The influence of preexisting stratification and tropical rain modes on the mixed layer salinity response to rainfall

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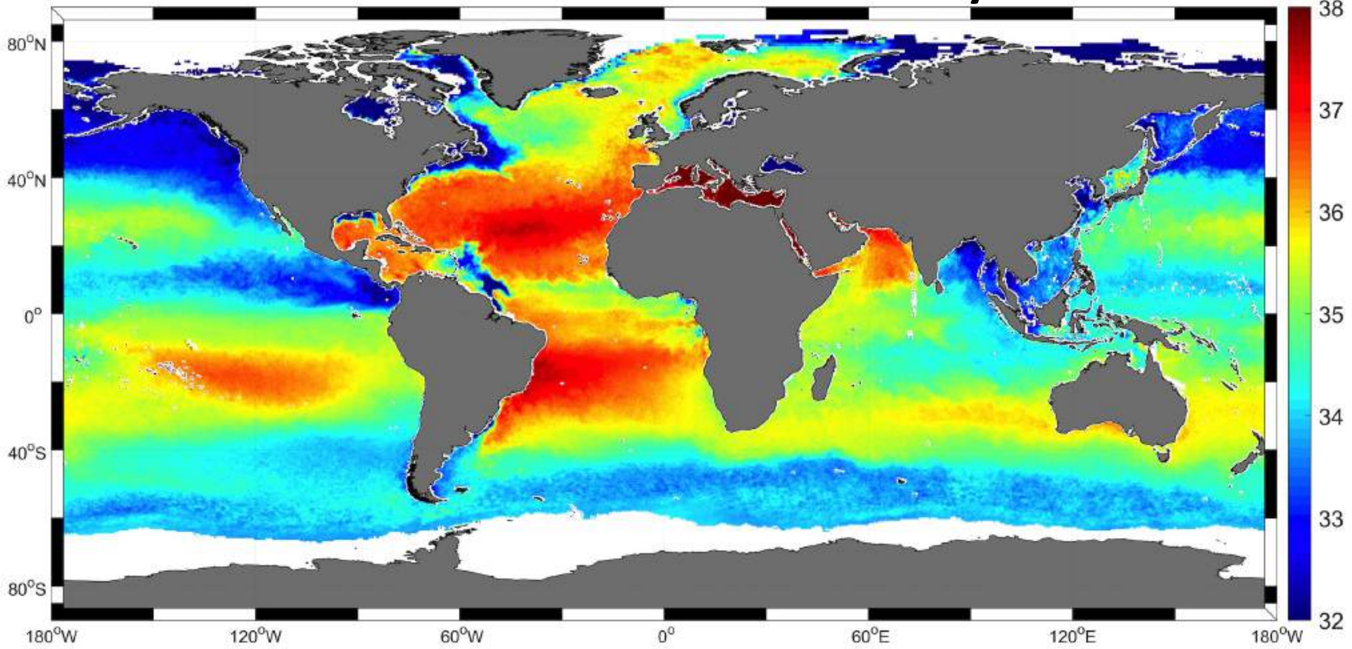
Motivation: Global salinity variability is a proxy for water cycle changes

- Satellites: Low salinities near the inter-tropical convergence zone

- In situ observations: Salinity anomalies from rainfall are transient features

Satellite Sea Surface Salinity



European Space Agency, 2022

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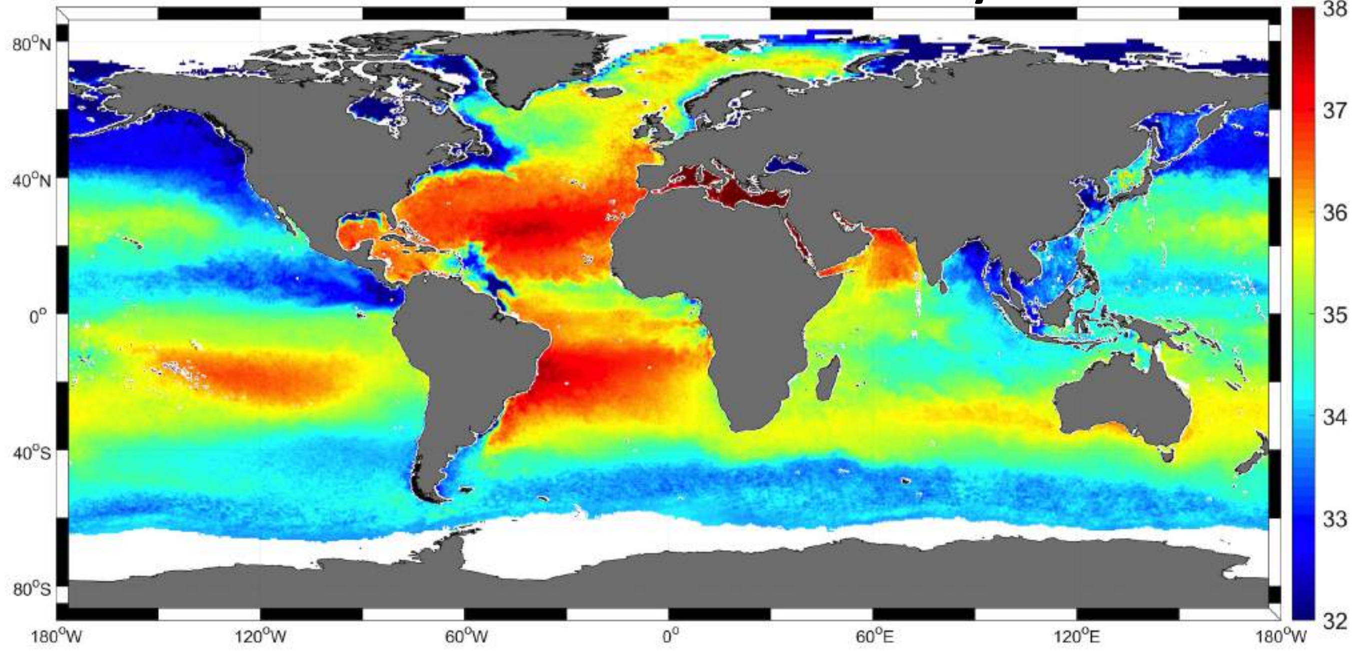

