

# **Will Smartphone Pressures Revolutionize Nowcasting?**

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# Question

**Can Real-Time Pressure  
Observations from Hundreds of  
Millions or Billions of  
Smartphones Improve Nowcasting  
and Short-term Prediction?**

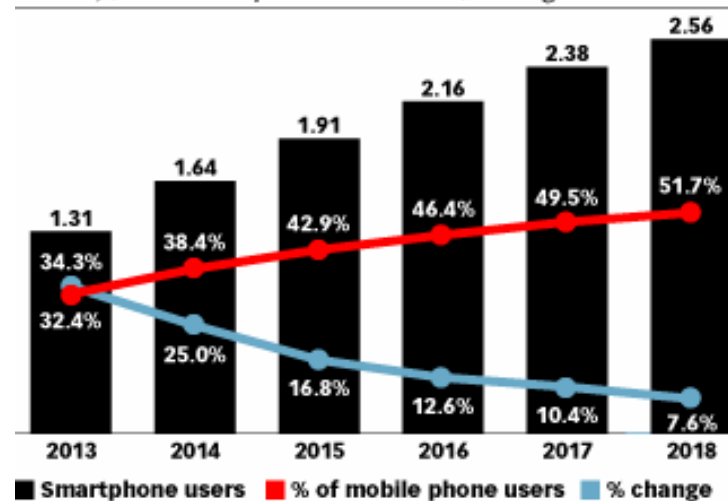


# Billions Sold

There are now over 1 billion smartphones in operation and that number should be over 2 billion by 2017

## Smartphone Users and Penetration Worldwide, 2013-2018

billions, % of mobile phone users and % change



Note: individuals of any age who own at least one smartphone and use the smartphone(s) at least once per month

Source: eMarketer, Dec 2014

# Pressure Sensors

- 25-50% of these phones have pressure sensors
- So we are talking about **hundreds of millions of real-time pressure sensors**, perhaps as high as a billion by the end of 2017.



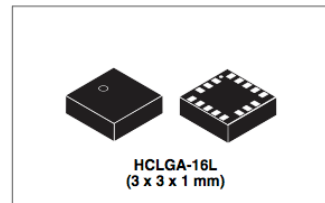
LPS331AP

MEMS pressure sensor: 260-1260 mbar absolute digital output barometer

Datasheet –production data

## Features

- 260 to 1260 mbar absolute pressure range
- High-resolution mode: 0.020 mbar RMS
- Low power consumption:
  - Low resolution mode: 5.5  $\mu$ A
  - High resolution mode: 30  $\mu$ A
- High overpressure capability: 20x full scale
- Embedded temperature compensation
- Embedded 24-bit ADC
- Selectable ODR from 1 Hz to 25 Hz
- SPI and I<sup>2</sup>C interfaces



The sensing element consists of a suspended membrane realized inside a single mono-silicon substrate. It is possible to determine the absolute pressure.

# Smartphone Pressure Sensors

- Absolute accuracy  $\sim\pm 2$  hPa
- Relative accuracy  $\sim\pm .1$  hPa
- **Thus, quite good for pressure change.**
- Smartphones also have GPS and cell tower location services (good to within 10s of meters)
- Also accelerometers, light sensors, and internal temperature sensors

# Some of the smartphones/pads with pressure sensors

- iPhone 6
- Samsung Galaxy III, IV, V, VI
- Nexus 4 and 10
- Some Sony, Nokia, and Chinese phones

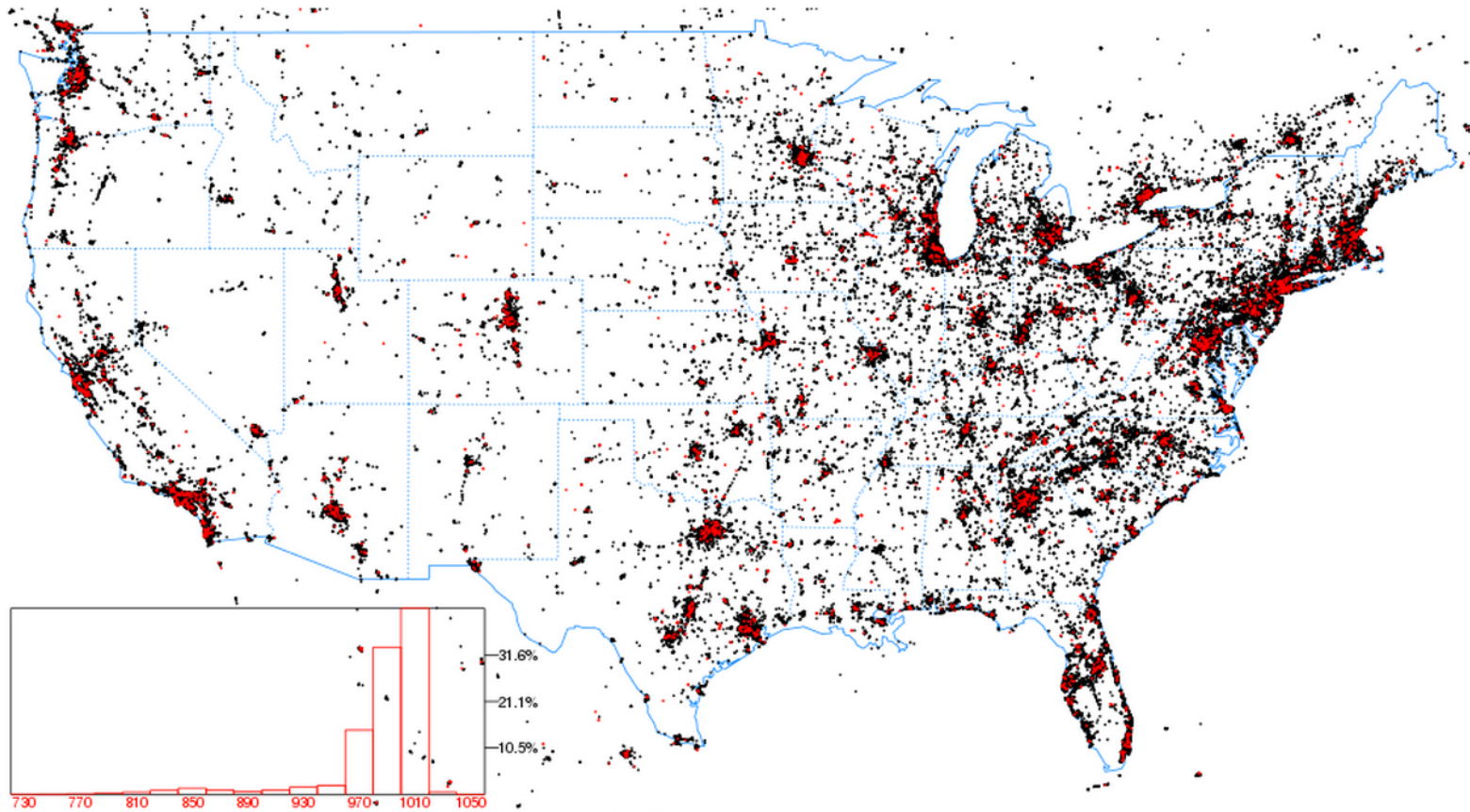


# Who is collecting smartphone pressure observations?

- Several small private sector firms have been collecting pressure through their apps
  - Cumulonimbus Inc. (PressureNet): **Terminated**
  - Opensignal, Inc. (WeatherSignal)
- Some new firms has started to collect pressures (e.g., Dark Sky app)
- Unfortunately, these firms have only collected a **small** proportion (1/1000) of the possible pressure observations.

