



The influence of roughness and sea spray on storm-generated waves

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Ocean Surface Layer Structure in Hurricane

(Peter Black - cbast 2003)

Outline

Introduction

Sea spray and roughness

- coupled model

Storm-generated waves

- storm cases
- effects of spray and roughness on waves

Conclusions



200 m
Wind speed ~28m/s

200 m
Wind Speed ~ 46 m/s

Introduction

high storm winds: breaking waves → *spray & wave drag*
→ surface flux → storm development → waves

Storm translation: impacts spatial distribution of waves

fast: high wave region ~ determined by *C_g & storm speed*
slow: high wave region ~ determined by *distance from storm center.*

Case studies: 2 winter meteorological “bombs”

- 1) **Superbomb of 2000**
- 2) **Bomb of 2002**



Sea spray

$$\Gamma = \rho_a C_D U_{z1}^2$$

$$H_L = \rho_a L_v C_E U_{z1} (q_o - q_{z1})$$

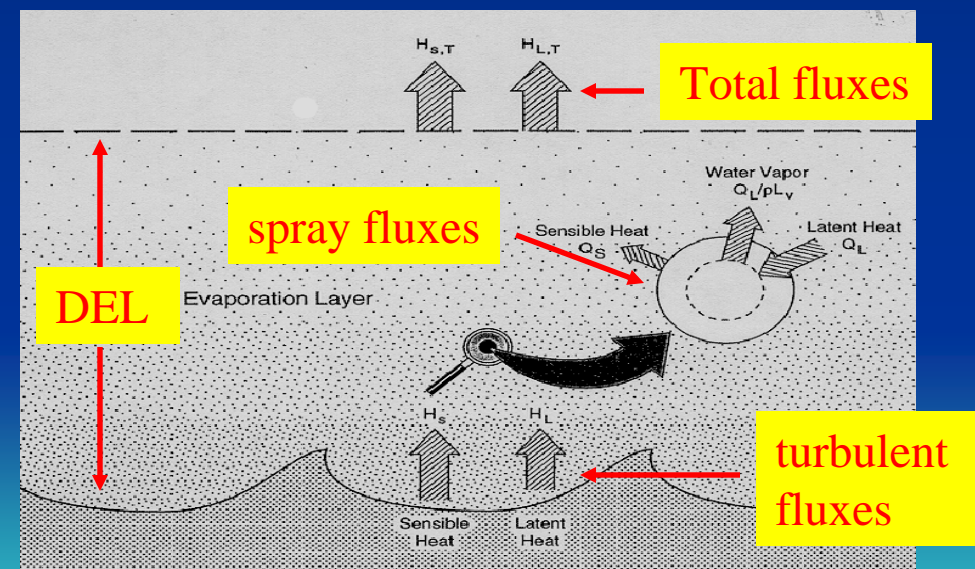
- Total fluxes

$$\Gamma_T = \Gamma + \Gamma_{sp}$$

$$H_{L,T} = H_L + Q_{L,sp}$$

$$H_{s,T} = H_s + Q_{s,sp}$$

$$H_s = \rho_a c_{pa} C_H U_{z1} (\theta_o - \theta_{z1})$$



Andreas's conceptual scheme of processes in DEL

Sea spray

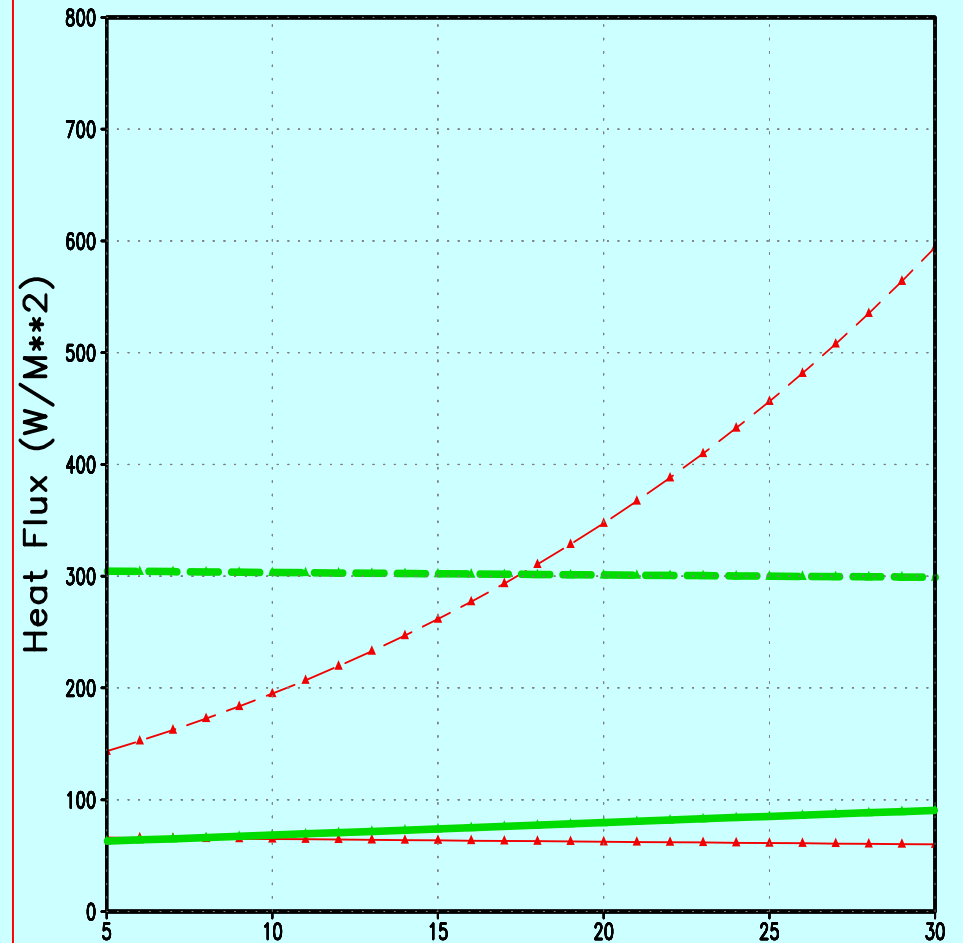
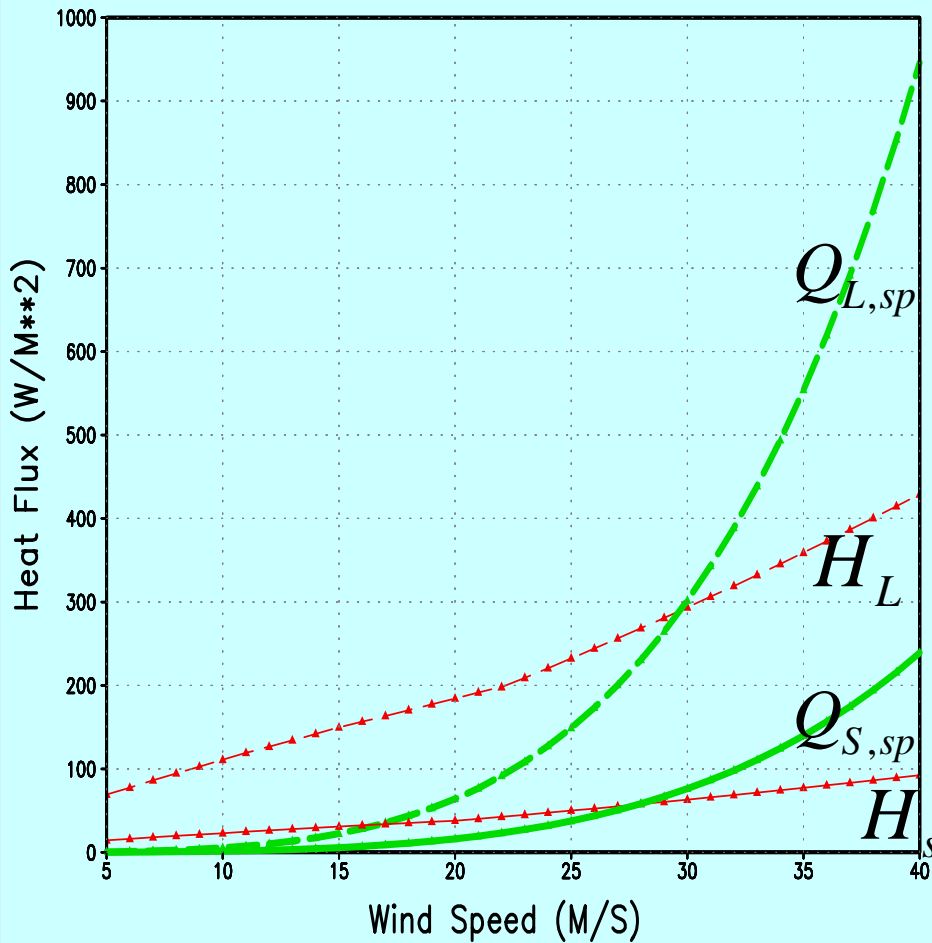
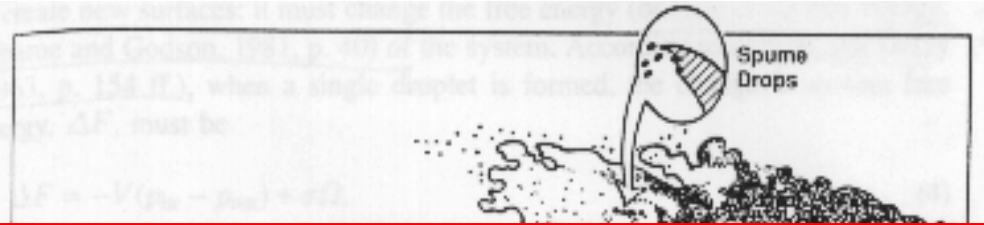


$$Q_{S,sp} = \rho_w c_w (T_s - T_{eq,100}) V_S (u_*)$$

$$Q_{L,sp} = \rho_w L_v \left\{ 1 - \left[\frac{r [\tau_f (50 \mu m)]}{50 \mu m} \right]^3 \right\} V_L (u_*)$$

