Comparison of Atmosphere Models for Atmospheric Predictions

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Introduction

- Re-entry prediction at ESA:
  - Automated re-entry prediction service via LASCO (Lifetime Assessment of Catalogued Objects)
  - Web-based portal: https://reentry.esoc.esa.int
  - IADC campaigns

- Comparison of 3 ISO-27852:2016 recommended atmosphere models
- Effects of solar activity proxy forecasts: SOLMAG
- Evaluate optimal model combination using ESA re-entry tools
- Data set: re-entered objects since May 2017

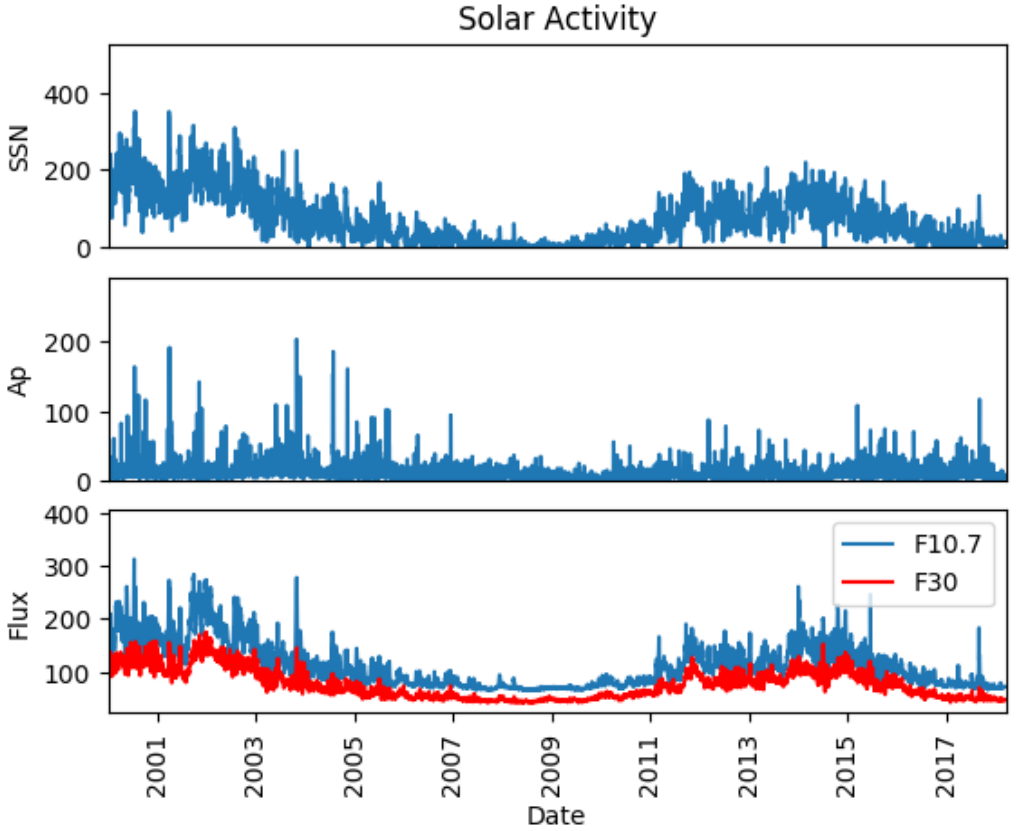
Atmosphere Models

- ISO-27852:2016 provides list of atmosphere models for estimation of orbit lifetime
- Aim: determine if models show significant differences when applied to lower thermosphere (< 250km)

Model	Solar activity proxy index	Geomagnetic activity index Kp
NRLMSISE-00(d)	F10.7	Daily
NRLMSISE-00(h)		8x 3 hour
GOST-2004	F10.7	Daily
DTM-2013	F30	8x 3 hour

Space Weather

- SOLMAG (Solar and Geomagnetic activity prediction model):
  - Prediction of daily Ap (for following solar rotation)
  - Very short term (3 days) SIDC expert prediction



Re-entry Prediction Tools

Fit Tool	Bc Fit Method	Data Used
RAPID	fit from sma decay	20 TLEs
		Set Time Span TLEs
		20 TLEs (A posteriori)
RACER (prototype)	fit from L	20 TLEs (A posteriori)

