Orbit Selection for a Wide-Swath Hydrosphere Mapper Mission

Don Chambers, John C. Ries

Center for Space Research
The University of Texas at Austin

Richard Ray

NASA Goddard Space Flight Center

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Some Constraints on Search

- No sun-synchronous orbits
- Altitudes lower than 1000 km to avoid radiation exposure
- Inclinations greater than 75° in order to sample most rivers in Siberia
- Repeat period ~ 20-days in order to meet groundtrack spacing requests of mesoscale oceanography and hydrology

Why not consider Sun-Synchronous Orbits?

- TOPEX/POSEIDON and Jason-1 only observed oceans between 66°S and 66°N
  - » Only observations of tides in the Arctic Ocean and around Antarctica are from sun-synchronous orbits or Geosat (which has nearly as bad aliasing properties)
- Groundtrack spacing is about 300 km at equator
  - » Shallow water tides have wavelengths significantly smaller than this
- Significant fraction of Earth's oceans have never had tides measured with an optimized altimeter system
  - » Includes shallow oceans and estuaries

Calculating Tidal Aliasing

Table 1

Tide Symbol	Period, hours	Equilibrium Amplitude, cm
M2	12.420601	16.83
K1	23.934470	9.83
S2	12.000000	7.83
O1	25.819342	6.99
N2	12.658348	3.26
P1	24.065890	3.25
K2	11.967235	2.13
Q1	26.868357	1.35
S1	24.000000	

$$\Delta\phi_P = \frac{2\pi P}{T} \qquad (-\pi \ \ to \ \ \pi)$$

$$\tau_P = abs\left(\frac{2\pi P}{\Delta\phi_P}\right)$$

- P is satellite repeat period
- T is tide period
- τ_p is tide alias period

Minimum Alias Frequency

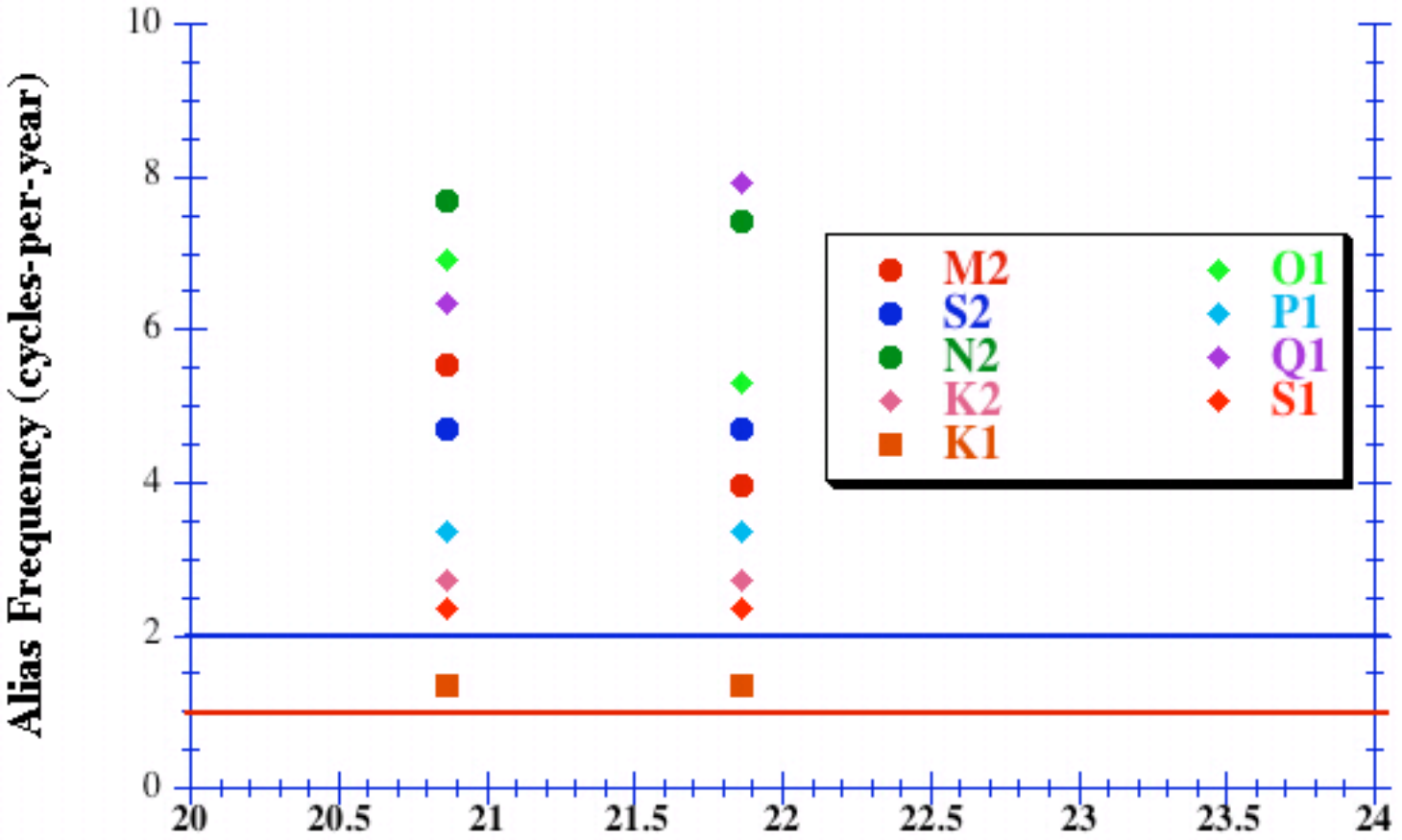
- For applications in oceans and estuaries, we desire a satellite orbit that aliases all tides to frequencies greater than 2 cycles-per year
  - The alias period is shorter than the semi-annual (half-year) signal
  - Can observe multiple cycles of the alias period within a few years

