

Dispersion in bar-built estuaries

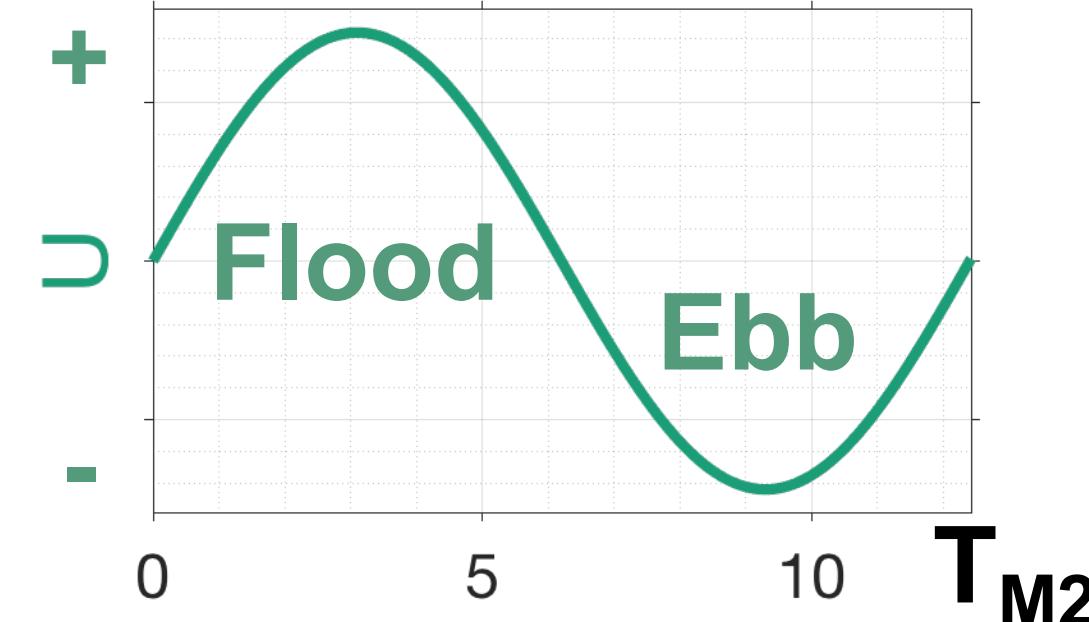
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A one-dimensional estuary



$$\frac{\partial S}{\partial t} + U \frac{\partial S}{\partial x} = K_x \frac{\partial^2 S}{\partial x^2}$$

↑
Advection
K_x: Longitudinal dispersion Coefficient

Salinity is a conservative tracer in estuaries. Salinity measurements can be used to calculate estuarine dispersion.

For a step function (S_o : salinity 0 to ocean salinity), this can be solved:

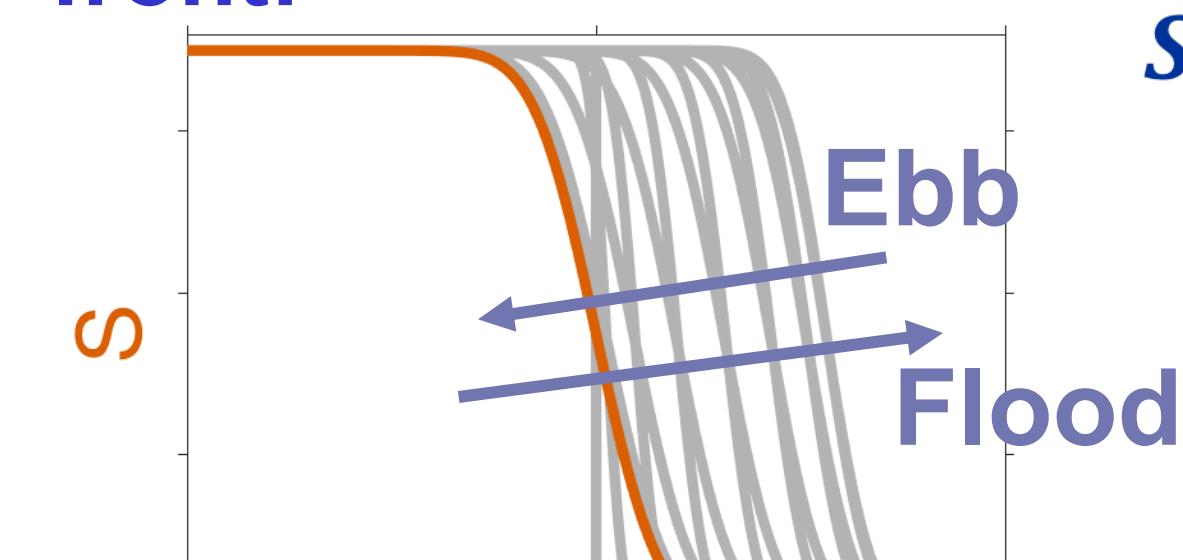
$$S(x, t) = \frac{S_o}{2} \left(1 + \operatorname{erf} \left(\frac{x - x_c}{\sqrt{4K_x t}} \right) \right)$$

