WFIP 2 – The Second Wind Forecast Improvement Project: Model Development Plans and Preliminary Results

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American Meteorological Society Annual Meeting, New Orleans, LA, 2016

Wind Forecast Improvement Project 2

WFIP 2 is a multiagency project funded by the Department of Energy to improve forecasting for wind-energy applications

Vaisala (**DOE FOA Awardee**) leads a team including individuals from CU, NCAR, Sharply Focused, Lockheed Martin, Texas Tech, Notre Dame, Iberdrola, Southern California Edison, Cowlitz County Public Utility District, Eurus Energy, Bonneville Power Administration, and Portland General Electric.

DOE National Labs: **NREL, PNNL, LLNL, ANL**

NOAA (**OAR: ESRL** and **ARL; NWS: NCEP**)

GOALS:

- Improve the understanding of atmospheric flows and processes that occur in complex terrain and impact wind forecasts at hub heights (40-150 m AGL).
- Instrument the Columbia River Basin study area and carry out a 18 month field campaign (**01 October 2015 – 31 March 2017**).
- Develop physical parameterizations in WRF-ARW to better represent physical processes and increase accuracy of wind forecasts in the 0-15 hour range, with positive implications for day-ahead forecasts (focus on RAP/HRRR physics).
- Test and evaluate these improvements in an advanced version of the RAP, HRRR, and a higher resolution nest.
- Develop decision support tools, e.g., probabilistic forecast information, uncertainty quantification and forecast reliability for system operations.

WFIP 2 Time Line

	Jan-Feb-Mar	Apr-May-June	July-Aug-Sept	Oct-Nov-Dec
2015	Instrument Deployment			Event Log
	NWP Code Development			
2016	Event Log			
	Case Studies			
	NWP Code Development			
2017	Short-Term Retros			
	Long-Term Retros			
	Event Log	Data Analysis		
2018	Write-up			

Event Logging

- Classify weather events
- Document main features
- Compare model performance
- Weekly weather discussions
- Discuss results of RAP/HRRR testing
- Select case studies

Event Log

File Edit View Insert Format Data Tools Add-ons Help All changes saved in Drive

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Reminder: watch period spans 0000-235

Consult "Event Logging Responsibilities" documentation here.

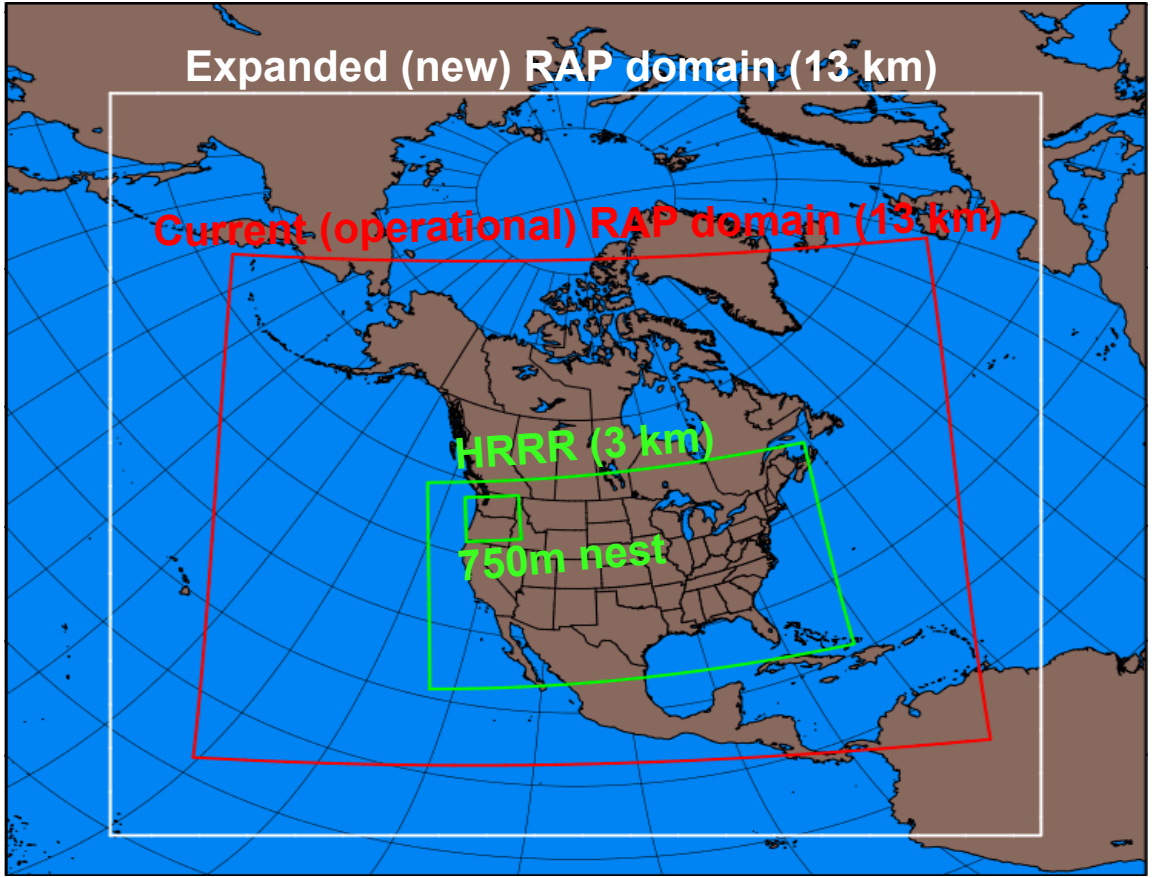
HRRR-WFIP Configuration

Regime Types ->

(WF) Warm FROPA w/mix-out
(EG) Easterly gap flow
(CO) Convective outflows
(WS) Significant diurnal wind shift
(CF) Cold FROPA
(MP) Marine push
(IS) Inversion-level shear
(WG) Westerly gap flow
(TW) Topographic wakes
(MW) mountain waves
(SA) Surface anticyclone
(SW) Extended pre-frontal S/SWly flow
(OT) Other (free-form description)

