Testing the Water Vapor Variance Similarity Relationship in the Interfacial Layer Using Raman Lidar and Radar Wind Profiler Observations with LES

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Support for this Research

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LAFE 2017

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$\overline{q_I'^2}$ - WV Variance at z_i

w_* - Convective velocity scale

g_I - WV gradient at z_i

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Able to measure the variables in red

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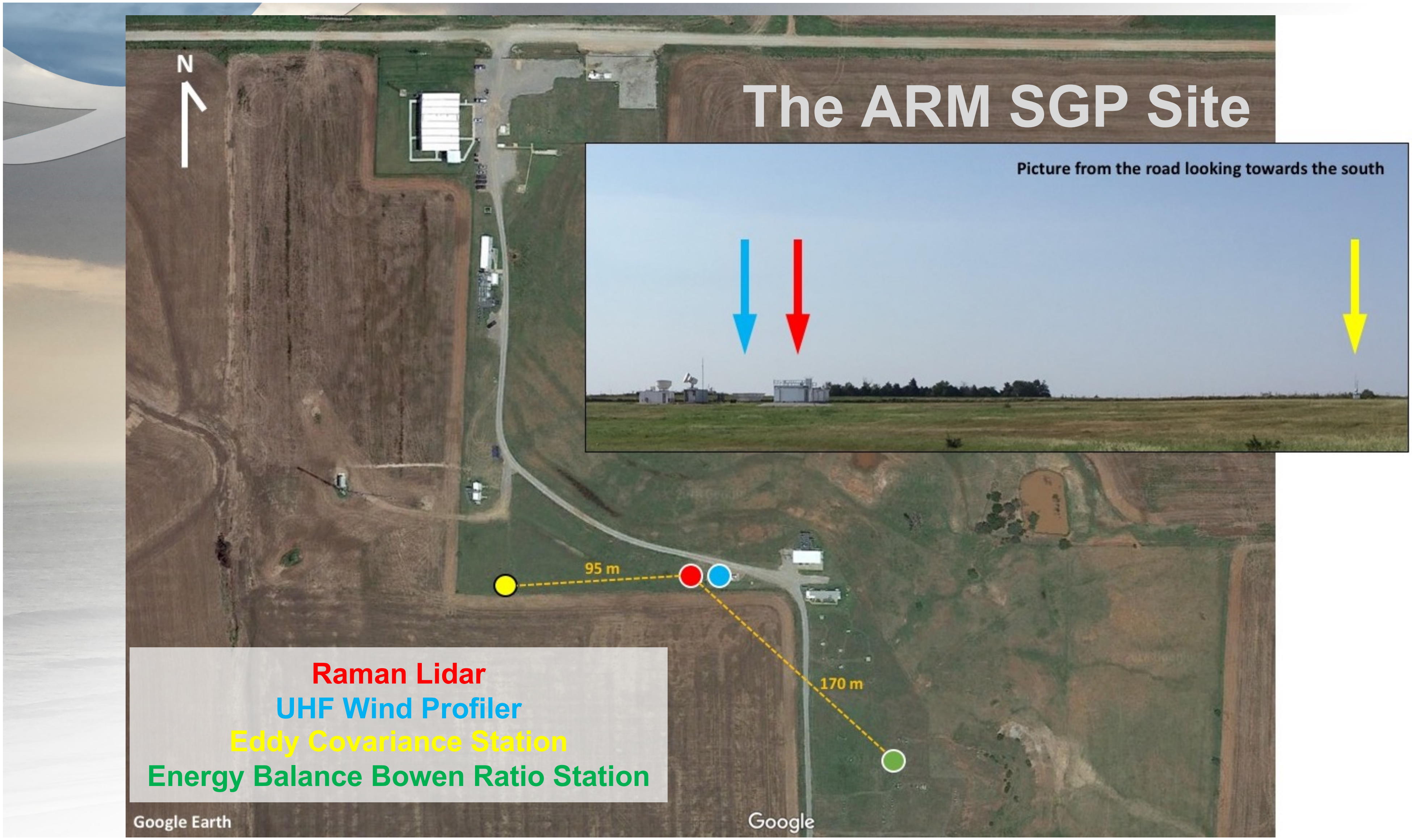
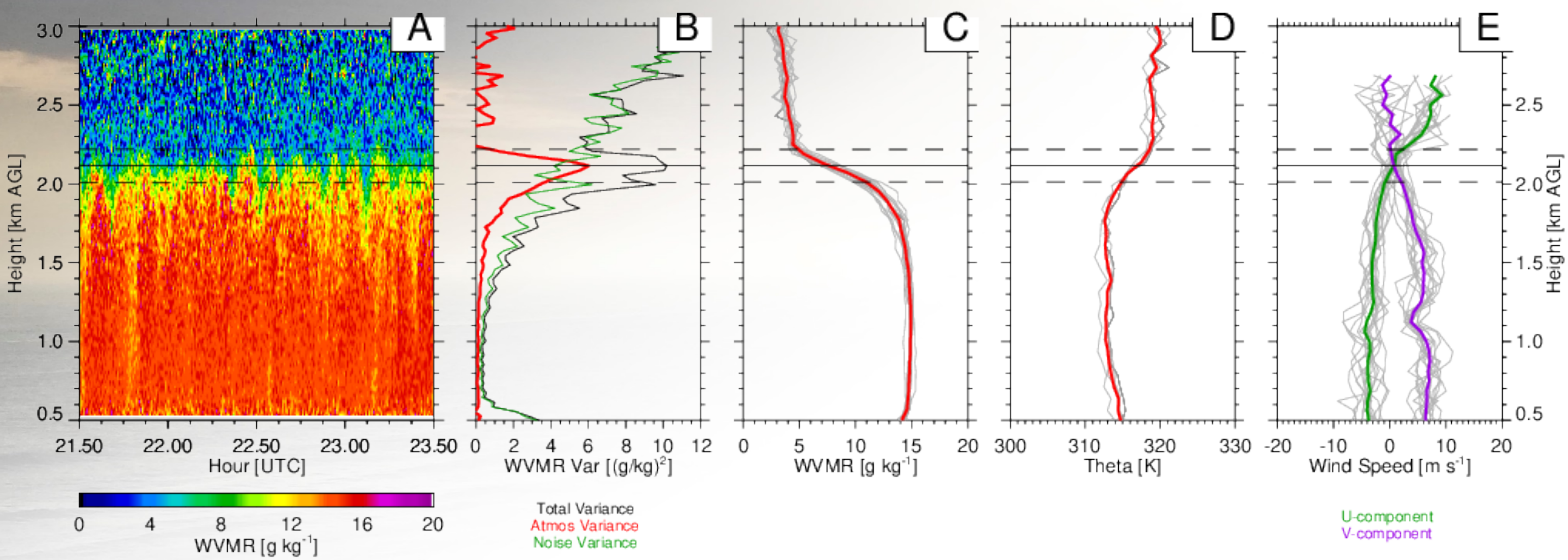
Instruments and Model

