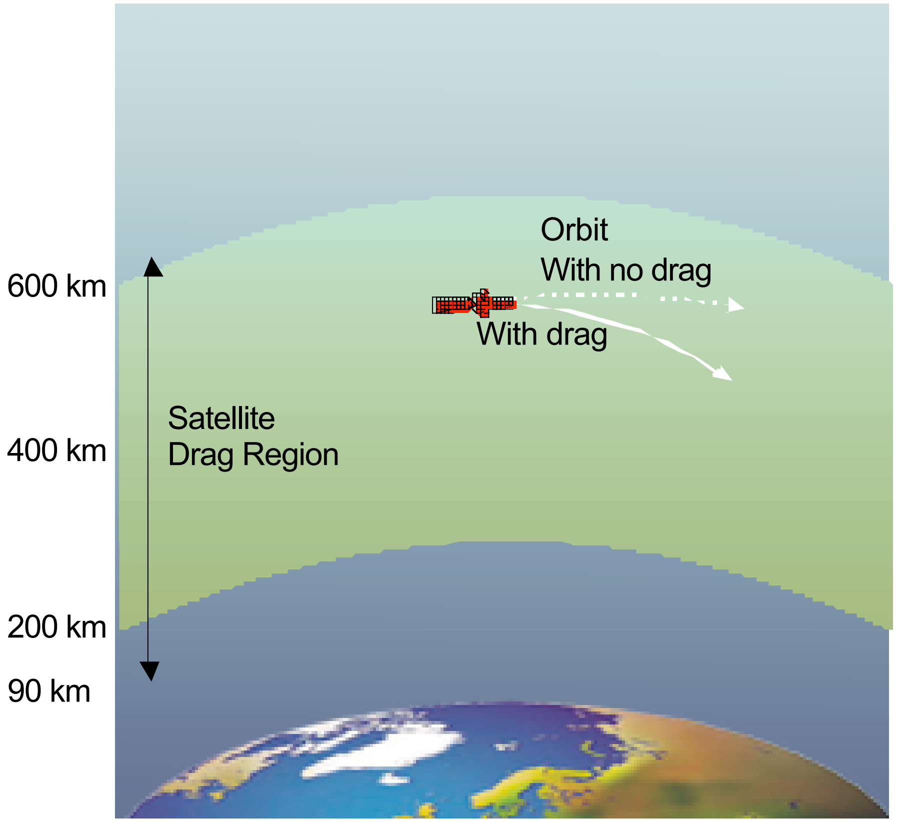
AFRL Satellite Drag/Neutral Density Program

Presented to:
Living With a Star Measurement Requirements Workshop
NASA/GFSC 9 Feb 2000



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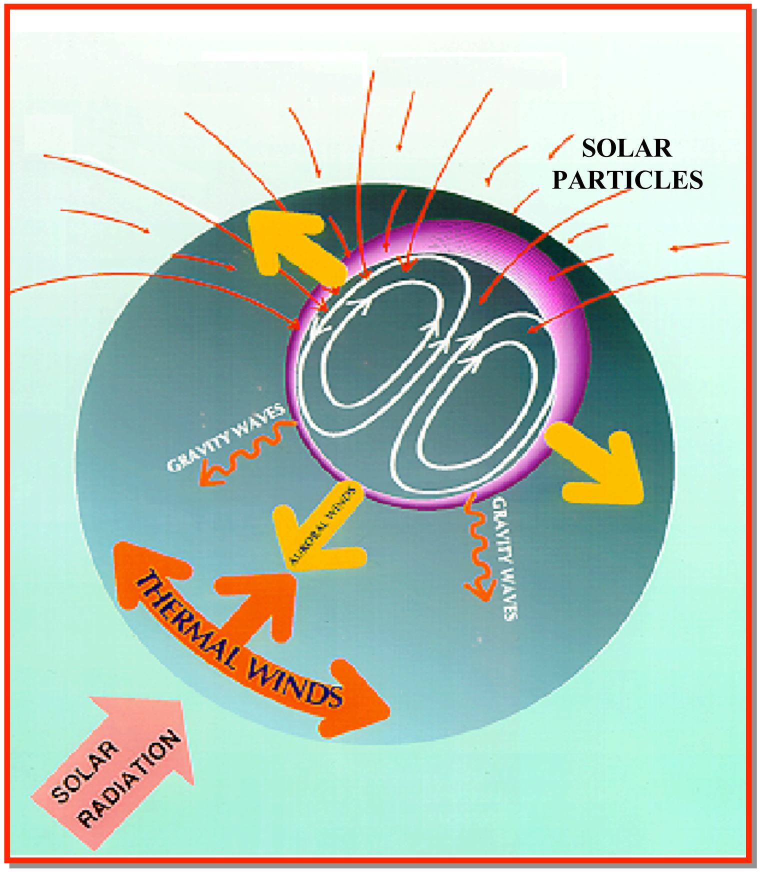
OUTLINE

