Practical, real-time weather data interoperability: the National Mesonet Program
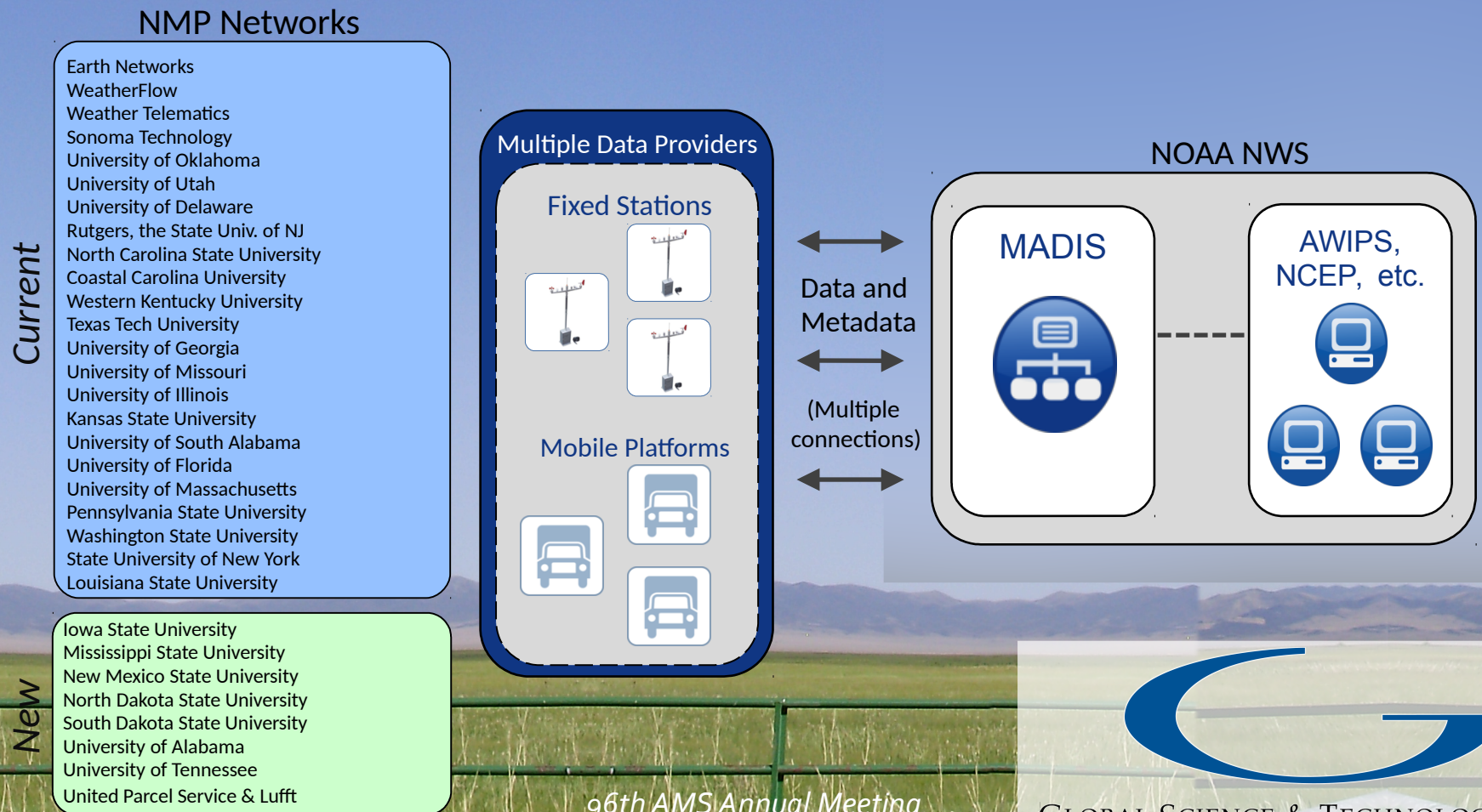
John Evans, Brian Werner, and Paul Heppner
GST, Inc.

