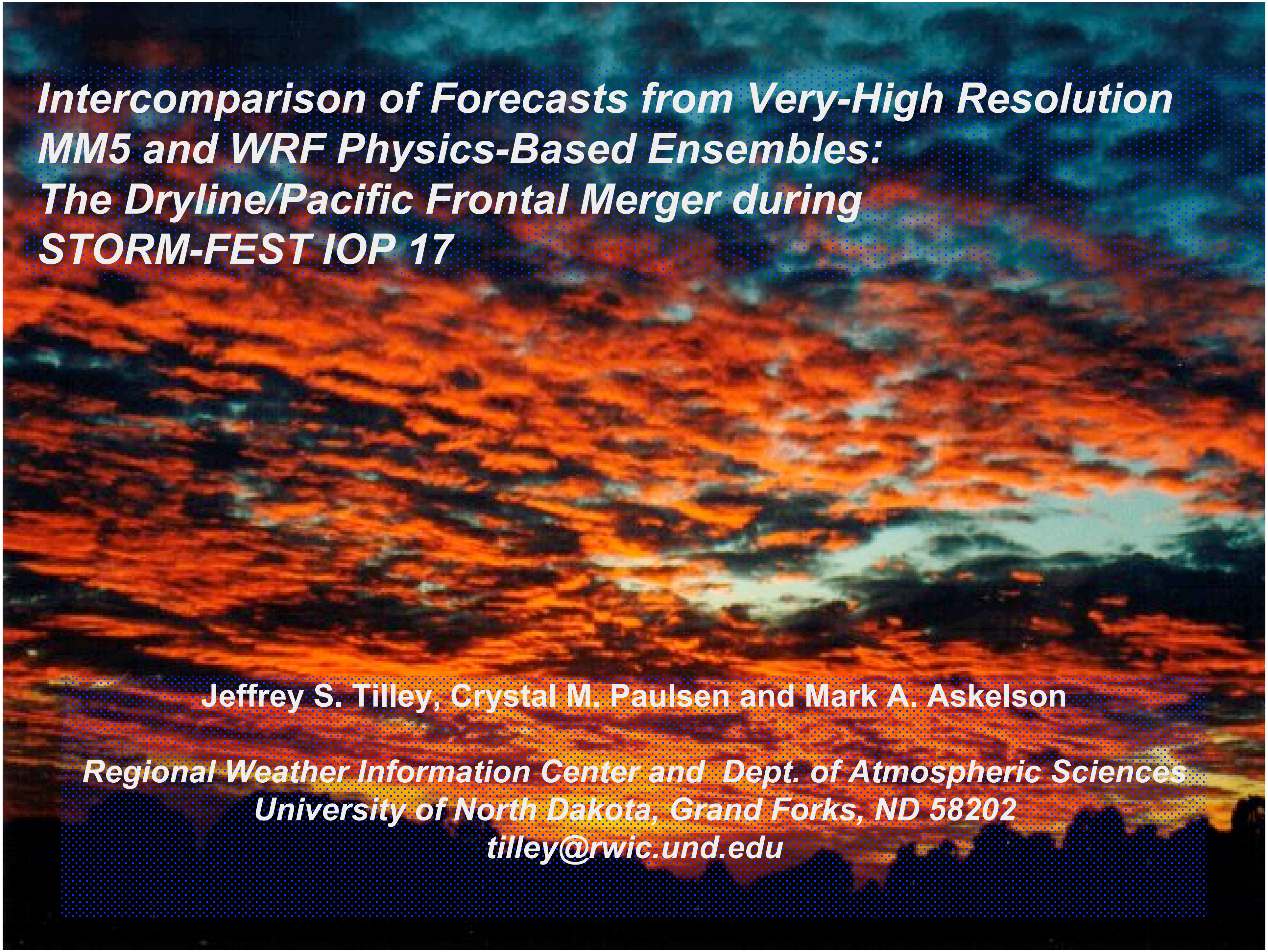

Intercomparison of Forecasts from Very-High Resolution MM5 and WRF Physics-Based Ensembles: The Dryline/Pacific Frontal Merger during STORM-FEST IOP 17

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Outline

- ***Motivation and Goals***
- ***Ensembling Approach: Full Set Envisioned, Physics Subset and Substudy (this talk)***
- ***Brief Review of STORM-FEST IOP 17***
- ***Case-Specific Methodology***
- ***Early Results: Outer Nests***
- ***Early Results: 1 km ensembles***
- ***Summary***

Ultimate Motivation: Meso-γ/Micro-α scale N/C_n^2 Prediction

- *Army field commanders desire information on "refractivity parameters" (N/C_n^2) in relation to field-level optical (EM) turbulence effects which impact:*
  - ***Communications, including w/ UAVs***
  - ***Range and Detection (IR, Microwave)***
  - ***Future Directed Energy Weapon Targeting (e.g., Laser technologies)***
- *Information is desired on at least 1-2 km scale, if not finer; also PBL focus*
- *Previous examination indicated mesoscale models have some skill in predicting larger scale (meso-β ⇑) N and C_n^2 from standard formulae developed to relate these quantities to mean atmospheric fields*

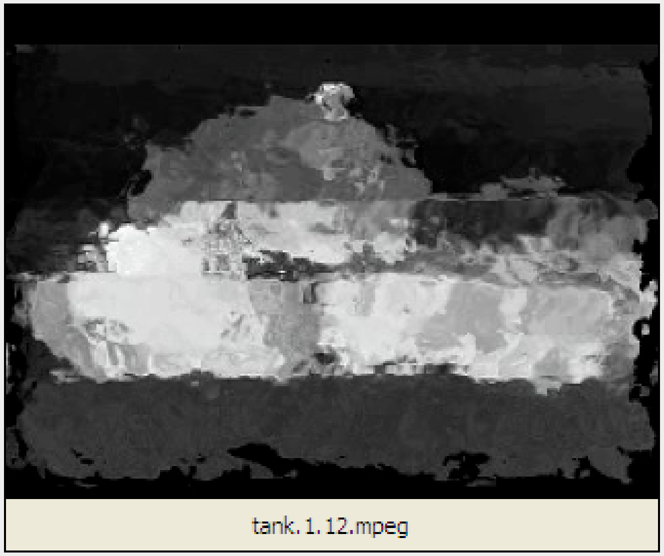


Image Distortion in the Far IR (8-12 mm FLIR) over a 2 km path for $C_n^2 = 10^{-12}\ m^{-2/3}$.

