RADIATIVE ZONE IN JUPITER'S DEEP ATMOSPHERE?

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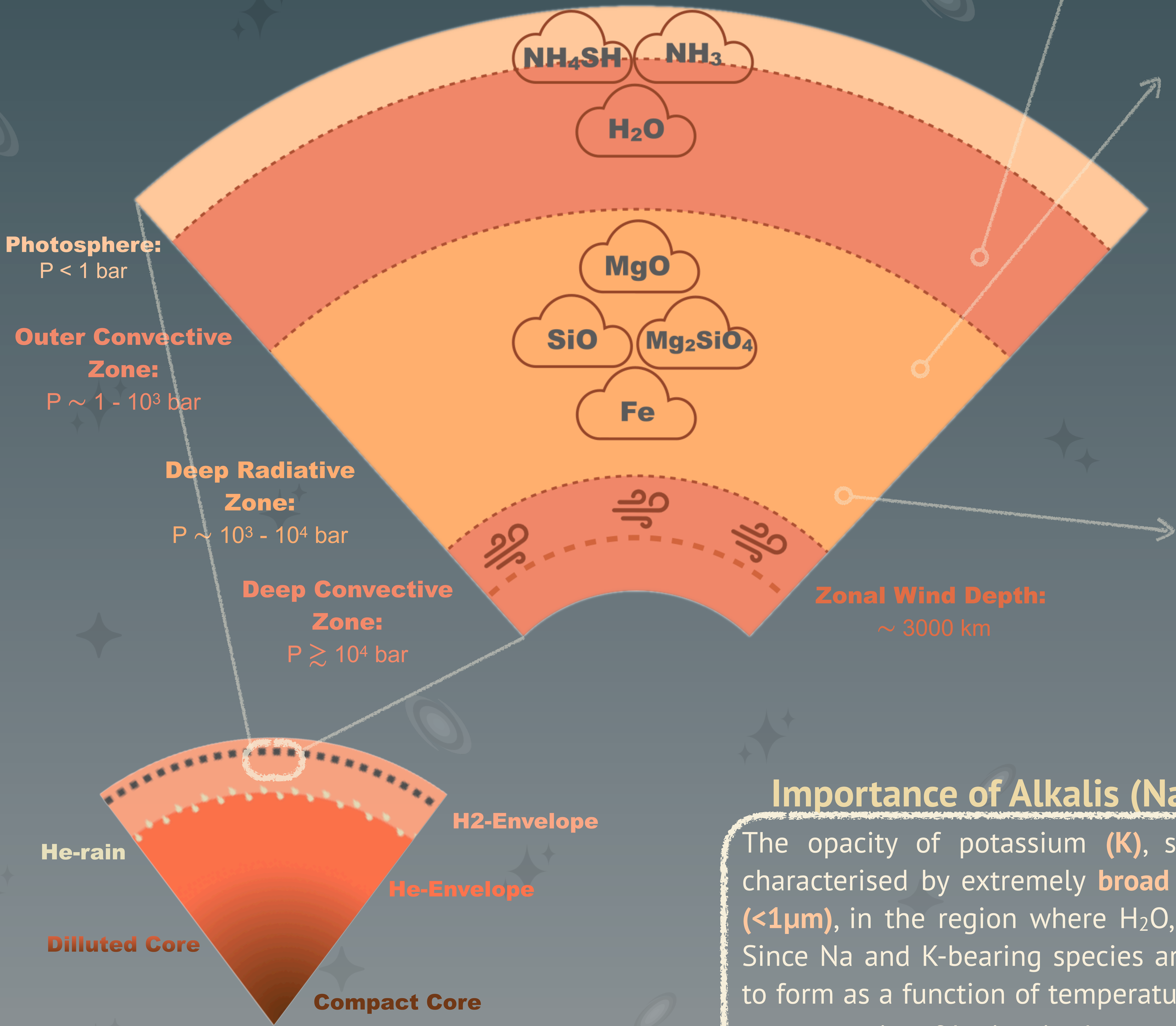
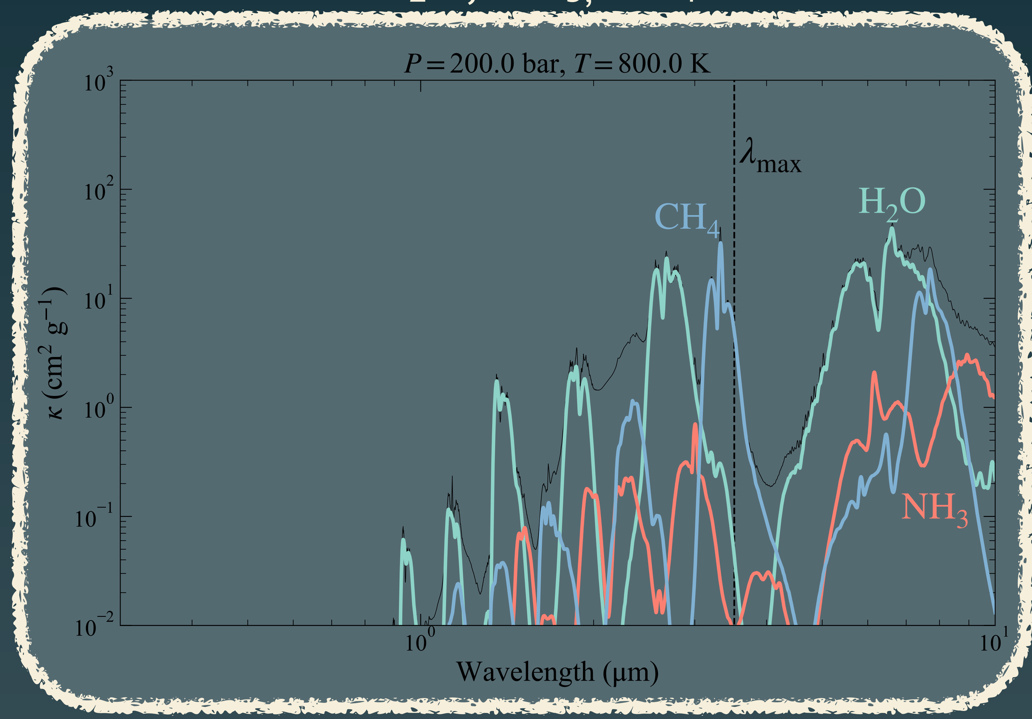
Background