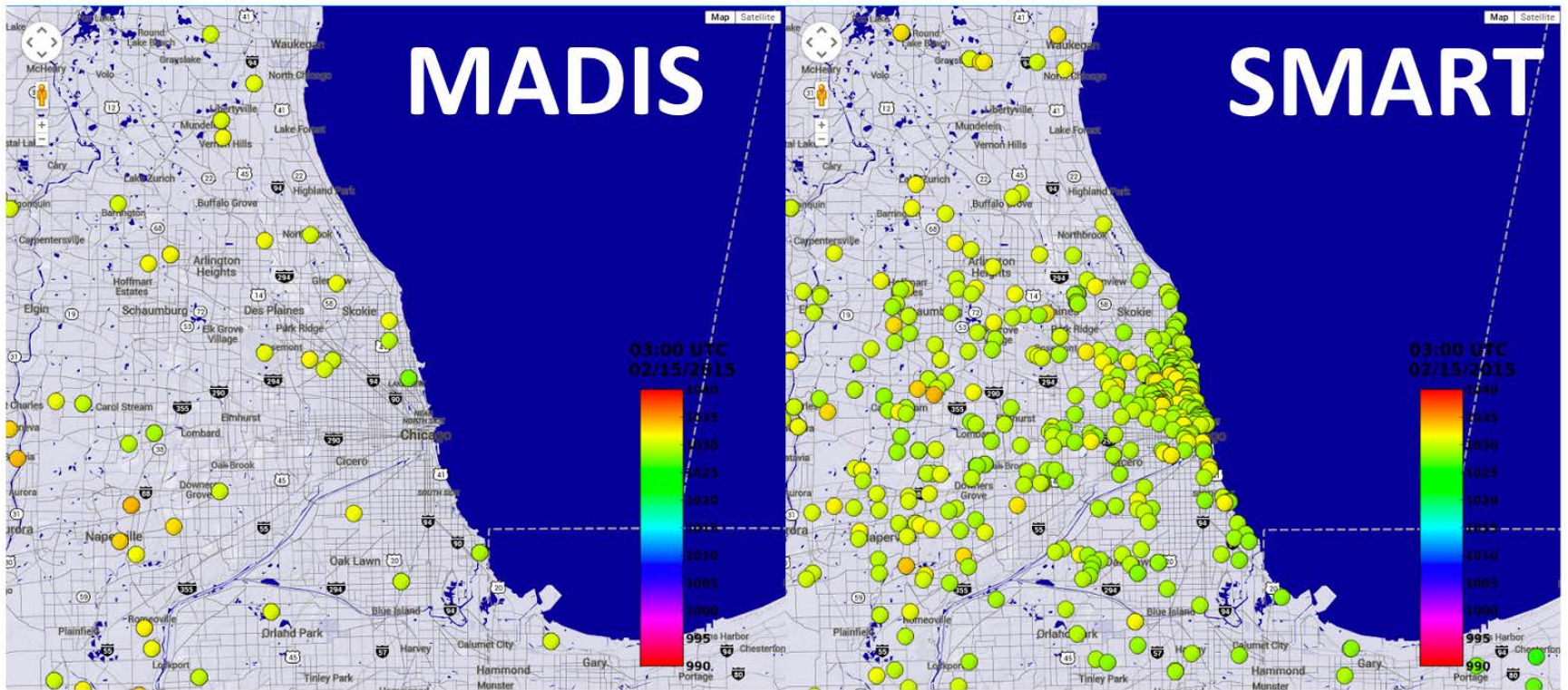
# 114K Pressures in One Hour over US: A Very Small Proportion

2015062622 contained 114324 points ( 107982 PressureNet [black], 6342 OpenSignal [red]). Mean= 986.56 Median= 994.77





