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The GPS-SLR bias: dynamics, attitude and current experiments

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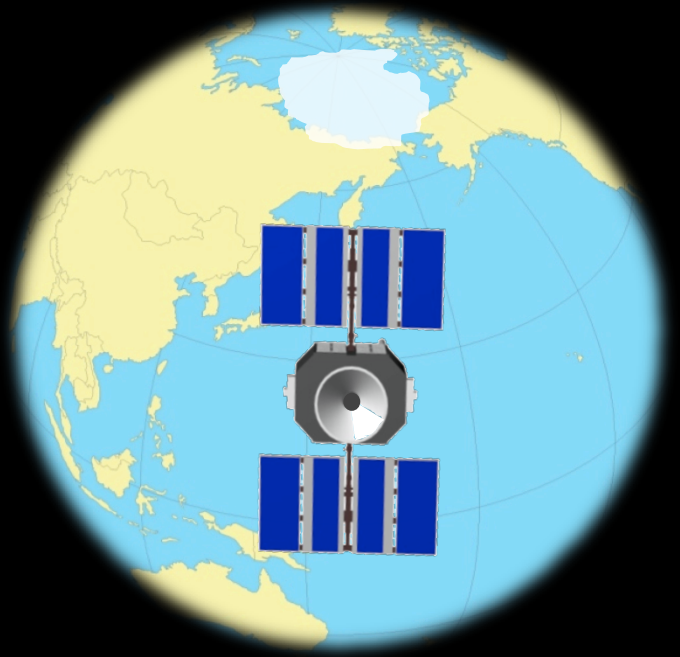
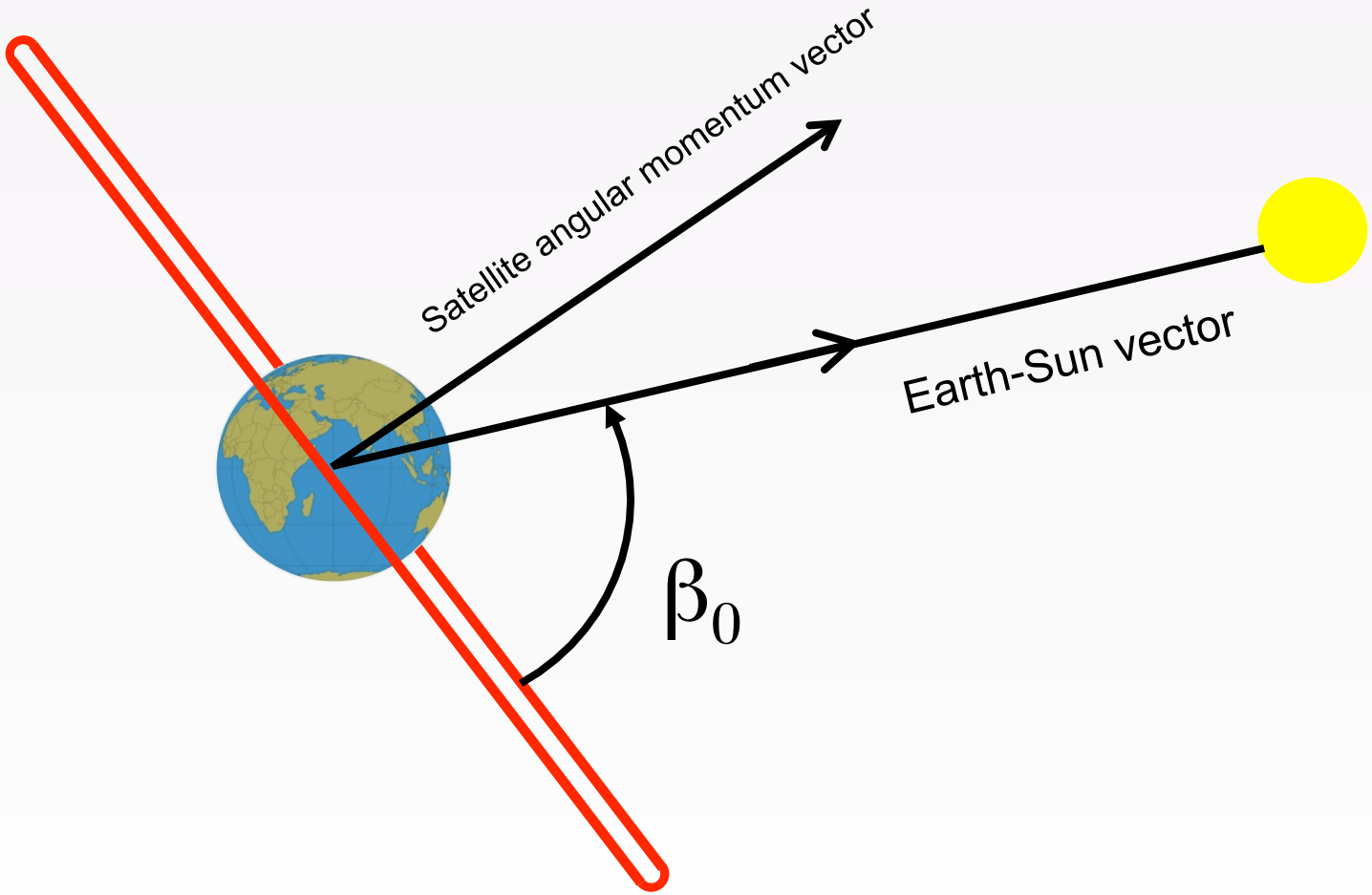


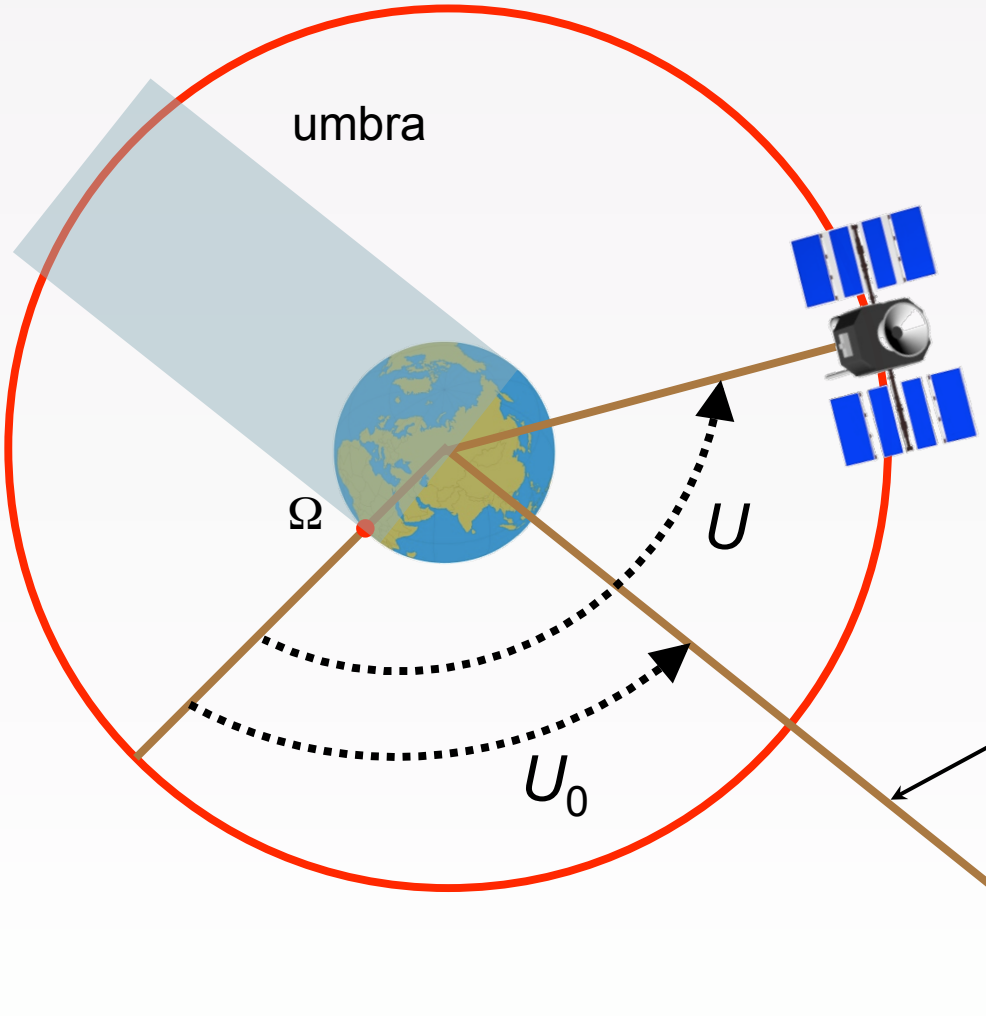
Issues addressed in presentation:

- Characterisation of the GPS-SLR bias
- Force modelling approaches that significantly reduce the bias
- Physical explanation for the improvements
- Issues concerning Block IIA attitude
- Implementation issues/choices
- On going experiments

