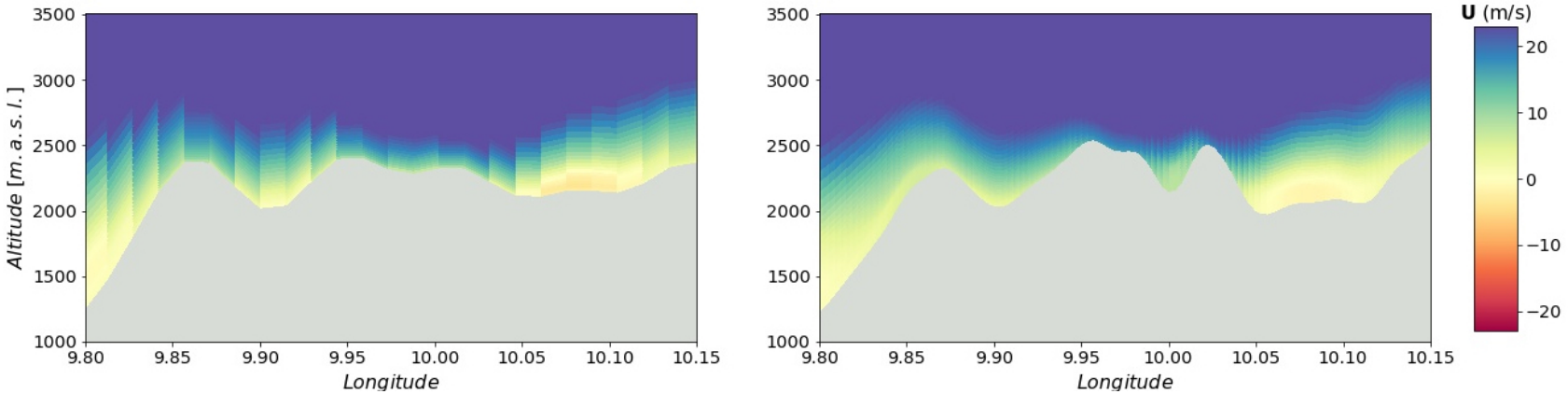
Dynamical downscaling to sub-km resolutions in complex alpine terrain:

The performance of the Intermediate Complexity Atmospheric Research (ICAR) model.



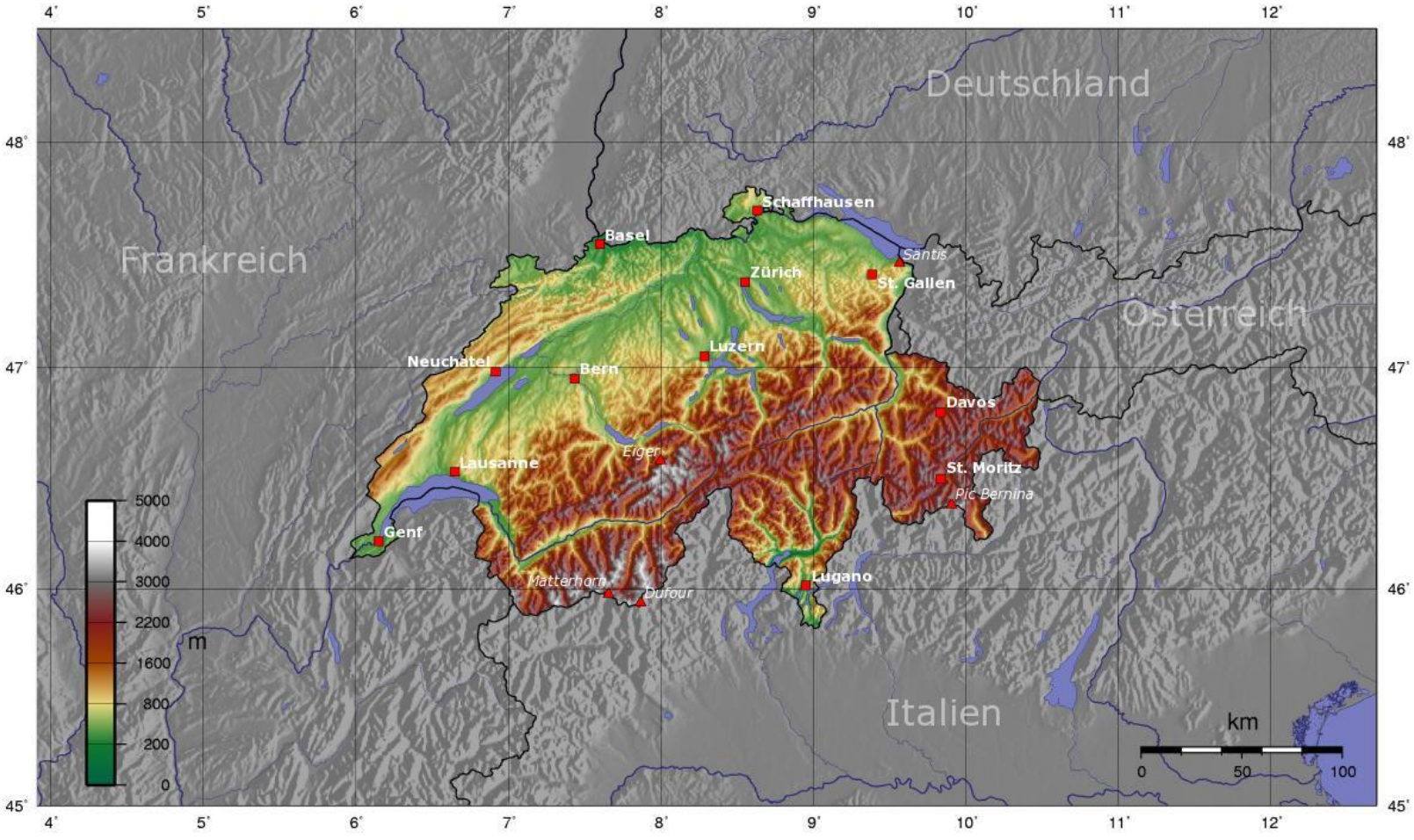
Bert Kruyt,
Ethan Gutmann*, Dylan Reynolds, Rebecca Mott

