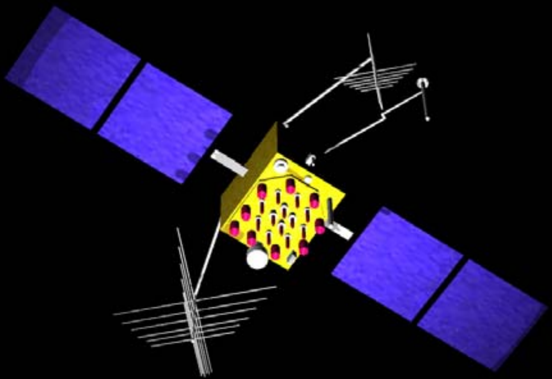
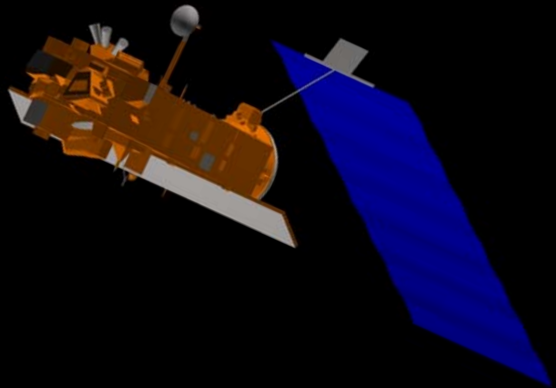
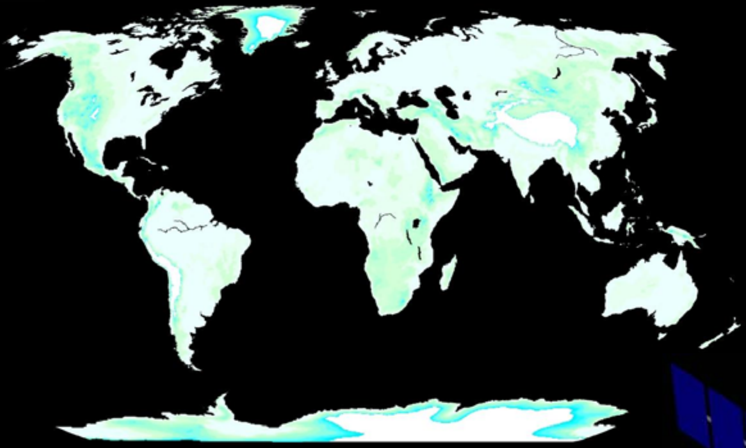
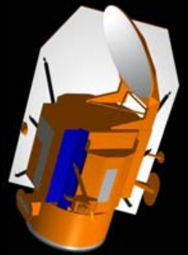
London’s Global University

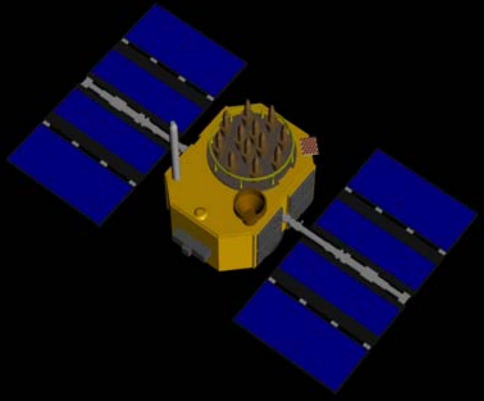




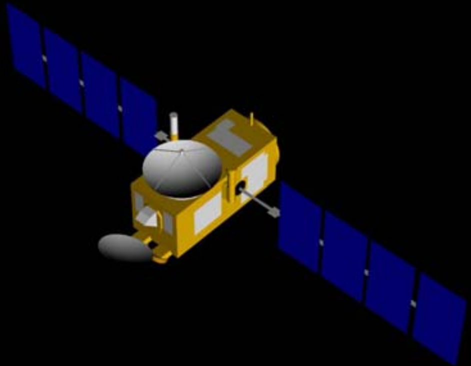
High Accuracy Non-Conservative Force Modeling



