Modelling salt intrusion in an estuarine tidal network

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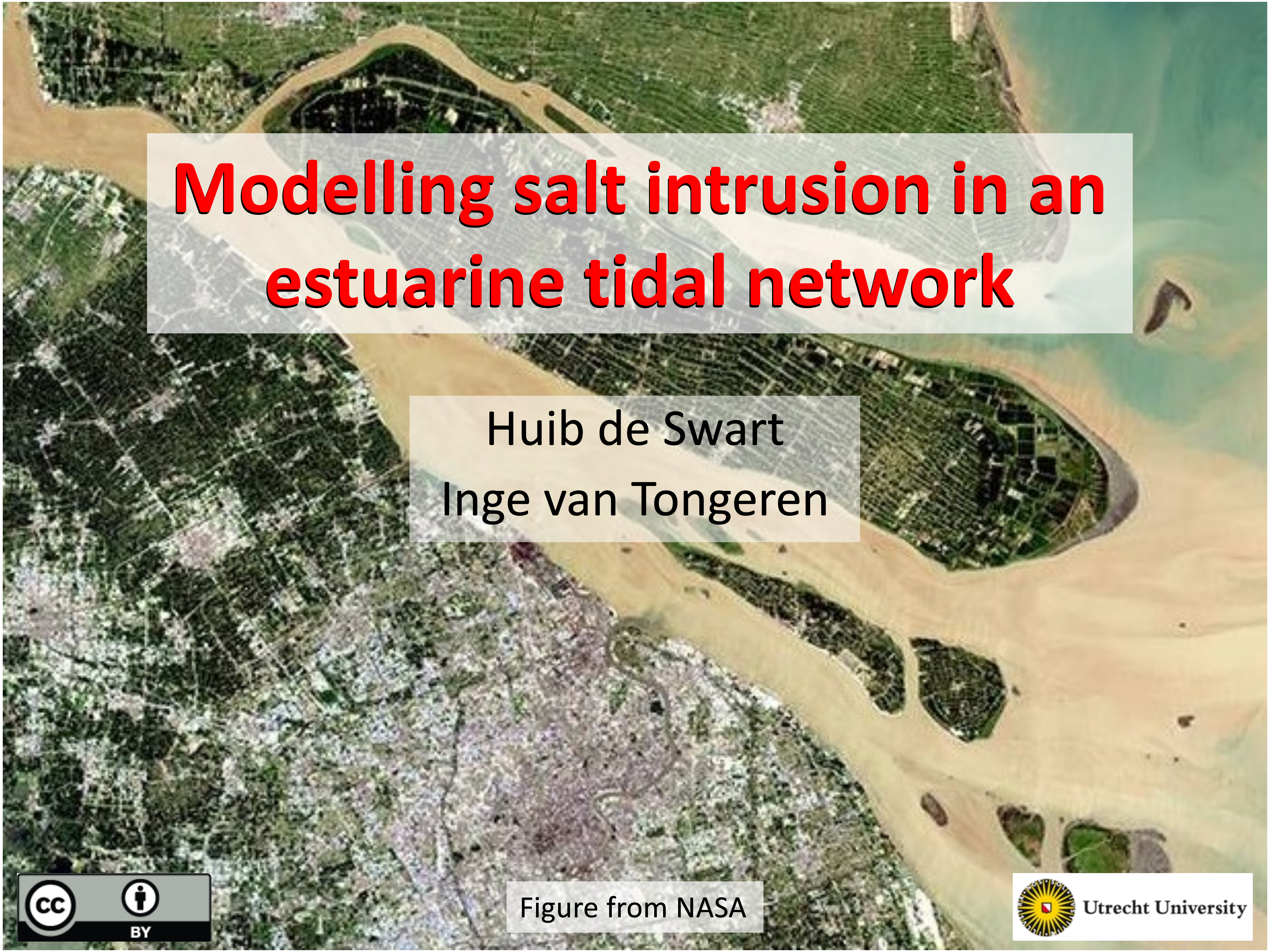


Figure from NASA

Utrecht University

Estuarine network

System of multiple channels, in which water motion is primarily forced by river run-off and by tides.

Figure Yangtze: http://www.delta-alliance.org/wings/China-Yangtze-wing

Figure Rhine Meuse estuary: [Maximilian Dörrbecker](#) via en.wikipedia.org

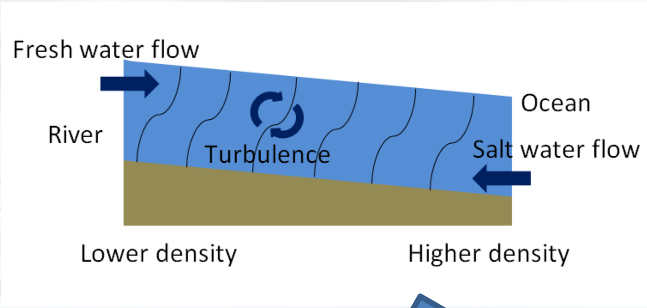
Salt intrusion

affects fresh water supply, agriculture, ecology, ..

