Developing the Next Generation Assimilative Drag Model: Lessons Learned

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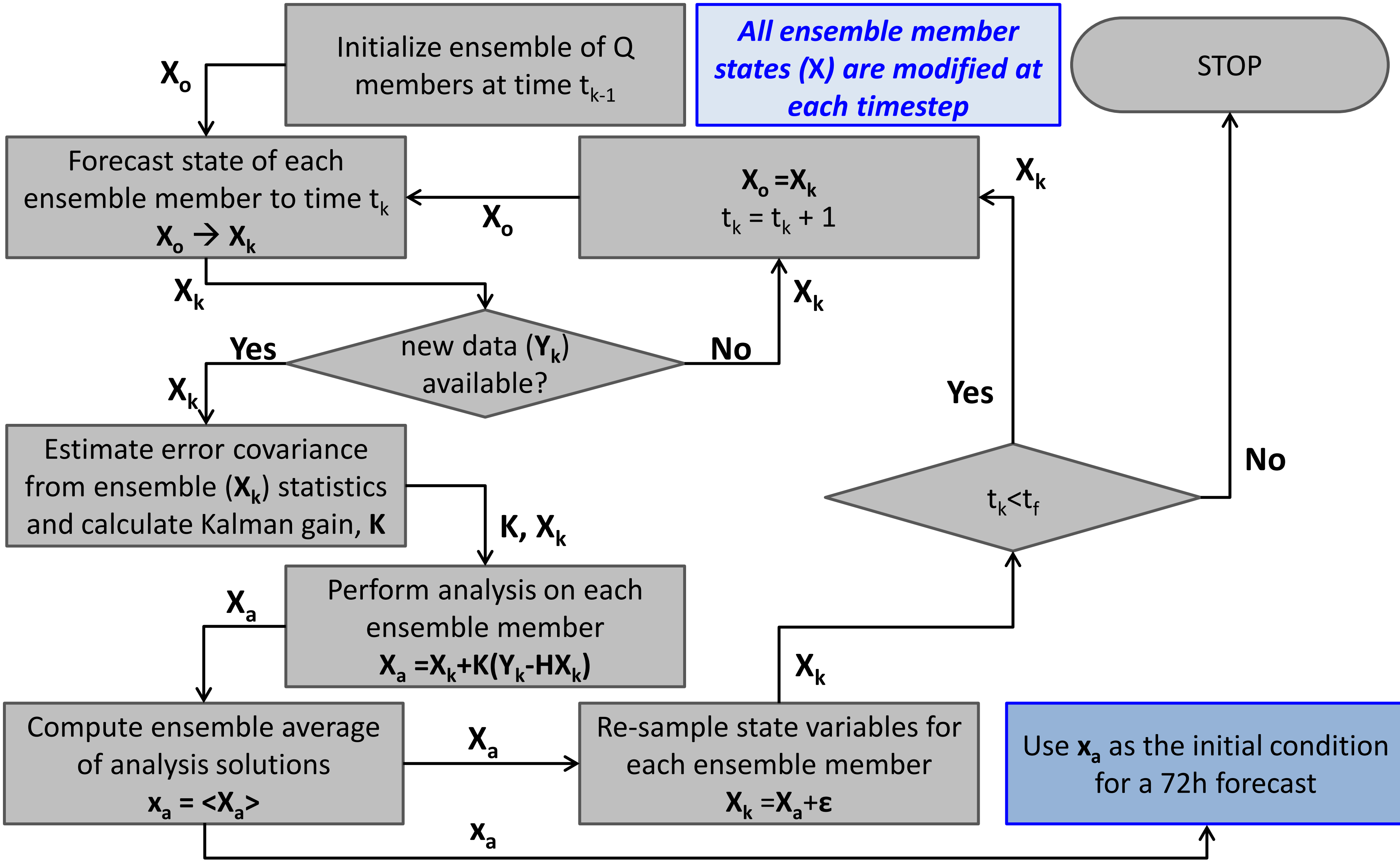
Special Thanks to: G. Crowley, M. Codrescu, E. Sutton

Satellite Drag Assimilation: Ensemble Kalman Filter (EnKF)



