



Modeling diurnal sea surface warming in the tropical ocean

An interactive boundary condition for
idealized atmospheric simulations

Master Defense of Reyk Börner
September 7, 2021

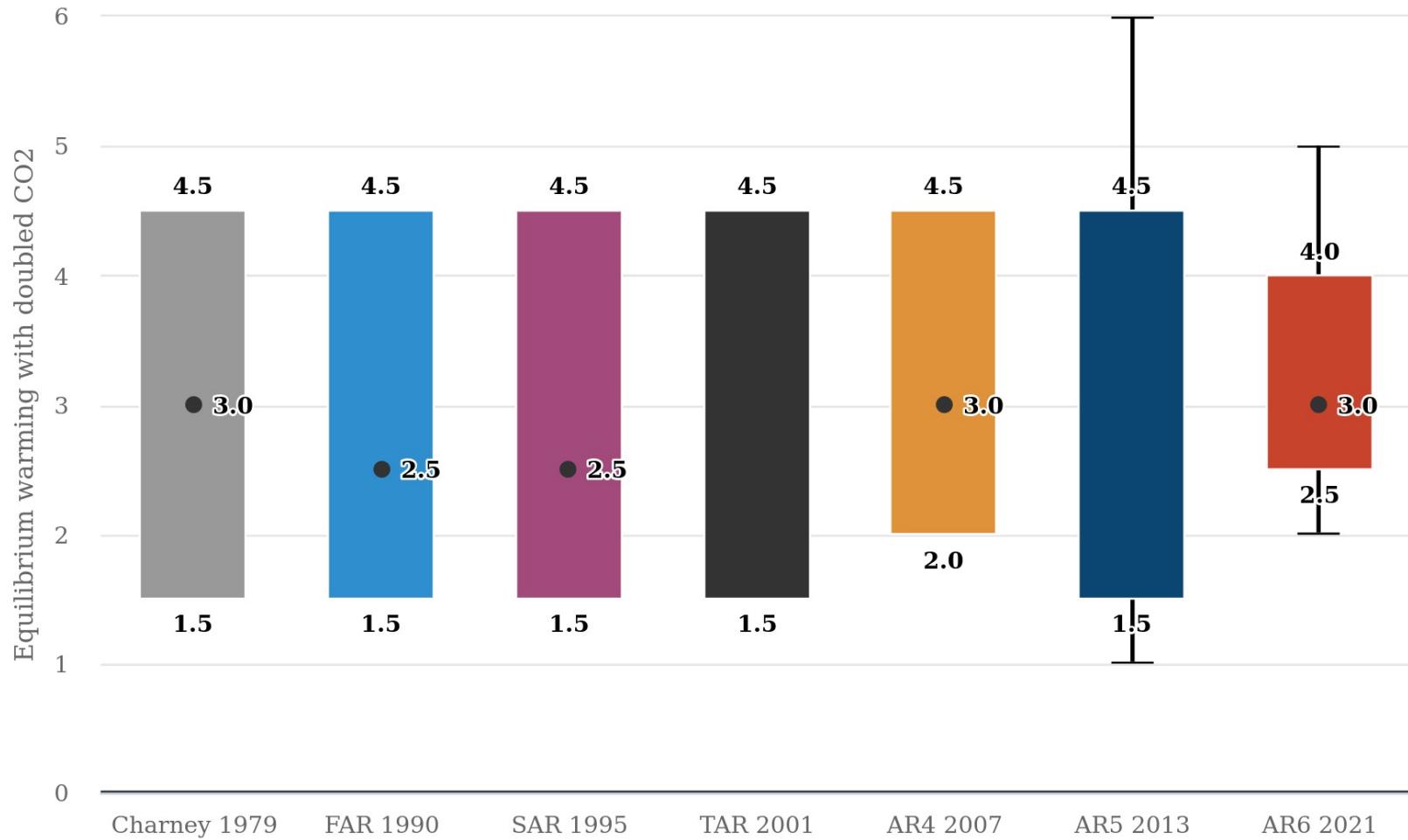
Supervisors:

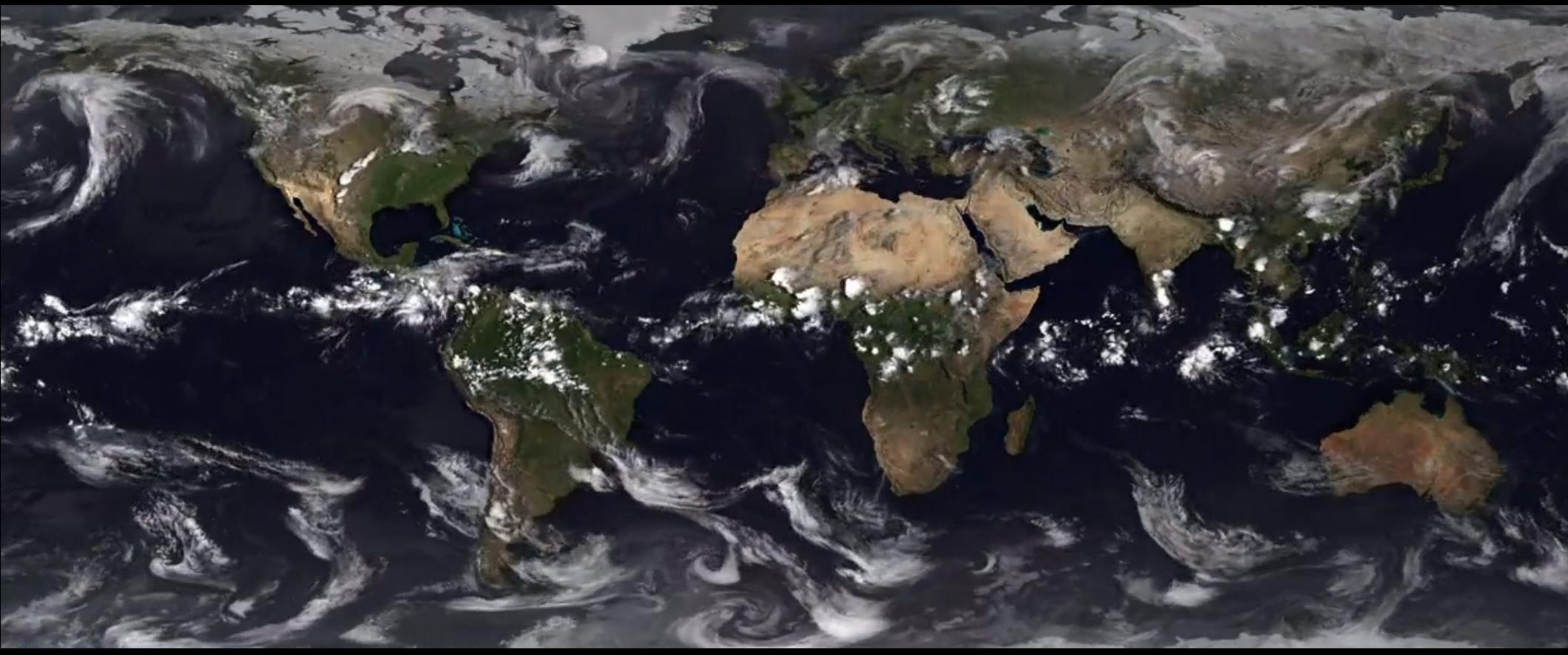
Jan O. Haerter (NBI, Jacobs Univ. Bremen, ZMT)
Romain Fiévet (NBI)
Peter Ditlevsen (NBI)

Censor:

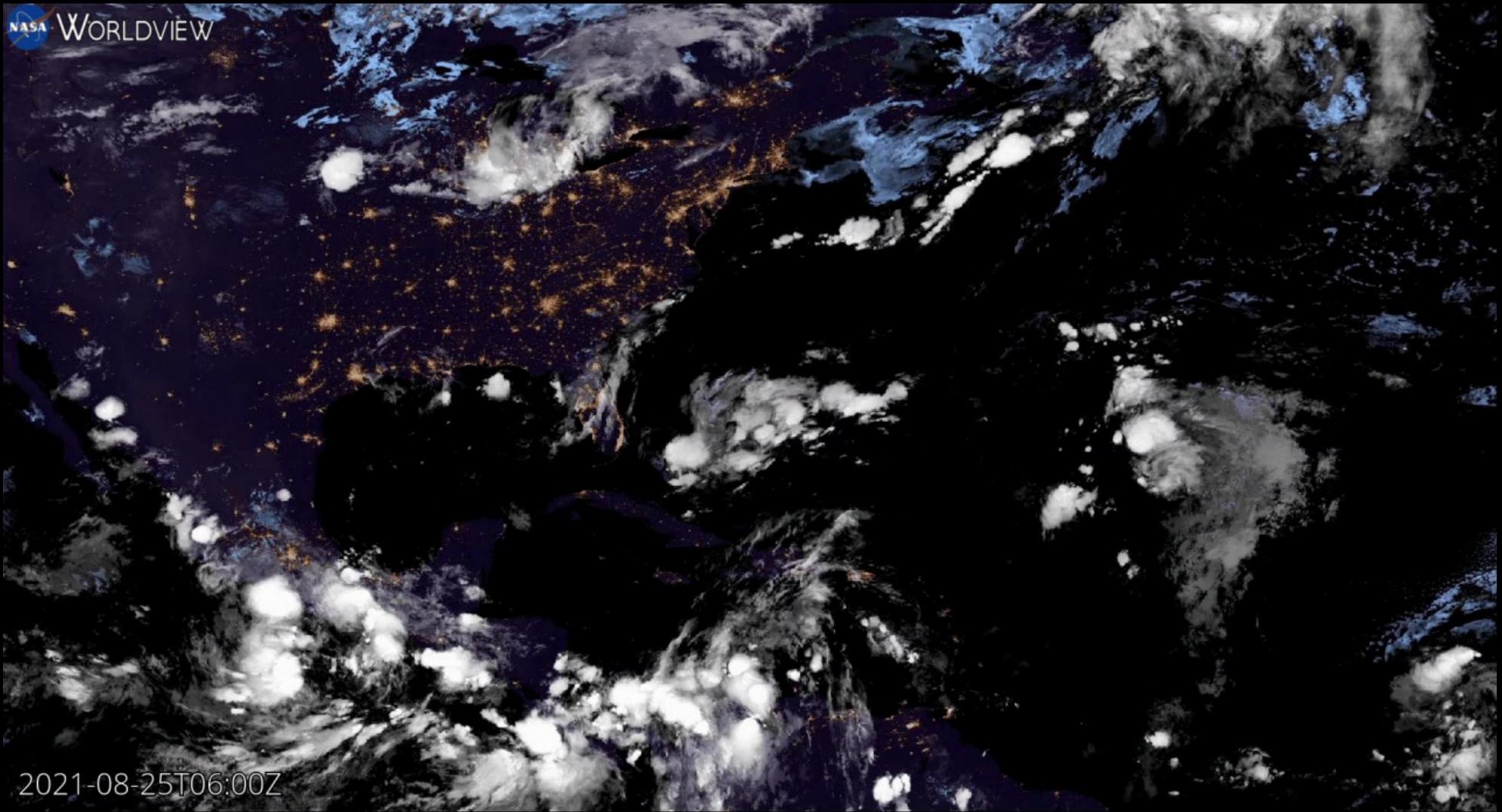
Søren Larsen (DTU)

Equilibrium climate sensitivity



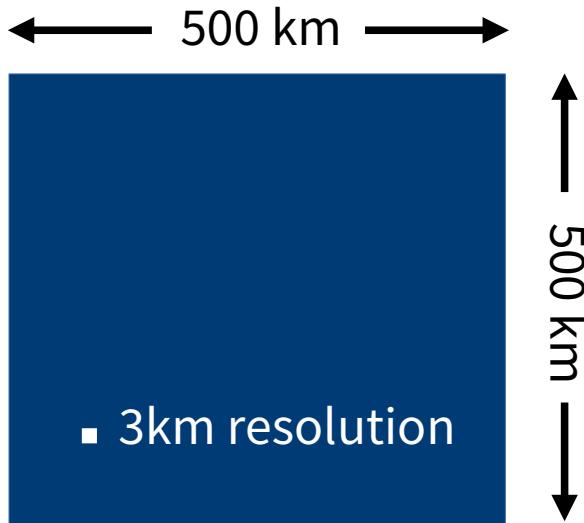


Source: A Year of Weather 2019 (YouTube)



2021-08-25T06:00Z

Idealized Large Eddy Simulations



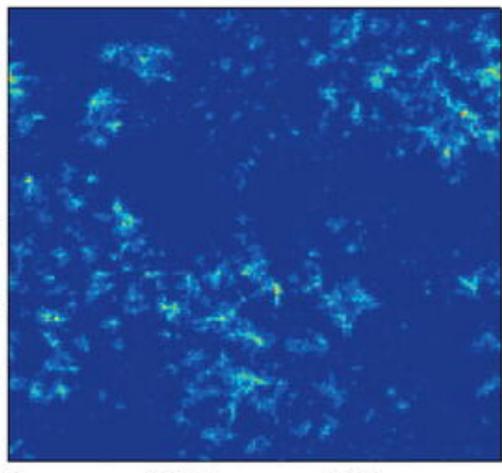
Radiative convective equilibrium (RCE)