				Regional Characterization: use model guidance to supplement observational evidence, as needed			Wasco-Area Measurements		Summary (This should be "tweet-length". Put more extensive write-up on "Remarks" sheet)
				Subjective Regime Classification (enter "Type" ID)			PEAK RAMP (Wasco "Dalek2" Lidar, 100m)		
	Date (UTC)	DOW	Event Logger	Dominant	Secondary	Tertiary	magnitude (m/s)	duration	
53	5-Dec-15	Sat	Qing Yang	CF	EG	IS	no ramps		mainly weak easteries/southlies associated with the weak frontal system
54	6-Dec-15	Sun	Qing Yang	WF	WG	IS	4 m s-1	2h	pick up in wind speed and shift to westeries at around 20 UTC
55	7-Dec-15	Mon	Eric Grimit	SW	WS	IS	9 m s-1	2h	Strong SW flow aloft, warm/wet, ramp down at 3 UTC with stable BL, then mixout large up ramp 21
56	8-Dec-15	Tue	Eric Grimit	SW			-9 m s-1	3h	Strong W flow aloft relaxes 7-13 UTC, increased low-level shear, then mixout w/ WSW flow 14-20 U
57	9-Dec-15	Wed	Eric Grimit	CF	MW		-4 m s-1	1h	Strong SW flow persists until cold frontal passage at 10-11 UTC, then W post-frontal flow with wave
58	10-Dec-15	Thu	Mark Stoelinga	CF	WF	EG	"+11 m s-1"	3h (twice)	Westerly postfrontal to easterly gap/warm advection aloft back to SW'ly postfrontal.
59	11-Dec-15	Fri	Mark Stoelinga	WG			-9 m s-1	3h	Downramping of postfrontal flow, then weak flow, then slight easterly upramp with approach of dyin
60	12-Dec-15	Sat	Mark Stoelinga				-7/+10/-10/+8 m/	3h/6h/4h/3h	
61	13-Dec-15	Sun	Jaymes Kenyon	TW	CF	MW	7	3 h	CFROPA at Wasco between 08-09Z, then pronounced afternoon waking from Mt Hood
62	14-Dec-15	Mon	Jaymes Kenyon	SA			no ramps		Fair weather; steadily weakeneing low-level WNW flow
63	15-Dec-15	Tue	Jaymes Kenyon	TW	WG		6	2.25 h	Development of modest westerly gap flow between Hood, Adams wakes
64	16-Dec-15	Wed	Joe Olson	WG	MW		4/-9	2/1.5h	Weak disturbance passes eastern edge of WFIP2 region; westerly GF with mountain wakes
65	17-Dec-15	Thu	Joe Olson	EG	IS	WF-non mix-out	3	2h	Warm front passes WFIP2 area later in the day. Easterly GF is not mixed out

RAP, HRRR, and 750m Nest Domains

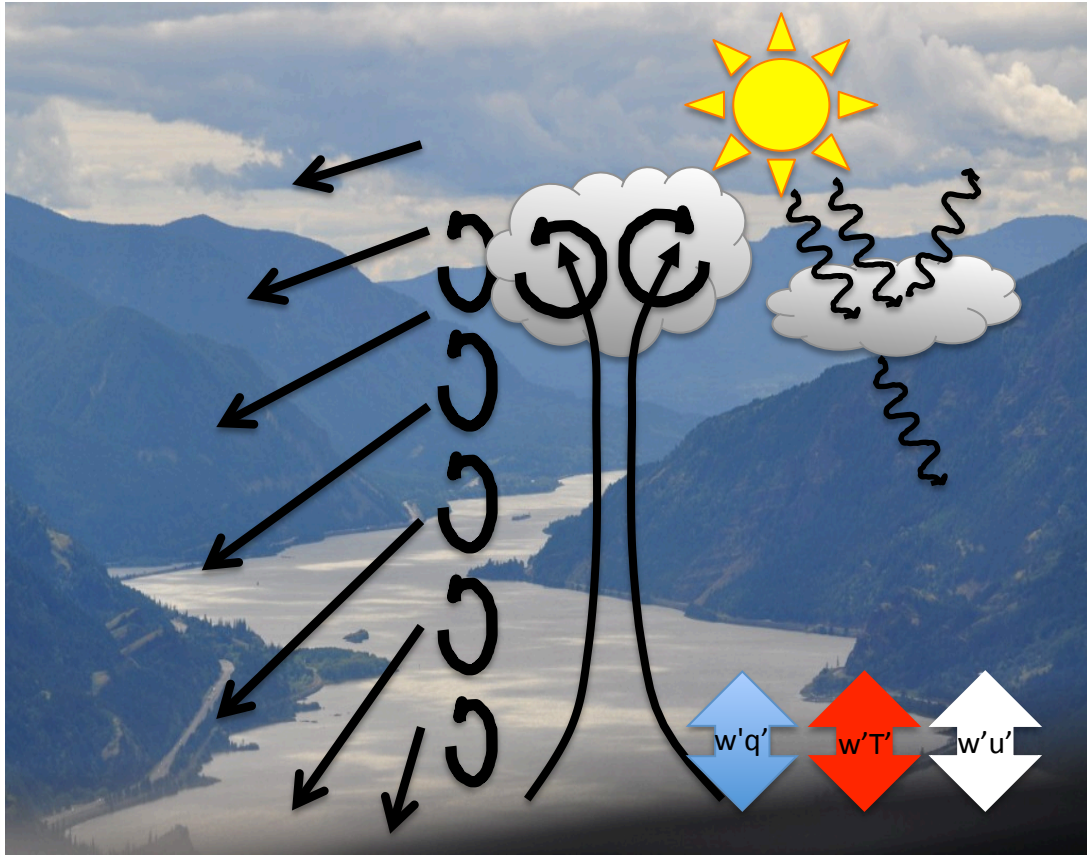


Models	Physics Version
RAP-NCEP	Version2 (oper/CTL)
RAP-ESRL	Version3 (May2016)
HRRR-NCEP	Version1 (oper/CTL)
HRRR-ESRL	Version2 (May2016)
HRRR-WFIP	Next-Gen (2x-daily)
HRRR-Nest	Next-Gen (2x-daily)