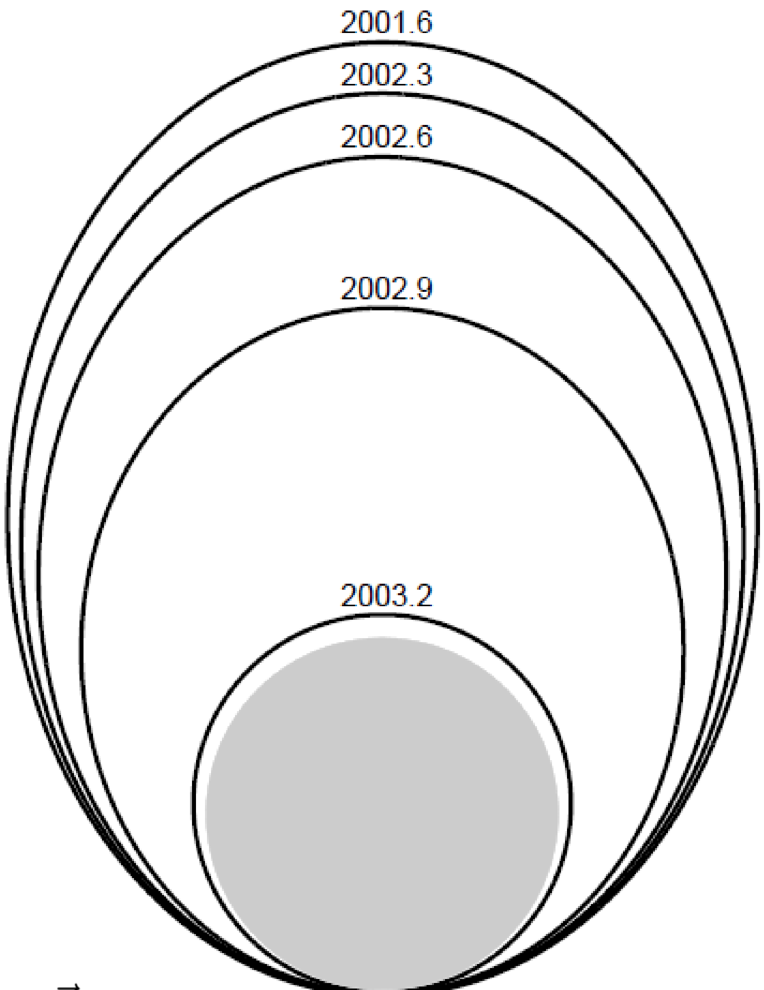
Preliminary Validation

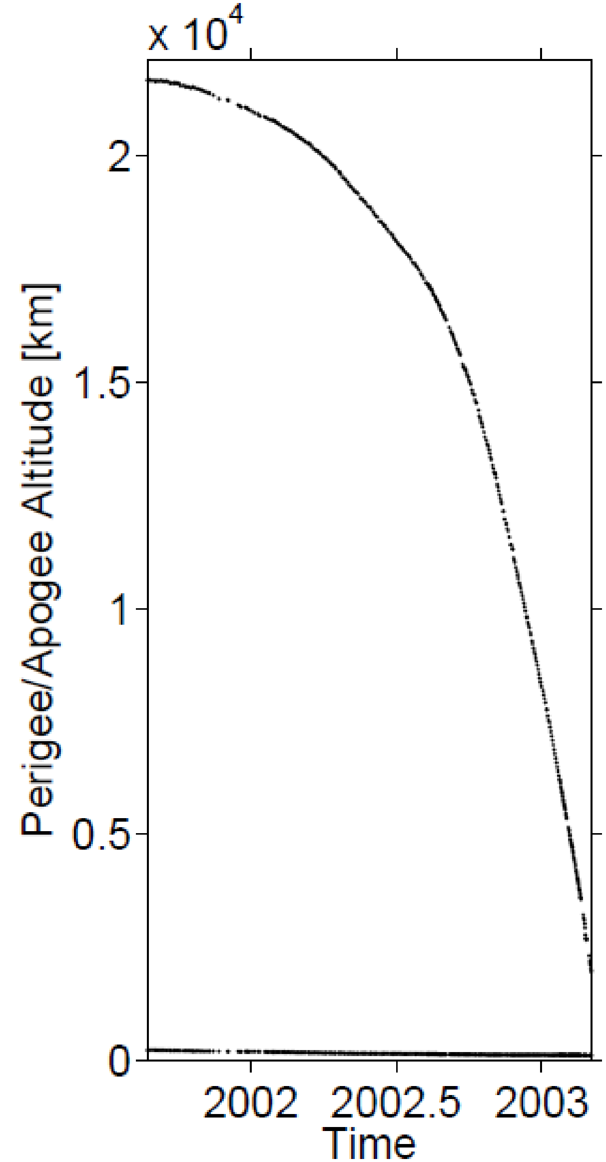
- Assimilating orbital data from approximately 75 objects with perigees between 200 and 750km altitudes (this is configurable)

- Data is assimilated in a 36 hour window and the window is advanced at 12 hour intervals (this is configurable)

- THESE RESULTS ARE PRELIMINARY: We are in the process of expanding the validation to other years, satellites, and data-types (accelerometers).