Courtesy of Dave Tofstad, ARL, WSMR

Possible Modeling Approaches

- *Some type of microscale model (LES, possibly driven by mesoscale model output).*
  - *Limited areal application unless actually nested within meso-model (very expensive)*
- *Use mesoscale model output and a statistical downscaling technique*
  - *Downscaling parameters may need adjustment even over scales of interest (where does data for downscaling come from?)*
- *Run mesoscale model at micro-a scale resolution (400 m max)*
  - *Relatively modest expense; not very well posed for MM5; better for WRF but are physics schemes realistic at such scales?*
- *Ensemble Approach: less expensive than #1, more than #3 but has built-in advantage of using the uncertainty in our knowledge (as manifested in the model) and data to the forecast's benefit*

General Ensembling Approach: 36 members

- Capture more of the possible uncertainty by:
  - Using a larger ensemble, with two different mesoscale models
    - MM5, WRF
  - Vary initial condition/data assimilation input to the models
    - NAM/NNRP/NARR (etc), LAPS hot start +enhanced, 3DVAR, Lagged avg. forecast technique (etc), nudging
  - Vary treatment of physical processes in models (20+; this talk)
    - Large laundry list (see table, next slide)
- Focus on 1 km horizontal grid over > $(200 \text{ km})^2$ area
  - Domain size forecast period dependent
- Try to keep computation cost within reasonable bounds
  - For future ARL applications, primarily 0-6/24 hr timeframes
- Examine value of probabilistic forecasts/ensembling at these scales

Substudy: How do MM5/WRF physics (sub)ensembles compare?

MM5 Member	Cumulus	PBL	Microphysics	Radiation	Land Surface
Control	None	Eta	Reisner 2	RRTM	NOAH
Blackadar	None	Blackadar	Reisner 2	RRTM	5 Layer
Gayno-Seaman	None	Gayno-Seaman	Reisner 2	RRTM	5 Layer
Grell	Grell + Shallow	Eta	Goddard	RRTM	NOAH
Fritsch-Chappell	Fritsch-Chappell	Eta	Reisner 2	RRTM	NOAH
Goddard	None	Eta	Goddard	RRTM	NOAH
Reisner 1	None	Eta	Reisner 1	RRTM	NOAH
Schultz	None	Eta	Schultz	RRTM	NOAH
Cloud	None	Eta	Reisner 2	Cloud	NOAH
CCM2	None	Eta	Reisner 2	CCM2	NOAH
5 Layer	Shallow only	Eta	Reisner 2	RRTM	5 Layer
5 Layer/ MRF	None	MRF	Reisner 2	RRTM	5 Layer
Slab/GaynoSeaman	None	Gayno-Seaman	Reisner 2	RRTM	Slab

10 MM5 members

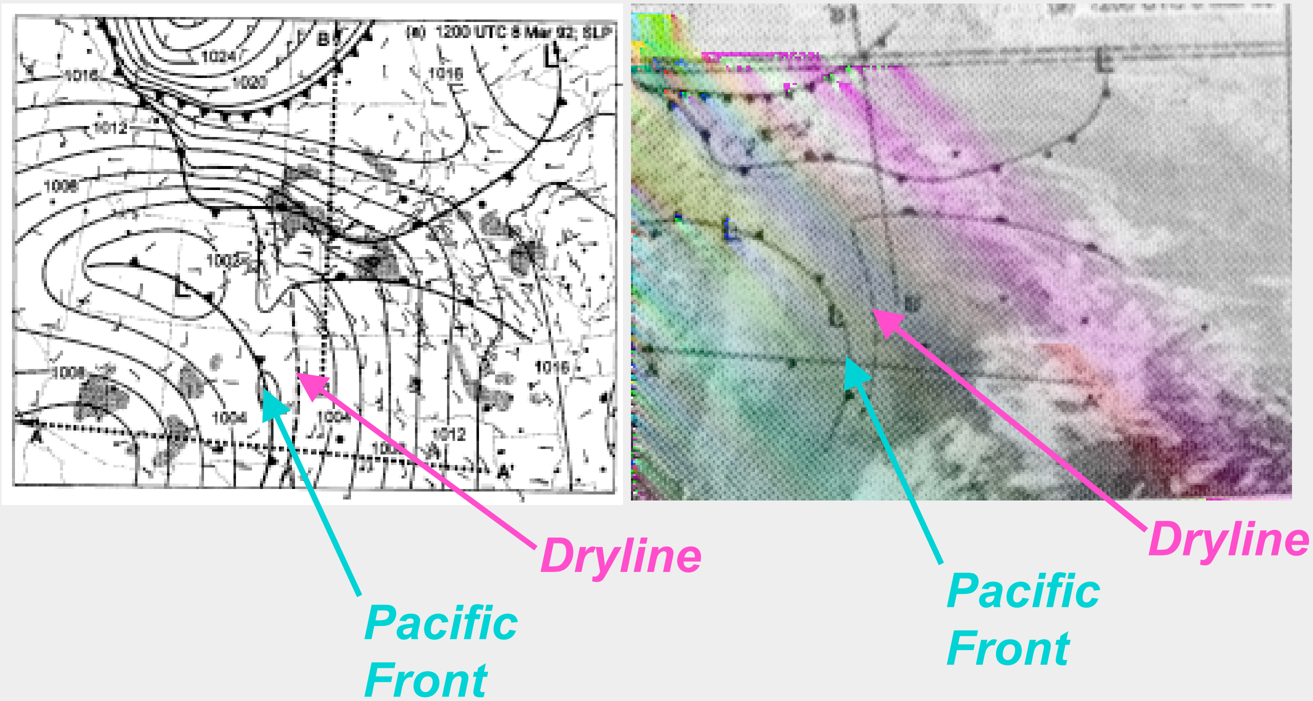
10 WRF members

WRF Member	Cumulus	PBL	Surface Layer	Microphysics	Longwave Radiation	Shortwave Radiation	Land Surface
Control	None	MYJ	Monin -Obukov (M-O) -Janjic	Ferrier	RRTM	Goddard	NOAH
YSU/M-O	None	YSU	M-O	Ferrier	RRTM	Goddard	NOAH
Grell	Grell	MYJ	M-O -Janjic	Ferrier	RRTM	Goddard	NOAH
BMJ/YSU	BMJ	YSU	M-O	Ferrier	RRTM	Goddard	NOAH
5 Class	BMJ	MYJ	M-O -Janjic	WSM 5-Class	RRTM	Goddard	NOAH
3 Class	None	MYJ	M-O -Janjic	WSM 3-Class	RRTM	Goddard	NOAH
6 Class	Grell	MYJ	M-O -Janjic	WSM 6-Class	RRTM	Goddard	NOAH
RRTM/Dudhia	None	MYJ	M-O- Janjic	Ferrier	RRTM	Dudhia	NOAH
GFDL	None	MYJ	M-O -Janjic	Ferrier	GFDL	GFDL	NOAH
5 Layer	None	MYJ	M-O -Janjic	Ferrier	RRTM	Goddard	5 Layer
RUC	None	MYJ	M-O- Janjic	Ferrier	RRTM	Goddard	RUC
Call Times	None	MYJ	M-O -Janjic	Ferrier	RRTM	Goddard	NOAH
Lin/ Kain-Fritsch	Kain-Fritsch	MYJ	M-O -Janjic	Lin	RRTM	Goddard	NOAH

