P53 Development and Evaluation of Model Physics:

Analysis of seasonally-dependent bias in WRF PBL schemes for the southern Appalachian Mountains, USA.

Chris Thaxton and Quinlin Riggs, Department of Physics and Astronomy, Appalachian State University, Boone, NC (thaxtoncs@appstate.edu; afl.appstate.edu)

Appalachian STATE UNIVERSITY

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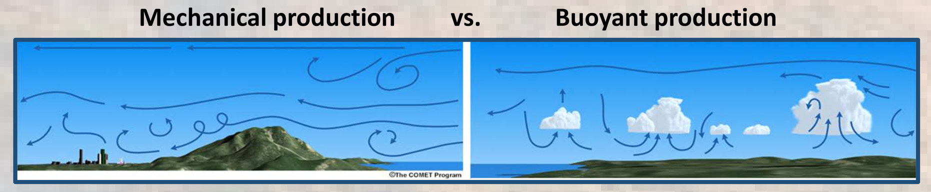
Motivation

The aim of this investigation is to:

- Improve our understanding of mechanically-driven (passive) vs. buoyancy-driven (active) turbulence production and turbulence dissipation for the Southern Appalachians over a range of synoptic conditions;
- Assess the effectiveness of sub grid scale turbulence parameterization in WRF; Propose solutions.
- Develop a recommended suite of coupled WRF Planetary Boundary Layer (PBL)-surface layer parameterizations optimized to support modeling of aerosol load dynamics, aerosol-meteorology coupling, and operational forecasting in the Southern Appalachians.



http://www.comet.ucar.edu/

Site Description & Methods

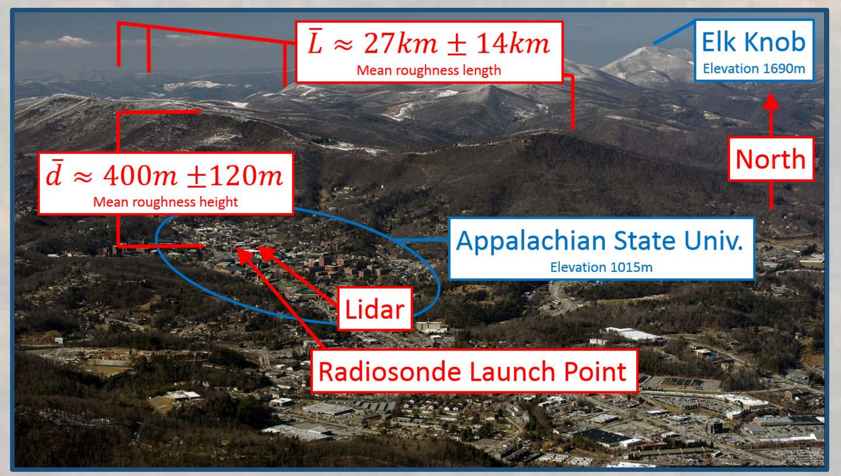
AppalAIR houses the only co-located NOAA-Global Monitoring Division (NOAA-GMD) and NASA AERONET aerosol monitoring sites in the eastern U.S., in addition to an aerosol/cloud lidar, trace gas instrumentation, a surface MET station, and an iMet radiosonde launching system.

Field campaigns

Launched radiosondes from two sites – APPM (Appalachian Main Campus) and APPA (AppalAIR tower) over summer 2013 and winter 2018 seasons. Collected Rawinsonde (RAOB) Data Archive [3] mesonet radiosonde data for surrounding sites.

