GABLS3 LES Intercomparison Study

GABLS Workshop, ECMWF, 7-10 Nov, 2011

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Acknowledgements: AAM Holtslag, FC Bosveld, G-J Steeneveld, P Baas, BJH van de Wiel, J Vilà-Guerau de Arellano, G Svensson, H Klein-Baltink
&
GABLS3-LES Participants

Participants

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- A. F. Moene (Wageningen U., The Netherlands)
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- J. R. Stoll and F. Porté-Agel (U. Utah, USA & EPFL, Switzerland)
- B. Zhou and F. Chow (UC-Berkeley, USA)

Case Description

Initial Conditions (0 UTC)

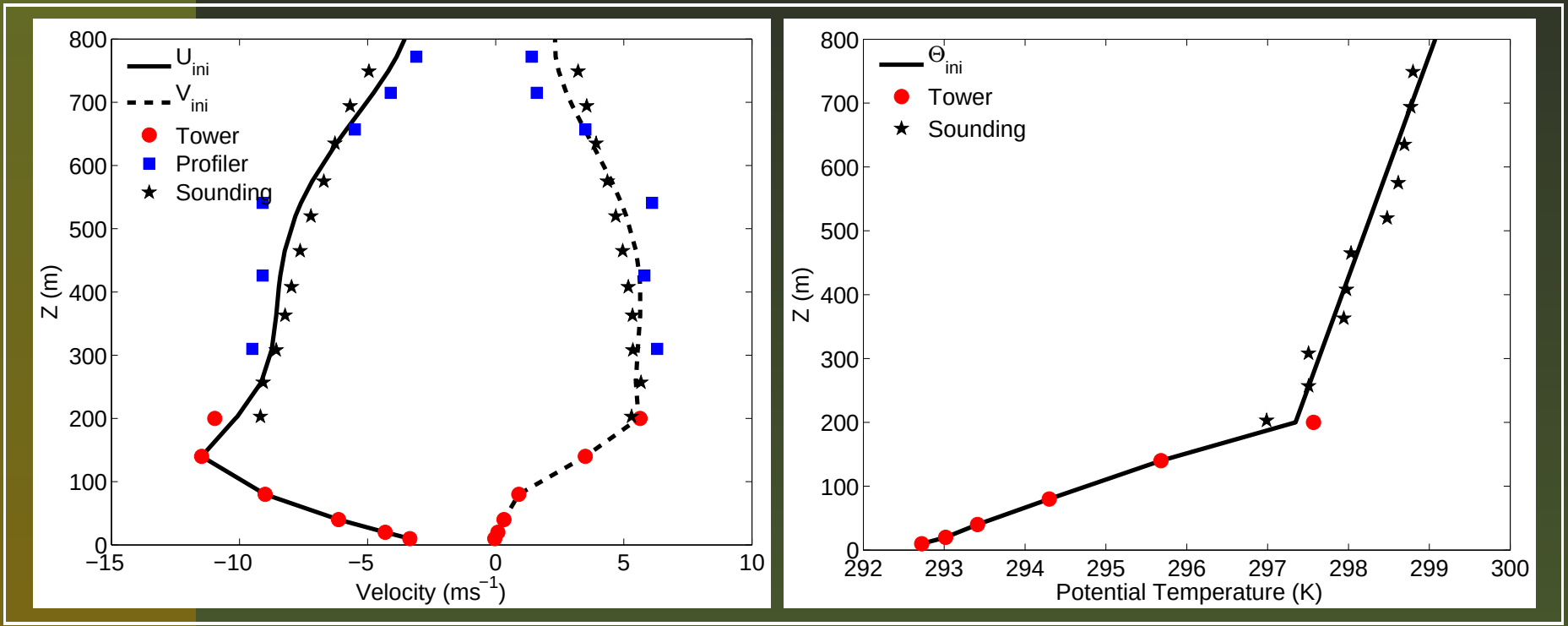


Figure 1: Left panel: velocity; right panel: potential temperature.

- Above 200 m: fourth-order Chebyshev polynomial fit for velocity; linear fit for potential temperature and specific humidity.

Lower Boundary Conditions (0-9 UTC)

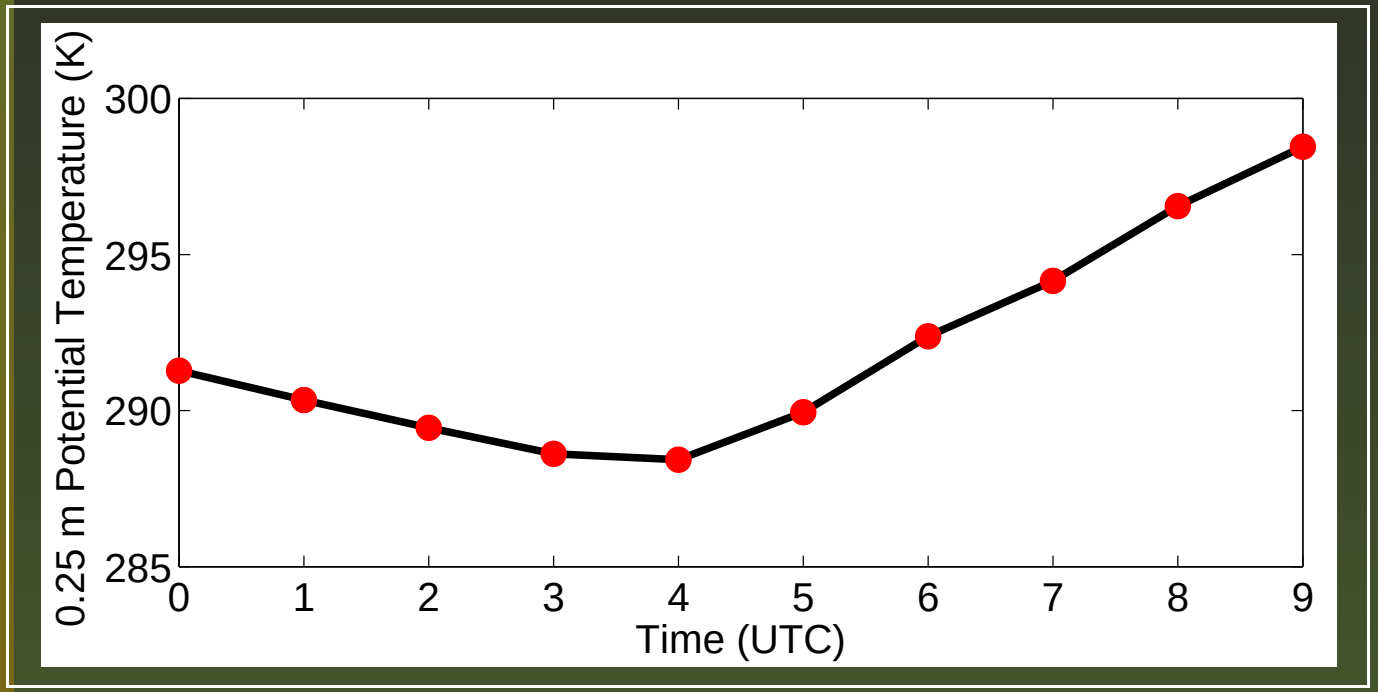


Figure 2: Near-surface potential temperature time-series.

- Sensible heat flux should not be used as a lower B.C.
- Uncertainty in the estimates of z_{ot} and surface temperature.
- High-res LES run ($\Delta = 1$ m) required 0.25 m lower B.C.

Large-Scale Forcings (0-9 UTC)

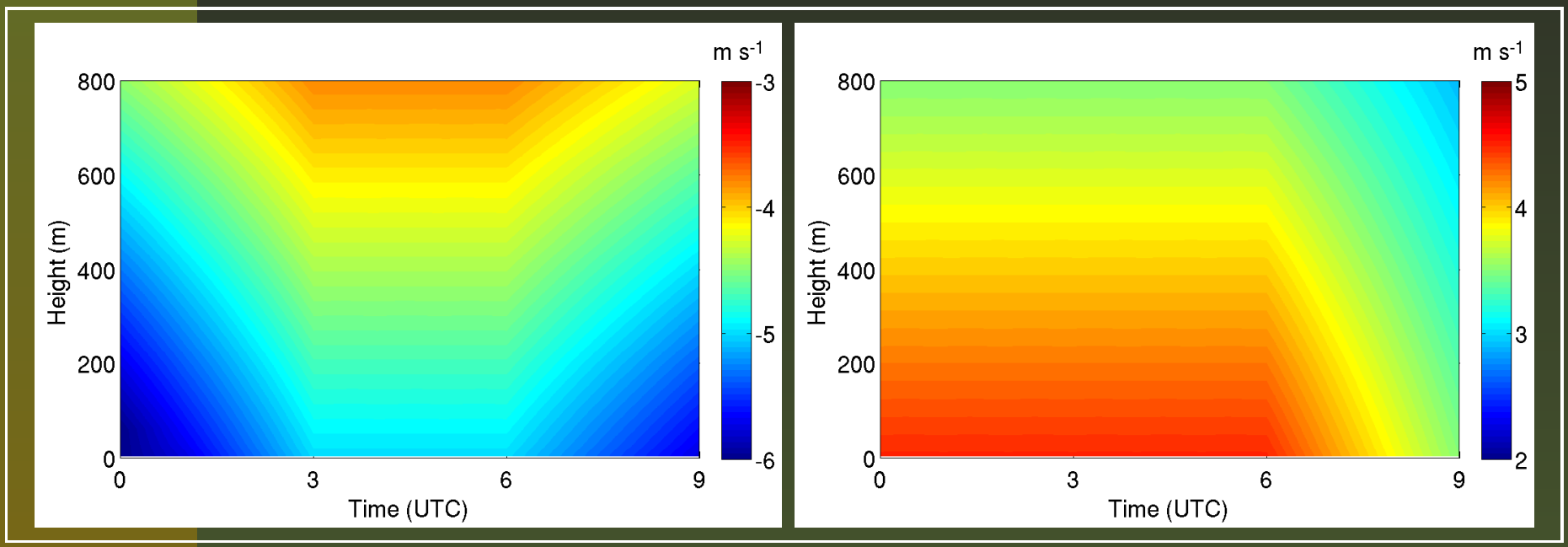


Figure 3: Geostrophic wind components: longitudinal (left panel) and lateral (right panel).

- Geostrophic wind and large-scale advection forcings: same as the GABLS3 SCM intercomparison study.

Other Simulation and Validation Information

- $L_x = L_y = L_z = 800$ m
- Standard runs: $\Delta_x = \Delta_y = \Delta_z = 6.25$ m
- Aerodynamic roughness length: 0.15 m
- $\psi_m = \psi_h = -5\frac{z}{L}$ for stable condition
- Periodic lateral boundary condition
- Free slip upper boundary condition
- Damping layer around 550-600 m

- Direct validation against Cabauw tower (200 m tall) data
- Comparison with a high-res run by S. Raasch: $\Delta_x = \Delta_y = \Delta_z = 1$ m (called **09HR**)
- Validation against well-established hypothesis (e.g., Nieuwstadt's local scaling hypothesis)

Results: A Qualitative View

Time-Height Plots of Wind Speed (0-9 UTC)

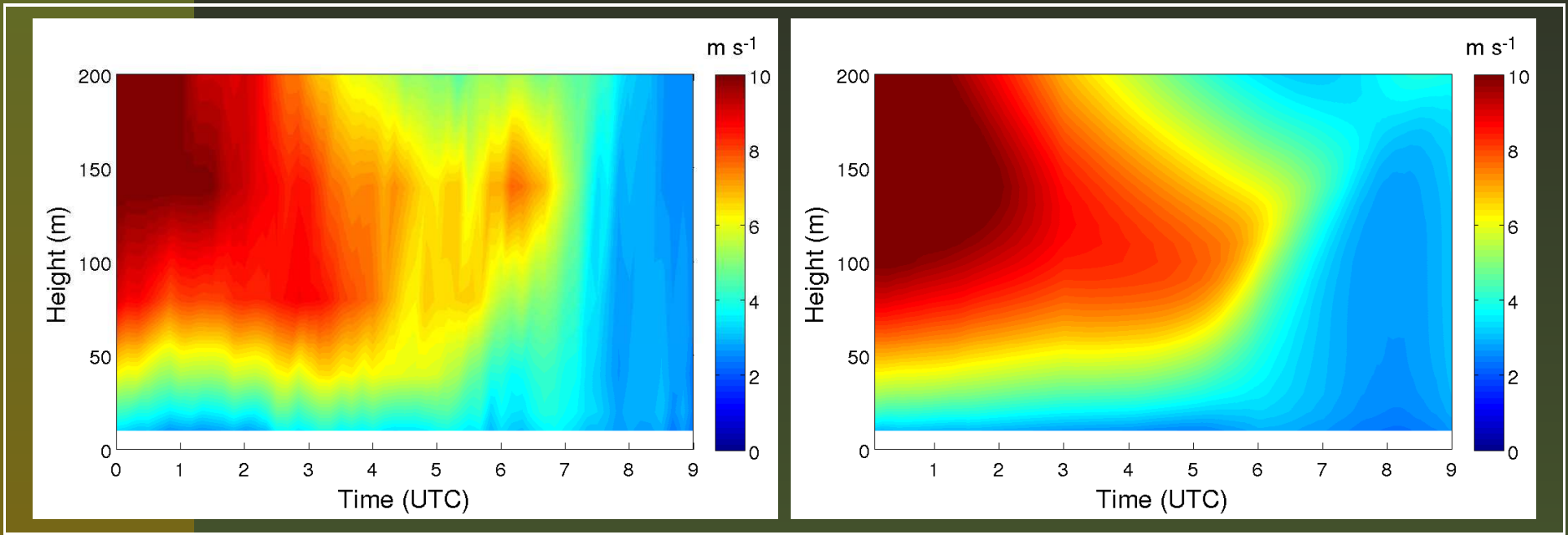


Figure 4: Left panel: Cabauw tower; right panel: composite LES

- The LES ensemble captures the development, magnitude, and location of the LLJ accurately (in a qualitative sense)

Time-Height Plots of Potential Temp. (0-9 UTC)

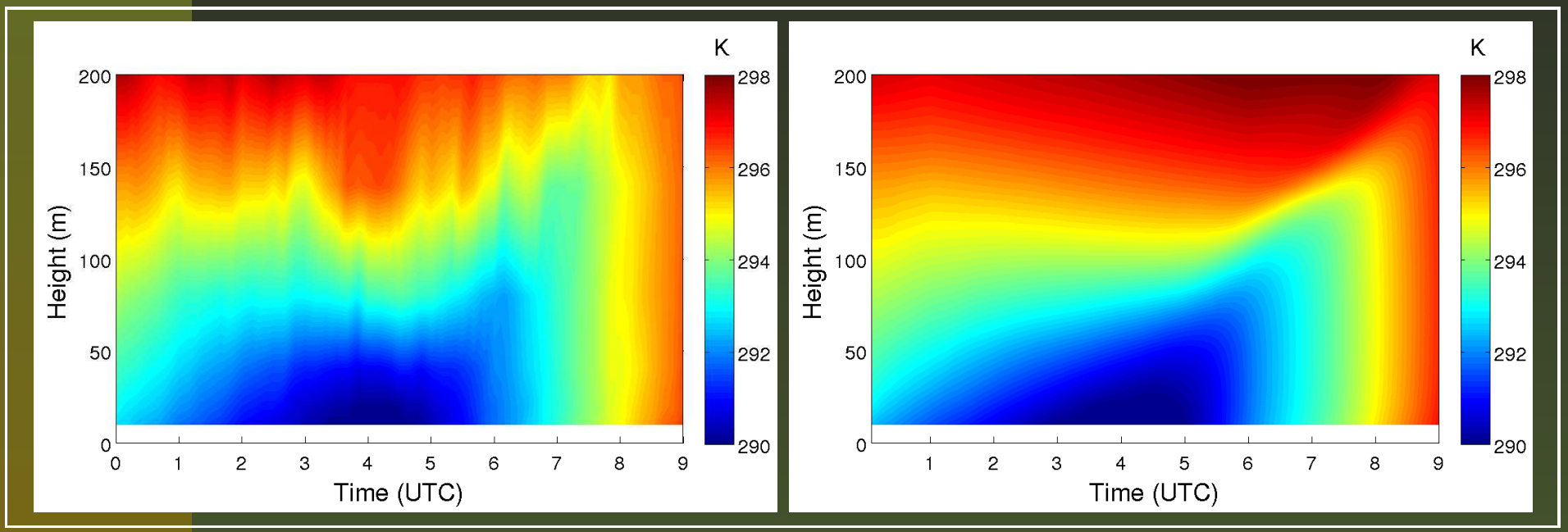


Figure 5: Left panel: Cabauw tower; right panel: composite LES

- The LES ensemble captures the evolution of the SBL reasonably well (in a qualitative sense). The warm bias in the ensemble is likely due to lack of radiation parameterizations.
- Sub-meso motions in tower observations?

