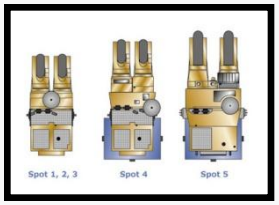
London's Global University

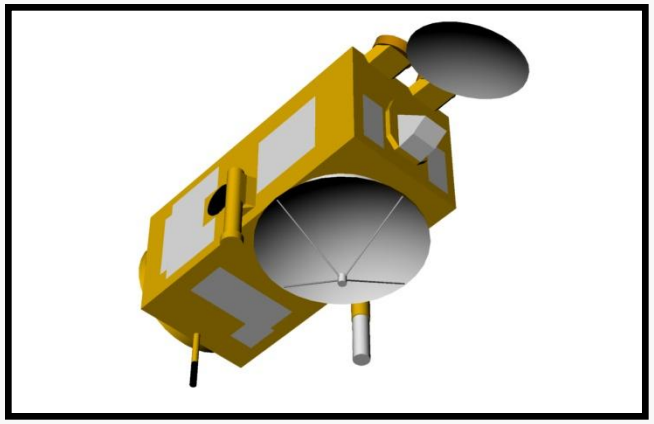
UCL

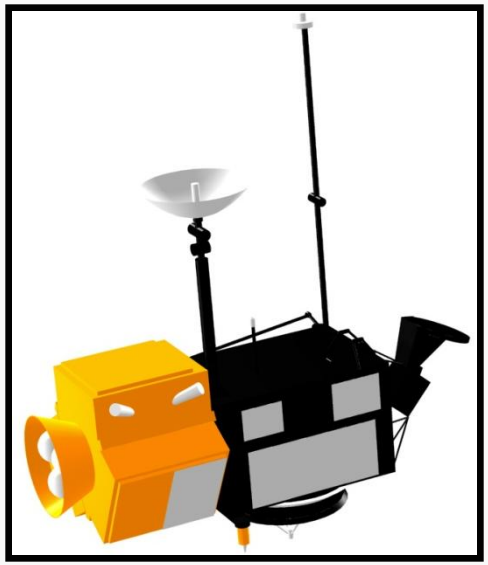
Non-Conservative Force Modelling for DORIS Satellites at UCL

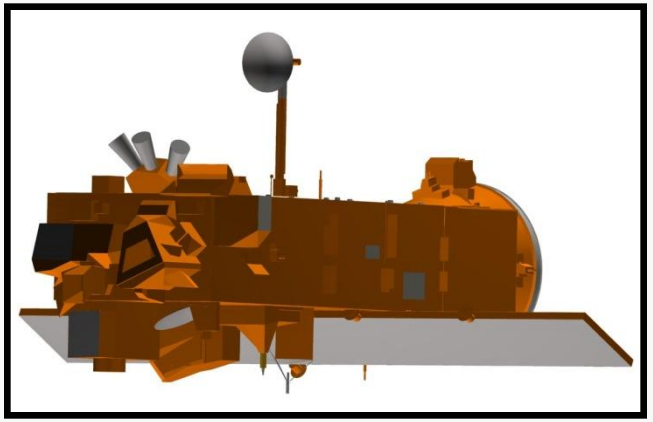


Ant Sibthorpe

Marek Ziebart

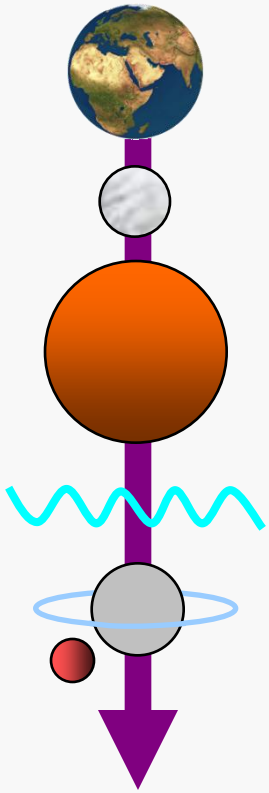






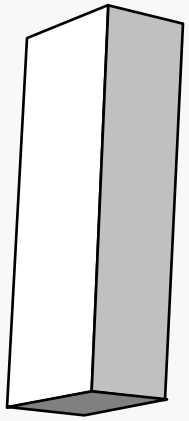
Forces acting on a spacecraft

- Earth gravity
- Lunar gravity
- Solar gravity
- Solar radiation pressure
- Atmospheric Drag
- Thermal forcing



- Planetary Radiation Pressure
- Tidal effects
- Antenna thrust
- Planetary gravity & general relativistic effects

Modelling Satellite Surface Forces



Conventional approach

UCL approach

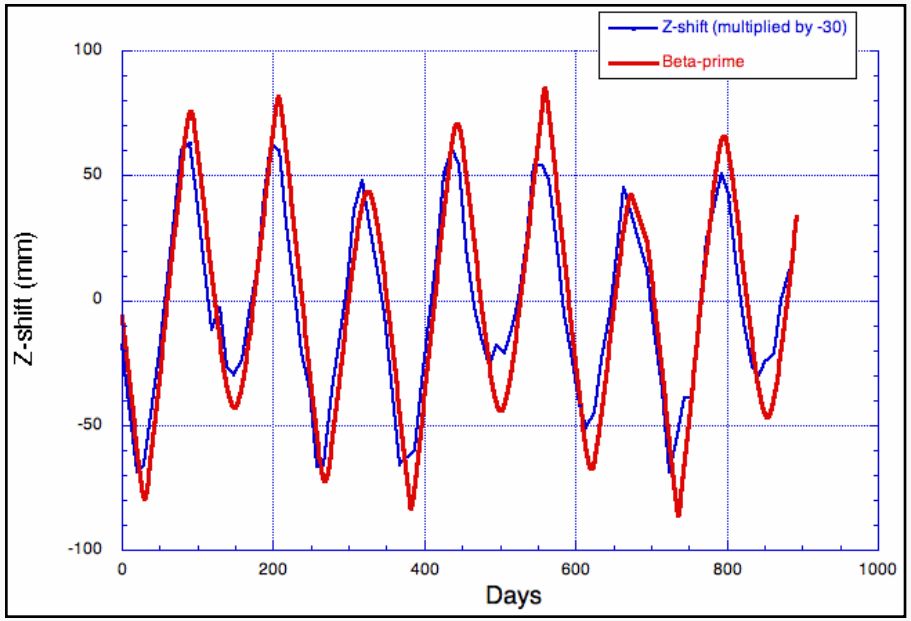
‘Box and wing’ model, rely upon empirical parameters to ‘Soak up’ mismodelling.

