Enabling Vertical Grid Refinement for Concurrently Run Nested Grids

15th Annual WRF Users' Workshop

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Summary

- Why do we want vertical grid nesting in WRF?
- Explanation of vertical grid nesting in WRF
- Validation of WRF dynamics and vertical grid nesting using an ideal test-case
- Validation of vertical grid nesting with atmospheric physics using an ideal test-case
- WRF test-case with and without vertical nesting
- Vertical nesting applied to the San Francisco Bay Area

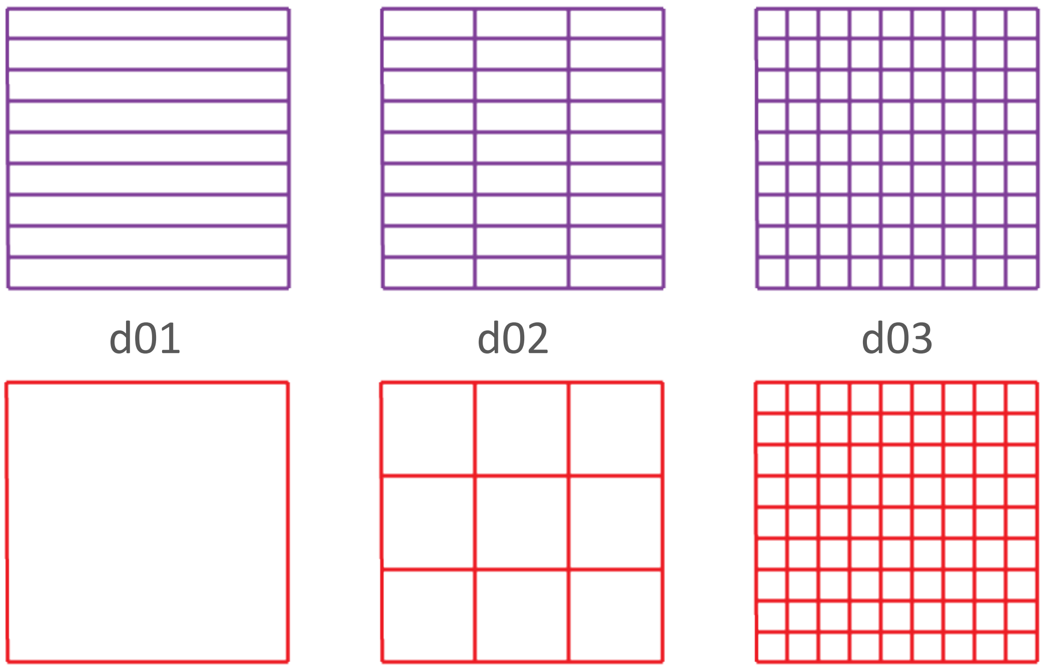
Advances in Modeling

- Modelers continue to push towards higher resolutions
- Historically we've been able to use boundary layer parameterizations, which are not concerned with the grid aspect ratio
- Many modelers now run large eddy simulations, where grid aspect ratio is extremely important [(1)]

(1) Mirocha, J., G. Kirkil, E. Bou-Zeid, F. Chow, and B. Kosovic, 2013: Transition and equilibrium of neutral atmospheric boundary layer flow in one-way nested large-eddy simulations using the weather research and forecasting model. *Monthly Weather Review*, 141, 918–940, doi:10.1175/MWR-D-11-00263.1.

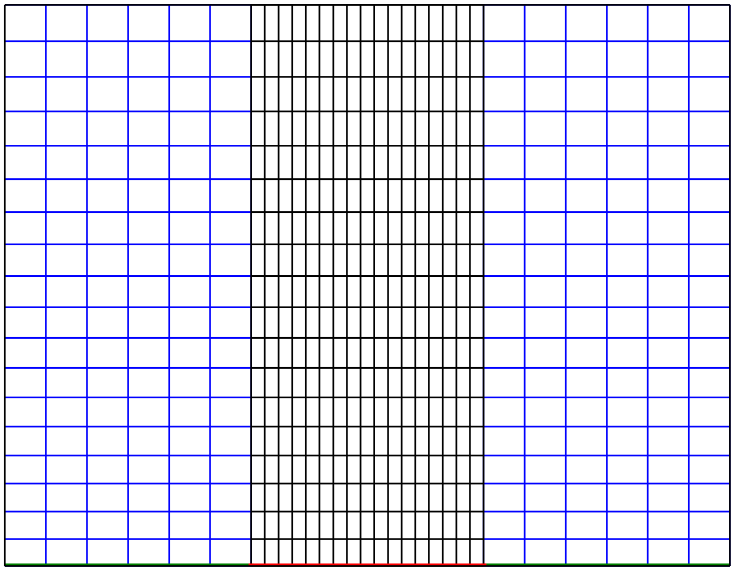
Vertical Grid Nesting in WRF

- Allows the user to put more vertical levels on high-resolution domains and avoid using excessive amounts of vertical levels on coarse domains
- Provides control over the grid aspect ratio of each domain

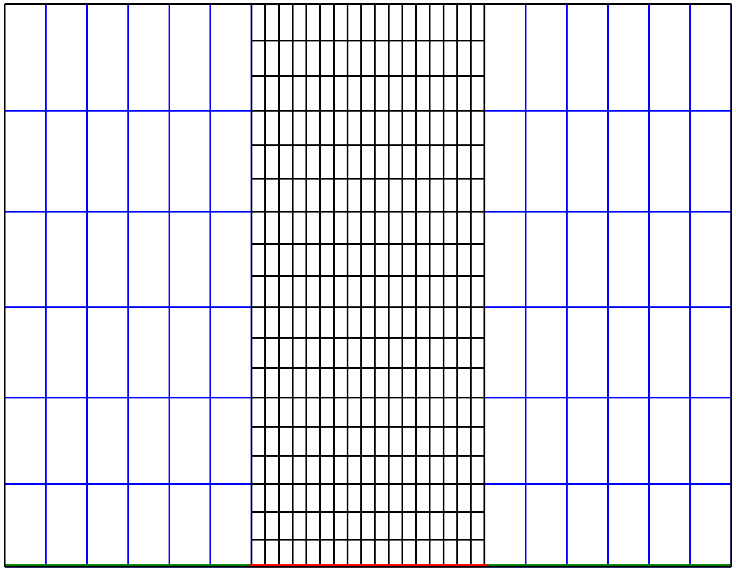


Existing Vertical Grid Nesting in WRF

- Concurrent simulation
  - All domains must have identical vertical levels



- Serial simulation with "ndown" [(2)]
  - Nest boundary conditions update at the frequency of parent grid history
- Uses integer refinement of parent vertical levels



(2) Moustaoui, M., A. Mahalov, J. Dudhia, and D. Gill, 2009: Nesting in wrf with vertical grid refinement and implicit relaxation. WRF Users' Workshop 2009, Boulder, CO, National Center for Atmospheric Research.

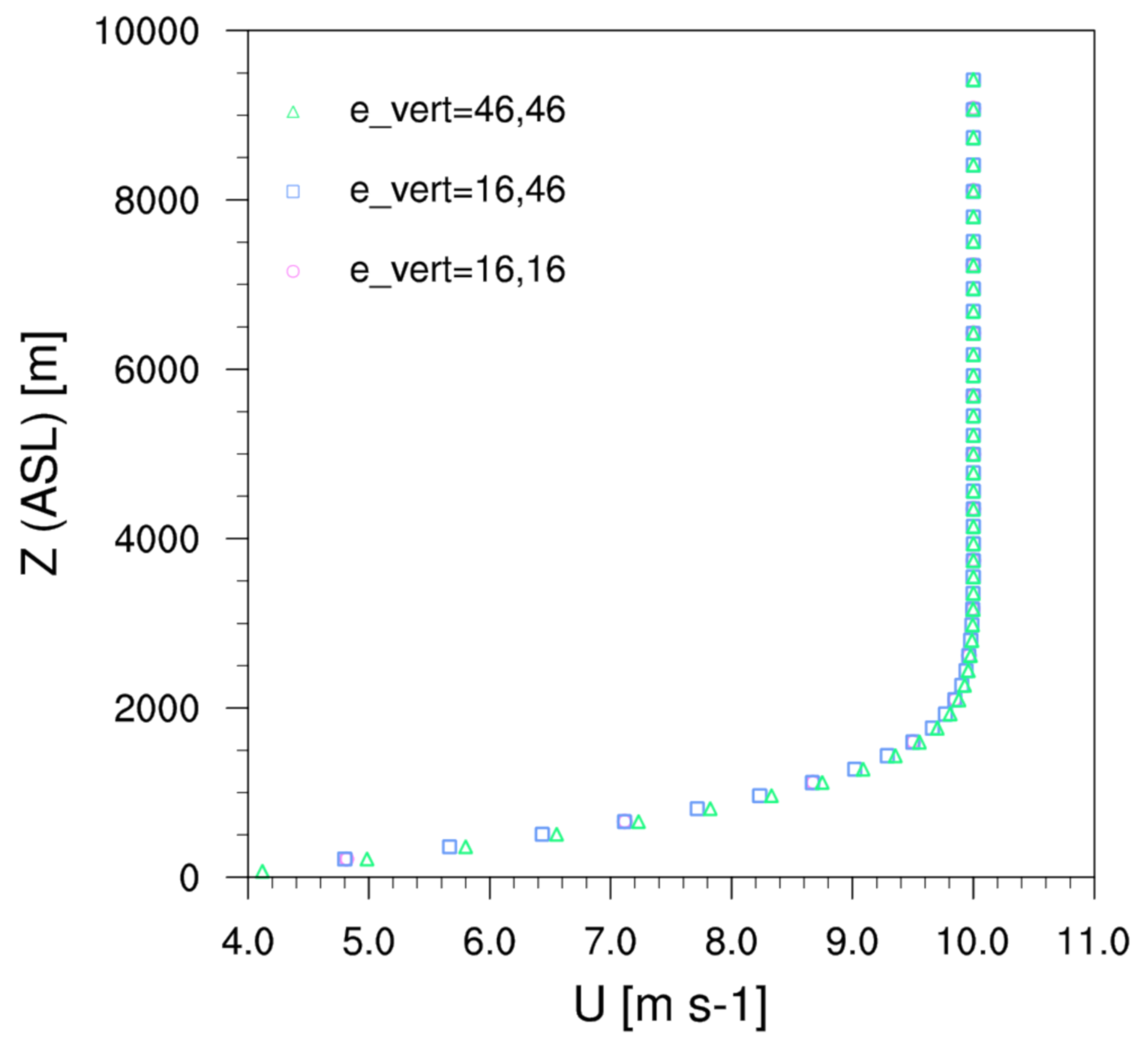
Concurrent Vertical Grid Nesting

- Utilizes the interpolation scheme from ndown
  - Cubic Hermite interpolation
    - Matches value at known points and first derivative
  - Can use an arbitrary number of vertical levels for nested domain compared to parent domain
- Implemented in WRFv3.5.1
  - Vertical grid nesting is not yet included in the public release
- Enabled by adding one new variable to namelist.input

Validation of Vertical Grid Nesting

- Flat plate
- Periodic lateral boundary conditions
- No atmospheric physics
- Initialized with idealized sounding
  - 10 m s^{-1} wind speed at all heights
  - Dry and neutral temperature profile
- Forced by maintaining initial conditions in top 3000 meters of domain