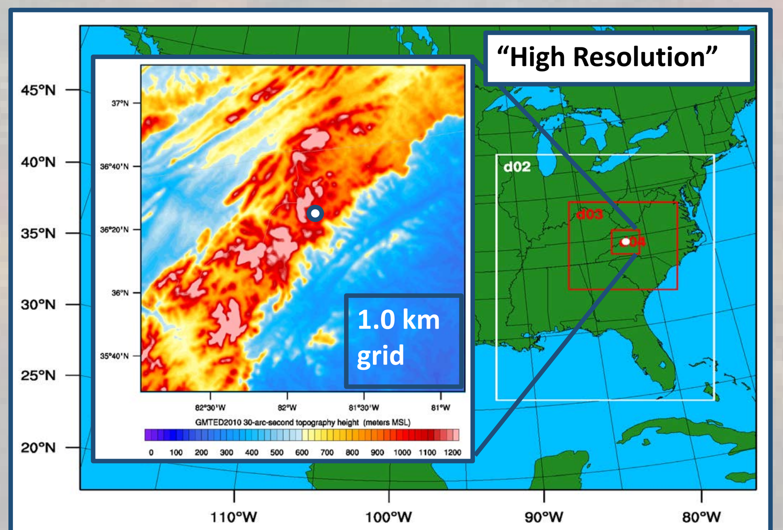
Surface characterization

Performed GIS-based statistical analysis on complex terrain in Southern Appalachians to determine distributed surface roughness heights and lengths.