Defining β_0



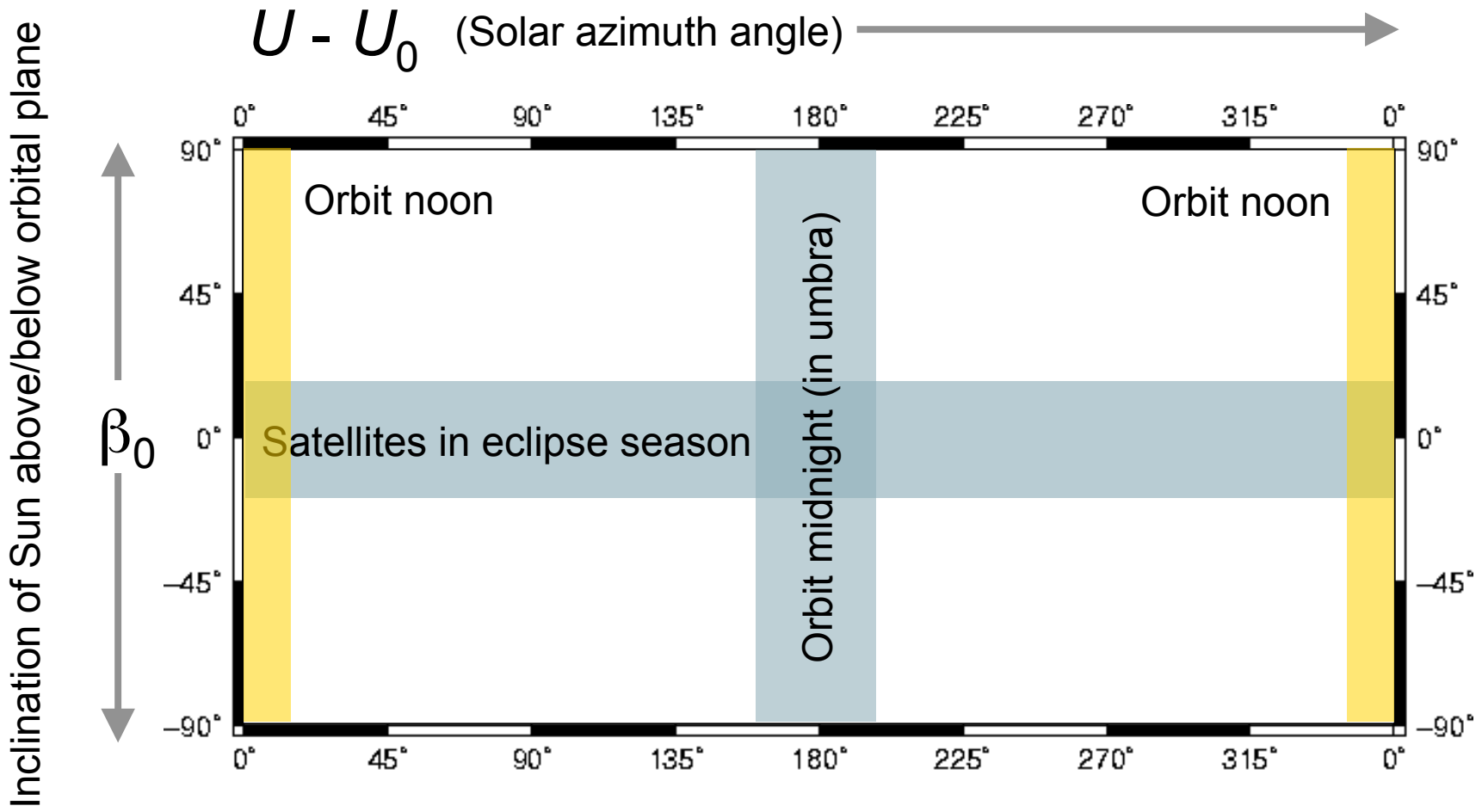
Defining $U - U_0$ (solar azimuth angle)

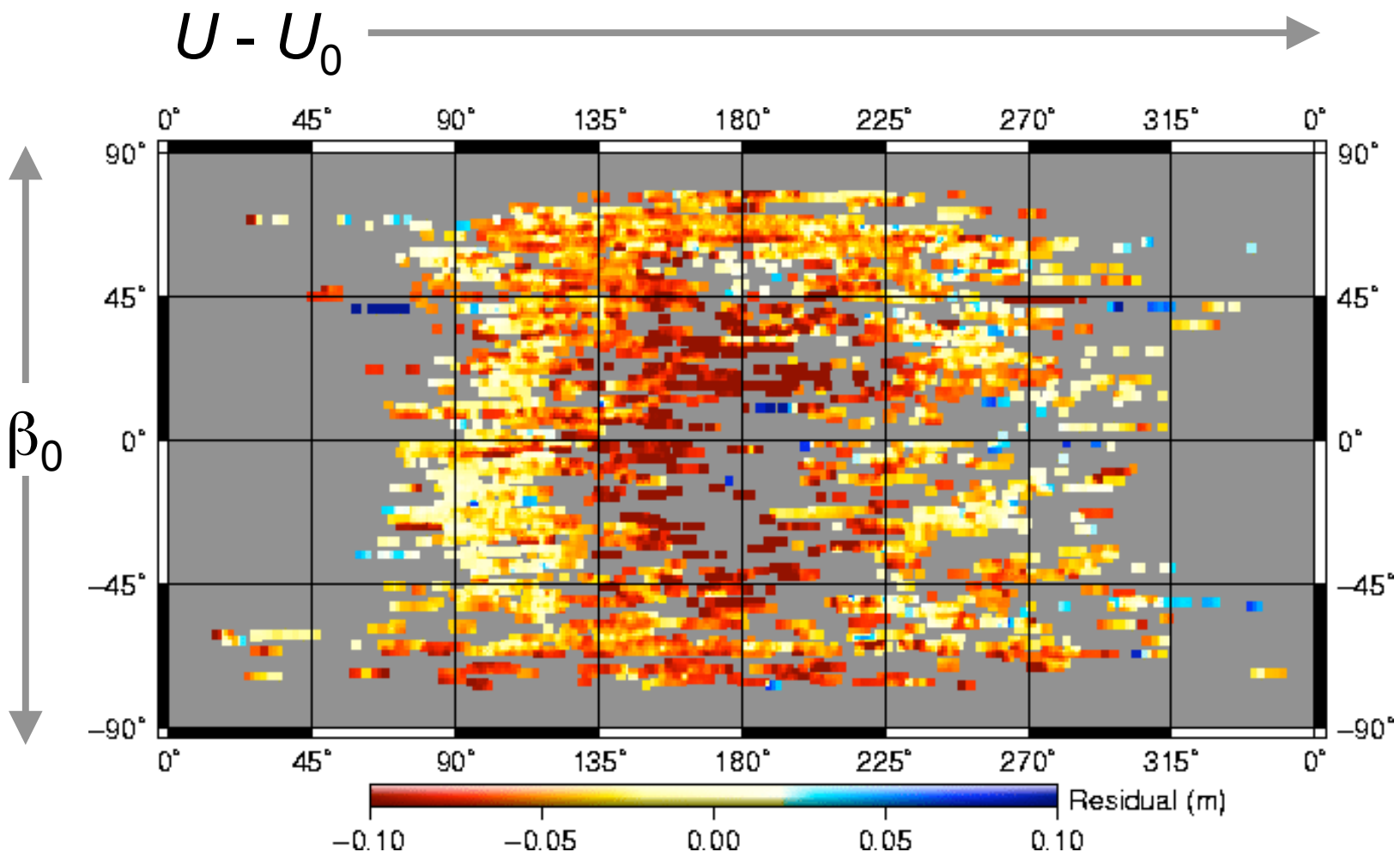


Ω = Right ascension of ascending node
U = argument of latitude
$U - U_0$ = solar azimuth angle

Earth-Sun direction projected onto orbital plane

Plot used to characterise SLR – GPS residuals





SLR – GPS two way range residuals
(divide by two for range residuals)

Progress in attacking the GPS - SLR bias

- Several groups have experimented with planetary radiation pressure models (UCL/JPL, ESOC, CNES)
- All report significant reduction in bias
- What characterises these forces?
- Why do they impact upon the bias?
- What should we do next?

