Additional Data via Autonomous Systems to Supplement Traditional Sparse Sources for Weather Forecasting and Atmospheric Science

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Director, NASA Kentucky Space Grant and EPSCoR Programs
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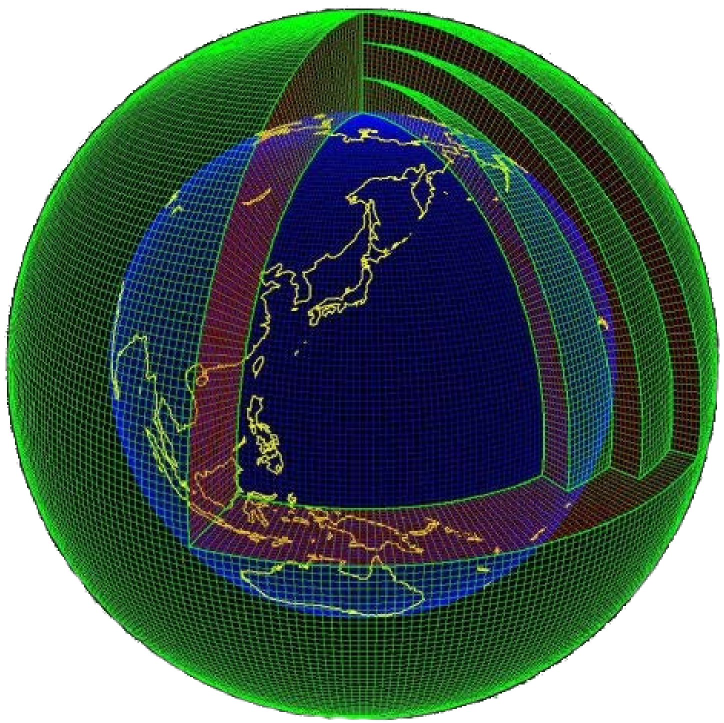
Commonwealth Computational Summit

October 17, 2017

Predictive Weather Models

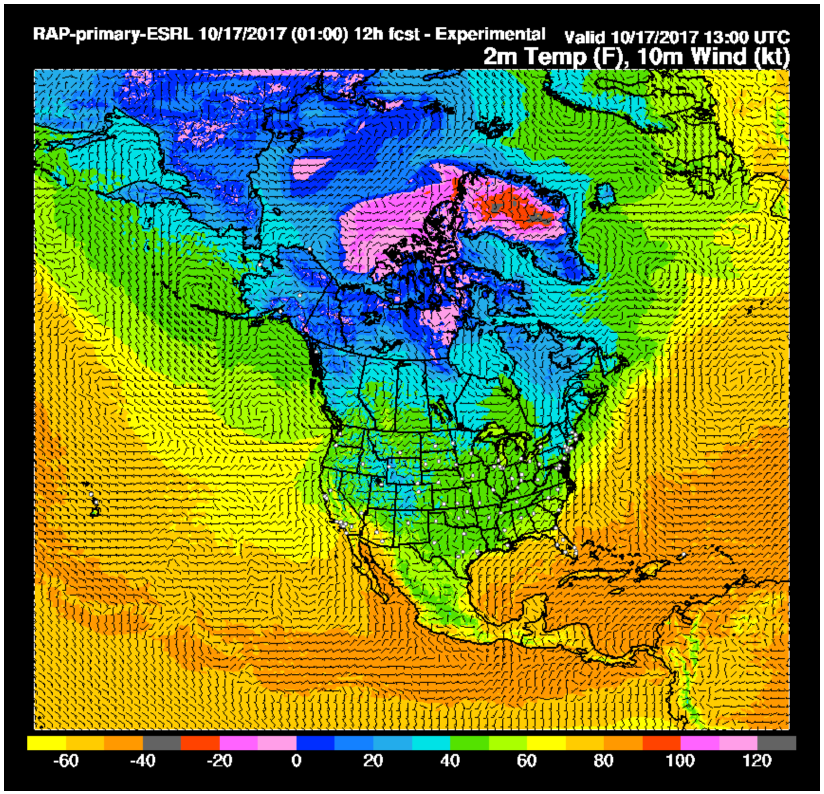


https://public.wmo.int/en/our-mandate/weather

- Foundations in the early 1900s
- Supercomputing in the 1970s
  - Numerical methods for scale interactions, boundaries, initialization, time-stepping
- Hierarchy of models and complexity
  - Physical process representation
  - Ensemble forecasting
  - Model initialization

Bauer, P., A. Thorpe, and G. Brunet (2015) “The quiet revolution of numerical weather prediction,” *Nature*, 525, 47-55.

U.S. Weather Prediction



https://rapidrefresh.noaa.gov/

https://rapidrefresh.noaa.gov/hrrr/

Current RAPv3/HRRRv2 Models

Applications (2 to 24-48 hrs)

- General forecasting, renewable energy, severe storms, and aviation planning

RAPv3 (1 hr update, 13 km grid)

- Continental scale assimilation/modeling

HRRRv2 (1 hr update, 3 km grid)

- Assimilation of 3 km radar @15 min
- Assimilation of RAP 13 km @ 1 hr
- Cloud/convection model

Est grid points/surface area:

