INVESTIGATING THE STABILITY & COMPOSITION OF LLSVP-LIKE MATERIAL IN MANTLE CONVECTION MODELS

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ABSTRACT PICO POSTER VERSION

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MOTIVATION

LLSVPs ARE INVOKED AS POTENTIAL RESERVOIR FOR PRIMITIVE MANTLE

CAN MANTLE CONVECTION MODELS GENERATE LLSVP-LIKE MATERIAL ?

WHAT ARE THE MODELLED LLSVPs MADE OF ?

HOW TO PRESERVE THE PRIMITIVE MANTLE ?

WORKFLOW

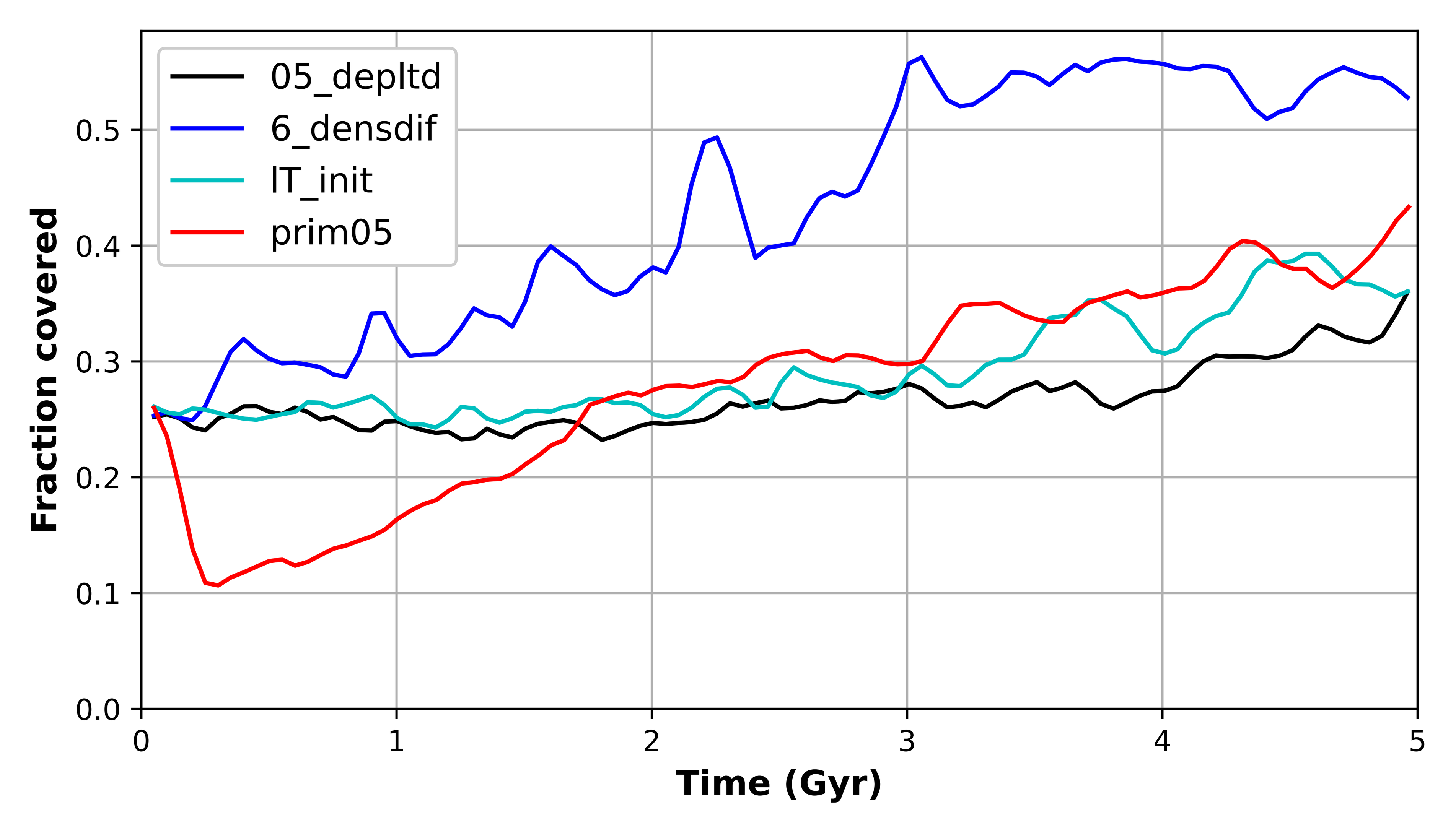
THERMO-CHEMICAL CONVECTION WITH 3D SPHERICAL CODE TERRA

SYNTHETIC SEISMIC PROPERTIES

STRUCTURE DETECTION

RETRIEVE TRACER INFORMATION

CMB Coverage



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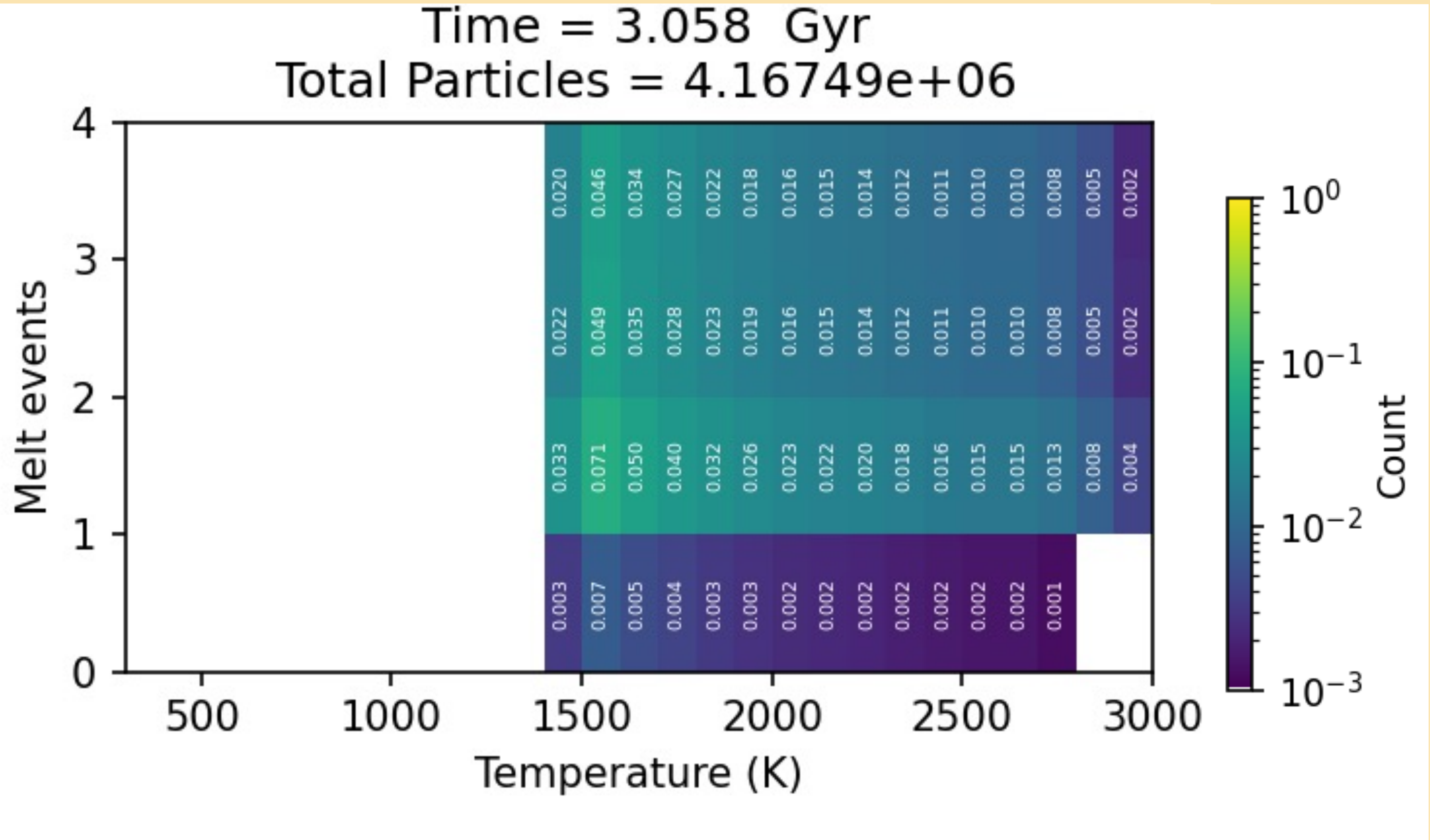
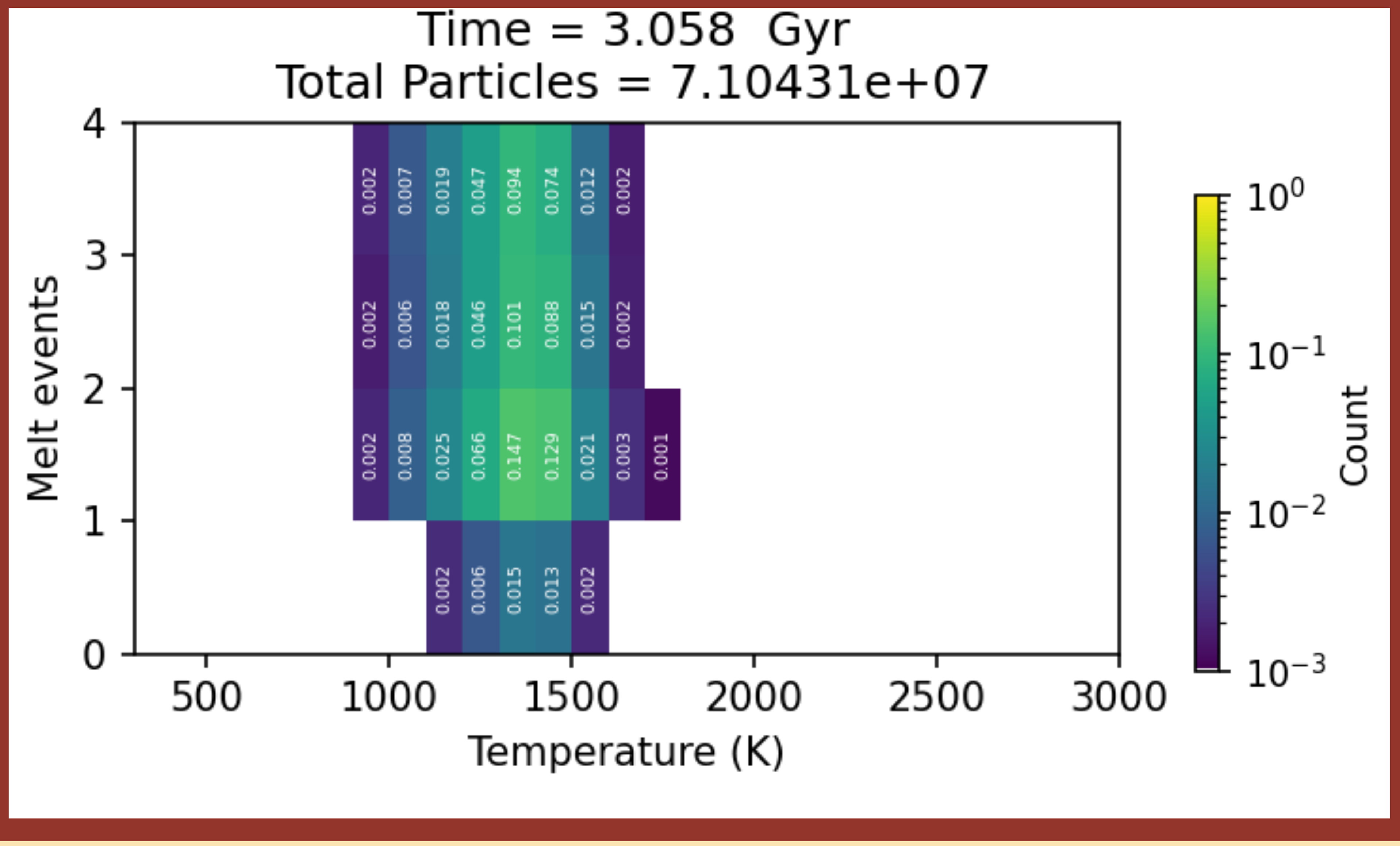
LLSVP-LIKE