Case I: STORM-FEST Dryline/Frontal Interaction 3/8-9/1992

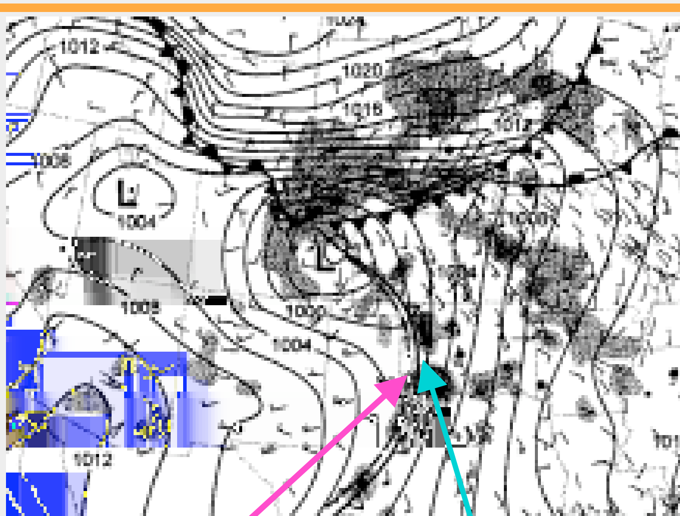
- **Strong outbreak of severe weather in southern plains associated with complex interactions between multiple systems--Pacific front (mainly aloft), dryline, Arctic front, low level warm front----during period**
- **Focus of 1 km runs 12 UTC 3/8 - 12 UTC 3/9**

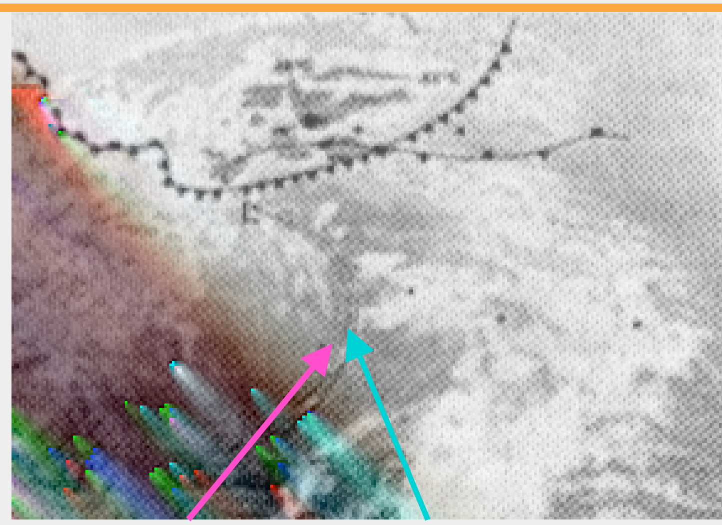
after Neiman et al (1998)



12 UTC 3/8/92

Case I: STORM-FEST Dryline/Frontal Merger 3/8-10/1992

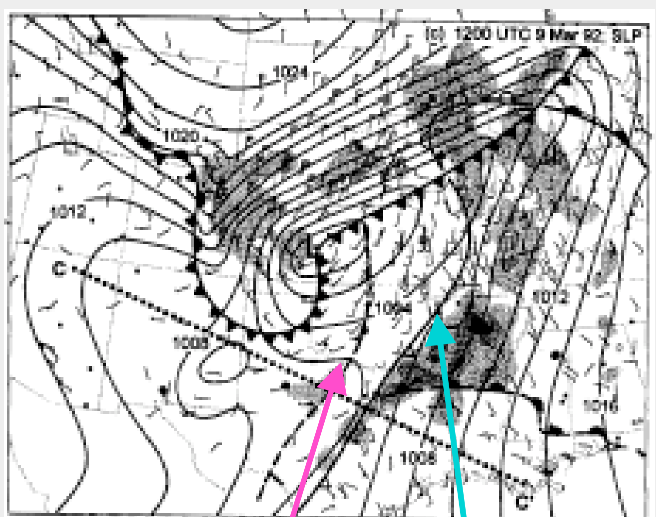




Dryline Pacific Front Dryline Pacific Front

00 UTC 3/9/92

after Neiman et al (1998)