- RAP: 300,000; HRRR: 5,000,000

Weather Observations and Data

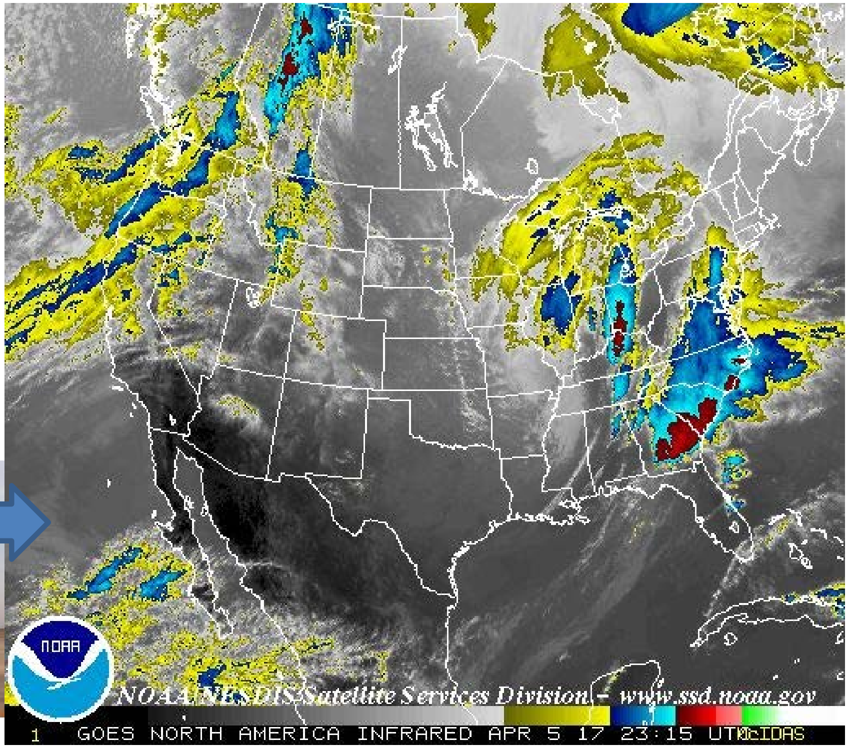
Hourly sources for observations



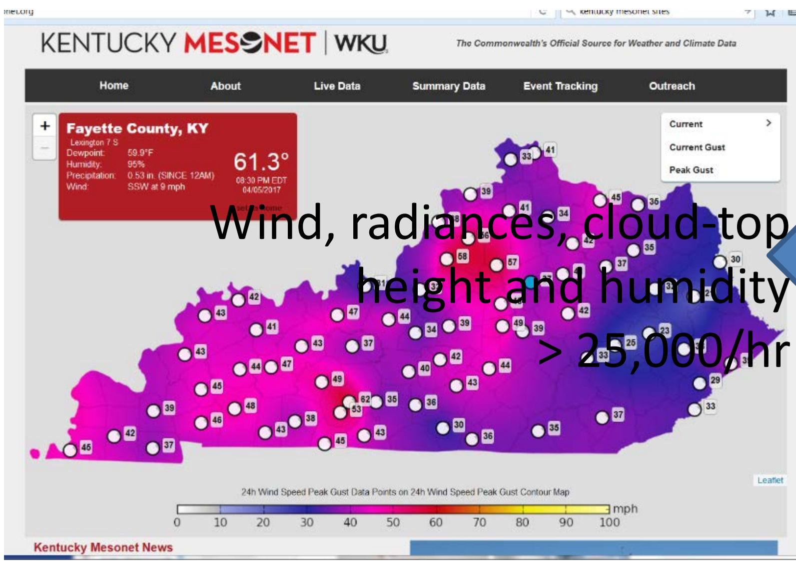


Weather Observations and Data

Wind, radiances, cloud-top height and humidity
> 25,000/hr



Weather Observations and Data



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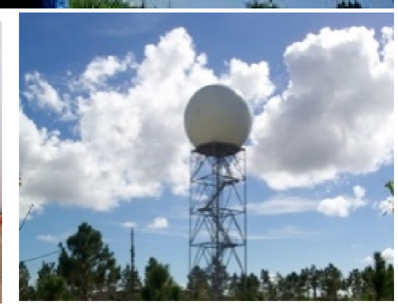
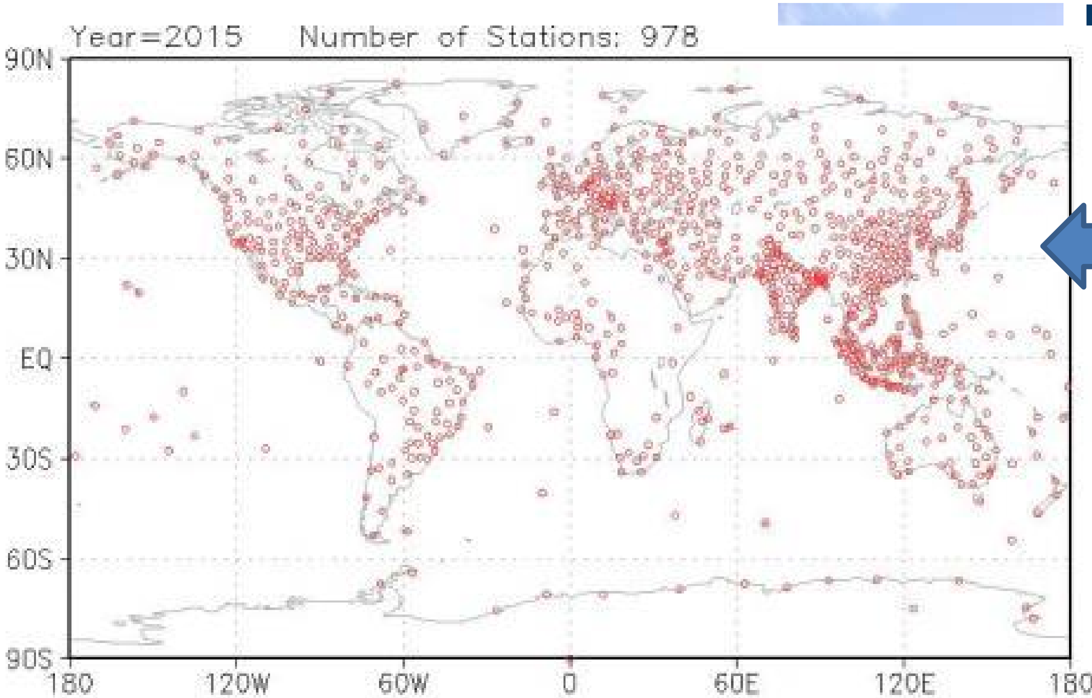
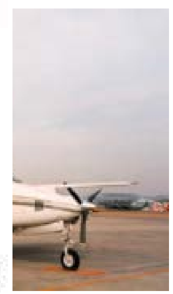
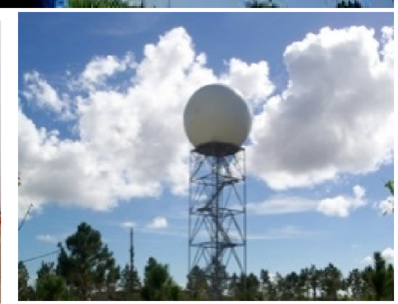