Time-Height Plots of Sp. Humidity (0-9 UTC)

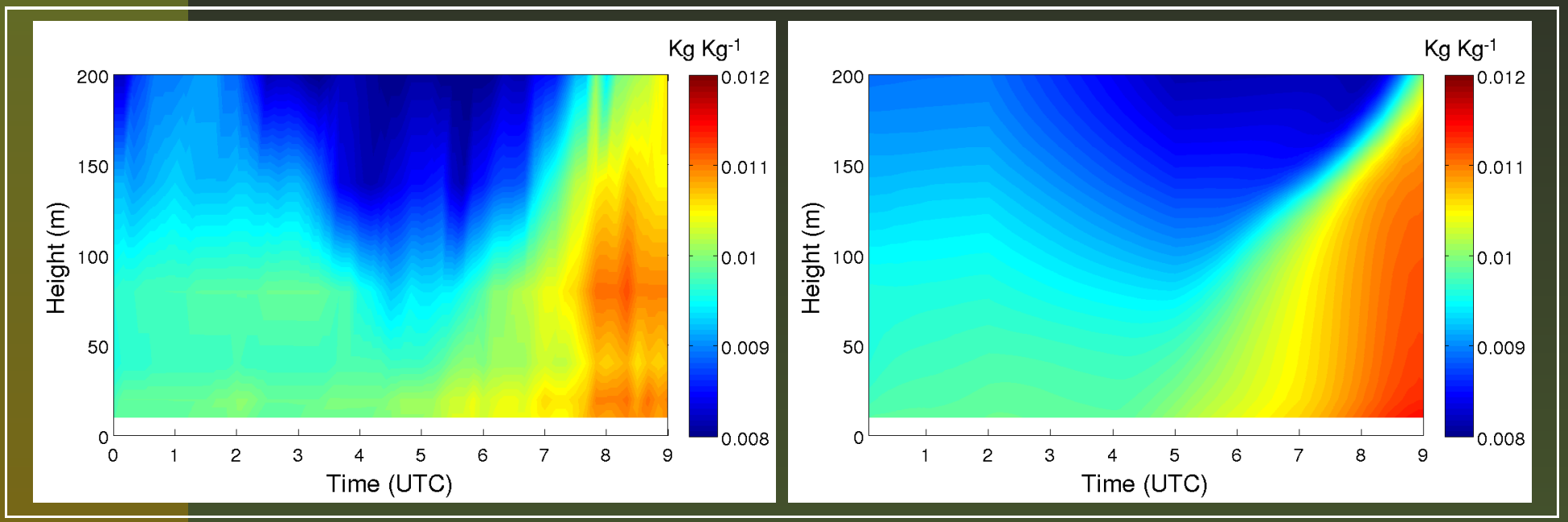


Figure 6: Left panel: Cabauw tower; right panel: composite LES

- Moist bias in the LES ensemble.

Results: First-Order Statistics

Details of Graphical Representation

- 11 standard LES runs
- Output interval: 5 min (planar averaging; no temporal averaging)
- For each hour: $11 \times 12 = 132$ simulated data for each model level
- Model output are linearly interpolated to 10:10:800 m levels
- 10, 25, 50, 75, and 90 percentiles are shown

- Cabauw tower data interval: 10 min (temporal averaging)
- For each hour: 6 data points for each instrument level
- Min, median, and max values are shown
- Profiler data interval: 30 min
- Median values from the 09HR run are also plotted for comparison

Hodographs

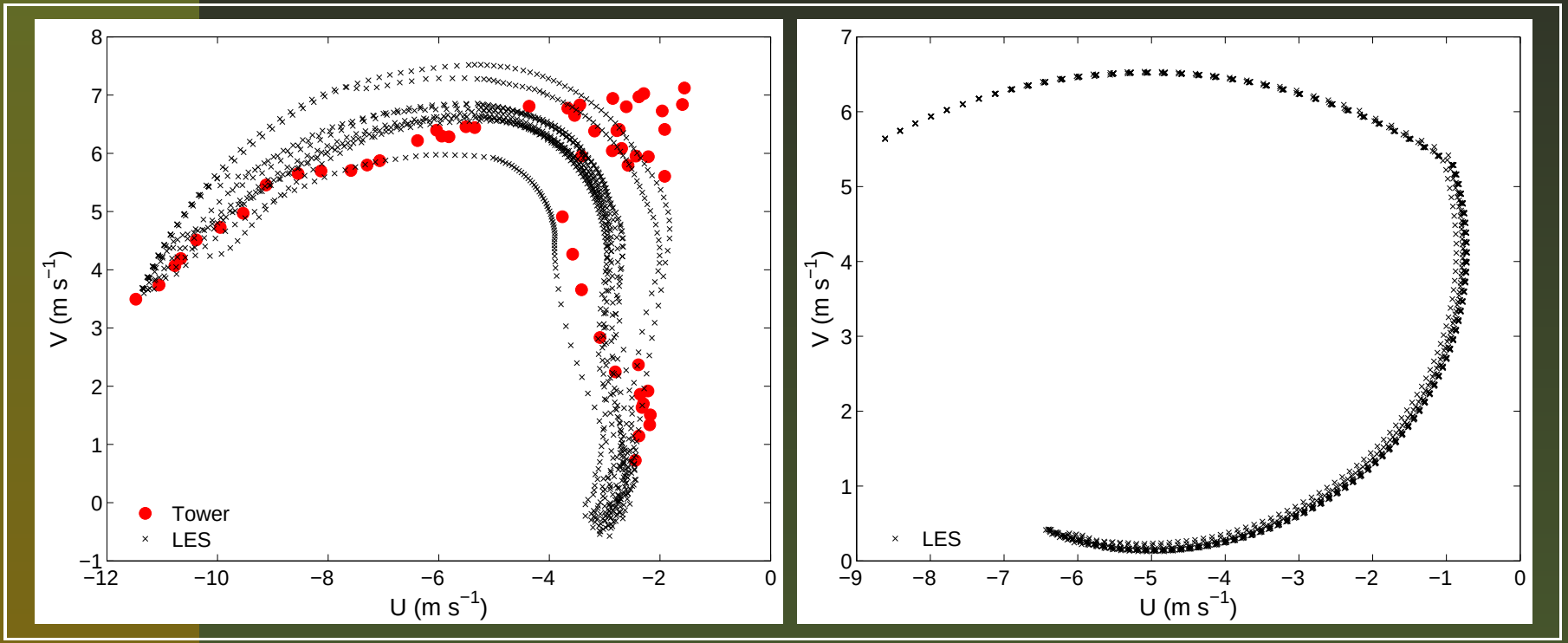


Figure 7: Left panel: 140 m (AGL); right panel: 300 m (AGL)

- Inertial oscillation
- Agreement of hodographs outside the SBL: large-scale forcings are correctly implemented by all the participants
- Variability of hodographs within the SBL: SGS effects

Longitudinal Velocity Component

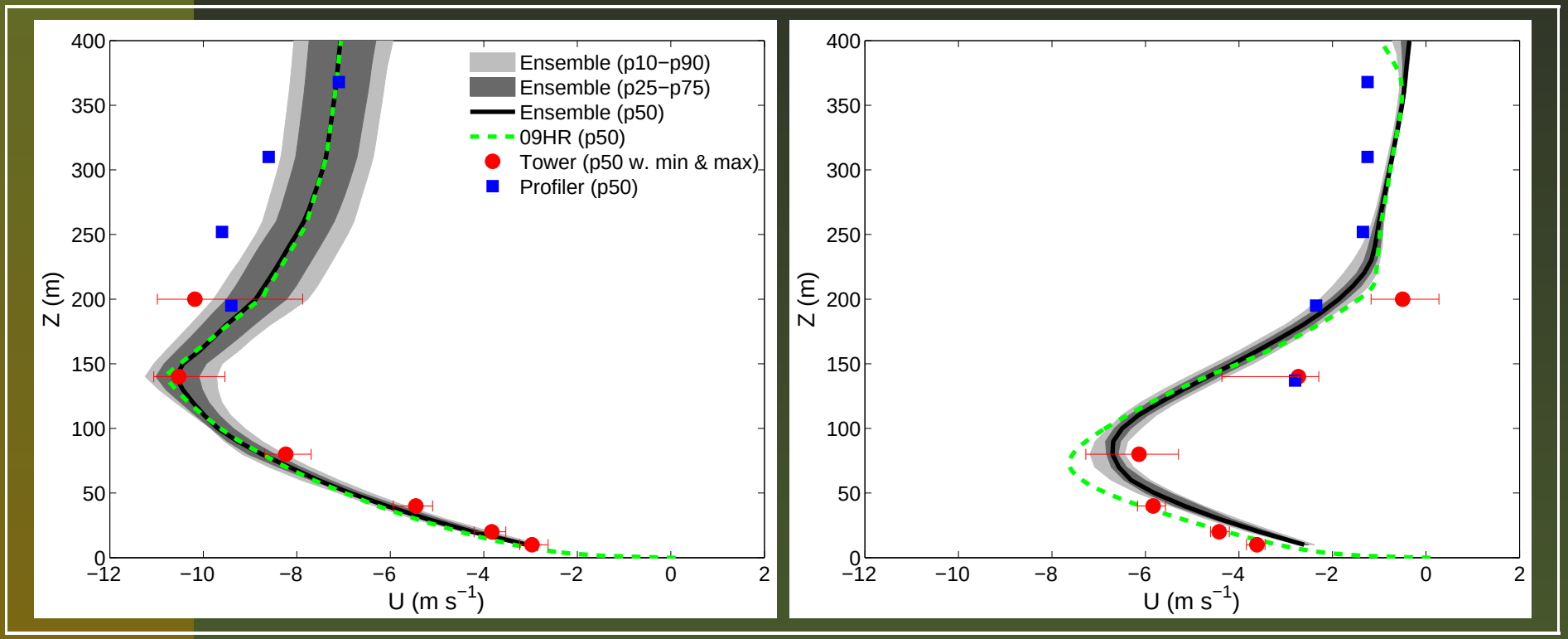


Figure 8: Left panel: 0-1 UTC; right panel: 3-4 UTC.

- LLJ height decreased with time; not observed in GABLS1.
- Quite often the high-resolution run (09HR) has sharper peak.
- Large variability of upper-SBL observations: sub-meso motions?

Longitudinal Velocity Component (Cont.)

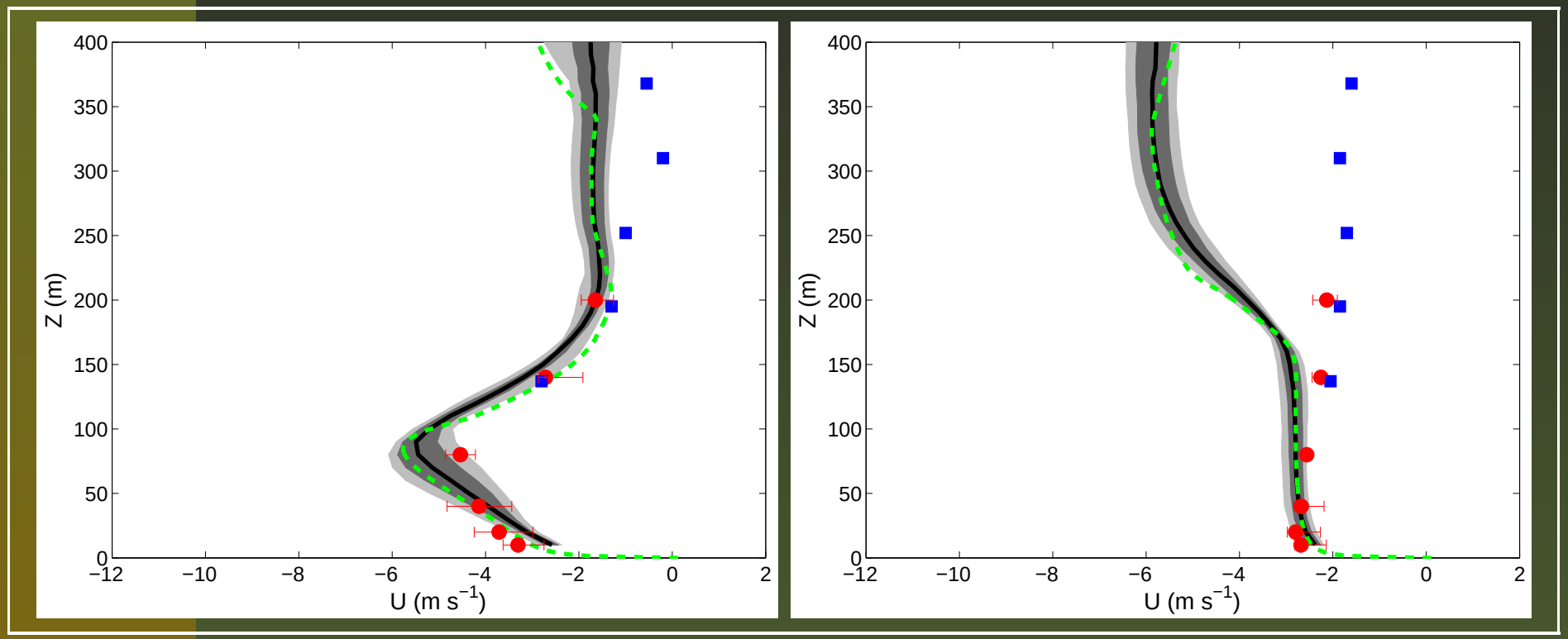


Figure 9: Left panel: 5-6 UTC; right panel: 8-9 UTC.

- In contrast to GABLS1, all the LES runs agree on the LLJ height: why? [effects of initial conditions, SGS model improvement, ..?]
- Problematic large-scale forcings during daytime.

