Numerical Stratigraphic Modeling of Climatic Controls on Basin-Scale Sedimentation*

Ashley D. Harris[1], Cristian Carvajal[2], Jake Covault[2], Martin Perlmutter[2], and Tao Sun[2]

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Abstract

Stratigraphic concepts interpret stratal architecture and sediment distribution as results of the interaction of sea level, sediment supply, and tectonism. Typically, these concepts emphasize changes in accommodation driven by sea level as a principal control on deposition with sediment supply held constant. Yet, sediment supply to a basin can vary over time due to autogenic processes, tectonism, and climate change. Additionally, the supply to a basin may be out of phase with sea-level changes. We use a numerical forward stratigraphic modeling program to generate basin-scale (shelf to abyssal plain) numerical end-member cases that examine the dynamic interaction of sediment supply cycles that are at a 0, 90, 180, or 270 degree phase relationship with sea-level amplitudes typical of icehouse and greenhouse conditions on the 100 kyr timescale (eccentricity). These numerical models quantify the impact of sea level and climate driven sediment supply on sediment distribution and preservation during long-term basin evolution. Our results demonstrate the utility of sediment transport modeling by testing concepts of basin fill typically applied to exploration areas.

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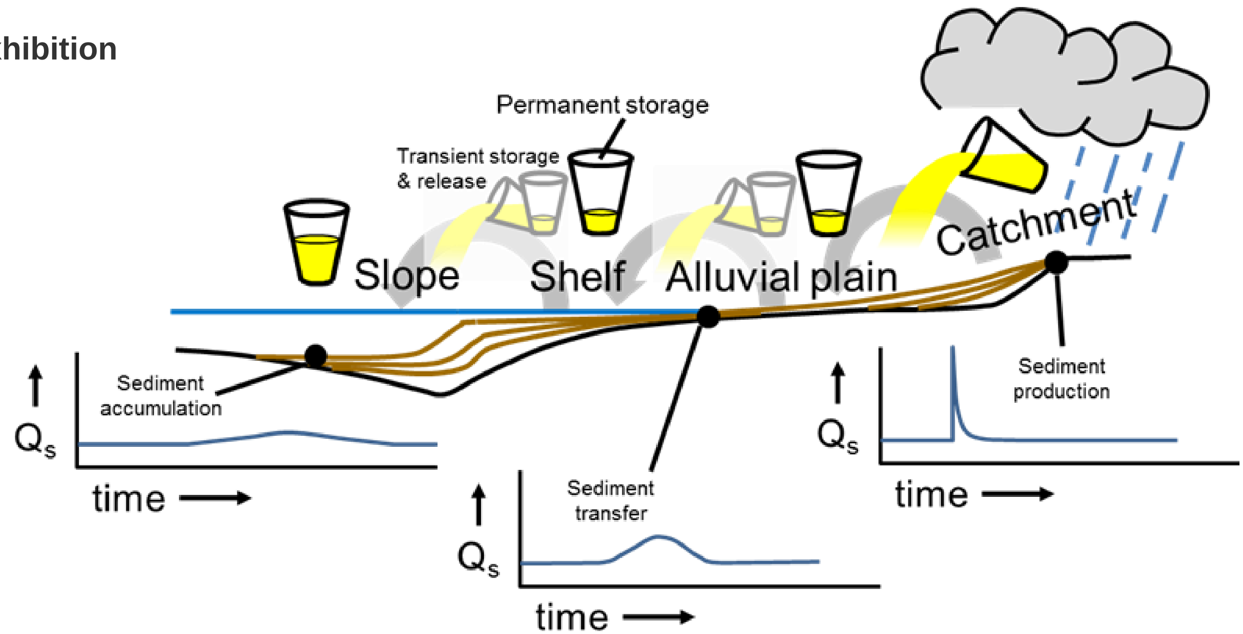
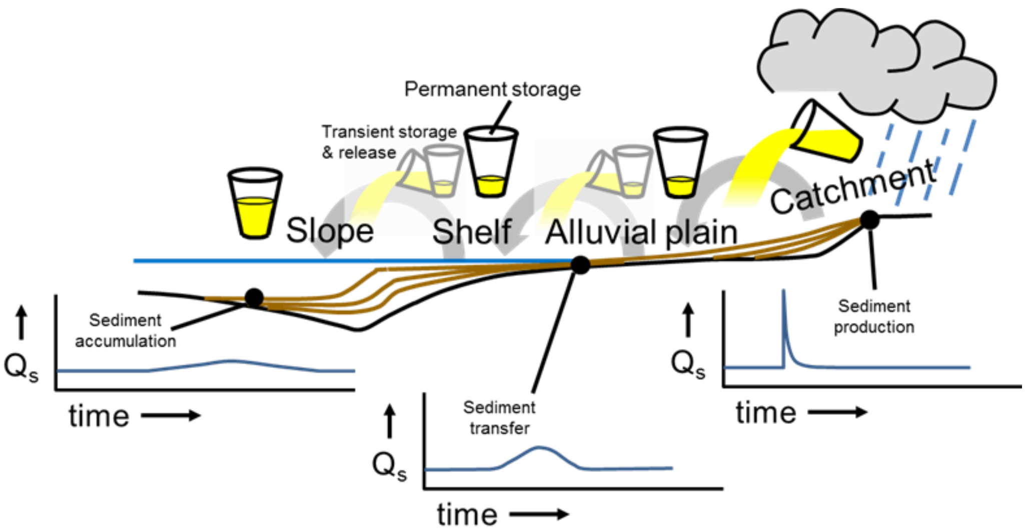
AAPG 2015 Annual Convention & Exhibition



Motivation



- Sediment supply & distribution are related to the complex dynamics of upstream and downstream forcings
  - One forcing (e.g., climate) can be responsible for different responses across the entire sed. routing system
  - Lead, lags, & out of phase relationship with sea level

Objectives

- Test sediment supply phase relationships with sea-level amplitudes typical of greenhouse and icehouse settings
  - What are the differences in volumetric distribution and sediment delivery?
  - Does long-term shoreline or delta position really matter?
  - Is there need for different stratigraphic models for each setting?

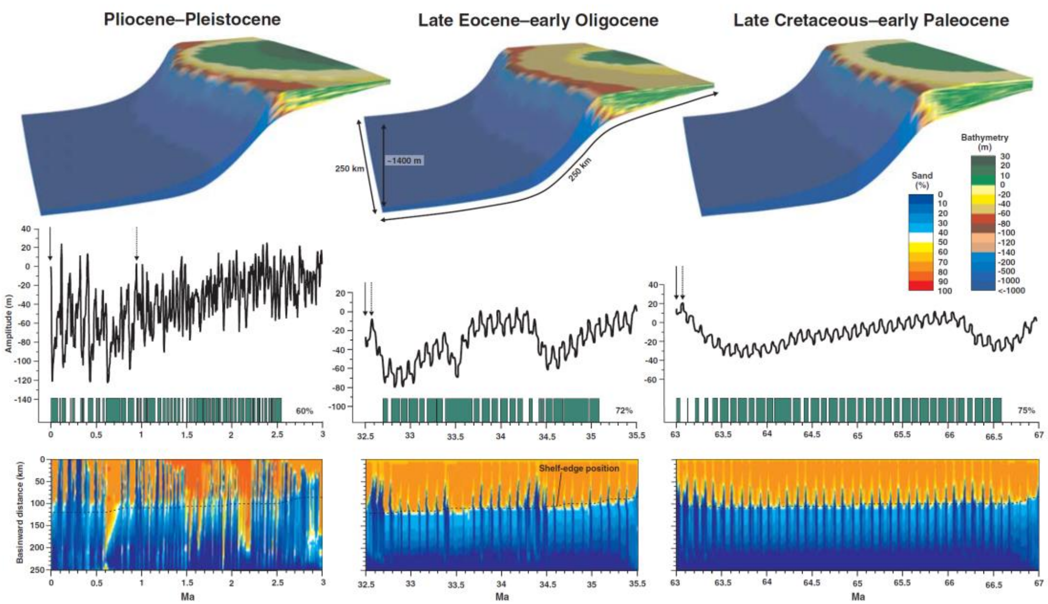
greenhouse

Vs.

icehouse

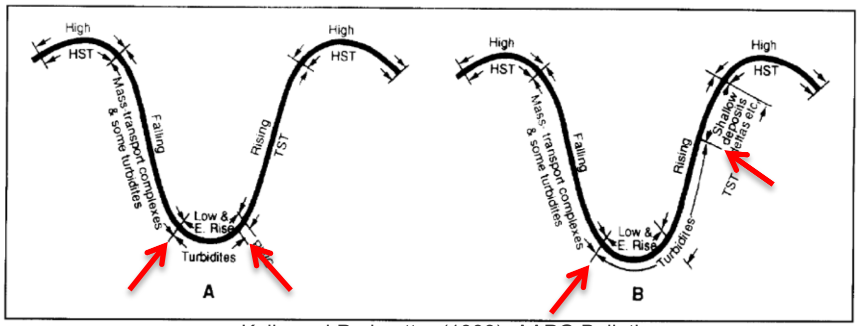
Greenhouse vs. Icehouse

- Greenhouse
  - Warm temp. & High CO_2
  - Small to no ice sheets
  - Low amplitude SL changes
- Icehouse
  - Cool temp & Low CO_2
  - Large ice sheets
  - High amplitude SL change