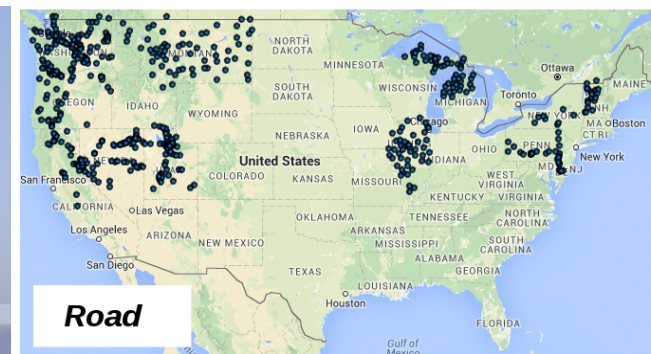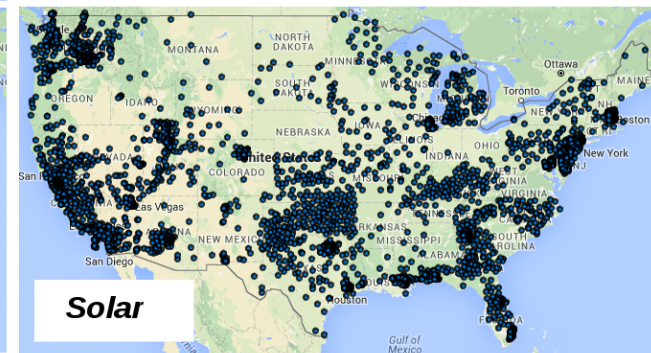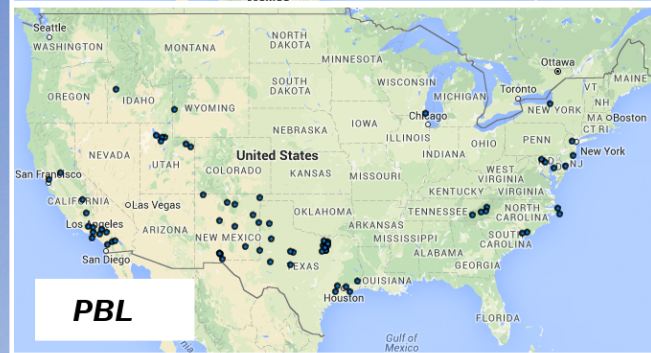GLOBAL SCIENCE & TECHNOLOGY, INC.
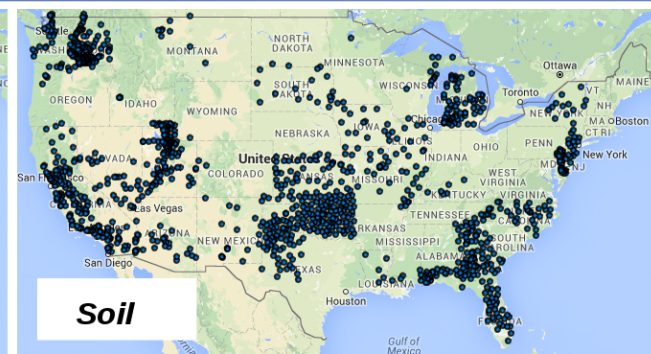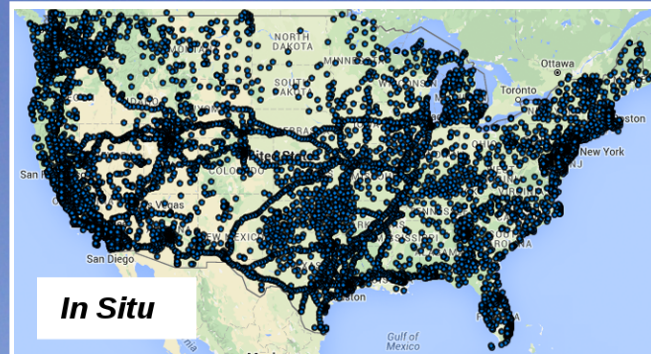
NMP, MADIS

The **National Mesonet Program (NMP)** brings non-federal data sources into the **Meteorological Assimilation Data Ingest System (MADIS)** of the National Weather Service, for use in operational weather forecasting and numerical modeling.

NMP Networks

Current

Earth Networks
WeatherFlow
Weather Telematics
Sonoma Technology
University of Oklahoma
University of Utah
University of Delaware
Rutgers, the State Univ. of NJ
North Carolina State University
Coastal Carolina University
Western Kentucky University
Texas Tech University
University of Georgia
University of Missouri
University of Illinois
Kansas State University
University of South Alabama
University of Florida
University of Massachusetts
Pennsylvania State University
Washington State University
State University of New York
Louisiana State University

New

Iowa State University
Mississippi State University
New Mexico State University
North Dakota State University
South Dakota State University
University of Alabama
University of Tennessee
United Parcel Service & Lufft

Multiple Data Providers

Fixed Stations

Mobile Platforms

Data and Metadata

(Multiple connections)

NOAA NWS

MADIS

AWIPS, NCEP, etc.

