

Orbit Choices and Orbit Issues

C.K. Shum

Geodetic Science

The Ohio State University

Don P. Chambers

Center for Space Research

The University of Texas at Austin

**GAMBLE Workshop - An EC Thematic Network
to Consider Future Developments in Satellite Altimetry
Themes 1 (Sea surface height) and 3 (Orbit Determination)**

Delft Technical University, Delft, The Netherlands

7-8 November, 2002



Orbit Choices and Orbit Issues

- Choice of orbits to minimize tidal and seasonal signal aliasing (single-satellite scenario)
 - NPOESS (Ocean Observer System) results:
 - Sun-synchronous orbit, free-flyer orbit [Chambers et al., 2000; 2002]
- Precision orbit determination issues
 - High-low (GPS-LEO) tracking, kinematic OD for near-real time applications (e.g., GPS meteorology [Brzezinska et al., 2002])

Calculating “Theoretical” Tidal Aliasing

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

[Chambers et al., 2002]:

$$P = \frac{2P}{T} \quad (- \text{ to })$$

$$P = abs \frac{2P}{P}$$

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

Study to recommend optimal orbit(s) for NPOESS (or Ocean Observer System) altimetric satellites: Sun-synchronous and non-sun-synchronous orbits [Chambers et al. 2001]



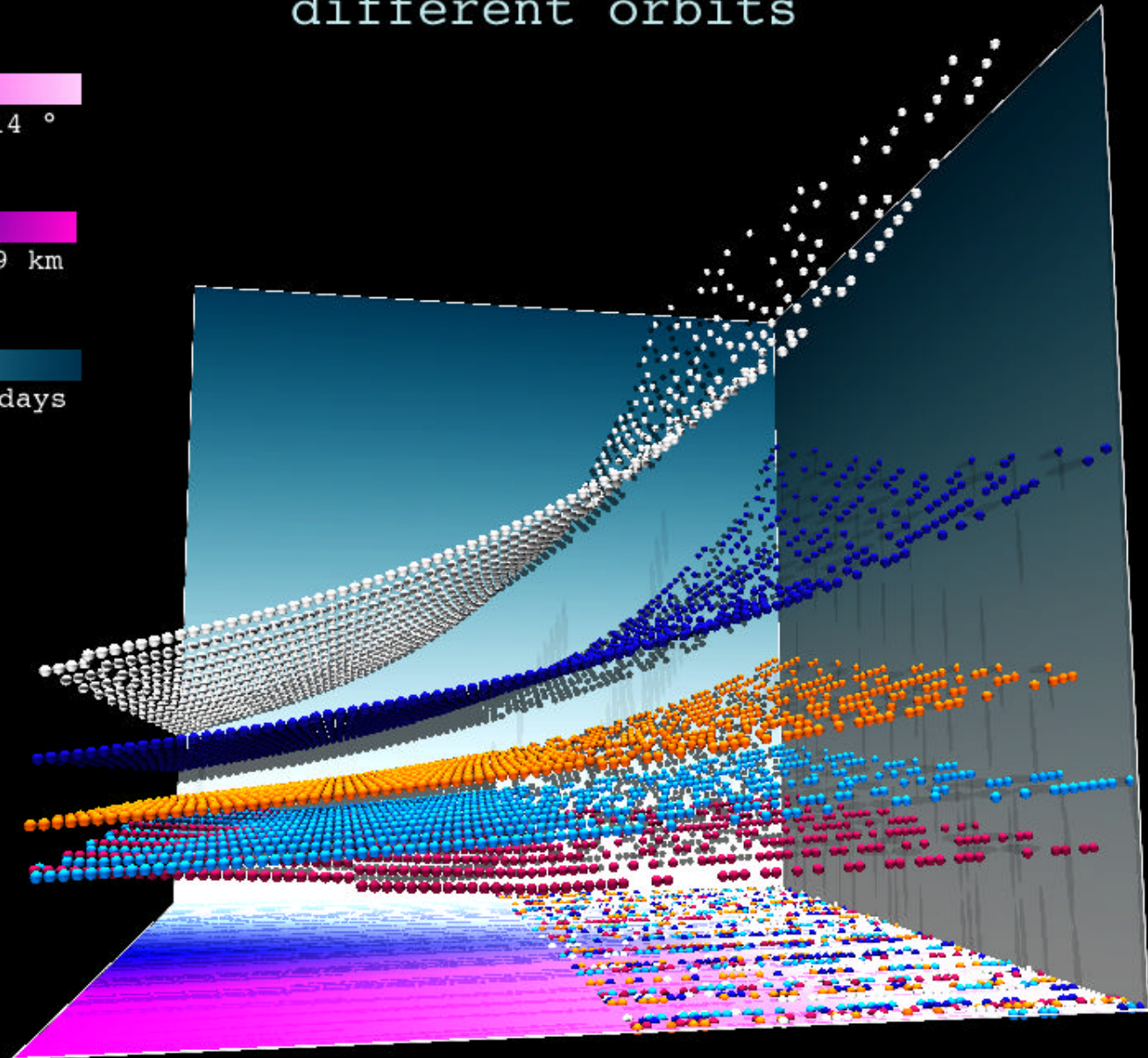
Tidal Aliasing of M2 for different orbits

