WRF with spectral bin microphysics: Now Part of the WRF Software Repository

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Hydrometeor types:

FULL _SBM

Aerosols: CCN

Water drops

Plates
Columns
Dendrites

Snow (aggregates)

Graupel

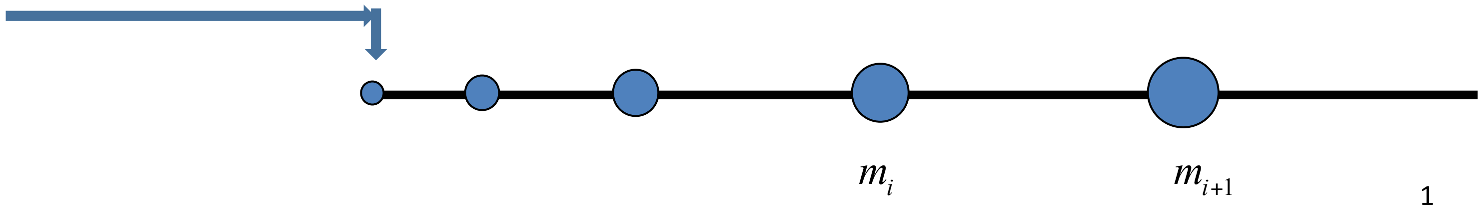
Hail

8 size distributions

FAST _SBM

Aerosols: CCN

Water drops



Snow (aggregates)

Graupel

4 size distributions

Main principles

1) The model is based on solving an equation system for number (size) distribution functions $f_i(m)$, defined as:

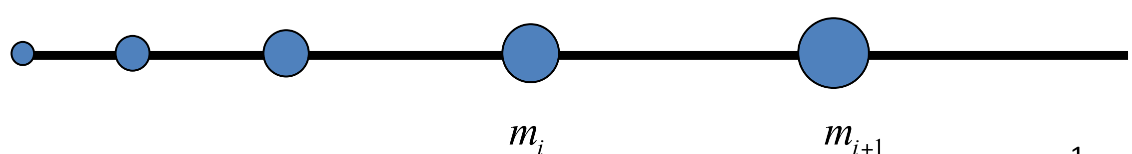
$$N_i = \int_{m_{\min}}^{m_{\max}} f_i(m)dm$$ for all hydrometeors; $\left[f_i(m)\right] = g^{-1}cm^{-3}$, *i* is the hydrometeor type.

For aerosols:

$$N_{CCN} = \int_{m_{\min}}^{m_{\max}} f_{CCN}(r)d\ln r \qquad \left[f_{CCN}(r)\right] = cm^{-3}$$

2) Properties of all particles *depend on the particle mass and hydrometeor type.*

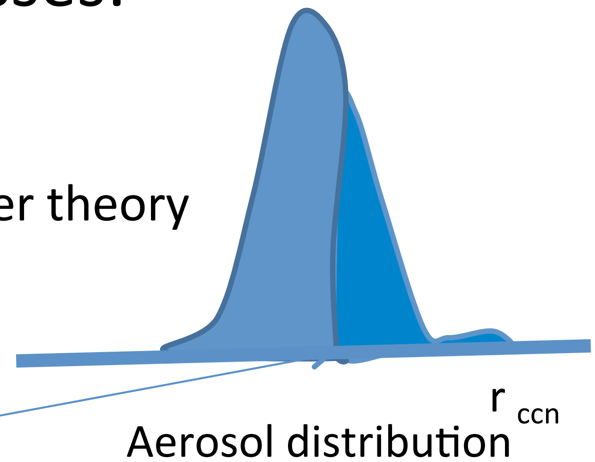
Size distributions are defined on a logarithmically equidistant mass grid (Berry and Reinhard, 1974).

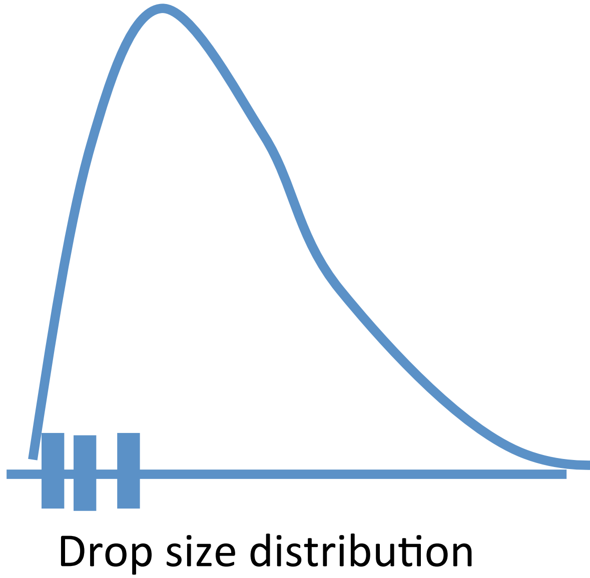


$$\frac{m_{i+1}}{m_i} = 2$$

Microphysical processes:

CCN activation: using Koehler theory





$w \rightarrow S \rightarrow r_{ccn\_cr}$

Diffusional Growth

Collisions

Melting/Freezing

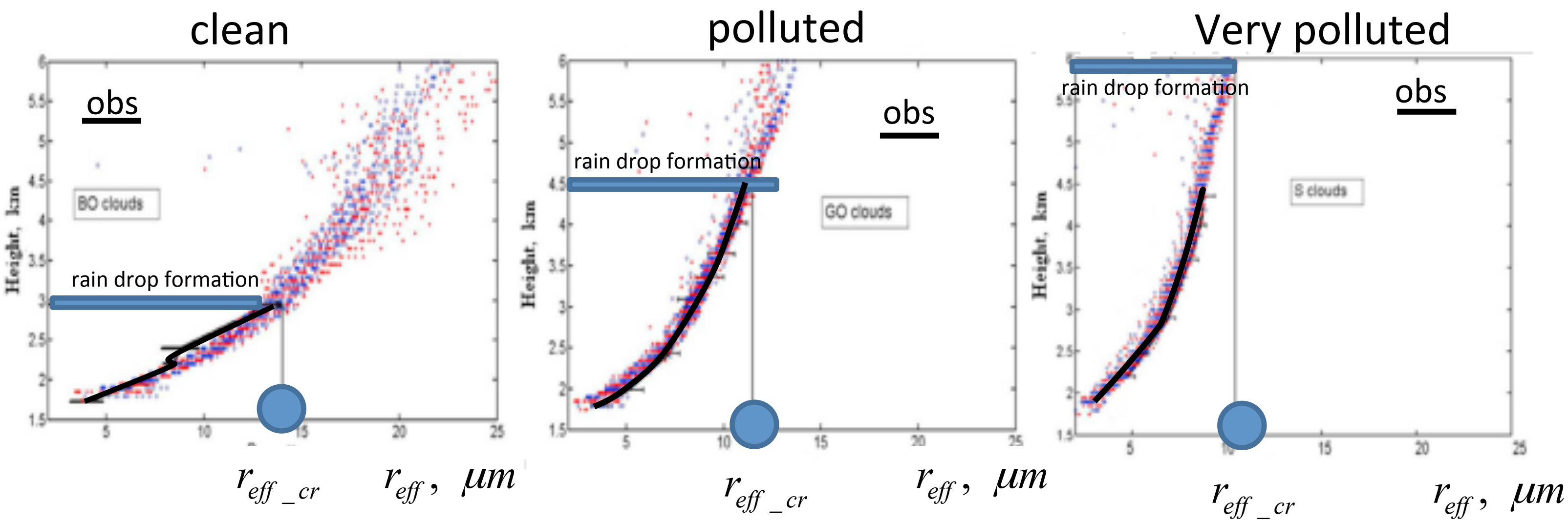
Sedimentation

→ EACH SOLVED FOR EACH OF THE 33 (or 43) BINS

Examples of application of SBM

Example 1: Simulation of cloud microphysical structure, rain formation (Benmoshe 2012, Khain et al. 2013)

