Impact of Assimilating PECAN IOP Observations on the Numerical Prediction of Bores and Bore-Initiated Convection

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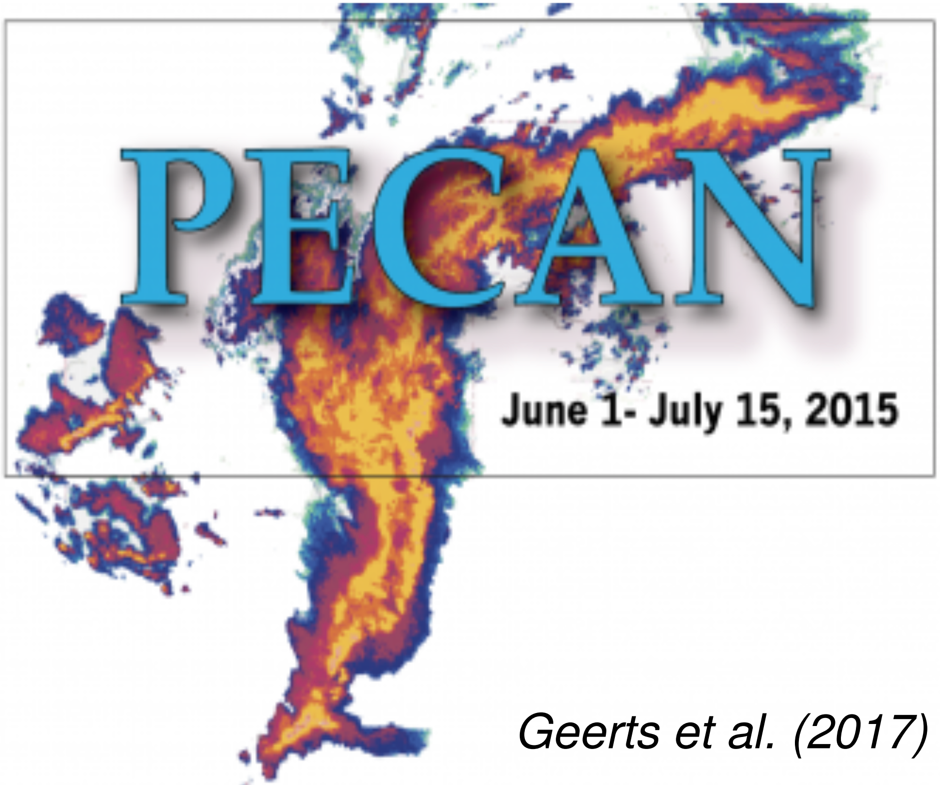
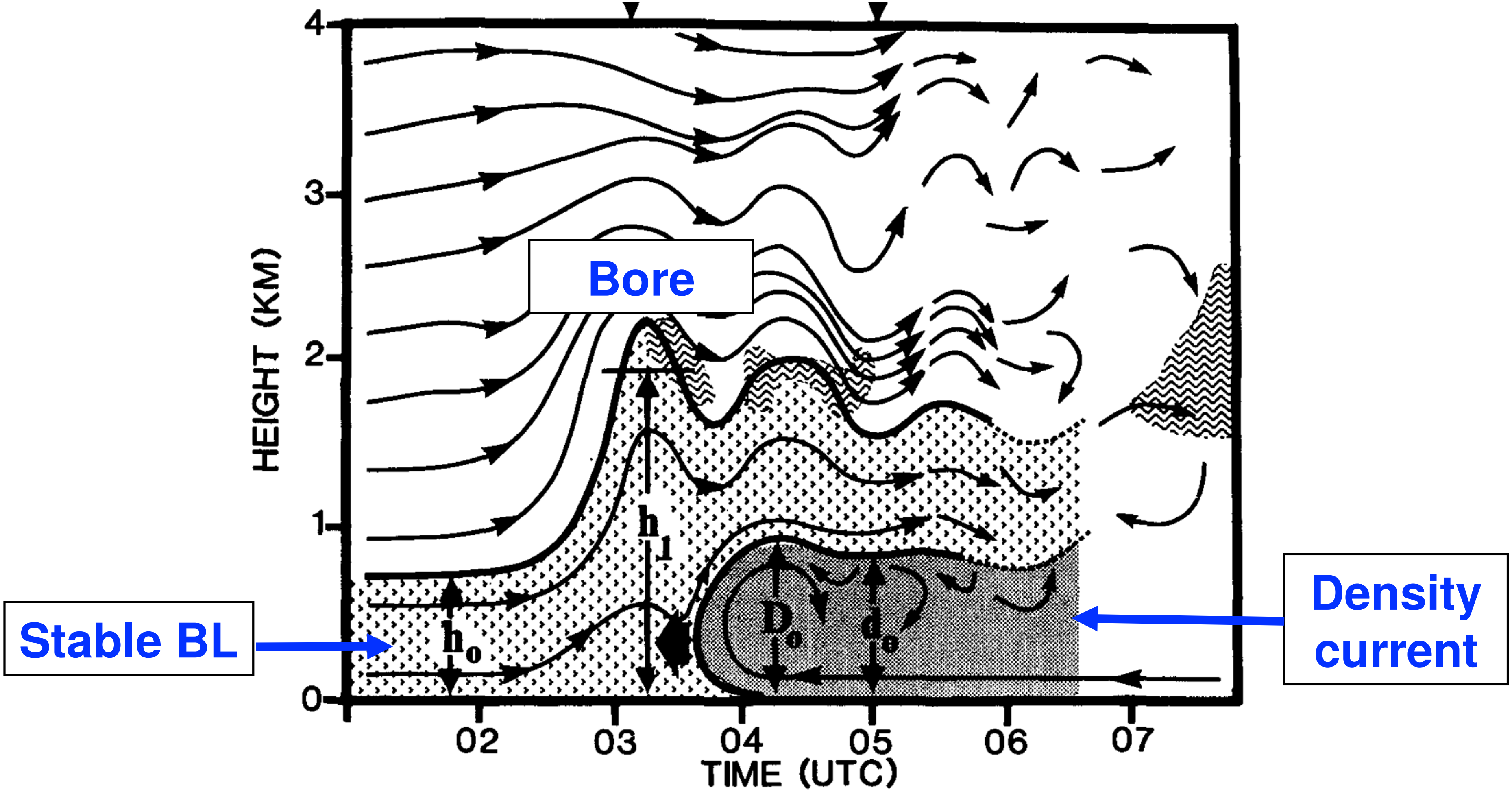
Plains Elevated Convection at Night
PECAN



Geerts et al. (2017)

- The **PECAN** field campaign was launched back in 2015 to advance our understanding of **night-time convection** over the Great Plains.

