Goddard Space Flight Center

Mesoscale Dynamics and Modeling Group

Implementation of NASA/GSFC Cloud Microphysics Schemes into WRF

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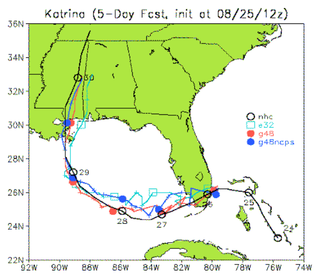
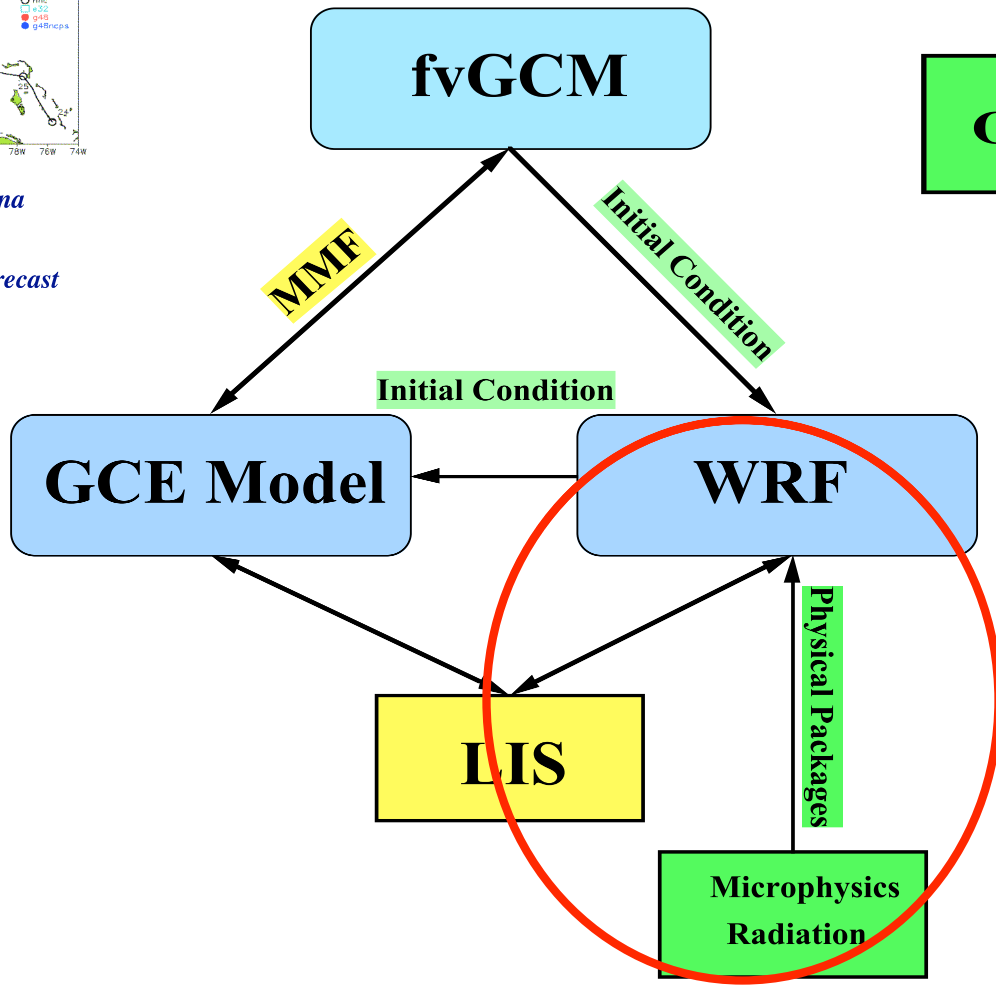
Outline

- Brief introduction of Goddard cloud microphysics scheme
- Model setup
- Comparing WRF results from different cloud microphysics schemes
- Summary and future works

Multi-Scale Modeling Systems



Hurricane Katrina
High-resolution
fvGCM 5 day forecast



Microphysical Package (4 options)
Long/Shortwave Radiative Transfer
GOCART

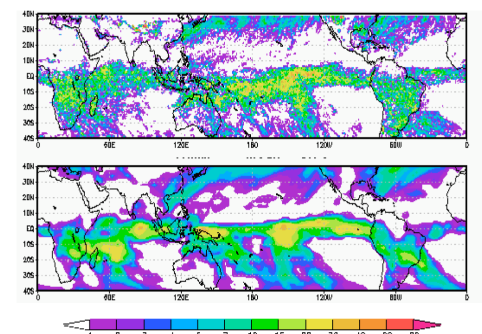
Observation

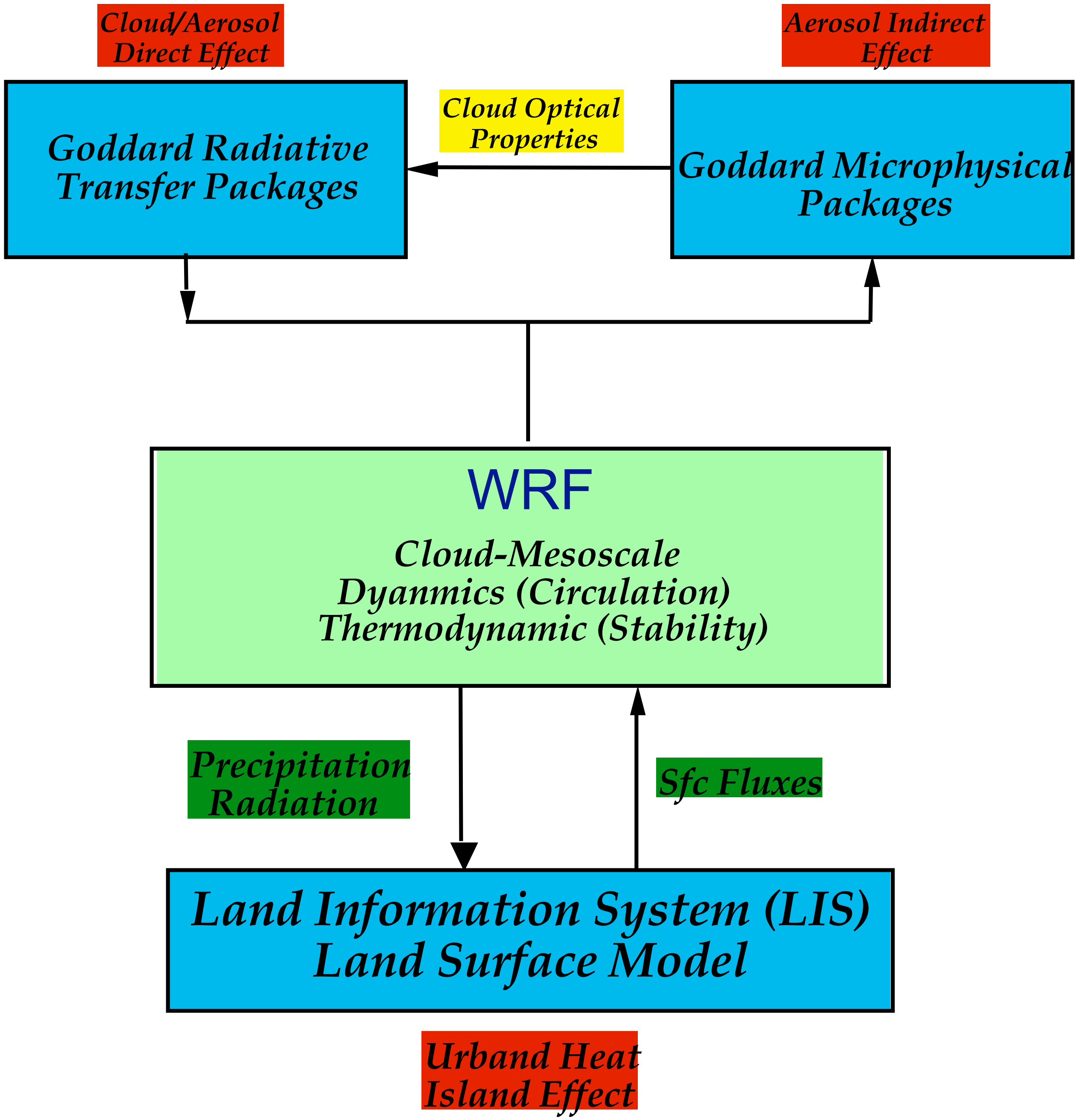
Satellite Data
Field Campaigns
Re-analyses

