A new vertical grid nesting capability in the WRF model

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Vertical Nesting in WRF

- What is it?
  - higher grid resolution in the vertical direction on nested grids
- What are current applications?
  - Grid aspect ratio control
    - Mesoscale: Can affect model stability in complex terrain
    - Large-Eddy Simulations: Shown to affect results, e.g. Mirocha et al. 2012
  - Potential for computational savings
- Future applications?
  - Important step toward multi-scale modeling with WRF

Vertical Nesting in WRF

- Available since WRF 3.6.1
- Test results in this presentation are with WRF 3.6.1
- We plan to have improvements and fixes in WRF 3.8

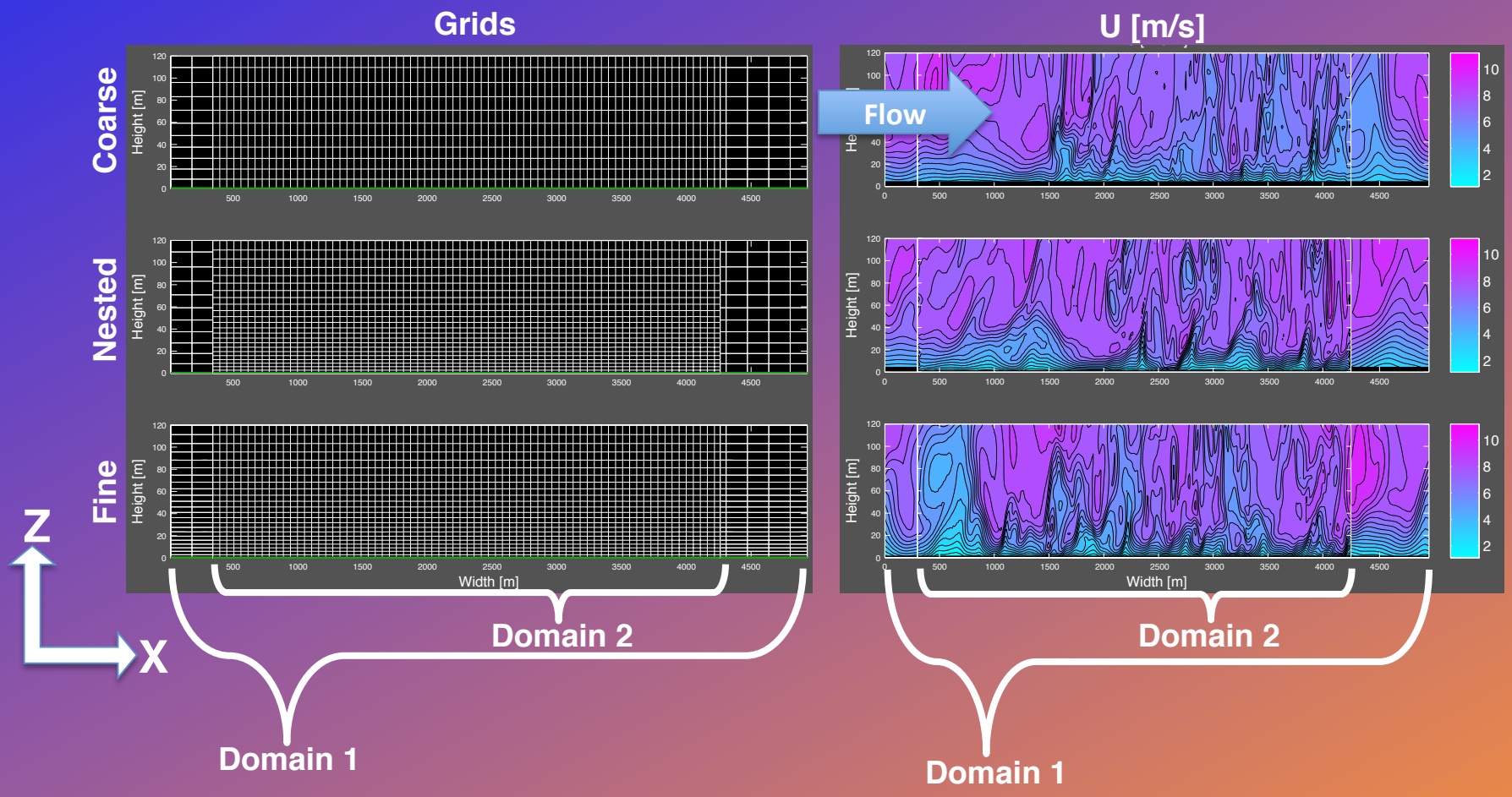
Overview

- Idealized simulations
  - Brief summary of error analysis
- Large-eddy simulations
  - Aspect ratio control
- Meso-scale simulations
  - Test case results

