# *Future Euro-Mediterranean climate sensitivity to anthropogenic aerosols*


Thomas Drugé
PhD student

Photography encouraged

*UMR3589, CNRM, Météo-France/CNRS, Toulouse, France*

**Supervised by: Pierre Nabat, Marc Mallet and Samuel Somot**


Wednesday 10th April 2019

CNRM

La Région Occitanie Pyrénées - Méditerranée

CHARMEX Chemistry-Aerosol Mediterranean Experiment

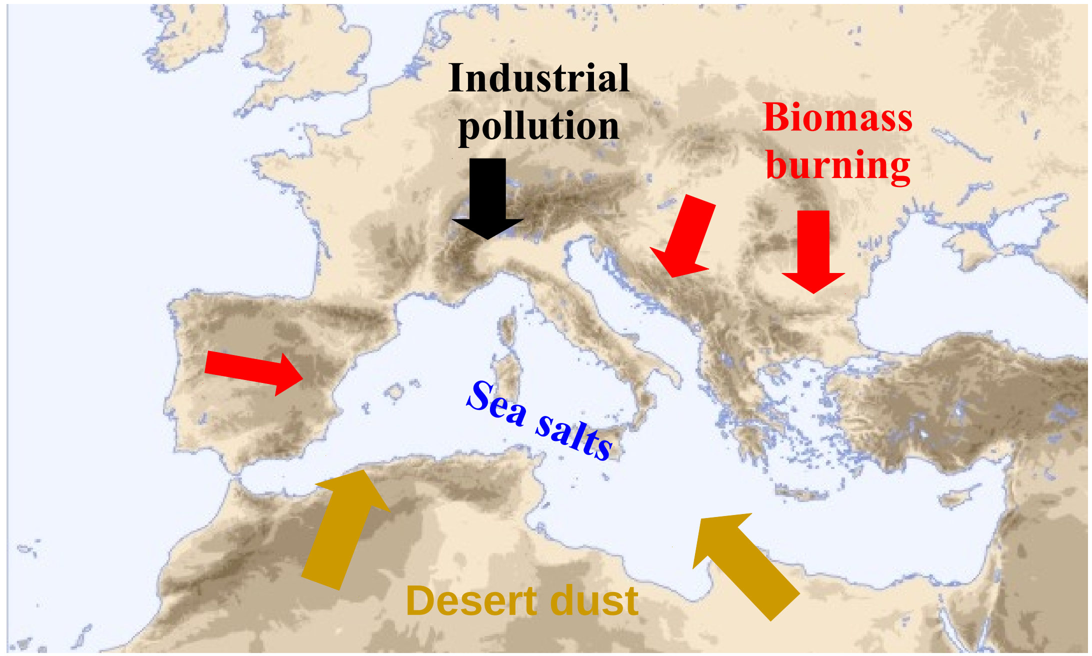
MISTRALS

METEO FRANCE

CNRS

# Why study aerosols over the Mediterranean ?

– > Crossroads of various aerosols (natural + anthropogenic sources)

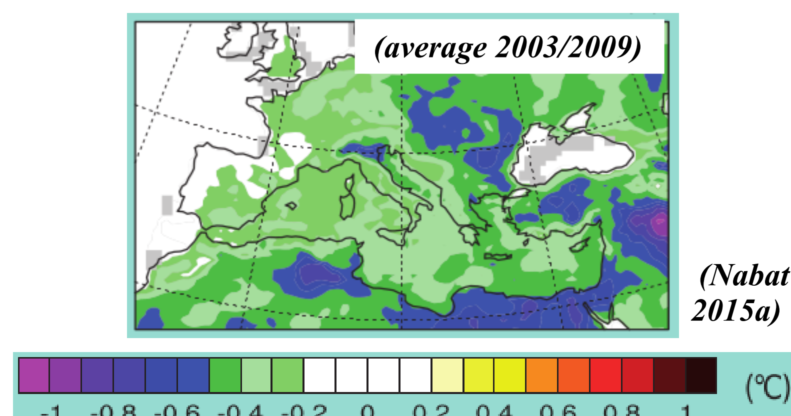



Aerosols = Important impact on radiative budget and climate

| *Aerosols direct radiative forcing (average 2003-2009, surface, all sky)* | **SW DRF ($W.m^{-2}$)** |
|---|---|
| **Europe** | - 14 .7 |
| **Mediterranean Sea** | - 20.9 |
| **Northern Africa** | - 19.4 |