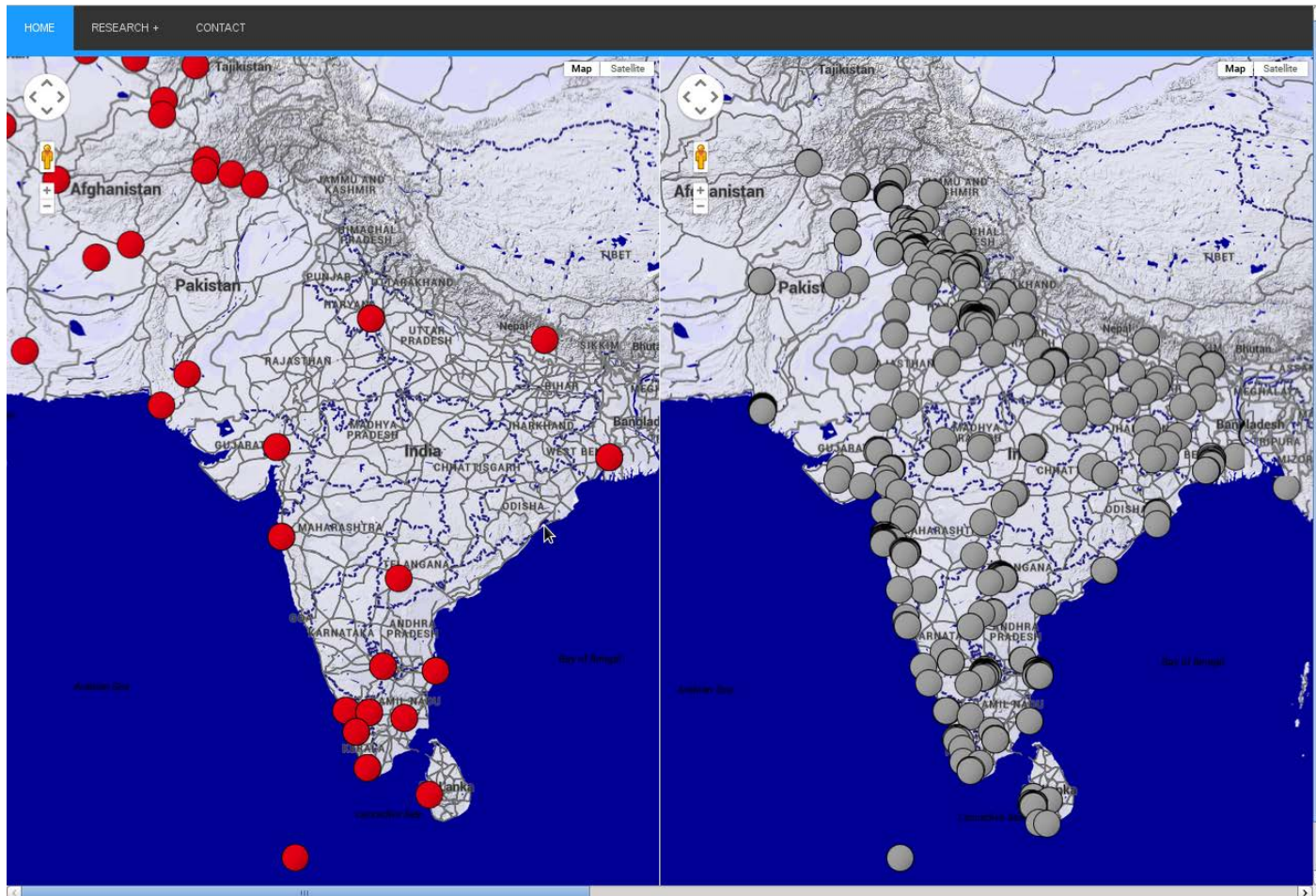
# Smartphone Density Chicago



# Where would smartphone pressures have the biggest impact?

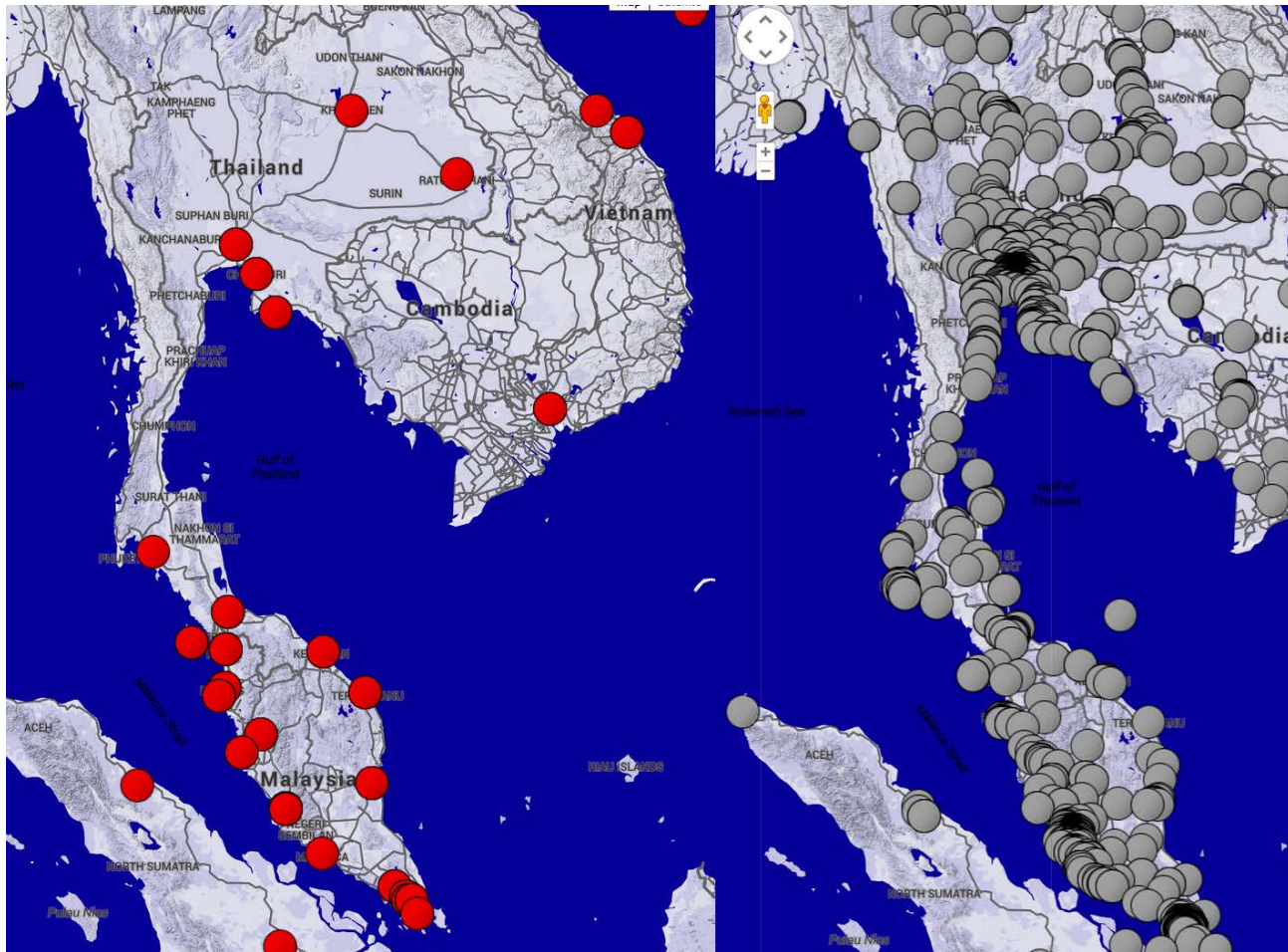
- Countries with poor observational density but where there are a lot of smartphones
- Locations where there is insufficient mesoscale data for initialization
- For mesoscale phenomena sensitive to mesoscale initial conditions
- Mesoscale features that have persistent structures (e.g., dry lines)

# Conventional (Left), Smartphone (right)





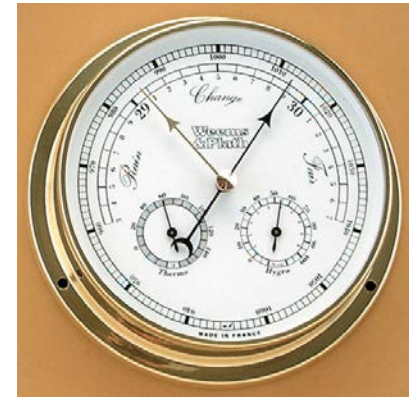
# Conventional (left), Smartphone (right)



# **What is the Value of Smartphone Pressures for Numerical Weather Prediction?**

# Pressure Is the Most Valuable Surface Variable for Assimilation

- The one surface parameter that provides information about the full vertical column of the atmosphere.
- Less sensitive to representativeness error than most variables.
- Exposure is less of a problem (e.g., inside or outside of buildings)
- Bias and systematic error relatively easy to remove



# Proven Value for Global NWP Assimilation

- Example: 20<sup>th</sup> century reanalysis (Whitaker et al 2004)

MAY 2004

WHITAKER ET AL.

1197

OO UTC Dec 14

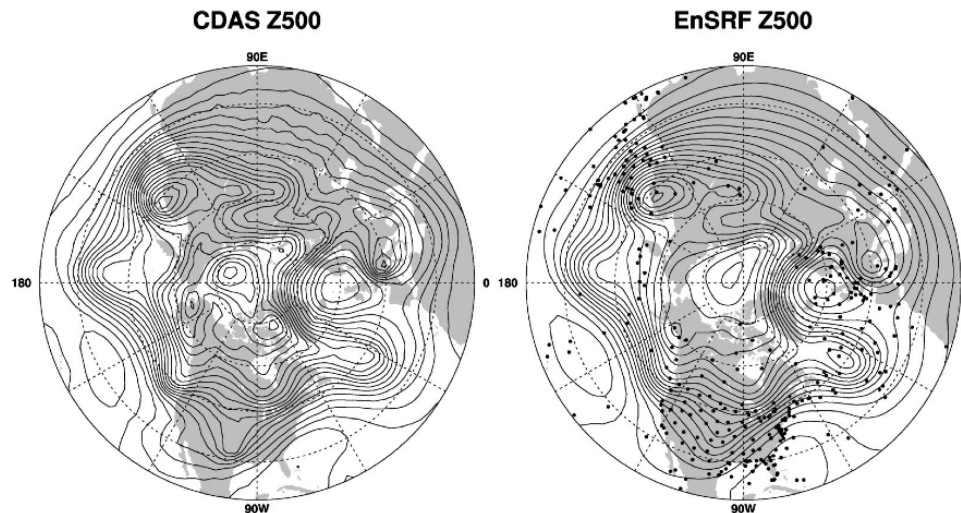


FIG. 5. The 500-hPa geopotential height analysis for 0000 UTC 14 Dec 2001 (contour interval is 50 m). (left) CDAS analysis, using all available observations, and (right) EnSRF analysis, using the simulated 1915 surface pressure observation network. Black dots indicate locations of surface pressure observations used in the EnSRF analysis.

