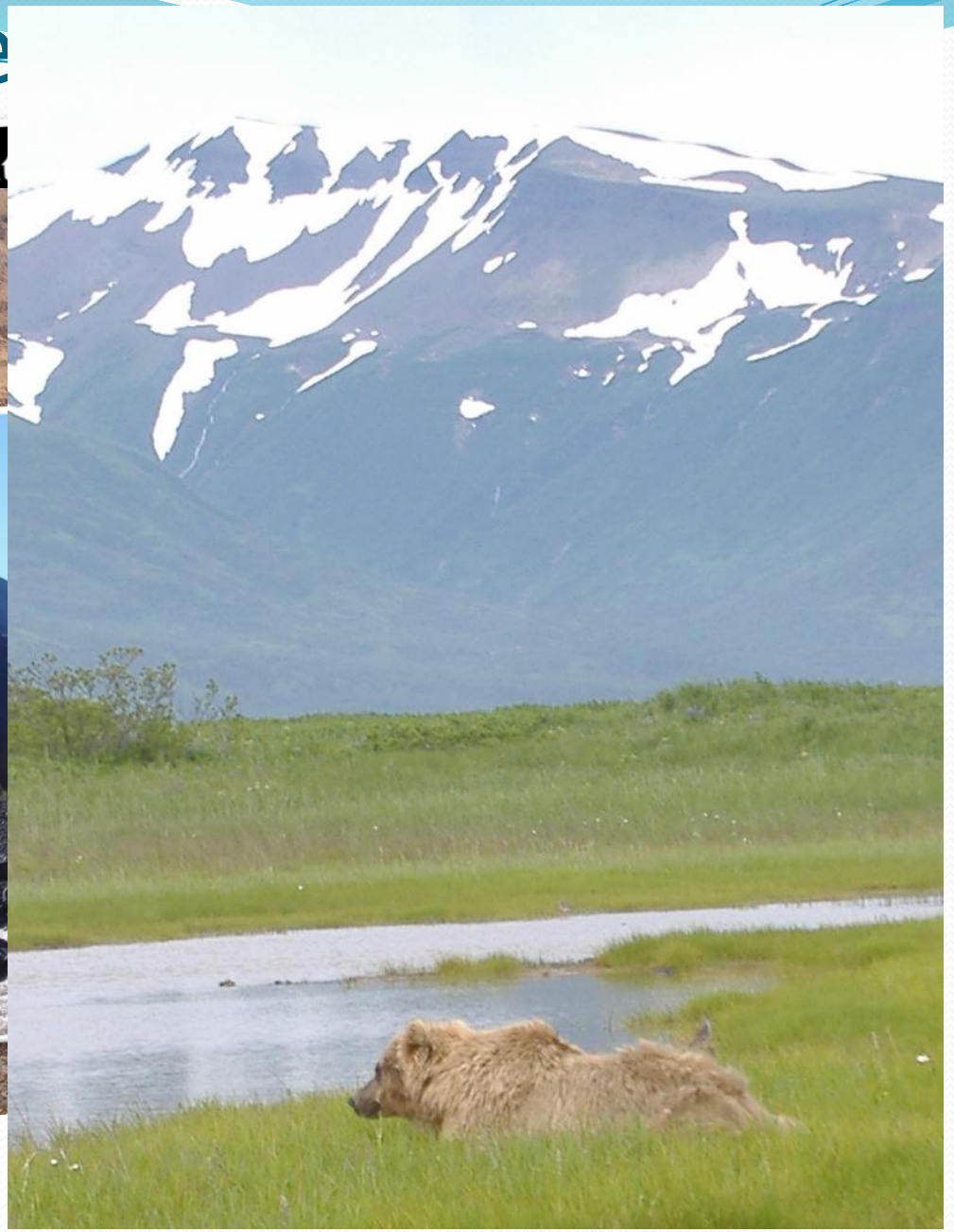
Atmospheric Science to Support Renewable Energy

Melinda Marquis
NOAA/ESRL
Oct. 21, 2010

Solar farm photo courtesy of Will von Dauster of NOAA/ESRL. Wind farm photo courtesy of AWS TrueWind.

How did you spe
vacation?



Key Message: NOAA is the nation's best choice for providing the required enhanced weather forecasts and climate information needed for a renewable energy economy.

OUTLINE

- What advances in atmospheric science are required to support renewable energy (RE).
- NOAA to collaborate with DOE.
  - First example: Wind forecast improvement field project.

Renewable Energy

Advances

- Energy Independence
- Energy Diversity
- National Security
- Economic Strength
- Mitigation of Climate Change

Requires

- Improved observations, predictions, and studies for those renewable energies that are weather- and climate-dependent.

Atmospheric Science for RE

- NOAA's observations, forecasts and products were not developed for RE applications. In most cases do not provide the accuracy, geographic coverage, or resolution needed.

Concentrating Solar Power Tower. Photo courtesy of DOE NREL.

- Improved predictions across a range of time scales are needed.
- RE industry has made a strong statement:
  - An increase in accuracy in short-range wind forecasts from NOAA is essential for the future of wind energy in the U.S.
- DOE has stated that it is looking to NOAA to support the atmospheric and oceanic science needed for developing RE.

Weather Research and Services

Improved forecasts of winds, clouds, rain (for balancing by hydropower dams), icing conditions are needed.

