JPL esoc UCL

Refinements in GNSS Orbit Modelling

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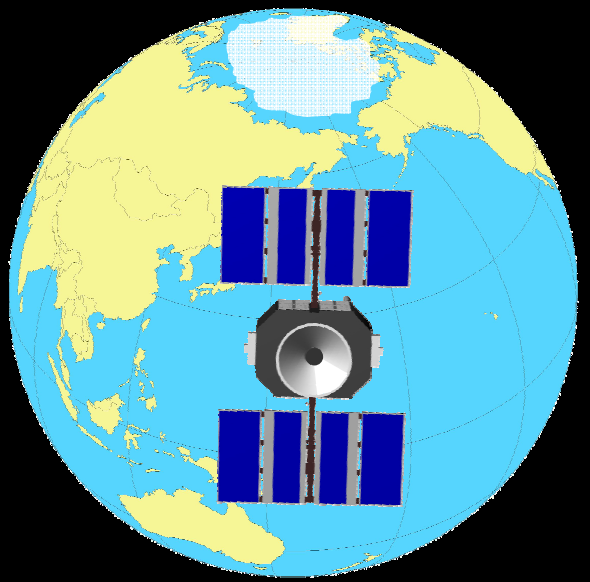
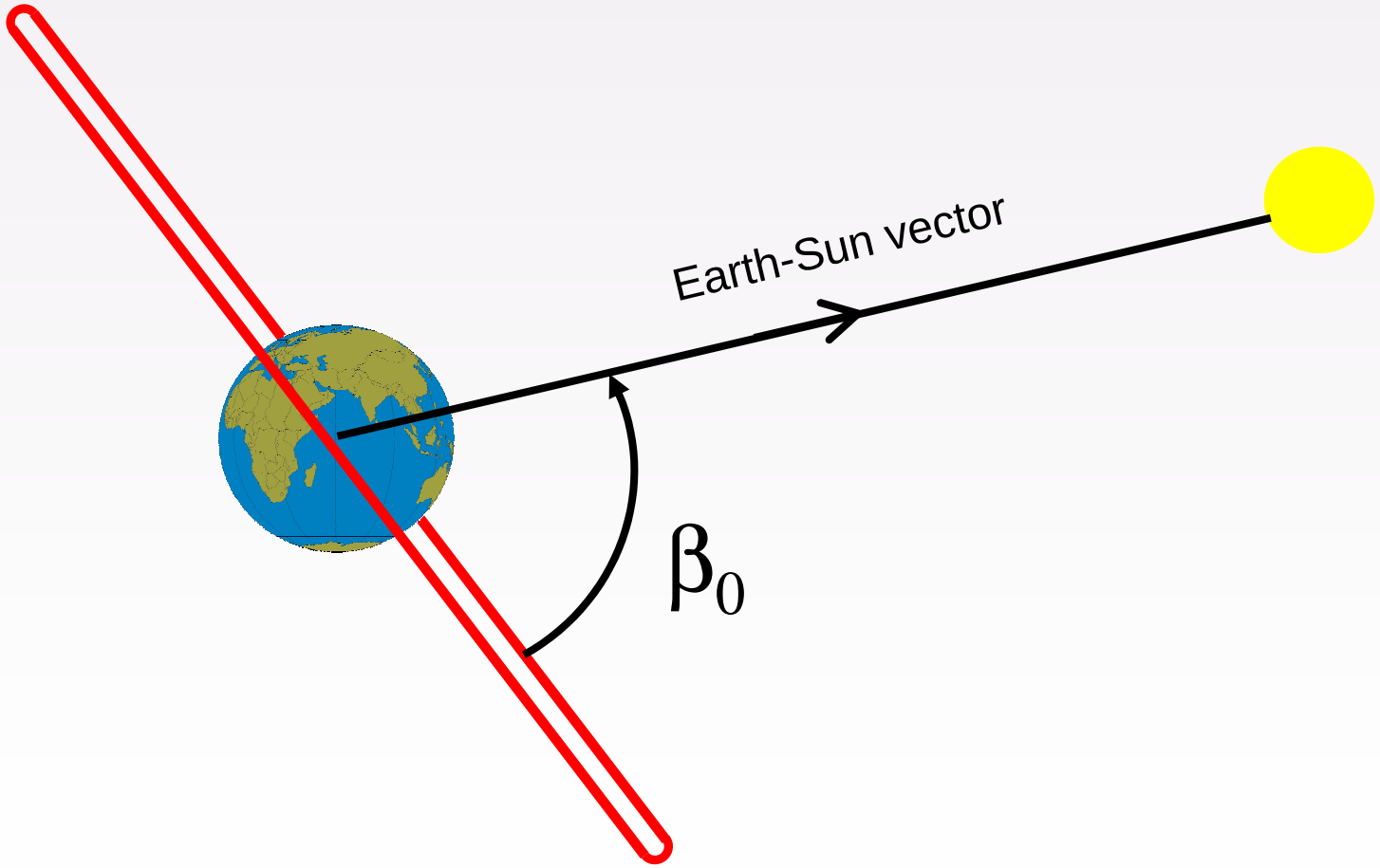


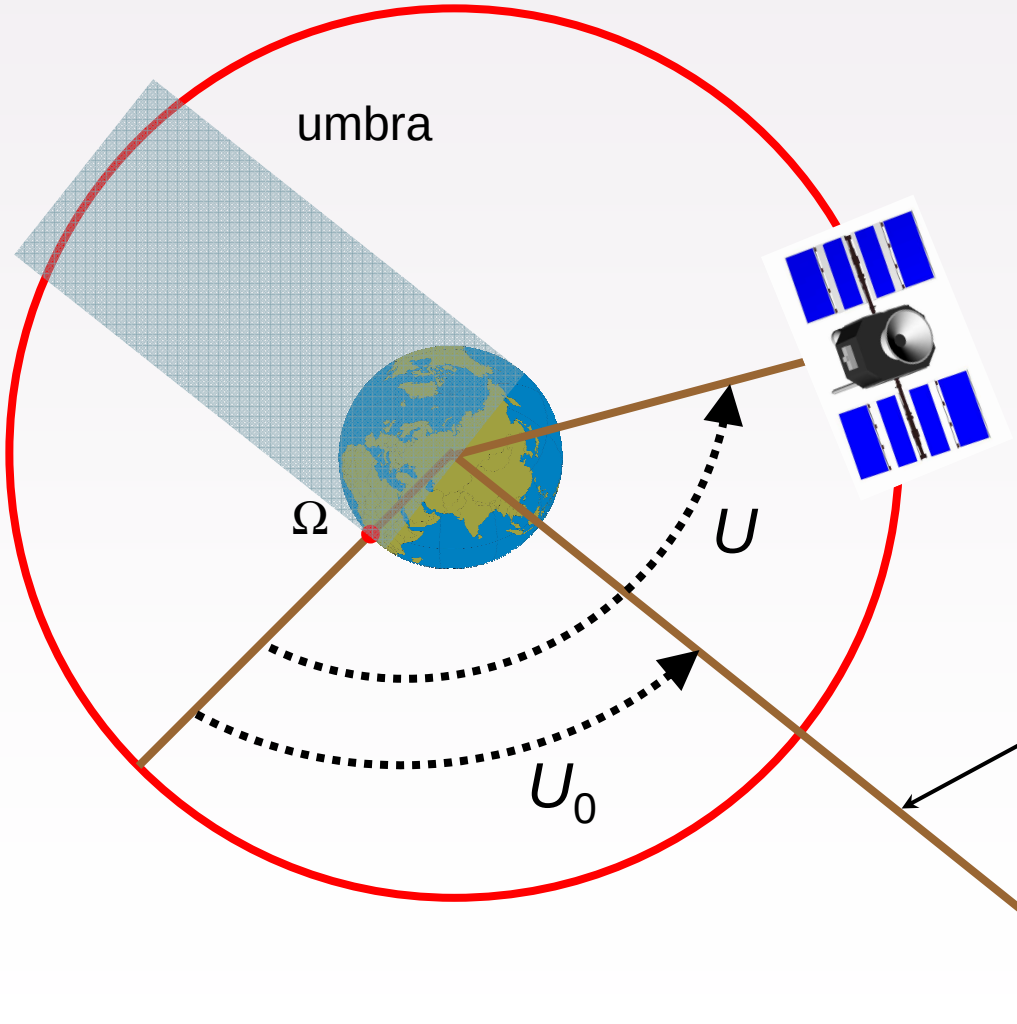
Issues addressed in presentation:

- Characterisation of the GPS-SLR bias
- Force modelling approaches that significantly reduce the bias
- Physical explanation for the improvements
- Implementation issues/choices
- Future developments