Lateral Velocity Component

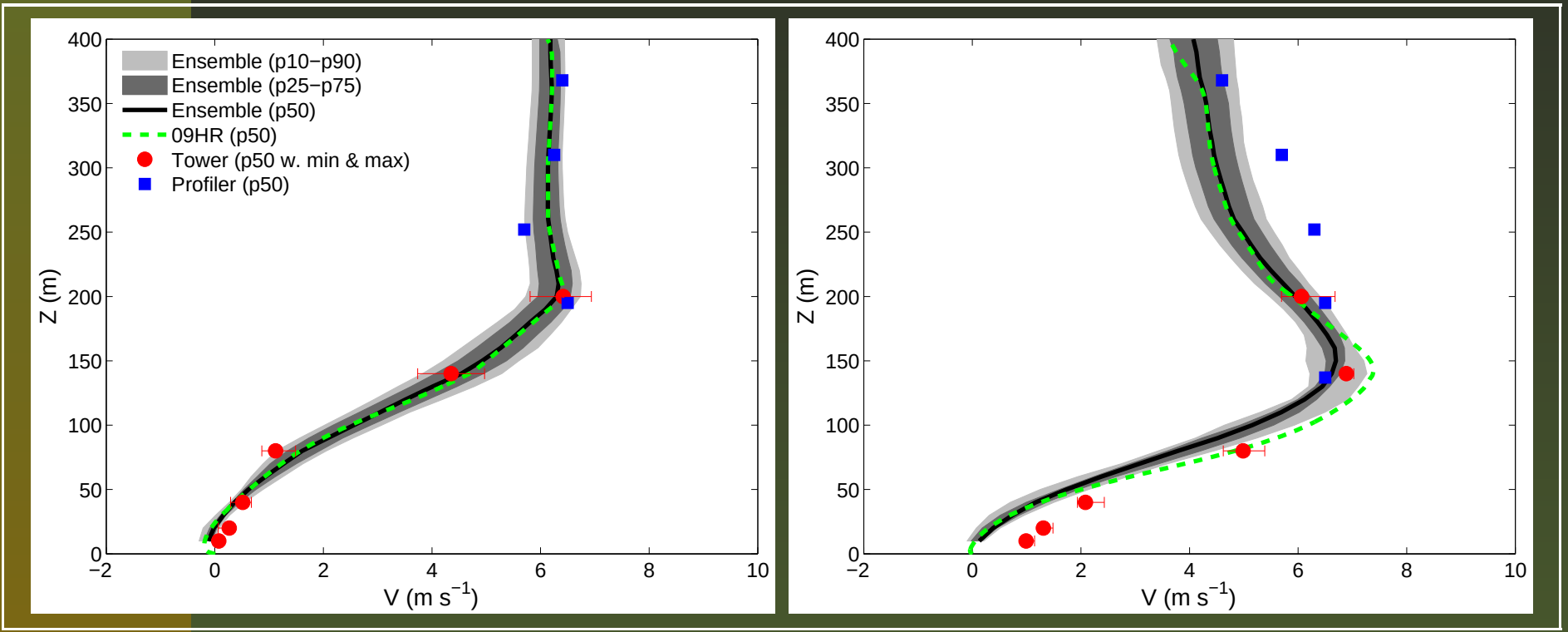


Figure 10: Left panel: 0-1 UTC; right panel: 3-4 UTC.

- Approximately $80°$ wind turning within SBL during strongly stratified conditions (possibly due to baroclinicity); Nieuwstadt's local scaling hypothesis predicted $60°$ wind turning; GABLS1 reported $\sim 35° - 40°$ wind turning.

Lateral Velocity Component (Cont.)

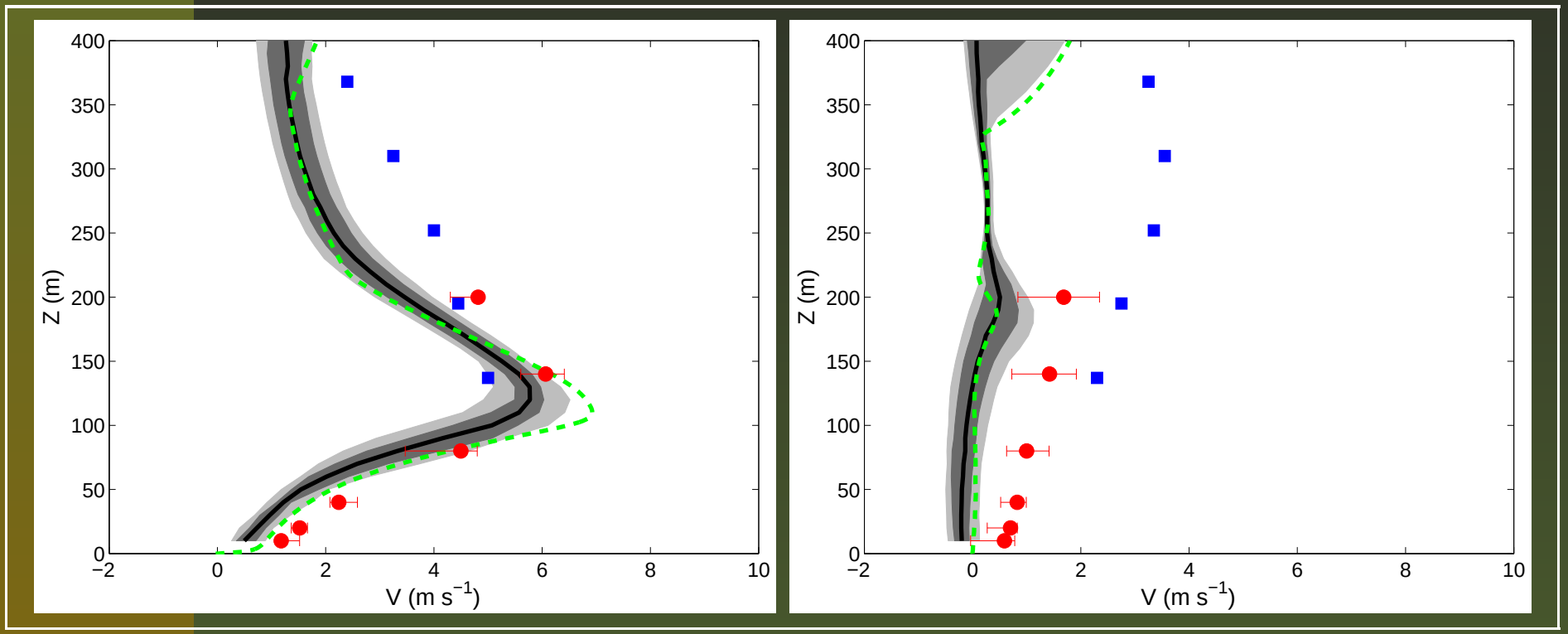


Figure 11: Left panel: 5-6 UTC; right panel: 8-9 UTC.

- Quite often the high-resolution run (09HR) has sharper peak.
- Problematic large-scale forcings during daytime.

Potential Temperature

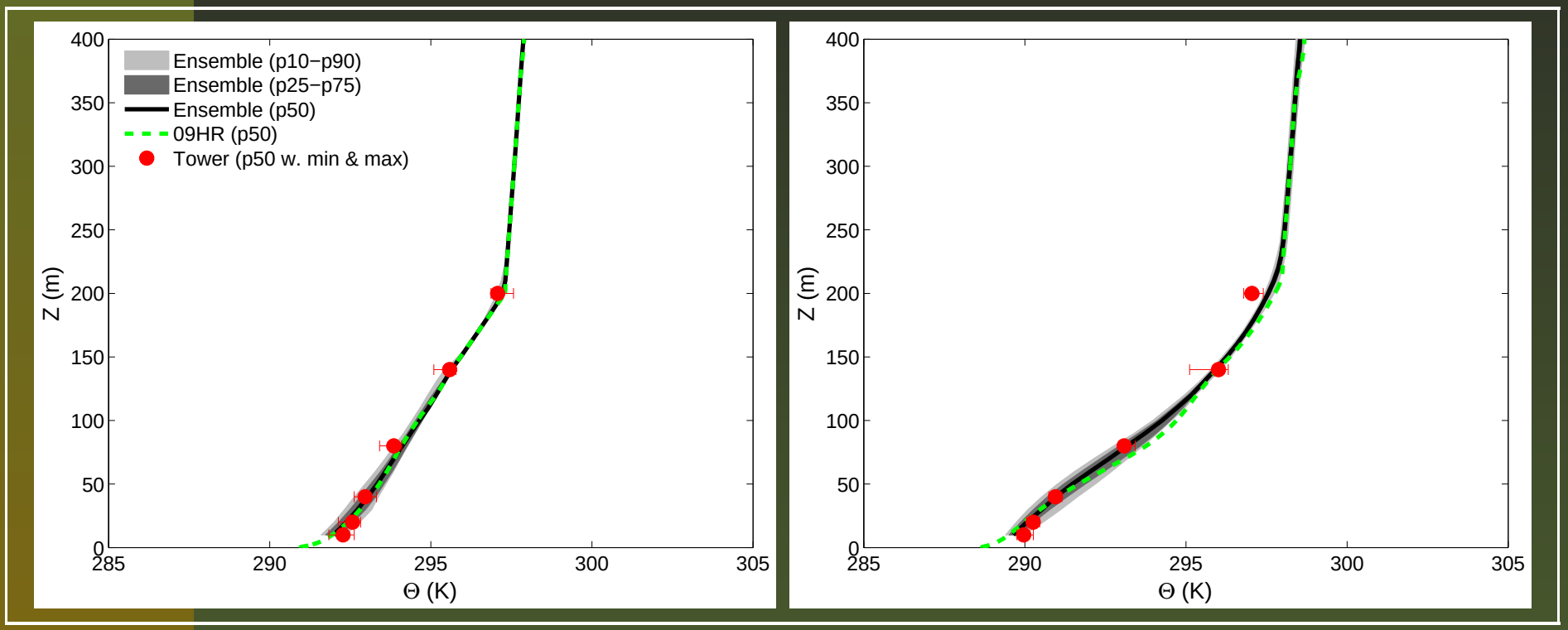


Figure 12: Left panel: 0-1 UTC; right panel: 3-4 UTC.

- Inversion height did not change much during the night.
- Marginal convexity of the potential temperature profile: equal importance of turbulence and radiation?

Potential Temperature (Cont.)

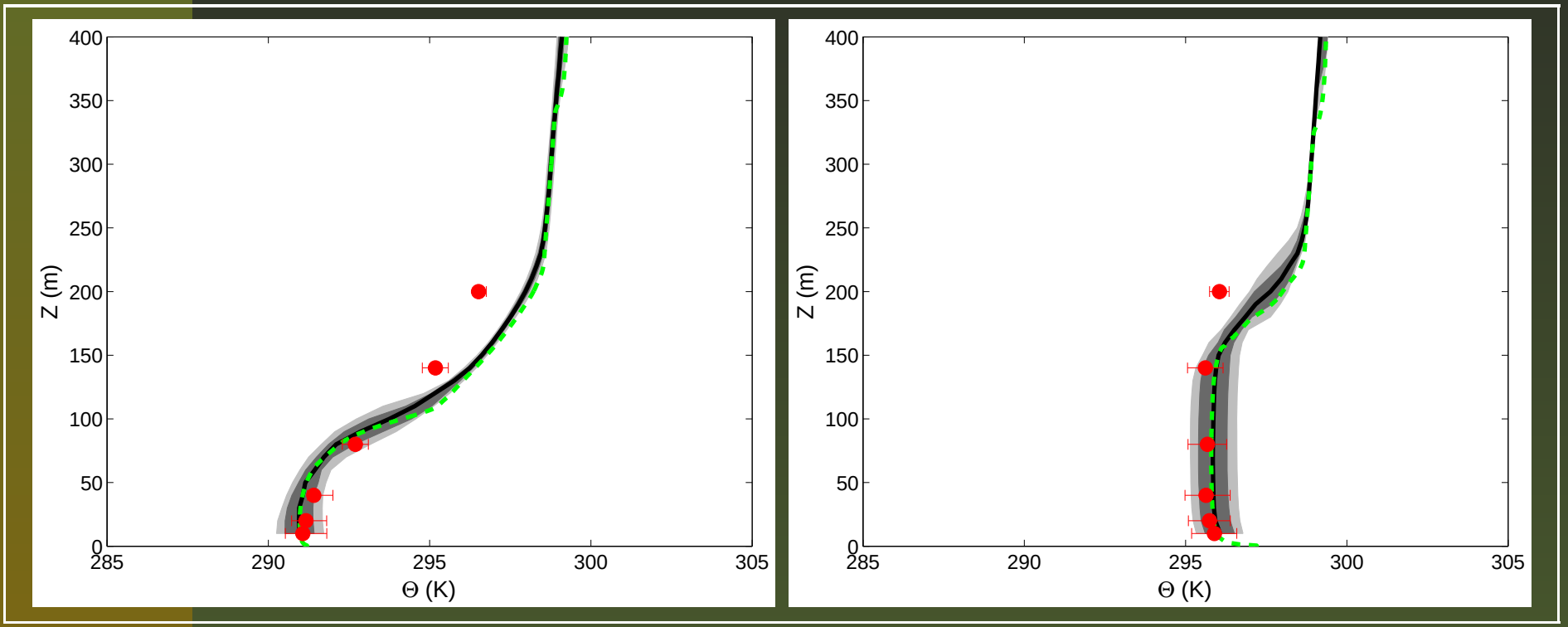


Figure 13: Left panel: 5-6 UTC; right panel: 8-9 UTC.

- Warming (and mixed layer height) bias can be removed by invoking atmospheric radiation parameterizations (Edwards)
- Enhanced variability in LES runs after morning transition: the case description did not specify ψ_m and ψ_h for unstable conditions.

Specific Humidity

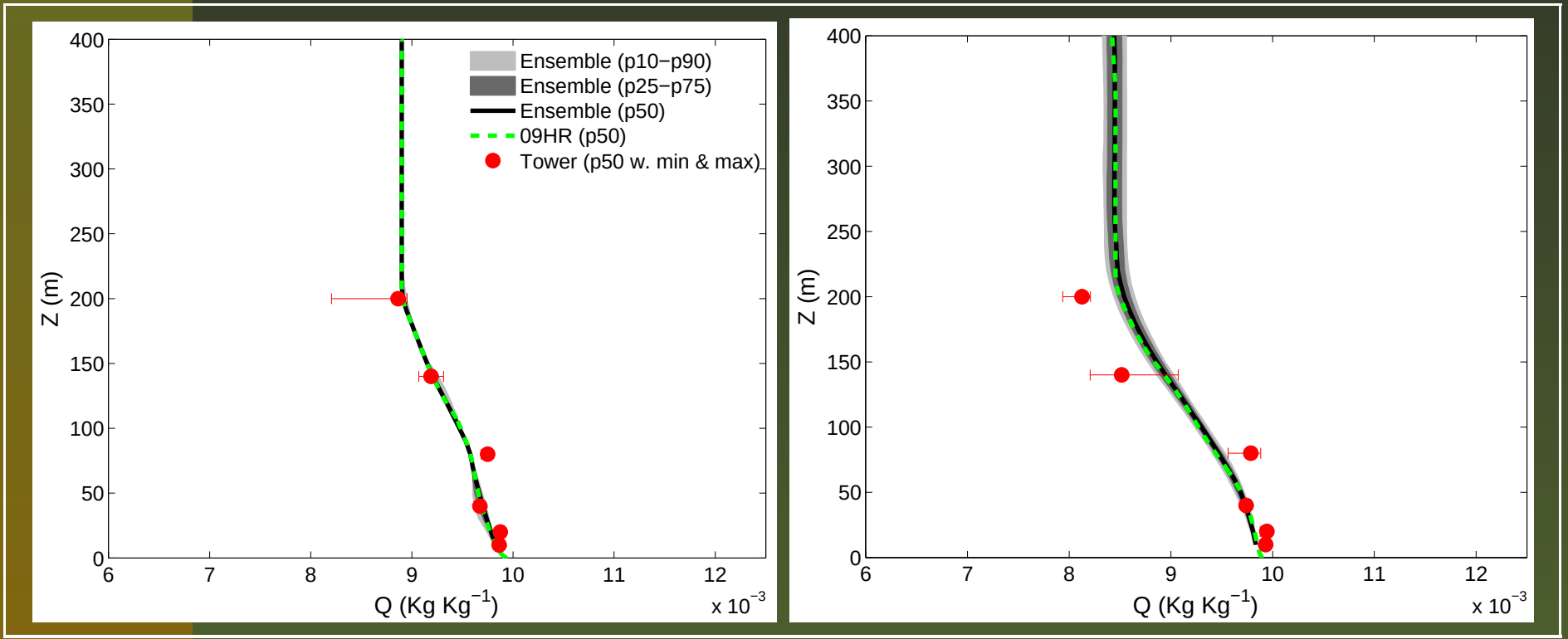


Figure 14: Left panel: 0-1 UTC; right panel: 3-4 UTC.

