PRIMARY OCEANIC SOURCES OF SEASONAL TO INTERANNAUL EARTH ROTATION

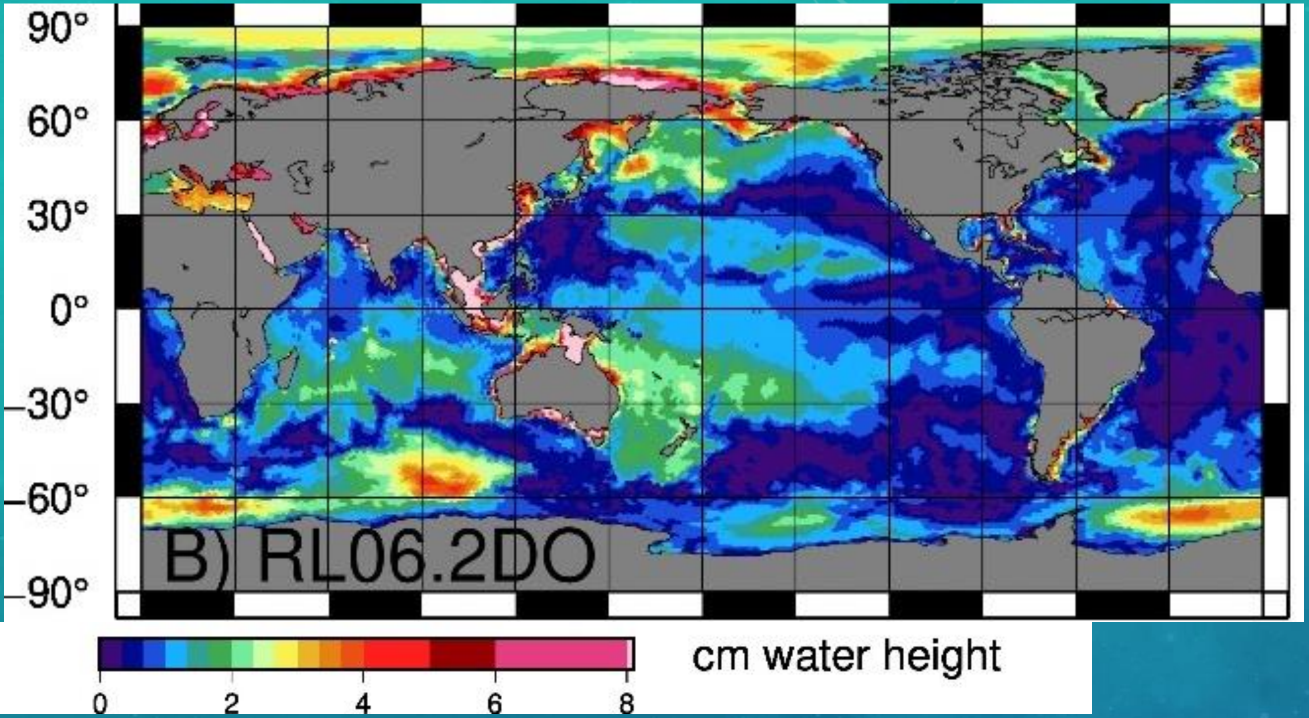
DON P. CHAMBERS

UNIVERSITY OF SOUTH FLORIDA COLLEGE OF MARINE SCIENCE

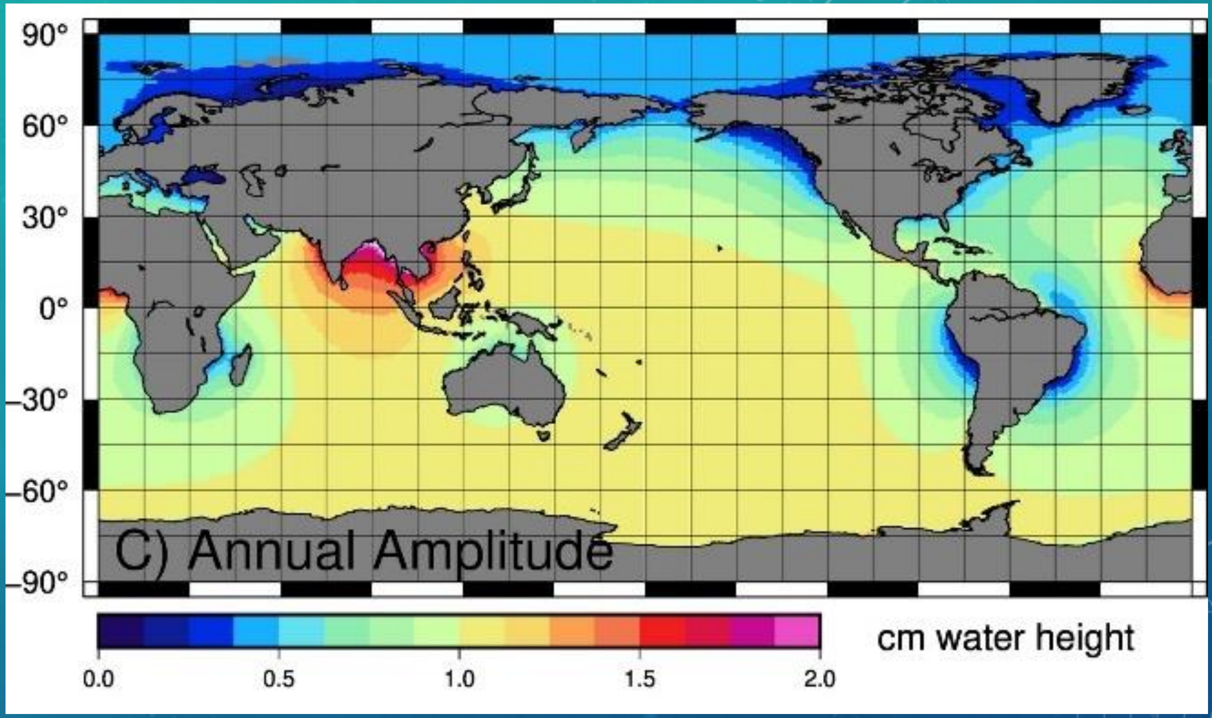
GOALS

- It has been established that ocean bottom pressure variations contribute a majority of Chandler Wobble and long-period excitations to polar motion
  - Gross, R (2000) The excitation of the Chandler wobble, Geophys. Res. Lett., 27, 2329–2332, doi:10.1029/2000GL011450.
- However, no subsequent studies looking at the precise sources in the ocean driving these excitations.
- Look at global mass redistribution in various ocean basins using a new dynamic ocean (DO) set of GRACE/FO mascons and quantify contribution to Earth Rotation excitation functions.