Defining β_0

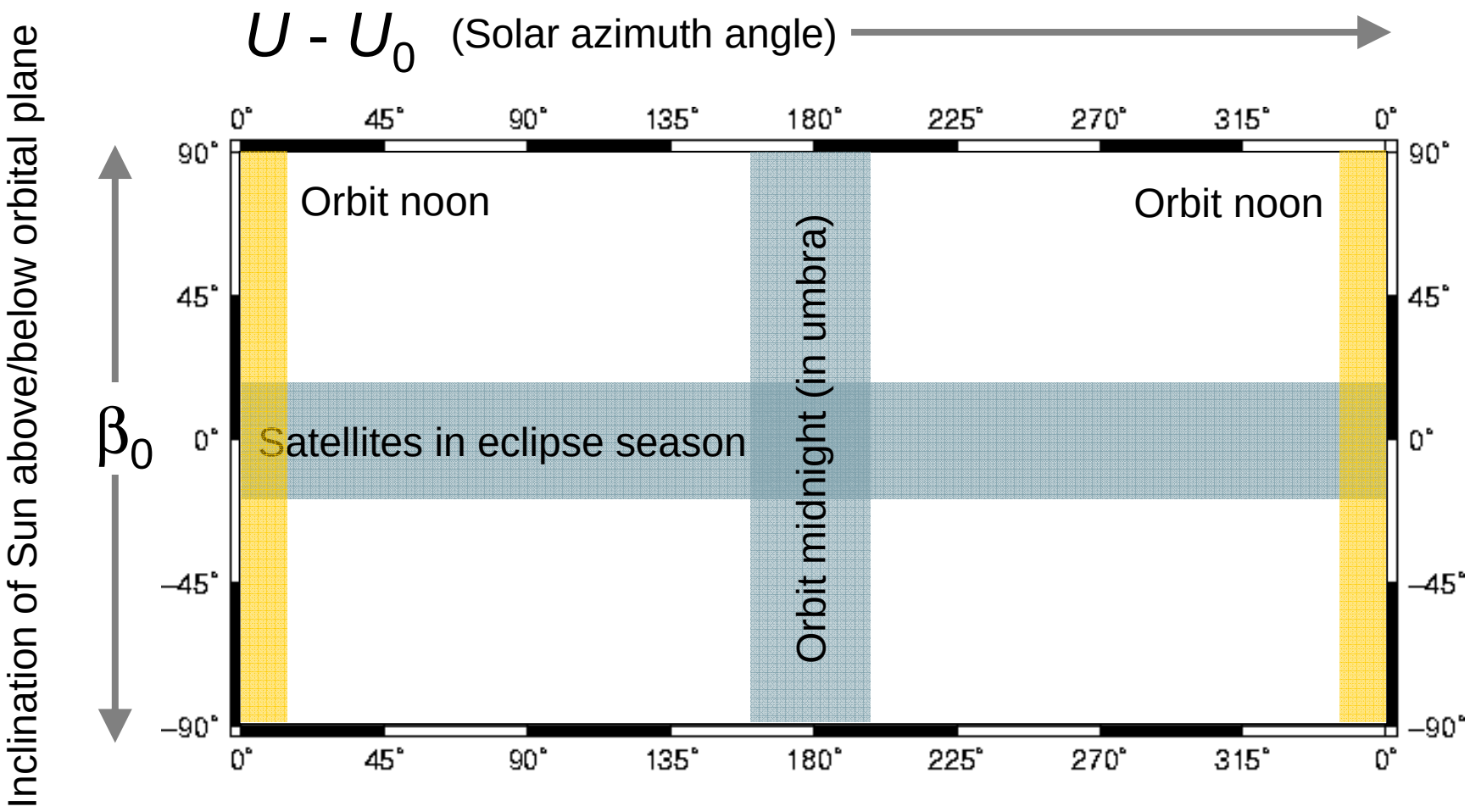


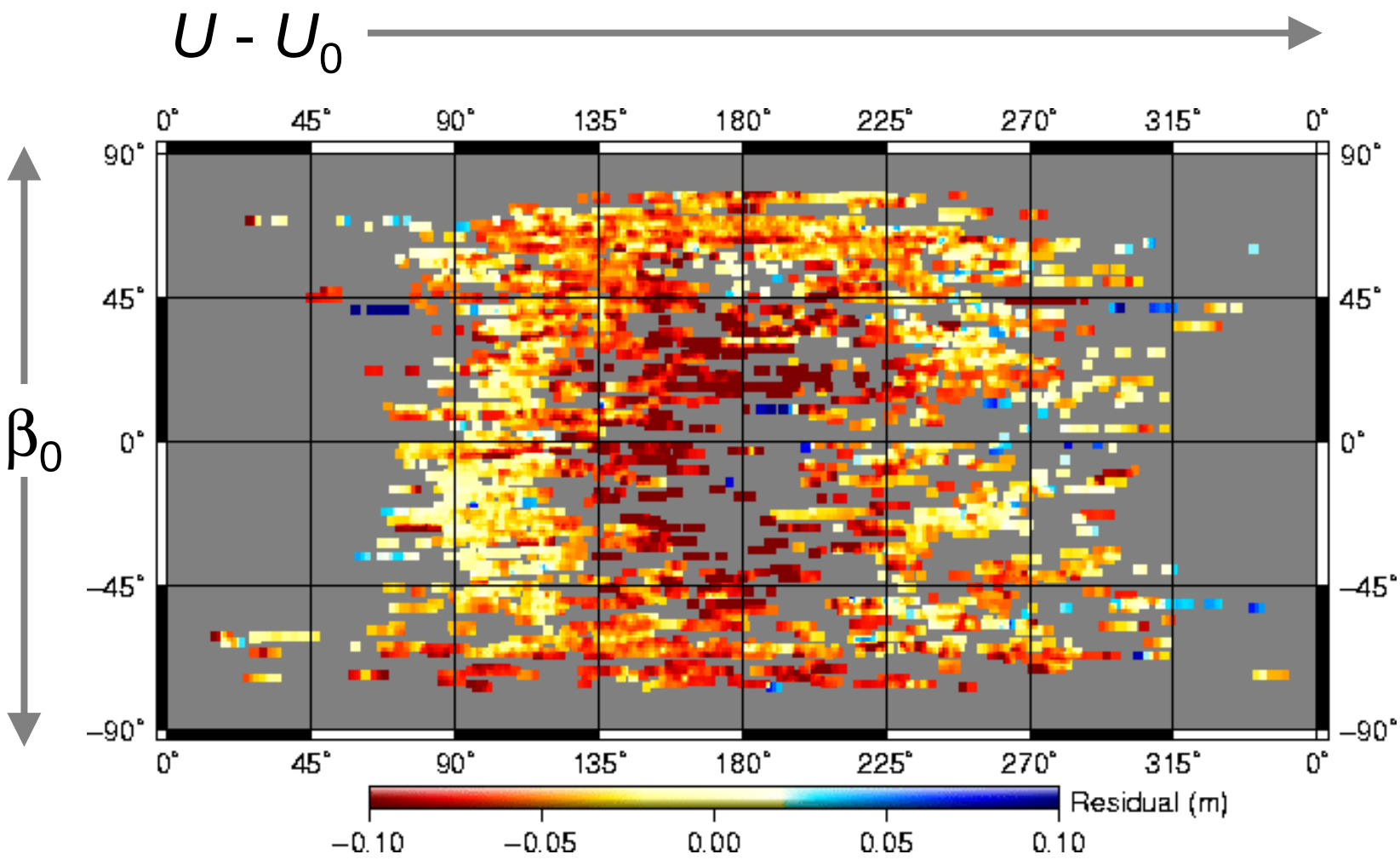
Defining $U - U_0$ (solar azimuth angle)



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

Earth-Sun direction projected onto orbital plane


U - U0 (Solar azimuth angle)
Inclination of Sun above/below orbital plane
β0
0° 45° 90° 135° 180° 225° 270° 315° 0°
90°
45°
0°
–45°
–90°
Orbit noon
Orbit noon
Orbit midnight (in umbra)
Satellites in eclipse season

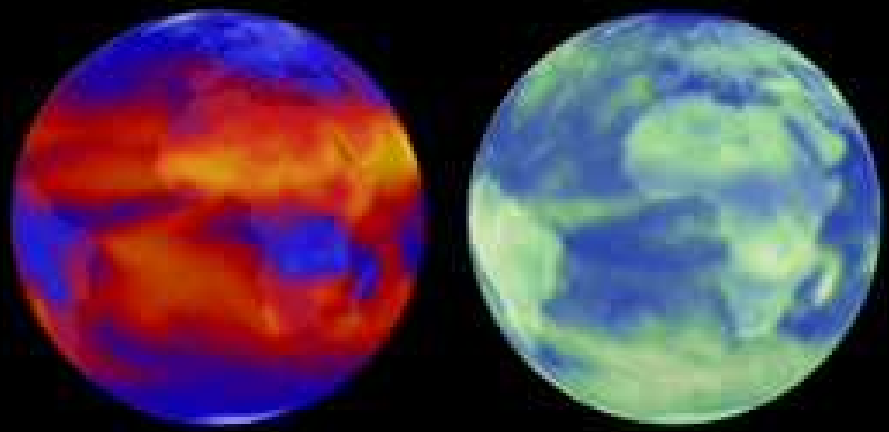


SLR – GPS two way range residuals
(divide by two for range residuals)