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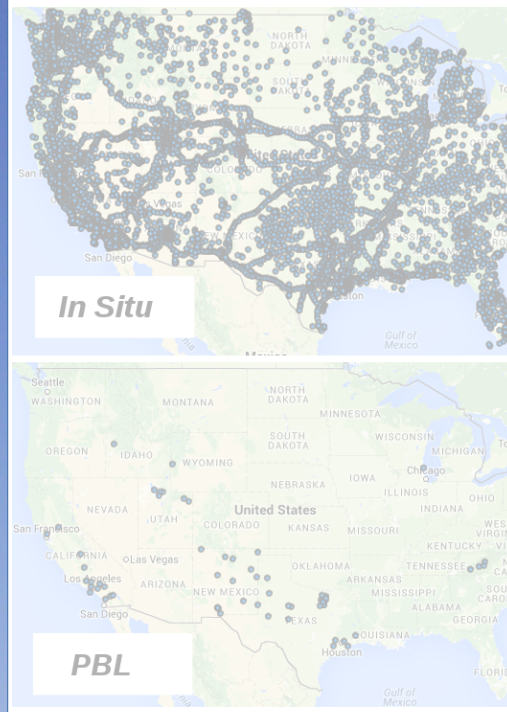
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Overview:
Fixed weather stations

GST's 28+ National Mesonet partners provide over a million observations per day from 8,000+ fixed surface weather stations throughout the conterminous United States.

In Situ

Soil

PBL

Solar

Road

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Overview:
Fixed weather stations

GST's 28+ National Mesonet partners provide over a million observations per day from 8,000+ fixed surface weather stations throughout the conterminous United States.

In Situ

PBL

| Provider	In Situ	Soil	Solar	PBL	Road
Coastal Carolina Univ.	6	1	1	2	0
Earth Networks UrbaNet	1485	0	1485	9	0
Iowa State Univ.	17	17	17	0	0
Kansas State Univ.	69	52	69	0	0
Louisiana State Univ.	9	9	9	0	0
Mississippi State Univ.	11	11	11	0	0
New Mexico State Univ.	12	12	12	0	0
North Carolina State Univ.	39	39	39	0	0
North Dakota State Univ.	82	82	82	0	0
Pennsylvania State Univ.	73	0	43	0	22
Rutgers	60	16	36	0	0
Sonoma Technology	835	0	283	26	0
South Dakota State Univ.	24	19	24	0	0
State Univ. of New York	14	14	14	1	0
Texas Tech Univ.	92	72	92	6	0
Univ. of Alabama - Huntsville	16	0	0	0	0
Univ. of Delaware	77	31	49	1	0
Univ. of Florida	41	41	41	0	0
Univ. of Georgia	80	80	80	0	0
Univ. of Illinois	19	19	19	0	0
Univ. of Massachusetts	0	0	0	8	0
Univ. of Missouri	30	28	29	0	0
Univ. of Oklahoma	123	123	123	0	0
Univ. of South Alabama	28	28	28	0	0
Univ. of Utah	4482	451	1126	8	517
Washington State Univ.	166	166	166	0	0
WeatherFlow	369	0	0	7	0
Western Kentucky Univ.	67	6	67	0	0
TOTAL	8326	1317	3945	68	539

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Overview:
Mobile weather stations

Mobile Platform Environmental Data (MoPED): Calibrated vehicle-mounted sensors report roadway weather conditions every 10 seconds.
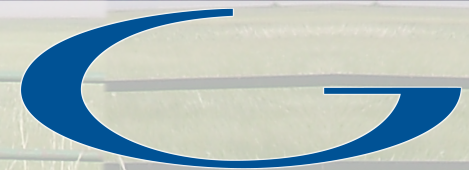
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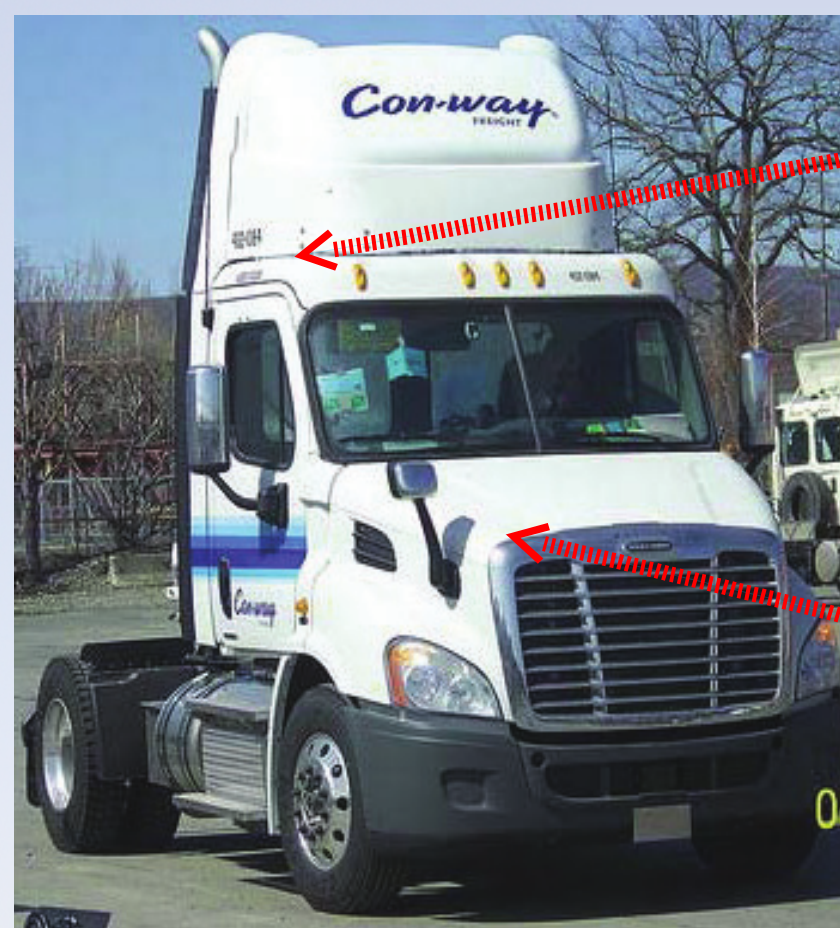
Overview:
Mobile weather stations

