
Anomalous Force Model Status

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JPL

Characteristics

- **Fixed Yaw: Large Daily semi-major axis change**
 - 15 to 25 cm/day boost or “decay”
 - “Flying Forward:” Boost in “lead”, decay in “lag”
 - “Flying Backward:” Decay in “lead”, boost in “lag”
- **Yaw Steering: Smaller but significant sma change**
 - Up to 10 cm/day decay (>0) or boost (<0)
 - Comparable Magnitude to Drag

Variables

- θ : angle between sun-line and orbit plane
- β : Solar Array pitch bias
 - magnitude
 - direction
- Distance from sun
- Time in yaw mode (hysteresis)

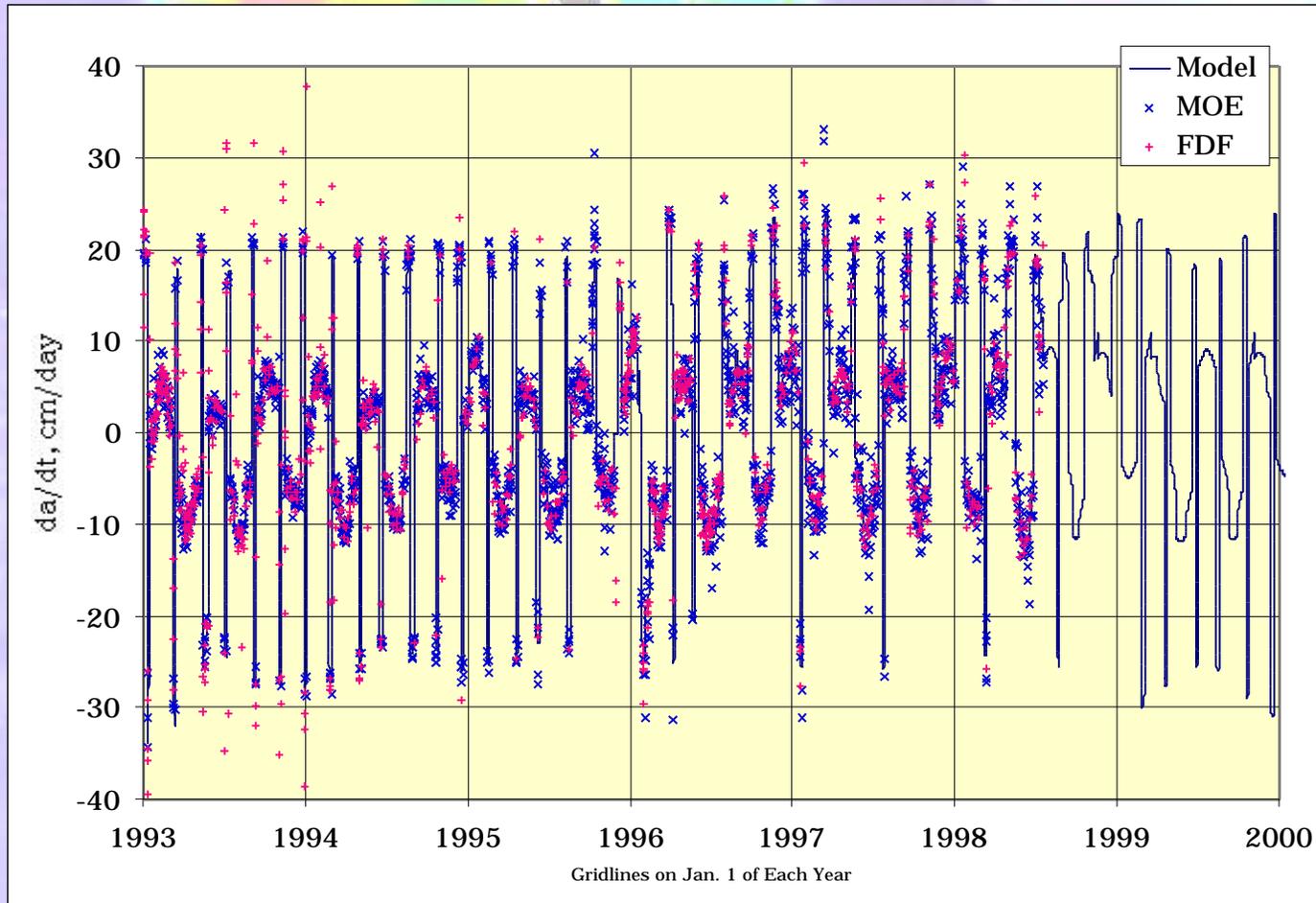
Software model

- Based on Richter's model

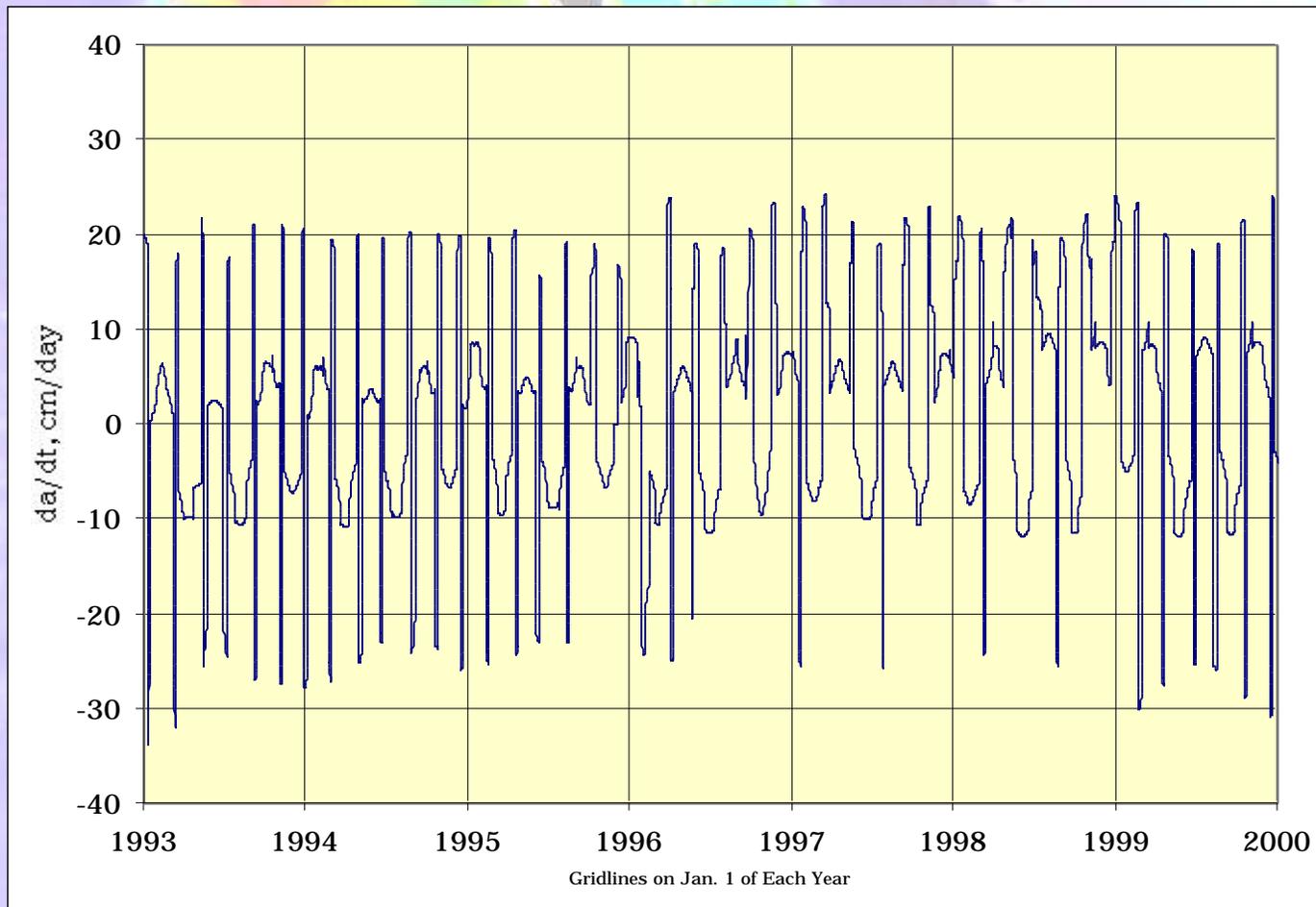
$$\frac{da}{dt} = \left\{ c_k ()^k \right\} + \begin{array}{l} \text{day of year} \\ \text{correction} \end{array} + \{bias\}$$

- Bias based on experience in same yaw mode
- Does not model memory/hysteresis effect (time in yaw mode)