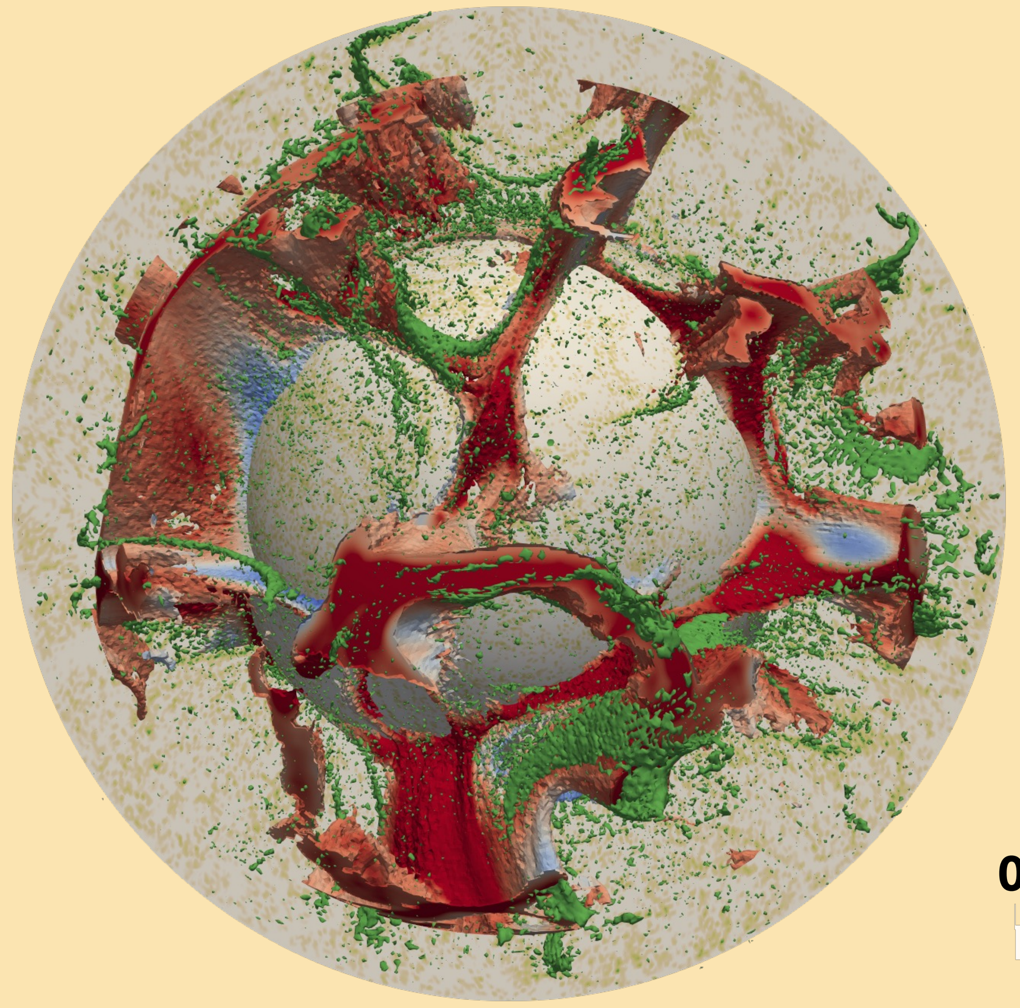
AMBIENT MANTLE

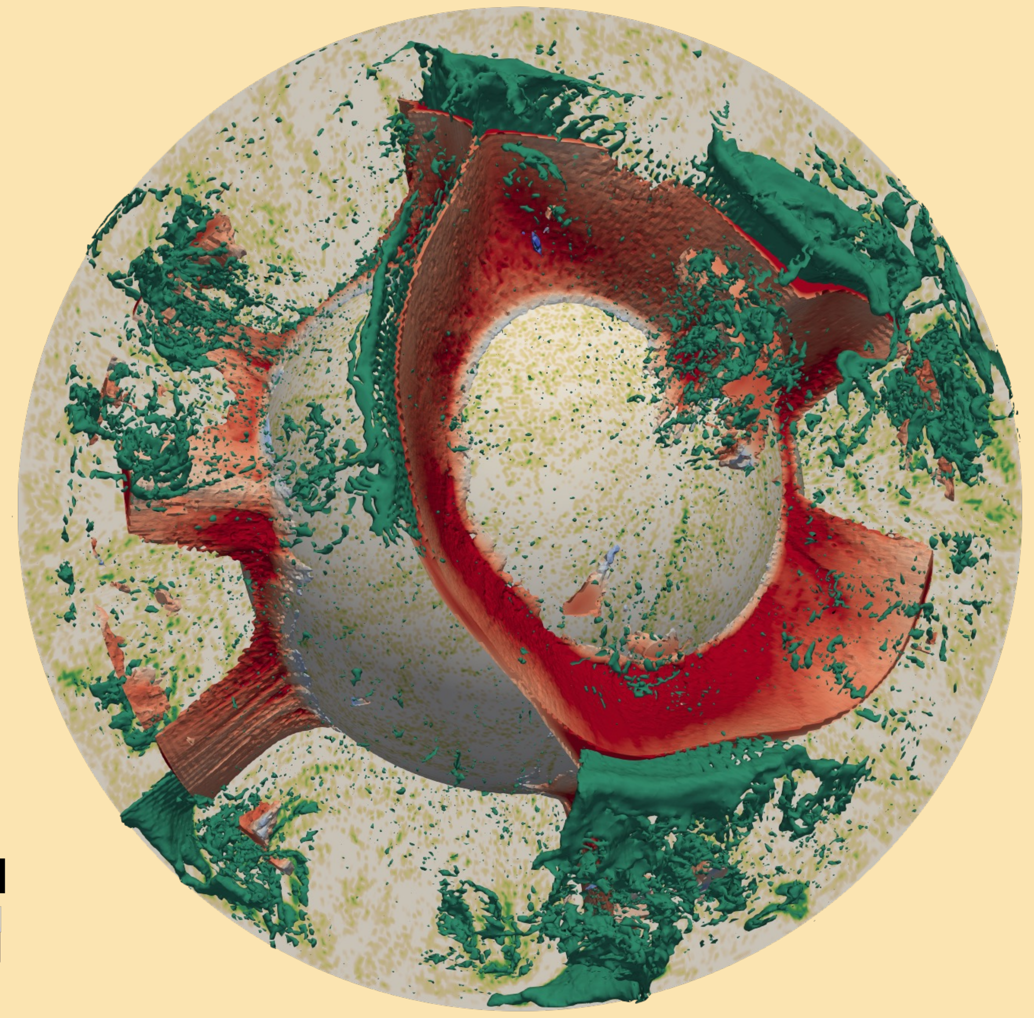


6_densdif

prim05

t = 1.75 Gyr





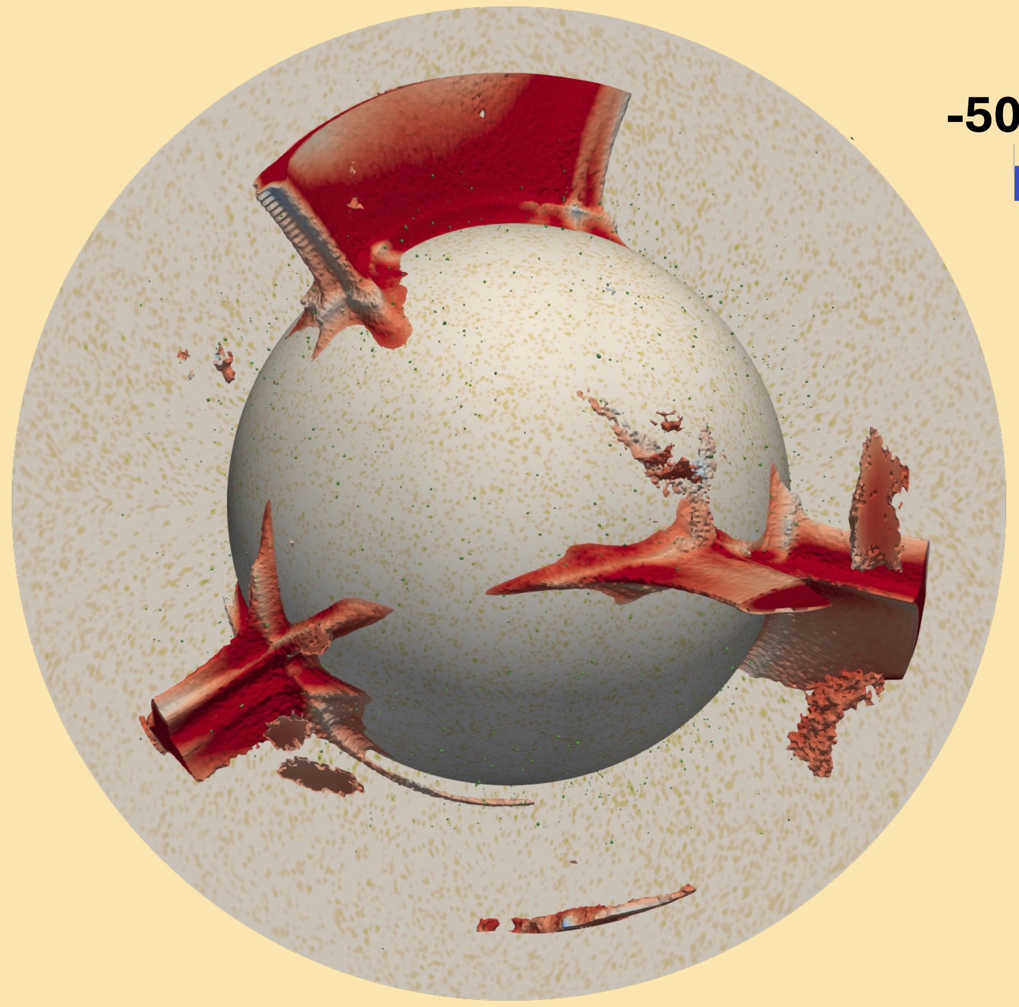
Primitive Particle Concentration (PPC)

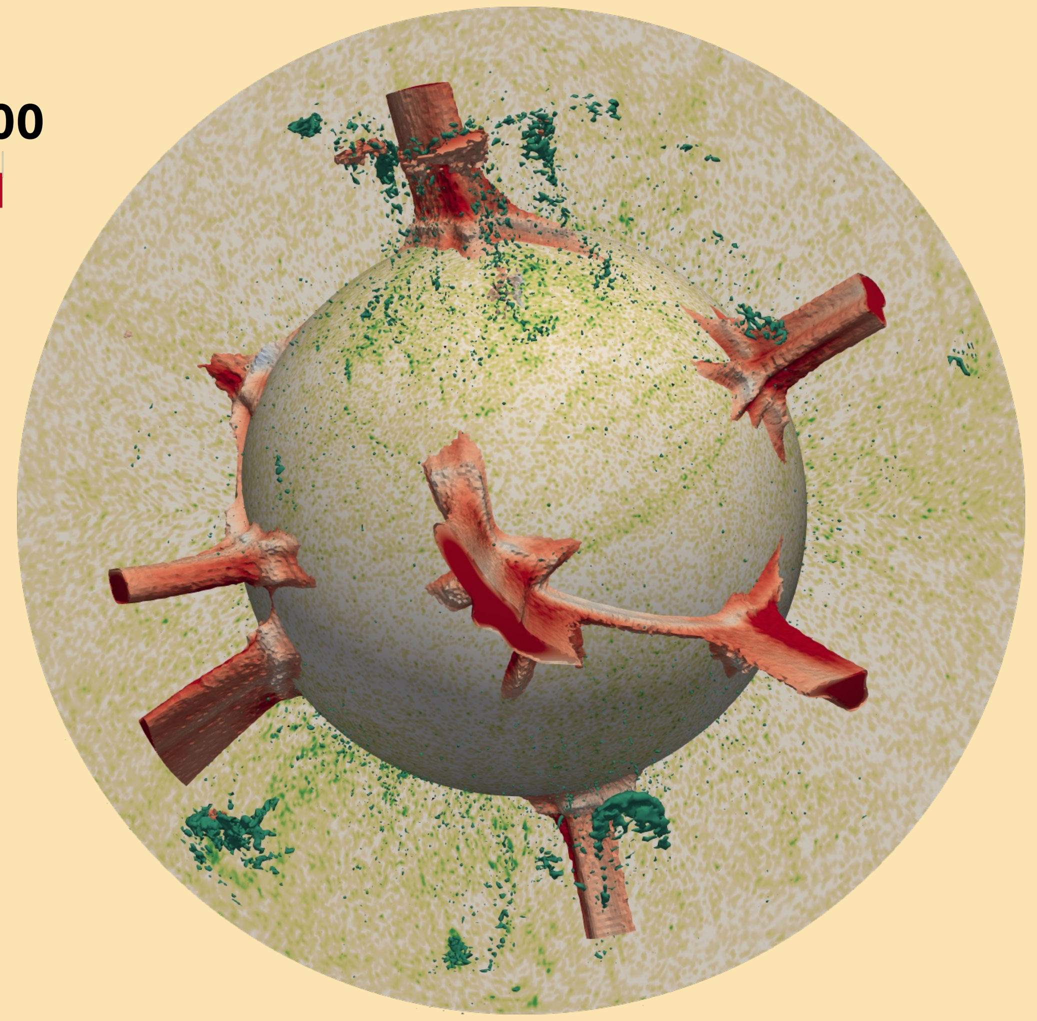
0 0.2 0.4 0.6 0.8 1

dT (K)

-500 -200 0 200 500

t = 4.5 Gyr





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I INTRODUCTION

- Large Low Shear Velocity Provinces (LLSVPs) are **basal mantle structures** defined by **negative anomaly in ΔVs**.
- The reason for their seismic signature has been questioned (purely thermal, chemical or thermo-chemical) as **plumes** seem to be **associated with these structures** and correlate with intraplate volcanism locations.
- **LLSVPs** are often invoked as a **potential reservoir** to store primitive mantle to explain **primitive He ratios** observed **in OIBs**. Such a scenario would suggest that at least some **part of the LLSVPs** are **long-lived**, quasi-stable structures.
- Previous 3D geodynamic experiments suggest that **LLSVP longevity** is achieved through **replenishment of the constituent material** (Panton *et al*, 2023) potentially disqualifying them as a reservoir of primordial material.
- However, **2D experiments** have shown that **remnants of a primordial layer** may become **trapped within accumulations** of recycled, **dense oceanic crust** for extended periods of time (Jones *et al*, 2021).
- We investigate the **ability of 3D mantle convection models to generate** material with **similar Vs anomaly as LLSVPs**, tracking their **composition, age and stability** throughout the simulation.