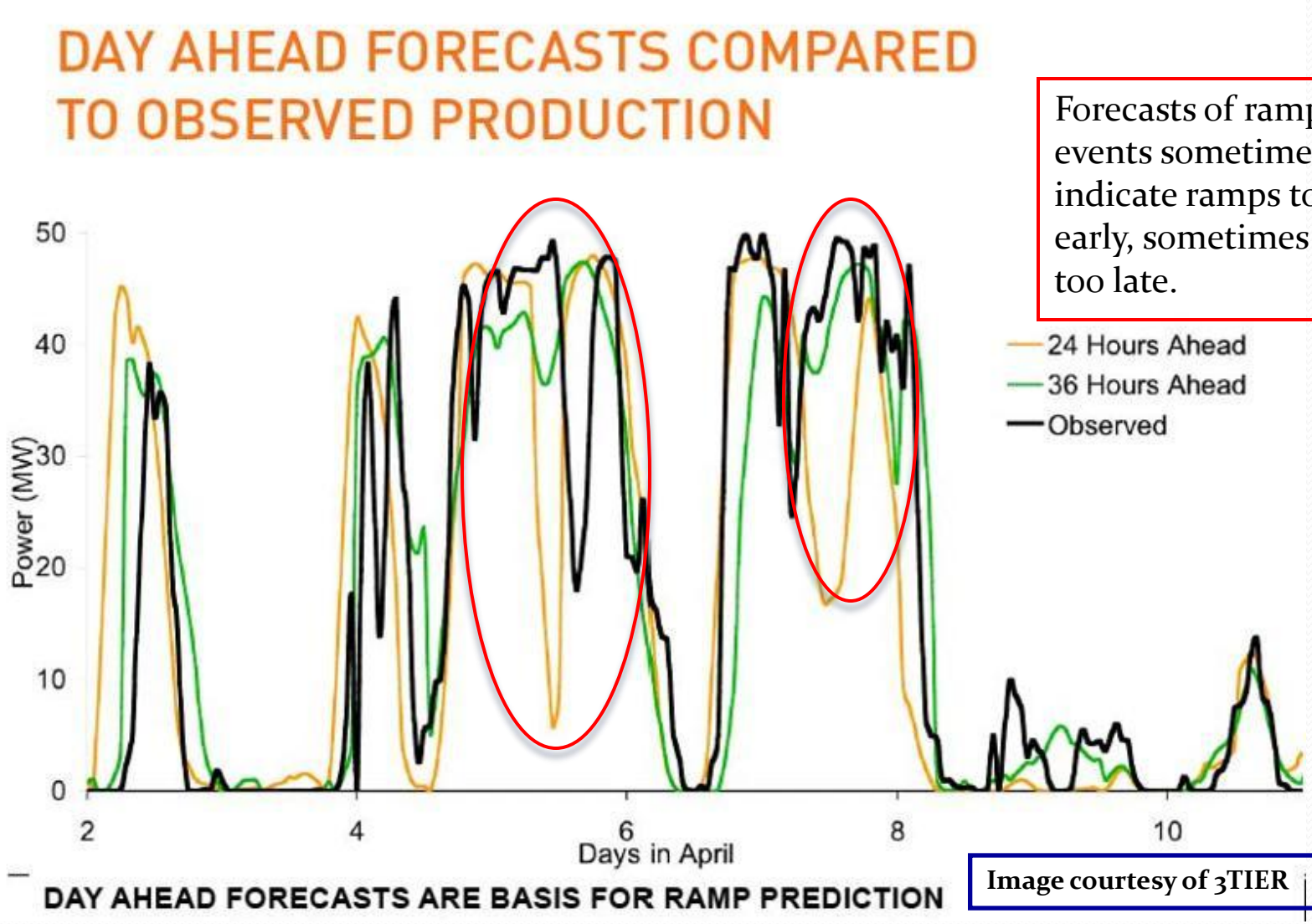
Especially of short-term "ramp" events, e.g., 1-6 hr.

Improve our understanding of:

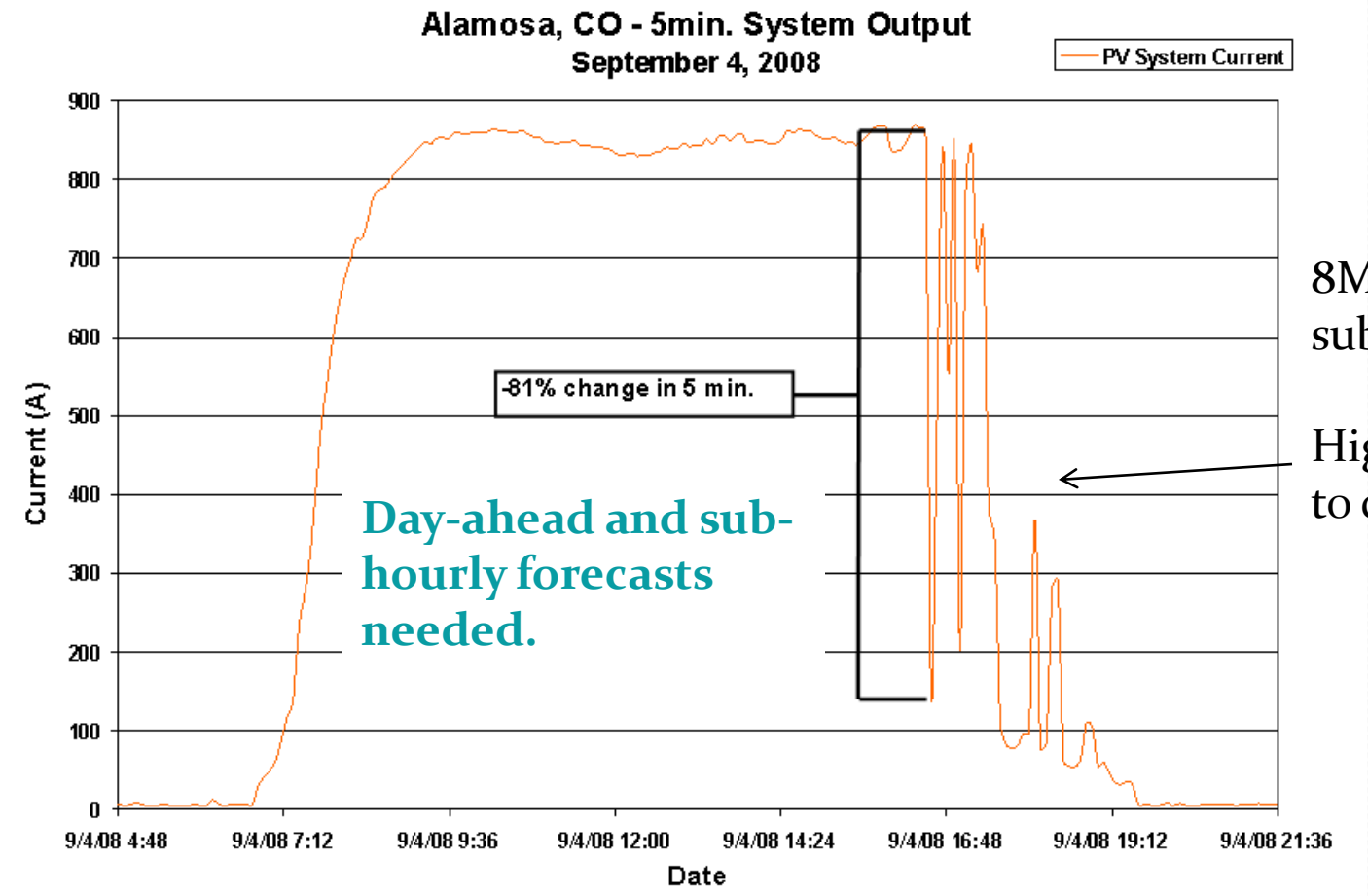
- Boundary layer processes
- Mesoscale modeling
- Terrain effects
- Upwind turbine effects
- Extreme wind events