WSL Institute for Snow and Avalanche Research SLF
** National Center for Atmospheric Research NCAR*

OUTLINE

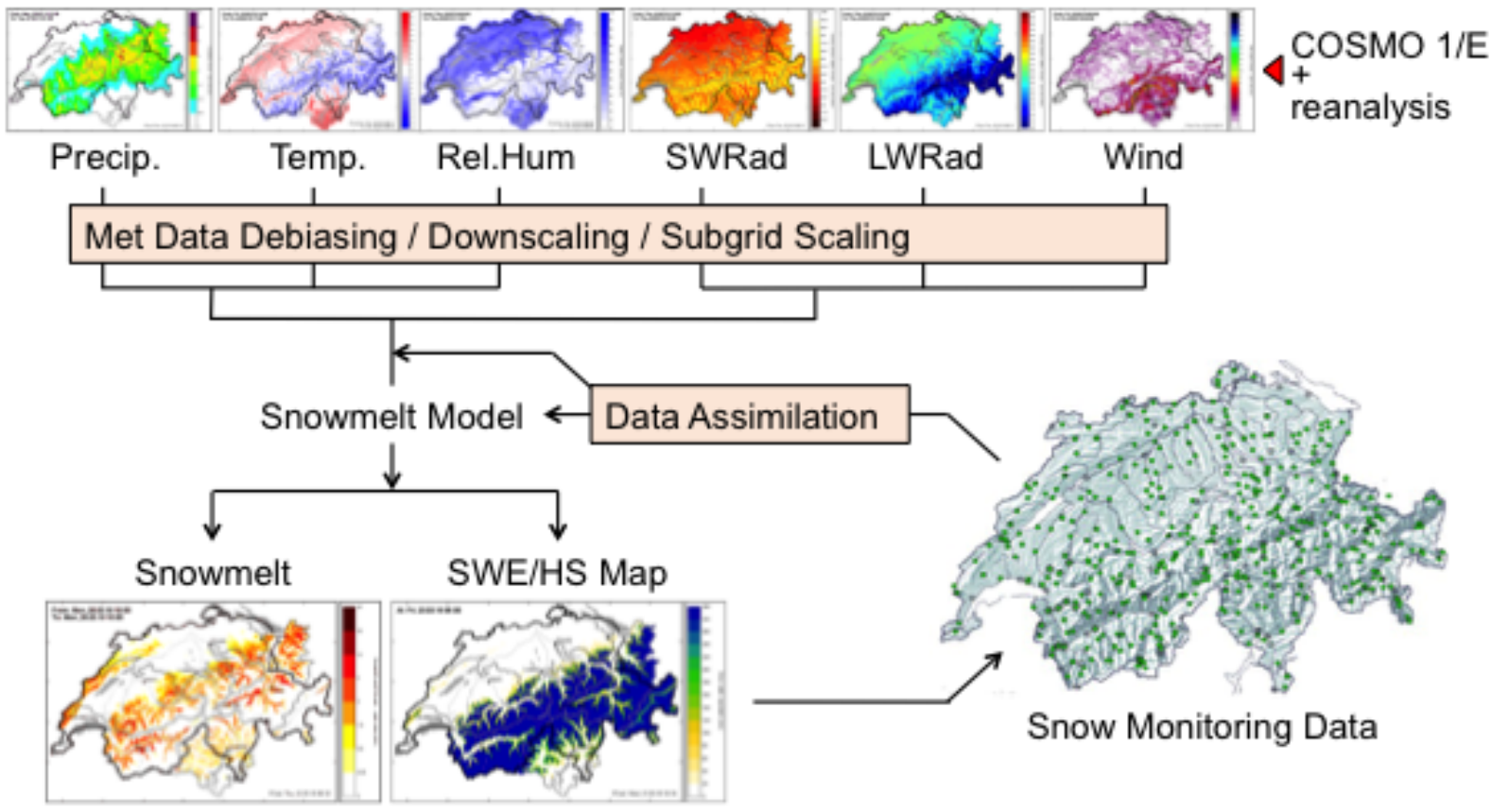
- Intro: Operational snow hydrology in Switzerland
- The Intermediate Complexity Research (ICAR) model
- Coupling ICAR to COSMO-1
- HICAR: high-resolution modeling in complex terrain
- Conclusions and Outlook for future development