Sømme et al. (2009): Geology

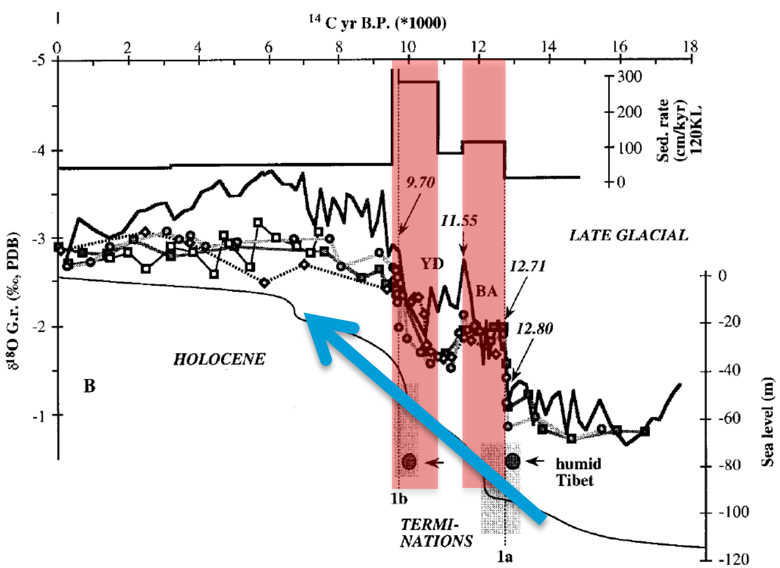
Motivation



Kolla and Perlmutter (1993): AAPG Bulletin

- Glacial meltwater pulses

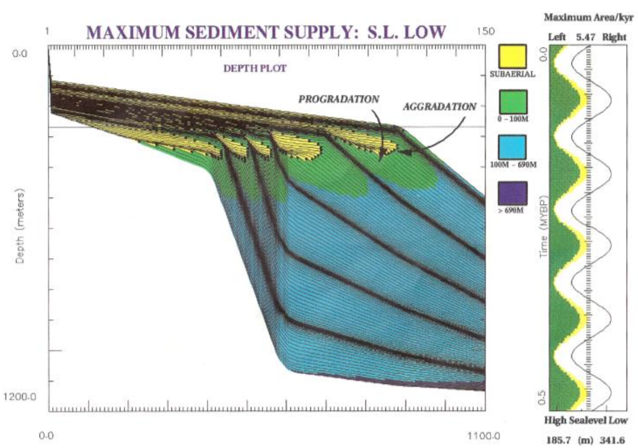
- Monsoon



Weber et al. (1993): Geology

Previous Work

- Position of sequence stratigraphic surfaces and system tract volumes differ
- Correlation of shelf to deepwater deposits is difficult
- Sea level is effective at pumping sediment to deepwater



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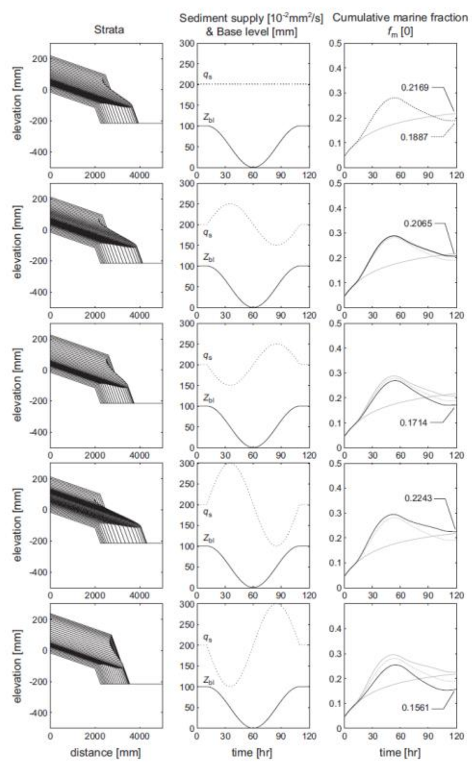

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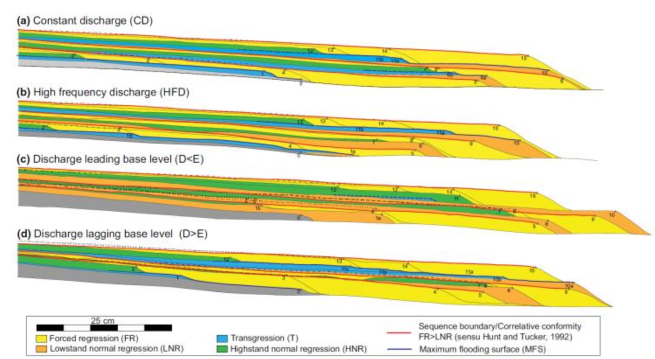
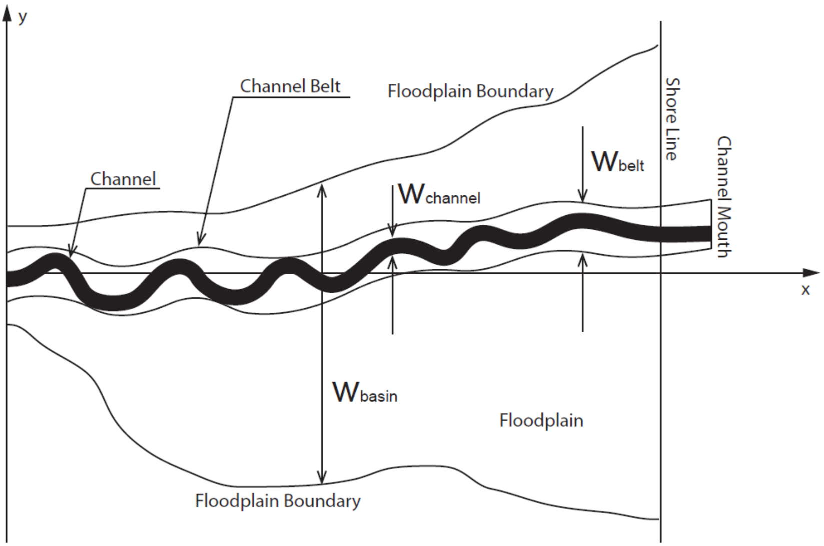
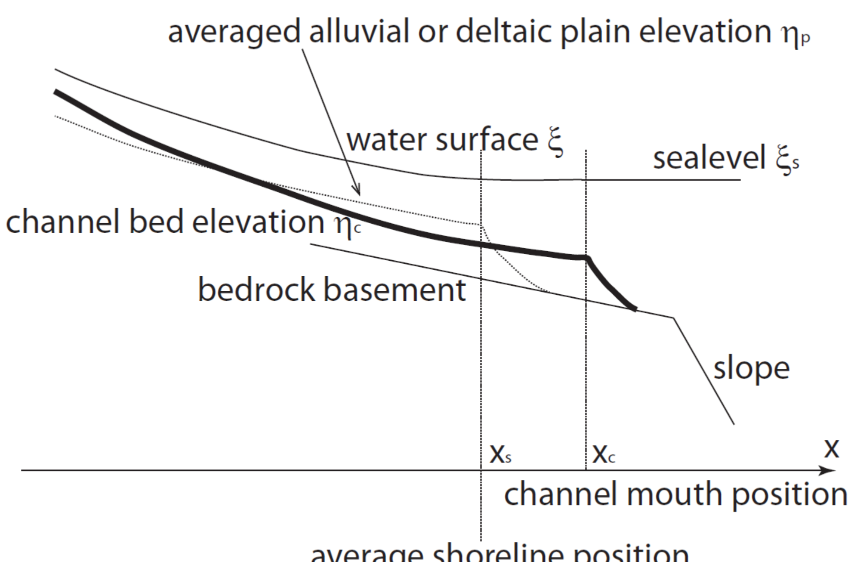


Bijkerk et al. (2014): Basin Research

Model Setup





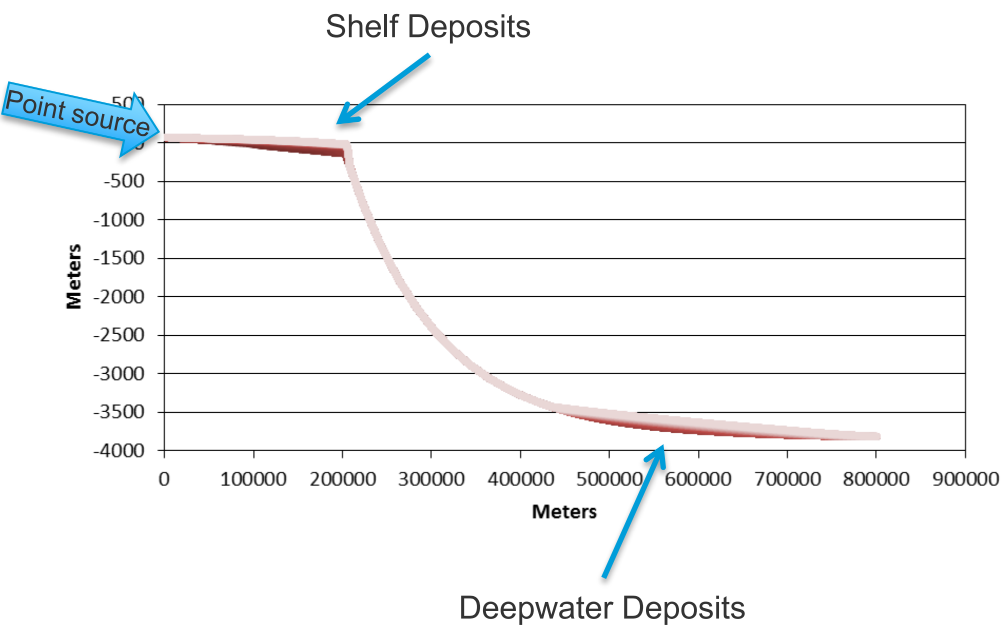
- Greenhouse SL
  - 2m amp. w/ 100kyr periodicity
- Icehouse SL
  - 50m amp. w/ 100kyr periodicity
- Subsidence
  - 25m/Myr @ shelf slope break

