WFIP2: The Second Wind Forecast Improvement Project: Observing Systems and Model Evaluation

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University of Notre Dame

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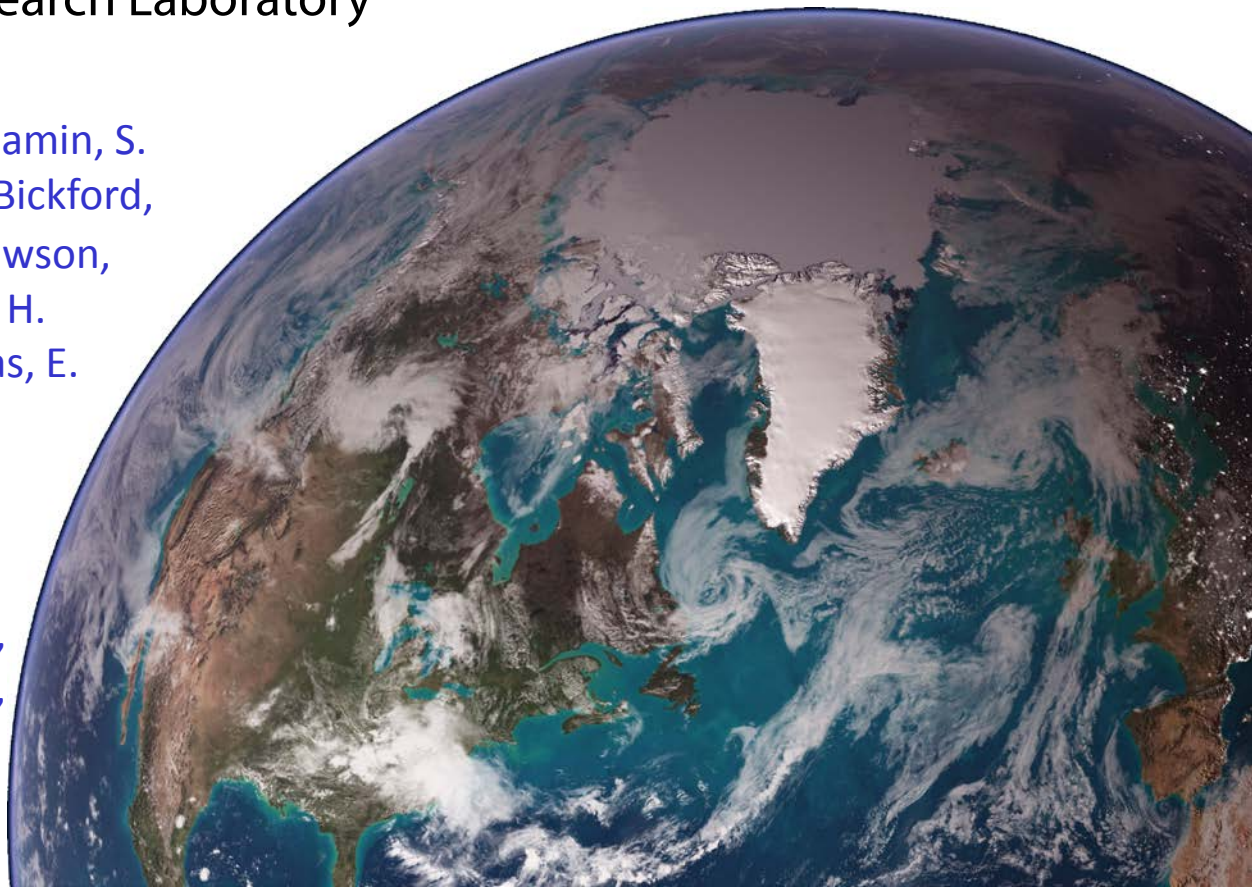


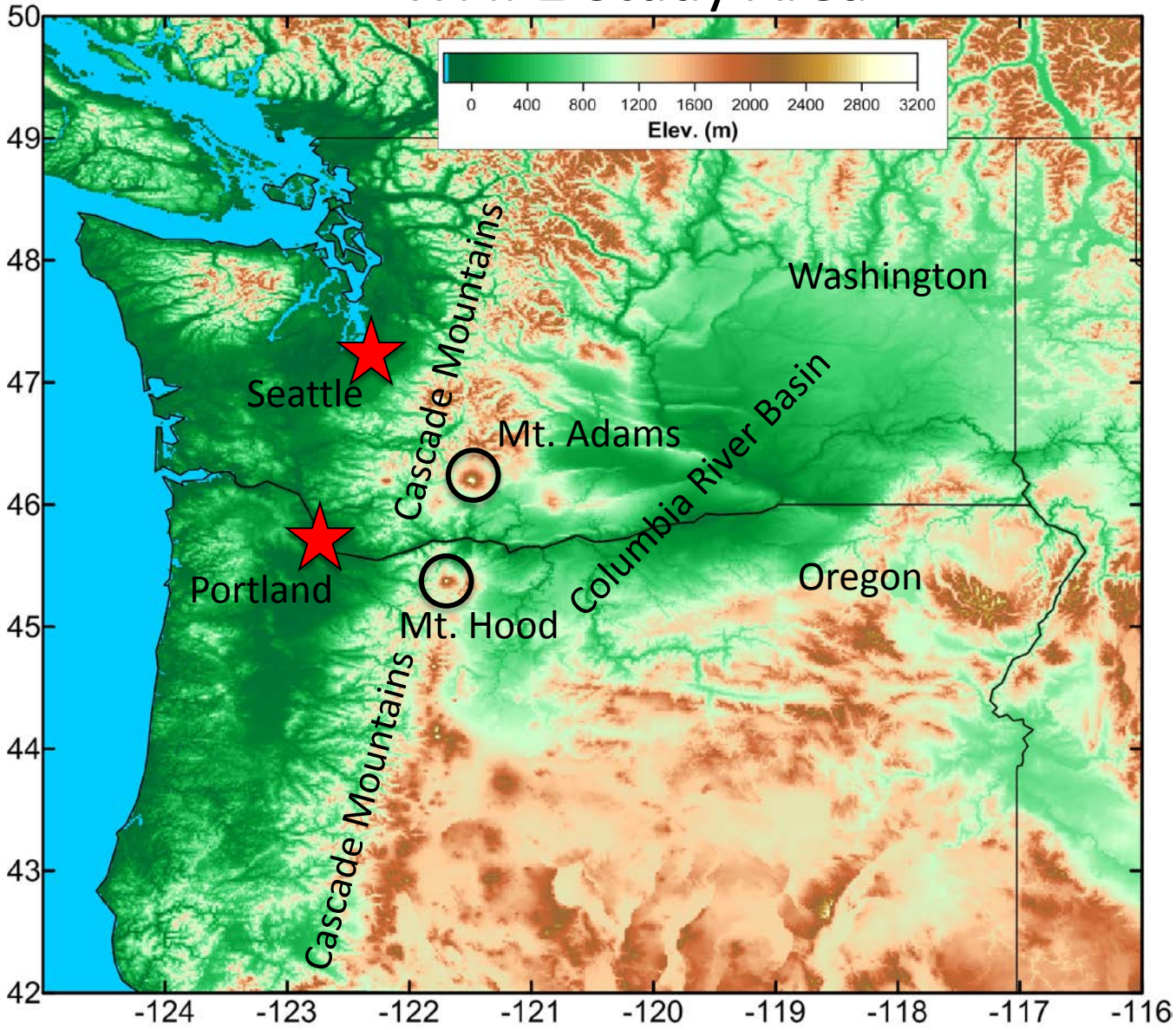
GMU ATD, June 14, 2016

WFIP2 is funded by U.S. Department of Energy and NOAA to improve forecasting for wind-energy

GOALS:

- Improve our understanding of atmospheric flows and processes that occur in complex terrain and impact wind forecasts at hub heights.
- Instrument the Columbia River Basin study area and carry out a 12-18 month field campaign (beginning October 1, 2015).
- Develop physical parameterizations in WRF-ARW (with a focus on RAP & HRRR) to better represent physical processes and increase accuracy of wind forecasts in the 0-15 hour range, as well as day-ahead forecasts.
- Develop decision support tools, e.g., probabilistic forecast information, uncertainty quantification and forecast reliability for system operations.
- Transfer model improvements to NOAA/National Weather Service, other international forecast centers, and private industry.