Temperature, moisture, wind, pressure, clouds, visibility, weather
> 15,000/hr

Weather Observations and Data

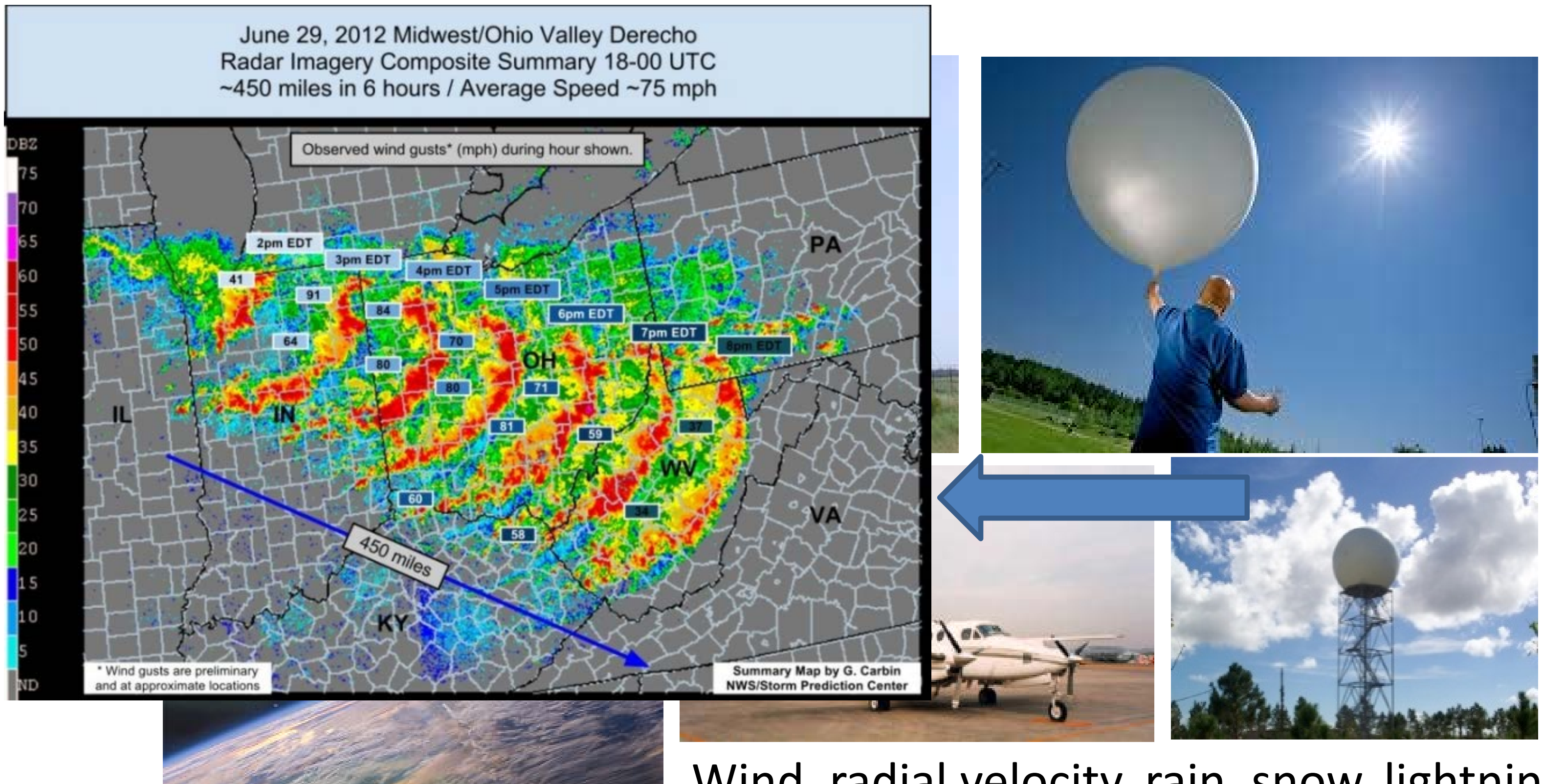






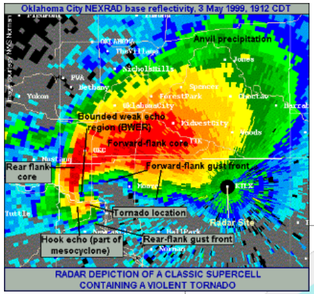
Temperature, humidity, wind, pressure
~ 150/hr

