

Sensitivity analysis of Planetary Boundary Layer height parameterization in the ICON - CHIMERE modeling chain

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COSMO General Meeting, September 14th-19th 2026, Rome



ICON-2I is the implementation
of ICON over the Italian
domain managed by ARPAE



Chemistry-transport model
for atmospheric composition
analysis and forecast

Meteorological preprocessing is
necessary to retrieve variables that
describe the Planetary Boundary
Layer (PBL) structure

PBLH parameterizations

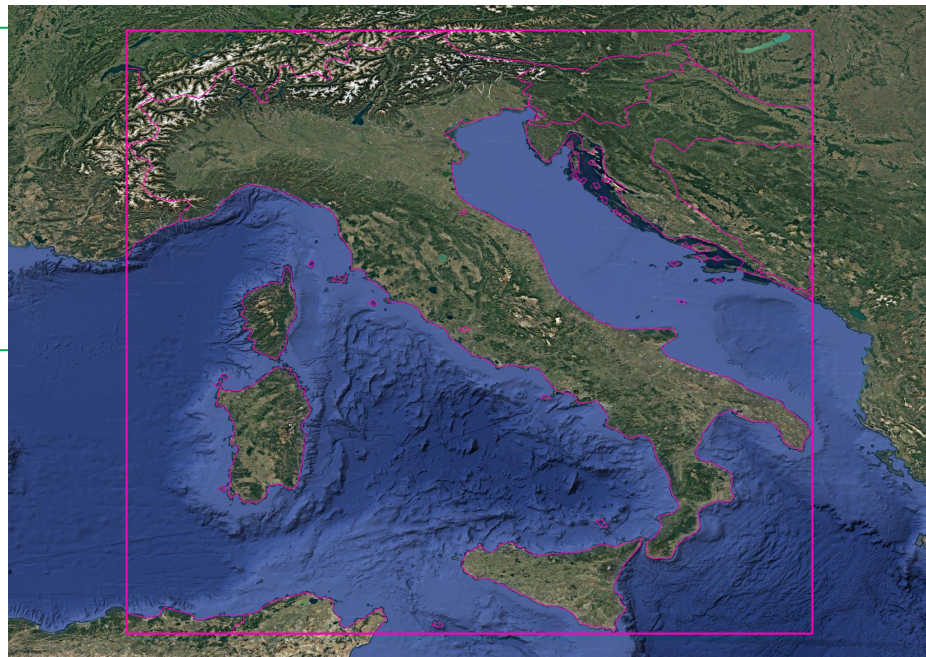
	ICON	CHIMERE
Unstable	Bulk Richardson number (Ri Critical = 0.39) ₁	Plume rise based on the surface virtual heat flux and level-by-level buoyancy/lateral entrainment ₂
Stable	PBLH $\approx f(u^*, L, N)$ ₃	Bulk Richardson number (Ri Critical = 0.5) ₄
		PBLH $\approx f(u^*)$ _{3, 5}

1. Zhang, Y., Gao, Z., Li, D., Li, Y., Zhang, N., Zhao, X., and Chen, J.: On the computation of planetary boundary-layer height using the bulk Richardson number method, Geoscientific Model Development, 7, 2599–2611, 2014.
2. Cheinet, S.: A multiple mass-flux parameterization for the surface-generated convection. Part I: Dry plumes, Journal of the atmospheric sciences, 60, 2313–2327, 2003
3. Zilitinkevich, S. and Mironov, D. V.: A multi-limit formulation for the equilibrium depth of a stably stratified boundary layer, Boundary-Layer Meteorology, 81, 325–351, 1996.
4. Troen, I., & Mahrt, L. (1986). A Simple Model of the Atmospheric Boundary Layer: Sensitivity to Surface Evaporation. Boundary-Layer Meteorology, 37, 129-148.
5. Rossby, C.-G. and Montgomery, R. B.: The layer of frictional influence in wind and ocean currents, 1935.

