Spatial Correlation Between Mixed Layer Depth and Surface Properties at SGP

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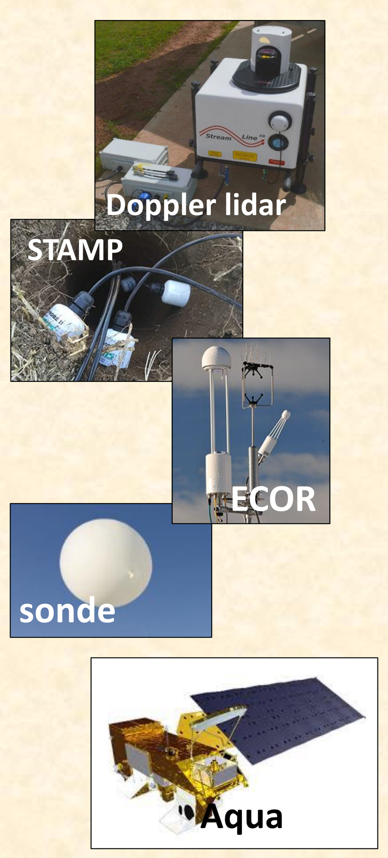
Introduction

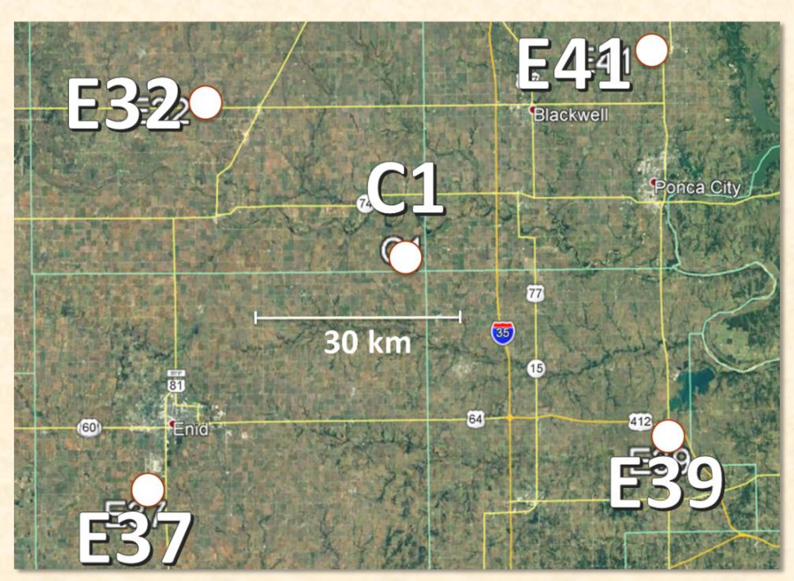
Understanding the spatial and temporal variability in the planetary boundary layer (PBL) height, zi, is key to improving the skill of climate, weather and air quality models in representing near-surface turbulent mixing, entrainment across the PBL top, and the cloud-base height of shallow convection.

In this study, we use observations from the SGP PBL profiling network to examine the spatial variability in the convective boundary layer (CBL) depth, and its correlation with surface and subsurface parameters including soil moisture, horizontal velocity variance, sensible heat flux, and surface albedo from satellite observations. The goal is to identify surface properties that most explain the variation in the maximum zi from day to day.

The approach is to use observations from SGP C1, E32, E37, E39 and E41 to compute the spatial correlation between surface variables and the daily maximum zi. The analysis spans the warm seasons (May through September) for the years 2016 through 2018, and makes use of the following instruments:

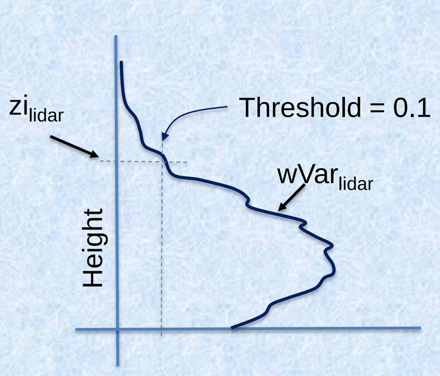


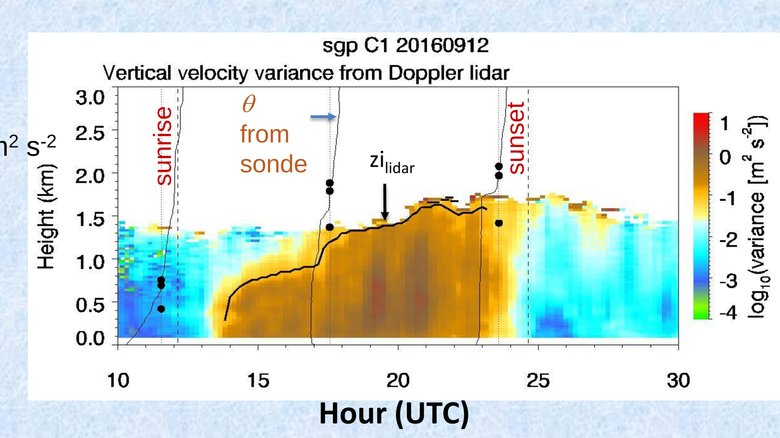
- Doppler lidar
  - Used to estimate zi
  - All facilities (C1, E32, E37, E39, and E41)
- Soil Moisture and Temperature Profiling (STAMP) system
  - Soil water content at a depth of 5 cm
  - All facilities
- Eddy Correlation (ECOR) system
  - Turbulence parameters
  - C1, E37, E39, and E41
- Radiosonde
  - Used to compare zi with Doppler lidar
  - C1 only
- Modis
  - Black sky albedo
  - MCD43A3 Version 6 Albedo product
  - 16-day moving weighted average
  - 0.3 to 5.0 μm
  - Spatial resolution = 500m



Estimating the Mixed Layer Depth from the Doppler Lidar

- Doppler lidar measures w at a resolution of 1 sec and 30 m.
- 30-min averaged profiles of vertical velocity variance ($wVar_{lidar}$) are computed from the 1-sec data.
- CBL mixed layer depth is estimated by thresholding $wVar_{lidar}$ using a value of 0.1 $m^2 s^{-2}$.

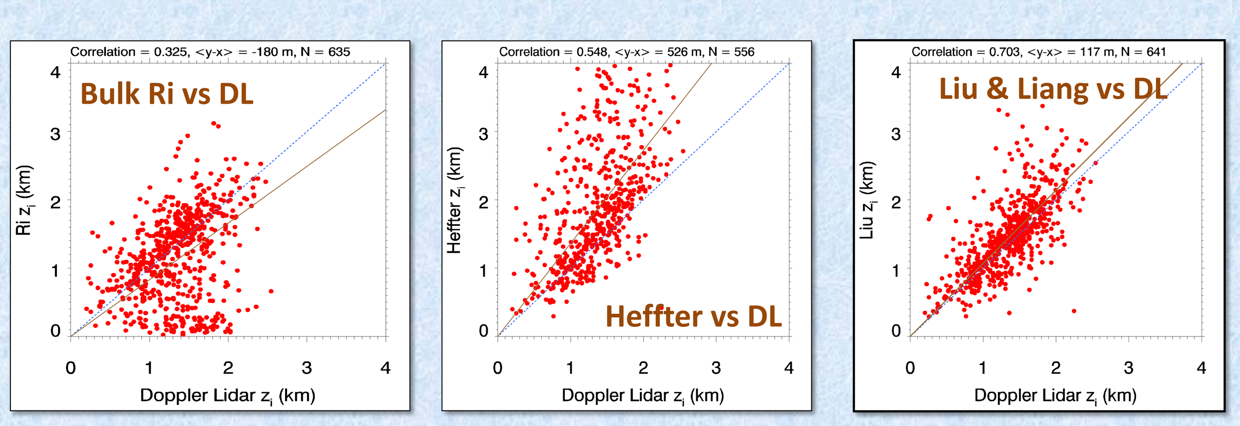




Mixed Layer Depth from the Radiosonde

- Current ARM PBL VAP (pblhtsonde1mcfarl.c1) processes radiosonde profiles to generate zi estimates using three different methods:
  - Liu & Liang
  - Heffter
  - Bulk Ri number
- These methods are described in “Planetary Boundary Layer (PBL) Height Value-Added-Product (VAP): Radiosonde Retrievals, DOE/SC-ARM/TR-132”
- Radiosondes are launched 4x daily at C1