x_c: center of salinity front

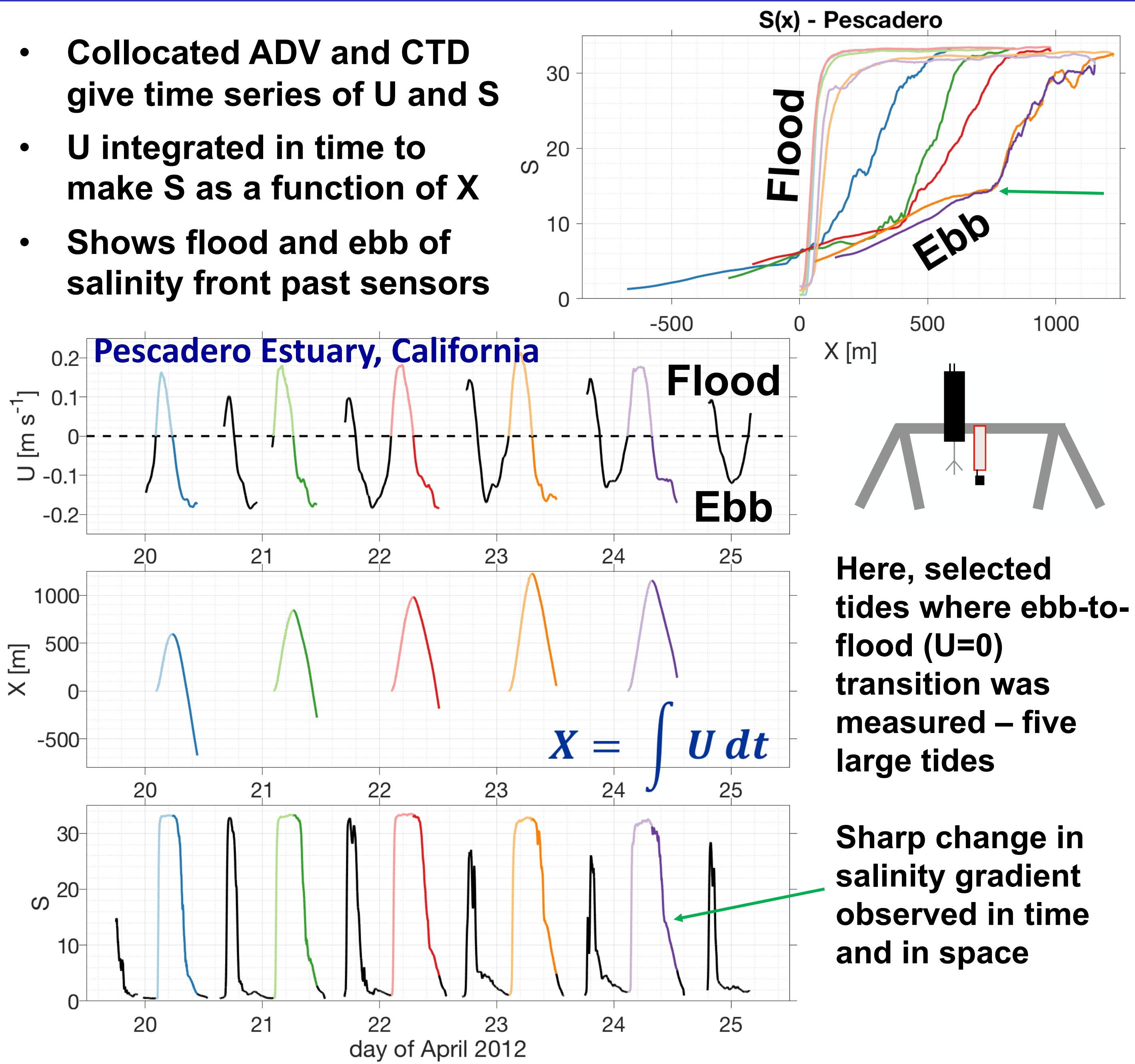
S_o: maximum salinity (assumes min. salinity is zero)

