Assessing the Short-Term Predictability of Daily Space Weather Indices with Simplex Projection

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Why short-term space weather prediction remains difficult

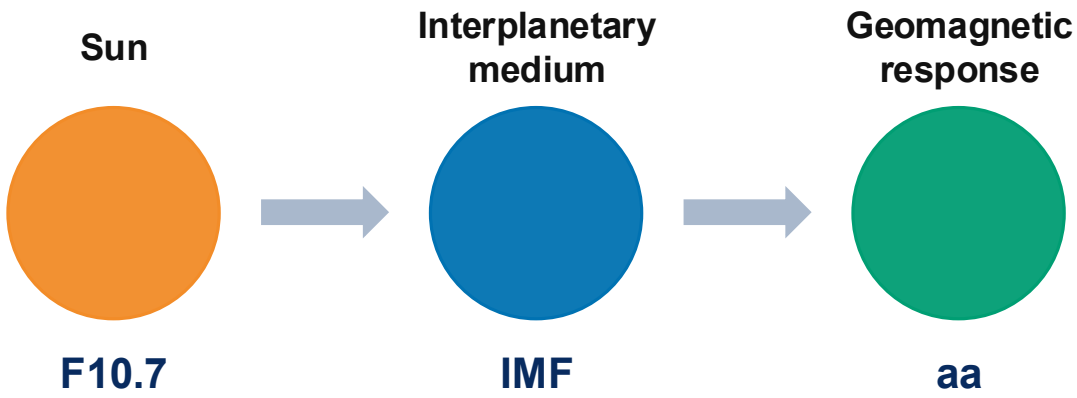
Space weather indices contain both smooth evolution and sudden disturbances.

- Solar, interplanetary and geomagnetic activity vary on strongly time-dependent scales.
- Gradual background variations and abrupt enhancements represent different prediction regimes.
- A useful short-term test should therefore ask where a univariate nonlinear method succeeds and where it fails.

Research question

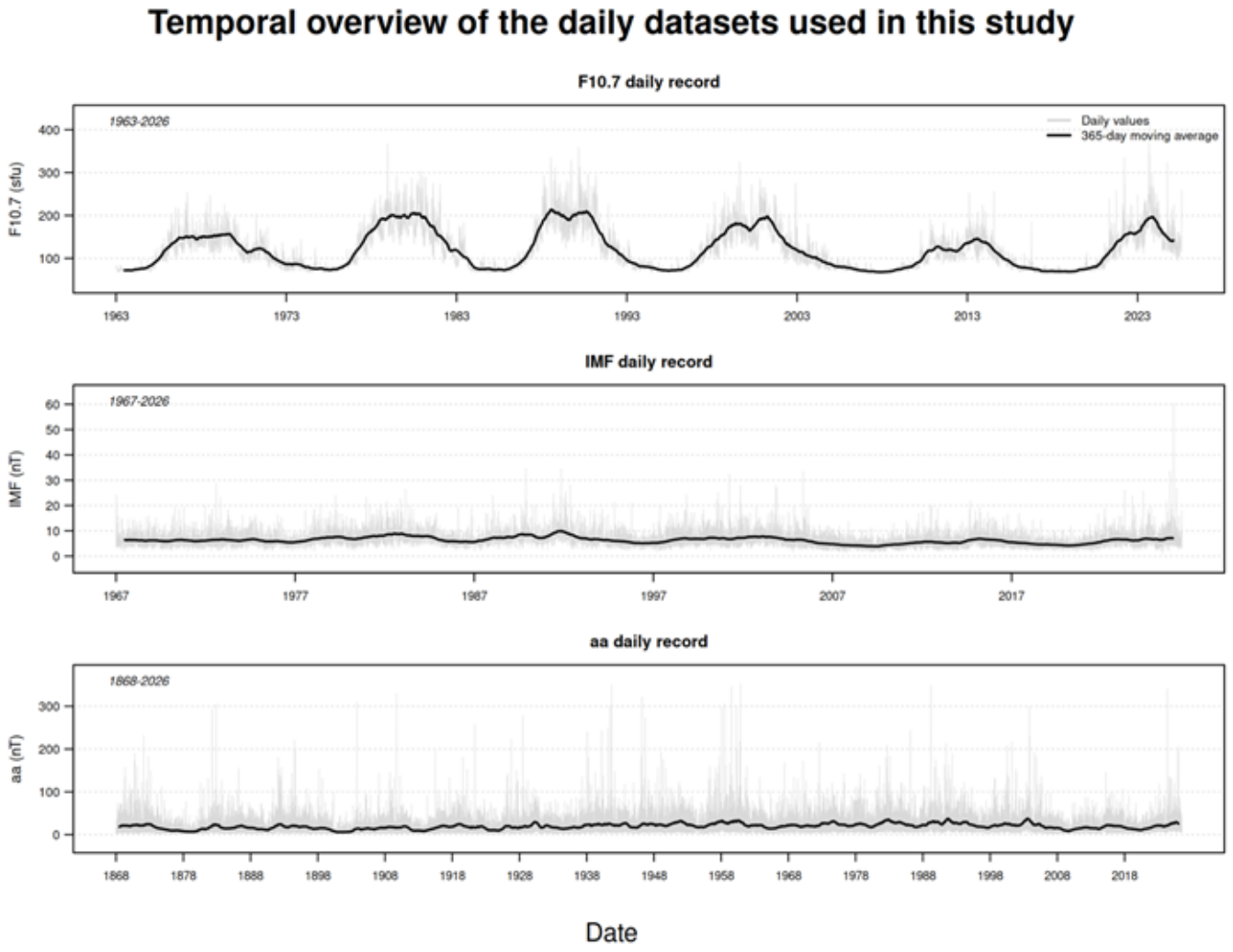
Can short-term evolution be reconstructed from each index's own historical dynamics?