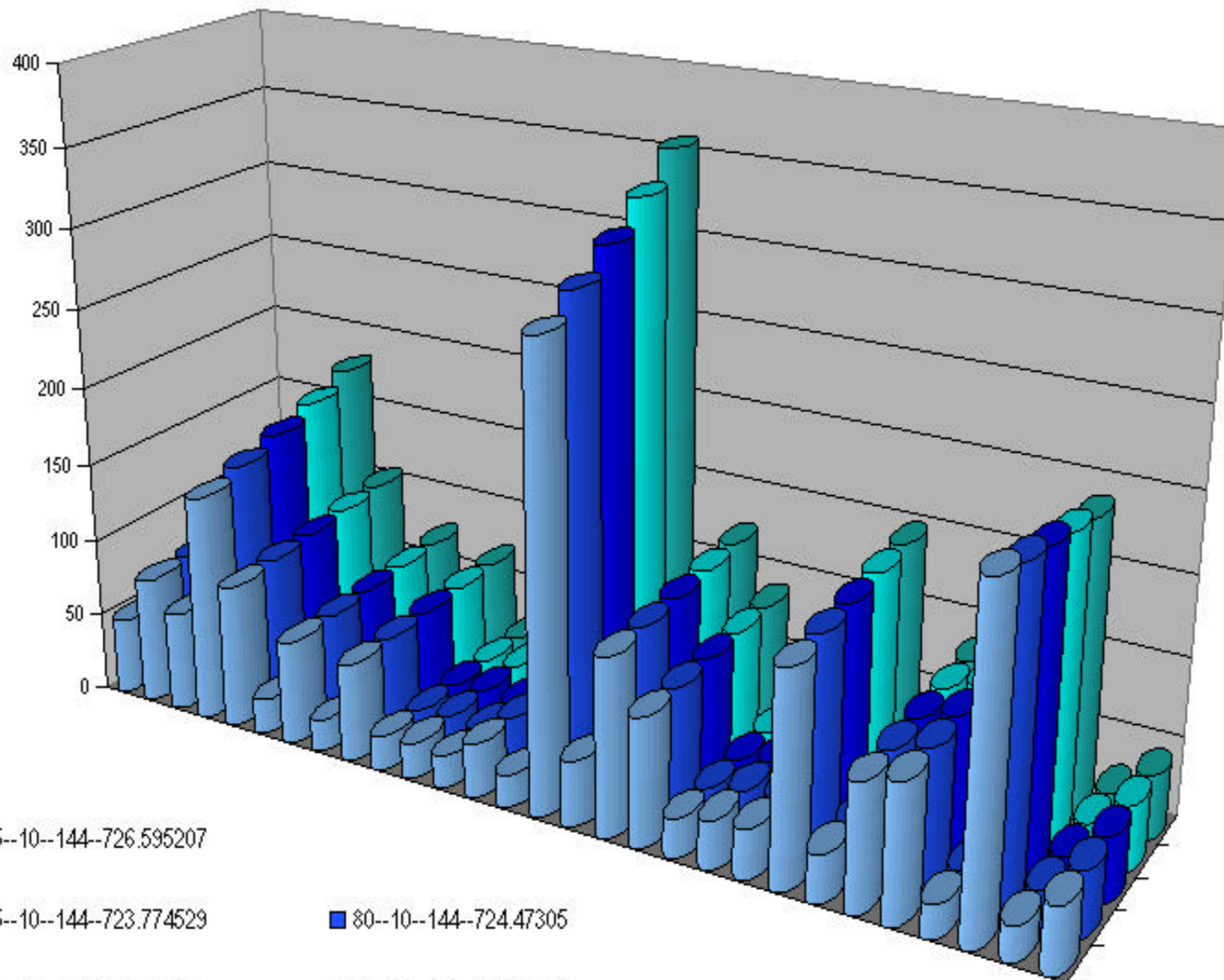
7 8 9 10 11
repeat in days

<inclination> 66 to 114 °

<altitude> 578 to 1429 km

<alias> 0.5 to 111 days





- 81.5--10--144-726.595207
- 79.5--10--144-723.774529
- 80.5--10--144-725.176032
- 80--10--144-724.47305
- 81--10--144-715.883433

