Low-Level Jets and Mixing Layer Heights in the Plains Elevated Convection at Night (PECAN) Campaign

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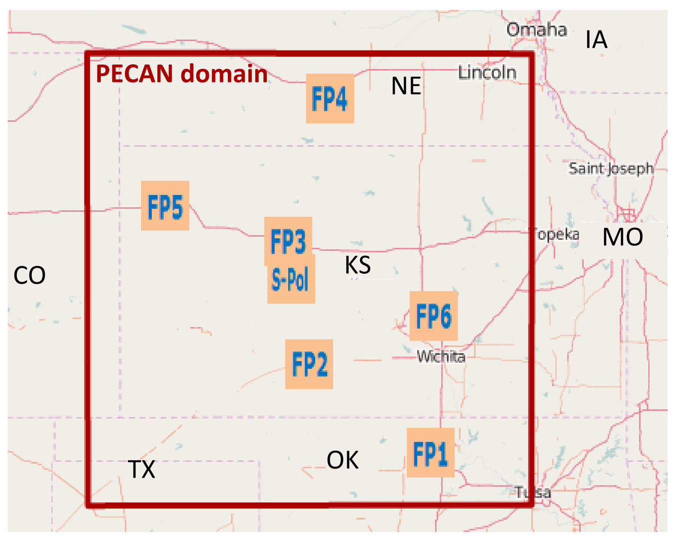
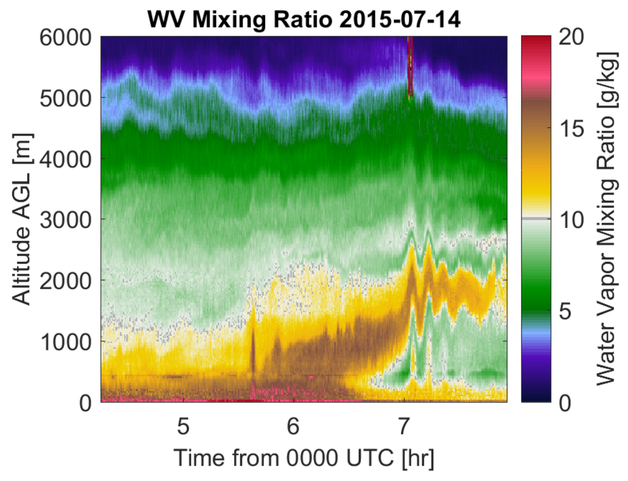
PECAN Overview

Nocturnal warm season thunderstorms are a common phenomenon in the Great Plains region of the United States. These storms have a crucial impact on the local agriculture and everyday life, and yet the forecasting of these events and their quantitative rainfall remains a difficult task. PECAN was designed to study Great Plains nocturnal rainfall and related phenomena with unprecedented temporal and spatial coverage.

- Focused on nocturnal convection with a stable boundary layer (SBL), low-level jet, and largest convectively available potential energy (CAPE) above the SBL
- Domain: southern Great Plains from June 1 – July 15, 2015
- 200+ scientists from multiple agencies and universities
- 6 fixed sites (FPs), 4 mobile sites, and 3 aircraft