- Andreas and DeCosmo (2001), Andreas (2003, 2006)

Sea spray



- higher wind speed → larger spray fluxes

Wave roughness

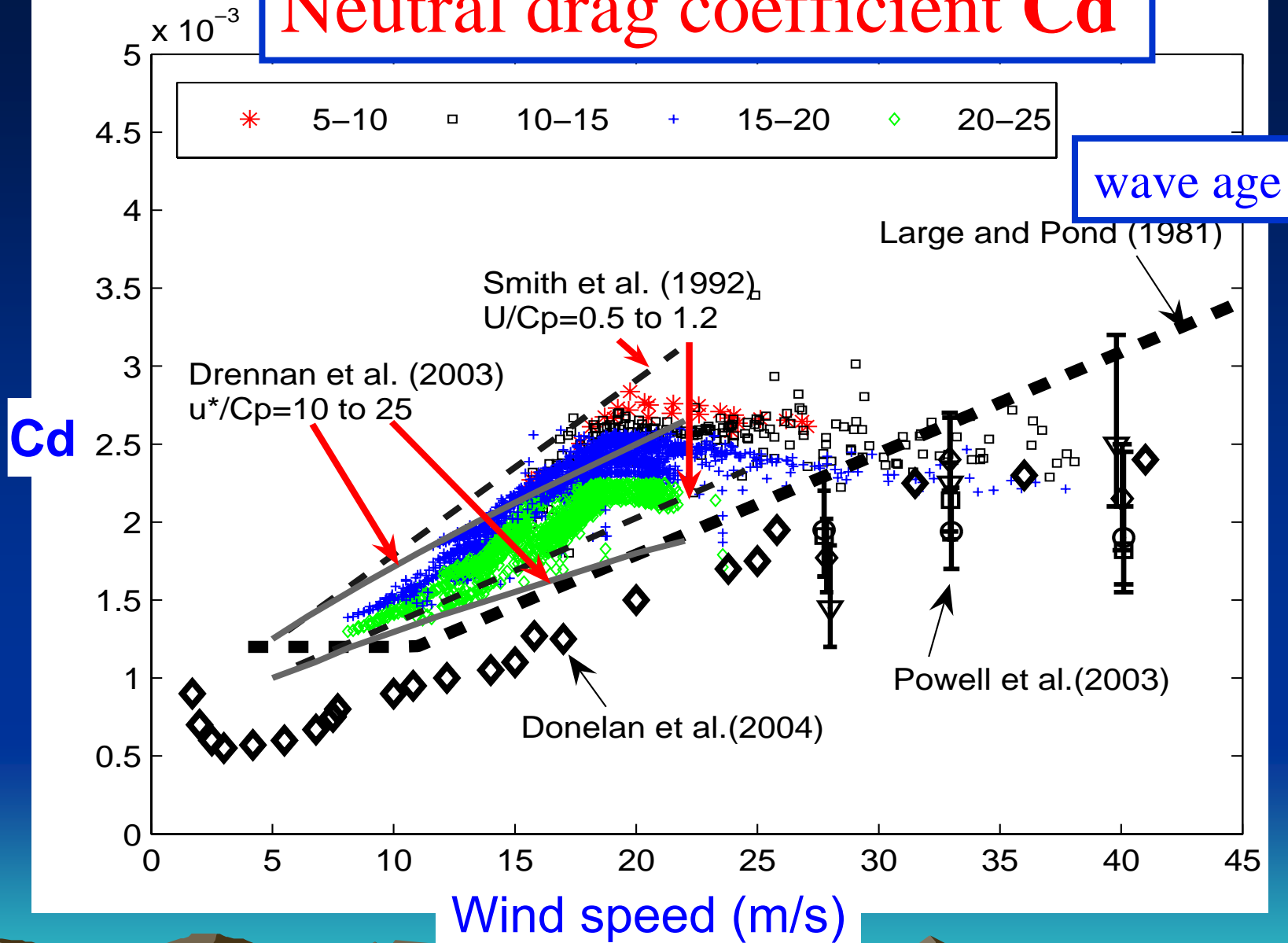
- Charnock (1955)
 $z_o = \alpha_c u_*^2 / g$
 $\alpha_c \sim 0.011 - 0.0185$
 \Rightarrow old waves ...
- Smith et al. (1992) HEXOS
 $z_o = 0.48 u_*^2 / g (C_p / u_*)^{-1}$
- if $C_p / u_* > 26$ use Charnock

Drennan (2006) update

56-63 kts



Neutral drag coefficient C_d

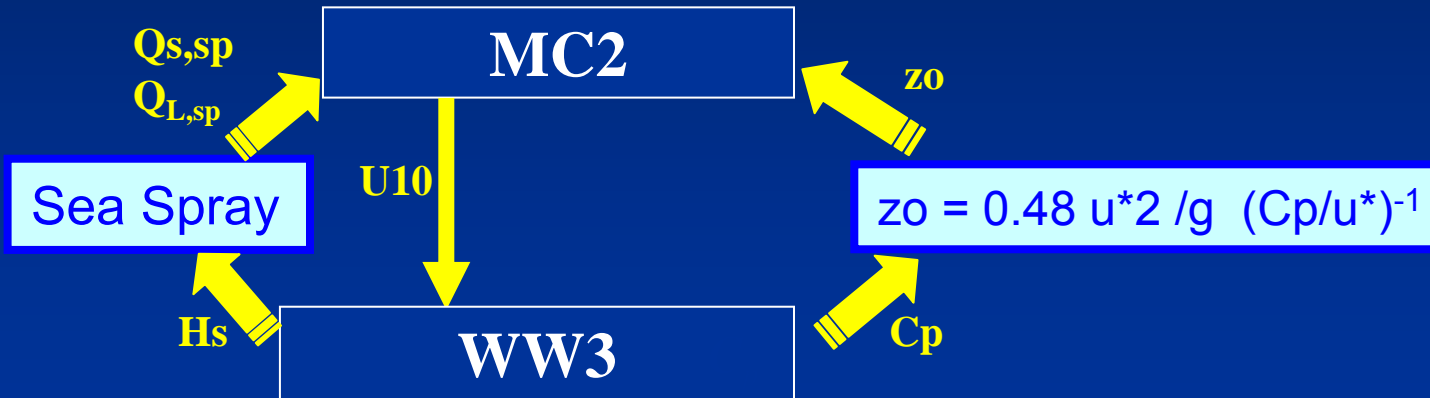


when $U_{10} > 30 \text{ ms}^{-1}$ we limit $Z_0 = 0.0034$

Coupled model

Canadian Atmospheric model MC2:

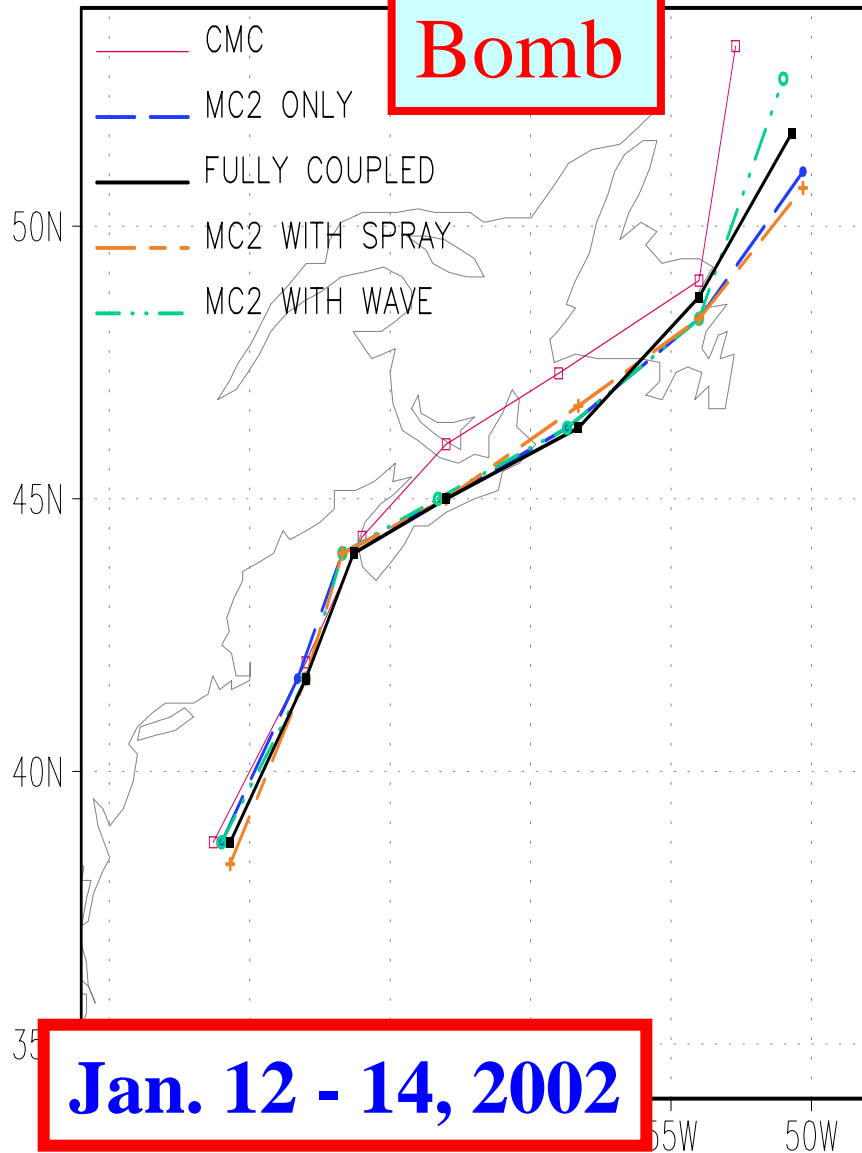
- surface fluxes Monin-Obukhov similarity
- 0.25° resolution, 30 vertical layers, 600s time step