Sea smoke. Photo courtesy of Uni-Fly A/S.

Example of the Need for Improved Weather Forecasts: Wind



Example of the Need for Improved Weather Forecasts: Solar



8MW connected to substation

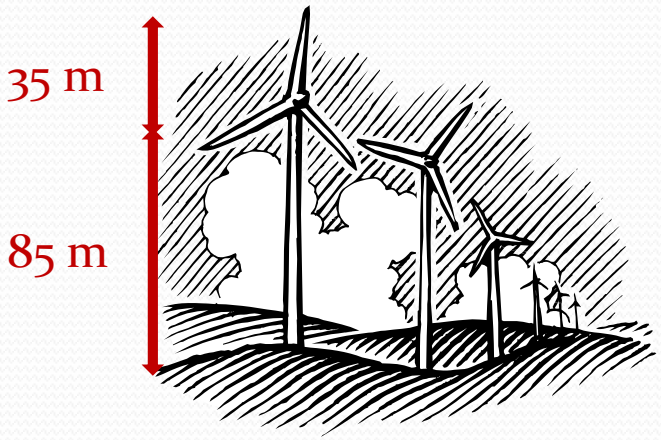
High Variability due to clouds

Slide courtesy of NREL, Dave Mooney

Improved Observations Needed: Wind

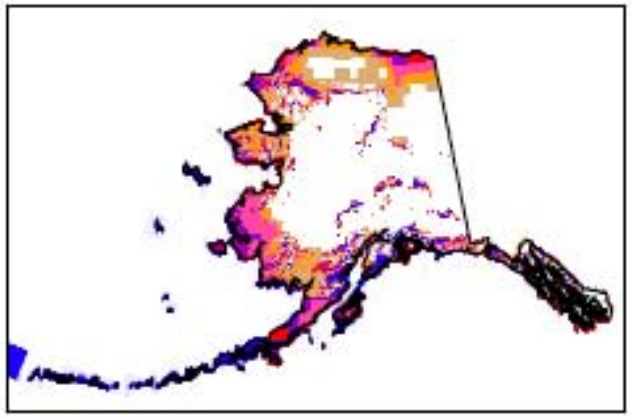
NOAA takes almost no measurements of wind at turbine height regularly.

To advance our understanding of boundary layer processes and to make improvements to our models, we need measurements of wind speed and direction at 20 - 300 m.



United States - Wind Resource Map

This map shows the annual average wind power estimates at 50 meters above the surface of the United States. It is a combination of high resolution and low resolution datasets produced by NREL and other organizations. The data was screened to eliminate areas unlikely to be developed onshore due to land use or environmental issues. In many states, the wind resource on this map is visually enhanced to better show the distribution on ridge crests and other features.



Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m^2	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

[a] Wind speeds are based on a Weibull k value of 2.0

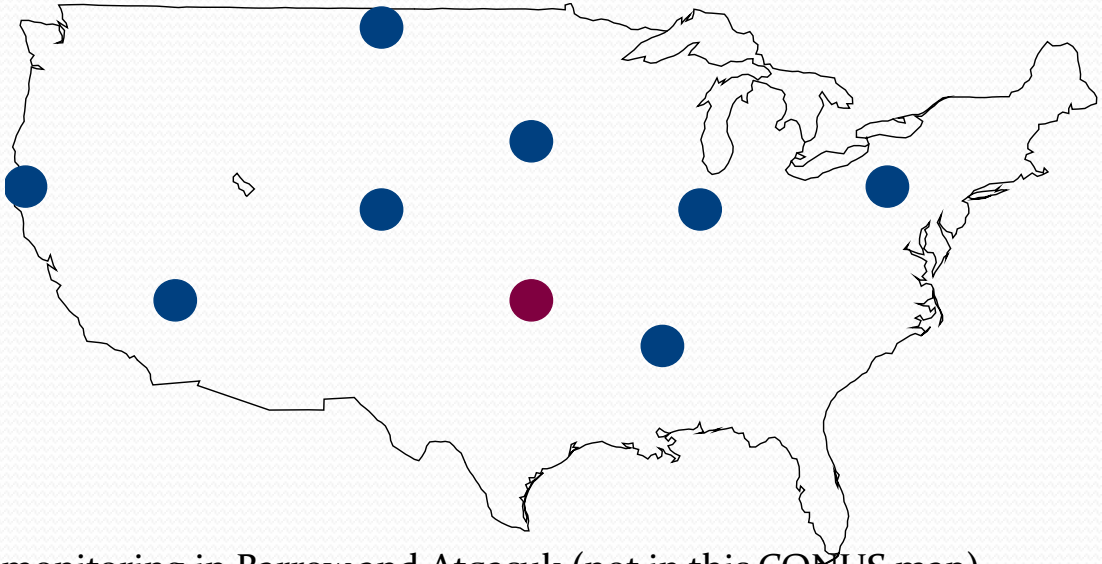
U.S. Department of Energy
National Renewable Energy Laboratory

Improved Observations Needed: Solar

DOE's ARM program and NOAA's SurfRad are monitoring solar radiation.