- constant, uniform sea surface temperature (SST)
- constant forcing

Idealized Large Eddy Simulations

Day 10

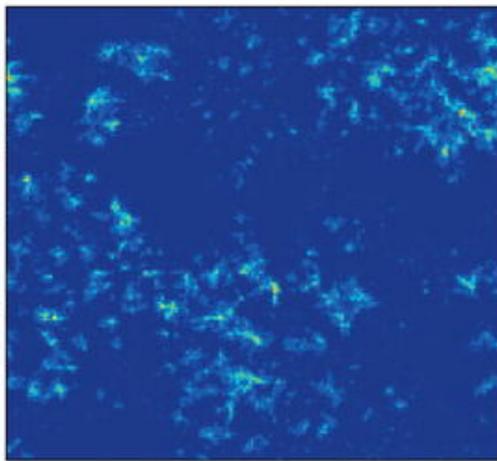
$P \text{ [mm d}^{-1}\text{]}$



Idealized Large Eddy Simulations

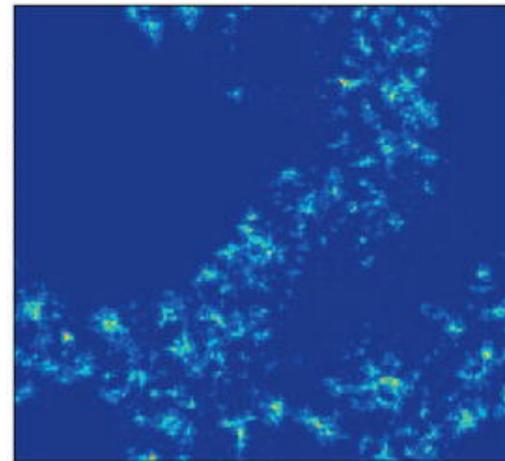
Day 10

$P \text{ [mm d}^{-1}\text{]}$

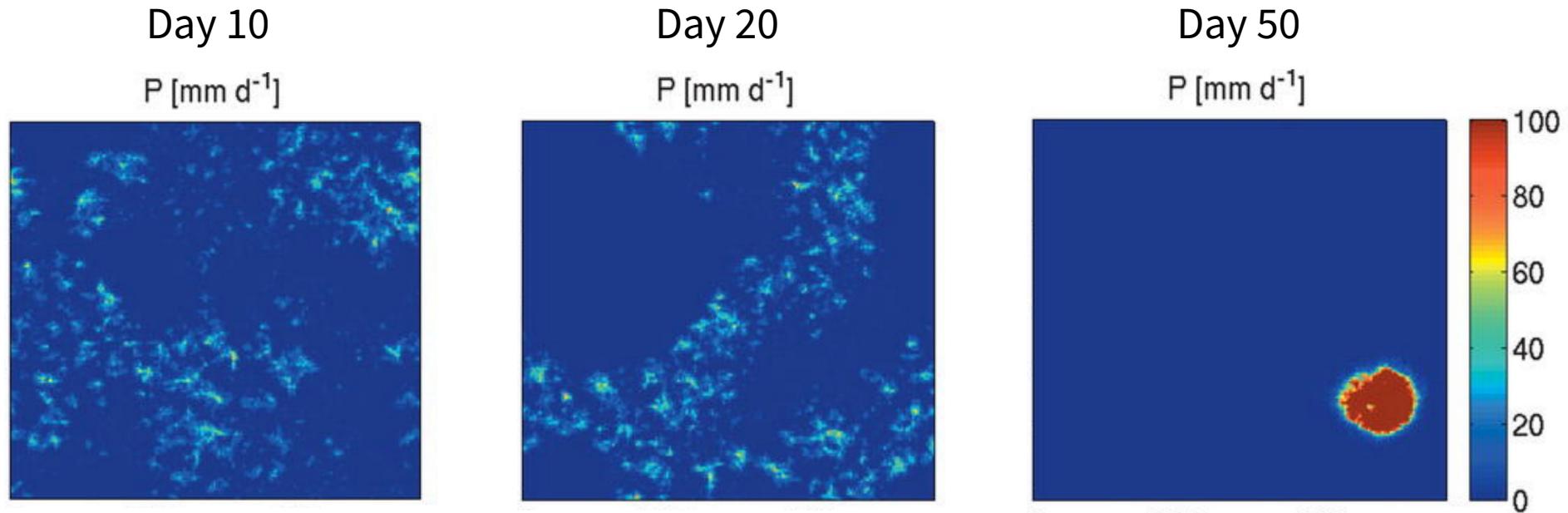


Day 20

$P \text{ [mm d}^{-1}\text{]}$

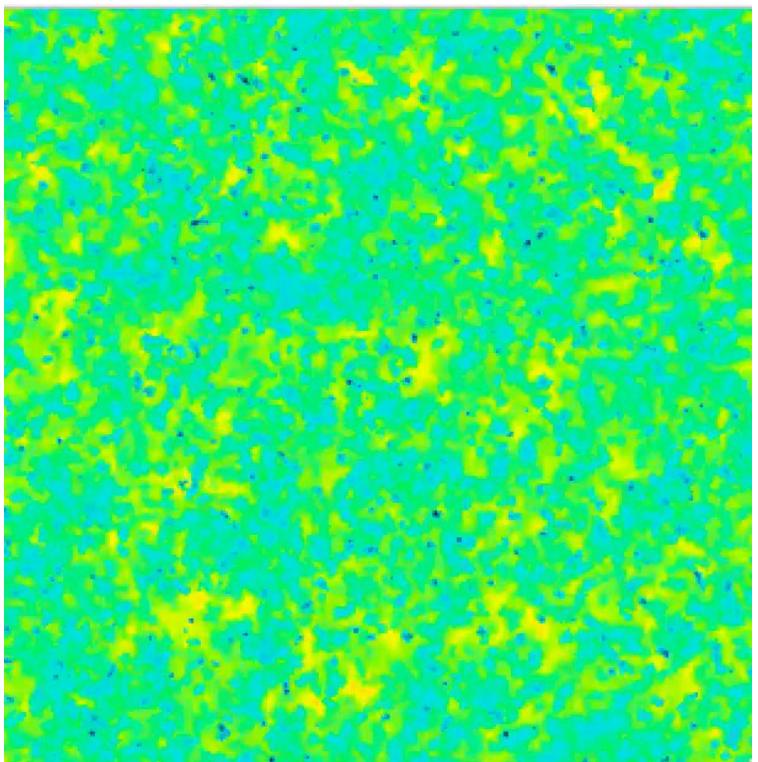


Idealized Large Eddy Simulations



► Convective self-aggregation

Constant SST

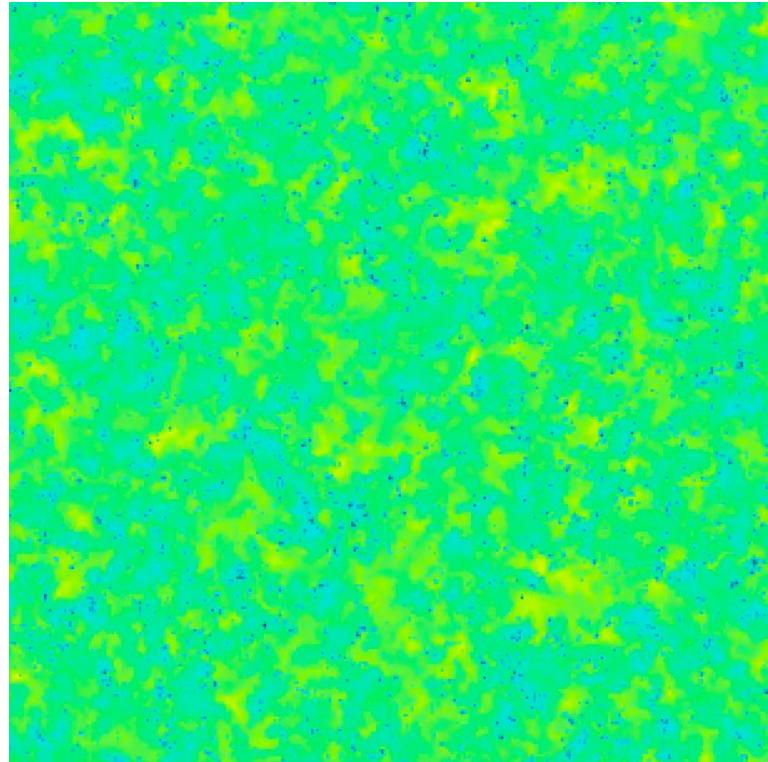


