



THE UNIVERSITY OF NORTH DAKOTA

UAS Research Program Review

Atmospheric Sciences Application Research

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UAS Research Program Review

Primary Thrusts

- Electromagnetic Propagation Characterization
 - Obtain ground range, height of target in real-time, using a flexible model of atmospheric refractivity
 - ***Understand the EM propagation environment in North Dakota for application to (and use within) ground-based sense-and-avoid systems***
- Low-cost Atm Sci UA-based Observing System
 - Educational component for UASE students w/r/t payload & data system development
 - ***Telemaster Prototype for observations in the lowest 400-500 m***
- Numerical Weather Prediction (NWP) Data Assimilation
 - Exploring benefits to short-term (0-3 hours) NWP and ground-based sense-and-avoid from the assimilation of phased-array radar data.
 - ***Examine impact of synthetically-generated data representative of GPARS in a commonly-used NWP/DA system (WRF)***



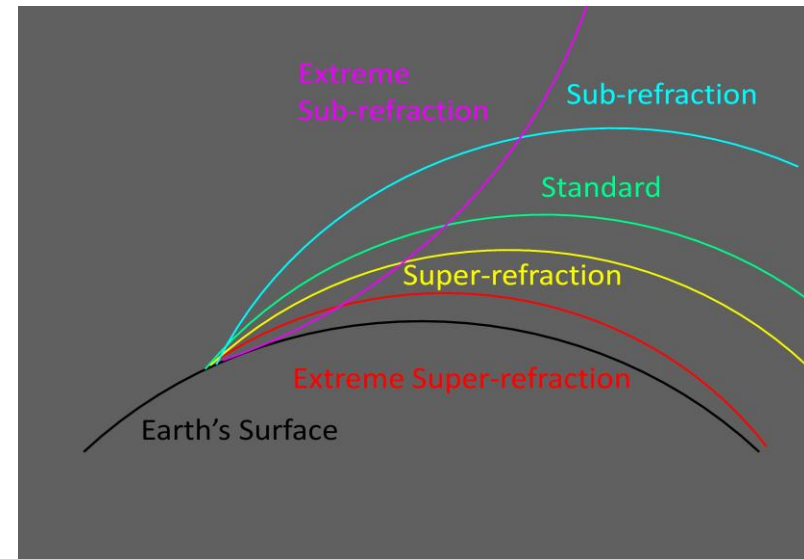


Electromagnetic Propagation

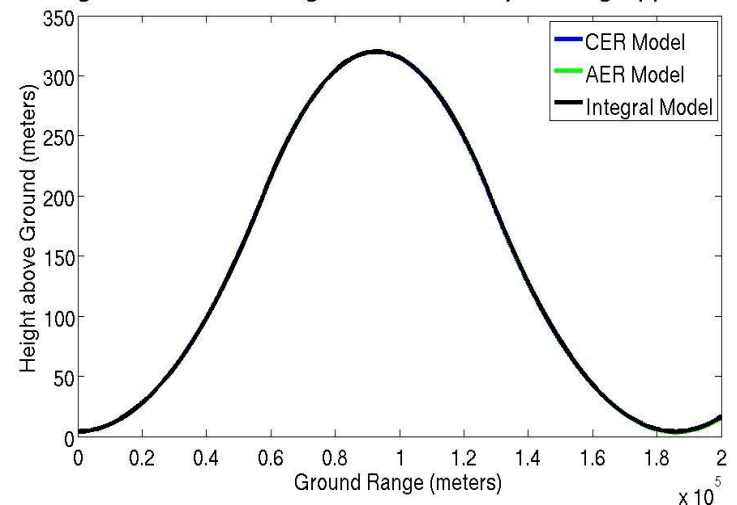
Right: categories of EM wave propagation based on refractive conditions obtained from the vertical gradient of n .