(e.g. Fischer et al. 1979, Ralston & Stacey, 2005)

Moving with the salinity front:



- Collocated ADV and CTD give time series of U and S
- U integrated in time to make S as a function of X
- Shows flood and ebb of salinity front past sensors



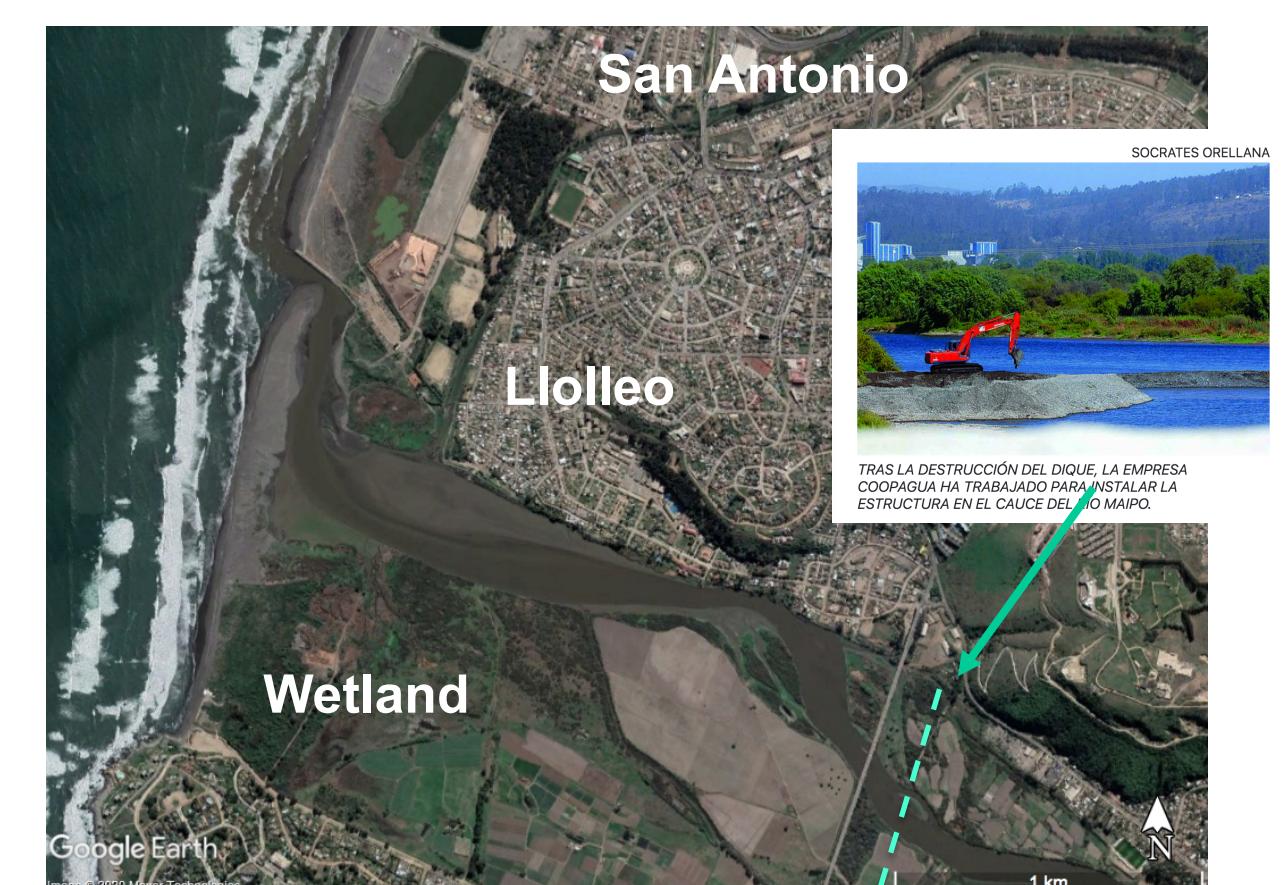
Pescadero Estuary, California



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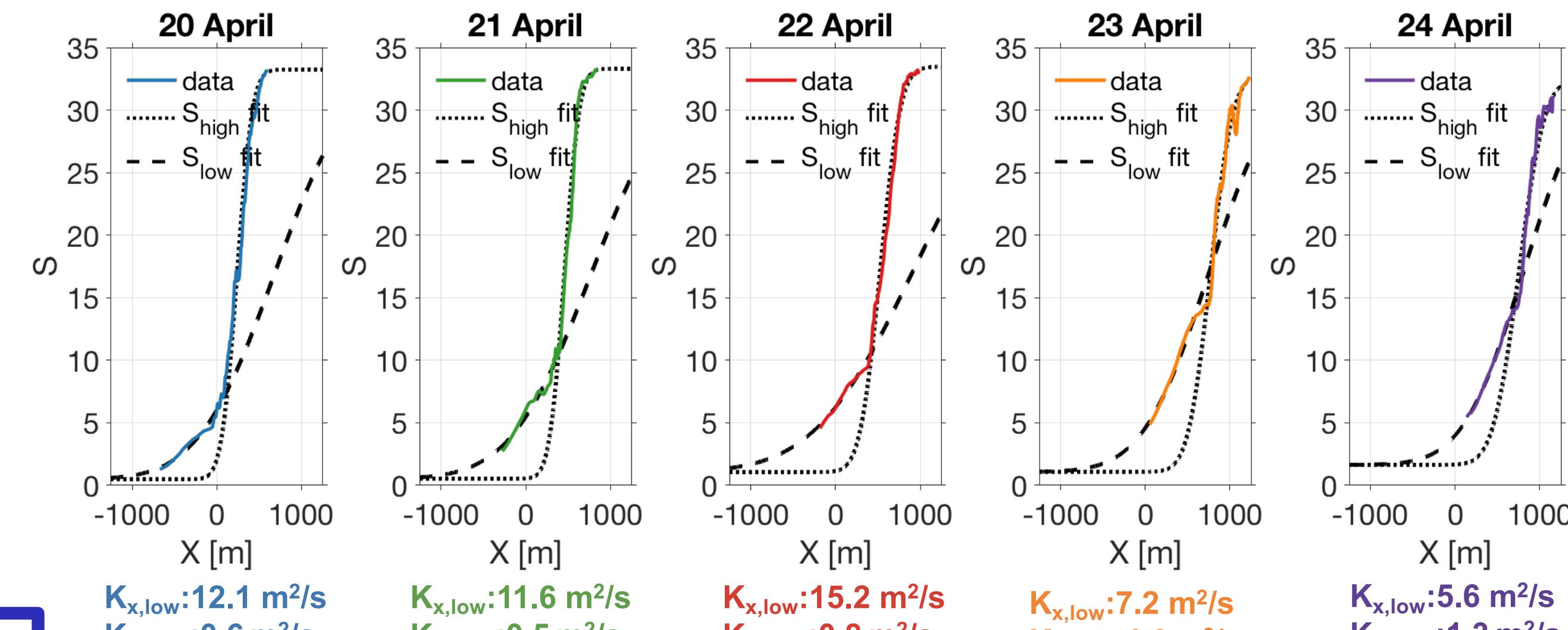
Measurements made in April 2012 (see also Williams & Stacey, 2016)

