Simulating the morning transition of flow over the Eastern Snake River Plain

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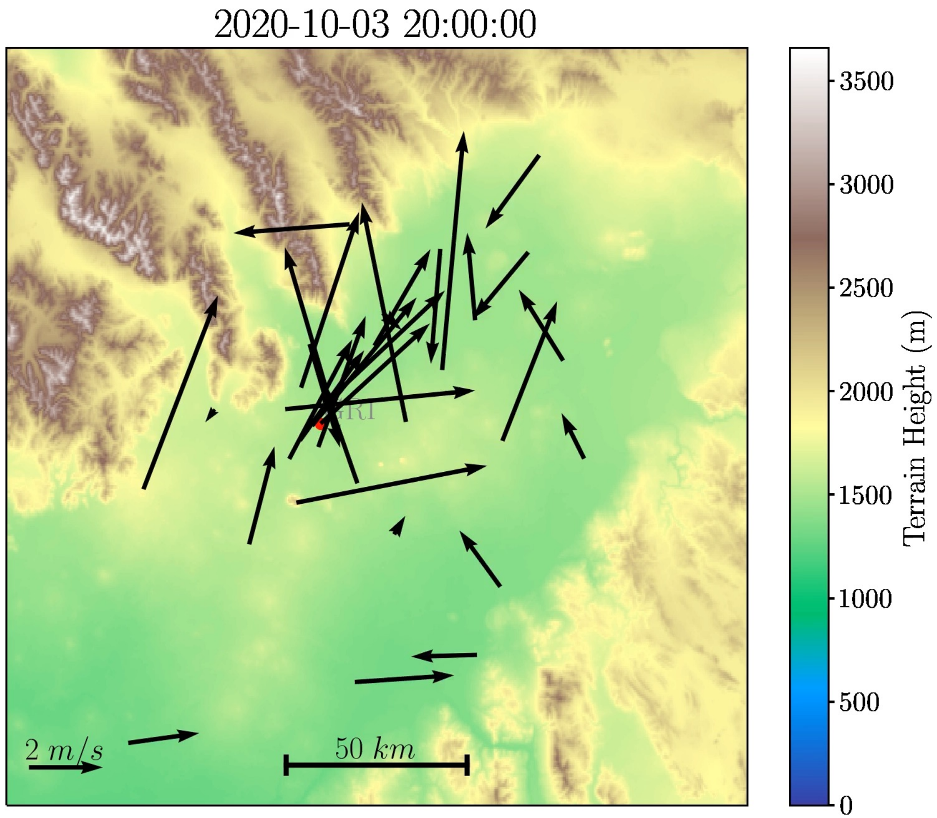

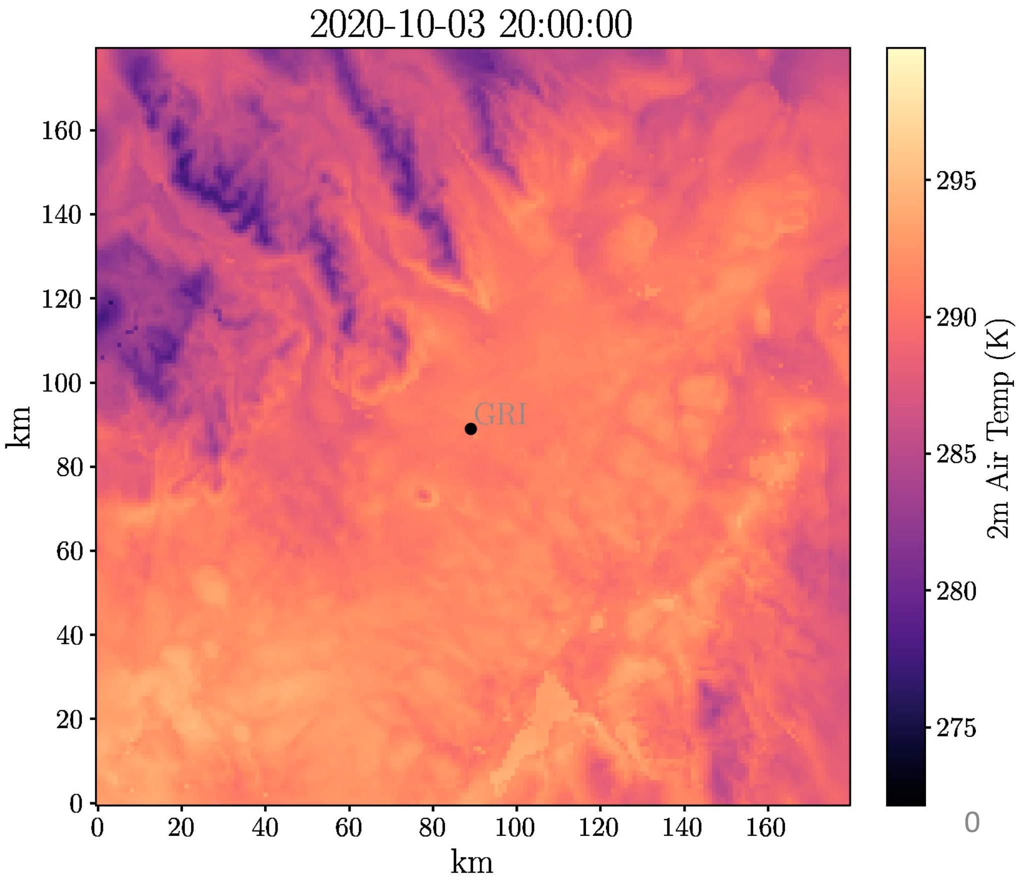

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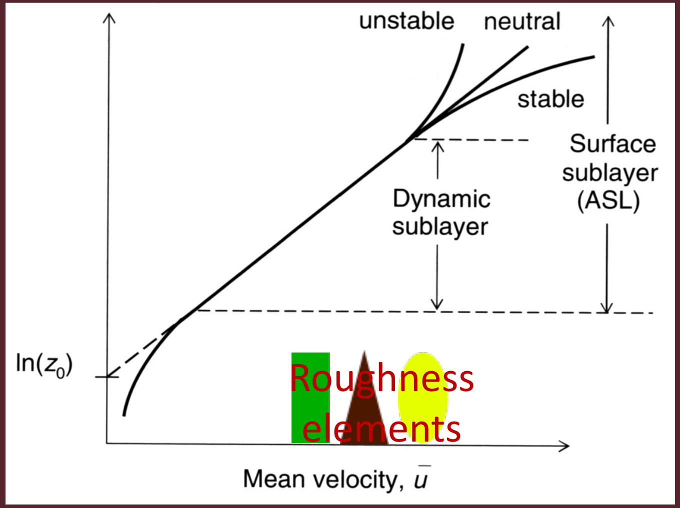
Effects of topography features

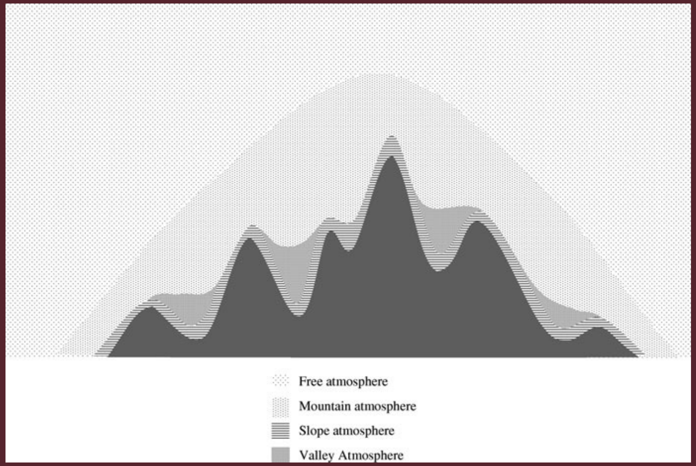
"perfect site" :
Flat, uniform and horizontally-homogeneous

Real terrain

"imperfect site" :
Complex terrain, spatially-inhomogeneous



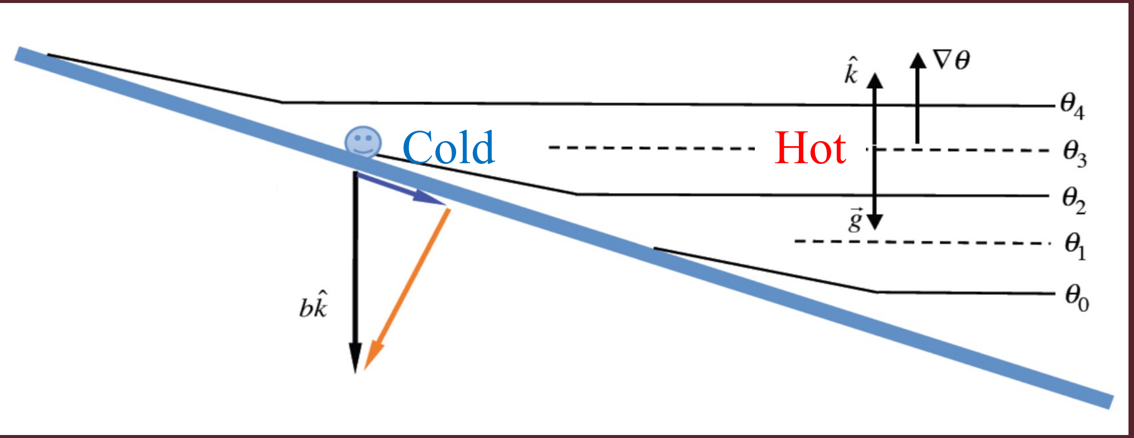
(Online photo)



Local circulation could complicate the land-atmospheric interaction processes and result in deviation from the MOST-based parameterizations.

