Quantifying the Effects of Mantle Processes and Climate Variability on Hinterland Denudation in the Central and Eastern Alps since the Oligocene

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Present-day tomographic mapping of the Alpine Moho identified two remnant mantle lithospheric slabs beneath the Central to Eastern Alps at ca. 135-165 km depth approximately along-strike the Periadriatic Lineament. This observation led to new hypotheses on mantle processes and mantle lithospheric slab geometries of the European and Adriatic plates since initial continental collision during the Oligocene. For example, slab break-off events are being proposed for the Oligocene and Early/Middle Miocene followed by subduction polarity reversal. Their potential influence on surface processes, i.e. hinterland denudation, preserved in the Miocene stratigraphic record and present-day bedrock will be the main focus of this proposal. We will take advantage of 2D kinematic fields created along the NFP-20E, TRANSALP and EASI profiles to reconstruct the 3D kinematic history of the Central to Eastern Alps and use this as input to state-of-the-art numerical landscape evolution / surface processes models (LEMs). By testing a range of magnitudes and wavelengths of mantle-induced surface uplift, added to this 'baseline' 3D kinematic field, we will be able to quantify the effect of mantle processes to hinterland denudation through modelling of erosional flux, bedrock and detrital thermochronological data. In order to distinguish mantle and climatic effects caused, for example, by the Miocene Climatic Optimum our LEMs will be subject to spatially and temporally variable precipitation. Hinterland denudation modelled in LEMs that contain both, mantle and climate components, will be compared to existing present-day bedrock and Miocene stratigraphic detrital thermochronologic data to evaluate whether any of the proposed mantle processes resulted in an observable surface response (Fig. 1). Our novel mantle-to-surface numerical modelling approach not only continues our work during the first phase of the MB-4D SPP (e.g., Eizenhöfer et al., under review) but also directly addresses its second phase Theme 2.

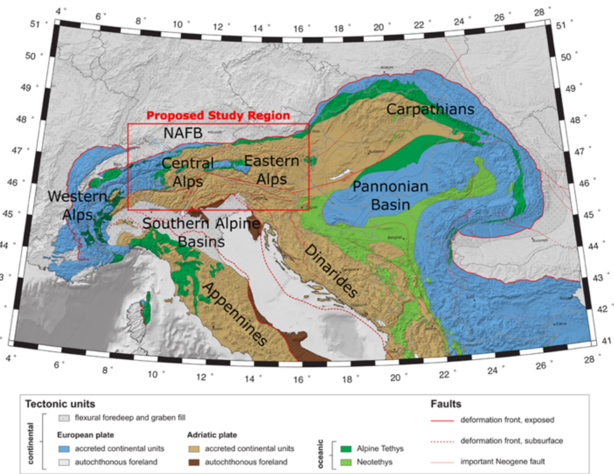

Figure 1. Study region.

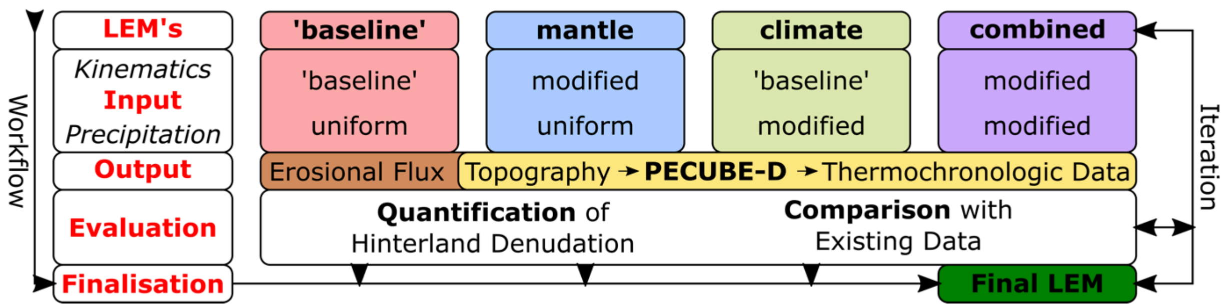

Figure 2. Project workflow.

