Use of HPC to Leverage Operational Mesoscale Meteorological Support for ATEC Test Ranges

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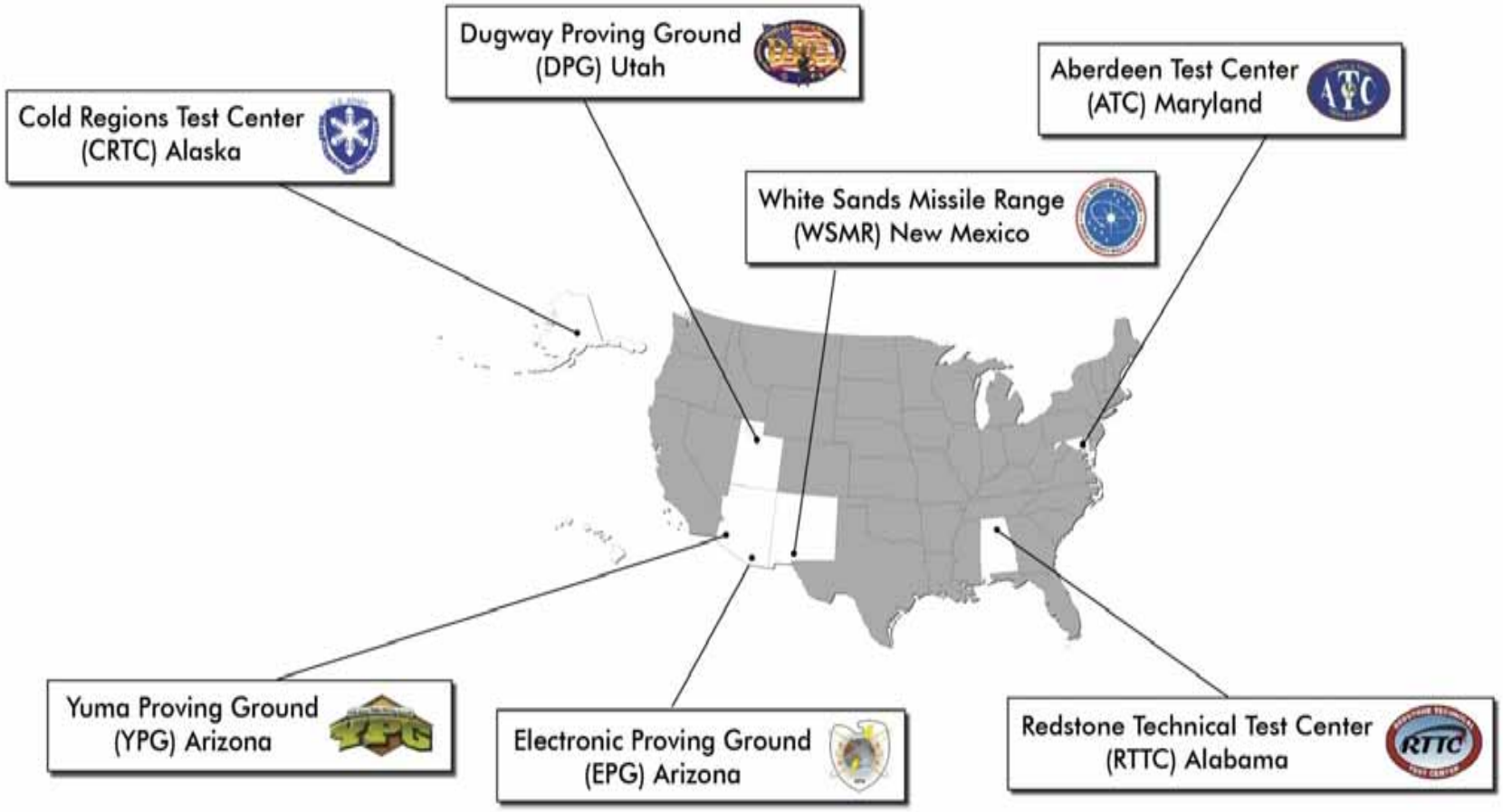
Outline

- Review of ATEC 4D Weather (4DWX) models
- Goals of DPG HPC Applications
- DPG HPC System (hardware)
- R&D of advanced 4DWX Models on HPC
  - Ensemble Real Time Four Dimensional Data Assimilation and forecasting system (E-RTFDDA)
  - Range climatology using Climo-FDDA
  - Very high-resolution modeling of range weather
  - Global Meteorology on Demand (GMOD)
  - T&D applications coupling with E-RTFDDA
- Summary

ATEC Test Centers



Primary Type of Modeling Support at ATEC Ranges

Aberdeen Test Center – maritime conditions

- Ballistic testing and sound propagation

Cold Regions Test Center – arctic weather

- Missiles, wheeled and tracked vehicles, various ground forces

Dugway Proving Ground – desert atmospheric boundary layer

- Chemical and biological dispersion and diffusion

Electronic Proving Ground (Ft. Huachuca) – RF propagation

- Transmission and path loss, UAV flights

Redstone Technical Test Center – subtropical humid weather

- Convective precipitation and lightning effects, visibility

White Sands Missile Range – upper air in desert environments

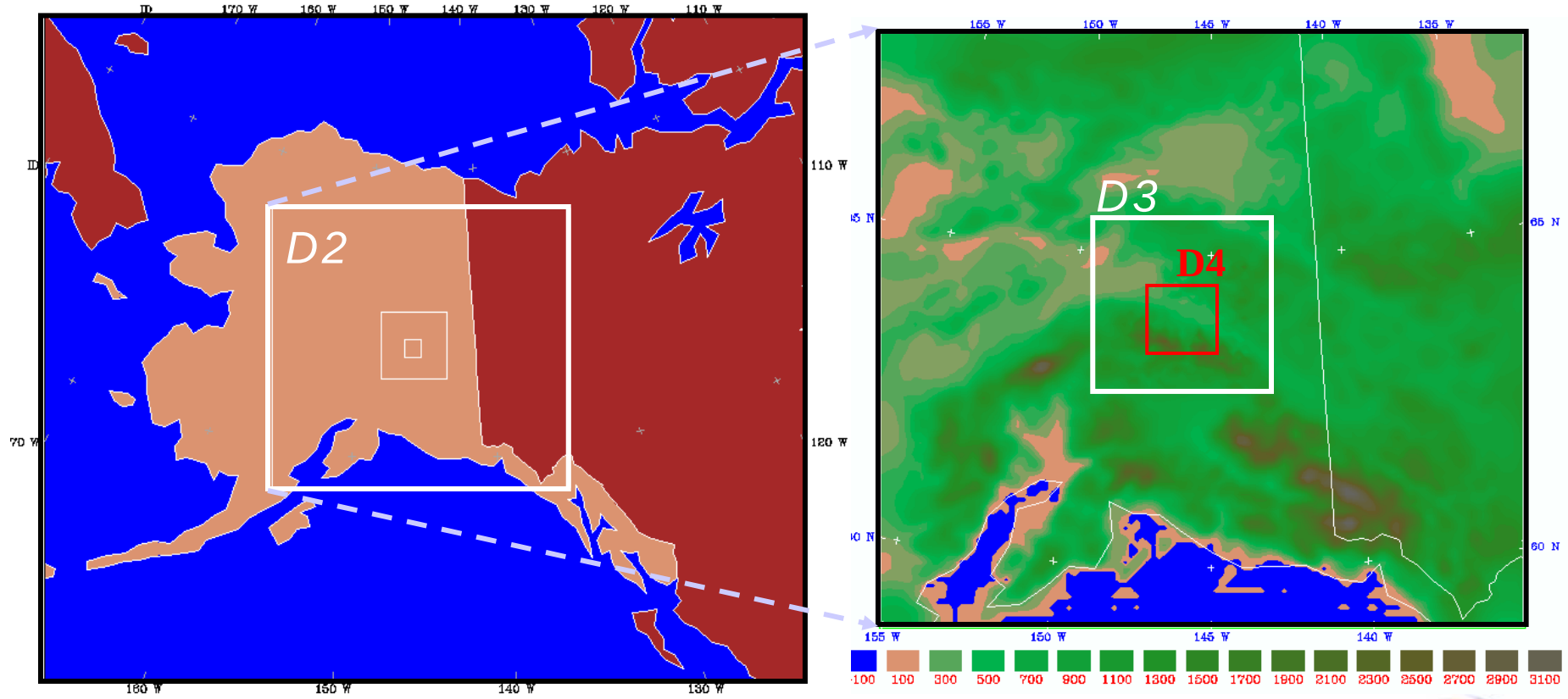
- Missiles, ballistic wind effects, live fire testing, wind drift effects

Yuma Proving Ground – desert atmospheric effects

- Parachute drops, medium to long-range artillery

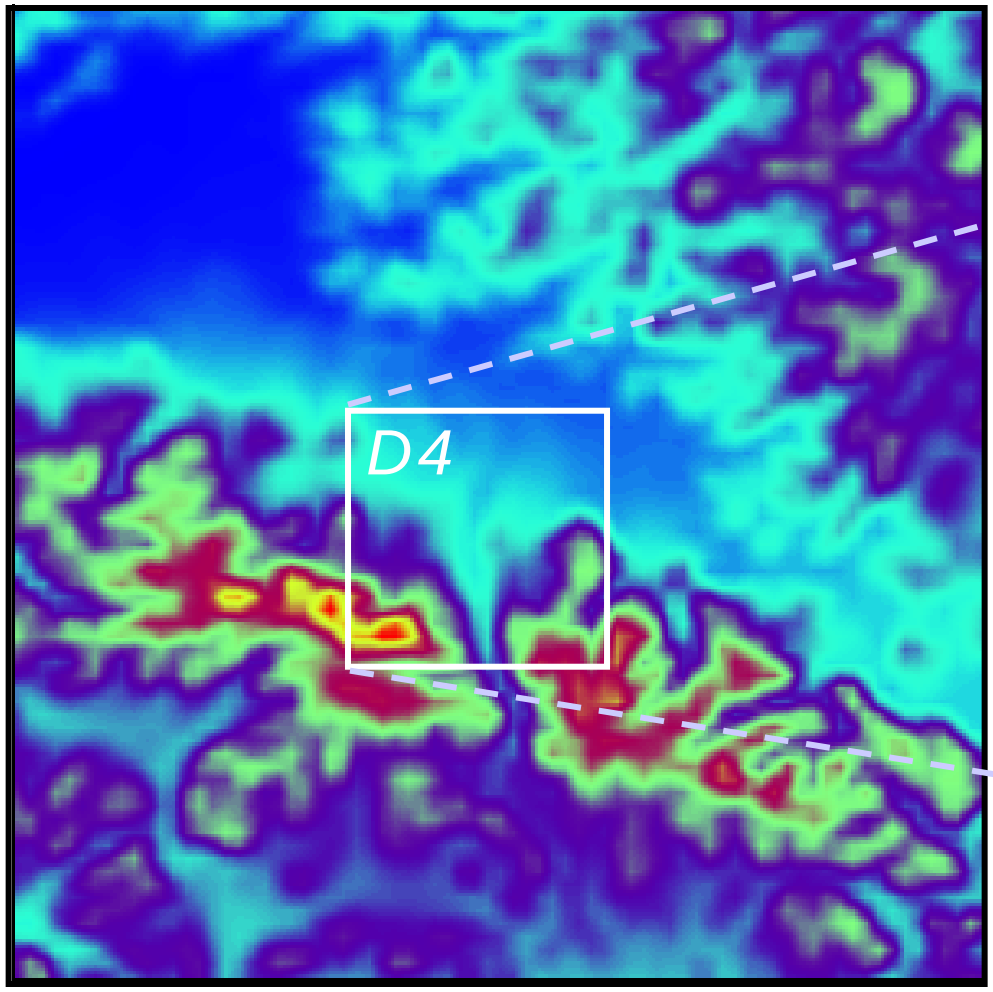
Example: CRTC Model Domain Configuration

CRTC D1 (DX=30 km) **CRTC D2 (DX=10km)**

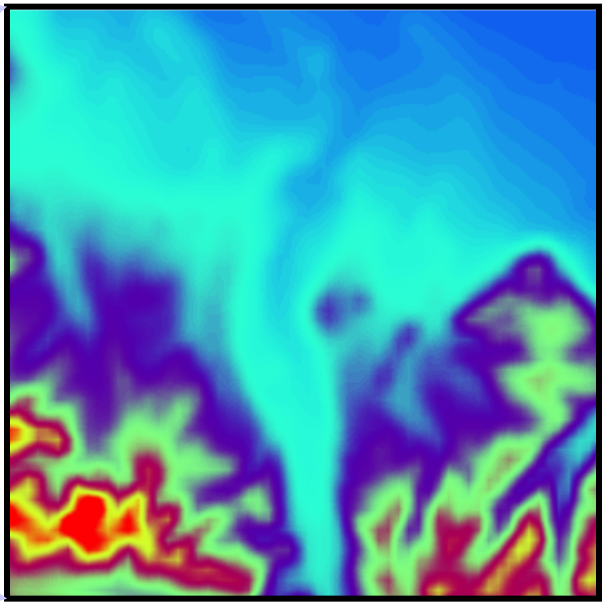


Example: CRTC Model Domain Configuration (Terrain in Domains 3 and 4)

CRTC D3 (DX=3.3km)

