Convective BL profiles

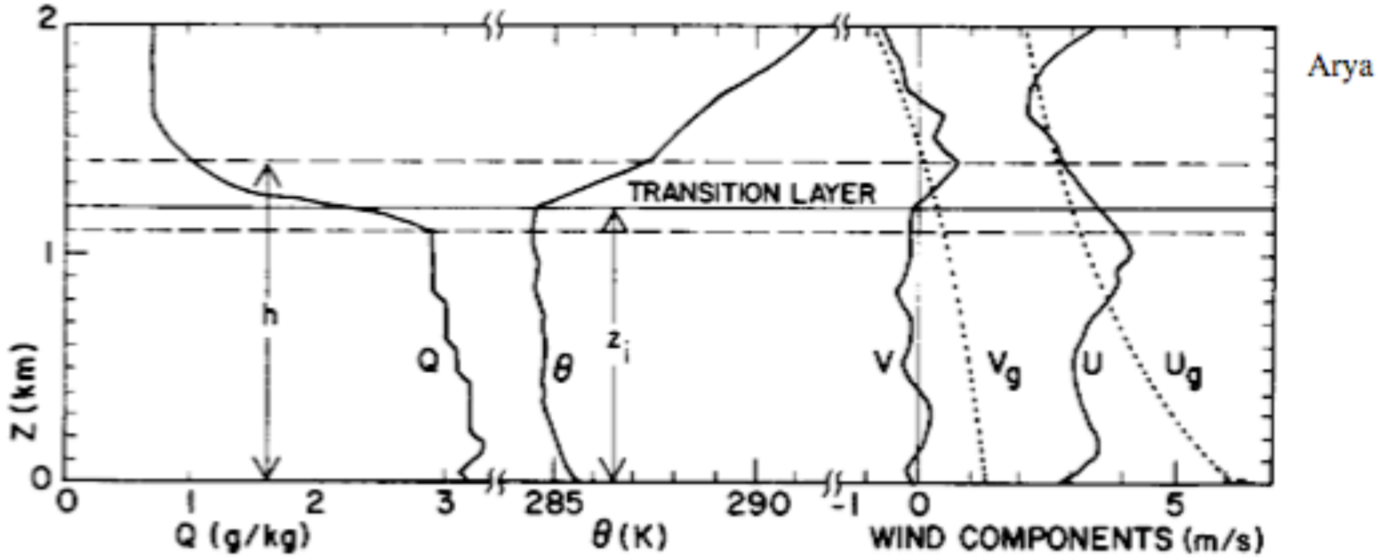


Fig. 6.5 Measured wind, potential temperature, and specific humidity profiles in the PBL under convective conditions on day 33 of the Wangara Experiment. [From Deardorff (1978).]