As shown in graphic, only nine sites measure the direct beam, which is needed for CSP.

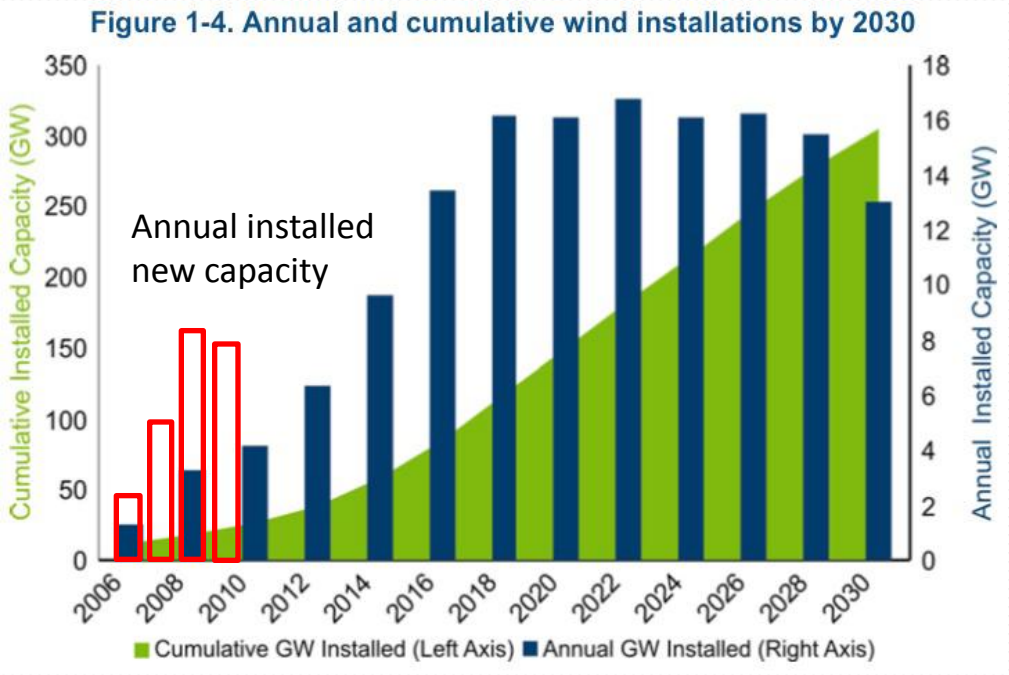
These are not adequate for improving models for solar energy (clouds and aerosols).



Alaska also has monitoring in Barrow and Atqasuk (not in this CONUS map)

Slide courtesy of Betsy Weatherhead, Univ. of Colorado.

Climate and RE



DOE/NREL Study:
20% of electricity from wind by 2030

US DOE: 80% RE by 2050?

NOAA could provide the climatological information about RE resource projections and possible environmental impacts of RE plants to support RE, a part of any climate change mitigation strategy.

Arguably, the most effective way that NOAA could support mitigation of climate change.

Complex Relationship of Renewable Energy and Climate

- Quantification and understanding of historic trends and variability of wind resources.
- Improved predictions of wind resource mean and variability
- Characterization of interactions between wind plants and local, regional, and global climates.

Iberdrola's Klondike wind farm, near Wasco, OR. Photo courtesy of Iberdrola.

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Atmospheric Science for RE

Renewable energy community requires …

- Additional observations
- New climate information and analyses
- Improved weather forecasts for large amounts of renewable energy into U.S. energy system.

RE research community is capable of meeting these needs.

- The atmospheric science and operational communities are eager to meet these needs.
- Collaboration and close communication among the public, private, and academic sectors are required.
- NOAA could be “Honest broker”
  - Facilitate data sharing
  - Protect proprietary rights
  - More data -> Improved models
  - NOAA did this with airline data

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Improved RE forecasts would have benefits for many other national priorities

- Within NOAA
  - Aviation (NextGen)
  - Fire weather
  - Air quality
  - Severe weather (warn-on forecasts)
- Beyond NOAA
  - DHS (plume dispersion)

NOAA's role in renewable energy resource forecasting

- NOAA'S role would be to provide an improved **foundational** forecast of winds (wind speed and direction; also temperature and precipitation for icing conditions) for wind energy.
  - Analogous improved foundational forecasts of clouds and aerosols for solar energy.
  - Analogous improved foundational forecasts of waves and tides for hydrokinetics.
  - Available to all.
  - Reliable, consistent, and standard.
- NOAA's efforts would spur commercial sector growth.
  - Allowing the private sector to provide tailored forecasts for wind and solar energy uses.
  - Allowing small scale providers equal access to critical information for RE development and use.

Draft MOU between DOE and NOAA

- Necessary advancements in short-term forecasts and long-term environmental resource predictions for *integration* of variable renewable energy systems … to support the effective deployment of and efficient use of weather-dependent and oceanic renewable energy technologies.

- Covers weather-dependent and oceanic renewable energy, including wind (onshore and offshore), solar, biofuels and biopower, hydropower, hydrokinetic (wave, tides, currents), and new innovations that may develop in the future.

- Improvements in relevant atmospheric and oceanic observations, modeling, numerical weather prediction, and climate research are required.

- For success, the results of this research must be transitioned to operations and made publically available.