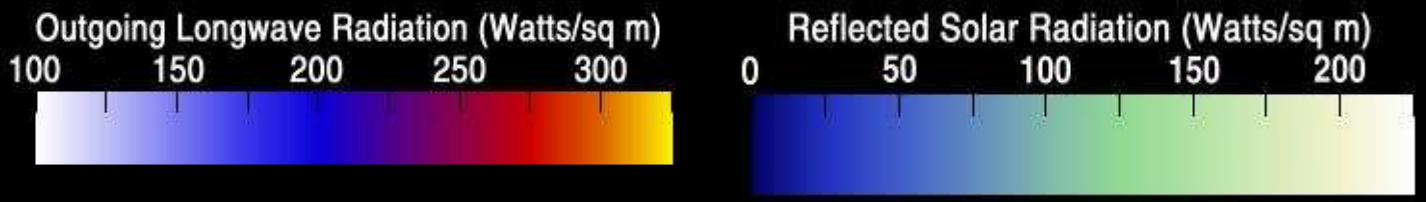
Progress in attacking the GPS - SLR bias

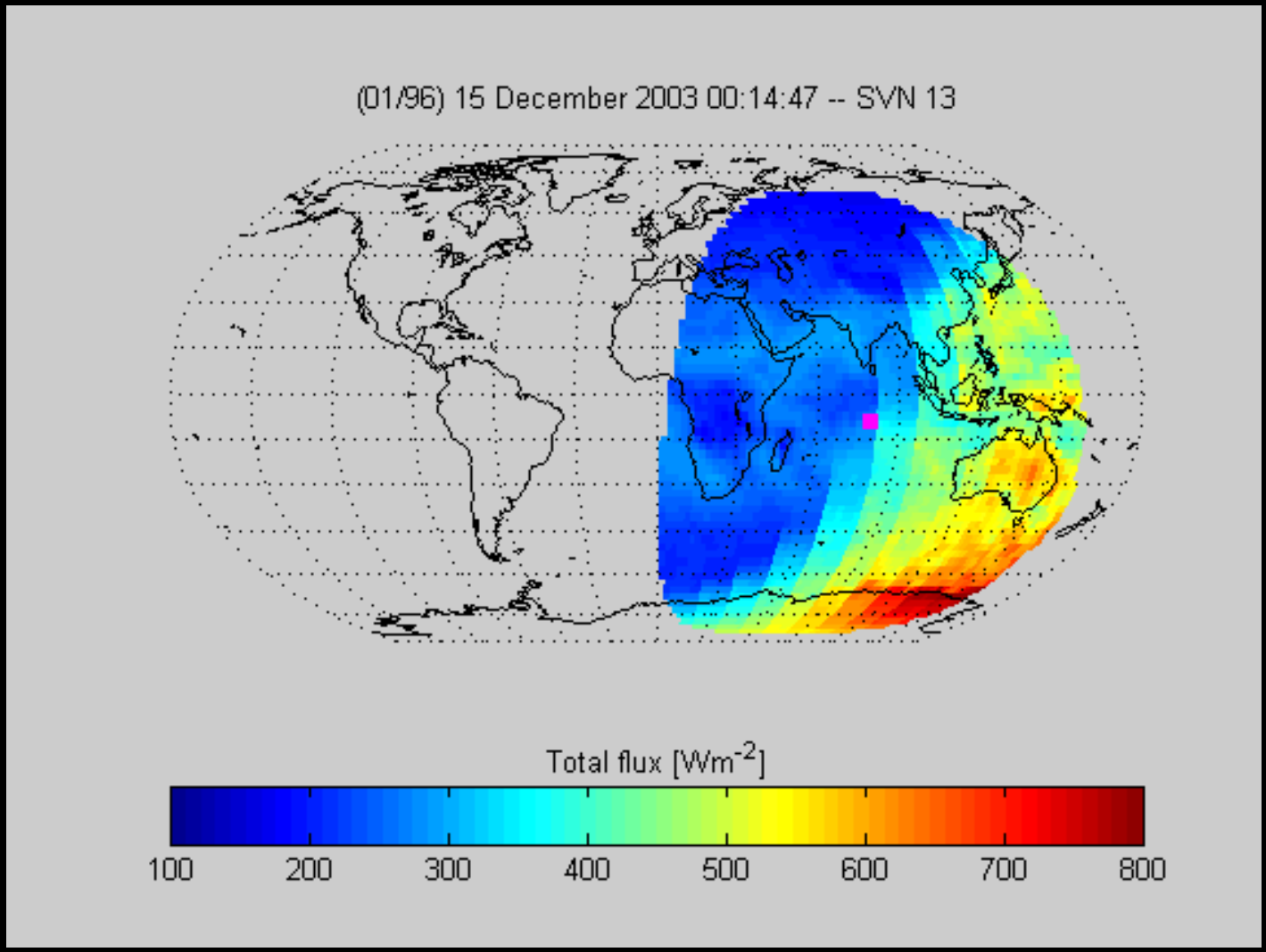
- Several groups have experimented with planetary radiation pressure models (UCL/JPL, ESOC, CNES)
- All report significant reduction in bias
- What characterises these forces?
- Why do they impact upon the bias?
- What should we do next?