- Examined performance of existing ray tracing models w/in a theoretical context under normal, super-refraction, sub-refraction, surface & elevated ducting conditions (RJ thesis, 2 papers in revision)

- *'4/3 Earth' model*
- *Adaptive Earth Radius (AER) model*
- *Integral/Doviak and Zrnic model*
- *Constant Earth Radius (CER) model*



Height vs. Ground Range with Three Ray Tracing Approaches



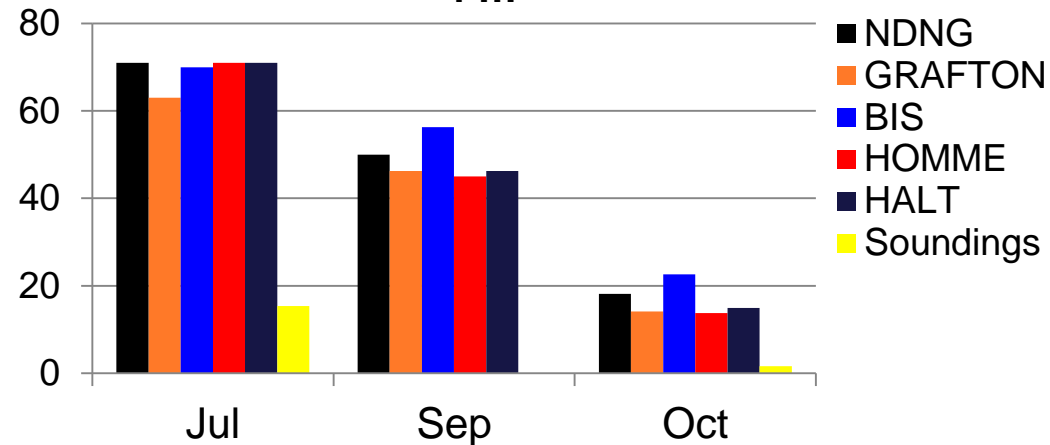


Electromagnetic Propagation

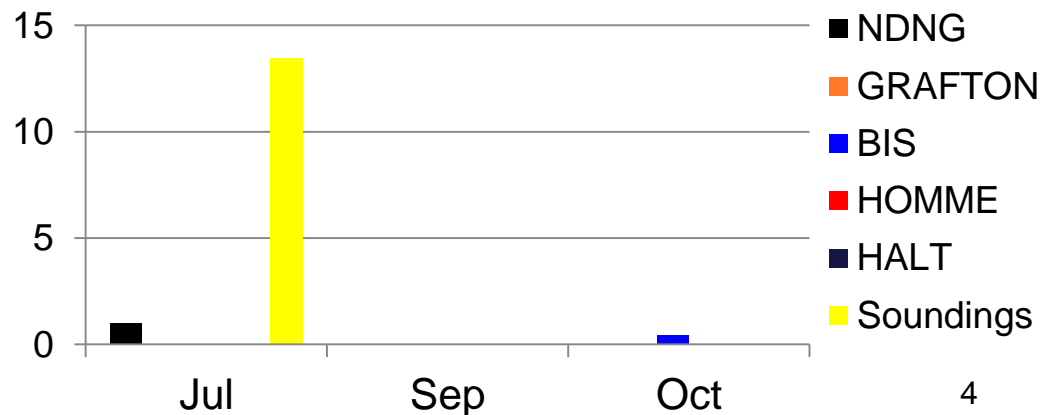
- Examined the variability in EM propagation characteristics near the surface as determined via the use of the optimal EM ray tracing model applied to:

- observed Bismarck balloon-based sounding profiles of wind, temperature, humidity
- NWP model (WRF; Skamarock et al. 2008) analysis/forecast profiles of the same variables

Percentage of Profiles w/ Ducting/Trapping
4 m



26 m





Telemaster Senior Atmospheric Observing System

• Successful prototype airframe:

- **Wing Span 2.38m**
- **Length Nose-to-Tail: 1.62m**
- **Flying Weight: 4.76 kg**
- **Maximum Payload: 3.18 kg**
- **Cruise Speed: 10.3 m/s**
- **Operating Ceiling: 365.8m**
- **Endurance: 1 hour**

• Fly days (CGS) : Aug., Oct., Nov. 2010 as well as Sept. and Nov. 2011

- **Includes tests in marginal conditions w/r/t both wind and low stratus**
- **Sufficient quality for EM analysis**
- **Fine spatial scale (O ~100m) T/RH variations detectable near surface**
- **OPC data useful for aerosol studies**
- **Incremental Improvements to sensor, overall payload design**