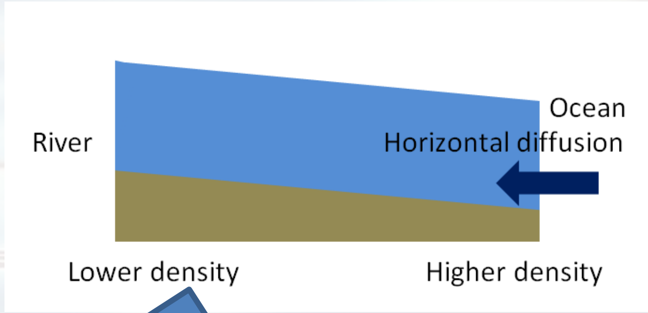
From https://scienceline.org/2007/06/env_webster_salt-water-global-warming/

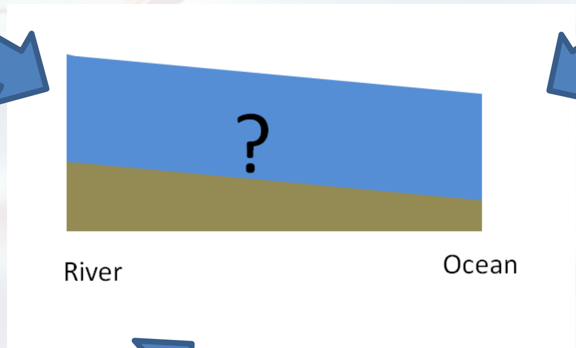
Drivers of net salt transport

density gradients
and river run-off

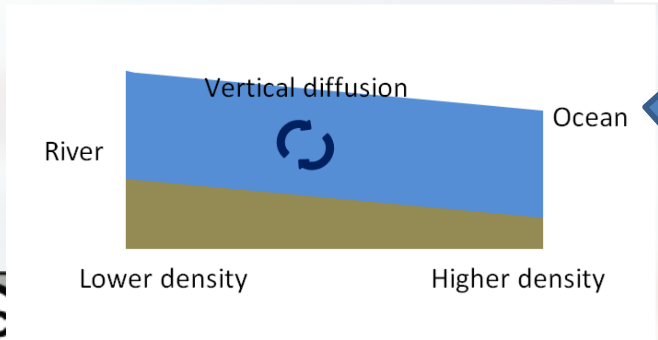


horizontal diffusion
and tidal pumping





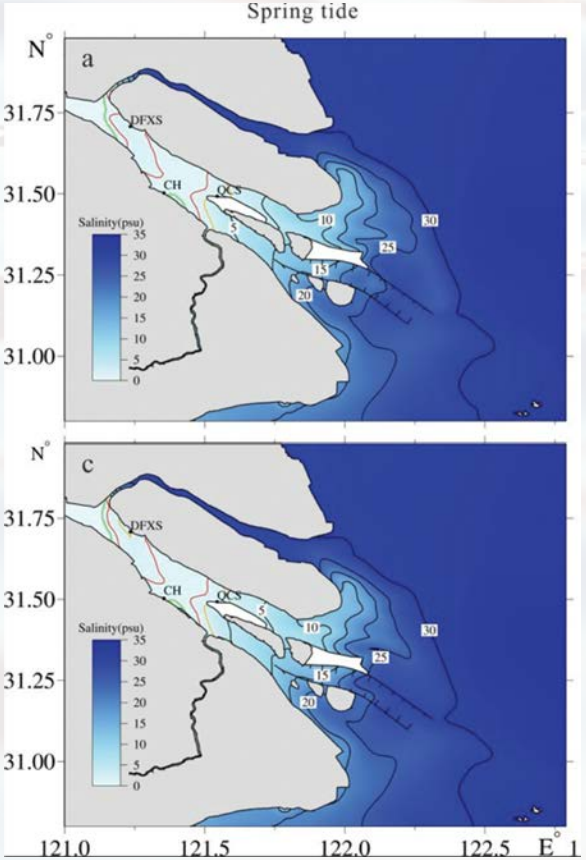
vertical diffusion



Weaker when stratification ↑,
stronger when tidal current ↑ .