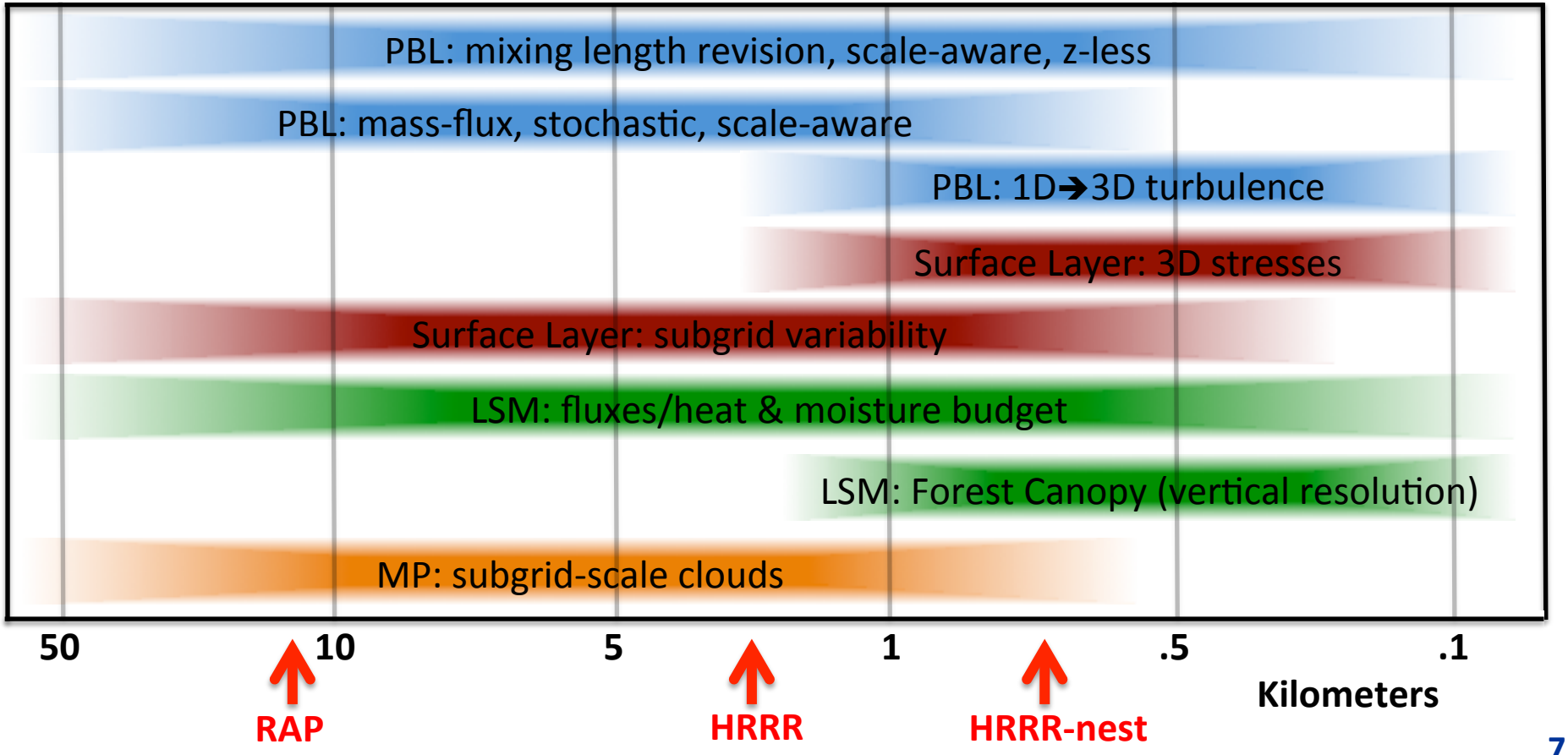
RAP:
http://rapidrefresh.noaa.gov/
HRRR:
http://rapidrefresh.noaa.gov/hrrrconus
HRRR-WFIP:
http://rapidrefresh.noaa.gov/HRRRwfipsubh/

Physical Processes & Parameterizations

Model Component	RAP/HRRR Scheme	Component
Turbulent diffusion	MYNN PBL/ 3d-Blended TKE	• Mixing length ○ Scale-aware ○ Z-less • 1D➔3D as $f(\Delta x)$
Non-local Turbulent transport	MYNN Mass-flux	• Multi-plume • TKE transport • Momentum transport • Scale-aware
Surface Fluxes	RUC LSM/ MYNN Sfc Layer	• Scalar roughness • M-O alternatives • 3D surface stress
Clouds	Thompson Aero/ Chaboureau-Bechtold	• Subgrid scale clouds • Coupled to radiation • prognostic
Numerics/ dynamics	IBM, σ/cartesian mixing	• Vertical grid • Surface stress

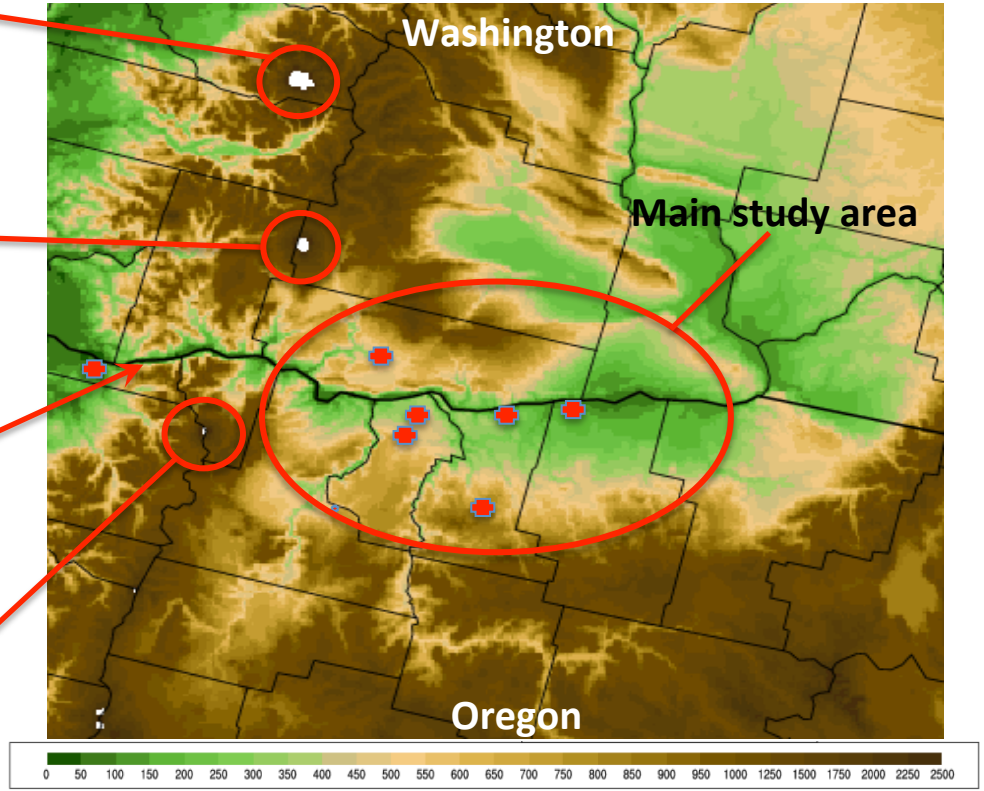


Expected Scales of Impact



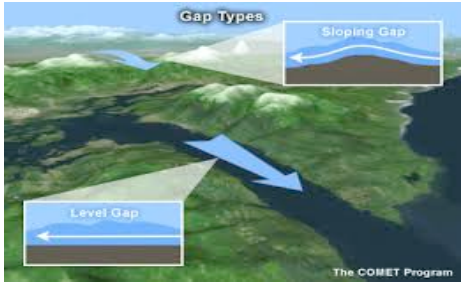
The Topography of the WFIP 2 Study Area

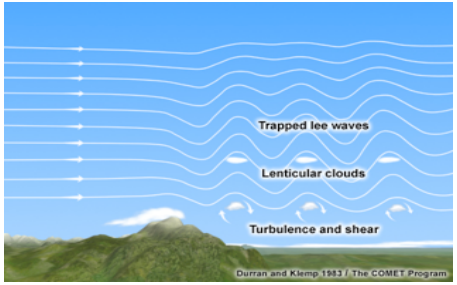
750m HRRR-Nest Terrain Elevation (m)

