Sub-km WRF configuration for testing over the U.S. Army Research Laboratory's Meteorological Sensor Array in the Jornada Experimental Range

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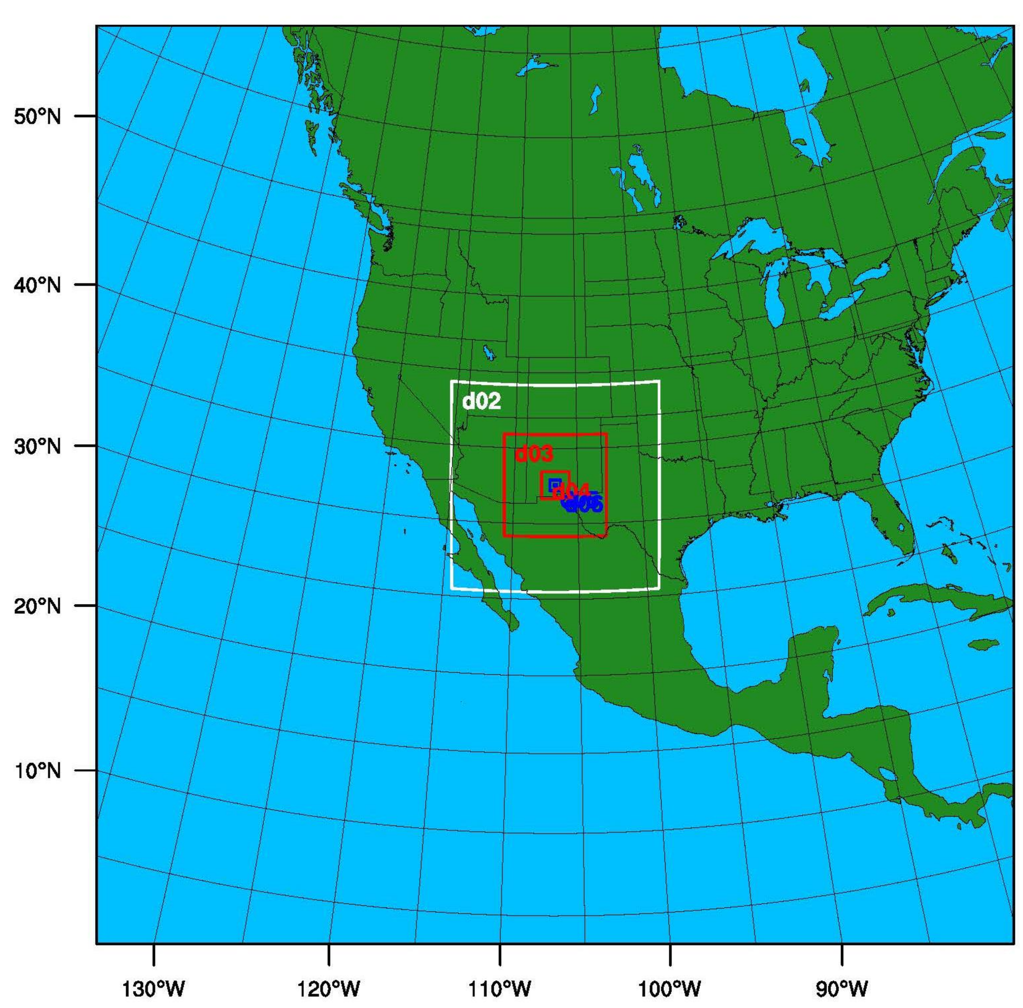
Introduction

- WRF-ARW nested configuration for supporting modeling & theoretical research over ARL's Meteorological Sensing Array (MSA) across the Jornada Experimental Range (JER).
- Focus on surface and boundary layer processes using MSA observation network resources.
- WRF-ARW Version 3.9.1.1 (upgrade to V 4 soon).

