Improved Forecasts of Cold Pools in Complex Terrain from WFIP 2

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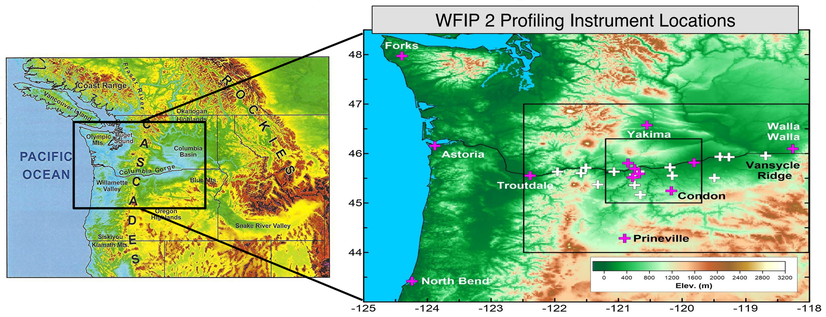
Motivation

- Wind Forecast Improvement Project 2 (WFIP2): improve NWP forecasts of low-level winds in complex terrain for the benefit of wind-energy applications
- Main WFIP2 efforts: (1) high-quality measurements from an 18-month field campaign, and (2) model development, focusing on NOAA's RAP/HRRR physics suite

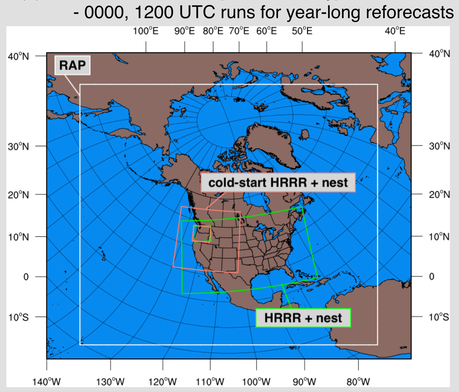


- **Preliminary finding**: forecast errors are largest in the cold season, and often associated with the **premature erosion of cold pools** in complex terrain by NWP

WFIP 2 Model Development

Modeling Framework: NOAA's RAP and HRRR w/ Nests

- 13-km Rapid Refresh (RAP)
- 3-km High Resolution Rapid Refresh (HRRR) with 750-m nest; two HRRR domains:
  - (1) regular CONUS domain (data assimilation + cycling)
    - three-hourly runs for 10-day retrospectives
  - (2) western U.S. domain (cold-start only)
    - 0000, 1200 UTC runs for year-long reforecasts



RAP/HRRR Physics-Suite Development for WFIP 2 in the WRF–ARW Framework

Component	Control ("CTL"): *the pre-WFIP2 RAP/HRRR suite*	Experimental ("EXP"): *encompasses WFIP2 developments to the RAP/HRRR suite* (new)
Land Surface	RUC 9-level	RUC 9-level
Surface Layer	MYNN	MYNN
PBL	MYNN level 2.5	MYNN–EDMF
Radiation	RRTMG (SW, LW)	RRTMG (SW, LW)
Microphysics	Thompson Aero	Thompson Aero
Deep Convection	Grell–Freitas (RAP only)	Grell–Freitas (RAP only)
Shallow Convection	Grell–Freitas (RAP only)	MYNN–EDMF (all scales)
Horizontal Diffusion	Smagorinsky on sigma	Smagorinsky on z
Small-Scale Gravity-Wave Drag	---	Steeneveld et al. 2007 (JAMC)
Wind-Farm Drag	---	Fitch et al. 2012 (MWR)
Vertical Coordinate	51-level sigma	51-level hybrid sigma–pressure

Key Physics Changes to Improve Cold-Pool Representation

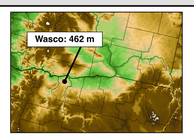
(1) MYNN–EDMF mixing-length revision (namelist: `bl_mynn_mixlength = 2`)
- reduced magnitude in stable layers
- z-less: transitions to local calculation away from surface more rapidly than before