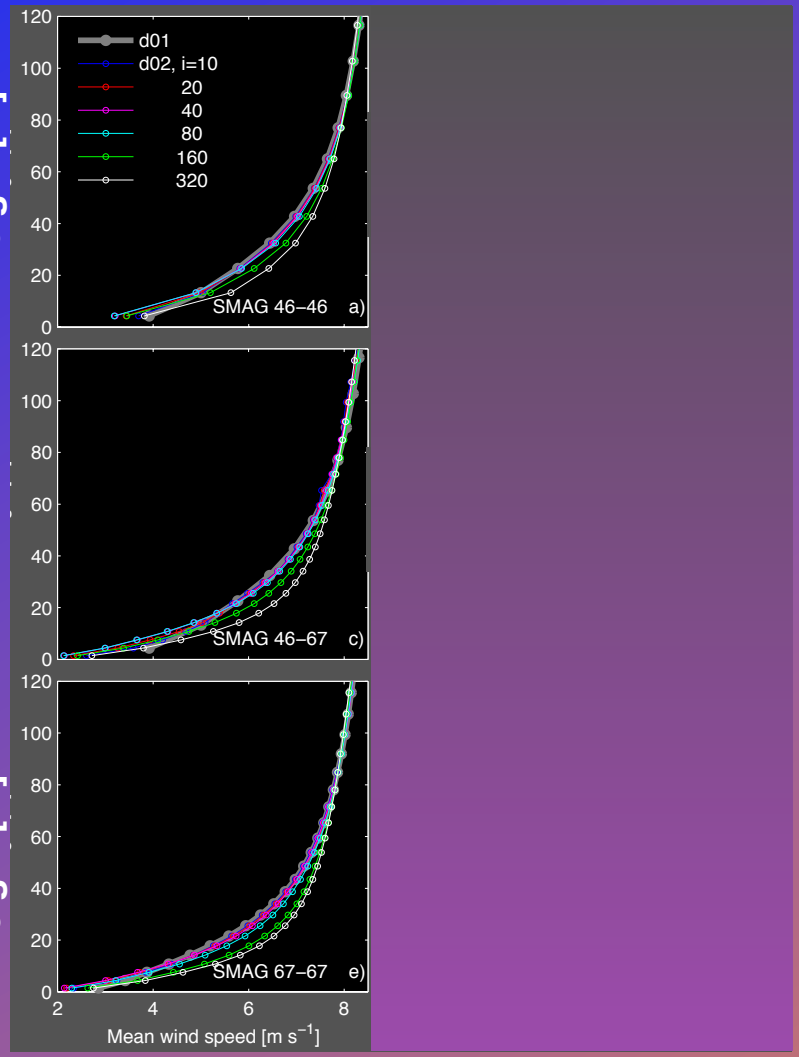
Idealized simulations

- Purpose
  - Analyze error sources/propagation/growth
- Set-up
  - Flat terrain, periodic lateral boundary conditions
    - Initialization: (a) Neutral, (b) Stable
    - Forcing: (c) None (quiescent), (d) Pressure gradient
- Summary of results
  - Neutral cases:
    - Errors are on the order of WRF without vertical nesting (e.g. 10^{-3} m/s for U, V, W)
    - Diminish in time (48 hours)
  - Stable cases:
    - Issues leading to error growth at lateral boundaries are currently being addressed

Large-eddy simulations



Large-eddy simulations – comparison with similarity theory



- **Only outer domain (d01) is optimized**
  - ***(coarse vertical grid -** no vertical nesting**)***
- **Outer and inner domains (d01 and d02) are both optimized**
  - ***(coarse grid on outer domain, fine grid on inner domain -** vertical nesting**)***
- **Only inner domain (d02) is optimized**
  - ***(fine vertical grid -** no vertical nesting**)***

Mean wind speed [m/s]

z/H

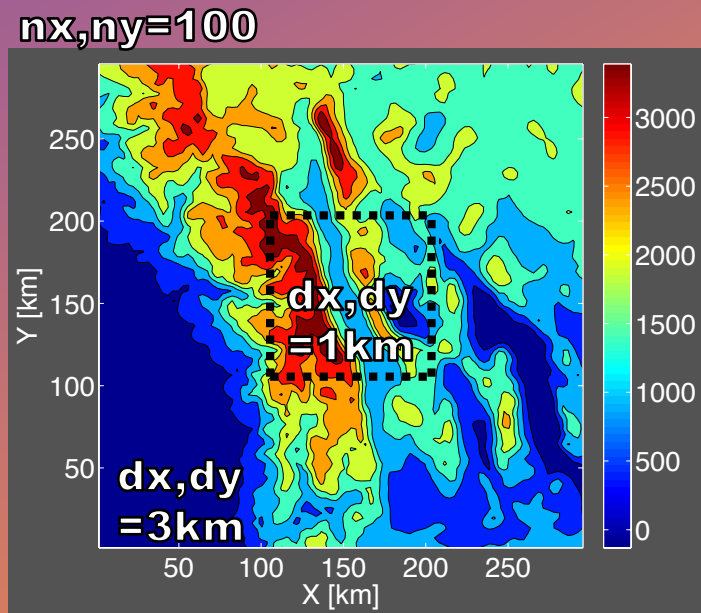
z = height above the surface
H = boundary layer height

