AAS 03-165

Comparison of MSIS and Jacchia atmospheric density models for orbit determination and propagation

Keith A. Akins

Pennsylvania State University
and Naval Research Laboratory

Liam M. Healy

Naval Research Laboratory

Shannon L. Coffey

Naval Research Laboratory

J. Michael Picone

Naval Research Laboratory

11 February 2003

Ponce, Puerto Rico

Overview

- Background on Density Models
    - Jacchia
    - MSIS-class
- Initial Vector Quality (discussed in detail in paper)
- Test Procedures
    - RMS Test
        - Differential Correction
        - Prediction
    - Orbit-to-orbit Test
- Results
- Conclusions

Common Density Model Families

Two common density model families:

- Jacchia
  - Developed 1960's by Luigi Jacchia
  - Valid above 90 km
  - Fit to densities derived from satellite orbits between 1961-1970
  - Model of choice for astrodynamics community
- MSIS-class
  - **M**ass **S**pectrometer – **I**ncoherent **S**catter
  - Developed 1980's and 90's by Alan Hedin and others
  - Valid above ground level
  - Fit to individual species densities and temperatures as measured by ground- and satellite-based sensors mostly from 1960's-1980's
  - Model of choice for atmospheric scientists

MSIS-class Density Models

Two widely used MSIS models:

- MSISE-90
- NRLMSISE-00

Improvements in NRLMSISE-00 over MSISE-90

- Includes extensive set of total mass density data, including all of the data used by Jacchia in his model, which was previously absent in MSIS models.
- Also added data from accelerometer analysis.

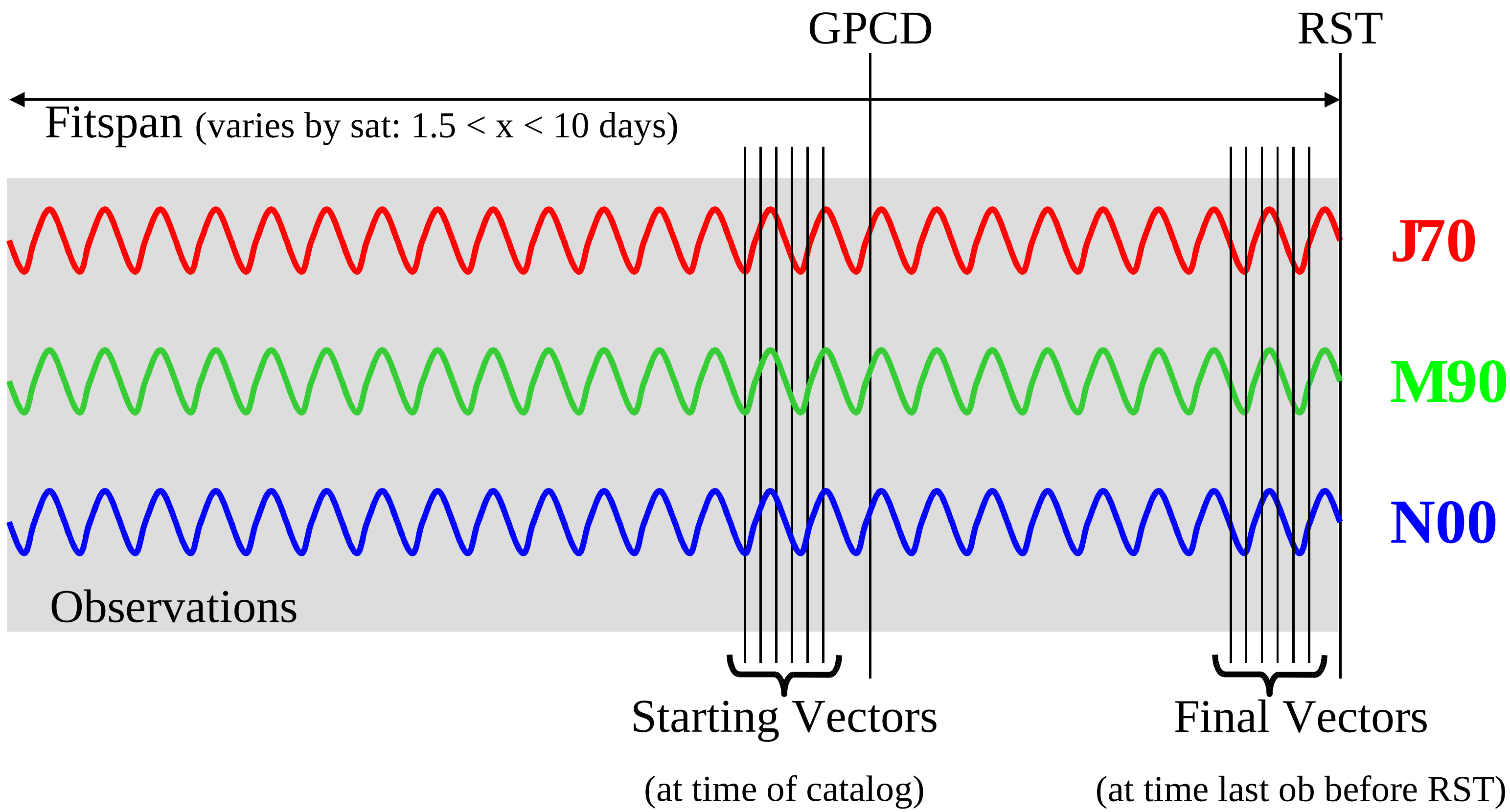
The Future of MSIS…

- Dynamic scaling of the constituent data in NRLMSISE-00 would allow more real-time representation of the atmosphere.
- UV data has been collected from the LORAAS instrument and is currently being incorporated into NRLMSISE-00.
- An analysis of the effects of this is underway.

