

Using Python to Store, Display, and Analyze Pressure Observations from Earthscope's USArray Network

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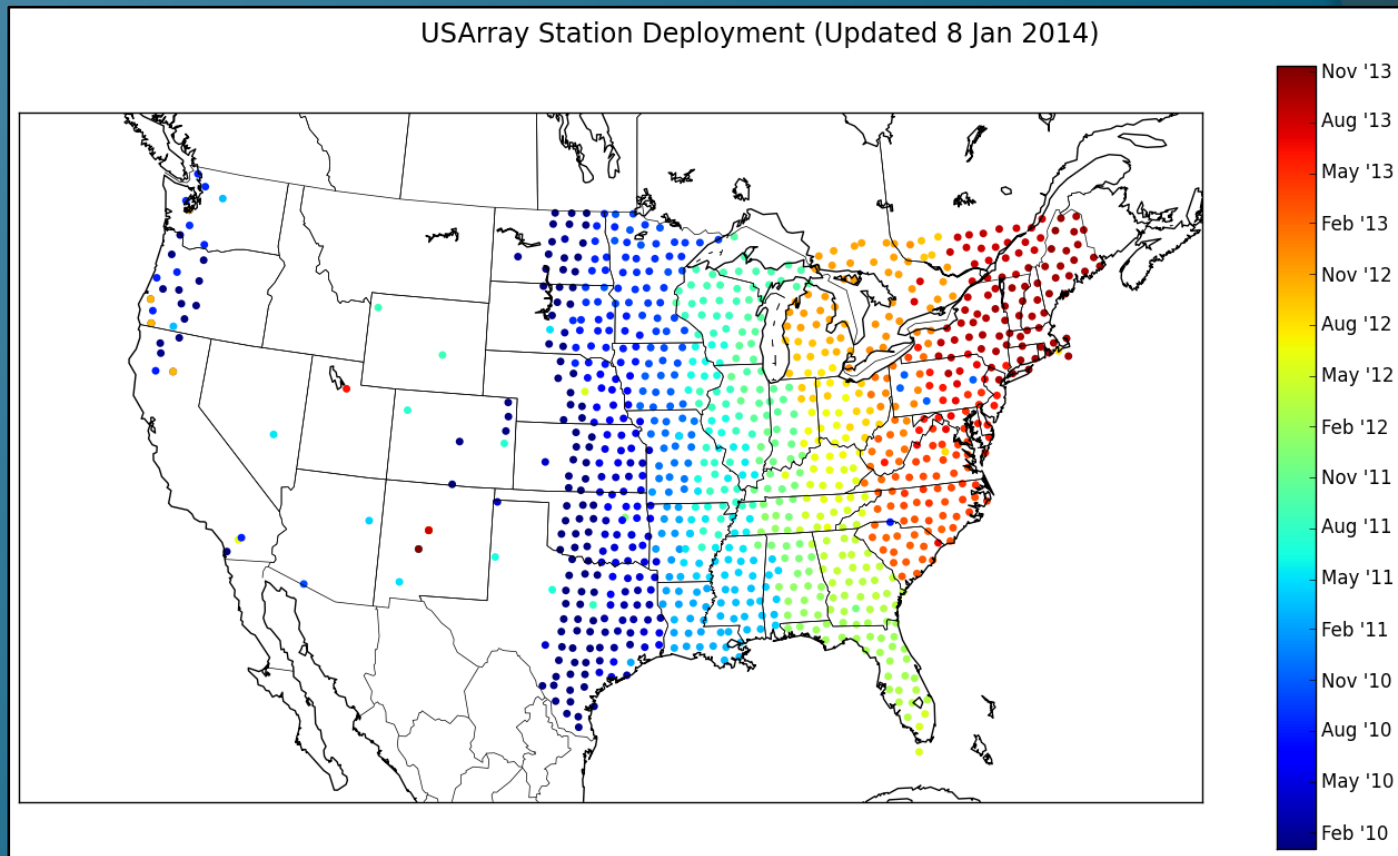
Atlanta, GA

February 3, 2014



What is the US Transportable Array (USArray)?

- EarthScope-funded project of ~ 400 seismic stations traversing across the CONUS in an effort to catalogue and study seismic activity
- Stations outfitted with microbarometers in 2010 (1 Hz reporting frequency)



Project Objectives

- Improve access for the atmospheric science community to both real-time and archived pressure observations through displays and other web-based products at varying sample intervals (1-second, 5-minute, etc.)
- Develop and analyze climatologies at each observing site of pressure perturbations and signatures in terms of frequency and amplitude
- Examine pressure perturbations and perturbation gradients in the context of local, mesoscale, and synoptic-scale flows (waves, terrain-flow interactions, thermally-forced systems, etc.)

