



NCEP Meteorological Model Predictions for Dispersion Applications

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***NOAA/NWS
National Centers for Environmental Prediction
Environmental Modeling Center***

March 30, 2007

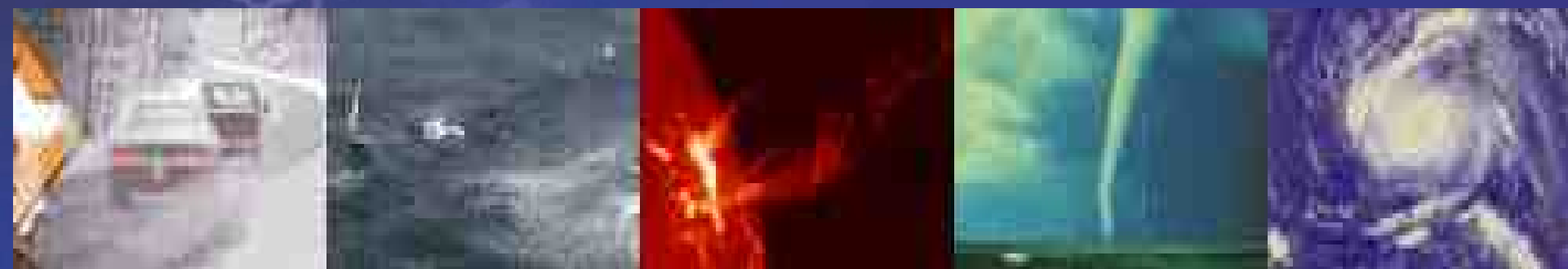


National Centers for

Environmental Prediction (NCEP)



- Among the Nation's leaders in providing global and national climate and weather analysis, forecasts and guidance
- Develop and Improve numerical weather, climate, hydrological, space and ocean prediction systems
- Applied research in data analysis, modeling and product development

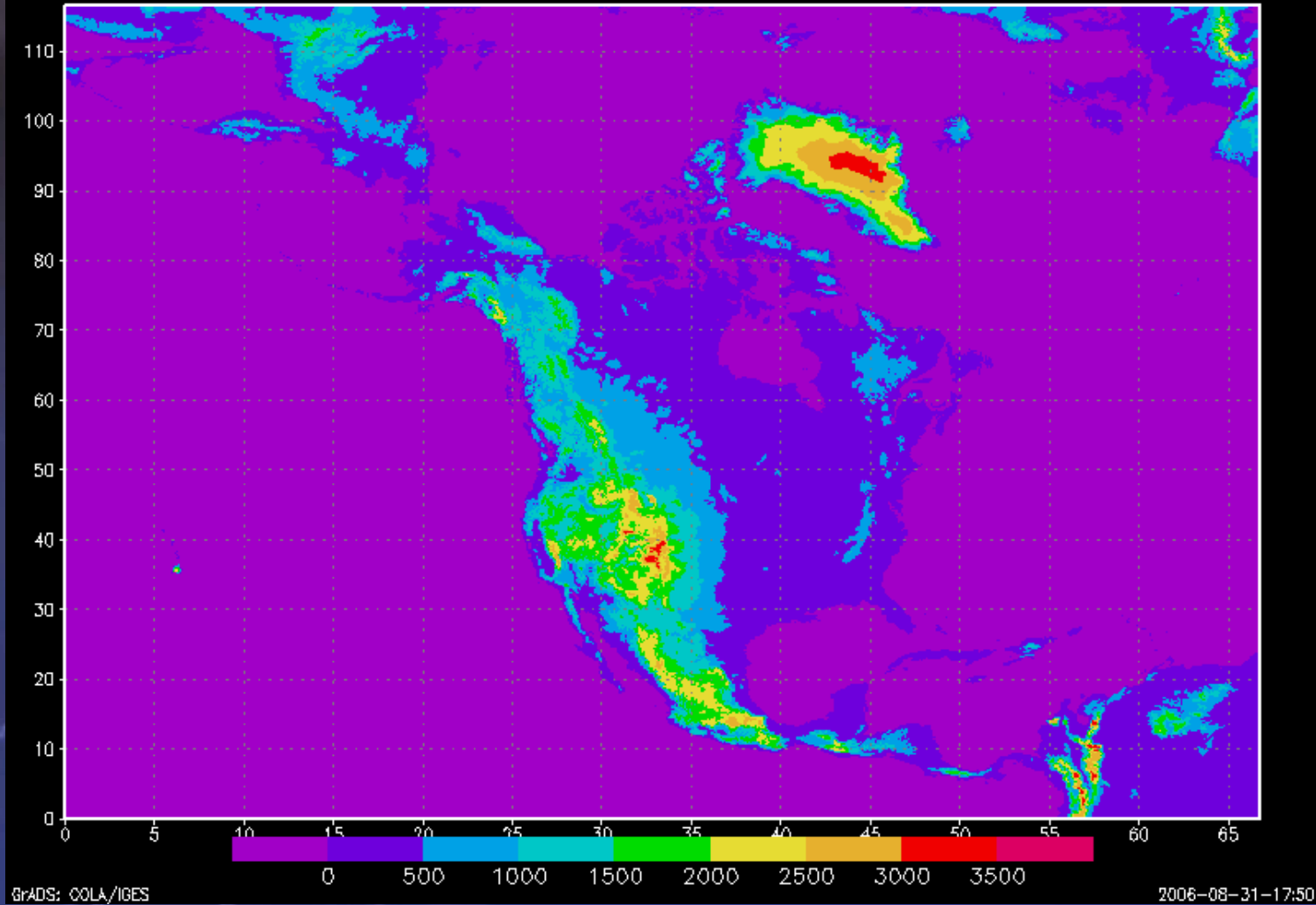




North American Model (NAM-WRF)



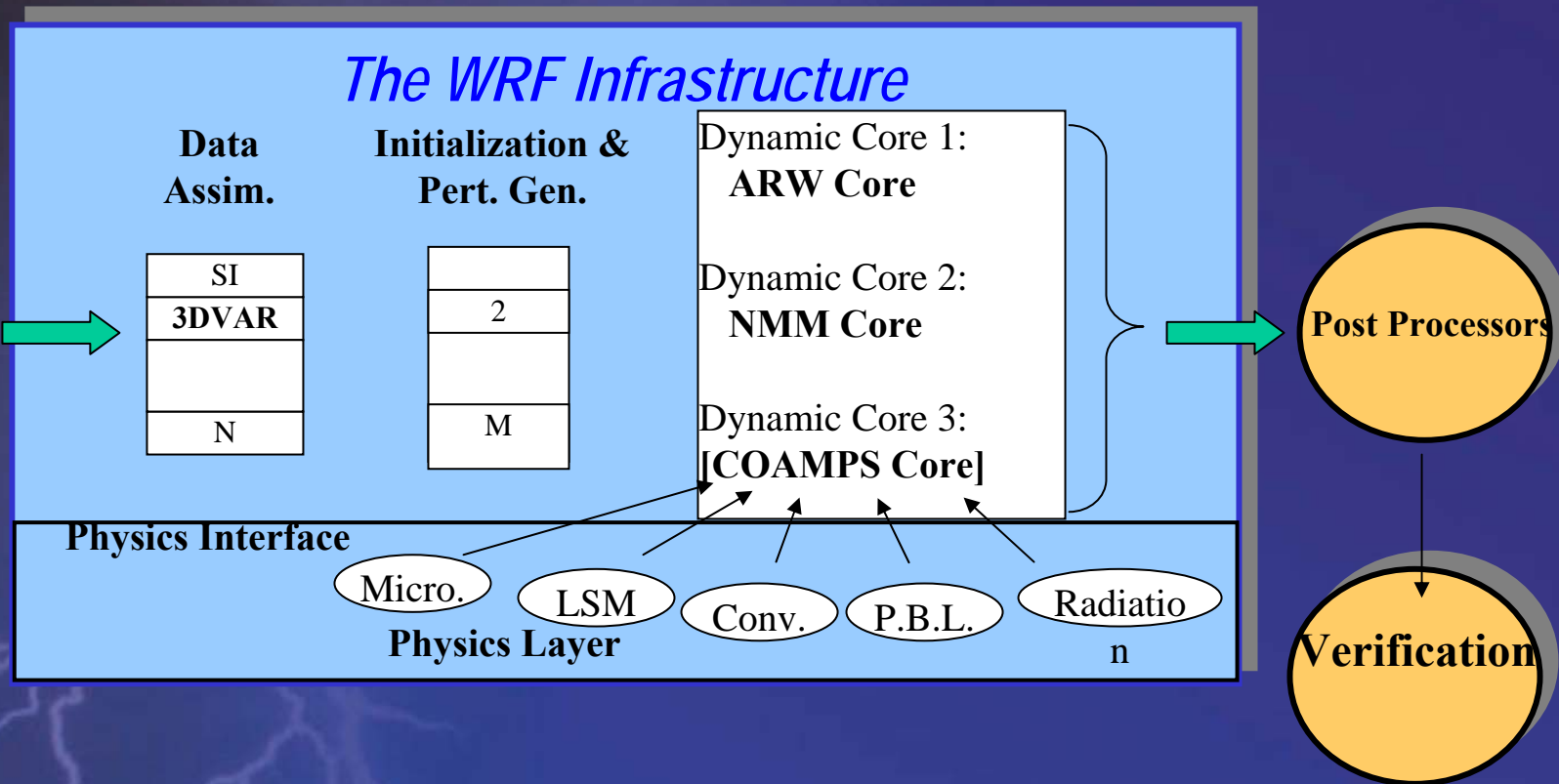
NEW EXPANDED NAM



North American Model (NAM) WRF run 4x/day at 12 km to 84 hours



Weather Research and Forecast (WRF) System

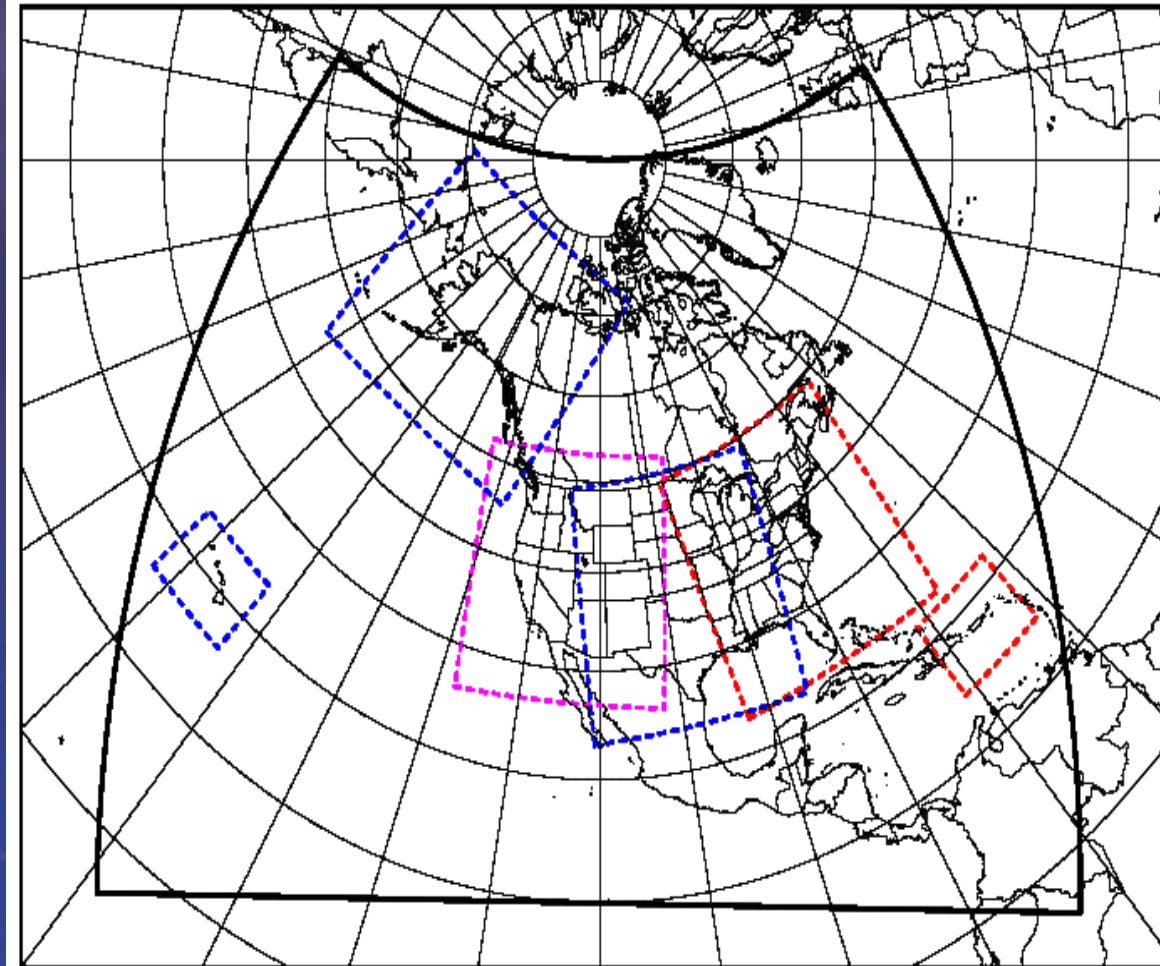




HiRes Window Fixed-Domain Nested Runs



- **FOUR** routine runs made at the same time every day (5 km)
- 00Z : **Alaska & Hawaii**
- 06Z : **Western & Puerto Rico**
- 12Z : **Central & Hawaii**
- 18Z : **Eastern & Puerto Rico**
- Everyone gets daily high resolution runs *if & only if* hurricane runs are not needed



<http://www.emc.ncep.noaa.gov/mmb/mmbpll/nestpage/>



Global Forecast System



Run Slot #/day	Mission & (Notes)	F Hrs	Resolution (hor/ver)
<u>Global Forecast System (GFS)</u> 4/day	<ul style="list-style-type: none"> Global general weather and aviation guidance to 15 days (winds, temp, rainfall) Boundary + initial conditions for NAM, Ocean models Initial conditions for ensemble generation Supports Model Output Statistics Hurricane tracks 	384 hr	<ul style="list-style-type: none"> ✓ 35 km/ 64l ✓ 55 km/ 42l after 84 hr ✓ 75 km/28l beyond 180 hr
<u>Global Data Assimilation System (GDAS)</u> 4/day	<ul style="list-style-type: none"> Provides best guess for GFS analysis, verification & validation 3-D Variational 6-hr update frequency with digital filter 	9 hr with 6 hr update	35 km/ 64l
<u>Global Ensemble</u> 4/day	<ul style="list-style-type: none"> <i>Probabilistic rainfall (QPF) and general weather to 15 days</i> 14 members with initial condition perturbations generated from Ensemble Transform Technique 	360 hr	✓ 100km/28l



Additional NCEP Models with applications for AT&D



- **On-Demand Homeland Security Nests**
 - *On-demand real-time High Resolution WRF 4km Grid Runs*
 - *26 pre-defined nests*
 - *NOAA responsible for met. model CONUS predictions*
- **Rapid Refresh WRF**
 - *13 km CONUS hourly analyses to 18 forecast hours*
- **Real-Time Mesoscale Analysis system (RTMA)**
 - *2-D Variable data assimilation at the surface*
 - *hourly analyses at 5 km resolution*
- **Analysis Of Record**
 - *Downscaled from NDAS analysis to provide high resolution climatology than 32 km Regional Reanalyses*
- **WRF-CMAQ Air Quality Forecasts (O3 / PM)**
 - *CONUS 12 km 48 hour forecasts 2x/day*



Provision of Additional Products



- **NCEP Products to DTRA-MDS**
 - *Global Forecast System 1/2 degree 3 hrly predictions to 16 days*
 - *Global Ensemble Mean and Spread files to 16 days*
 - *Short Range Ensemble to 84 hours (4x/day)*
 - *NAM-WRF high resolution 12 km CONUS and North American grids*



WRF Output to improve HPAC coupling



- Instantaneous and *time-averaged* surface sensible heat, latent heat, and momentum fluxes
- Roughness length, vegetation types and fraction
- Shelter level, skin, and soil temperature, moisture, and wind
- Cloud fraction
- Mixing length
- 3 D Wind, temperature, and specific humidity
- 3 D Turbulent Kinetic Energy
- 3 D eddy diffusivity of heat
- PBL height
- *Time-averaged winds, TKE and mixing lengths*
- *Eddy energy dissipation rates*
- *3-D eddy diffusivity of momentum*
- *3-D wind variance from ensemble*
- *Large Scale Variance proportional to wind variance ?*

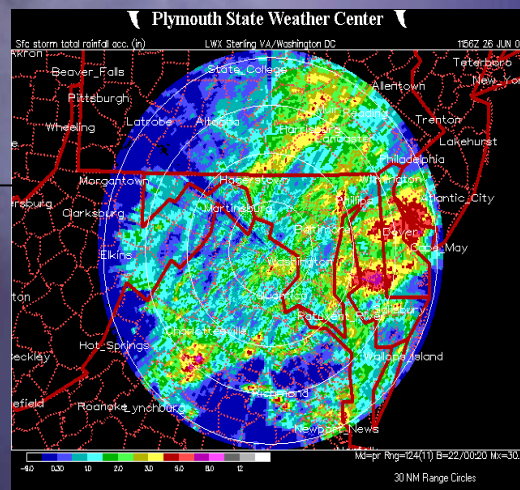
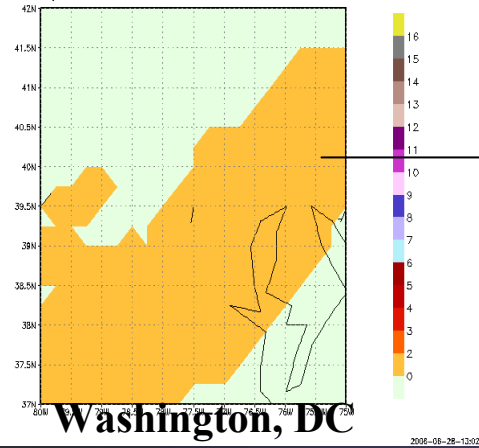


