Rapid Prototyping of Cutting-Edge Meteorological Technology: The ATEC 4DWX System

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Agenda

- 4DWX System Overview
- 4DWX Forecast and Analysis Modeling Systems
- Coupled Model Applications
- Rapid Prototype Cycle
- Near-Term Enhancements
- Summary

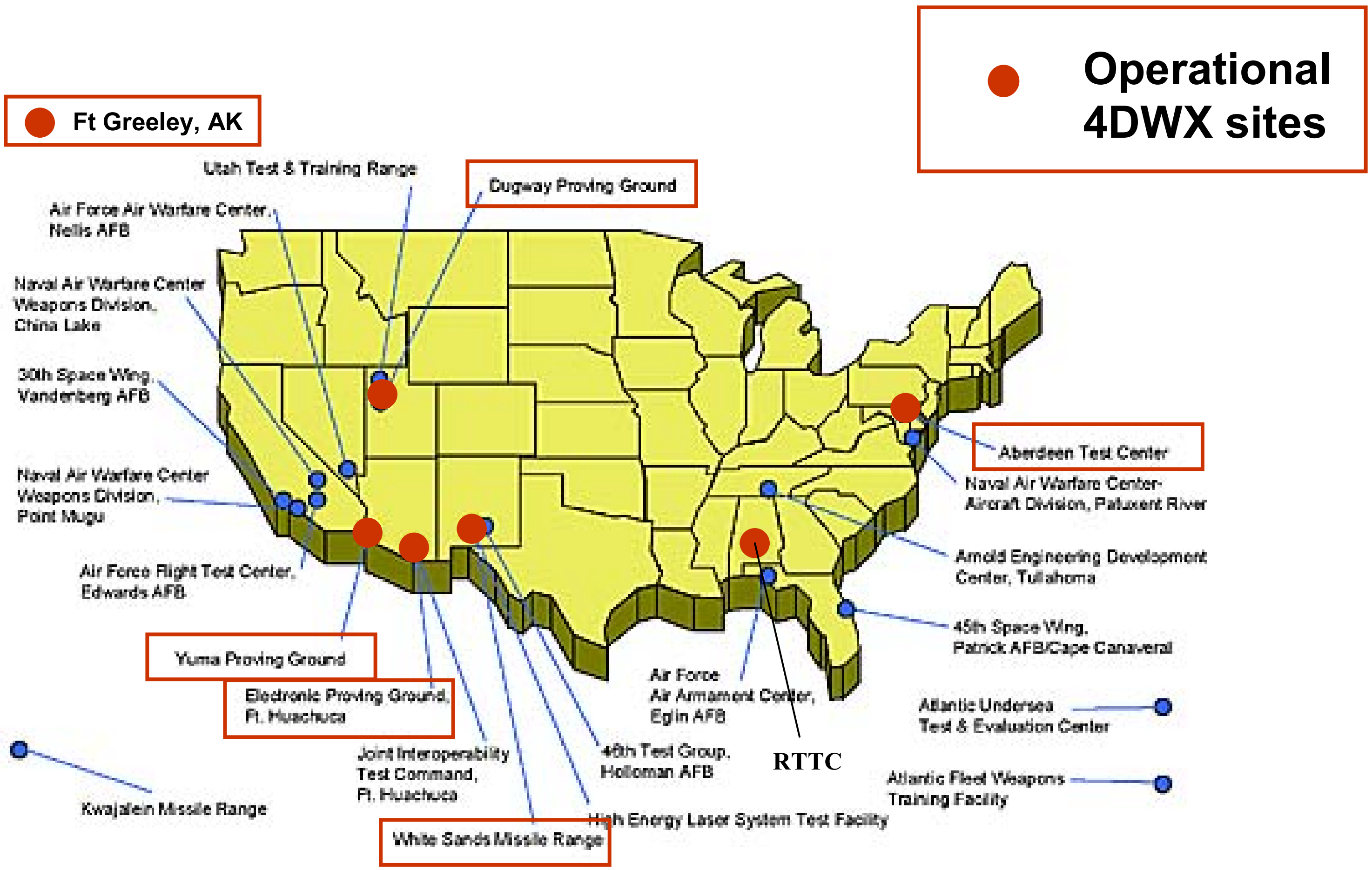
4DWX System Overview

- System Objective: Provide next-generation meteorological support to Army RDT&E
- Development Approach: Transition research-grade technology to operational use through collaboration between operational users and research scientists/systems engineers

4DWX System Overview

- Major 4DWX Components:
  - High-resolution meteorological models
  - Data archival and retrieval system
  - Data and model-output displays (including web-based)
  - Coupled range applications models (sound, dispersion, etc.)
  - Automated thunderstorm forecast system (0-60 min)