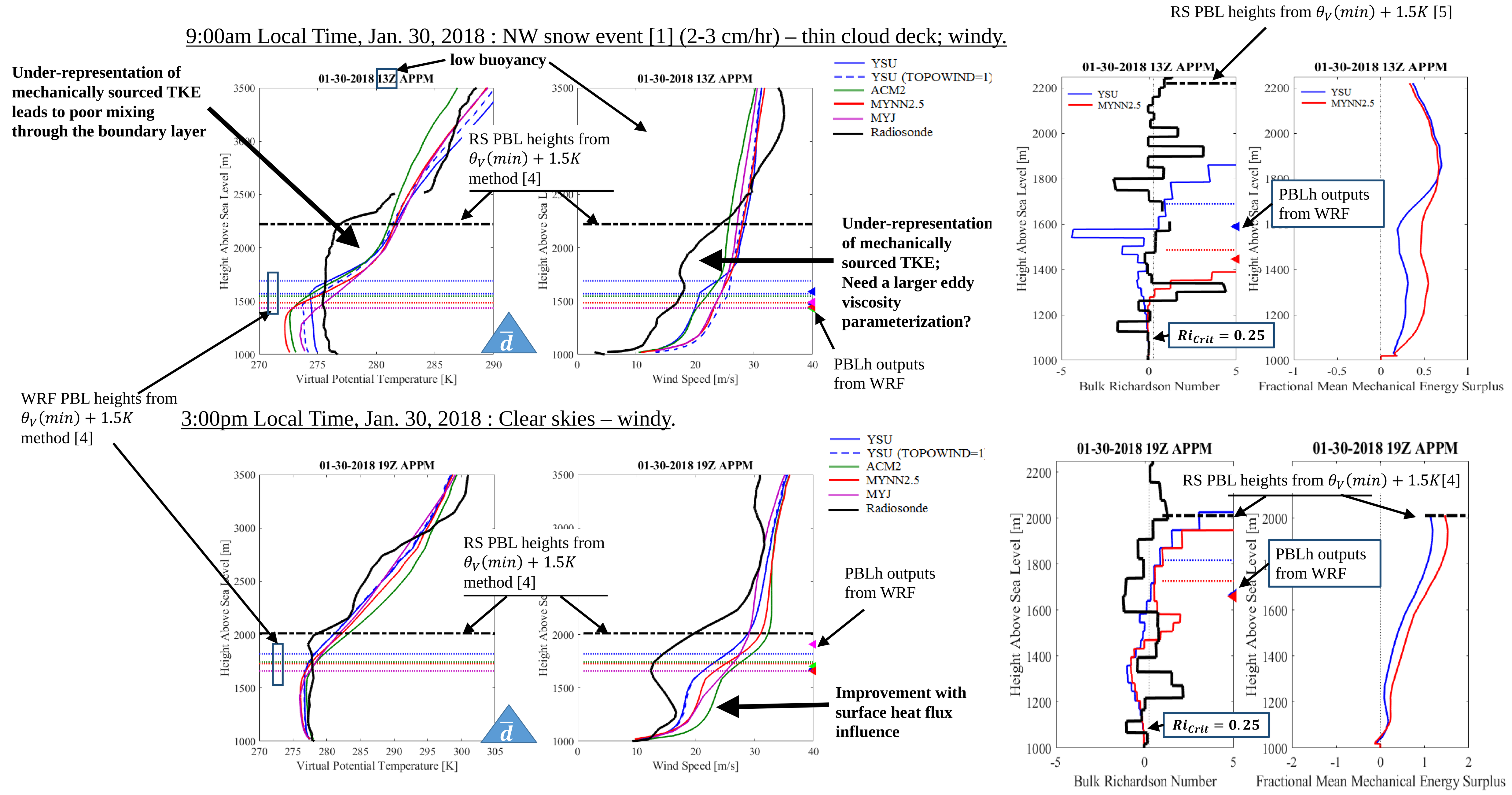
WRF (v3.9 w/HVC) Setup

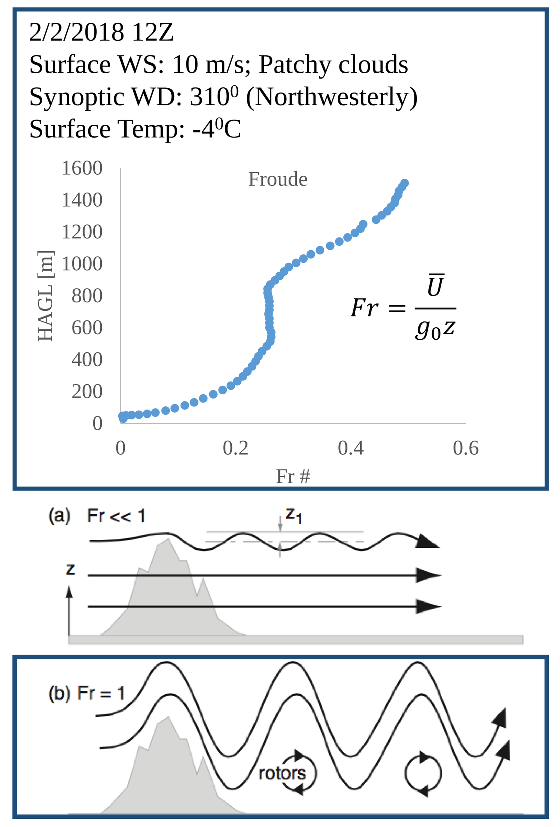
NAM; 4-nested domains; d01=27km; d02=9km; d03=3km; d04=1km
Microphysics: Thompson scheme
LW /SW rad: RRTM schemes
Surface: Unified Noah land-surface model
Cumulus physics: Kain-Fritsch (new Eta) scheme (outer 2 domains only); cu-rad feedback=.true.
Dynamics: No 6thO diff; diff_opt=0/1/2 (turbulence); Rayleigh damping; km_opt=4 (Smagorinsky first order closure)
64 boundary-layer weighted user-defined eta levels



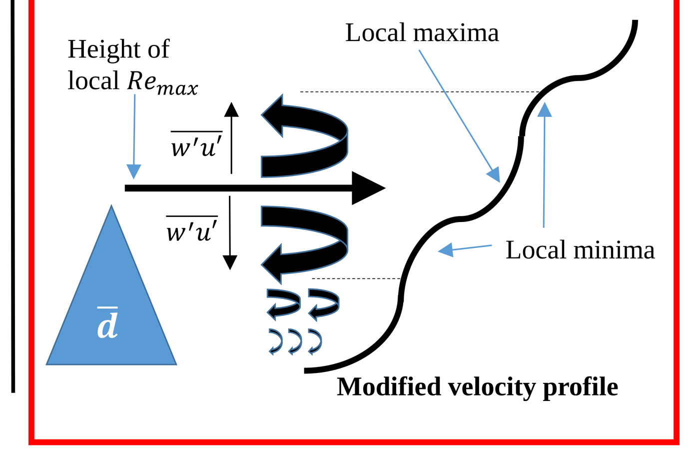
Stable, shear-driven boundary layers (e.g. winter NW flow event)

