Opportunities provided by fine-scale meteorological sensor array

R.M. Randall, C.M Hocut, D.K. Knapp, B.T. MacCall, & J.A. Smith

Army Challenge

- Research gaps exist which challenge the predictability of weather in complex terrain and urban environments that are of importance to the Army for successful battlefield operations.
- To improve the accuracy of atmospheric boundary layer modeling, high-resolution spatial and temporal data is needed to refine process parameterizations (mesoscale) and for development of microscale models.

Key Technical Challenges

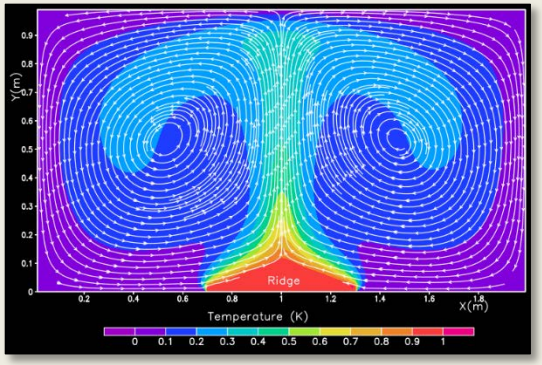
- To overcome these challenges a mesonet is required that encompasses a large continuous domain of varying topography at high spatial and temporal resolution, with continuous operation throughout varying seasonal background meteorological conditions.
- Extremely challenging due to: cost (equipment / installation / operation / maintenance), logistics and data management.

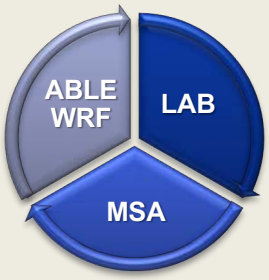
Community Context

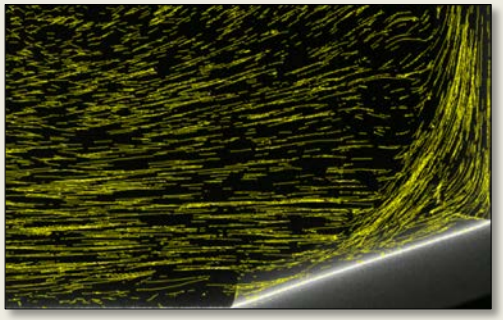
- High Resolution: Multi-agency field campaigns (e.g. MATERHORN, Perdigão, etc.) – short in duration (~1-2 months), focused on specific background meteorological conditions.
- Lower Resolution: Mesonets such as Iowa Environmental, Washington AgWeatherNet, New York State, Quantum Weather, and Oklahoma have 100+ stations – temporal resolution (~ 5 min avg.) and spatial resolution (~ variable, 8 – 32 km)

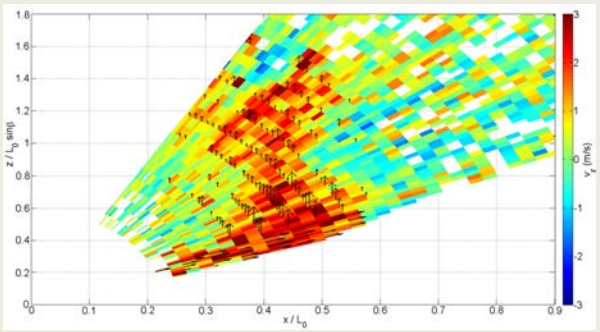
Research Methodology

Use of laboratory experiments and field experiments to refine mesoscale process parameterizations for NCAR's Weather Research and Forecasting (WRF) model and develop microscale models such as ARL's Atmospheric Boundary Layer Environment (ABLE) model to attain the capability to more accurately model atmospheric processes in complex terrain and urban environments.