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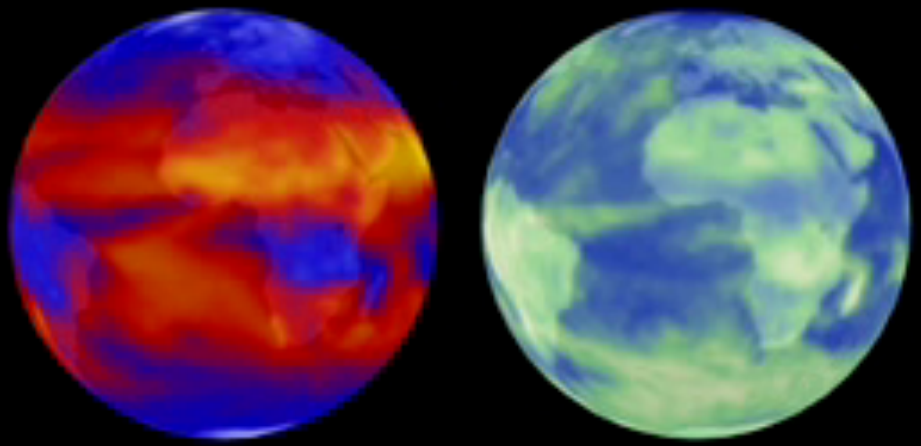
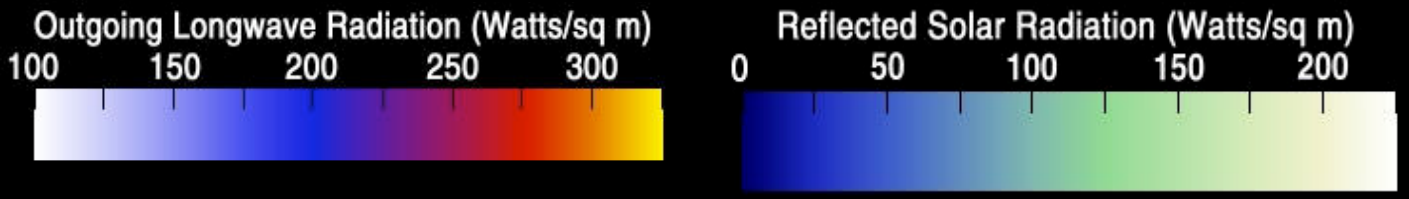
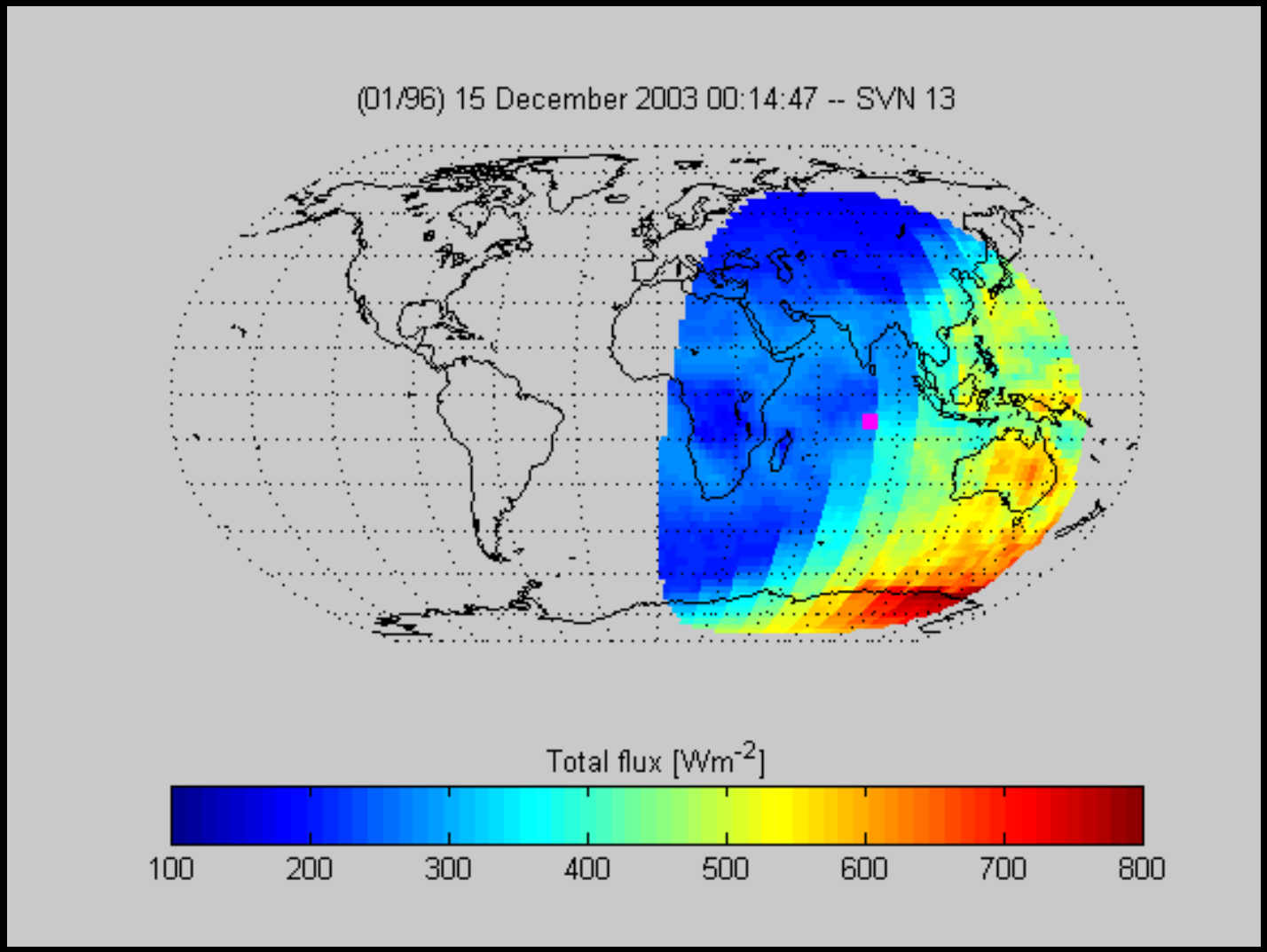
Earth radiation flux patterns