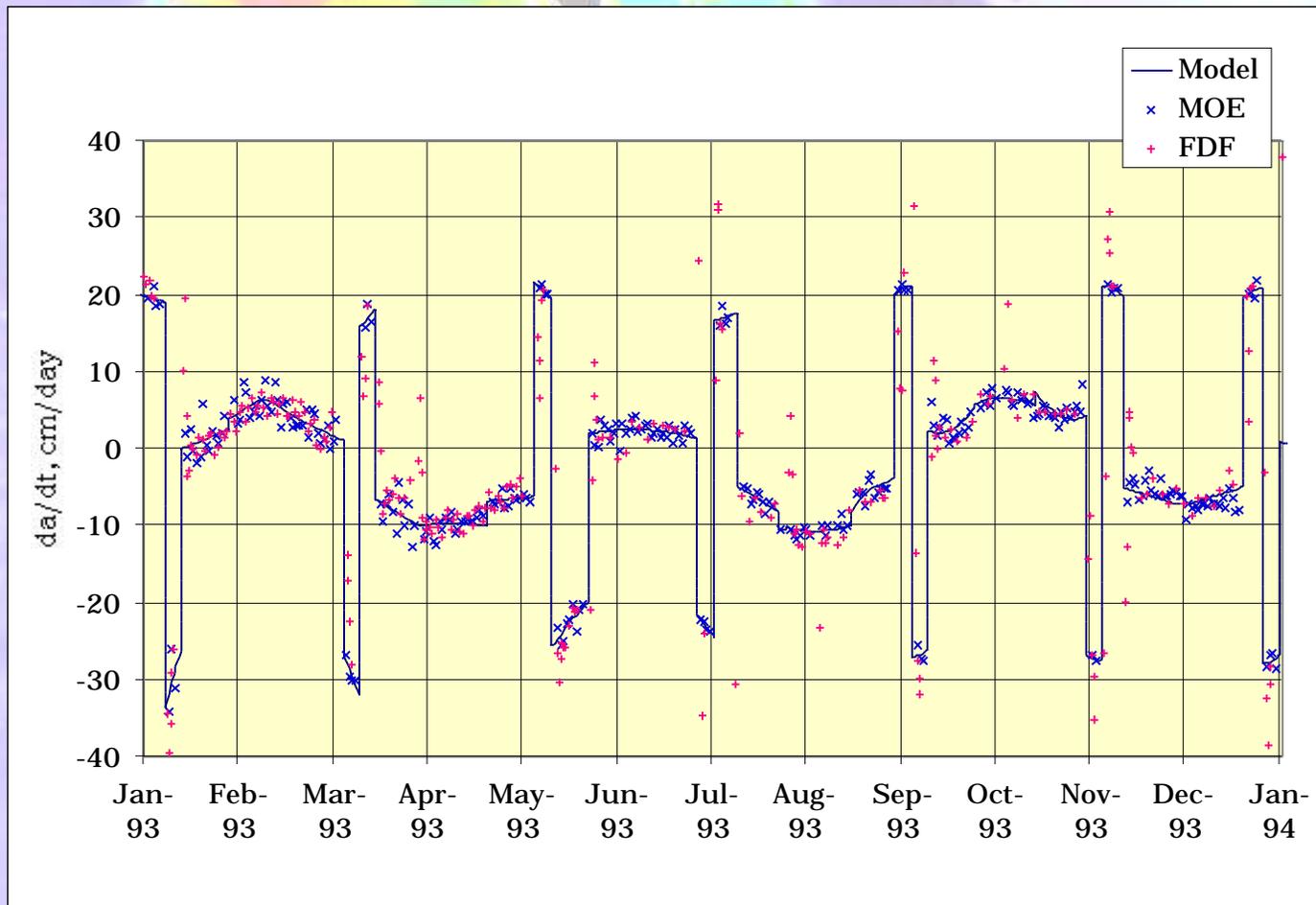
Observations



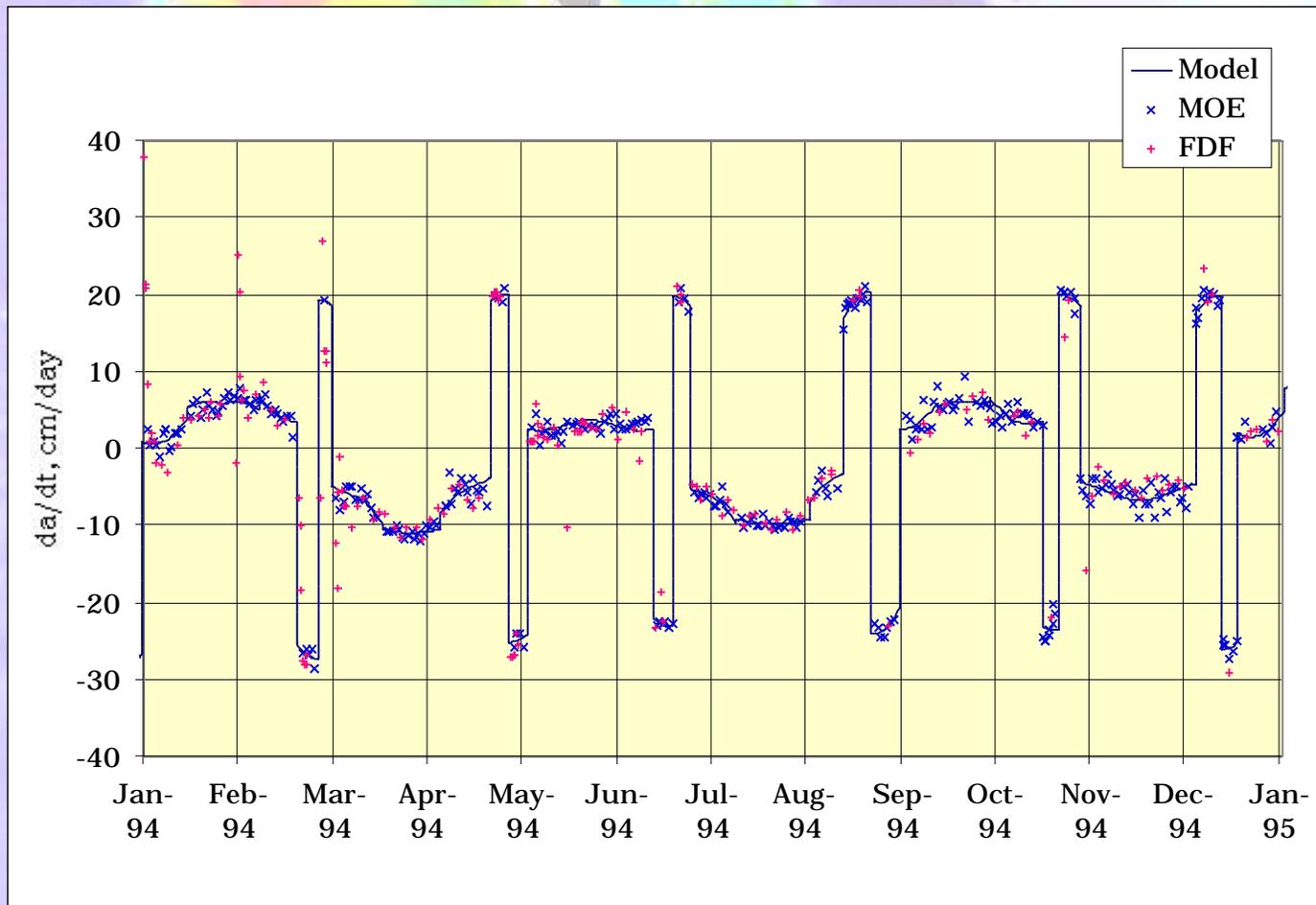
Model



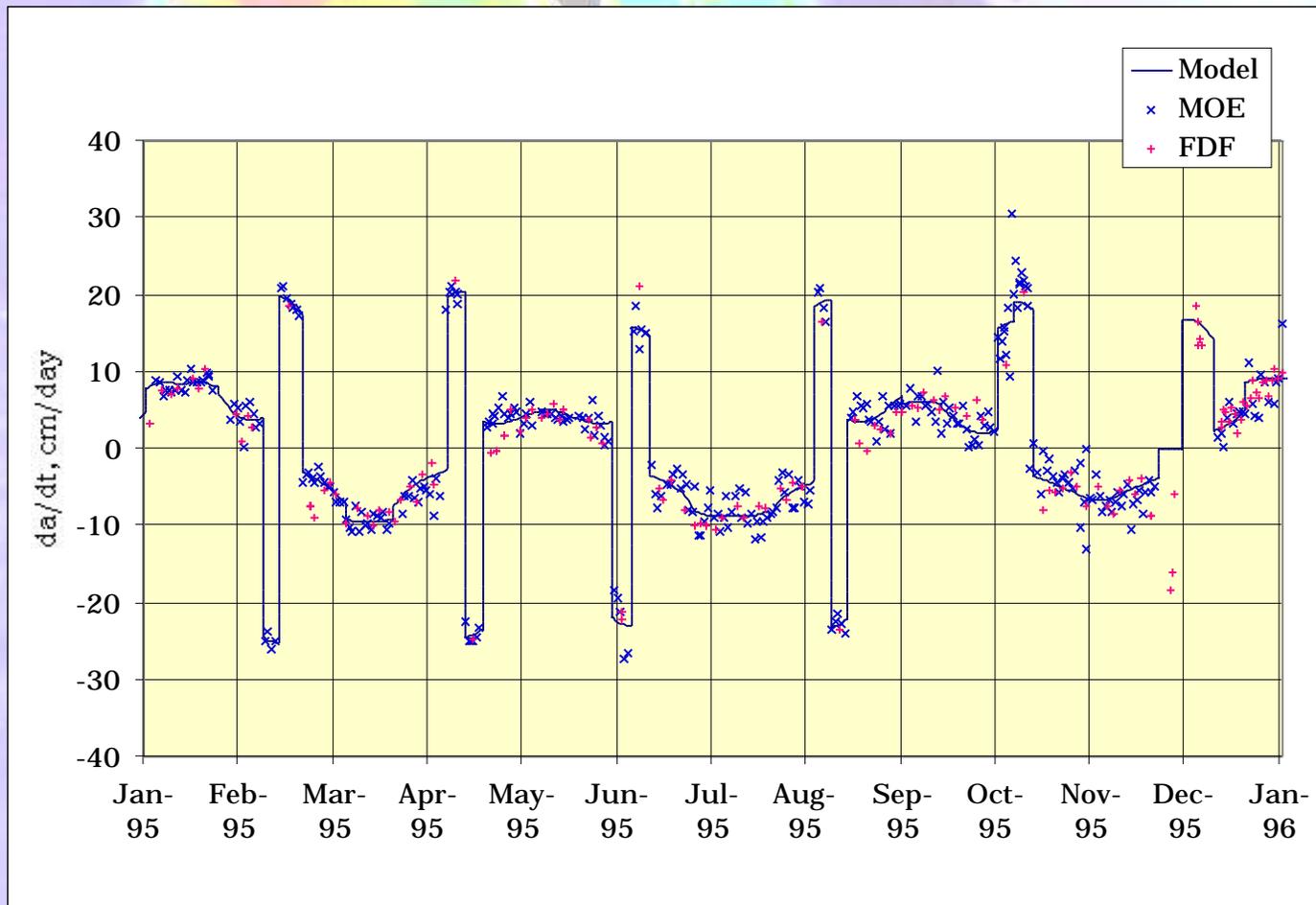
1993 Observations



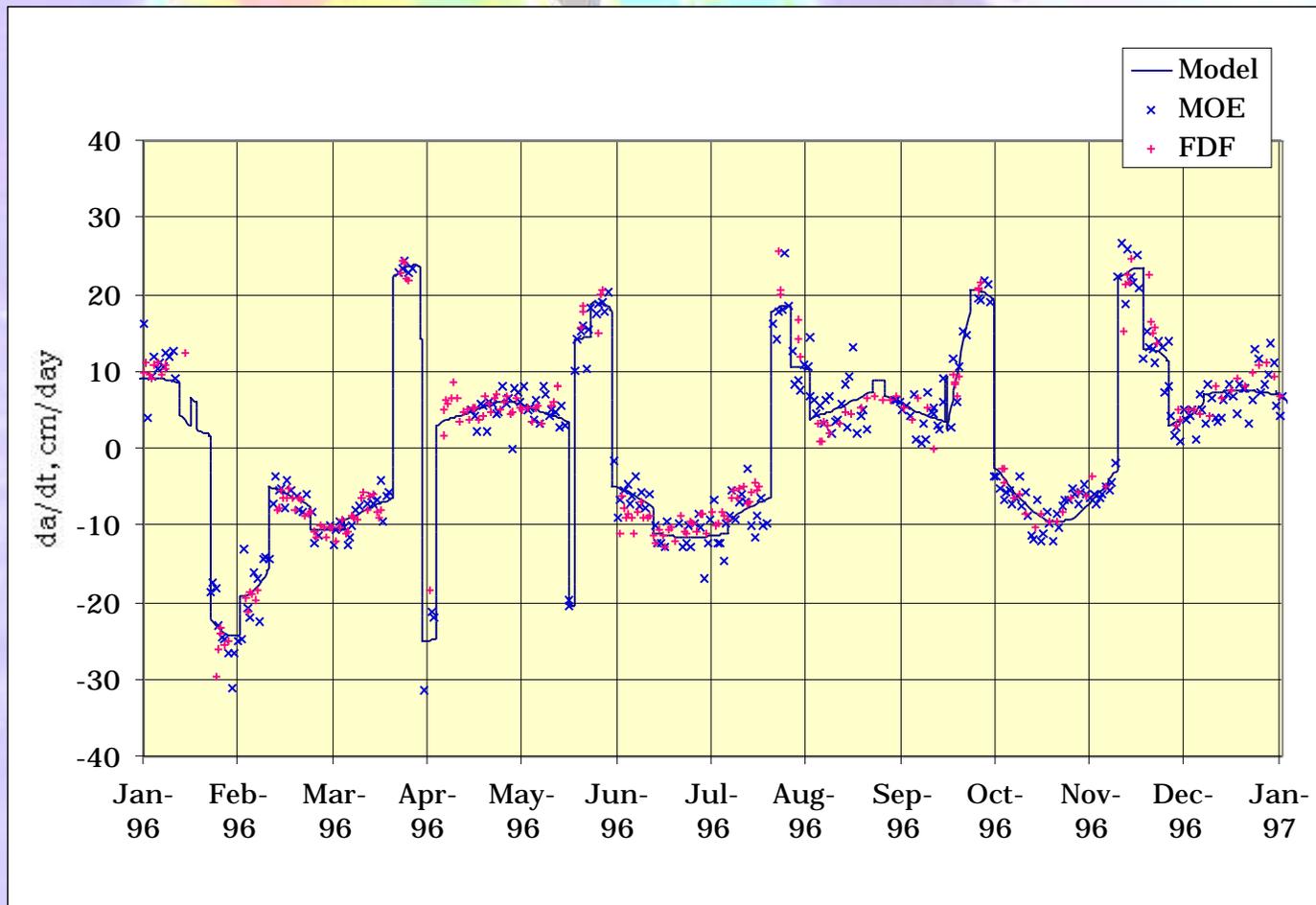
1994 Observations



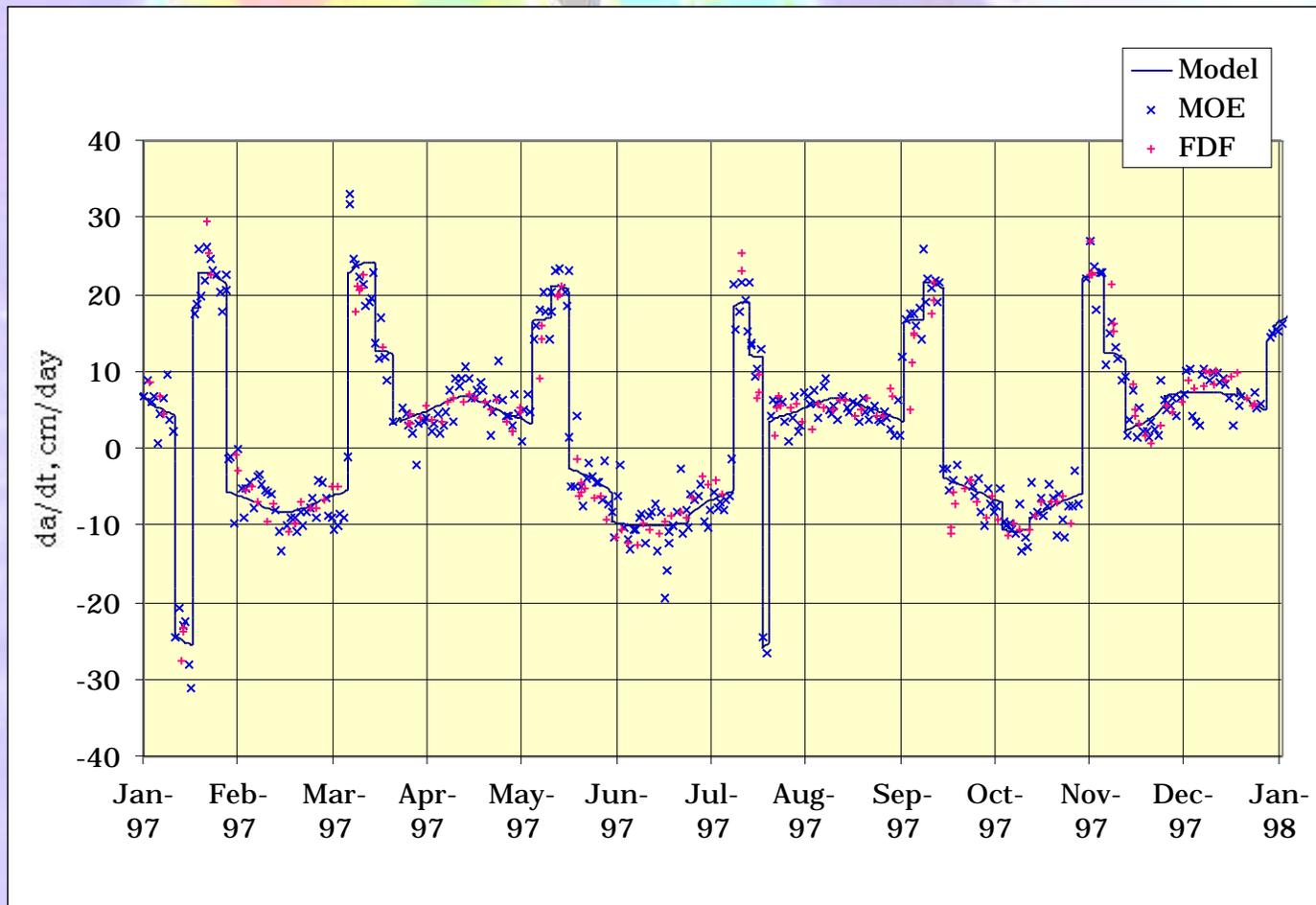
1995 Observations