*(Nabat et al., 2015a)*

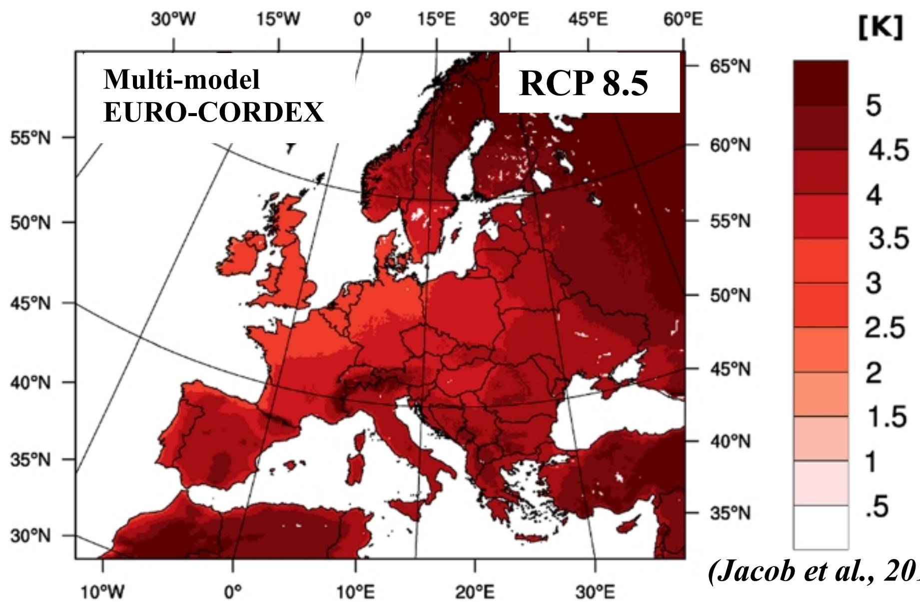
***Aerosol effects on surface temperature***




*(Nabat et al., 2015a)*

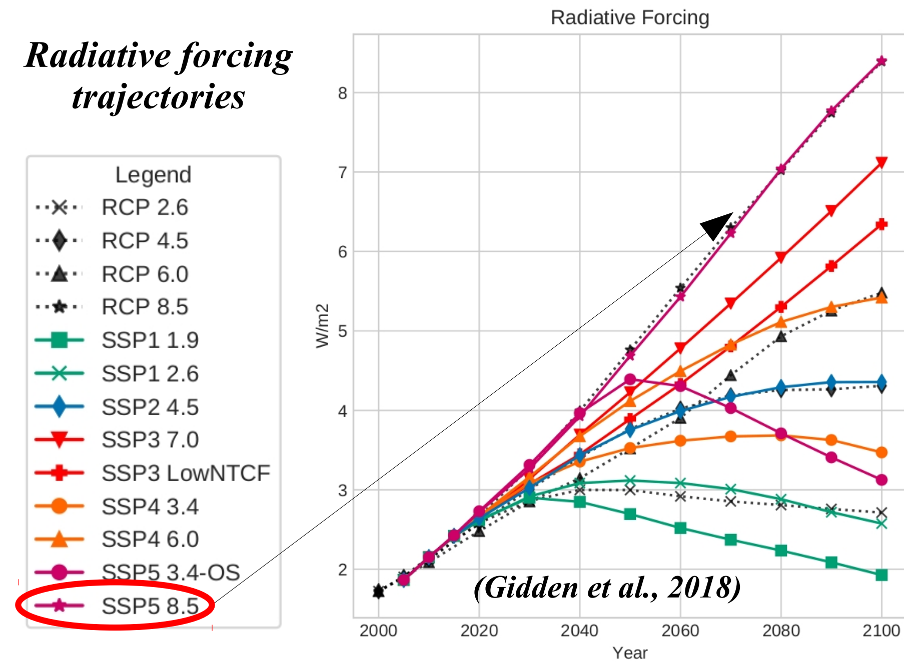
# Use of climate scenarios:
## CMIP5 (RCP, Representative Concentration Pathway) / CMIP6 (SSP, Shared Socioeconomic Pathway)

***Mean temperature (2071/2100 - 1971/2000)***




*(Jacob et al., 2013)*

***Radiative forcing trajectories***




*(Gidden et al., 2018)*

► Sensitive region to climate change

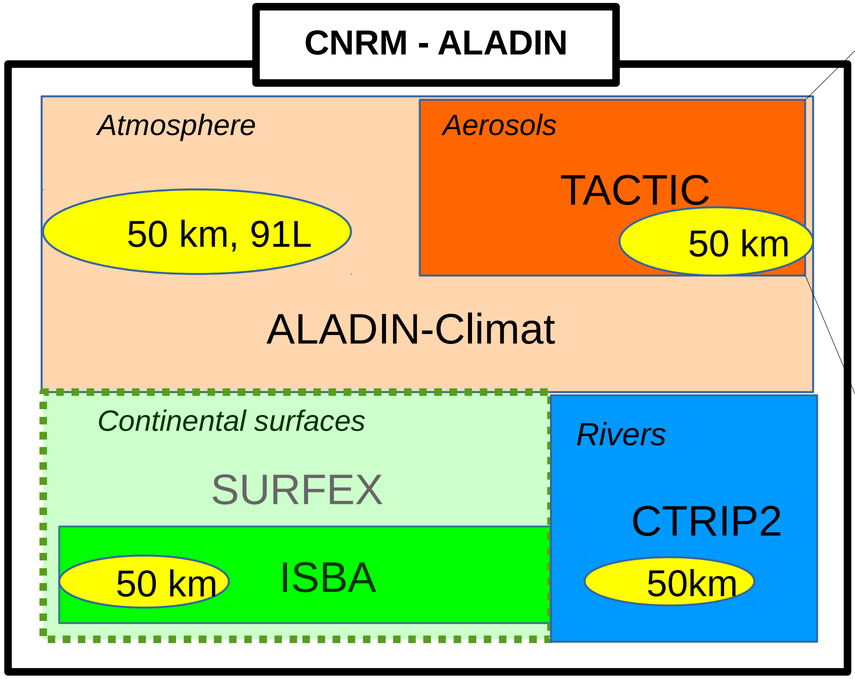
*Aerosol evolution not taken into account by most EURO-CORDEX and MED-CORDEX models.*