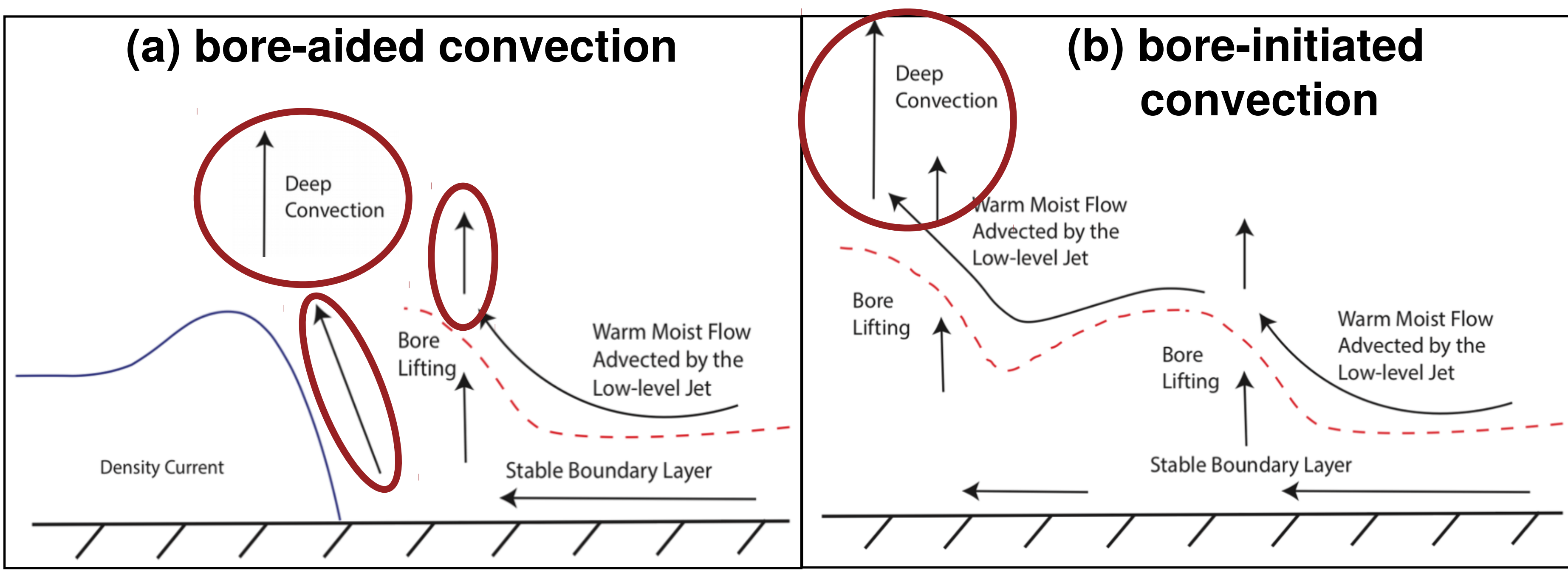
What is an atmospheric bore?
Conceptual Model



Adopted from Koch et al. (1991)

Link Between **Bores** and **Nocturnal Convection**

- There are **two mechanisms** that explain how **convectively-generated bores** make the night-time environment more conducive for convection (Parsons et al. 2018).



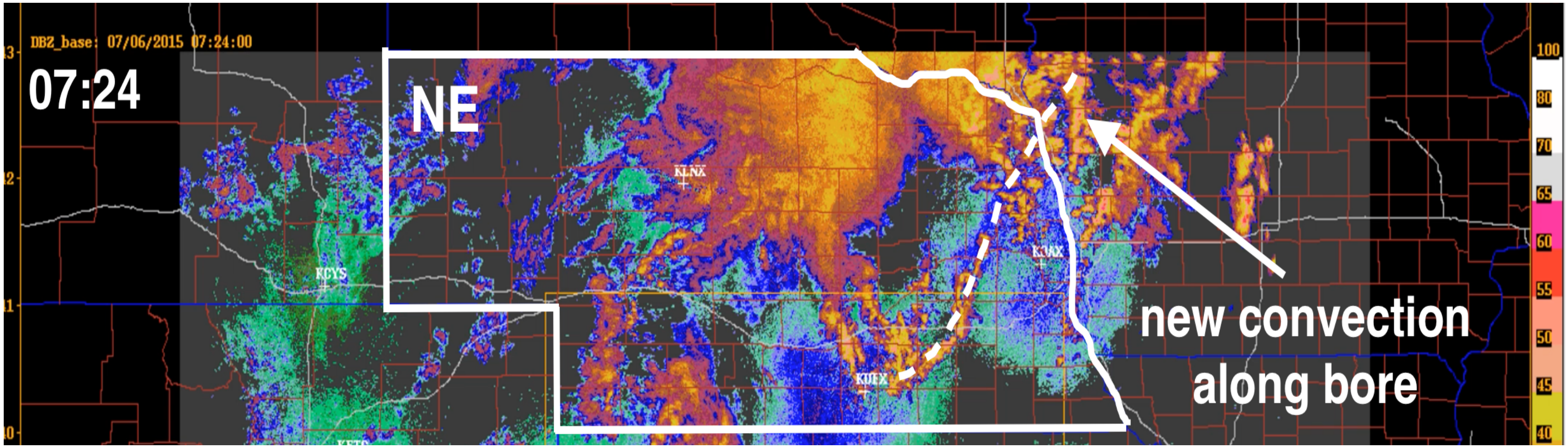
Adapted from Parsons et al. (2018)

Presentation **Outline**

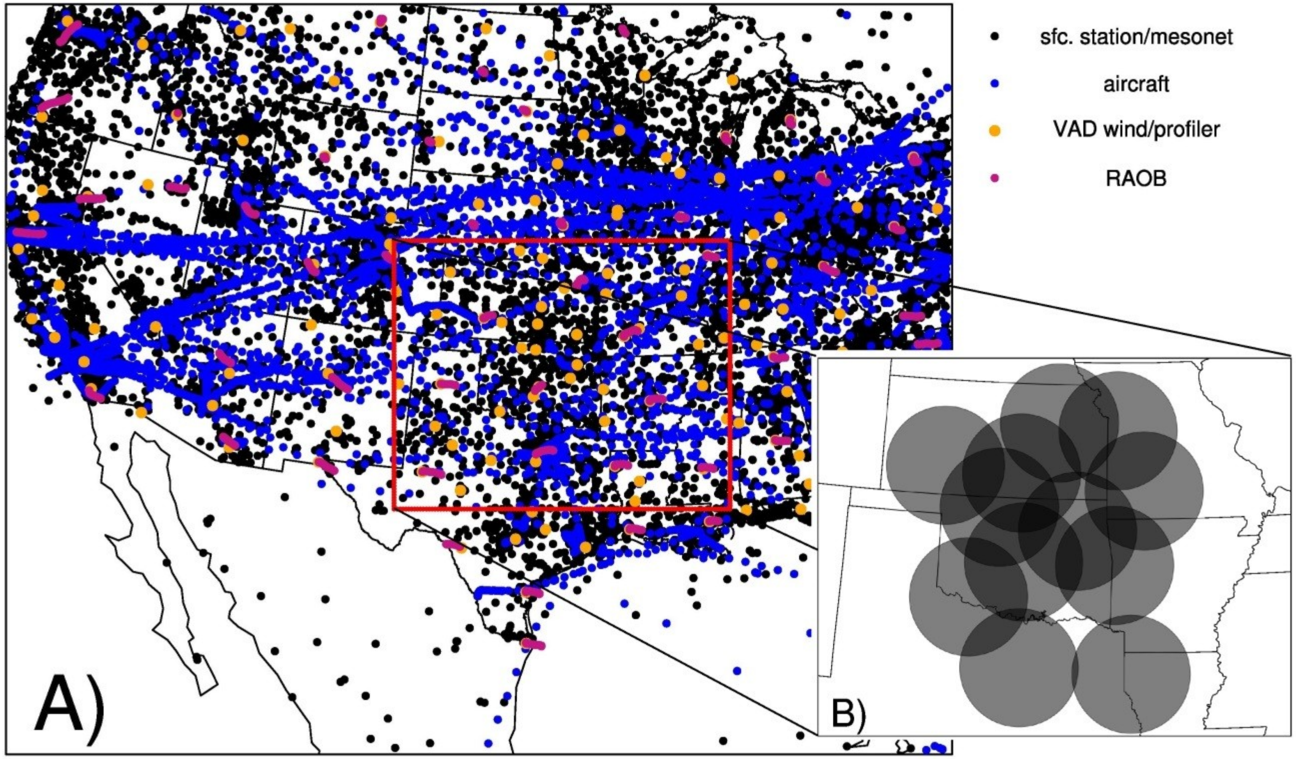
- Current research focuses on **bore-initiated convection**.
- **Data addition study** - examine the impact of PECAN IOP data on the forecast skill related to the 3 components of bore-initiated convection:

1. bore environment | **2. bore** | **3. bore-initiated convection**

- Data comes from **IOP20** (5-6 July 2015):

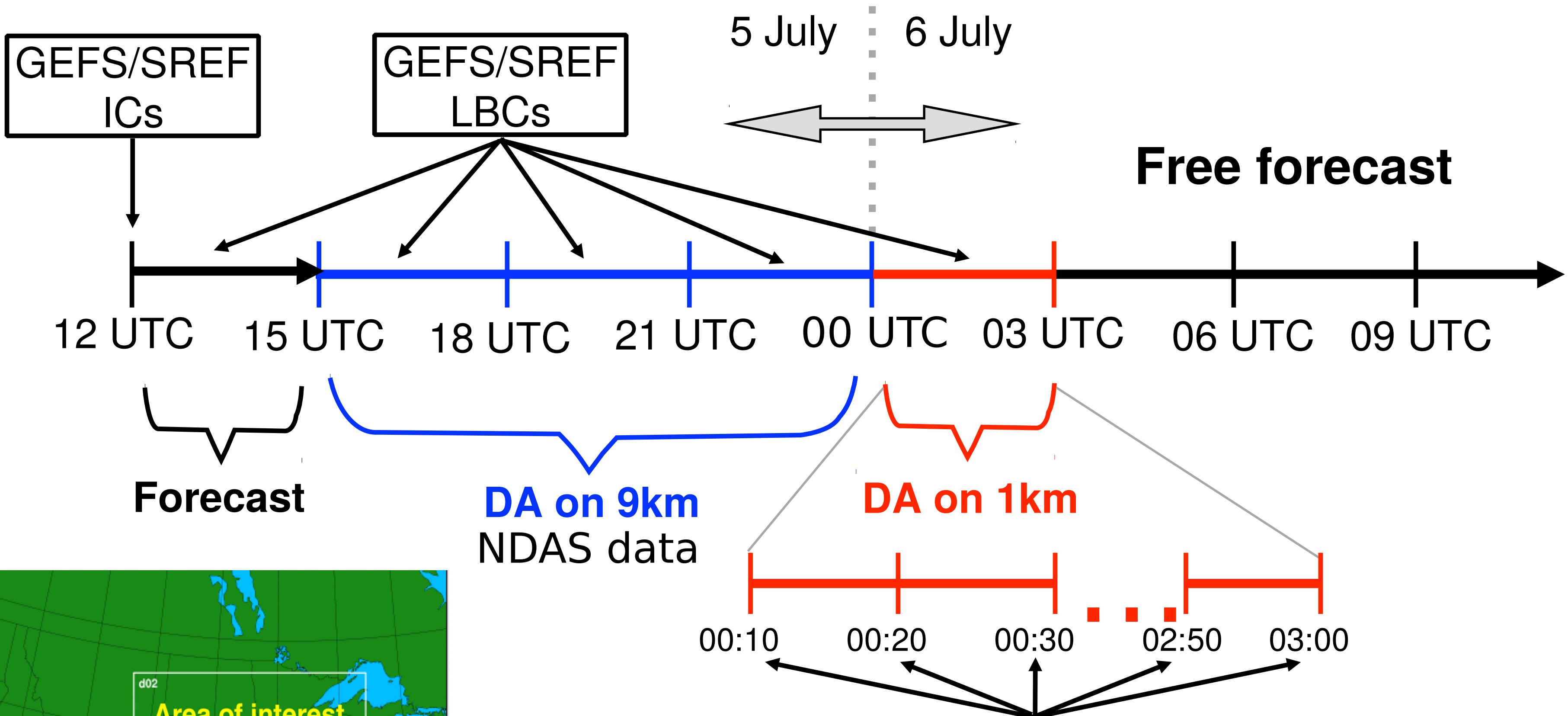


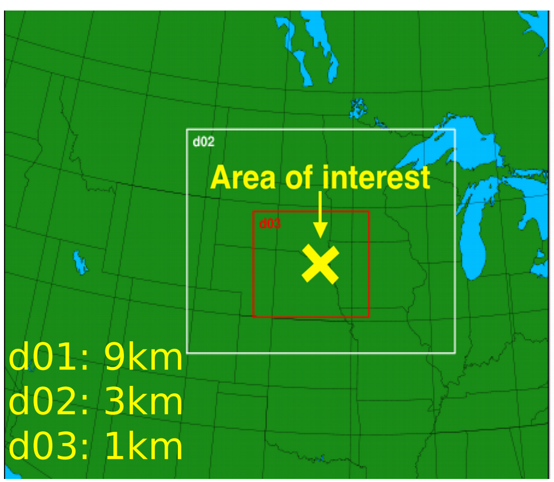
GSI-based EnKF DA System



- The GSI-based EnKF system was extended to assimilate radar data (Johnson et al. 2015) so that the system assimilates observations resolving **multiple scales** (see keynote talk from Xuguang Wang).

Experimental Design



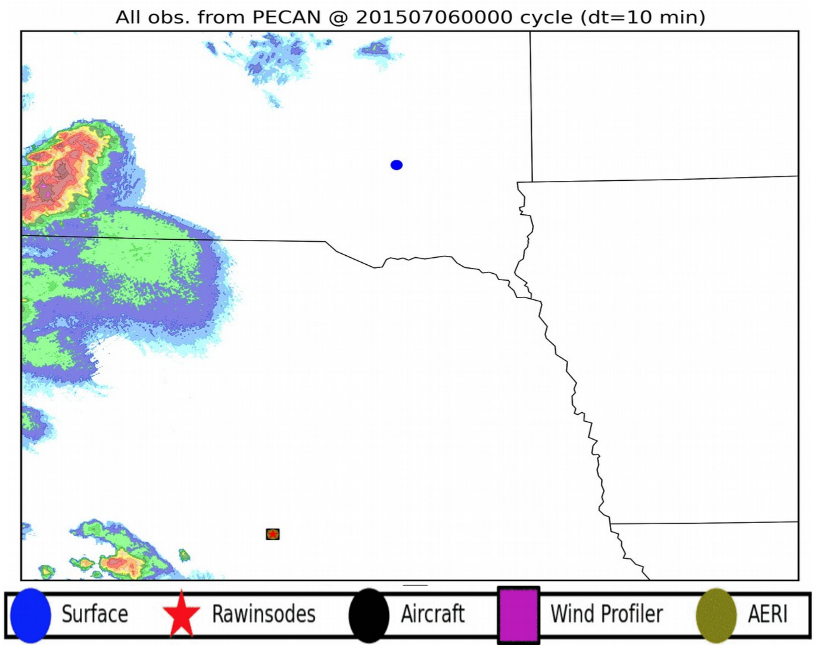


Assimilate:

1) Conventional data
- NDAS
- radar

2) PECAN data
- AERI
- aircraft
- wind profiler
- lidar VAD
- surface

PECAN Observations for IOP20



Instrument description

- **AERI**: Vertical retrievals of **T** an **q** @ **5min**.
- **Aircraft**: Both flight level data (NOAA P-3; **1s**) and vertical profiles of **q** (NASA DC-8; **<1 min**).
- **Lidar**: **u**,**v** winds @ **2min** using VAD technique.
- **Wind profiler**: **u**,**v** wind profile @ **30min** using NIMA (fuzzy logic technique).
- **Sounding**: Fixed and mobile units. Frequency can be down to **1h** for mobile units.
- **Surface**: Fixed & mobile @ < **5min**.

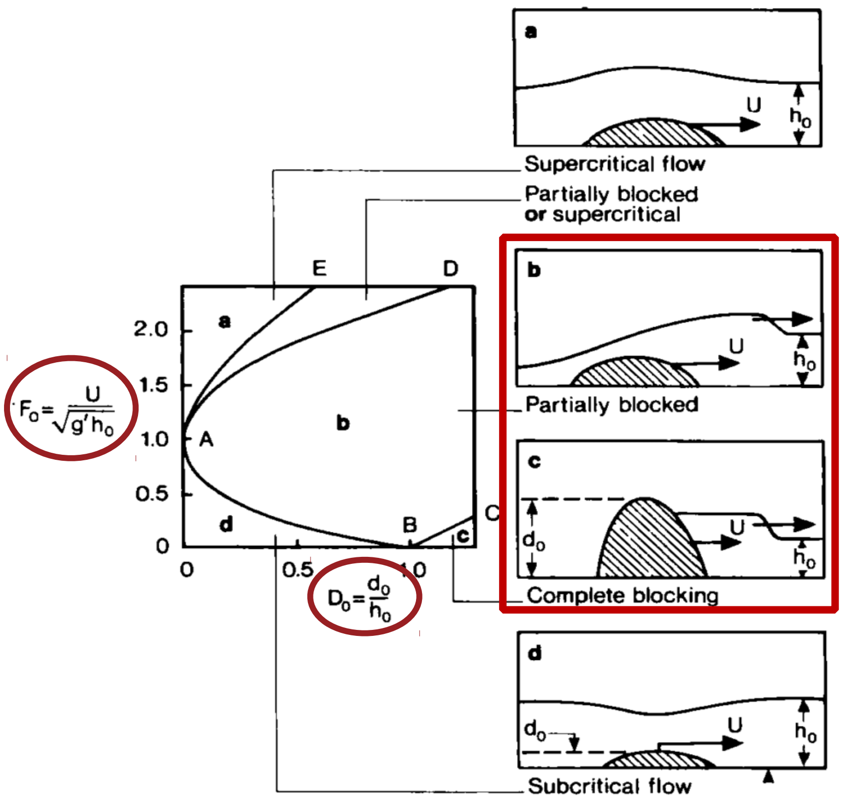
Experiments	hloc [km]	vloc [$\ln(p/p_{ref})$]	½ window [min]	pre-processing
BASELINE	200^{conv}, 18^{radar}	1.1^{conv}, 0.55^{radar}	2.5	N/A
AERI	100	0.55	2.5	superob (10 hPa), cap (3km or cloud level)
AIRCRAFT	200	0.28	5	FL: thinning (5 min); DC-8: no data thinning
LIDAR_VAD	200	1.1	2.5	superob (100 m), gross-check, cap (3km)
SURFACE	200	0.28	2.5	thinning (5 min)
SOUNDING	200	0.28	5	superob (10 hPa)
WIND_PROF	200	1.1	2.5	exclude mobile data
PECAN_ALL	combined	combined	5	combined

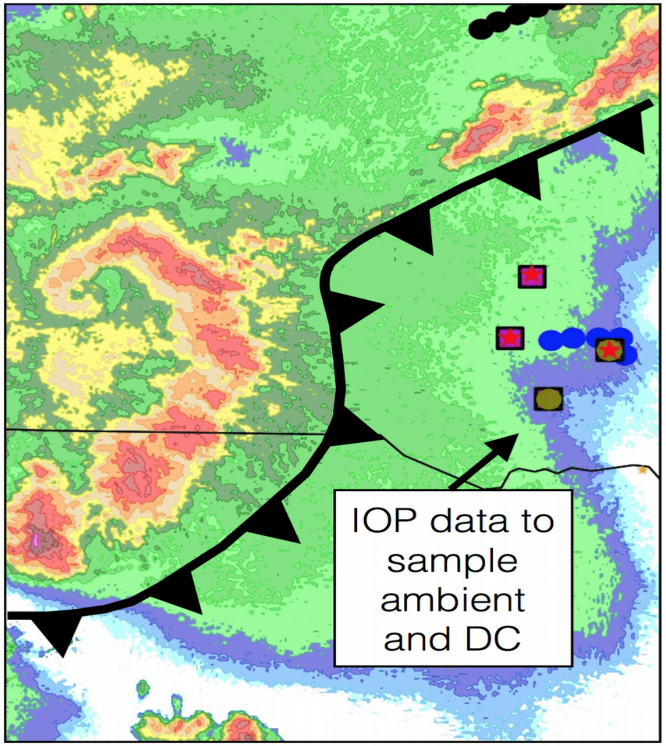
Part I of results:

Impact of PECAN data on
bore environment and bore forecasts

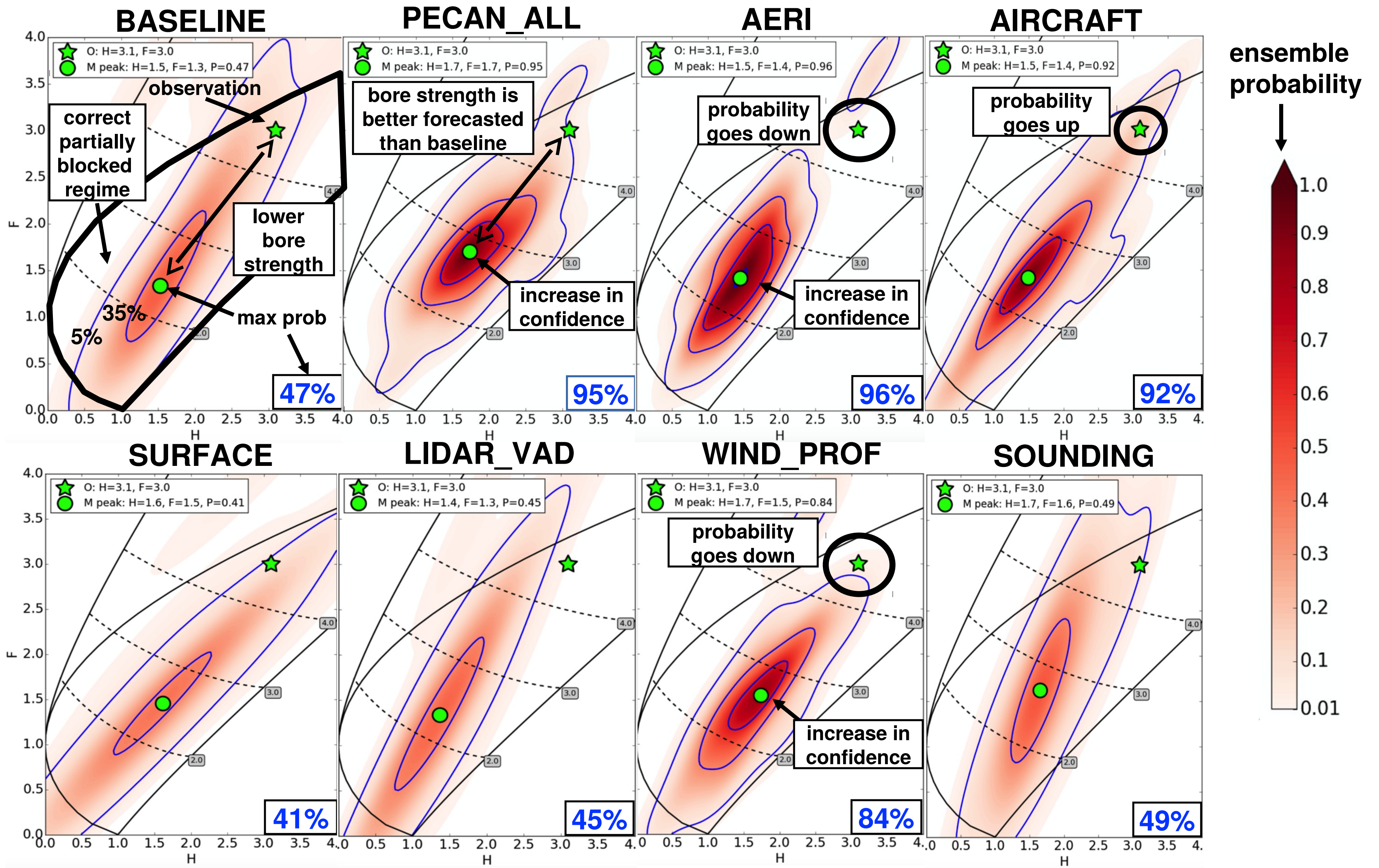
Validation of **bore environment**: *Methodology*

- The **environment in which the bore develops** is assessed through the **flow regime diagram** of Rottman and Simpson (1989).
- **Mobile IOP observations** are used to determine the **observed flow regime** that the model is later verified against.