Mar 2000

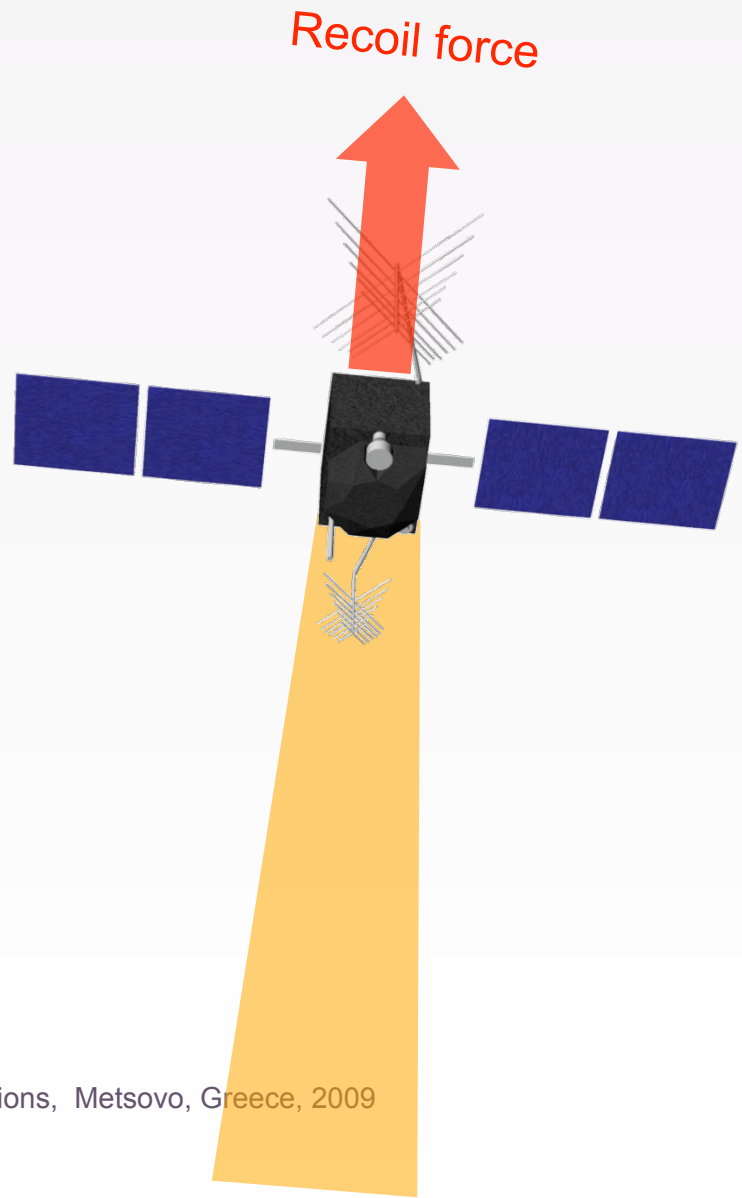




Radiation flux visible to SVN13, Dec 15th 2003

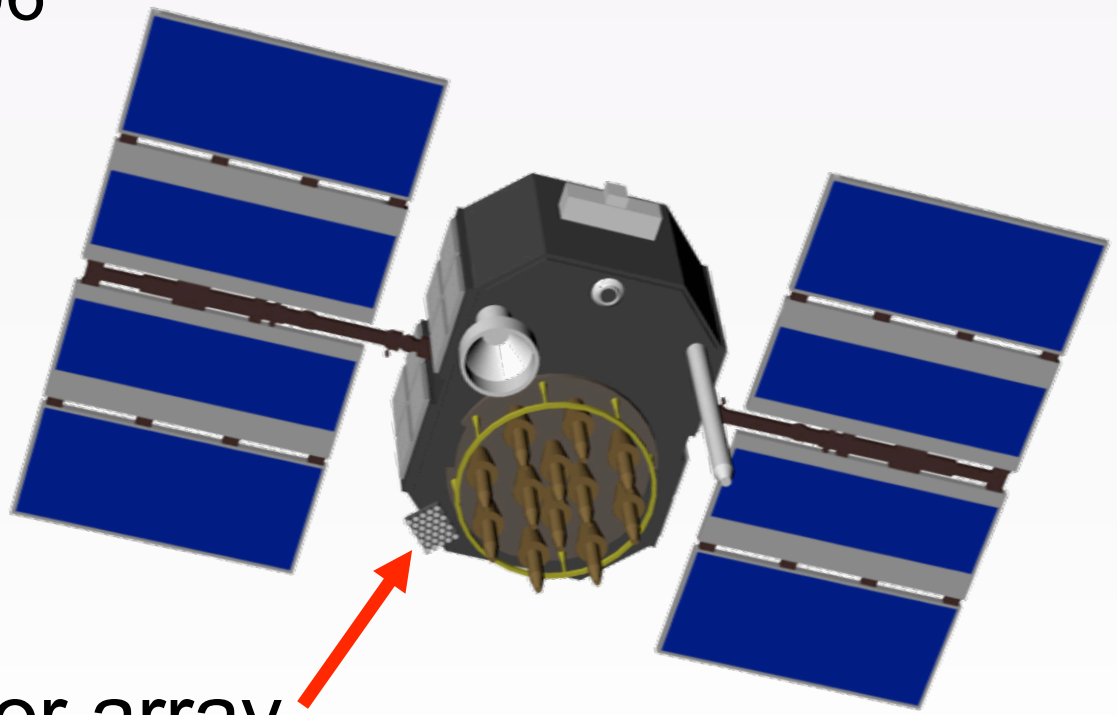
Antenna Thrust (AT)

- Recoil force on satellite due to transmitted L1/ L2 carriers
- Systematic and observable effect
- Requires knowledge of power transmission of satellites



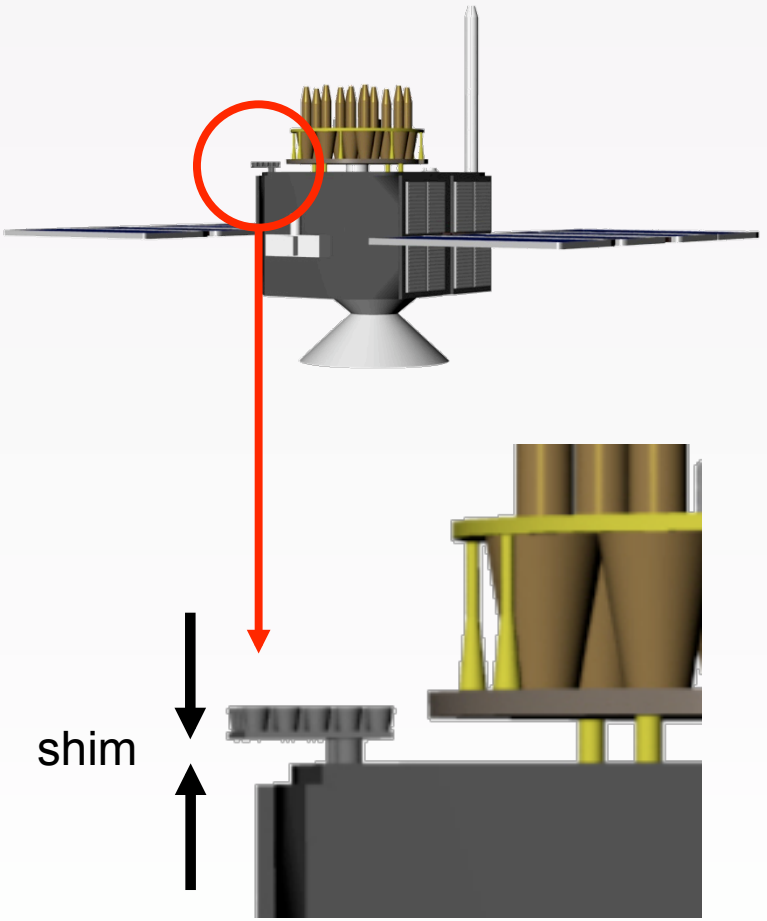
GPS satellites carrying retro-reflectors