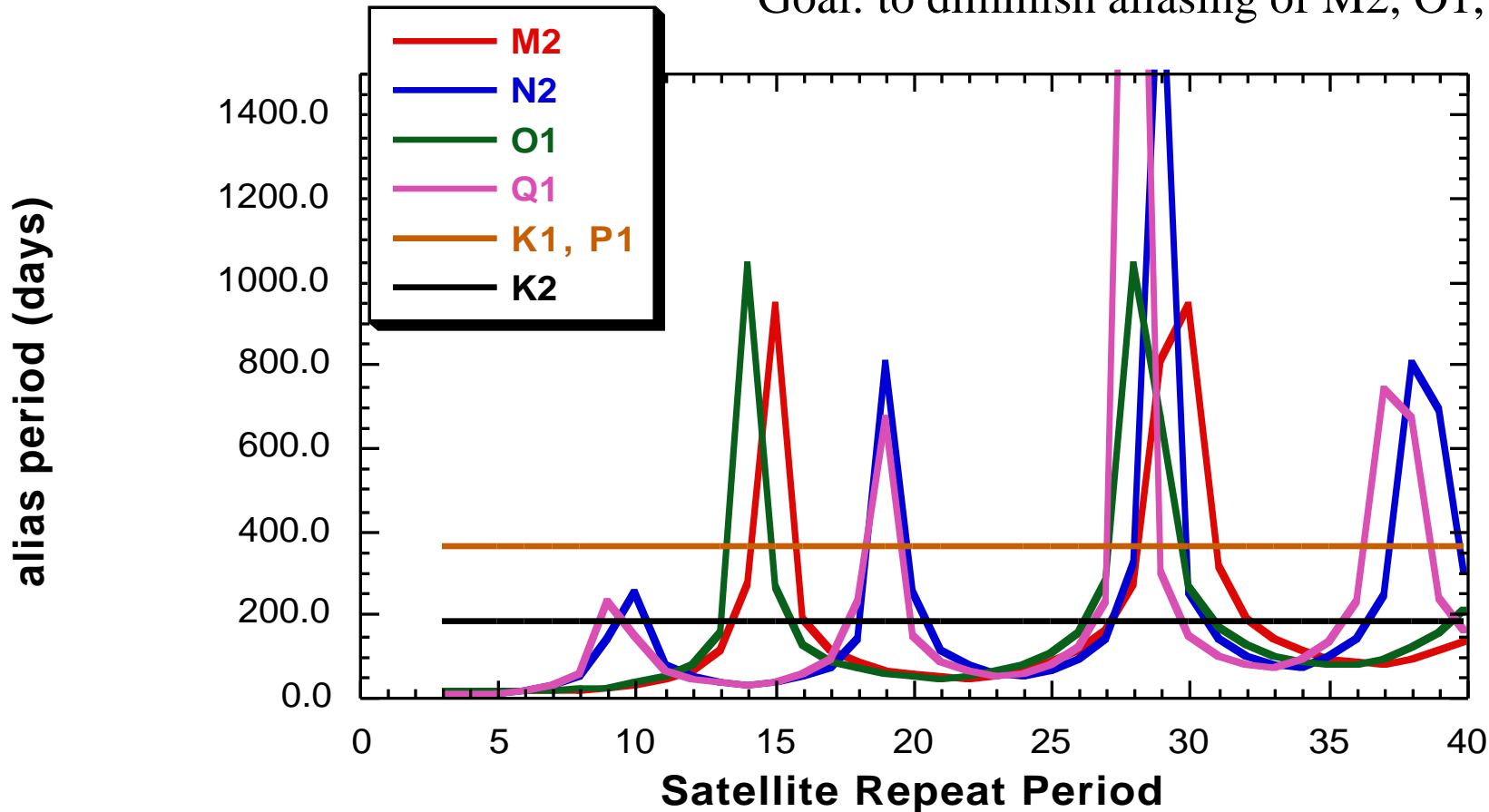
semi_l_M2
semi_s_S2
semi_l_N2
semi_ls_K2
semi_l_ny2
semi_ll_L2
semi_s_T2
semi_l_2N2
semi_l
semi_my2
semi_l
semi_l_lambda2
semi_l_KJ2
semi_l
dium_ls_K1
dium_l_O1
dium_s_P1
dium_l_Q1
dium_ll_M1
dium_l_J1
dium_l_OO1
dium_l_rho1
dium_l
dium_l
dium_s_pi1
dium_l_2Q1
dium_s_phi1
dium_l_sigma1
dium_l