II METHODS

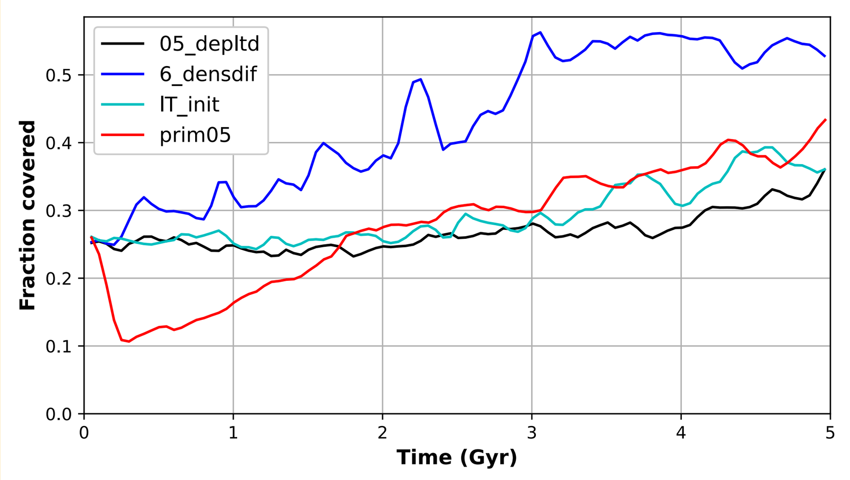
- **TERRA is a 3D finite element code** solving mass, momentum and energy conservation equations for **heat transfer in spherical shell** (J. Baumgardner, 1983).
- **Particles** are used to **track bulk composition** and various **isotopes**, allowing to model **thermo-chemical convection** and **mantle differentiation** (van Heck *et al*, 2016).
- **Synthetic seismic properties** are computed from **pressure**, **temperature** and **bulk composition** (proportions of end-member lithologies), details in Panton *et al* (2023).
- **Material** is considered **LLSVP-like** when the anomaly in **ΔVs is similar to that of the LLSVPs, i.e. < - 0.27%**. **Detection** starts **from the CMB** and must be **continuous** in the **radial column**.

TABLE: Presented models are **incompressible**, **Boussinesq**, **free-slip** with **radiogenic heating** based on **tracer concentration** of heat producing elements.
Reference Viscosity=5.10^{21} Pa.s

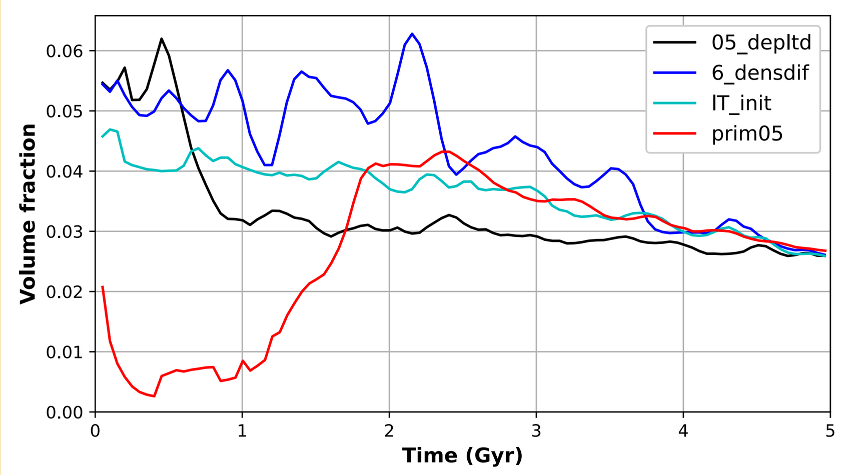
Model	Initial mantle depletion	Basalt density excess	Average Initial temperature	Primordial dense layer
05_depltd	50%	2%	1930 K	no
6_densdif	50%	6%	1930 K	no
IT_init	50%	2%	1480 K	no
prim05	50%	2%	1930 K	200km +5% density excess