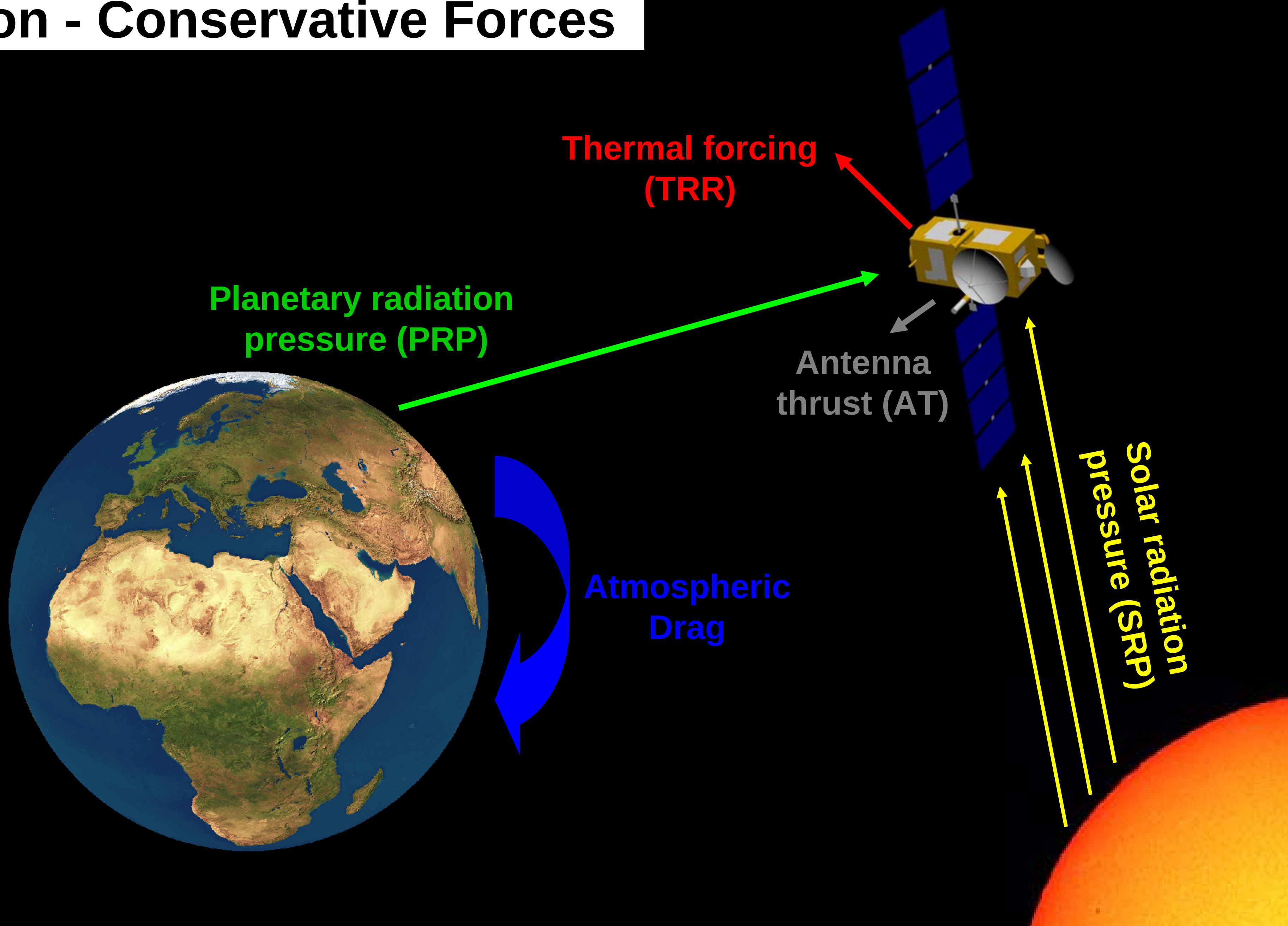




Ant Sibthorpe
Marek Ziebart

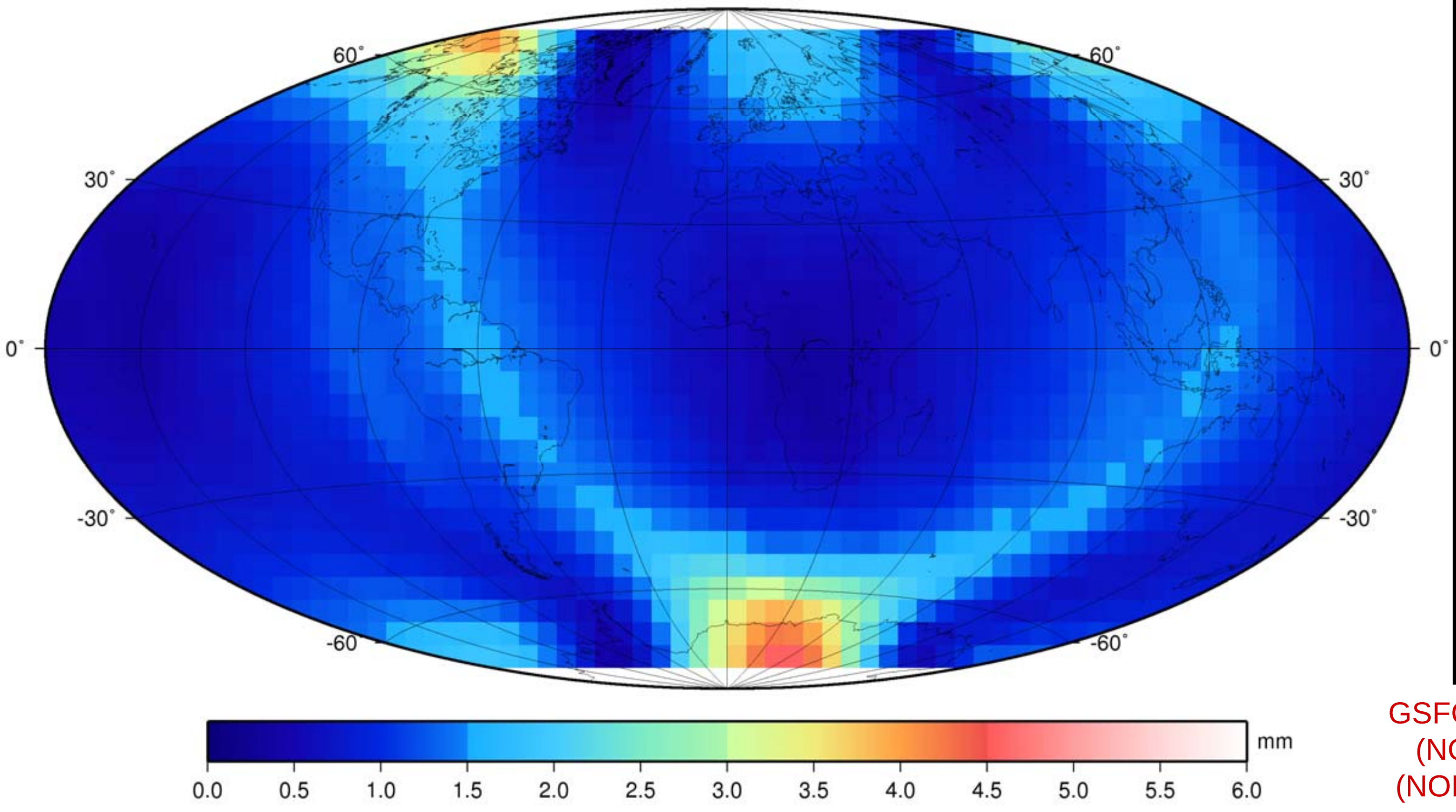


Non - Conservative Forces



Mis-modeling Satellite Surface Forces

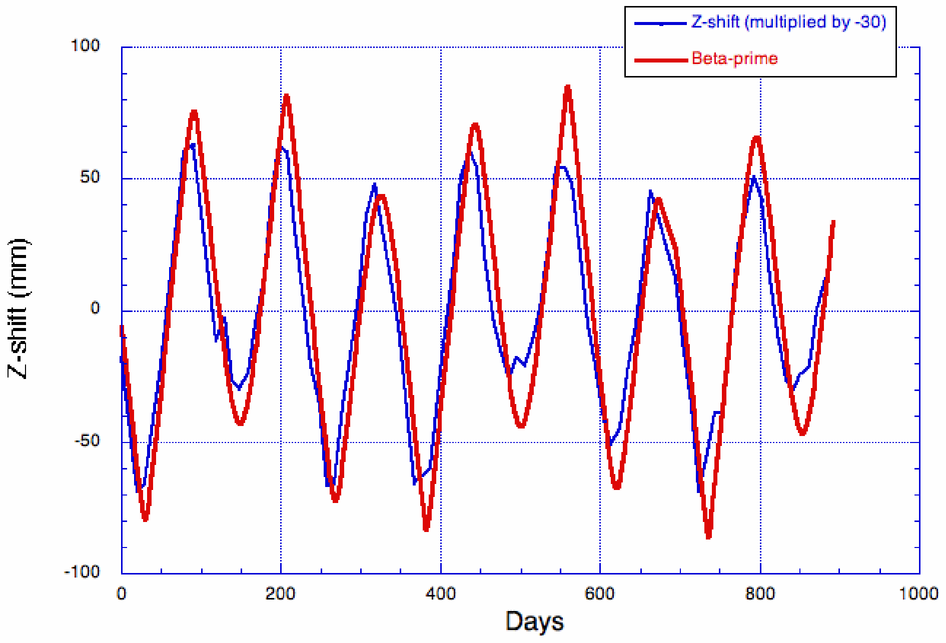
JASON-1 120-day radial orbit difference amplitude (mm): (Figure by N. Zelensky).