What is satellite drag?



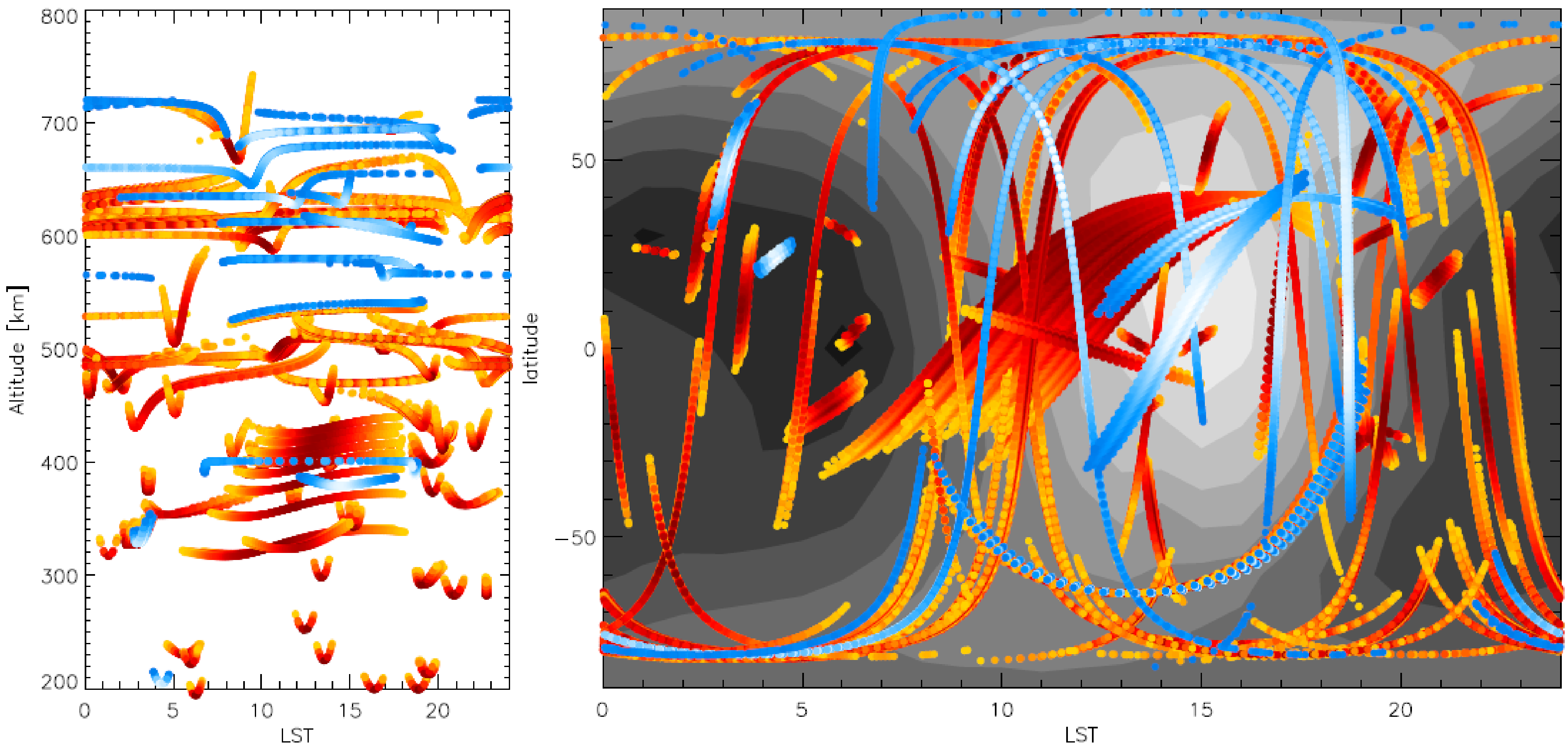


$$\vec{a} = \frac{1}{2}\frac{\vec{C}_a A}{m_{sc}}\rho {V_r}^2$$

$$V_r = \left\|\vec{V}_{sc} - \vec{V}_w\right\|$$

Testing with Orbital Data, Dataset Locations

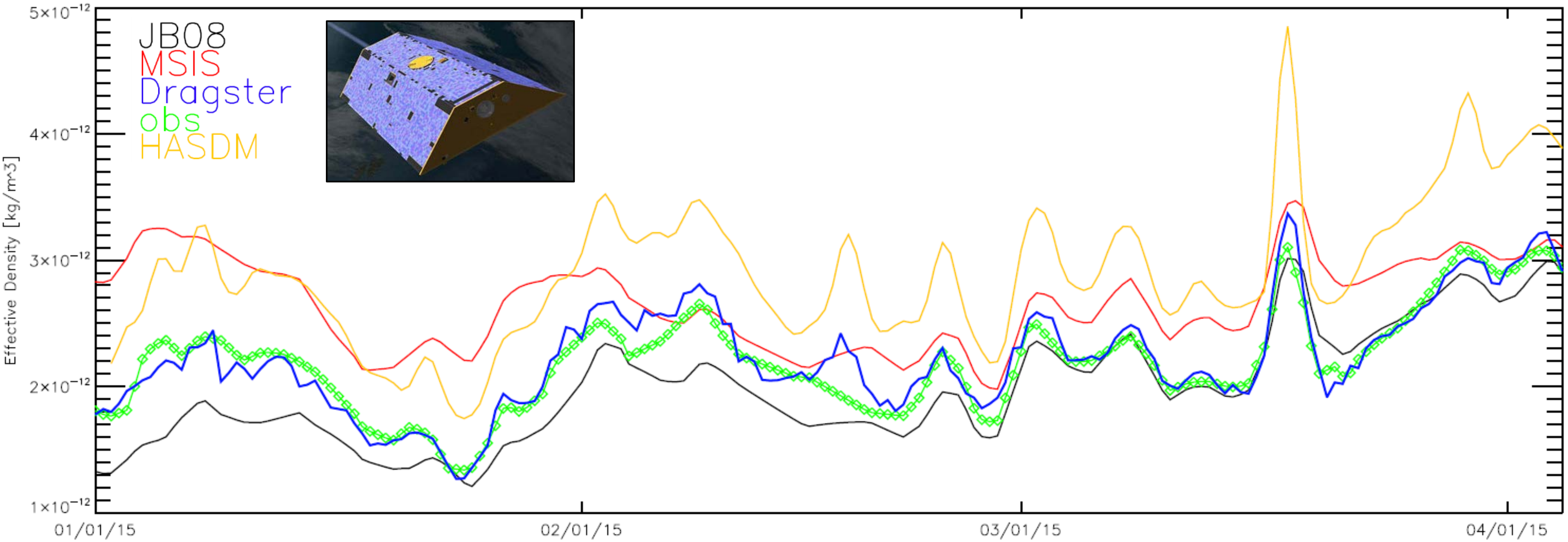
Local time, latitude, and altitude distribution of assimilation and validation satellites



RED – Assimilation Satellites

BLUE – Validation Satellites

GRACE (1/2015 - 4/2015)



GRACE-A (#27391) satellite effective densities (bright green) as a function of time. Model effective densities from NRLMSIS-00 (red), JB08 (black), HASDM (gold), and Dragster (blue) are also plotted.