Data Management
Visualization

TRMM

MMF





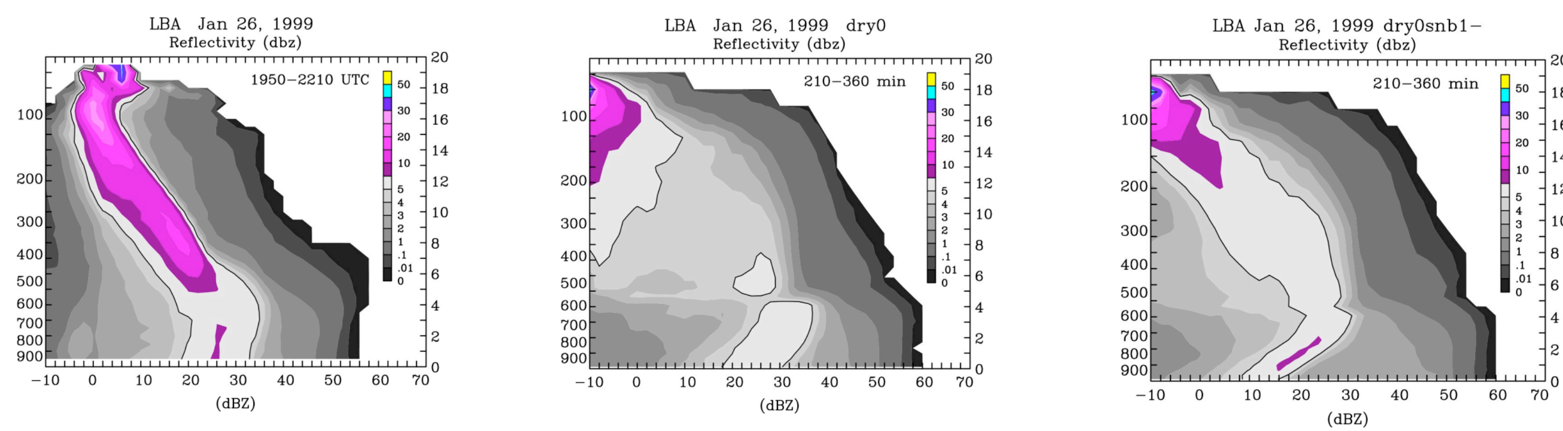
Cloud/Aerosol Direct Effect
Aerosol Indirect Effect
Goddard Radiative Transfer Packages
Cloud Optical Properties
Goddard Microphysical Packages
WRF
Cloud-Mesoscale
Dyanmics (Circulation)
Thermodynamic (Stability)
Precipitation
Radiation
Sfc Fluxes
Land Information System (LIS)
Land Surface Model
Urband Heat Island Effect

Goddard Bulk Microphysical Scheme

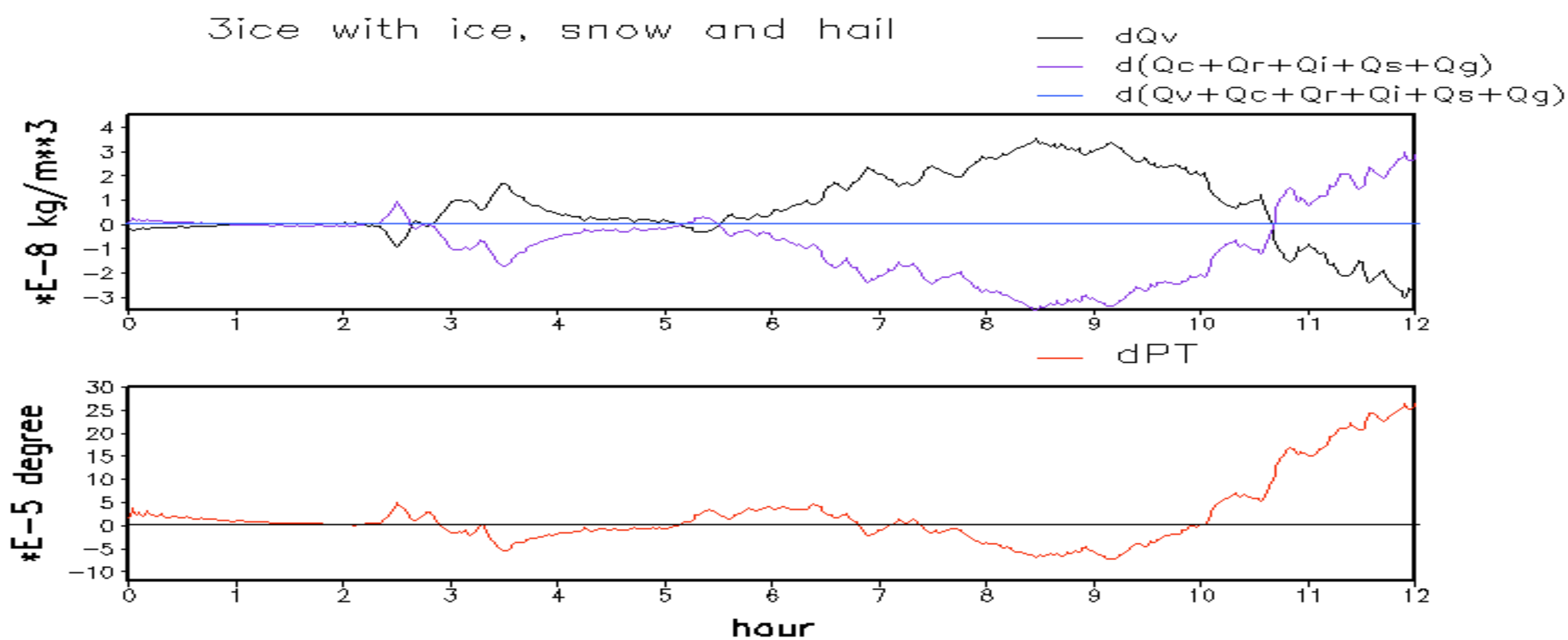
- Warm Rain (**Soong and Ogura 1973**)
- Ice-Water Saturation Adjustment (**Tao *et al.* 1989**)
- 3ICE-Graupel and 3ICE-Hail (**Tao and Simpson 1989, 1993; MuCumber *et al.* 1990**)
  Option 3ICE-Graupel (Rutledge and Hobb 1984) or 3ICE -Hail (Lin *et al.* 1983)
  The sum of all the sink processes associated with one species will not exceed its mass - (Water budget balance)
  All transfer processes from one type of hydrometeor to another are calculated based on one thermodynamic state (ensure all processes are equal)

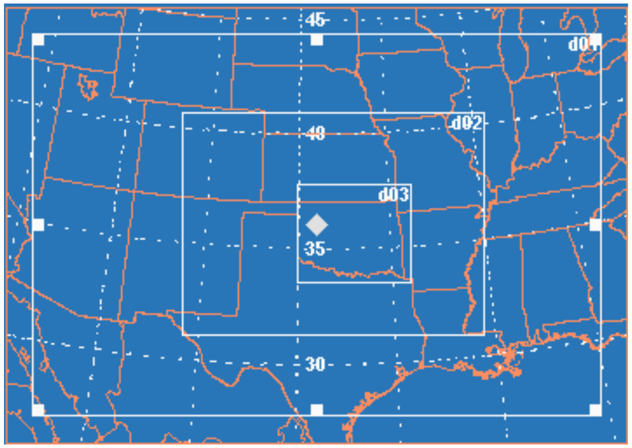
- 3ICE Modification (**Tao *et al.* 2003a**)
  Saturation adjustment
  Conversion from Ice to Snow
- 2ICE scheme (**Tao *et al.* 2003b**)
  Ice and Snow
- 3ICE-Graupel Modification (**Lang *et al.* 2006**)
  Conversion from cloud to snow
  Dry growth of graupel