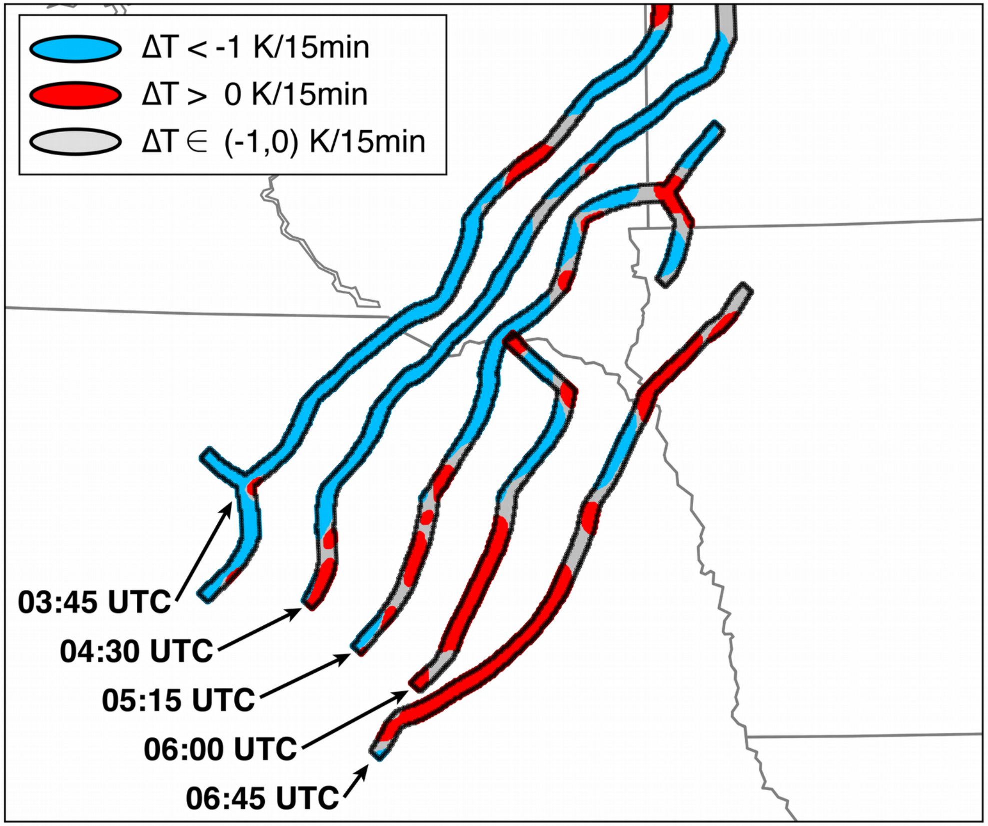


Validation of **bore environment**: *Results*

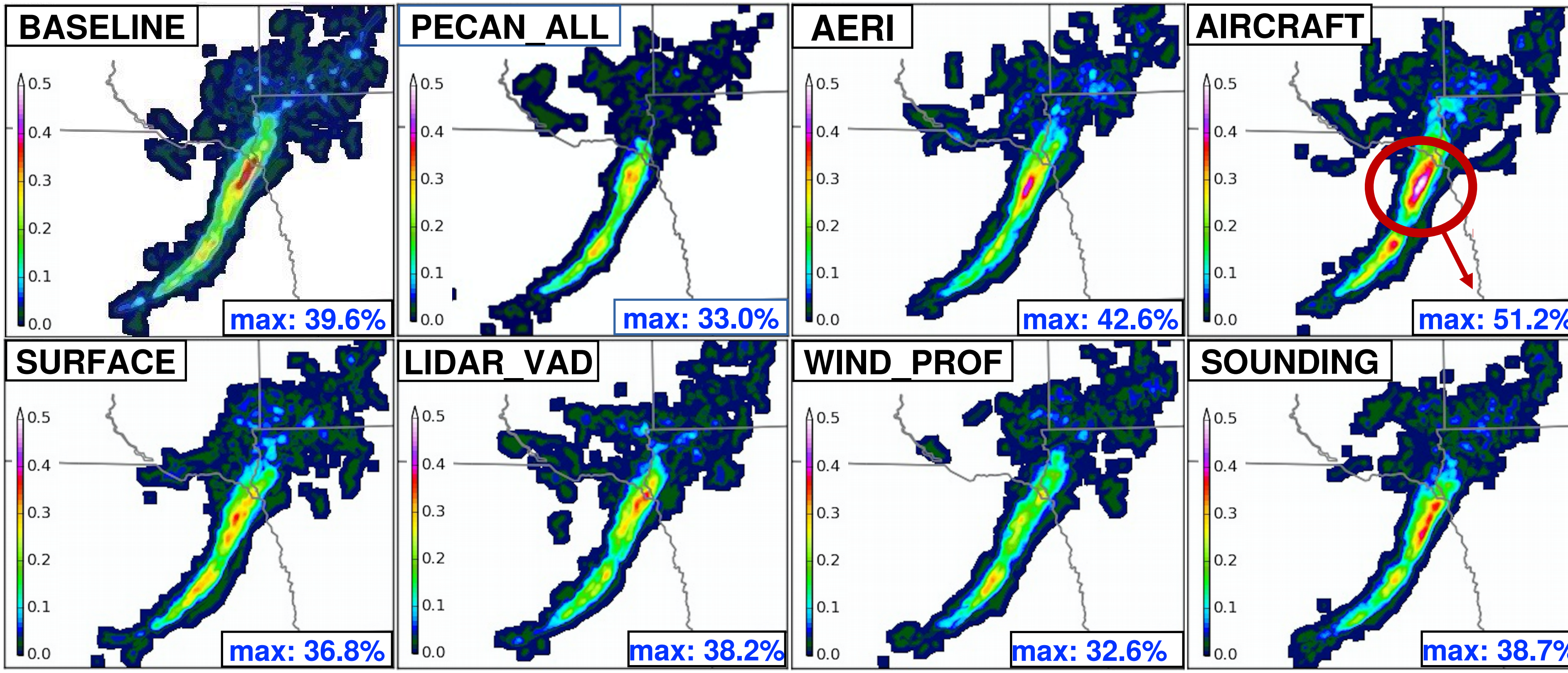


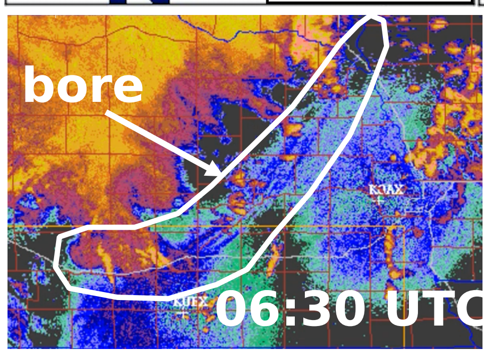
Validation of **explicit bore forecast**: *Methodology*

- **Detection of bores** in model data is challenging.
- Verification of explicit bore forecasts is based on an **object-based algorithm** from Chipilski et al. (2018).



Validation of **explicit bore forecast**:
Results



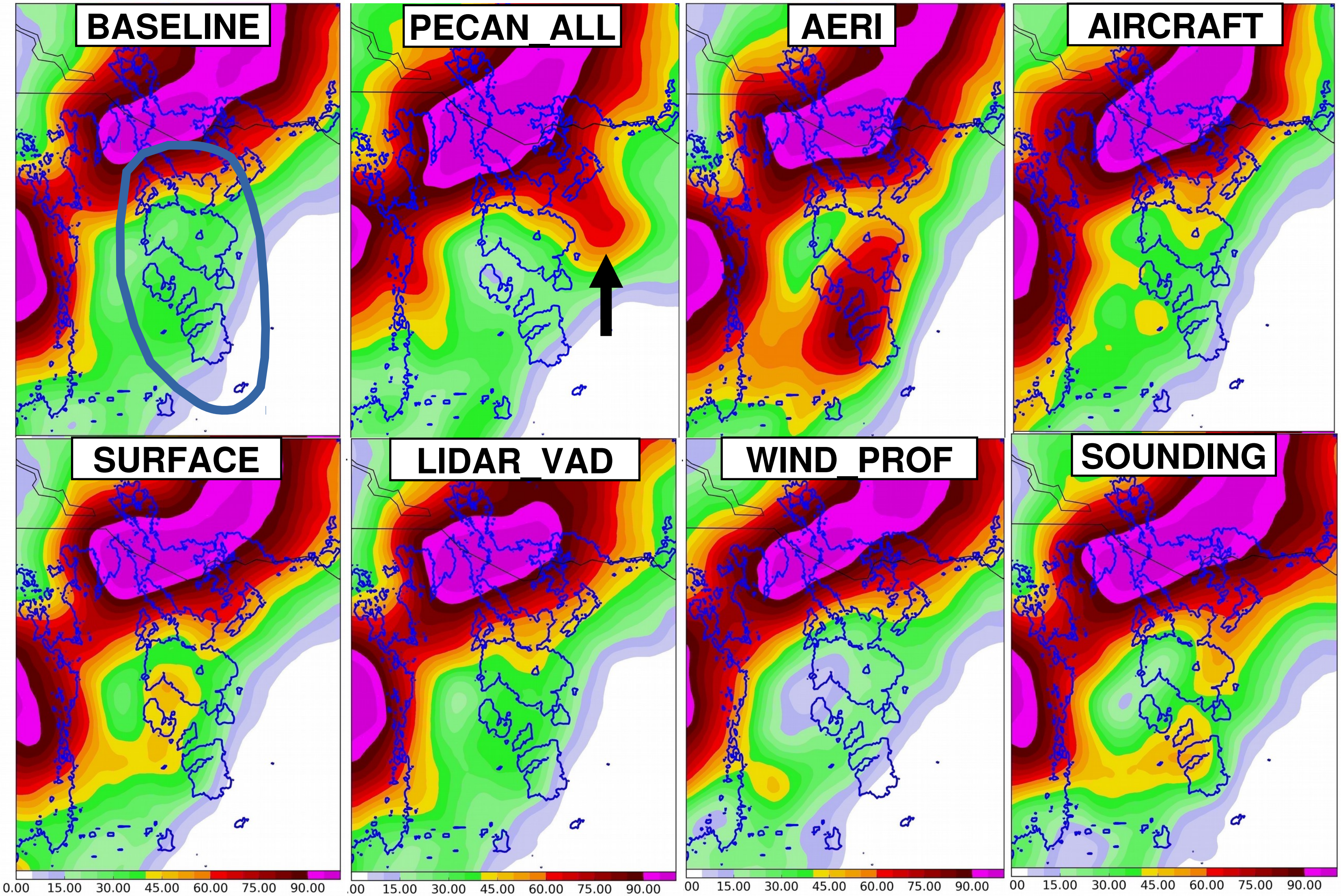


- All experiments have an **excellent handle** on the **position of the bore.**
- Generally **small/no impact** of PECAN data except **AIRCRAFT**.