Moderately stable BL profiles

Arya

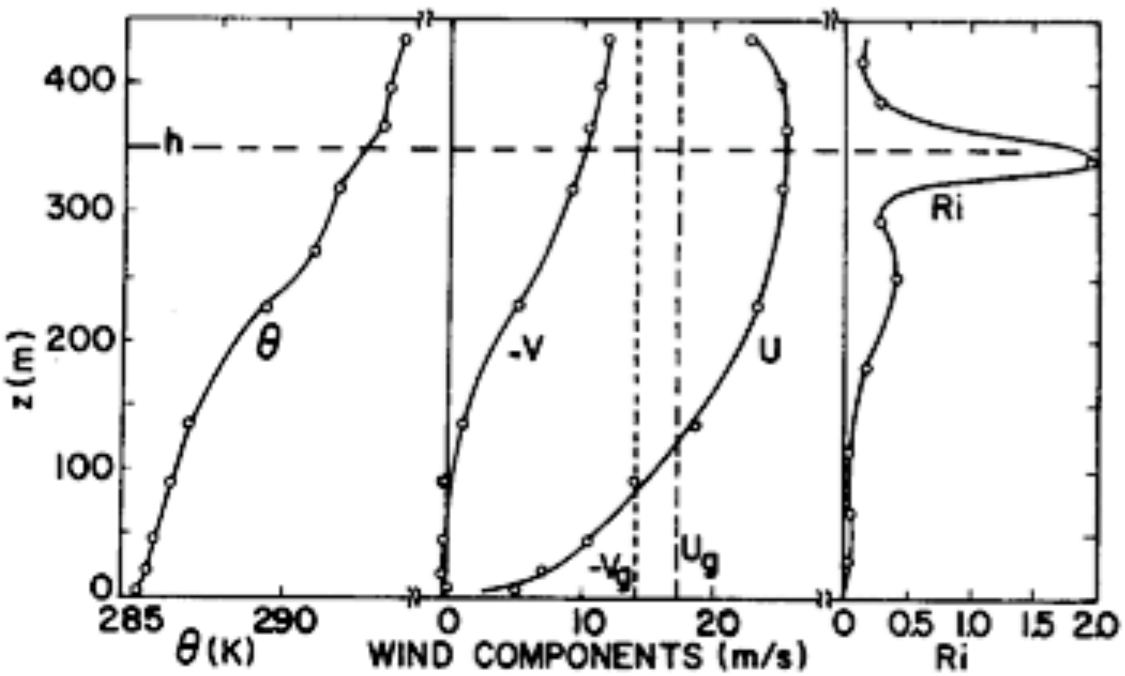


Fig. 6.7 Observed vertical profiles of mean wind components and potential temperatu and the calculated Ri profile in the nocturnal PBL under moderately stable conditio [From Deardorff (1978); after Izumi and Barad (1963).]

Highly stable BL profiles

Arya

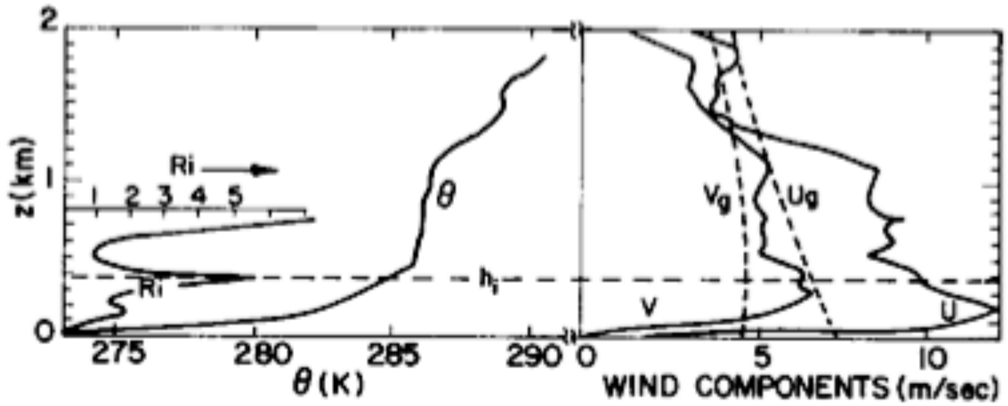
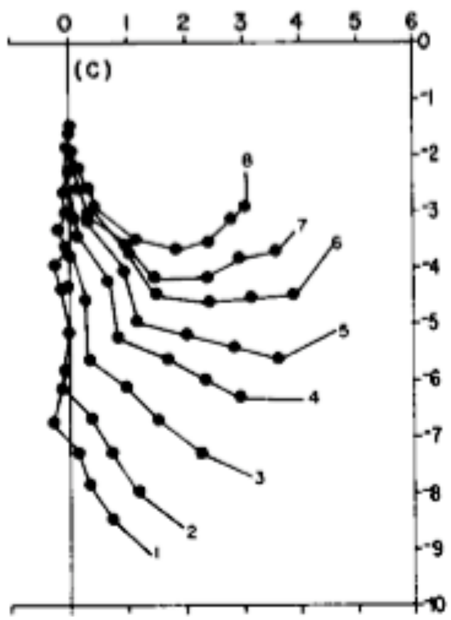


Fig. 6.8 Observed wind and potential temperature profiles under very stable (sporadic turbulence) conditions at night during the Wangara Experiment. [From Deardorff (1978).]