Model data

ICON-2I analysis runs:

- 2 km resolution
aggregated to 5 km
- Italian domain
- June 2024 to May 2026



Model data

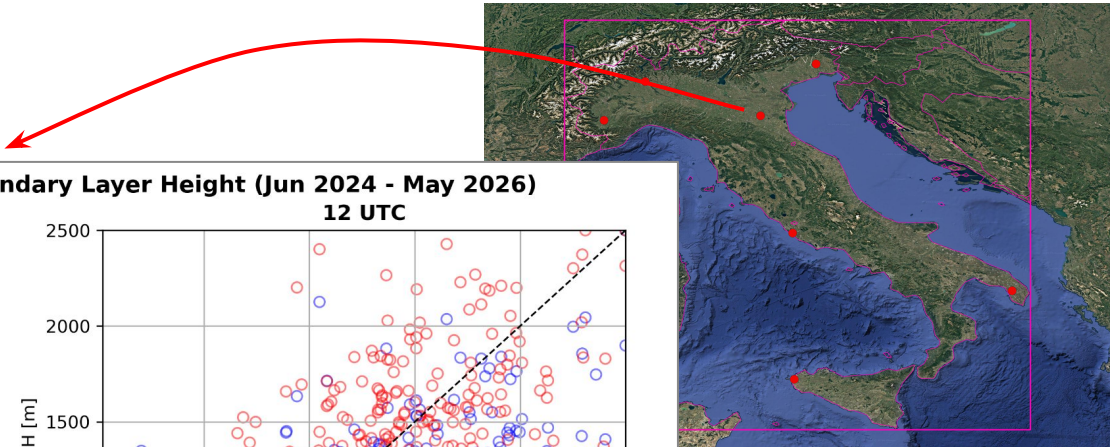
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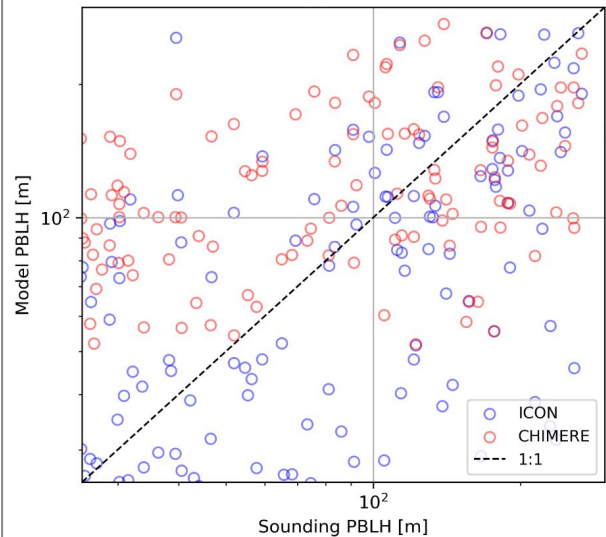
Reference data

- 8 Italian sounding stations
- PBLH reference computed through the Bulk-Ri method with $Ri_{Critical} = 0.25$



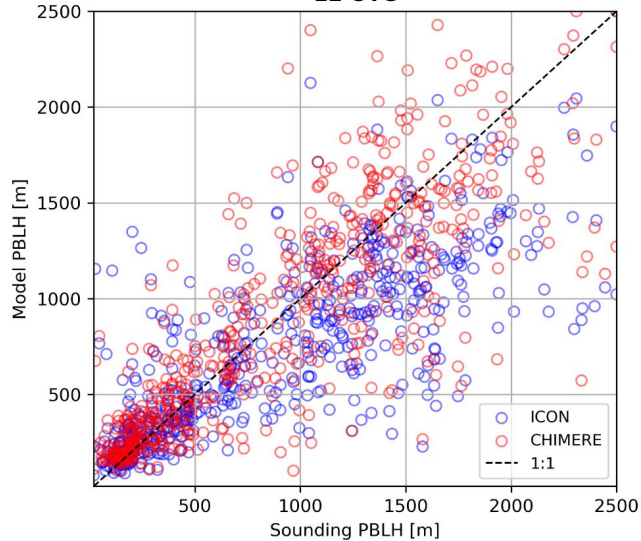


San Pietro Capofiume — Planetary Boundary Layer Height (Jun 2024 - May 2026)
00 UTC



CHIMERE: n=143 RMSE=305 MAE=131 bias=-65 R²=0.01 Spearman=0.47
ICON: n=142 RMSE=254 MAE=108 bias=-81 R²=-0.01 Spearman=0.59

12 UTC



CHIMERE: n=567 RMSE=358 MAE=244 bias=-21 R²=0.66 Spearman=0.85
ICON: n=576 RMSE=419 MAE=292 bias=-166 R²=0.54 Spearman=0.81