---

**Objectives:**

- Study the aerosols evolution between the past and future period
- Quantify the future Euro-Mediterranean climate sensitivity to anthropogenic aerosols

# Methodology:




- Not coupled with ocean
- Forced by CNRM-ESM2 ***(Séférian et al., 2019)***

TACTIC ***(Michou et al., 2015 ; Nabat et al., 2015)***

- Prognostic aerosol scheme
- 7 aerosol types : Dust, sea-salt, organic carbon, black carbon, sulfate, ammonium and nitrate ***(Drugé et al., 2019)***
- Interactions with SW and LW radiation (direct aerosol effect)
- Cloud albedo indirect effect for sulfate, sea-salt, organic matter and nitrate (first indirect aerosol effect): not discussed in this presentation

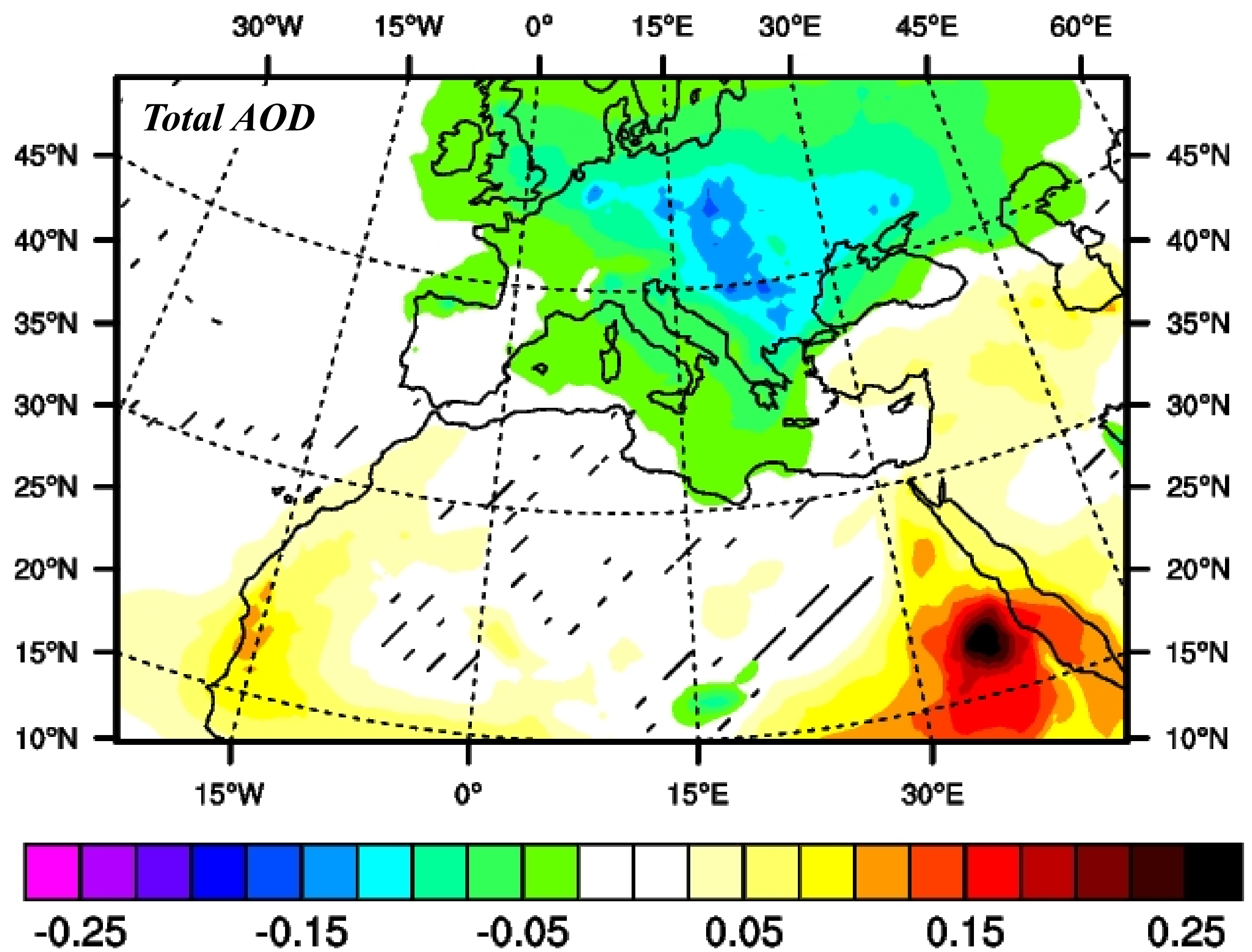
– > Simplified scheme to keep a low numerical cost