Data Sets

- LowSats
  - 4587 objects
  - September – October 1999
  - All cataloged objects with perigees below 1000 km
  - Good representation of satellite environment
- HASDM
  - 60 “calibration” objects
  - January – February 2001
  - Very high number of observations

Test Procedure – RMS Test
Differential Correction



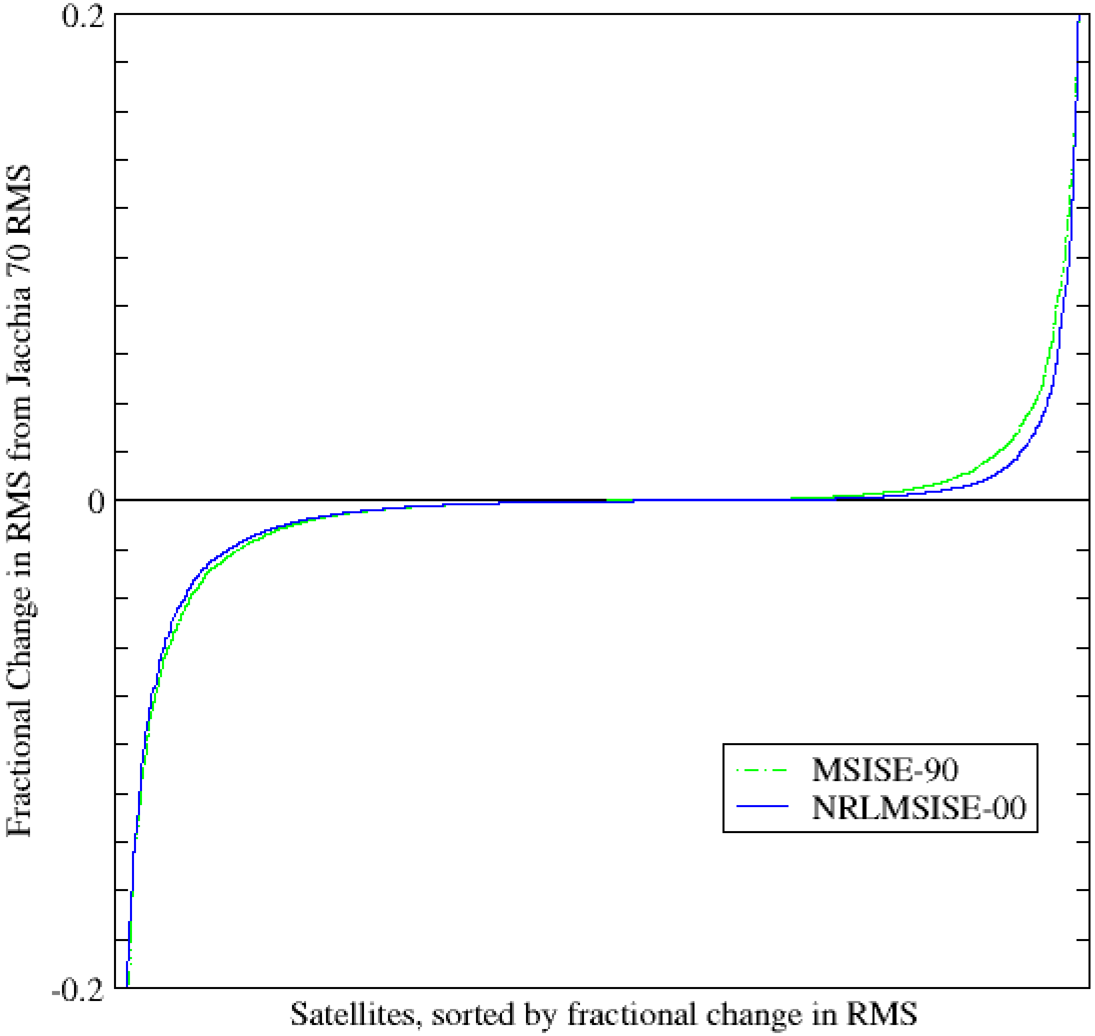
Abbrev	Description	LowSats	HASDM
GPCD	General Perturbations Catalog Date	30 Sept 1999	13 Feb 2001
RST	Requested Stop Time	01 Oct 1999	15 Feb 2001