Motivation for Use of Python

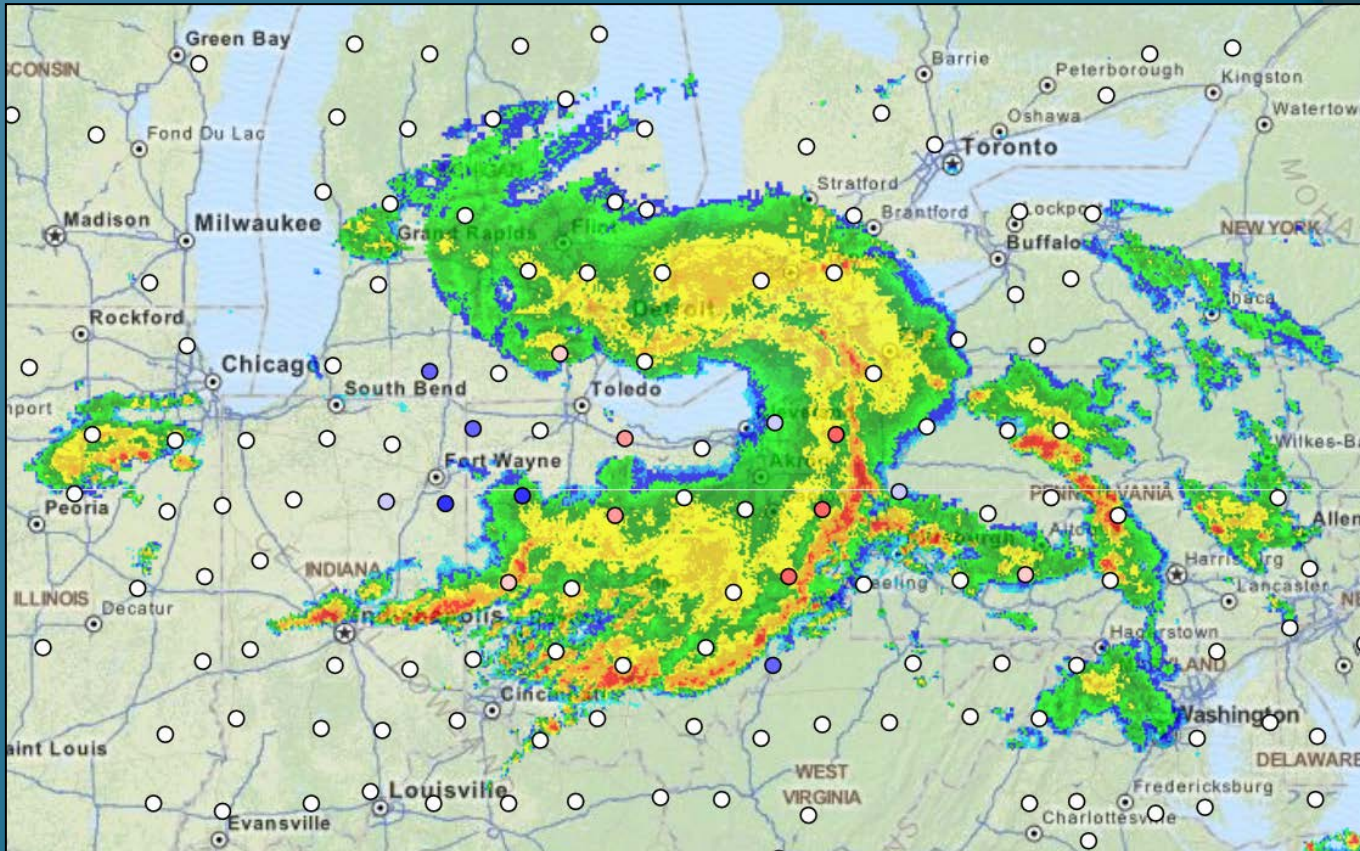
- USArray pressure dataset provides a unique opportunity to catalogue meteorological events at multiple spatial and temporal scales
 - Semi-regular station spacing (~ 70 km between locations)
 - 1 Hz temporal resolution
 - Station deployment ~ 1.5 -2 years
- Python chosen due to its numerous advantages in the following areas...
 - Storage and querying of large arrays of data
 - Object-oriented nature for fast manipulating
 - Time series filtering procedures
 - Leveraging of interactive web displays