Annual Amplitudes

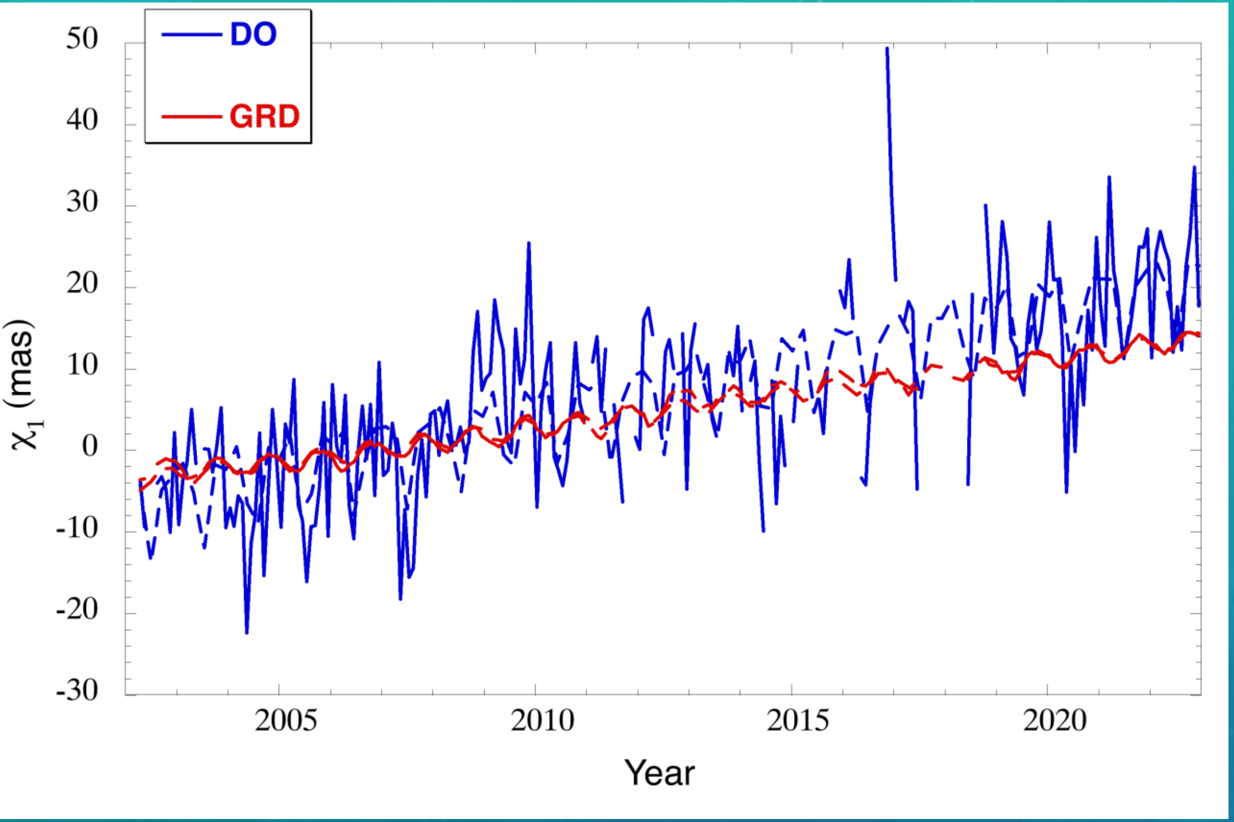


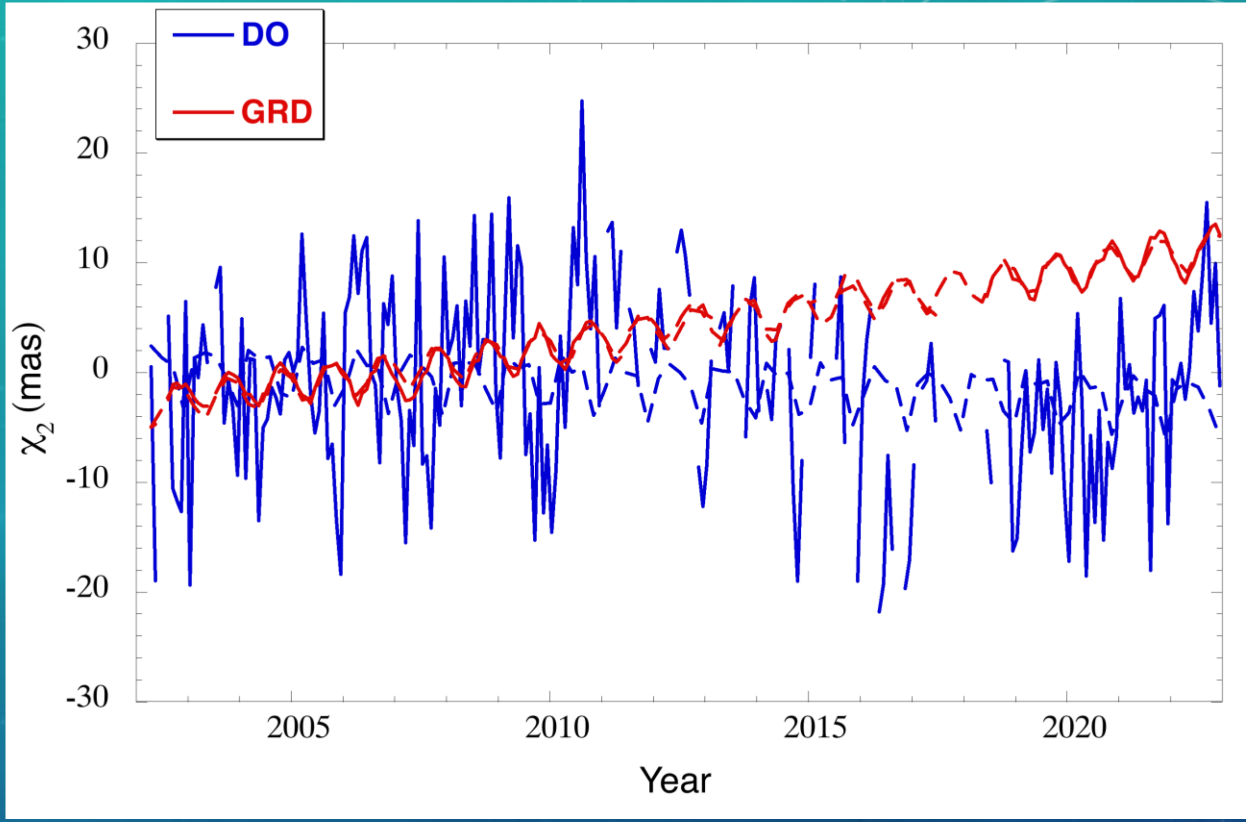
Dynamic Ocean (DO) mascons



Global Ocean mass + Gravity, Rotation, deformation (GRD) effects

Pie et al. (2025) CSR GRACE & GRACE-FO Dynamic Ocean Mascons RL06.2DO", https://doi.org/10.18738/T8/3VUPEW, Texas Data Repository, V3.





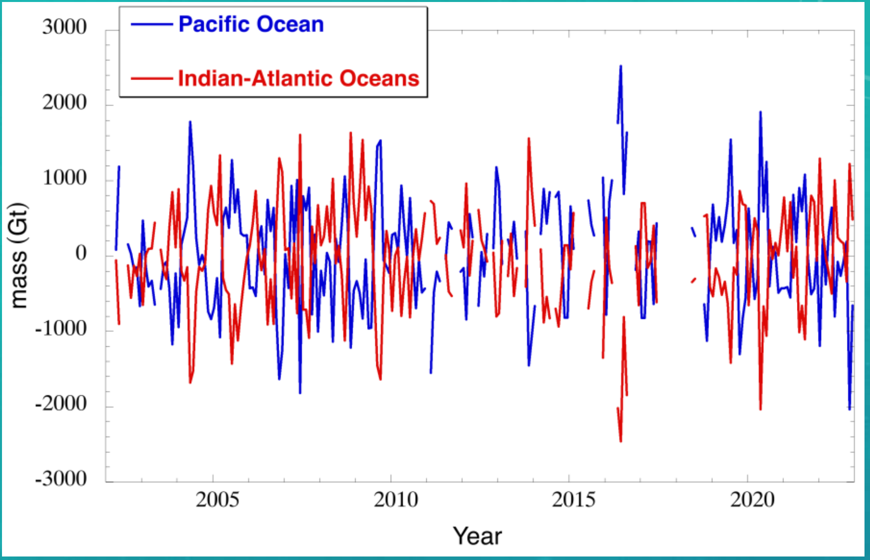
$$\begin{bmatrix}\chi_1^{mass} \\ \chi_2^{mass}\end{bmatrix} = -\frac{1.098 R_E^2}{(C-A)} \iint q(\phi, \lambda, t) \sin(\phi) \cos(\phi) \begin{bmatrix}\cos(\lambda) \\ \sin(\lambda)\end{bmatrix} ds$$

$$ds = R_E^2 \cos(\phi)\, d\phi d\lambda$$

Global Ocean mass + GRD mainly causes trend + small seasonal variations in polar motion excitation functions. Larger annual + interannual fluctuations from DO mass redistributions

