Wednesday, 15 October 14:15 – 15:00 PM

Session 5

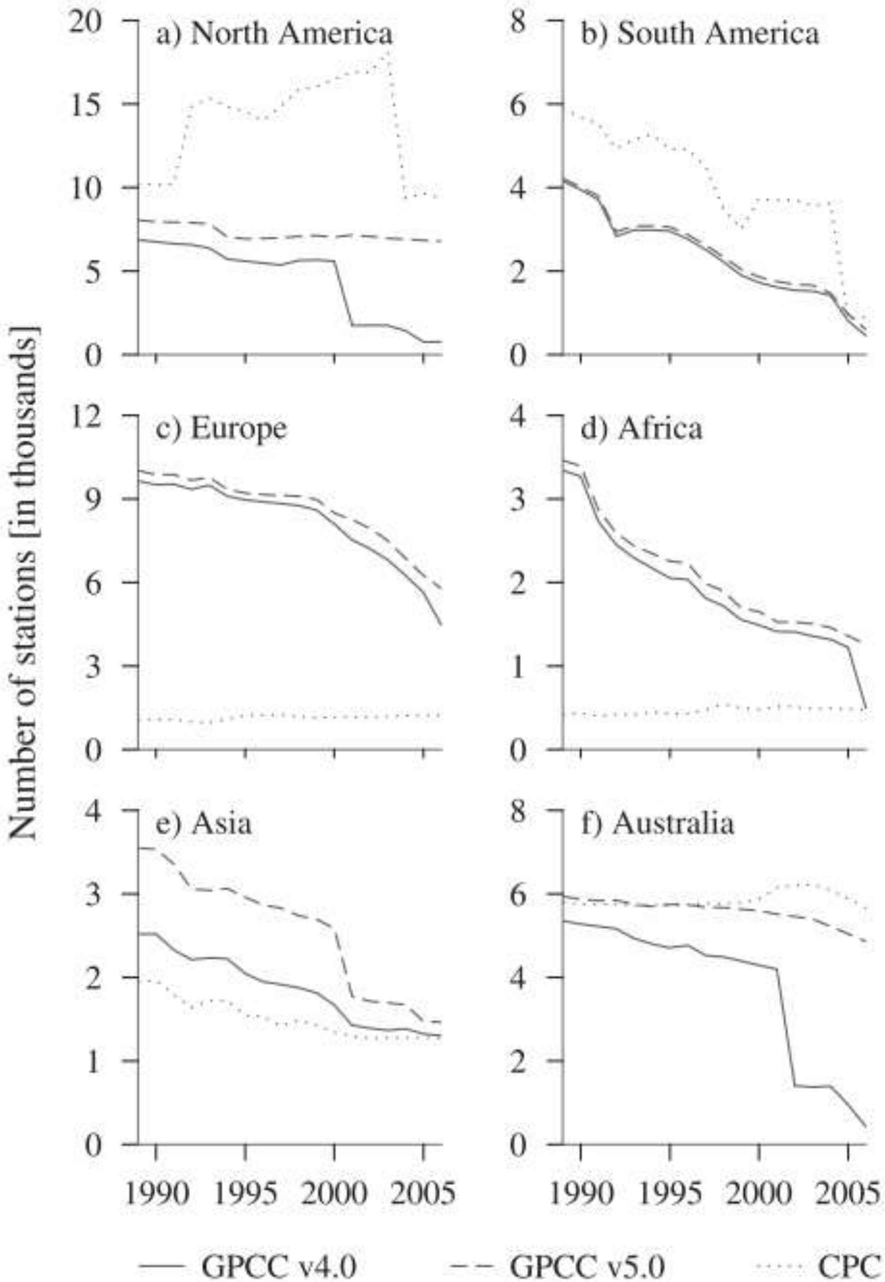
Novel Observing Approaches: New and Emerging Technologies

John Snow, CTA Meteorology, Climate Monitoring and Forecasting

Not an endorsement or a sales pitch

The hardware shown and the software mentioned during this presentation are provided solely as exemplars.

There is no endorsement intended or implied of particular hardware or software.



The Continuing Problem

Data on the declining number of rain gauges on the six continents, 1990 to 2006

FIG. 4. (a)–(f) Mean annual number of gauges used in the precipitation observations from GPCC v4.0, GPCC v5.0, and CPC. Version 4.0 shows a significant drop in the number of gauges between 2000 and 2001 over North America and Australia, while version 5.0 of the GPCC product is based on a nearly constant number of observation stations during the complete time series. Over South America, Europe, and Africa, the update from v4.0 to v5.0 results in little improvement only, as both versions show a nearly constant decline over time. Over Asia, GPCC v5.0 is using about 1000 gauges more than version 4.0 until 2000. The CPC product is based on about 1000 gauges over Europe and 500 gauges over the whole of Africa, while more than 14 000 gauges are used to generate the gridded precipitation observations over North America between 1991 and 2003.

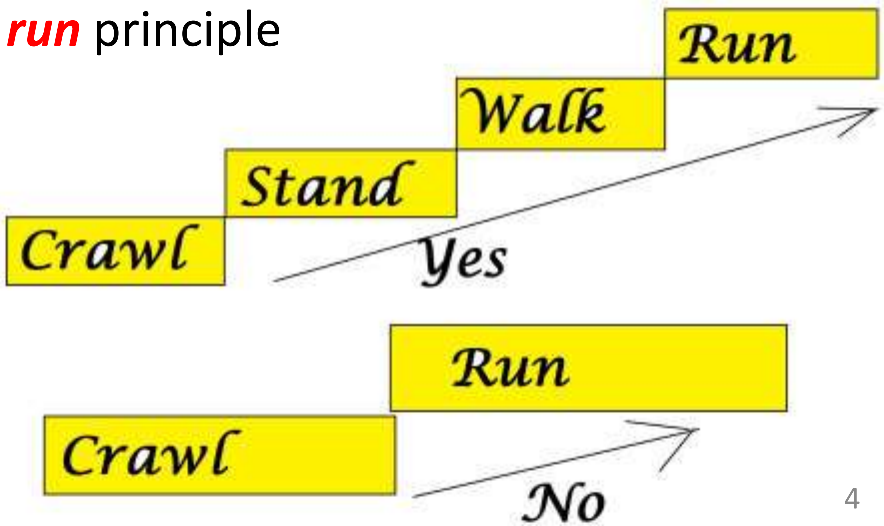
Fig. 4 from Christof Lorenz and Harald Kunstmann, 2012: The Hydrological Cycle in Three State-of-the-Art Reanalyses: Intercomparison and Performance Analysis. *J. Hydrometeor*, **13**, 1397–1420.
doi: http://dx.doi.org/10.1175/JHM-D-11-088.1

Improving Observing Networks and Enhancing NHMS Capacity → a widely accepted goal whose attainment has proved to be elusive, leading to frustration in both the NHMS and the supporting international aid community

The challenges are well known:

- Lack of supporting technical infrastructure within the NHMS and the nation
- Limited choices w/r/t number of sites, equipment; too often budget limited
- The chosen technology can be too big of step for the NHMS
- Lack of a long-term sustainability plan for the network

→ The above suggest focusing on improving the capabilities of NHMSs in small steps, e.g., apply the ***crawl, stand, walk, run*** principle



Time for a new approach – CIRDA!