Python for USArray Data Storage

- Dataset produces a number of challenges due to its large size, spatial irregularities (non-gridded), and temporal irregularities
- PyTables chosen as mechanism to store observations in two “databases” based on station and time in compressed HDF5 format
- Database #1: Individual station tables of all observations
 - Level-7 Zlib compression
 - New data appended on a daily basis
 - Statistics from 1 Jan 2010 – 31 Dec 2013
 - Total observations: 46,086,051,637
 - Disk Space Used: 58 GB
 - **~1.26 bytes per observation (time, station, value)**

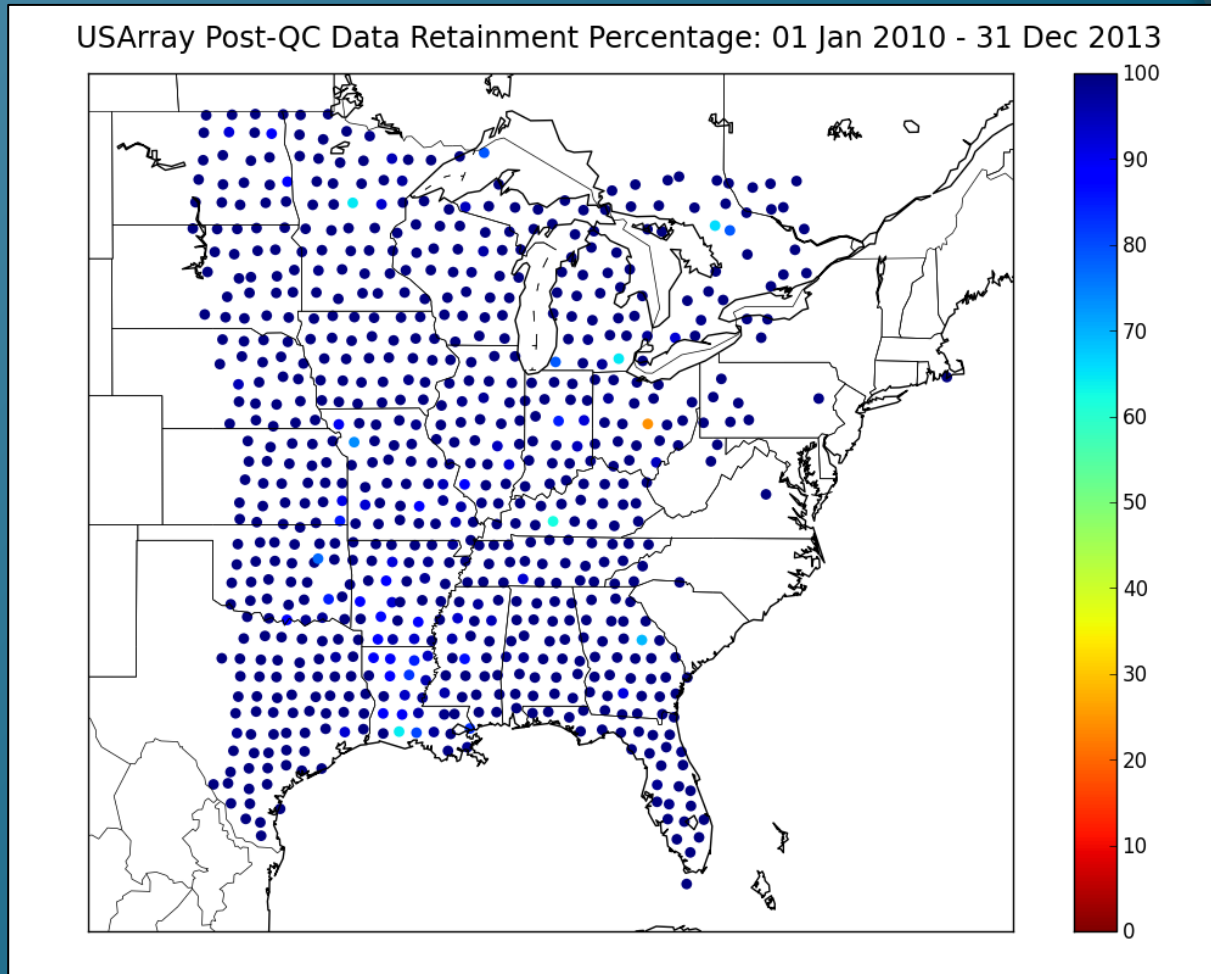
Python for USArray Data Storage

- Database #2: Daily files of all active USArray Stations
 - Nested tables used to store data in pseudo-gridded format
 - Supplemental metadata schema used to leverage dataset onto maps