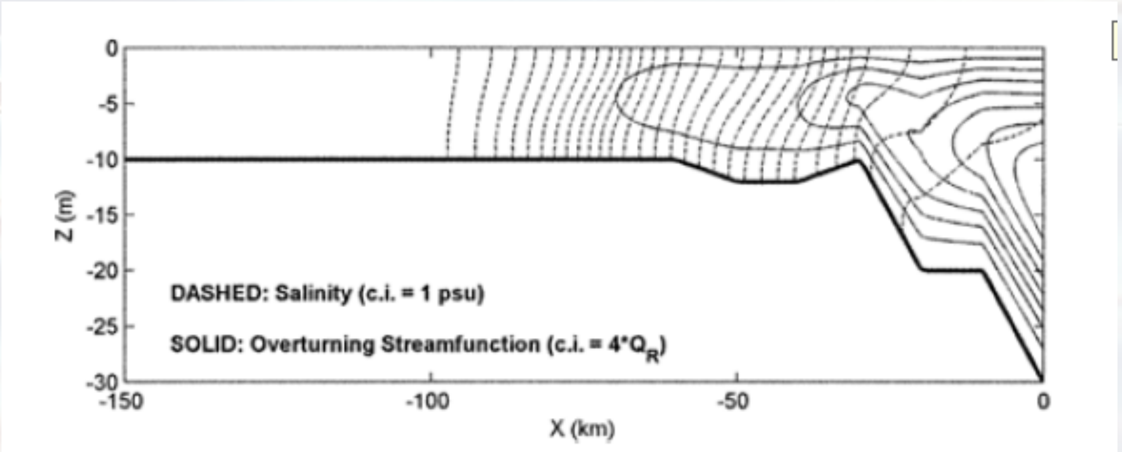
Salt intrusion, studying methods

Complex numerical model



From Zhu et al., 2018

Idealized semi-analytical model
(to gain fundamental insight)



From MacCready, 2004

Aims

Gain fundamental insight into physics of salt intrusion
in an estuarine network,

in particular the case of salt water-spilling-over from one channel
to another, as occurs in e.g. the Yangtze estuary
(Zhu et al. 2018, see slide 5)

Research questions

1. Dependence of salt intrusion in an estuarine network on river run-off, tidal forcing and geometry?

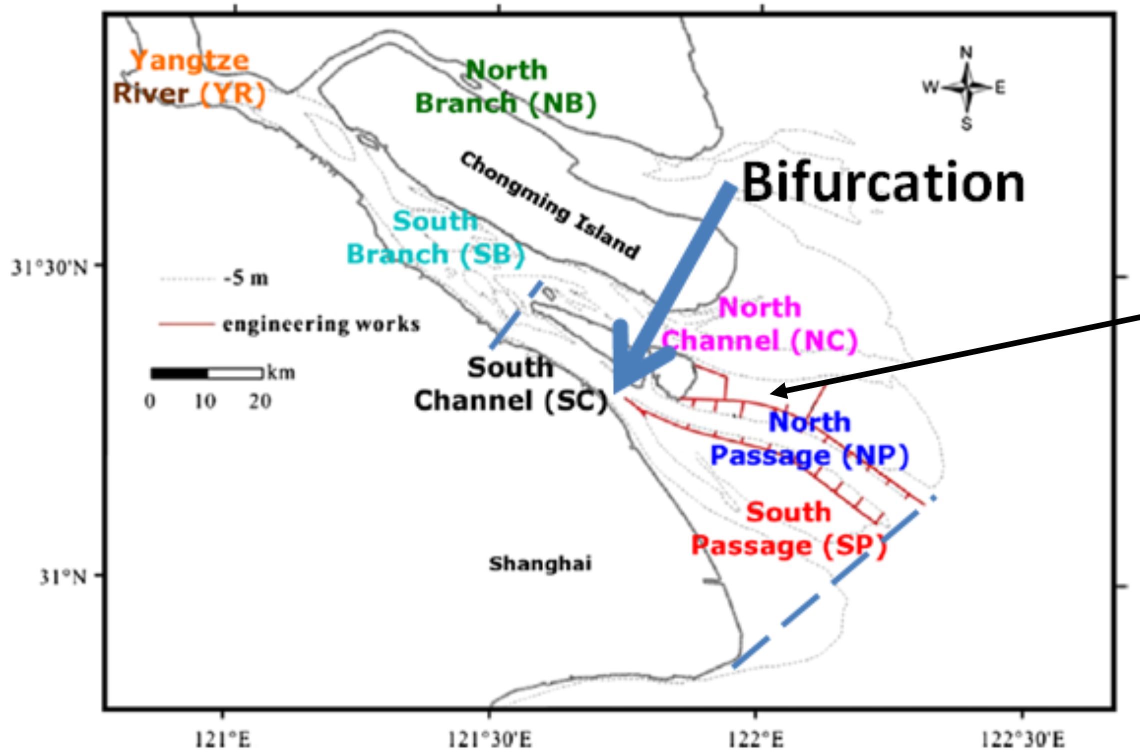
2. Under what conditions does saltwater-spilling-over occur?