Doppler Lidar CBL Depth Versus the ARM PBL VAP

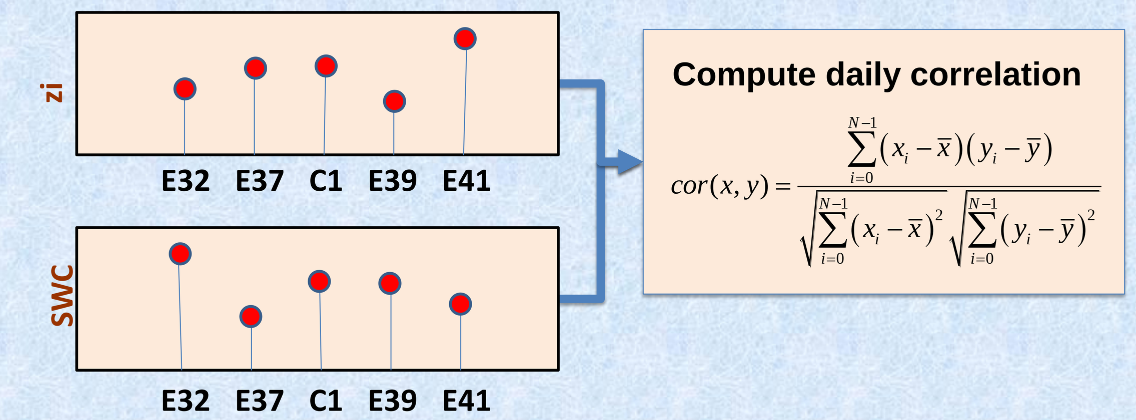


- zi from radiosondes (Liu, Heffter and Bulk Ri) versus simultaneous zi from the Doppler lidar.
- Analysis performed at SGP C1, for May-Sept 2016, 2017 and 2018
- Clear or shCu days only
- Liu & Liang method results in the best agreement with the DL
  - Linear correlation = 0.7
  - Bias (Liu-DL) ~ 120m

Spatial Correlation Analysis

For a given day we compute the linear correlation coefficient of variable x (e.g. zi from the lidar) with variable y (e.g. soil moisture from STAMP) over five SGP facilities (C1, E32, E37, E39, and E41). Variables include:

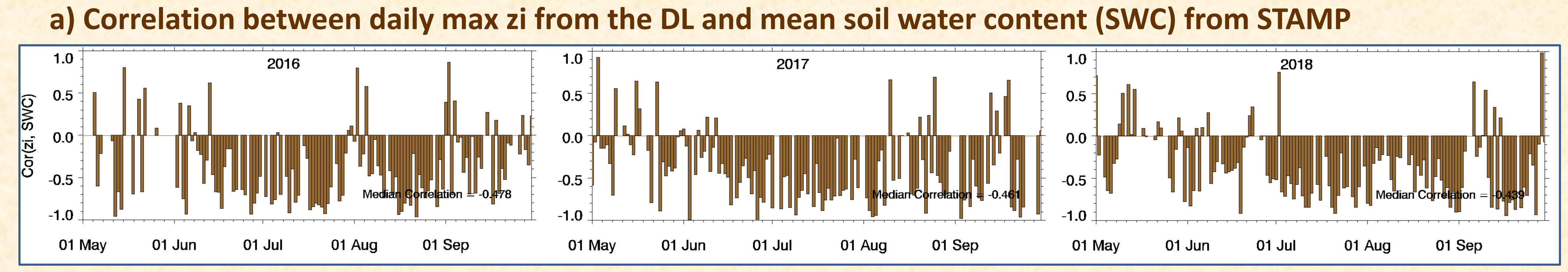
- Daily maximum zi from Doppler lidar
- Daily maximum surface latent and sensible heat flux from ECOR
- Soil water content at -5 cm (from STAMP) averaged over 2-hour window centered on time of maximum zi
- Surface TKE, vertical velocity variance, and horizontal velocity variance averaged over a 2-hour window centered on time of maximum zi.
- Daily black sky albedo (BSA) from Modis



