Multiple Scale WRF Simulations of Boundary Layer Clouds

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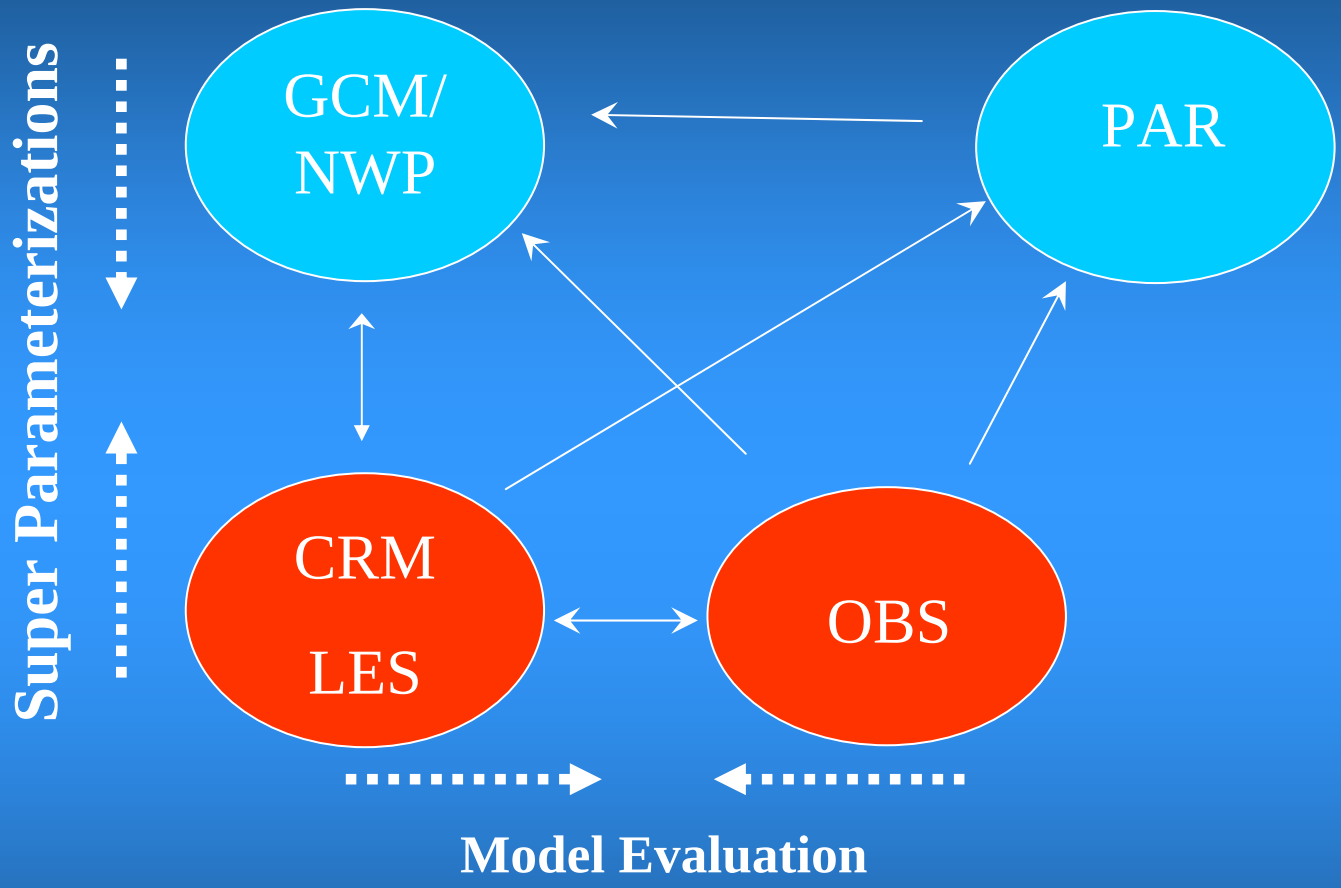
Parameterization Development and Testing Strategy



How can high resolution simulations be effectively and efficiently evaluated using observational data?

High Resolution 3-D Radar Observations
(e.g. MilliMeter Cloud Radar and W-Band ARM Cloud Radar)

- In-cloud turbulence, large-eddy circulations, and cloud structures.
- Possibility to obtain cloud liquid water fluxes by combining the liquid water estimates with the vertical velocities.
- Doppler Radar simulator.

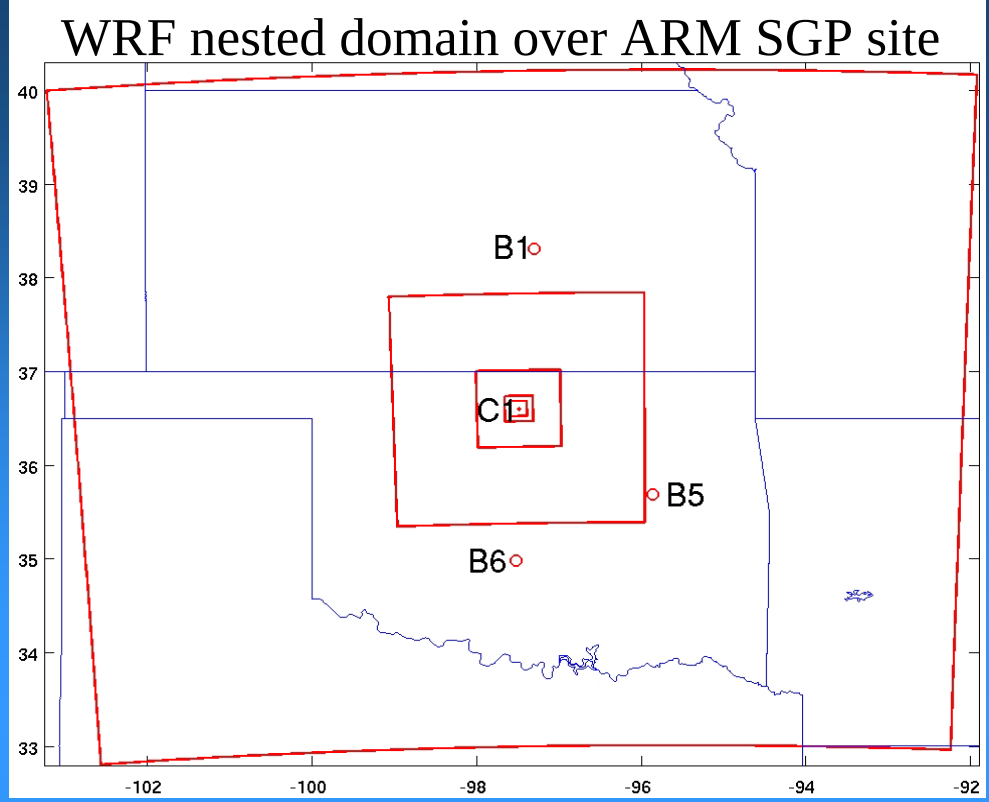
Classic large eddy simulation (LES) framework