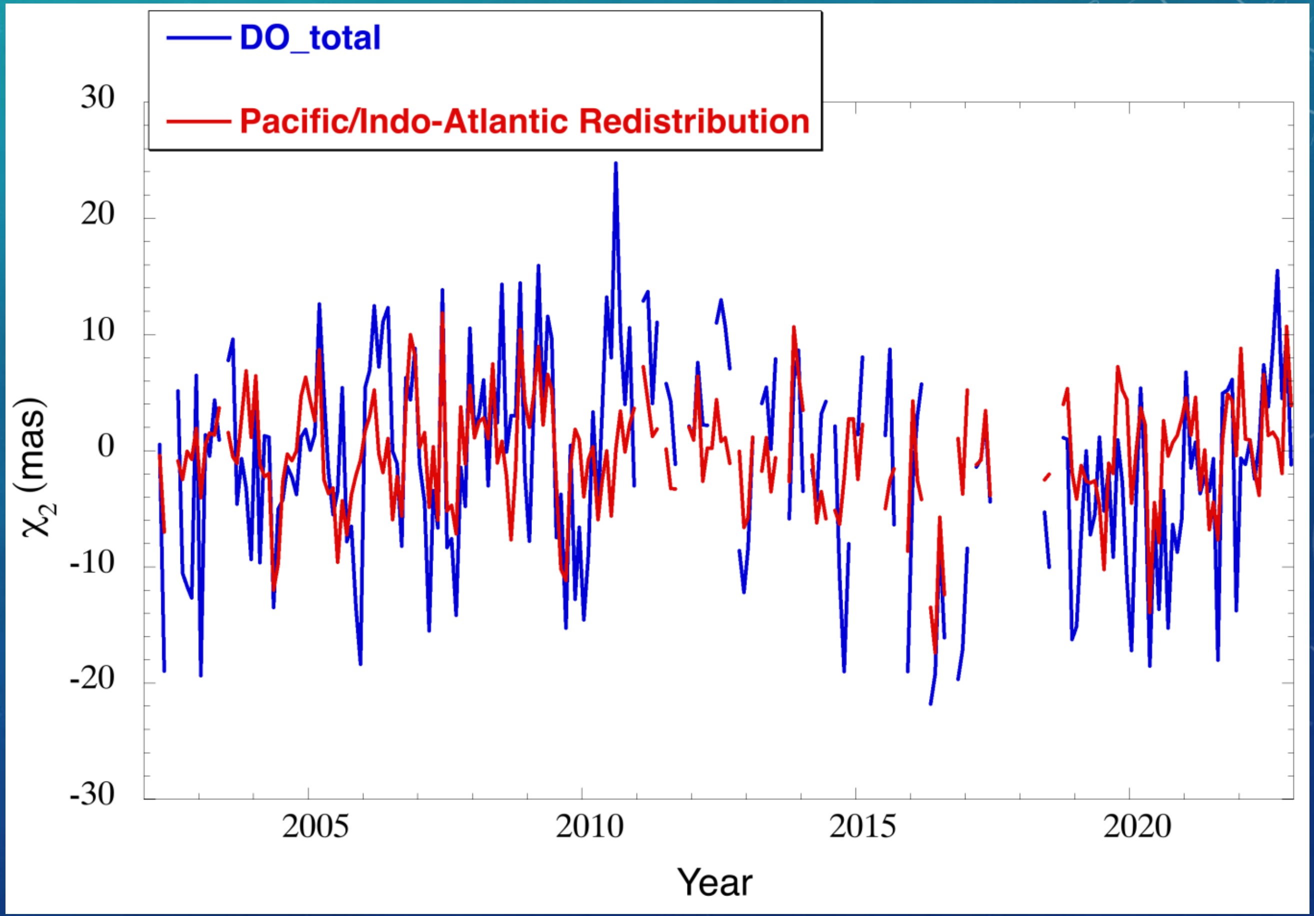
EXPERIMENTS

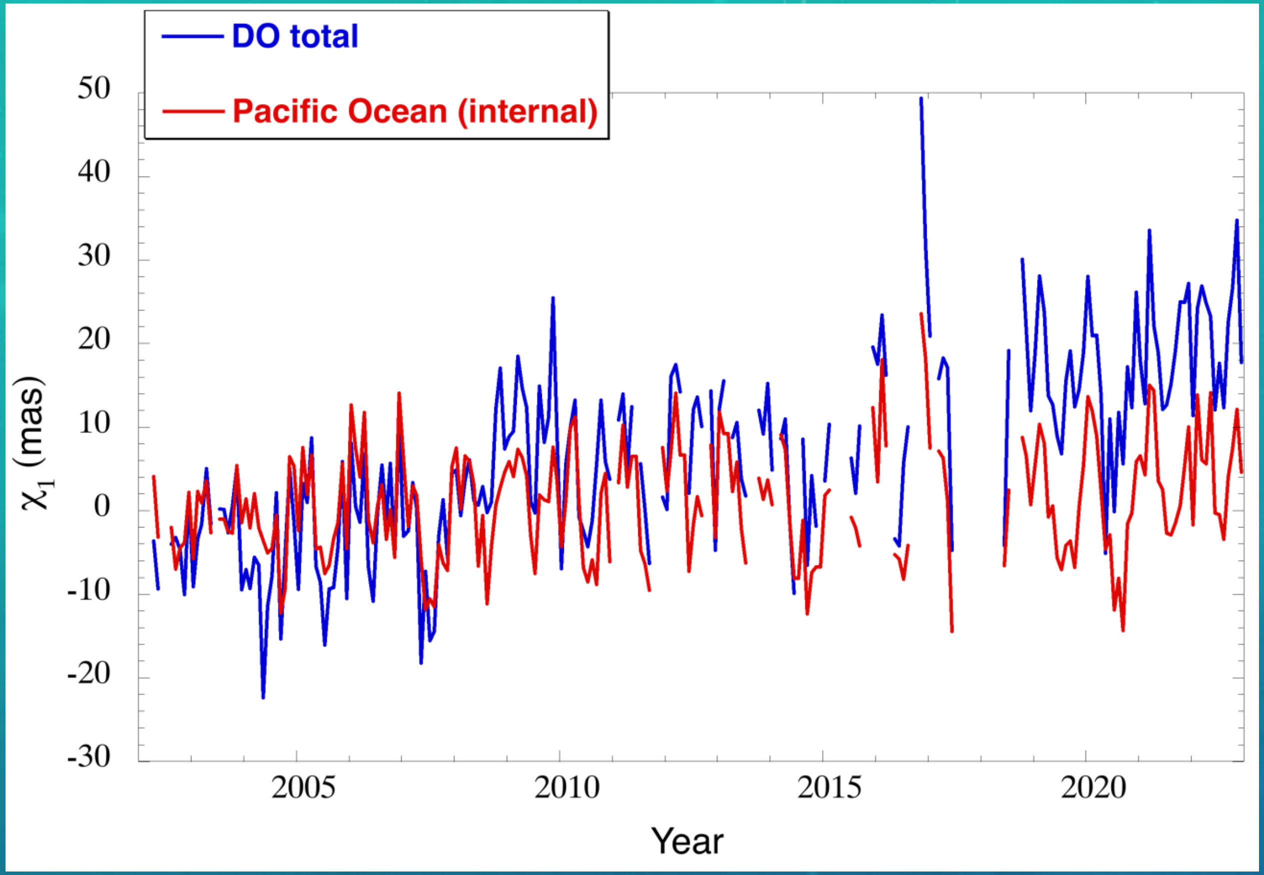
Name	Description
Full dynamic ocean (DO)	Integration of all ocean mascons
Pacific/Indo-Atlantic Redistribution	Average of Pacific and Indo-Atlantic basins. These averages are then used in each mascon in the basin to integrate.
Pacific Internal	Difference between Pacific Ocean mascons and basin average integrated.
Atlantic Internal	Difference between Atlantic Ocean mascons and Indo-Atlantic average integrated.
Indian Internal	Difference between Indian Ocean mascons and Indo-Atlantic average integrated.
Arctic	All Arctic Ocean mascons integrated.