OR

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

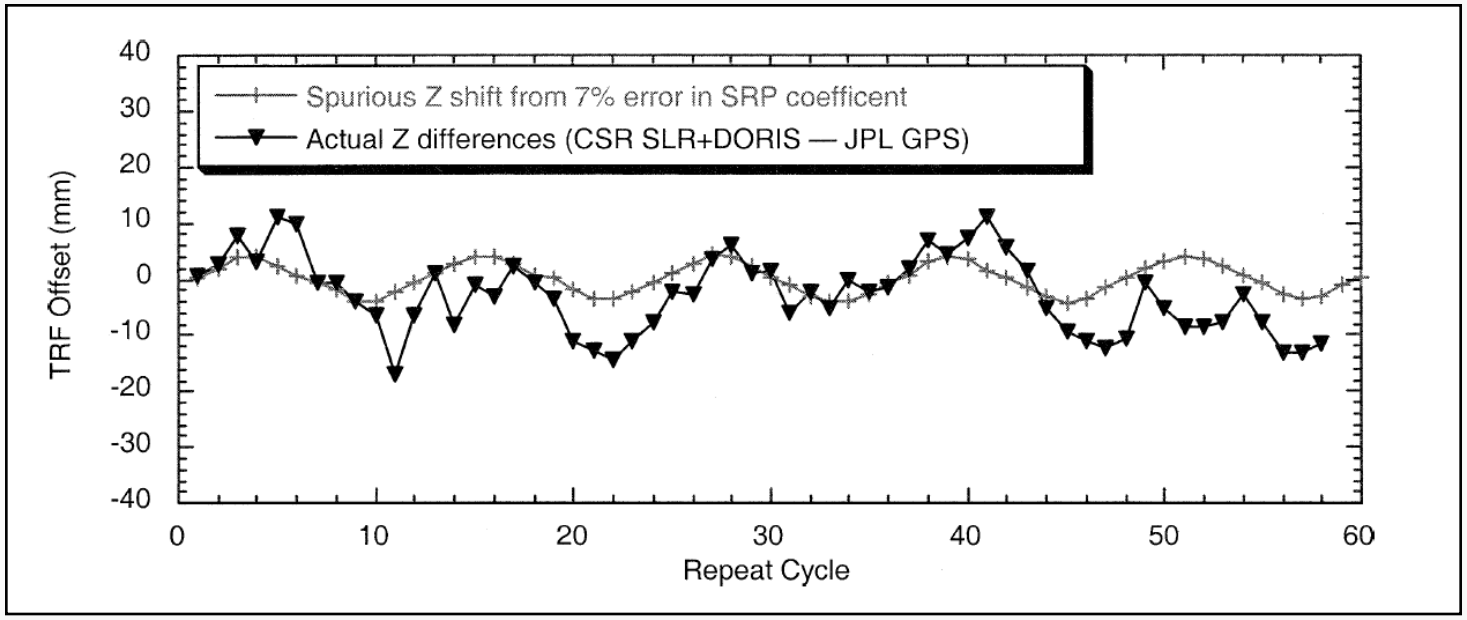
Scale Factors

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

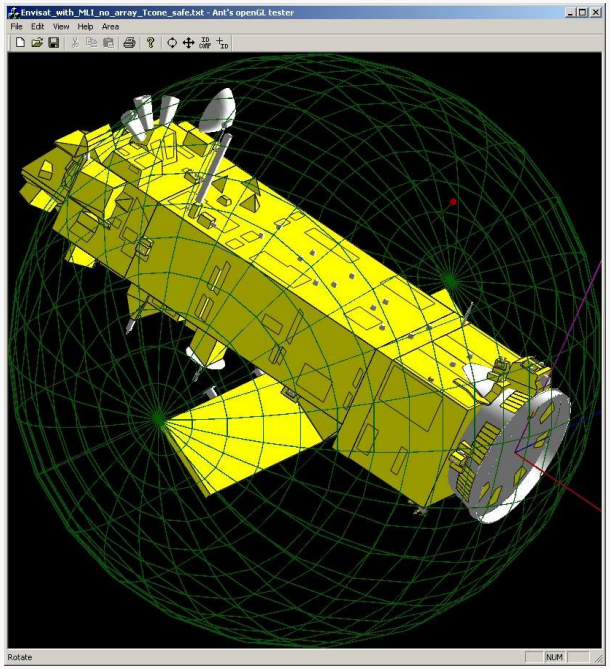


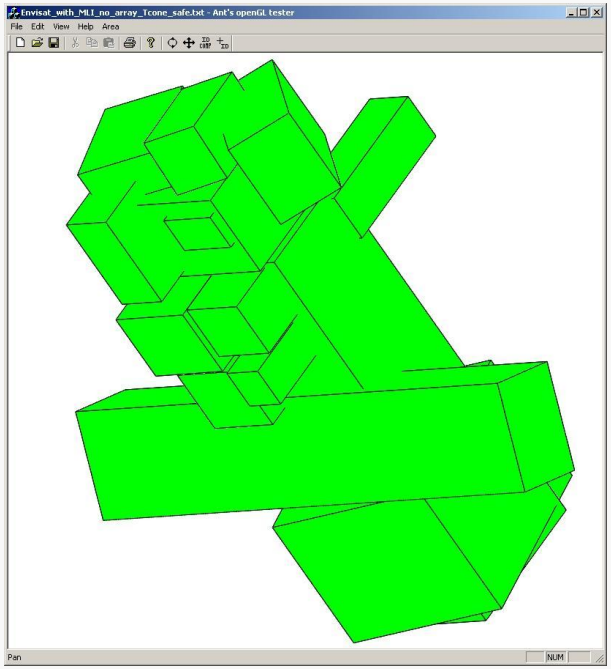
JASON-1 tests using different (3%) solar radiation pressure scale factors (John Ries, CSR)

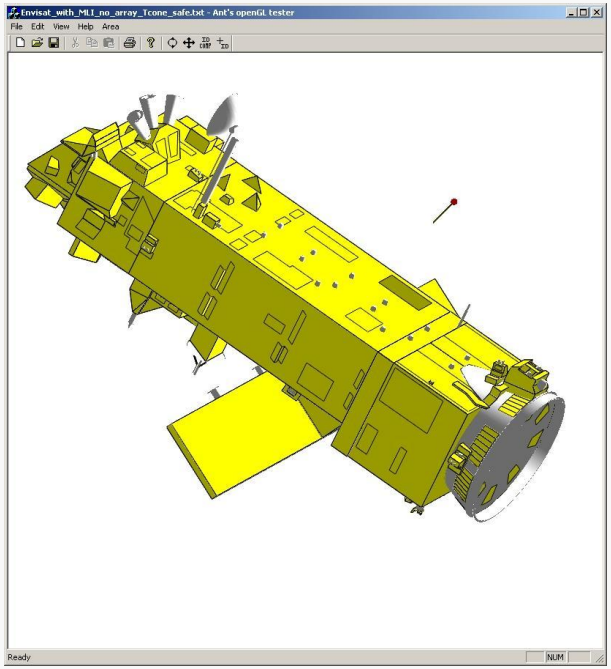
JASON-1 tests using different (7%) solar radiation pressure scale factors (Bruce Haines, JPL)



