Effects of partial melting on the dynamic of SSC developing in a plume-fed layer beneath a moving plate

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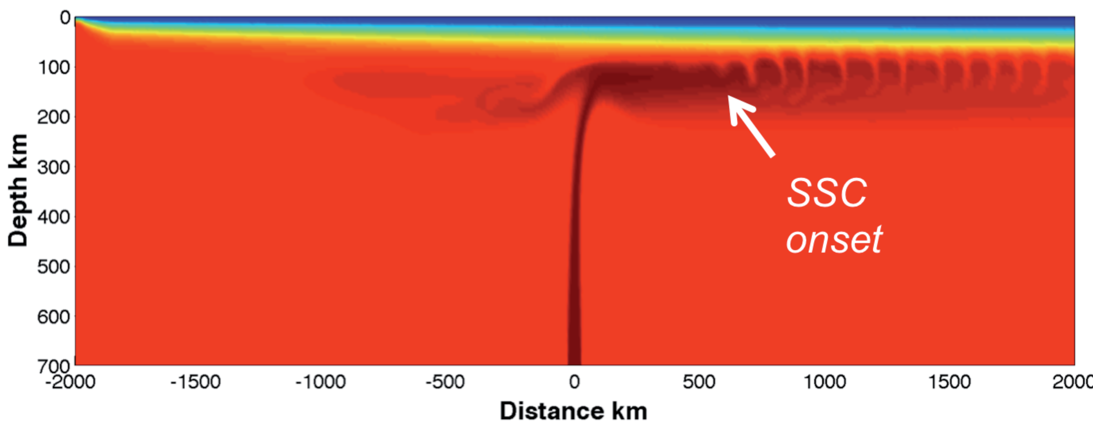
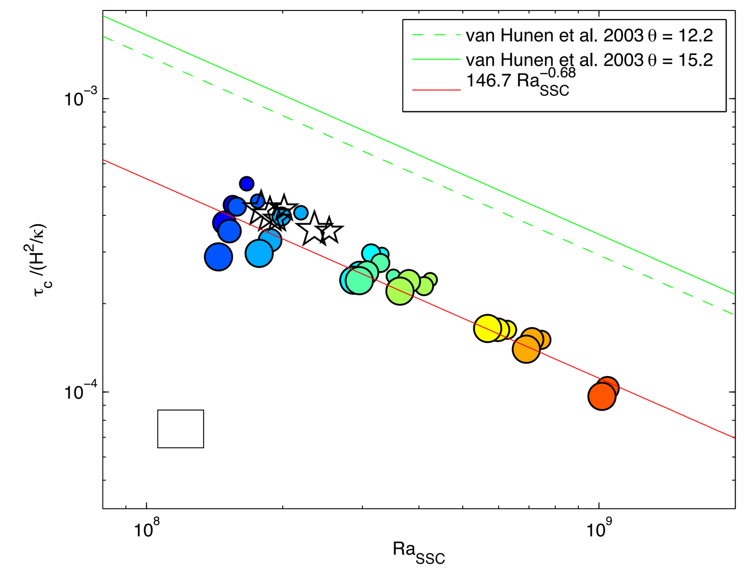
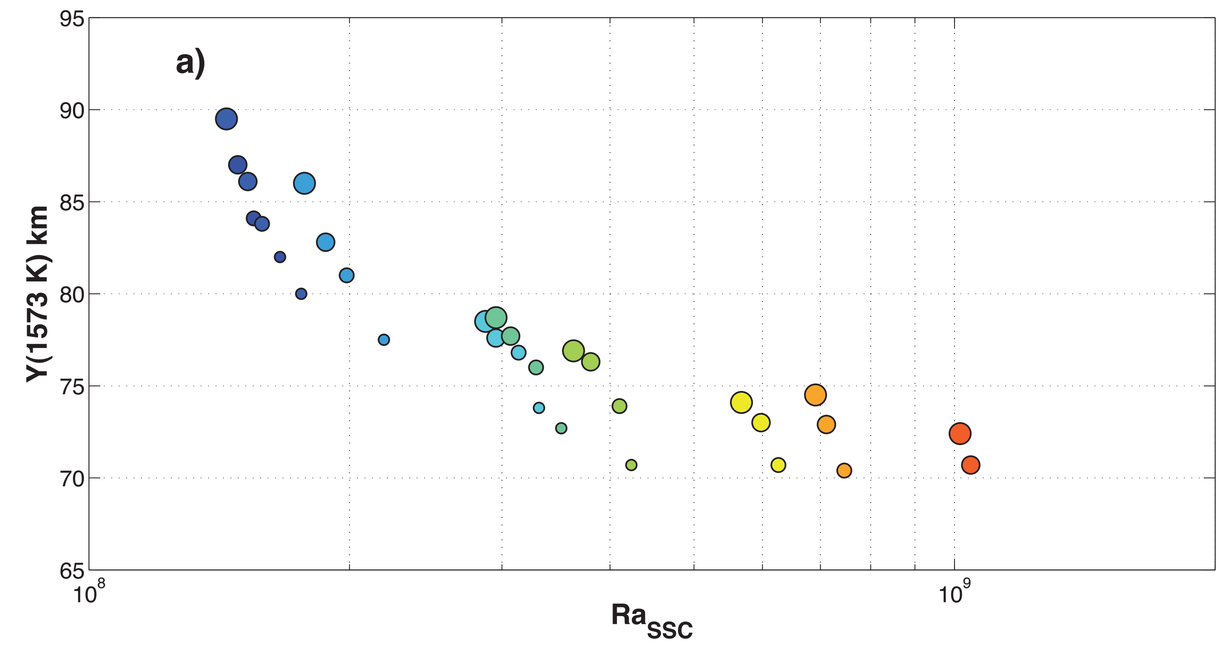
INTRODUCTION