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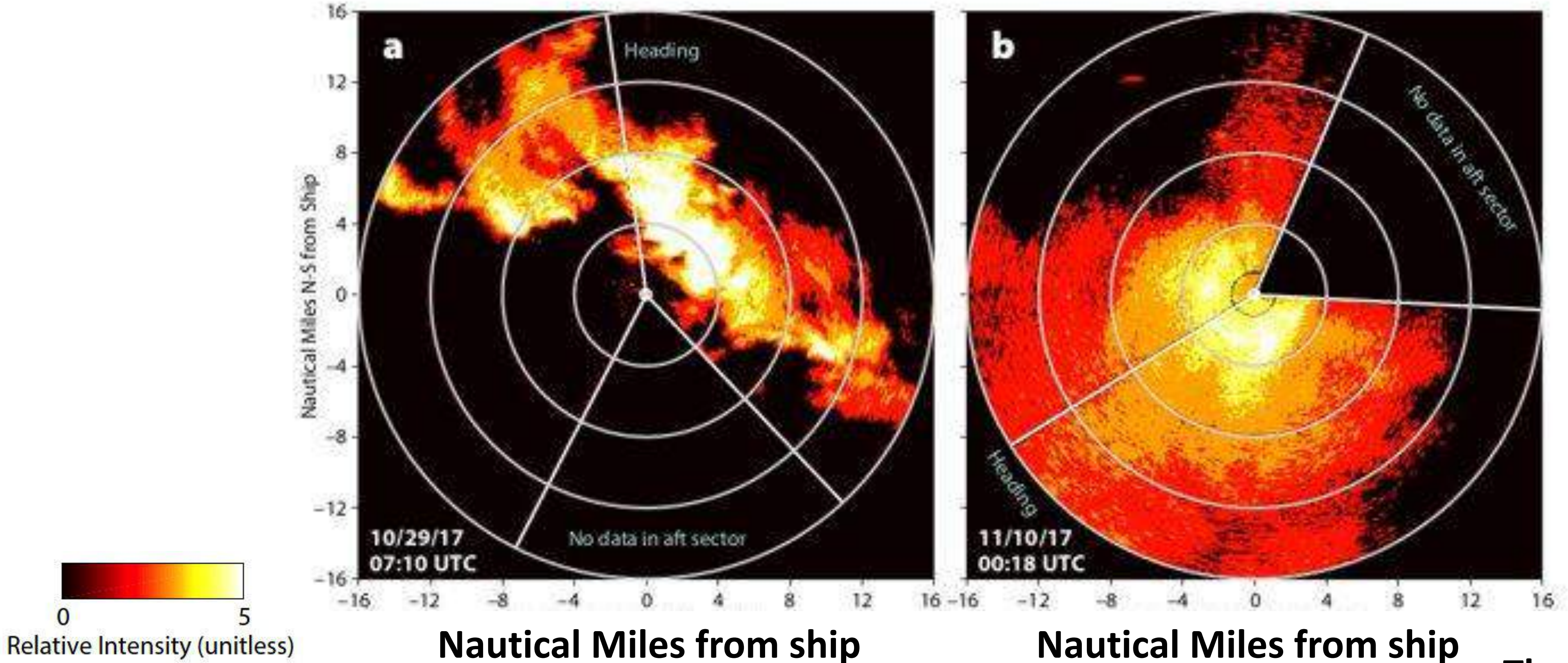
Analysis: Idealized model experiments considering atmospheric rain types and preexisting stratification

Tropical rainfall can loosely be categorized into two classes: Convective rain (short, small-scale, intense) and stratiform rain (large-scale and less intense).