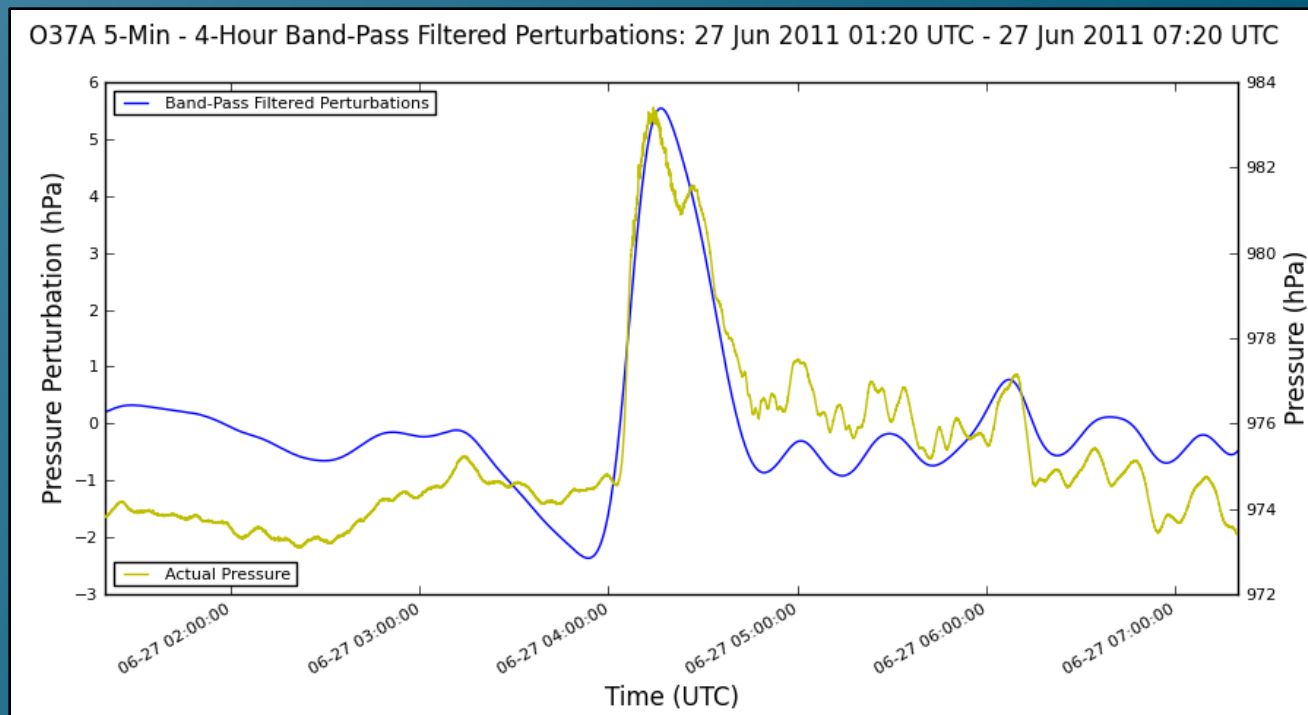
Python for USArray Data Analysis

- Quality Control: the ability of NumPy to efficiently parse large data arrays aided significantly in identifying missing/spurious data periods