Currently deployed 4DWX systems



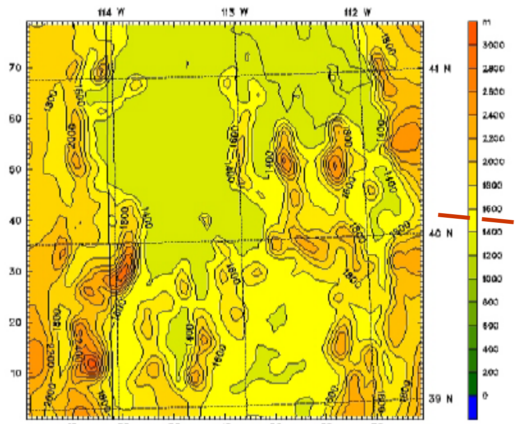
4DWX Forecast and Analysis Modeling Systems

- Real-Time Four-Dimensional Data Assimilation (RT-FDDA)
- Global Meteorology on Demand (GMOD)
- Variational Doppler Radar Analysis System (VDRAS)
- Variational Lidar Assimilation System (VLAS)

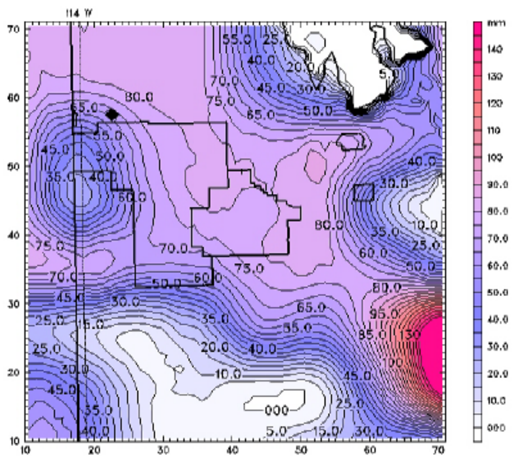
RT-FDDA Overview

- Based on Penn State/NCAR full-physics MM5 mesoscale meteorological model
- High resolution (1 to 3 km horizontal grid spacing) achieved through nested computational domains
- Analyses (“observation nudging”) of many types of meteorological observations and 48-hour forecasts updated every 3 hours