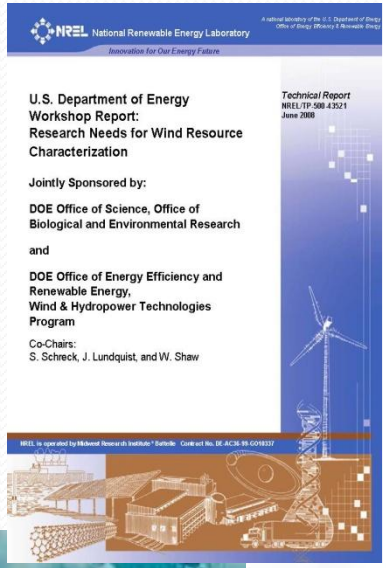
NOAA to collaborate with DOE and private sector to improve short-term wind (ramp) forecasts

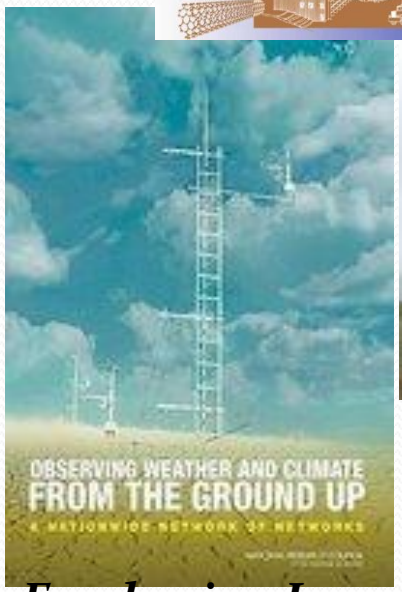
DOE is providing funds to deploy additional instrumentation to collect vertical profiles of ABL by remote sensing, to assimilate these new observations into the HRRR, and to use the enhanced model output to produce improved predictions of wind power production.

- NOAA (ESRL, ARL, NWS) - $2 million
- AWS Truepower, LLC (Albany, New York) - $2.15 million
- WindLogics, Inc. (Saint Paul, Minnesota) - $1.25 million

Grid Integration Barriers: Resource Characterization

- **Resource assessment** for financial viability and optimized siting
- **Wind turbine inflow/turbulence modeling** to allow better turbine design
- **Wind plant array modeling** for effective power prediction
- **Data sets, models, and forecasting** for efficient power system operation
- **National observations network** serving weather-driven renewables
- **Climate change assessment** for wind resource impacts





Key Emphasis – Leveraging NOAA and DOE Science capabilities

Slides 19-27 from Charlton Clark, DOE.

Overview

Solicitation

Enhancing Short Term Wind Energy Forecasting For Improved Utility Operations: DE-FOA-0000343

Motivation

Substantial savings in annual electric power system production costs can be achieved with improved accuracy of wind forecasts in the range of 0 to 6 hours ahead

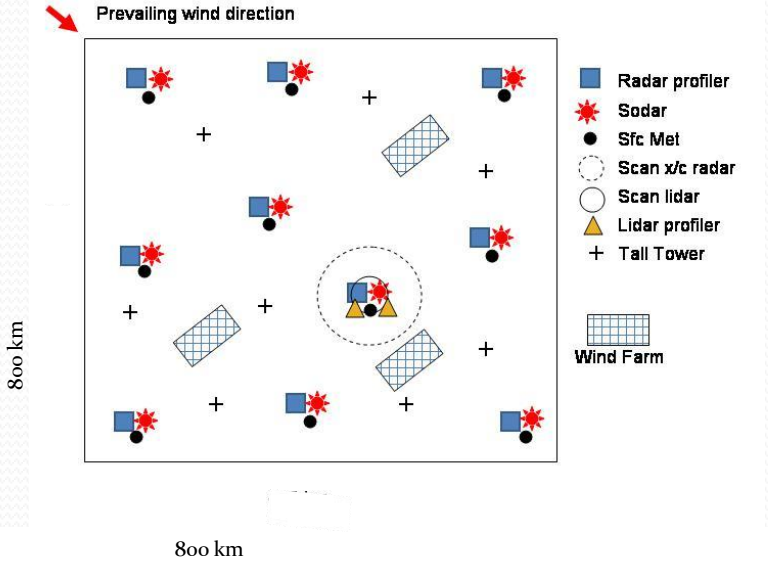
FOA Objectives

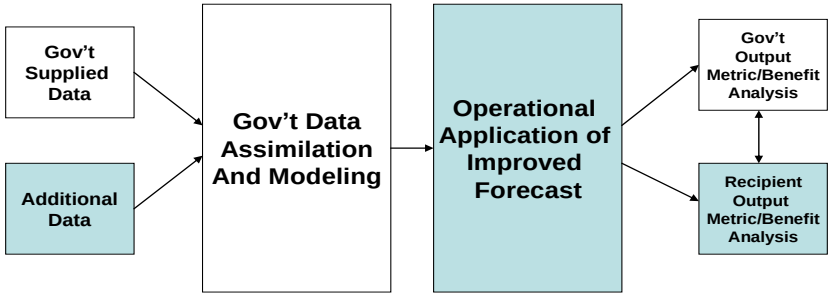
1. Increase **accuracy of predicted wind direction and speed** change in short-term (0-6 hr) forecasts.
2. Analyze the impact of improved short-term forecasts on **wind plant power output predictions**, and determine resultant **economic benefits** to electric power system operations.
3. Inform efforts to define **national-scale mesonet weather data systems** needed to support wind energy forecasting.