All observations

Only surface pressure

# But What About the Mesoscale?

Both pressure/altimeter and 1-h pressure tendencies (METAR ONLY) improved coarse (30-km) forecasts of cold pools of two convective events in an EnKF system (Wheatley and Stensrud 2010)

MAY 2010

WHEATLEY AND STENSRUD

1693

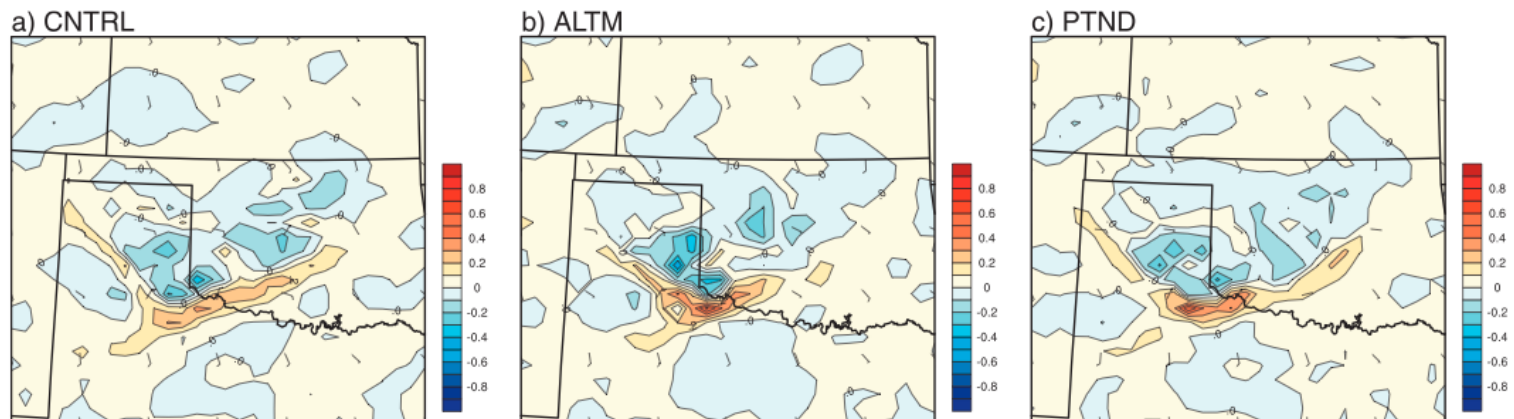


FIG. 18. Approximately 500-m AGL horizontal cross section of vertical motions depicted in the ensemble-mean fields of (a) CNTRL, (b) ALTM, and (c) PTND at 0600 UTC 20 Jun 2007.



**Recent work is even more  
suggestive of benefit (later in this  
talk)**

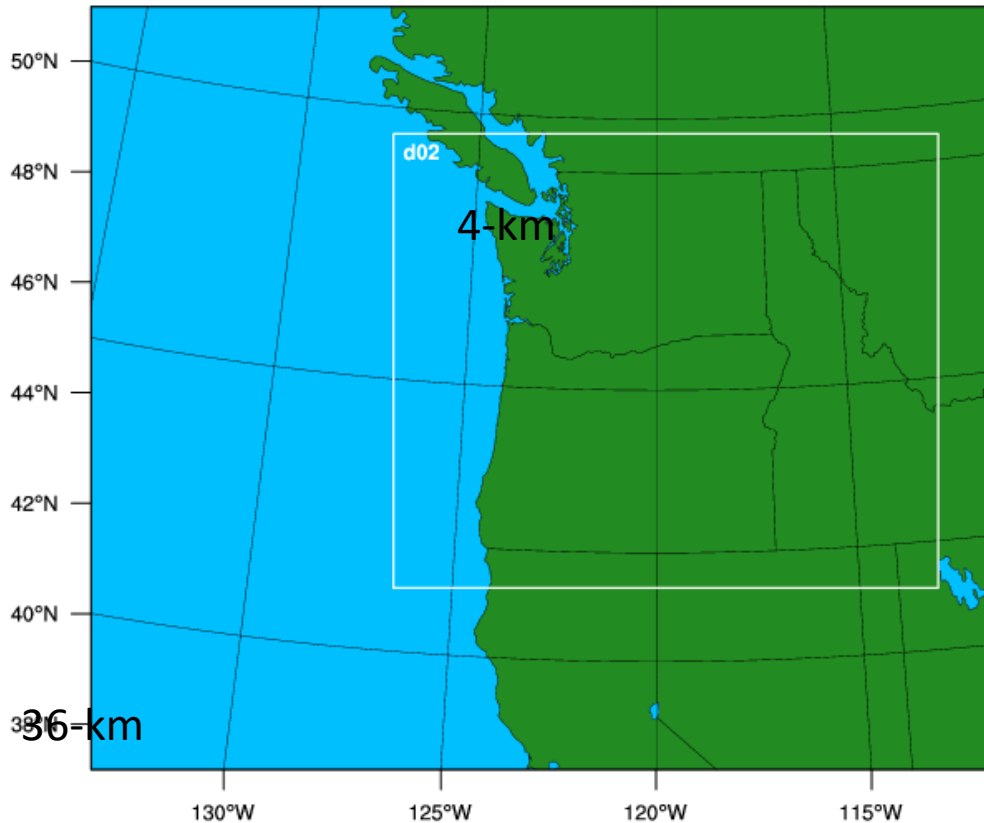
# Issues

- Use the pressure, pressure change, or both?
- Need software to determine when phones are moving.
- What is the best way to determine phone altitude? GPS and terrain maps, phone pressures, or ?
- Calibration.
- Can we prove that very dense pressure networks can substantially improve mesoscale prediction?

# Quality Control of Pressure Observations: An Essential Step

- Range check (880-1100 hPa)
- Bias correction
  - Many smartphone pressure observations have biases (e.g., elevation problem, sensor calibration)
  - Most biases are systematic and constant and can be removed.
  - Made use of regional pressure analysis and note biases over an extended period.
  - Buddy checks
- Movement check for pressure change.

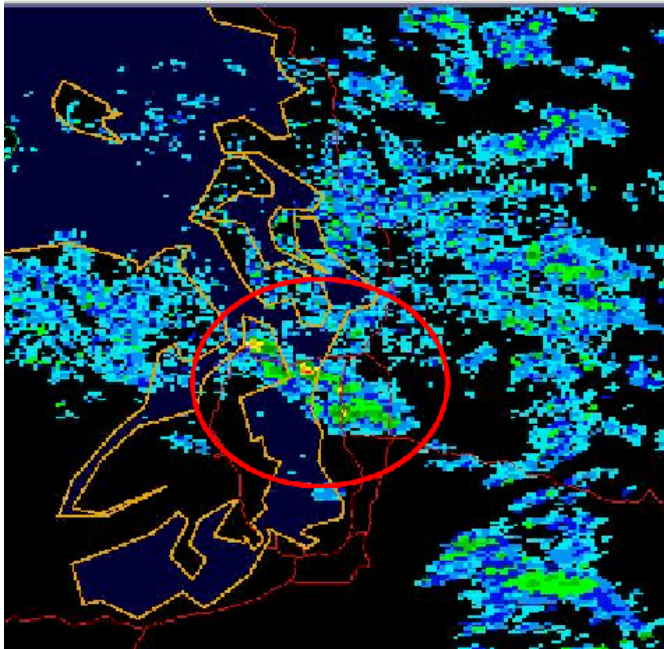
# University of Washington 36-4 km Testbed



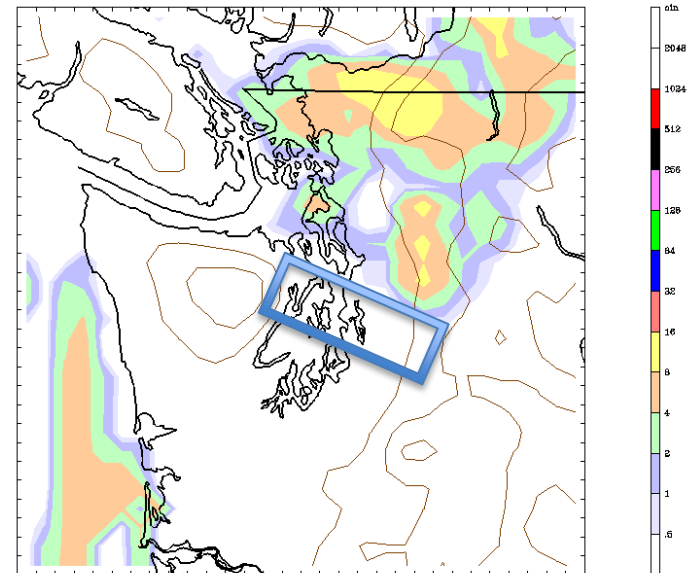
- DART EnKF Assimilation System
- WRF Model
- Run in real-time operationally and for test periods.