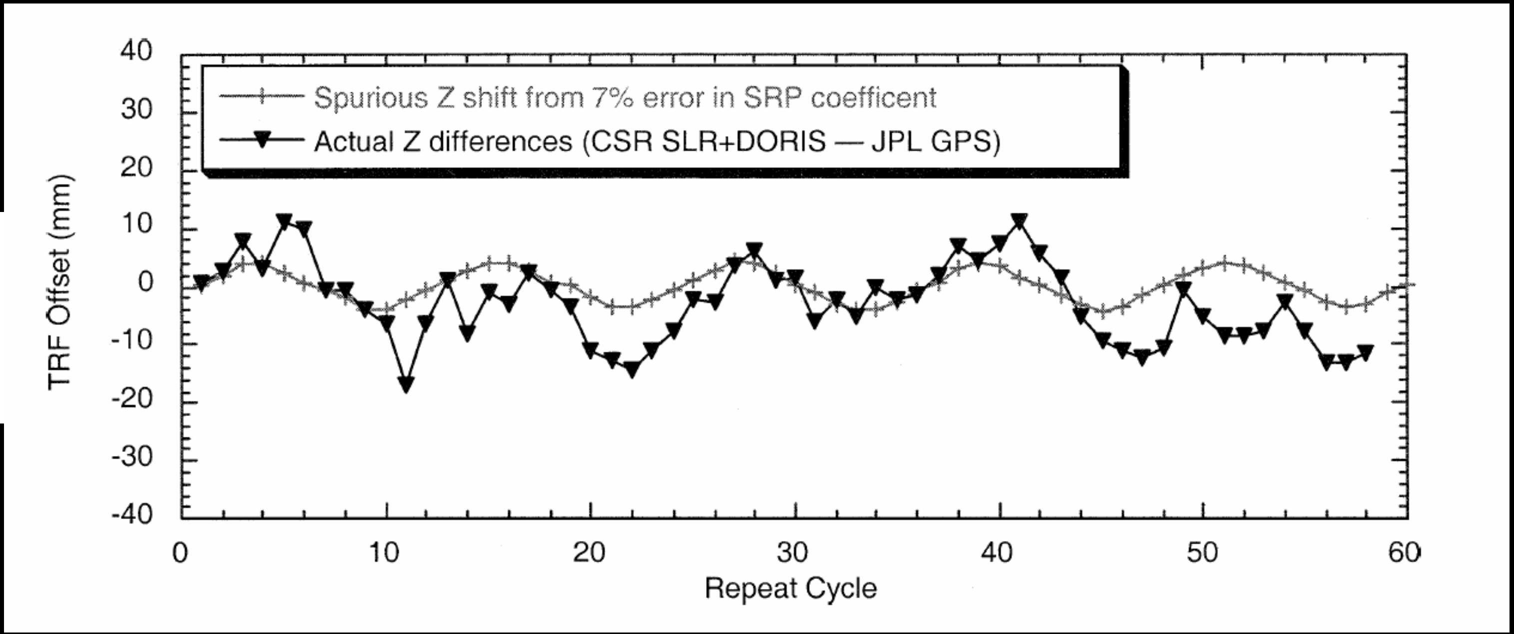
GSFC SLR/DORIS:
(NOM, Cr = 1) -
(NOM, Cr = 0.914)

Scale Factors

- Cr correlated with other parameters
- Scale errors cause spurious Z-axis variations in orbit

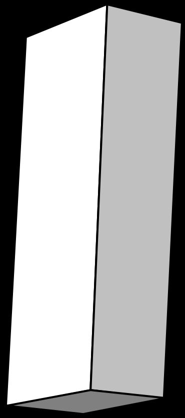


JASON-1 tests using different (3%) solar radiation pressure scale factors (John Ries, CSR)



JASON-1 tests using different (7%) solar radiation pressure scale factors (Bruce Haines, JPL)

Modeling Satellite Surface Forces



Conventional approach

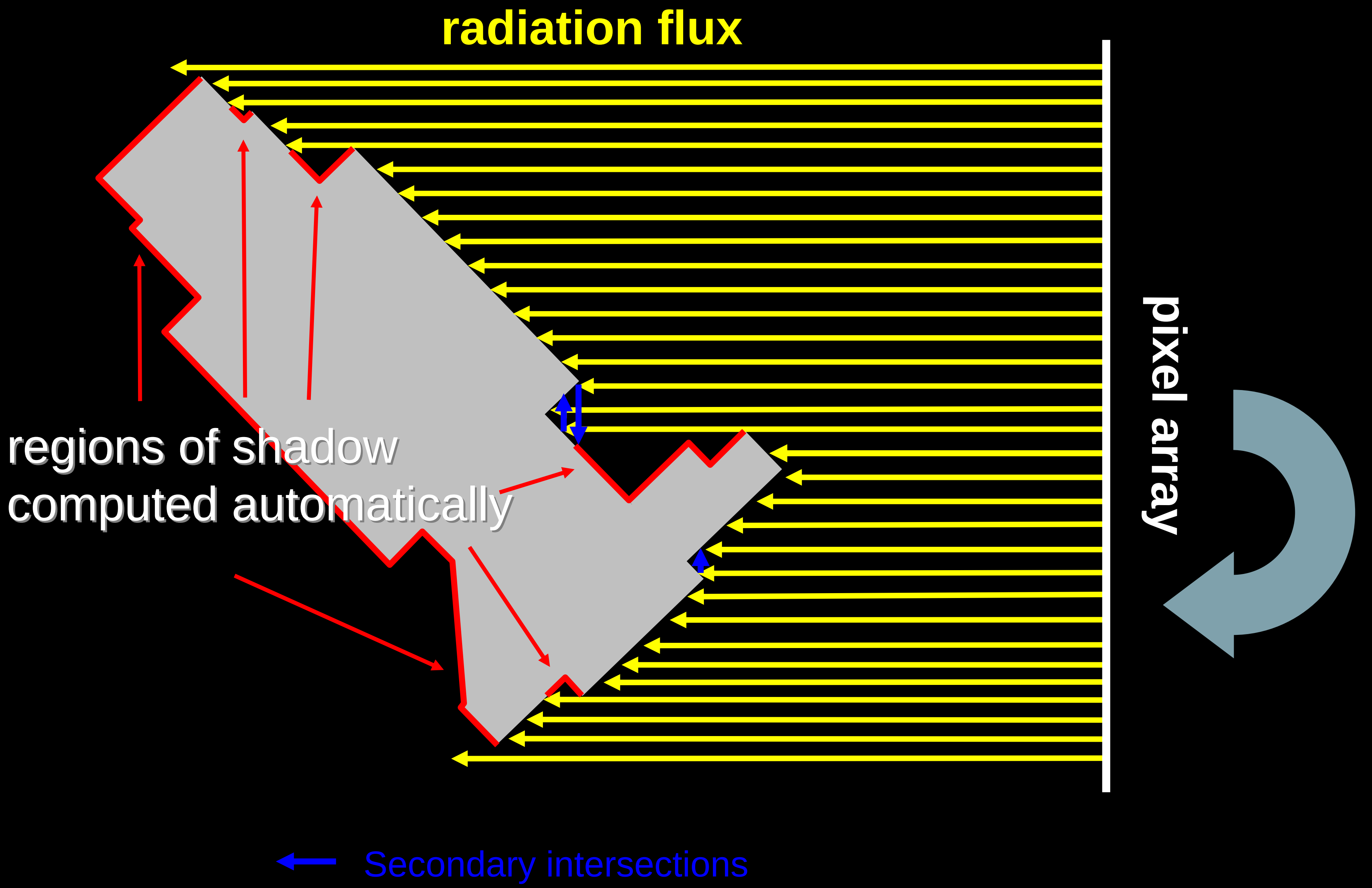
UCL approach

- ‘Box and wing’ radiation pressure model.
- ‘Soak up’ mismodelling with empirical SF & ‘1-CPR’ terms.