Thermally-driven slope wind system

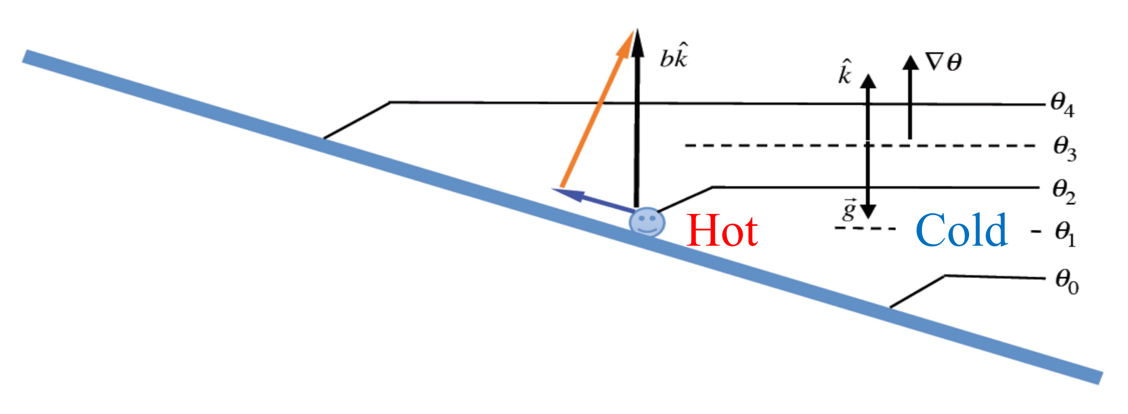
Katabatic case (nighttime)



$$b = \frac{g}{\theta_r}[\theta_2 - \theta_3] < 0$$

Buoyancy forces pushes the air parcel downward.

Anabatic case (daytime)



$$b = \frac{g}{\theta_r}[\theta_2 - \theta_1] > 0$$

Buoyancy forces pushes the air parcel upward.

Why does the diurnal slope wind system matter?

- The distribution of air temperature
- Air quality forecasts
- Local weather forecasting
- Wind farms
- Agriculture
- Low clouds/fogs

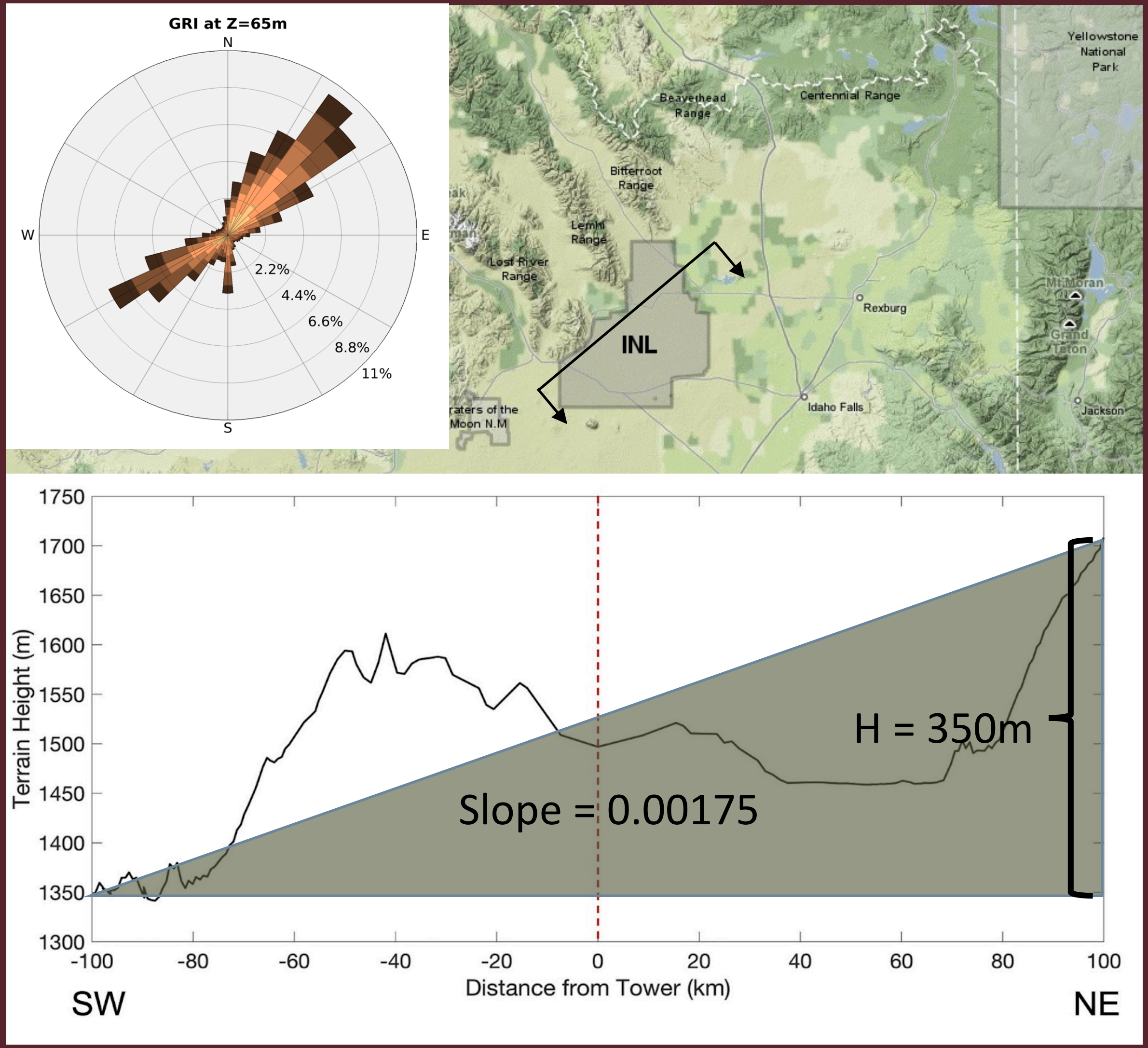
Challenges & Objectives

- The nocturnal boundary layer is hard to parameterize.
- One needs to prevent the “run-away” cooling in the model.
- The assumptions under MOST are violated.
- High-resolution land surface data are required.

We aim to explore the performance of numerical weather models in simulating the morning transition of flow over the terrain with a mild slope.

- How well can numerical models capture the local flow and temperature features under the influence of slope winds?
- What are the key factors that affect the simulation of the slope winds?

Study area: Eastern Snake River Plain



Geography features:

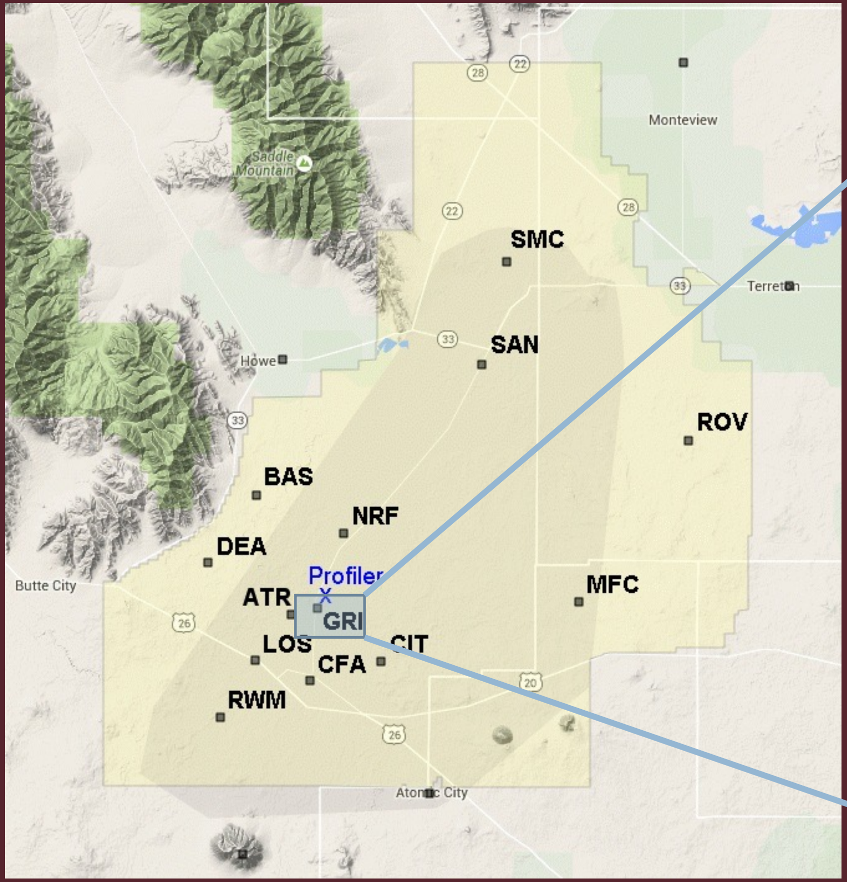
- Mid-latitude
- Bordered by high-rise mountains
- **Northeast-southwest oriented**
- **Very mild slope**
- Mostly covered by sagebrush

Climatology:

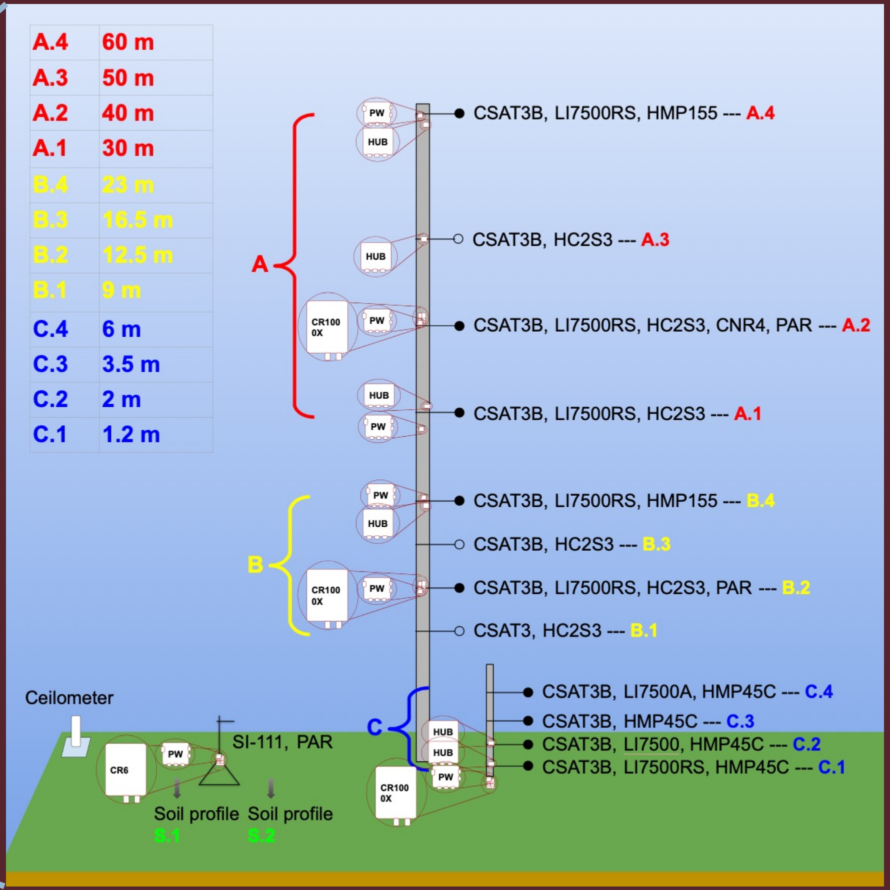
- Thermally-driven drainage flow during the night
- Westerly and channel winds during the day