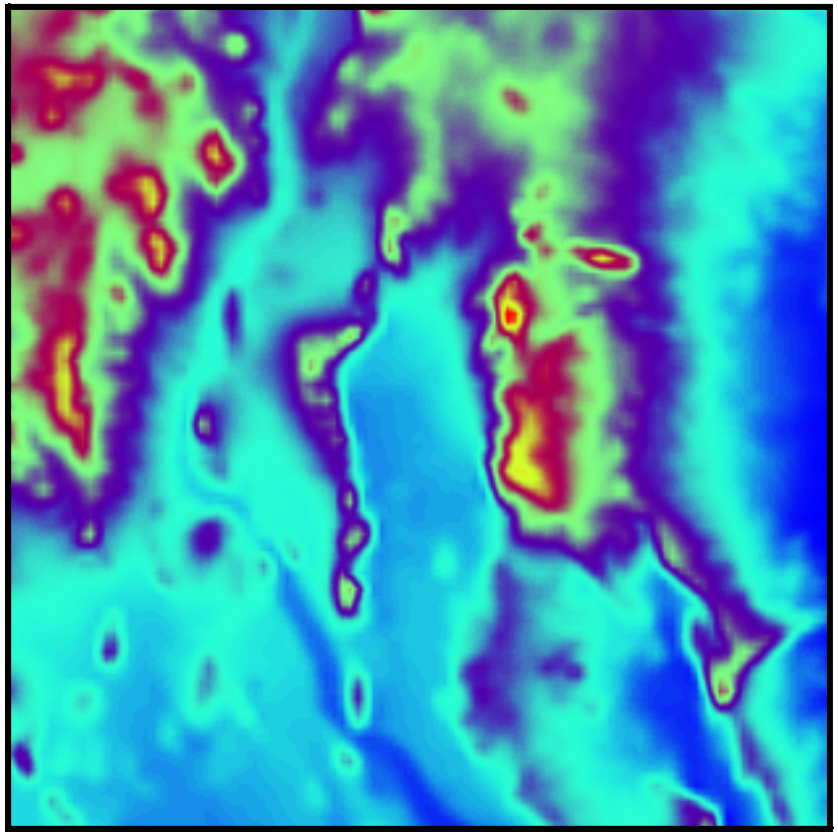


CRTC D4 (DX=1.1km)

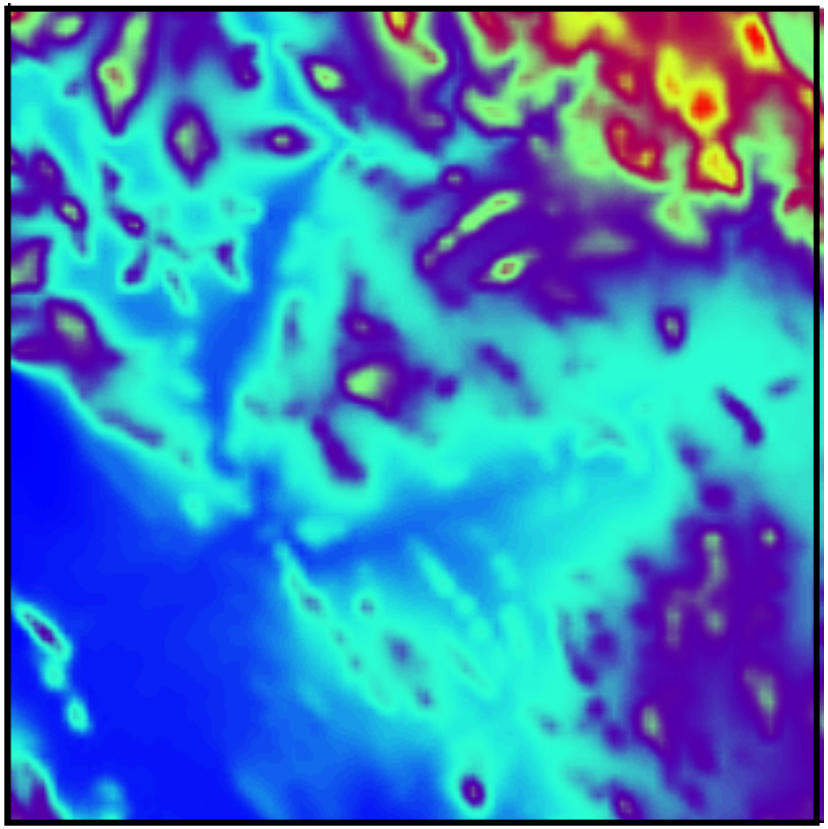


Example: WSMR and YPG Model's Fine-mesh (Terrain in Domain 3)

WSMR D3 (3.3km)



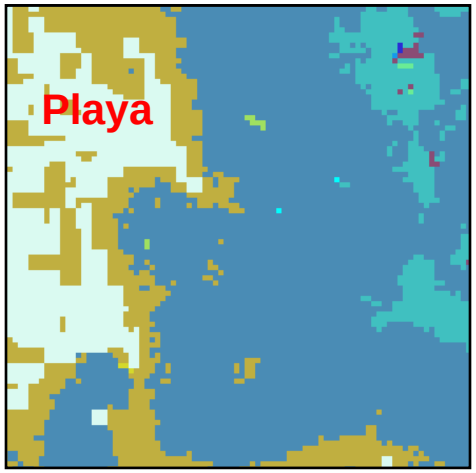
YPG D3 (3.3km)



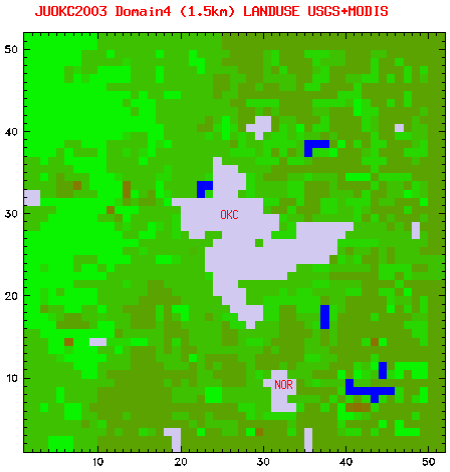
The model simulates detailed range local terrain forcing

Specify “Non-standard” Land Use and SST

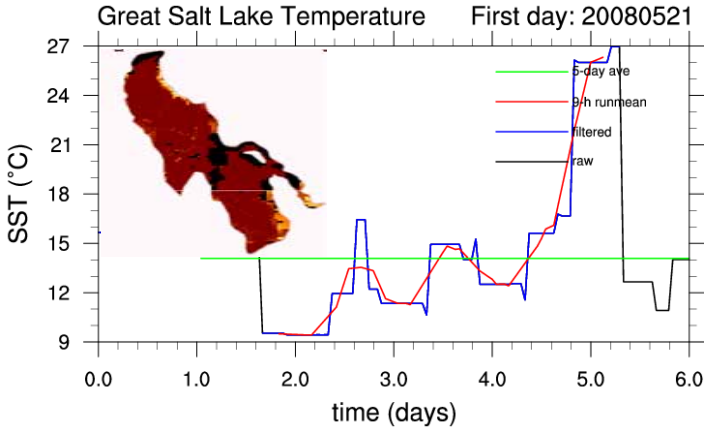
DPG D4



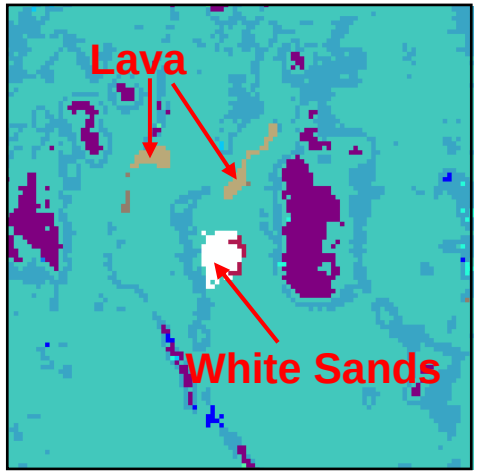
MODIS Urban Areas



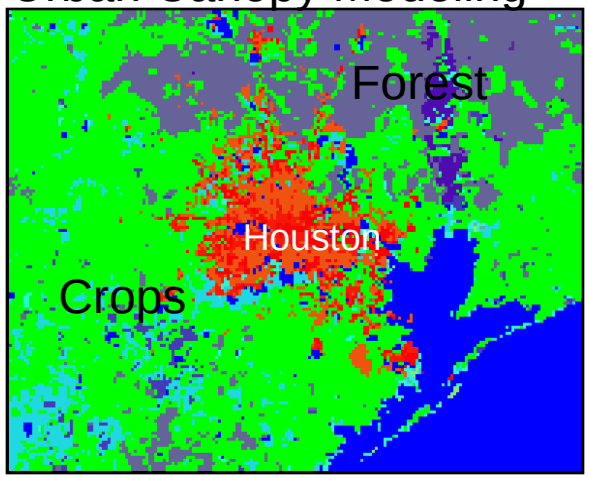
AVHRR SST



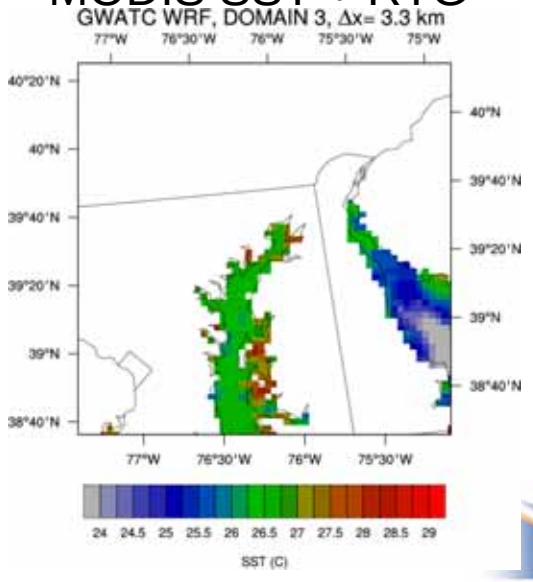
WSMR D3



Urban Canopy Modeling



MODIS SST + RTG



DPG HPC – An Impetus to 4DWX

- **ATEC/NCAR 4DWX Modeling System**

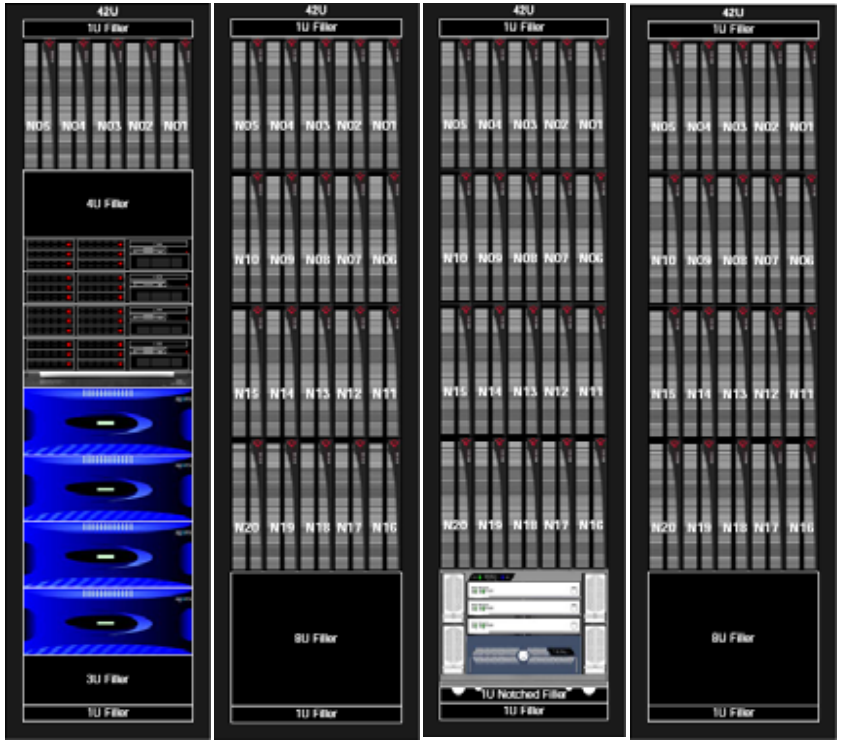
→ **To provide superior recent and current analyses, nowcasting and short-term forecasting of range weather, and climatology, to support tests at Army test ranges and off-site regions**

- **DPG HPC Platform**

→ **A springboard for leveraging 4DWX weather technologies and sciences that critically rely on HPC supercomputing capabilities**

Dugway HPC

- 2 administrative nodes
- 2 interactive nodes
- 65 compute nodes
- 4 storage Agami raid



- 4X Infiniband interconnect
- Gigabit file system network
- 100Mbit management network
- Remote power control
- Environmental monitoring
- BIOS/system console interaction
- EM64T 3.73GHz Intel Dempsey chip set
- Split 2MB + 2MB L2 cache
- 260 processors
- 65 systems, dual core, dual processor
- 4 19” cabinets
- SuSE SLES 9 64-bit operating system
- Clusterworx cluster management system

DPG HPC – Application Goals

- **R,D,T&E cutting-edge mesoscale numerical weather analyses and prediction technologies**