We propose to quantify hinterland denudation during the evolution of the Central and Eastern Alps since the Oligocene using coupled landscape evolution and thermo-kinematic modelling (Fig. 3). Our approach will establish links between long-wavelength climatic variability and mantle processes to the, potentially delayed, surface response preserved in the stratigraphic record of the Alpine foreland basins. We will evaluate changes in hinterland denudation as a response to (i) Early Oligocene mantle lithospheric slab break-off in the Eastern Alps, (ii) a potential second slab break-off event in the Central to Eastern Alps during Early to Middle Miocene time, (iii) the Miocene Climatic Optimum, and (iv) proposed slab reversal in the Eastern Alps. First phase MB-4D SPP results (e.g., Eizenhöfer et al., under review), i.e., components of the thermo-kinematic models along strategically selected seismic profiles (e.g. short-wavelength fault activity), global-scale palaeoclimate models and updated AlpArray deep-seismic interpretations will serve as primary inputs to constrain rock displacement and precipitation. Modelled geomorphic indices, erosional flux, bedrock and detrital thermochronology data will be validated with existing bedrock, stratigraphic and geomorphic data.

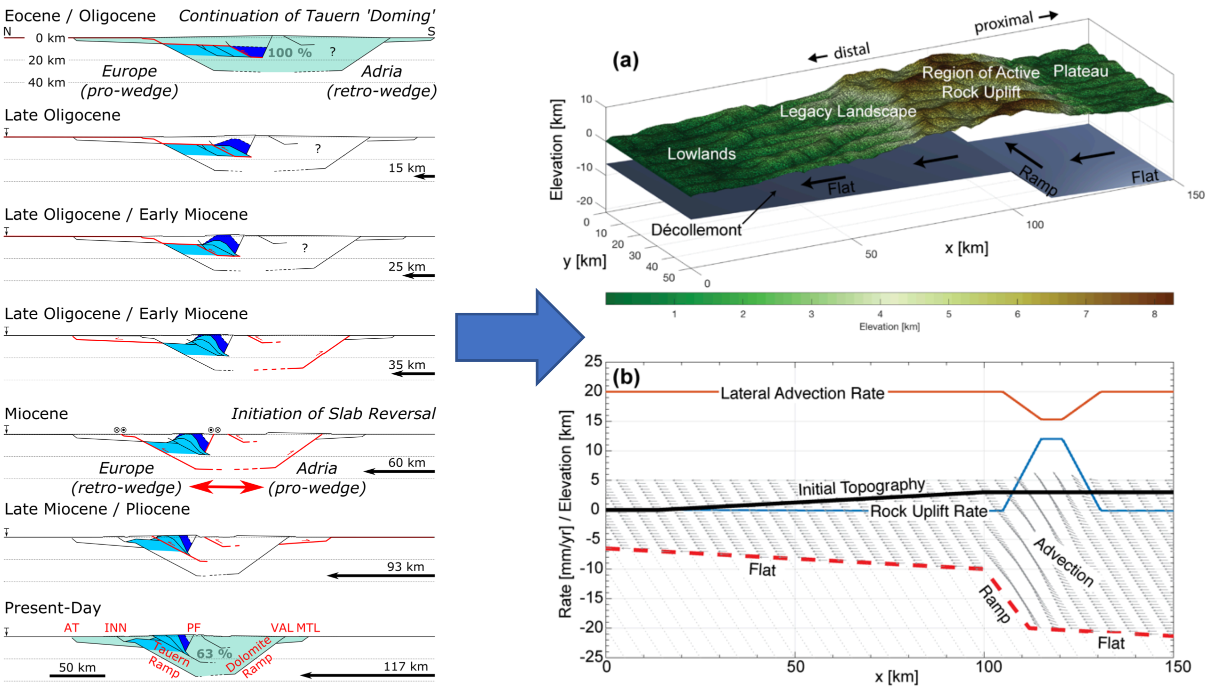

Figure 3. General modelling approach illustrating the tectonic input elements for the LEMs. (left) Orogen-scale kinematic solution based on a semi-balanced cross-section along the TRANSALP geophysical transect (1st phase 4DMB; Eizenhöfer et al., in prep); (right) geomorphic responses to tectonic displacement in a coupled LEM-MOVE™ numerical modelling set-up (modified after Eizenhöfer et al., 2019).

References

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