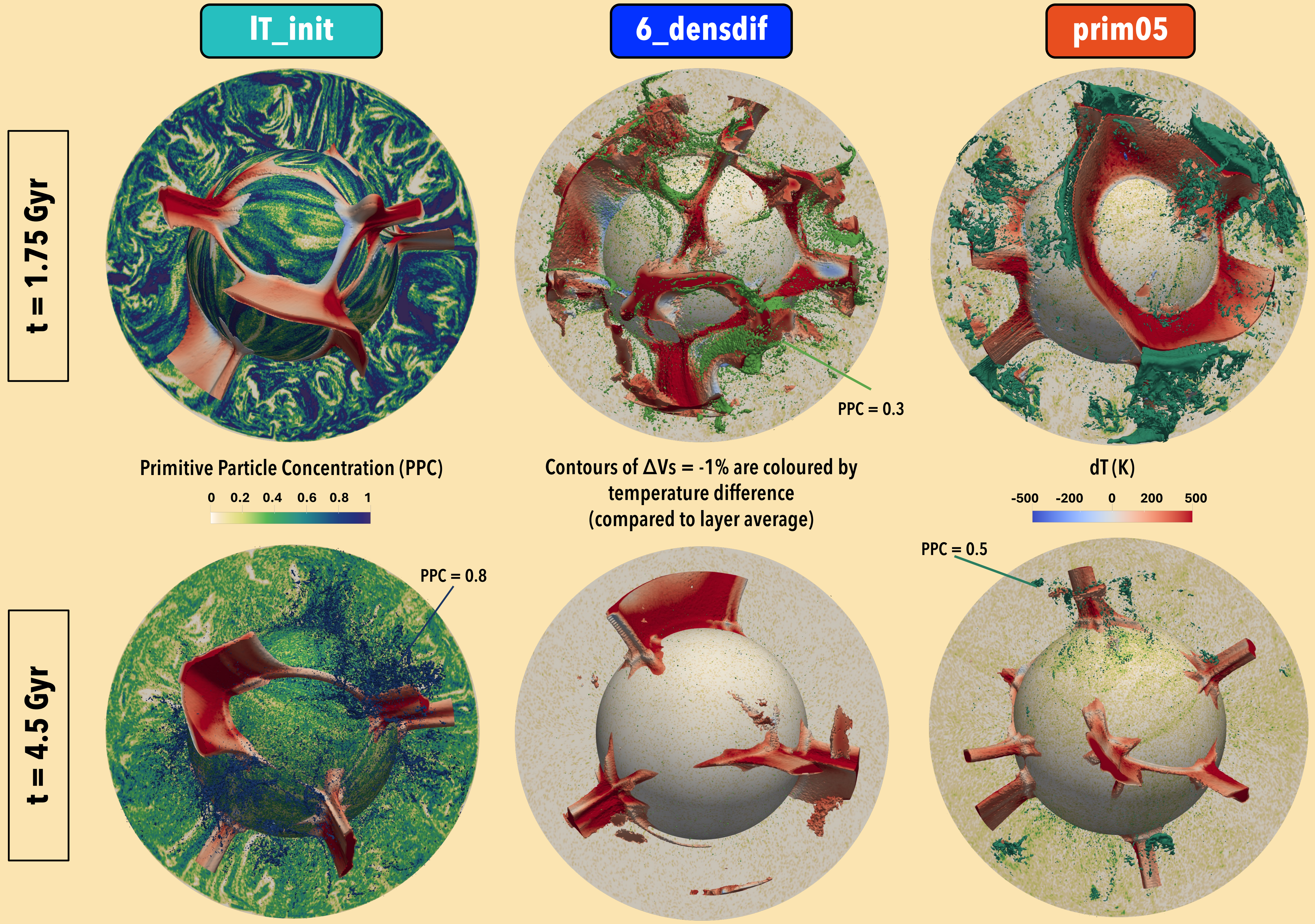
III RESULTS

CMB Coverage

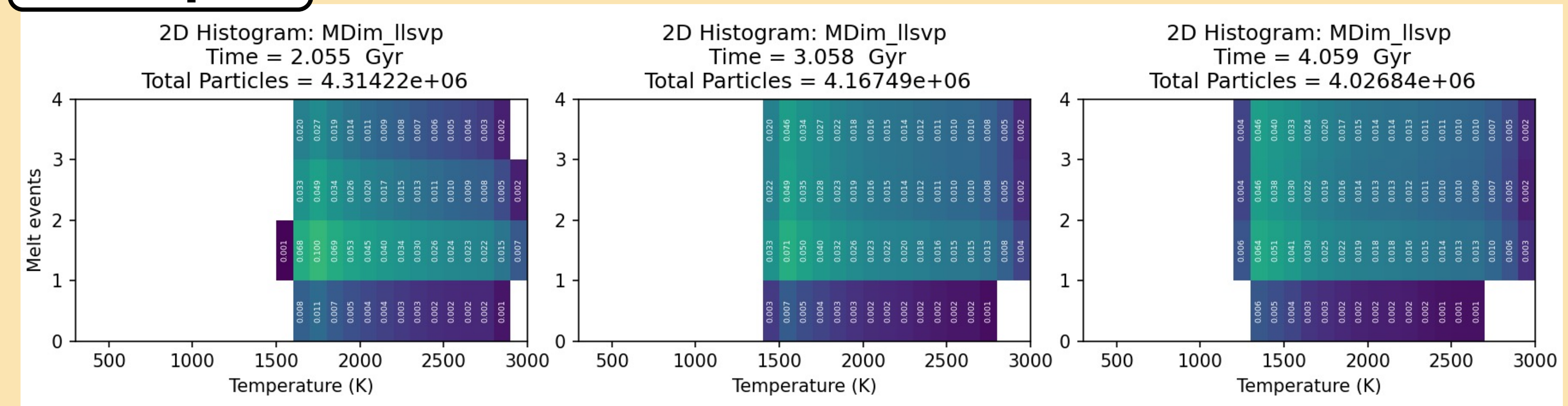


Volume fraction

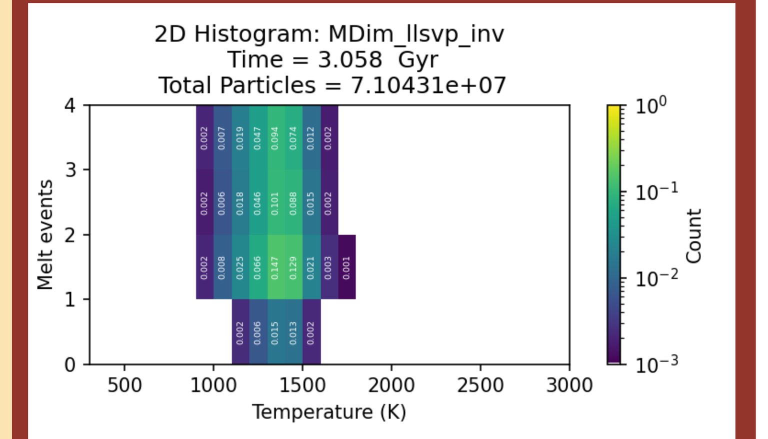




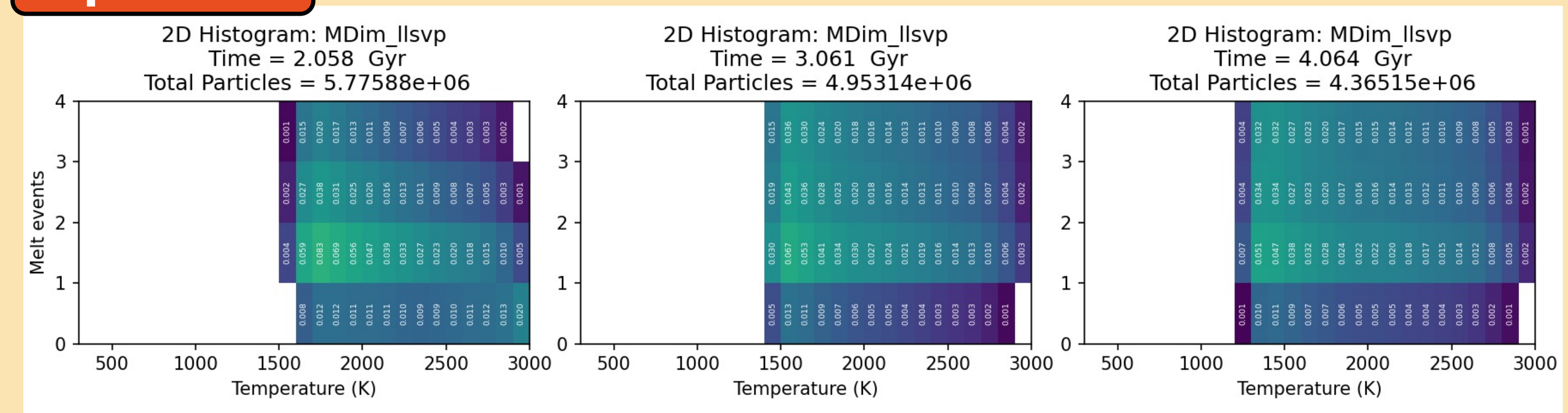
05_depltd — LLSVP-like

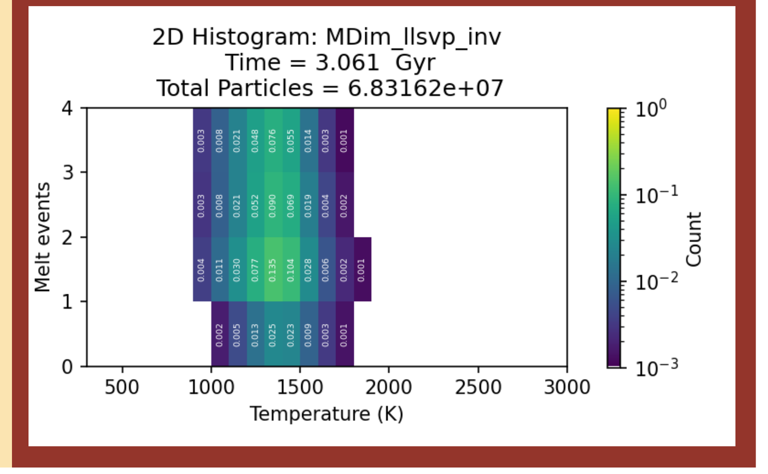


AMBIENT MANTLE



prim05





IV CONCLUSIONS

- Mantle convection models generate material with a similar ΔVs anomaly as LLSVPs throughout the simulation with stable CMB coverage.
- The constituent material seems to be renewed throughout the simulation and is hotter than ambient mantle (see histograms and visualisations).
- Case with primordial dense layer captures more primitive material and preserves it longer within the detected structure.
- In other cases, we observe that primitive material is not particularly concentrated within the detected structure compared to the ambient mantle. Preservation of primitive material is strongly dependent of the processing history and therefore the thermal history as show by model IT_init.
- Due to the detection method and lack of tomographic filtering, we likely underestimate heterogeneity within what we consider to be LLSVP-like.

