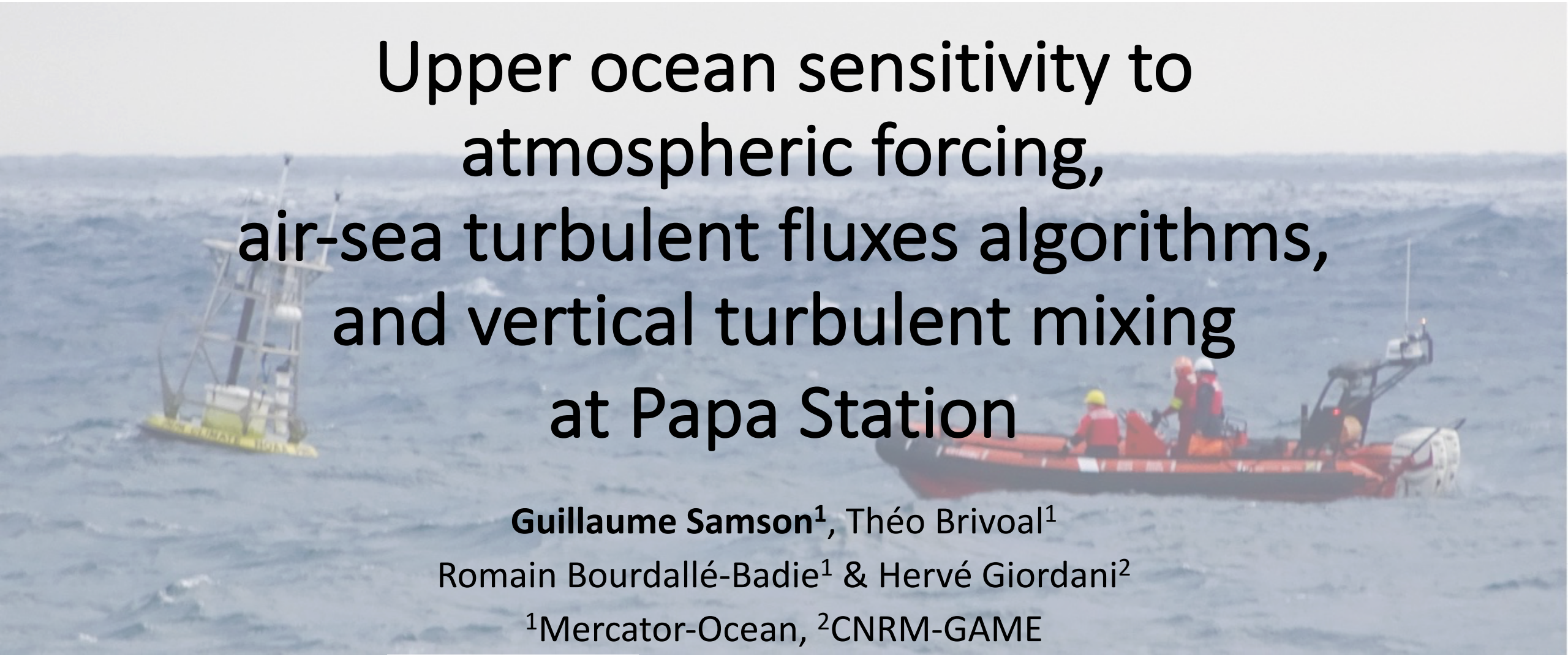

# Upper ocean sensitivity to atmospheric forcing, air-sea turbulent fluxes algorithms, and vertical turbulent mixing at Papa Station

**Guillaume Samson**[1], Théo Brivoal[1]

Romain Bourdallé-Badie[1] & Hervé Giordani[2]

[1]Mercator-Ocean, [2]CNRM-GAME

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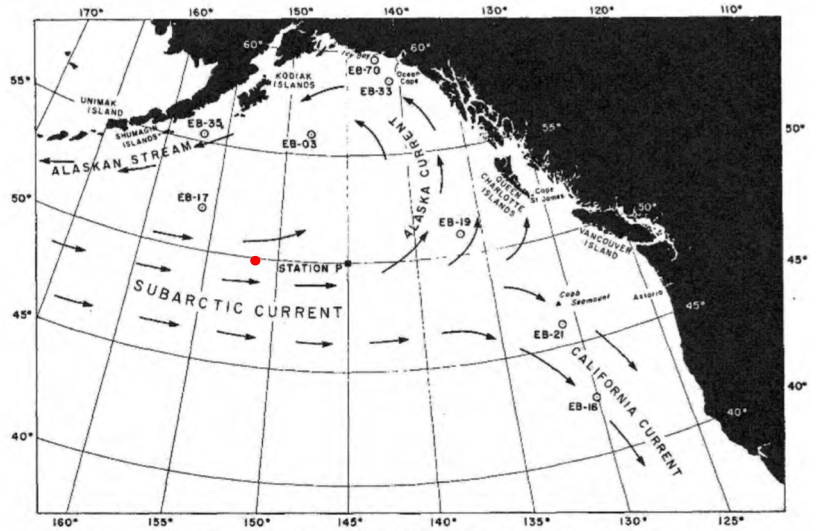
Monitoring Service

# Why the Papa Station ?

- Atmospheric & oceanic measurements  from 1949 to 1981 by US and Canadian Coast Guard weather ships




*Tabata 1977*

*Canadian Cost Guard Ship Vancouver 1969*

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  - Mellor & Durbin 1975
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  - …
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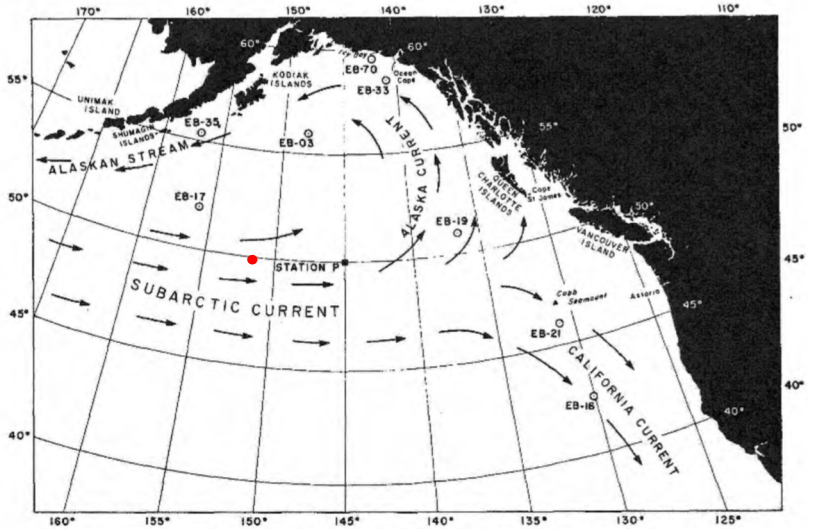


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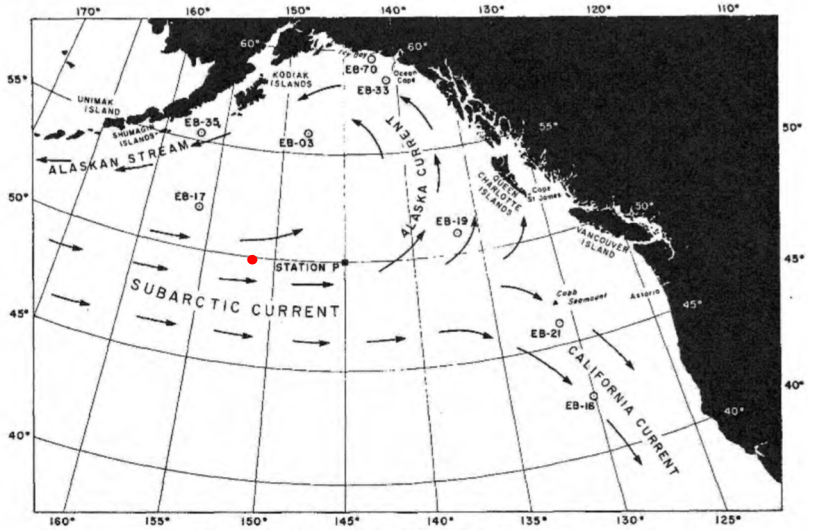
- **Opportunity to revisit the oceanic mixed layer sensitivity at Papa with modern measurements and NEMO model ?**

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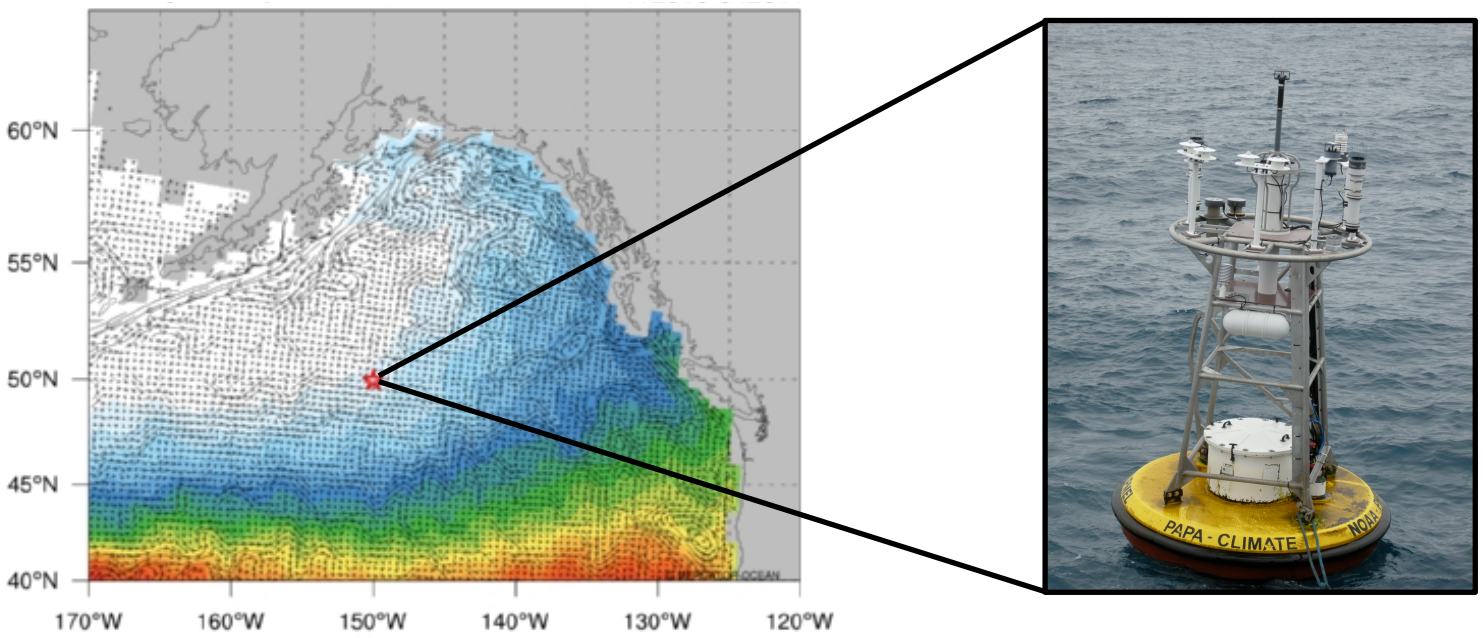

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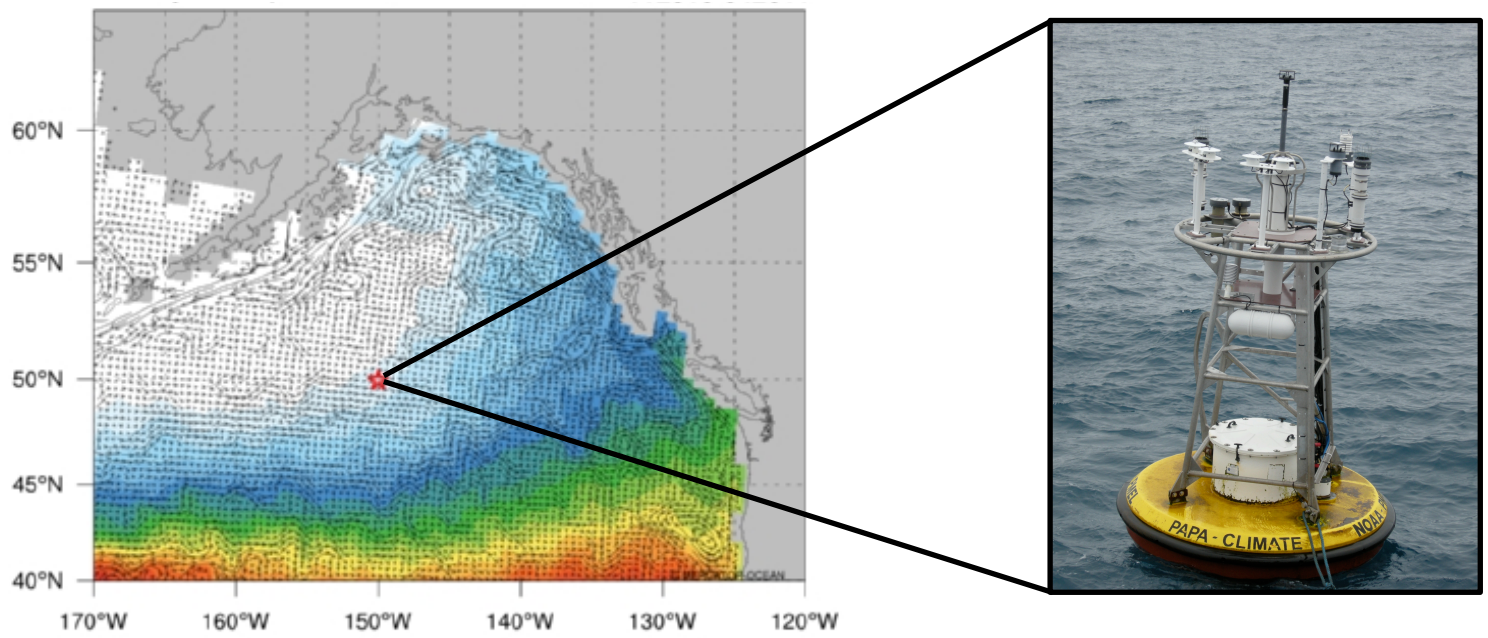
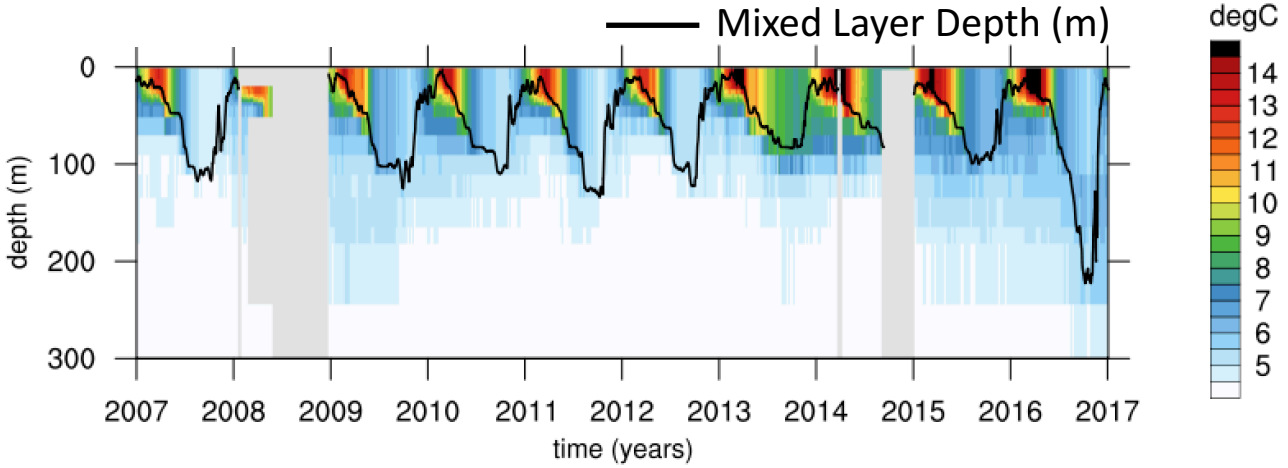



