Sensitivity Analysis on FLake

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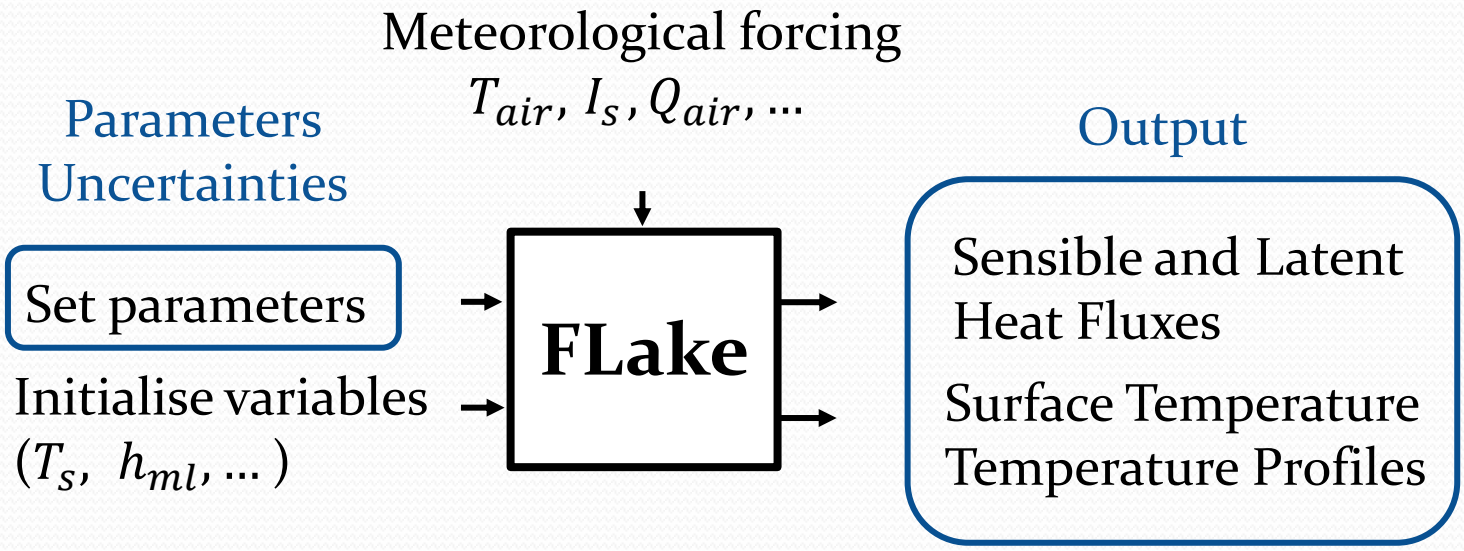
Context

- What is the impact of lake on global climate ?
- Implementation of lakes in climate model

Lake energy budget modelisation



Objective

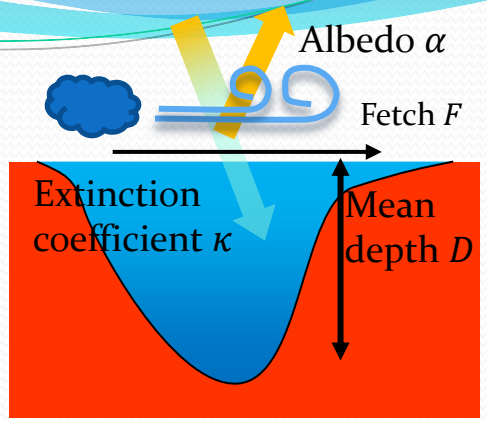
How do we set the FLake parameters for lakes in climate models such as ORCHIDEE?

Which are the parameter uncertainties that lead to large variability on the outputs?

Approach

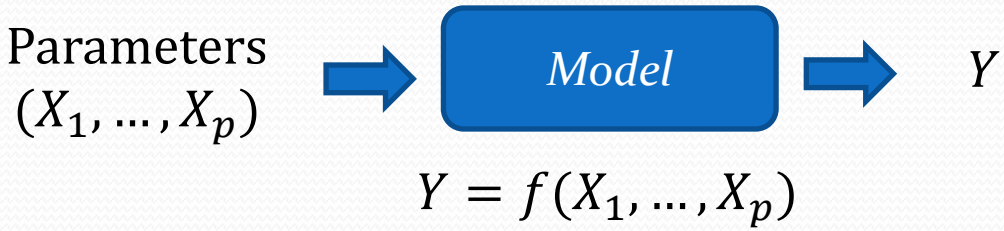
1. List the parameters
2. What Informations/Databases exist for each parameter
3. Uncertainties on the parameters
4. Estimation of model sensitivities to each parameter

Parameters range



Parameters	Available Information	Source of uncertainties
Depth D	A value per lake	Seasonal evolution of depth
Albedo α	Mean value	Distribution of lake optical properties
Light Extinction Coefficient κ	Only for several lakes	Distribution of lake optical properties
Fetch F	A value per lake	Large uncertainties (Wind direction, Lake shape, …)
Internal Flake Constant C_{relax}	Set to 0.003 for normal use	Physics unknown