# Convergence Zone Case

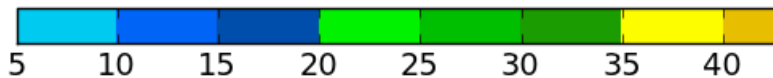
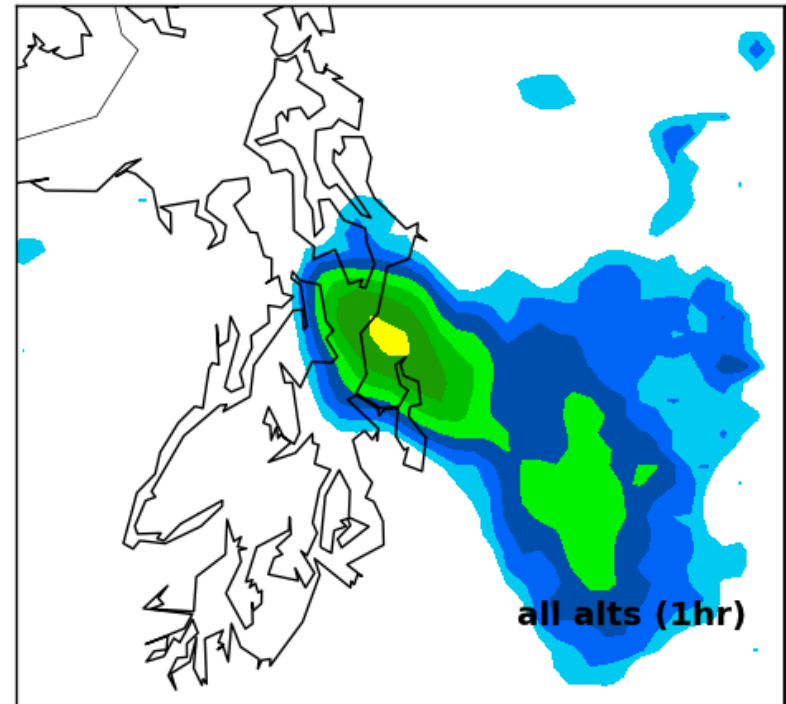
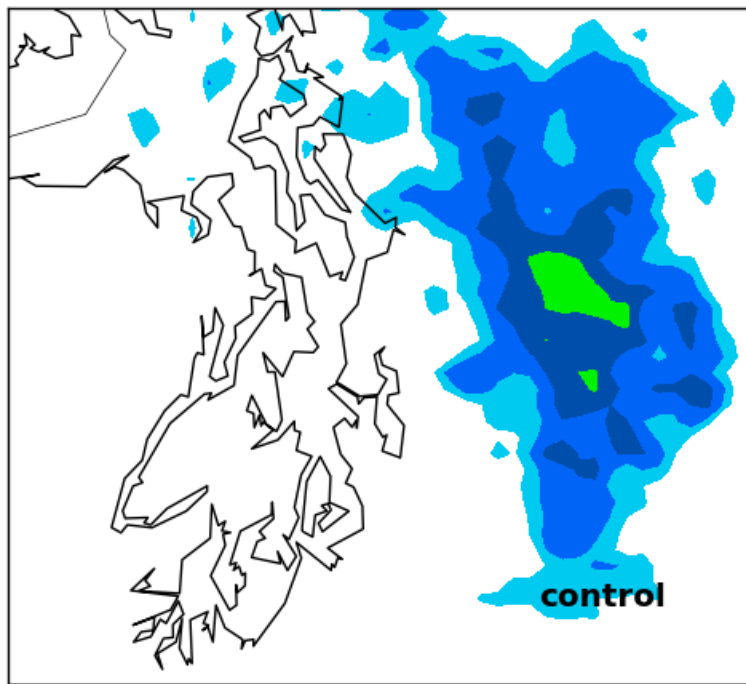
- A “poorly-forecast” convergence zone forms around 1400 UTC (6AM PDT) and moves south across north Seattle during the morning commute



UW WRF-GFS 12km Domain Init: 12 UTC Mon 24 Oct 11  
Fest: 6 h Valid: 18 UTC Mon 24 Oct 11 (11 PDT Mon 24 Oct 11)  
Total Precip in past 3 hrs (.01in)



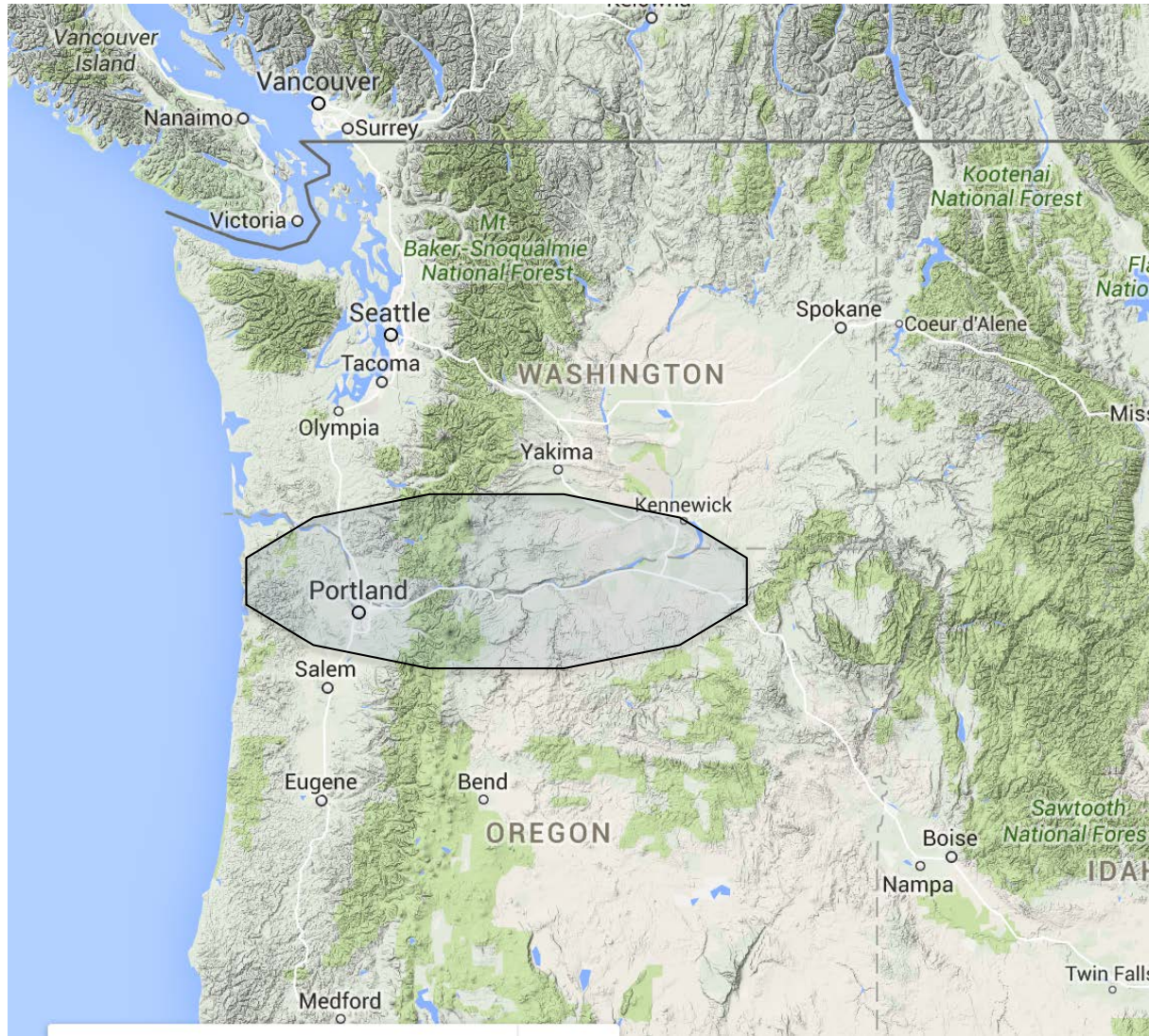
# 3-hour forecasts from fully cycled EnKF of simulated composite reflectivity valid at 1500 UTC, Oct. 24, 2011