Results – RMS Test – LowSats

Differential Correction

	MSISE-90
Mean	**–0.00189**
Std. Dev.	**0.0913**

	NRLMSISE-00
Mean	**–0.00298**
Std. Dev.	**0.0848**

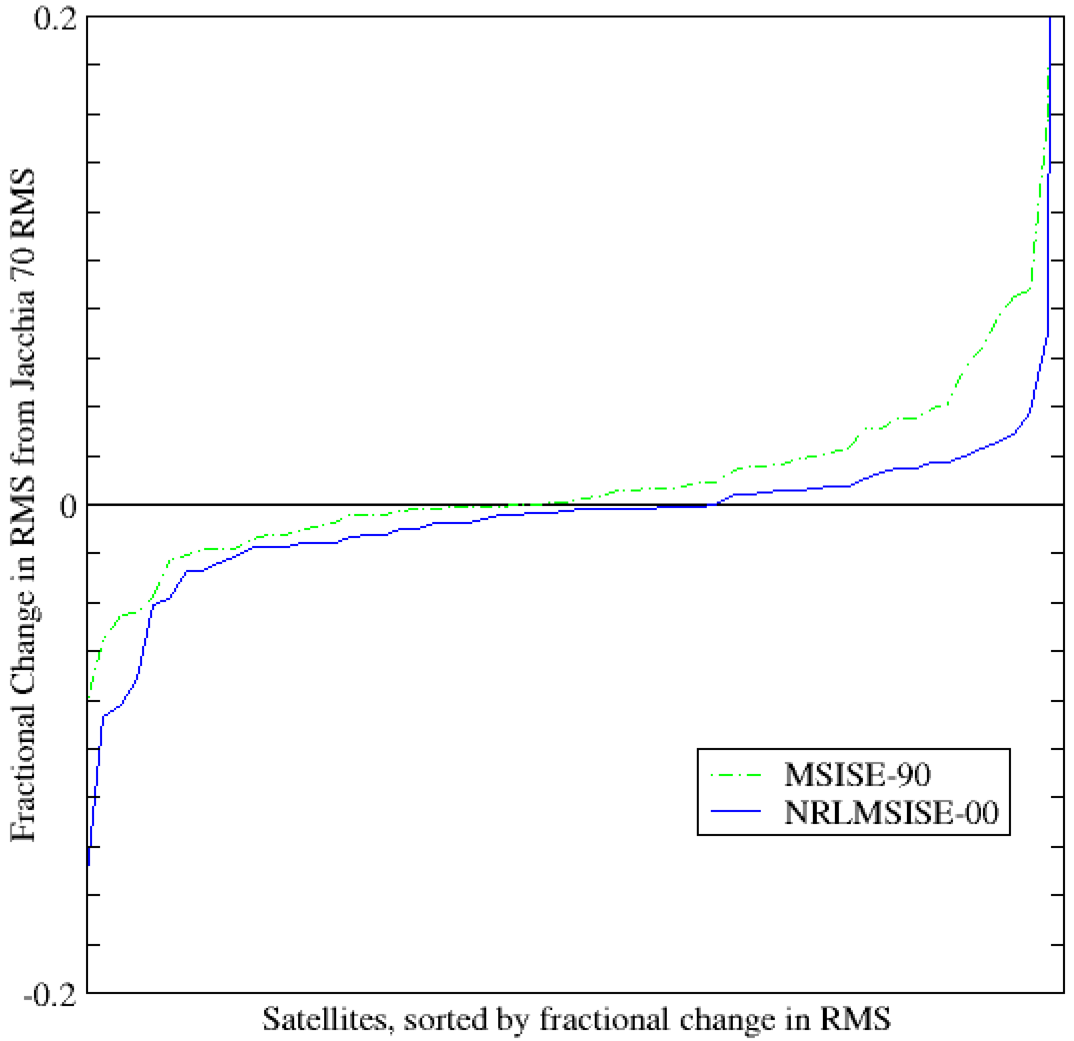


Results – RMS Test – HASDM

Differential Correction

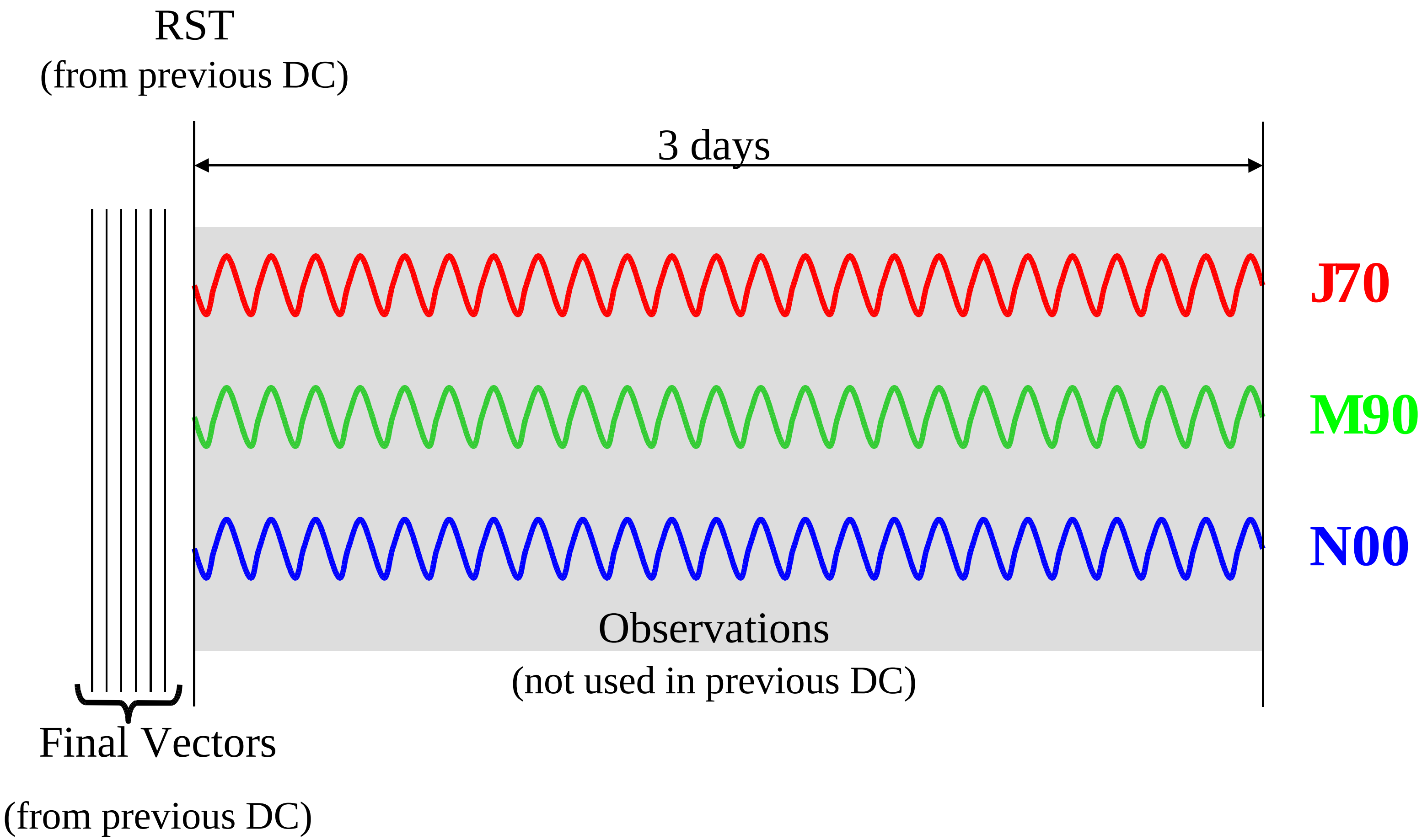
	MSISE-90
Mean	**0.0170**
Std. Dev.	**0.0754**