Sensitivity analysis



The Sobol Method

$$S_i = \frac{V_i}{Var(Y)}$$

$$S_{T_i} = 1 - \frac{Var\left(E(Y|X_{\sim i})\right)}{Var(Y)}$$

$S_i \sim 1$: Very influential parameter

$S_i \sim 0$: Not influential parameter

Sensitivity analysis for time series

$$Y = f(X_1, \dots, X_p, t)$$

The Sobol Method for time series:

Plot the Sobol indices depending on time
OR
Use the generalised Sobol indices:

$$GS_i = \sum_t \frac{Var(Y(t))}{\sum_{t_1} Var(Y(t_1))} S_i(t)$$

$$GST_i = \sum_t \frac{Var(Y(t))}{\sum_{t_1} Var(Y(t_1))} S_{T_i}(t)$$

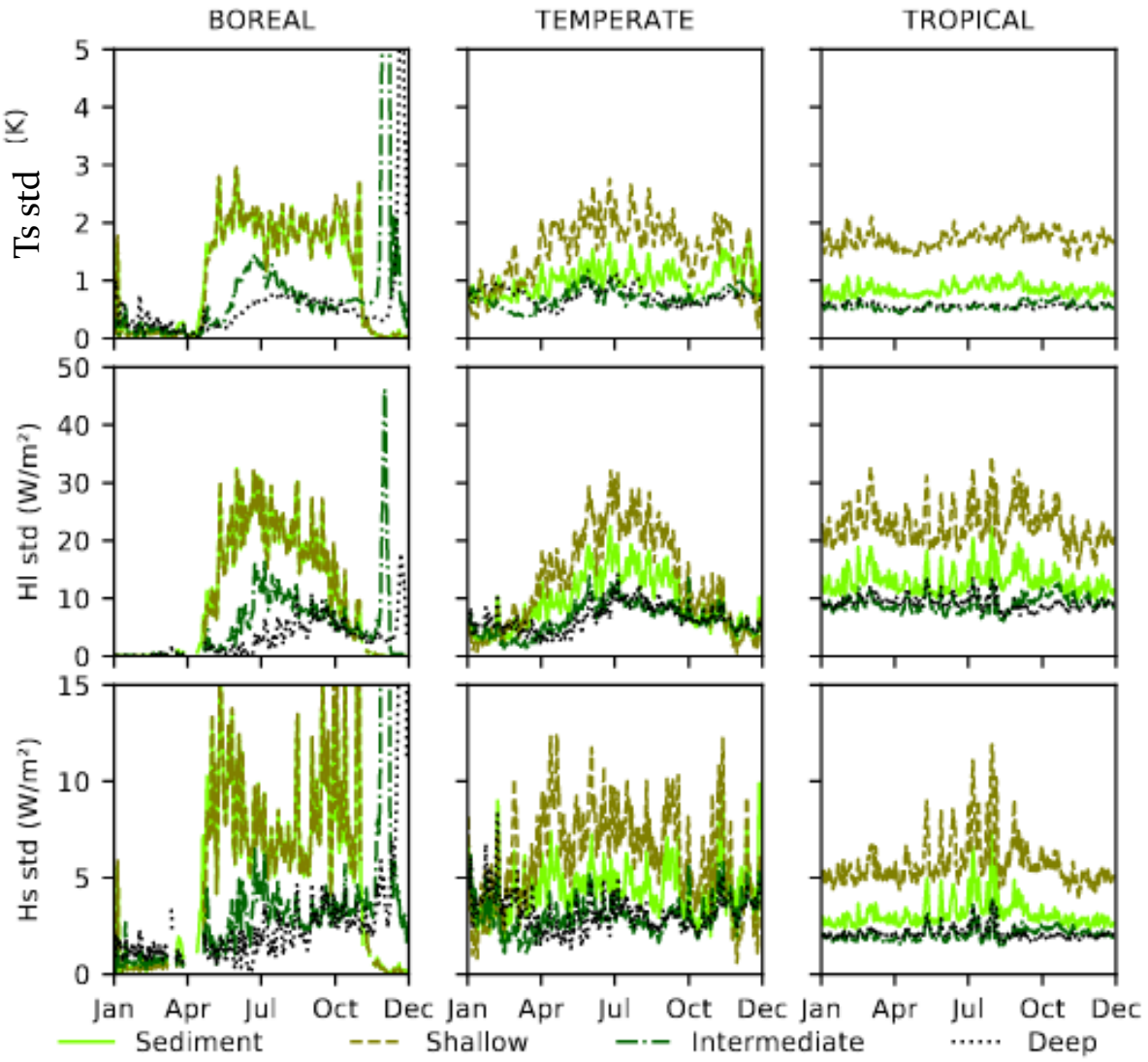
Experiment Design

Design Sensitivity Analysis for global applications:

- Simulations over 5 years (2000-2004), one year shown
- Climates: Boreal, Temperate, Tropical
- 3 depth range for Shallow lakes, Medium and Deep lakes
- Additionnal case: Shallow lake with activated sediment layer