NCEP AT&D Focus for HPAC

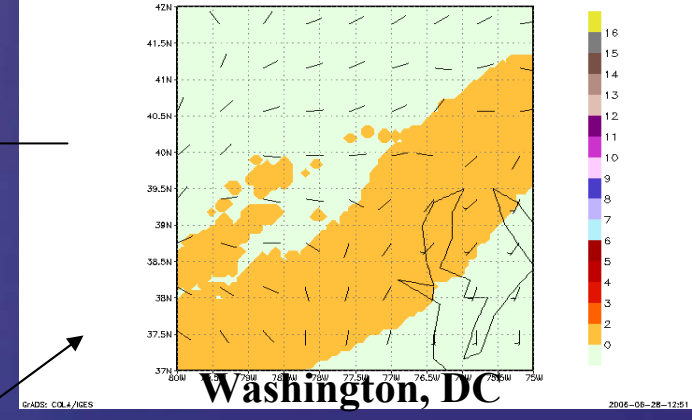


- **Improved Coupling of Mesoscale Models w/ HPAC**
 - *Special real-time High Resolution Nested Grid Runs (eg: Torino Olympics)*
 - *Additional turbulence Fields output to NCEP GRIB files and to DTRA servers*
 - *Evaluation of WRF turbulence characteristics with PSU & Hanna Consultant.*
 - *Development of a real-time PBL height and cloud cover verification system*
- **Development and Testing of a High Resolution Ensemble Prediction Systems**
 - *NCEP WRF ensemble breeding system for initial condition diversity*
 - *Uses both ARW and NMM cores and physics suites*
 - *Began testing a 10 member WRF HREF*
 - *Providing experimental ensemble wind variance fields needed to drive HPAC uncertainty calculations*
- **Incorporation of probabilistic verification for Ensemble System evaluation**
 - *Deterministic FVS developments: pbl hgt & cloud cover verification*
 - *Probabilistic: Ranked Histograms, spread, statistical consistency, outlier diagrams added for ensemble verification*

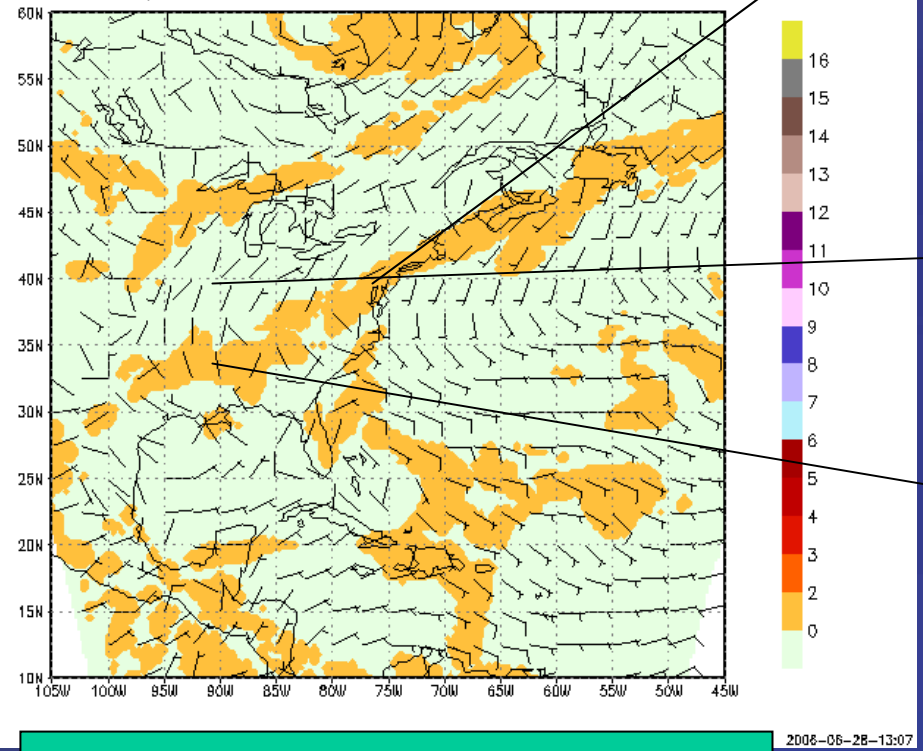
JUN 24, 2006 12Z: DC METRO-PARENT FCST: 3



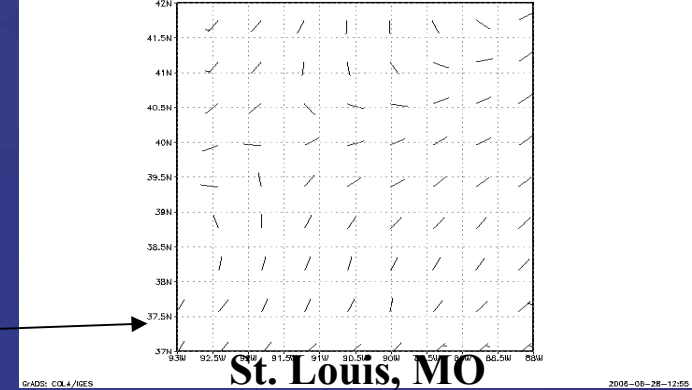
JUN 24, 2006 12Z: DC METRO-NEST FCST: 3



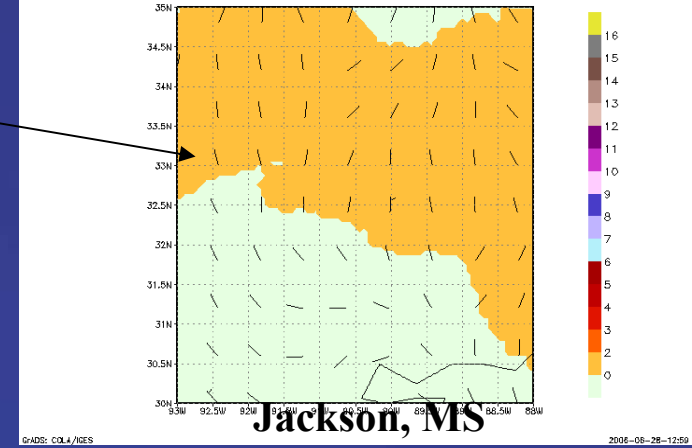
JUN 24, 2006 12Z: LOW RESOLUTION FCST: 3



JUN 24, 2006 12Z: St.Louis METRO-NEST FCST: 3



JUN 24, 2006 12Z: Jackson,MS METRO-NEST FCST: 3



High Impact on-demand Nests



Torino Olympics

WRF nested runs (Dusan Jovic)

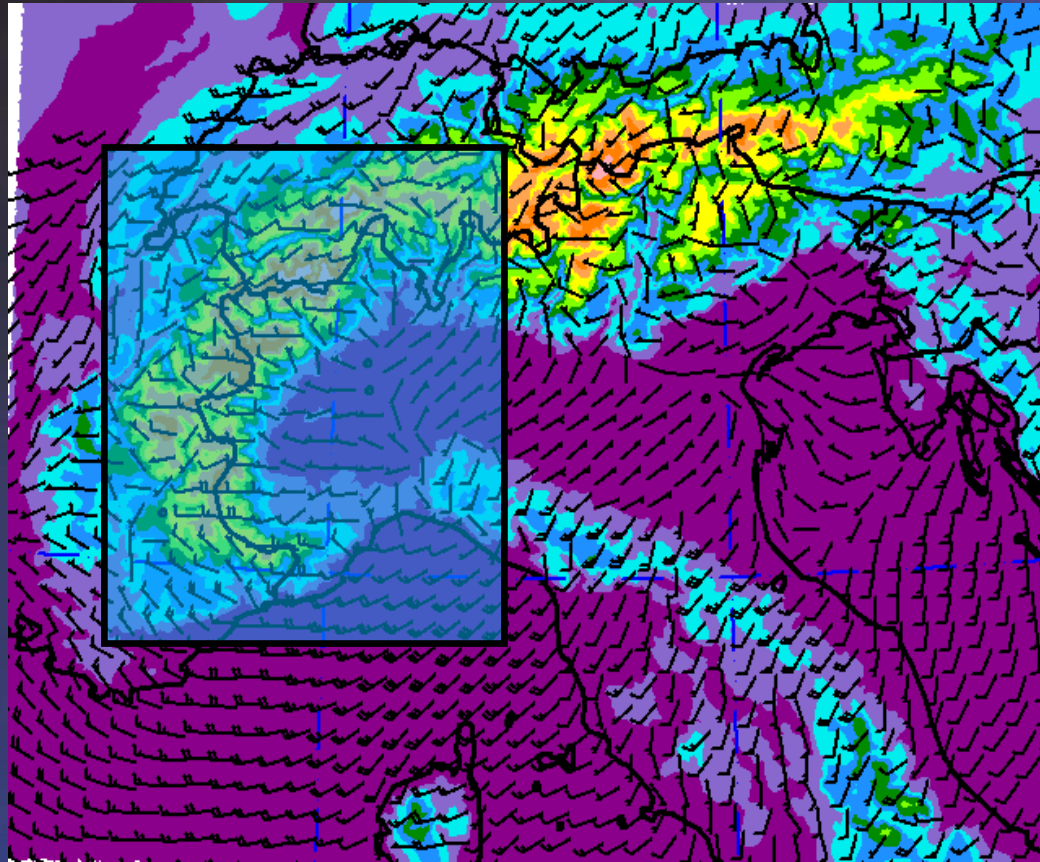


- WRF-NMM V2.1 using H-WRF nested grid configurations
- 24 h forecasts at 00 and 12 UTC
- 4 km Alps nest w/in 12 km Europe Domain
- 50 levels
- **90 mins w/ 64 IBM Processors**
- Initialized with $\frac{1}{2}$ degree GFS Pressure grids
- Ferrier Microphysics → No convective Param.
- MYJ TKE, NOAH LSM

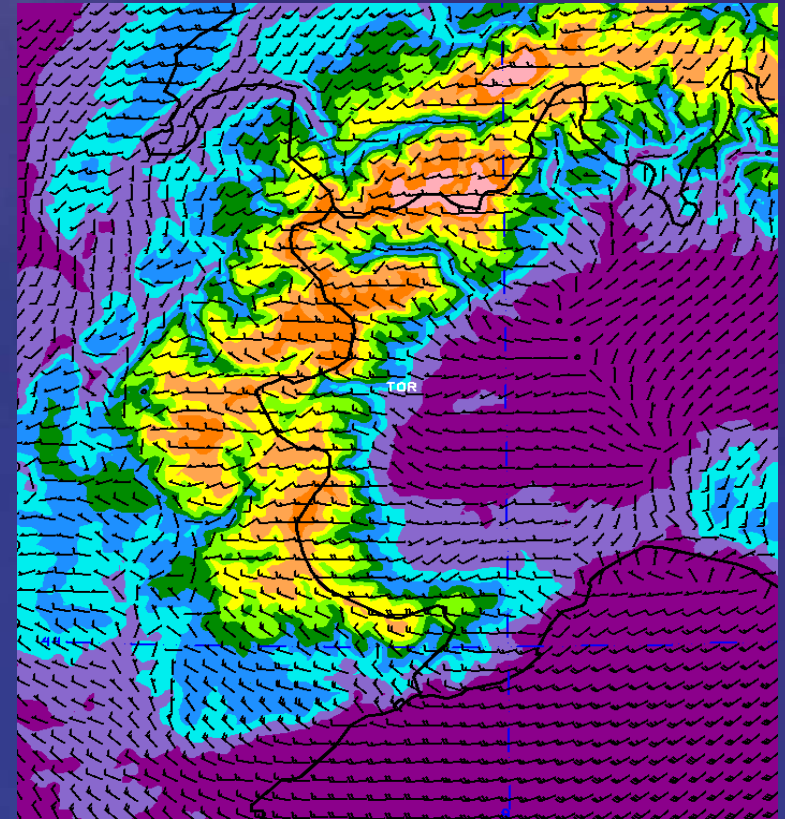


Torino Olympics

NCEP 4 km Domain



Full 4 km WRF Nested Grid Domain



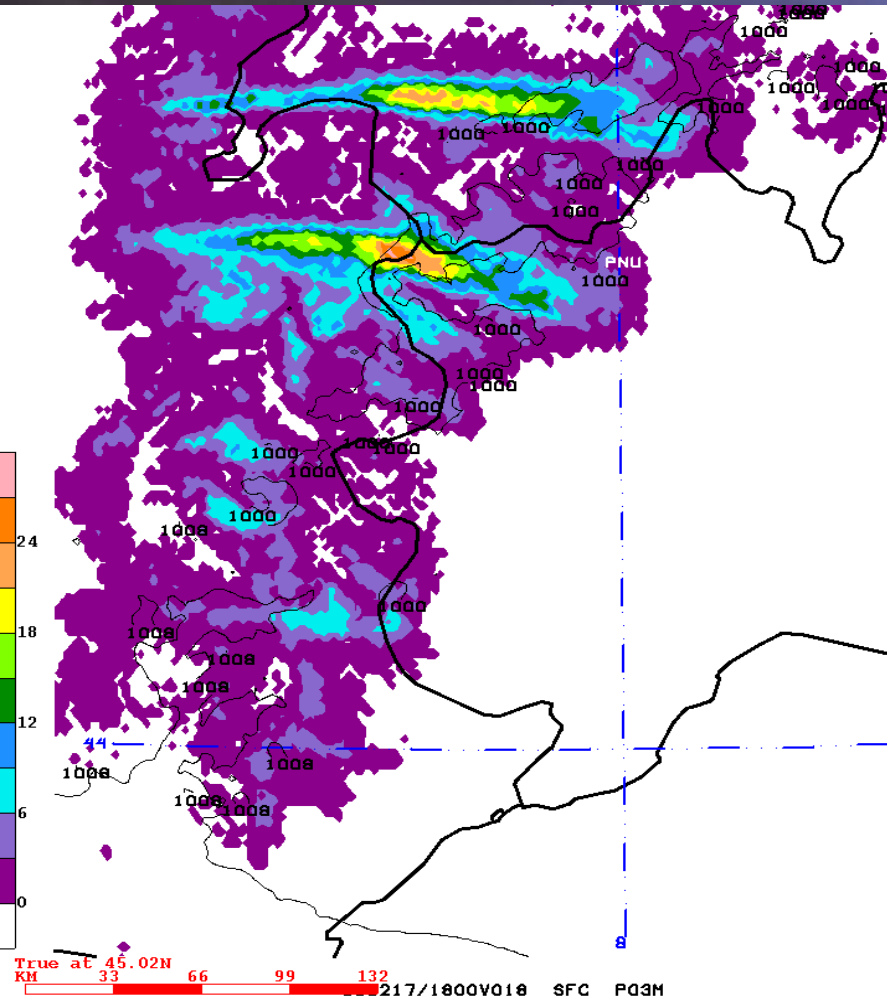
Zoomed view around Torino



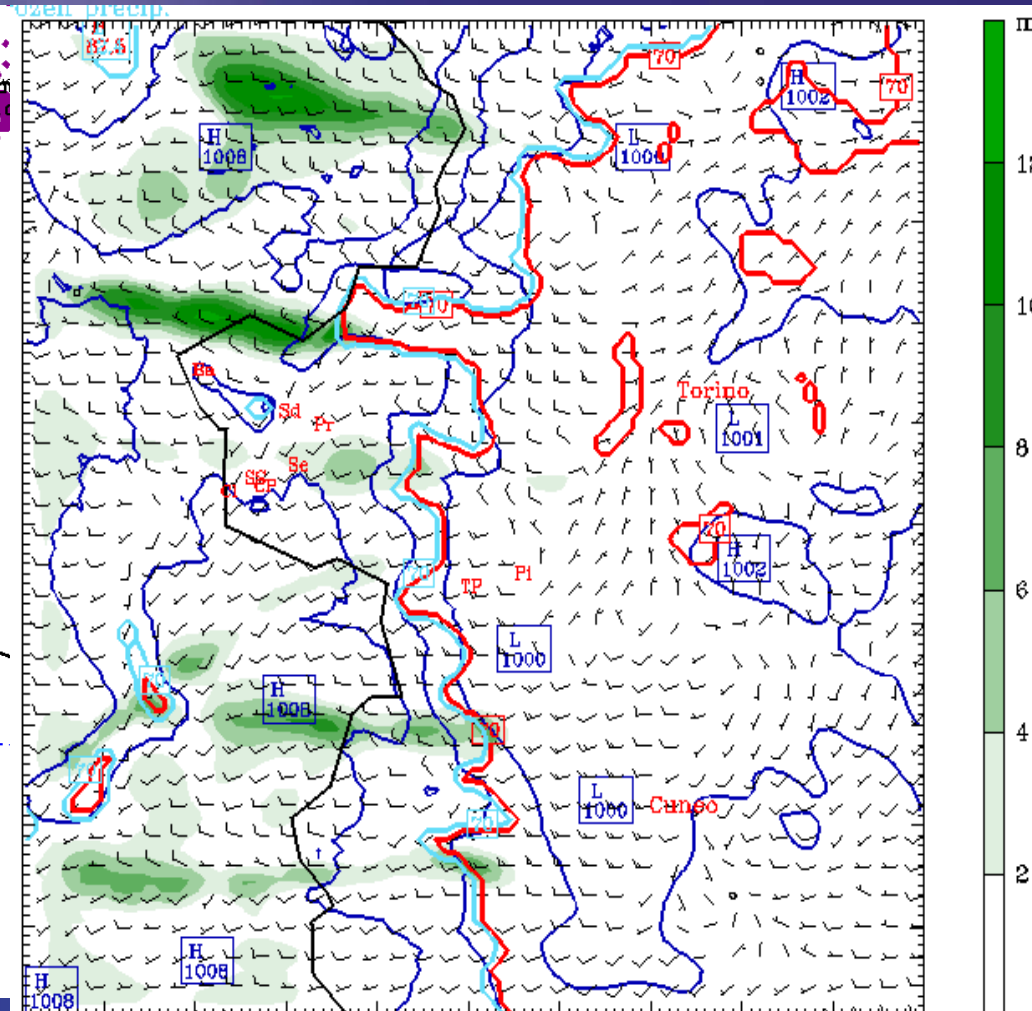
Torino Olympics

Snow Storm Forecasts (3h precip)