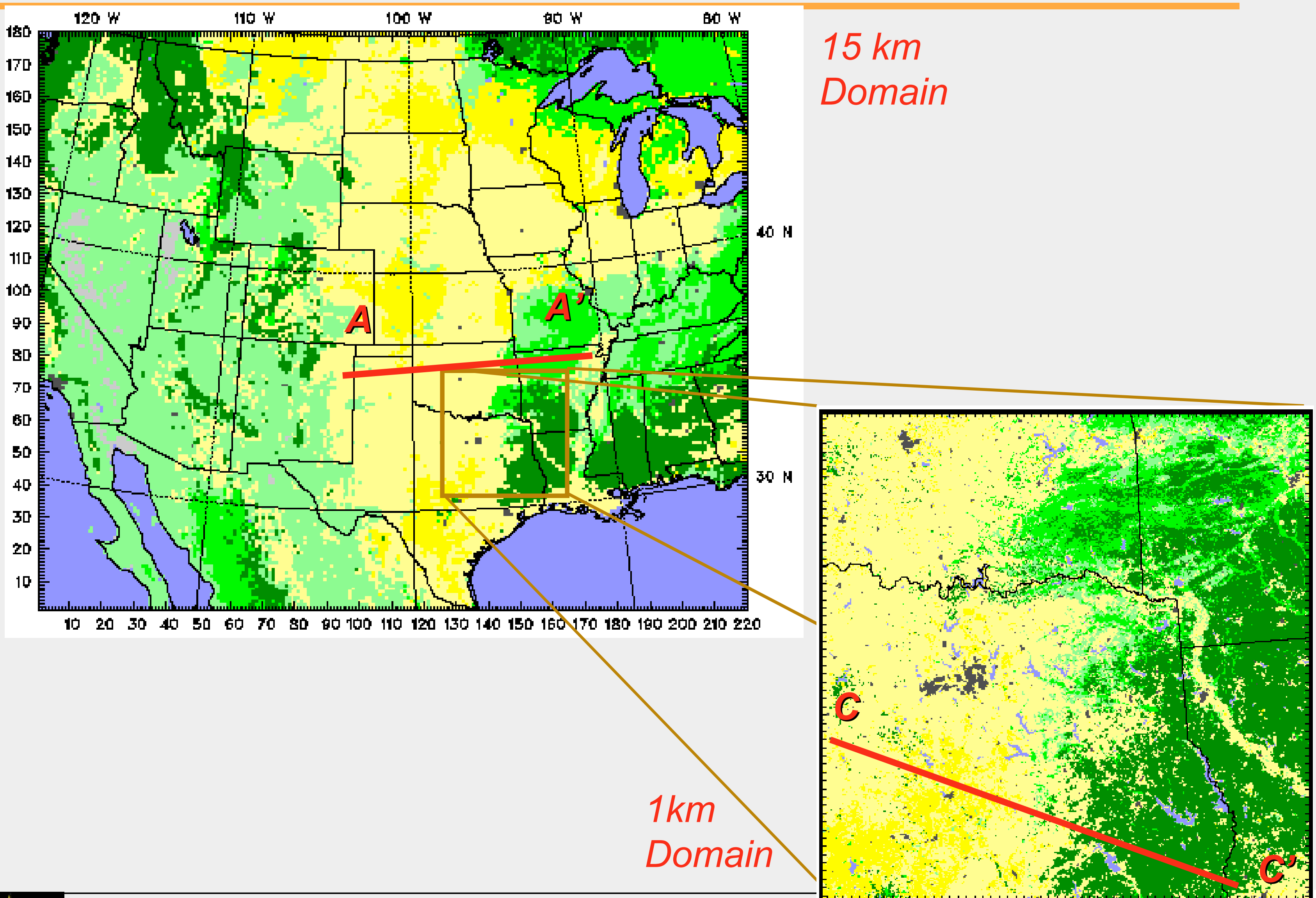
12 UTC 3/9/92

Dryline Pacific Front (aloft)

Case Specific Methodology

- 1 km ensemble domain focus area: eastern TX/OK
- Nesting approach utilized to avoid issue of boundary conditions ultimately dominating solution since most robust dataset available for initialization is NCAR/NCEP Reanalysis (> 1^o x 1^o resolution)
- "Conventional wisdom" for nesting=> domains of 81, 27, 9, 3, 1 km => expensive for 36 members!!
- => experiment w/only double nest---- w/ grids:
  - 15 km: 180 x 220 x 51 vertical levels (~ 8:1 nest ratio)
  - 1 km: 601 x 601 x 51 vertical levels (15:1 nest ratio)
  - 1-way nesting but with large 15 km upstream area

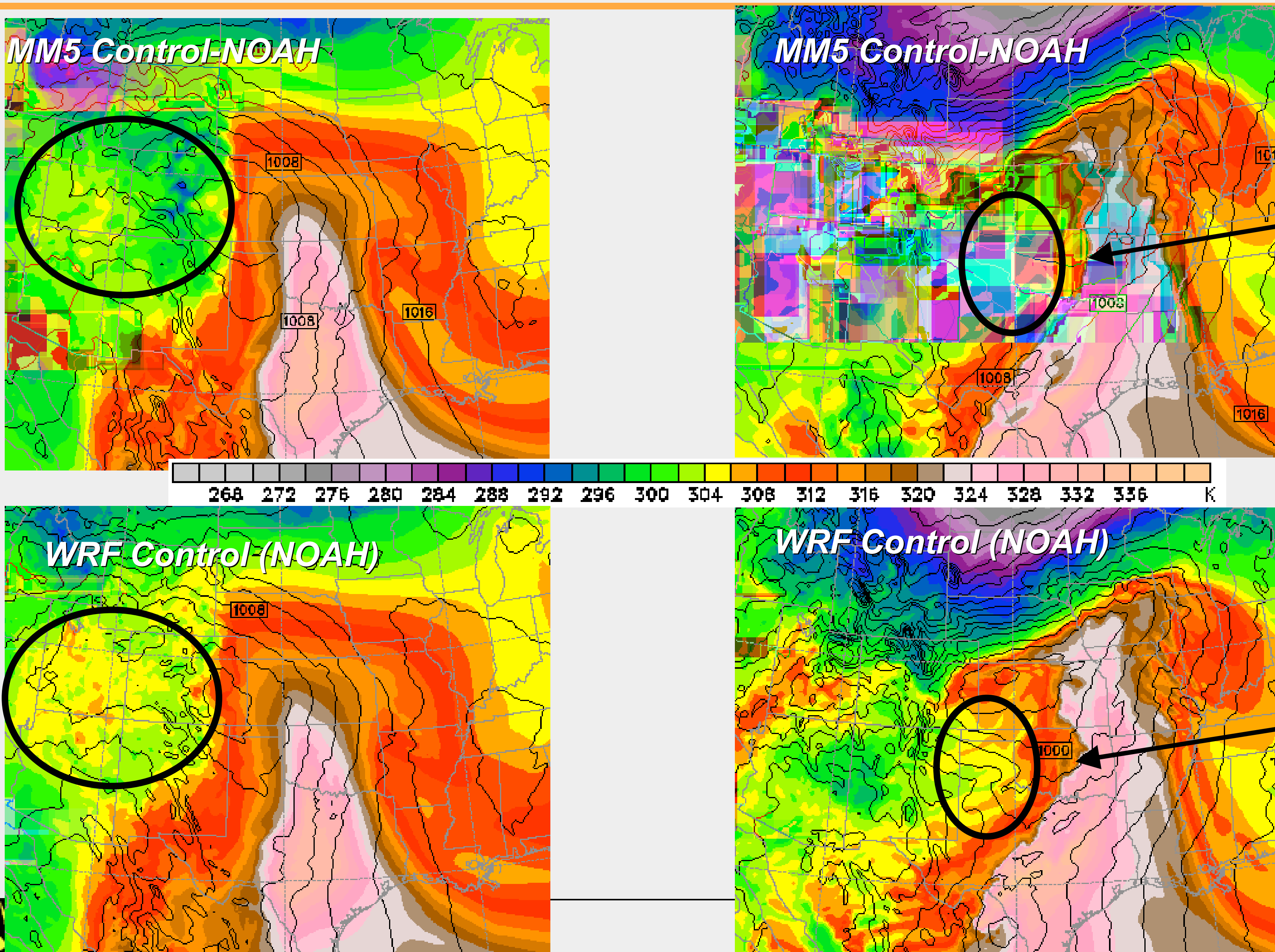
Domains



120 W
110 W
100 W
90 W
80 W
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
40 N
30 N
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220
A
A'
15 km
Domain
C
C'
1km
Domain