Part II of results:

Impact of PECAN data on bore-initiated convection

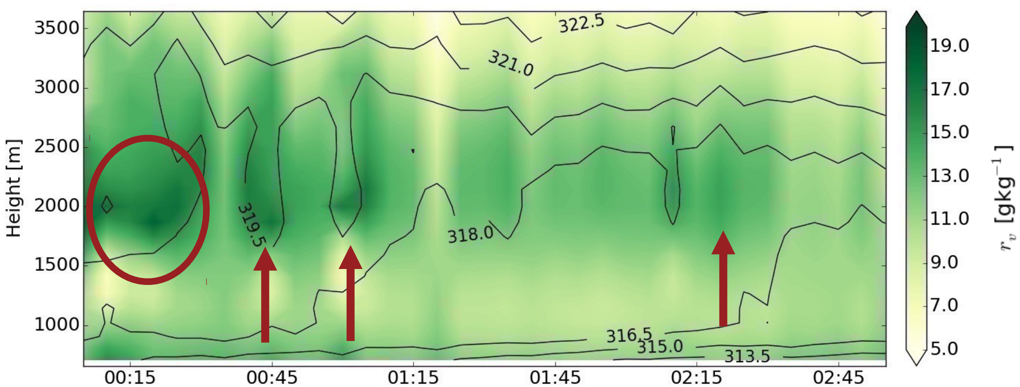
Validation of ensemble forecasts during the **initial convective development**



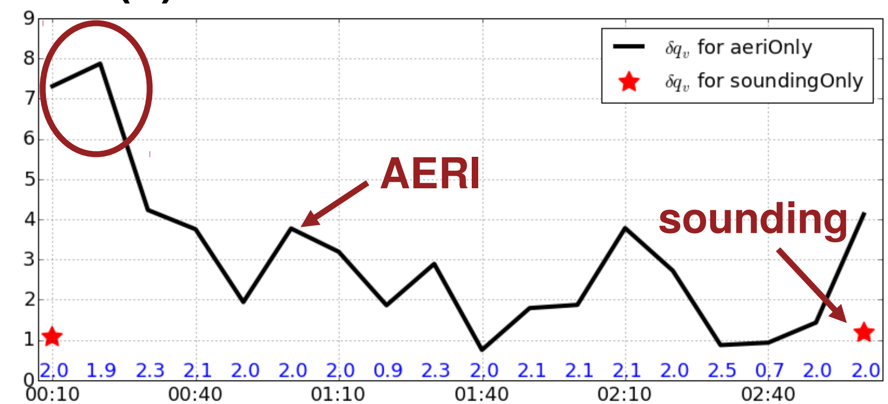
NEP of dBZ > 35 valid at 05:30 UTC: **initial bore convection**

Why did **AERI** have a **positive forecast impact?**

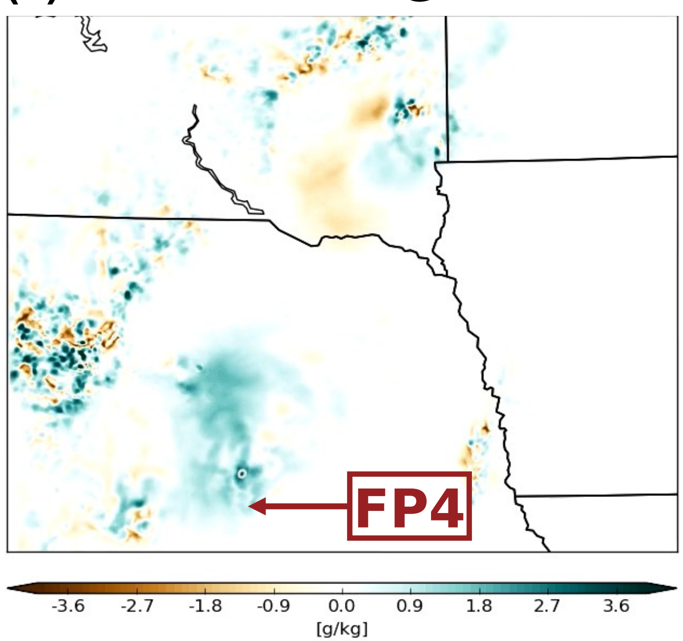
(a) AERI mixing ratio from FP4



(b) Maximum r_v^o-r_v^b for FP4 site



(c) r_v^{AERI} - $r_v^{BASELINE}$ @ 850 hPa



- The **AERI cross-section** (panel a) reveals the presence of *highly transient* (< 10 minutes) **surges of moisture** within the convective boundary layer.
- The **BASELINE** forecast cannot resolve these moisture plumes (panel b).
- The moisture that is added to the model background **spreads towards region of bore-maintained convection** and contributes to its development (panel c).
- **Frequent assimilation** of AERI produces better results.

Conclusions

- The **impact** of assimilating **PECAN data** can be summarized as follows:
  - **Bore environment**: Forecast was improved either i) by **increasing** the **confidence** about the **observed flow regime** or ii) by **improving** the **mean** of the ensemble forecasts in terms of the theoretically predicted **bore strength** (or both).
  - **Explicitly resolved bore forecast**: **All experiments** showed **good skill** in predicting the **location** of the explicitly resolved bore. Generally **small or no impact** of PECAN data except the aircraft data.
  - **Bore-initiated convection**: Positive forecast impacts from observation types containing **thermodynamic information**, but the **AERI instrument** played a **dominant role**.

Thank you very much for your attention!

References

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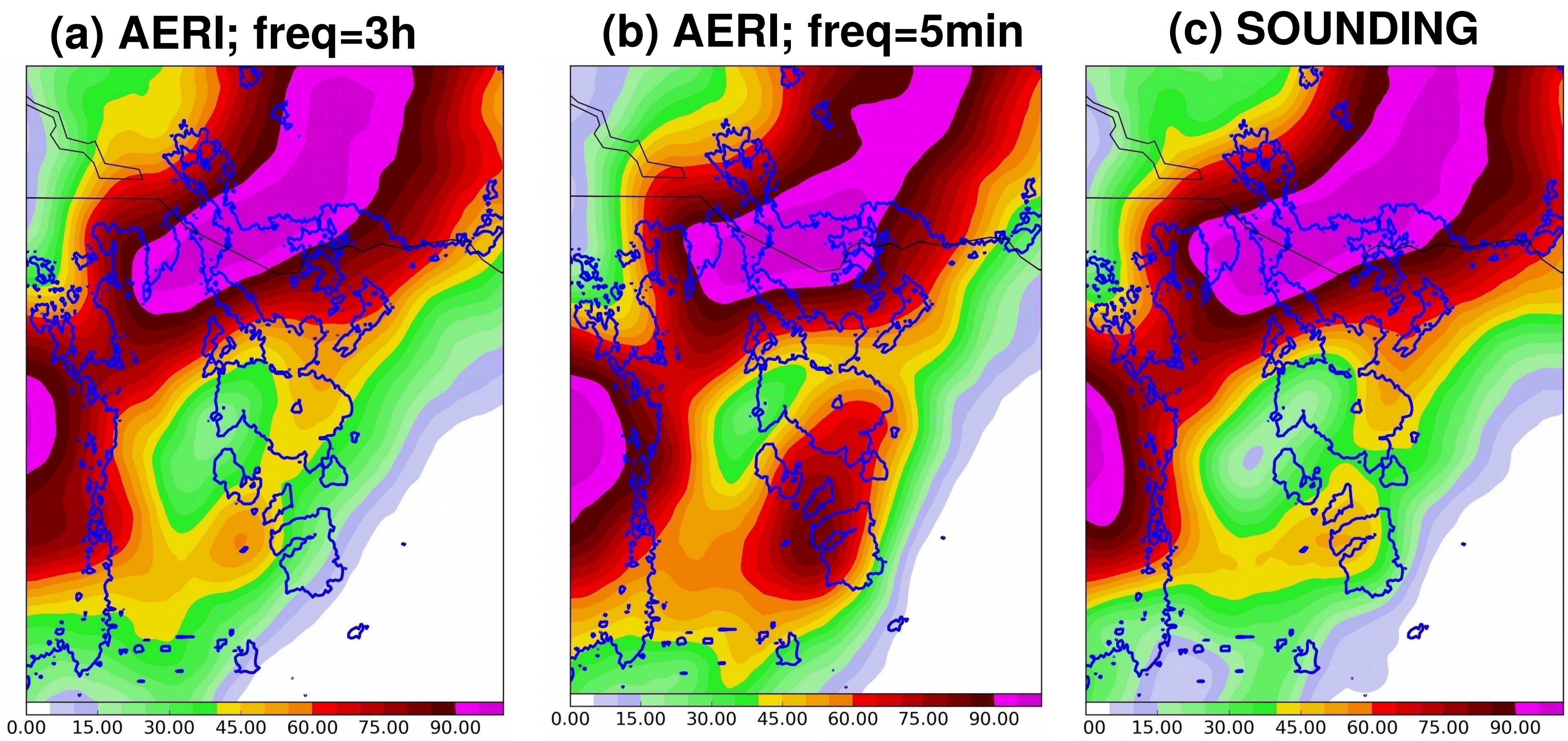
Parsons, D. B., K. Haghi, K. Halbert, E. Blake, and J. Wang: The Potential Role of Atmospheric Bores in the Initiation and Maintenance of Nocturnal Convection Over the Southern Great Plains. *J. Atmos. Sci.* In Review.