Specific Humidity (Cont.)

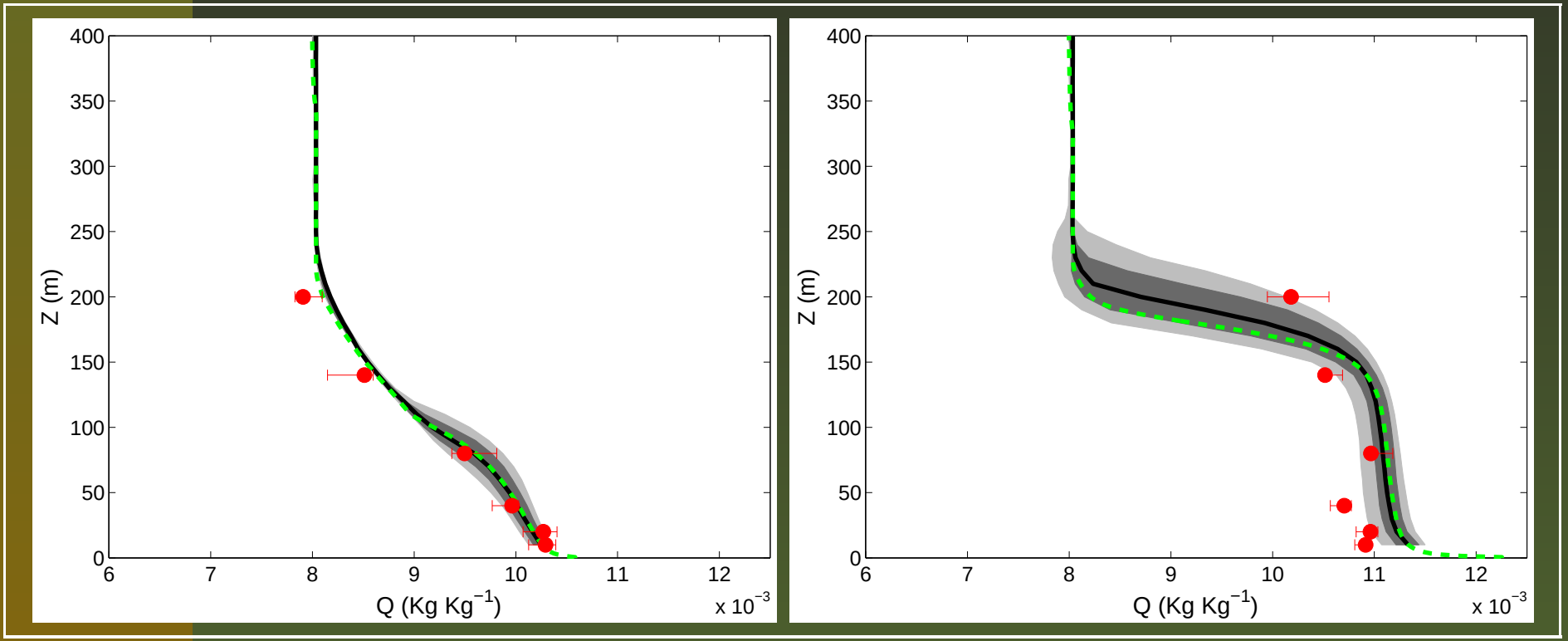


Figure 15: Left panel: 5-6 UTC; right panel: 8-9 UTC.

Time-Series Analysis

Observed Turbulence Time-Series (180 m AGL)

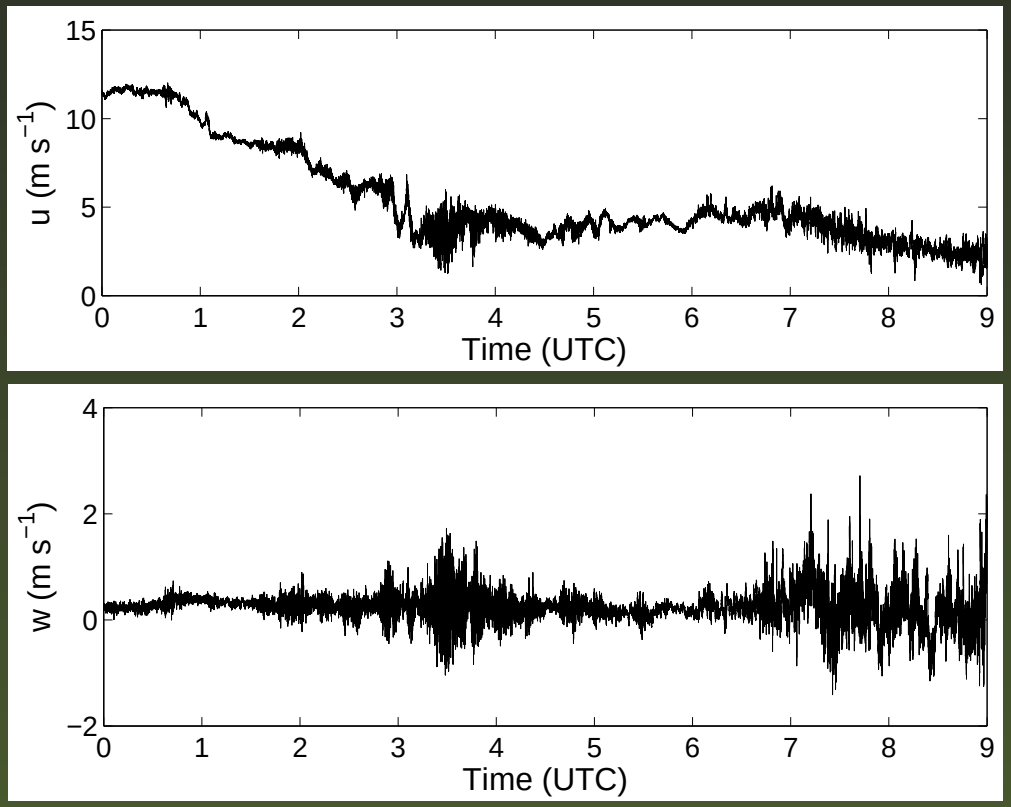


Figure 16: Top panel: longitudinal velocity; bottom panel: vertical velocity

- Bursting event (3-4 UTC), upside-down SBL.

Filtering of Sub-meso Motions (180 m AGL)

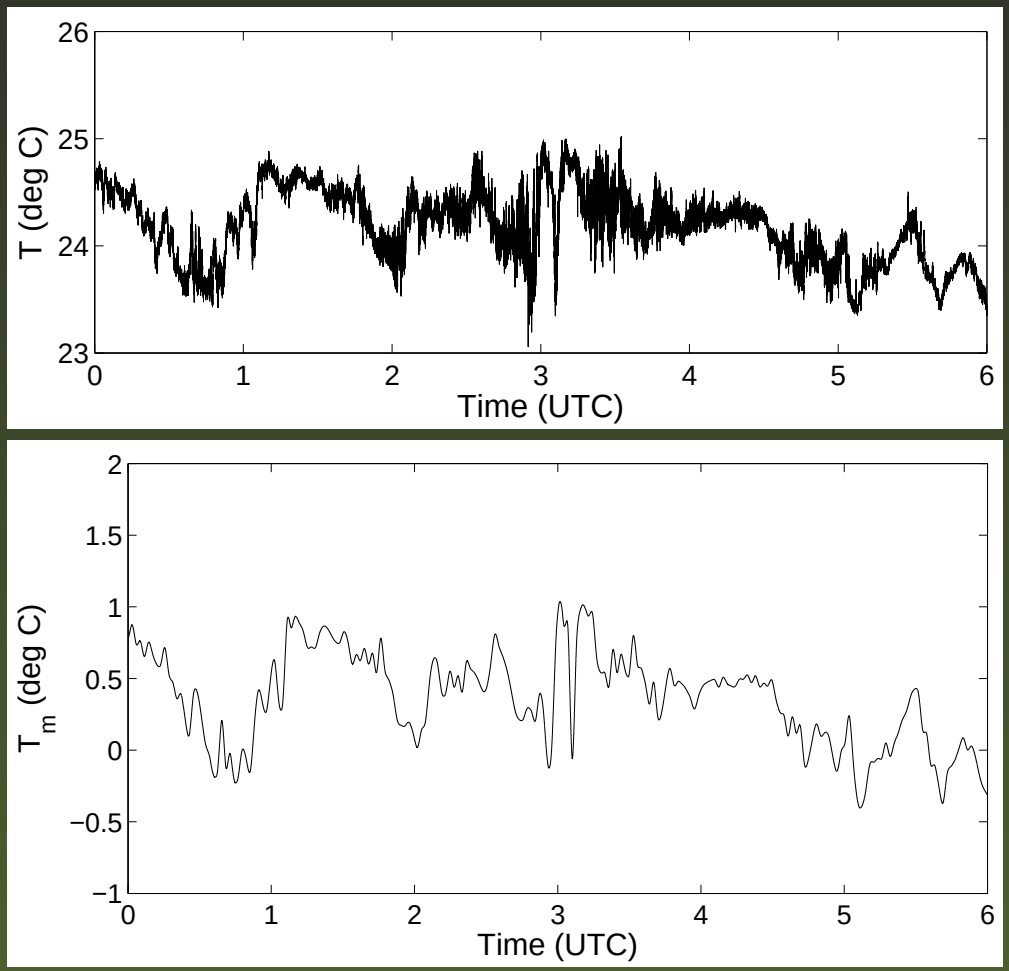


Figure 17: Top panel: temperature; bottom panel: filtered temperature

- Wavelet-based filtering (Symmlet 8, filter width = 100 s)

Other QA/QC and Pre-Processing Steps

- Filtering of sub-meso motions was not performed for 6-9 UTC (unstable conditions)
- Despiking (algorithm by Vickers and Mahrt 1997)
- Rotation of horizontal velocity components (no tilt correction)

Results: Second-Order Statistics

Horizontal Velocity Variance

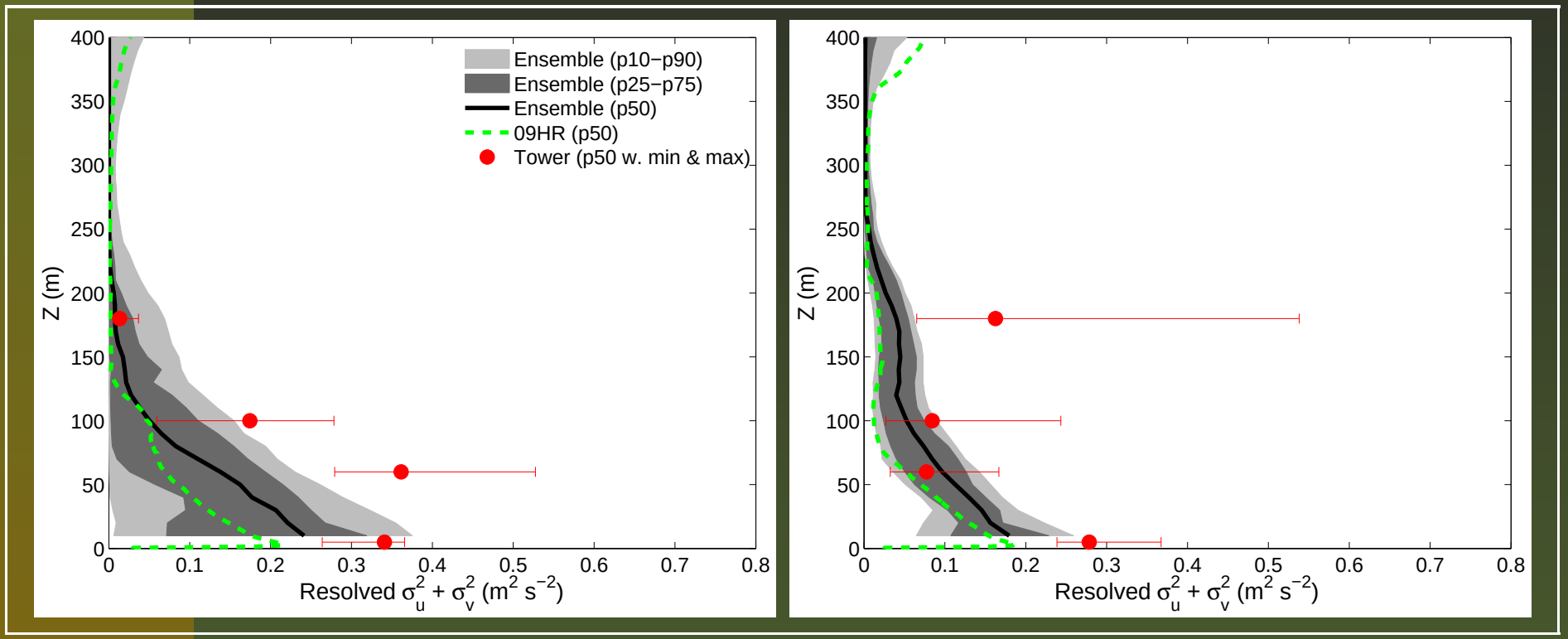


Figure 18: Left panel: 0-1 UTC; right panel: 3-4 UTC.

- LES profiles: only resolved variance; observed: total variance
- Is resolved variance from 09HR >> standard runs (stable)?
- Insufficient SGS dissipation above LLJH (some standard runs).

Horizontal Velocity Variance (Cont.)

