Mixed layer height measurements from Doppler lidar using a composite method

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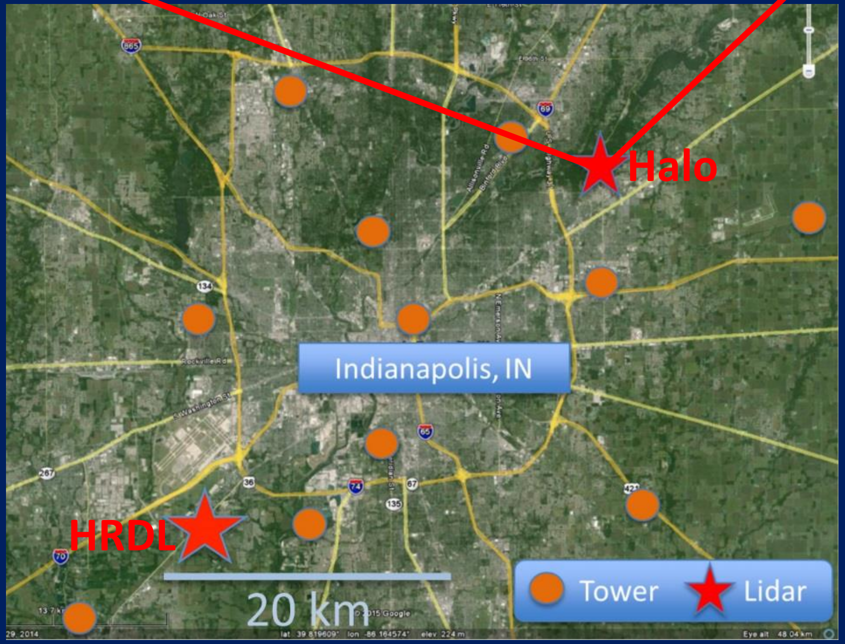
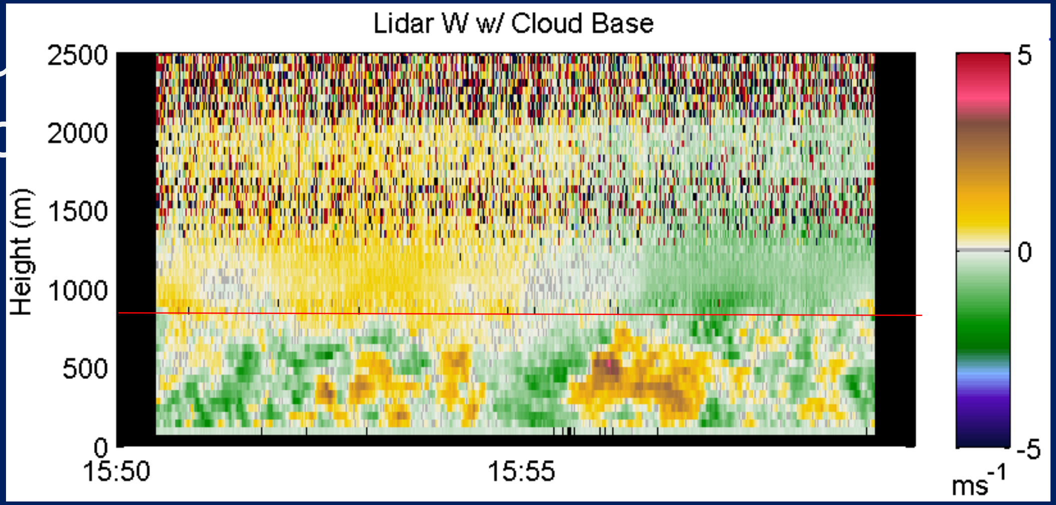
INFLUX Doppler lidar deployment

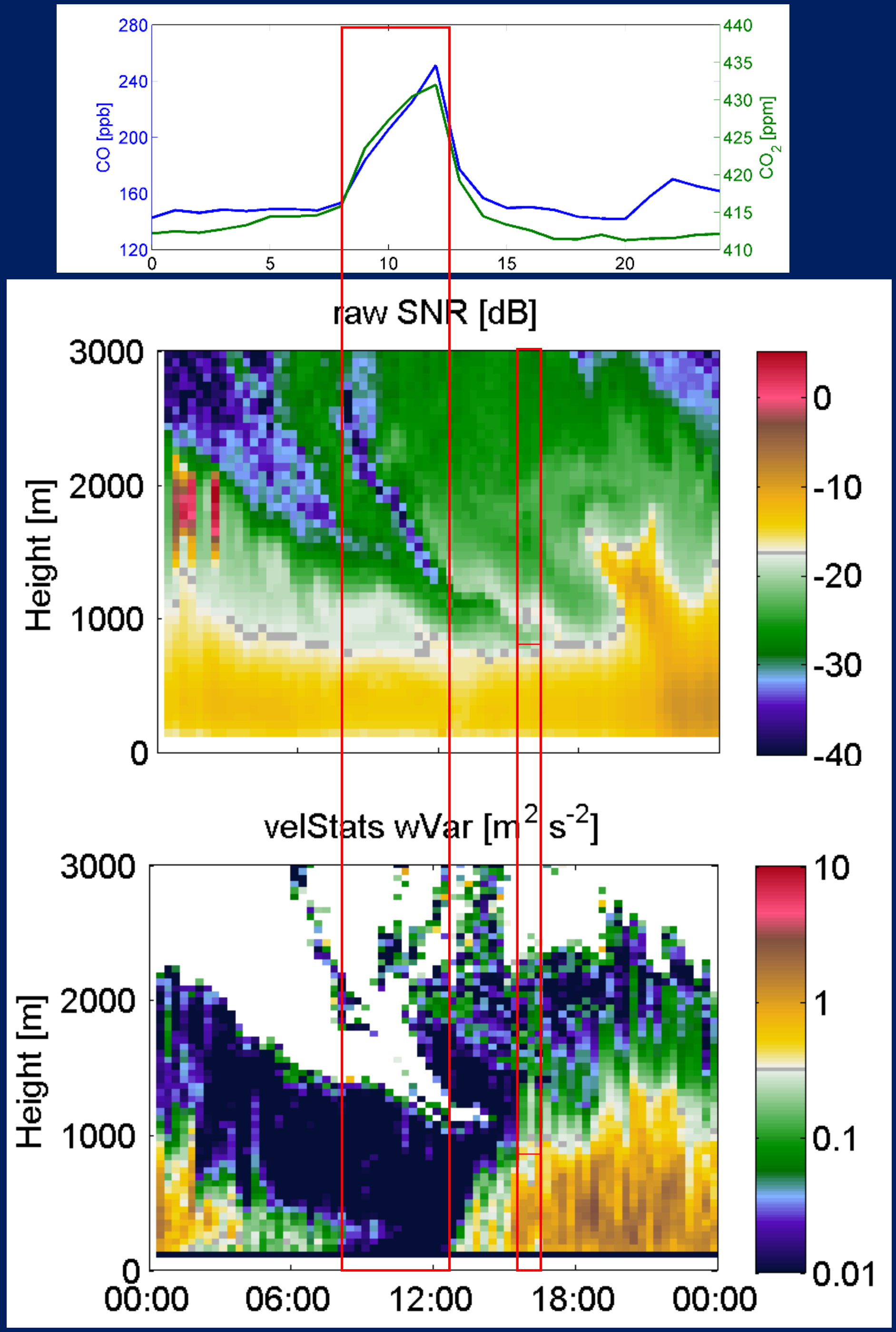
- Halo Streamline lidar deployed on roof of Ivy Tech Building (4 stories above ground) in Aug 2013 until June 2015
- Lidar was upgraded at the end of 2015, and Halo Streamline XR was redeployed at same location in January 2016 to present
- Motivation: Measuring greenhouse gas emissions from city
  - Need wind profile and MH



Motivation for composite fuzzy-logic technique

- Backscatter alone is not always sufficient to determine mixing height, especially when residual layer is present
- Variance alone may lead to a high determination of the mixing height, especially when non-turbulent wavelike motions are present
- Need to u
  scans to c