Obs — *CFAD - Radar Reflectivity* — *Improved*

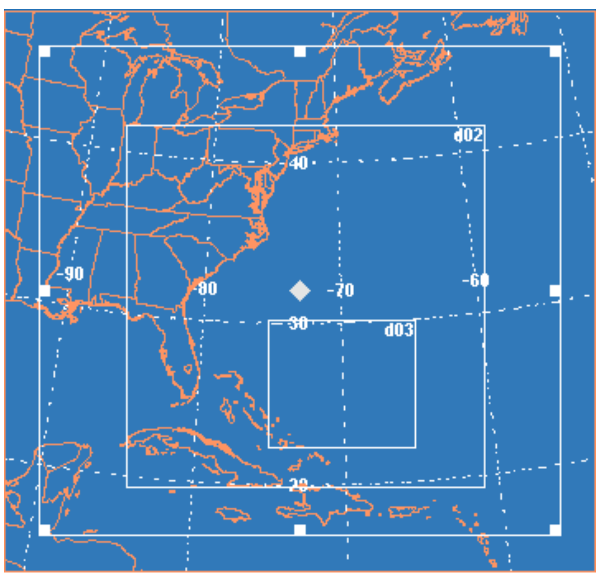


Water Budget: WRF-GCE Microphysics





Resolutions: 9, 3 and 1 km
Grid size: 301x202, 481x352, 541x466, 31 vertical layers
Δt = 30 seconds
Starting time: 00Z 6/12/2002
Initial and Boundary Conditions: NCEP/GFS, no data assimilation



Resolutions: 18, 6 and 2 km
Grid size: 244x217, 472x469, 520x493, 31 vertical layers
Δt = 60 seconds
Starting time: 00Z 9/15/2003
Initial and Boundary Conditions: NCEP/GFS, No bogusing and data assimilation

Physics:

- Cu parameterization: Kane and Fritsch scheme (for the outer grid only)
- Cloud microphysics:

  1. WSM6 scheme
  2. LIN scheme
  3. Goddard microphysics
- Radiation:

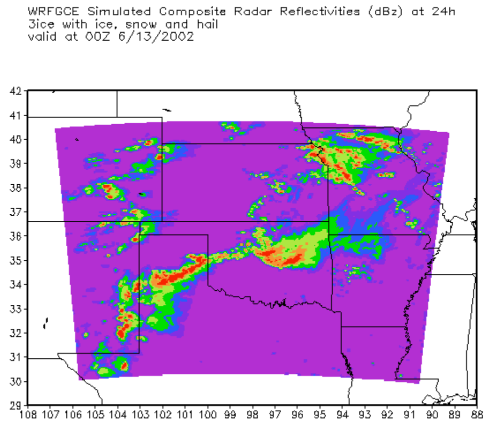
  shortwave: Dudhia

  longwave: RRTM
- PBL parameterization:

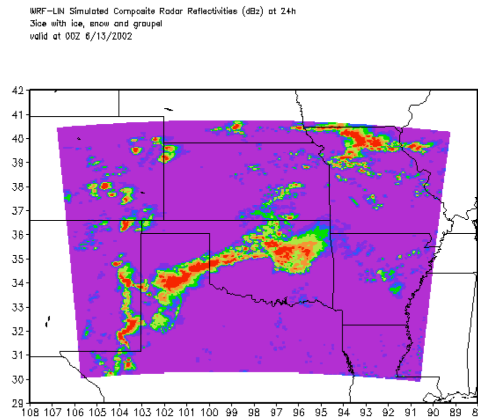
  Mellor-Yamada-Janjic TKE scheme
- Surface Layer:

  Monin-Obukhov
- Land Surface Model:

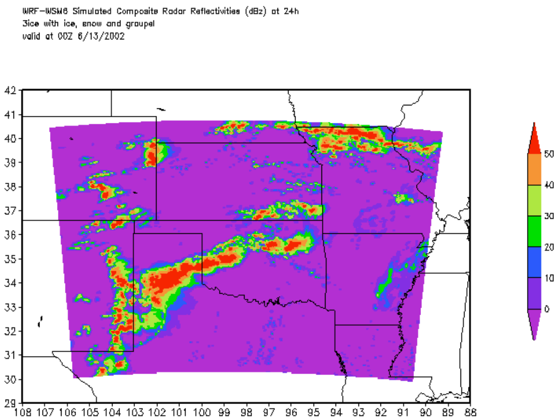
  Noah land-surface



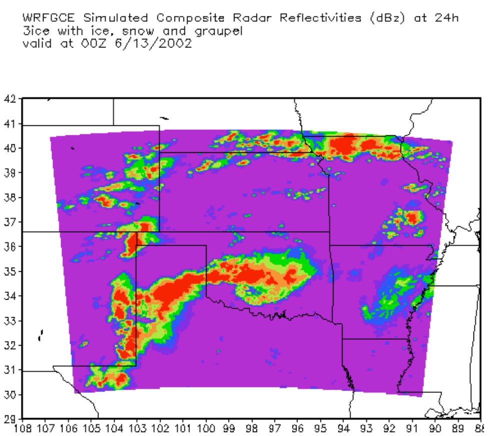
3ice/hail



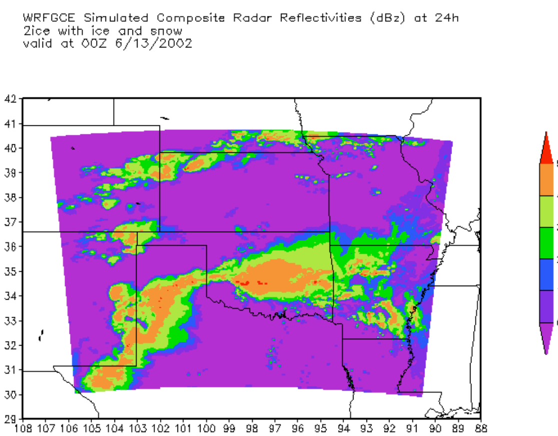
WSM6



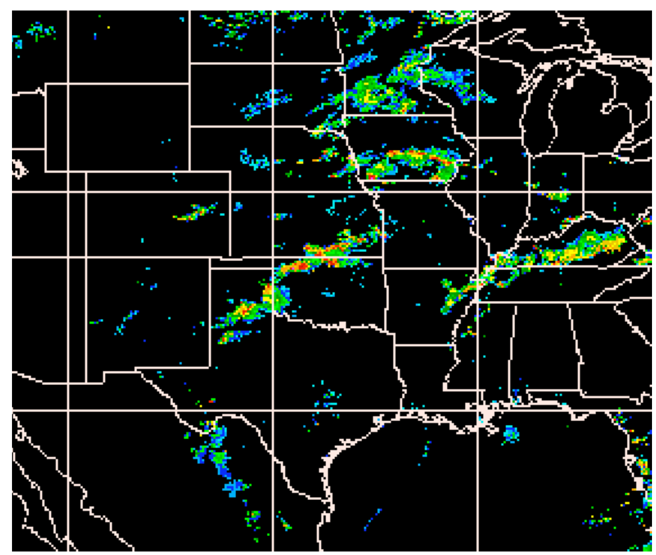
Lin

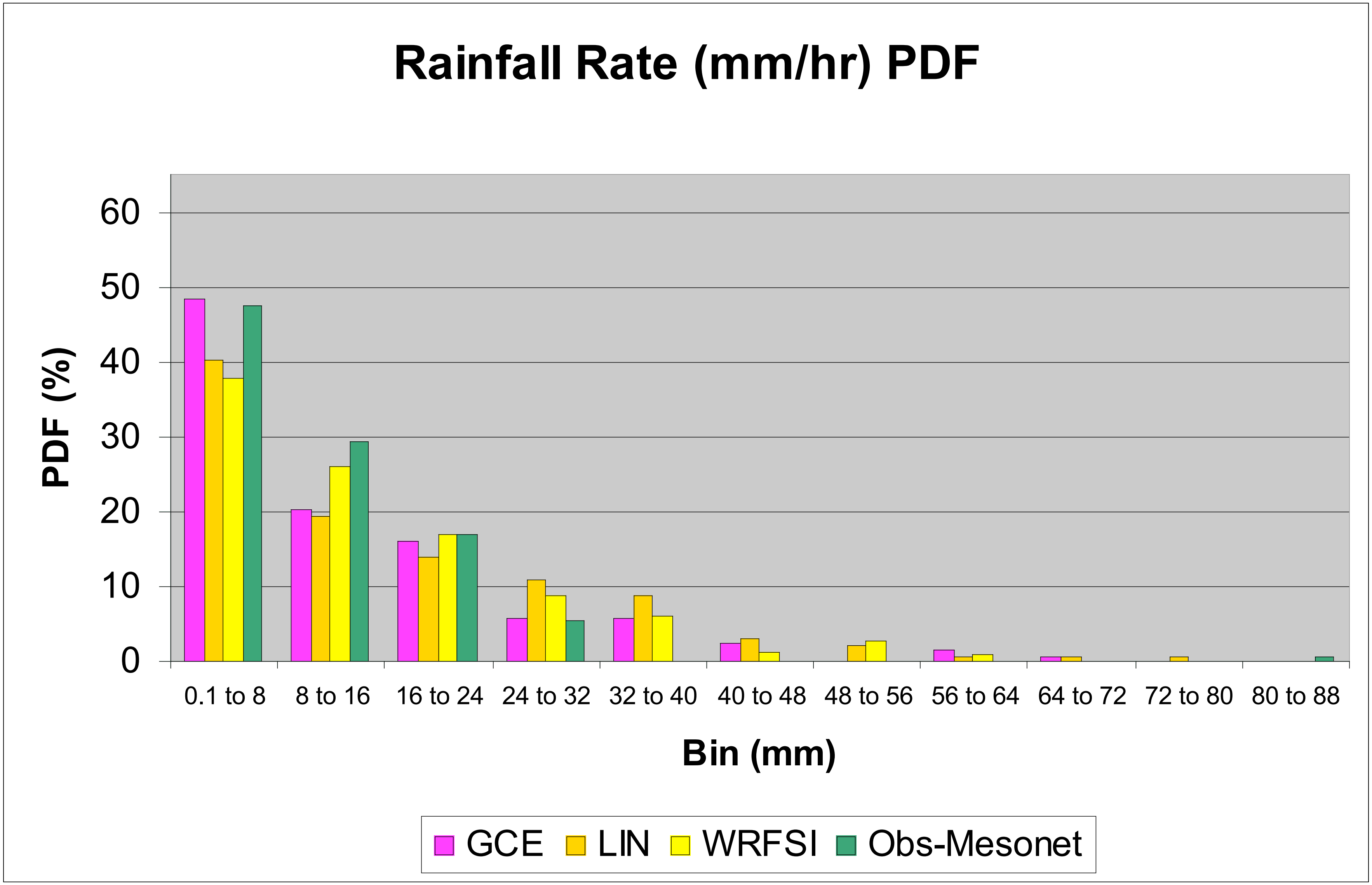


3ice/graupel

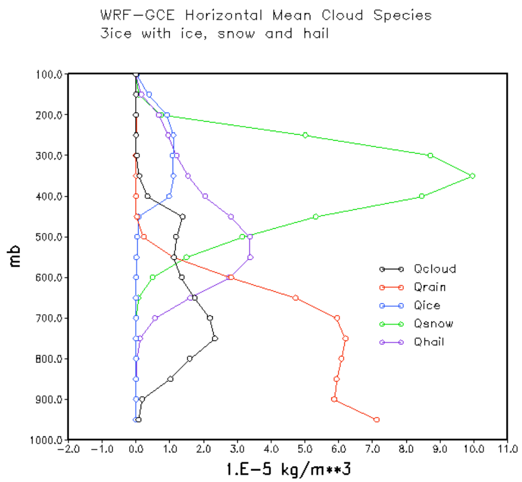


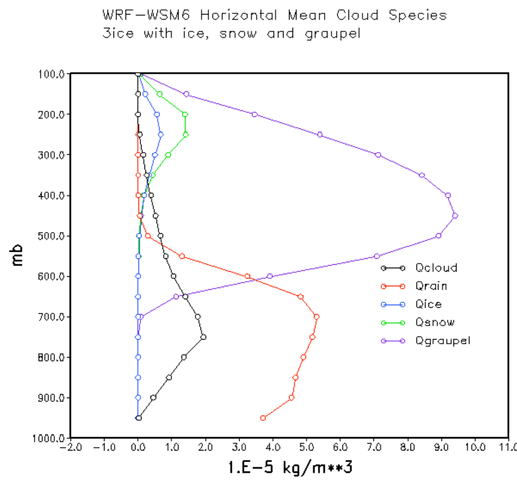
2ice

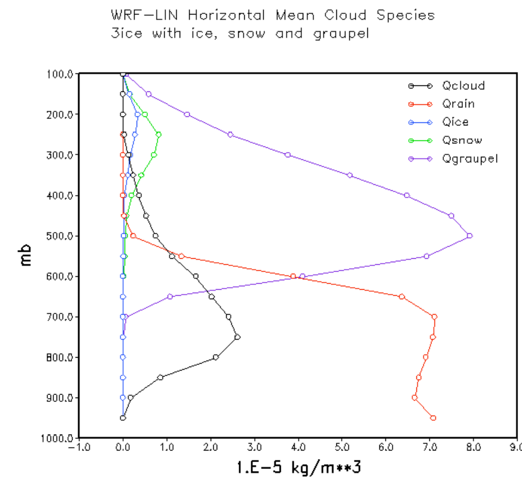


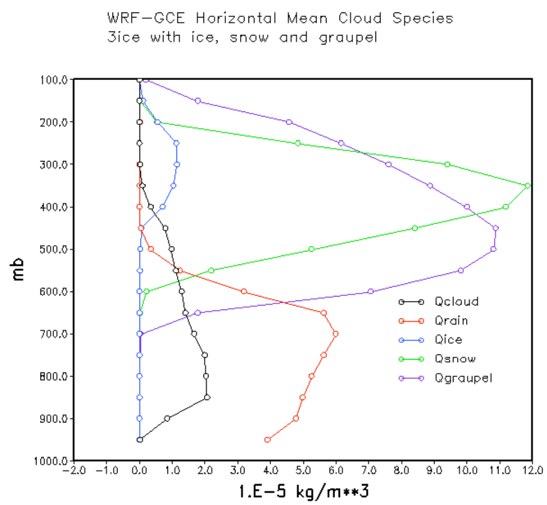

Rainfall Rate (mm/hr) PDF
PDF (%)
60
50
40
30
20
10
0
0.1 to 8
8 to 16
16 to 24
24 to 32
32 to 40
40 to 48
48 to 56
56 to 64
64 to 72
72 to 80
80 to 88
Bin (mm)
GCE
LIN
WRFSI
Obs-Mesonet

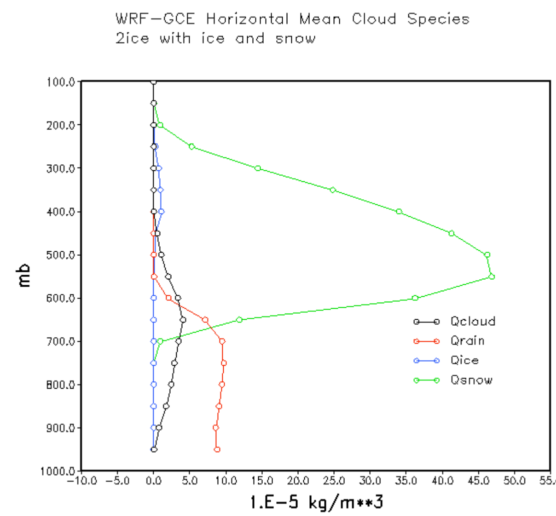
Horizontal domain average of cloud species (1-km grid)



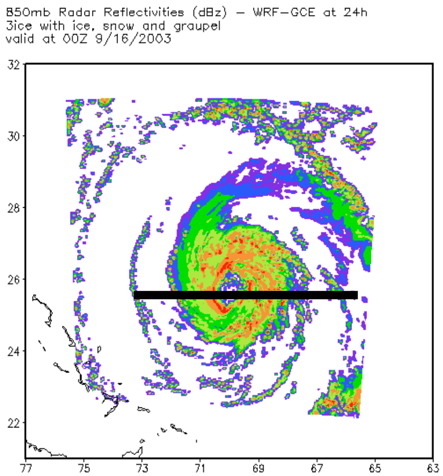




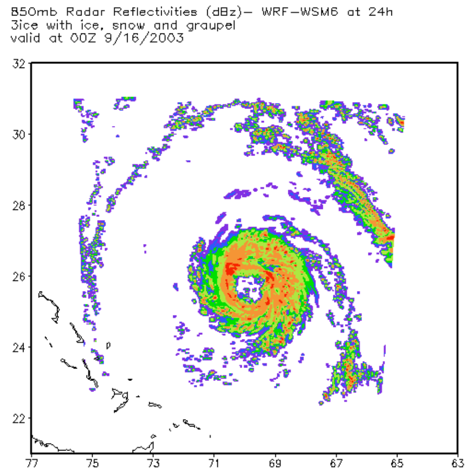




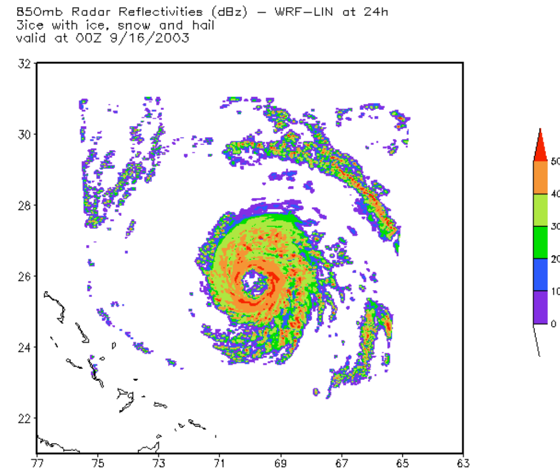
	Goddard microphysics			WSM6	LIN
	3ice/hail	3ice/graupel	2ice		
warm	37.3%	28.5%	15.5%	42.5%	48.9%
cold	62.7%	71.5	84.5%	57.5%	51.1%