With Smartphones

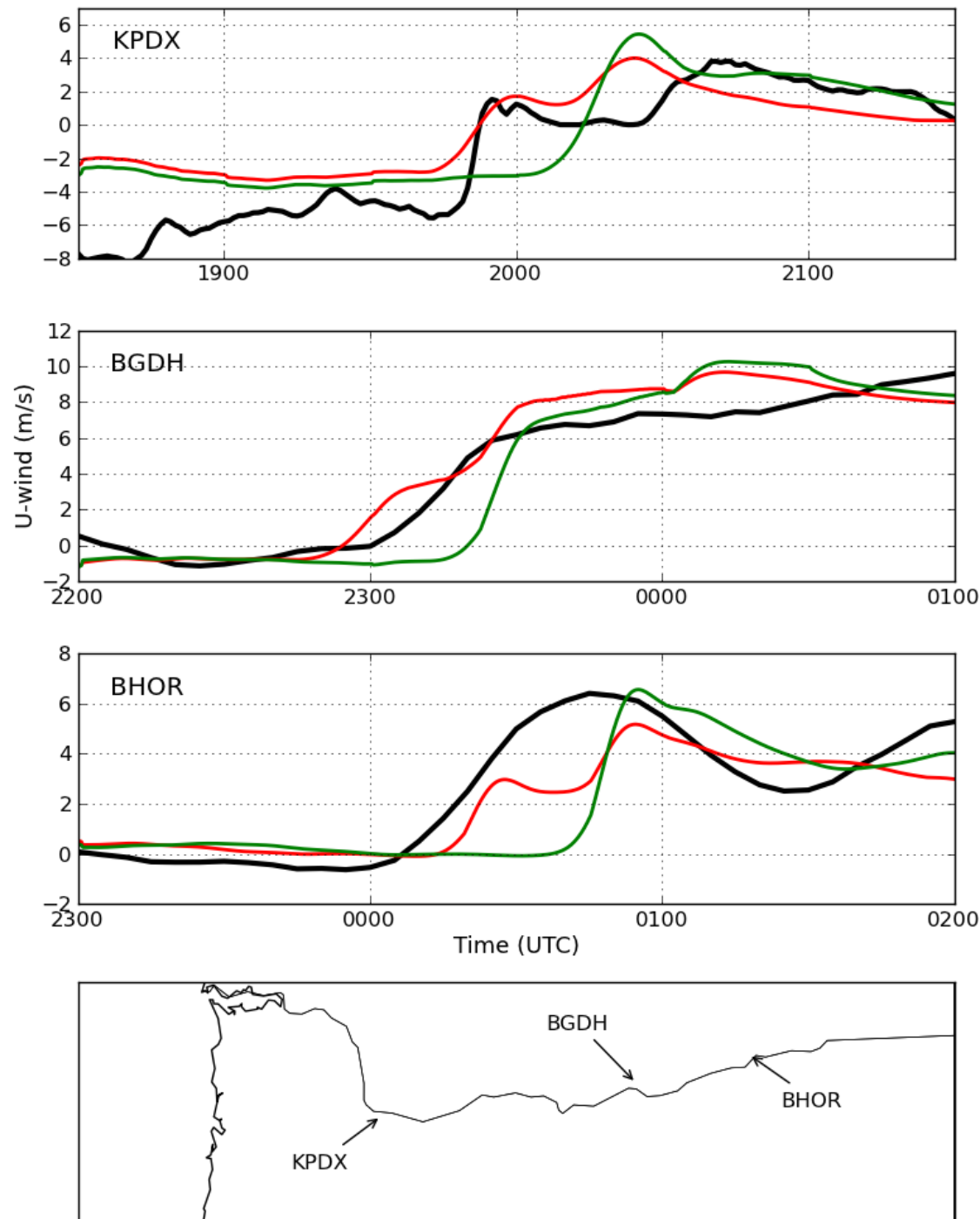


# What about nowcasting wind energy in the Columbia River Gorge?



# Nov. 17, 1800 UTC Frontal Passage Case

- WRF U-wind component (m/s) for **METAR only** and **All Altimeters Only** cases with **5-minute observations**
- **Timing of frontal passage improved by 20-45 minutes**

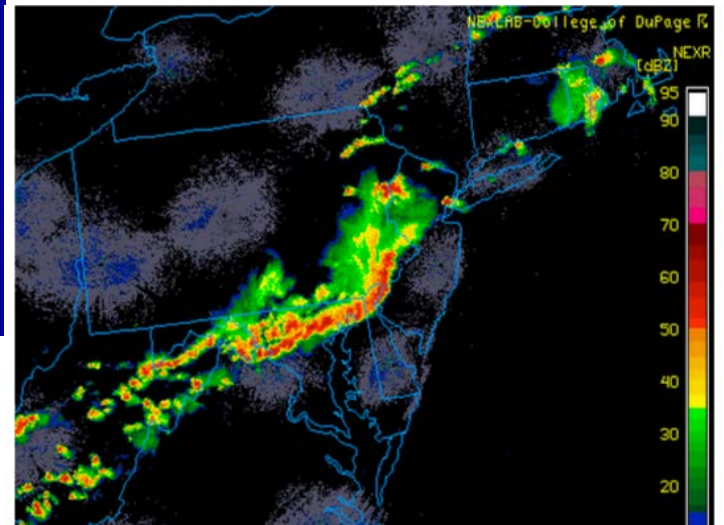
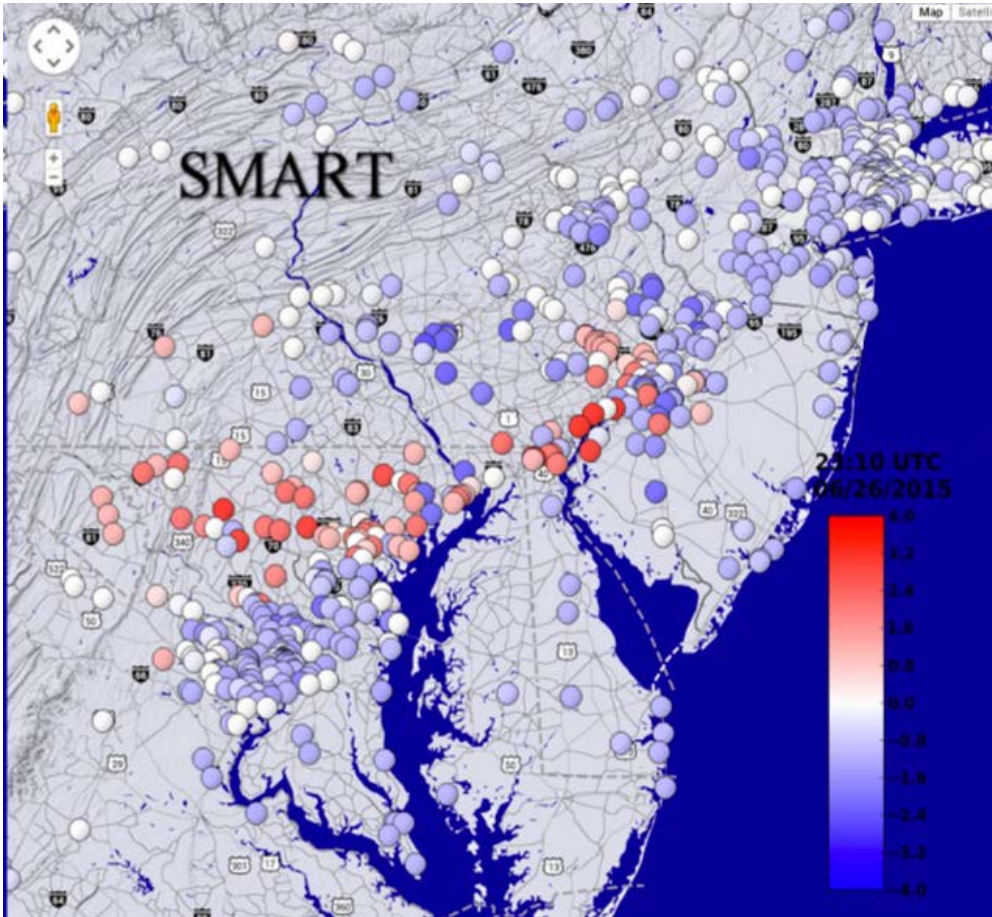