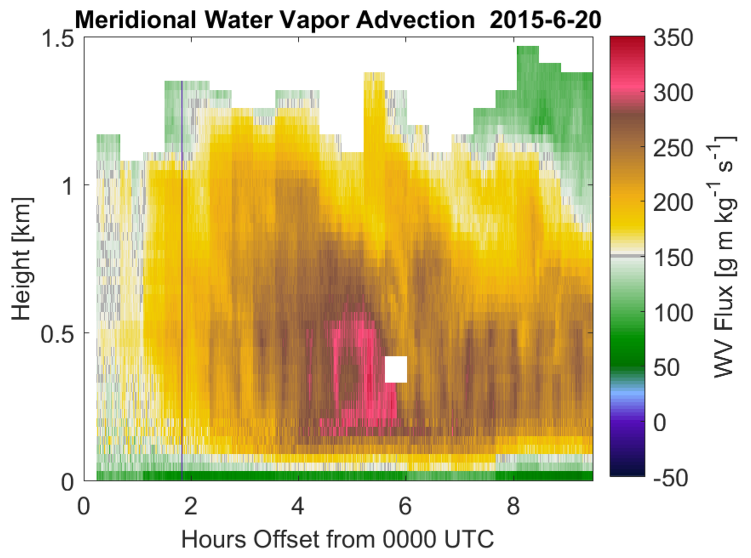


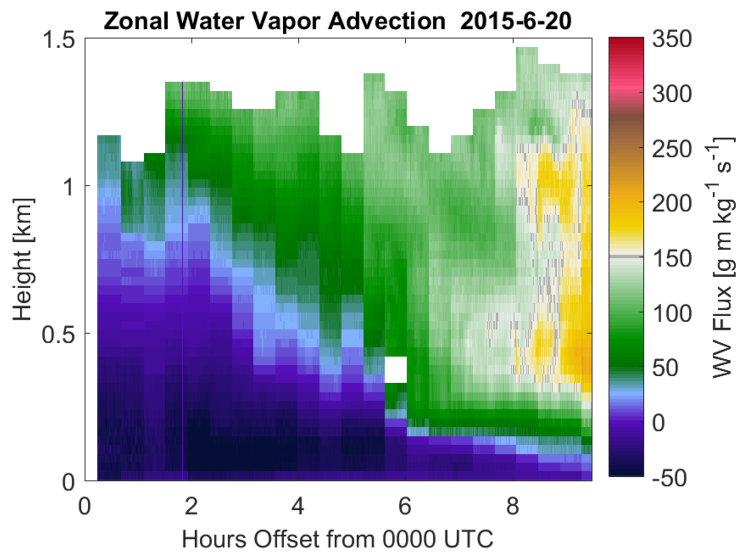
PECAN FP2 Instruments:
- Water vapor lidar
- Doppler wind lidars
- Radiosondes
- Microwave radiometer
- X-band Doppler Radar
- Celiometer
- Micropulse lidar
- Surface instruments
- Tethersonde
- Sodar
- Airborne instrument flyovers
- Atmospheric Emitted Radiance Interferometer (AERI)



Strong bore wave observed at FP2

Low-Level Jets and Moisture Transport



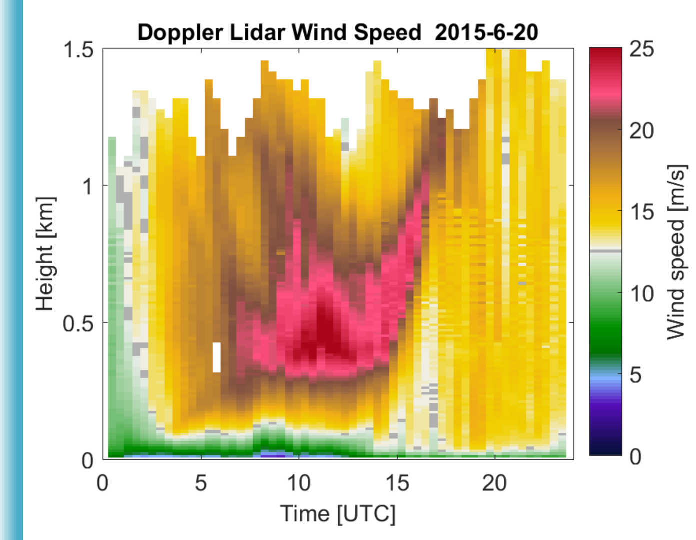


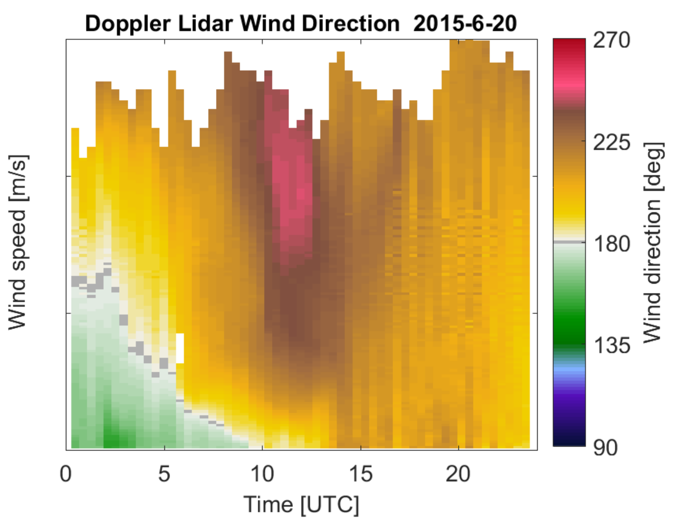
The Warm Season Great Plains Nocturnal LLJ