Mesoscale simulations

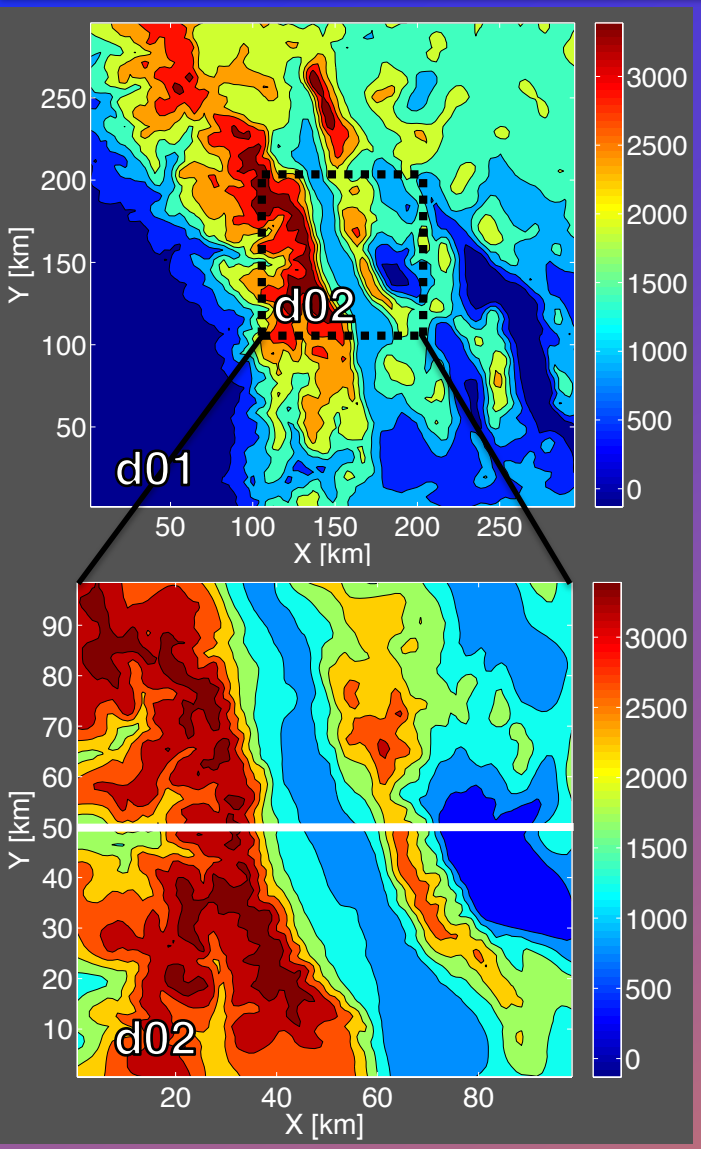
- Test cases from Terrain-induced Rotor Experiment (T-REX)
  - March-April, 2006
  - Owens Valley, California
  - Soundings every 1.5 hours during Enhanced Observation Periods (EOP)
- Set-up
  - Lateral forcing on outer domain: North American Mesoscale Model (NAM)

Vertical Grid Setup

Simulation Name	d01 (outer domain) nz	d02 (inner domain) nz
Coarse	40	40
(Vertically) Nested	40	120
Fine	120	120