A posteriori: removes uncertainty from SOLMAG predicted solar activity

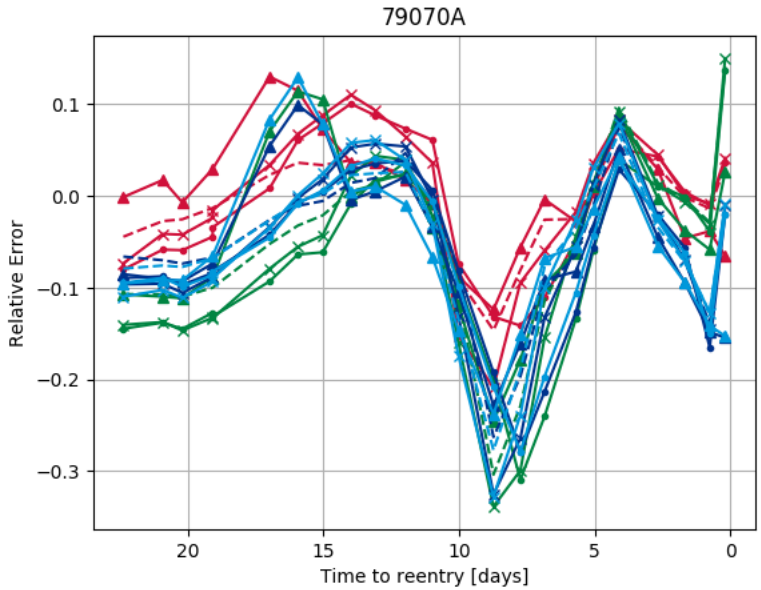
- 4 atmosphere models
- 4 lifetime assessment tool combinations

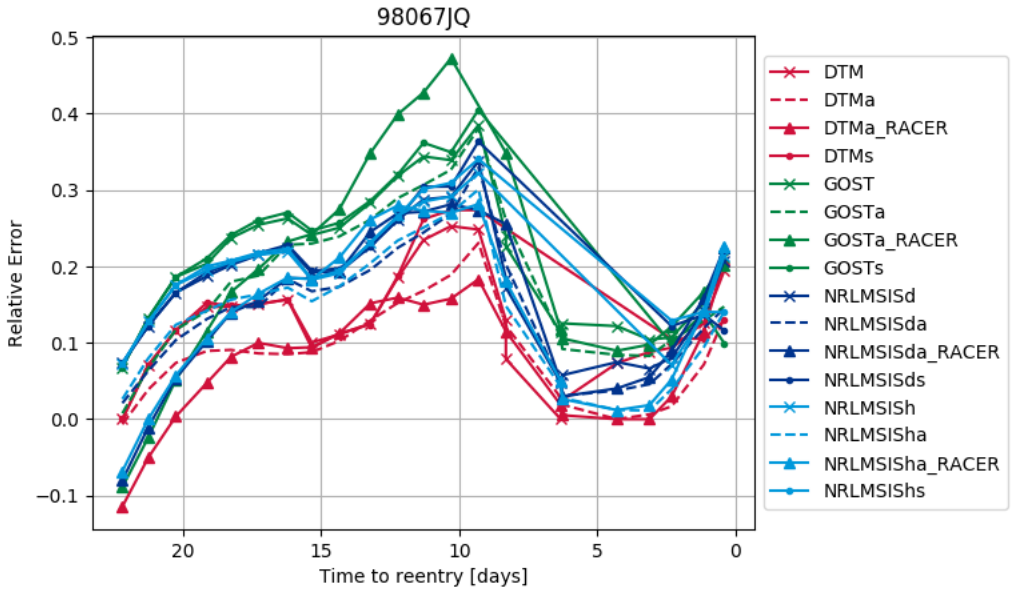
} 16 combinations

Relative Error & Object Specific Trends

35 objects with real time prediction service (since May 2017)

14 objects a posteriori (Jan to May 2017)

