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Sensitivity of tides and net water transport in an estuarine network to sea level rise

Jinyang Wang and Huib de Swart

Feedback by readers is highly appreciated

Photo credit: SupChina illustration

Estuarine networks: bodies of water that consist of multiple channels and in which water motion is drive by tides and river discharge.

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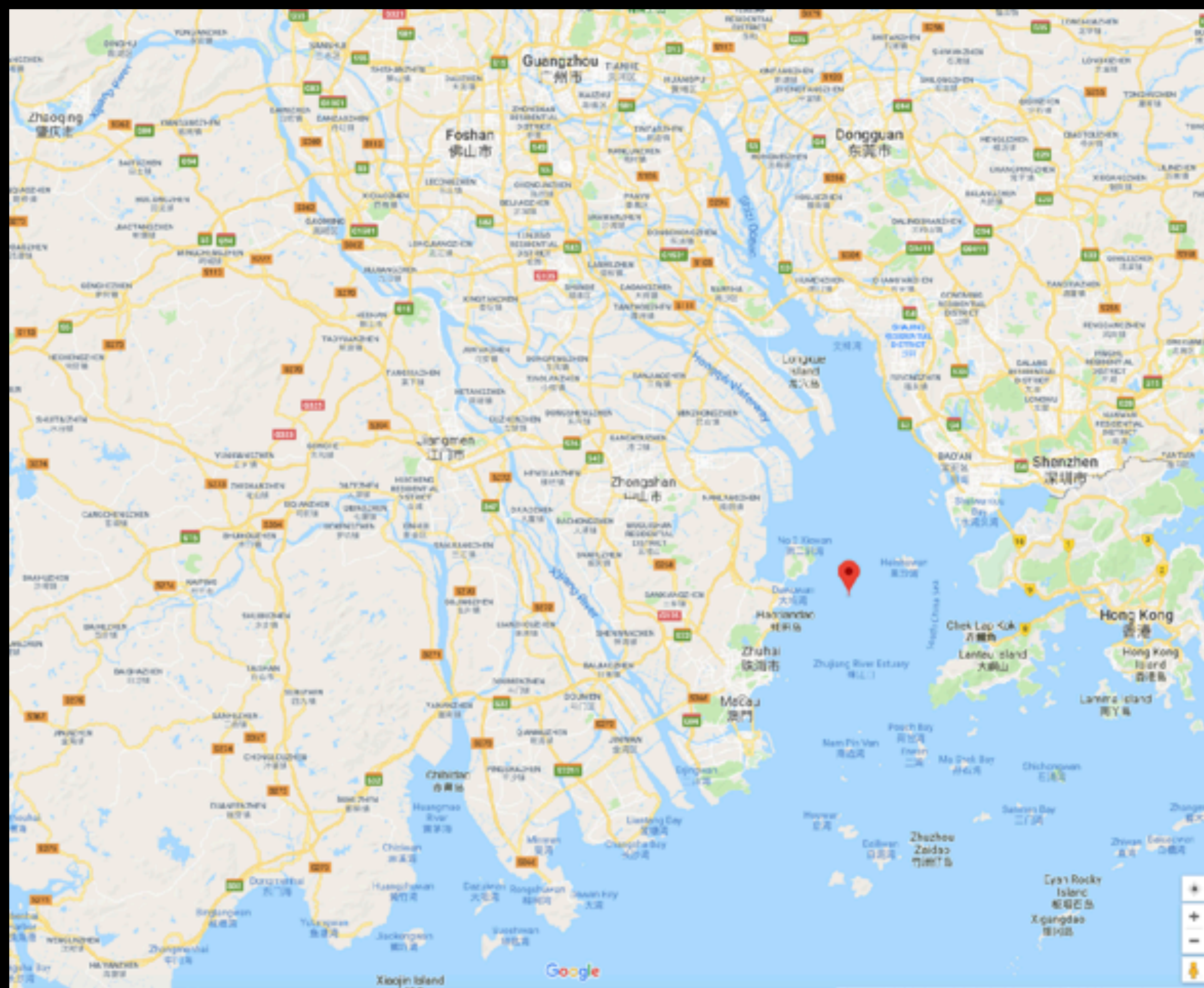
Example 1: The Berau Delta (Indonesia)

Estuarine networks: bodies of water that consist of multiple channels and in which water motion is drive by tides and river discharge.

Example 2: The Pearl River Delta (China)



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Main messages:

1. **Tides are sensitive to sea level rise.**
2. **Water transport is less sensitive to sea level rise.**

Photo credit: SupChina illustration

Research question

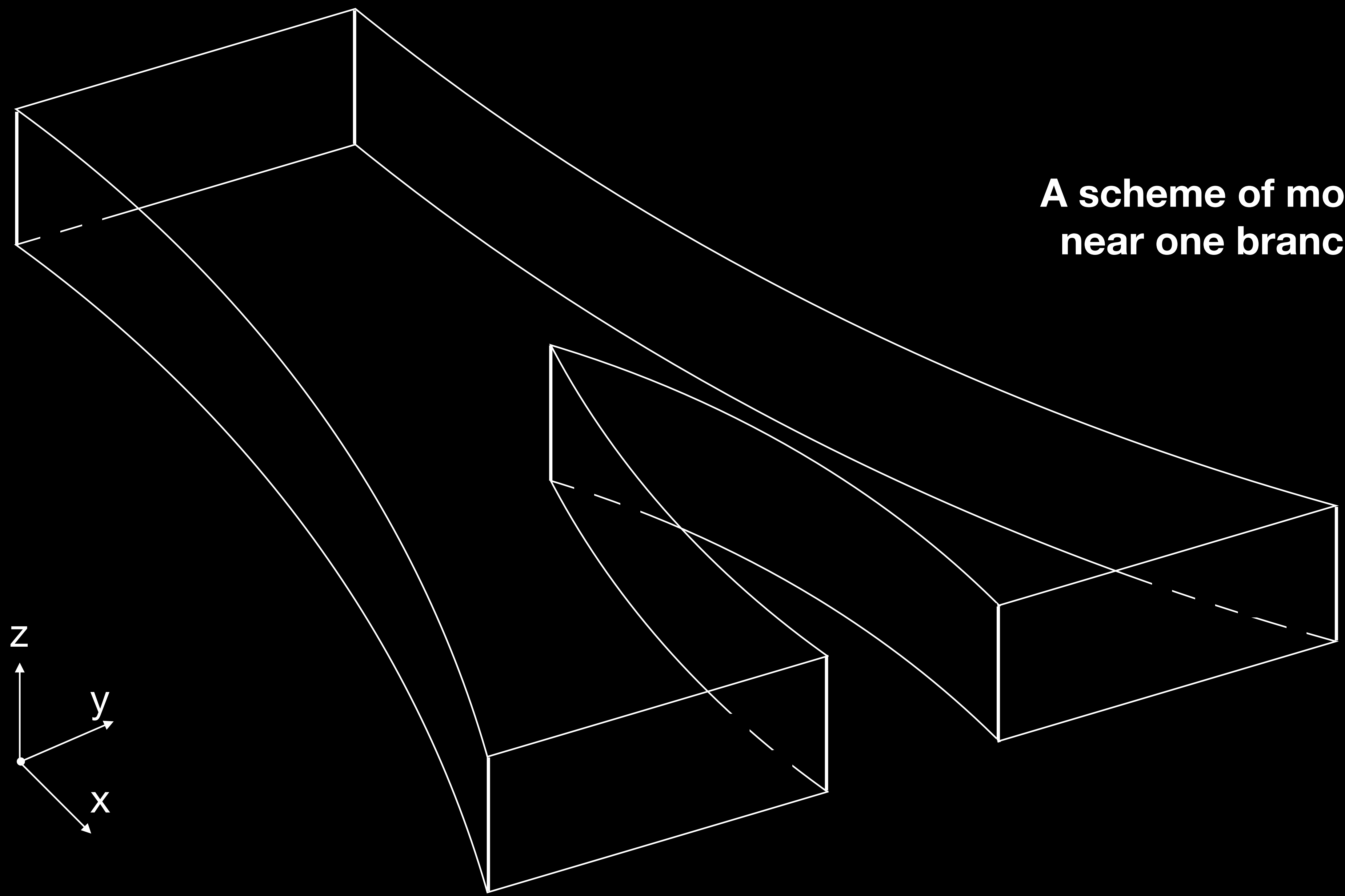
How will ***tide*** and ***net water transport*** in the estuarine network respond to ***sea level rise*** (***SLR***)?

Net water transport: tidally averaged integral of velocity over cross-section.

Tide
- surface elevation
- current

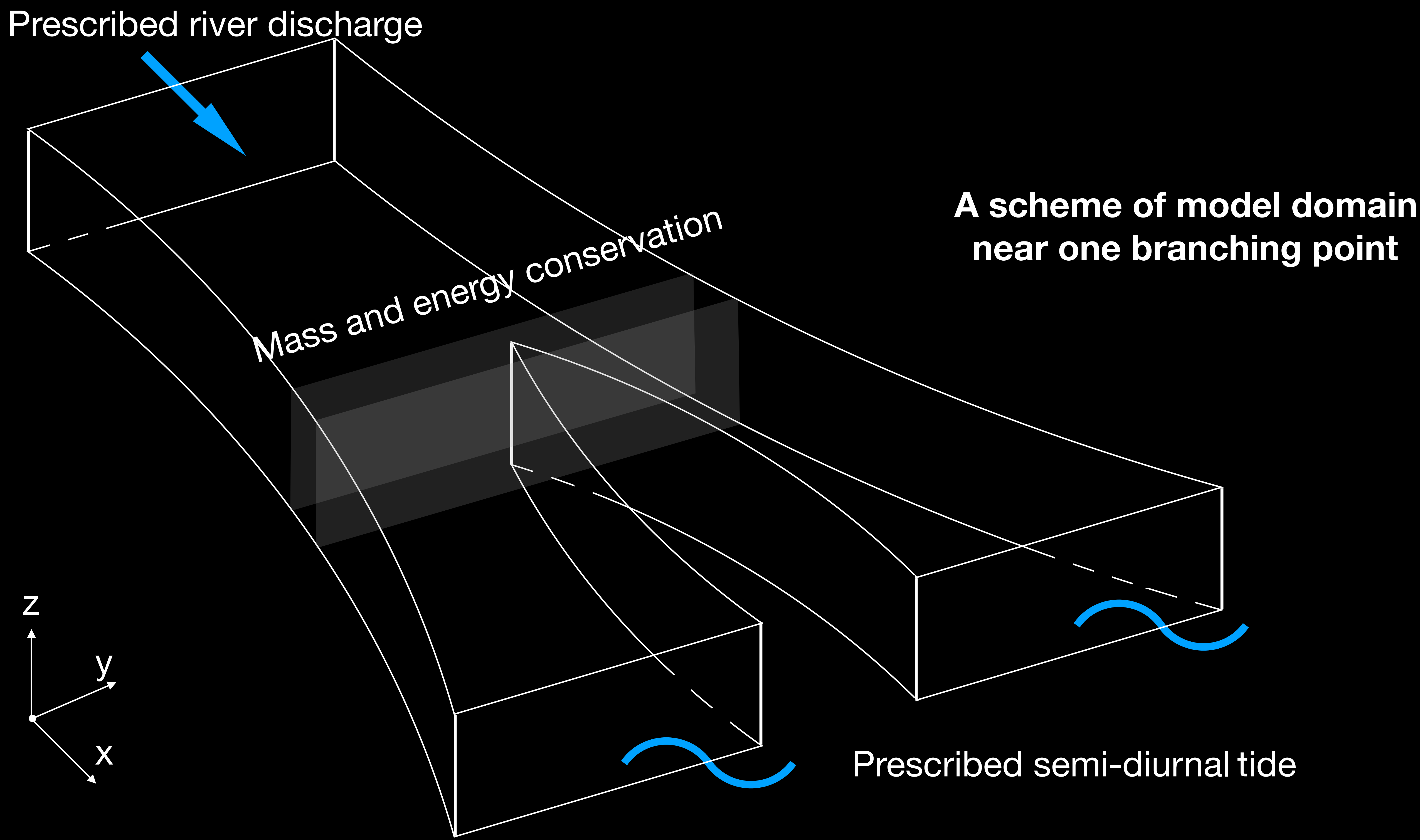
Water transport induced by
- river discharge
- density gradient
- other nonlinear effects…