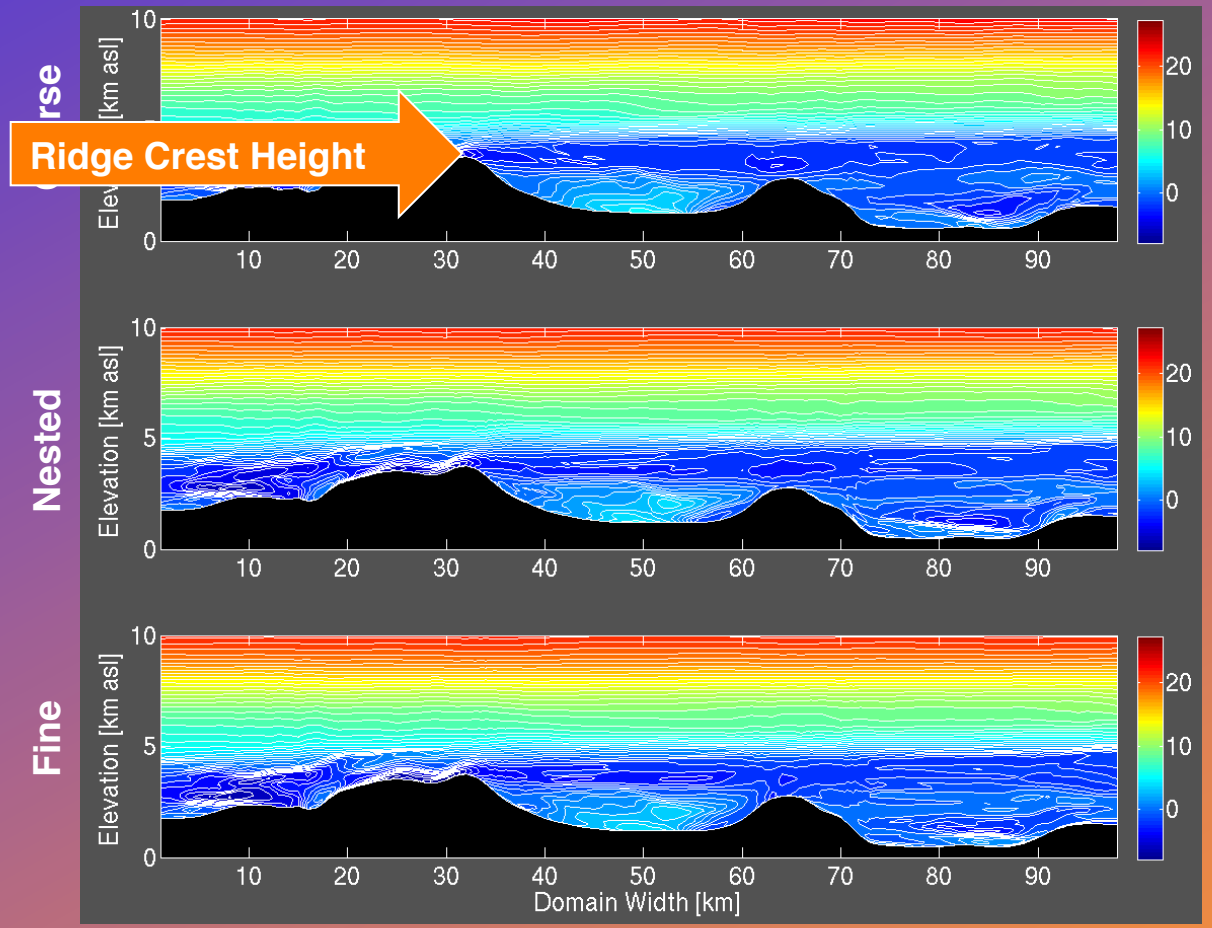


Mesoscale simulations – T-REX



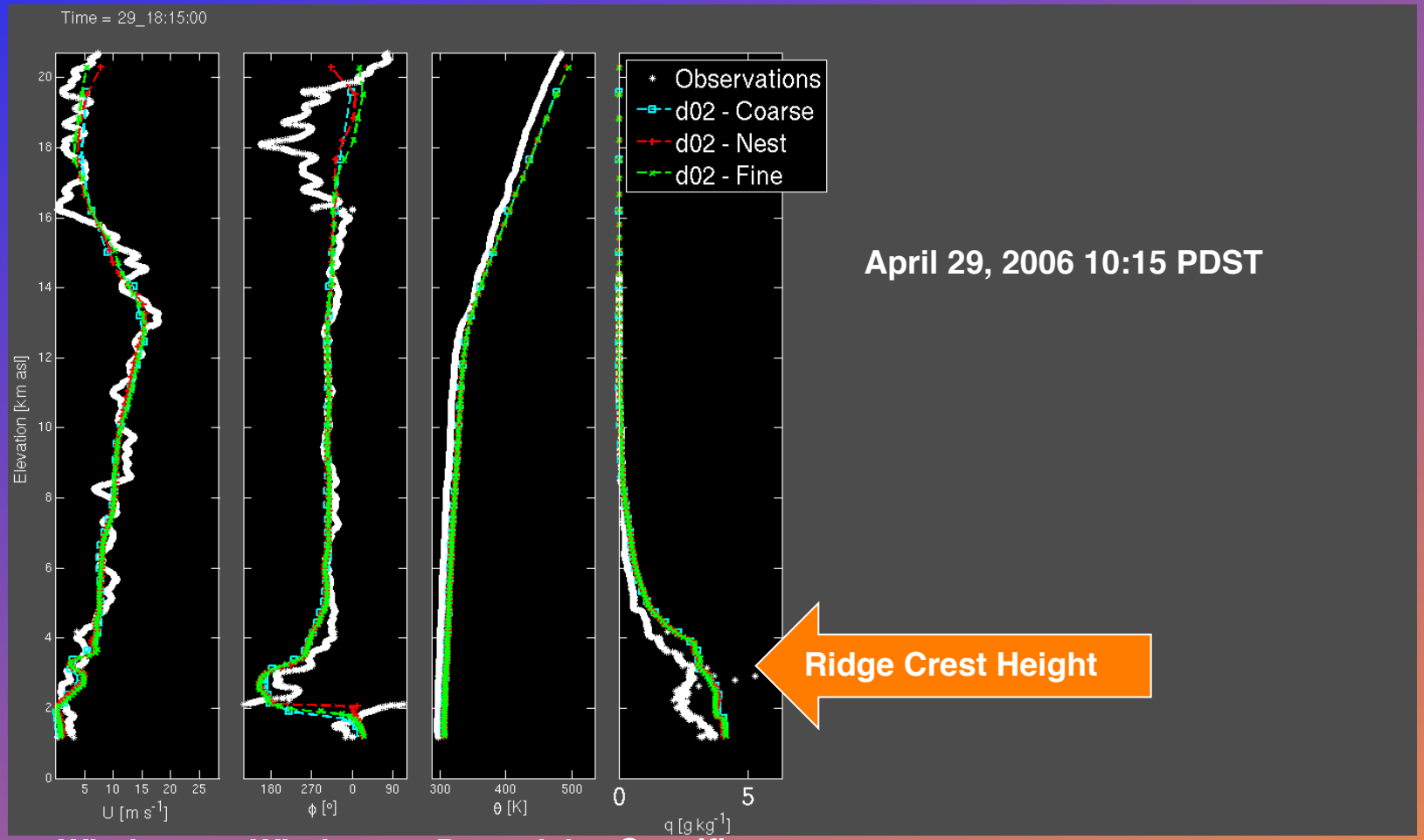
Domain 1 – 3 km horizontal grid spacing
Domain 2 – 1 km