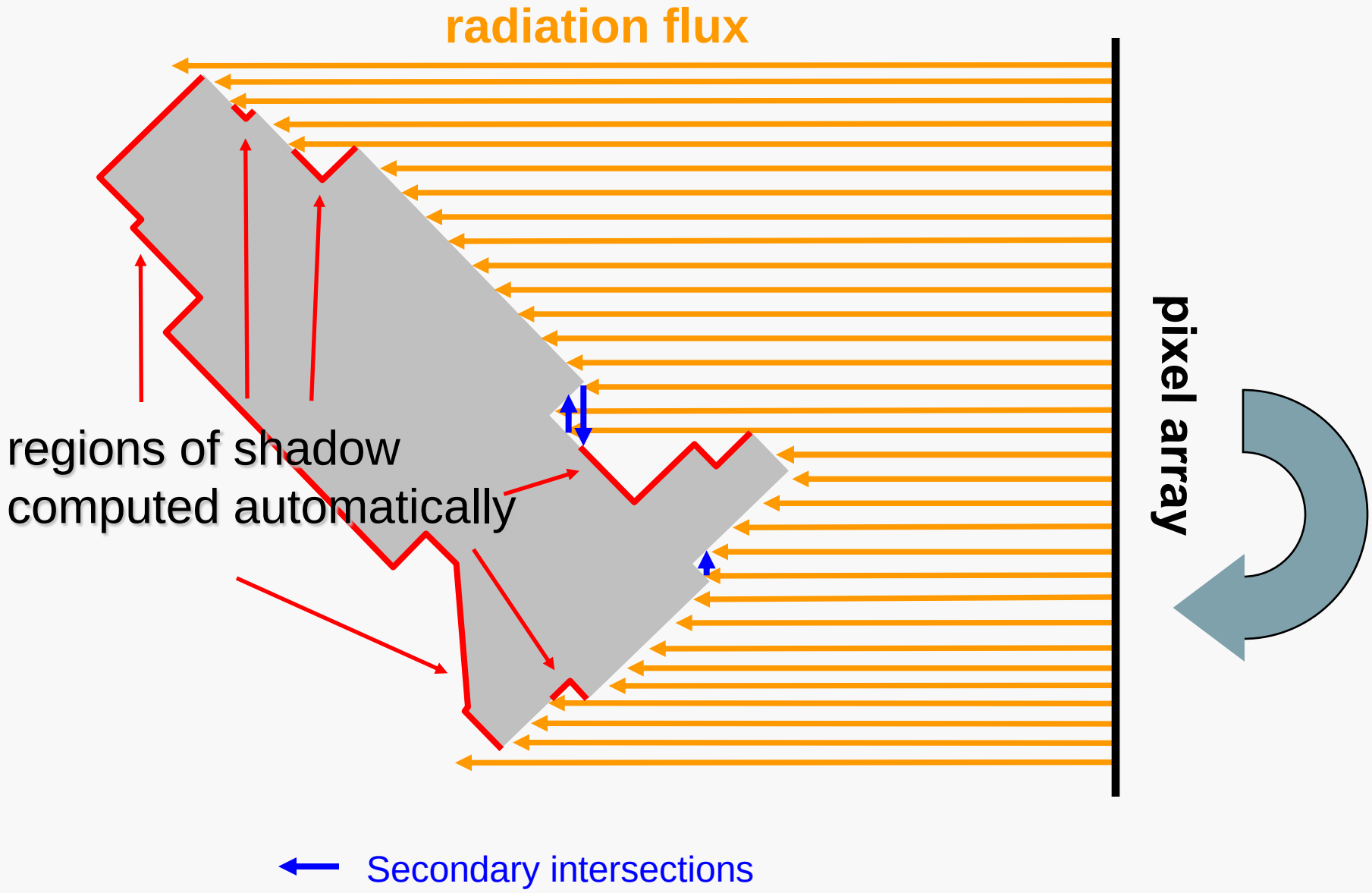
UCL Quality Control: View Tools



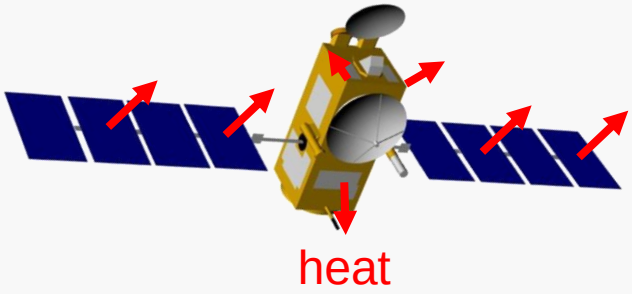




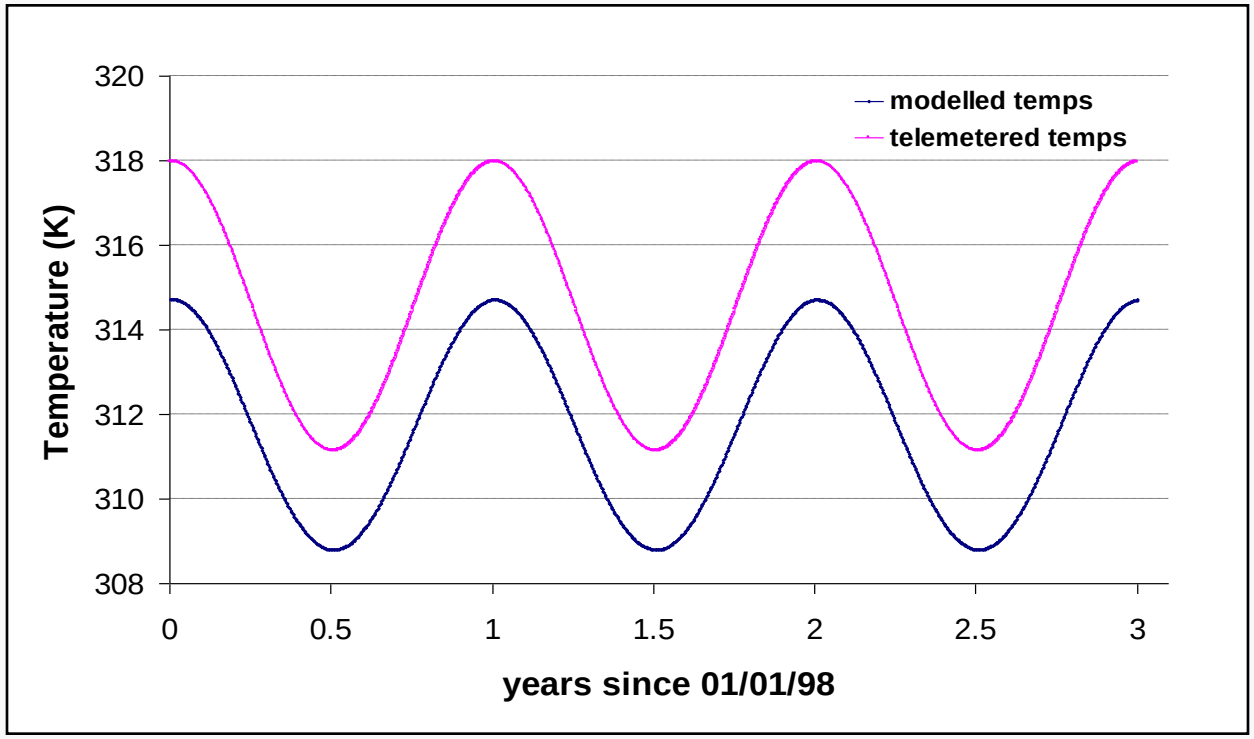
Ray Tracing


radiation flux
regions of shadow
computed automatically
pixel array
Secondary intersections

Thermal Modelling



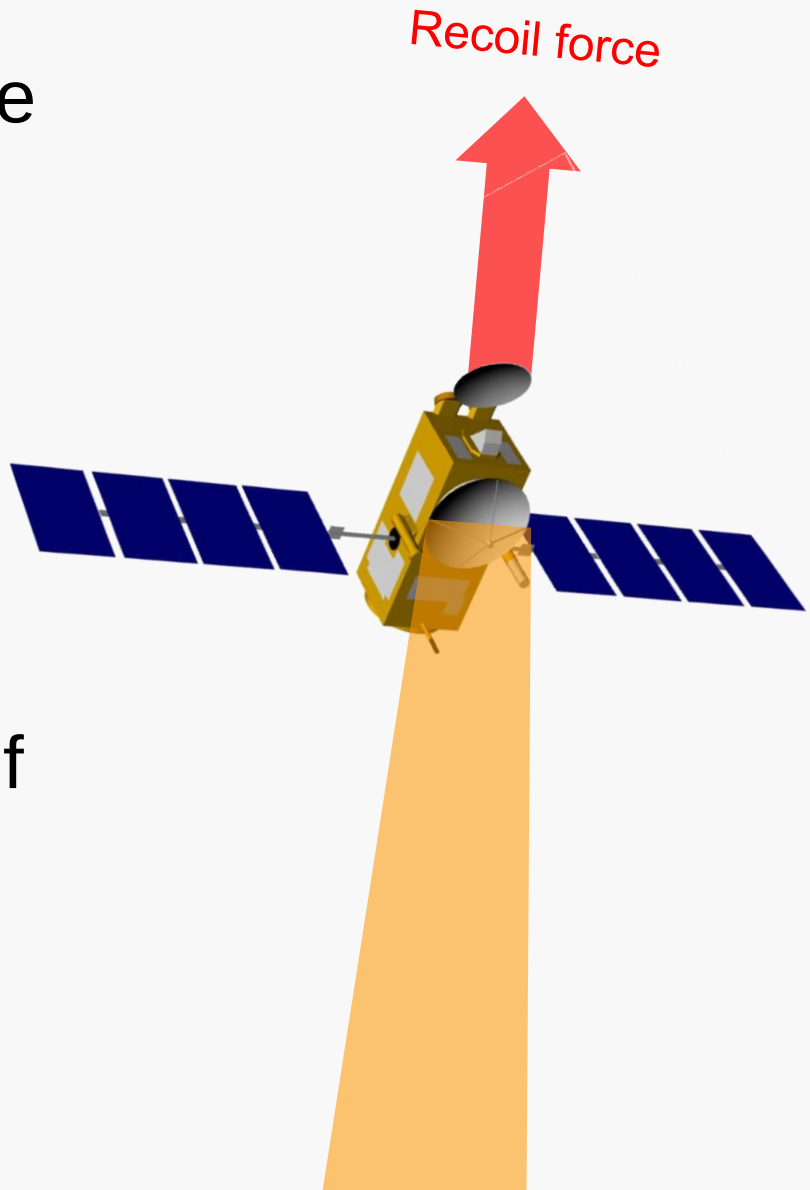
Anisotropic thermal emission from spacecraft results in a net acceleration



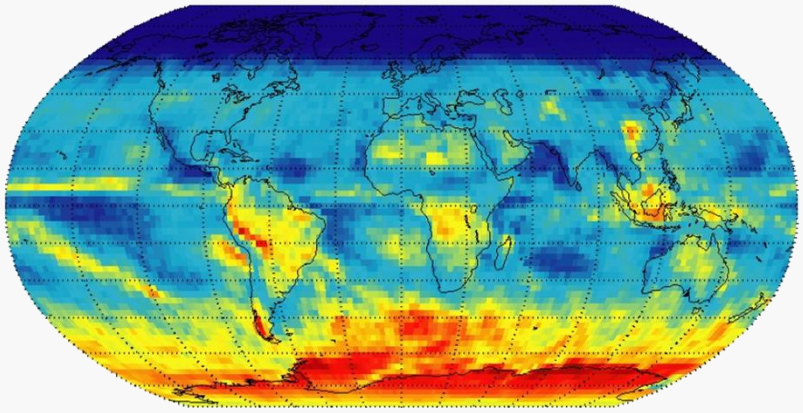
Temps: modelled vs telemetered

Antenna Thrust

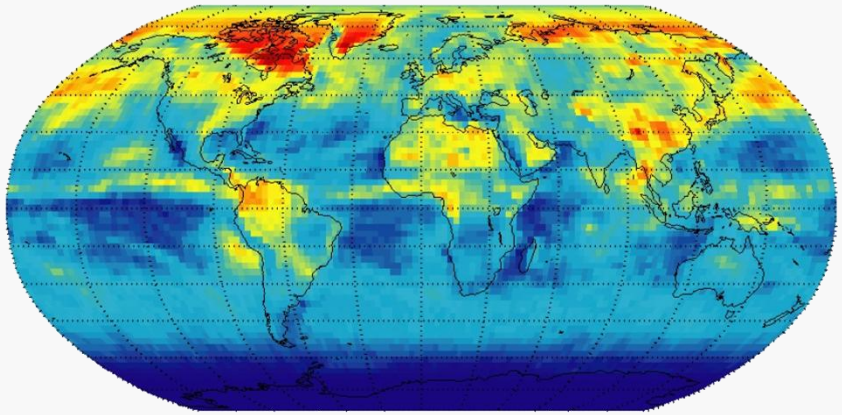
- Recoil force on satellite due to transmitted navigation, SAR & altimetry signals etc.
- Systematic and observable effect
- Requires knowledge of power transmission of satellites



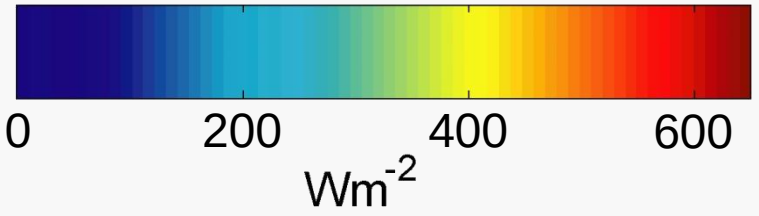
PRP: radiation complexity



Maximum SW: Dec 2003



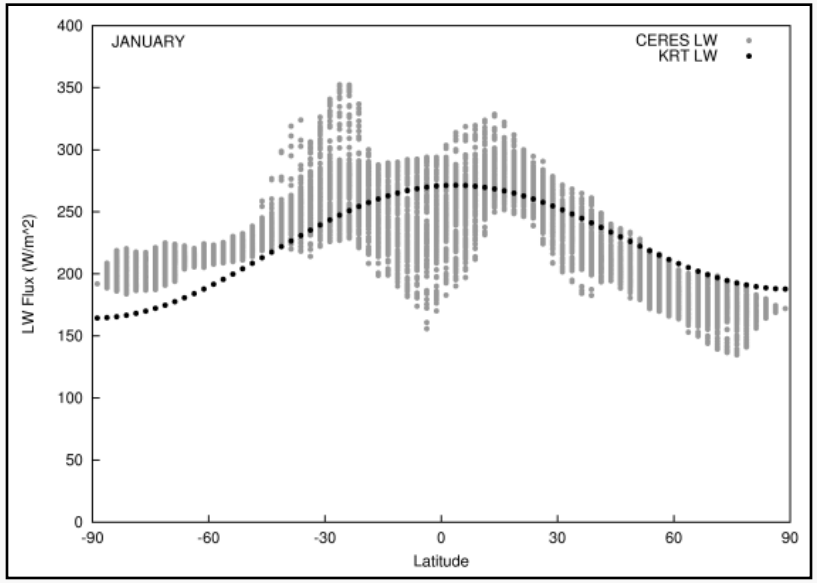
Maximum SW: May 2004

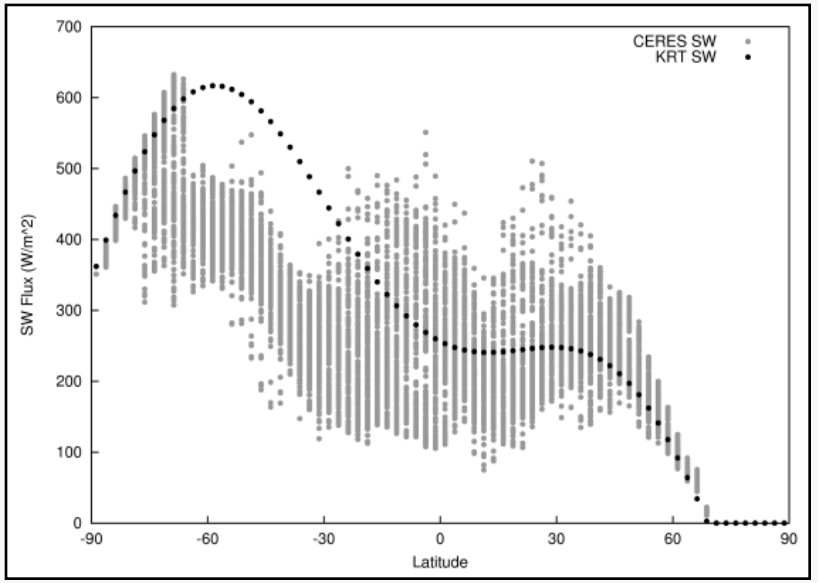


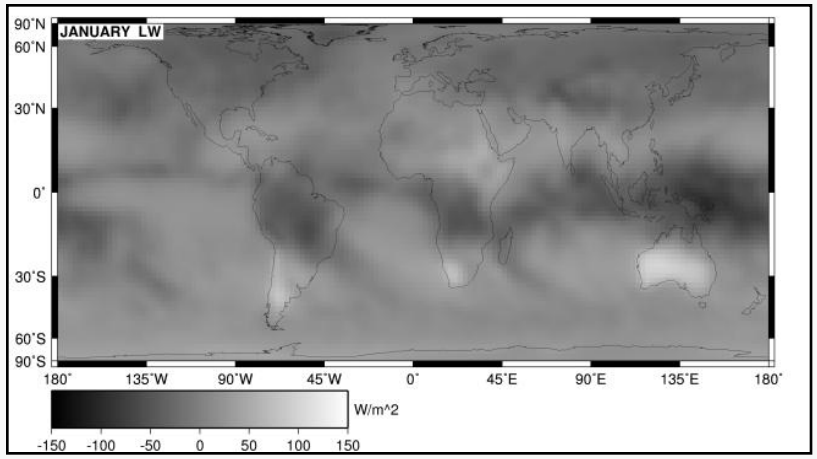
Radiant exitance: top of atmosphere

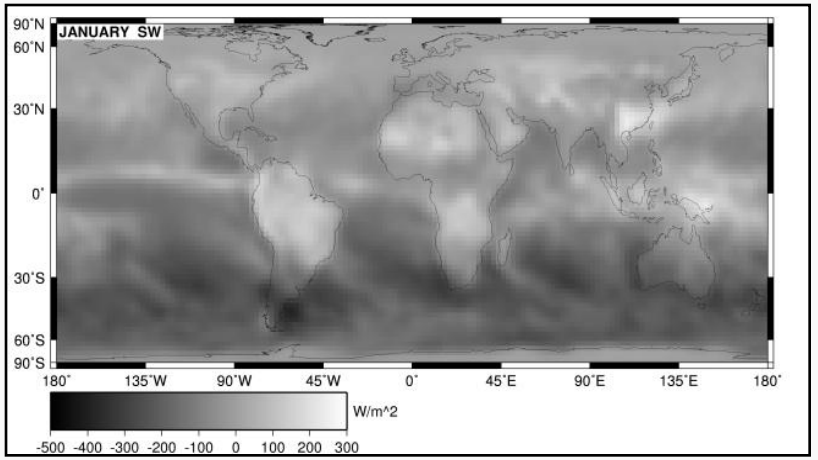
PRP

Radiant Exitance: CERES Vs KRT. January 15th, 2005.





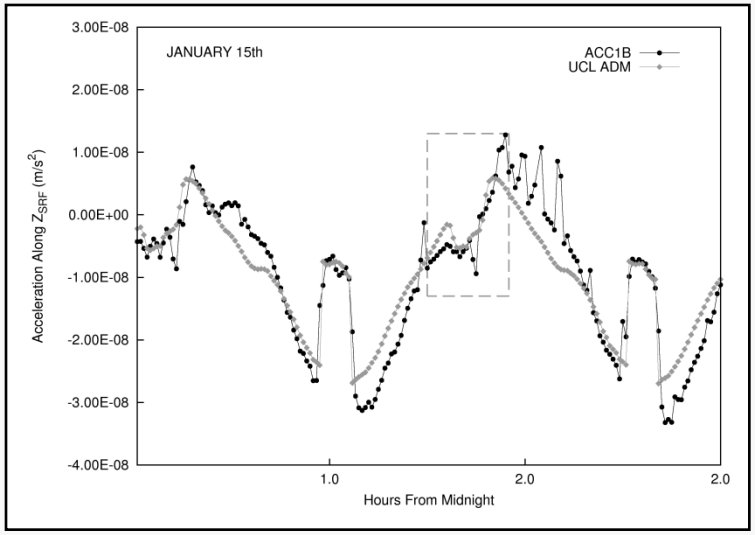




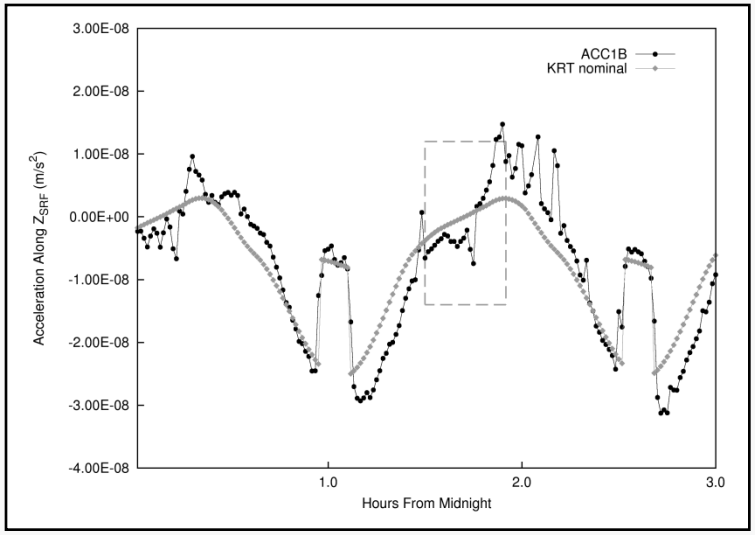
Radiant Exitance: CERES – KRT. January 15th, 2005.