Physical chain and index mapping



Prediction is evaluated separately for each daily index.

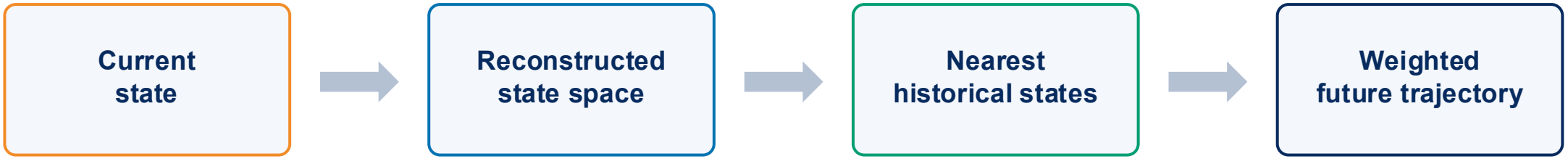
Long daily records across three space weather domains



Daily unsmoothed values are used for prediction; the 365-day curve only shows long-term context.

Simplex Projection: prediction from analogous past states

The method reconstructs the state space of a single time series and follows the future evolution of similar historical states.



State vector $$X(t) = [\, x(t), x(t-\tau), \ldots, x(t-(E-1)\tau) \,]$$

E controls the embedding dimension; τ controls the delay. Similar past states are selected, and their subsequent trajectories are combined to form the prediction.