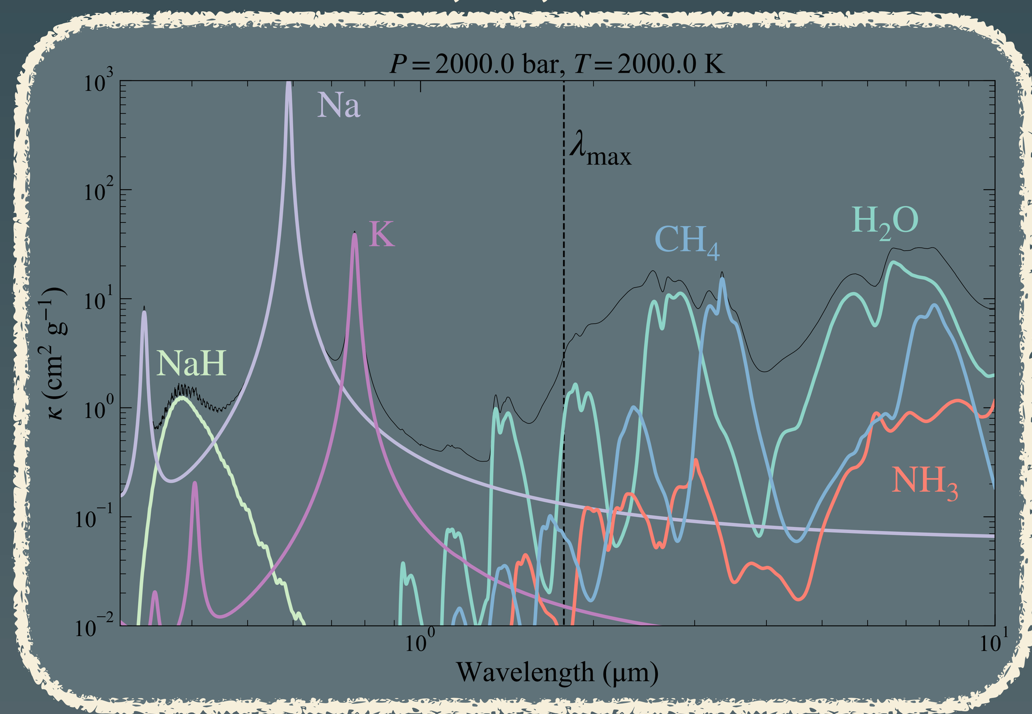
One of the outstanding questions of Jupiter remains the heat transport throughout the molecular hydrogen envelope. Traditionally, interior models for gas giants assume a convective interior due to the rapid rise of opacity with increasing pressure. However, in the temperature range **between ~1500 - 2000K**, abundant molecules such as **H_2O, NH_3** and **CH_4** become more **transparent**. Depending on the decrease in opacity, convection can be inhibited and a **radiative zone develops** in Jupiter's deep atmosphere [1]. The presence of a radiative zone changes the temperature-pressure profile of Jupiter, which in turn affects all the thermodynamical properties of the interior.