PBLH parameterizations

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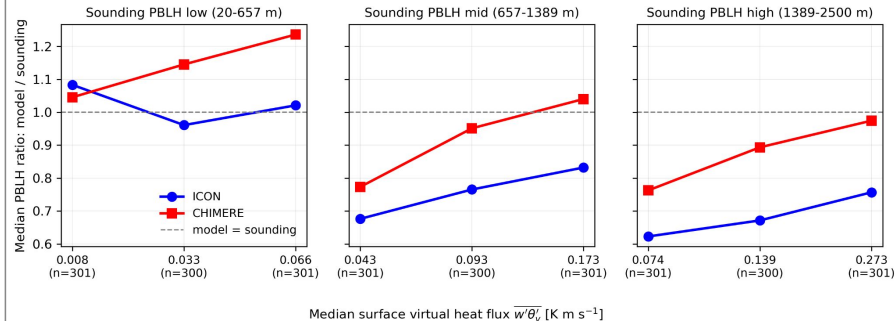
1. Zhang, Y., Gao, Z., Li, D., Li, Y., Zhang, N., Zhao, X., and Chen, J.: On the computation of planetary boundary-layer height using the bulk Richardson number method, Geoscientific Model Development, 7, 2599–2611, 2014.
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Results: unstable parameterizations

Surface virtual heat flux

In well developed PBL-cases, both parameterizations increase performance with increasing surface heat flux, which is the main driver of convective PBL development.

Model/sounding PBLH ratio vs. surface virtual heat flux (12 UTC)

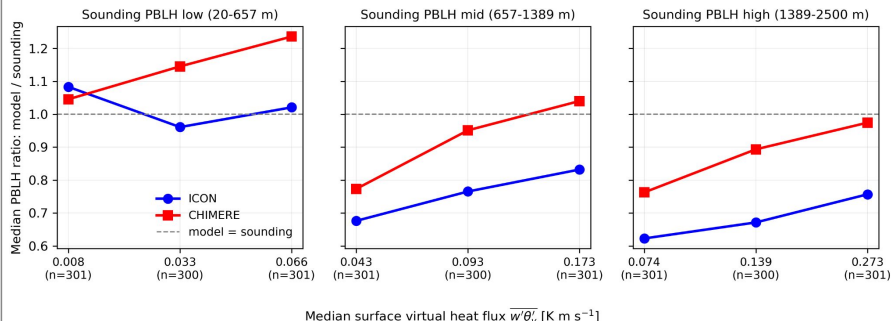


Results: unstable parameterizations

Surface virtual heat flux

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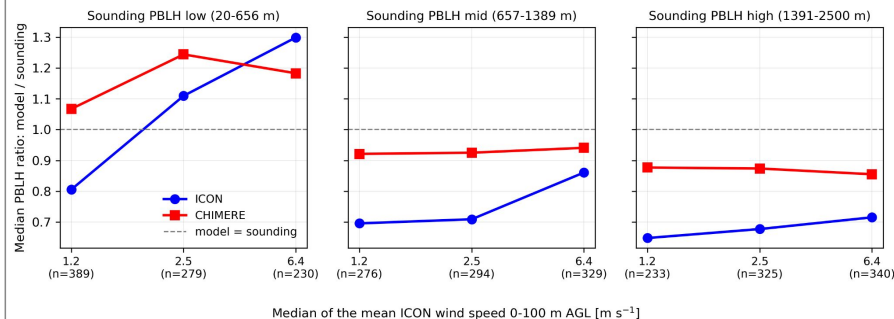
Model/sounding PBLH ratio vs. surface virtual heat flux (12 UTC)



Low levels wind speed

Mechanical shear dominates ICON in shallow PBLs, while its influence decreases with increasing PBL height.