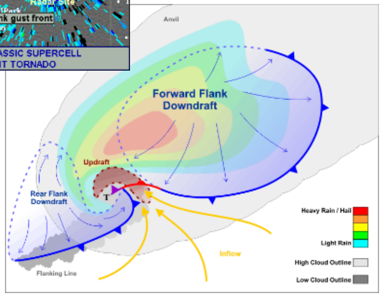
Weather Observations and Data

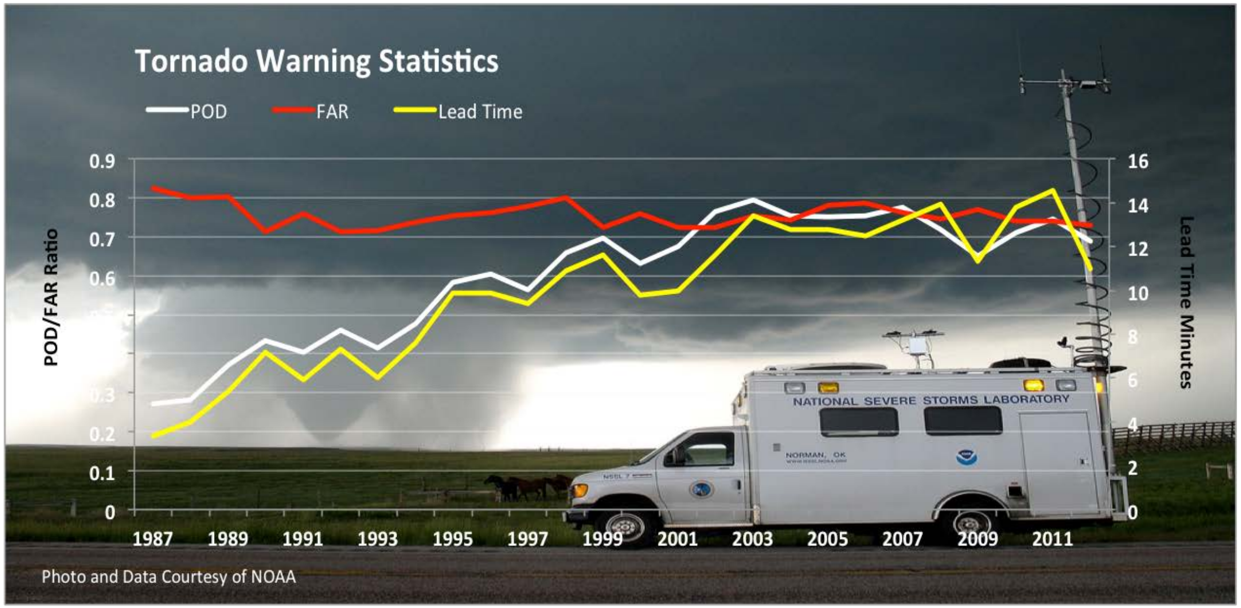


Wind, radial velocity, rain, snow, lightning
1,500,000/hr, plus 125 radars

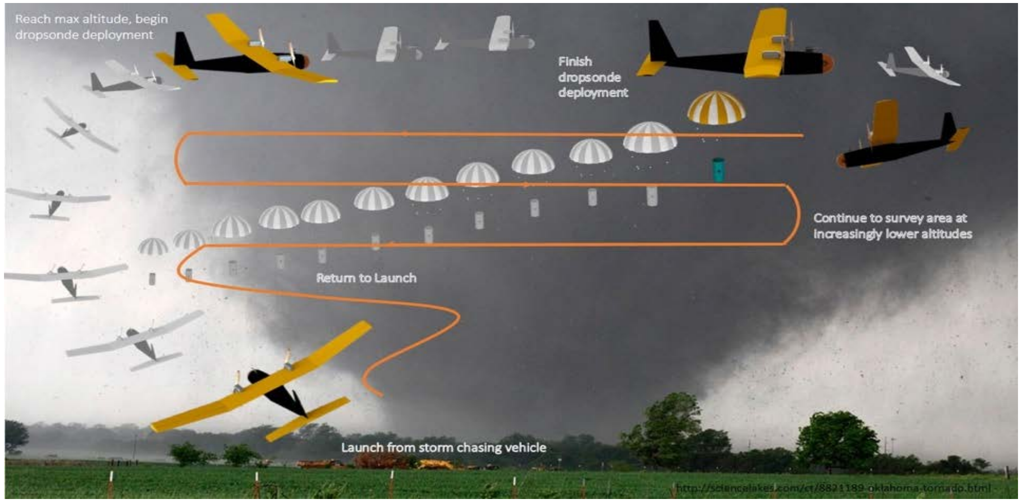
Severe Weather –
Anatomy of a Supercell

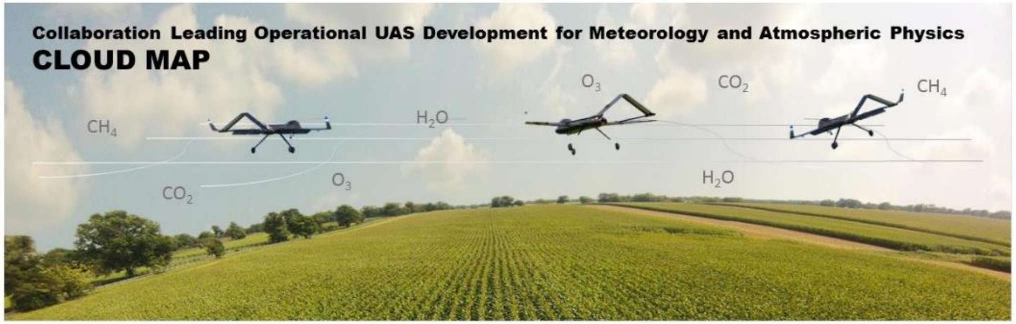






Research Toward Envisioned Reality



