State Wind Mapping and Validation

Dennis Elliott

FY2005 DOE Wind Program R&D Implementation Meeting

November 18, 2004

Objectives

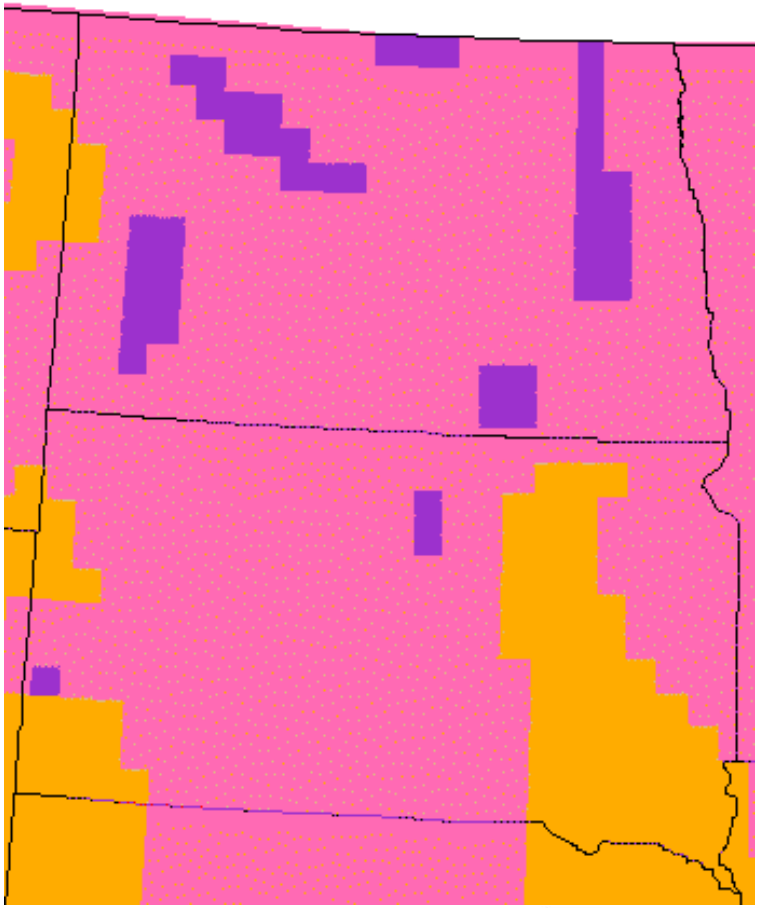
- Provide technical assistance in wind resource assessment and mapping in support of
  - DOE, Wind Powering America
  - Regional, State, and Native American interests

- Primary disciplines
  - Updated regional and state wind mapping
  - Validation of resource estimates
  - Wind and meteorological data sets development and analysis
  - GIS data sets and tools development

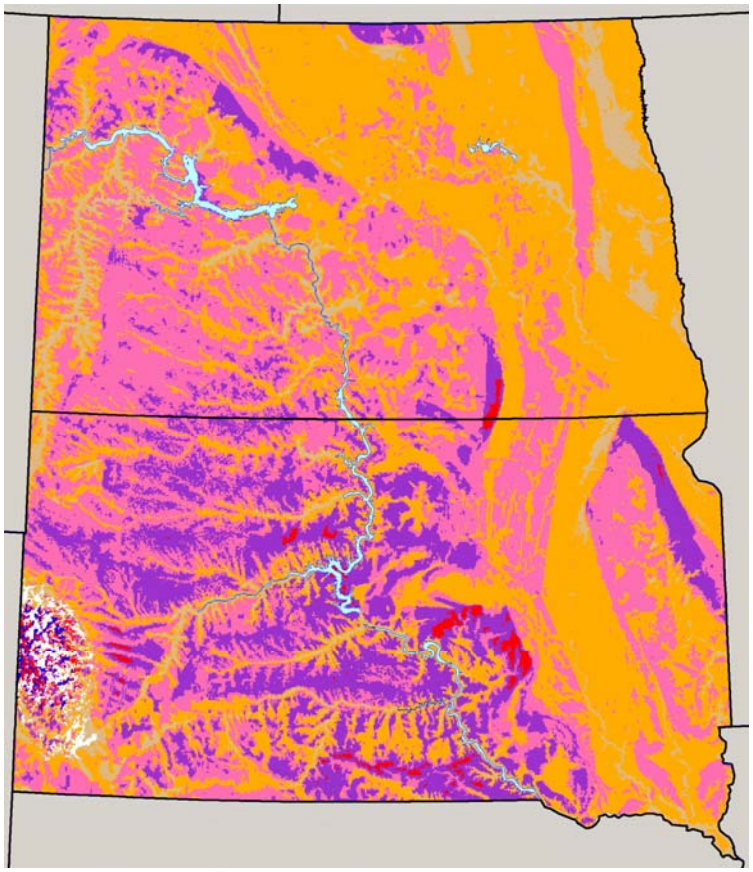
Why Re-Map the U.S. Wind Resource?

- Increased interest in wind energy development
  - U.S. Department of Energy's Wind Powering America initiative
  - New state policies and funds being considered for renewable energy
  - Larger market for utility-scale and small wind turbines
  - Need more detail than provided in 1987 Atlas
- Advanced mapping tools available
  - Better meteorological and topographic data sets
  - Increased utility of computer hardware and software

Comparison of Digital Wind Map from 1987 U.S. Wind Atlas and New (2000) High-Resolution (1-km^2) Wind Map North and South Dakota



1987



2000

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
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
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

North Dakota Validation

Station	Lon (W)	Lat (N)	Pred/Meas	Pred. Class	Meas. Class
Olga	99d 04m	48d 44m	1	4	4
Petersburg	98d 01m	47d 59m	0.81	3	4
Benedict	101d 06m	47d 53m	0.87	5	6
Ray	103d 12m	48d 16m	0.94	5	5
Green River	102d 56m	47d 04m	1.18	5	4
Wilton	100d 42m	47d 08m	0.89	4	5
Alfred	99d 01m	46d 35m	0.78	5	6

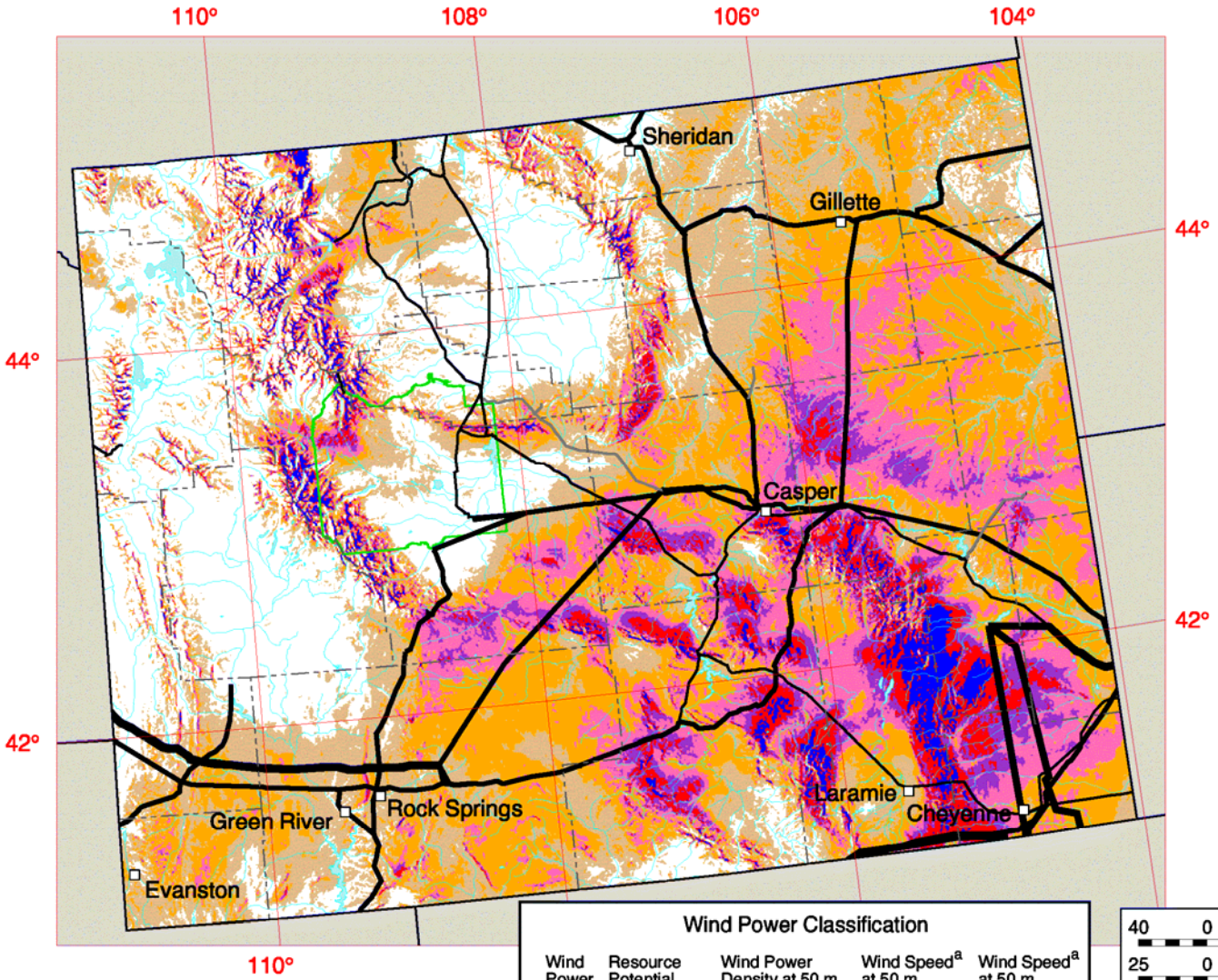
Wind power density estimates at 6 out of 7 locations are within 20% of measured values.

High-Resolution Wind Mapping Approach

- Produces finer than 1 km^2 horizontal resolution wind resource maps using numerical models
- Maps designed for regional wind mapping and not micrositing
- Does not depend on high-quality surface wind data
- Preliminary maps are validated and modified
  - Formal validations limited to 50 m speed and power maps
- Combination of numerical (AWS Truewind), empirical and analytical methods (NREL validation)
- Many states re-mapped as part of Wind Powering America

Wyoming

Wind Power Resource Estimates



Wind River Indian Reservation