500m resolution

Moisture

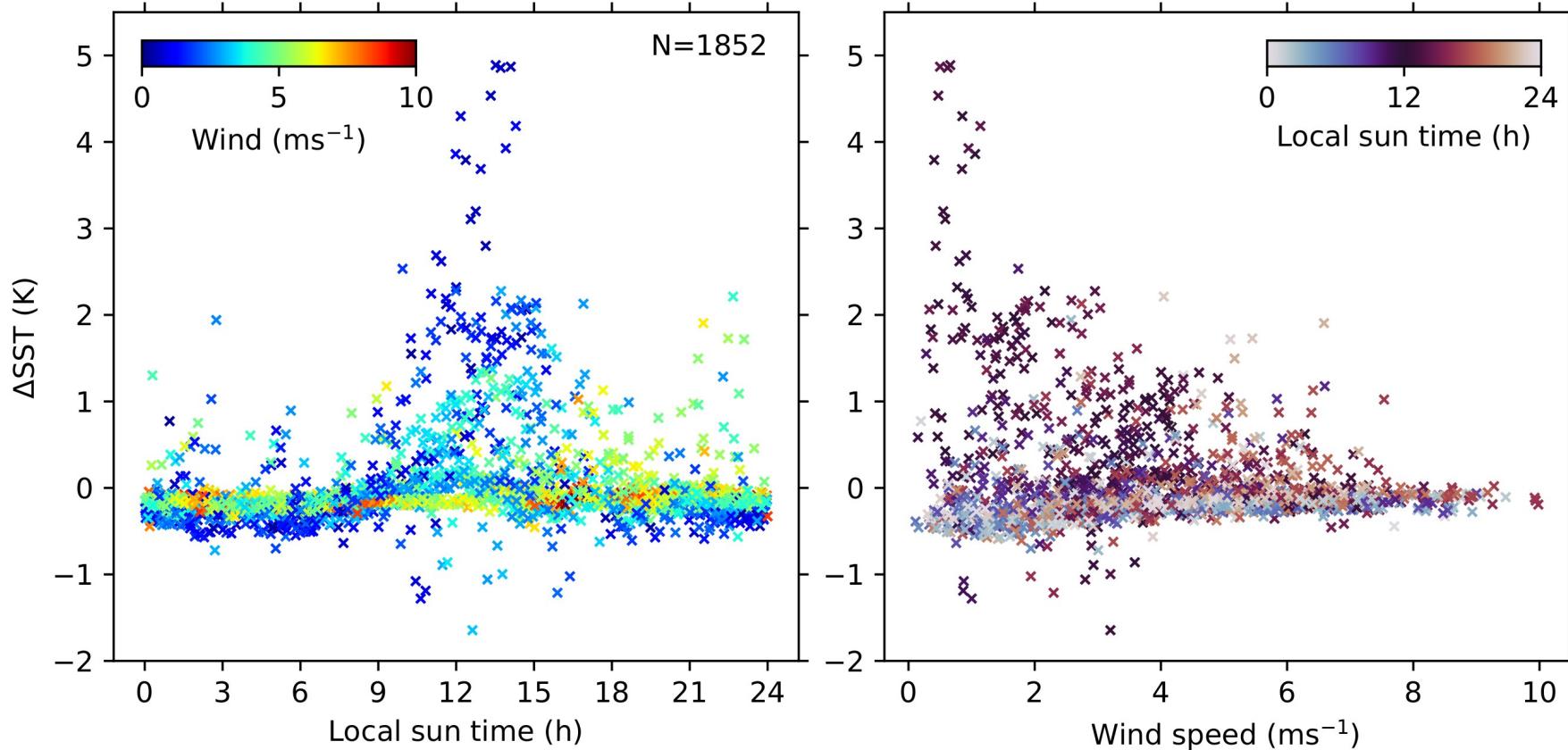


Diurnal SST

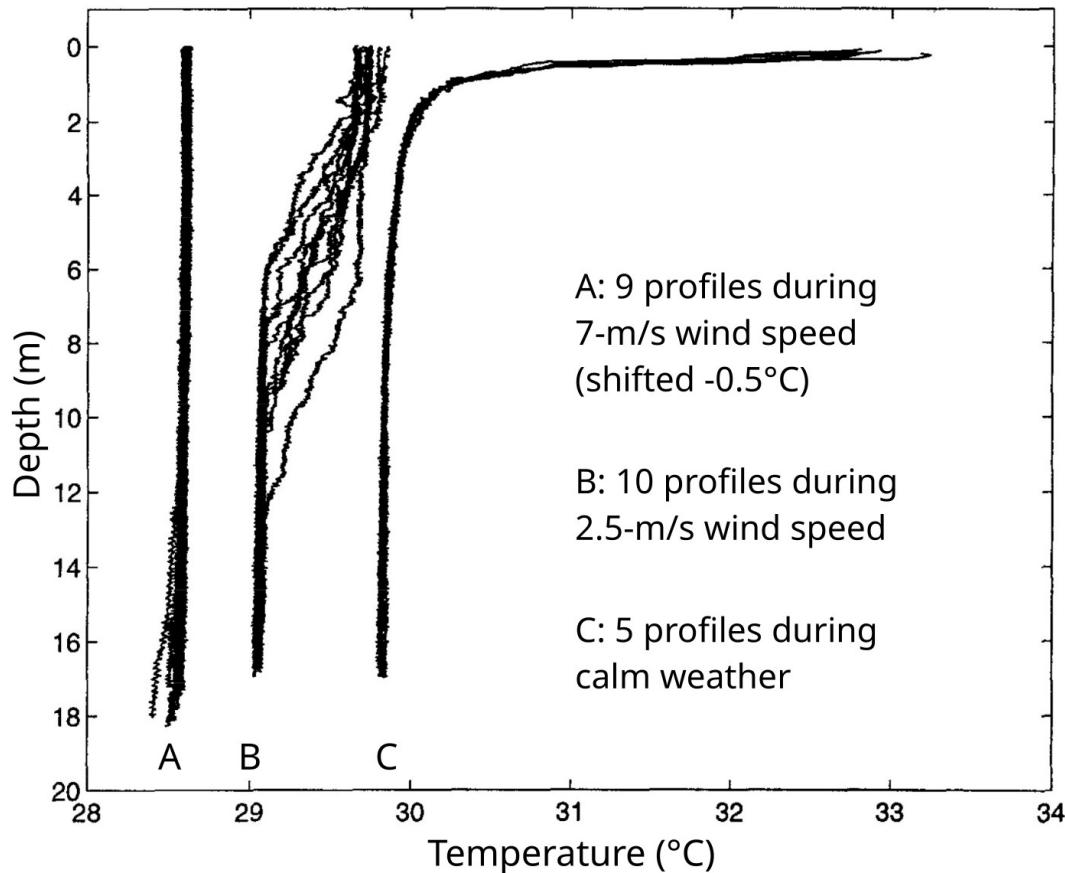


Diurnal warming at the sea skin

MOCE-5 cruise, Pacific Ocean and Gulf of California

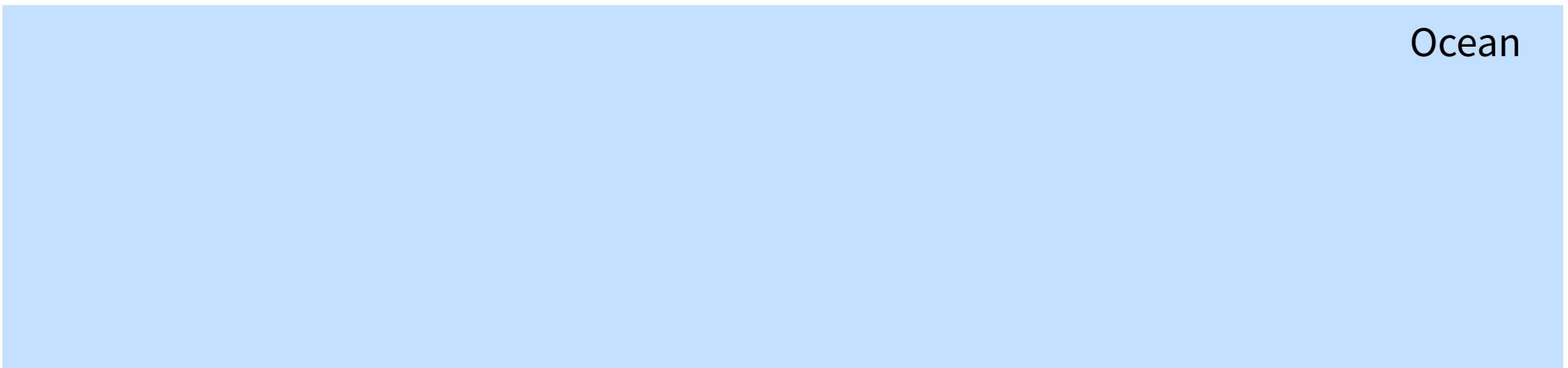


Vertical profiles of warming



► Low winds:
Heat trapping near the surface

Modeling diurnal SST warming



Modeling diurnal SST warming

Surface heat fluxes

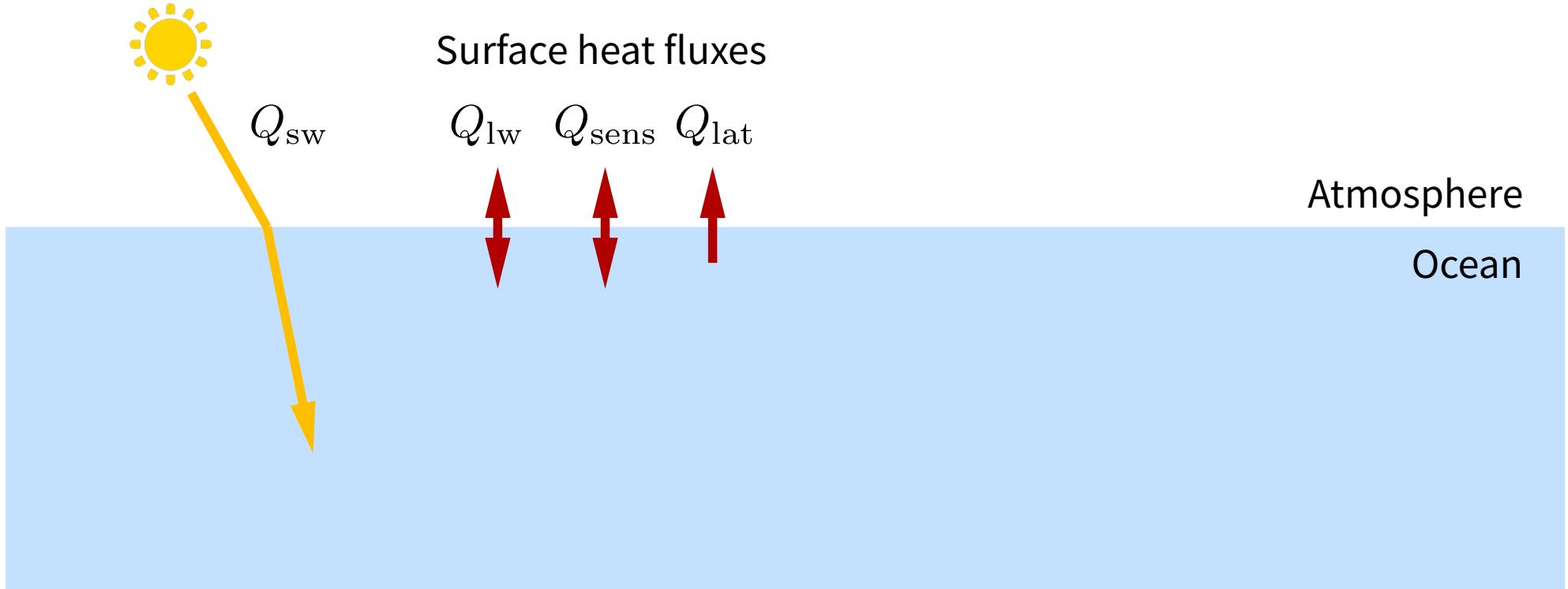
$$Q_{\text{lw}} \quad Q_{\text{sens}} \quad Q_{\text{lat}}$$