Tidal Aliasing for Sun Synchronous Orbits

[Chambers et al., 2002]:

Cannot avoid aliasing of S2, K1, P1, or K2

Goal: to diminish aliasing of M2, O1, N2, Q1



Summary

- Repeat periods where orbits have good aliasing
 - » < 7 days
 - » 9.9 days
 - » 13.9 days
 - » 18.8, 19.8 20.8 days
- Highest inclination to maintain optimal aliasing characteristics
 - » 70°, ~850 km altitude, PI = 0.31
- At 68° inclination, ~1040 km altitude, 9.9 day and 18.8 day orbits have PI > 0.3 (e.g., PI for T/P is 0.1)

Note: Performance index [Chambers et al., 2002]: $PI = (f_{min} - 2.0) \frac{f_{min}}{0.16667}$

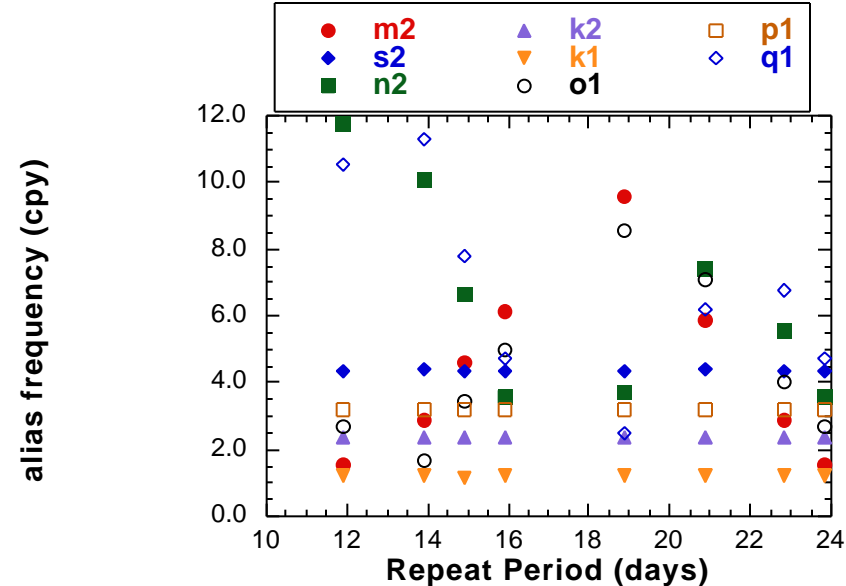
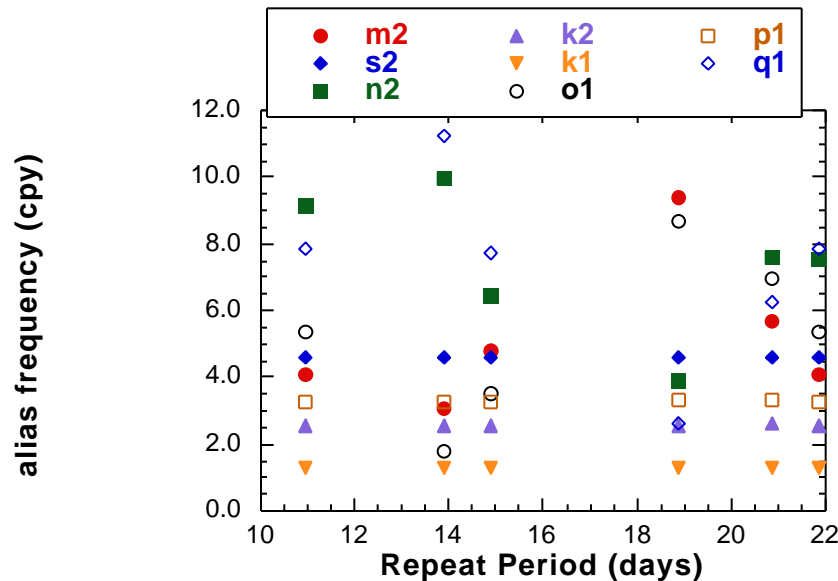


Summary for Tidal Aliasing of Non-SS Orbits

[Chambers et al., 2002]:

78°, ~950 km

79°, ~950 km



- 78° has better separation than 79°
- For 78°, 10.9 and 20.9 day repeats have largest separations
- For 79°, choose 14.9, 18.9, 20.9, or 22.9 day repeats, although each as two pairs with close frequency



Center for Space Research
The University of Texas at Austin



Tidal Aliasing Conclusions

- If an altimeter is placed on the NPOESS platform in a sun-synchronous orbit
 - » Use 22-day repeat cycle, altitude = 846.952 km (semi-major axis = 7225.088 km), inclination = 98.803° , 311 revolutions per cycle
- If an altimeter is placed on a free-flying platform
 - » Recommend ~1050 km altitude, 68° inclination, 18.8 day repeat (drag issues, tidal aliasing, mesoscale)
 - » If only aliasing considered, ~850 km altitude, 70° inclination orbits are viable
 - » If aliasing restrictions relaxed for K1, then one can consider orbits at ~950 km altitude and $78-79^\circ$ inclination.

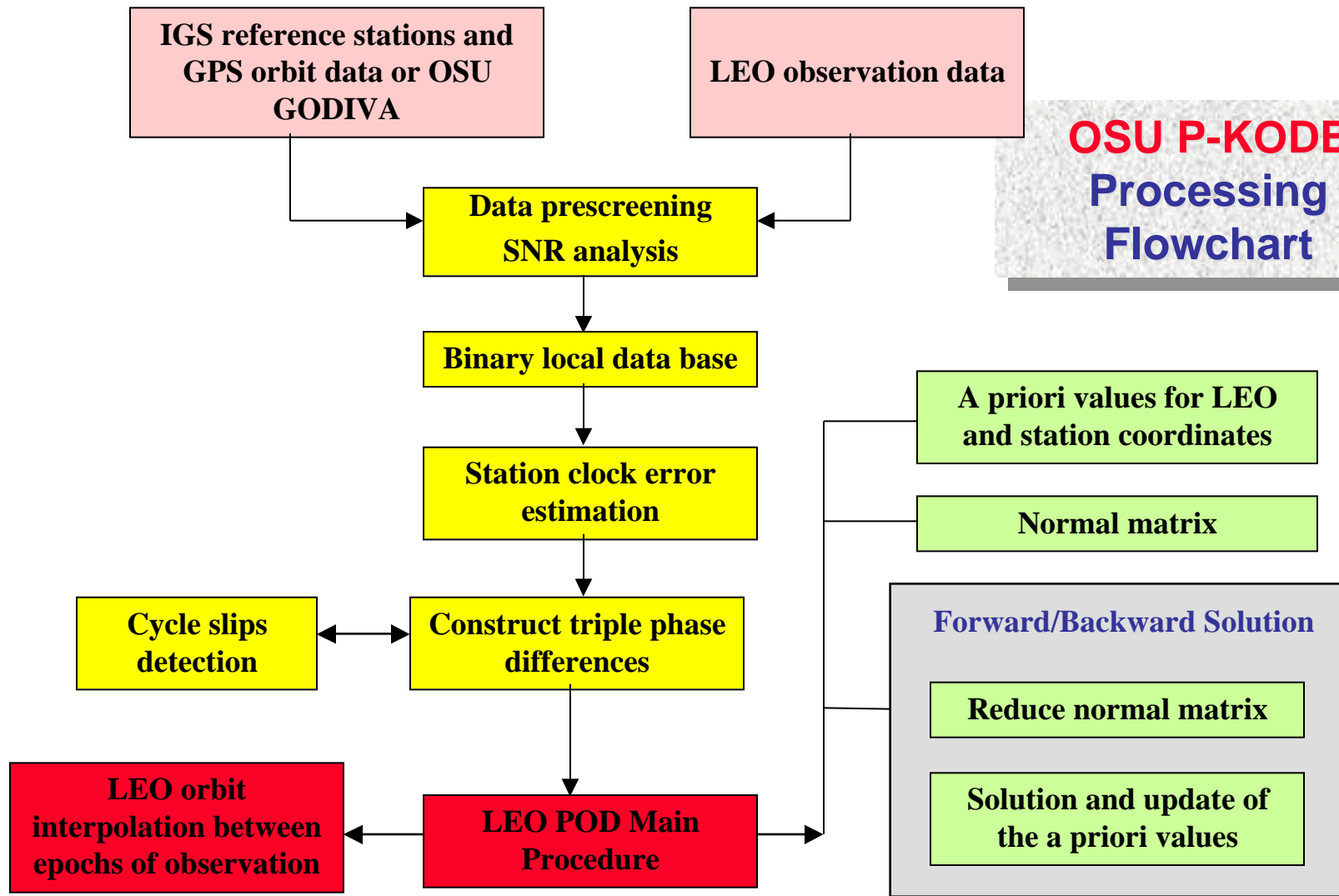
[Chambers et al., 2002]:



Center for Space Research
The University of Texas at Austin



LEO KINEMATIC ORBIT DETERMINATION



Brzezinska et al. [2002]

Goal: Near-real time LEO OD for meteorological and other applications



Kinematic POD: CHAMP Test Data

➤ Test data set:

- ✓ June 15, 2001 (24 hours)
- ✓ 65 IGS stations
- ✓ Data interval 10s (CHAMP), 30s (ground stations)

➤ Data processing conditions

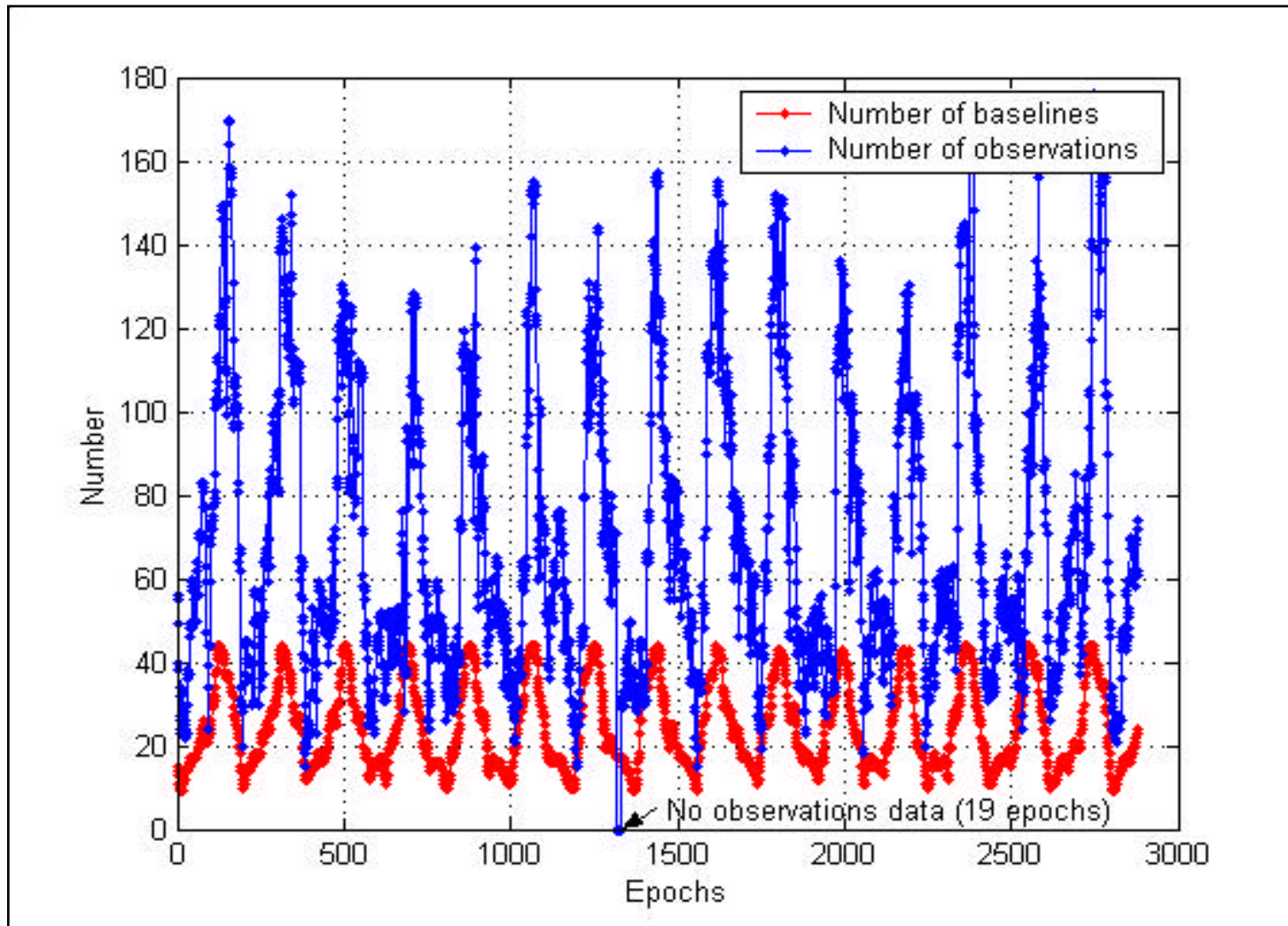
- ✓ Elevation cut off angle 0° (CHAMP) and 10° (Stations)
- ✓ CS detection based on initial SNR prescreening, and triple difference residual analysis
- ✓ Normal matrix is accumulated until a singularity point is reached (too few observations or very bad geometry)
- ✓ Initial epoch released