Tool

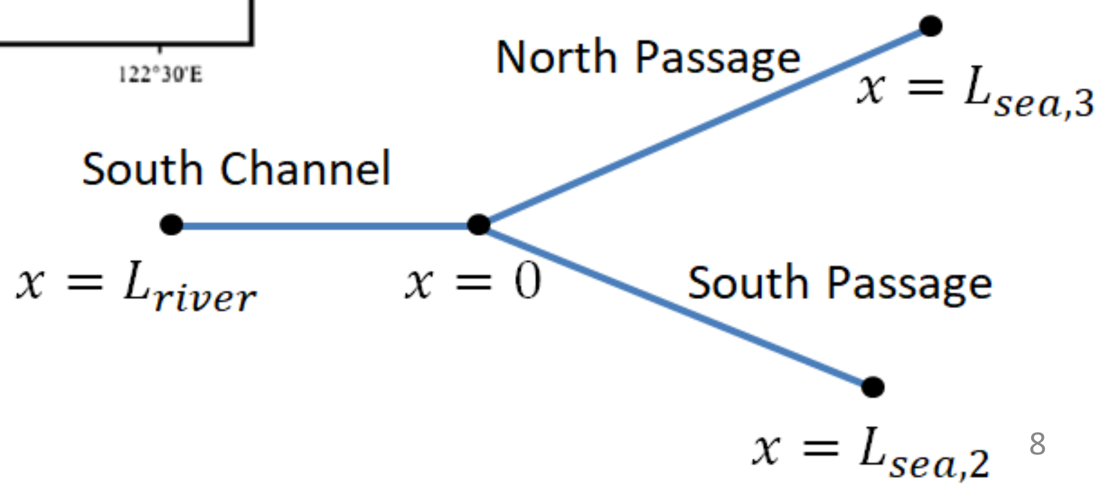
Semi-analytical model

(extension of MacCready, 2004, to a network geometry)

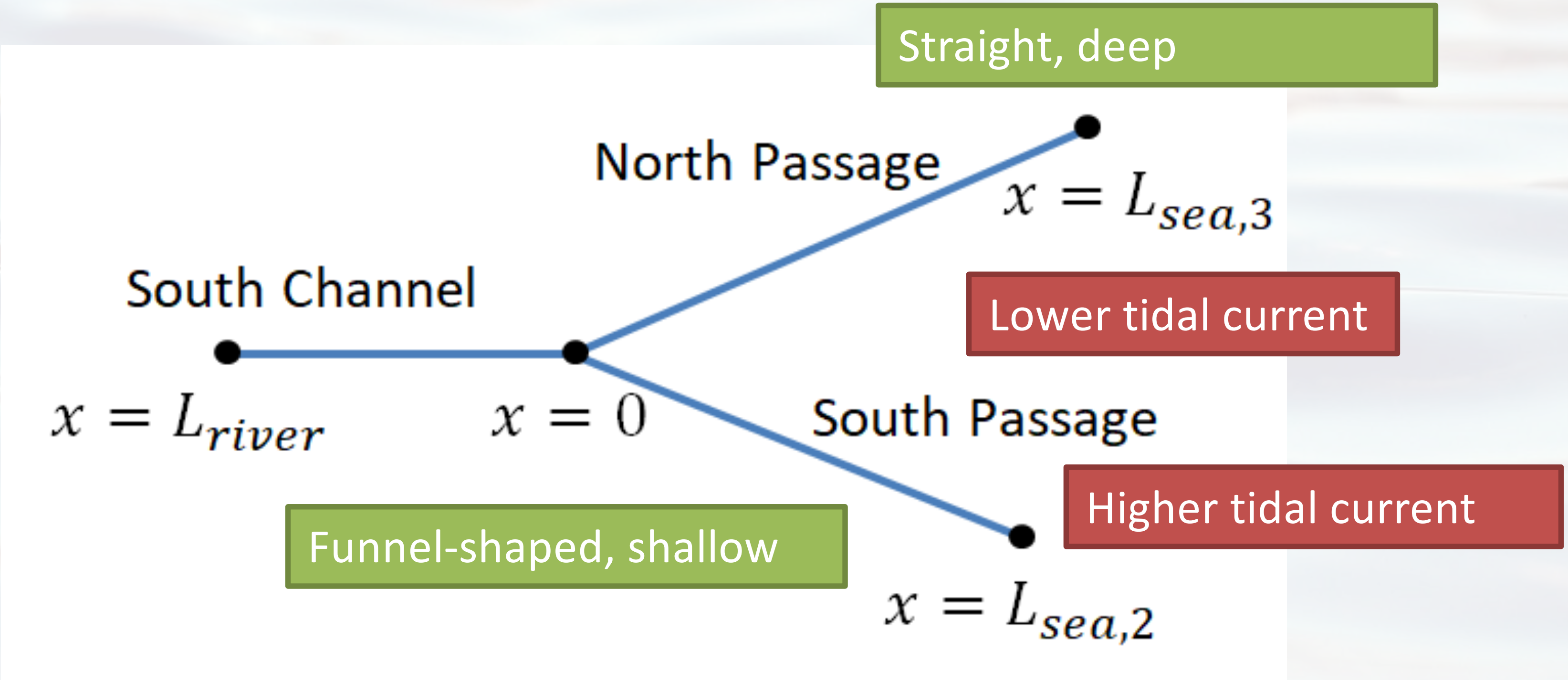
Apply model to lower part of Yangtze estuary



Red lines in North Passage indicate locations of training walls and groins (constructed in 1998-2010: DNC project).