PRP

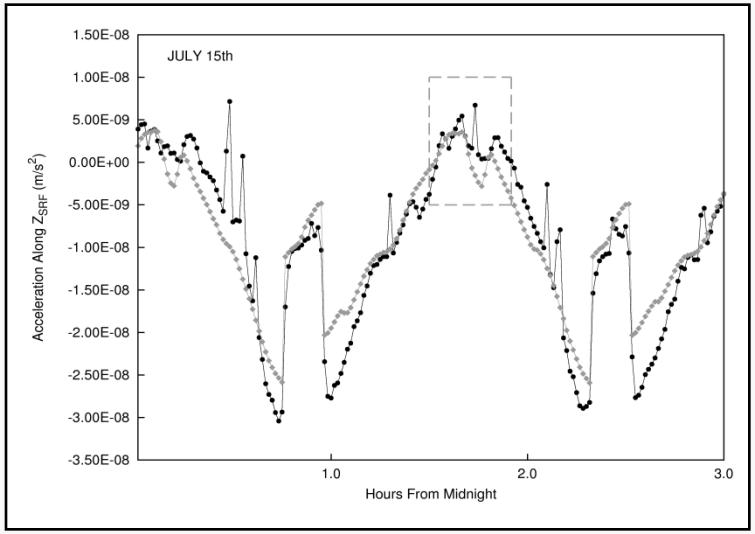
SRP + (UCL & Knocke) Vs GRACE ACC1B_Z

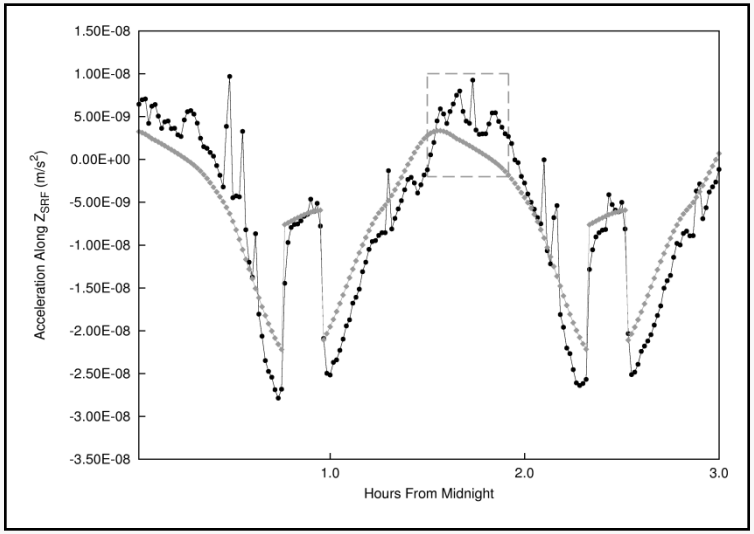


UCL: ADM



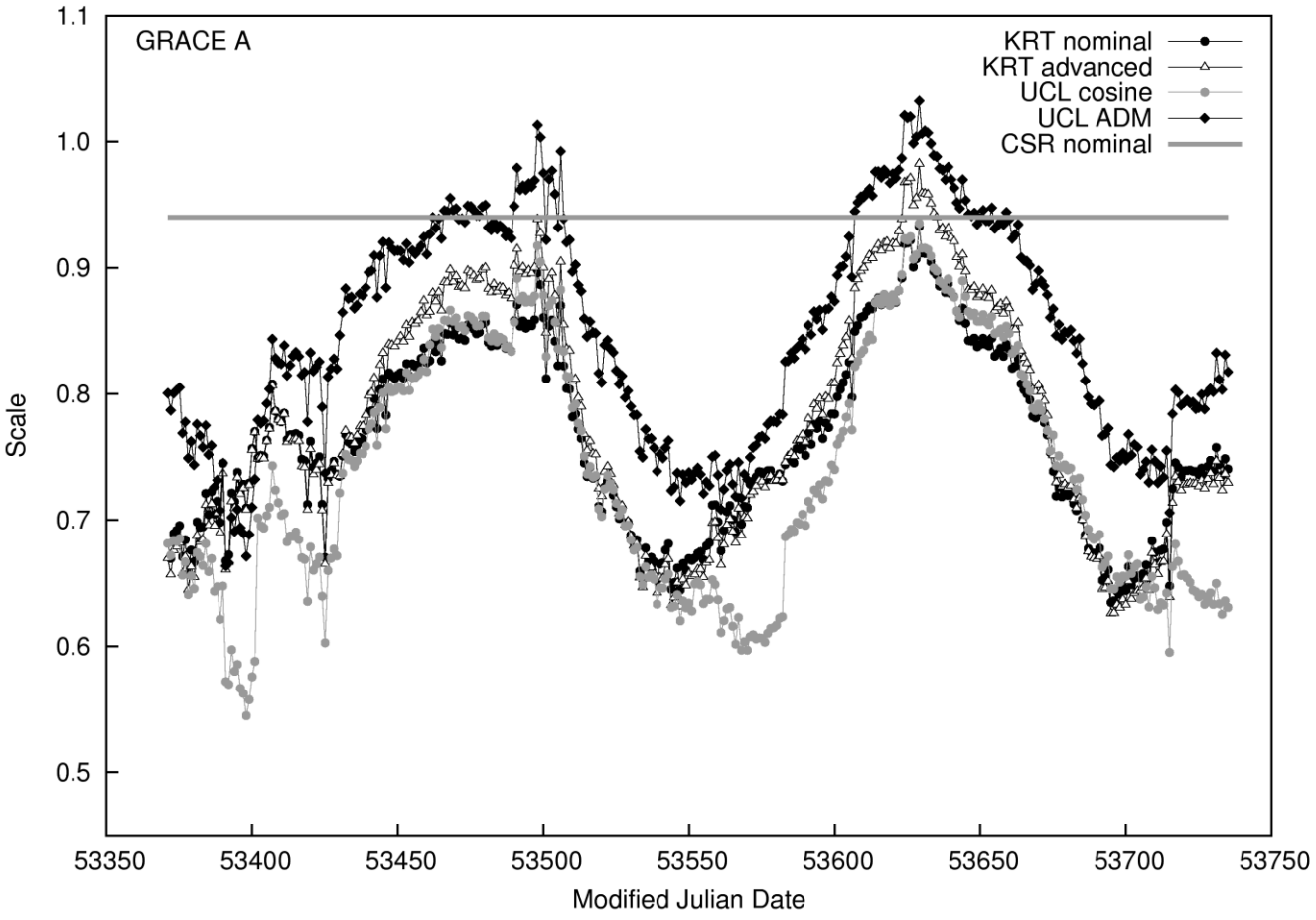
Knocke: Diffuse





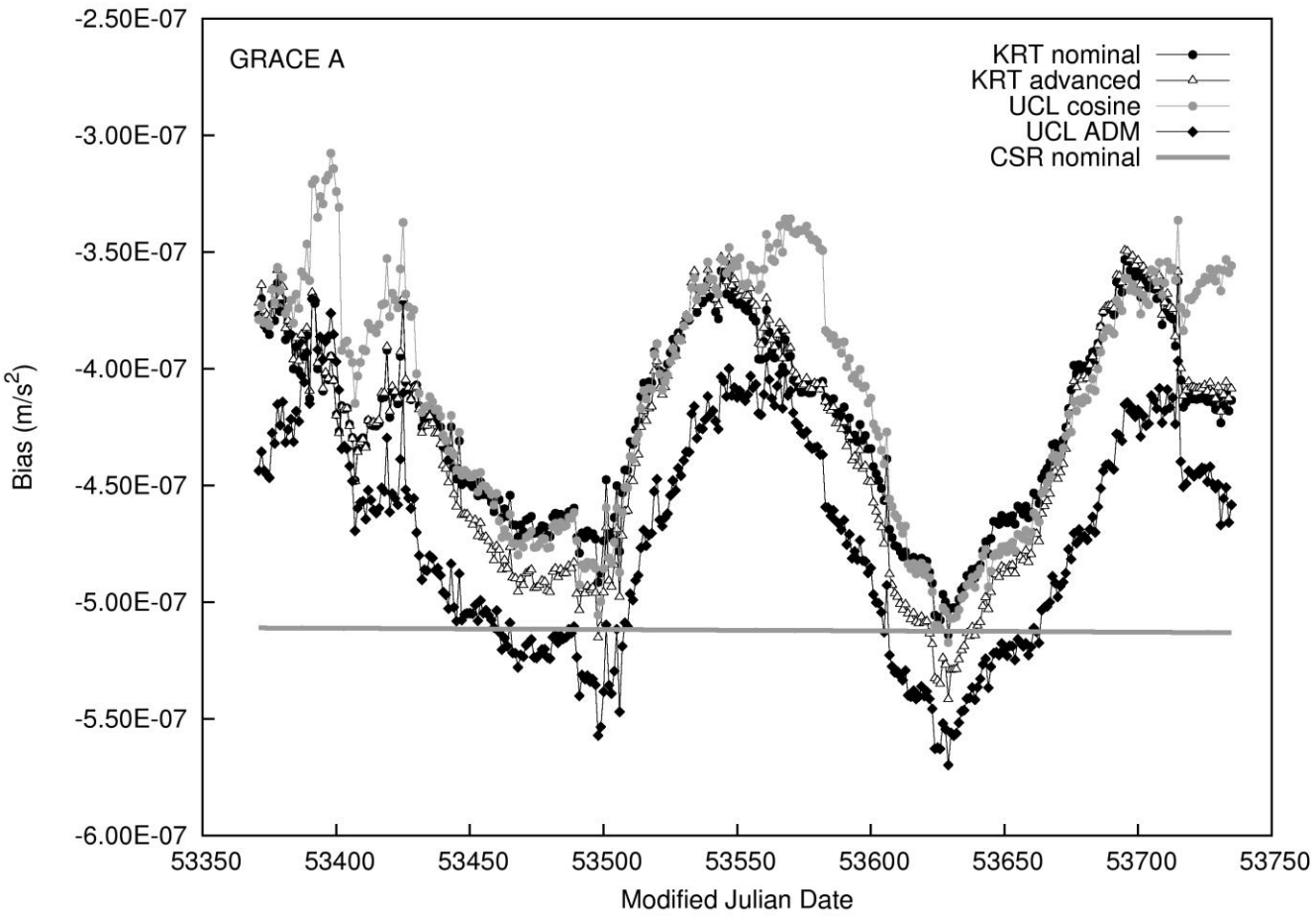
PRP

Scale to fit radial SRP+PRP to GRACE ACC1B_Z in 2005



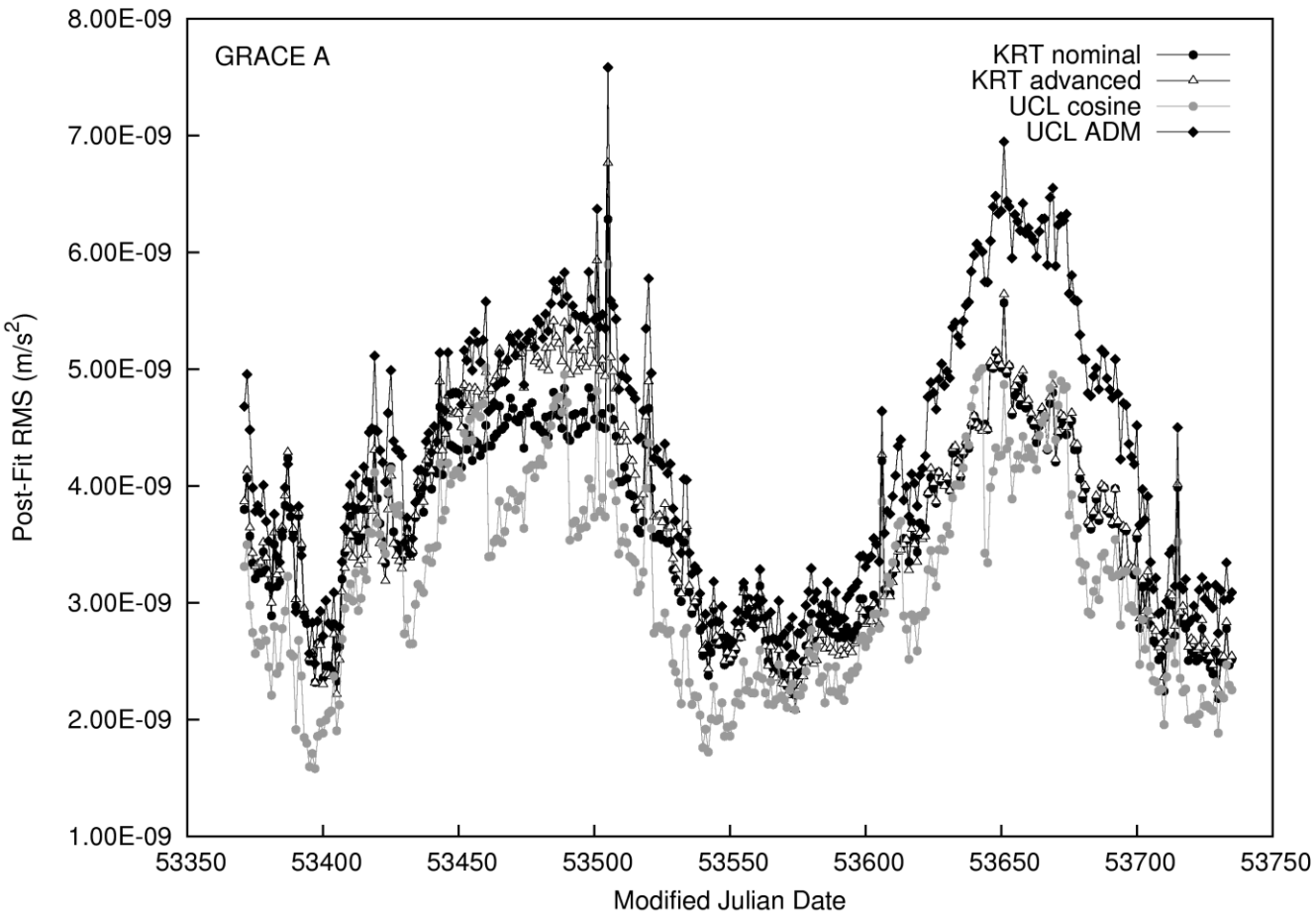
PRP

Bias to fit radial SRP+PRP to GRACE ACC1B_Z in 2005



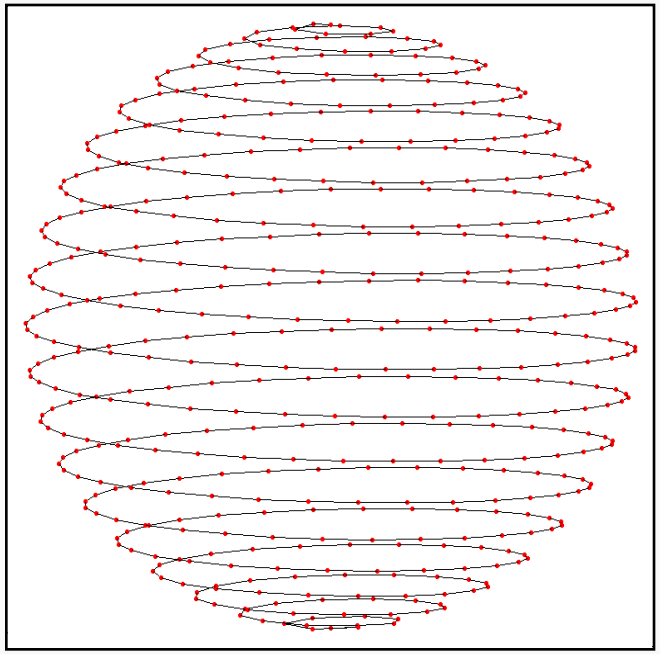
PRP

Post-fit RMS of radial SRP+PRP and GRACE ACC1B_Z, 2005

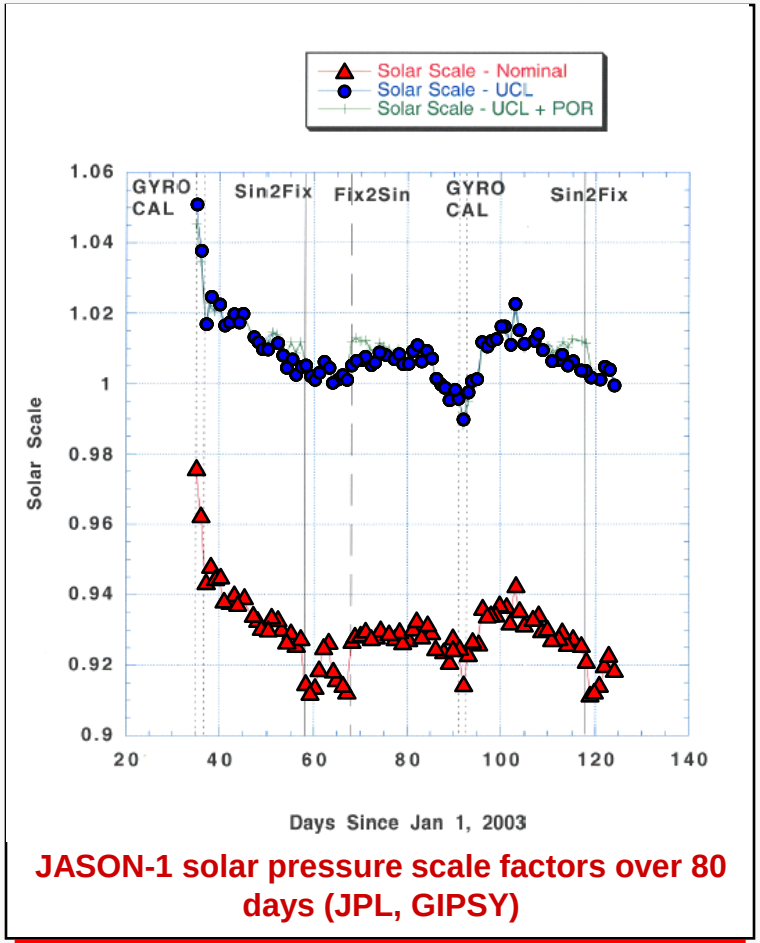