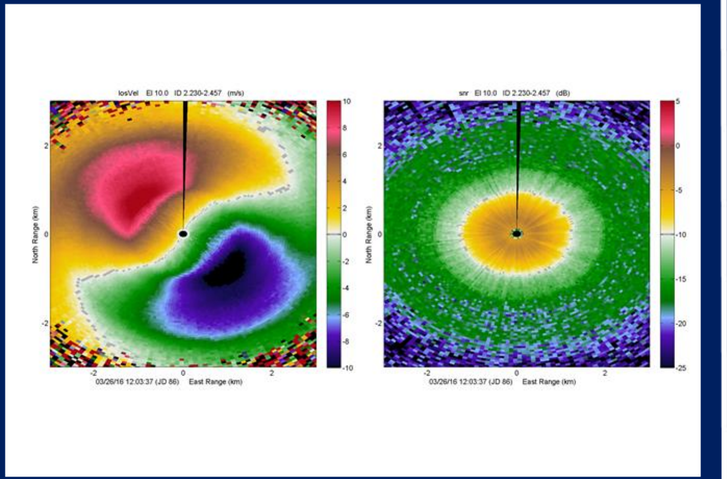


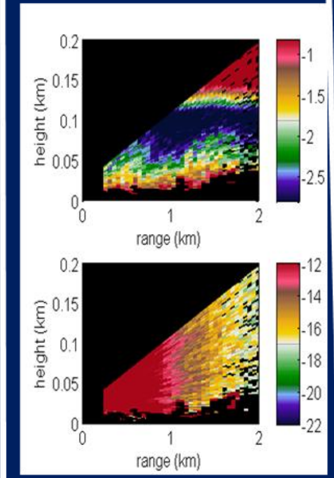


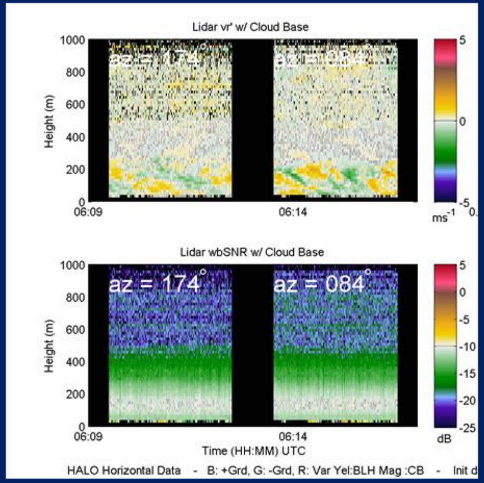
Scanning strategy for INFLUX

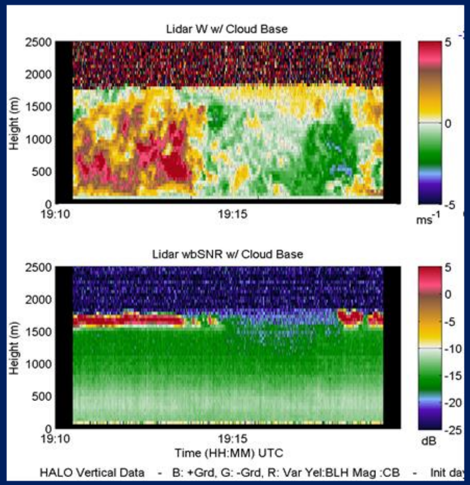
20 minute repeating cycle

Day:	3°	10°	35°	60°	S	E	Vertical Stare	
Night:	PPI	PPI	PPI	PPI	RHI	RHI	S/E 20° EL Stares	Vertical Stare





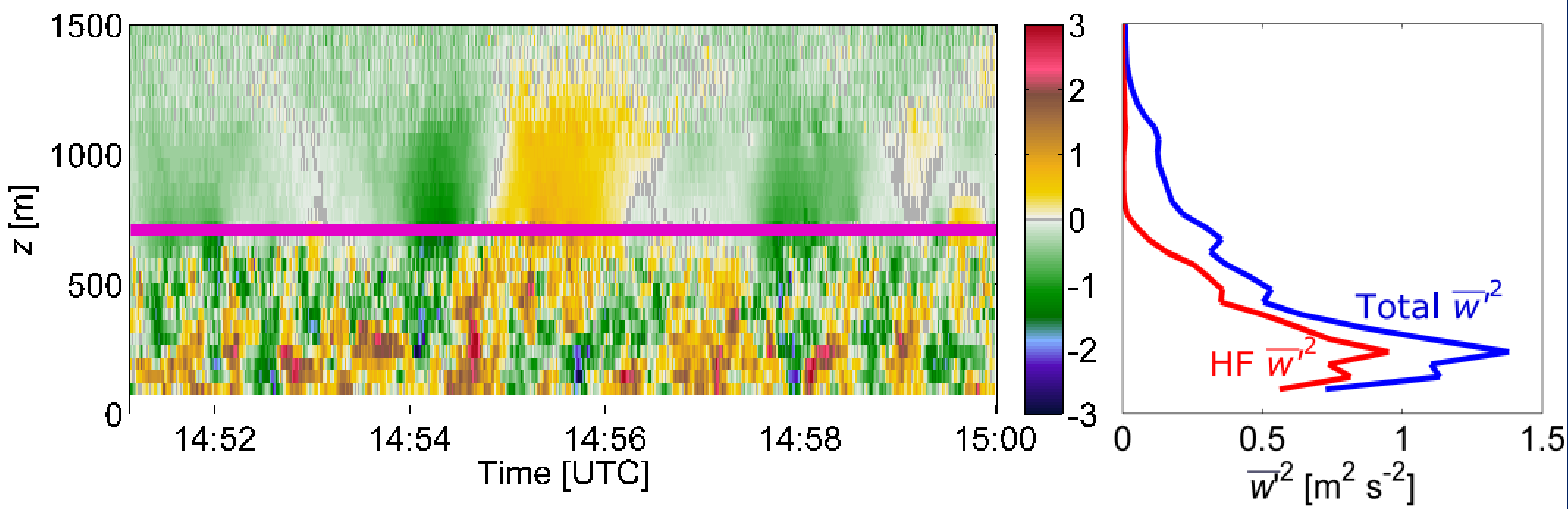




	PPI	RHI	S/E 20° EL Stares	Vertical Stare
Key Variables:	u, v, σ_{vr}^2 , TKE	σ_u^2, σ_v^2	σ_u^2, σ_v^2, SNR, σ_{SNR}^2	σ_w^2, SNR, σ_{SNR}^2
Heights Covered:	30 m – PBL top	0 – 200m	60 m – ≈1000 m	140 m – PBL top

MLH Detection Overview

1) Detect gravity waves and other non-turbulent sub-meso motions



Use relation between HF w'^2 (T<1 min, f>0.017 Hz) to total w'^2 to differentiate turbulent and non-turbulent motions

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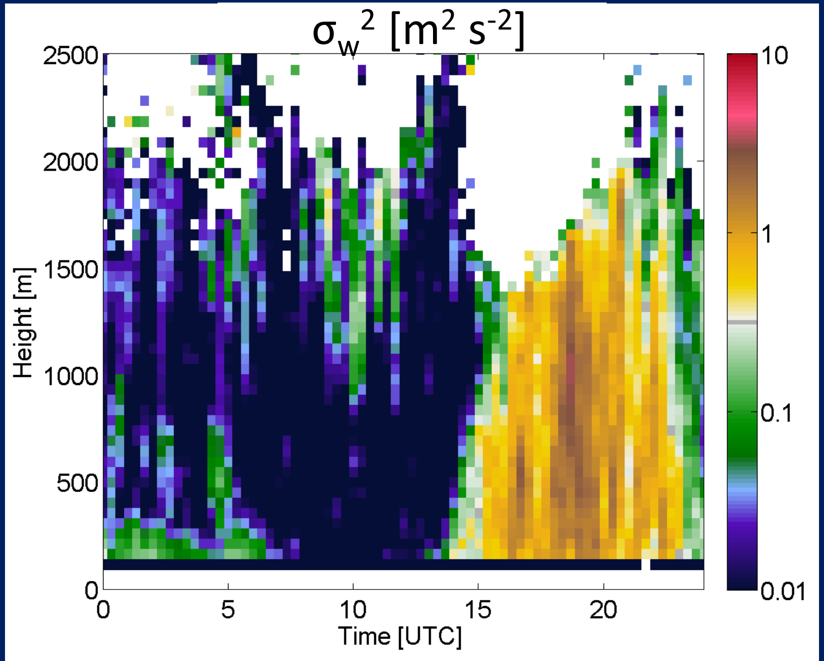