	NRLMSISE-00
Mean	**0.0139**
Std. Dev.	**0.169**



Test Procedure – RMS Test

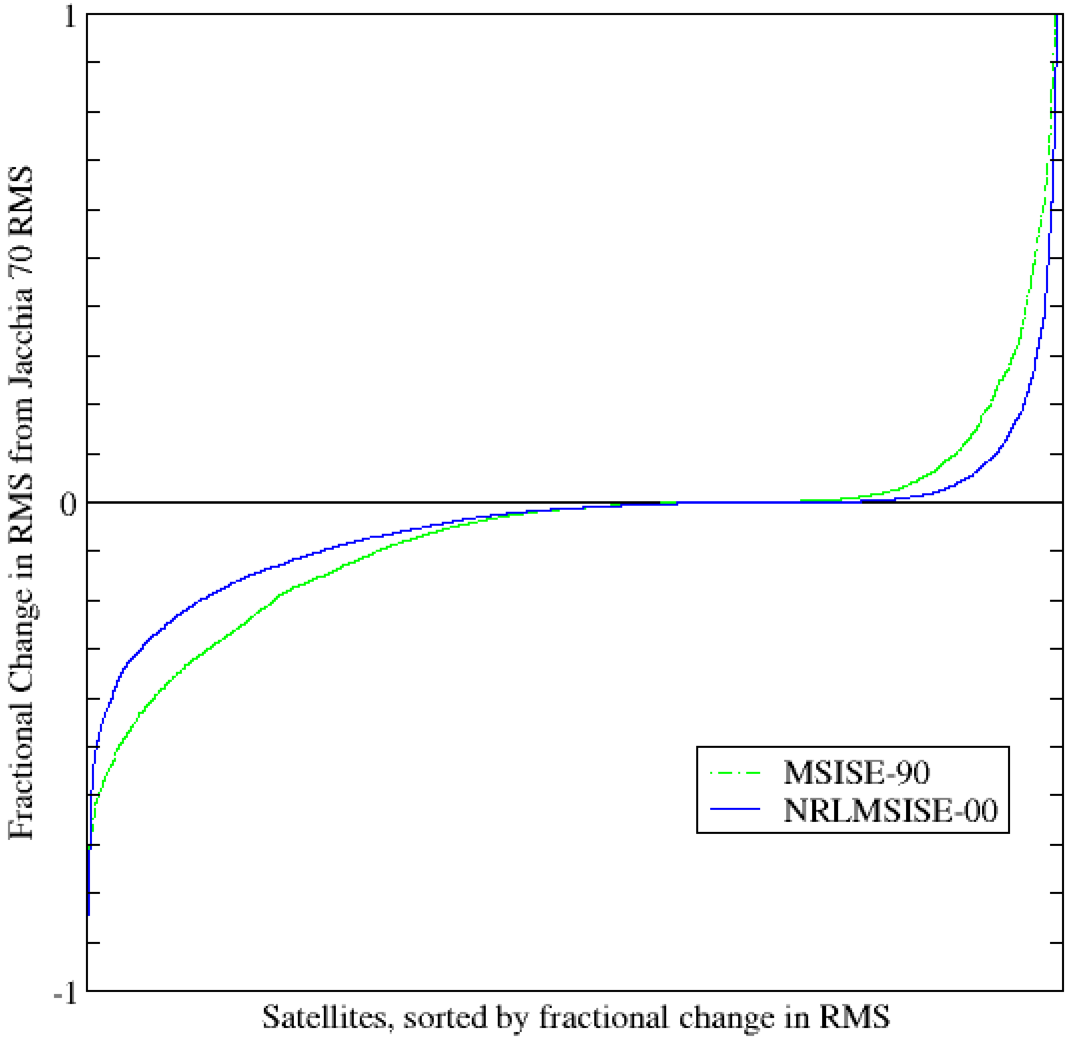
Propagation



Results – RMS Test – LowSats
Propagation

	MSISE-90
Mean	**–0.0451**
Std. Dev.	**0.271**

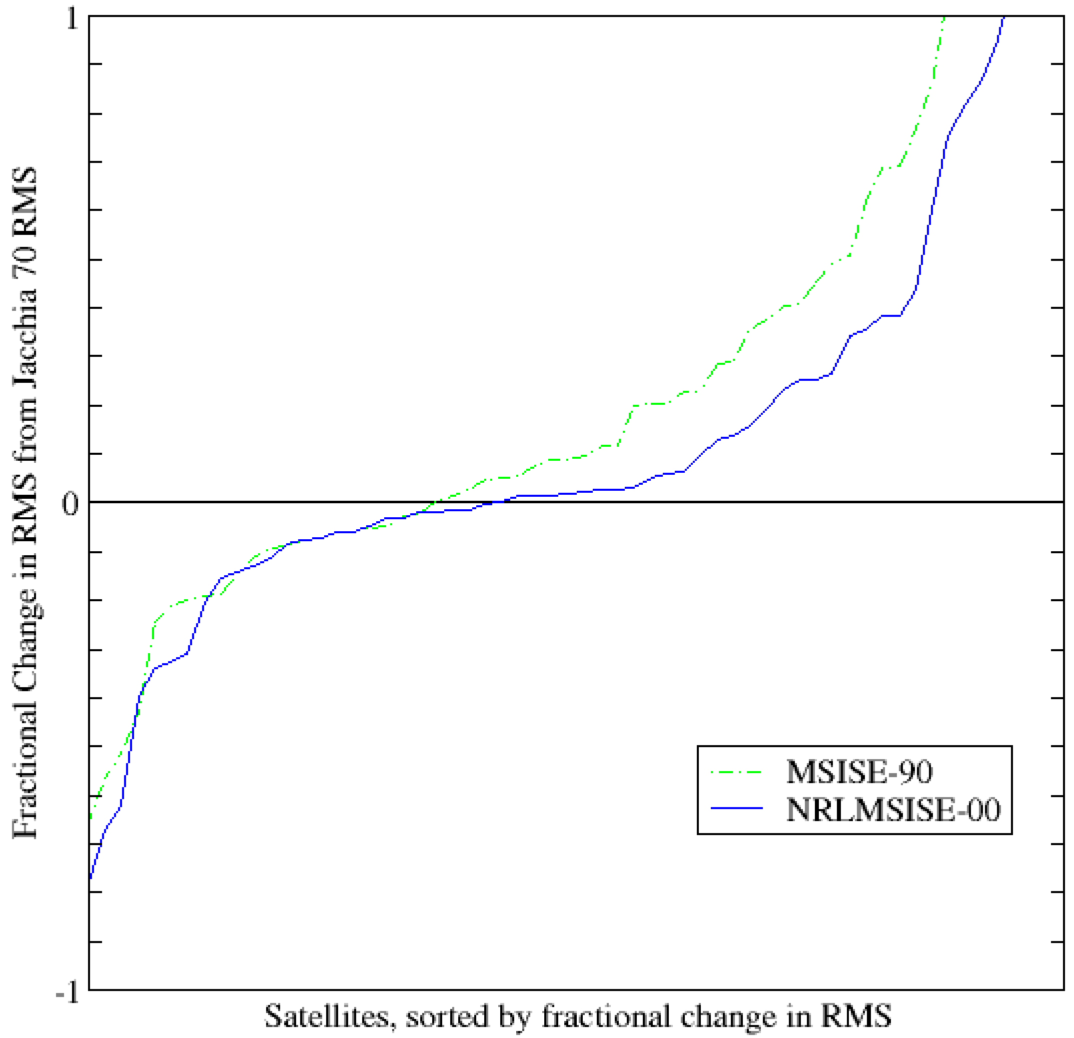
	NRLMSISE-00
Mean	**–0.0325**
Std. Dev.	**0.328**