A lithospheric plate passing atop a mantle plume is likely to be thermally thinned or "rejuvenated" (Ribe 2004). Development of small-scale convection (SSC) in the sub-lithospheric layer formed by the spreading of the hot plume material at the base of the lithosphere may erode it (Moore et al. 1998; Agrusta et al. 2013). These numerical models show, the thermo-mechanical erosion of the base of the lithosphere atop a plume does not upwell the lithosphere-asthenosphere boundary (LAB) by more than 30 km (Thoraval et al 2006; Agrusta et al. 2013). However, these studies do not consider the effect of partial melting on the dynamics of the plume-lithosphere interaction.



Partial melting has multiple possible consequences on the dynamics of SSC convection, because they directly impact the behavior of the unstable layer at the base of the lithosphere. The absorption/release of latent heat during melting/crystallization may affect the thermal structure, and, consequently, the thermal buoyancy (McKenzie and Bickle 1988). The effective buoyancy may, on the other hand, increase both by melt retention (Scott and Stevenson, 1989) and by removal of dense mineral phases from the solid residue (Schutt and Lesher 2006). Convection may also be enhanced due to a viscosity reduction, as the presence of even low volume fractions of melt has been shown to decrease the peridotites' strength (Takei and Holtzman 2009).

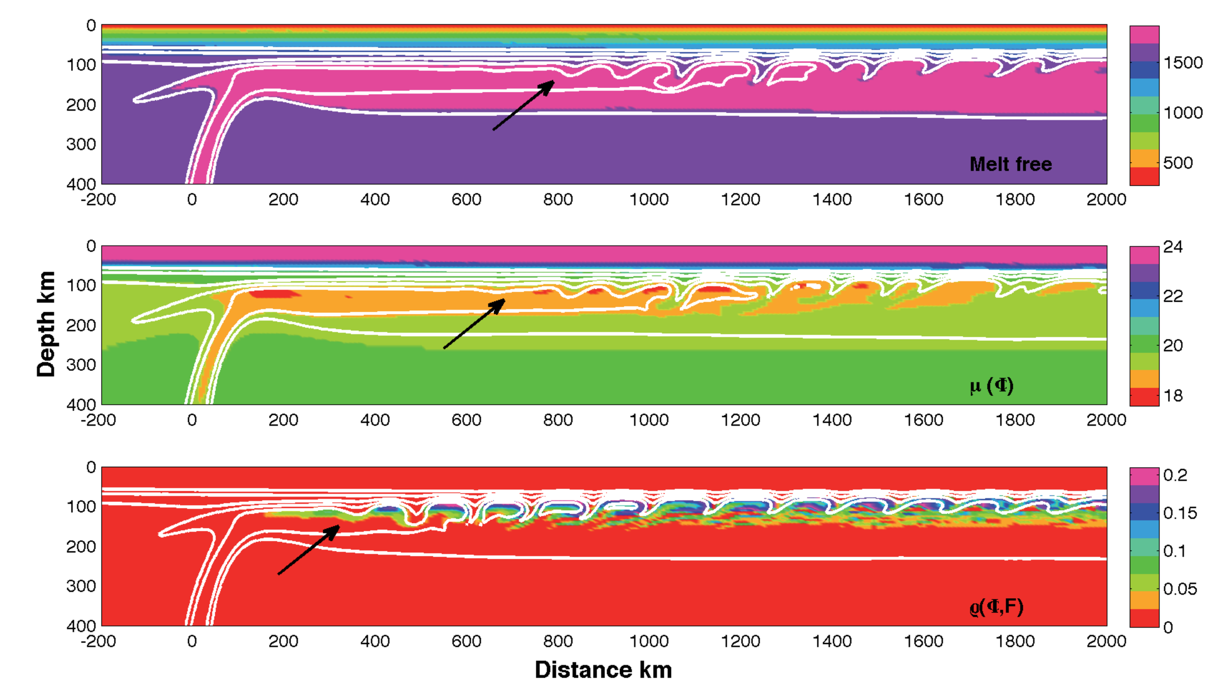


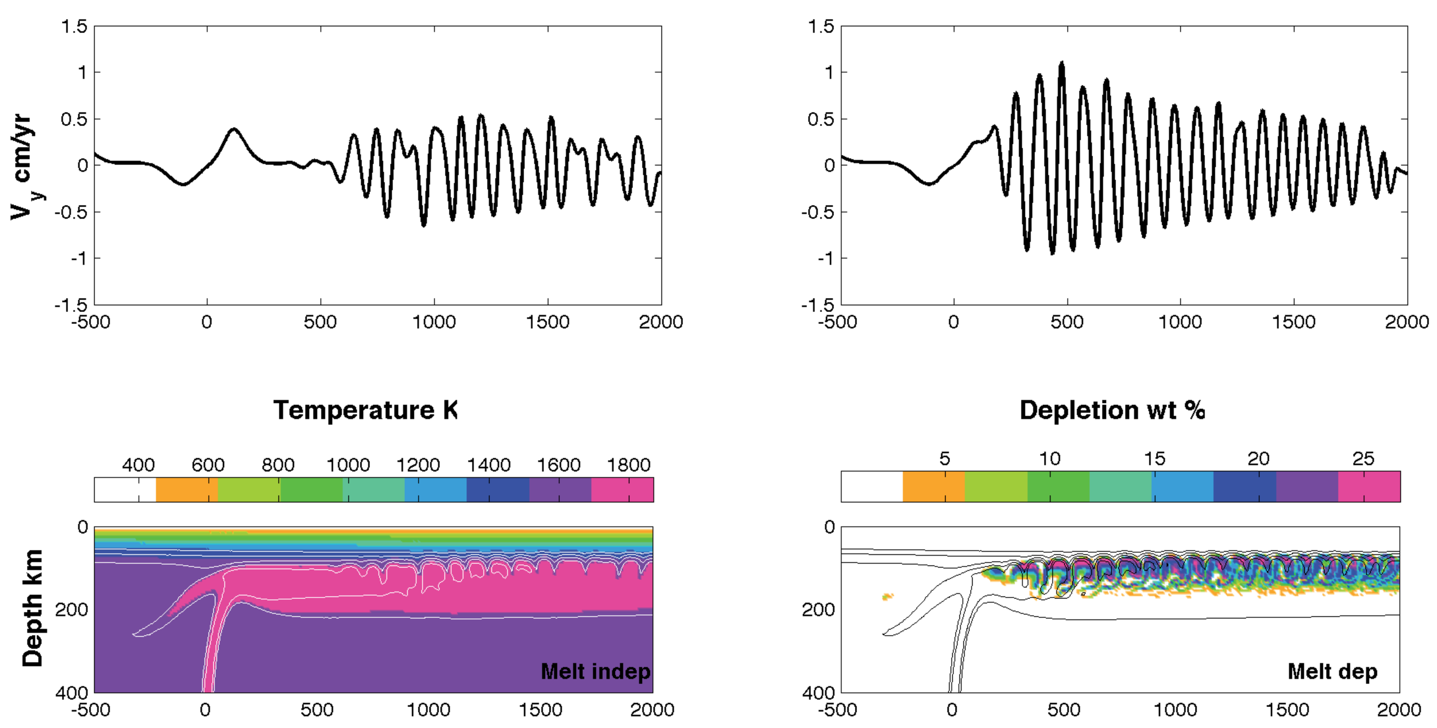


SSC ONSET

The models with melting-dependent physical properties show an accelerated development of the gravitational instabilities at the base of the lithosphere. The