Towards downscaling of precipitation phase from high resolution meteorological forecast model output over complex terrain

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Why to downscale precipitation phase?

- Plan to use the French NWP model AROME (Seity et al. 2011) and its ensemble forecast version PEAROME (Raynaud and Bouttier 2016) to provide surface meteorological variables in a future gridded snow cover forecast system at 250 m horizontal resolution.
- Model resolution:
  AROME 1.3km
  PEAROME 2.5km
- precipitation phase is crucial for snow cover modelling and highly dependent on altitude and atmospheric conditions
- substantial altitude difference between pixels at different resolutions over complex terrain

Study area: Grandes Rousses Massif in the French Alps

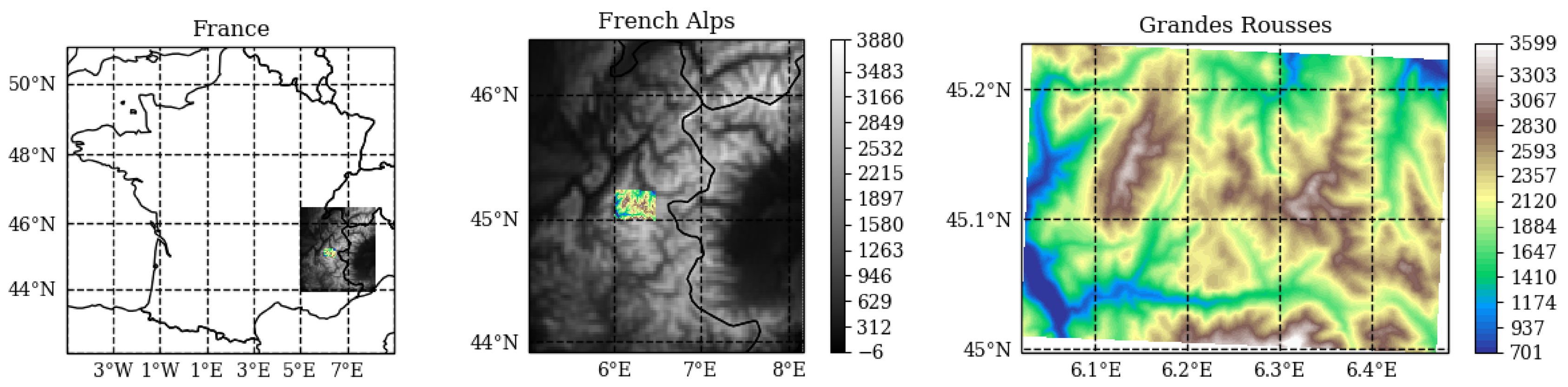

Fig. 1: Left: France, center: zoom to the French Alps with pixel heights at the forecast model resolution of 2.5km, right: Zoom to the Grandes Rousses Massif with pixel heights of the 250m target grid

How to determine precipitation phase?

Precipitation type model diagnostic

- PEAROME model output contains a precipitation type classification based on the vertical wet-bulb temperature profile (Fig. 2)

Wet-bulb temperature iso-heights

- Snow melts at wet-bulb temperatures (Tw) $> 0^oC$
- Snow limit, i.e., altitude where snow is completely melted, is sometimes assumed at the height where Tw $= 1.5^oC$