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Meteorological Sensor Array (MSA) near WSMR, NM

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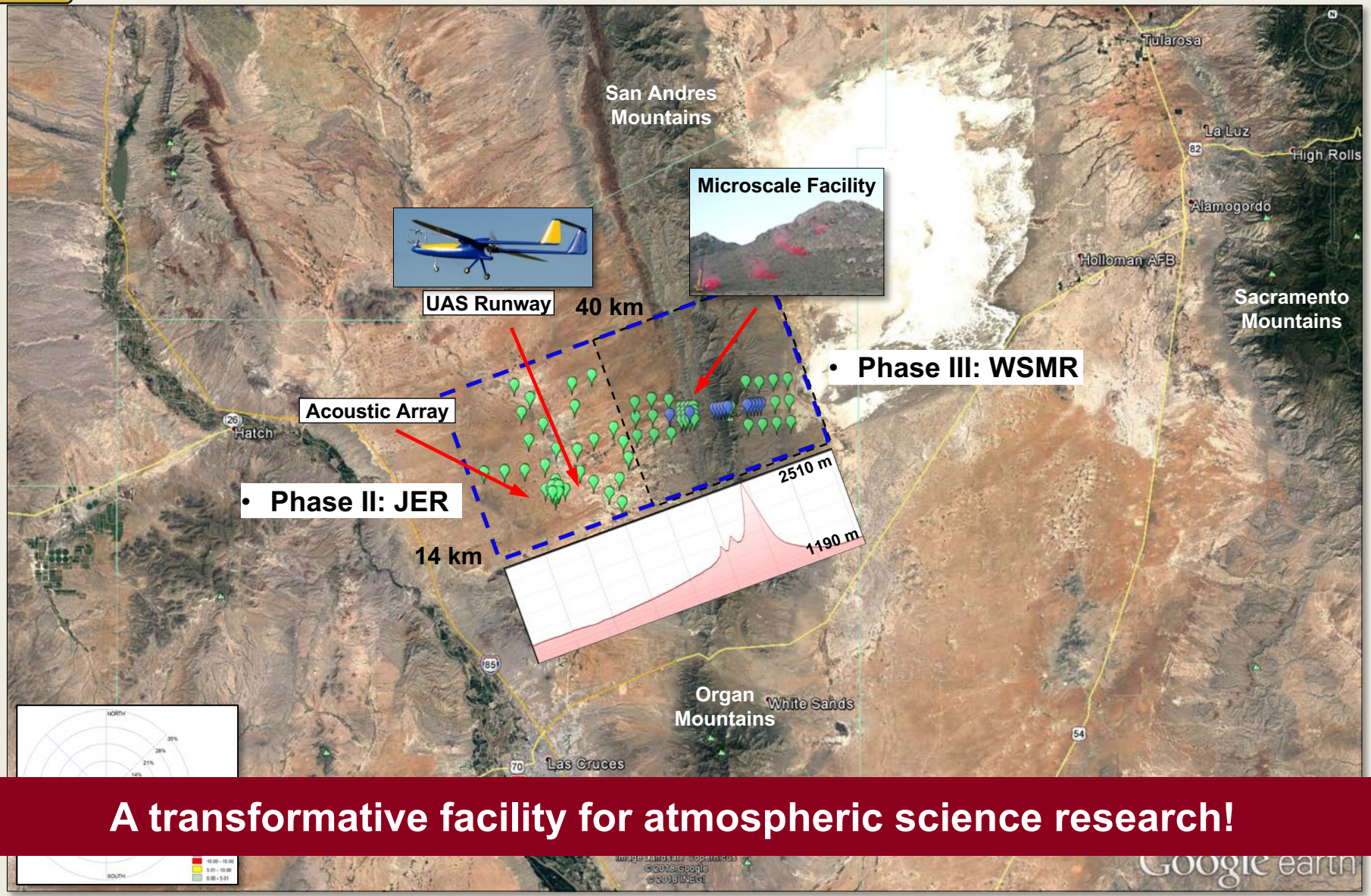

A transformative facility for atmospheric science research!

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USDA-ARS Jornada Experimental Range