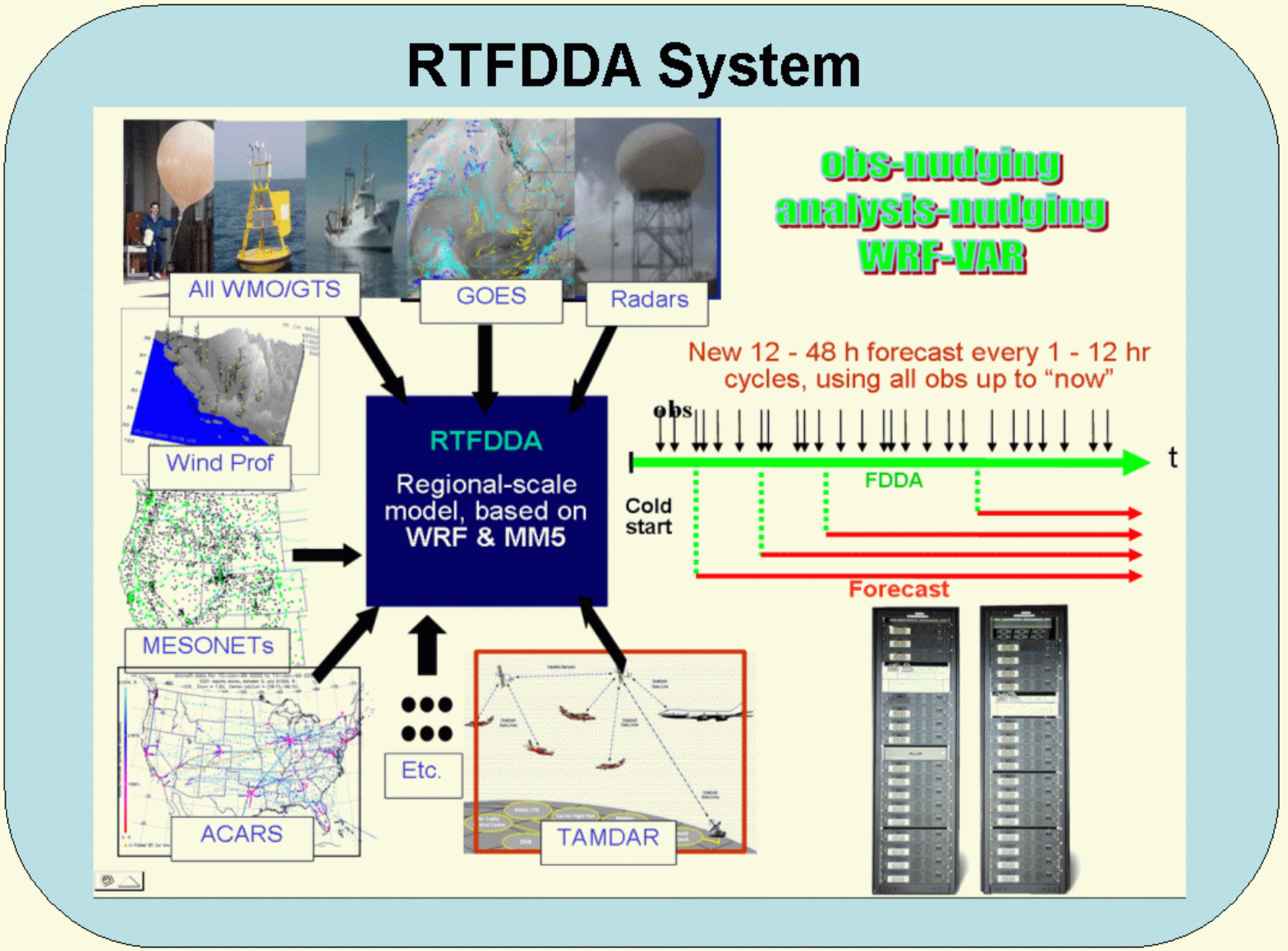
  (RTFDDA, E-RTFDDA, EnKF, C-FDDA …)

- **Provide advanced weather products for Army applications: real-time and/or historical**
- **Improve 4DWX DSS capabilities for ATEC range tests, e.g. SCIPUFF, NAPS, …**
- **Build a GMOD tool for applying the 4DWX models for ATEC emergent and/or special events**
- **To demonstrate and prepare an ATEC operation next-gen 4DWX capability for future implementation**

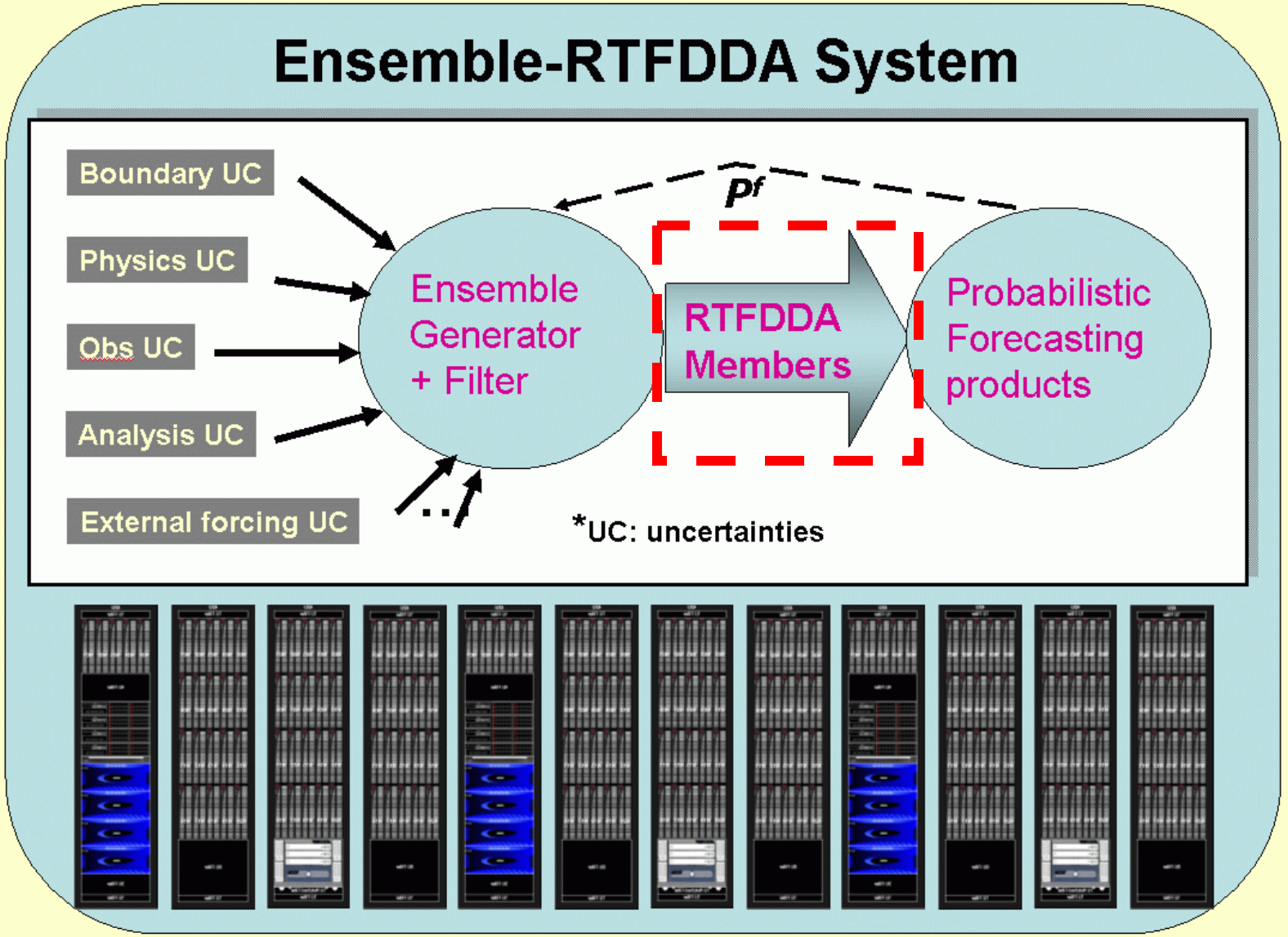
1. Ensemble Prediction System

- Predict the observed distribution of events
- Predict uncertainty in the day's prediction (variance)
- Predict the distribution of observed atmospheric states (covariance)
- Predict the extreme events that are possible on a particular day
- Provide a range of possible scenarios for a particular forecast

4DWX-RTFDDA: the Current Capabilities



4DWX E-RTFDDA: New capabilities



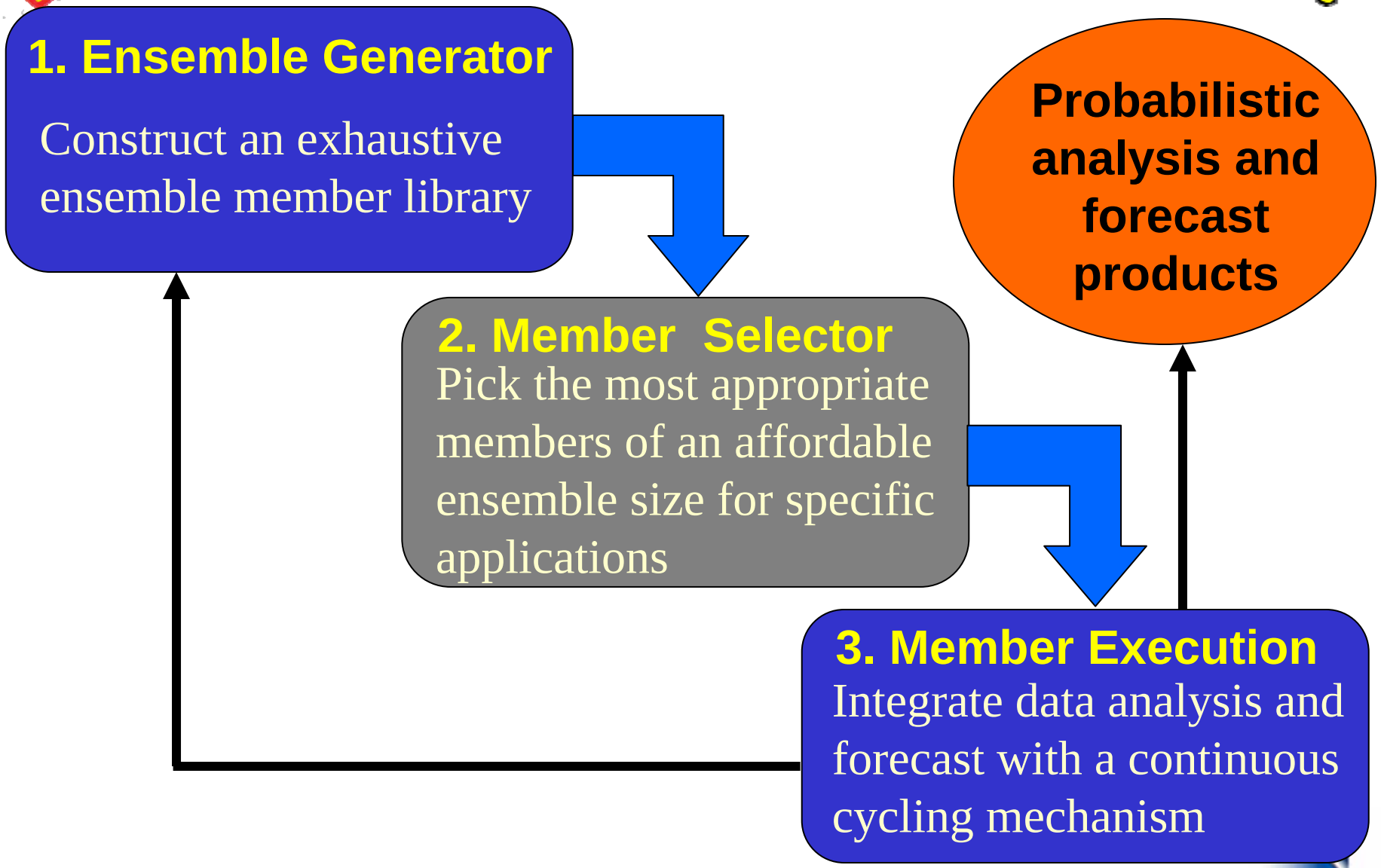
E-RTFDDA: Capability Design

Ensemble **R**eal-**T**ime **F**our-**D**imensional **D**ata **A**ssimilation and Forecasting System.

