OCEAN-ATMOSPHERE COUPLING IN THE MEDITERRANEAN: ROLE OF OCEANIC EXCHANGES AT THE STRAIT OF GIBRALTAR

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INTRODUCTION

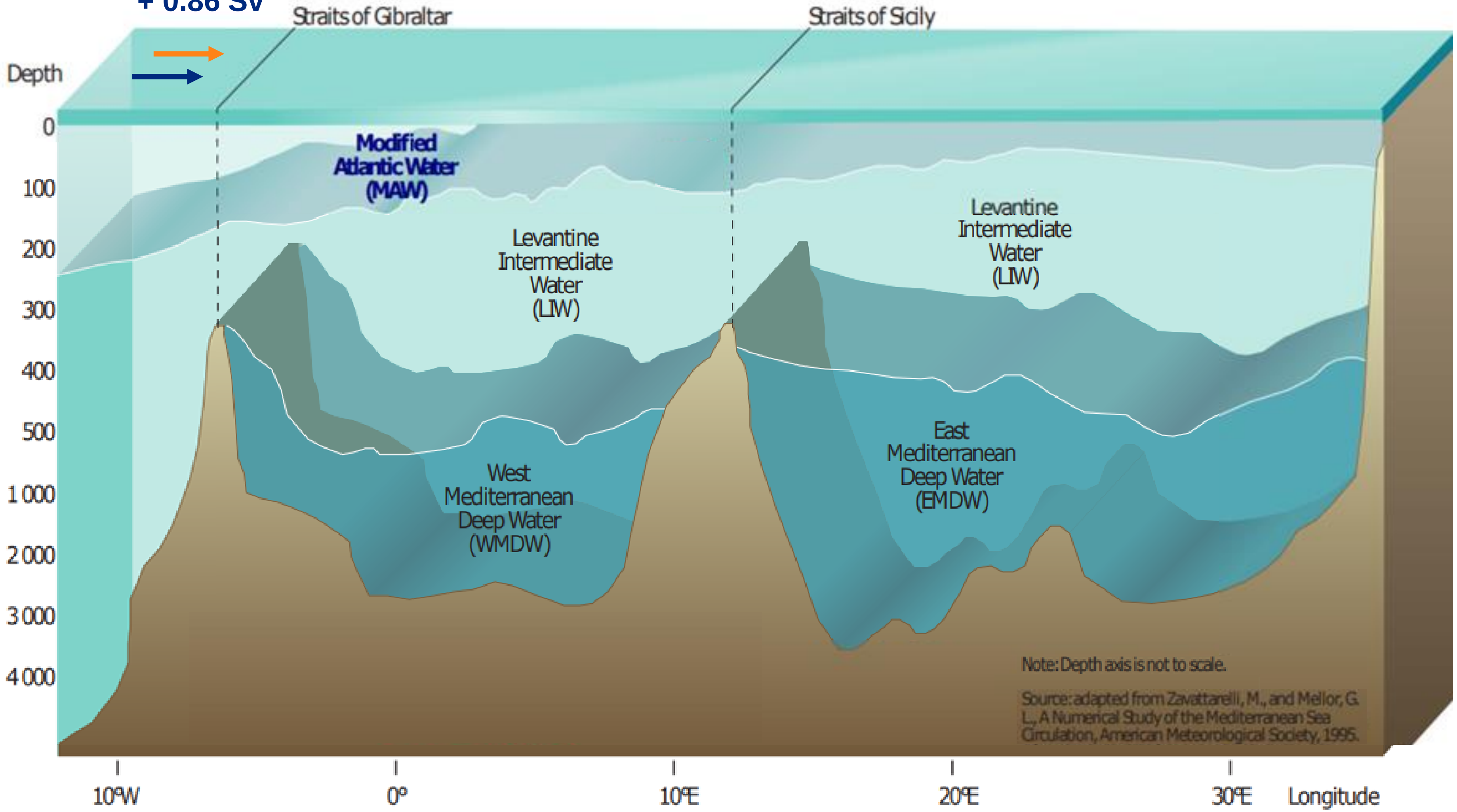
SoG = Strait of Gibraltar

Mediterranean Sea: Volume, heat and salt budgets are closed at the SoG

Jorda et al. 2017

+ 4.5 $W.m^{-2}$

+ 0.86 Sv



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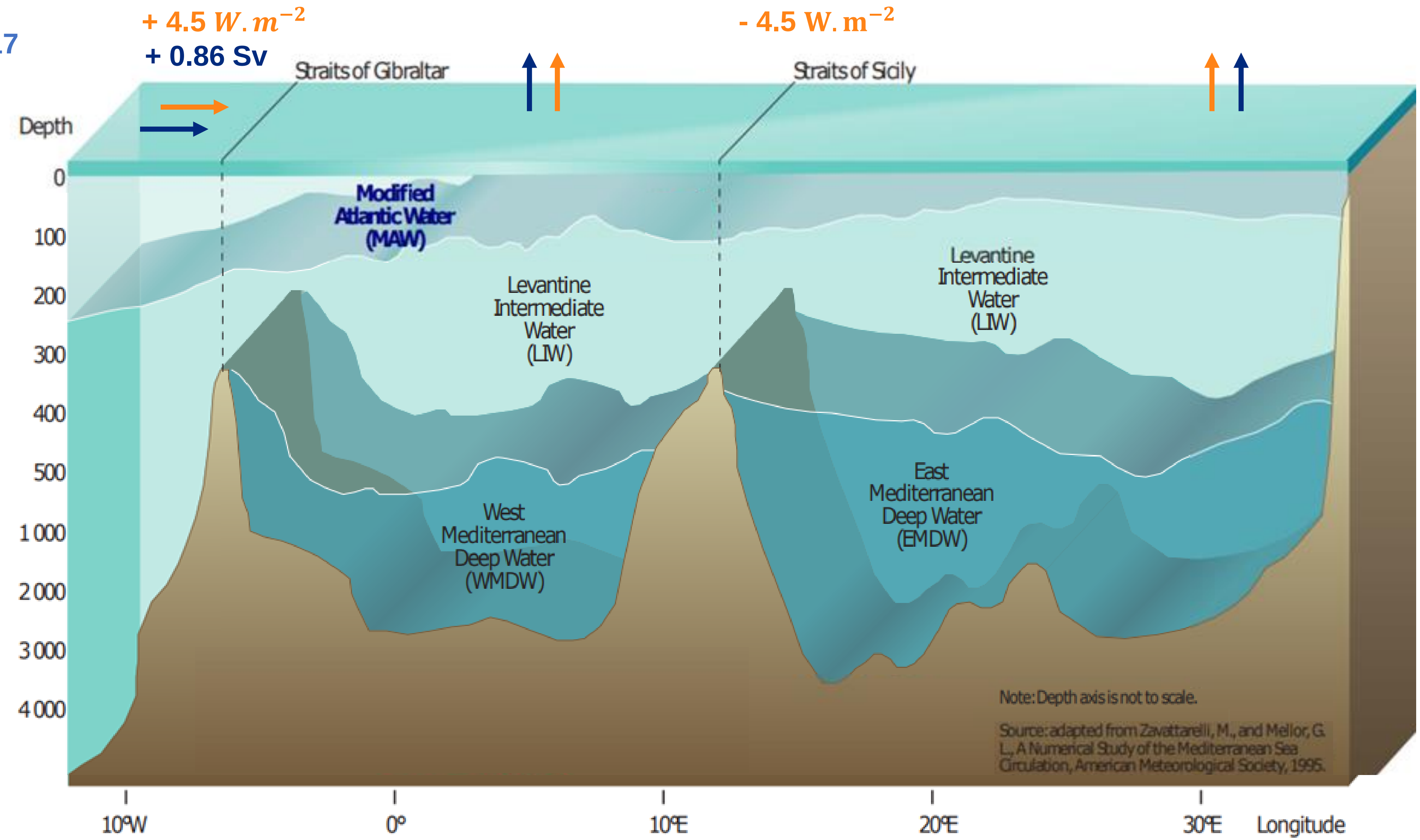

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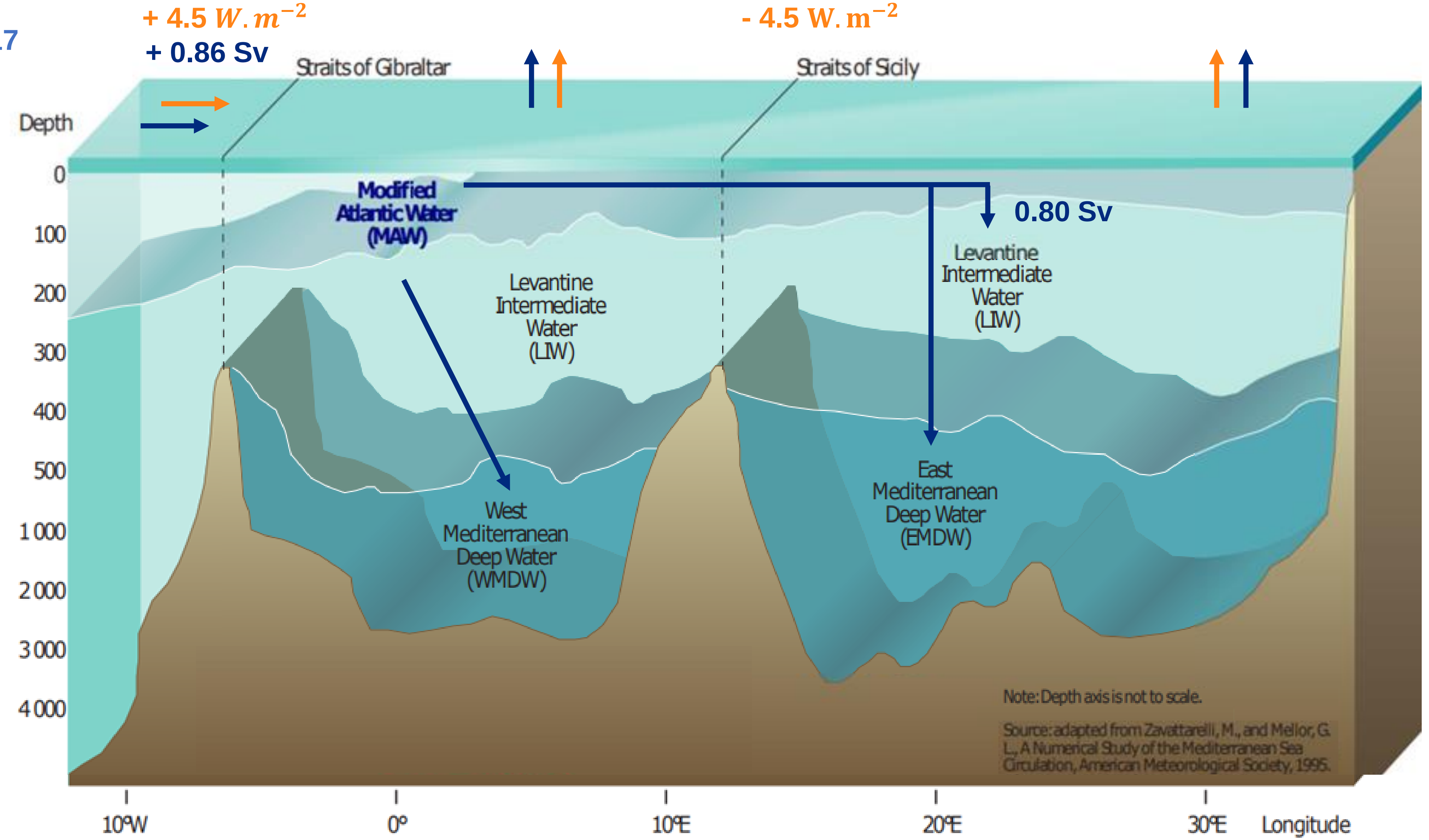

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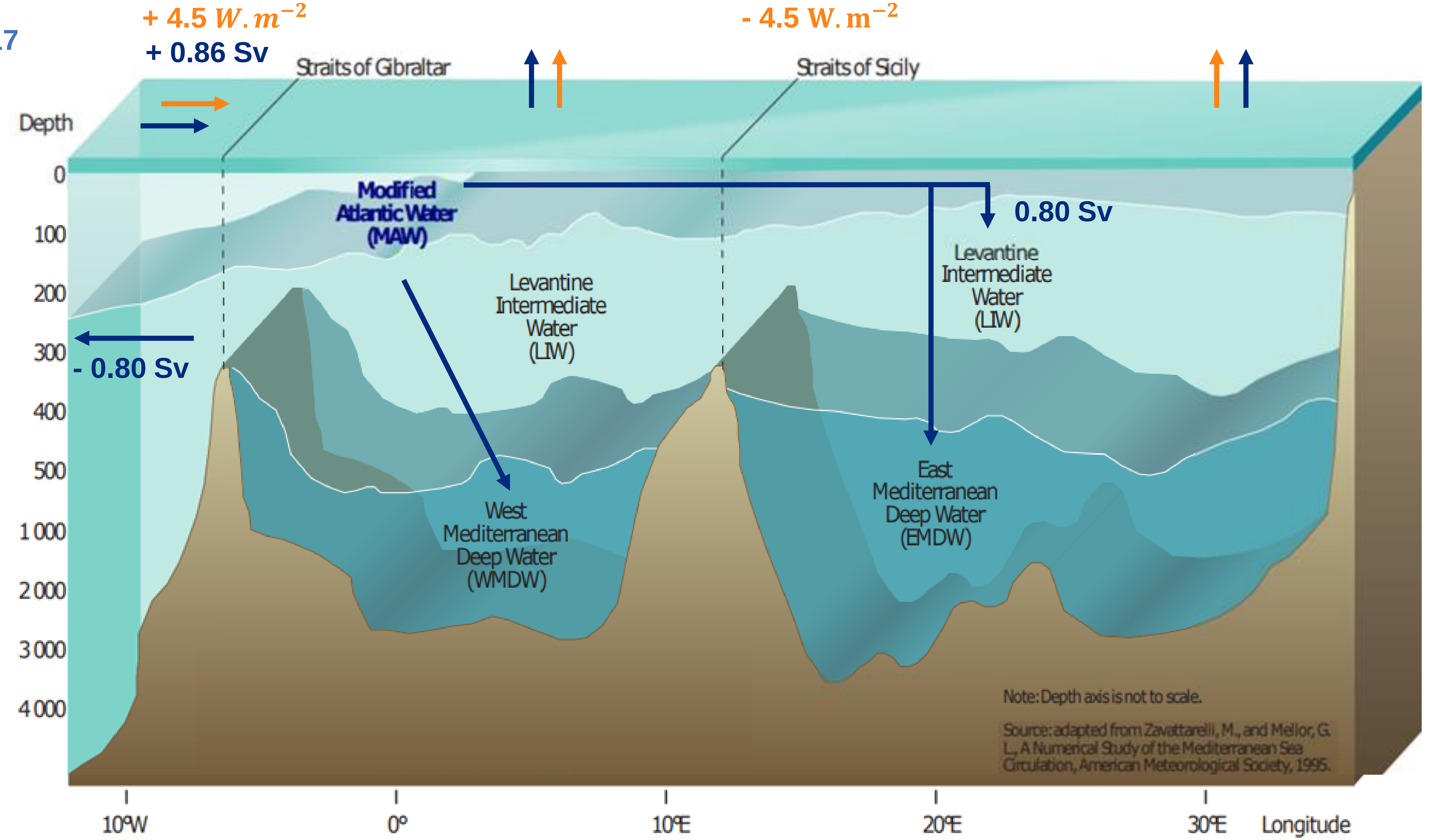

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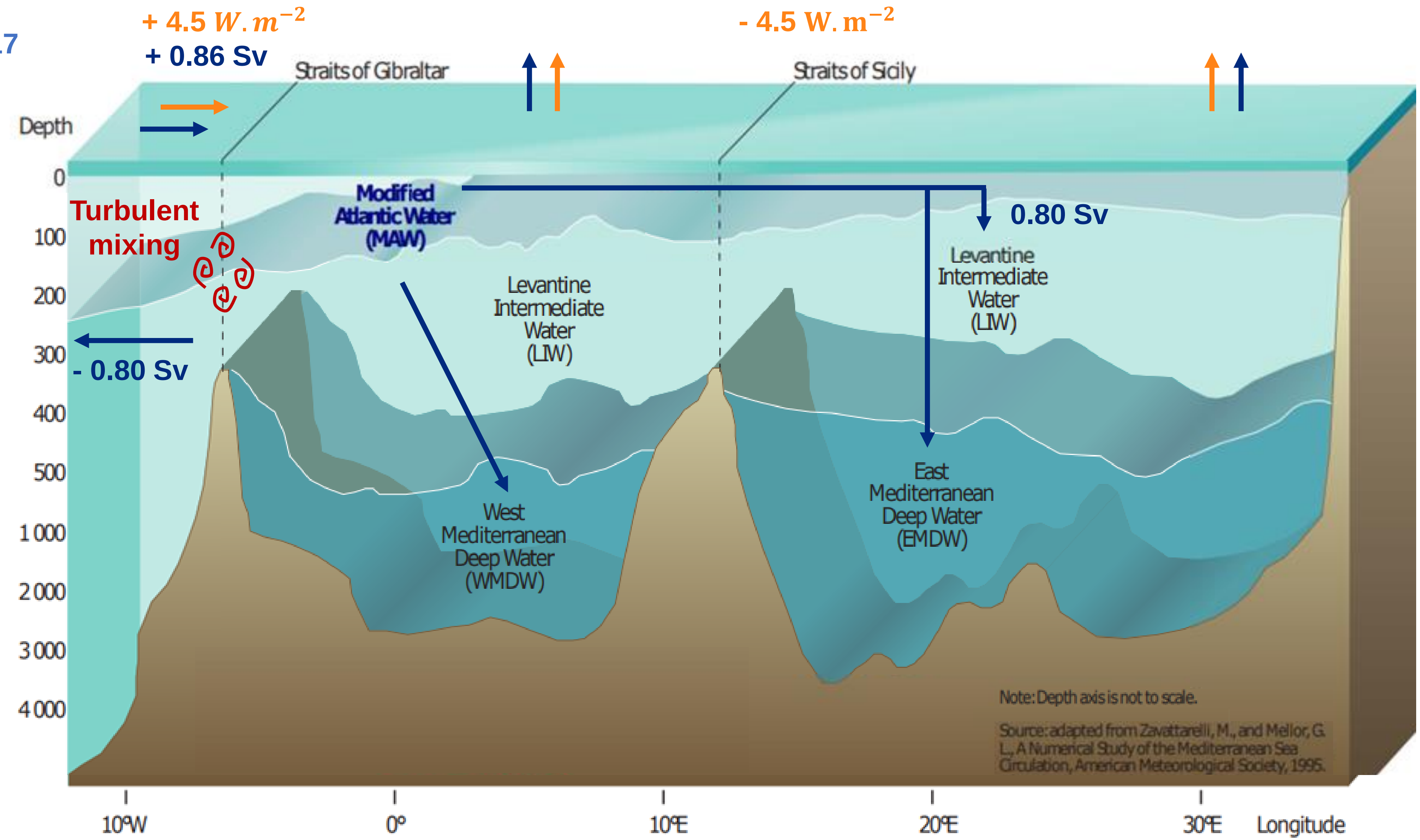
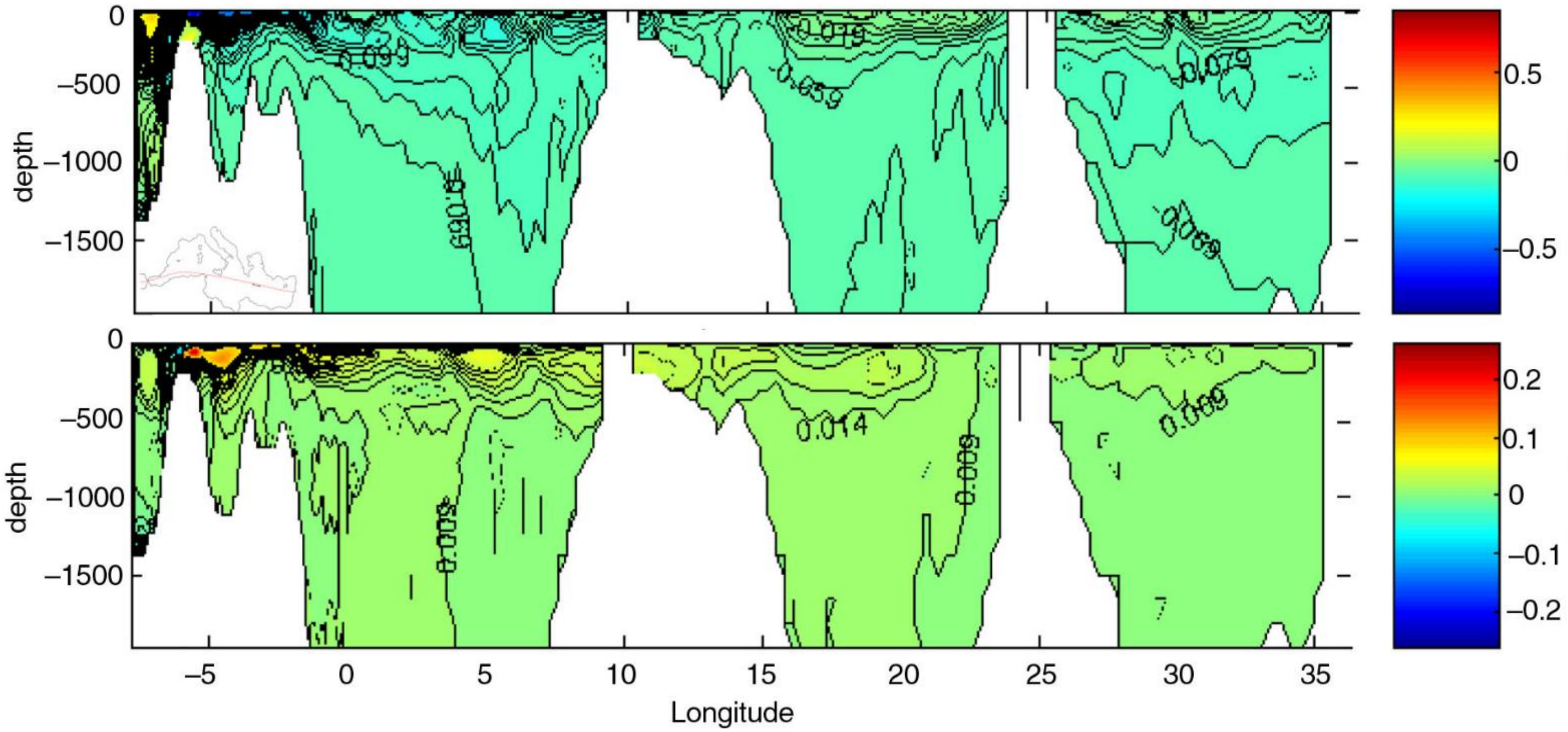


On climatic scales: Basin-scale impact of turbulent mixing at the SoG

Figs 15 and 16 Harzallah et al. 2014
Zonal section of temperature and salinity anomalies induced by tidal mixing at the SoG (1998-2007 average)



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- Over 50-year-long simulations: **General cooling and saltening** ($\sim -0.08°C$ and $0.012psu$)

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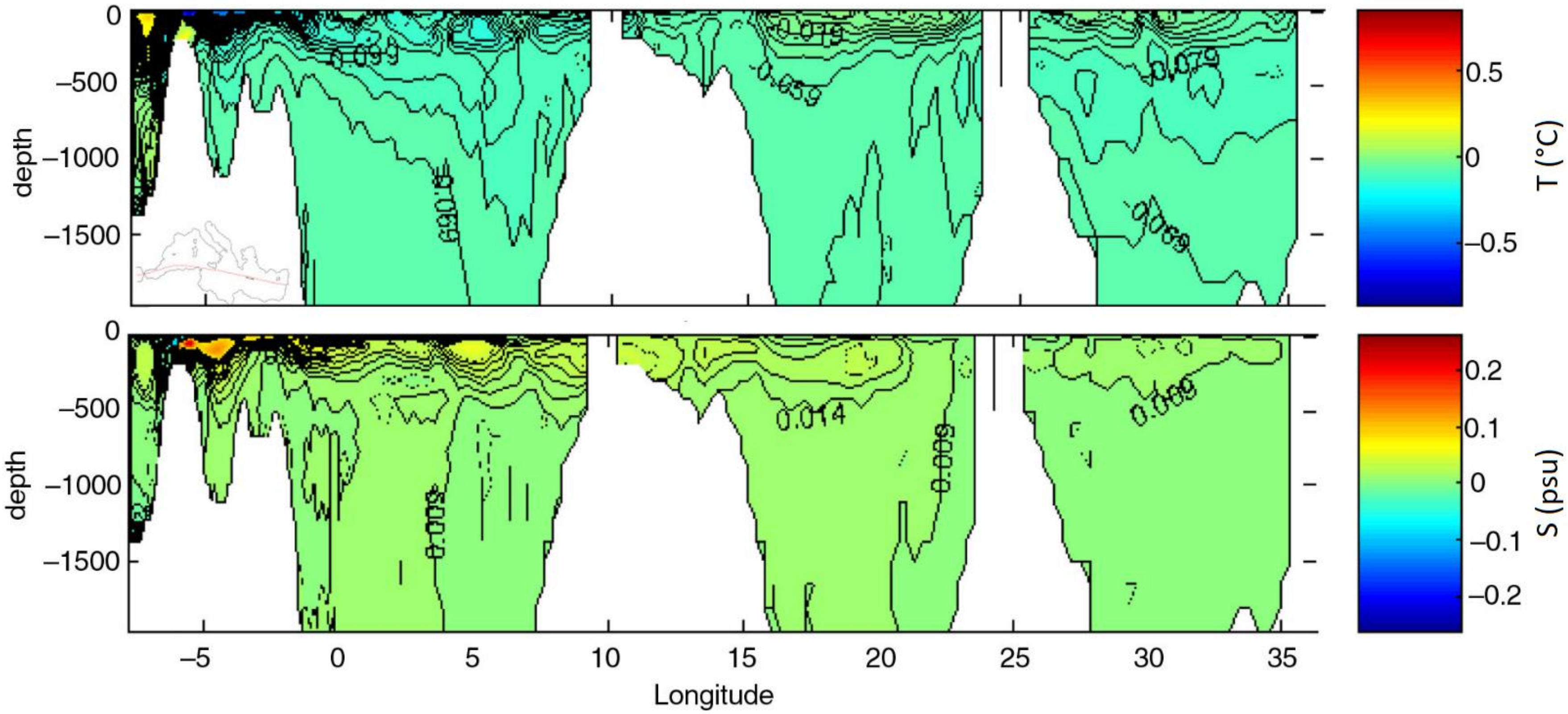