reduction of the onset time may be explained by an increase in the local Rayleigh number of the unstable layer, resulting from both a viscosity reduction and an increase of the buoyancy force, due to depletion in solid dense phases. The development of SSC instability is mainly promoted by the buoyancy of depleted residue, compared to melt retention models, in particular in case of cold plumes. The melting in the plume-fed layer occurs in small isolated domains, and the viscosity reduction is mostly localized in the vicinity of the impact point, consequently the viscosity contrast necessary to initiate the gravitational instability in TBL is not reached.

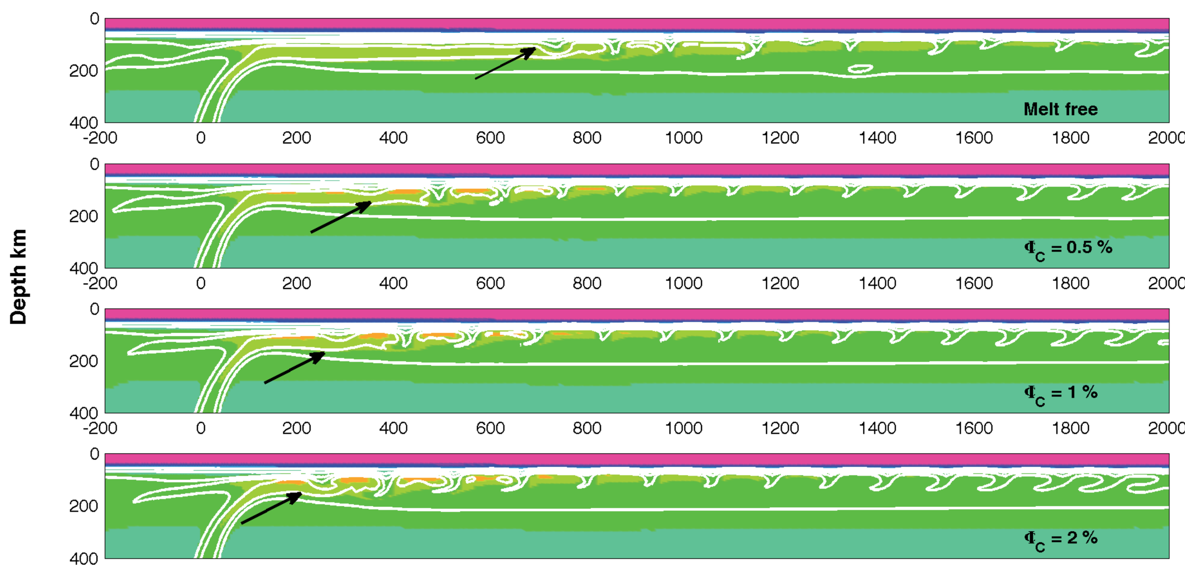
The development of SSC instability is mainly promoted by the buoyancy of the depleted residue, compared to melt retention models.