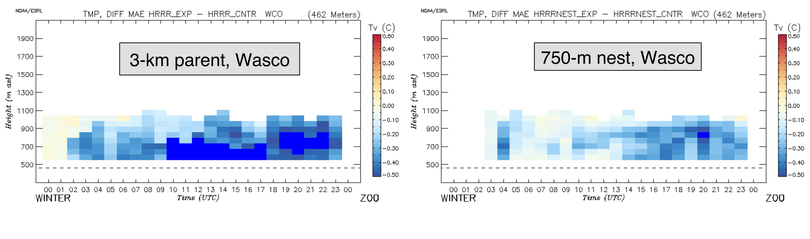
(2) refined horizontal diffusion (namelist: `diff_opt = 2`)
- evaluate gradients along z = const (i.e., in Cartesian coordinates), instead of along model-coordinate surfaces, with may be sloped

(3) new small-scale gravity-wave drag [adapted from Steeneveld et al. (2008)]
- account for wave stress from unresolved topography

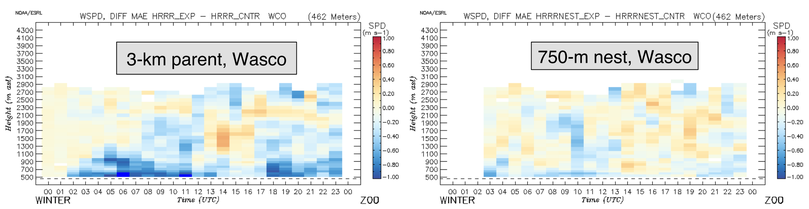
6-Week Winter Reforecast Results: 25 December 2016 to 7 February 2017

△[temperature MAE] EXP minus CTL

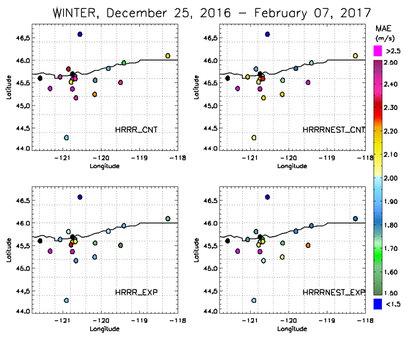




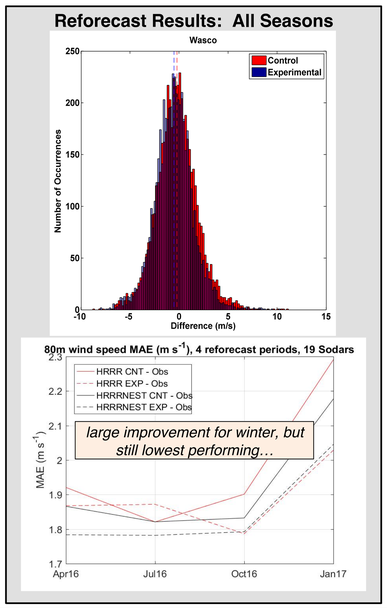
△[wind speed MAE] EXP minus CTL



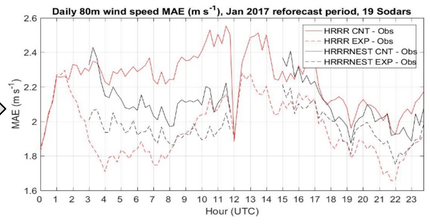
80-m wind speed MAE, all sodars, by location



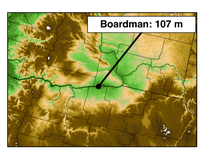
Reforecast Results: All Seasons



80-m wind speed MAE, all sodars, by time of day



Forecast-Improvement Attribution Case Study: 13 January 2016 Cold-Pool Erosion at Boardman