FY 10 Funding	Total Funding (2 years)
$1.5M	**$3.6M**

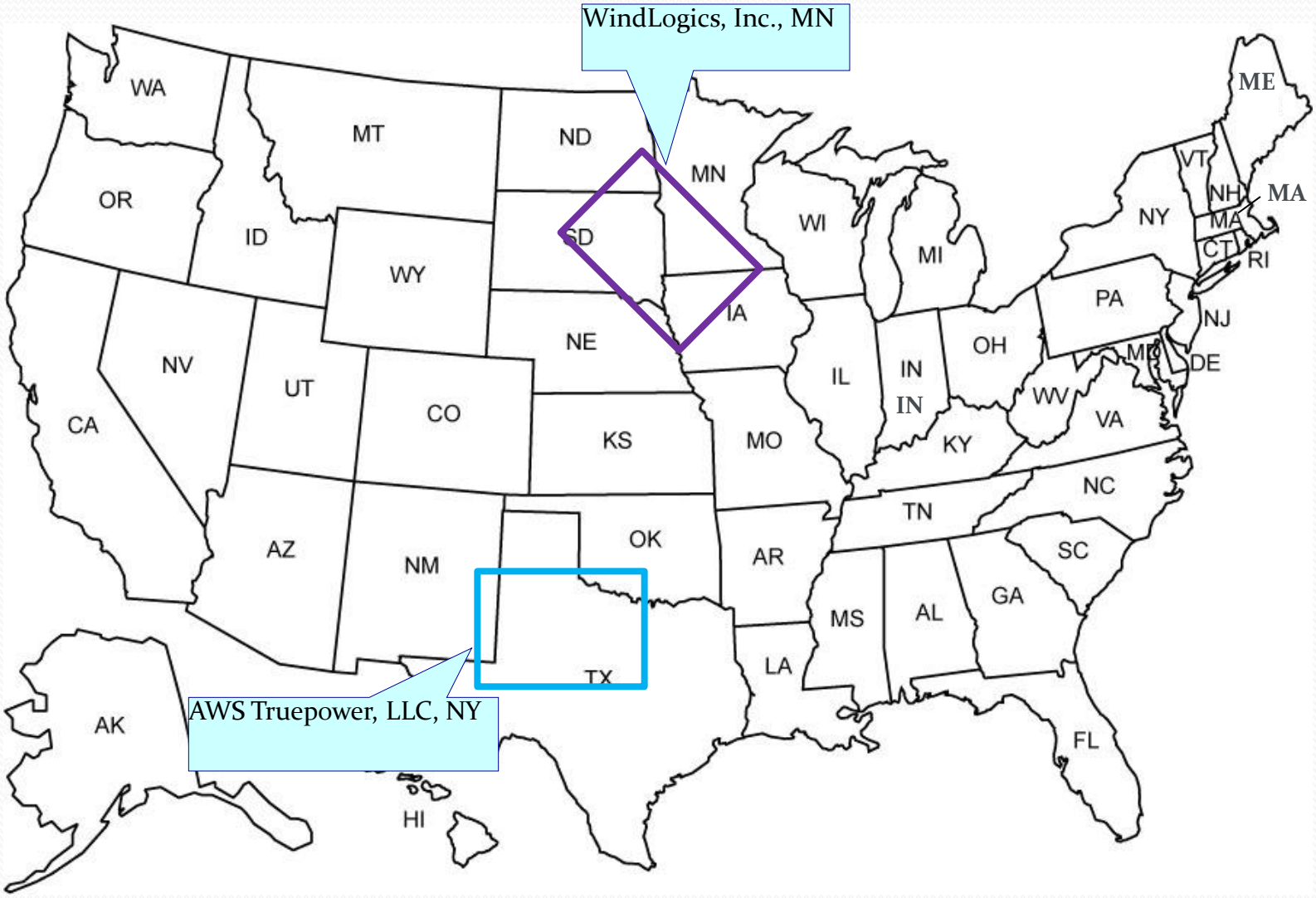
Project Approach

- **Context:** NOAA currently provides base wind forecast data; industry uses to develop specific wind energy forecast products
- NOAA and DOE furnishing numerous advanced instruments (radar profilers, sodar, etc)
- Recipients identify large wind region for deploying instruments, partners, and project plan
- New and existing atmospheric observations provided to NOAA for advanced forecast modeling
- Recipients apply NOAA model output to improve specific wind and wind power plant output forecasts
- Recipient work with utility Balancing Authority to assess operational cost savings
- DOE and NOAA analyze benefits of additional instrumentation and validate utility operational cost savings





Geographic Location of Selected Applications



AWS Truepower Partners

Project partners (funding contributors)

- MESO Inc.
- ERCOT (Balancing Authority)
- Texas Tech University
- Oklahoma University
- North Carolina State University
- ICF Incorporated, LLC

- University Supporters
  - Texas Tech University
  - North Carolina State University
  - Oklahoma University
- Balancing Authority
  - ERCOT
- Other Supporters and Vendors
  - NREL

WindLogics, Inc.
Partners

Project Partners (funding contributors)

- NextEra

- University Supporters
  - South Dakota State University
- Balancing Authority
  - MISO
- Other Supporters and Vendors
  - NREL
  - Itaska Technology Exchange
  - Cell Phone network provider (TBD)
  - Campbell Scientific

Important Elements of Project

- Enhanced observations – public and private
  - Maintaining data confidentiality as required
- Advanced modeling
- Geographic scale appropriate for 6 hour timeframe
- Utility and wind plant operator involvement – verifying benefits of improved forecasting
- Project is a true public/private partnership – not a Government prescription
- Technology transfer – scaling project results to national network

NOAA's Roles in Project

1. Deploying additional instruments to collect new observations
2. Modeling and Data Assimilation
3. Observations and Modeling Archive and Display
4. Analysis and Model Evaluation

NOAA's Observations

- (7-8) 915 MHz Wind Profiling Radars
  - Measure winds @ 2-4 km, lowest range gate ~ 100 m, vert res 60 m.
- (2) 449 MHz Wind Profiling Radars (Quarter Scale)
  - Measure winds @ 5-8 km, lowest range gate ~ 200 m, vert res 100 m.
- (3) sodars
  - Measure winds up to 200-400 m, vert res 5-15 m
- (10) Surface Met Stations (10 m wind, 2 m T and RH, pressure, precip, solar and net radiation)
- Real-time QC tuned to these wind profilers

Modeling

- Assimilation of data from profilers, sodars, met towers, and wind farms
- High Resolution Rapid Refresh (HRRR) model output
  - 3 km horizontal res
  - Data assimilated each hour with Fx out to a 15-hr lead time
- Data Denial Experiment
  - 30 days (non-continuous) will be re-run through HRRR without additional obs -> impact of of add'l obs on Fx skill
- HRRR (3 km) vs. RR (13 km) Experiment
  - Same 30 days as above -> impact of higher res of HRRR
- HRRR vs. RR Experiment
  - HRRR with add'l obs vs. RR without add'l obs -> combined impact of higher res of HRRR and add'l obs

The High-Resolution Rapid Refresh (HRRR)

NOAA/ESRL/GSD/AMB
Stan Benjamin
Steve Weygandt
Curtis Alexander
Tanya Smirnova
Ming Hu