OPERATIONAL SNOW HYDROLOGY AT SLF

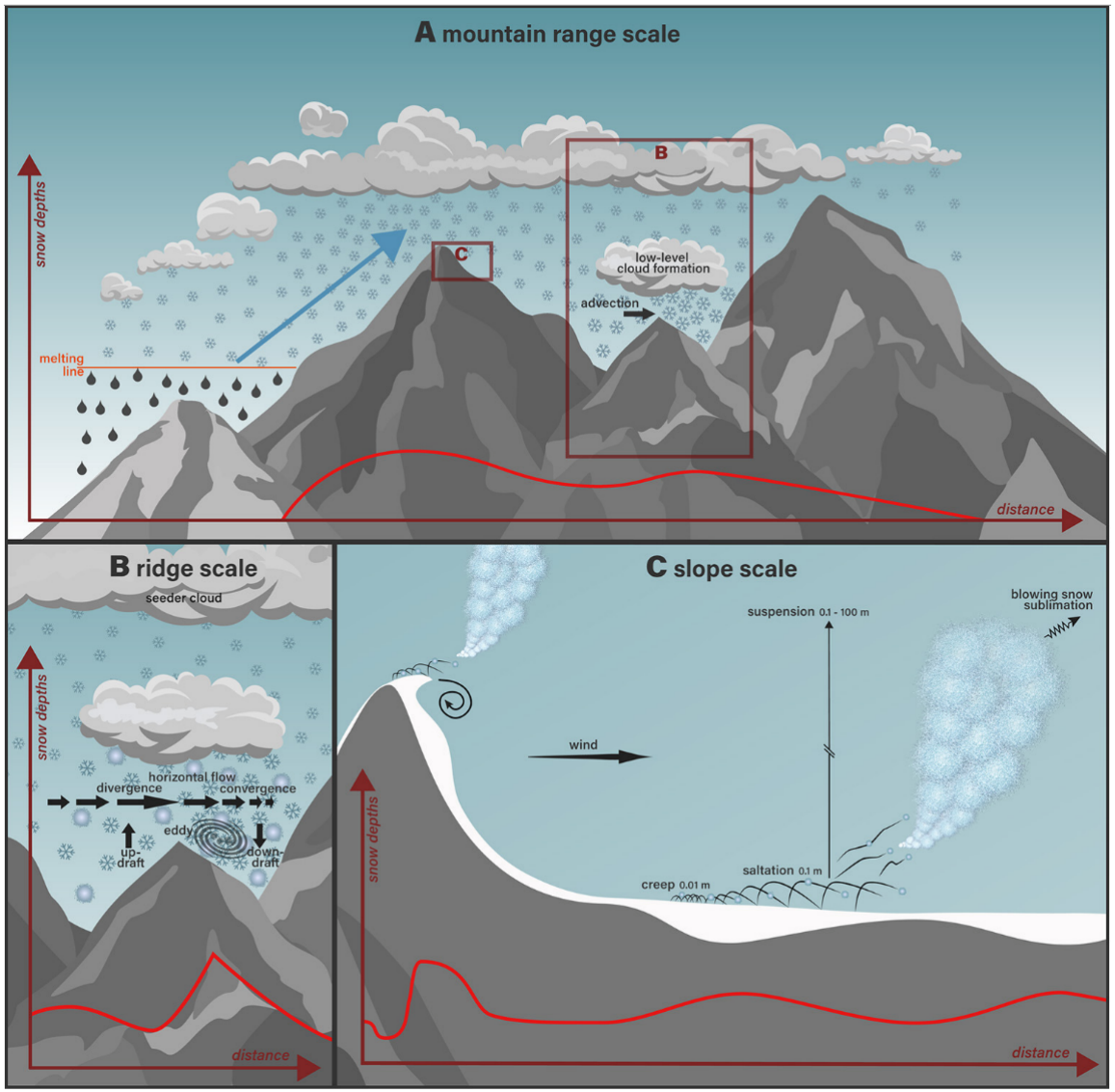


OPERATIONAL SNOW HYDROLOGY AT SLF

THE OSHD FRAMEWORK



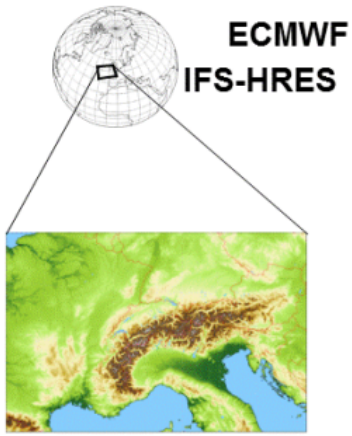
HYDROLOGICAL FORECASTING ACROSS SCALES



Mott et al. 2018

DYNAMICAL DOWNSCALING TO SUB-KM RESOLUTIONS

GOAL: A new model chain to *dynamically* downscale meteorological parameters relevant to hydrological forecasting to the sub-km scale, in order to force an energy balance snow model.