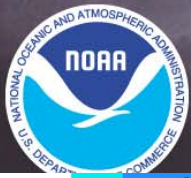
00 UTC Feb. 17, 2006 18 h Forecasts



WRF-NMM 4km Zoom

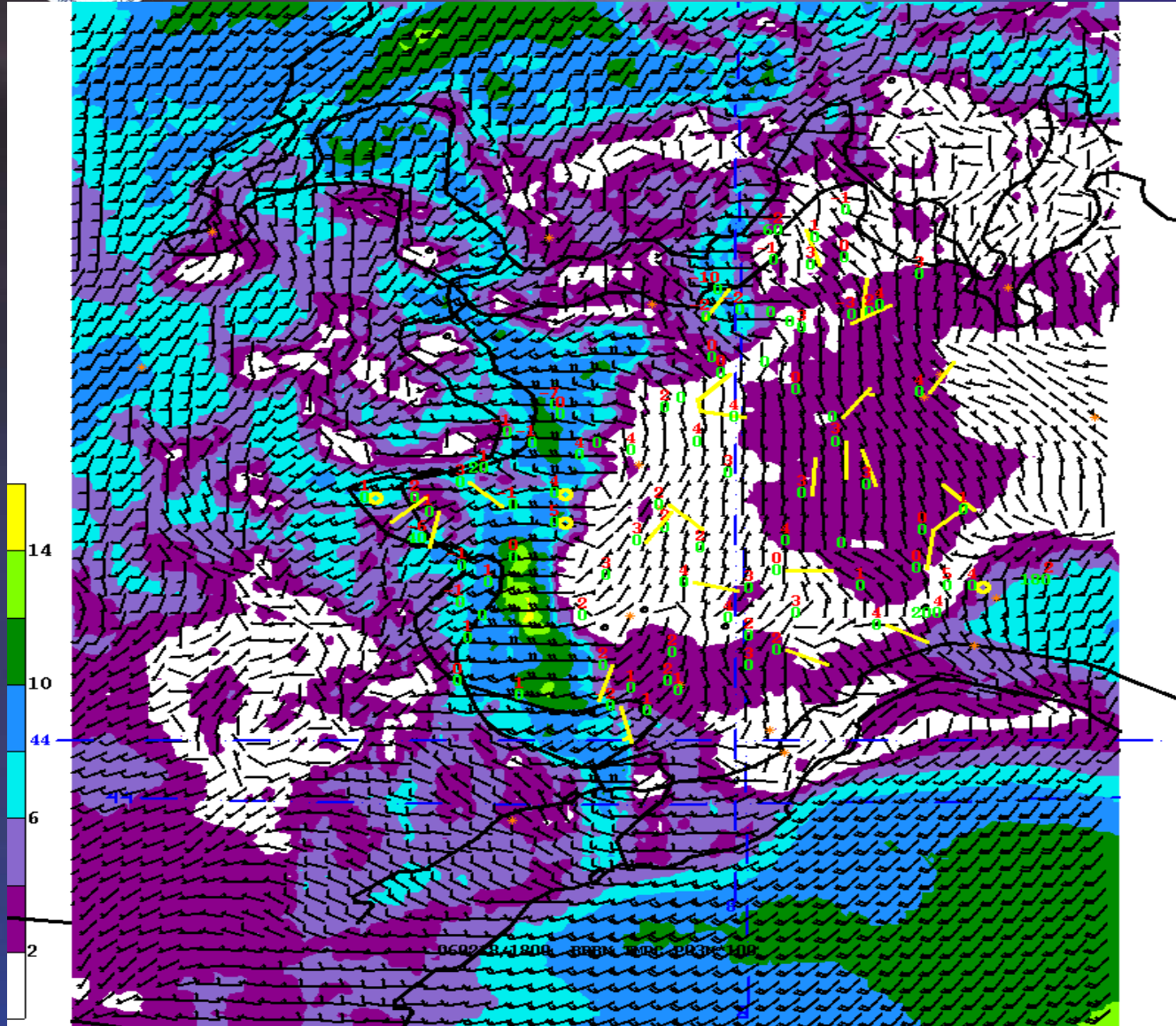


MM5 4 km



Torino Olympics

February 18, 2006 case winds



Some down valley
Flows captured

Mediterranean low is
better captured in
larger domain

Synoptic-orographic
interactions are
important



HPAC multi-model simulations

MM5 & WRF

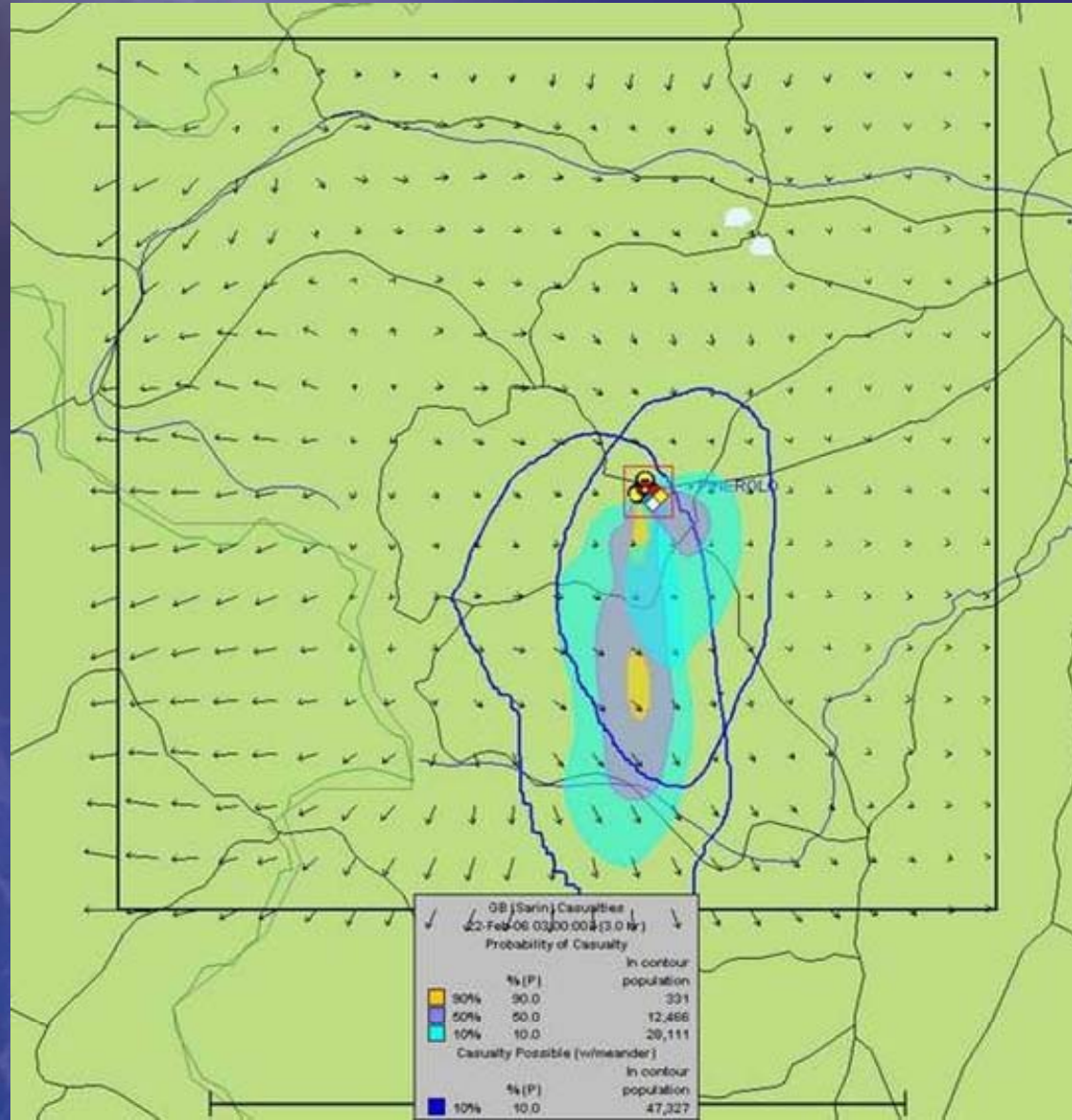


- WRF & MM5 Plumes near Torino Olympics

- Blue lines: HPAC uncertainties w/ constant large scale variances

- Courtesy Pat Hayes, DTRA-NGC

Feb. 22, 00Z release
(Case 5)





Short Range Ensemble Forecast

WRF members added to : 21 multi-model members

Run 4x/day to 84 hours (6 WRF, 10 Eta, 5 RSM)



Core	3 NMM members	3 ARW members
Horizontal	40km	45 km
Vertical	50 hybrid sigma-P levels	35 Mass levels
Adv/Physics Time Step	110/600 sec	108/200 sec
Computer usage	(32 procs/member)	(40 procs/member)
Diffusion	Increased Smagorinsky deformation	Vertical damping
Physics	NOAH LSM MYJ TKE PBL BMJ Convection Ferrier Microphysics	NOAH LSM MRF 1 st order PBL Kain-Fritsch Convection Ferrier Microphysics



Ensemble Products to DTRA-MDS



Means/ Spread(uncertainties)

- Heights at 1000, 850, 700, 500, 250 mb
- U+V at 1000, 850, 700, 500, 250 mb & 10 m
- Temperature 850, 700, 500 mb & 2 m
- Dew Point (RH) 850, 700, 500 mb & 2 m
- QPF at 3, 6, 12 and 24 hour totals
- 12-hr Snowfall
- Sea Level Pressure
- Precipitable Water

Probabilistic Fields

- 3-hr/6-hr QPF GE .01", .25", .50", 1.0"
- 12-hr/24-hr QPF GE 0.1", .25", .50", 1.0", 2.0"
- 12-hr Snowfall GE 1", 4", 8", 12" (have 2.5, 5, 10, 20")
- Temperature at 2 m & 850 mb LE 0°C
- 10 m Wind GE 25 kt, 34 kt, 50 kt
- CAPE GE 500, 1000, 2000, 3000, 4000
- Lifted Index LE 0, -4, -8
- Surface Visibility LE 1 mi, 3 mi
- Cloud Ceiling* LE 500 ft, 1000 ft, 3000 ft
- Probability of precipitation types (have rain, frozen, & freezing)
- 6-hr/12-hr/24-hr QPF Best Category



Ensemble Covariance Products



Daily ensemble products

Binbin Zhou, EMC

http://www.emc.ncep.noaa.gov/mmb/SREF_avia/TEST/web/html/variance.html

$$EKE = 0.5 * (UUE + VVE + WWE)$$

$$UUE = \frac{1}{N} \sum (U_{ij}^m - U_{ij})^2$$

$$VVE = \frac{1}{N} \sum (V_{ij}^m - V_{ij})^2$$

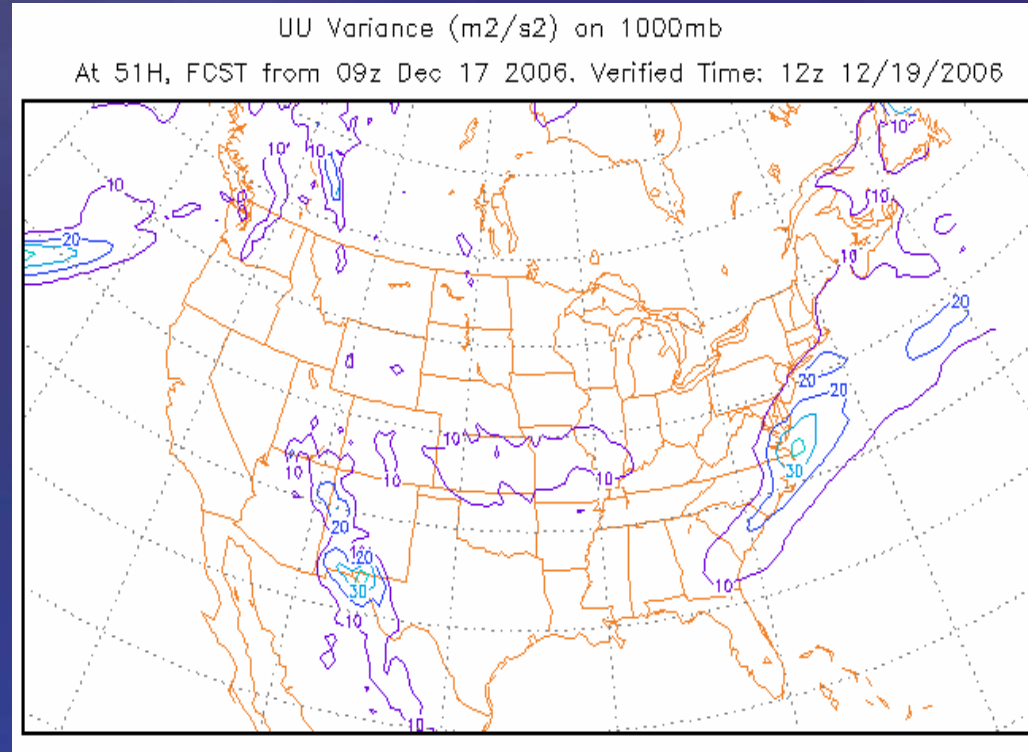
$$UVE = \frac{1}{N} \sum (U_{ij}^m - U_{ij})^2 (V_{ij}^m - V_{ij})^2$$

$$WWE = \frac{1}{N} \sum (W_{ij}^m - W_{ij})^2$$

Ensemble mean sensible heat flux

Ensemble mean latent heat flux

U and V spread





NCEP's FVS Verification System

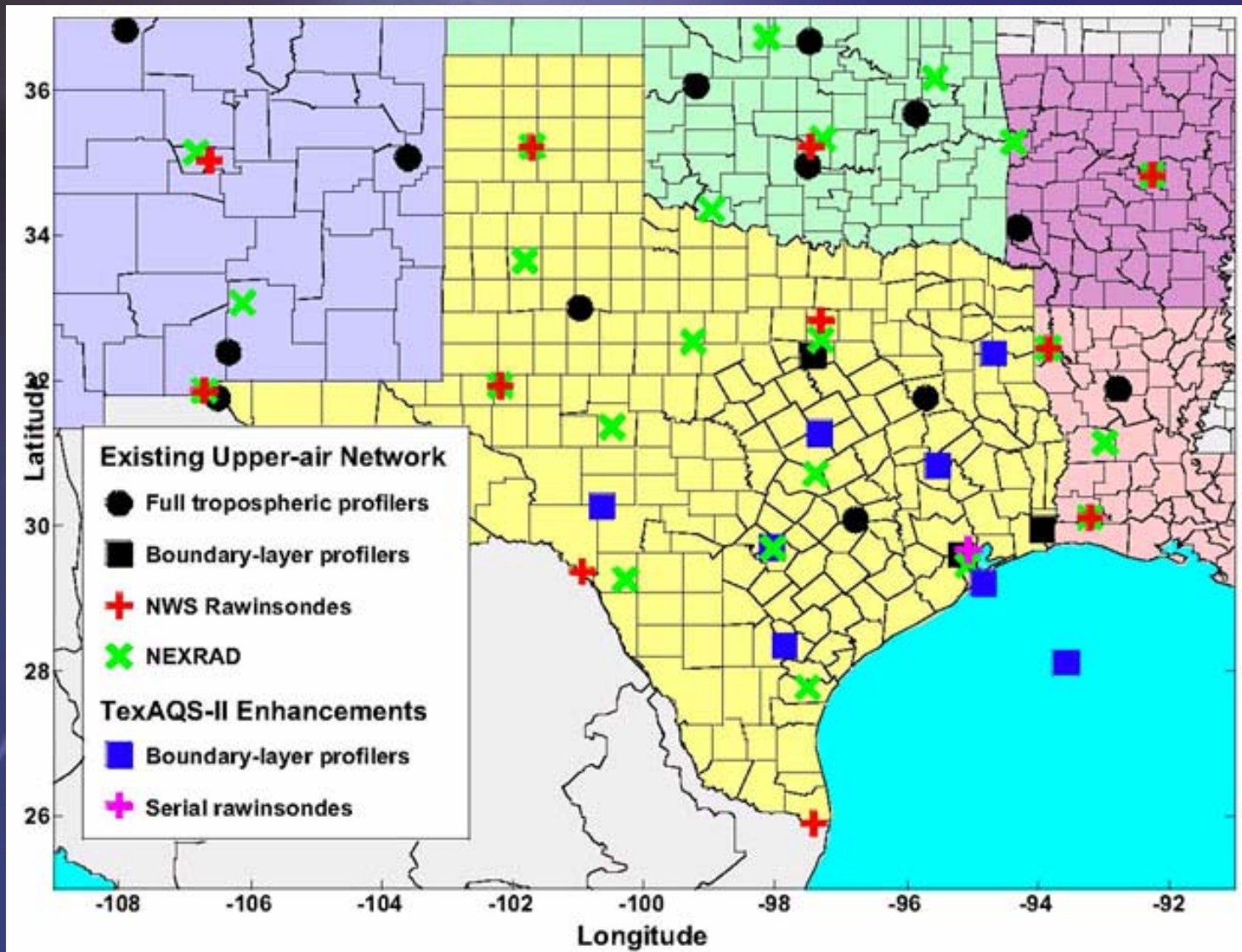


- Input observations are from NCEP operational PREPBUFR files which include 1) radiosonde & dropsonde Z, temp, wind & moisture; 2) surface land & marine P, temp, wind, moisture observations; 3) ACARS & conventional aircraft wind, temp [moisture], and 4) Profiler winds.
- Verified Fields include *temperature, wind and moisture fields on pressure and shelter levels.*
- Recently added *sensible weather (eg: Visibility) , wind shear, and PBL height*
- Grid verification of *cloud cover using AFWA cloud cover products*

New FVS On-line System
Web-based MYSQL Database



Texas Air Quality Experiment Aug-Oct 2006



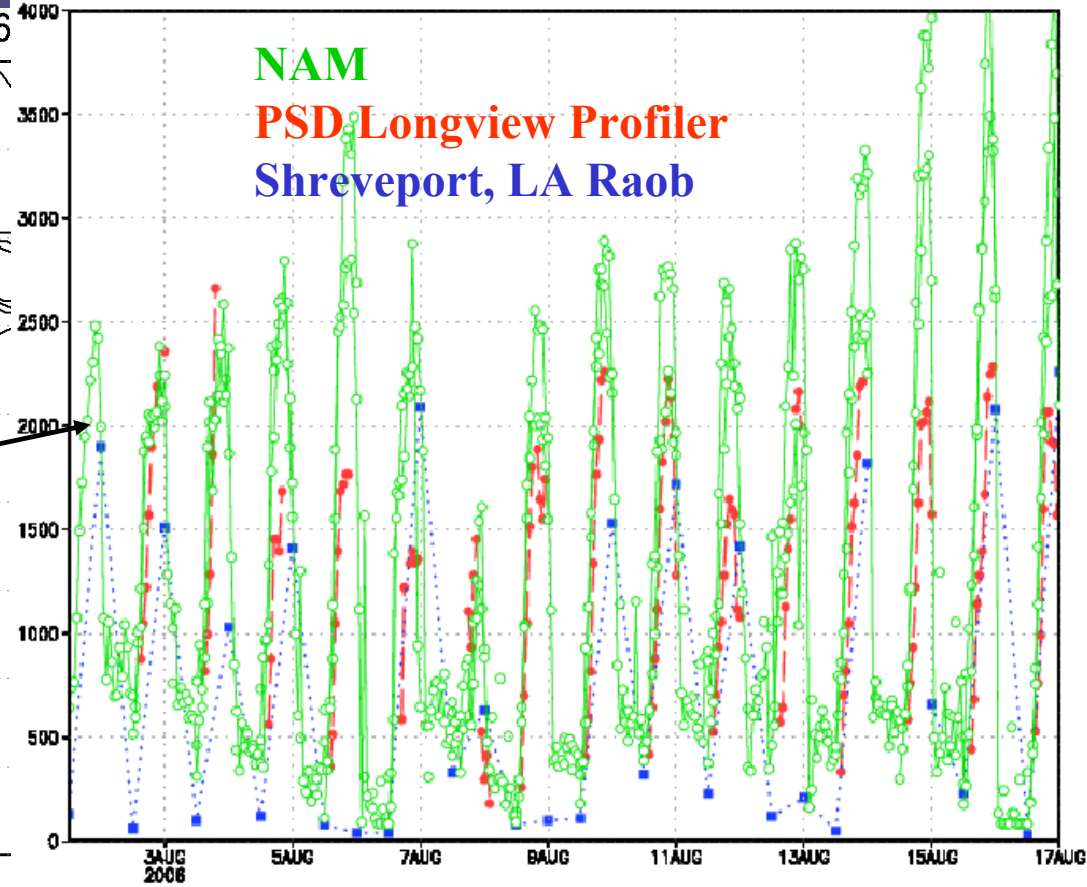
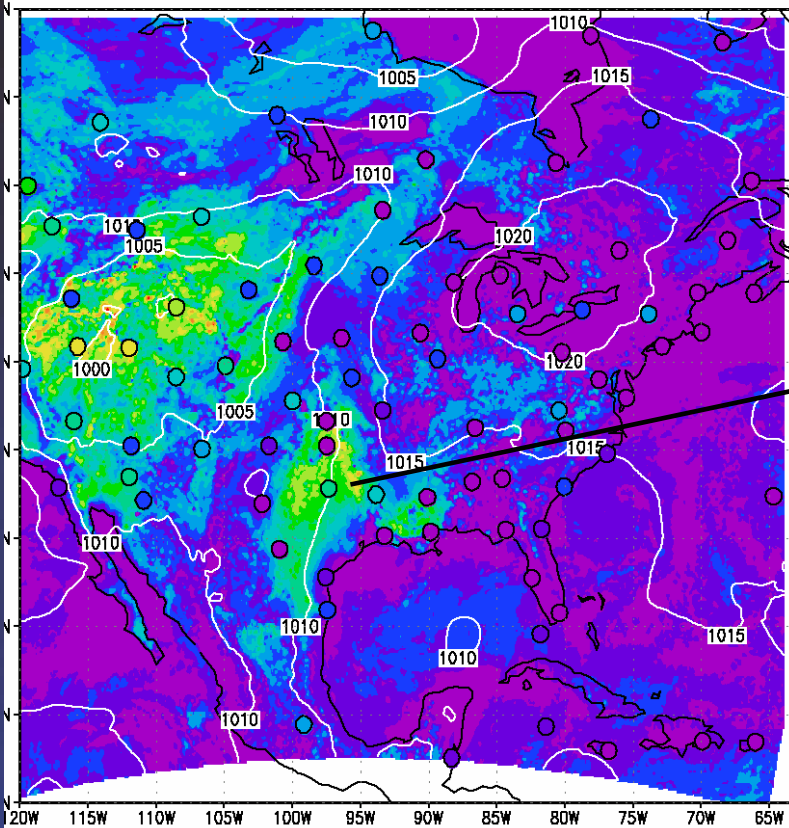