2DV idealised channel network

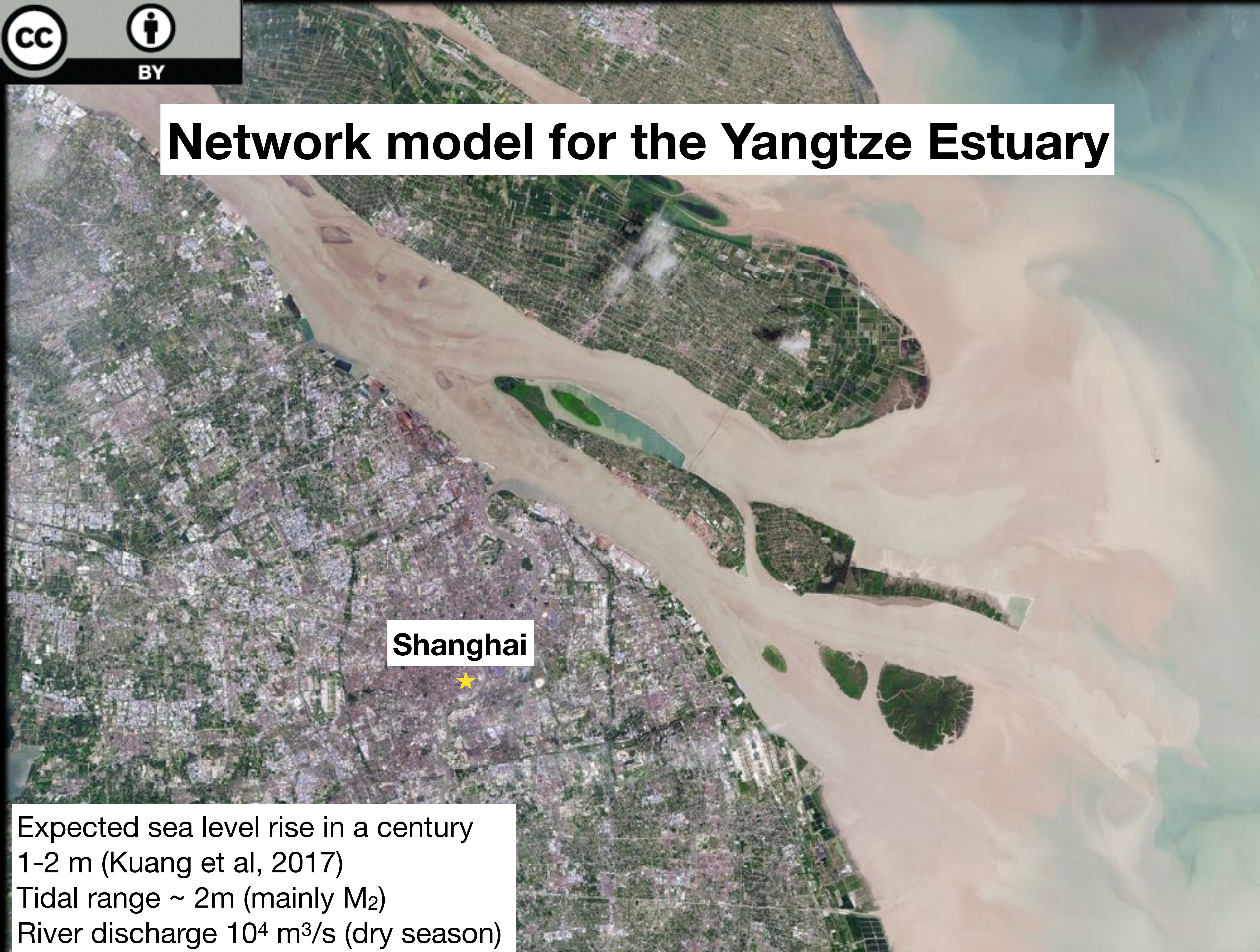


A scheme of model domain near one branching point

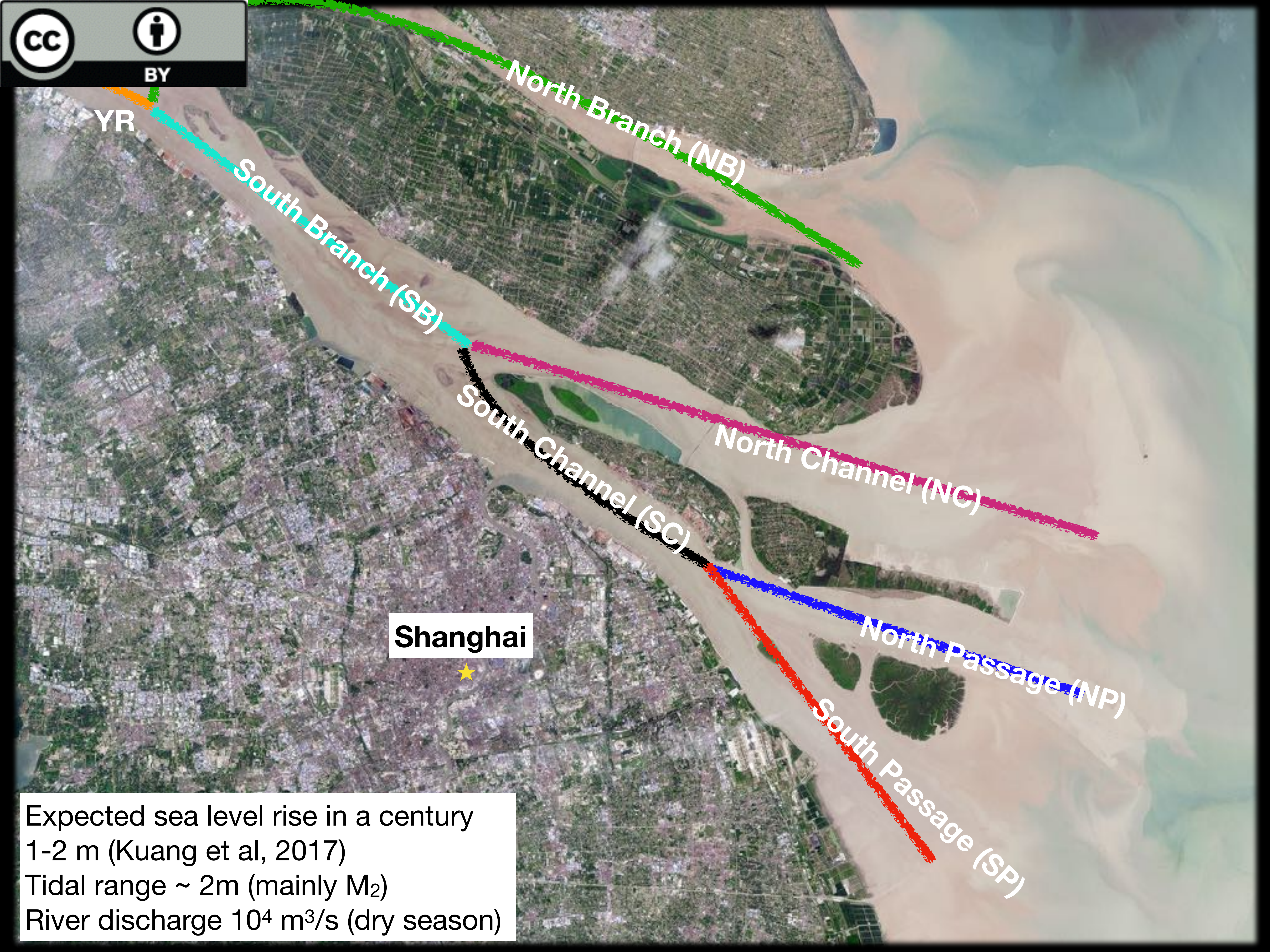
2DV idealised channel network



Network model for the Yangtze Estuary



Expected sea level rise in a century
1-2 m (Kuang et al, 2017)
Tidal range ~ 2m (mainly M_2)
River discharge 10^4 m^3/s (dry season)


YR
North Branch (NB)
South Branch (SB)
North Channel (NC)
South Channel (SC)
North Passage (NP)
South Passage (SP)
Shanghai
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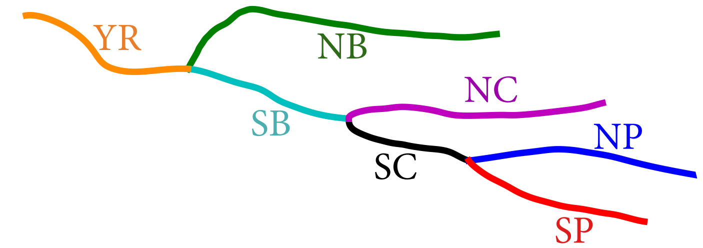
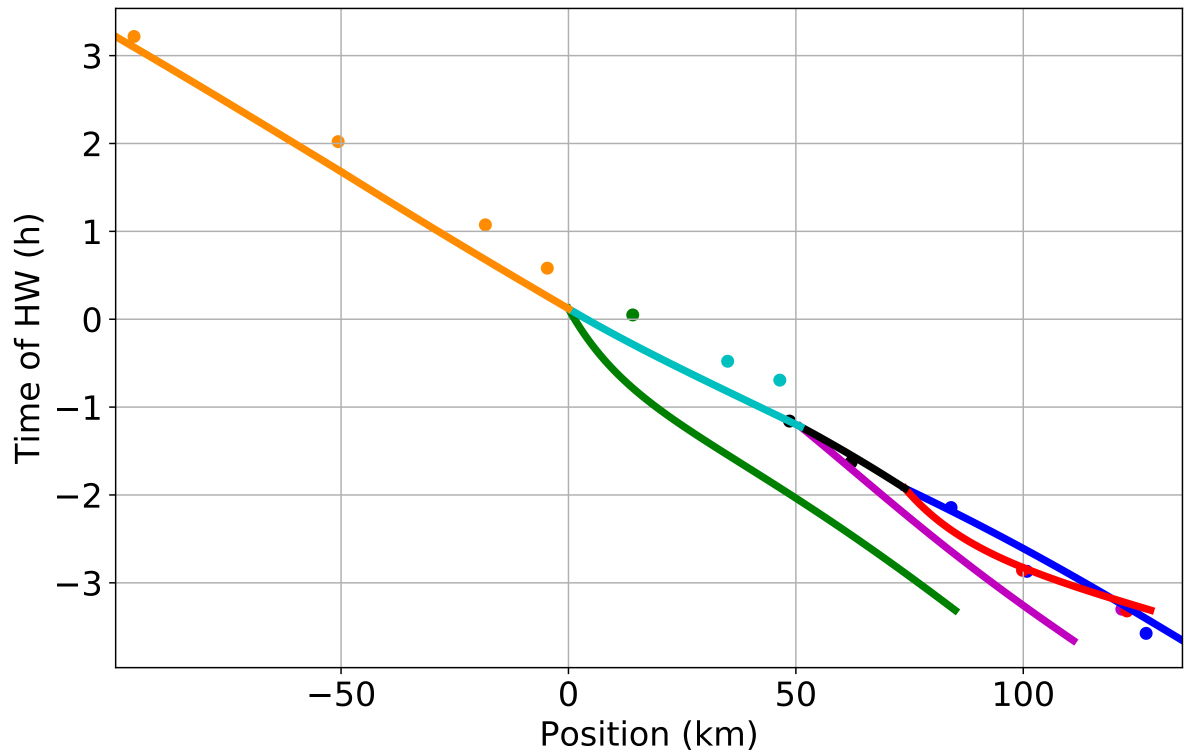