- Idealized initial conditions
- Homogeneous large-scale forcings

(e.g., BOMEX, ATEX, DYCOM, ARM-SGP)

A New LES Framework:

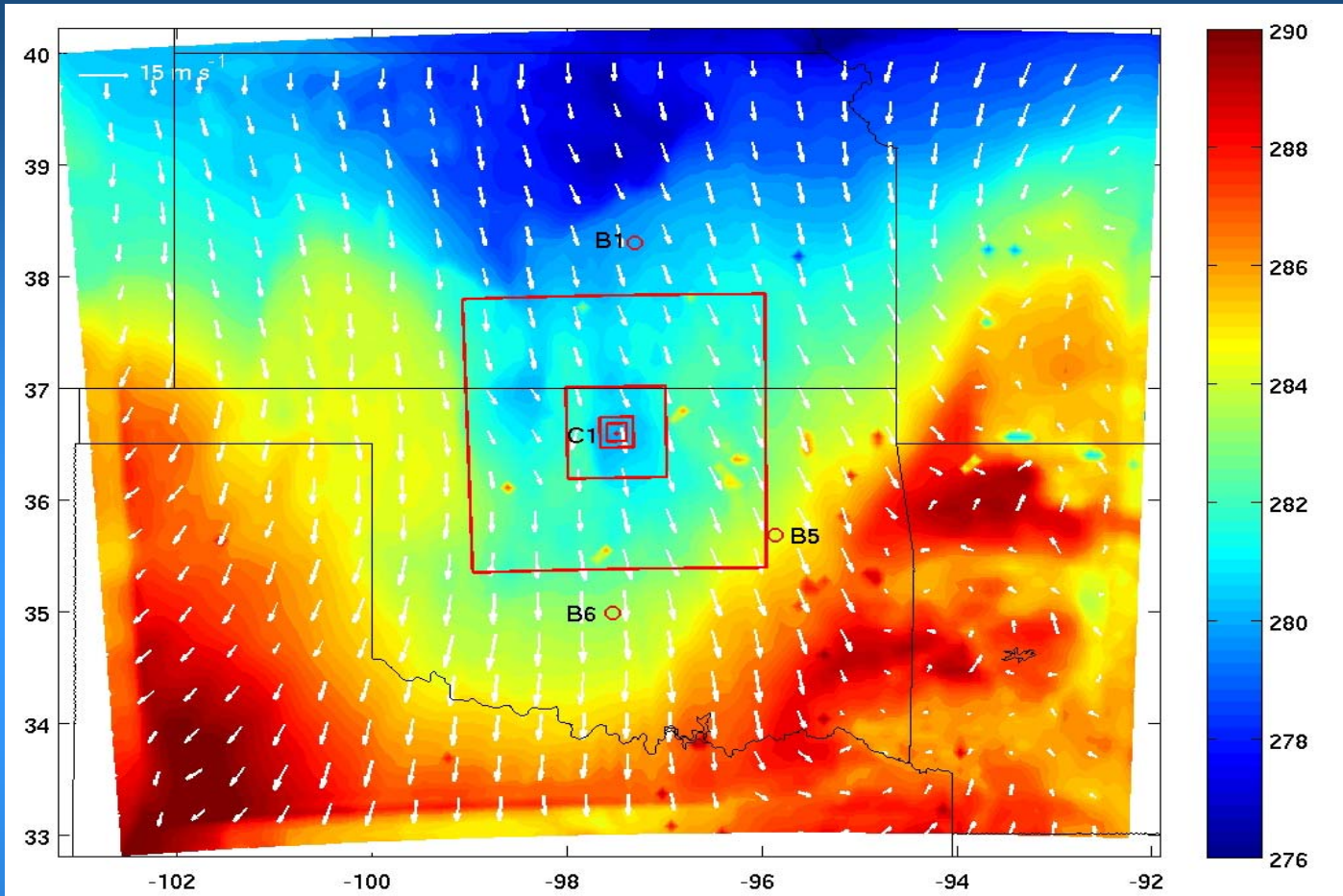
A multiple two-way nested model to explicitly simulate a spectrum of scales from synoptic scale flow, meso-scale organizations, down to fine scale turbulent eddies in a unified system.



WRF-LES

- Nested within WRF mesoscale simulations to ensure robust up-scale and down-scale interactions cross a spectrum of scales.
- Potential to be executed at regular bases in parallel with routine observations (e.g. ARM observations.)
- Initialized with real time forecast or reanalyses data. Initialization can be improved through assimilating observations.
- Generating forcing data to drive various existing LES models in the community.

Stratocumulus case, March 25, 2005



2 m high potential temperature with 10 m high wind vectors at 11:30 UTC

5 domains with 4 two-way nests.

Vertical resolution varying from 6.0 m to 65.0 m below 2000 m.