- Analysis at the ARM Southern Great Plains (SGP) site
- Raman lidar
  - Water vapor gradient, water vapor variance, temperature gradient
- Radar wind profiler
  - Wind shear
- Doppler lidar
  - Started in 2016 data; that system did not have S/N to see shear at z_i
  - DL upgraded at sgpC1 in spring 2017, so now able to profile higher
- Surface energy budget station (to get w_*)
- MicroHH large eddy simulation model
- ARM's Objective Analysis dataset for forcing the MicroHH



N
The ARM SGP Site
Picture from the road looking towards the south
95 m
170 m
Raman Lidar
UHF Wind Profiler
Eddy Covariance Station
Energy Balance Bowen Ratio Station
Google Earth
Google

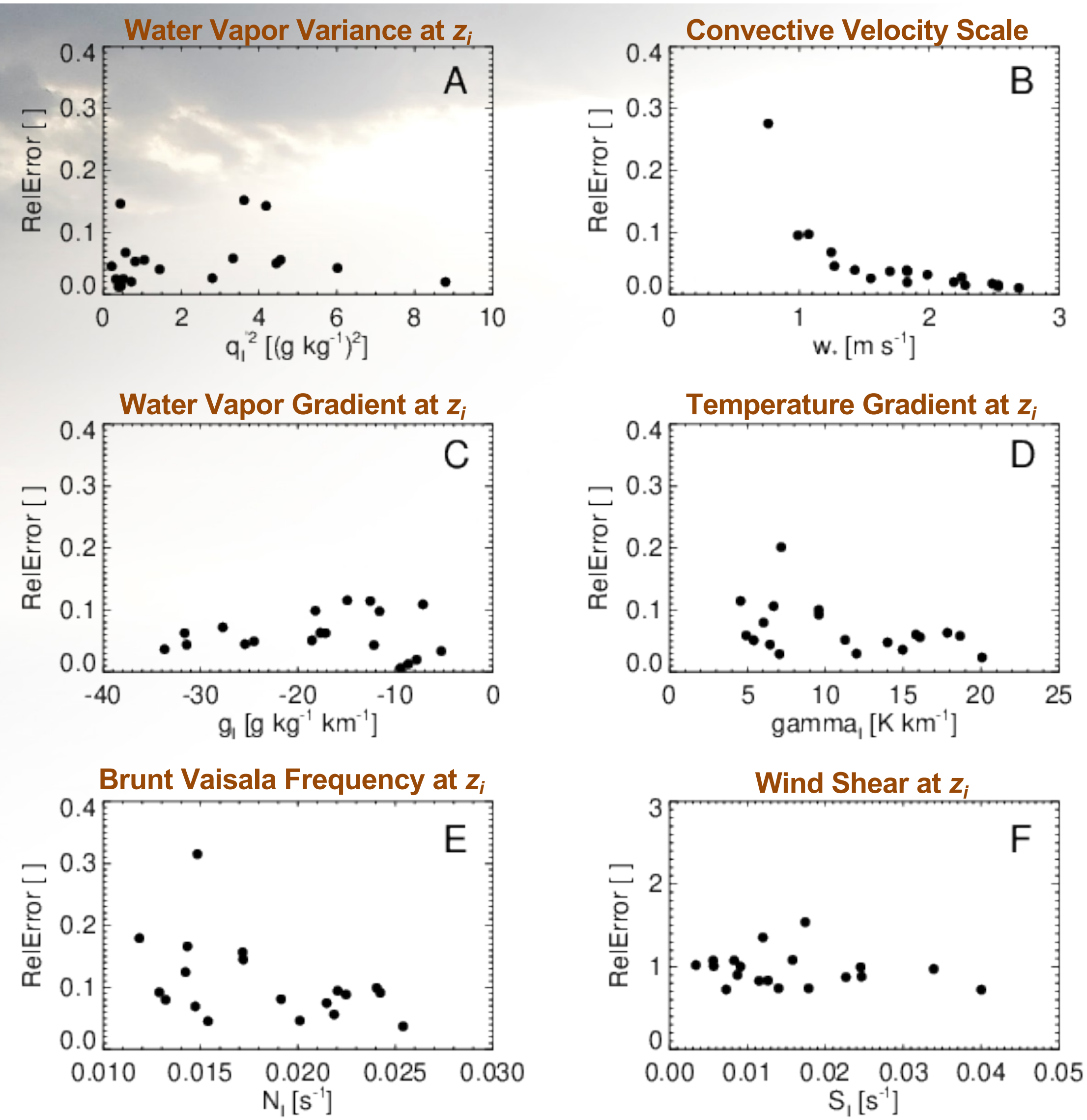
Observational Example



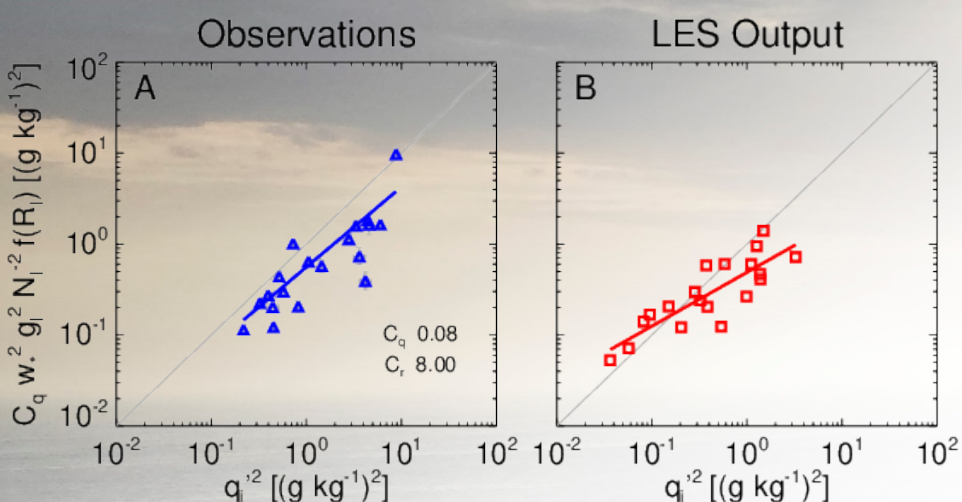
Identified 19 cases like this (all from SGP in 2016), and ran LES model on all cases (tested 10 and 25 m Δz)