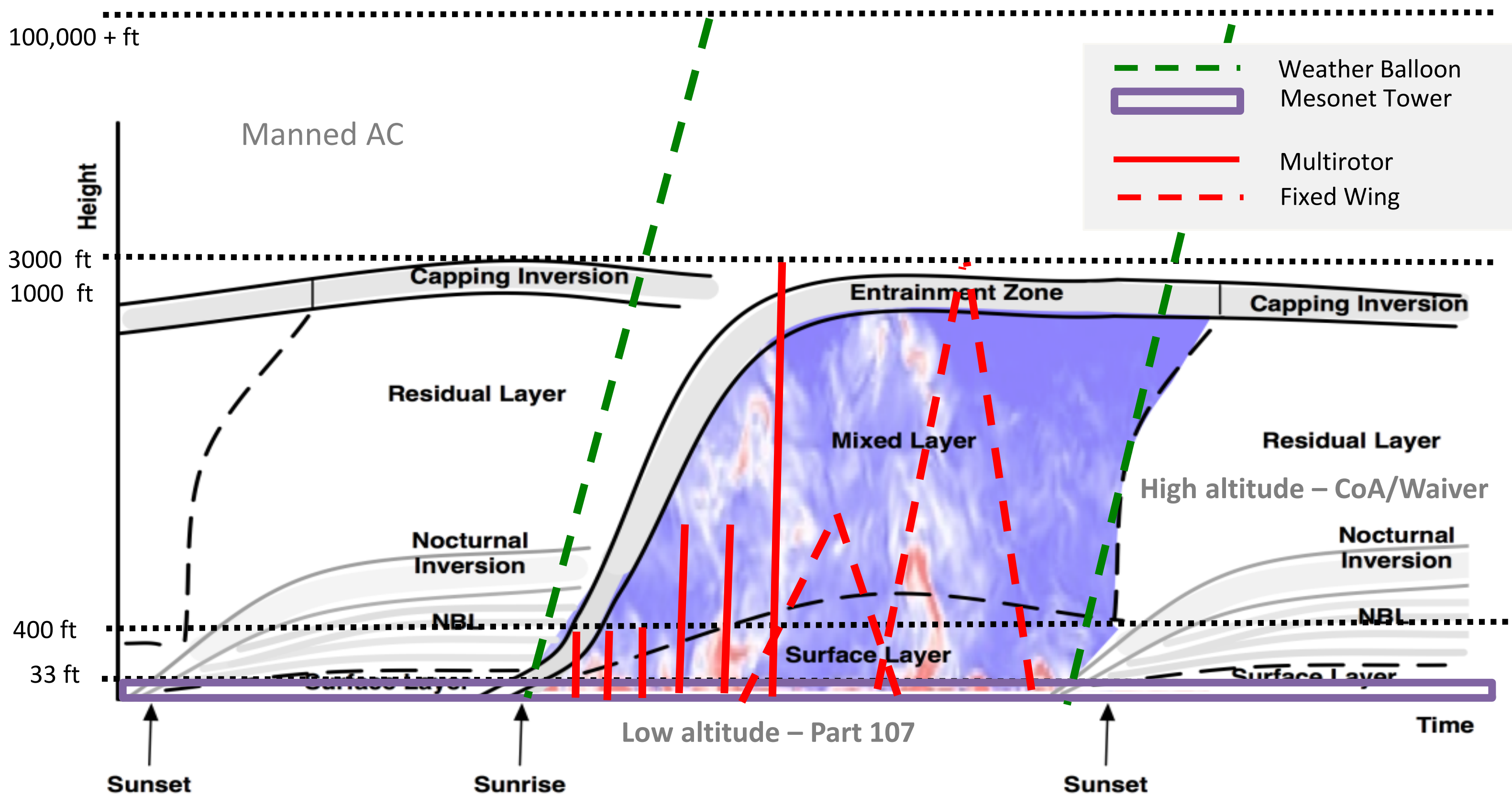


Drones for Weather Observations

The lowest part of the atmosphere (boundary layer) is directly influenced by terrain, ground use (forest, crops, urban, etc.) and diurnal cycle affecting heat transfer, pollution dispersion and advection, turbulence, and agricultural and urban meteorology.