15 km Domain Conditioning via BC?: 850 Q_e, SLP

12 UTC 3/8/92 | 06 UTC 3/9/92



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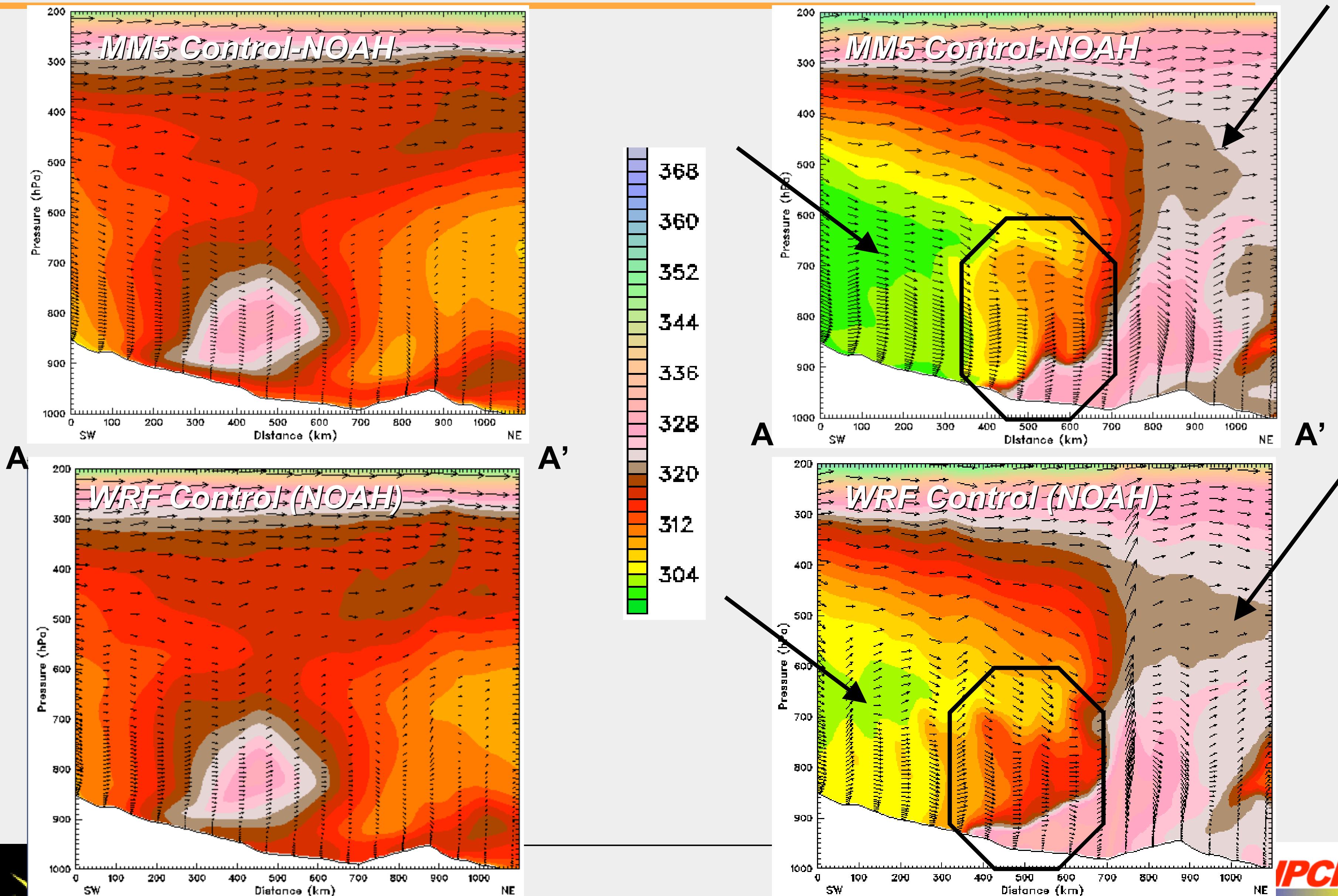
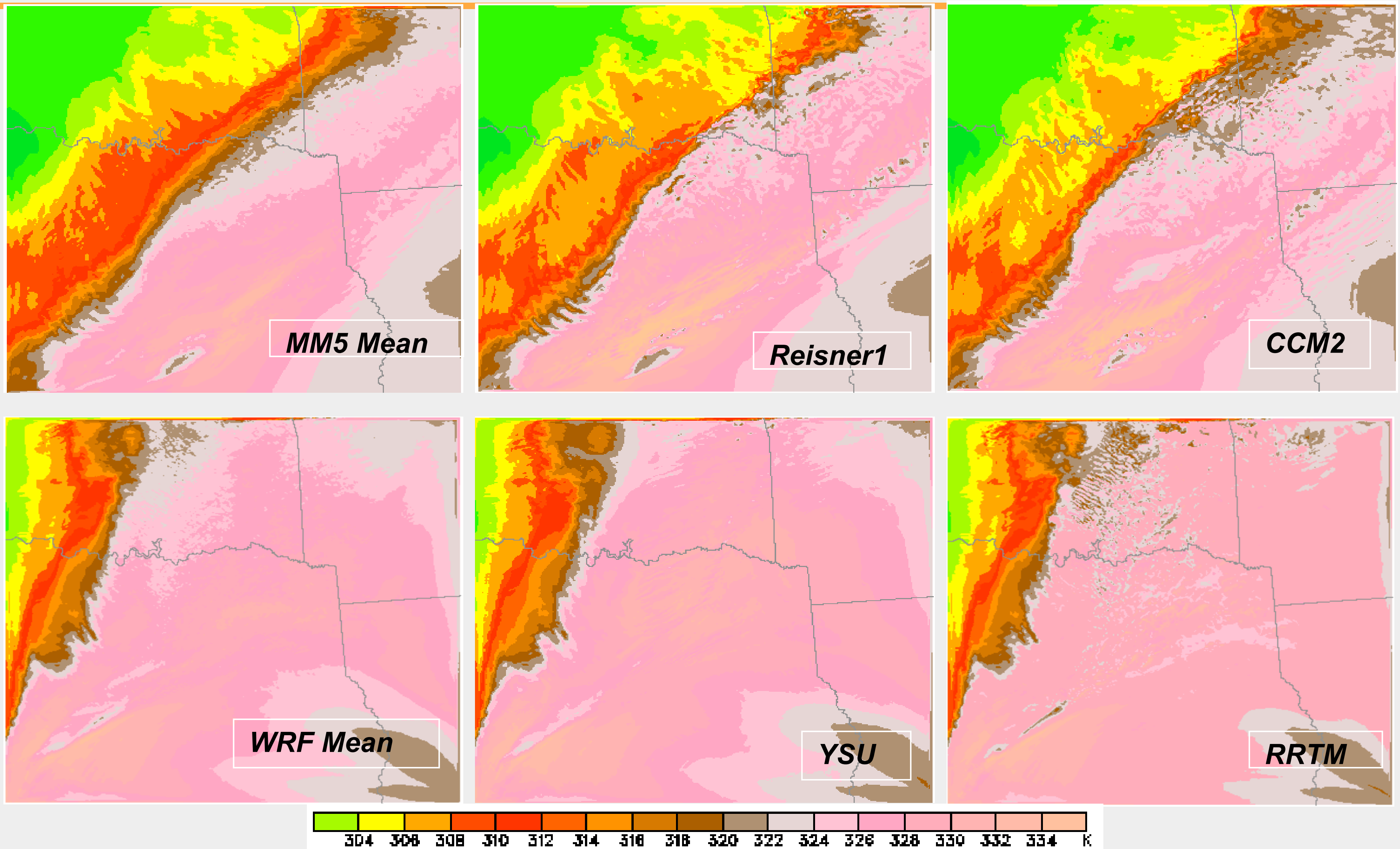
15 km Domain Conditioning via BC?: Q_e, V