- long-term observational dataset (10 years)
- **oceanic horizontal advection negligible** (< 10 cm.s$^{-1}$)
- **energy transfers mainly vertical** (1D)
- hourly atmospheric measurements (forcing)
- hourly oceanic measurements (initial conditions)
- no direct turbulent fluxes measurements




*Data from NOAA/PMEL/OCS*

# Modeling strategy

- **1D vertical version** of the 3D ocean model NEMO (*Reffray et al. 2015*) (vertical mixing and Coriolis force only) with 75 levels
- simulation restarted each year (15$^{th}$ June) during 10 years
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ECMWF IFS model (with observed radiative fluxes and precipitation)
MOORING observations

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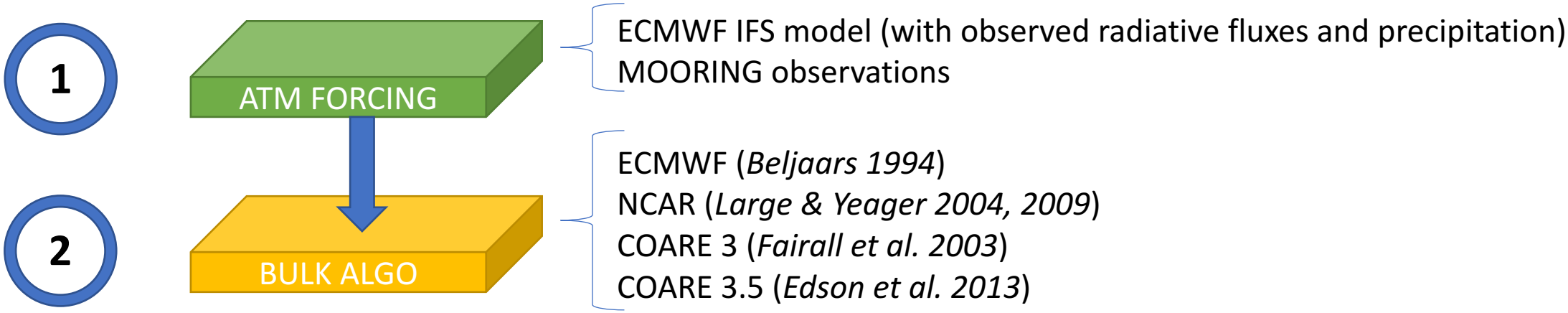

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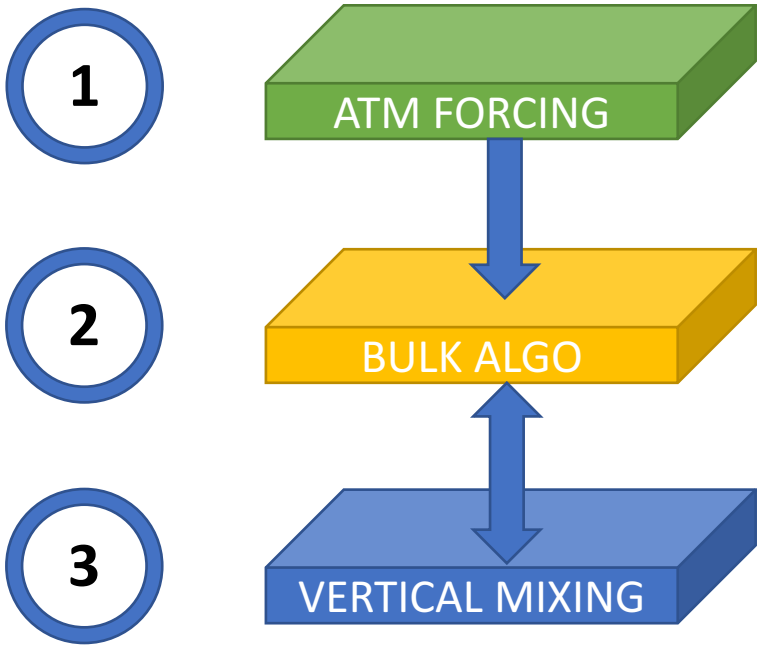


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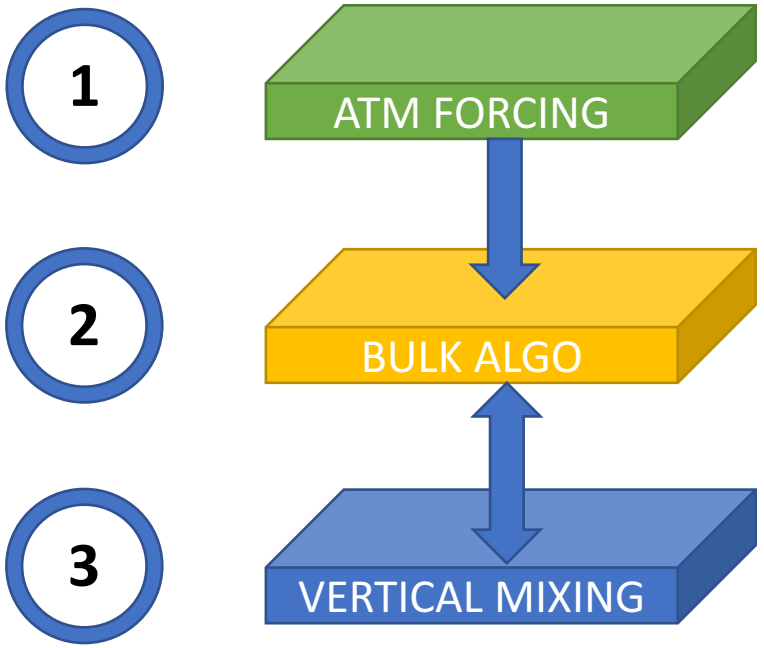


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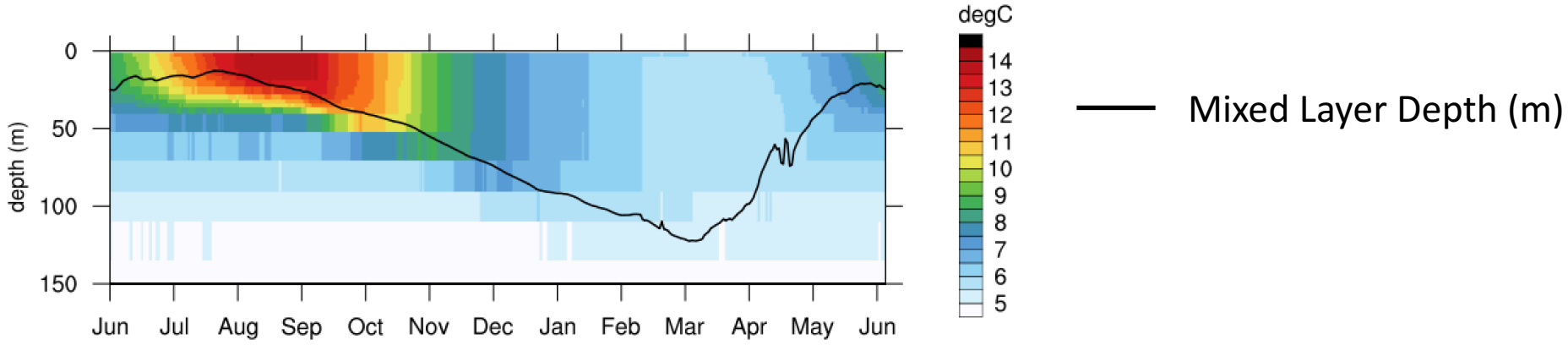
**TOTAL**: 24 x
10-years long 1D simulations

# Temperature & MLD seasonal cycle

**Papa Station**
**daily seasonal cycle mean**



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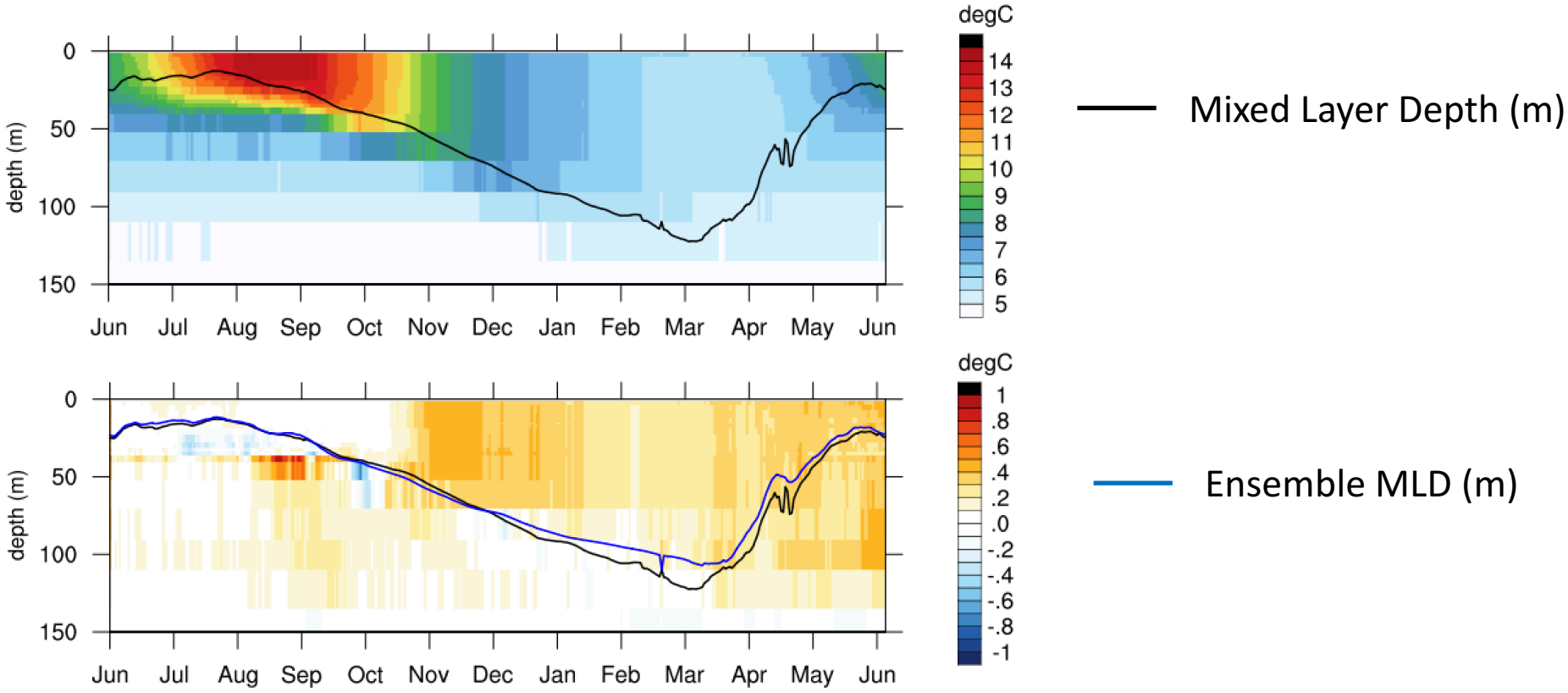


**Full ensemble**
**mean bias**

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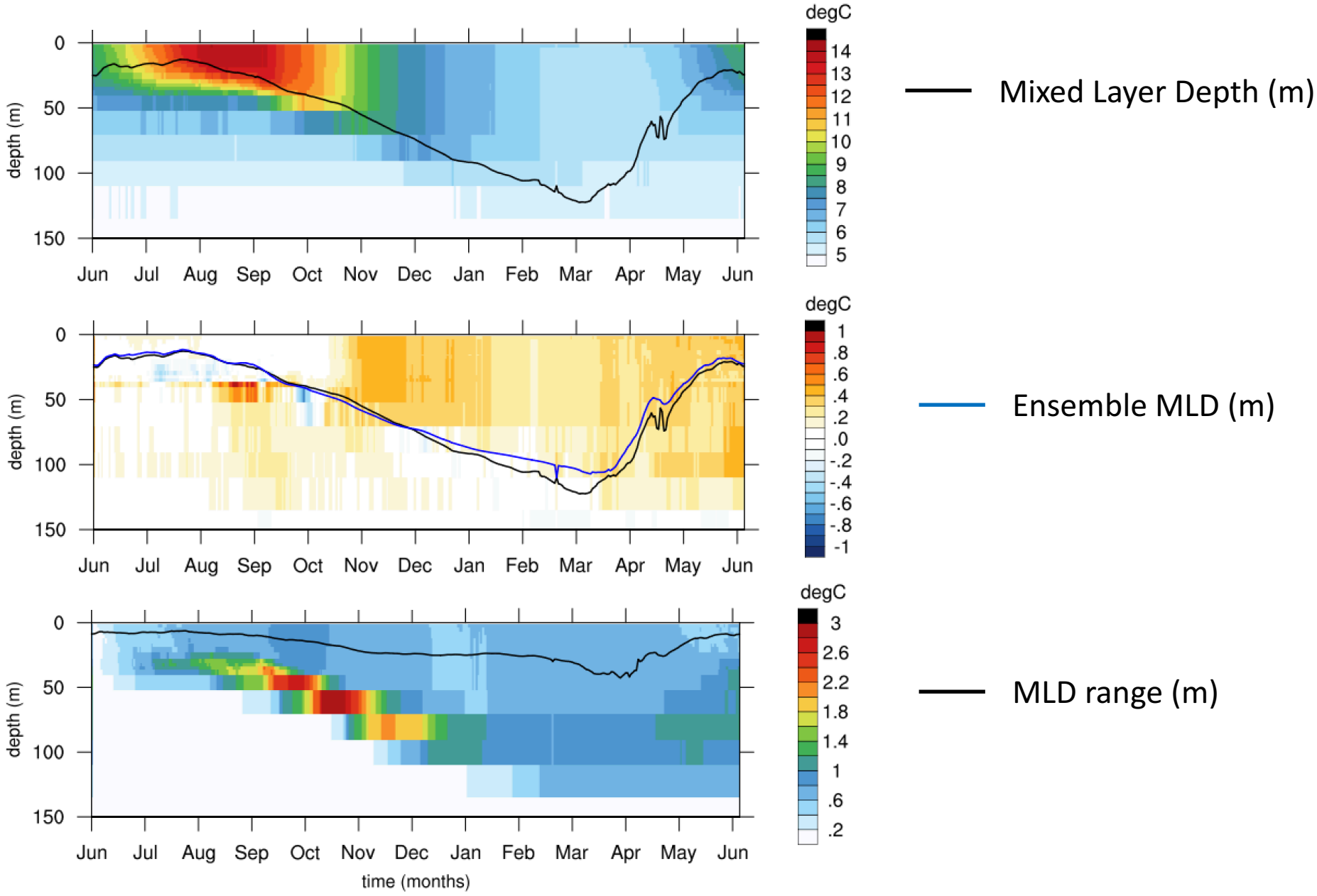