- Introduction
- Satellite Drag Variations and Models
- Neutral Density Space Weather Programs
- Future Requirements
- Conclusions

DRIVERS OF NEUTRAL DENSITY VARIABILITY



- **Solar EUV Heating**
- **Auroral Heating**
- **Upward Propagating Waves**

Variability (400 Km)	**Factor**	**Time Scale**
Solar cycle	8.6	Years
Daily solar flux	1.15	Day
Geomagnetic storm	3.2	Hours

Empirical Neutral Density Model

•	Solar EUV	$F_{10.7}$	- daily solar flux measured at 10.7 cm
		FBAR	- 81 day or 162 day mean (centered) of $F_{10.7}$
•	Solar Wind Interactions	ap	- planetary geomagnetic activity index
•	Upward Waves	Not included in empirical models	

a. Nighttime Minimum Exospheric Temperature

TC = a + bFBAR + c[F10.7-FBAR]

b. Diurnal correction

TL = TC x f (position)

c. Geomagnetic activity correction

TG = ap + 100[1 - exp(0.08ap)]

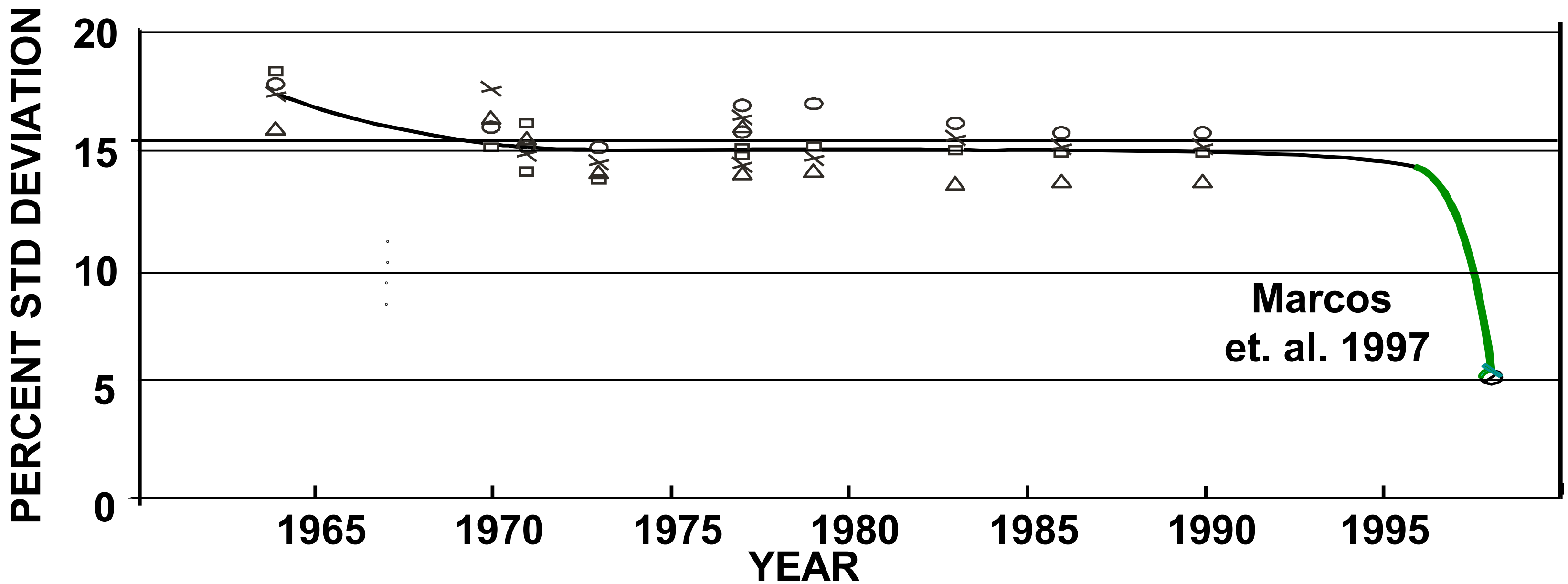
d. Semiannual correction

TS = f (day of year)