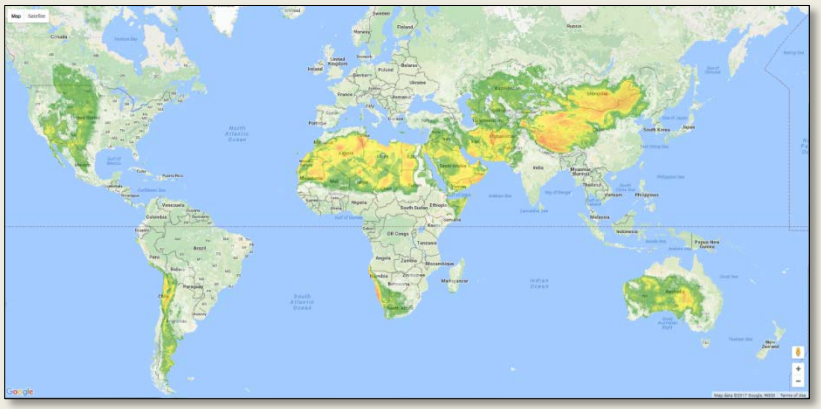
National Wind Erosion Research Network

The Jornada
http://jornada.nmsu.edu
Rangeland Research Programs

- Coordinating multi-partner National Wind Erosion Research Network.
- Basic and applied research into wind erosion and dust emission processes.
- Data assimilation for national and global modeling.
- 80,000 ha research facility with dedicated long-term ecological and dust monitoring.
- Jornada collaboration with ARL supporting data and knowledge sharing.

Jornada's National Wind Erosion Research Network Site

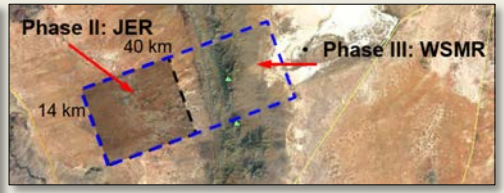
Horizontal sediment mass flux (2000 – 2014). Estimate produced using MODIS albedo-driven dust emission scheme with GLDAS. 500 m, 3 hr estimates. Model calibrated using Network data.



USDA Agricultural Research Service | NRCS Natural Resources Conservation Service | USGS science for a changing world | The Nature Conservancy

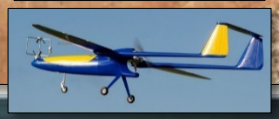
MSA – JER

Phase II: Jornada Experimental Range (JER) (USDA/NMSU)