Convective

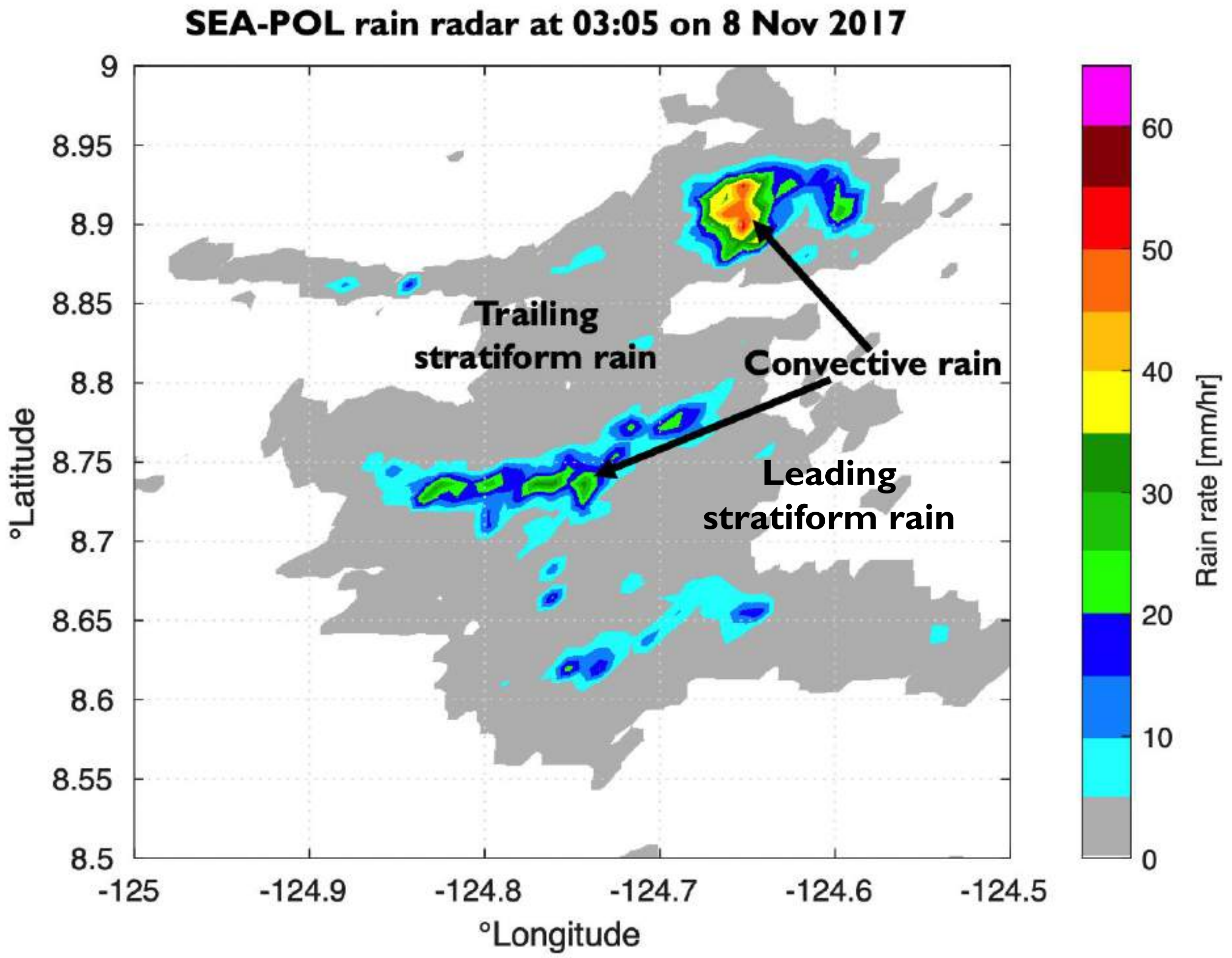
Stratiform



Nautical Miles from ship **Nautical Miles from ship**

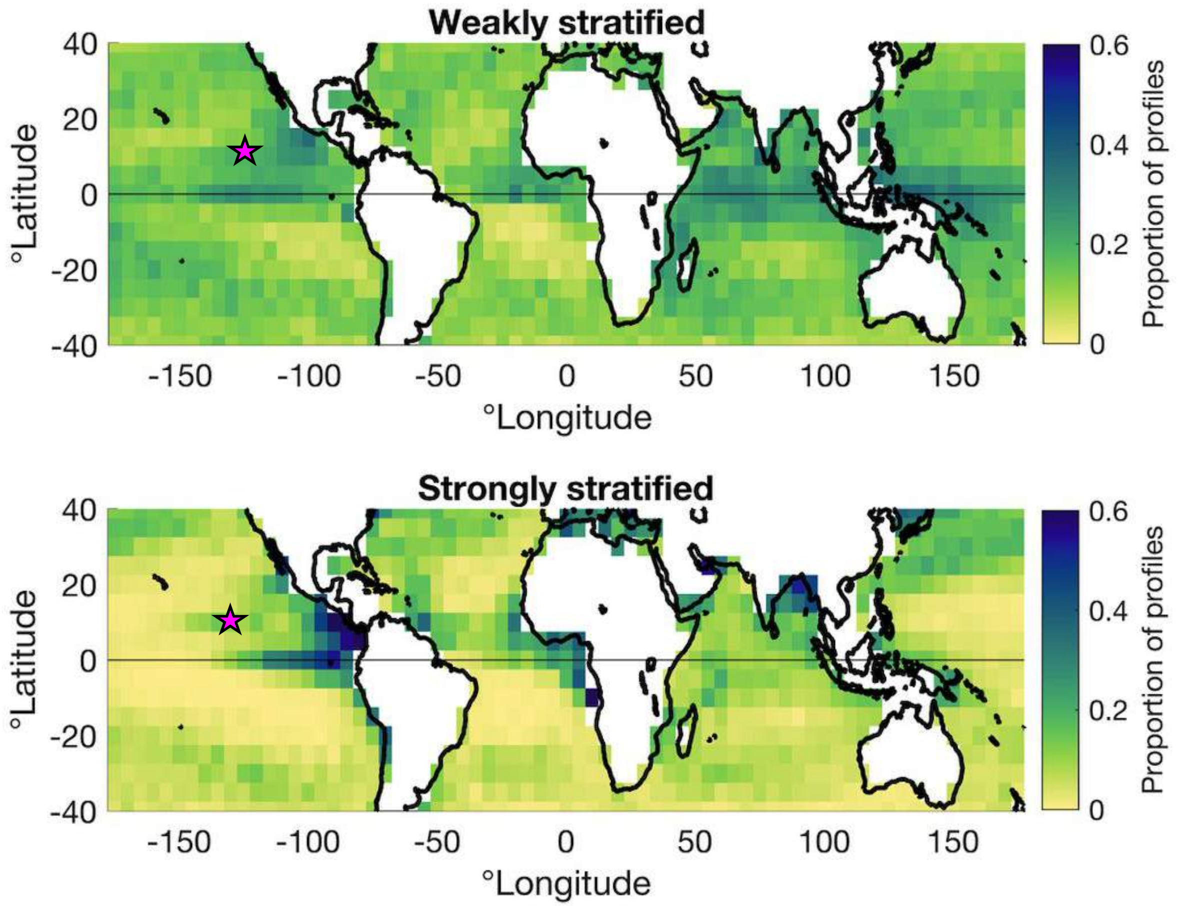
Thompson et al. (2019)