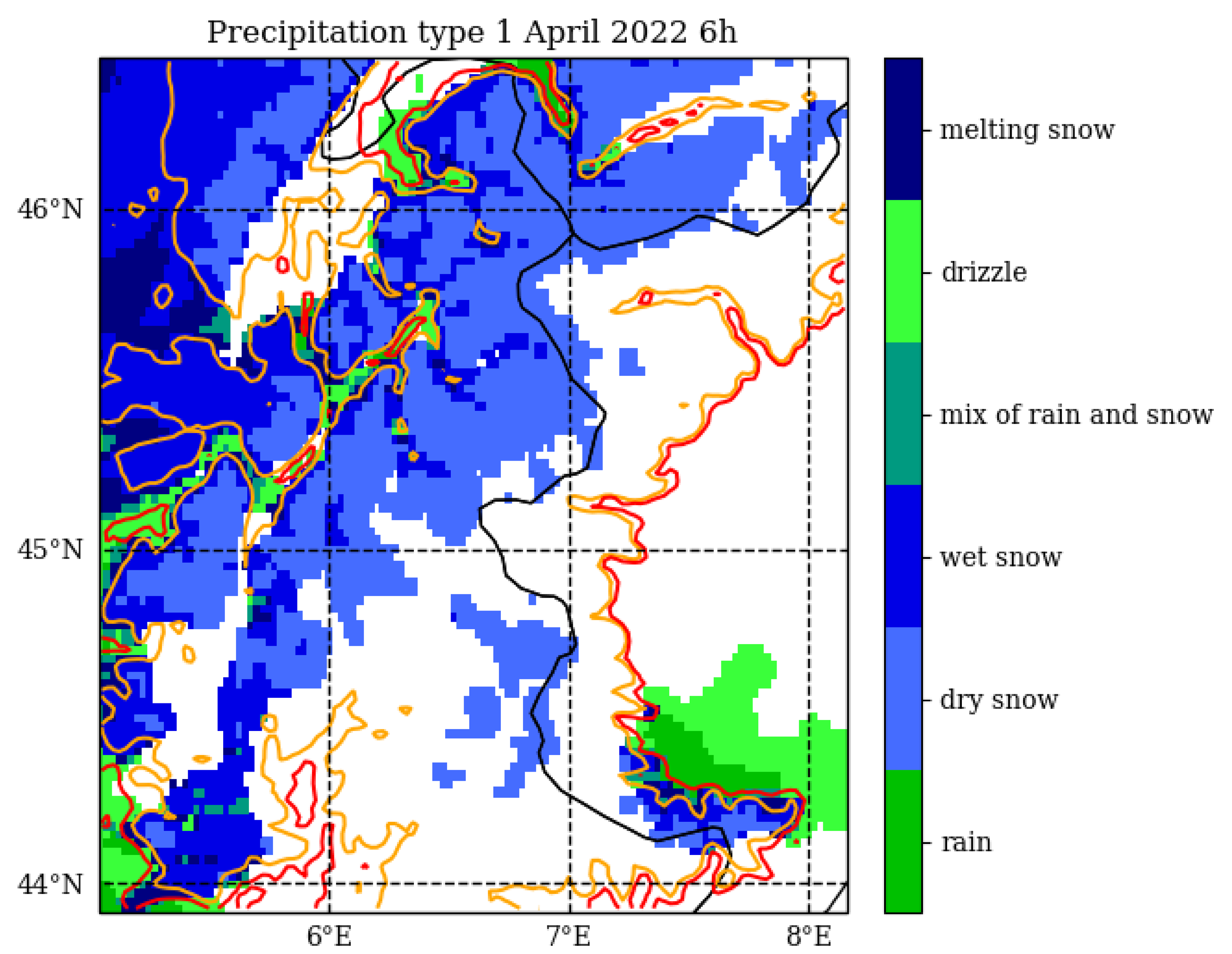

Fig. 2: Simplified Precipitation type classification from PEAROME forecast (3h lead time) over the French Alps for 1 April 2022 6h UTC. Wet-bulb temperature iso-lines: 0^oC in orange and 1.5^oC in red. Mix-phase types (melting snow and mix of rain and snow) mainly occur between those two Tw levels. However, drizzle also occurs at Tw $< 1.5^oC$, which illustrates that the snow level also depends on the precipitation mass to melt.

Latent heat method (Vionnet et. al (2022))

- Given a wet-bulb temperature profile, the available melting energy is calculated in each layer
- Snow limit is considered at the level where the accumulated energy is sufficient to melt all the precipitation falling through
- Accounts for precipitation intensity

Precipitation phase at 250m resolution?