Local observing network

INL Mesonet system



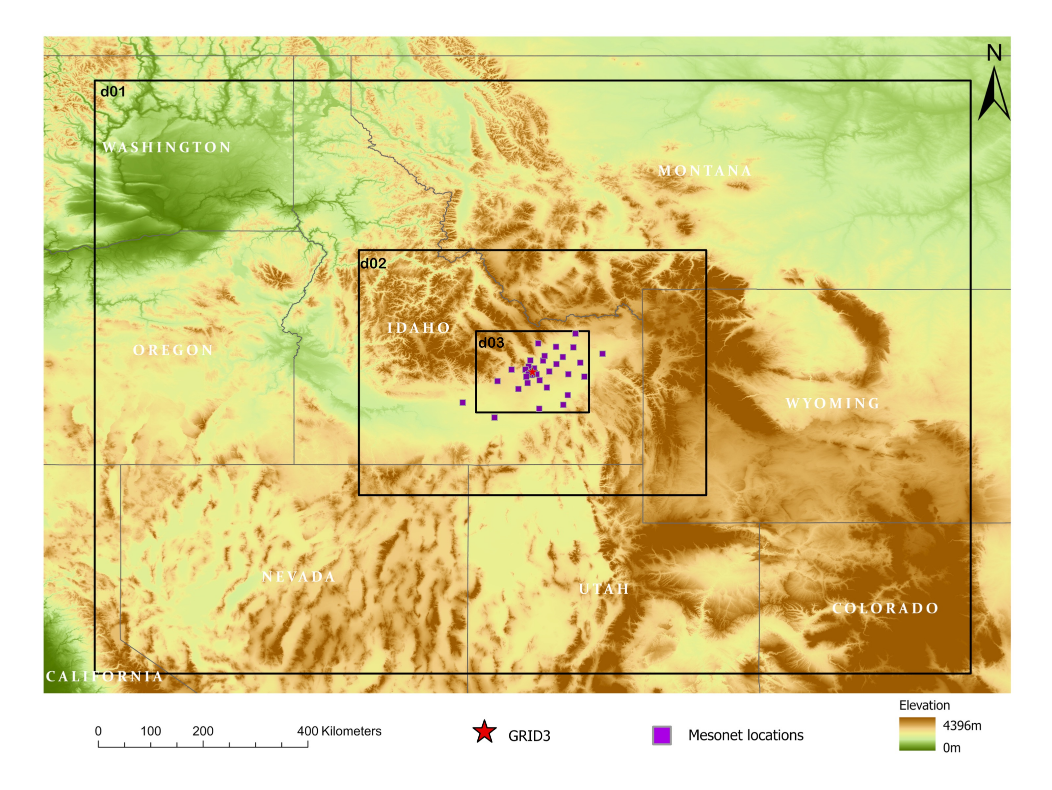
Eddy covariance at GRI



Clawson, K. L. et al. (2018) *NOAA Technical Memorandum OAR ARL*

WRF configuration

- D03 horizontal resolution: 1 km by 1 km
- Lowest model level: 10 m

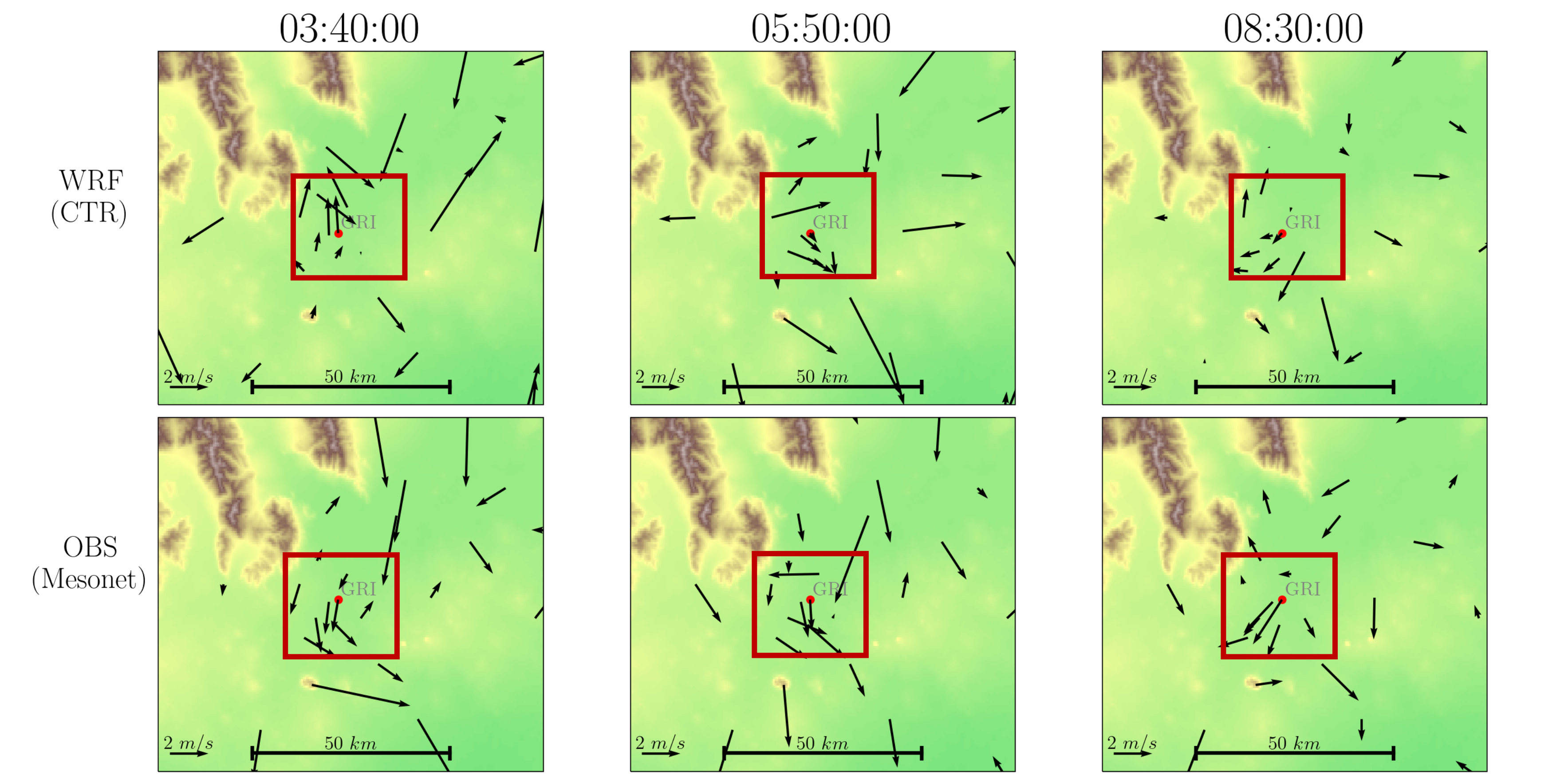


- Baseline simulation: 2020-10-04, 7h spin-up
  - NARR
  - RRTM radiation scheme
  - ACM2 PBL scheme
  - Pleim-Xiu LSM
  - Pleim-Xiu surface layer scheme
- Sensitivity test:
  - YSU, MYJ
  - Noah LSM
  - Revised MM5, Janjic Eta
  - Spin-up, grid spacing, initial soil conditions, FNL bc

Land surface dataset: topography (STRM_30m), land use (NLCD~270m), GVF (ASTER_15m)