REFERENCES

- Baumgardner, J. R. (1983). *A three-dimensional finite element model for mantle convection*. University of California, Los Angeles.
- Jones, T.D., Sime, N., and van Keken, P. E. (2021). "Burying Earth's Primitive Mantle in the Slab Graveyard". Geochemistry, geophysics, geosystems: G3 22.3.
- Panton, J., Davies, J.H., and Myhill, R. (2023). "The Stability of Dense Oceanic Crust Near the Core-Mantle Boundary". Journal of Geophysical Research: Solid Earth 128.2.
- Van Heck, H. J., Davies, J. H., Elliott, T., & Porcelli, D. (2016). Global-scale modelling of melting and isotopic evolution of Earth's mantle: melting modules for TERRA. *Geoscientific Model Development*, *9*(4), 1399-1411.

ACKNOWLEDGEMENTS

This work was supported by the Natural Environment Research Council. This work used the ARCHER2 UK National Supercomputing Service (https://www.archer2.ac.uk).

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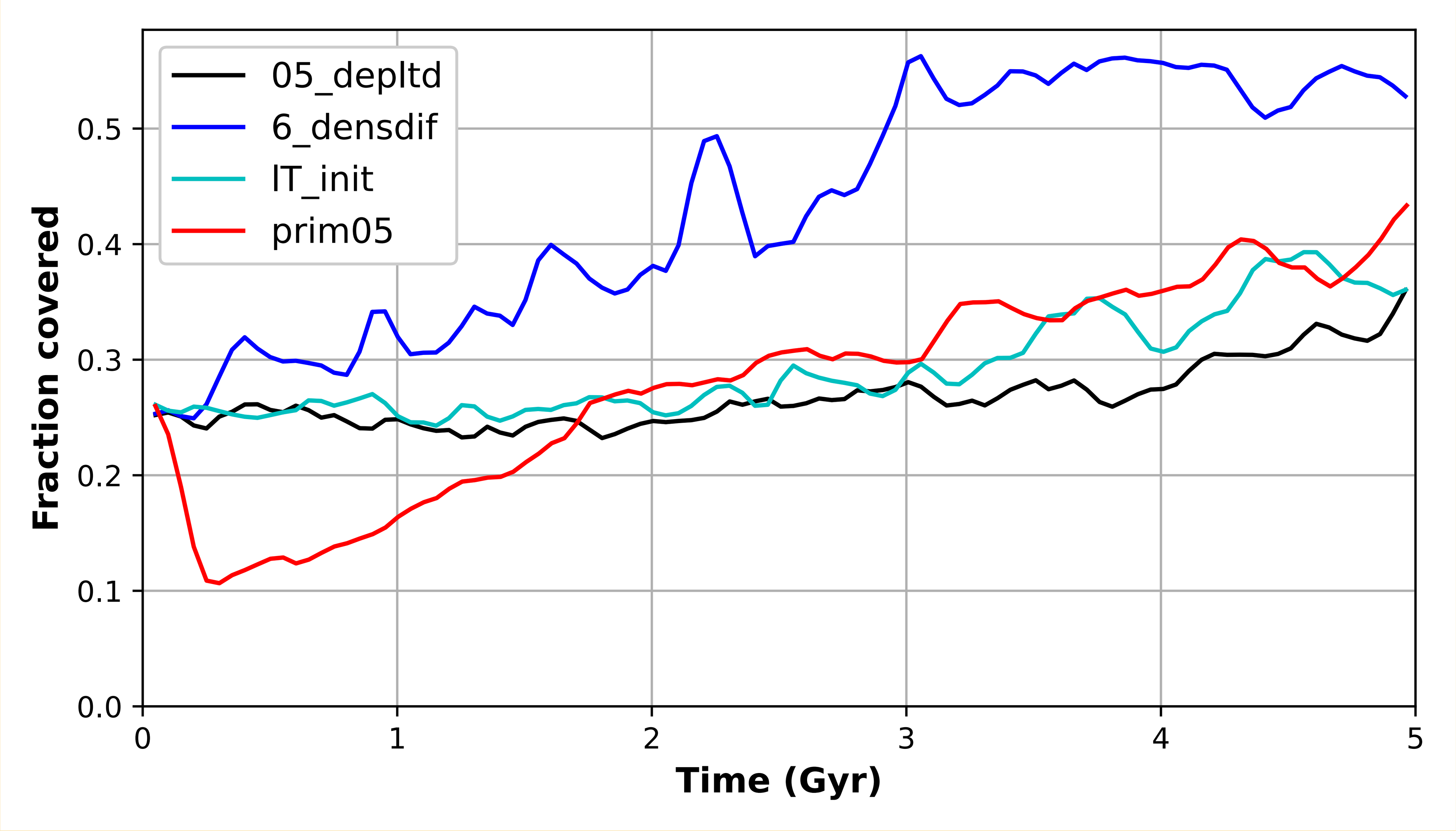
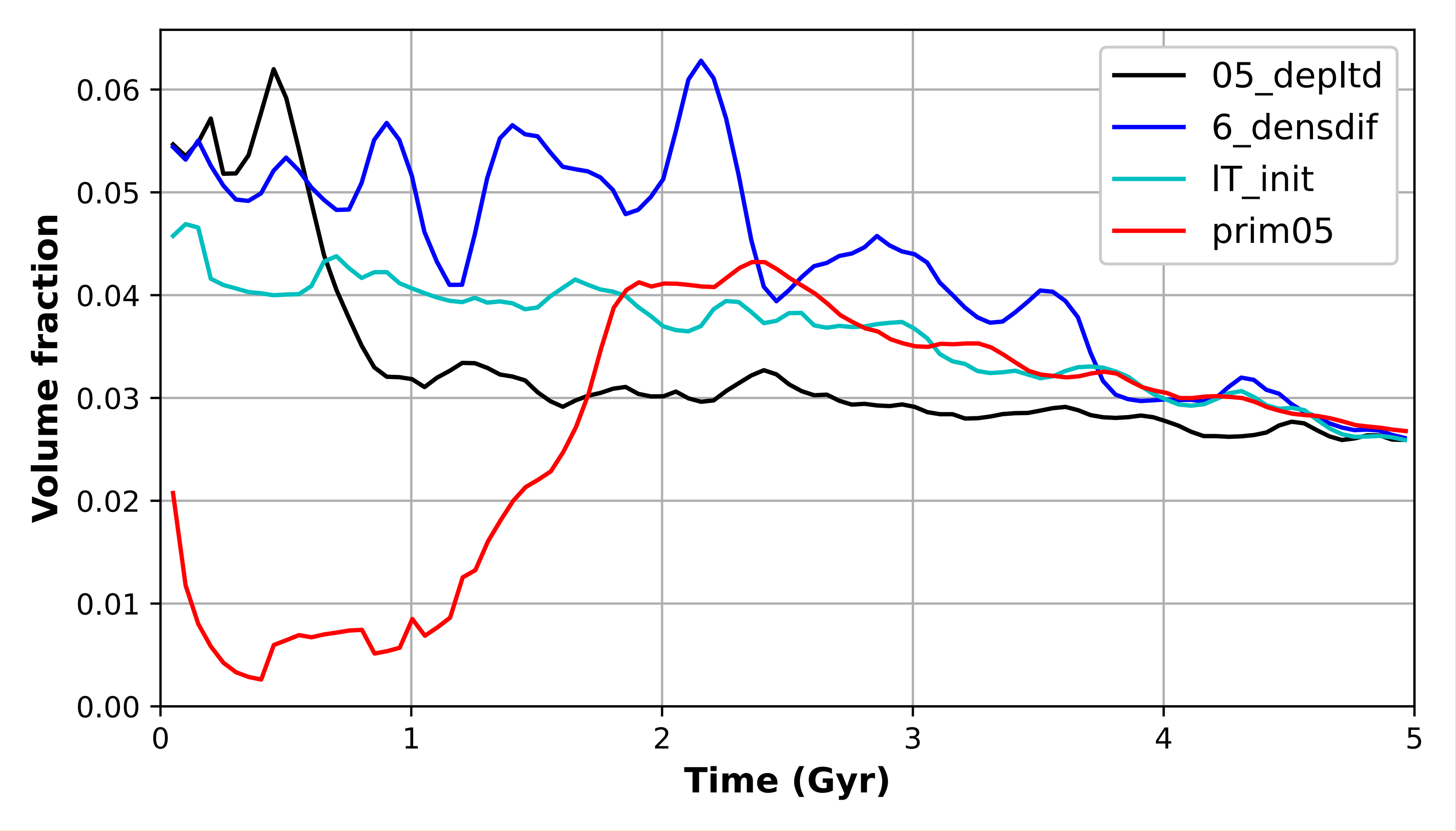
III RESULTS | DETECTED STRUCTURE METRICS