- 2 Block IIA spacecraft
- PRN05, PRN06

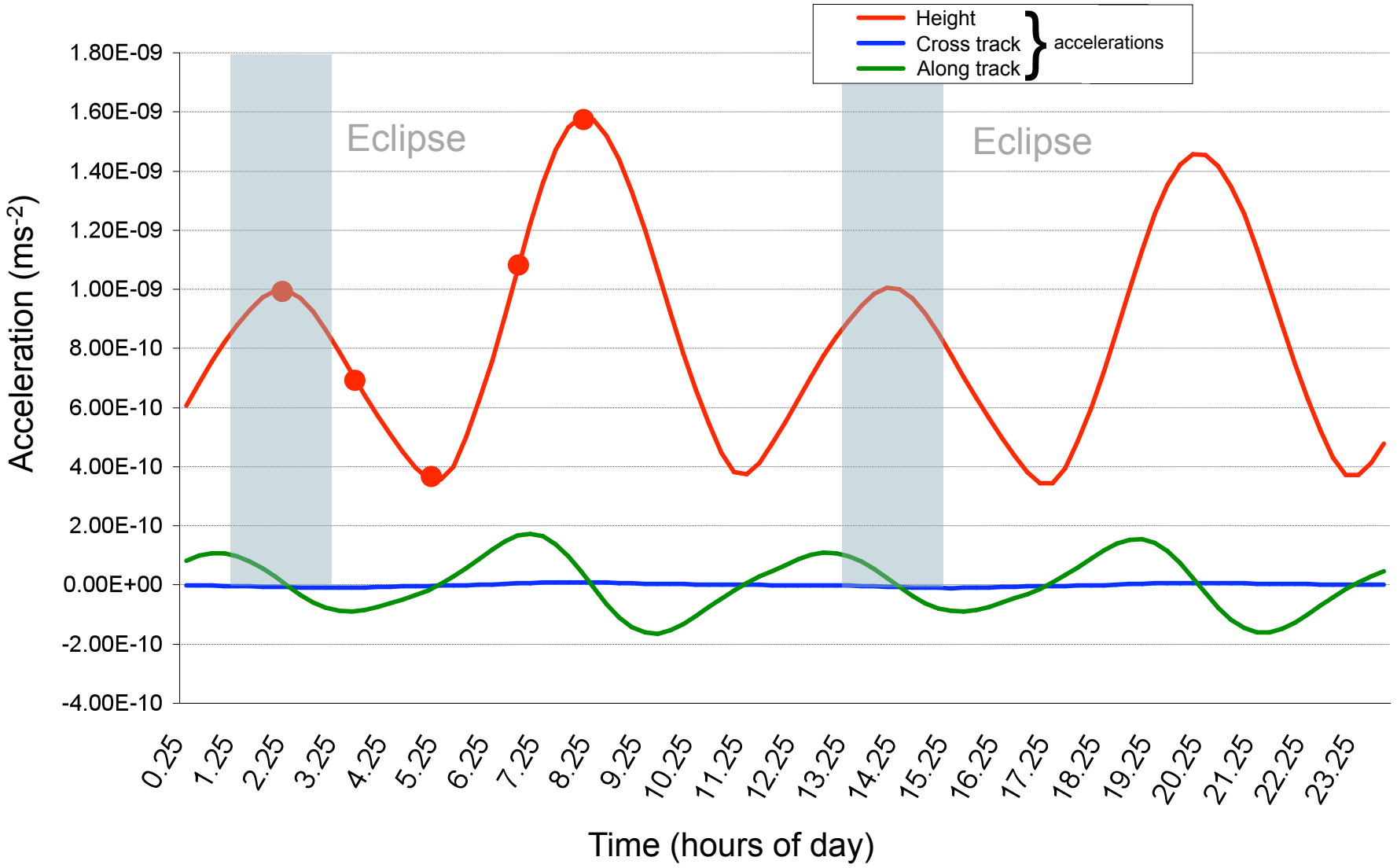


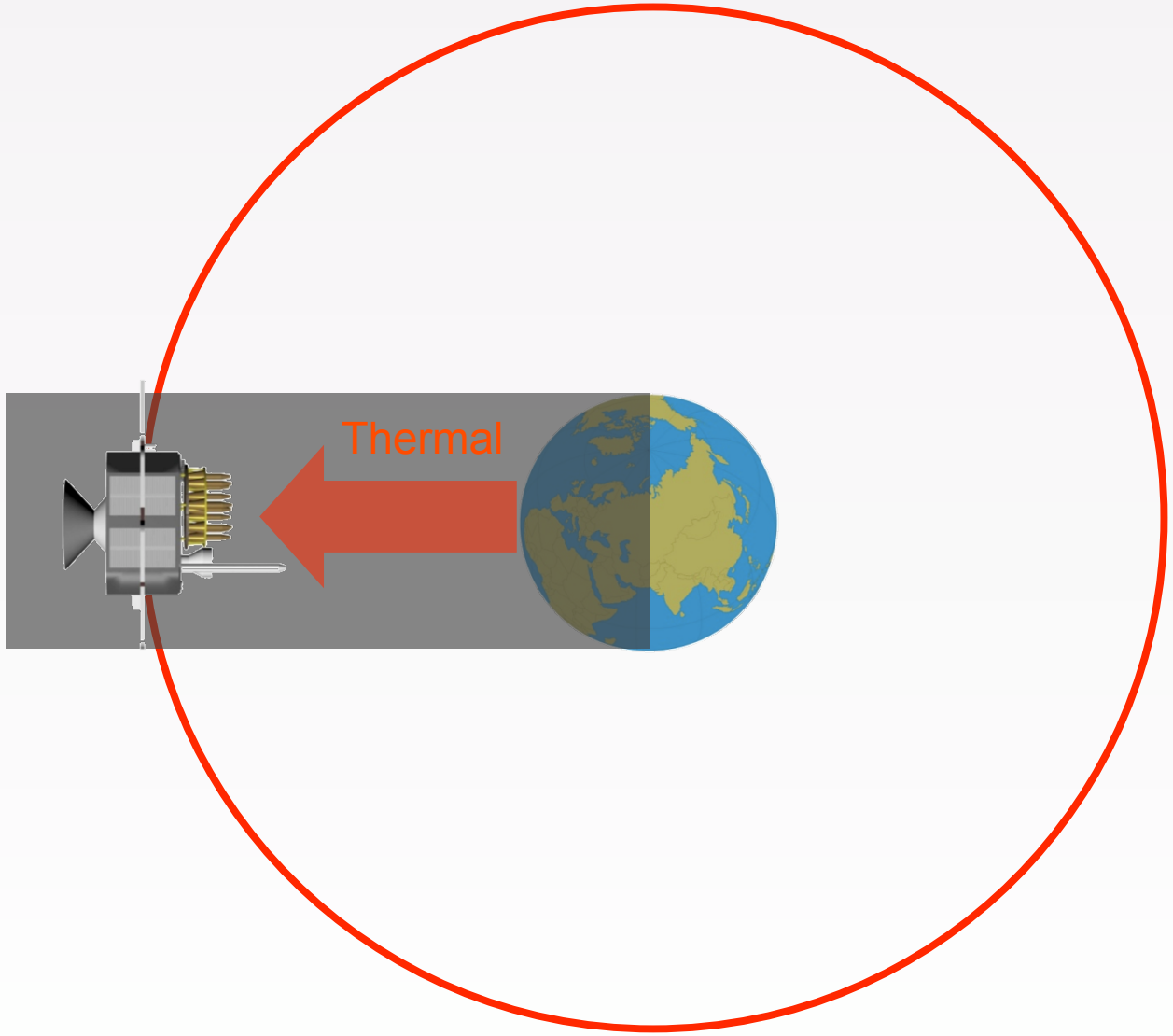
Laser Retro-reflector Array (LRA) offset

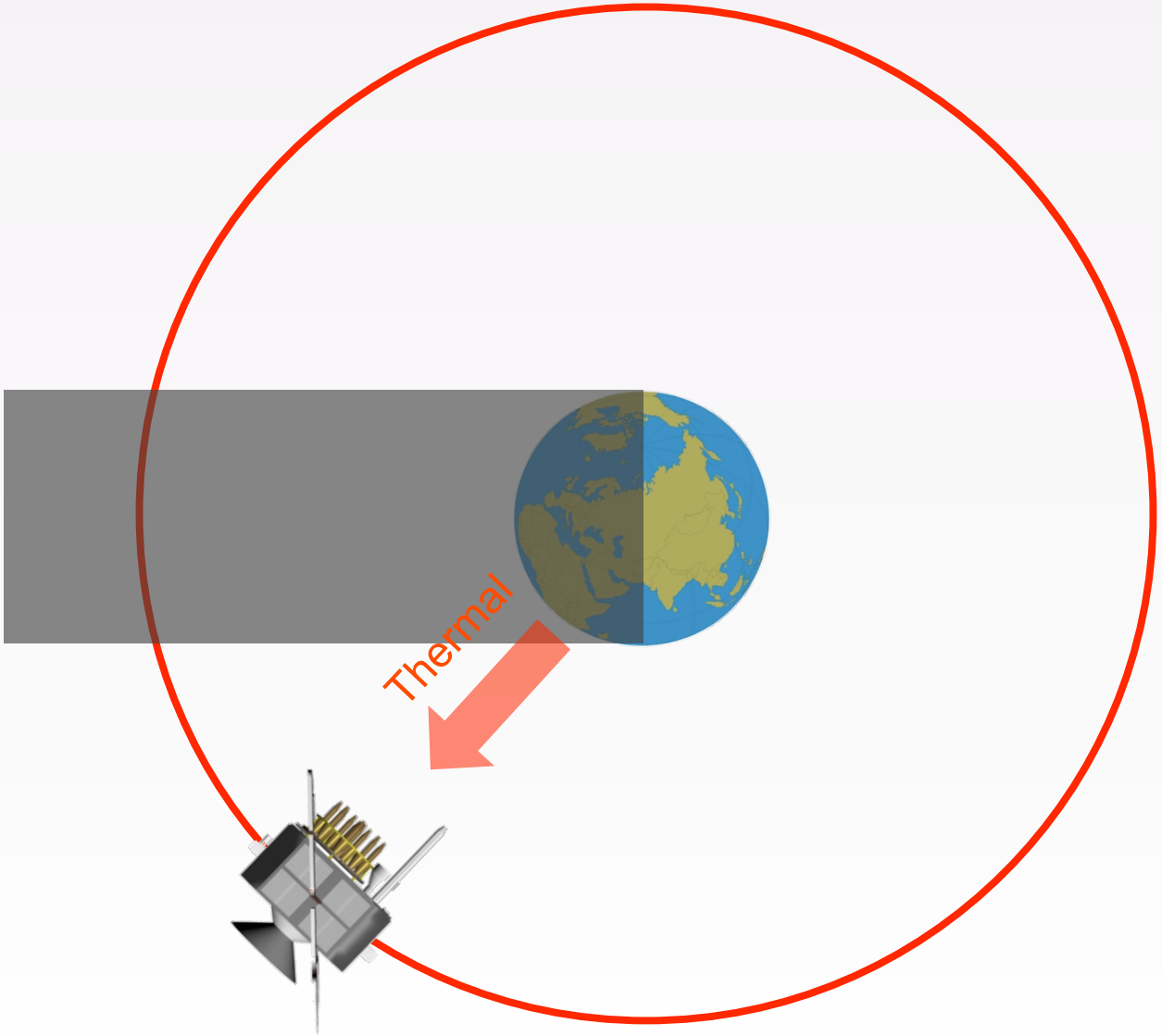
- LRA position in s/c body frame required for analysis of laser ranging
- New data suggests LRA offset further from centre of mass than previously understood
- Shim corrections: +11 mm (PRN05), +13 mm (PRN06)