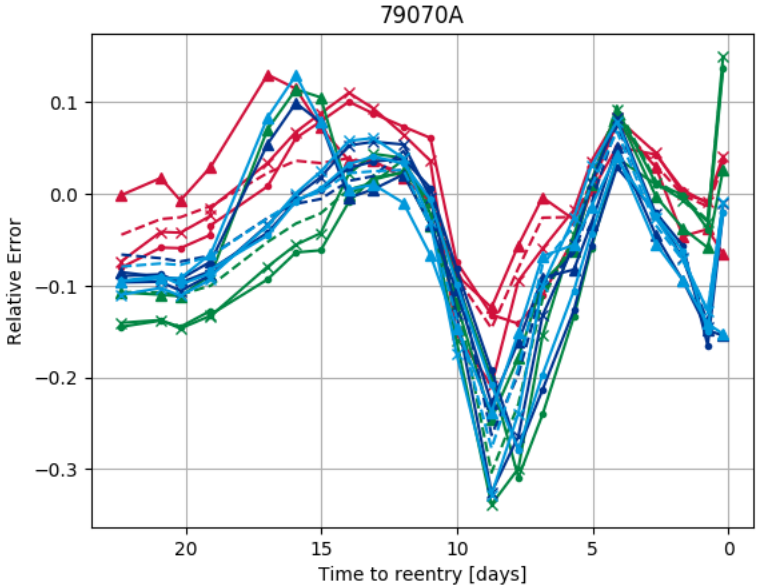


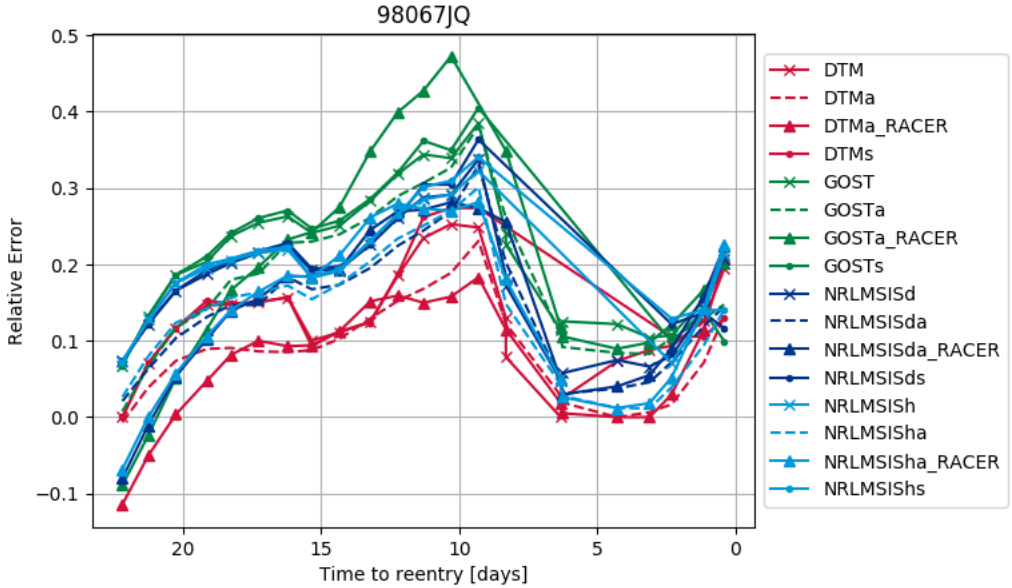


Relative Error & Object Specific Trends

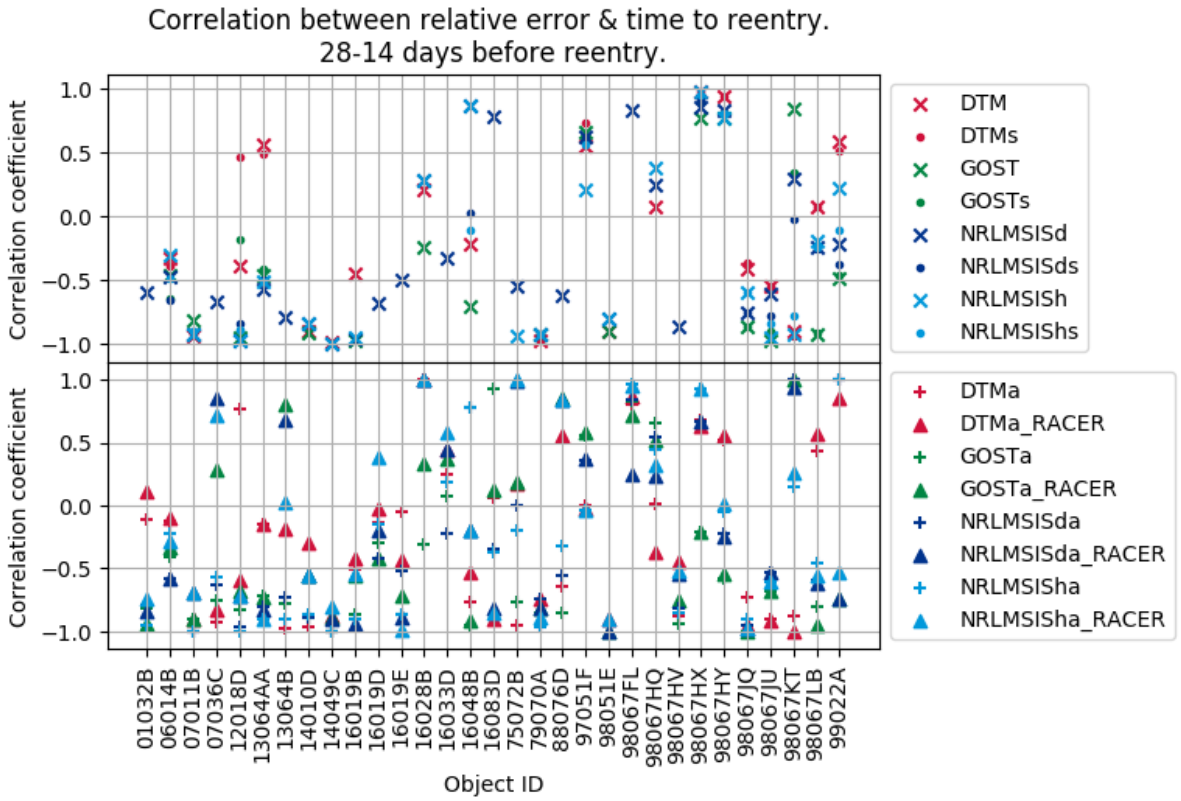
Relative error = (predicted – reference re-entry epoch)/remaining time

Space-track.org