The Boundary Layer is Accessible Using UAS

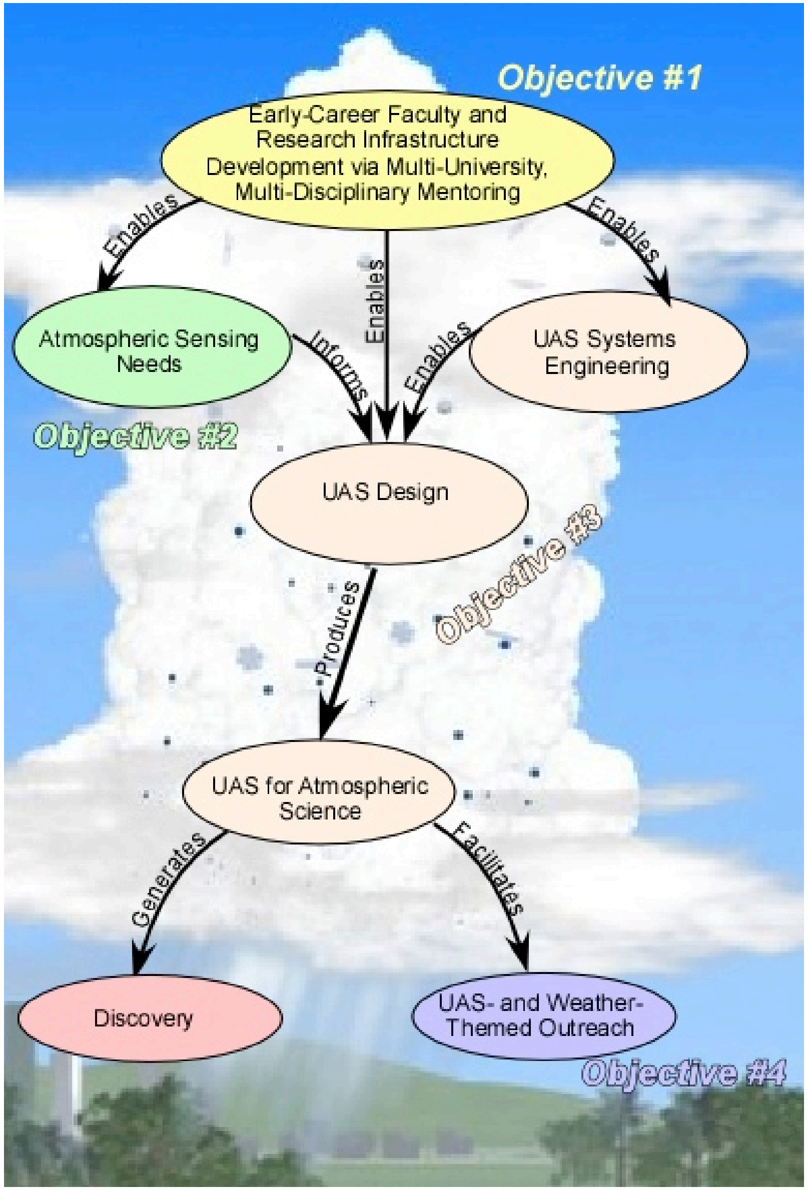
Small UAS In Boundary Layer Meteorology



CLOUD-MAP

Collaboration Leading Operational Uas Development for Meteorology and Atmospheric Physics

1. Develop a strong mentoring program and intellectual center of gravity in the area of *UAS in Weather* and develop joint efforts for the development of a national center in use of UAS in Atmospheric Science.
2. ***Create and demonstrate UAS capabilities needed to support UAS operating in the extreme conditions typical in atmospheric sensing, including the sensing, control, planning, asset management, learning, control and communications technologies.***
3. ***Develop and demonstrate coordinated control and collaboration between autonomous air vehicles.***
4. Develop and conduct UAS themed outreach in support of NSF's technology education and workforce development.



CLOUD-MAP Team









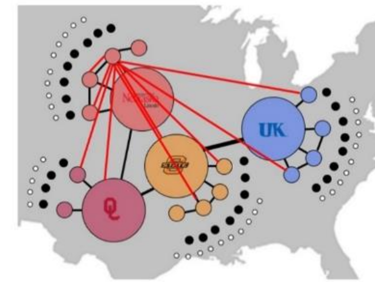








Atmospheric Physics
Risk Dissemination
RF Communication
Storm Microphysics
Public Perception
Distributed Data
Convection Init.
Climatology
Hydrology
Chemistry
Swarming
Infrasonics
Sensors
GIS
UAS



>100 NSF participants including faculty and trainees (even more w/staff)

2017 UK-only Campaign Summary

Fixed Wing Flights

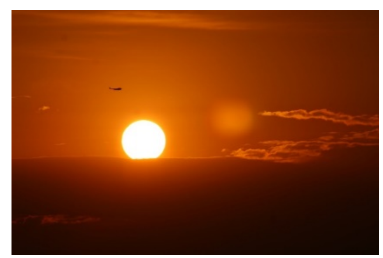
- Skywalker X8's in triples or pairs
  - Turbulence transects or multi-unit control
  - 39 flights, 33.183 hrs

Rotorcraft Flights

- Solo (Sonic), DJI Phantom (Chem and BAE), S1000+ Octocopter (BAE)
  - Profiling or remote ground sensing
  - BAE: 20 flights, 5.017 hrs
  - Chem: 36 flights, 9.055 hrs
  - ME: 44 flights, 9.733 hrs

Total: 139 flights; 57 hrs

UK to host researchers in Kentucky in 2018!









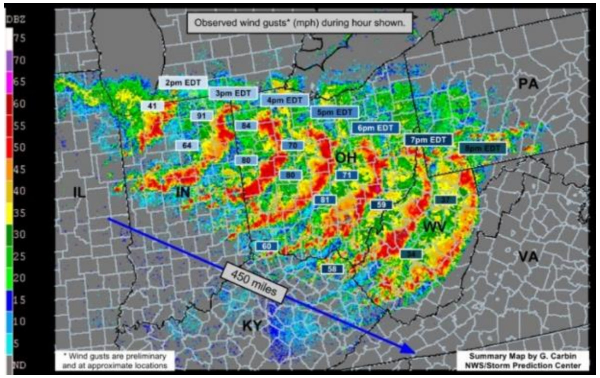
CLOUDMAP



Drones Can Answer Important Questions

Science:

- Identify Fuel for Bow Echo (Straight Line) Winds?
- Influence of Cold Pools on Storms and in Valleys?
- Effects of Ground Features?