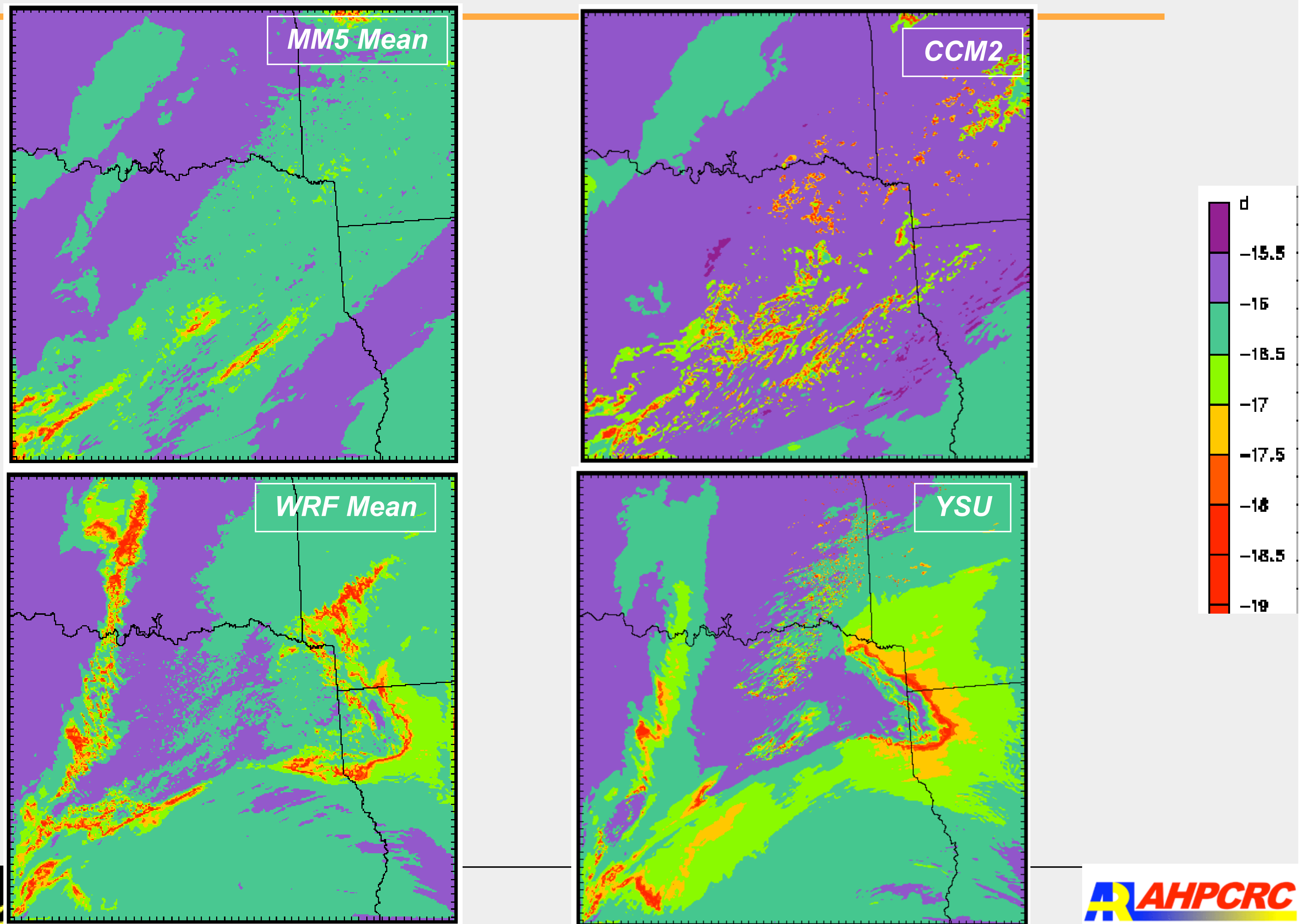
12 UTC 3/8/92 | **06 UTC 3/9/92**



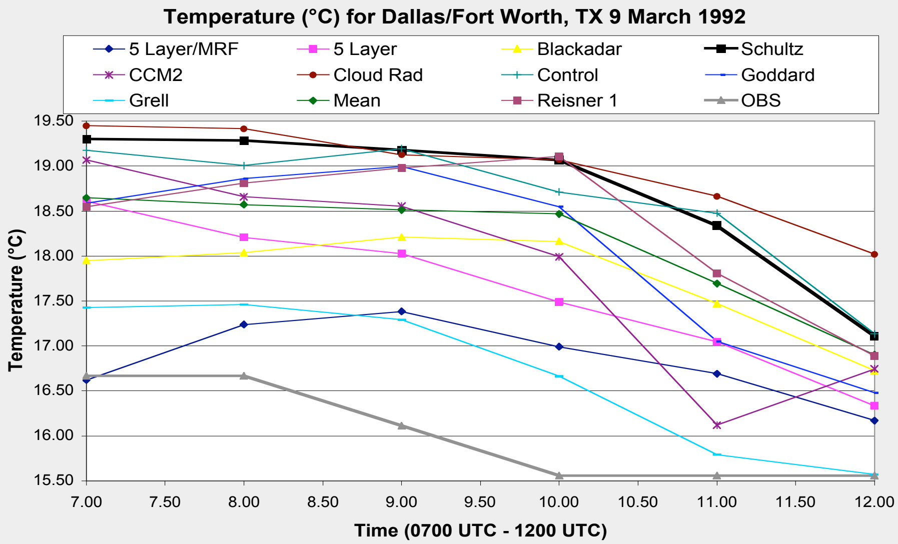
1 km Ensemble Results: 12 UTC 3/9/92 850 Q_e