# Might Smartphones Provide Crucial Data for Short-Term Convective Forecasts, Particularly in Areas of Low Density of Observations?

- Better define confluence lines, dry lines, preexisting cold pools, etc. BEFORE convection starts?
- Define cold pool structure, gust fronts, etc. after convection forms.

# Smartphone Pressure Tendency



# A Poorly Forecast Convective Case

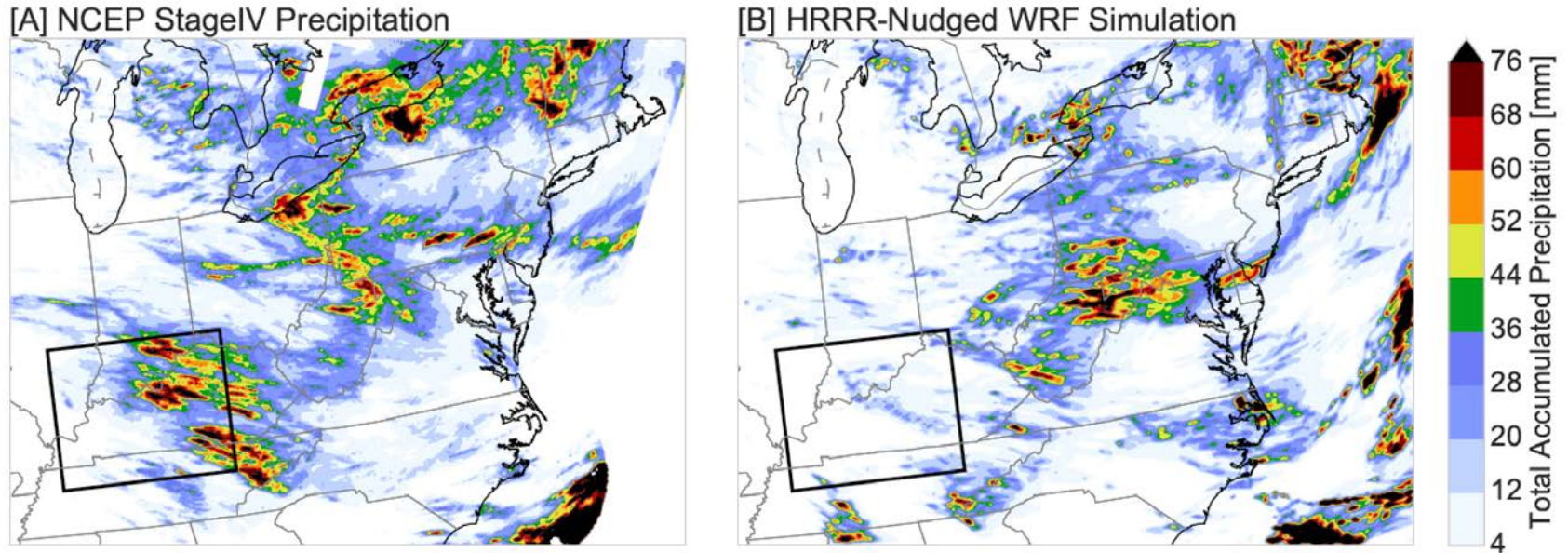
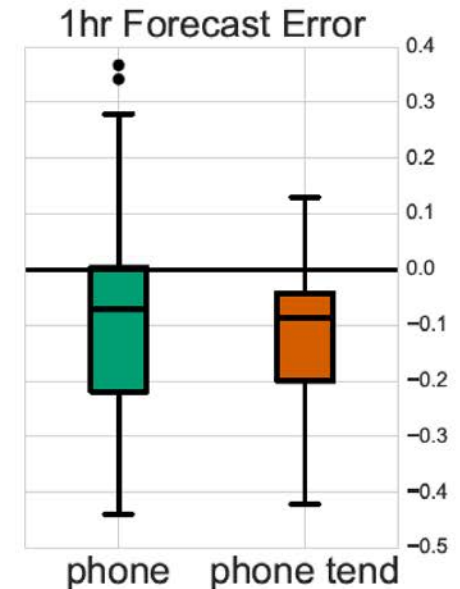
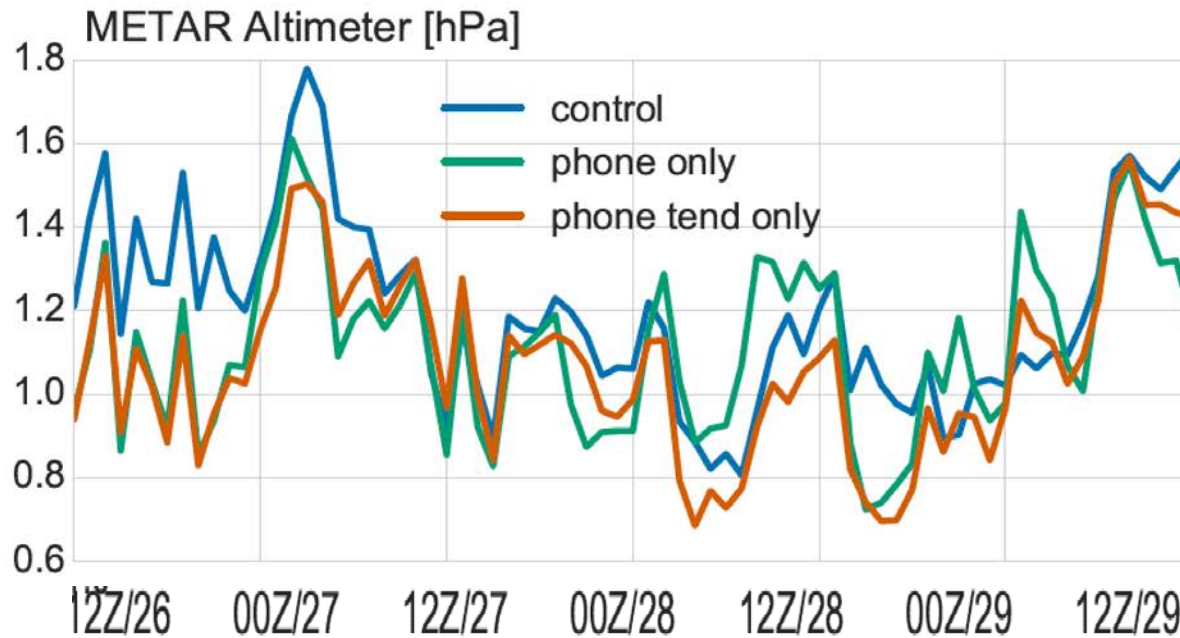


FIG. 1. Total accumulated precipitation [mm] from 1200 UTC 26 July 2014 through 1200 UTC 29 July 2014 as derived from [A] the NCEP Stage IV hourly precipitation analyses and from [B] a WRF simulation over the same period. The lower Ohio River valley is outlined in black.