Insufficient WRF PBL mixing

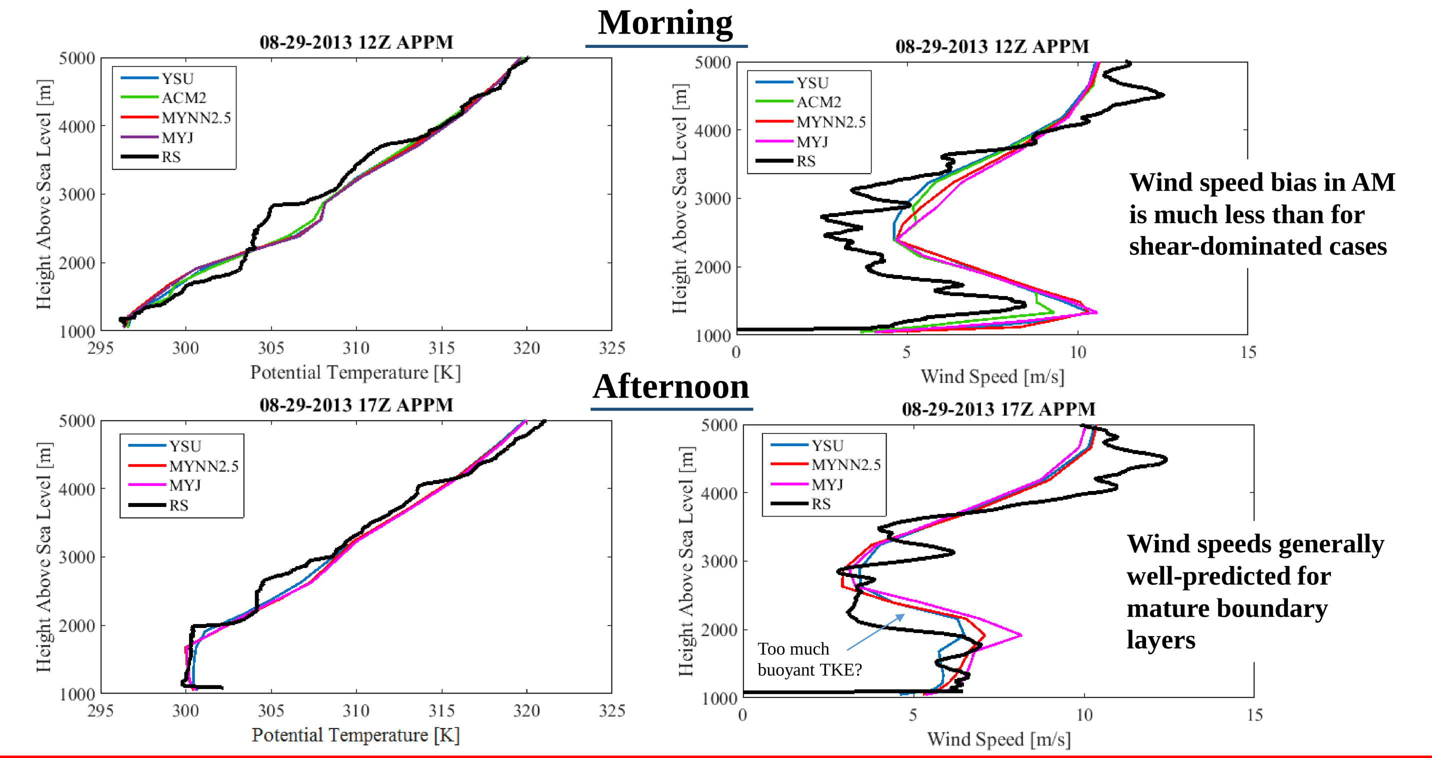




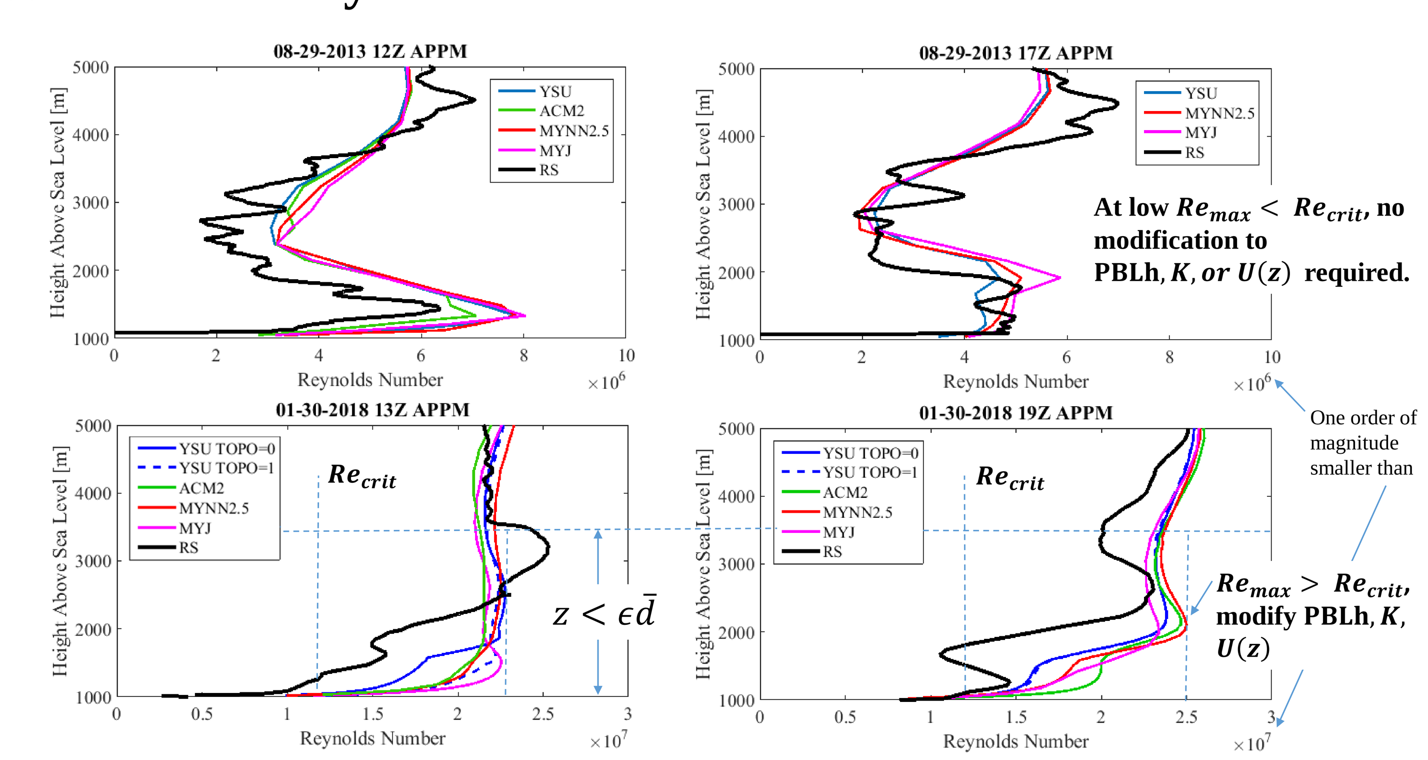
Flow dynamics in shear-driven PBL