Time of high water relative to that at sea



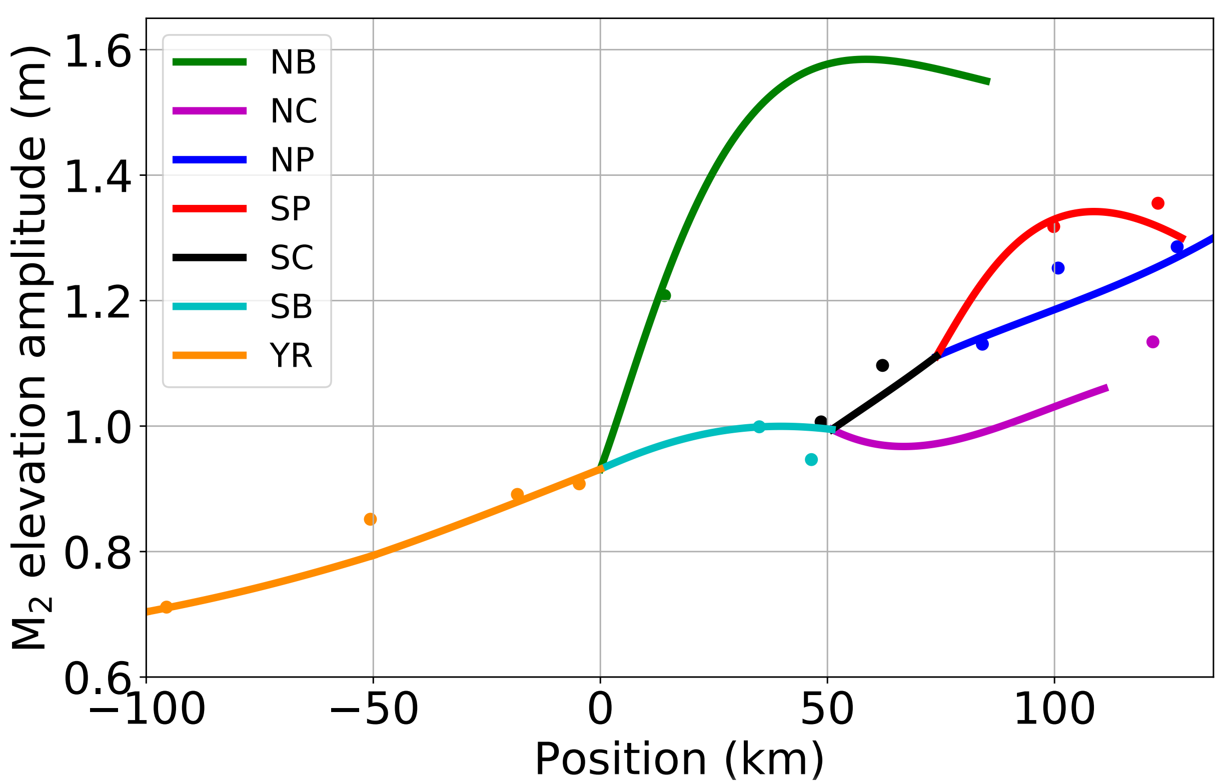
Default settings: 2014

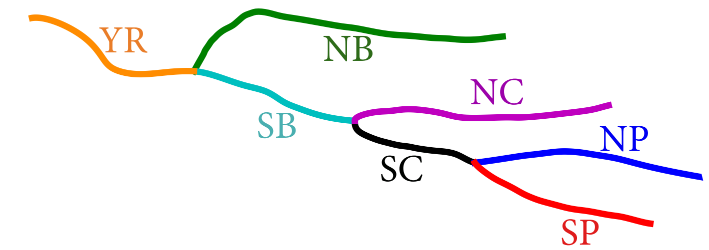
Dry season

Monthly averaged tidal forcing

Solid lines: modelled tide
Dots: observed tide

Tidal elevation amplitudes





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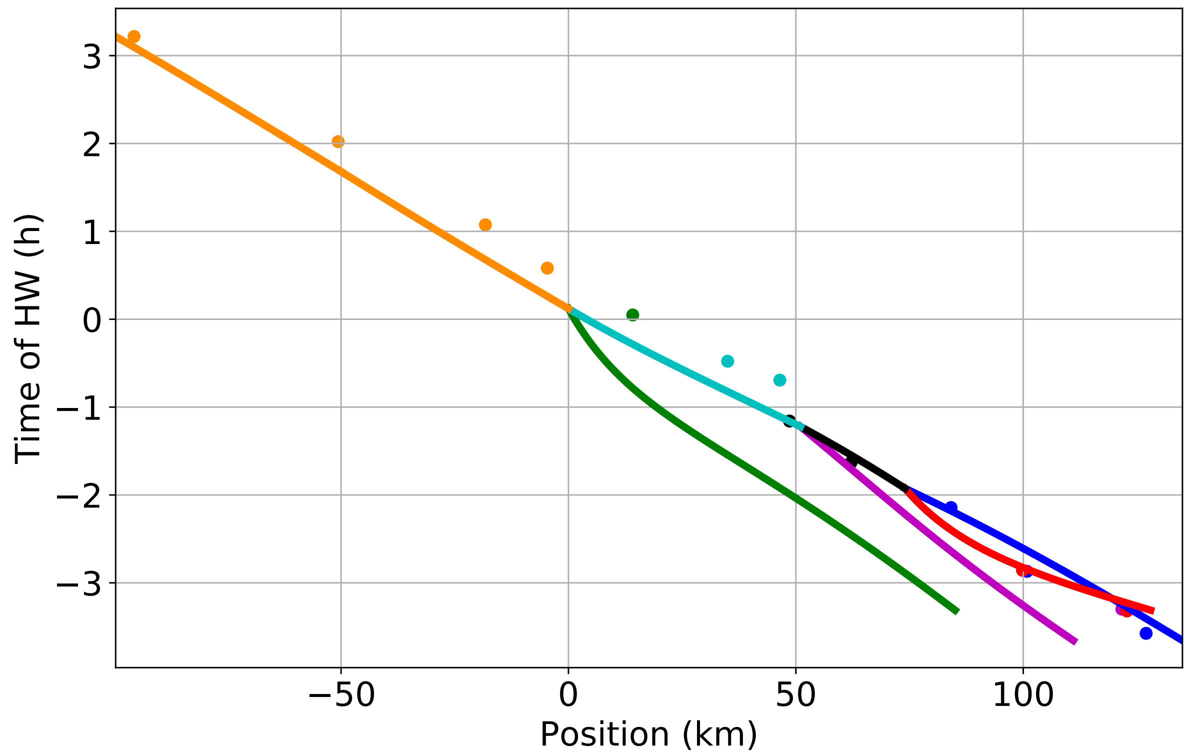
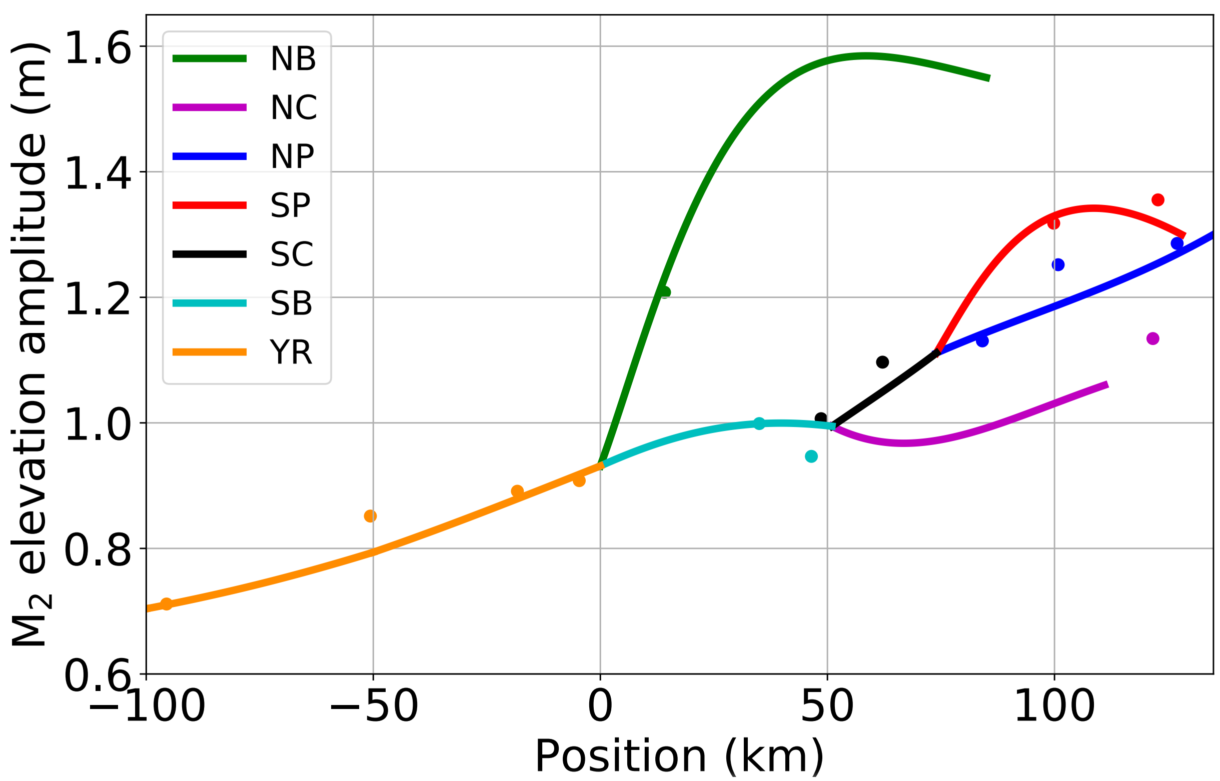