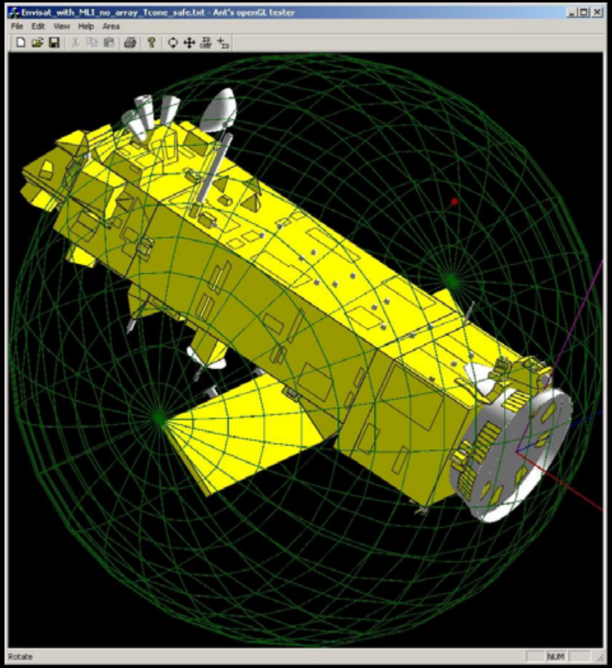
OR

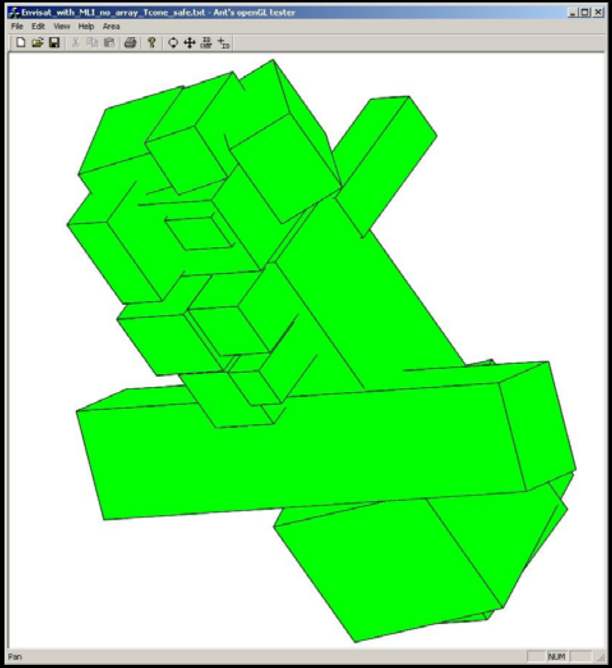
- Base modeling on physics and engineering.
- Just get it right.

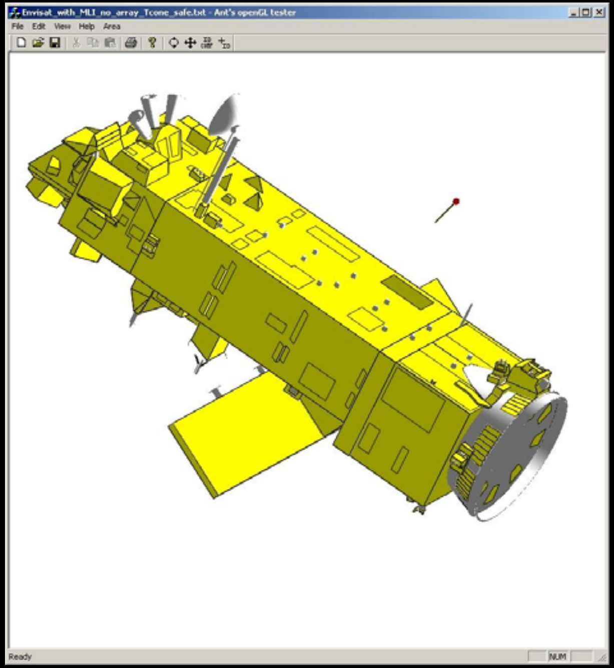
Ray Tracing


radiation flux
pixel array
regions of shadow
computed automatically
Secondary intersections

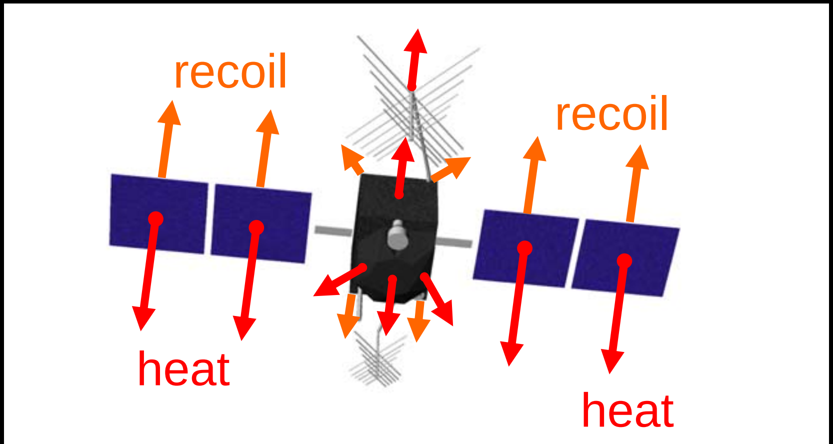
UCL Quality Control: View Tools



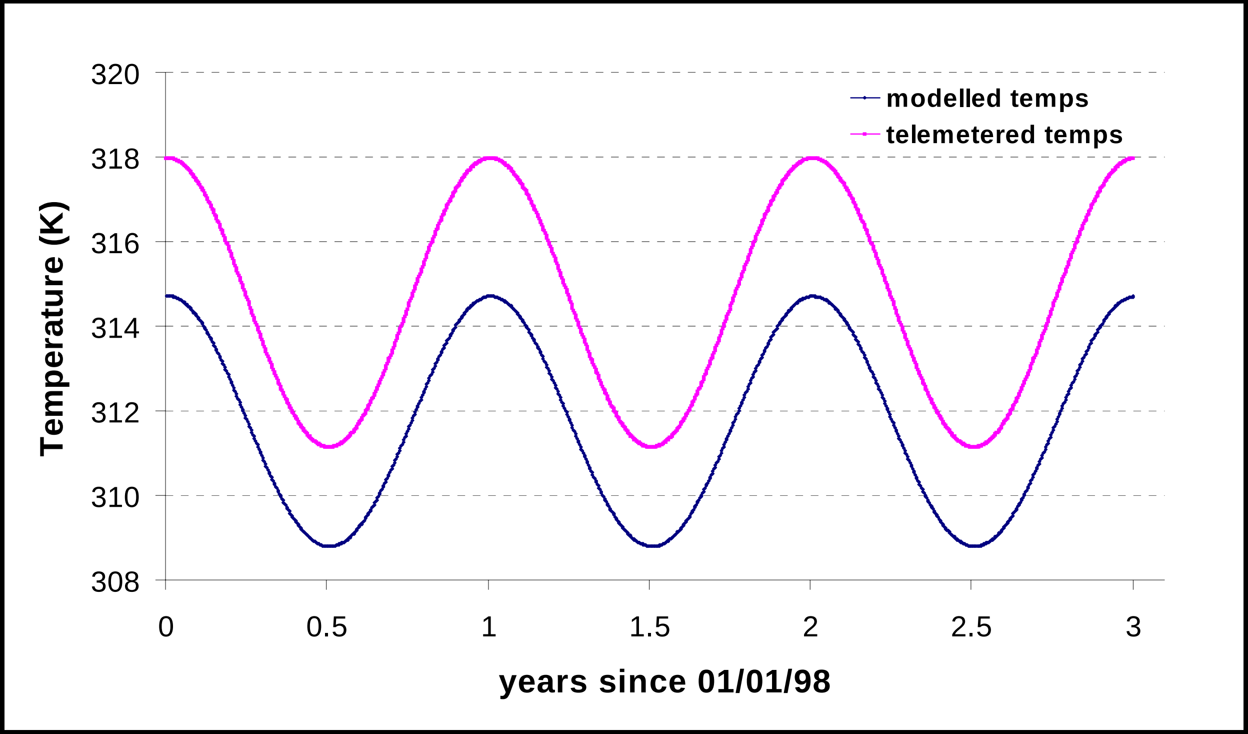




Thermal Modeling



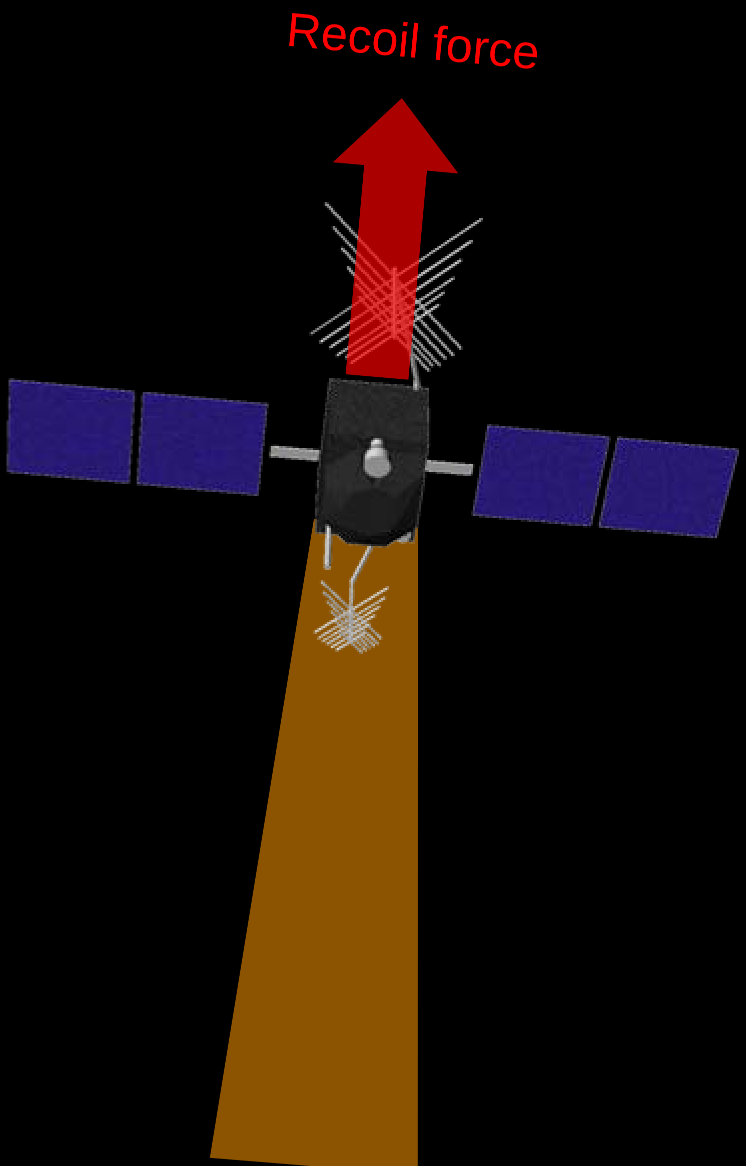
Anisotropic thermal emission from spacecraft results in a net acceleration



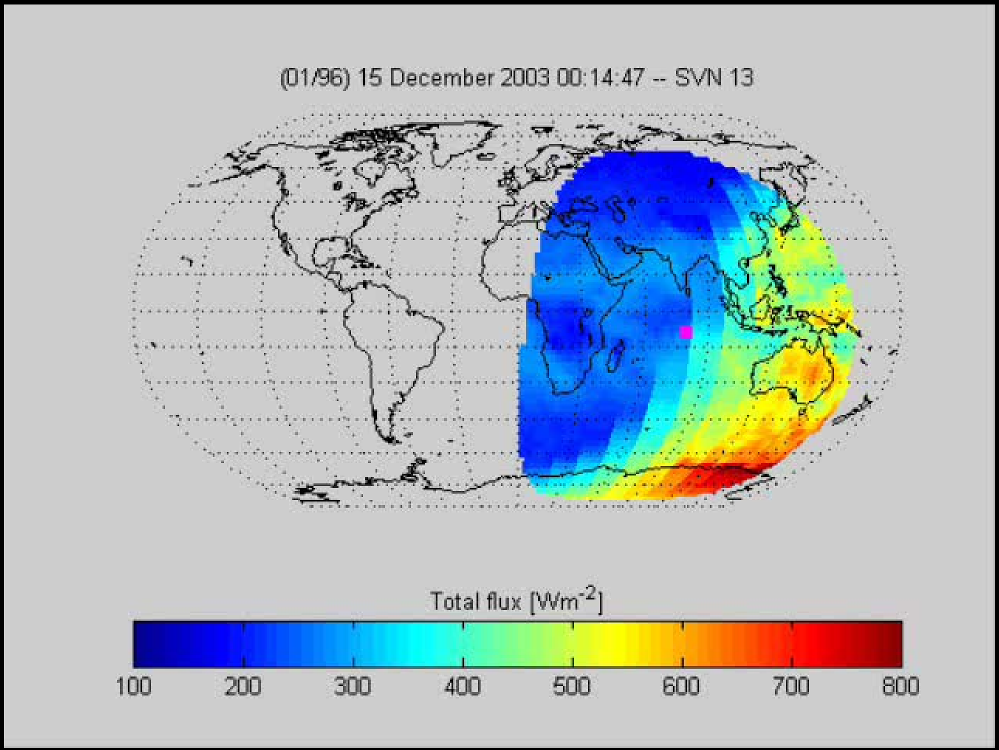
GPSIIR temps: modeled vs telemetered

Antenna Thrust (AT)

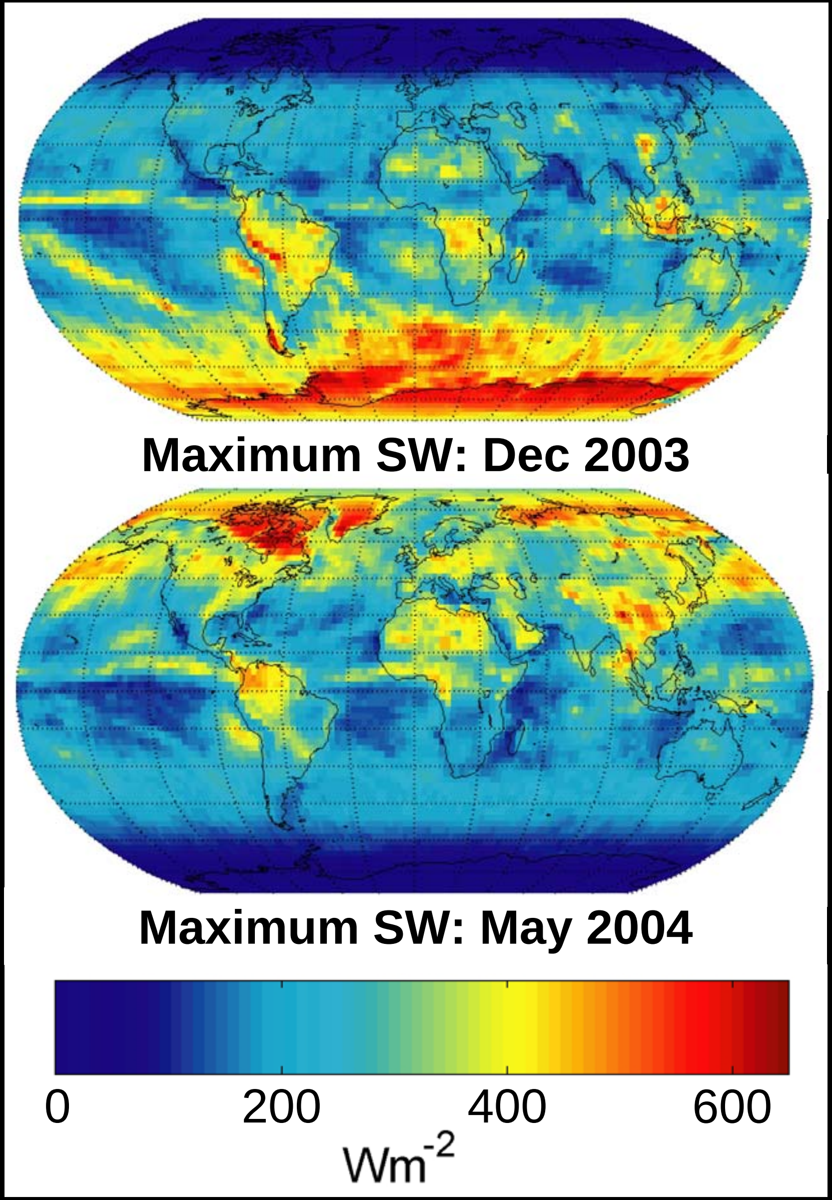
- Recoil force on satellite due to transmitted navigation, SAR & altimetry signals etc.
- Systematic and observable effect
- Requires knowledge of power transmission of satellites