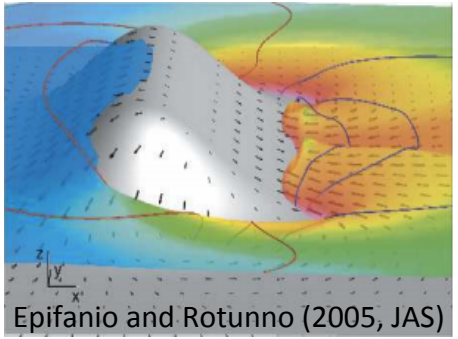


Flow Features in Columbia River Basin

- Frontal Passages with Stable Mix-Out
- Gap Flows
- Convective Outflows
- Mountain Waves/trapped lee-waves
- Topographic Wakes
- Marine Pushes



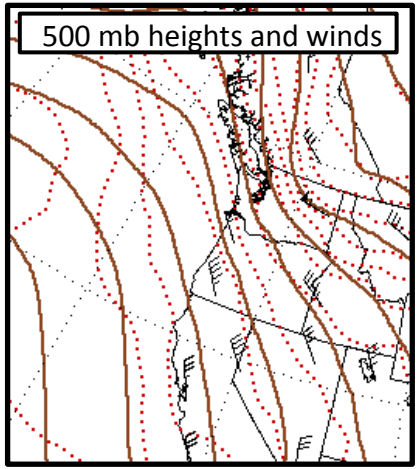


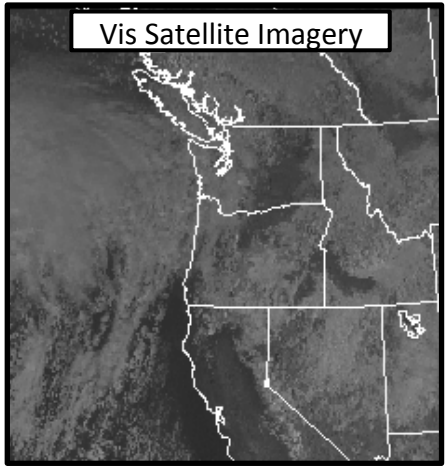


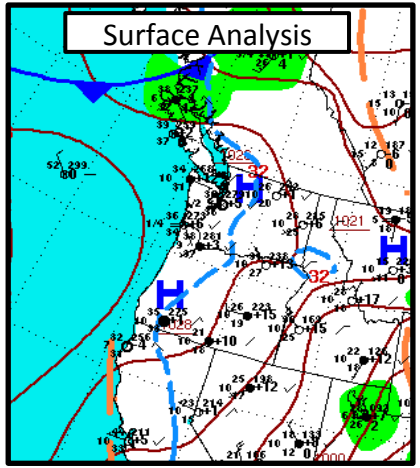
Epifanio and Rotunno (2005, JAS)

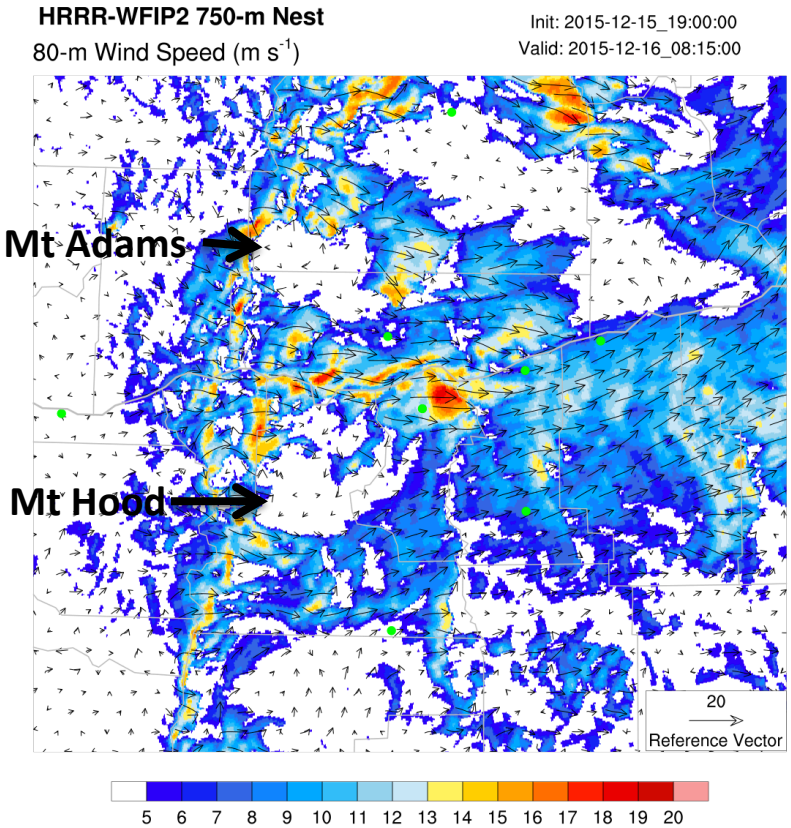
Case of 15-16 December 2015

- Upper-level short-wave over WA
- Higher surface pressure offshore accelerates westerly flow through the Columbia River Gorge.