Acoustic Array

UAS Runway



Google earth

1st tower installed
1 Dec 2016

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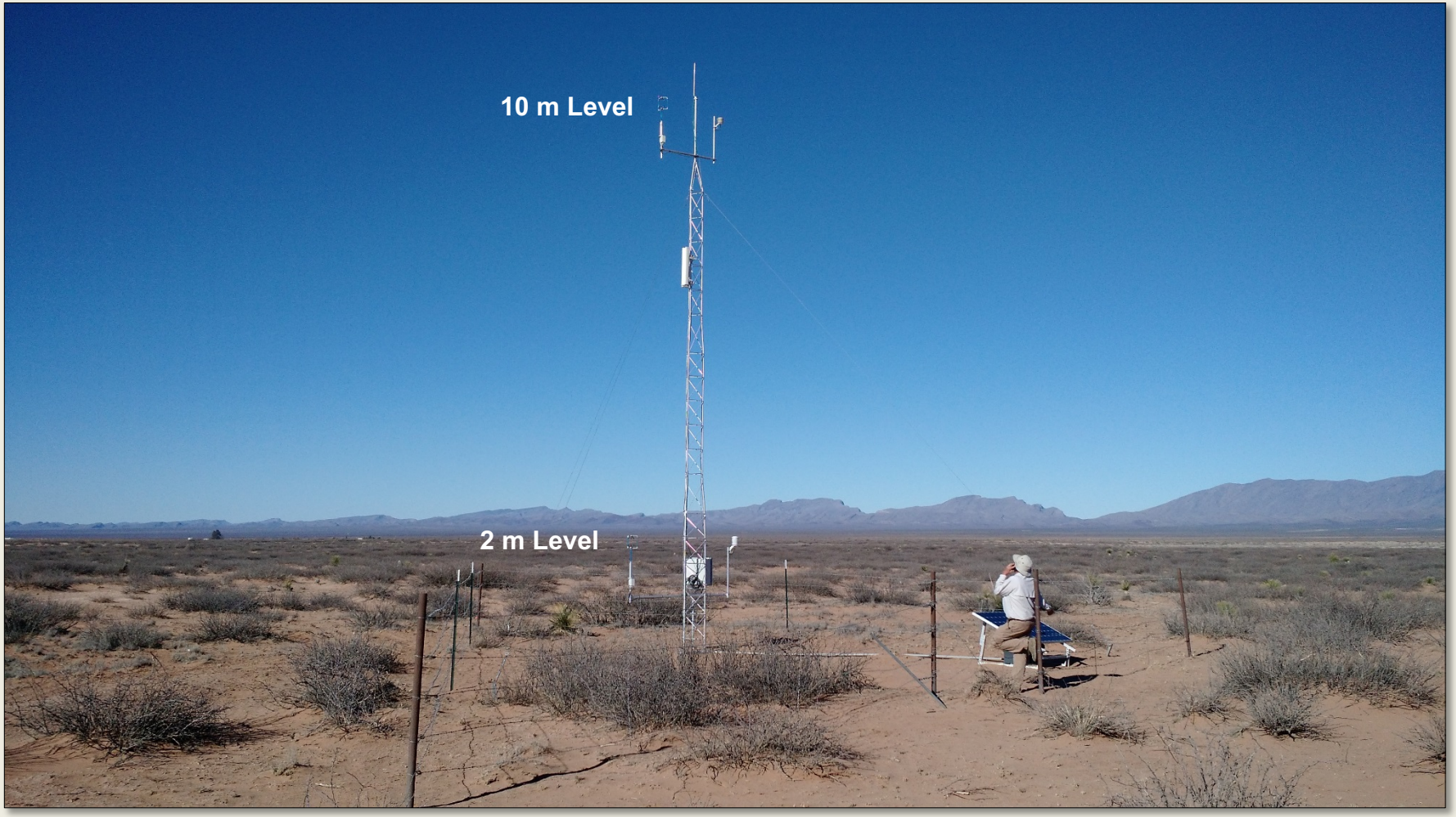
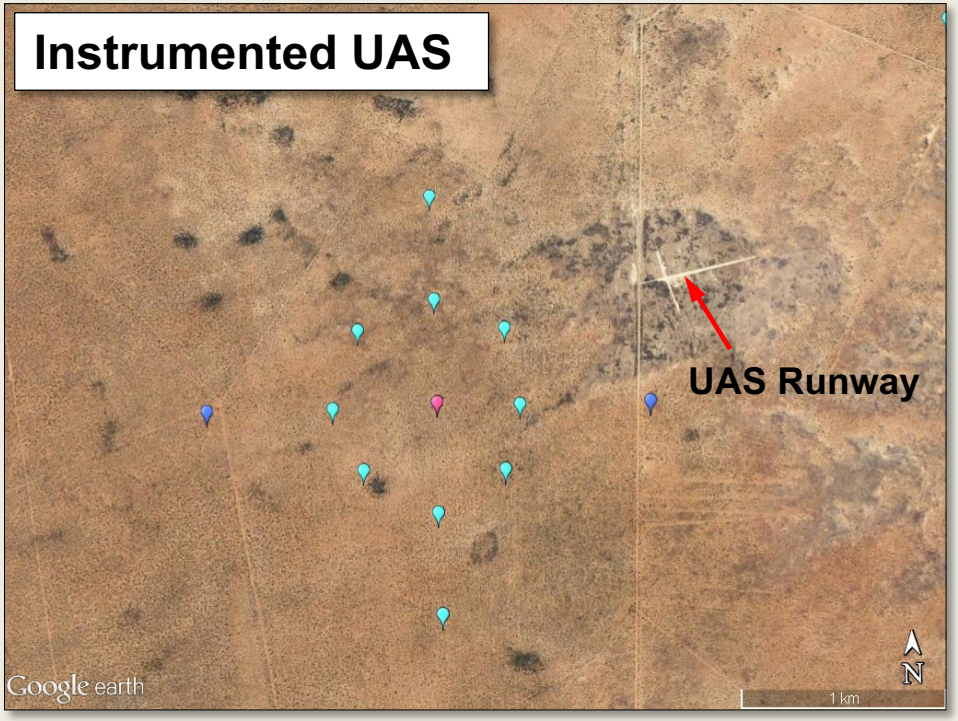
MSA – 10m Tower Configuration



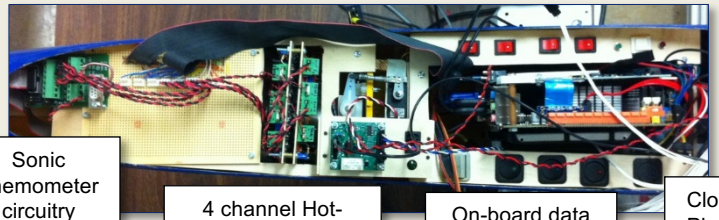
2 m Level: U, WD, T, RH, p
10 m Level: U, WD, T

Soil moisture probes at 5 and 10 cm, rain gauge, pyranometer.