Dominant opacity sources at ~200 bar: H_2O, NH_3, CH_4



Dominant opacity sources at ~2000 bar: K, Na, NaH



Dominant opacity sources at ~8000 bar: K, Na, NaH, CaH, MgH, FeH

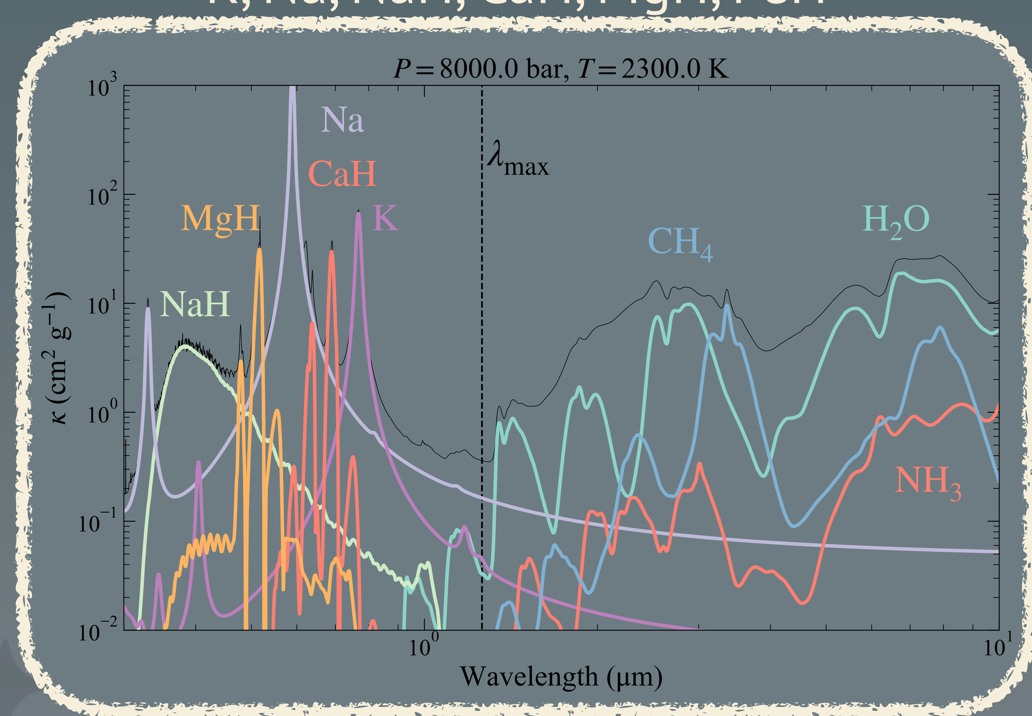


Figure 1: Opacity as a function of wavelength at different pressures in the molecular hydrogen envelope of Jupiter.

Importance of Alkalis (Na/K)

The opacity of potassium **(K)**, sodium **(Na)** and sodium hydride **(NaH)** is characterised by extremely **broad absorption features at shorts wavelengths (<1μm)**, in the region where H_2O, NH_3 and CH_4 become relatively transparent. Since Na and K-bearing species are the first short wavelength-opaque species to form as a function of temperature, they have significant contributions to the mean opacity of Jupiter in the pressure range of ~1000 - 4000 bar, and are able to **control the existence of a radiative zone.**