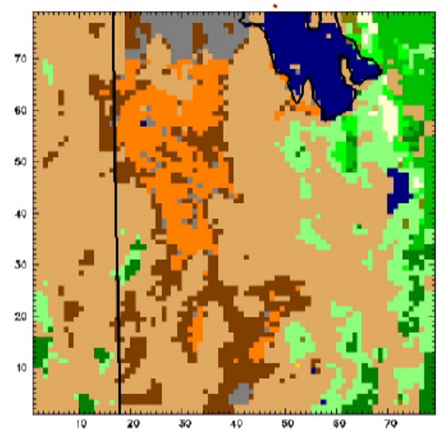
RT-FDDA: example model setup at Dugway



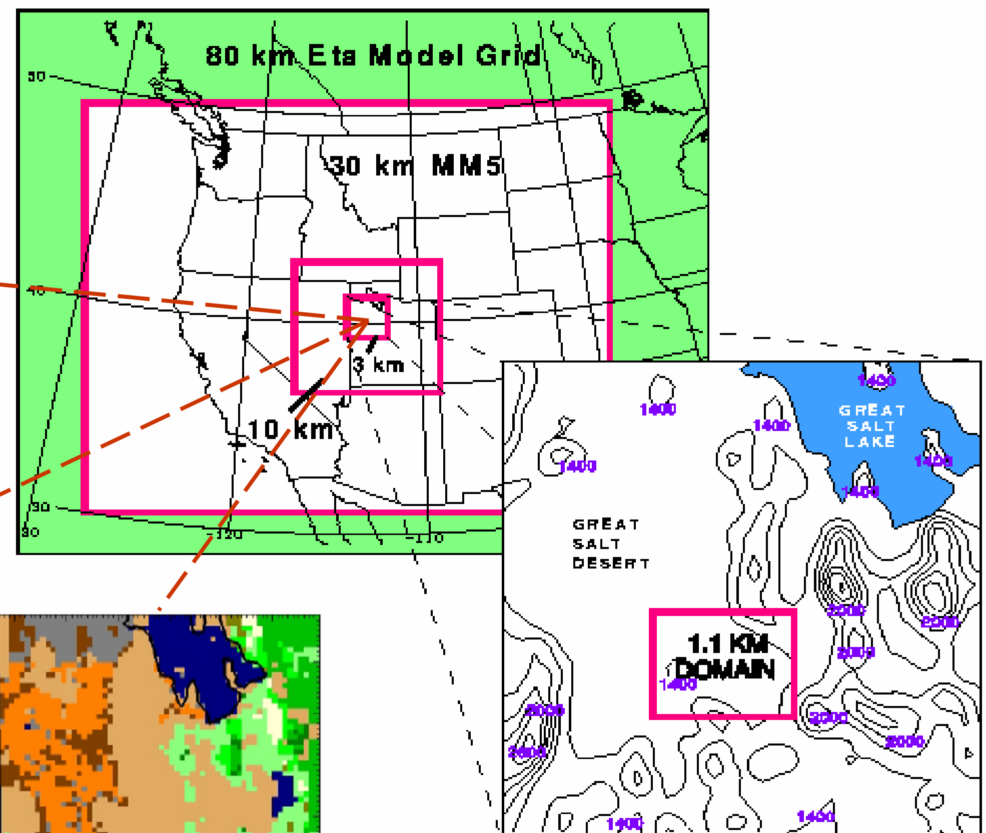
Domain 3 topography



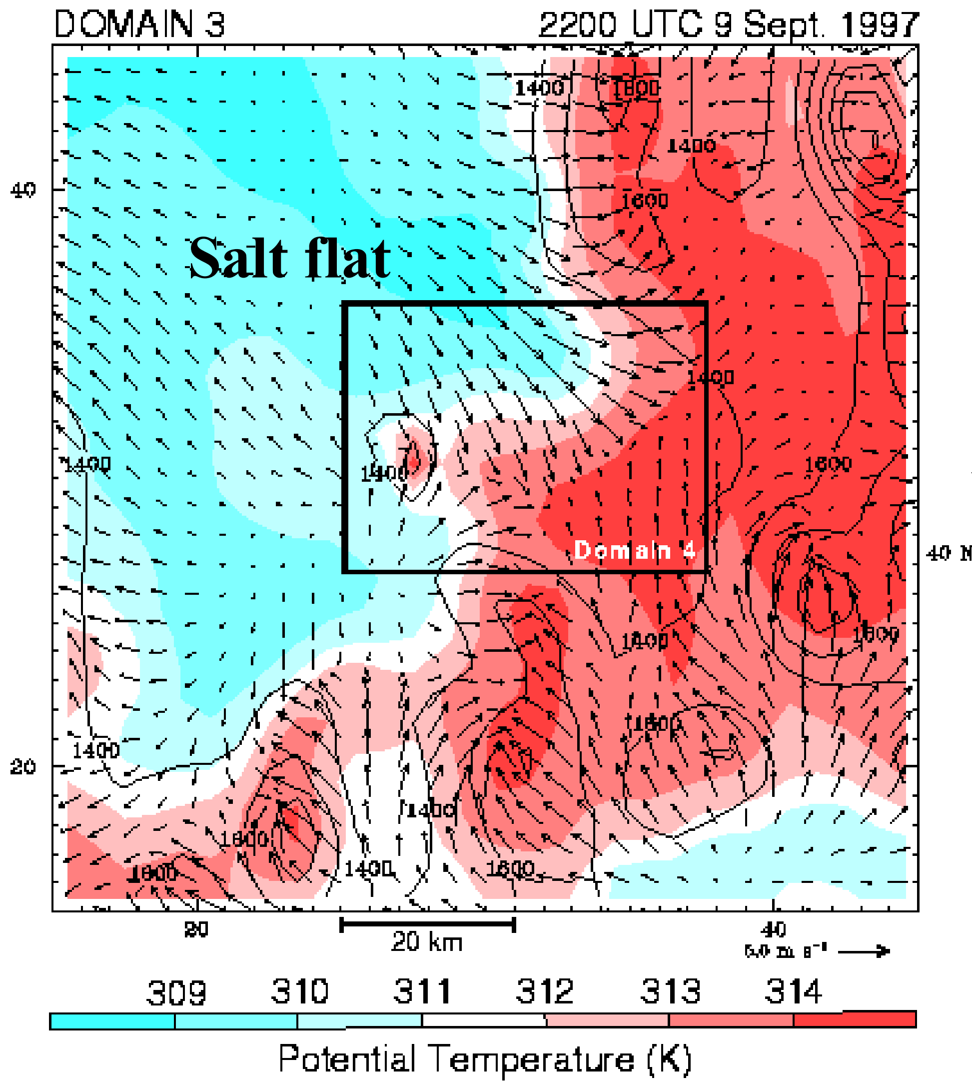
Domain 3 snow cover



Domain 3 land use



Sample RTFDDA Output



Salt breeze at DPG

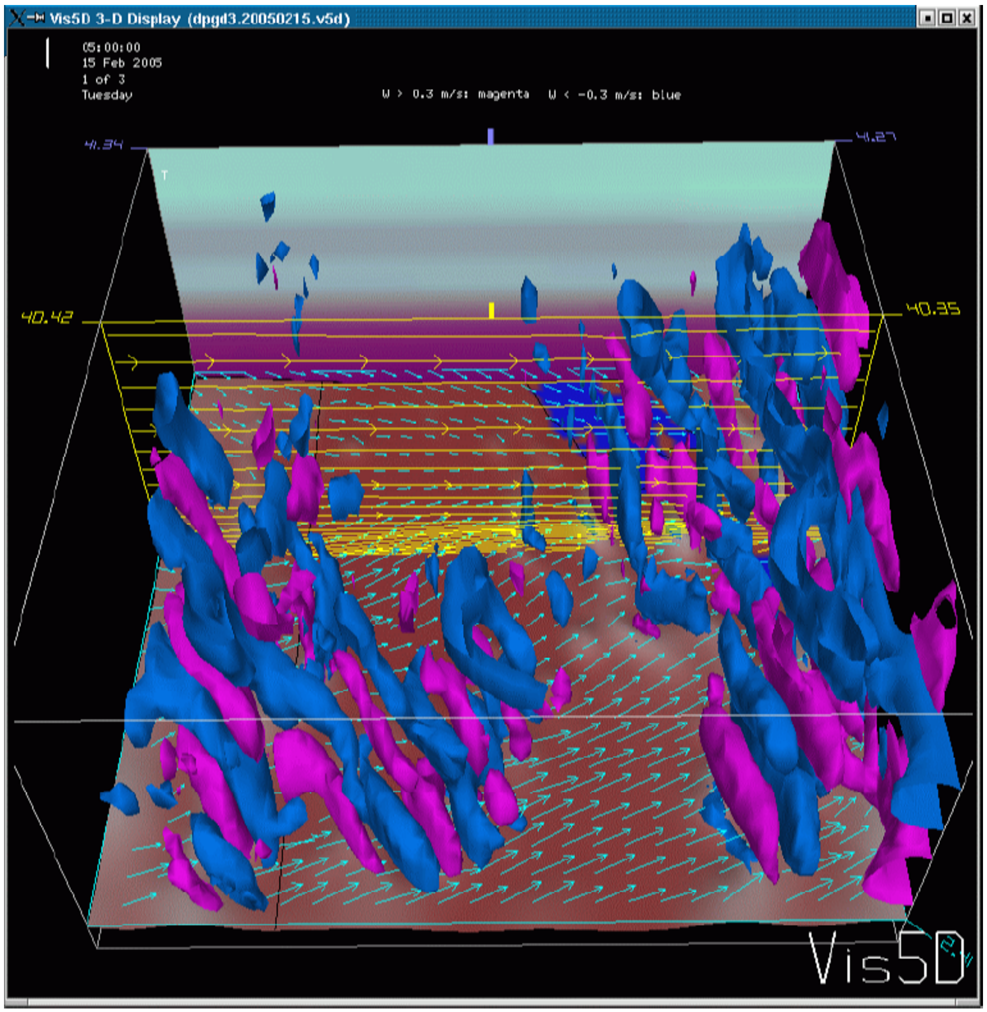
Velocity vectors

and

Temperature

(1500 LT)

Sample RT-FDDA output



DPG Forecast

Velocity vectors

and

Vertical motion
blue = downward