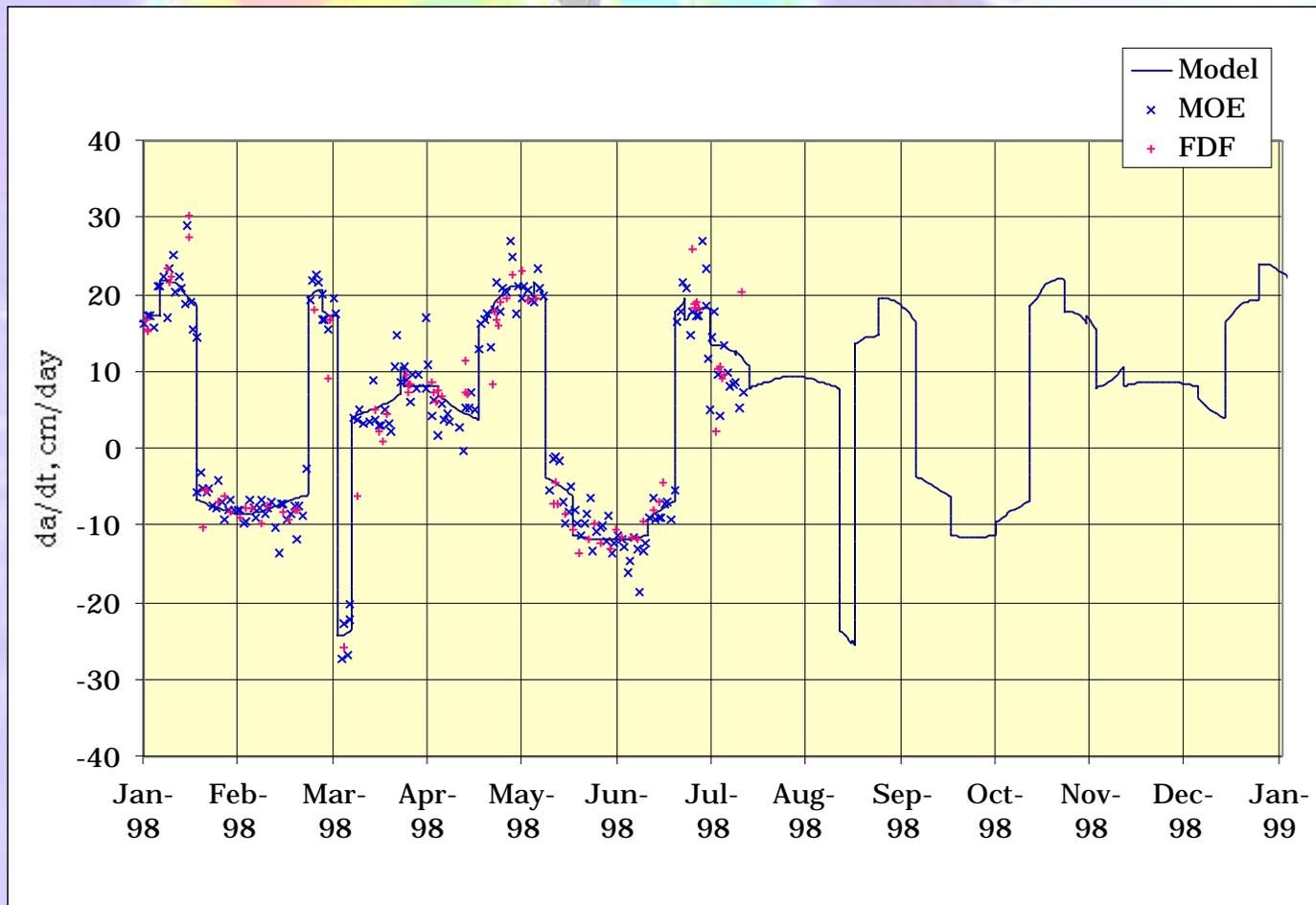
1996 Observations



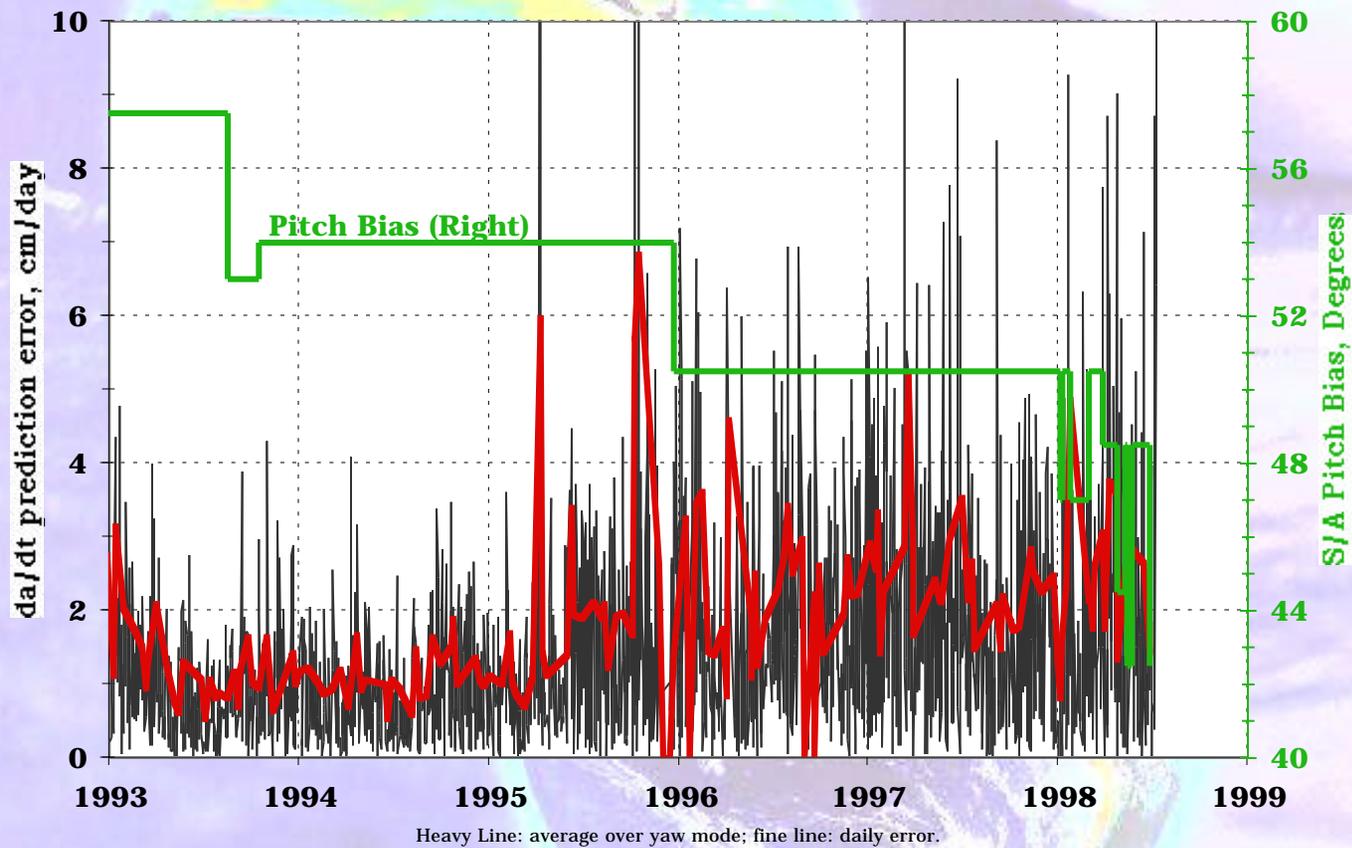
1997 Observations



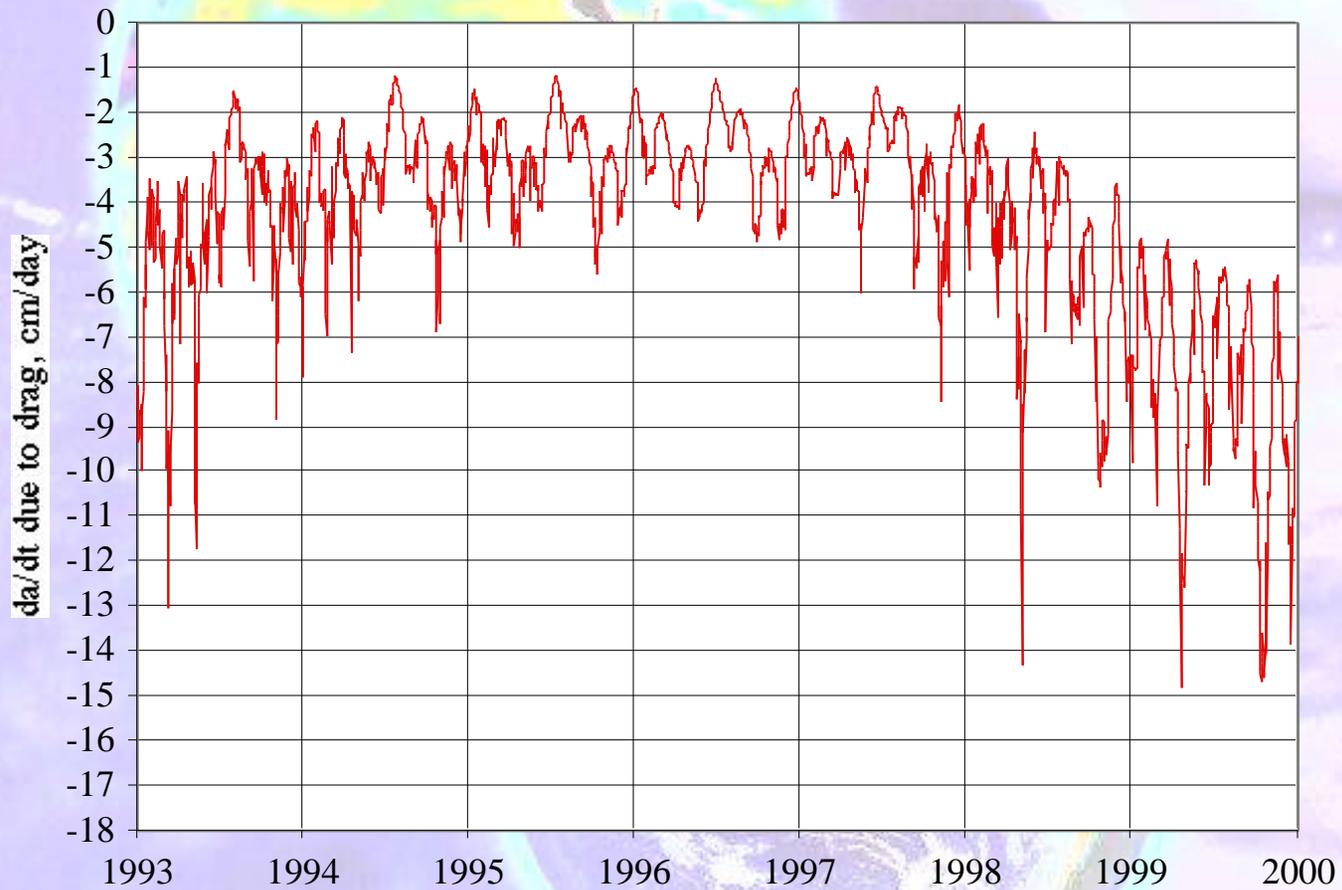
1998 Observations



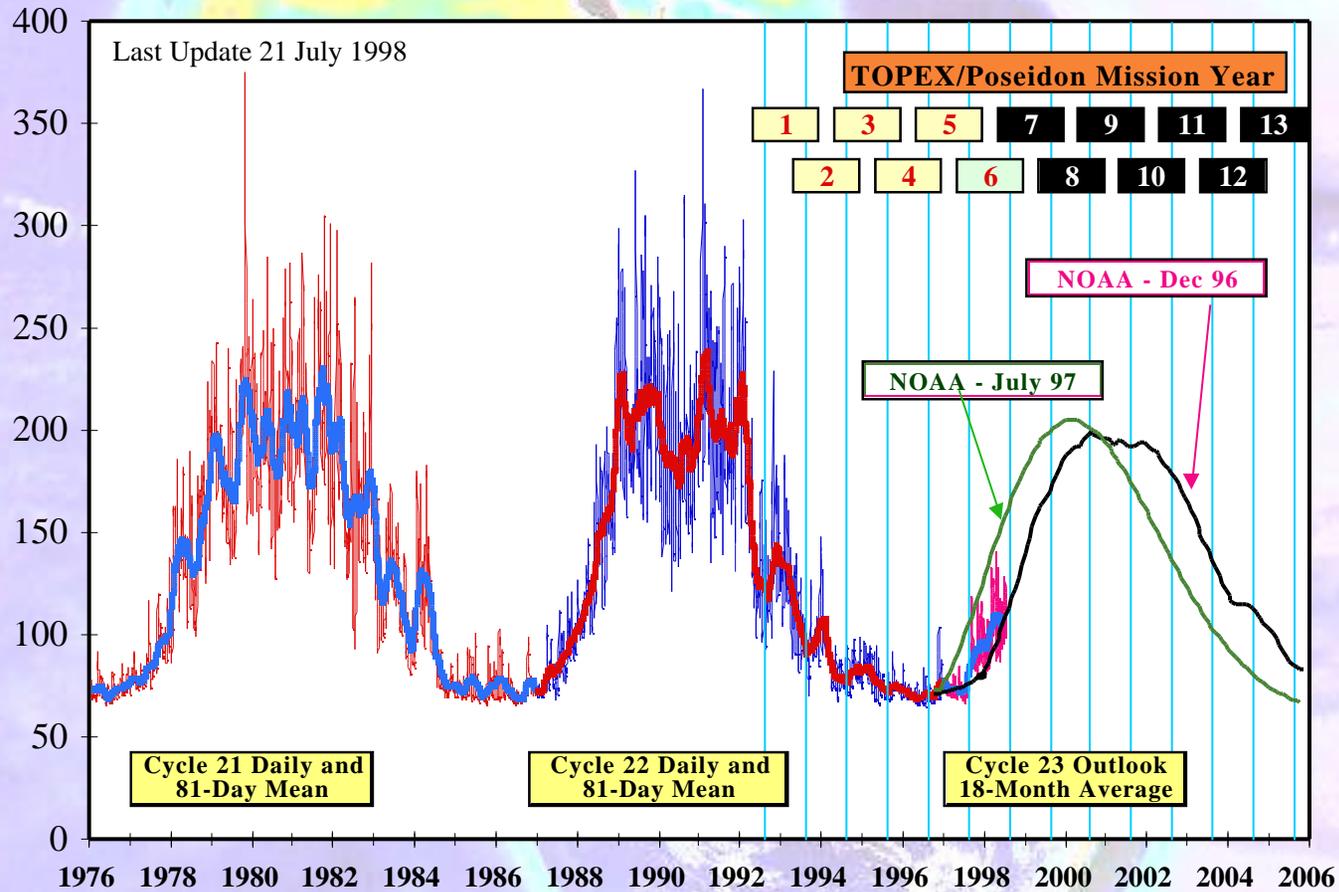
Statistics



Drag



Solar Activity



MOE Data Conversion

- MOE non-gravitational accelerations $\frac{dv}{dt}$