Python for USArray Data Analysis

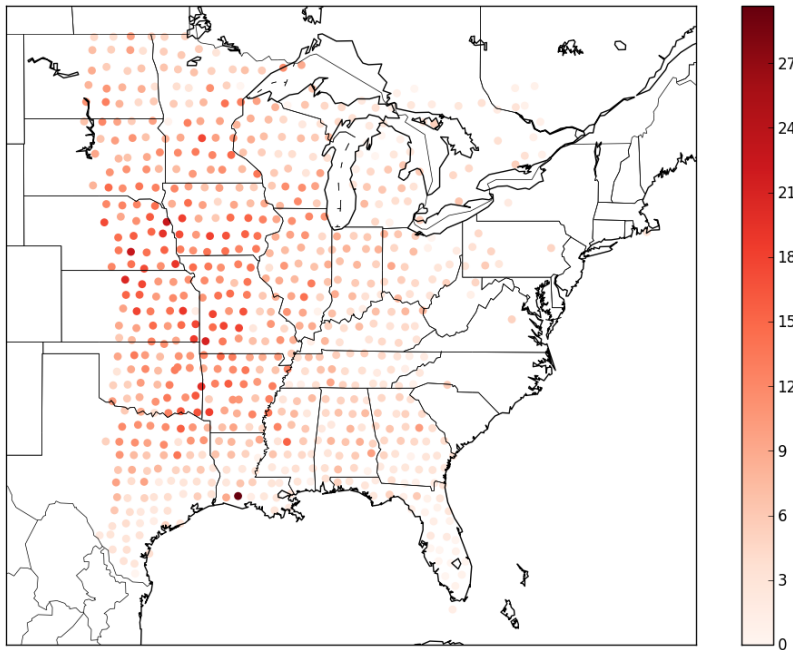
- Mesoscale/Synoptic Pressure Signature Identification Algorithms
 - SciPy Butterworth filtering techniques applied to generate perturbation time series from the original time series data
 - Large pressure signatures identified using local min/max functions



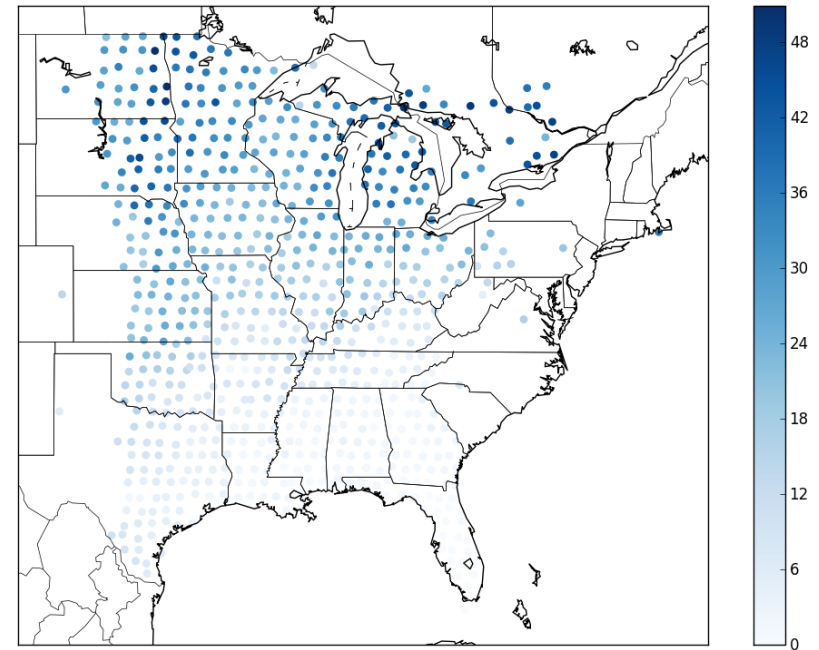
Python for USArray Data Analysis

- Descriptive quantities of the pressure signature fields stored in HDF5 PyTables file for fast querying based on user-defined preferences