Uncertainties in the Observations

Uncertainties all less than ~20% except for shear, where uncertainties on order 50% to 150%



Original Sorbjan (2005, 2006) Relationships



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C_{q2} = 0.08
C_r = 8.0

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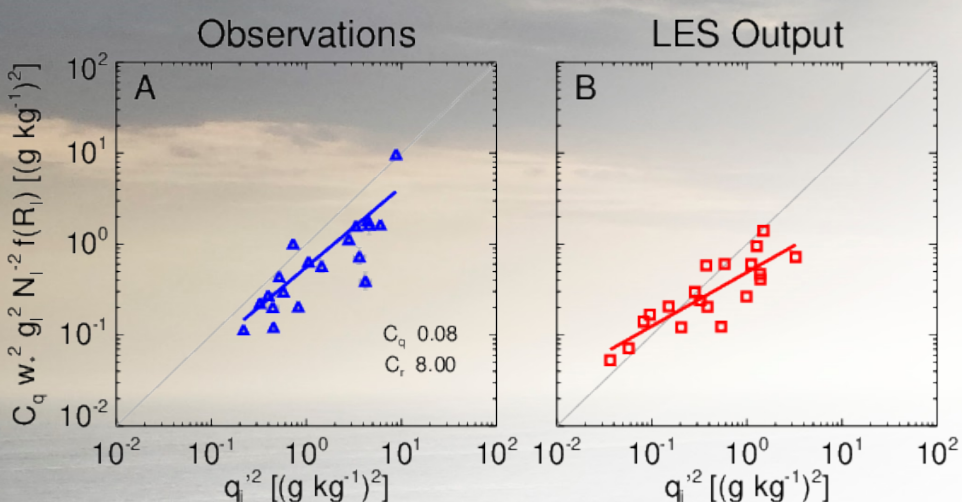

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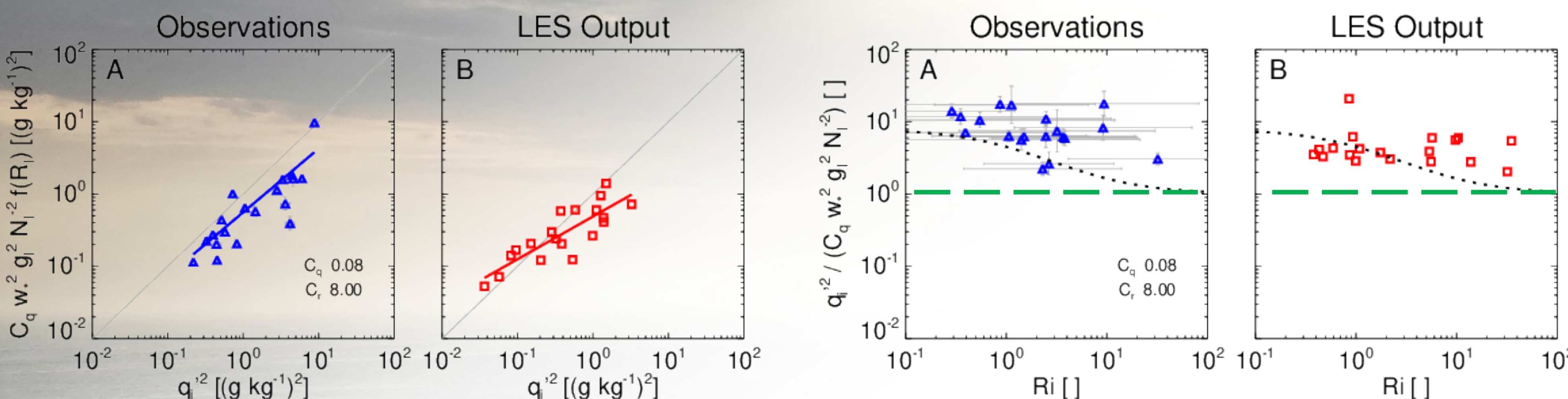

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Testing Another Formulation?