Nearly 1 million mobile observations are reported each (week)day.
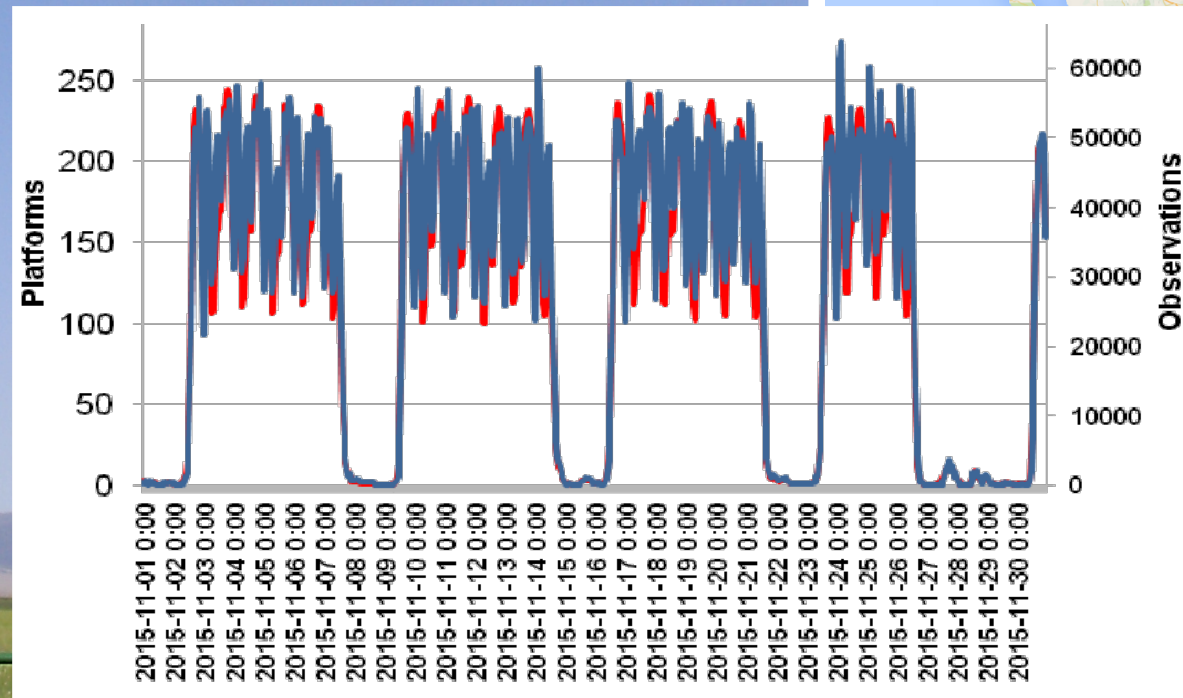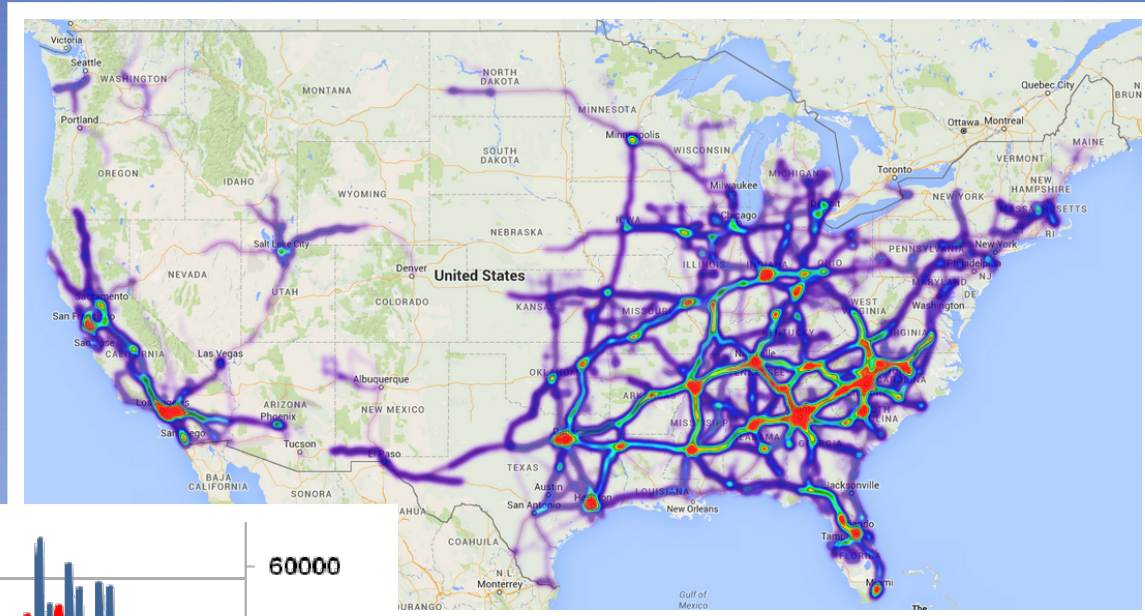
"Heatmap" of monthly mobile observations (Oct. 2015).