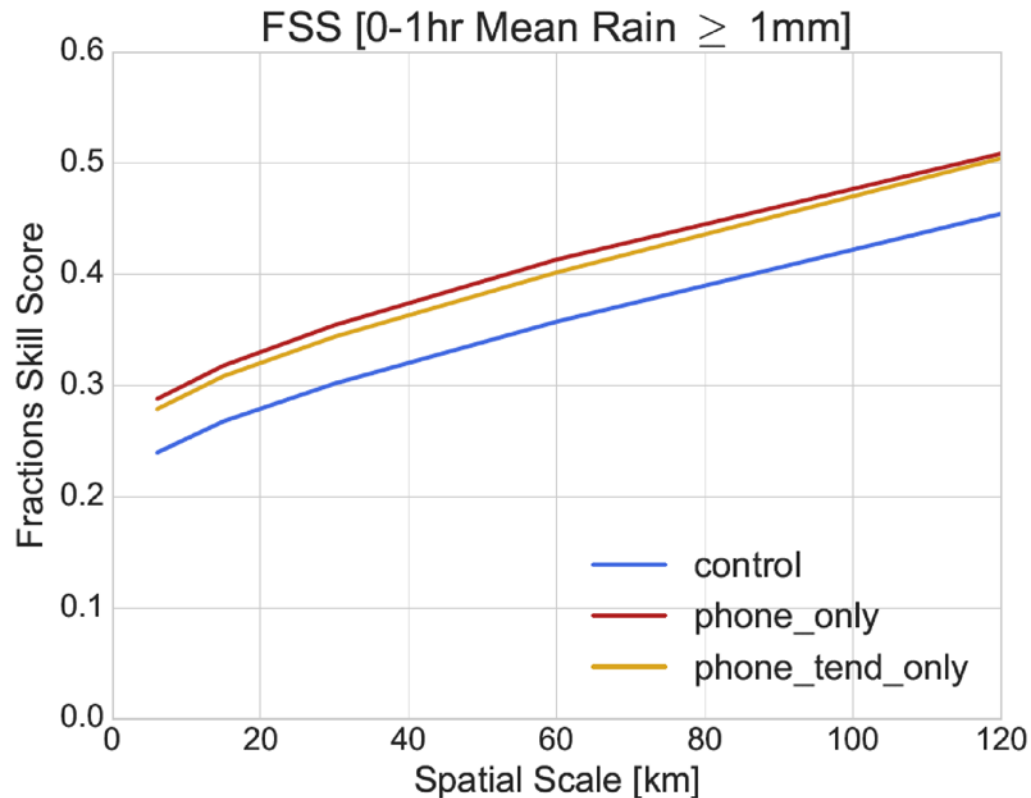


# Improved Pressure Forecasts Verified with Unassimilated Observations



Smartphone pressures assimilated in a 1-h  
cycled EnKF system using WRF

# Improves Short-Term (1-hour) Precipitation Forecast



# The Big Question: How Can We Collect Large Numbers of Smartphone Pressures?

- Only a few small apps are collecting smartphone pressure information today.
- Would be useful if major operating systems (e.g., Android, iOS) or hardware manufacturers would help.
- Or help from a very big app used by millions of people.
- Now working with one possible group.

# To experiment and test ideas, we developed our OWN smartphone weather app: **uWx**

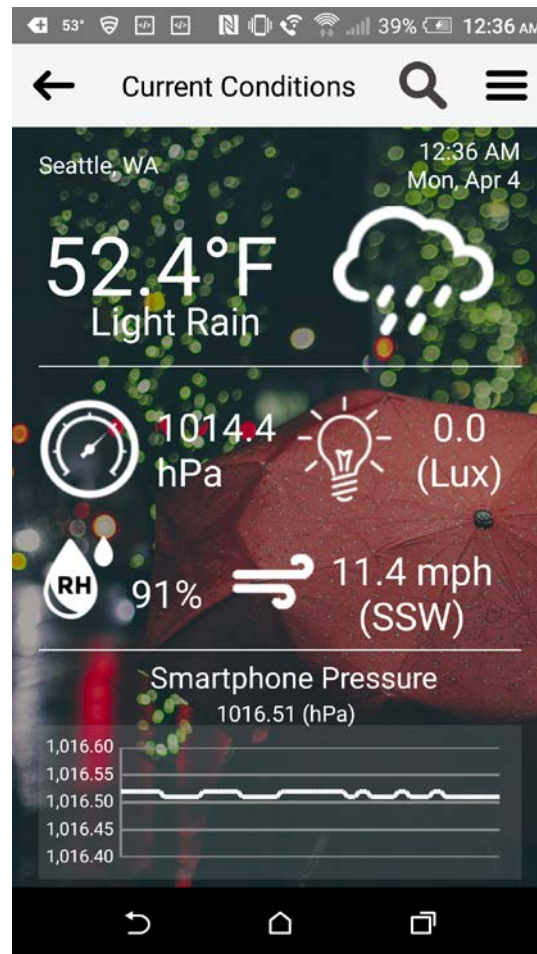
The image shows a screenshot of the Google Play Store interface. At the top, the Google Play logo and a search bar are visible. Below the search bar, there are navigation options: 'Apps', 'Categories', 'Home', 'Top Charts', and 'New Releases'. On the left side, there is a sidebar menu with options: 'My apps', 'Shop', 'Games', 'Family', 'Editors' Choice', 'Account', 'My Play activity', 'My wishlist', 'Redeem', 'Send gift', 'Add credit', and 'Parent Guide'. The main content area displays the app page for 'uWx'. The app icon is a blue circular gauge. The app title is 'uWx', and it is categorized under 'Weather'. The developer is 'UW, Atmospheric Sciences'. The app is rated 'Everyone' and has 10 reviews. There is a warning icon and text: 'You don't have any devices'. Below this, there are buttons for 'Add to Wishlist' and 'Install'. At the bottom, there are three preview images of the app's interface. The first image shows 'Current Conditions' for Seattle, WA, with a temperature of 52.4°F, light rain, and other weather details. The second image shows 'Visible Satellite' with a satellite map. The third image shows 'Forecast Maps' with a color-coded weather forecast map. Each preview image has a navigation bar at the bottom with 'RADAR', 'SATELLITE', and 'MAPS' options.

Android

On Google  
Play

More information at:

<https://www.cmetwx.com/>





# Conclusions

- Millions or even billions of pressure observations could be available globally from smartphones
- Both pressure and pressure change can be acquired in real time.
- Studies of the impacts of dense pressure observations on mesoscale analysis and prediction look promising.
- **We need a way to collect a higher percentage of the smartphone pressure observations and test their value for nowcasting and short-term forecasting.**

**The End**