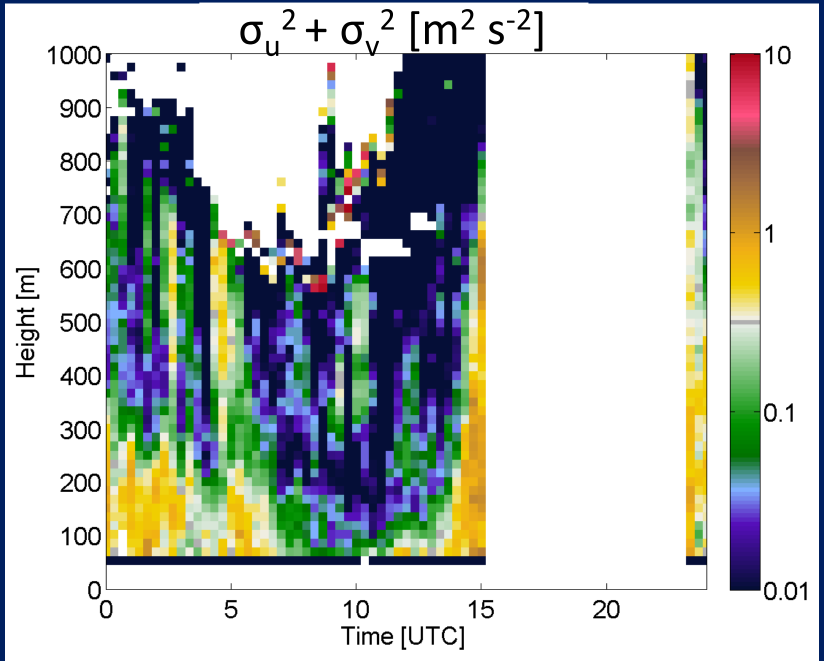

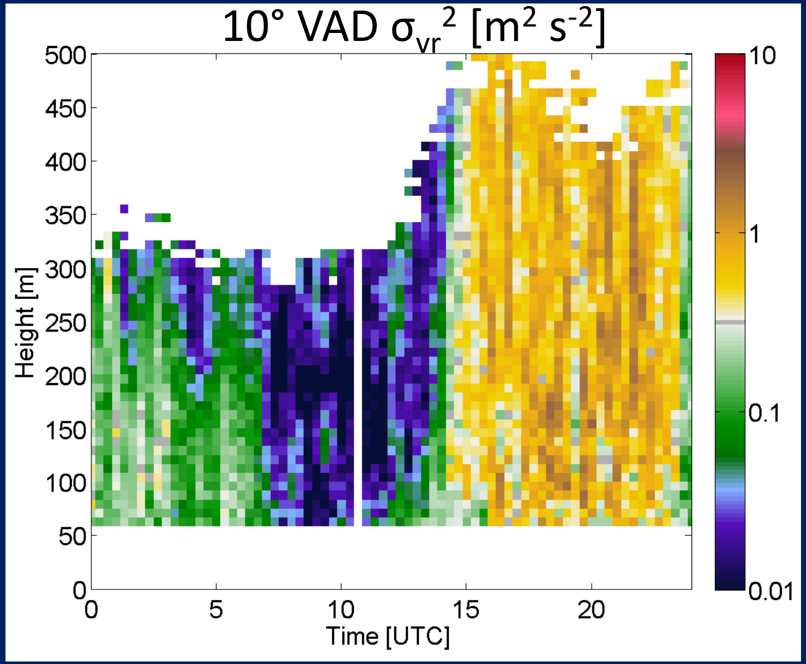

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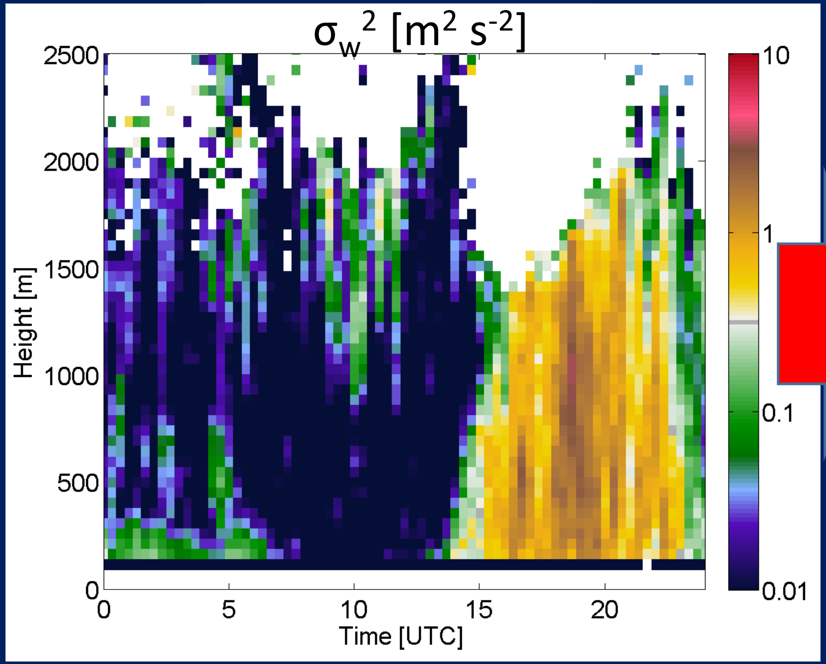