Major transitions for RUC, RR, HRRR:

- RUC13 changes at NCEP
  - Nov 08, Mar 09, Feb10
    - radar reflectivity assimilation, TAMDAR, mesonet, cloud analysis, snow trimming, 18h extension

- Rapid Refresh – final testing at ESRL, planned for NCEP implementation
  - 4Q-FY10

- 3km HRRR @ESRL – now CONUS-wide

http://ruc.noaa.gov/hrrr/
http://rapidrefresh.noaa.gov/

Slide courtesy of Stan Benjamin

NCEP

Earth System Research Laboratory
SCIENCE, SERVICE & STEWARDSHIP

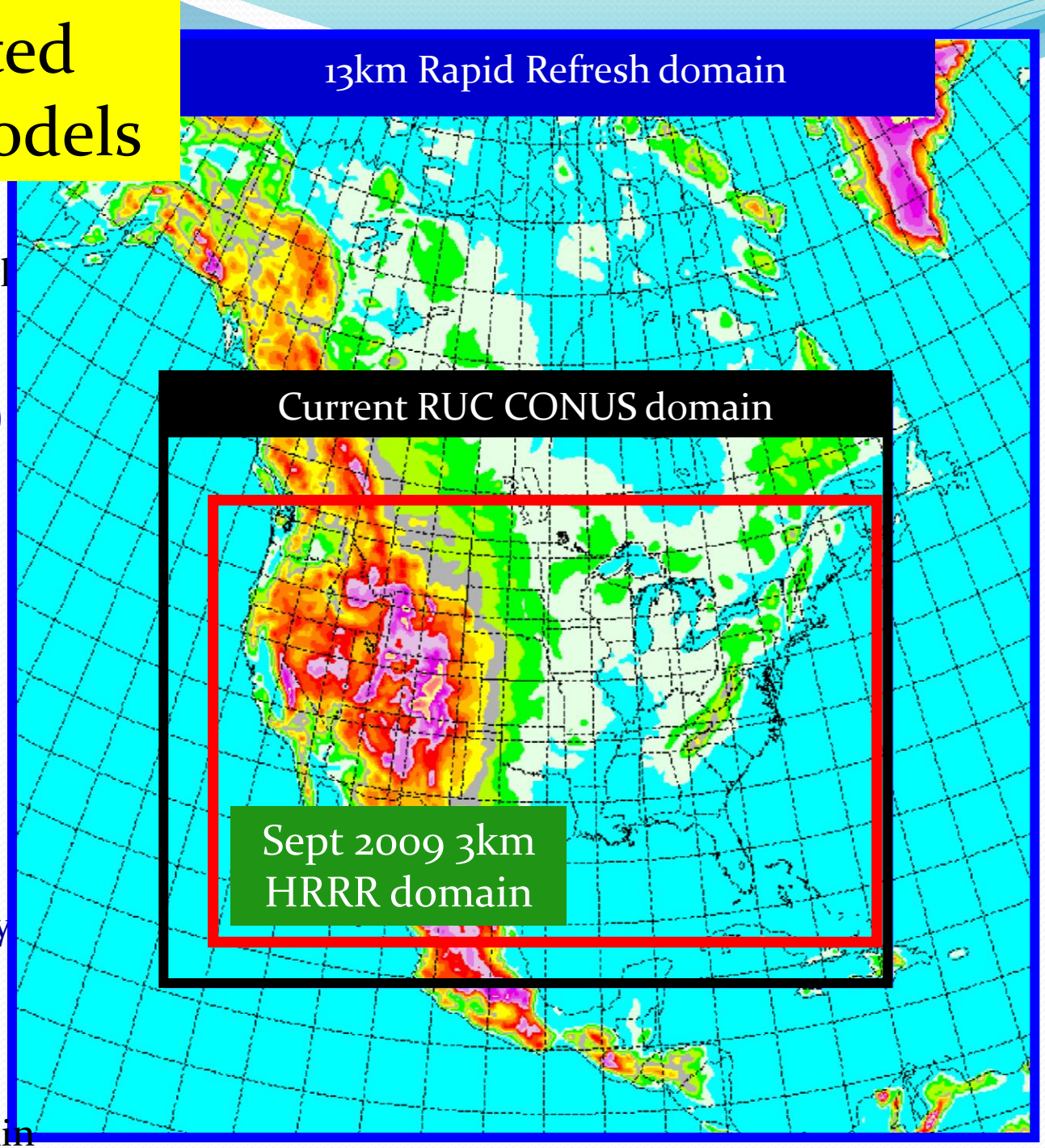
Hourly Updated NOAA NWP Models

RUC – current oper model
- 13km

Rapid Refresh (RR)
– replace RUC at NCEP in 2010 -
WRF, GSI
w/ RUC-based enhancements

HRRR - Hi-Res Rapid Refresh
-Experimental 3km

12h (or 18h) fcst updated every hour



Slide courtesy of Stan Benjamin

http://ruc.noaa.gov/hrrr/

Earth System Research Laboratory
High Resolution Rapid Refresh (HRRR)

Current and Forecast Graphics

3km HRRR-CONUS domain
3km HRRR-15min VIL/echotop
Western US HRRR-chem-fire
HRRR Reflectivity Matrix
CONUS-HRRR domain parms
Rapid Refresh web page
RUC GRIB viewer

HRRR Status

HRRR Status Page

HRRR Convective Probabilities

HCPF

Soundings

Interactive (Java)

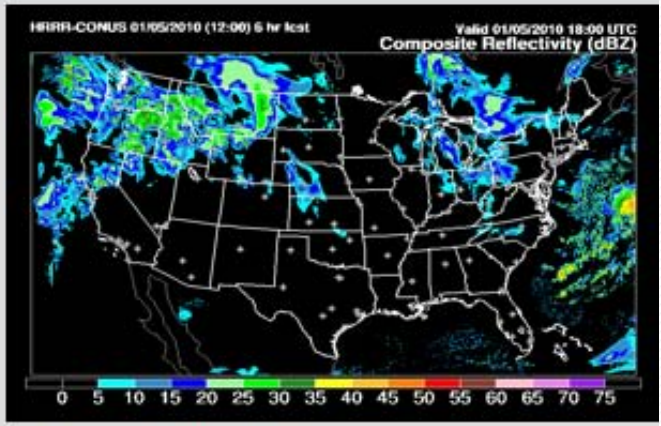
Other Products

NCEP Model Products (GFS,etc.)