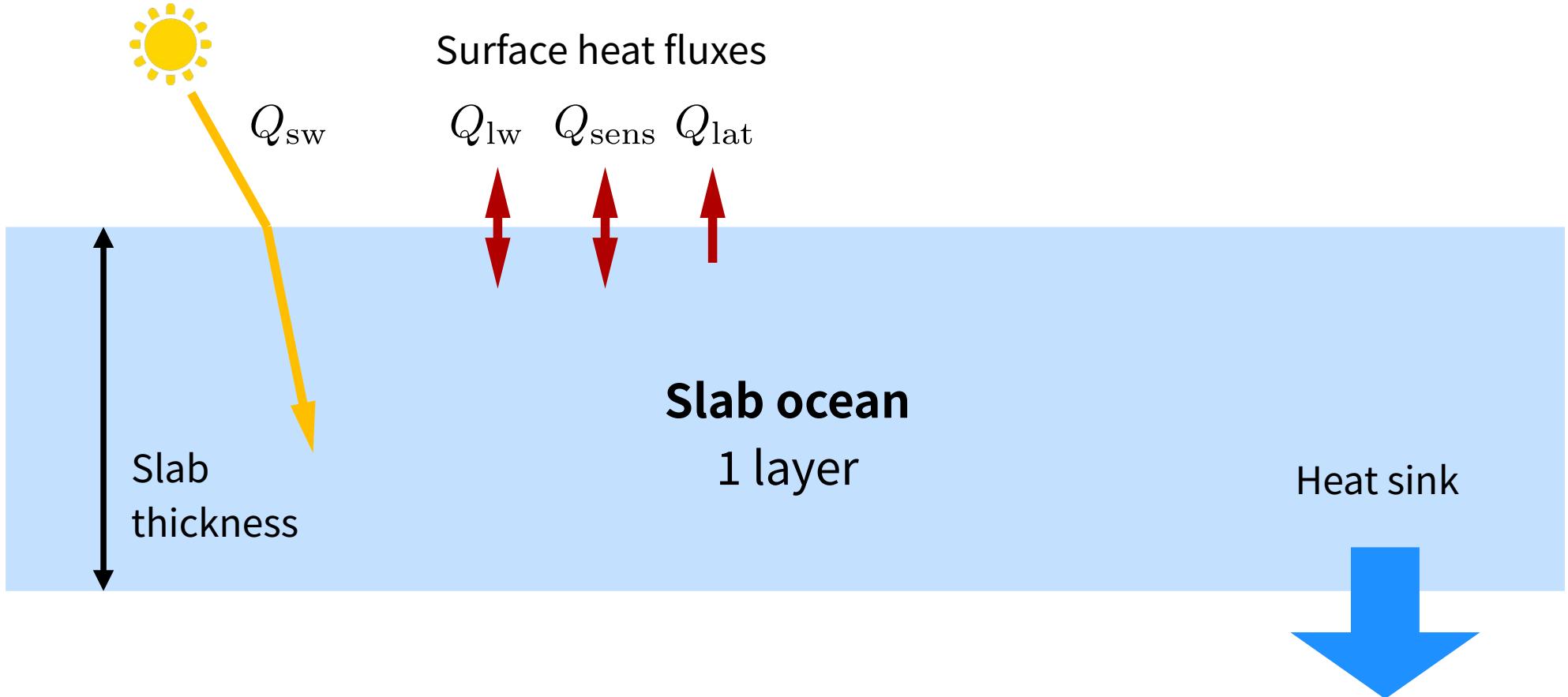
Atmosphere

Ocean

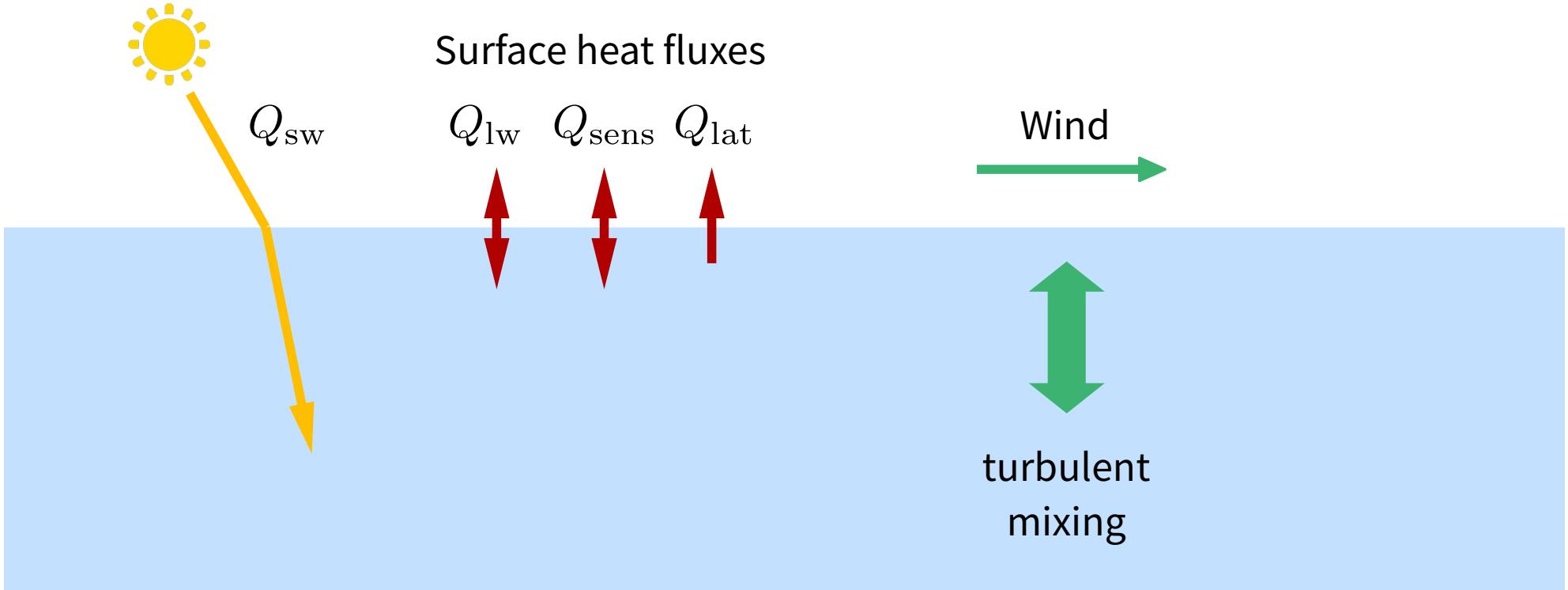
Modeling diurnal SST warming



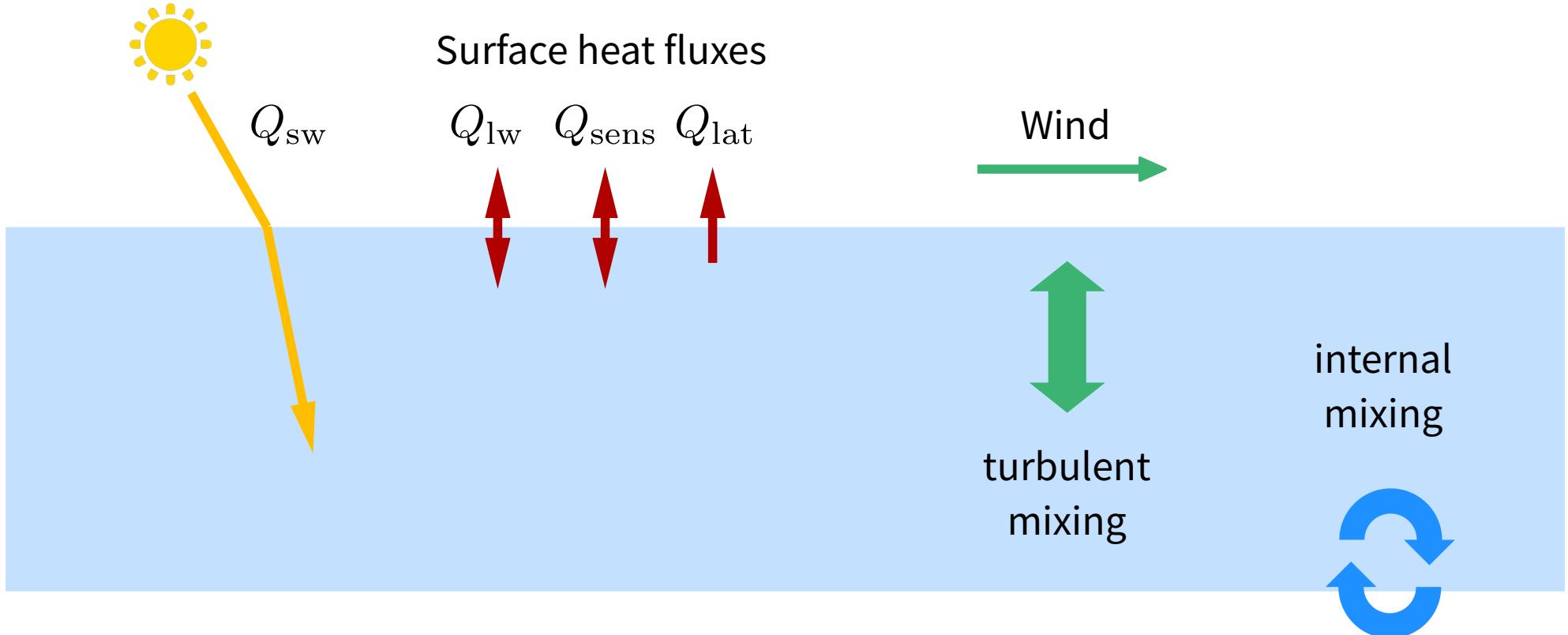
Modeling diurnal SST warming



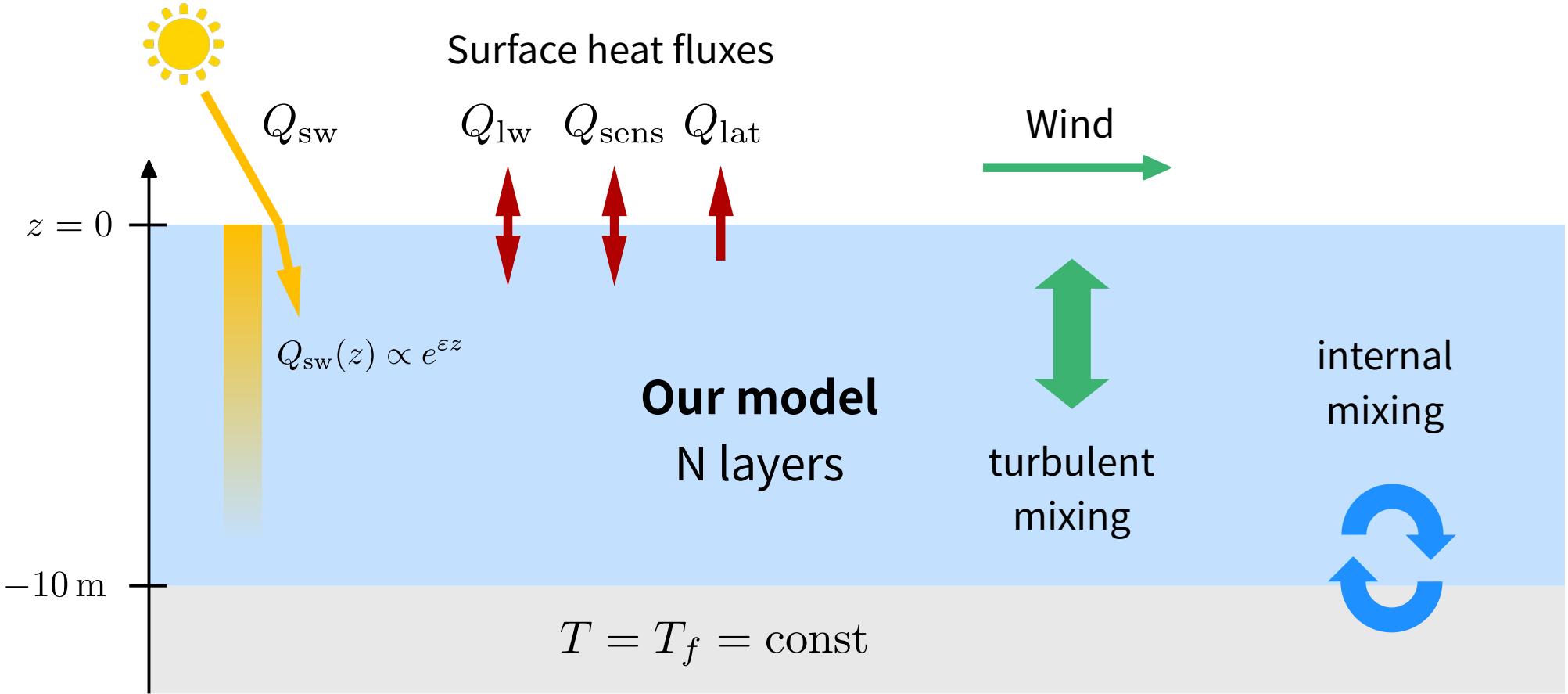
Modeling diurnal SST warming



Modeling diurnal SST warming



Modeling diurnal SST warming



Our model

$$\frac{\partial T}{\partial t} = \underbrace{\kappa(t) \frac{\partial^2 T}{\partial z^2}}_{\text{diffusion}}$$

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diffusion

$$\kappa(t) := \kappa_{\text{mol}} + \tilde{\kappa} \frac{u(t)^2}{u_0^2}$$

Our model

$$\frac{\partial T}{\partial t} = \underbrace{\kappa(t) \frac{\partial^2 T}{\partial z^2}}_{\text{diffusion}} - \underbrace{\mu \frac{T - T_f}{|z - z_f|}}_{\text{mixing}}$$

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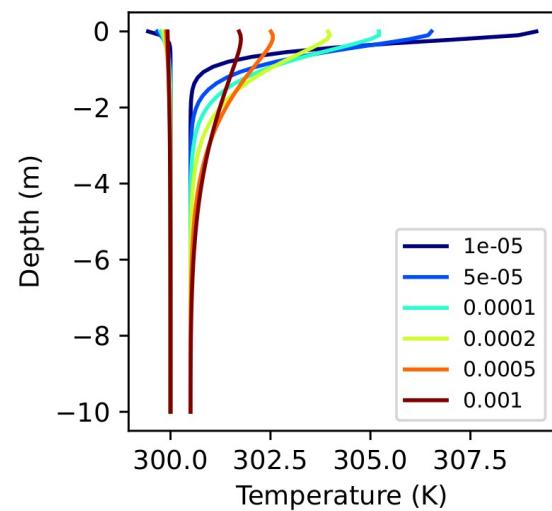
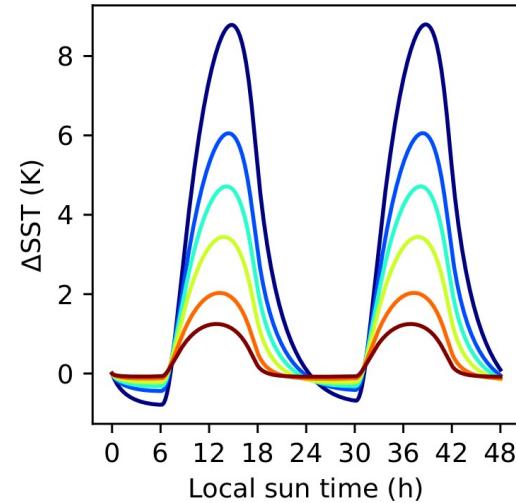
Our model

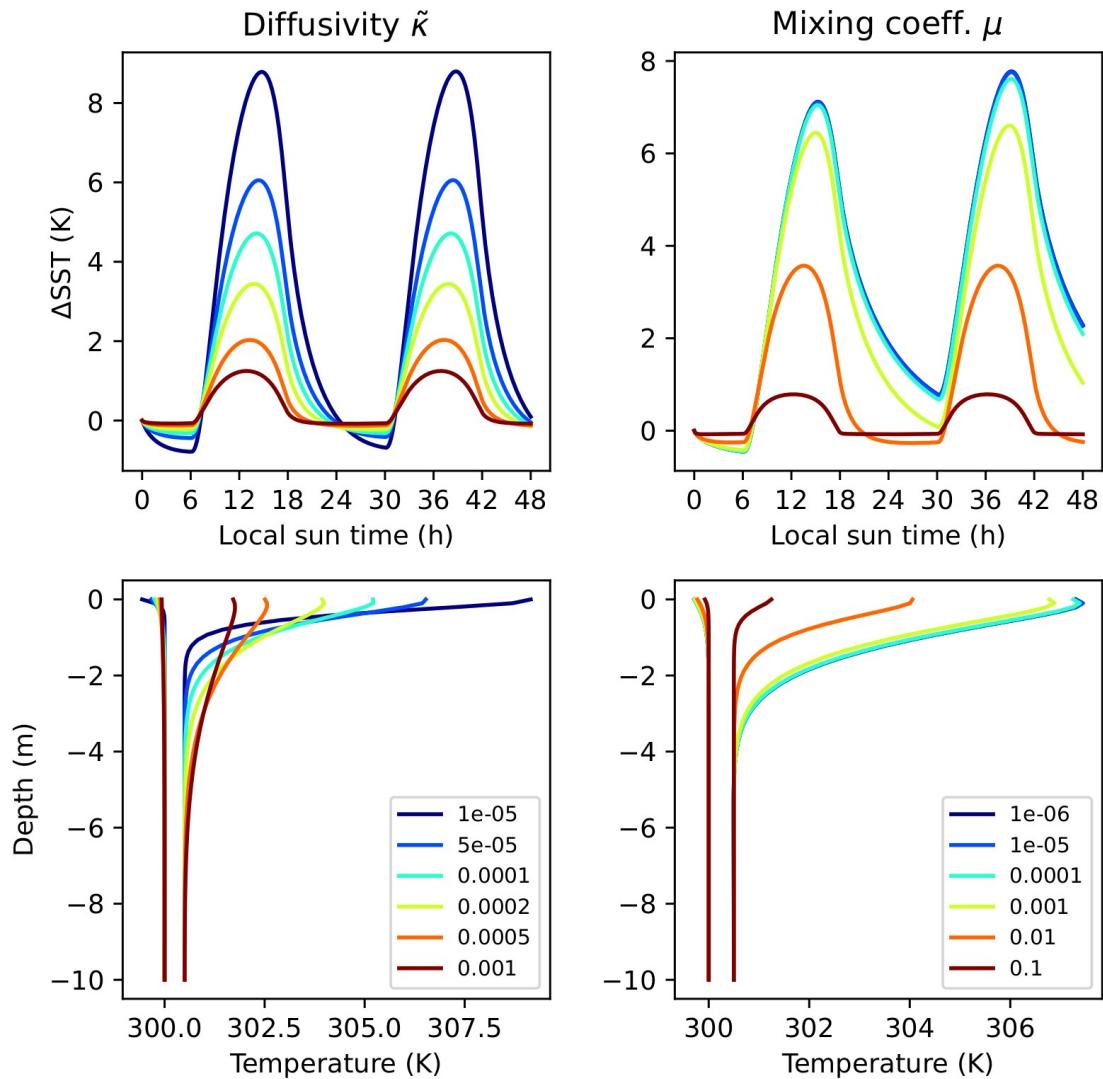
$$\frac{\partial T}{\partial t} = \underbrace{\kappa(t) \frac{\partial^2 T}{\partial z^2}}_{\text{diffusion}} - \underbrace{\mu \frac{T - T_f}{|z - z_f|}}_{\text{mixing}} + \underbrace{\frac{1}{\rho_w c_p} \frac{\partial Q(z, t)}{\partial z}}_{\text{source}}$$