pink = upward

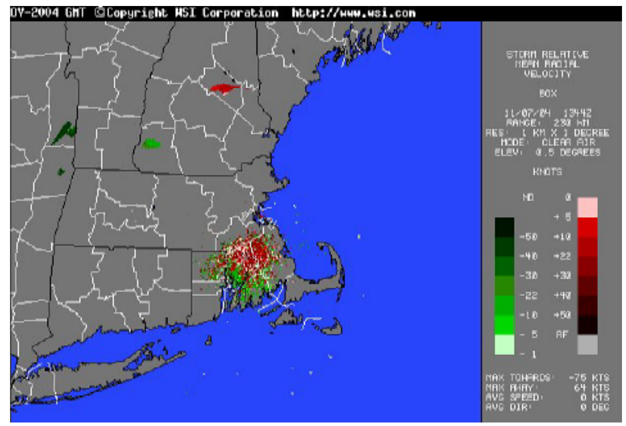
GMOD Overview

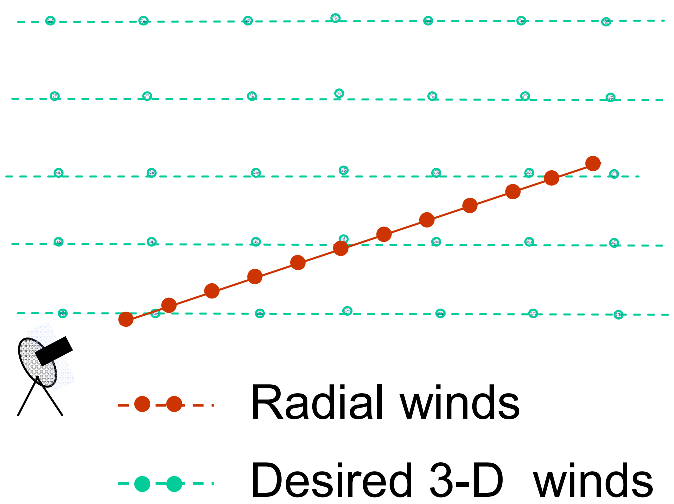
- Globally relocatable and reconfigurable by non-expert meteorologists
- Provides RT-FDDA forecast and analysis capabilities anywhere in the world
- Provides back-up when a range system fails
- Examples of applications
  - Missile launches in Hawaii
  - DTRA/DHS dispersion experiment in Oklahoma City
  - DARPA dispersion experiment in Washington DC