Frequency Separation

- Another important factor to consider is the separation between alias frequencies and between the aliases and annual/semi-annual **(Δf)**
- Determines time needed to separate two tides in altimeter observations
  - » Time to separate ~ 1/Δf
- T/P did not have optimal separation for some constituents
    - K1 aliased to within 0.11 cpy of semi-annual
      - » 9-years to separate

General Observations

- Only orbits with an inclination < 66° alias all major constituents to frequencies > 2 cpy
- Retrograde orbits have poor aliasing of solar tides
- If we do not require that the K1 alias > 2 cpy
  - » Good orbits do exist up to 80° inclination
  - » This covers more of the Arctic Ocean, all of the Antarctic boundary, and most rivers in Siberia



Orbit 1

Altitude = 845.111 km
Inclination = 78°
Repeat Period = 20.86521 days

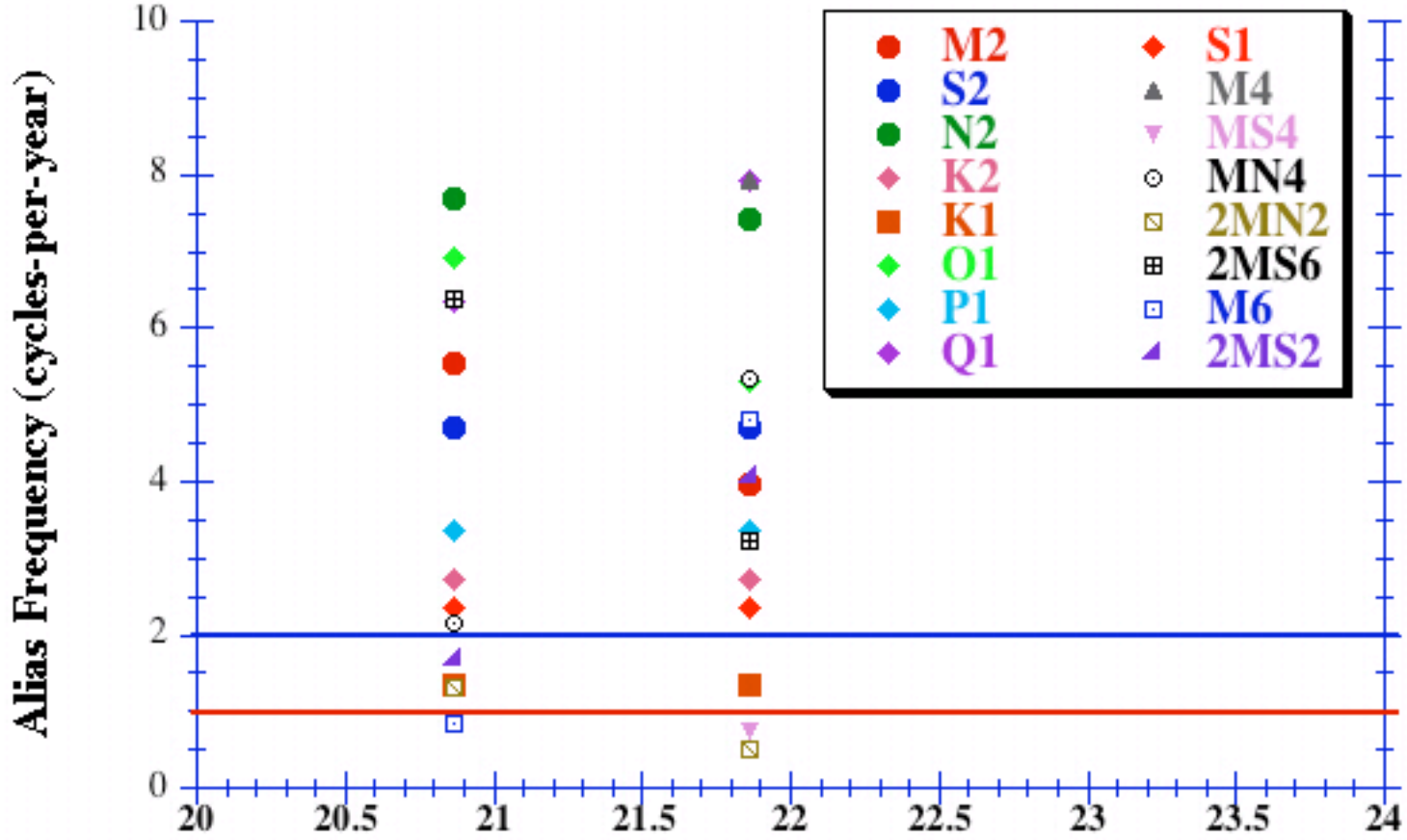
Orbit 2

Altitude = 845.859 km
Inclination = 78°
Repeat Period = 21.85882 days

- Except for K1, these two orbits have very good aliasing properties for 9 major constituents

Shallow Water Tides

- In shallow water (including estuaries) tides are nonlinear and have much smaller wavelength than in the deep ocean
  - » In 40 m, tide wavelength is 10x smaller than in 4000m
- Shallow water tides are poorly observed by current altimeter systems
- Examine aliasing of select nonlinear tides for 2 potential orbits
  - » Does either one sample these nonlinear tides better?



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- Some close aliases between nonlinear and primary tides (Table 2)