COSMO-1

1.1km resolution

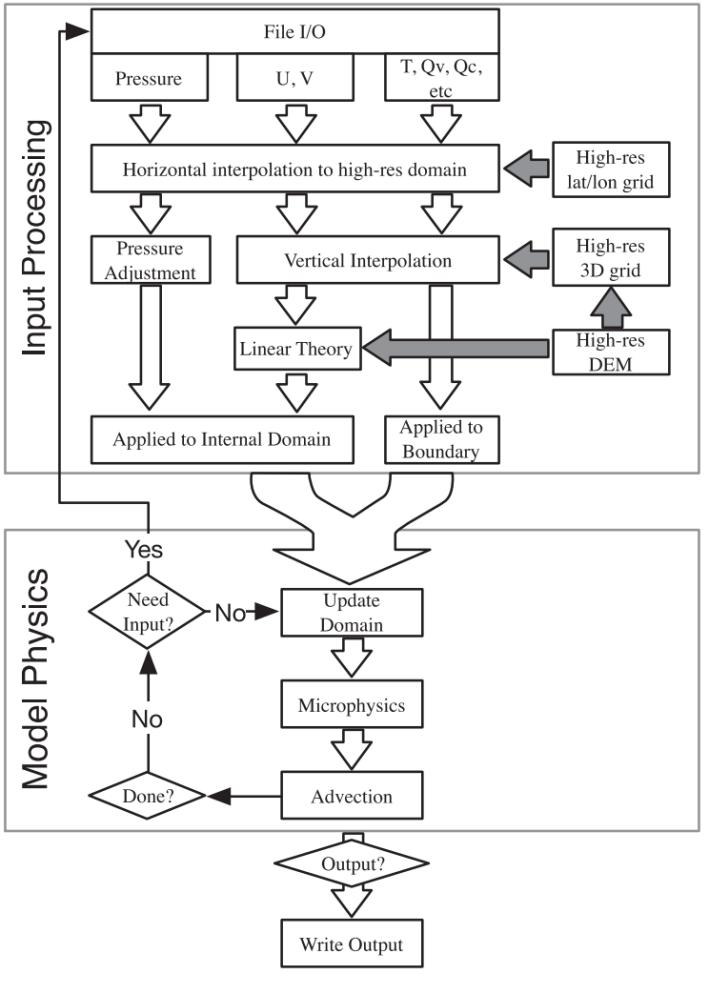
→ **ICAR**

250 m resolution

→ **FSM**

snow model

THE INTERMEDIATE COMPLEXITY ATMOSPHERIC RESEARCH (ICAR) MODEL



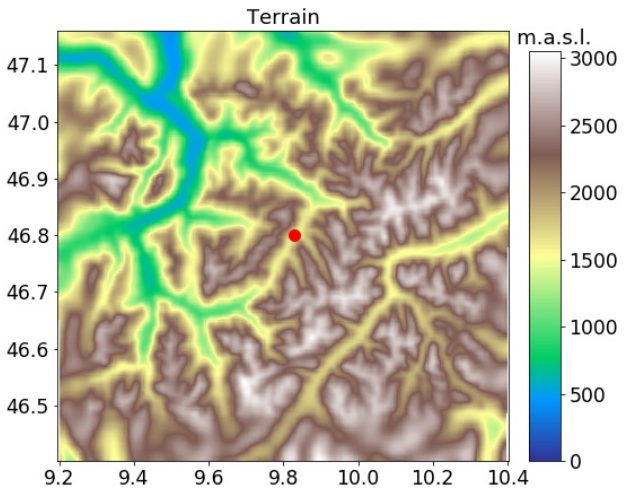
Gutmann et al. 2016

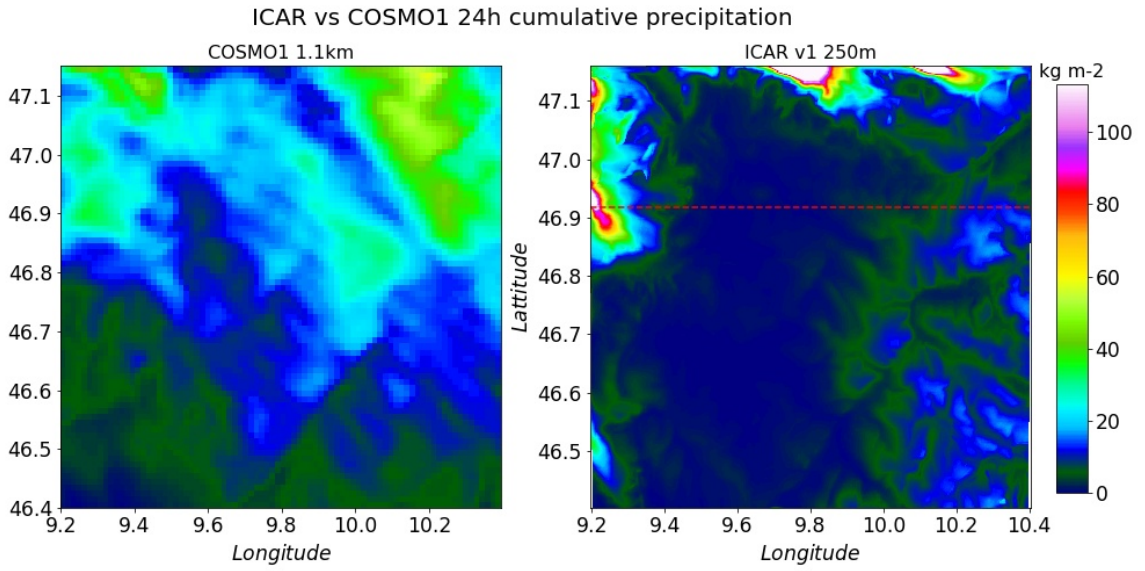
- ~~Navier-Stokes~~ ← too heavy
- P, U/V interpolated to domain
- Mass conservation; divergence