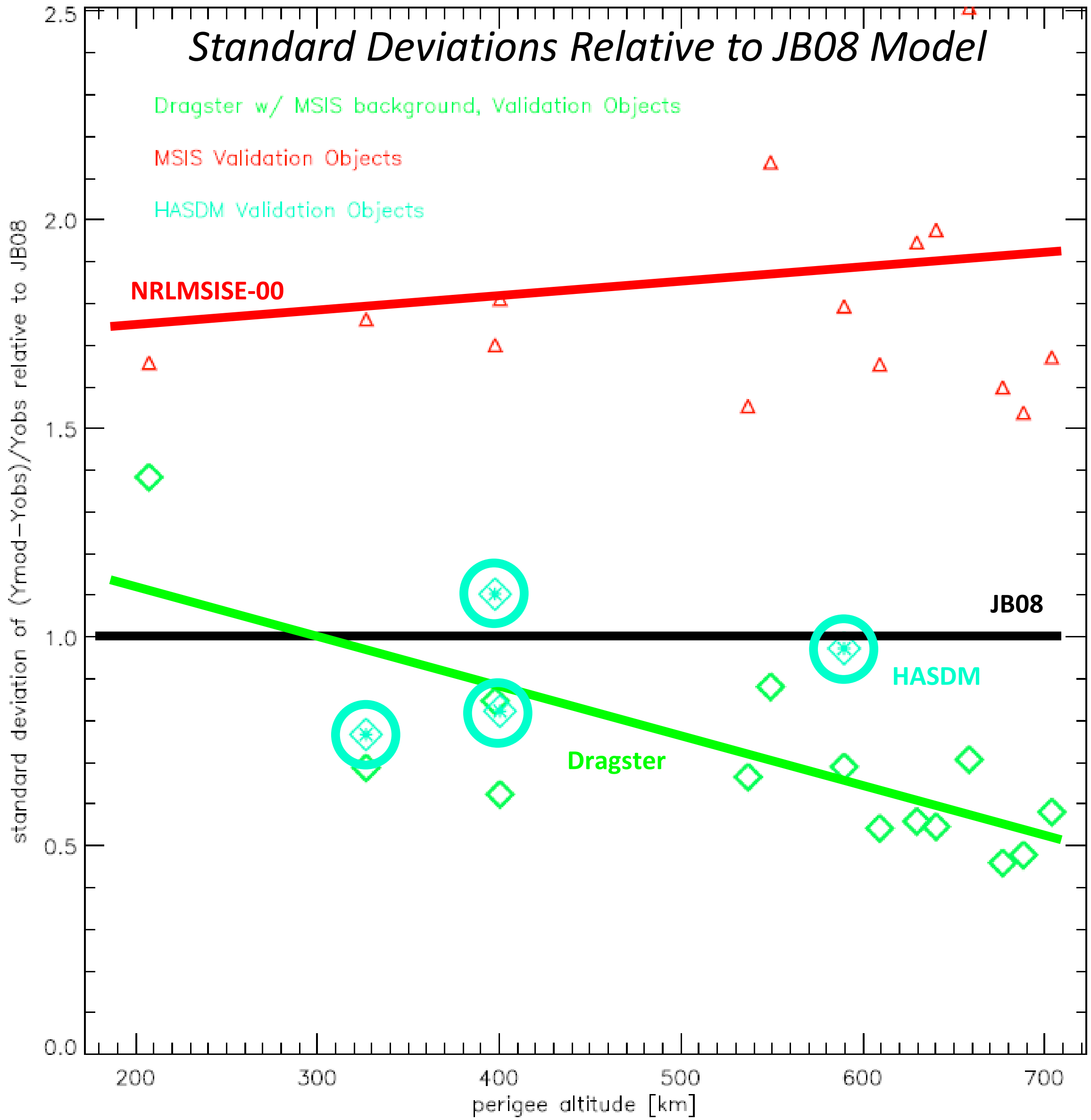
GRACE-A is in a 390km near circular orbit at the time of this plot

Next Steps: use accelerometer data

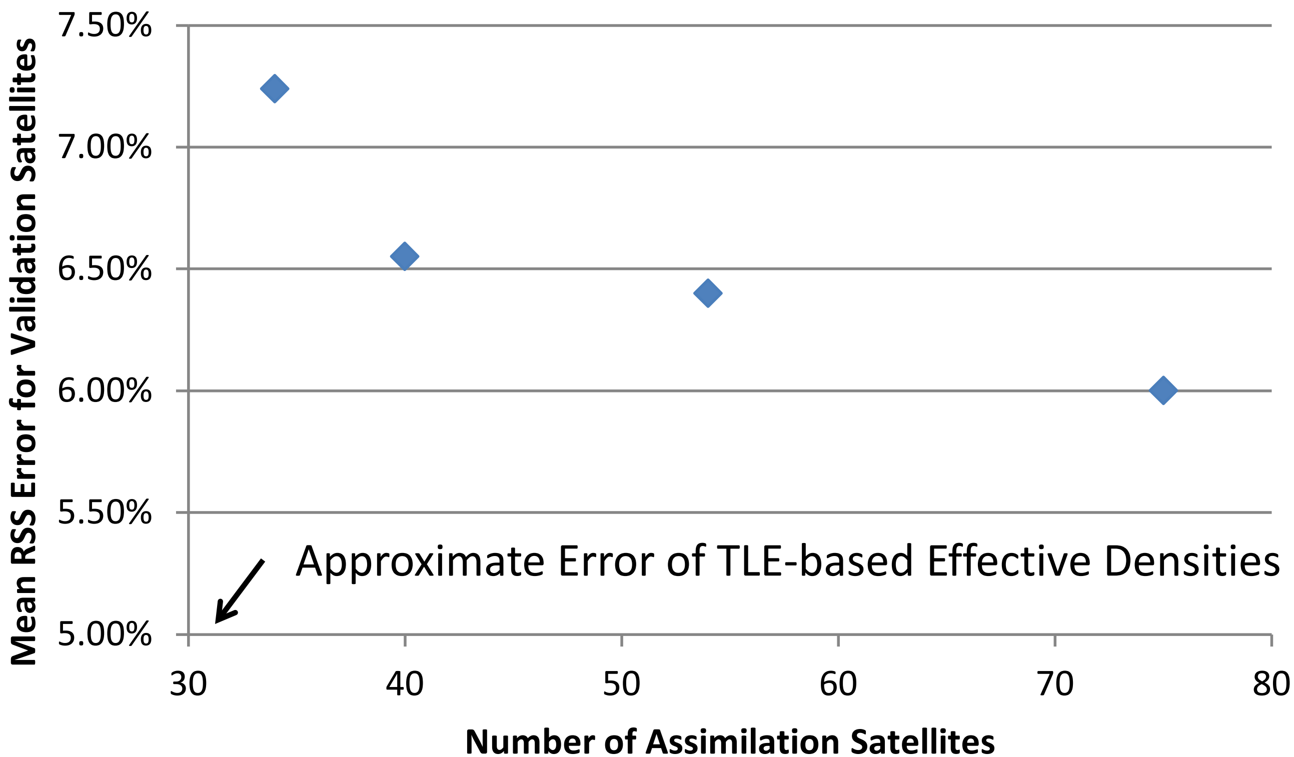
Satellite	Perigee Altitude [km]	MSIS Standard Deviation	JB08 Standard Deviation	HASDM Standard Deviation	*Dragster* Standard Deviation
GRACE-A (27391)	393	17%	9%	8%	6%