ΔT_{plume} = 250 K - V_{plate} = 10 cm yr^{-1}

ΔT_{plume} = 200 K - V_{plate} = 10 cm yr^{-1}



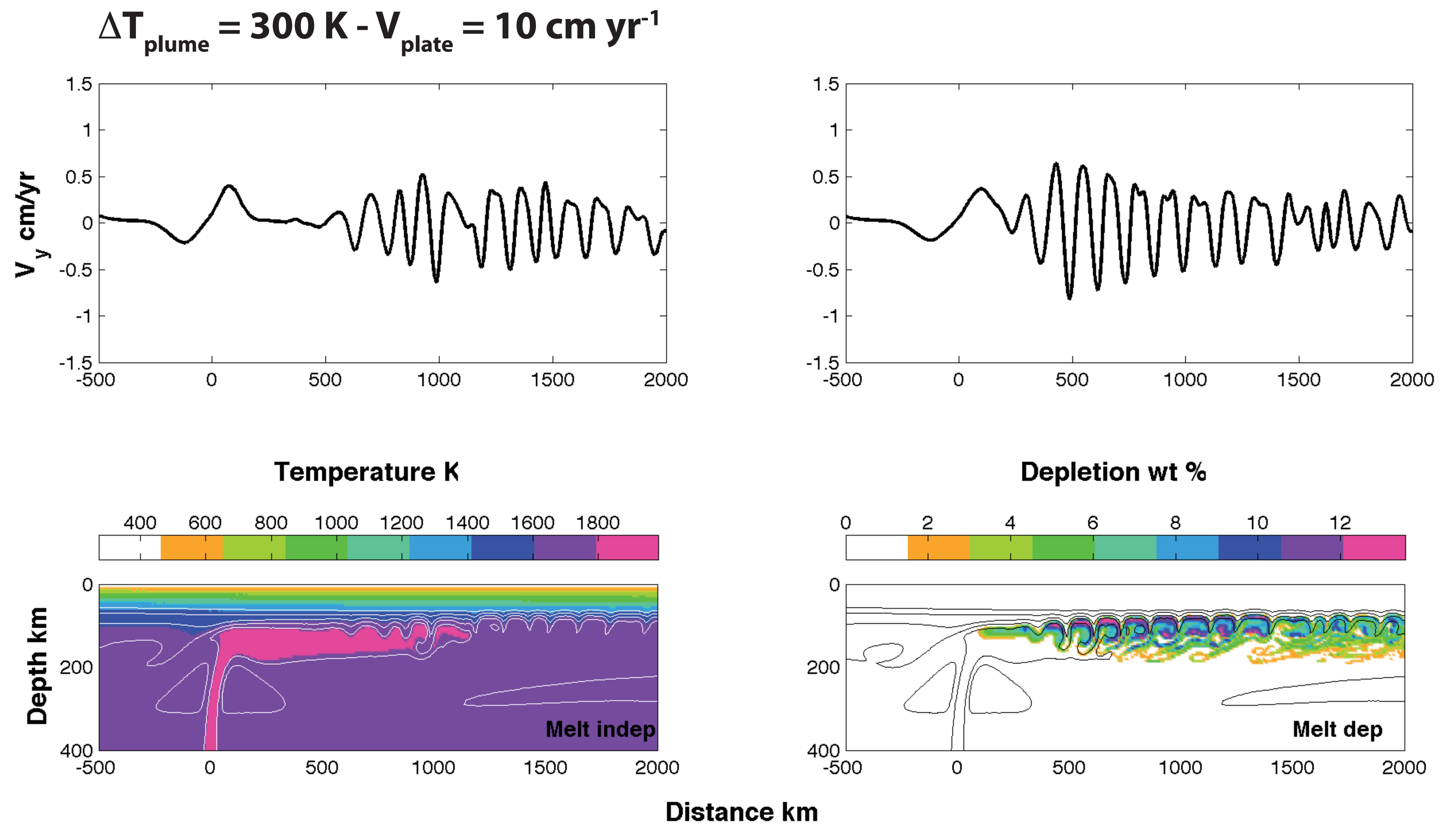
ΔT_{plume} = 250 K - V_{plate} = 10 cm yr^{-1}

- Melting occurs in small isolated domains
- Viscosity reduction is mostly localized in small pocket.
- Increasing the threshold extraction, from 0.5 % to 2%, strongly affects viscosity, producing enlarged areas of melting.