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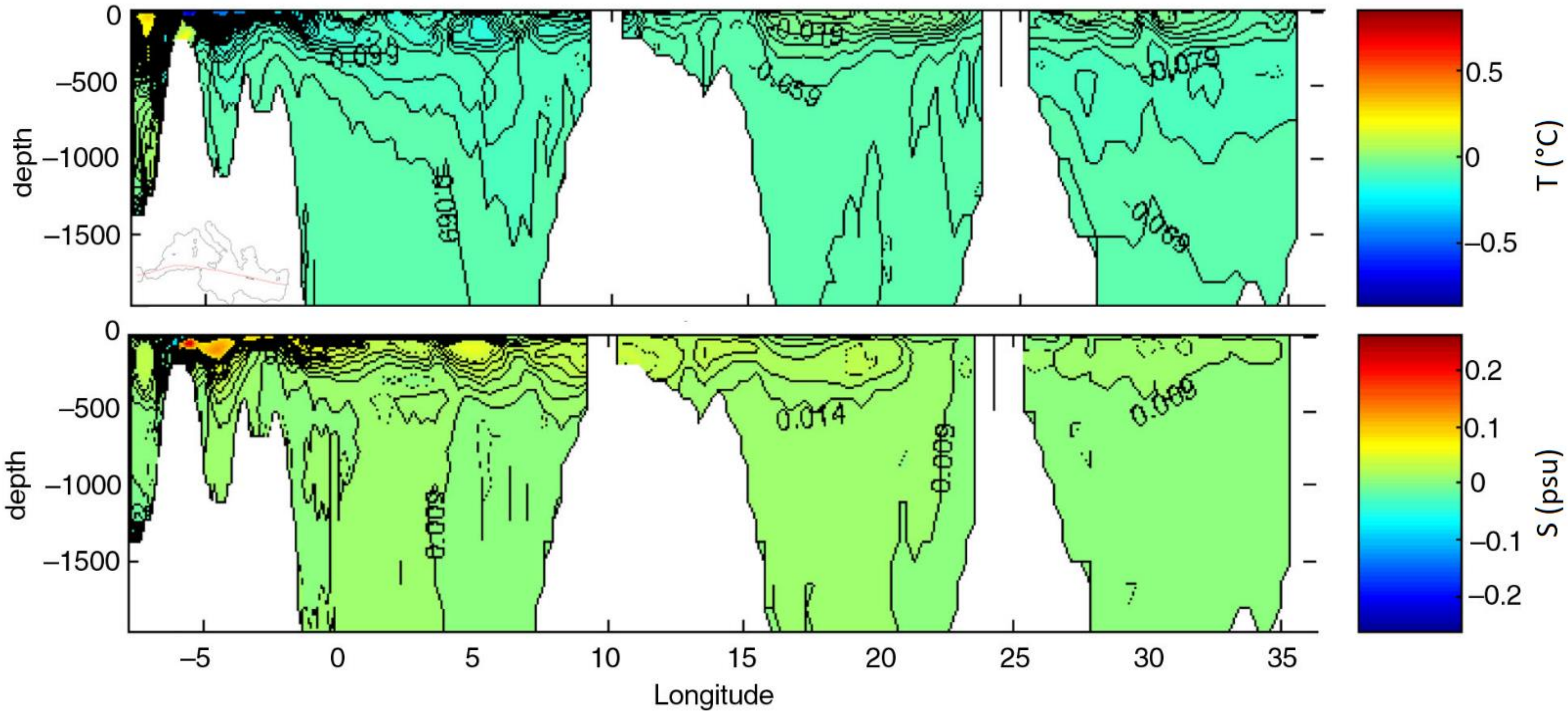

- Over 50-year-long simulations: **General cooling and saltening** ($\sim -0.08°C$ and $0.012 psu$)

- Modifications mainly contained in **the upper 150m depth.**

INTRODUCTION

Scientific question: Understanding the role of the SoG for the Mediterranean climate

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⇳ What role does the SoG representation play for the Mediterranean climate?

OUTLINE

Introduction

I. Methods: A coupled regional climate model of the Mediterranean region

II. Oceanic adjustment to tidal mixing at the SoG

III. Impacts on the ocean-atmosphere interface

Conclusions et perspectives

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Introduction

I. **Methods: A coupled regional climate model of the Mediterranean region**

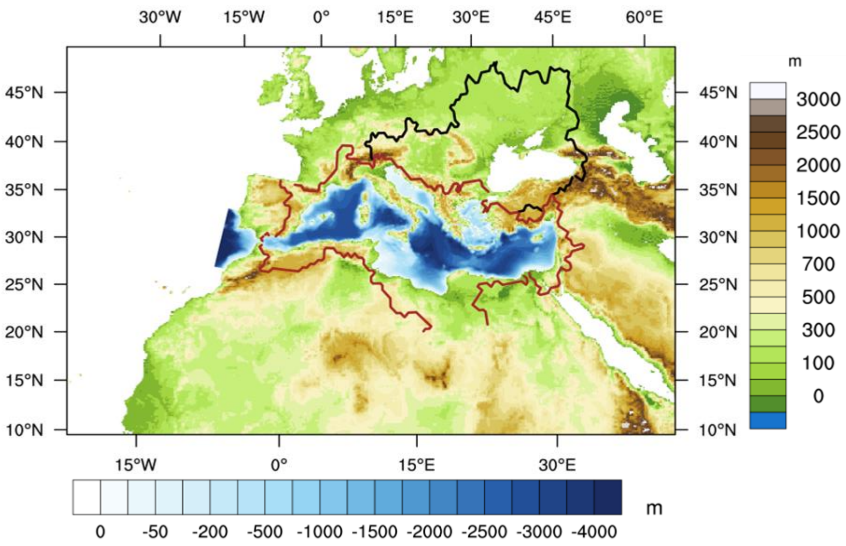
II. Oceanic adjustment to tidal mixing at the SoG

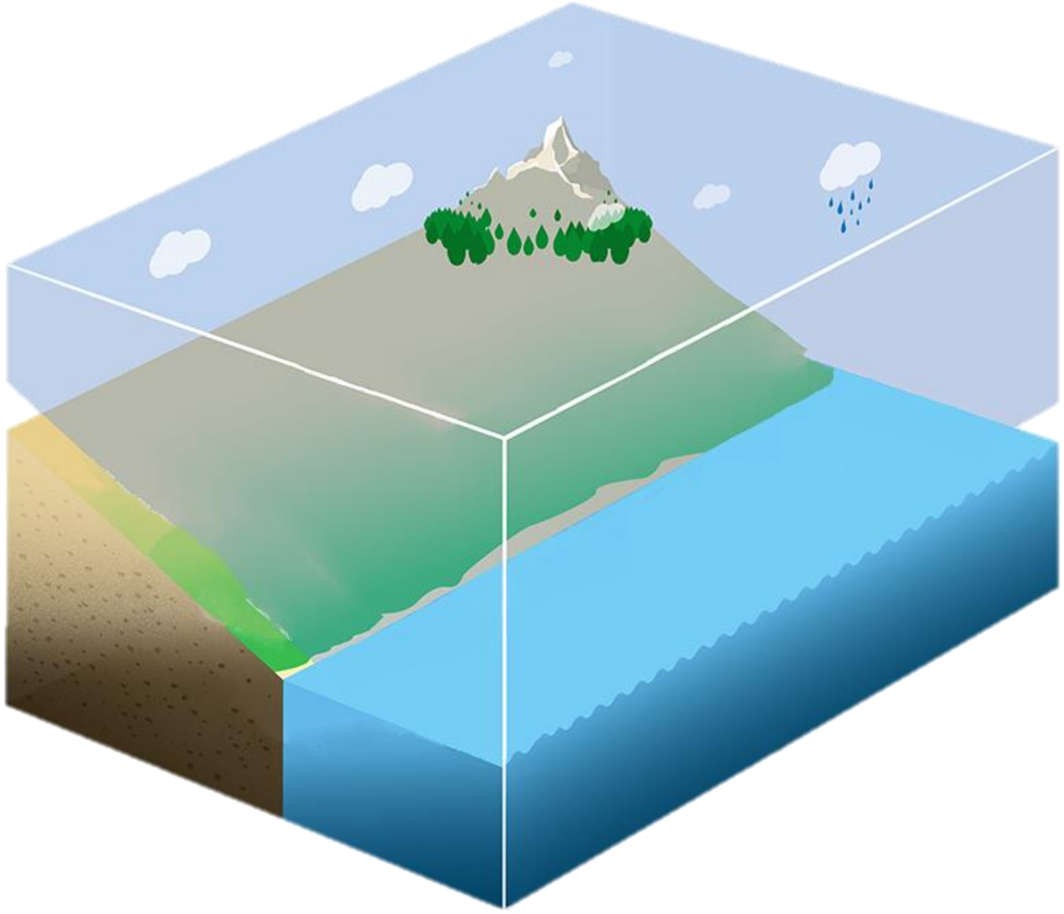
III. Impacts on the ocean-atmosphere interface

Conclusions et perspectives

I. METHODS: A COUPLED REGIONAL CLIMATE MODEL OF THE MEDITERRANEAN REGION

CNRM-RCSM6 coupled regional climate system model





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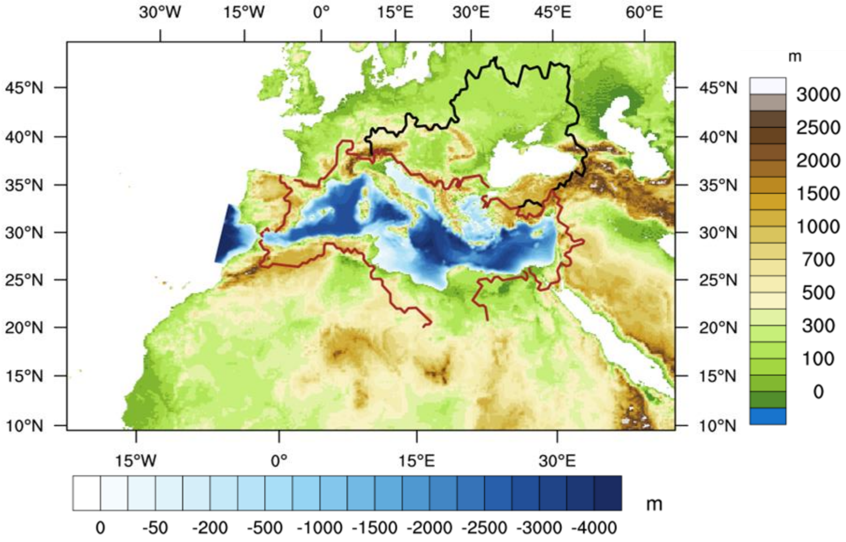
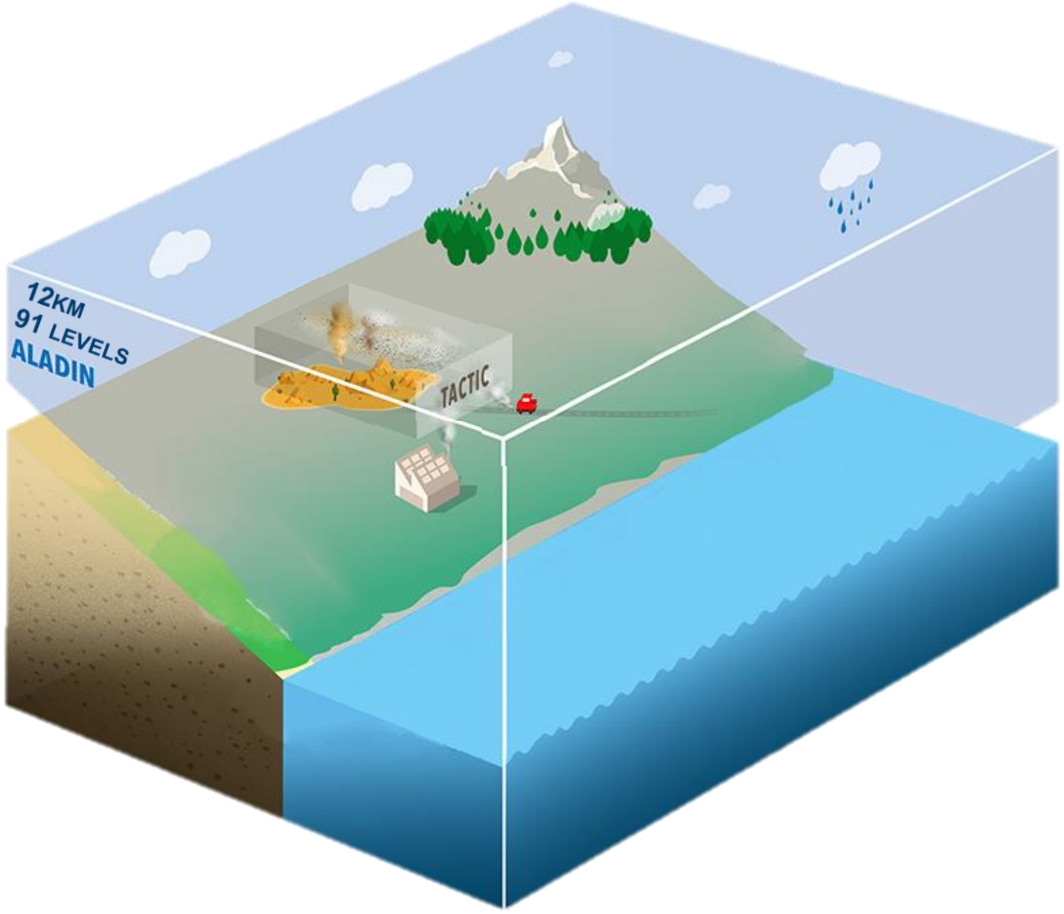
- **Atmosphere:** ALADIN coupled with interactive aerosols scheme TACTIC.





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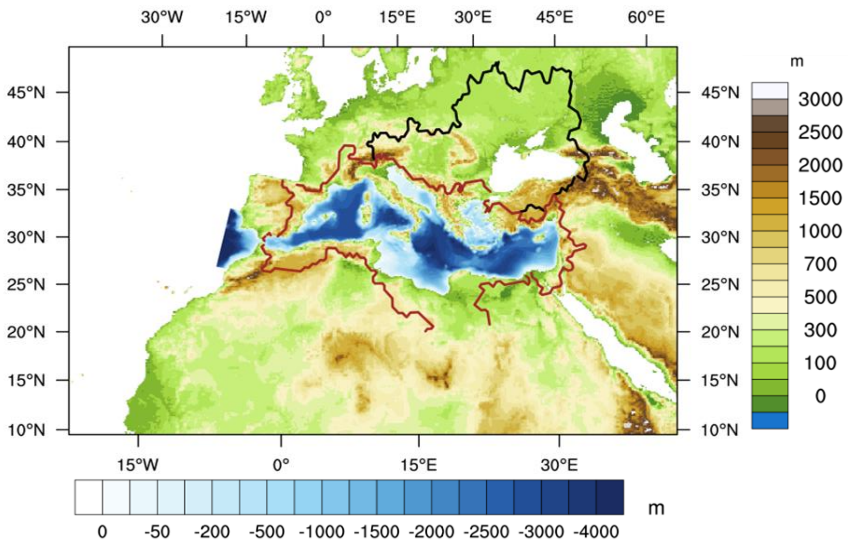

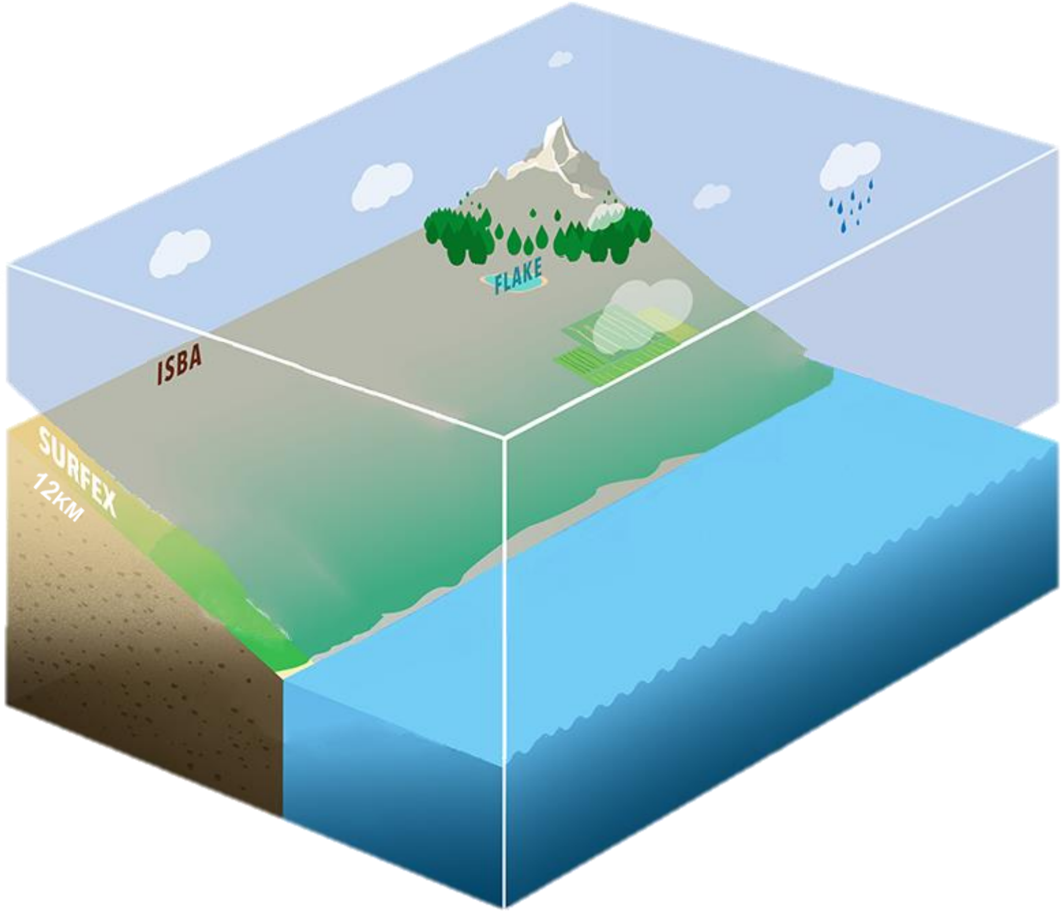

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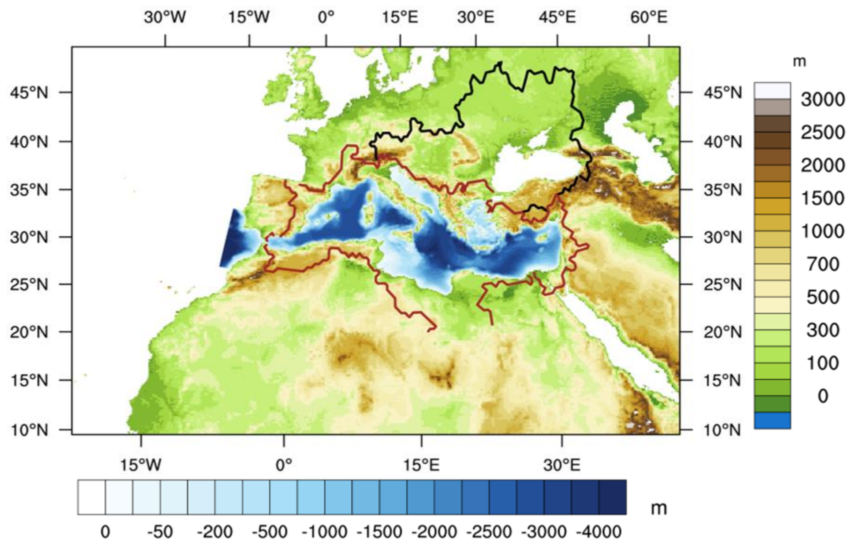

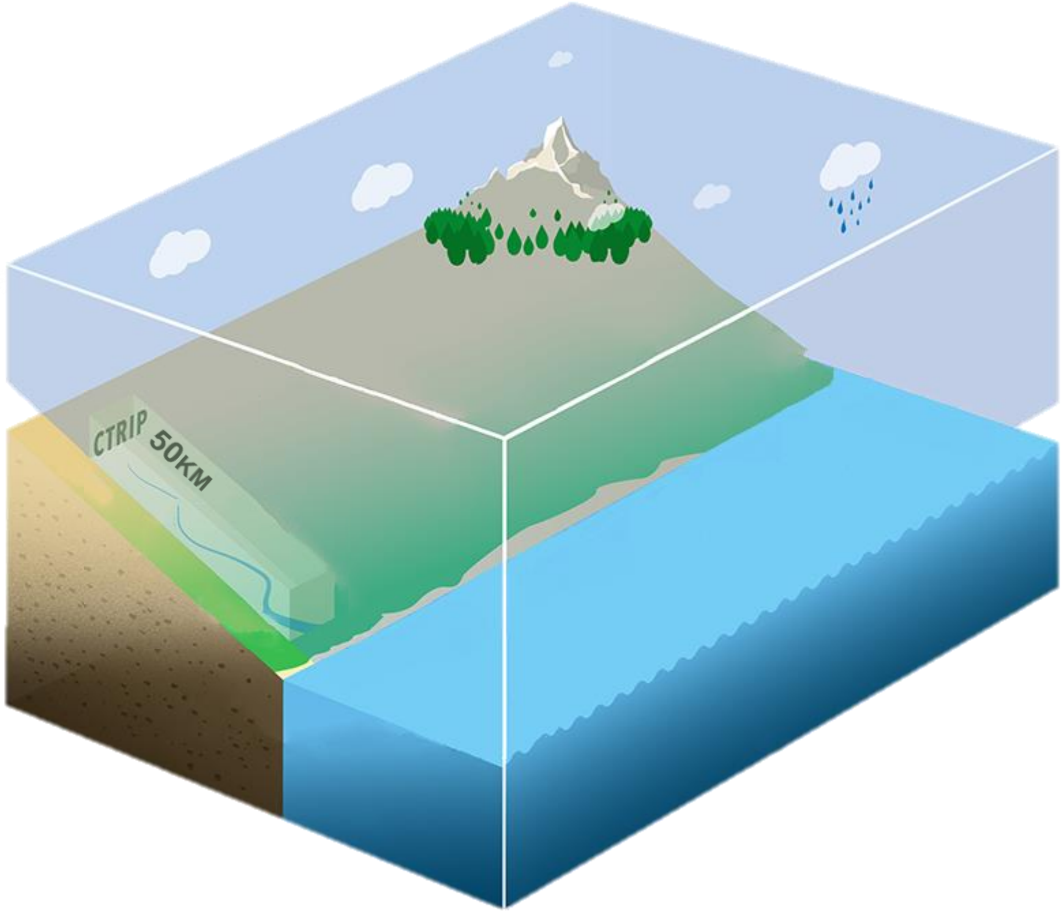

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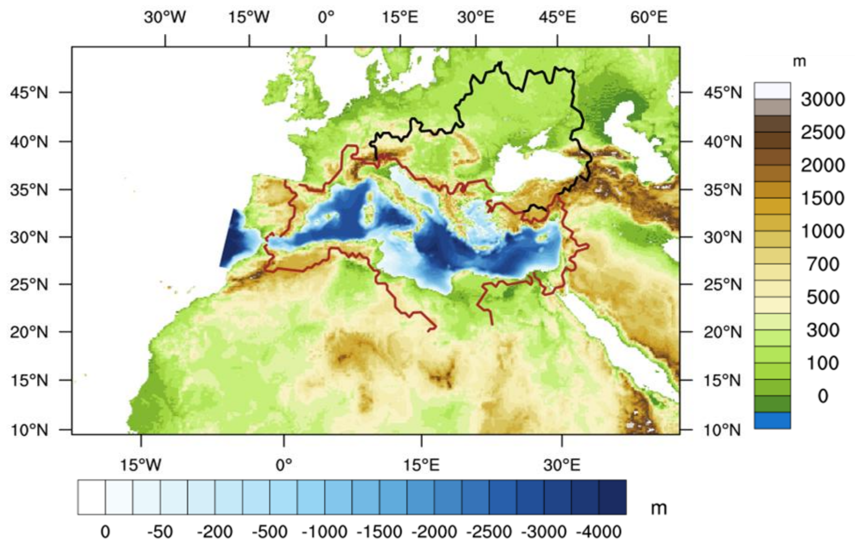