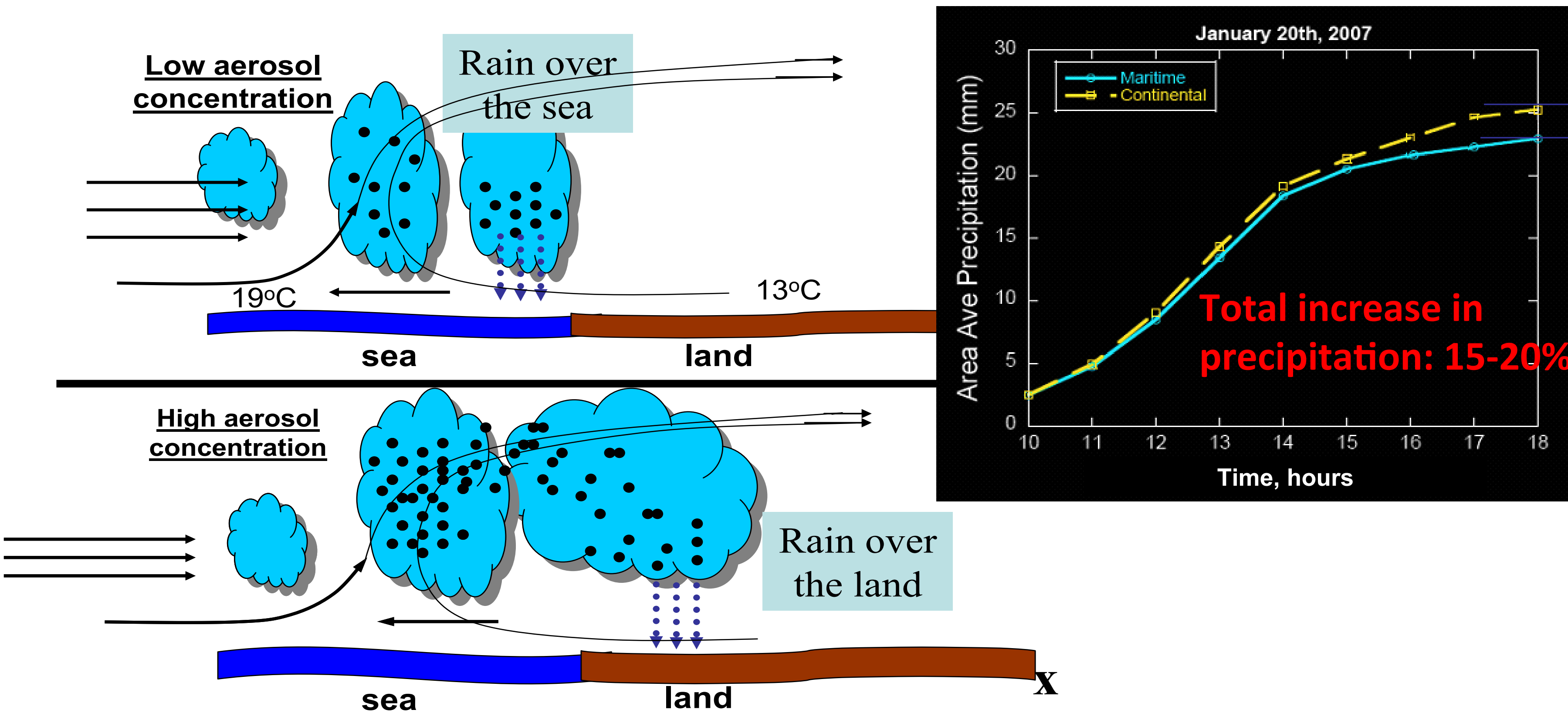
Vertical profiles of effective radius in simulations of deep convective clouds in Amazon region



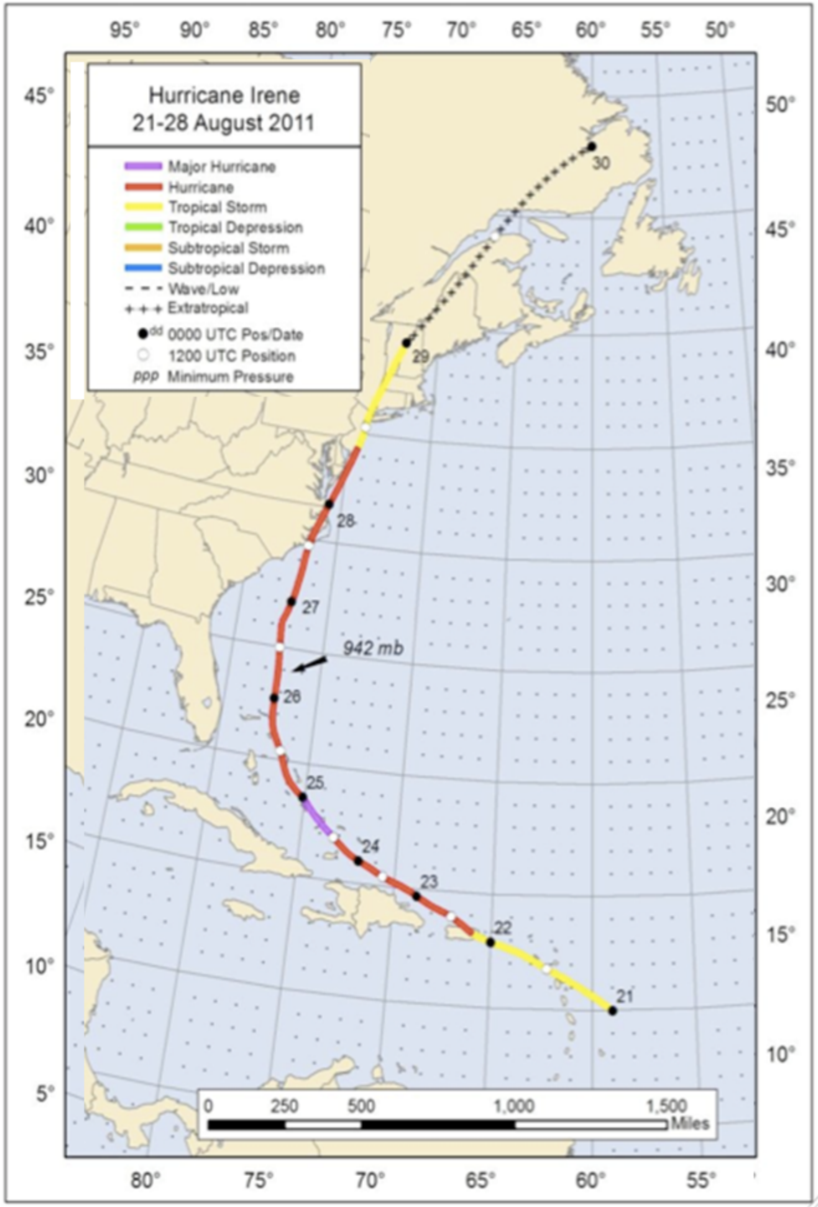
First rain drops form in undiluted cloud volumes where effective radius reaches a critical value.
Rain drop formation depends on Height.

Example 2. Simulation of aerosol effects on spatial shift of precipitation from Sea to land (Noppel et al, 2012)

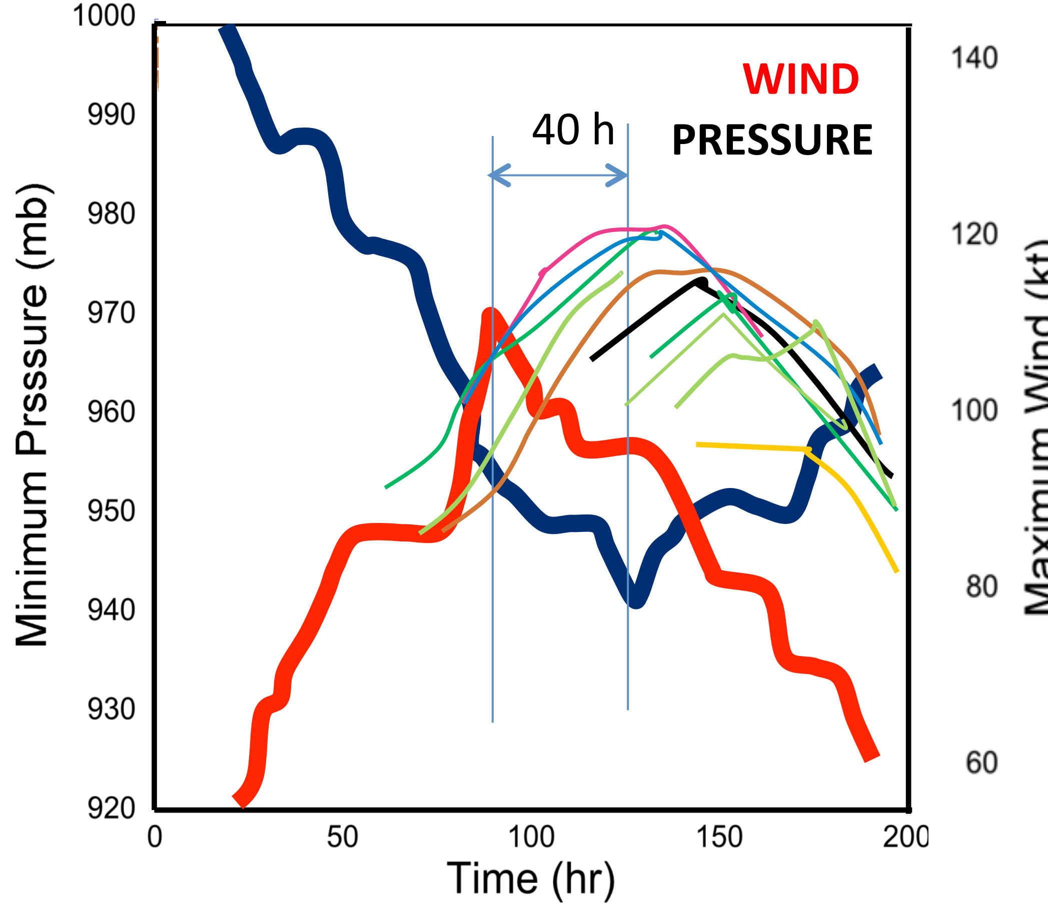
During winter time clouds form in the convergence zone over sea ~20 km off the coastal line. So, most precipitation take place over the sea.
Increase in the CCN concentration leads to delay of precipitation formation and to shift precipitation from sea to the land.