Evaluation of the wind field

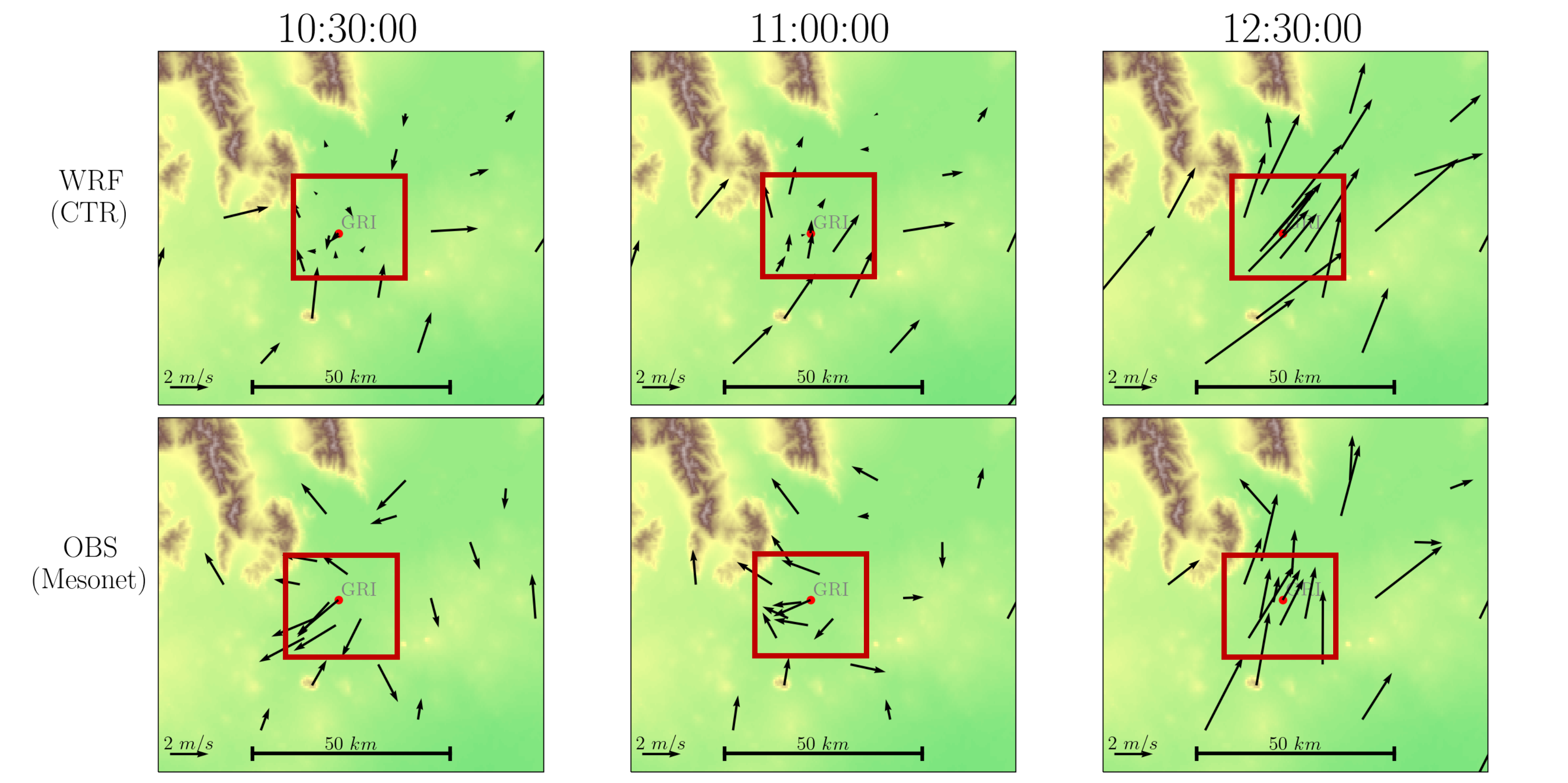
Before sunrise



Underestimation of the drainage flow (northeast and northwest)

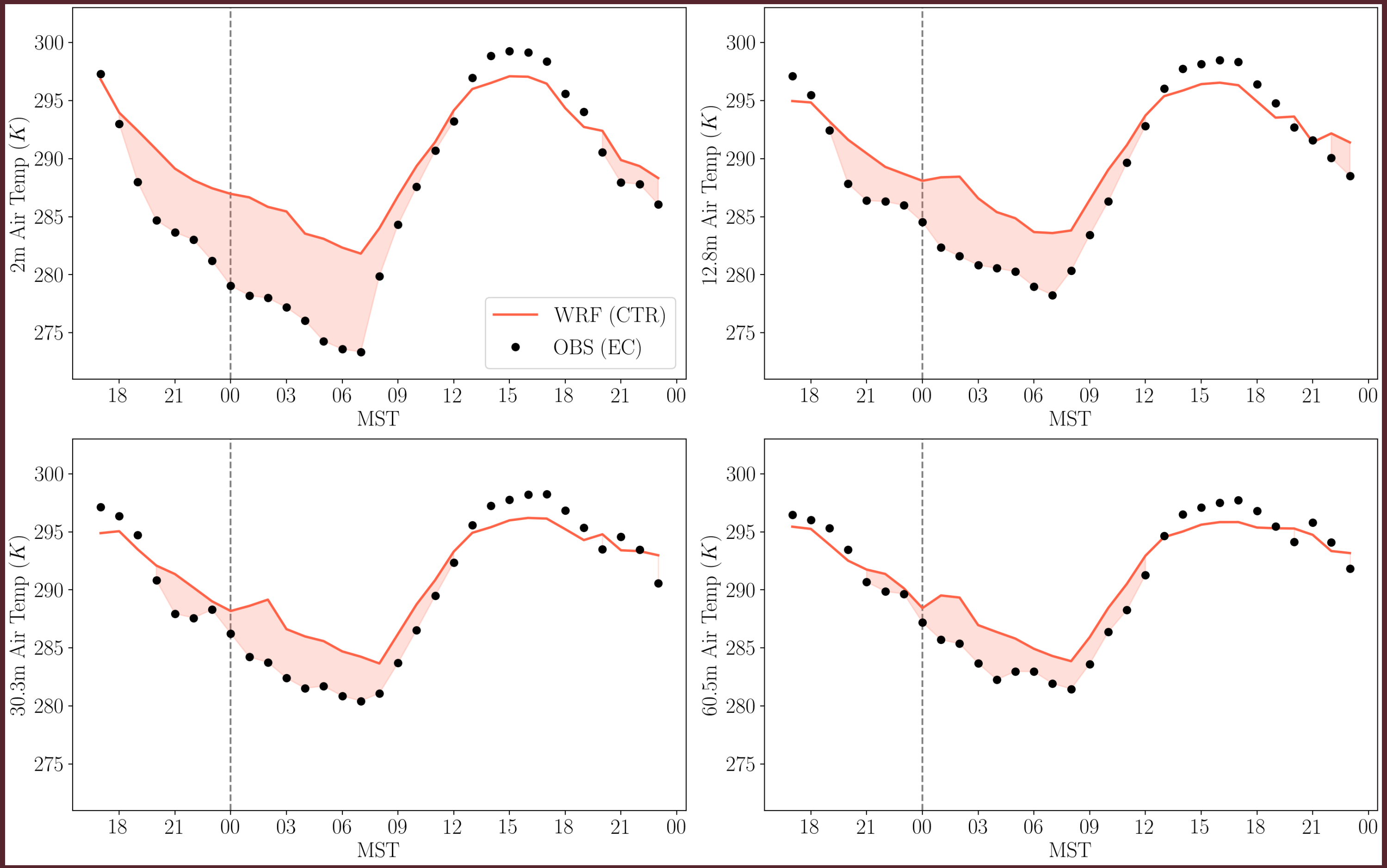
Evaluation of the wind field

After sunrise



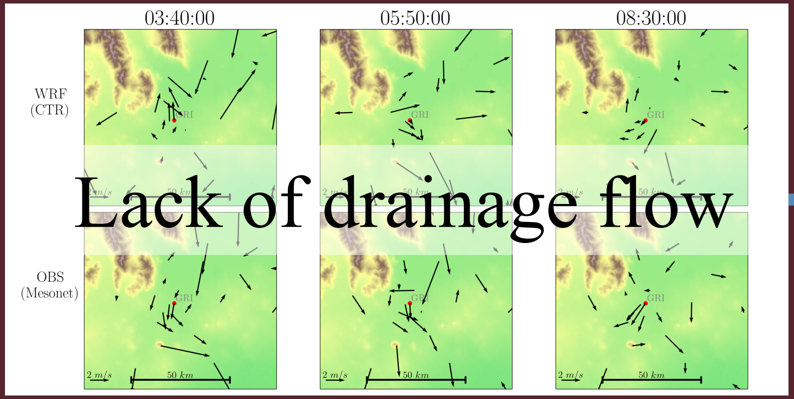
Earlier morning transition (from northeast to southwest)

Evaluation of the 2-m temperature

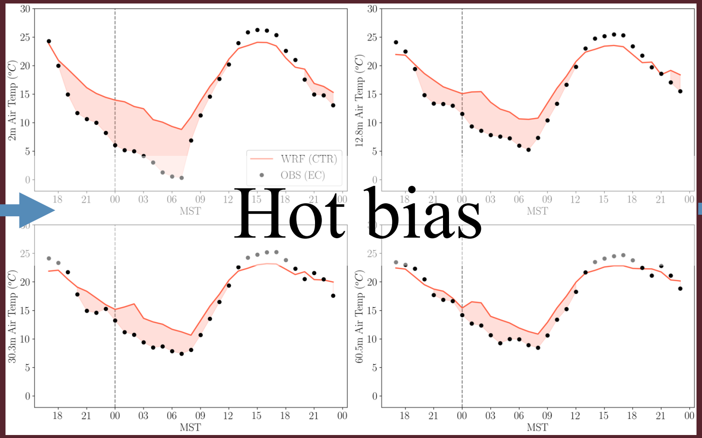


- Air temperature increases with height, namely, positive vertical temperature gradient.
- The hot bias accumulates throughout the night.
- The hot bias is the largest at the lowest level and gradually collapses when it goes up.

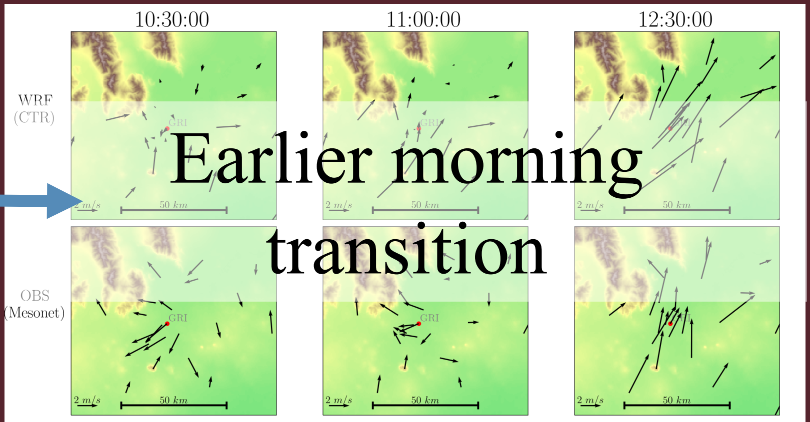
Connection between temperature and wind biases