Payload Major Components



Pressure
Omega
PX40-15G5V



T/RH Sensor
Vaisala HMP50



OPC
Met One
9012



OPC
Pump/Charger
Clark 15317



GPS Unit
Trimble
Condor



Microcontroller



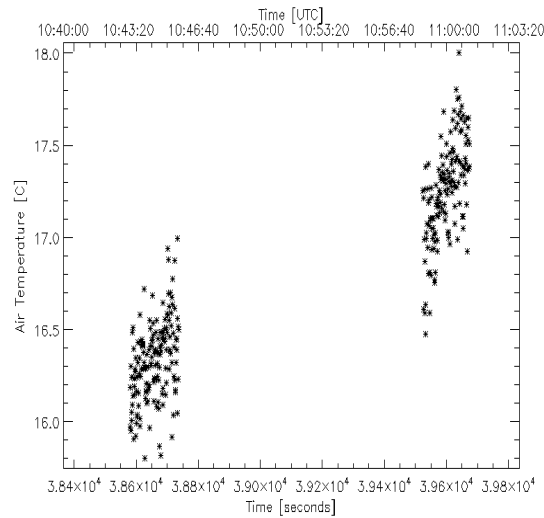
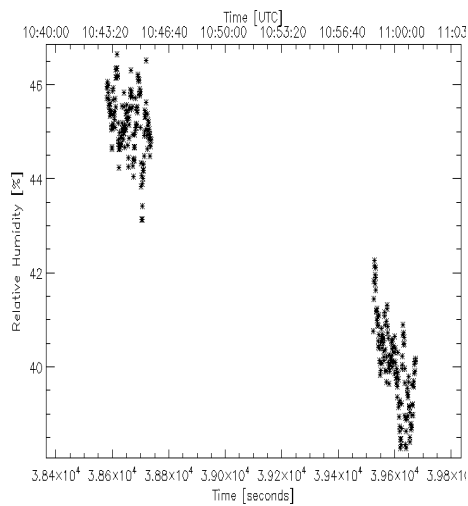
Murata DC-DC
Power Board