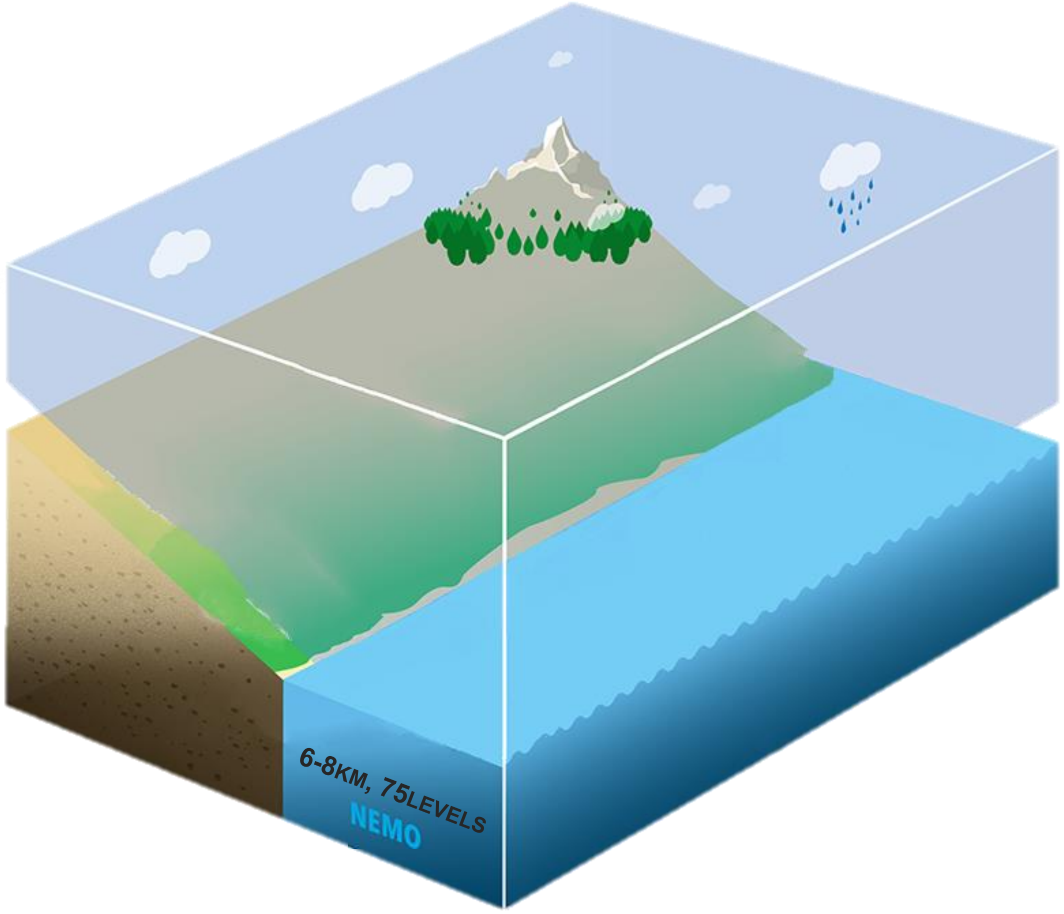

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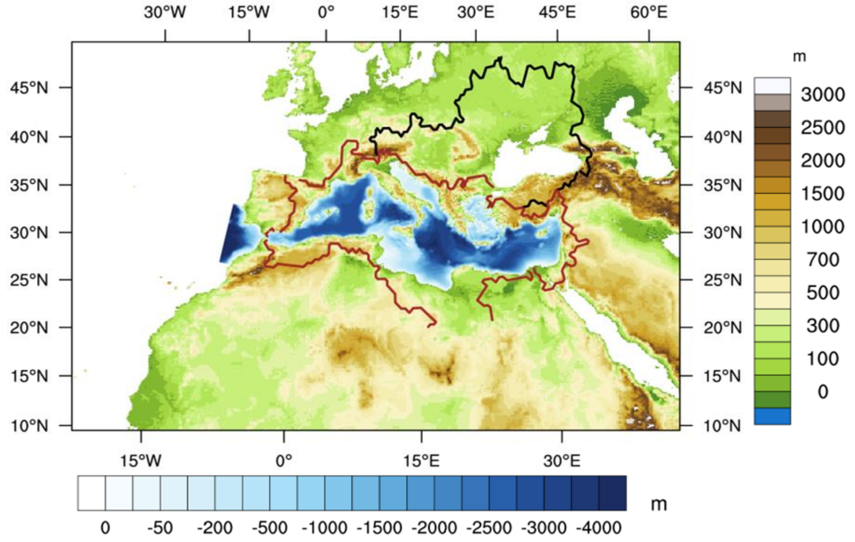

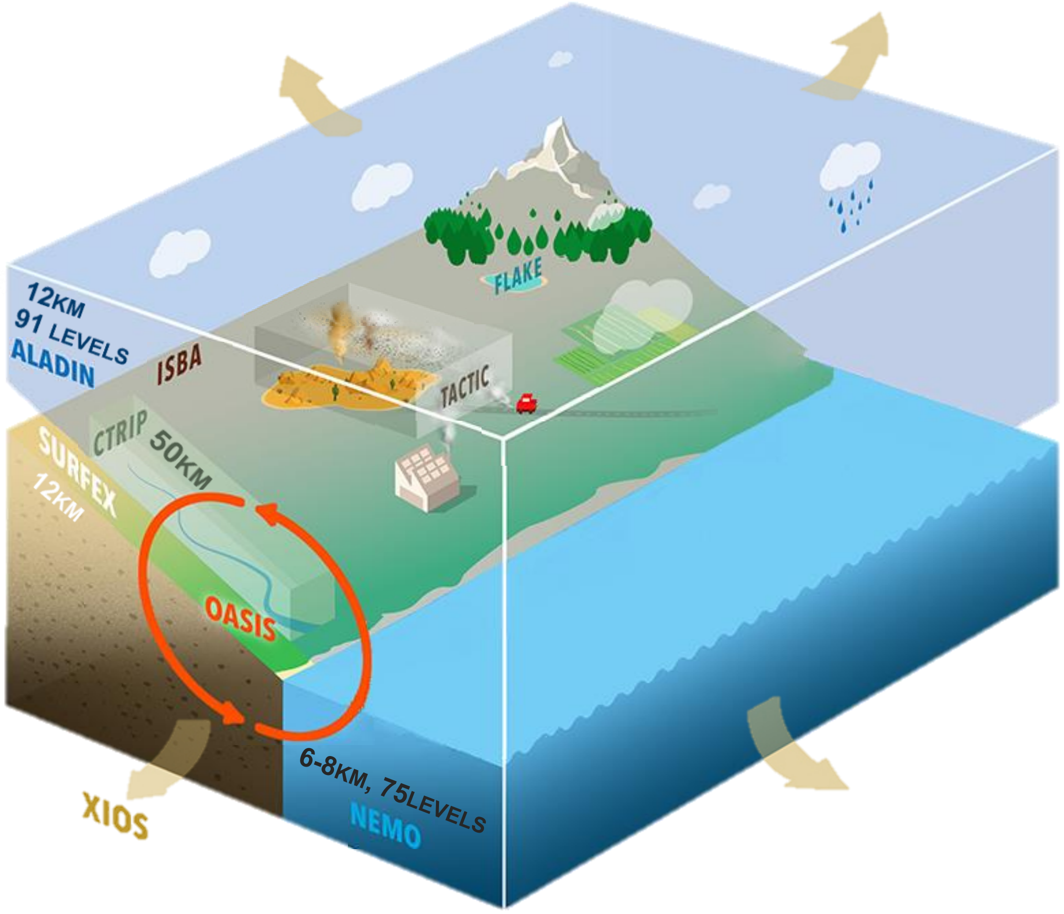

I. Methods: A coupled regional climate model of the Mediterranean region

NEMOMEDGIB regional configuration

- **Horizontal resolution of** 1/12° (5.5 - 7.5km);
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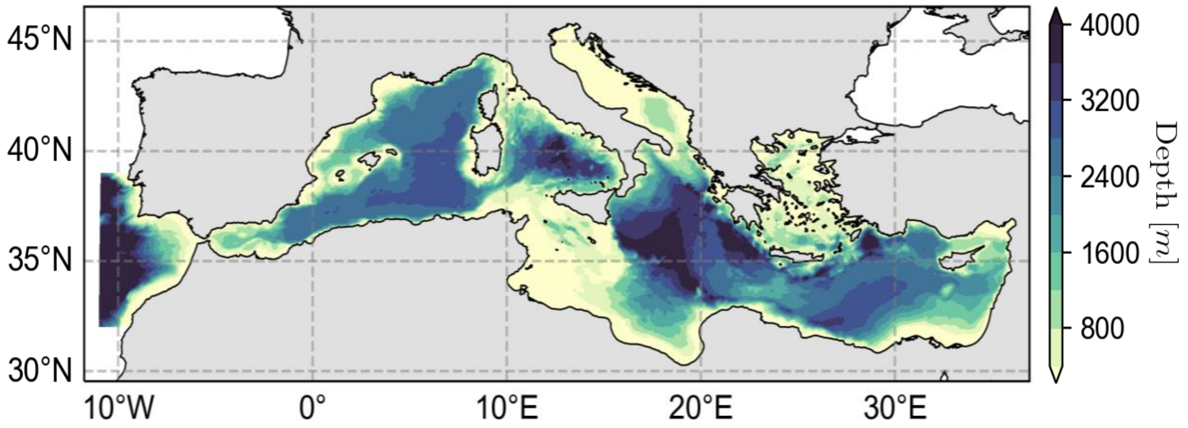
  z partial-step coordinates.

NEMOMEDGIB (1/12°) bathymetry



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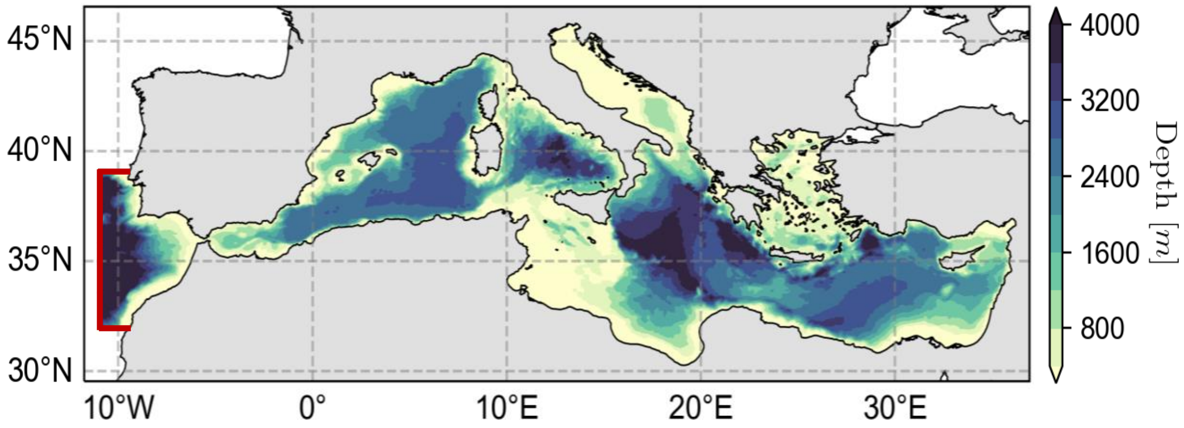

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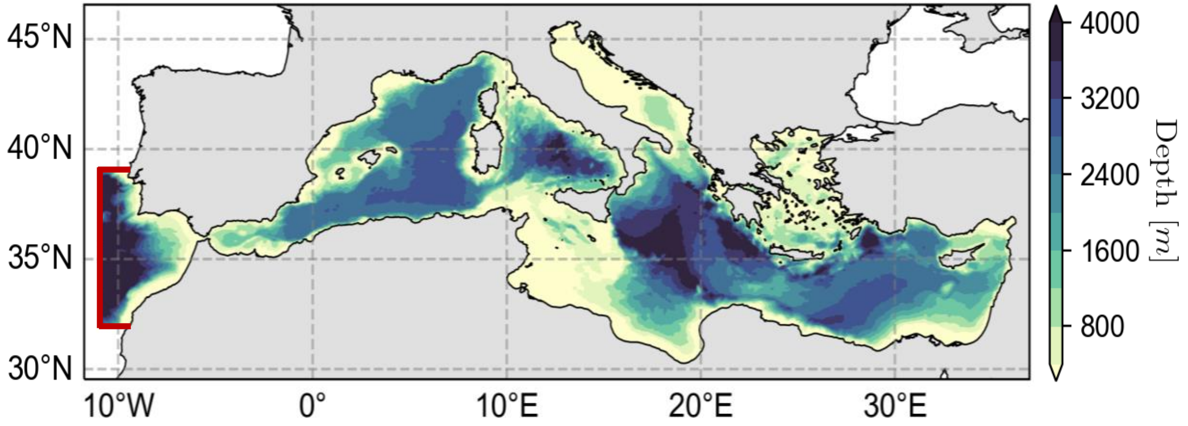

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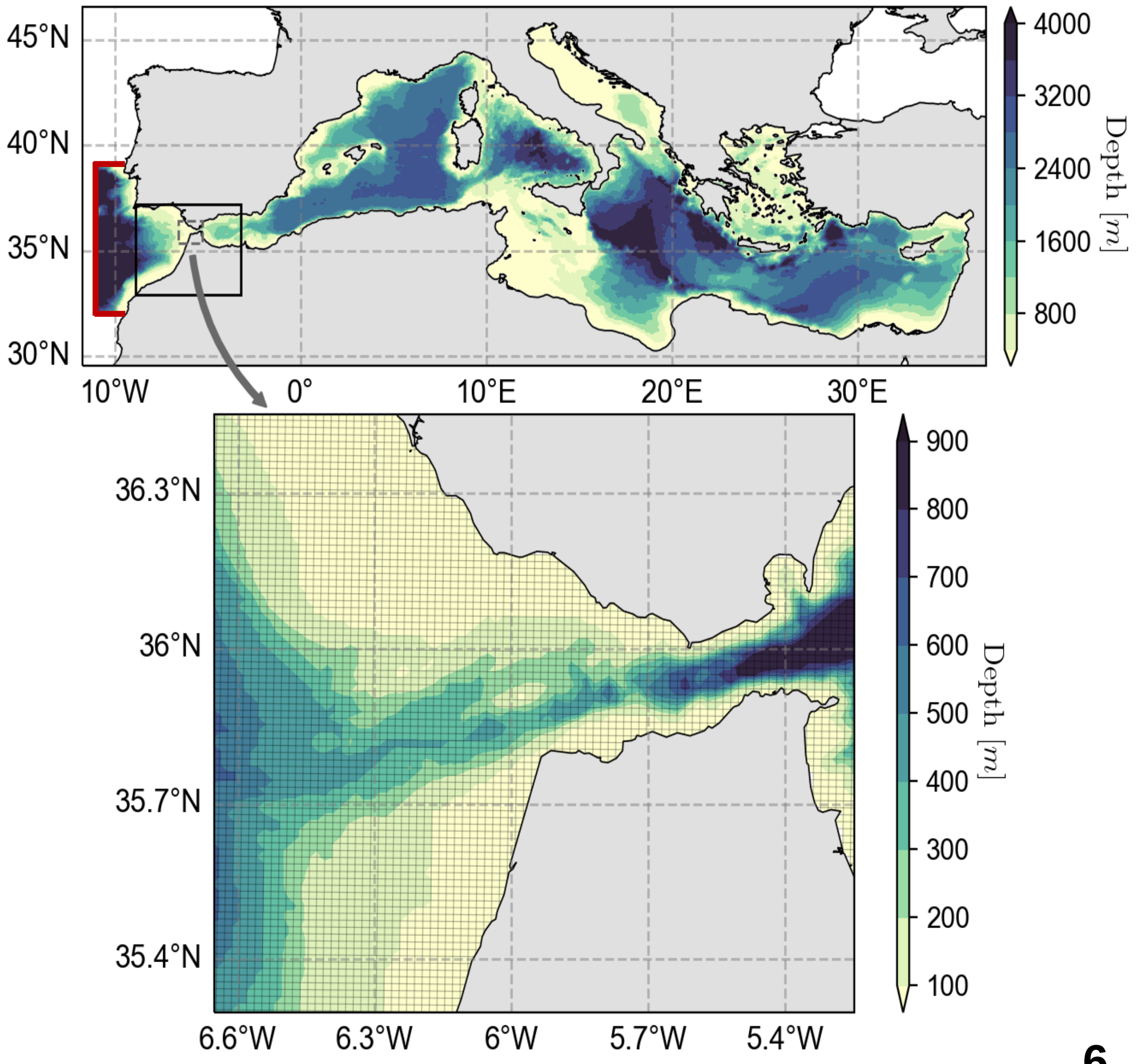
- **Open boundary conditions** in the Atlantic Ocean.
- **Time-splitting** of the baroclinic dynamics.
- **Realistic representation of the SoG:**
  - Tidal forcing at the Atlantic boundaries (FES2014) and tidal potential in the Mediterranean Sea.
  - AGRIF zoom at the SoG (1/60°).

Upper panel: NEMOMEDGIB (1/12°) bathymetry
Lower panel: AGRIF zoom (1/60°) bathymetry



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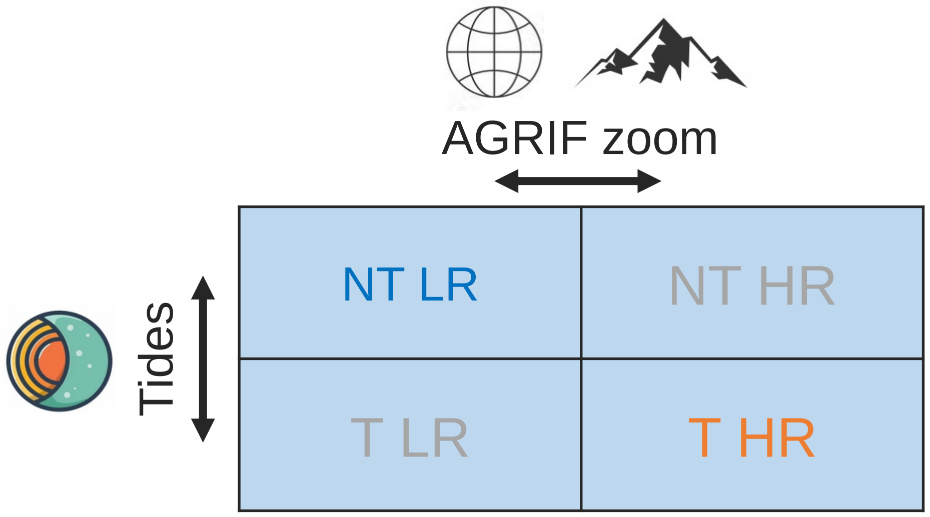
Two simulations in hindcast mode

- One simulation with a **Non-Tidal and Low-Resolution** representation the SoG, one with a **Tidal and High-Resolution** (1/60°) representation.



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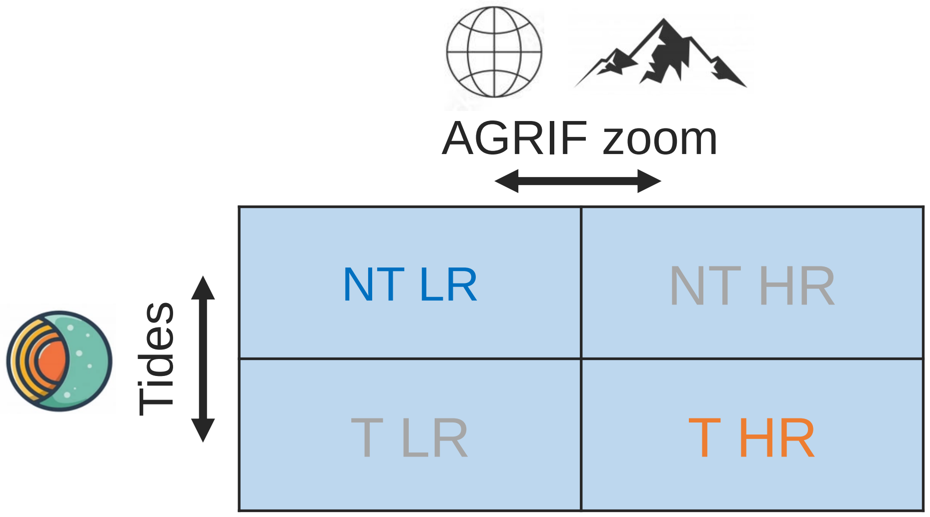
- Forcings:
  - Atmosphere: **ERA-Interim** (reanalysis)
  - Ocean: **ORAS4** (reanalysis)



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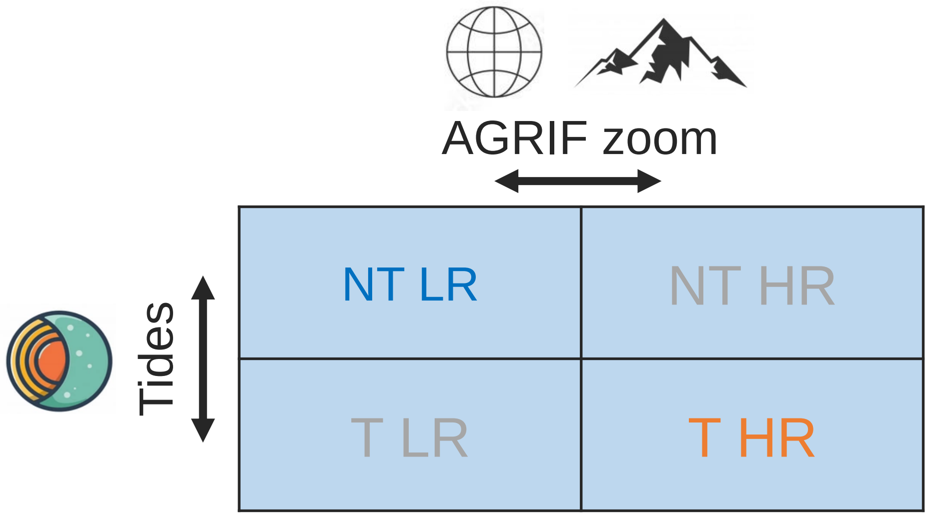

