A coupling strategy to run daily cycle simulations of thermally stratified flows over forests

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Outline

Daily cycle modeling of stratified flows over forest

- Turbulent transport decreases inside forests. Isolating temperature at ground level from the wind above the forest.
- To impose a time dependent ground temperature is an ineffective methodology to run daily cycles in a forested wind farm.
- Along the day radiation is absorbed/emitted by the forest.
- Temperature evolution is driven by the prescribed radiative heat flux at the top of the canopy; obtained from field measurements.

Daily cycle modeling of stratified flows over forest

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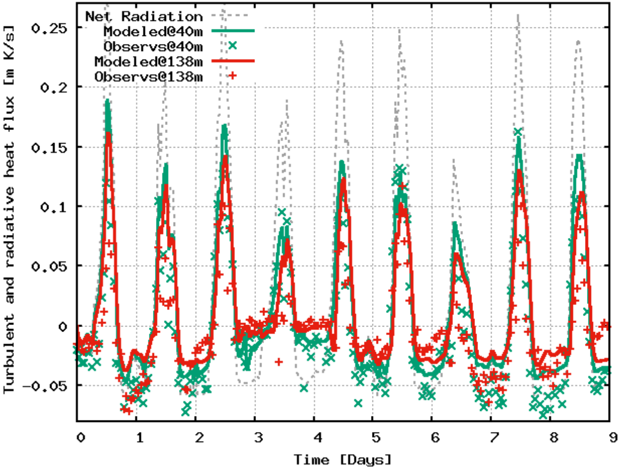
- Temperature evolution is driven by the prescribed radiative heat flux at the top of the canopy; obtained from field measurements.
- We assume a radiative heat flux decreasing inside the canopy (Following Brown and Covey (1966). Radiation penetrates different layers of the canopy.

Modeling of thermally stratified flows over forested site

- Modelling of flat Ryningsnäs forested site. Height of forest $z_c = 20m$. LAI=3.
- A prescribed radiative heat flux at the top of the canopy $Q_(z_c, t)$, obtained from field measurements, drives the heat transport through the Armospheric Boundary Layer.
- Pressure gradient, obtained from mesoscalar simulation, drives the wind velocity in the ABL.
- No slip velocity and fixed temperature at the ground.
- Humidity is not modelled.

Measured radiative heat flux is imposed at canopy top

Turbulent heat flux at 40m and 138 agl along 9 days.

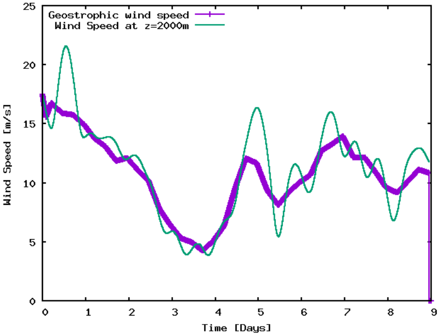


- Large differences of heat fluxes found during nights at 40 m.

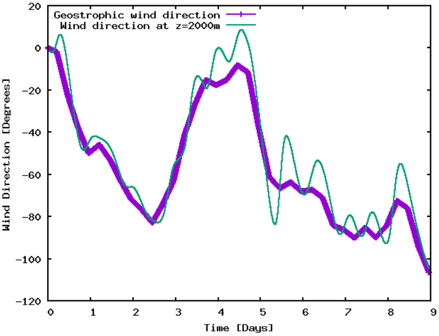
Daily cycle simulation

Imposed geostrophic pressure gradient, from WRF, driving the flow

Wind Speed



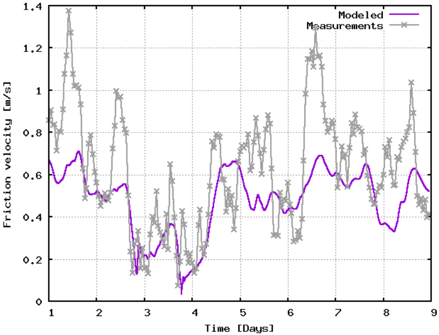
Wind Direction.



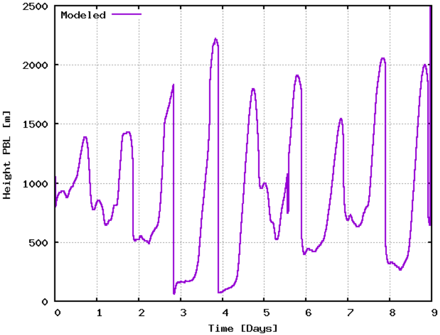
- Geostrophic pressure gradient is assumed as uniform.

Daily cycle simulation

Friction Velocity



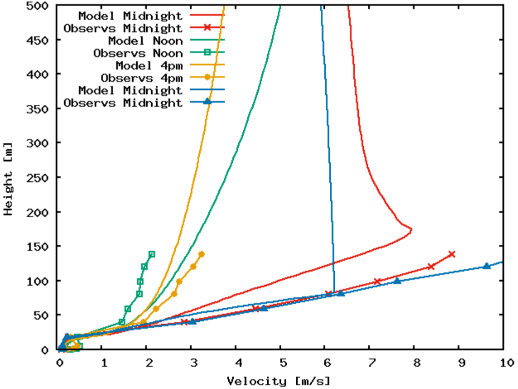
Height of PBL.