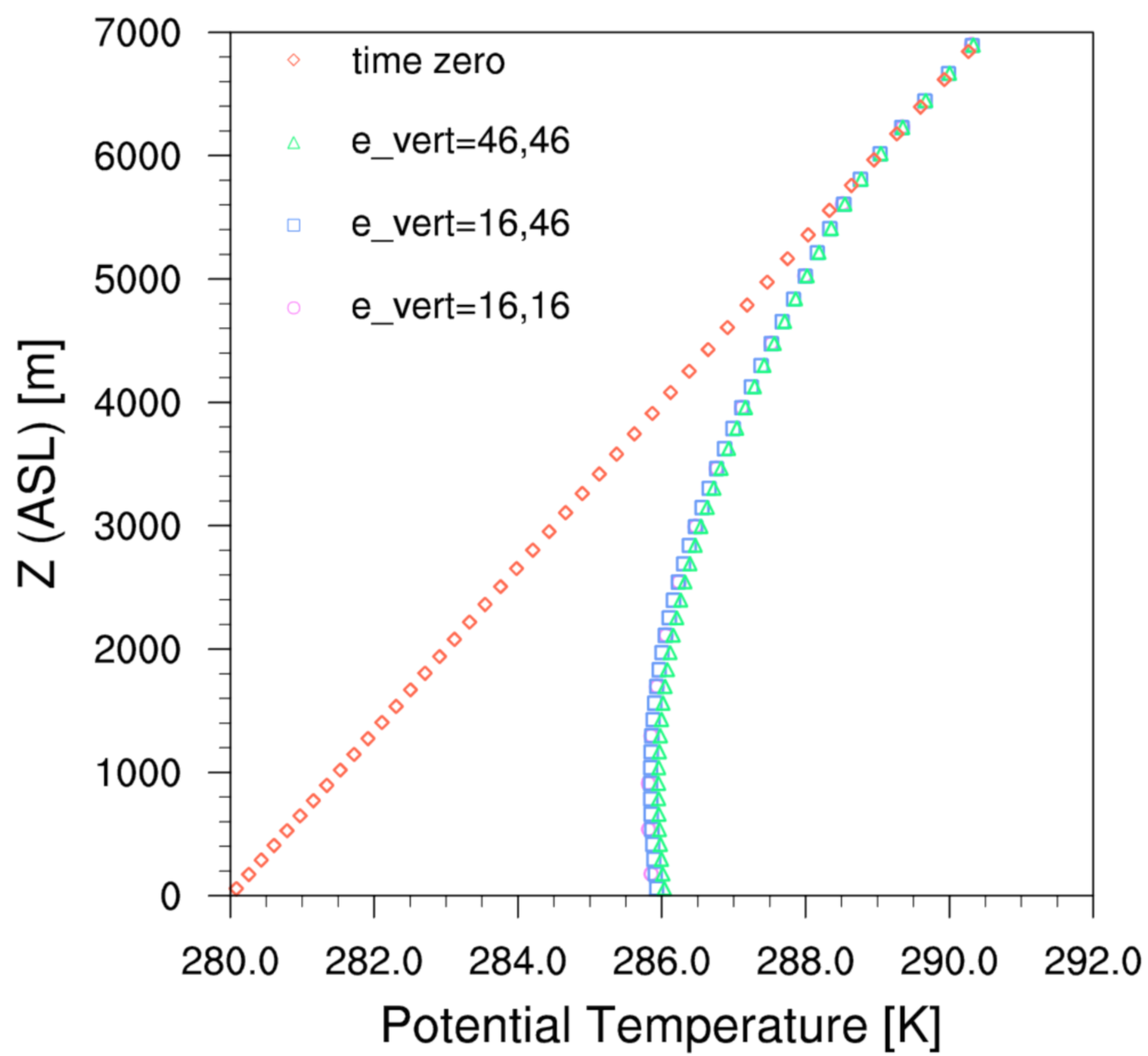
Flow Over a Flat Plate



Vertical Nesting with Atmospheric Physics

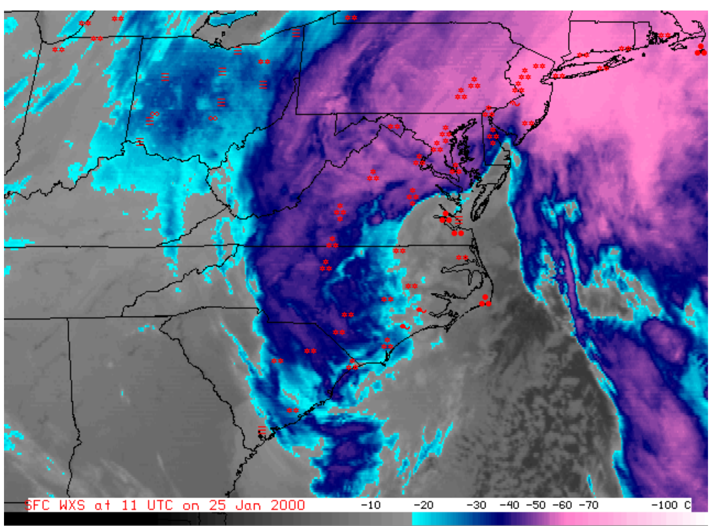
- Testing atmospheric physics with vertical nesting
  - Flat plate with uniform land surface and soil properties
  - Initialized with a stable, dry, quiescent idealized sounding
  - Periodic lateral boundary conditions
  - RRTM longwave radiation scheme
  - Dudhia shortwave radiation scheme
  - Noah land surface model
  - Monin-Obukhov surface layer scheme
- Difficulties with radiation schemes
  - We are currently evaluating which schemes are working properly with our modifications and enabling the use of several popular schemes with vertical nesting

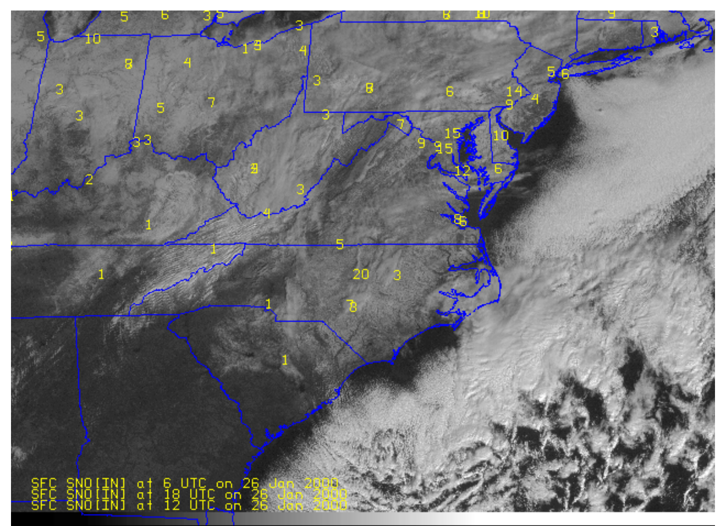
Heating of a Flat Plate



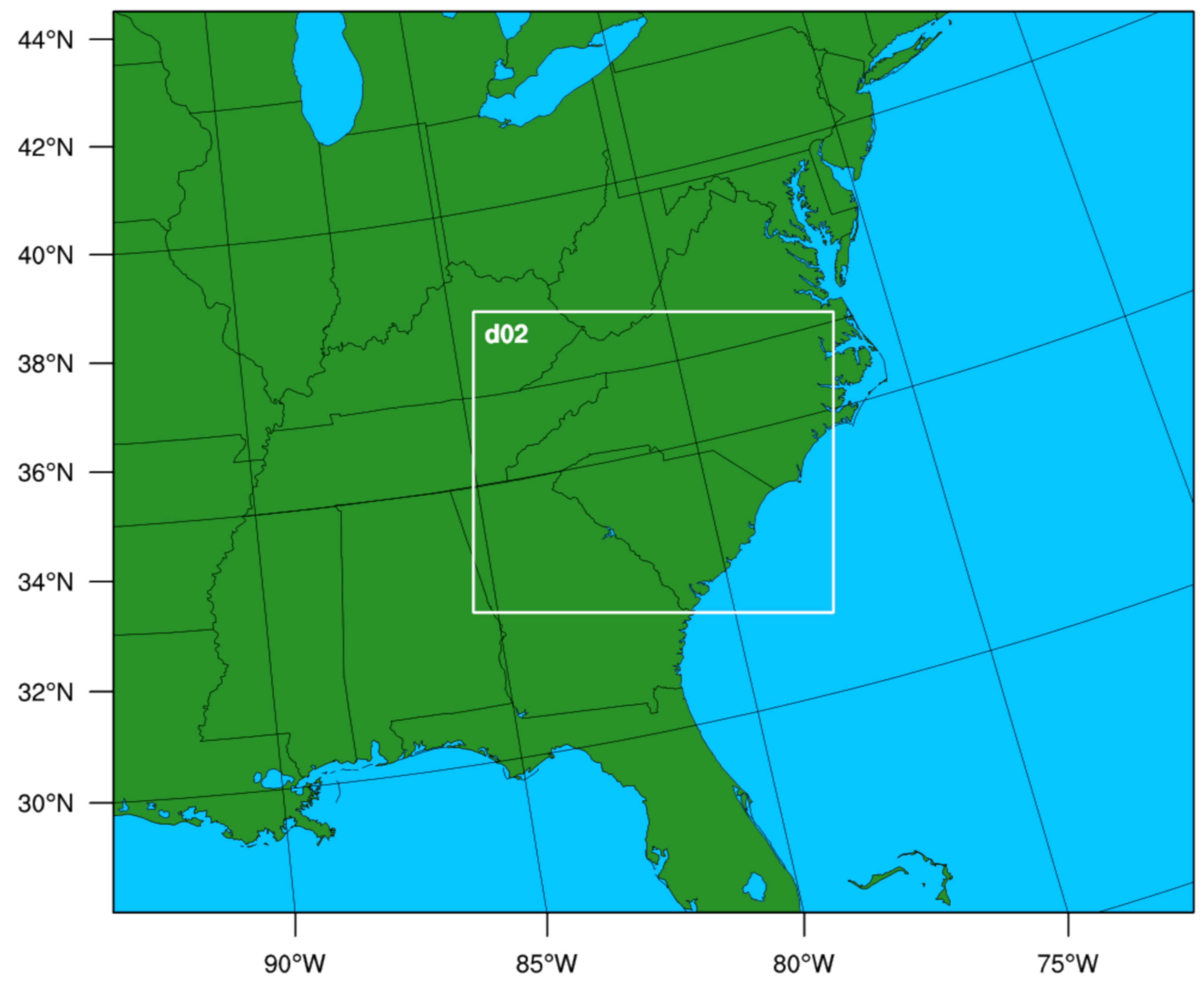
WRF Test-Case, January 2000

- WSM 3-class microphysics
- RRTM longwave radiation scheme
- Dudhia shortwave radiation scheme
- Thermal diffusion scheme
- Monin-Obukhov surface layer scheme
- YSU Planetary Boundary Layer Scheme
- Kain-Fritsch Cumulus Parameterization