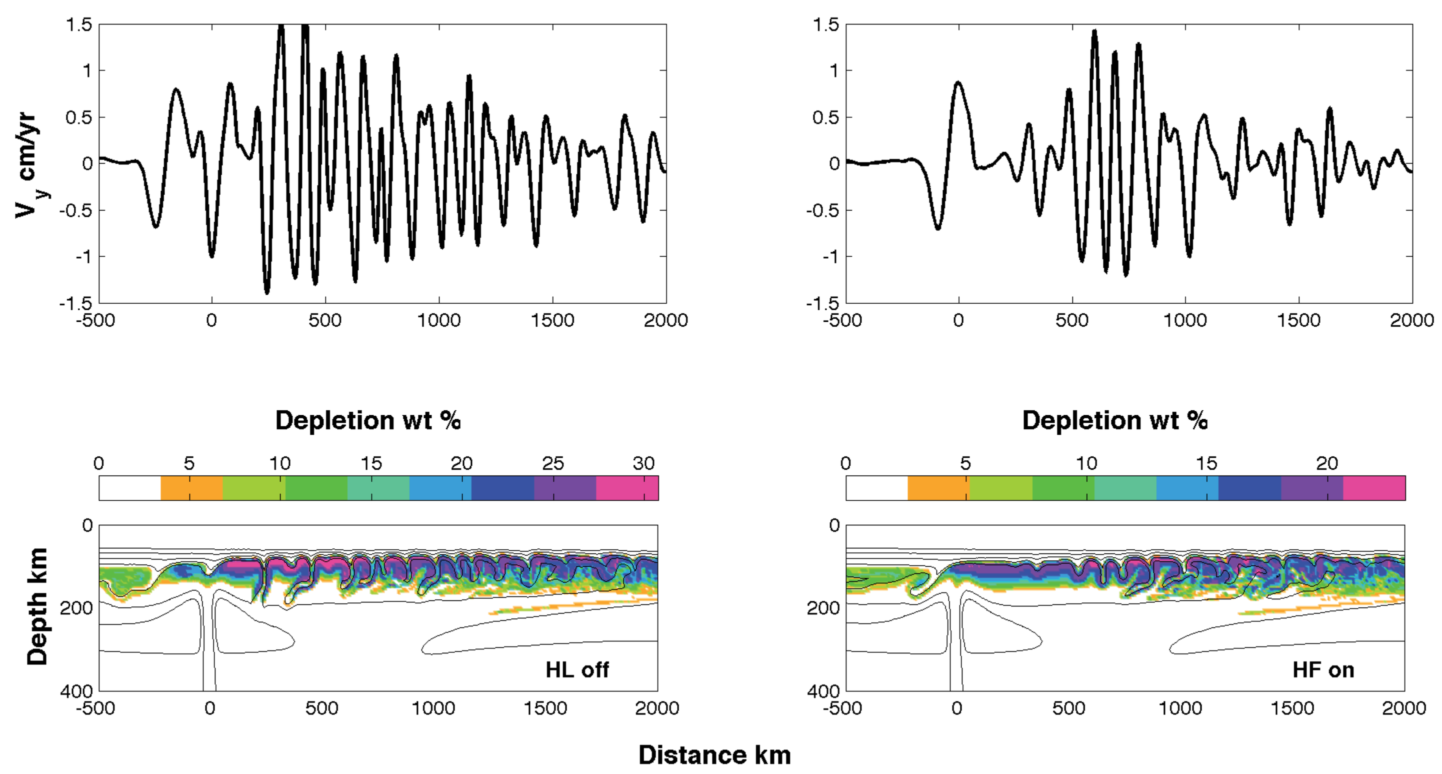
EBA

Comparison between models where the effects of shear heating, adiabatic heating and latent heat productions have been considered.
- The major difference is the faster cooling of the plume material, during plume rising, due to decrease in temperature by adiabatic cooling.
- A slightly larger effect is, however, played by the heat consumption during melting.