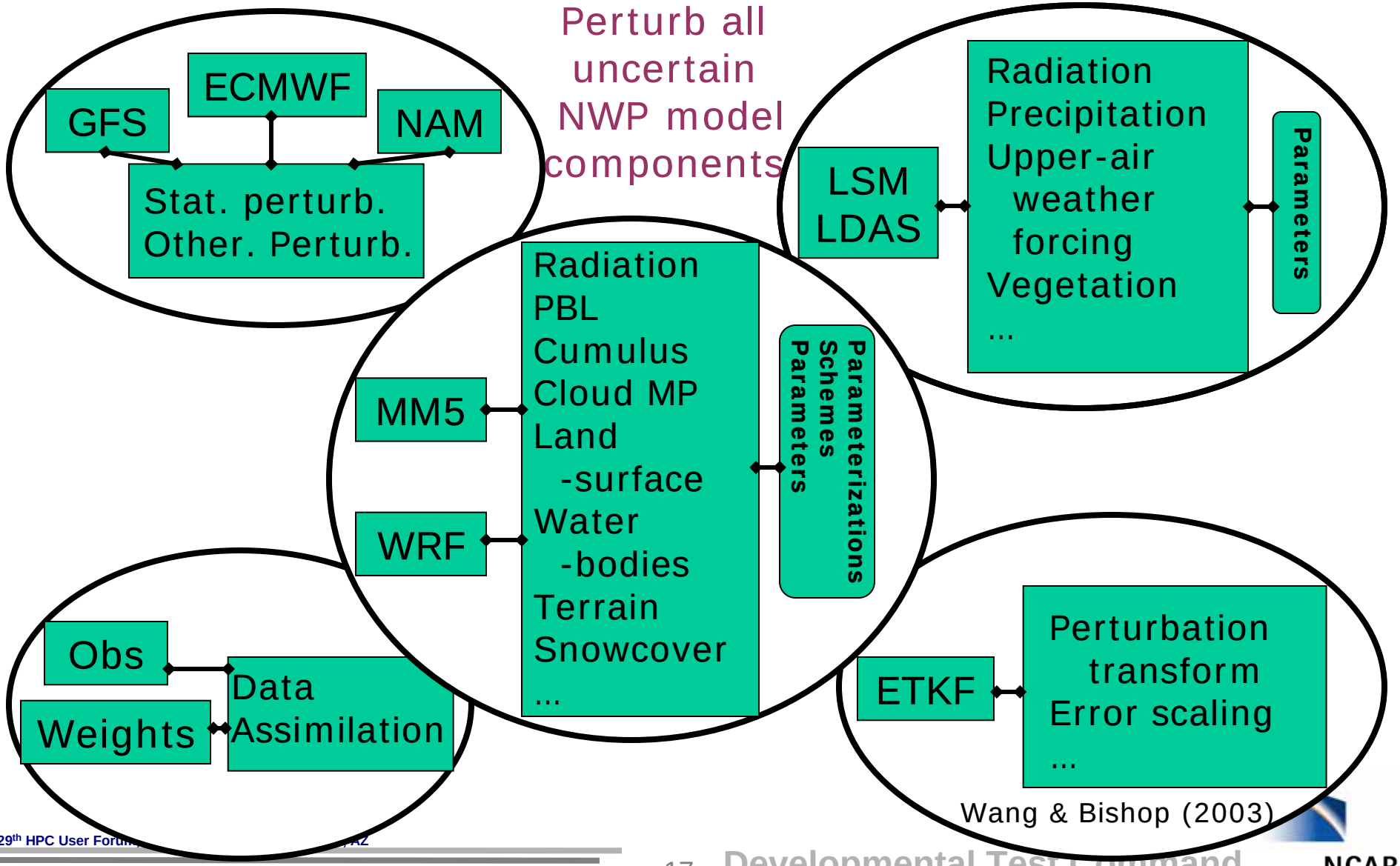
- **Built upon 4DWX RTFDDA (upon WRF and MM5) that are operated at the ATEC ranges**
- **Multiple models and multiple ensemble schemes**

  WRF and MM5; Perturbations for B.C., I.C., Obs., Data assimilation weights, model physics, including static and evolving land surface properties; 3DVAR default error statistics; ETKF; time-lag breeding; EnKF ...
- **Member (perturbations) selection based on weather regimes and special application needs**
- **Flexibility: research, operation and incorporation of new community achievements**

Implementation Strategy: 3-Tiers

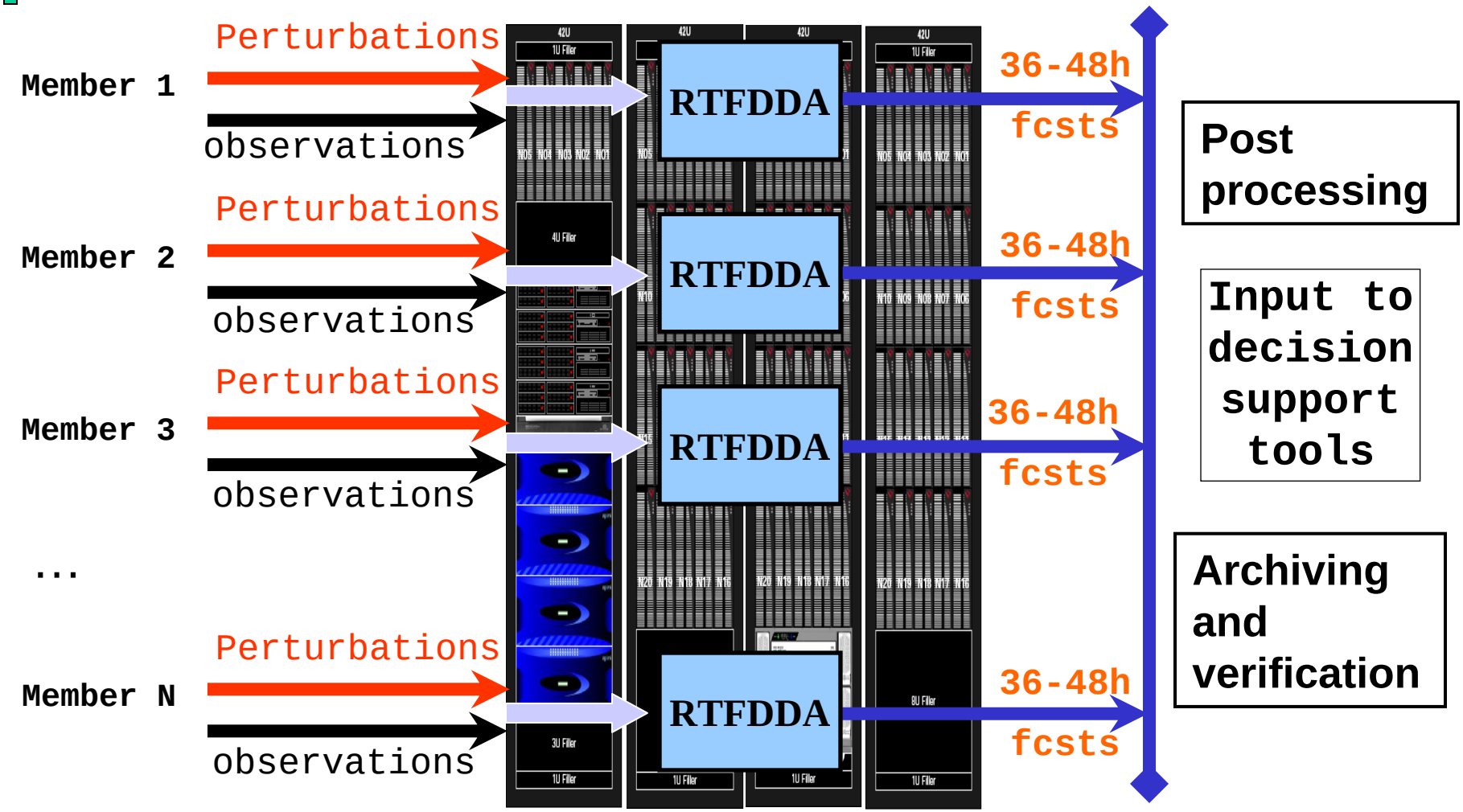


Ensemble Generator



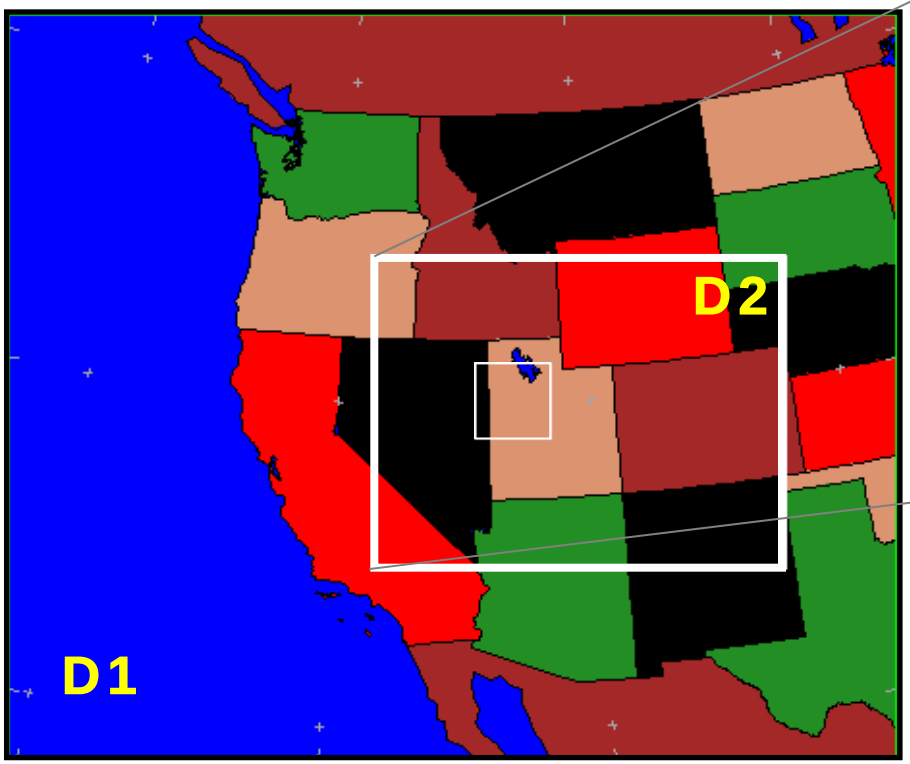
Wang & Bishop (2003)

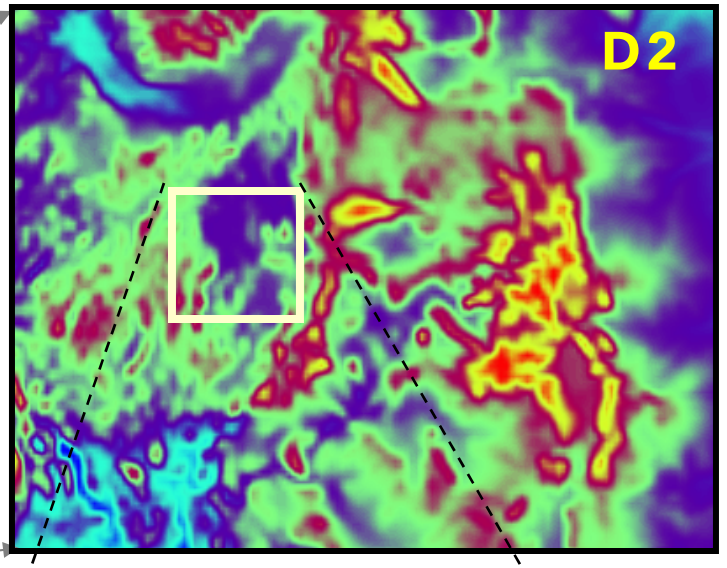
HPC E-RTFDDA Executions

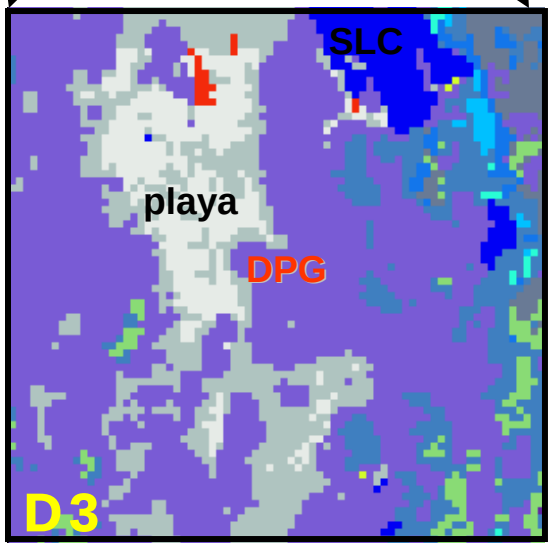


Each member runs on 1 – 10 nodes dependent on the member model sizes, using MPP with Infiniband

E-RTFDDA Demo Op for DPG







D1: map ΔX=30 km
D2: terrain ΔX=10 km
D3: land use ΔX=3.33 km

250 km
X
250 km

30 WRF and MM5 Members of DPG E-RTFDDA

E#	LBC	WRF Members (15)	E#	LBC	MM5 Members (15)
1	NAM	Control: WRF baseline physics	16	NAM	Control: MM5 baseline physics
2	GFS	Control: WRF baseline physics	17	GFS	Control: MM5 baseline physics
3	NAM	SLAB land surface	18	NAM	Simple cloud-effect radiation
4	NAM	MYJ PBL	19	NAM	ETA TKE PBL
5	NAM	MYJ PBL + GD Cumulus	20	NAM	Kain-Fritsch cumulus
6	NAM	WMS6 microphysics	21	NAM	Goddard microphysics
7	NAM	GD cumulus	22	GFS	Betts-Miller cumulus
8	GFS	Thomason microphysics	23	GFS	Reisner 3-ice microphysics
9	GFS	MYJ PBL + WMS5 microphysics	24	GFS	CCM2 radiation
10	GFS	MYJ PBL	25	GFS	GFS LBC Phase-uncertainty 1
11	GFS	MYJ PBL + GD Cumulus	26	GFS	Symmetric perturb to Member 25
12	GFS	BMJ cumulus	27	GFS	GFS LBC Phase-uncertainty 2
13	GFS	BMJ cumulus in 3.3 km grid	28	GFS	Symmetric perturb. to Member 27
14	GFS	GD cumulus in 3.3 km grid	29	GFS	Correlated sounding perturbation
15	GFS	KF cumulus in 3.3 km grid	30	GFS	Symmetric perturb. to Member 29

DPG E-RTFDDA Web-based Products

DPG Ensemble RT-FDDA (E-RTFDDA) - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://dpg-ingest.4dwx.org/images/en

WebMail Radio People Yellow Pages Research Applic

4DWX

DPG Ensemble RT-FDDA (E-RTF

Probabilistic Products

- Ensemble Image Viewer
- Ensemble Meteogram at SAMS01
- Ensemble Meteogram at SAMS 07
- Ensemble Meteogram at SAMS 08
- Ensemble Meteogram at SAMS 12
- Ensemble Meteogram at Cedar Mtn
- Ensemble Meteogram at Boulder