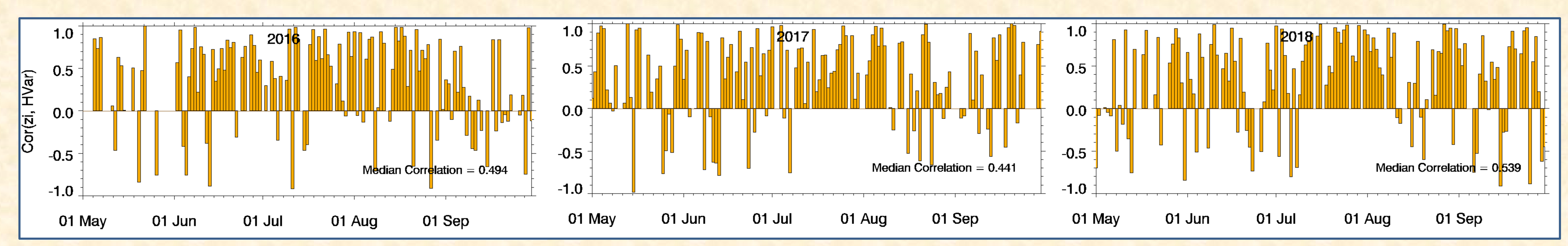
$$cor(x,y)=\frac{\sum_{i=0}^{N-1}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=0}^{N-1}(x_i-\bar{x})^2}\sqrt{\sum_{i=0}^{N-1}(y_i-\bar{y})^2}}$$

Spatial Correlation Results

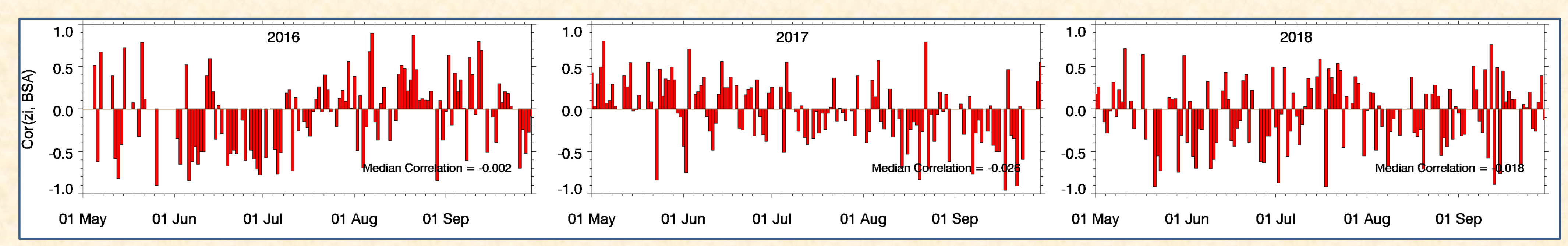
a) Correlation between daily max zi from the DL and mean soil water content (SWC) from STAMP



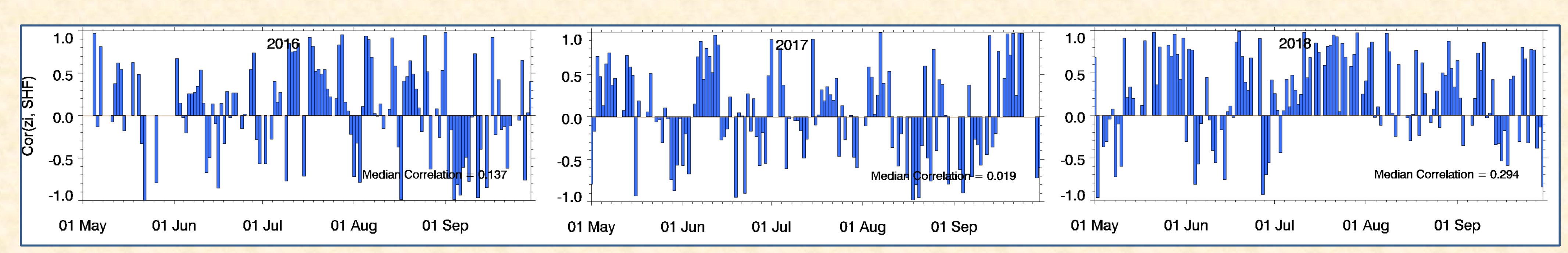
b) Correlation between daily max zi from the DL and mean surface horizontal velocity variance (hvar) from ECOR



c) Correlation between daily max zi from the DL and black sky albedo (BSA) from Modis



d) Correlation between daily max zi from the DL and surface sensible heat flux (SHF) from ECOR



- The daily maximum zi is significantly anti-correlated with soil moisture. Results suggest that the correlation is strongest (most negative) between June and August.
- The daily maximum zi is significantly correlated with the surface horizontal velocity variance. This result exhibits less seasonal dependence than the correlation with soil moisture.
- On average we found the daily maximum zi to be poorly correlated with the daily maximum sensible heat flux, and the black sky albedo from Modis. Additionally, we also found zi to be poorly correlated with the surface vertical velocity variance, latent heat flux, evaporative fraction, relative humidity, daily min/max temperature difference, wind speed, and friction velocity.

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