Part 1: Leapfrog Technologies

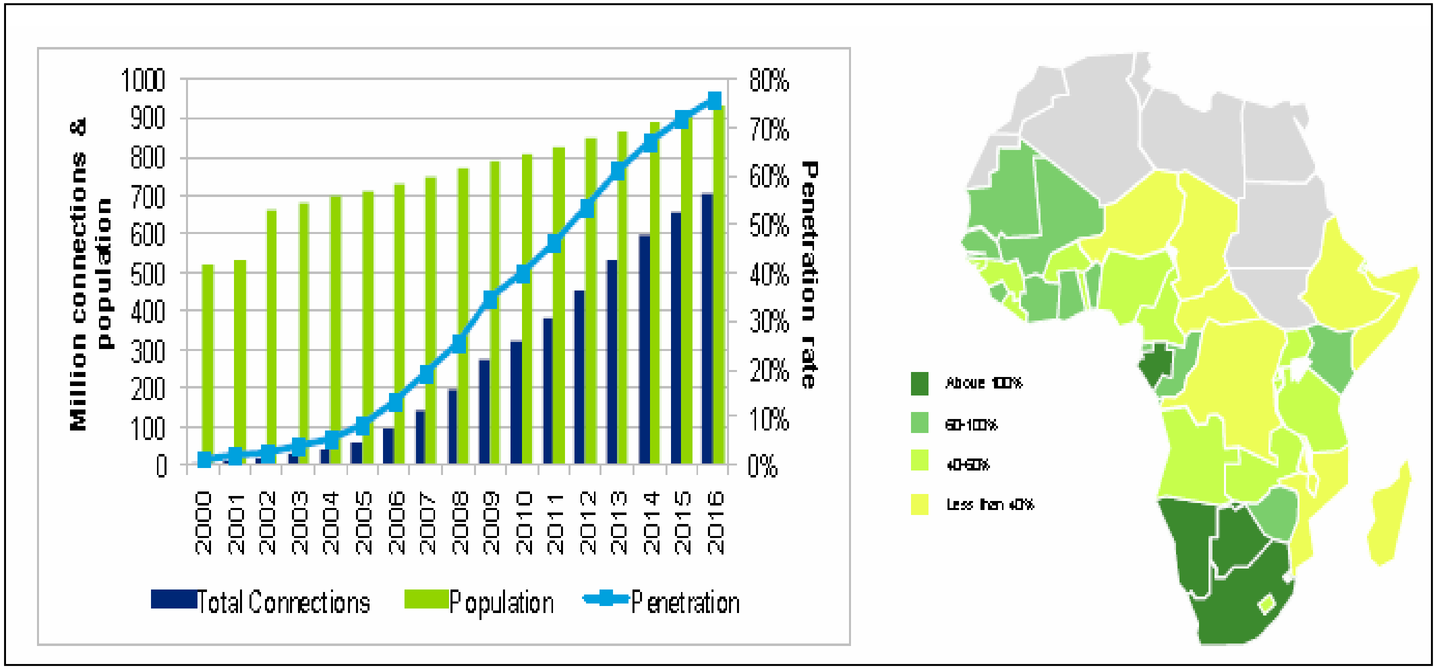
Leapfrog Technologies 101

"Leapfrogging" is the notion that areas which have under-developed technology or economic bases can move forward rapidly through the adoption of modern systems *without going through intermediary steps*. Examples: cell phones (planet wide), solar power (Pakistan); free broadband and Linux machines (Brazil)

Three examples:

- Cell phones in Africa (happening now)
- Social media comes to Africa (happening now)
- Cloud computing (coming soon)

Spread of the Cellular Telephone Network in Sub-Saharan Africa



The spread of cell phone coverage across Sub-Saharan Africa during the period 2000 to date, and projected for the next two years. This rapid spread will likely continue for some years to come. This spread is giving rise to "information access" villages around cell towers.

The Next Wave: *Facebook* for Every Phone

Social media companies are beginning to deploy technologies that provide smart phone capabilities on the low-price, simple feature phones found in developing countries → market-driven

Cellular companies offering a feature phone Facebook service as of July 2013:

Aircel (India)	Reliance (India)
Airtel (India)	Smart (Philippines)
Banglalink (Bangladesh)	Smartfren (Indonesia)
Beeline (Russia)	elkomsel (Indonesia)
Etisalat (Egypt, Nigeria)	Three (Indonesia, United Kingdom)
Globe (Philippines)	TIM (Brazil)
Idea (India)	TMN (Portugal)
O2 Telefonica (Germany)	Ufone (Pakistan)

Cloud Computing

Most of the observing techniques discussed here require significant computing capability to go from data to meteorological products to decision support information. **“Cloud” computing** can support or supply the data processing infrastructure required for analysis, assimilation, product generation, and archiving at fiscally challenged NHMS

- Cloud computing provides a viable and relatively inexpensive alternative to the implementation and maintenance of in-house IT infrastructure
- Only need is for an appropriate bandwidth Internet connection.
- With archiving and computing “in the cloud”, the NHMS and its partners can focus on the data collection infrastructure, forecaster tools and techniques, an appropriate web browser, and marketing their products and services

Cloud computing is computing resources i.e. hardware and software, that are delivered through a network.

Leapfrog Technologies 101, continued 1

Looking across a range of technologies that have been implemented or were tried to be implemented in the developing world, several lessons can be learned:

Technologies and ideas which seem somewhat powerful when implemented in the West ***may be*** utterly transformative in locations not laden down with legacies of past development, but **there is no guarantee that take-off will occur.**

Most of the time, to go high-tech, one must go medium-tech first → capacity to absorb and benefit from new technology depends on staff capabilities and the availability of more basic forms of infrastructure: crawl, walk, run, etc…

Leveraging the investments of other rapidly growing technology organizations is often a successful strategy → mutually beneficial partnerships (e.g., social media on cell phone network)

Leapfrog Technologies 101, continued

Leapfrogging doesn't always work. There may be government policies or mandates requiring the adoption of certain technologies which made sense a decade or two ago, but are less useful now. There may be resistance for reasons of tradition or marketing. And chosen leapfrog technologies may simply not work well in the natural and cultural environment of a developing country.

To successfully leapfrog an organization requires a shared vision, leadership at all levels, ‘inclusive growth‘, a staff suited to cope with rapid growth and changes, rapid diagnostics of bottlenecks, and focused reforms

The future belongs to those best able to change along with it; sometimes, starting from nothing can be an engine for just that sort of change.

Possible technology approach for NHMS: leverage cell phone network for both data collection and information distribution to customers; anticipate social media will both increase and promote interactivity with users of weather information

Part 2: Observing System Technologies that are sustainable (affordable to acquire and operate, maintainable)

Consider the new generation of sensing systems that apply novel technological approaches to meteorological observations that satisfy the requirements for many meso- and micro-scale applications, e.g., ag met

General Thoughts
On Selecting, Utilizing Instrumentation

- Ensure suitability for the intended operating environment → operational experience; field testing ***only way*** to ensure suitability
- QA/QC system to track each instrument's performance, identify need for service
- Minimize moving parts, expendables
- Open source or accessible software
- Minimize in-field maintenance – sufficient stock to swap out instrumentation for repair
- Major repair, calibration done by a service company or original manufacturer
- Could field service be done by telephone company or other partner's staff?

All-in-one sensing systems

There have been remarkable advances in recent years in the design and fabrication of all-in-one sensing systems. These units are physically sturdy, hold calibration well, modest electrical input, minimal maintenance, and are relatively inexpensive. They can be configured by the manufacturers to provide data on a wide range of meteorological parameters.

Biggest advances have come in the areas of ultrasonic anemometers and, very recently, radar-based rain gauges.

Ultrasonic anemometers

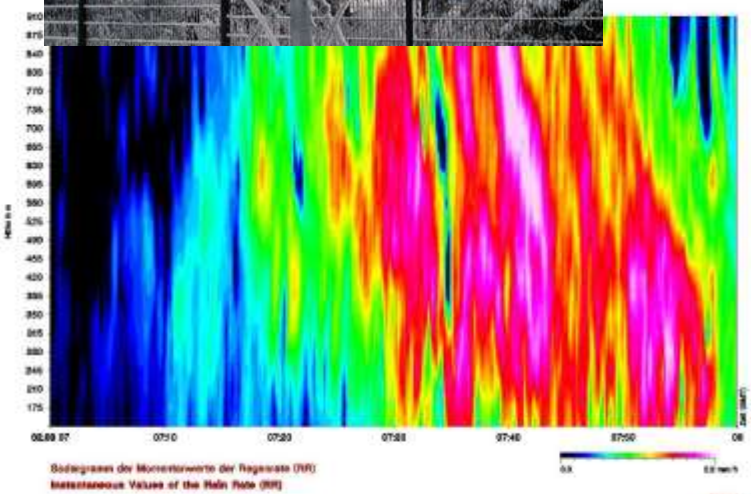
These units can be made relatively inexpensively.

The fundamental design lends itself to being made very sturdy.