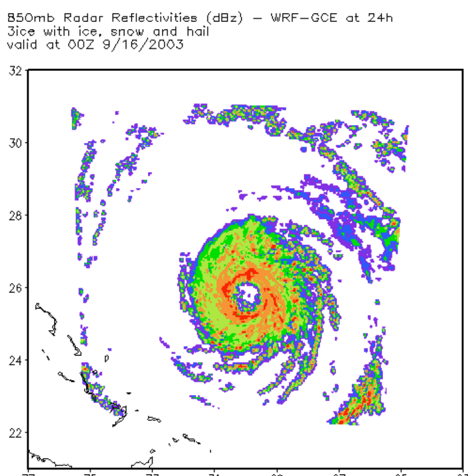
3ice/graupel



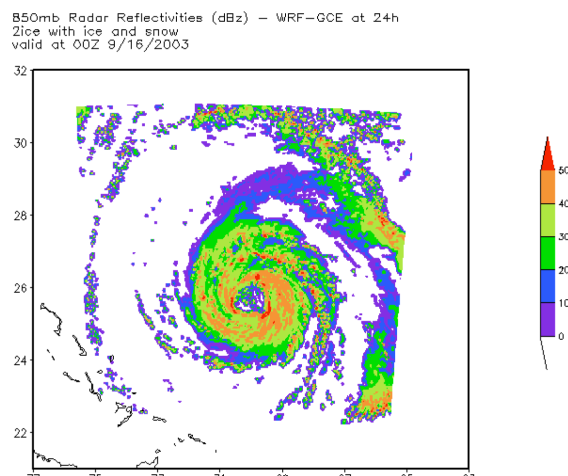
WSM6



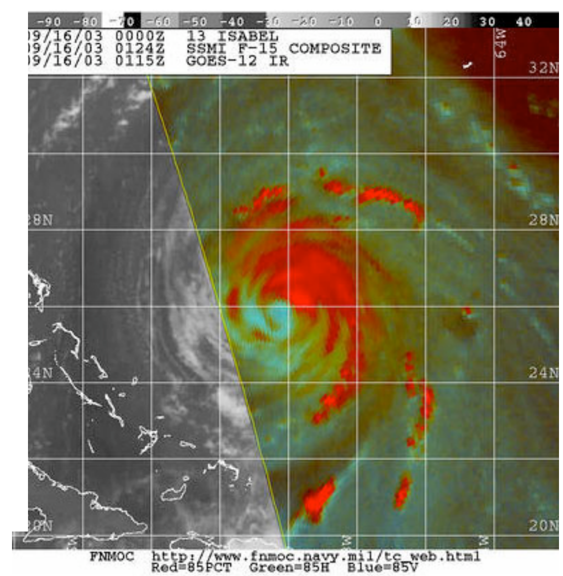
Lin



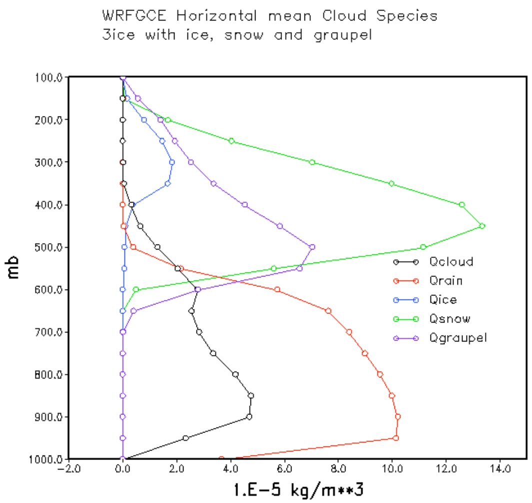
3ice/hail

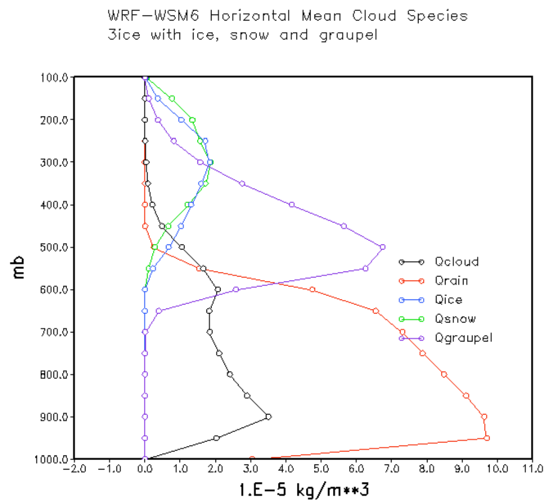


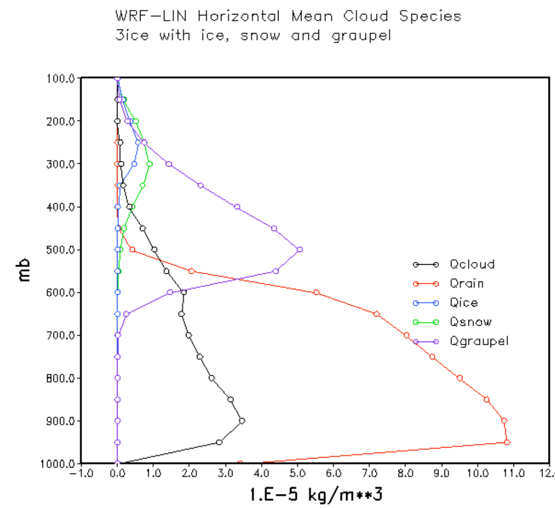
2ice

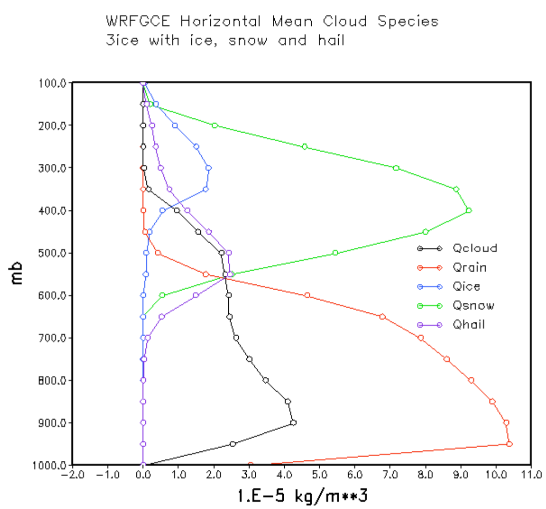


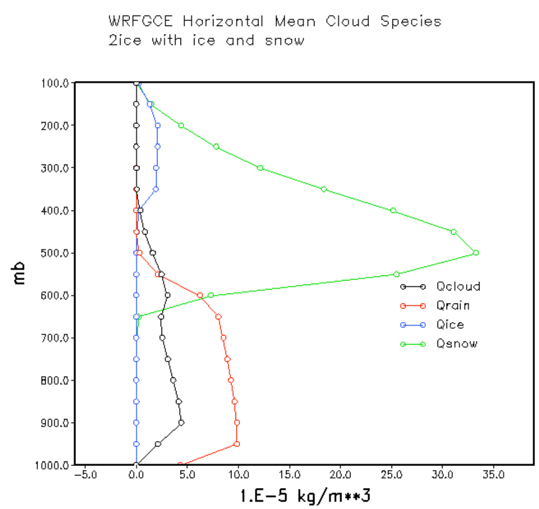
Horizontal domain average of cloud species (2-km grid)