Brzezinska et al. [2002]



Observations and Baselines per Epoch



Brzezinska et al. [2002]

Distribution of Cycle Slips for 24 h Data Set Screening Based on TD Residuals

# of Epochs with no C/S	2007
# of Epochs with C/S	873
Total # of Epochs	2880

Total No. of Observations	166495	
Number of C/S	Total = 9495 (5.7%)	
	CHAMP	Stations (65)
	9226 (5.5%)	269 (0.2%)
	97% of all CS	3% of all CS



Brzezinska et al. [2002]



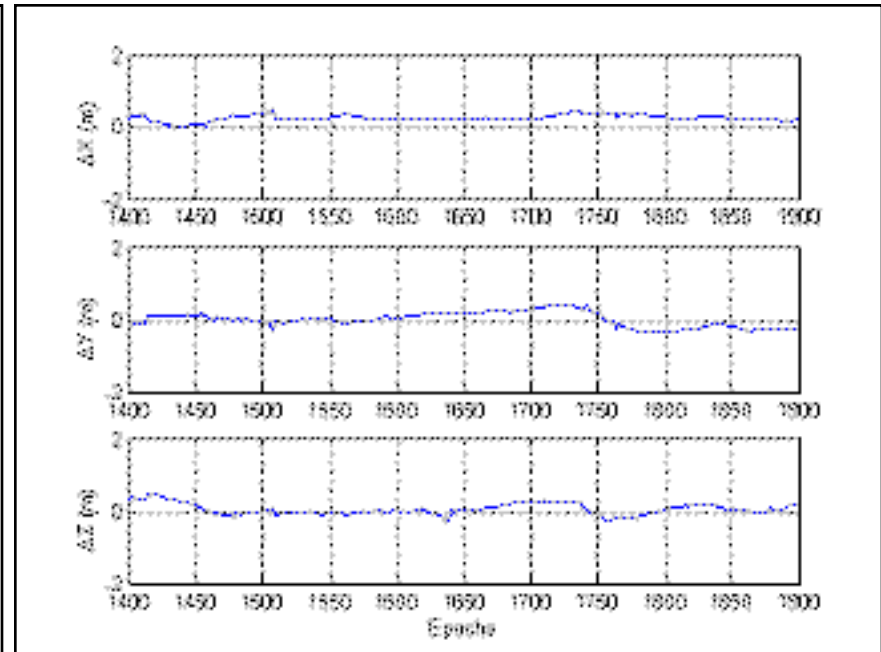
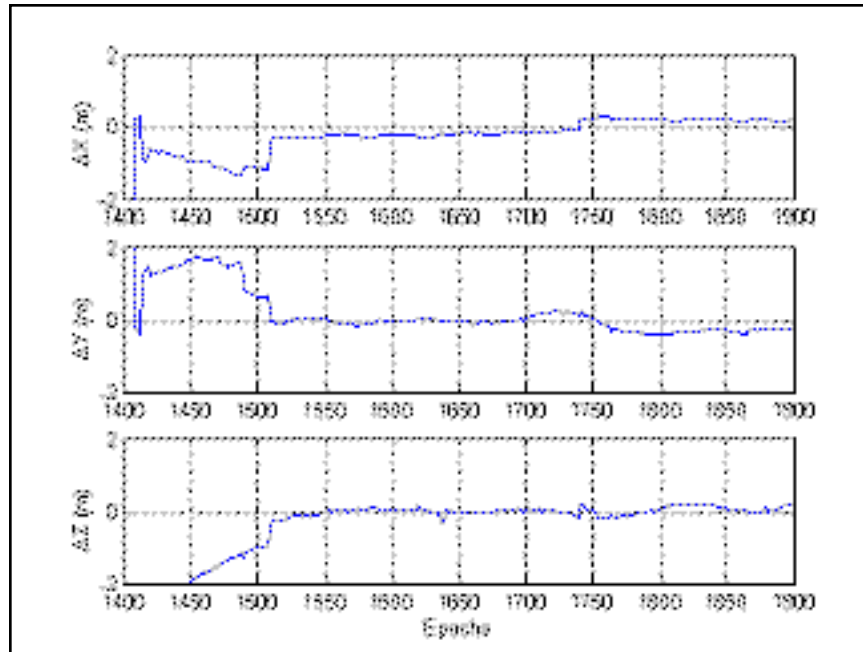
Forward vs. Smoothed Solution RMS of Fit to RSO