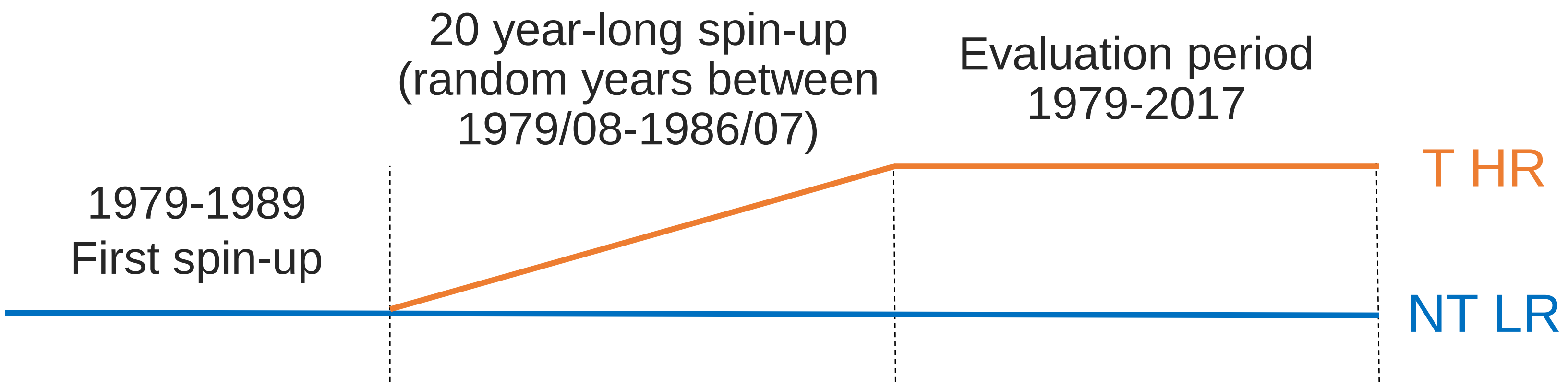

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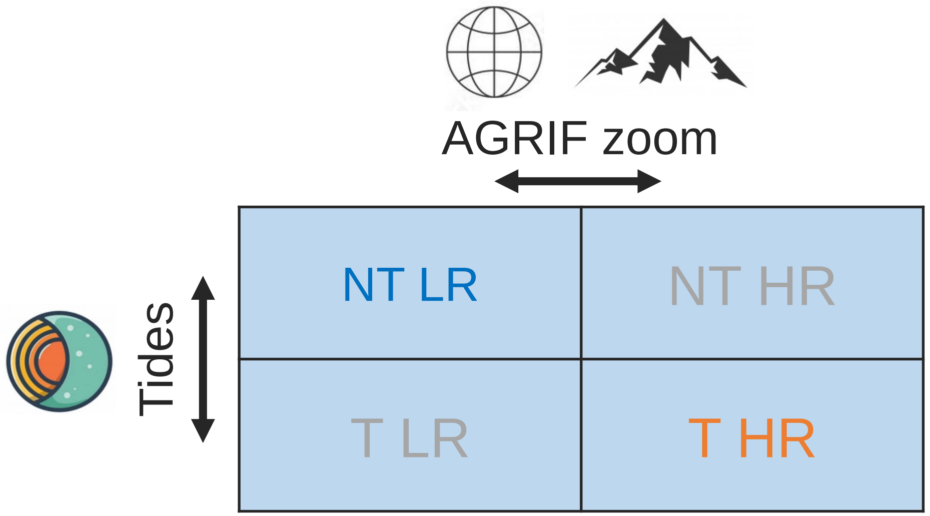
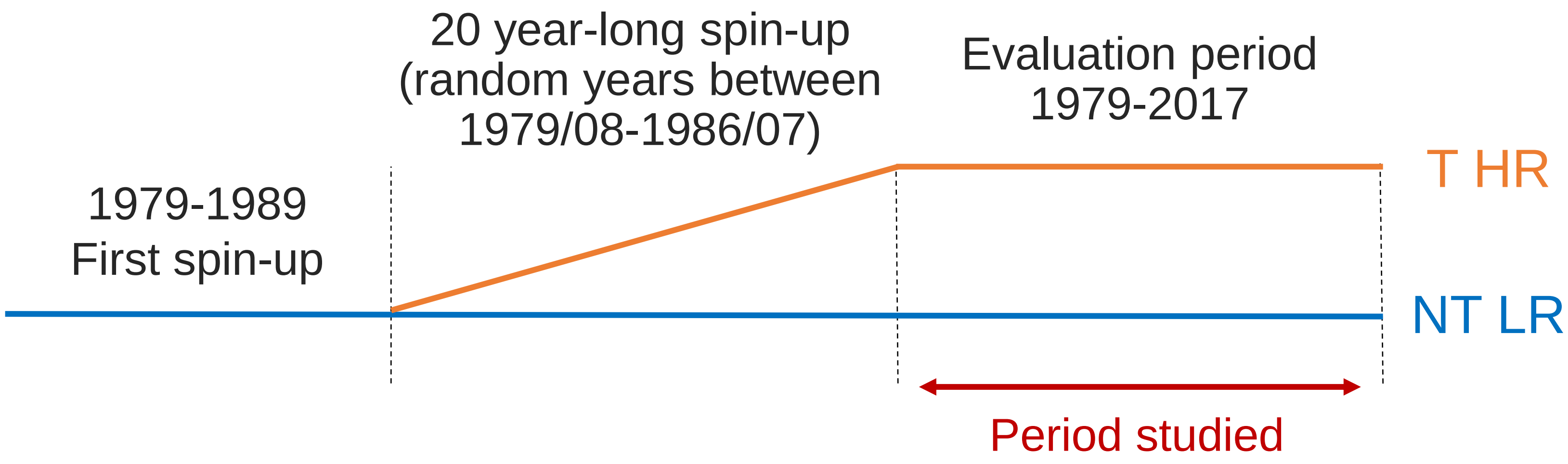
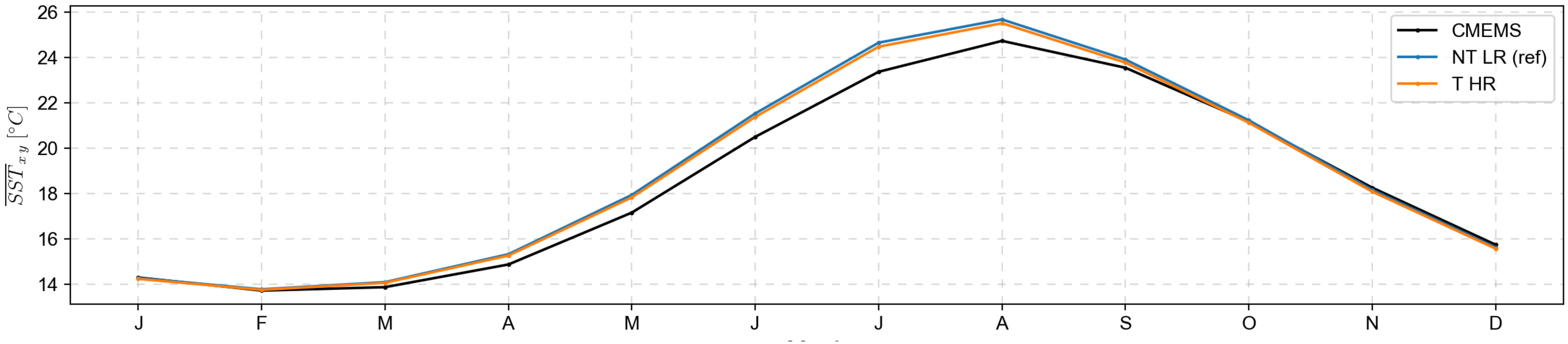




OUTLINE

II. OCEANIC ADJUSTMENT TO TIDAL MIXING AT THE SOG

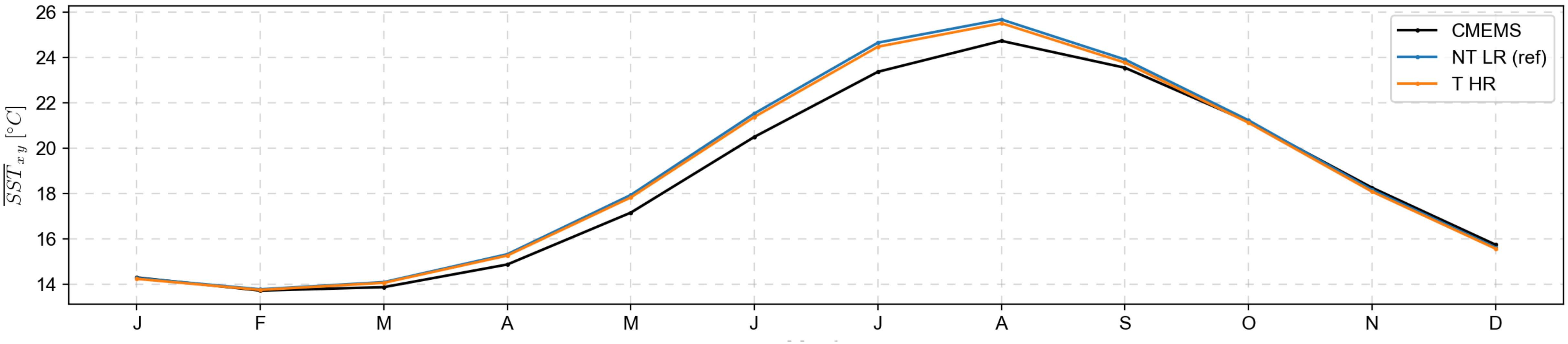
Modified seasonal cycle of surface temperature over the western Mediterranean



II. Oceanic adjustment to tidal mixing at the SoG

Modified seasonal cycle of surface temperature over the western Mediterranean

- **Warm bias in summer** with respect to satellite measurements. Moderate improvement in T HR



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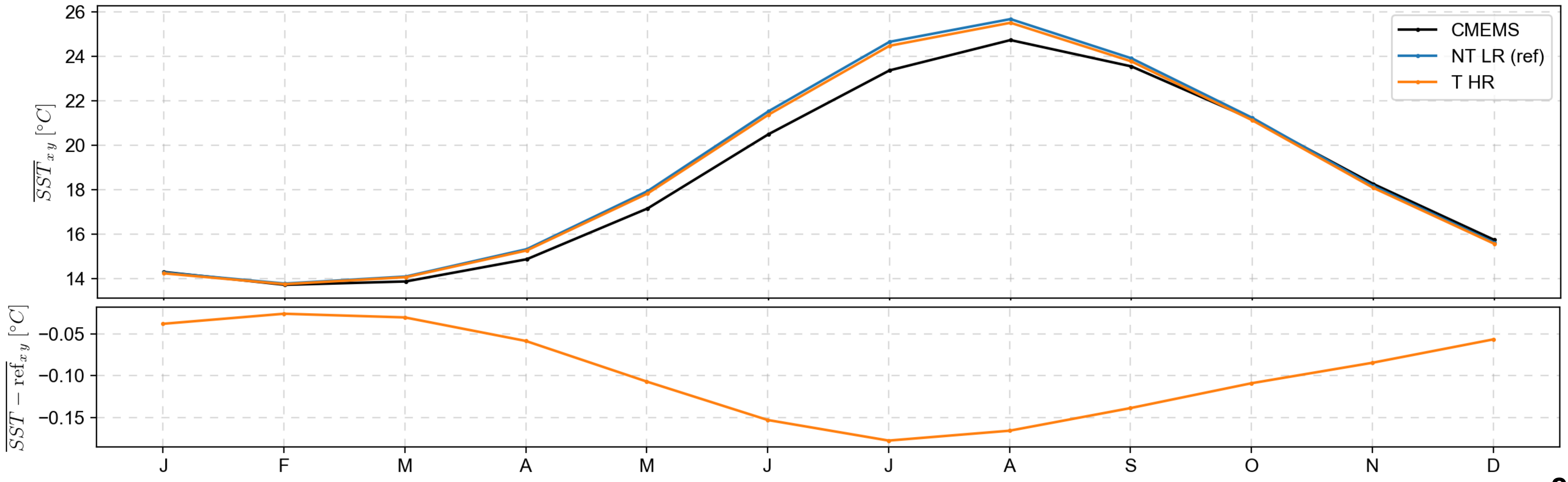
- The cooling effect of tidal forcing and AGRIF zoom at the SoG is **maximal in summer**.



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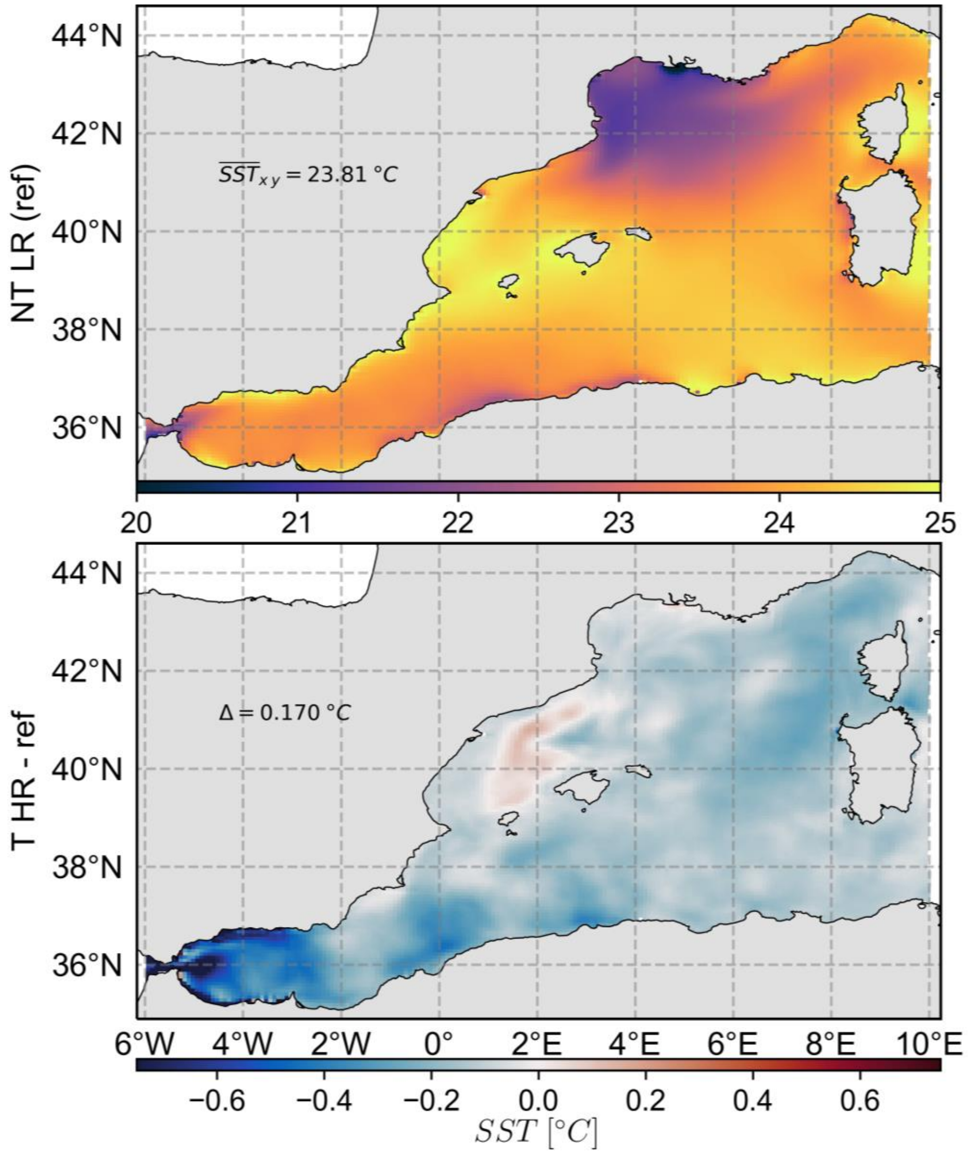
Cooling of the summer surface temperature in T HR

JJA sea surface temperature
Lower panel: Tidal and AGRIF zoom anomalies



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Cooling of the summer surface temperature in T HR

- The cooling is maximal in the **Alboran Sea** where it reaches up to -1.5°C.

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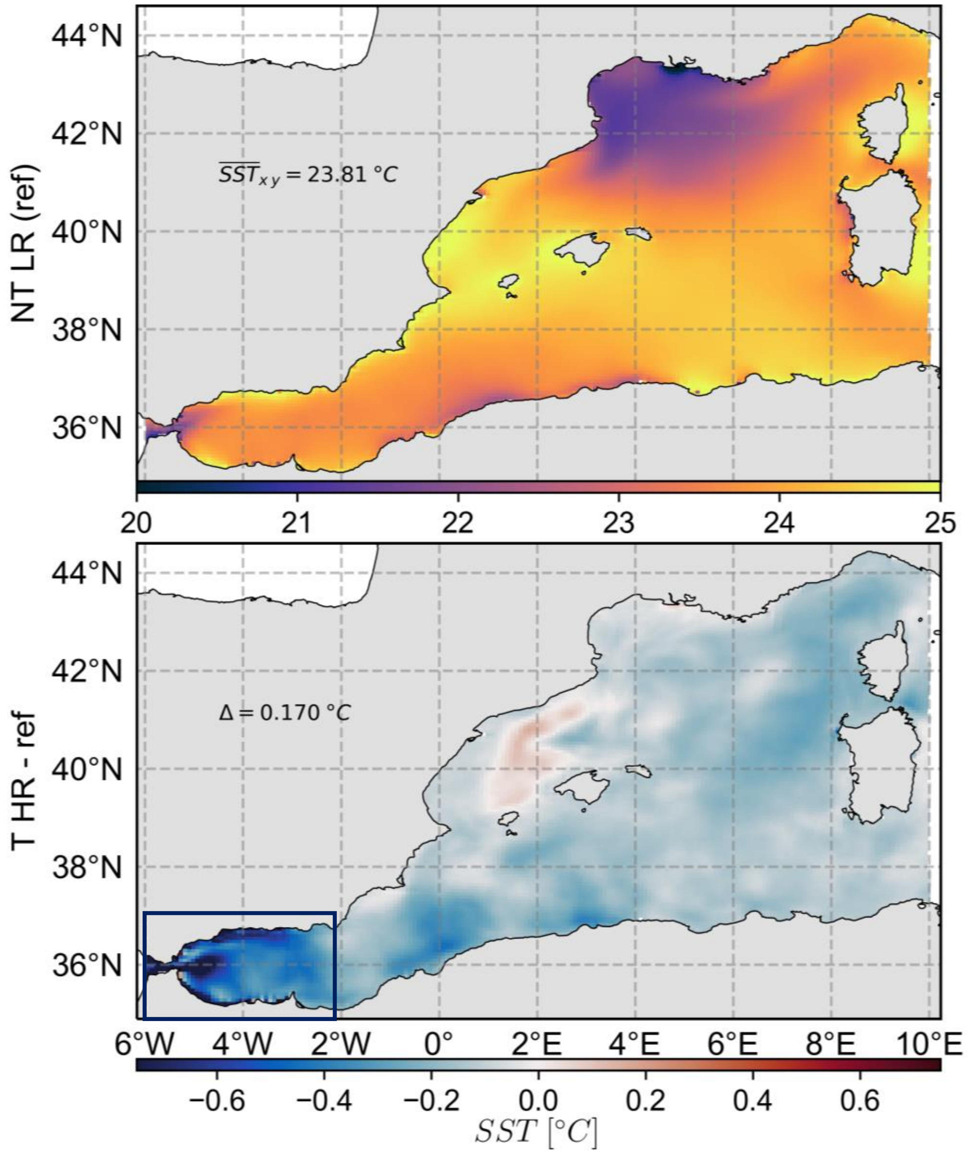

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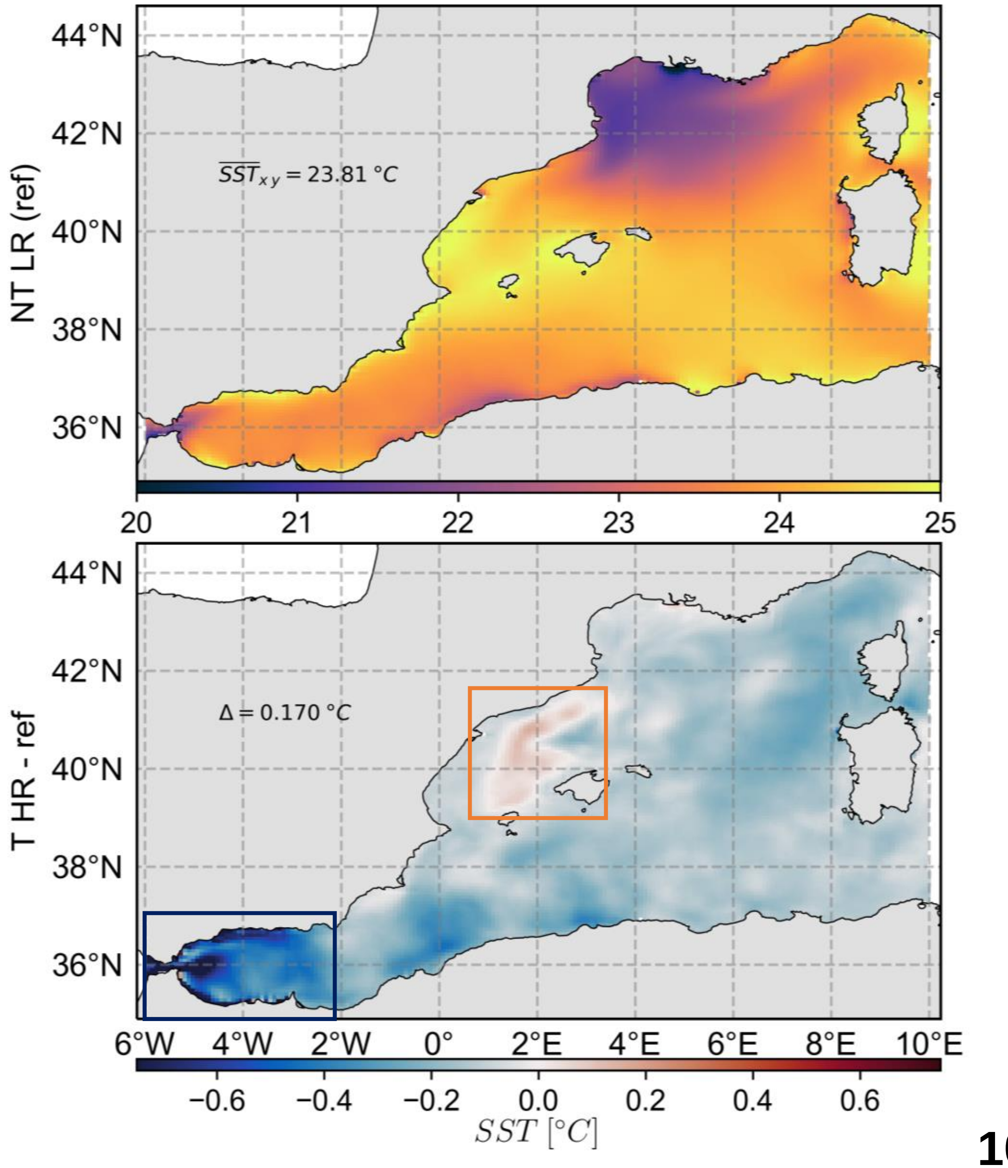

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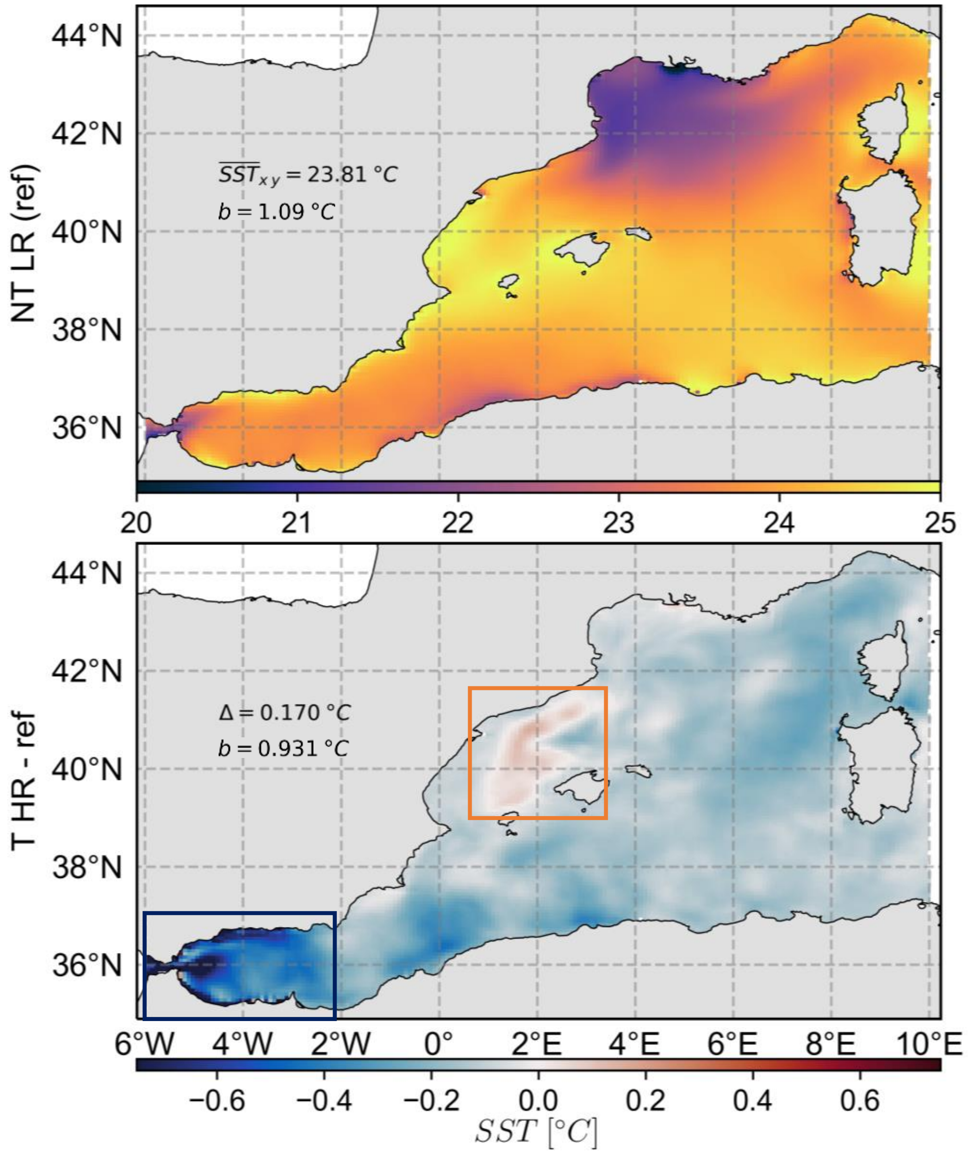