Tidal elevation amplitudes



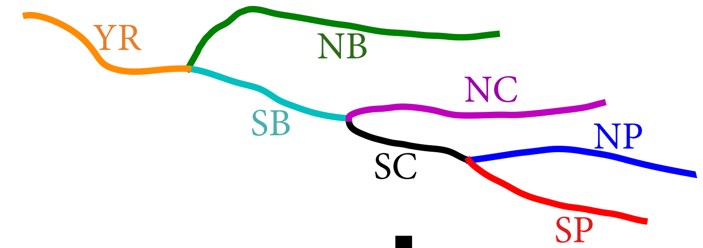
Default settings: 2014

Dry season

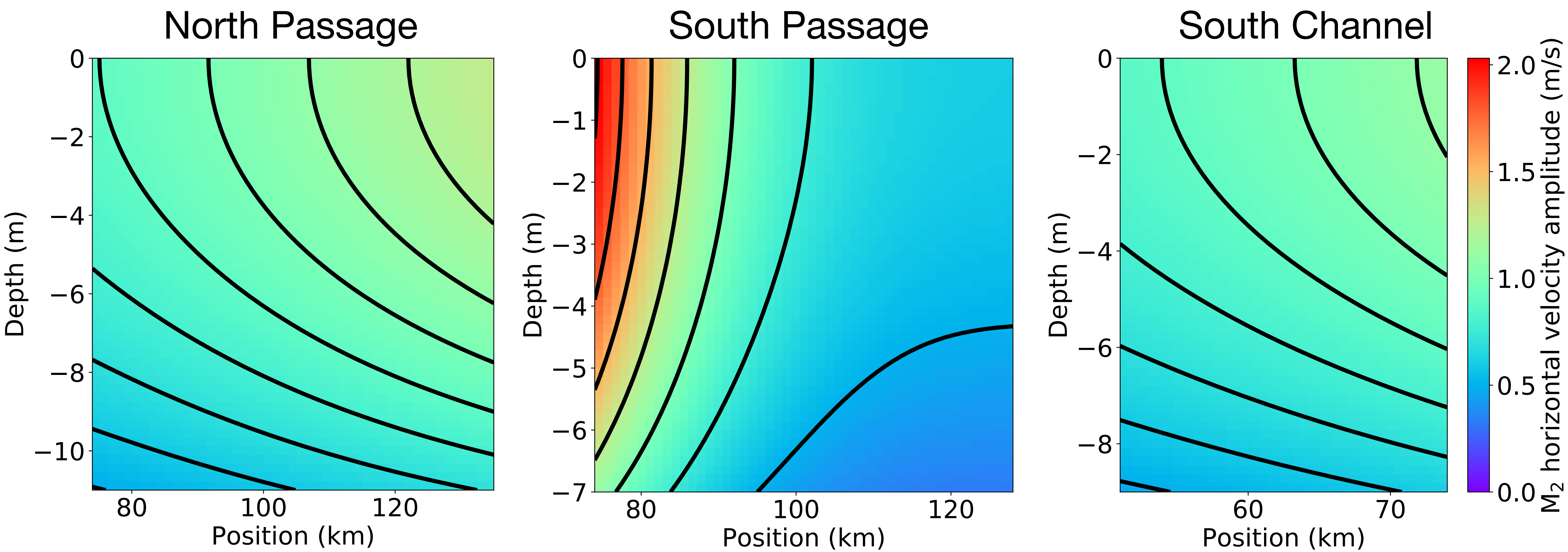
Monthly averaged tidal forcing

Solid lines: modelled tide
Dots: observed tide

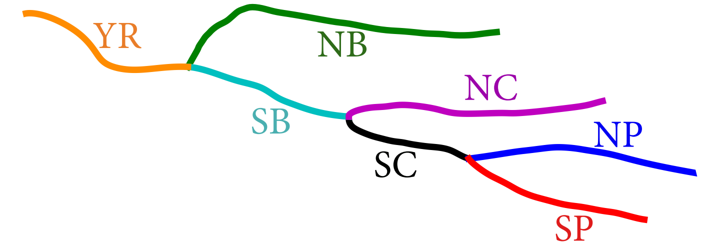
Model is reliable



Vertical structure of tidal current

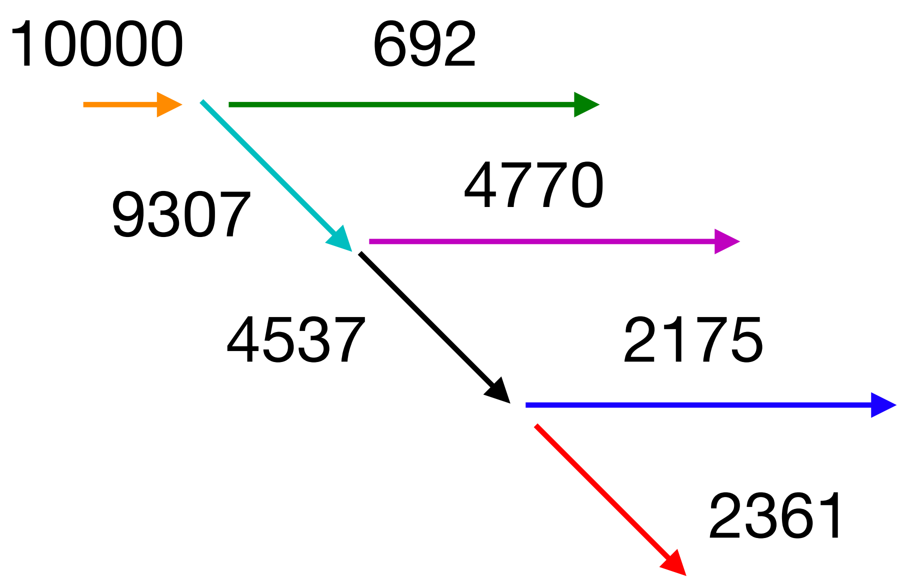


Maximum tidal current at the surface.
Strong current in the SP due to channel convergence.

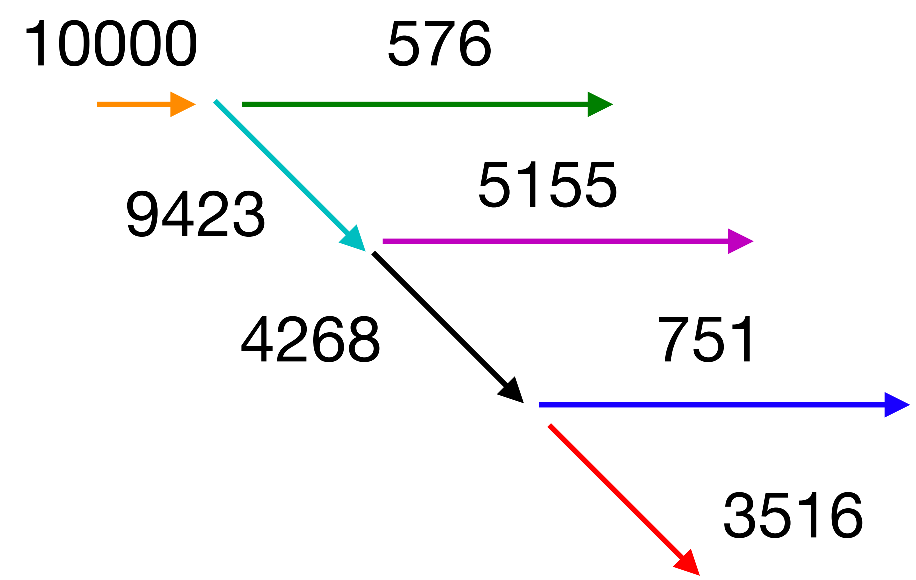


Water transport

River water transport (m^3/s)

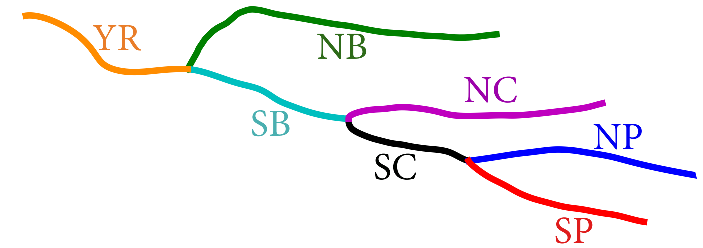


Net water transport (m^3/s)



Different from 1D model of Alebregtse and de Swart (2016) due to two additional subtidal components in this 2DV model:

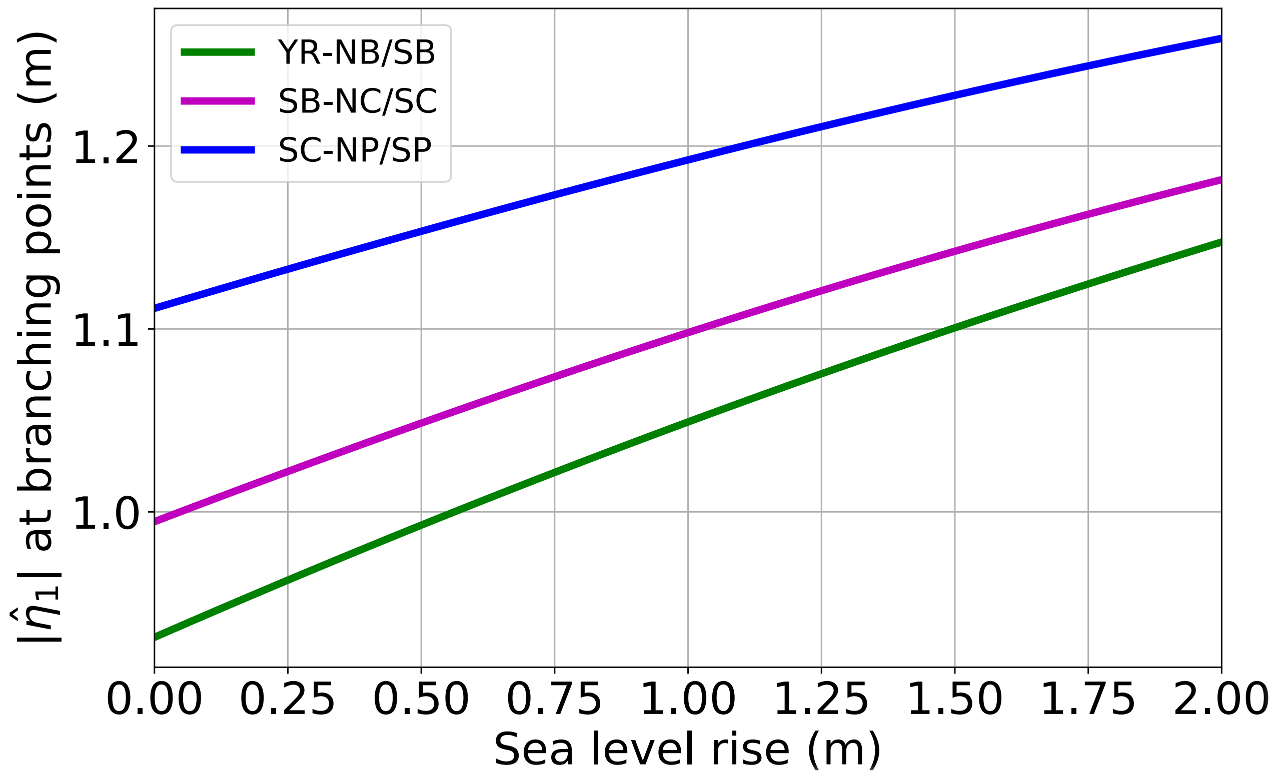
1. **baroclinic pressure/density driven flow**
2. **excess mass transport due to free surface variation.**