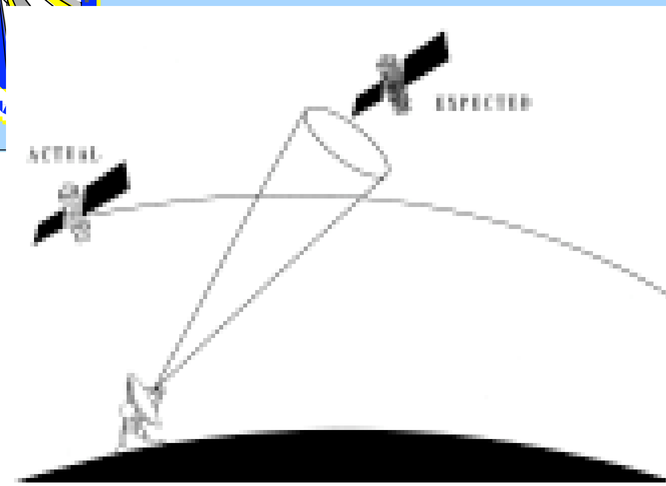
e. Global Exsopheric temperature

TE = TL + TG + TS

HISTORICAL TREND OF EMPIRICAL MODEL ERRORS



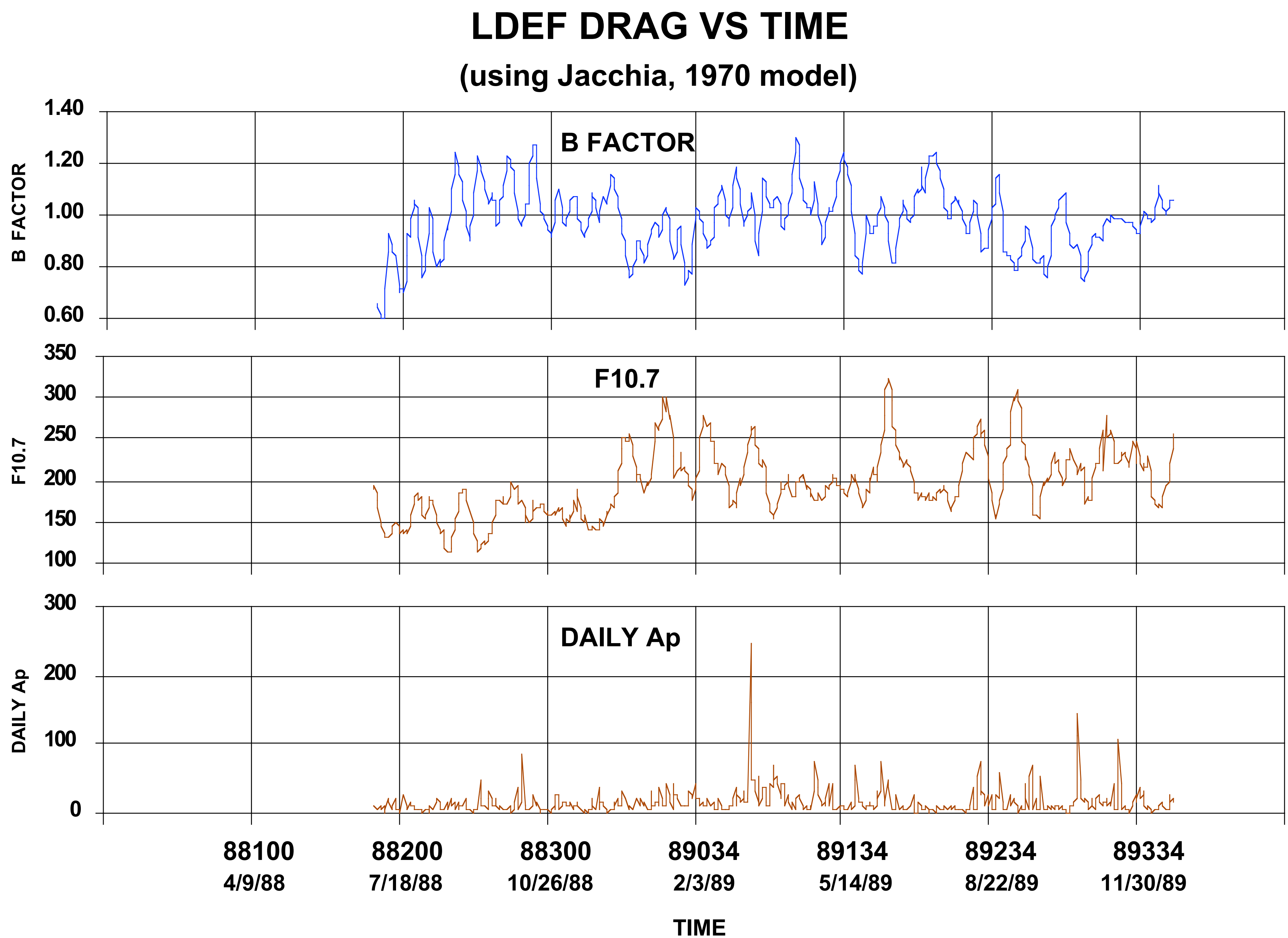
ELEVANCE



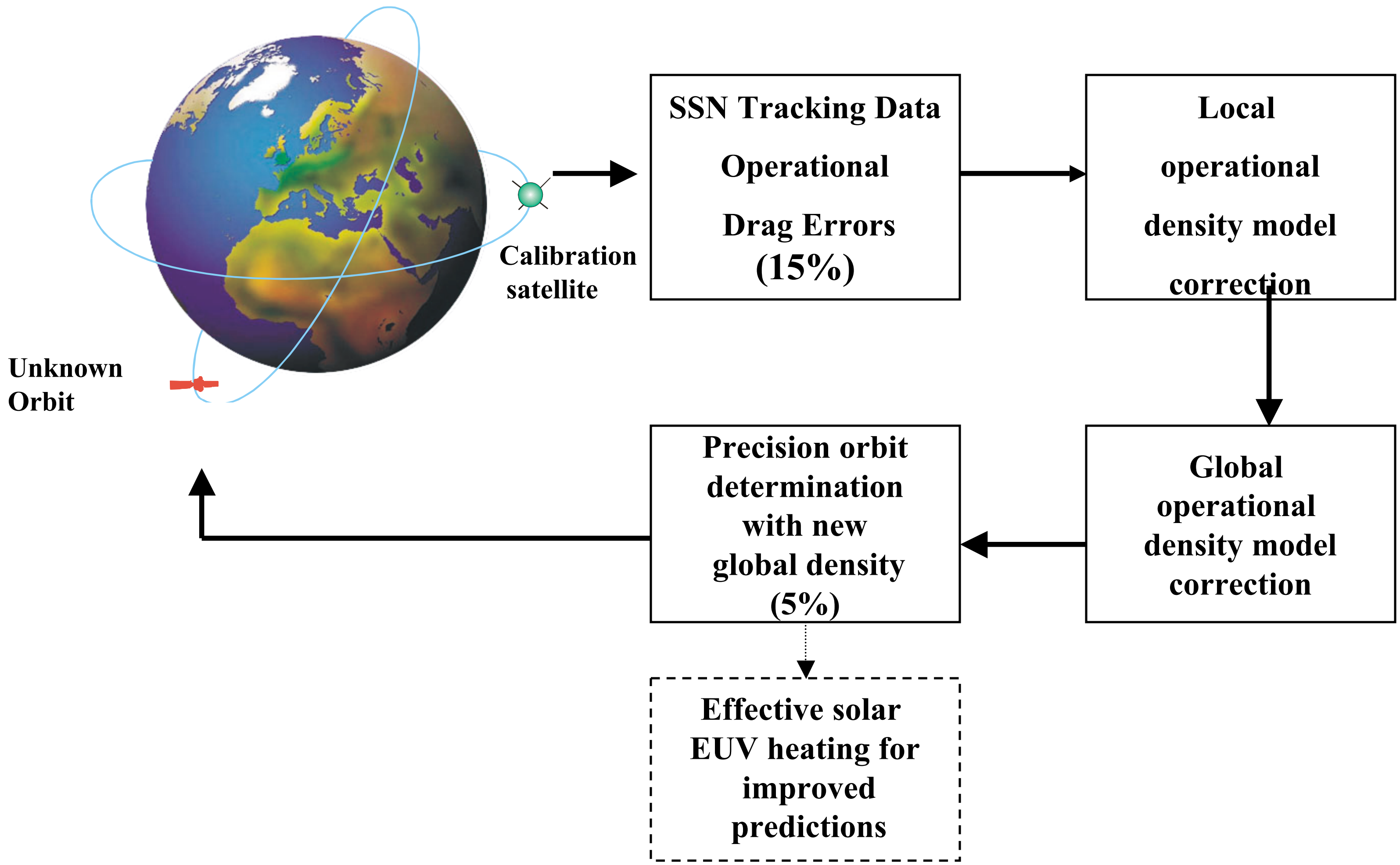
Actual Expected