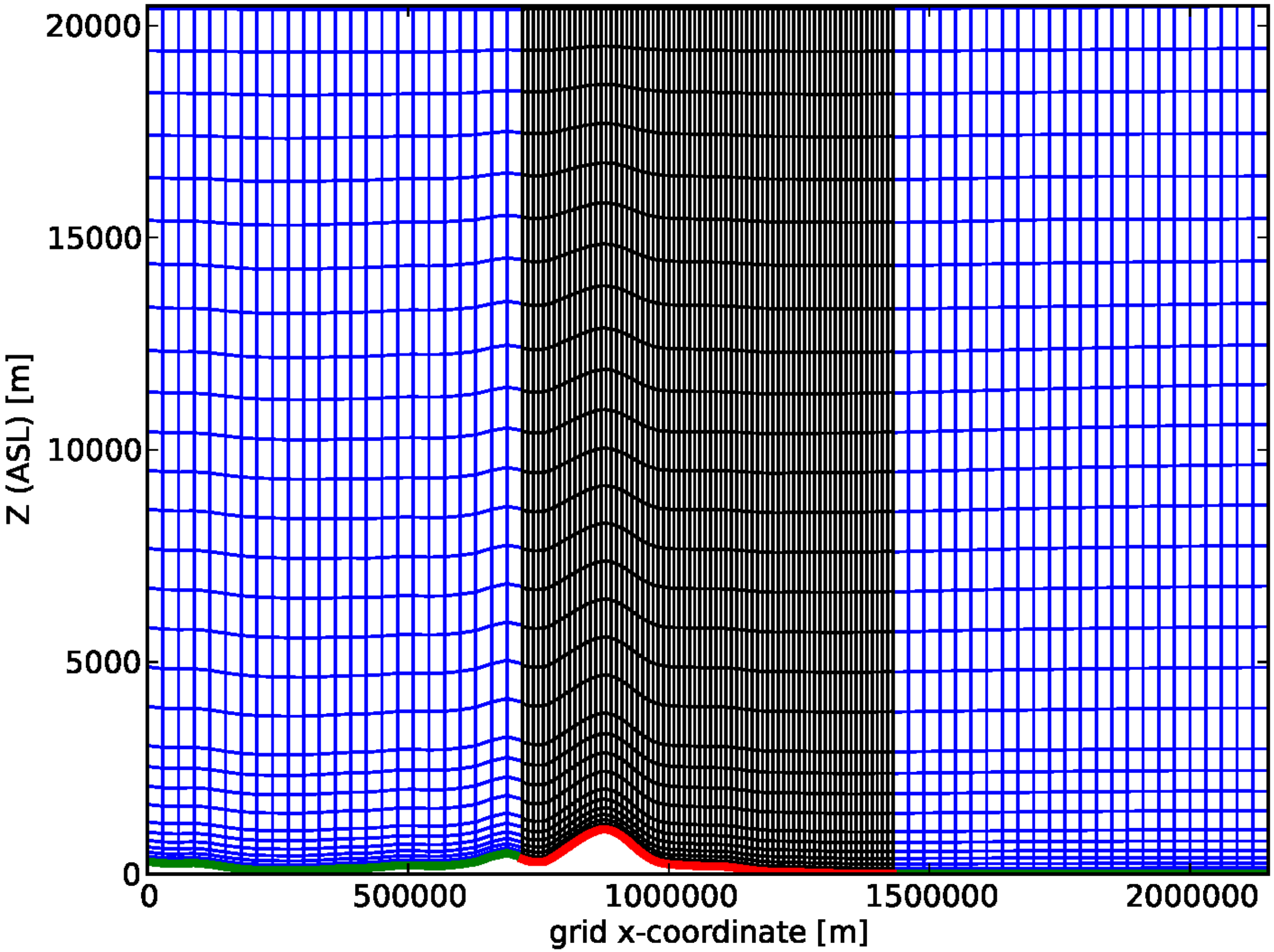




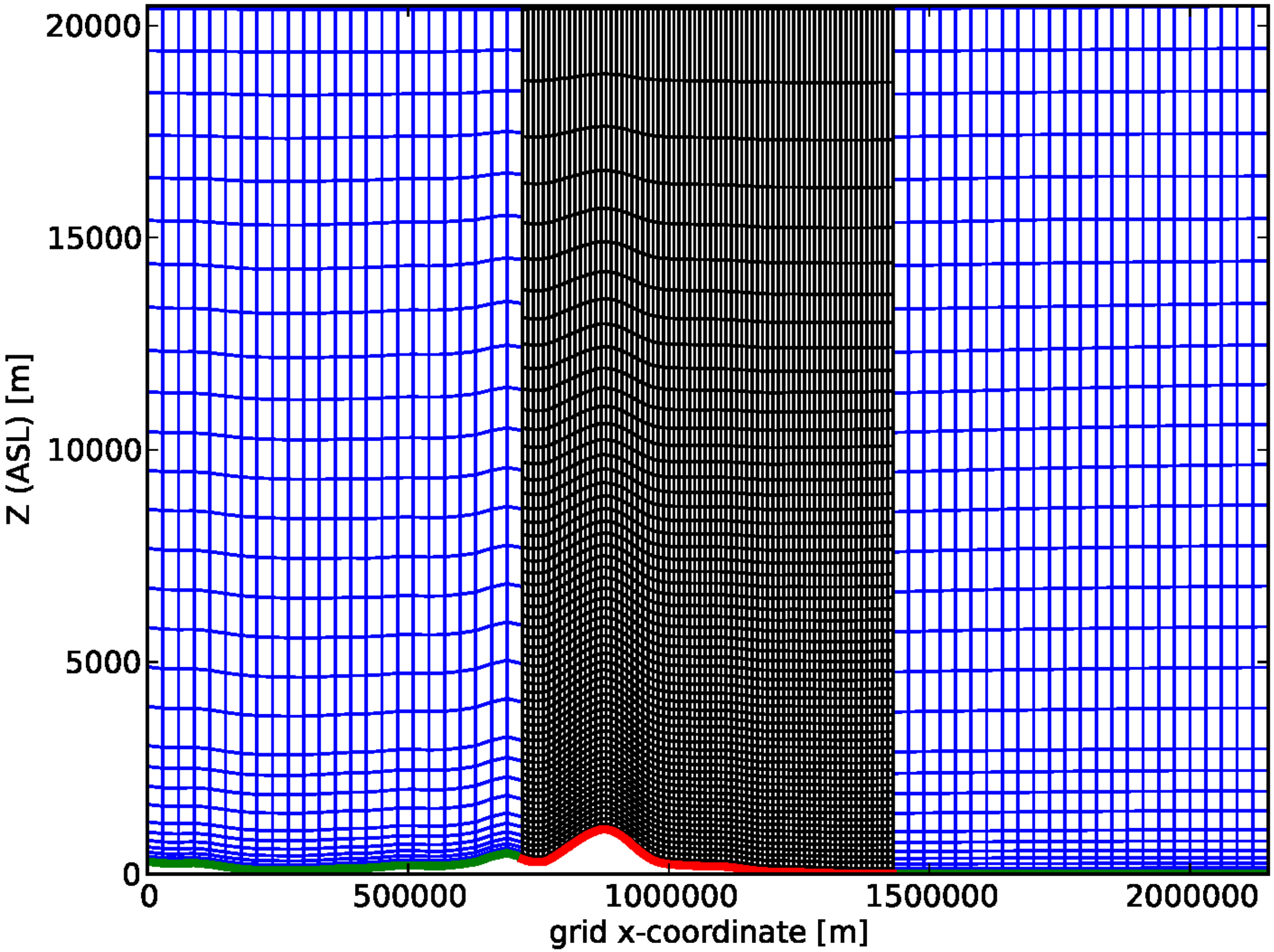
WRF Test-Case, January 2000



Without Vertical Grid Nesting



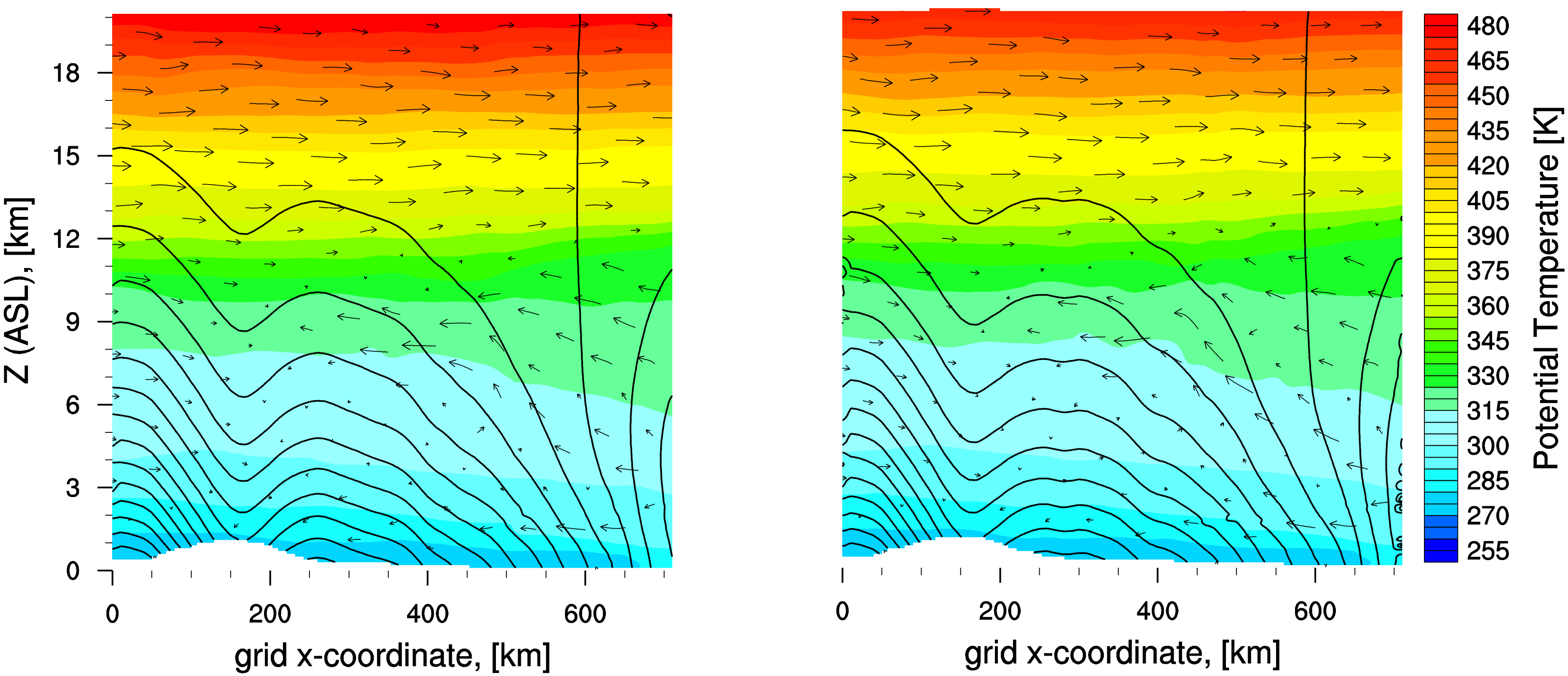
With Vertical Grid Nesting



Potential Temperature [K]