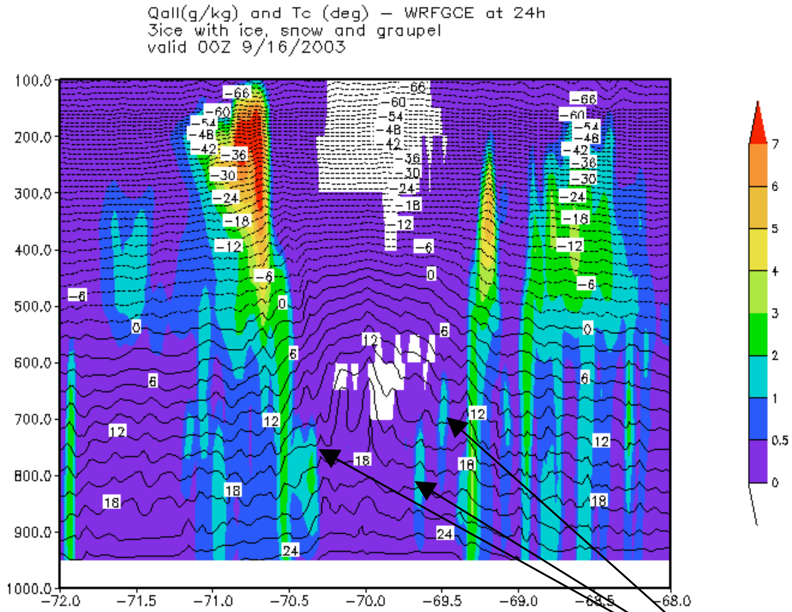


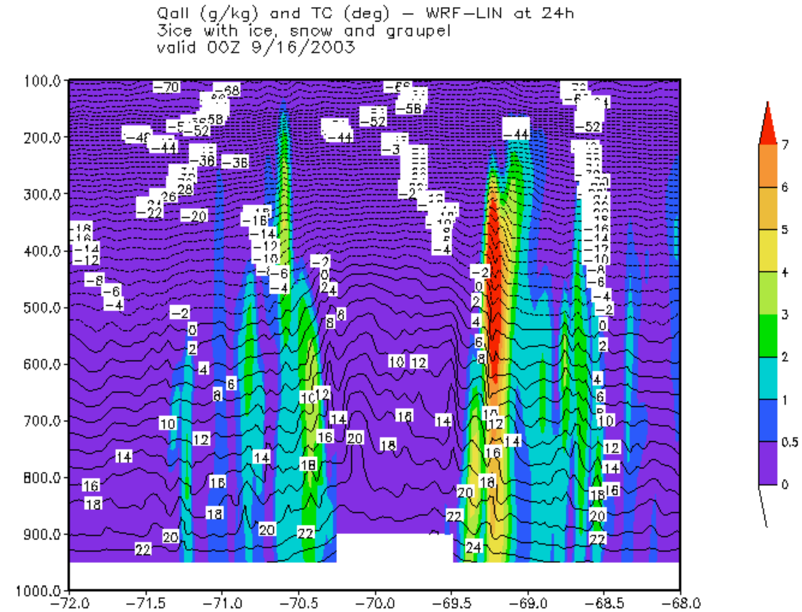




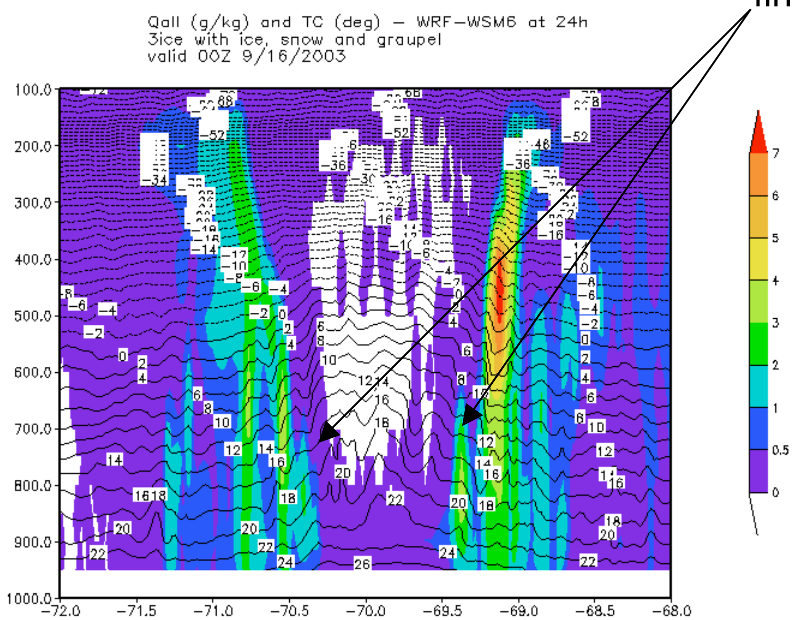






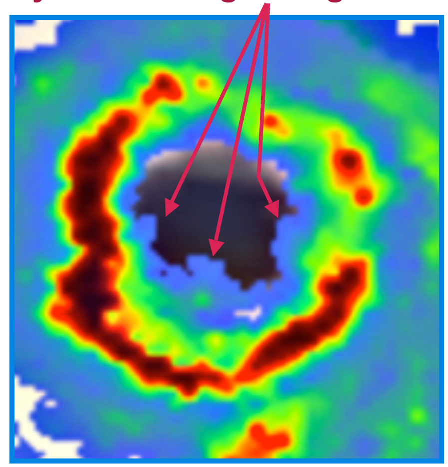


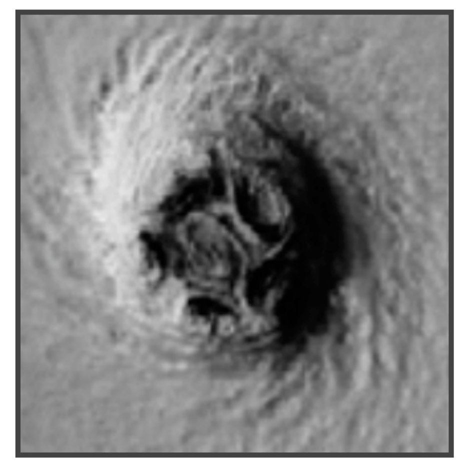
fingers



Composite Analysis (PR and GOES)

PR reveals interesting "fingers" of weak reflectivity inside eye in convergent regions between eyewall mesovortices.





SUMMARY

- For IHOP 2002 June 12 case, all three microphysics captured the narrow rain band passing through Oklahoma, except they all moved about 2 hours faster than the obs. Goddard microphysics (with hail option) produced more cold rain and narrower rain band as compared to WSM6 and Lin schemes.

- WRF have done an adequate job in simulating Isabel and its inner core structure regardless which microphysics scheme was used.

- No significant difference in track and intensity forecasts among three cloud microphysics.

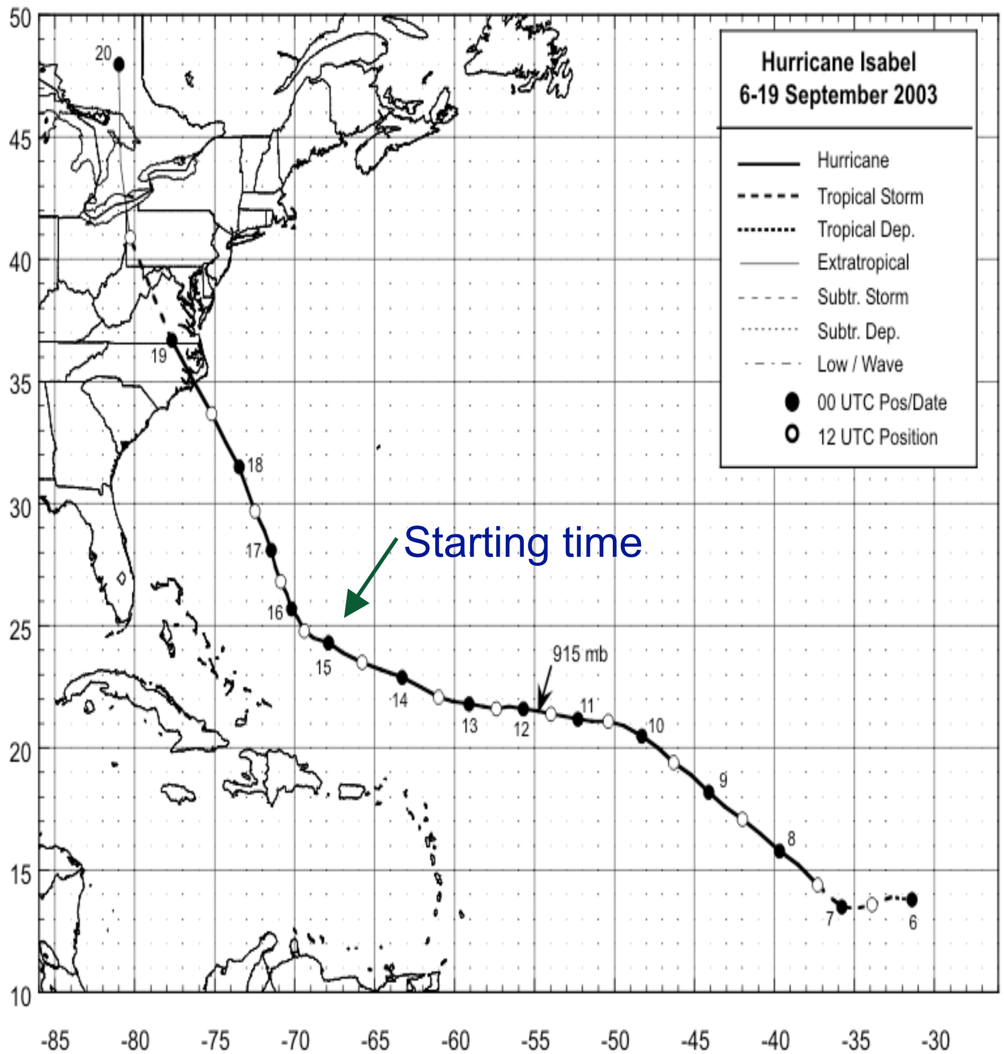
- Goddard microphysics seems to do better in simulating the outer rain band.