## Three simulations (use of CMIP6 forcing)

| | **HIST** | **SSP585** | **SSP585avg** |
|---|---|---|---|
| **Anthropogenic aerosol emissions** | CMIP6 historical | SSP 5-8.5 scenario | CMIP6 historical (average) |
| **Period** | 1971-2000 | 2021-2050 | 2021-2050 |

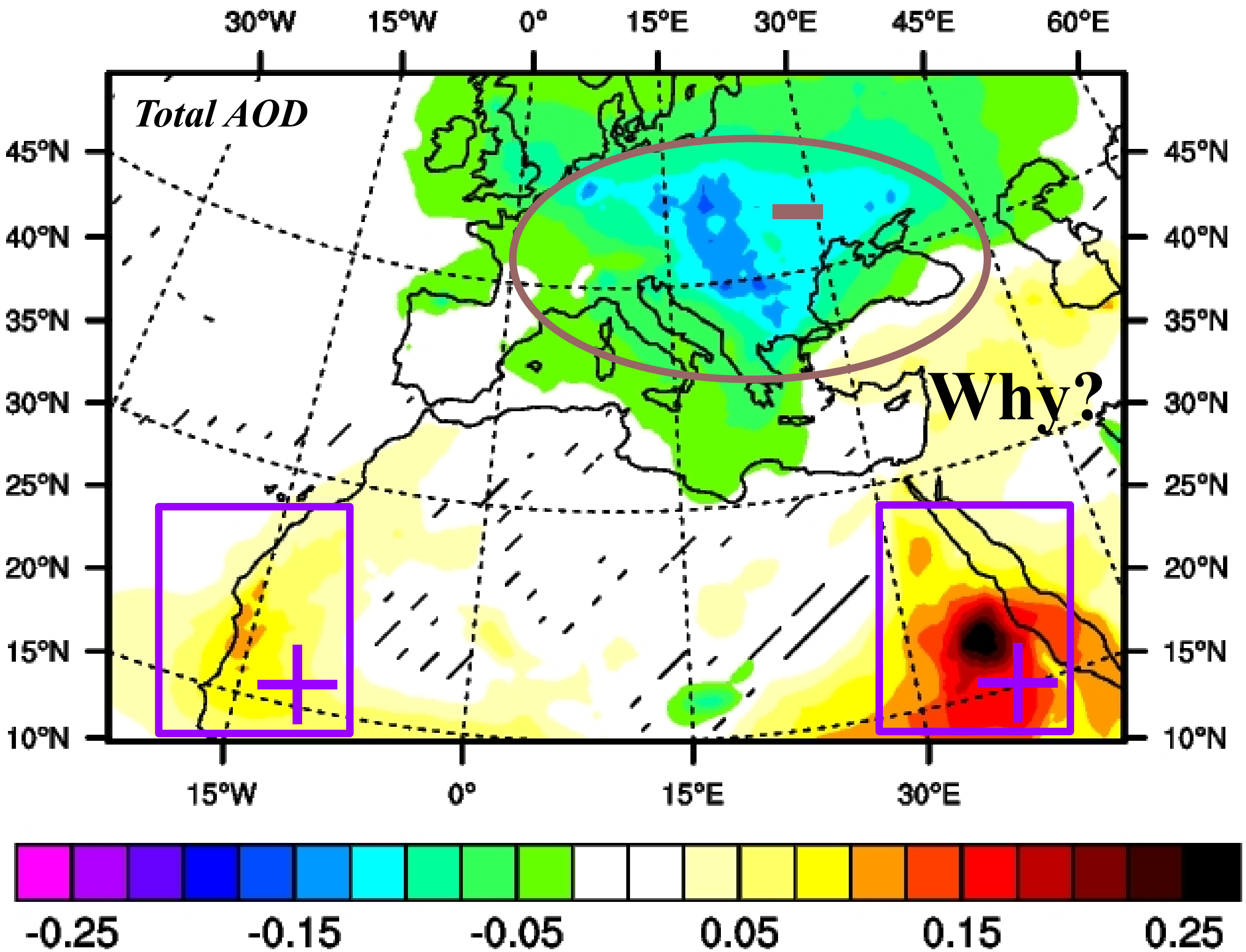
Results = summer (June, July and August)