CMB Coverage



Volume fraction



- **LLSVP-like material form basal mantle structures in all cases throughout the simulation**
- **Due to the detection method and lack of tomographic filtering, we likely underestimate the volume fraction and heterogeneity within what we consider to be LLSVP-like.**

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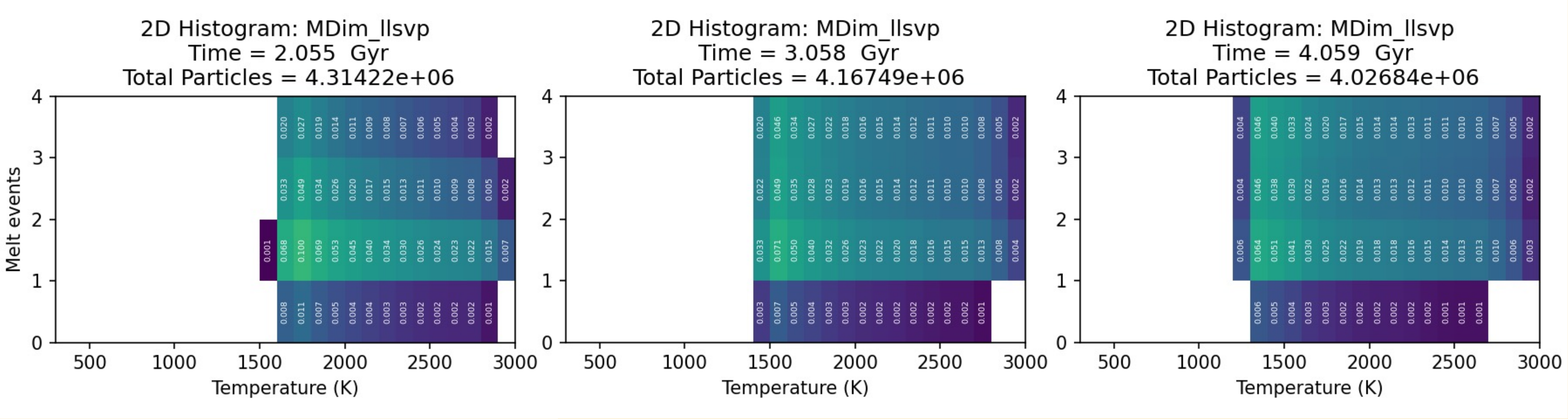
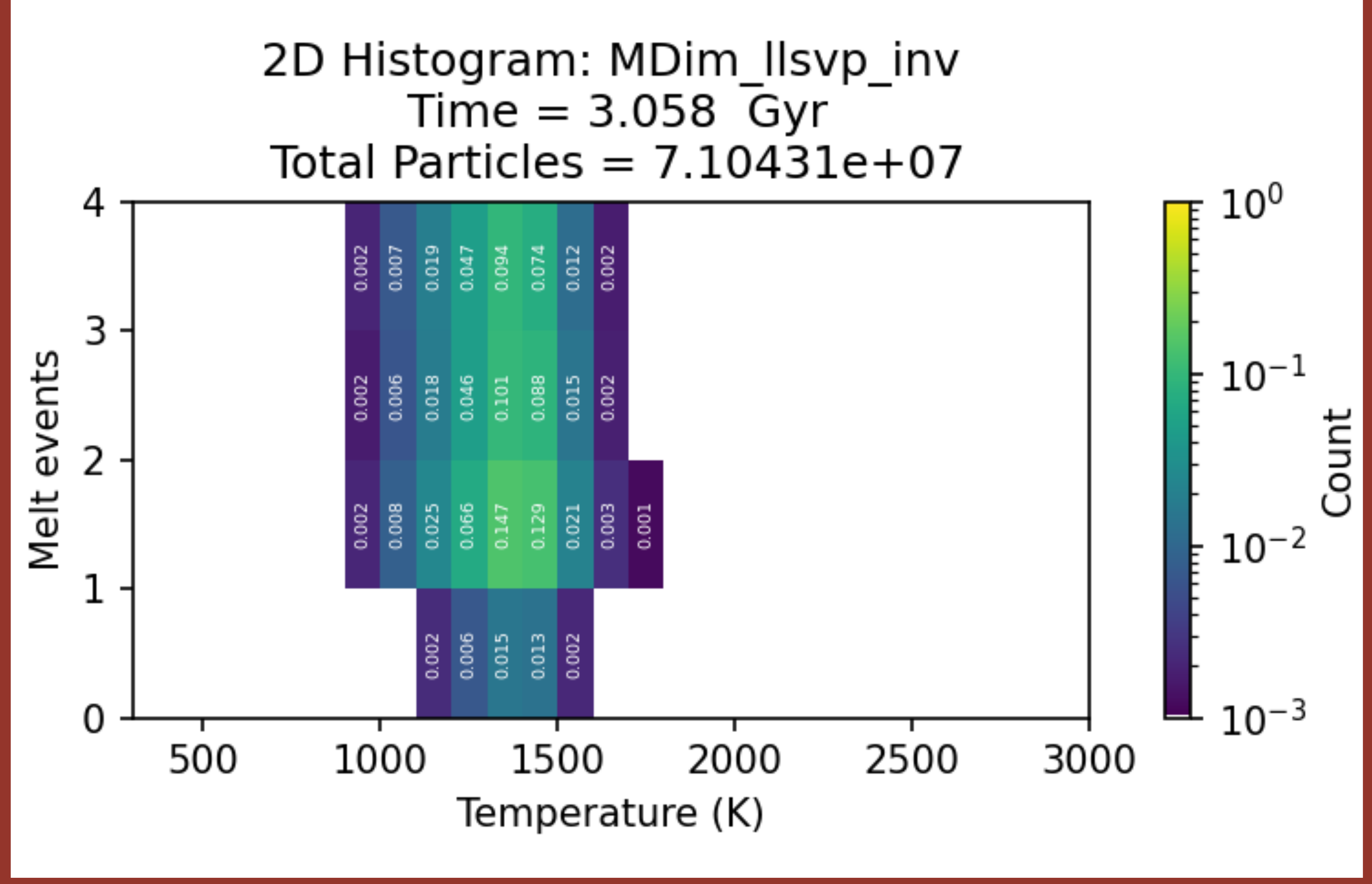
III RESULTS | CONSTITUENT MATERIAL