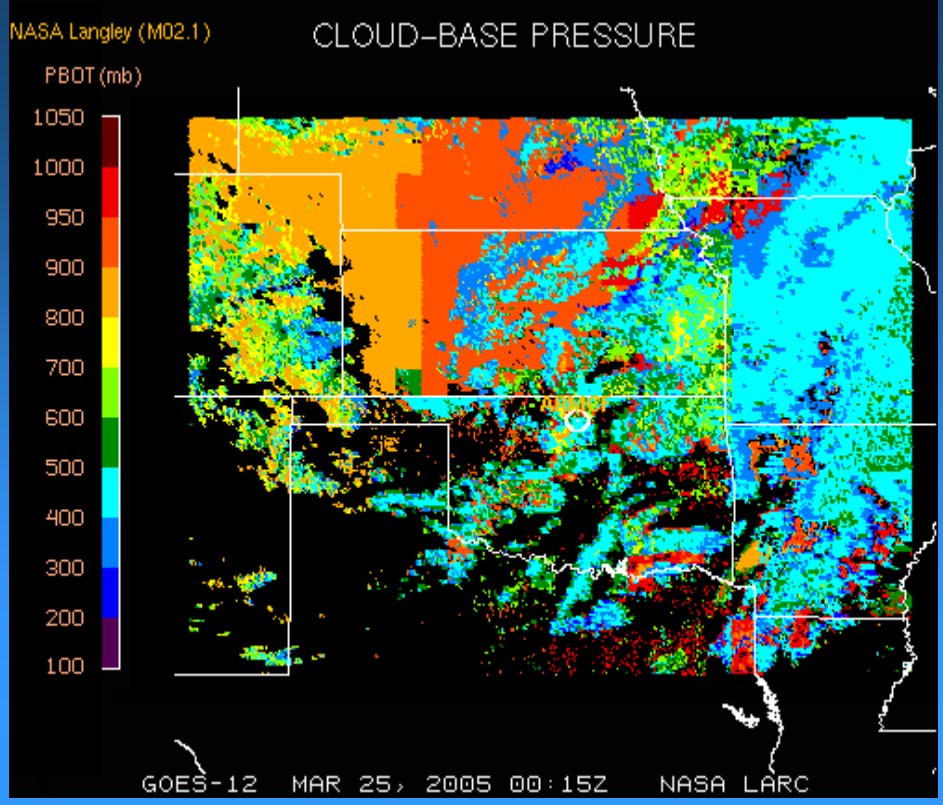
Domain - 1: $121 \times 101 \times 54$, $\Delta x = 8100$ m

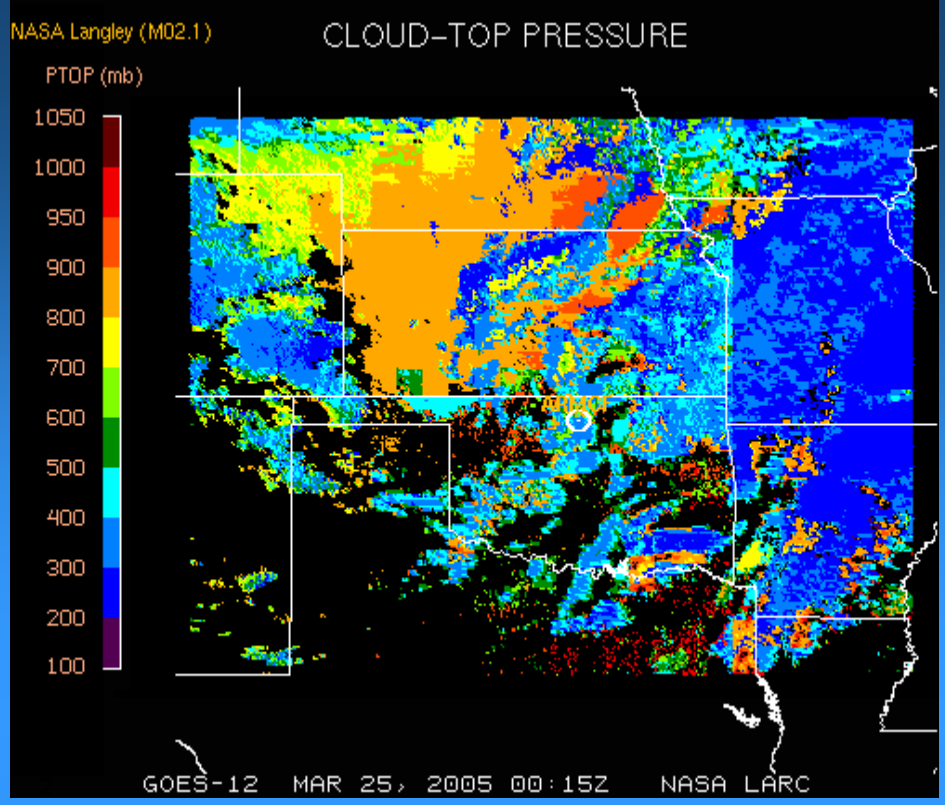
Domain - 2: $103 \times 103 \times 54$, $\Delta x = 2700$ m

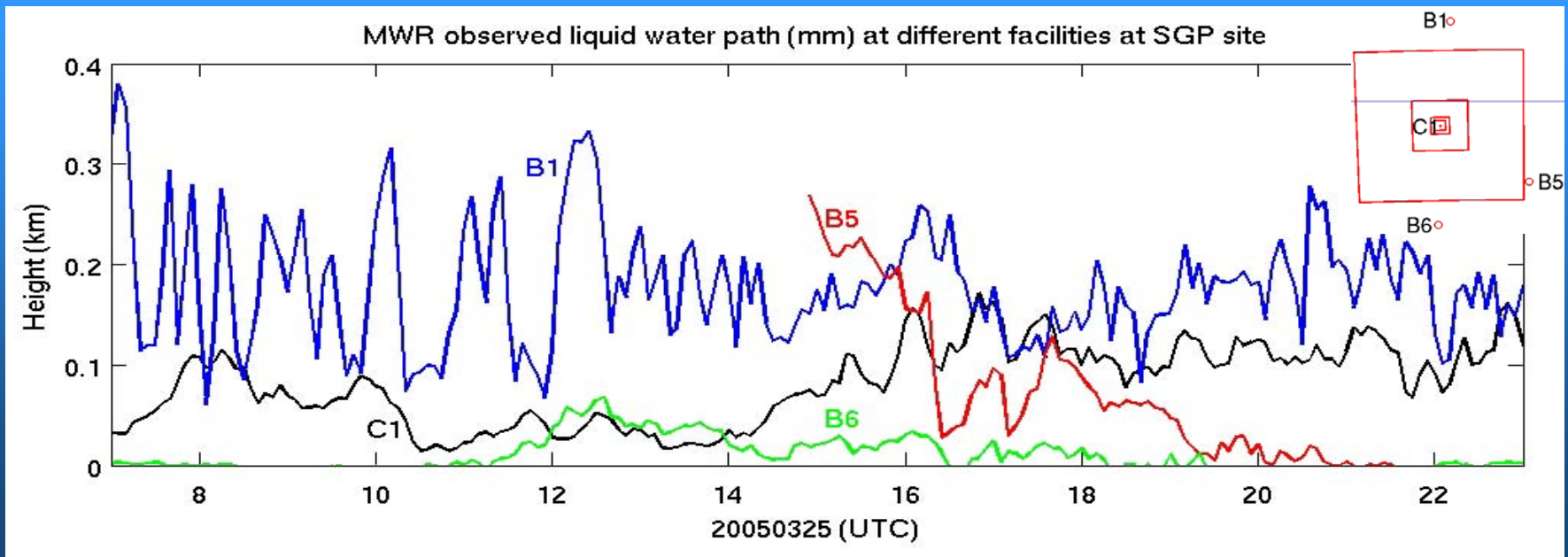
Domain - 3: $103 \times 103 \times 54$, $\Delta x = 900$ m