NAM PBL evaluation

using *TEXAQS06* profilers



12hr fcst PBL height Valid 00Z17AUG2006

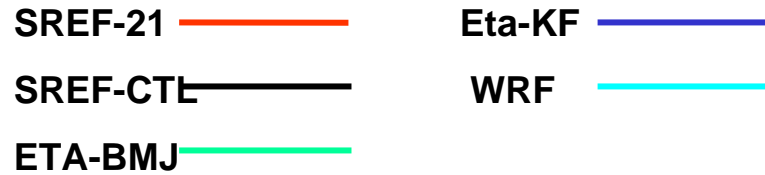




Statistical Consistency (August 2006)



48 hour Forecast Winds

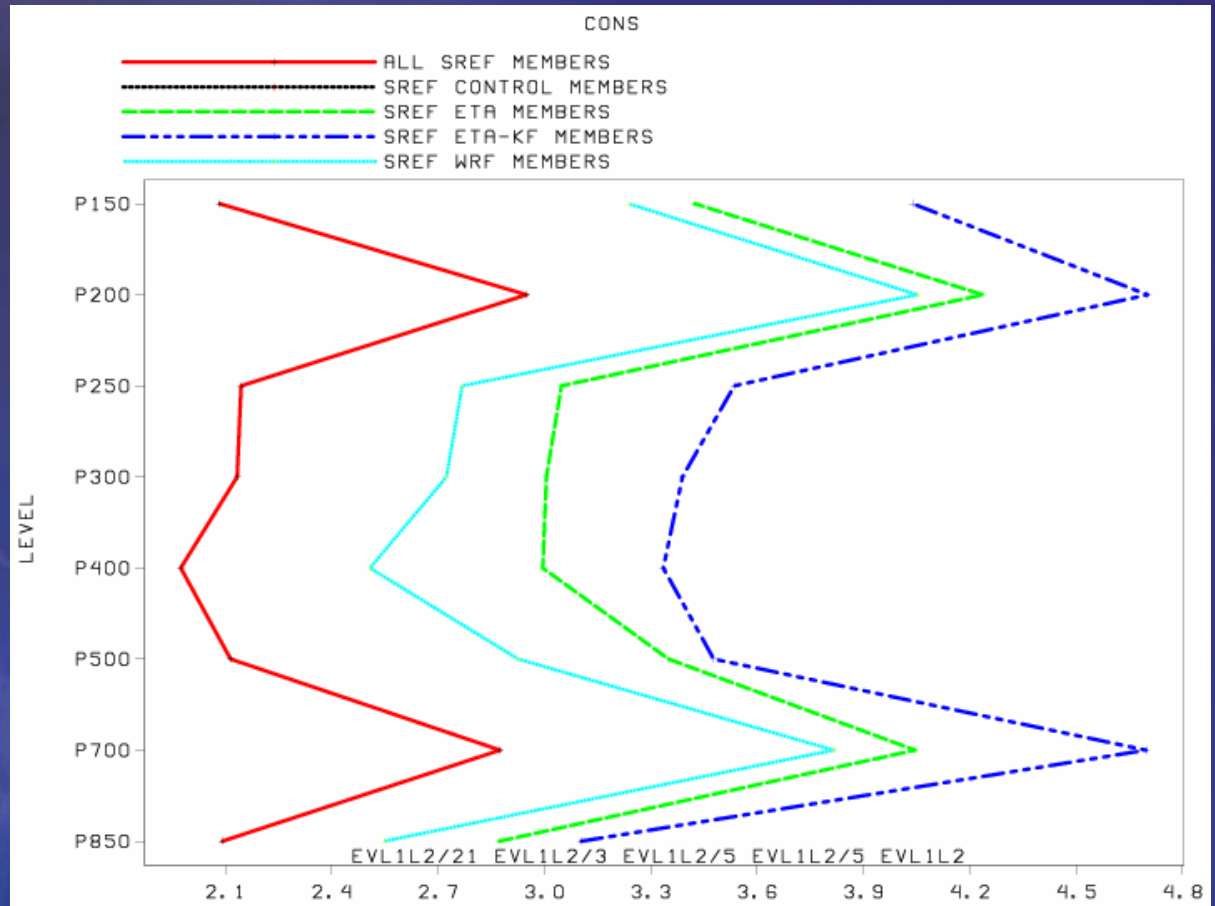


Mean Squared Error Ensemble Variance

best ~ 1 (Buizza, et al. 1999)

• *SREF-21 improved*

• *WRF subset yields lowest statistical consistency compared to Eta subsets*





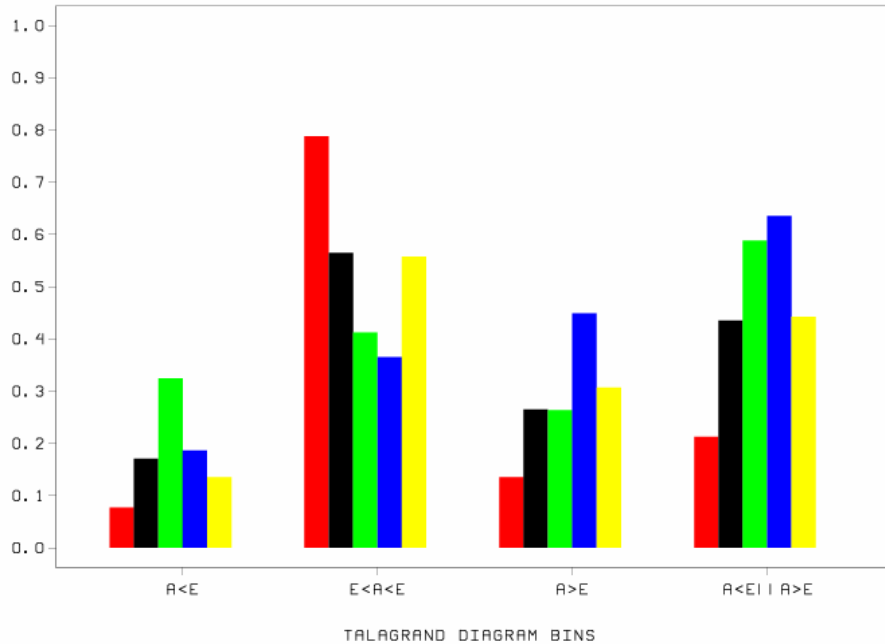
SREF Operational Performance



Outlier Percentage 48 h forecasts (August 2006)

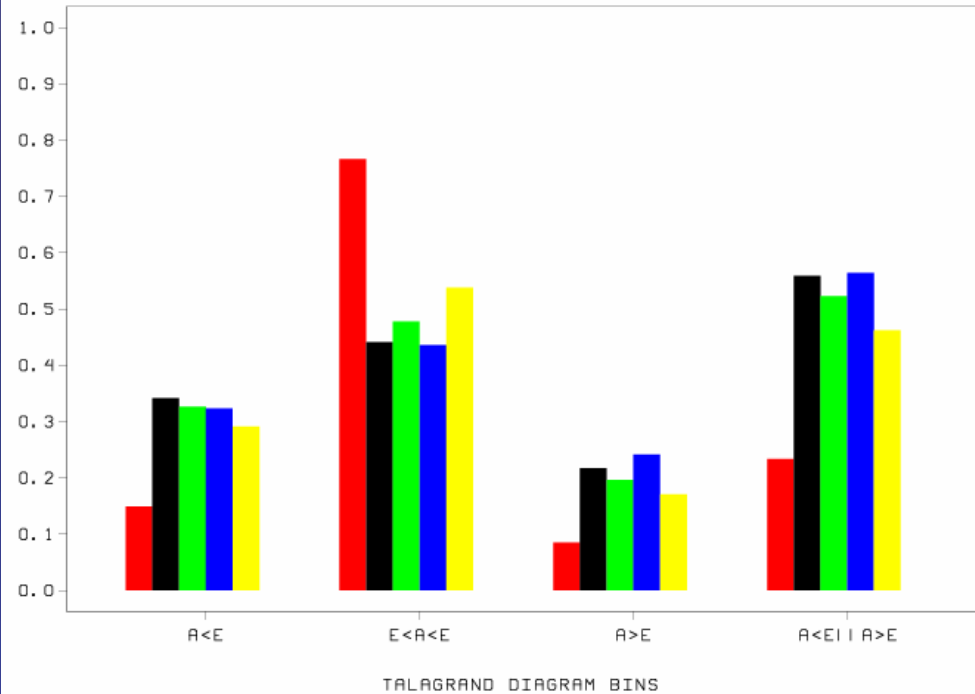
OUTL T ERROR AVERAGED BY DAY FOR FORECAST HOUR: FORECAT HRS: 48

- ALL SREF MEMBERS
- SREF CONTROL MEMBERS
- SREF ETA MEMBERS
- SREF ETA KF MEMBERS
- SREF WRF MEMBERS



OUTL VWND ERROR AVERAGED BY DAY FOR FORECAST HOUR: FORECAT HRS: 48

- ALL SREF MEMBERS
- SREF CONTROL MEMBERS
- SREF ETA MEMBERS
- SREF ETA KF MEMBERS
- SREF WRF MEMBERS



2 m Temperature

10 m Wind

- *Outlier percentage reduced for SREF/21 system*
- *WRF sub-member agree best w/ obs as compared to Eta and RSM sub-members*



Met. Ensembles For ATD

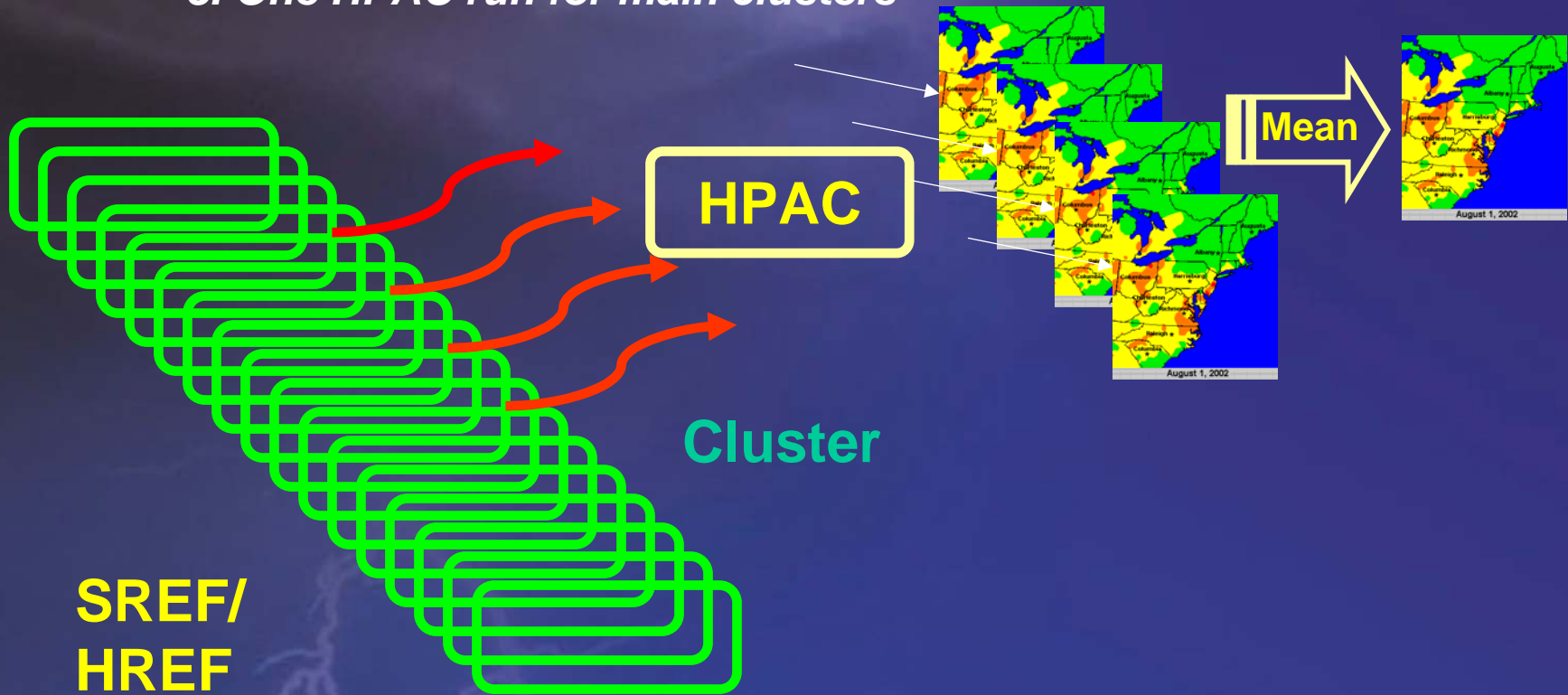
- **For ATD: physics perturbation techniques are promising**
 - *PBL parameterization*
 - *Land Surface Model specifications*
 - *Convective parameterizations*
 - *Stochastic physics efforts*
- **Will also need IC perturbations esp. for strong synoptically forced events**
- **Postprocessing**
 - *Bias correct winds, temp, rh, precip*
 - *Use ensemble wind variance as estimate of LSV (Wind error correlated with Wind variance, Coielle, 2005)*
 - *Reforecasting Project*
 - *Cluster ensemble members to drive Scipuff most likely scenarios (COSMO-LEPS approach)*



Dispersion Ensemble Configurations



1. One HPAC run (Ens. Median/variance)
2. One HPAC run for each member
3. One HPAC run for main clusters



Cluster analysis can choose a smaller set of members statistically different from one another that correspond to the daily weather pattern.



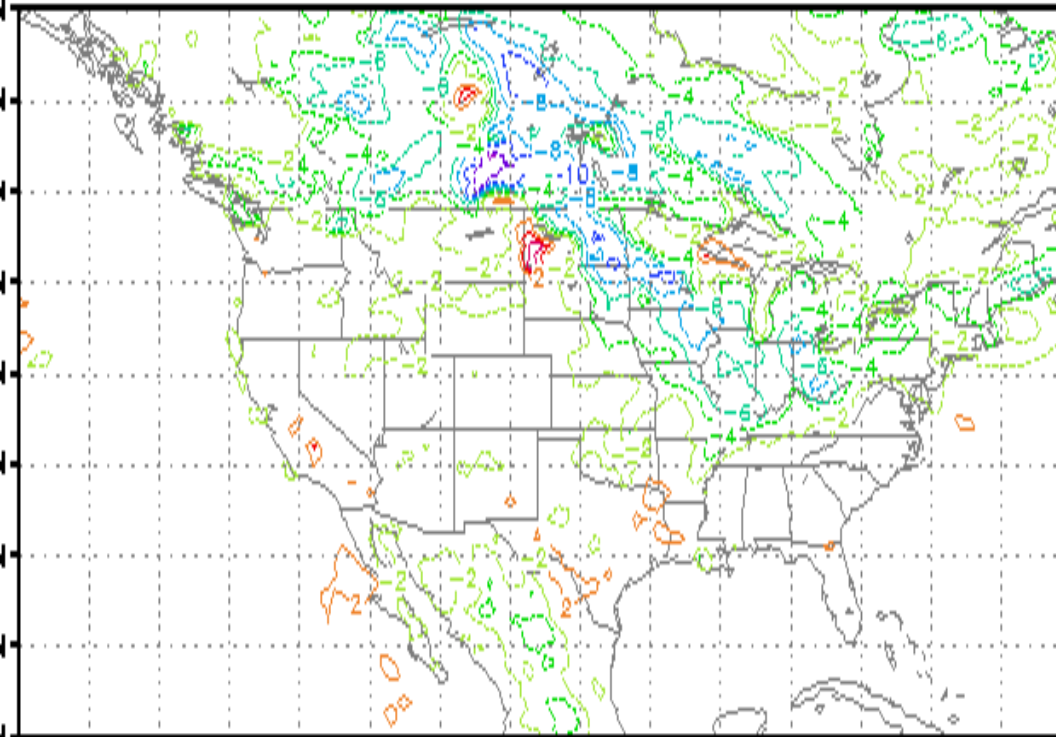
Soil Moisture Perturbations

Impact on T2m is significant

Jun Du & George Gayno

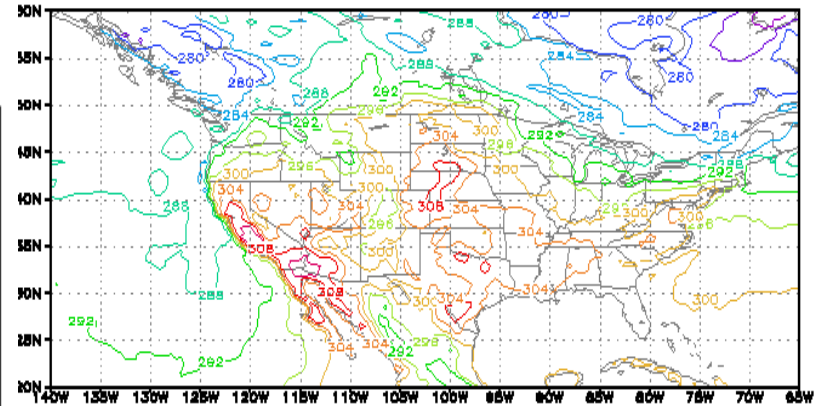


Diff of T2m, F72 fr 06082021(NMM_ctl3-NMM_ctl4)



