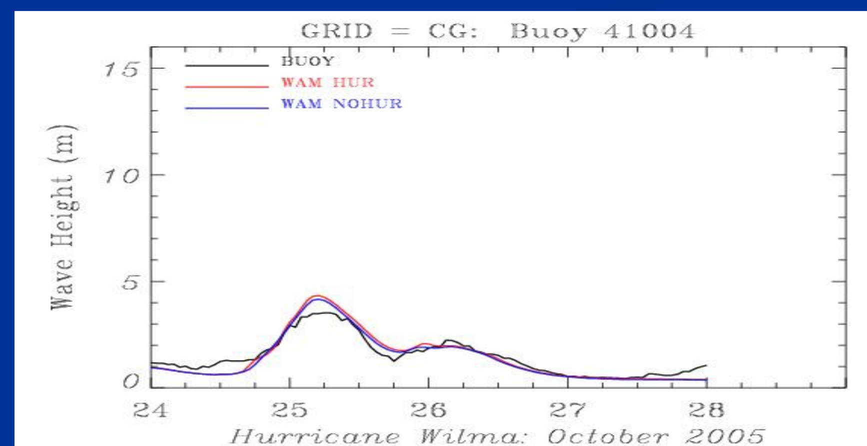
41002 **41004**





Wind Speed



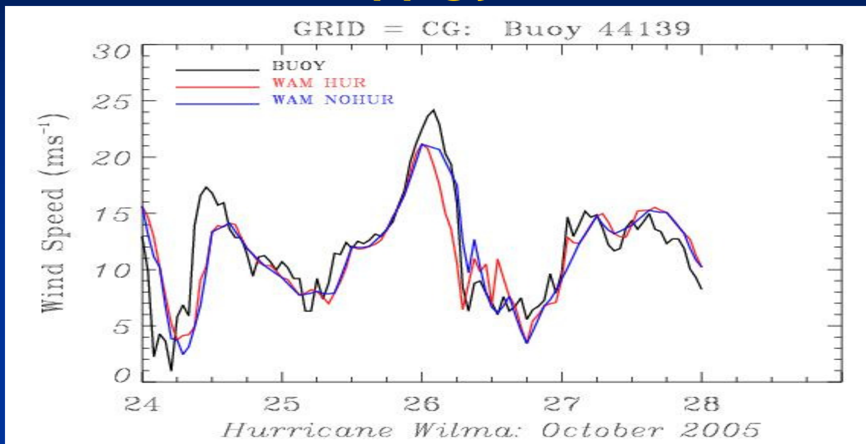


Wave Heigth

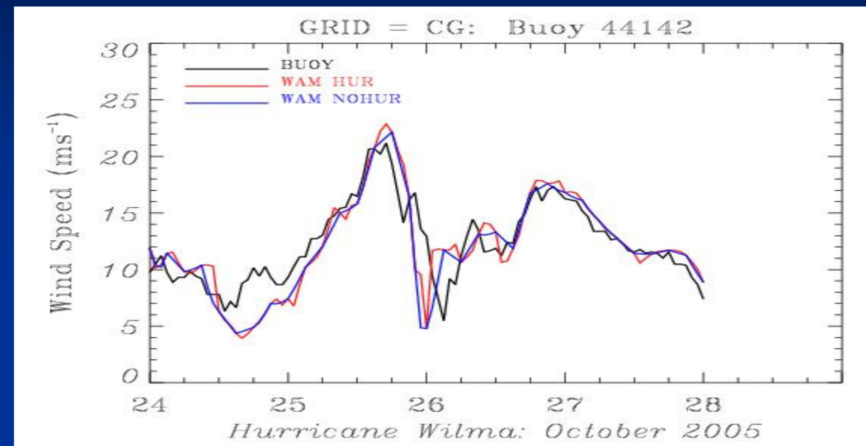
Legend: *HUR = Hurricane blending*
NOHUR = No hurricane blending
CG = Coarse grid (0.5° res.)

Wind /Wave time series : Wilma

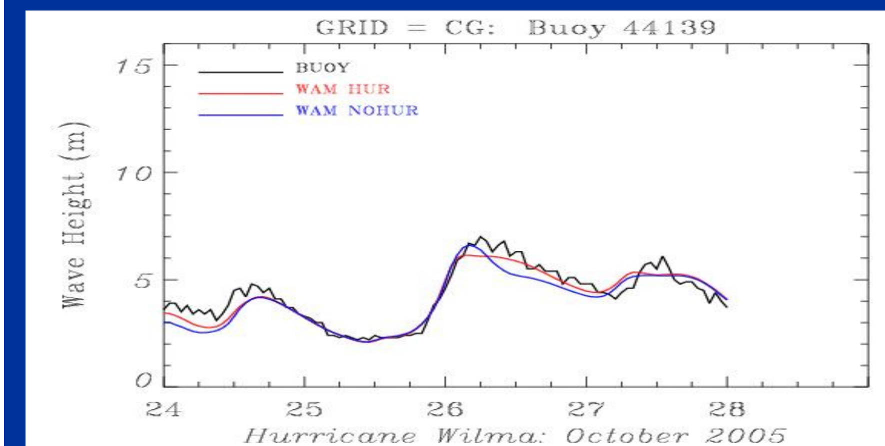
44139



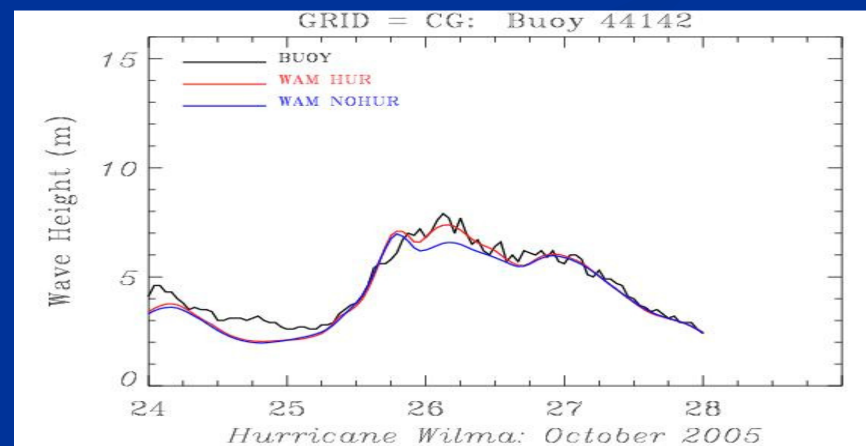
44142



Wind Speed



Wave Heigth



Legend: *HUR = Hurricane blending*
NOHUR = No hurricane blending
CG = Coarse grid (0.5° res.)

FUTURE WORK

- **Technical side :**
  - **Enlarging the model2 domain inside HURSWIM for the laplacian computation.**
  - **Toward an operational implementation for next hurricane season**

- **Studying more past cases (blended versus observations)**

- **Refining the methodology**
  - **Targeting more higher impact events.**
  - **Reducing the jump in the vortex distance (caused by model flip-flop ?)**
  - **Tuning the environment weight function**

- **Publication of the results**

www.ec.gc.ca

Thank you!

Environment Canada Environnement Canada

Canada