Organization

The High-Resolution Rapid Refresh (HRRR)

The HRRR is a 3-km resolution, hourly updated, cloud-resolving atmospheric model, initialized by DFI-fields from the 13km radar-enhanced Rapid Update Cycle (RUC) run at NOAA/ESRL/GSD. (soon to be initialized similarly by the 13km radar-assimilating Rapid Refresh).



Composite Reflectivity

The HRRR uses

- a configuration of the WRF model, similar to that used for the Rapid Refresh (ARW core, Thompson microphysics, RUC-Smirnova land-surface model, etc., as defined here), but without any convective parameterization.
- initialized with latest 3-d radar reflectivity via 13km backup RUC at ESRL/GSD, which includes radar reflectivity assimilation via its radar-DFI (digital filter initialization) technique.

Observations and Modeling Archive and Display

- Web site to provide access to new obs (not proprietary wind farm data), model output and any errors
- Vertical profile data
- Horizontal maps of wind speeds, displaying model winds overlaid with observed values
- Post-processing correction of model output
- Statistical skill of HRRR, RR, and NAM will be shown in multiple formats

ESRL : PSD : TEXAQS Program Model Verification 2006

http://www.esrl.noaa.gov/psd/programs/2006/texaqs/verification//

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Model Cycle
Select the model cycle initialization:
00Z Aug 14
12Z Aug 14

Sites
Select site type:
(•) Profiler
( ) Chemistry
Select site location:
Arcola

Data Archive
Select a date:

August 2006 >

Sun	Mon	Tue	Wed	Thu	Fri	Sat
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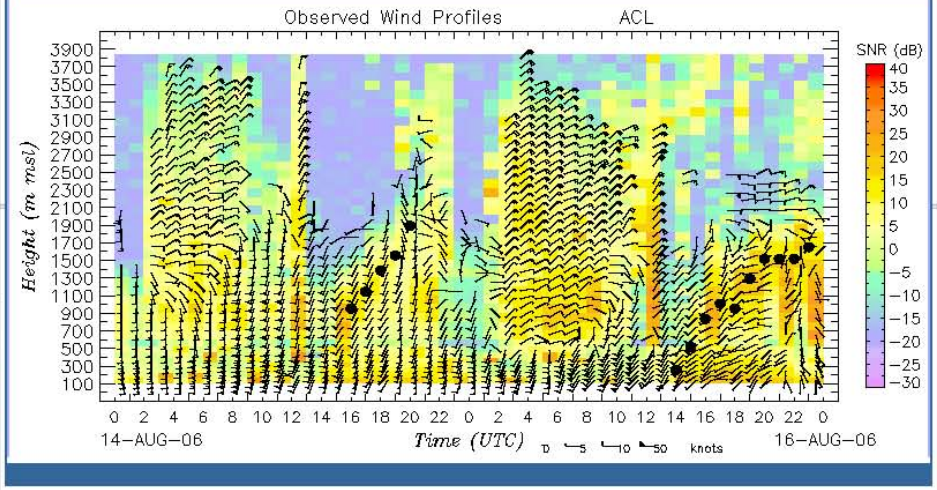
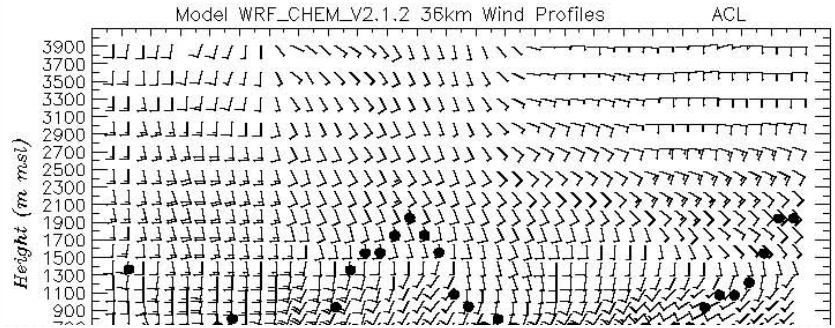
Contact
James Wilczak

AURAMS-28 | CHRONOS-21 | NMM/CMAQ-12 | WRF_36 | WRF_12 | WRF/NMM | BAMS_15 | BAMS_5 | STEM-12

SNR/Winds | RASS/Winds | Chem Profiles | Surface





Analysis and Model Evaluation

- In close collaboration with our private sector colleagues, develop new metric(s) for ramp events
- Evaluation of HRRR output as fn of geographic location, season, height, met parameter, and met condition (e.g., cold front, summer convection, morning or evening stability transitions times, etc.) comparing the HRRR with RR and NAM.
- Detailed case studies of Fx "busts."





Thanks

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303-497-4487

Communication with Private Sector: Clear Request for NOAA's Support in RE

- AMS Commission of Weather Climate Enterprise
- AMS Board on Enterprise Economic Development (Incoming Chair)
- AMS Renewable Energy Subcommittee (Chair)
- Multiple public meetings:
  - AMS Summer Community Meeting Aug. 2009
  - AGU Annual Meeting Townhall on RE Dec. 2009
  - AMS Annual Meeting Jan. 2010
  - AMS Public-Private Partnership Meeting Apr. 2010
  - AMS Summer Community Meeting Aug. 2010

Senate Bill 2852

- Renewable Energy Environmental Research Act of 2009
- Senate Bill S.2852, introduced in December 2009, proposes "to establish, within the National Oceanic and Atmospheric Administration, an integrated and comprehensive ocean, coastal, Great Lakes, and atmospheric research, prediction, and environmental information program to support renewable energy."
- http://thomas.loc.gov/cgi-bin/query/z?c111:S.2852: