Energy Technologies Area Lawrence Berkeley National Laboratory

United States Wind Turbine Database

Release Webinar
April 23rd, 2018

Ben Hoen & Joe Rand Lawrence Berkeley National Laboratory

James Diffendorfer, Louisa Kramer & Chris Garrity United States Geological Survey

Hannah Hunt American Wind Energy Association

Please Note:

- All participants will be muted during the webinar
- Please submit questions via the chat window

The preparation of the USWTDB was funded, in part, by the Wind Energy Technologies Office of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Meet The USWTDB Team

Lawrence Berkeley National Laboratory

Ben Hoen

Joe Rand

American Wind Energy Association

Hannah Hunt

United States Geological Survey

Jay Diffendorfer

Louisa Kramer

Chris Garrity

Meet The USWTDB Team & Today's Speakers

Lawrence Berkeley National Laboratory

Ben Hoen

United States Geological Survey

Jay Diffendorfer

Joe Rand

Louisa Kramer

American Wind Energy Association

Hannah Hunt

Chris Garrity

Outline Of The Presentation

1. Project Background
2. Database Management
3. Visual Verification
4. Website and Viewer Demo

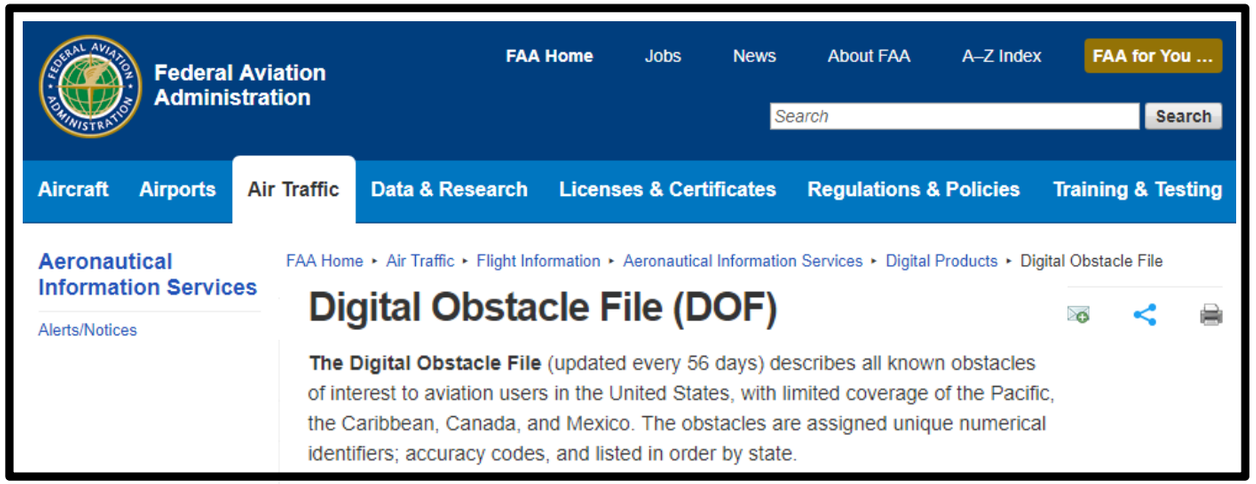
2014 Wind Turbine Radar Interference Mitigation Working Group (WTRIM) Was Established

A Consortium Of Federal Agencies To Address Wind Turbine Interference With Radar

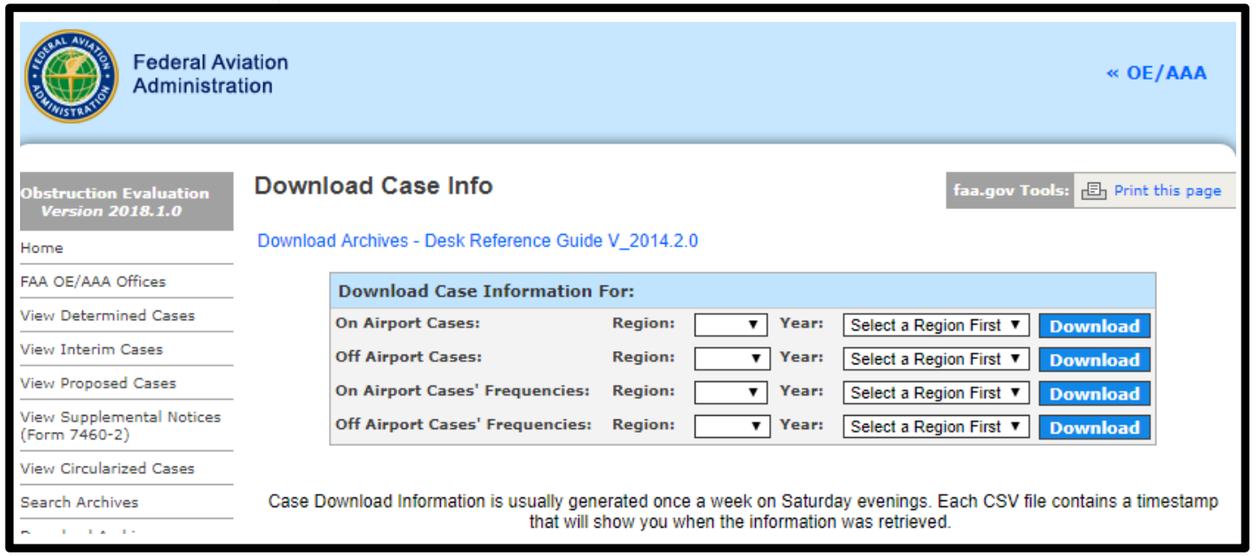
2014

Two Public Datasets Were Available From The FAA

#1 Digital Obstacle File (DOF)



#2 Obstruction Evaluation/Airport Airspace Analysis (i.e., "Study") Files (OE/AAA)



2014

Three Other Datasets Existed That Added Key Information To FAA Data…

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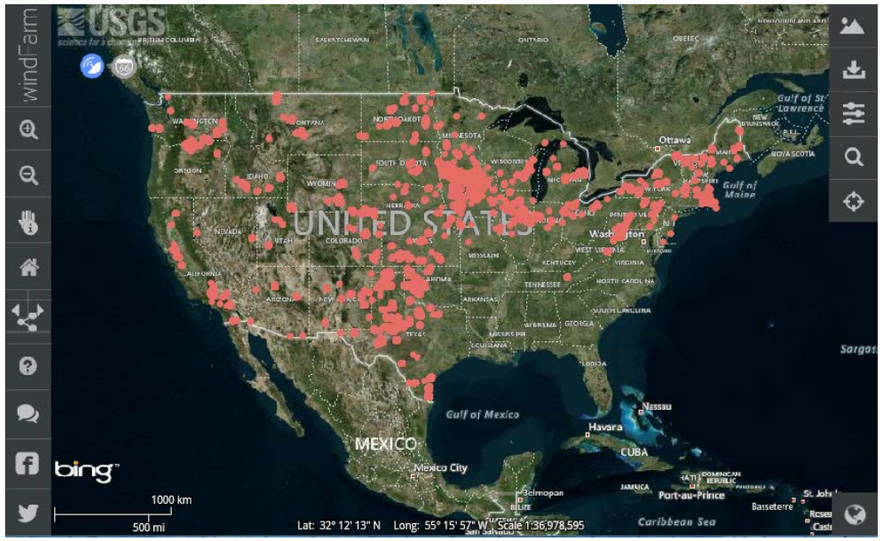

AWEA

2014

...But They Were Either No Longer Being Updated Or Privately Held

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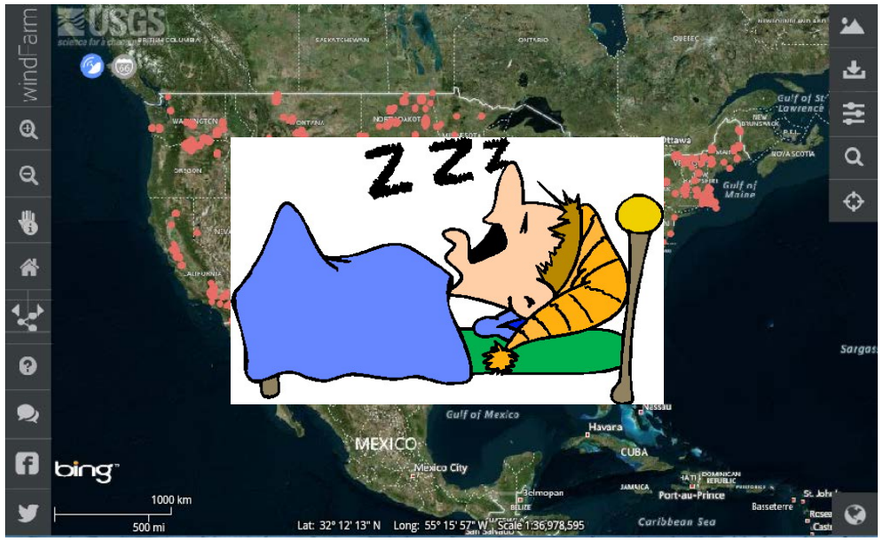

AWEA

2014 WTRIM Used FAA & USGS Files With Other .Gov Data To Conduct Radar Operational Impact Assessments

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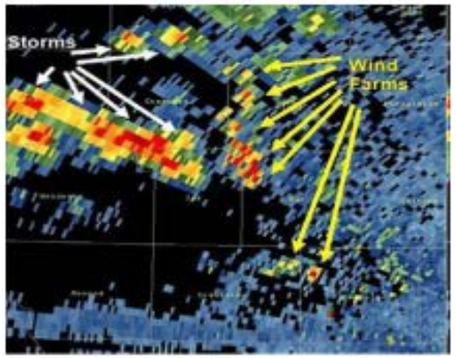
FEDERAL AVIATION ADMINISTRATION

OE/AAA & DOF

+

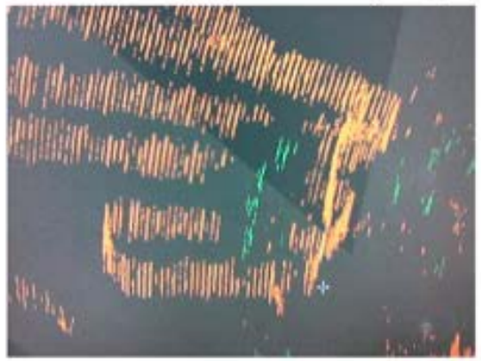
Other .gov Sources

Weather Radar (Iowa)

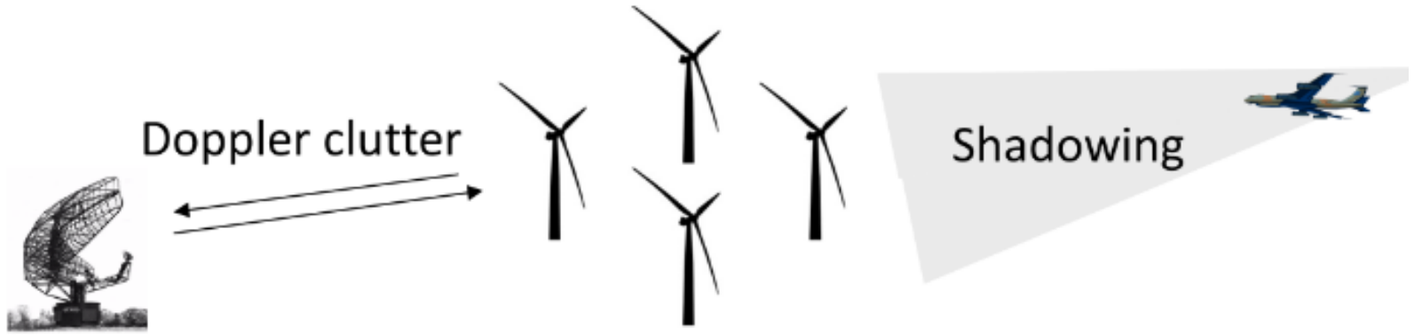


Marine Radar (UK)

Air Traffic Control (UK)



Source: UT Austin



2014 There Were Problems With The WTRIM Data Collection And Maintenance That Needed To Be Resolved

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+

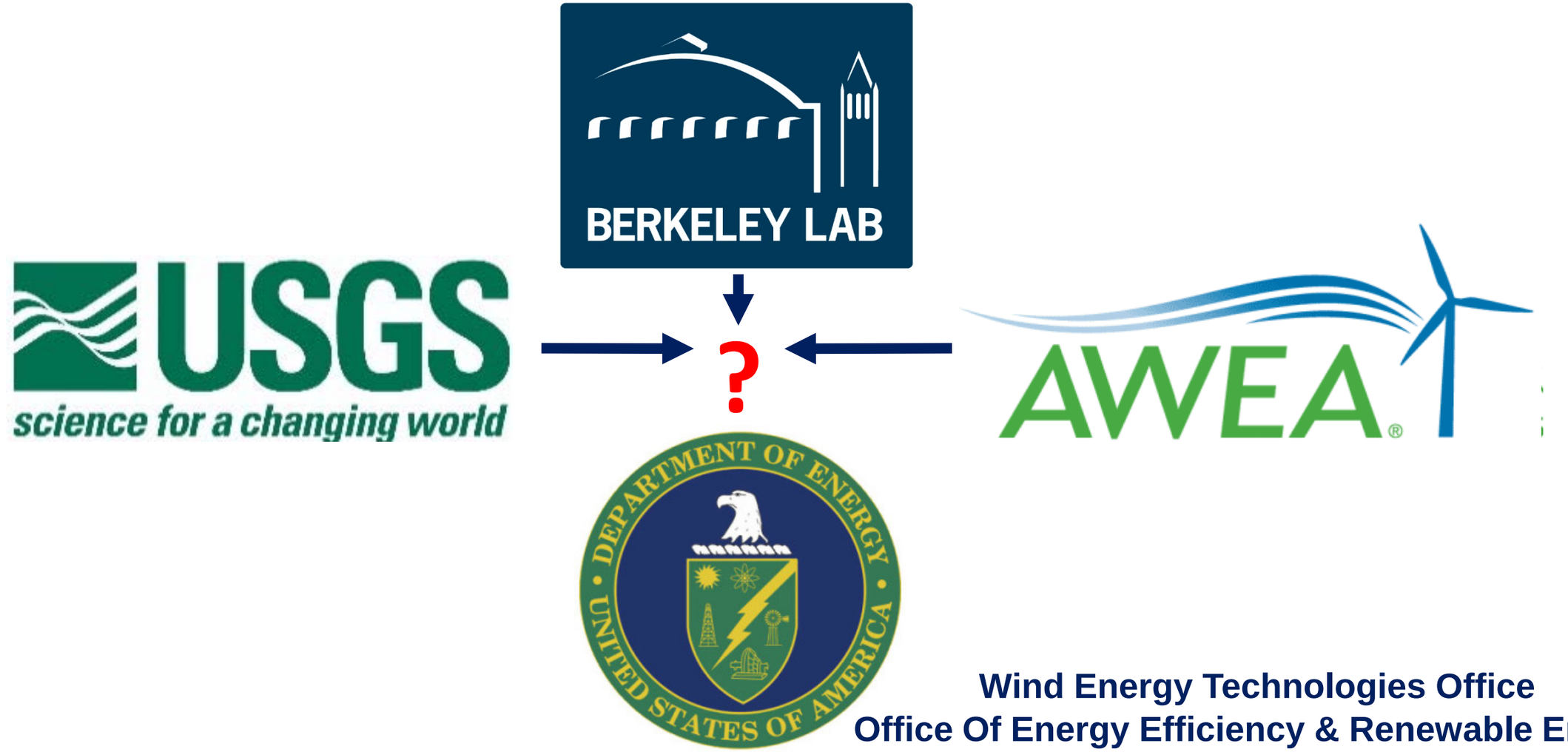
Other .gov Sources

Problems:

1. Overlapping datasets had unresolved duplicates
2. Limited information on turbine characteristics
3. Limited geo-rectifying
4. No decommissioned turbine screening
5. No option for public release of the data
6. Not inclusive of repowered & retrofitted turbines
7. Limited long-term institutional support

2015

U.S. DOE Proposed The Idea Of A Collaborative Dataset Between LBNL, USGS And AWEA



Wind Energy Technologies Office
Office Of Energy Efficiency & Renewable Energy

2016 Negotiations Began On A Cooperative Research and Development Agreement (CRADA)

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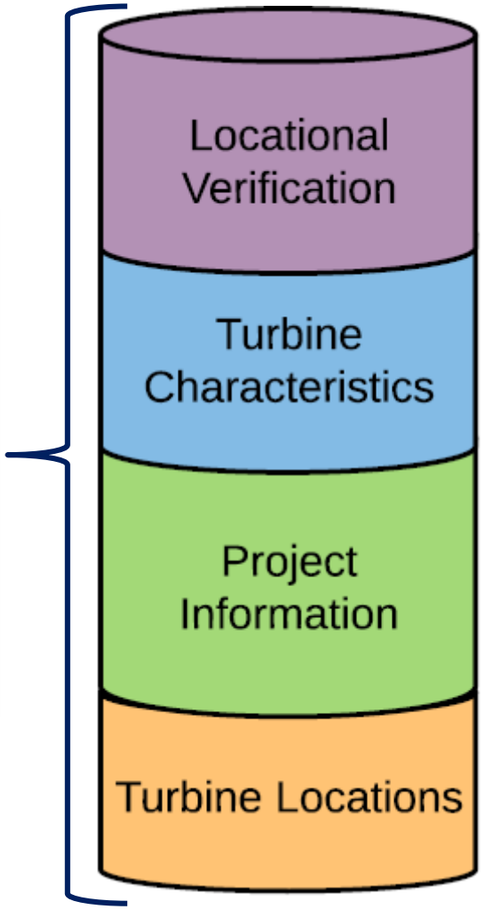
AWEA

U.S. Wind Turbine Database (USWTDB)



2017 The CRADA Was Signed By All Parties!

Roles

Overall Project & Database Management

Visual Verification & Portal Design

Characteristics Sourcing & Initial Locational Assessment

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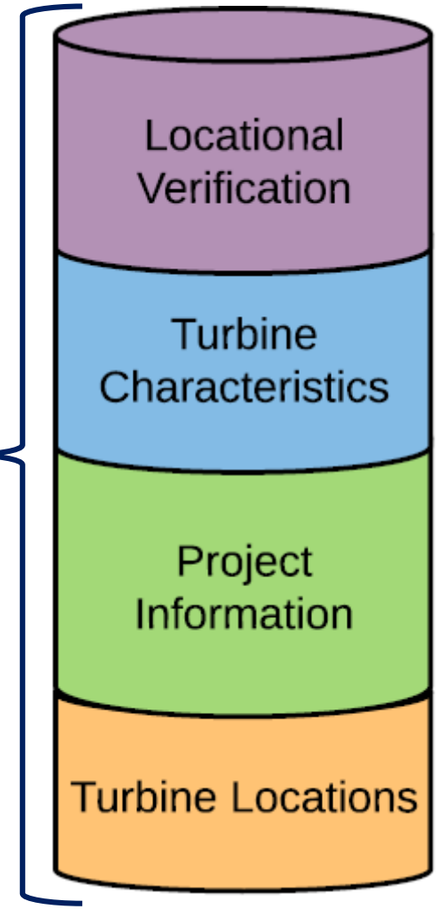
AWEA

U.S. Wind Turbine Database (USWTDB)



2017 Building The USWTDB Began

Q1

+

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OE/AAA & DOF

2017 Building The USWTDB Continues

Q1

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OE/AAA & DOF

Q2

Q1 USWTDB

+

Updated OE/AAA & DOF

2017 Building The USWTDB Continues

Q1

+

+

OE/AAA & DOF

Q2

Q1 USWTDB

+

Updated OE/AAA & DOF

Q3

Q2 USWTDB

+

Updated OE/AAA & DOF

+

2017 Building The USWTDB Continues

Q1

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FEDERAL AVIATION ADMINISTRATION

OE/AAA & DOF

Q2

Q1 USWTDB

+

Updated OE/AAA & DOF

Q3

Q2 USWTDB

+

Updated OE/AAA & DOF

+

AWEA

Q4

Q3 USWTDB

+

Updated OE/AAA & DOF

+

Updated AWEA

+

Manual Duplicate Removal

2017 Building The USWTDB Continues

Q1

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FEDERAL AVIATION ADMINISTRATION

OE/AAA & DOF

Q2

Q1 USWTDB

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Updated OE/AAA & DOF

Q3

Q2 USWTDB

+

Updated OE/AAA & DOF

+

AWEA

Q4

Q3 USWTDB

+

Updated OE/AAA & DOF

+

Updated AWEA

+

Manual Duplicate Removal

WTRIM Served As An Advisor During This Process

Outline Of The Presentation

1. Project Background
2. Database Management
3. Visual Verification
4. Website and Viewer Demo

Database Management: Five Main Sources of Data

1. USGS Dataset (*March 2014*)
2. LBNL Dataset (*March 2017*)
3. FAA Digital Obstacle File (DOF) (*Jan 2, 2018*)
4. FAA Obstacle Evaluation / Airport Airspace Analysis (OE/AAA) (*Jan 6, 2018*)
5. AWEA Q4-2017 Database (*Jan 26, 2018*)

Data Sources Were Merged (i.e., Matched) Using Two Methods:

1. Merging tables using unique IDs shared between two datasets (inner join)

Table 1

faa_ors	deg_lat	deg_long
27-022940	44.33035	-95.82217
27-022941	44.33423	-95.81953
27-022942	44.32887	-95.81773
27-023549	43.95522	-94.54684
27-023836	43.72861	-95.76858
27-024249	43.68543	-95.12814
27-024457	44.02798	-96.30871
27-024698	46.38934	-94.80887
27-025394	45.99834	-95.98917
27-025421	46.72309	-96.24853
27-025422	46.68703	-96.24133
27-025423	46.7038	-96.27348
27-025424	46.70572	-96.25833
27-025425	46.70715	-96.25601

Table 2

faa_ors	site_name
27-022940	Marshall Wind
27-022942	Marshall Wind
27-021686	Marshall Wind
41-021390	Sheperds Flat South
41-021545	Sheperds Flat South
41-021523	Sheperds Flat South
41-021391	Sheperds Flat South
41-021524	Sheperds Flat South
41-021513	Sheperds Flat South
41-021489	Sheperds Flat South
41-021433	Sheperds Flat South
41-021389	Sheperds Flat South
41-021432	Sheperds Flat South
41-021422	Sheperds Flat South
41-021440	Sheperds Flat South
41-021425	Sheperds Flat South

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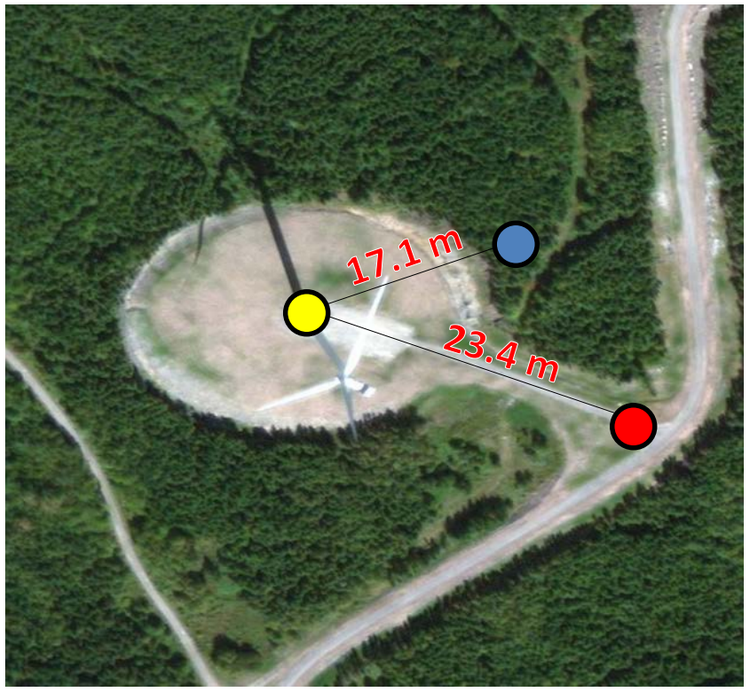
41-021440	Sheperds Flat South
41-021425	Sheperds Flat South

2. Merging datasets by matching XY locations and turbine attributes (geospatial matching)



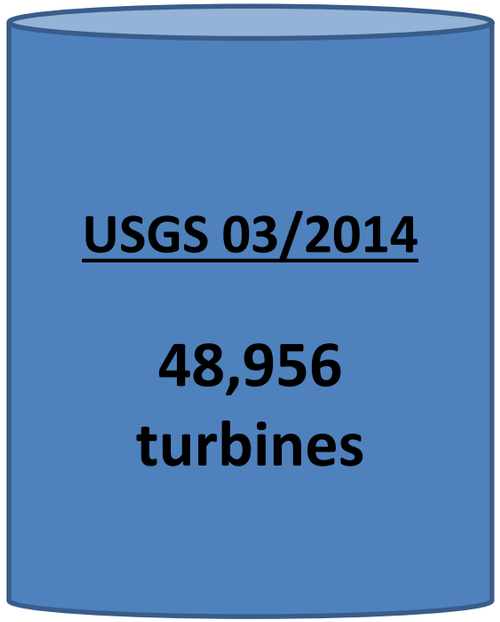
- USGS/LBNL data point
- AWEA data point
- FAA DOF data point

Geospatial matching is conducted using Stata's "geonear" function (Picard), which uses distance between two x/y coordinates using the Haversine equation on a reference ellipsoid (Vincenty, 1975)

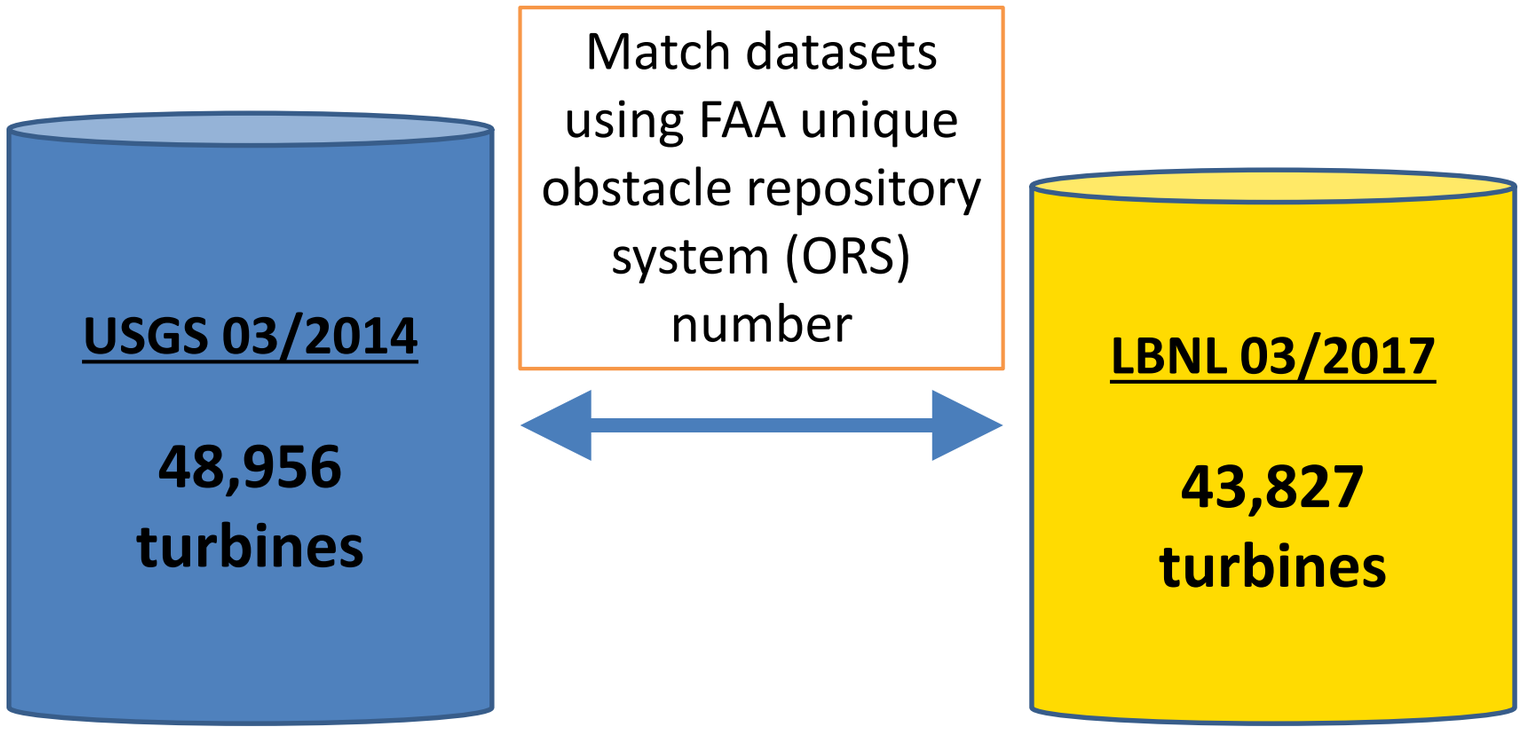
Started With USGS Dataset

Data Sources:

1. USGS Dataset



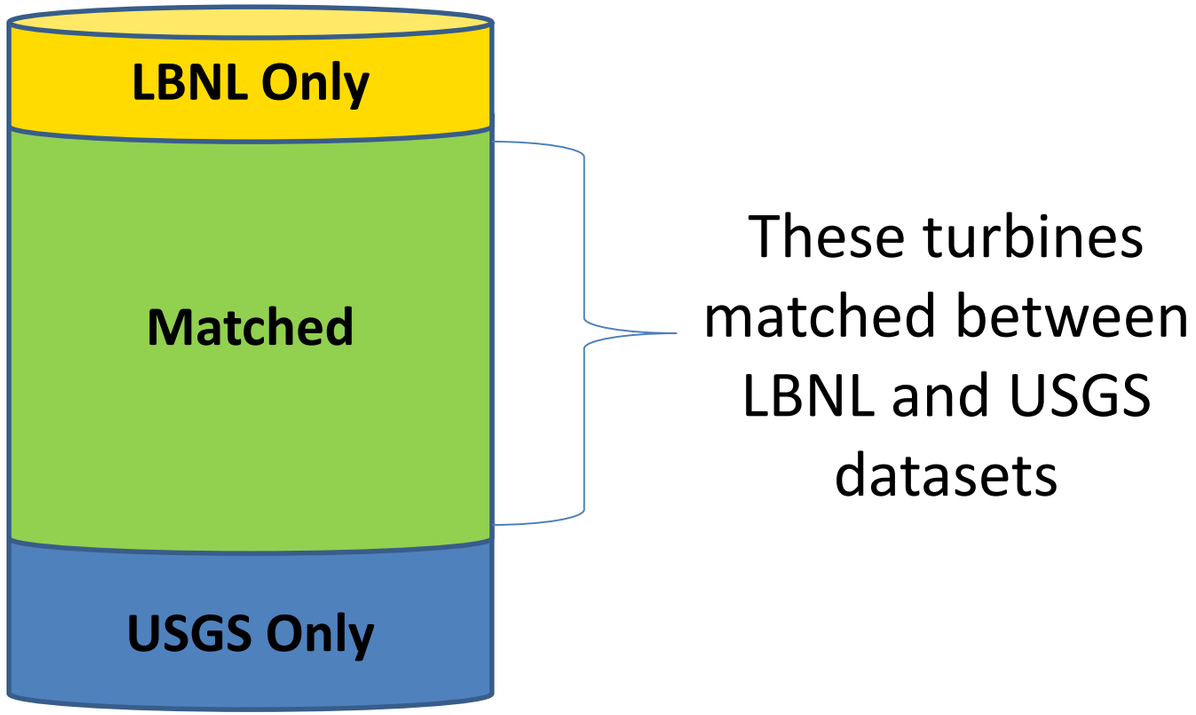
Joining LBNL and USGS Datasets



Data Sources:

1. USGS Dataset
2. LBNL Dataset

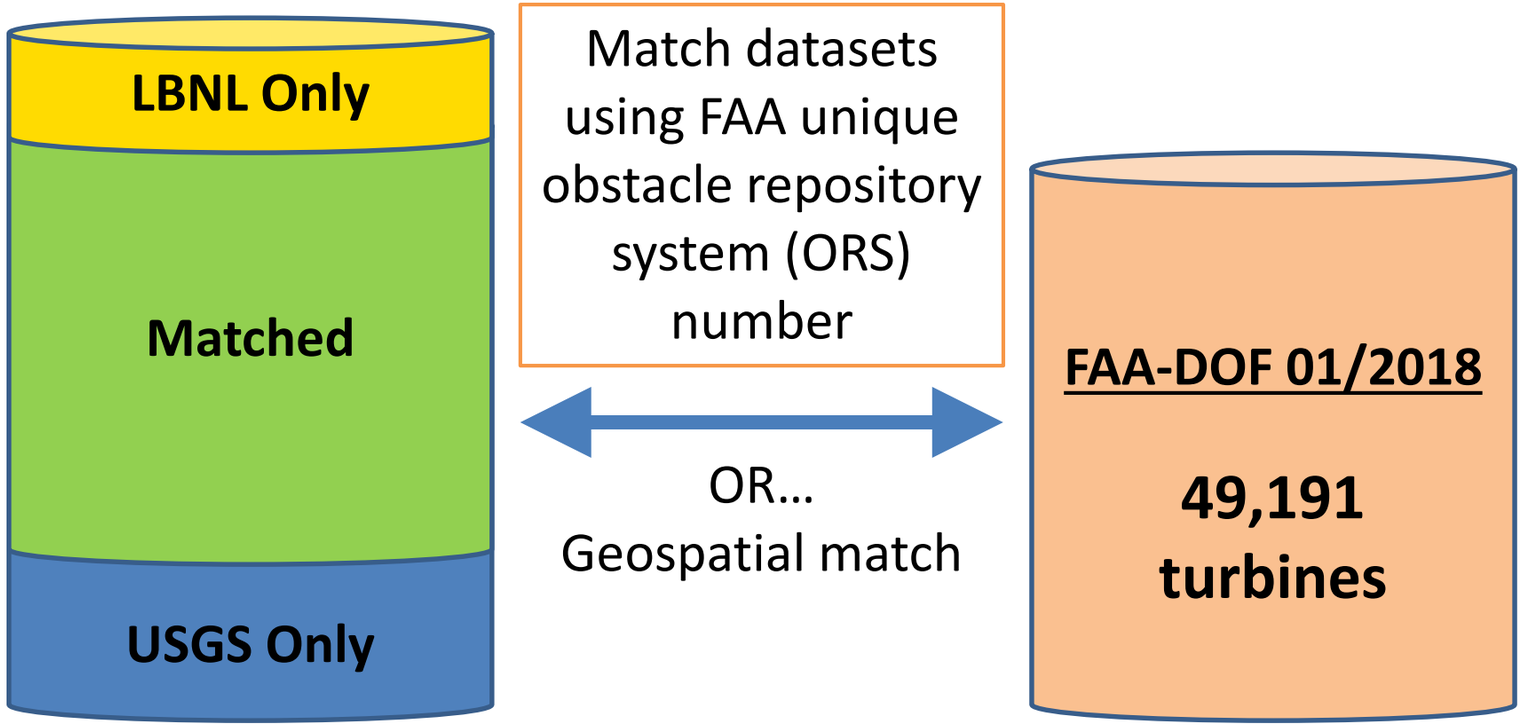
USGS & LBNL Joined



Data Sources:

1. USGS Dataset
2. LBNL Dataset

Adding FAA-DOF Data



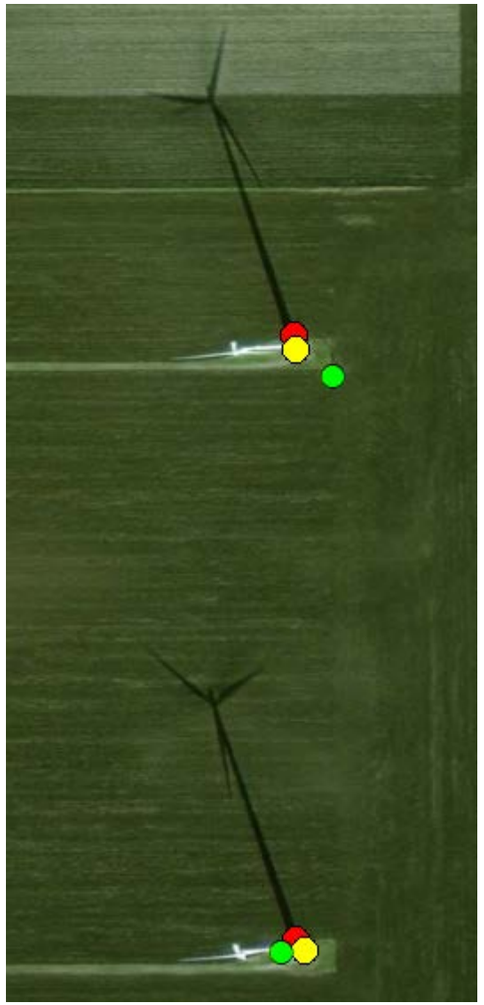
Data Sources:

1. USGS Dataset
2. LBNL Dataset
3. FAA DOF

When Not Possible To Join Datasets on ID (e.g., ORS), *Geospatial* Matching Was Used

- Designed to capture only **highest confidence** matches
  - If left unmatched, two duplicate points might appear in database
  - But, USGS visual verification would subsequently capture any duplicates that were not matched

- Two types of geospatial matching criteria were used:
  - Type 1:
    - Points were within **10 feet** of each other, AND
    - Install years were +/- 1 year
  - Type 2:
    - Turbines were within **50 feet,** AND
    - Install years were equal

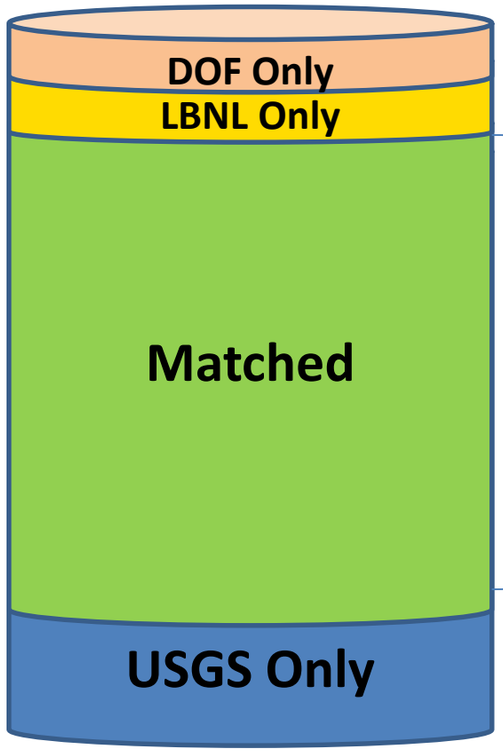


USGS/LBNL data point

FAA OE/AAA data point

FAA DOF data point

USGS, LBNL, & DOF Joined

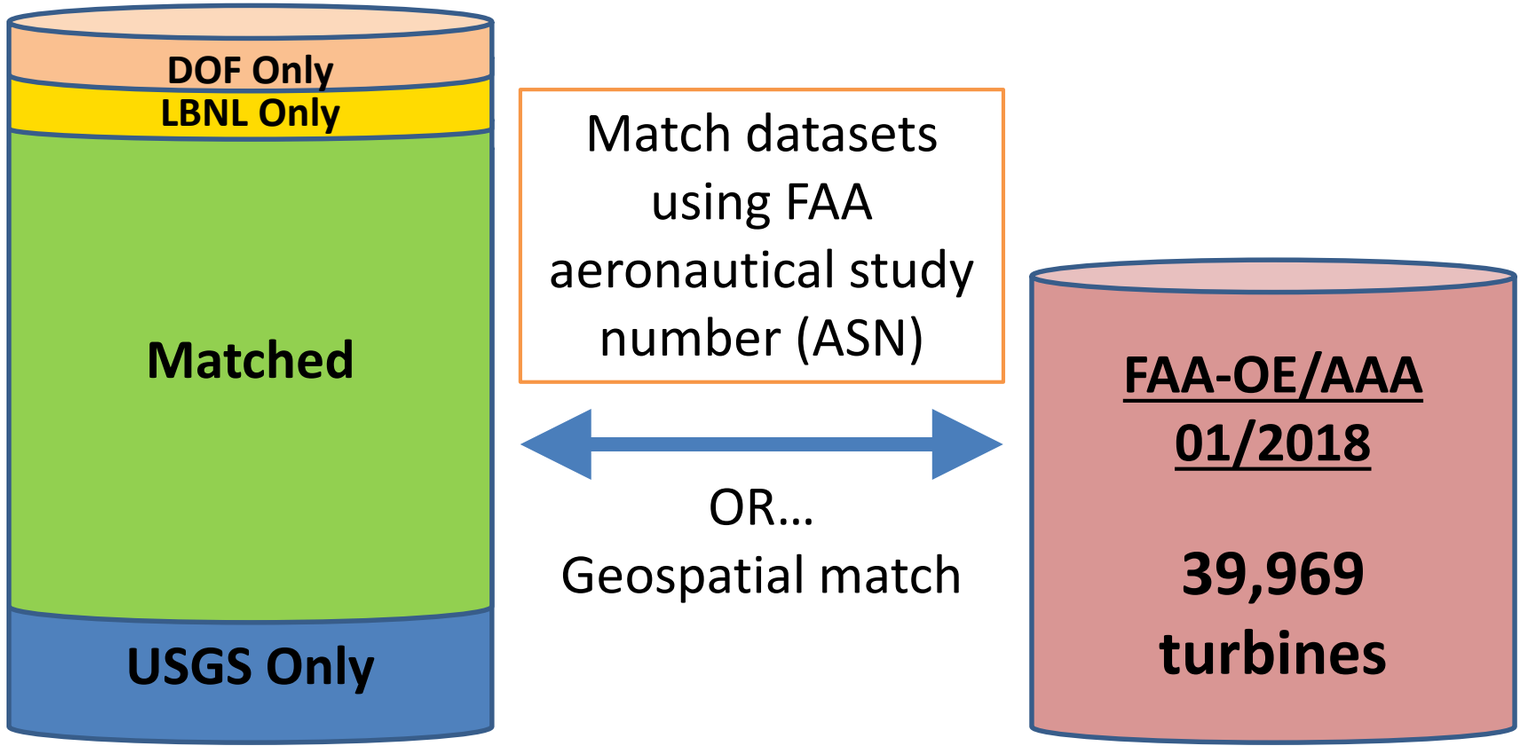


These turbines matched between 2 or 3 of the datasets

Data Sources:

1. USGS Dataset
2. LBNL Dataset
3. FAA DOF

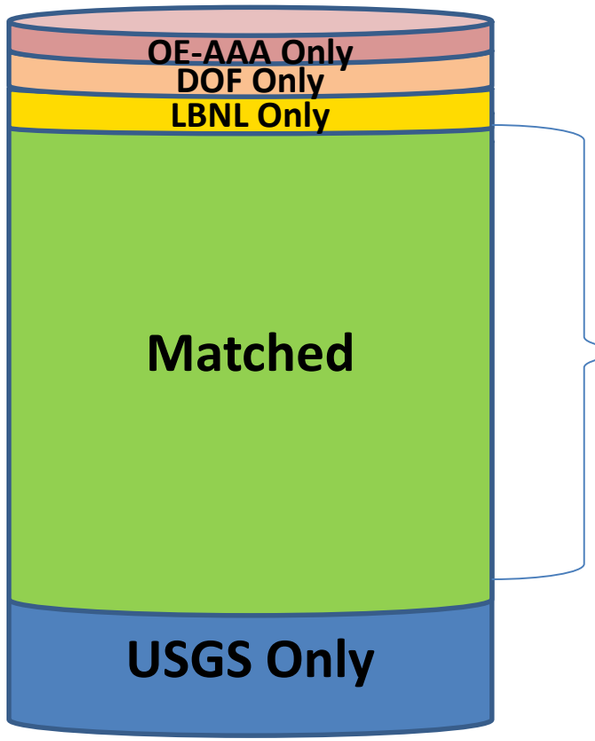
Adding FAA-OE/AAA Data



Data Sources:

1. USGS Dataset
2. LBNL Dataset
3. FAA DOF
4. FAA OE/AAA

USGS, LBNL, DOF, & OE/AAA Joined

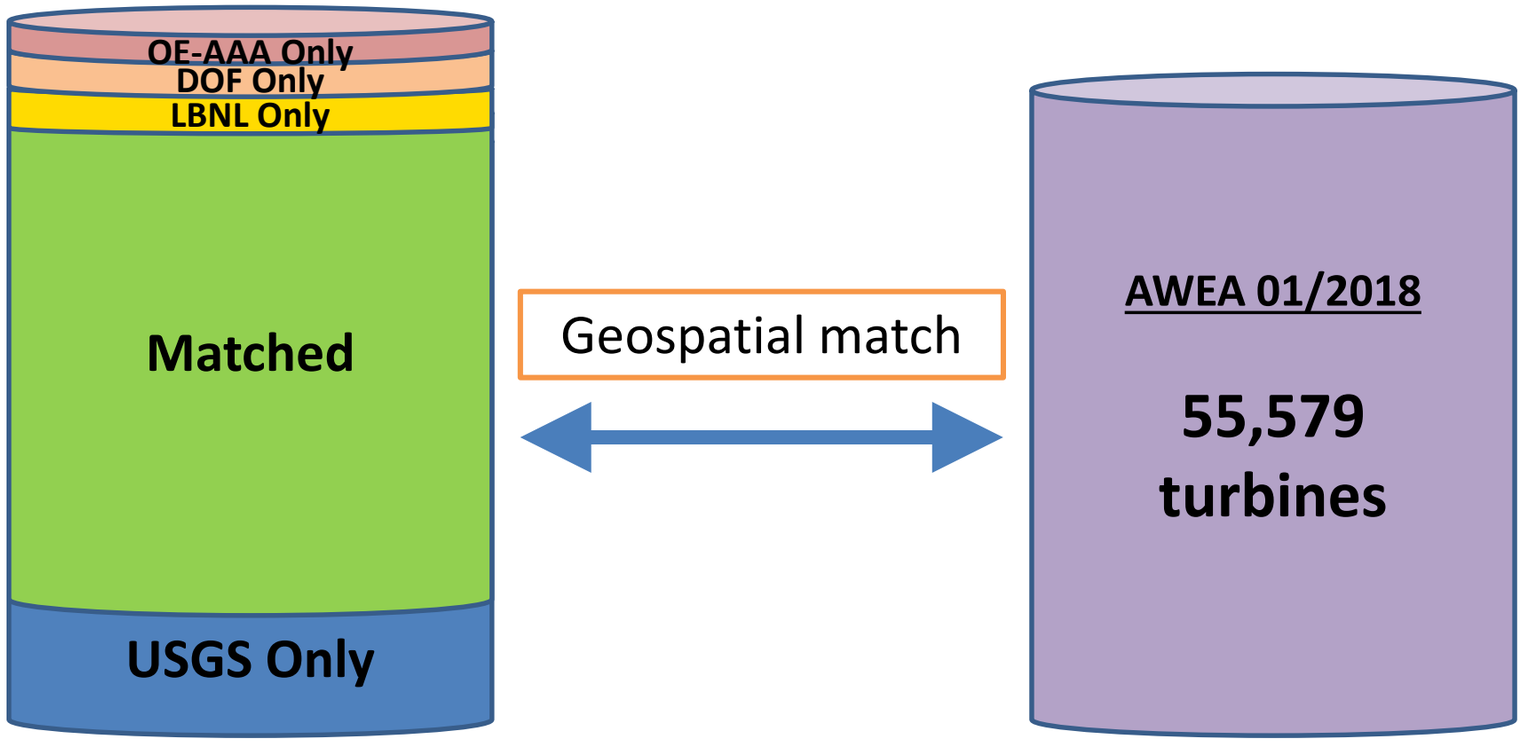


These turbines matched between 2, 3, or all 4 of the datasets

Data Sources:

1. USGS Dataset
2. LBNL Dataset
3. FAA DOF
4. FAA OE/AAA

Adding AWEA Data



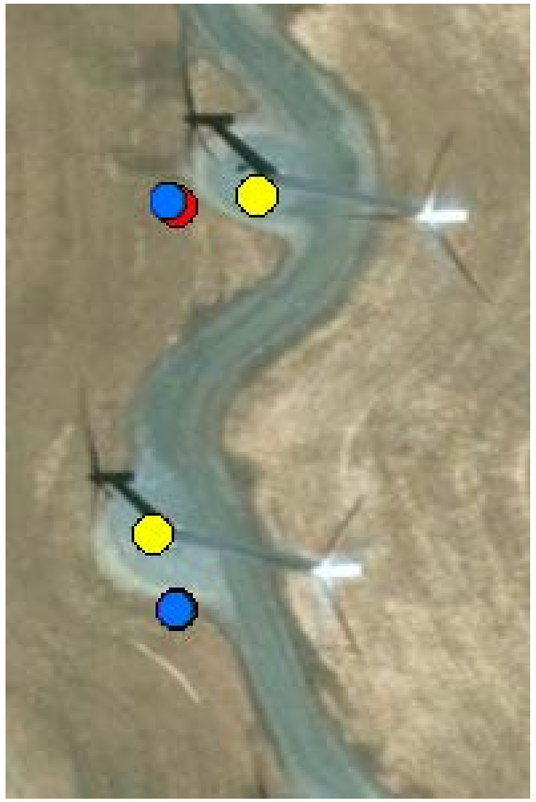
Data Sources:

1. USGS Dataset
2. LBNL Dataset
3. FAA DOF
4. FAA OE/AAA
5. AWEA Q4-2017 Dataset

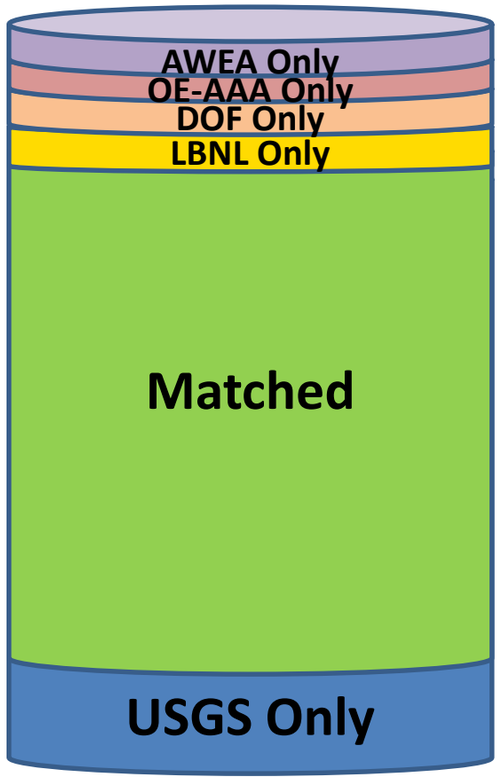
AWEA Data Have No ID To Match To Other Datasets; Geospatial Matching Was Used

- Designed to capture only **highest confidence** matches
  - If left unmatched, two duplicate points might appear in database
  - But, USGS visual verification would subsequently capture any duplicates that were not matched

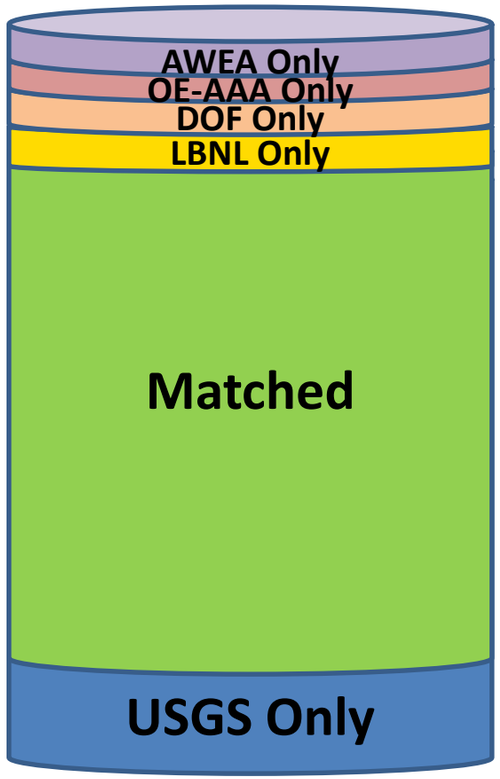
- Two types of matching criteria were used:
  - Type 1:
    - Turbines were within **100 feet** of each other, AND
    - Hub height, rotor diameter, and install year were equal
  - Type 2:
    - Turbines were within **10 feet** of each other, AND
    - Install years were within one year



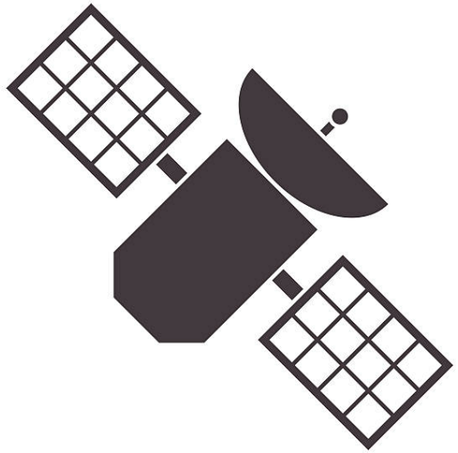
Interim Fully-Merged Database to USGS for Visual Verification; Returned to LBNL to Remove Duplicates & Decommissioned



Interim Fully-Merged Database to USGS for Visual Verification; Returned to LBNL to Remove Duplicates & Decommissioned*



To USGS

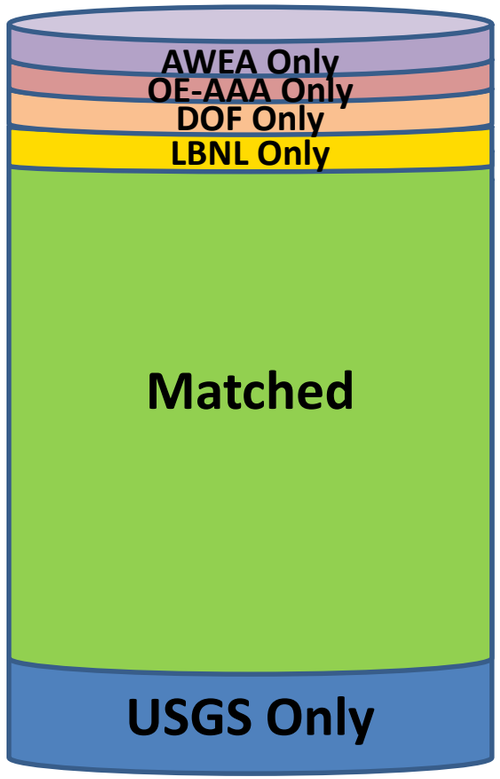


USGS Visual Verification:

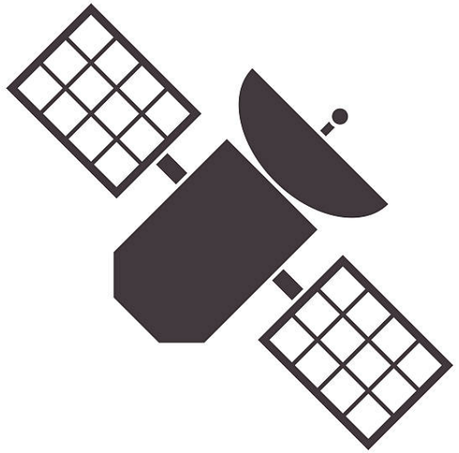
- Identify duplicate points
- Identify decommissioned turbines
- Update XY coordinates (if needed)

*Note: 5,897 turbines were marked as decommissioned

Interim Fully-Merged Database to USGS for Visual Verification; Returned to LBNL to Remove Duplicates & Decommissioned*



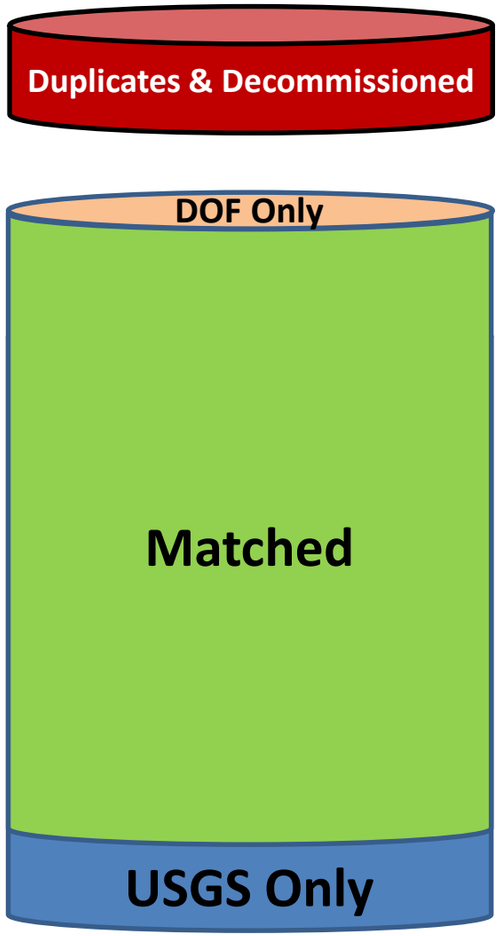
To USGS



USGS Visual Verification:

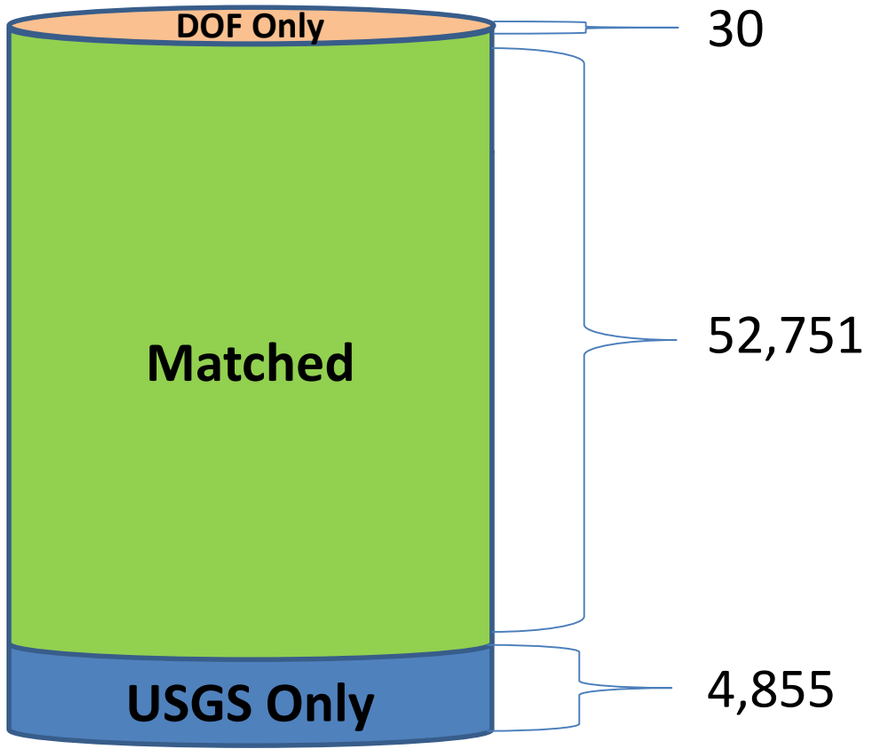
- Identify duplicate points
- Identify decommissioned turbines
- Update XY coordinates (if needed)

To LBNL



*Note: 5,897 turbines were marked as decommissioned

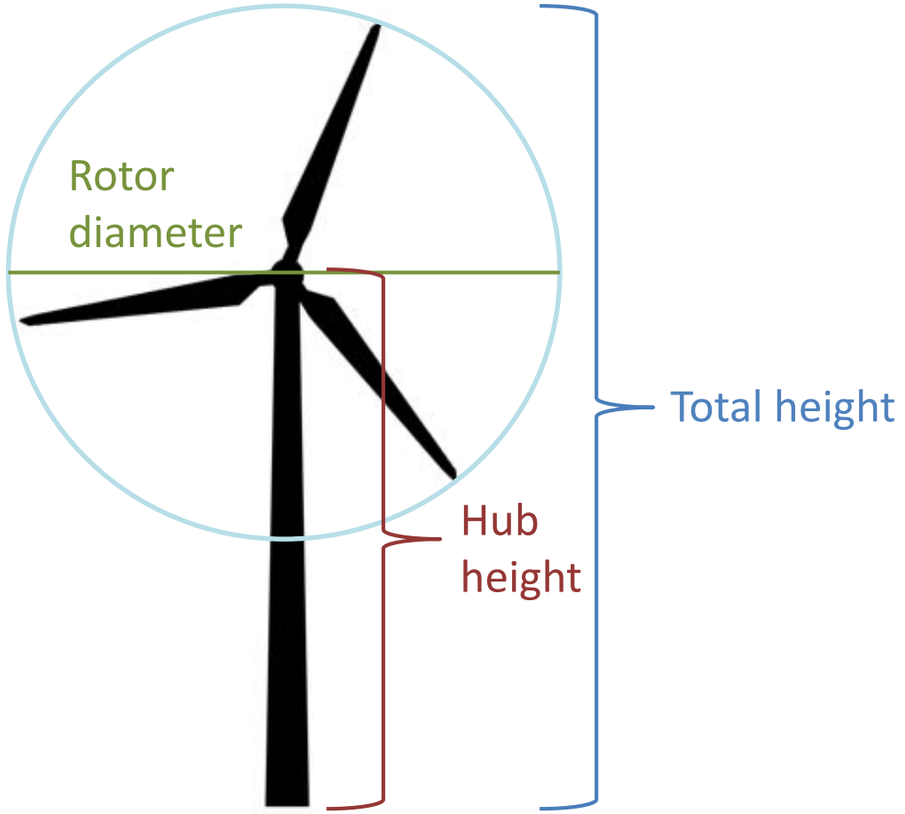
Final Database After Merging 5 Sources and Removing Duplicates & Decommissioned Turbines:



5-Source Matches	32,139
4-Source Matches	10,670
3-Source Matches	4,982
2-Source Matches	4,960
OE/AAA Only	-
DOF Only	30
LBNL Only	-
USGS Only	4,855
AWEA Only	-
Total Turbines:	**57,636**

Key Turbine Attributes (and their sources)

Attribute	LBNL / AWEA / USGS	FAA DOF / OE/AAA
X/Y coordinates	●	●
Online/install year	●	●
Total height (m)	●	●
Hub height (m)	●	
Rotor diameter (m)	●	
Rated capacity (kW)	●	
Manufacturer	●	
Model	●	
Project name	●	



Key Turbine Attributes Are Well Populated In USWTDB

Attribute	# of Turbines Populated	% of Database Populated	Minimum	Median	Maximum
X/Y coordinates	57,636	**100%**	n/a	n/a	n/a
Online/install year	57,523	**99%**	1981	2009	2018
Total height (m)	52,334	**91%**	9.1	123.1	181.1
Hub height (m)	51,431	**89%**	18.2	80	116.5
Rotor diameter (m)	52,499	**91%**	11	87	150
Rated capacity (kW)	54,595	**95%**	40	1650	6000
Manufacturer	54,413	**94%**	n/a	n/a	n/a
Model	53,541	**93%**	n/a	n/a	n/a

Over 87% of turbines in the USWTDB have data populated for ALL of these key attributes.

For More Details, See Release Memo & Codebook

Latest Database Release

Version: USWTDB_V1_0_20180419 - Changelog | Detailed memo & codebook

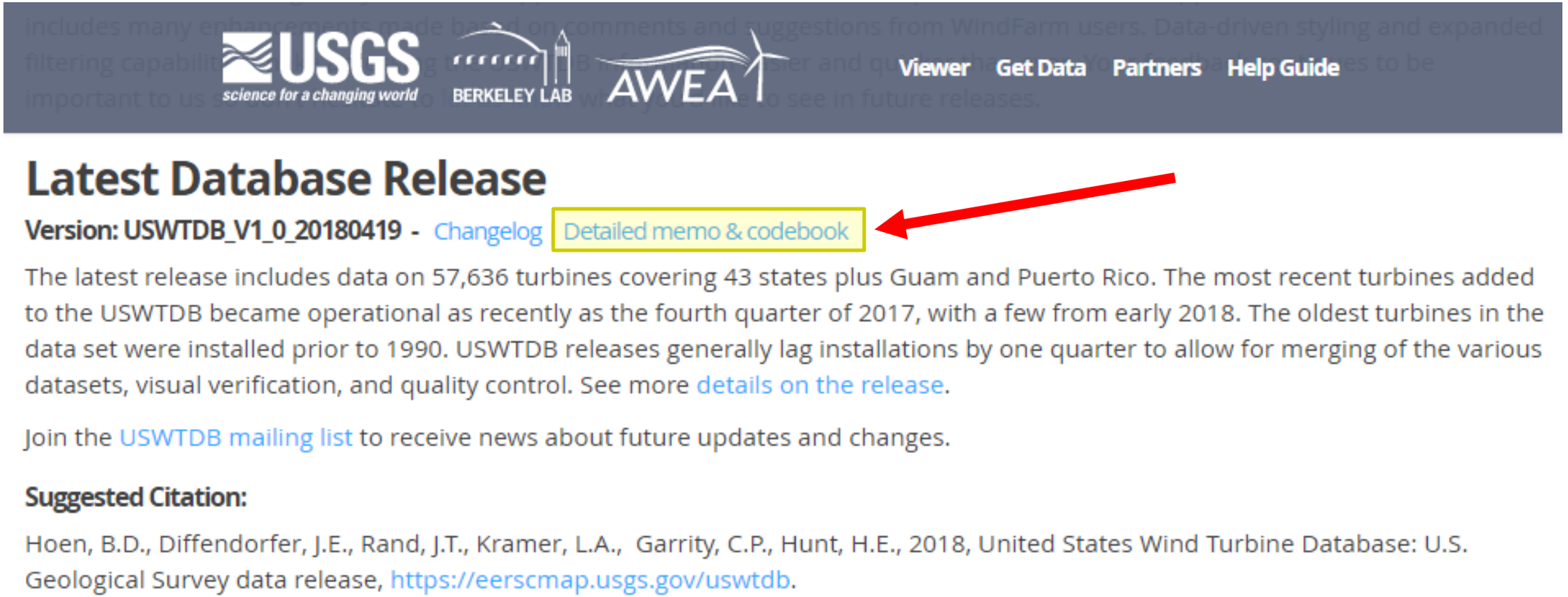
The latest release includes data on 57,636 turbines covering 43 states plus Guam and Puerto Rico. The most recent turbines added to the USWTDB became operational as recently as the fourth quarter of 2017, with a few from early 2018. The oldest turbines in the data set were installed prior to 1990. USWTDB releases generally lag installations by one quarter to allow for merging of the various datasets, visual verification, and quality control. See more details on the release.

Join the USWTDB mailing list to receive news about future updates and changes.

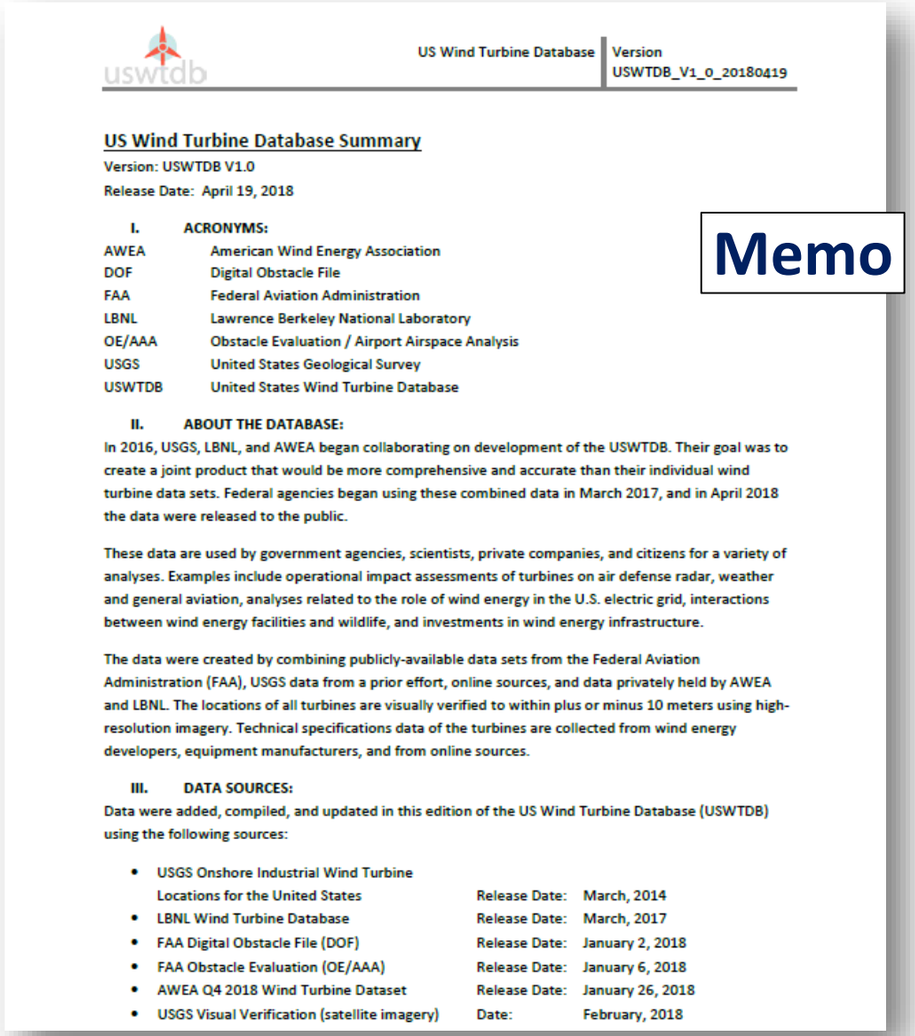
Suggested Citation:

Hoen, B.D., Diffendorfer, J.E., Rand, J.T., Kramer, L.A., Garrity, C.P., Hunt, H.E., 2018, United States Wind Turbine Database: U.S. Geological Survey data release, https://eerscmap.usgs.gov/uswtdb.

For More Details, See Release Memo & Codebook



For More Details, See Release Memo & Codebook



uswtdb | US Wind Turbine Database | Version USWTDB_V1_0_20180419

US Wind Turbine Database Summary

Version: USWTDB V1.0

Release Date: April 19, 2018

I. ACRONYMS:

AWEA	American Wind Energy Association
DOF	Digital Obstacle File
FAA	Federal Aviation Administration
LBNL	Lawrence Berkeley National Laboratory
OE/AAA	Obstacle Evaluation / Airport Airspace Analysis
USGS	United States Geological Survey
USWTDB	United States Wind Turbine Database

II. ABOUT THE DATABASE:

In 2016, USGS, LBNL, and AWEA began collaborating on development of the USWTDB. Their goal was to create a joint product that would be more comprehensive and accurate than their individual wind turbine data sets. Federal agencies began using these combined data in March 2017, and in April 2018 the data were released to the public.

These data are used by government agencies, scientists, private companies, and citizens for a variety of analyses. Examples include operational impact assessments of turbines on air defense radar, weather and general aviation, analyses related to the role of wind energy in the U.S. electric grid, interactions between wind energy facilities and wildlife, and investments in wind energy infrastructure.

The data were created by combining publicly-available data sets from the Federal Aviation Administration (FAA), USGS data from a prior effort, online sources, and data privately held by AWEA and LBNL. The locations of all turbines are visually verified to within plus or minus 10 meters using high-resolution imagery. Technical specifications data of the turbines are collected from wind energy developers, equipment manufacturers, and from online sources.

III. DATA SOURCES:

Data were added, compiled, and updated in this edition of the US Wind Turbine Database (USWTDB) using the following sources:

- USGS Onshore Industrial Wind Turbine Locations for the United States — Release Date: March, 2014
- LBNL Wind Turbine Database — Release Date: March, 2017
- FAA Digital Obstacle File (DOF) — Release Date: January 2, 2018
- FAA Obstacle Evaluation (OE/AAA) — Release Date: January 6, 2018
- AWEA Q4 2018 Wind Turbine Dataset — Release Date: January 26, 2018
- USGS Visual Verification (satellite imagery) — Date: February, 2018

Memo

Codebook

field	category	description	type	non-missi	Min	Median	Max
case_id	id	unique uswtdb id	long	57636	3000001	3037291	3083470
faa_ors	id	faa digital obstacle file (dof) for obstacle repository syste	str9	48712	n/a	n/a	n/a
faa_asn	id	faa obstruction evaluation - airport airspace analysis (oe	str17	49024	n/a	n/a	n/a
usgs_pr_id	id	usgs id from prior turbine dataset	long	43429	1	27111	49135
t_state	location	state where turbine is located	str2	57636	n/a	n/a	n/a
t_county	location	county where turbine is located	str31	57636	n/a	n/a	n/a
t_fips	location	state and county fips where turbine is located	str5	57636	n/a	n/a	n/a
p_name	project characteristic	project name	str42	57636	n/a	n/a	n/a
p_year	project characteristic	year project became operational	int	57523	1981	2009	2018
p_tnum	project characteristic	number of turbines in project	int	57636	1	84	1846
p_cap	project characteristic	project capacity (MW)	double	54610	0.05	126	495.01
t_manu	turbine characteristic	turbine original equipment manufacturer	str31	54413	n/a	n/a	n/a
t_model	turbine characteristic	turbine model	str18	53541	n/a	n/a	n/a
t_cap	turbine characteristic	turbine capacity (kW)	int	54959	40	1650	6000
t_hh	turbine characteristic	turbine hub height (meters)	double	51431	18.2	80	116.5
t_rd	turbine characteristic	turbine rotor diameter (meters)	double	52499	11.0	87.0	150
t_rsa	turbine characteristic	turbine rotor swept area (meters^2)	double	52499	95.03	5944.68	17671.46
t_ttlh	turbine characteristic	turbine total height - calculated (meters)	double	52334	9.1	123.1	181.1
t_conf_atr	turbine characteristics qa/qc	turbine characteristic confidence (0-3)	byte	57636	0	3	3
t_conf_loc	visual inspection qa/qc	location confidence (0 -3)	byte	57636	1	3	3
t_img_date	visual inspection info	date of image used to visually verify turbine location	int	32649	n/a	n/a	n/a
t_img_srce	visual inspection info	source of image used to visually verify turbine location	str16	57623	n/a	n/a	n/a
xlong	location	longitude (decimal degrees - NAD 83 datum)	double	57636	-171.7131	-100.2981	144.7227
ylat	location	latitude (decimal degrees - NAD 83 datum)	double	57636	13.3894	37.7694	66.8399

Outline Of The Presentation

1. Project Background
2. Database Management
3. Visual Verification
4. Website and Viewer Demo

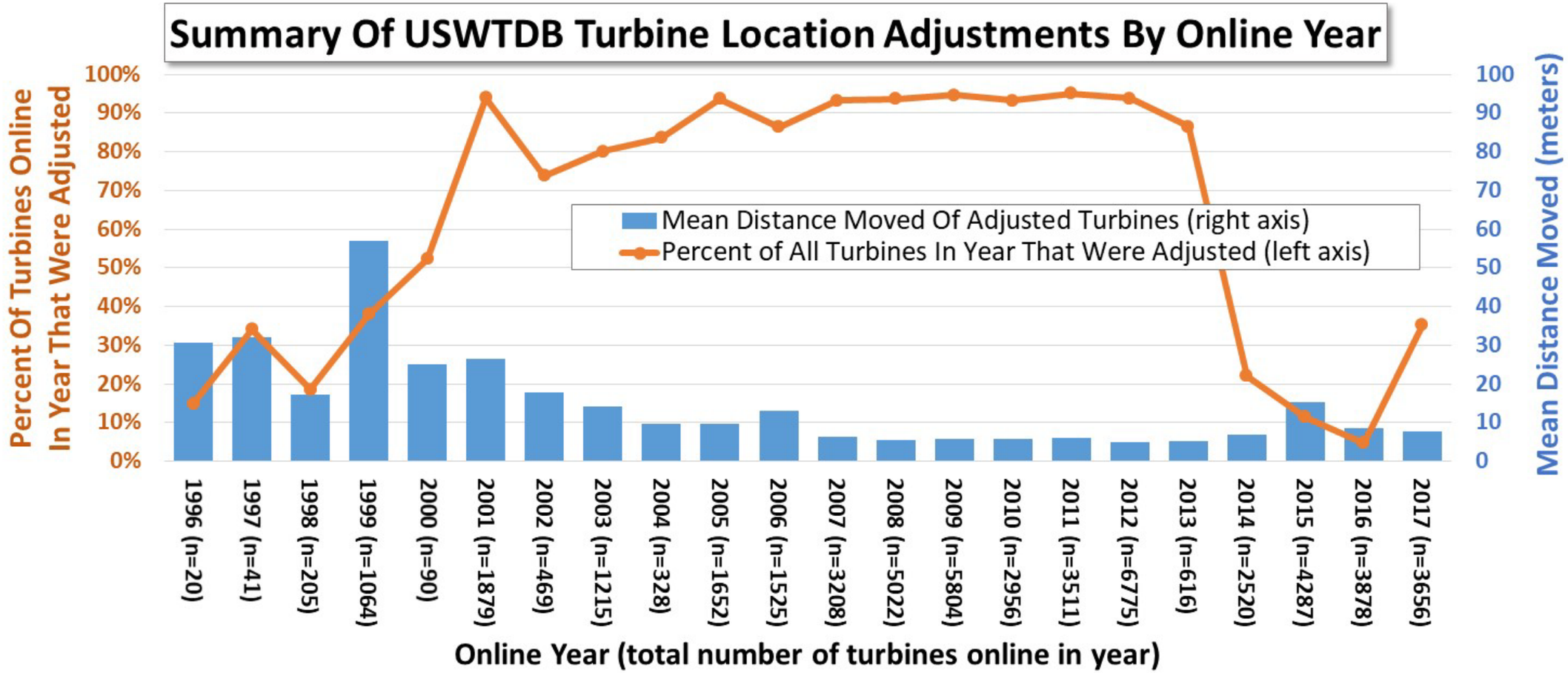
Visual Verification

- Visual Verification Types
  - ❑Already Completed
  - ❑Moved
  - ❑Added
  - ❑Removed
    - Duplicates or Extra Data Points
    - Not a turbine
    - Small (less than 65 kW and blade size less than 30 meters)
    - Dismantled
- Imagery Types and Access
- Confidence of Location

Already Completed – Visually Checked In Previous USGS Data

Moved

Distance Moved Summary Statistics



Note: Figure includes adjustments made to turbines in legacy USGS database, and which were incporporated into the USWTDB. Comparison is made between final location and that of the FAA DOF file, and excluding any adjustments of <1 meter or > 300 meters.

Added

Extra Points Removed

Quarter	Number of Extras Removed
Q2-2017	730
Q3-2017	3,100
Q4-2017	2,861
Q1-2018	4,716
Total	11,407

Removed – Mismarked and Residential

Data that were not a wind turbine such as water pump with a small windmill.

Turbines that are smaller than 65 kW and blade size less than 30 meters.

Removed - Dismantled

118°14'18.925"W 35°12'29.857"N, California

Imagery Types

1. *Bing Maps Aerial - ESRI ArcMap Base maps, available from ESRI ArcMap*
2. *Google Earth - Available from Google*
3. *NAIP - National Agriculture Imagery Program County Mosaics from https://datagateway.nrcs.usda.gov/*
4. *USGS EDC SDDS - SGS Seamless Data Distribution System (SDDS) orthoimagery from internal USGS EROS Data Center Servers*
5. *Digital Globe - Digital Globe EV WebHosting Imagery from evwhs.digitalglobe.com*

Location Confidence

Location Confidence t_conf_loc	Definition
0	Not been visually verified (yet).
1	Turbine was not seen on image.
2	Turbine was in partial construction, image shows developed pad with base and/or turbine parts on ground.
3	Turbine clearly seen.

Confidence = 2 And Confidence = 3

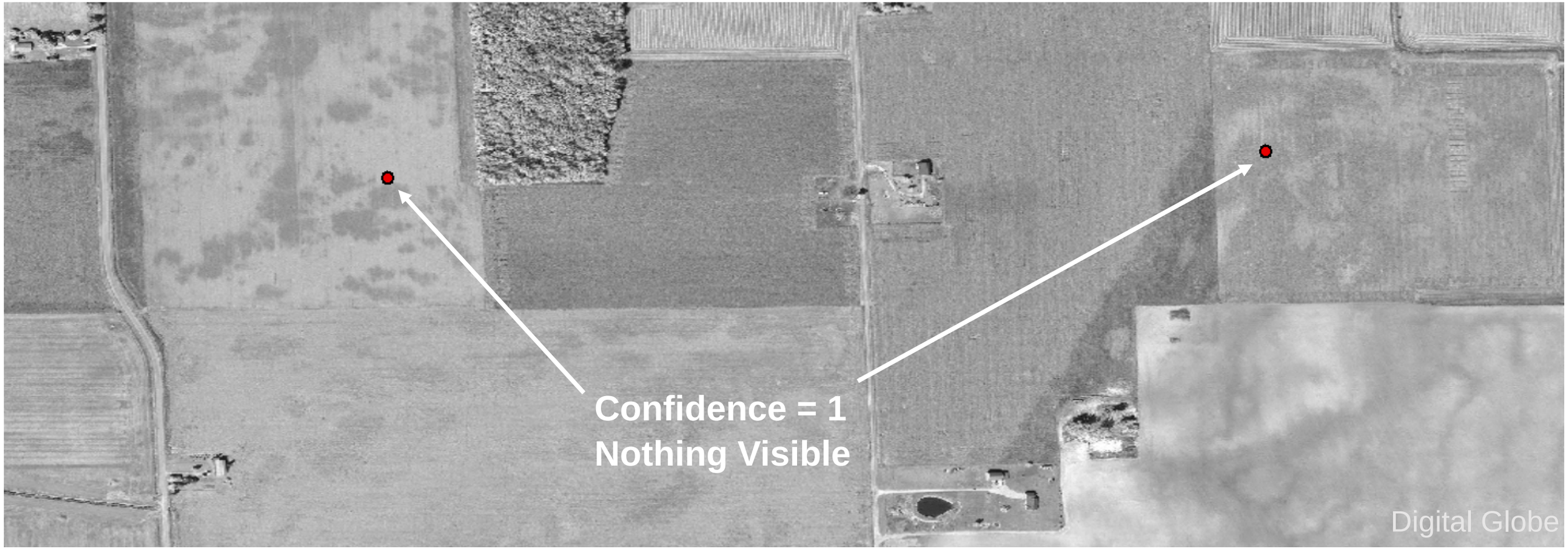
101°1'4.506"W 32°54'20.779"N in Texas

Confidence = 2

84°58'13.888"W 40°17'54.855"N Indiana

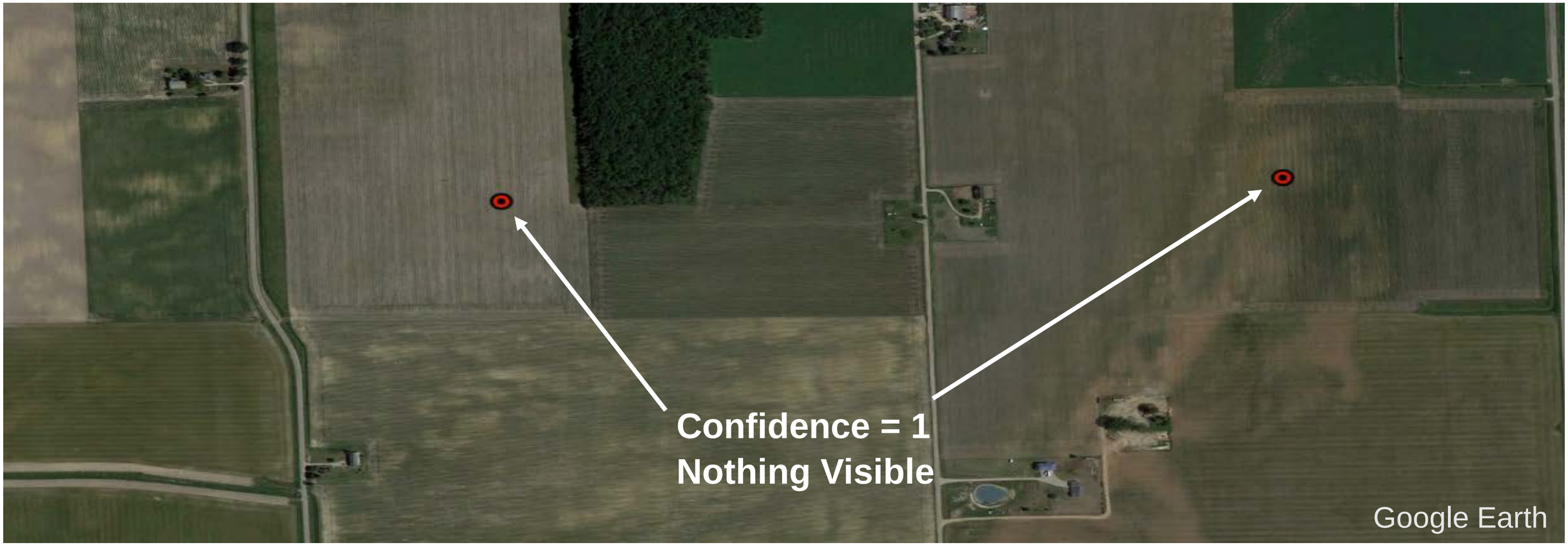
Confidence = 1 (Digital Globe)

(83°24'13.358"W 43°39'49.307"N) in Michigan. 9/3/2016 DG Image Date. 2/15/18 Access Date



Confidence = 1 (Google Earth)

(83°24'13.358"W 43°39'49.307"N) in Michigan. 6/23/2016 GE Image Date. 4/17/18 Access Date



Confidence = 3

(83°24'13.358"W 43°39'49.307"N) in Michigan. 3/24/2018 DG Image Date. 4/17/18 Access Date

In General, Cloud Cover (depending on coverage) is not available to the general population.

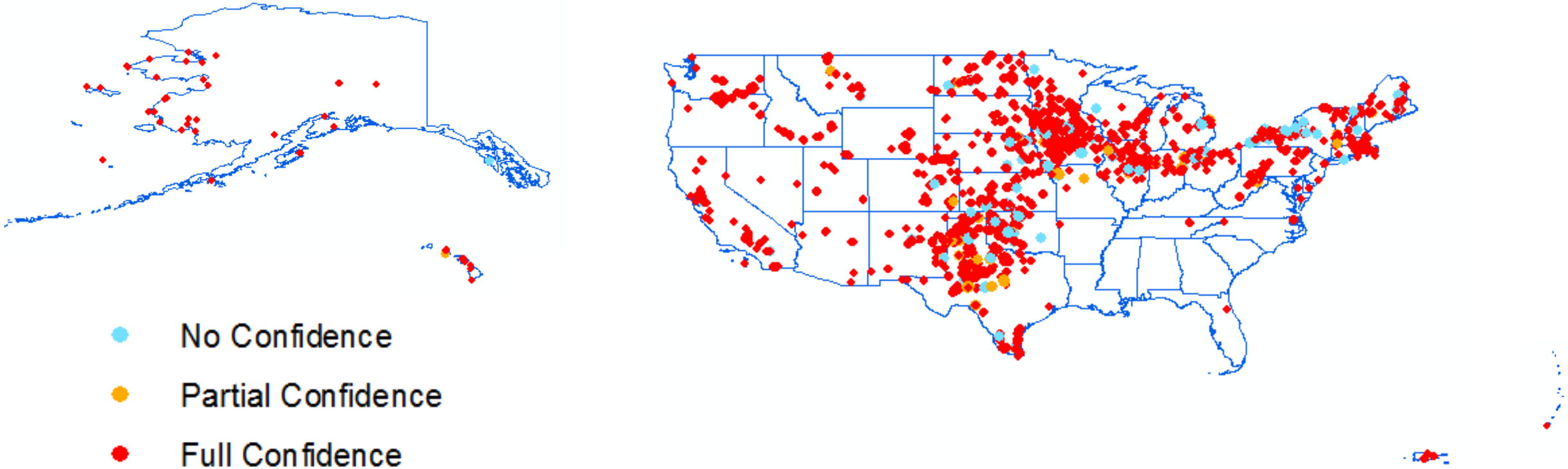
Location Confidence - April 2018 Status

Location Confidence t_conf_loc	Definition	Status April 2018	
		Number	Percent
0	Not been visually verified (yet).	NONE	0%
1	Turbine was not seen on image.	920	1%
2	Turbine was in partial construction, image shows developed pad with base and/or turbine parts on ground.	1159	2%
3	Turbine clearly seen.	55,557	96%

Visual Verification - April 2018 Status

USWTDB has 57,636 turbines (April 2018 release)

All of them looked at by a human!



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Questions?

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Email the USWTDB Team at: uswtdb@lbl.gov

Link to USWTDB: https://eerscmap.usgs.gov/uswtdb