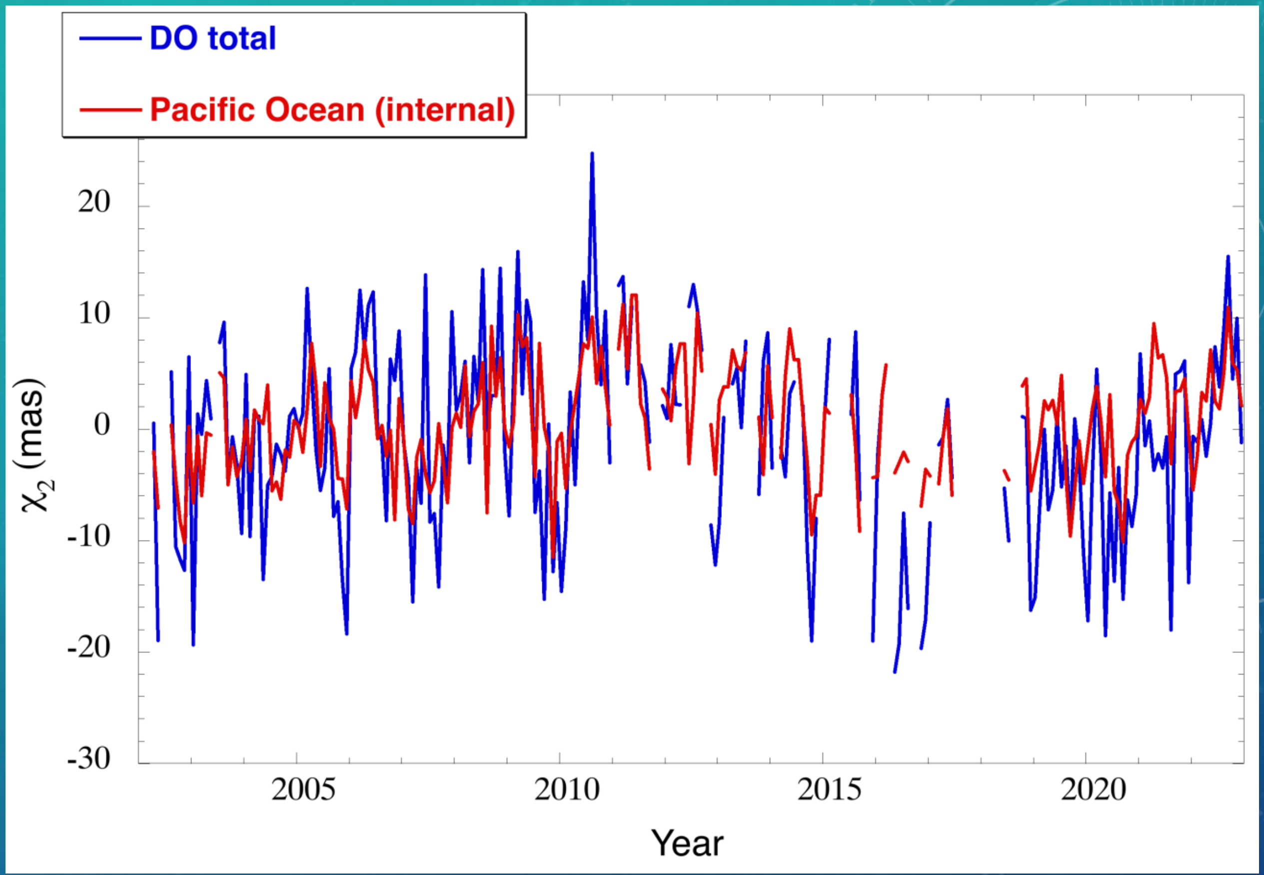


Large annual to interannual exchanges of mass between Pacific and Indo-Atlantic Oceans (likely from small changes in ACC transport < 1 mSv). Updated from Chambers and Willis (2010).

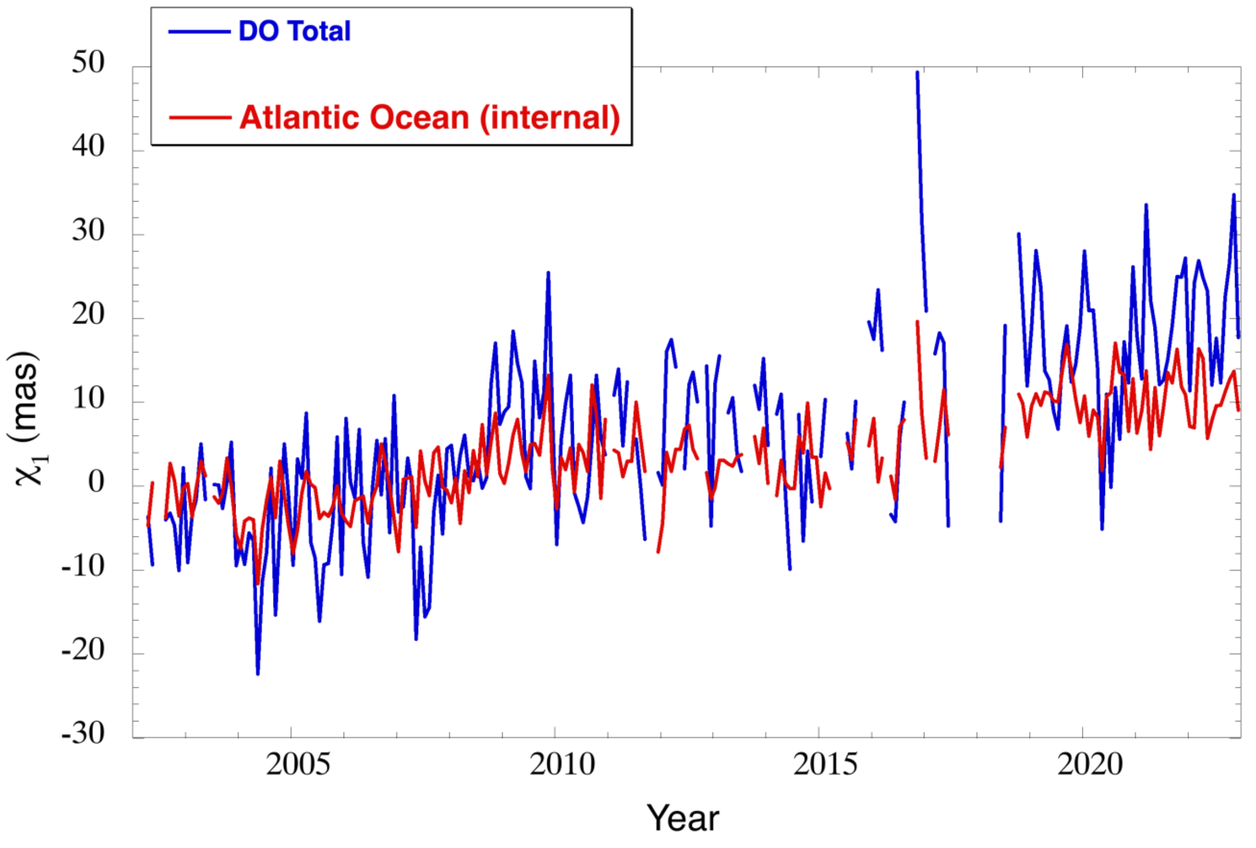
This contributes significantly to χ_2 variations at annual and < 2-year periods, but with little influence on χ_1. Accounts for 40% of overall variance of DO χ_2.