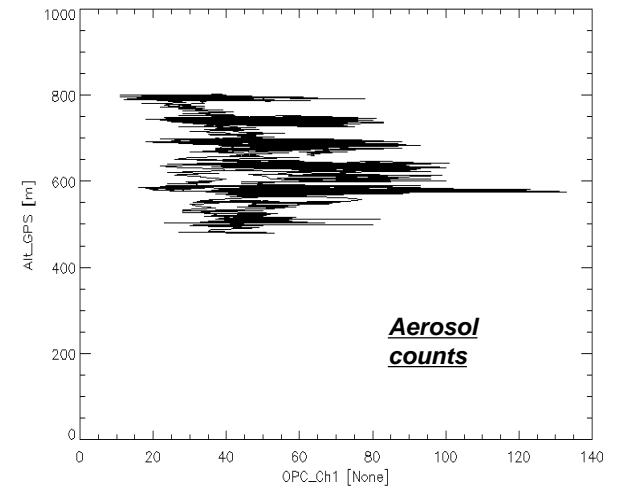


Telemaster Atmospheric Observing System Data

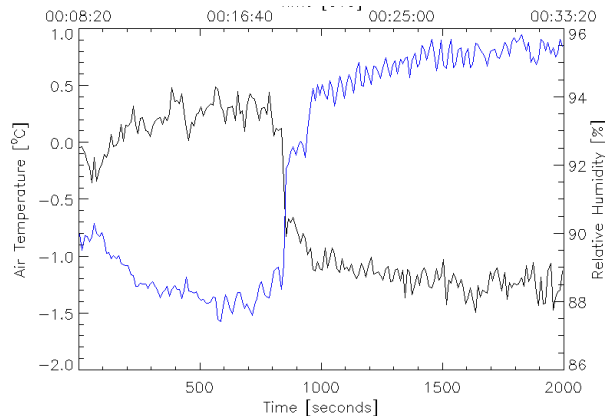
• **Raw Data** ~1040 CDT 19 Sept 2011



~1110 CDT 5 Nov 2010



~1430 CDT 25 Nov 2011

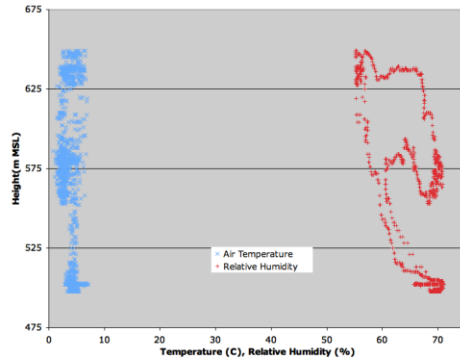




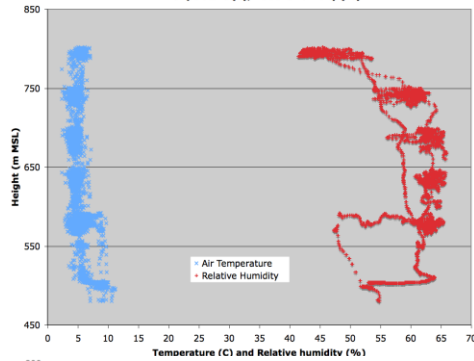
The 5 November 2010 Dataset

T/RH Profiles

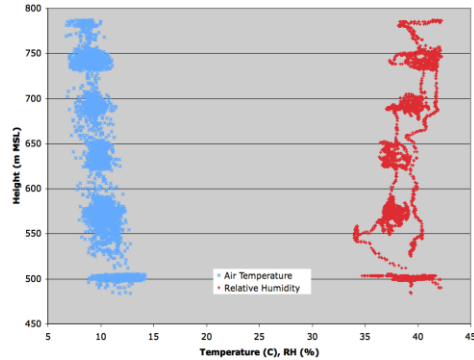
1036
CDT



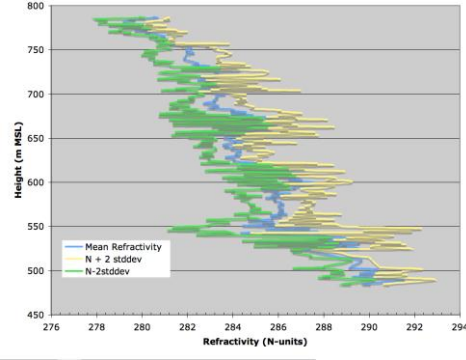
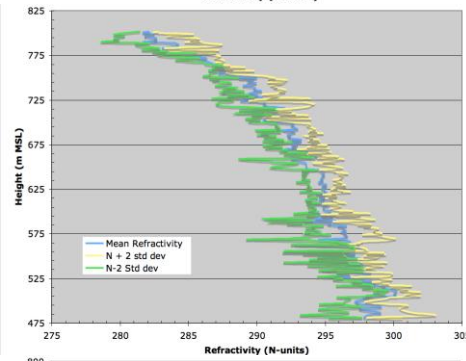
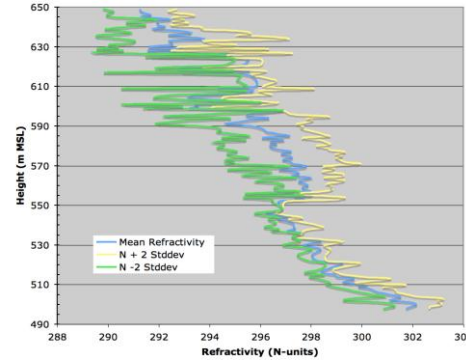
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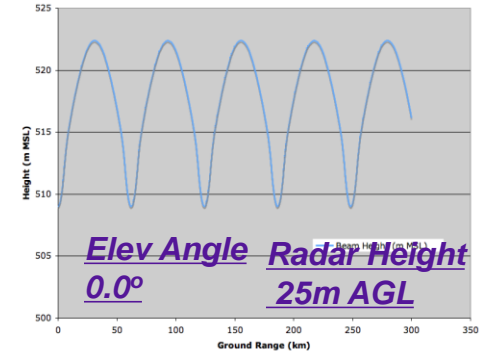
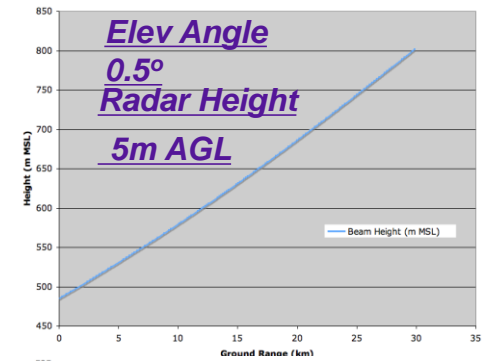
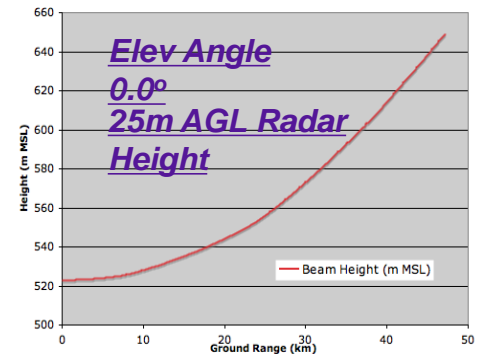
1513
CDT