Domain - 4: $103 \times 103 \times 54$, $\Delta x = 300$ m

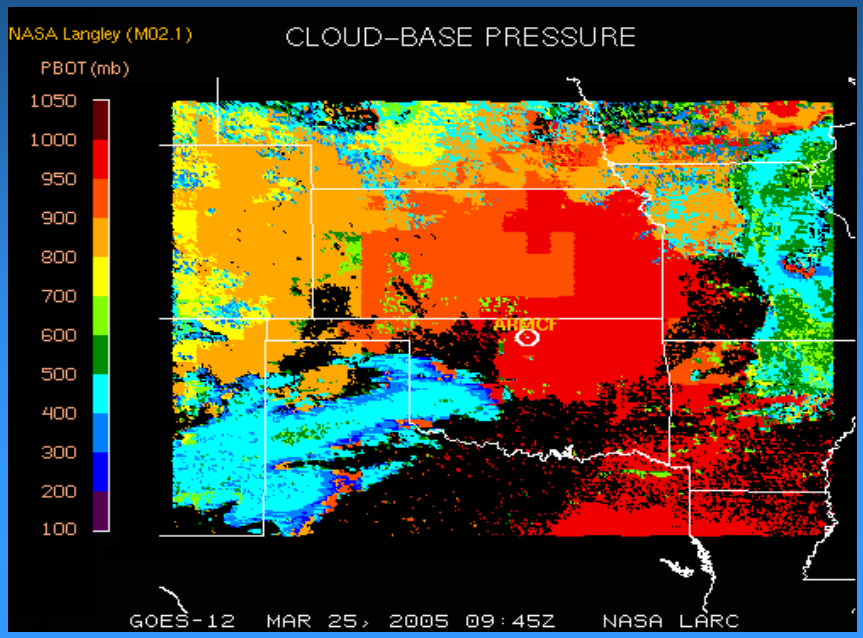
Domain - 5: $181 \times 181 \times 54$, $\Delta x = 100$ m

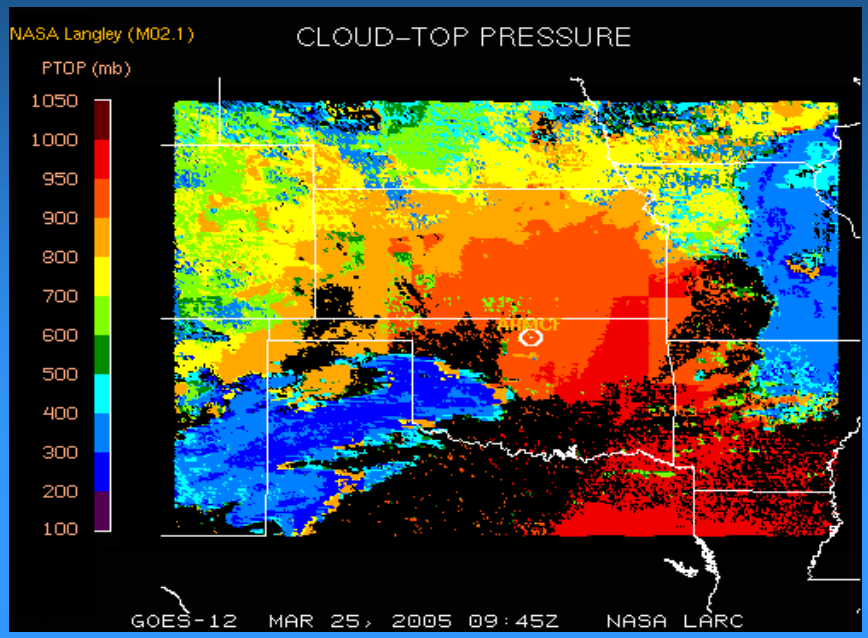

NASA Langley (M02.1)
CLOUD-BASE PRESSURE
PBOT (mb)
1050
1000
950
900
800
700
600
500
400
300
200
100
GOES-12 MAR 25, 2005 00:15Z NASA LARC


NASA Langley (M02.1)
CLOUD-TOP PRESSURE
PTOP (mb)
1050
1000
950
900
800
700
600
500
400
300
200
100
GOES-12 MAR 25, 2005 00:15Z NASA LARC

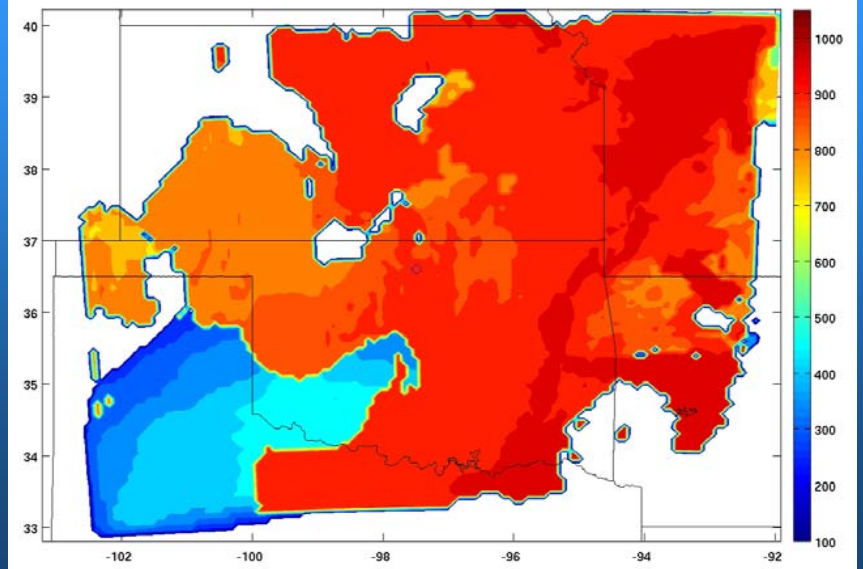

MWR observed liquid water path (mm) at different facilities at SGP site
Height (km)
0.4
0.3
0.2
0.1
0
8
10
12
14
16
18
20
22
20050325 (UTC)
B1
B5
B6
C1
B1
C1
B5
B6