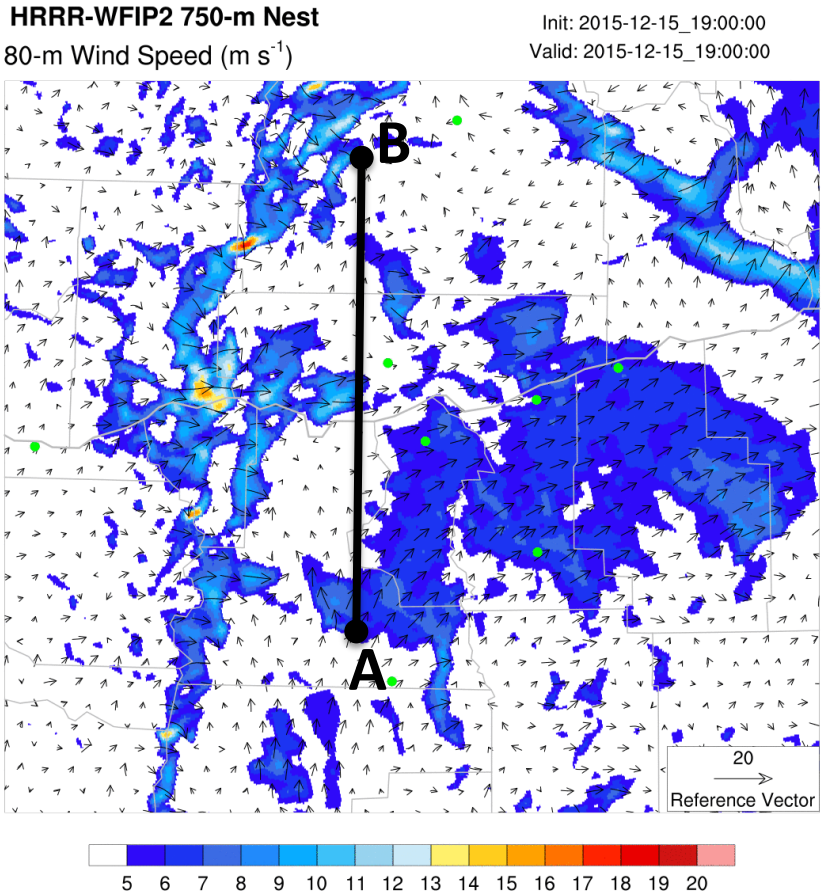


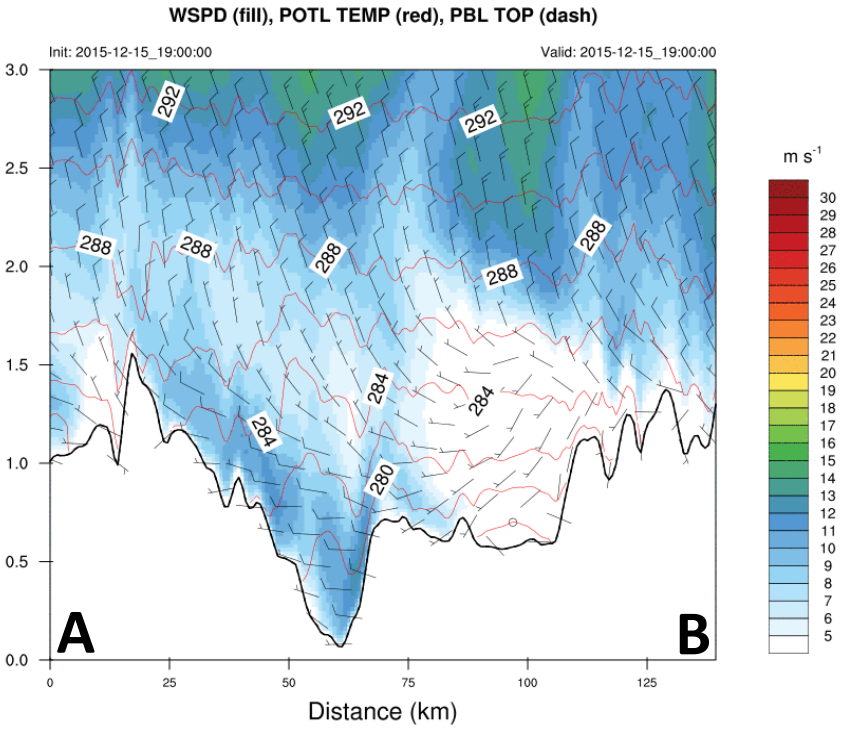






80-m Wind Speed & X-Section Loop





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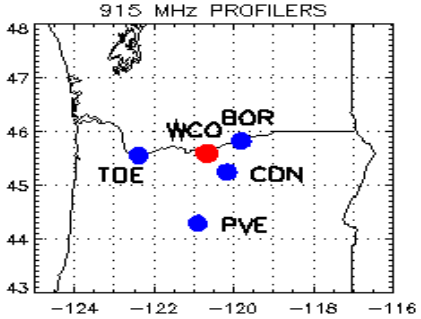
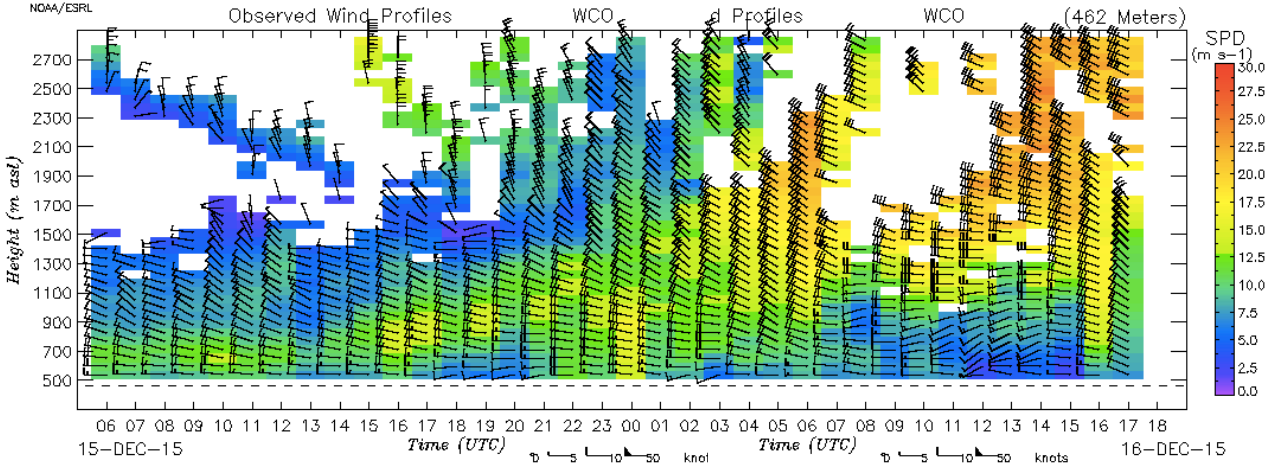
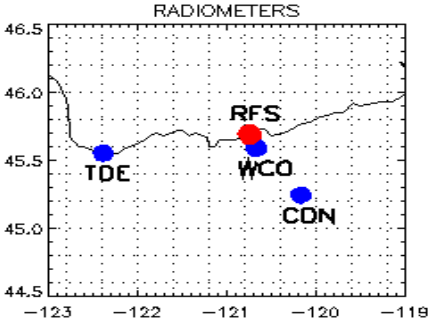
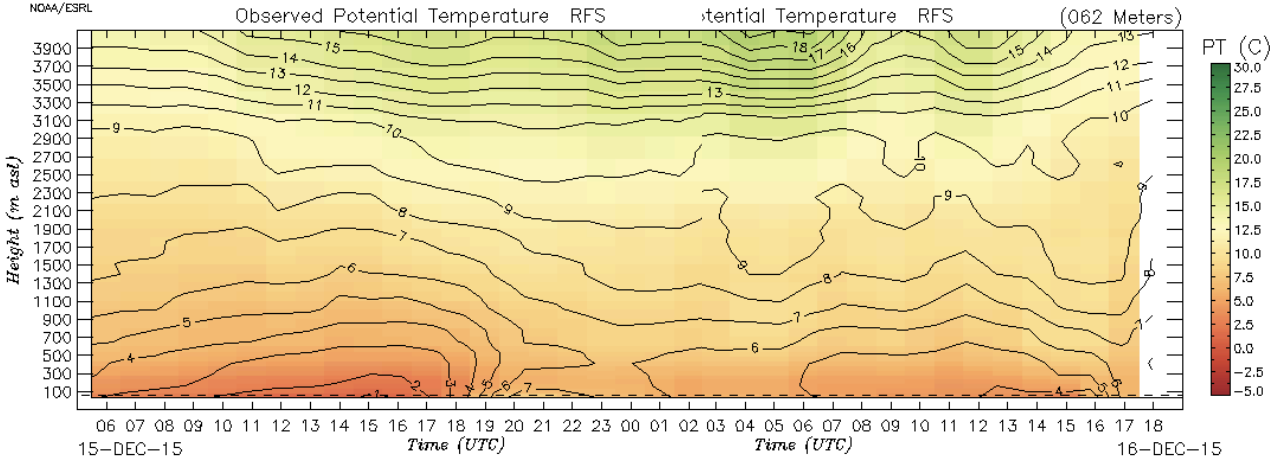
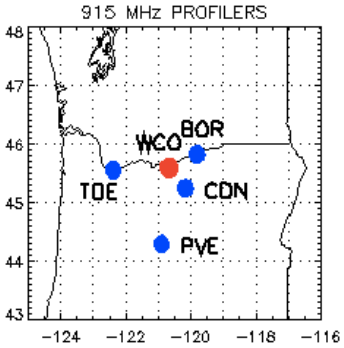