Radar-based rain gauges

These devices can provide data on accumulated rainfall, rain intensity, and duration → works best in heavy rain

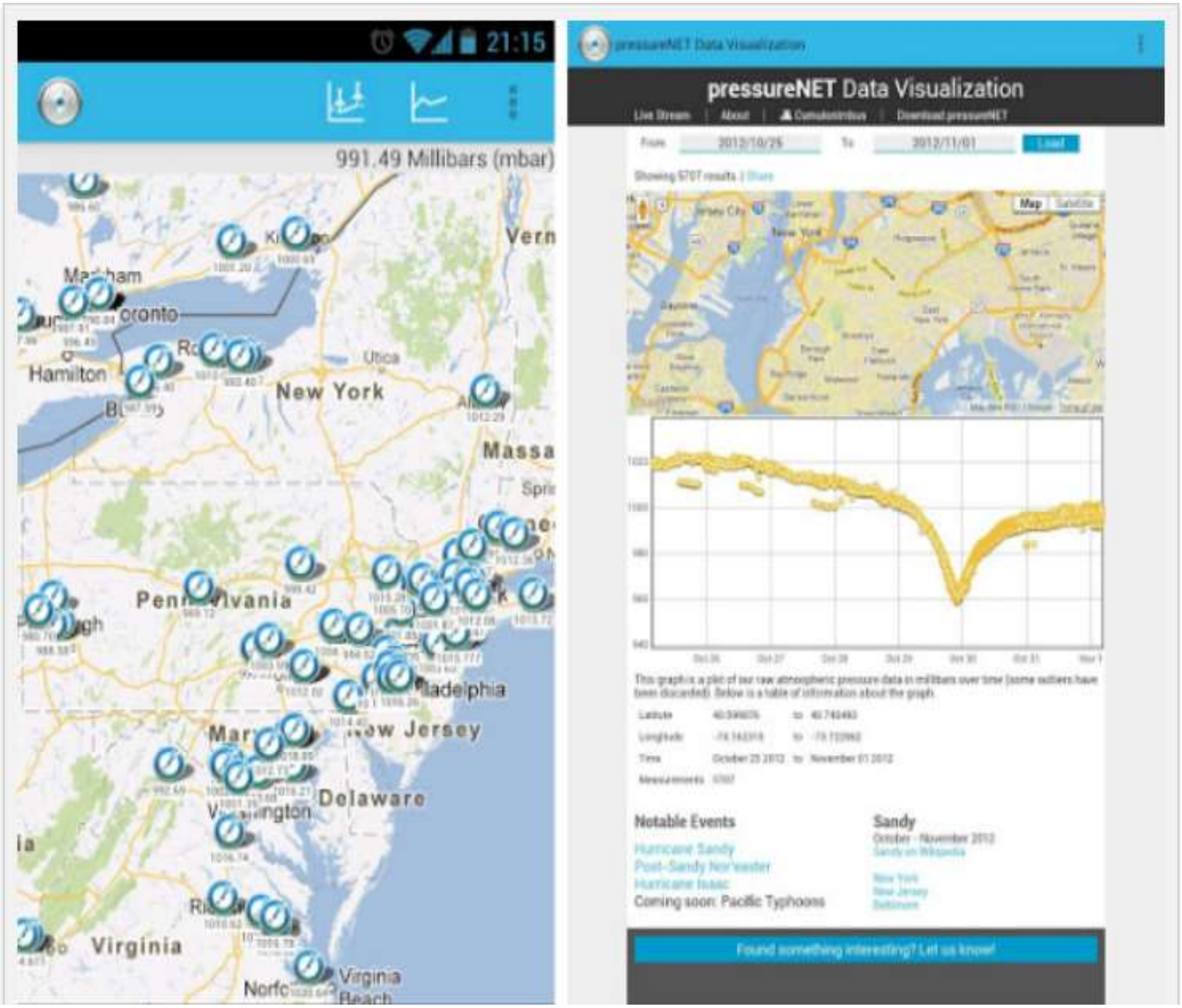
No moving parts



Crowd-sourced observations 1

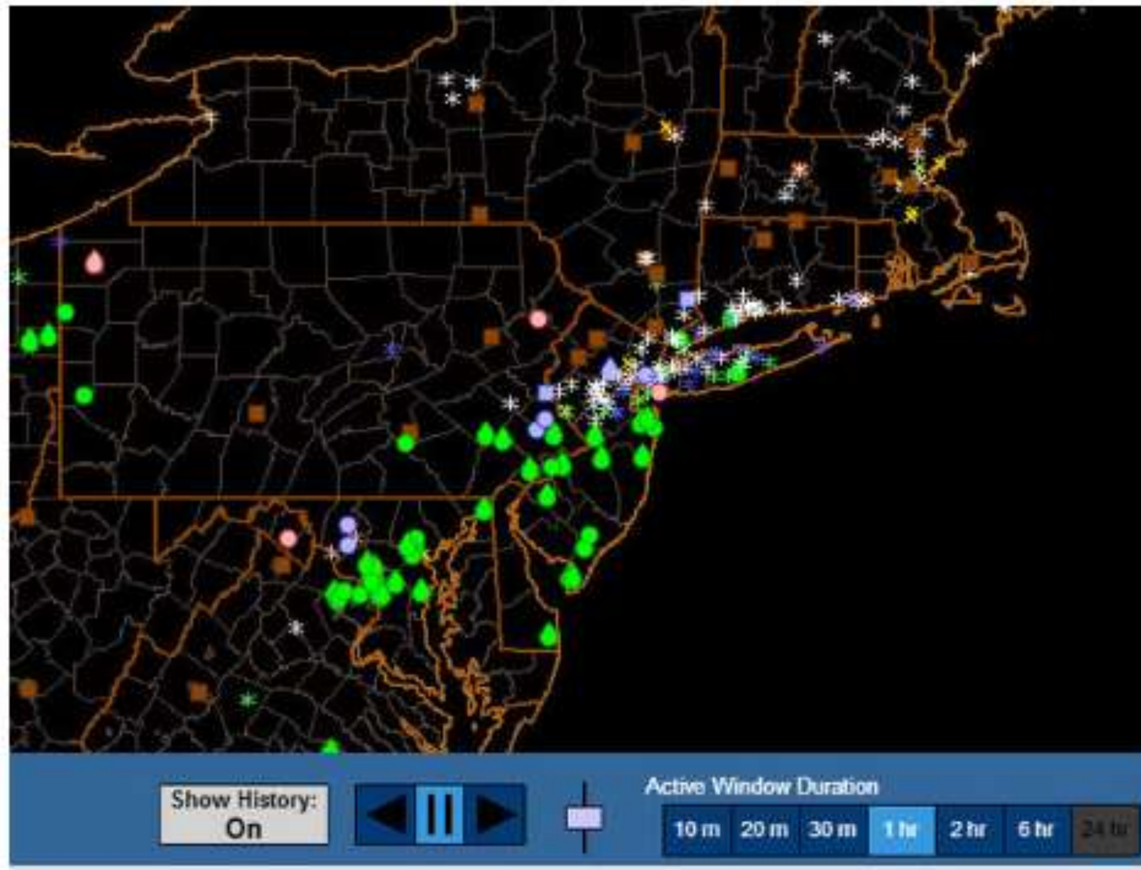
Example: Barometric Readings from Smart Phones

Examples of supplementary barometric readings from Android-based smart phones using the *pressureNET* application to bring out the value of atmospheric pressure sensed by the phones' integral barometer. In this case, the data are displayed as markers on an embedded Google map provided by the application.



Example: Meteorological Phenomena Identification Near the Ground (mPING)

- Developed by NOAA National Severe Storms Laboratory in 2012
- Free application for smart phones provides ground-truth data to researchers, operational forecasters in real time
- Used to verify remotely sensed precipitation
- Aids individuals in becoming "weather aware" as they contribute



This map shows data reported by users of the mPING app during Friday's blizzard in the Northeast.