- Converted to semi-major axis rate change

$$\frac{da}{dt} \frac{cm}{day} \underset{Non-Grav}{=} 2 \sqrt{\frac{a^3 (km^3)}{\mu (km^3/sec^2)}} \times \frac{dv}{dt} \frac{km}{sec^2} \times \frac{86400 sec}{day} \times \frac{10^5 cm}{km}$$

- Drag is estimated using Jacchia-Roberts

$$\frac{da}{dt} \underset{Non-Grav}{=} \frac{da}{dt} \underset{Anomalous-Force}{=} + \frac{da}{dt} \underset{Drag}{=}$$

FDF Data Conversion

- Anomalous force is estimated by a parameter δ , in terms of an effective along-track thrust in $\mu\text{Newtons}$,

$$m \frac{dv}{dt} = [1 + \delta](\mu N)$$

- Converted to a sma change in cm/day:

$$\frac{da}{dt} \frac{cm}{day} = \frac{2(1 + \delta)(\mu N)}{m(kg)} \sqrt{\frac{a^3(km^3)}{\mu(km^3/sec^2)}} \times 8.64$$

Anomalous Force: Summary

- **Mission observations through 8/1/98:**
 - 2260 MOE Non-gravitational accelerations
 - 1163 FDF estimates
 - No discernable bias MOE vs. FDF data
 - **± 2.27 cm/day RMS prediction error (mission)**
 - **Principle Events**
 - S/A bias 50.5° to 48.5° (42.5° in fixed yaw)
 - “Standardization” of $\pm 30^\circ$ fixed yaw
 - Lunar avoidance maneuvers
 - **No discernable changes in behavior this year**
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