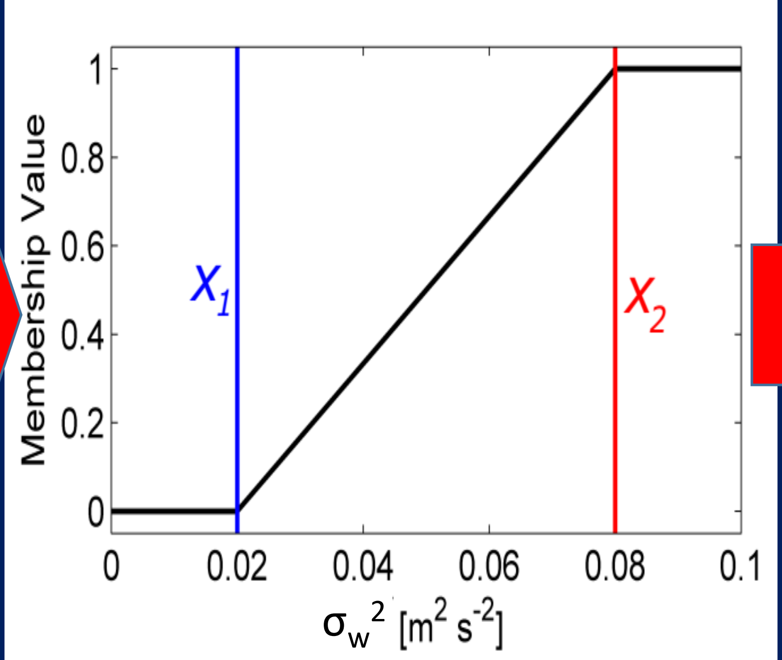

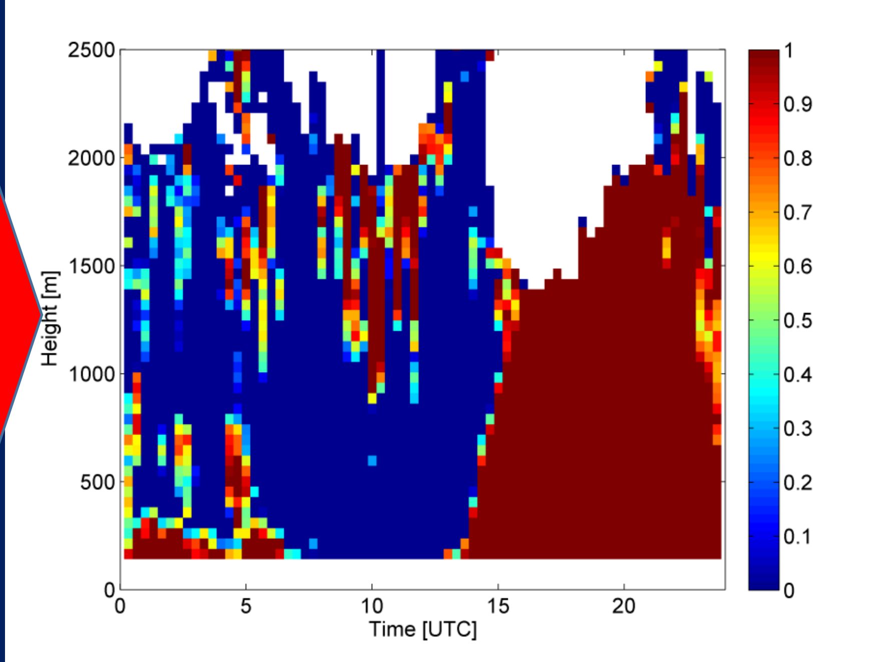

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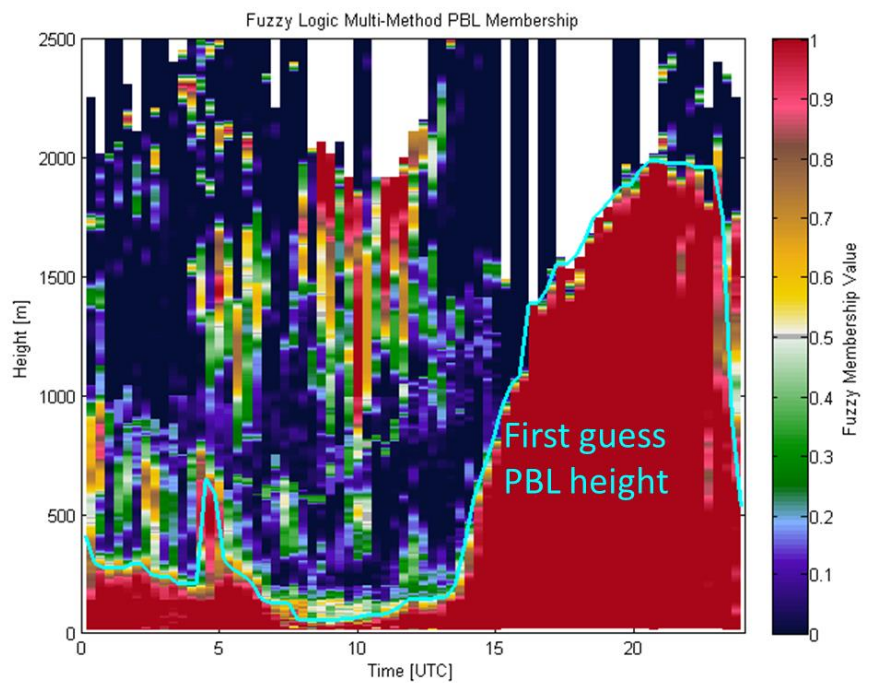
3) Identify a first guess for the top of the mixed layer (z_{i_fg}) based on fuzzy aggregation



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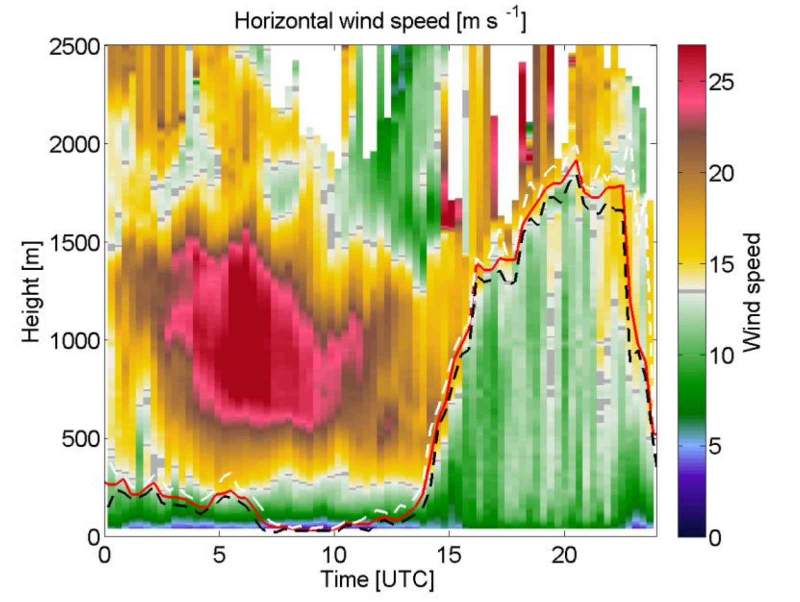
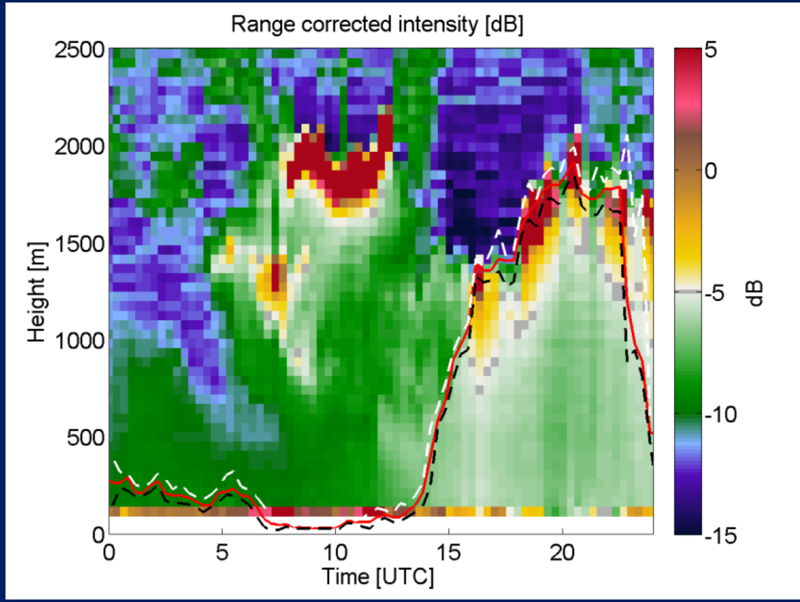
   - Wind shear
   - Large variance or gradients in RCI





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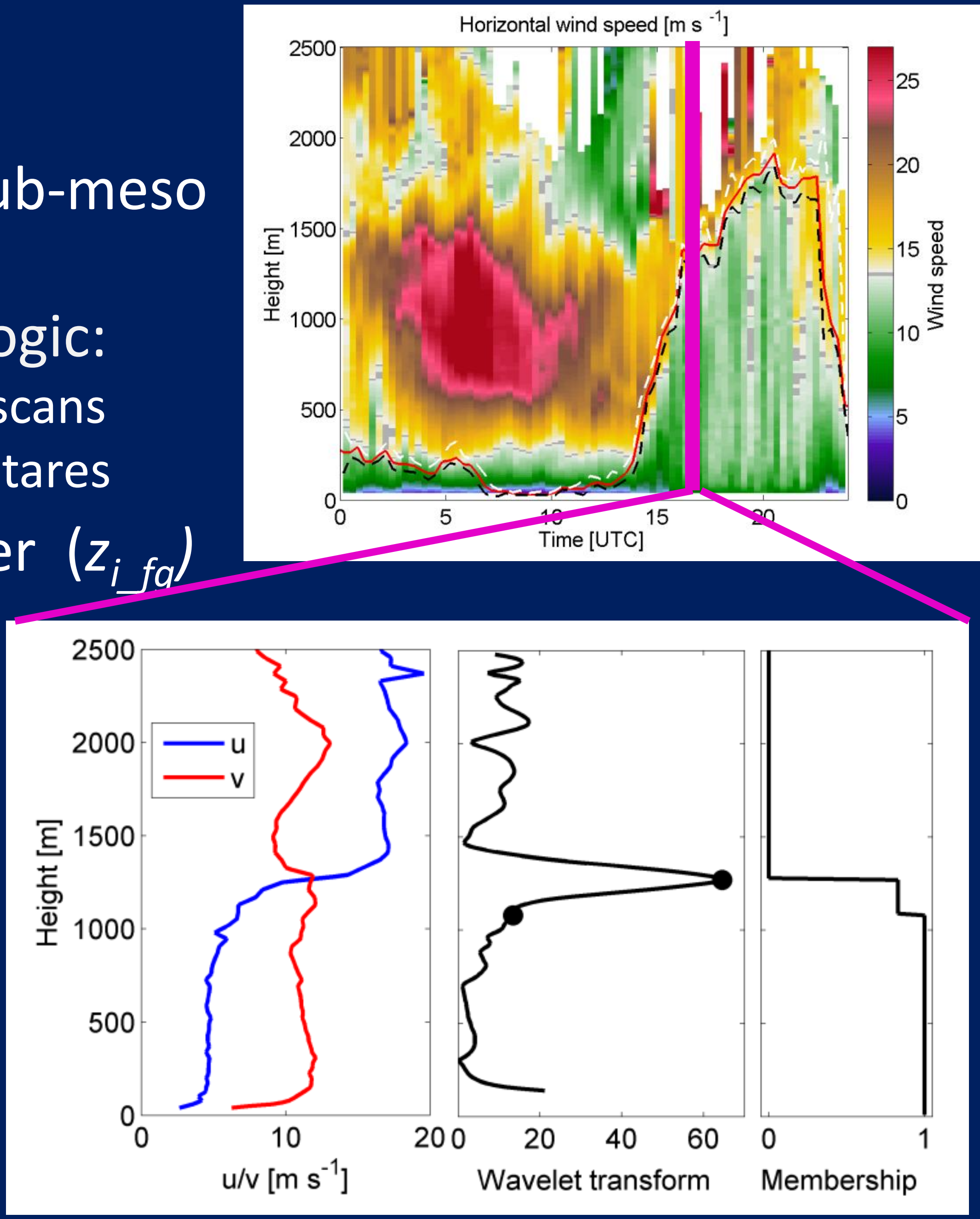