Major effect of drag is on satellite in-track position

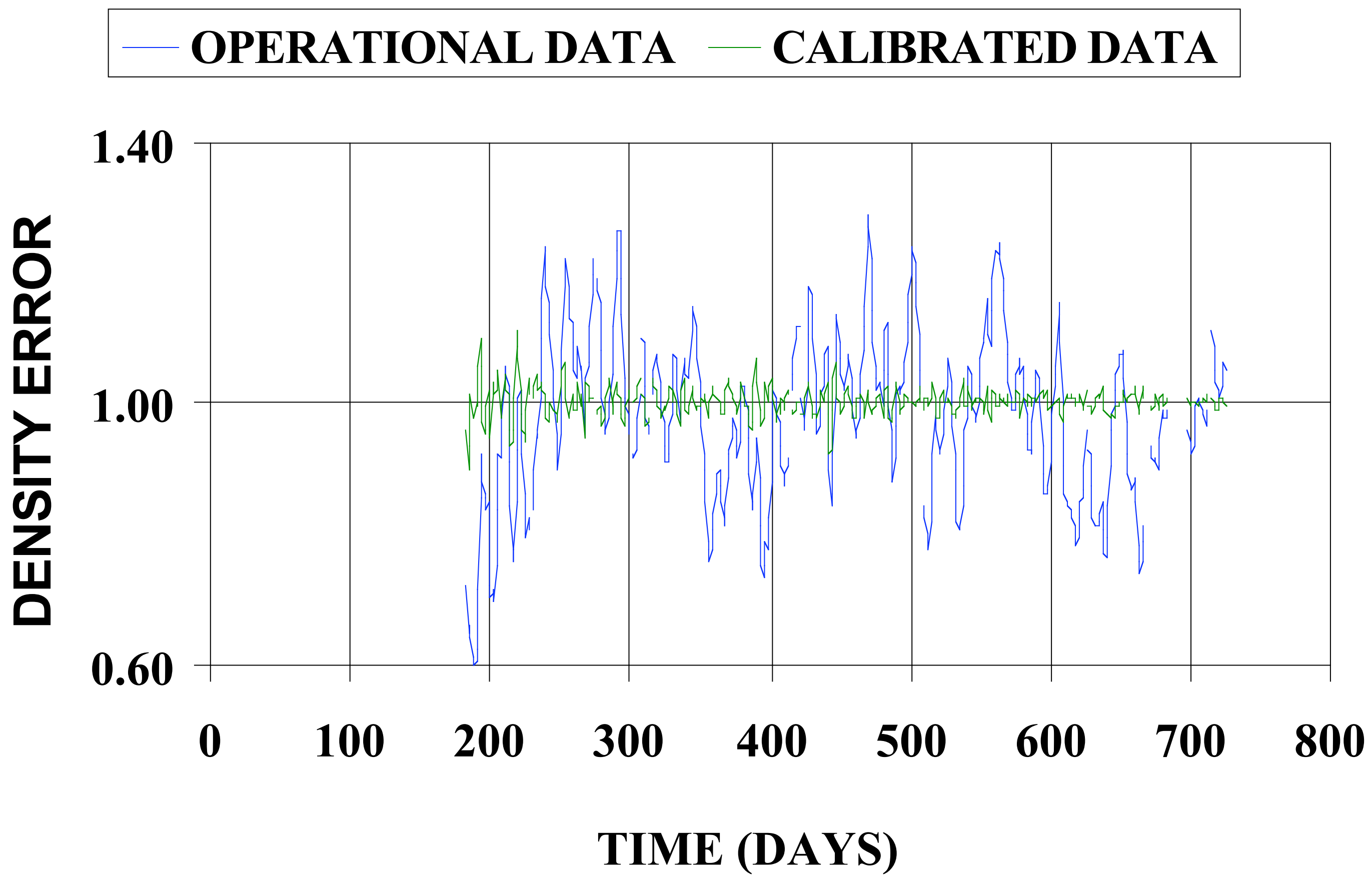
- **Unpredictedneutral density errors degrade capabilities to:**
  - **Catalog all space objects**
  - **Precisely determine orbits**
  - **Provide Collision Avoidance warnings**
  - **Predict satellitereentries**
  - **Estimate satellite lifetimes**
  - **Determine on-board fuel requirements**
  - **Control orbital parameters**
- **Operational density model: 15% error**
- **Goal: 90 - 600 km: 5% error**


LDEF DRAG VS TIME
(using Jacchia, 1970 model)
B FACTOR
1.40
1.20
1.00
0.80
0.60
B FACTOR
F10.7
350
300
250
200
150
100
F10.7
DAILY Ap
300
200
100
0
DAILY Ap
88100
4/9/88
88200
7/18/88
88300
10/26/88
89034
2/3/89
89134
5/14/89
89234
8/22/89
89334
11/30/89
TIME