Internal mass redistribution in Pacific ocean (i.e., after removing monthly Pacific mean) explains large fractions of variance in both χ_1 (60% of variance after trends removed) and χ_2 (44% of variance).



Internal mass redistribution in Atlantic ocean (i.e., after removing monthly Atlantic mean) explains the residual variance χ_1 (20% of variance after trends removed) and about 50% of the observed trend. No significant contributions from Indian Ocean internal variability.

Annual Period Signals

χ_1

Source	Amp (mas)	Phase (°)
Global DO	2.3 ± 0.8	138.6 ± 20.8
Pac/Ind-Atl Redistribution	2.9 ± 0.4	3.7 ± 8.5
Pac internal	2.4 ± 0.4	129.3 ± 10.6
Atl internal	0.7 ± 0.2	159.2 ± 16.0
Ind internal	0.6 ± 0.2	17.5 ± 23.0
Arctic	1.1 ± 0.1	145.2 ± 3.6

χ_2

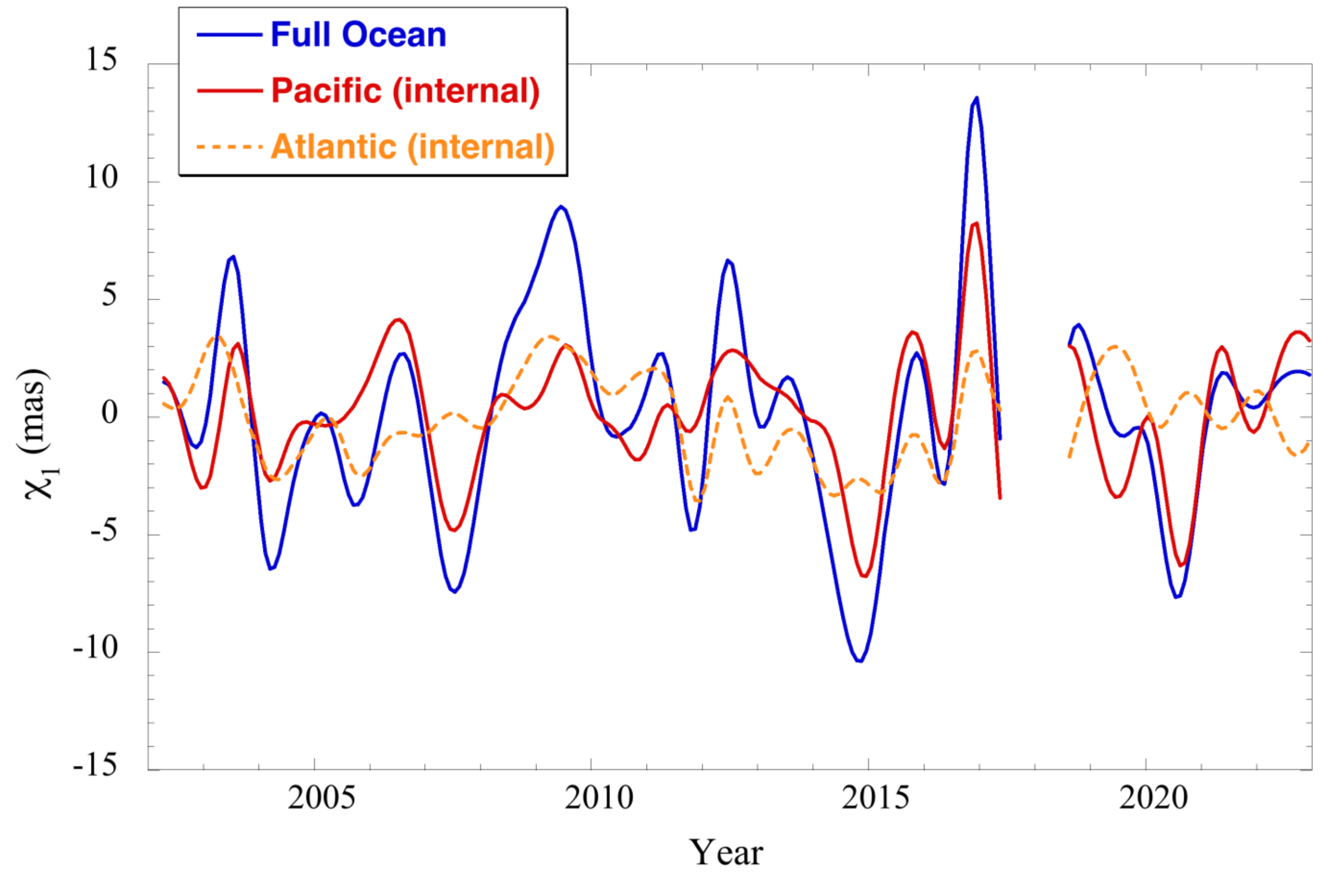
Source	Amp (mas)	Phase (°)
Global DO	4.7 ± 0.7	7.0 ± 8.8
Pac/Ind-Atl Redistribution	0.6 ± 0.1	10.2 ± 8.6
Pac internal	5.9 ± 0.5	39.5 ± 4.8
Atl internal	1.8 ± 0.3	251.5 ± 10.0
Ind internal	0.6 ± 0.2	213.2 ± 15.9
Arctic	0.9 ± 0.1	284.5 ± 3.6

χ_1 annual variations are small compared to overall variance, leading to higher uncertainty in phase. No single ocean region accounts for majority of signal, although the Pacific internal component is at same phase/amplitude, and others more or less cancel each other.

χ_2 annual variations are stronger, and Pacific internal variations dominate, although other components contribute to reducing amplitude and shifting phase earlier.