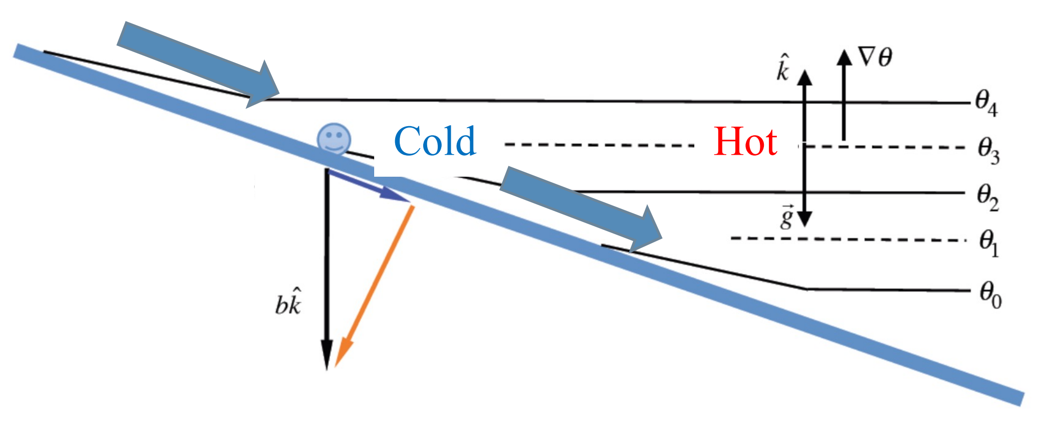
Lack of drainage flow



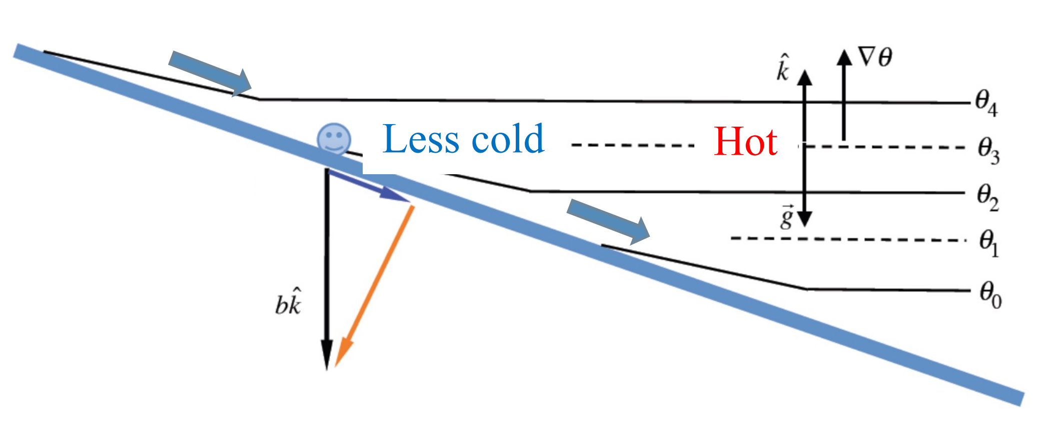
Hot bias



Earlier morning transition

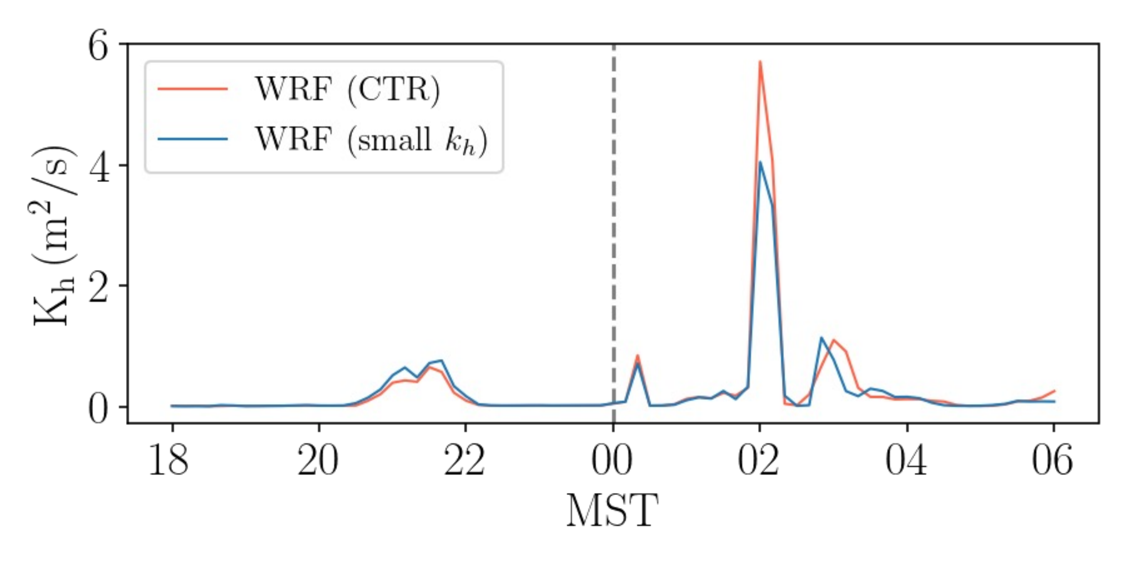


OBS: downslope wind sustained



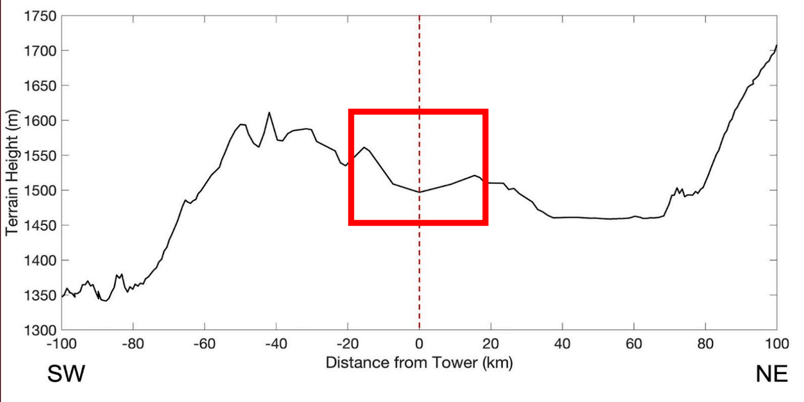
WRF: downslope wind weakened/ceased

Assumptions of the causes of “hot bias”



- To much turbulent mixing from above to the surface.

$$H = \overline{w'\theta'} = -\rho C_P K_h \frac{\partial \bar{\theta}}{\partial z}$$



- Under-resolving of local topography
  - Cold pool effect
  - Gravity waves

Summary

- WRF underestimates the drainage flow and significantly overestimate the near-surface temperature at night over the study area.
- There exists a feedback loop between the underestimation of cold air drainage effect and the hot bias at night, which in turns leads to an earlier reversal of wind direction in the morning transition.
- The parameterization of the eddy diffusivity in stably-stratified boundary layer generates over-mixing between the surface and atmosphere above. (needing further examination)

Any suggestions and remarks are very welcome!