LLSVP-like material

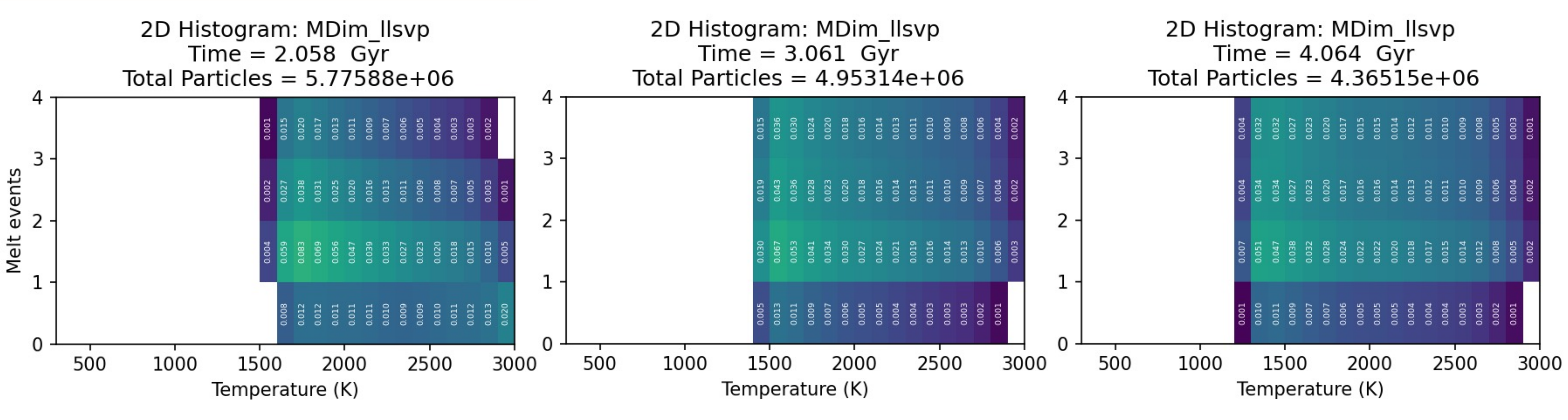
Complementary reservoir

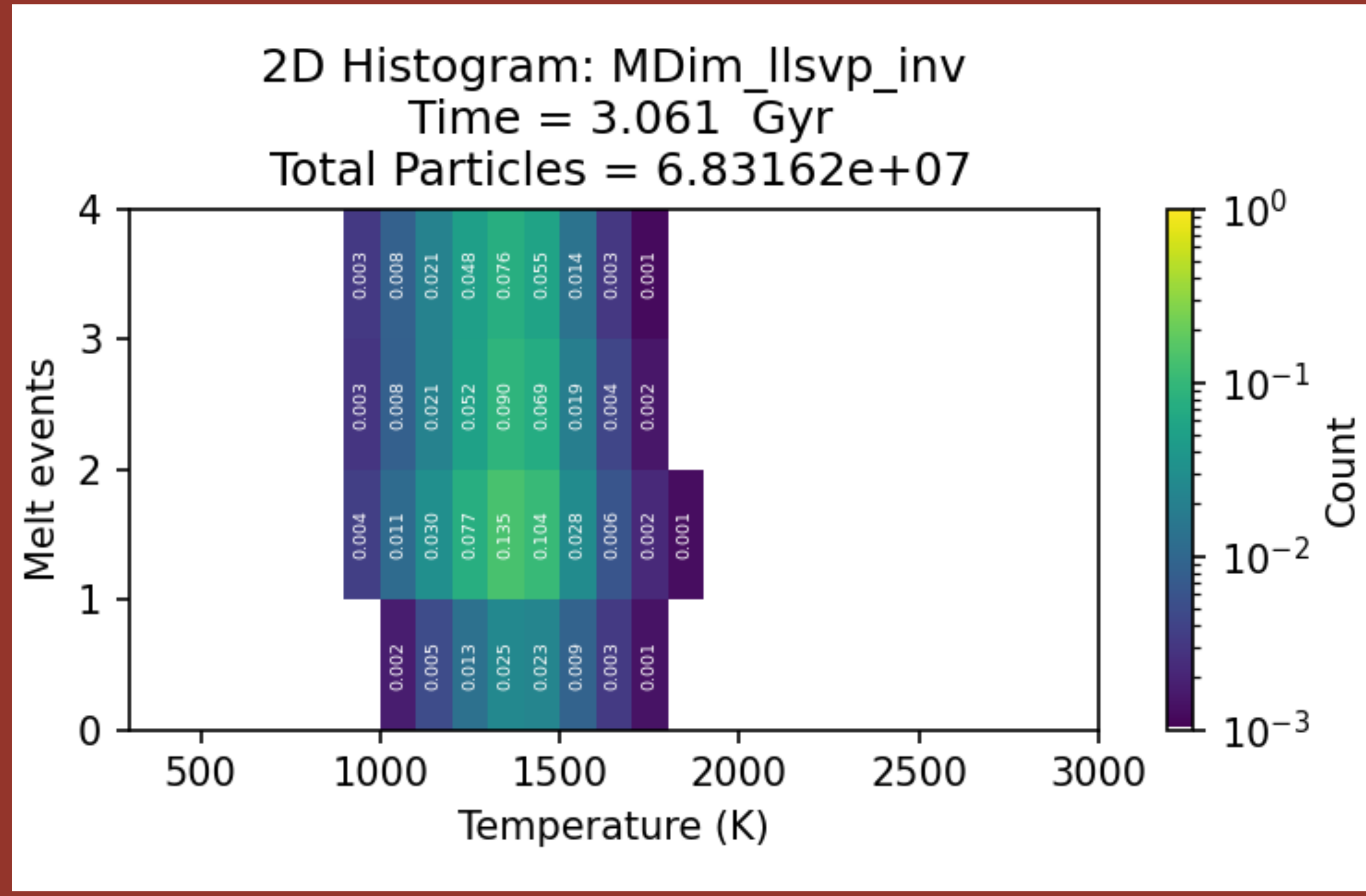
05_depltd





prim05





- **Constituent material is renewed, primitive compositions are progressively replaced by more evolved ones.**
- **Case with primordial dense layer holds more primitive material for longer within the detected structure**
- **Constituent material is significantly hotter than ambient mantle**

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III RESULTS | VISUALISATIONS

- **LLSVP-like material is hotter than average mantle**
- **Case with primordial dense layer holds more primitive material within the structure for longer**
- **Eventually, primitive material is not necessarily associated with LLSVP-like material**
- **Preservation of primitive material is strongly dependent of the processing history and therefore the thermal history as show by model IT_init**