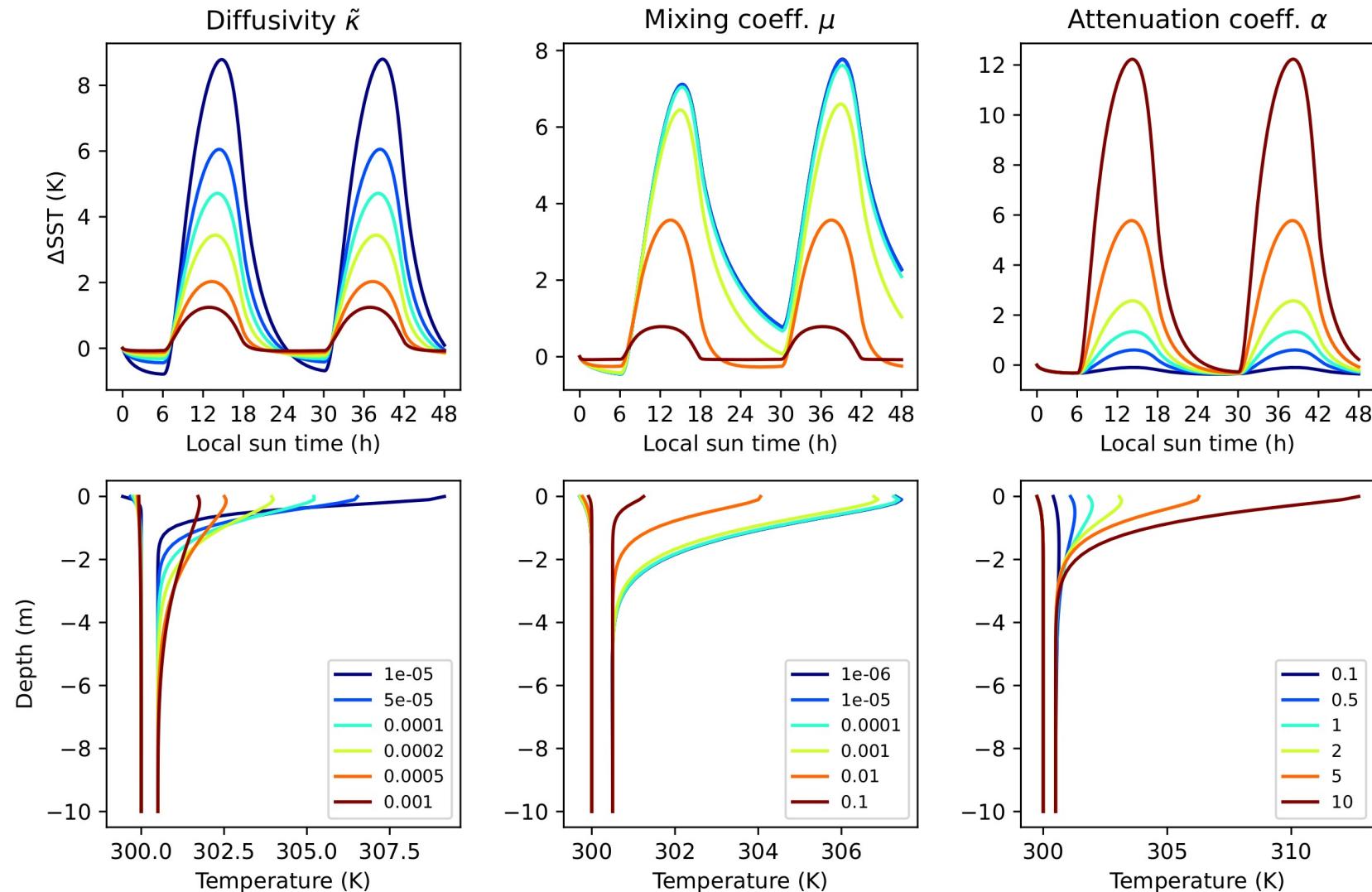
3 key parameters:

- eddy diffusivity $\tilde{\kappa}$
- mixing coefficient μ
- attenuation coefficient α

Diffusivity $\tilde{\kappa}$

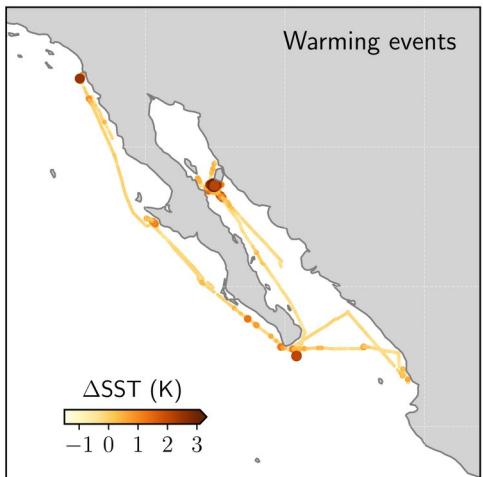
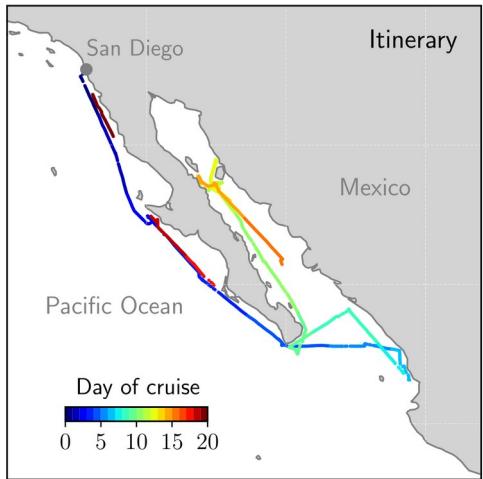


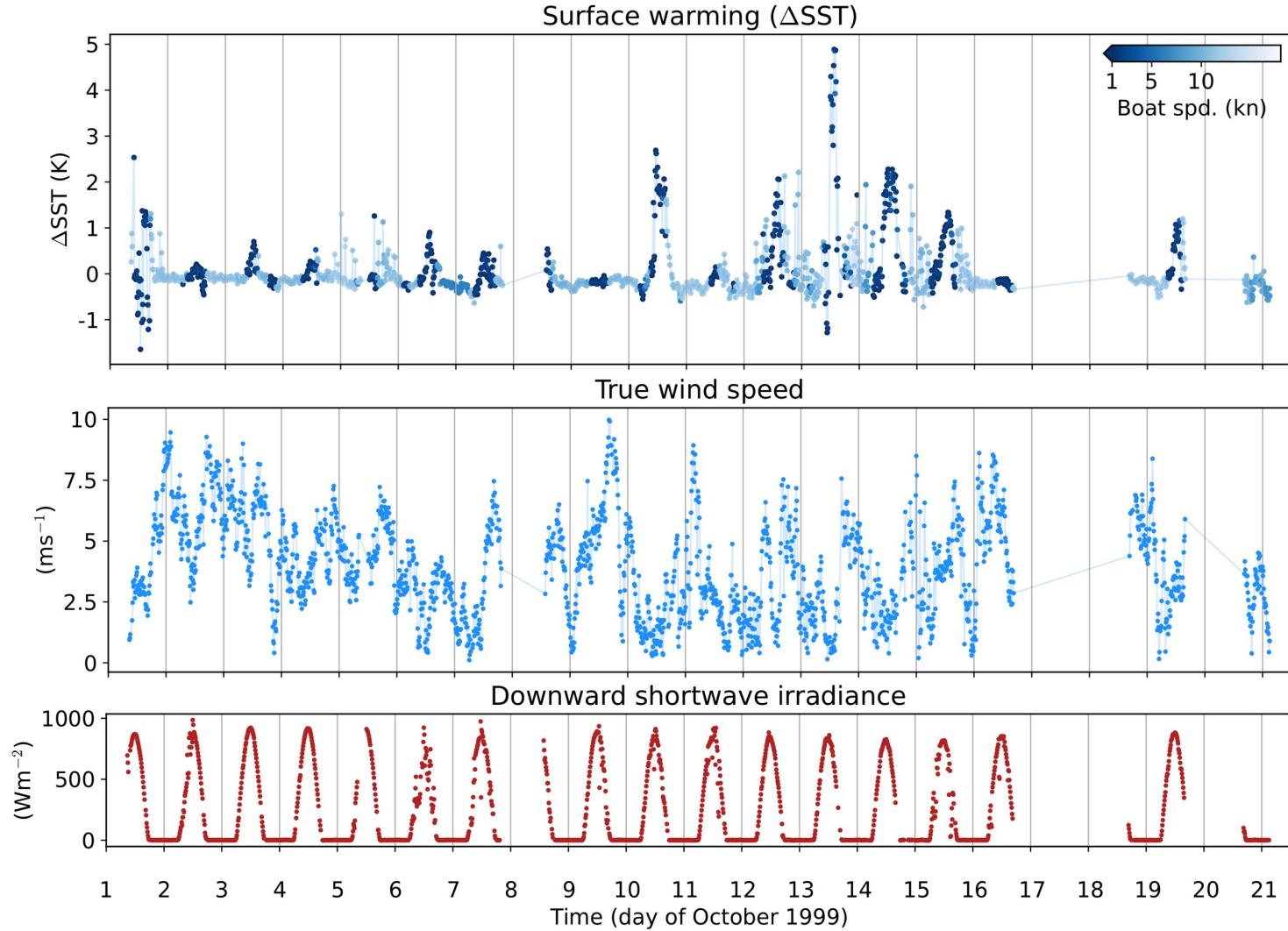
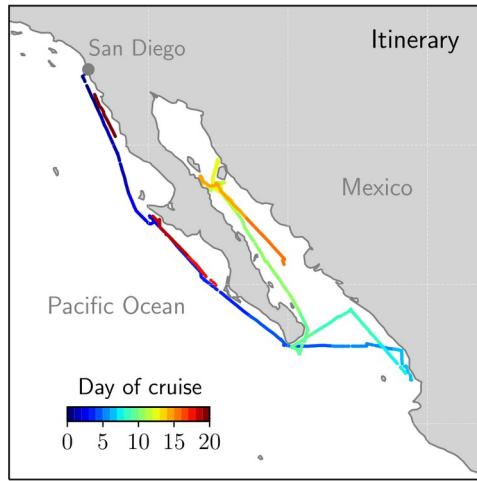


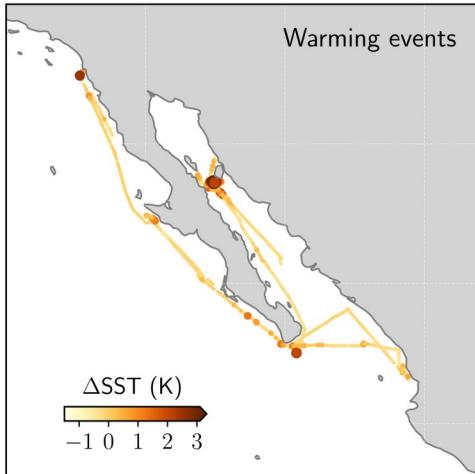
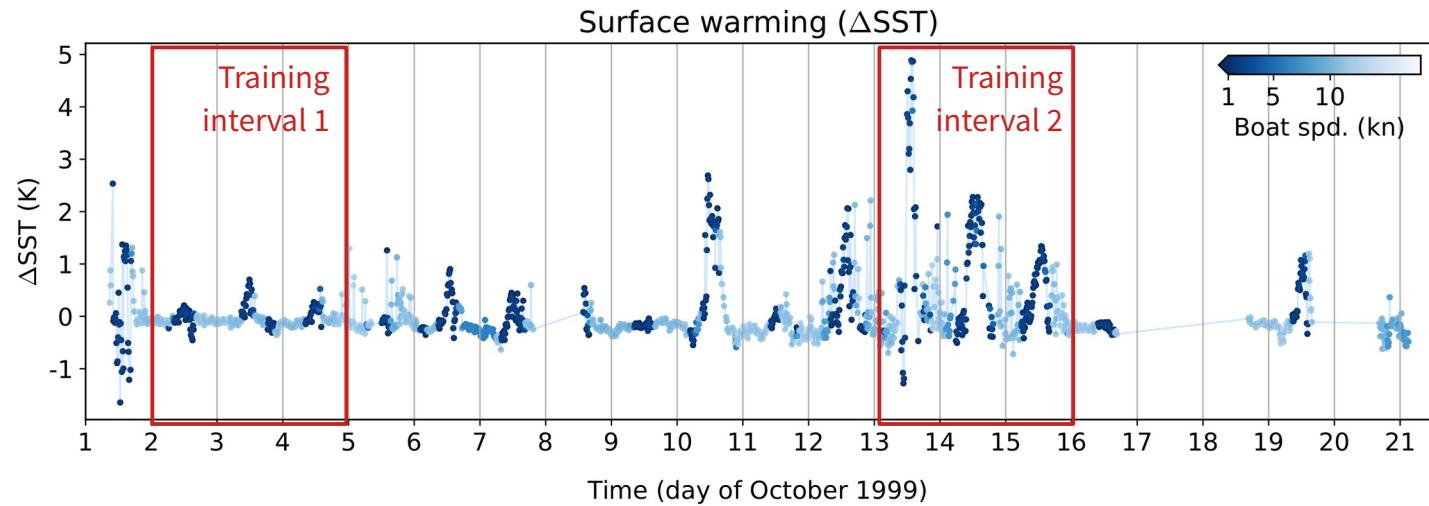
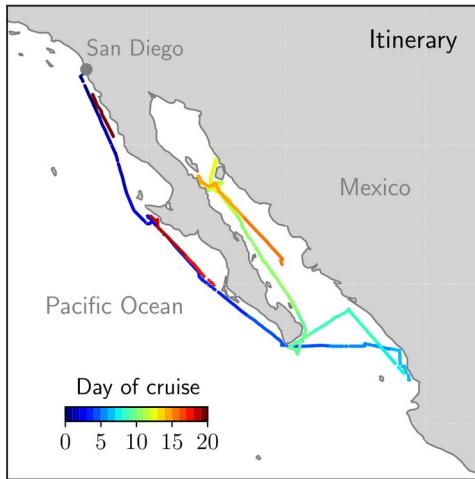


Real weather data: MOCE-5 cruise

October 1999







Model input

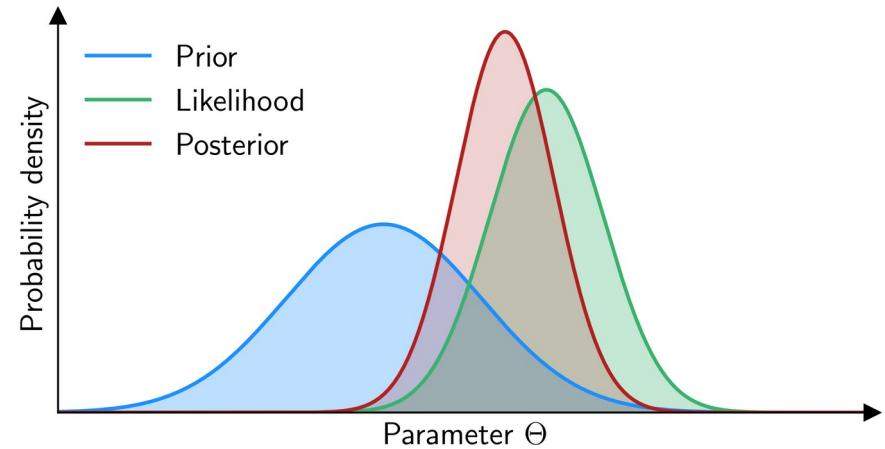
- Wind speed
- Solar radiation
- Air temperature

Bayesian inference

Posterior Likelihood Prior

$$P(\Theta|\mathcal{D}) \propto P(\mathcal{D}|\Theta) \cdot P(\Theta)$$

Data Parameters

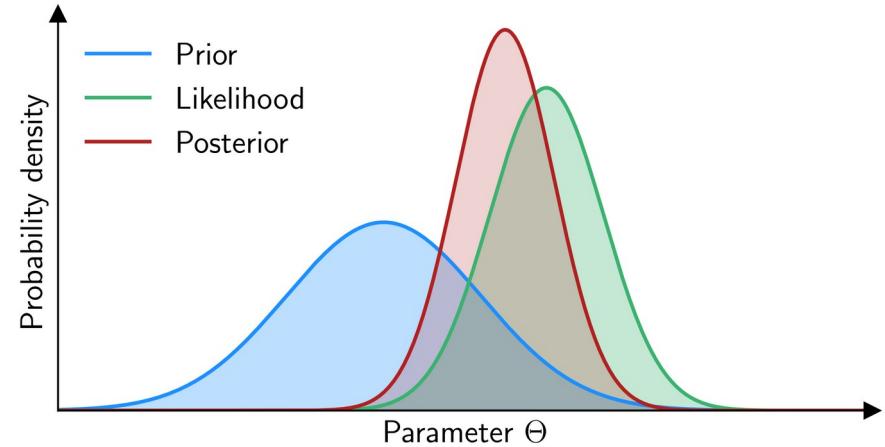


Bayesian inference

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$$P(\Theta|\mathcal{D}) \propto P(\mathcal{D}|\Theta) \cdot P(\Theta)$$

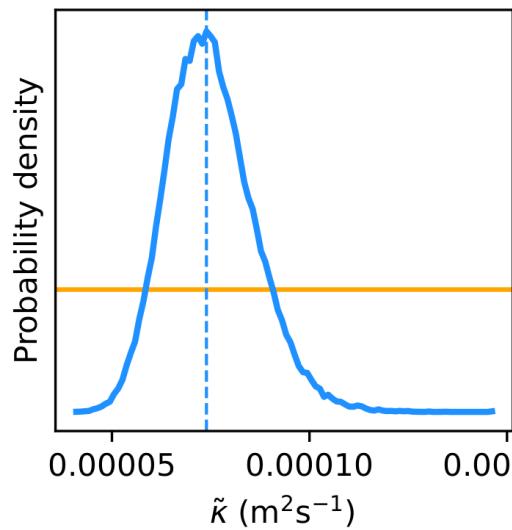
Data Parameters



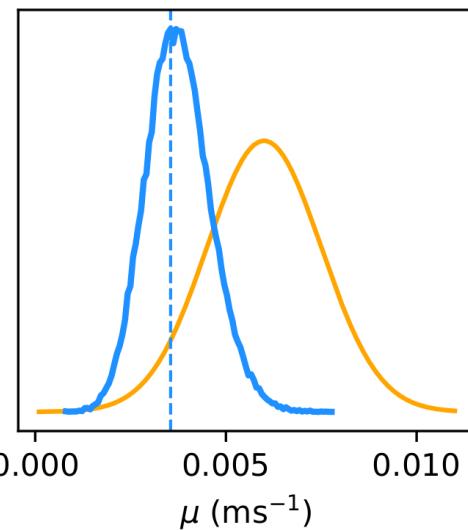
1. **Specify prior**
2. **Define likelihood:** Least-square error between data and model
3. **Compute posterior:** MCMC sampling

Prior and posterior distributions

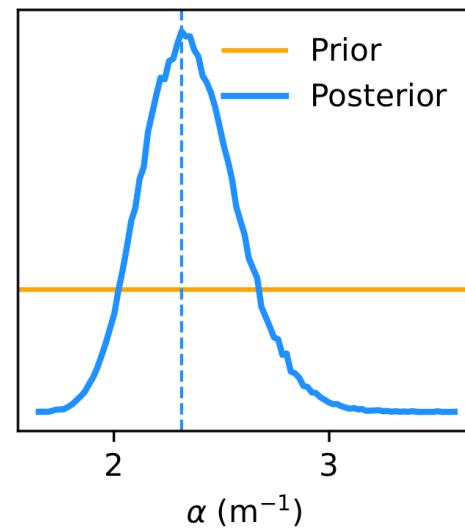
eddy diffusivity

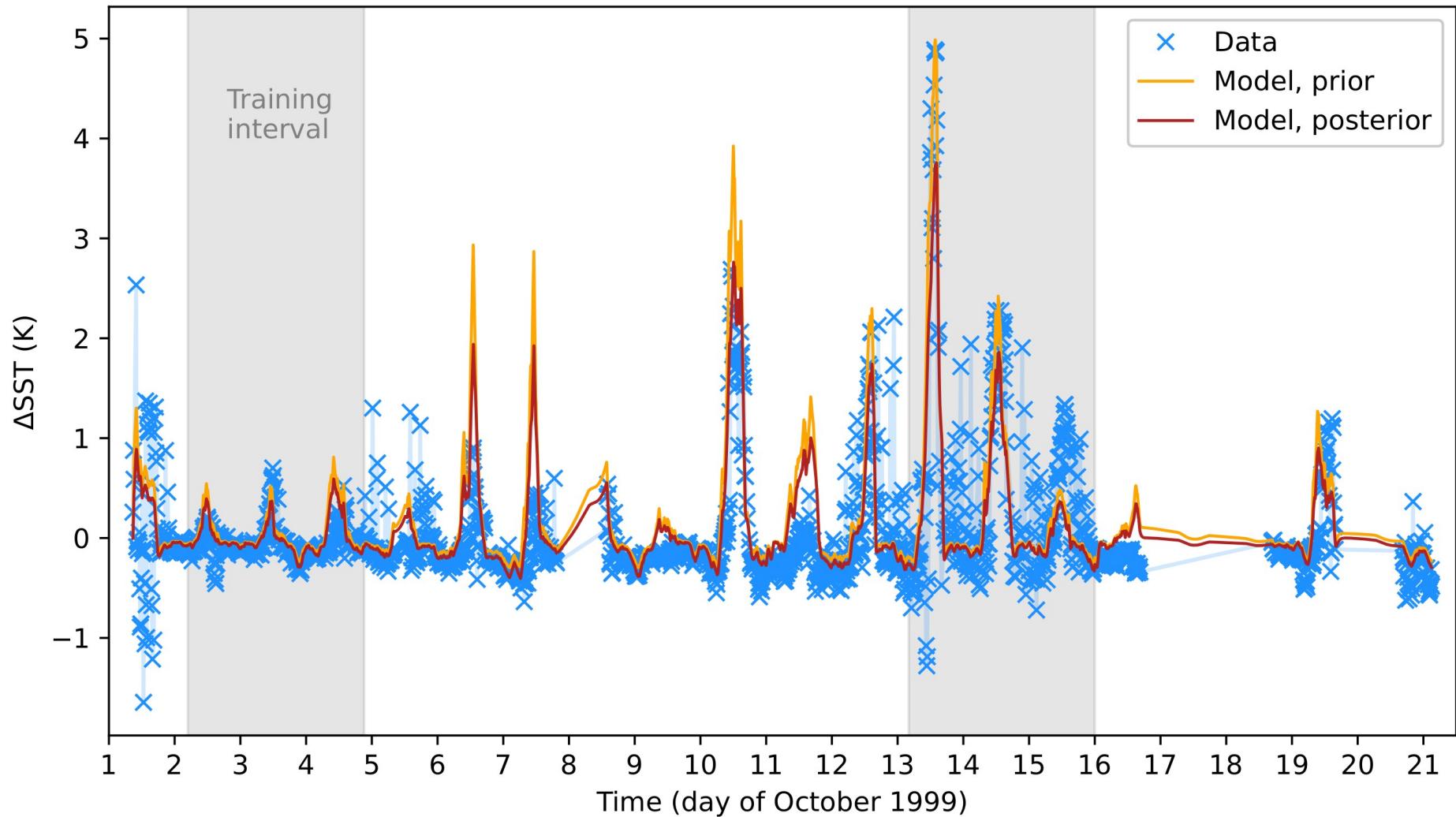


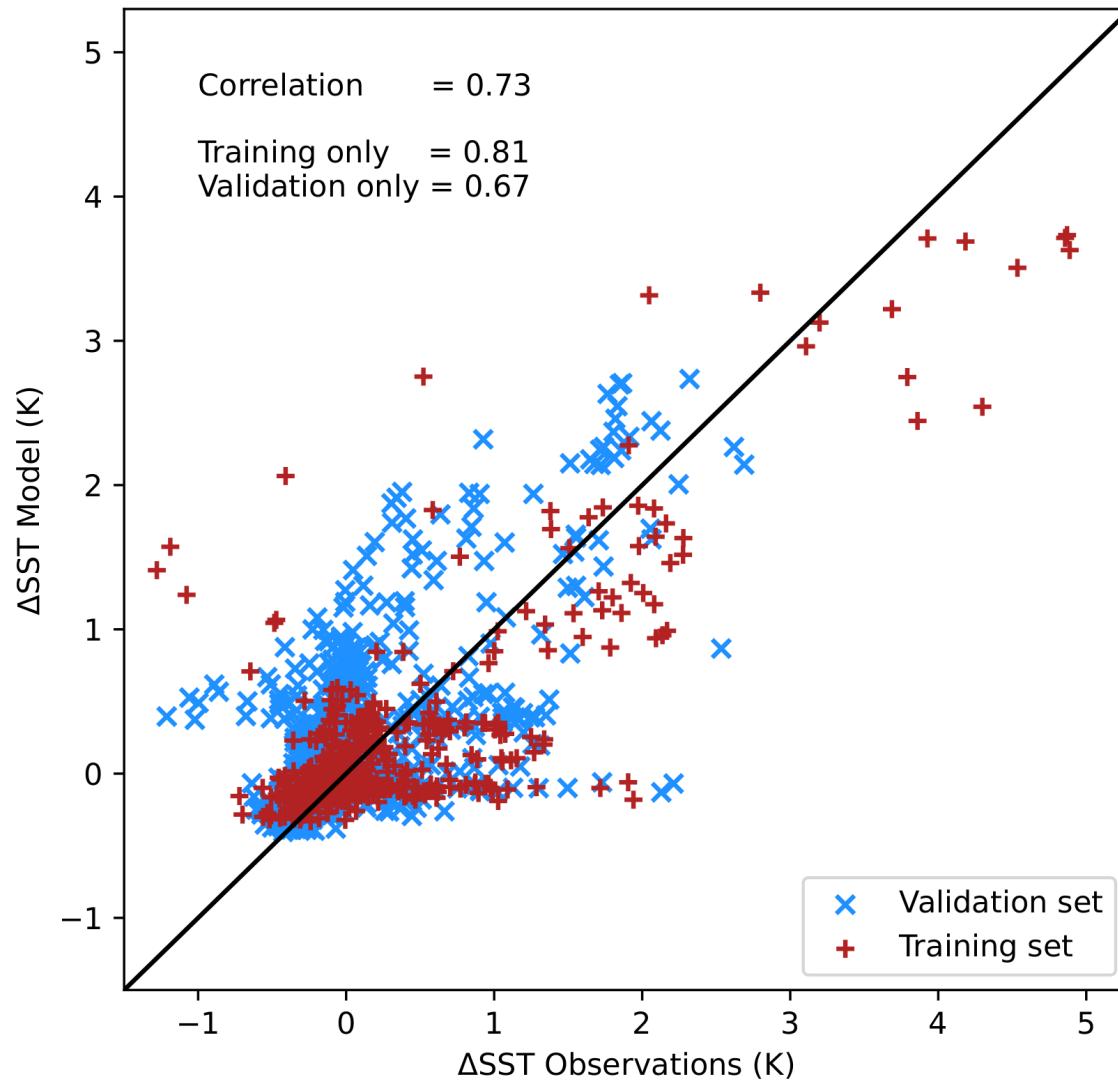
mixing coeff.



attenuation coeff.