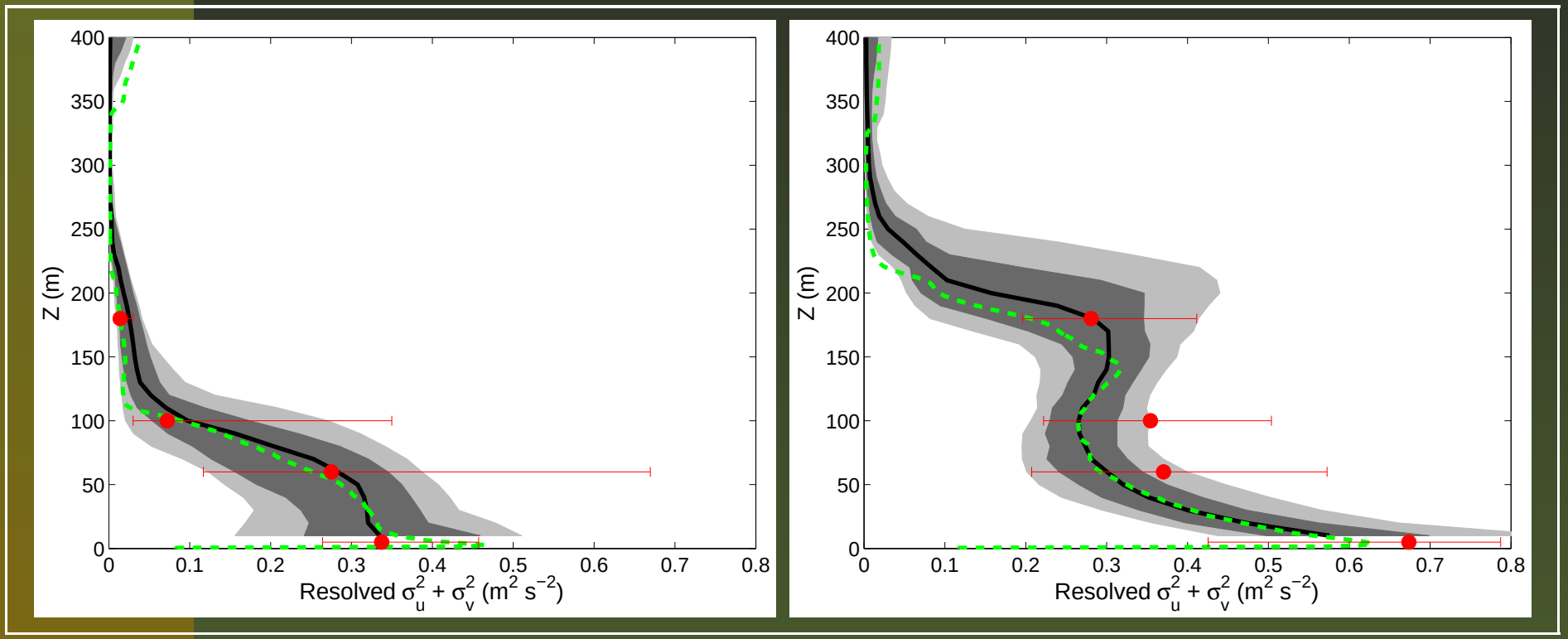


Figure 19: Left panel: 5-6 UTC; right panel: 8-9 UTC.

- Intuitively, resolved variance from 09HR $\sim$ standard runs (unstable).

Effects of Grid Resolution & Advection Schemes

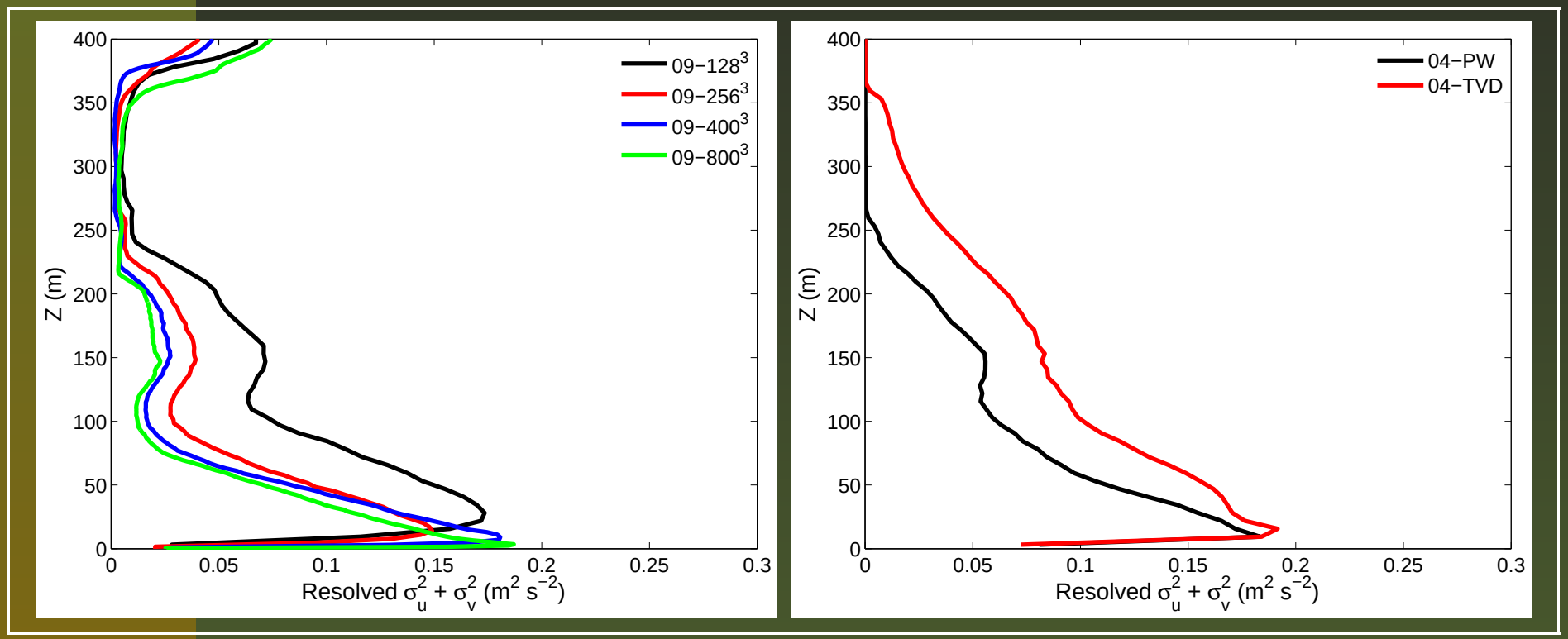


Figure 20: Dependency of SGS energy dissipation w.r.t. resolution (left panel) and advection schemes (right panel). Time: 3-4 UTC.

Effects of Advection Schemes (Cont.)

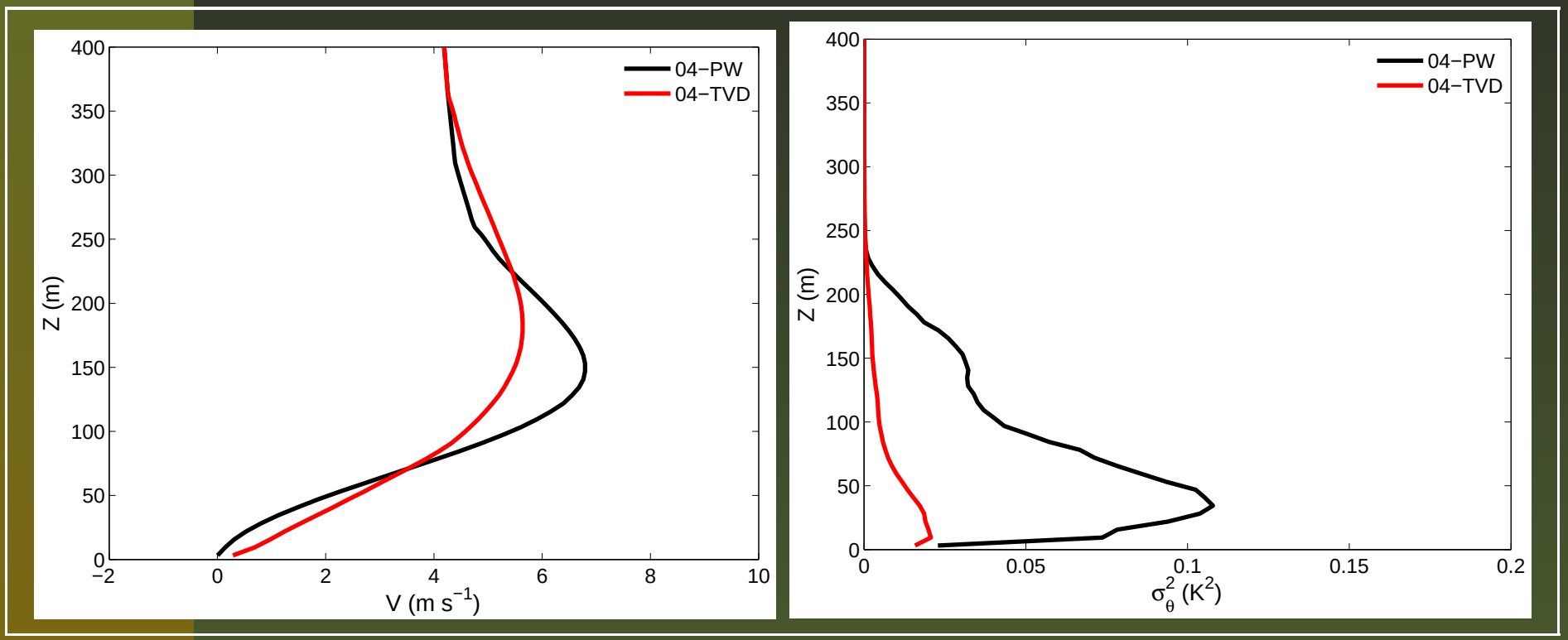


Figure 21: Left panel: lateral velocity component; right panel: temperature variance. Time: 3-4 UTC.

Vertical Velocity Variance

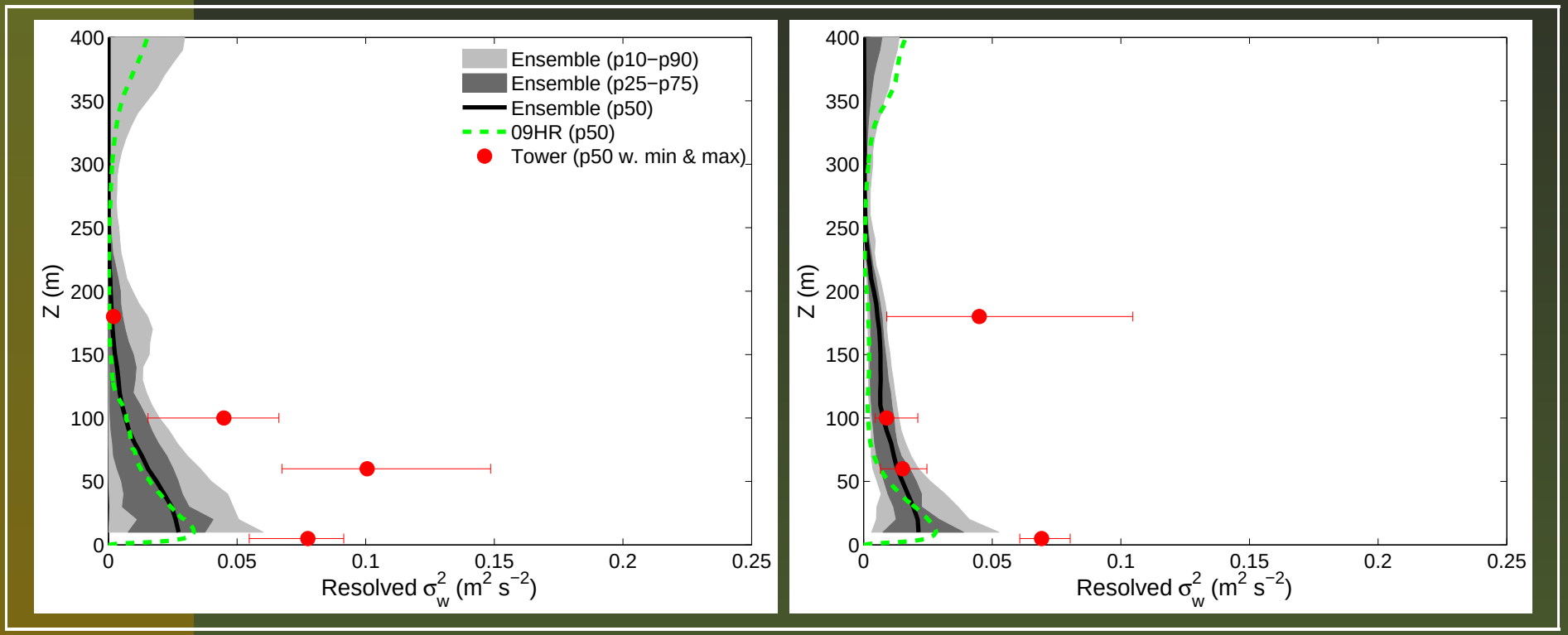


Figure 22: Left panel: 0-1 UTC; right panel: 3-4 UTC.

Vertical Velocity Variance (Cont.)

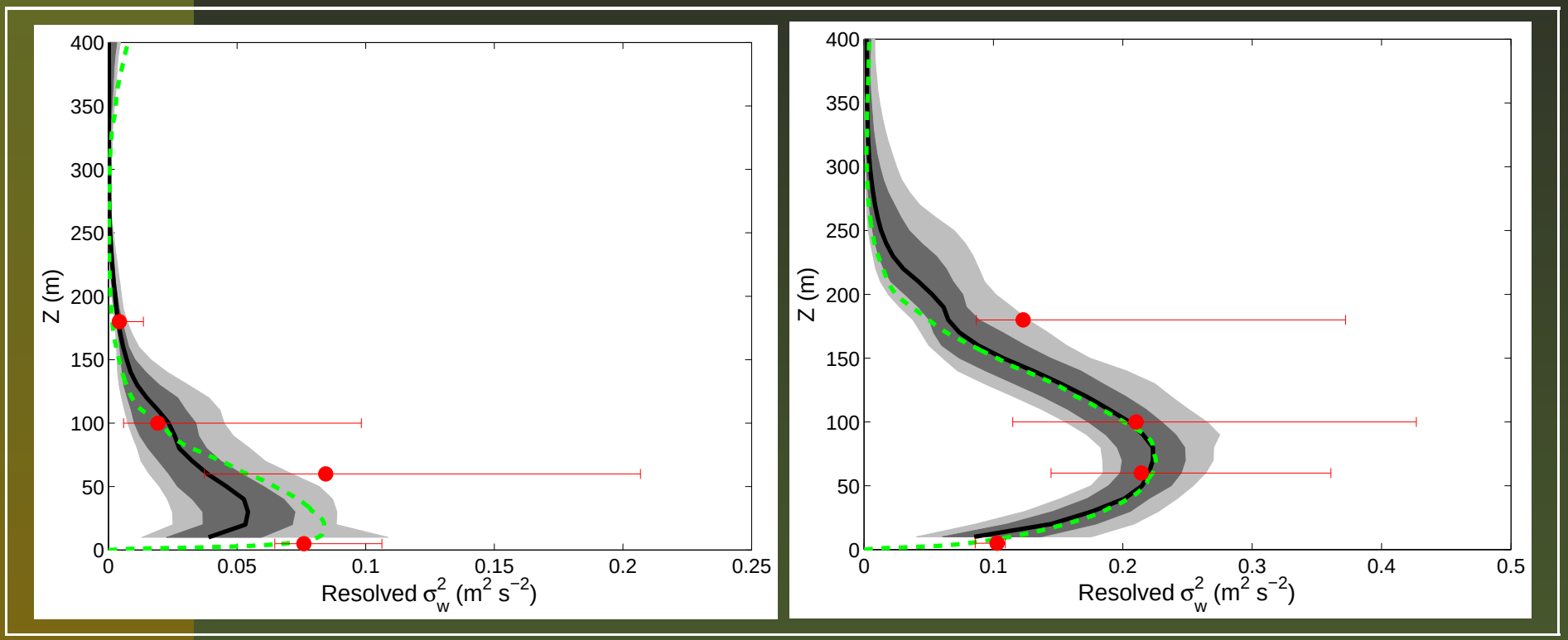


Figure 23: Left panel: 5-6 UTC; right panel: 8-9 UTC.