Preliminary Validation Results 1/2015-4/2015

- Data assimilated into NRLMSIS-00 to test the assimilation software
- Public TLE's ingested from 75 satellites
- State vector includes both solar (F10.7) and geomagnetic (Ap) forcing
- Errors from 14 validation satellites shown scaled to JB08 at right
- Test demonstrates significant reduction in errors over background model
- Preliminary test results are promising
  - **Background**: 10%-35%
  - **JB08**: 6%-21%
  - **HASDM**: 7%-18%
  - **Dragster**: 6%-15%

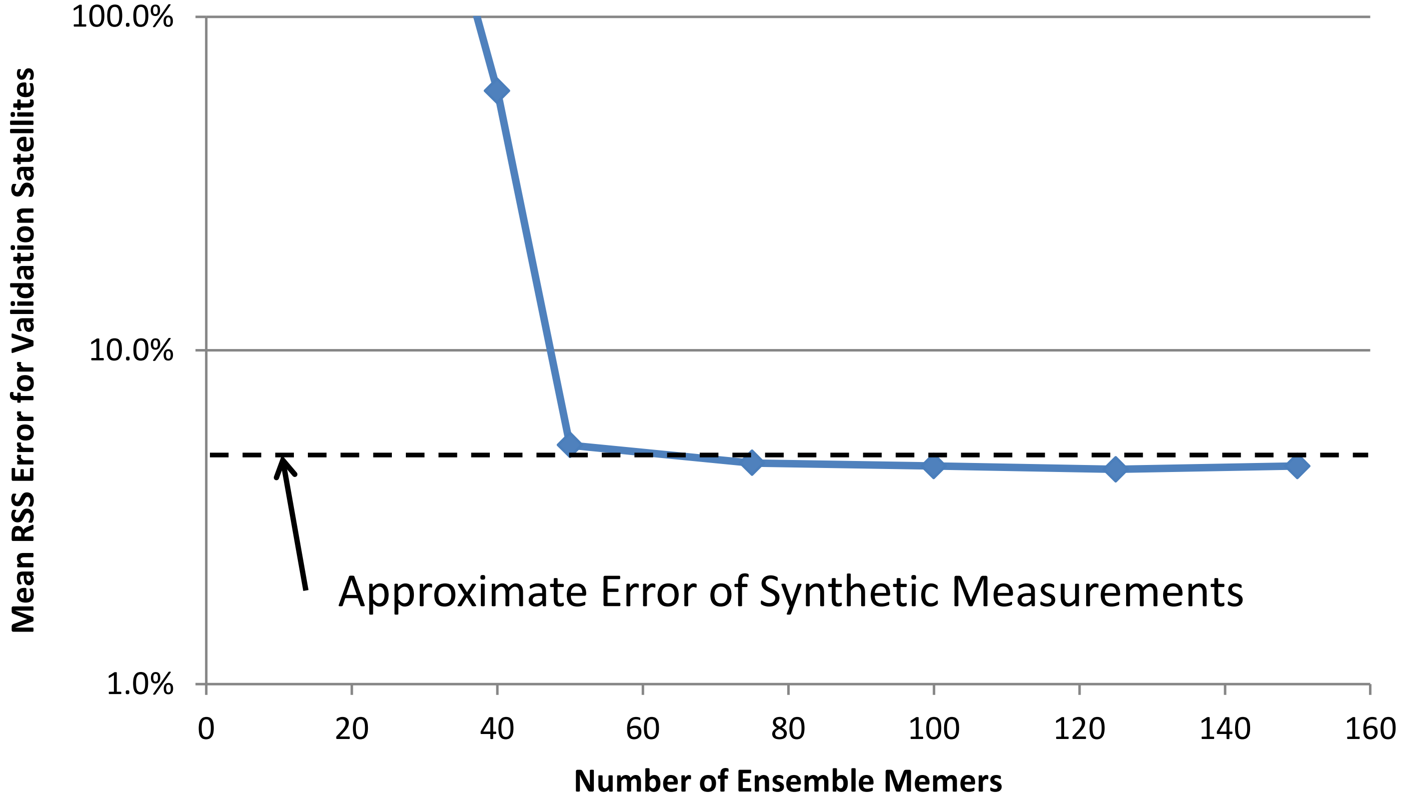


Sensitivity: Number of Satellites



- March 2015
- TLE-based inputs
- 90 ensemble members