**Full ensemble**
**mean bias**

**Full ensemble**
**range (spread)**

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**Papa Station**
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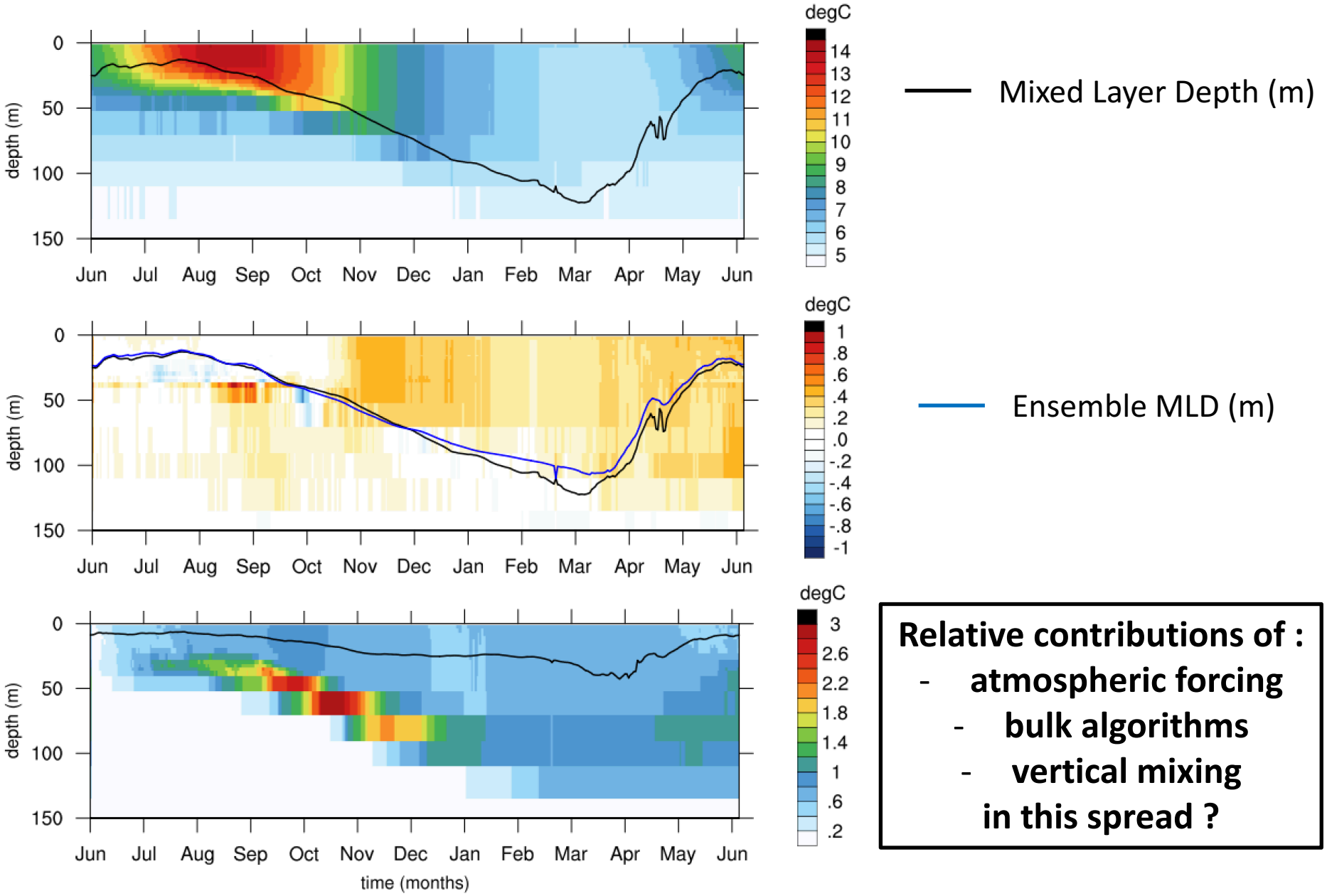



**Full ensemble**
**mean bias**

**Full ensemble**
**range (spread)**

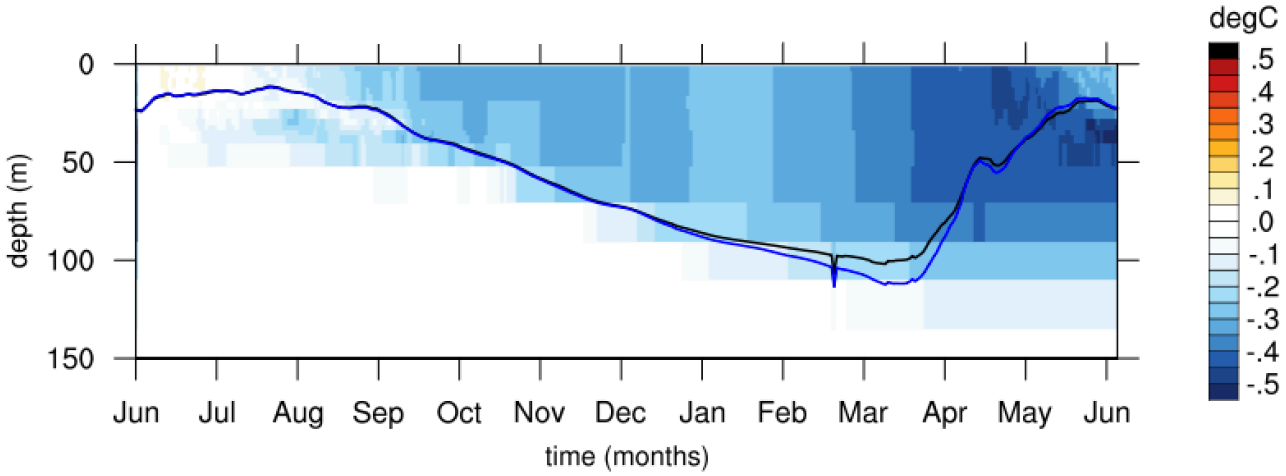
**Relative contributions of :**
- **atmospheric forcing**
- **bulk algorithms**
- **vertical mixing**

**in this spread ?**

# 1 - Sensitivity to atmospheric forcing


2 x 12 simulations

ECMWF IFS model (with observed radiative fluxes and precipitation)
MOORING observations

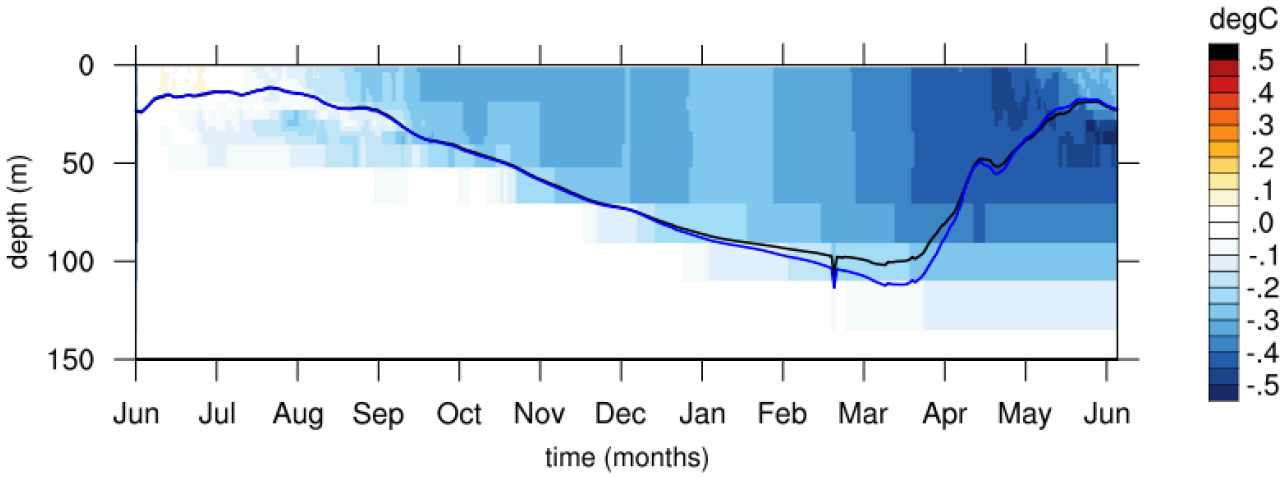



**IFS forcing ensemble - PAPA forcing ensemble**

# 1 - Sensitivity to atmospheric forcing


ECMWF IFS model (with observed radiative fluxes and precipitation)
MOORING observations

2 x 12 simulations

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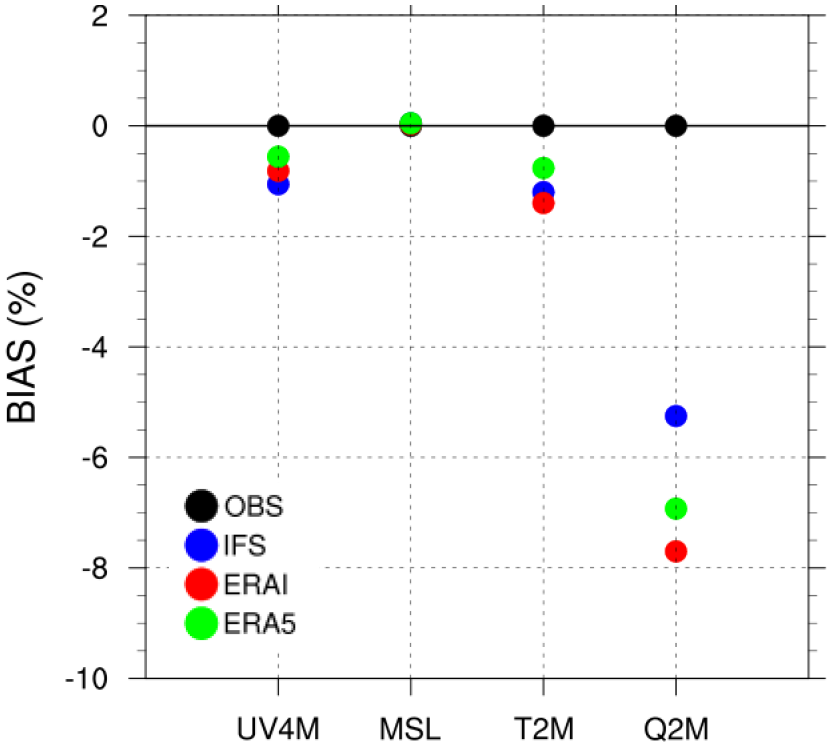
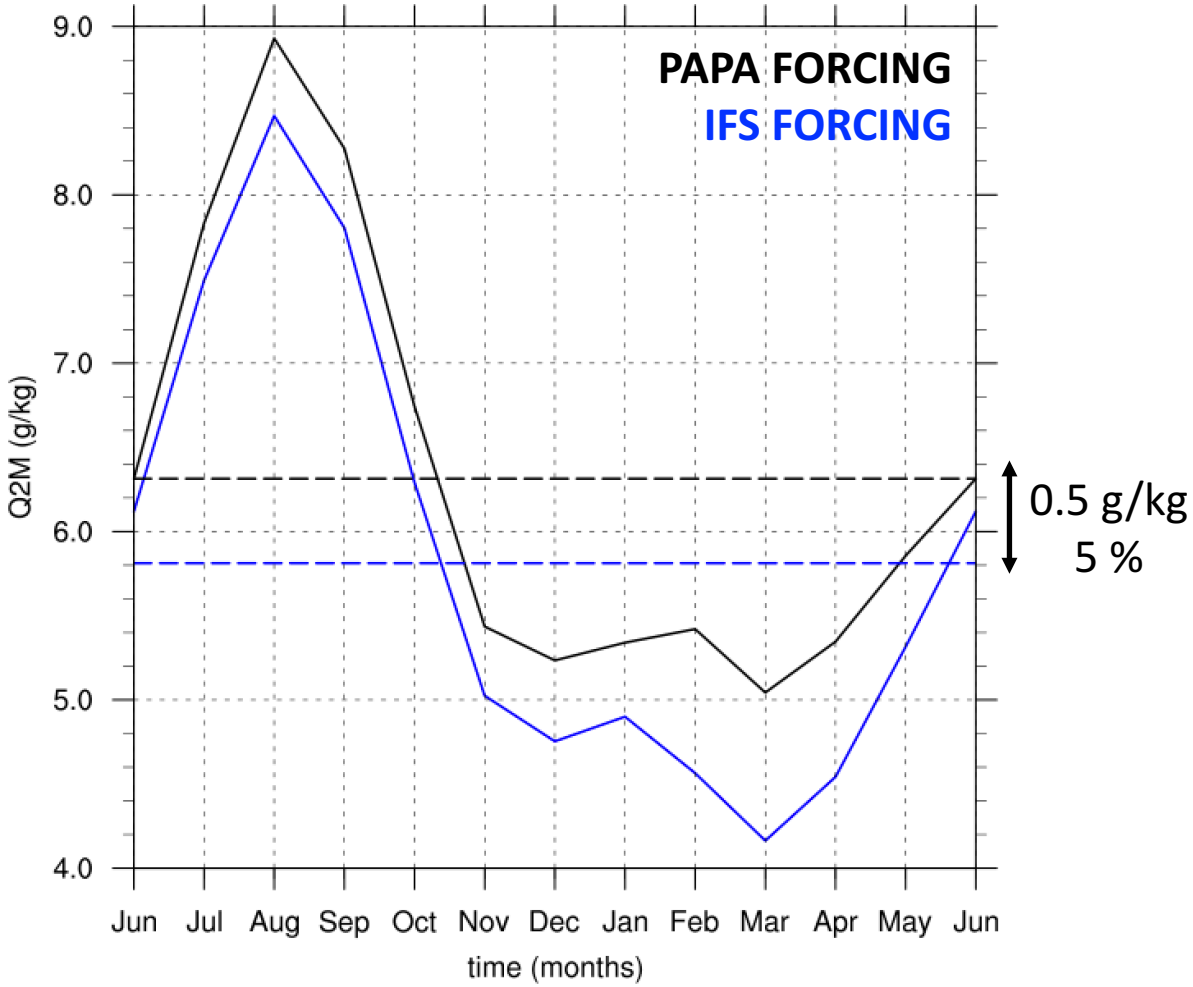