Earth radiation flux patterns



Mar 2000

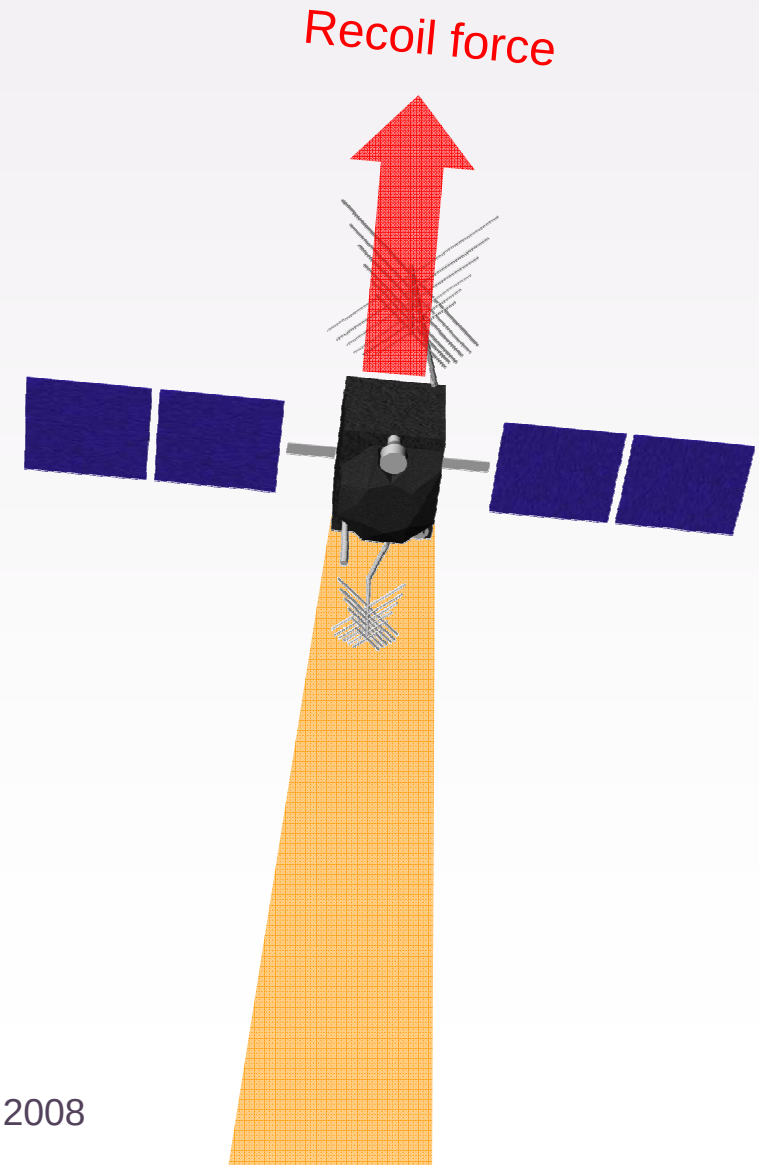




Radiation flux visible to SVN13, Dec 15th 2003

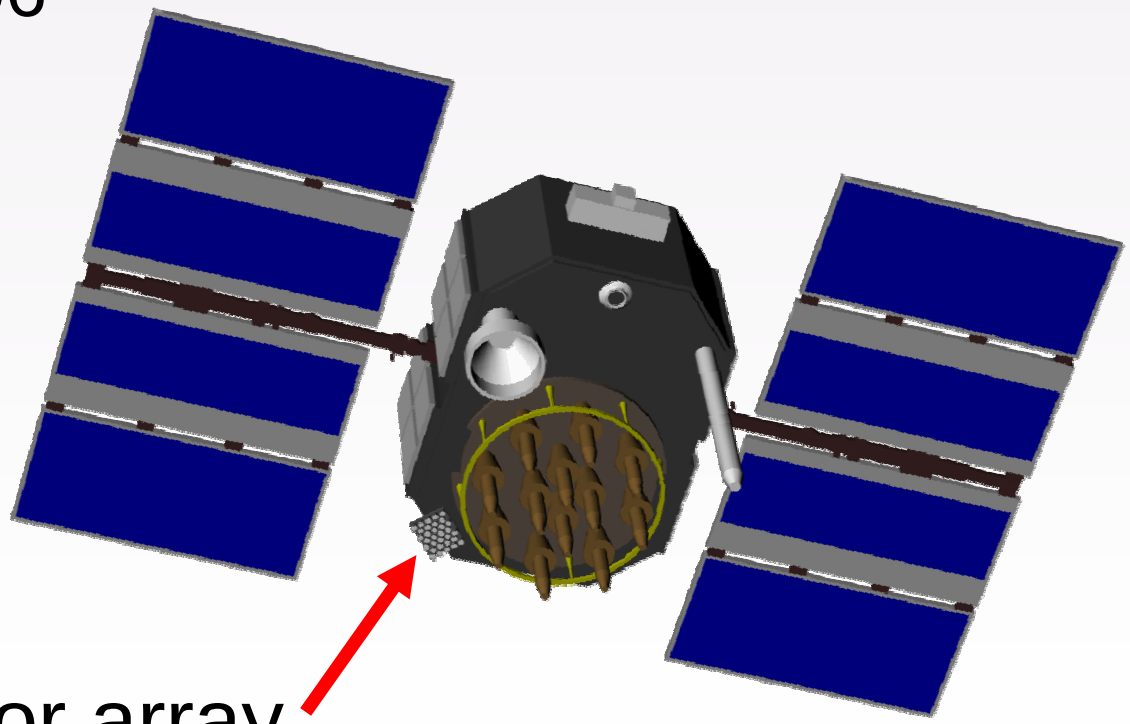
Antenna Thrust (AT)

- 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

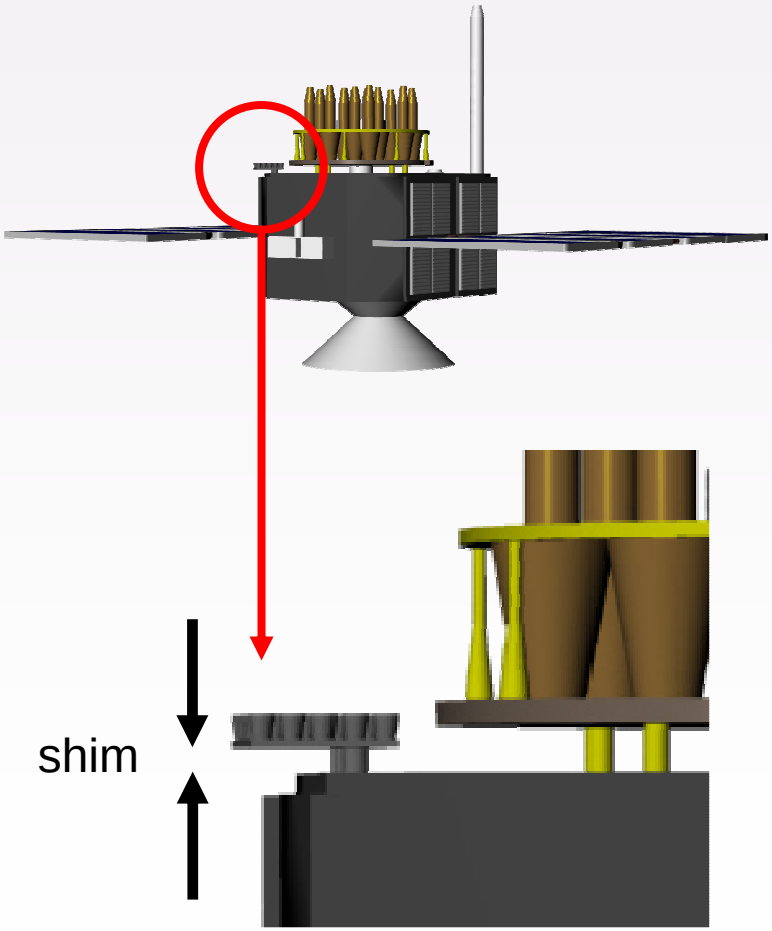
- 2 Block IIA spacecraft
- PRN05, PRN06



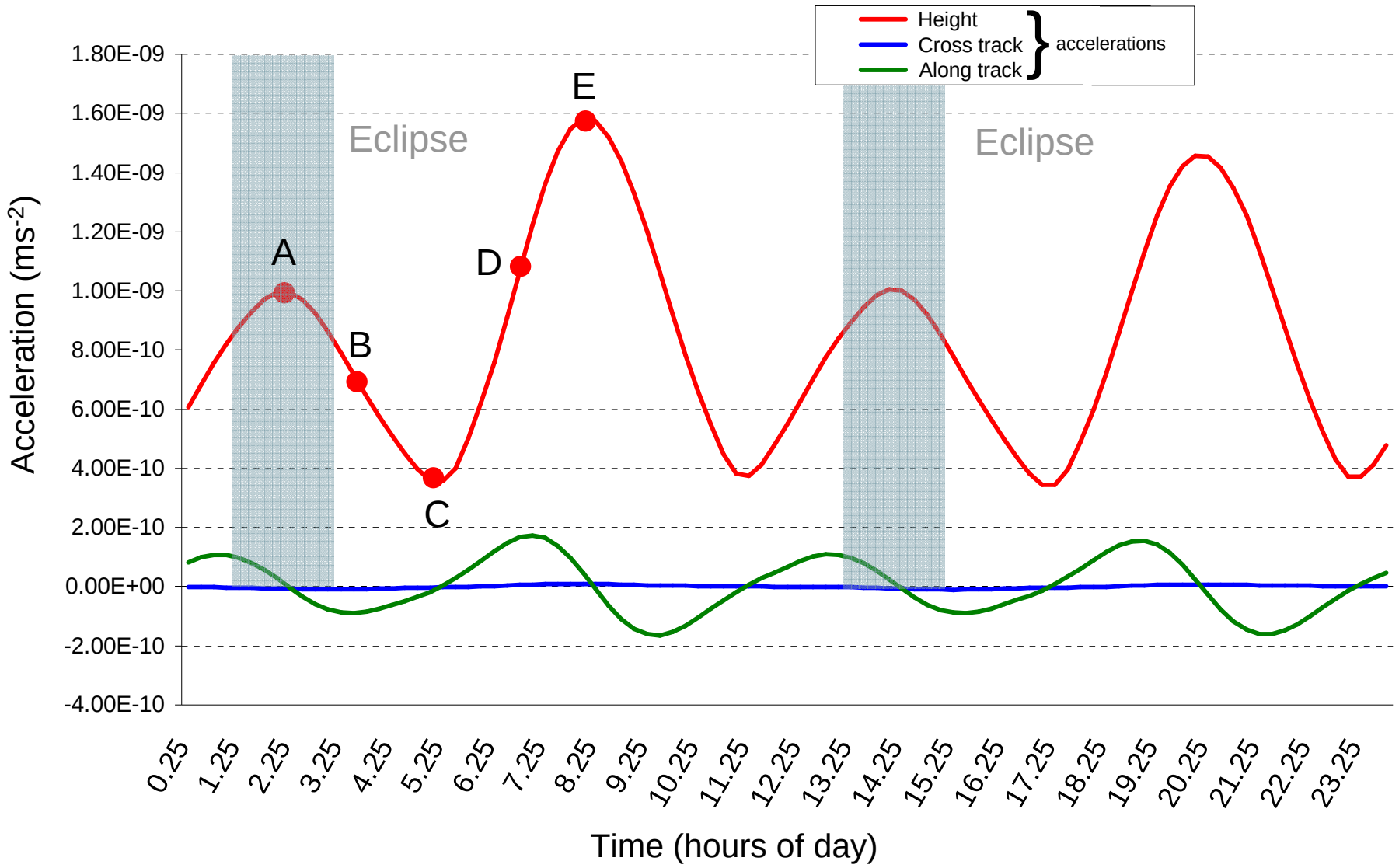
Retro-reflector array

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)