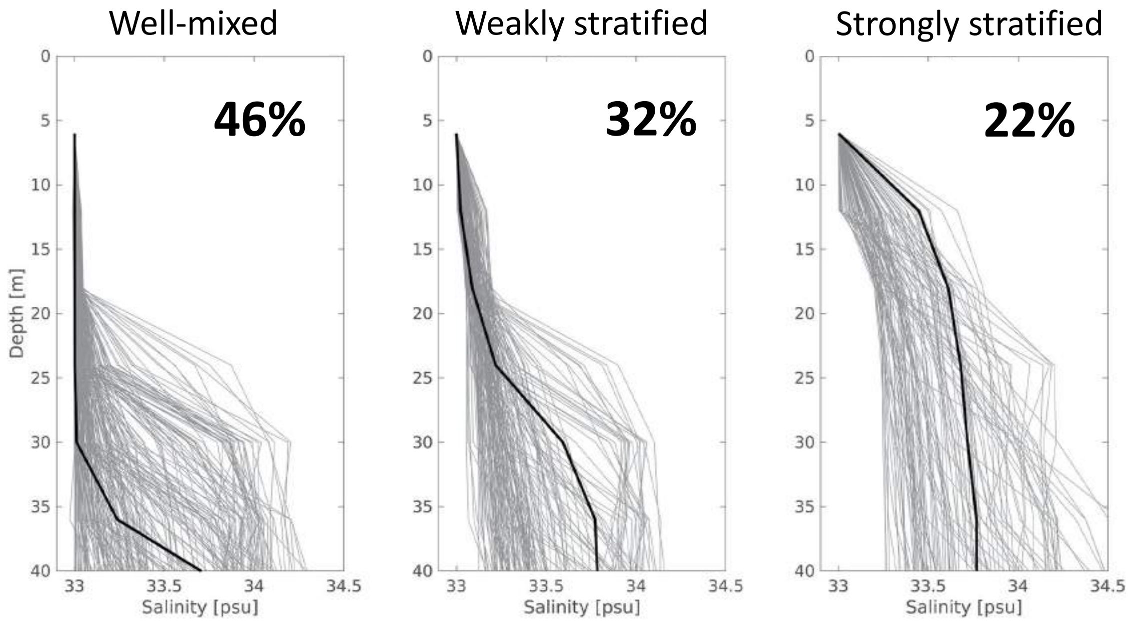
During the SPURS-2 Experiment in the eastern tropical Pacific, rain events with stratiform rain leading and/or following convective rain were responsible for 75% of the total accumulation*.



*At the SPURS-2 Central Mooring, Aug 2016 to Nov 2017

At the SPURS-2 site, frequent rainfall creates weak* (32% of Argo profiles) and strong stratification (22%) in the top 20m. Well-mixed conditions are only present 46% of the time.**





Observed profiles (uCTD)

Typical profiles

*Density differences of > 0.04 kg m^{-3}

**Density differences of > 0.15 kg m^{-3}

Research Questions

1) **Rain modes:** *How does the salinity response to rain in the upper 20 meters differ following different modes of rainfall consisting of convective and stratiform precipitation?*
2) **Preexisting stratification:** How does the salinity response to rain differ when rain falls over a well-mixed ocean compared to a weakly stratified or strongly stratified ocean?

Research Questions

1) **Rain modes:** How does the salinity response to rain in the upper 20 meters differ following different modes of rainfall consisting of convective and stratiform precipitation?
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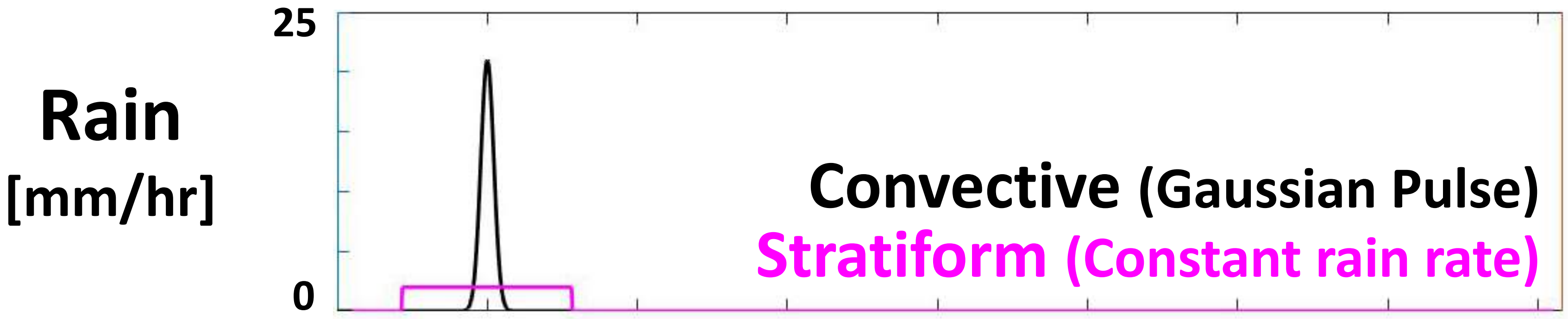
General Ocean Turbulence Model (GOTM)

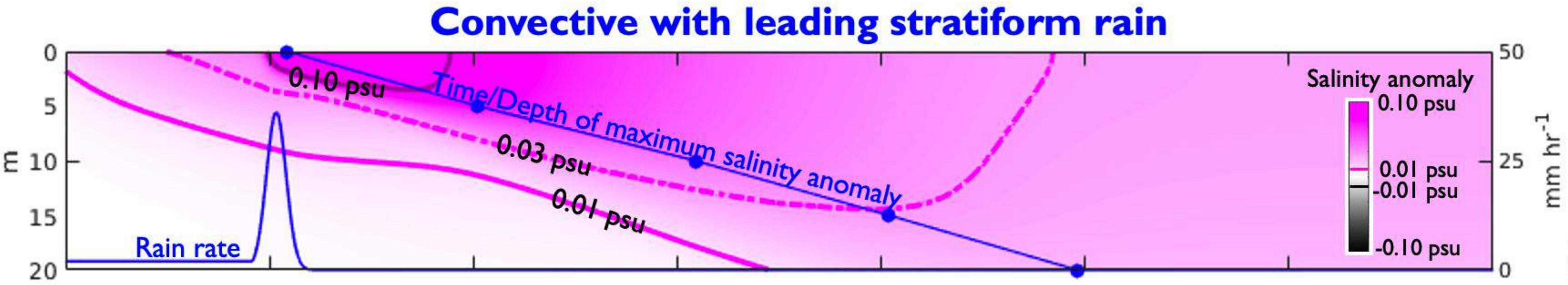
- 1-D ocean model (forced by atmosphere)
- Modeled salinity and turbulence are consistent with observations

Idealized model experiments

Rain mode experiments: Evaluate salinity response in the hours following independent idealized events with different rain forcing (consistent with mixed convective and stratiform events) ***with the same total rain accumulation***