Transmission Line*
Voltage (kV)
- 69
- 115
- 230
- 345

* Source: POWERmap,©2002 Platts, A Division of the McGraw-Hill Companies

Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m²	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
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	> 8.8	> 19.7

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

40 0 40 80 120 160 Kilometers
25 0 25 50 75 100 Miles

The wind power resource data for this map was produced by TrueWind Solutions using the Mesomap system and historical weather data. It has been validated with available surface data by the National Renewable Energy Laboratory and wind energy meteorological consultants.

U.S. Department of Energy
National Renewable Energy Laboratory

NREL

06-JUN-2002 2.1.2

Why Independent Validation?

- Independent validation idea originated at 2001 technical conference to update US wind atlas
  - Decided to use numerical approach for upcoming pilot Northwest mapping project supported by Wind Powering America
  - Limited evidence on skill of model approach for different climates and terrain at that time
  - Independent validation necessary for acceptance by wind energy community and developers
  - Intended to produce best wind maps possible - not a research project

Validation Process

- Collaborative process among AWS Truewind, NREL, and consulting experts
- Validators -- NREL and expert consultants
  - consultants have access to proprietary data
  - use own methods and data
  - provide both quantitative scores via a spread sheet and qualitative comments
  - provide validation results to NREL/AWS Truewind
- AWS Truewind
  - produces preliminary map
  - reviews validation results to improve map
  - produces final validated map