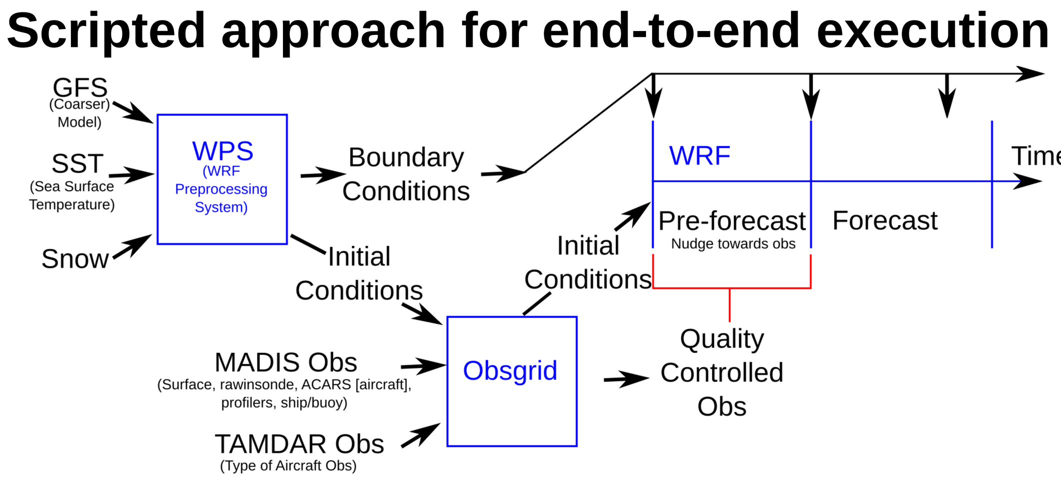
Approach

- Relocatable multinest strategy to go from operational global & mesoscale model resolutions (that supply lateral boundary conditions) to very large eddy simulation (VLES) resolution (as fine as 150 m grid spacing).
- Use NCAR's WRF VLES configuration physics & diffusion options as guidance.
- Four dimensional data assimilation (observation nudging) & radar reflectivity assimilation via latent heat adjustment methods are available for data assimilation.

WPS Domain Configuration



Scripted approach for end-to-end execution

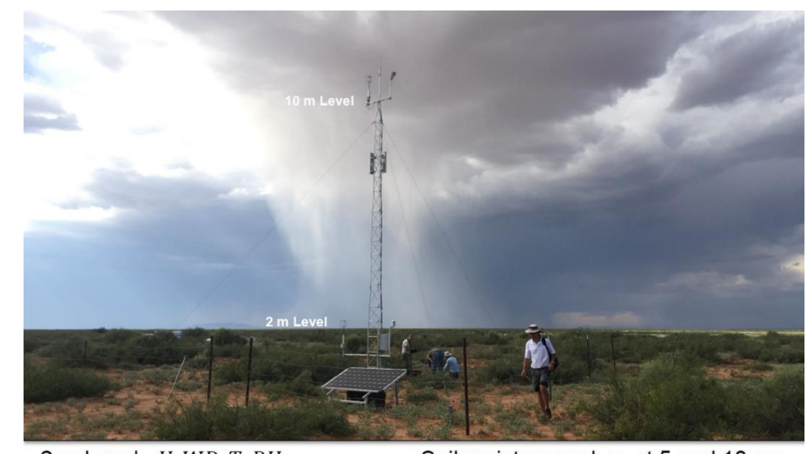


Radar reflectivity assimilation technique

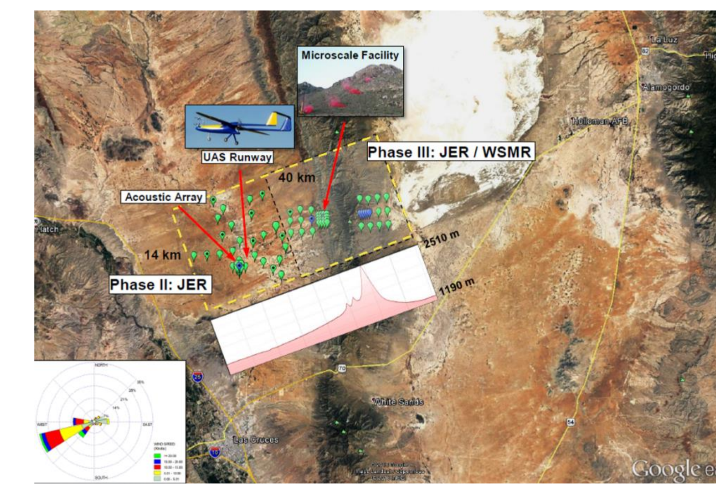
Method: Calculate latent heating terms based on radar reflectivity and apply during WRE-N pre-forecast:

- Based on NOAA operational CONUS 3-km HRRR model method.
  - Tests indicate method is beneficial on smaller, higher resolution domain than HRRR, even with very limited non-radar observations to assimilate.
  - The radar-derived latent heating term is calculated via GSD cloud analysis option in Gridpoint Statistical Interpolation (GSI; V3.6).