U [m/s]



Colorbar is terrain height in meters above sea level

Sounding profile comparisons: T-REX



April 29, 2006 10:15 PDST

Ridge Crest Height

Wind Speed [m/s]

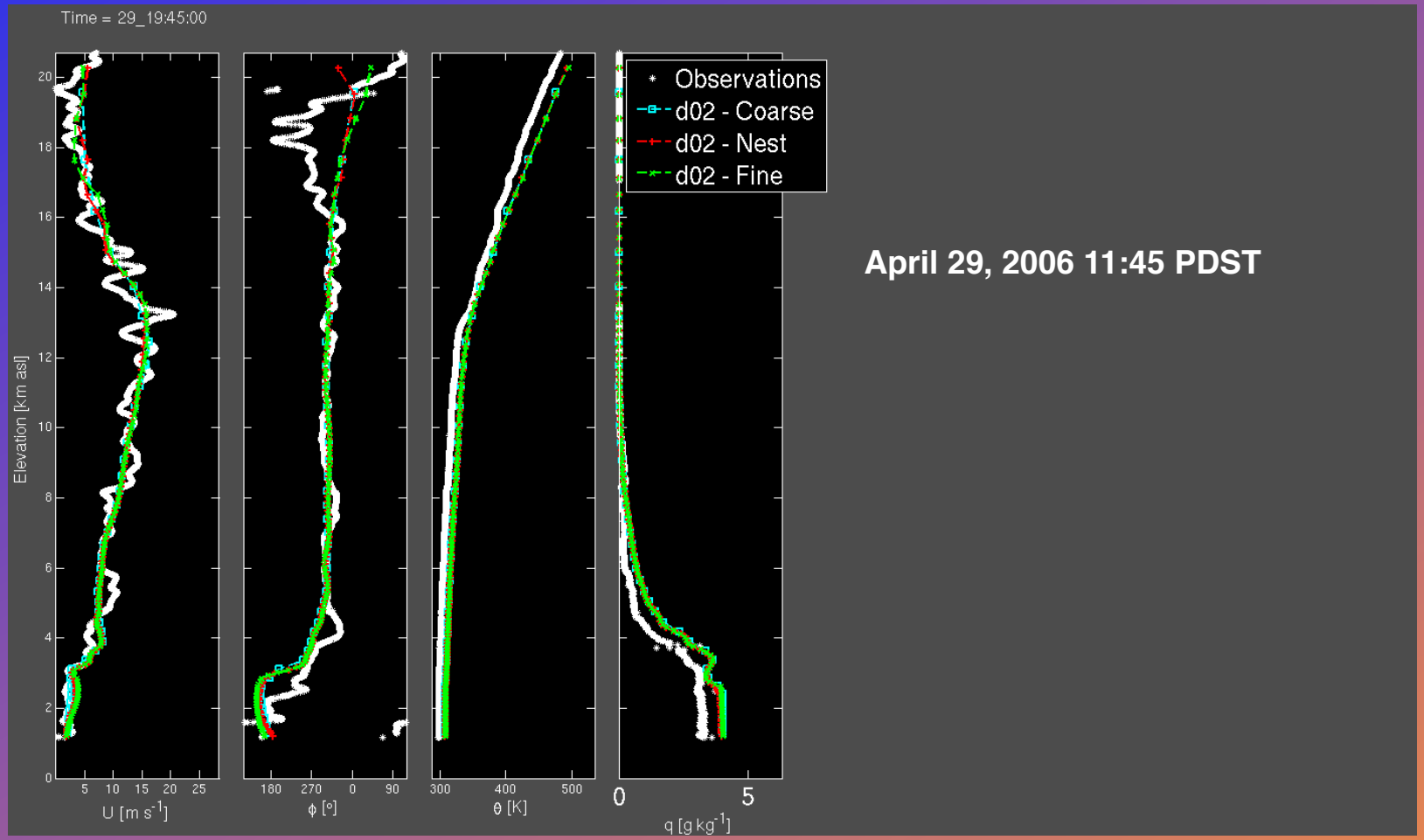
Wind Direction [°]