Salinity anomaly (relative to a no-rain case) for two rain types



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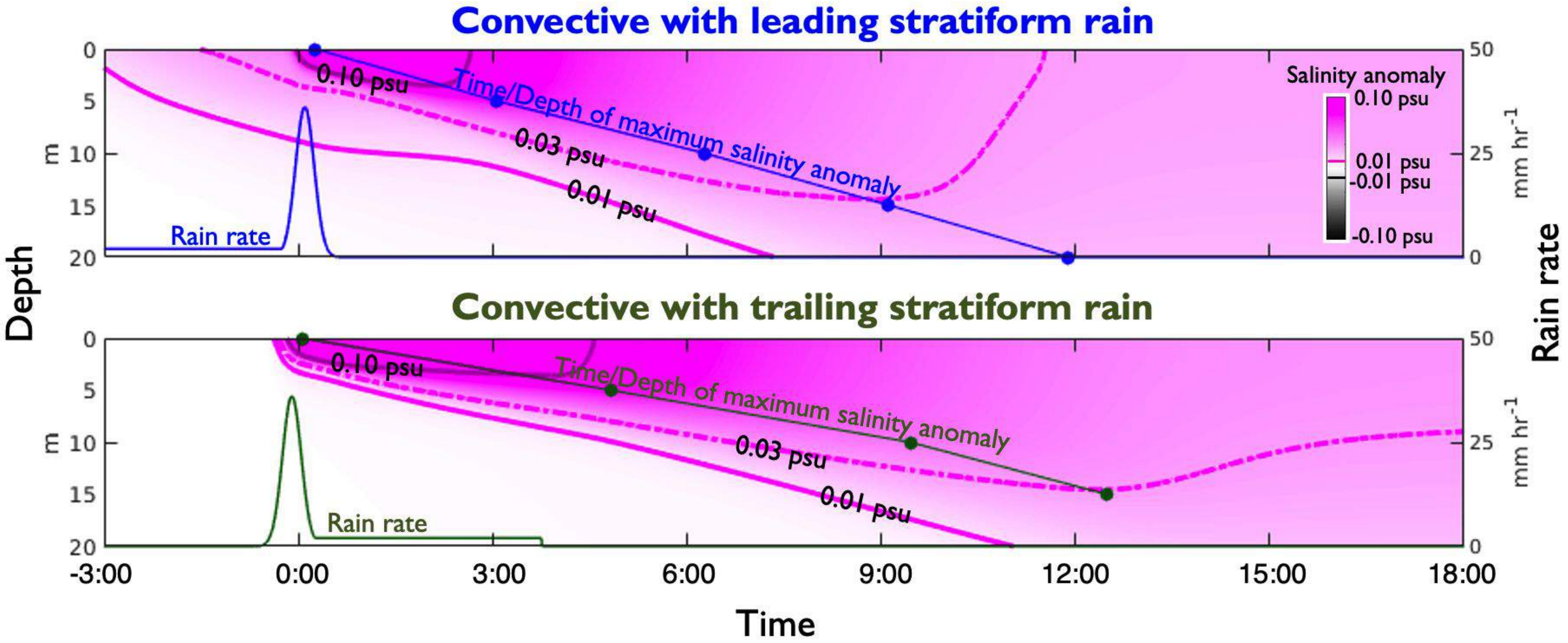
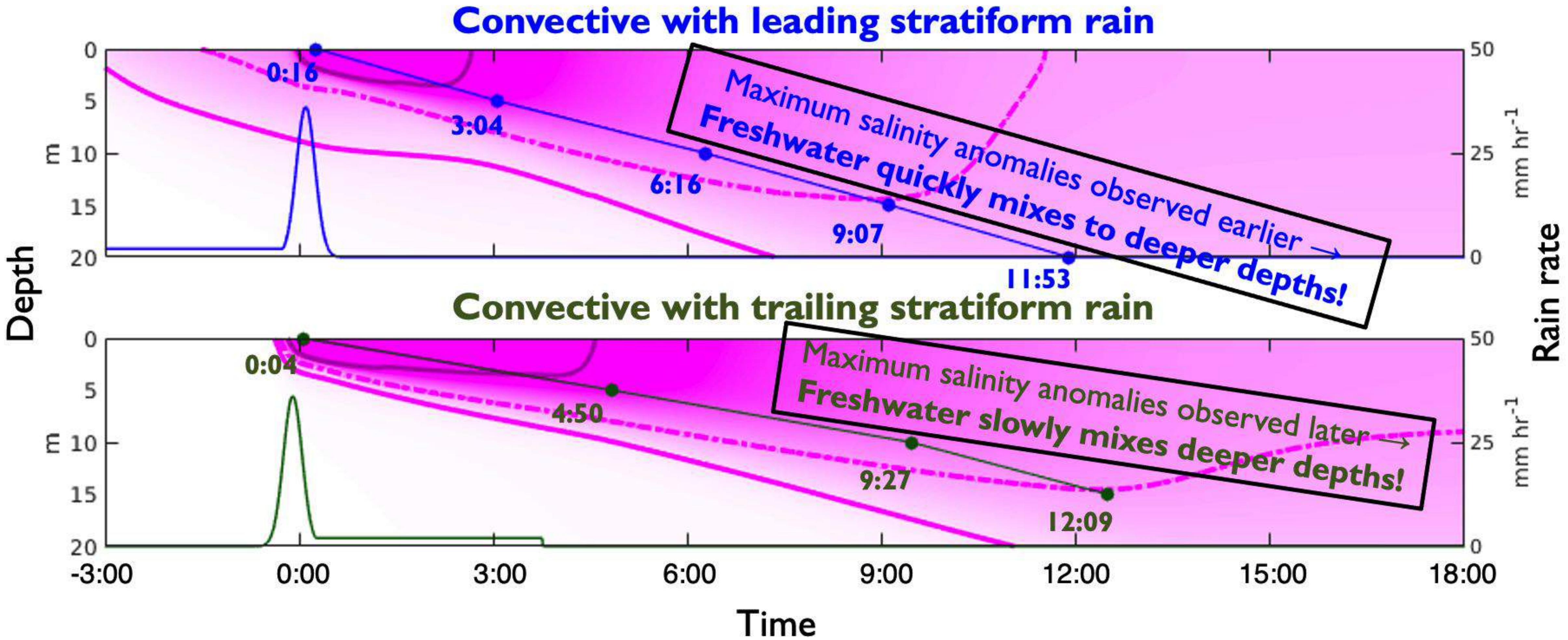