# Total AOD
## SSP585 (2021/2050) – HIST (1971/2000)



# Total AOD

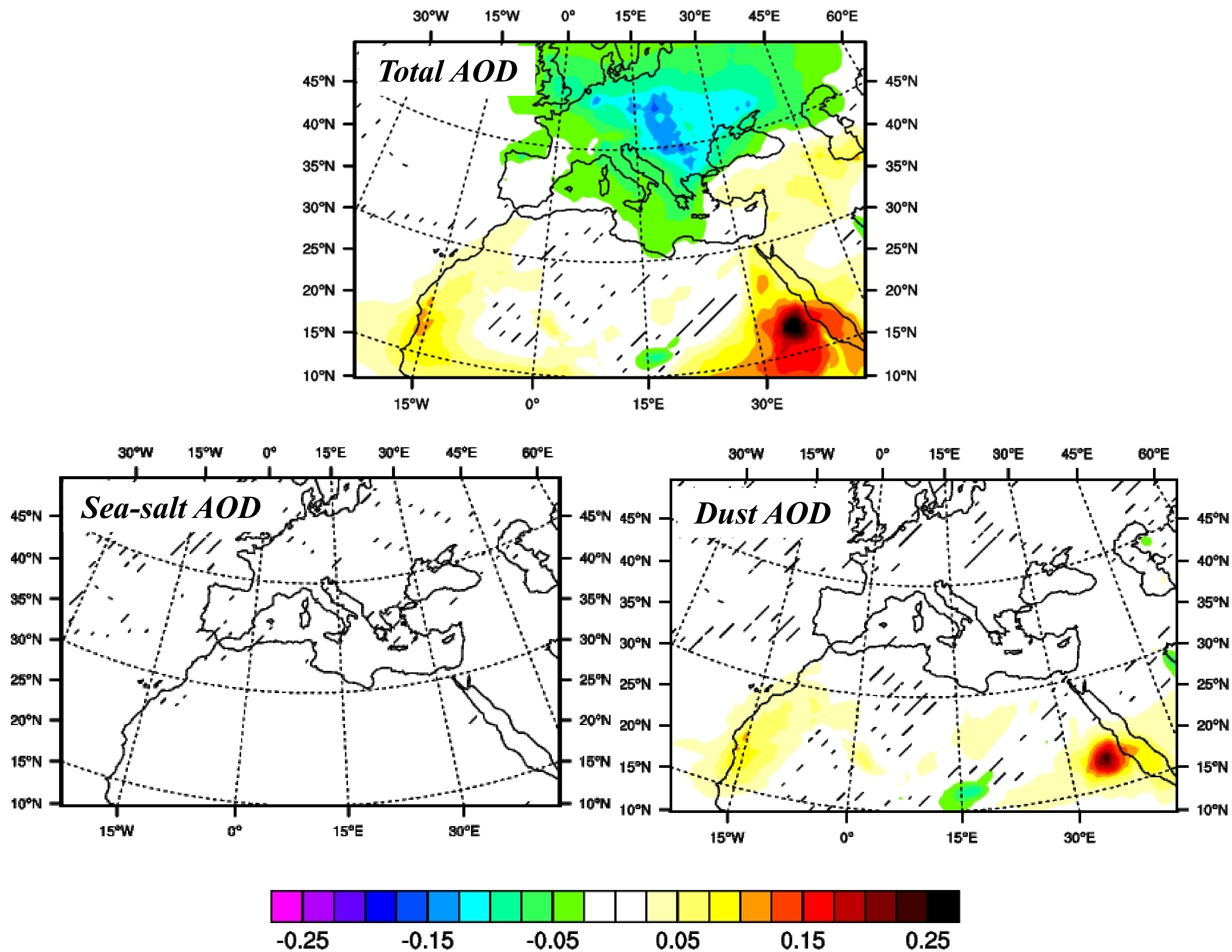
SSP585 (2021/2050) – HIST (1971/2000)




– > Separation by aerosol type

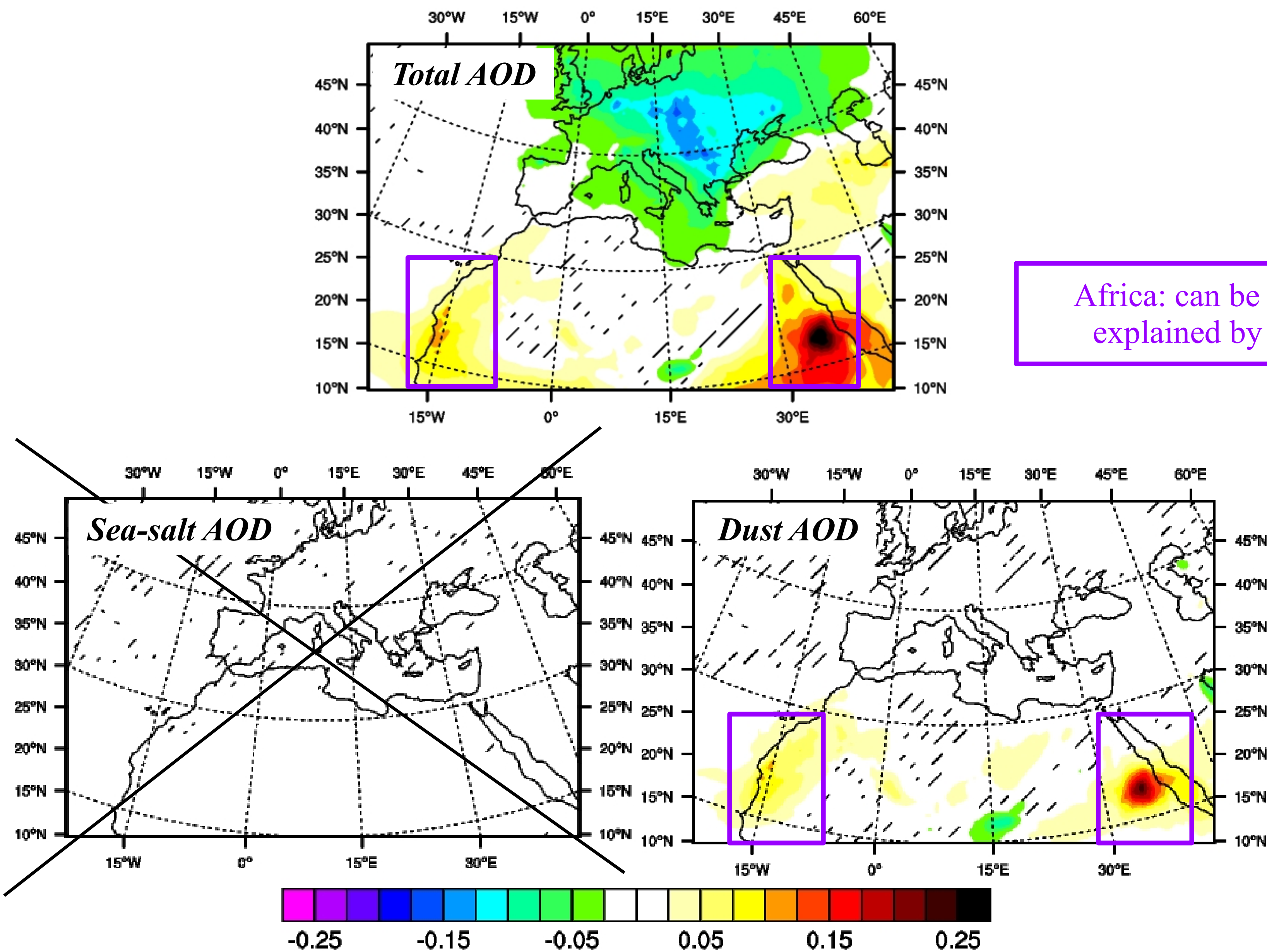
# Natural aerosols

## SSP585 (2021/2050) – HIST (1971/2000)



# Natural aerosols

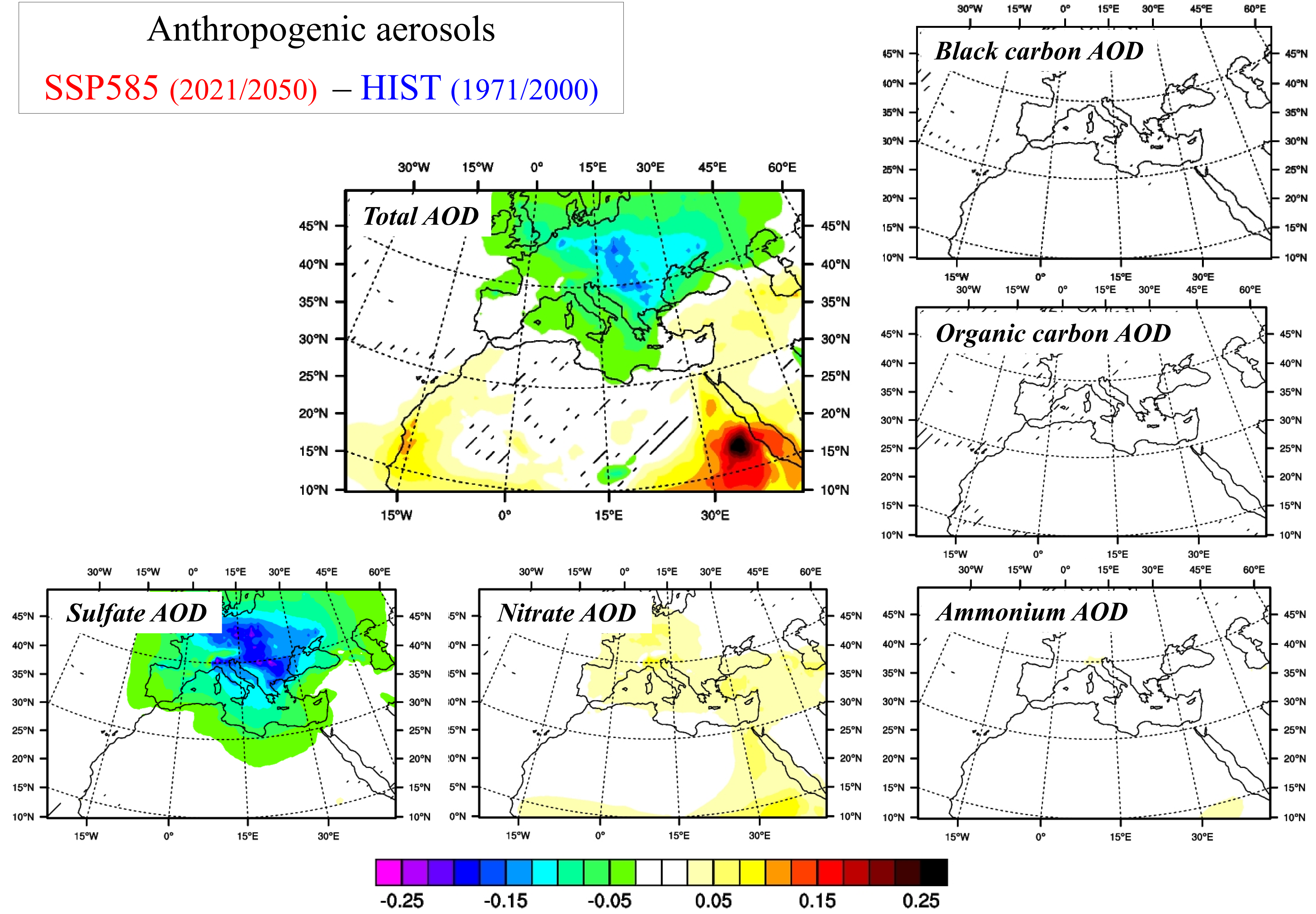
## SSP585 (2021/2050) – HIST (1971/2000)