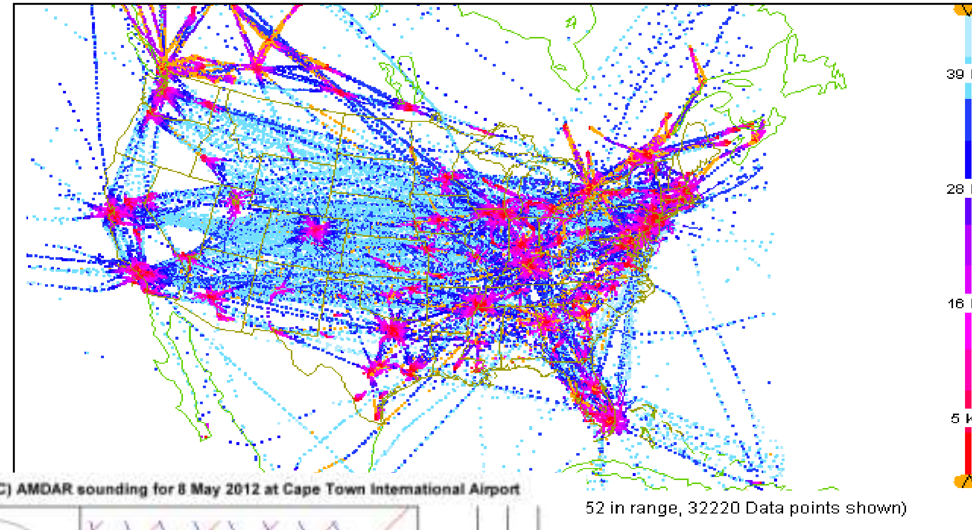
Upper air observing systems

GPS-based Atmospheric Sounding Systems

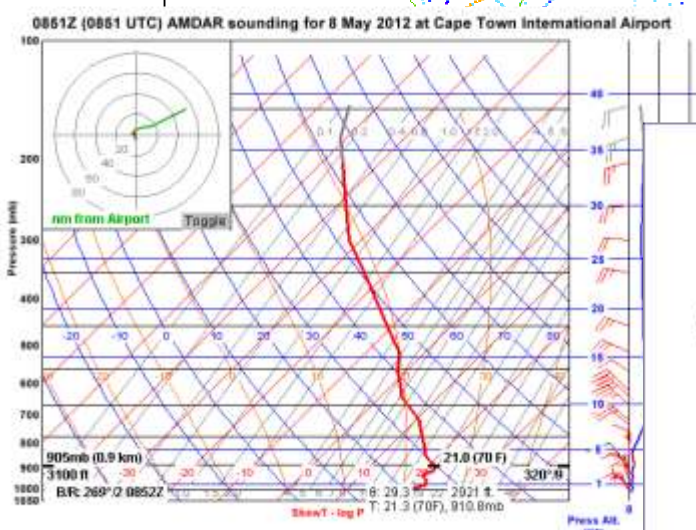
Use of GPS eliminates need for mechanical radio-direction-finding tracking systems, yields better sonde location data and hence better winds aloft.

Aircraft-based Systems

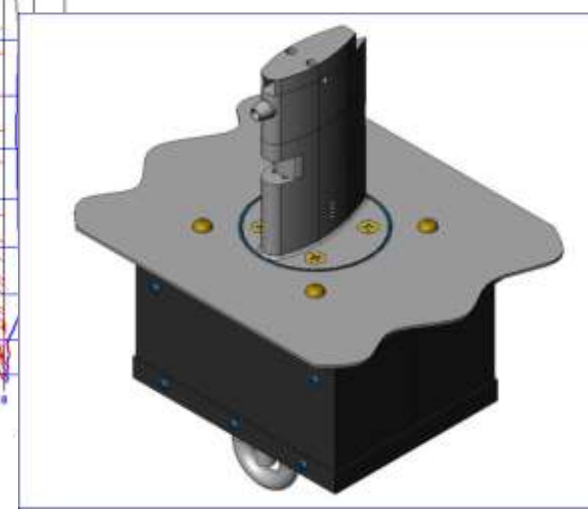
A complement to radiosonde data, providing upper-air data between the standard radiosonde releases at 00Z and 12Z



- **AMDAR** (Aircraft Meteorological Data Relay) – WMO project focused on long-haul commercial aircraft



- **TAMDAR** (Tropospheric Airborne Meteorological Data Reporting) – US regional commercial carriers



Passive area observing systems

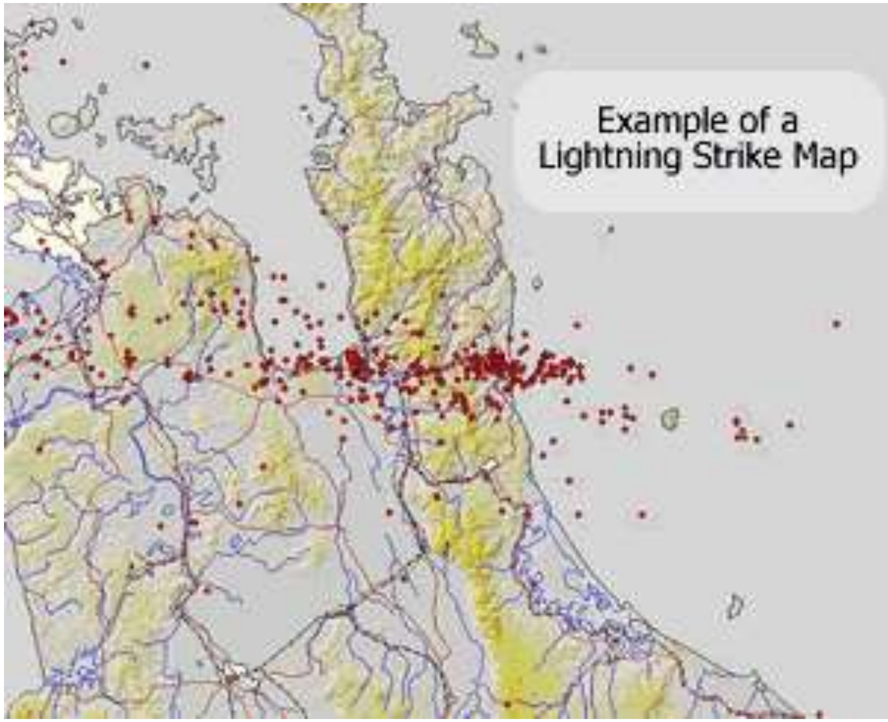
Lightning Detection Systems

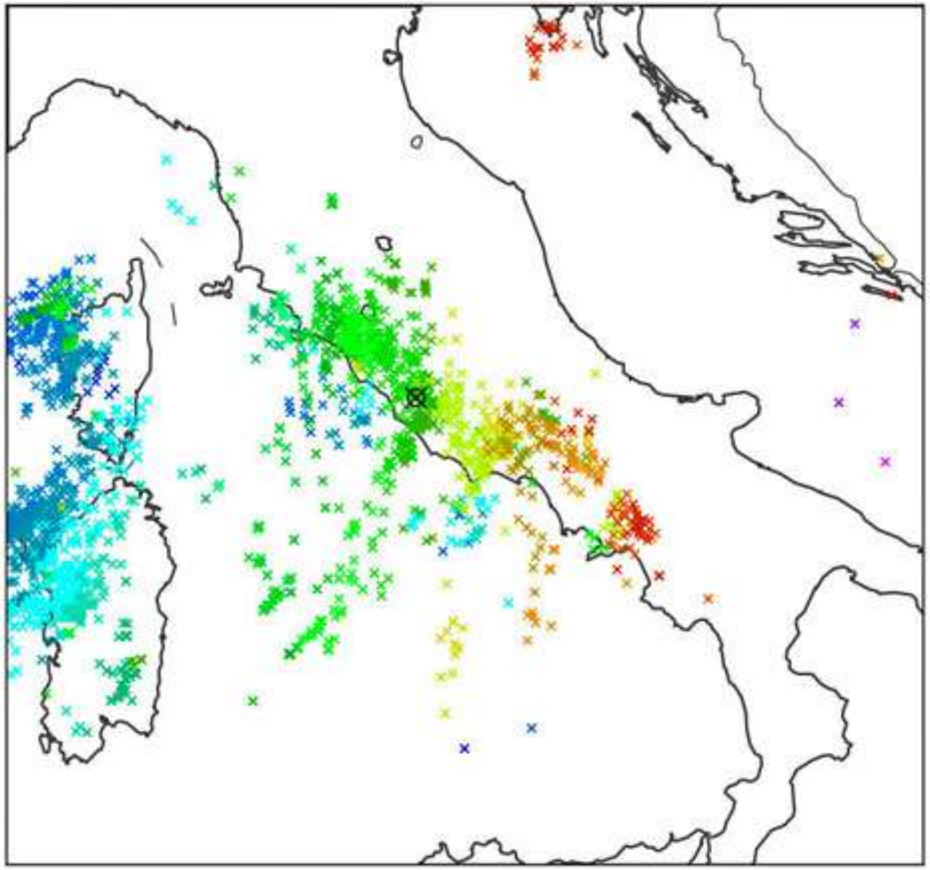
A lightning detection/locating system is composed of antennas, global positioning system (GPS) receiver, GPS-based timing circuit, digital signal processor and onboard storage and internet communication equipment.