Results – RMS Test – HASDM
Propagation

	MSISE-90
Mean	0.282
Std. Dev.	0.584

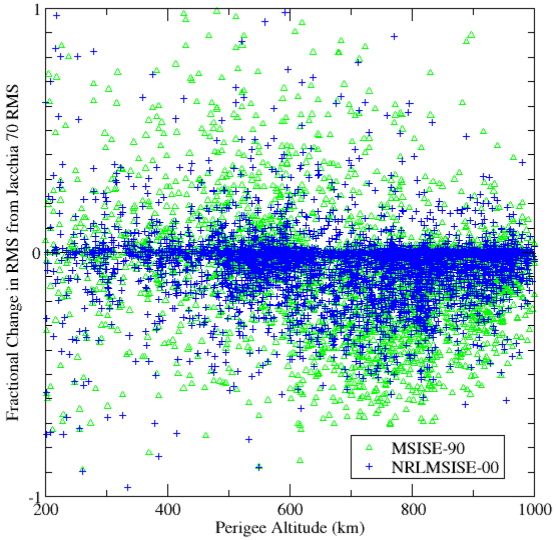
	NRLMSISE-00
Mean	0.142
Std. Dev.	0.456



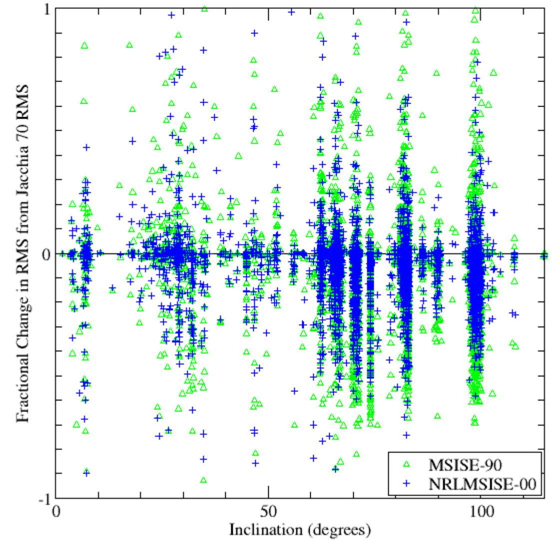
Results – RMS Test – LowSats

Propagation

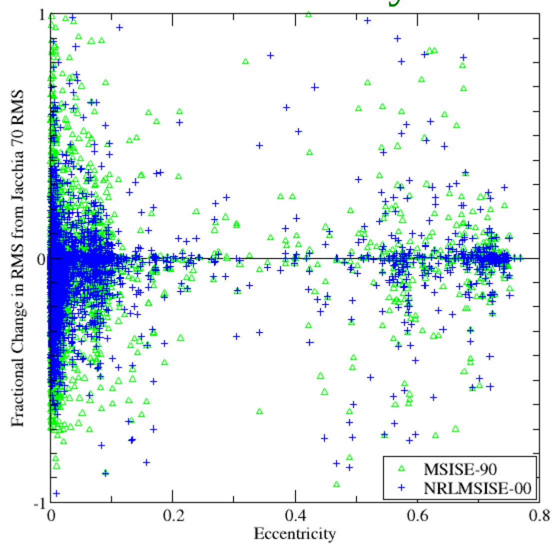
Perigee Altitude



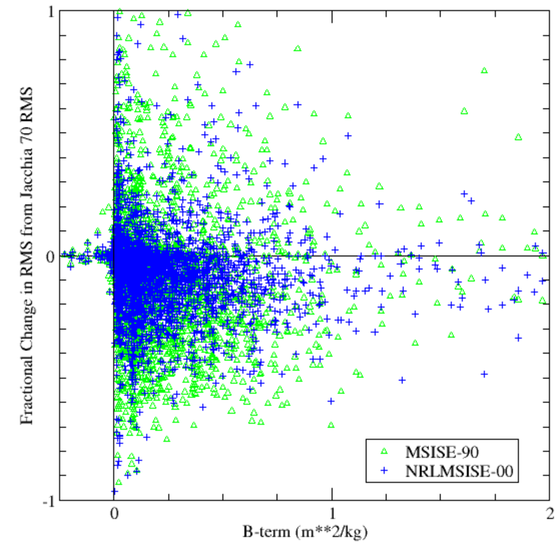
Inclination



Eccentricity

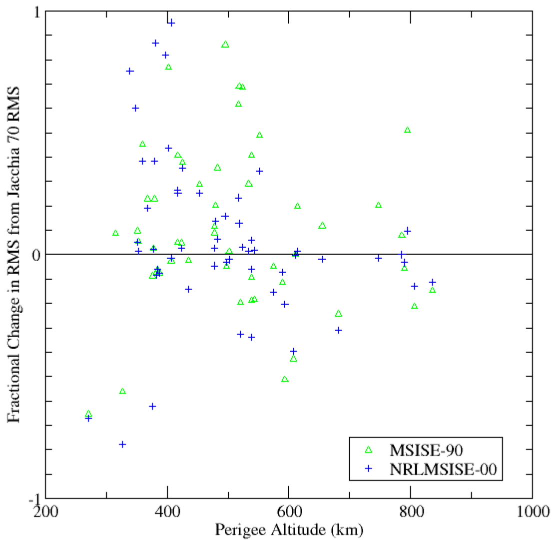


B-term

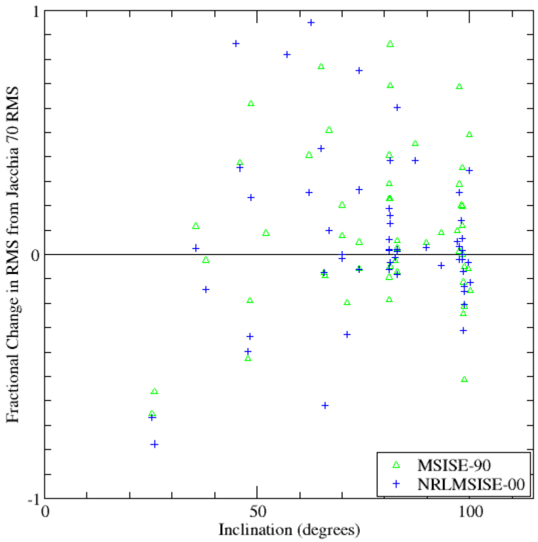


Results – RMS Test – HASDM
Propagation

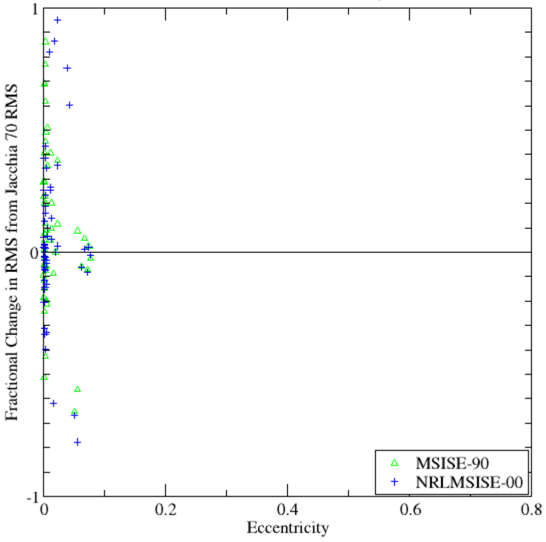
Perigee Altitude