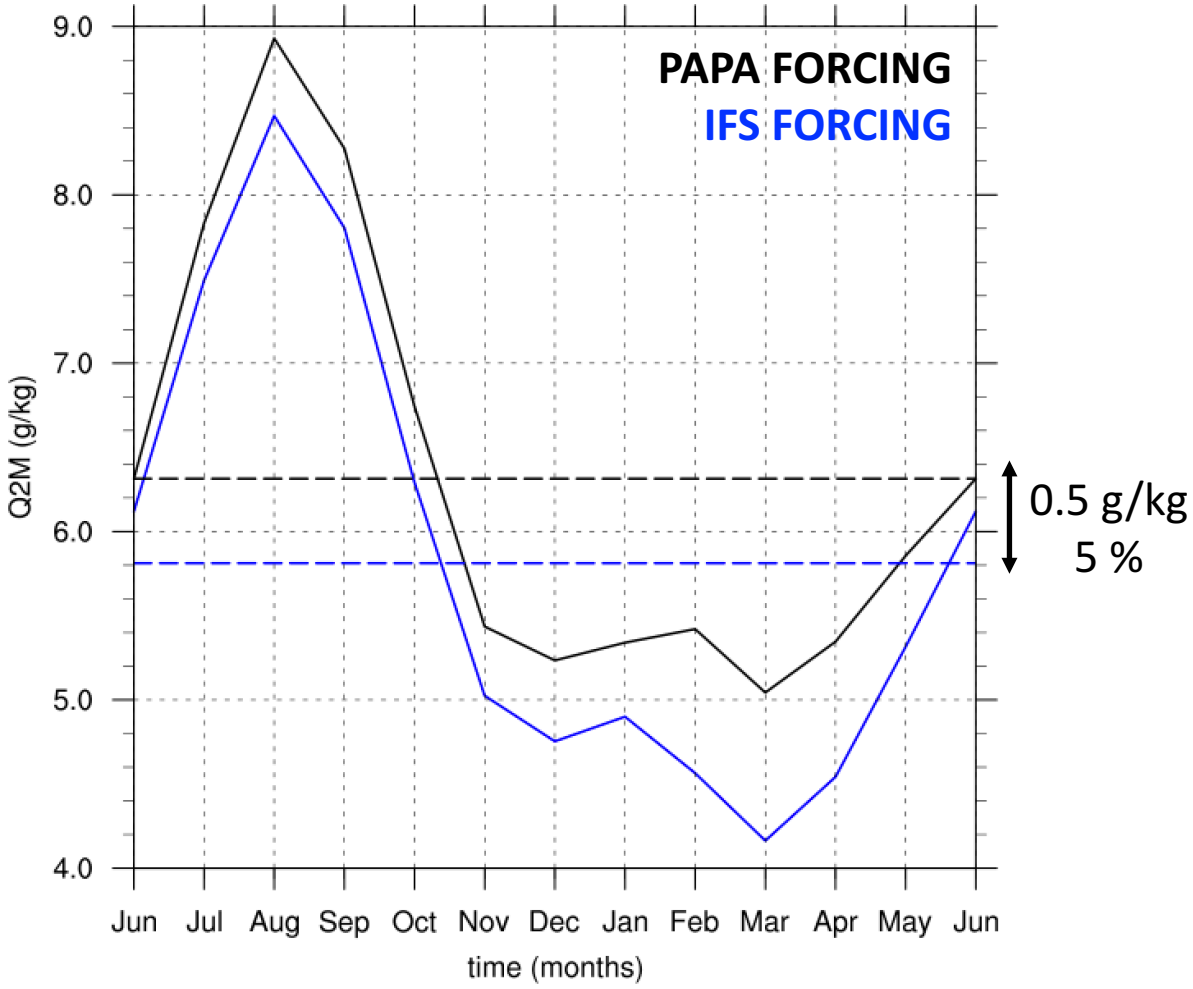

**ECMWF atmospheric variables bias compared to hourly observations over the 2007-2017 period**

# 1 - Sensitivity to atmospheric forcing




**$Q_{2m}$ seasonal cycle**

# 1 - Sensitivity to atmospheric forcing

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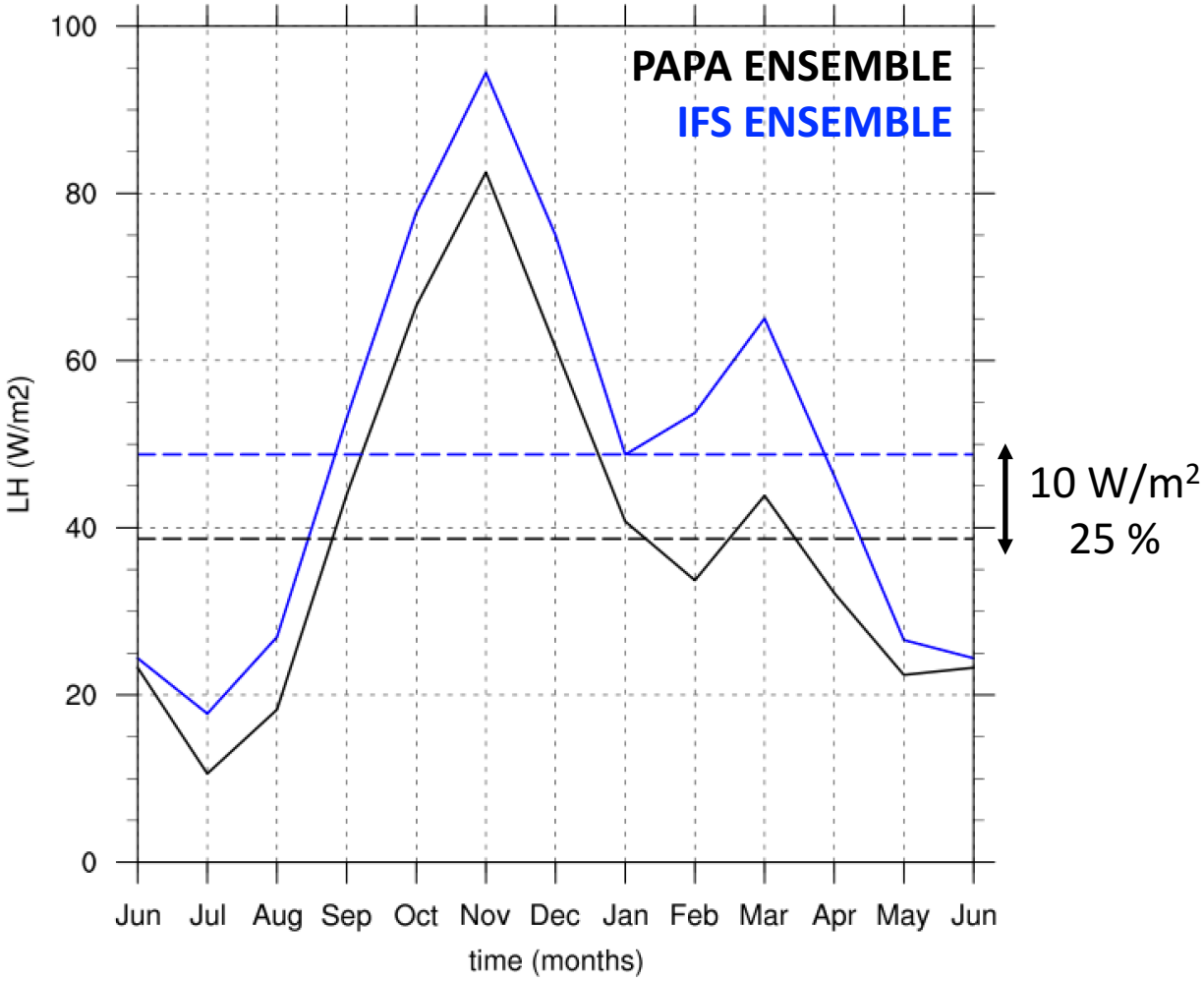


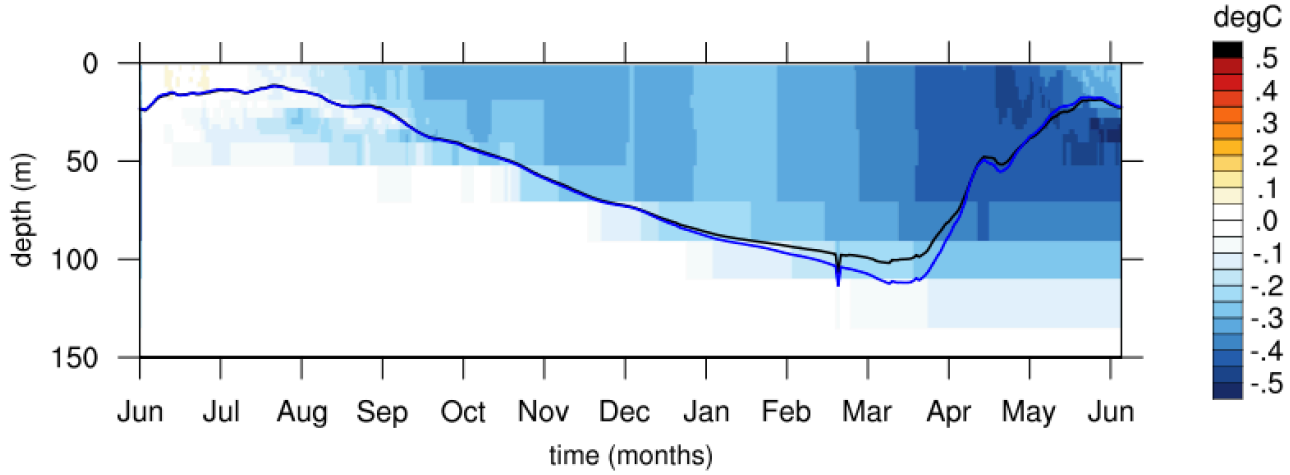

**Latent heat flux seasonal cycle**

# 1 - Sensitivity to atmospheric forcing

**IFS forcing ensemble**

**-**

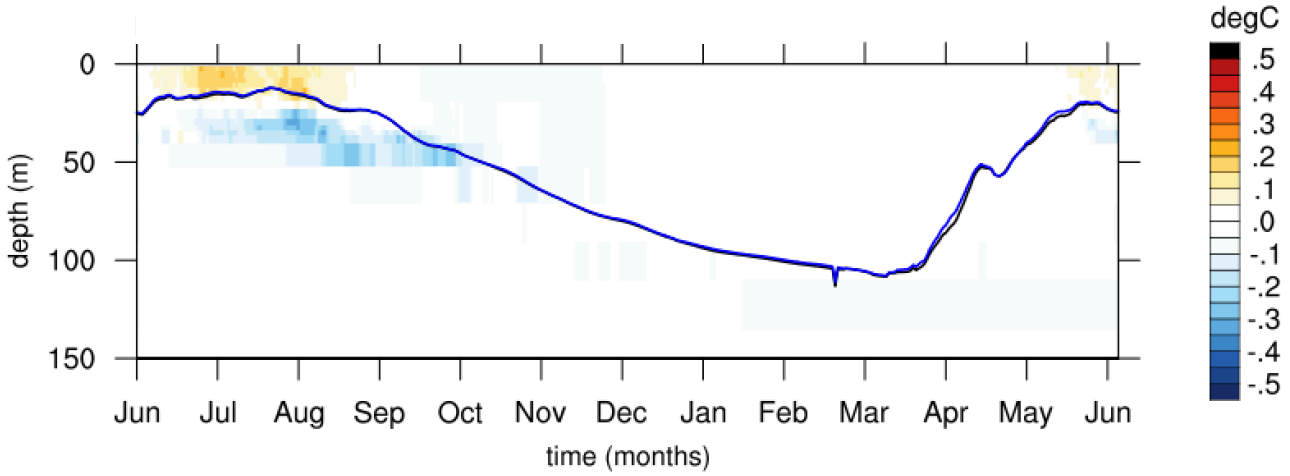
**PAPA forcing ensemble**




**IFS forcing + PAPA $Q_{2m}$ ensemble**

**-**

**PAPA forcing ensemble**




**IFS $Q_{2m}$ bias totally explains temperature differences between IFS and OBS forcing ensembles**

# 2 - Sensitivity to bulk algorithms

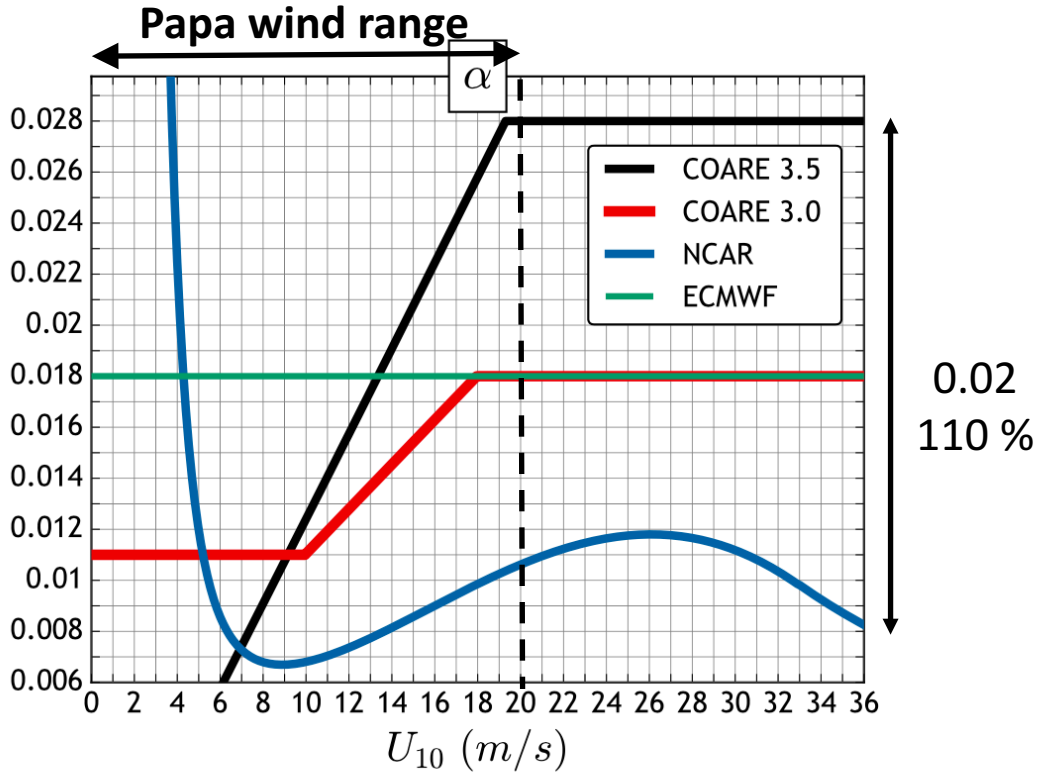

4 x 6 simulations

ECMWF (*Beljaars 1994*)
NCAR (*Large & Yeager 2004, 2009*)
COARE 3 (*Fairall et al. 2003*)
COARE 3.5 (*Edson et al. 2013*)