- Localization for density-state corrections
- “Bad” satellites can broaden the error distribution or cause the filter to crash
    - Implemented an acceptance procedure for TLE data
    - Implemented method for identifying and ignoring data outliers

Sensitivity: Number of Ensemble Members



- March 2015
- Synthetic inputs generated using JB08
- 49 assimilation satellites
- Localization for density-state corrections

Sensitivity: State Vector

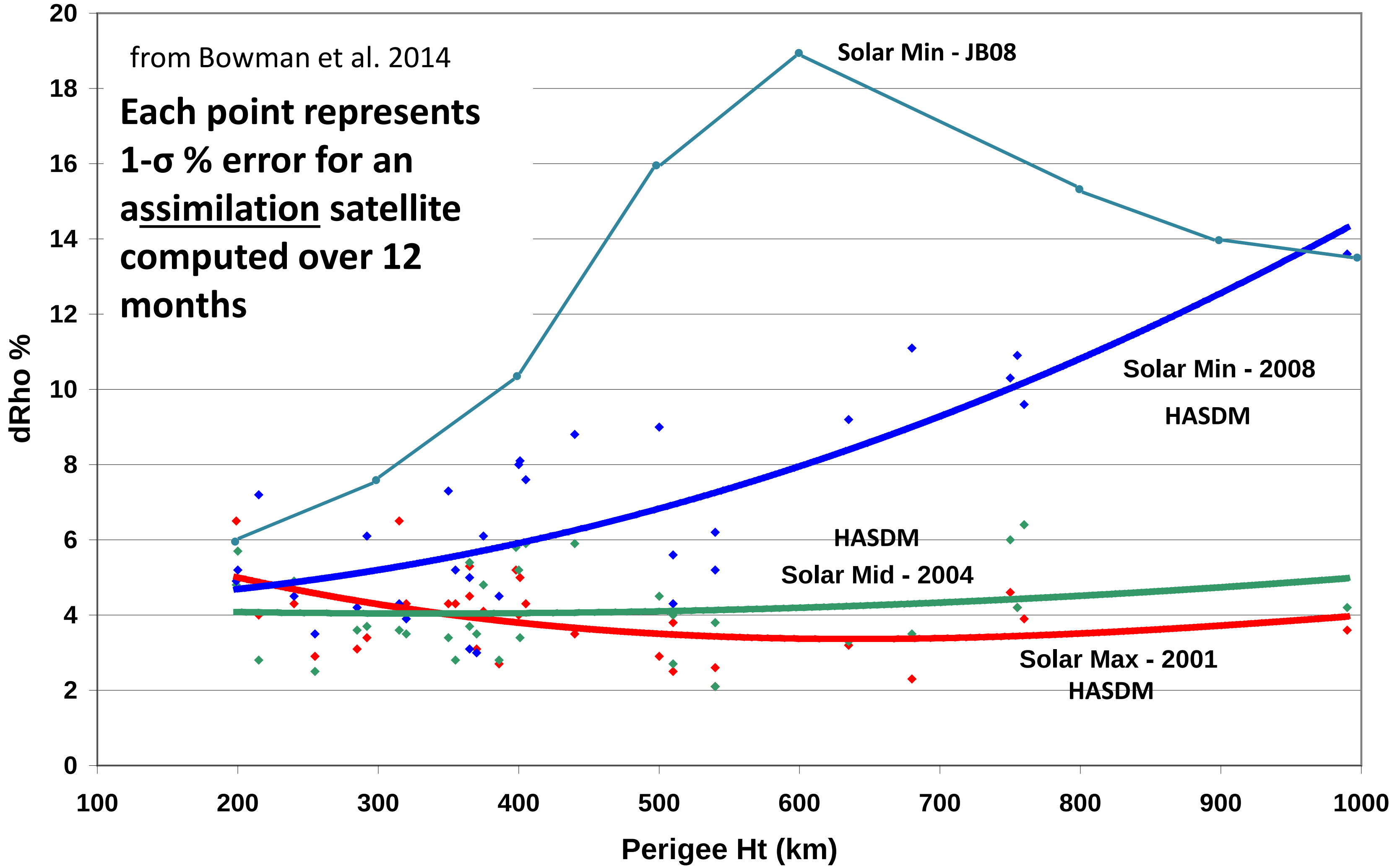
Technique	RSS Range
Forcing Estimates Only	7%-10%
Density Corrections only	6%-12%
Forcing + Density Corrections	6%-9%
Forcing + Density Corrections + Localization	6%-8%