- Peak of variance in mixed-layer is located at $z/z_i \sim 0.3$.

Subgrid-scale TKE

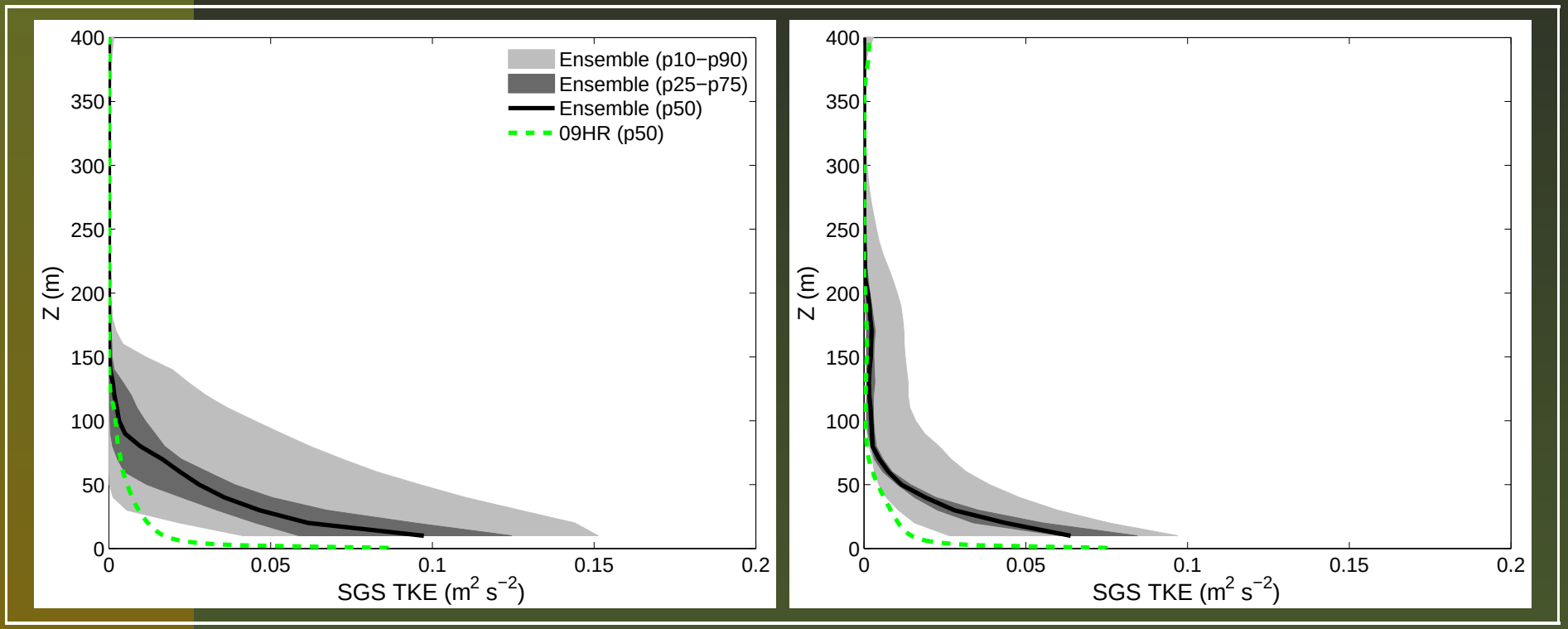


Figure 24: Left panel: 0-1 UTC; right panel: 3-4 UTC.

- Is SGS TKE from 09HR << standard runs?
- Overall, resolved TKE > SGS TKE (not 80% resolved though).

Subgrid-scale TKE (Cont.)

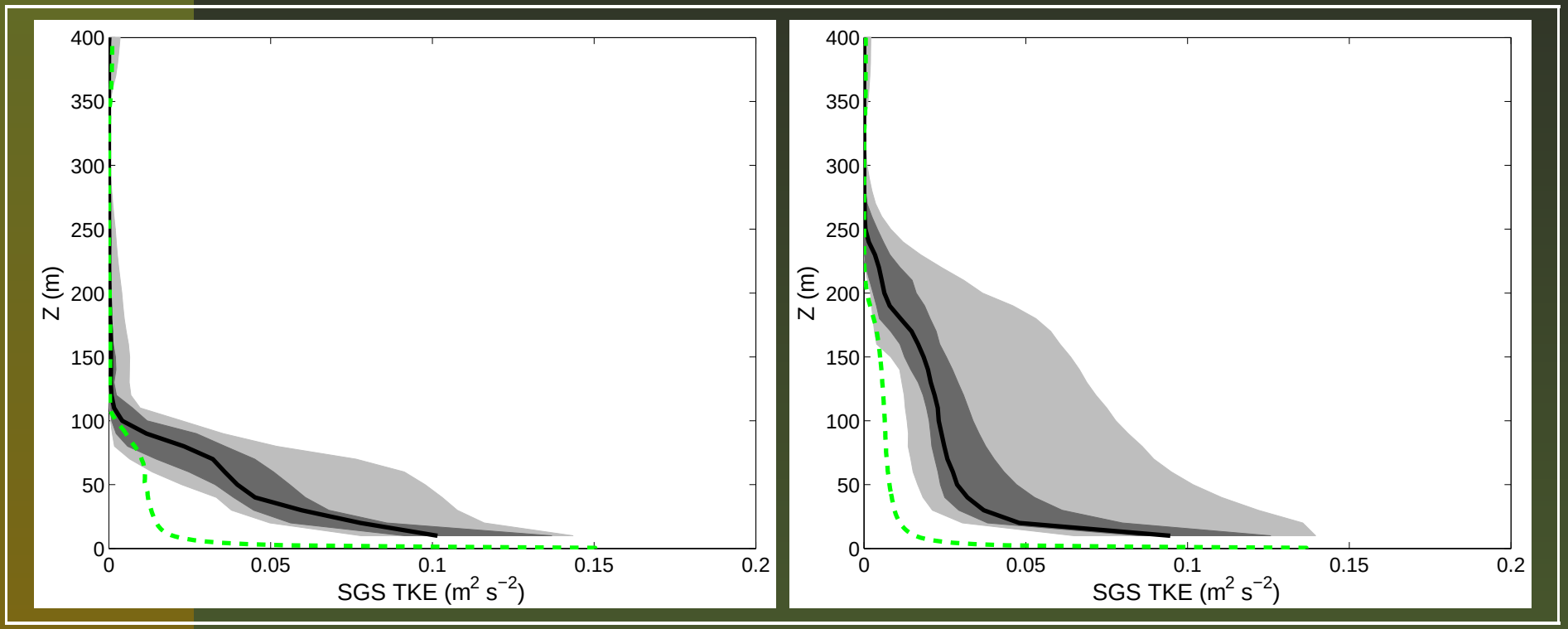


Figure 25: Left panel: 5-6 UTC; right panel: 8-9 UTC.

Sensible Heat Flux (3-4 UTC)

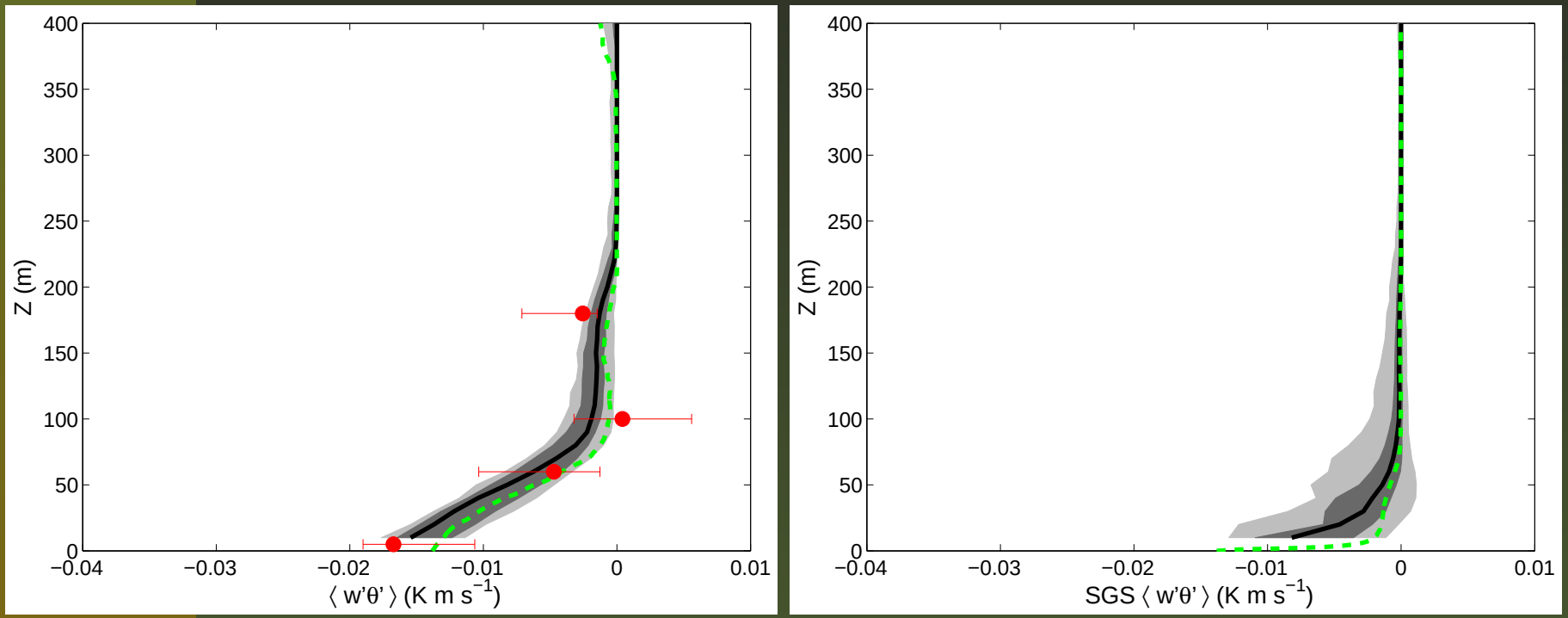


Figure 26: Left panel: total flux; right panel: SGS flux.

Sensible Heat Flux (5-6 UTC)

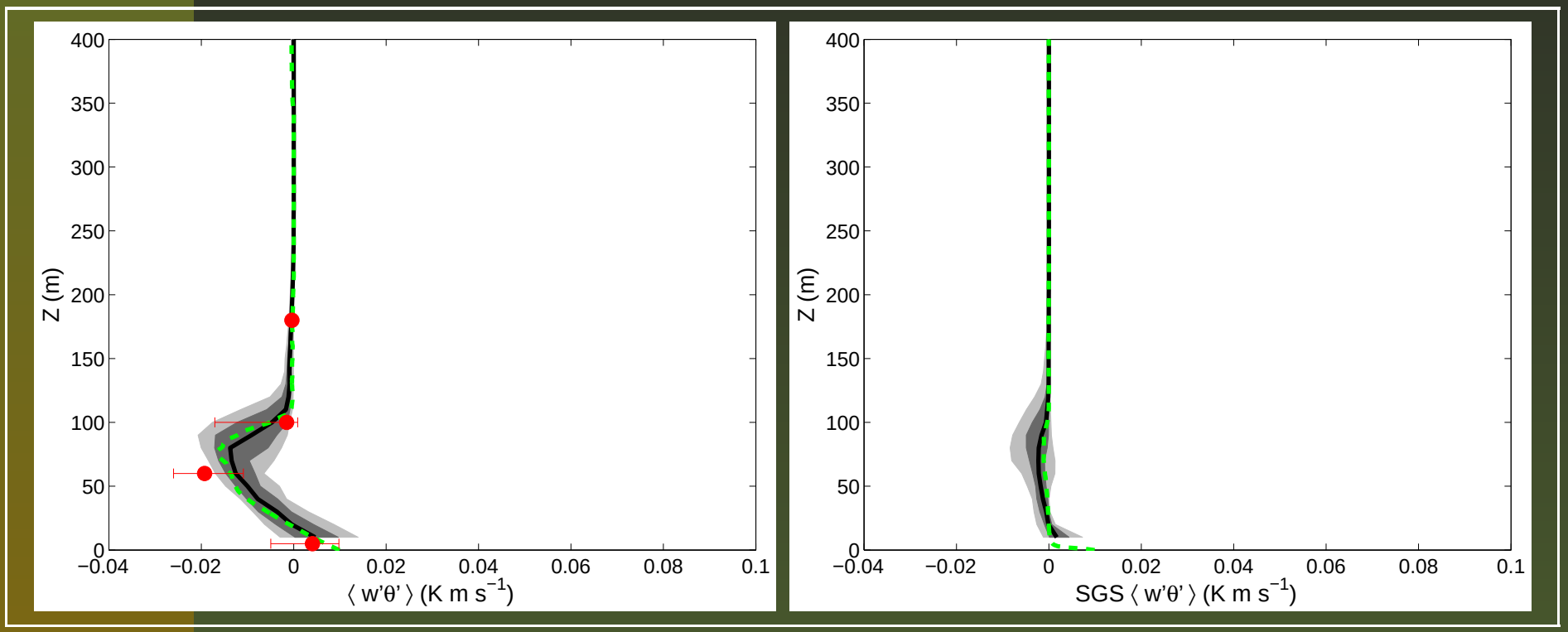


Figure 27: Left panel: total flux; right panel: SGS flux.

Sensible Heat Flux (8-9 UTC)

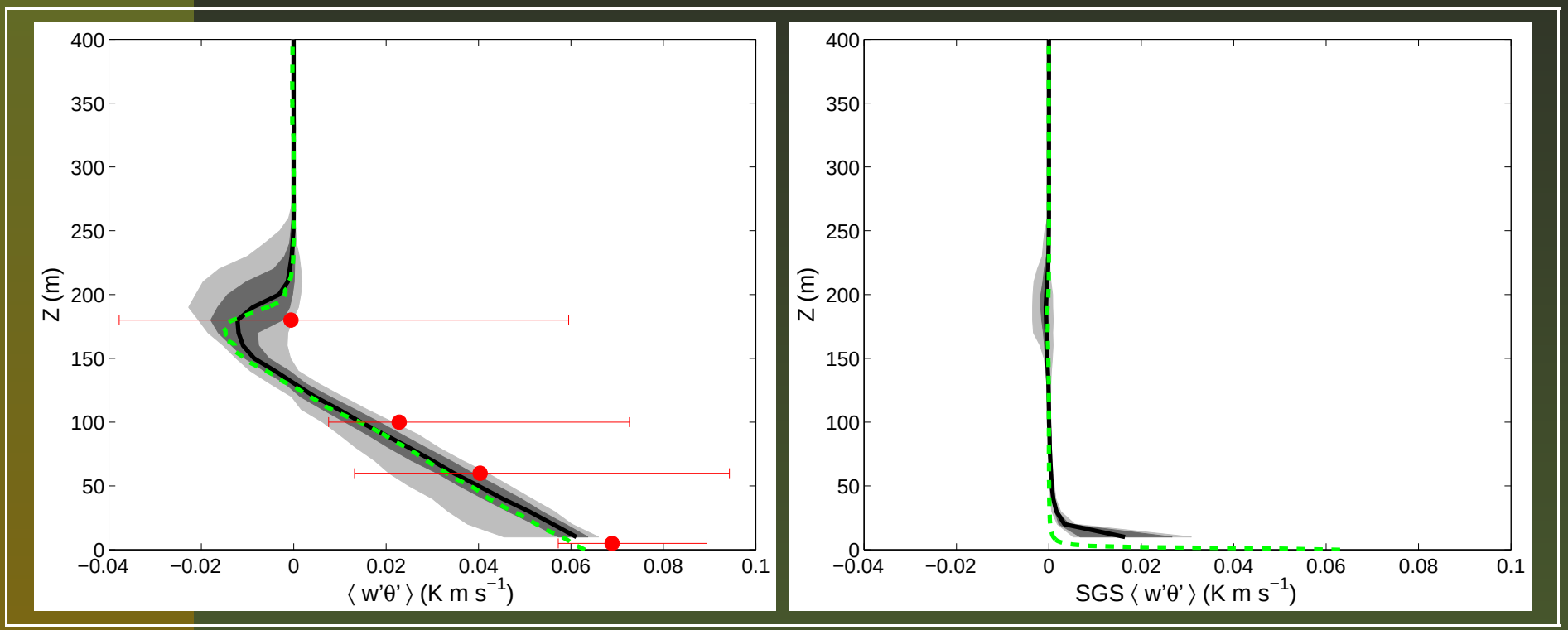


Figure 28: Left panel: total flux; right panel: SGS flux.