Water and Sed. Discharge

- $Qw = 2,000\ m^3/sec$
- $Qs = .32\ m^3/sec$
- 100 kyr periodicity
- Max. 3x > Min.
- 0º, 90º, 180º, 270º phase

Sun et al. (2014), (in prep)

Model Setup



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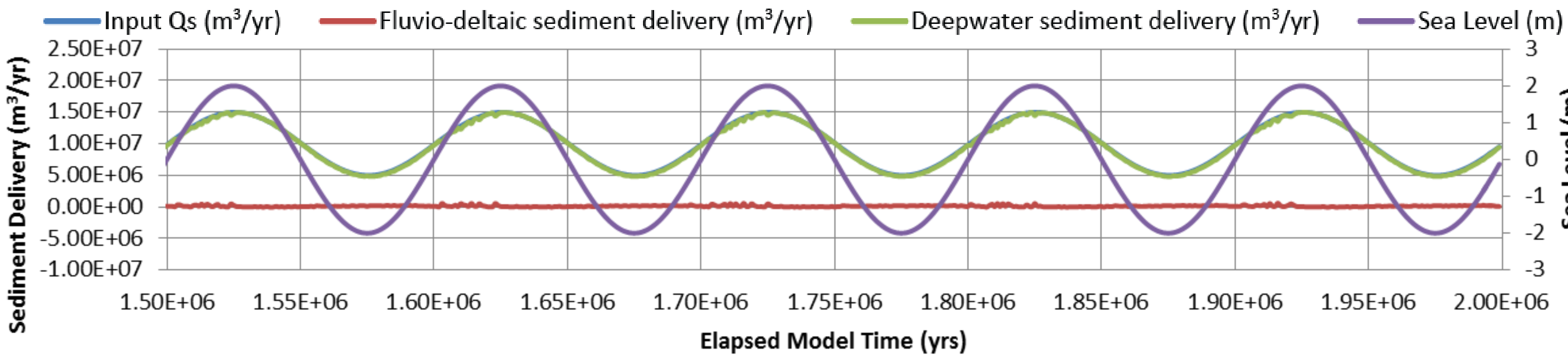
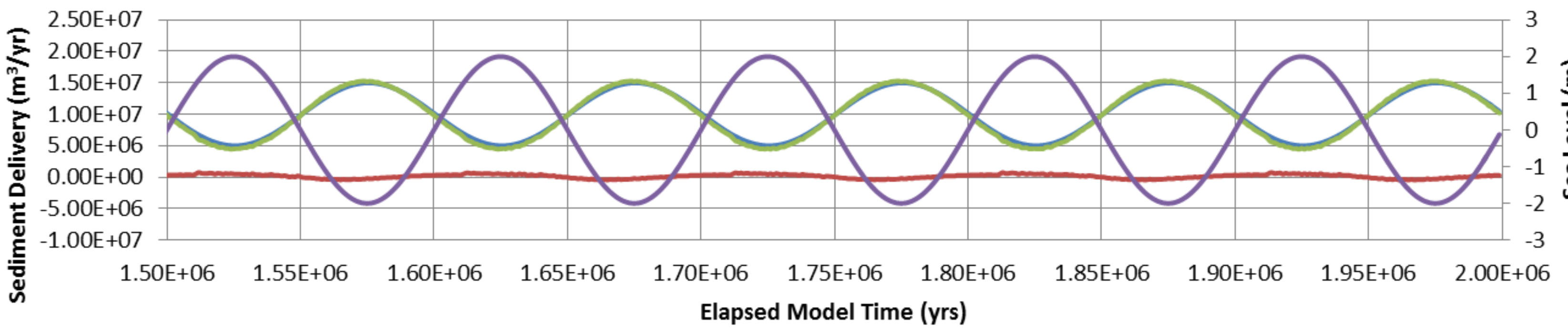
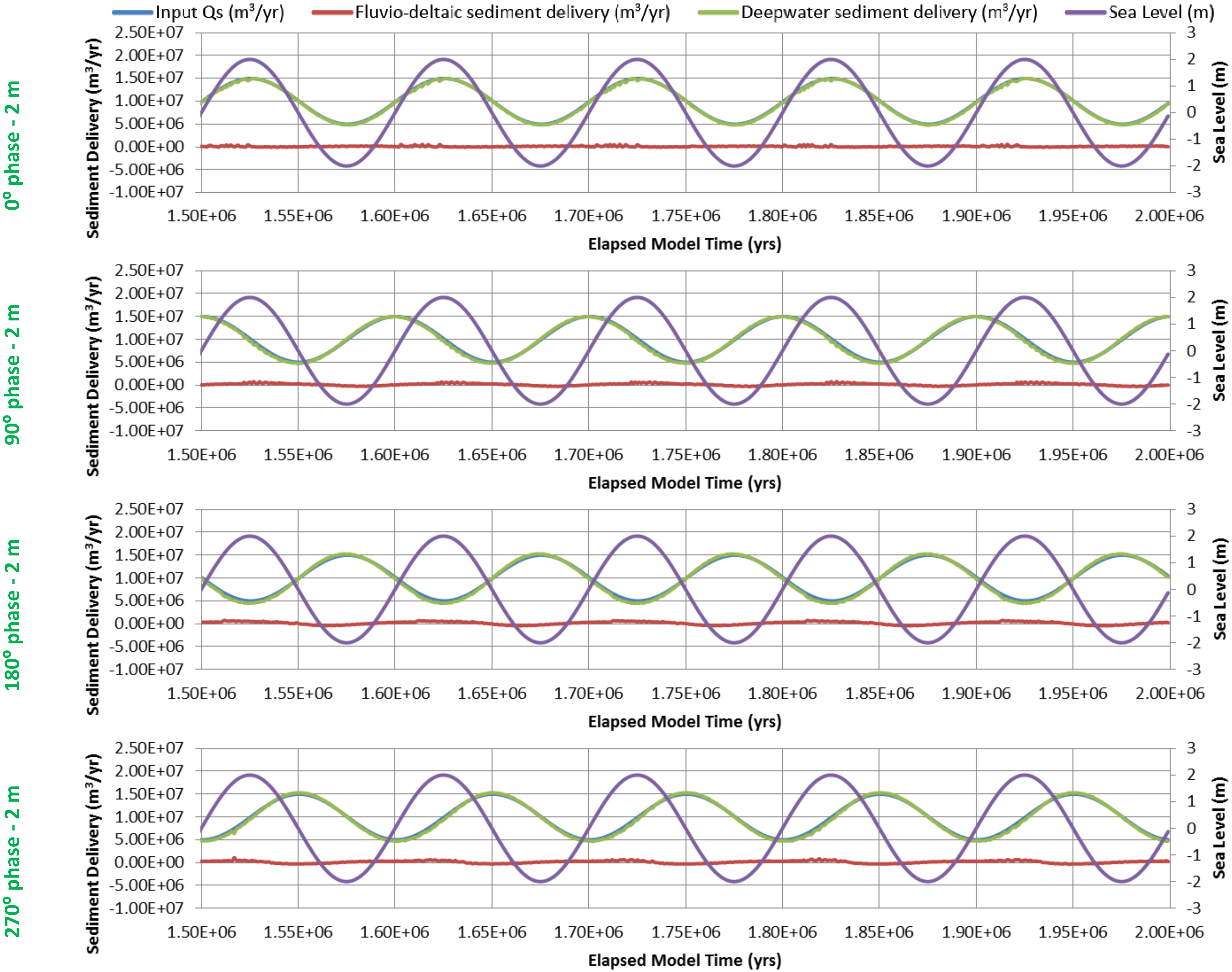
0° phase - 2 m