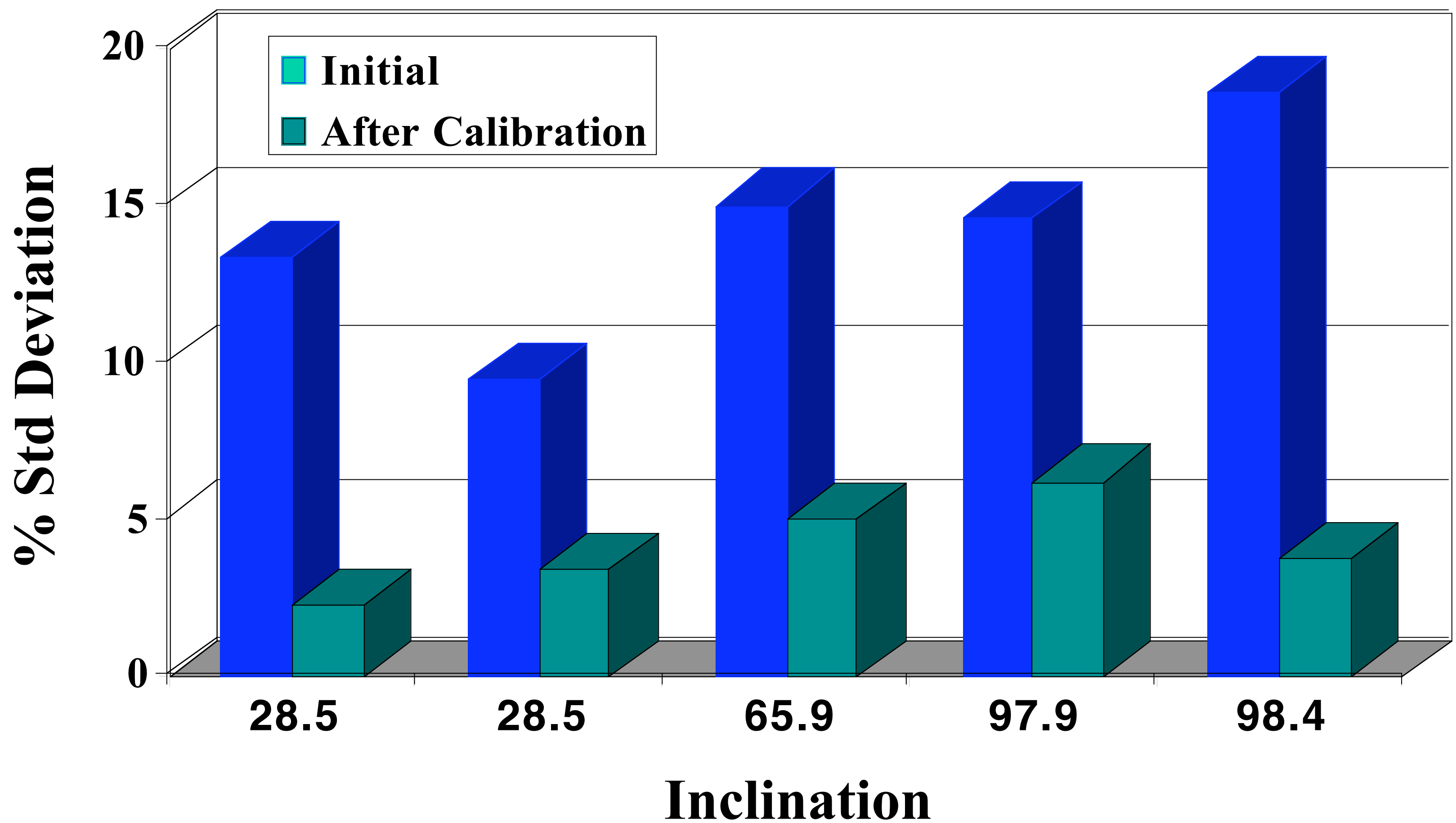
ATMOSPHERIC CALIBRATION



ERROR REDUCTION USING ATMOSPHERIC CALIBRATION



RESULTS OF ATMOSPHERIC CALIBRATION TECHNIQUE



Neutral Density
Space Weather Program Summary

- Satellite Drag/Re-entry Atmospheric Calibration Studies

- Data-Driven Models Using Satellite Accelerometer Data
  - CHAMP
  - GRACE

- Atmospheric Density Specification (ADS) Flight Dec 00
  - SSULI calibration
  - Real-time data for models