Height difference 2.5km vs. 250m resolution

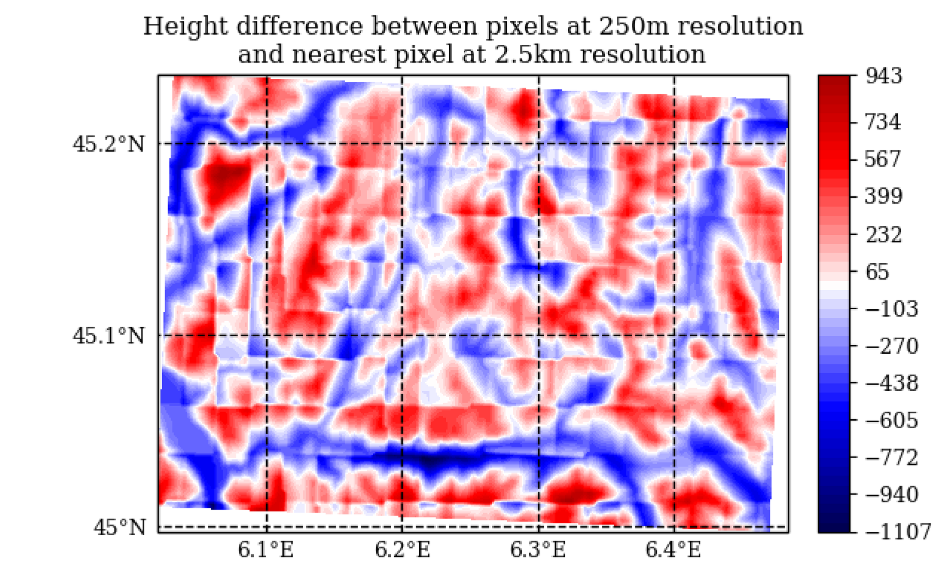

Fig. 3: Height difference between the pixels at 250m resolution and the pixels at 2.5km resolution over the Grandes Rousses domain. Red: 250m pixel above 2.5km pixel, blue: 250m pixel below 2.5km pixel.

- Height differences up to 1100m occur in and around the Romanche valley and la Meije in the Southern part of the domain (Fig. 3)

Precipitation type diagnostic

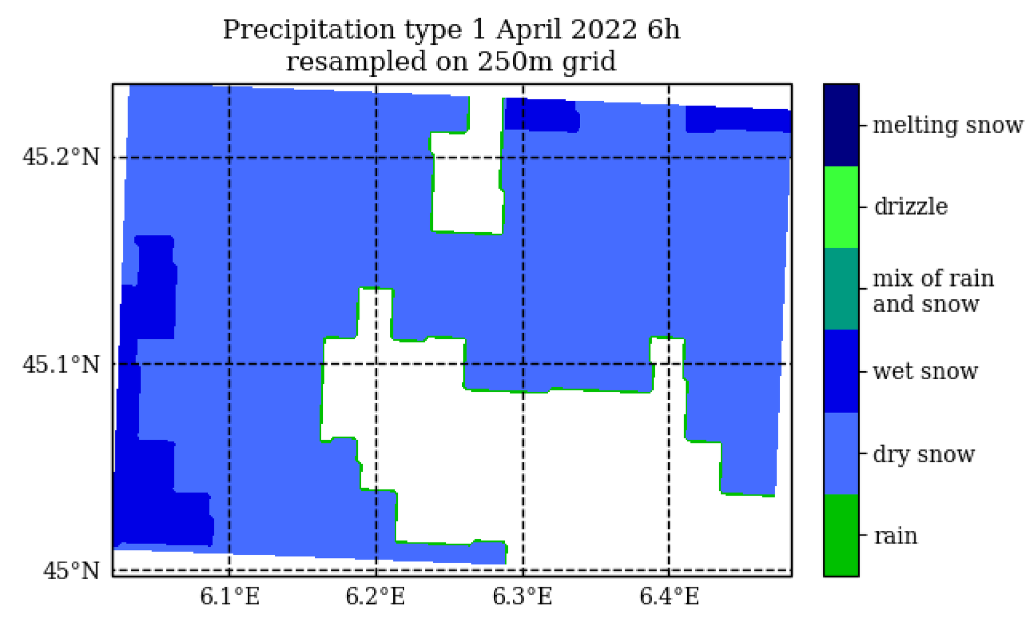

Fig. 4: Precipitation type from PEAROME forecast resampled at the 250m grid without taking height difference into account