Northwest Map Validation

Validation Sites by Consultant and State

	ID	MT	OR	WA	WY	Total
Bob Baker	8					8
Ron Nierenberg		10	4	30	9	53
Rich Simon	5	25	39	60	28	157
John Wade	114	106		12		232
Stel Walker (OSU/BPA)	28	26	147	102		303
Total	155	167	190	204	37	753

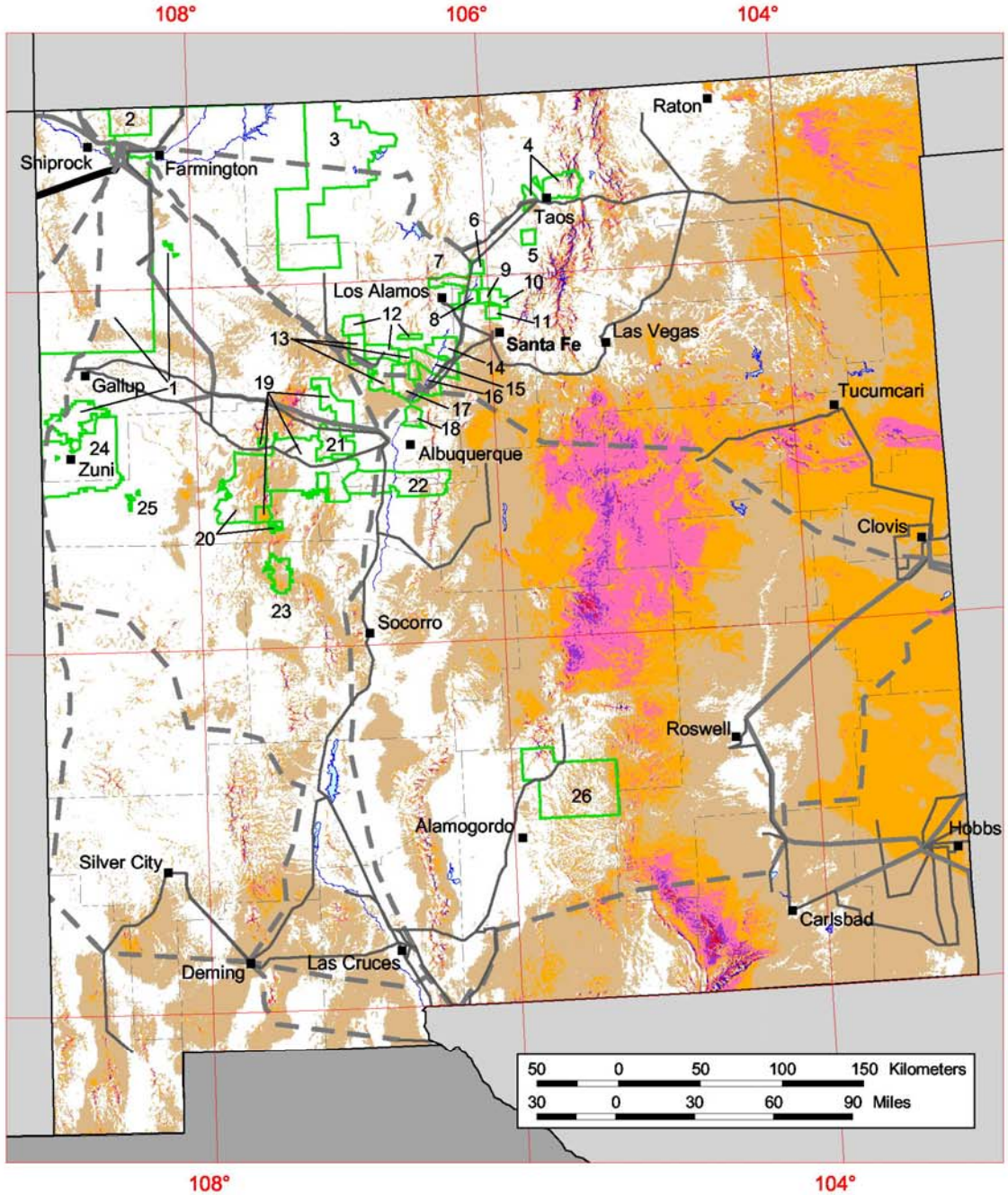
Selected NREL Validation Sites by Source and State