Doppler radar-based VDRAS

NEXRAD

Radial winds



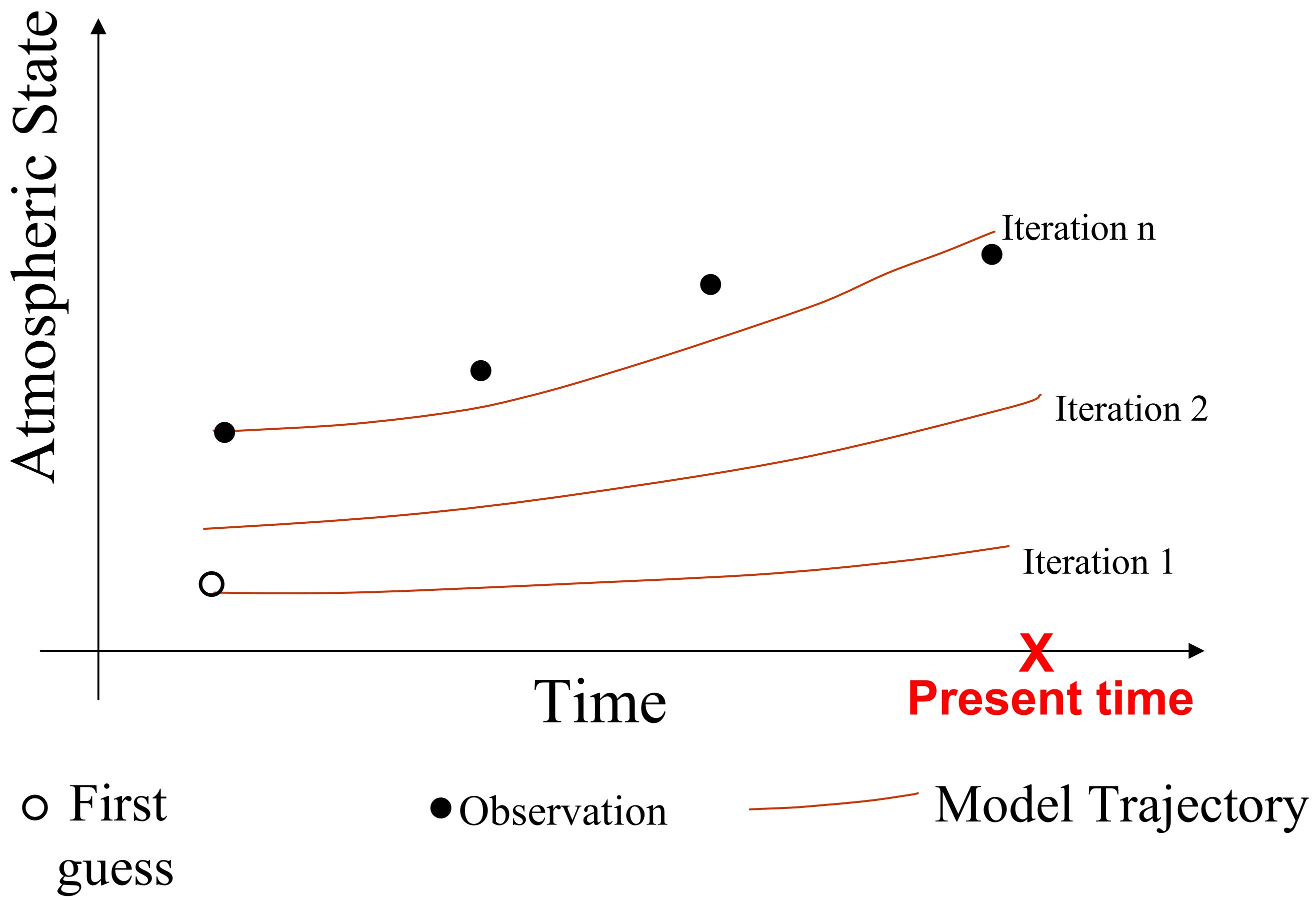


Doppler radars and lidars compute radial velocity and reflectivity. But for many applications, need full 3-D windfield