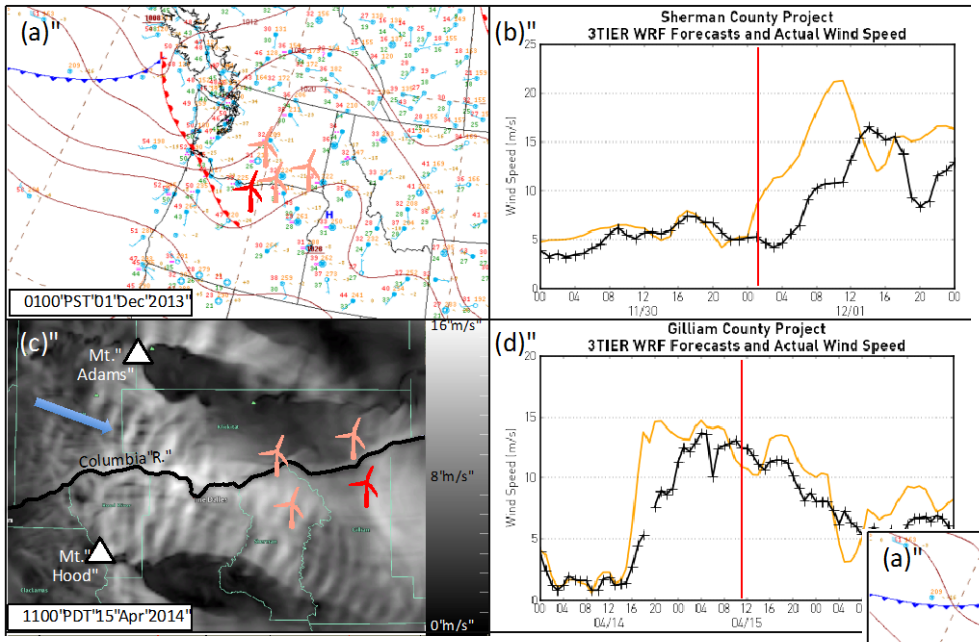
WFIP2 Study Area



Columbia River Gorge

Columbia River Basin

Key Phenomena in WFIP2 Region

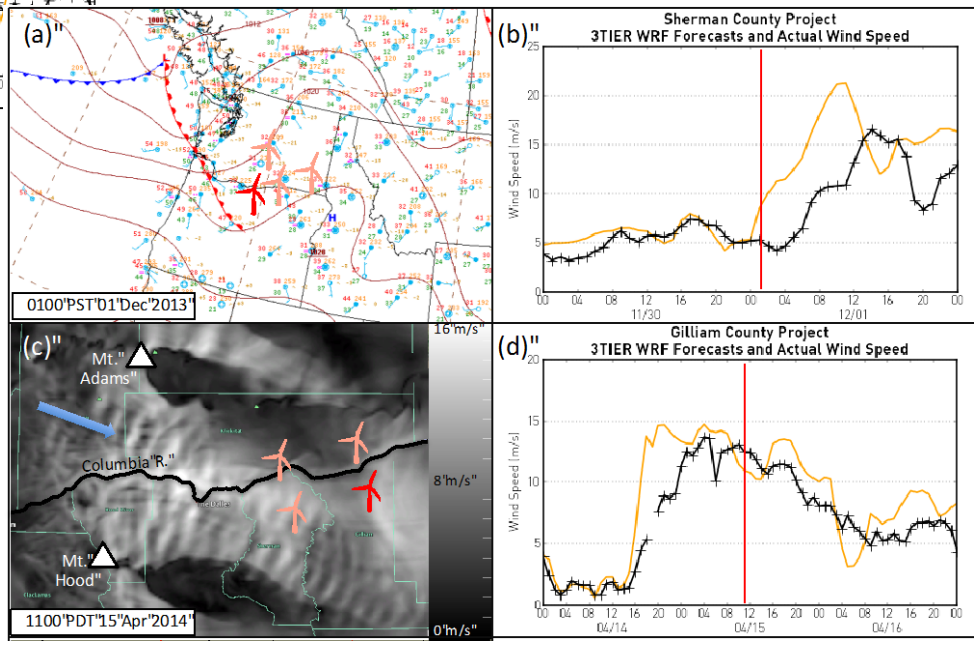


Timing and intensity of frontal passages

Orographic lee waves and wakes

Convective outflows

Marine layer / regional thermal contrast / gap flows



Ever-present challenge:
Build up and erosion of stable layers

WFIP2 Partners

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

VAISALA

Hay Canyon Wind Farm – with Mount Hood in the background – is among those in the study area. Photo courtesy of Iberdrola Renewables

Argonne NATIONAL LABORATORY

Lawrence Livermore National Laboratory

NREL National Renewable Energy Laboratory

Pacific Northwest NATIONAL LABORATORY

NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce

NOAA Earth System Research Laboratory
Serving Society through Science

ARL Air Resources Laboratory
Conducting research and development in the fields of air quality, atmospheric dispersion, and climate

National Weather Service

Data Partners:

IBERDROLA RENEWABLES

Southern California Edison
An EDISON INTERNATIONAL Company

PGE

Eurus Energy

Team Members:

University of Colorado Boulder

Texas Tech University College of Arts & Sciences

Lockheed Martin

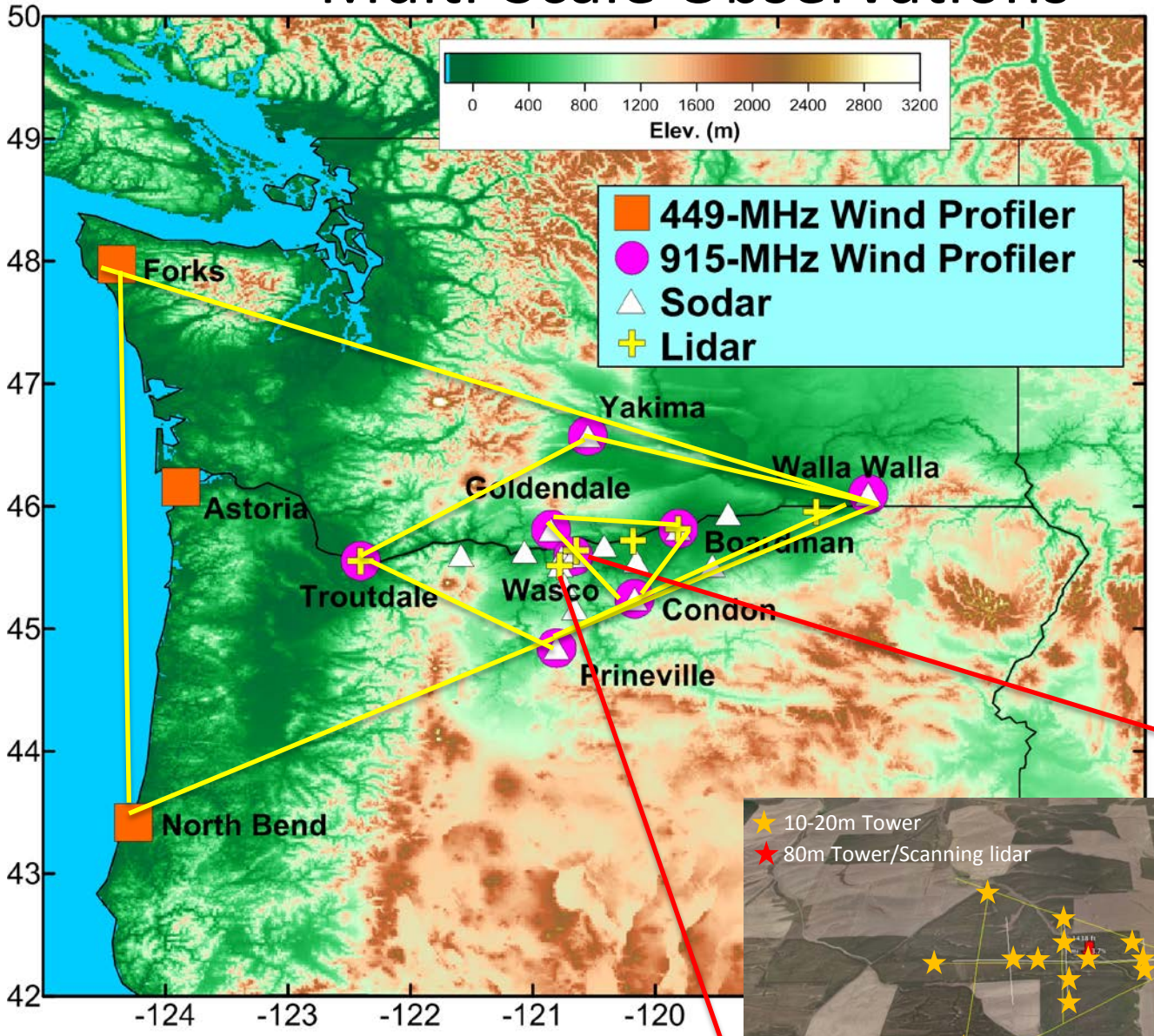
University of Notre Dame

NCAR
National Center for Atmospheric Research

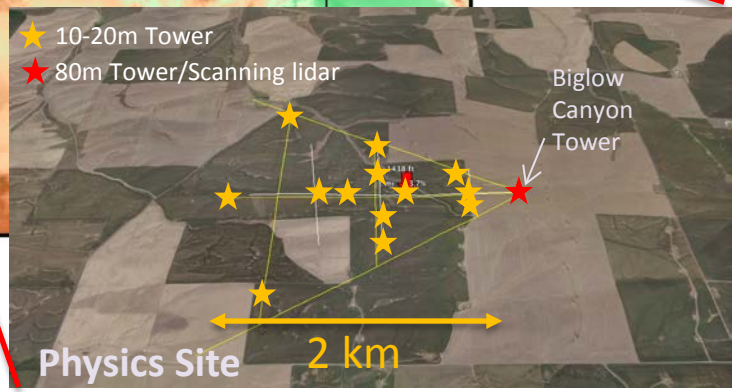
Sharply Focused

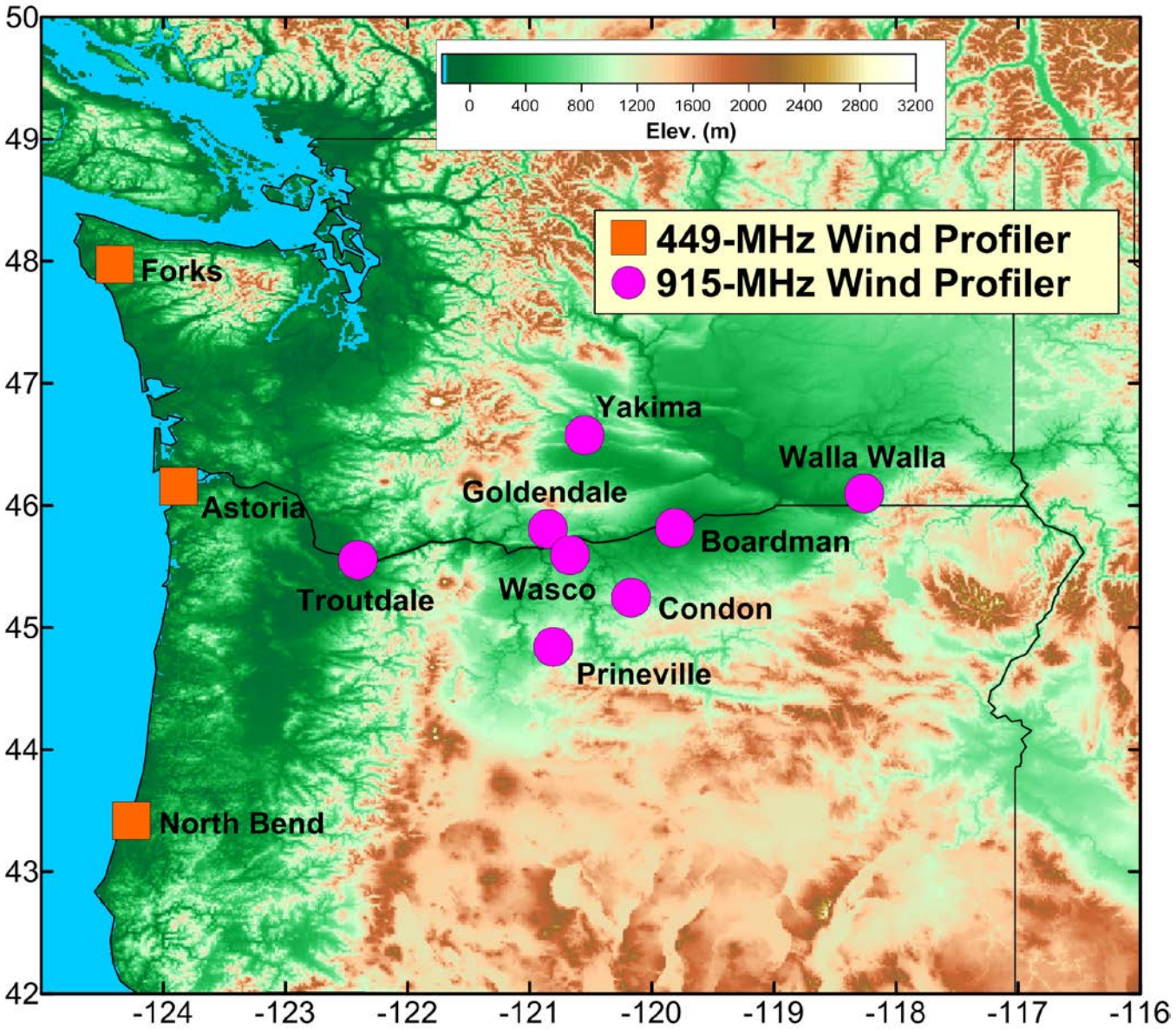
Bonneville Power Administration

Multi-Scale Observations

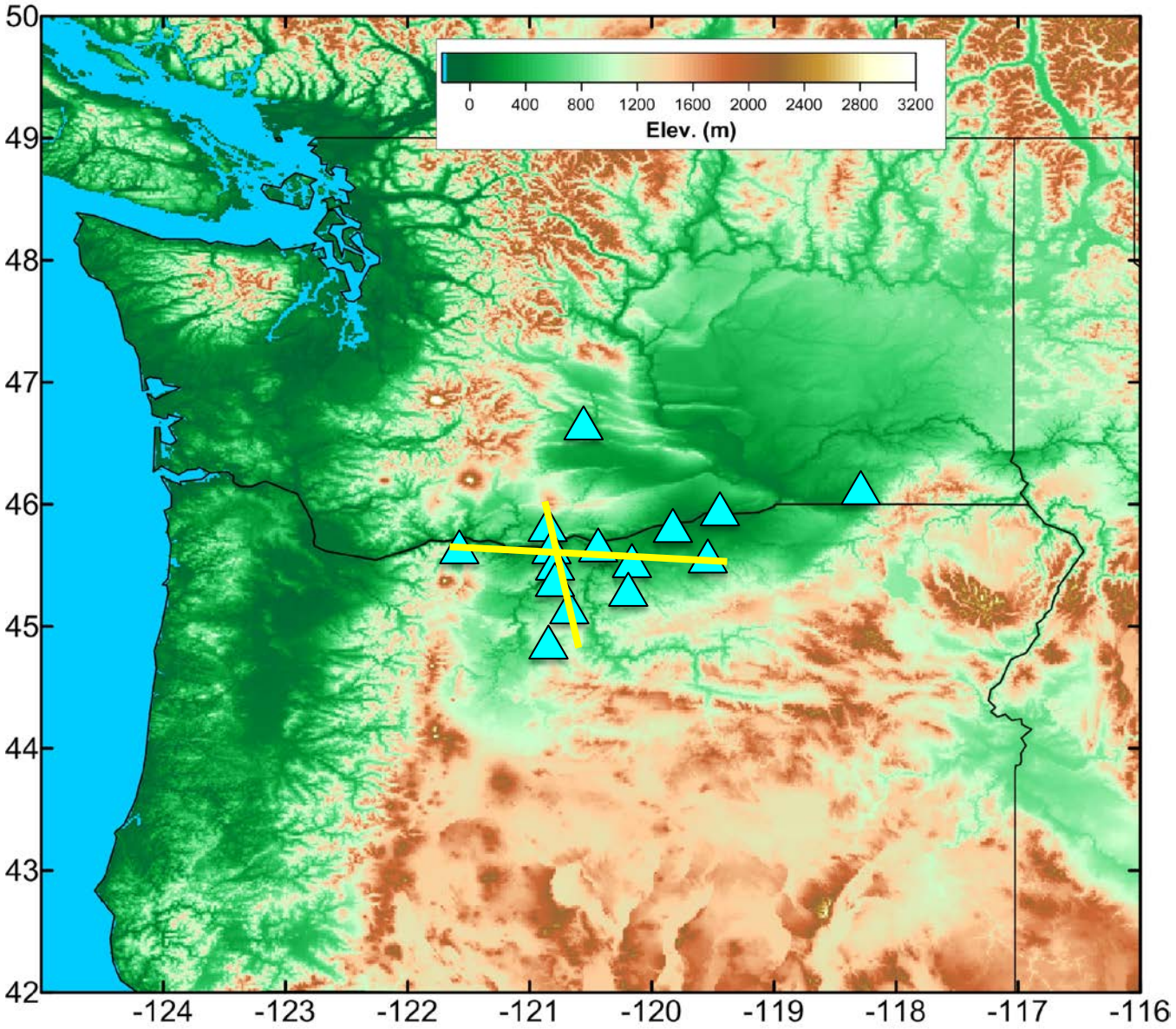


- 11 wind profiling radars
- 17 sodars
- 5 wind profiling lidars
- 5 scanning lidars
- 4 radiometers
- 10 microbarographs
- 1 Ceilometer
- 2 scanning radars
- 28 sonic anemometers
- 5 radiative flux systems
- & soil moisture

