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Optimization of parameters of CME initiation in the MHD simulation suite

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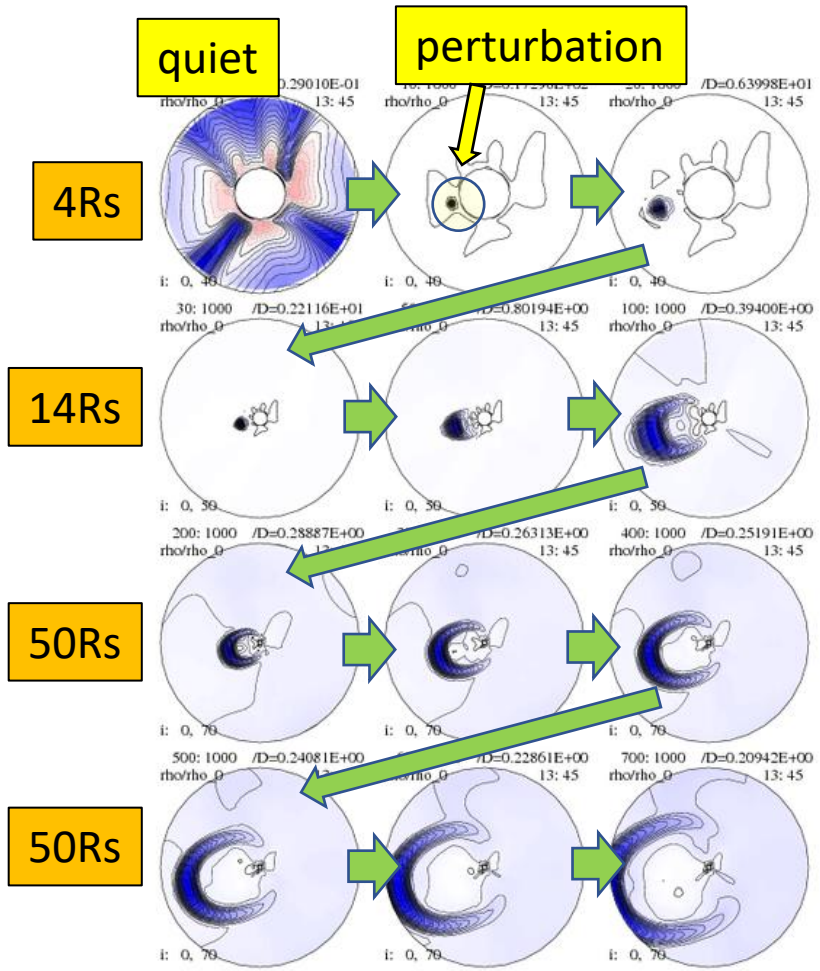
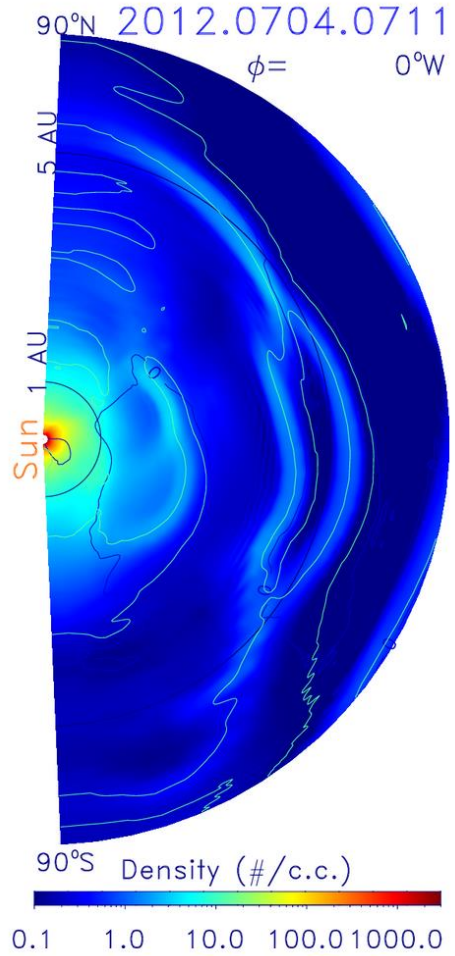
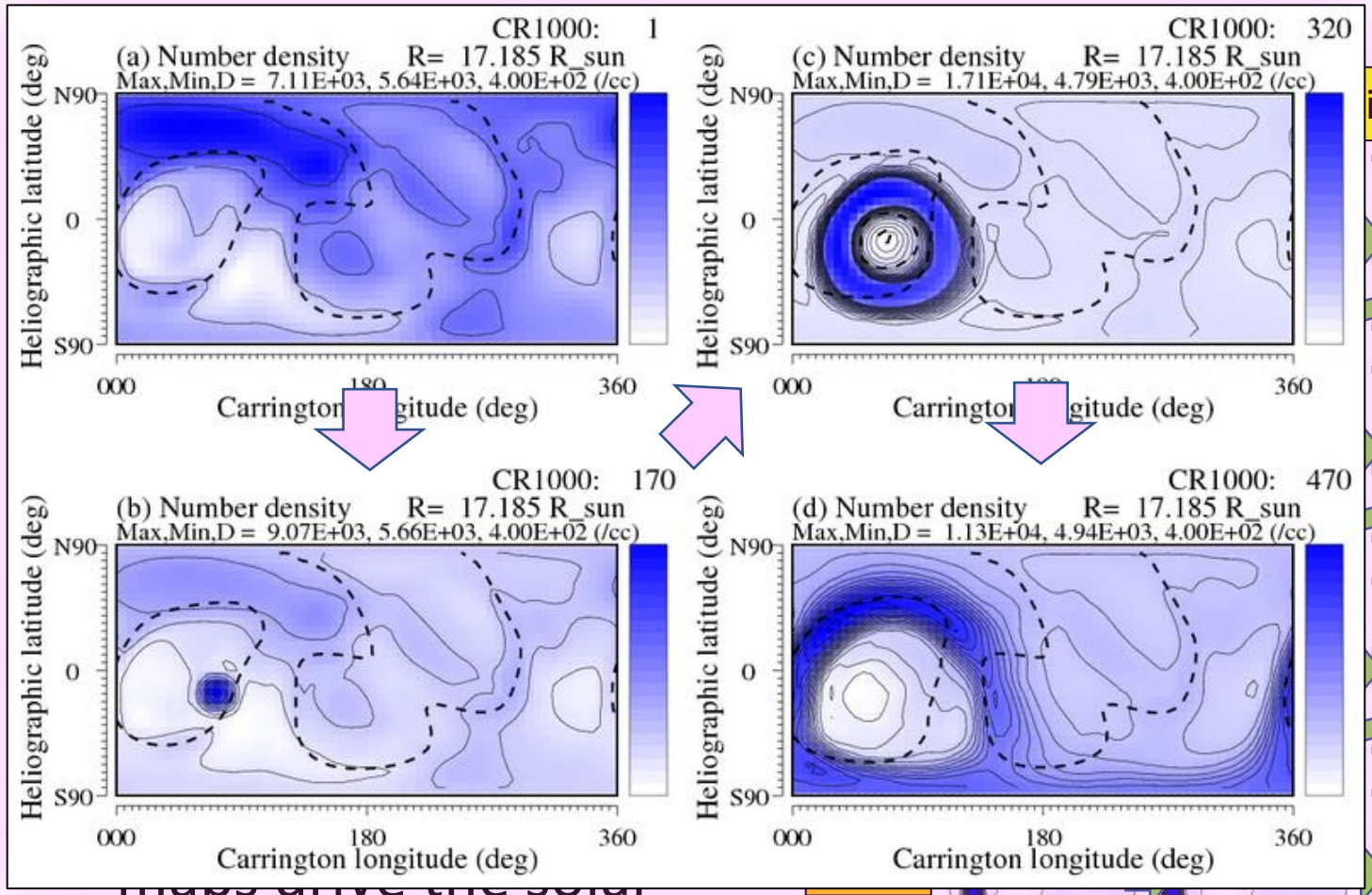
Sun-to-Earth CME MHD model framework