- Improved Empirical Models
  - Solar EUV proxies
  - Convert EUV into effective F10.7
  - Analyze current models

REQUIREMENTS MATRIX

CUSTOMER NEEDS	AFRL PLANS/PRODUCTS	HOW NASA CAN HELP	LWS PRODUCTS
1. Higher Accuracy & Resolution Density Measurements (100 - 600 km altitude range of interest)	1a. Orbital drag & dynamics calculations and reentry performance 1b. Real time data from accelerometers: CHAMP, GRACE 1c. ADS Satellite Experiment (Mass Spectrometers & accelerometer?)	1a. Monitor global neutral atmosphere in the altitude region 100 – 600 km and supply data 1b. Support GRACE data to AFRL 1c. Develop miniature mass spectrometer/ triaxial accelerometer and fly on multiple spacecraft	1a. Global neutral density, composition & winds 1b. Management support and accelerometer data 1c. Simultaneous neutral density and composition measurements from multiple spatial locations
2. Specify Solar Flux	2. Use data from TIMED, SOHO, and SNOE missions and various proxies	2. Spectral monitoring of solar EUV, and UV	2. Solar EUV inputs to models
3. Specify Geomagnetic Activity	3. Use NOAA data center products	3. Monitor fields & particles	3. Auroral heating parameters; IMF
4. Improve Empirical Models	4. Improve indices; convert solar EUV to F10 effective; study latitude, flux, geomagnetic effects	4. Provide supporting measurement data (density, solar EUV, joule heating etc.), analyses and modeling	4. Neutral density, composition & winds; Solar UV & EUV; auroral heating
5. Forecast Solar Flux	5. Use NOAA products and assess others	5. Develop solar EUV forecast model tailored to density/ionosphere model input needs	5. Solar Physics sensing (UV, EUV, heliomagnetic field, etc.)
6. Forecast Geomagnetic Activity	6. Use NOAA products and assess others	6. Develop geomagnetic forecast model tailored to density/ionosphere model input needs	6. Solar wind parameters, IMF, geomagnetic field,
7. Improve Physical Thermosphere Models	7. Validate with 100 - 600 km altitude data; study ionospheric coupling; examine long-term trends	7. Monitor neutral atmosphere, ionosphere & inputs; support analyses	7. Coordinated studies of thermospheric model inputs & response

ORBITAL DRAG REQUIREMENTS

Needs	AFRL Plans	How NASA Can Help	LWS Products
High-accuracy, High-resolution Neutral Atmosphere Measurements	Orbital Drag, & Re-entry Studies CHAMP & GRACE ADS	Global Neutral Data (100 - 600 km) New Small Sensors Support Grace/ADS	Density, Winds, Composition Multiple Locations
Improved Models Data-driven, Empirical & Physical	Improved Indices Thermospheric Response Studies	Provide Supporting Data	Coordinated Studies of Thermosphere
Solar & Geomagnetic Specification & Forecast	Analyze New Measurements & Proxies	Measure Solar EUV /UV, Solar Physics , Fields & Particles	Tailored Solar & Geomagnetic Forecasts

CONCLUSIONS

- Neutral density errors can be reduced to the 5% level with data assimilation
  - AFRL demonstrated concept with historical orbital drag data

- To meet satellite drag specification/forecast requirements need multi-faceted attack:
  - High accuracy global monitoring of important state variables including density
  - Data assimilation using high-accuracy real-time data
  - Improved understanding of solar EUV and UV fluxes
  - Time-dependent specification of magnetospheric energy, particle and momentum inputs
  - Detailed understanding of thermospheric response to important forcings
    - -- Incorporate into data-driven semi-empirical and physical models