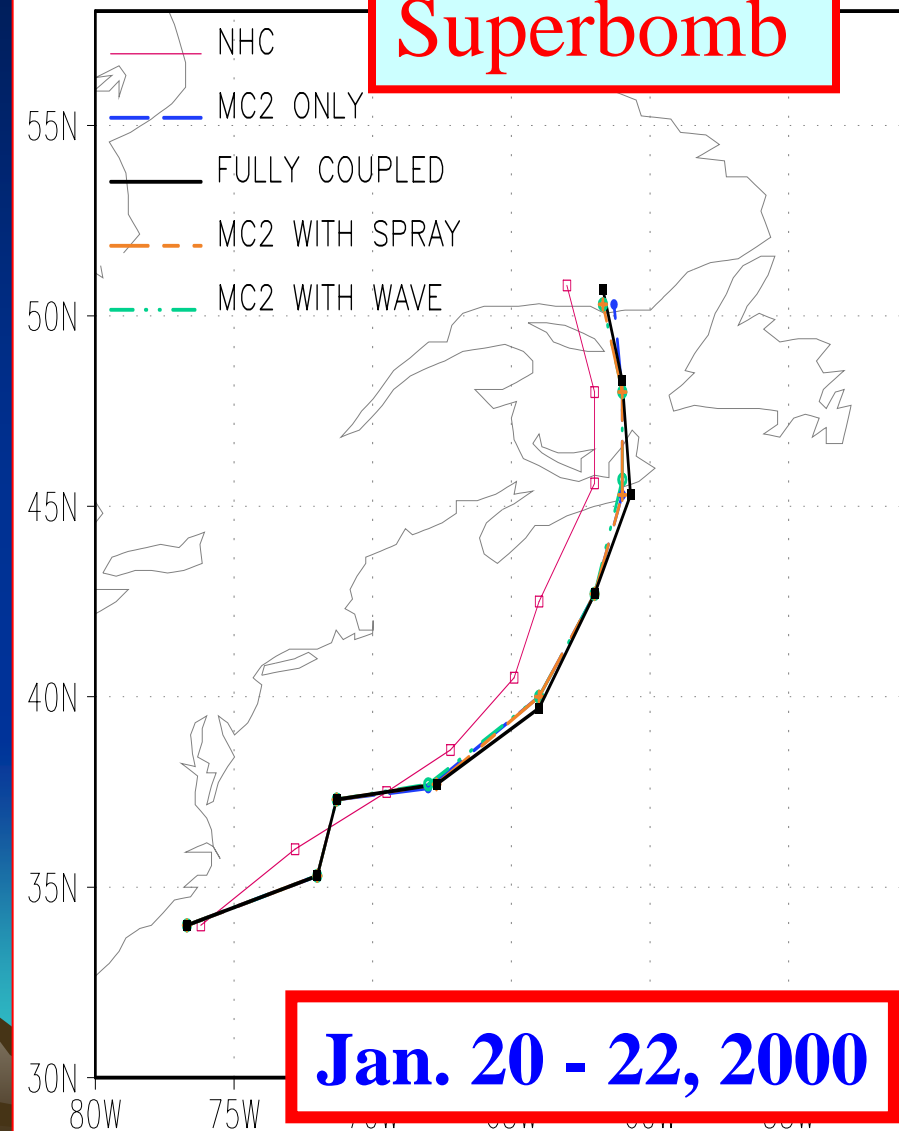
- spectrum: 25 frequency + 24 directional bands
- projection: longitude-latitude on $0.25^\circ \times 0.25^\circ$ grid