Simplicity Captures Complexity

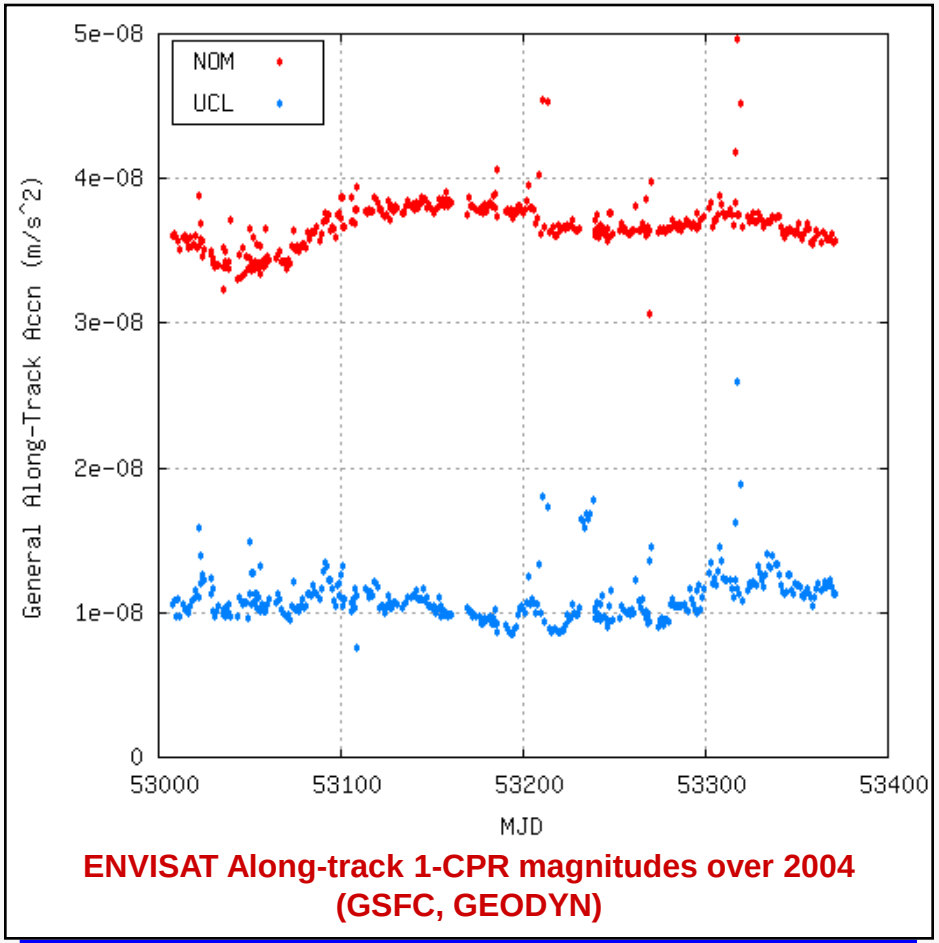
- Geometry sampled discretely by placing pixel array at points in a plane or along a spiral.
- Fourier series or surface fitted to resulting accelerations using custom interpolation
- Final output is a Fourier series or a grid file to be interpolated bi-linearly in an integrator



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)

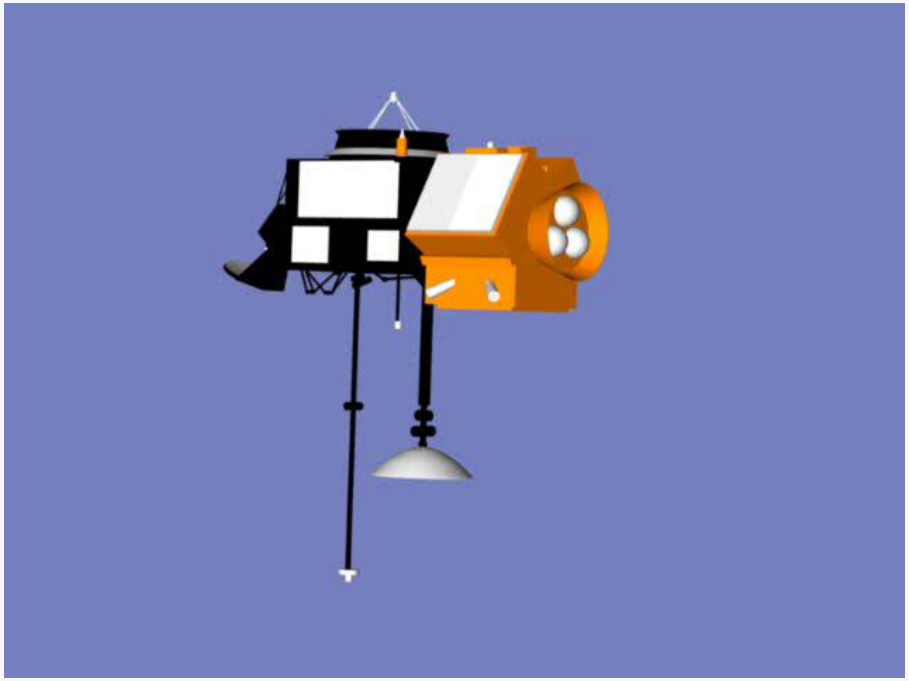
- UCL model Cr ~ 1.01
- More stable behaviour
- Macromodel Cr ~ 0.93

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

Conclusions

- Simplified satellite surface force models lead to reference frame and orbital biases
- UCL models significantly mitigate these errors without using empirical terms
- UCL modelling 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 hope to continue working on a range of satellite missions such as SPOT & TOPEX
- Better modelling technologies now exist. They can, and should, be used

UCL TOPEX Geometry



Thankyou

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