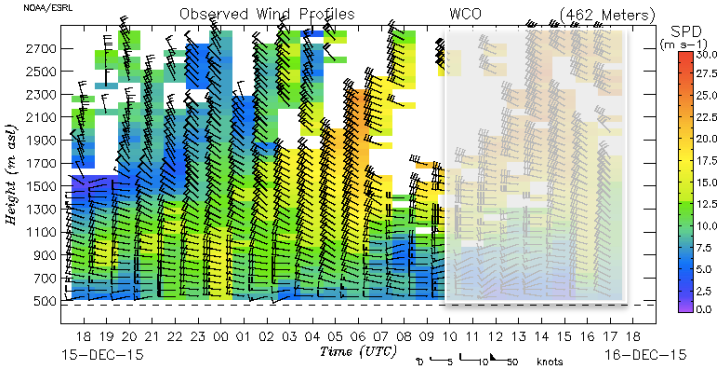


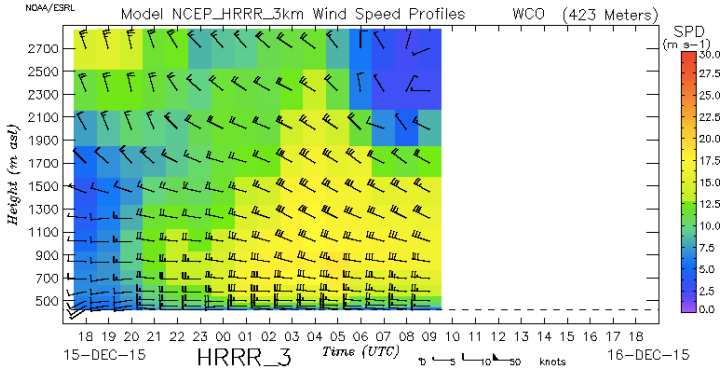


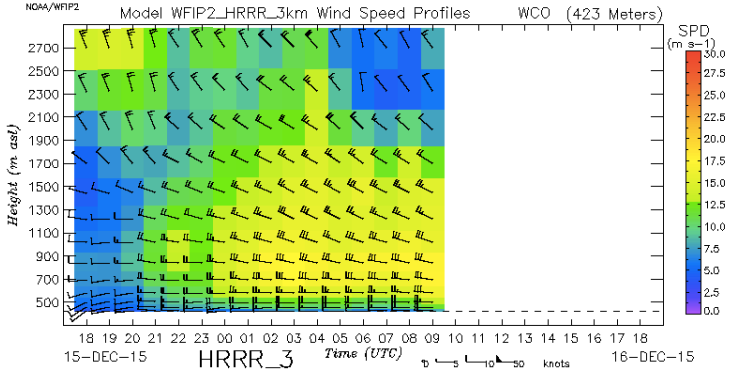


Comparison of CTL & EXP HRRR



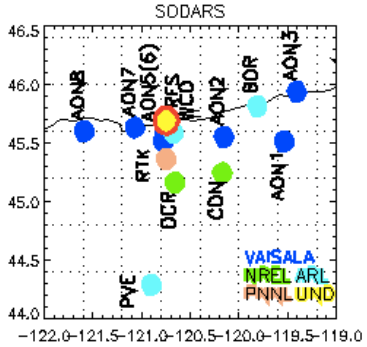


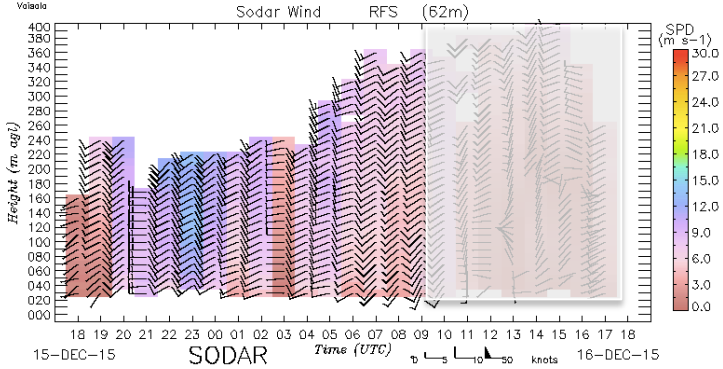


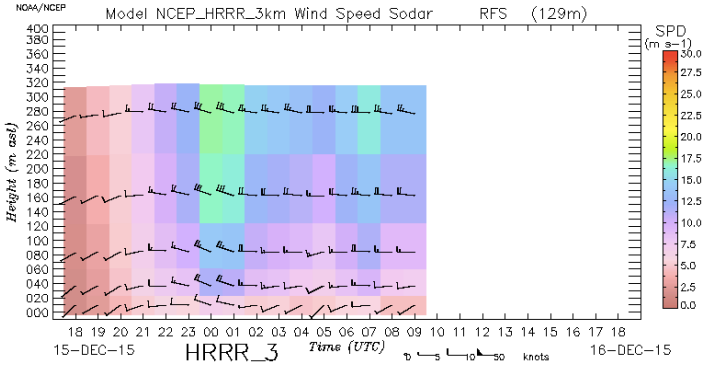


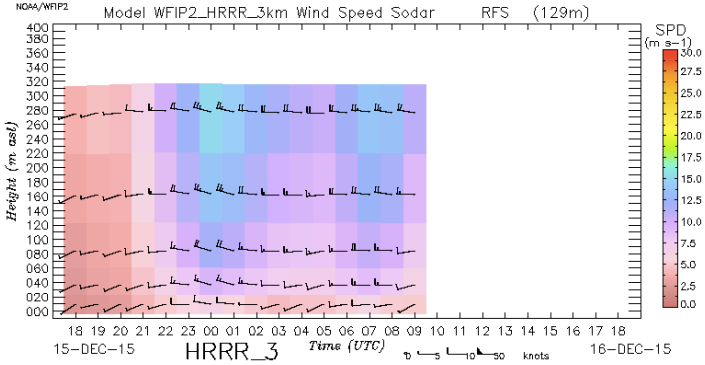
- **Both HRRRs strengthen the gap flow too quickly and too much near the surface.**
- **HRRR-WFIP is slightly weaker (better match to obs) than the operational HRRR.**
- **Both HRRRs do poorly above 1500-m after 03 UTC, by advecting the Mt Adams wake too far south, over Wasco.**

Comparison of CTL & EXP HRRR



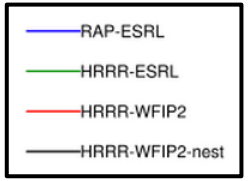