"Heartbeat" of hourly mobile observations (Nov. 2015).

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Need for standards

Legacy data feeds

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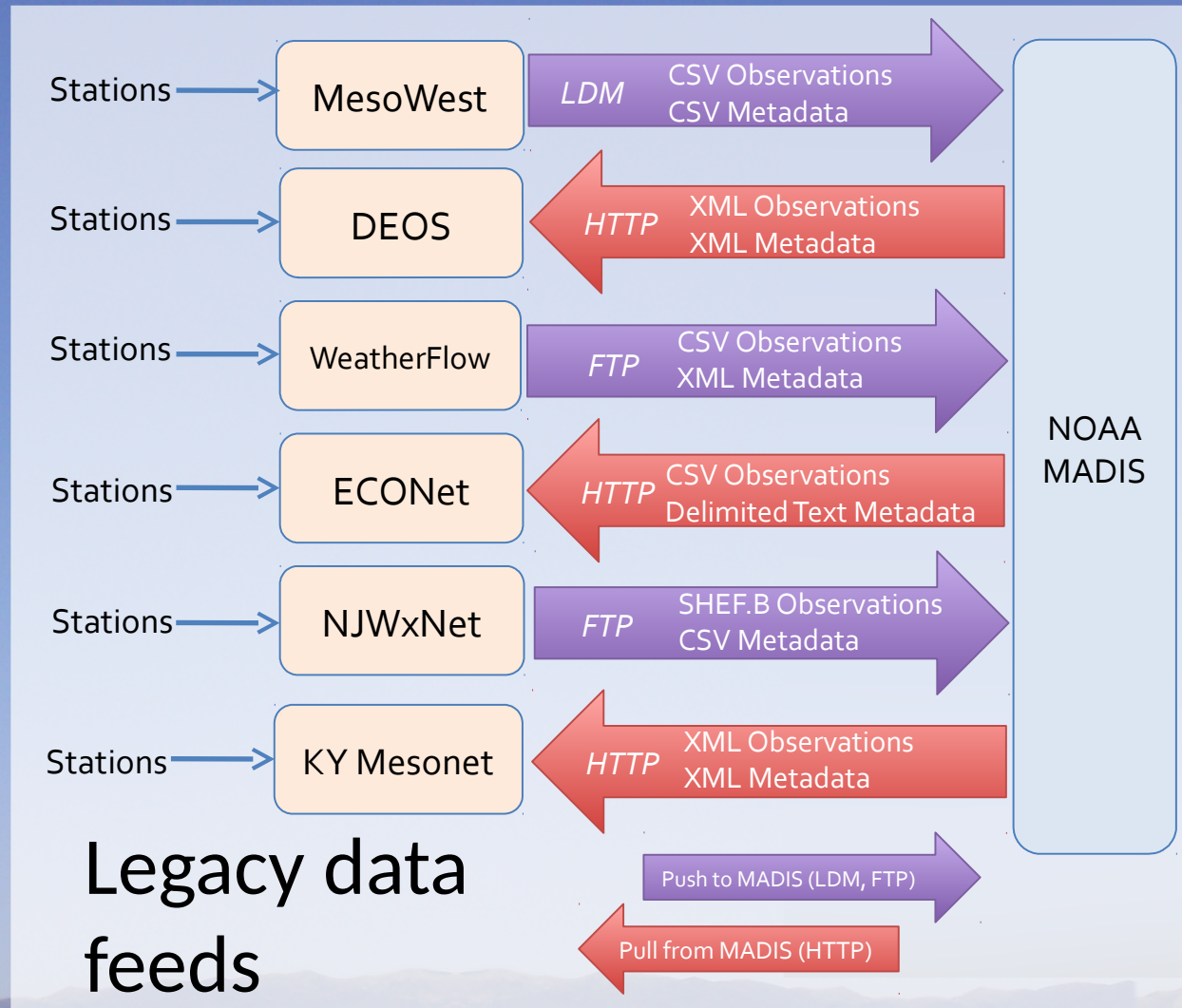
Need for standards

- Needed to link thousands of stations maintained by disparate entities (gov't, businesses, universities, etc.)