Ensemble Mean

- Ensemble Mean - FDDA Image Viewer

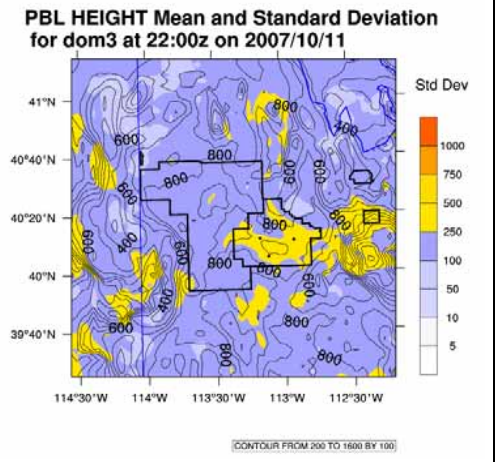
Control Members: NAM/MM5 and GFS/W

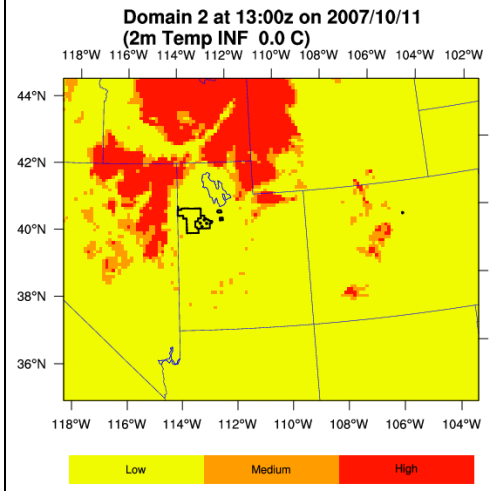
- MM5 baseline member - FDDA Image View
- MM5 baseline member - status monitor
- WRF baseline member - FDDA Image View
- WRF baseline member - status monitor
- Ensemble Node Status monitor

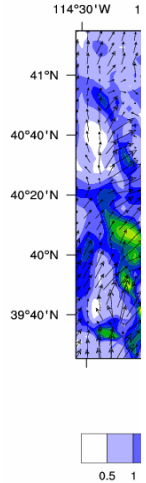
Dugway Proving Grounds Forecast Mode

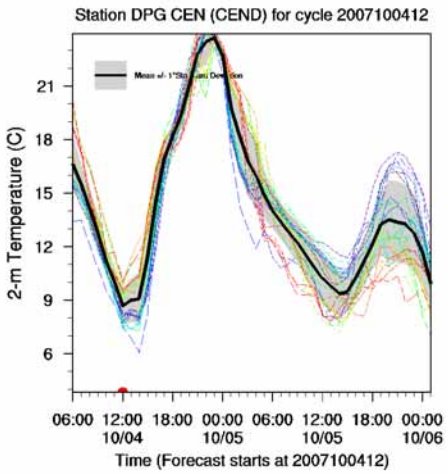
- DPG high resolution (1.1km) WRF RTFDD
- DPG high resolution (1.1km) MM5 RTFDD

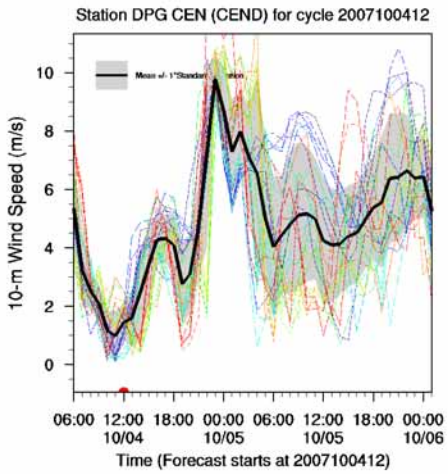
System Description and References

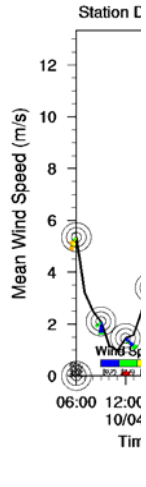








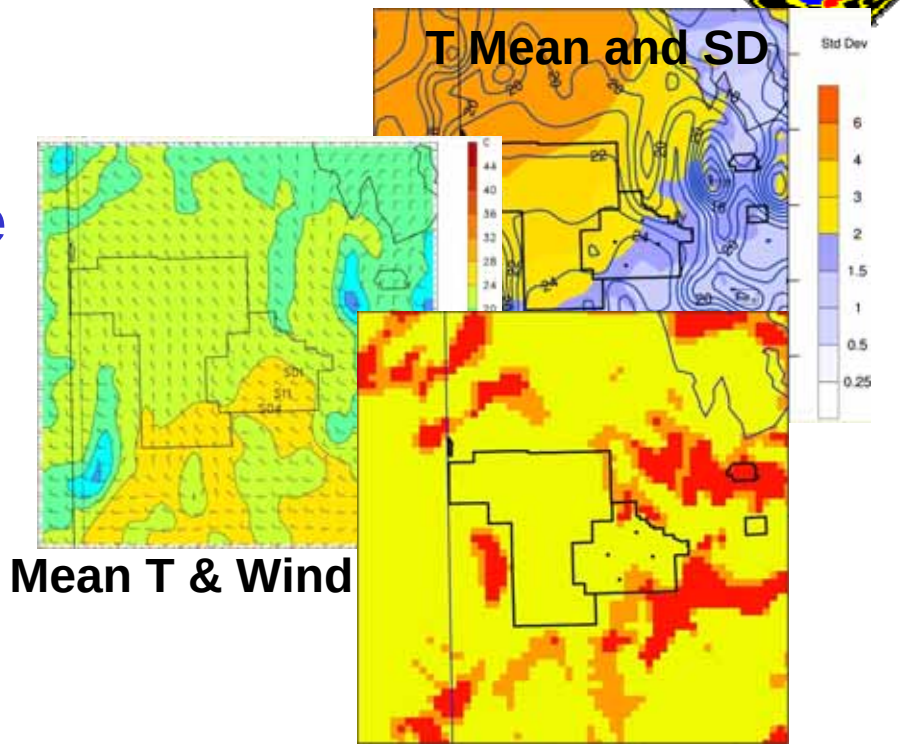


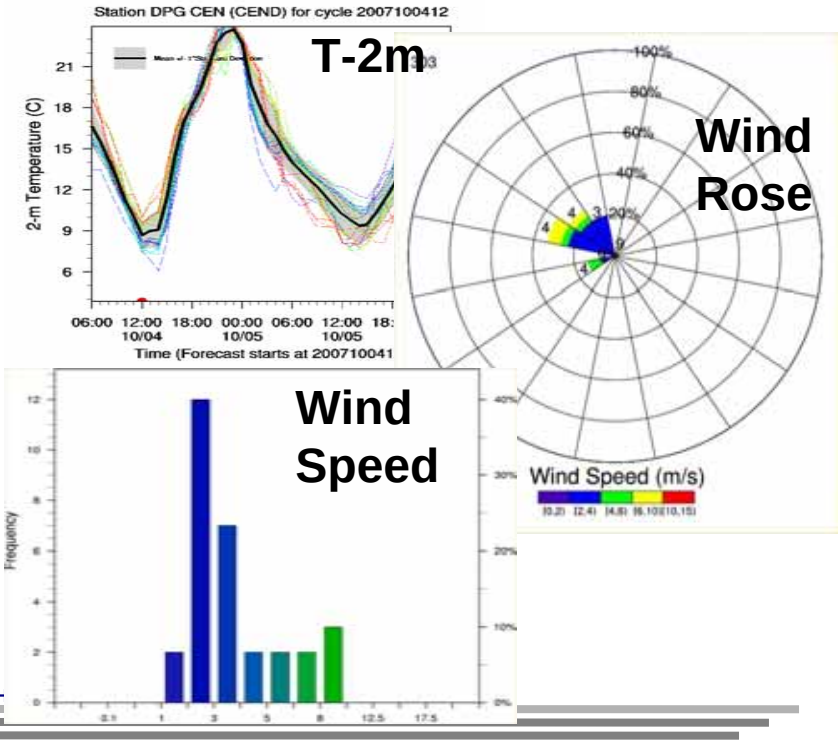


DPG E-RTFDDA Product Summary

Surface and X-sections

– Mean, Spread, Exceedance Probability, Spaghetti, …

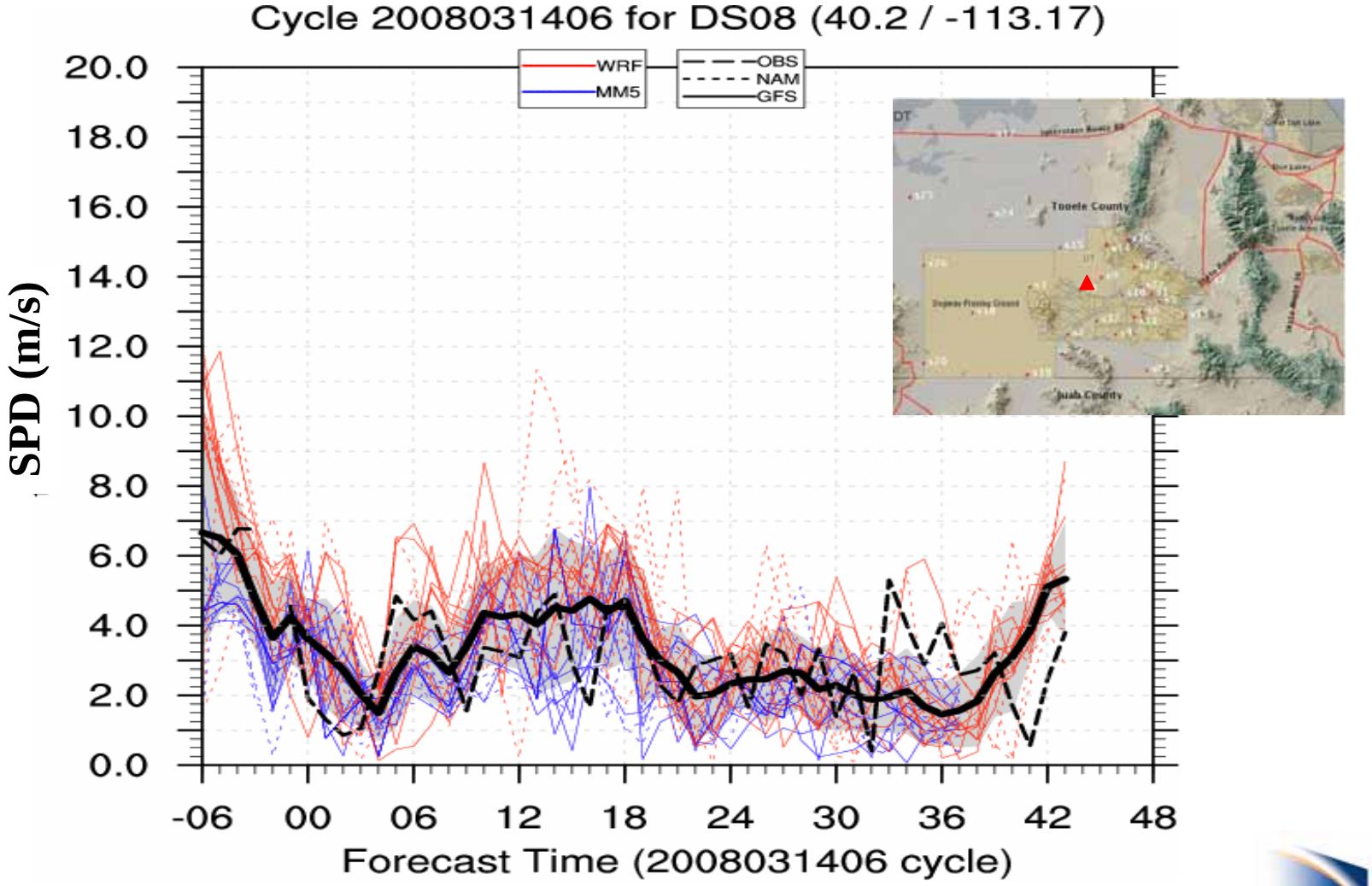




Pin-point surface and profiles

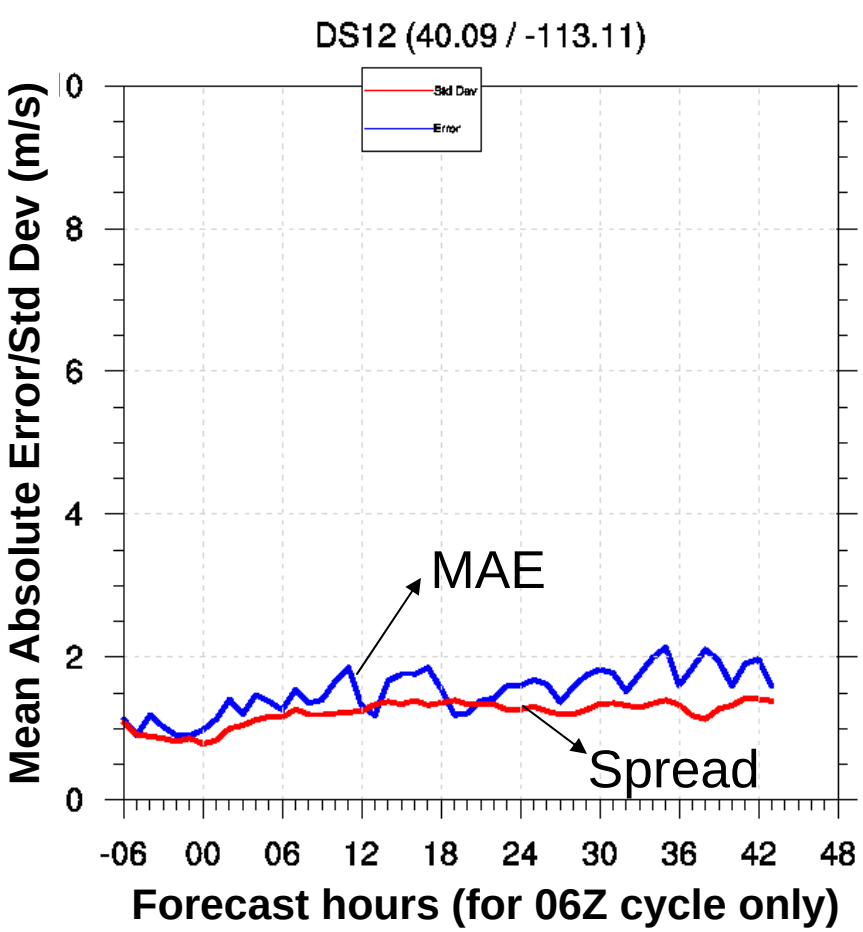
– Mean, Spread, Exceedance Probability, Spaghetti, wind roses, histograms …