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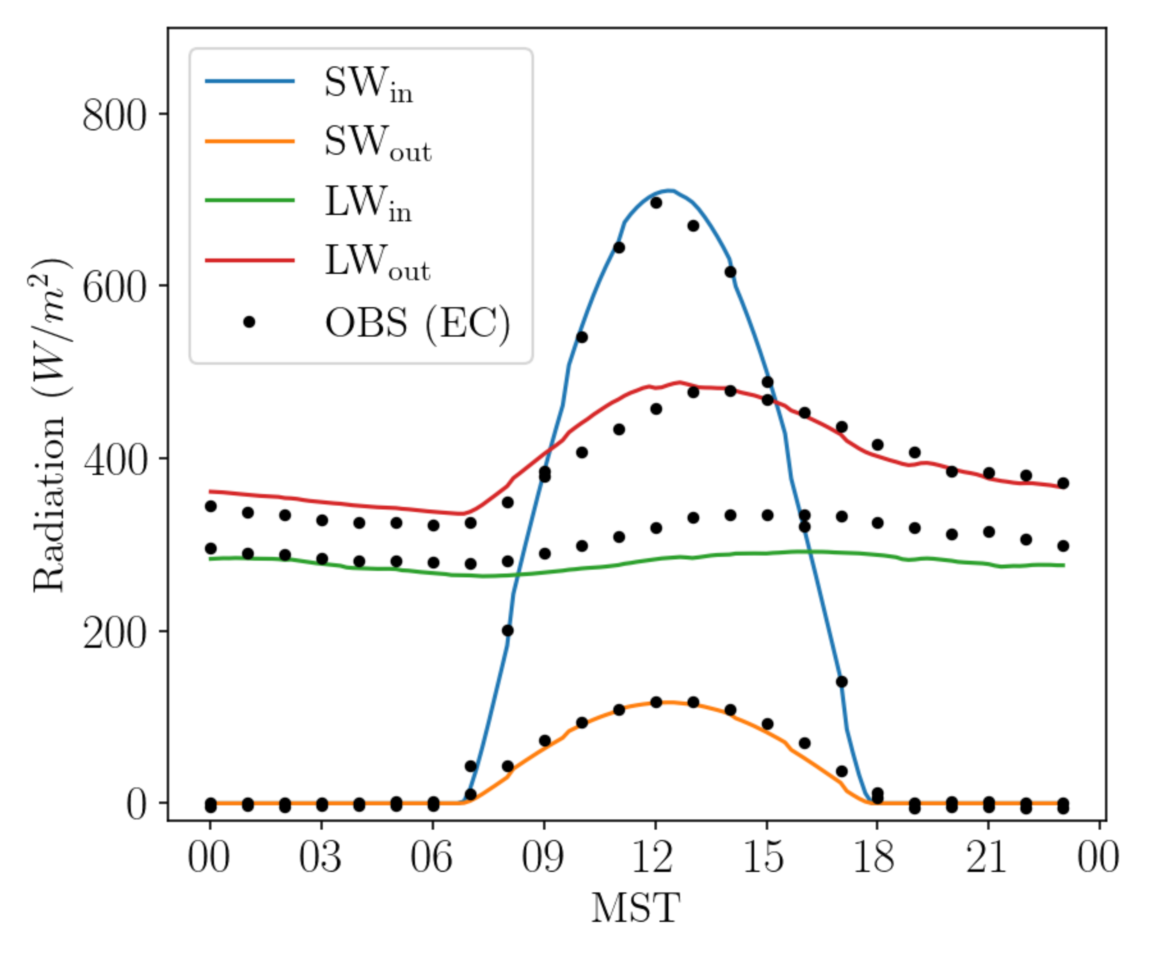
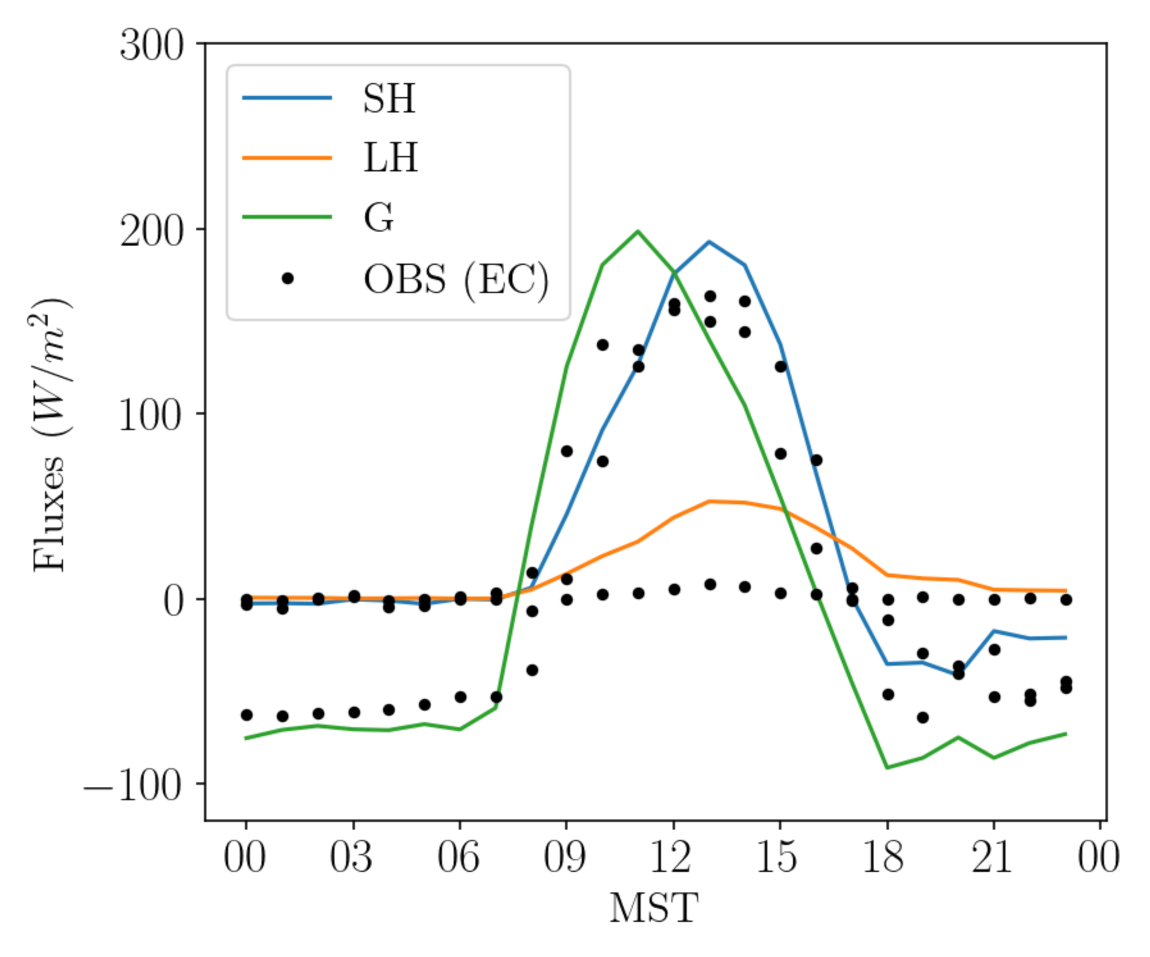
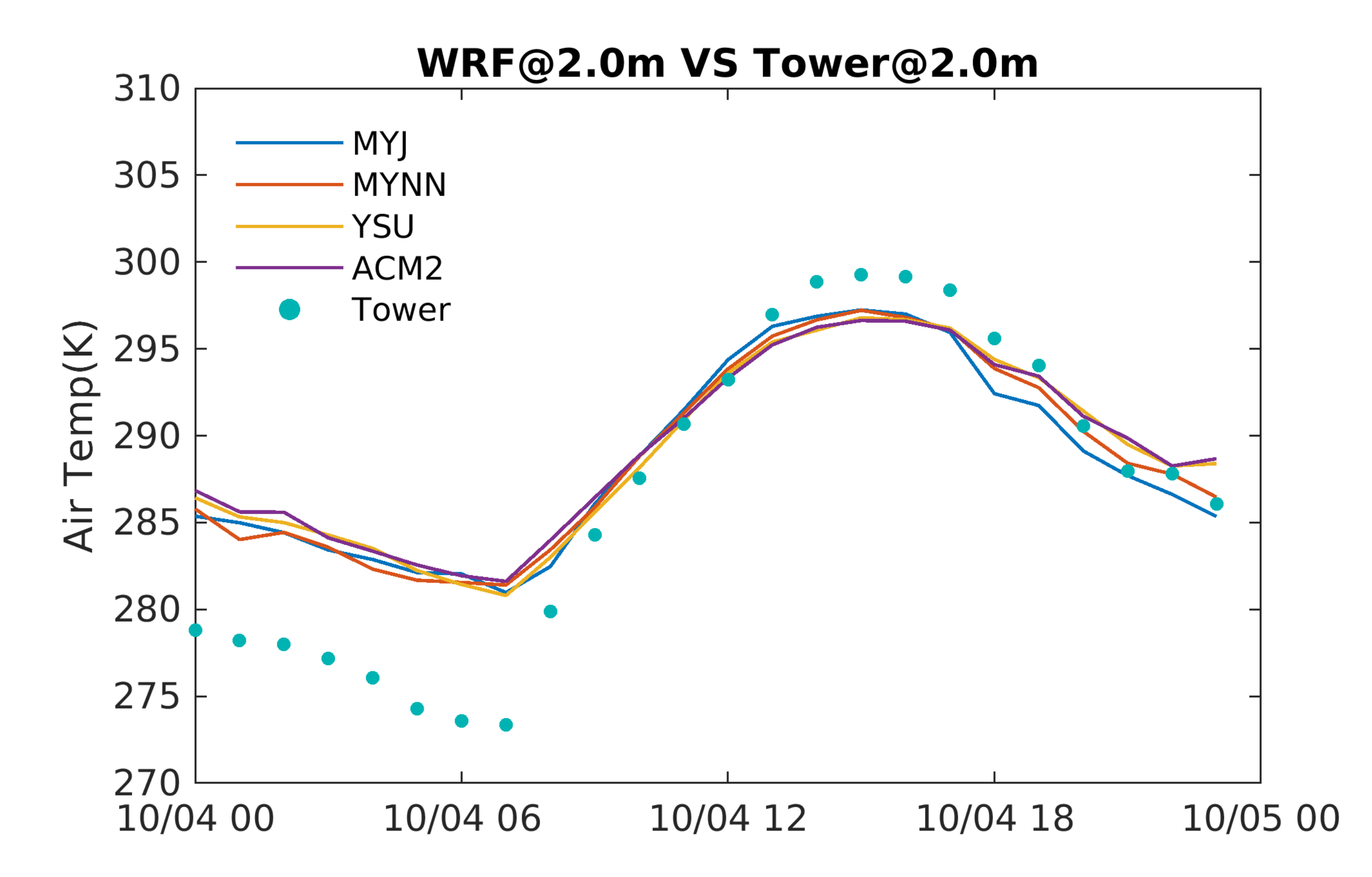
Radiation & Fluxes