	ID	MT	OR	WA	WY	Total
Tall Towers (DOE, etc.)		4		3	1	8
Kenetech	4				14	18
Airport	12	21	12	15	18	78
Highway Sites	2	25			16	43
CstGrd/LtHse/Buoy			8	13		21
Forest Service					10	10
Other	16	22	2	3	19	62
Total	34	72	22	34	78	240

Validation Issues

- Many data sources and short time to analyze data for all locations
- Inadequate metadata for many sites and proprietary issues
- Time constraints to complete review of maps and validation
- Produced most accurate map possible given constraints

New Mexico 50 m Wind Power



Indian Reservation

1	Navajo
2	Ute Mountain
3	Jicarilla Apache
4	Taos
5	Picuris
6	San Juan
7	Santa Clara
8	San Ildefonso
9	Pojoaque
10	Nambe
11	Tesuque
12	Jemez
13	Zia
14	Cochiti
15	Santo Domingo
16	San Felipe
17	Santa Ana
18	Sandia
19	Laguna
20	Acoma
21	Canoncito
22	Isleta
23	Alamo Navajo
24	Zuni
25	Ramah Navajo
26	Mescalero

The annual wind power estimates for this map were produced by TrueWind Solutions using their Mesomap system and historical weather data. It has been validated with available surface data by NREL and wind energy meteorological consultants.

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
1	Poor	0 - 200	0.0 - 5.6	0.0 - 12.5
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
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	> 8.8	> 19.7

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

Transmission Line*

Voltage (kV)

- 115 - 138
- 230
- 345
- 500

* Source: POWERmap, ©2002 Platts, a Division of the McGraw-Hill Companies

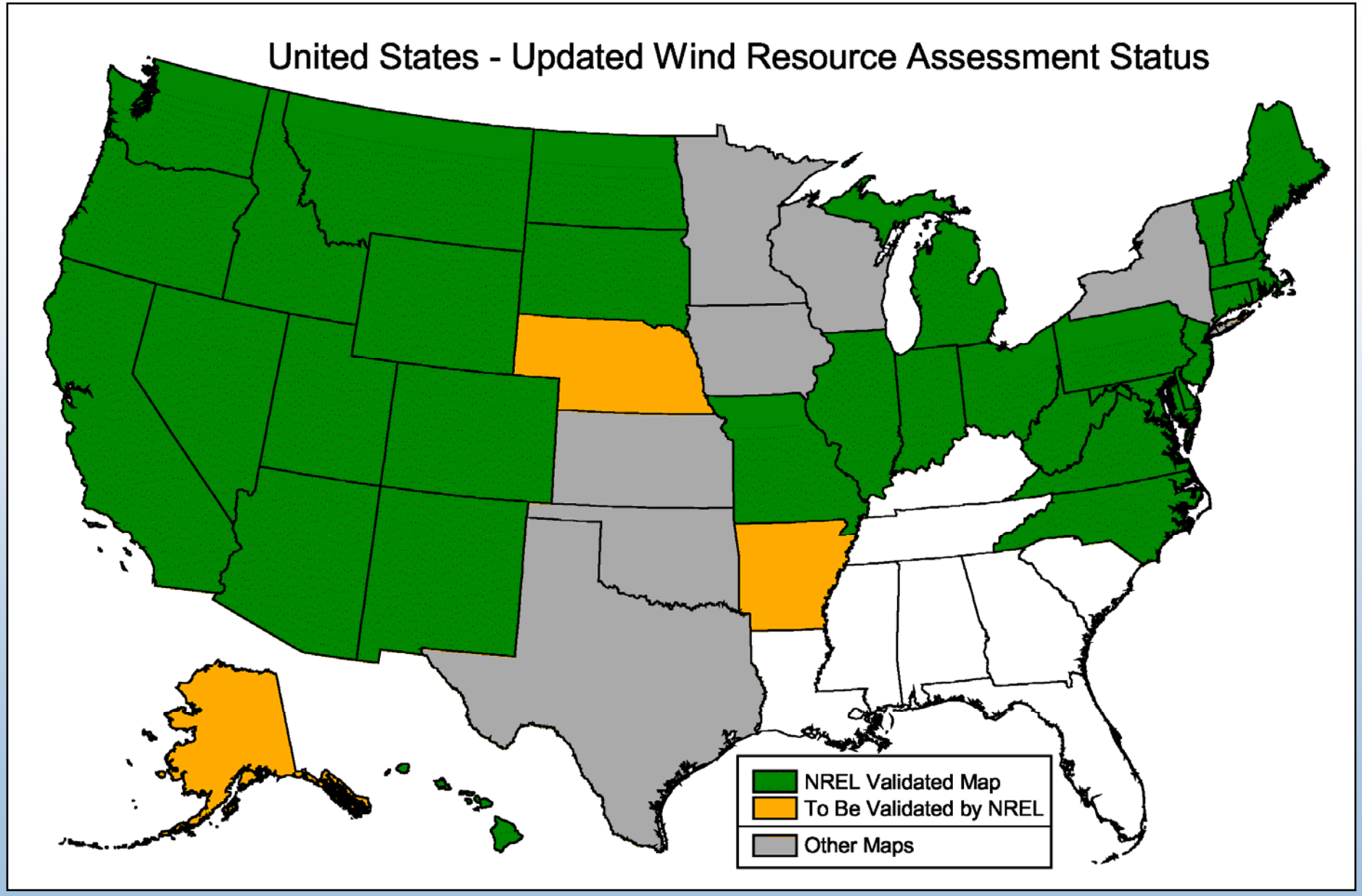
U.S. Department of Energy
National Renewable Energy Laboratory