Model/sounding PBLH ratio vs. low-level wind: mean ICON wind speed 0-100 m AGL (12 UTC)



PBLH parameterizations

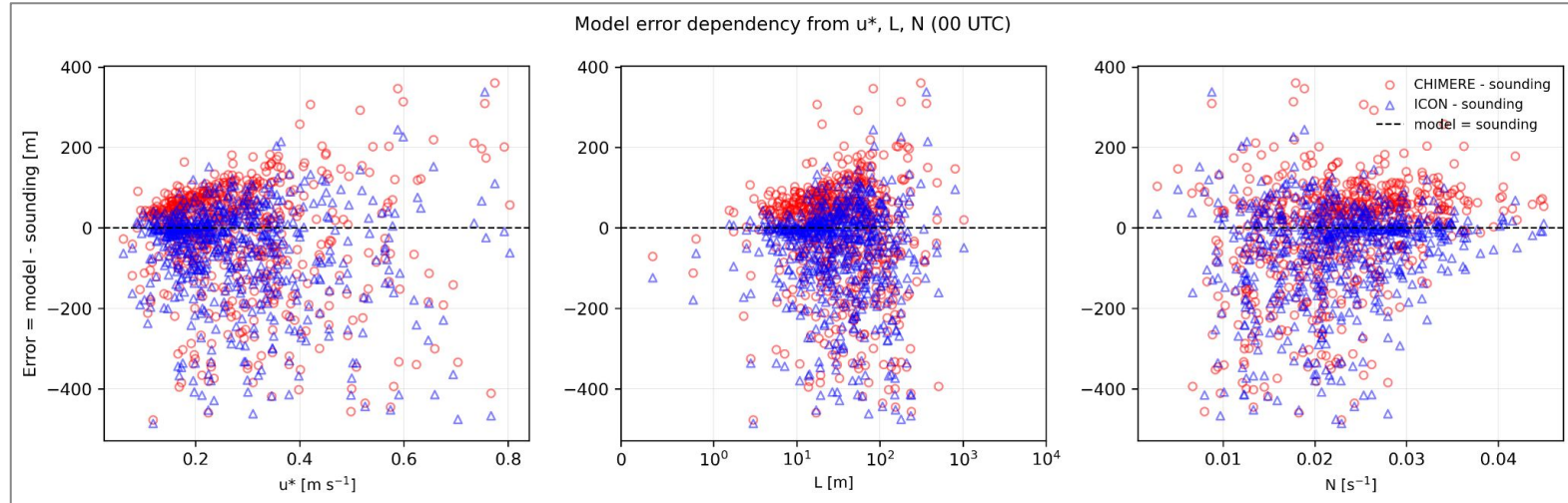
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Results: stable parameterizations

The Monin Obukhov length (L) and the Brunt-Väisälä buoyancy frequency (N) help describing very stable nocturnal PBL.

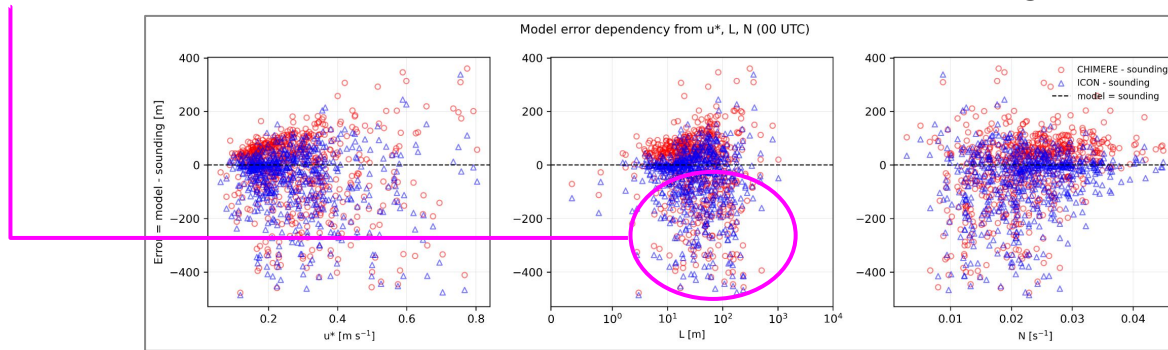
	Bias (m)	MAE (m)	RMSE (m)	R^2
BLADE	-56	89	136	0.29
HMIXDIAG	-15	101	137	0.27



Conclusions and next steps

- The new **ICON parametrization for the stable PBL** is capable to get a better representation of the very stable nocturnal Boundary Layer

BUT: a pull of underestimated cases remains, and has to be investigated



- The **unstable parametrization** based on the Bulk Richardson number tends to underestimate the diurnal depth of the Boundary Layer

My hypothesis: since the Bulk Ri method deeply relies on the modelled vertical profile, a deviation of the modelled profile from the sounding could heavily affect the retrieved PBLH

Thank you for listening

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