Vertical Levels
Parent: 60
Nest: 60

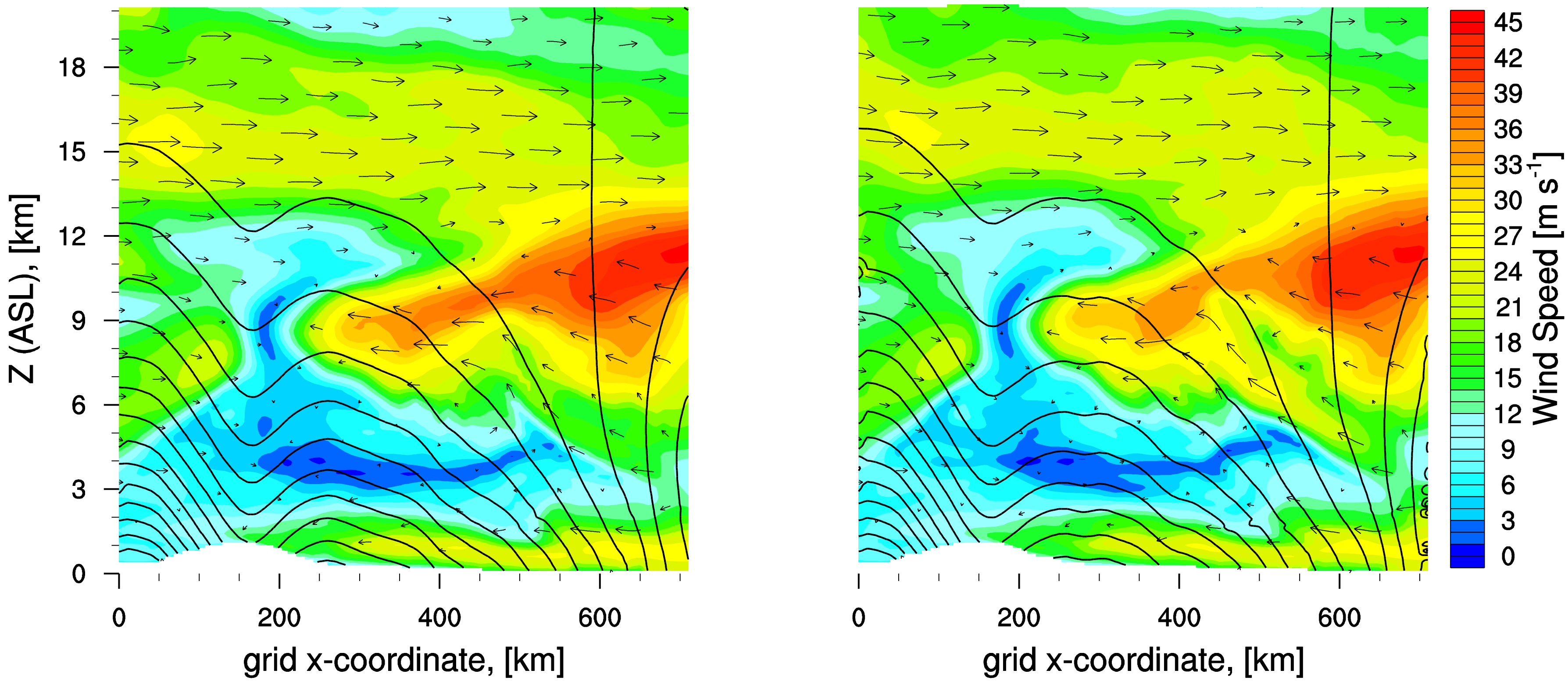
Vertical Levels
Parent: 30
Nest: 60



Wind Speed [m s^{-1}]

Vertical Levels
Parent: 60
Nest: 60

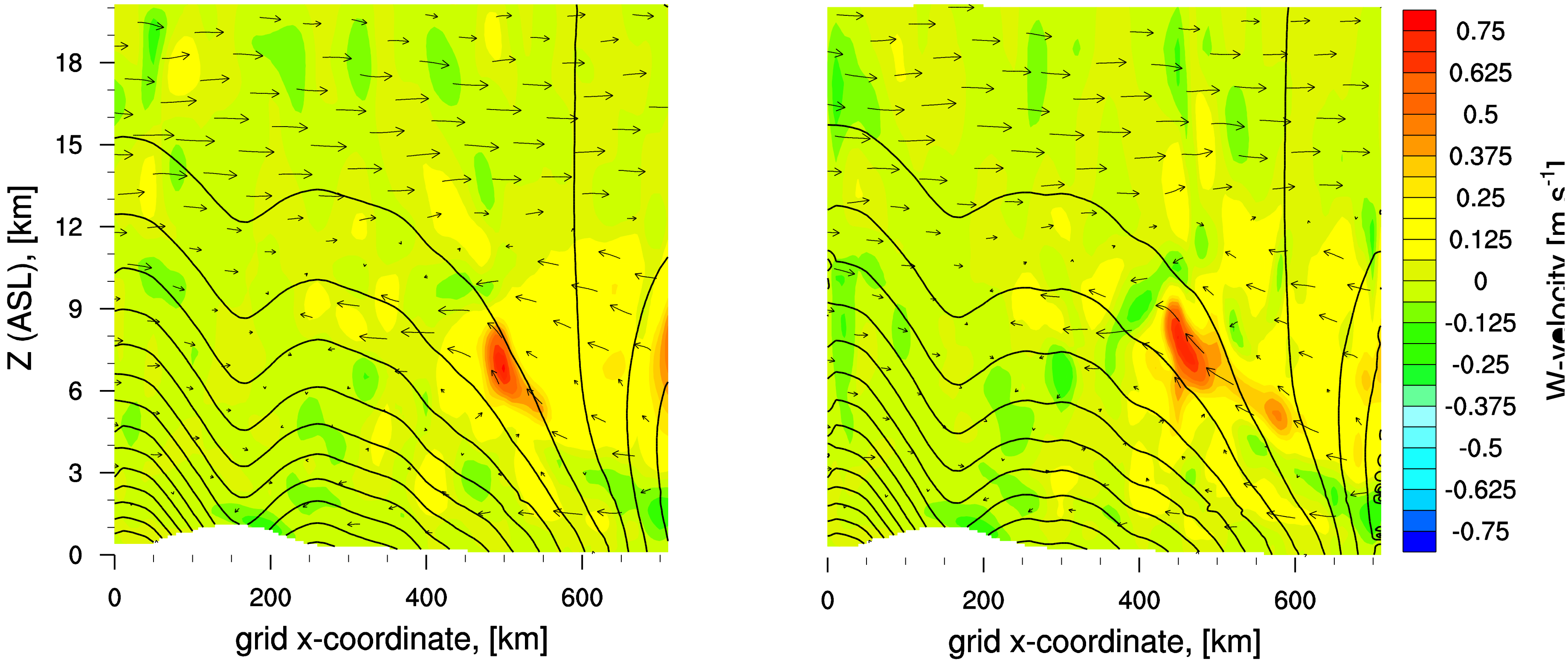
Vertical Levels
Parent: 30
Nest: 60



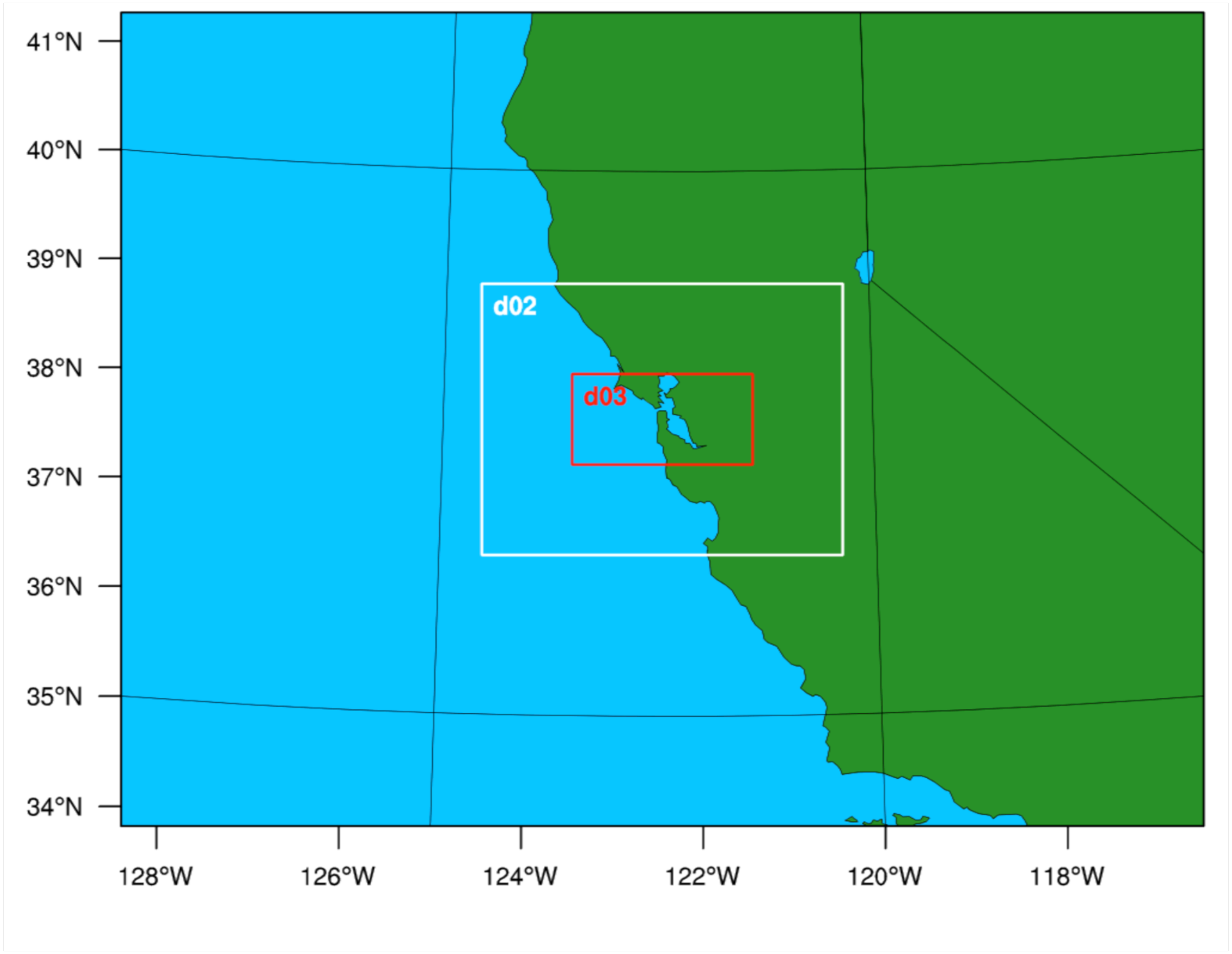
W-Velocity [m s^{-1}]