**Charnock parameters**
(figure from *Brodeau et al. 2017*)

$$z_0 = \frac{0.11\nu}{u*} + \frac{\alpha u*^2}{g}$$

$$C_D^{N10} = \frac{\kappa^2}{[\ln(10/z_0)]^2}$$




0.02
110 %

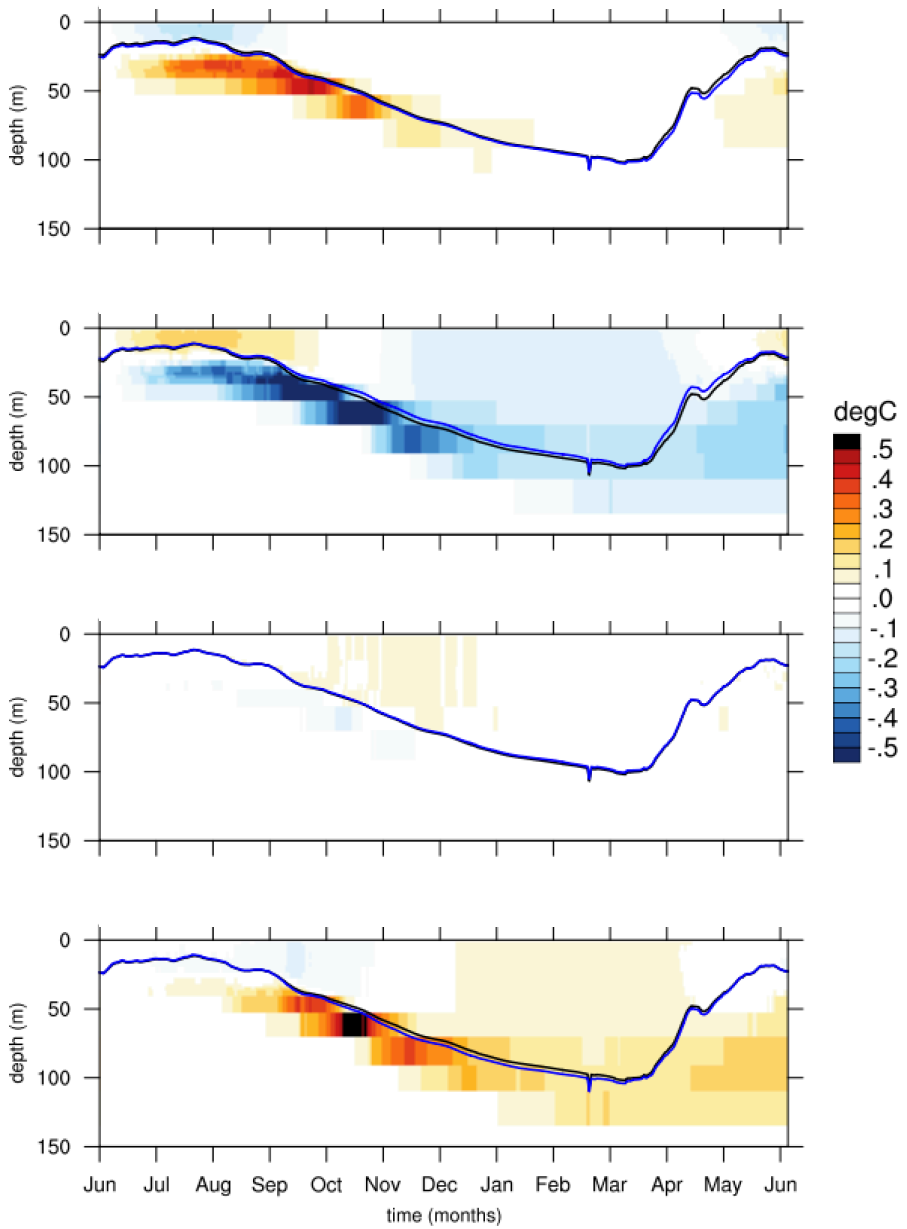
# 2 - Sensitivity to bulk algorithms

**ECMWF bulk ensemble**

**NCAR bulk ensemble**

**COARE3 bulk ensemble**

**COARE3.5 bulk ensemble**




warmer mixed layer base = more mixing

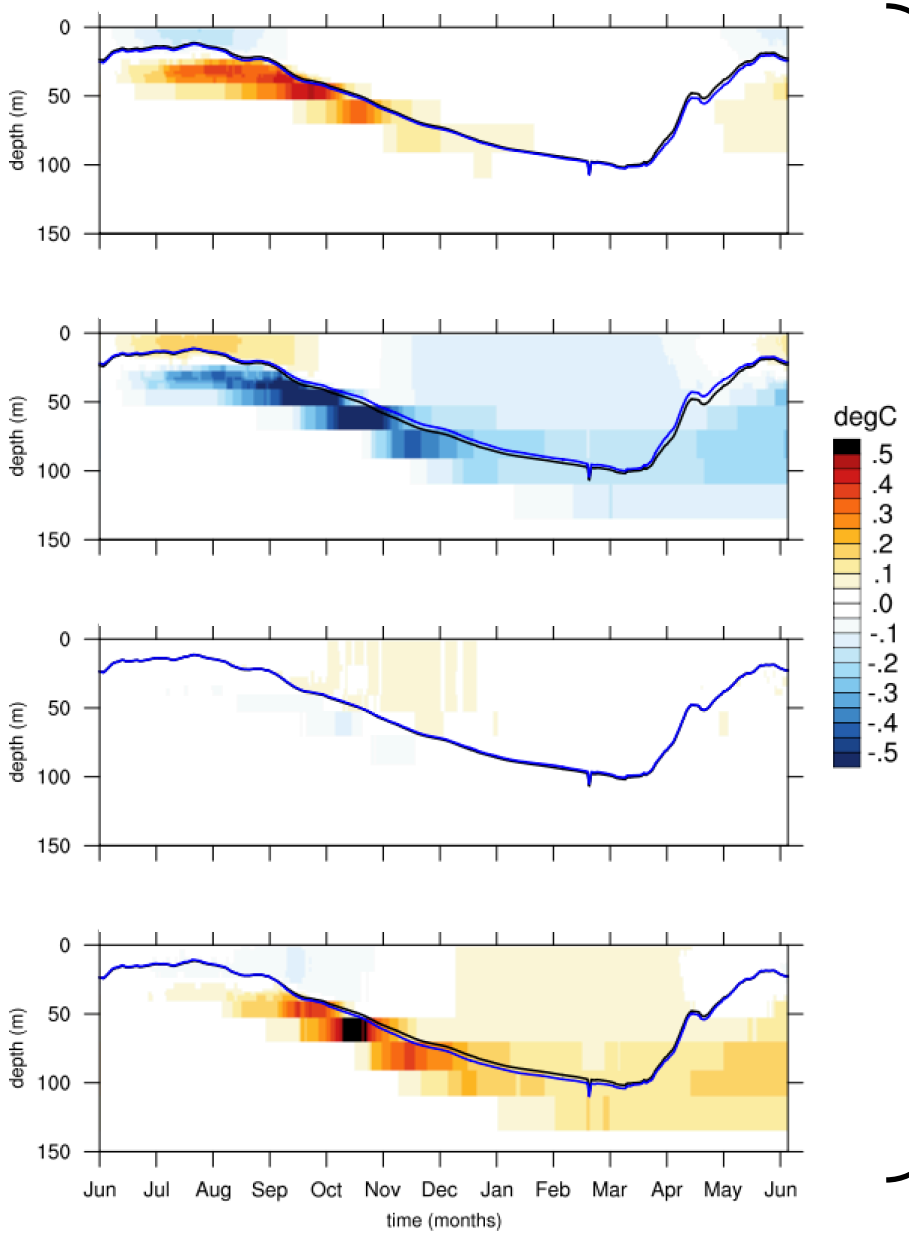
# 2 - Sensitivity to bulk algorithms

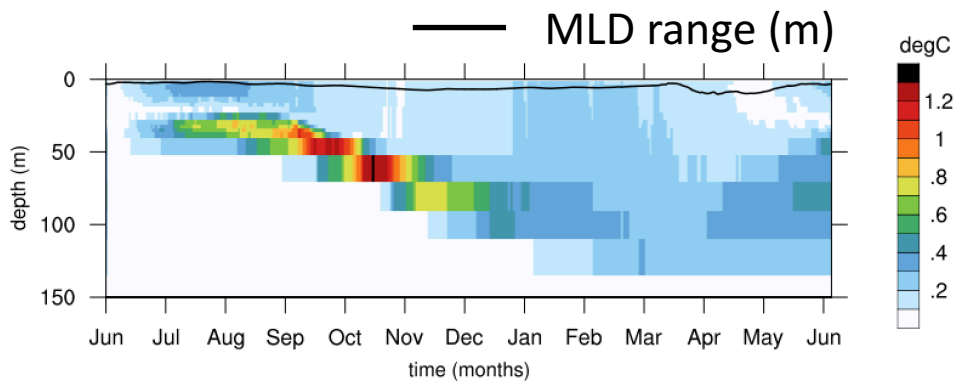
**ECMWF bulk ensemble**

**NCAR bulk ensemble**

**COARE3 bulk ensemble**

**COARE3.5 bulk ensemble**

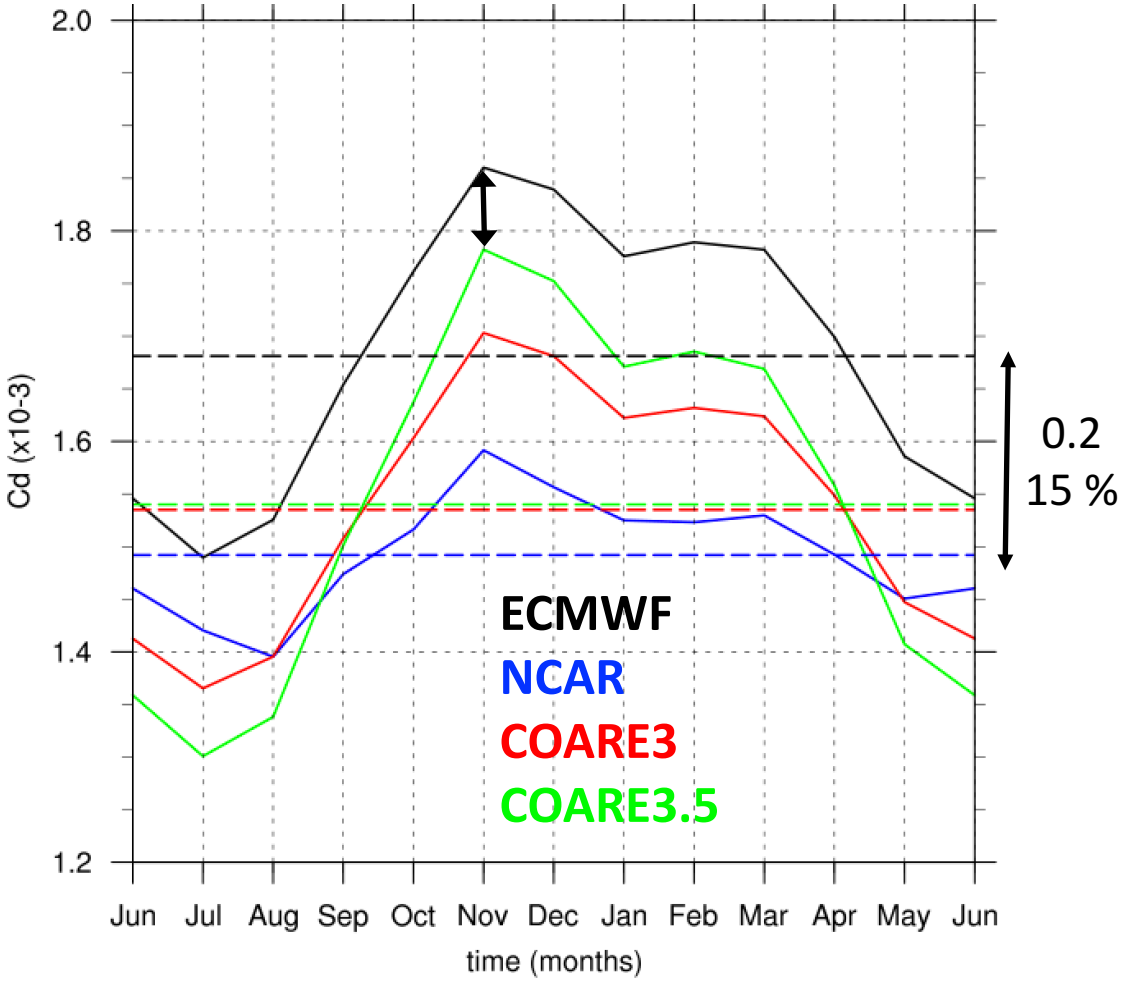


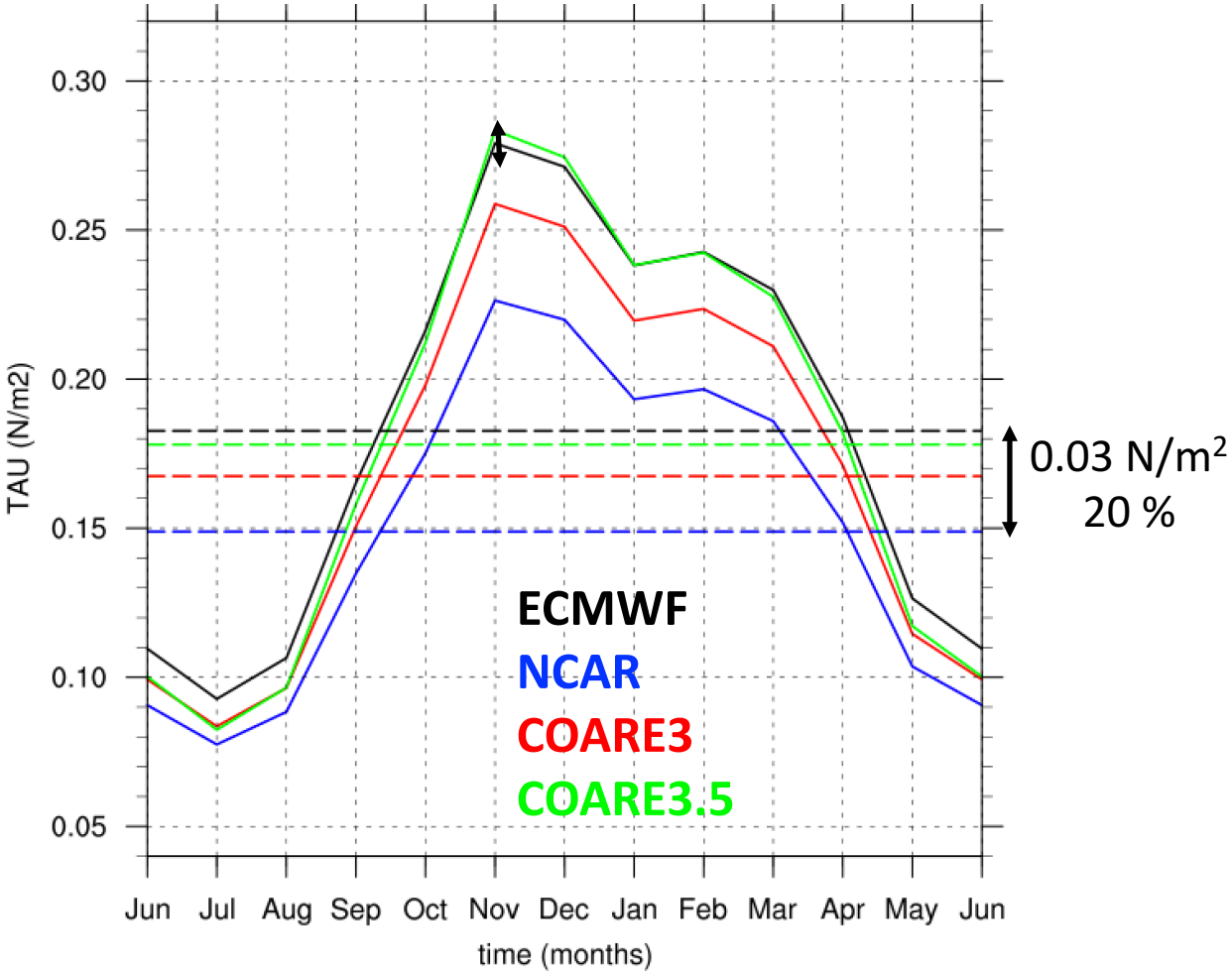