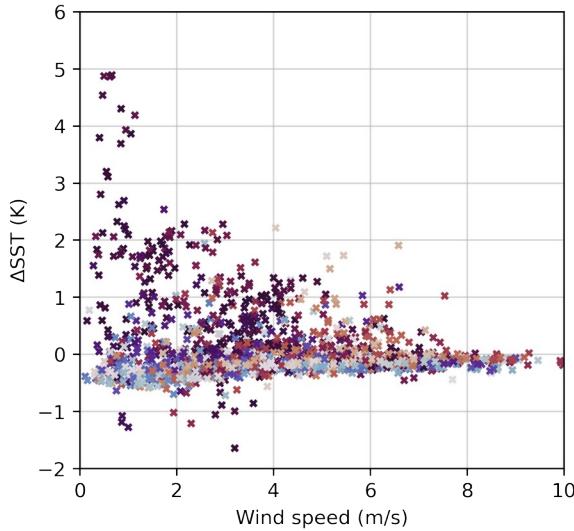
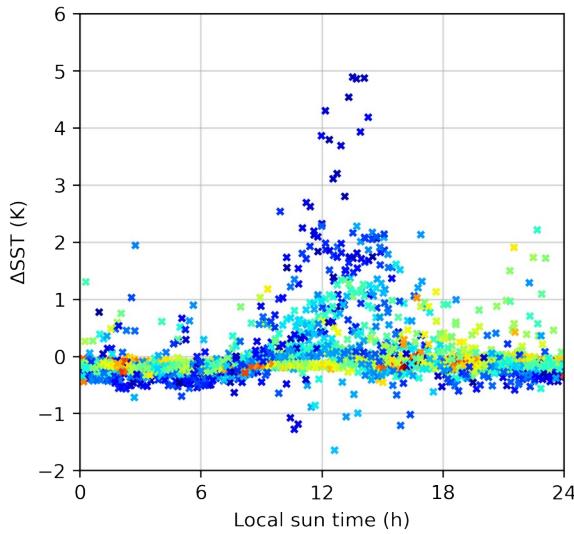




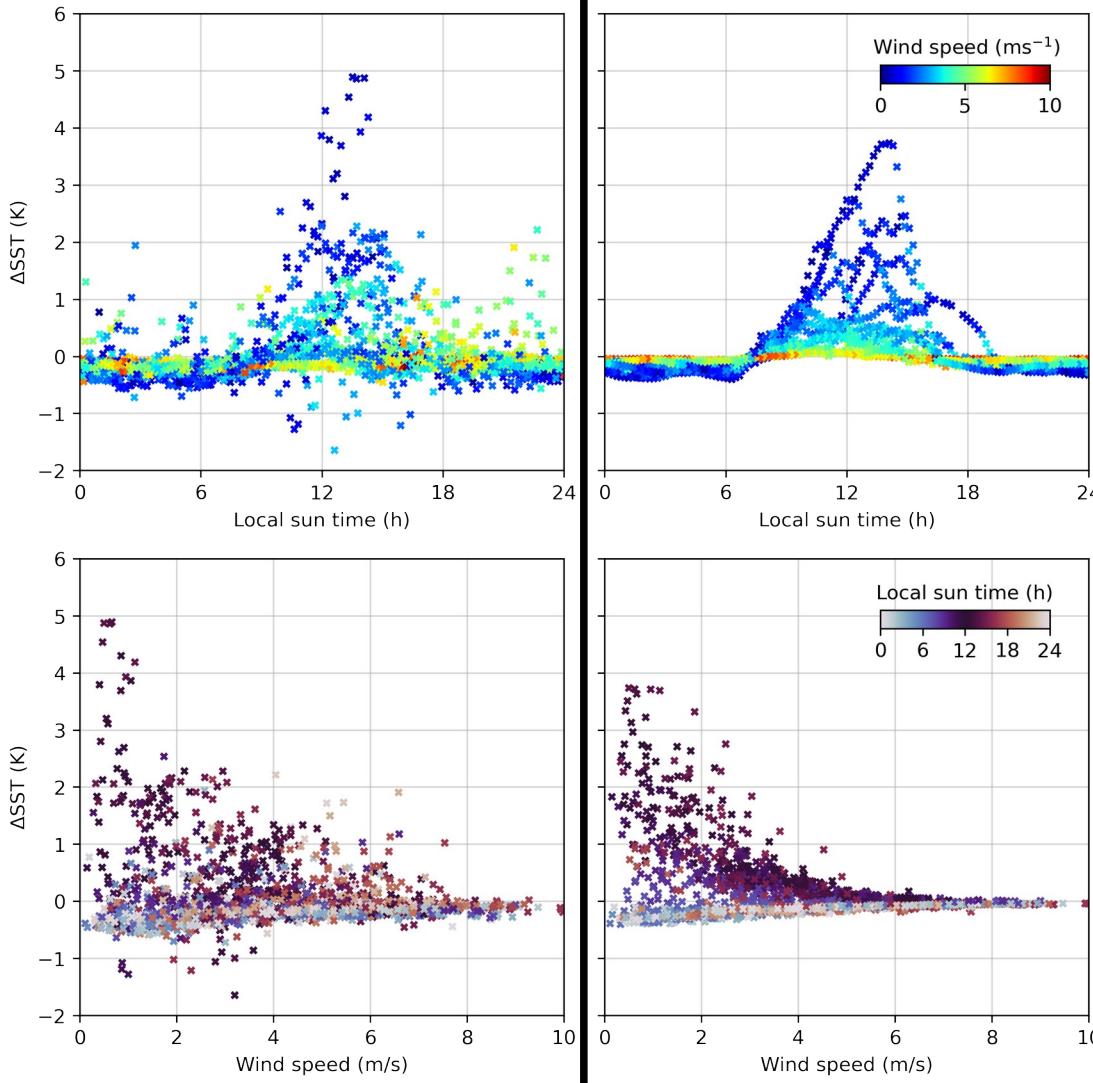


► Predictive skill!

Observations

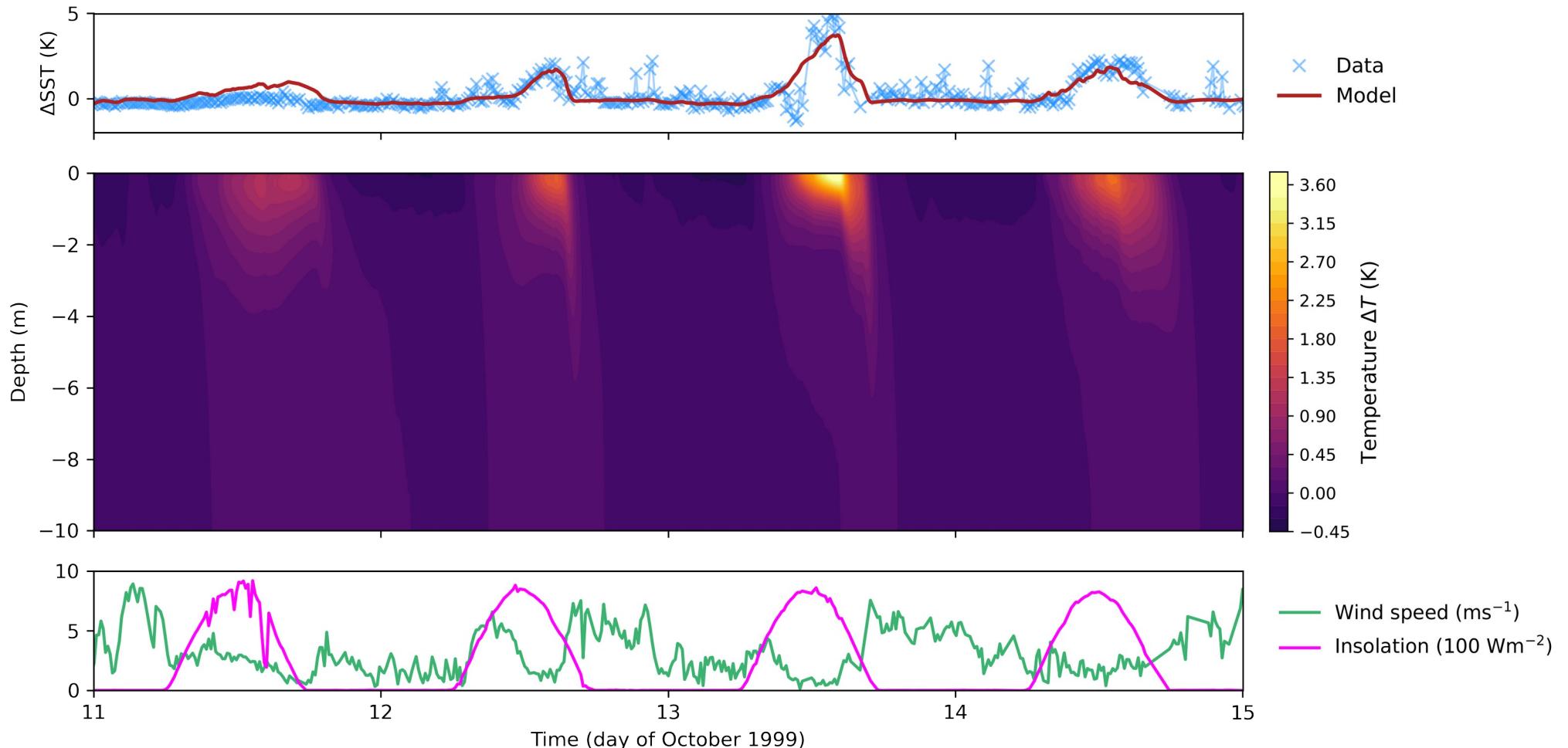


Observations

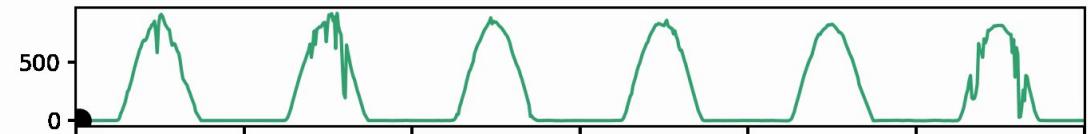


Model

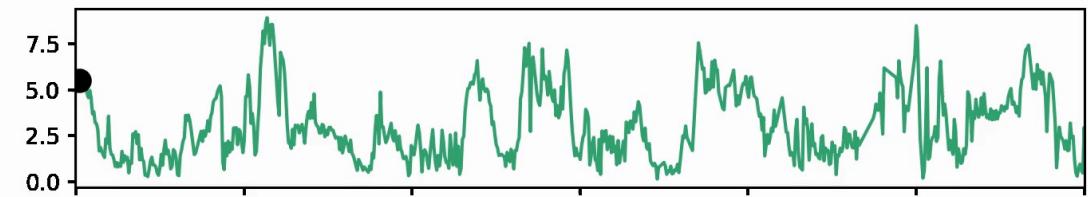
A vertical view



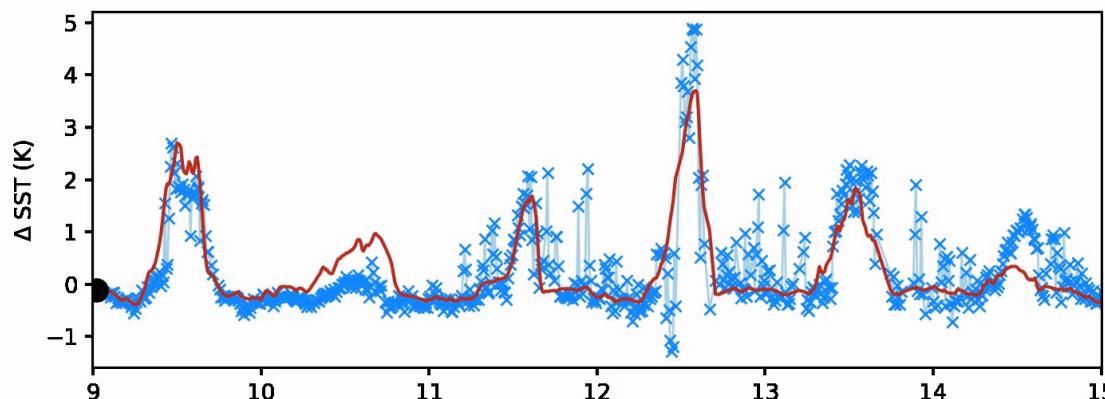
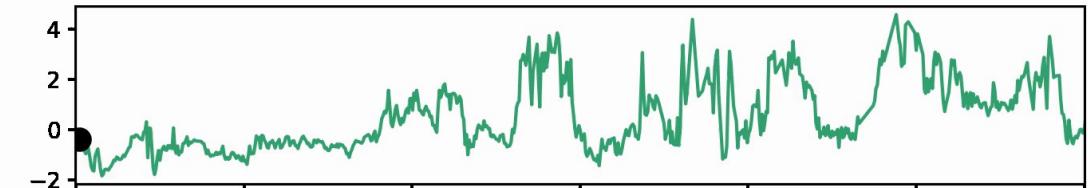
Insolation



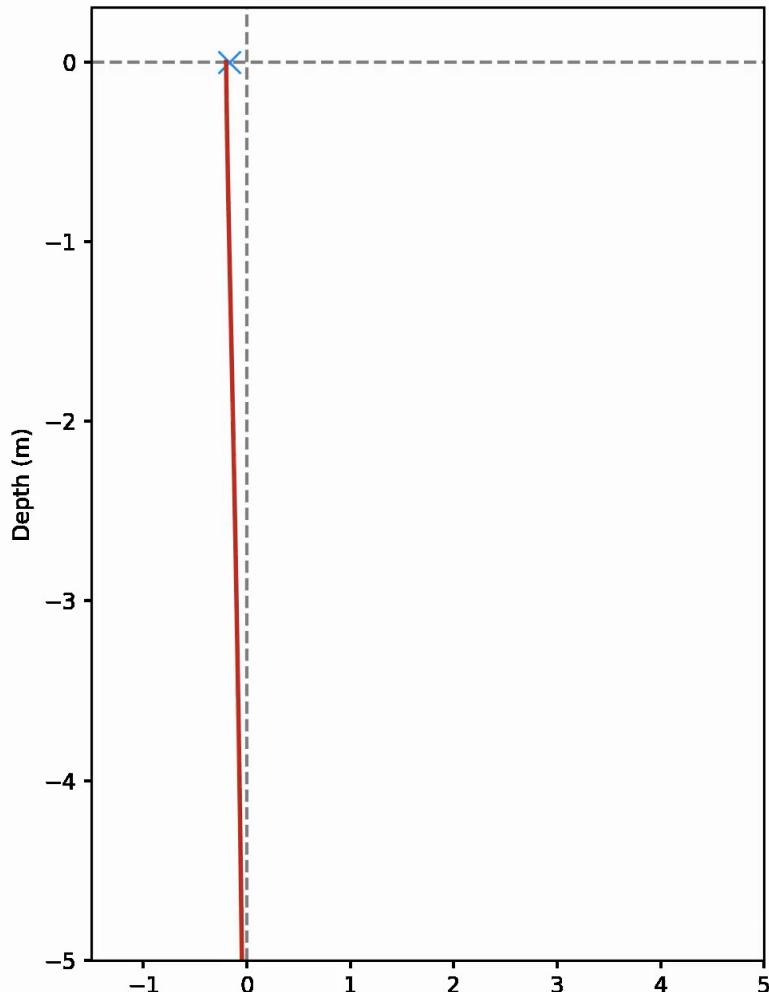
Wind



Air temp.