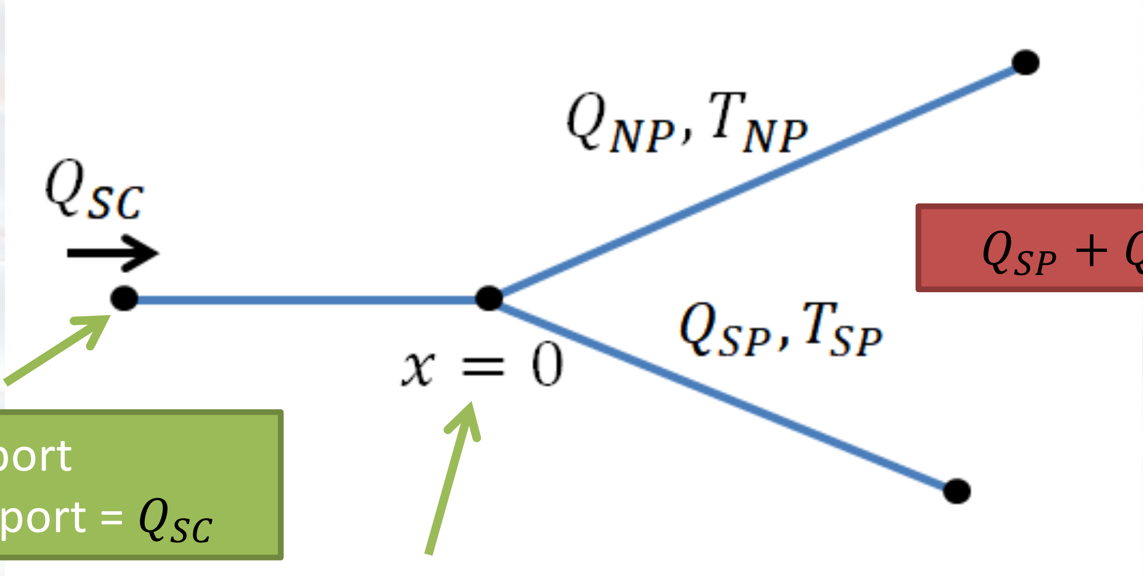


Apply model to lower part of Yangtze estuary



Model

width-averaged



No salt transport
Volume transport = Q_{SC}

$Q_{SP} + Q_{NP} = Q_{SC}$

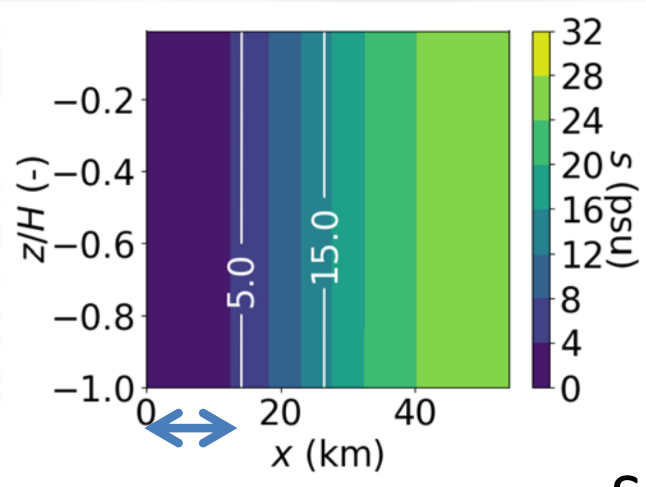
Sea surface/salinity continuous

Q: river water transport
T: net salt transport

$T_{SP}, + T_{NP} = 0$
$T_{SP} > 0$ Salt transport NP → SP
$T_{NP} > 0$ Salt transport SP → NP

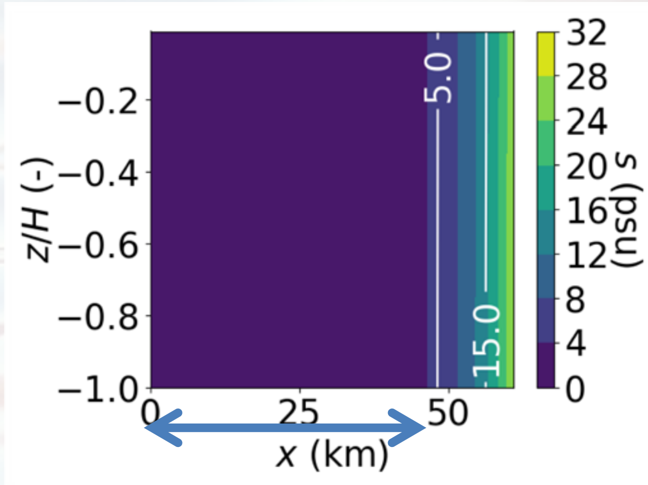
Results:
spring tide, dry season salinity distributions

South Passage (SP)



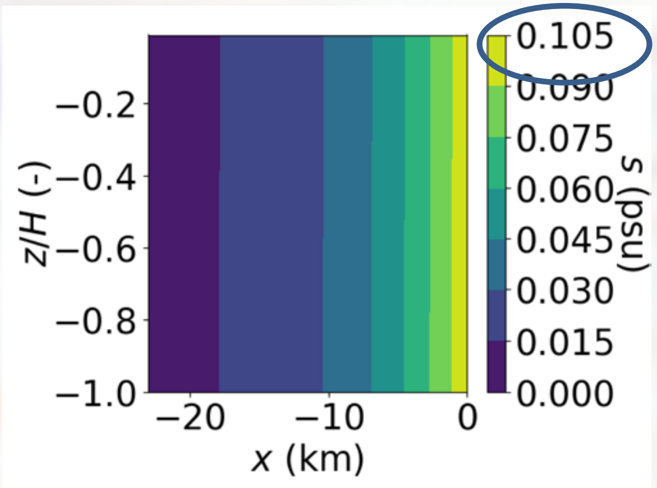
Q_{SP} =2152 m^3/s (58%)