MC2-uncoupled *and* MC2-spray or waves

Bomb

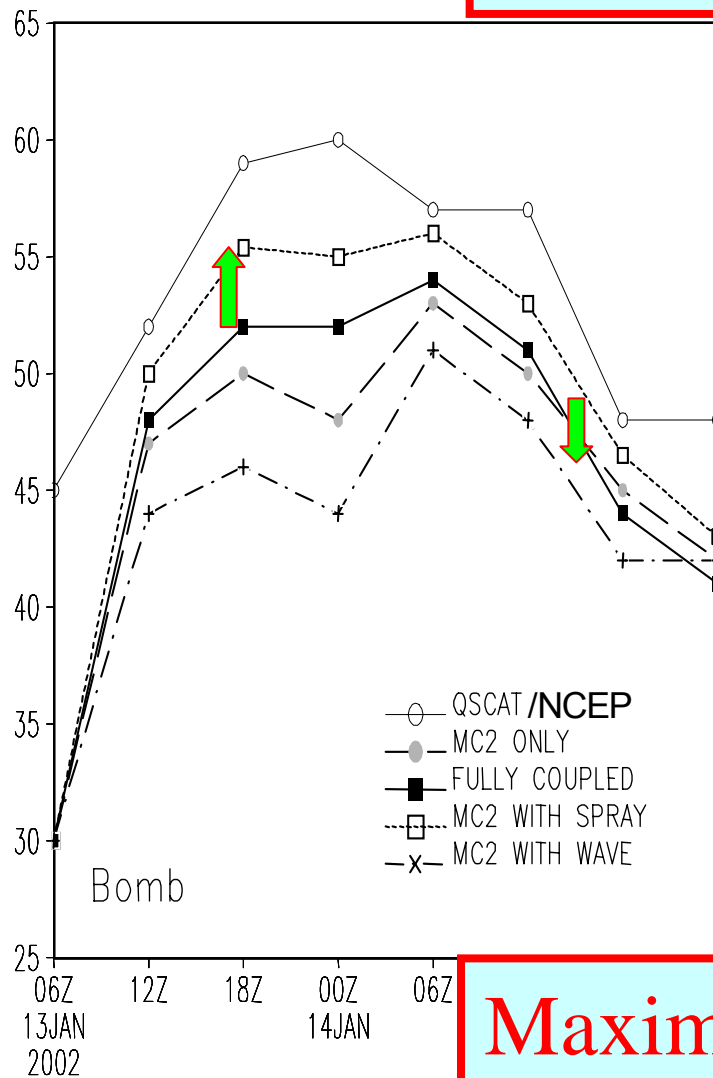


Superbomb

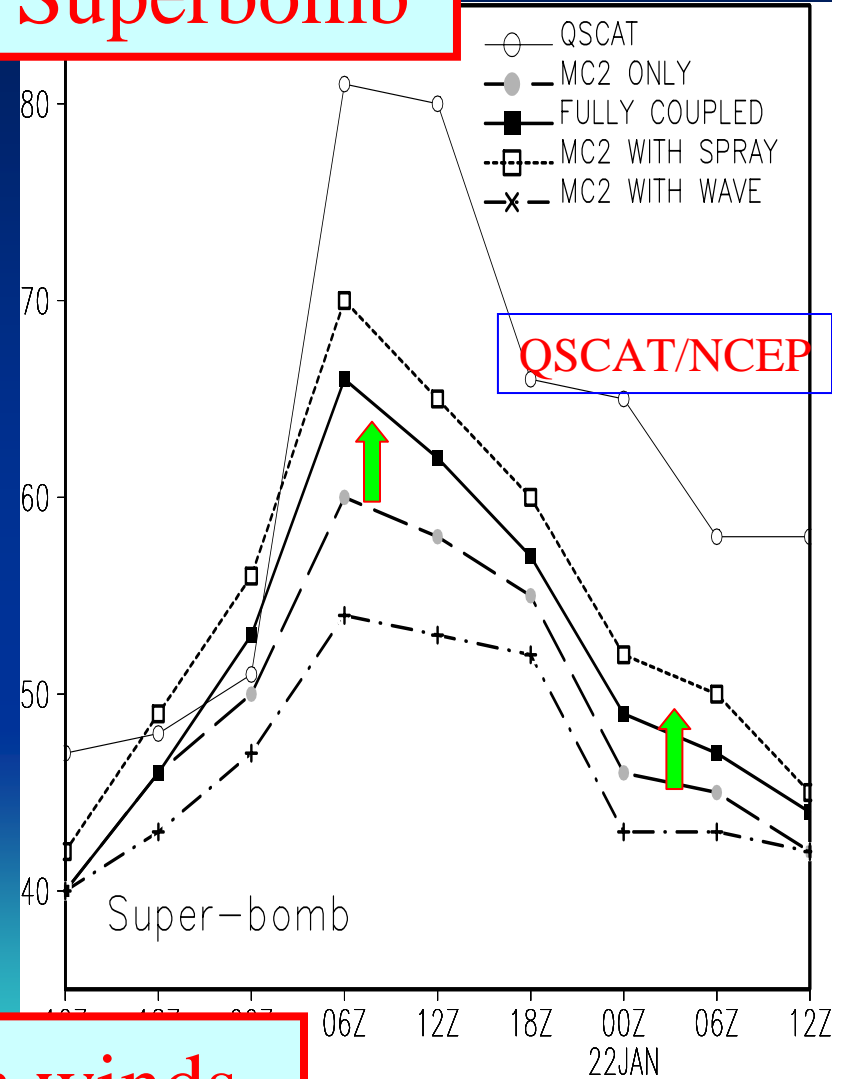


MC2-uncoupled and MC2-spray or waves

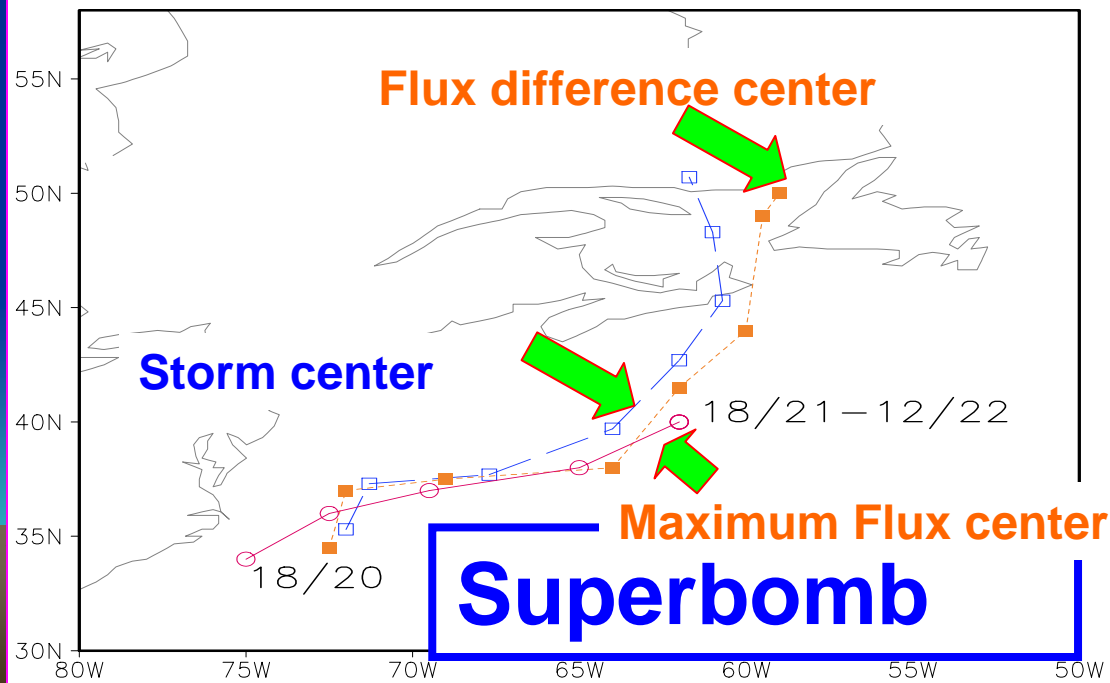
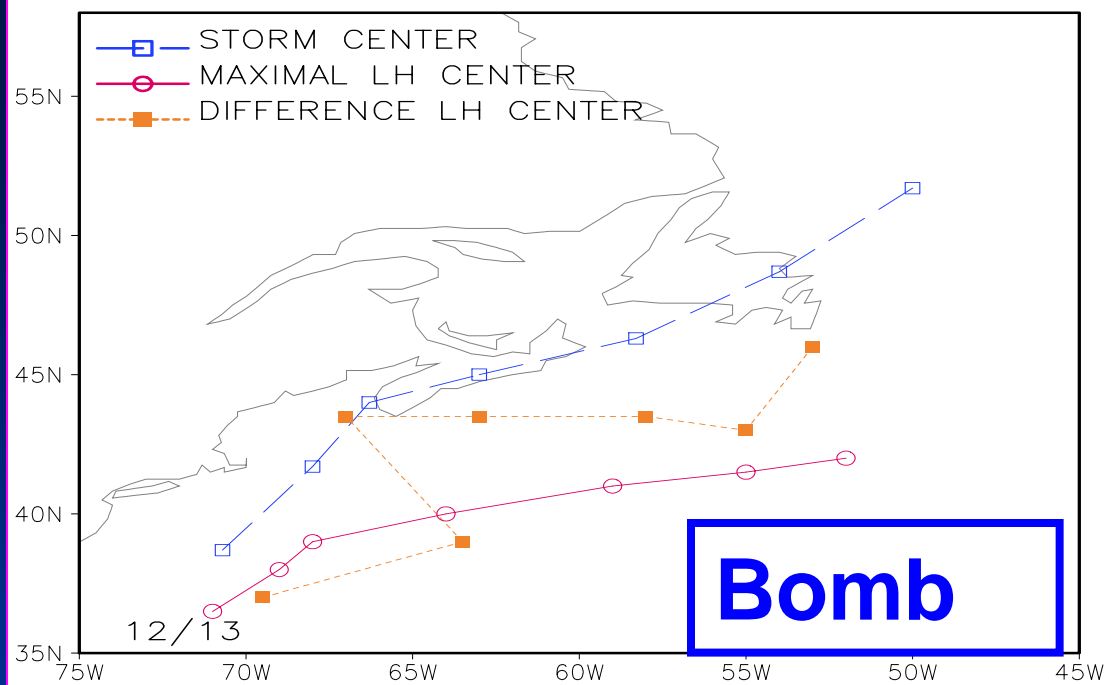
Bomb



Superbomb

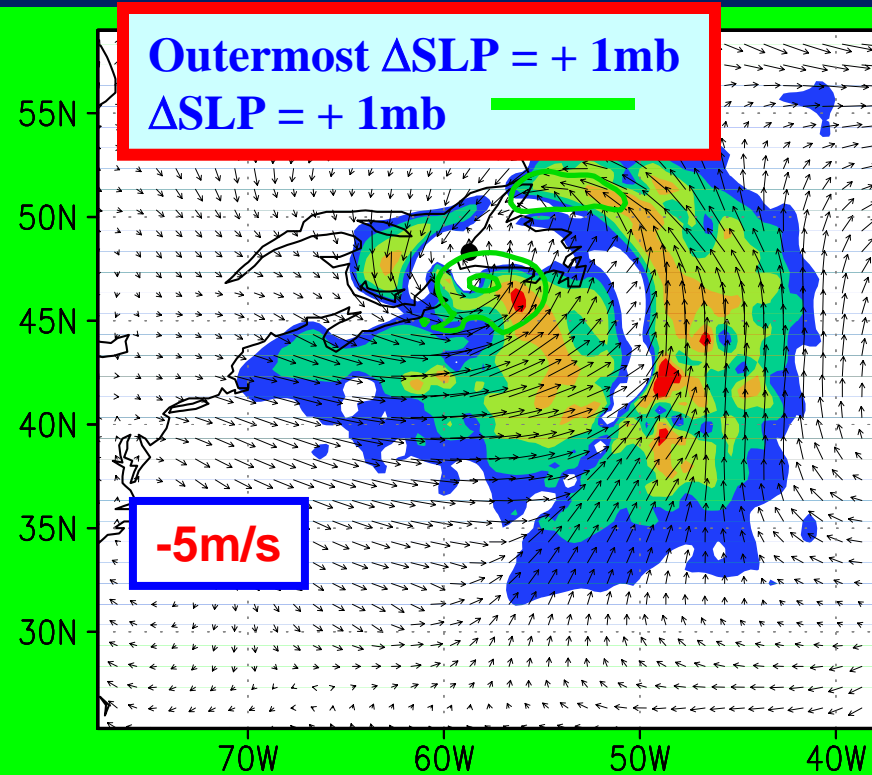
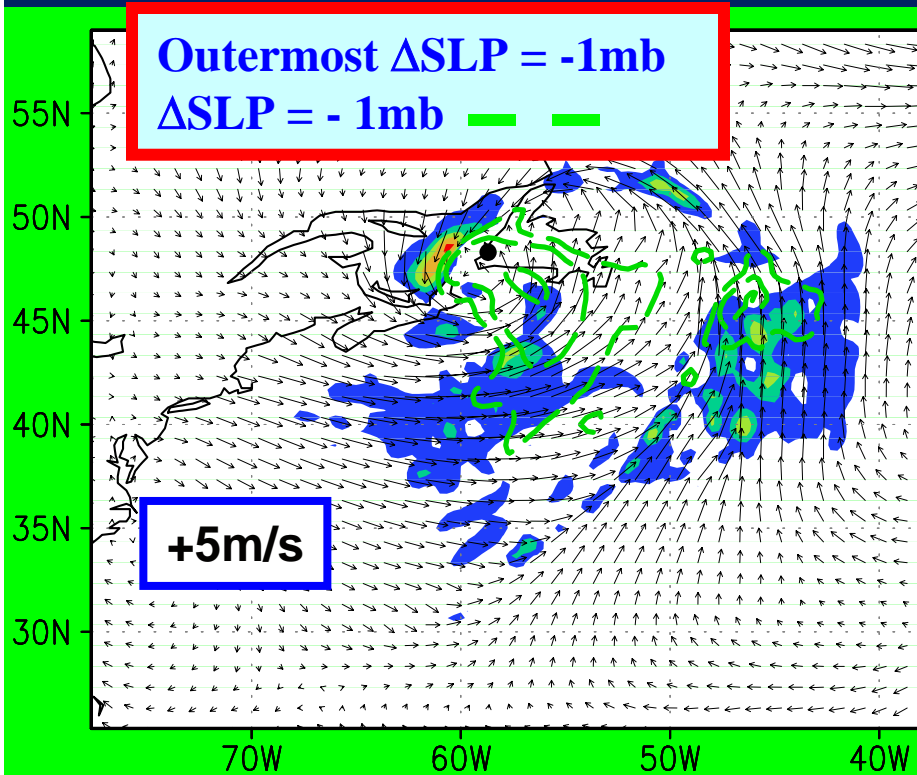