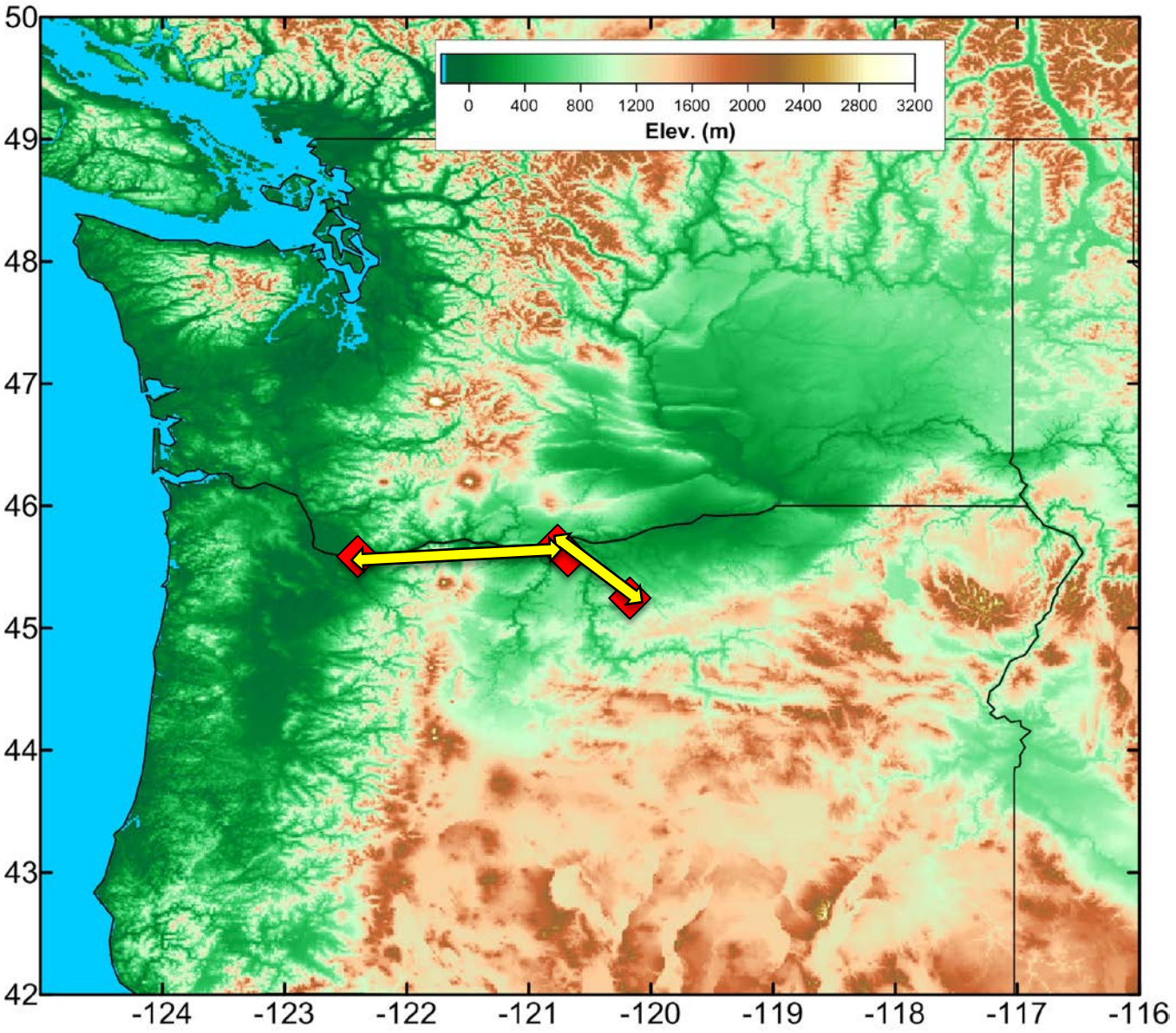




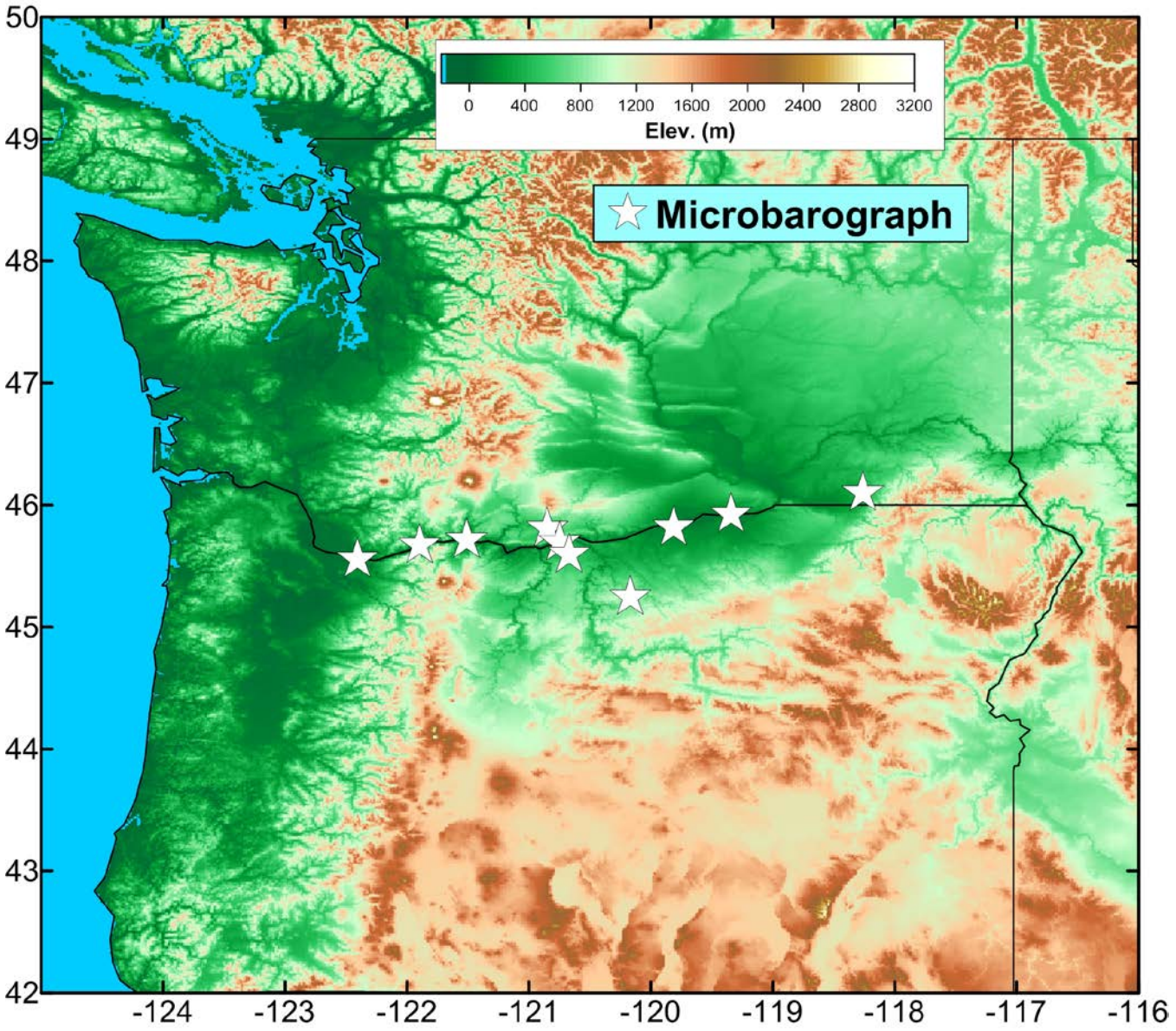
Wind Profiling Radars w/RASS

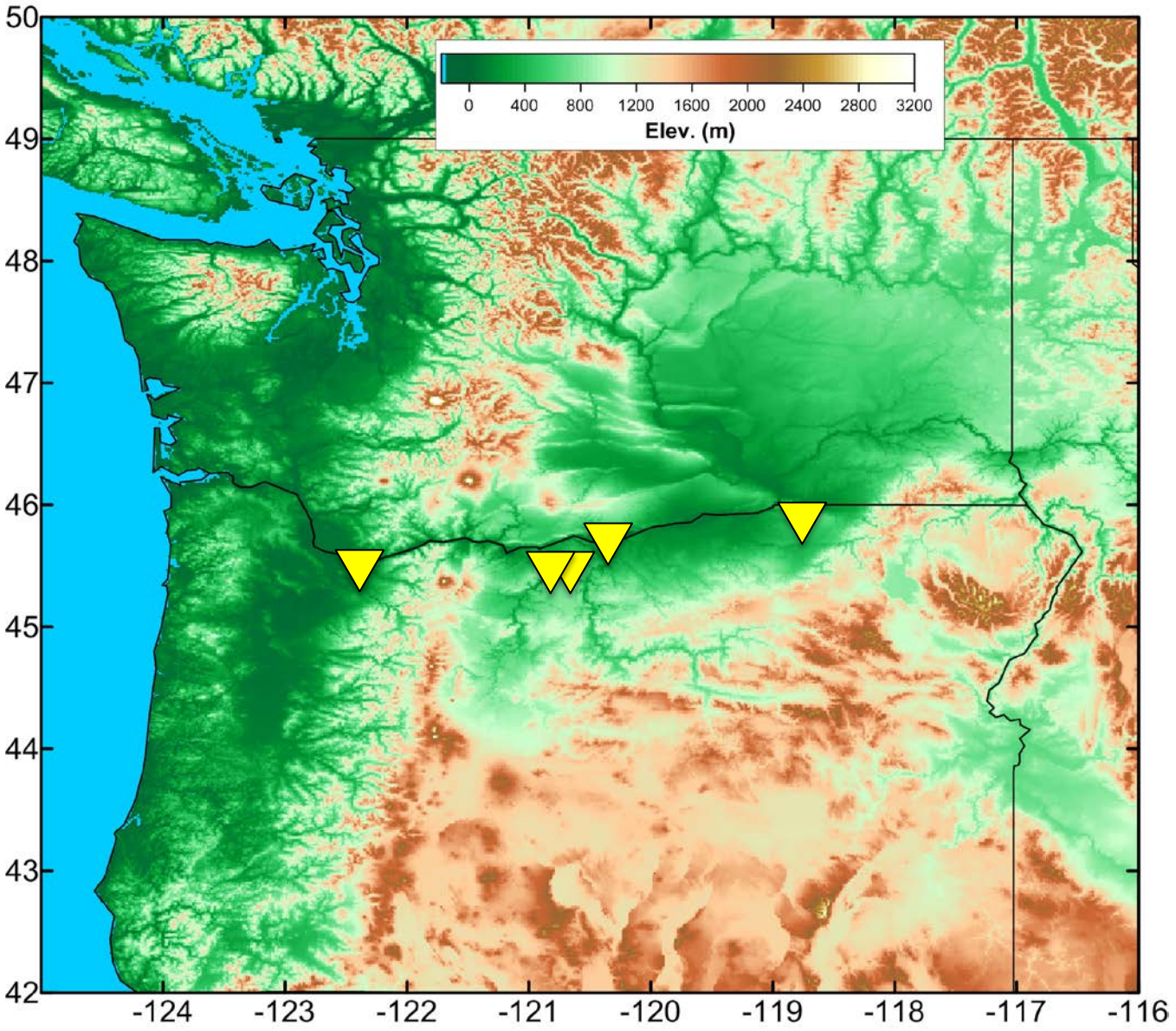

0 400 800 1200 1600 2000 2400 2800 3200
Elev. (m)
50
49
48
47
46
45
44
43
42
-124 -123 -122 -121 -120 -119 -118 -117 -116

Sodars

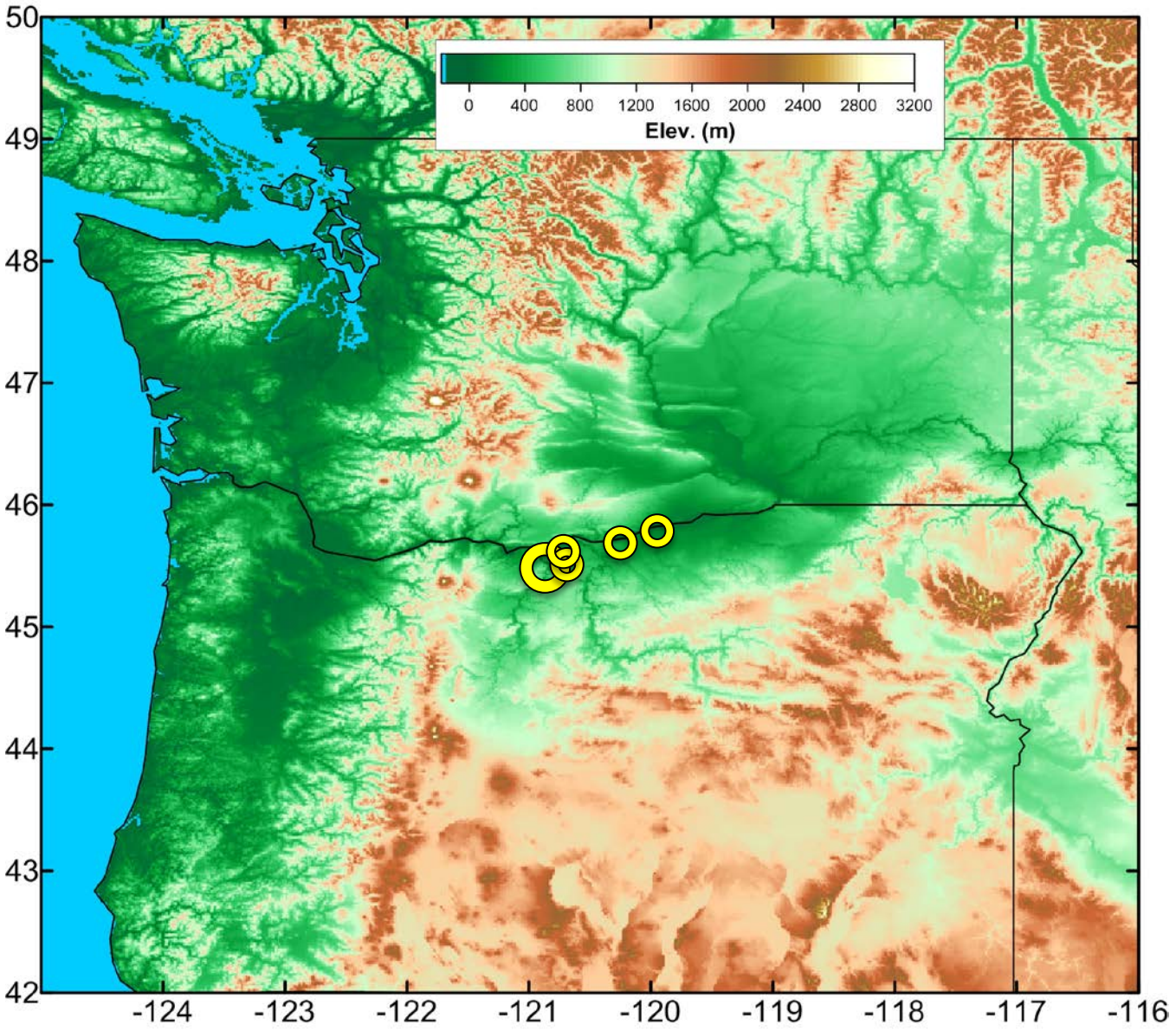


Microwave Radiometers


0 400 800 1200 1600 2000 2400 2800 3200
Elev. (m)
Microbarograph
50
49
48
47
46
45
44
43
42
-124 -123 -122 -121 -120 -119 -118 -117 -116