Potential Temp [K]

Specific Humidity [g/kg]

Simulation time 18:15 UTC
Sounding release time 18:04 UTC

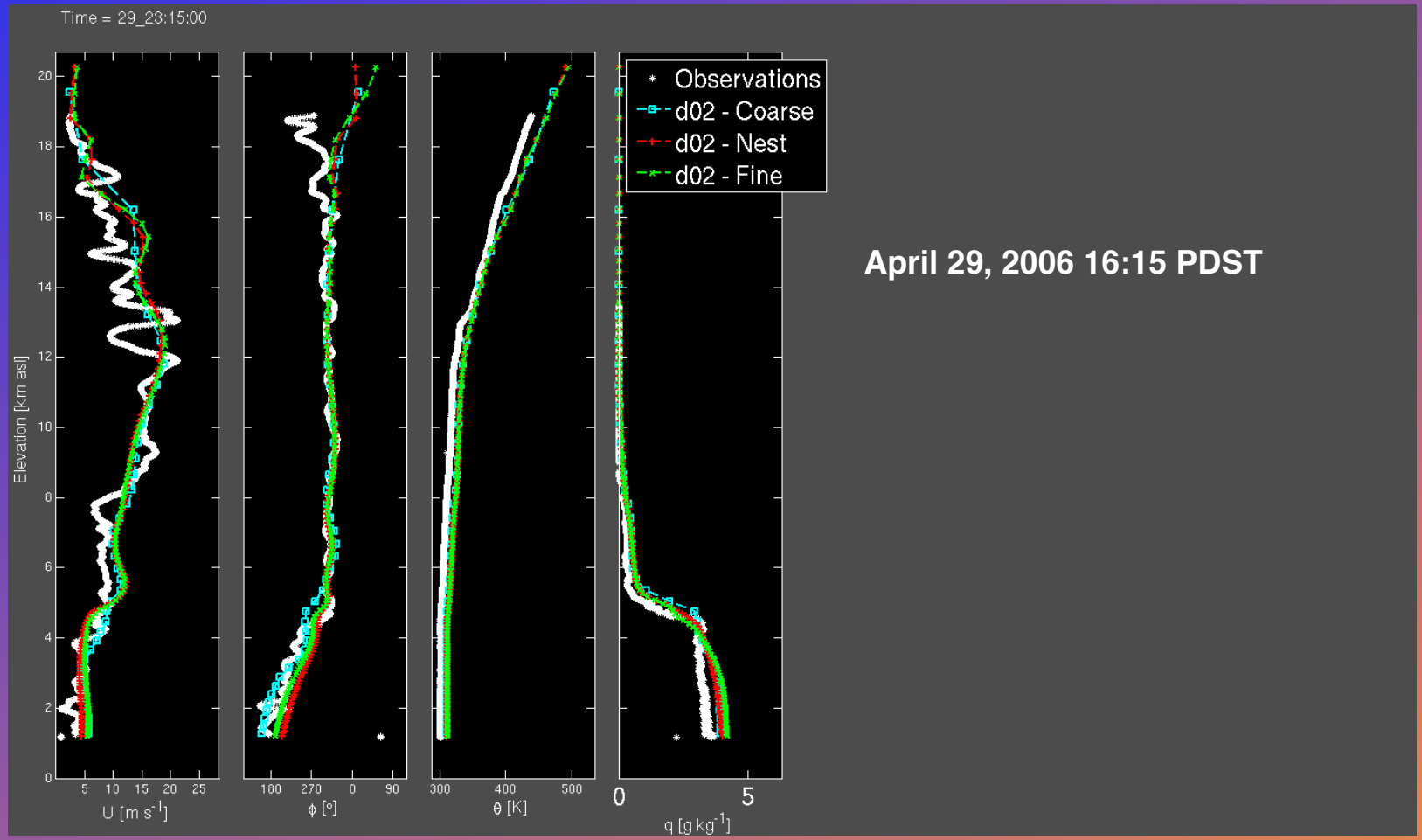
Sounding profile comparisons: T-REX



April 29, 2006 11:45 PDST

Simulation time 19:45 UTC
Sounding release time 19:38 UTC

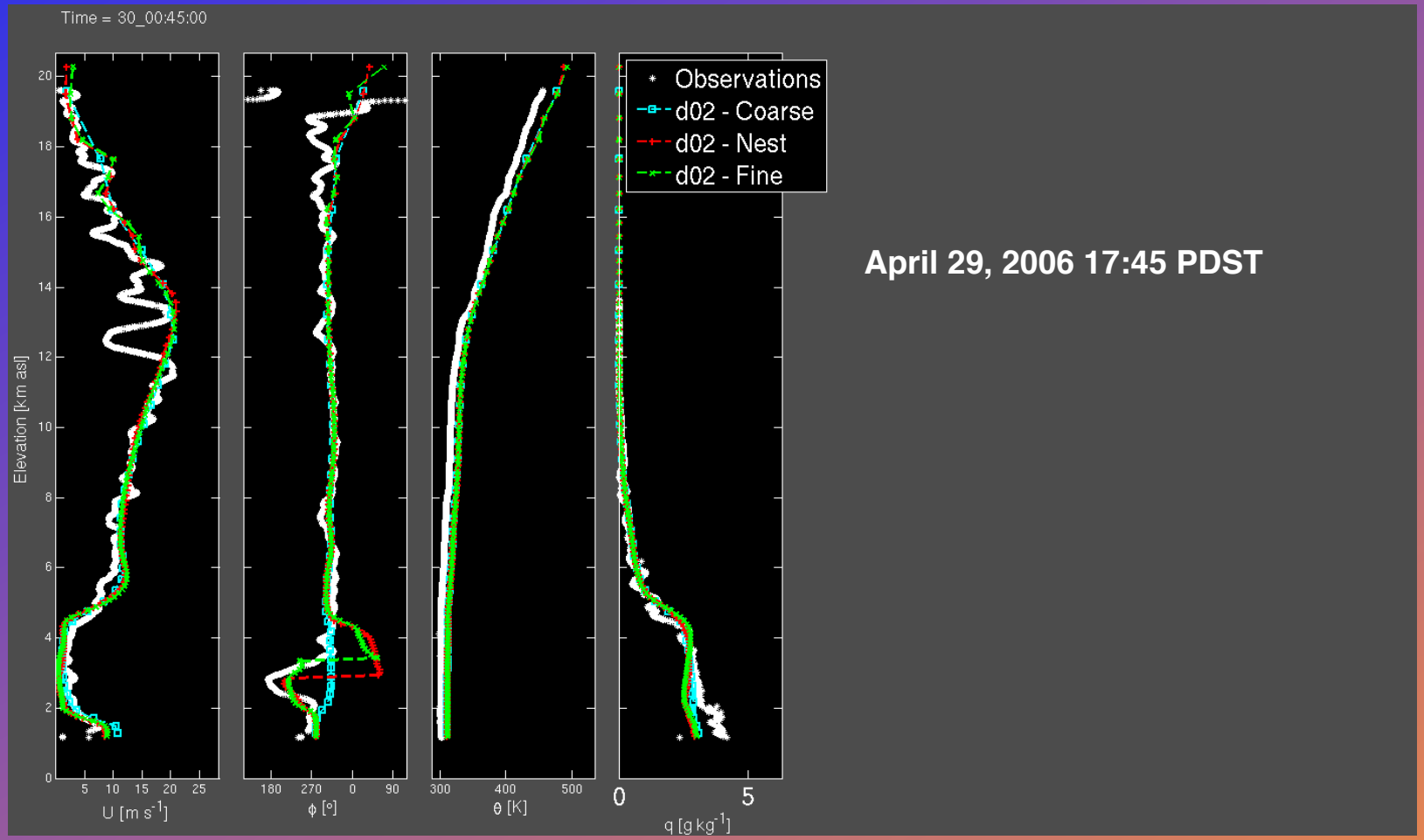
Sounding profile comparisons: T-REX



April 29, 2006 16:15 PDST

Simulation time 23:15 UTC
Sounding release time 22:57 UTC

Sounding profile comparisons: T-REX



April 29, 2006 17:45 PDST

Simulation time 00:45 UTC
Sounding release time 00:35 UTC

Surface time series

Sensible Heat Flux [W m^{-2}]