Maximum 10 m winds



MC2-uncoupled *and* MC2-spray or waves

Jan. 02 Bomb

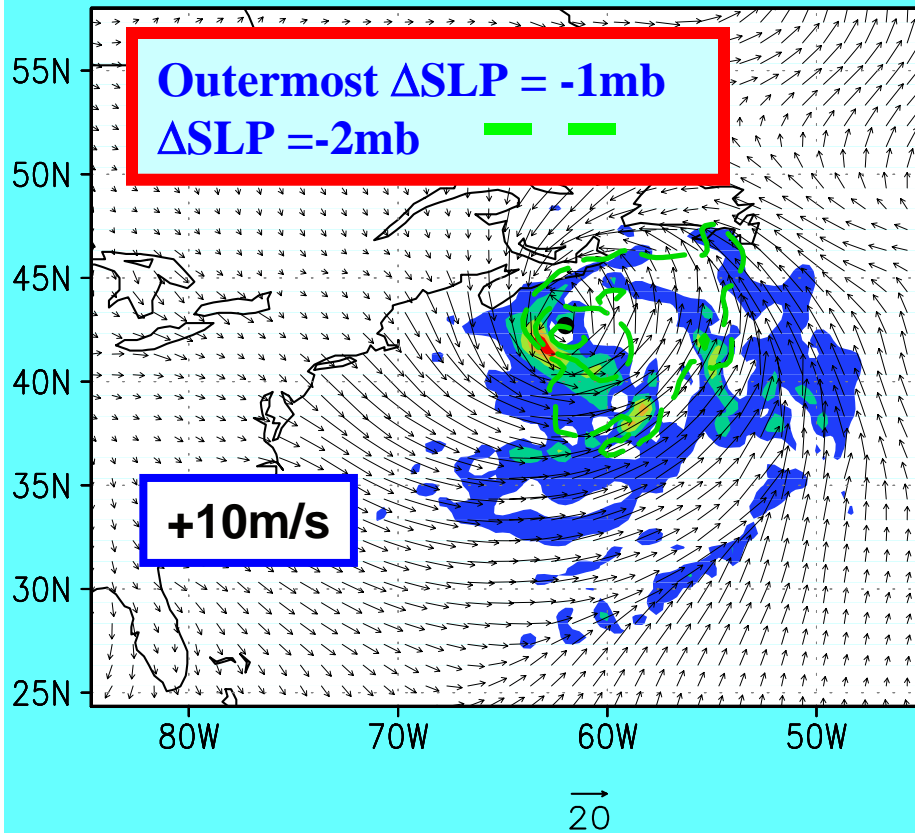


MC2-spray *minus* MC2

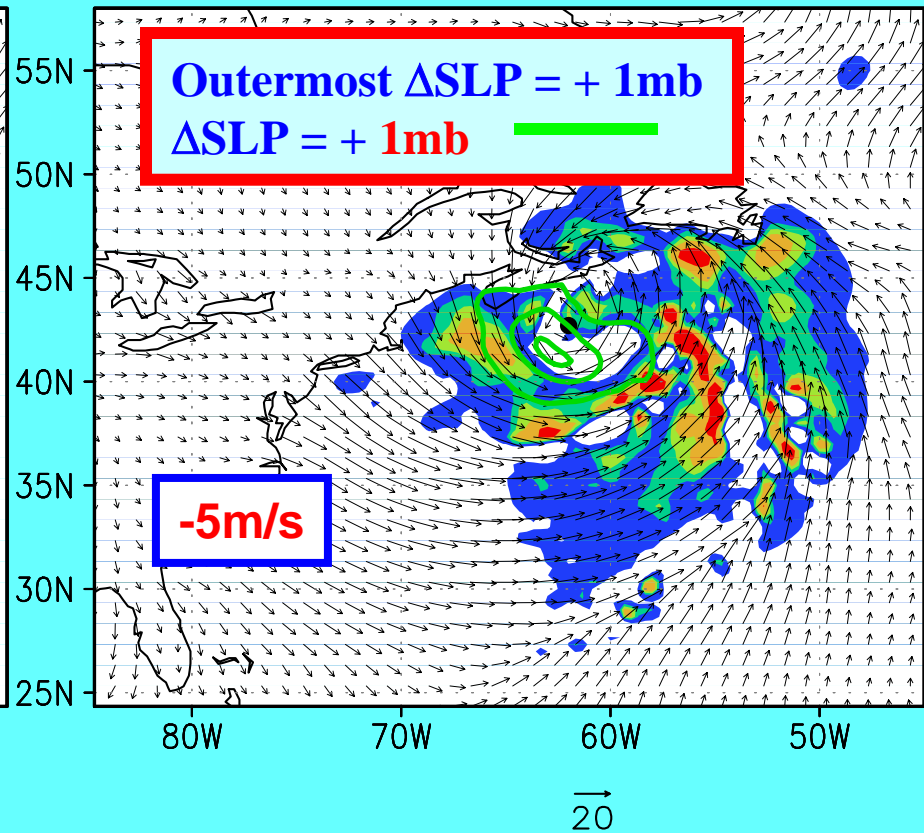
MC2-waves *minus* MC2

MC2-uncoupled *and* MC2-spray or waves

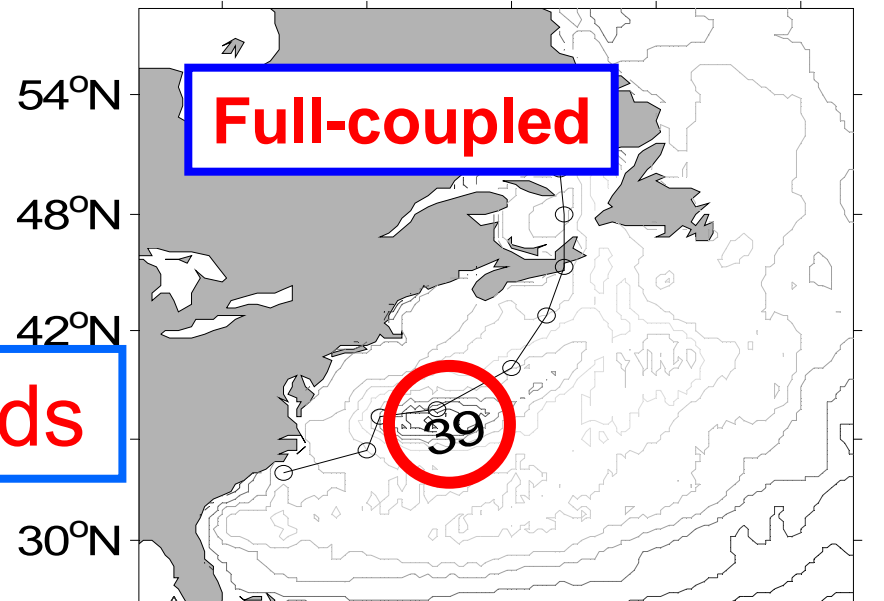
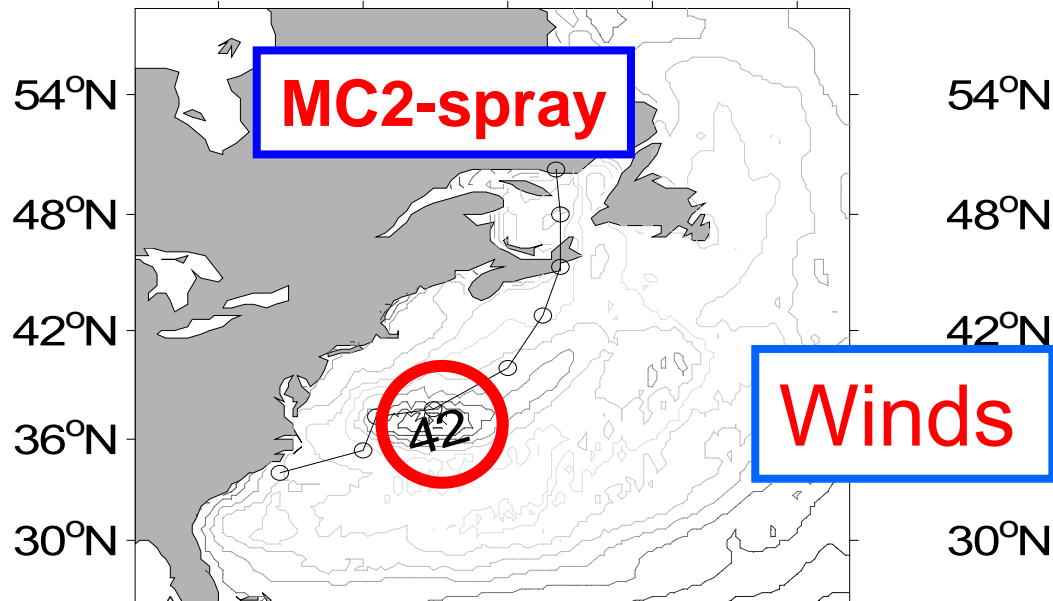
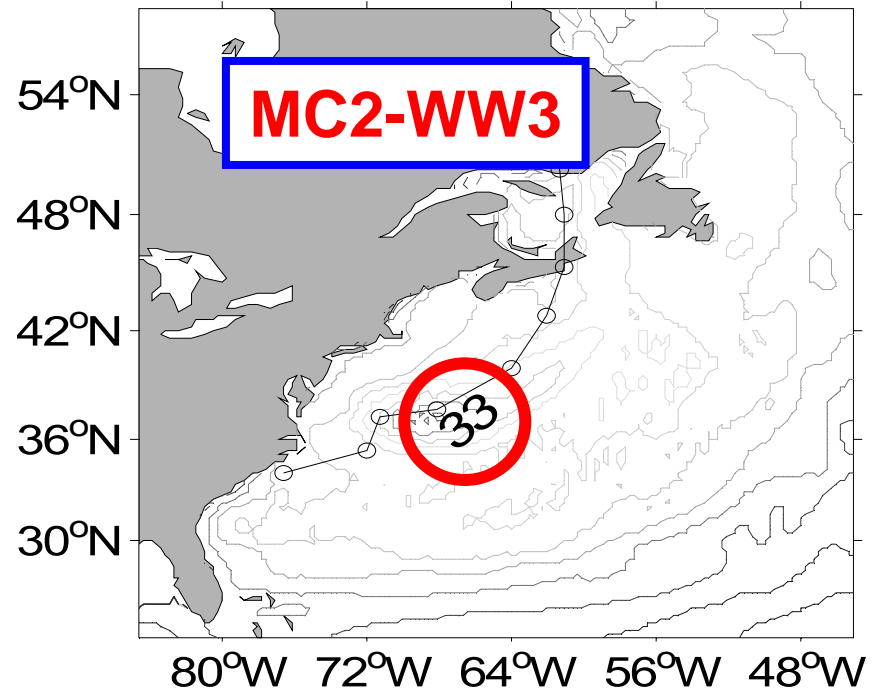
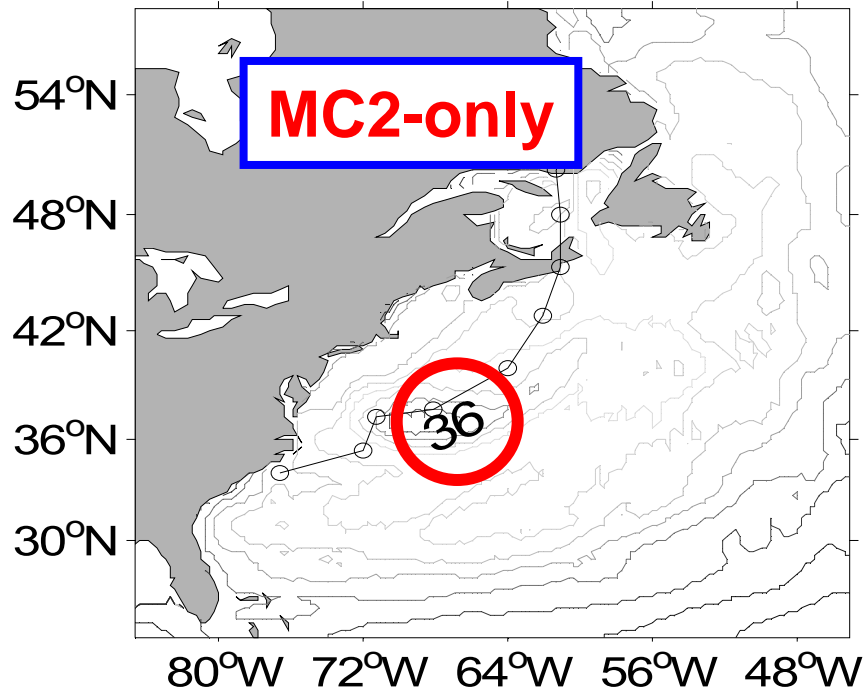
Superbomb