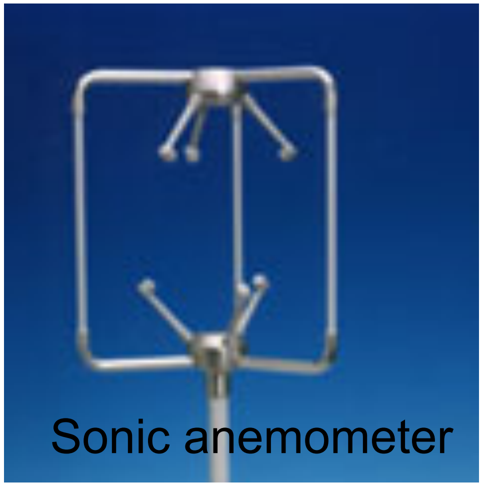
Wind hodograph at South Pole Station

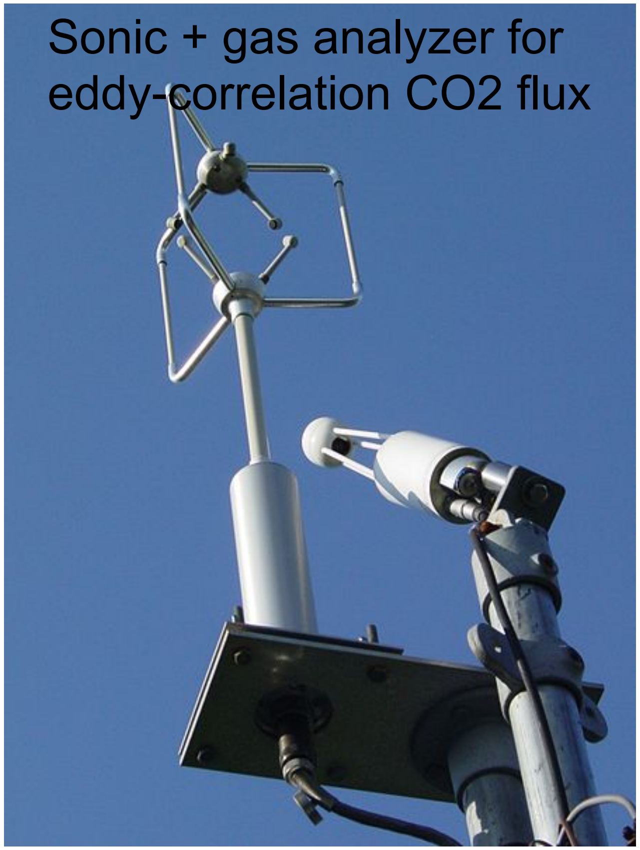
Categories 1-8 correspond to increasingly stable BLs; dots are composites of measurements at 0.5, 1, 2, 4, 8, 12, 16, 20, 24, 32 m; *y*-axis is in the surface wind direction. Note large turning of the wind with height in stable BLs.

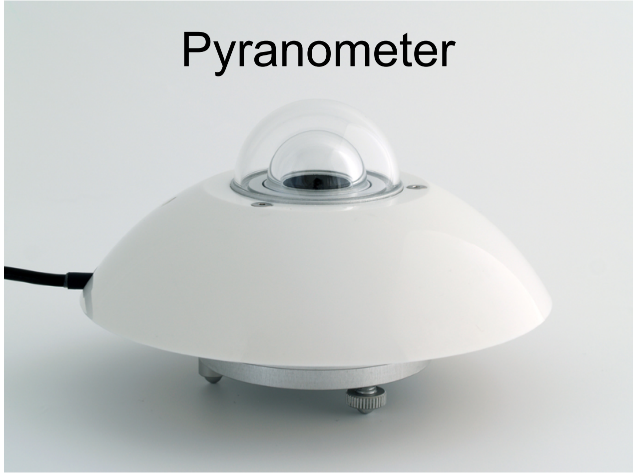
ABL observing technologies - Surface measurements

Surface measurements

- Sonic anemometers (fast-response air velocity), ocean buoys
- Fast-response temperature, humidity, gas sensors
- Surface meteorology, chemistry, aerosols
- Downward radiation

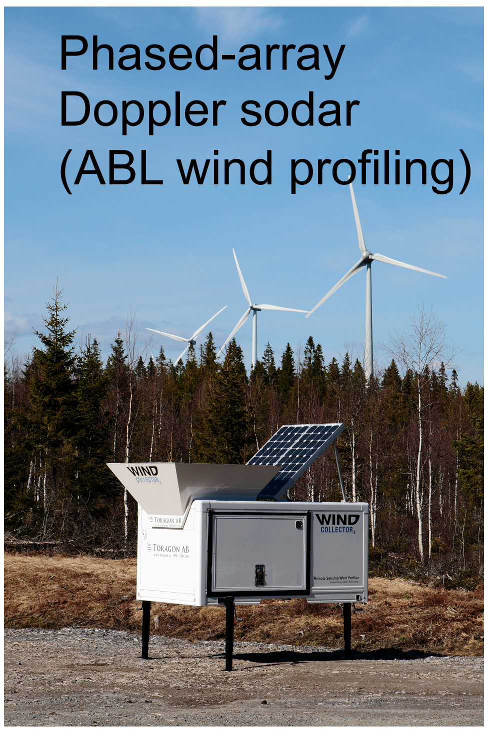






ABL obs - Remote sensing

- Doppler lidar (aerosol scattering), ceilometers, nephelometers
- mm-wavelength radar (cloud scattering)
- Sodar and 915 MHz wind profilers
- RASS (virtual temperature profiling via Bragg scattering of radar waves from sound-induced density anomalies moving away at sound speed)