Summer (2013) – Example of "Developing" and "Mature" boundary layers (Synoptic Code 1[2]). WRF shows good skill.



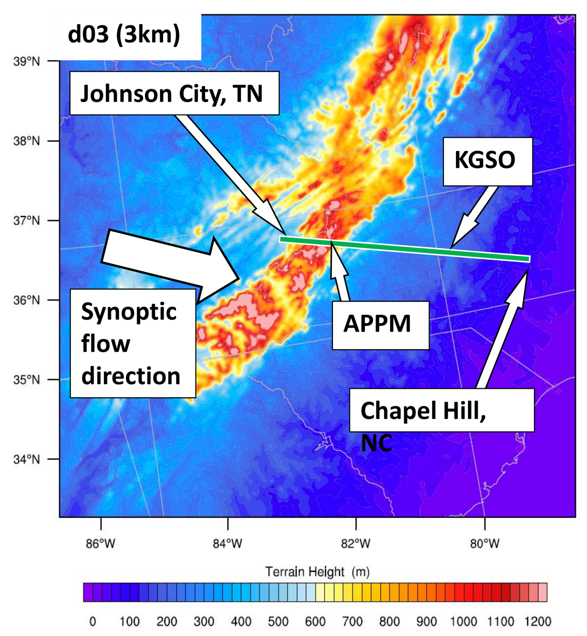
What about Reynolds Number?