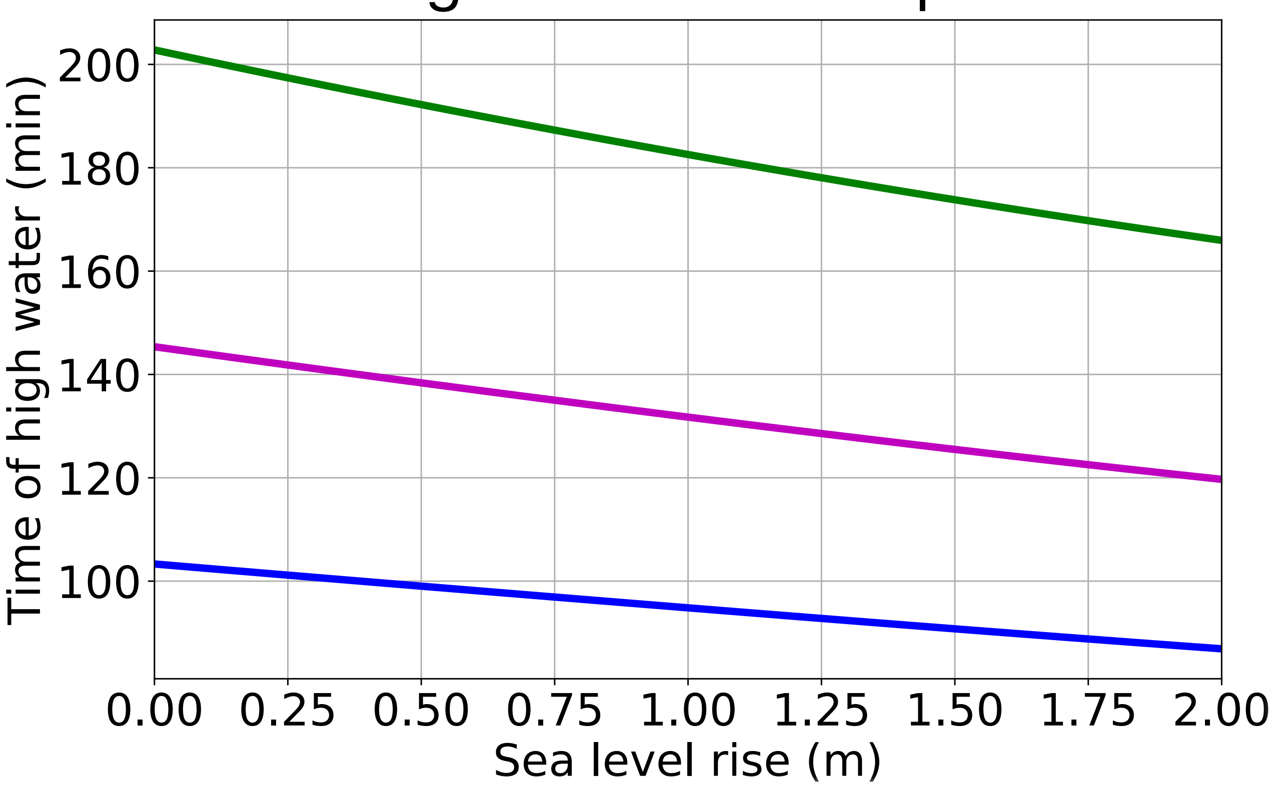
Sensitivity of tides to SLR

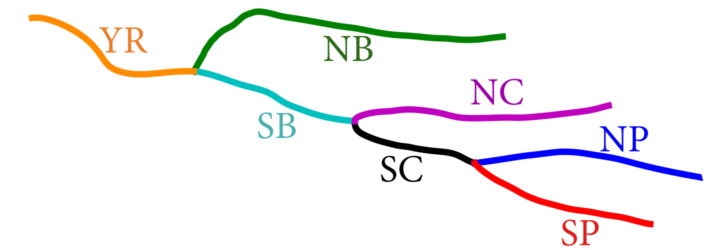
Tides become stronger and propagate faster if sea level rises

Tidal elevation amplitudes at branching points



Time of high water with respect to sea





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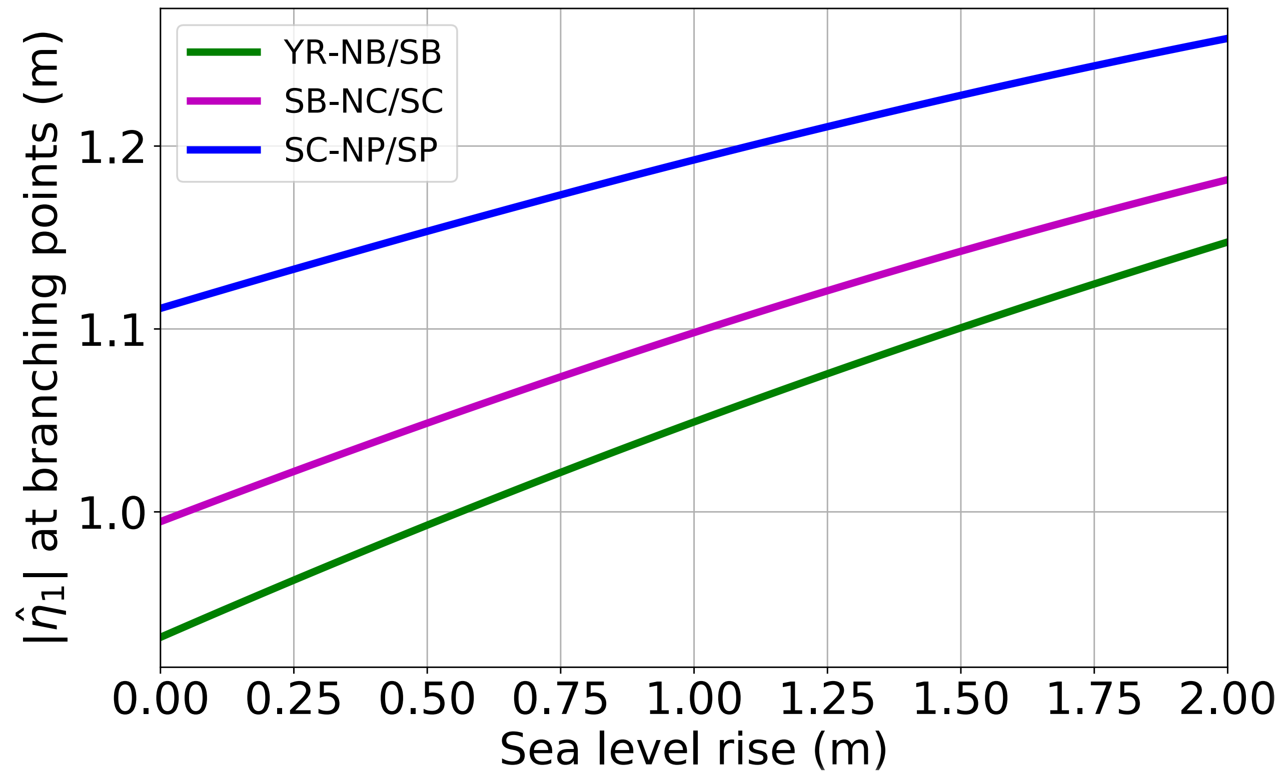
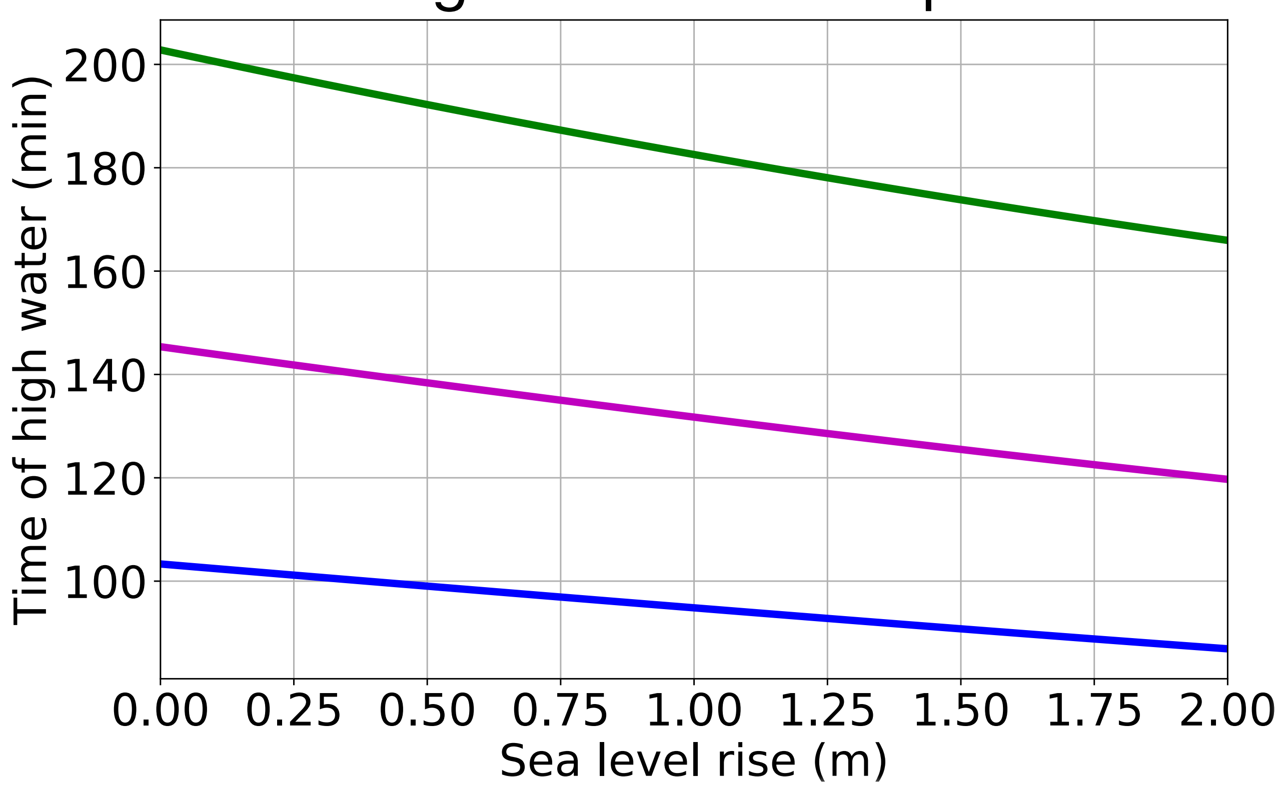


Tides become stronger and propagate faster if sea level rises

Reasons:

Time of high water with respect to sea



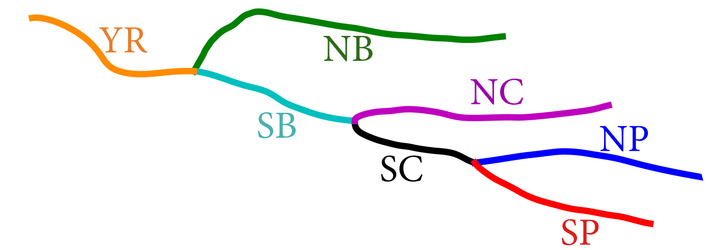
Increasing water depth ⇓ Less friction ⇓ Weaker river flow