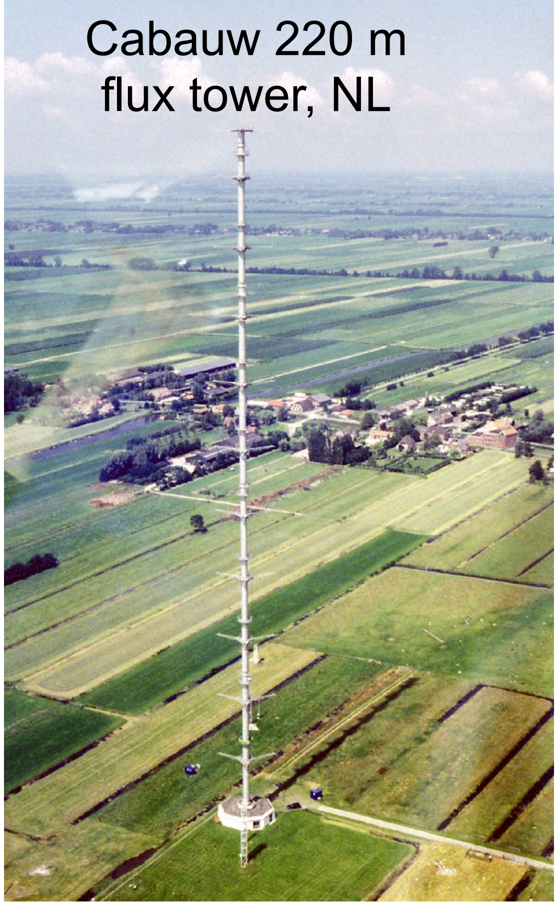
Phased-array Doppler sodar (ABL wind profiling)

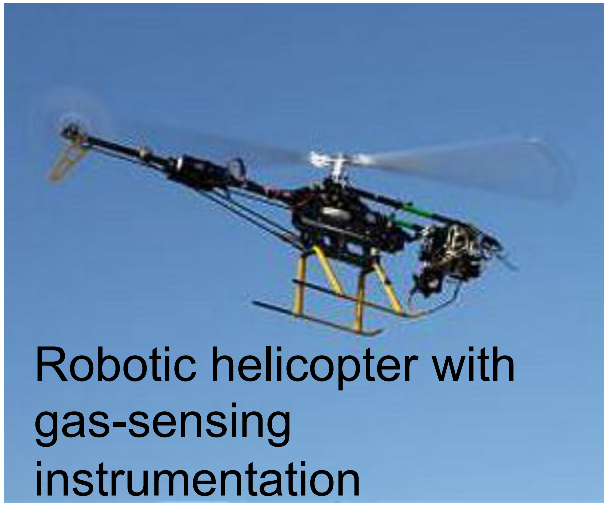
RASS + wind profiler

Doppler lidar

ABL obs - Specialized platforms

- Flux towers for measurements at multiple heights
- Tethered balloons
- Aircraft/helicopter





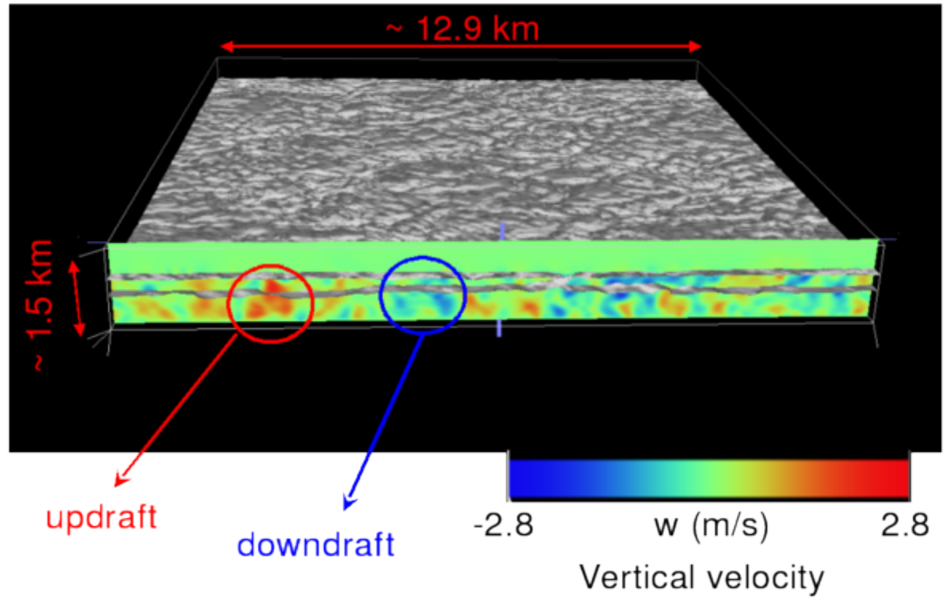
Large eddy simulation (e. g. SAM or WRF)