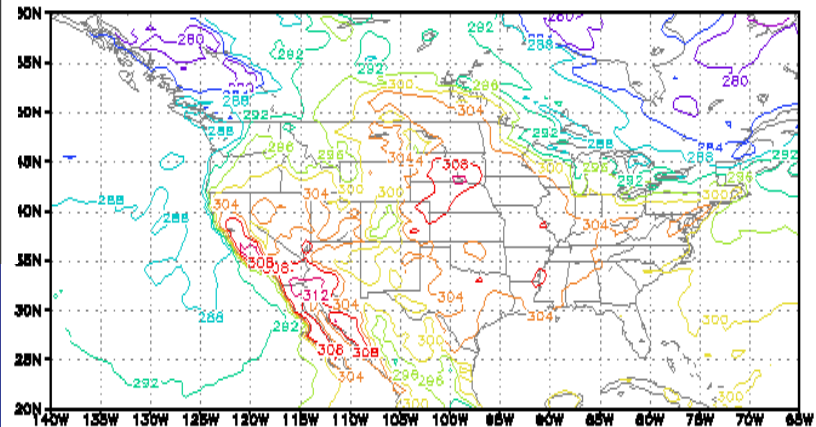
T2m diff (namSM – gfsSM, NMM)

FCST of T2m, F72 fr 06082021(NMM_ctl3)



With nam soil moisture (NMM)

FCST of T2m, F72 fr 06082021(NMM_ctl4)



With gfs soil moisture (NMM)



Met Ensembles for ATD HREF 12 km Experiment

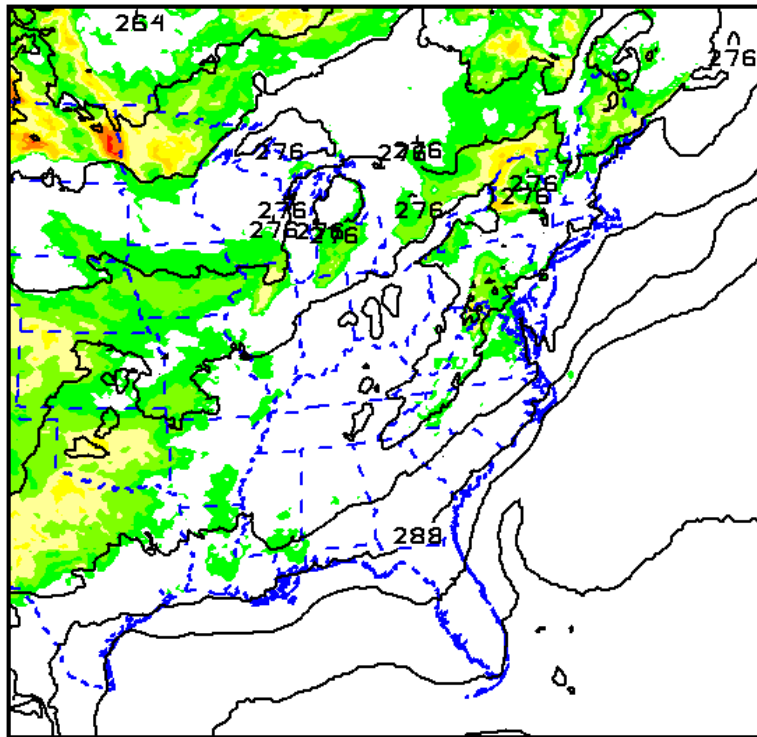


- **10 WRF members configured for Eastern U.S.**
 - *12 km DX, 48 hour forecasts, 2x/day (06 & 18 Z)*
 - *5 WRF ARW members (1 control, 2 breeding pairs)*
 - Physics: YSU PBL, Kain-Fritsch Convection, RRTM radiation
 - *5 WRF NMM members (1 control, 2 breeding pairs)*
 - Physics: MYJ TKE, Betts-Miller-J convection, GFDL radiation
- **Synoptic diversity: LBC & Breeding**
 - *Breeding: 12 hour forecast differences to drive IC perturbations*
 - *Lateral Boundary Conditions updated every 3 hours*
 - GENS 1-4 ET members for 2 NMM perturbed pairs
 - GENS 5-8 ET members for 2 ARW perturbed pairs
 - GENS Ctl for NMM and ARW control



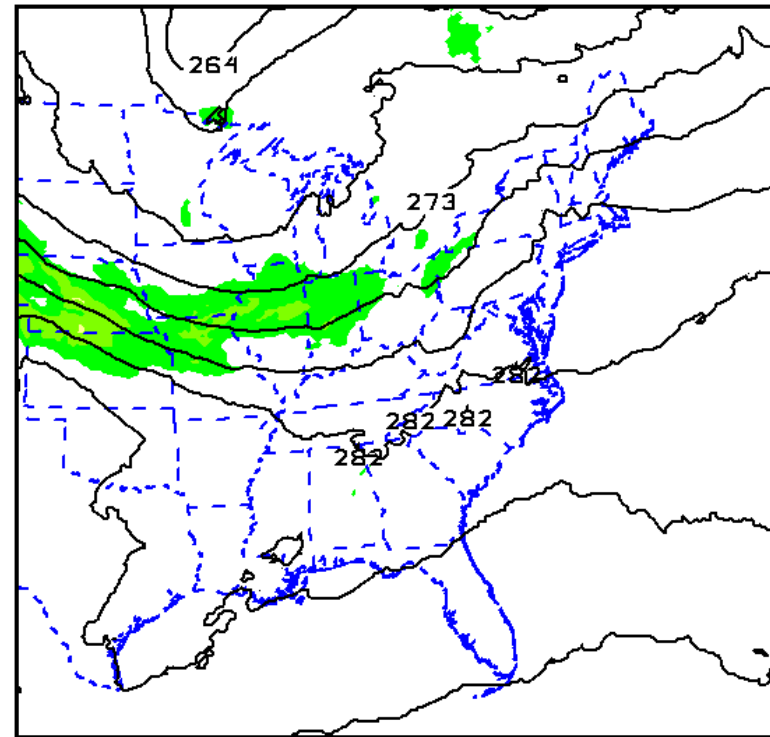
Met Ensembles for ATD

HREF 12 km mean/spread



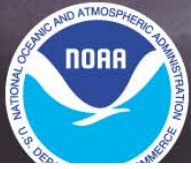
061215/0600V048 2 M TMPK

2 m Temperature
mean/spread



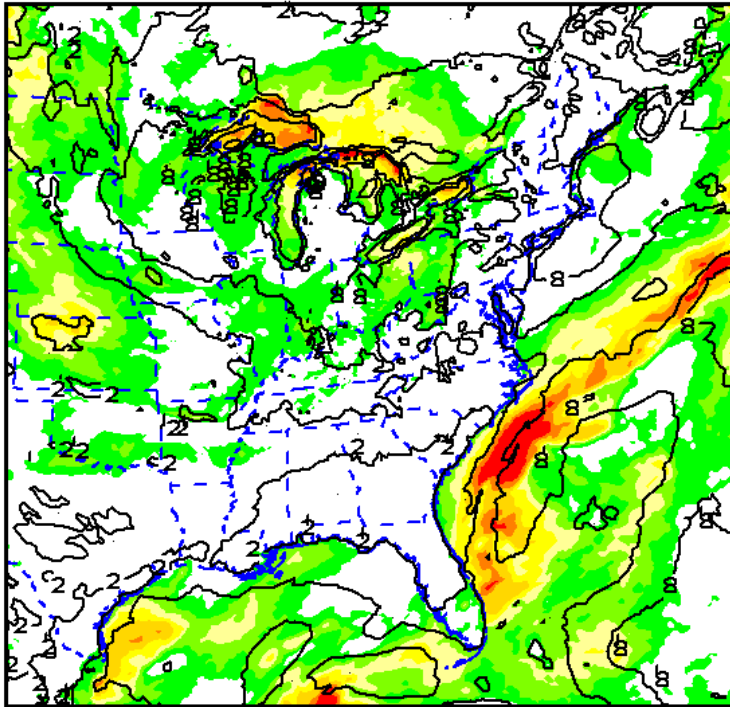
061215/0600V048 850 MB TMPK

850 mb Temperature
mean/spread

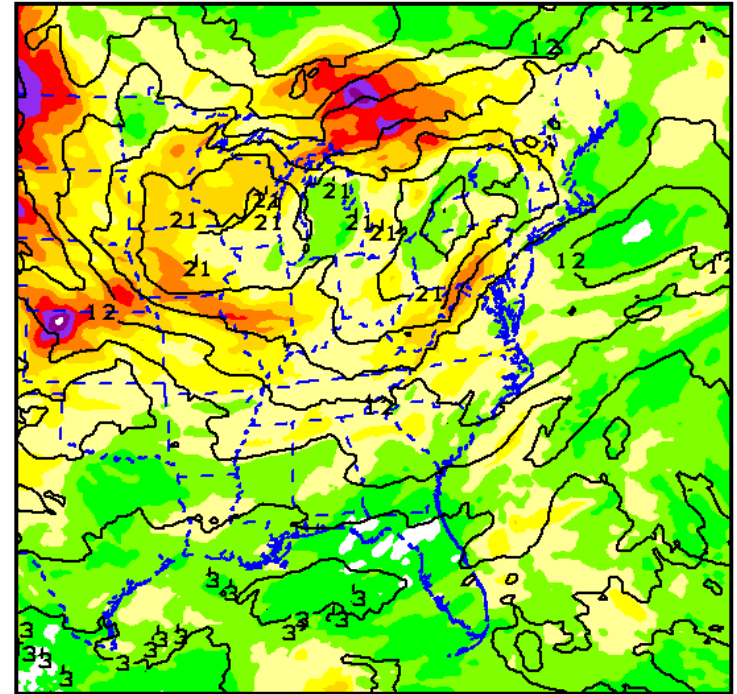


Met Ensembles for ATD

HREF 12 km mean/spread



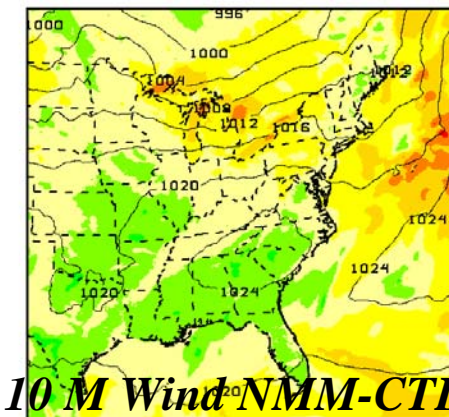
061215/0600V048 10 M



061215/0600V048 850 MB SPED

10 m Winds

850 mb Winds



10 M Wind NMM-CTL

061214/0600V048 10 M SPED



Future Work

- Evaluate 12 km Relocatable HREF System
 - *Add pbl & LSM diversity to initial condition diversity system*
 - *Compare against SREF, GENS, ARPS 4 km for NCEP/SPC spring program*
- High Resolution Testing
 - *Test the addition of a 4 km nest to HREF NMM control*
 - *Evaluate with DCNET and URBANET data*
- Provision of Products
 - *Provision of ensemble median, wind variance and length scales to MDS for SCIPUFF sensitivity testing*
- Complete evaluation of WRF turbulence & PBL fields for coupling with HPAC w/ PSU, Titan and Hanna Consultants
- Improved probabilistic verification package



BACKUPS

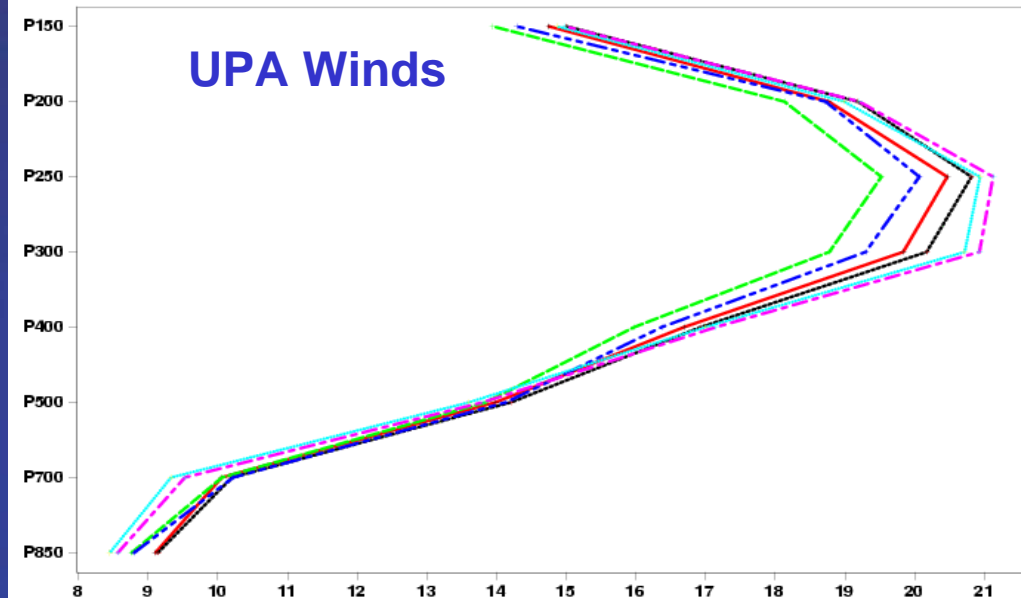
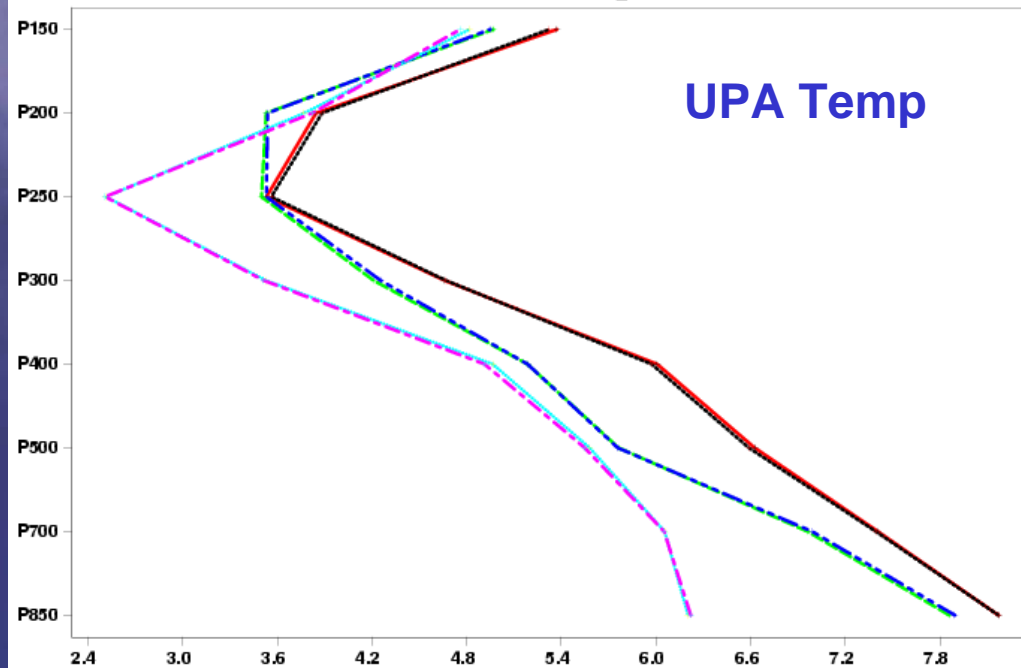


SREF Performance

48 h forecast Spread (Nov. 2005)



CONUS	
CONUS-21	
EAST-15	
EAST-21	
West-15	
West-21	



- SREF-21 improved over SREF-15
- Temperature:
 - Spread is smallest in West and near Tropopause
- Winds:
 - Spread is greatest in West and near Tropopause



SREF Operational Performance



Outlier Percentage

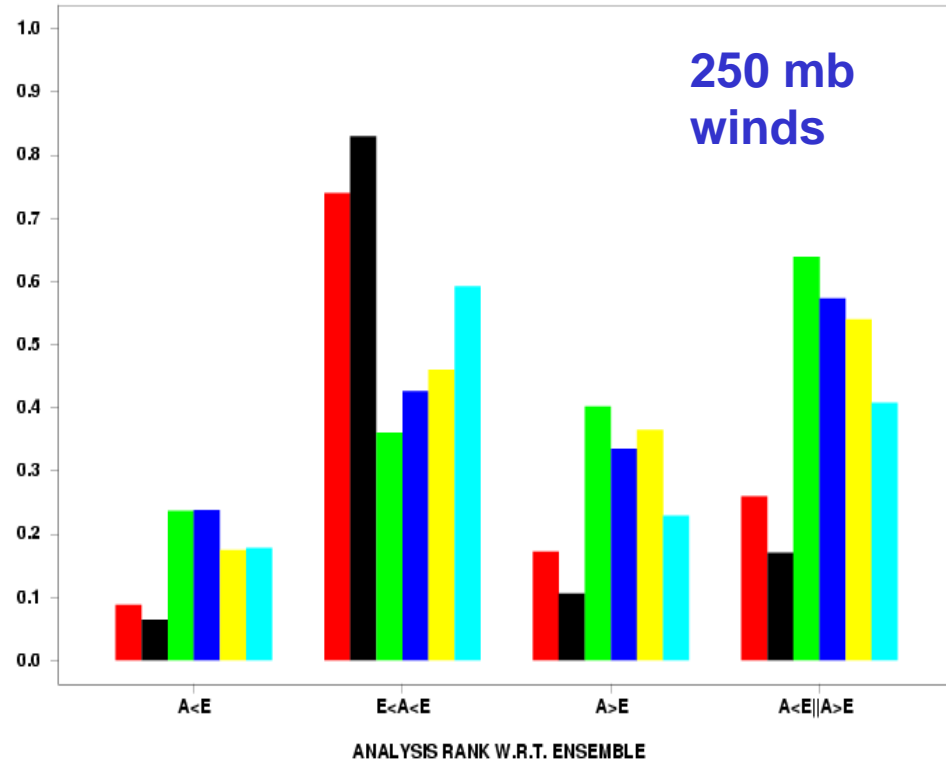
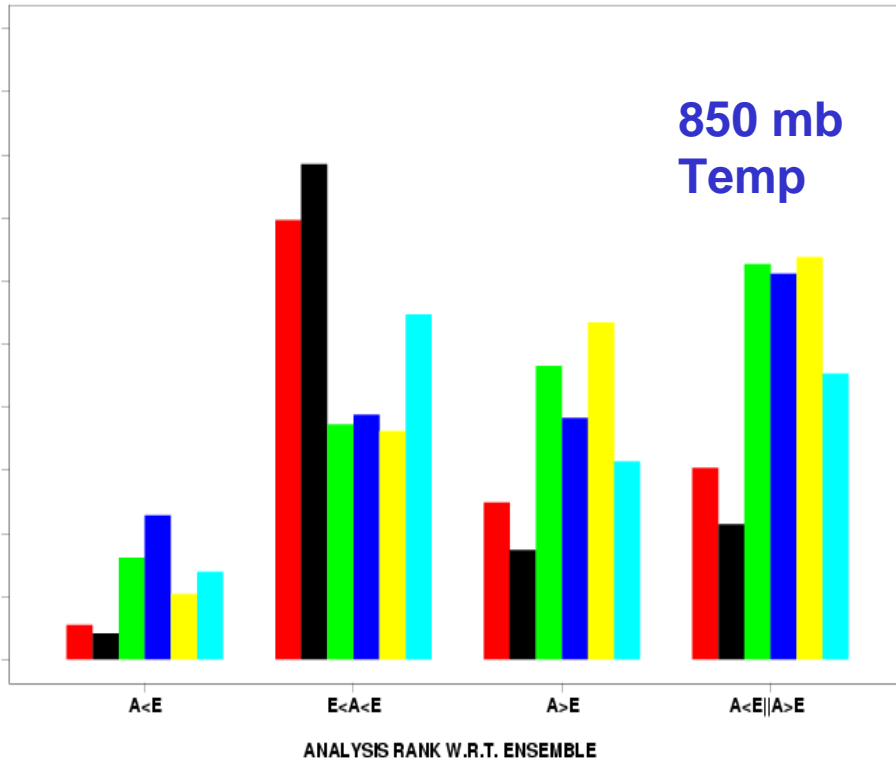
48 h forecasts (November 2005)