MSA over JER



2 m Level: U, WD, T, RH, p Soil moisture probes at 5 and 10 cm, rain gauge, pyranometer.
10 m Level: U, WD, T



Technical Significance

Once complete, MSA will be the premier meso/micronet for atmospheric science research due to unprecedented resolution (spacing less than 2 km and sampling of f = 20 hz) and a domain which includes diverse topography ranging from a valley at 1300 m to a mountain which peaks at 2500 m.

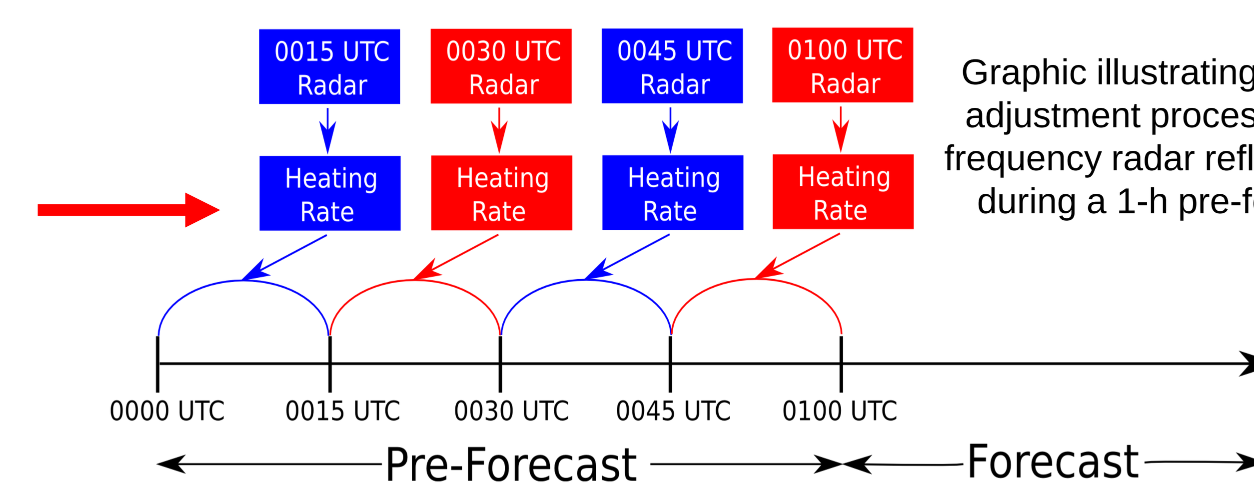
Impact to Scientific Community

The MSA will address community need for high-resolution observational data for advancing state of science in development, verification, and validation of fine-scale atmospheric prediction models, and provides testing ground for atmospheric sensor development.

Atmospheric modelers in Air Force, Navy, NOAA, NCAR, DOE and academia will have access to very unique multi-scale sources of boundary layer atmospheric data for their research efforts targeting future improvements to operational weather forecasting capabilities.

Impact to Army/DoD

Will provide more accurate weather information and advanced decision aids to increase the probability of mission success.



Graphic illustrating the latent heat adjustment process using 15-min frequency radar reflectivity products during a 1-h pre-forecast period

Nesting over JER from GFS ½ deg to VLES

36.45 km:	187x187x90
12.15 km:	127x127x90
4.05 km:	187x187x90
1.35 km:	151x151x90
0.45 km:	175x175x90
0.15 km:	101x101x90