MSA – UAS



UND/ARL Flamingo UAS



Boundary Layer Research:

- Test aerial platforms, Instrumentation, and sampling methods for process characterization

ARL's Automated Impacts Routing (AIR):

- Effect of turbulence on efficiency - flight time, ability to maintain an automated flight path
- Aircraft thresholds

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MSA – Complex Terrain

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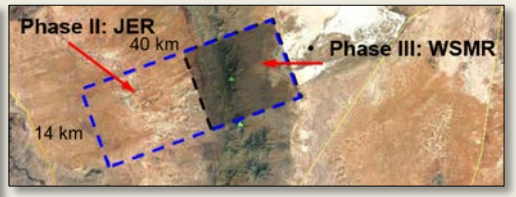
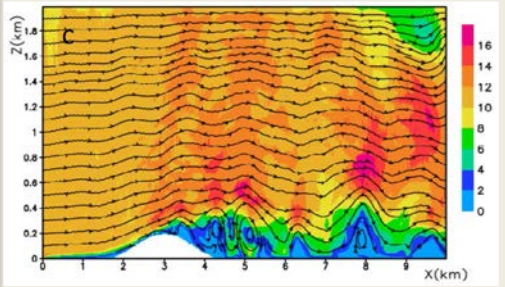
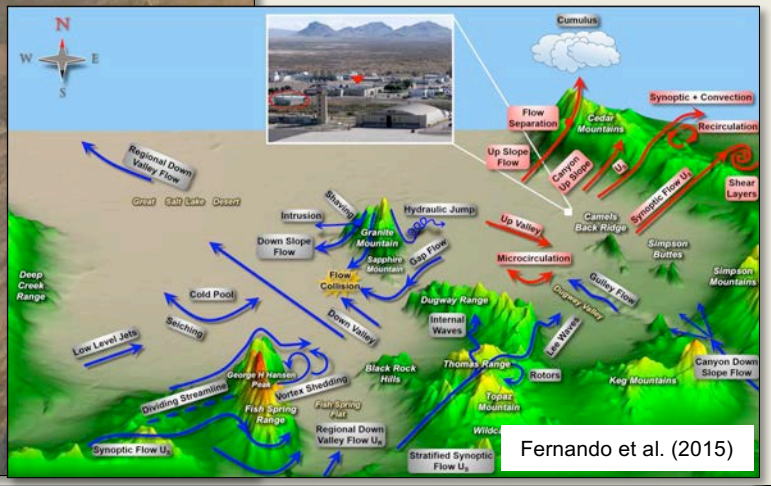
Phase III: JER / WSMR - San Andres Peak: 2510 m / 8235 ft

Microscale Facility

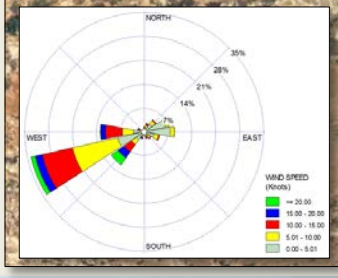




Y. Wang et al. (2018)



Fernando et al. (2015)



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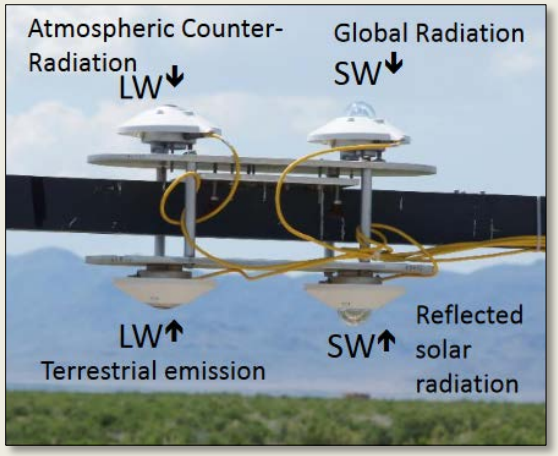
MSA – Surface Energy Budget Measurements