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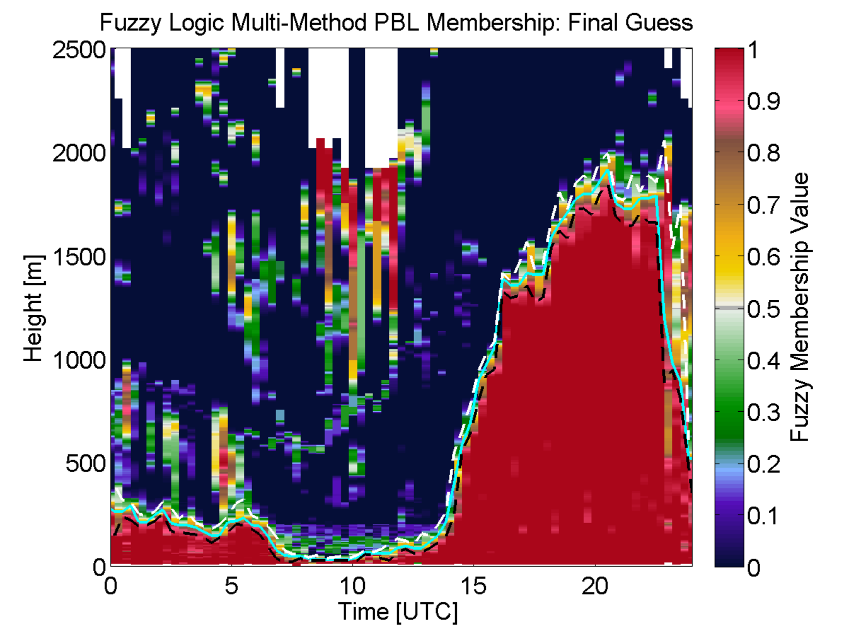

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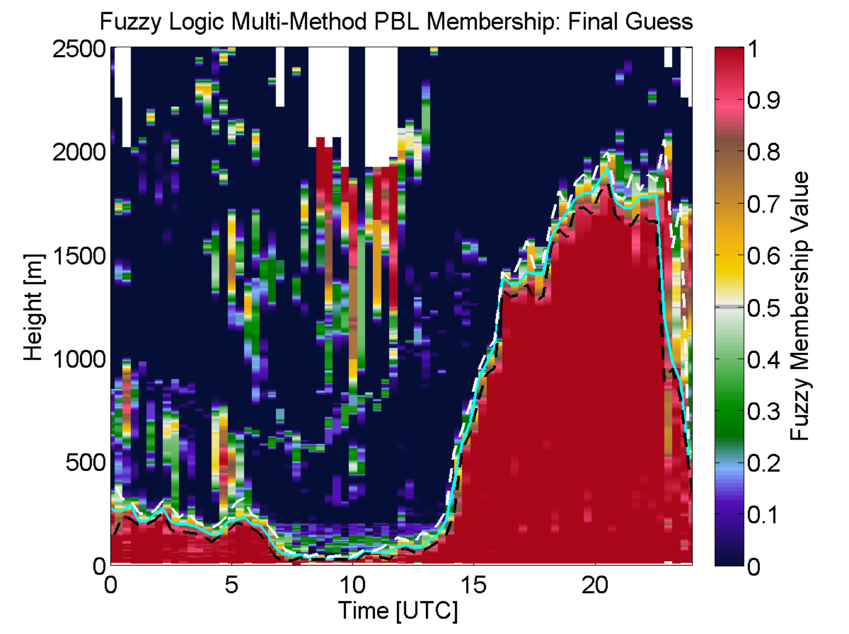
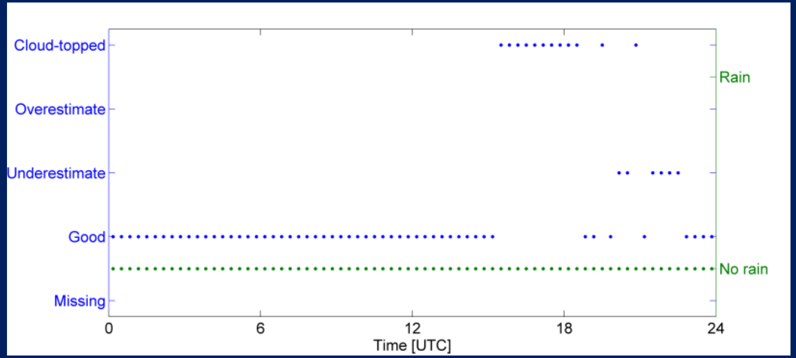
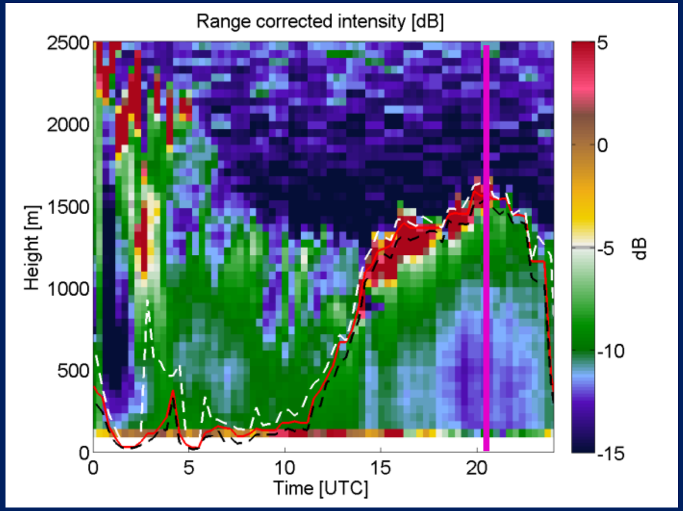
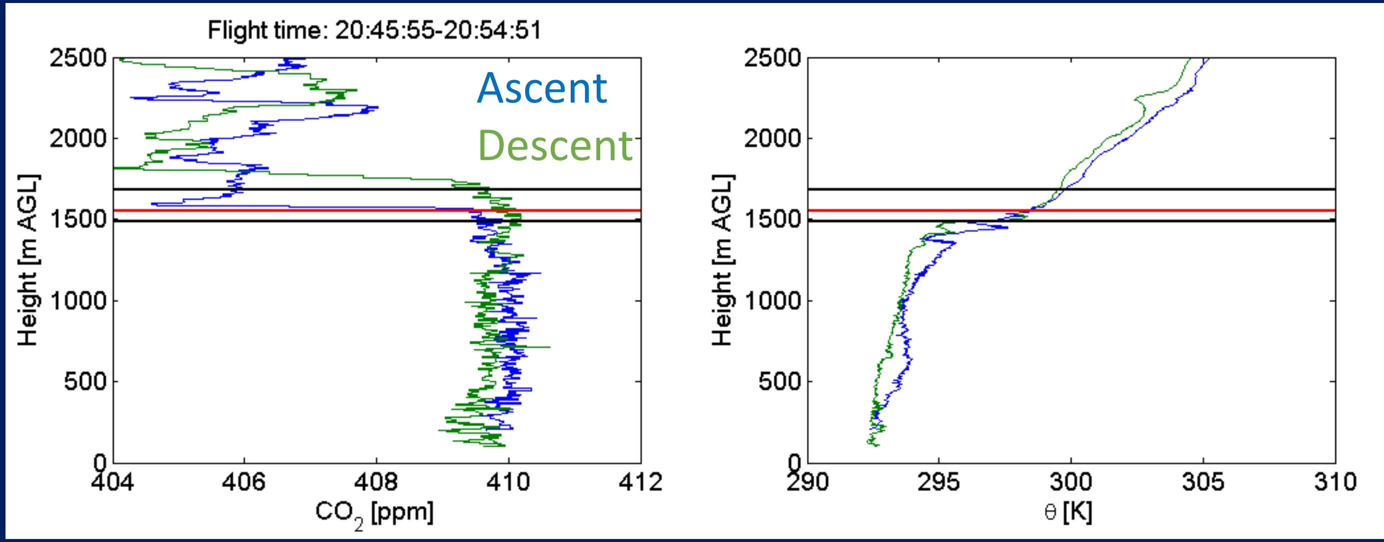
5) Determine final estimate for top of mixed layer & uncertainty
6) Flag the final estimate:
   - Is it raining?
   - Can we see the top of the ML?
   - Is the ML cloud-topped?
   - Is ML below minimum height?