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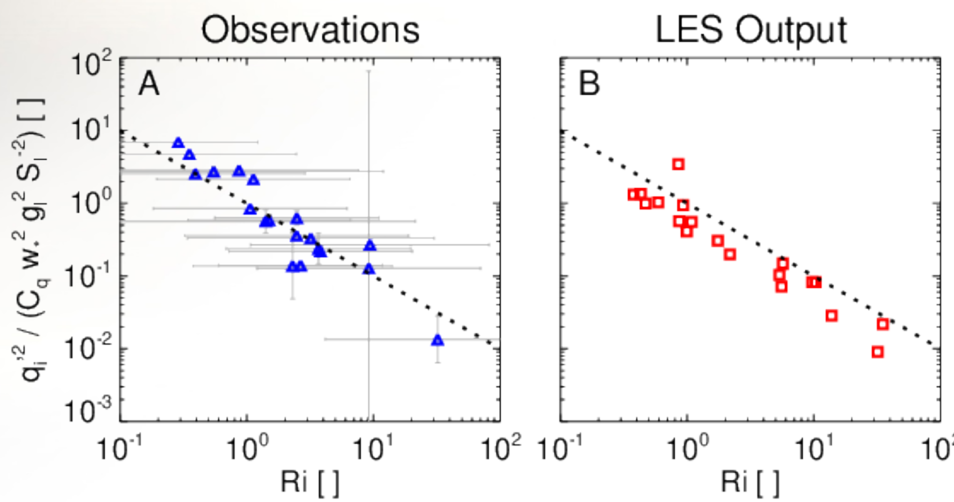

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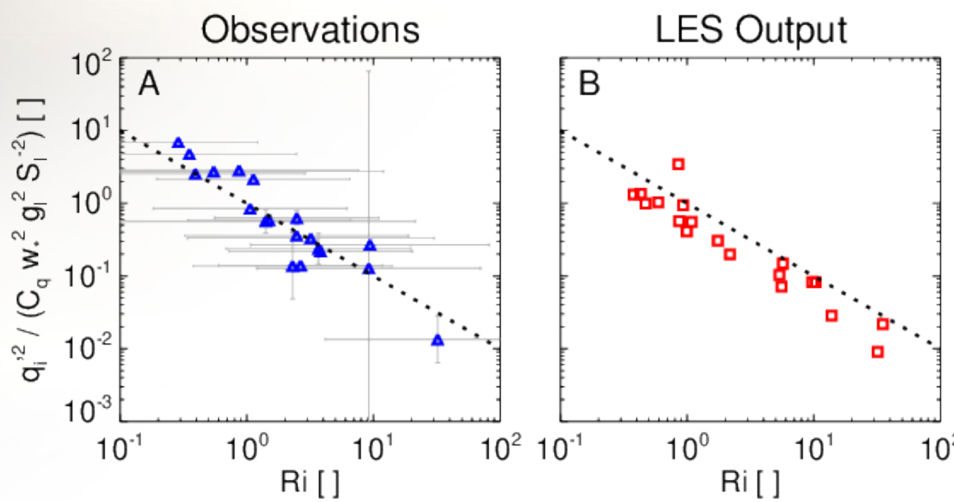

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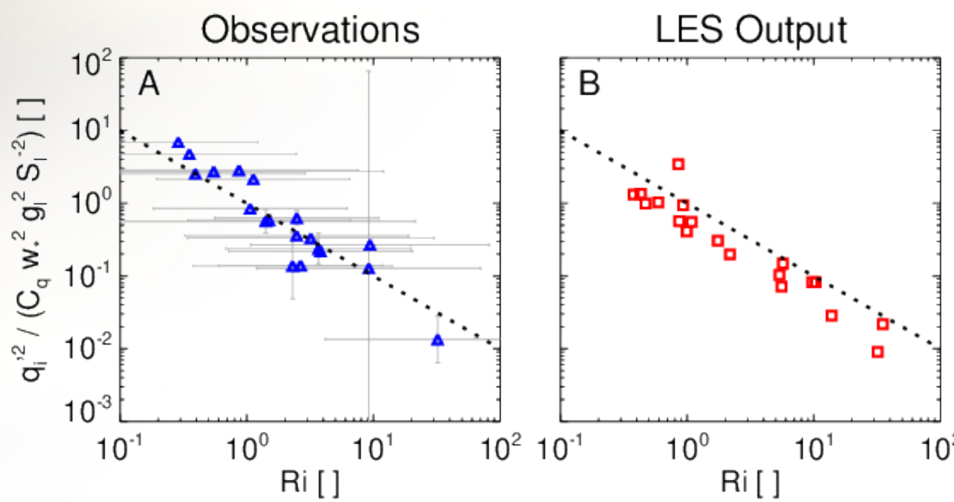