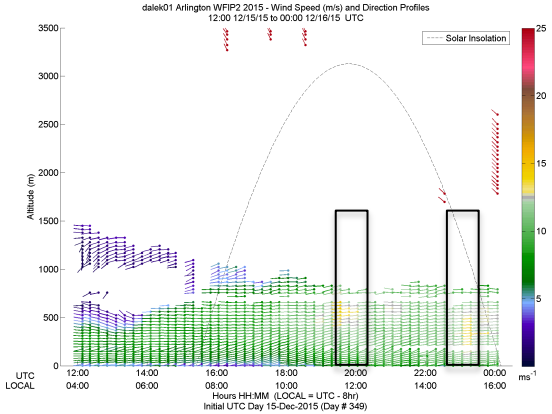


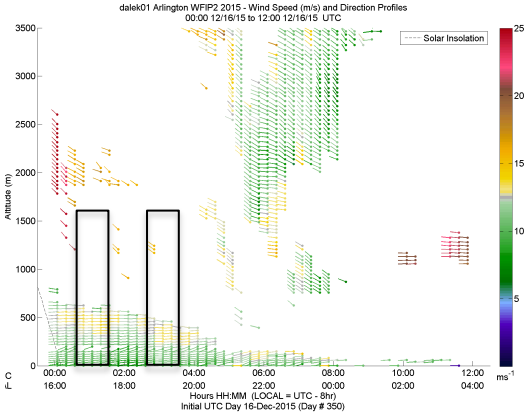


- **Sodar suggests wind speeds at Rufus (RFS) were generally weaker than operational HRRR forecasts.**
- **HRRR-WFIP improves high wind speed bias.**
- **Second wind max at 280-m AGL was over-predicted by both HRRRs.**

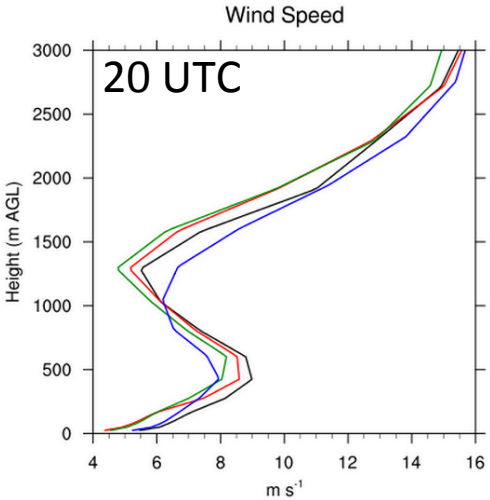
Comparison of RAP, HRRRs & Nest

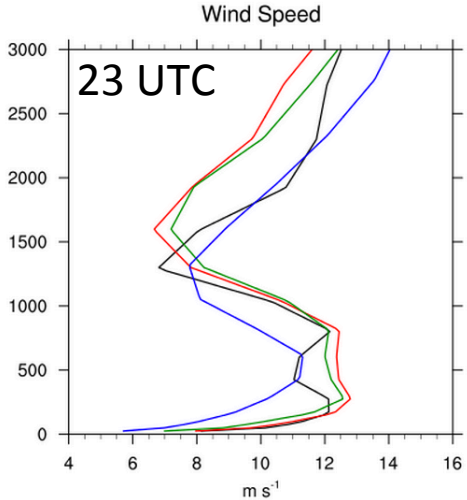


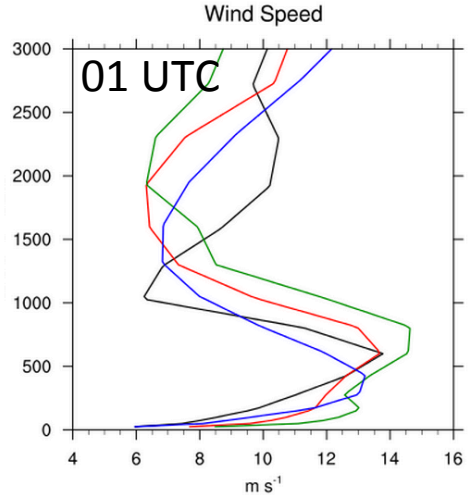


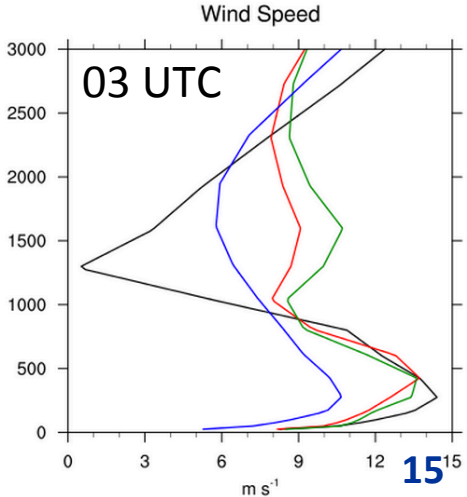


- **Differences outside mountain wake are generally small**
- **Revised mixing-length typically reduces excess of near-surface momentum**