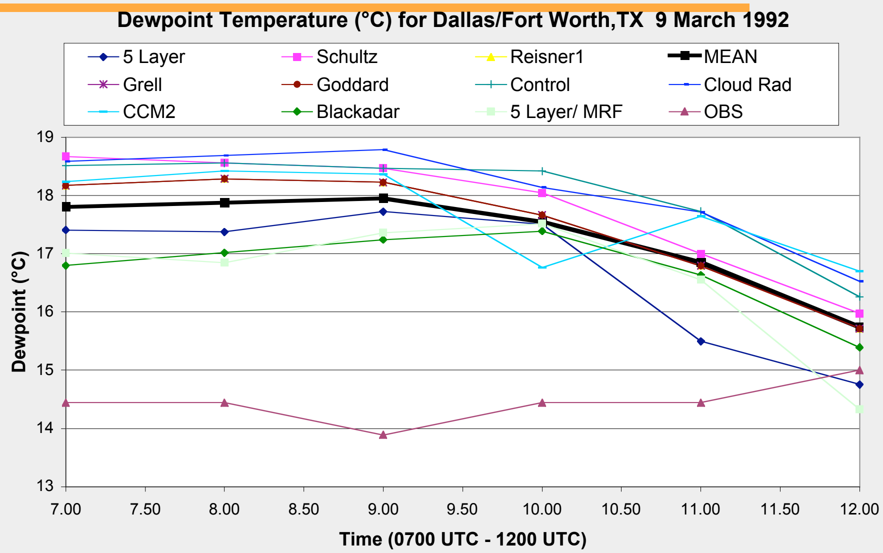


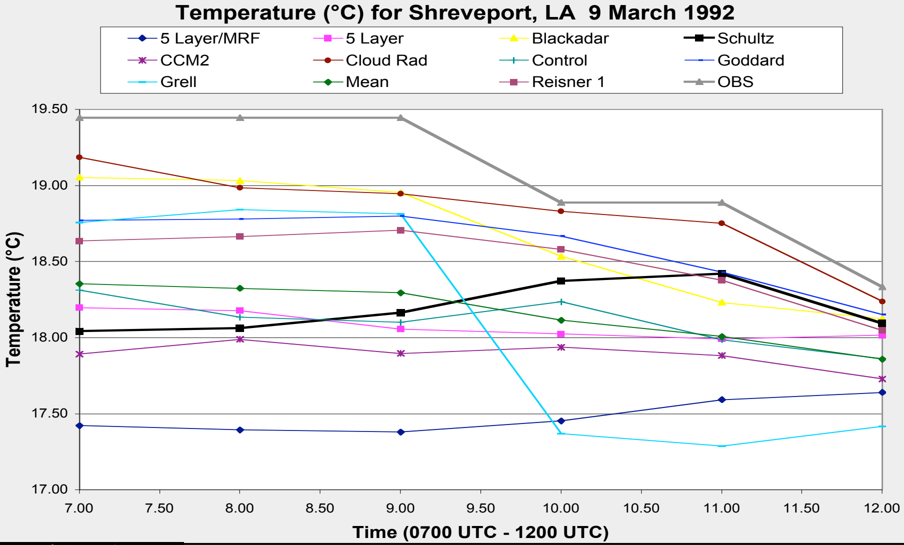
Sample 1 km C_n^2 results: 03/09/92 12 UTC 850 mb

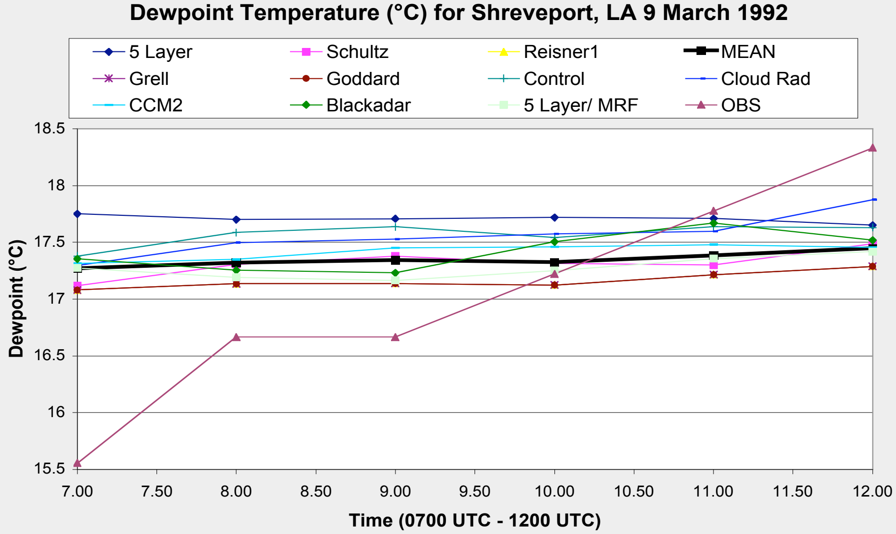


Early Verification, 1 km MM5 Ensemble: T and Td









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Summary

- *MM5 vs. WRF substudy part of larger process to determine ensemble/probabilistic prediction of meso-γ/micro-α scale refractivity parameters*
- *Double nested approach not entirely ideal but for shorter time scales of prime ARL interest (0-12 hr) may be workable*
- *Key points to date*
  - **15 km outer domain evolutions agree reasonably in synoptic/meso-α aspects**
  - **15 km domain evolutions differ significantly at meso-β and finer scales between MM5 & WRF--both phase and structure differences**
  - **These differences translate to the nested 1 km subensembles, often dominating over variability from variety of physics choices**
  - **MM5 members tend to show greater variability from physics**
  - **C_n^2 shows substantial degree of variability (uncertainty), even w/o moisture, and w/in each subensemble**
  - **Thus far, some general biases present in both models in 1 km members/means at night: WRF warm; MM5 cool; moisture biases less general--how much systematic, how much phenomenology/phasing?**
  - **More work to determine if there is a "clear winner"**


Questions?