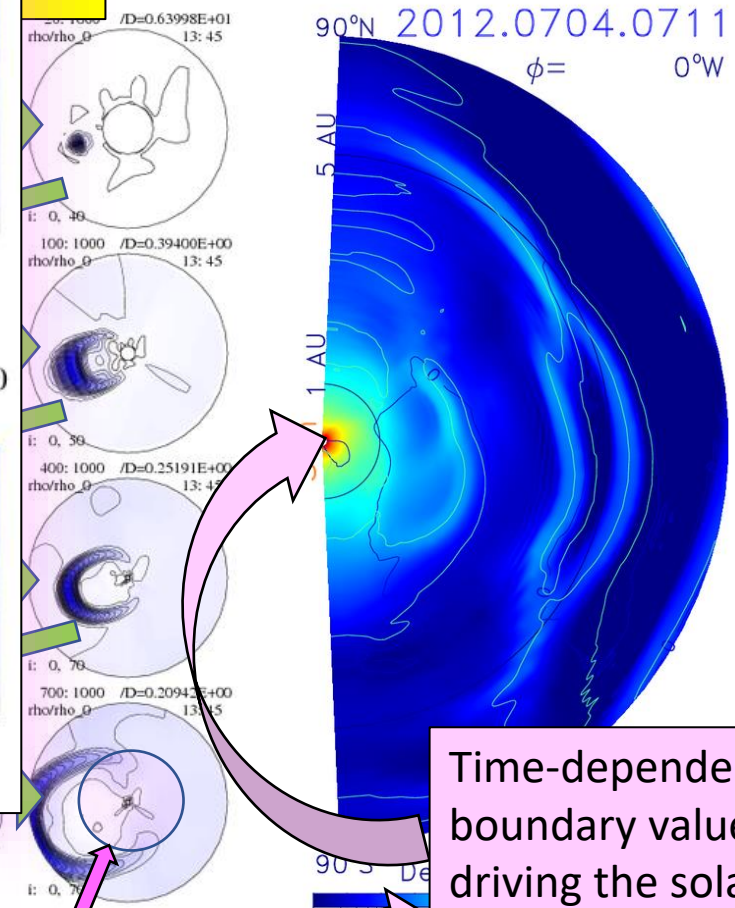
- Coronal MHD model (Hayashi, 2005) & Solar wind MHD model (H3DMHD; Wu+ 2011)
- A CME simulation starts by giving ***parameterized*** numerical perturbation(s) to the quasi-steady state of the solar corona
- Interface at 18Rs
- 18-Rs time-dependent maps drive the solar-wind model





Sun-to-Earth CME MHD model framework





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maps drive the solar-wind model