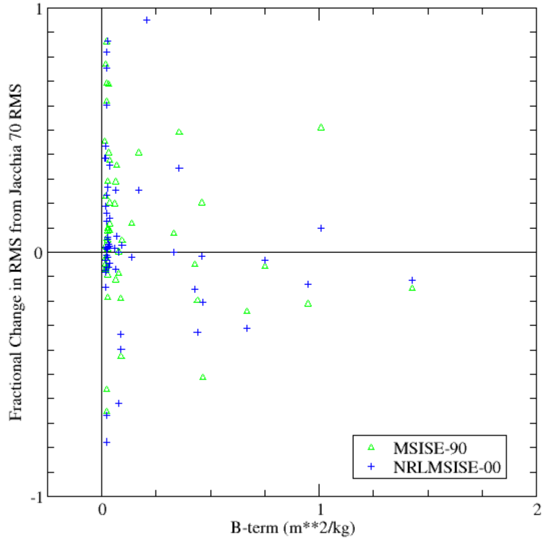
Inclination



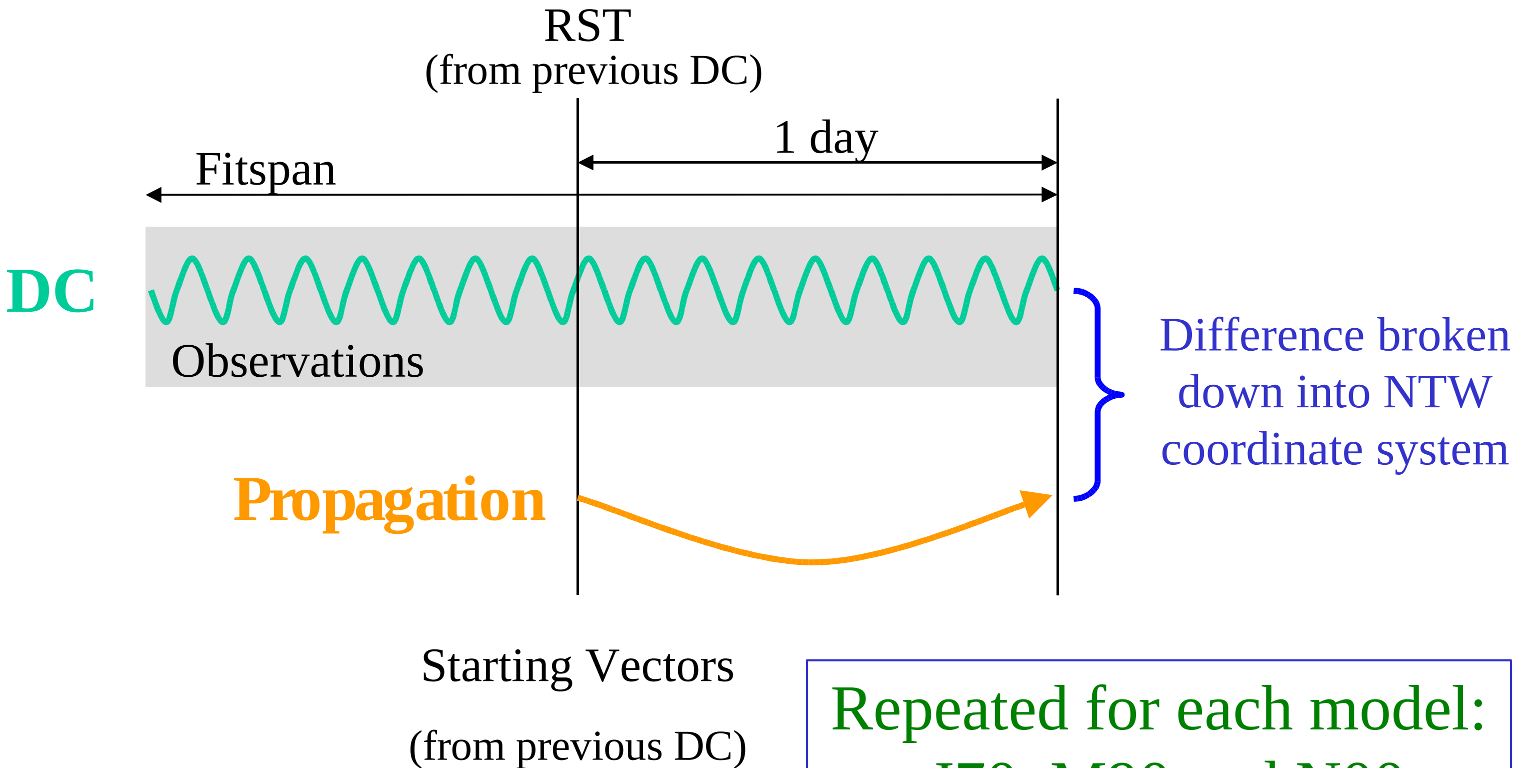
Eccentricity



B-term



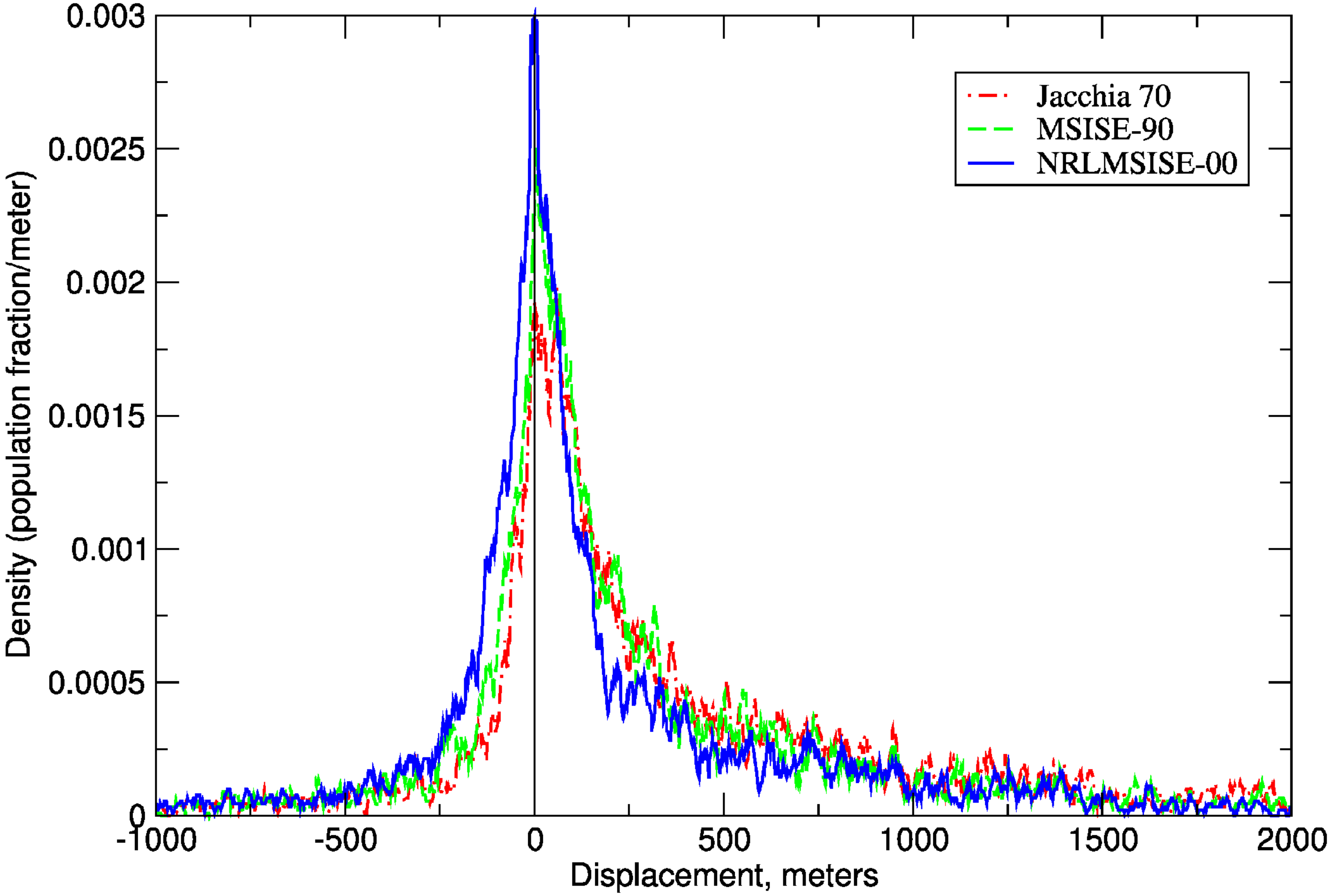
Test Procedure – Orbit-to-orbit Test



Repeated for each model: J70, M90 and N00

Results – Orbit-to-orbit Test – LowSats

Intrack Component

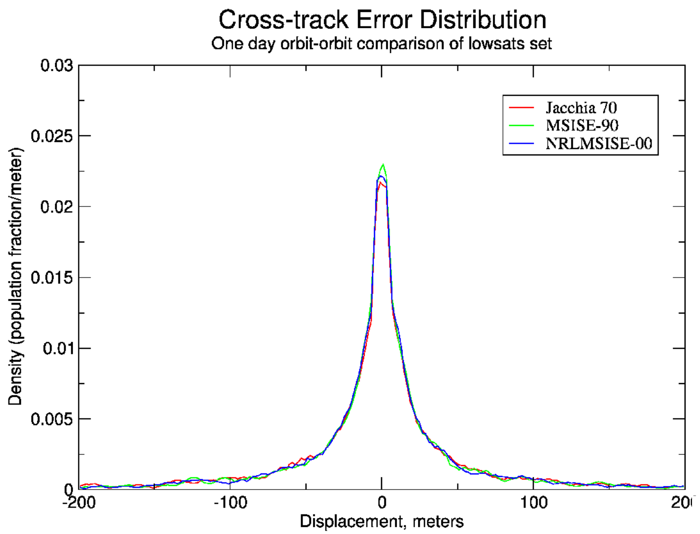


INTRACK	Jacchia 70	MSISE-90	NRLMSISE-00
Mean	493.5	166.9	172.1
Std. Dev.	16592.0	16588.2	16534.3

–Statistical units are meters.

Results – Orbit-to-orbit Test – LowSats

Crosstrack and Normal Components