- Most of these provided only minimal metadata on sensors and stations

- New, consistent formats would facilitate

  – enhanced observational data and metadata,

  – standardized processing, and

  – participation by new networks.

- Lightweight solutions were needed for real-time data feeds and large-scale analytics

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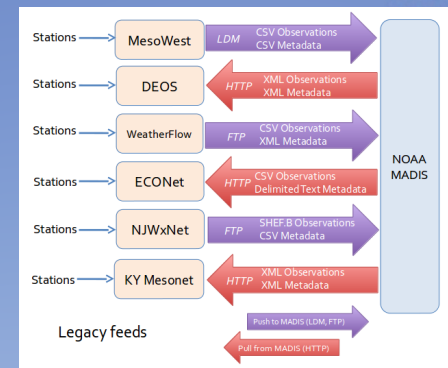
Data / metadata standards evolution

- ***Observations:*** ASCII Comma-Separated Values **(CSV)** with conventions derived from the Integrated Ocean Observing System **(IOOS)**

- ***Metadata*** *(sensor & station details)***: StarFL**, an XML schema inspired by the Sensor Markup Language of the Open Geospatial Consortium (OGC)

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Data / metadata standards evolution:
IOOS-based CSV for Observations

- **Header row** states units of measure for each attribute

- **Positive height** is above ground (*vs.* IOOS' depth in water)

```
Station_id, LAT [deg N], LON [deg E], date_time, ELEV [m], T[C], RH [%], P
   [mb], height [m] # FF [m/s] # DD [deg] # FFGUST [m/s] # DDGUST [deg],
   PCPTOTL [in], SOLRAD [W/m^2], SOILT [C], SOILMP [%], PAR [W/m^2]
AURO, 35.36232, -76.7163, 2012/01/04 11:00:00, 1.2, 0.3, 37.2, 1028.5, 10;2
   # 0.859; 1.6 # 241.3; 249 # 2.176; # ; , 0,553.2, 2.535, 0.31, 919
BEAR, 35.46135, -82.35822, 2012/01/04 11:00:00, 1286, -0.3, 12.3, 875.3,
   10; 2 # 5.281; 0 # 5.919; # 288.8; 0, 0, 510.7, -0.233, 0.219, 933
BOON, 36.2214, -81.6295, 2012/01/04 11:00:00, 99, 1.8, 3.234, 15.81, 907,
   10; 2 # 1.313; # ; # 208.4; , 0, 0, 0.754, 0.378, 764
BUCK, 36.46955, -76.7609, 2012/01/04 11:00:00, 7.6, 0, 36.7, 1026.5, 10; 2
   # 2.803; 2.6 # 3.508; # 221.6; 241, 0, 415, 3.737, 0.439, 881
CAST, 34.32107, -77.91611, 2012/01/04 11:00:00, 13.1, 1.8, 35.3, 1028.6,
   10; 2 # 2.984; 2.1 # 3.312; # 349.2; 6, 0, 521.3, 5.115, 0.232, 994
```

Example CSV observation data

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Data / metadata standards evolution:
IOOS-based CSV for Observations

- **Nested fields** use additional delimiters for array-valued attributes (e.g. windspeeds at multiple heights)

```
Station_id, LAT [deg N], LON [deg E], date_time, ELEV [m], ... ,
  height [m] # FF [m/s] # DD [deg] # FFGUST [m/s] # DDGUST [deg], ...
AURO, 35.36232, -76.7163, 2012/01/04 11:00:00, 1.2, ... ,
  10 ; 2 # 0.859 ; 1.6 # 241.3 ; 249 # 2.176 ; # ; , ...
```

height [m]	FF [m/s]	DD [deg]	FFGUST [m/s]	DDGUST [deg]
10	0.859	241.3	2.176	null
2	1.6	249	null	null
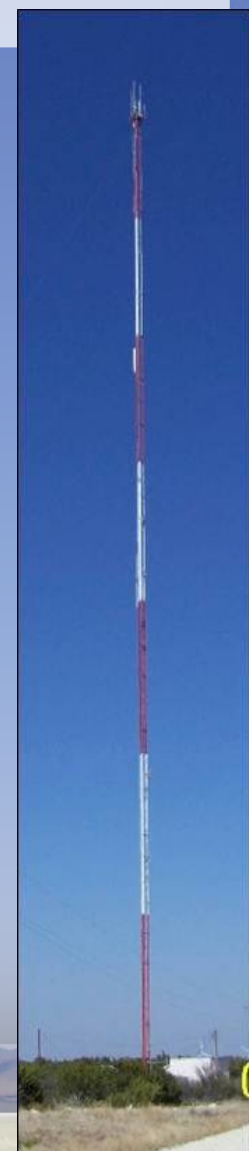
Data / metadata standards evolution: StarFL for Metadata