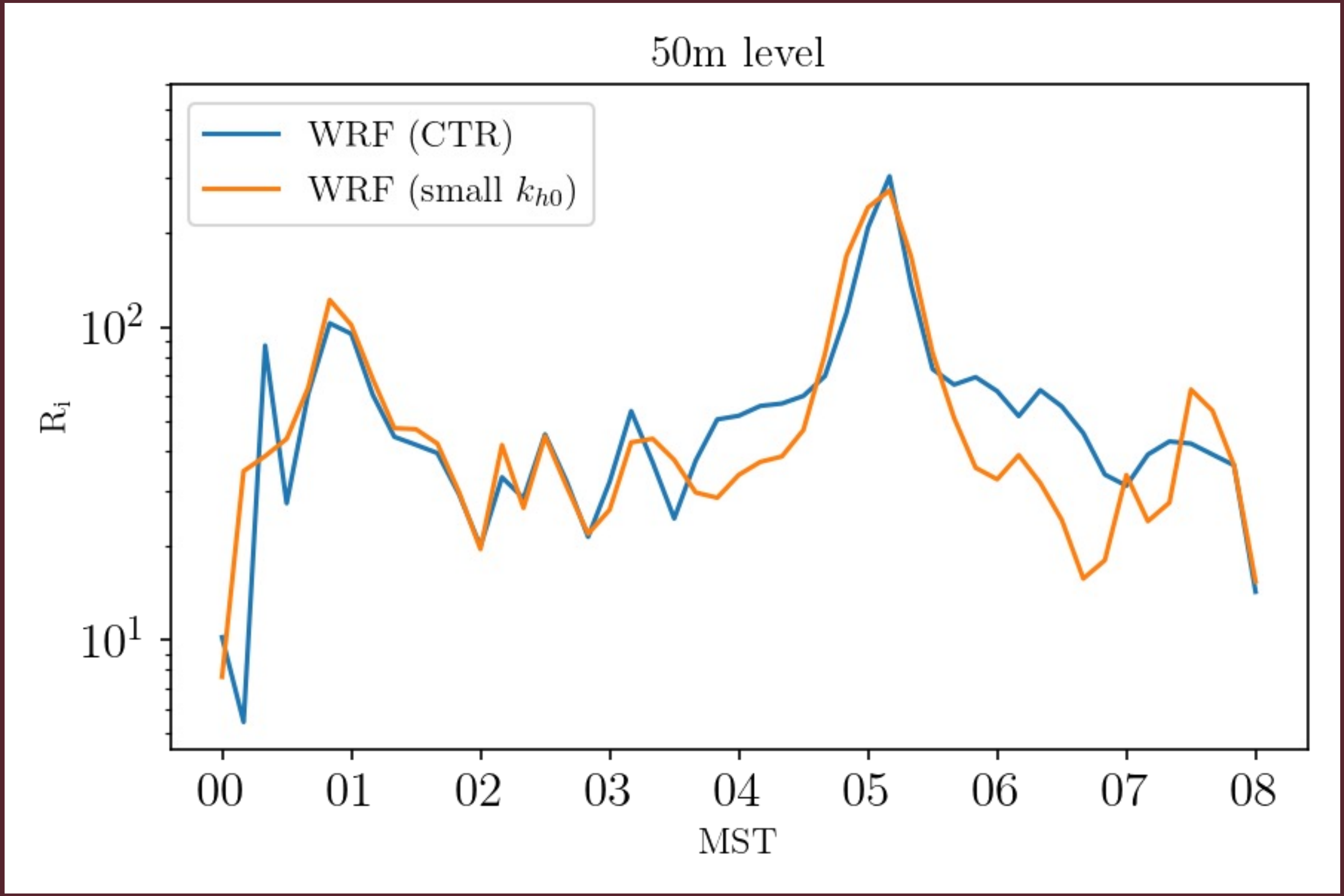




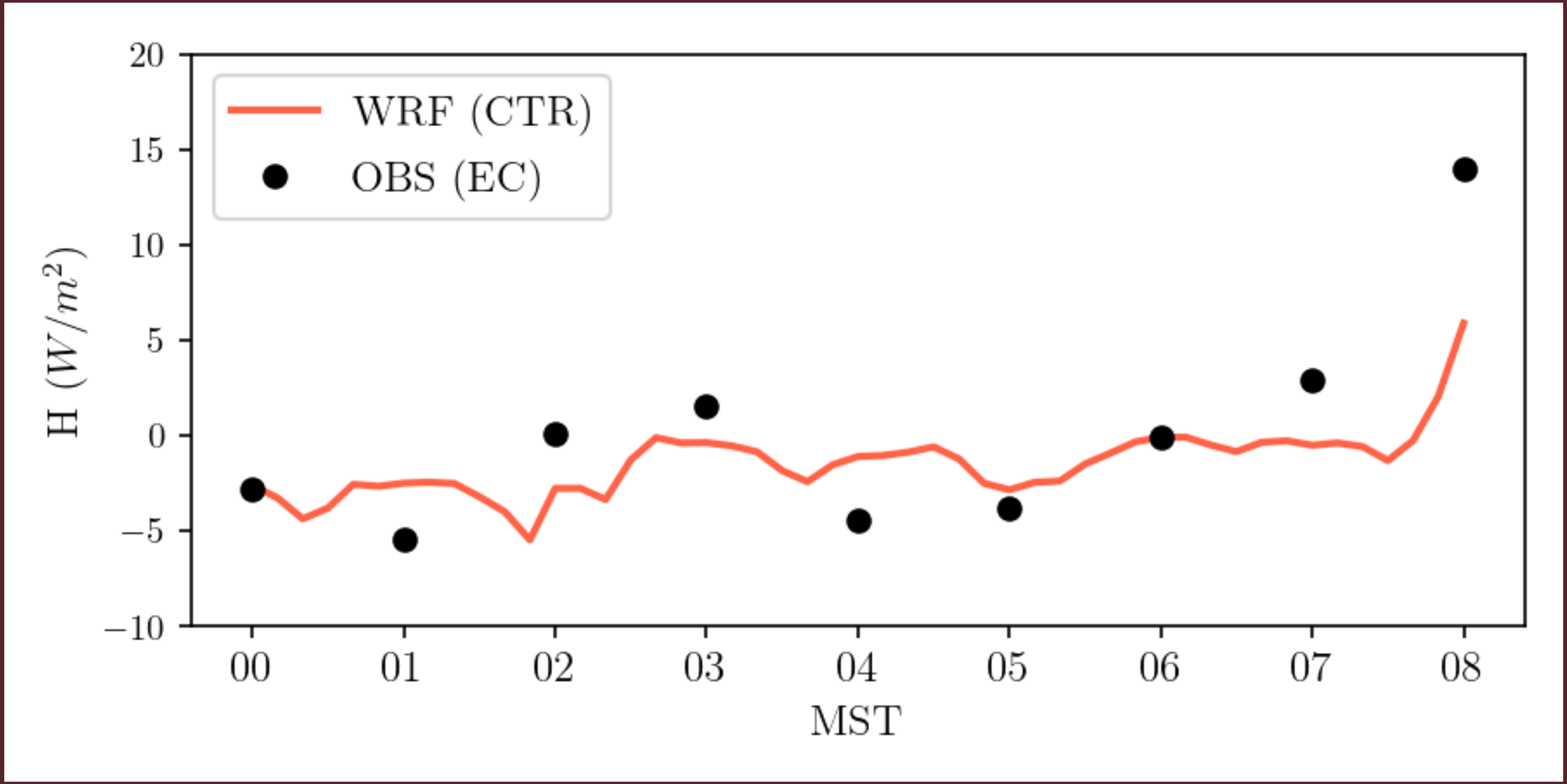
2-m temperature



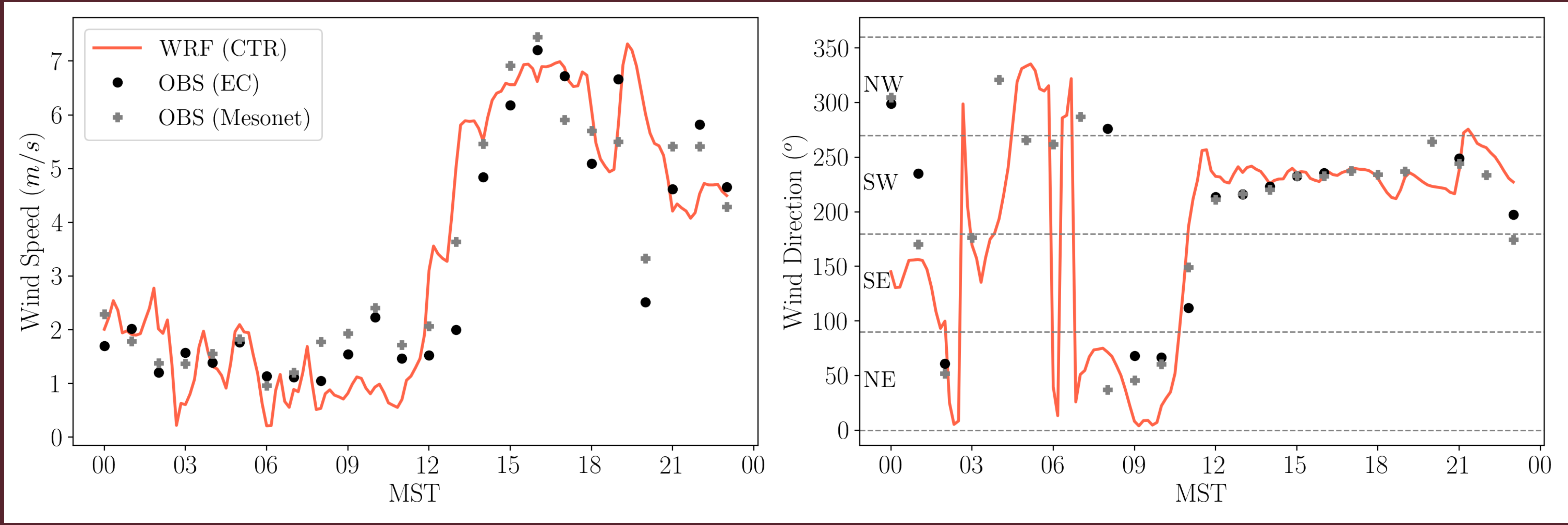
Richardson Number



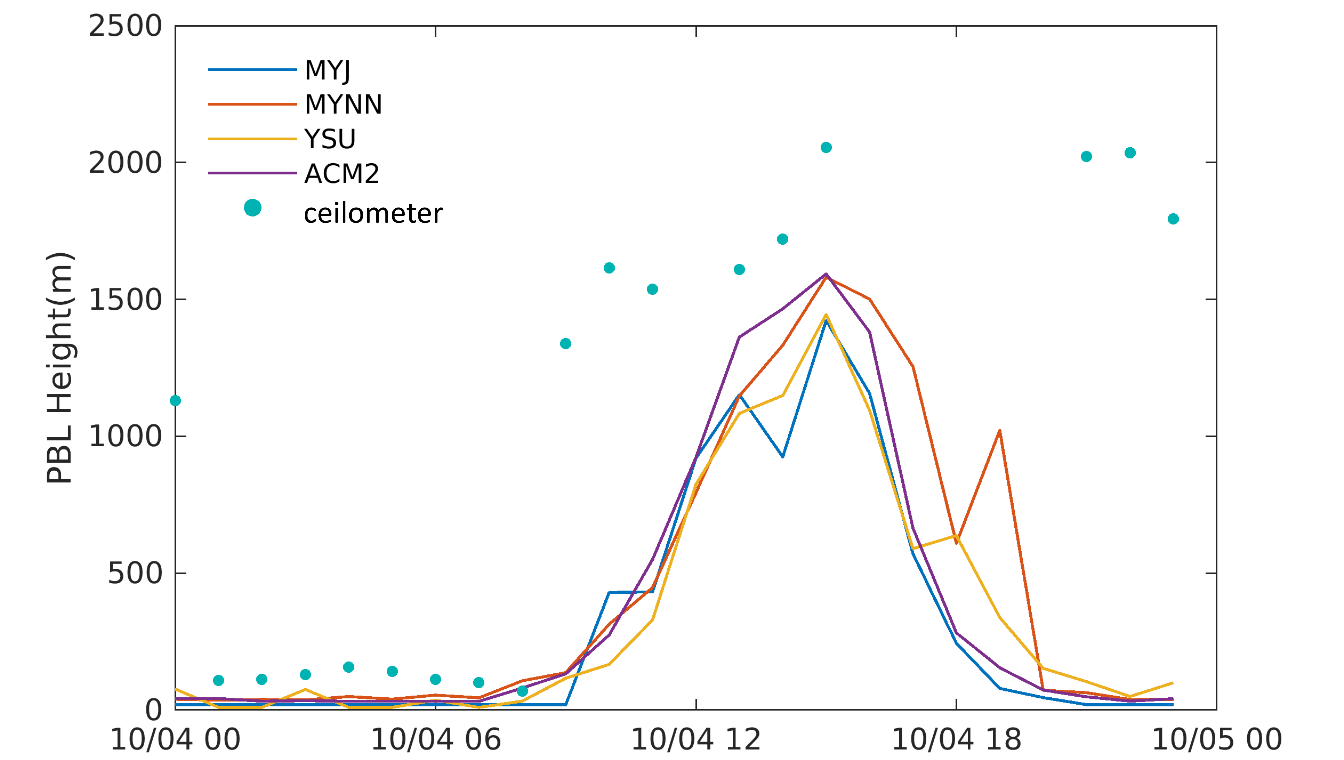
Sensible heat



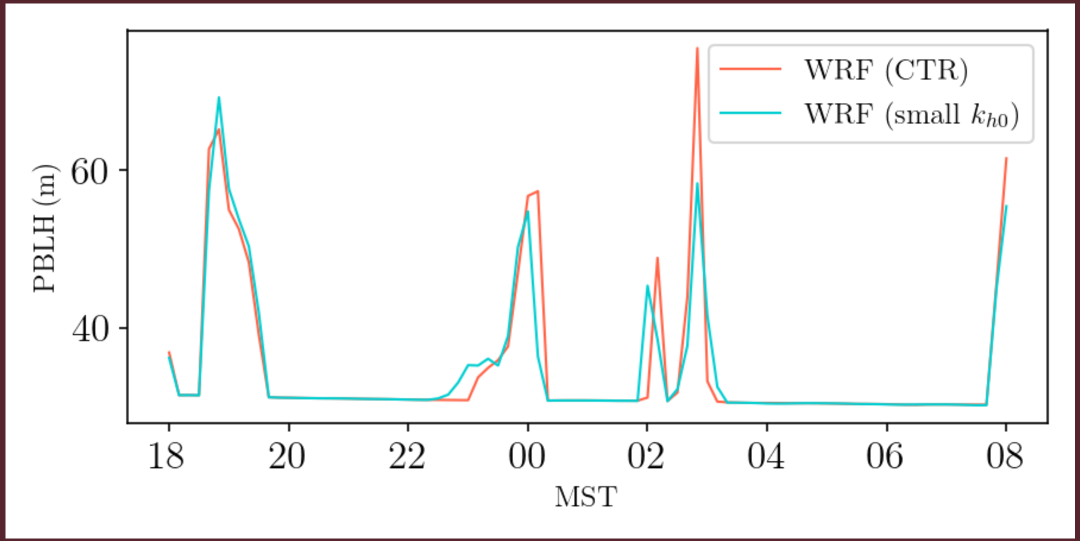
Wind speed and wind direction



PBLH

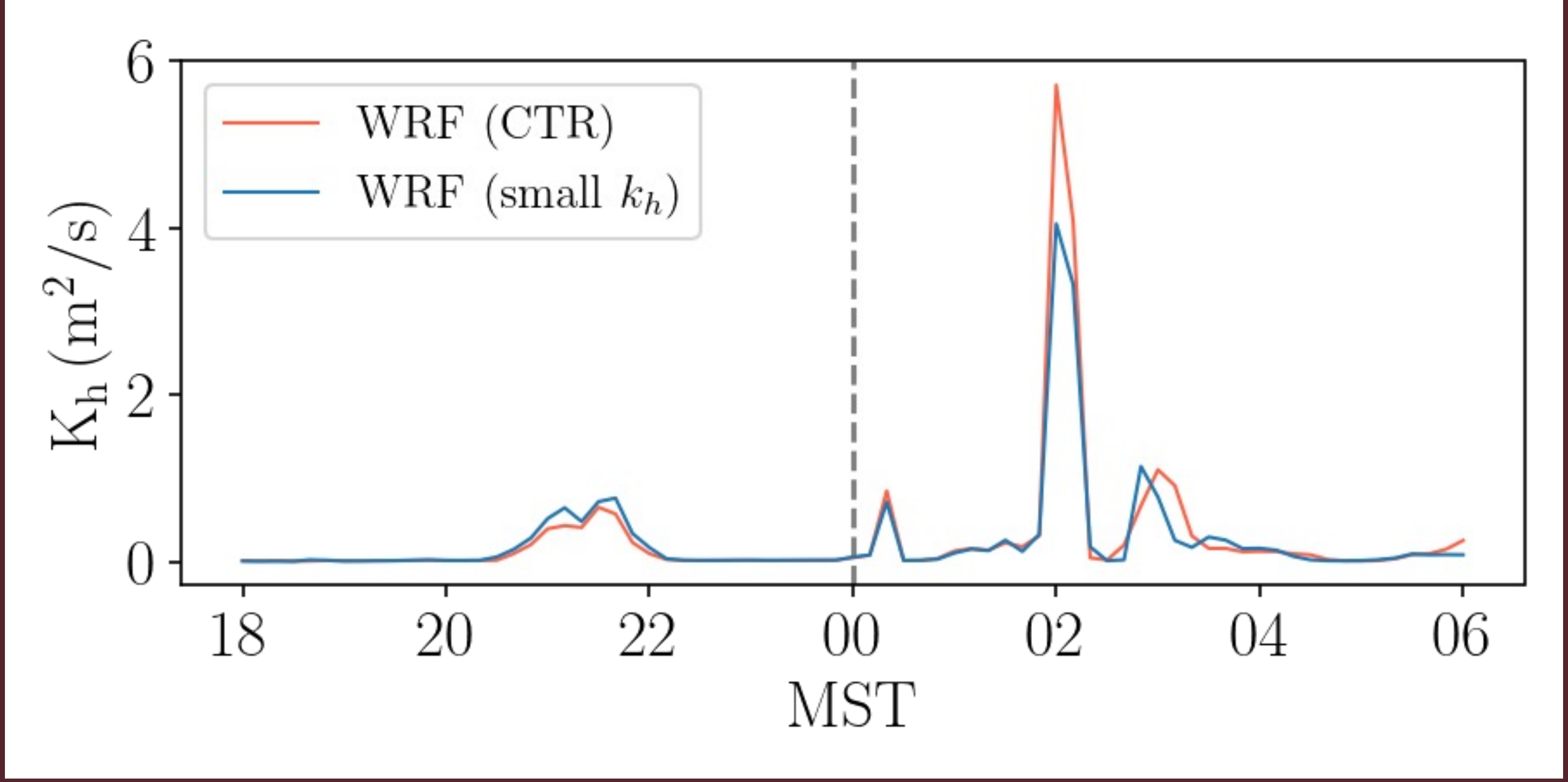


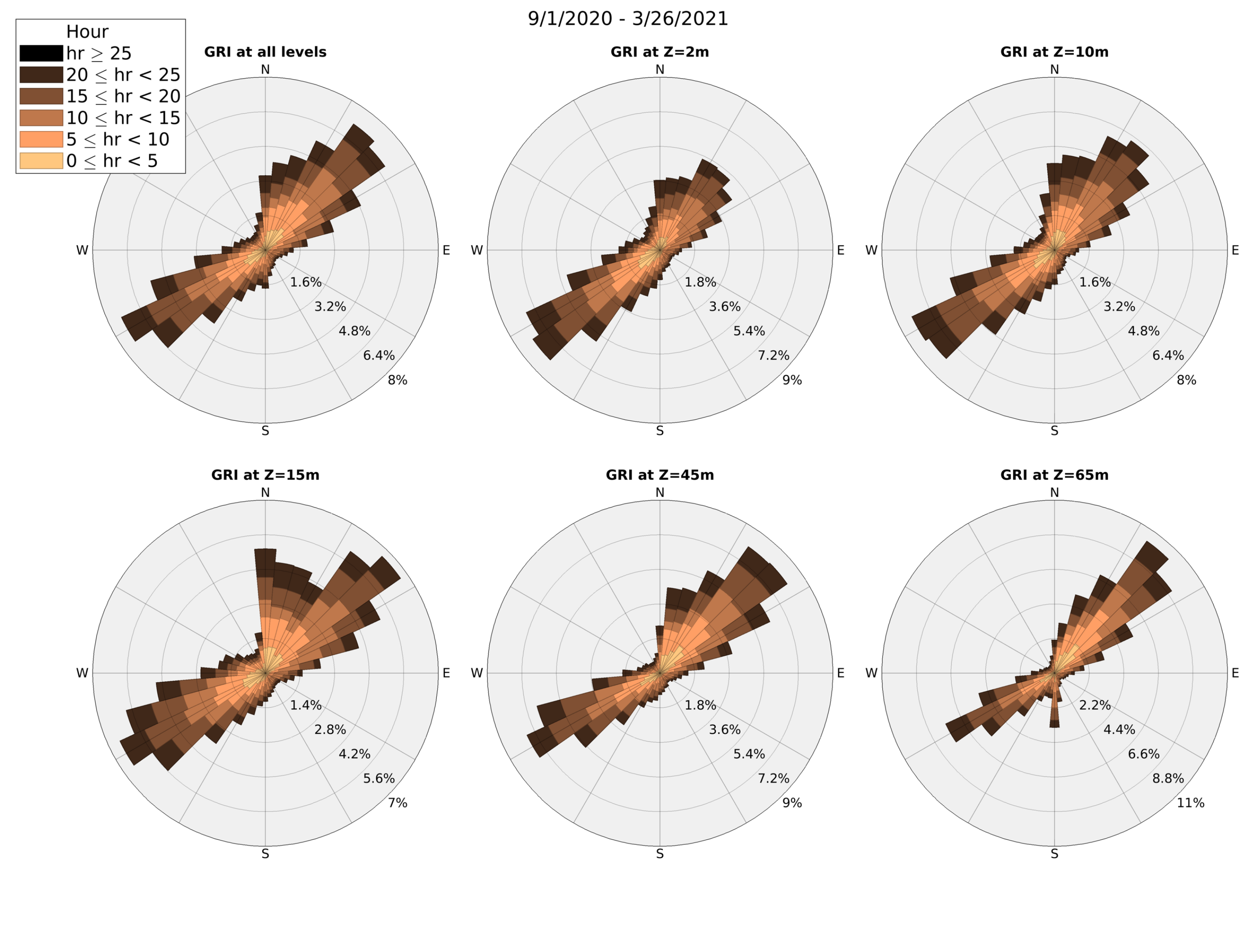
2500
2000
1500
1000
500
0
PBL Height(m)
MYJ
MYNN
YSU
ACM2
ceilometer
10/04 00
10/04 06
10/04 12
10/04 18
10/05 00



WRF (CTR)
WRF (small k_{h0})
60
40
PBLH (m)
18
20
22
00
02
04
06
08
MST

Decrease eddy diffusivity




9/1/2020 - 3/26/2021
Hour
hr ≥ 25
20 ≤ hr < 25
15 ≤ hr < 20
10 ≤ hr < 15
5 ≤ hr < 10
0 ≤ hr < 5
GRI at all levels
GRI at Z=2m
GRI at Z=10m
GRI at Z=15m
GRI at Z=45m
GRI at Z=65m
N
E
S
W
1.6%
3.2%
4.8%
6.4%
8%
1.8%
3.6%
5.4%
7.2%
9%
1.4%
2.8%
4.2%
5.6%
7%
2.2%
4.4%
6.6%
8.8%
11%