- NCEP Global Tropospheric Analyses (1 X 1).
- NCEP reanalysis and ARM sounding

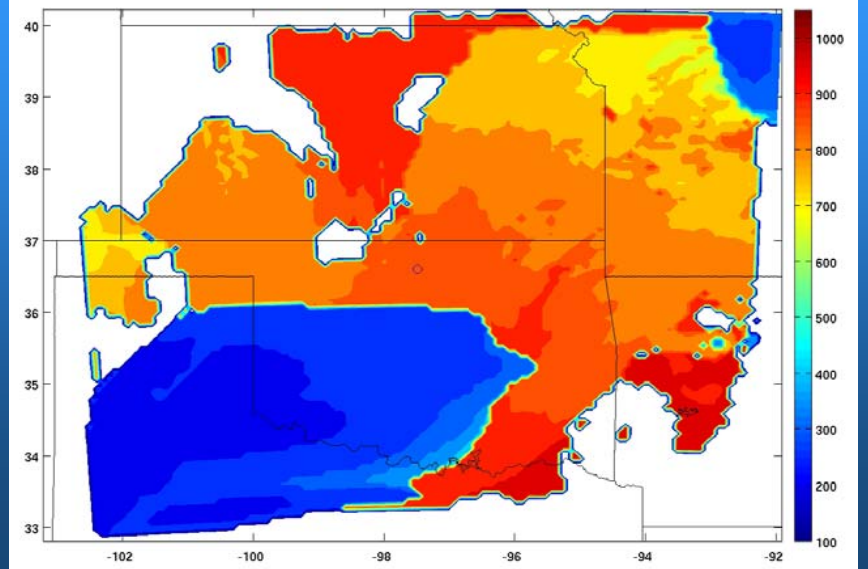


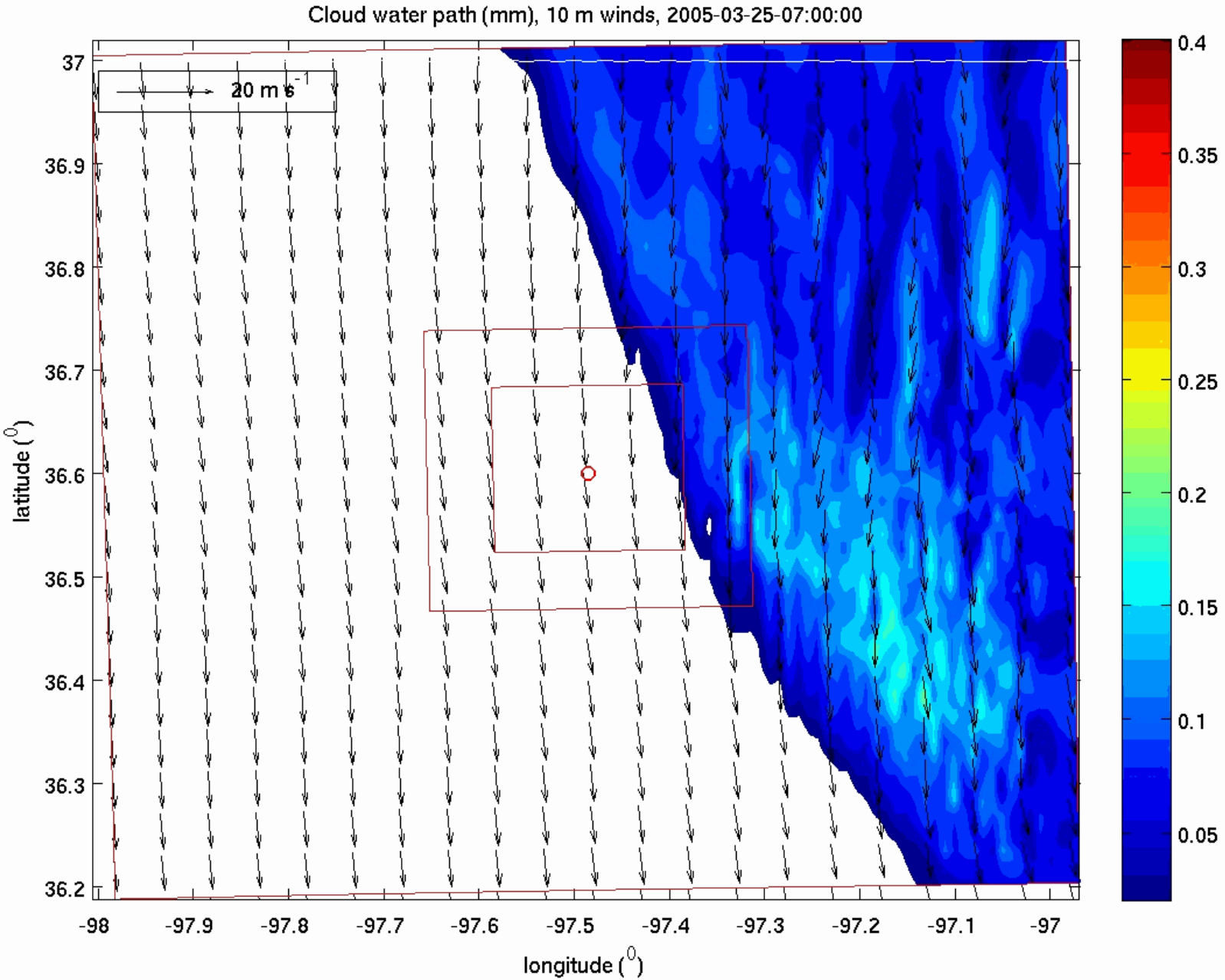


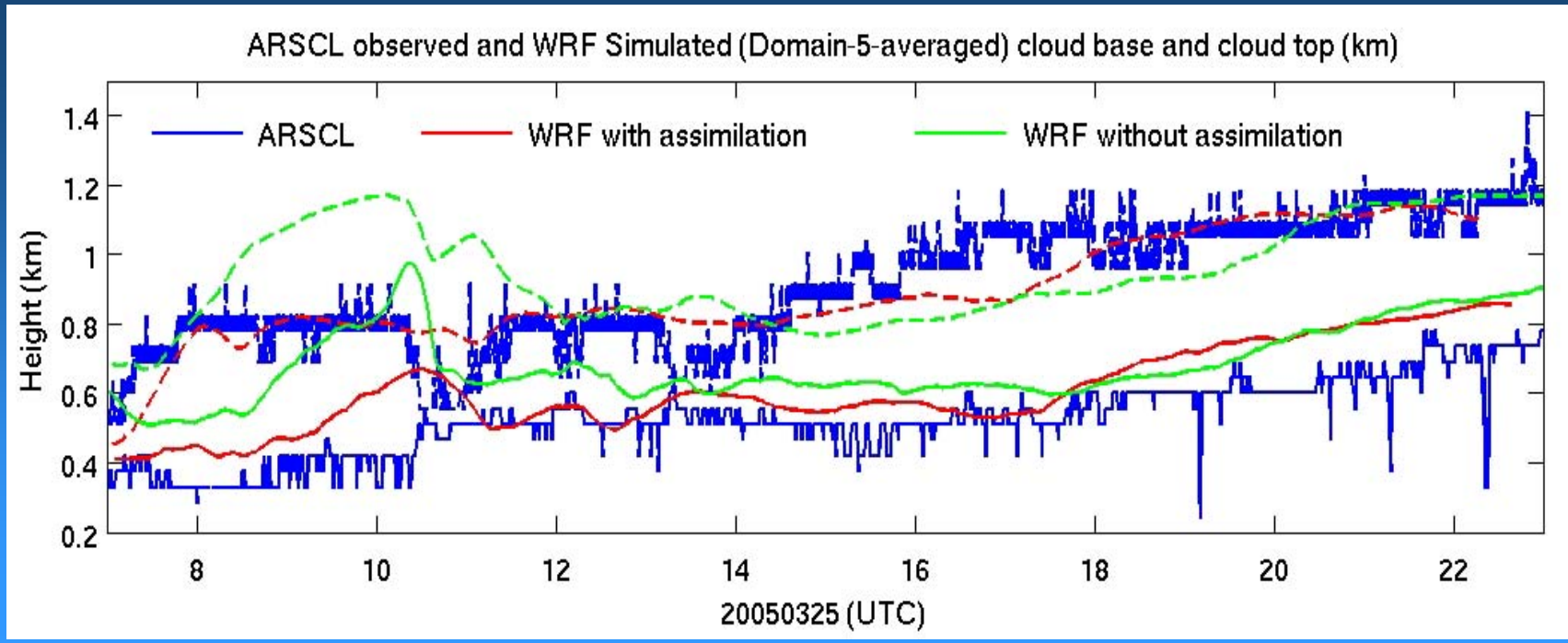
SIMULATED DOMAIN-1 CLOUD-BASE PRESSURE MAR 25 09:45Z

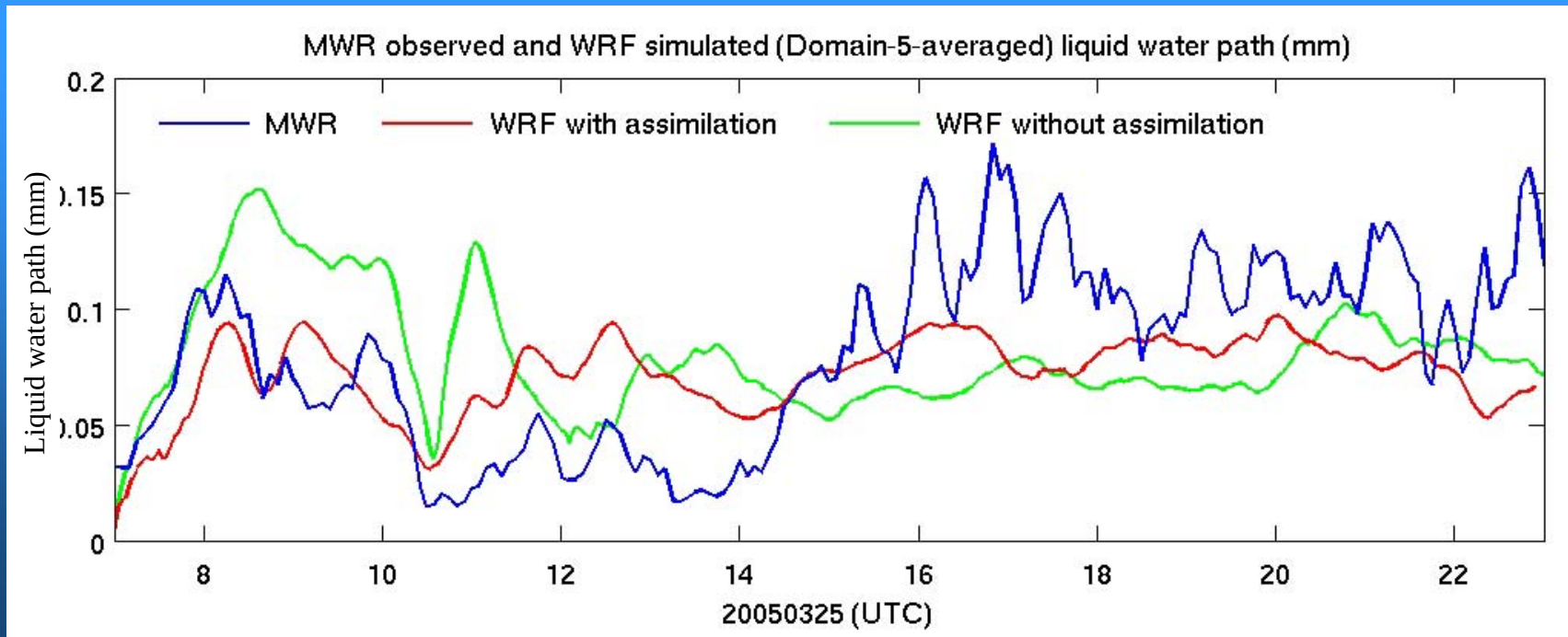


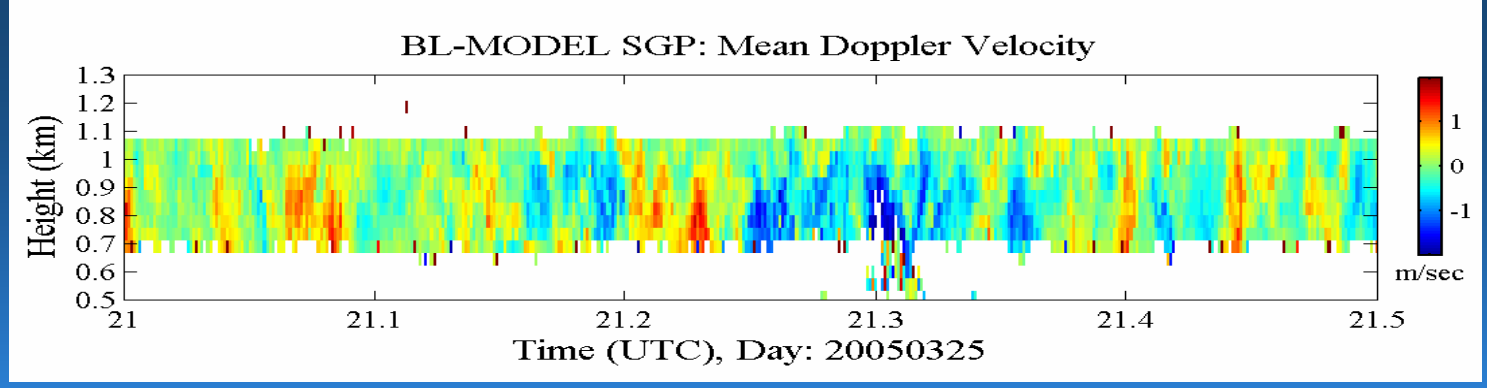