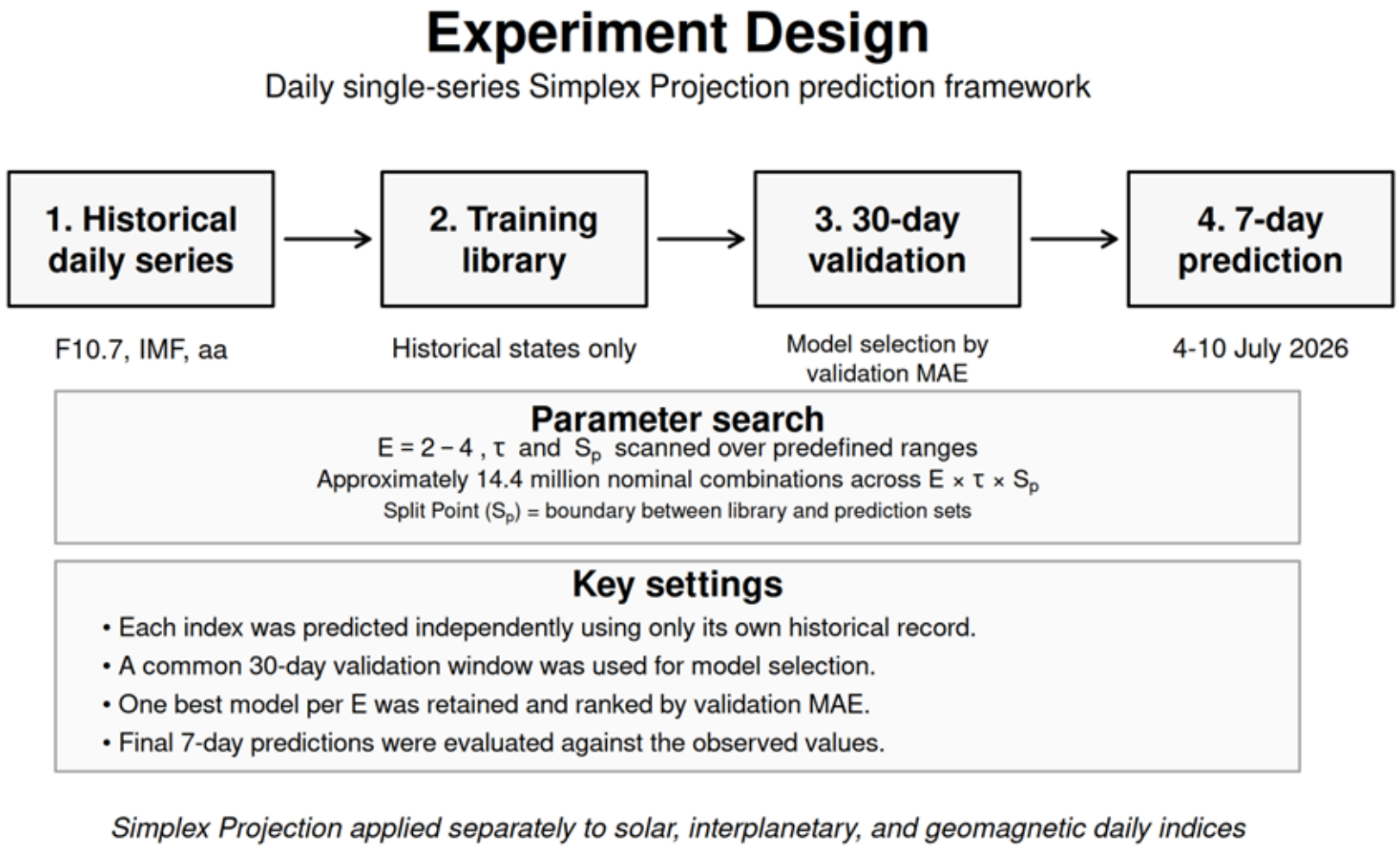
Split Point (S_p): boundary between the library and prediction sets.

Previously defined and systematically examined as a key setting parameter in Gerçeker et al. (2025).

No cross-variable predictor is used in this study.