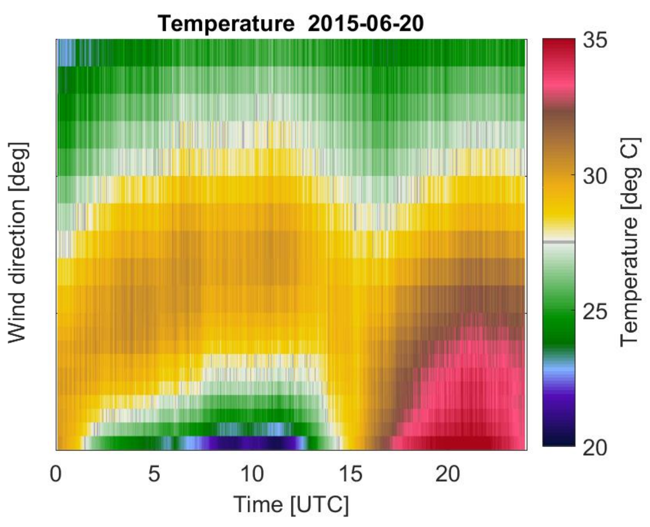
- Typically forms around sunset (~1 UTC) with dissipation of constraining boundary layer turbulence, and often persist until sunrise. Wind speed maximum in early morning hours.
- Characteristic southerly flow from the Gulf of Mexico
- Most common in Oklahoma and Kansas but can reach Canada
- Moisture and momentum and can feed into mesoscale convective systems

Objectives

- The broad array of instrumentation operating during PECAN will be used for a statistical study characterizing moisture transport and jet wind structure and evolution with unprecedented detail.
- Data from the PECAN site FP2 along with other fixed sites and aircraft will be utilized to examine mesoscale spatial variations.



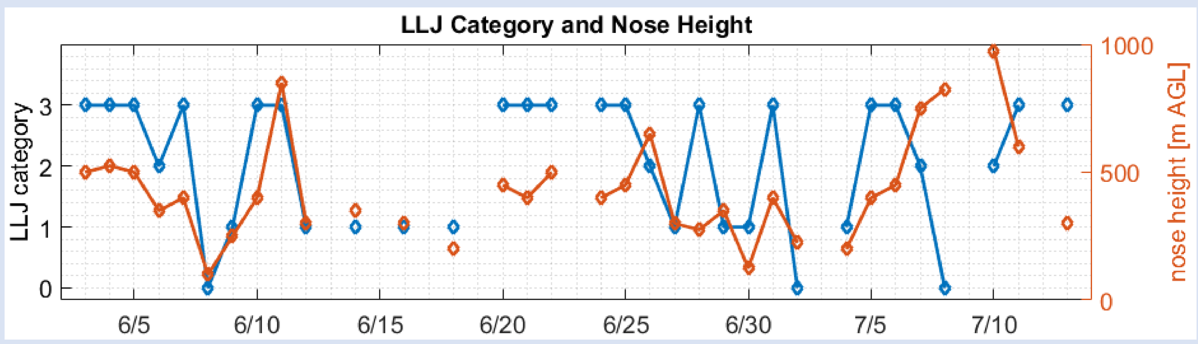




LLJ Statistics from PECAN FP2

LLJ category	V_{max} (m/s)	ΔV (m/s)	Count in PECAN
No jet	---	---	5
LLJ-0	≥ 10	≥ 5	3
LLJ-1	≥ 12	≥ 6	9
LLJ-2	≥ 16	≥ 8	4
LLJ-3	≥ 20	≥ 10	17

V_{max} is the maximum wind speed at jet nose. ΔV is the difference between V_{max} and the minimum speed above nose.



LLJ categories and nose heights at FP2 for every night during PECAN. Gaps are nights with no jet or one of 3 missing data nights.

What's Next?

This research will improve our understanding of the atmospheric phenomena related to Great Plains rainfall, opening the door for better models and weather forecasting.