Vertical Levels
Parent: 60
Nest: 60

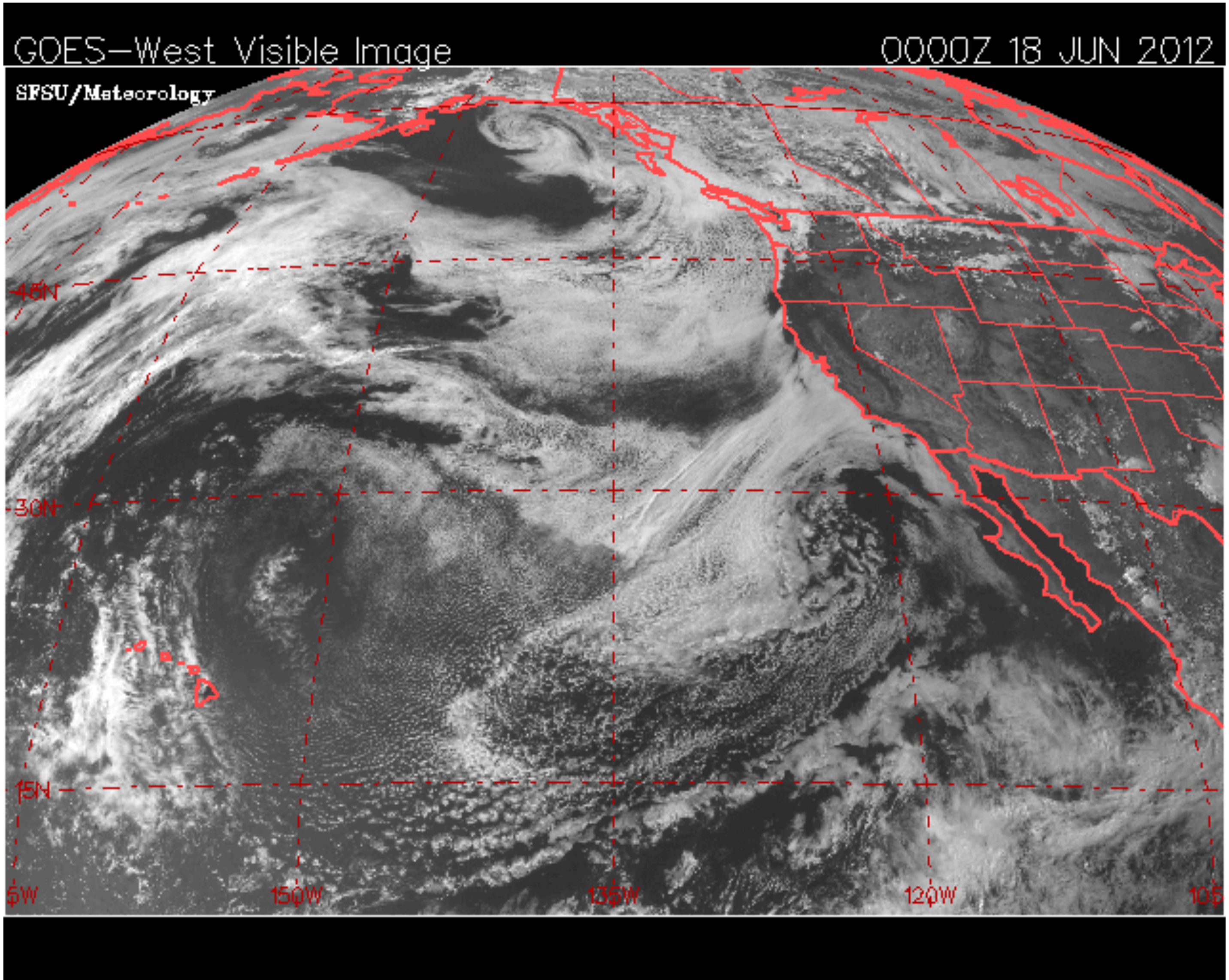
Vertical Levels
Parent: 30
Nest: 60



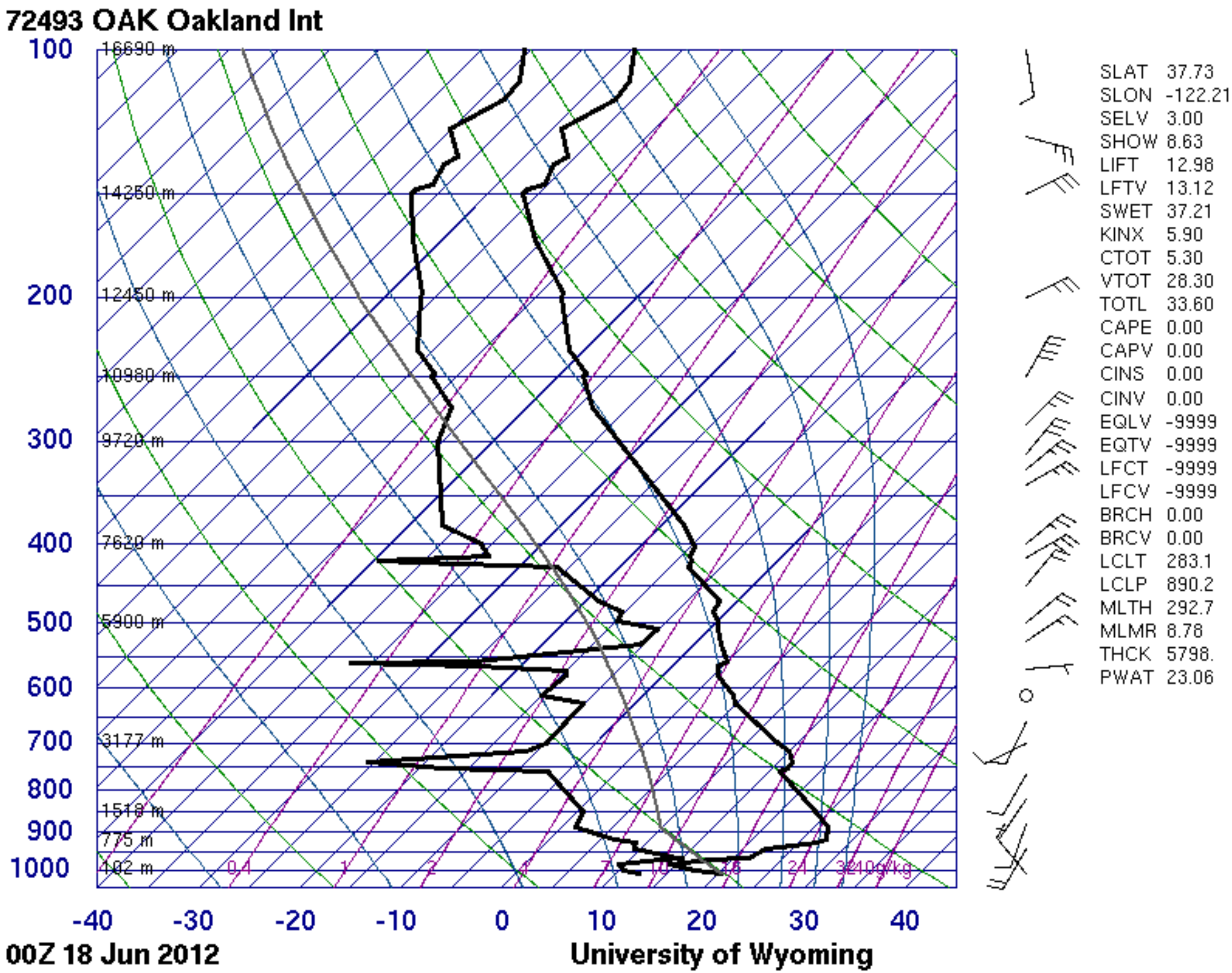
Multi-Scale Modeling of the San Francisco Bay Area