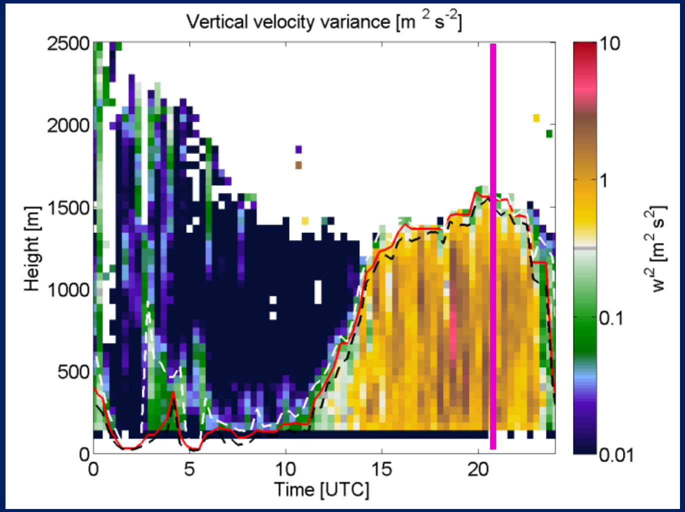


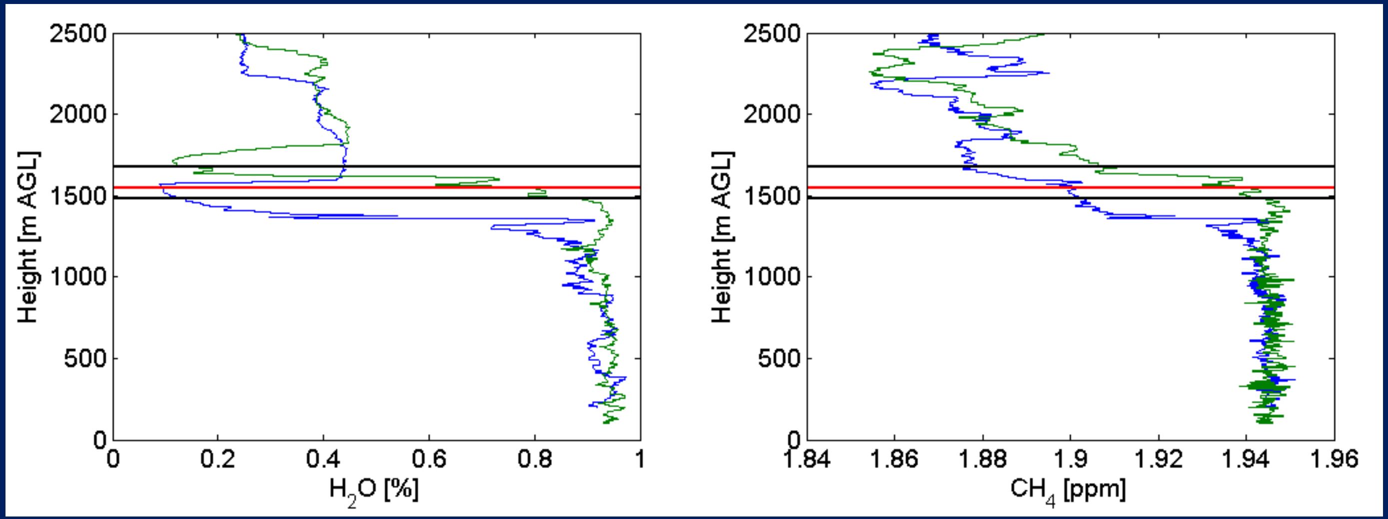


Verification of MLH with aircraft observations 5/13/16 in Indianapolis



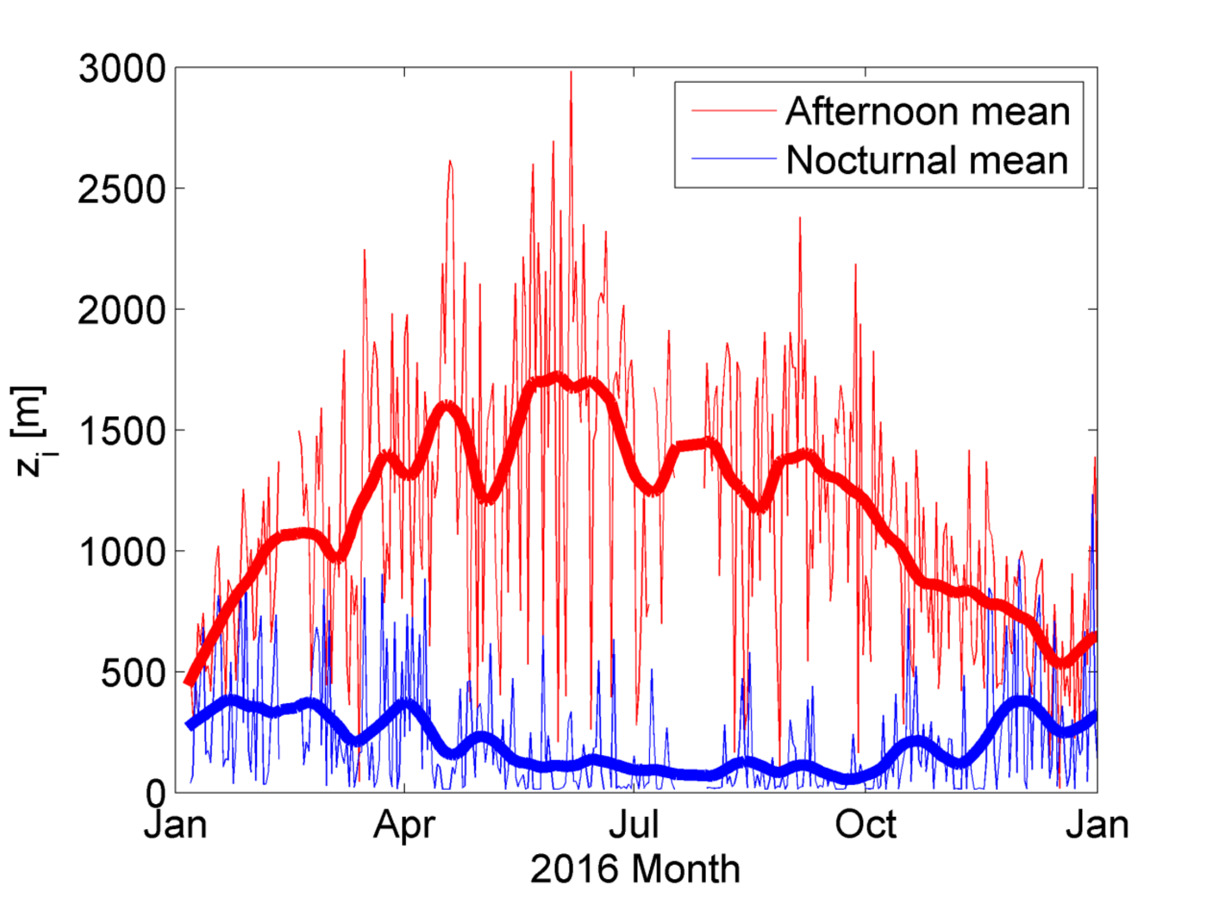


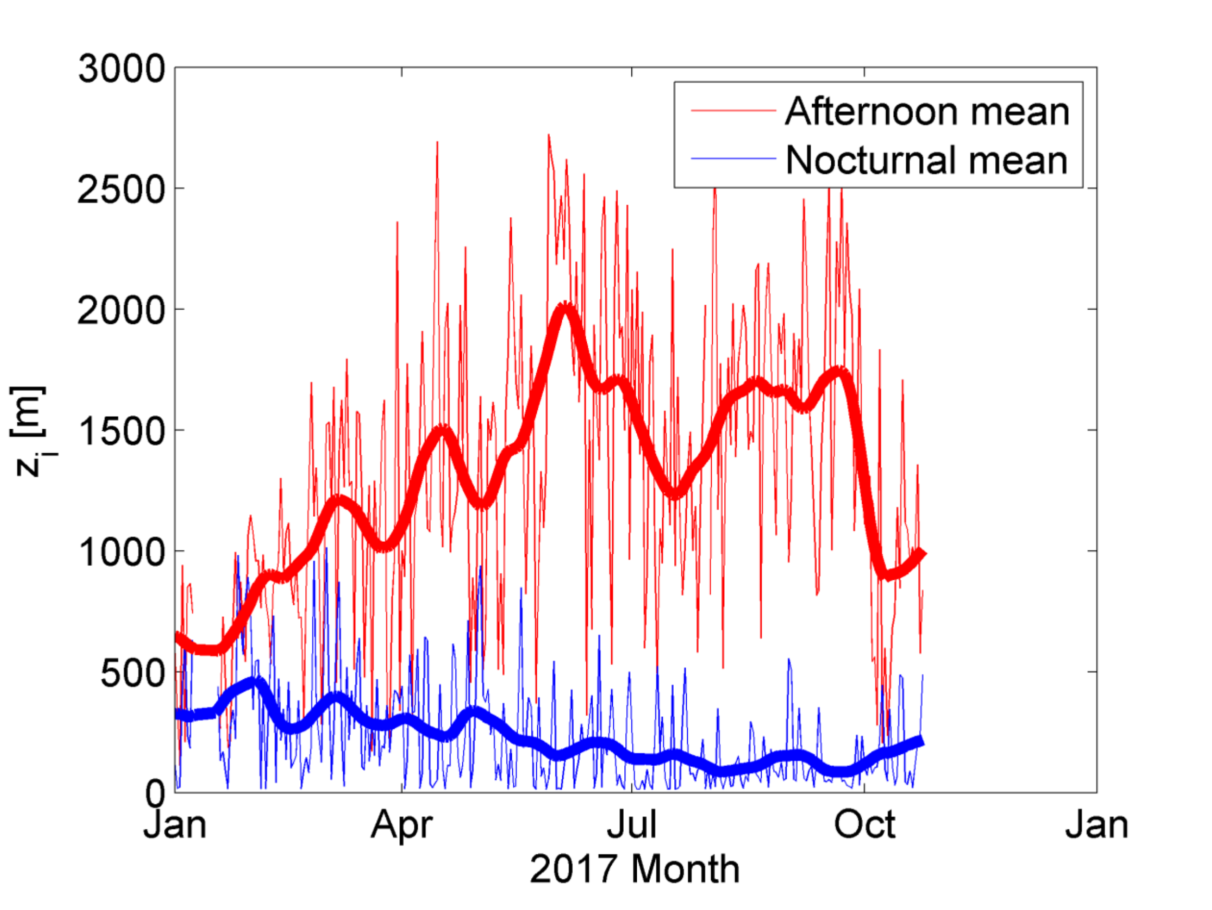