- Nearest neighbour resampling
- All precipitation is classified as snow. (Fig. 4)
- no downscaling

Adjusted precipitation type using Tw iso-heights

For pixels with precipitation:

- dry snow and wet snow are kept if the pixel height is above the 0^oC Tw height
- melting snow is assigned if the pixel height is between the 0^oC Tw and the 1^oC Tw height
- mix of rain and snow is assigned if the pixel height is between the 1^oC Tw and the 1.5^oC Tw height
- rain if the pixel height is below the 1.5^oC Tw height

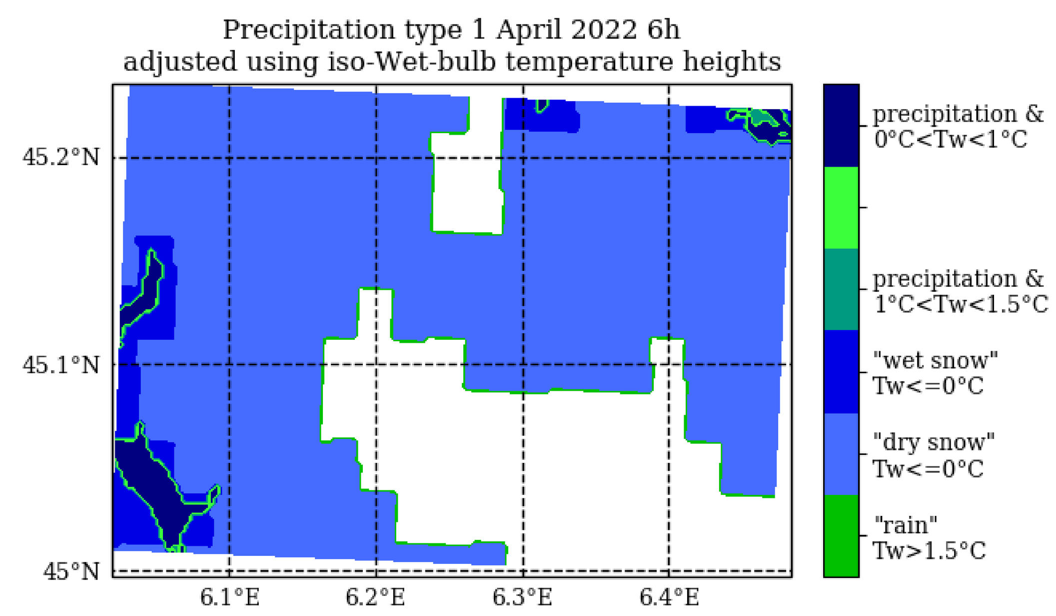

Fig. 5: Precipitation type from PEAROME forecast resampled at the 250m grid adjusted using Tw iso-heights

- using those decision rules mix-phase types occur in some valleys (Fig. 5)
- some Tw and height information included
- easy to apply, no extrapolation needed
- no quantitative information on solid and liquid precipitation fraction
- does not account for precipitation intensity

Future plans and challenges

Apply the latent heat method for downscaling

Advantages:

- account for precipitation intensity
- possibly quantitative information on fraction of solid and liquid precipitation

Challenges:

- How to extrapolate the Tw profile below the original model pixel height in narrow valleys?
- Which assumptions on vertical temperature and humidity gradients in valleys are the most appropriate ones?

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References

Raynaud, L., and F. Bouttier, 2016: Comparison of initial perturbation methods for ensemble prediction at convective scale. *Quarterly Journal of the Royal Meteorological Society, 142 (695), 854–866, doi:10.1002/qj.2686.*

Seity, Y., P. Brousseau, S. Malardel, G. Hello, P. Bnard, F. Bouttier, C. Lac, and V. Masson, 2011: The AROME-France convective-scale operational model. *Monthly Weather Review, 139 (3), 976–991, doi:10.1175/2010MWR3425.1.*

Vionnet, V., M. Verville, V. Fortin, M. Brugman, M. Abrahamowicz, F. Lemay, J. M. Thériault, M. Lafaysse, and J. A. Milbrandt, 2022: Snow level from post-processing of atmospheric model improves snowfall estimate and snowpack prediction in mountains. *Under review*