SIMULATED DOMAIN-1 CLOUD-TOP PRESSURE MAR 25 09:45Z

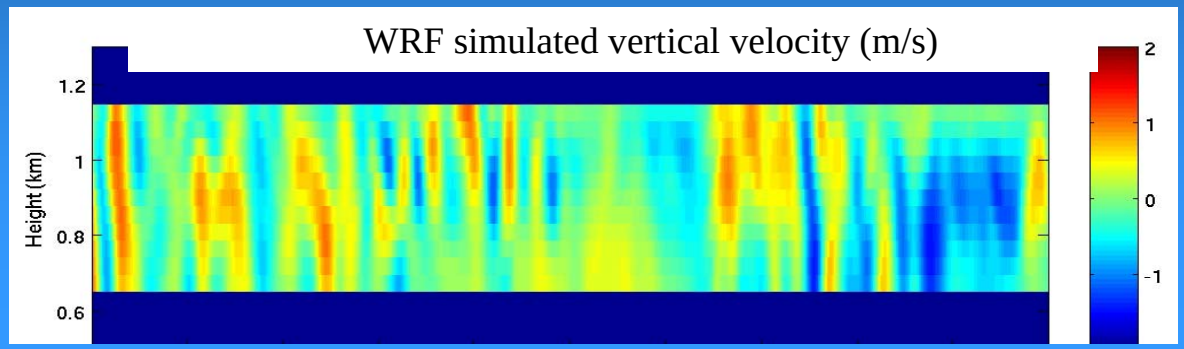


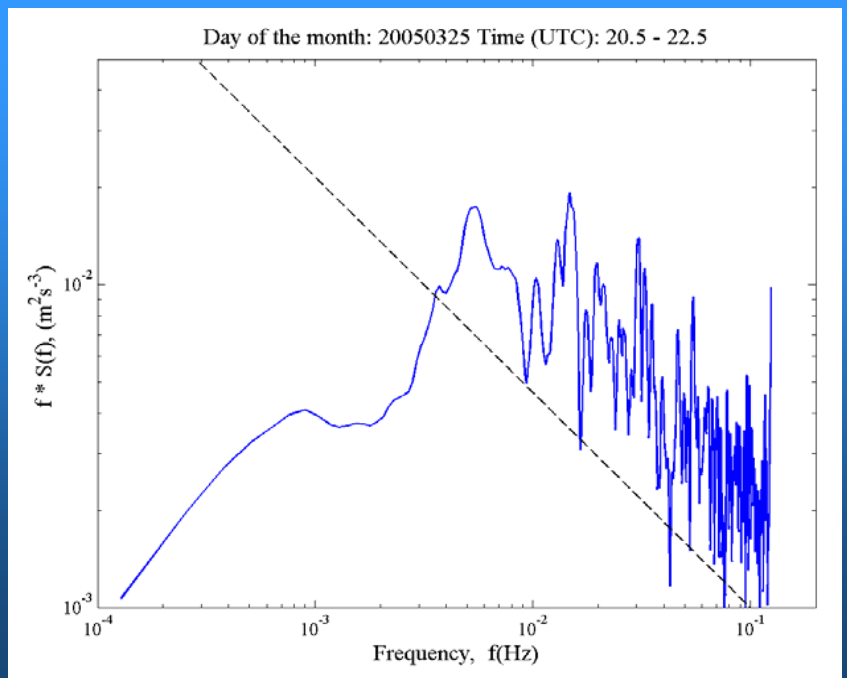

Cloud water path (mm), 10 m winds, 2005-03-25-07:00:00
20 m s-1
37
36.9
36.8
36.7
36.6
36.5
36.4
36.3
36.2
latitude (0)
-98
-97.9
-97.8
-97.7
-97.6
-97.5
-97.4
-97.3
-97.2
-97.1