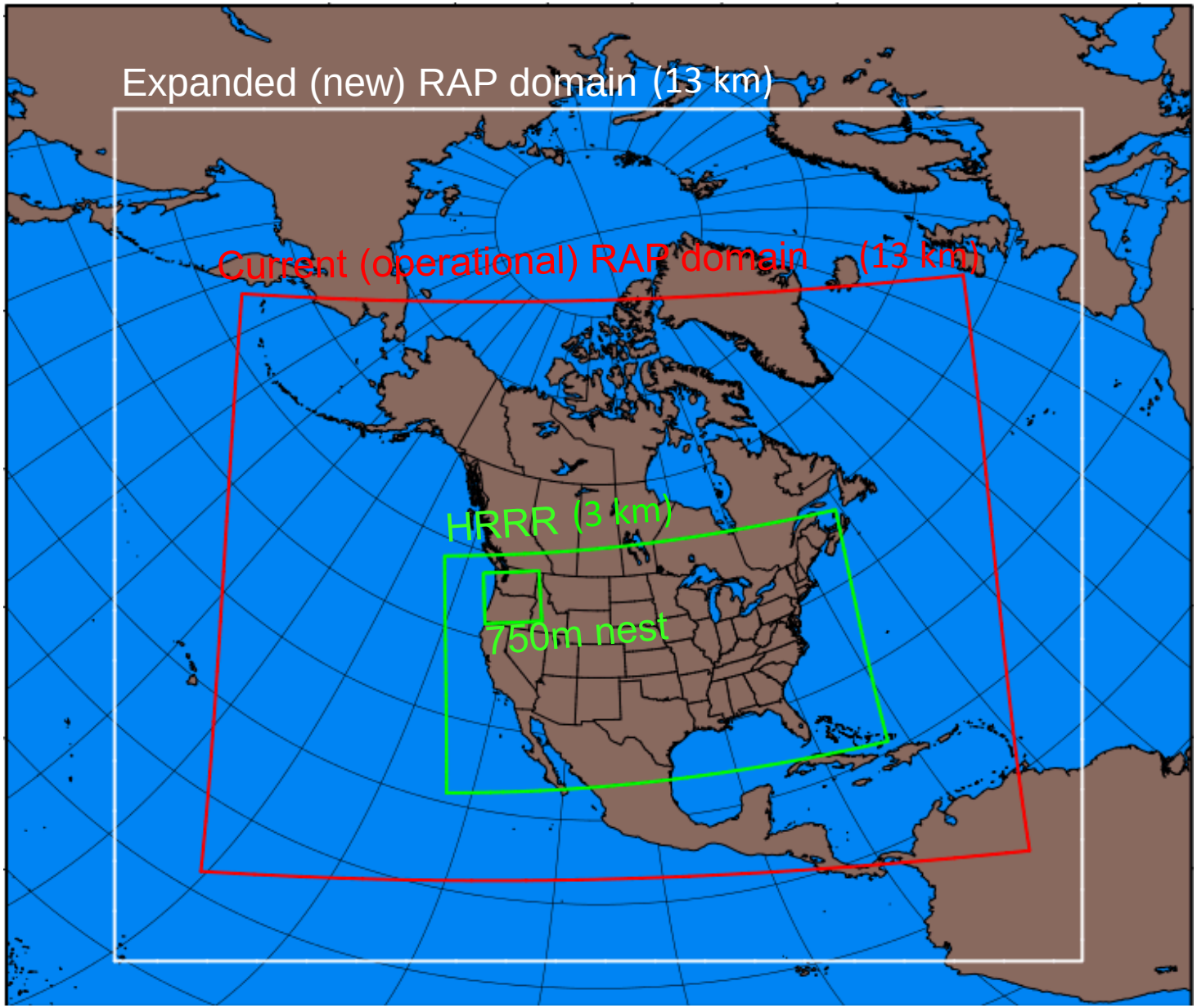


Profiling lidars



Scanning lidars

Primary Models (Hourly Updated)



RAP (13km)
Rapid Refresh

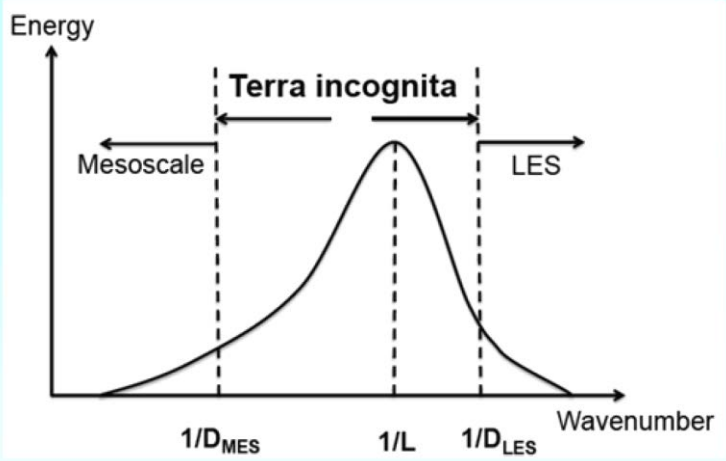
HRRR (3km)
High Resolution
Rapid Refresh

HRRR Nest (750m)

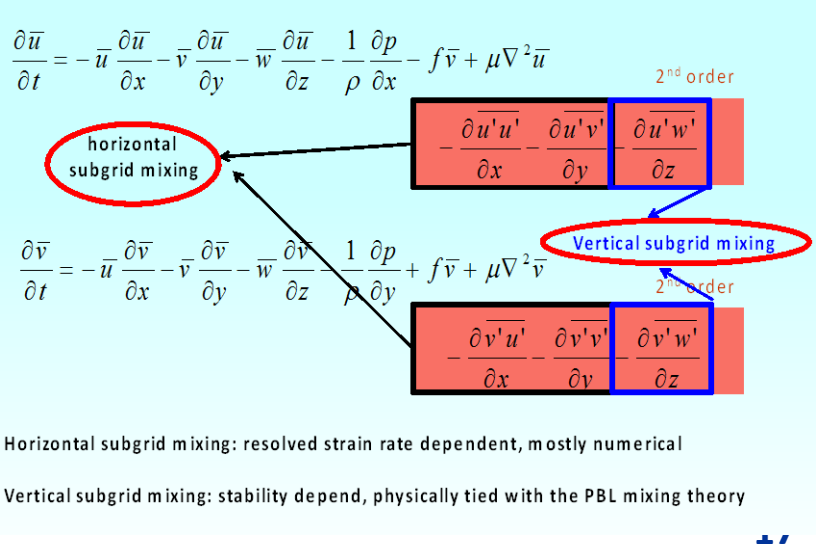
Model Development

- Scale-aware boundary layer physics - transition from 1D to 3D (Bao, 2014)
- 3D surface stress coupled to 3D turbulence (Epifanio, 2007)
- Scale-aware cloud mass-flux coupled to PBL scheme
- Scale-aware subgrid-scale clouds
- Improved numerics
  - IBM - Immersed Boundary Method (K. Lundquist, 2012)

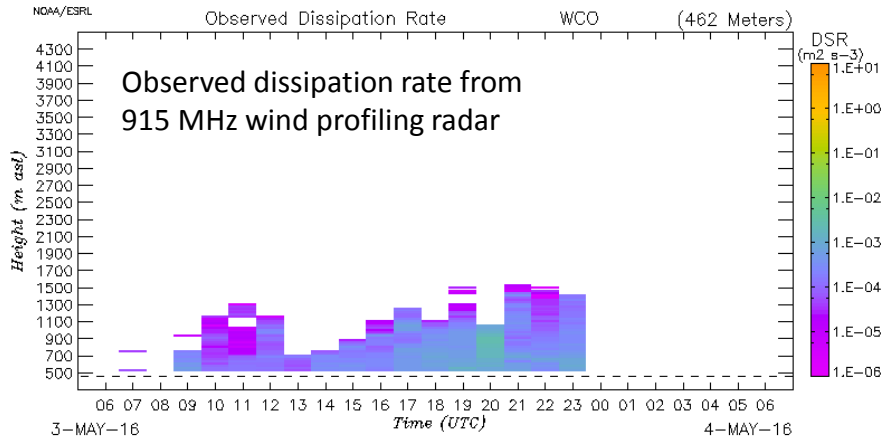
Note: New model physics not yet implemented