Example 3: Aerosol effects of intensity and structure of hurricanes (simulation of Hurricane Irene (2011) (Lynn et al, 2014)

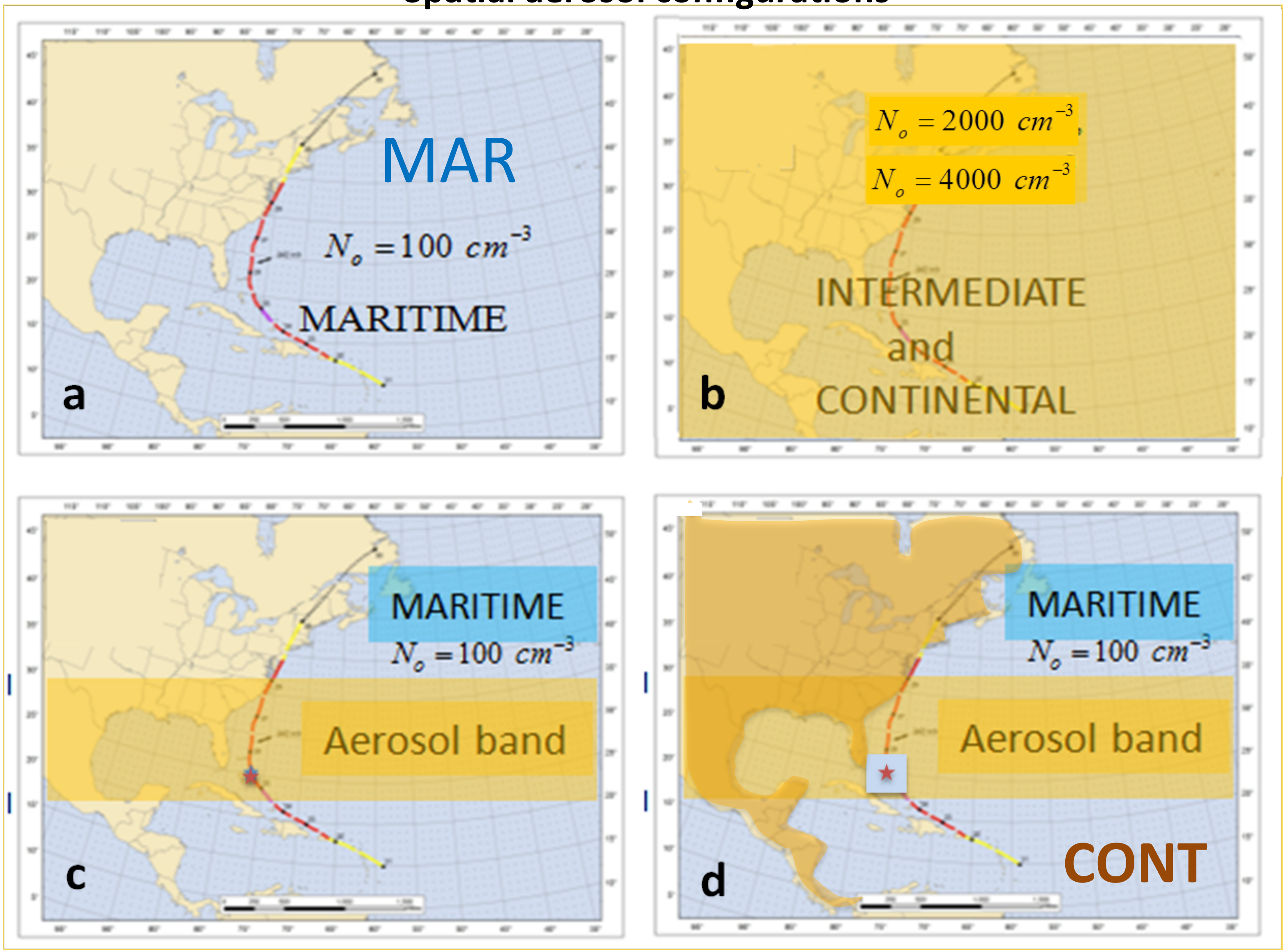


1 km Grid Spacing

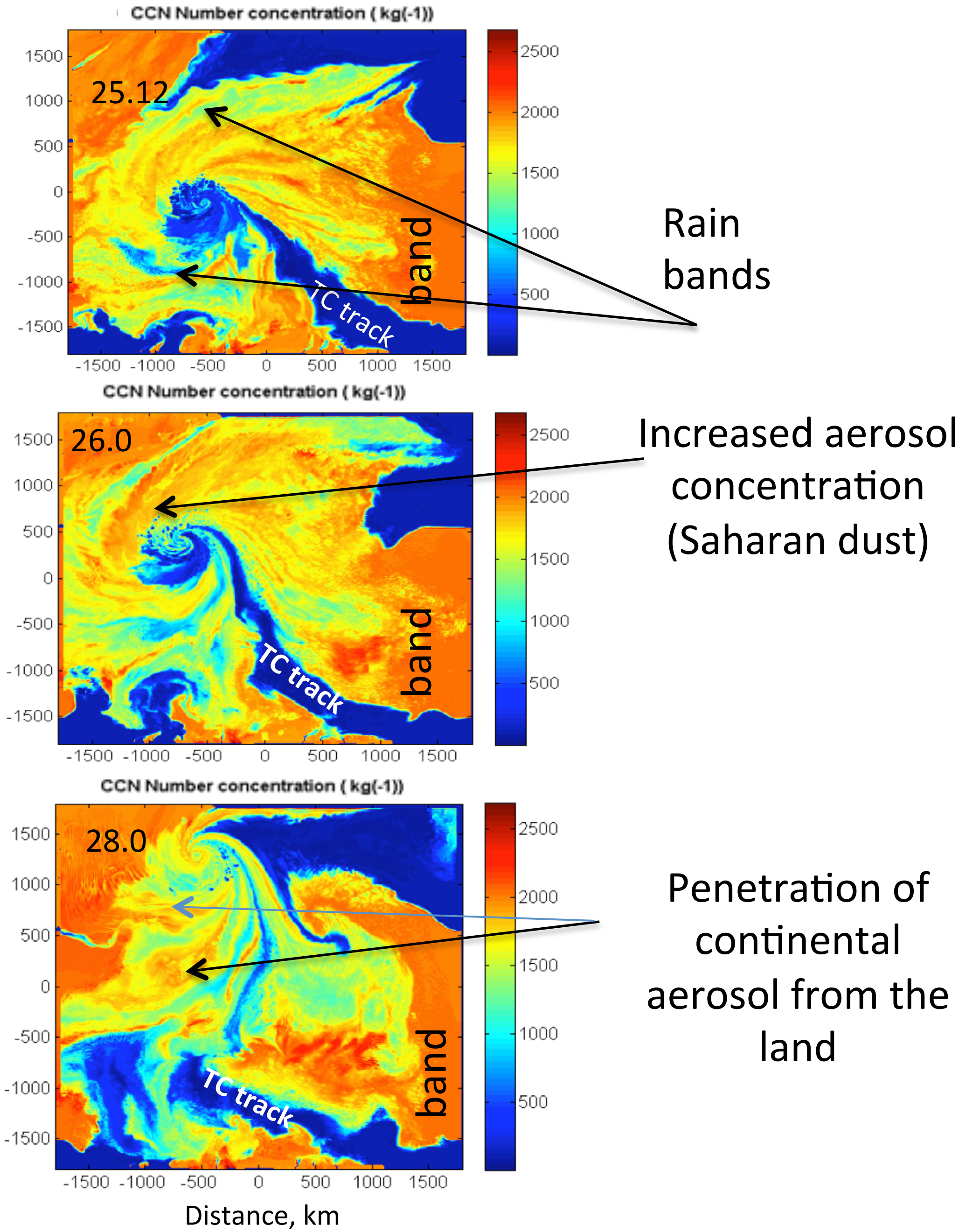


We hypothesized that Irene weakening and the time shift between maximum wind and minimum pressure is caused by aerosols