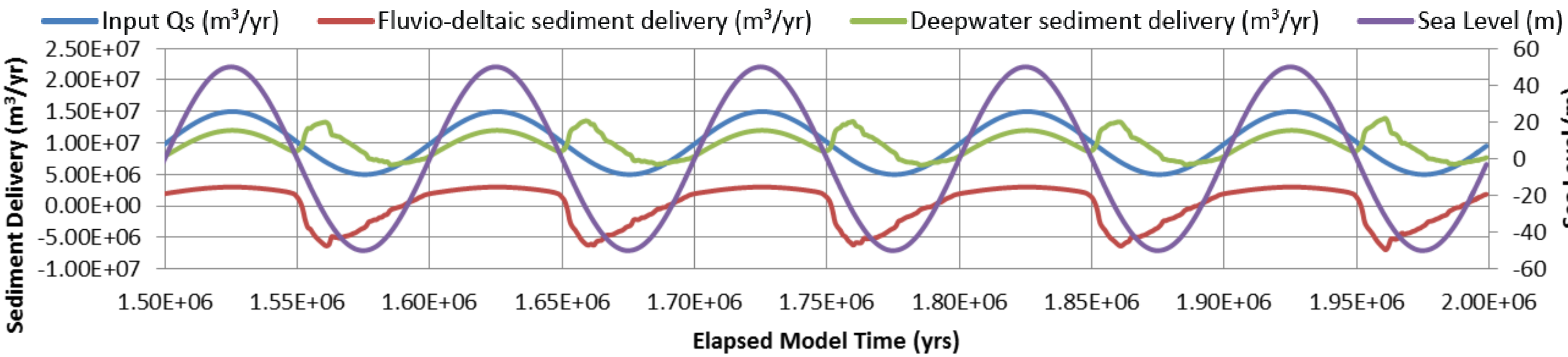
180° phase - 2 m



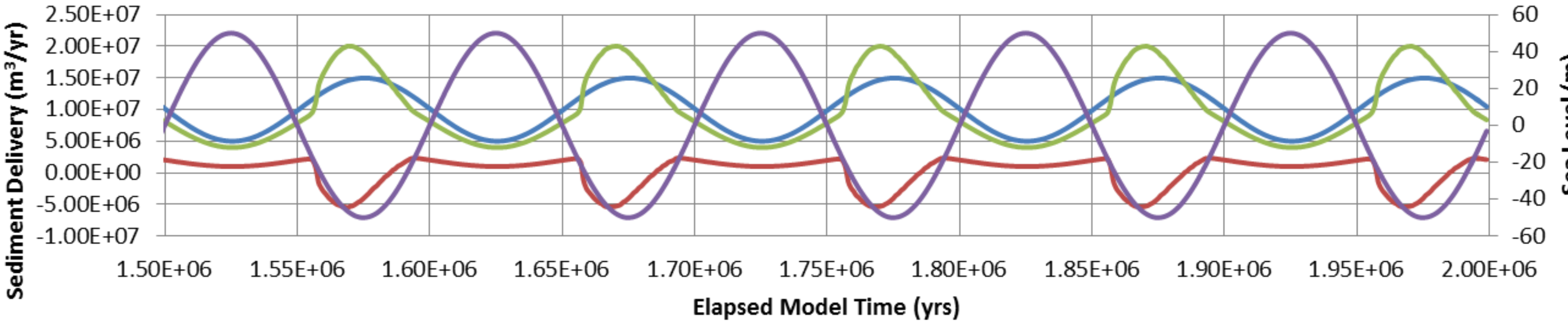


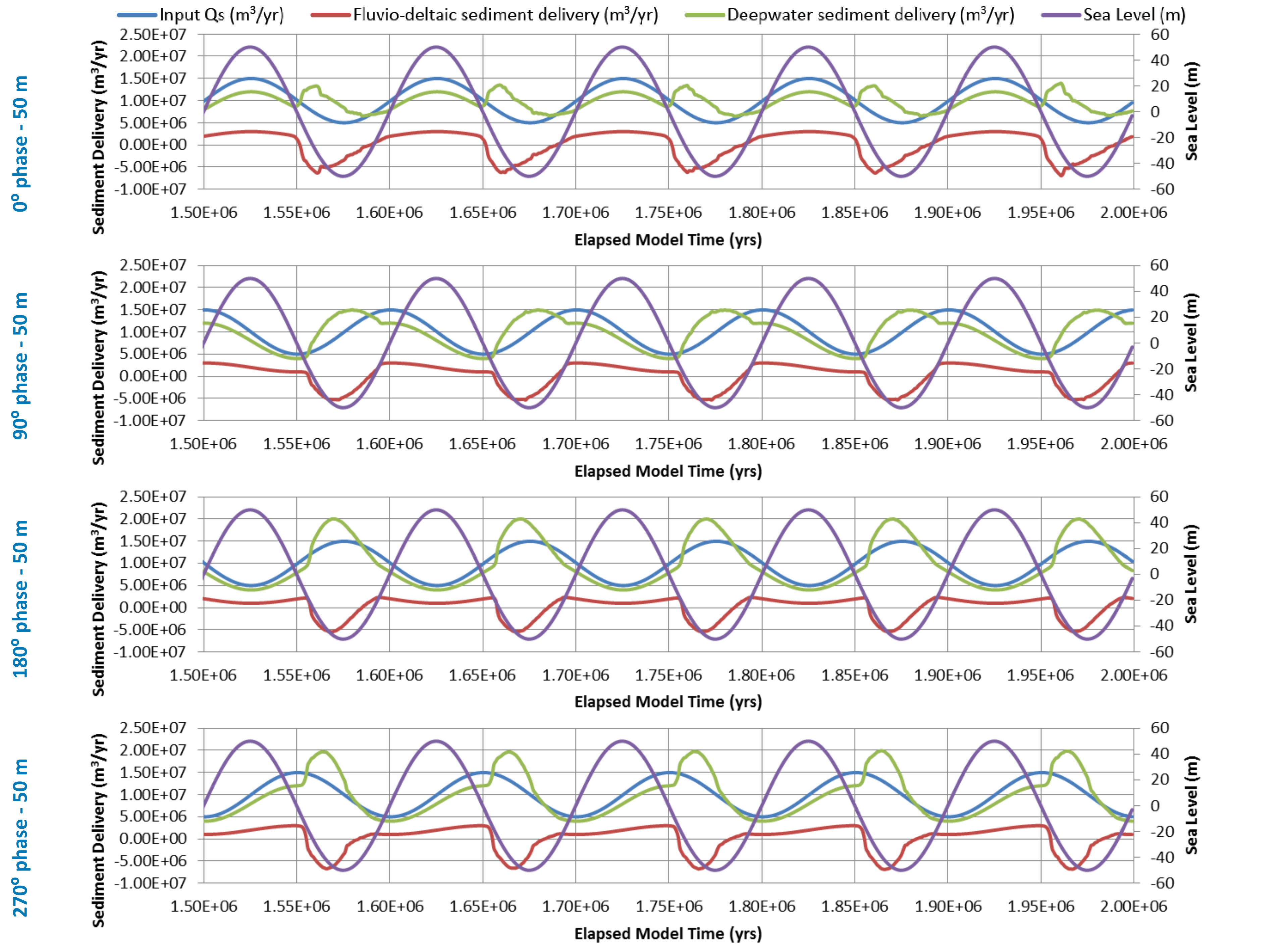
Input Qs (m³/yr)
Fluvio-deltaic sediment delivery (m³/yr)
Deepwater sediment delivery (m³/yr)
Sea Level (m)
0° phase - 2 m
90° phase - 2 m
180° phase - 2 m
270° phase - 2 m
Sediment Delivery (m³/yr)
Sea Level (m)
Elapsed Model Time (yrs)
2.50E+07
2.00E+07
1.50E+07
1.00E+07
5.00E+06
0.00E+00
-5.00E+06
-1.00E+07
1.50E+06
1.55E+06
1.60E+06
1.65E+06
1.70E+06
1.75E+06
1.80E+06
1.85E+06
1.90E+06
1.95E+06
2.00E+06