Less friction ⇙ Slower decay

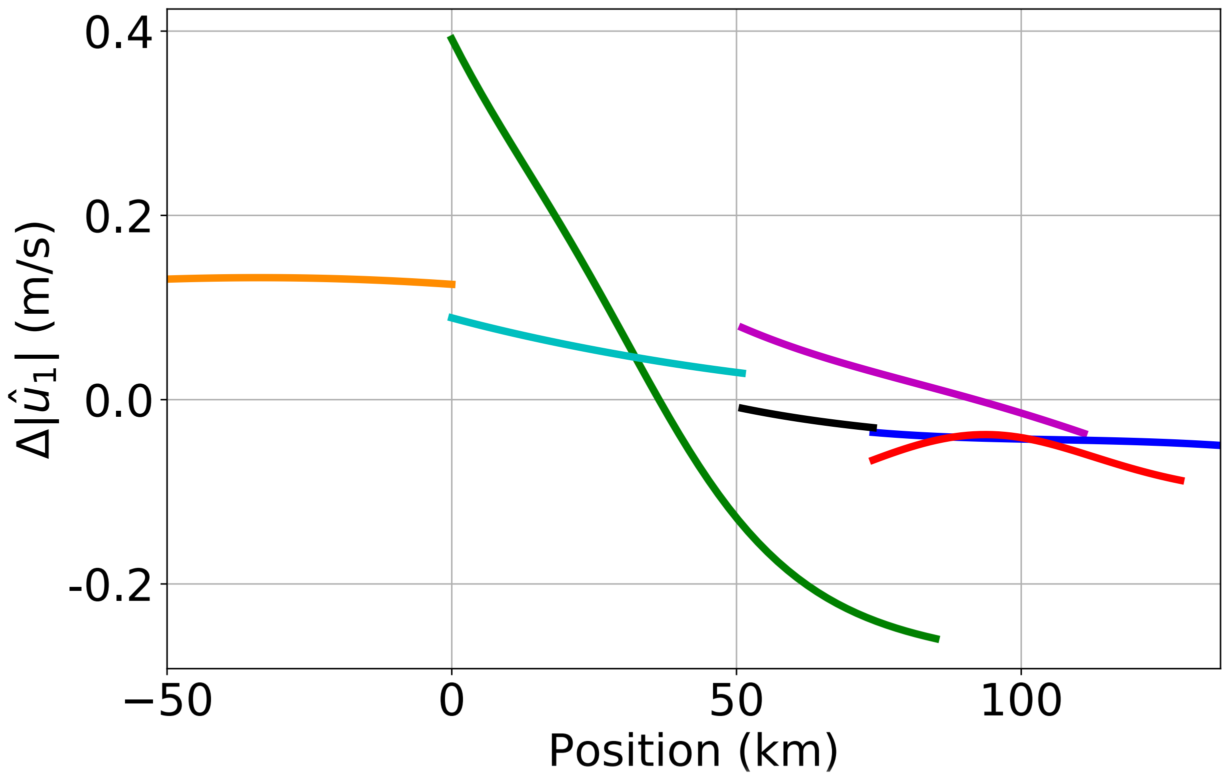
Less friction ⇘ Tides propagate faster

Weaker river flow ⇙ Tides propagate faster

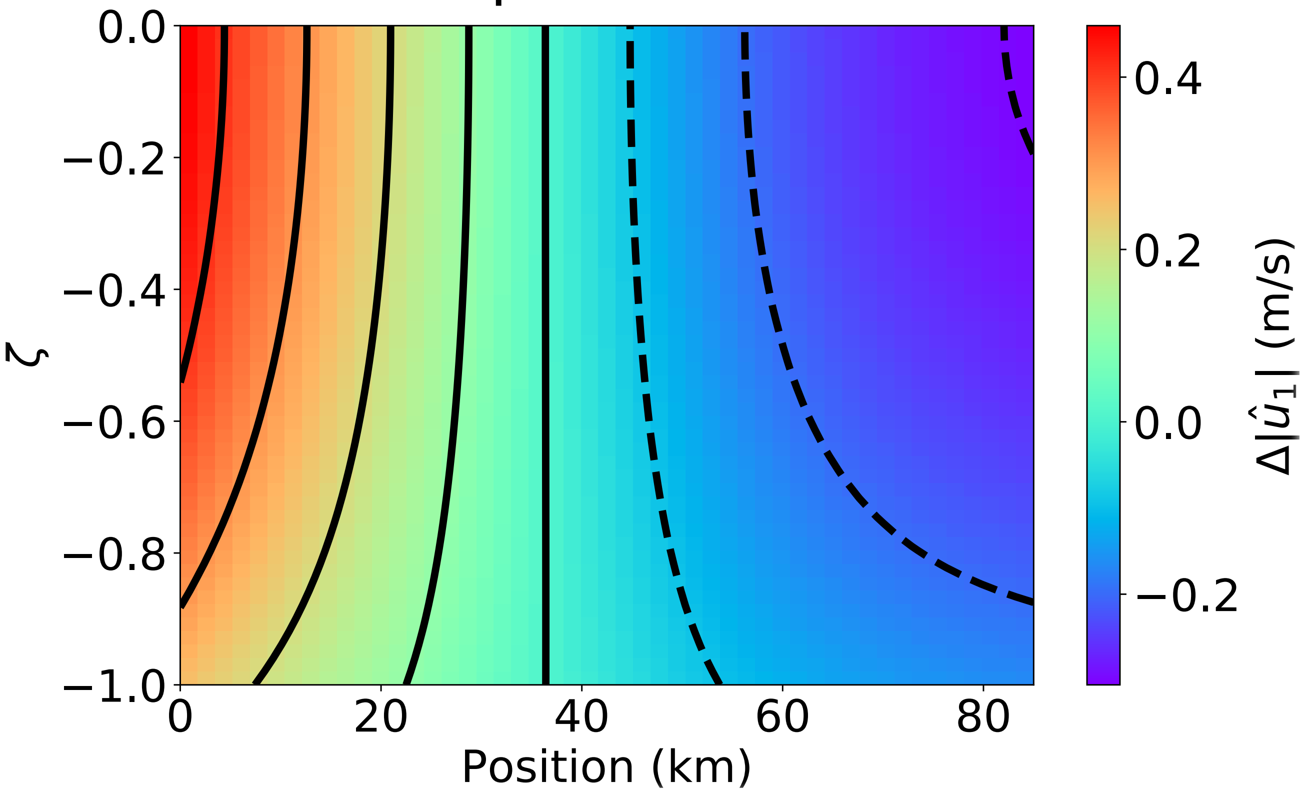
Slower decay ⇓ Convergence wins



Difference in depth-averaged tidal current amplitudes



Tidal current amplitude difference in the NB



Response of tidal current to 2m SLR

Reason for the changes:

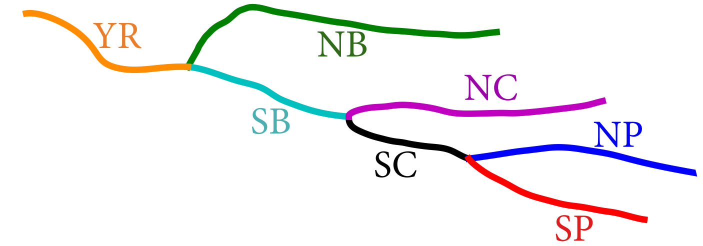
Tidal current is proportional to local pressure gradient