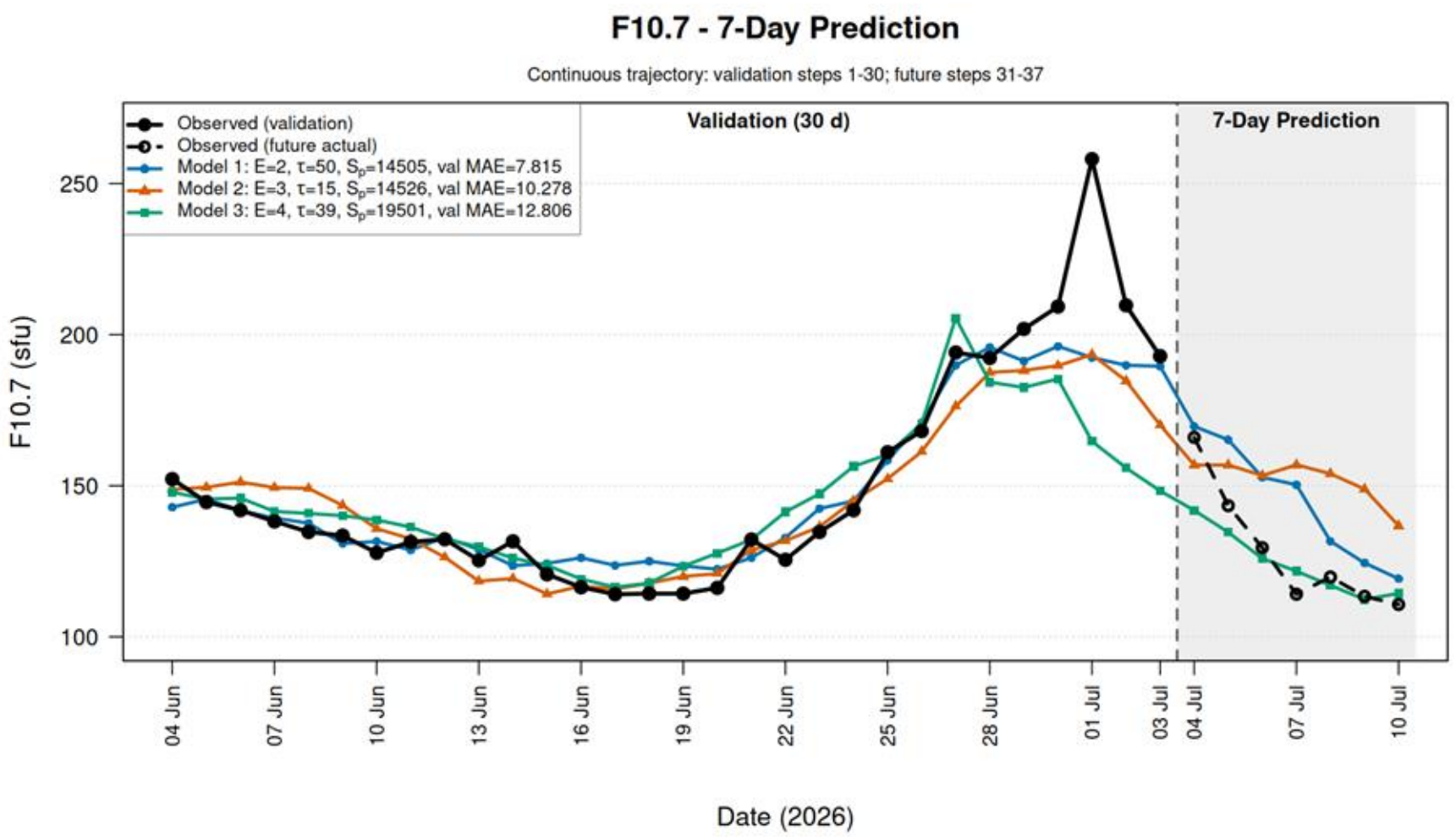
Gerçeker et al. (2025), Solar Physics, 300:169

Common 30-day validation and 7-day prediction experiment



Common validation length was used for methodological consistency, not as an optimized universal choice.