Mesoscale Signatures (events per year ≥ 10.0 hPa/hr): 01 Jan 2010 - 31 Dec 2013

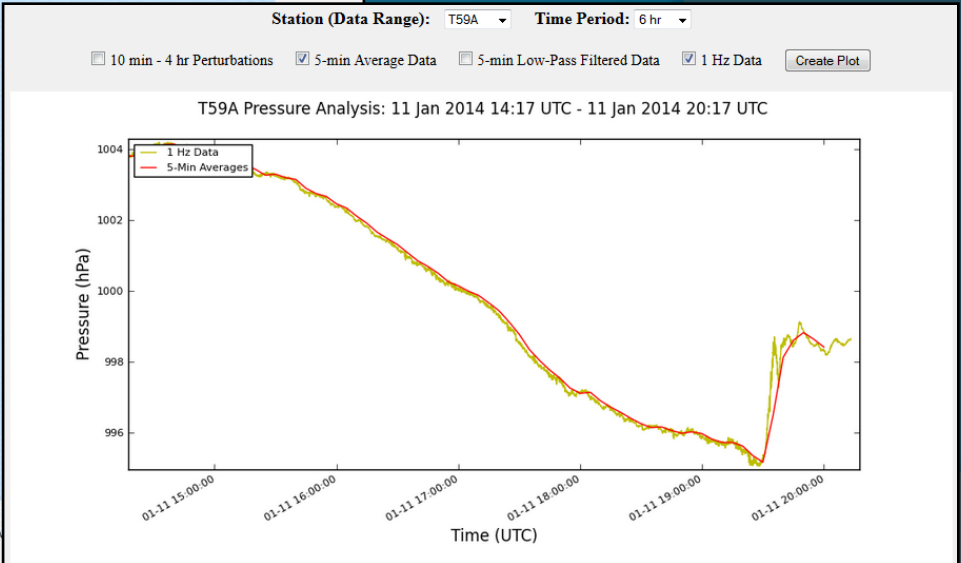
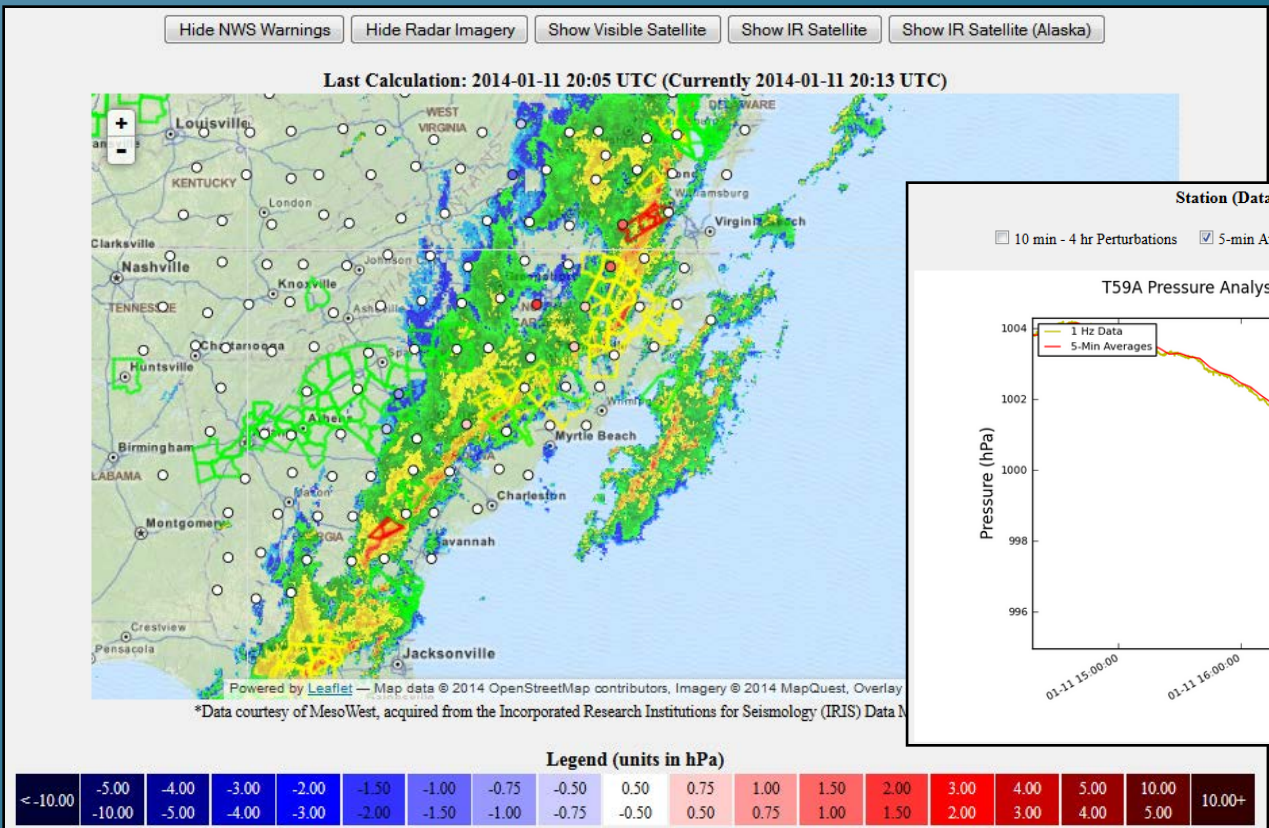


Synoptic Signatures (events per year ≥ 0.5 hPa/hr): 01 Jan 2010 - 31 Dec 2013



Python for USArray Web Displays

- Website (<http://meso1.chpc.utah.edu/usarray>) uses Python in conjunction with JQuery and Leaflet to generate interactive maps and plots



Python for USArray Web Displays

- Real-time displays utilize 5-minute observations courtesy of MesoWest (<http://mesowest.utah.edu>). MesoWest data is also forwarded onto MADIS.