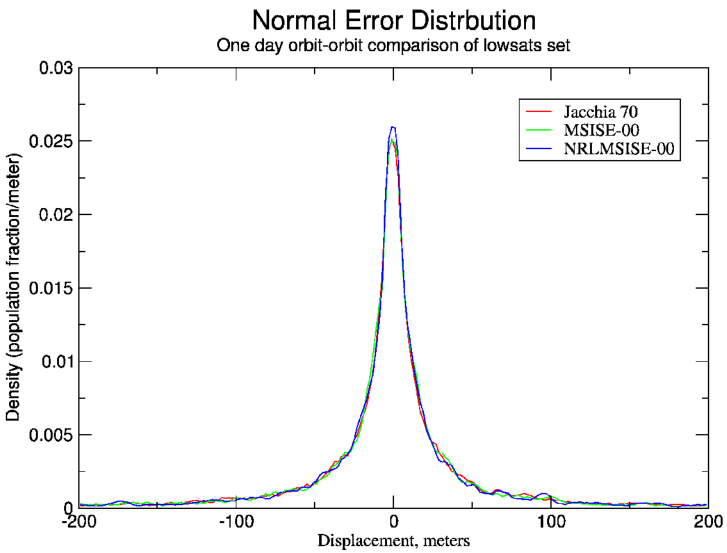


X-TRACK	Jacchia 70	MSISE-90	NRLMSISE-00
Mean	-0.8	-11.8	-11.8
Std. Dev.	748.8	820.0	824.4

NORMAL	Jacchia 70	MSISE-90	NRLMSISE-00
Mean	29.8	34.1	40.5
Std. Dev.	1902.4	1941.1	1950.5

–Statistical units are meters.

NOTE: NRLMSISE-00 did better with Satellite 25228, a spent rocket body that decayed less that 10 days directly following this test. J70 and M90 had errors of 2231km while N00 had only 568km.



Results – Orbit-to-orbit Test – HASDM

INTRACK	Jacchia 70	MSISE-90	NRLMSISE-00
Mean	1365.8	-7.4	393.1
Std. Dev.	2552.1	2224.4	2128.4

X-TRACK	Jacchia 70	MSISE-90	NRLMSISE-00
Mean	-0.2	8.3	3.9
Std. Dev.	21.6	59.0	42.0

NORMAL	Jacchia 70	MSISE-90	NRLMSISE-00
Mean	-16.4	-7.4	-12.6
Std. Dev.	34.2	37.8	42.4

– Figures not shown. Statistical units are meters.

Conclusions

- For the majority of the tests performed, MSIS-class models show improvement over Jacchia
- Overall, the improvements are very minimal
- Individual satellites can show wide differences between any of the models
- No specific orbital regime correlations
- There is hope that the dynamic NRLMSISE-00 will be much improved

Questions