- Intercomparison of high-resolution moisture and wind profiles for the 33 LLJ events observed at FP2. Calculate Richardson numbers.
- Expand some case studies to the entire PECAN domain of data; report on spatial variation of LLJ moisture transport
  - Incorporate airborne instrument flyover data
- Continue validation and fine-tuning of MLH algorithm
- Examine nighttime busts of mixing using MLH algorithm in conjunction with other profiling and surface instruments
- Utilize MLH algorithm and individual products to explore turbulence above and below LLJ nose

Mixing Layer Heights from Doppler Lidar: A New Algorithm

1) Detect and remove effects of gravity waves and large scale, non-turbulent motions

2) Find turbulent layer via velocity variance of all useful scans:
σ_{vr}^2 from each VAD scan; σ_u^2, σ_v^2 from RHI scans; σ_w^2 from vertical stares

Combine using fuzzy logic for a first guess of the MLH

3) Find nearby proxies for mixing:
Peaks in wind shear and SNR variance, large gradients in SNR

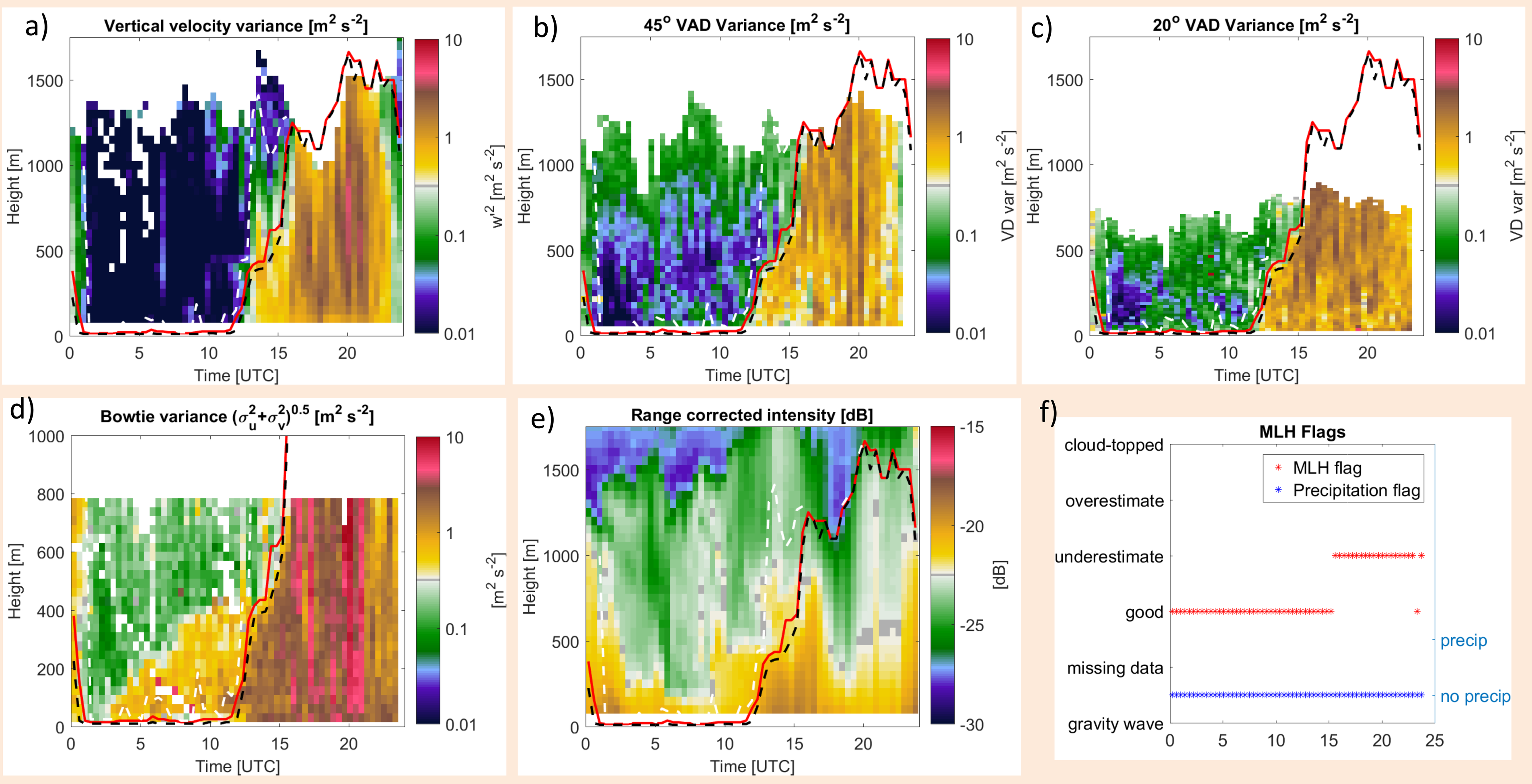
If locations of these proxies are within 15% of the first guess MLH, combine them with first guess to determine final MLH

4) Flag the final estimate of the MLH:
Is it raining? Is the MLH cloud-topped?
Is MLH estimate near max or min of measurement range?