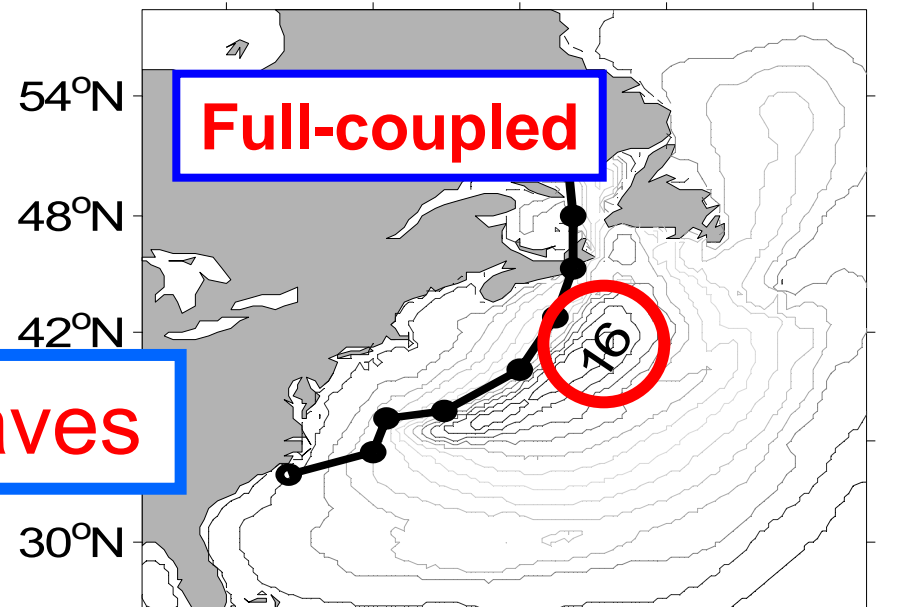
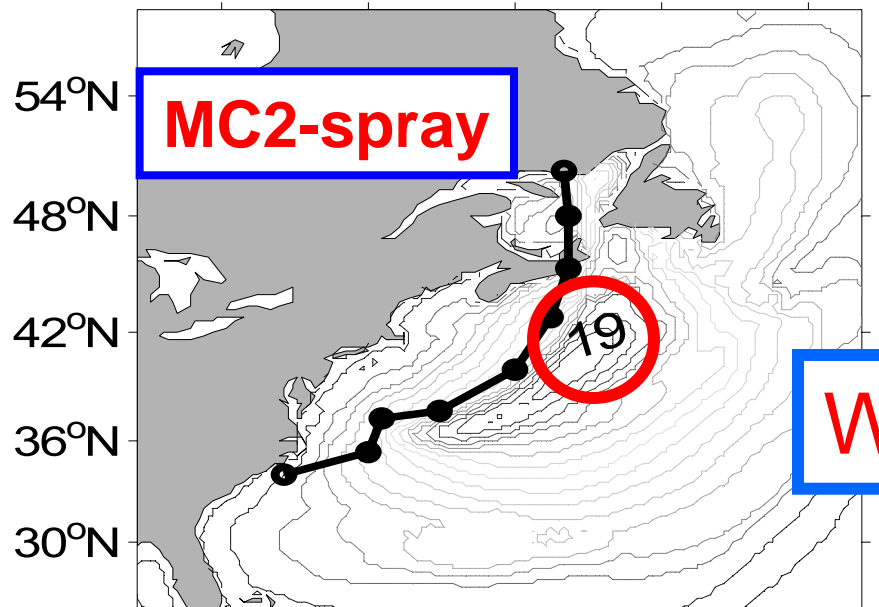
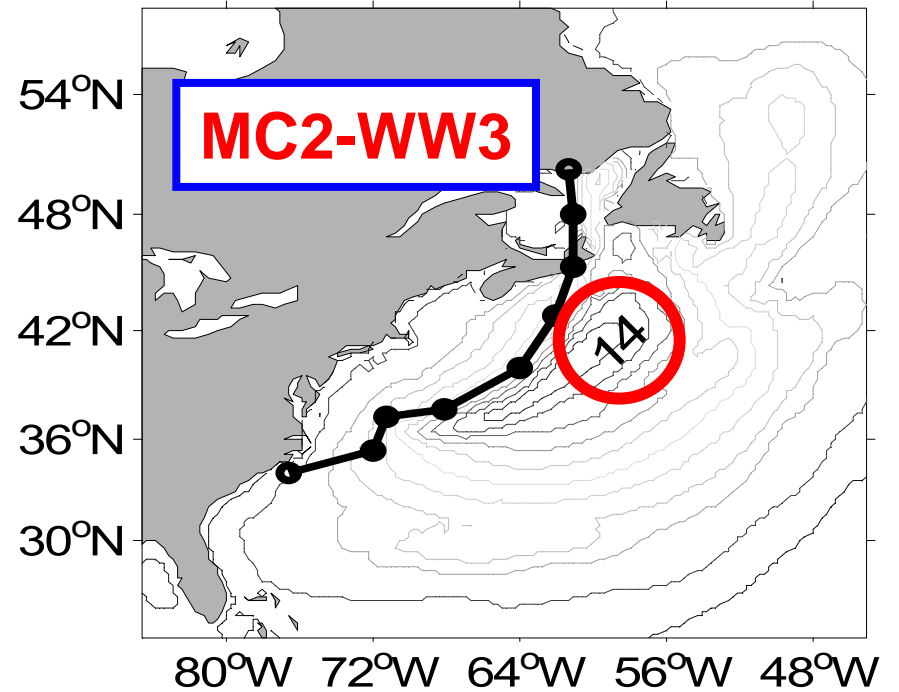
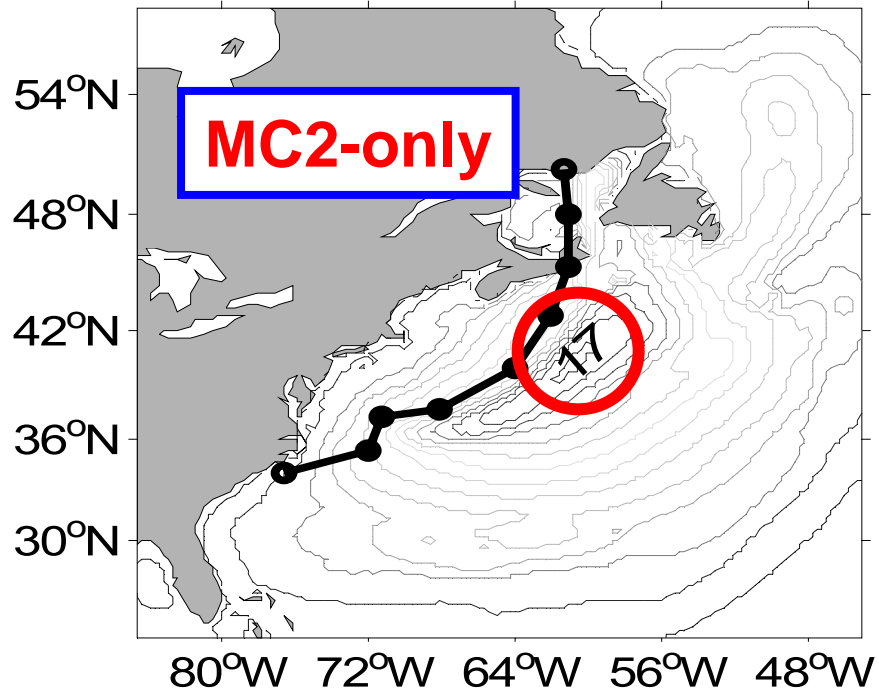
MC2-spray *minus* MC2