STAT=RHET PARAM=T FHOURL=51 V_ANL=ADPUPA V_RGN=G236 LEVEL=P850 VHHMM=1200

STAT=RHET PARAM=VWND FHOURL=51 V_ANL=ADPUPA V_RGN=G236 LEVEL=P250 VHHMM=1200

- MODEL-SREF/ALL
- MODEL-SREF/21
- MODEL-SREF/CTL
- MODEL-SREF/ETA
- MODEL-SREF/RSM
- MODEL-SREF/WRF

- MODEL-SREF/ALL
- MODEL-SREF/21
- MODEL-SREF/CTL
- MODEL-SREF/ETA
- MODEL-SREF/RSM
- MODEL-SREF/WRF



- *Outlier percentage reduced for SREF/21 system*
- *WRF sub-member agree best w/ obs as compared to Eta and RSM sub-members*



ARL HYSPLIT Web Interface

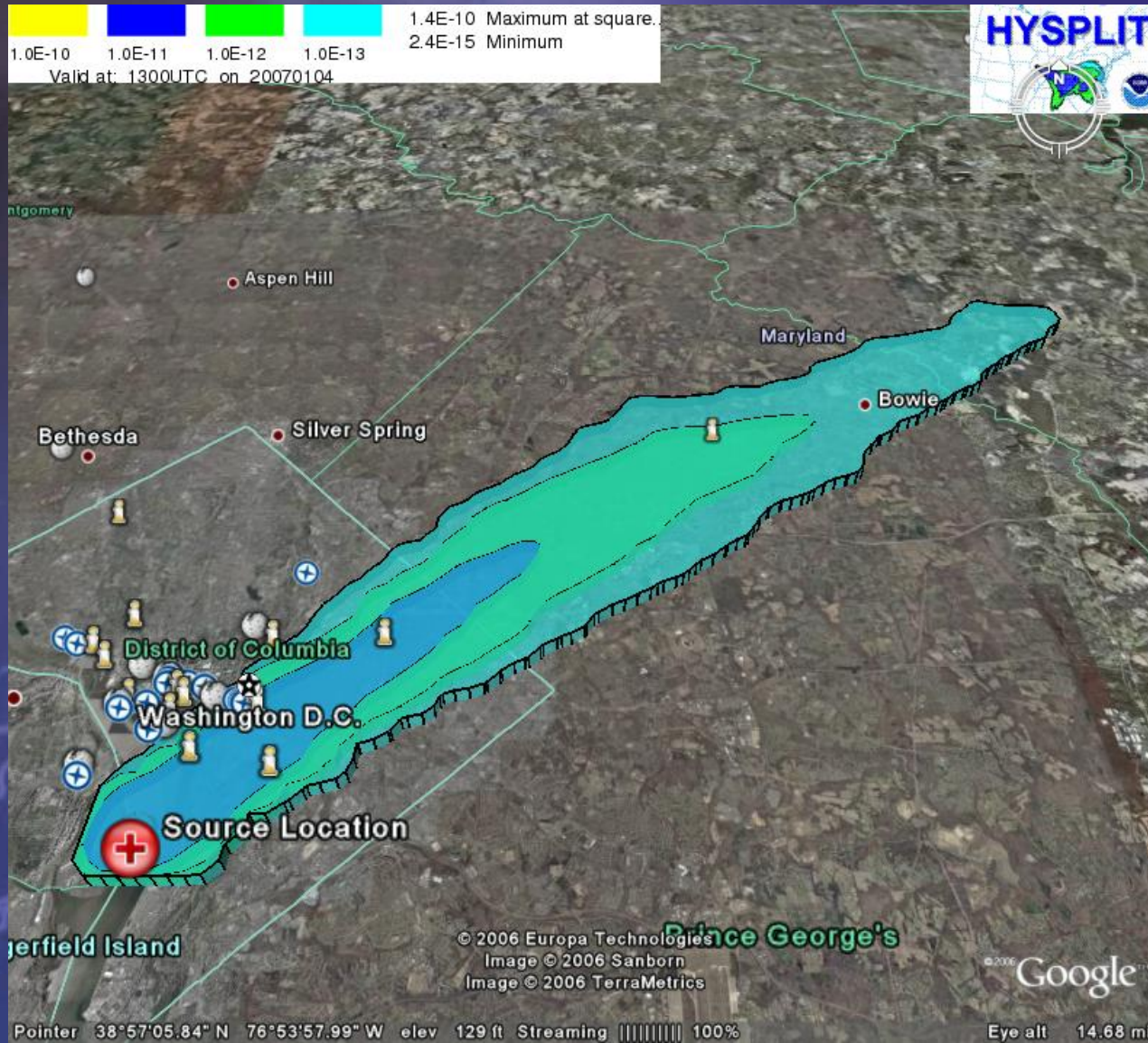
- Web based interface that allow user to customize:
- Source location
- Source strength
- Deposition effects
- Release Duration
- Forecast Length
- Graphical Display
- ESRI GIS
- Google Earth Interface



ARL HYSPLIT Web Interface



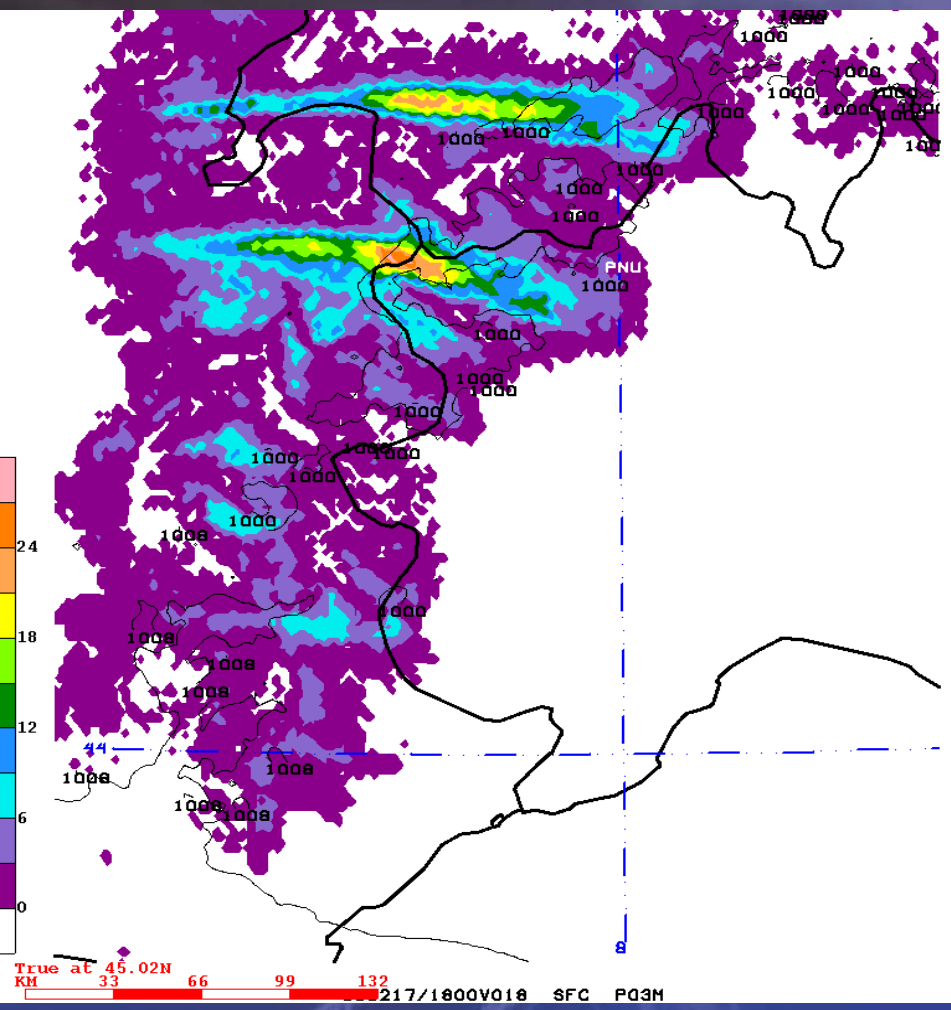
Google Earth Display



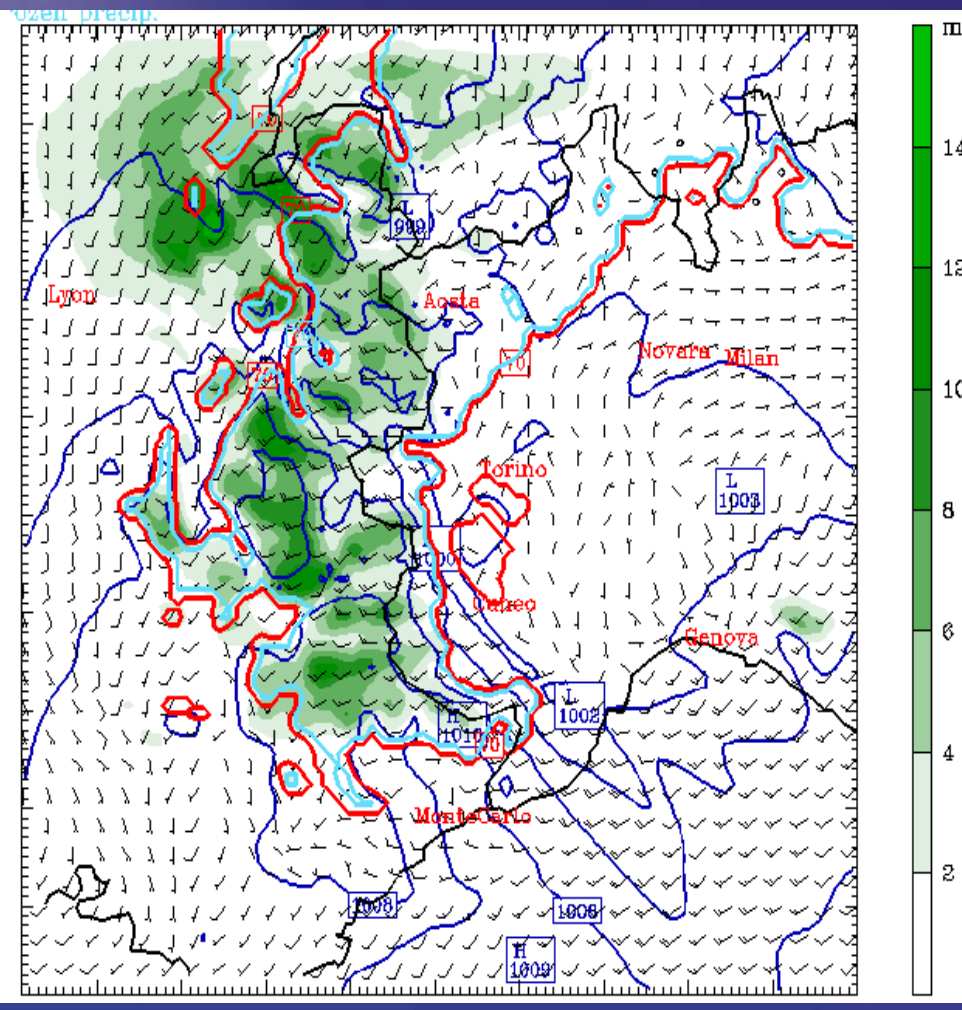


Torino Olympics

*Snow Storm Forecasts (3h precip)
00 UTC Feb. 17, 2006 18 h Forecasts*

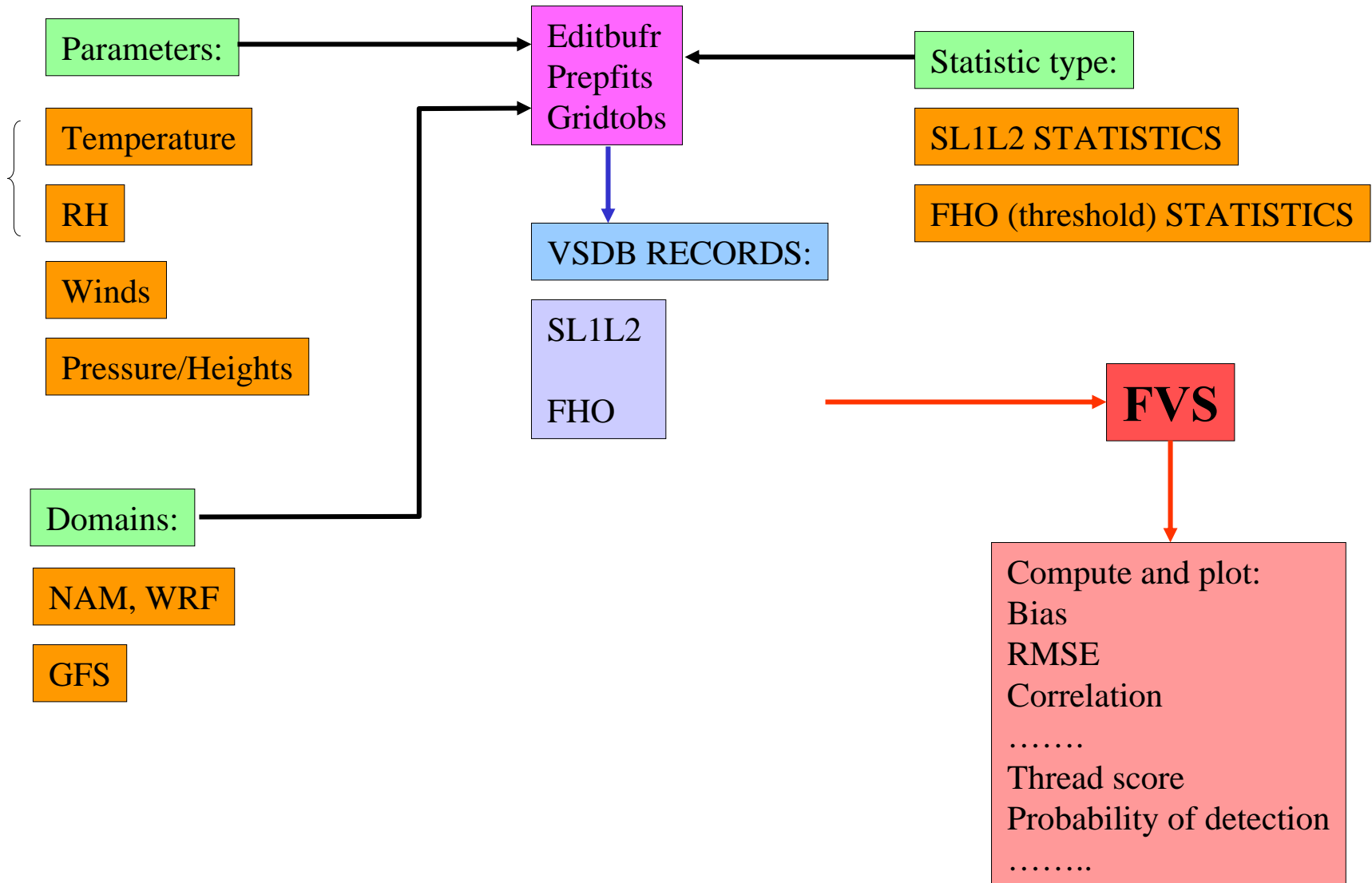


WRF-NMM 4km Zoom

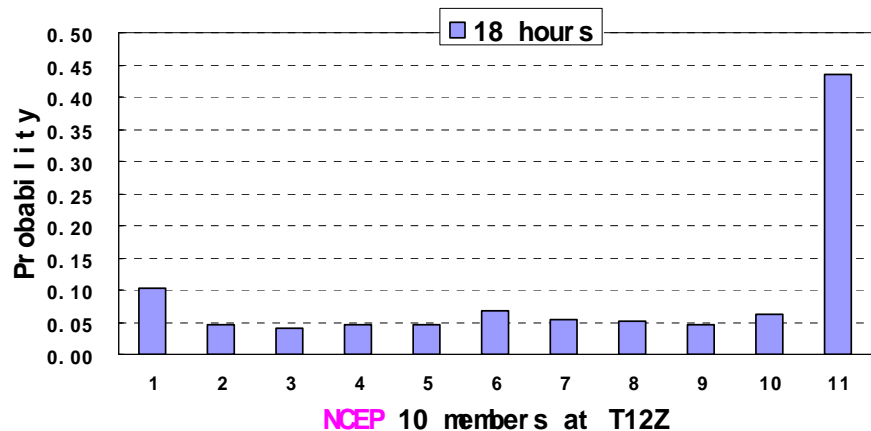


MM5 4 km

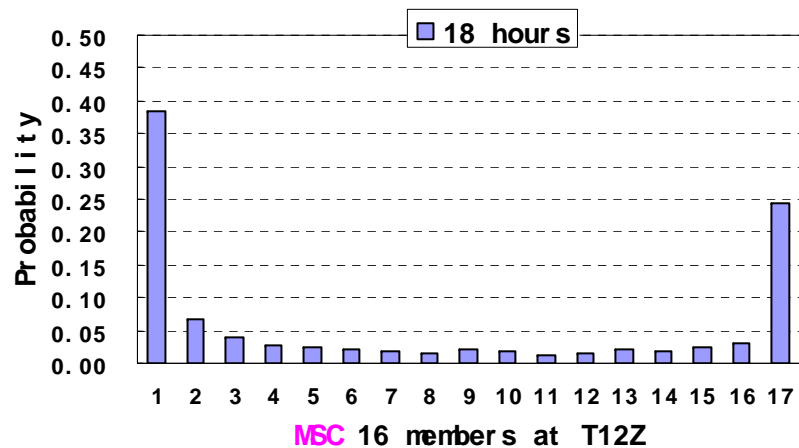
FVS VERIFICATION



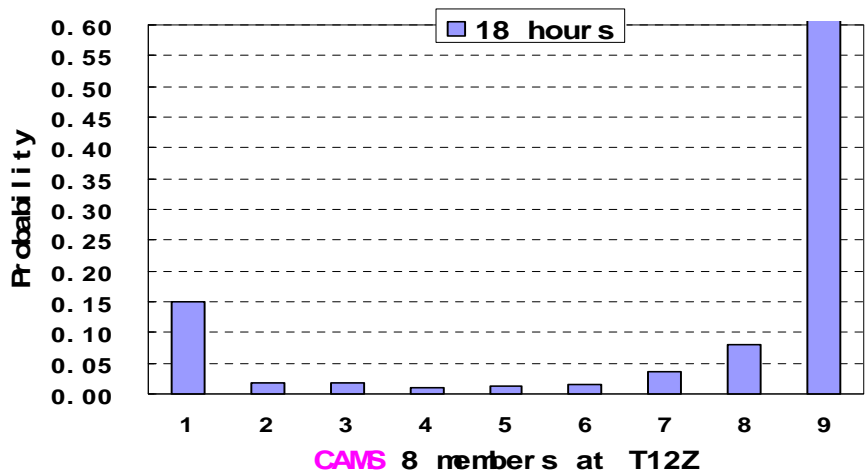
Tal agr and Di st r i but i on (2m t e m p e r a t u r e) average for 20060808-20060824