3 climates x (3 depth range + 1 additionnal case) = 12 cases

Standard Deviation



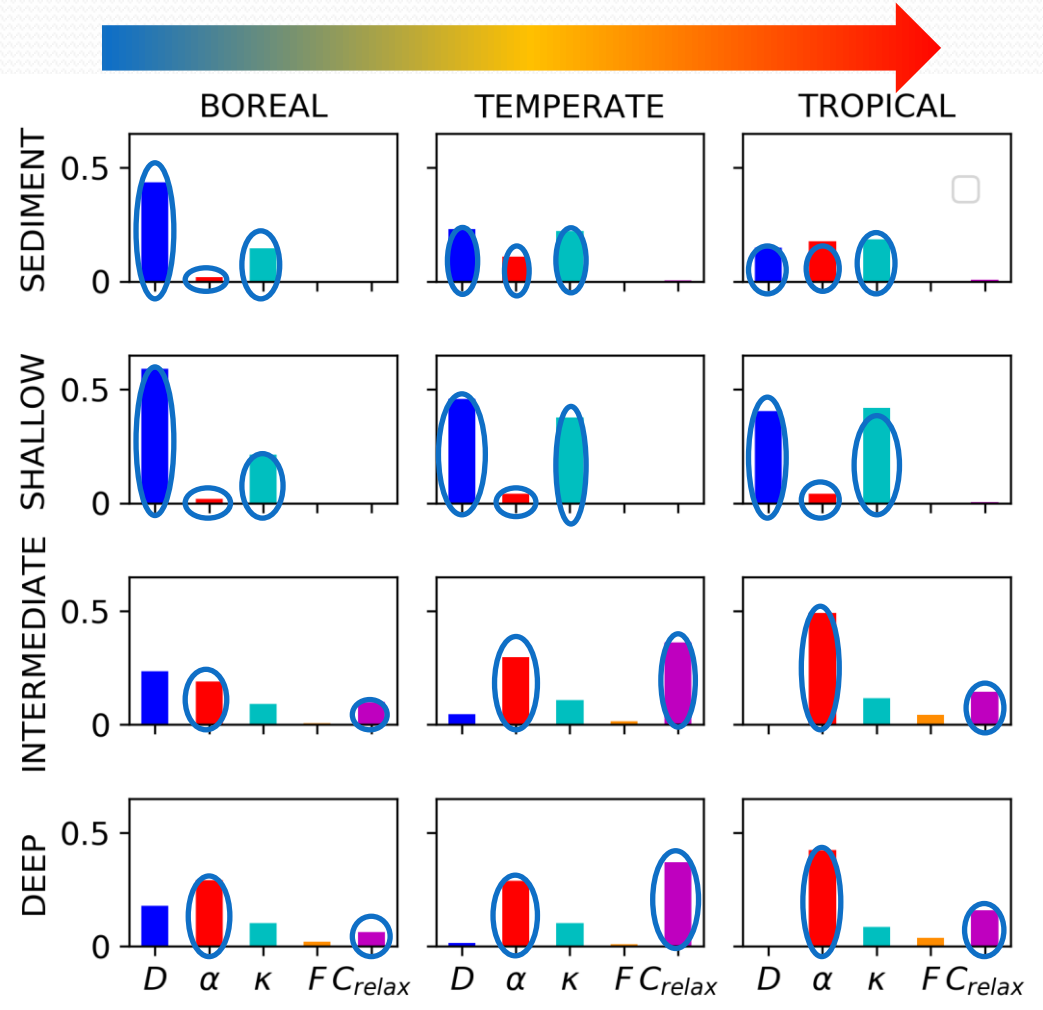
Total Standard Deviation for each climate and each output (Surface temperature (Ts), Latent (Hl) and sensible (Hs) heat fluxes) during one year

General Sobol Indices on Surface Temperature

- Two different responses from shallow and deep lakes:
Shallow: T_s sensitive to D and κ
Deep: T_s sensitive to α and C_{relax}