Depending on the design, systems can detect only cloud-to-ground strikes, or both cloud-to-ground and in-cloud discharges (total lightning)

Lightning Strike Mappings

Data from lightning detection systems can be plotted to show locations of strikes and their polarity. Such plots can be used to follow the progress of individual thunderstorm cells and to infer thunderstorm intensity from the strike rate. Applications: life, livestock safety, including large venues; wildland/bush and structure initiation; insurance verification; power grid management

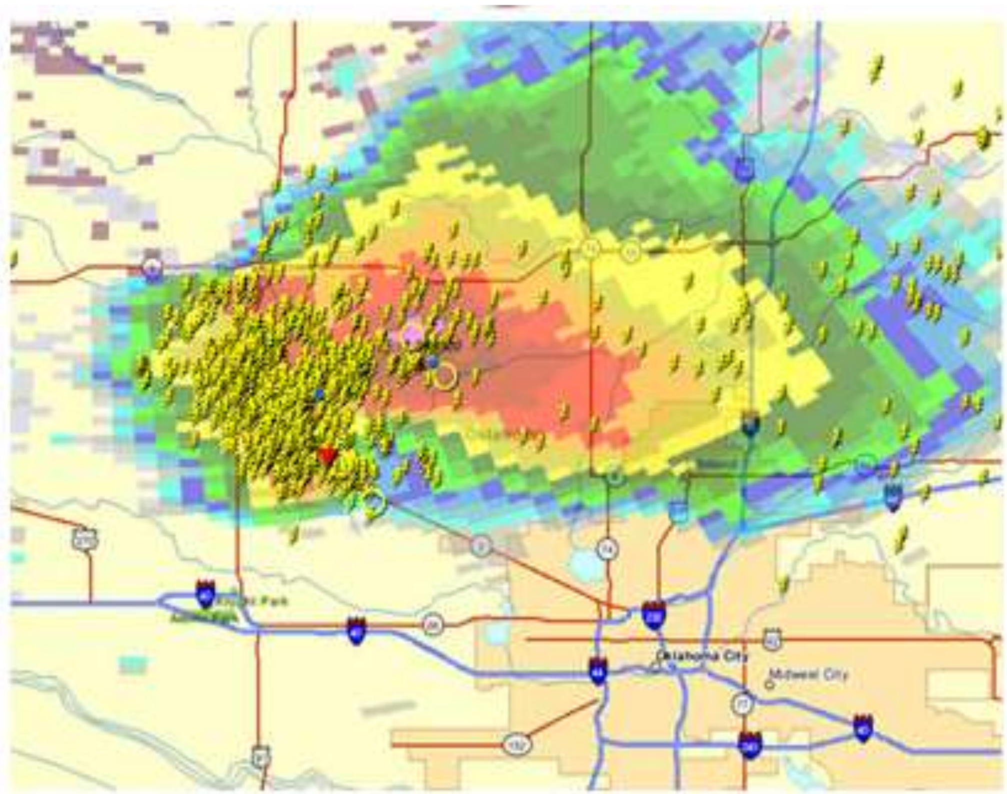




Lightning Detection in Deep Convection

Overlaying lightning locations with radar observations allows determination of correlations between lightning and storm features. As shown in figure, strikes are often concentrated in the updraft region, the most active region of the storm.

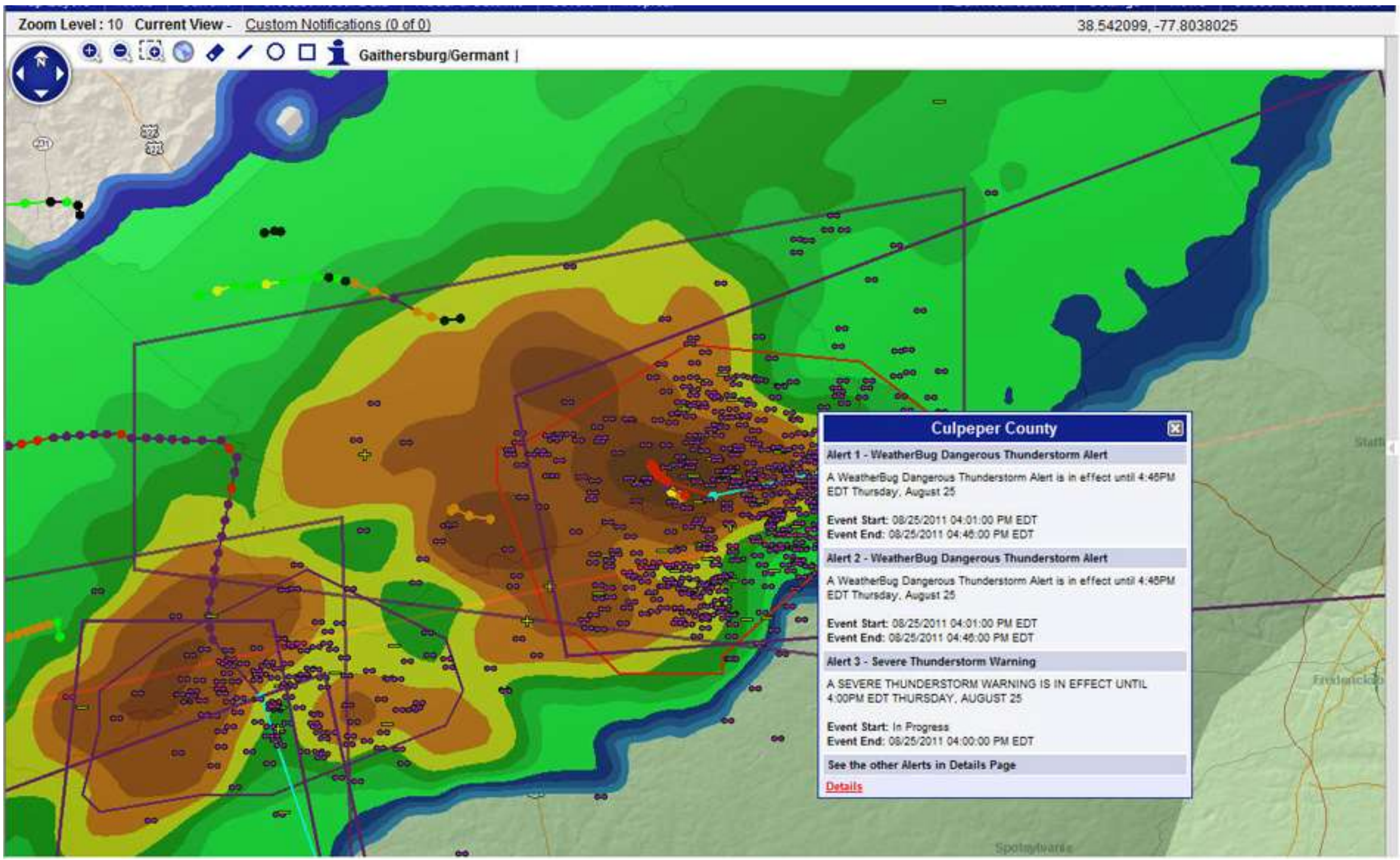
Can serve as a complement or substitute for weather surveillance radar and/or satellite observations



A near-real time meteorological product marketed by Weather Decision Technologies. This product is a composite of radar and lightning strikes. The latter are derived from lightning data produced by the United States Precision Lightning Network, Inc. (USPLN). The USPLN was developed and is now operated by a partnership of WSI Corporation and TOA Systems, Inc.

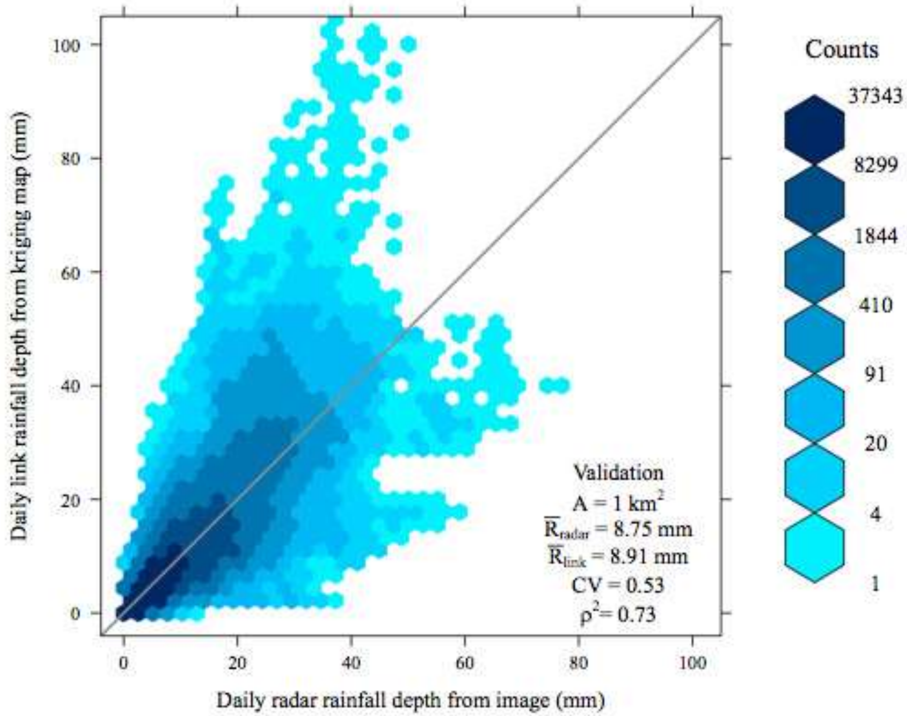
Estimating storm structure and evolution

Using statistical relations, one can infer a great deal from the rate and pattern of lighting flashes (in this case, total lightning) and even use such a system to automatically issue warnings.