MC2-waves *minus* MC2

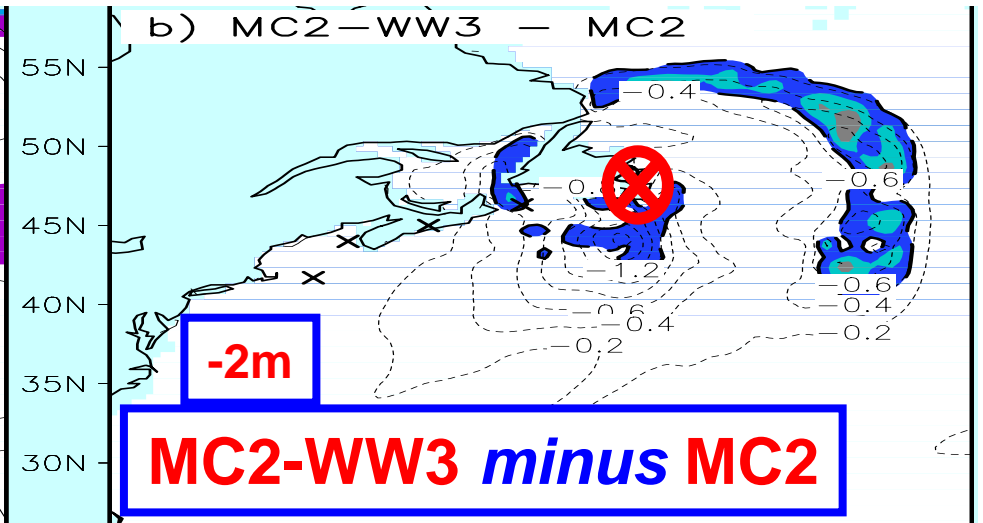
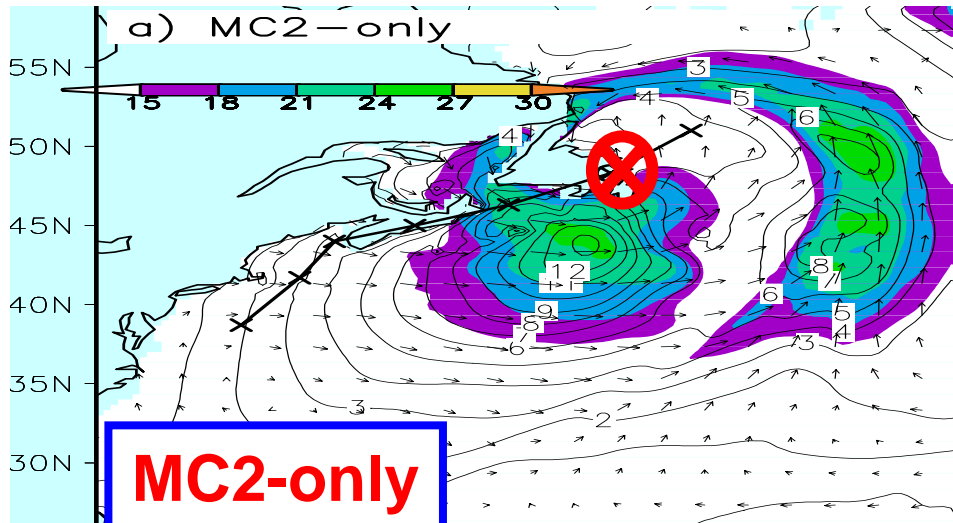


Superbomb swath maps of U10 (m/s) @ 3 m/s intervals: +6 hourly storm track

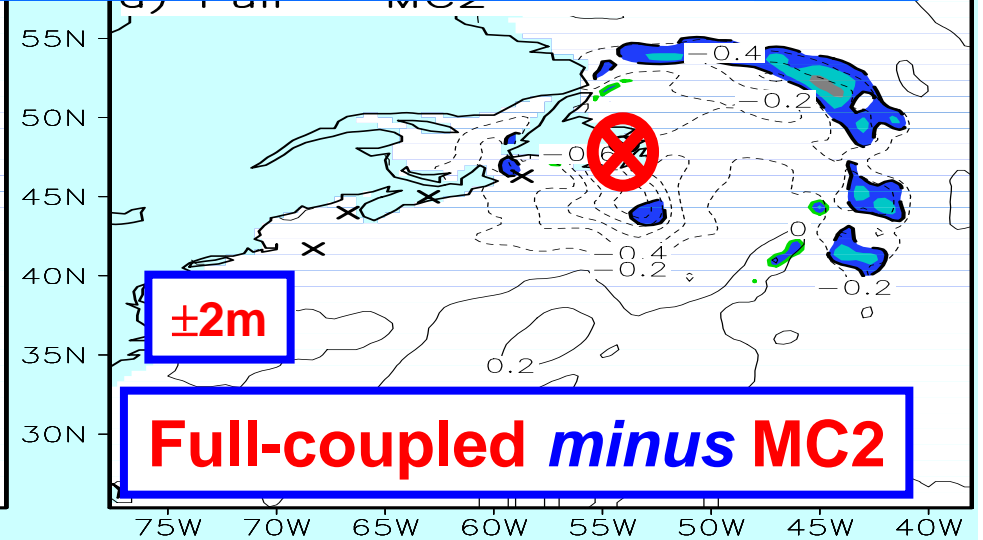
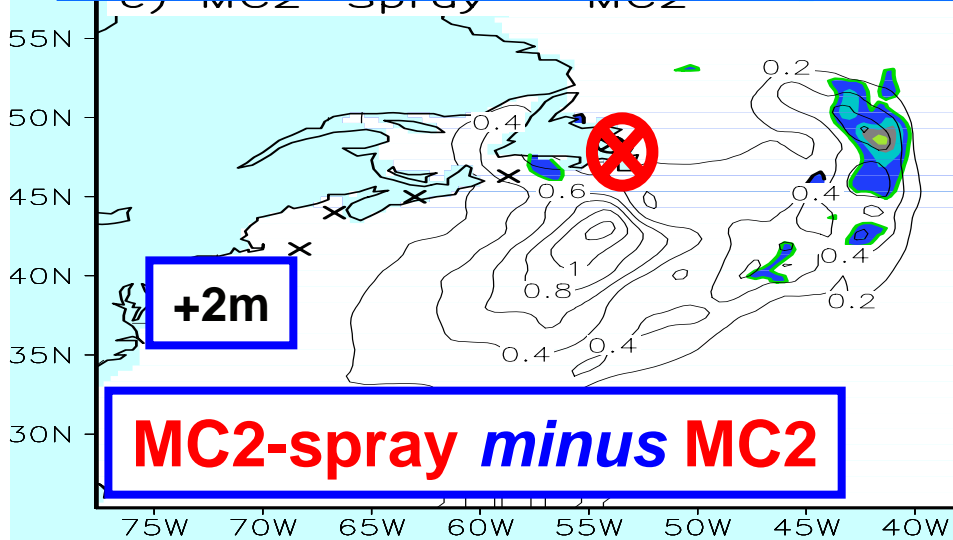


Waves

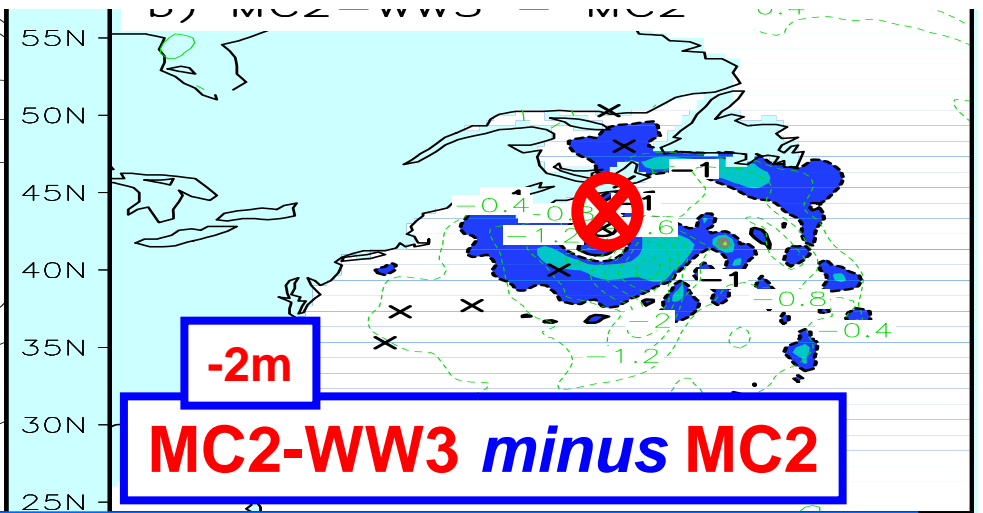
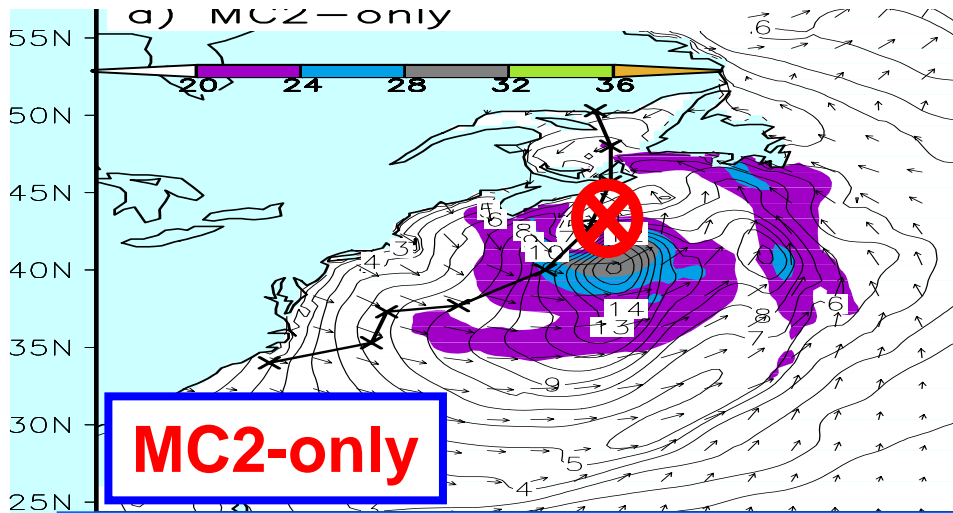
Swath maps of SWH (m) with the passage of **Superbomb** at 1 m intervals.