Local pressure gradient

$\Downarrow$

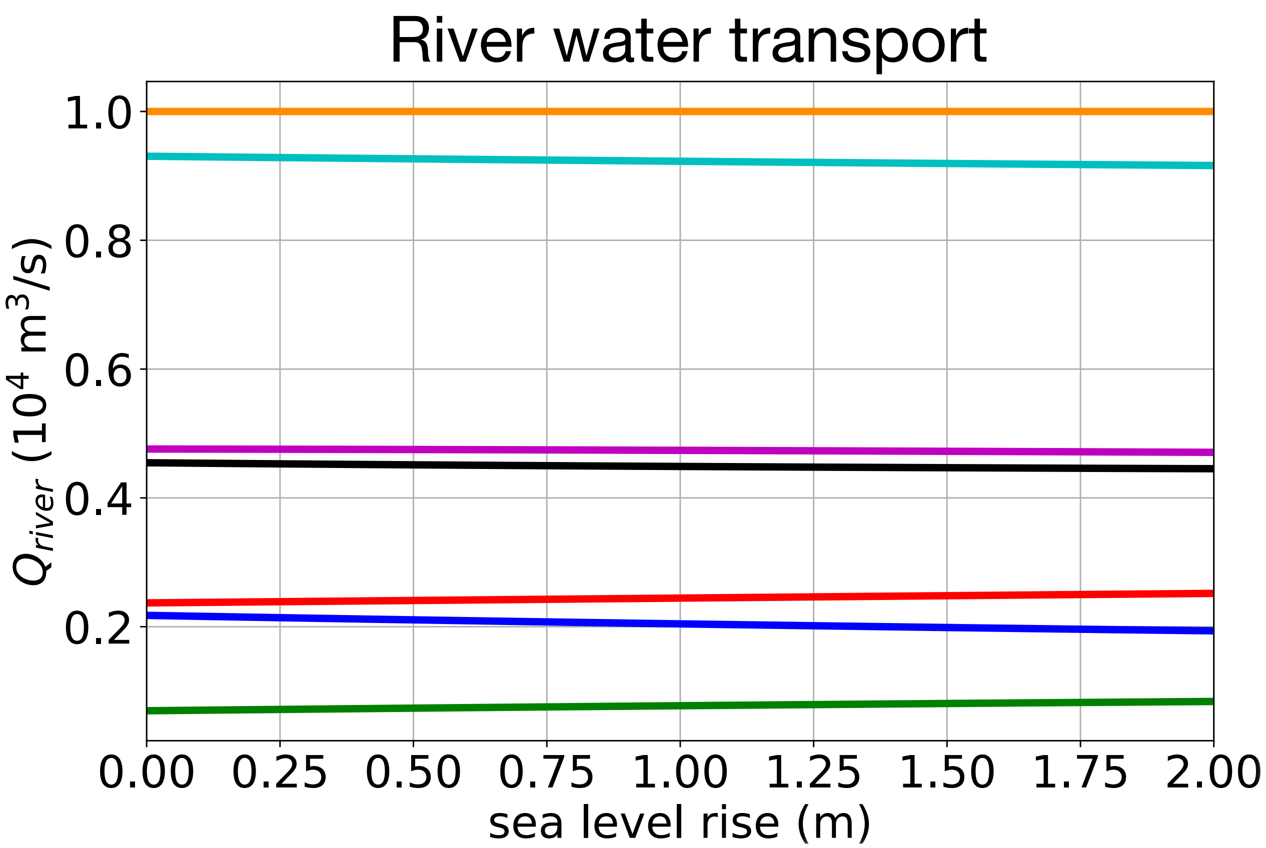
Tidal current

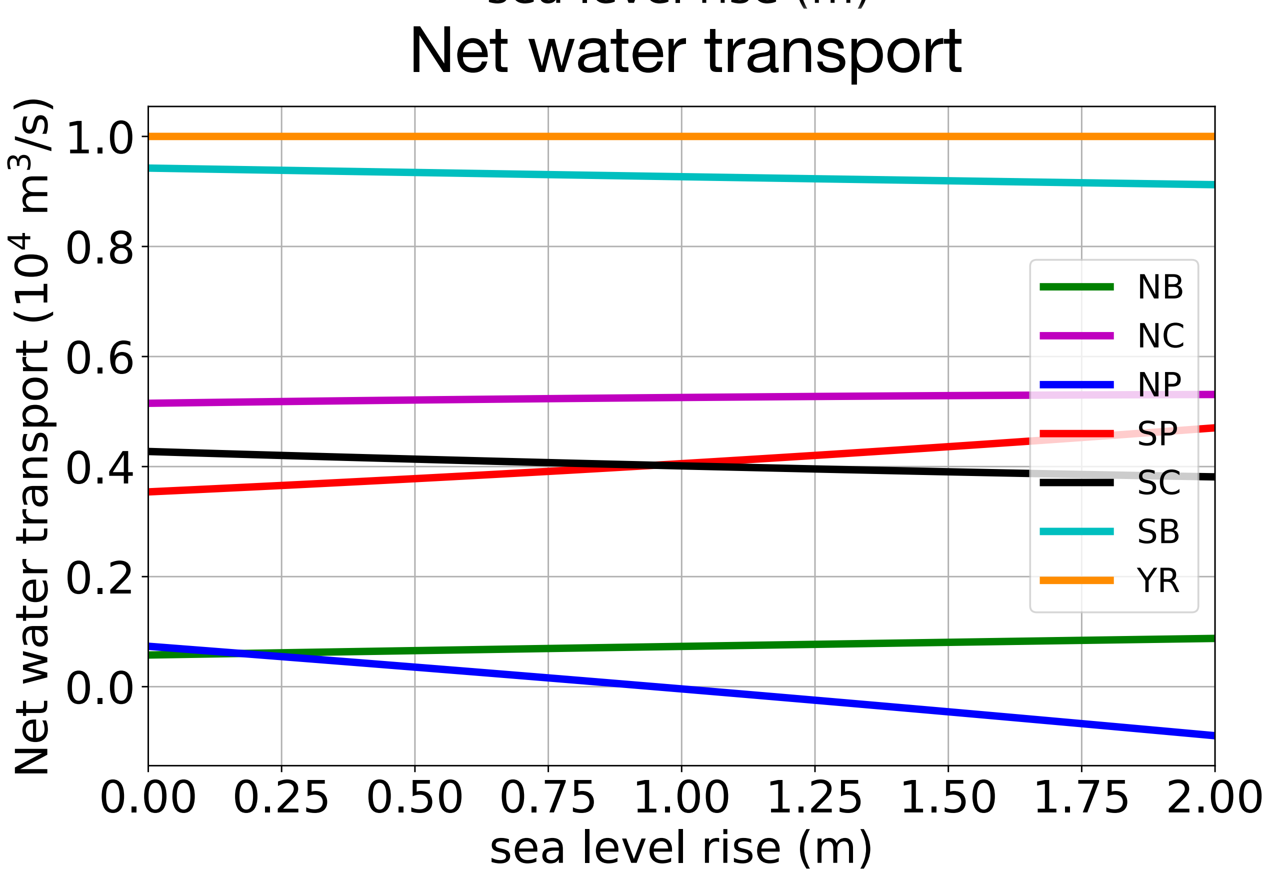
$$\zeta = \frac{z}{H}$$

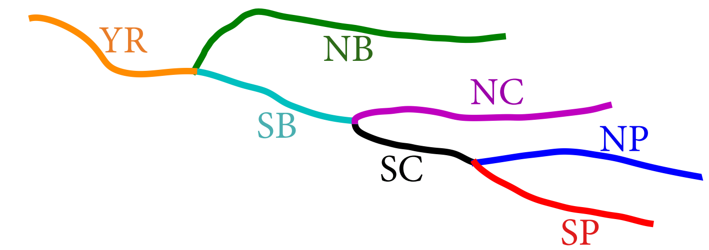


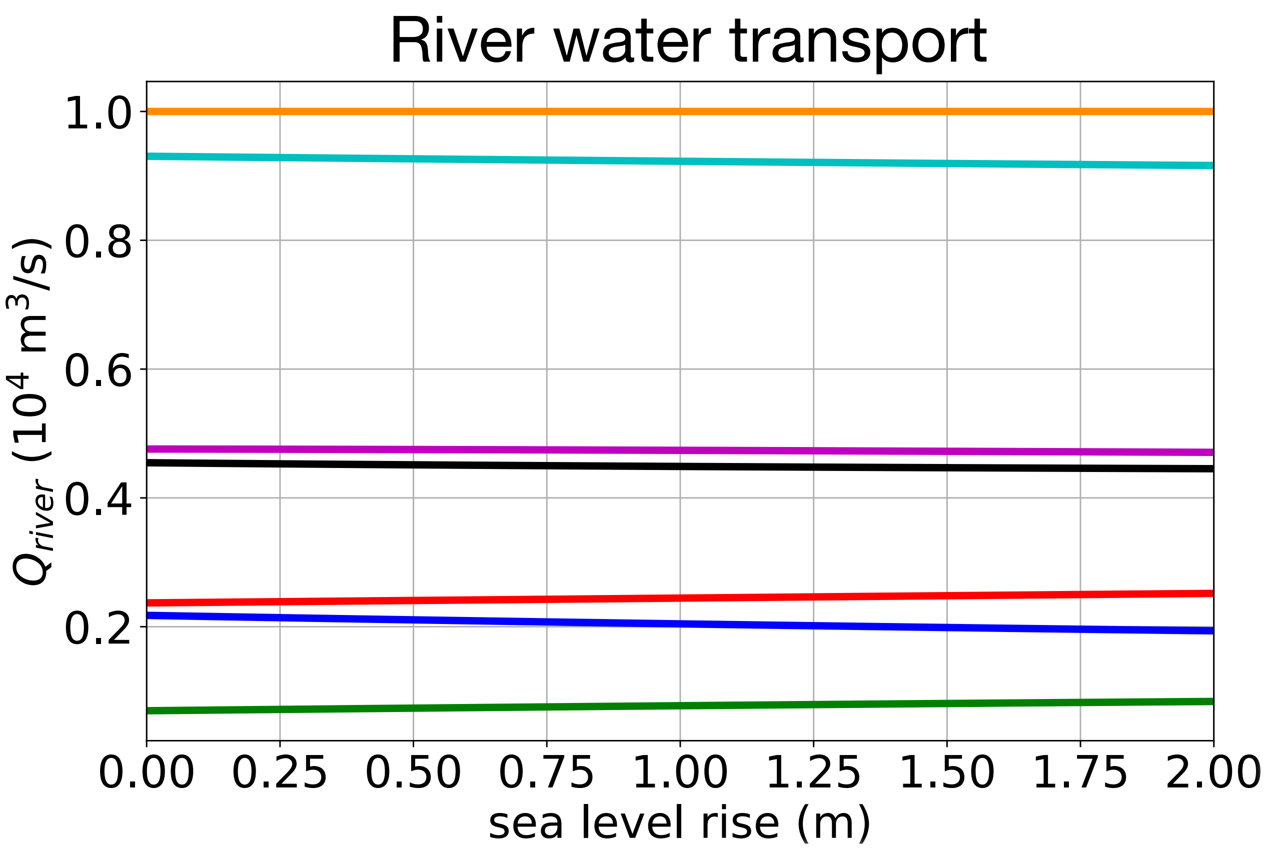
Sensitivity of water transport to SLR

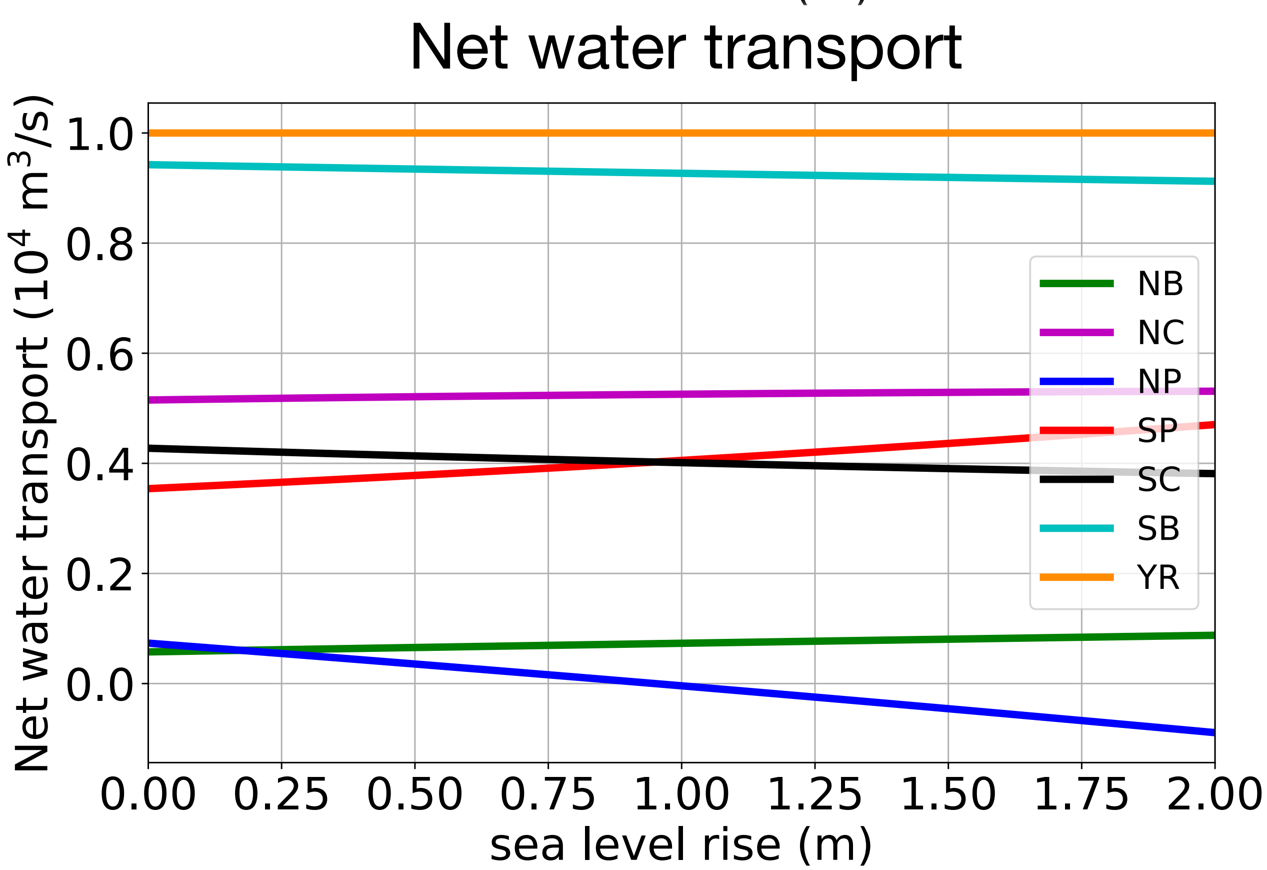
River water transport is hardly affected.