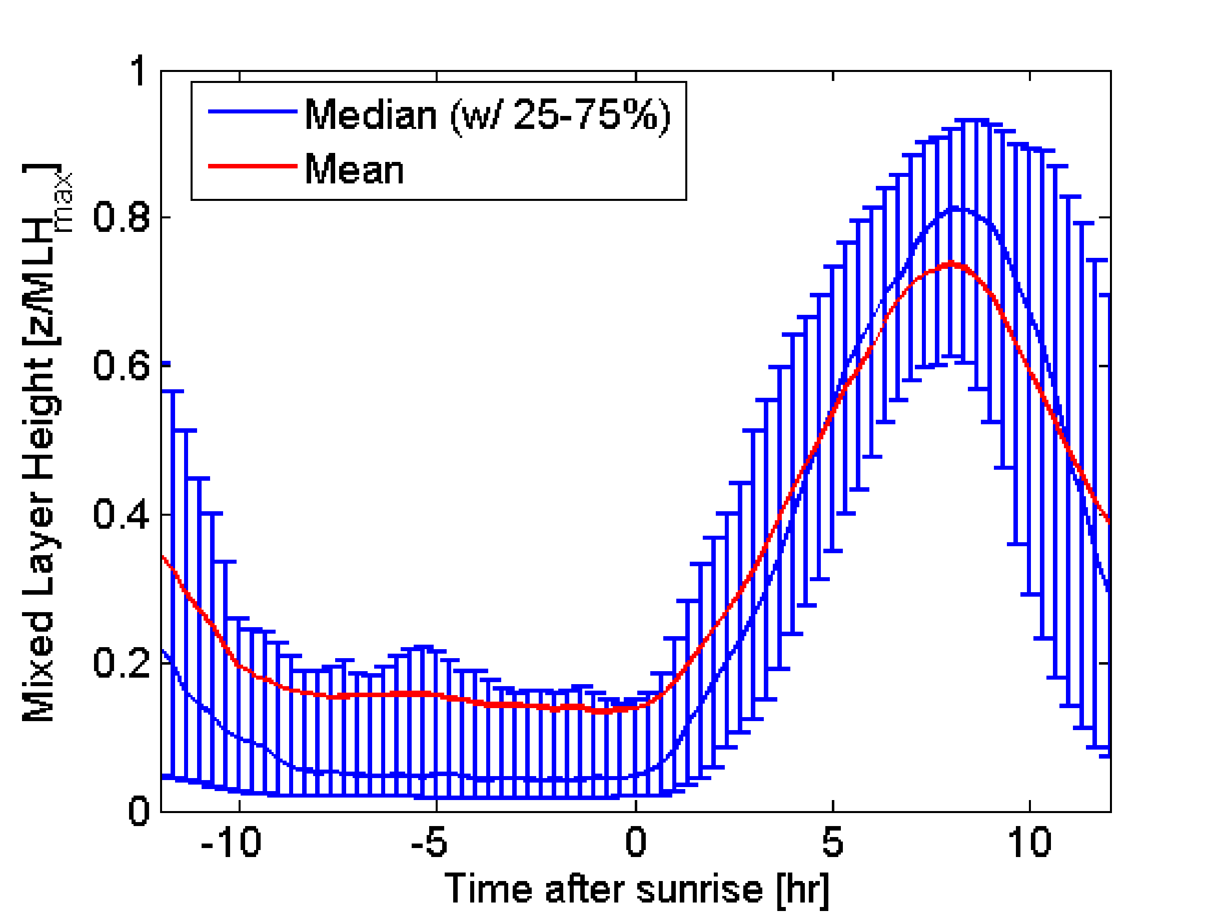
We thank Paul Shepson, Olivia Salmon, and the entire Atmospheric Chemistry group Purdue University for taking profiles over the lidar site and providing the independent observations for comparison