- Discretize and solve 3D compressible or Boussinesq fluid equations on a grid.
- Grid spacing << size of most energetic eddies

  (typically 5 -50 m in vertical, 1-5x larger in horizontal)
- Horizontal domain size > size of most energetic eddies

  (typically 2 km (stable BL) – 20 km (convective BLs w
- Typically use horizontally periodic boundary conditions
- Advect potl. temp, other quantities of interest, (moisture, chemical constituents) using sophisticated schemes that minimize spurious oscillations, maintain accuracy
- Subgrid turbulence scheme (‘Smagorinsky’ eddy diffusion)
- Other relevant physics (surface fluxes, radiation, clouds)
- Effects of large-scale advection added if periodic BCs used

LES of atmospheric boundary layer



Application I: Visualization

See class web-page links to animations of LES-simulated:

Sc-capped BL (4x4 km, courtesy B. Stevens, UCLA):

- Vertical cross-section of w
- horizontal view of cloud albedo

Cu rising into Sc (6x6 km, courtesy I. Sandu, ECMWF)

(white is cloud; grey blobs are rain)

Application II: Turbulence fluxes and statistics

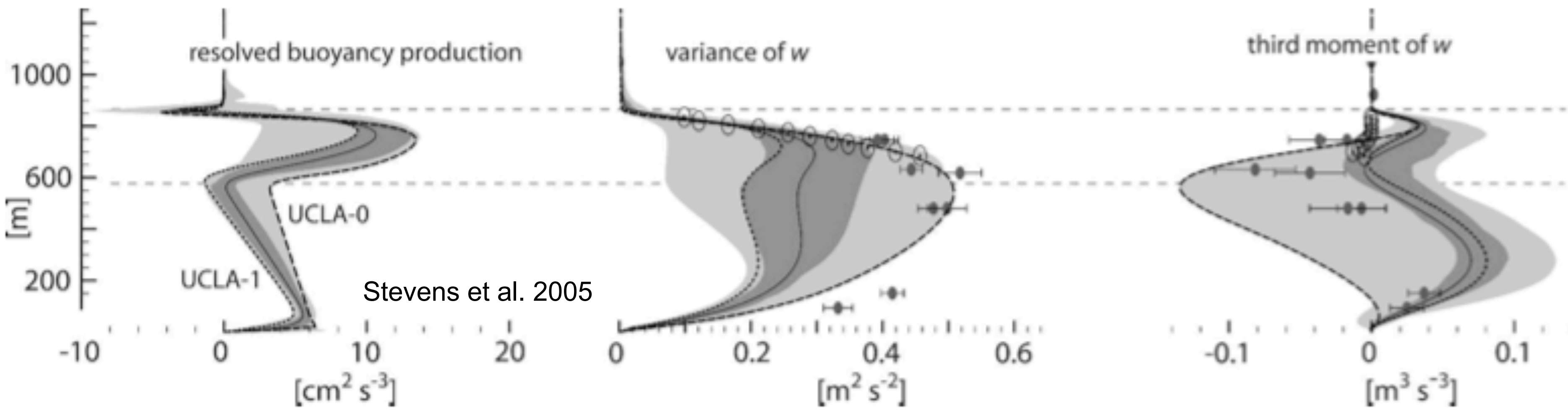