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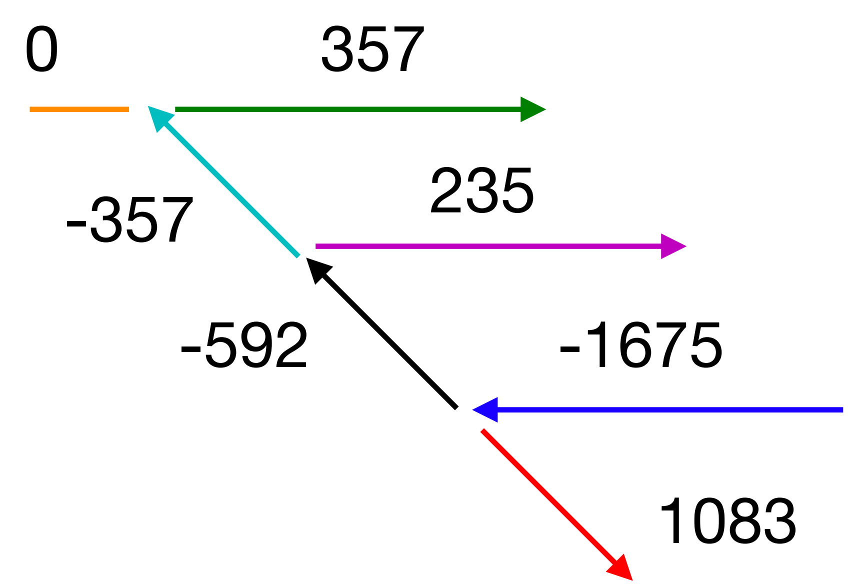
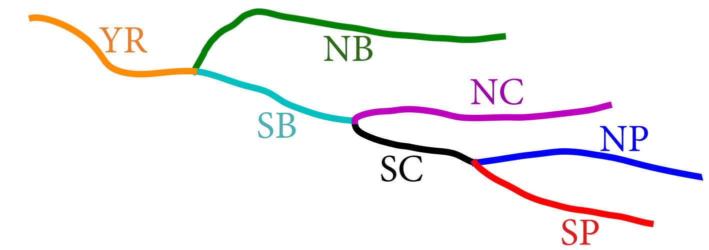
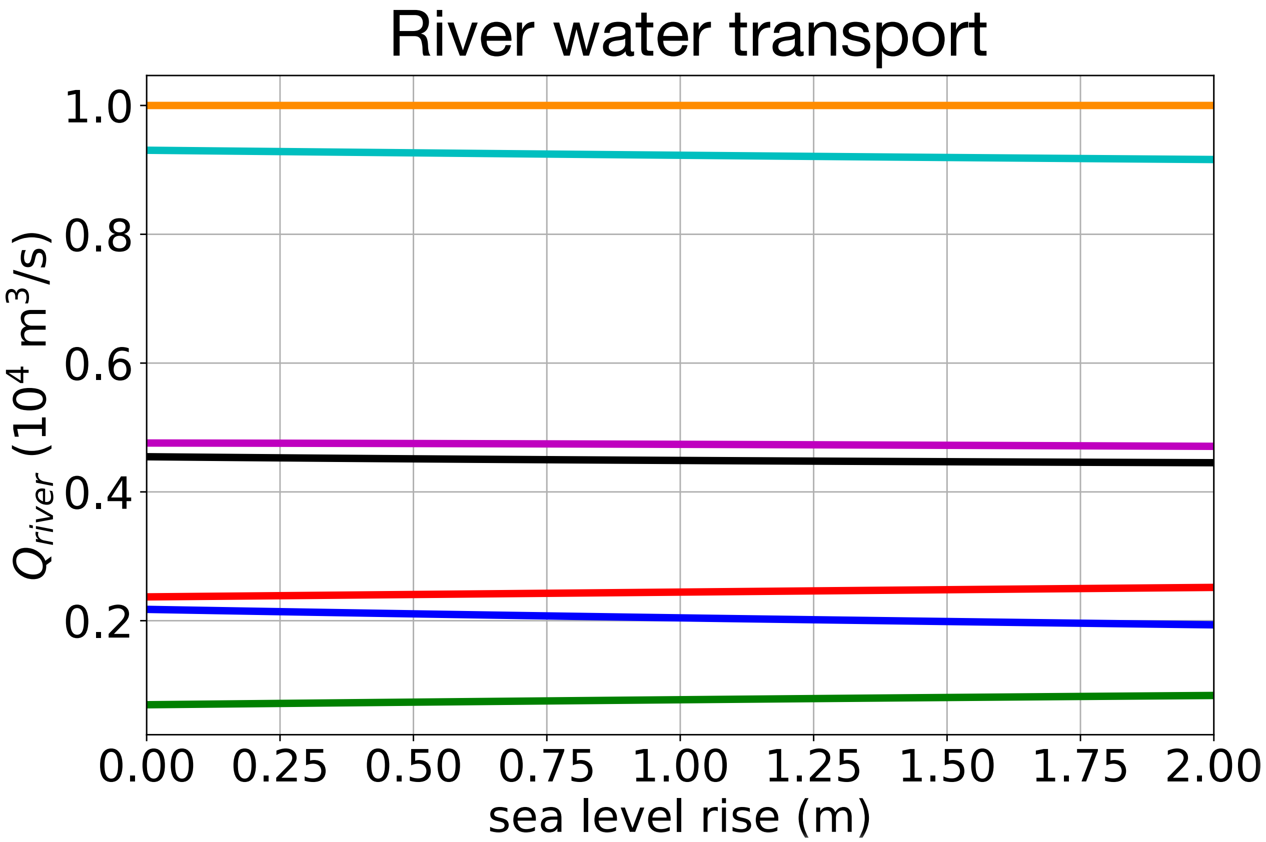
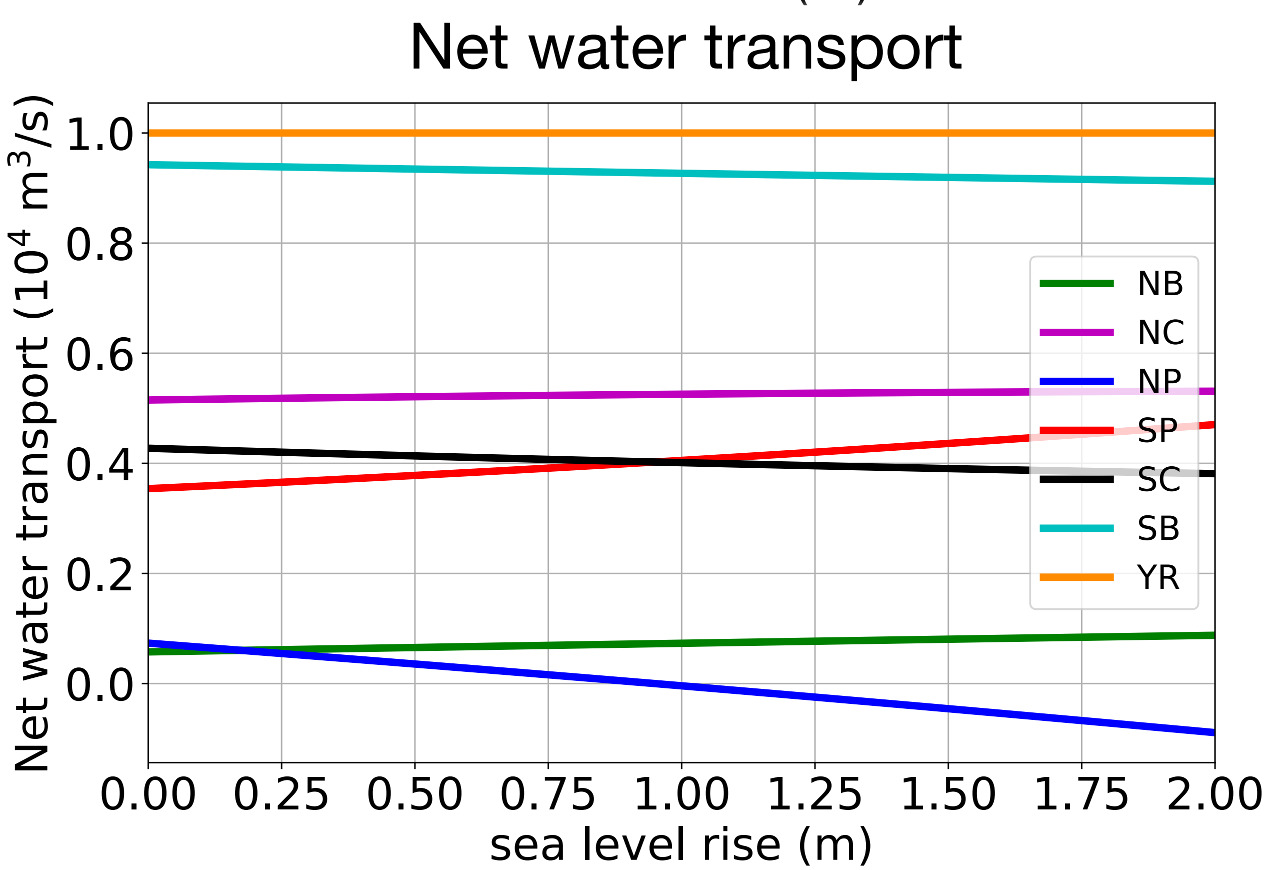
Difference in net water transport after 2m sea level rise (m^3/s)









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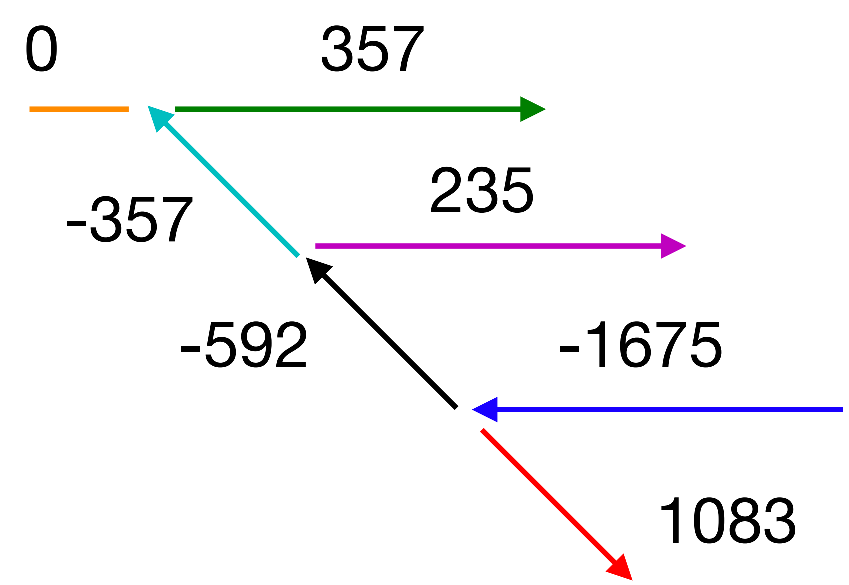

Most important contribution: density driven flow

Conclusions

Impacts of 2 metre sea level rise on

Tides

1. Tidal amplitudes increase due to weaker exponential decay of tidal wave.
2. Tidal waves travel faster due to less friction and weaker river flow.

Net water transport

1. River water transport is almost unaffected by SLR.
2. Subtidal transports due to baroclinic pressure, advection and dynamic pressure might be important.

Questions? Feedback?

References

Alebregtse, N.C. and H.E. de Swart, 2016.
Effect of river discharge and geometry on tides and net water transport in an estuarine network, an idealised model applied to the Yangtze Estuary. Continental Shelf Research 123, 10-29, doi: 10.1016/j.csr.2016.03.028

Kuang, C., Liang, H., Mao, X., Karney, B., Gu, J., Huang, H., Chen, W., Song, H., 2017.
Influence of potential future sea-level rise on tides in the China Sea. Journal of Coastal Research , 105–117, doi: 10.2112/JCOASTRES-D-16-00057.1.