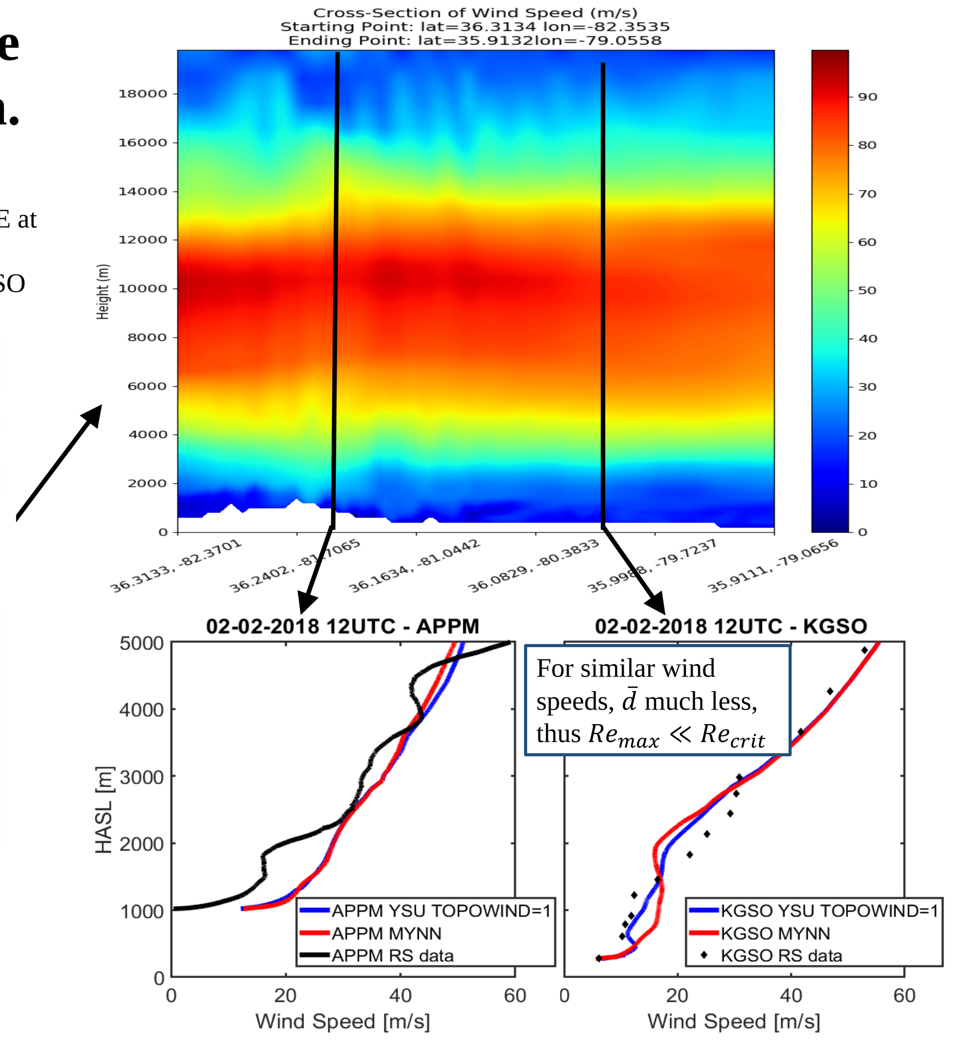


Comparison of APPM site to KGSO [3] downstream.

Here, Feb. 2, 2018 1200Z.

- Under-representation of mechanically sourced TKE at APPM (Complex terrain);
- Good boundary layer wind profile for YSU at KGSO





Under shear-driven, stable PBLs: increase eddy viscosity for PBL schemes based on terrain statistics, wind speed (or diagnostic, such as Reynolds or Froude number), and surface heat flux.