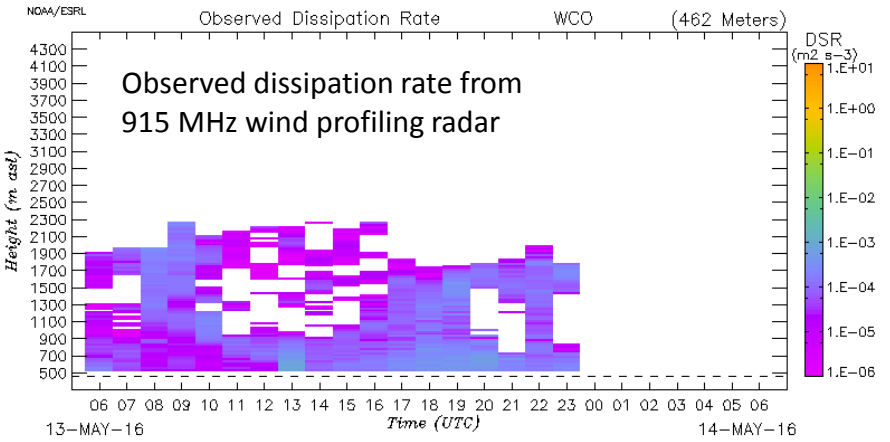


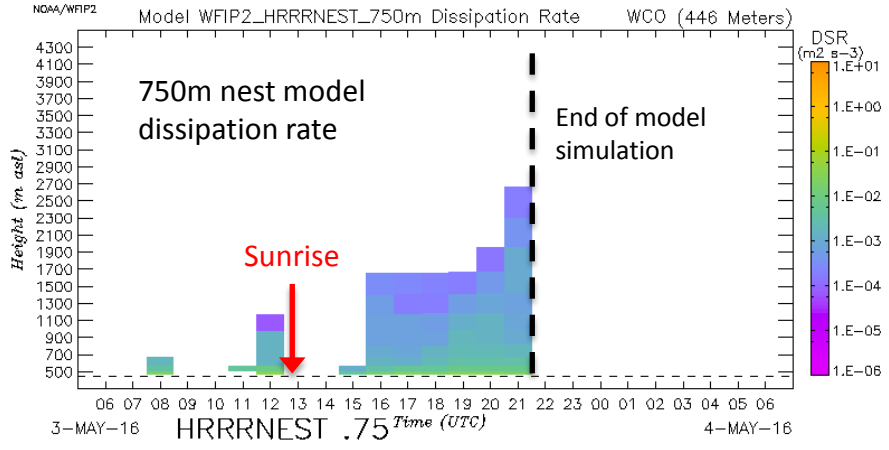
1-2 km 0.1 km

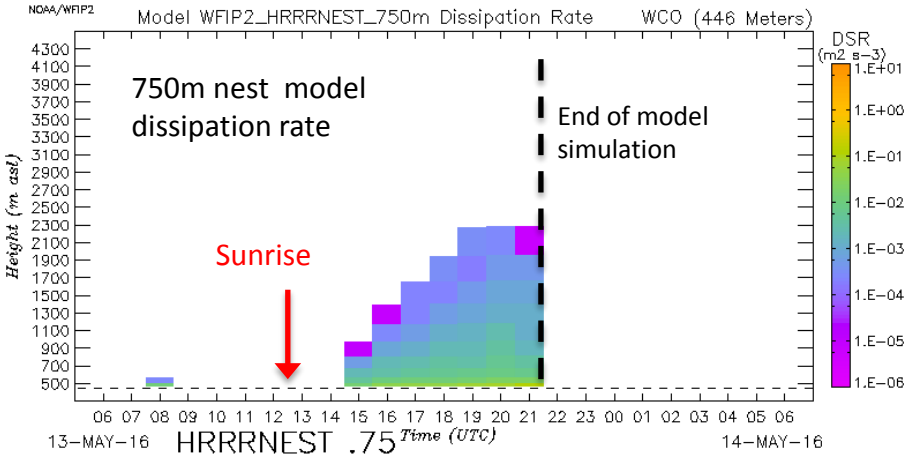


Turbulence Dissipation Rate Analysis







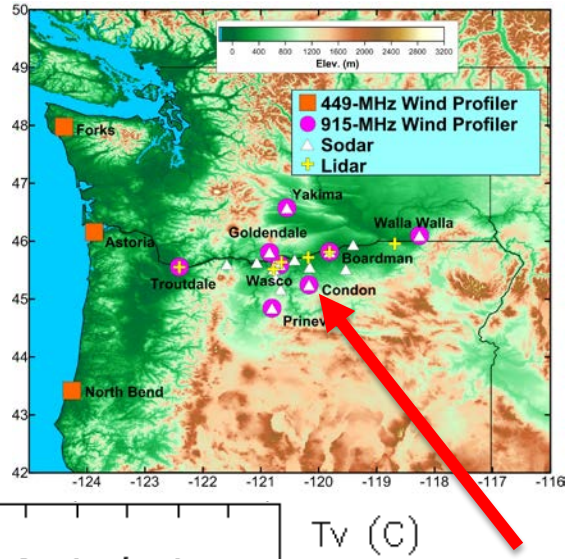


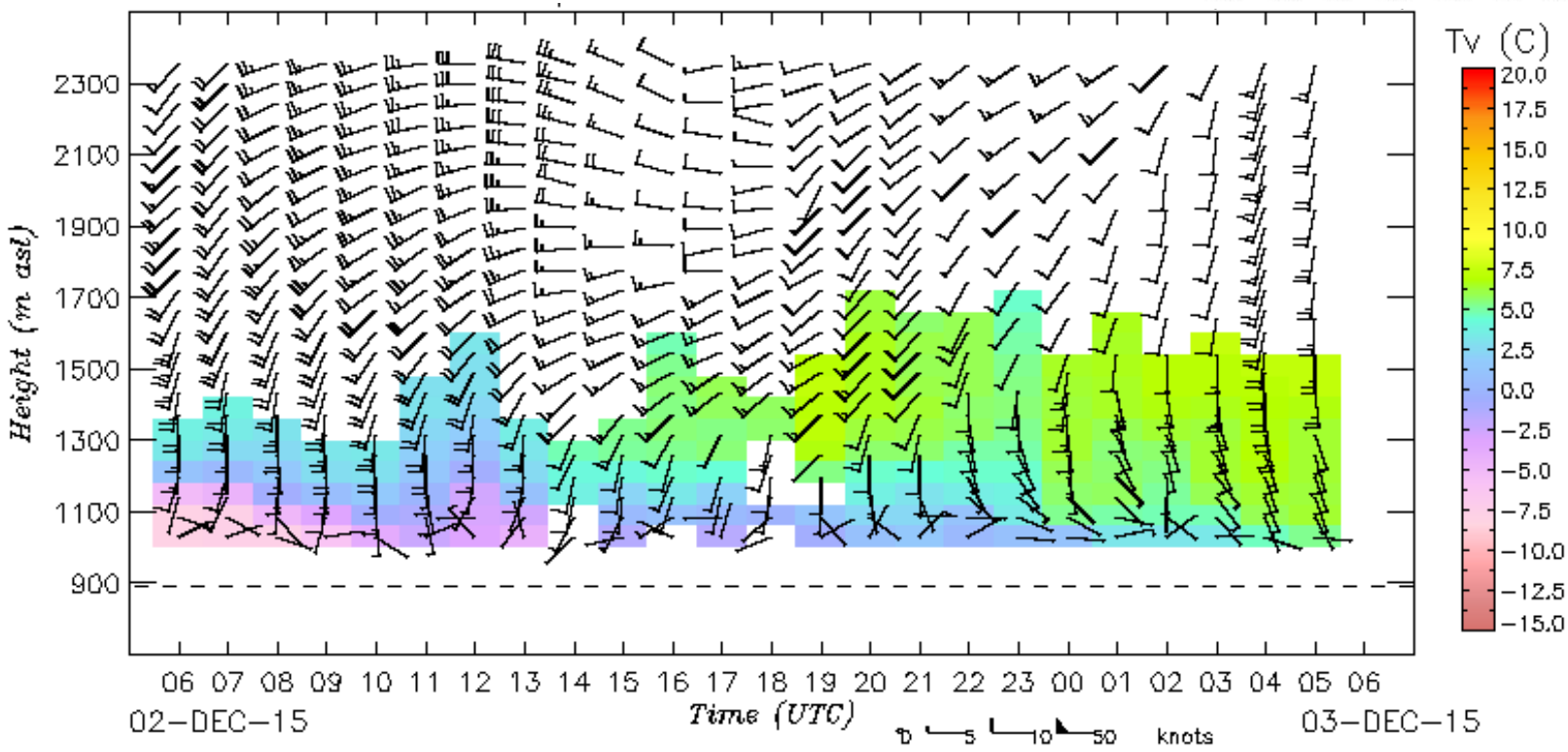
3 May 2016

13 May 2016

Case Study: Erosion of Cold Pool

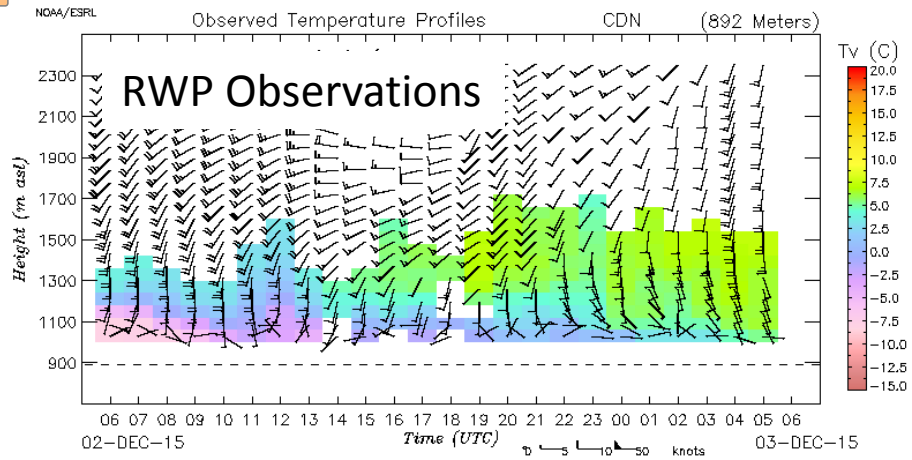
02 December 2015, Condon OR

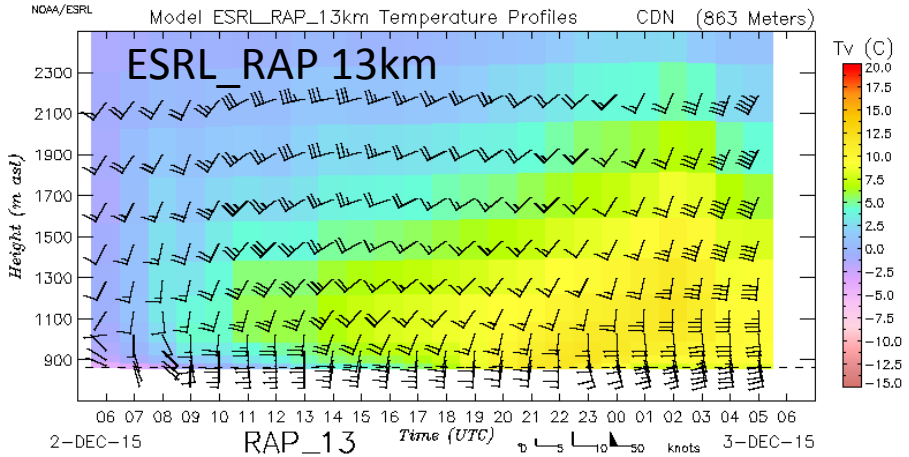


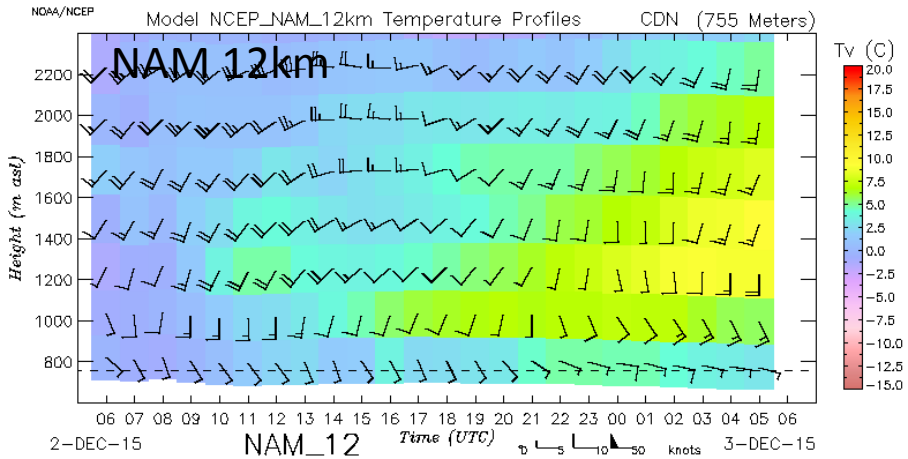


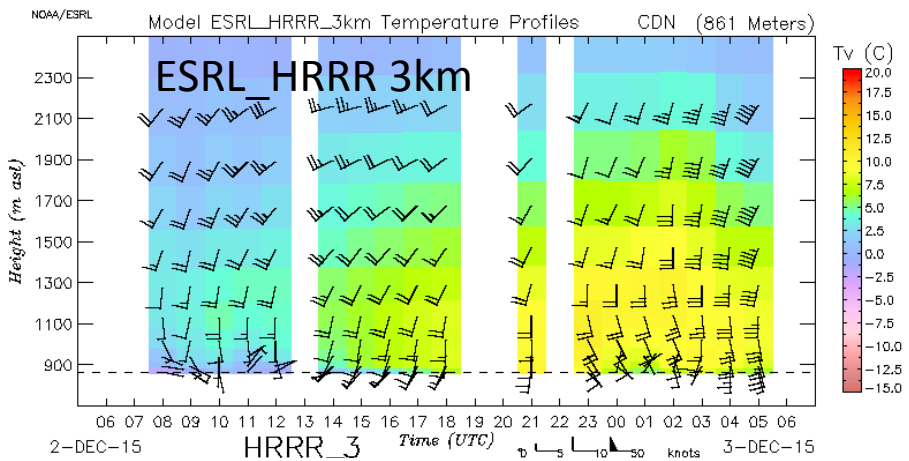
915 MHz Radar Wind Profiler w/RASS, Condon OR

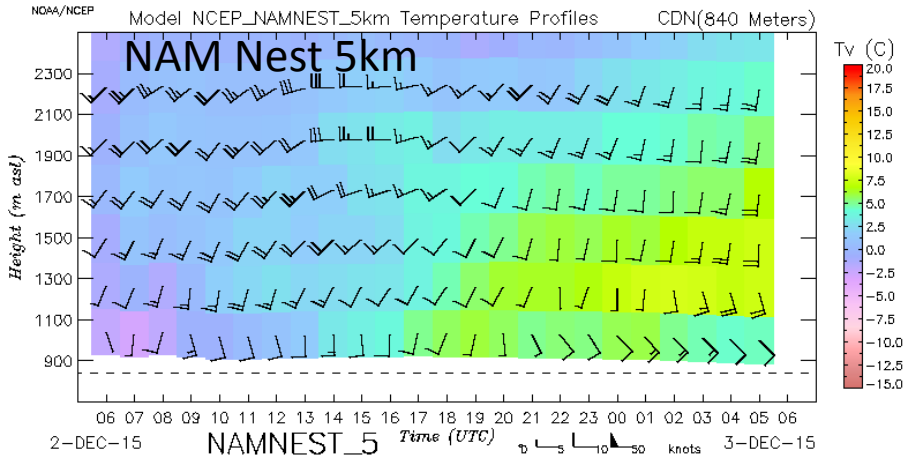
02 Dec 2015

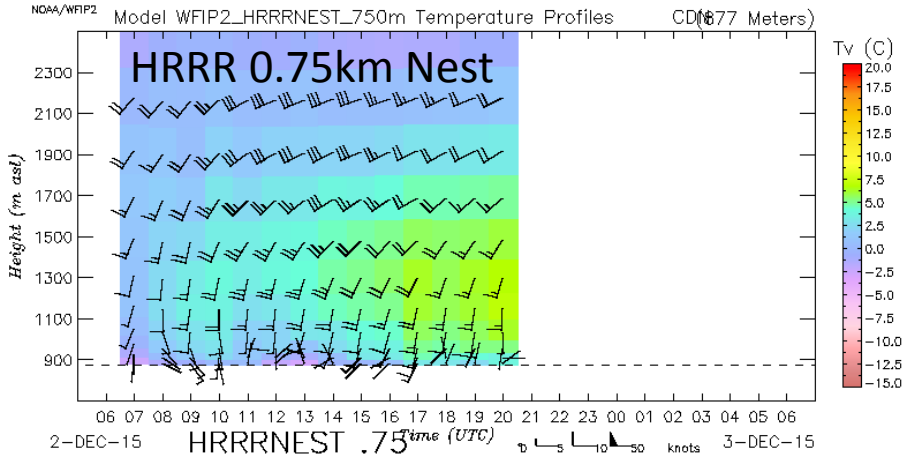