Africa: can be partly explained by dust

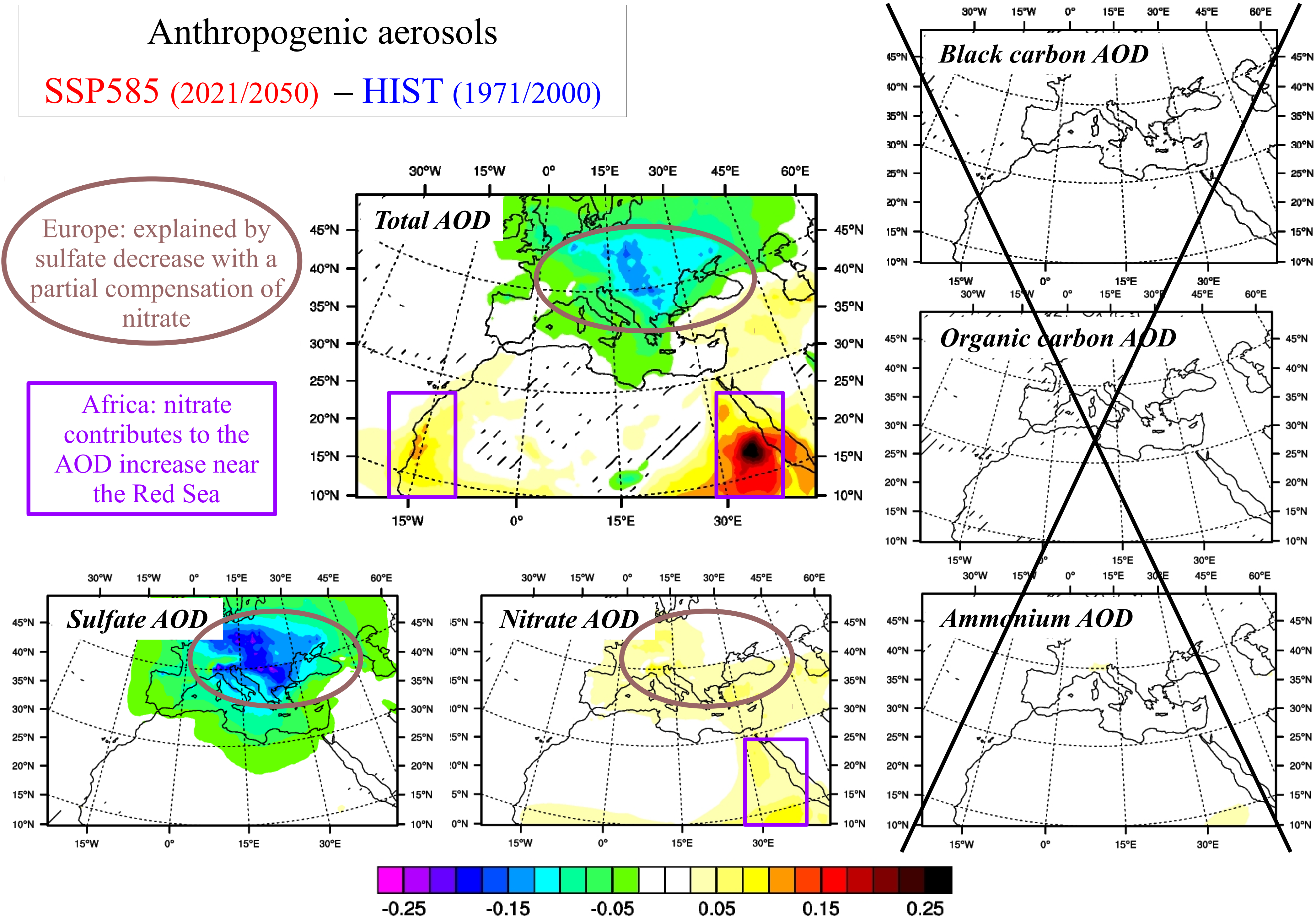
# Anthropogenic aerosols

SSP585 (2021/2050) – HIST (1971/2000)