Uncertainty is one standard error

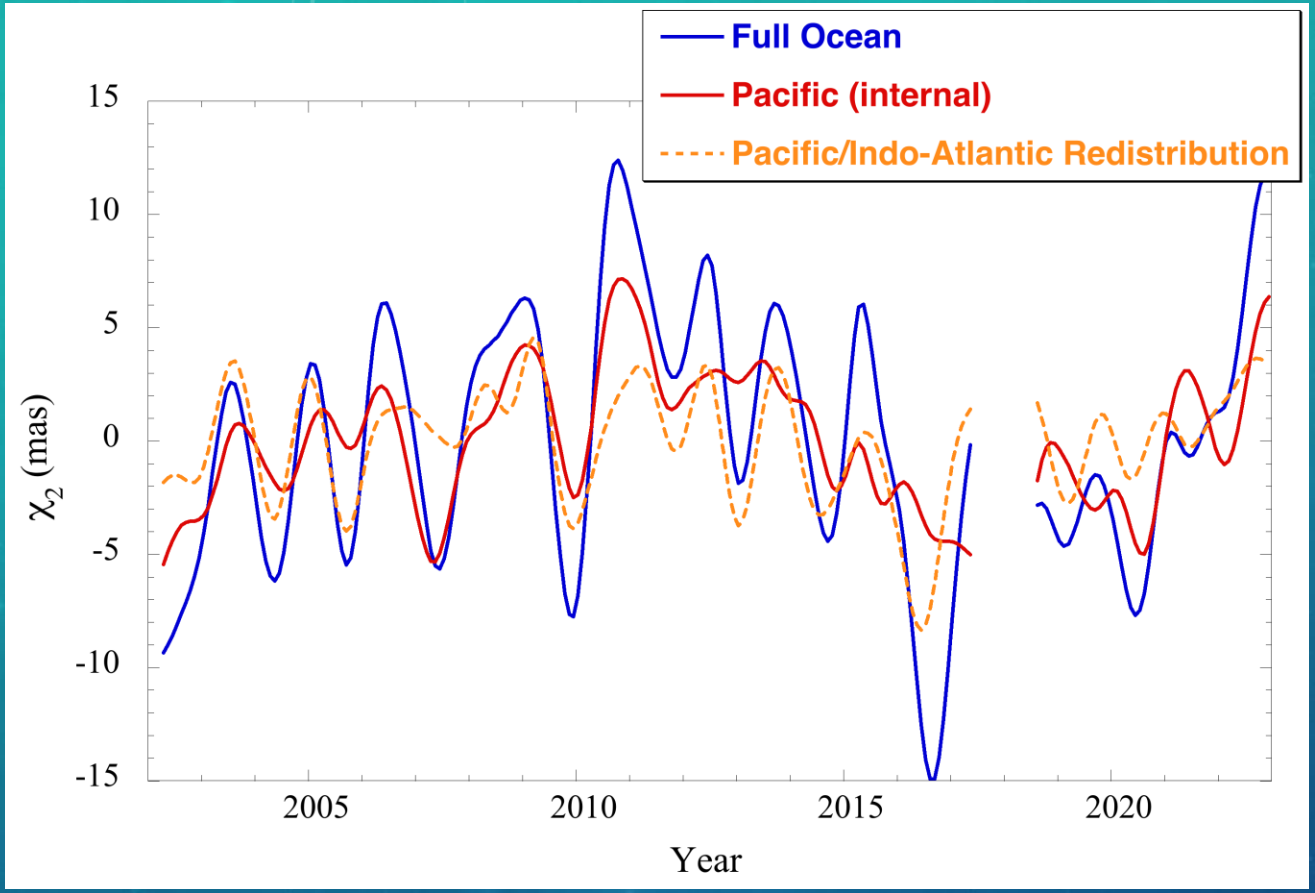
χ_1



Largest contributor is Pacific internal variability (62% variance explained), with Atlantic internal variability accounting for 33% variance explained. Notably, much of the variability at periods between 1 and 2 years is from the Pacific internal variations.

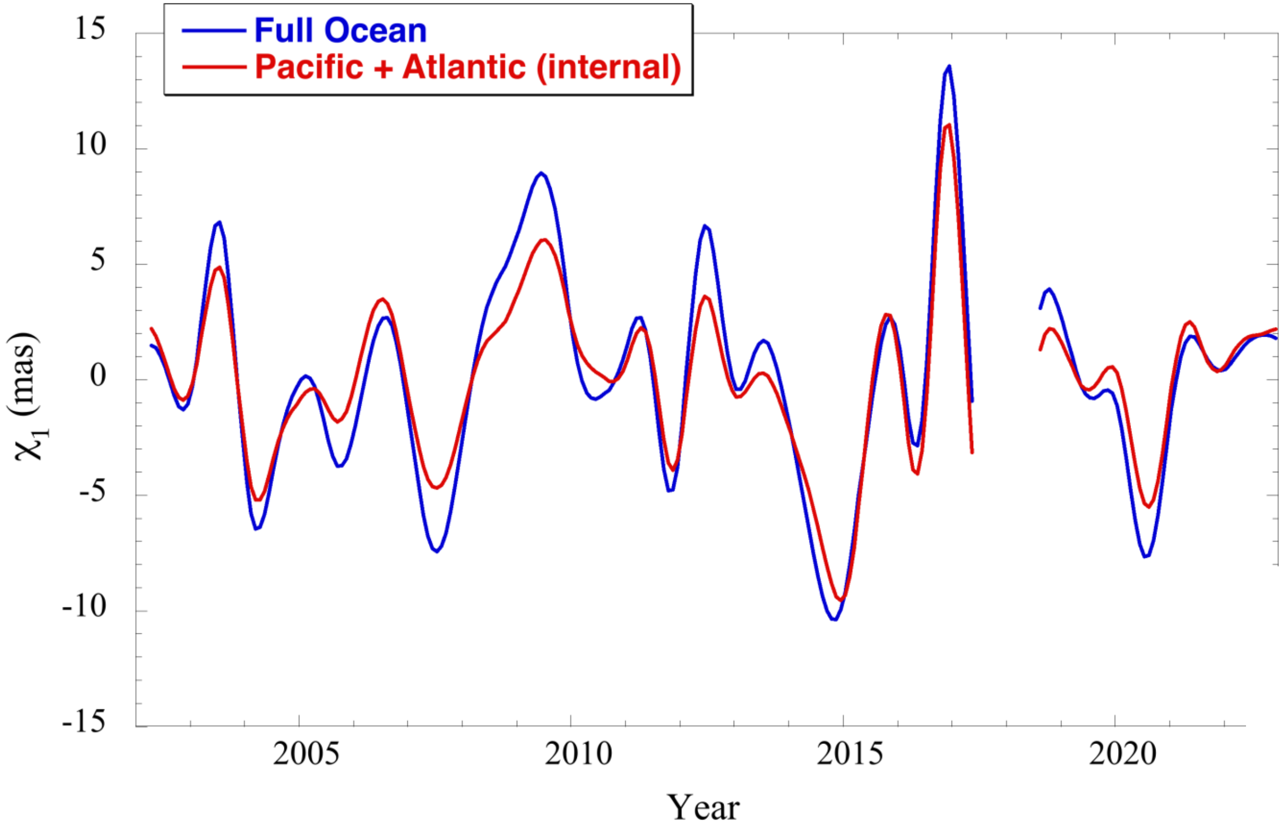
Annual signal and trend estimated and removed, then low-pass filtered with Gaussian to retain signals > 1-year. Will likely attenuate any Chandler Wobble variations at ~1.18 years.