VDRAS Overview

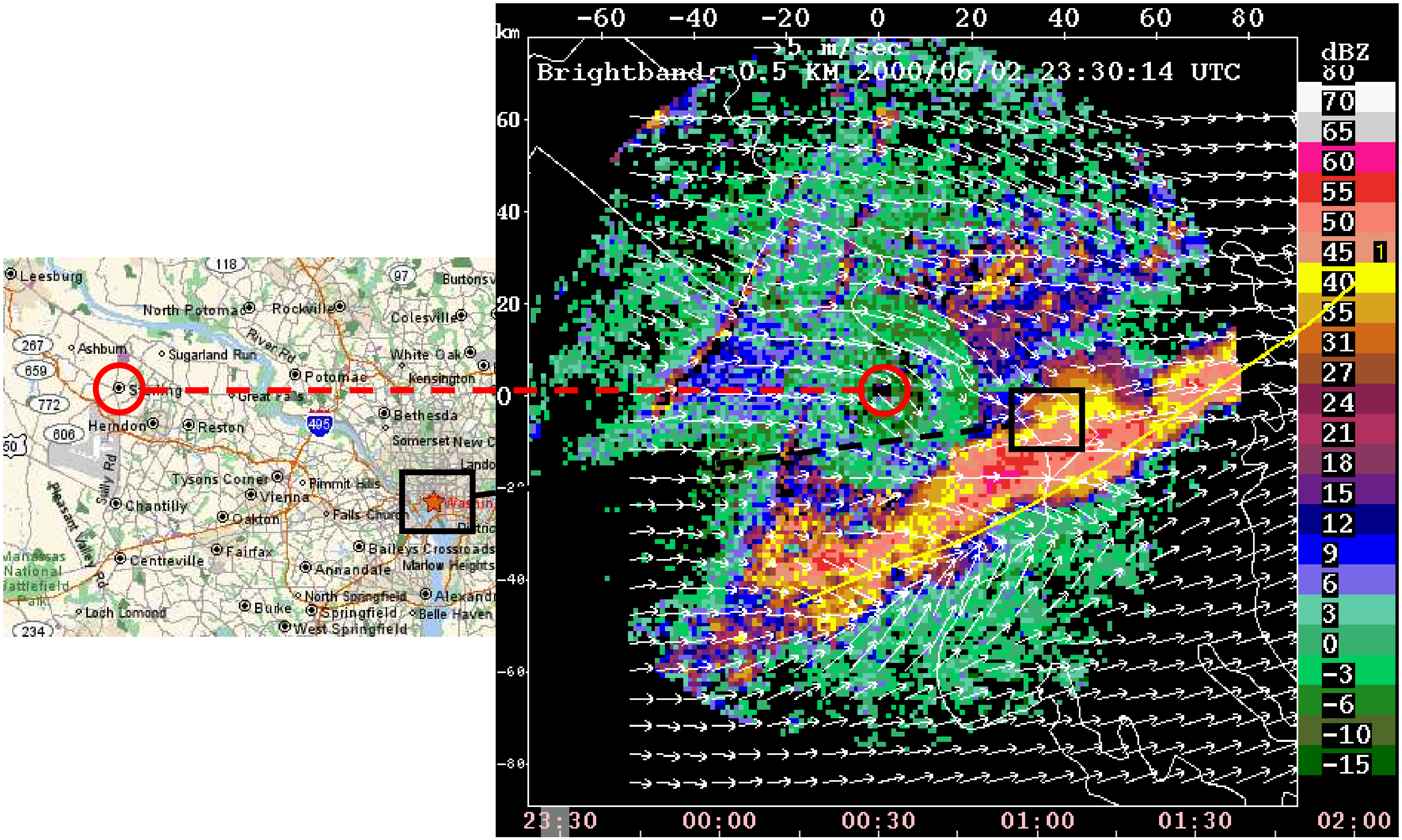
- Derives 3D wind fields from Doppler radar clear-air returns
- Uses Doppler radar radial velocities and reflectivities plus other available meteorological observations as input
- Four-dimensional variational (4DVAR) methodology fits a physics-based model to a time-series of observations
- Model extrapolated forward in time to produce a short-term (~30-min) forecast

4D-Variational Data Assimilation



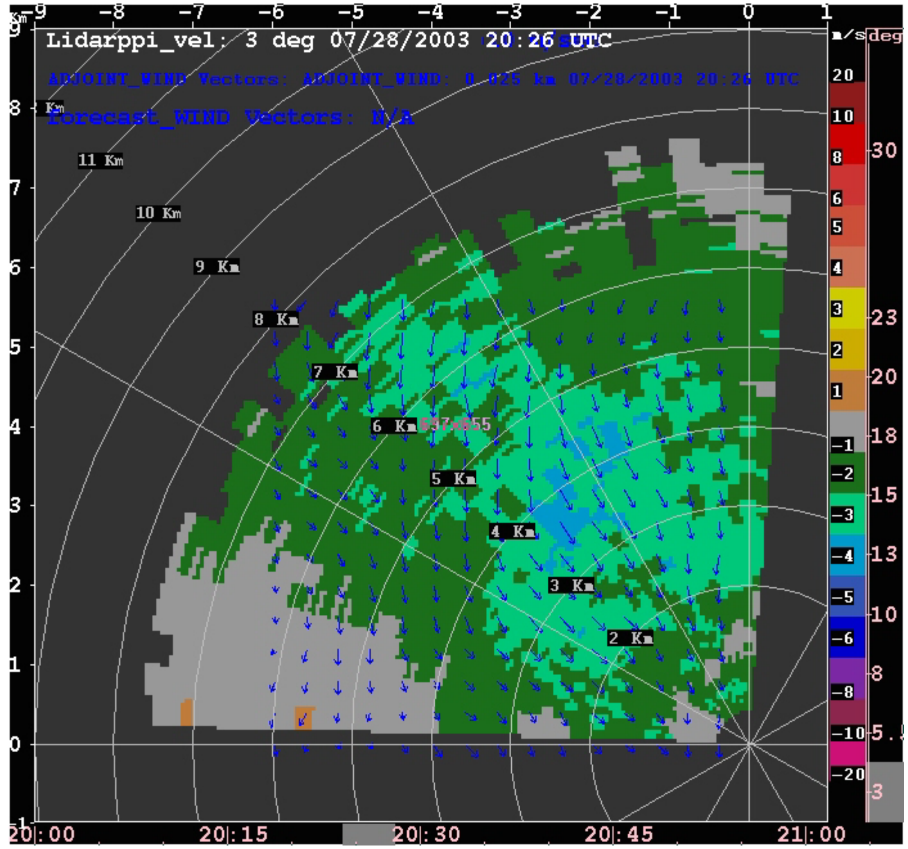
Fit model to observations over a time window to minimize the difference between model trajectory and observations