Dynamic elements (*Platform*, *SensorDeployment*) maintained by providers
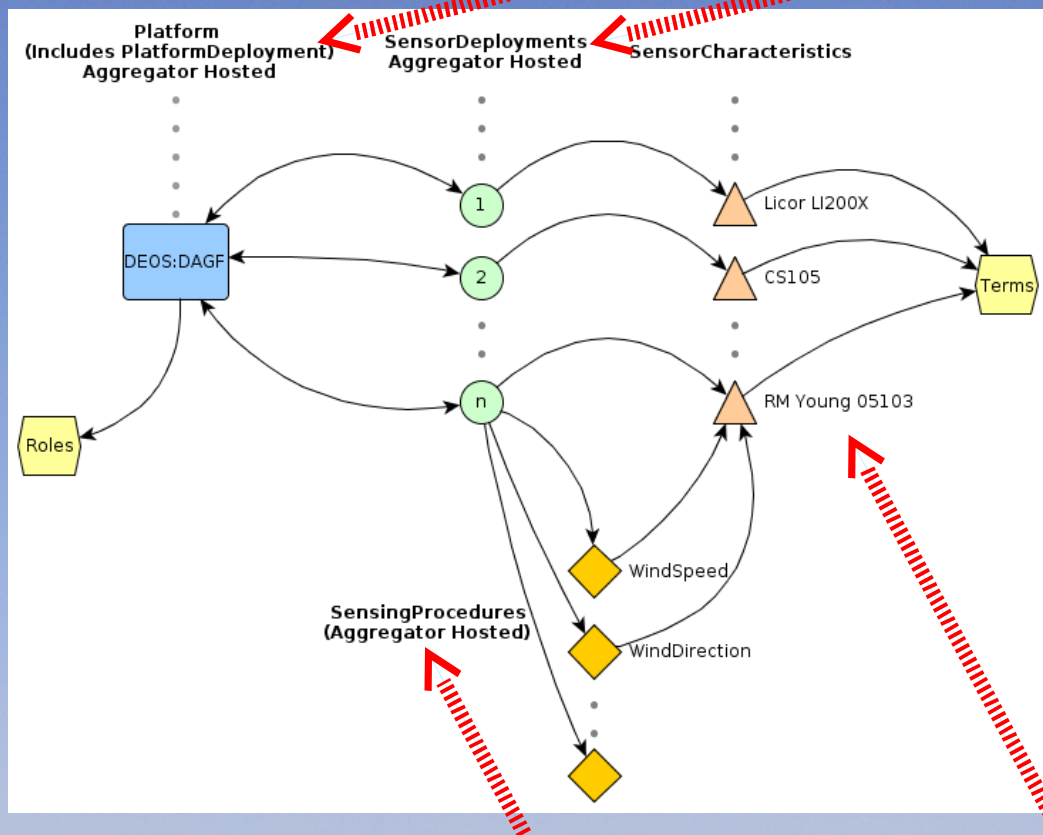

```
...
sfl:operationalComponent>
    <swe:QuantityRange
    definition="http://sawi.gst.com/nmpa/docs/terms.h
    tml#operatingTemperature">
        <swe:uom code="Cel"/>
        <swe:value>-52.0 60.0</swe:value>
    </swe:QuantityRange>
</sfl:operationalComponent>
<sfl:operationalComponent>
    <swe:QuantityRange
    definition="http://sawi.gst.com/nmpa/docs/terms.h
    tml#storageTemperature">
        <swe:uom code="Cel"/>
        <swe:value>-60.0 70.0</swe:value>
    </swe:QuantityRange>
</sfl:operationalComponent>
<sfl:operationalComponent>
    <swe:QuantityRange
    definition="http://sawi.gst.com/nmpa/docs/terms.h
    tml#operatingVoltage">
        <swe:uom code="V"/>
        <swe:value>5.0 32.0</swe:value>
    </swe:QuantityRange>
</sfl:operationalComponent>
...
```
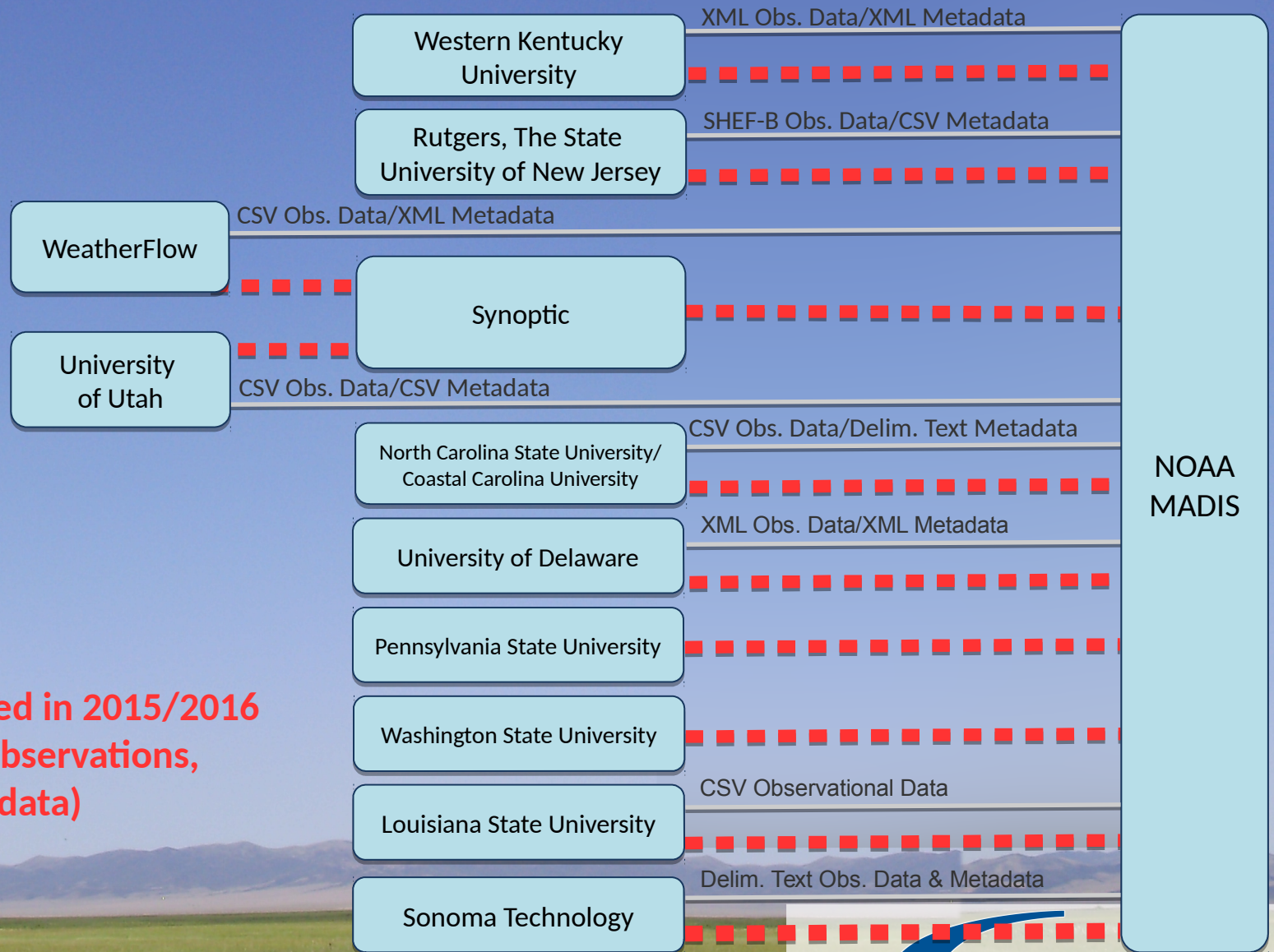
Static elements (*SensorProcedure, SensorCharacteristics*) hosted by GST and shared