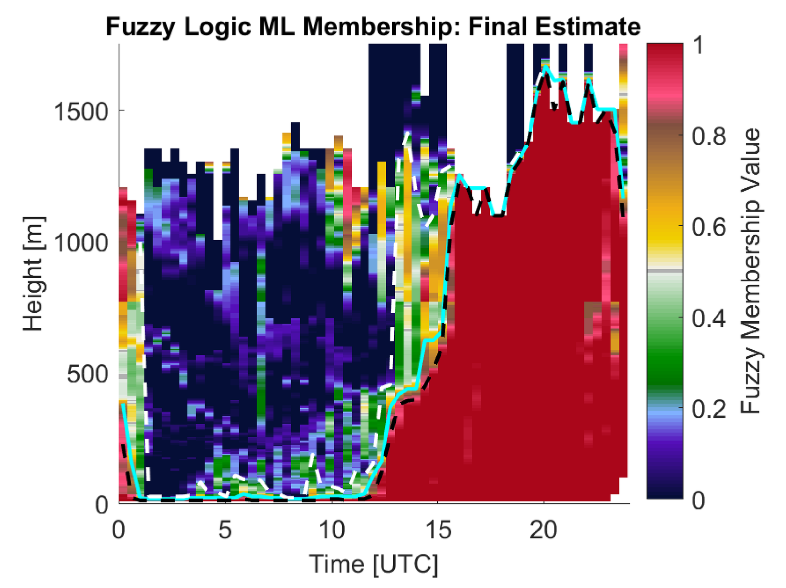
- All Doppler lidar scan types are incorporated (conical, slice, stare). Covers heights from 10m AGL upwards
- 7 independent products contribute to MLH estimate
- **Fuzzy logic**: Each product at each height is converted to a "membership value" of confidence in mixing; 1.0 most, 0.0 least likely to be in ML. Combined by averaging.
- New MLH estimate with each scan cycle; ~25min cycle during PECAN. Applicable in near real-time.

Applications to PECAN

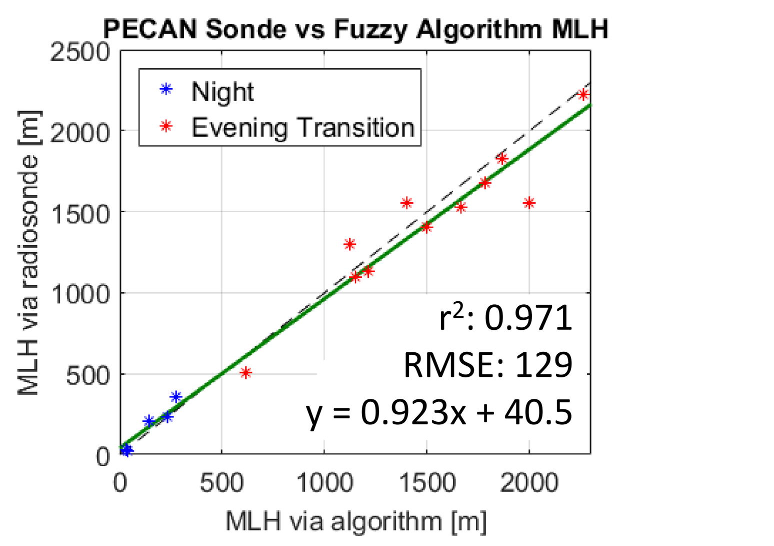
- Relate daytime convective boundary layer heights to evening/night phenomena
- Examine MLH before and after bore wave passage
- Nocturnal bursts of mixing



a) – e): Some of the processed data products that feed into the MLH algorithm f): Flags of the final MLH estimate



Final estimate for MLH requires surface-connected membership of 0.7 or higher [cyan line]. Convective daytime layer is clearly mixed. Transition periods are difficult to characterize, expanding the 0.2 and 0.9 confidence bounds [white, black dashed lines].



Comparison with radiosondes shows good agreement. Sonde MLHs were determined by surface-connected constant potential temperature. Only 17 data points are available because most other sondes were launched during stable nighttime conditions (MLH within 20m of surface) or transition periods with no clear MLH.

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