-97
longitude (0)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05

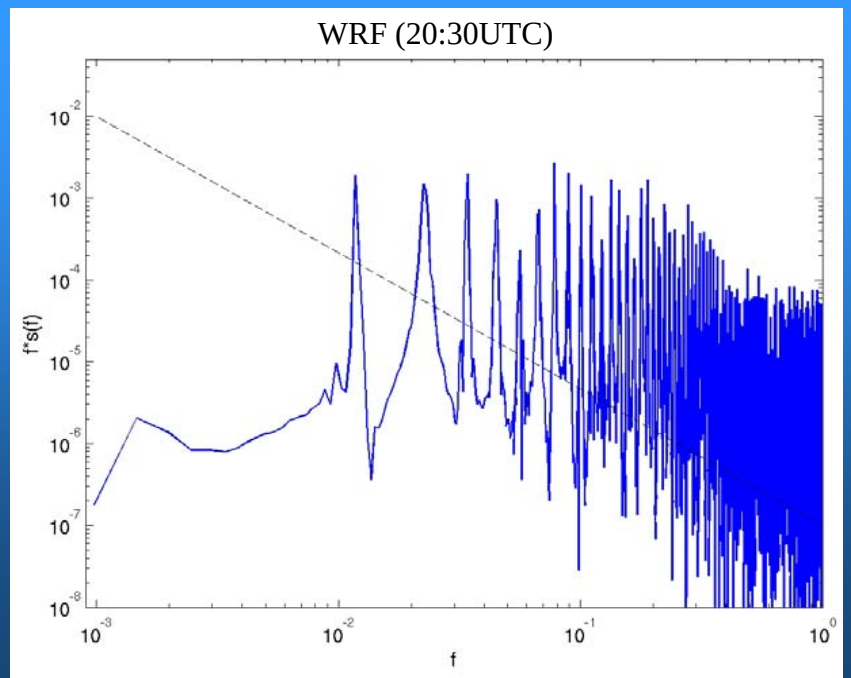

ARSCL observed and WRF Simulated (Domain-5-averaged) cloud base and cloud top (km)
ARSCL
WRF with assimilation
WRF without assimilation
Height (km)
1.4
1.2
1
0.8
0.6
0.4
0.2
8
10
12
14
16
18
20
22
20050325 (UTC)