Home Real-Time Maps Last 24 Hours Map Archive Data Archive Climatology

Perturbations
Pressure Tendency
array Real-Time Mesoscale Perturbations

This page displays real-time mesoscale pressure perturbations calculated for active USArray stations. For each station, a time series of pressure observations is filtered to remove large-scale trends, leaving behind perturbations on the timescale of 10 minutes to 4 hours. Magnitude perturbation values typically indicate variations in pressure associated with convection, gravity waves, and other phenomena. However, due to the real-time nature of the filtering, some aliasing of other phenomena such as the diurnal and semi-diurnal cycles may be included in the calculations if benign conditions are occurring at the station.

Values are in hPa, with **blue** indicating negative perturbations with respect to the mean pressure field, **red** indicating positive perturbations.

Click on the map below for station IDs, perturbation magnitudes, and links to graphical products.
 Current radar, satellite, and NWS watches/warnings can also be shown or hidden using the buttons below.

Last Calculation: 2014-01-21 18:05 UTC (Currently 2014-01-21 18:18 UTC)

Powered by [Leaflet](#) — Map data © 2014 OpenStreetMap contributors, Imagery © 2014 MapQuest, Overlay data © 2014 Iowa Environmental Mesonet
 *Data courtesy of MesoWest, acquired from the Incorporated Research Institutions for Seismology (IRIS) Data Management Center (DMC)

Legend (units in hPa)

<-10.00	-5.00	-4.00	-3.00	-2.00	-1.50	-1.00	-0.75	-0.50	0.30	0.75	1.00	1.50	2.00	3.00	4.00	5.00	10.00	10.00+
-10.00	-3.00	-4.00	-3.00	-2.00	-1.50	-1.00	-0.75	-0.30	0.50	0.75	1.00	1.50	2.00	3.00	4.00	5.00	10.00	10.00+

MesoWest Graphical Interface Display

Region: Alaska GCA Product: Surface Weather Maps Go

STATION INFO
 ID: H61AX
 NAME: H61A Lyndonville
 LATITUDE: 44.53390
 LONGITUDE: -71.92710
 ELEVATION: 1515 ft
 MNET: USARRAY
 LAND COVER: 2001 USGS
 DATA COURTESY OF:
 Incorporated Research Institutions for Seismology

NEW PRODUCTS
[About New Displays](#)

[Change to Weather Map](#)
[Change to Tabular Display](#)
[Change to Metric Units](#)
[Change to UTC Time](#)
[Change Date/Time](#)

ORIGINAL PRODUCTS
[Original Tabular Display](#)
[Original Graphical Display](#)
[Download Data](#)

Note: This product is currently a beta test version that has been released for use, and additional versions will be forthcoming (see this [Help Section](#) for additional explanation on the beta test products). The MesoWest staff encourage feedback to help make this product better. Comments and suggestions may be posted on the [MesoWest Facebook Page](#).

Primary Parameters: Chart Size: Medium Time Period: Previous 1 Day

Plot #1 Station ID: H61AX Variable(s): Pressure Sensor Options: All Change Graph

H61A Lyndonville (H61AX)

Pressure
 Altimeter



Python for USArray Web Displays

USArray Map Archive Interface

This page provides interactive map analyses utilizing the archived USArray pressure dataset. Options include mesoscale perturbations (usually indicative of convection/gravity waves), synoptic-scale tendency (usually indicative of large storm systems and tropical systems), derived altimeter readings, and pressure changes at intervals of 1 and 3 hours. WSR-88D radar composites are also included on the map, and will reload when a new time is selected using the slide bar. Composites are courtesy of the Iowa Environmental Mesonet.

Markers colored in **blue** indicate negative perturbations or pressure falls while **red** markers indicate positive perturbations or pressure rises.

To choose a different day or a different filter, please use the options given here and click "Change Options".

Year: 2013 Month: 04 Day: 17 Filter Option: Short-term Perturbations Change Options

Utilize the slide bar below to toggle over the entire day. A color legend is displayed below the map.