PRP: emitted and reflected radiation complexity



Irradiance seen by a single GPS satellite at TOA

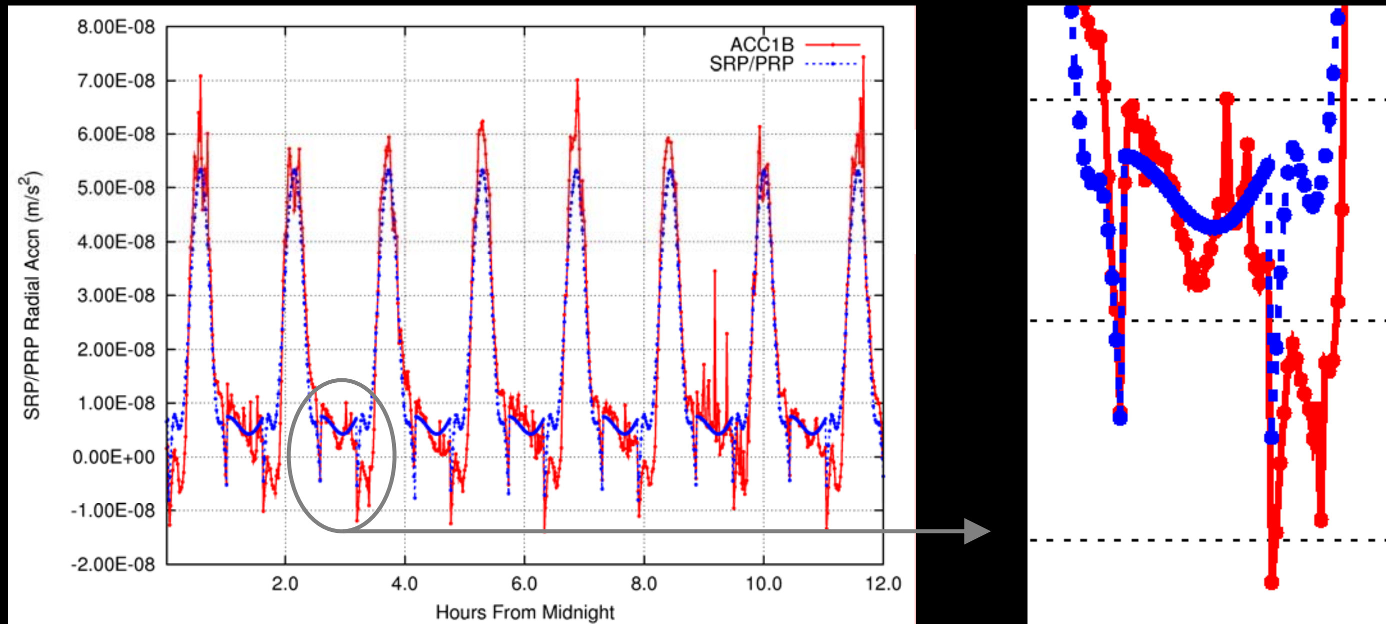


Maximum SW: Dec 2003

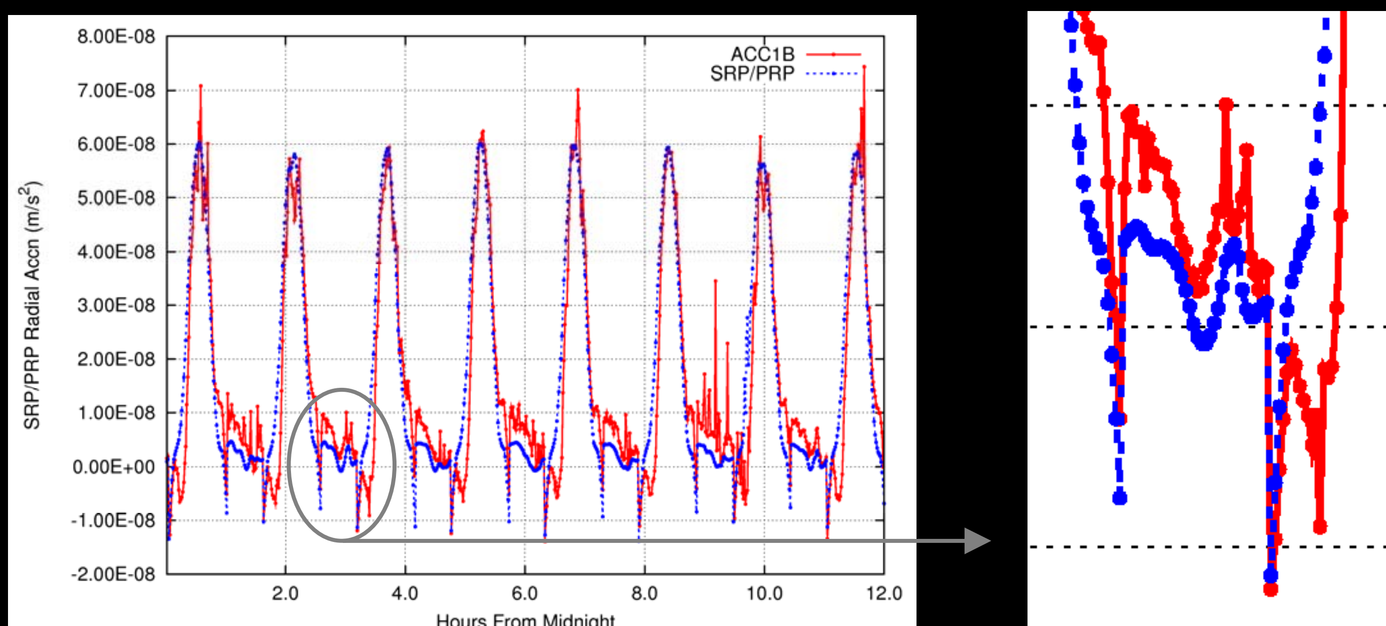
Maximum SW: May 2004

PRP

Knocke & Ries

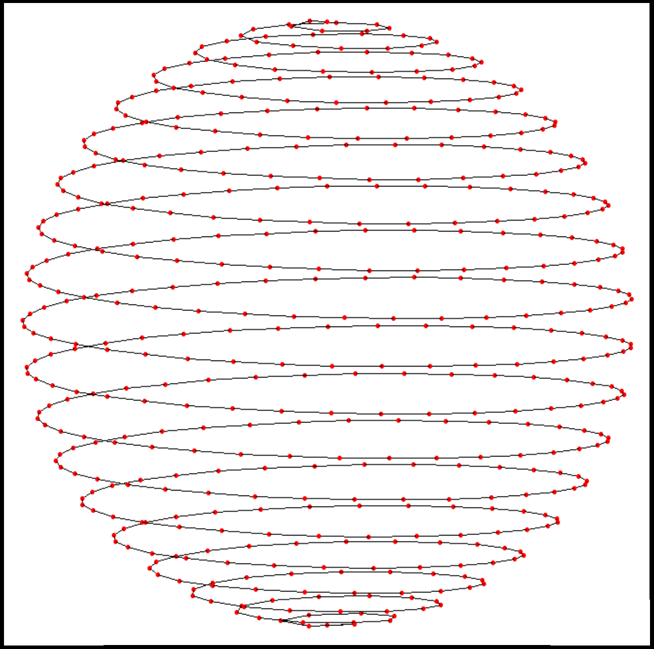


UCL CERES

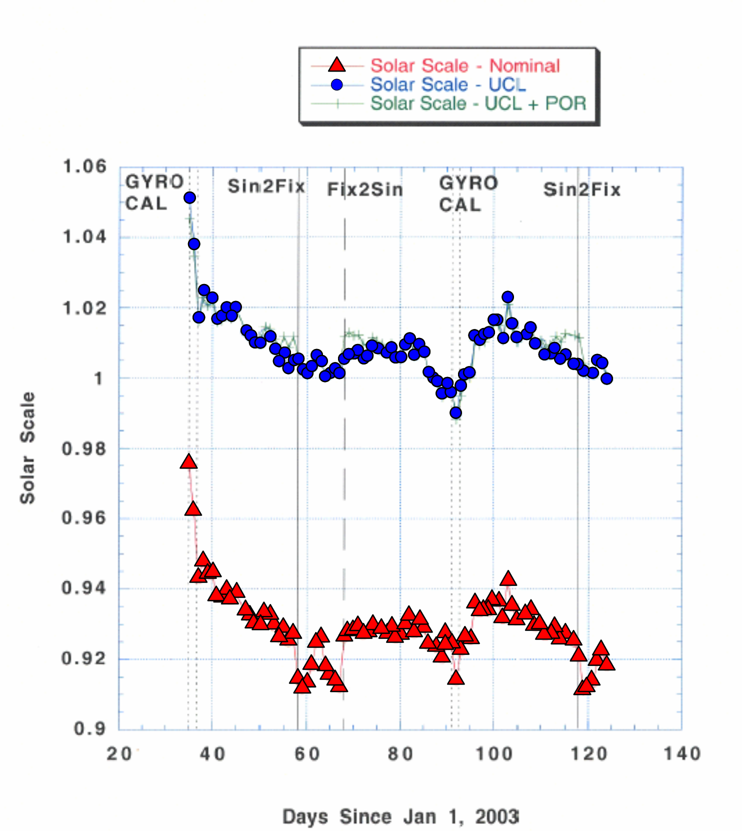


UCL Output: Simplicity Captures Complexity

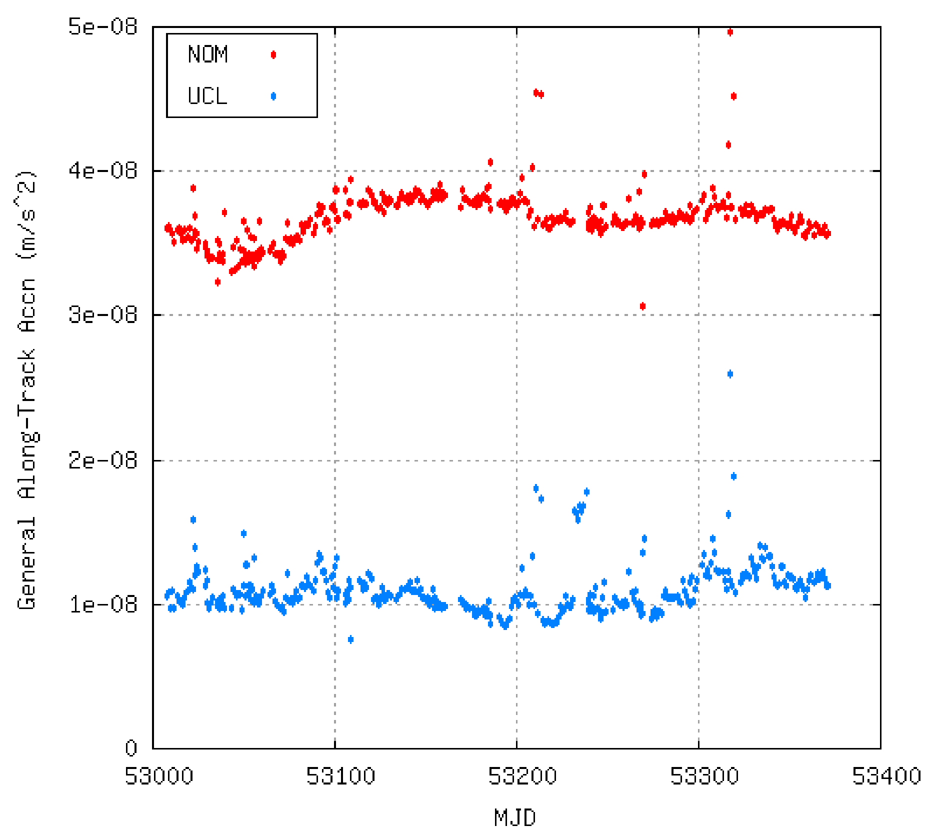
- Geometry sampled discretely over entire satellite by placing pixel array at points along a spiral
- Surface fitted to resulting accelerations using custom bivariate interpolation
- Final output is a grid file to be interpolated bi-linearly in an integrator



UCL Model Results: JASON-1 & ENVISAT



JASON-1 solar pressure scale factors over 80 days (JPL, GIPSY)