MWR observed and WRF simulated (Domain-5-averaged) liquid water path (mm)
MWR
WRF with assimilation
WRF without assimilation
Liquid water path (mm)
0.2
0.15
0.1
0.05
0
8
10
12
14
16
18
20
22
20050325 (UTC)


BL-MODEL SGP: Mean Doppler Velocity
Height (km)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
21
21.1
21.2
21.3
21.4
21.5
Time (UTC), Day: 20050325
1
0
-1
m/sec


WRF simulated vertical velocity (m/s)
Height (km)
1.2
1
0.8
0.6
2
1
0
-1


Day of the month: 20050325 Time (UTC): 20.5 - 22.5
f * S(f), (m2s-3)
Frequency, f(Hz)

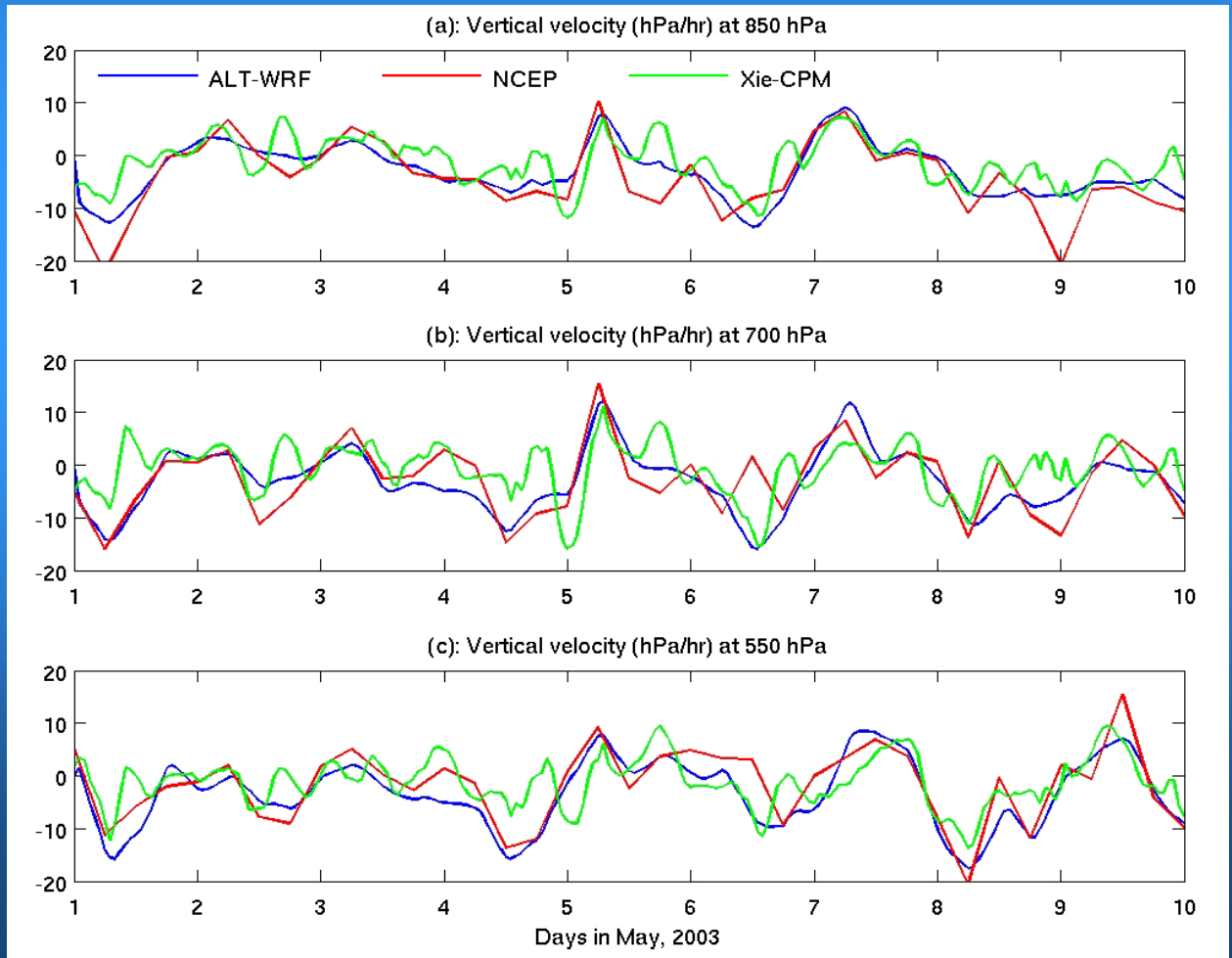

WRF (20:30UTC)
f*s(f)
f

Cloud Parameterization Development

LES
SCM

WRF-LES
CAPT

CAPT: Climate Change Prediction Program – CCPP-ARM Parameterization Testbed.



Data assimilation of ARM observations.

1. sounding data
2. surface observations
3. radar radial velocities
4. radar reflectivity
5. wind profile data

Conclusion

With further improvements, WRF-LES can serve as an appropriate modeling platform to address key issues regarding the treatment of boundary layer cloud processes in climate models.

Model physics

- Microphysics: Thompson et al. (2004) graupel scheme.
- Radiation: RRTM (Rapid Radiative Transfer Model) longwave scheme, Dudhia shortwave scheme.
- Boundary layer: Mellor-Yamada-Janjic TKE scheme, Monin-Obukhov scheme.
- Cumulus: Kain-Fritsch scheme (domains 1 and 2).
- Soil model: Noah land-surface model.