Propose: Modify PBL schemes based on flow regime, via $\boldsymbol{Re} = \frac{\rho\bar{U}\bar{d}}{\mu}$

If $Re_{max}(z < \epsilon\bar{d}) > Re_{crit}$, where $\epsilon \sim 1-10$; $Re_{crit} \sim O(10^7)$ then…

YSU:

- PBL height criteria currently [3,4]:

$$h = Ri_{bc}\frac{T_v[(\Delta u)^2+(\Delta v)^2]}{g[\theta_V(h)-\theta_V(z_0)]} + f(Re) \quad \text{where } Ri_{bc} = 0.25$$

- K-theory closure relation, currently:

$$\overline{w'\psi'} = -K_\psi\left(\frac{\partial\bar{\psi}}{\partial z} - \gamma_\psi\right) + \overline{(w'\psi')_h}\left(\frac{z}{h}\right)^3;$$

$$K_{\psi=m} = \frac{\kappa u_* z}{\phi_m}\left(1-\frac{z}{h}\right)^3 \times/\pm f(Re) \text{ and/or } u_*$$

MYNN:

- PBL height criteria currently [3,4]:

$$h = h_e(1-w_f) + h_\theta w_f \quad \text{where}$$

$$\theta_V(h_\theta) = \theta_{V,min} + 1.5K;\ TKE(h_e) = TKE_{cr}$$

$$w_f = \left(0.5tanh\left(\frac{h_\theta - 200}{400}\right) + 0.5\right) \times (f(Re) < 1)$$

- K-theory closure relation, currently:

$$\overline{w'\psi'} = -K_\psi\frac{\partial\bar{\psi}}{\partial z};\ K_\psi = l_e q S_c;\ \frac{1}{l_e} = \frac{1}{l_s}+\frac{1}{l_t}+\frac{1}{l_b};\ l_t = 0.23\frac{\int qzdz}{\int qdz} \times/\pm f(Re)$$

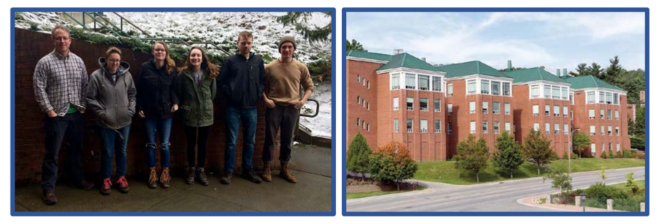
? **Numerical Approach:** Provide distributed roughness length stats in WPS, check conditions early in PBL solver?

Context

The Applied Fluids Lab at Appalachian State is working to develop a new WRF suite, APPSAM, that will guide WRF/MPAS model users in their investigations of the Southern Appalachian region. These efforts currently include:

- Aerosol/meteorology coupling (seasonal and diurnal);
- Lidar and satellite PBLh retrieval algorithm validation and guidance;
- NW snow event modeling;
- UPCOMING:
  - WRF-CHEM; RAPv4/HRRRv3; Operational support

Applied Fluids Laboratory Appalachian State



The Applied Fluids Lab at Appalachian State investigates a broad range of topics related to the fluid mechanics of boundary layers and the coupling between fluids and terrestrial surfaces, as well as the development and application of instrumentation and analytical/numerical tools and methodologies.

Atmospheric Science Curriculum

Appalachian's minor in atmospheric science is an interdisciplinary program that can help prepare students for graduate study and professional careers in meteorology, climate science, and atmospheric chemistry and air quality. Several research opportunities exist including: Regional weather modeling; Air pollution effects on plants; Aerosol monitoring, chemical analysis; Synoptic climatology, orographic precipitation, snow and ice, and tropical climate-glacier interactions; Ecosystems and hydrologic cycles; Image processing, wavelets, parallel and distributed computing, stochastic simulations.

References & Acknowledgements

[1] Perry, B & Konrad, C.E. 2006, Climate Research, 32: 35-47
[2] Sherdian, 2002, Int. J. Climatol. 22: 51–68 (2002) DOI: 10.1002/joc.709.
[3] Iowa Environmental Mesonet, Iowa State University, https://mesonet.agron.iastate.edu/archive/raob/, last accessed, June 8, 2018
[4] Milovac, J., et. Al, 2016. JGR Atmospheres, doi:10.1002/2015JD023927
[5] Xie, B. et al. 2013. JGR Atmospheres, 118:7799-7818, doi:10.1002/jgrd.50621.2013

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