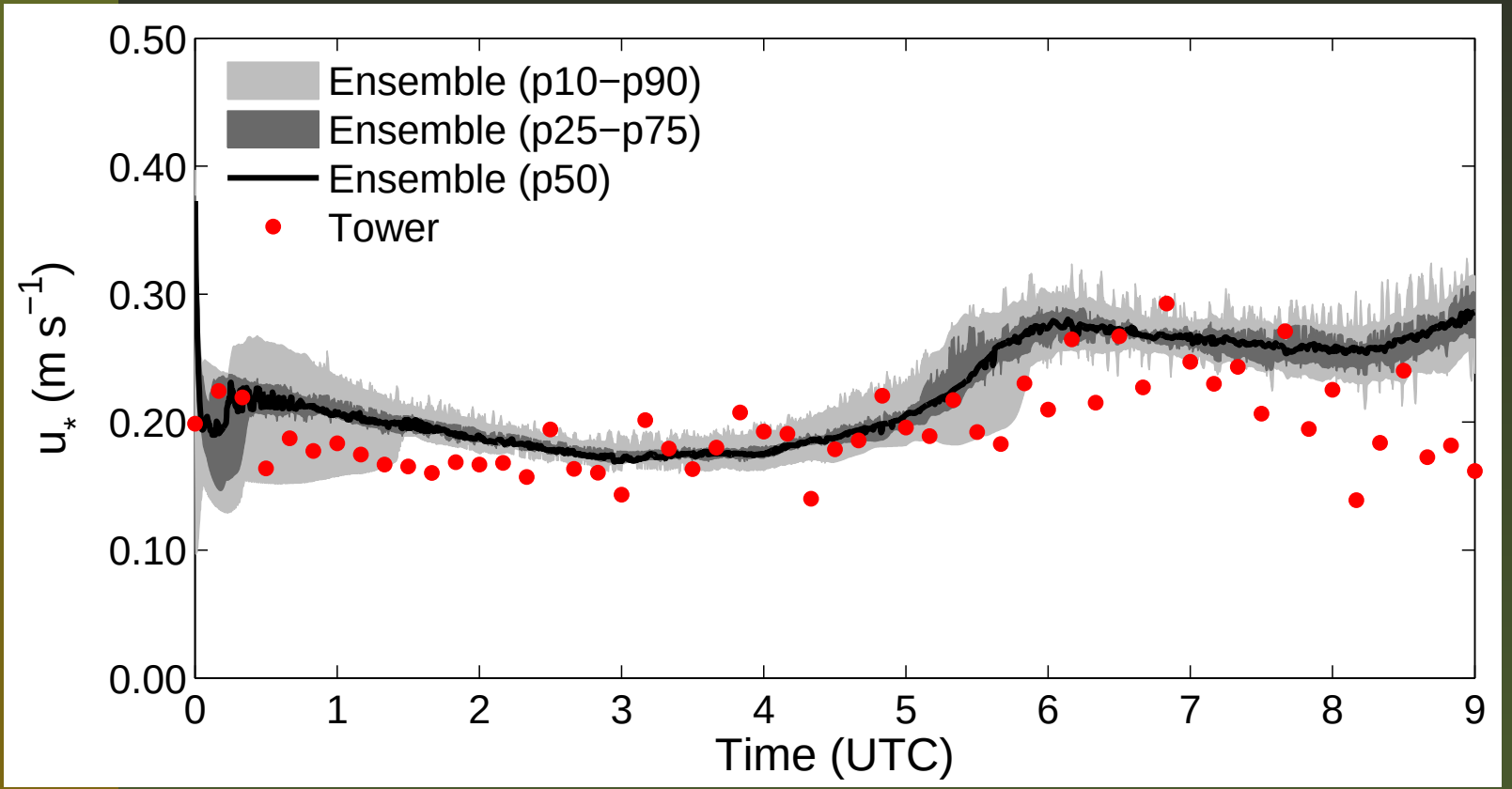
Other Results

- Time-series of surface fluxes
- Similarity theory (M-O, Nieuwstadt's local scaling, etc.)
- Flux and gradient Richardson number
- Momentum flux, eddy viscosity/diffusivity, turbulent Prandtl number
- ...

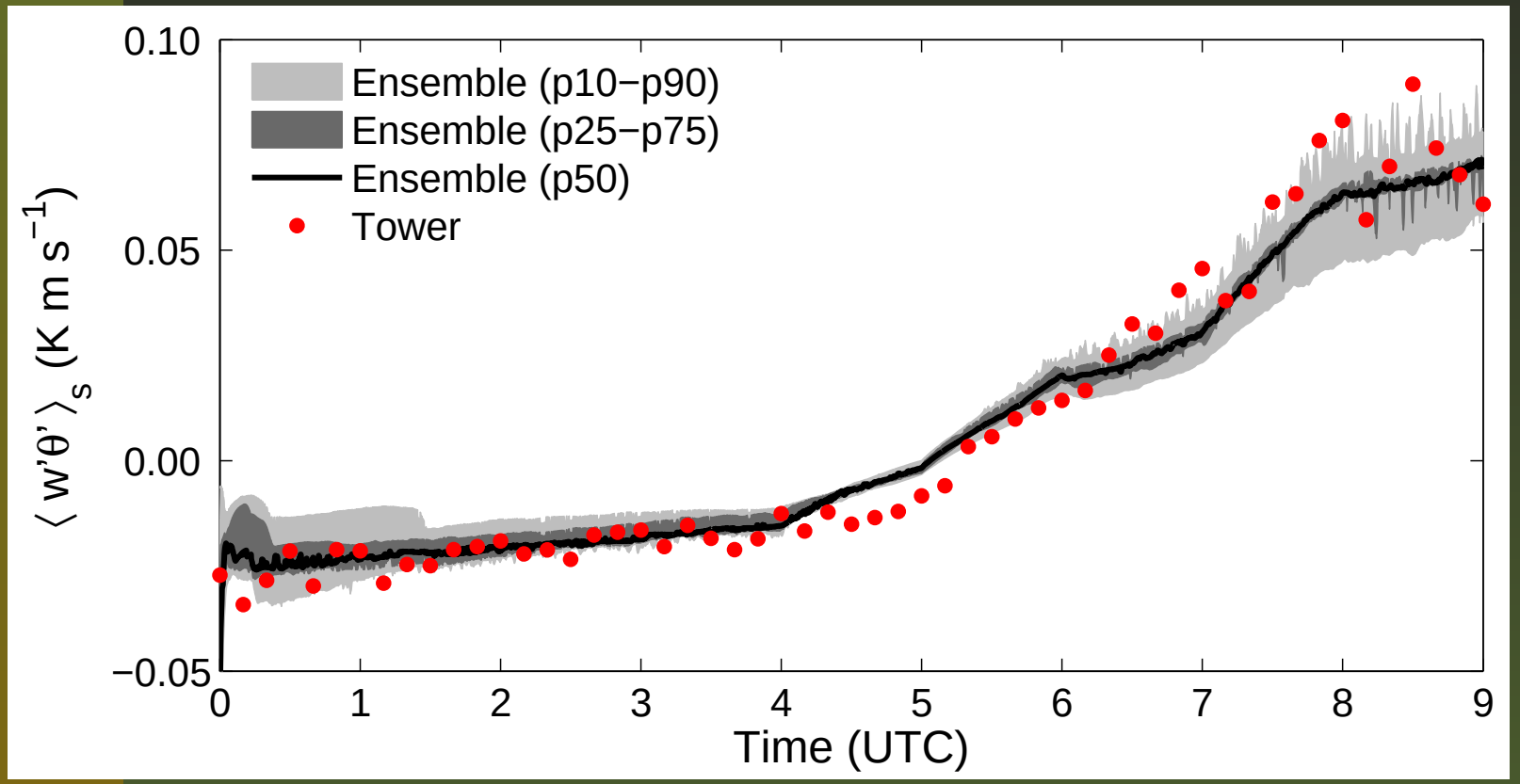
Thank You!