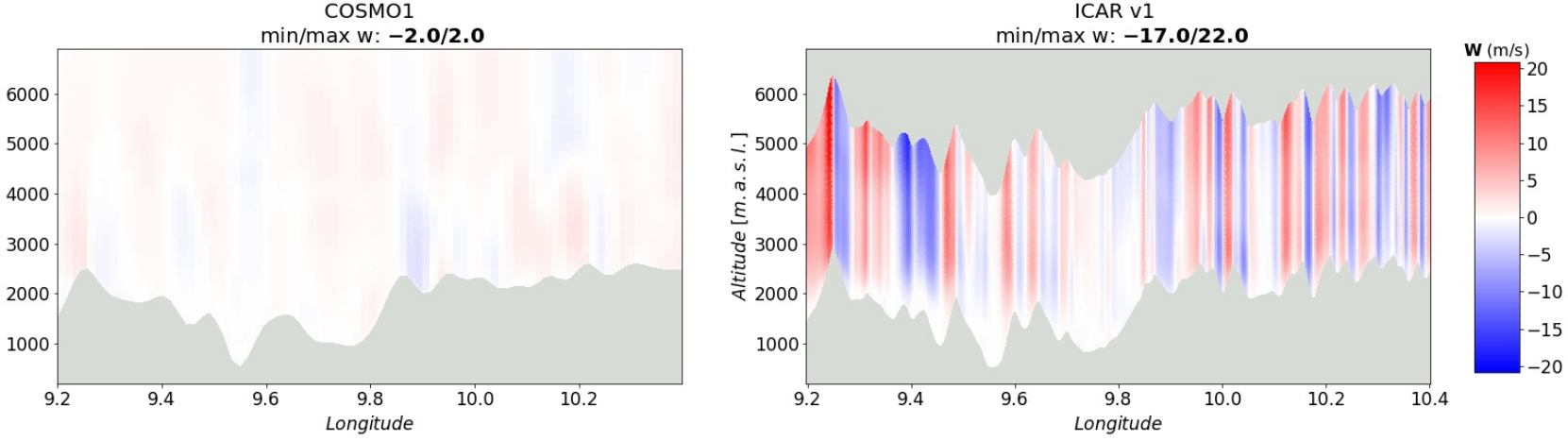
$$-\frac{\partial \rho w}{\partial z} = \frac{\partial \rho u}{\partial x} + \frac{\partial \rho v}{\partial y},$$

- (Linear mountain wave theory)
- T, QV, ... at boundary
- various microphysics, advection and pbl schemes
- Noah LSM