Mean Refractivity N & $\pm 2\sigma$



EM Ray Propagation





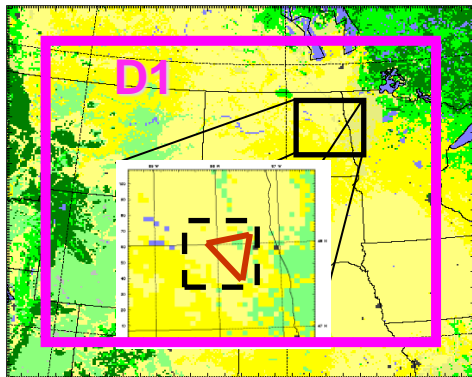
Synthetic PAR Data Assimilation

- Experiments: 2007 Northwood, ND tornado case with synthetic PAR data and WRFDA



Damage caused by the EF4 Tornado that struck Northwood, ND (~ 40 km SW of Grand Forks) at 0143 UTC 27 August 2007. This tornado was the most severe of the outbreak which covered eastern ND and northwestern MN. (Damage photos courtesy D. Kellenbenz, G. Grochocinski)

Experimental Domains



Synthetic PAR data generated from the 222.2 m resolution innermost nest of the quadruple nest configuration was utilized in the 2 km (D1) assimilation experiments.



Synthetic PAR Data Assimilation

- *Clear impact of synthetic PAR data apparent in dynamically consistent way*
- *Impact of # of PAR obs more apparent closer to the surface than upper levels*