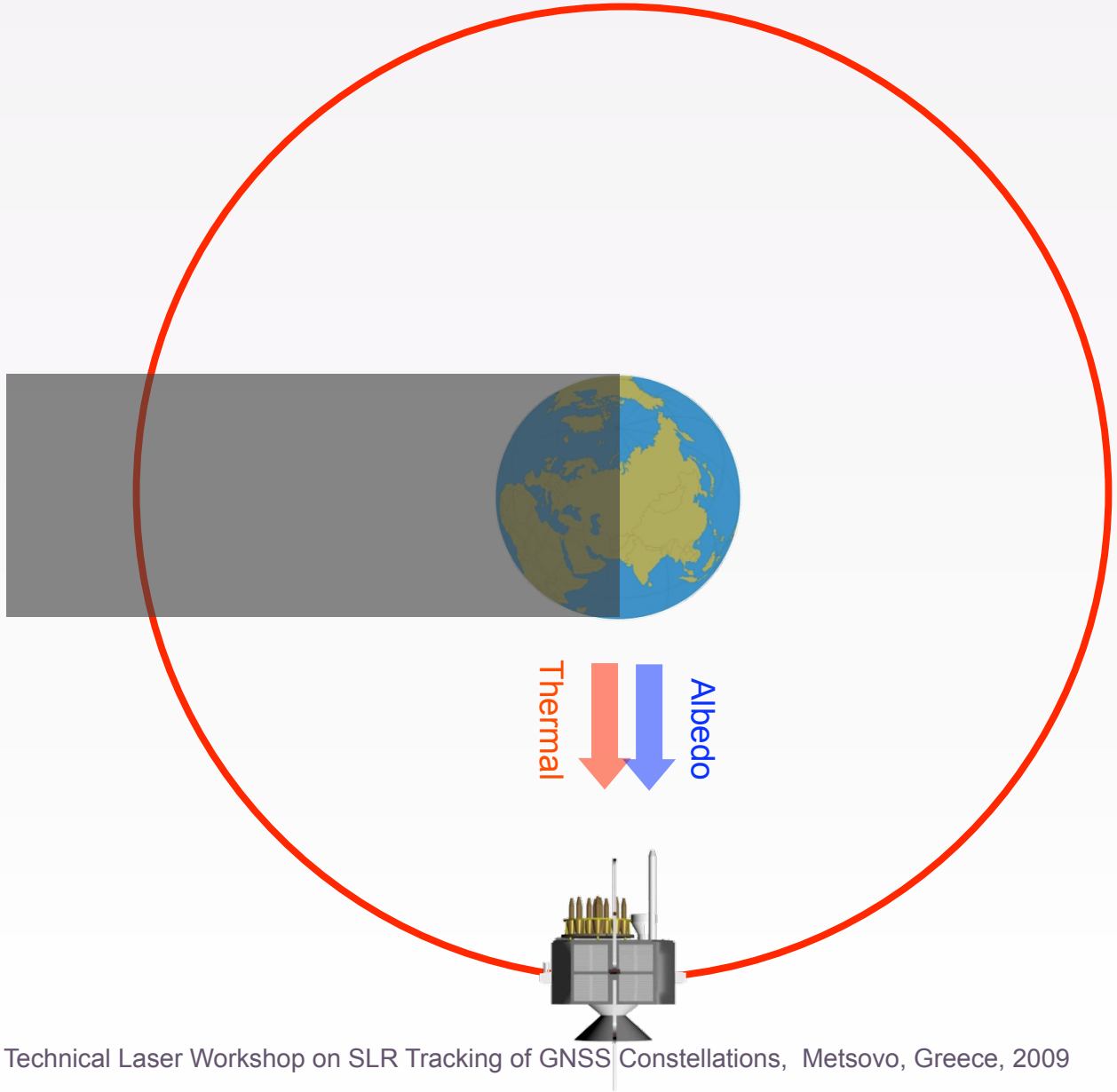


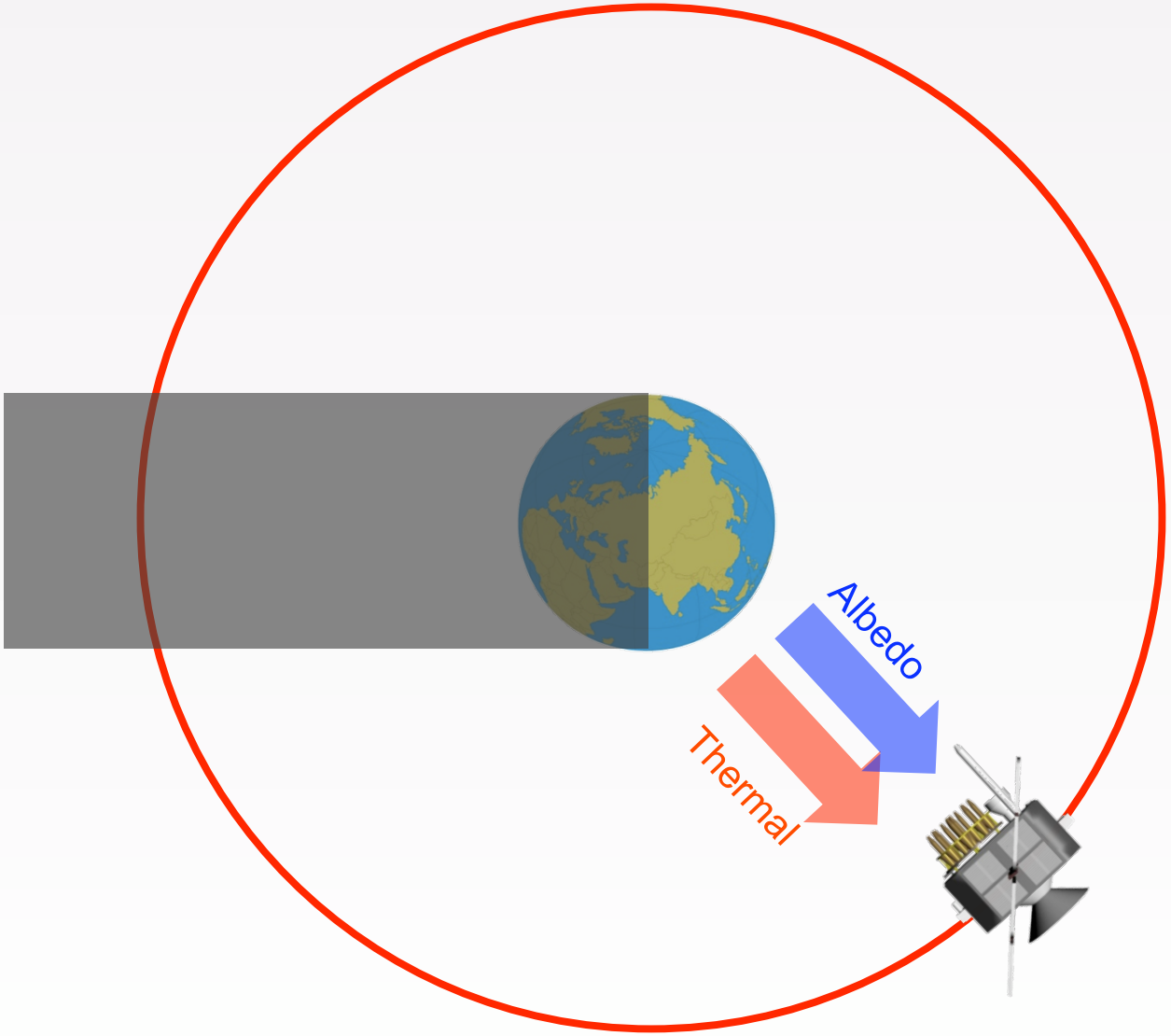
Modelled Earth Radiation pressure (SVN35, UCL ADM model