- Friction velocity determined from 40 m sonic as $\overline{u'w'}$
- Large variations of height of PBL from day to night.
- Lower height of PBL during 3rd and 4th nights due to the low geostrophic wind speed may indicate strong nocturnal stratification.

Daily cycle simulation. Results vs measurements.

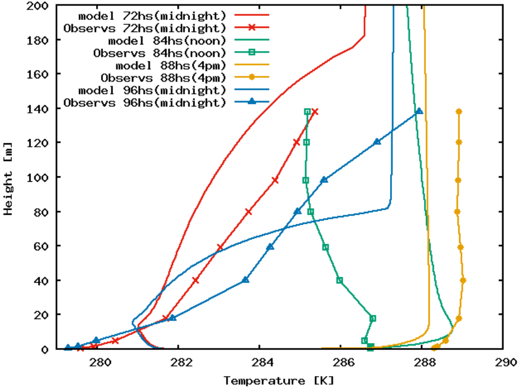
Velocity Profiles at different times along 4rd day



- Nocturnal boundary layers too shallow compared to measurements.

Daily cycle simulation. Results vs measurements.

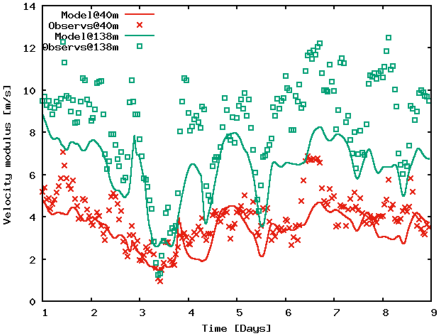
Temperature profiles at different times along 4rd day



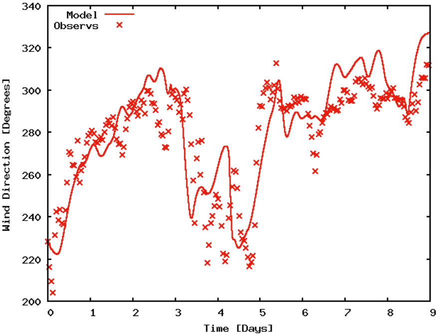
- Similar modeled and measured temperature gradients.
- Opposite temperature gradient found inside the forest at midnight.

Daily cycle simulation. Time series.

Wind Speed at 40m and 138m agl



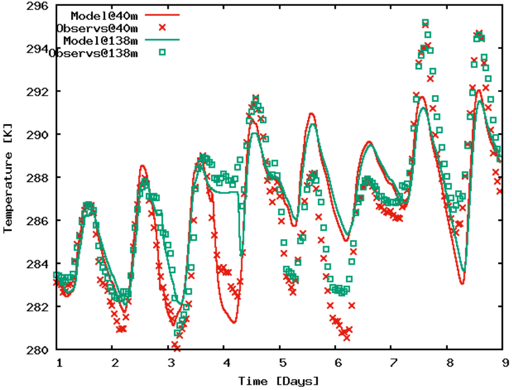
Wind Direction a 138m agl.



- Reasonably good agreement at lower height z=40m
- Underestimation of wind speed during nightime at height 138m. Maybe because nocturnal boundary layers are modeled too shallow.

Daily cycle simulation. Time series.

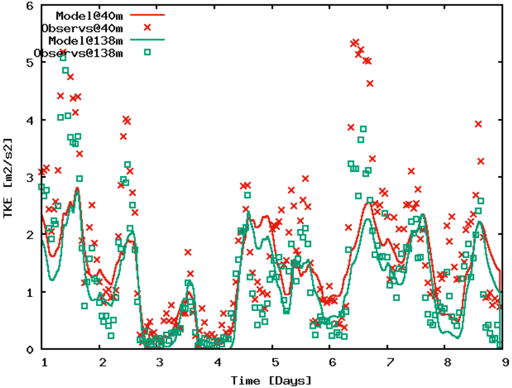
Temperature at 40m and 138m agl



- Although temperature is held constant at ground level, temperature variation above the forest is well captured by the model.

Daily cycle simulation. Time series.

Turbulent Kinetic Energy at 40m and 138m agl.



- Strong variations of TKE from day- to night-time
- TKE is underestimated at noon.

Conclusion

- A methodology for full daily cycle simulation over forested terrains has been presented. Which uses mesoscalar results or wind measurement data.
- Very simple coupling prescribing net radiative heat flux balance at the top of the canopy, and geostrophic pressure gradient.
- Reasonably good agreement against measurements. Capture of convective and stably stratified profiles.
- Future work is to extend this methodology to complex terrain.
- Details of the methodology have been submitted to wake conference.

Thank you!