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# *Anomalous Force Model Status*

**TOPEX/Poseidon Satellite/Sensors Workshop #9**

**August 8, 2000**

**Ephrem S. Paredes**

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**JPL**  
**Raytheon**

# *Anomalous Force Modeling*

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## 1. Least Squares Fit of Empirical Data from MOE and FDF

$$\frac{da}{dt} = \sum c_k(\theta) \beta^k + [BIAS]$$

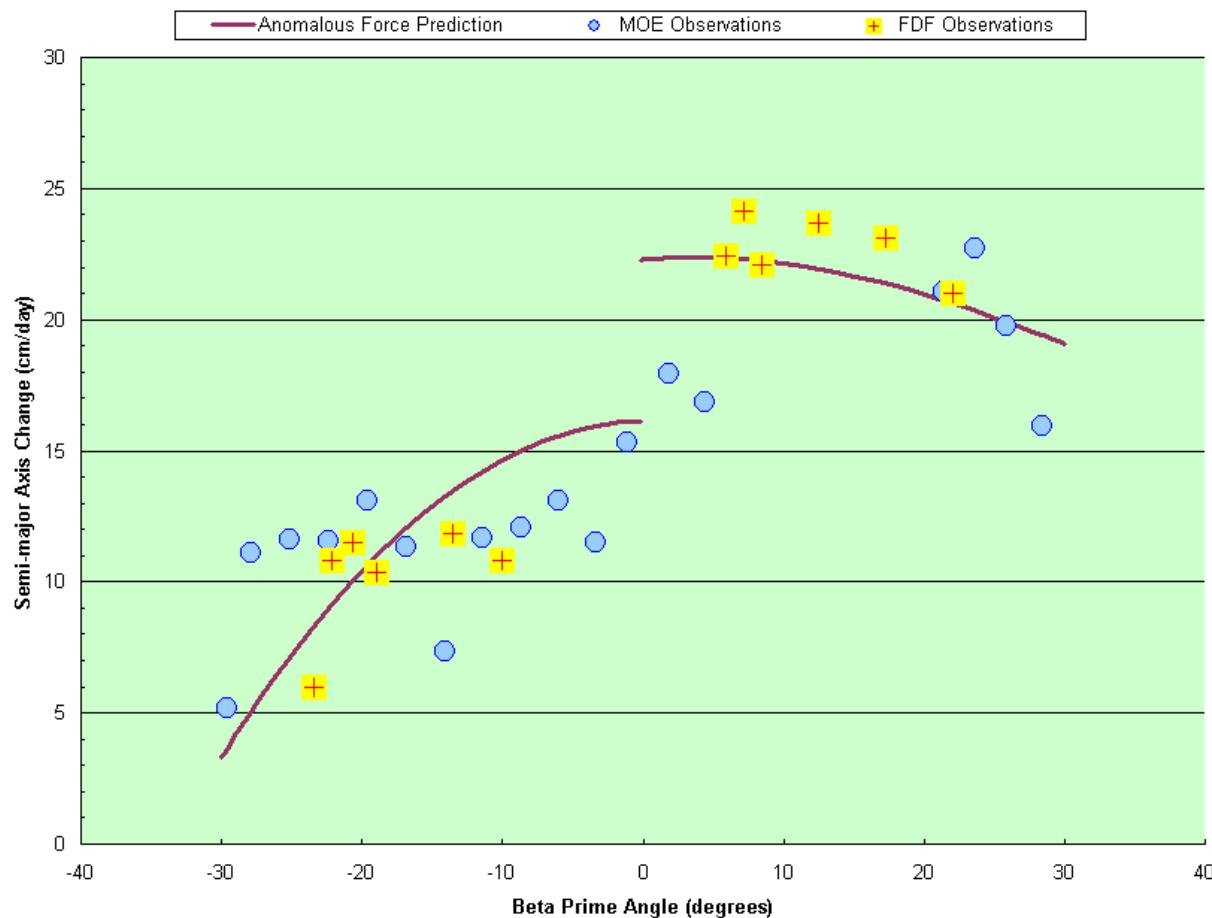
a: semi-major axis

$\beta$ : angle between sun line and orbital plane

$\theta$ : solar array pitch bias (magnitude and direction)

## 2. *BIAS* based on experience in same yaw mode and time period

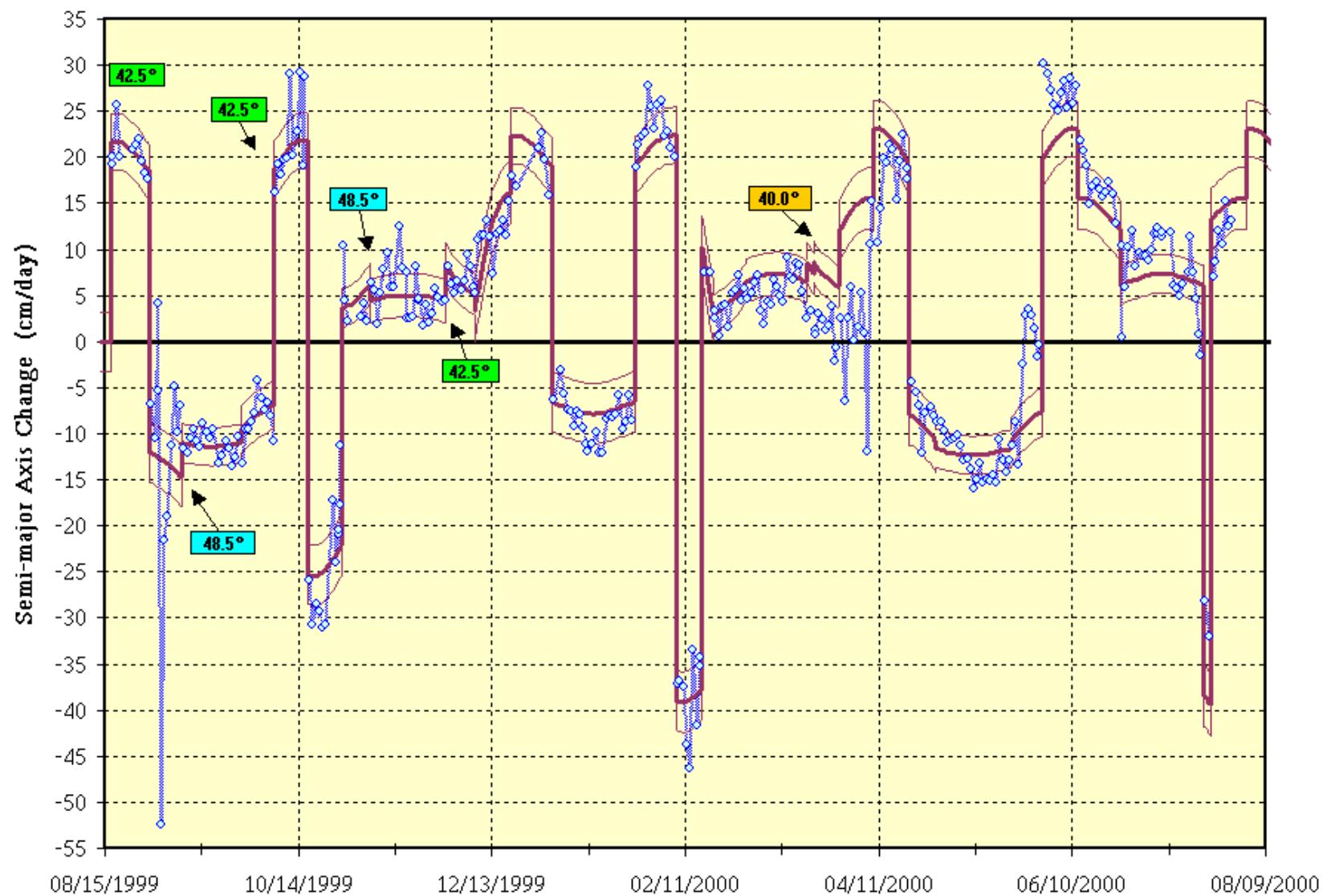
# Least Squares Fit



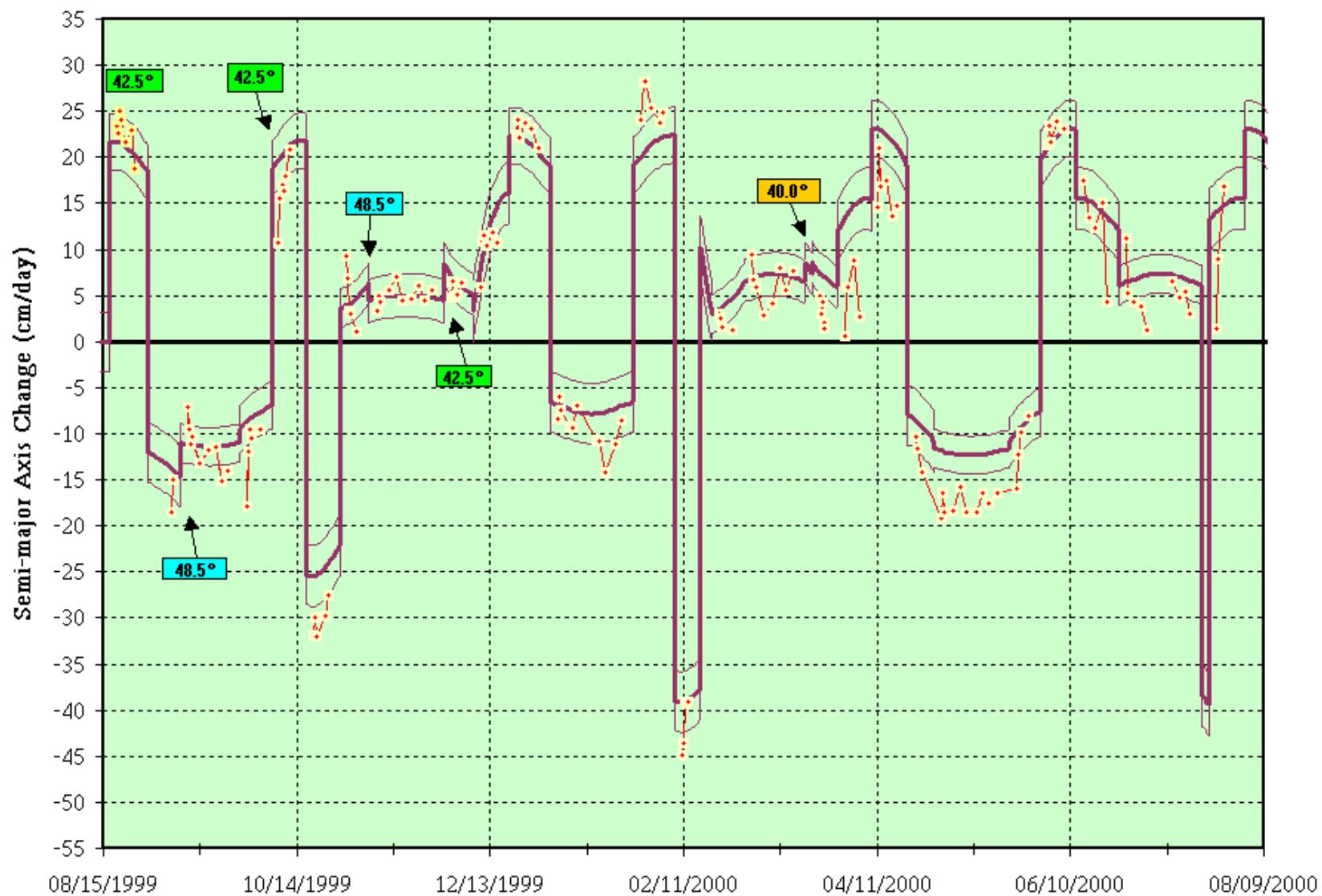
$$\frac{da}{dt} = 16.1 + 0.0\beta^1 - 0.014\beta^2 - 4.4 \times 10^{-6}\beta^3 + [-3.48], (-30 \leq \beta \leq 0)$$

$$\frac{da}{dt} = 22.3 + 0.057\beta^1 - 7.45 \times 10^{-3}\beta^2 + 6.6 \times 10^{-4}\beta^3 + [7.16], (0 \leq \beta \leq 30)$$

# MOE Observations



# FDF Observations



## *Observations and Summaries*

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- **MOE and FDF Observations (Since August 10, 1999)**
  - 340 MOE non-gravitational accelerations
  - 129 FDF  $\tau$  estimates
  - No discernable changes in behavior
  - 4.98 cm/day RMS prediction error
- **Solar Array Pitch Bias (Since August 10, 1999)**
  - Changes between 42.5° and 48.5° dependent on Yaw Mode
  - Fixed Pitch Bias to 40.0° on March 21, 2000

# *Lead and Lag Strategy*

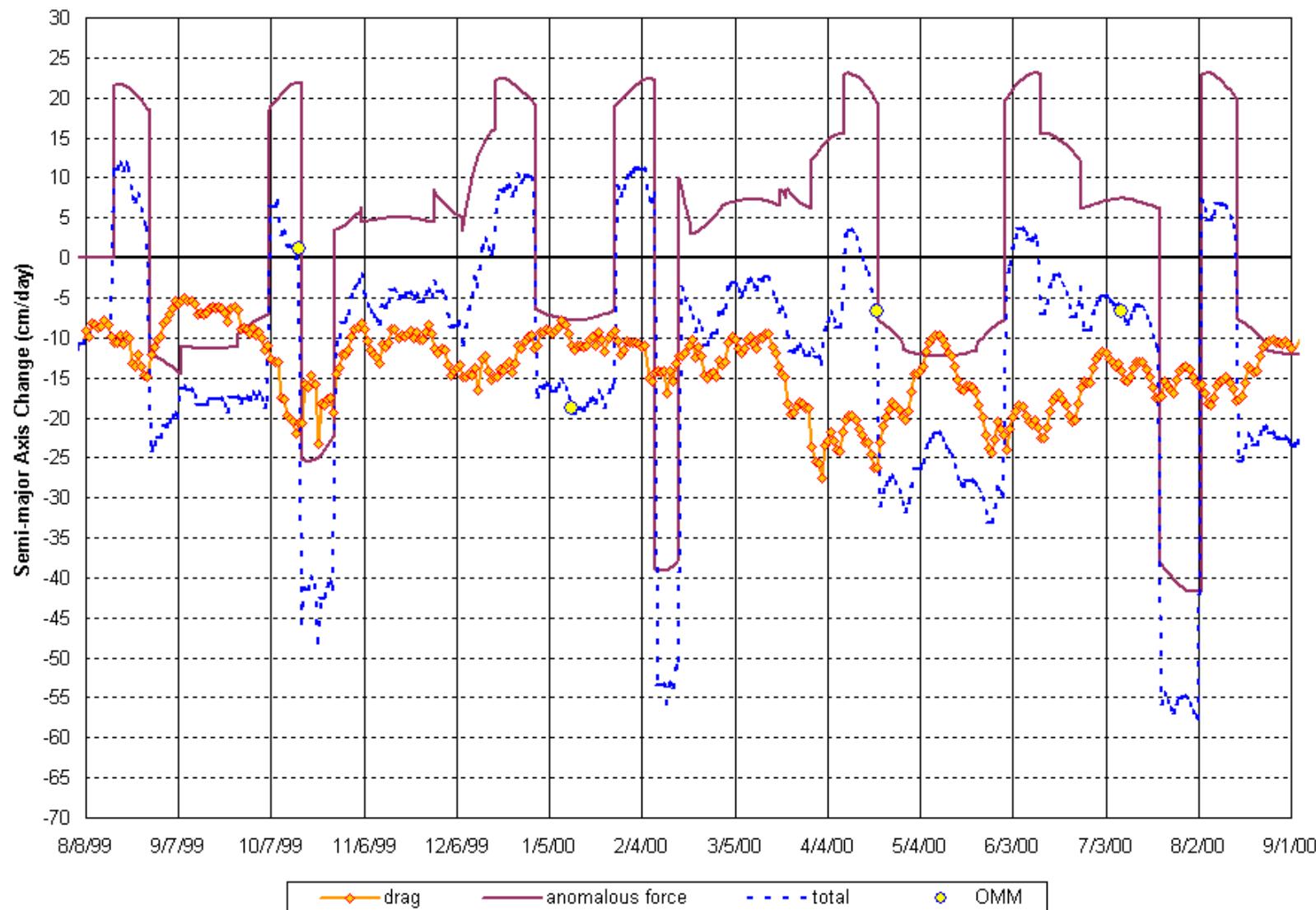
- Fixed Yaw:

	Solar Array Pitch Bias 40.0°	Solar Array Pitch Bias - 40.0°
$0^0 \leq \beta \leq 30^0$	<b>Variable Boost</b> 15 – 27 cm/day	<b>Variable Decay</b> <b>(No Experience)</b>
$-30^0 \leq \beta \leq 0^0$	<b>Variable Decay</b> 30 – 40 cm/day	<b>Variable Boost</b> 7 – 17 cm/day

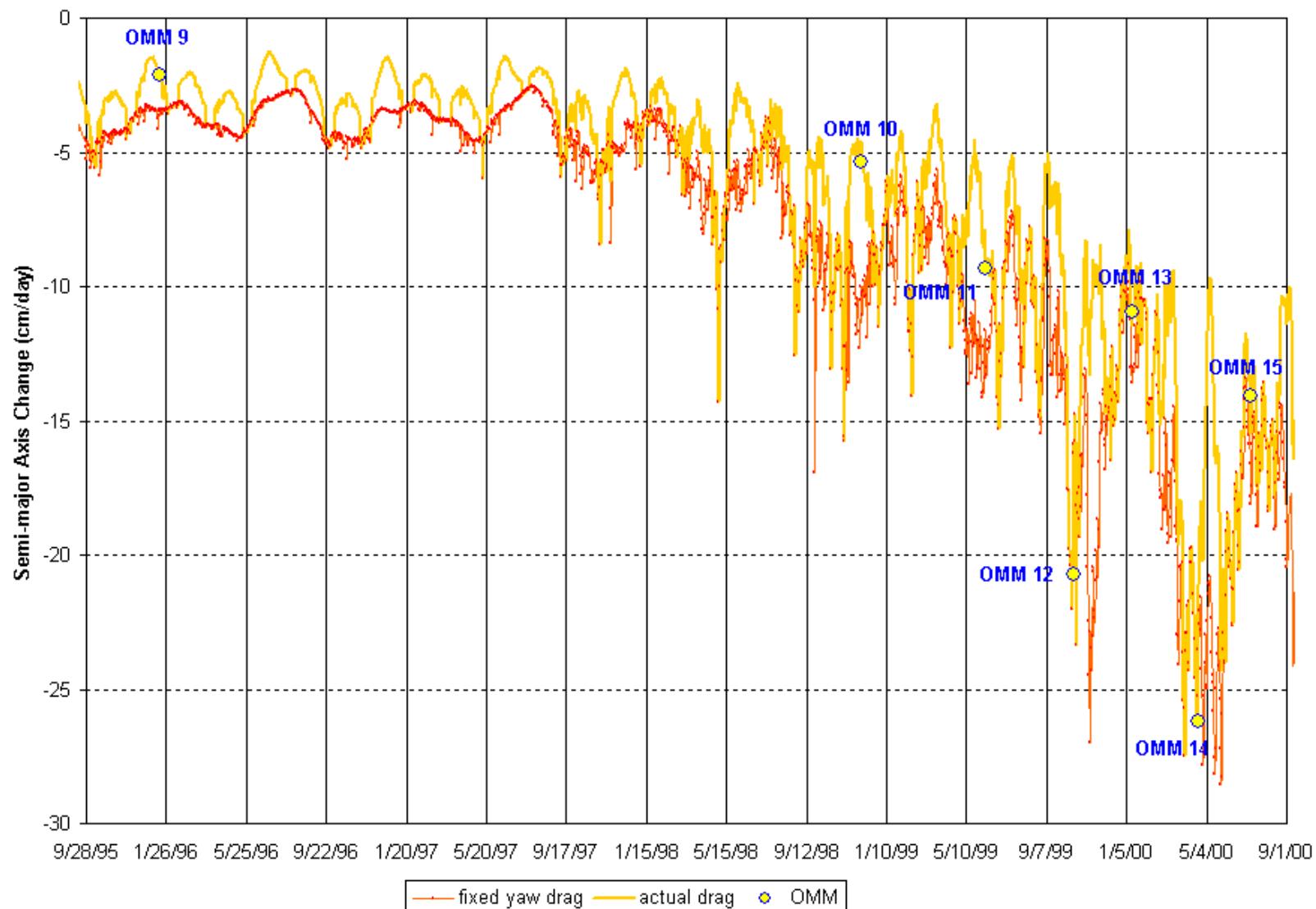
- Yaw Steering:

$\beta > 30^0$	<b>Variable Decay</b> 5 – 15 cm/day
$\beta < -30^0$	<b>Variable Boost</b> 3 – 13 cm/day

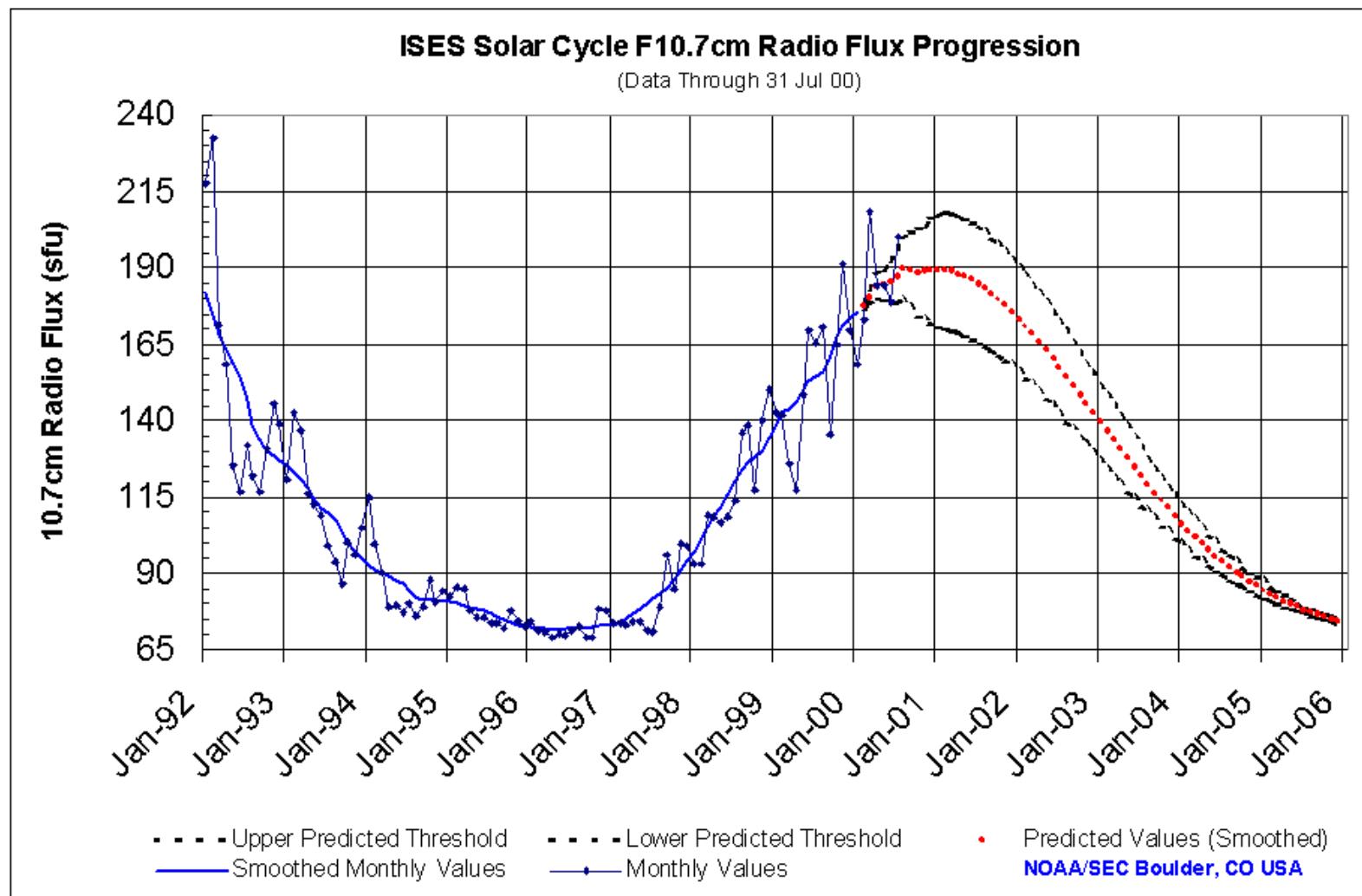
# Anomalous Force and Drag



# Drag History



# SEC Solar Flux Predicted Maximum



# Anomalous Force and OMM15

EVENT	Duration (days)	EFFECT	$\equiv \Delta v$ (mm/s)
OMM 15	--	Boost	+ 3.39
Solar Activity (Changes in Drag)	1	Either	$\pm 0.03$
Solar Activity (Changes in Drag)	30	Either	$\pm 1.0$
Switch from $40.0^\circ$ to $-40.0^\circ$ $-30^\circ \leq \beta \leq 0^\circ$	1	Boost	+ 0.25
Switch from $40.0^\circ$ to $-40.0^\circ$ $-30^\circ \leq \beta \leq 0^\circ$	10	Boost	+ 2.5

# *Anomalous Force Modeling Changes*

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## **Model 233 (Created July 21, 2000)**

- 1.** Switched SAB from  $40.0^\circ$  to  $-40.0^\circ$  on July 23, 2000
  - Increased Boost Period up to 10 days to gain an equivalent Delta-V of 2.5 mm/s for OMM15
- 2.** Includes Modeling of the SAB change to  $40.0^\circ$  on March 21, 2000

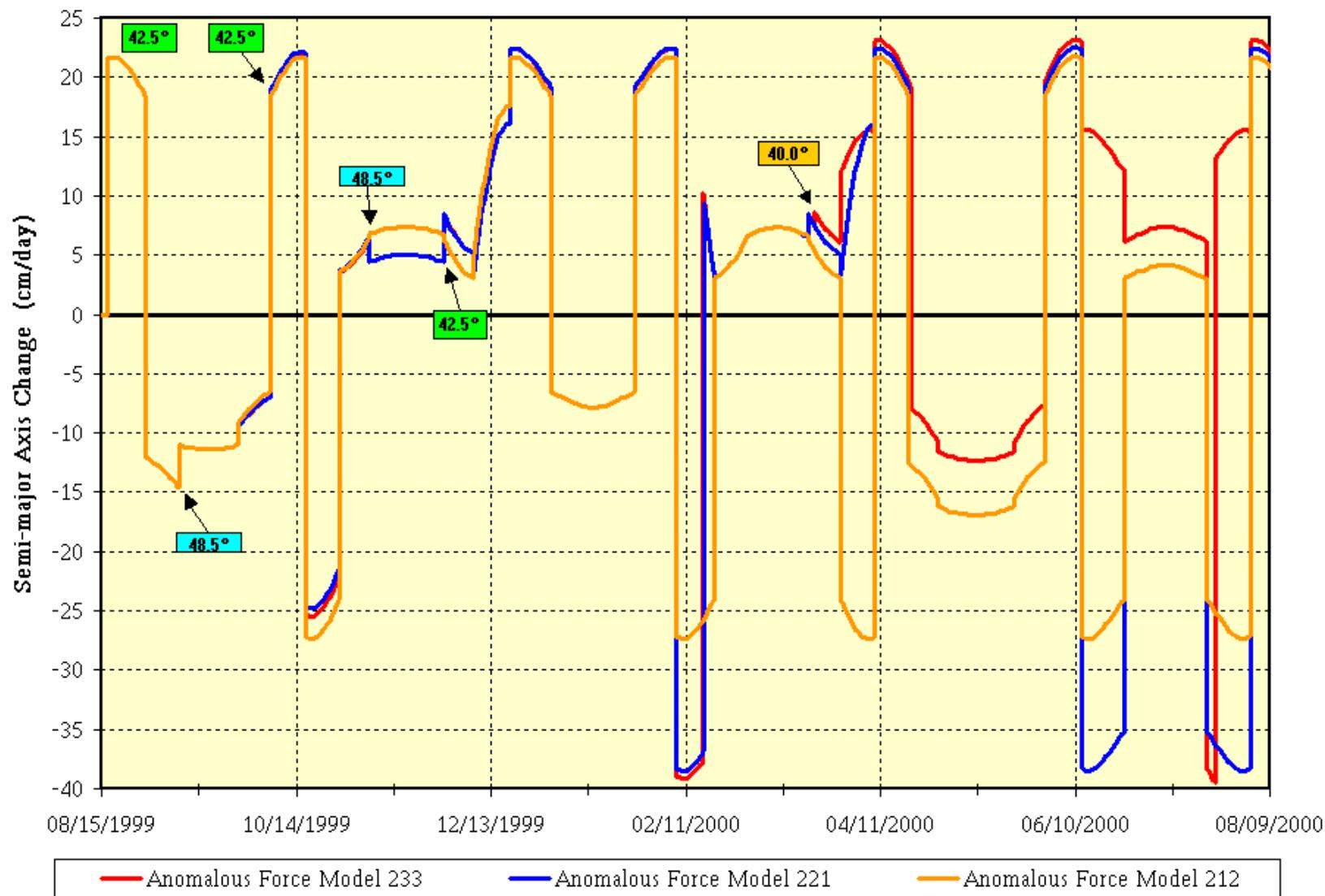
## **Model 221 (Created February 15, 2000)**

- 1.** Decreased Decay Period by 2 days on February 16, 2000
  - Forced Model Change due to large errors in prediction (15 cm/day difference between observed and predicted values since January 31, 2000)
- 2.** Includes Modeling of SAB Change from  $48.5^\circ$  to  $42.5^\circ$  on November 28, 1999 during Yaw Steering and October 11, 1999 during Fixed Yaw

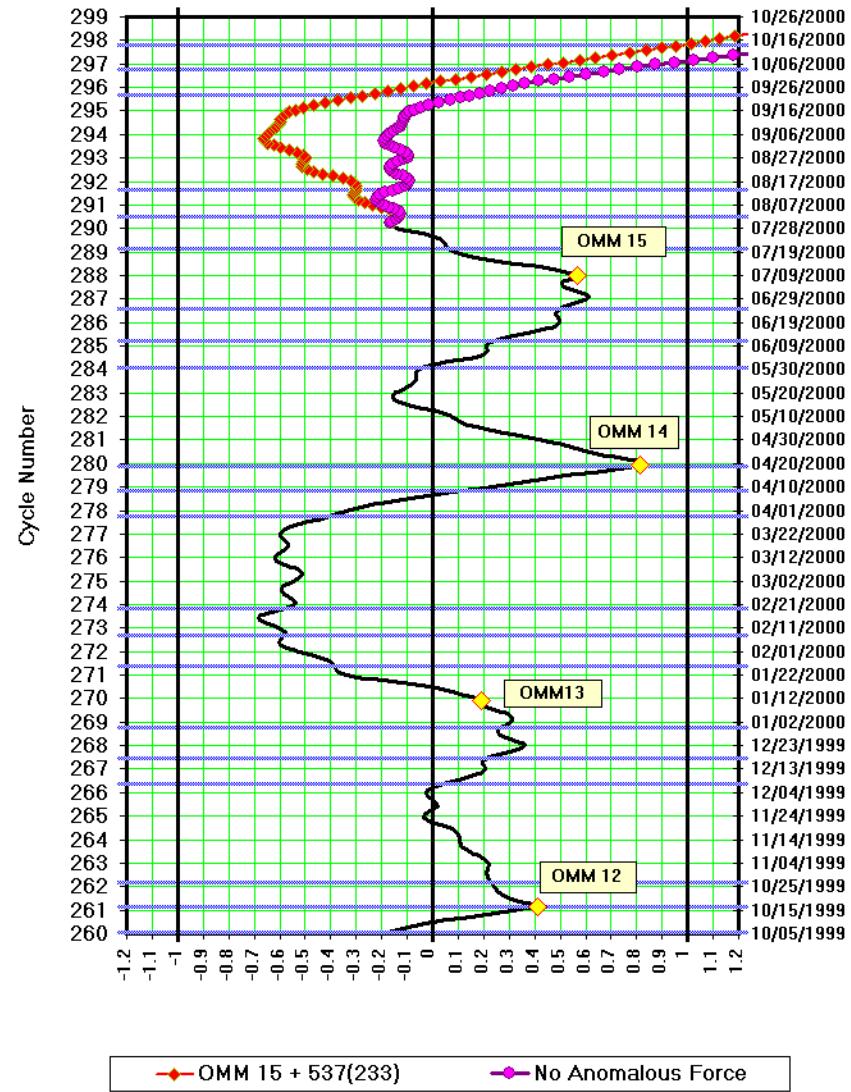
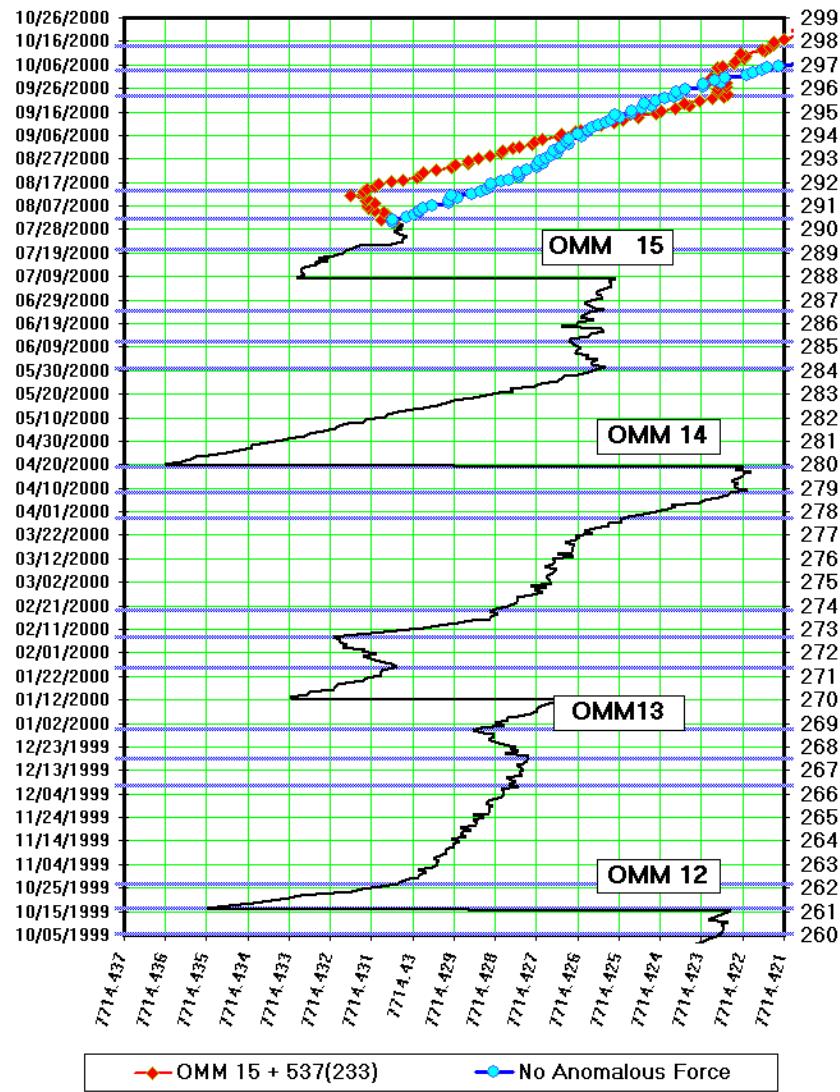
## **Model 211 (Created November 23, 1999)**

- 1.** Nominal Modeling of Anomalous Force
  - SAB Magnitude Always Kept Positive (Lead) in Fixed Yaw Periods

# Anomalous Force Plot Comparisons



# Anomalous Force on Ground Track



# *Anomalous Force Highlights*

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## **Observations and Events since August 10, 1999:**

- **Solar Array Pitch Bias Angle fixed to 40.0° on March 21, 2000**
- **4.98 cm/day RMS prediction error from MOE and FDF Observations**
- **Increasing Solar Flux Values due to approaching Solar Maximum**

## **Lead and Lag Strategy since August 10, 1999**

- **Variable Boost of 7 – 27 cm/day during Fixed Yaw Periods**
- **Variable Boost of 3 – 13 cm/day during Negative Yaw Steering**
- **Provided Delta-V of 2.5 mm/s for OMM15**