**Bulk Ensemble Range**

**Maximum T spread between NCAR and COARE3.5 = 1.5°C**

# 2 - Sensitivity to bulk algorithms

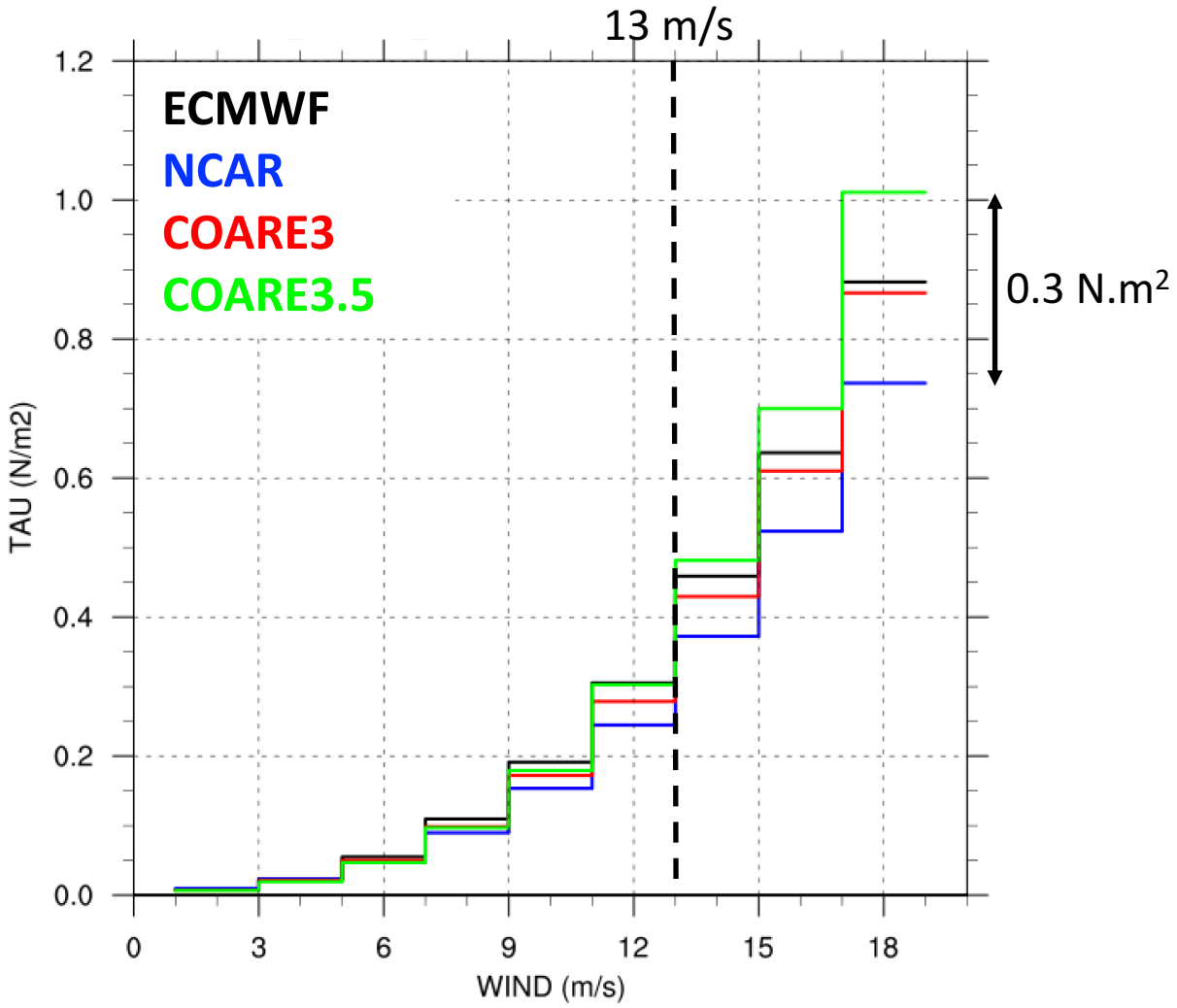



**Drag coefficient seasonal cycle**




**Wind stress seasonal cycle**

# 2 - Sensitivity to bulk algorithms



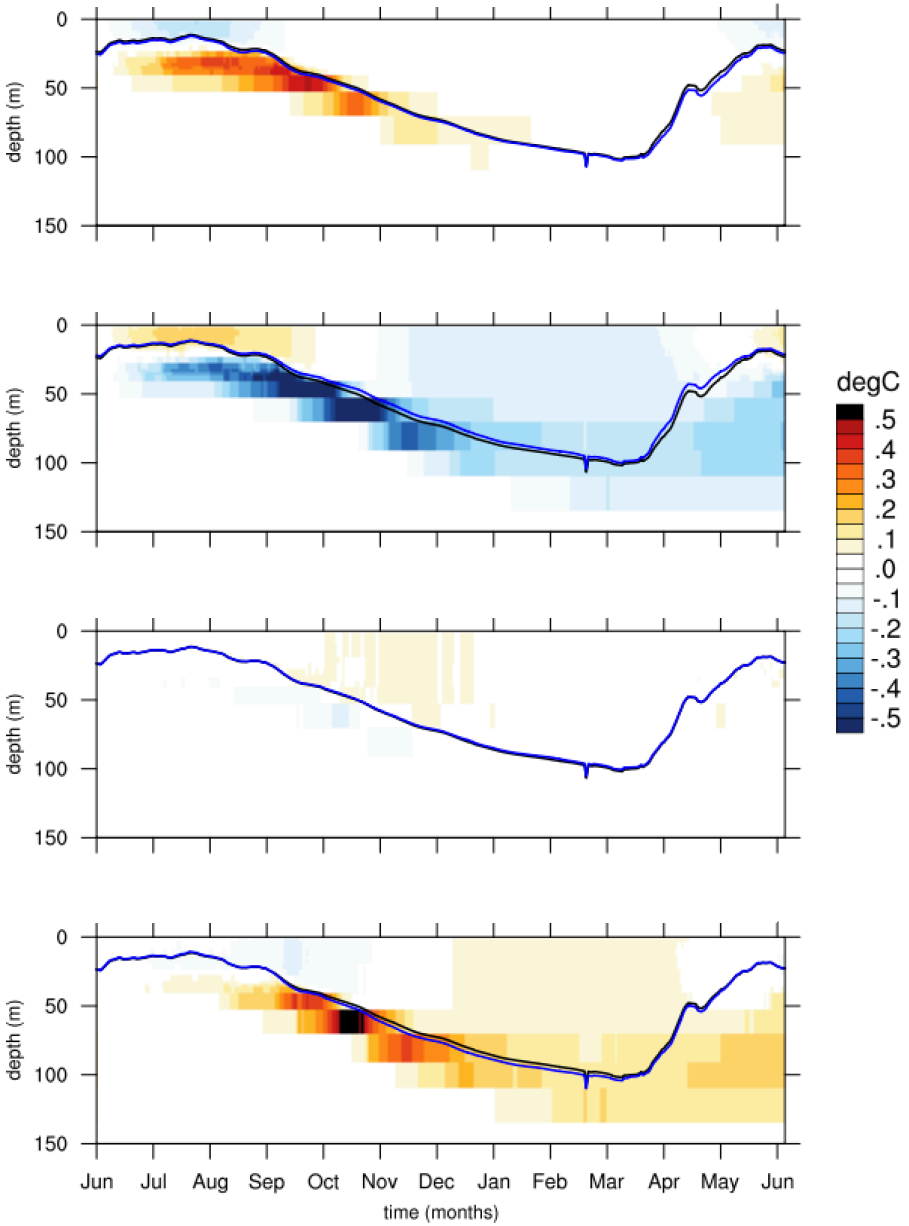

**Wind-binned averaged wind stress**

**ECMWF bulk ensemble**

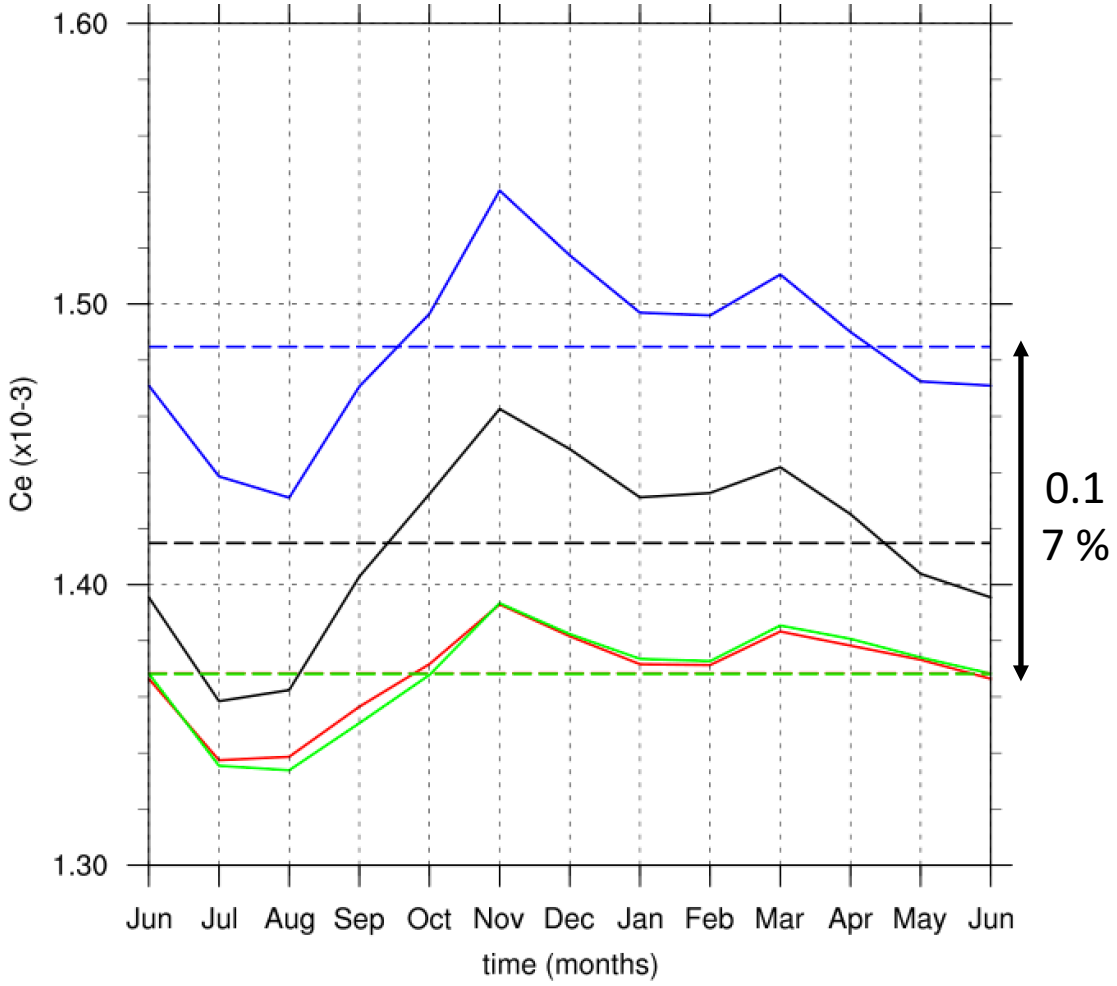
**NCAR bulk ensemble**

**COARE3 bulk ensemble**

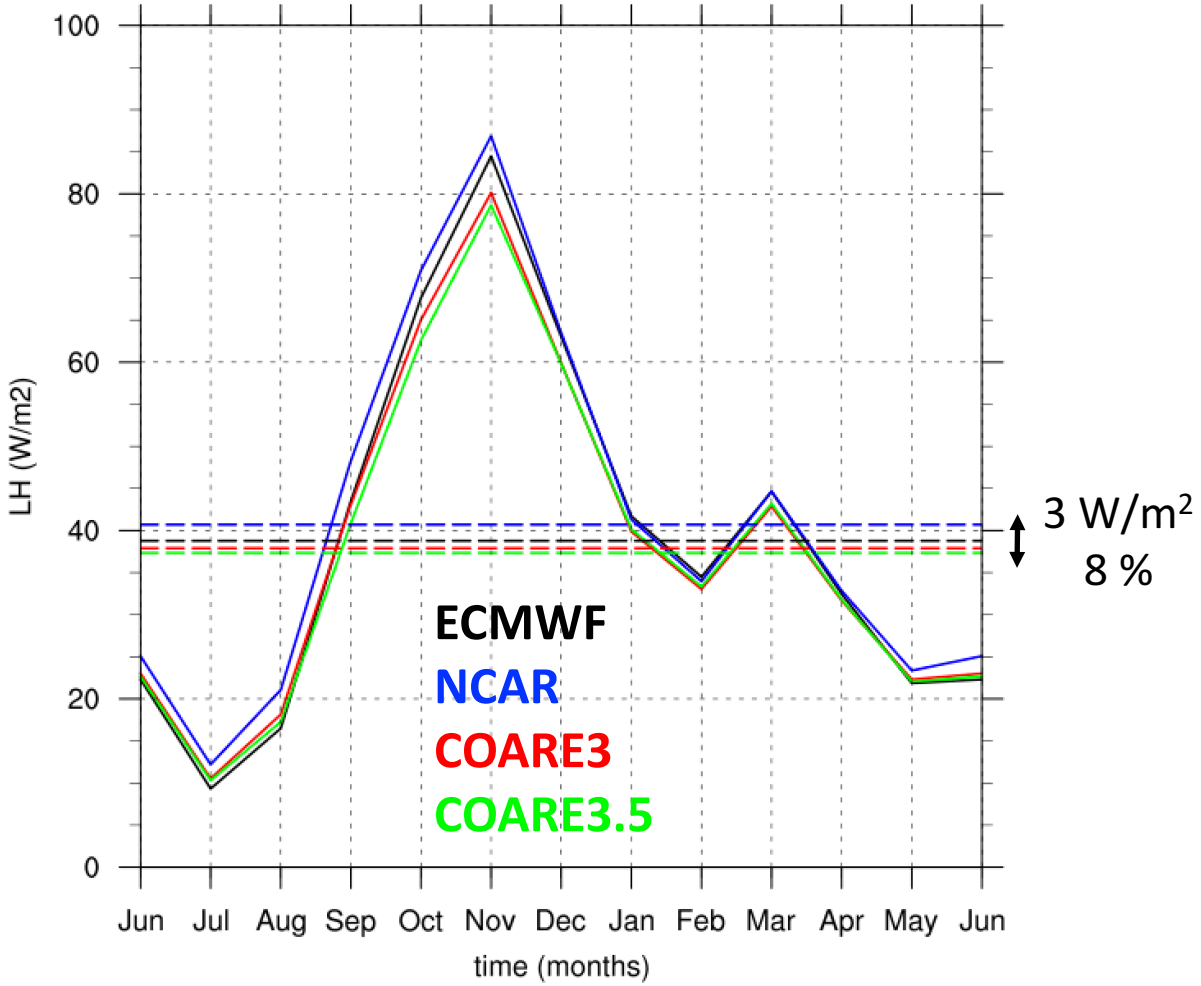
**COARE3.5 bulk ensemble**



# 2 - Sensitivity to bulk algorithms




**Moisture transfer coefficient seasonal cycle**




**Latent heat flux seasonal cycle**

# 3 - Sensitivity to vertical mixing

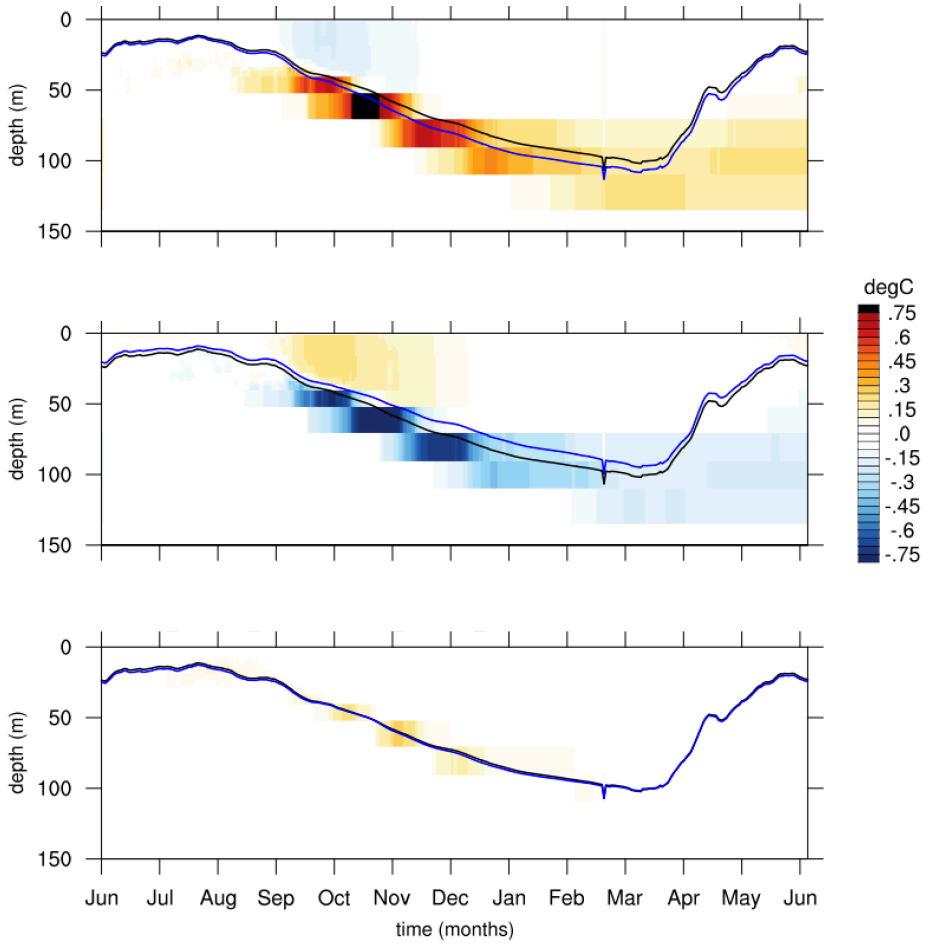

3 x 8 simulations

TKE (*Blanke & Delecluse 1993*)