Net Radiometer



Sonic Anemometer

+

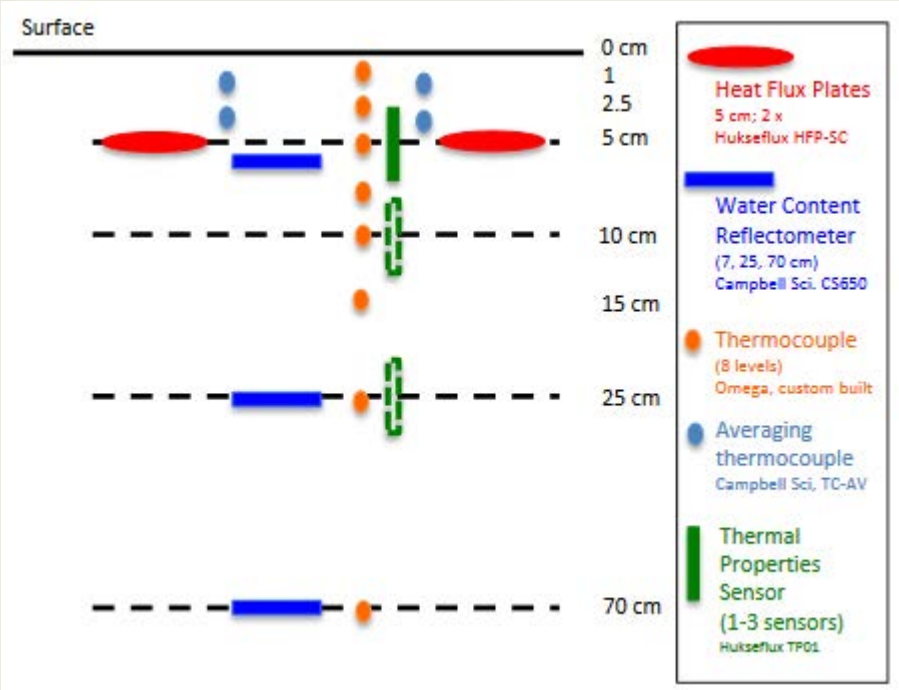
IRGAsonde

Sensible (H) & Latent (L_vE) Heat Flux

Soil Thermal Property

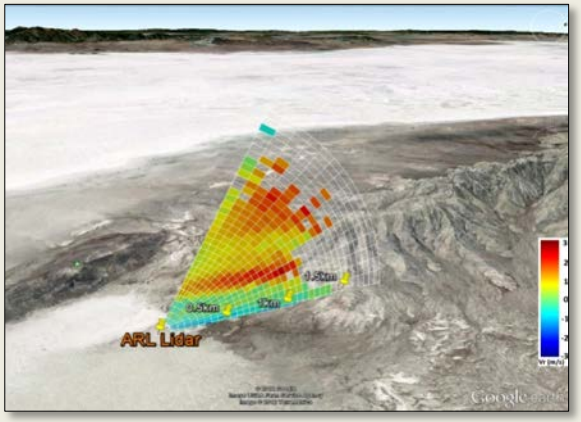
Water Content Reflectometer

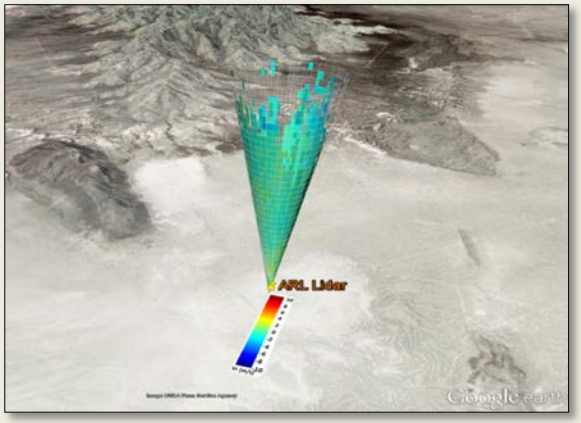
Heat Flux Plate



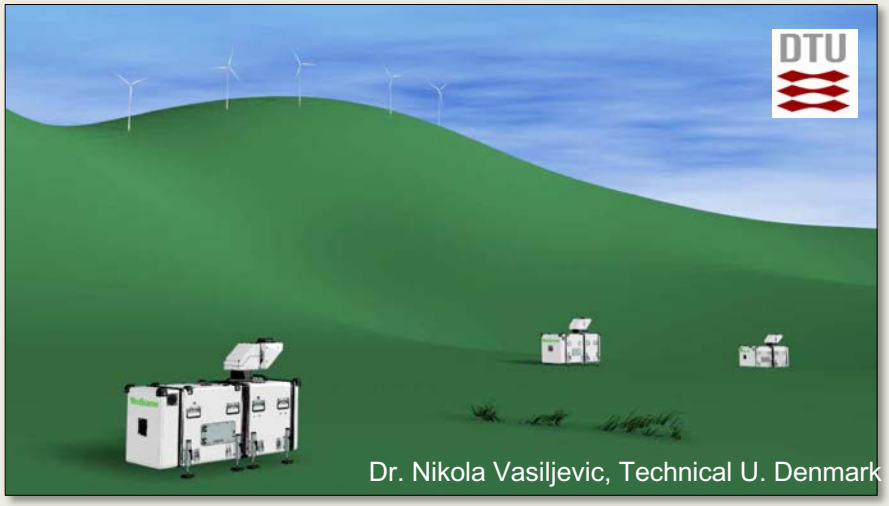
Doppler LiDAR: (Light Detection And Ranging)