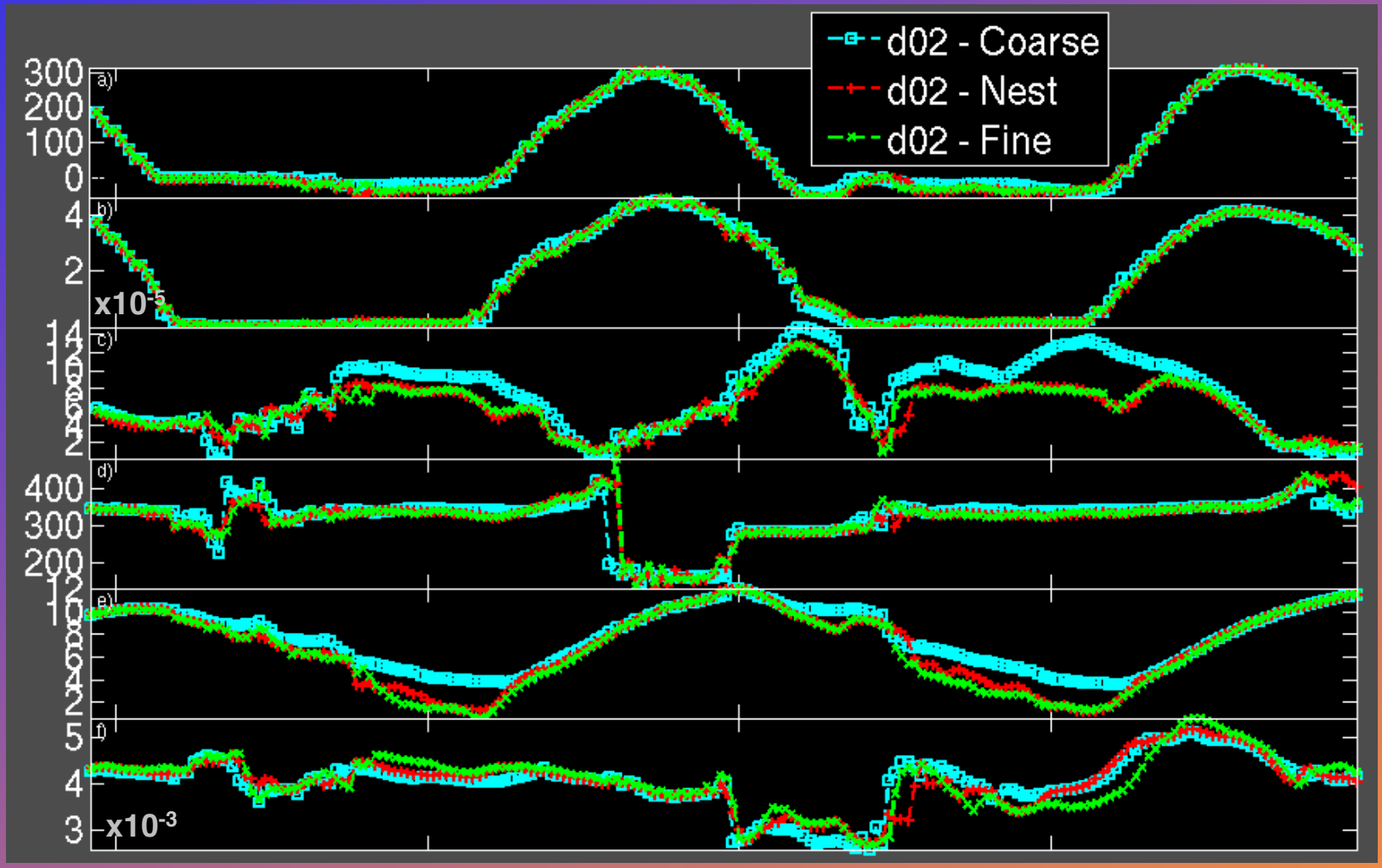
Moisture Flux [kg m^{-2}s^{-1}]

Wind Speed [m/s]

Wind Direction [°]

Potential Temperature [K]

Water vapor mixing ratio [kg/kg]



Summary

- Vertical nesting is in WRF 3.6.1
- Feel free to try it out, BUT
  - keep in mind that we are still working on some issues!
  - Let us know how it works for you
- Conference paper available
  - Details on how to turn on vertical nesting
  - Results of testing to date

Thank you

LES set-up

Vertical Grid		α	Δx (m)	Δz^1 (m)	L_x (m)	L_y (m)	L_z (m)	nx	ny	nz
Course	d01	4	33	8.68	4950	3300	1400	151	101	46
	d02	1.3	11	8.68	3960	2640	1400	361	241	46
Nested	d01	4	33	8.68	4950	3300	1400	151	101	46
	d02	4	11	2.88	3960	2640	1400	361	241	67
Fine	d01	11.5	33	2.88	4950	3300	1400	151	101	67
	d02	4	11	2.88	3960	2640	1400	361	241	67