North Passage (NP)



Q_{NP} =1562 m^3/s (42%)

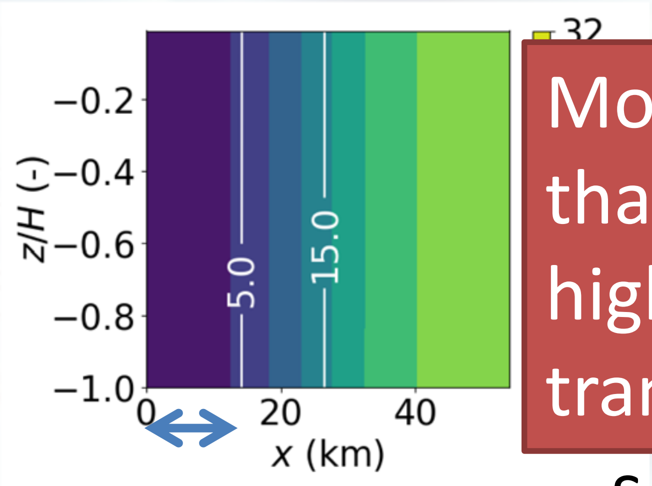
South Channel (SC)



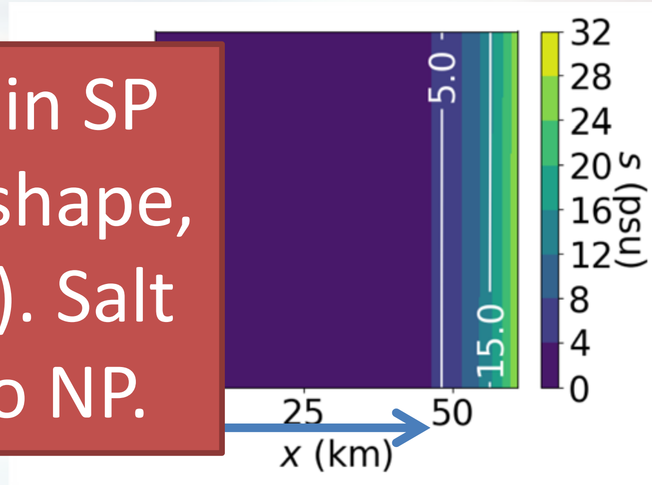
Q_{SC} =3714 m^3/s

Results:
spring tide, dry season salinity distributions

South Passage (SP)



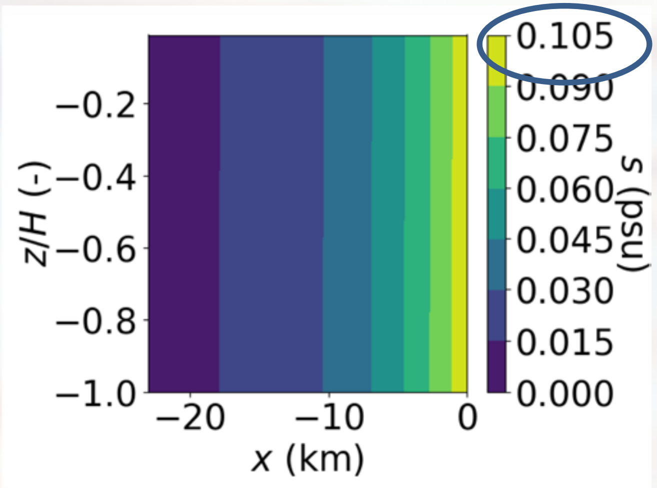
North Passage (NP)



More salt intrusion in SP than in NP (funnel-shape, higher tidal current). Salt transport from SP to NP.

South Channel (SC)

Q_{SP} =2152 m^3/s (58%)



Q_{NP} =1562 m^3/s (42%)