Results: Surface Fluxes

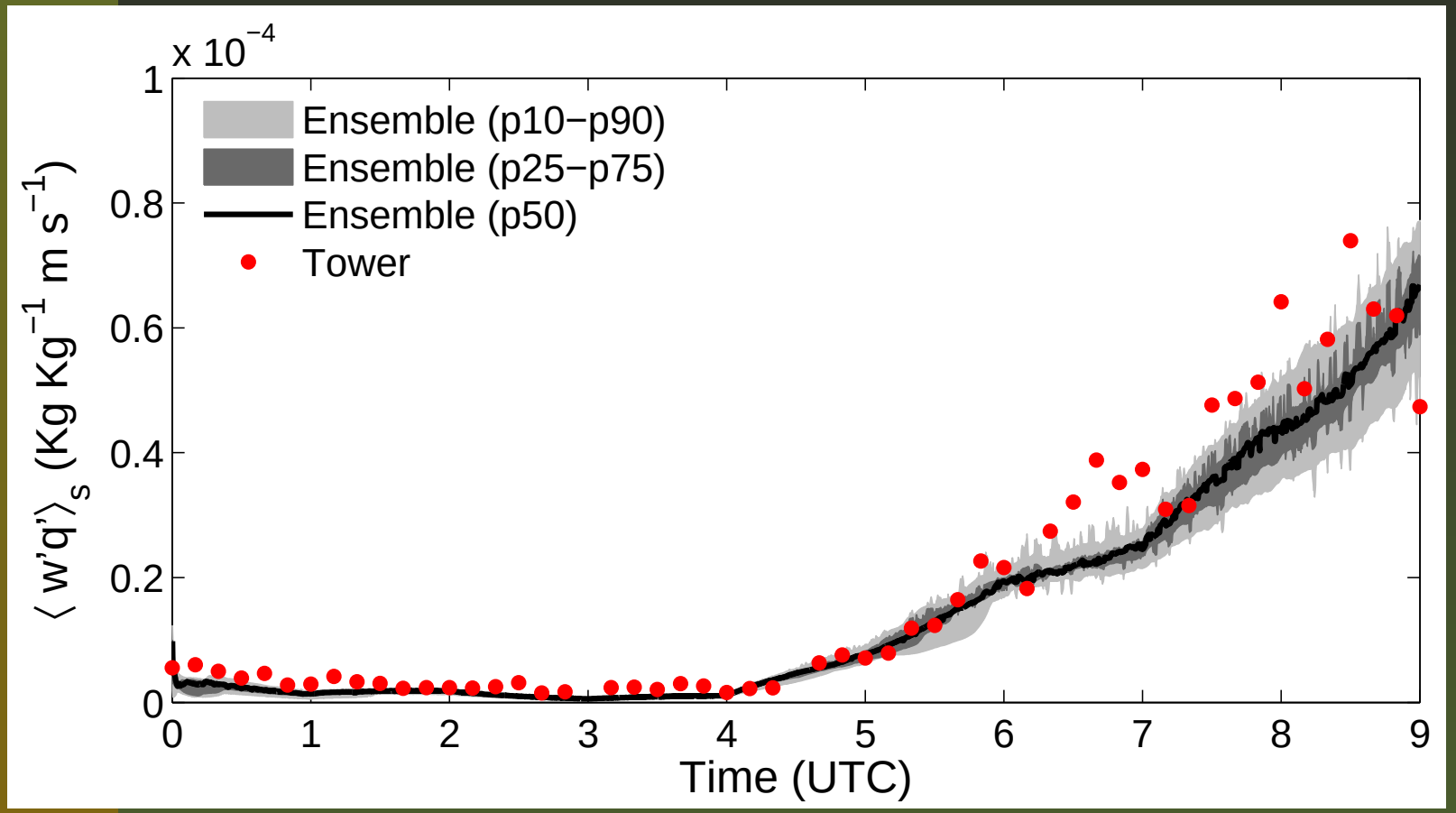
Surface Friction Velocity



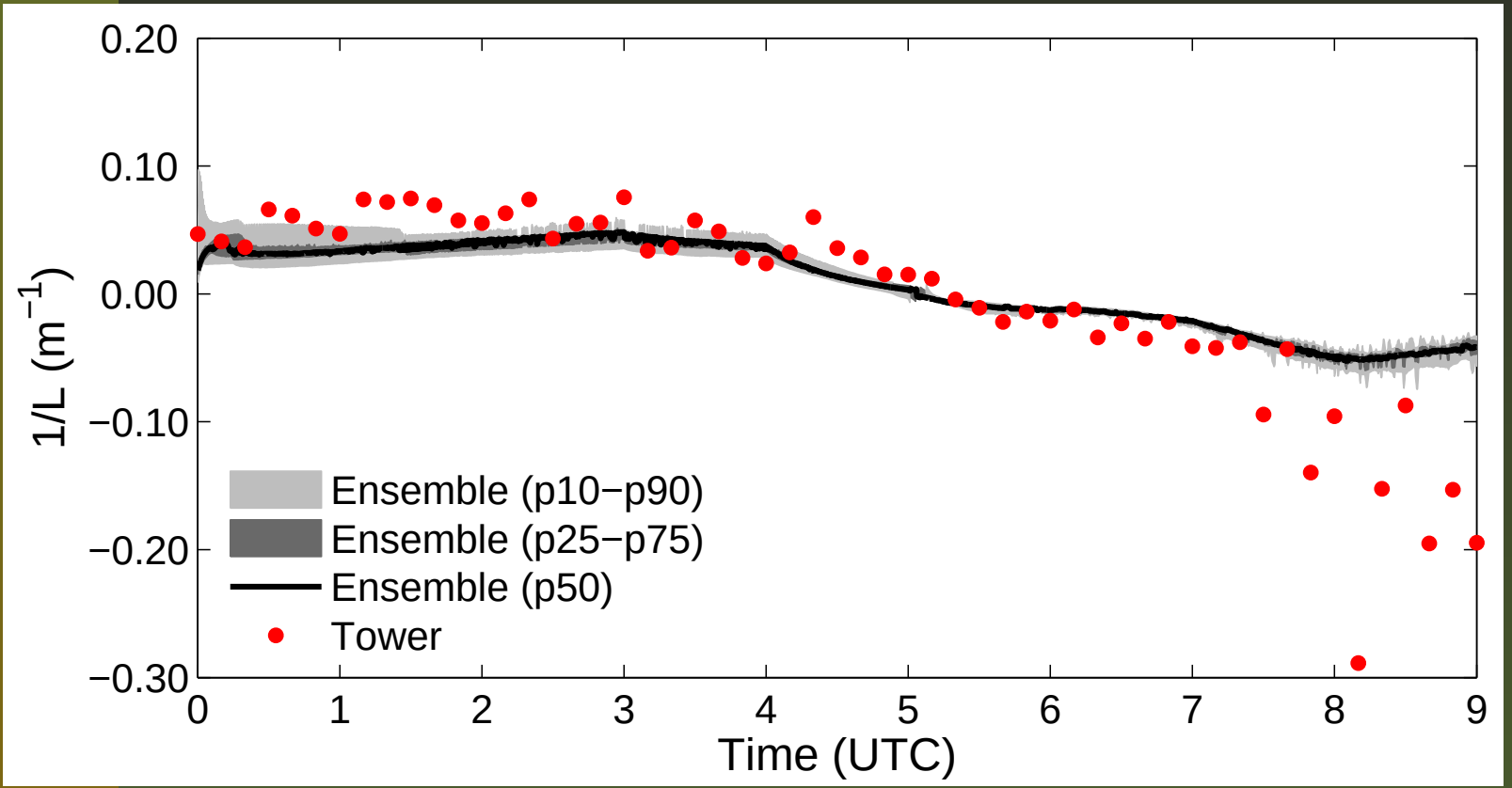
Surface Sensible Heat Flux



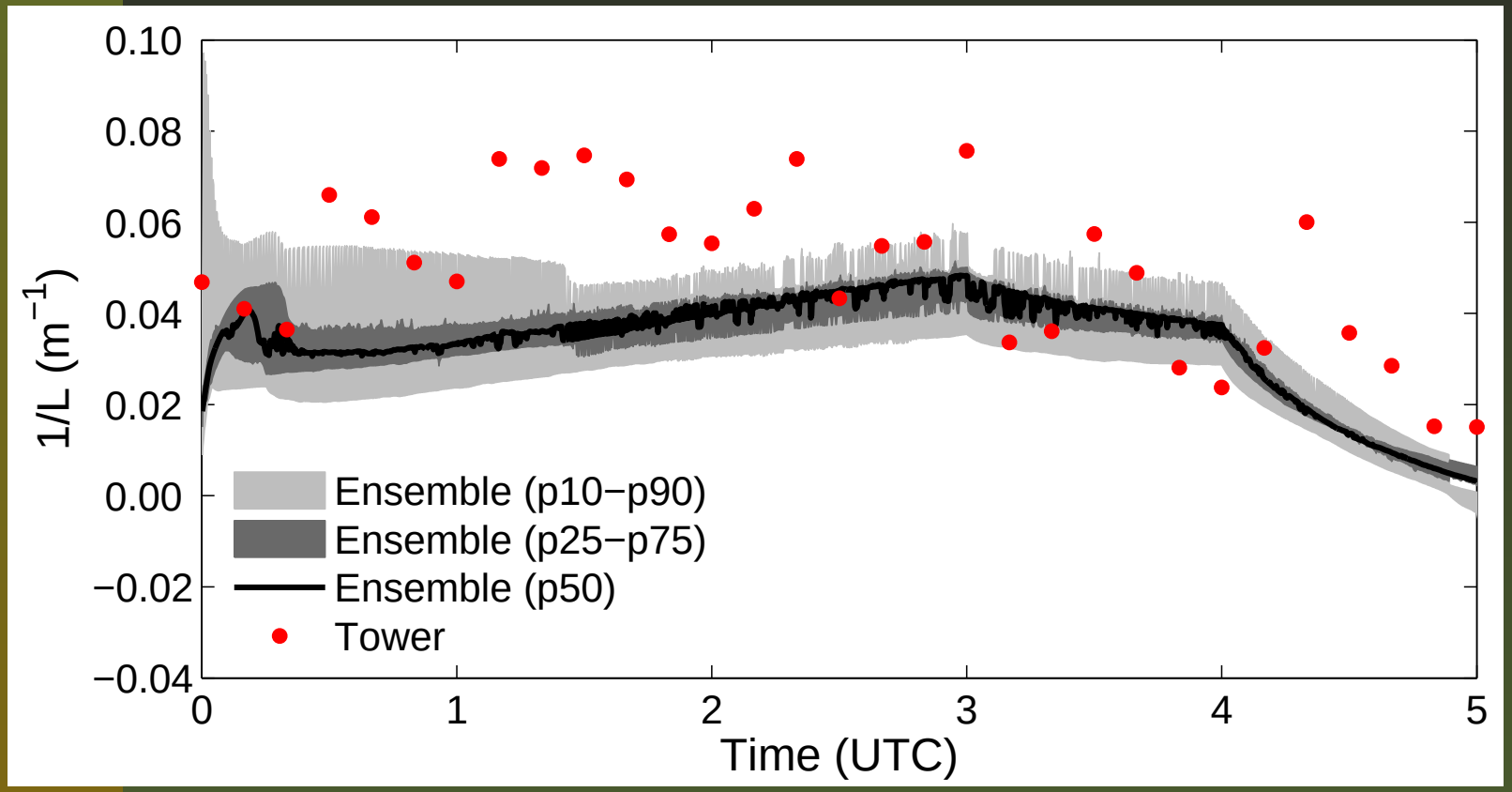
Surface Latent Heat Flux



Obukhov Length



Obukhov Length (Cont.)



Local Friction Velocity (3-4 UTC)

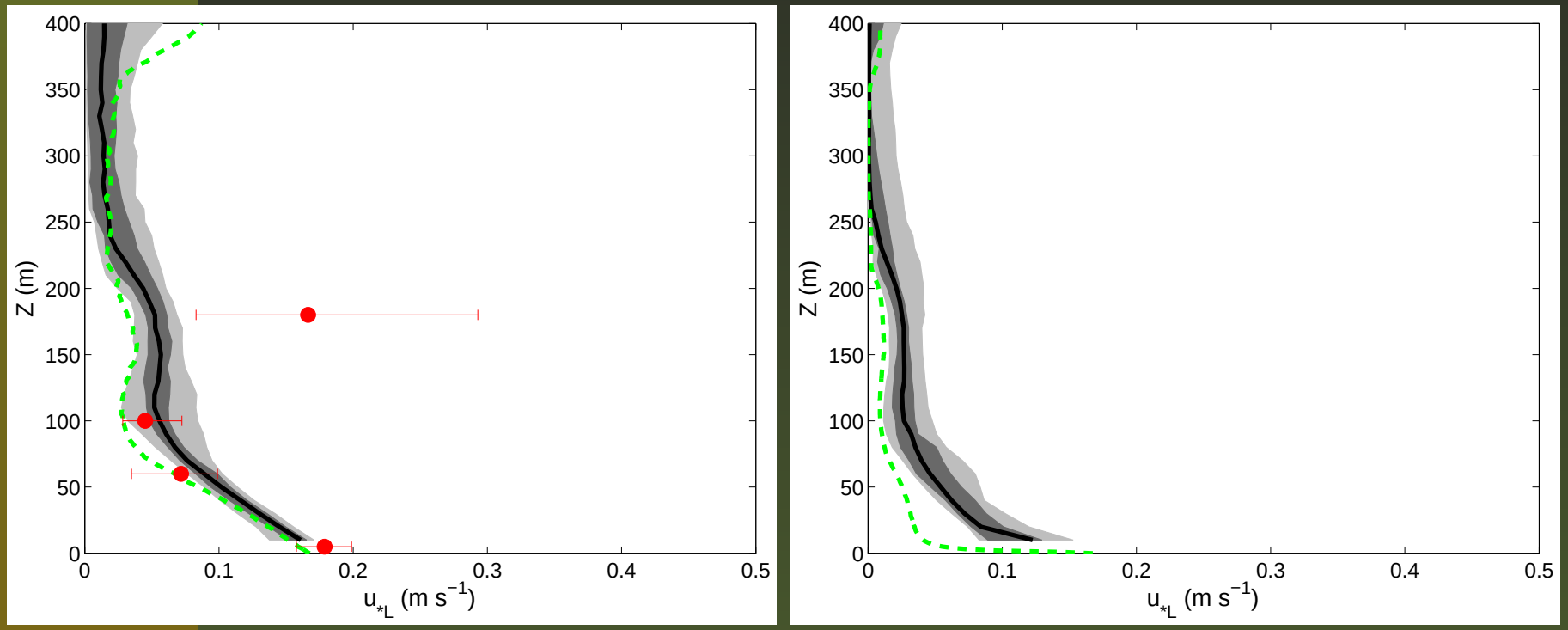


Figure 29: Left panel: total flux; right panel: SGS flux.

Local Friction Velocity (5-6 UTC)

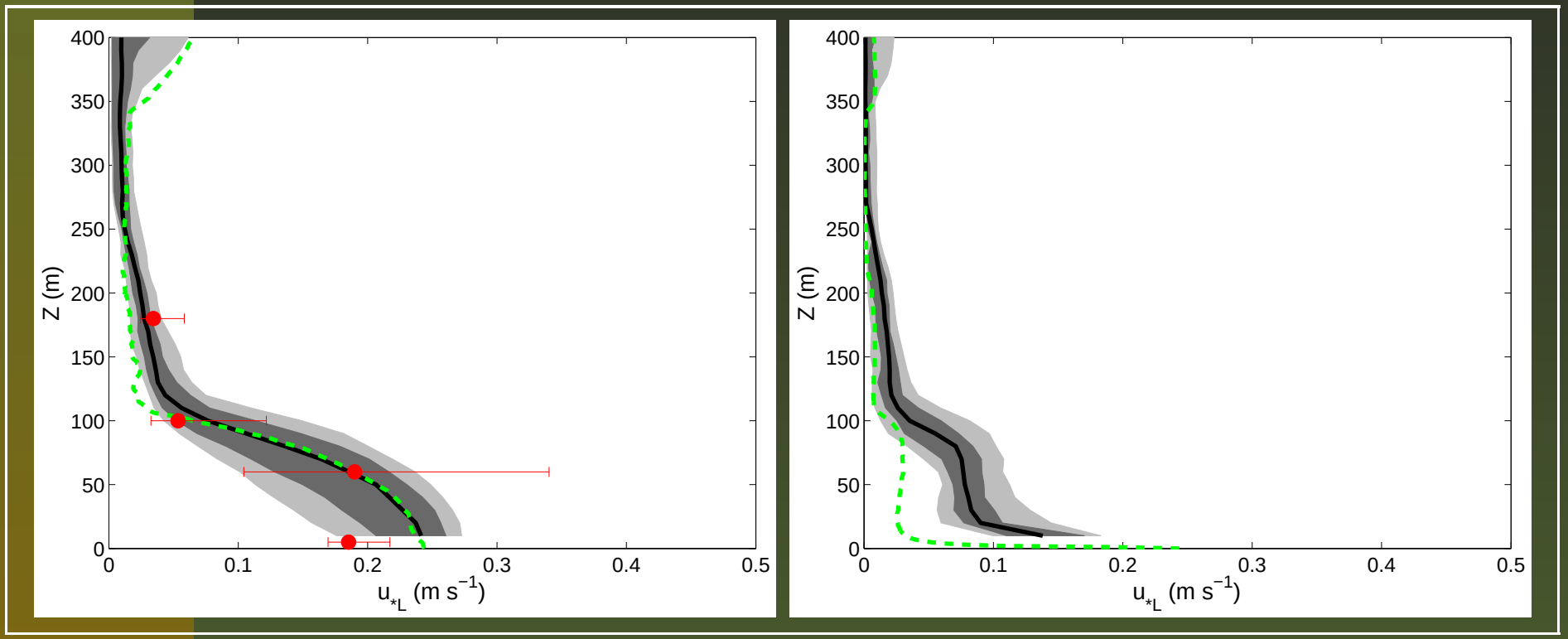


Figure 30: Left panel: total flux; right panel: SGS flux.

Local Friction Velocity (8-9 UTC)

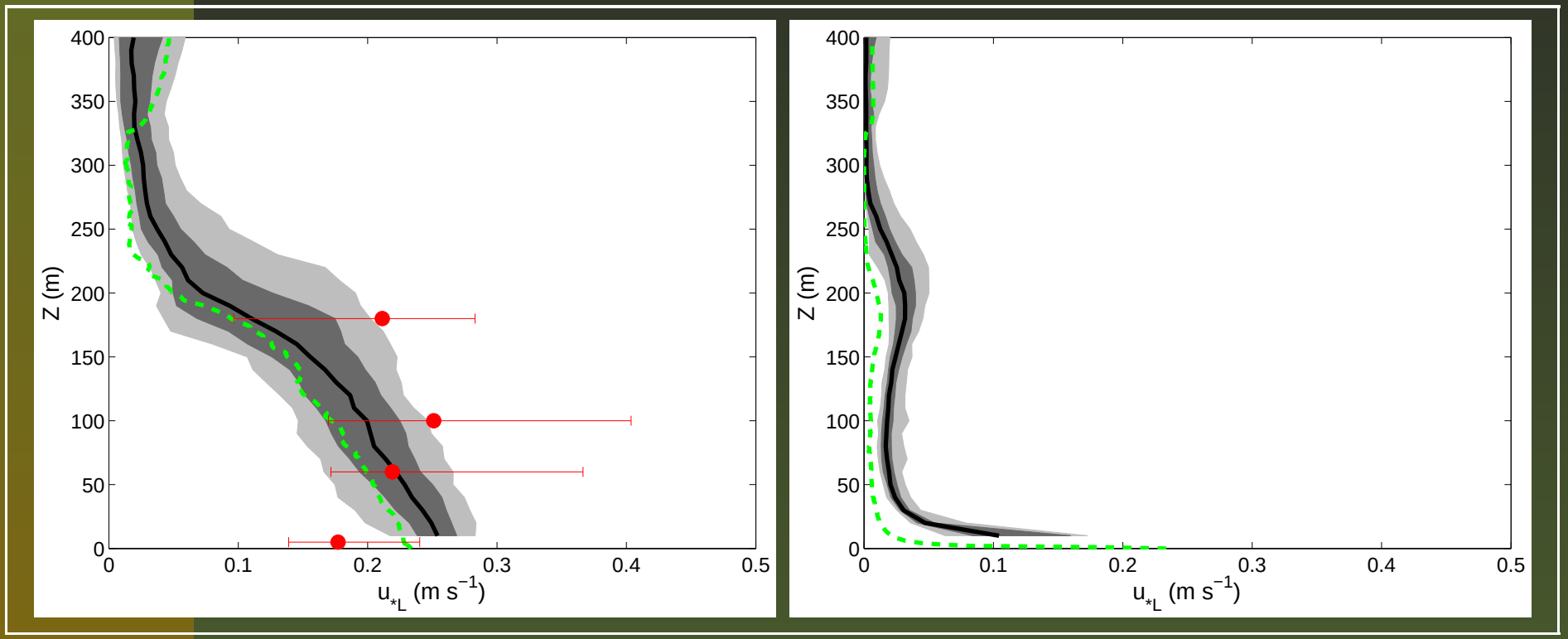


Figure 31: Left panel: total flux; right panel: SGS flux.