Physics

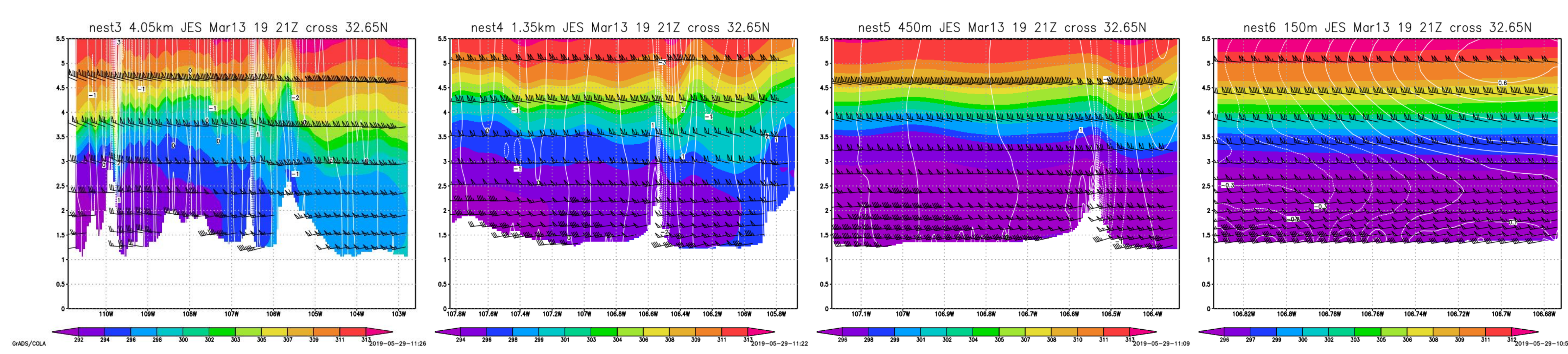
- Dudhia shortwave (slope, shadow, and swint parameters: on).
- RRTM long wave
- Thompson aerosol-aware microphysics
- Shin-Hong scale-aware PBL (QNSE-EDMH for some efforts) all nests
- Grell-Frietas scale-aware (with shallow convection and cu_rad_feedback parameters: on) for all nests > 1 km grid spacing.
- Noah land surface with enhanced 19 category STATSGO, 1 arc sec NLCD 2006 (mapped to USGS 28 cat), and 3 arc sec SRTM topography (may move to NOAH-MP in future)
- Optional dust-only WRF-CHEM mode

Dynamics/diffusion

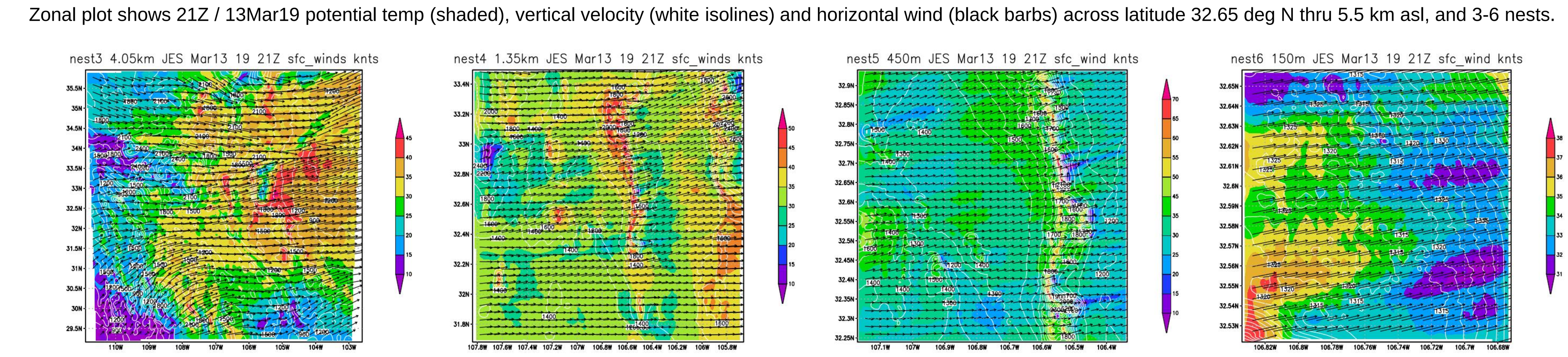
- epssm = 0.5 (damps vertically propagating sound waves over steep slopes)
- diff_opt=2 (Cartesian) and km_opt=4 (Smagorisnky 2D) horizontal turbulence diffusion
- damp_opt=3 (w-Rayleigh upper damping to prevent reflection of vertically propagating gravity waves from model top)
- advection: 5th order horizontal; 3rd order vertical
- 6th order diffusion parameter: on
- Two-way nest feedback parameter: off

Areas of sub-km modeling research that can benefit from the availability of the JER MSA