Annual Variation of MLH

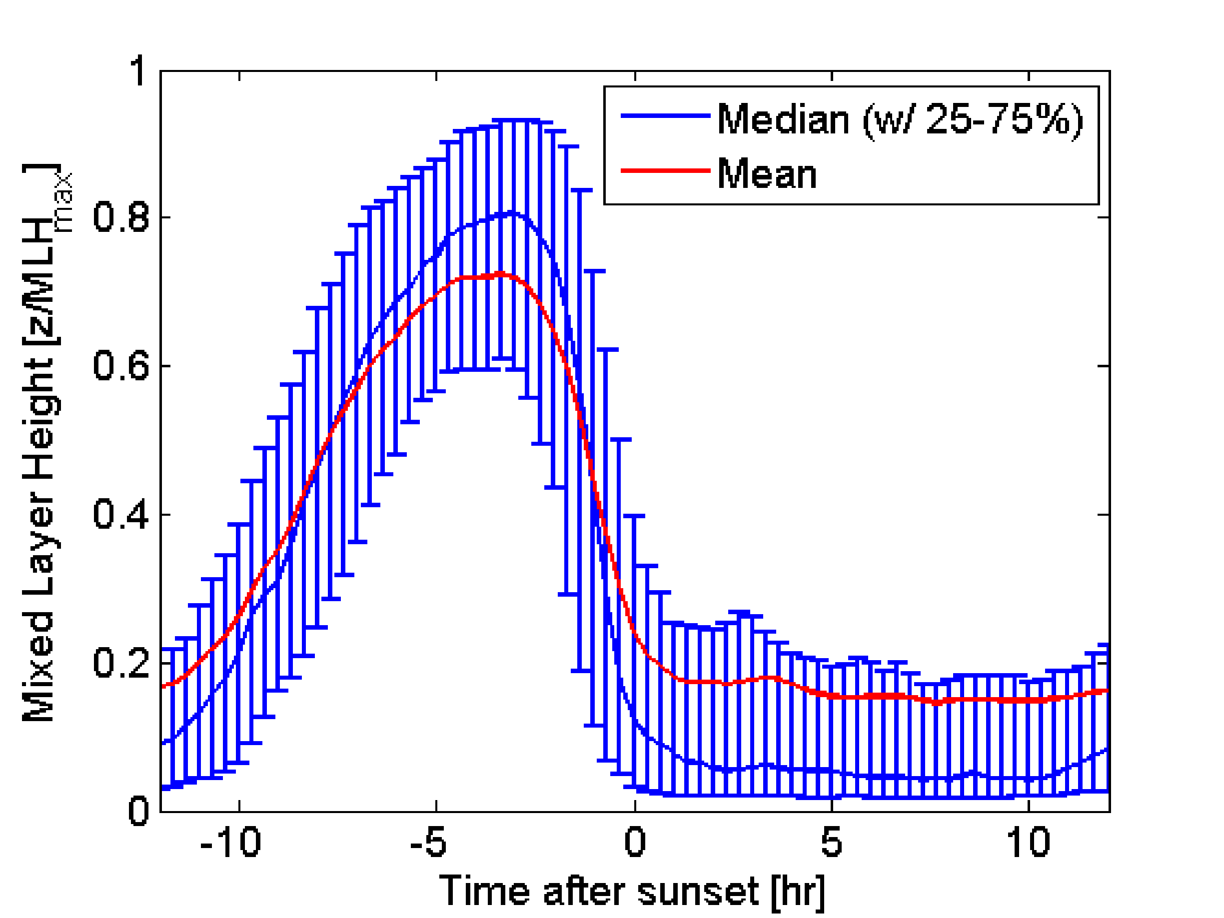




Normalized Diurnal variability in MLH in Indianapolis

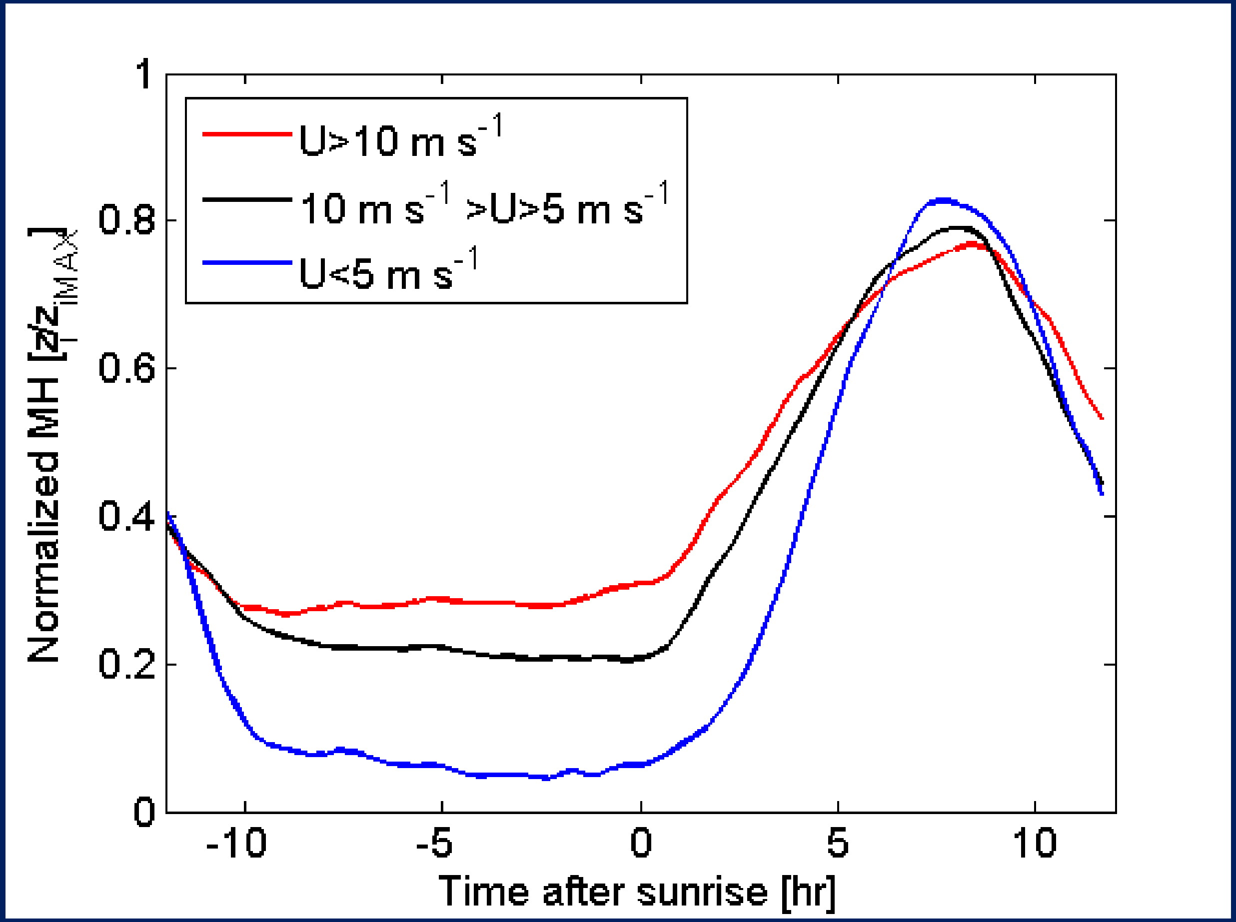


Morning transition



Evening transition

MLH evolution depends on mean wind speed



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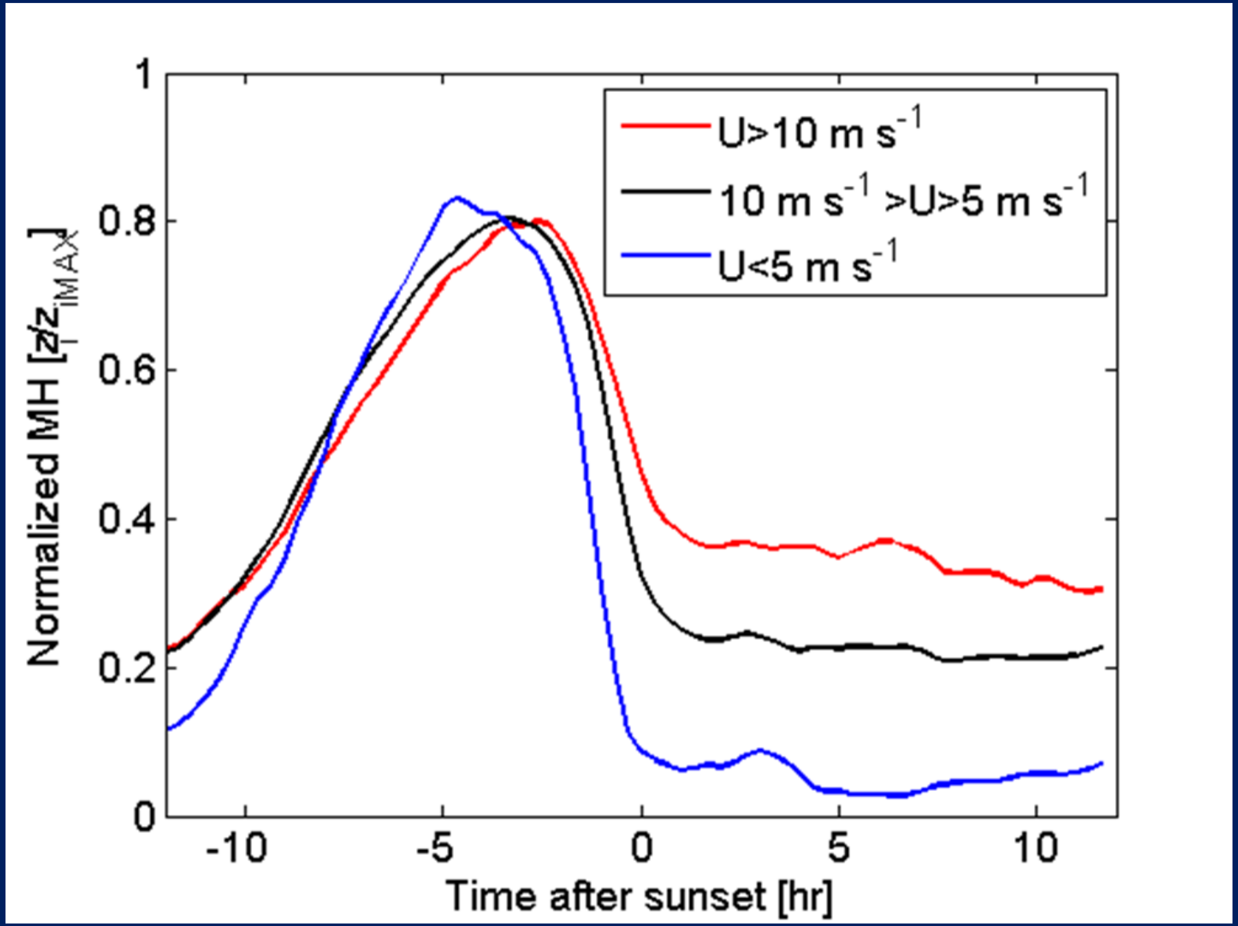

Evening transition

Summary

- A composite fuzzy logic algorithm has been developed and applied to different Doppler lidar systems to continuously detect the MLH at high temporal resolution (15-20 min)
  - Uses inputs of velocity variances (turbulence), backscatter intensity, and wind profiles from all scans
  - Gravity waves and other non-turbulent motions are identified and flagged for exclusion from analysis
- We have applied this algorithm to other Doppler lidars at in different locations (Oregon, California, Las Vegas, Alaska)
  - Algorithm adjusts to use whatever data it can get; do not need the scanning pattern discussed here
- Ongoing efforts to validate MHs through intercomparison with other instruments and NWP output