VDRAS winds for Washington D.C. area



VLAS: VDRAS algorithm adapted to Doppler lidar

CTI Doppler lidar

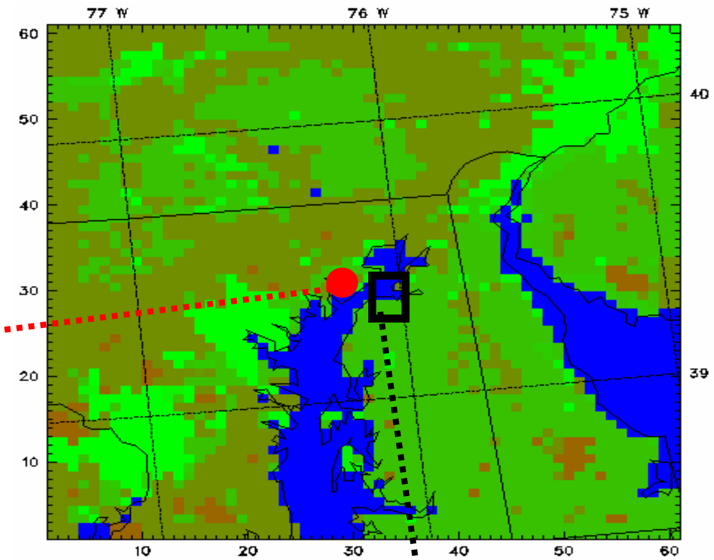


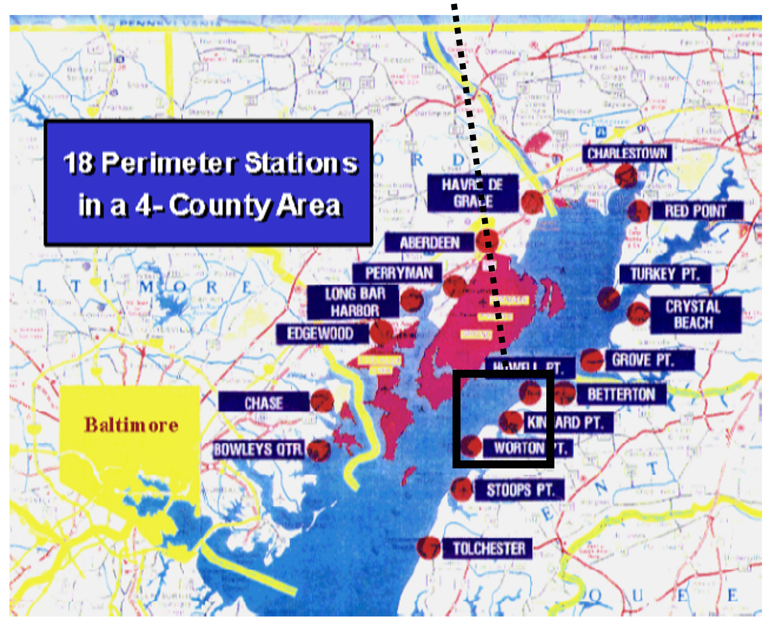
Radial velocity field with VLAS wind vectors:
70 m horizontal resolution in 7x7 km area

Coupled Model Applications

- RT-FDDA, VDRAS, or VLAS analyses or forecasts used as meteorological inputs to other models
- Example application: sound propagation at Aberdeen Test Center (ATC), Aberdeen Proving Ground, MD