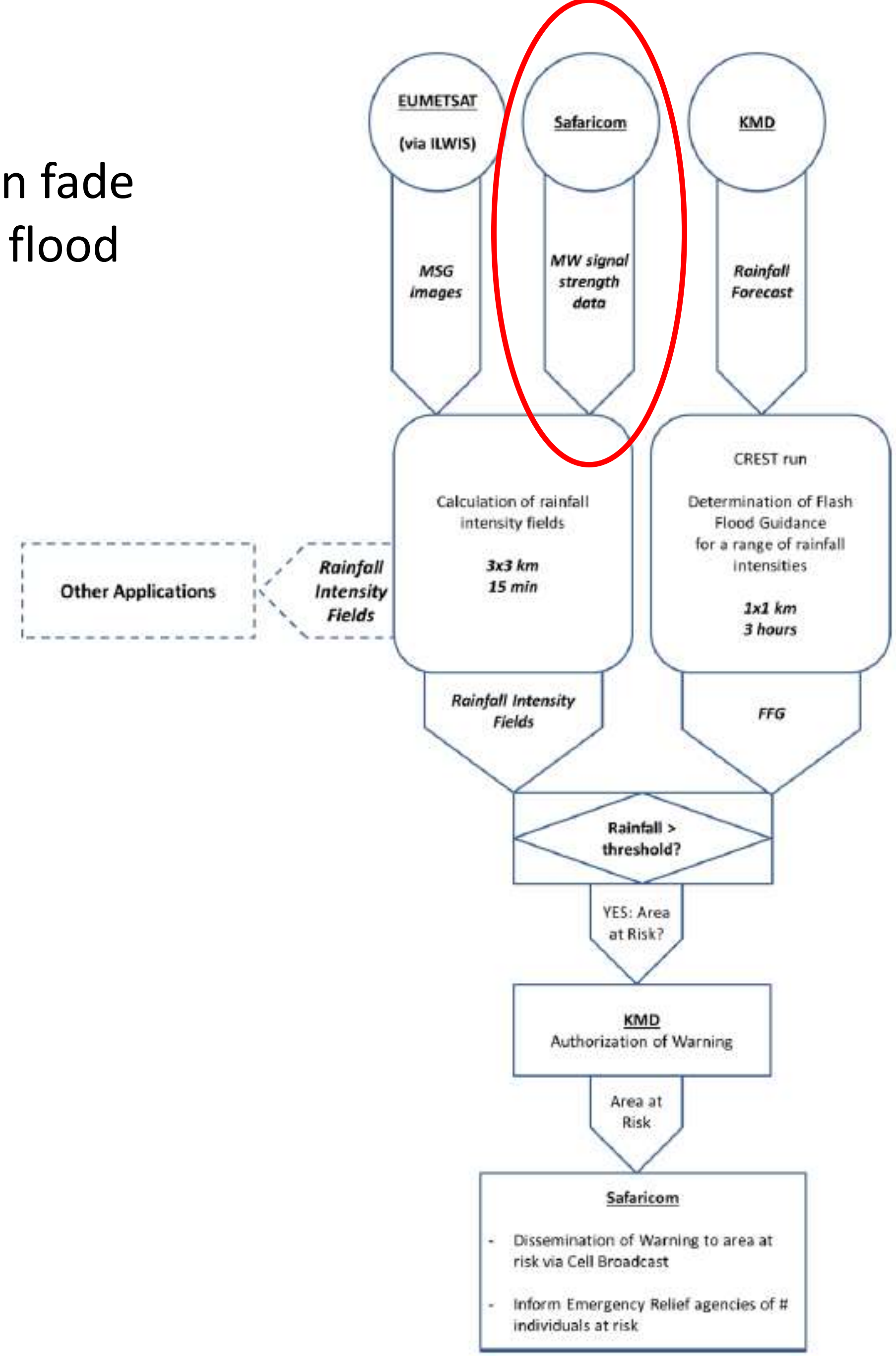
Rain-fade in Cell Phones: An Emerging Complement to Lightning-based Systems

- By definition, lightning-based systems require lightning → adequate for deep convective rainfall
- For shallow convection (showers) and stratiform rain, use a different approach → rain fade in cell phone signals. Data already available at cell tower sites
- Also works in thunderstorm rain, though signal may saturate; in this case, supplementary to lightning system
- Needs data brought to a central site for processing
- Best where there are many cell towers – in and near urban areas; along major roadways



Validation of cell link rainfall estimates against corresponding radar rainfall estimates -- daily rainfall depths for each radar pixel of 1 km^2. Only those rainfall depths have been used where link and/or radar have measured >0.1 mm. Gray line is y= x line; R = average rainfall depth at the radar pixel, CV = coefficient of variation, and ρ^2 = correlation coefficient. Overeem et al. (2013).

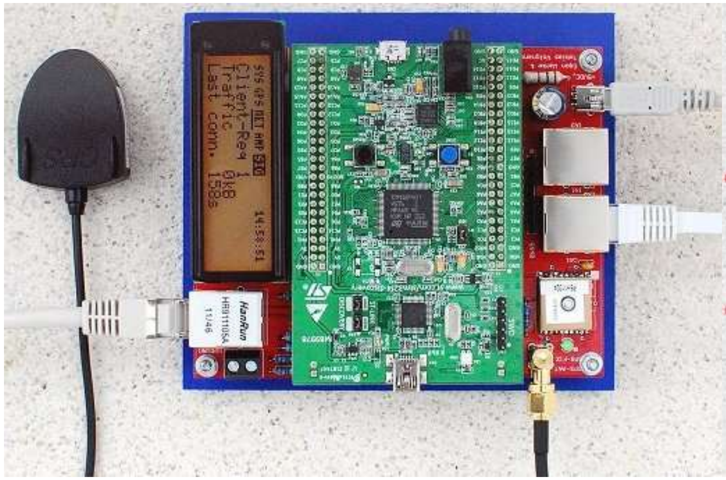
A concept sketch showing how rain fade information might contribute to a flood warning system in Kenya

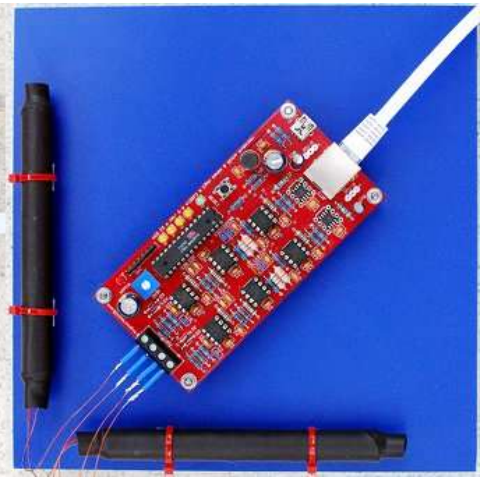


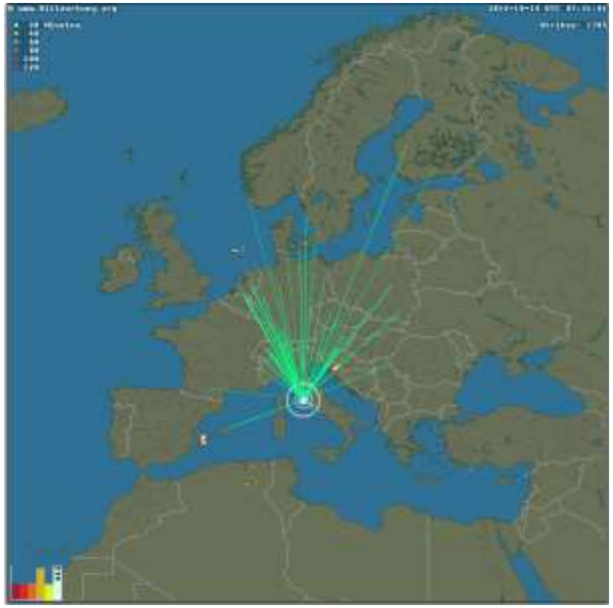
Crowd-sourced observations 2

Lightning Location Data from Weather Enthusiasts

Simple detectors connected via the Internet to an equally simple central process. Simple realization of a sophisticated design.