- Warm climate
=> T_s more sensitive to α

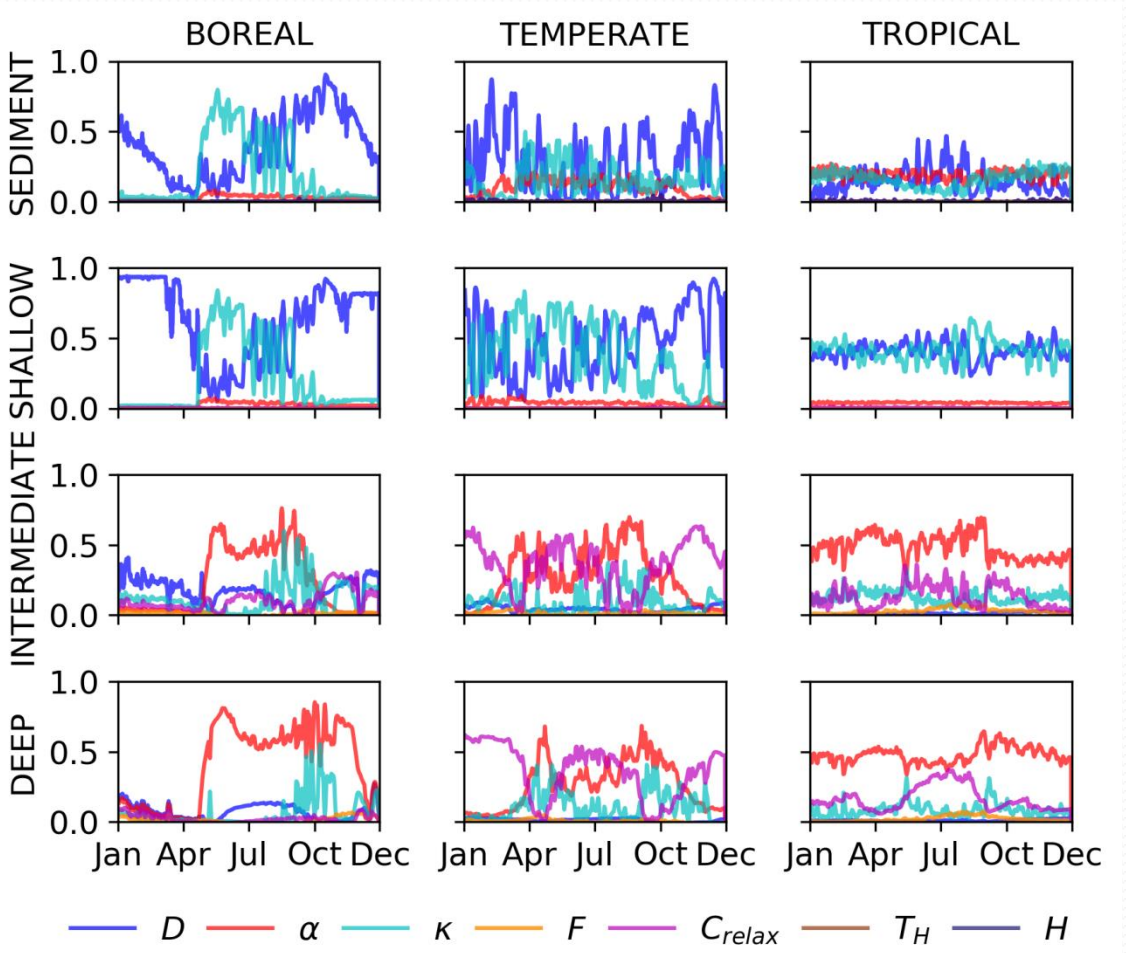
- Activation sediment layer
=> T_s more sensitive to α



First Order Generalised Sobol indices on T_s sensitivity for a period of one year

Sensitivity of Surface Temperature

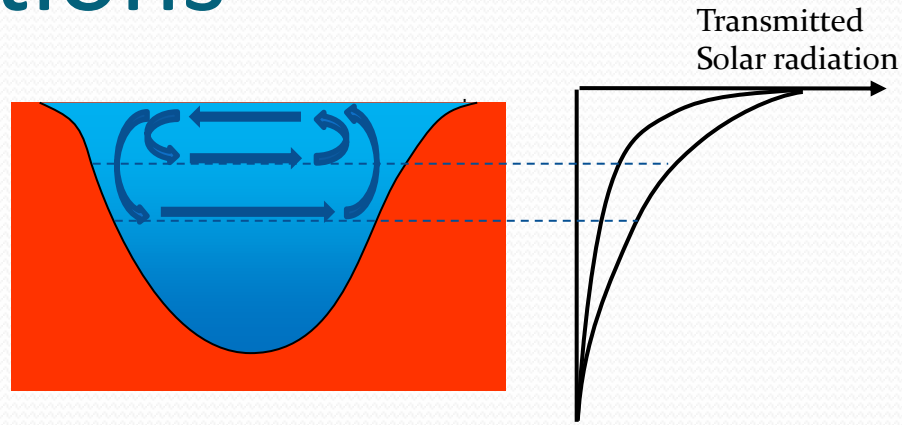
- Shallow lakes:
  - Stronger solar radiation
  => T_s more sensitive to κ
  - Activation sediment layer and warm period
  => T_s sensitive to α

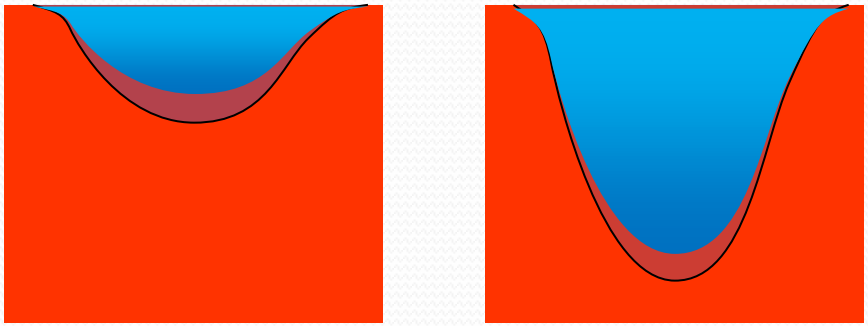


First Order Sobol indices on T_s sensitivity for one year period

Sensitivity Explanations

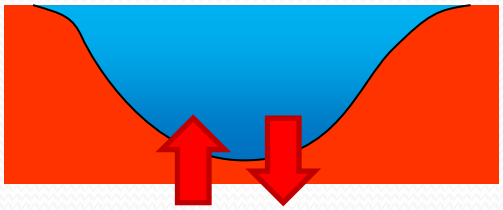
- κ more influential for shallow lakes





- D more influential for shallow lakes:
- Deep lakes sensitive to α and C_{relax} only