ΔT_{plume} = 300 K - V_{plate} = 10 cm yr^{-1}

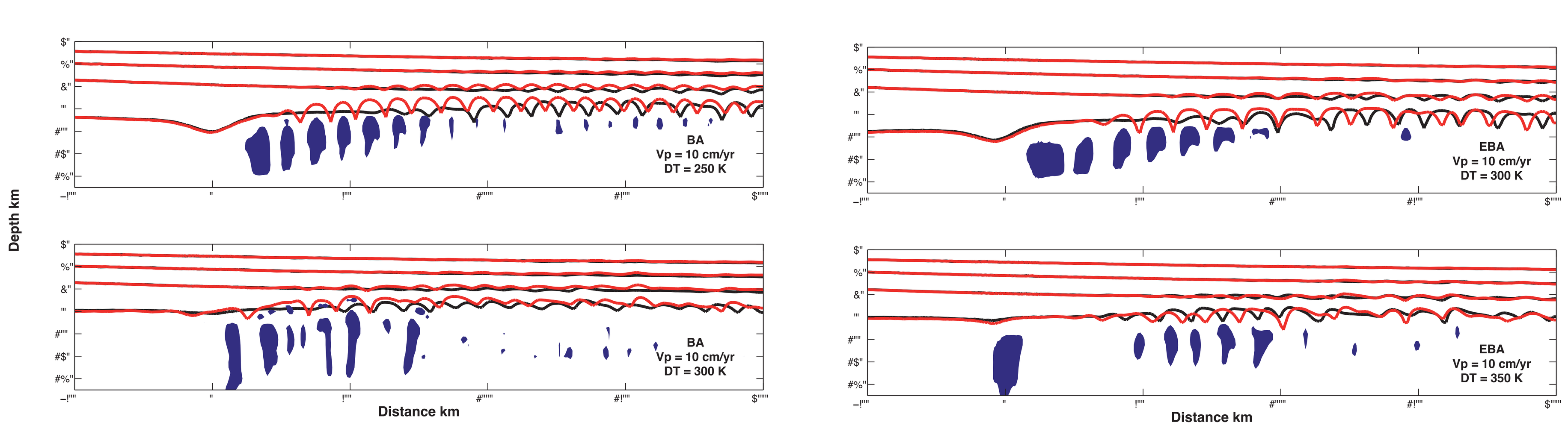


ΔT_{plume} = 350 K - V_{plate} = 10 cm yr^{-1}

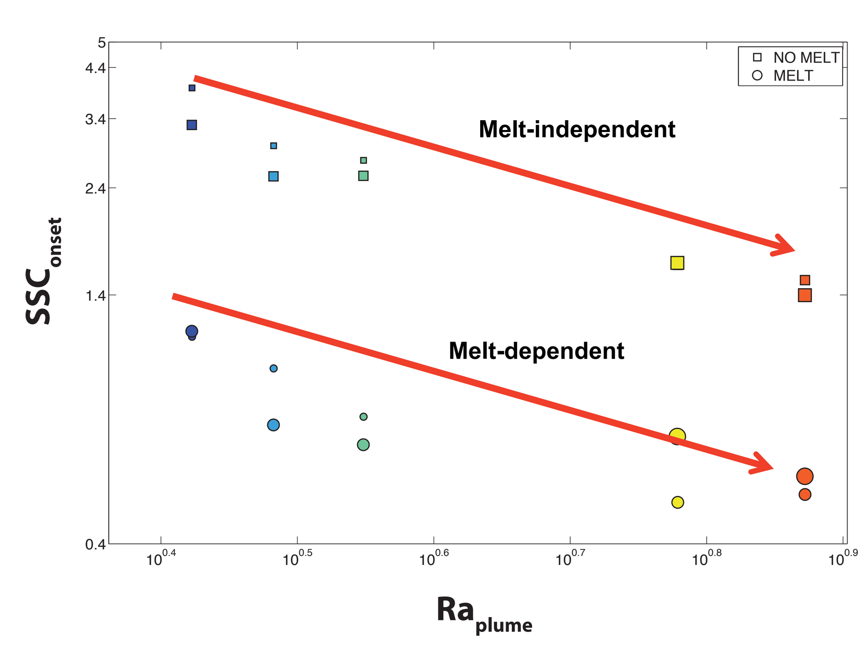


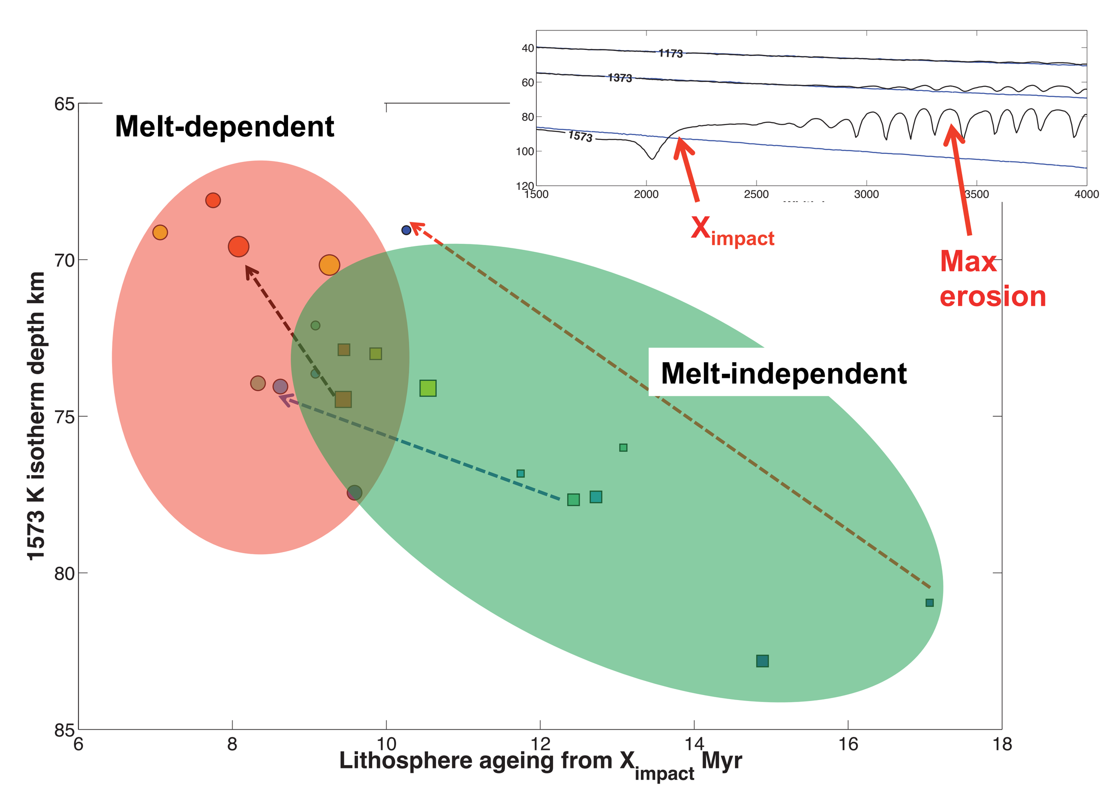
LITOSPHERE EROSION

The low viscosity and increased density contrast between the two layers (molten vs. un-molten layers) produce a more vigorous SSC, favoring the thermo-mechanical erosion of the lithosphere. The lithospheric thinning is accelerated, and the maximum variation in the minimum depth of the 1573 K isotherm (10 km) is observed for models with weak plumes and low plate velocities and the minimum (~5 km) for strong plumes and high plate velocities.



CONCLUSIONS





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