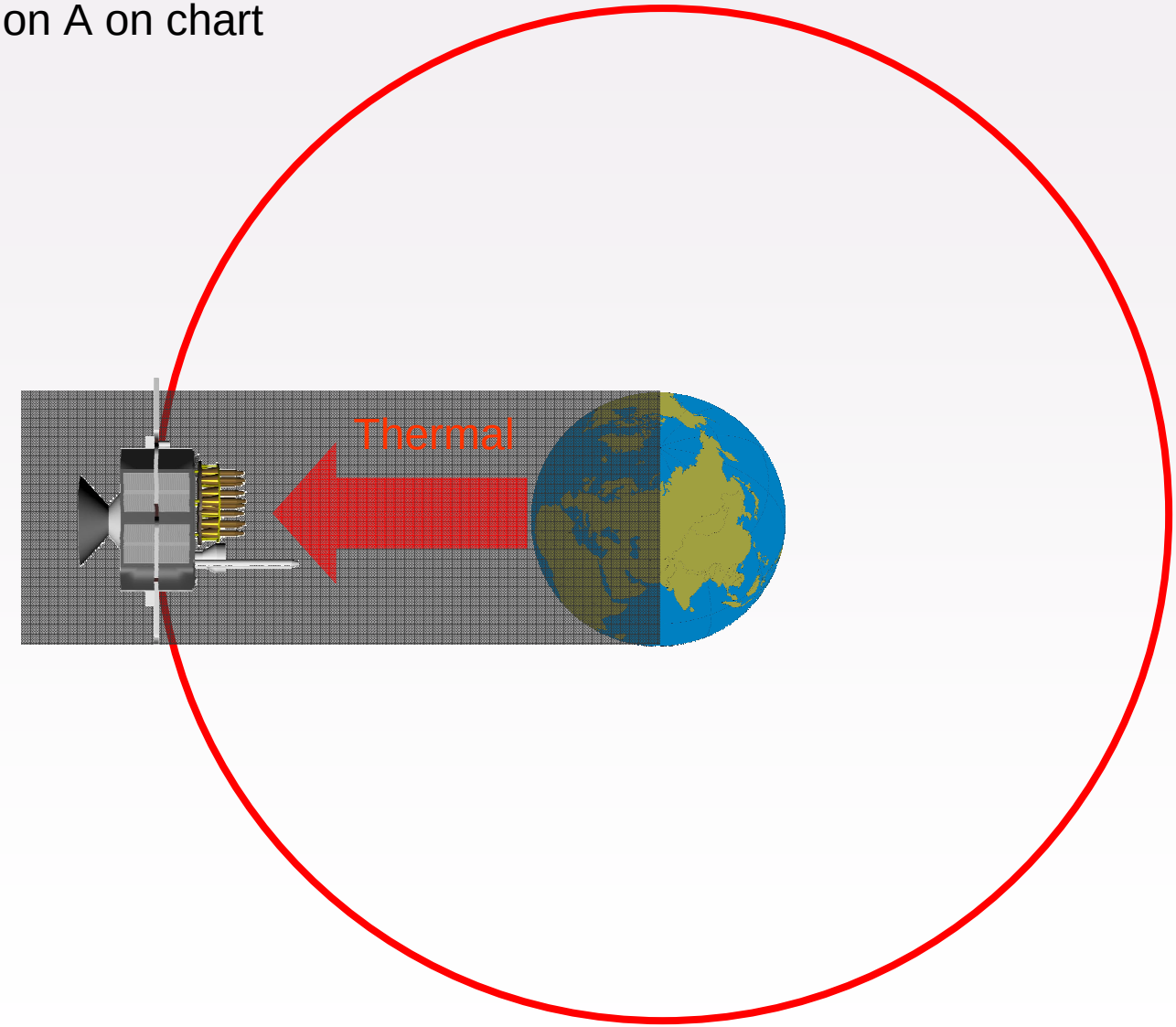


Modelled Earth Radiation pressure (SVN35, UCL ADM model)

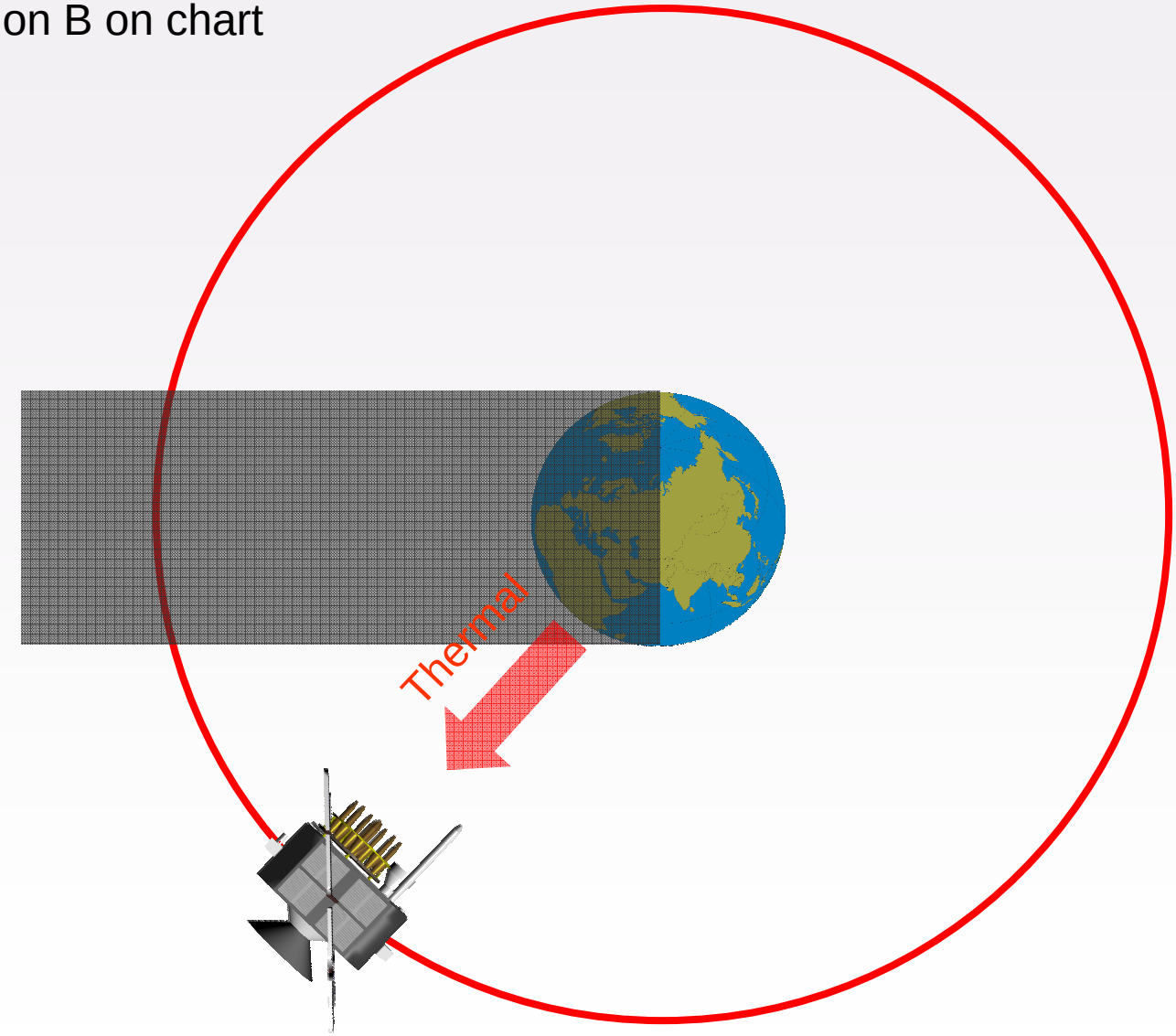


ADM = angular distribution model, deals with distribution of Earth radiation flux as a function of azimuth and elevation from ‘cells’on the surface of the Earth