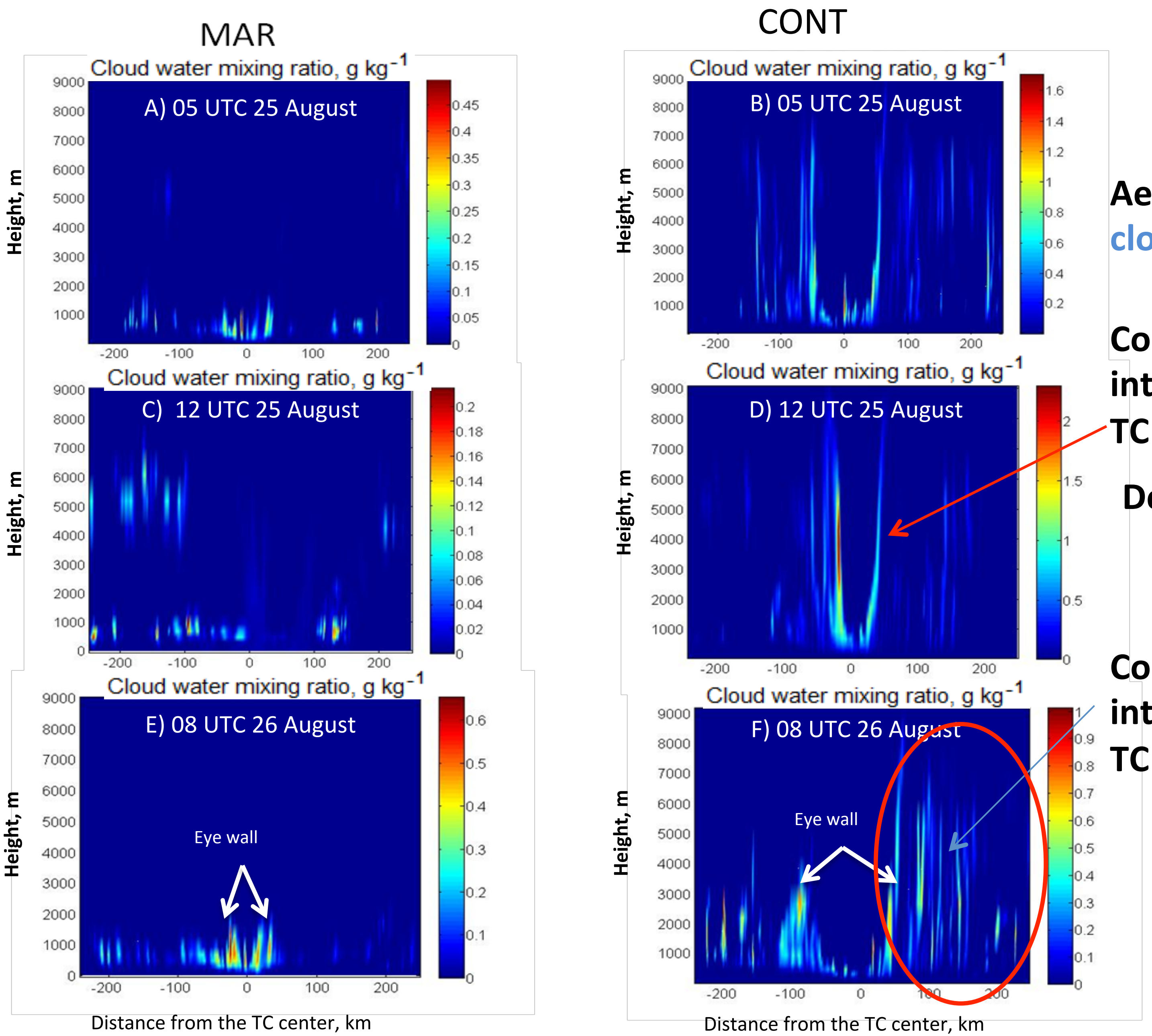
Spatial aerosol configurations



Fields of aerosol concentration in the boundary layer in the CONT



Evolution of cloud water content:



Aerosol effect on cloud water:

Convection intensification in the TC eyewall:

Deepening

Convection intensification at the TC periphery:

TC weakening

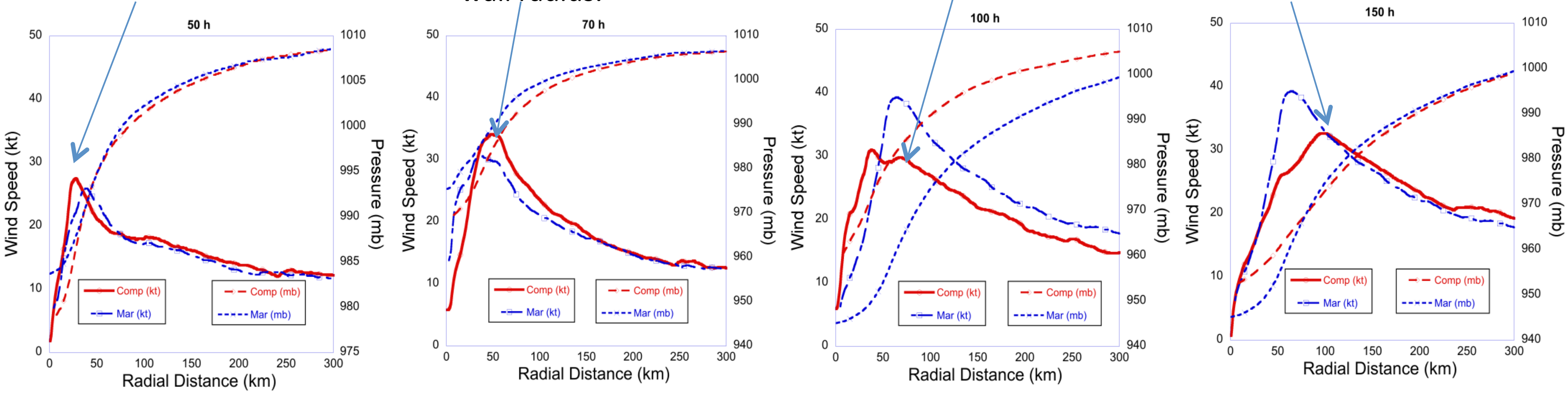
Evolution of TC intensity in CONT (aerosol effects are taken into account) and MAR (low const aerosol concentration)

Aerosols intensify convection in the TC center

Aerosols begins to affect convection at the TC periphery, increase in the eye wall radius.

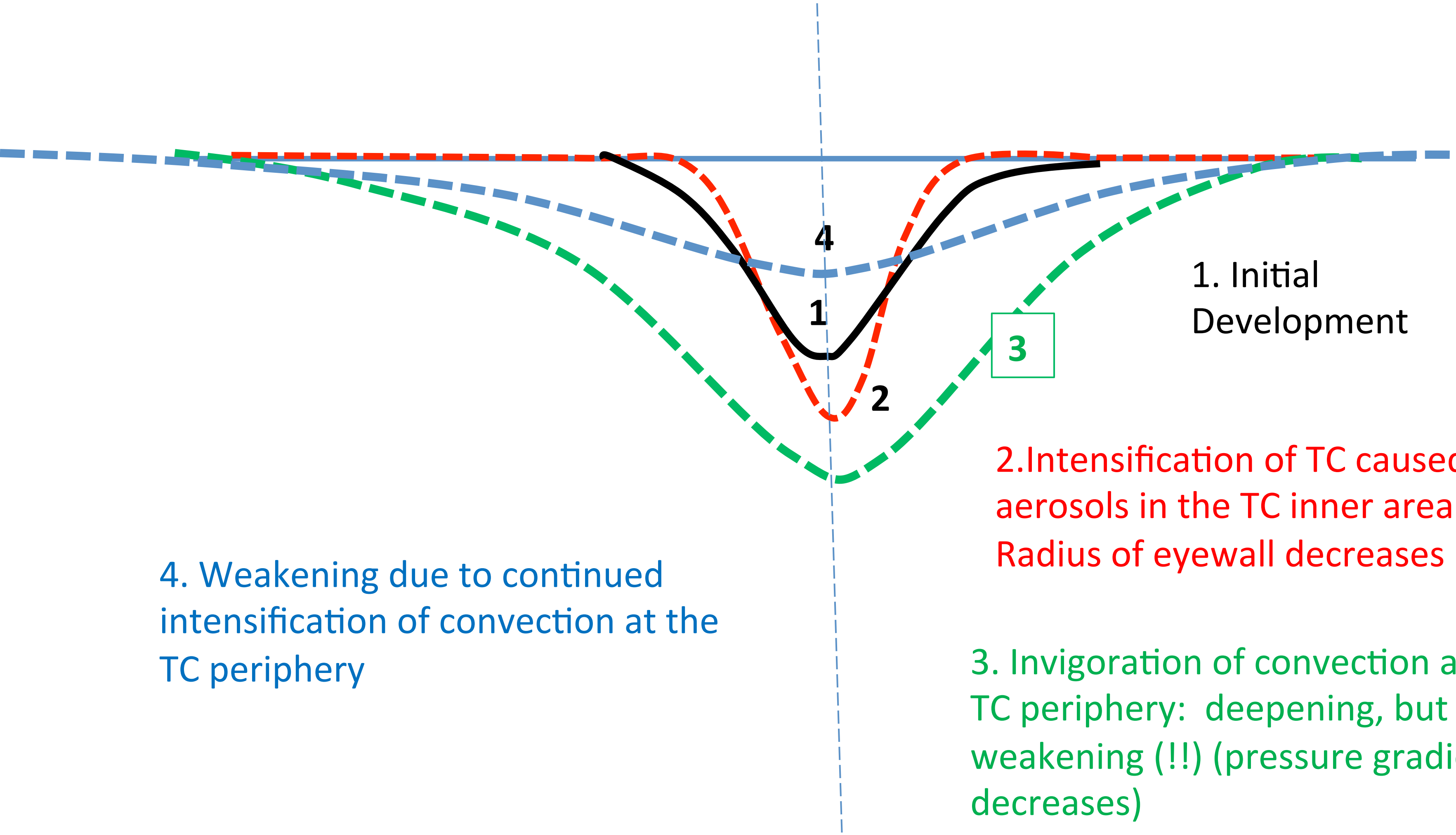
Aerosols intensify convection at TC periphery. Appearance of the second wind maximum.

Aerosols intensify convection at the TC periphery, maximum wind shifts to r=100 km, first maximum disappears.



There were no these changes of TC structure in the case of maritime aerosols, Radius of maximum wind remains at radius of about 50 km.