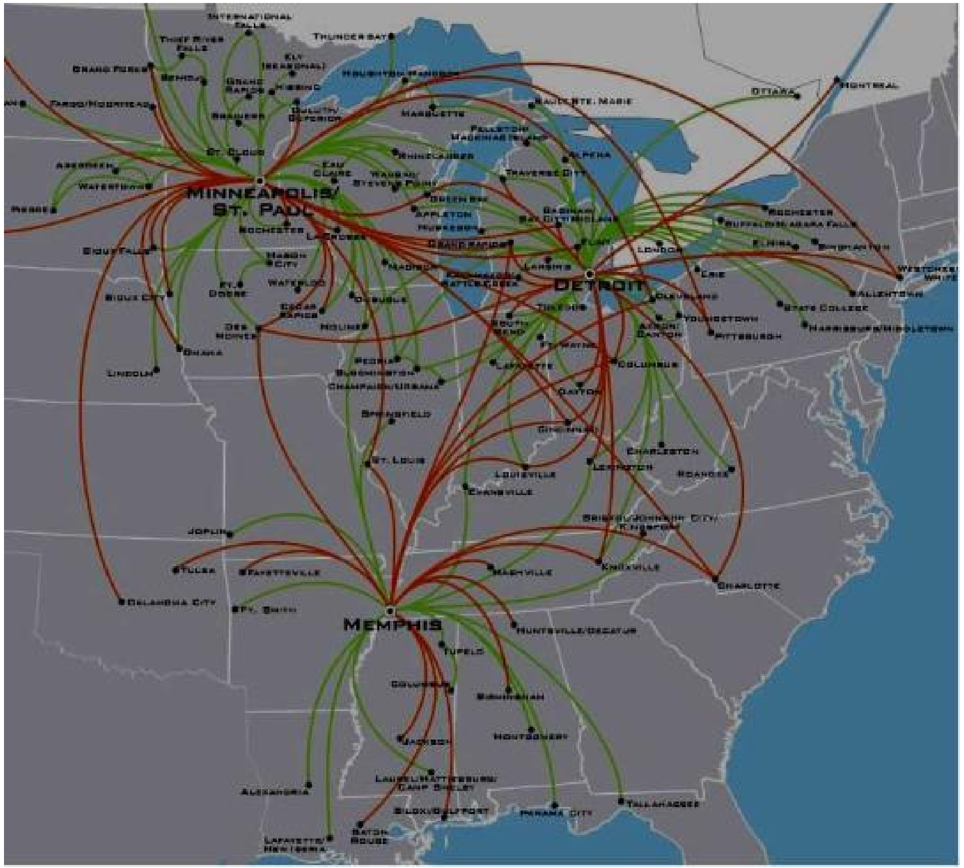
Modeling:

- Validate Physical Process Models

Observations:

- Assimilation Data

Flights and Weather

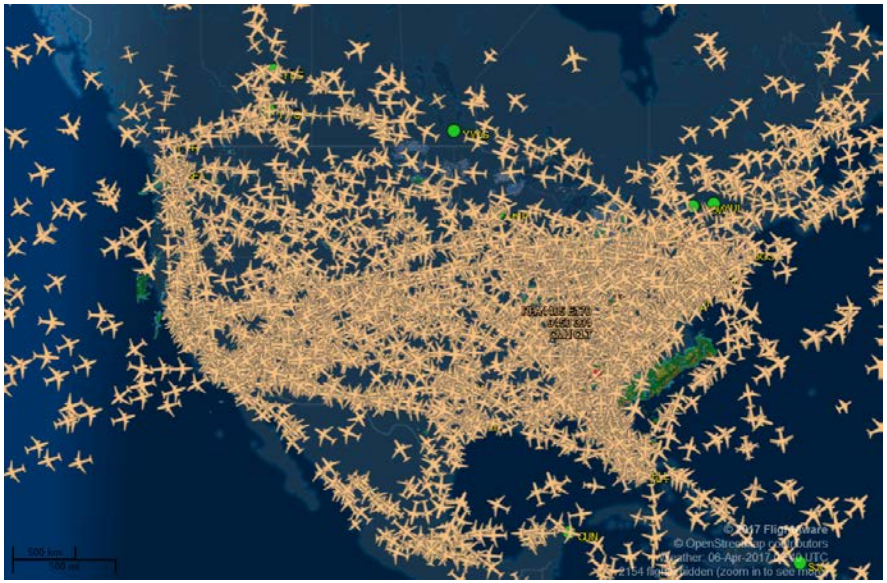


From NASA Evaluation (2006) Tamdar Sensor on Commuter Flights

Today, TAMDAR sensors on >400 aircraft flights daily contribute observations to AirDat forecasting

http://www.airdat.com
/tamdar/index.php

Flights and Weather



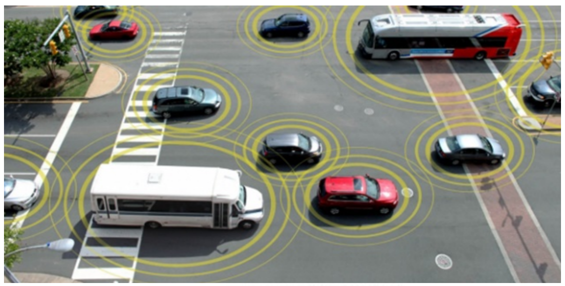
Flight Tracker (4/5/17)