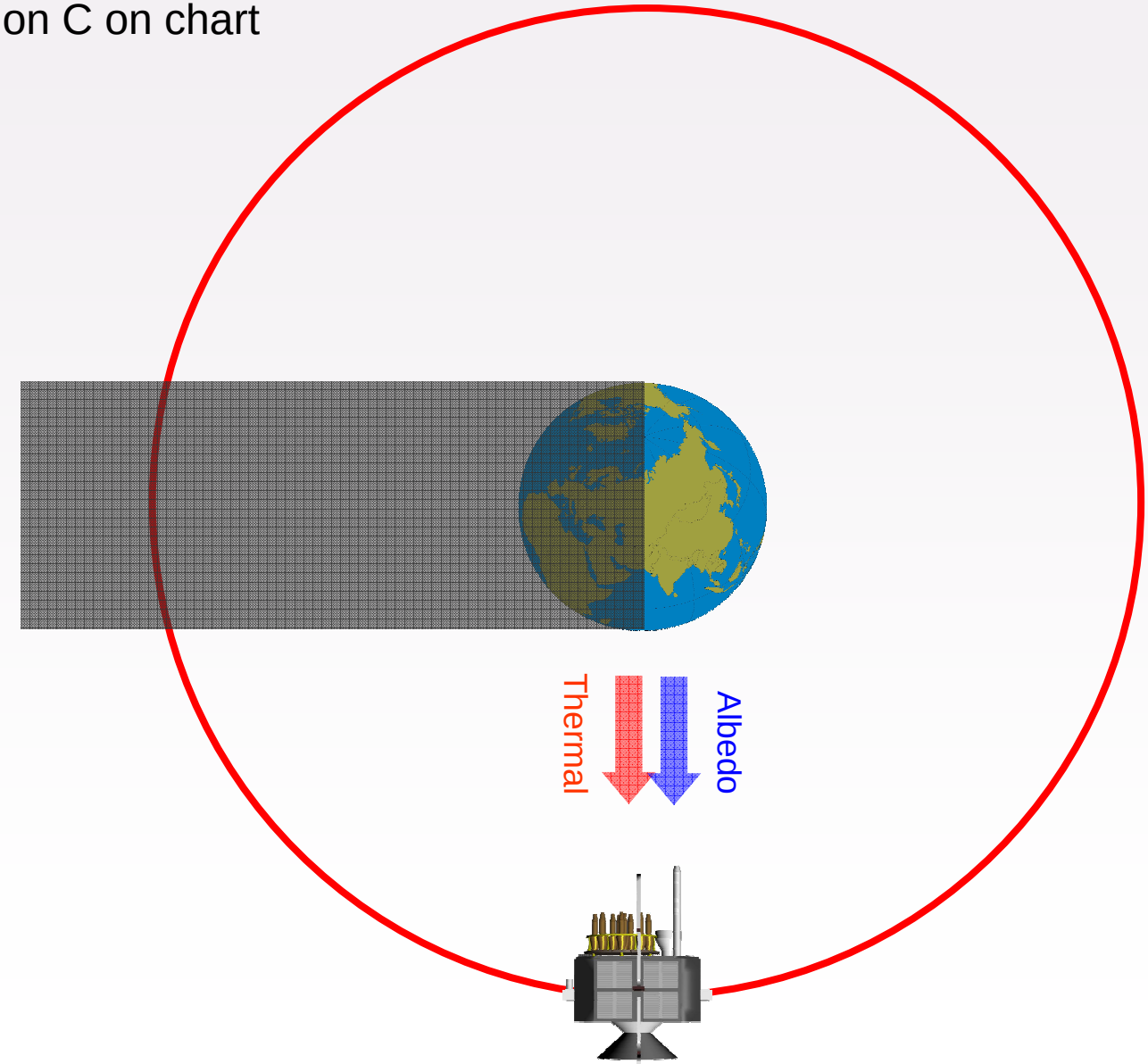
Position A on chart



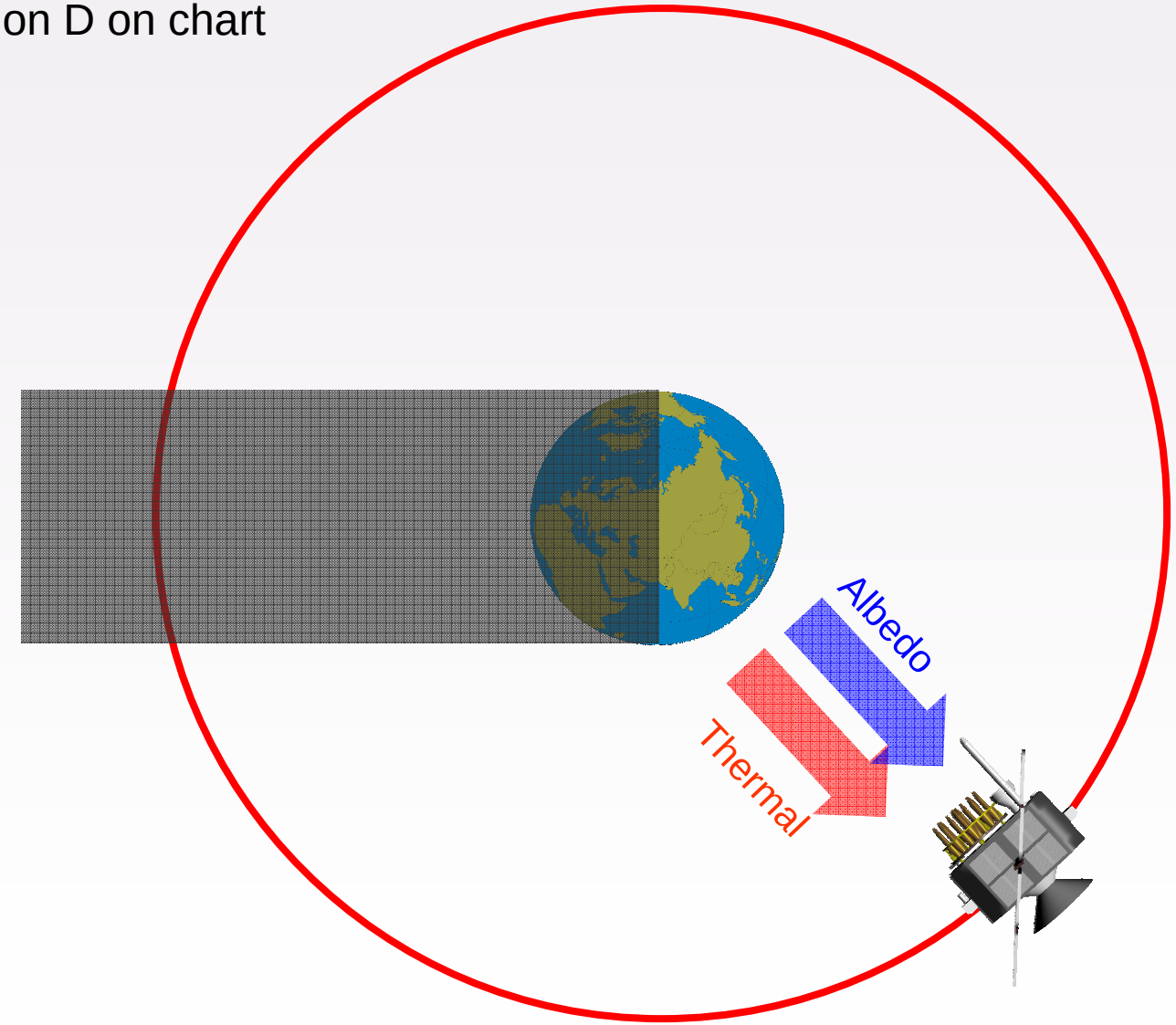
Position B on chart



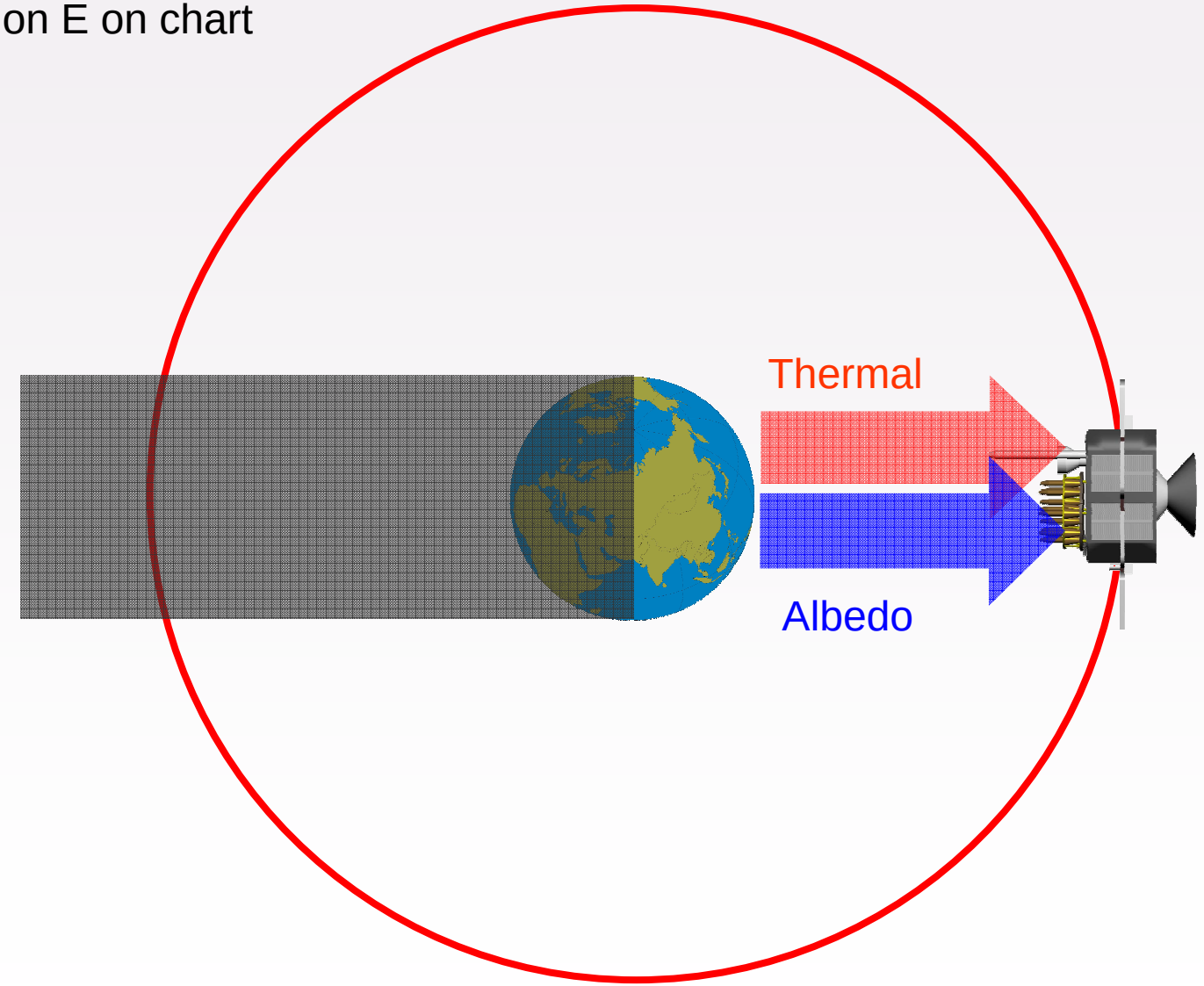
Position C on chart



Position D on chart