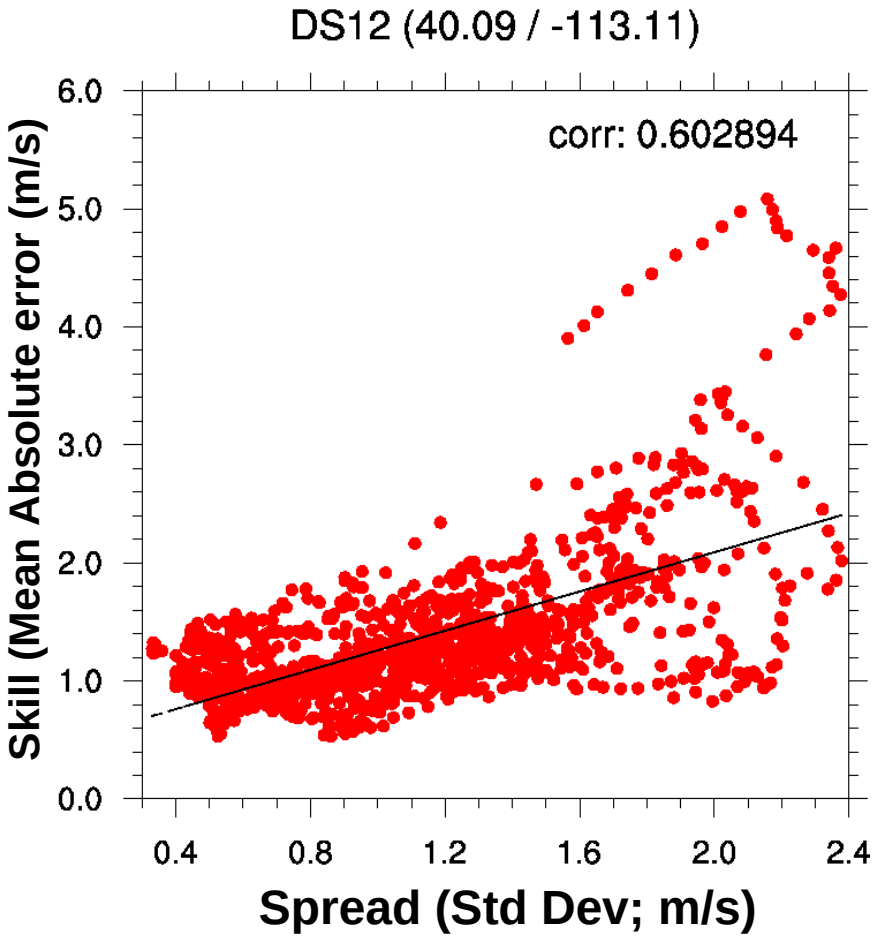
10-m Winds at SAMS08 Site



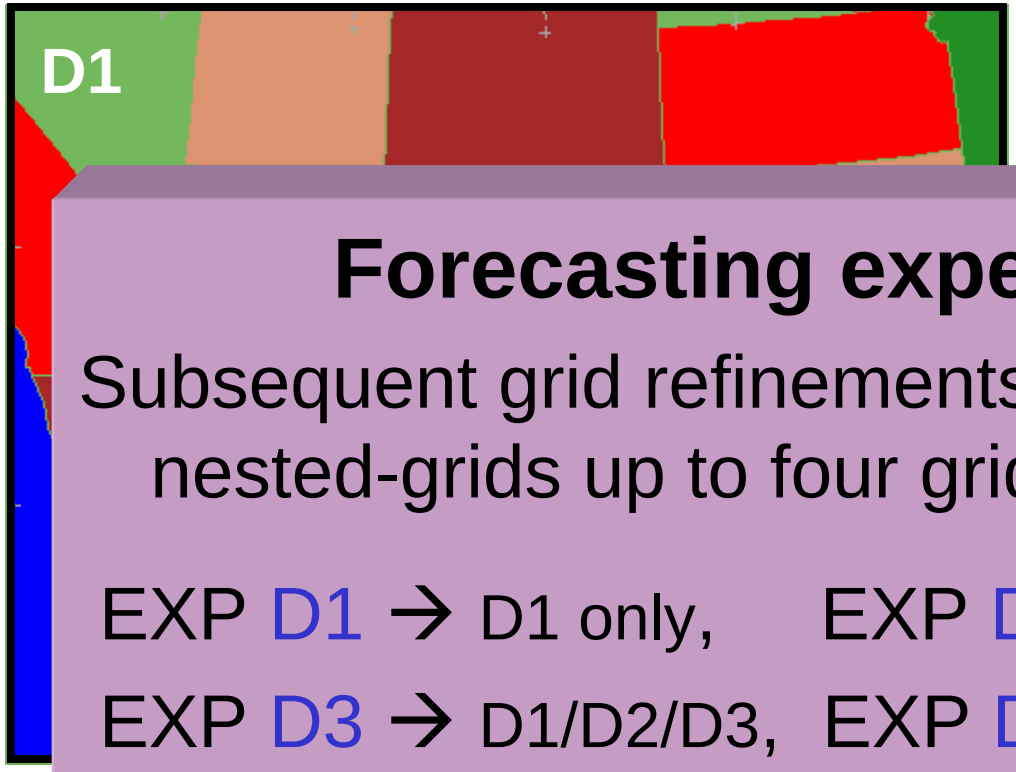
2008 Feb-Mar Stats of DPG E-RTFDDA

Ensemble spread-skill (speed absolute error) correlation for winds at SAMS12, DPG





2. Evaluation of the impact of model resolution on a summer convection event at WSMR



Note:

The model result analysis

Forecasting experiments

Subsequent grid refinements with 2-way nested-grids up to four grids:

EXP D1 → D1 only, EXP D2 → D1 / D2,

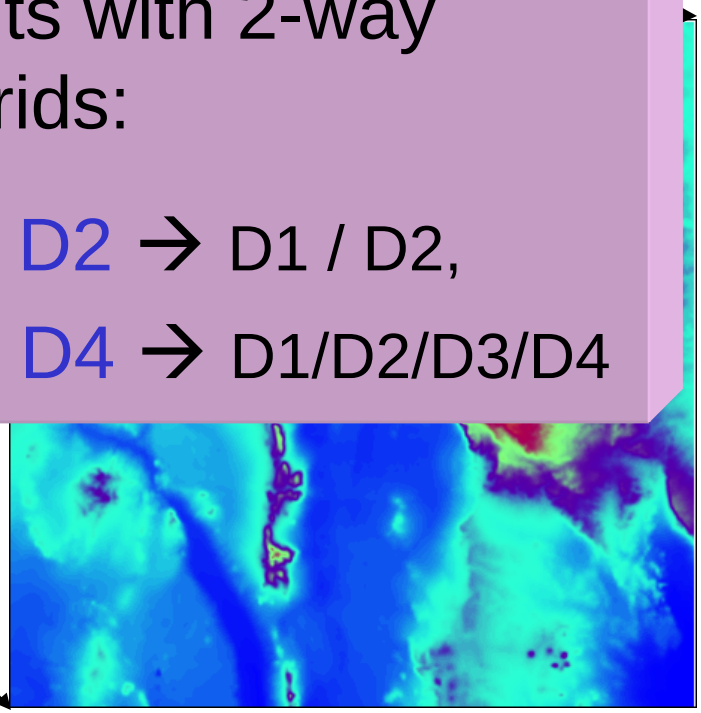
EXP D3 → D1/D2/D3, EXP D4 → D1/D2/D3/D4

D1: 160 x 121, DX = 13.5 km

D2: 166 x 166, DX = 4.5 km

D3: 316 x 322, DX = 1.5 km

D4: 460 x 460, DX = 0.5 km

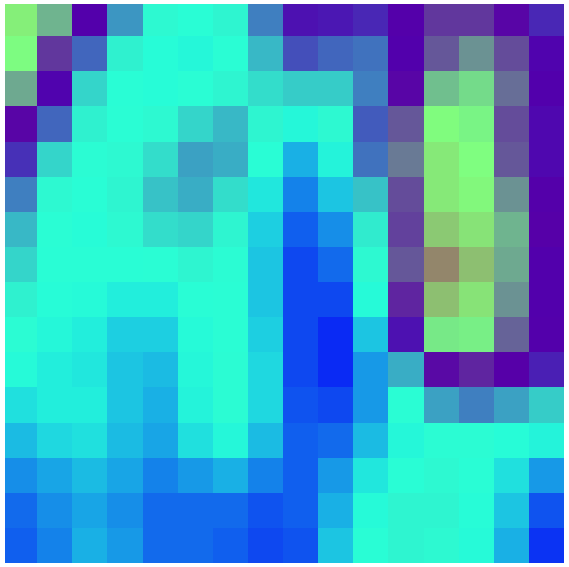


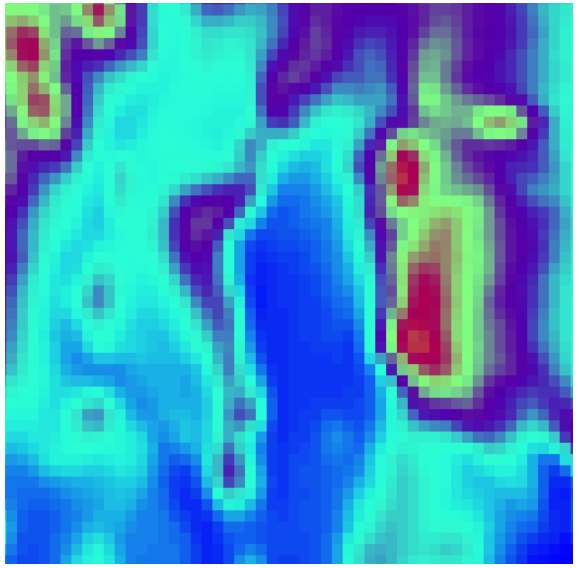
40 nodes (160 procs) with Infiniband

Terrain Height at Different Resolutions

D1

13.5km



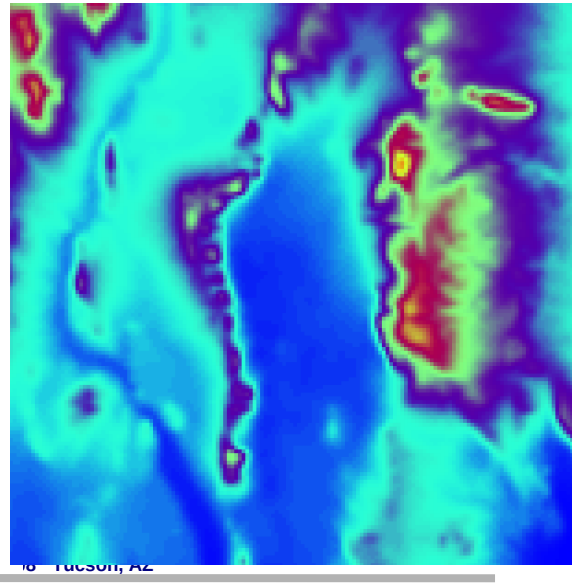


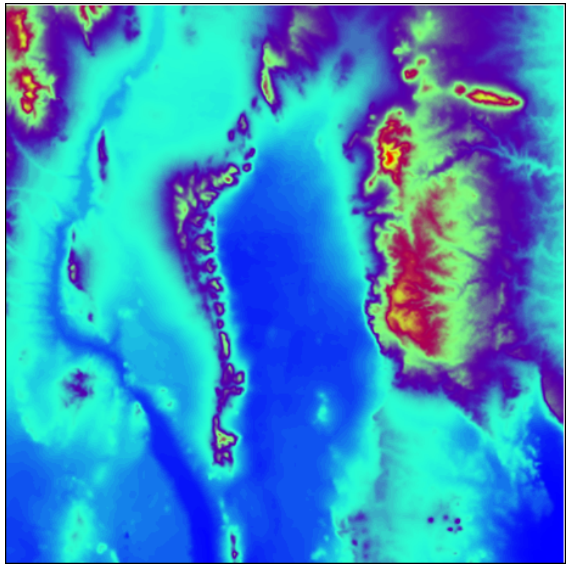
D2

4.5km

D3

1.5km

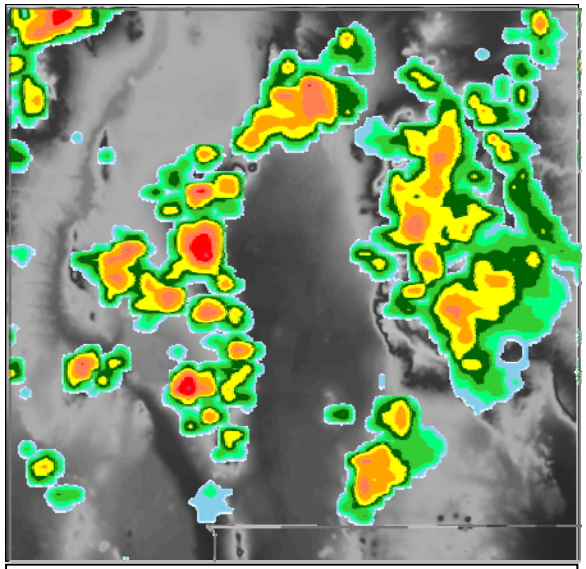




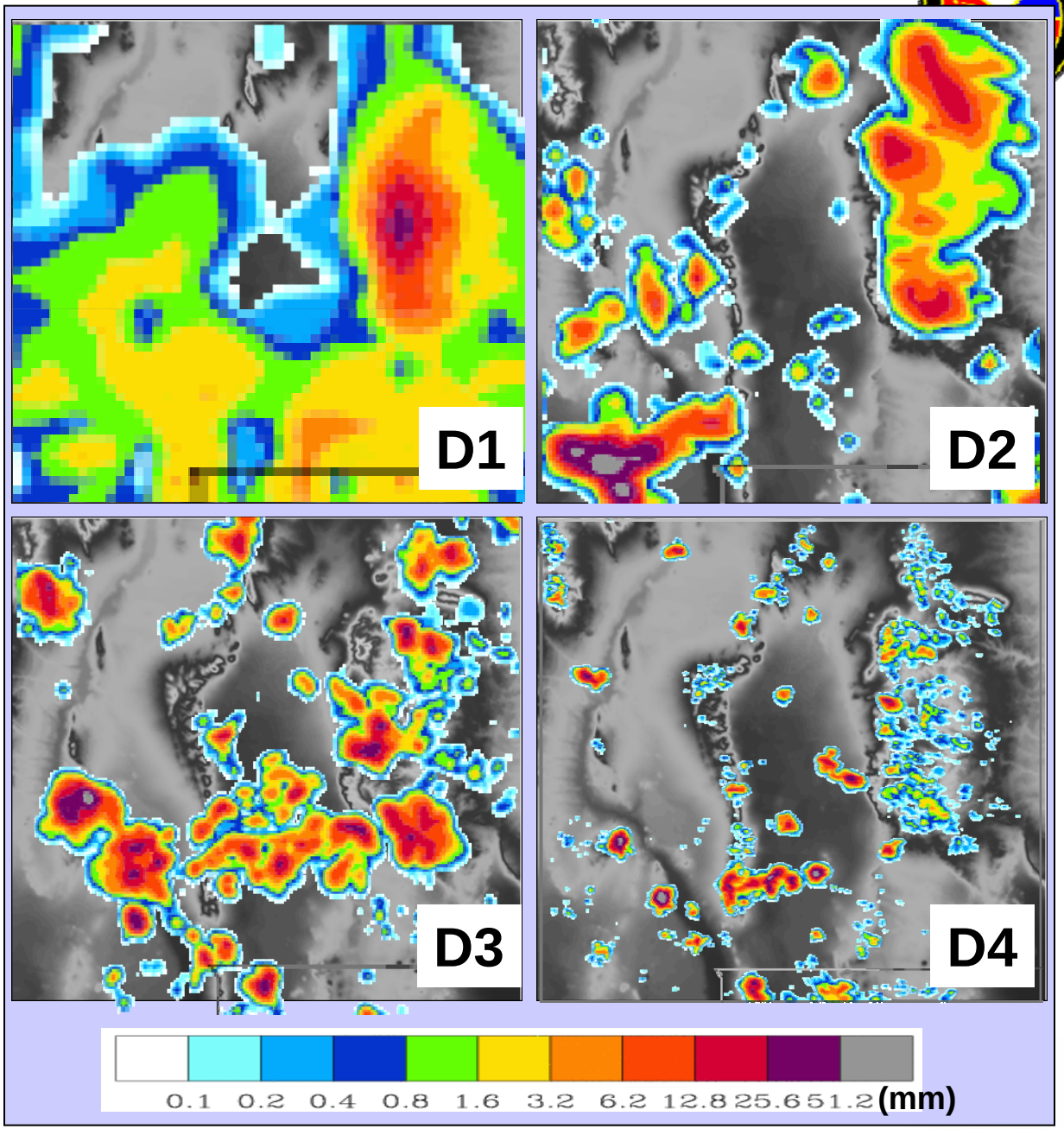
D4

0.5km

Verification of the model 3-h rain ended at 21Z, 8 August 2005



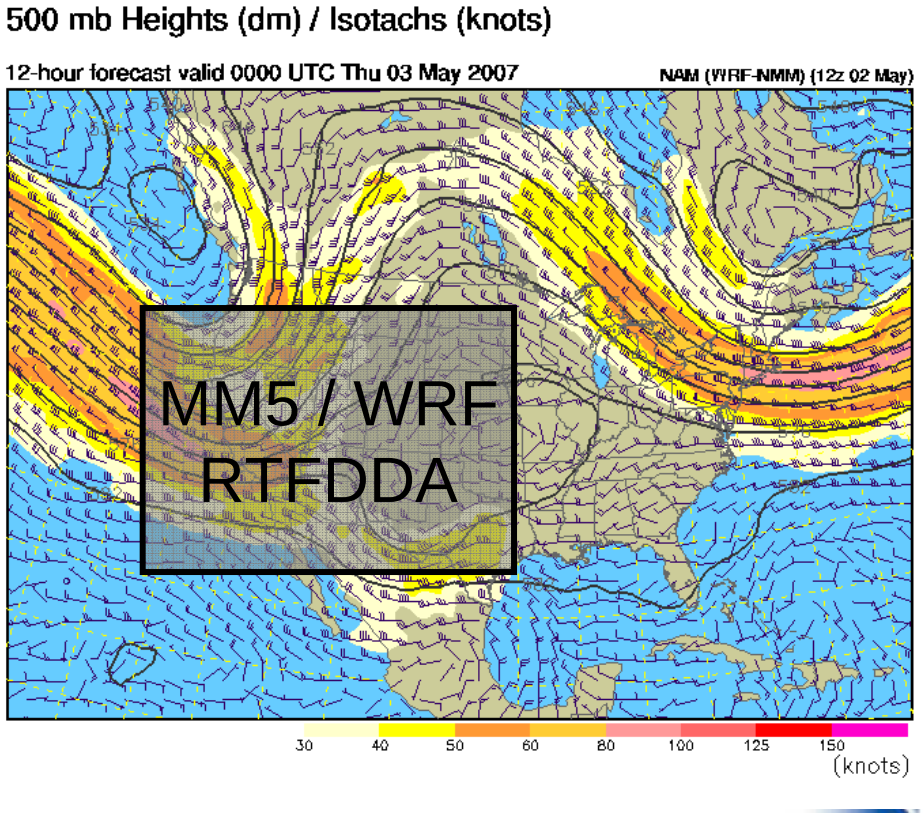
StageIV Observation



3. CFDDA for Army Range mesoscale climate reanalysis

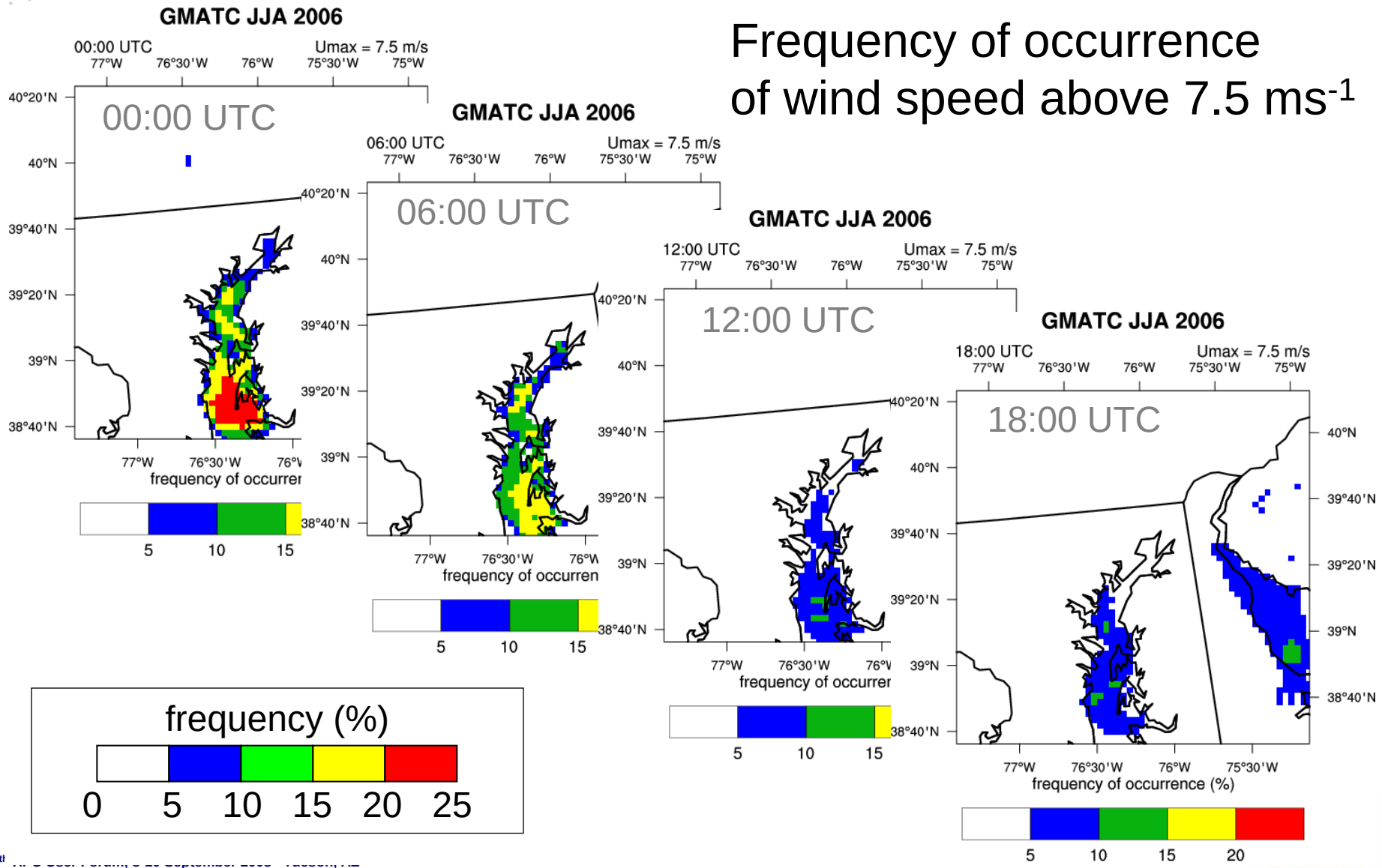
- **4DWX CFDDA: Climo Four-Dimensional data assimilation with WRF or MM5**

→ A dynamical climatology downscaling from the available coarse grid climate analysis (~200 km) and local underlying forcing and observations to the range scale (1 - 3 km) for 30 or more years



CFDDA: An Example

Frequency of occurrence of wind speed above 7.5 ms^{-1}



4. DPG-HPC GMOD Tool

- **Run 4DWX models (RTFDDA, E-RTFDDA and C-FDDA) at any region over the globe with button-click**

  (Using dedicated group HPC nodes as needed)

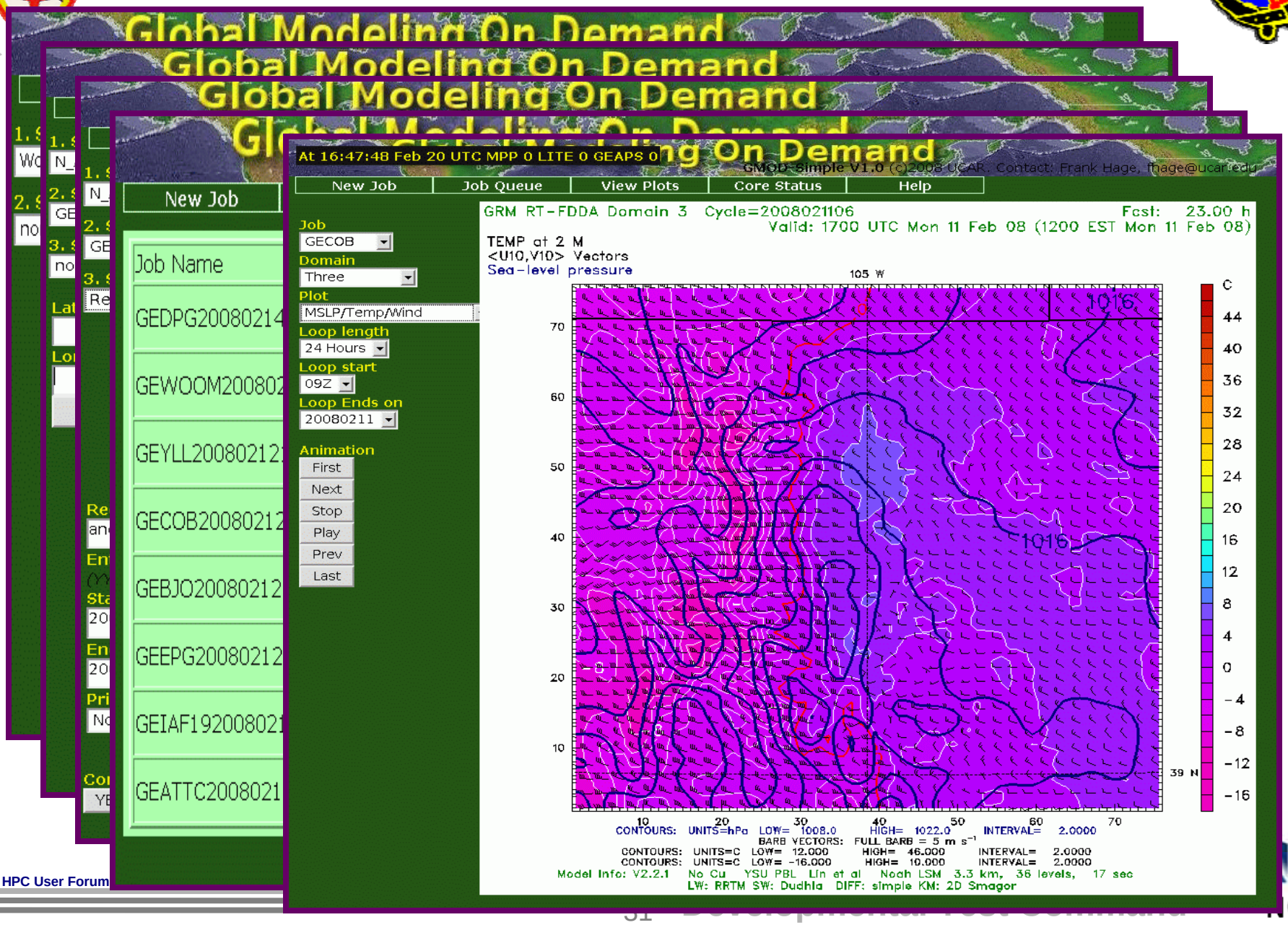
- **Backup the real-time modeling and/or facilitate case studies at the Army ranges and off-sites of interest**