0° phase - 50 m



180° phase - 50 m

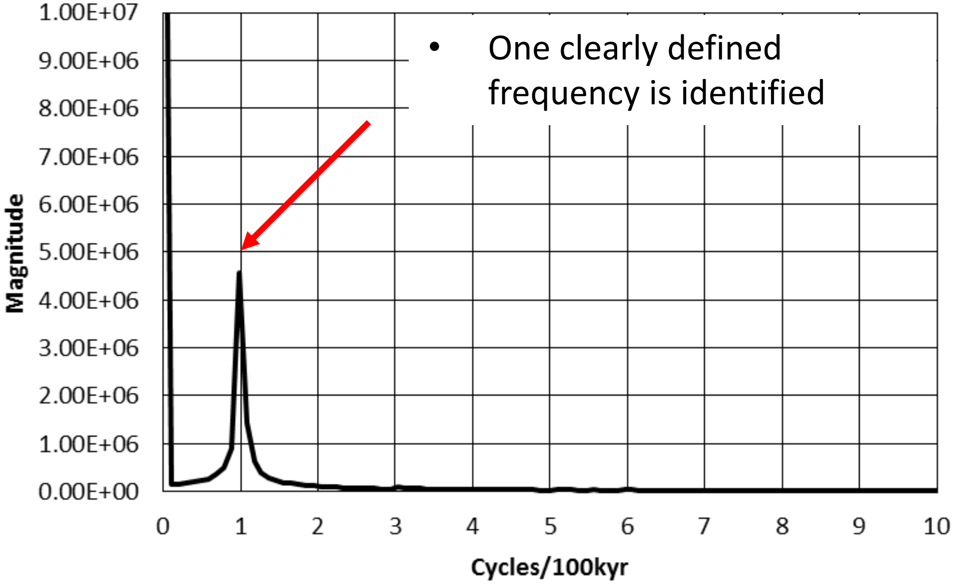




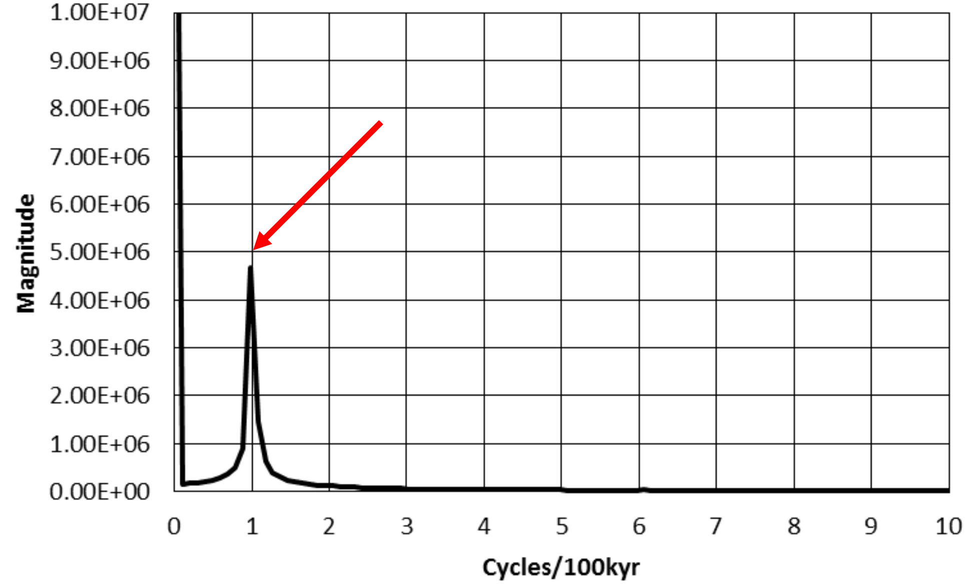
Input Qs (m3/yr)
Fluvio-deltaic sediment delivery (m3/yr)
Deepwater sediment delivery (m3/yr)
Sea Level (m)
0° phase - 50 m
90° phase - 50 m
180° phase - 50 m
270° phase - 50 m
Sediment Delivery (m3/yr)
Sea Level (m)
Elapsed Model Time (yrs)
2.50E+07
2.00E+07
1.50E+07
1.00E+07
5.00E+06
0.00E+00
-5.00E+06
-1.00E+07
60
40
20
0
-20
-40
-60
1.50E+06
1.55E+06
1.60E+06
1.65E+06
1.70E+06
1.75E+06
1.80E+06
1.85E+06
1.90E+06
1.95E+06
2.00E+06