Stratiform rain falls before convective rain = freshwater quickly mixes downward

Stratiform rain trails behind convective rain = freshwater slowly mixes downward



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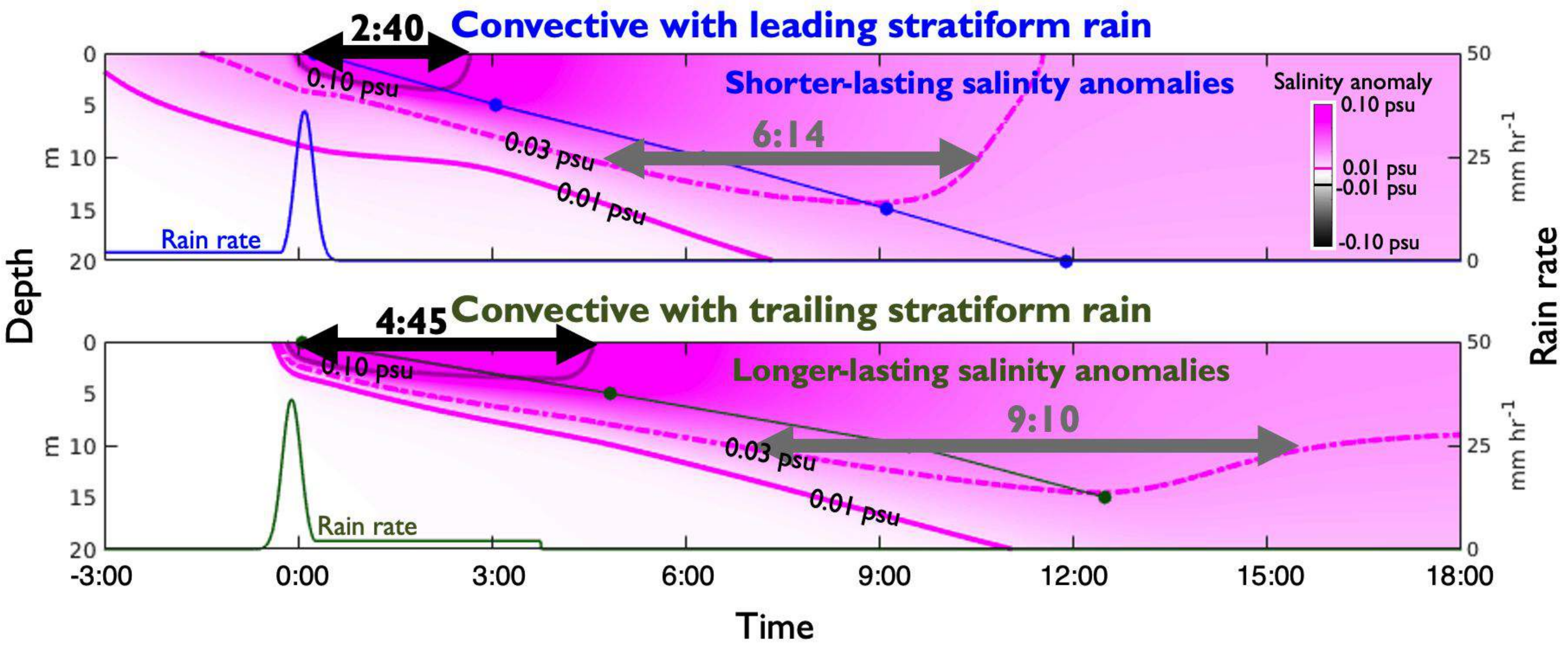
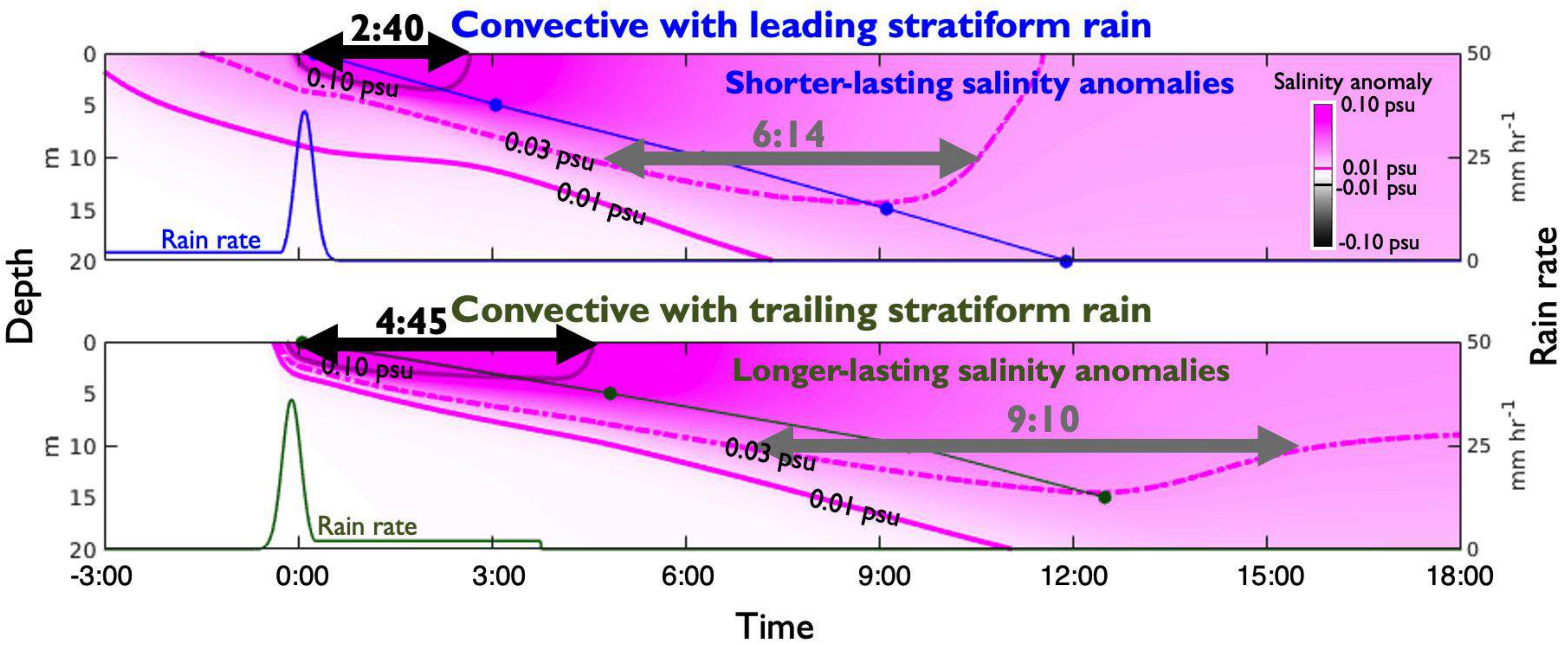
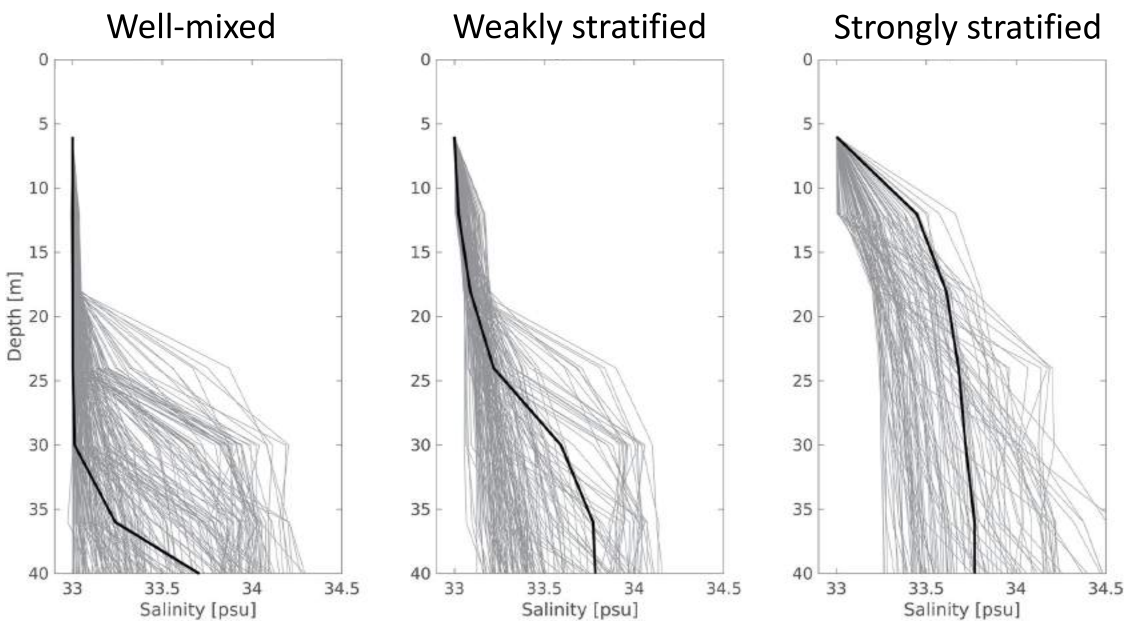