FUTURE WORKS

- Using NASA/GMAO's GEOS5 0.25^0 global analysis as intitial and boundary conditions.

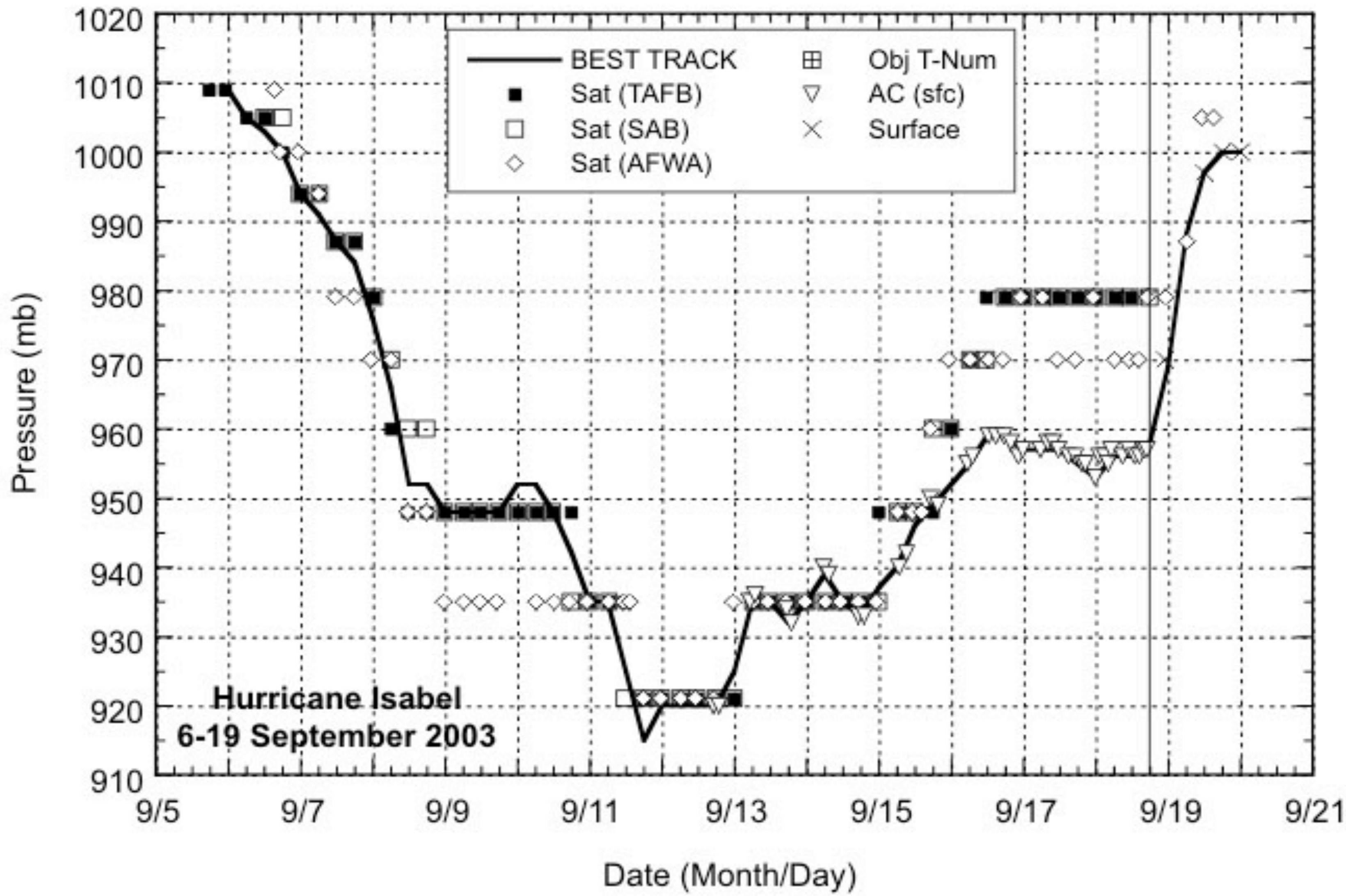
- Implementing Goddard radiative transfer (both longwave and shortwave) packages, which provides better interaction with Goddard cloud microphysics, into WRF.

- Adding our 2-moment and spectral bin schemes into the Goddard cloud microphysics into WRF.



00Z 9/06/03	Tropical depression
06Z 9/06/03	Tropical storm
12Z 9/07/03	Hurricane
9/11/03	Category 5
18Z 9/11/03	915 mb
17Z 9/18/03	Landfall near Drum Inlet of North Carolina as a Category-2 hurricane

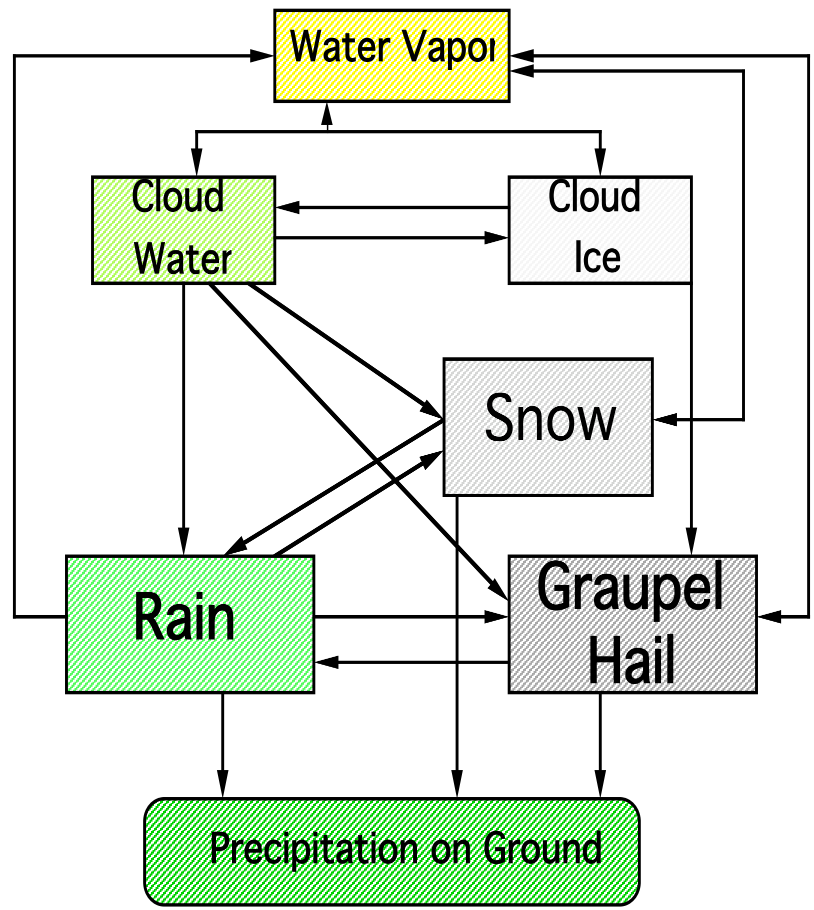
Courtesy of National Hurricane Center



Courtesy of National Hurricane Center

Goddard Microphysics (12 Different Schemes)