Spectral Analysis of Deepwater Sediment Delivery Curves

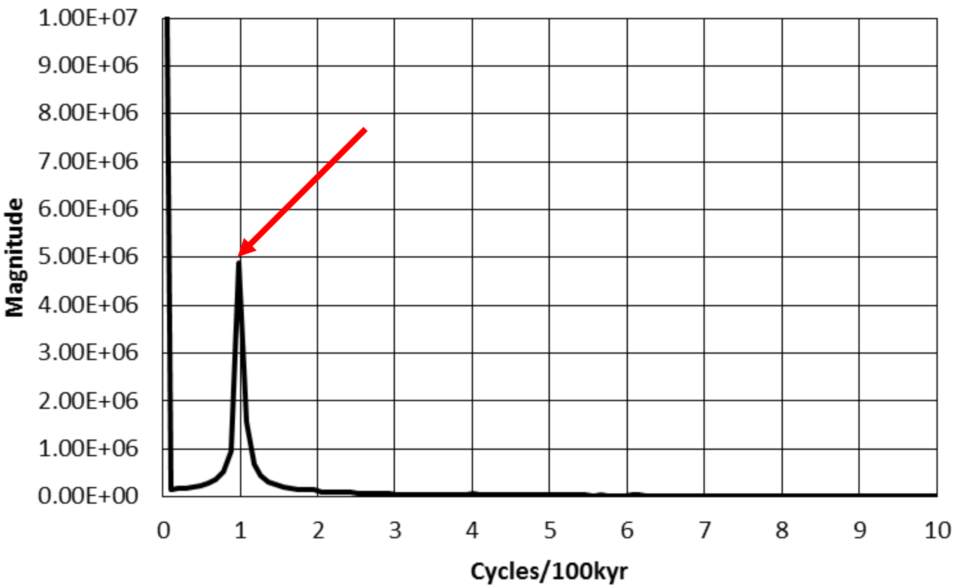
0º Phase - 2m Amp



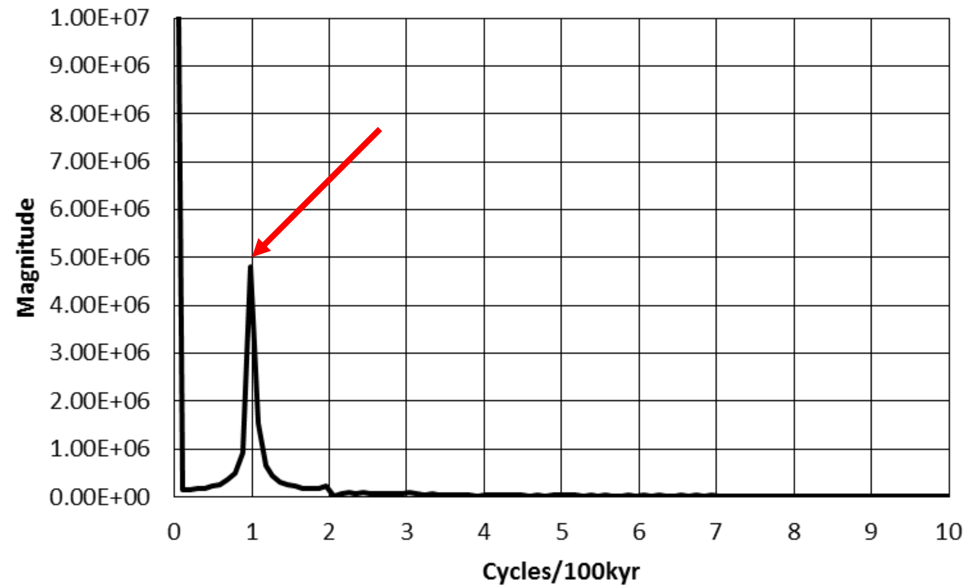
90º Phase - 2m Amp



180º Phase - 2m Amp

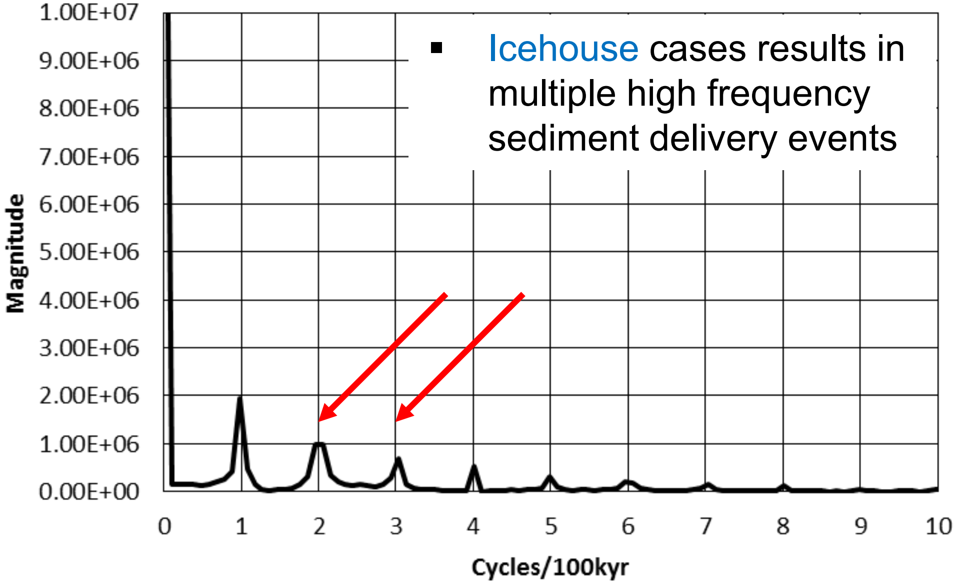


270º Phase - 2m Amp

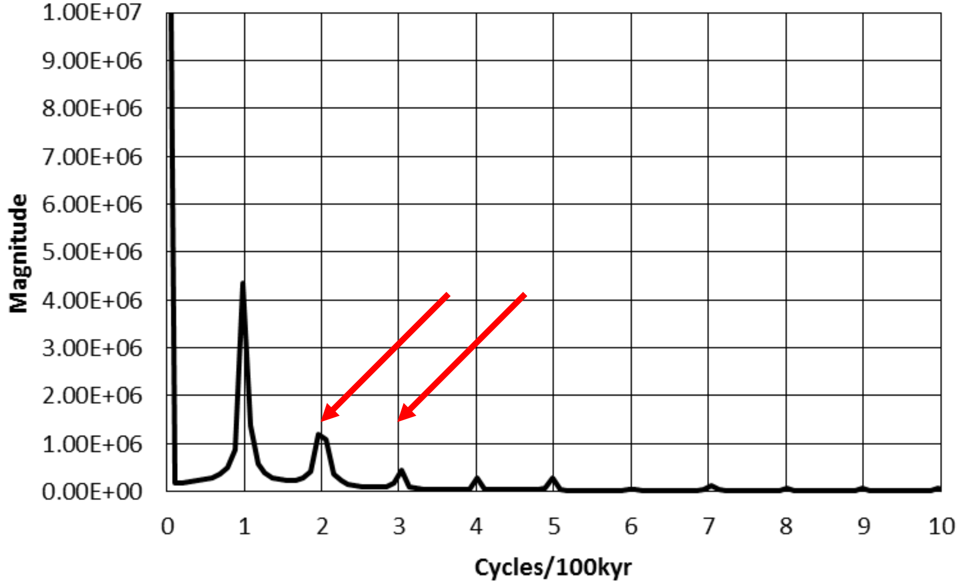


Spectral Analysis of Deepwater Sediment Delivery Curves

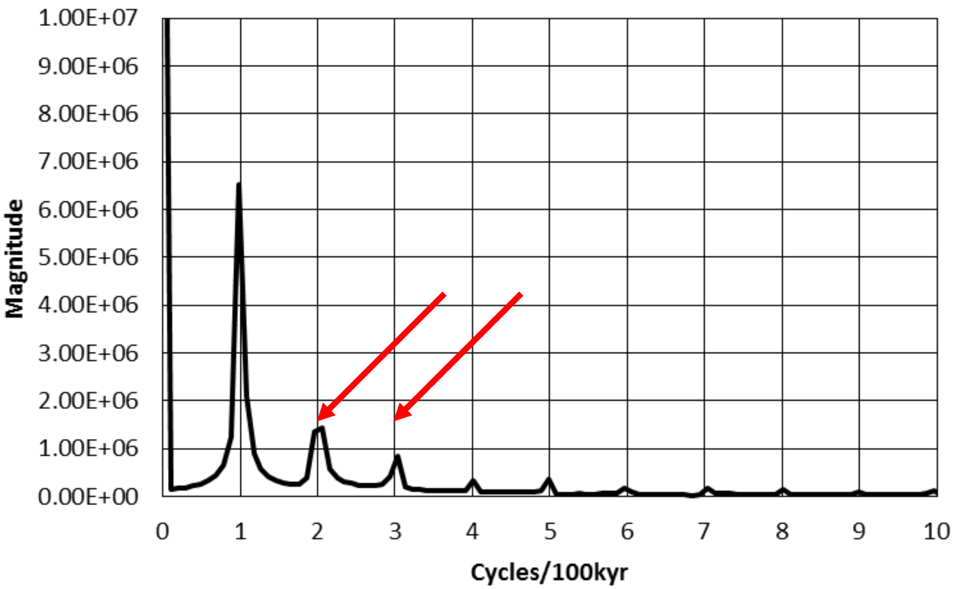
0º Phase - 50m Amp



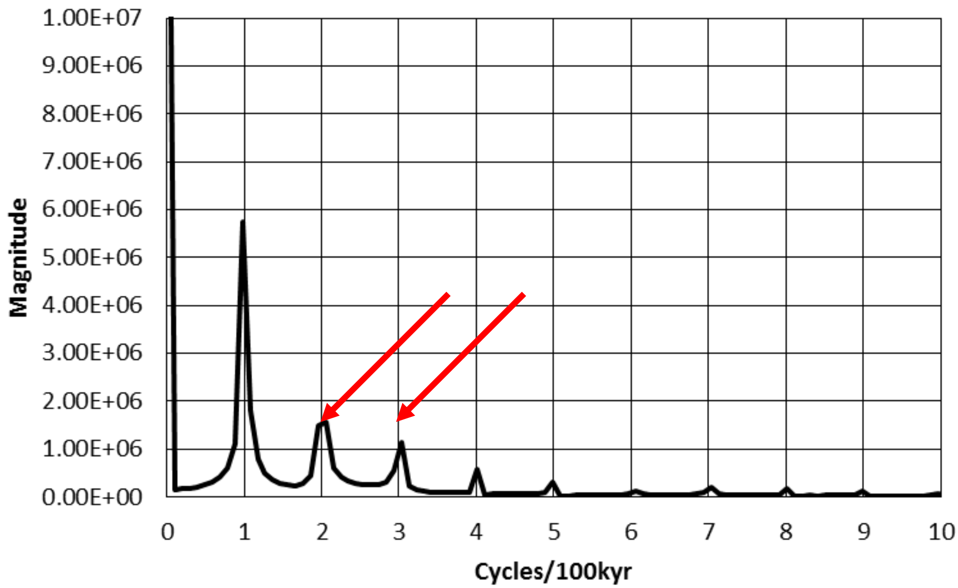
90º Phase - 50m Amp



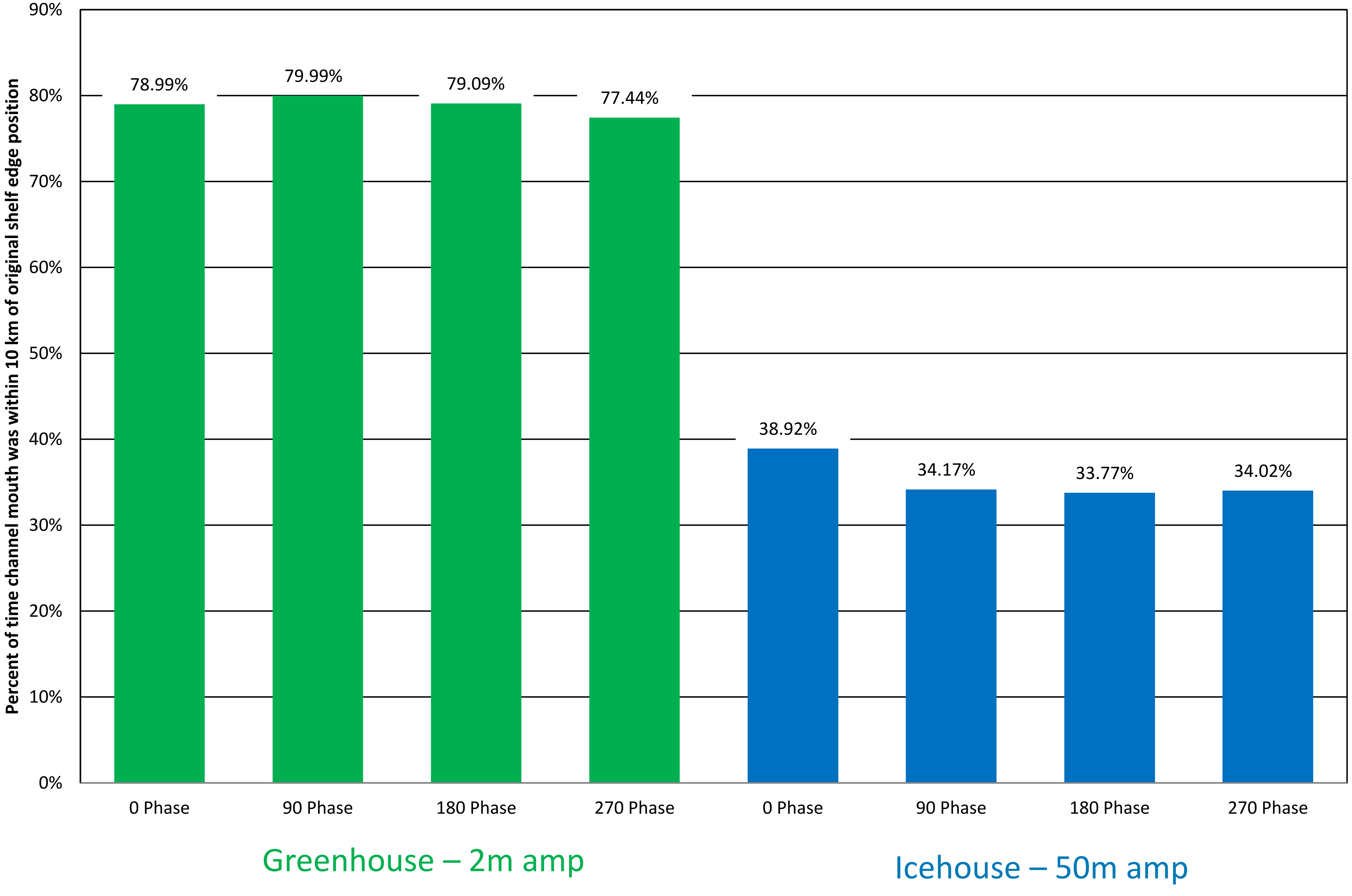
180º Phase - 50m Amp



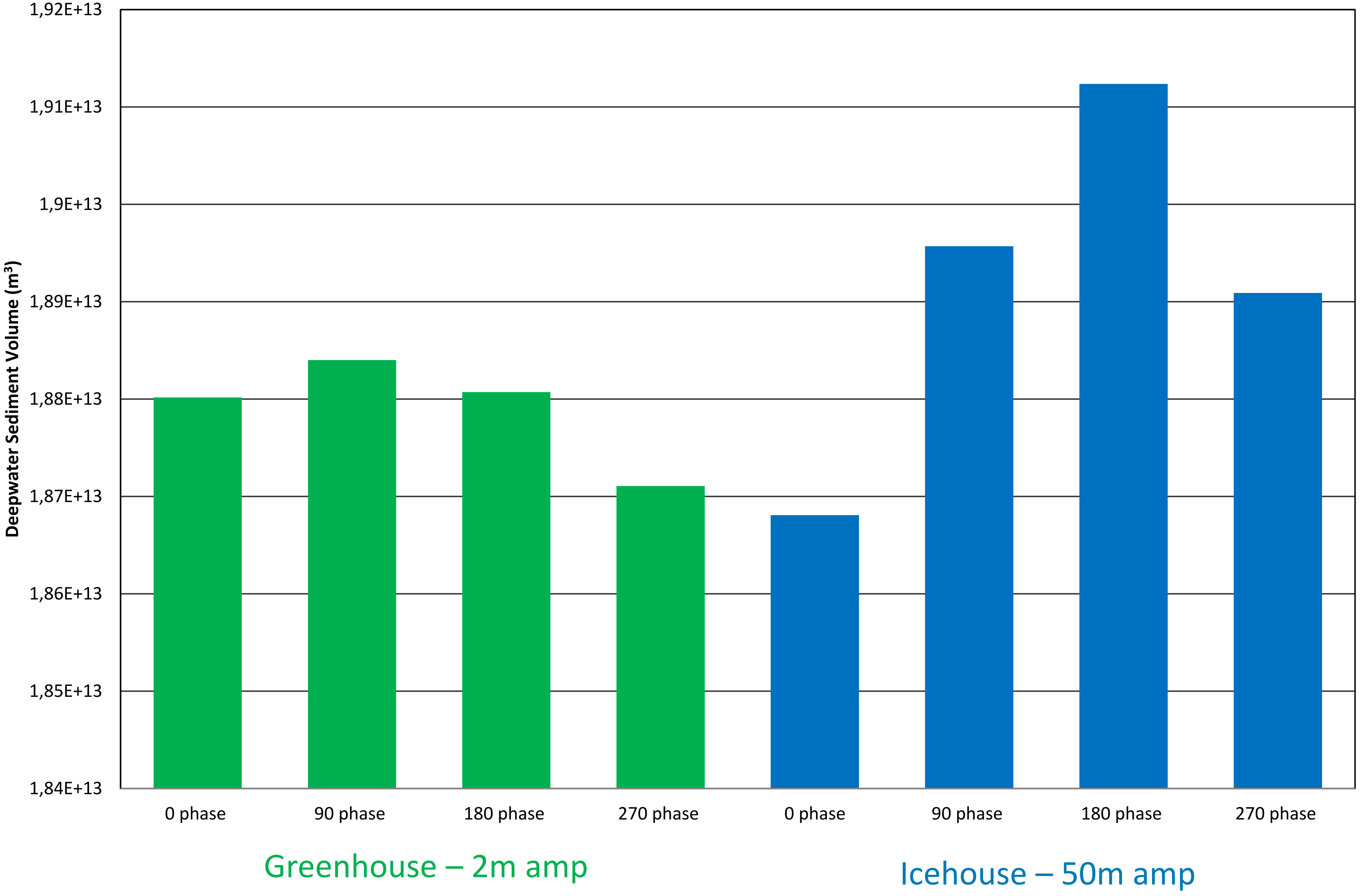