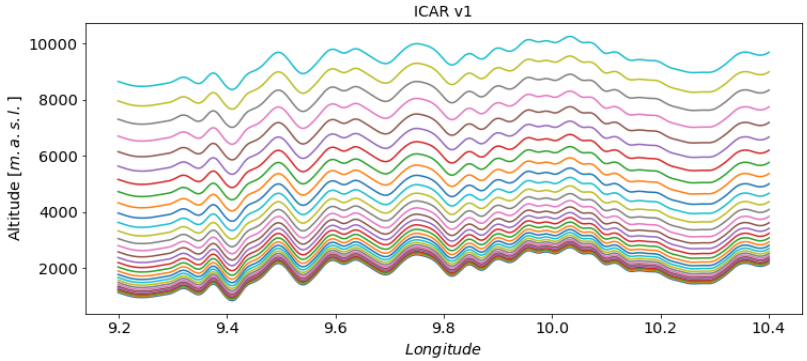
ICAR - COSMO COUPLING

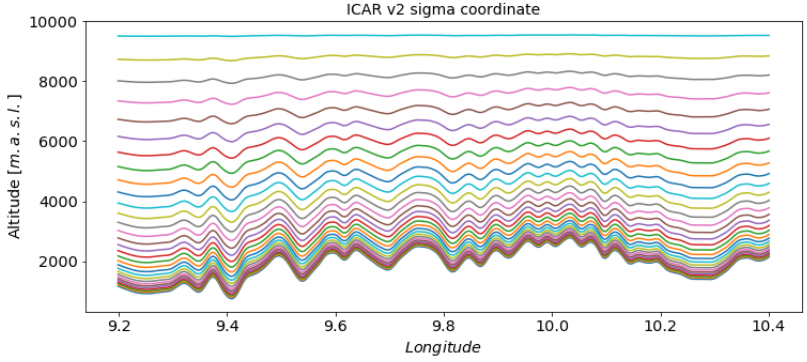


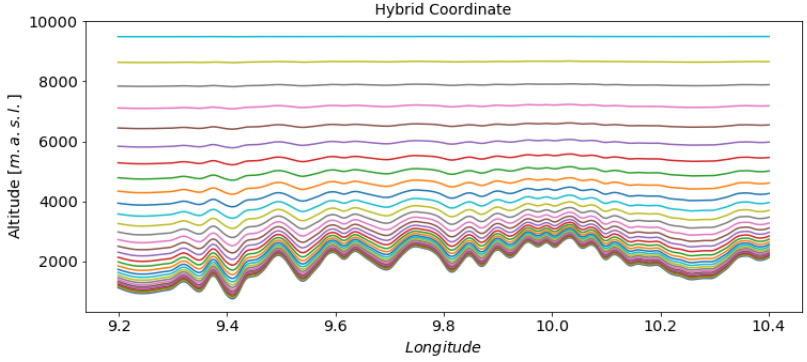




A HYBRID COORDINATE SYSTEM







Model top H
terrain $h(x, y)$

$$z(x,\ y,\ Z) = h(x,\ y) + Z[H - h(x,\ y)]/H.$$

linear terrain decay

$$z(Z) = Z + h\,\frac{\sinh[(H - Z)/s]}{\sinh[H/s]}.$$

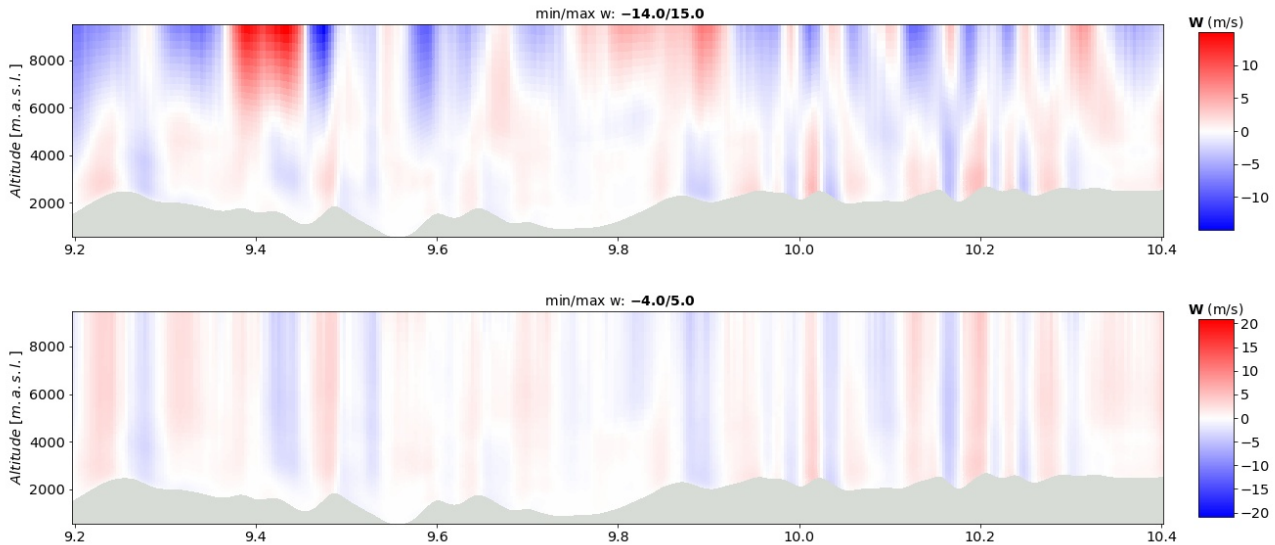
s controls terrain decay

$$b_i(Z) = \frac{\sinh[(Z_T/s_i)^n - (Z/s_i)^n]}{\sinh[(Z_T/s_i)^n]},$$

TERRAIN-INDUCED SPEED-UP

$$-\frac{\partial \rho w}{\partial z} = \frac{\partial \rho u}{\partial x} + \frac{\partial \rho v}{\partial y},$$