Valid: 2013-04-17 00:00 UTC

Python for USArray Web Displays

[Home](#) | [e Maps](#) | [Last 24 Hours](#) | [Map Archive](#) | [Data Archive](#) | [Climatology](#)

USArray Mesoscale Pressure Perturbations and Frequencies

[Mesoscale Events](#) | [Event Frequencies](#)

This page provides access to short-term (10-min to 4-hr) pressure rises and falls diagnosed from band-pass filtered perturbation data. The user has options to browse various statistics on the frequency of these signatures at each station over selected time periods, magnitude strength, station availability, etc. Choose different options below and then click "Change Settings".

Begin Time (YYYY/MM/DD): 2010 ▾ 01 ▾ 01 ▾ End Time (YYYY/MM/DD): 2013 ▾ 12 ▾ 31 ▾

Station Filtering Selection: Active For at least 1 Full Year ▾

Calculation: Total Events ▾ Signature Type: Rises Only ▾ Magnitude Rate >=: 20.0 ▾ hPa/hr

[Change Settings](#)

Clicking a station on the map will provide links to additional information on these perturbations.
Climatology statistics currently available for 1 Jan 2010 - 31 Dec 2013.

Powered by [Leaflet](#) — Map data © 2014 OpenStreetMap contributors, Imagery © 2014 MapQuest
*Data acquired from the Incorporated Research Institutions for Seismology (IRIS) Data Management Center (DMC)

Color Legend (events)

<1	1	2	3	4	5	6	7	8	9	10	10+
	1	1	2	3	4	5	6	7	8	9	

Z49A: Mesoscale Event Table

Z49A Columbiana (AL, USA)
 Latitude: 33.1942 Longitude: -86.5311 Elevation: 134.0 meters
 Data Range: 2011-12-19 to 2013-08-06

*Data acquired from the Incorporated Research Institutions for Seismology (IRIS) Data Management Center (DMC)
 Choose different options and click "Change Options".

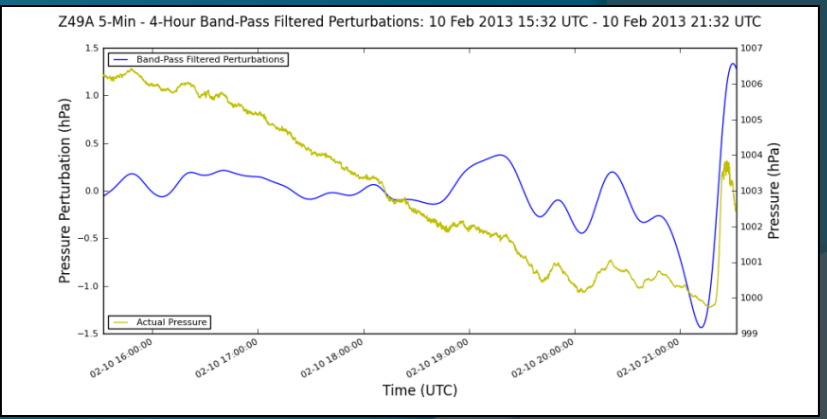
Begin Time (YYYY/MM/DD): 2010 ▾ 01 ▾ 01 ▾ End Time (YYYY/MM/DD): 2013 ▾ 12 ▾ 31 ▾

Signature Type: Rises Only ▾ Magnitude Rate >=: 20.0 ▾ hPa/hr

[Change Settings](#)

2 Mesoscale Events Found!

Begin Time	End Time	Duration (minutes)	Pressure Change (hPa)	Pressure Rate (hPa/hr)	Graphical Links
2012-07-31 09:56	2012-07-31 10:11	15.0	5.40	21.60	Click for Graph
2013-02-10 21:17	2013-02-10 21:27	10.0	3.78	22.68	Click for Graph



<http://meso1.chpc.utah.edu/usarray>



Future Tasks

- Continue developing climatologies of pressure perturbations and signatures for all USArray stations using Python storage/analysis techniques
- Explore wavelet analyses of time series using PyWavelets
- Develop algorithms to calculate pressure perturbation gradients
- Develop climatologies of the above pressure perturbation gradients for each USArray station in the database

Acknowledgements and References

This research is funded by National Science Foundation Grant Number 1252315. We would also like to thank Dr. Frank Vernon of Scripps Institution of Oceanography, the USArray Array Network Facility (ANF), and the Incorporated Research Institutions for Seismology (IRIS) for providing access to live data streams for the USArray project.

Additional work on this project can be found in tomorrow's poster session...

**Jacques, Alexander A. and J. Horel, 2014: Pressure Signatures of Extreme Weather Events Deduced from Earthscope's USArray Network
26th Conf. Weather Analysis and Forecasting - Poster #108**