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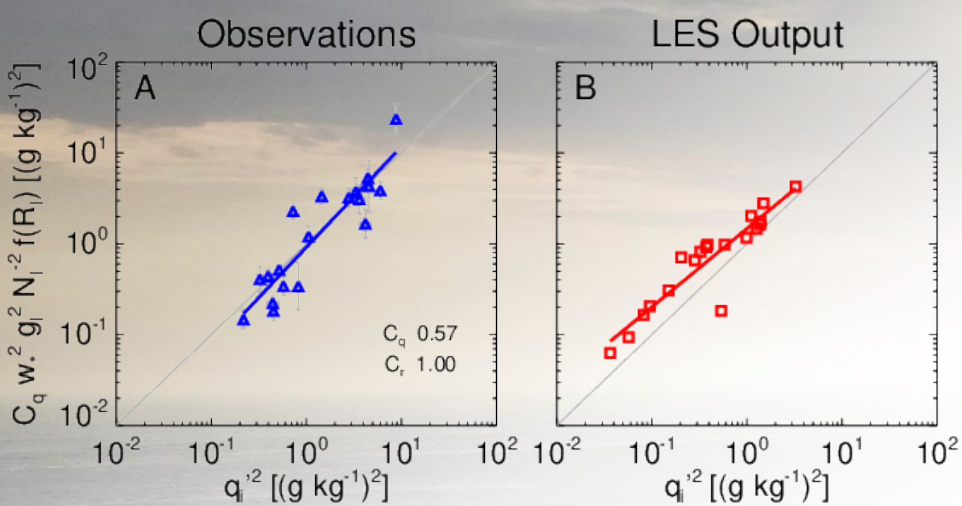
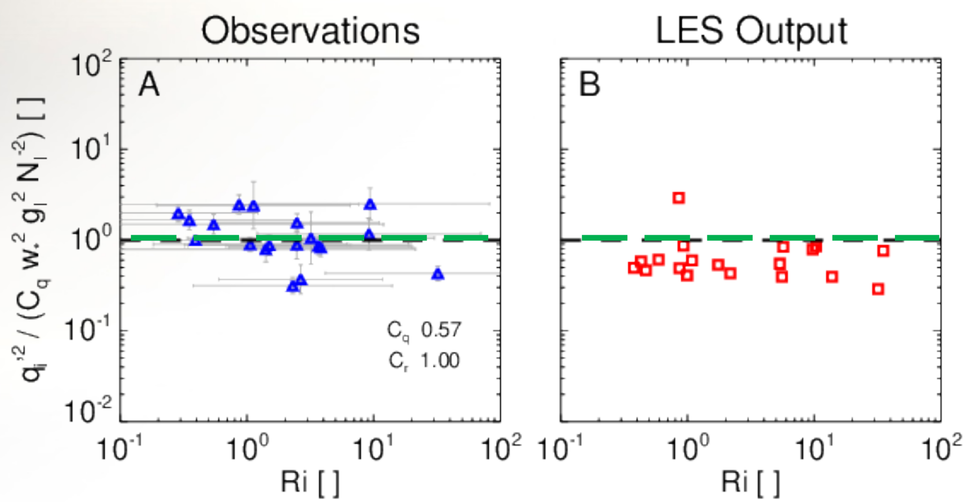
$$\overline{q_I'^2} = C_{q^2} w_*^2 \left(\frac{g_I}{S_I}\right)^2 \frac{c}{R_I} = C_{q^2} w_*^2 \left(\frac{g_I}{N_I}\right)^2$$

New Similarity Relationship





$$\overline{q_I'^2} = C_{q^2} w_*^2 \left(\frac{g_I}{N_I}\right)^2$$

$C_{q2} = 0.57$

Results from obs and LES are very similar!