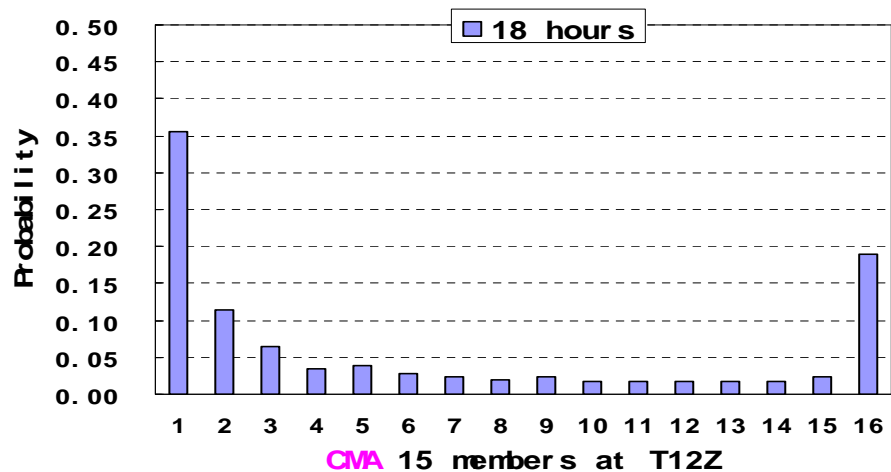
Tal agr and Di st r i but i on (2m t e m p e r a t u r e) average for 20060808-20060824



Tal agr and Di st r i but i on (2m t e m p e r a t u r e) average for 20060808-20060824



Tal agr and Di st r i but i on (2m t e m p e r a t u r e) average for 20060808-20060824



(from NMC/CMA, Y. Li)

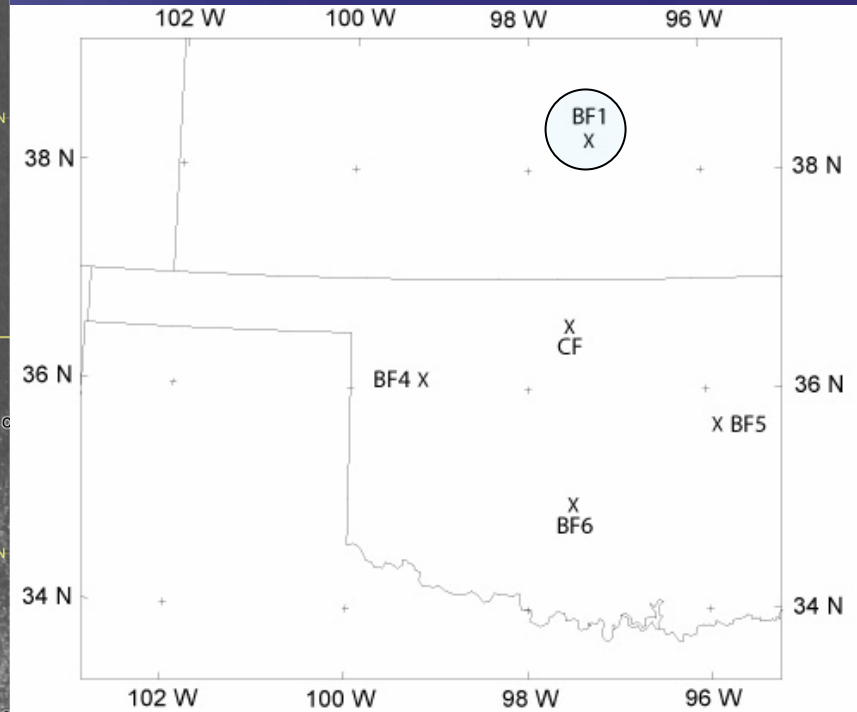
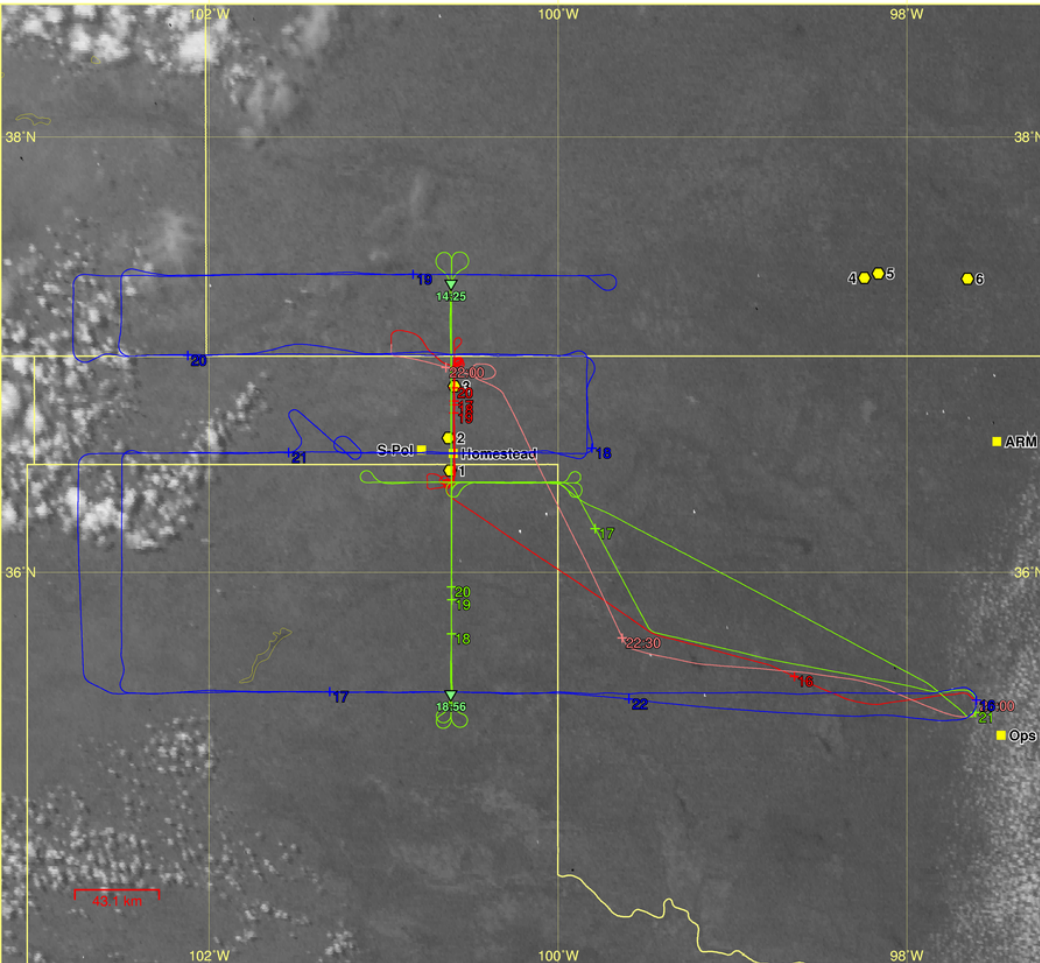


IHOP May 29, 2002 case



BLH Mission 2002/05/29 1530-0200 UTC
 GOES-8 1km visible 2002/05/29 18:55 UTC

- NCAR Integrated Surface Flux Facility
- ▼ Falcon Drogsondes(2) 05/29 14:25:18 - 05/29 18:56:02 UTC
- King Air 05/29 15:36 - 05/29 20:39 UTC
- King Air 05/29 21:46 - 05/29 23:01 UTC
- Falcon 05/29 16:30 - 05/29 21:01 UTC
- NRL P-3 05/29 15:47 - 05/29 22:28 UTC



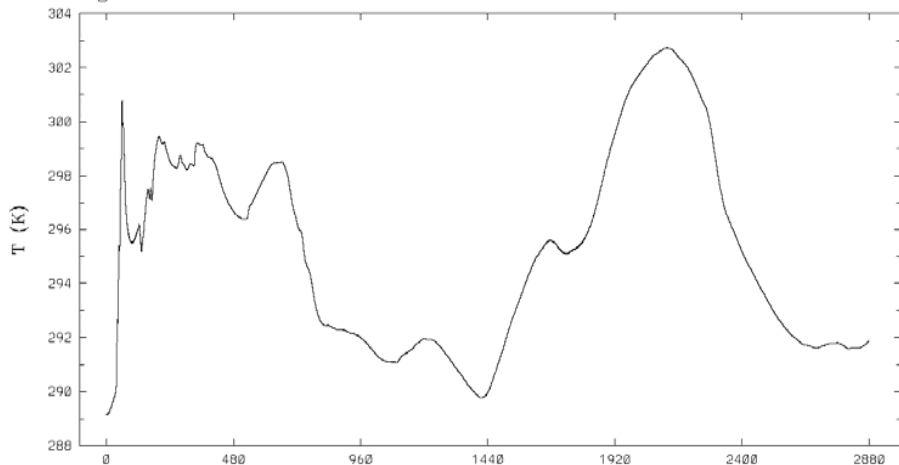


IHOP May 29, 2002 case



TEMPERATURE (T)
Time Series at Model Level 1
Location: 1 Lat=36.605 Lon=-97.485

Begin Time: 2002-05-28 12:00:00.0000 End Time: 2002-05-30 12:00:00.0000

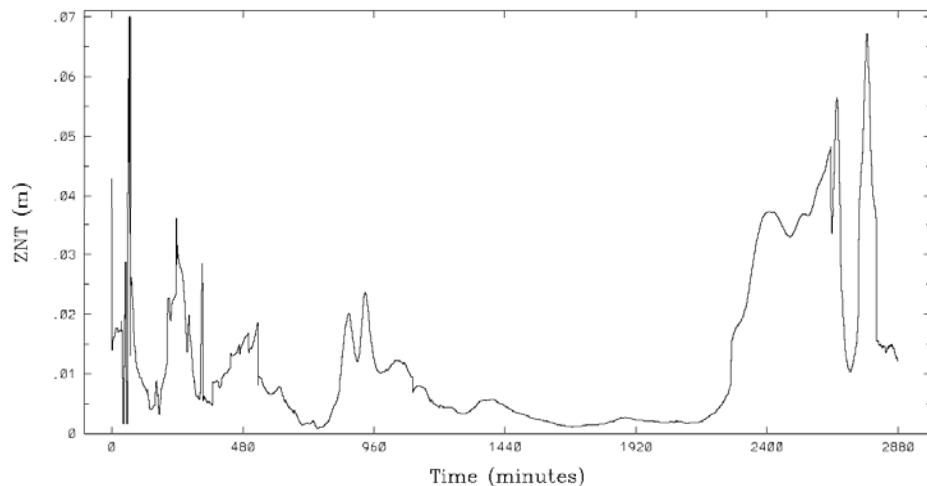


12Z 20Z 04Z Time **12Z** (minutes)
Loc. 1 (lat=36.60,lon=-97.49) for IHOP 29 May All Output

Roughness length (ZNT)
Time Series

Location: 1 Lat=36.605 Lon=-97.485

Begin Time: 2002-05-28 12:00:00.0000 End Time: 2002-05-30 12:00:00.0000

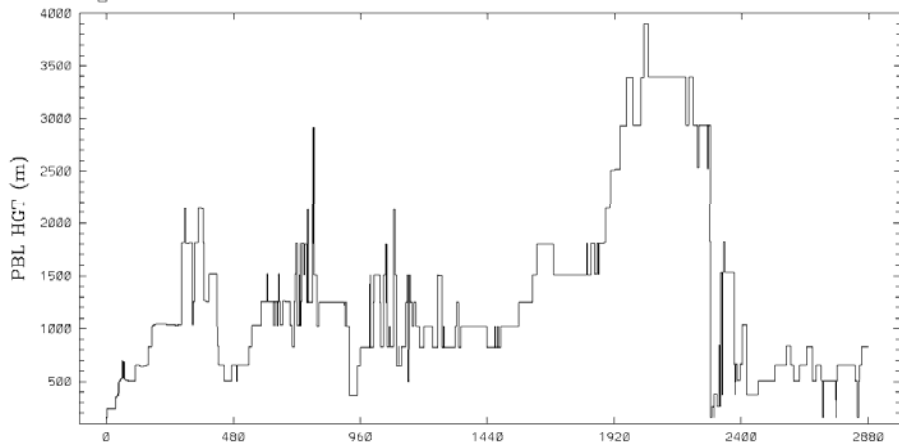


Time (minutes)
Loc. 1 (lat=36.60,lon=-97.49) for IHOP 29 May All Output

PBL Height (PBL HGT)
Time Series

Location: 1 Lat=36.605 Lon=-97.485

Begin Time: 2002-05-28 12:00:00.0000 End Time: 2002-05-30 12:00:00.0000



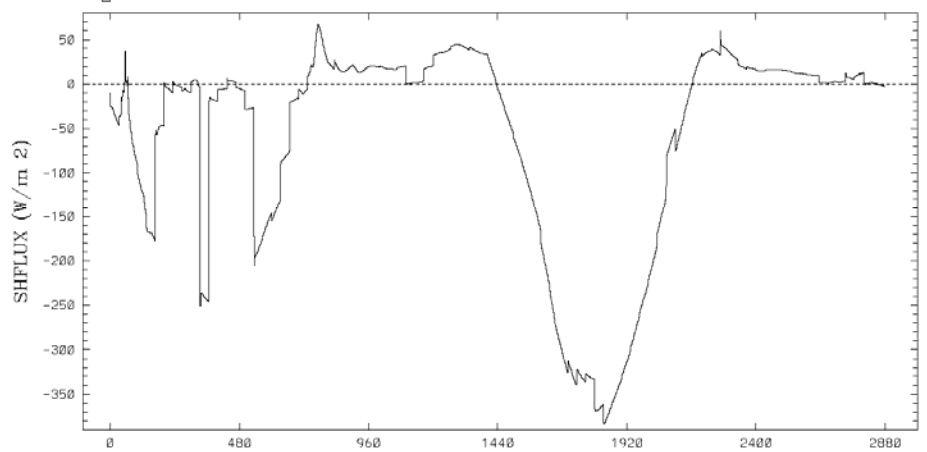
Time (minutes)
Loc. 1 (lat=36.60,lon=-97.49) for IHOP 29 May All Output

Surface sensible heat flux (SHFLUX)

Time Series

Location: 1 Lat=36.605 Lon=-97.485

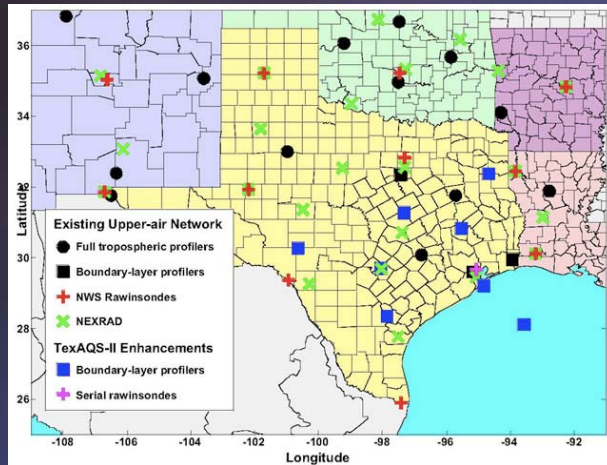
Begin Time: 2002-05-28 12:00:00.0000 End Time: 2002-05-30 12:00:00.0000



Time (minutes)
Loc. 1 (lat=36.60,lon=-97.49) for IHOP 29 May All Output



Two field campaigns provide intensive observations for potential use in regional analysis