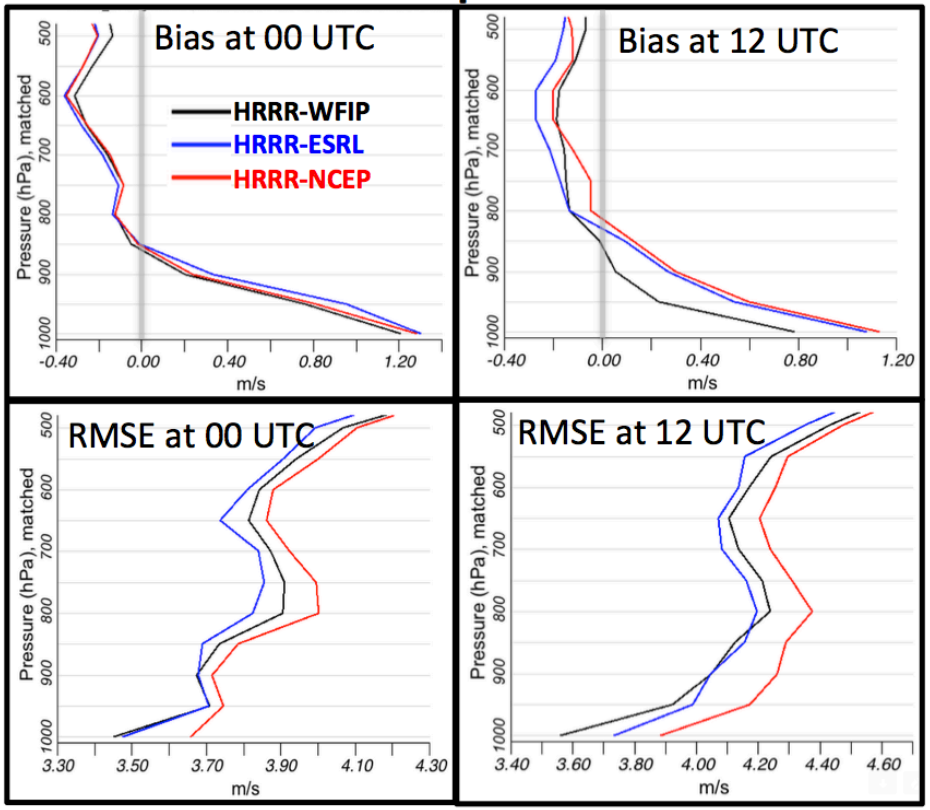
Model Validation

- Ongoing Development of WFIP 2 database and enhanced validation system
  - Collecting all observational data
  - Collecting all model data
- Developing Web Interface for visualizing:
  - Profile comparisons of model & observations
    - Different instruments
    - Selected stations
  - Time-series comparison
  - Probability distribution functions/histograms
    - i.e., compare PDFs of 80-m wind speed errors from two different retrospective test periods at 06 UTC.
  - Scatter plots
    - i.e., plot mean wind speed error between 50-200m as a function of shear between 50-200m.
- Prototype ready in Feb 2016

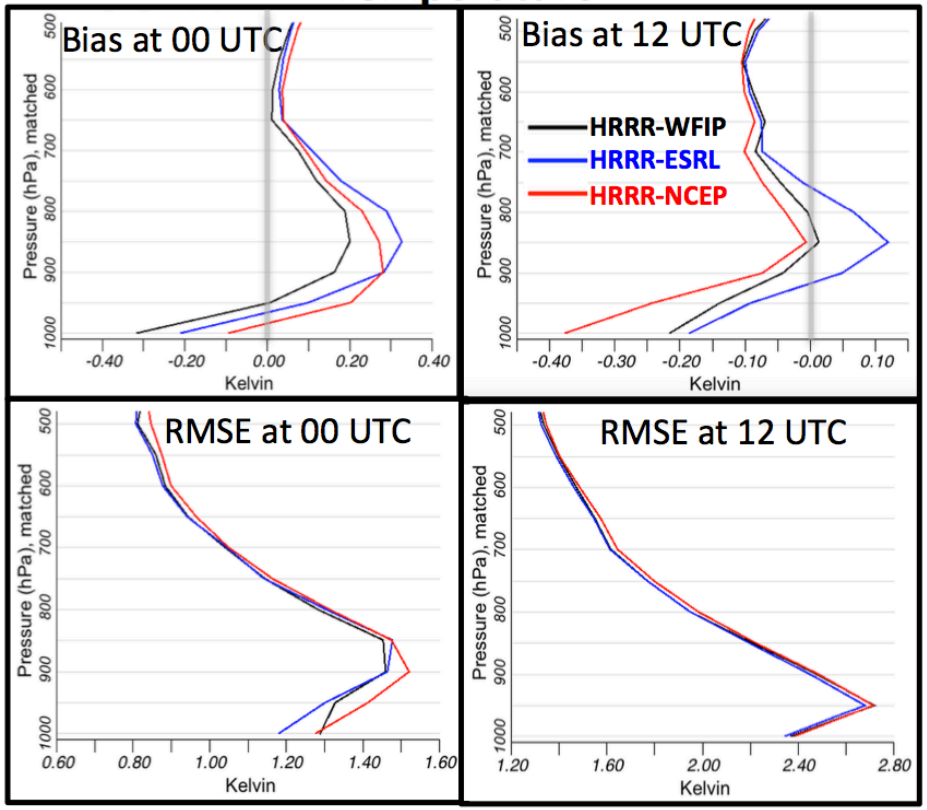
Validation against conventional data

6-hr forecasts validated against all radiosondes across CONUS (05 Nov 2015 - 08 Jan 2016)

Wind Speed



Temperature



Summary

- **WFIP2 provides an opportunity to improve RAP/HRRR physics for flows in complex terrain.**
  - Gap Flows.
  - Marine Pushes.
  - Mountain wakes.
  - Trapped Lee-Waves, etc.
- **Many aspects of RAP/HRRR targeted for development, both complex terrain-specific and general physics/dynamics.**
  - PBL: scale-aware, vertical diffusion and 1D to 3D transition.
  - PBL-ShCu: coupled (scale-aware) eddy diffusivity/mass-flux scheme.
  - Surface Fluxes: 3D, alternatives to Monin-Obukhov theory.
- **Event logging team has been examining/classifying events & selecting case studies.**
- **Model development team will perform case studies, testing new physics over the next year.**
- **The current real-time HRRR-WFIP seems to generally produce better forecast than the operational HRRR, but improvements are modest at the moment.**