k-epsilon (*Rodi 1987*) via GLS closure (*Umlauf and Burchard 2003*)
Mellor-Yamada (*1982*) via GLS closure

**K-EPSILON ensemble**

**TKE ensemble**

**MY82 ensemble**



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VERTICAL MIXING

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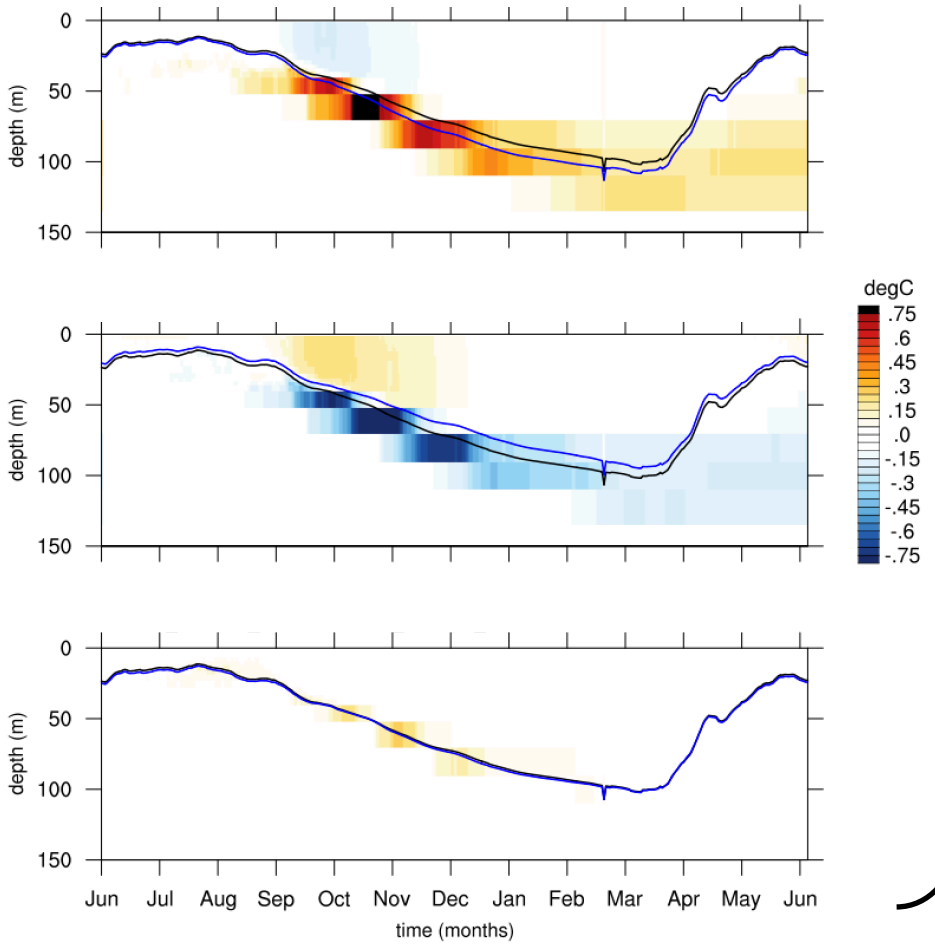
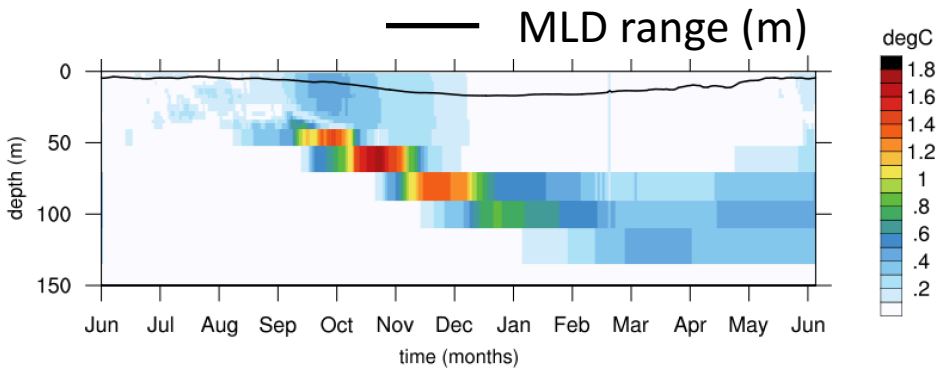
**TKE ensemble**

**MY82 ensemble**

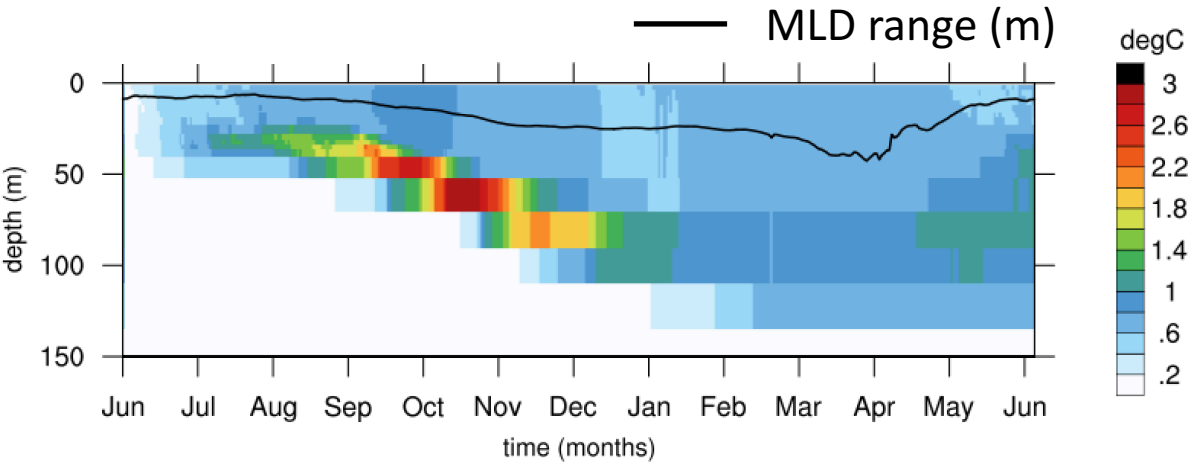



**Vertical Mixing Ensemble Range**

**Maximum T spread at ML base between TKE and K-EPS = 2°C**

# Relative contributions to upper ocean spread




**Full ensemble range (spread)**

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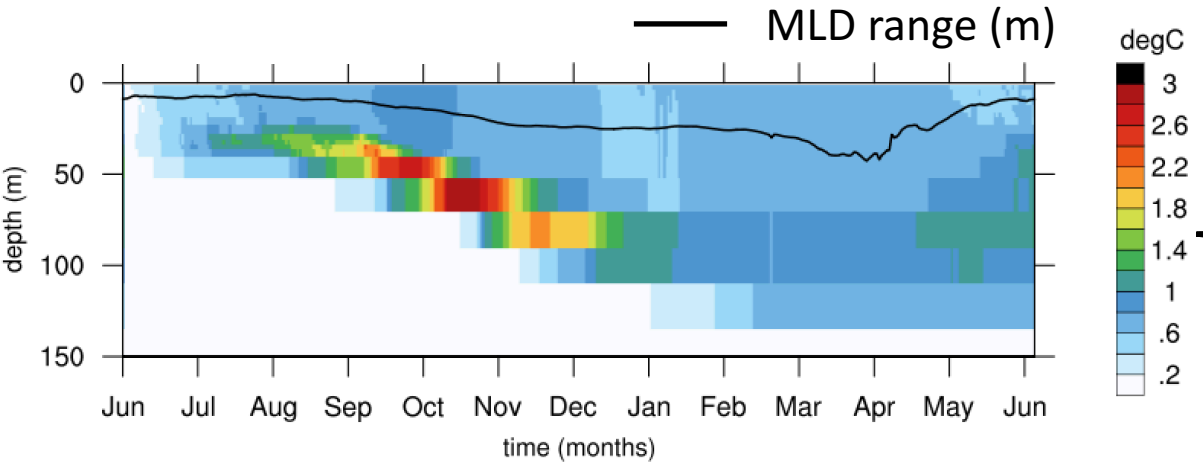
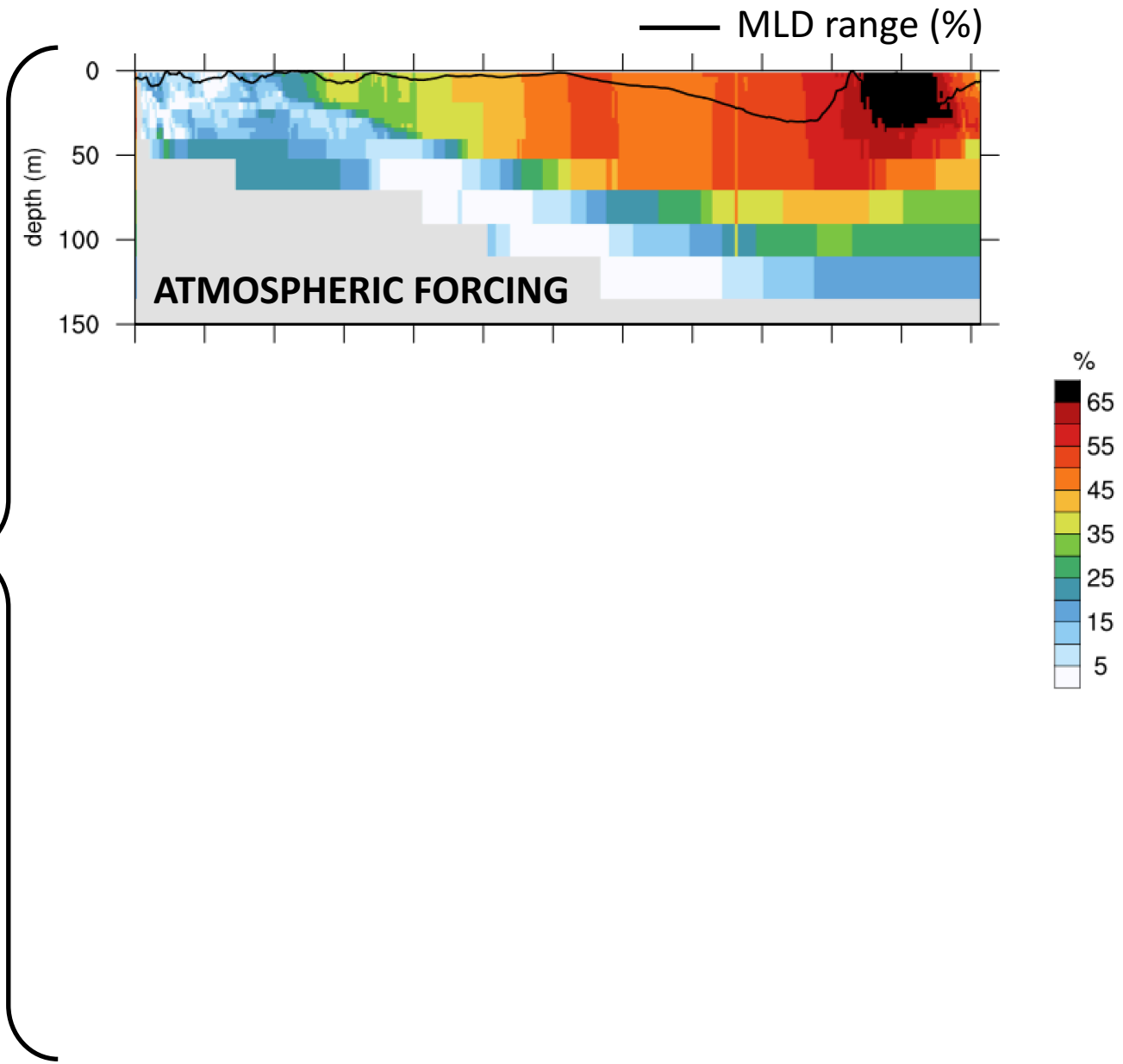