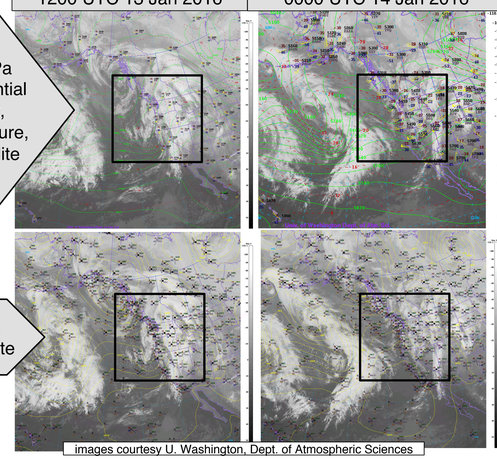


synoptic context

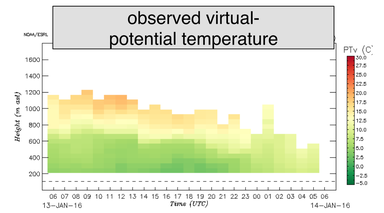
prior to cold-pool erosion: 1200 UTC 13 Jan 2016	during cold-pool erosion: 0000 UTC 14 Jan 2016

500-hPa geopotential height, temperature, IR satellite

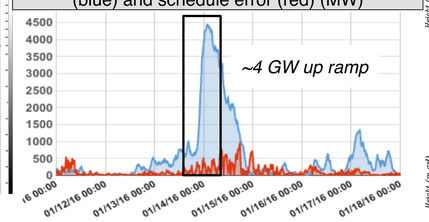
MSLP, IR satellite



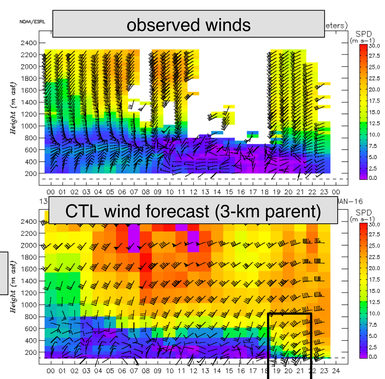
observed virtual-potential temperature



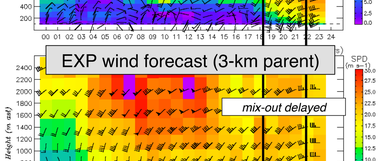
Bonneville Power Administration wind generation (blue) and schedule error (red) (MW)



observed winds

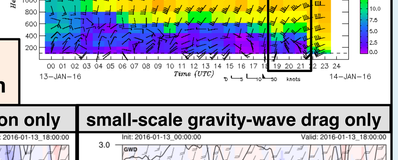


CTL wind forecast (3-km parent)



EXP wind forecast (3-km parent)