Forward filter solution

$RMS_x = 0.513$ m
 $RMS_y = 0.865$ m
 $RMS_z = 1.059$ m
 $RMS_{3D} = 1.460$ m

Backward filter solution

$RMS_x = 0.079$ m
 $RMS_y = 0.202$ m
 $RMS_z = 0.155$ m
 $RMS_{3D} = 0.266$ m



RSO plus error of 5 m used as an approximation

Brzezinska et al. [2002]



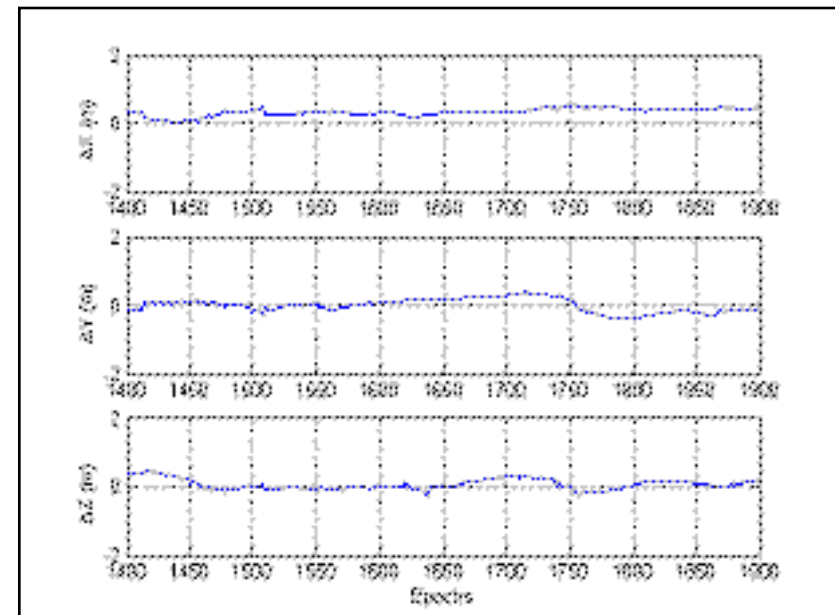
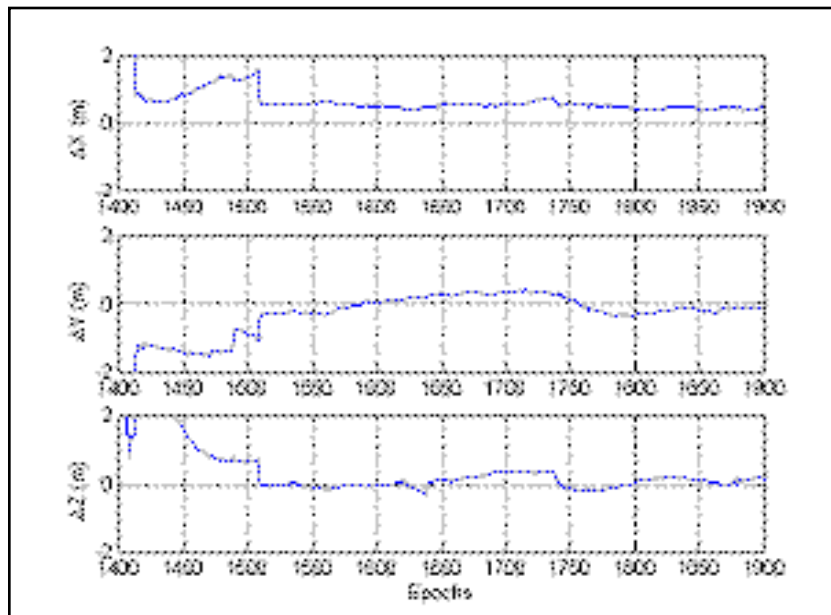
Forward vs. Smoothed Solution RMS of Fit to RSO

Forward filter

$RMS_x = 1.150$ m
 $RMS_y = 2.215$ m
 $RMS_z = 0.788$ m
 $RMS_{3D} = 2.617$ m

Backward filter

$RMS_x = 0.110$ m
 $RMS_y = 0.198$ m
 $RMS_z = 0.154$ m
 $RMS_{3D} = 0.274$ m



DD range solution used as an approximation

Brzezinska et al. [2002]