$$V_r = usin\varphi cos\theta + vcos\varphi cos\theta + wsin\theta$$

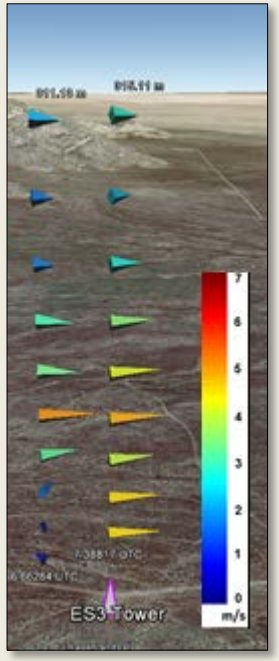




Single LiDAR Scans



Multiple Synchronized LiDAR Scans –
– directly measure u, v, w



Y. Wang et al 2016

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MSA – Background Measurements

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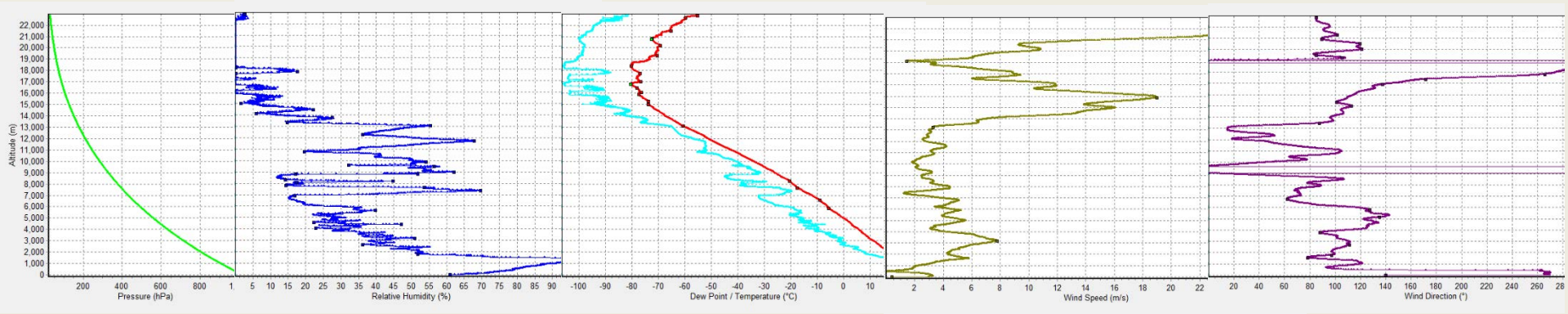
$T, RH, P,$
U, WD