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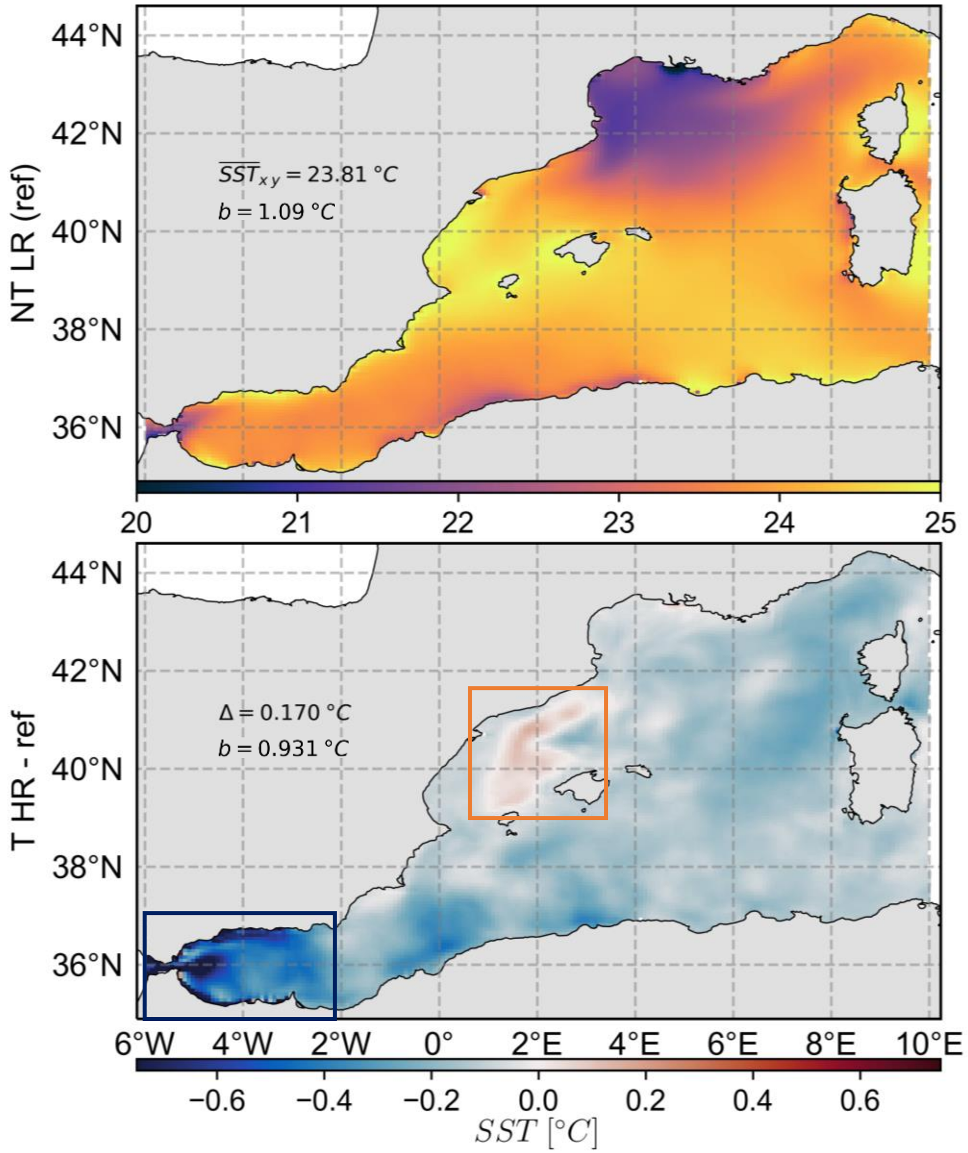

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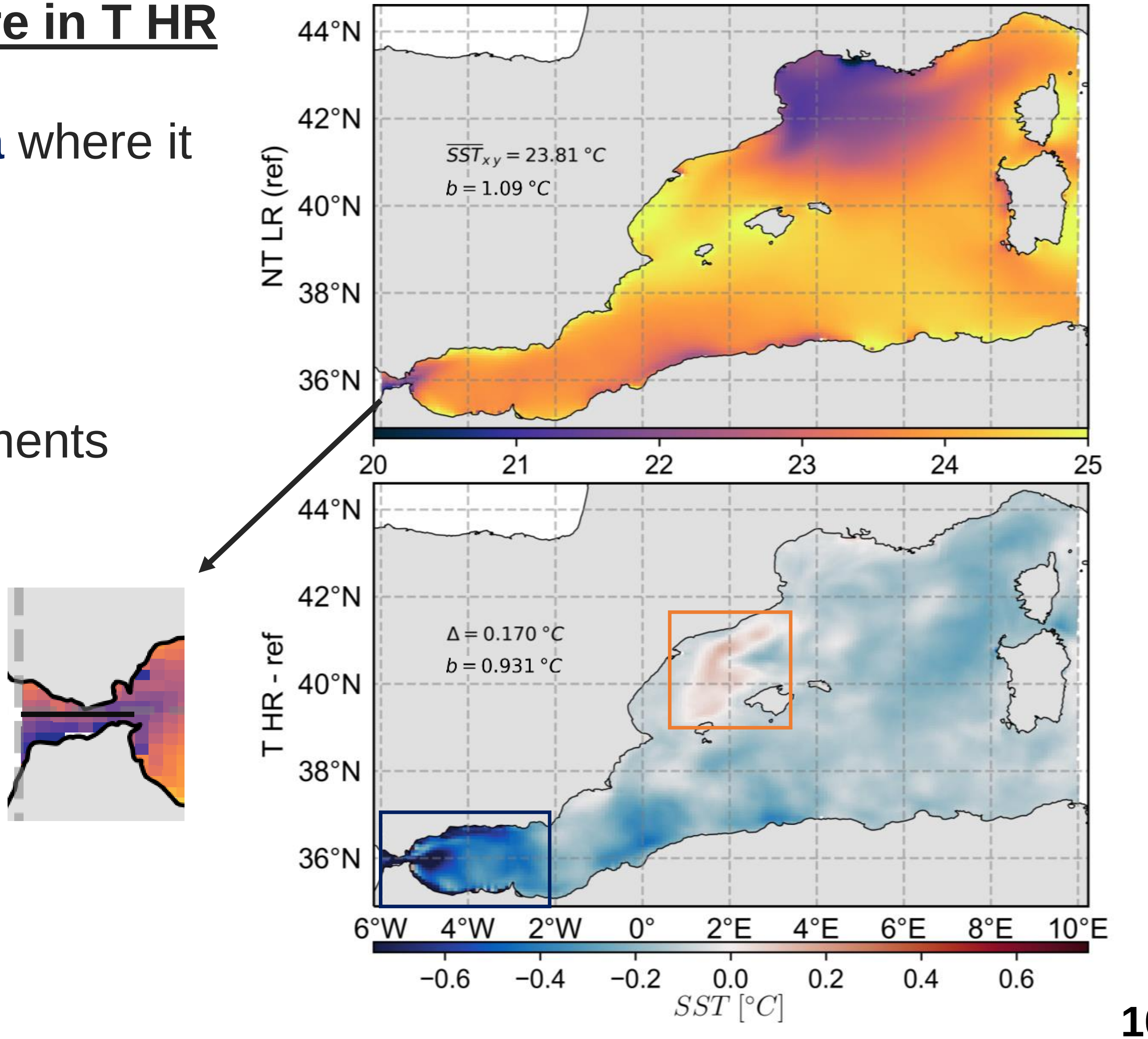

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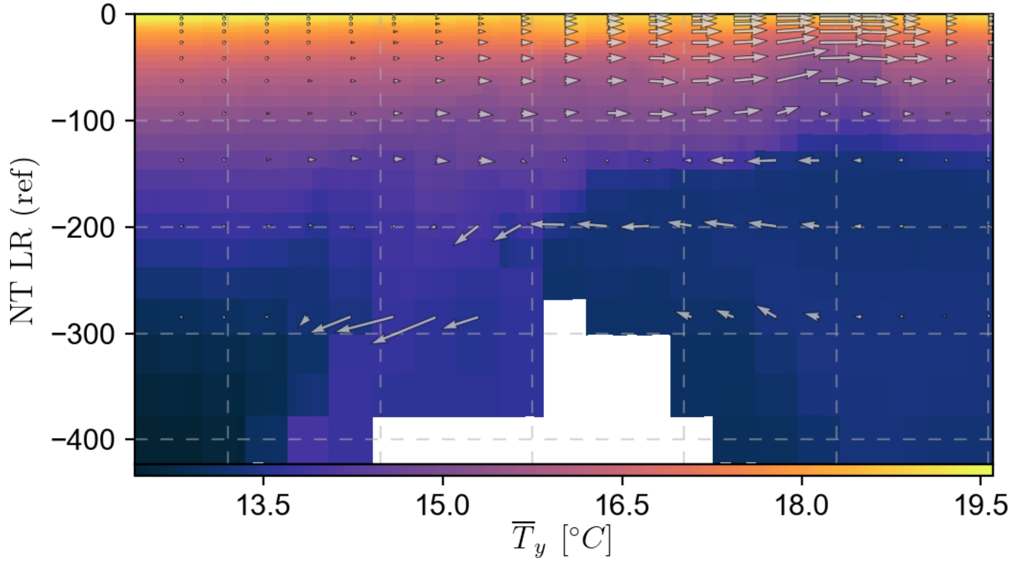
Tidal mixing at the SoG

Zonal section of temperature (shades) and currents at the SoG



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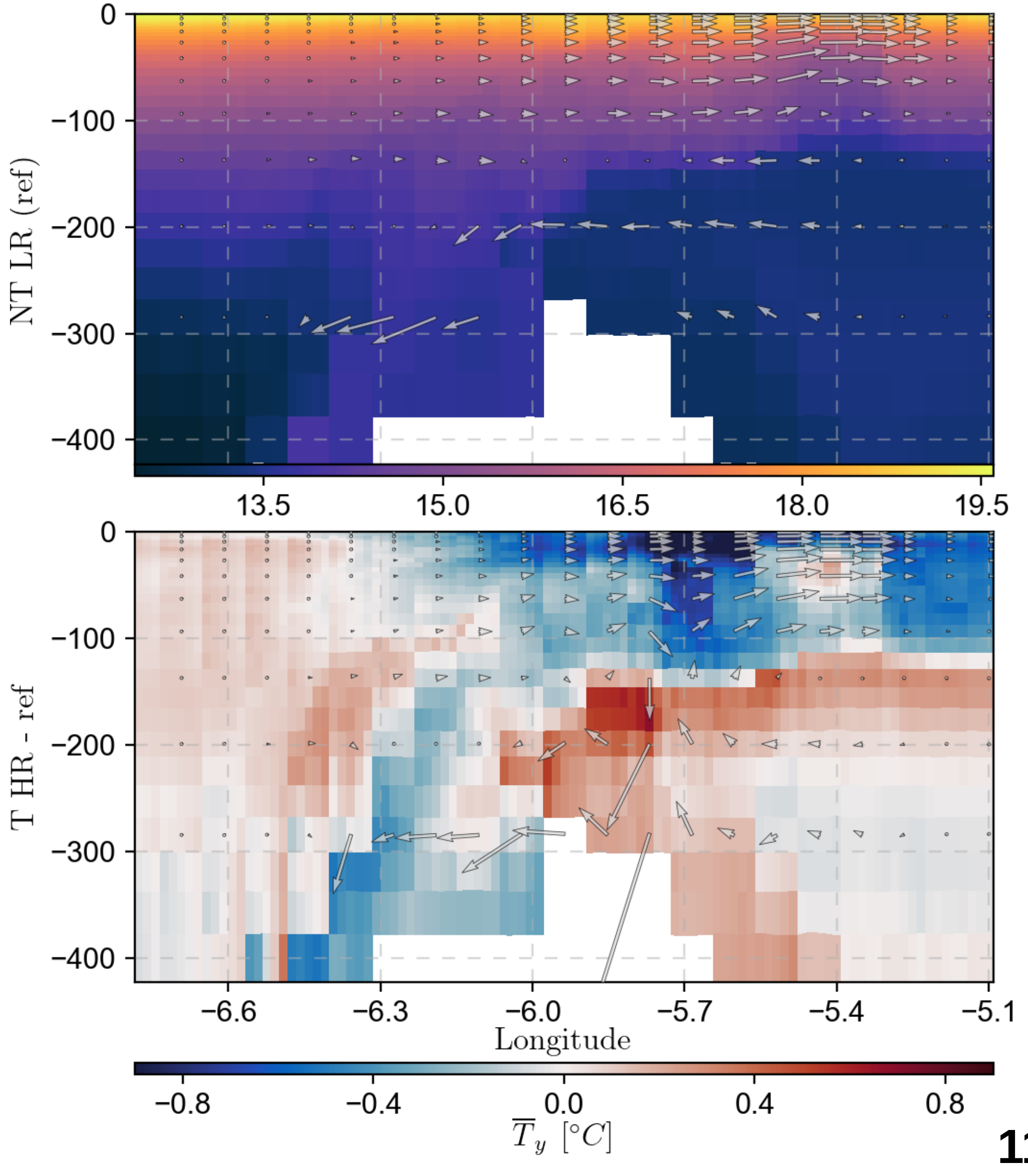
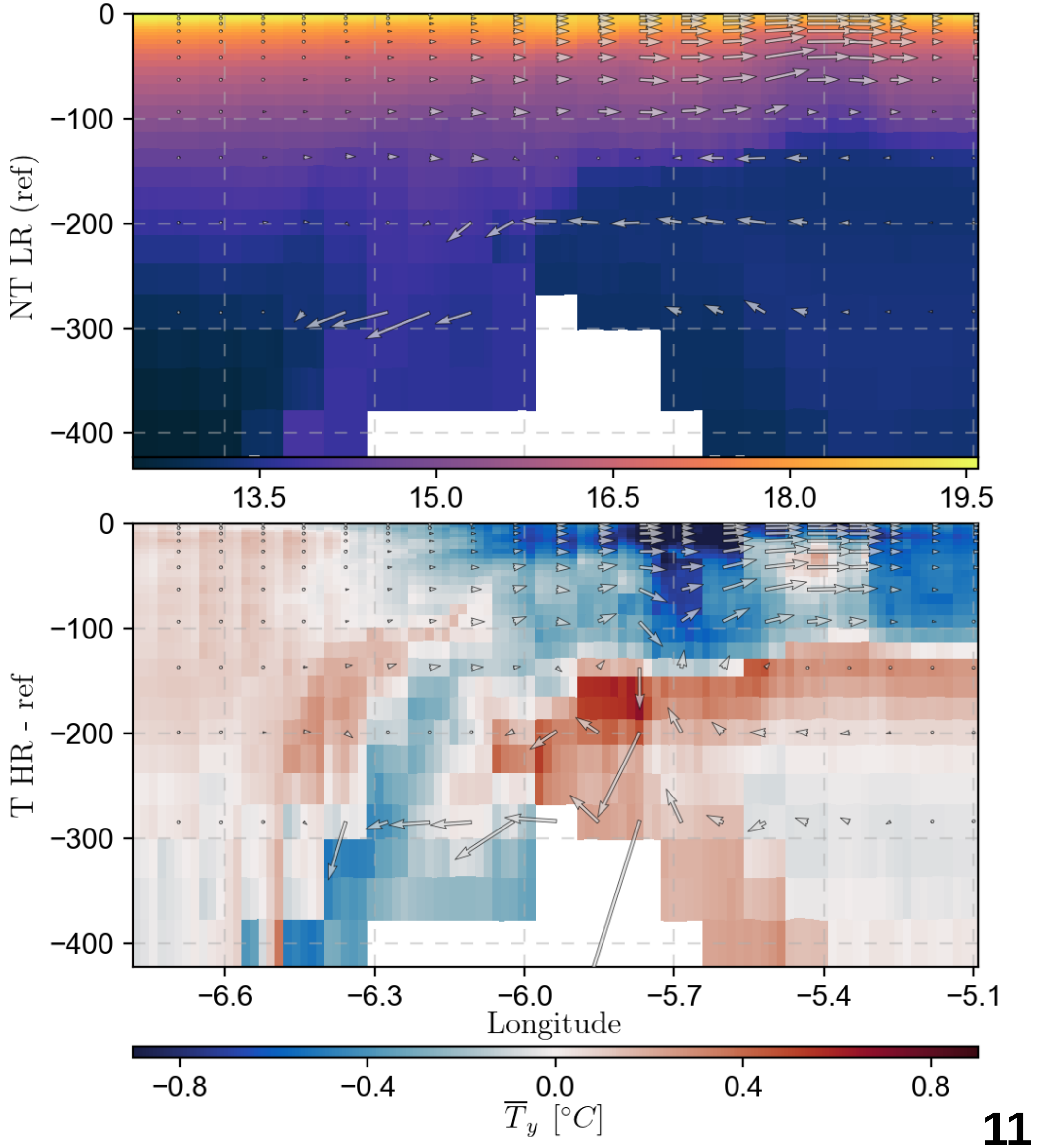


II. Oceanic adjustment to tidal mixing at the SoG

Tidal mixing at the SoG

- Tide-induced **vertical recirculation** of the outflowing Mediterranean waters.

Zonal section of temperature (shades) and currents at the SoG
Lower panel: Tidal and AGRIF zoom anomalies



II. Oceanic adjustment to tidal mixing at the SoG

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- Tide-induced **vertical recirculation** of the outflowing Mediterranean waters.
- The upwelled water masses are assimilated by **vertical mixing, mainly driven by static instabilities.**

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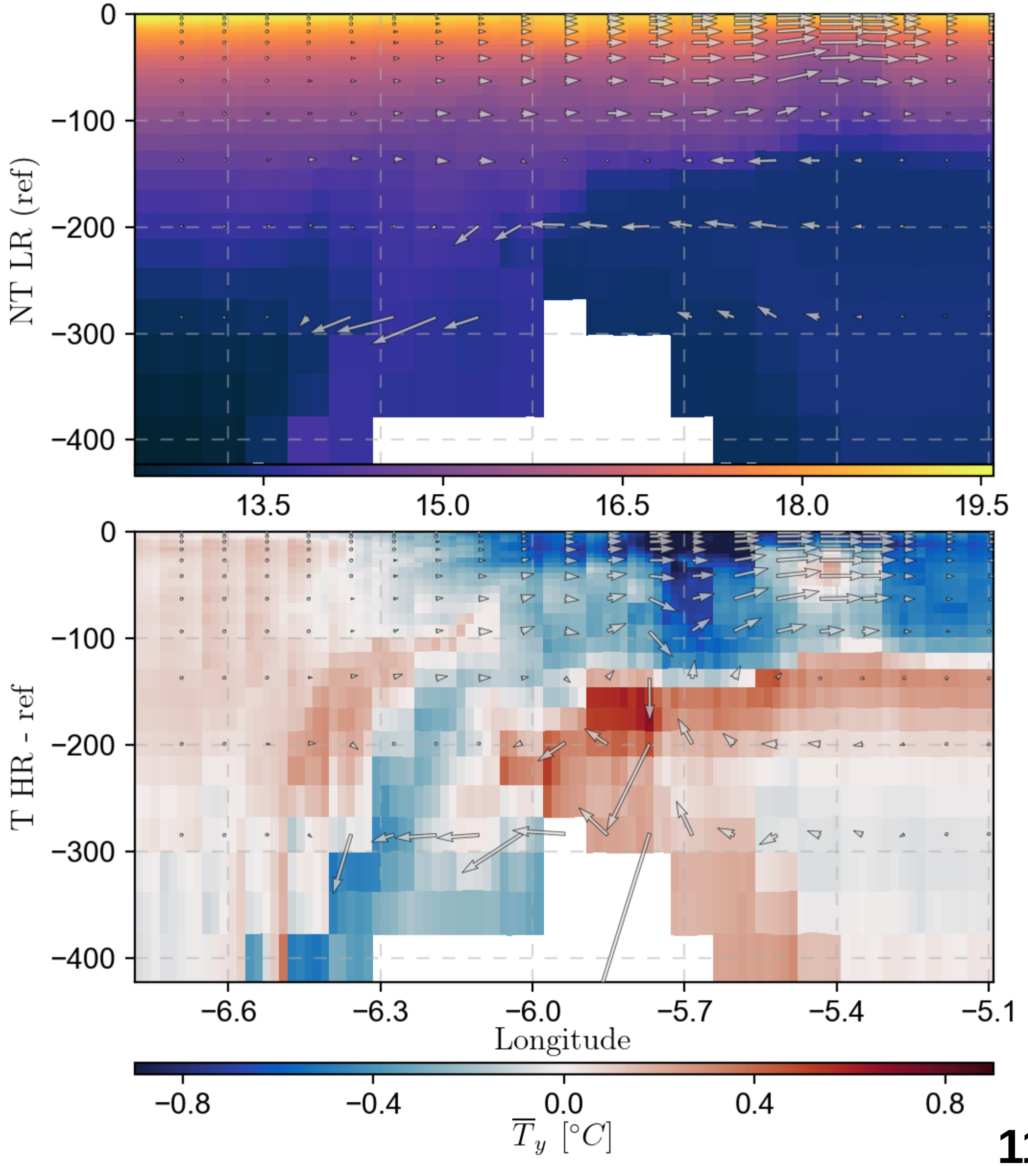
Lower panel: Tidal and AGRIF zoom anomalies



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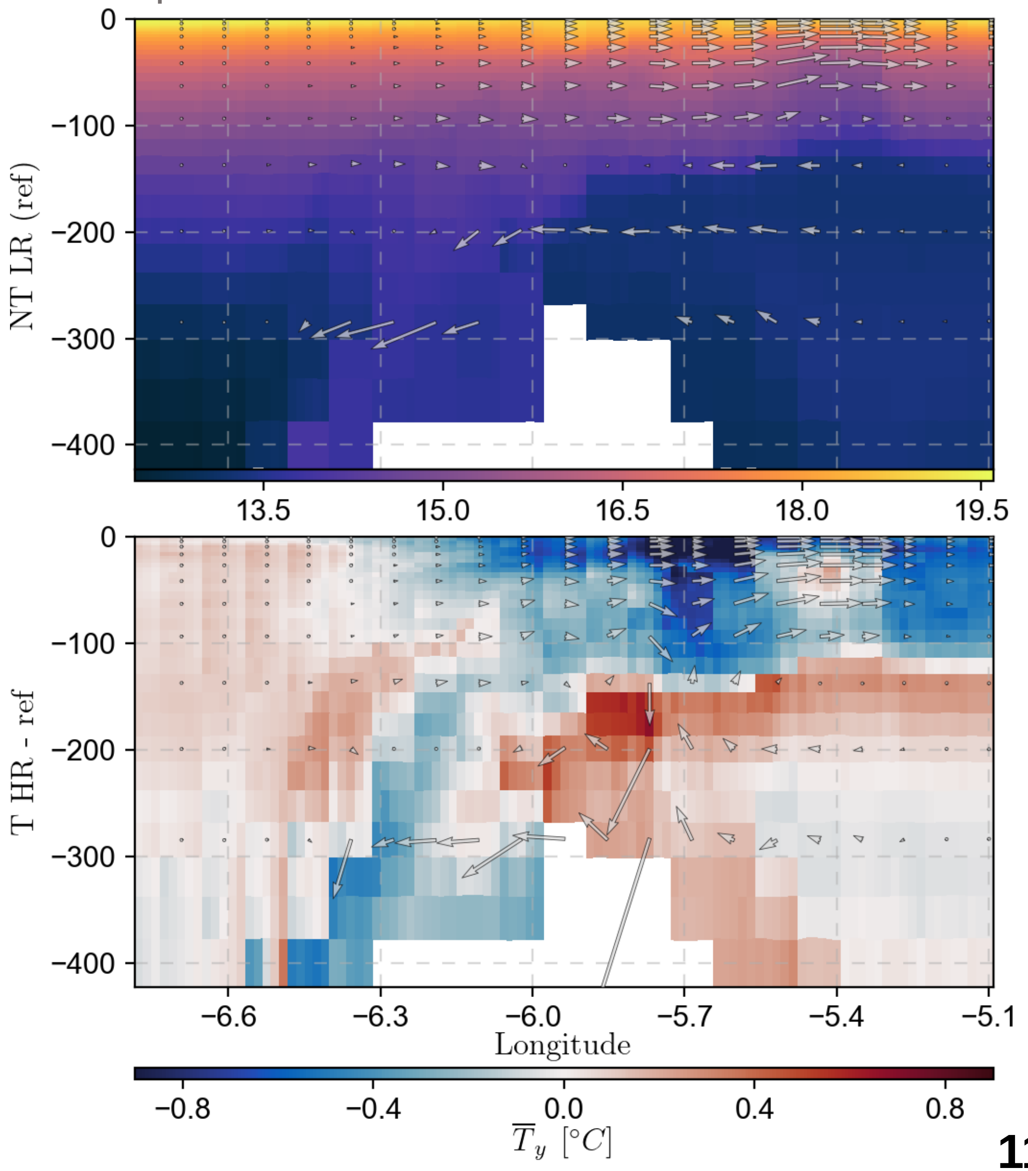

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- Tide-induced **vertical recirculation** of the outflowing Mediterranean waters.
- The upwelled water masses are assimilated by **vertical mixing, mainly driven by static instabilities.**
- As a result, inflowing Atlantic waters are **cooled and salted**.