http://www.blitzortung.org/Webpages/index.php?lang=en&page=3

Active area observing systems

Small, Networked X-band Radars

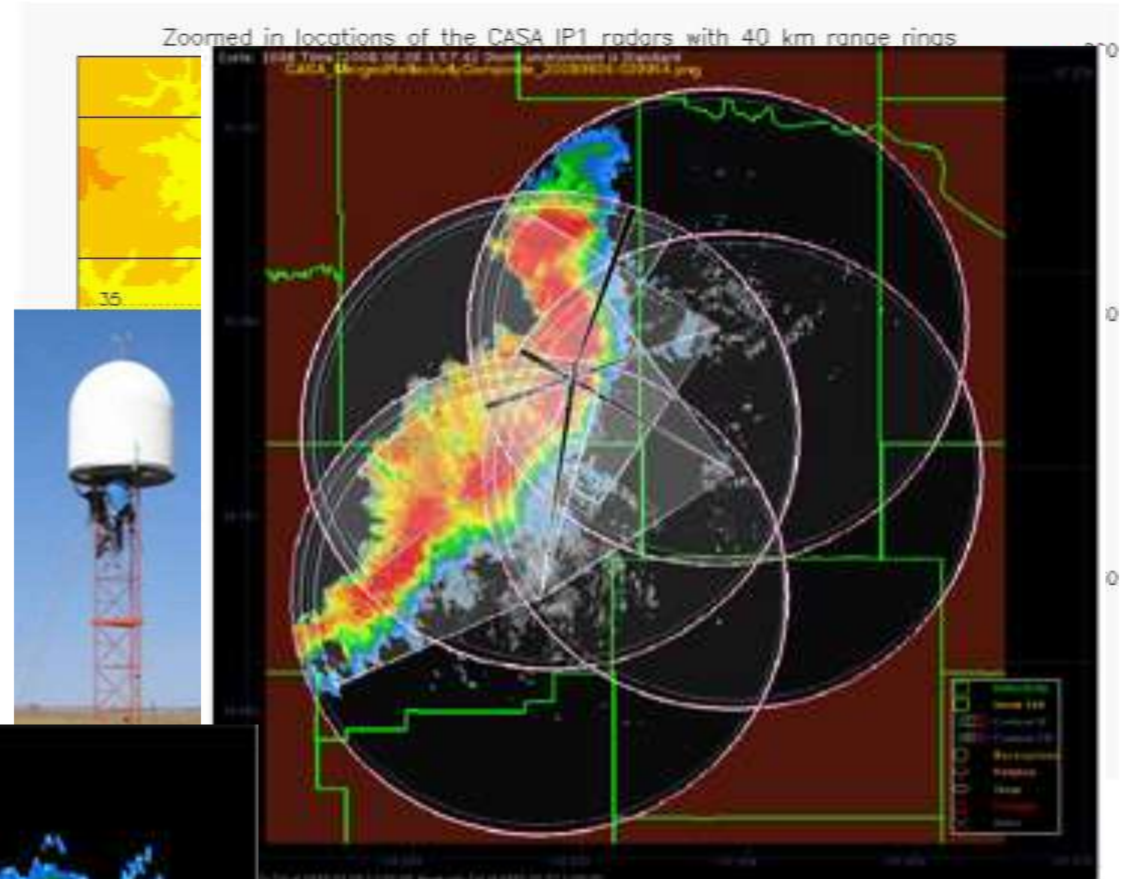
- **Self-contained X-Band dual-polarized, Doppler weather surveillance radars**, particularly when utilized in self-controlling networks
- Provides a radar capability where deemed essential.
- Maintenance handled by swapping out an entire unit or by major assembly replacement
- **Extraordinary value comes when a number of such radars are networked and operated using a central, highly autonomous weather-adaptive control system**

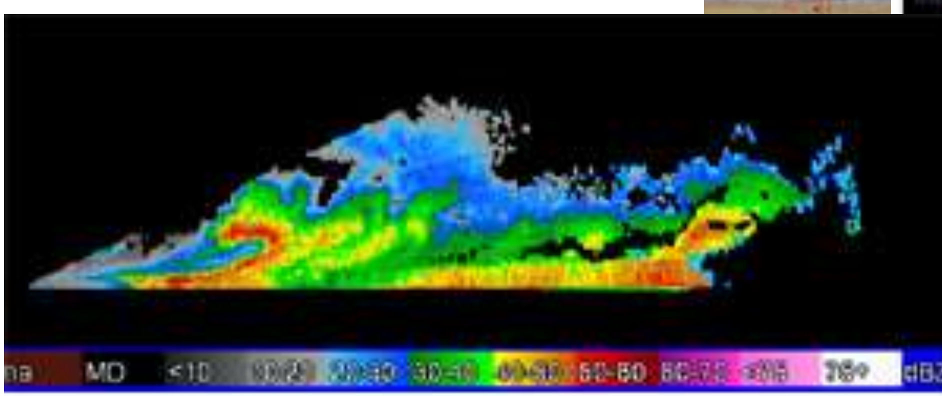
Example: A compact, fully-integrated X-band radar made by the Enterprise Electronics Corporation. It features Doppler and dual-polarization capability, choice of 100- or 500-Watt solid-state transmitters, and very low power consumption, all in a unit weighing less than 400 lbs/180kg.

Example: A Four-Radar X-band Network

Map shows the CASA IP1 four-radar network in southwestern Oklahoma; black circles are 40-km range rings for the indicated radars.

- Inset picture shows one of the CASA X-band systems; for size, note the technician about to work on the radar.





Final Comment: Training and professional development, and then retention of NHMS staff is key to successful deployment, operation, and sustainment

- Success hinges on the enthusiastic involvement of the NHMS administrative staff responsible for the project, the forecasters who will be using the data, and the supporting technical staff.
- To obtain the desired sense of ownership for the system by these individuals, **training and professional development in advance of and/or parallel with the deployment of new technologies are essential**
- Retention of staff through rewards and incentives such as pay increases and performance bonuses needs to be a priority with the NHMS senior management

Thank you very much

Questions?

jsnow@ou.edu

Observations on Cell Phone Towers

A Way Forward – Leverage Cell Towers as Observing Sites

Utilization of the cell phone systems – towers, communications, electrical power, etc… – as the backbone for national/regional weather observing networks

Weather Observations on Cell Towers: Good enough? *Yes!*

"Cell phone tower mounted meteostation and standard meteostation data four seasons inter comparisons."

By Roman Bakhtin, Arkadiy Koldaev, Yuri Lanin, Sergey Sarychev RPA "Typhoon", Roshydromet, Russia

http://www.wmo.int/pages/prog/www/IMOP/publications/IOM-109_TECO-2012/Session1/P1_14_Koldaev_Cell_phone_tower_meteostation.pdf

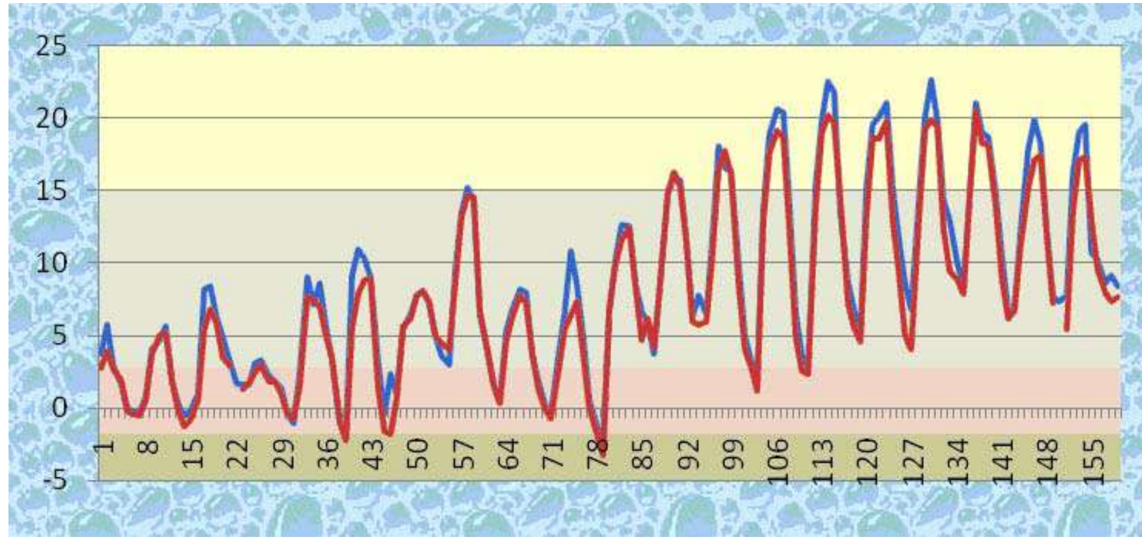
Extensive testing for traditional surface observations (p, T, T_d, wind, etc…) on open lattice towers