Río Maipo Estuary, Chile



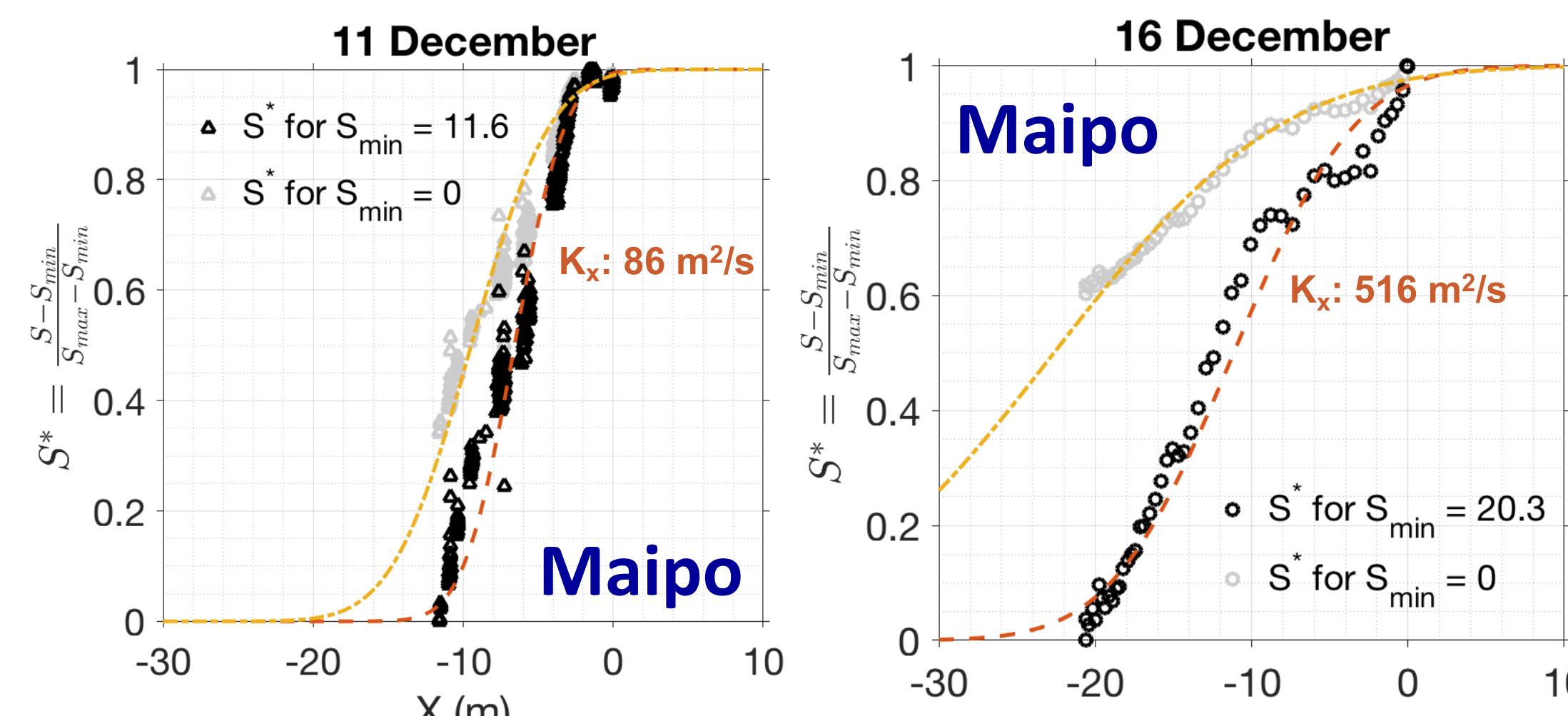
Measurements made in December 2019 - with initial CTD measurements from a kayak and ADCP-surfboard catamaran

Pescadero



Or, nondimensionalizing:

$$S^* = \frac{S - S_{min}}{S_{max} - S_{min}} = \frac{1}{2} \left(1 + \operatorname{erf} \left(\frac{x}{\sqrt{4K_x t}} + \frac{x_c}{\sqrt{4K_x t}} \right) \right)$$