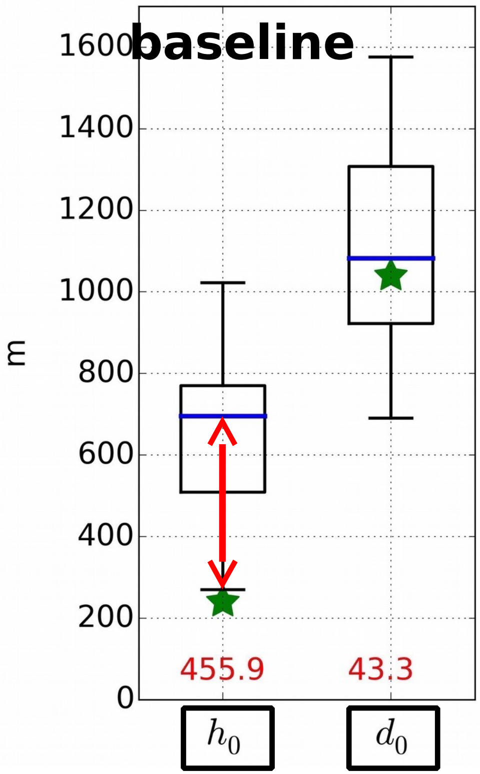
Rottman, J., and J. Simpson, 1989: The Formation of Internal Bores in the Atmosphere: A laboratory model. *Q. J. R. Meteorol. Soc.*, **115**, 941–963, doi:10.1002/qj.49711548809.

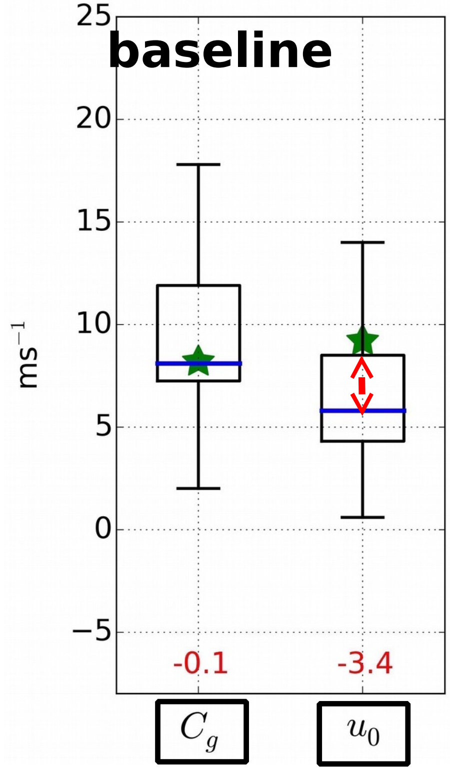
Back-up slides

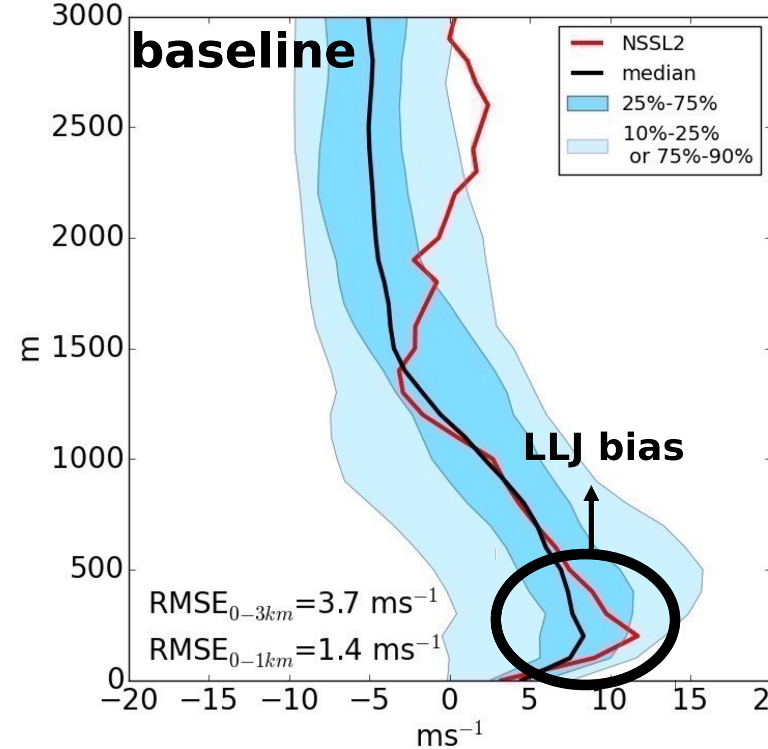
Temporal frequency of AERI data is critical for a successful convective forecast



What caused the **biases** in the forecasted bore environment?







$$\downarrow H = \frac{d_0}{h_0 \uparrow} \qquad \downarrow F_0 = \frac{\downarrow u_0 + C_g}{\sqrt{g' h_0} \uparrow}$$

Overestimating the inversion depth h_0 and underestimating the inversion winds u_0 resulted in the **flow regime bias**.

The bias in the inversion winds was caused by a **poor representation** of the **LLJ winds**.

More information about **AERI**

Source:
http://www.ssec.wisc.edu/aeri/instrument/

- AERI is a **passive remote sounding instrument**, which measures the downwelling IR radiation.
- Vertical **profiles** of **T, q** and **cloud properties** are derived via a physical **retrieval algorithm** (Turner and Loehnert 2014).
- Retrieval problem is ill-posed, so **optimal estimation framework** uses **model analysis fields** as a constraint.
- Very **high temporal frequency** of retrieved profiles: **5min** or **30s**.