Figure 2 Overall view of placement weather station on cellular tower

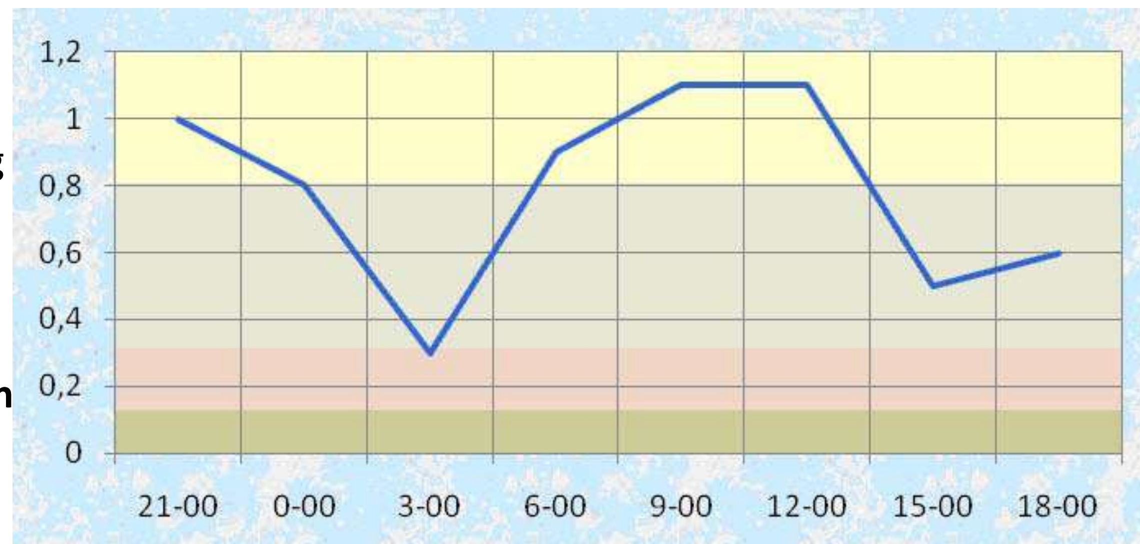
Figure 1 Wind speed and direction sensor, temperature and humidity sensor and precipitation sensor are placed on cellular communication tower

Findings of Bakhtin et al. (2012): Temperature

Upper plot shows time series of the observed atmospheric temperature at a cell-tower site (blue) and a nearby standard site (red) for a period of 20 days in March 2011. Values are at three-hourly intervals, for eight points per day; lower axis is labeled with the index number of the observation, starting from 1 at the left.



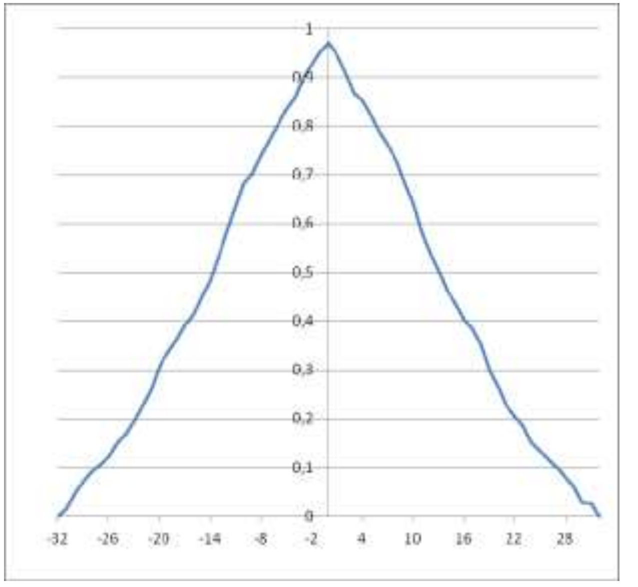
Lower plot shows average differences in temperature between the observing sites (with 20 observations at each three-hour observing time) versus observing time: **temperature differences never exceeded more than 1.1C^{o}**.

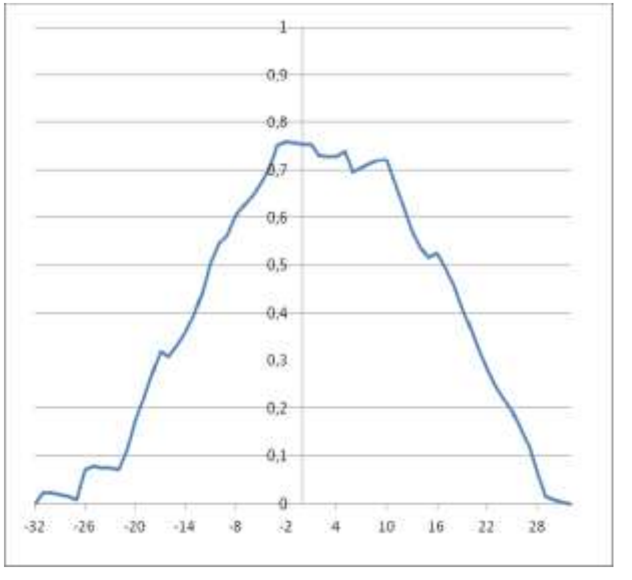


Findings of Bakhtin et al. (2012):

Wind Direction

Two plots showing the results of a correlation analysis of wind direction between cell-tower observations and those at a nearby standard observing site. The data were first sorted by average wind direction.





Upper plot: So long as the wind does not blow through the lattice tower before reaching the wind vane, the correlation is quite high, 0.95

Lower plot: If the wind blows through the tower before reaching the wind vane, then a significant fraction of the correlation is lost due to local effects, e.g., eddies from the tower structure

N.B.: Post-processing can restore some of the loss of correlation once details of local site are documented

Summary of findings of Bakhtin et al. 2012

It was shown that, comparisons for temperature, humidity, pressure and wind speed were surprisingly sustainable.

Only wind direction data demonstrated visible divergence and just in case when wind direction is corresponding to the aerodynamic shadow of the wind sensor

. The results of this work allow to state that the meteorological stations mounted on the cell phone tower are able to provide reliable data for 4 main meteorological parameters, and wind direction should be revised in case of specific situation

The specific situation, when the wind direction data are not useful, can be very easy calculated a-priory from the topological information about orientation of the cell tower and position of the wind sensor. Alternative solution is in utilization of two wind direction sensors.

Bottom line: Many cellular telephone towers are suitable sites for making weather observations that are sufficiently accurate to support local forecasting and climate studies

Partnership with cell company offers a viable path forward for development of national/regional surface network and delivery of services to a growing population

Effective coordination, collaboration to ensure buy-in, significant involvement of all partners: the NHMSs, telecom/utility co, instrument makers, data wholesalers, …

References

Cell phone tower mounted meteostation and standard meteostation data four seasons inter comparisons."
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RPA "Typhoon", Roshydromet, Russia
Available at https://www.wmo.int/pages/prog/www/IMOP/publications/IOM-109_TECO-2012/Session1/P1_14_Koldaev_Cell_phone_tower_meteostation.pdf

Development of the Specialized Automatic Meteorological Observational Network Based on the Cell Phone Towers and Aimed to Enhance Feasibility and Reliability of the Dangerous Weather Phenomena Forecasts, by M. B. Fridzon and Yu. M. Ermoshenko
Gidrometpostavka Federal State Unitary Enterprise, Novovagan'kovskii per. 8, Moscow, 123242 Russia
ISSN 1068-3739, Russian Meteorology and Hydrology, 2009, Vol. 34, No. 2, pp. 128–132. Allerton Press, Inc., 2009.
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