Relative Error & Object Specific Trends



- Group according to solar rotation period
- No trend in correlation between objects

For model comparison:
Remove object specific trends

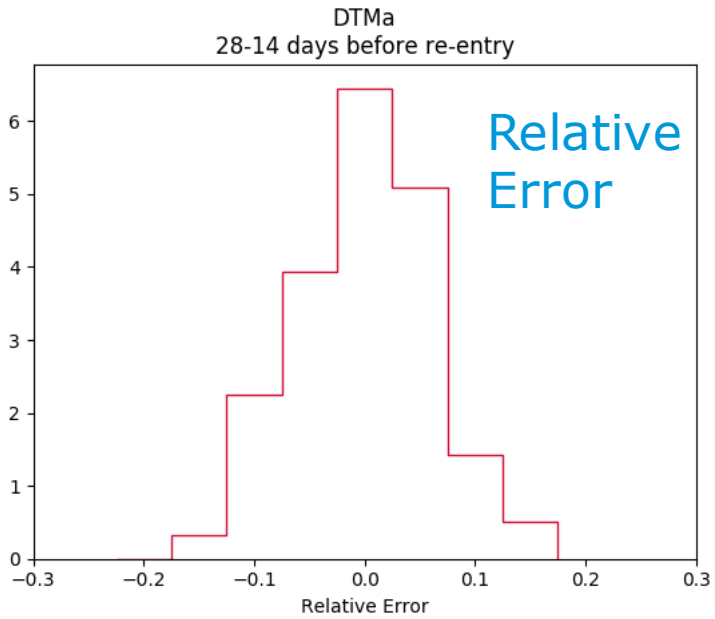
Relative Model Error (RME)