Evolution of radial profiles of minimum pressure

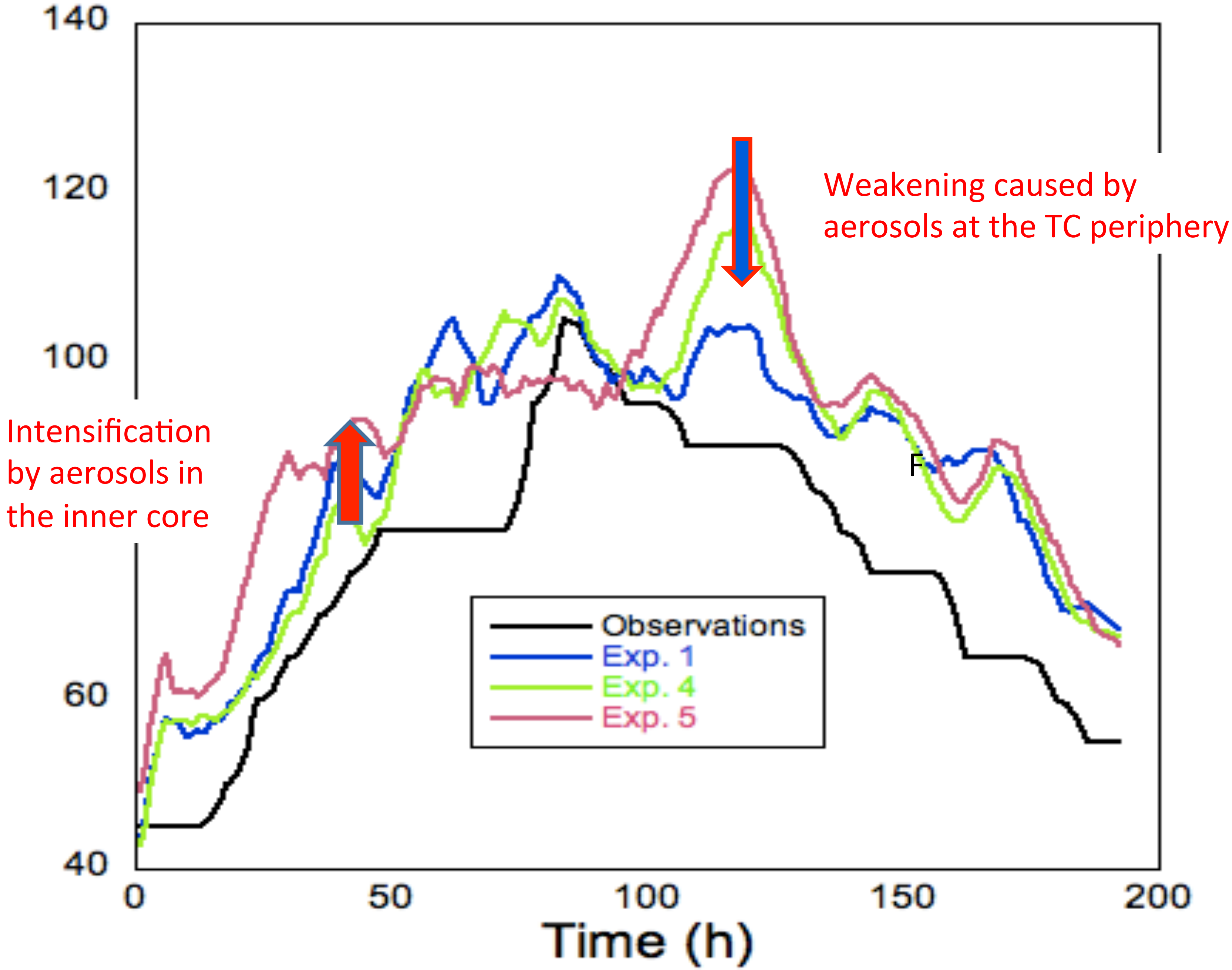


2.Intensification of TC caused by aerosols in the TC inner area. Radius of eyewall decreases

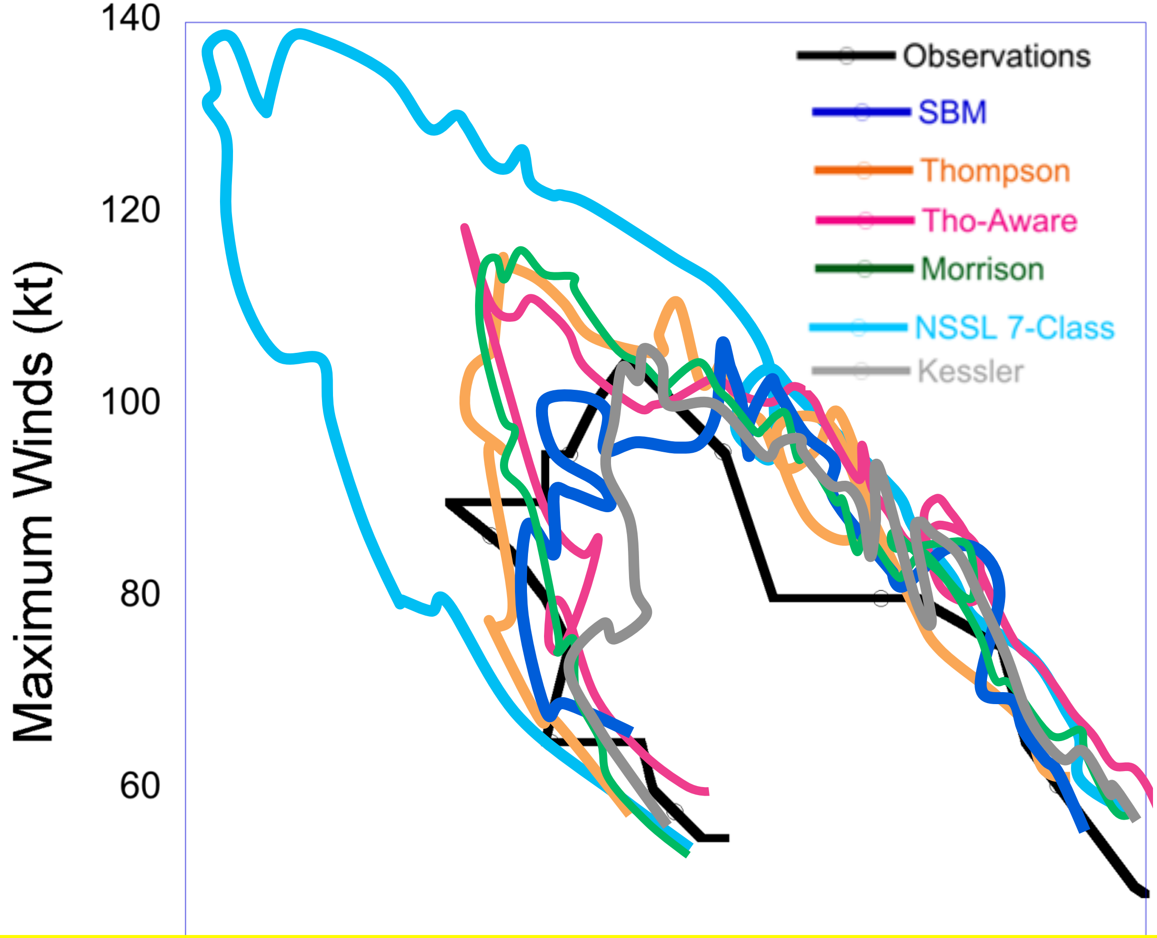
4. Weakening due to continued intensification of convection at the TC periphery

3. Invigoration of convection at the TC periphery: deepening, but weakening (!!) (pressure gradient decreases)
THIS IS THE REASON OF TIME SHIFT BETWEEN MAXIMUM WIND AND MINIMUM PRESSURE

Maximum wind (kt)



Maximum wind-minimum pressure relationship in simulations with different microphysical schemes



ONLY SBM that takes into account effects of aerosols was able to predict 40 h time shift between minimum pressure and maximum wind

Even the best bulk schemes predicted minimum pressure and maximum wind at the same time instant

PLANS OF FURURE MODIFICATIONS:

WRF 3.6.1 or 3.6.2

1) WRF SBM Full Melting

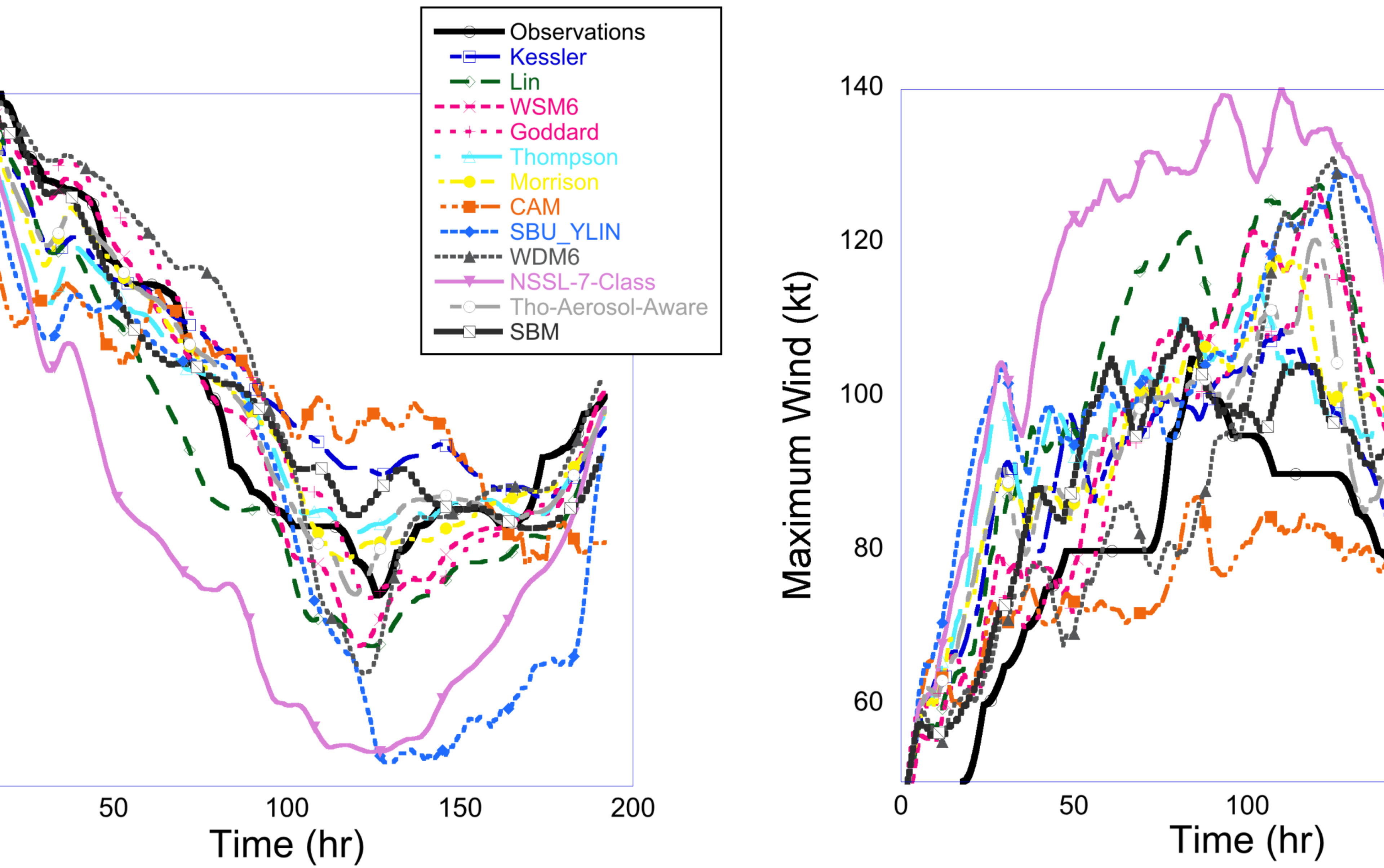
This version will include detailed melting: calculation of liquid water mass within melting particles.

2) WRF SBM w 43 Bin

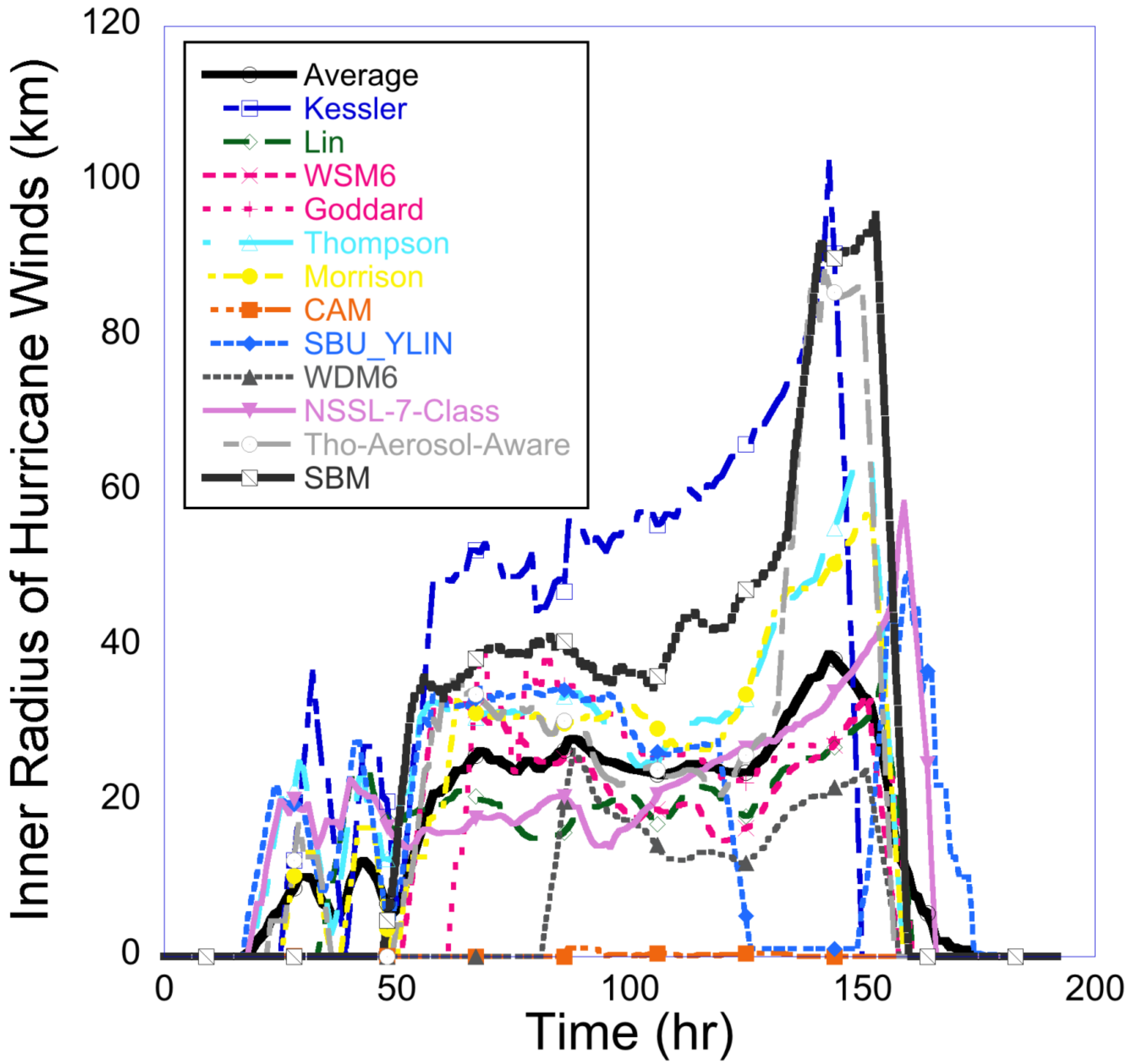
This version will include 43 bins. It will allow simulations of big hail of several cm in diameter. It is very important for proper representation of microphysics and precipitation of deep convective clouds over continents.

Polarimetric operator allowing calculation of all polarimetric variables will imported to the respository version.

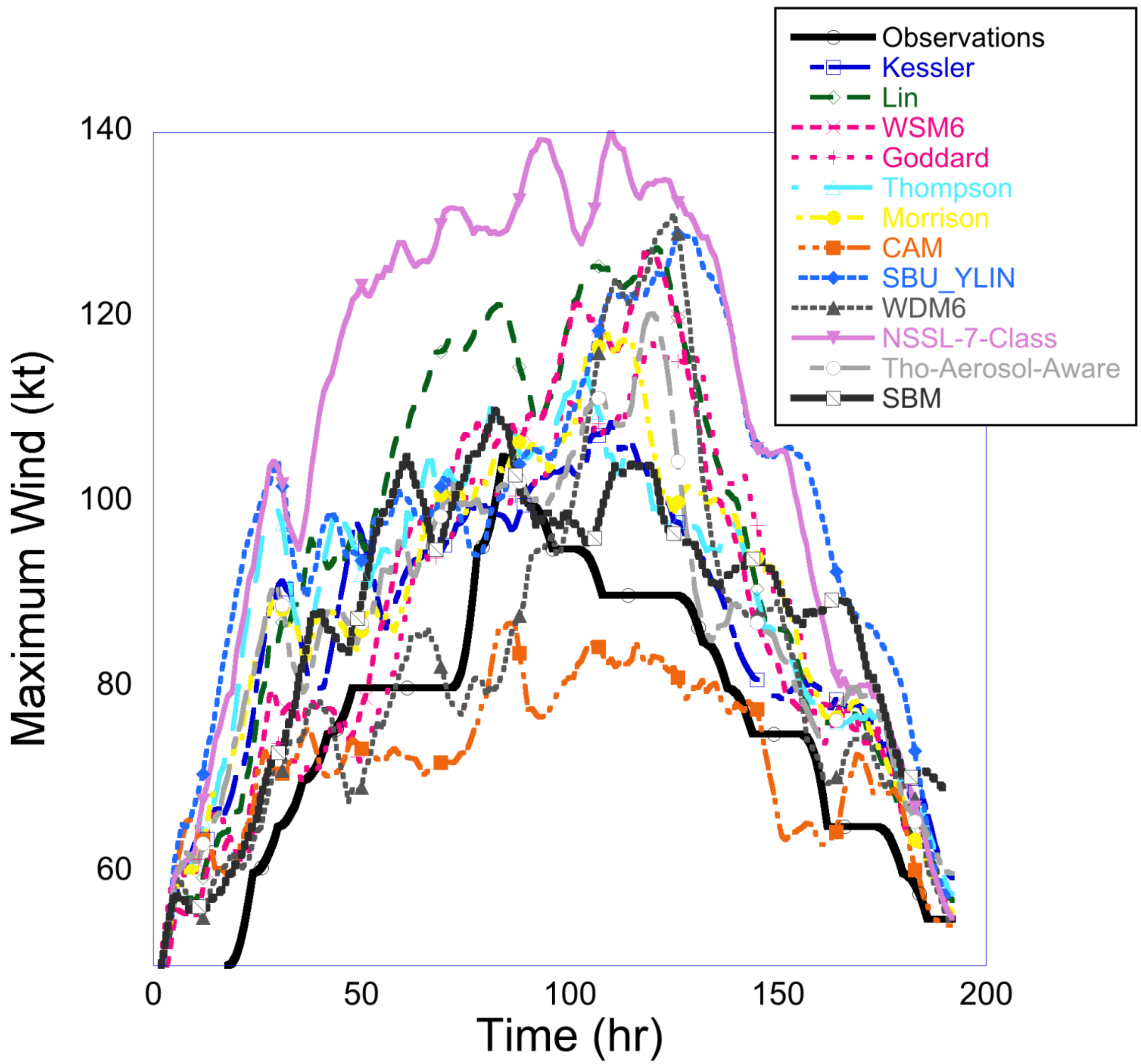
THANK YOU!