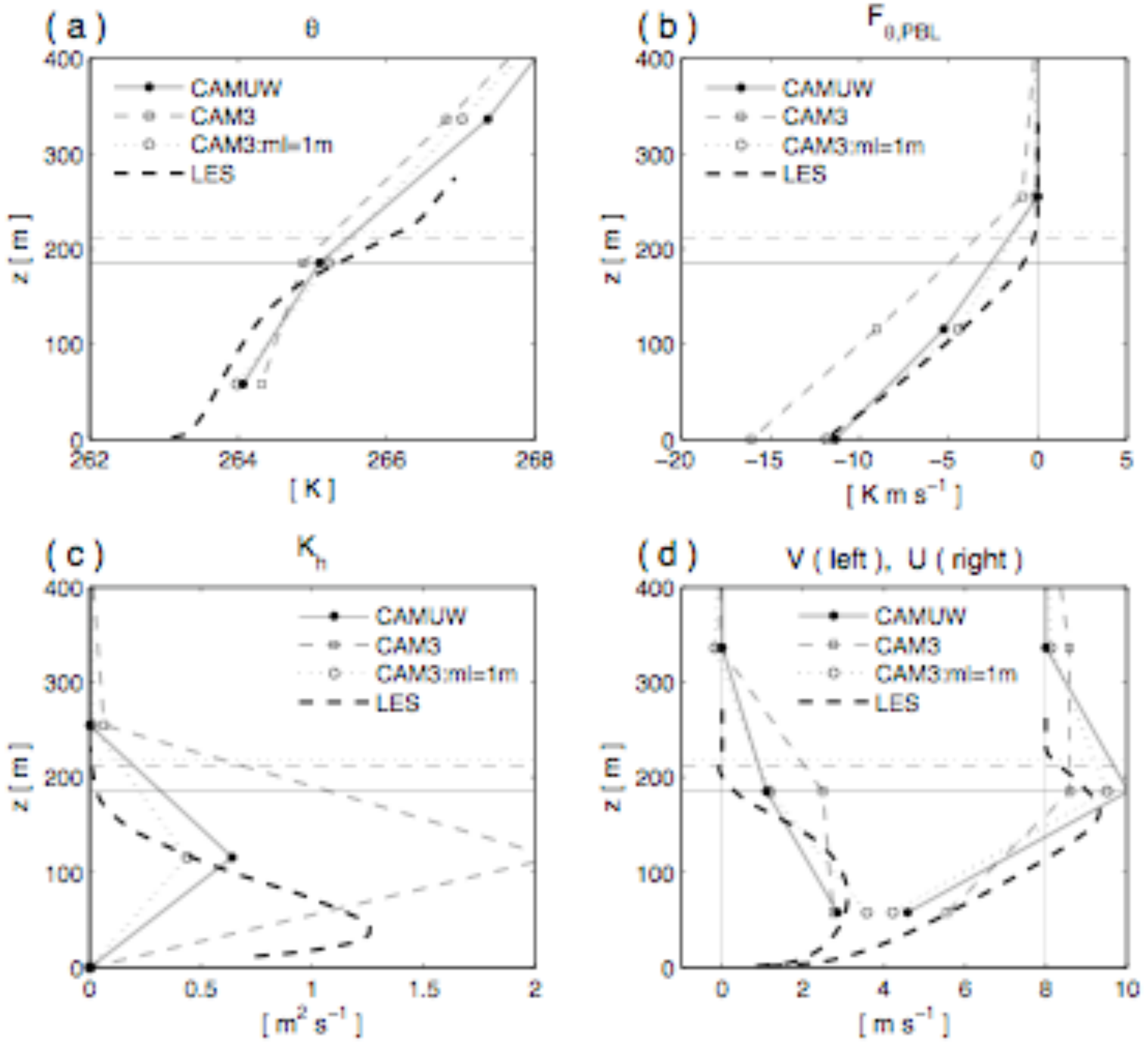


FIG. 5. Profile of vertical velocity statistics—(left) resolved buoyancy production, (middle) variance of *w*, and (right) third moment of *w*—from master ensemble averaged over the fourth hour. Markers indicate estimates of vertical velocity second and third moments as derived from in situ (solid with bar) and radar (circle–dot). Details of data analysis provided by Stevens et al. (2003a). As labeled in the left panel, the dashed lines are two simulations drawn from the master ensemble: UCLA-0 (long dash) and UCLA-1 (short dash). Horizontal dashed lines delimit cloud area. The shading is as in Fig. 2 and as described in the text.

Application III: Parameterization development/testing

GABLS-1 idealized stable boundary layer (Beare et al. 2006)

- Stable stratification, $V_g = 10 \text{ m s}^{-1}$
- Surface cooled at 0.25 K hr^{-1} for 9 hrs.
- Several LESs run with 3 m resolution.
- Compared with new (UW) and existing PBL parameterizations in NCAR's CAM3 climate model.
- New and modified schemes clearly outperform current approach compared to LES for this case.



Bretherton and Park (2009 J.Clim)