F10.7: gradual evolution is captured, rapid decline is harder



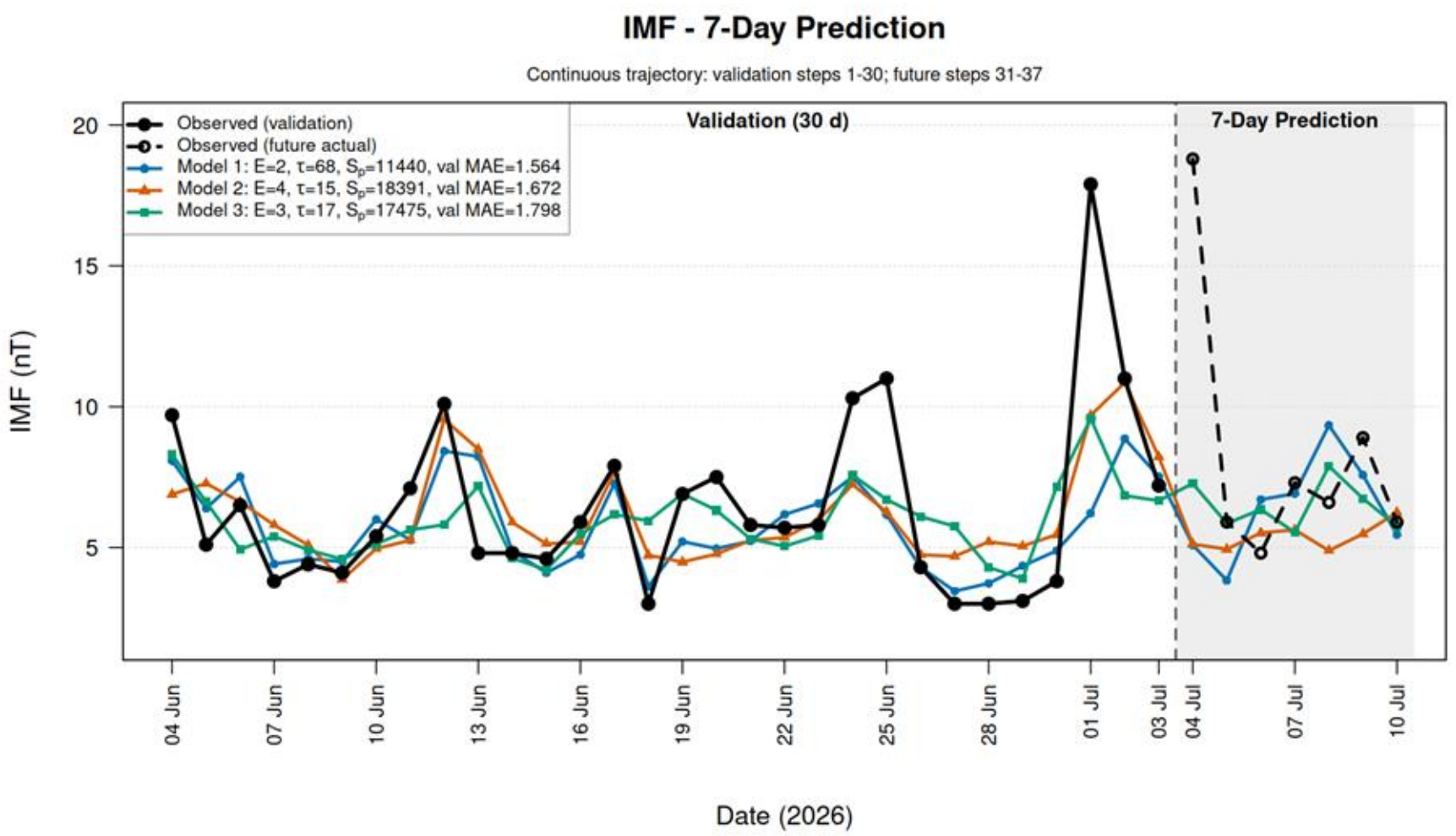
Rank-1 model

E = 2
τ = 50
S_p = 14505
Validation MAE = 7.82 sfu
7-day MAE = 16.63 sfu

Take-home

Errors concentrate during the rapid decline after the high-activity interval.