270º Phase - 50m Amp



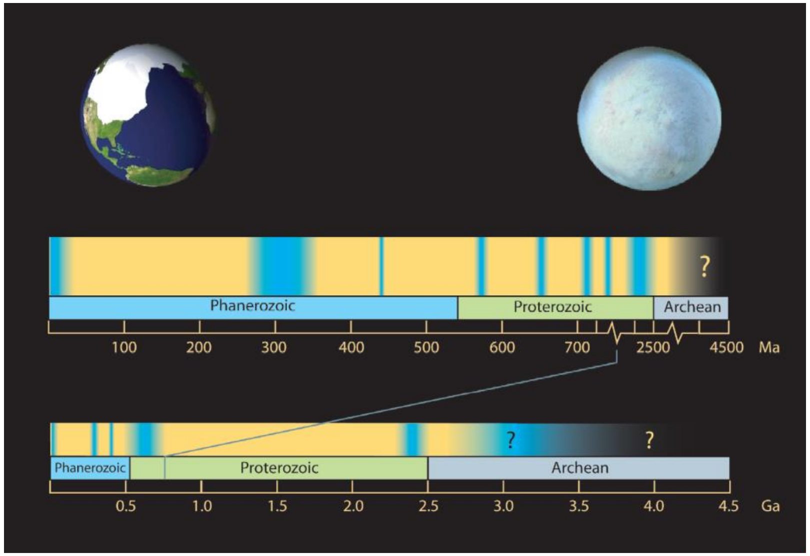
The residence time of deltas at the shelf edge are longer in the greenhouse cases



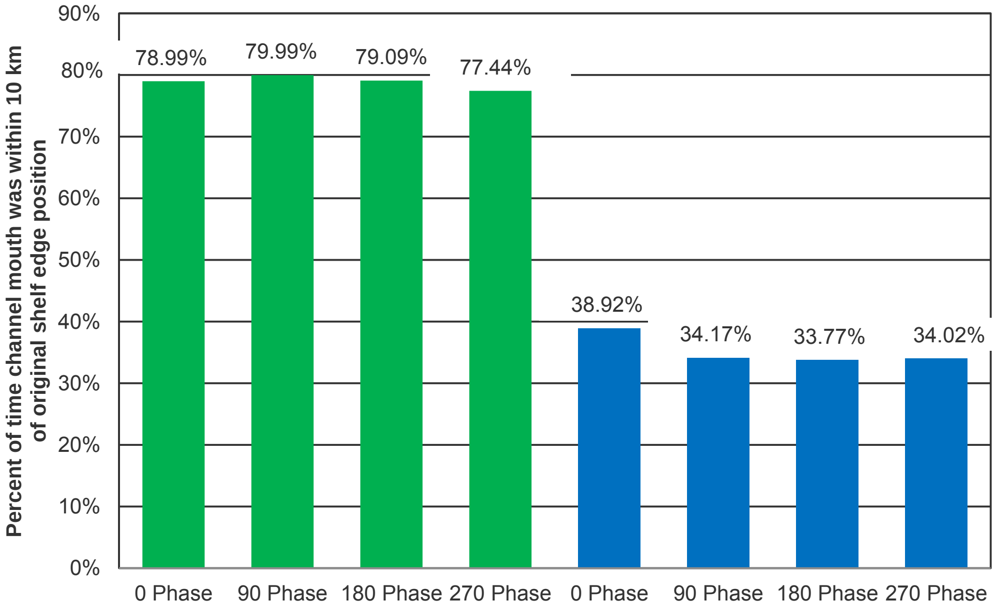
On average, icehouse volumes **larger** than greenhouse volumes



Conclusions

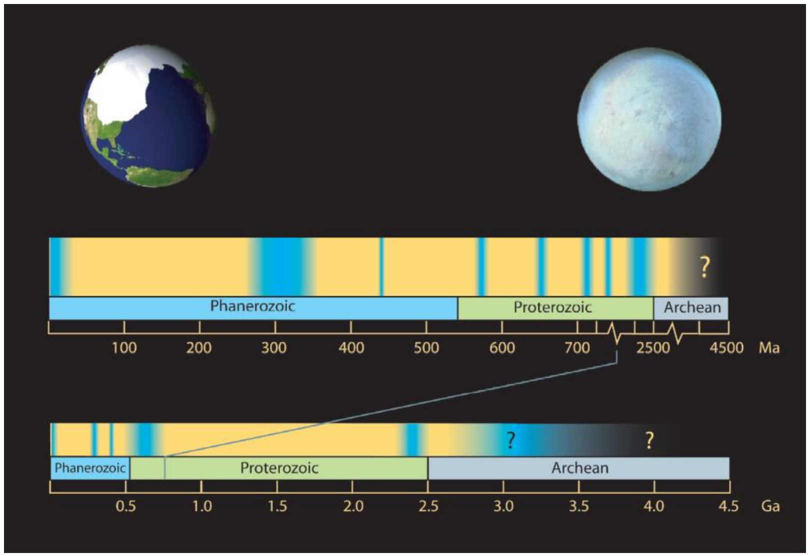


Parrish and Soreghan (2013): The Sedimentary Record



- Greenhouse model deltas reside at the shelf margin longer than icehouse models
  - This does not mean that it is more effective at depositing more sediment in deepwater.
  - What about reservoir sands or grain size partitioning? Future work