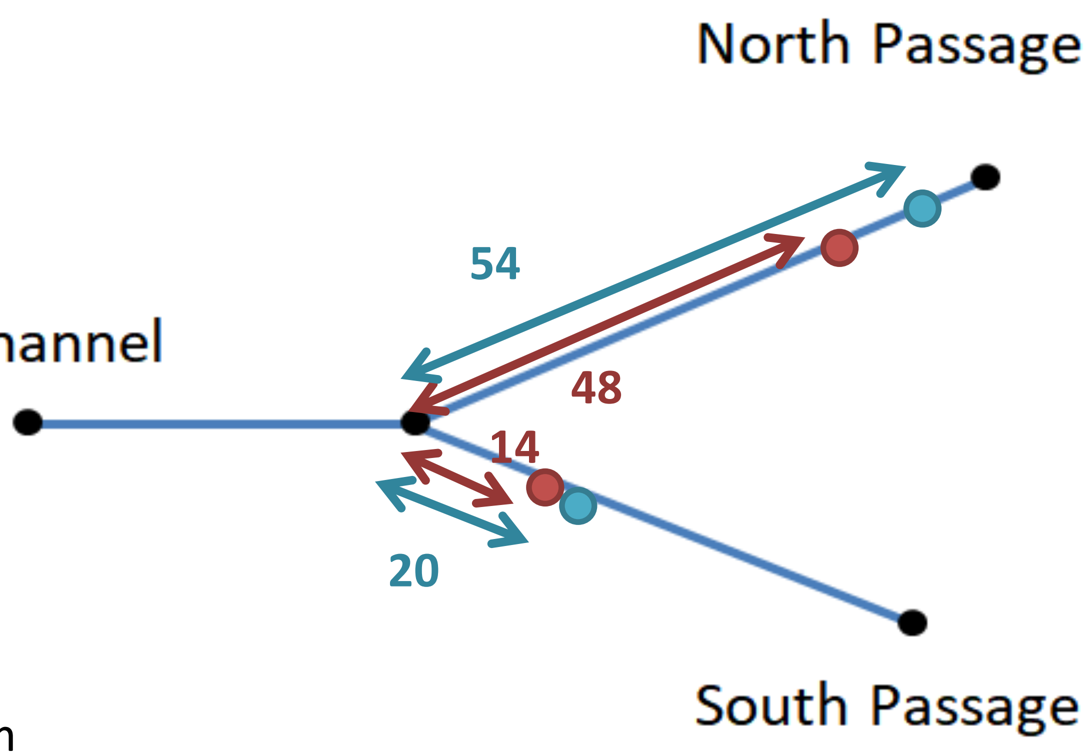
T_{SP} = -165 psu m^3/s
Salt transport SP → NP

Q_{SC} =3714 m^3/s

Effect of river discharge on salt intrusion

Spring tide, dry season	Q_{SC} =3714 $\mathrm{m^3/s}$
Spring tide, wet season	Q_{SC} =6440 $\mathrm{m^3/s}$

Dots indicate location of 5 psu bottom salinity.



T_{SP} = -165 psu $\mathrm{m^3/s}$

T_{SP} = -15 psu $\mathrm{m^3/s}$

Distances in km

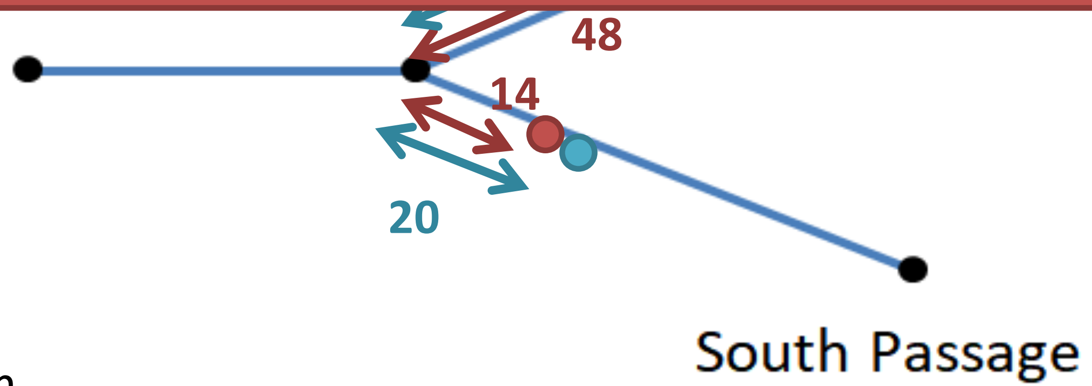
Effect of river discharge on salt intrusion

Spring tide, dry season	Q_{SC} = 3714 $\mathrm{m^3/s}$
Spring tide, wet season	Q_{SC} = 6440 $\mathrm{m^3/s}$

Dots indicate location of 5 psu bottom salinity.

Stronger river flow: less intrusion and spilling.

Stronger tides (not shown):
more salt intrusion and spilling.