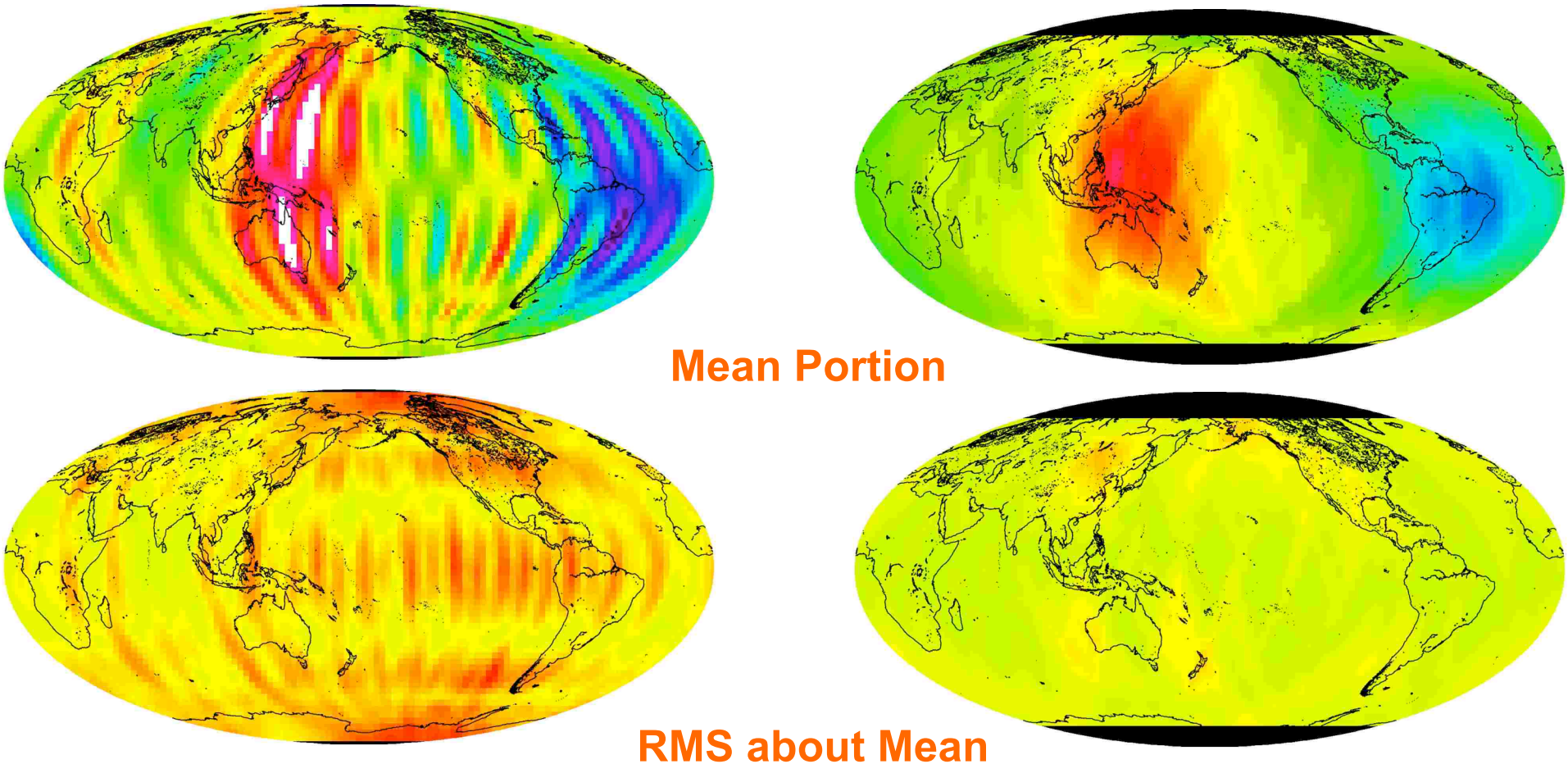
Table 2

Tide Symbol	Amplitude @ Dover UK (cm)	Orbit 1 Problems	Orbit 2 Problems	T/P Problems
M_4	25.5	none	Close to Q_1, Separation Time = 104 yrs	none
MS_4	16.4	Close to M_6, Separation Time = 140 yrs	Close to annual, Separation Time = 4.1 yrs	~3-year alias period
MN_4	9.4	Close to SA, Separation Time = 6.8 yrs	Close to 0_1, Separation Time = 719 yrs	none
$2MN_2$	7.0	Close to $2MS_2$, Separation Time = 2.7 yrs	Close to MS_4, Separation Time = 4.1 yrs	Close to M_6, Separation Time = 11.6 yrs
$2MS_6$	6.5	Close to Q_1, Separation Time = 1.9 yrs	Close to P_1, Separation Time = 6.7 yrs	Close to Q_1, Separation Time = 3.6 yrs

Orbit Error

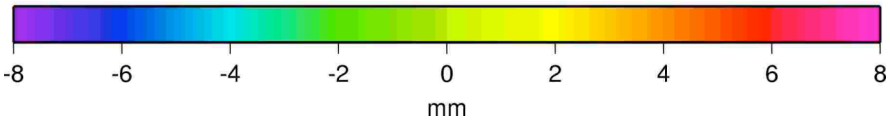
Proposed Wide-Swath Orbit

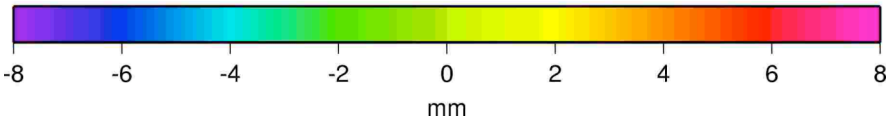
Jason Orbit



Mean Portion

RMS about Mean





Predicted using difference between GGM02C-GFZ04C

Conclusions

- Both Orbit 1 and Orbit 2 have good tidal aliasing properties for deep ocean tides and meet other mission requirements
- Only Orbit 1 will be able to additionally observe the M_4 tide as well as $2MN_2$, $2MS_6$, and $2MS_2$
  - » Will not be able to separate MS_4 and M_6 tides
- Orbit 2 will not be able to observe M_4 (the largest nonlinear tide) or several other nonlinear tides
- Recommend preliminary studies of Wide-Swath Hydrosphere Mapper Mission use **Orbit 1** (Altitude = 845.111 km, Inclination = 78°, Repeat Period = 20.86521 days)
  - » More effort might find an orbit that can sample both MS_4 and M_4 well