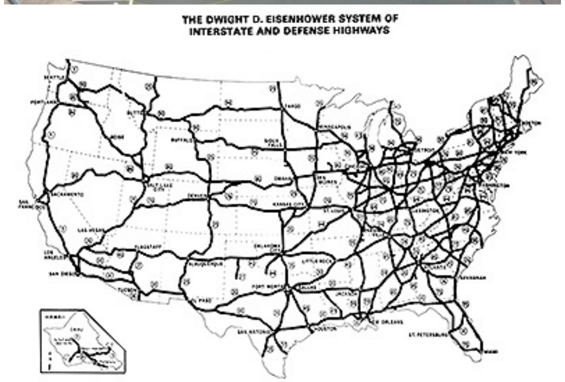
SkyWest Route Map (Oct 2017)

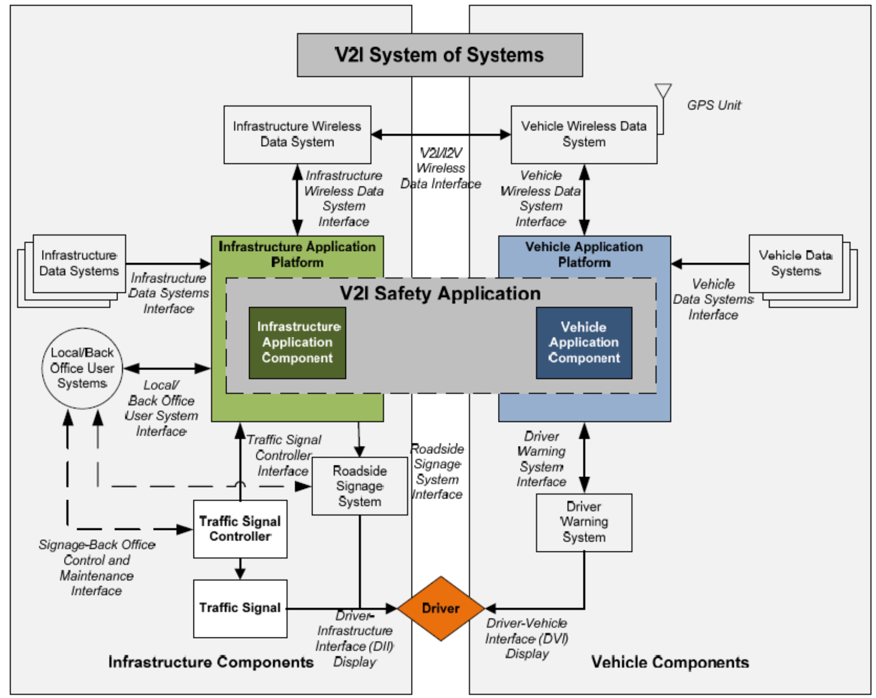
In one year, controllers handle an average of 64 million takeoffs and landings."
- From the National Air Traffic Controllers Association (https://www.natca.org/)

https://sos.noaa.gov/datasets/air-traffic/

Weather and Traffic Management







FHWA-JPO-16-253, "Vehicle-2-Infratructure (V2I) Safety Applications; Performance Reqts, Vol. 6, Spot Weather Information Warning – Diversion (SWIW-D)," Aug 2015

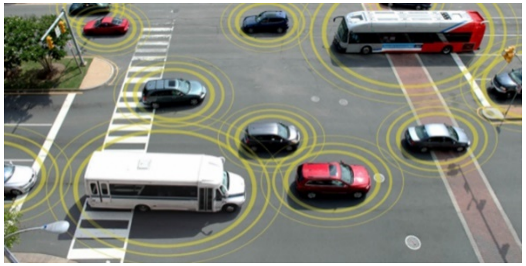
https://www.forbes.com/sites/oliviergarret/2017/03/03/10-million-self-driving-cars-will-hit-the-road-by-2020-heres-how-to-profit/#717faf8c7e50

http://fortune.com/2017/01/06/drones-registrations-soaring-faa/

Future Observations including Autonomous Systems

Hourly Observation Type	Variables Observed	Observation Count
Satellites	Wind, radiances, cloud-top height and humidity	>25,000
Ground Stations (Mesonets, etc.)	Temperature, moisture, wind, pressure, clouds, visibility, weather	>15,000
Balloons	Temperature, humidity, wind, pressure	~150
Radars	Wind, radial velocity, rain, snow, lightning	>1.5M, plus 125 radars
Aircraft (TAMDAR, US flights)	Temperature, pressure, winds, humidity, icing, turbulence	400 daily (TAMDAR); >87,000 daily U.S. flights
UAS	Current: Temp, wind, pressure, aerosols humidity, chemistry, weather; Future: TBD	600,000 registered in 2016; 7,000,000 by 2020
Urban Sensors (e.g., Chicago AoT)	Weather, light, pollution	Chicago:50(2016); 500 by 2018 Urban Heat Island data
Autonomous Vehicles	Future: TBD (weather, temp, humidity, and more affecting road conditions)	10,000,000 by 2020
V2I Infrastructure	Future: TBD (temp, humidity, precipitation, etc)	>75,000 km in U.S. Interstate

Autonomous Systems Weather Observations



Safer Autonomous Systems Operations and Improved Weather Forecasting

Future challenges include the following, among others: Numerical methods to incorporate more, possibly lesser quality, observations into models for forecasting and operations, public commitment to provide public services and standards for observation integration, and regional observation sparsity.

QUESTIONS?