	Characteristics	References
Warm Rain	qc, qr	Kessler (1969), Soong and Ogura (19
2 Ice	qc, qr, qi, qg	Cotton et al (1982), Chen (1 McCumber et al (1991)
3Ice - 1	qc, qr, qi, qs, qh	Lin et al (1983), Tao and Simps 1993)
3Ice - 2	qc, qr, qi, qs, qg	Rutledge and Hobbs (1984), Ta Simpson (1989, 1993)
3Ice - 3	qc, qr, qi, qs, qh	Lin et al (1983), Rutledge and (1984), Ferrier at al (199
3Ice - 4	qc, qr, qi, qs, qg or qh	Lin et al (1983), Scott et al
3Ice - 5	Saturation Technique	Tao et al (1989), Tao et al (
4Ice - 1	qc, qr, qi, qs, qg, qh Ni, Ns, Ng, Nh	Ferrier (1994)
4Ice - 2	qc, qr, qi, qs, qg, qh Ni, Ns, Ng, Nh	Tao, Ferrier et al (2000)
One-Moment Spectral - Bin	*33 bins for 6 types ice, water and cloud condensation nu*	Khain and Sednev (1996) Khain et al (1998)
Multi-componen Spectral - Bin	Liquid: 46 bins for water ma for solute mass Ice: water mass, solute mass, as ratio Aqueous-phase chemistry (NH_3, H_2SO_4, HNO_3, SO_2, O_3, H_2O_2, CO_2)	Chen and Lamb (1994, 199

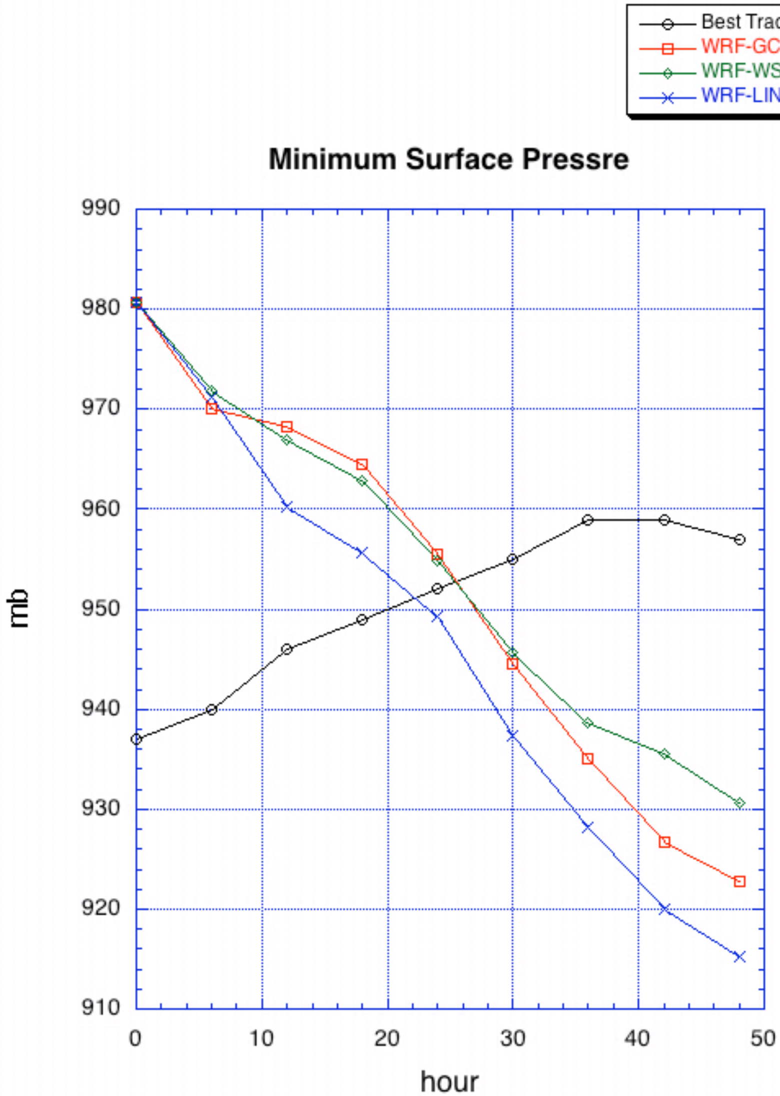


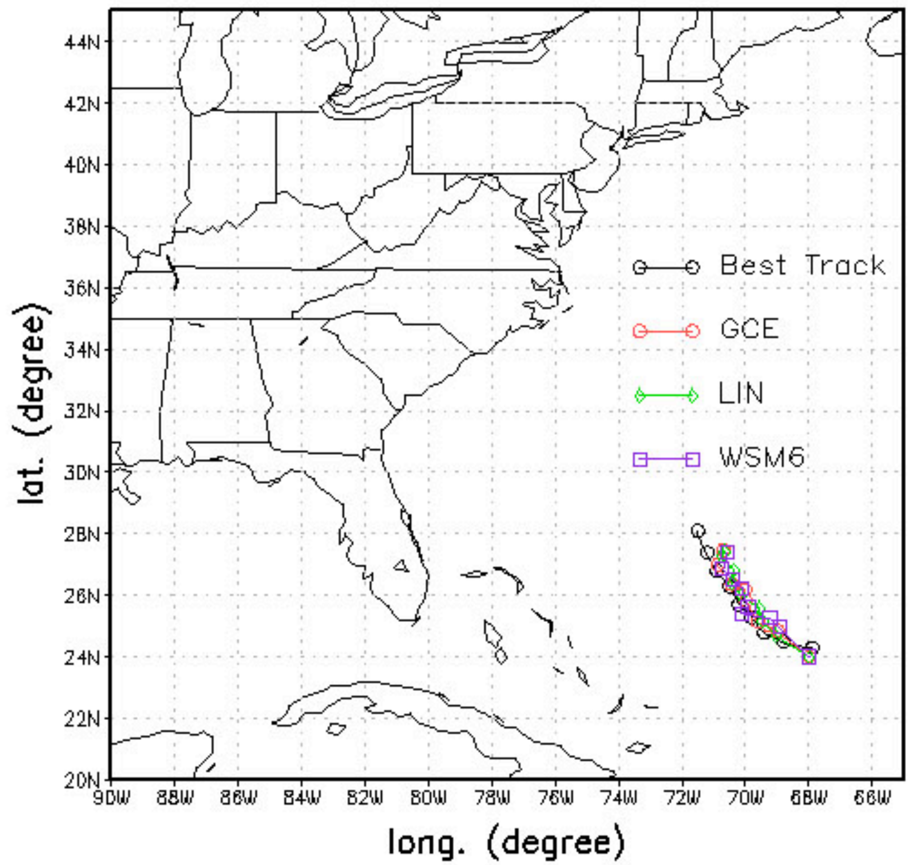
No Microphysical Scheme is perfect !

Modification of negative cloud species in WRF

- A 3rd order finite difference method is used for advection in WRF. It is well known that these difference methods can generate negative mass for hydrometeors near and at cloud boundaries. The adjustment used in WRF is to reassign all negative hydrometeors to be zero. This can cause an imbalance in the water budget. Note that the error grows with the number of time iterations not the length of model integration.

- To remedy this shortcoming (especially for long term model integration and for fine model resolution simulations), a mass conservation-adjustment scheme was implemented into WRF. The procedure for this mass conservation scheme for all hydrometeors is as follows: (i) compute the total positive mass (P) and negative mass (N) over the entire domain, (ii) set all negative mass to be zero, and (iii) recompute the positive mass by multiplying by a factor of (P-N)/P. This type of adjustment has been used in many cloud-scale models (i.e., the GCE model, and many others).


Best Track
WRF-GCE
WRF-WSM6
WRF-LIN
Minimum Surface Pressre
990
980
970
960
950
940
930
920
910
mb
0
10
20
30
40
50
hour


44N
42N
40N
38N
36N
34N
32N
30N
28N
26N
24N
22N
20N
90W
88W
86W
84W
82W
80W
78W
76W
74W
72W
70W
68W
66W
lat. (degree)
long. (degree)
Best Track
GCE
LIN
WSM6