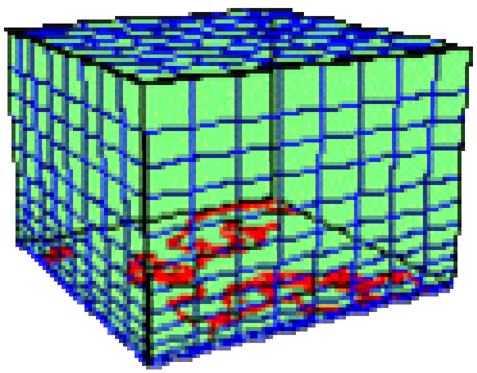
Sound propagation prediction at ATC

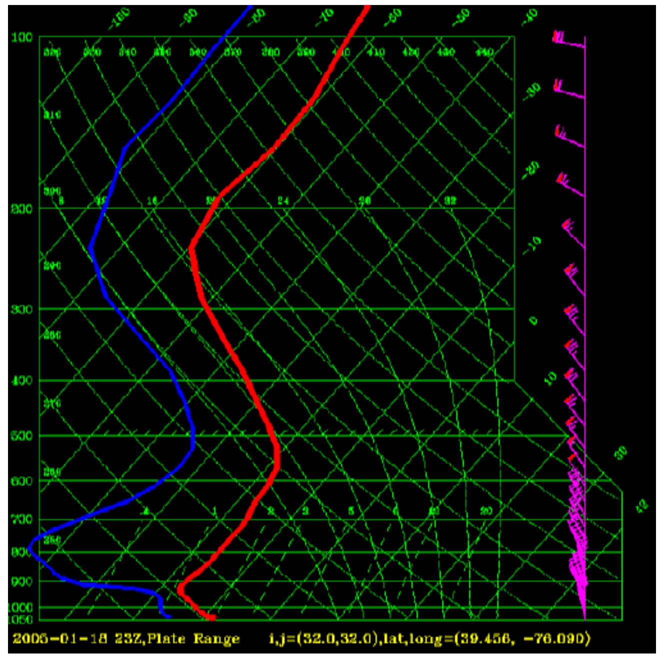




Explosives testing causes neighborhood disturbances during periods of high sound propagation

Solution: extract 1-D synthetic soundings from RT-FDDA forecasts



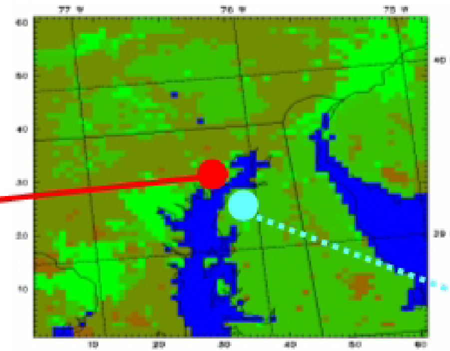


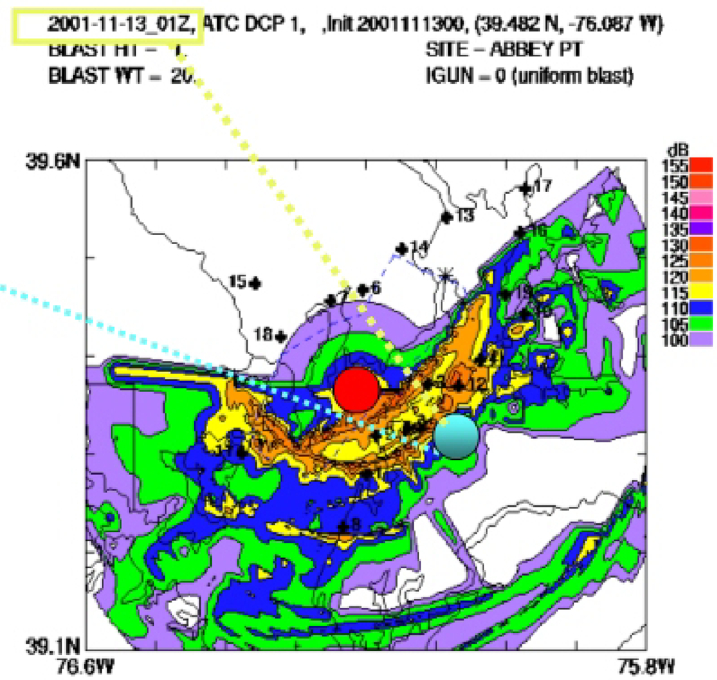
1-D
Sound model

Forecast of sound intensity

Soundings extracted from RT-FDDA forecasts, coupled to sound model provides sound propagation forecast

4DWX coupled-app guides test planning





Range forecaster analyzes sound intensity prediction, and recommends when to test on the following day

Rapid Prototype Cycle

- 4DWX enhancements constrained by
  - Hardware requirements (>100 processors per range) for 24/7 operational systems
  - Dependence on external data sources, which may fail
  - Variations in user requirements across ranges
  - Information security requirements

Rapid Prototype Cycle

- Development approach
  - Extensive user involvement in defining requirements and setting development priorities
  - Parallel tests of new products for 3-6 months before transition to operational systems
  - Standardization of system hardware, software, and data acquisition systems
  - Ongoing, iterative development to consider new user requirements and/or take advantage of recent advances in meteorology or computer technology

Near-Term Enhancements

- Transition from MM5 to next-generation Weather Research and Forecast (WRF) model
- Dynamic Integrated Forecast (DiCast) forecast system for 15-day point consensus forecasts (specific locations) from multiple weather models
- Operational ensemble mesoscale forecasts

Summary

- 4DWX provides Army test ranges with unique operational meteorological support capabilities
- Rapid transition of research-grade technology achieved by
  - Close, ongoing collaboration between developer and user
  - Ongoing, iterative development
  - Parallel tests of prototype and current systems before operational implementation