Longitudinal dispersion

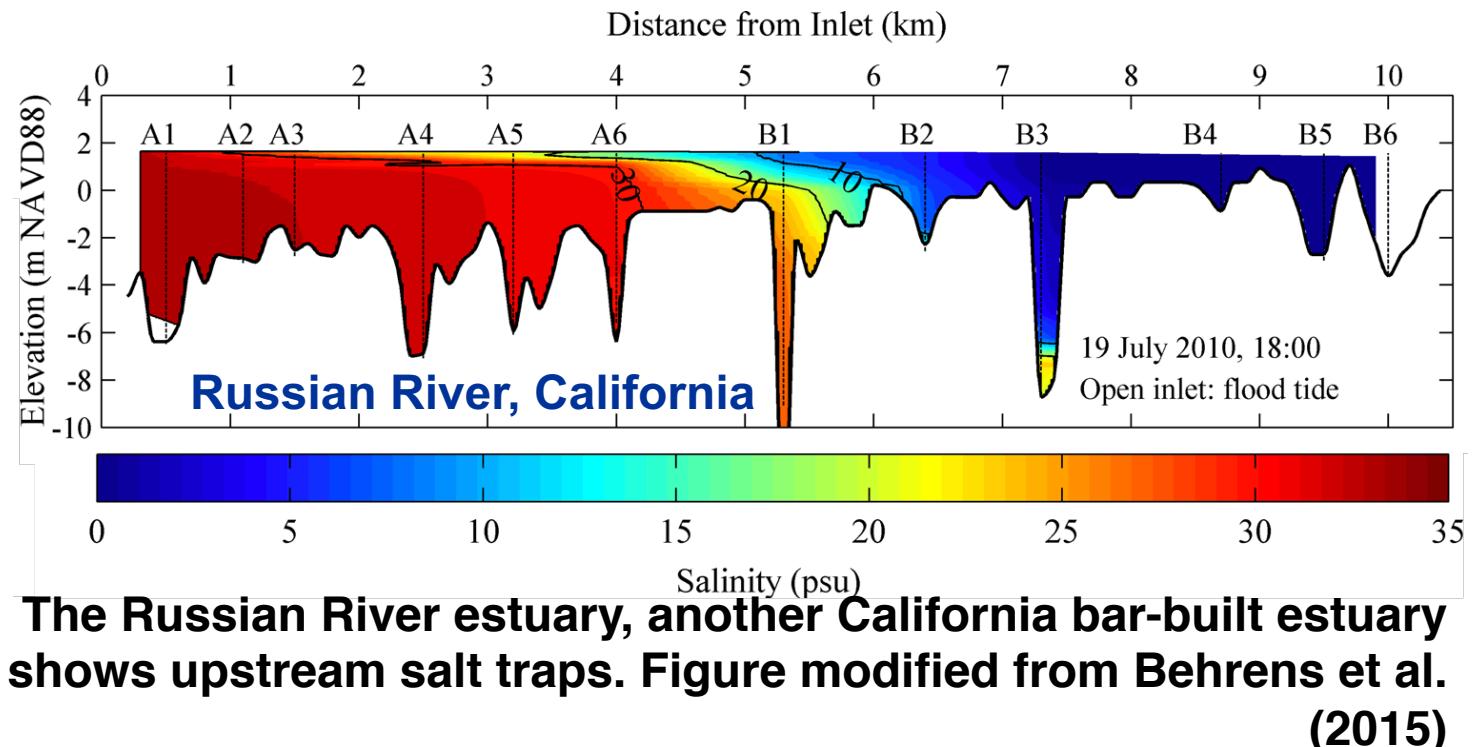
Values of longitudinal dispersion in the Maipo and at high salinities in the Pescadero estuary are of similar magnitude to shear dispersion (from Fischer: $K_x = 0.1 u'^2 T \left[\frac{1}{T} f(T') \right]$) gives $K_x \sim 1 \text{ m}^2/\text{s}$ for velocity and tidal periods in Pescadero, $K_x \sim 800 \text{ m}^2/\text{s}$ for velocity and tidal periods in the Maipo.