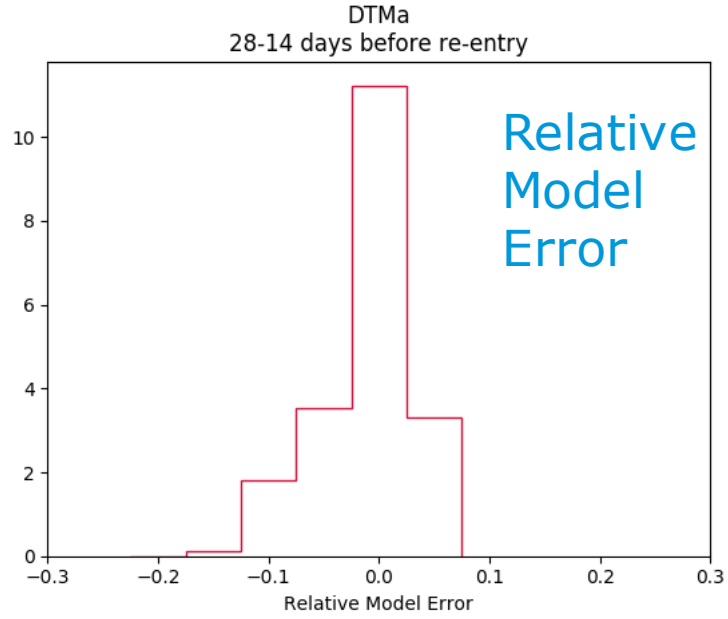
Relative Model Error

Express prediction accuracy via a delta relative error between the methods

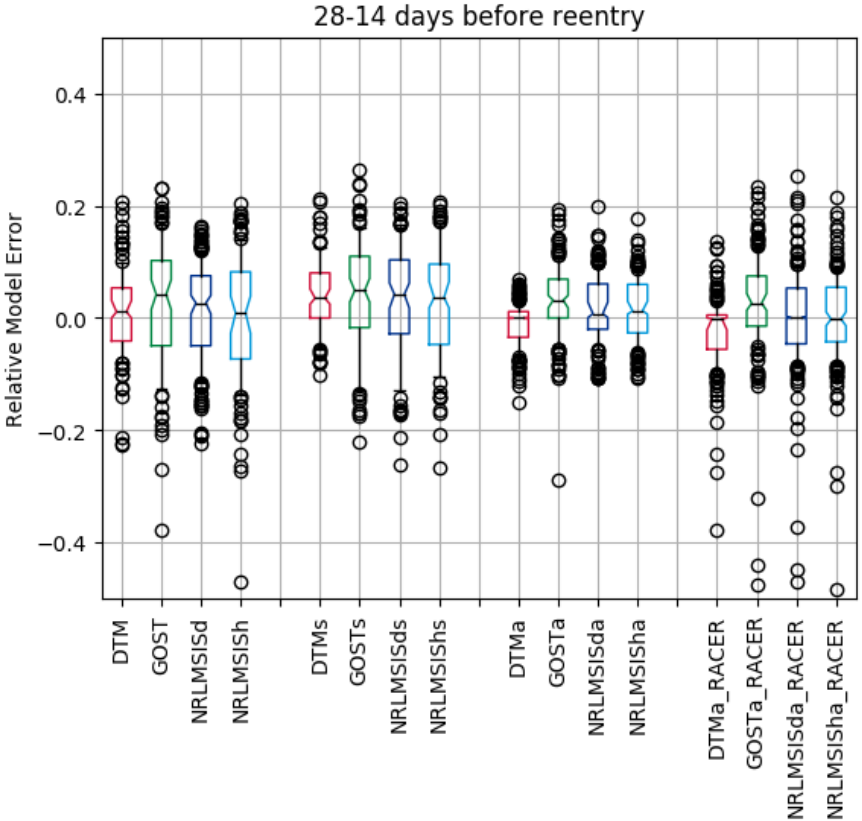
→ best performing model has centralised tendency

Empirical distribution:





Relative Model Error



Statistical comparison to distinguish an optimal method:

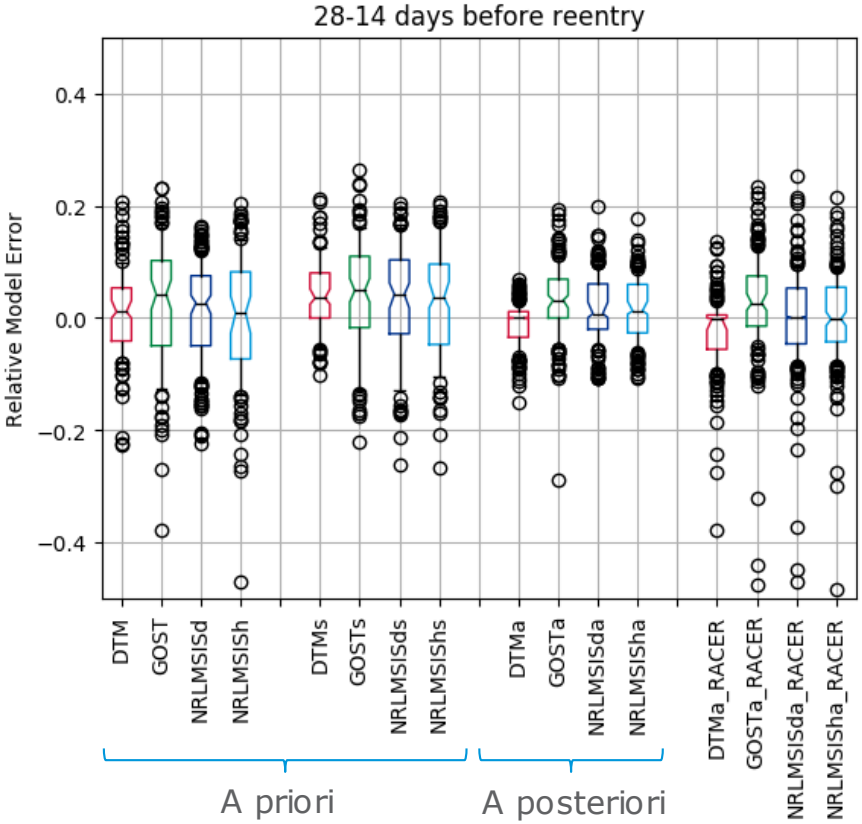
Kruskal-Wallis (KW) H-test:

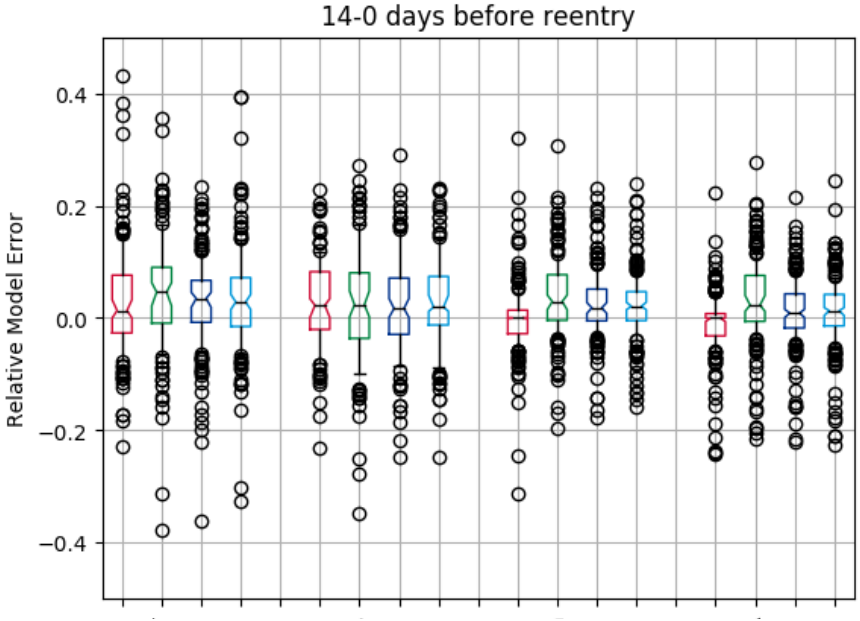
- Non-parametric rank test
- Null hypothesis: population median of all the groups are equal

Kolmogorov–Smirnov (KS) test:

- Null hypothesis: 2 independent samples drawn from same continuous distribution

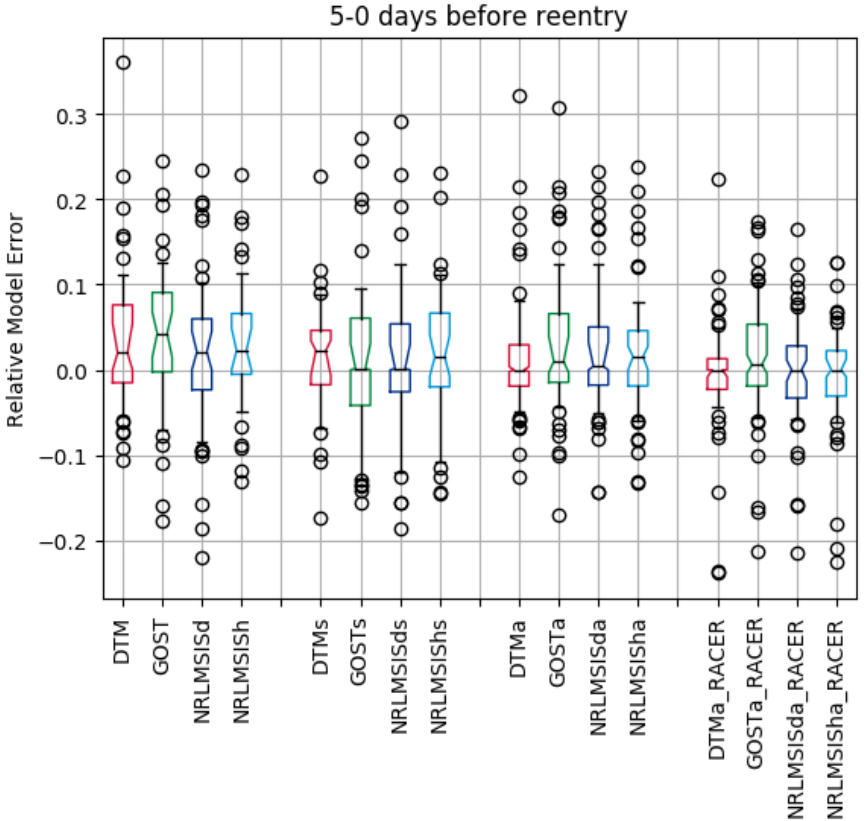
Relative Model Error





- A priori models not differentiable
- DTM differentiable from a posteriori
- Same KW & KS output (with $\alpha = 0.01$)

Relative Model Error: Close to re-entry



5-0 days before re-entry:

- KW: no groups or pairs discernible
- KS: no pairs disprove null except

DTMa & NRLMSISha (level of α = 0.05)

3-0 days before re-entry:

- No optimal method discerned

Conclusions & Summary

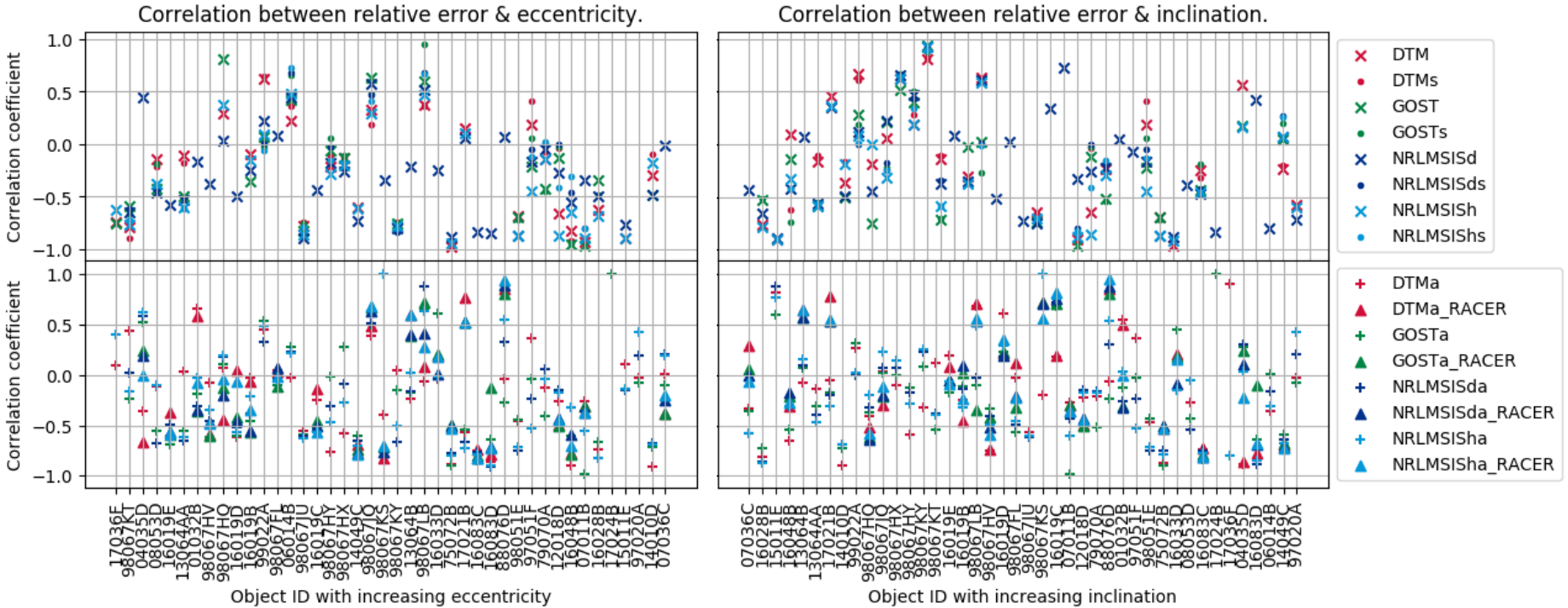
- Comparison of 3 ISO-27852:2016 atmosphere models
- 16 combinations of atmosphere models, solar activity proxies & observed data
- Real-time analysis limited to 35 re-entered objects since May 2017