II. Oceanic adjustment to tidal mixing at the SoG

Zonal section of salinity (shades) and currents at the SoG
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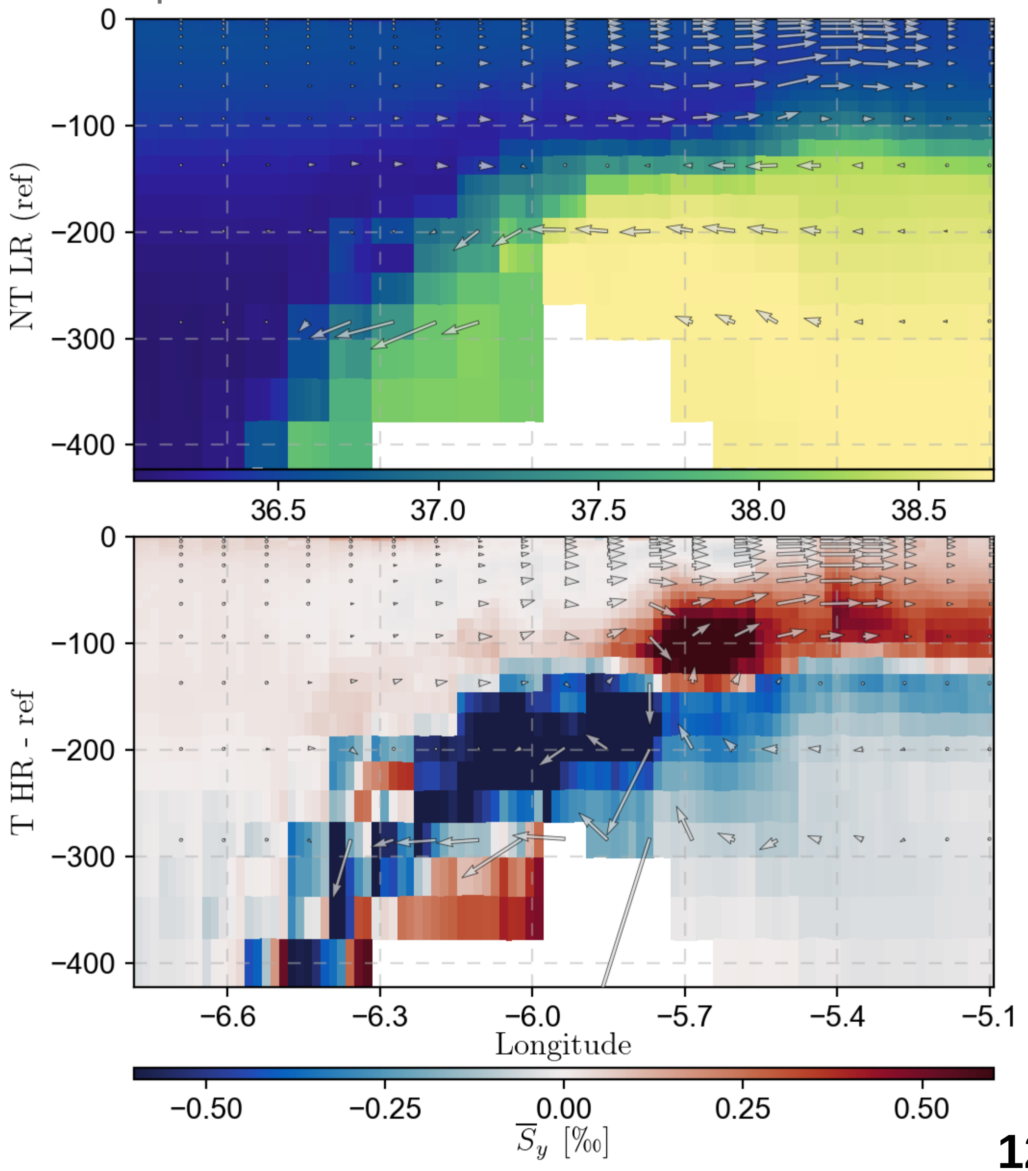

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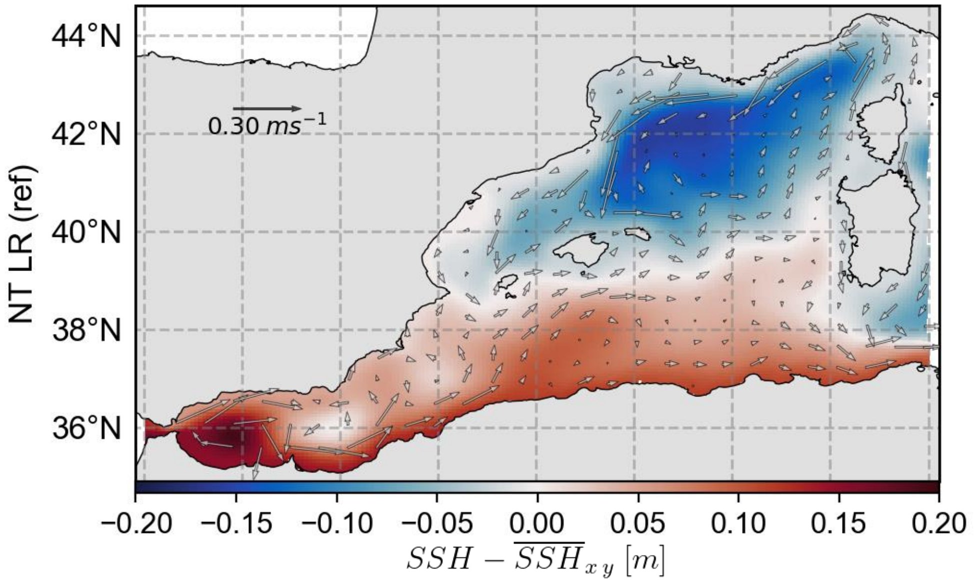
Modified circulation in the Western Mediterranean

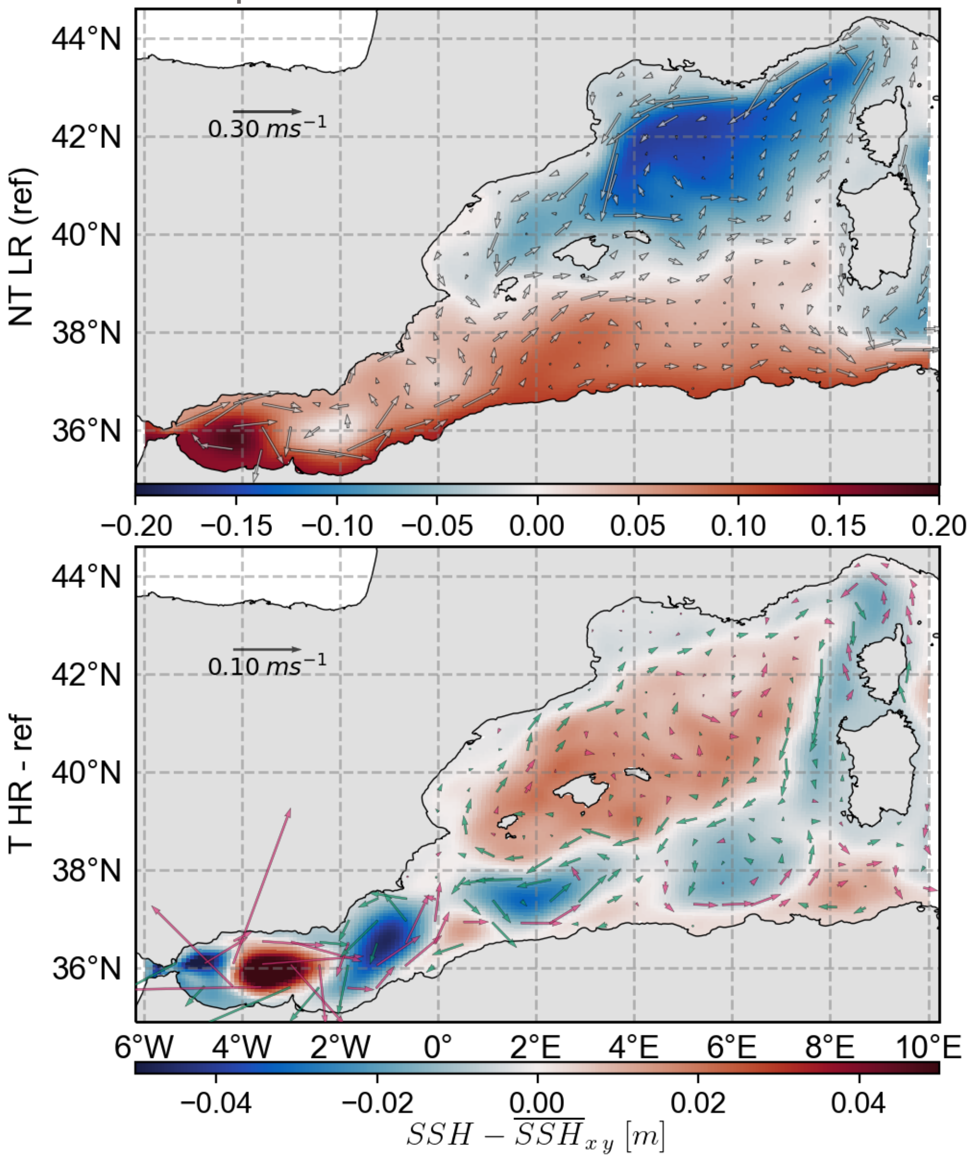
Dynamic sea level (shades) and near surface velocity.



II. Oceanic adjustment to tidal mixing at the SoG

Modified circulation in the Western Mediterranean

Dynamic sea level (shades) and near surface velocity.
Bottom panel: Tidal and AGRIF zoom anomalies



II. OCEANIC ADJUSTMENT TO TIDAL MIXING AT THE SOG

Modified circulation in the Western Mediterranean

- The anticyclonic gyre at the entrance of the Mediterranean Sea is **enhanced and displaced eastward**.

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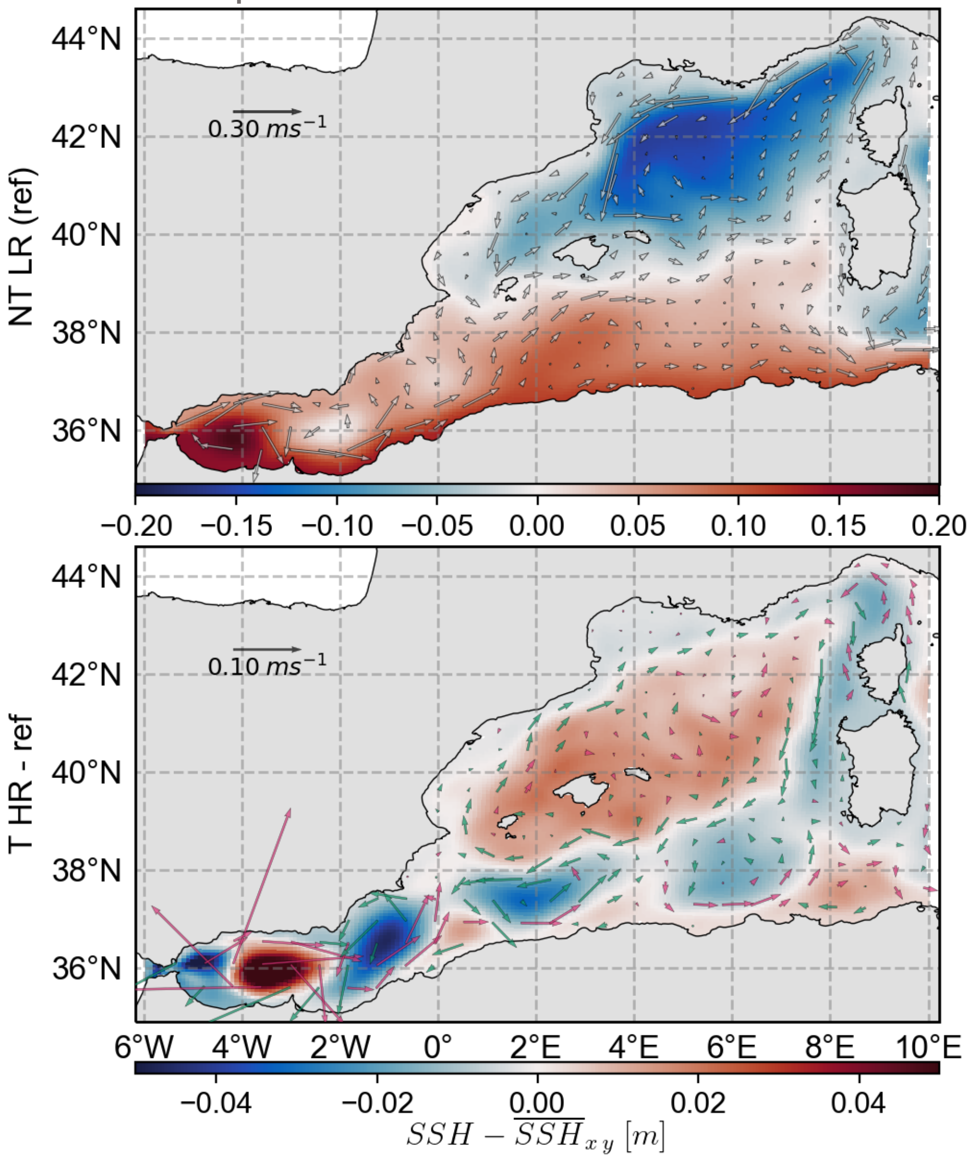

II. OCEANIC ADJUSTMENT TO TIDAL MIXING AT THE SOG

Modified circulation in the Western Mediterranean

- The anticyclonic gyre at the entrance of the Mediterranean Sea is **enhanced and displaced eastward**.
- **The Ligurian Sea cyclonic circulation weakens.** This induces the warm anomaly previously noted.

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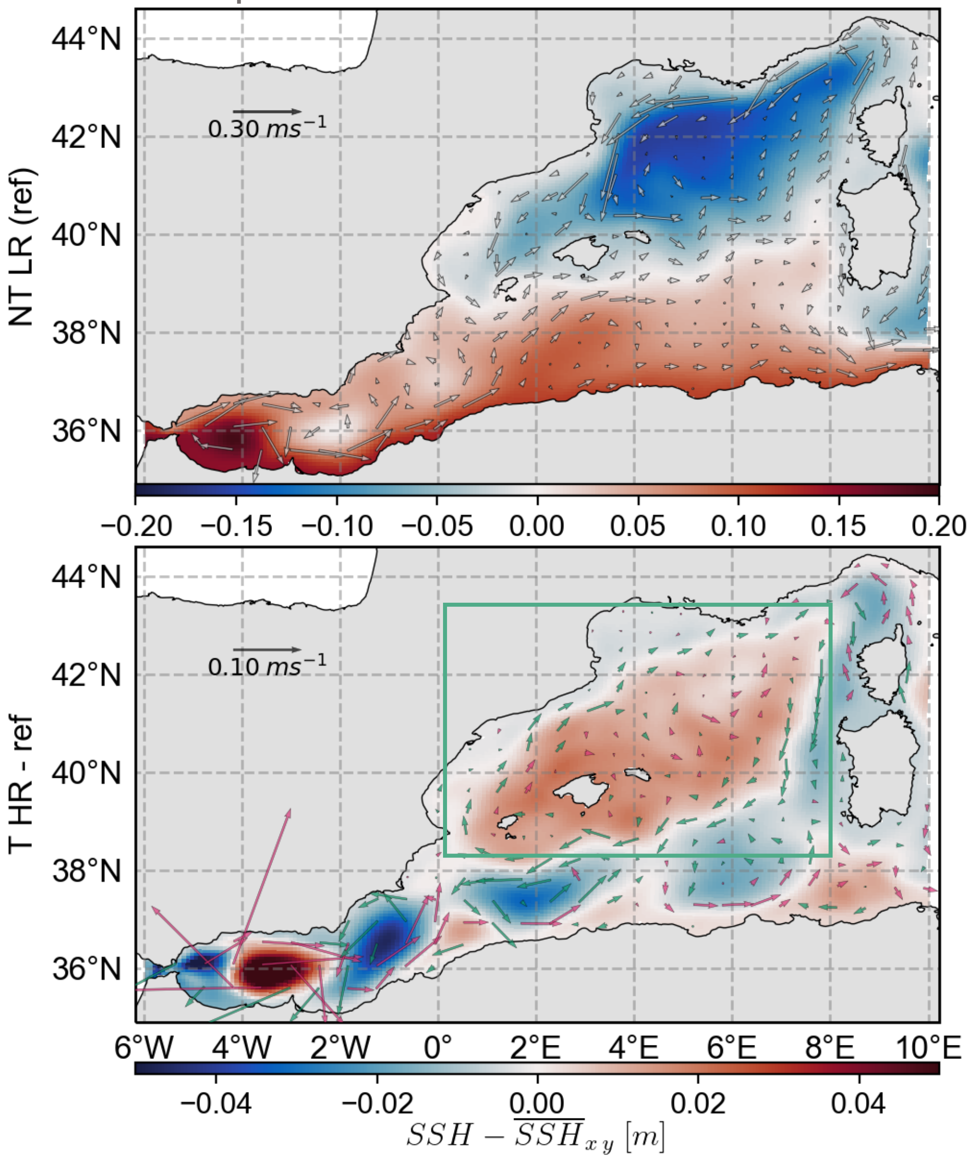
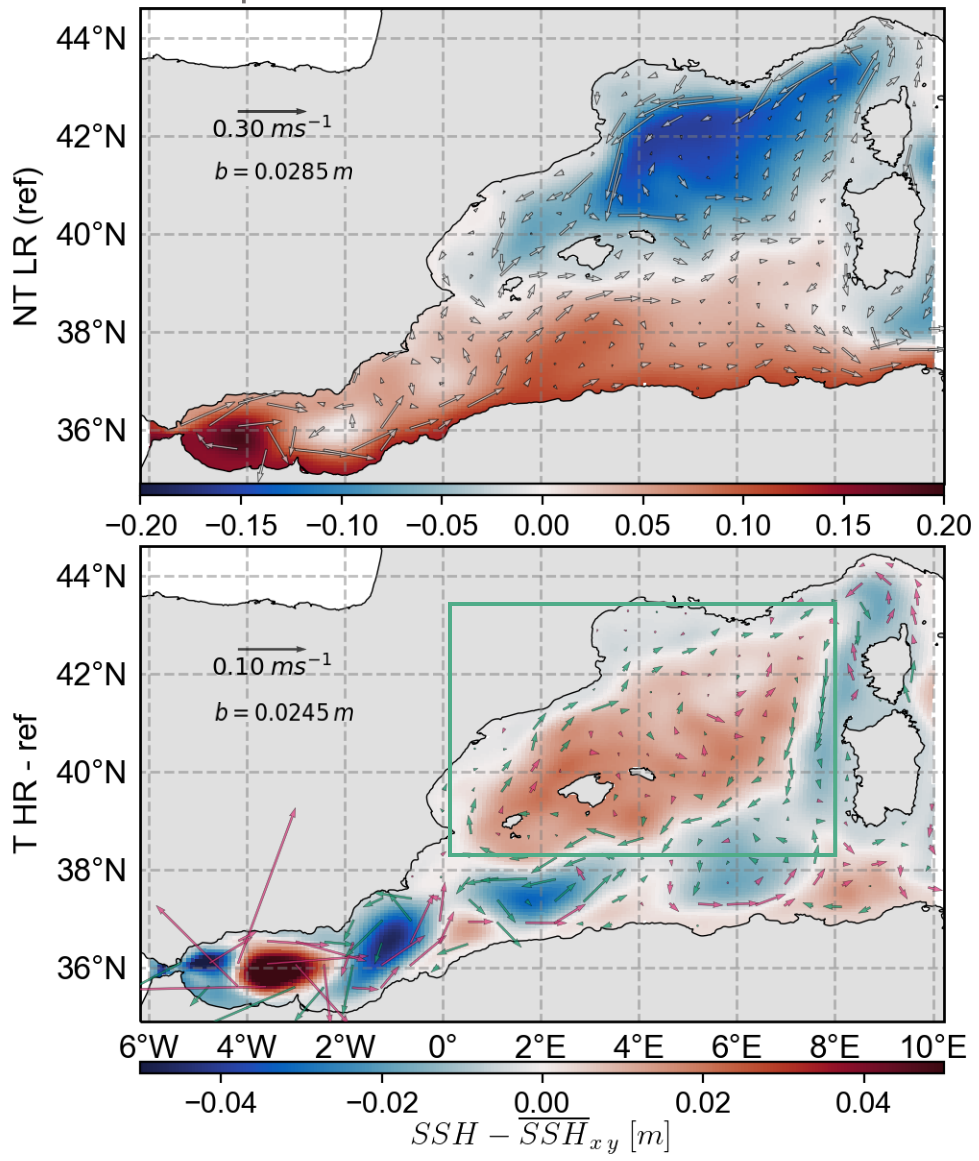


II. Oceanic adjustment to tidal mixing at the SoG

Modified circulation in the Western Mediterranean

- The anticyclonic gyre at the entrance of the Mediterranean Sea is **enhanced and displaced eastward**.
- **The Ligurian Sea cyclonic circulation weakens.** This induces the warm anomaly previously noted.
- In T HR, the bias with respect to **Rio et al. 2014** climatology of the Mediterranean Sea surface elevation **decreases by 14%**

Dynamic sea level (shades) and near surface velocity.
Bottom panel: Tidal and AGRIF zoom anomalies



OUTLINE

Introduction

I. Methods: A coupled regional climate model of the Mediterranean region

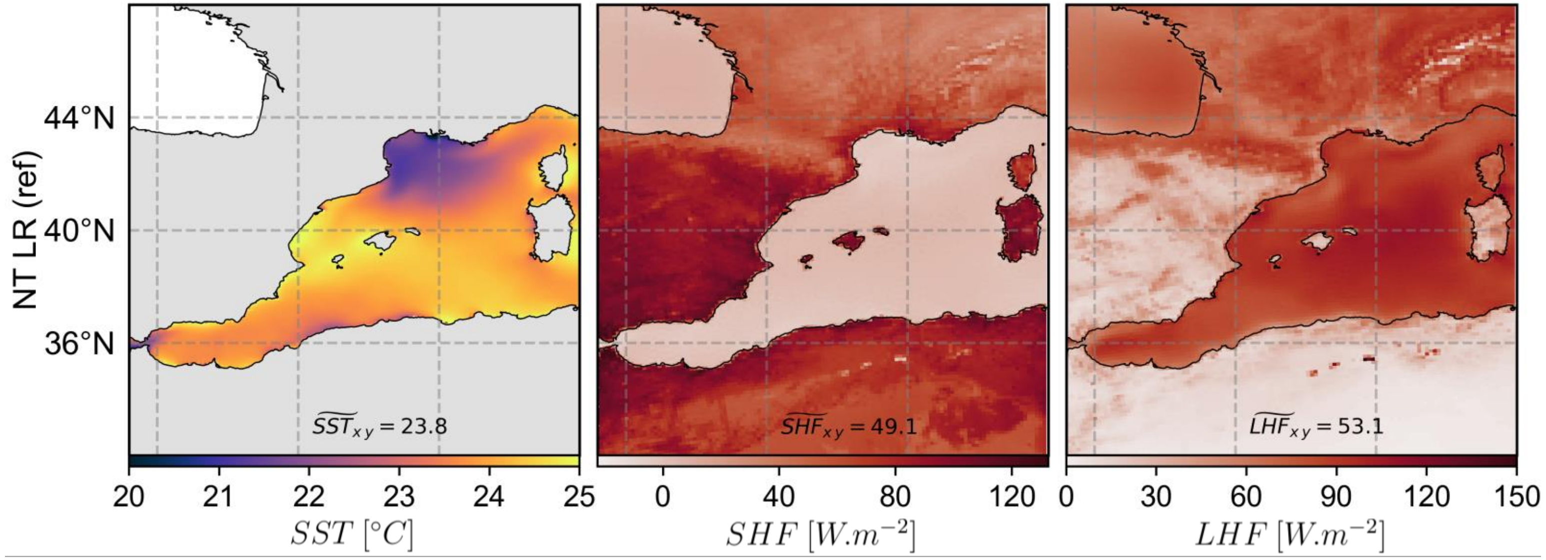
II. Oceanic adjustment to tidal mixing at the SoG

III. Impacts on the ocean-atmosphere interface

Conclusions et perspectives

Surface turbulent fluxes

JJA sea surface temperature, sensible heat flux, and latent heat flux
Bottom panel: Tidal and AGRIF zoom anomalies



III. IMPACTS ON THE OCEAN-ATMOSPHERE INTERFACE

Surface turbulent fluxes

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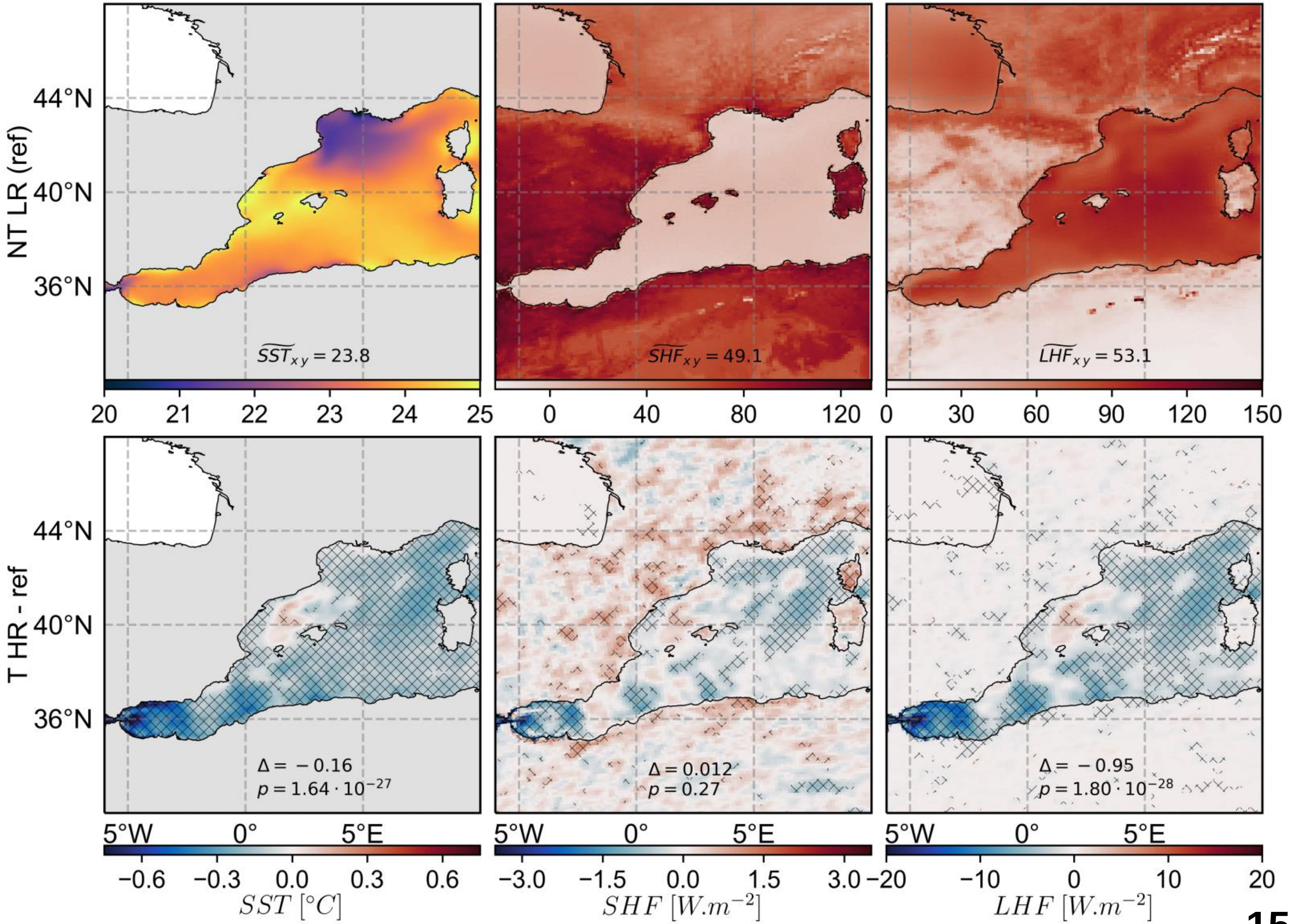

III. Impacts on the ocean-atmosphere interface

Surface turbulent fluxes

- Tidal cooling of the sea surface results in a **reduction of ocean heat loss,** mainly through the decrease of latent heat flux.