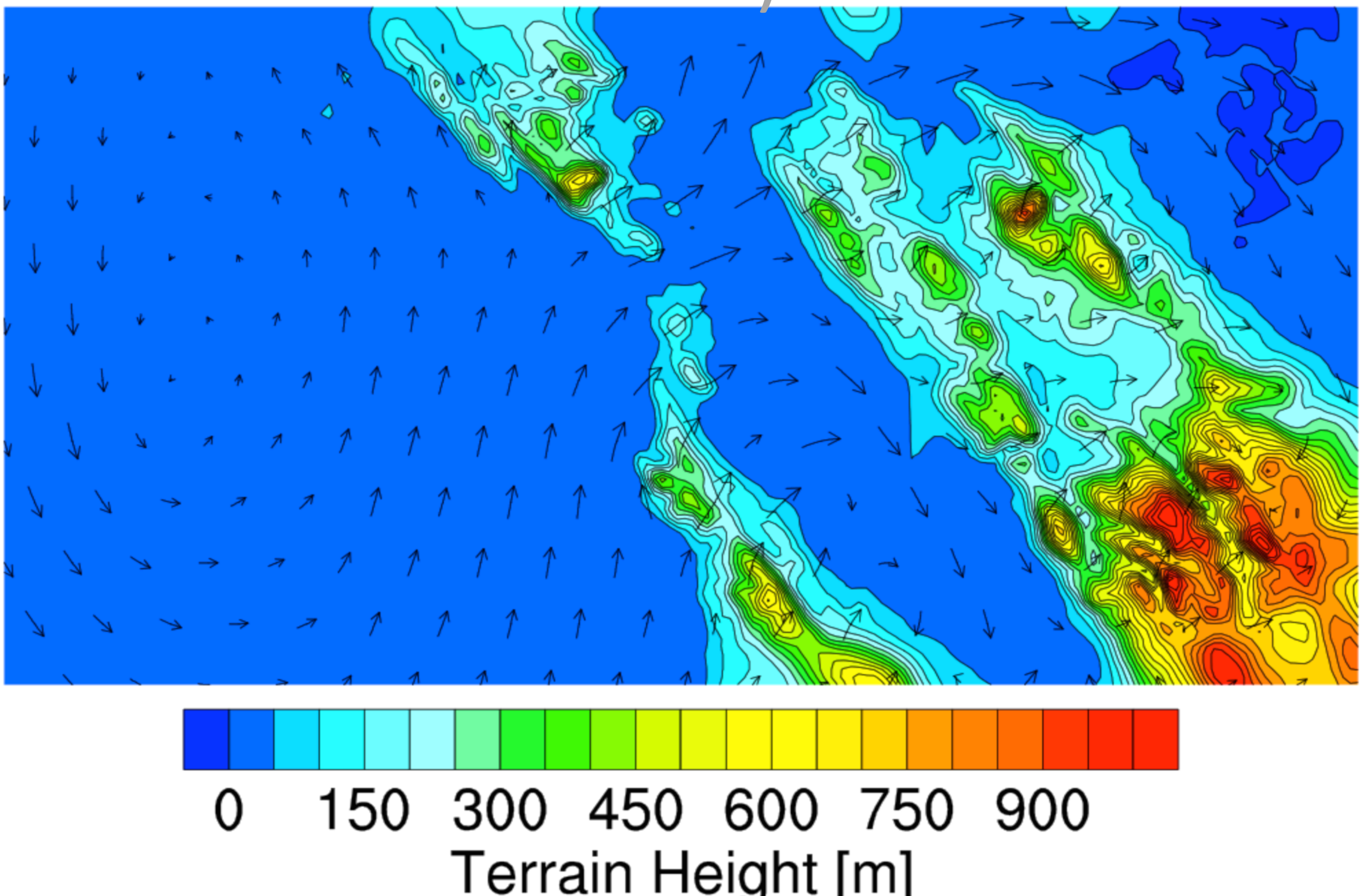
Western US, June 18 2012



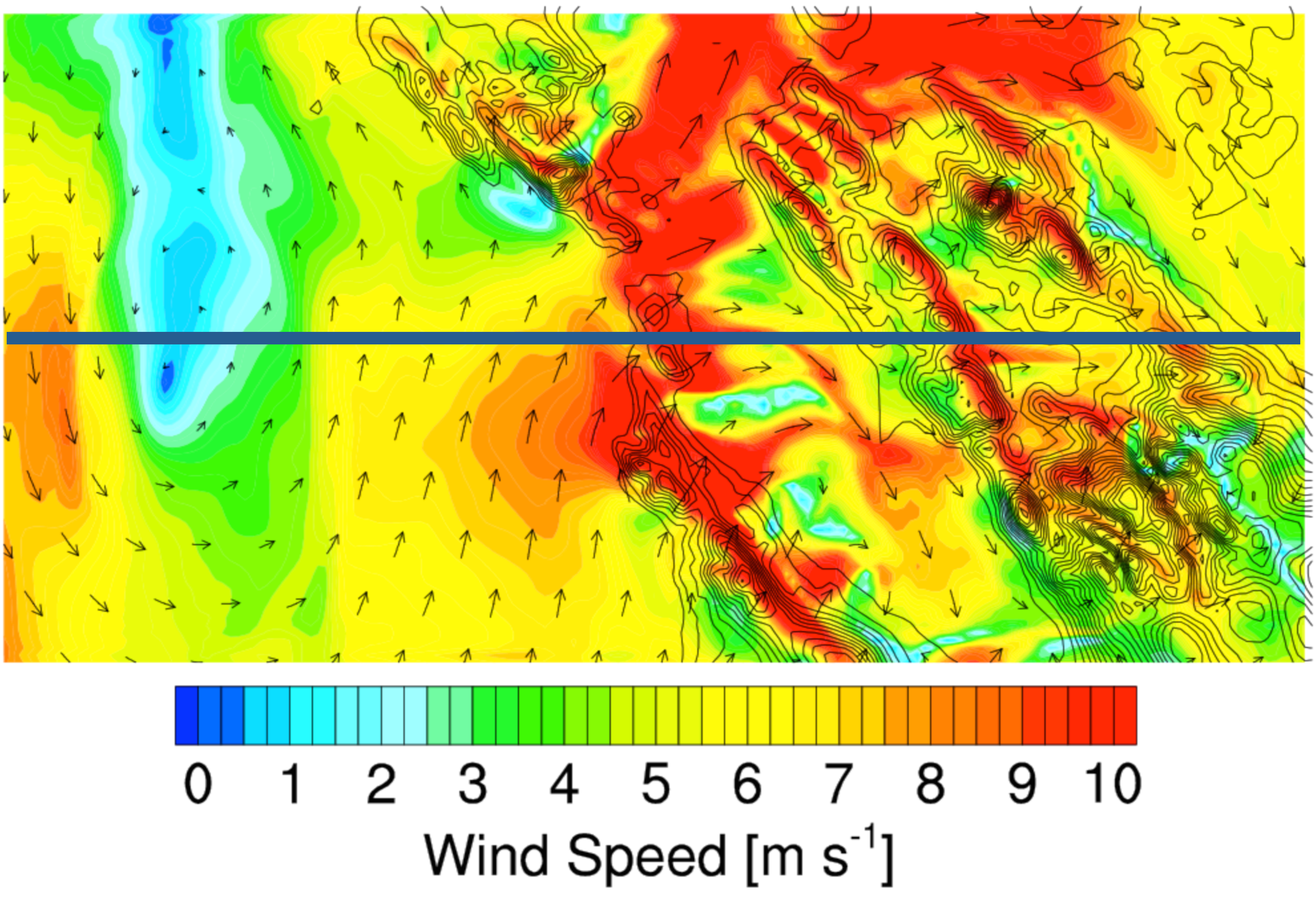
Oakland Radiosonde



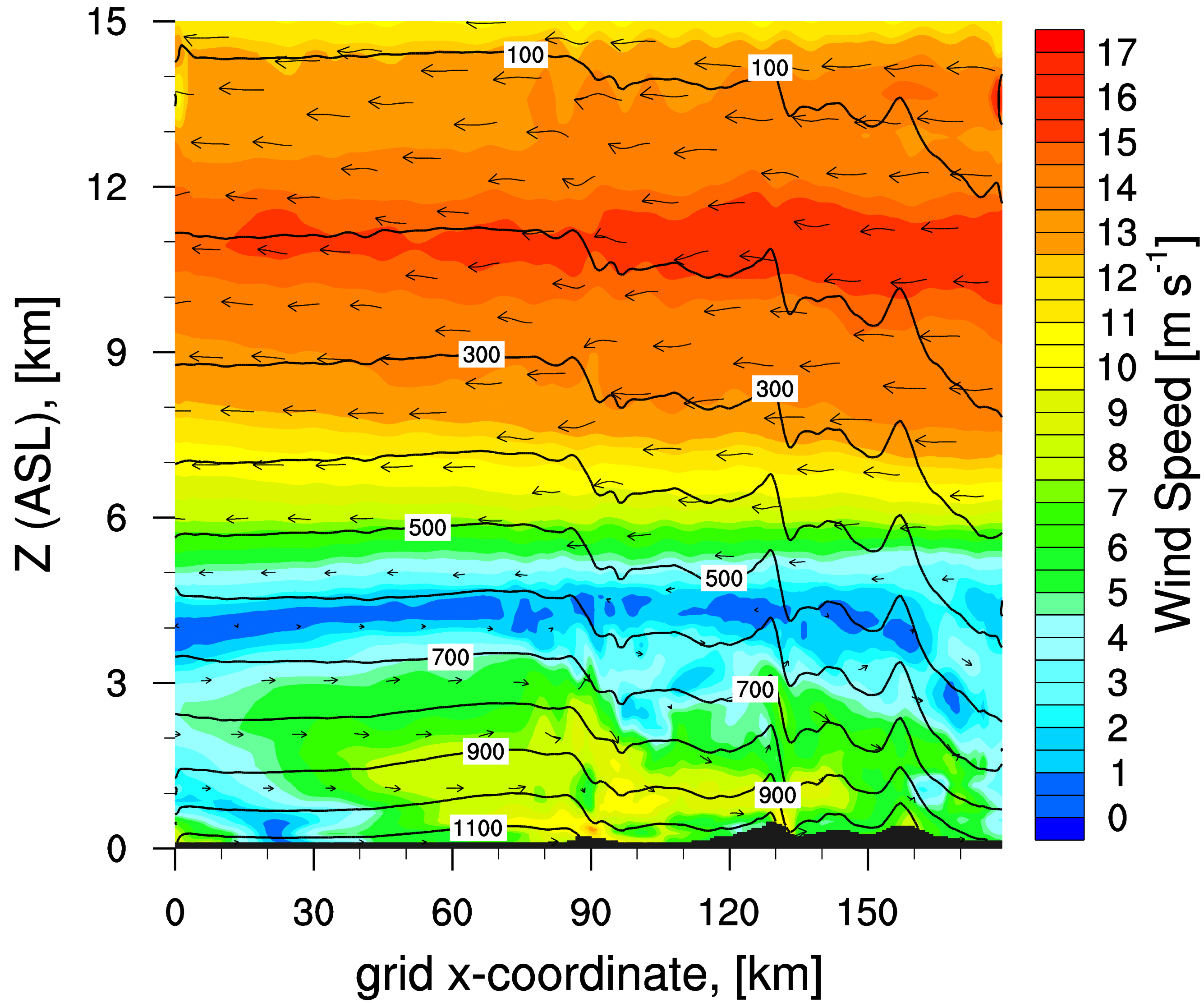
Terrain Height
(wind vectors from lowest model level)



Wind Speed at Lowest Model Level



Wind Speed Contours (filled)
Pressure Perturbation Contours (lines)



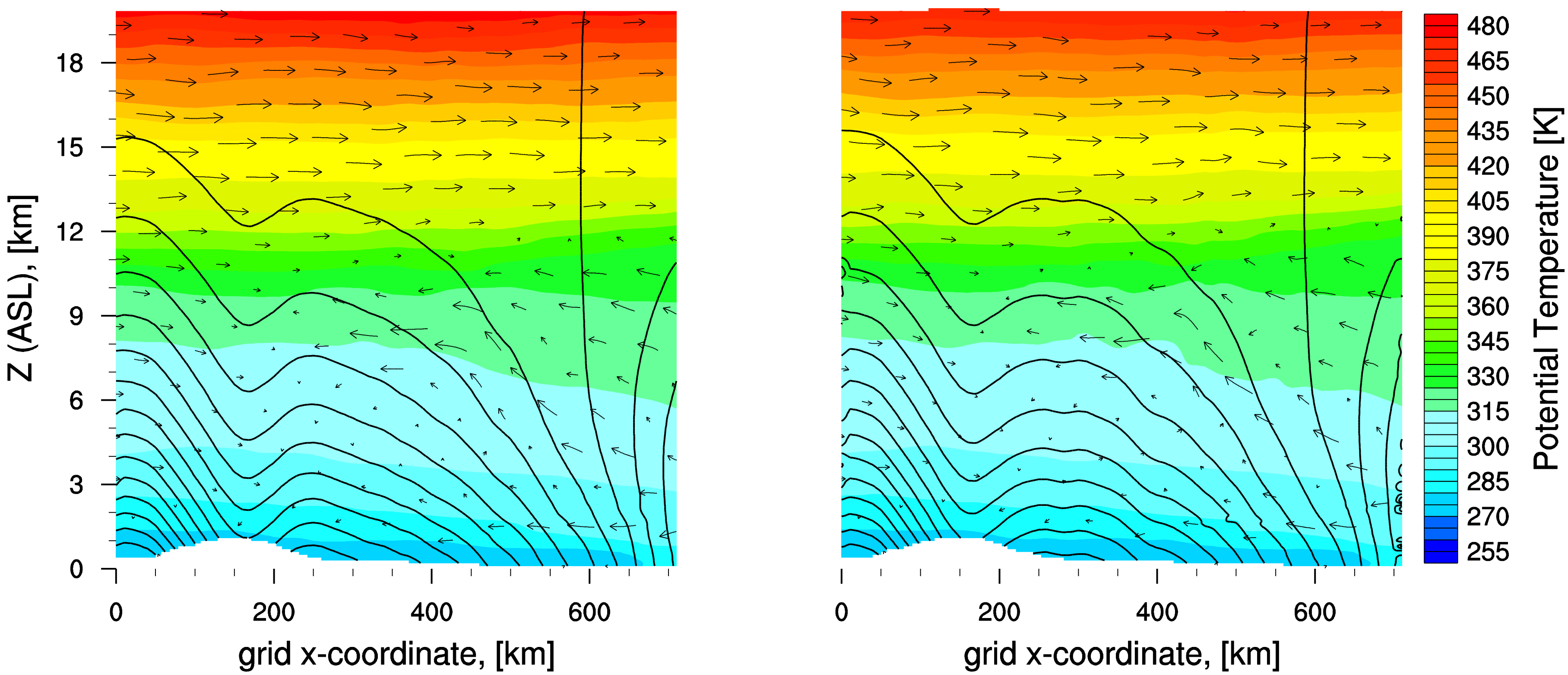
Conclusions

- Vertical nesting implemented in WRFv3.5.1
  - We are working towards getting the code included in a future release of the WRF model
  - Compatible with most atmospheric physics
  - Shows good agreement with WRF test-cases
- Thank you to Lawrence Livermore National Laboratory for the computational resources used on this project
- wiersema@berkeley.edu

JAN00, Potential Temperature [K]