IMF: stable model configurations, abrupt enhancement missed



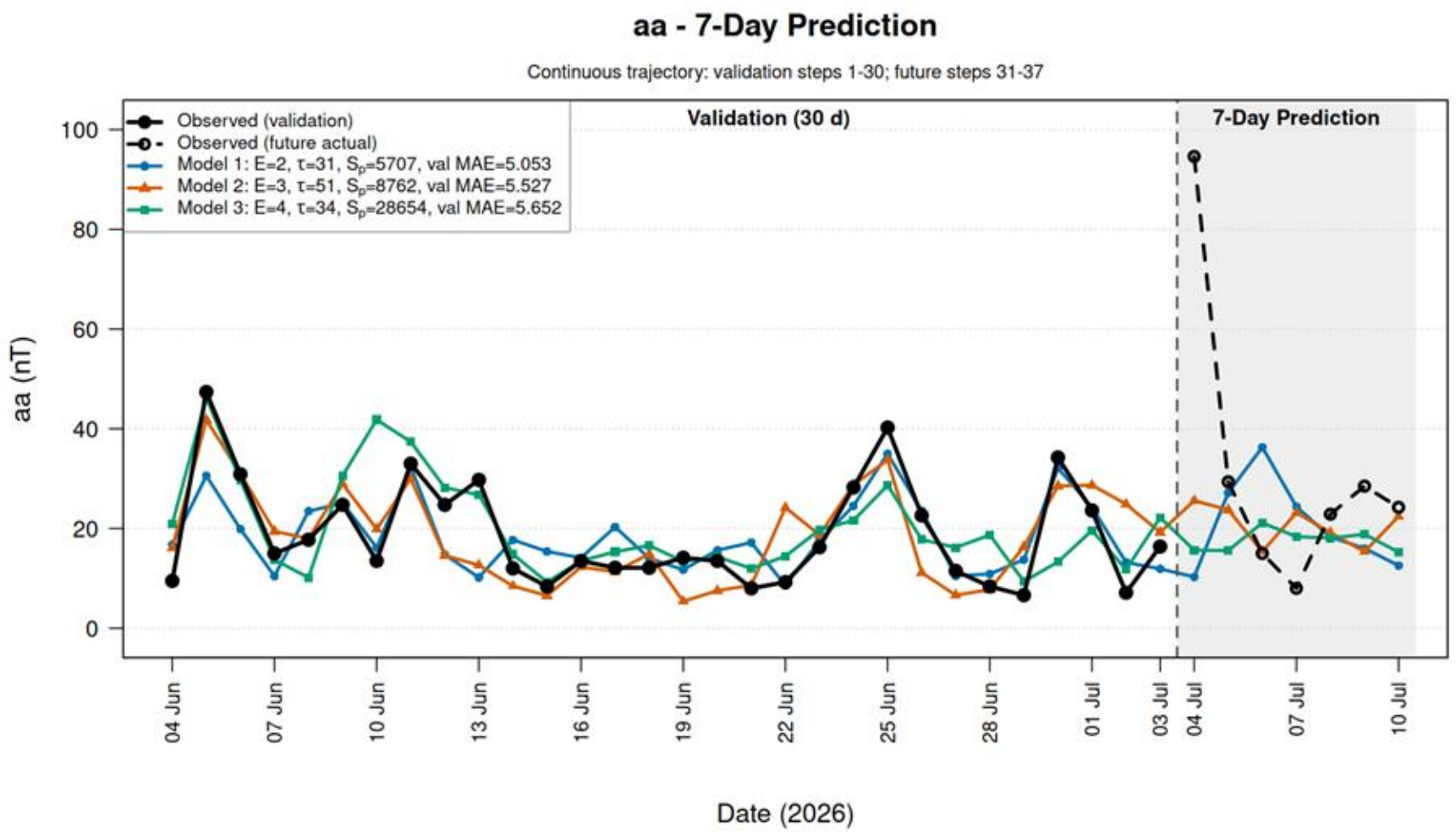
Rank-1 model

E = 2
τ = 68
S_p = 11440
Validation MAE = 1.56 nT
7-day MAE = 3.23 nT

Take-home

Background evolution is reproduced more consistently than the sharp 4 July increase.

aa: one abrupt event dominates the prediction error



Rank-1 model

E = 2
τ = 31
S_p = 5707
Validation MAE = 5.05 nT
7-day MAE = 21.85 nT

Take-home

The 4 July geomagnetic enhancement is strongly underestimated.

What do the three indices tell us together?

Across the solar, interplanetary and geomagnetic domains, the main difficulty is not gradual variability but rapid transitions and abrupt enhancements.

F10.7

7-day MAE

16.63 sfu

Rapid decline

Errors occur after the high-activity interval.

IMF

7-day MAE

3.23 nT

Abrupt enhancement

Sharp 4 July increase is underestimated.

aa

7-day MAE

21.85 nT

Event-dominated error

A single abrupt geomagnetic enhancement dominates.

Main interpretation — **Simplex Projection reproduces gradual/background evolution more successfully than abrupt or rapidly evolving conditions.**

MAE values are reported in different physical units and should not be interpreted as a direct cross-index ranking.

Conclusions and next step

Main conclusions

- Daily F10.7, IMF and aa can be predicted independently from their own historical dynamics using Simplex Projection.
- Gradual/background variations are reproduced more successfully than abrupt changes.
- Sharp IMF and aa enhancements were substantially underestimated, while F10.7 errors were concentrated during rapid decline.
- Short-term predictability depends strongly on the dynamical regime, not only on the selected parameters.

Next step

Quantify prediction skill separately under:

- quiet
- transitional
- disturbed

Multi-Simplex Method!

Thank you!

Questions?