Conditions for a Radiative Zone

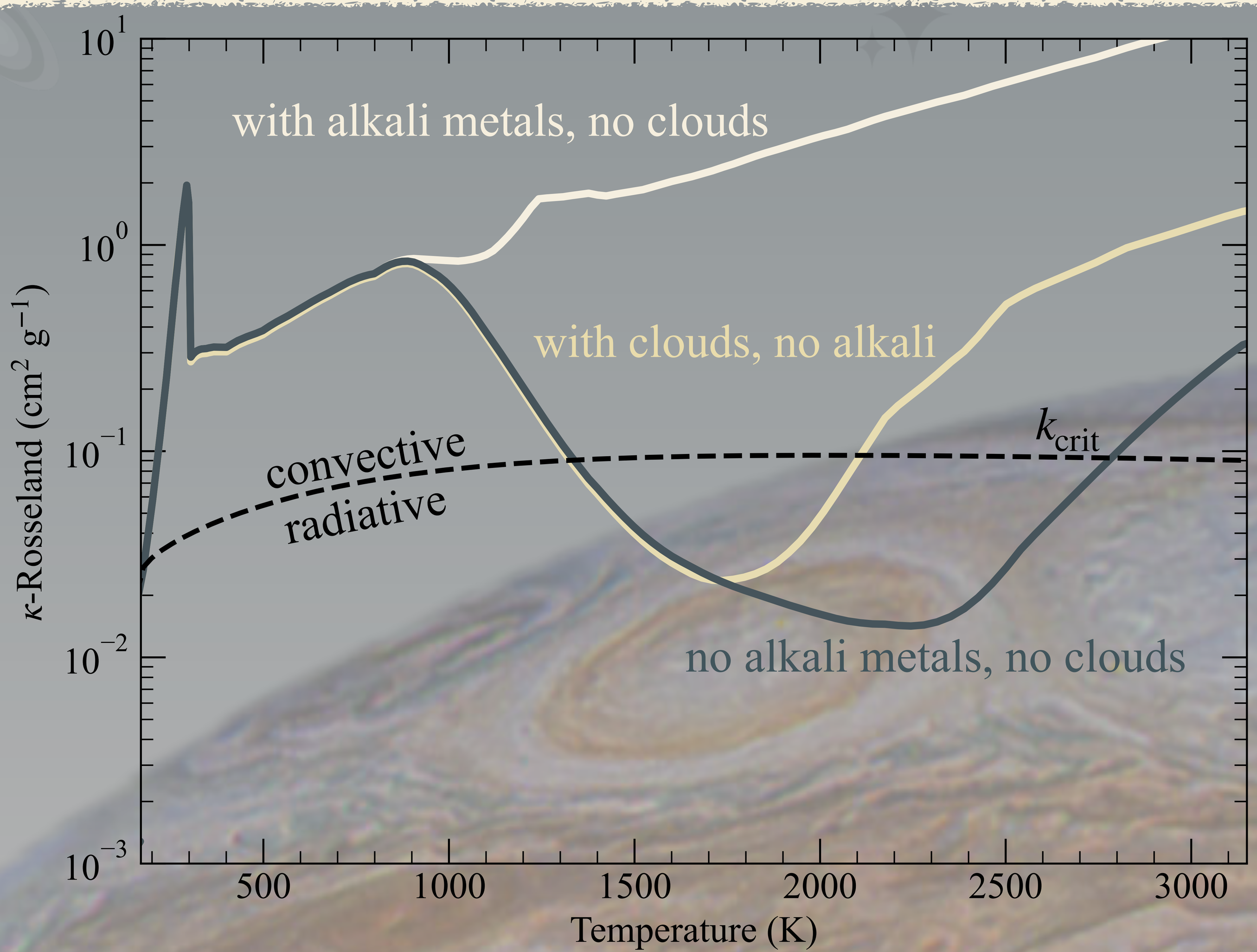


Figure 2:. Rosseland mean opacity as a function of temperature

We find that a simultaneous **Na and K enrichment greater than 10^{-3}** with respect to their protosolar abundance is enough to **prevent a radiative zone.** On the other hand, an atmosphere which is strongly **depleted in alkalis can develop a radiative zone** which extends between ~ 1500 - 2500K.

When **cloud opacities** at high pressures are included (ex. Fe, MgO, Mg_2SiO_4, SiO), we find that their opacity is **insufficient to ensure convection** for alkali depleted atmospheres. Their effect is to reduce the extent of the radiative zone to ~ 1500 - 2000K.

In summary:

- K, Na and NaH control the existence of a radiative zone
- Na/K enrichment smaller than 10^{-3} is needed to develop a radiative zone

References: [1] Guillot et al. 1994