- α more influential with activated sediment layer



Conclusion

	Boreal	Temperate	Tropical
Sediment	D κ	D κ α	κ D α
Shallow	D κ	κ D	κ D
Intermediate	α C_{relax}	α C_{relax}	α C_{relax}
Deep	α C_{relax}	α C_{relax}	α C_{relax}

Higher Variance

Lower Variance

The most influential parameters

Perspective on Lake Modelling

- Data Assimilation on the most influential parameters.
- Model the mass budget on the lakes and calculate the mean depth.
- SWOT Observation to create map of mean depth evolving over time.
- *Create map of extinction coefficient and albedo ?*
- *Better understanding of the internal constant Crelax*

Thanks you for your attention

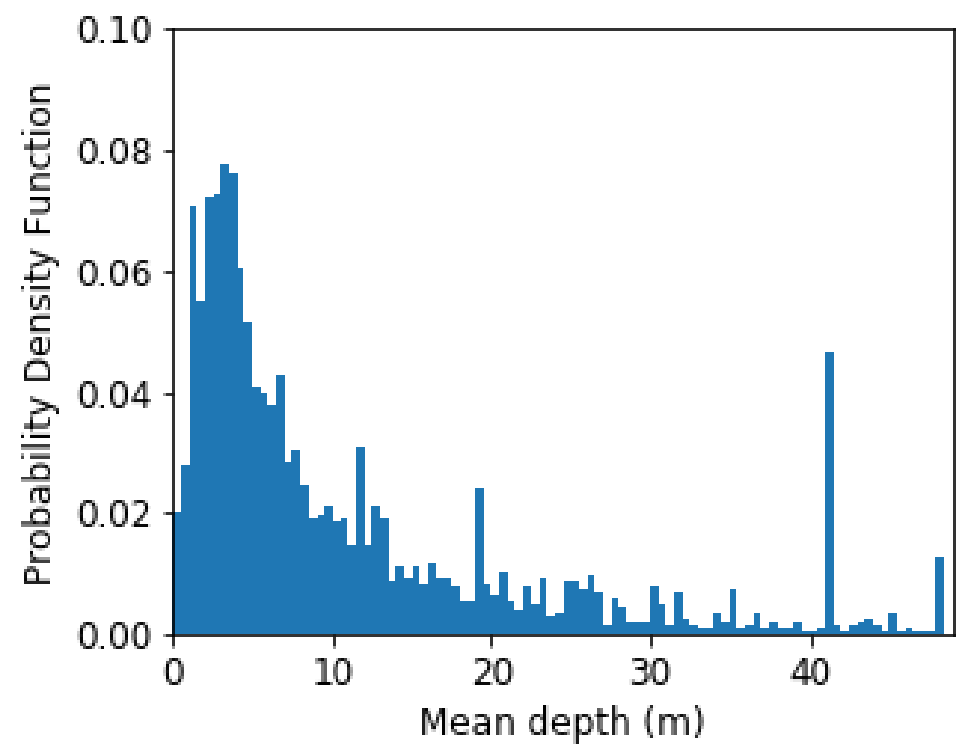
Variance based sensitivity analysis of FLake lake model for global land surface modeling (2019)