Mechanism: Intense convective rain produces strong near-surface stratification, which reduces turbulent mixing and inhibits the downward mixing of freshwater.



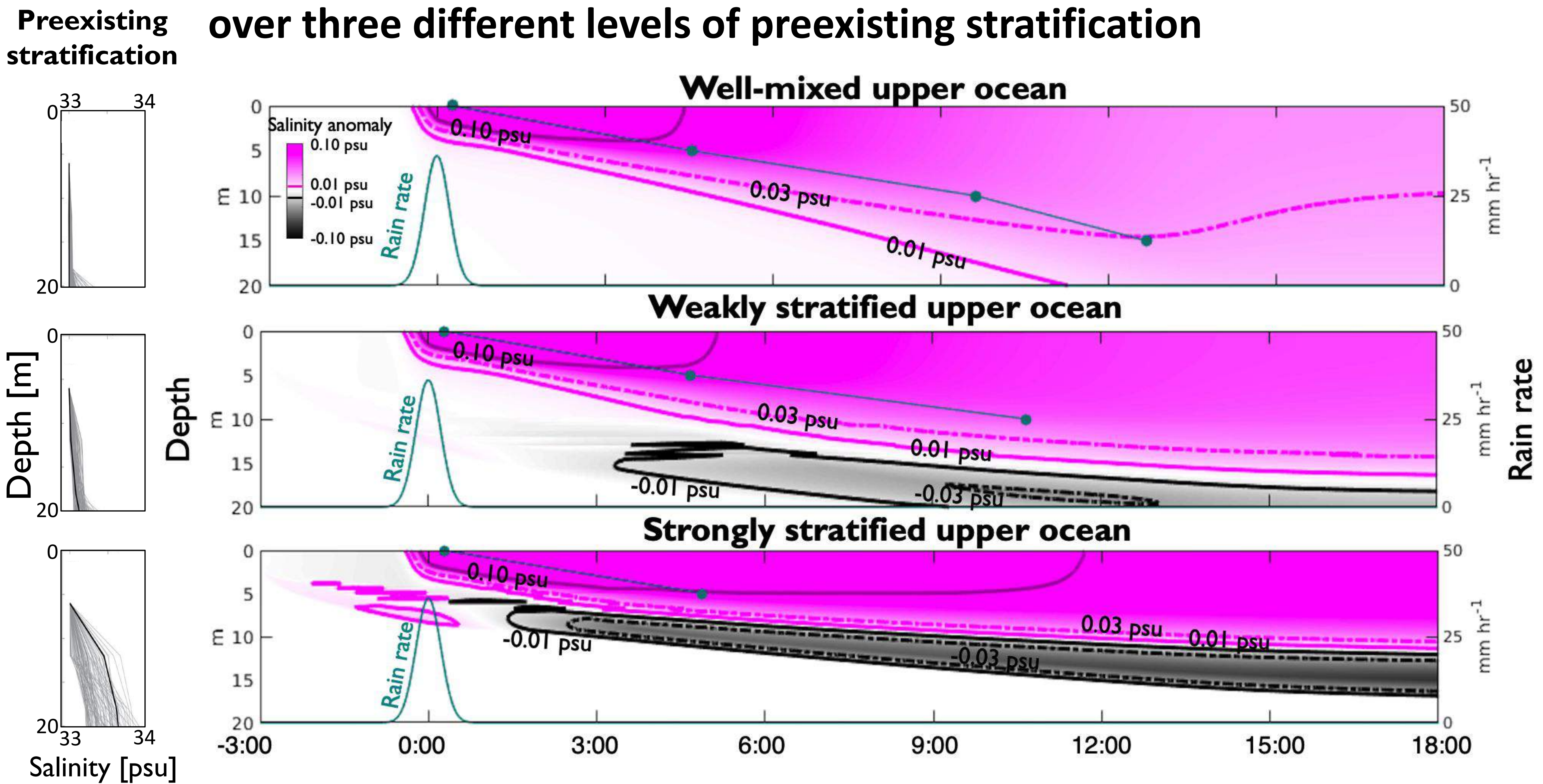
Idealized model experiments

Preexisting stratification experiments: Different preexisting stratification (well-mixed, stratified) and constant rain forcing

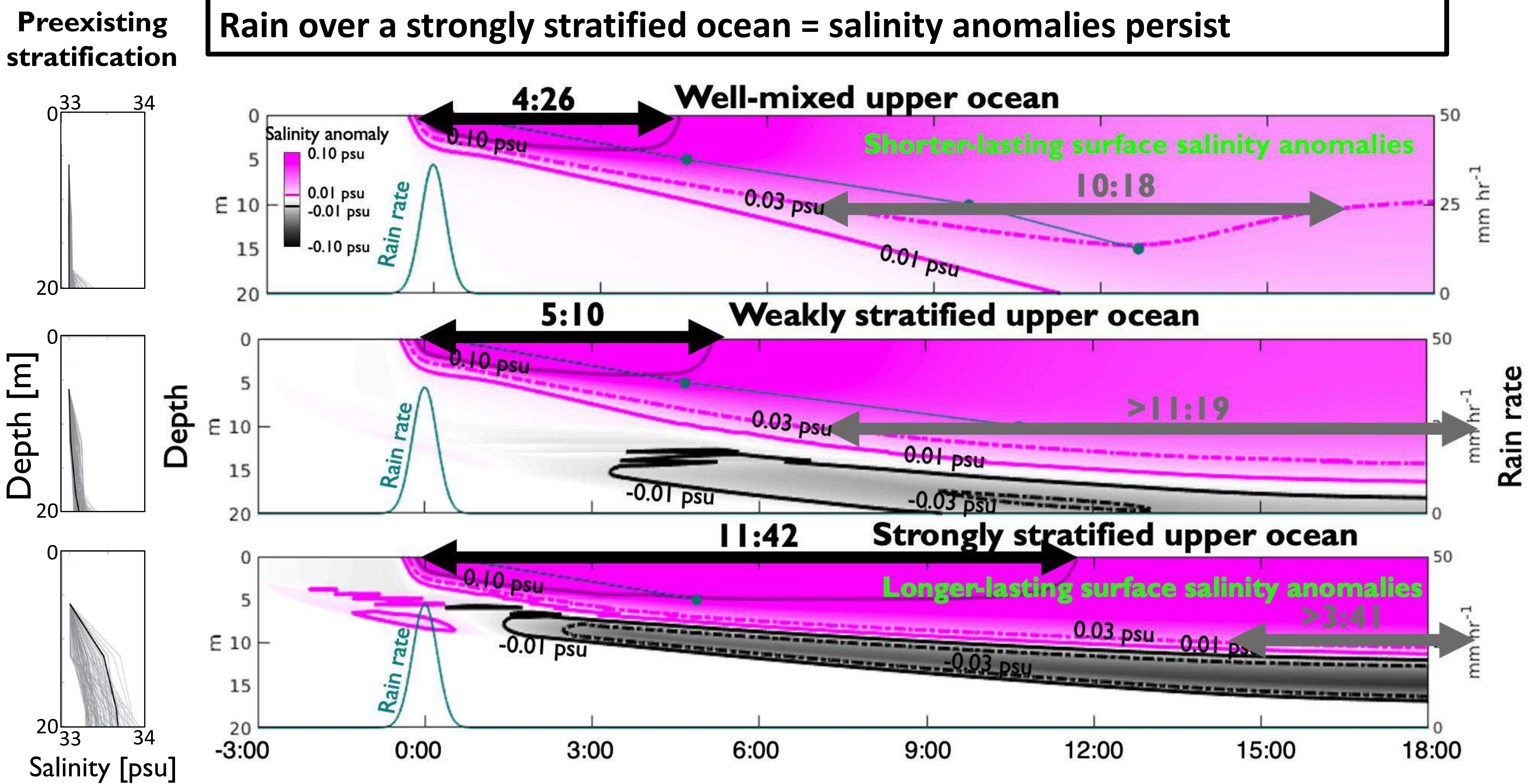


Observed profiles (uCTD)
Typical profiles prescribed into GOTM

A comparison of the salinity response to convective rainfall over three different levels of preexisting stratification



Rain over a well-mixed ocean = salinity anomalies quickly mix downward
Rain over a strongly stratified ocean = salinity anomalies persist



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Summary

- When convective rain falls before stratiform rain, mixed layer salinity anomalies persist for a long time due to strong stratification produced by the convective rain
- ***Implication:*** Most satellite rain observations do not represent the dominant modes of rain creating salinity anomalies in the ITCZ.

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Summary

- When convective rain falls before stratiform rain, mixed layer salinity anomalies persist for a long time due to strong stratification produced by the convective rain
- ***Implication:*** Most satellite rain observations do not represent the dominant modes of rain creating salinity anomalies in the ITCZ.

- Preexisting stratification slows downward mixing and greatly lengthens the time it takes for freshwater to propagate downward in the mixed layer. This effect is more pronounced than the differences between the responses of rain modes.
- ***Implication:*** Well-mixed conditions should not be assumed when predicting salinity from rainfall

*See our paper for more details: Iyer and Drushka (2021), JGR Oceans, doi: 10.1029/2021JC017574