2006 Texas Air Quality Study/Gulf of Mexico Atmospheric Composition and Climate Study (8/1 - 9/30)

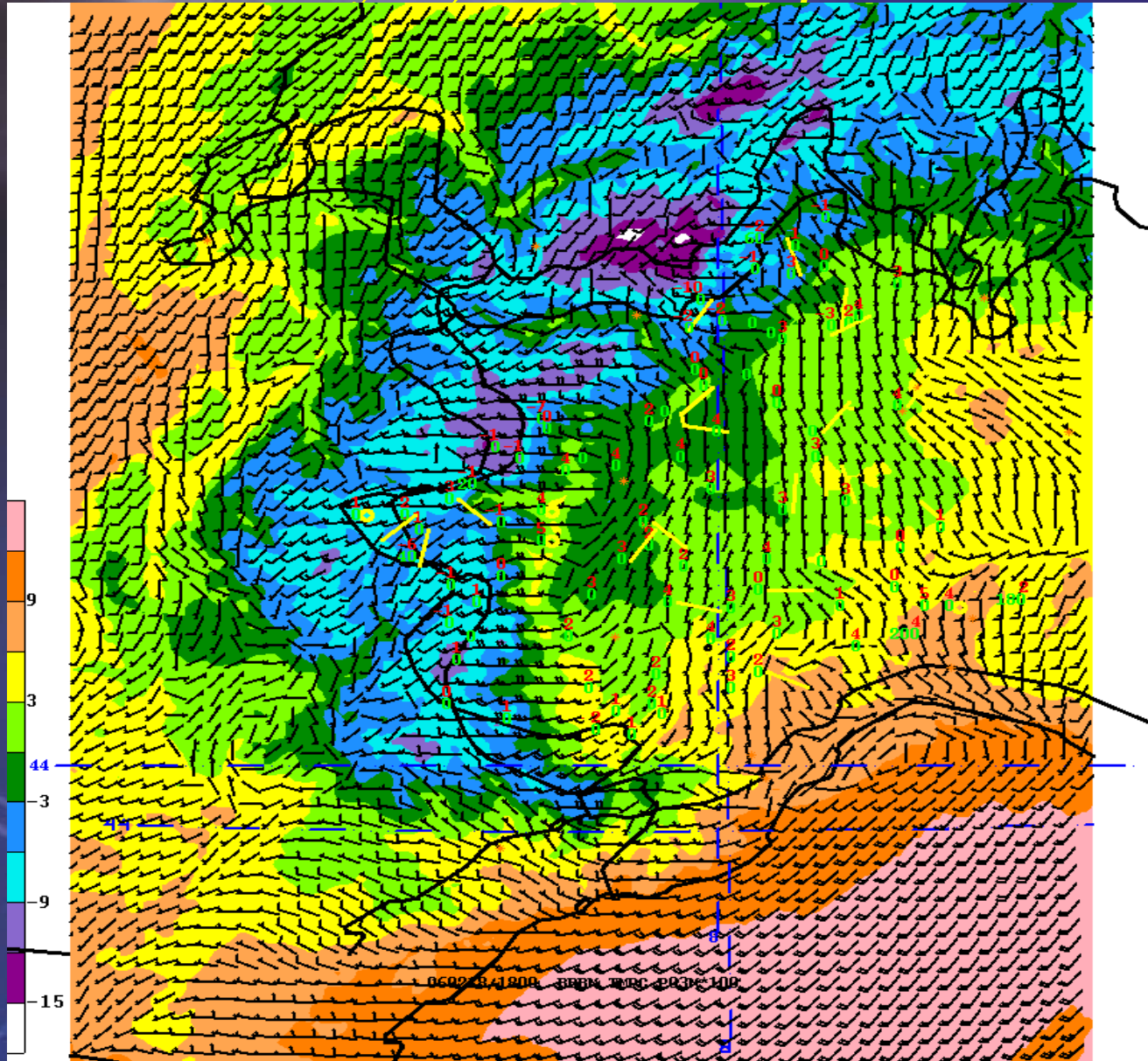


WAVES_2006: Water Vapor Validation Experiment – Satellite/Sondes in Beltsville, MD (7/17– 8/10)



Torino Olympics

February 18, 2006 case temperature

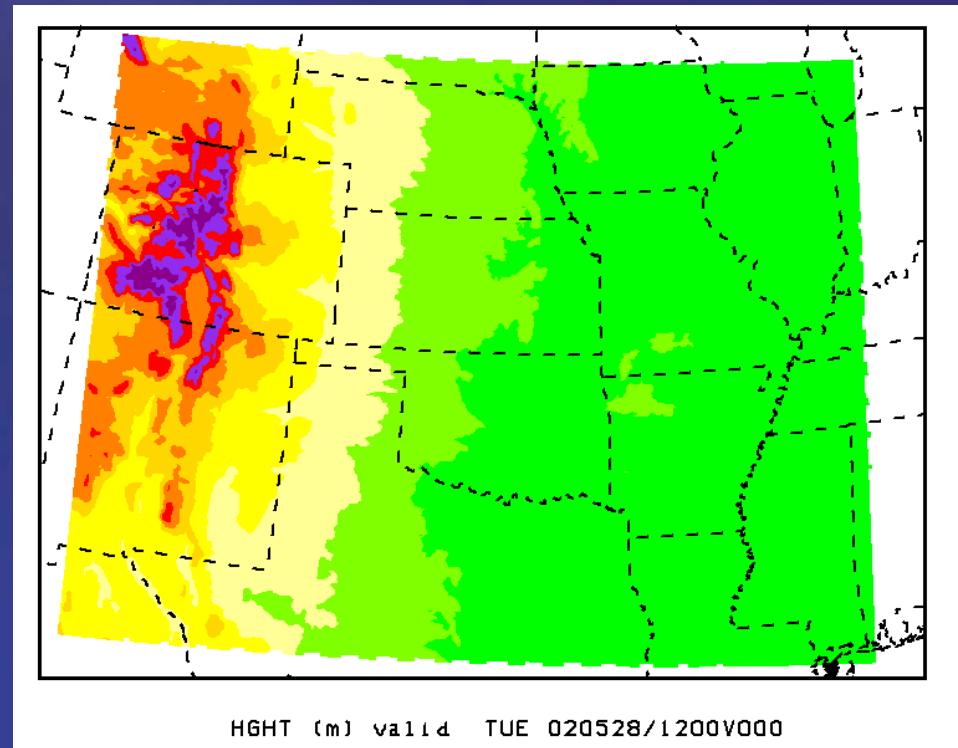


060218/1800V018 2 M TMPC



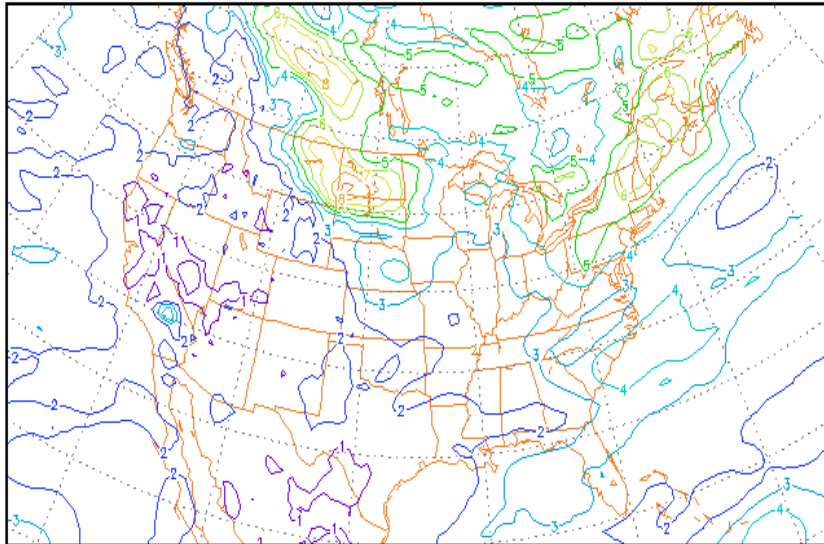
IHOP May 29, 2002 case

- WRF-NMM Initialized from NDAS at May 28, 2002, 12Z
- 4 km, 50 Level, 48 hour forecasts
- Central U.S. Nest (260x410)
- Mellor-Yamada-Janjic TKE
- NOAH LSM
- Ferrier Micro-physics
- Betts-Miller-J Convection



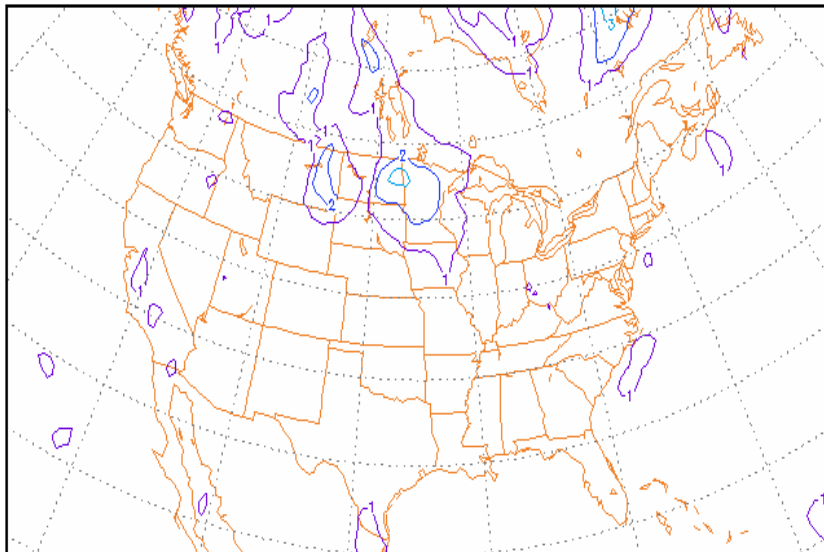
Sigma U (m/s) on 850mb

At 78H, FCST from 09z Jul 28 2006. Verified Time: 15z 07/31/2006



Sigma V (m/s) on 850mb

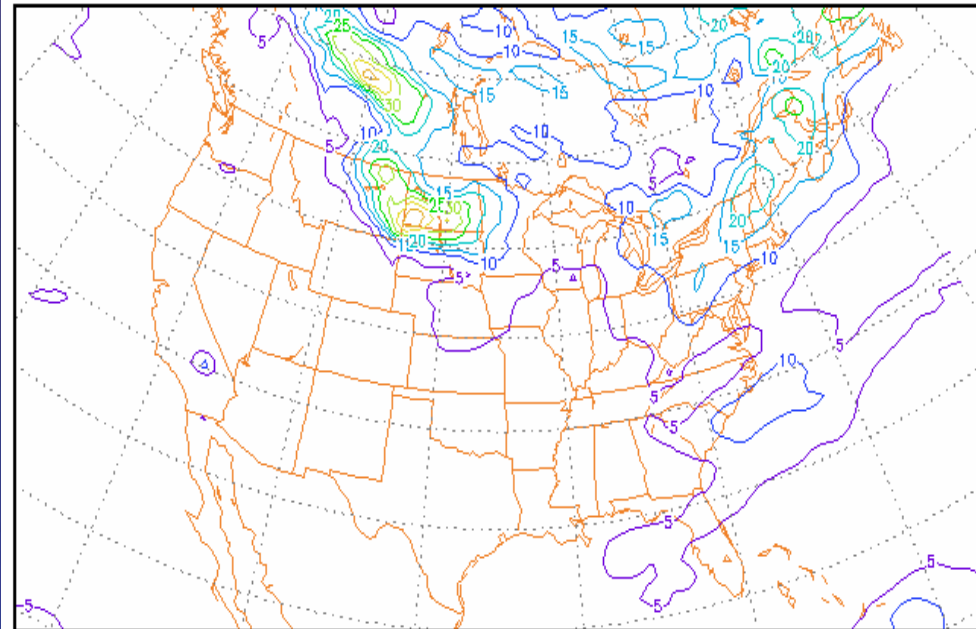
At 78H, FCST from 09z Jul 28 2006. Verified Time: 15z 07/31/2006



Binbin Zhou, EMC

Ensemble Kinetic Energy (J, $0.5*(u^2+v^2+w^2)$) on 850m

At 78H, FCST from 09z Jul 28 2006. Verified Time: 15z 07/31/2006



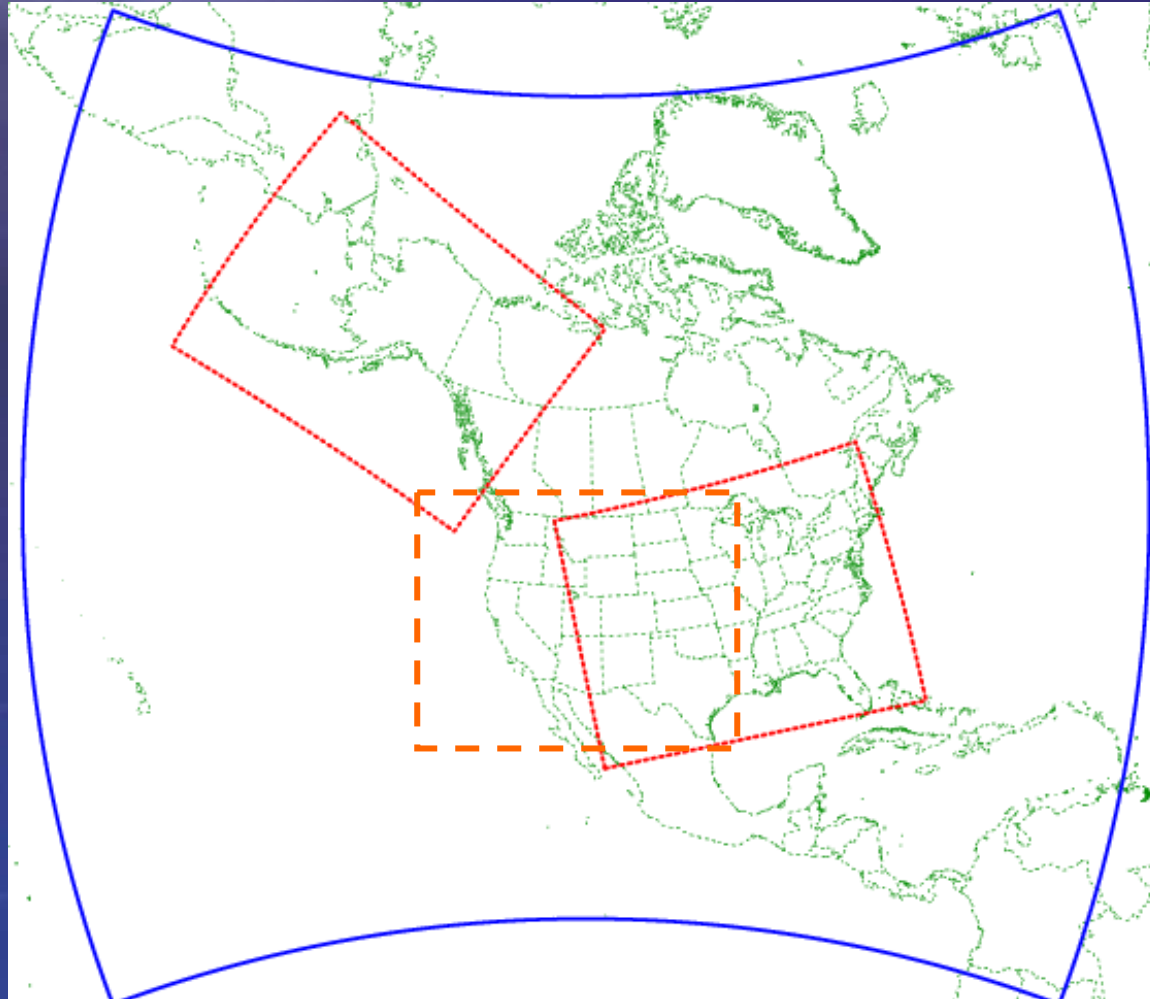
**$EKE=0.5*(UU+VV+WW)$, where
UU, VV, WW are ensemble variances**



HiResWindow Fixed-Domain Nested Runs



Proposed ~4km run Configuration



- **FOUR** routine runs made at the same time every day
- 00Z : ECentral & Hawaii
- 06Z : Alaska & Puerto Rico
- 12Z : ECentral & Hawaii
- 18Z : WCentral & Puerto Rico
- Everyone gets daily high resolution runs *if & only if* hurricane runs are not needed

SREF Performance

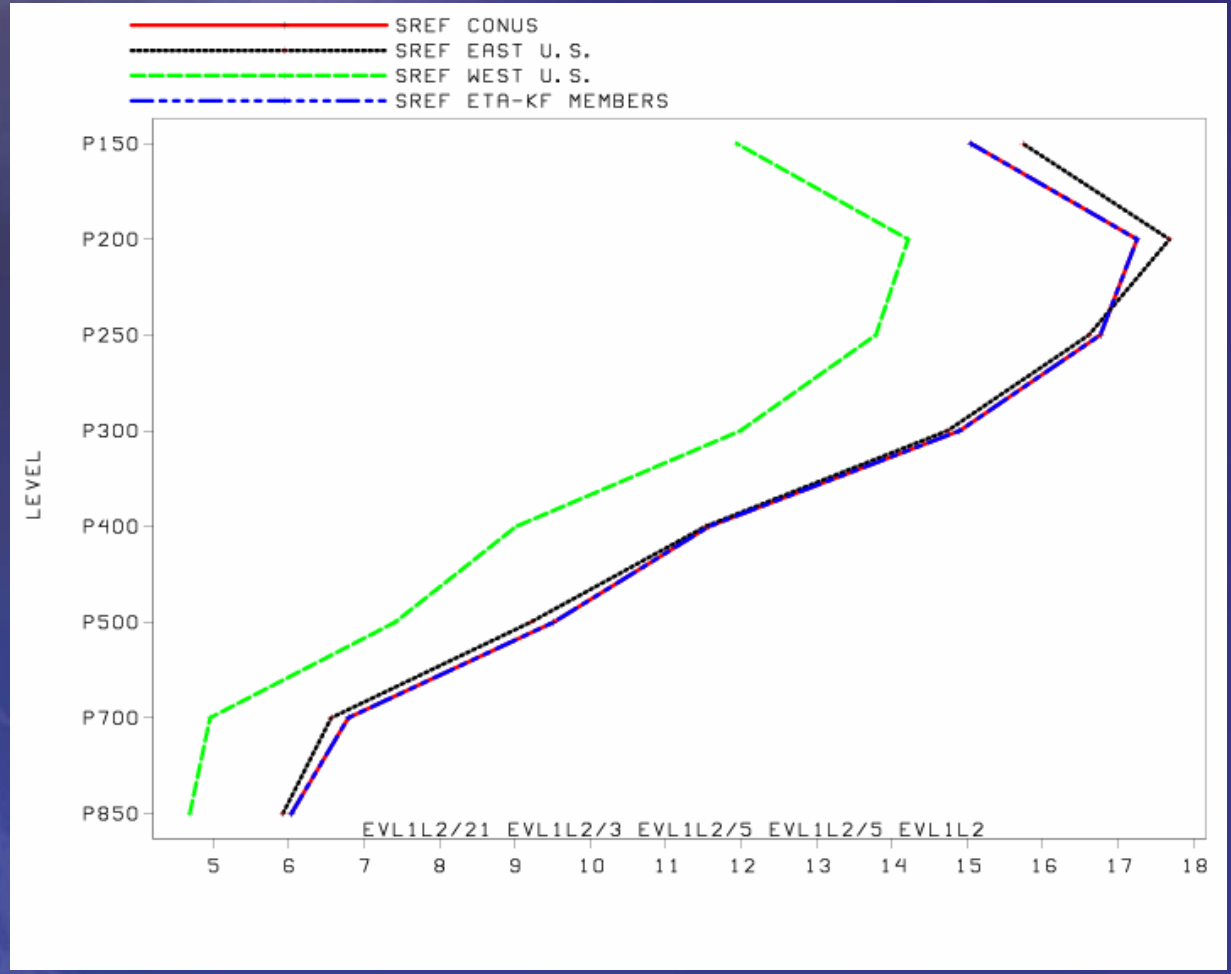
48 h Wind forecast Spread (August 2006)



CONUS ————

EAST-21 ————

West-21 ————



• Spread is largest in East and near Tropopause