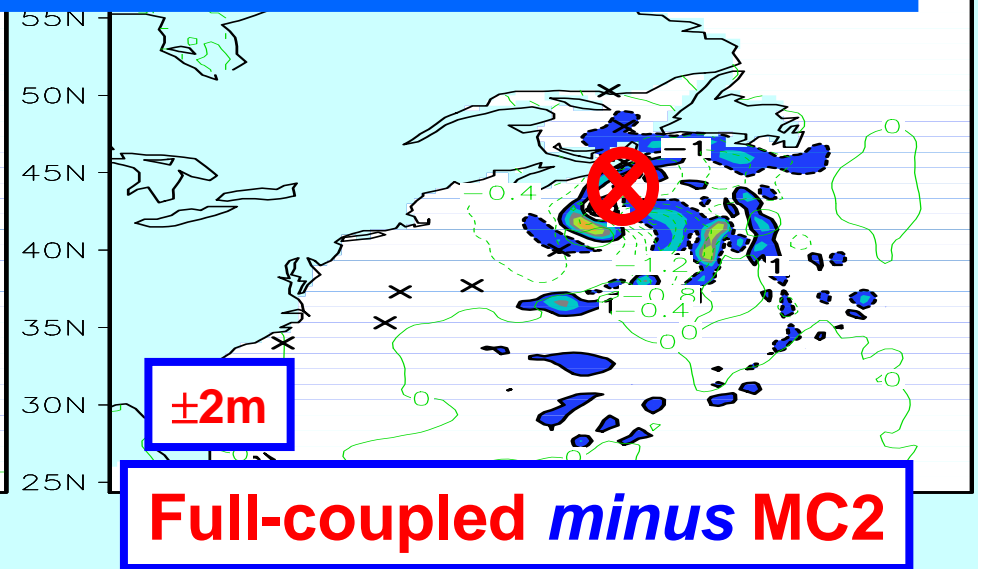
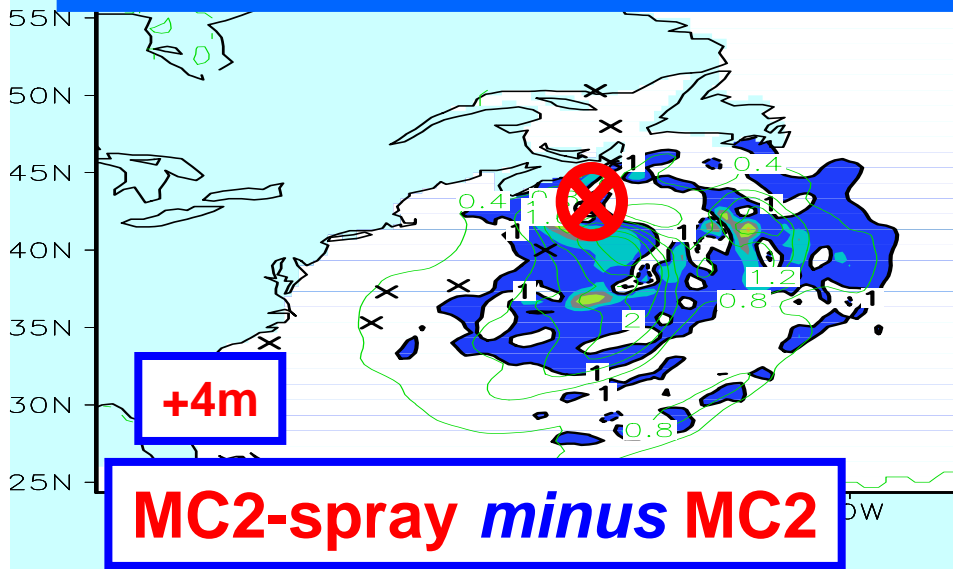
Waves (contour), Winds vector →, speed (shading)



Bomb Differences

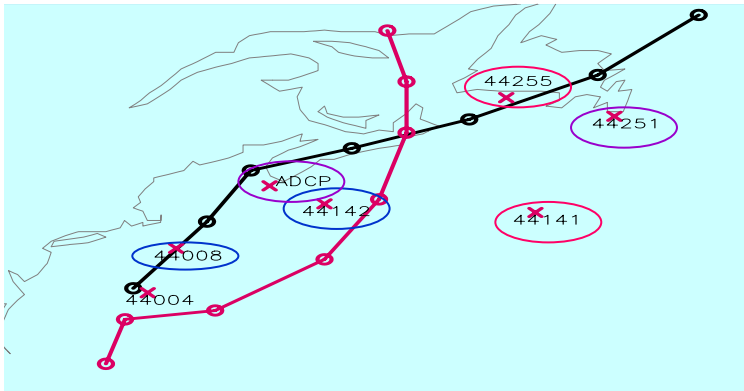


Waves (contour), Winds vector →, speed (shading)

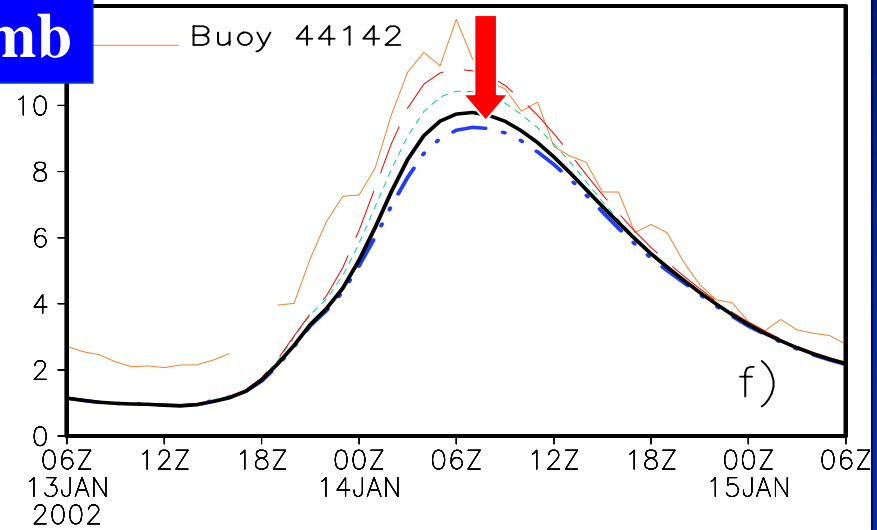
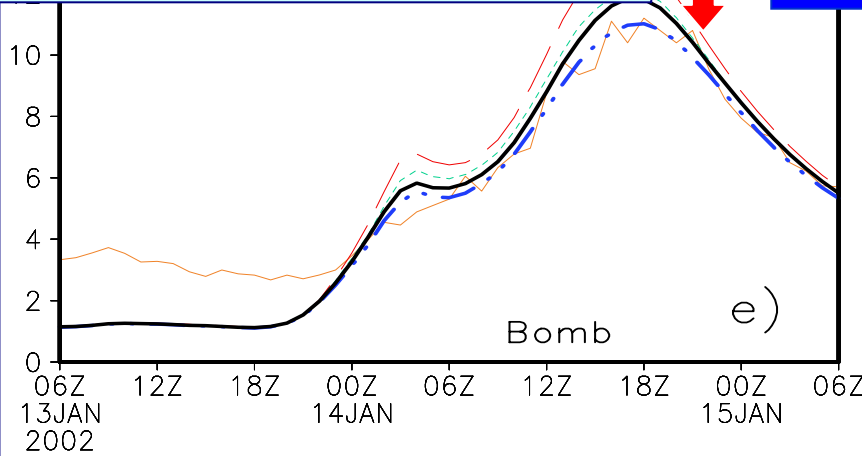


Superbomb Differences

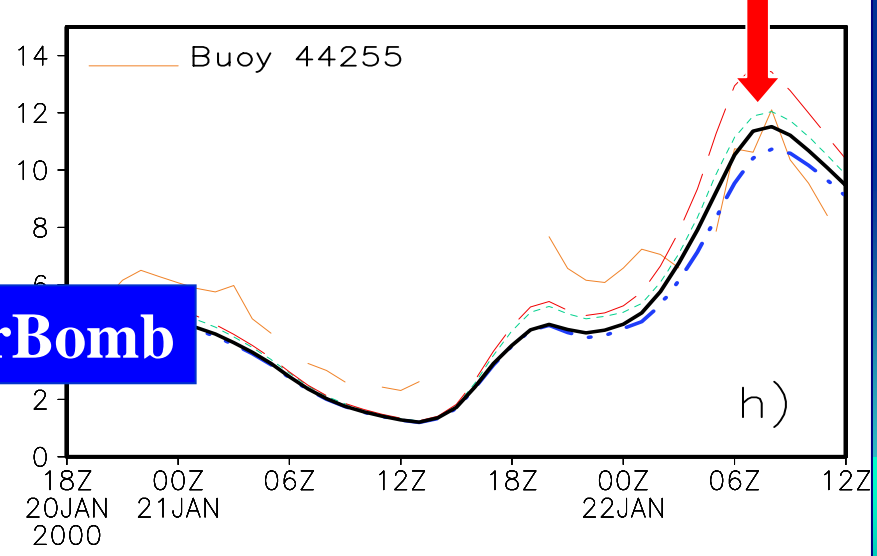
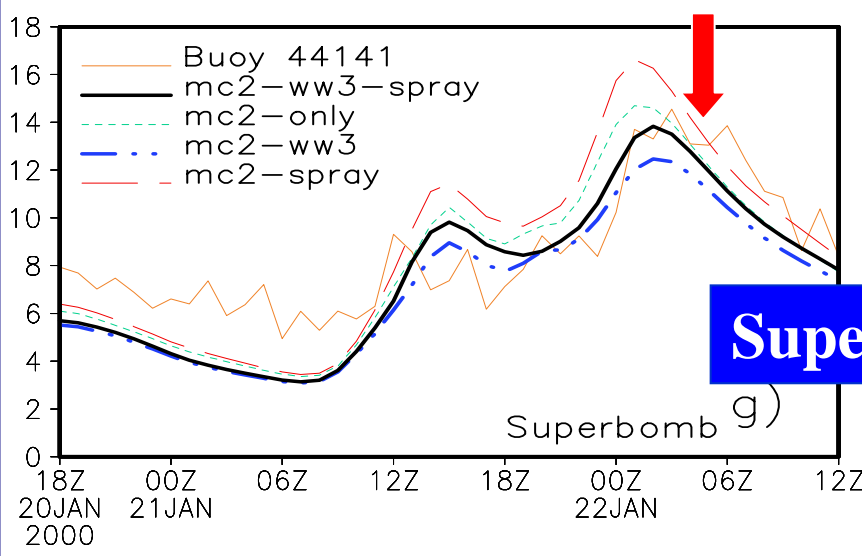
ay and wave drag



Bomb



SuperBomb



Conclusions

- 1) Sea spray impacts: intensify storm
 - can increase winds
 - importance in severe storms ?
- 2) Wave drag impacts: de-intensity storm
 - decreases winds
 - important in young seas, growing waves
- 3) Storm structure
 - track and radius of max. winds
 - warm SSTs
 - propagation speed
 - regions of high winds