NOAA/ESRL
Observed Temperature Profiles CDN (892 Meters)
RWP Observations
Height (m asl)
Tv (C)
02-DEC-15
Time (UTC)
03-DEC-15
knots


NOAA/ESRL
Model ESRL_RAP_13km Temperature Profiles CDN (863 Meters)
ESRL_RAP 13km
Height (m asl)
Tv (C)
2-DEC-15
RAP_13
Time (UTC)
3-DEC-15
knots

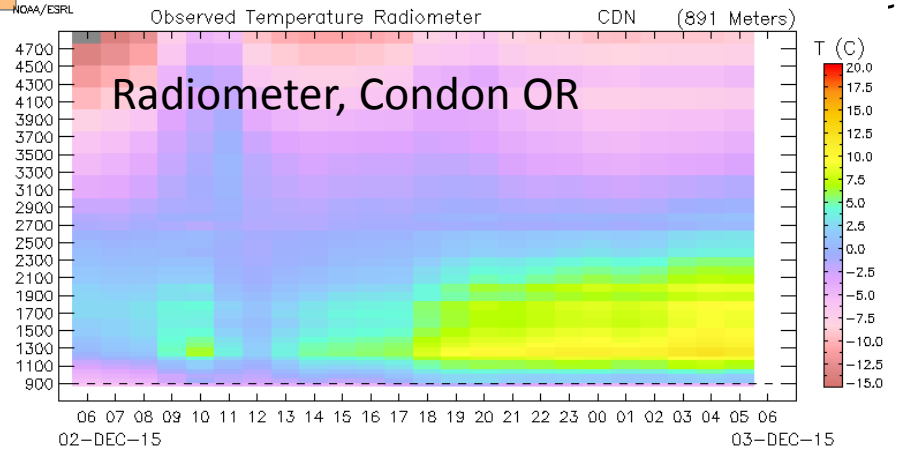

NOAA/NCEP
Model NCEP_NAM_12km Temperature Profiles CDN (755 Meters)
NAM 12km
Height (m asl)
Tv (C)
2-DEC-15
NAM_12
Time (UTC)
3-DEC-15
knots

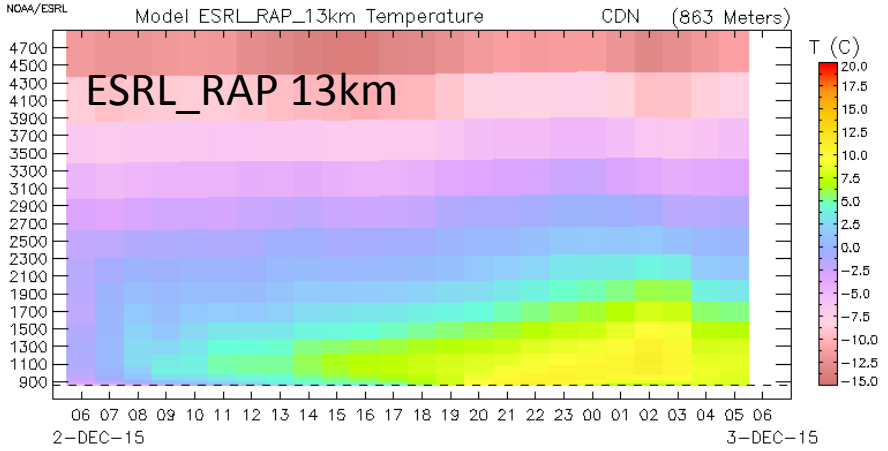

NOAA/ESRL
Model ESRL_HRRR_3km Temperature Profiles CDN (861 Meters)
ESRL_HRRR 3km
Height (m asl)
Tv (C)
2-DEC-15
HRRR_3
Time (UTC)
3-DEC-15
knots