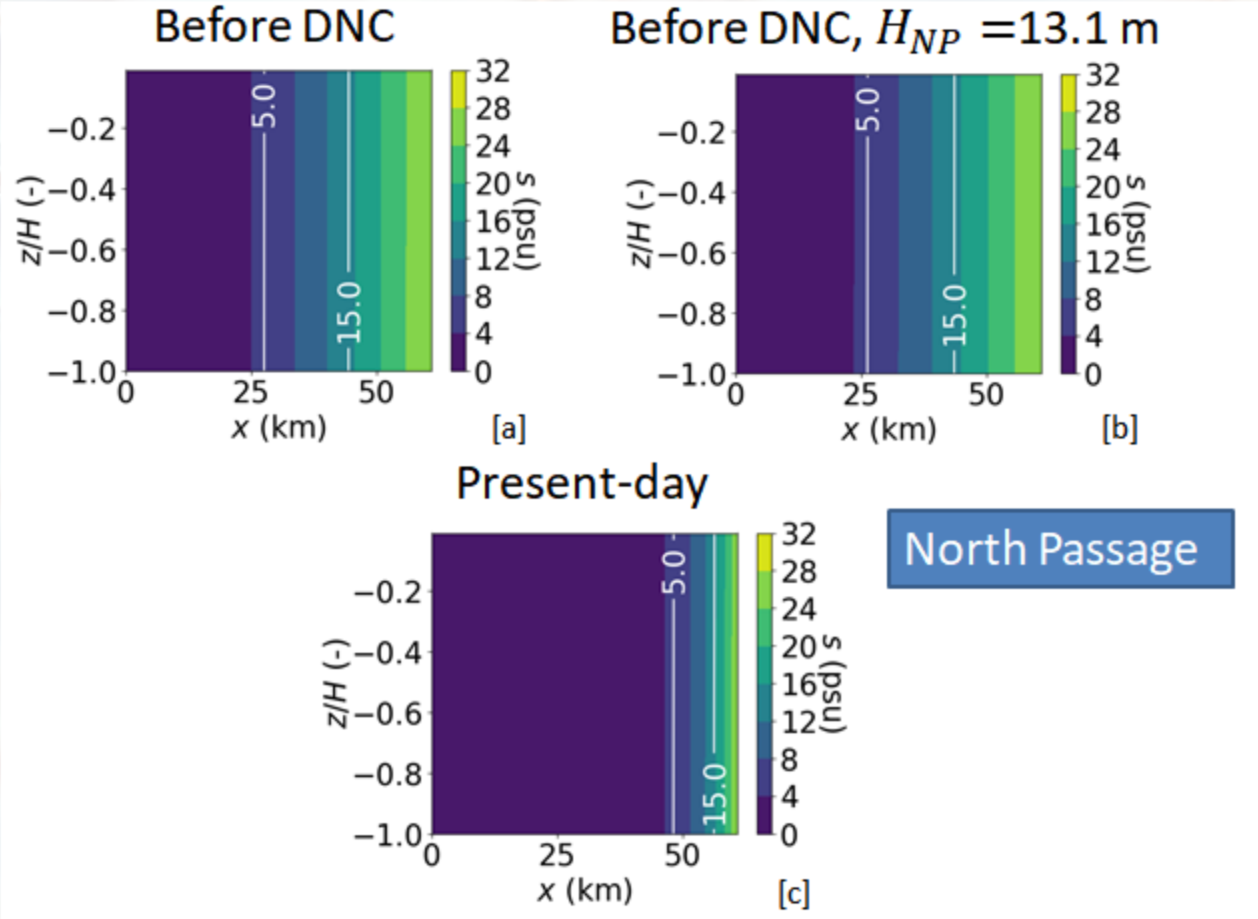
T_{SP} = -165 psu $\mathrm{m^3/s}$

T_{SP} = -15 psu $\mathrm{m^3/s}$

Distances in km

Effect of changes in network geometry

Before construction of Deep Navigation Channel (DNC) in 1990-2000 in North Passage: depth was 12.1 m and strong width increase towards sea.



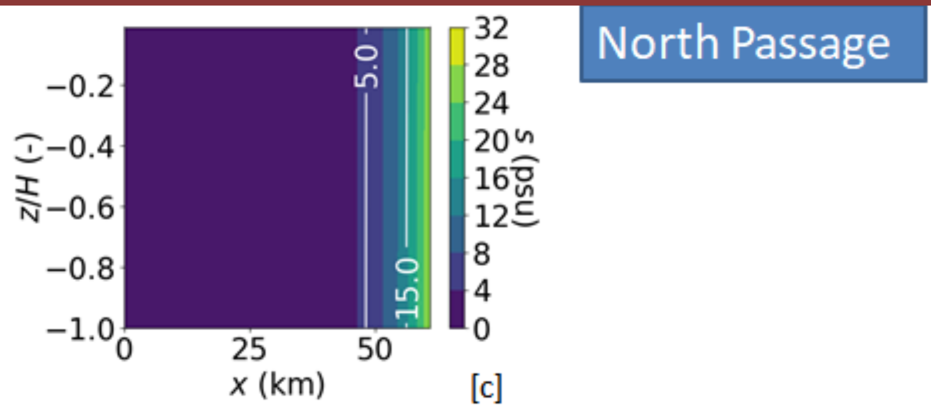
Effect of changes in network geometry

Before construction of Deep Navigation Channel (DNC)
in 1990-2000 in North Passage:
depth was 12.1 m and strong width increase towards sea.

Solely increase in depth: more salt intrusion (weak).

Add smaller width variations towards sea:
less salt intrusion (strong).

So before DNC: more saltwater-spilling-over.



Discussion

- Stratification is underestimated
  (eddy viscosity/eddy diffusivity overestimated? …?)

- Uncertainty in parameters (such as depth, total river flow, sea surface height at coast).

- Role of tidal pumping, tidal straining, lateral processes, … ?

Conclusions

1. **Dependence of salt intrusion in an estuarine network on forcing and geometry?**

Salt intrusion is strongly dependent on depth, width and length of the channels in the network.

2. **Under what conditions does saltwater-spilling-over occur?**

Preferred: weak river run-off, strong tides, deep channels with seaward increasing widths.