Extra Slides

Relations

$$C_n^2 = C_T^2[79x10^{-6}\left(\frac{P}{T^2}\right)]^2$$

(*Tatarski 1971)*

where **$C_n{}^2$ = refractive index structure parameter**
$C_T{}^2$ = temperature structure function parameter
P = dry atmospheric pressure (hPa)
T = temperature (K)

$$C_T^2 = 2.8L^{4/3}\left(\frac{\partial\theta}{\partial z}\right)^2 \qquad L^{4/3} = 10^{0.1(1.57+40S)} \qquad S = \sqrt{\left[\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial v}{\partial z}\right)^2\right]}$$

(*Dewan et al 1993)*

and **u, v = horizontal wind components (m/s)**
z = geometric height (m)
q = potential temperature, defined by

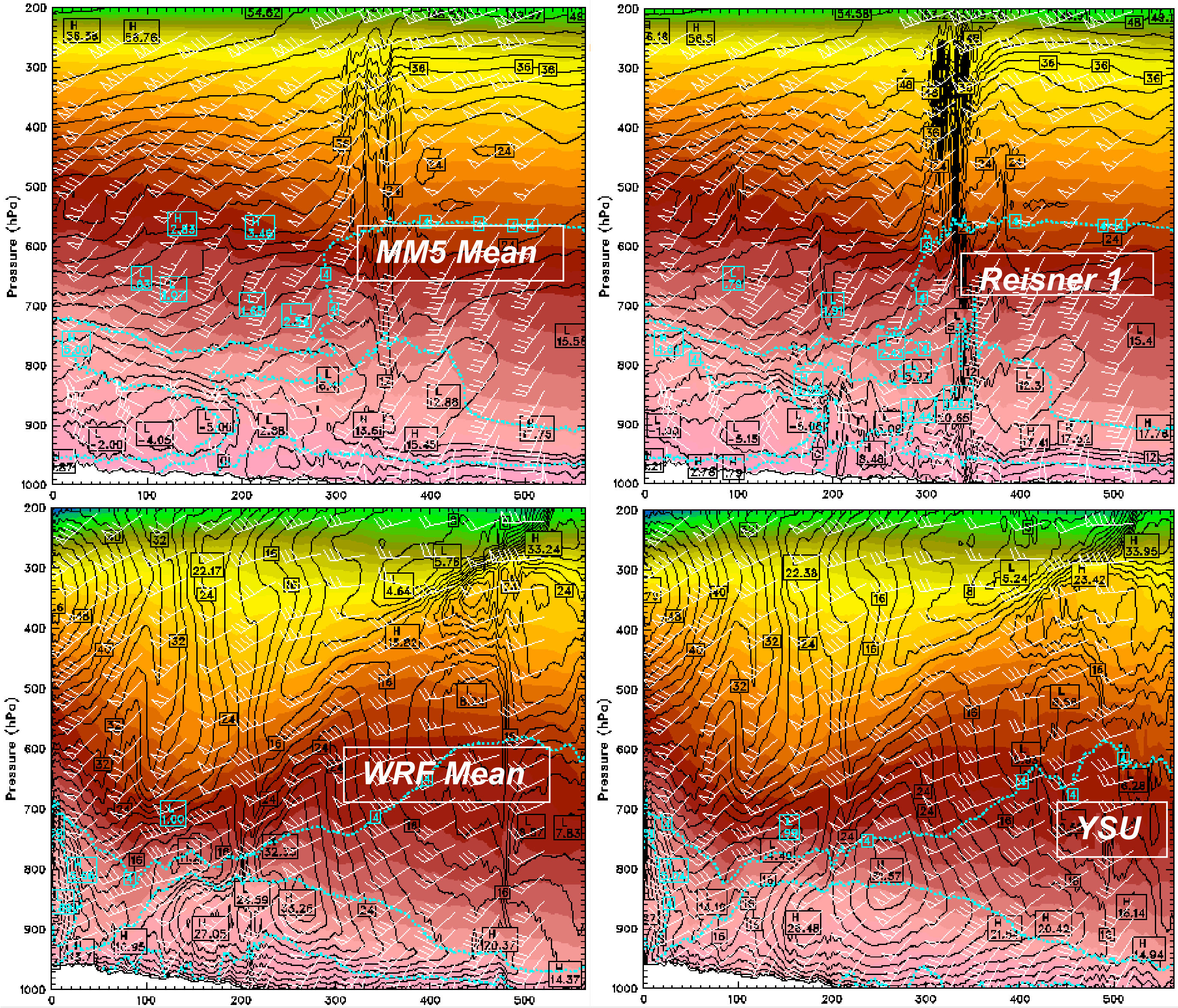
$$N = \underbrace{\frac{77.6}{T}(P + 4810\frac{e}{T})}_{\text{Dominant Tropospheric Terms}} - 4.03\cdot10^7\frac{N_e}{f^2}$$

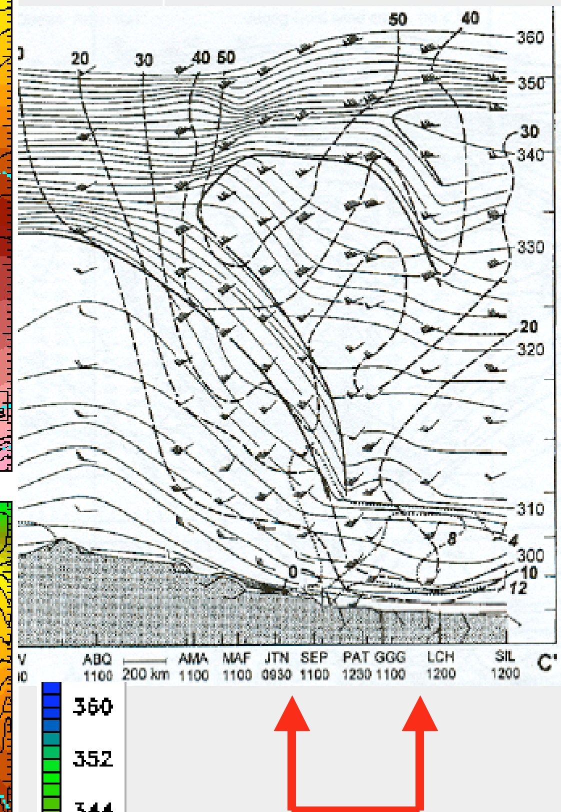
Dominant Tropospheric Terms

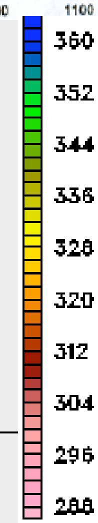
1 km Results: 12 UTC 3/9/92 $\Theta/V/Q_v$

C-C' Section

after Neiman et al (1998), Fig. 10







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Early Verification, 1 km WRF Ensemble: T and Td