NREL

26-AUG-2004 1.2.3

Technical Modeling Issues

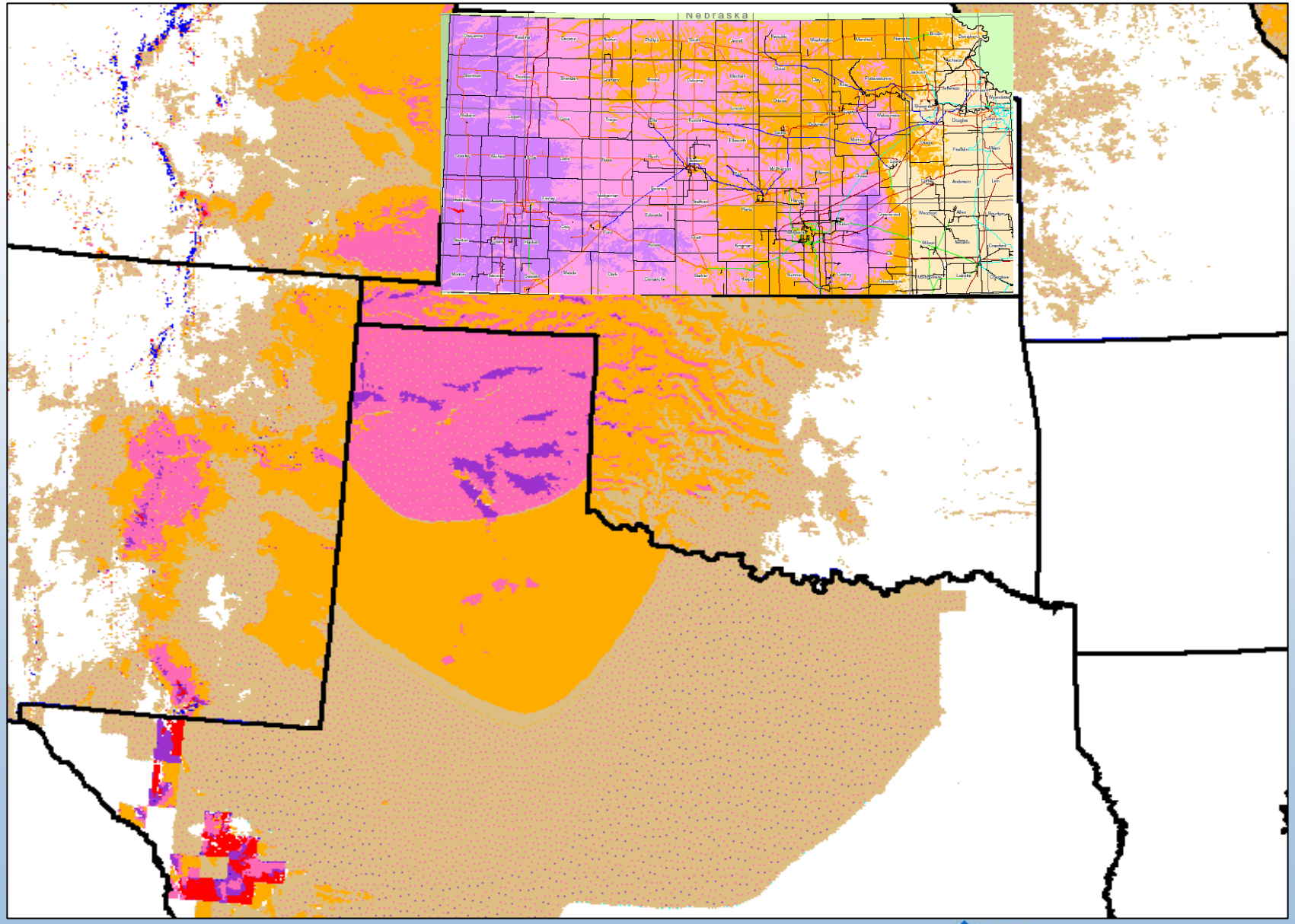
- Identified during validation process
- Surface Roughness Parameterization
  - Errors in land cover description
  - Imprecise roughness length assignments
- Atmospheric Stability Issues
  - Stable boundary layer depth
  - Stable atmosphere phenomena
    - Nocturnal jets
    - Mountain-valley circulations


United States - Updated Wind Resource Assessment Status
NREL Validated Map
To Be Validated by NREL
Other Maps

State Mapping and Validation Summary

- Validation successful largely due to iterative process among NREL, AWS Truewind, and validation team.
- Confident final maps are better than those that would have been produced without validation process
- Important technical issues better defined because of validation process
- Considerable high-quality data from region and validators knowledge enhanced the success of the validation

Mapping Region with Discontinuities



FY 05 NREL Activities

- Budget - $200K in-house
- Validation and development of final maps for
  - Nebraska
  - Western Alaska
- Preliminary maps and initial review for
  - Arkansas
  - Southeast Panhandle of Alaska
- Present mapping results at WPA meetings

Wind Mapping Issues

- Interest in wind maps for heights of 80-100m+ (not just 50m)
  - Lack of validation data at heights of 80-100m+
    - Data from taller anemometers becoming available for several areas but no data for many regions
    - Collection of data on existing tall towers and with remote sensing technology being encouraged to fill the data void
- Interest in using unvalidated seasonal and diurnal grids produced as part of the mesoscale modeling
  - Initial analyses indicate uncertainties in modeled data
  - Approach needed for validation and development of seasonal and diurnal profiles

Wind Mapping Issues and Future Plans

- NREL validated maps not available for 7 states
  - Different mapping techniques used
  - Major discrepancies of wind resource apparent along borders of states with different mapping techniques
  - Results in ‘patchwork quilt’ appearance in some regions
- Only old 1987 atlas maps available for 8 states
  - Generally states estimated to have low to marginal wind resources
- Plan for updated and validated maps for additional states?
  - WPA mapping activities winding down
  - Future plans for state mapping and validation TBD
- Should discontinuities among state maps be formally addressed?