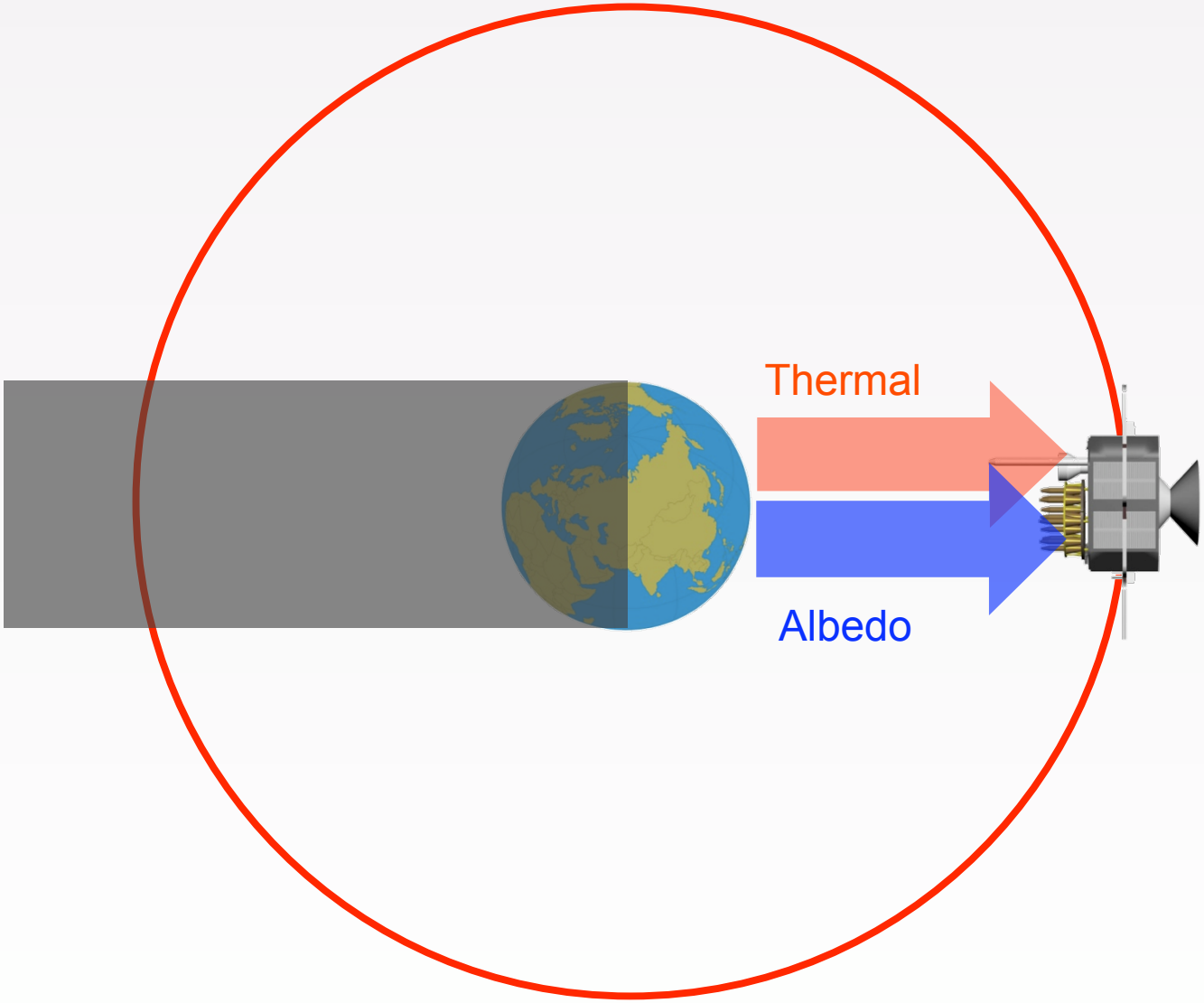



Thermal


Thermal


Thermal
Albedo


Albedo
Thermal


Thermal
Albedo

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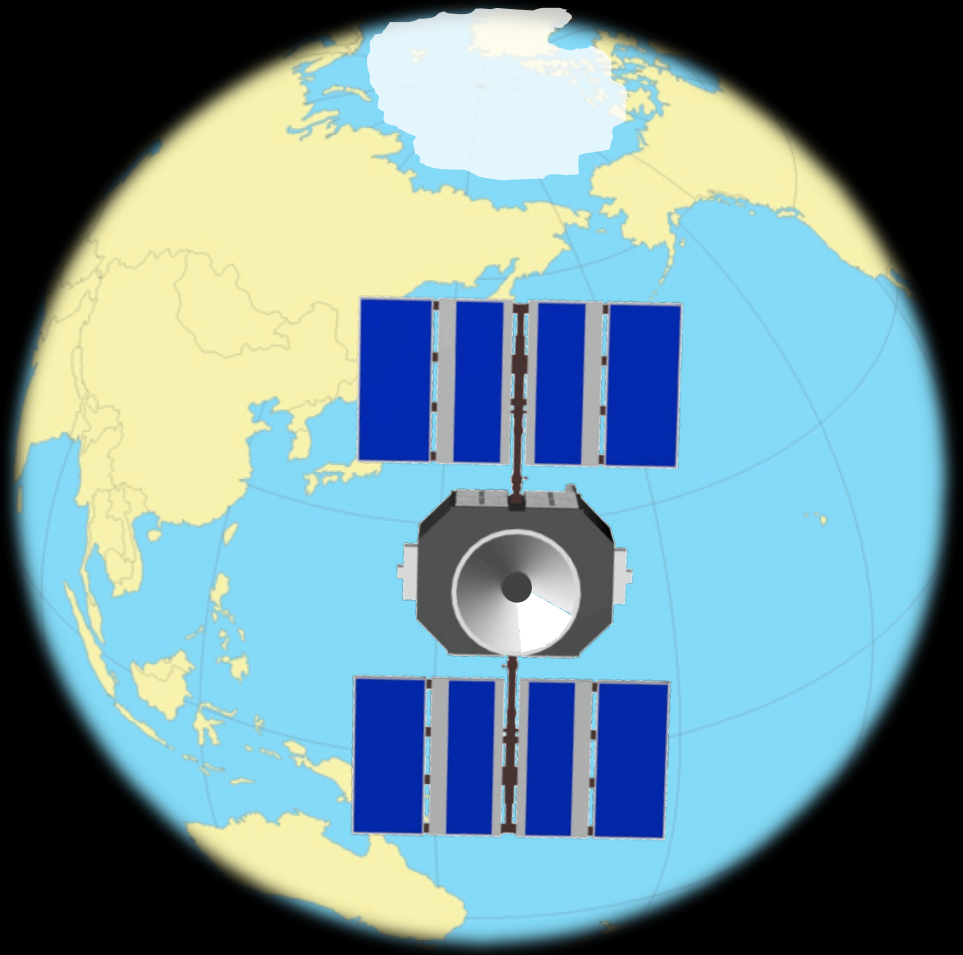
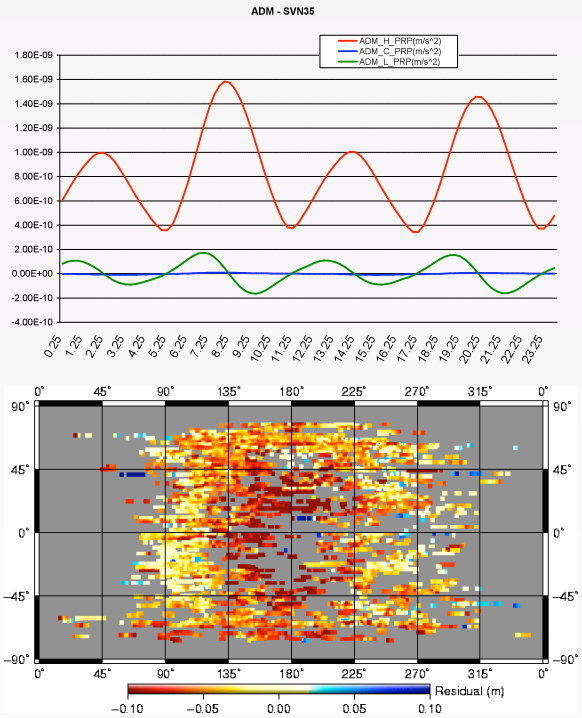
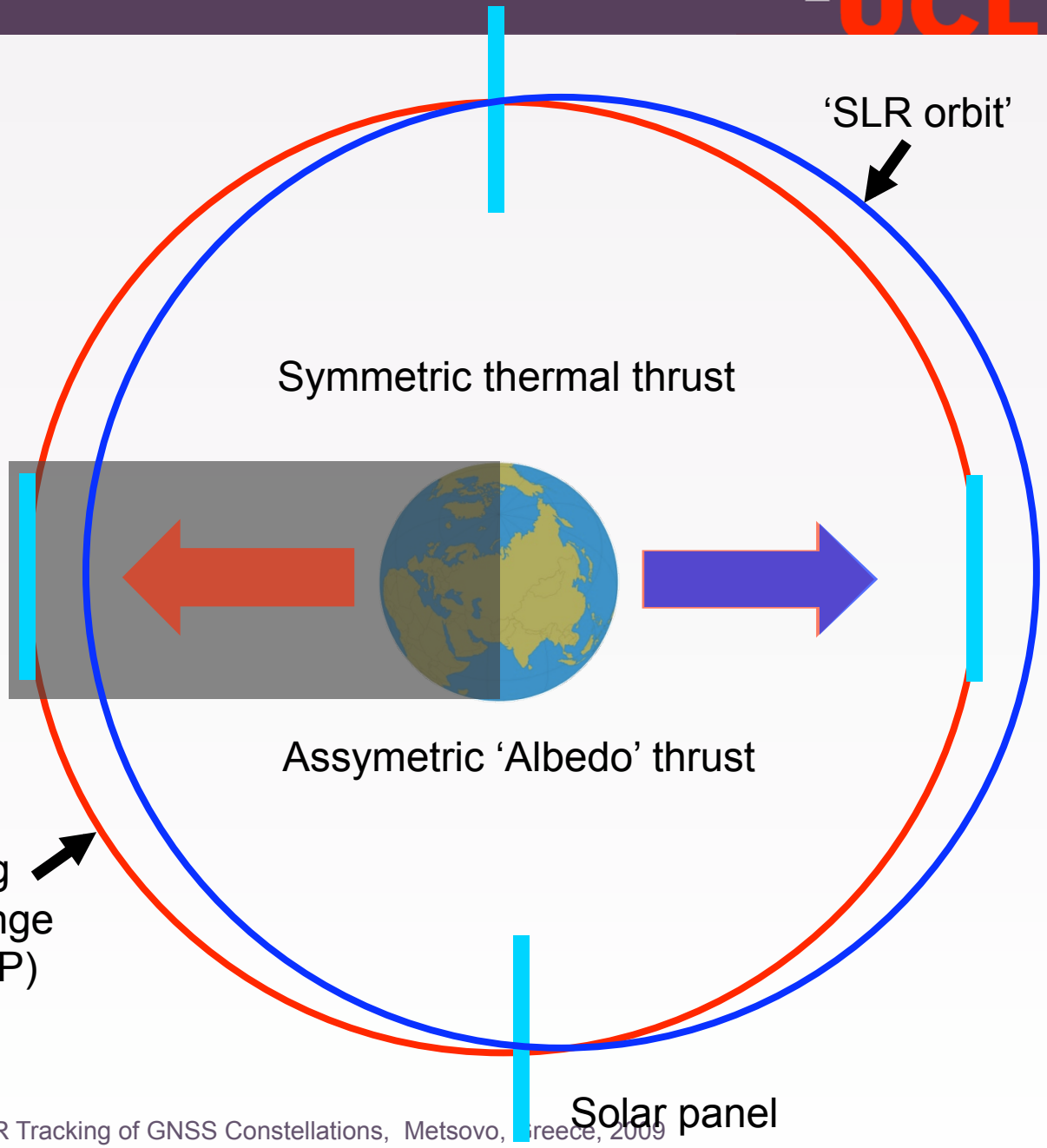


Explanation



Orbit estimated using using phase/pseudorange (without modelling PRP)