Vertical Levels
Parent: 30
Nest: 30

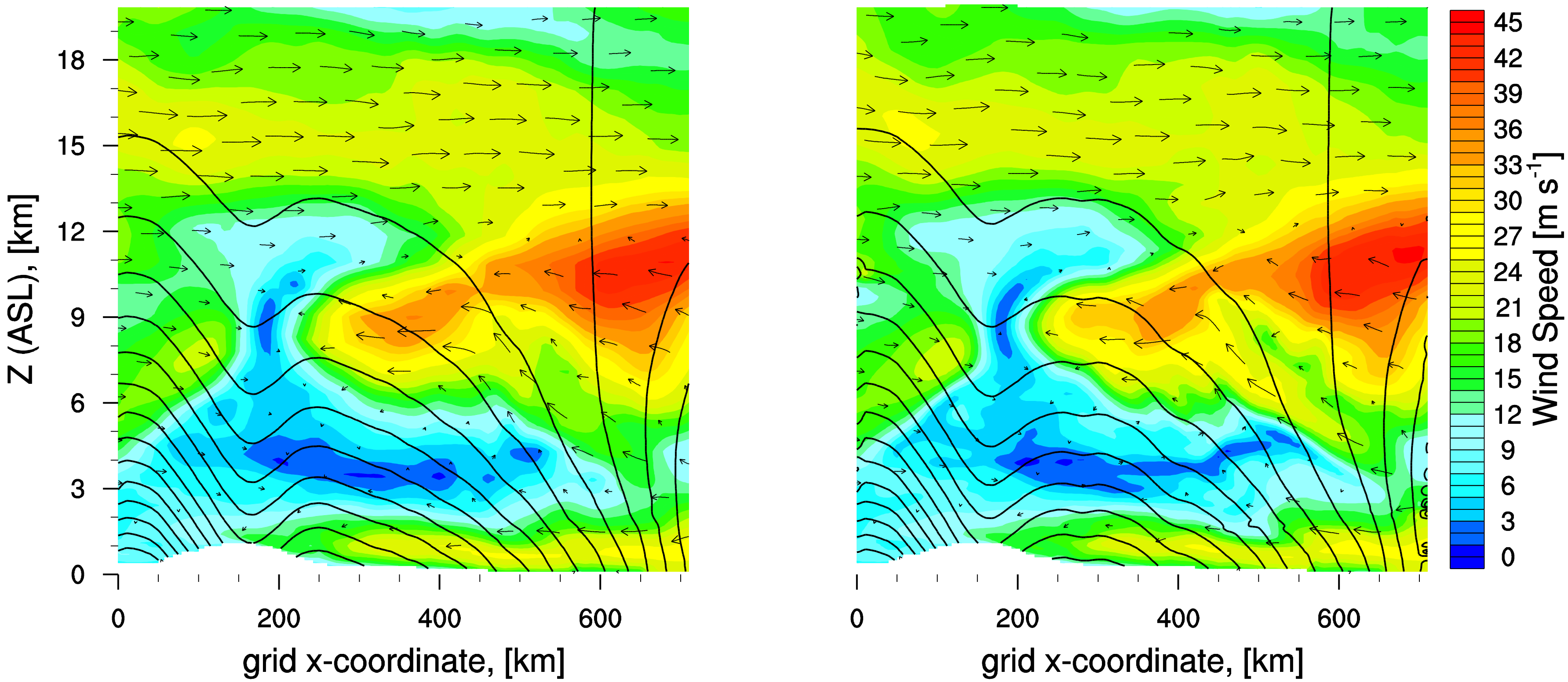
Vertical Levels
Parent: 30
Nest: 60



JAN00, Wind Speed [m s^{-1}]

Vertical Levels
Parent: 30
Nest: 30

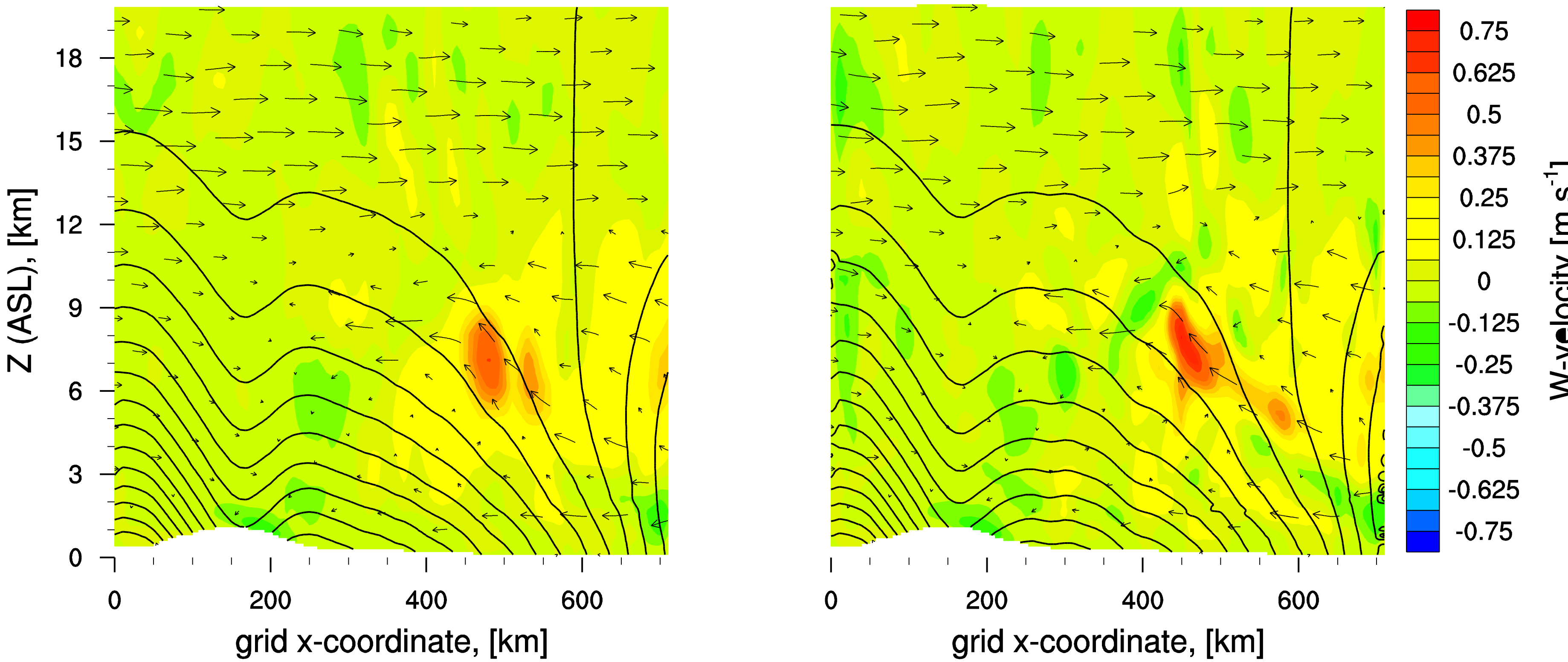
Vertical Levels
Parent: 30
Nest: 60



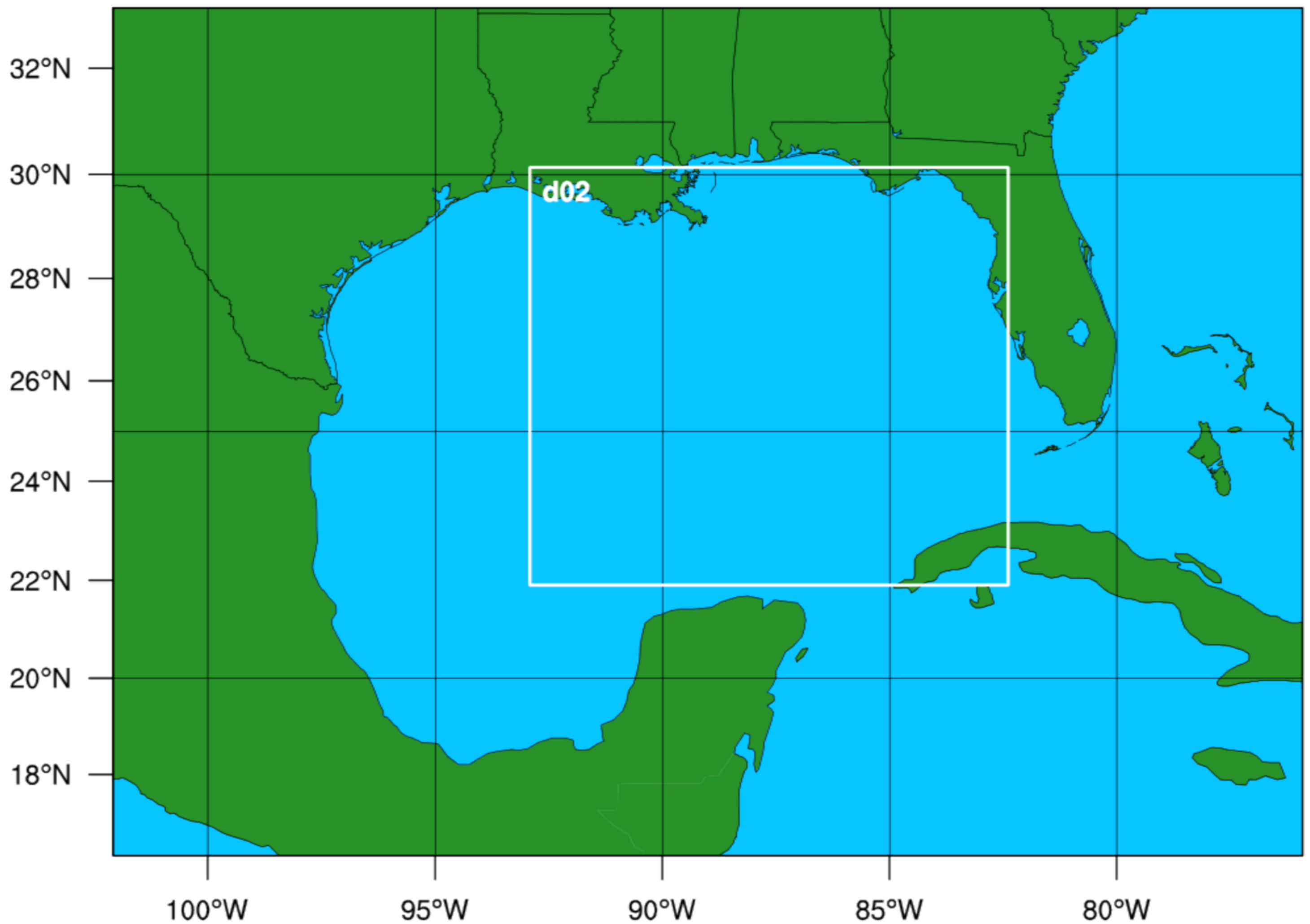
JAN00, W-Velocity [m s^{-1}]