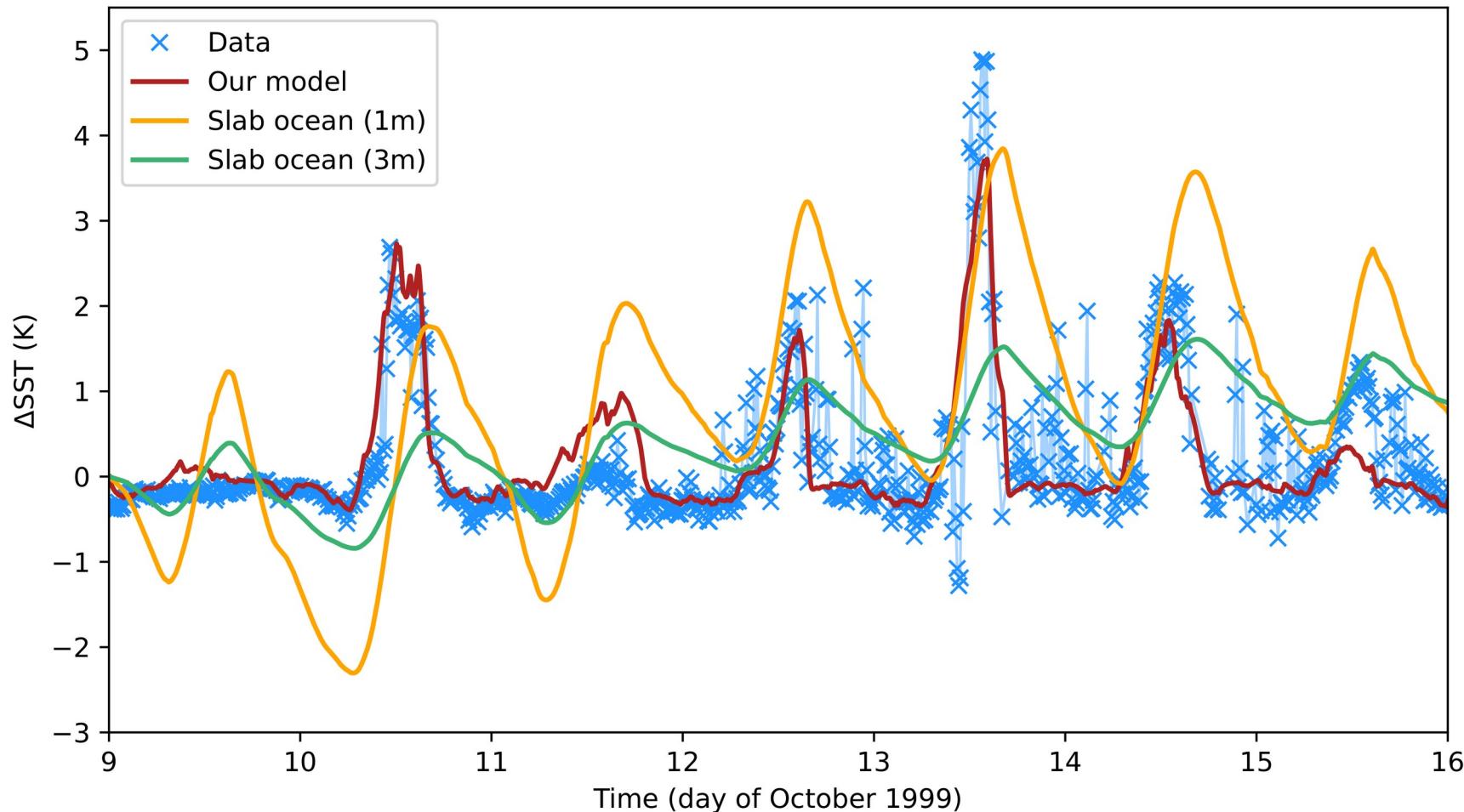


Time (days)

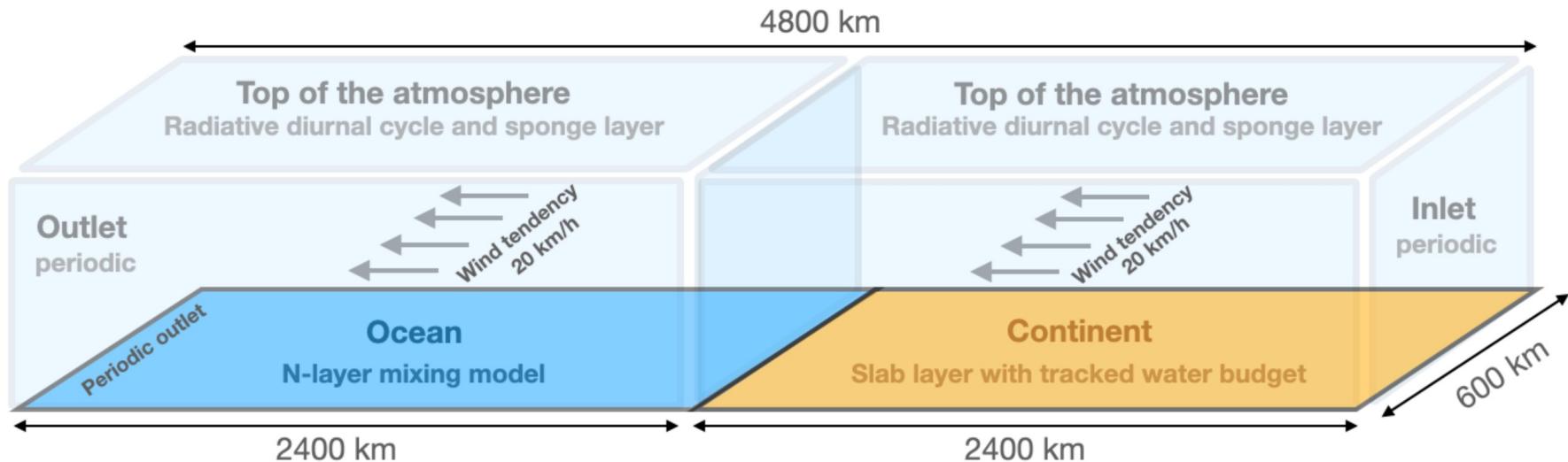
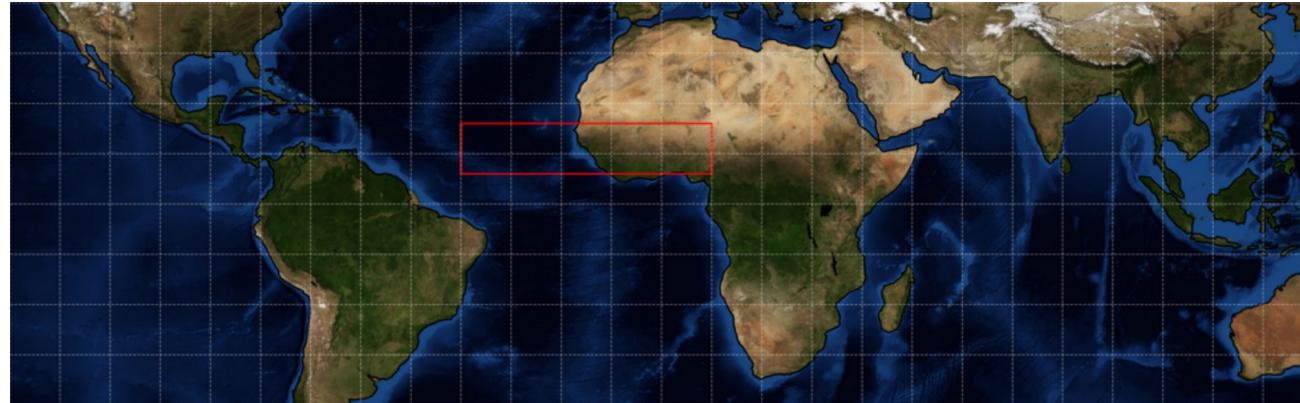


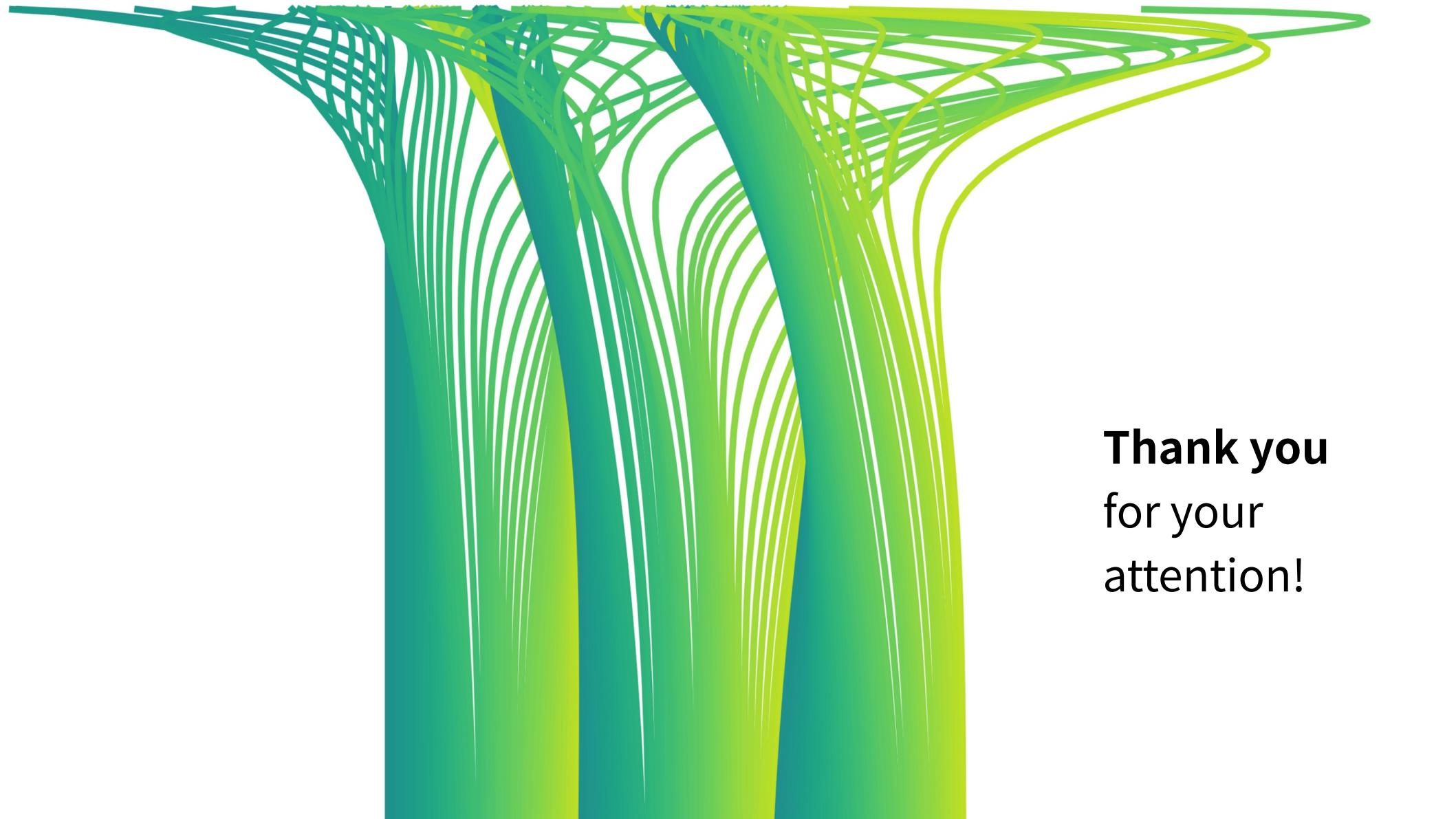
Temperature ΔT (K)

Better than a slab model?



Future work



A large, abstract graphic on the left side of the slide features a complex network of green lines forming a wireframe structure. The lines are primarily thin and light green, with some thicker, darker green lines that define the main vertical and horizontal axes. The structure is organic and fluid, resembling a stylized tree or a network of veins. It has a central vertical column and several curved, branching elements extending from the top and bottom.

**Thank you
for your
attention!**