A. Bernus, C. Ottle, N. Raoult, *Journal of Geophysical Research: Atmospheres*, in preparation

Intervals parameters

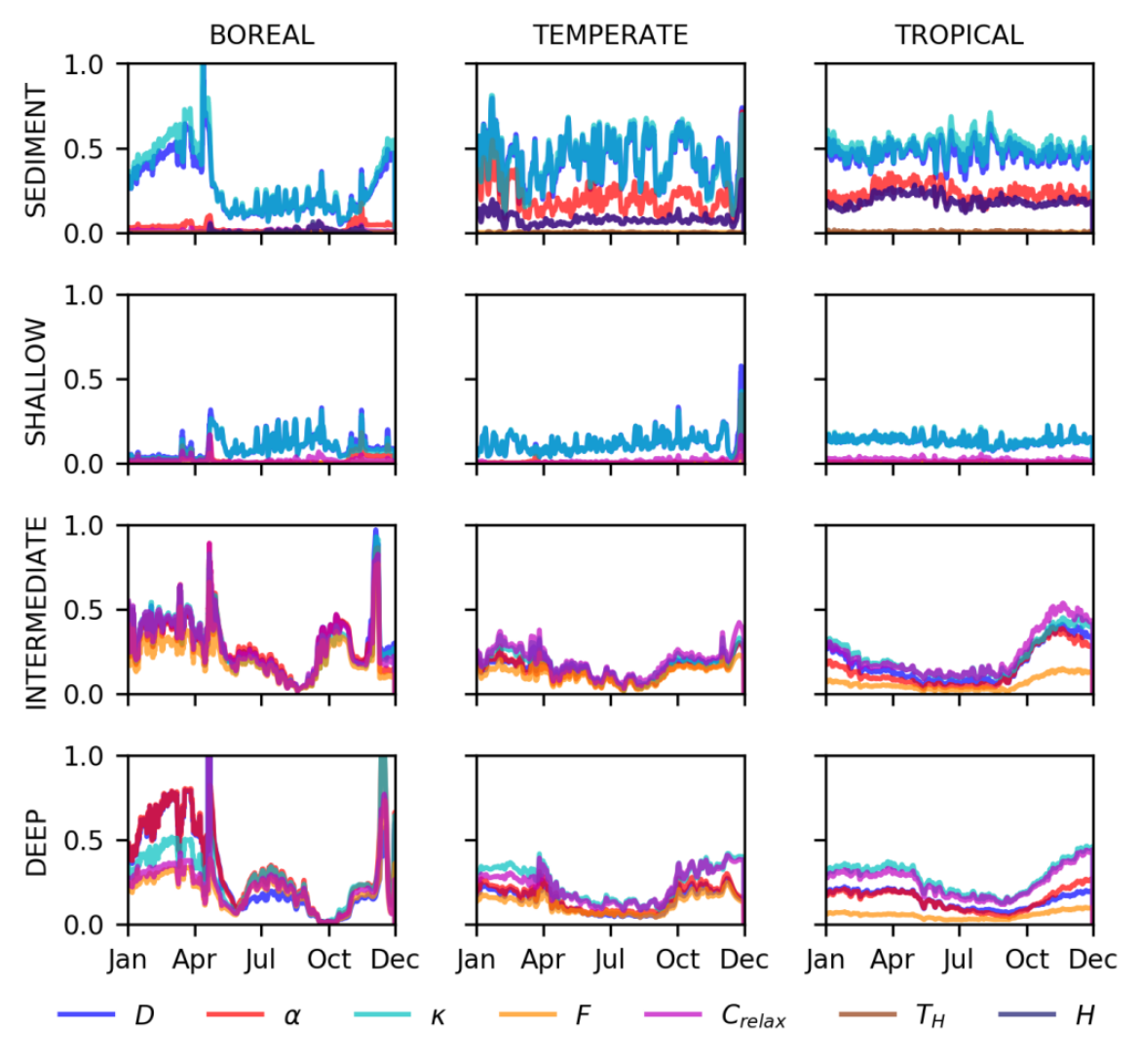
Parameters	Ranges				Source
	Sediment	Shallow	Intermediate	Deep	
D	0.5-5.5	0.5-5.5	22.5-27.5	47.5-52.5	Hydroweb *Cretaux (2011)*
F	0-1300	0-1300	0-10600	0-26600	Hydrolakes *Messager (2016)*
α	0.025-0.175				*McMahon and Moore (2017)*
κ	0.225-2.435				ILEC *(2005)*
C_{relax}	10^{-2}-10^{-5}				*Layden (2016)*
Temperature under sediment	Boreal 271.2_273.2				Meteorologic forcing WFDEI *Weedon (2014)*
	Temperate 282.7-284.1				
	Tropical 295-296.8				
Sediment layer thickness	3-10				Website: *www.igb-berlin.de*