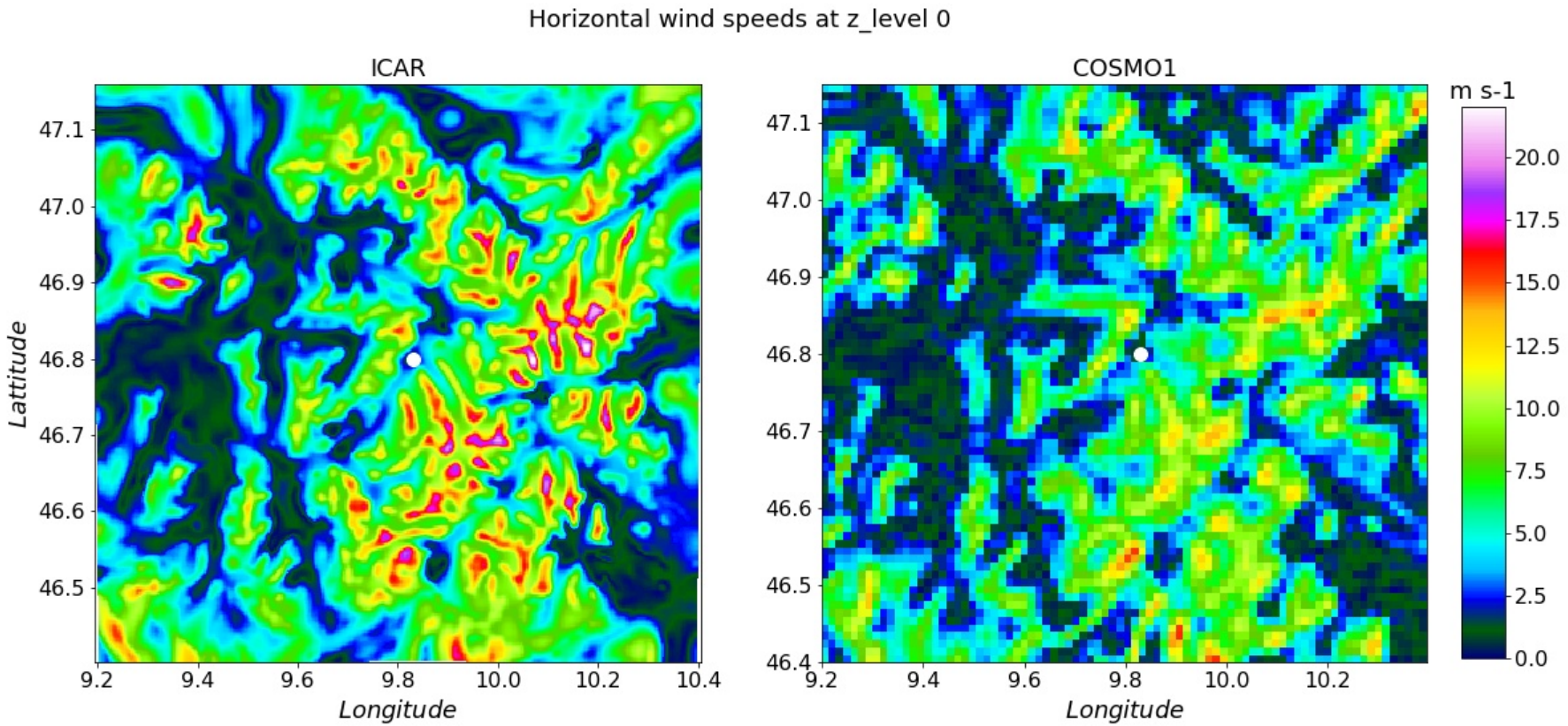
Need: Horizontal wind acceleration rather than vertical motion.
Initially parameterized based on the terrain height $h(x, y)$
New: difference between lo-res and hi-res terrain