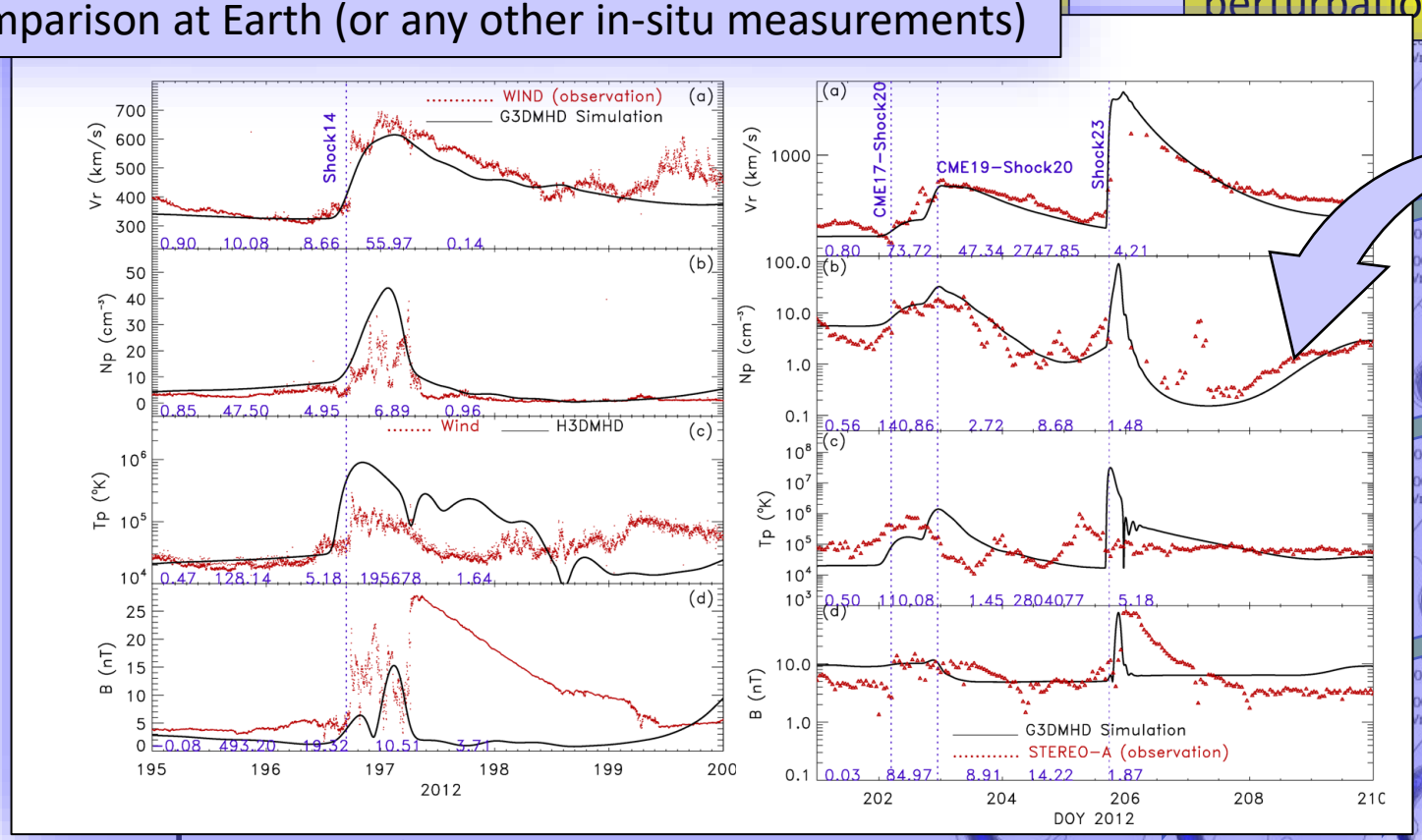
18Rs-map sampling

Time-dependent inner boundary values driving the solar-wind model

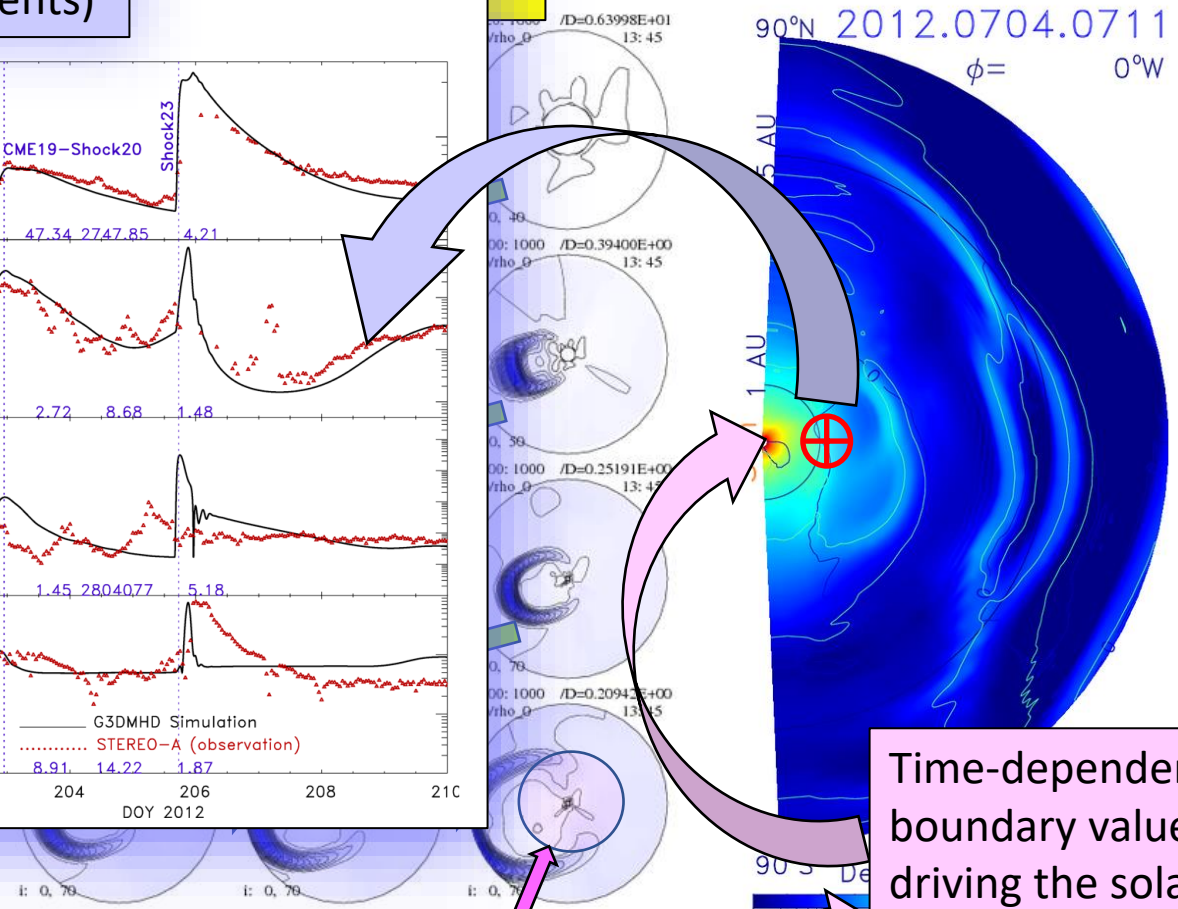
Sun-to-Earth CME MHD model framework

Comparison at Earth (or any other in-situ measurements)

perturbation



wind model



18Rs-map sampling

Time-dependent inner boundary values driving the solar-wind model

Optimizing CME-initiation parameters

- Check/validate whether the setting was reasonable. Determine a most plausible/probable properties of the CME at the early phase.
- Judgement criteria (or metrics, score) would be a **scalar** quantity calculated through comparison with in-situ data
  - MHD variables; IMF (B), plasma V, N, T
  - shock (discontinuity) arrival time
  - certain aspect of ICME passage, like variation of direction of B
  - (root) Mean Square Error, correlation coefficient etc.

Optimizing CME-initiation parameters

- Check/validate whether the setting was reasonable. Determine a most plausible/probable properties of the CME at the early phase.
- Judgement criteria (or metrics, score) would be a **scalar** quantity calculated through comparison with in-situ data