Observations
Kessler
Lin
WSM6
Goddard
Thompson
Morrison
CAM
SBU_YLIN
WDM6
NSSL-7-Class
Tho-Aerosol-Aware
SBM
50
100
150
200
Time (hr)
140
120
100
80
60
Maximum Wind (kt)
0
50
100
Time (hr)



Inner Radius of Hurricane Winds (km)
Time (hr)
0
20
40
60
80
100
120
0
50
100
150
200
Average
Kessler
Lin
WSM6
Goddard
Thompson
Morrison
CAM
SBU_YLIN
WDM6
NSSL-7-Class
Tho-Aerosol-Aware
SBM



Observations
Kessler
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SBU_YLIN
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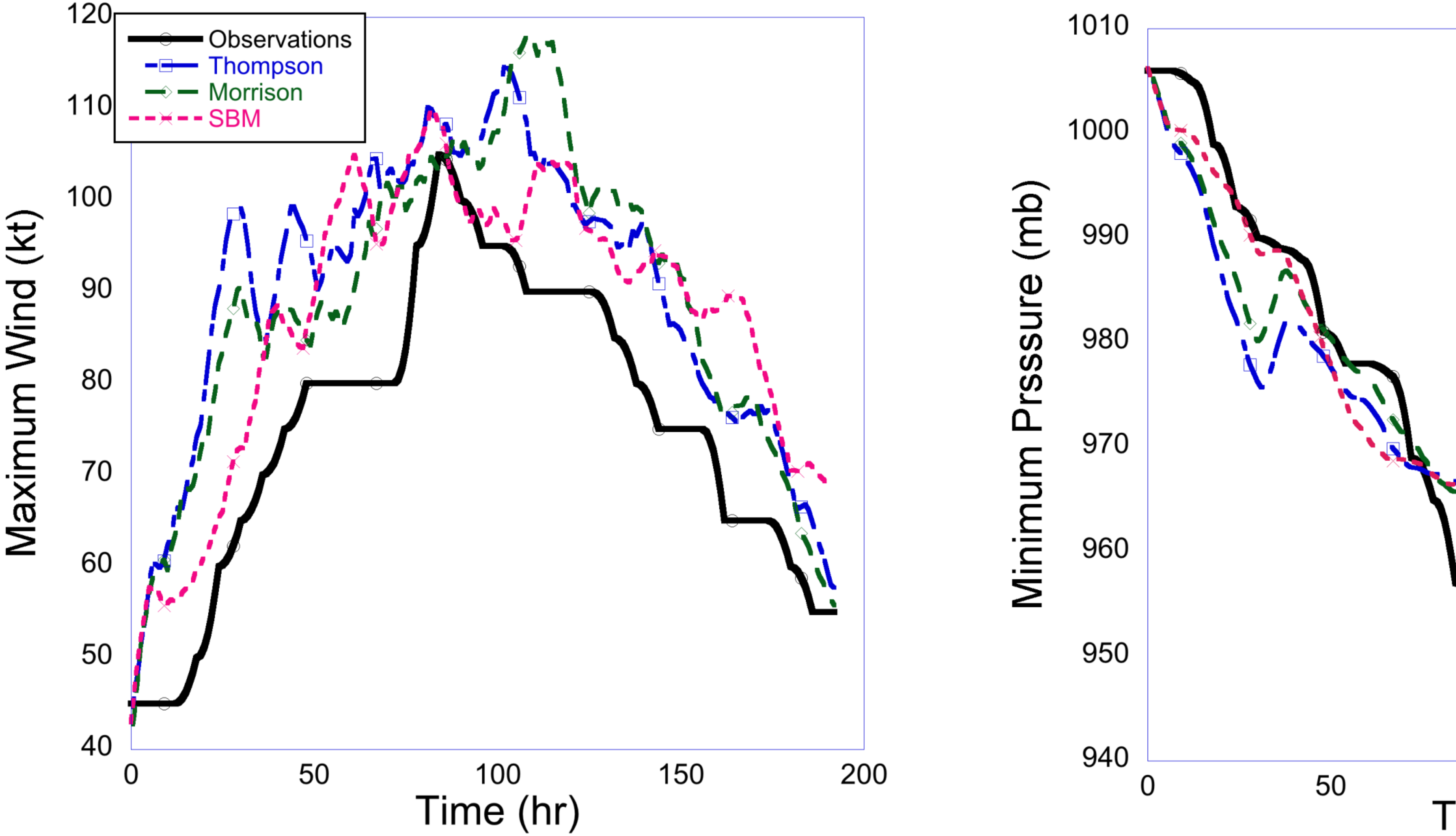
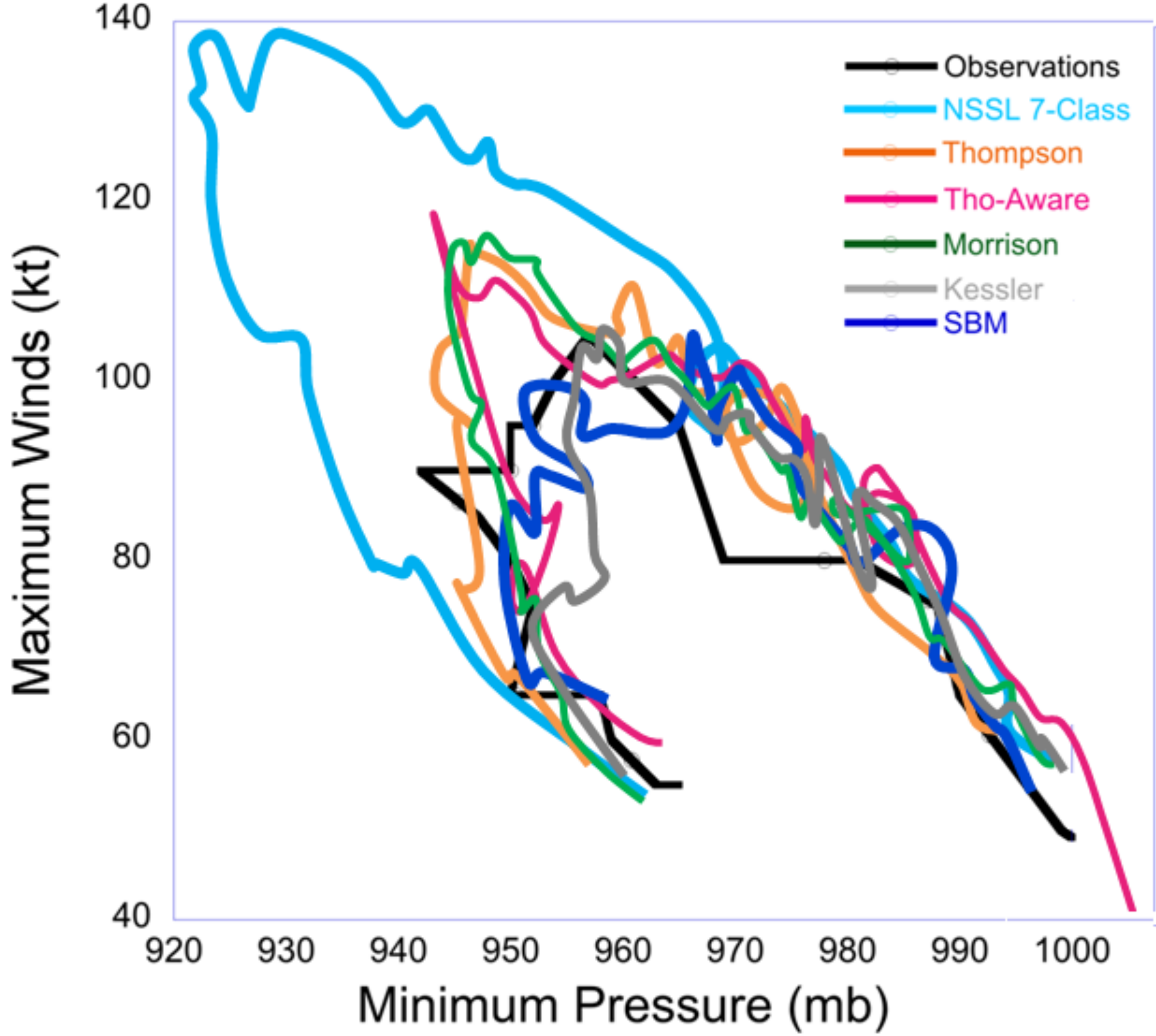
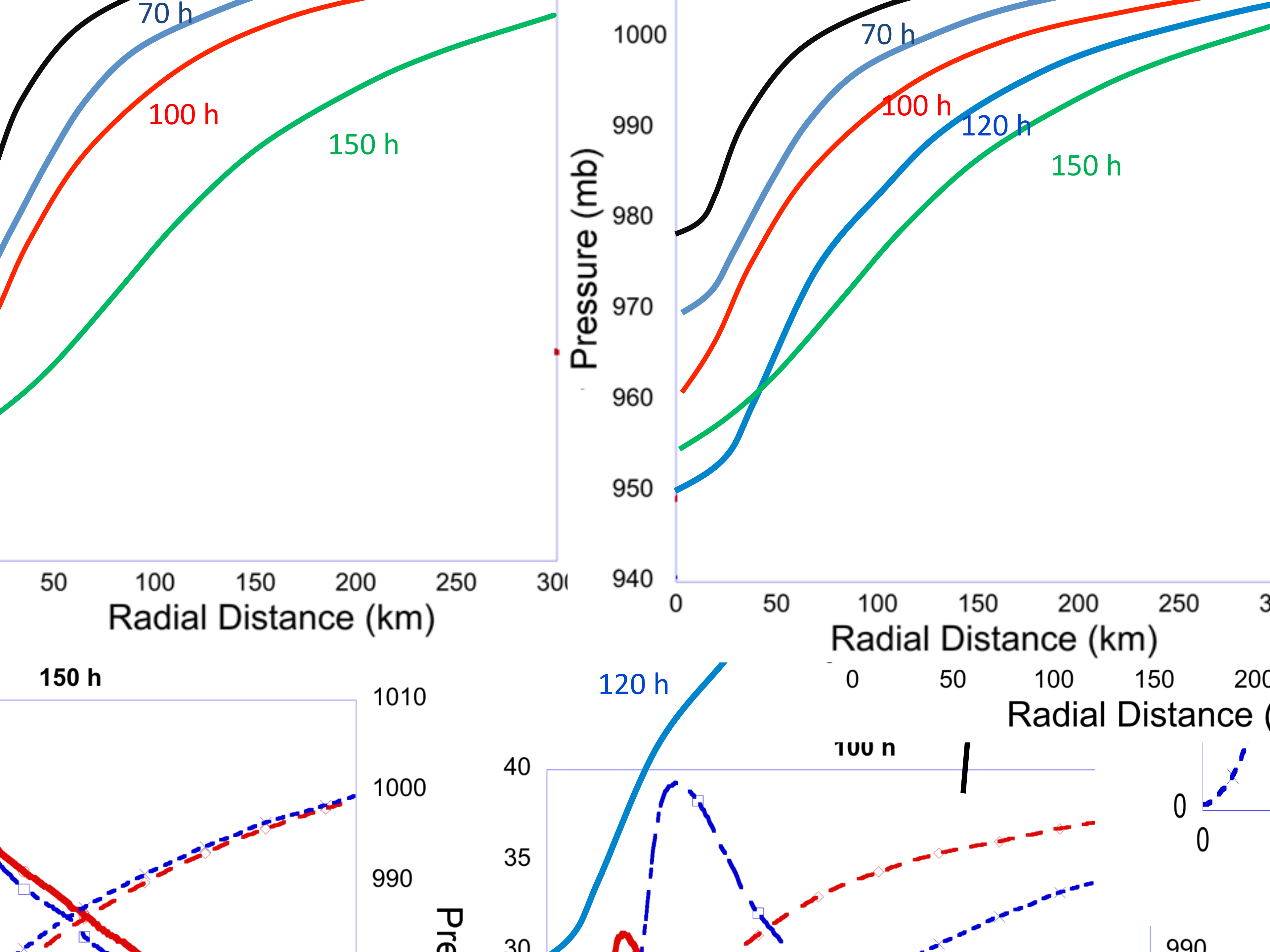
NSSL-7-Class
Tho-Aerosol-Aware
SBM
140
120
100
80
60
0
50
100
150
200
Maximum Wind (kt)
Time (hr)