Lake depth distribution



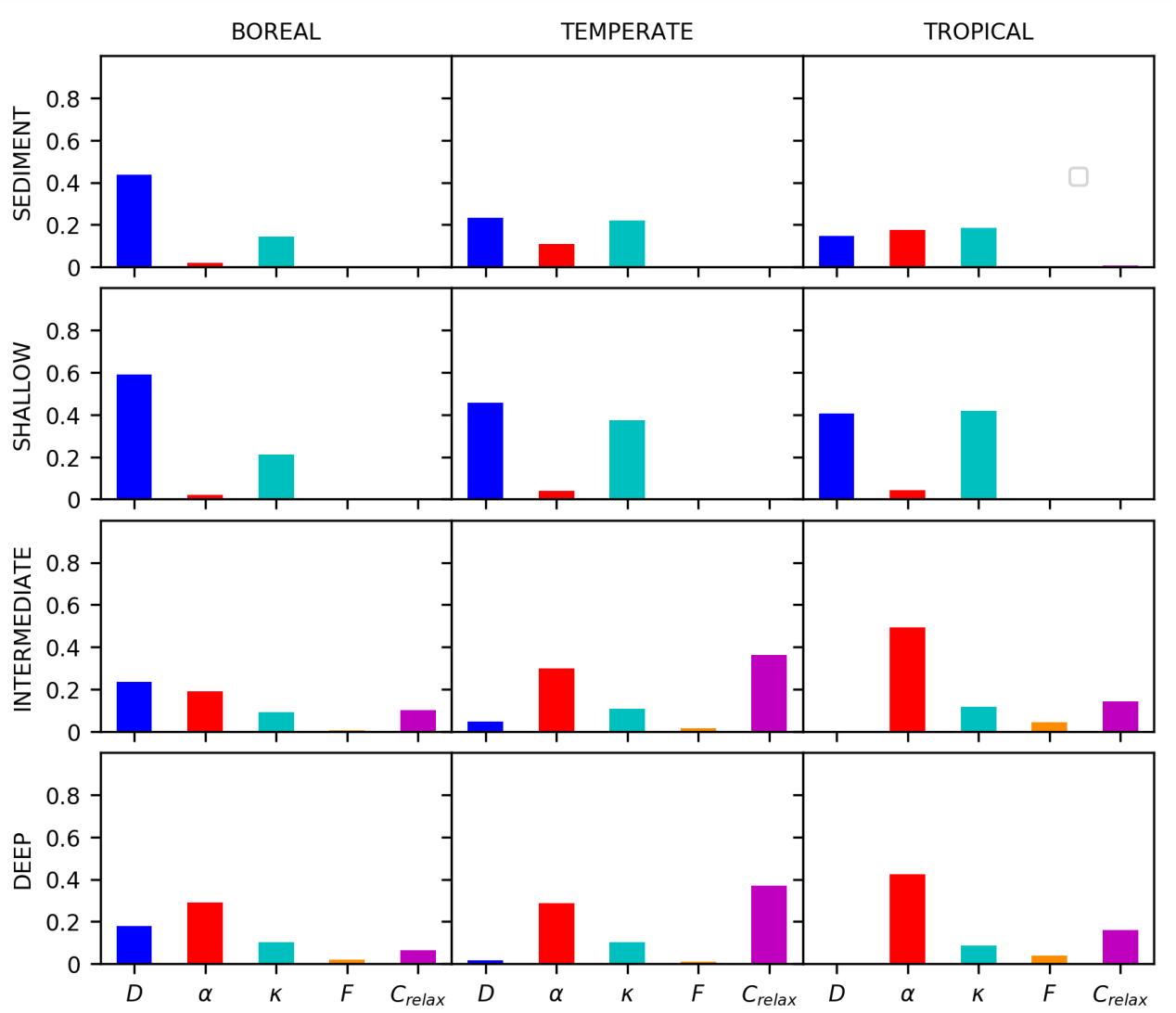
PDF represents the percentage of lake area which have the abscise depth (with a resolution of 0,5m)

Sensitivity of Surface Temperature



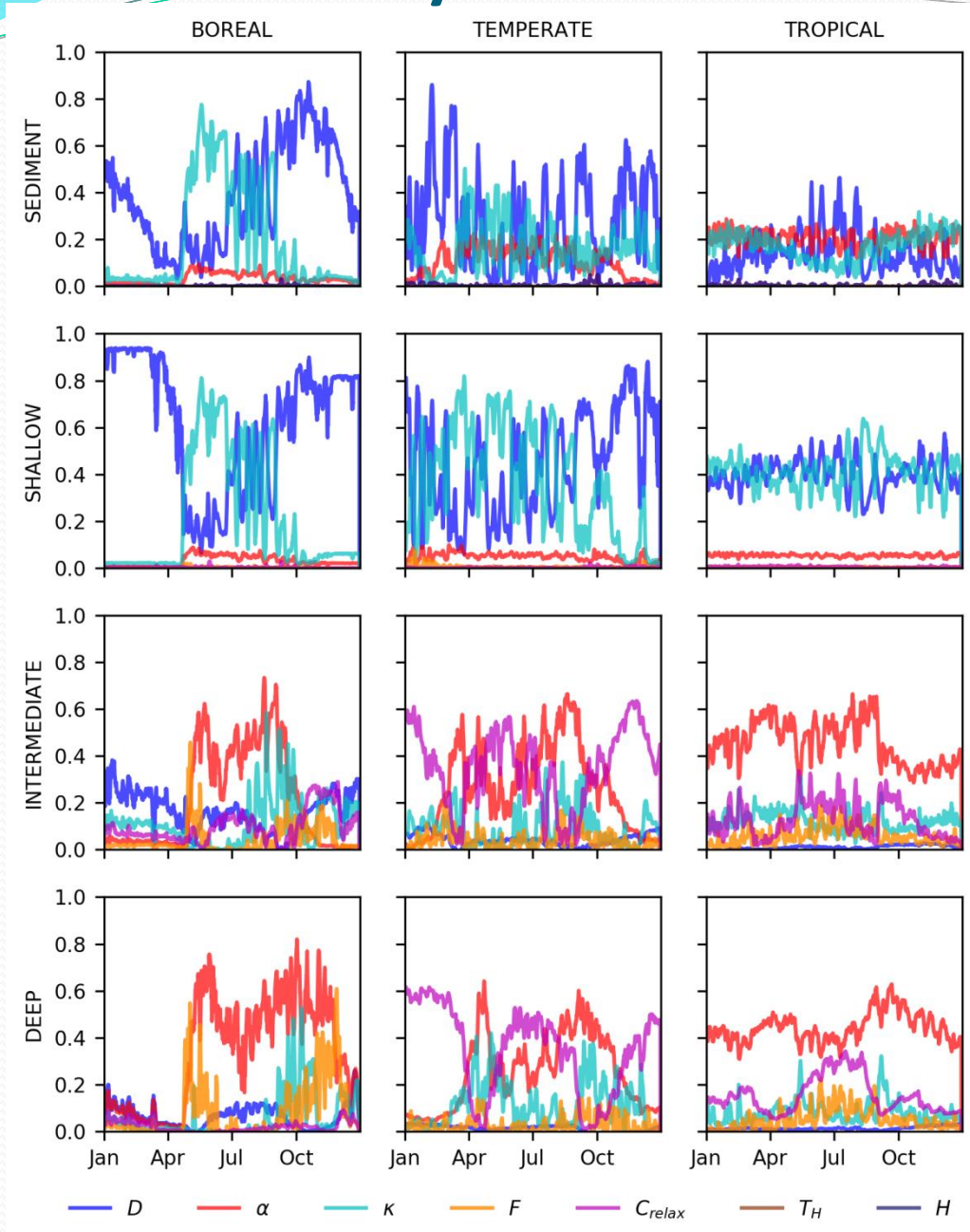
Difference of total and first order Sobol indices on T_s *sensitivity for one year period*