- The parameter set $\vec{a}$ be optimized such that the scalar $D(\vec{a})$ be minimized; $\vec{a} = \arg\min(D(\vec{a}))$.
  - The Newton-Raphson type iteration: for each parameter separately, or for all parameters simultaneously (through the use of the Hessian matrix).

$$a_j := a_j - \alpha \frac{\partial D(\vec{a})}{\partial a_j} \div \frac{\partial^2 D(\vec{a})}{\partial a_j^2}$$

$$\vec{a} := \vec{a} - \alpha \left[\frac{\partial D(\vec{a})}{\partial \vec{a}}\right] \left[\frac{\partial^2 D(\vec{a})}{\partial a_j \partial a_k}\right]^{-1}_{j,k}$$

Remarks

- We recently developed a new model combination:
  - Coronal MHD model (Hayashi, 2005 ApJS 161:480)
  - Solar wind MHD model (Wu+, 2011 JGR 116:A12103).
- The model is compact, runnable on a laptop computer in a few hours.
  - iteration (optimization) is computationally intensive/expensive.
  - applicable to real-time operational runs
- A module for optimization of the CME initiation parameters is under development:
  - a forward-fitting strategy
  - kinetic/magnetic/geometric CME properties at the early phase, and better simulations of evolution of interplanetary disturbance propagation.