Vertical Levels	
Parent:	30
Nest:	30

Vertical Levels	
Parent:	30
Nest:	60



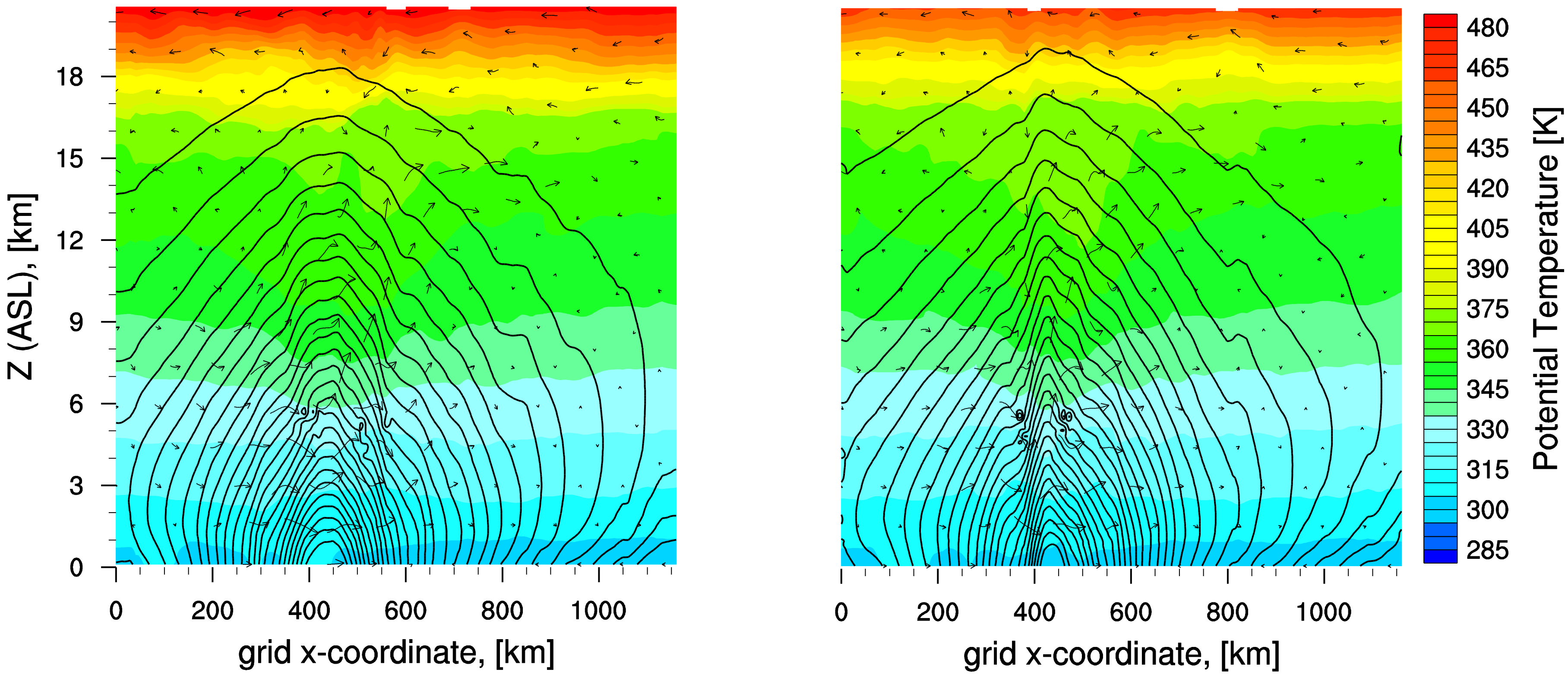
WRF Test-Case, Hurricane Katrina



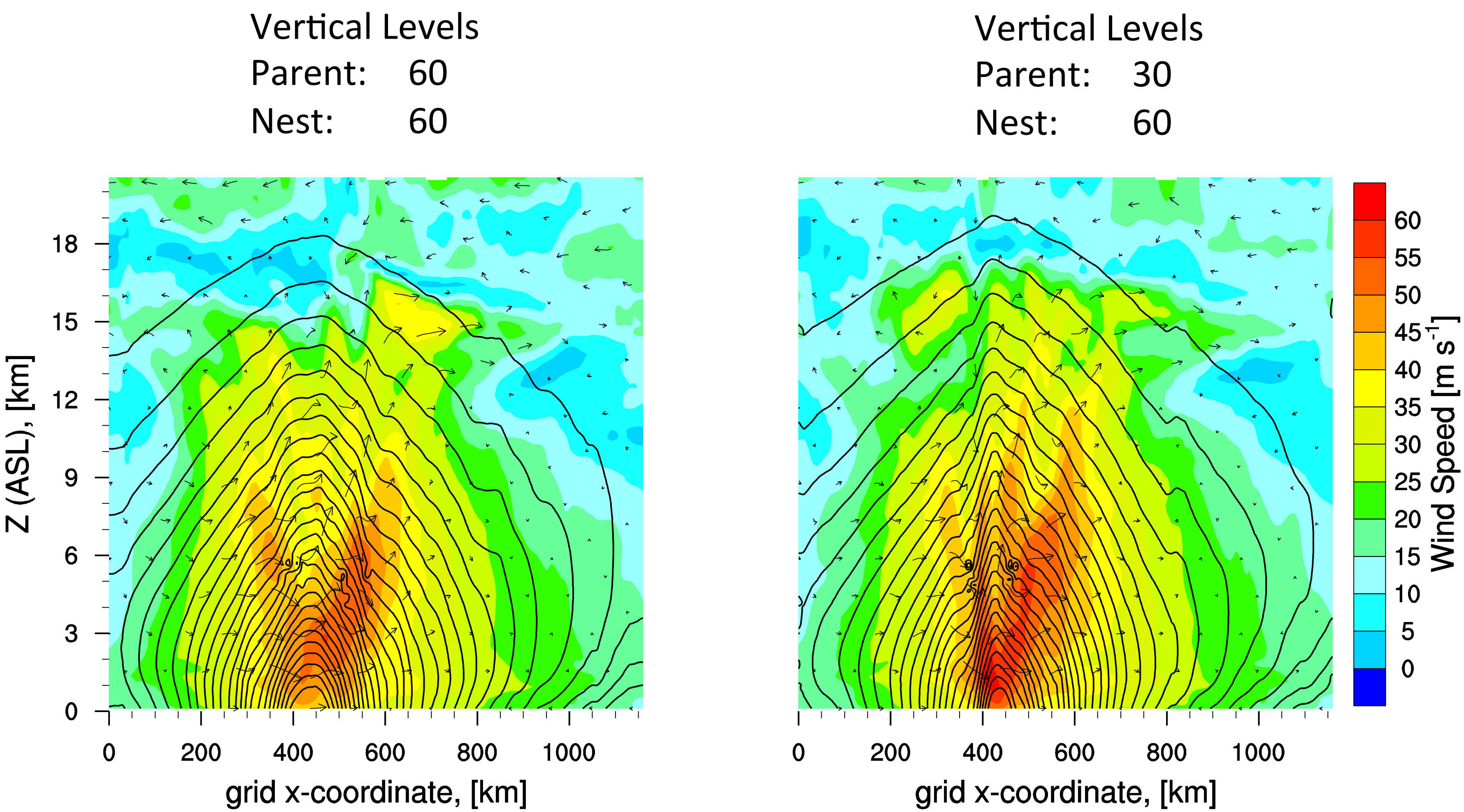
Katrina, Potential Temperature [K]

Vertical Levels
Parent: 60
Nest: 60

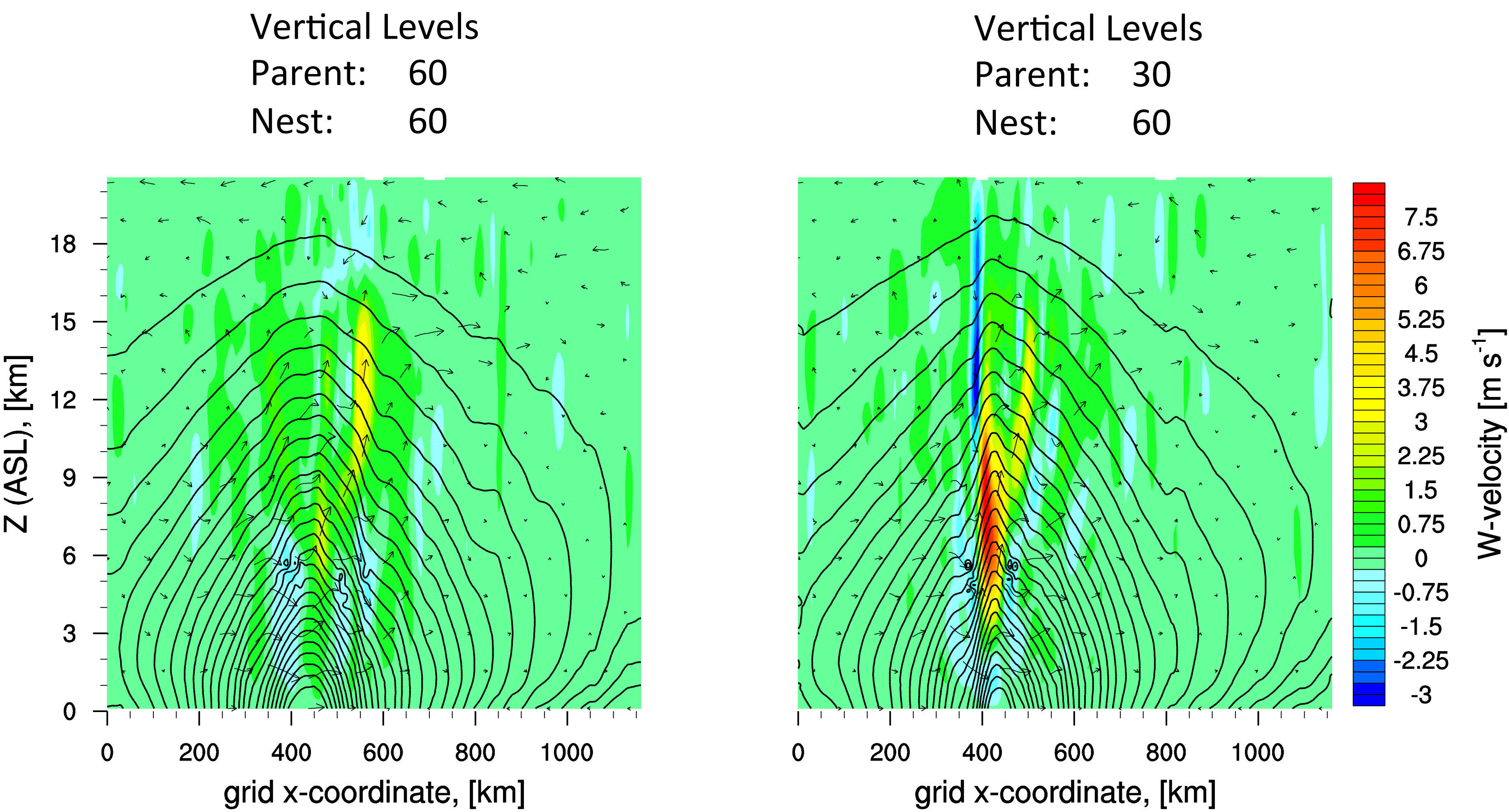
Vertical Levels
Parent: 30
Nest: 60



Katrina, Wind Speed [m s^{-1}]

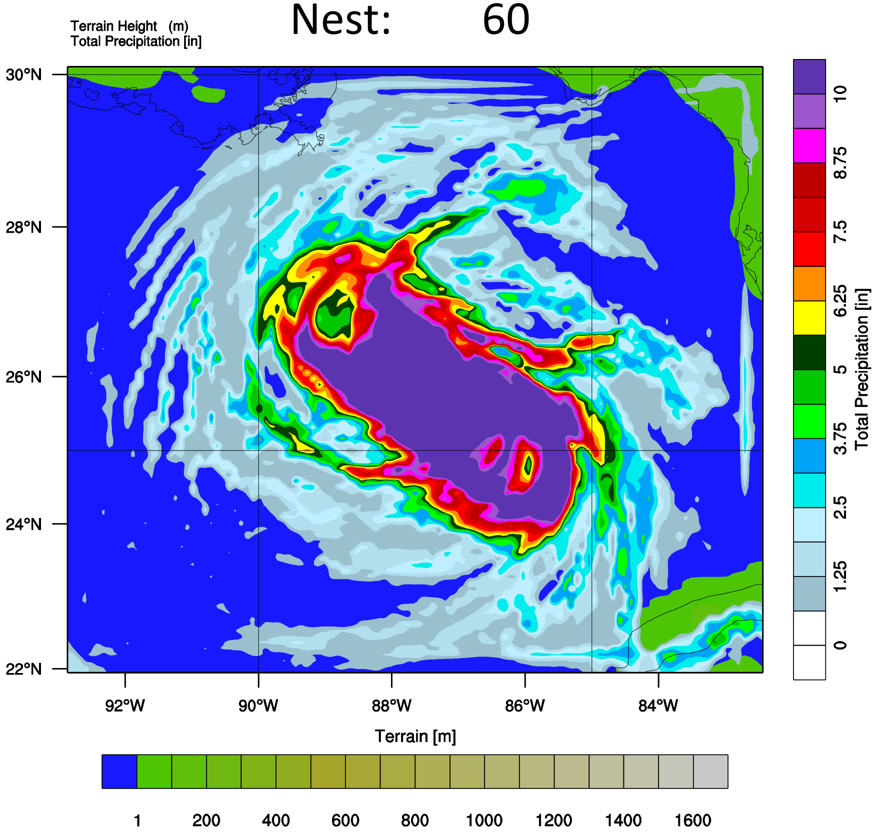


Katrina, W-Velocity [m s^{-1}]



Precipitation Since Model Start Time

Vertical Levels
Parent: 60
Nest: 60



Vertical Levels
Parent: 30
Nest: 60