Sensitivity of Surface Temperature



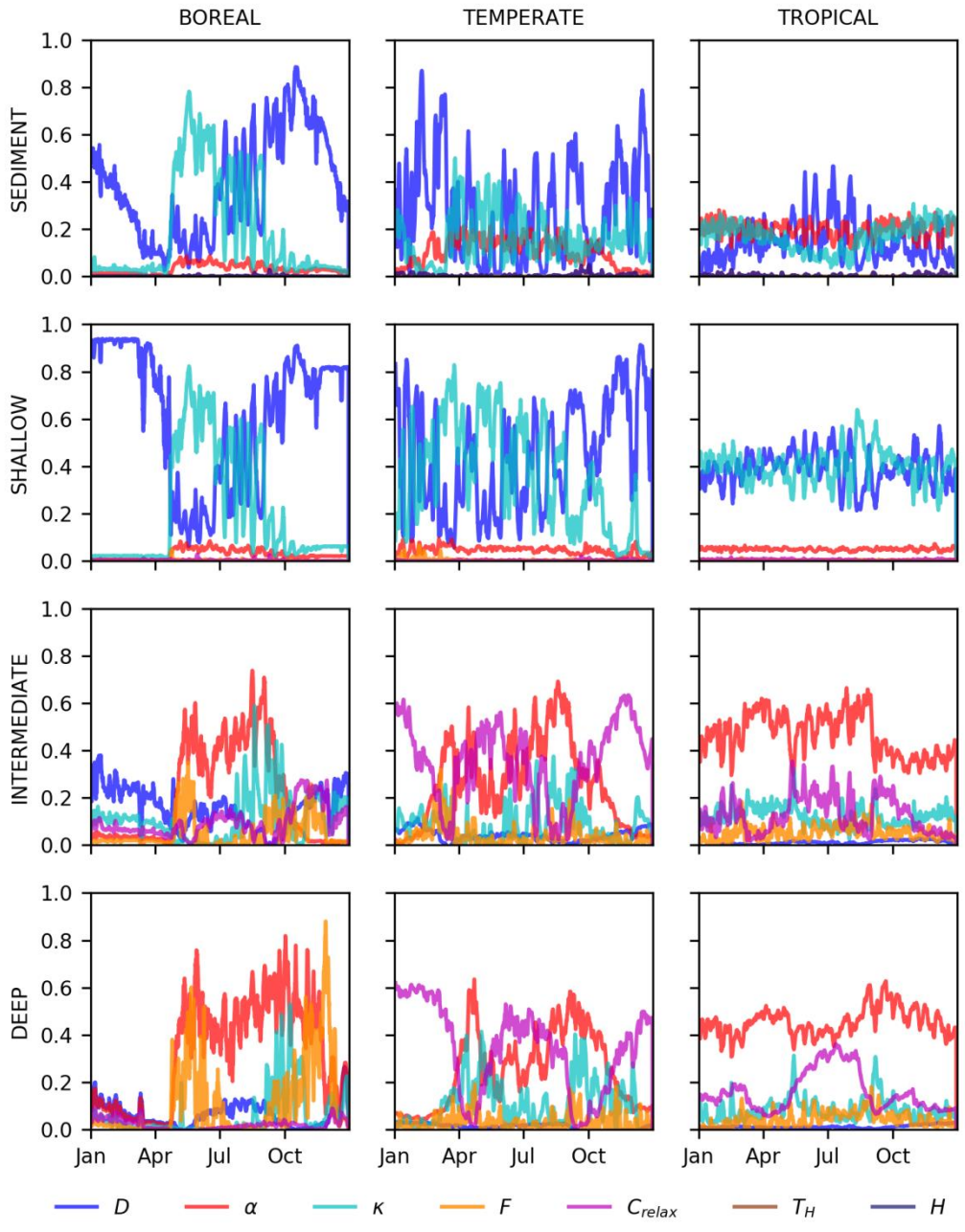
Difference of total and first order generalised Sobol indices on T_s sensitivity for one year period

Sensitivity of Latent Heat Flux



First Order Sobol indices on Q_l sensitivity for one year period

Sensitivity of Sensible Heat Flux



First Order Sobol indices on Q_s sensitivity for one year period