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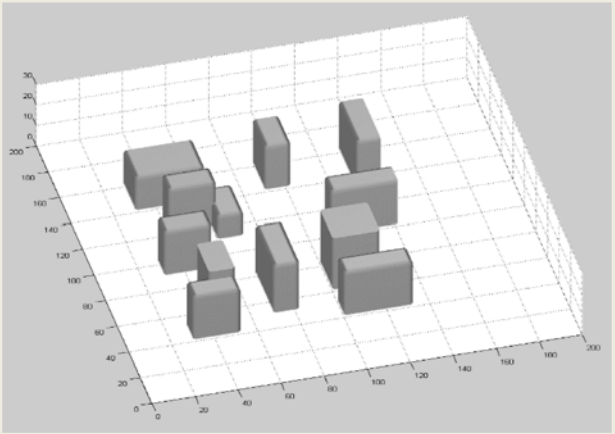
Phase IV: MSA – Dense Urban Environments (DUE)

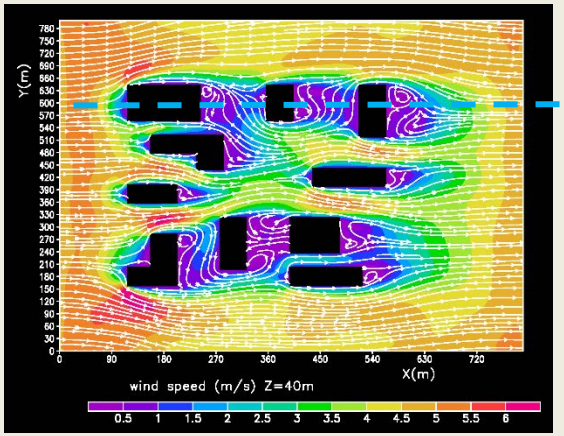
Field-scale mock urban cluster of buildings instrumented in unprecedented detail to replicate the measurement capabilities of a laboratory wind tunnel to provide the basis for basic research on the dynamics of DUE boundary layers

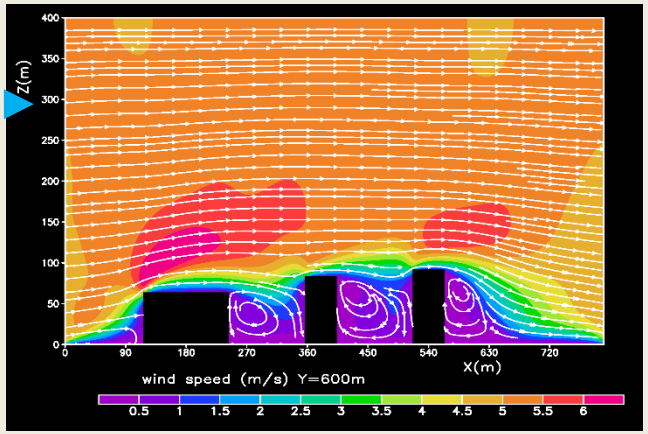
Objectives:

- Development, verification, and validation of microscale models (~10m grid)
- Development of DUE tactical decision aids including drone routing
- Improvement of mesoscale model DUE subgrid process parameterizations

Zajic et al. Environ Fluid Mech (2015) 15: 275. doi:10.1007/s10652-013-9311-6







Dr. Yansen Wang (LBM-ABLE)

Conclusions

Technical Significance

- Once complete, the MSA will be the premier meso/micro network for atmospheric science research due to unprecedented resolution (spacing less than 2 km and sampling of f = 20 hz) and a domain which includes diverse topography ranging from a valley at 1300 m to a mountain which peaks at 2500 m.

Impact to Scientific Community

- The MSA will address a community need for high-resolution observational data for advancing the state of the science in development, verification and validation of fine-scale atmospheric prediction models, and provides a testing ground for atmospheric sensor development.
- Atmospheric modelers in the Air Force, Navy, NOAA, NCAR, DOE and academia will have access to a very unique multi-scale source of boundary layer atmospheric data for their research efforts targeting future improvements to operational weather forecasting capabilities.

Impact to the DoD

Will provide more accurate weather information and advanced decision aids to enhance/increase mission success rates.

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Thank YOU! Questions?

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