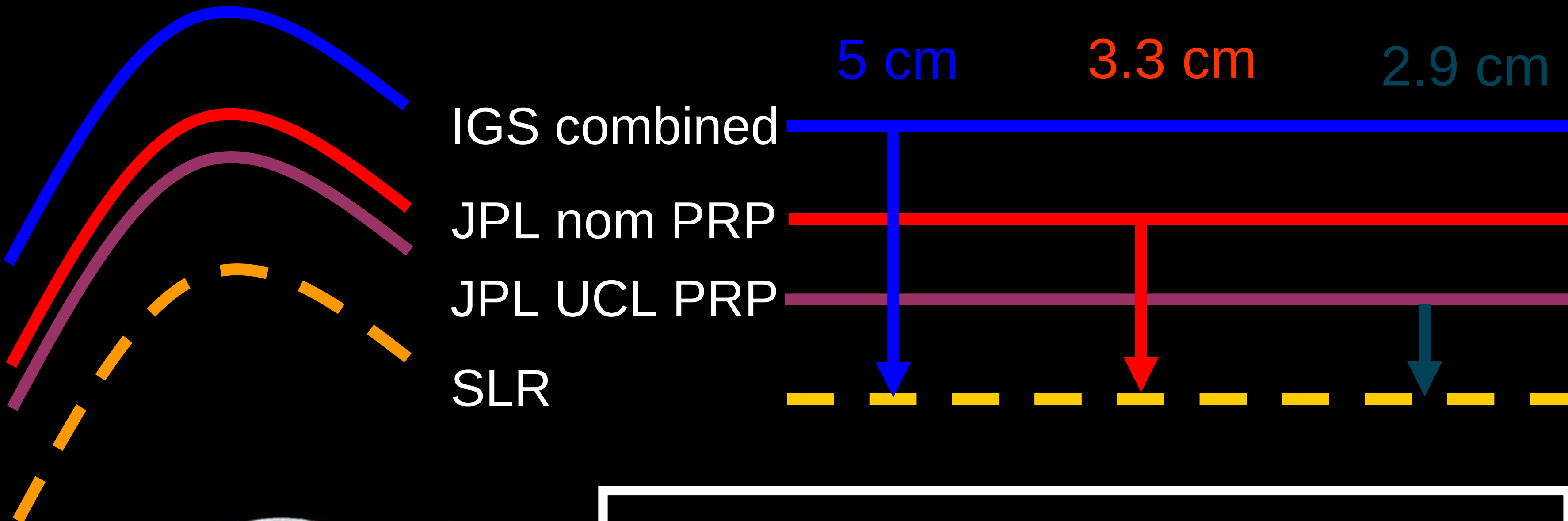


ENVISAT Along-track 1-CPR magnitudes over 2004 (GSFC, GEODYN)

- UCL model Cr ~ 1.01
- More stable behaviour
- Macromodel Cr ~ 0.93

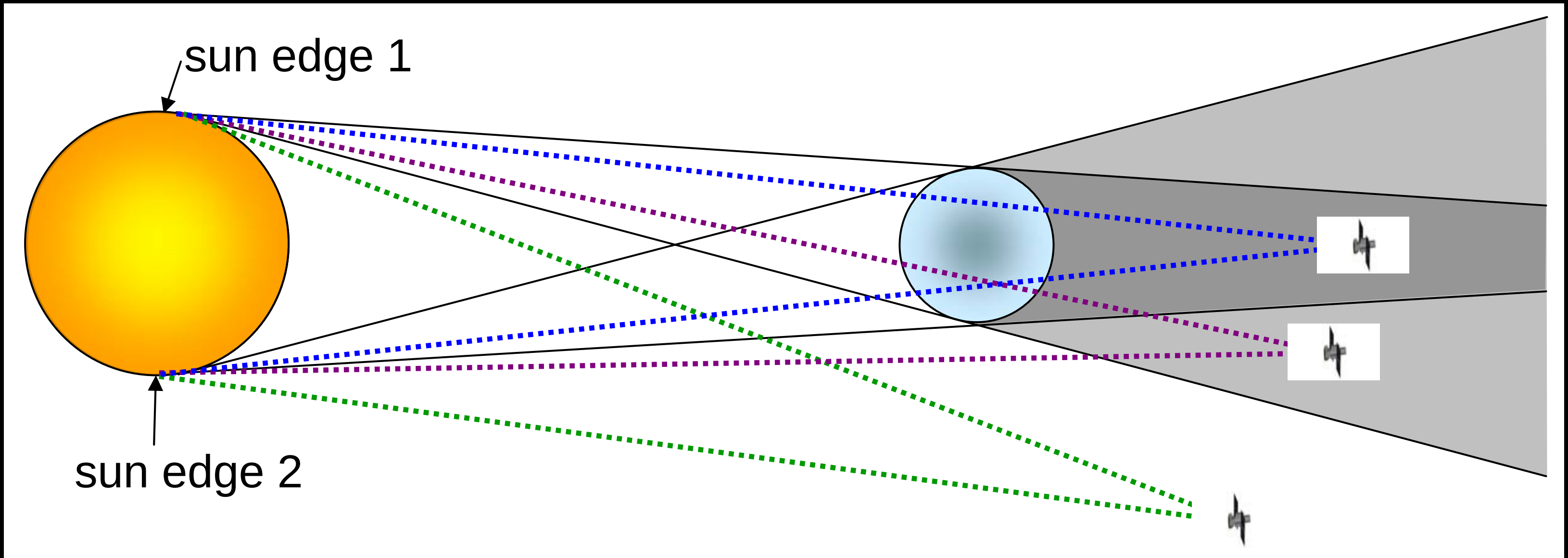
Nominal Box-Wing and UCL ENVISAT model performance over 2004, Cr = 1

GPS-SLR Orbit Anomaly: Mean Orbit Differences



Combined Earth radiation pressure and antenna thrust model reduces SLR bias by 21 mm

Oblate Earth Eclipse Determination



Eclipse state determined by counting intersections between 'sun edges' and the eclipsing body

Full phase = 0 intersections Penumbra = 1 intersection

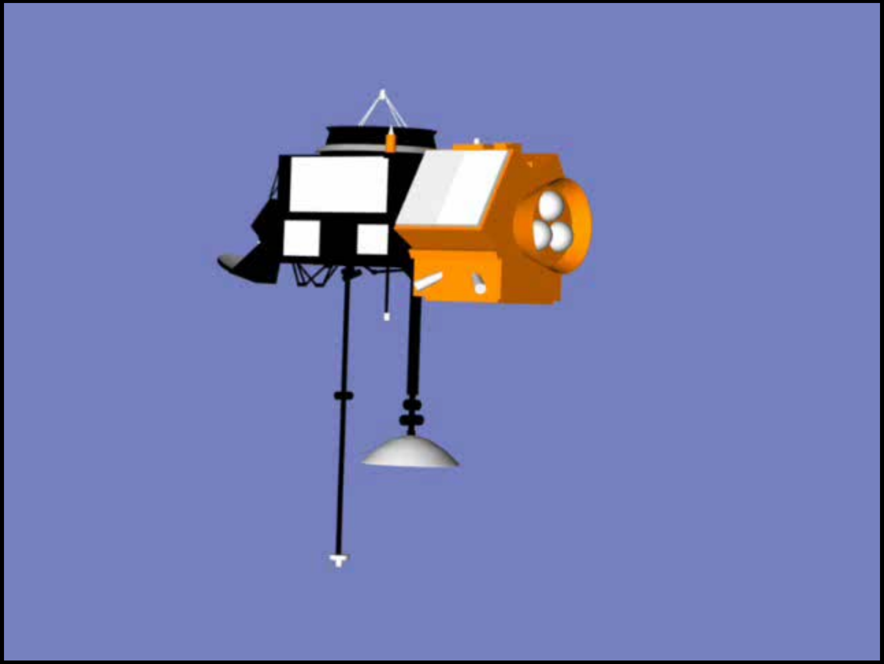
Umbra = 2 intersections

Adhya et al., "An Oblate Earth Eclipse State Algorithm for LEO Satellites", Journal of Spacecraft and Rockets, Vol. 41, No 1, 2004 (typo)

Conclusions

- Simplified satellite surface force models lead to reference frame and orbital biases
- UCL models significantly mitigate these errors without using empirical terms
- UCL modeling embraces complexity in spacecraft structure and environmental data and are accurate, fast and efficient when implemented
- This is still an active research area, and we are willing to work on other satellites (e.g. SPOT)
- Better modeling technologies now exist. They can, and should, be used

UCL TOPEX Geometry



Thankyou

ants@ge.ucl.ac.uk