Control-Experiment
950 hPa Wind Speed 02 UTC

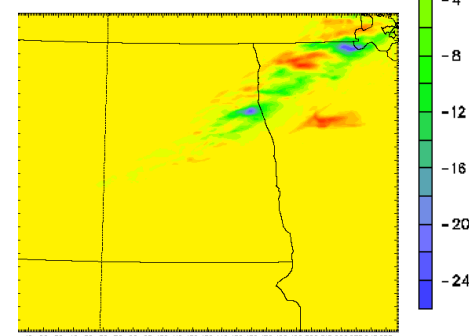
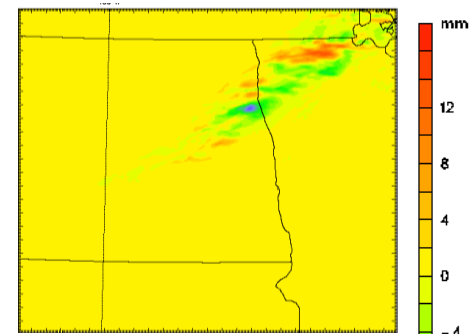
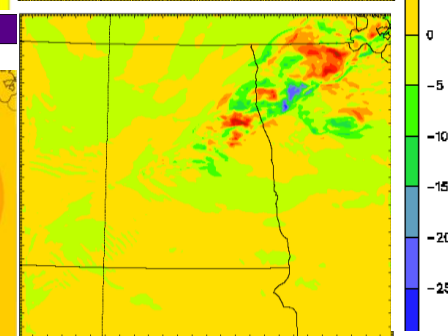
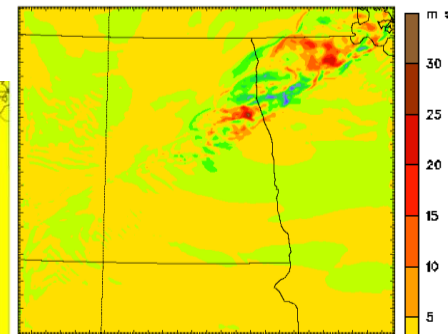
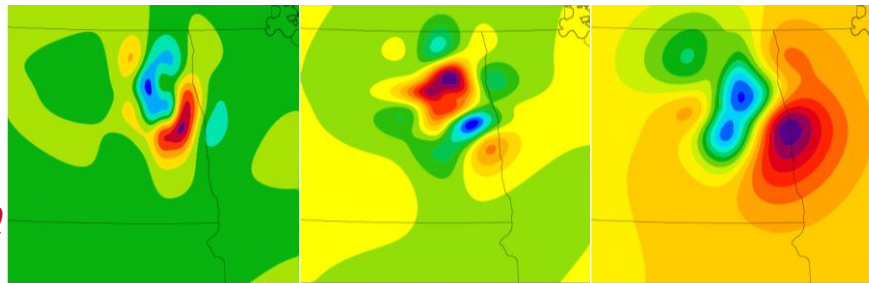
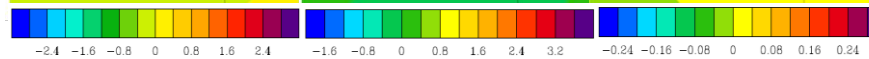
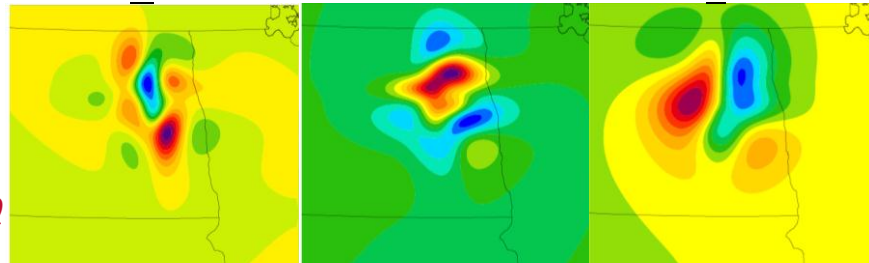
Control-Experiment
1-hr precip. 01 UTC

Analysis Increments, ~ 950 hPa

U

V

T



1000
obs

1600
obs





Summary and Future Work

- **Summary**
 - **We have successfully designed, constructed and tested a low-cost (\$10-12K) UAS**, including payload, suitable for near-surface/boundary-layer atmospheric science observations for research and operational applications.
 - **High-resolution datasets such as those that can be generated through data assimilation of PAR data into an NWP model, are a crucial requirement for an accurate lower atmosphere EM propagation climatology.** In addition, our test assimilation of synthetic PAR data into the WRF model support the utility of assimilating such data for nowcast numerical forecasts of severe storms.
 - Shallow/thin ducting layers, which can disrupt ground tracking of UAS by radars, may not be discernible from conventional observations and suggest greater complexity in the EM propagation environment than often assumed.





Summary and Future Work

- **Future Work**
 - Additional data assimilation tests over a variety of cases, are warranted to better evaluate the utility of the technique in a robust statistical fashion
 - Extension of EM Propagation climatology work to other areas of the country where UAS might be extensively utilized in the next several years
 - **Continued development of atmospheric instrumentation that can be borne on UAS (Telemaster/Superhauler/ScanEagle/Penguin/SUMO) for:**
 - (1) cloud condensation nuclei/microphysics measurements (upward pointing cloud radar, additional aerosol instrumentation) that can be used to validate cloud models (being actively pursued with NSF this quarter).
 - (2) surface and boundary-layer measurements to better understand details of the convective initiation process (NSF proposal to be written this FY)
 - (3) detailed aerosol measurements to better understand vertical aerosol transport within weakly convective boundary layers, with implications for long-range transport, climate processes, visibility and air quality (potential part of pending ND NSF EPSCoR cluster proposal)