Statistical analysis using scaled relative error:

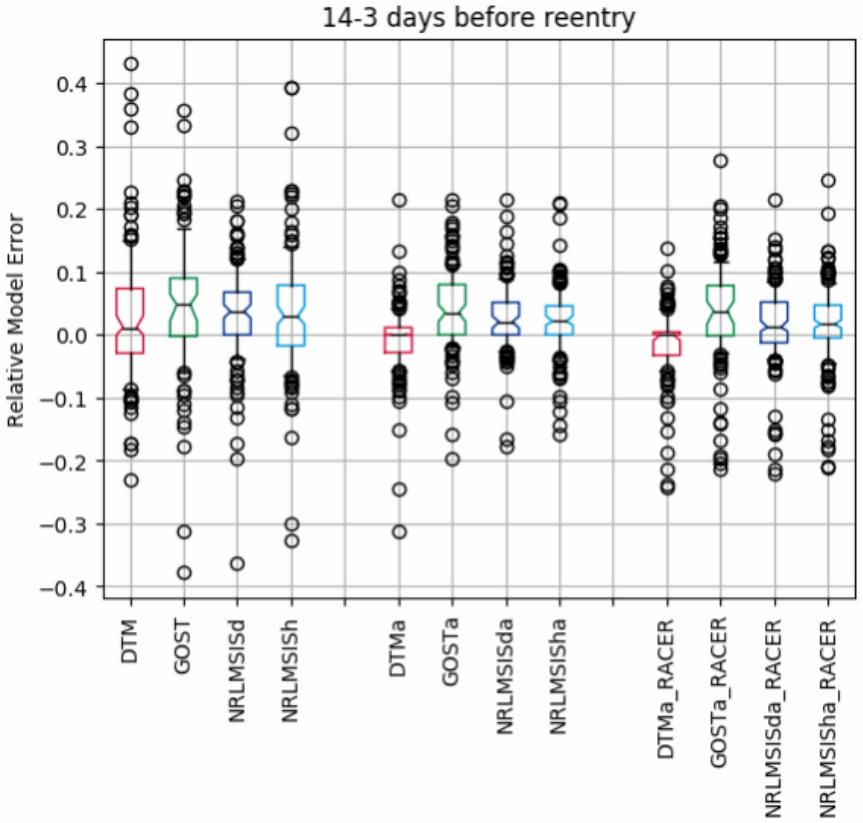
- A priori methods (using SOLMAG predicted space weather): no best method
- A posteriori (using known space weather): DTM-2013 optimal atmosphere model for 28-3 days before re-entry
- Close to re-entry (5/3-0 days before): no optimal atmosphere model

Additional Slides: eccentricity & inclination

Effect of orbit type on correlation:



Additional Slides: 14-3 days before re-entry



KW:

GOSTa may be differentiated from NRLMSISd/h (level of α = 0.05)

Otherwise same outcomes as 28-14 (better than 14-0)

KS:

Some 20TLE differentiation

All RAPID & RACER a posteriori differentiable (except NRLMSIS pair)