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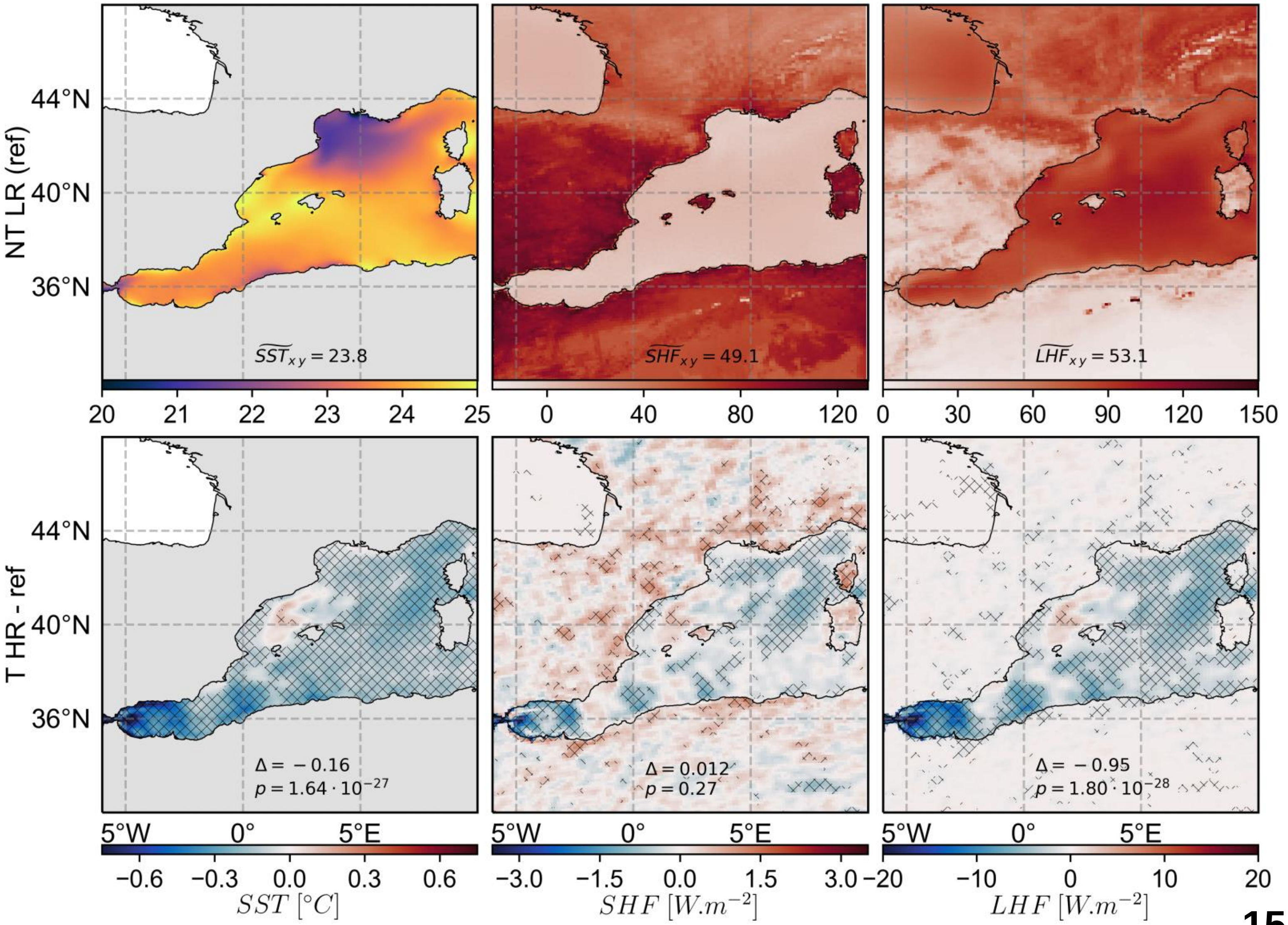

III. Impacts on the ocean-atmosphere interface

Surface turbulent fluxes

- Tidal cooling of the sea surface results in a **reduction of ocean heat loss,** mainly through the decrease of latent heat flux.

- This anomaly is significant in areas of **intense cooling and strong winds.**

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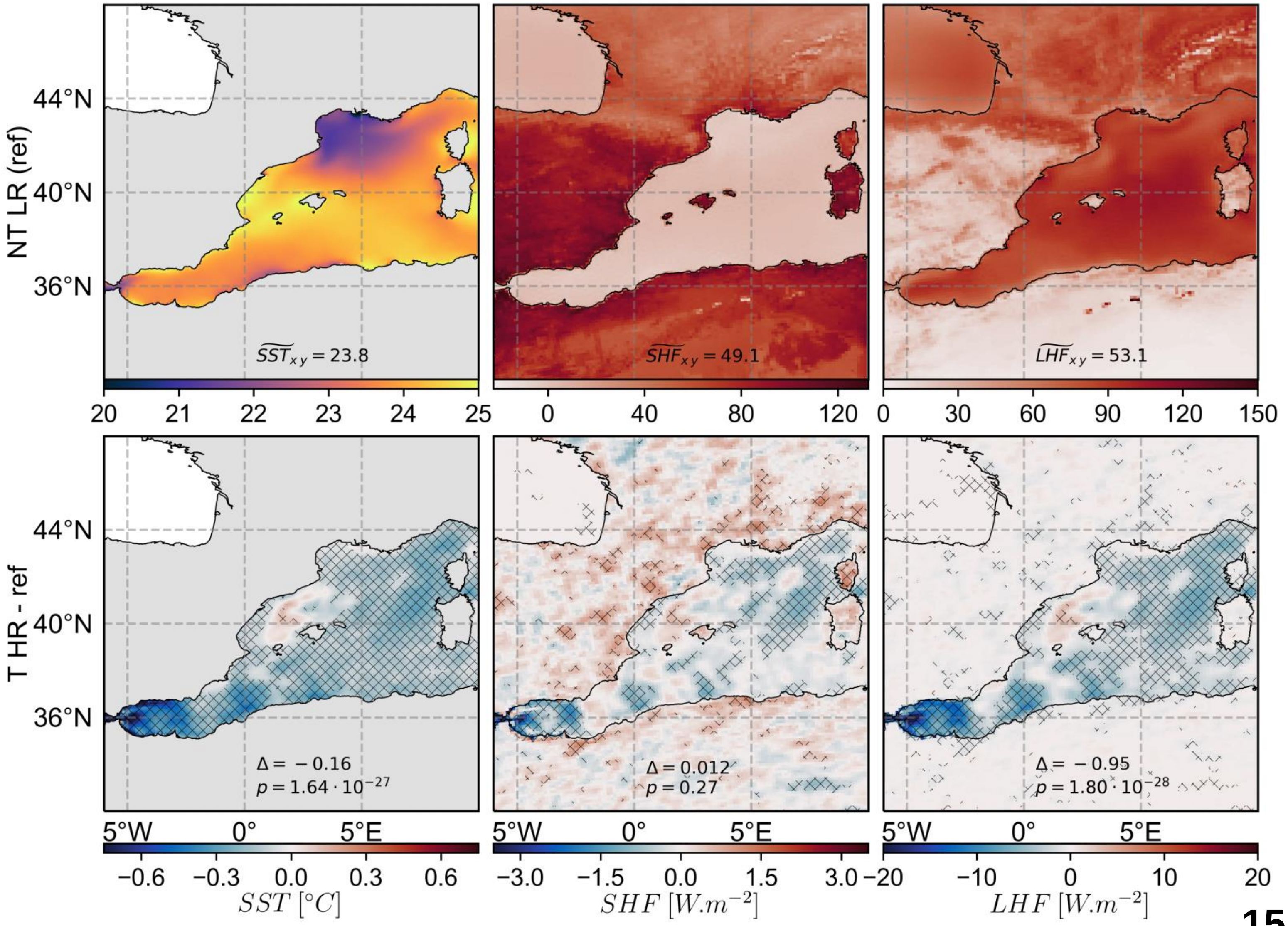

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Surface turbulent fluxes

- Tidal cooling of the sea surface results in a **reduction of ocean heat loss,** mainly through the decrease of latent heat flux.

- This anomaly is significant in areas of **intense cooling and strong winds.**

- The sensible heat flux is locally **intensified** over the northern Mediterranean coast. However, with a **low intensity** with respect to the mean fluxes.

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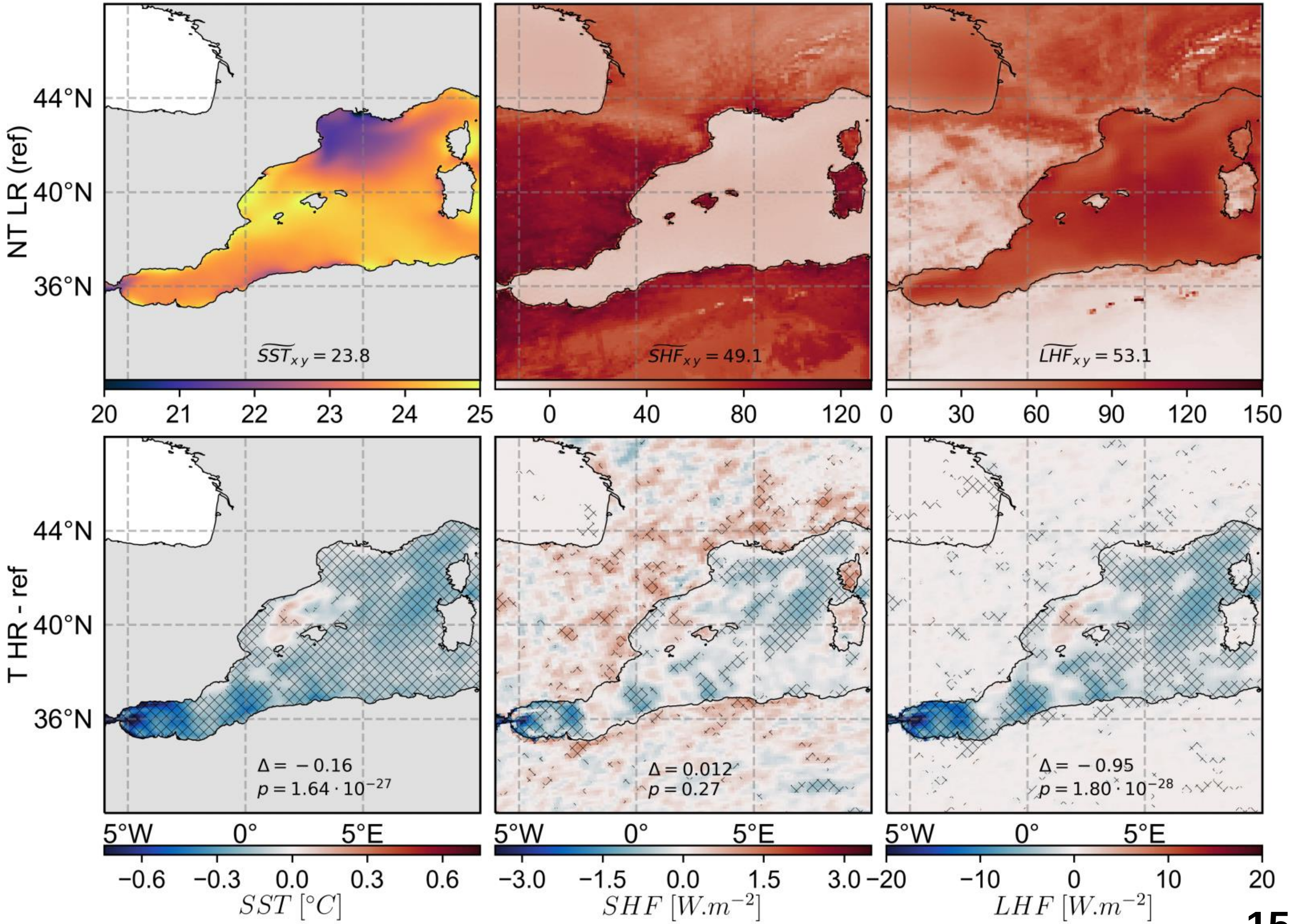

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Atmospheric surface properties

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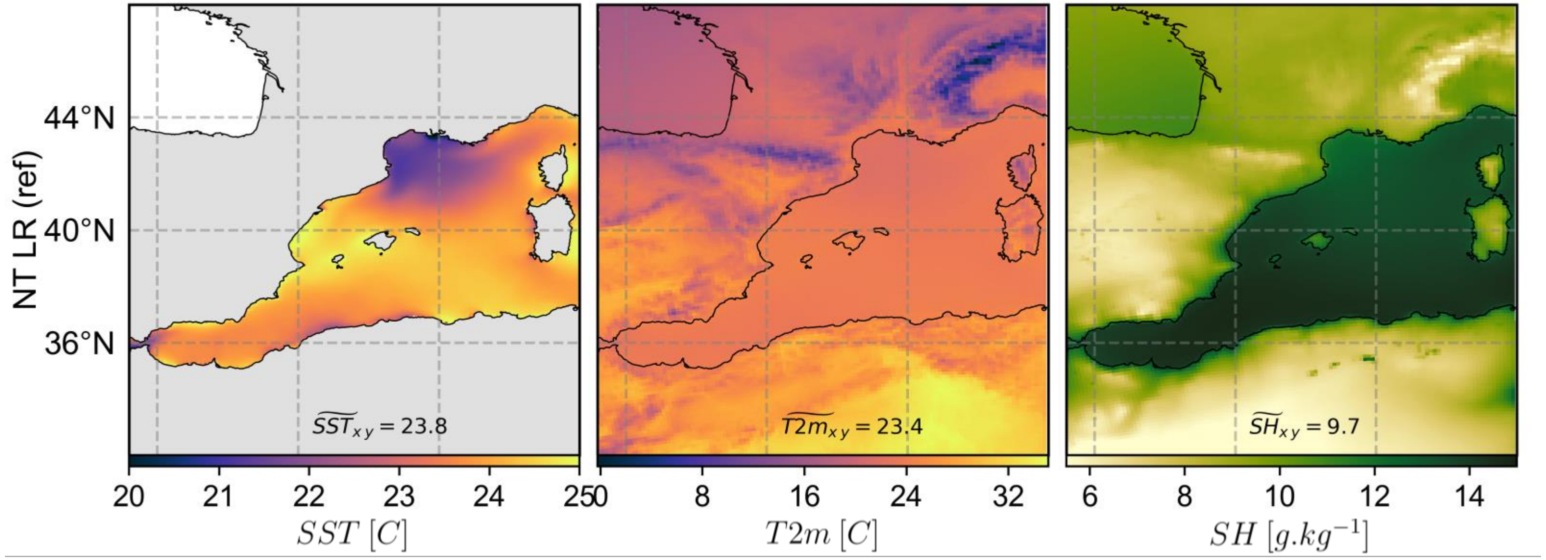

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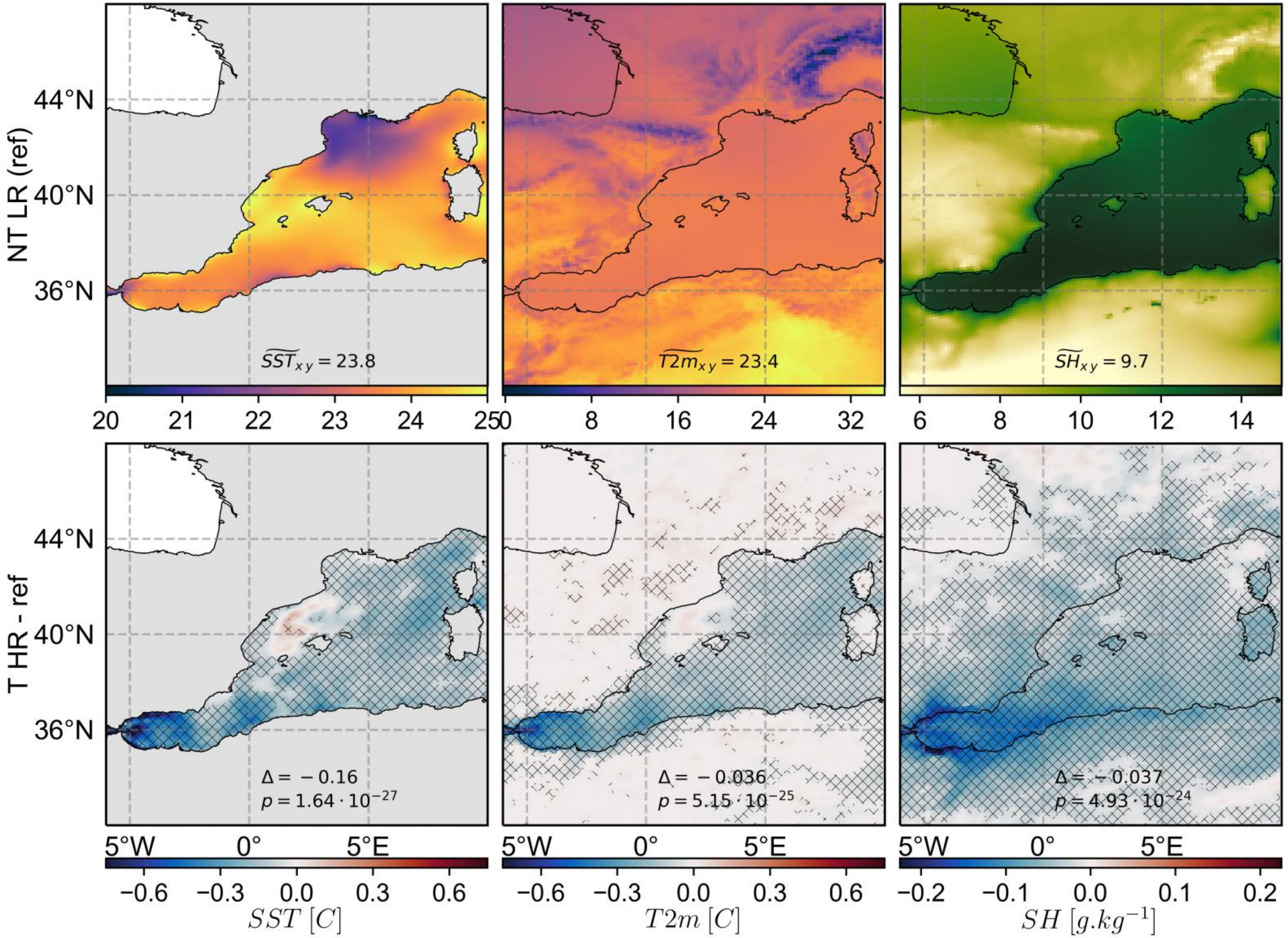

III. IMPACTS ON THE OCEAN-ATMOSPHERE INTERFACE

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- Over the sea, surface temperature mainly **decreases**. Over land, the anomalies are of lower amplitude.

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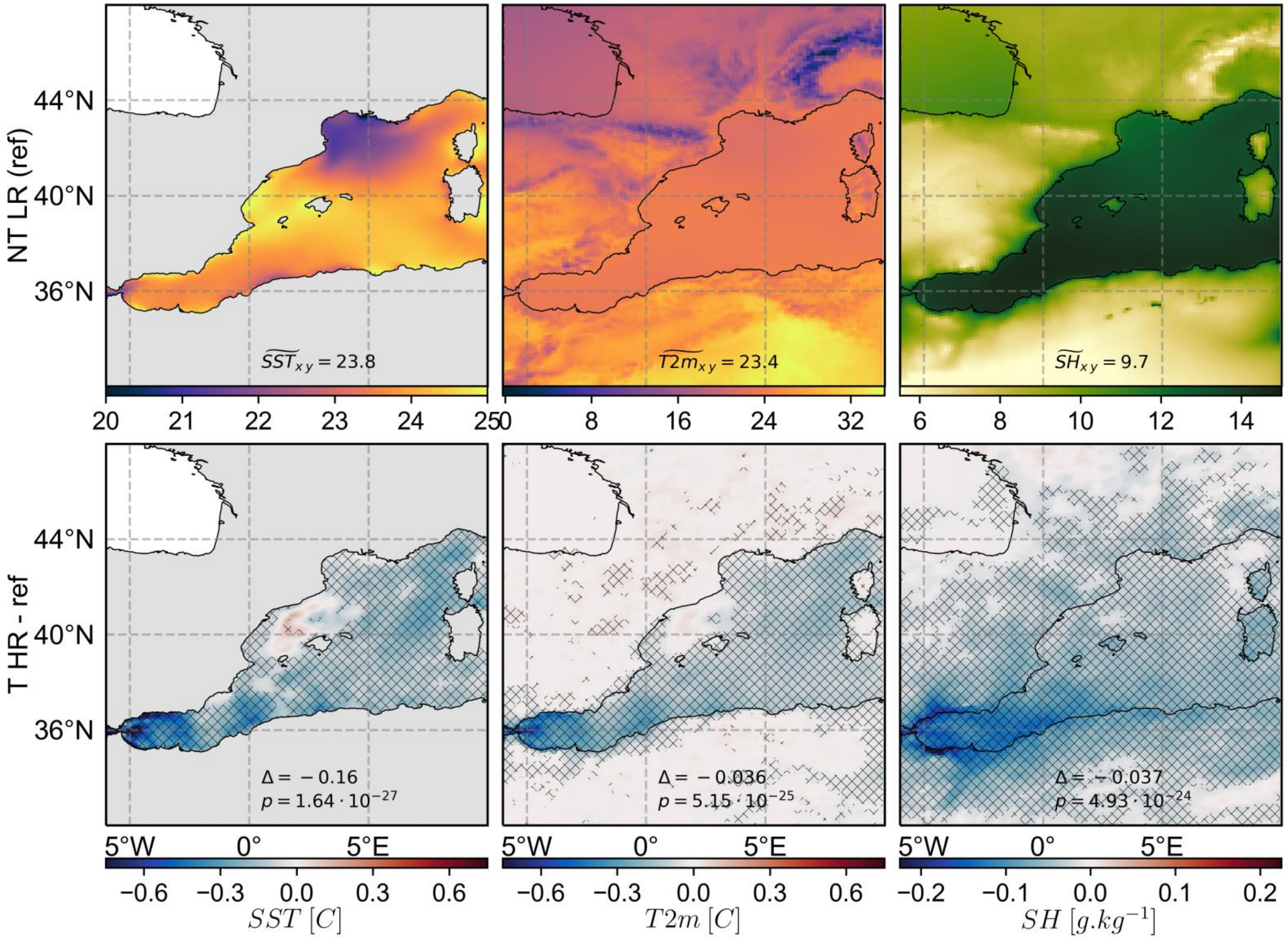

III. Impacts on the ocean-atmosphere interface

Atmospheric surface properties

- Over the sea, surface temperature mainly **decreases**. Over land, the anomalies are of lower amplitude.

- Specific humidity **decreases** over both the western Mediterranean Basin and coast.