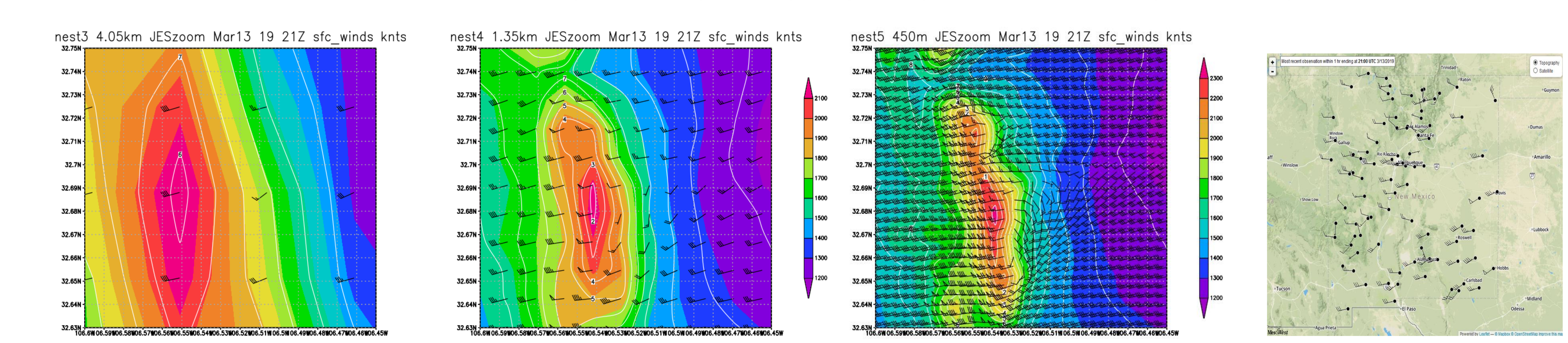
- Land surface/surface layer/ boundary layer fluxes & exchanges.
- Slope processes (such as flow separation).
- Terrain-driven diurnal flows and significant wind events (such as rotors/lee waves & hydraulic jumps).
- Improved treatment of soil and land use properties, and lower boundary initial conditions.
- Stratified stable boundary layer behavior near complex terrain.
- Deep dry convective boundary layers & convective rolls.
- SW U.S. "monsoon" convection.
- Lateral boundary treatment for LES nesting inside mesoscale NWP nests.
- Mesoscale to microscale atmospheric model exchanges (e.g., WRF VLES with ARL's ABLE-LBM microscale model).
- Treatment of shallow cumulus (SHCU) when nesting across various resolutions, since PBL & deep CPS physics can sometimes both handle SHCU (in addition to stand-alone SHCU options being available in WRF).
- Grey-area deep convective resolutions (5-10 km grid spacing) & "terra incognita" PBL turbulence grey-areas (150 m – 1.5 km grid spacing).
- Potential for exploring solar radiation in tilted vs vertical pixel approach.
- Dust aerosol & other chemical constituents (like ozone).
- Wildfire-atmosphere coupled processes.
- Two-way feedback between nests.
- Effect of various WRF diffusion options (explicit & implicit) at high resolution.



Zonal plot shows 21Z / 13Mar19 potential temp (shaded), vertical velocity (white isolines) and horizontal wind (black barbs) across latitude 32.65 deg N thru 5.5 km asl, and 3-6 nests.



The 21Z 13 Mar 2019 surface wind vectors (black arrows) , wind speed (shaded) , and terrain contours (white isolines) for nests 3,4,5 & 6.



Zoomed in area near San Andres Peak shows 21Z 13 Mar 2019 model results at 4.05 km, 1.35 km, and 450 m grid spacing, where higher resolution of grid 5 (450 m) appears to provide more important details in the flow field. Model terrain elevation (shaded), surface 2m agl air temp (white isolines), and surface 10 m agl winds (black barbs) are shown. Note: U.S. MesoWest-generated figure on far right actually shows 21Z NWS & RAWS wind observations across S. NM. This was a synoptically-driven high zonal wind speed event across most of southern NM.

Transitioning for Army applications

- Refine the WRF configuration (such as to a 9 km/1.8 km double nest strategy) for forward-deployed (laptop or workstation) convection-allowing nowcasting as a Weather Running Estimate-Nowcast or "WRE-N" tool (test results against the higher resolution WRF configuration as used for JER).
- WRE-N will provide Army's Distributed Common Ground System (DCGS-A) with end-to-end solution for providing atmospheric forecasts and impacts on Army operations at high-resolutions, including capability to function in non-networked, stand-alone configuration (aligns with Army Modernization).
- WRE-N can be further refined to provide unique support for specific Army programs related to Artillery Met firing, precision air drop, dust modeling, fire weather, and flight test & ballistics.
- WRE-N can be used to supply first-guess mesoscale meteorological boundary conditions for ARL atmospheric boundary layer microscale (spatial:1-100 m grid spacing; temporal: 1-15 minutes) models such as the Atmospheric Boundary Layer Experiment – Lattice Boltzmann Method (ABLE-LBM) model still under development and testing.