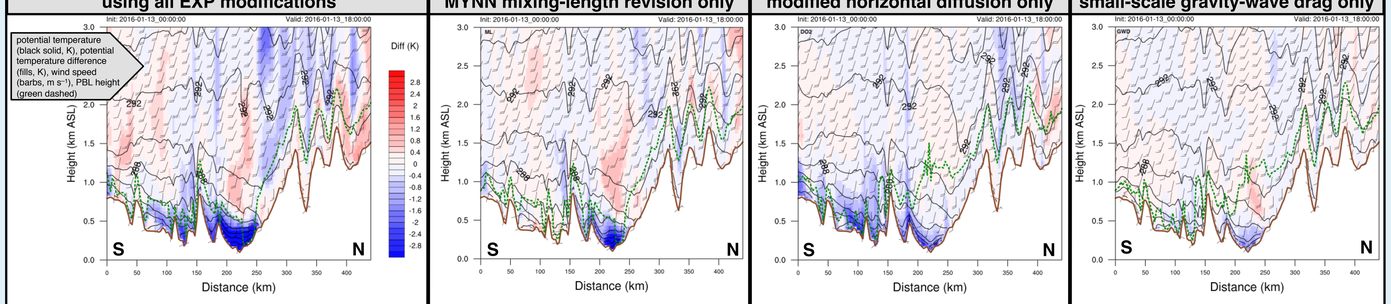
mix-out delayed



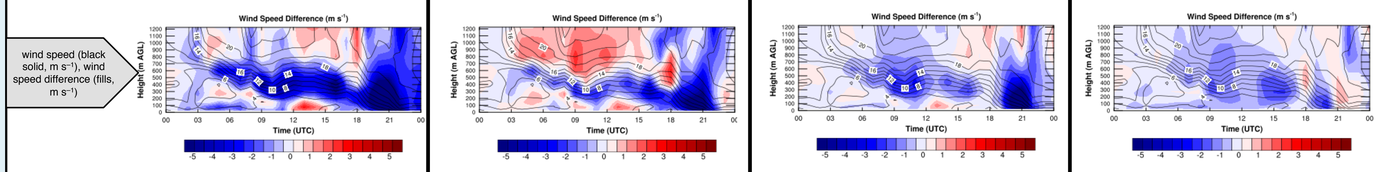
all figures below: forecast differences with respect to CTL configuration

using all EXP modifications	MYNN mixing-length revision only	modified horizontal diffusion only	small-scale gravity-wave drag only

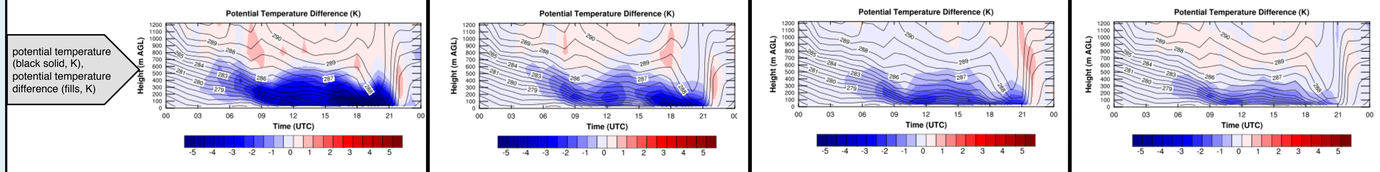
potential temperature (black solid, K), potential temperature difference (fills, K), wind speed (barbs, m s^{-1}), PBL height (green dashed)



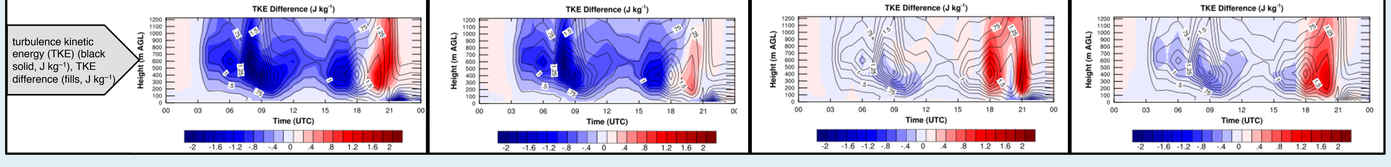
wind speed (black solid, m s^{-1}), wind speed difference (fills, m s^{-1})



potential temperature (black solid, K), potential temperature difference (fills, K)



turbulence kinetic energy (TKE) (black solid, J kg^{-1}), TKE difference (fills, J kg^{-1})



Conclusions

- WFIP 2 experimental physics package achieves significant forecast improvements during cold season in complex terrain, largely via improved retention of cold pools
  - MYNN–EDMF modifications, refined horizontal diffusion, and small-scale gravity-wave drag account for most of the improvement
- WFIP 2 modeling-related manuscripts in preparation (for 2018):
  - (1) WFIP 2 model-development overview (BAMS)
  - (2) WFIP 2 cold-pool case study and reforecast results (MWR)
  - (3) WFIP 2 thermal-trough case study and reforecast results (MWR)
  - (4) NOAA technical memorandum on the MYNN–EDMF scheme