  (With existing and/or enhance 4DWX modeling capabilities)

- **Support R&D modeling effort and experimental operation of the 4DWX modeling systems on HPC**

  (High-resolution modeling; E-RTFDDA model developments including reforecast for ensemble output calibration …)

HPC-GMOD System – A virtual tour

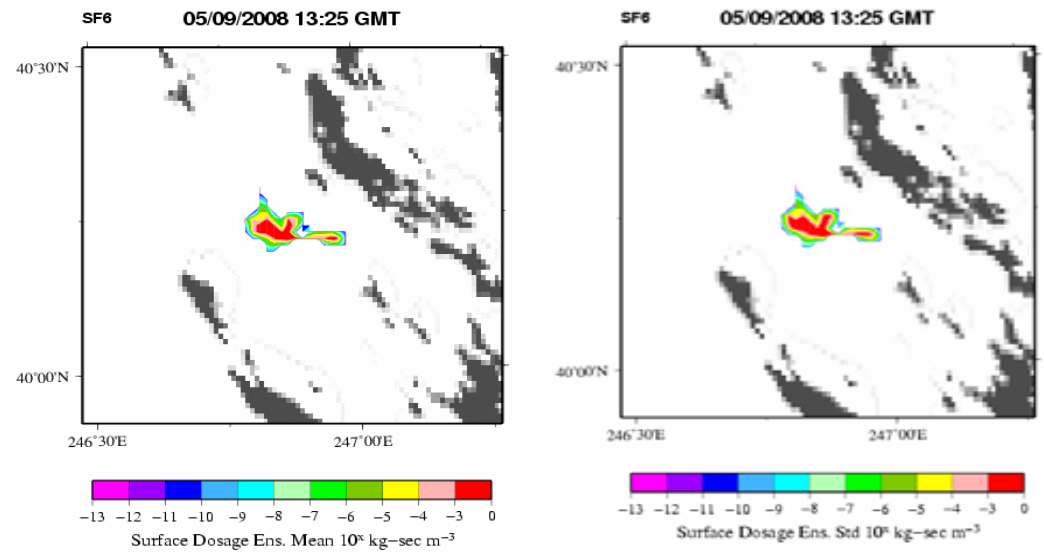


5. Couple T&D model with E-RTFDDA

- **Hourly E-RTFDDA analyses and forecasts are converted to MEDOC for download**
- **Run SCIPUFF on the HPC and produce the mean and spread of plume dosages and concentrations**

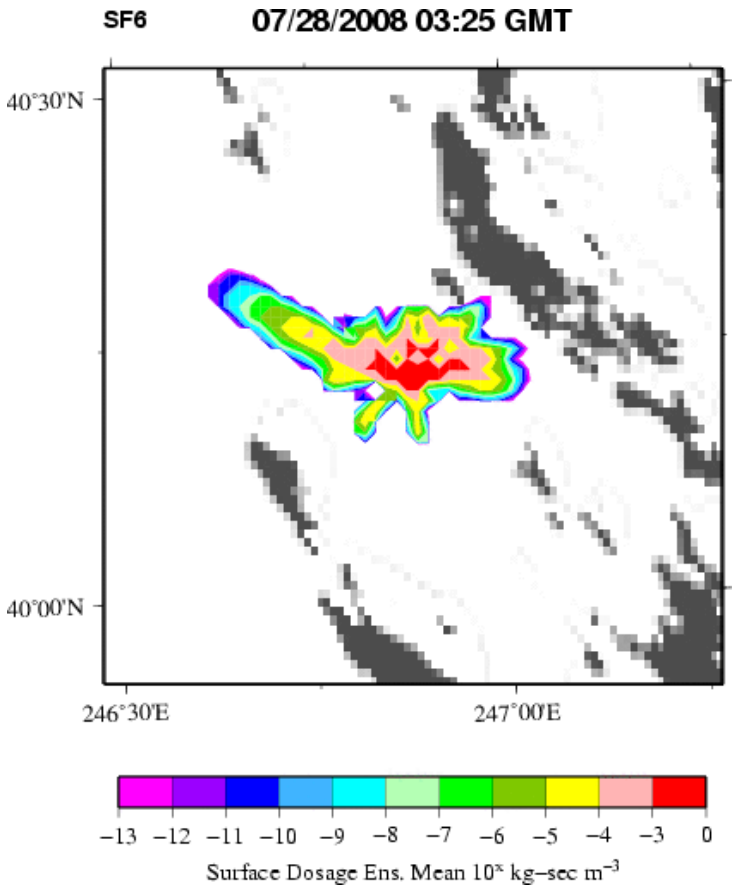
Web display:

Animation of dosage and concentration and thumbnail maps

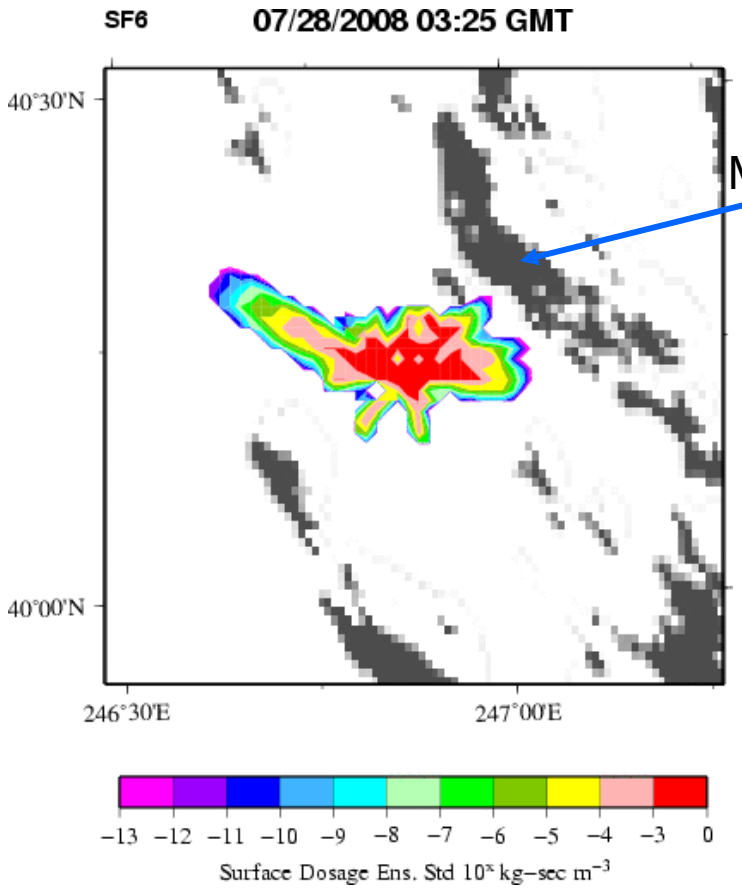


Ensemble Statistics of Dosage of Hypothetical Release SF6 (0300 – 0645 UTC July 28, 2008)

Ensemble Mean

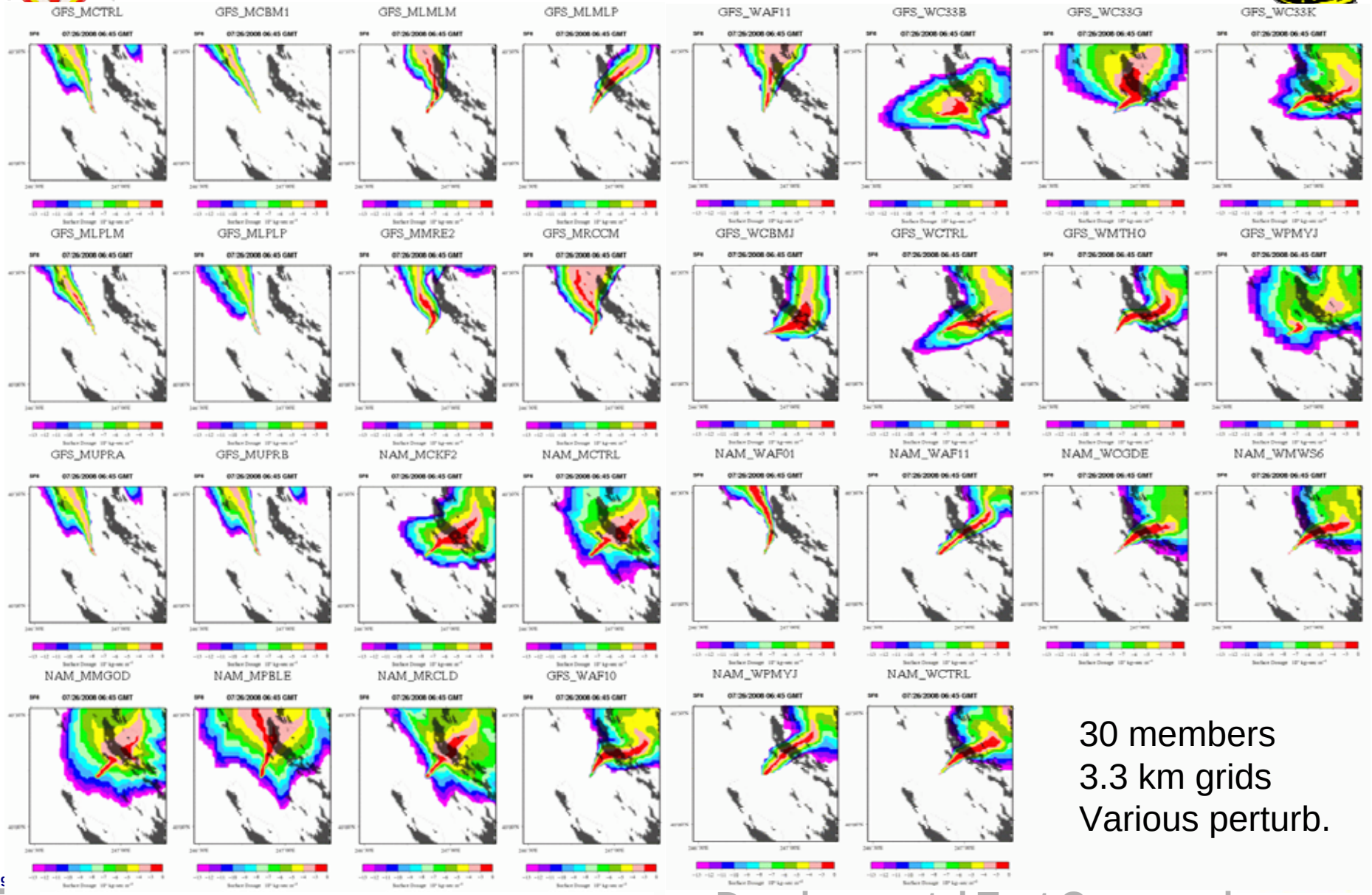


Ensemble Spread



Mountains

Scenario Dosage of Hypothetical Release SF6
(0300 – 0645 UTC July 28, 2008)



30 members
3.3 km grids
Various perturb.

Plan for FY09 - 10

- Continue to the R&D of E-RTFDDA sciences and technologies
- Customize probabilistic weather products, tailoring for range decision needs
- Continue to enhance the GMOD tools and DSS applications
- Conduct extremely high-resolution weather simulation over the Army range using WRF-LES RTFDDA
- Produce range-scale climatology using C-FDDA

Summary

- ATEC 4DWX modeling systems provide operational multi-scale, rapid-updated weather analyses and forecasts for seven Army test ranges.
- DPG HPC enables R,D,T&E of the advanced weather modeling capabilities including ensemble analysis and prediction, range micro-climatology construction, extreme high-resolution weather modeling and DSS application simulations.
- An experimental 30-member E-RTFDDA has been operated for Dugway Proving Ground since August 2007 and highly used and recommended by end-users.
- The 4DWX modeling R&D work on the HPC is on-going, toward next-Gen ATEC 4DWX capabilities.

End.