- March 2015
- Synthetic inputs generated using JB08
  (but different validation dataset than previous slide)
- 49 assimilation satellites

Thank You

Context for Dragster Performance

Improve the state of the art in orbit prediction, orbit nowcast, and conjunction analysis for LEO satellites by reducing the errors associated with atmospheric drag modeling



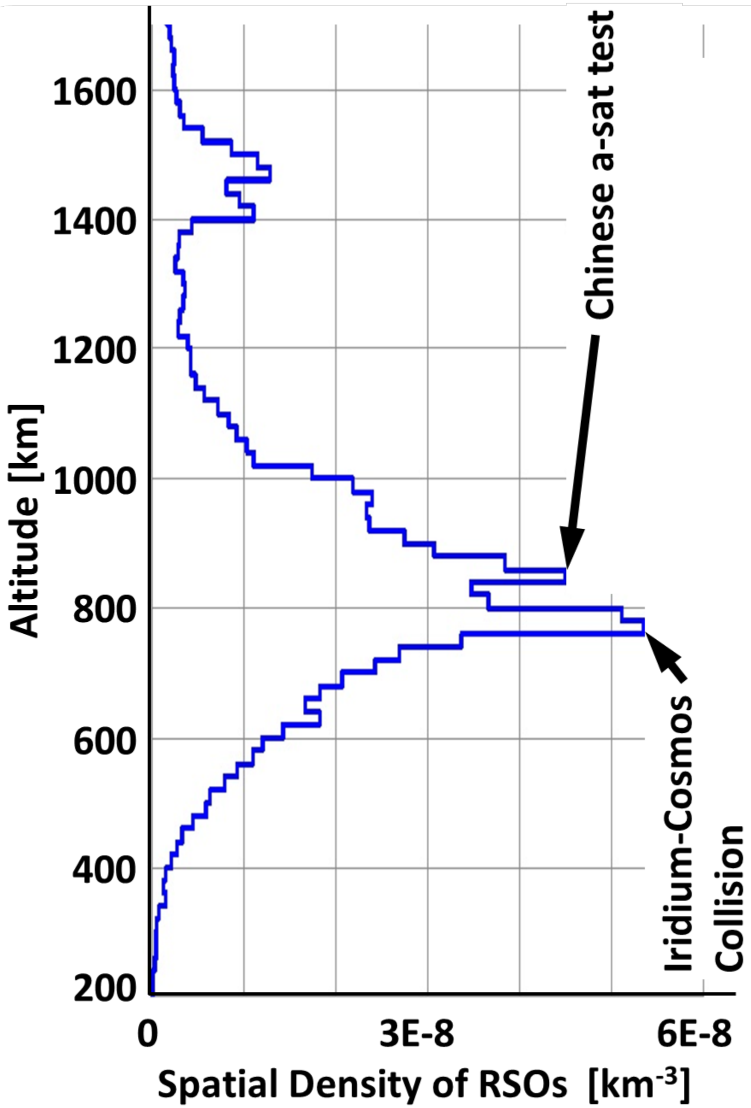
Storz et al. 20015 report HASDM assimilation satellite errors of 2%-10%

Context for Dragster Performance

Technique	Input Data Errors (1-σ)	Published Validation Errors (1-σ)
JB08	-	6%-19% (2000, 5 objects[1])
NRLMSIS-00	-	11%-27% (2000, 5 objects[1])
HASDM	2%	3%-25% (2002, 40 objects[2])
TLE Calibration of Empirical Models (Doornbos)	5%	5%-11% (2000, 5 objects[1])

[1]*Doornbos et al. 2008 (ASR)*
[2]*Storz et al. 2005 (ASR)*

Problem Motivation



While SRP[1] is larger in magnitude, aerodynamic drag is the most variable force and the primary contribution to orbit errors

Drag is the dominant non-conservative force

free-molecular flow

composition and temp. drives gradual changes in C_D

re-entry, extreme C_D variability

Dragster altitude coverage

Minimum Requirement

Forcing States