Position E on chart



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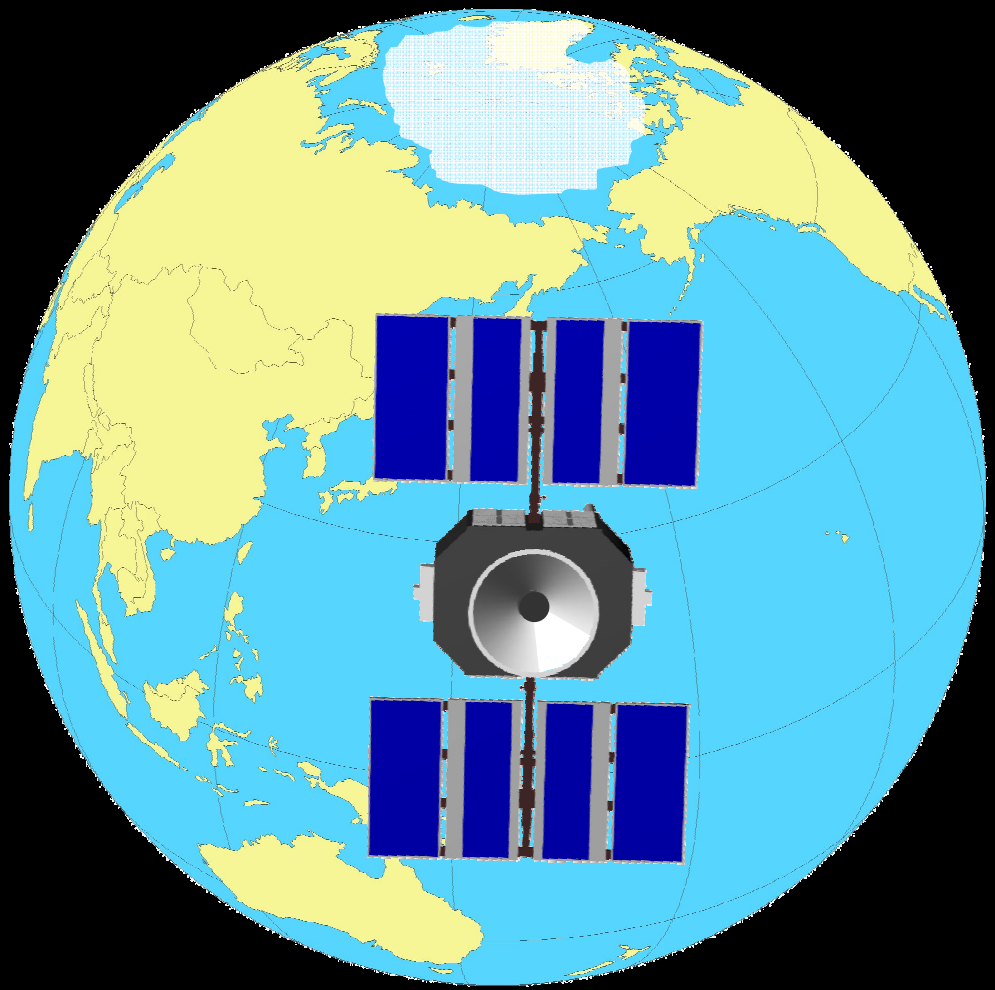
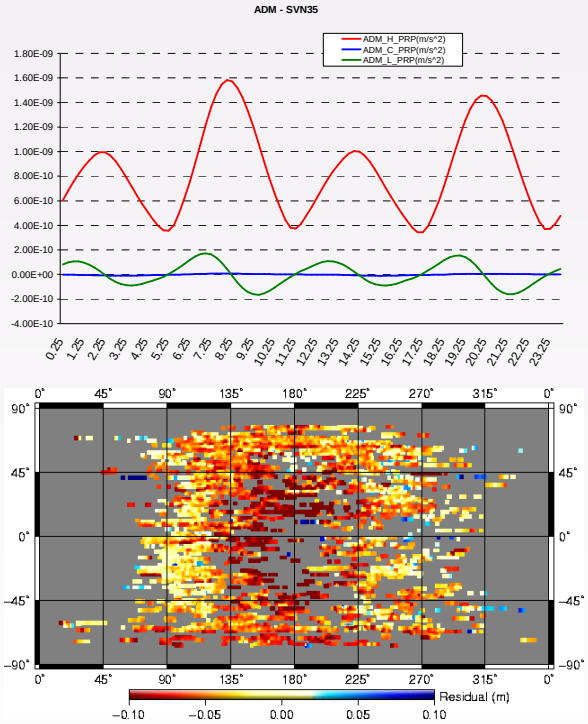
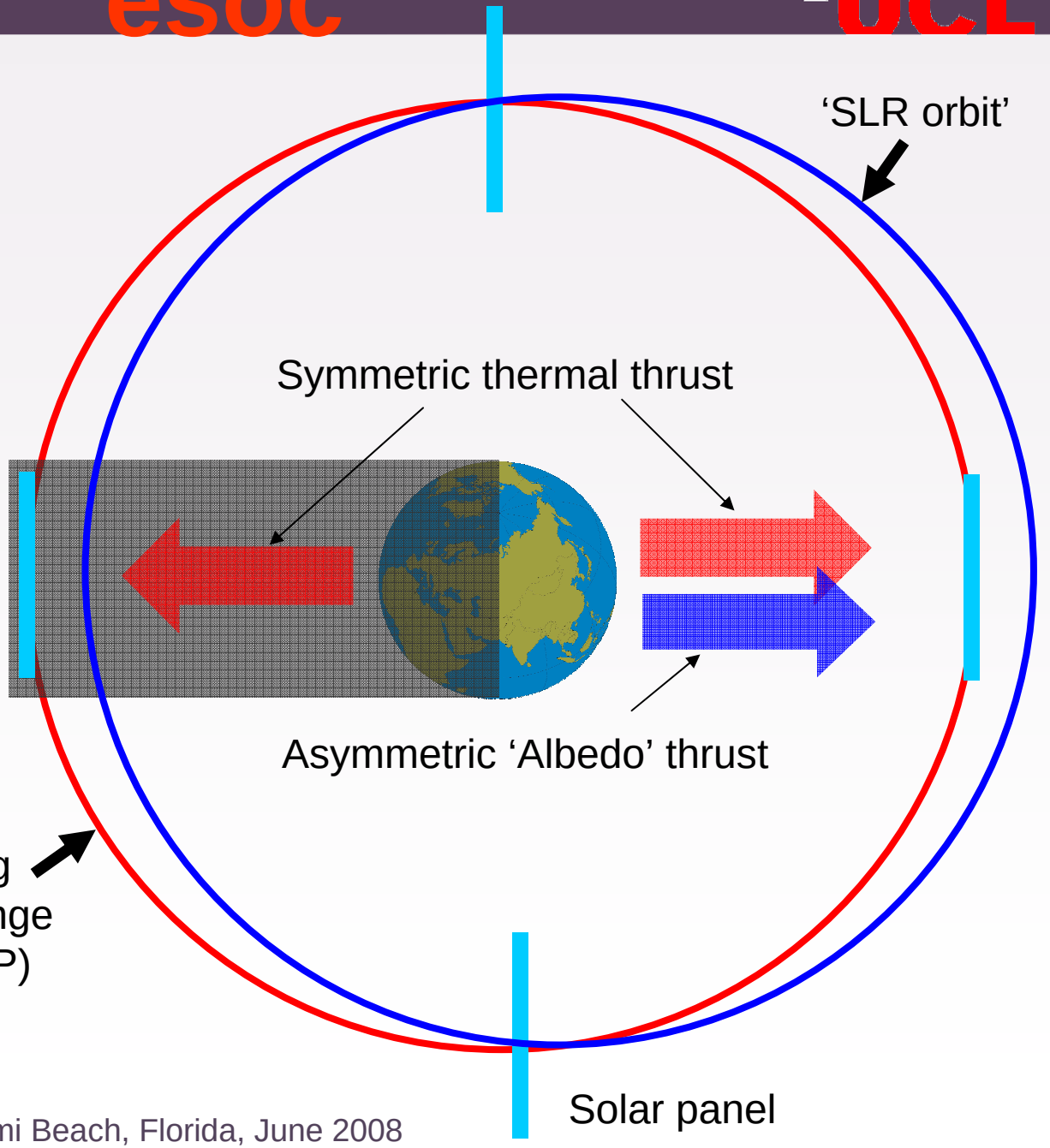