χ_2

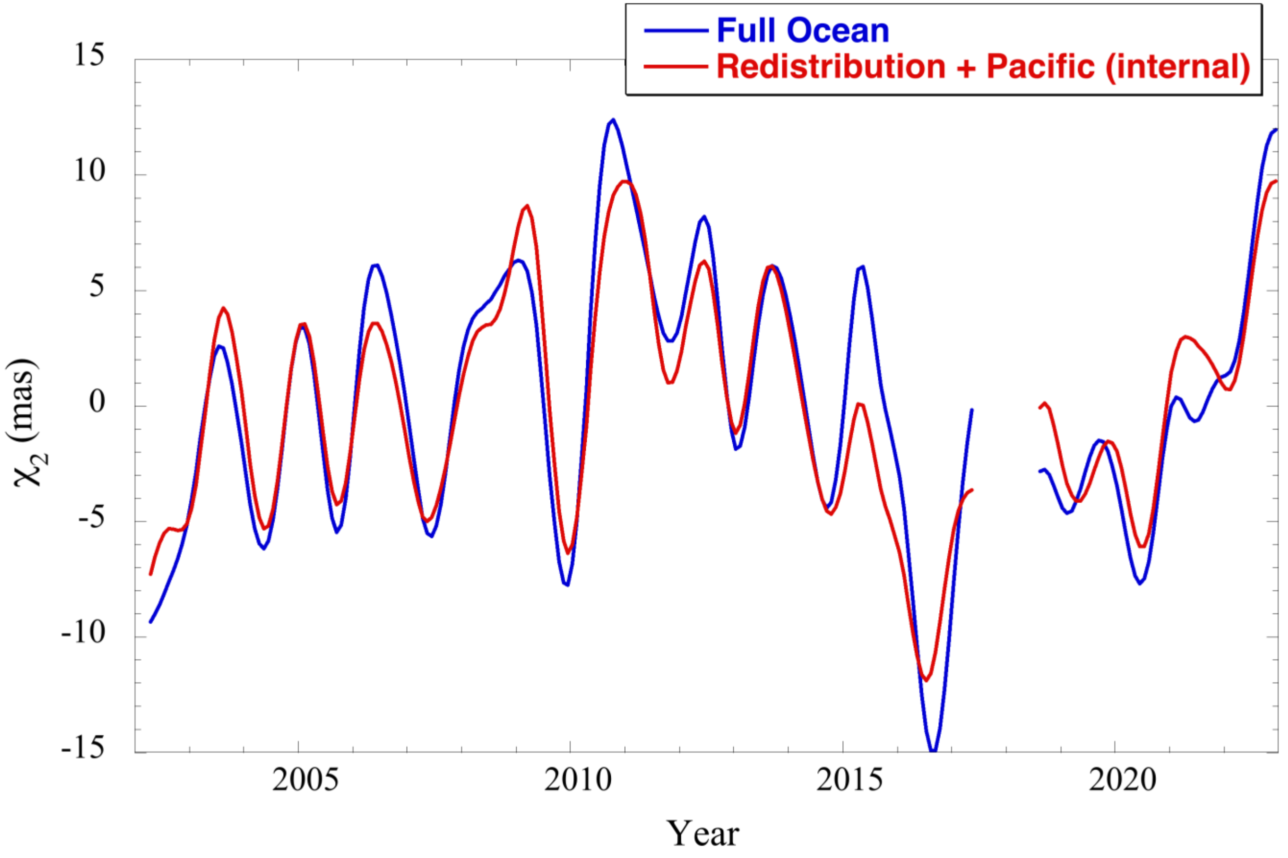


Contributions nearly equal between Pacific internal variability (60% variance explained) and Pacific/Ido-Atlantic redistribution (50% variance explained). Notably, much of the variability at periods between 1 and 2 years comes from both sources and is often in phase.

Annual signal and trend estimated and removed, then low-pass filtered with Gaussian to retain signals > 1-year. Will likely attenuate any Chandler Wobble variations at ~1.18 years.



Full Ocean
Pacific + Atlantic (internal)
χ_1 (mas)
15
10
5
0
-5
-10
-15
2005
2010
2015
2020
Year



Full Ocean
Redistribution + Pacific (internal)
χ_2 (mas)
15
10
5
0
-5
-10
-15
2005
2010
2015
2020
Year

CONCLUSIONS

- I have isolated the principle contributors to oceanic polar motion from
  - Pacific/Indo-Atlantic mass exchanges (primarily χ_2)
  - Internal mass exchanges within the Pacific Ocean (both χ_1 and χ_2).
  - Internal mass exchange within the Atlantic (χ_2).
- Next steps
  - look at specific high variability Pacific regions and isolate which area (or whether all) contribute to this
  - Understand where in Atlantic is causing trend in χ_1.