**Full ensemble range (spread)**



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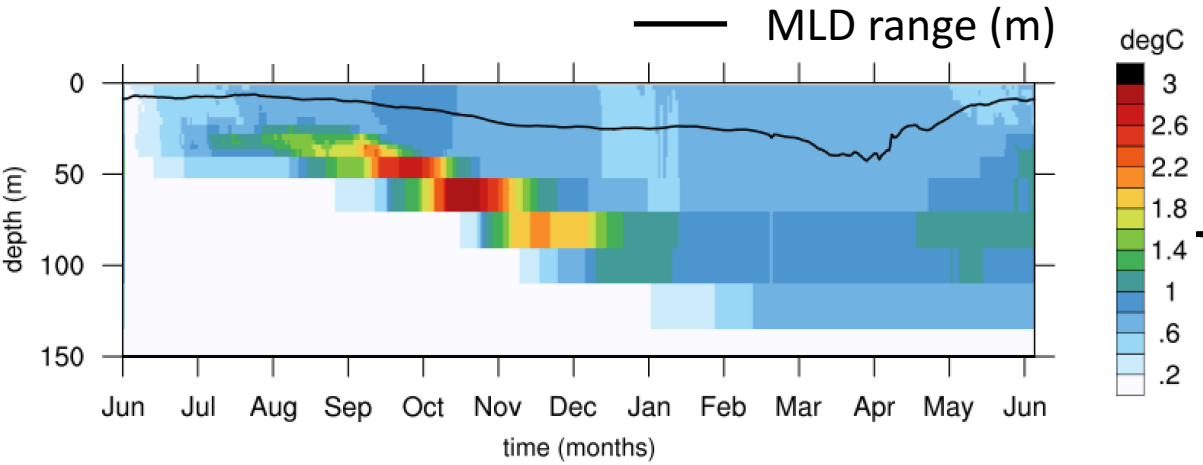


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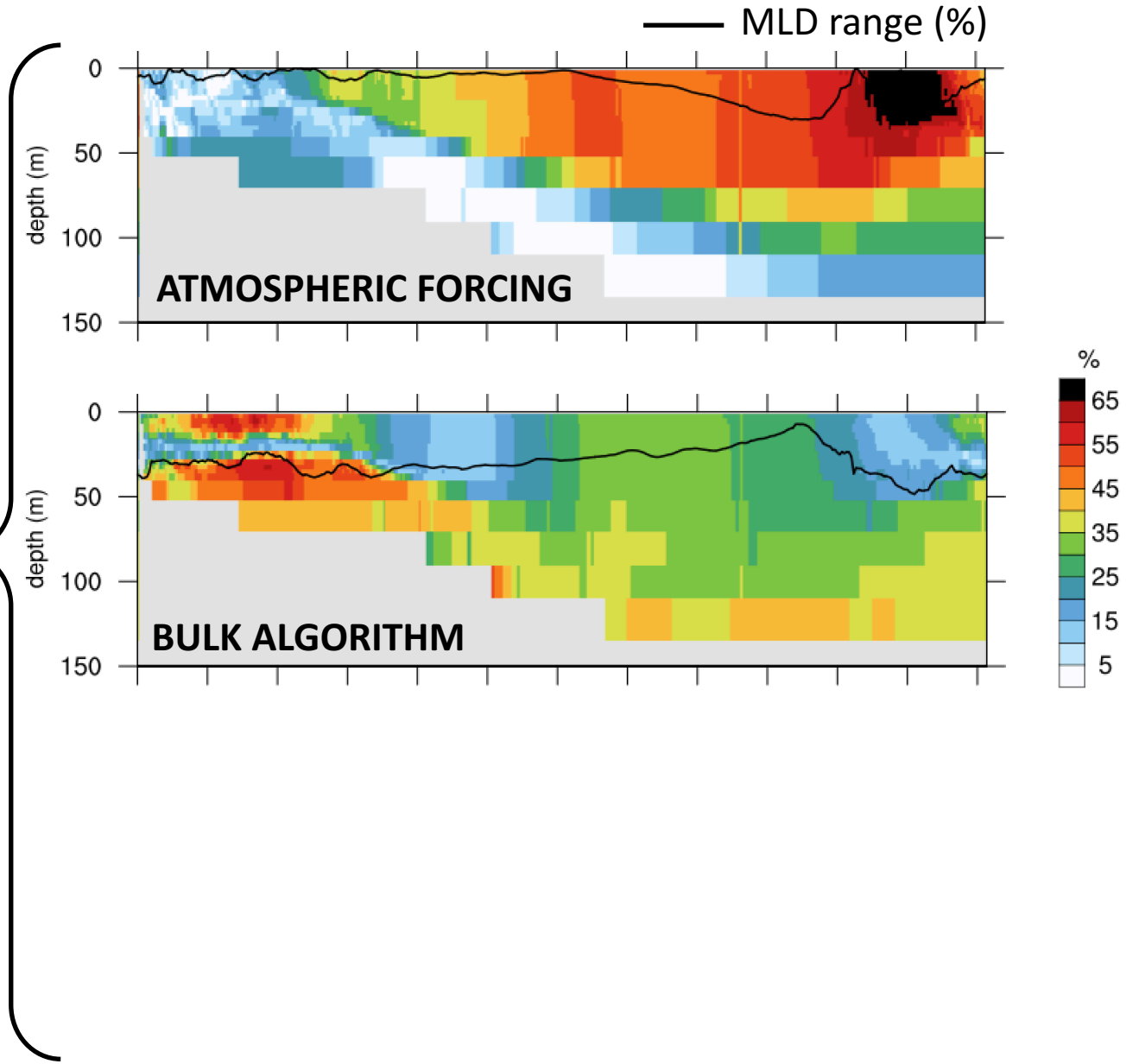

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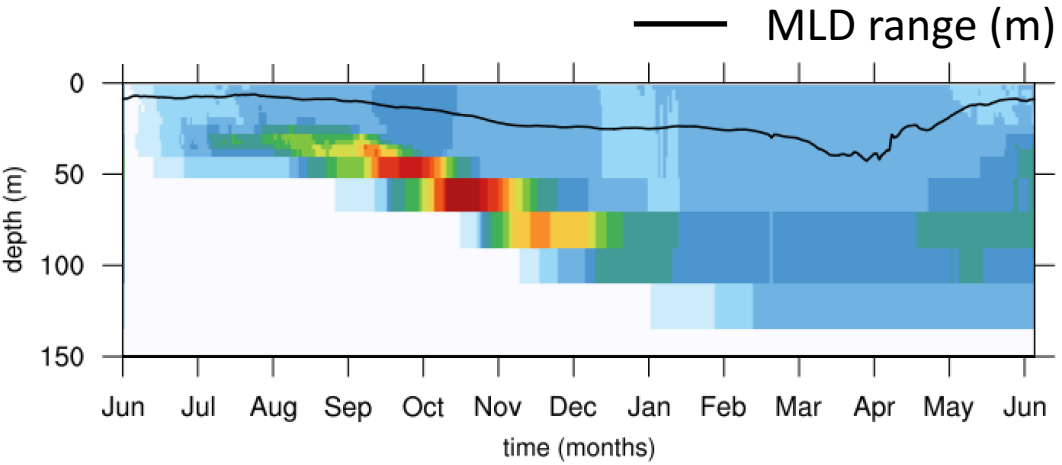
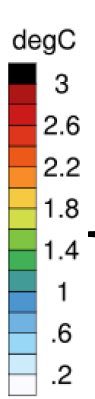
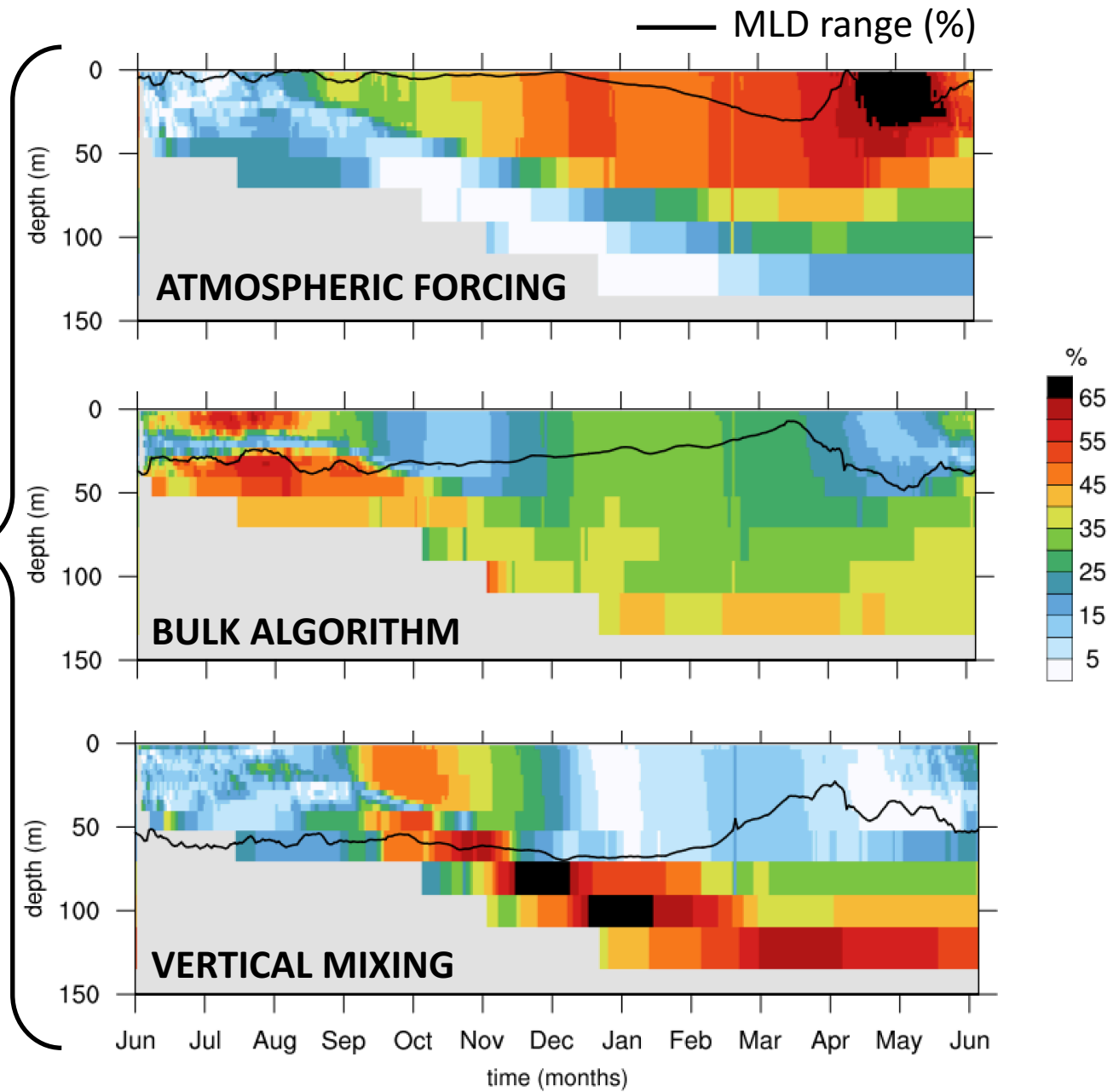



**Full ensemble range (spread)**



# Conclusions

**1D ocean modeling** combined with **Papa station observations** = simple, efficient and robust framework to understand and quantify upper ocean sensitivity to vertical processes

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OCEAN FORECASTERS

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**1. Atmospheric forcing**

ECMWF dry bias (0.5 $g.kg^{-1}$ / 5 %) → latent heat flux overestimation (10 $W.m^{-2}$ / 25 %)
→ colder mixed layer (0.5°C / 60 % of the spread in the ML in spring)

**2. Bulk algorithms**

- Large spread between drag coefficients (0.2 / 15 %) and between wind stress (0.03 $N.m^{-2}$ / 20 %).
→ 1.5°C T spread at the ML base, 0.5° in the ML (50 % of the spread in summer, 30 % otherwise).
- NCAR and COARE3.5 algorithms produce the most different turbulent fluxes and oceanic responses.

**3. Vertical mixing**

- Vertical mixing schemes produce a large T spread (2°C / 60 %) at the ML base, but the spread is negligible inside the ML compared to bulk algorithms (30 %) and atmospheric forcings (60 %).