Explanation



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



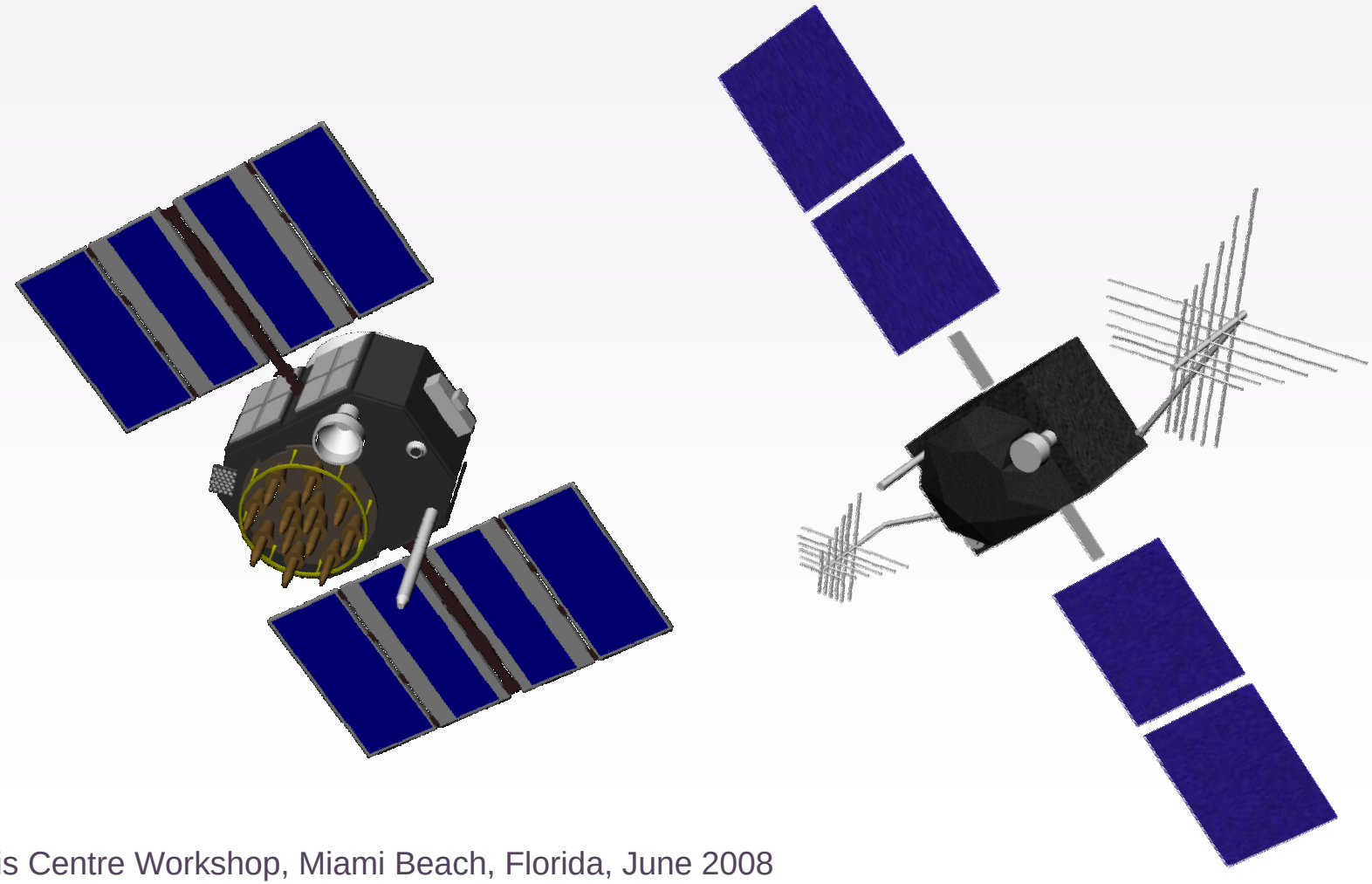
Which PRP modelling method to adopt?

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

Next developments…..

- Gravitational field tests (GRACE, EGM07, GOCE)
- UCL precision Solar Radiation/Thermal analytical models
- Impact of seasonal variations in PRP models
- Angular distribution models of PRP?

High resolution analytical SRP/TRR models: Block IIA Block IIR



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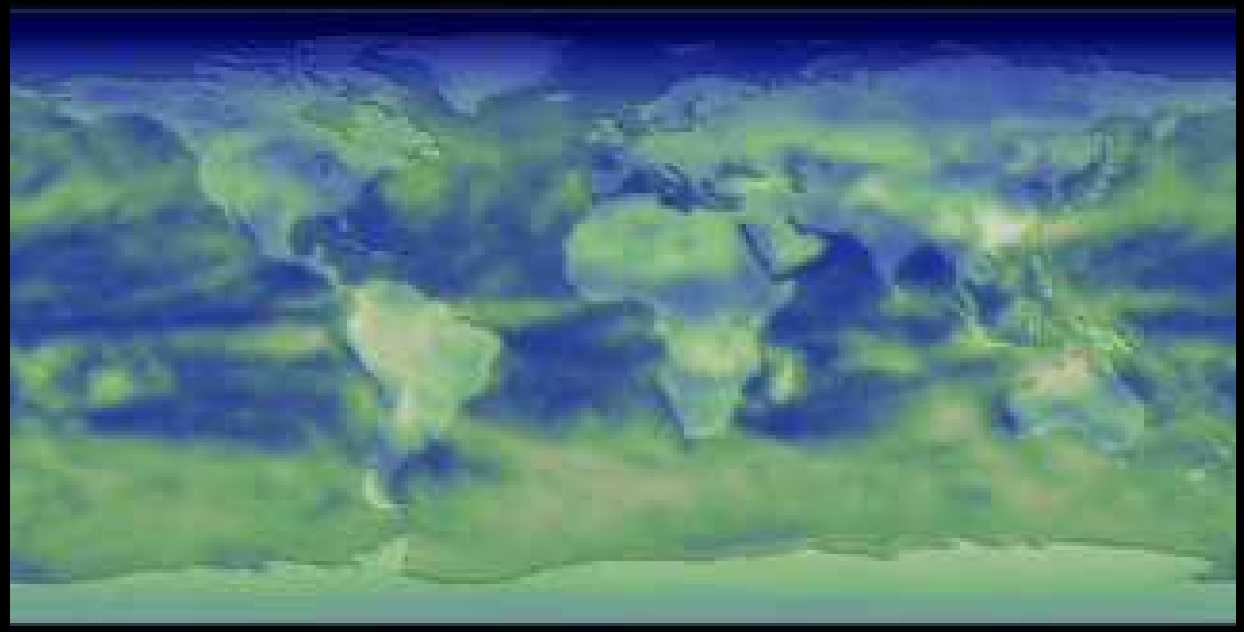
Shortwave annual pattern



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
- Remaining SLR residual signals can be mitigated by empirical force model terms
- Worth experimenting with new high precision physical models