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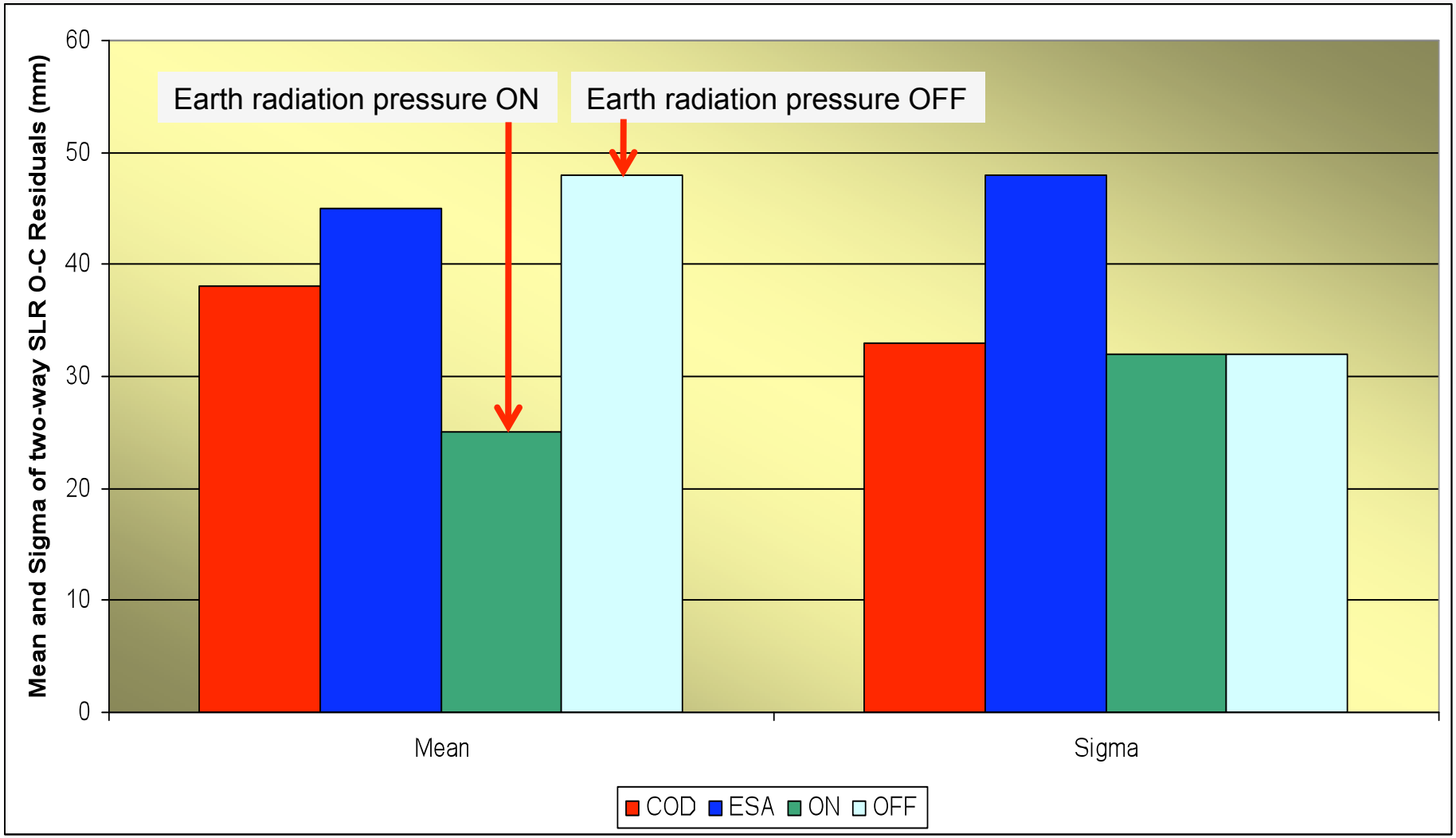
SLR Validation of ESOC Reprocessed Orbits: Two way laser ranging residuals to SV35 and SV36



Which PRP modelling method to adopt?

- Knocke-Ries model (basic, but proven, existing Fortran code)
- CERES/ERBE model, Lambert assumption
- CERES/ERBE Angular distribution model (ADM)
- ECMWF models (CNES implementation)
- CODE empirical model

Multi-centre experiment, aims

- Participants: University of Berne; CNES; ESOC; JPL and UCL
- Test varying approaches to Earth radiation pressure modelliing
- Assess impact on the GPS-SLR bias
- Assess impact of bias (and its elimination) on the global polyhedron, orbits, clocks, day boundary effect
- Assess impact on ITRF computation

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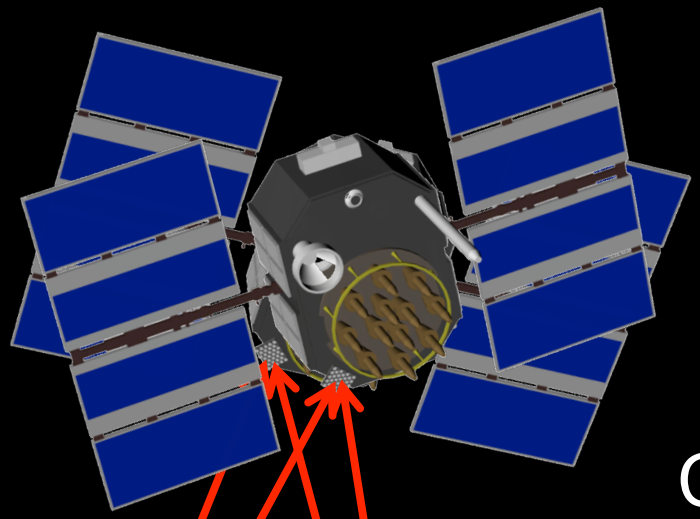
A brief comment on attitude: observing yaw state through SLR analysis



Can discriminate Yaw state through Laser analysis

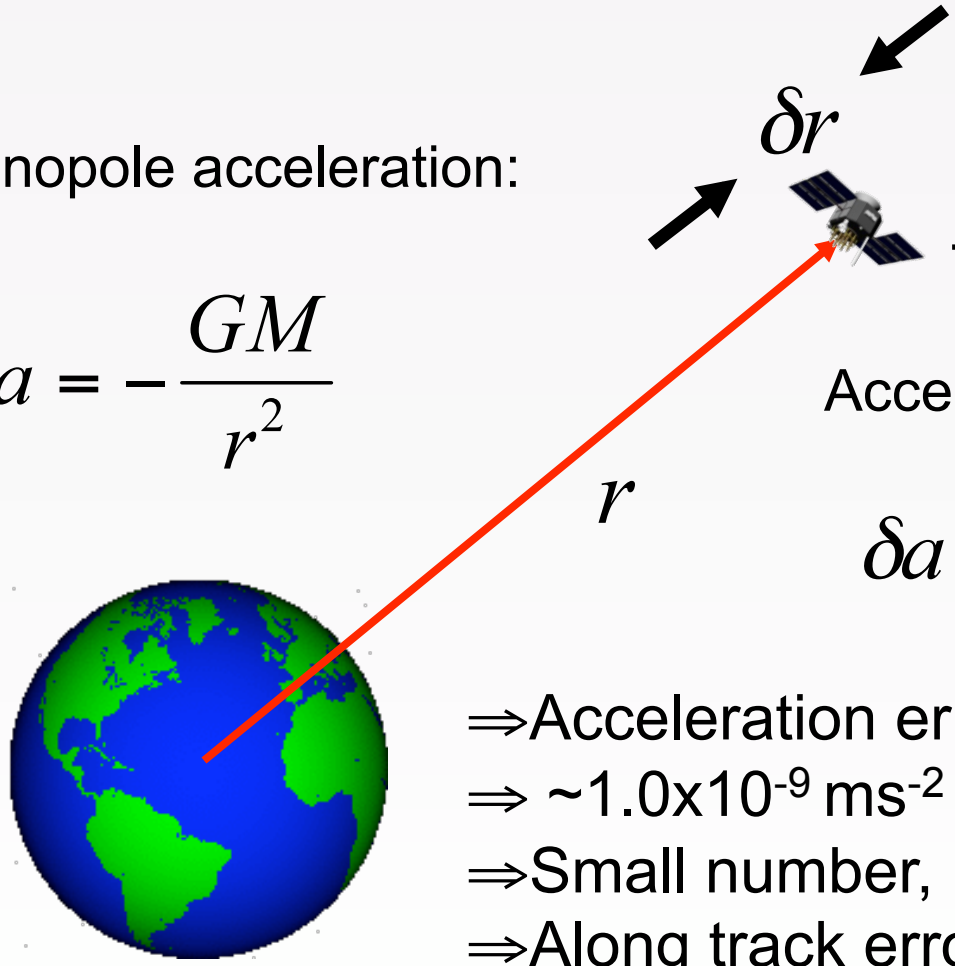
1 or 2 cm bias on orbit? Why should we care?

- Altitude determination of satellite altimetry sensors
- Orbit prediction

Gravity field mis-modelling in orbit prediction

Monopole acceleration:

$$a = -\frac{GM}{r^2}$$



Estimated position

True position of satellite

Acceleration error:

$$\delta a = \frac{2GM\delta r}{r^3}$$

⇒Acceleration error of:
⇒ ~1.0x10^{-9} ms^{-2}
⇒Small number, big effect in time
⇒Along track error of ~1.0m (12 hrs)

Conclusions

- GPS-SLR bias primarily affects satellites either in, or near to, eclipse season (circa half the constellation at any one time)
- ‘bias’ reaches 4-5 cm around an arc on the dark side of the Earth (mean ‘bias’ = ~ 2 cm)
- Modelling Earth Radiation Pressure effects significantly reduces the GPS-SLR bias
- Modelling antenna thrust reduces bias further
- Experiment underway to test impact on frame, clocks, orbits
- Great success story for the value of SLR data in system analysis