Low salinity K_x in the Pescadero is too high to be explained by shear dispersion.

Drivers of longitudinal dispersion in bar-built estuaries

The Pescadero estuary remains highly stratified throughout the tidal cycle. Here we have one-dimensionalized the estuary, but vertical stratification is likely causing high K_x at low salinities in this estuary.

Salt moves upstream, and is trapped in deep regions of the estuary (these systems have also been named "salt trap estuaries")

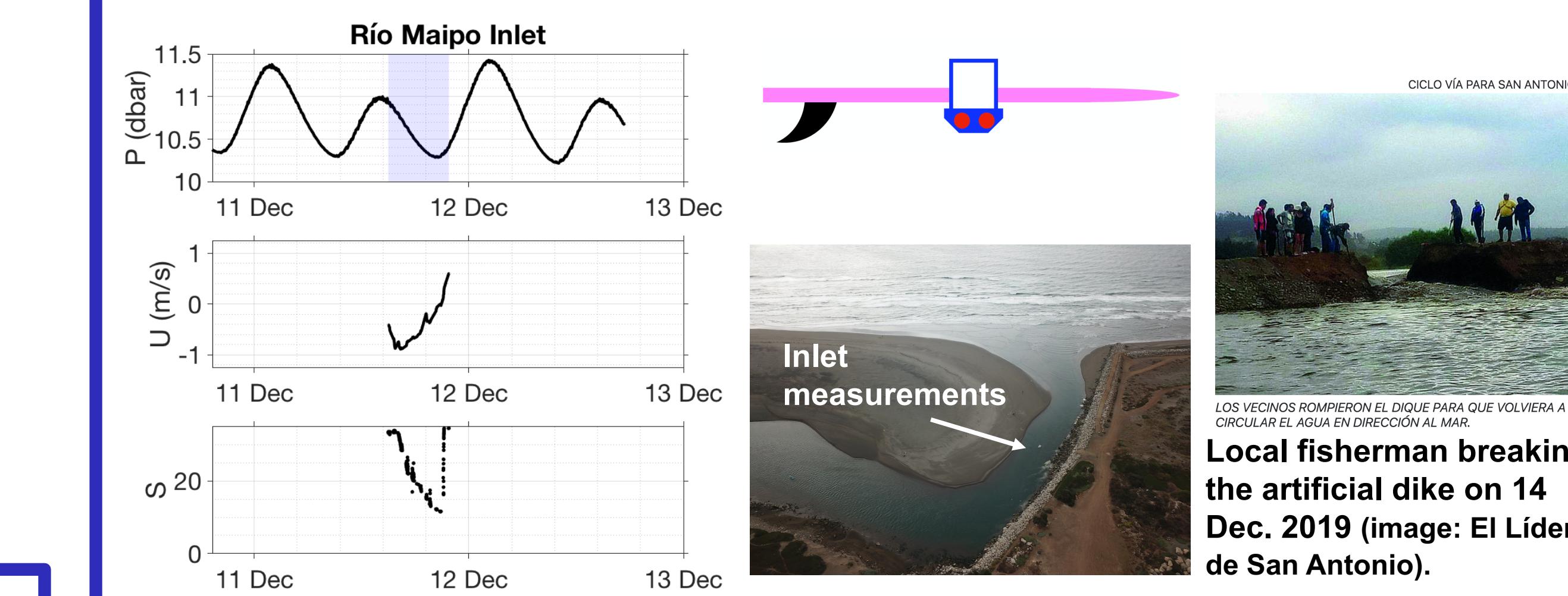


The Russian River estuary, another California bar-built estuary shows upstream salt traps. Figure modified from Behrens et al. (2015)

Challenges and conclusions

We have calculated longitudinal dispersion coefficients in two Pacific bar-built estuaries. In the Maipo, dispersion is consistent with shear dispersion, as it is for high salinities in the Pescadero estuary.

In the Maipo, measurements were made from a floating platform, and the construction of a dike to protect drinking water extraction upstream (Chile is in the 12th year of an extreme drought), the measurements made characterize a highly altered estuary.



References

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