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Migration to operational data feeds

Western Kentucky University

XML Obs. Data/XML Metadata

Rutgers, The State University of New Jersey

SHEF-B Obs. Data/CSV Metadata

WeatherFlow

CSV Obs. Data/XML Metadata

Synoptic

University of Utah

CSV Obs. Data/CSV Metadata

North Carolina State University/ Coastal Carolina University

CSV Obs. Data/Delim. Text Metadata

University of Delaware

XML Obs. Data/XML Metadata

Pennsylvania State University

Washington State University

Louisiana State University

CSV Observational Data

Sonoma Technology

Delim. Text Obs. Data & Metadata

NOAA MADIS

—— **Legacy feed**

▪ ▪ ▪ **Standard feed in 2015/2016 (IOOS CSV observations, StarFL metadata)**

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Challenges & lessons learned

- CSV files can do the job
  - Low bandwidth; small file sizes
  - Can be read by commodity software (Excel, R, MySQL, etc.)
  - Risk: implicit information (definitions, links, etc.)
  - Future extensibility may require JSON or XML encodings
- StarFL metadata: challenging but rewarding
  - The XML schema had a learning curve, but is very extensible
  - Separating static from dynamic elements allows concise encodings, shared resources, and local responsibility
  - StarFL has helped & encouraged providers to supply more complete and consistent metadata

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