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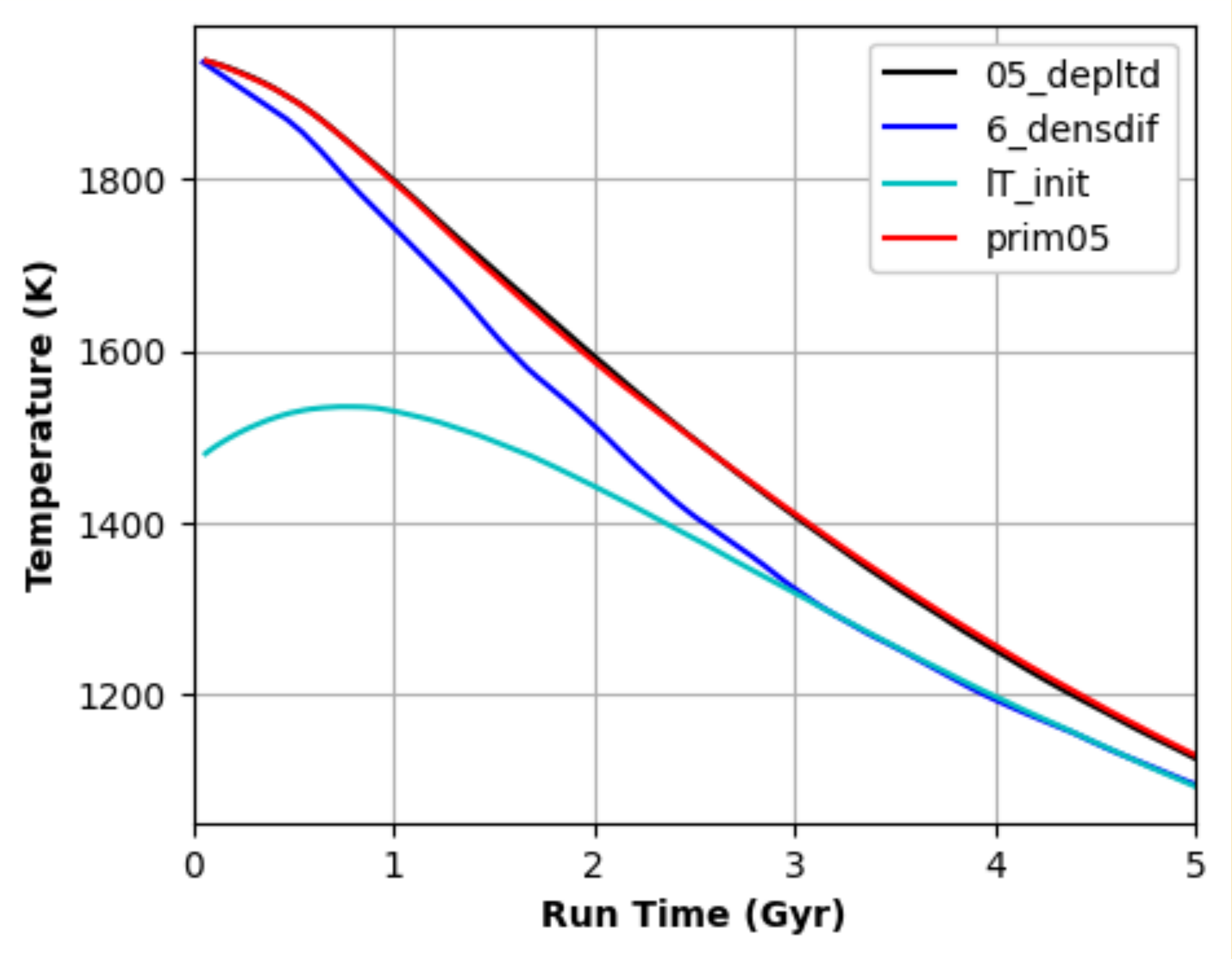
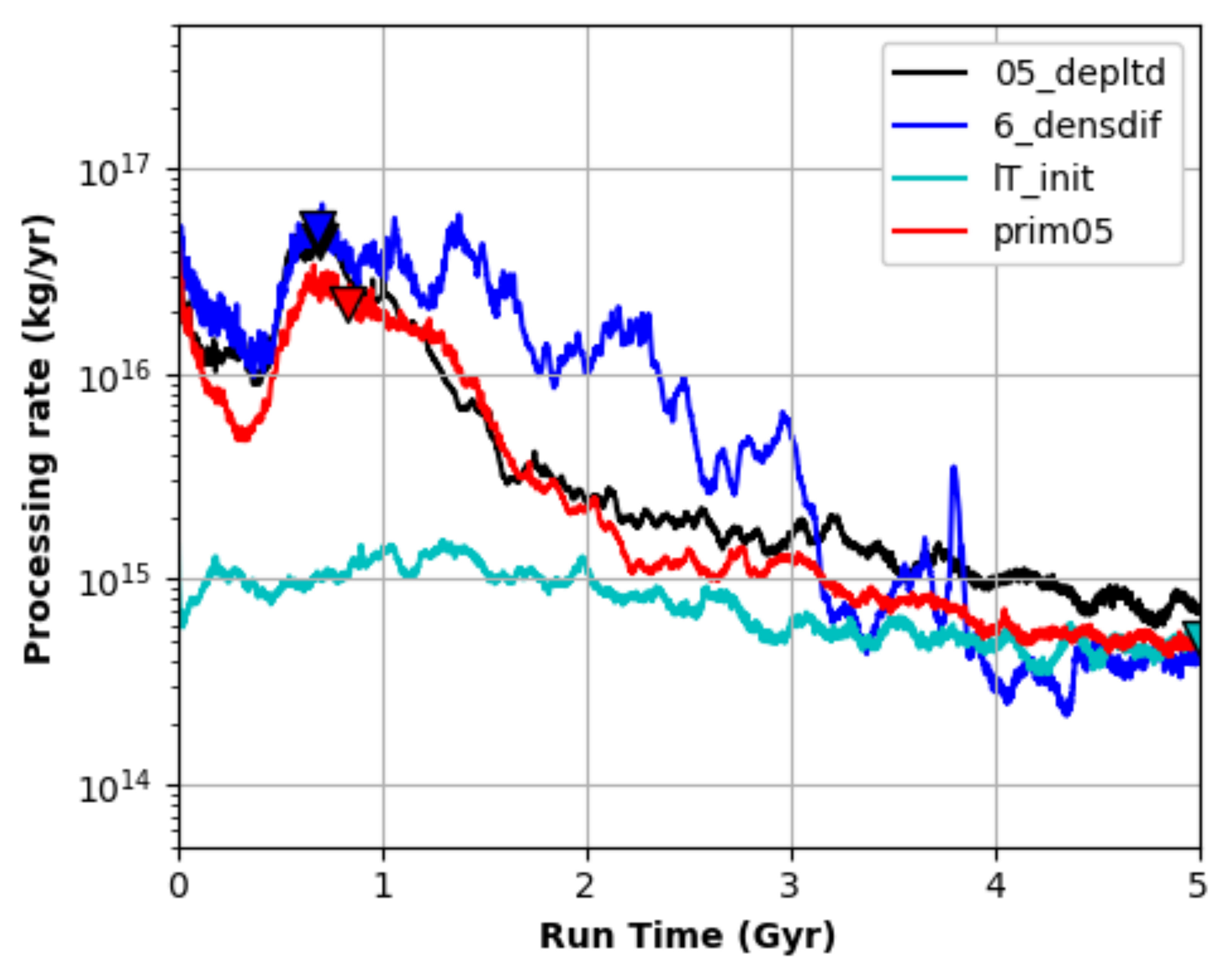
III RESULTS | SUPPLEMENTARY MATERIAL

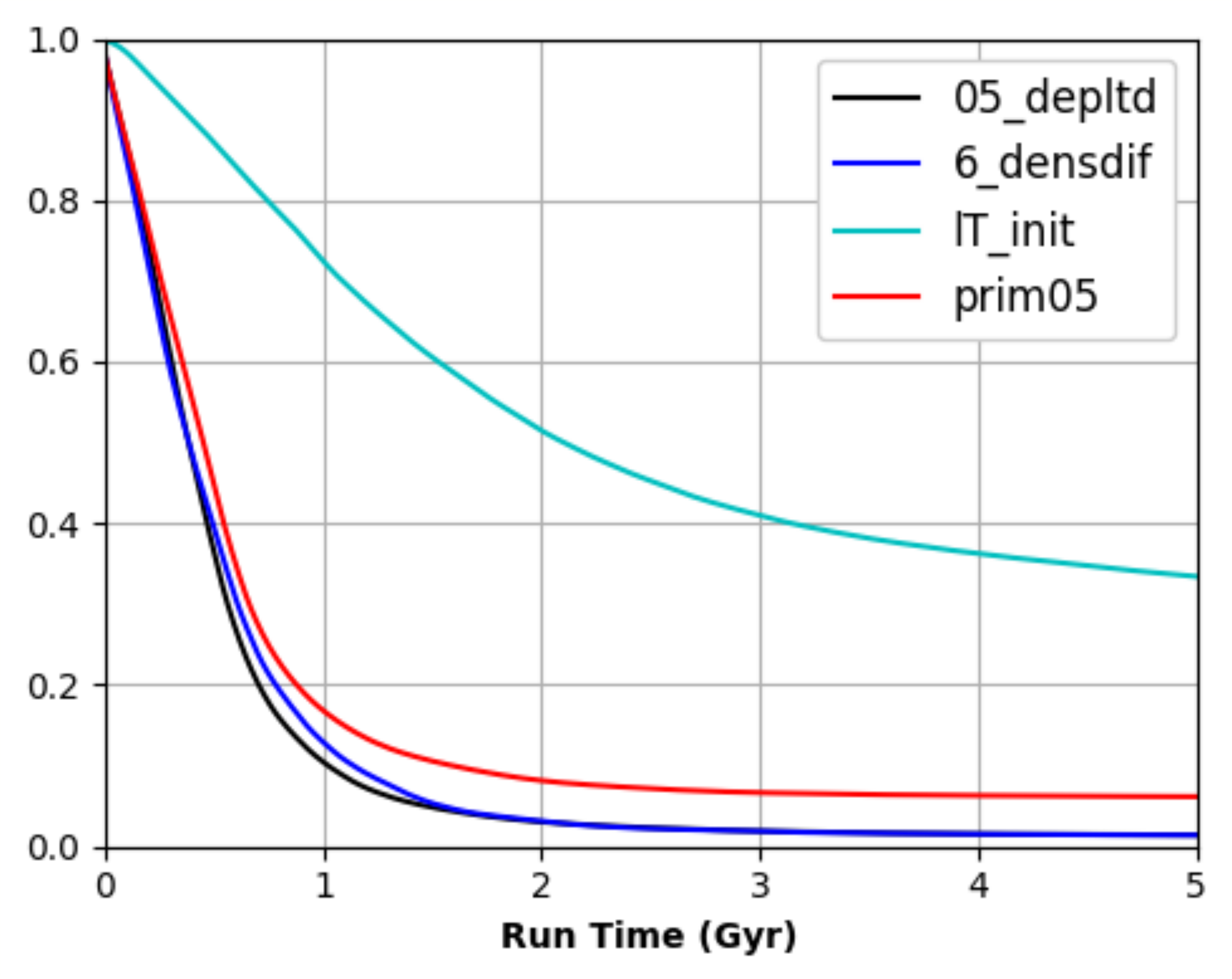
Average Temperature



Processing rate



Primitive material



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