Conclusions



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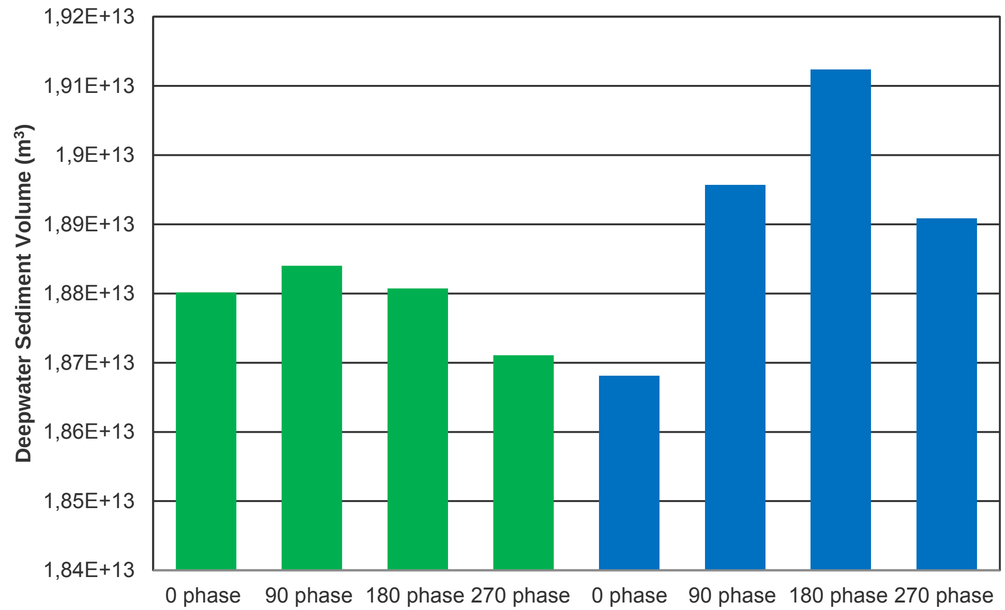

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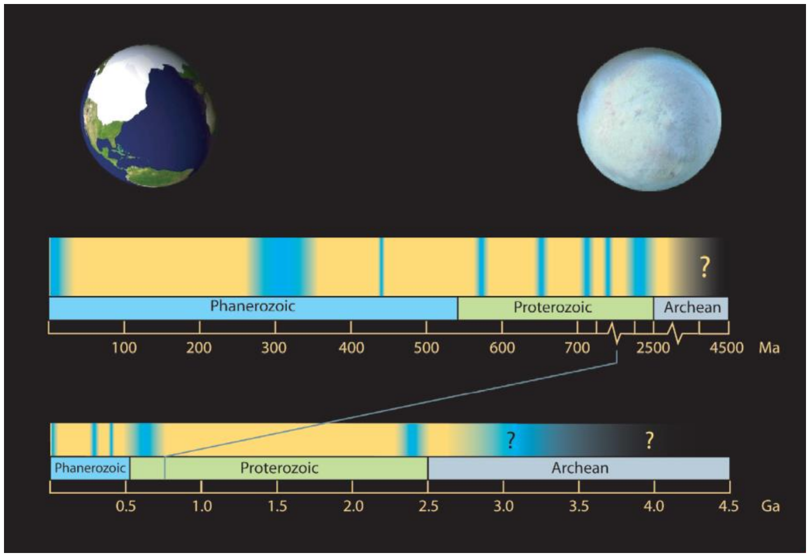
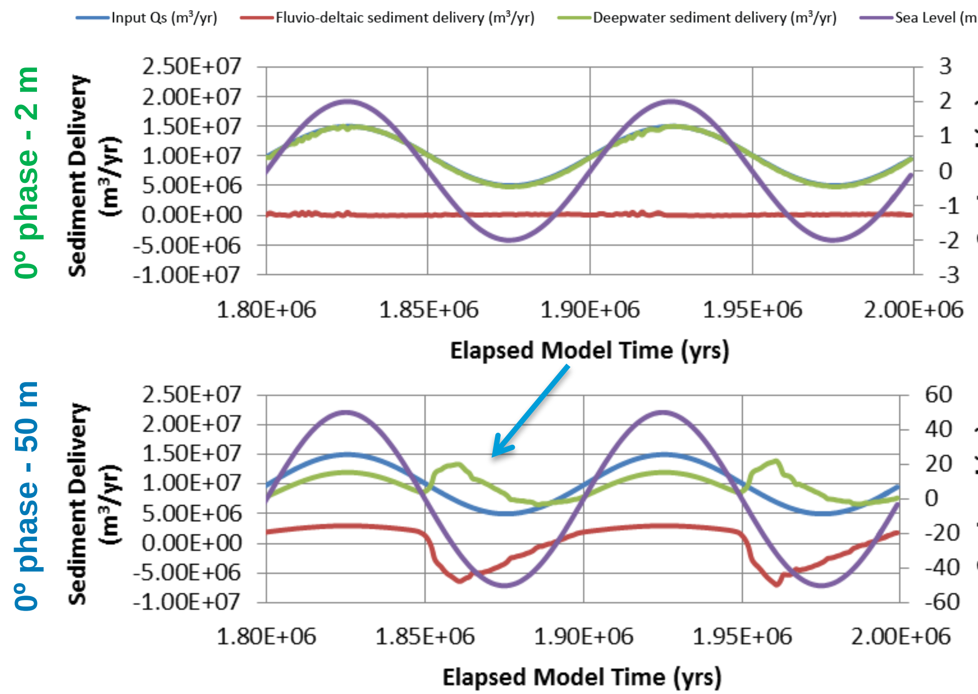
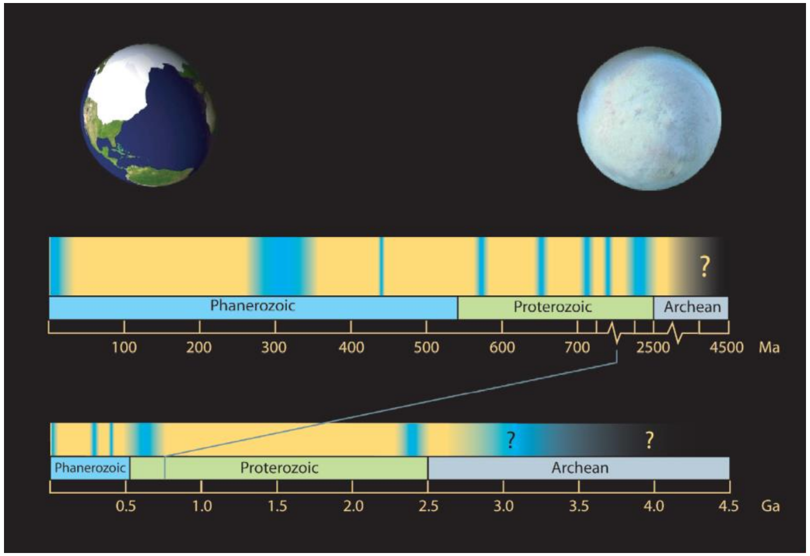


Parrish and Soreghan (2013): The Sedimentary Record



- Icehouse setting resulted in high frequency sedimentary delivery signals
    - Important implications for paleoclimate studies or inverting for the forcing

Conclusions



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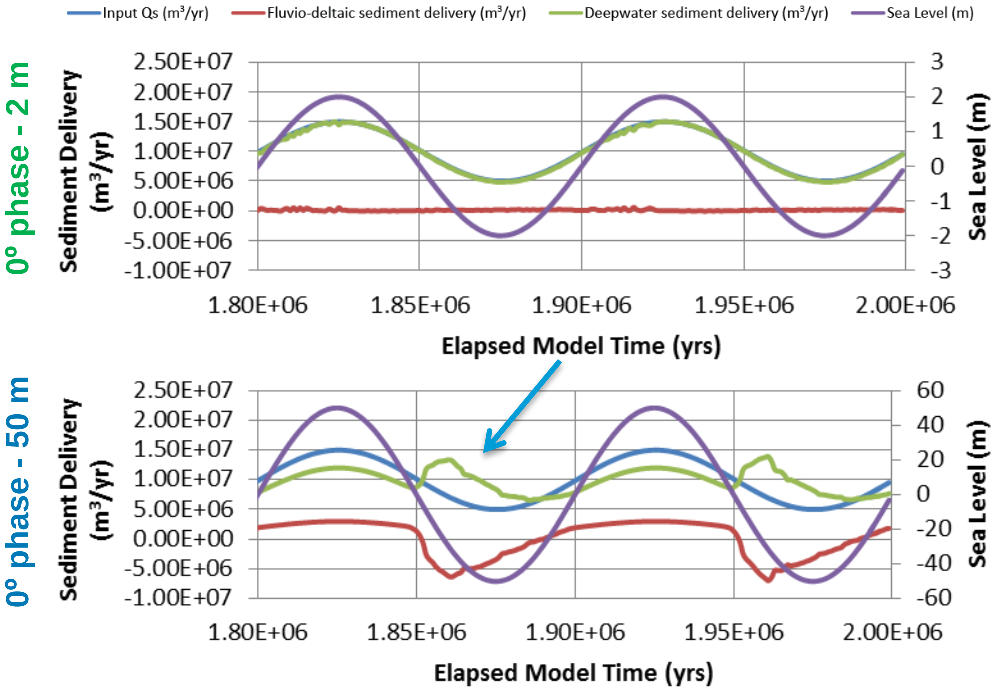

- Icehouse and greenhouse basin margin development may necessitate different stratigraphic concepts.
  - The geologic record is dominated by greenhouse settings
  - Understanding catchment dynamics related to tectonism and climate may be more important than sea level in greenhouse setting compared to icehouse settings.