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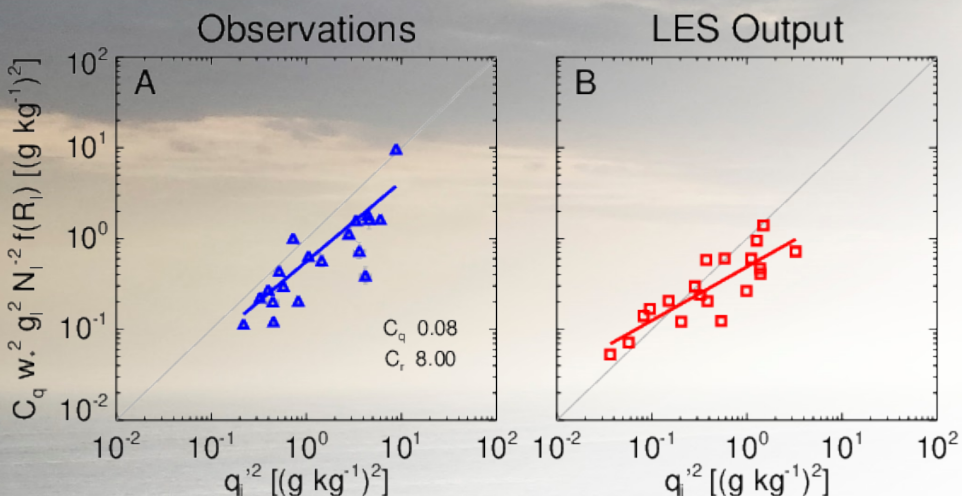

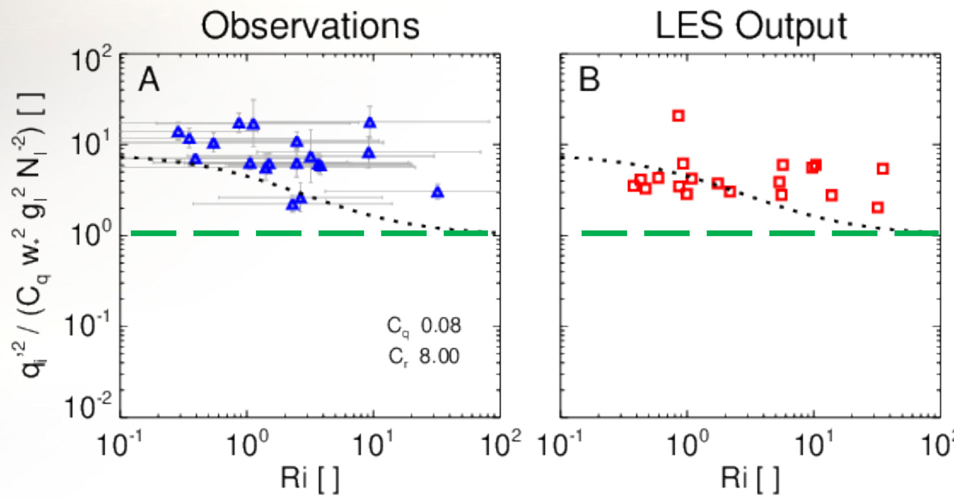

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Implications and Caveats

- These results suggest that shear is not important in predicting the water vapor variance at the top of the CBL
- By extension via other similarity relationships, this suggests
  - Shear is not important for predicting temperature variance or the variance in other tracers
  - Shear is not important for predicting temperature or moisture entrainment fluxes at top of the CBL either
- However, we limited our cases to conditions where the CBL was quasi-stationary for at least 2 hrs to reduce the sampling errors when computing the higher order moments
  - Perhaps we are excluding cases with very high wind shear where mechanical mixing would dominate the buoyancy mixing
  - However, our results do span over 3 orders of magnitude in wind shear
- We have large uncertainties in the wind shear observations; there could be a small dependence on the gradient Richardson number

Summary

- Observational capability over the last decade has advanced enough to measure higher-order moments of water vapor with good accuracy (shown here)
  - And temperature
  - And sensible and latent heat fluxes
- Coordinated observations can be used to evaluate similarity relationships used to diagnose higher order moments from prognosed gradients in large-scale fields
- Field campaigns dedicated to evaluating these similarity relationships (both at top of CBL and in surface layer) are needed to improve our treatment of turbulence in NWP and climate model PBL schemes
  - Need a wide range of atmospheric and surface conditions to really do this well
  - Example: the Land-Atmosphere Feedback Experiment (LAFE) at the SGP in 2017
  - Example: Land-Atmosphere Feedback Observatory at the Univ of Hohenheim (started 2018)
- Careful error analysis is critical
- This work is under review in Osman, Turner, Heus, and Wulfmeyer (JGR 2019)