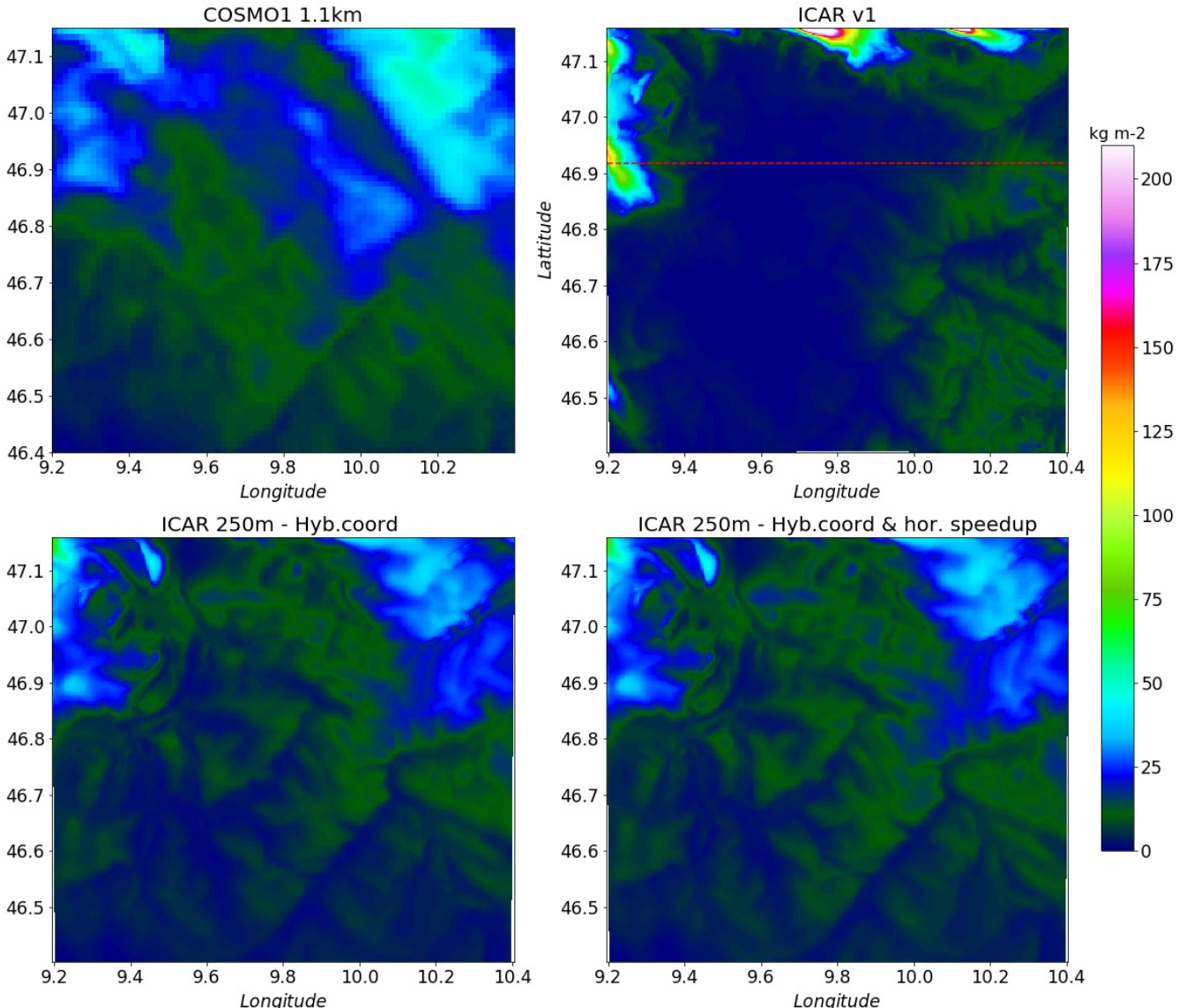
Initial parameterization

New parameterization based on terrain difference

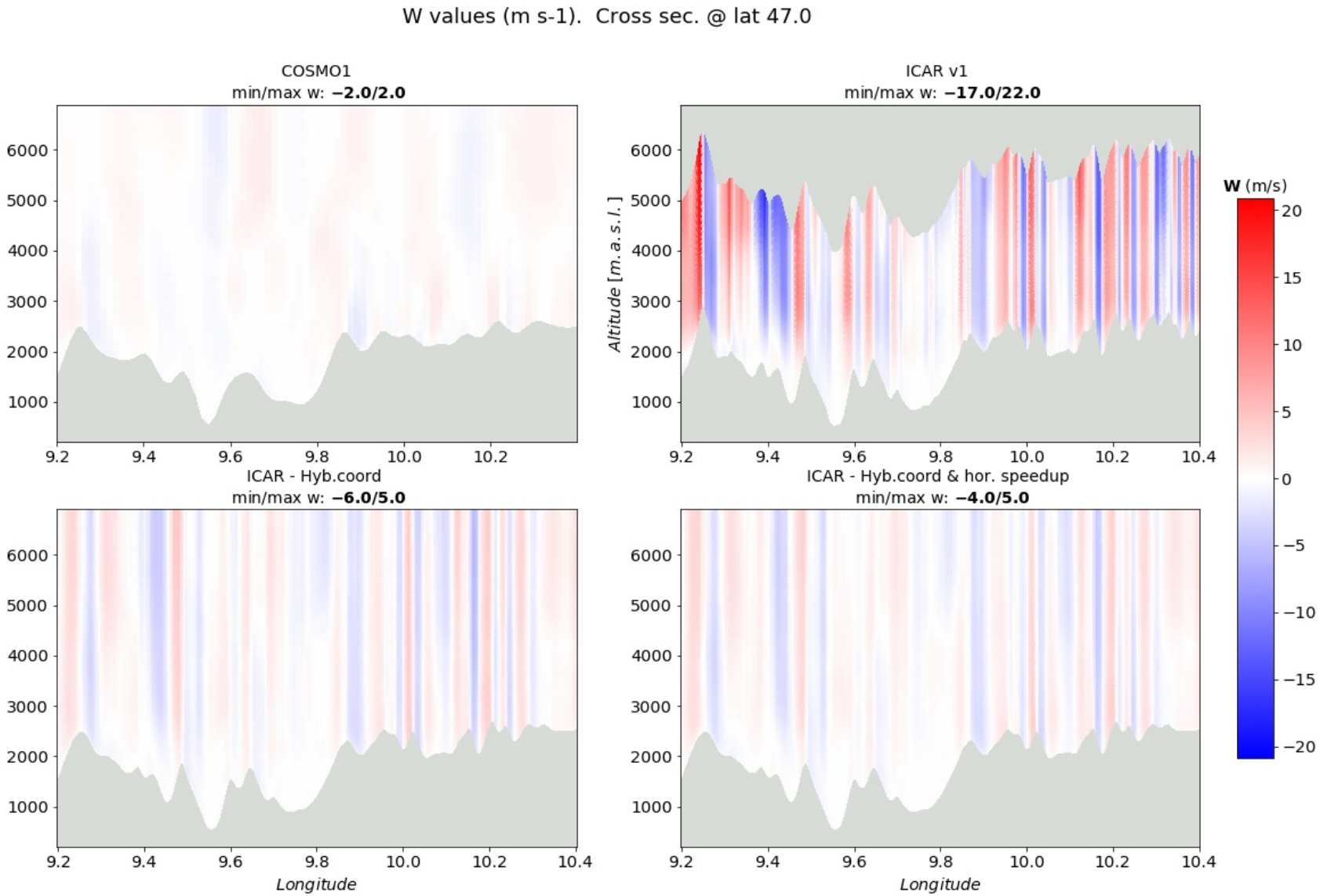
RESULTS: HORIZONTAL WIND



RESULTS: PRECIPITATION



RESULTS: VERTICAL WIND



Conclusions and Outlook

- Dynamical downscaling is hard! (Especially in complex terrain)
- Scales are relevant, $20 \rightarrow 4km \neq 1km \rightarrow 250m$
  - Avoid double counting
- Crux: how to maintain COSMO's excellent large scale performance, while *refining* the small scale processes

Outlook

- Nudging
- Higher order advection
- SLEVE coordinate system
- Horizontal wind deflection

QUESTIONS?

Wednesday, July 15,
2:10 PM Mountain Time (US)
10:10 PM Central European Time (CET)