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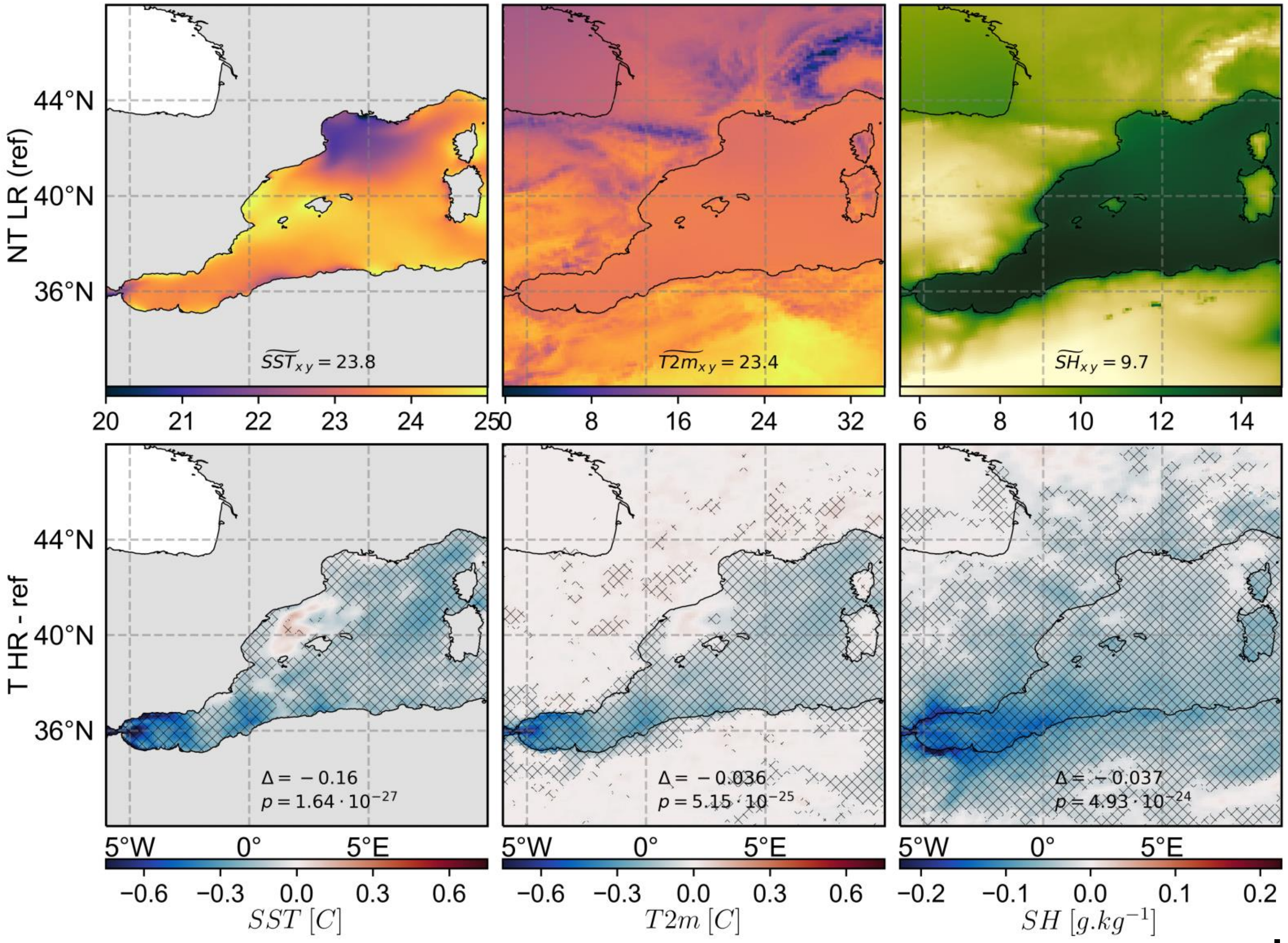

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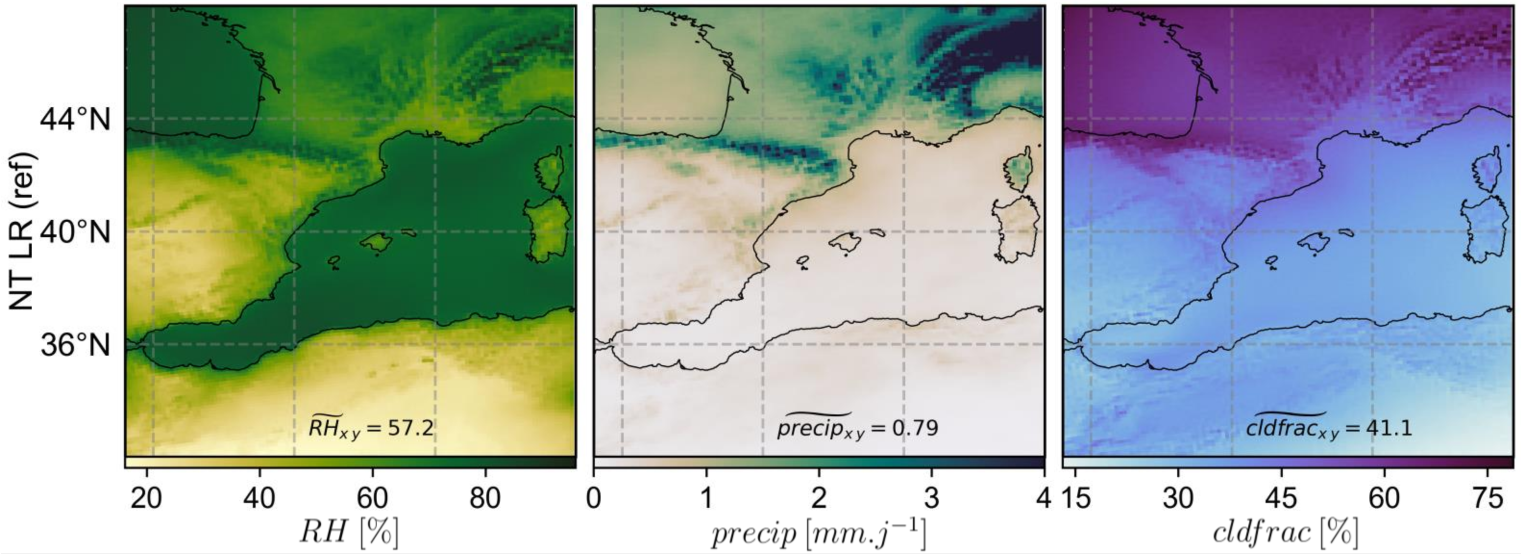
Precipitations and cloud fraction

JJA relative humidity, precipitations, and cloud fraction
Bottom panel: Tidal and AGRIF zoom anomalies



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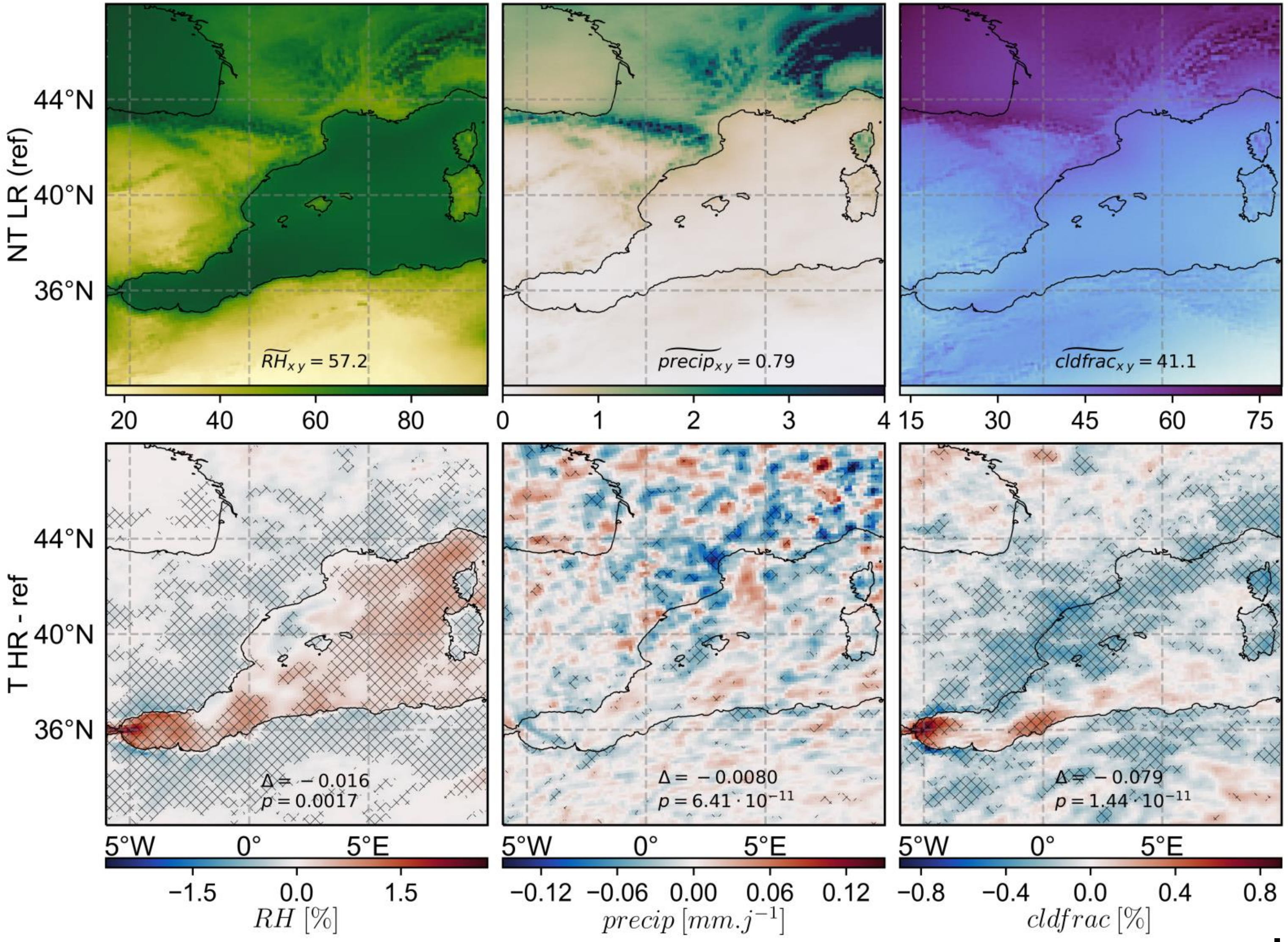

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- Relative humidity **decreases over the land**, but **increases over the ocean** due to the decrease of saturation humidity.

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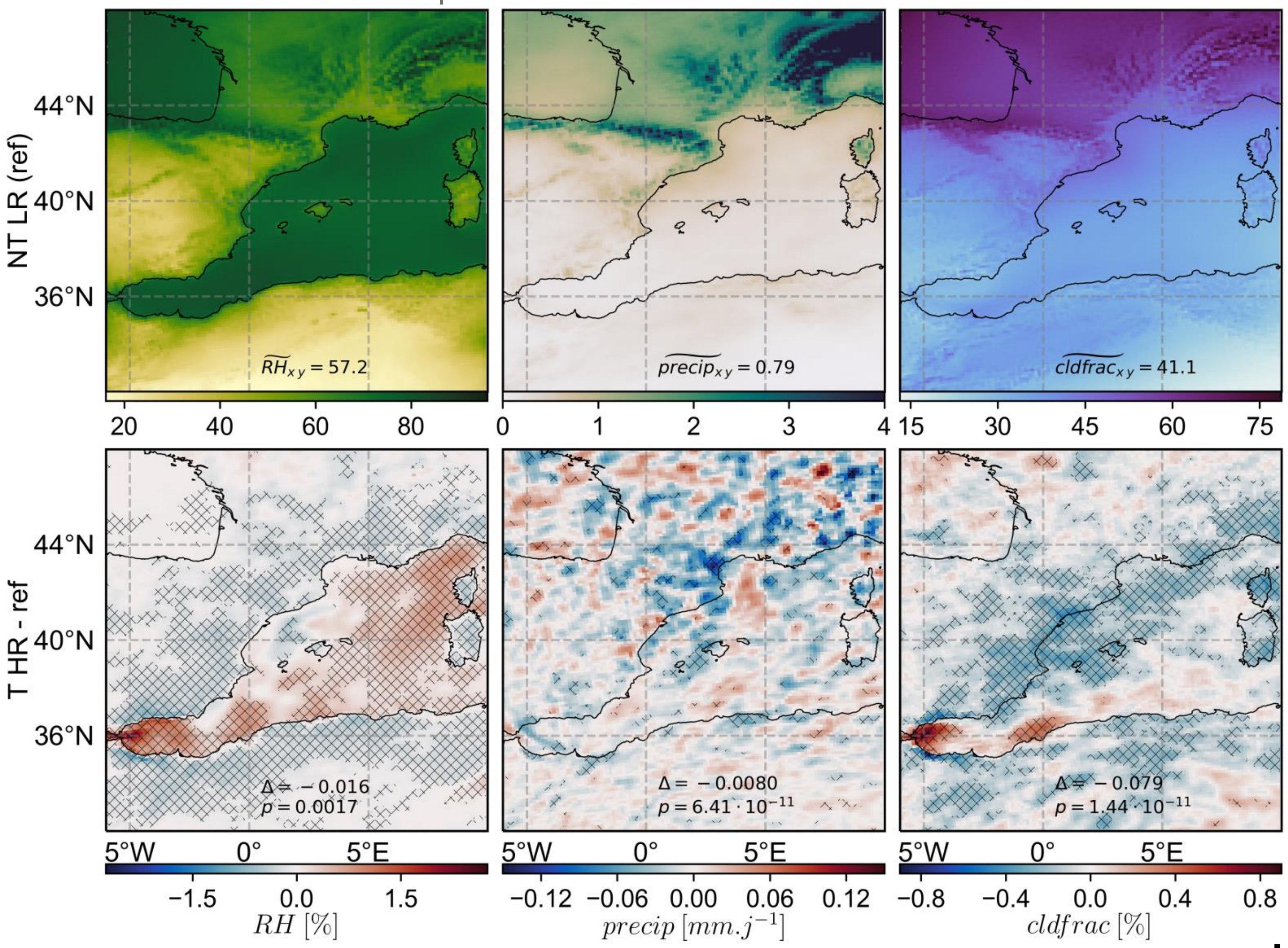

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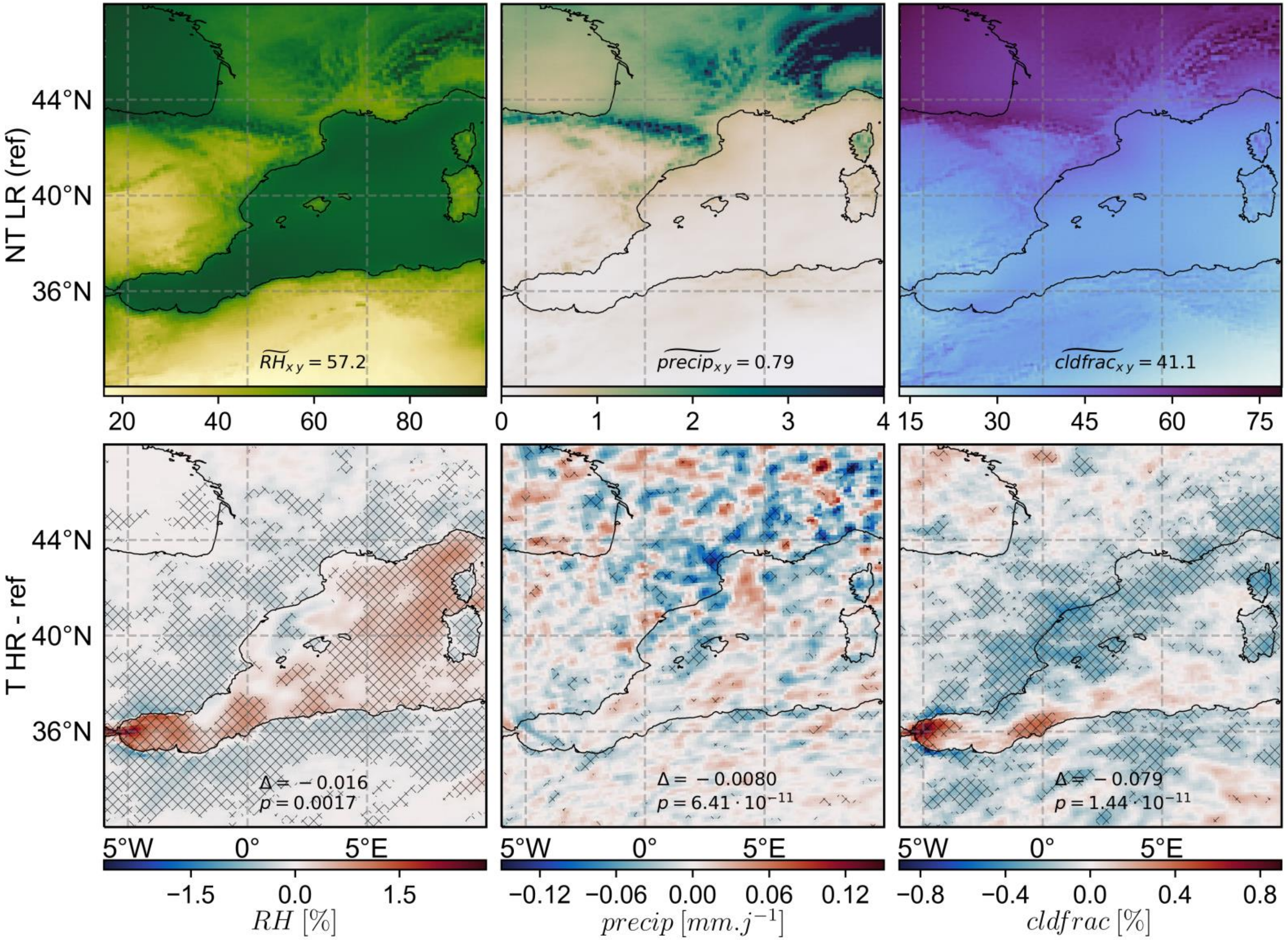
Precipitations and cloud fraction

- Relative humidity **decreases over the land**, but **increases over the ocean** due to the decrease of saturation humidity.

- Most of precipitation anomalies are **not statistically significant**. However, the **mean reduction of ~ 1%** over the western Mediterranean region is.

JJA relative humidity, precipitations, and cloud fraction
Bottom panel: Tidal and AGRIF zoom anomalies



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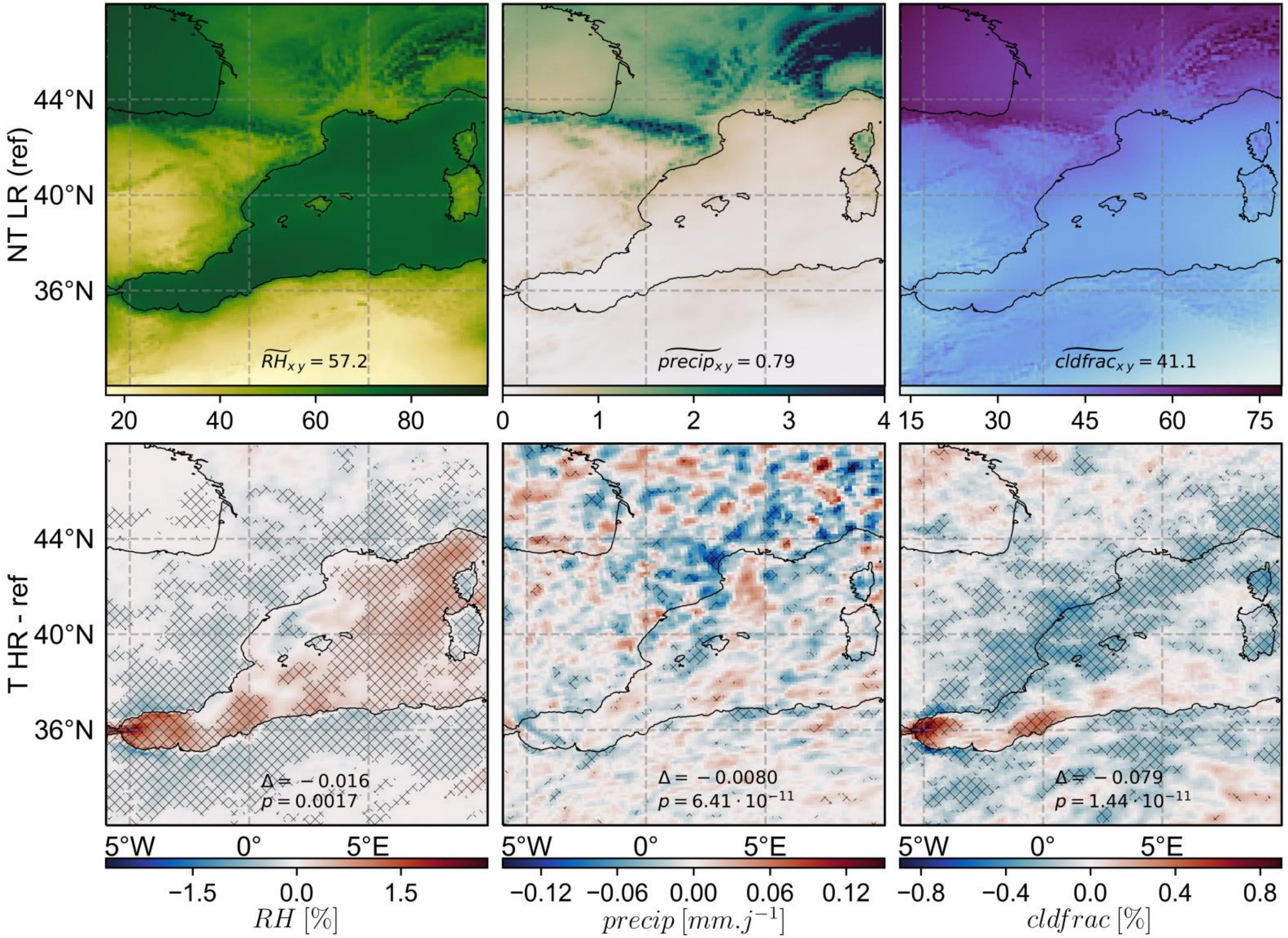

Precipitations and cloud fraction

- Cloud fraction **moderately diminishes** over most of the Western Mediterranean.

- In the Alboran Sea and at the north of Morocco, it **locally increases** because of the saturating humidify reduction.

JJA relative humidity, precipitations, and cloud fraction
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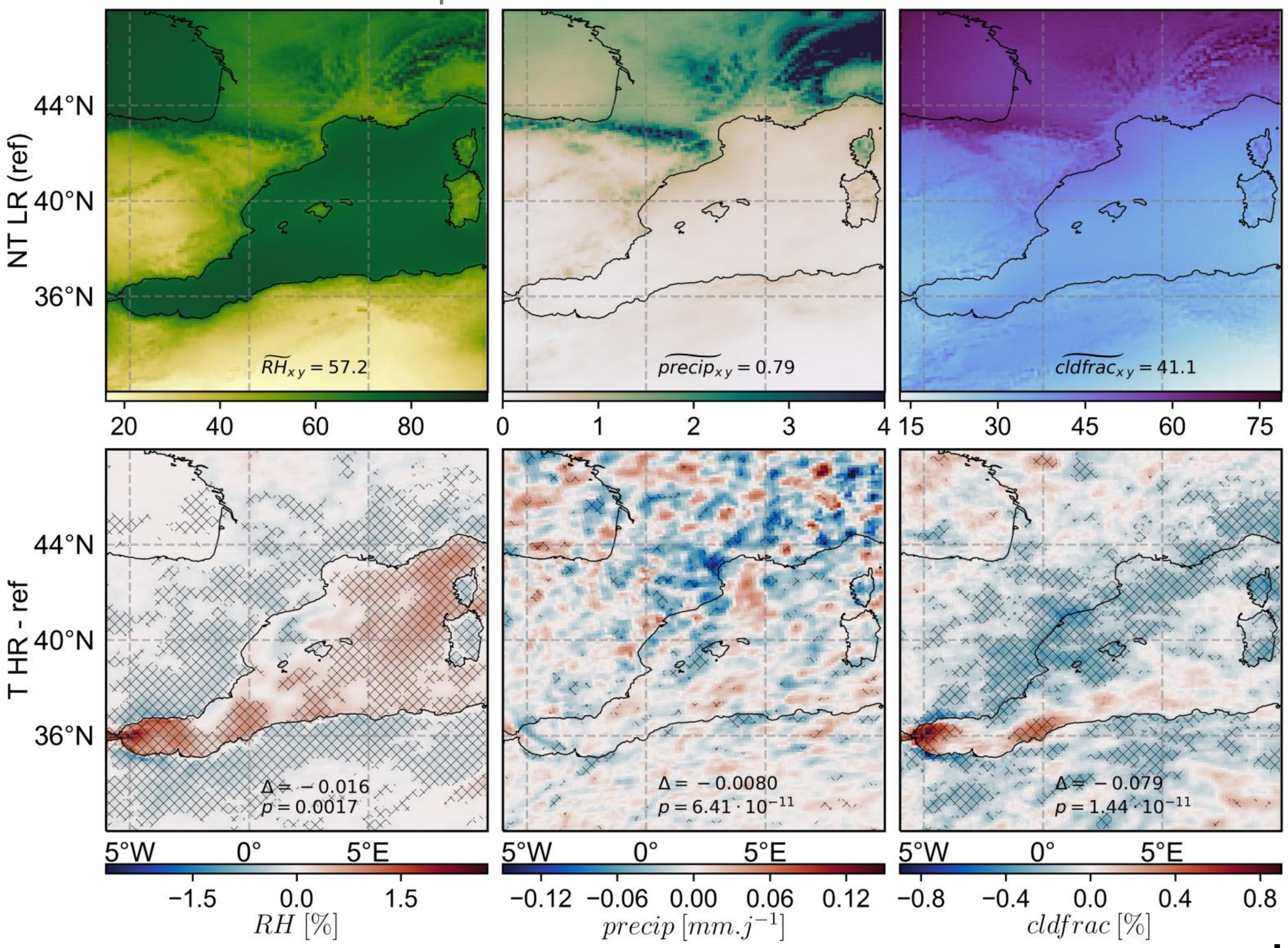

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- The atmospheric surface above the ocean is cooled and dried. As a result, precipitation and cloud fraction moderately decrease.

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- Land impacts are of lower intensity, but they remain significative in island and coastal areas.

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DISCUSSIONS

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- The underlined mechanisms should be studied in the context of global warming simulations, in which their effects may be intensified due to the projected increase of surface ocean stratification.

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