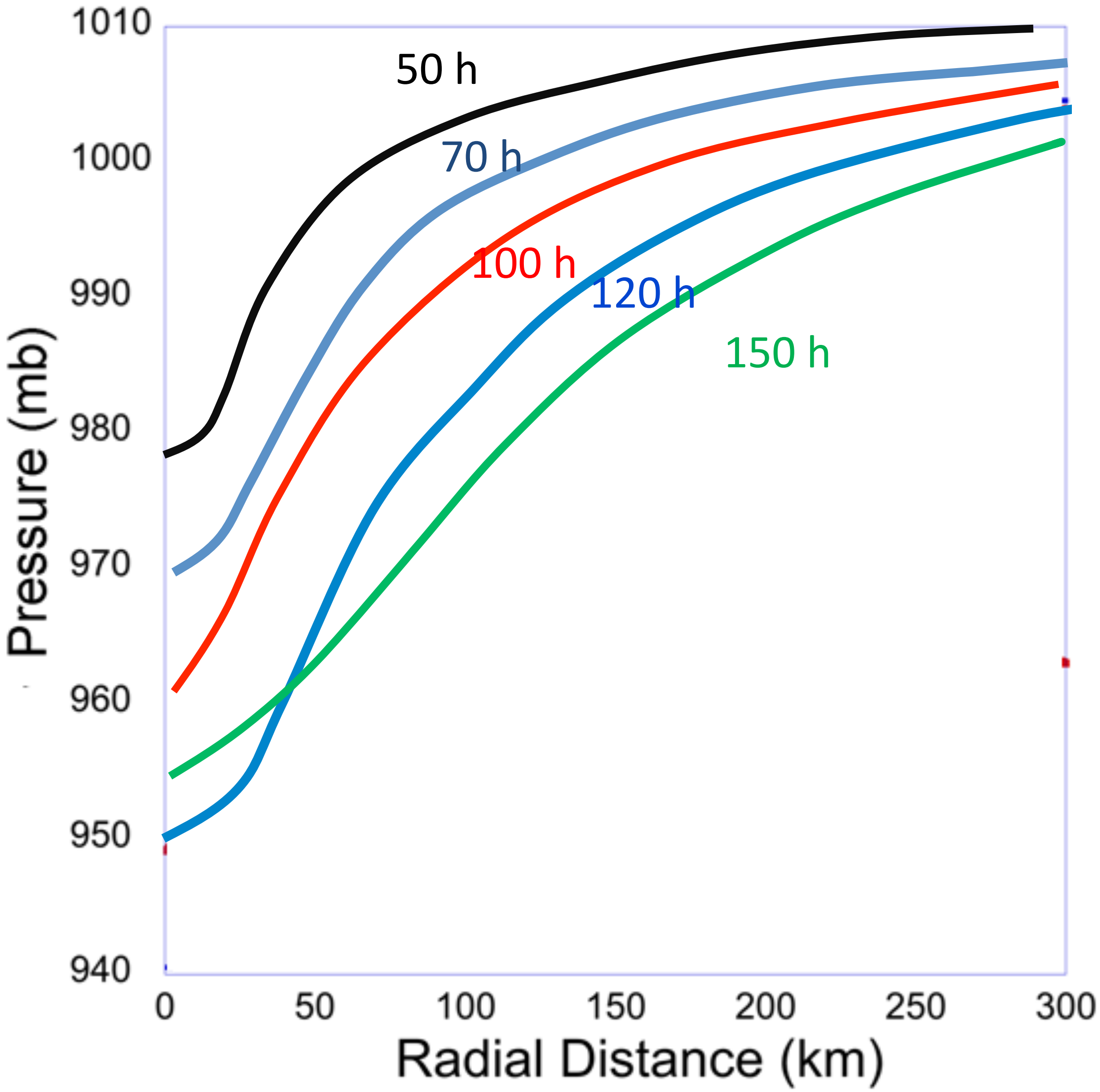

Observations
Thompson
Morrison
SBM
Maximum Wind (kt)
Time (hr)
120
110
100
90
80
70
60
50
40
0
50
100
150
200
Minimum Prsssure (mb)
1010
1000
990
980
970
960
950
940
0
50
T



Observations
NSSL 7-Class
Thompson
Tho-Aware
Morrison
Kessler
SBM
Maximum Winds (kt)
140
120
100
80
60
40
Minimum Pressure (mb)
920
930
940
950
960
970
980
990
1000



70 h
100 h
150 h
50
100
150
200
250
300
Radial Distance (km)
1000
990
980
970
960
950
940
Pressure (mb)
70 h
100 h
120 h
150 h
0
50
100
150
200
250
Radial Distance (km)
150 h
1010
1000
990
120 h
0
50
100
150
200
Radial Distance
100 h
40
35
30
0
0
990



1010
1000
990
980
970
960
950
940
Pressure (mb)
0
50
100
150
200
250
300
Radial Distance (km)
50 h
70 h
100 h
120 h
150 h