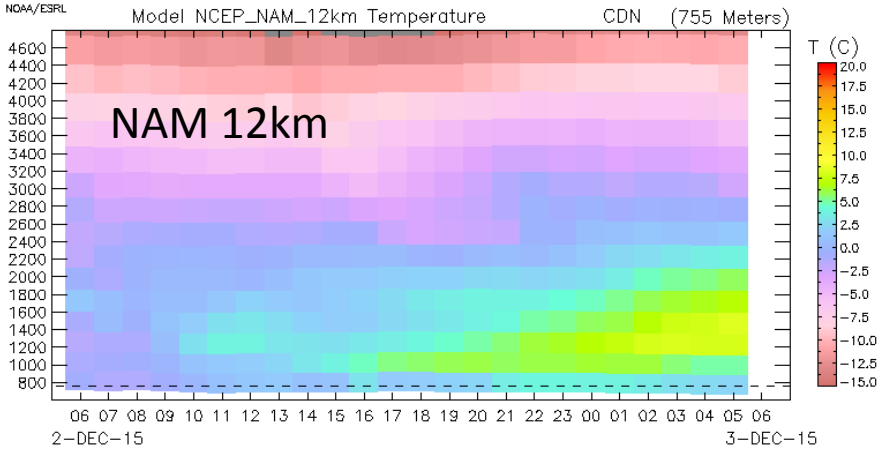

NOAA/NCEP
Model NCEP_NAMNEST_5km Temperature Profiles CDN(840 Meters)
NAM Nest 5km
Height (m asl)
Tv (C)
2-DEC-15
NAMNEST_5
Time (UTC)
3-DEC-15
knots

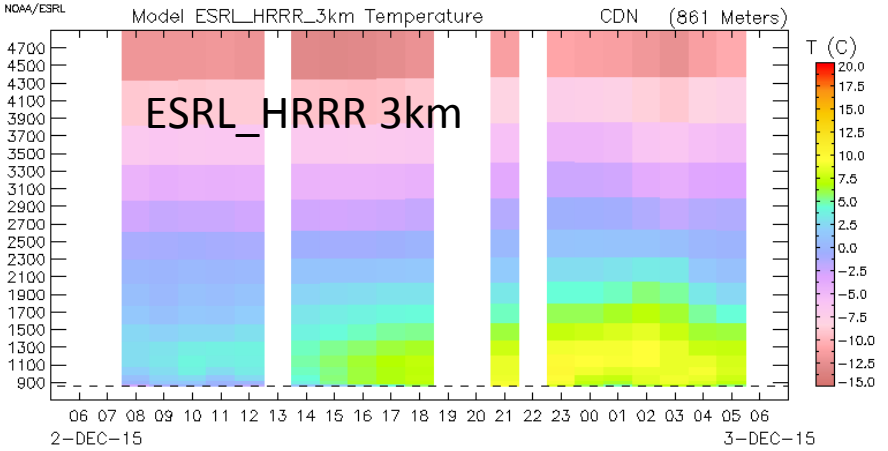

NOAA/WFIP2
Model WFIP2_HRRRNEST_750m Temperature Profiles CDN(877 Meters)
HRRR 0.75km Nest
Height (m asl)
Tv (C)
2-DEC-15
HRRRNEST .75
Time (UTC)
3-DEC-15
knots

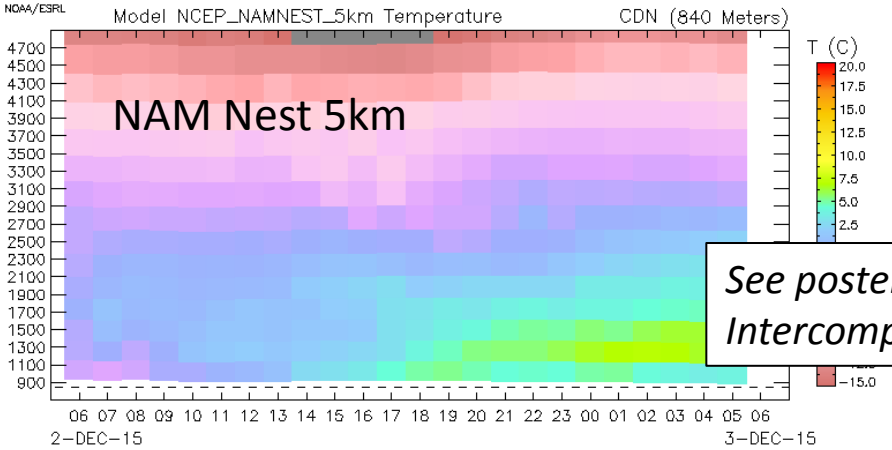
02 Dec 2015

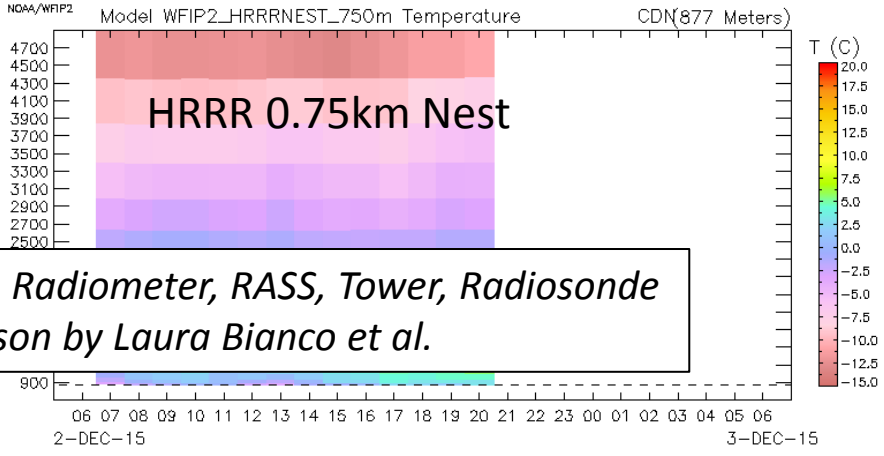






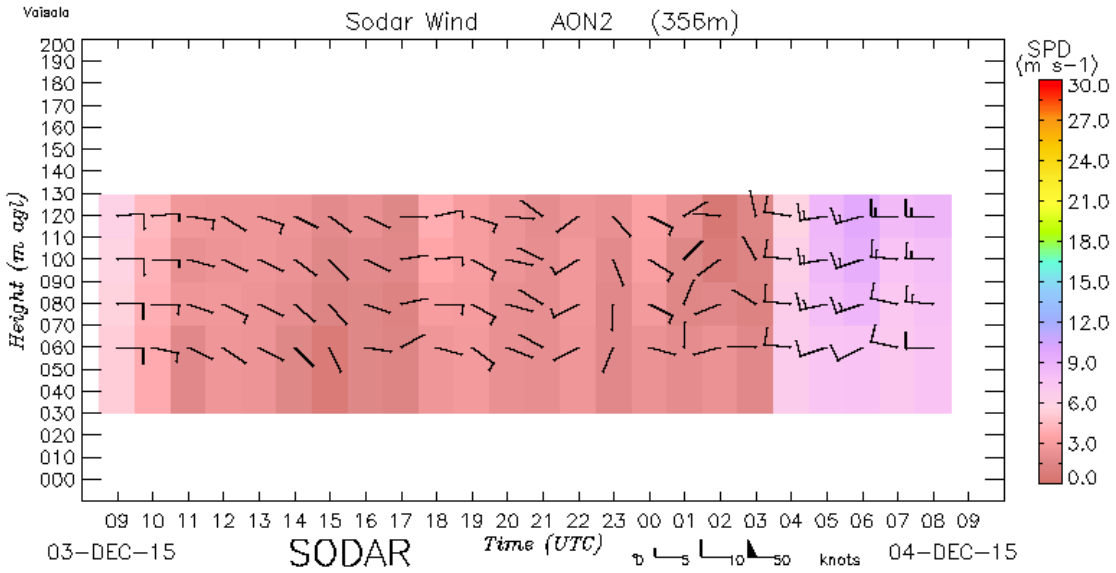




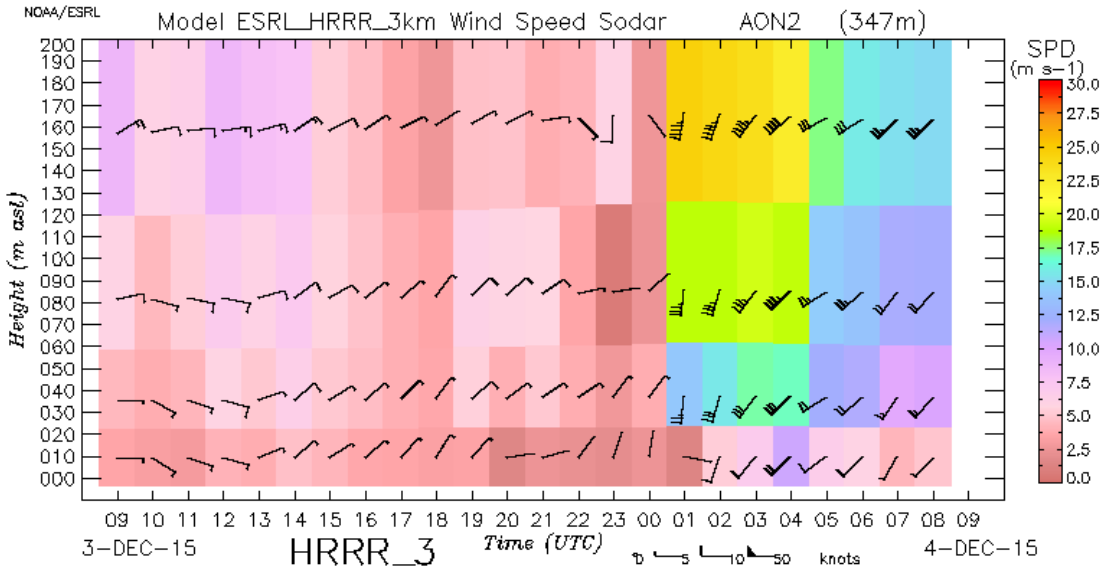


See poster on Radiometer, RASS, Tower, Radiosonde Intercomparison by Laura Bianco et al.

Sodar Observations



HRRR model (3 km)



Model & obs evaluation web page:

http://wfip.esrl.noaa.gov/psd/programs/wfip2/

- Displays observations from almost all instruments deployed for WFIP2
- Compares observations to model forecasts, both NWS operational and research

WFIP2 Summary

WFIP2 will provide a unique and powerful data set that will help improve NWP models:

- Observe and understand flows & processes in complex terrain
  - Gap Flows.
  - Thermally driven Marine Pushes.
  - Mountain Wakes.
  - Trapped Lee-Waves, etc.
  - Cold Pool erosion
- Improve NWP model physics in complex terrain
  - Scale-aware parameterizations
  - IBM, surface flux parameterizations

THANKS!