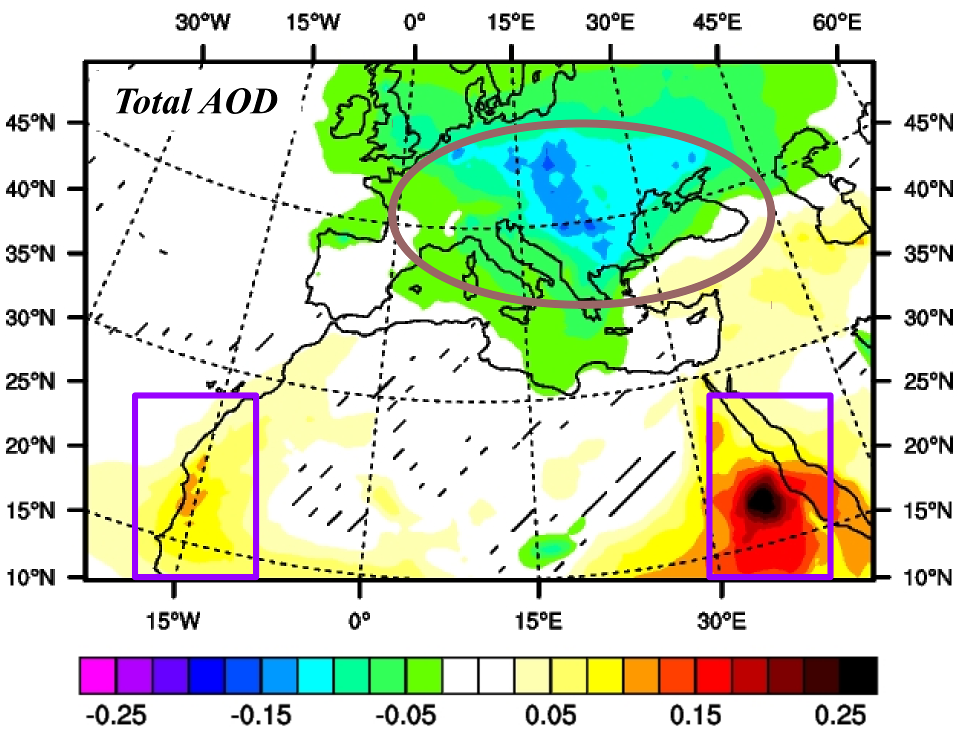
# Anthropogenic aerosols

## SSP585 (2021/2050) – HIST (1971/2000)



## Evolution causes

SSP585 (2021/2050) – HIST (1971/2000)



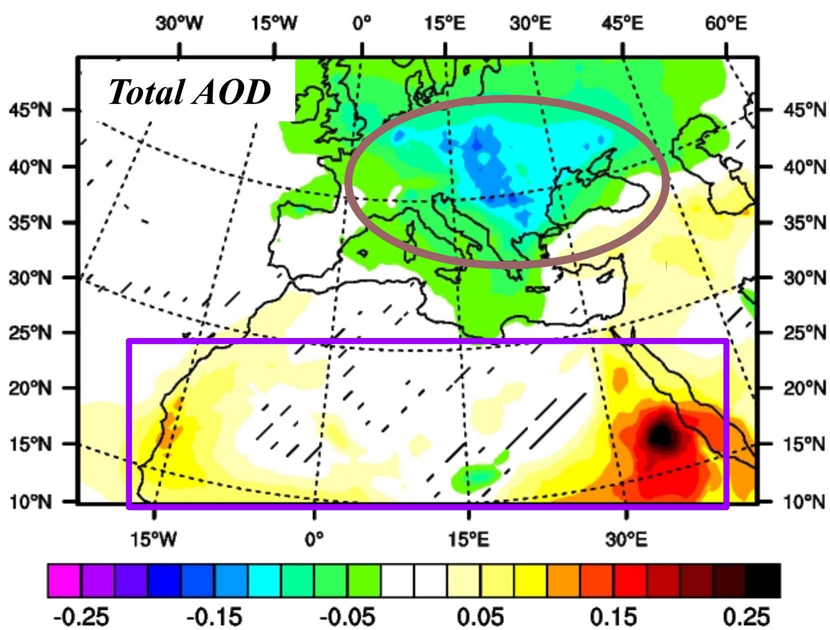

Europe: Total AOD decrease (- 0.10) due to the sufate decrease (- 0.13) and the nitrate compensation (+ 0.03)

Africa: Total AOD increase on West (+ 0.10) and East (+ 0.25) Africa due to the dust increase (wind rise) and the nitrate contribution

# Aerosol evolution causes?

## Evolutions causes

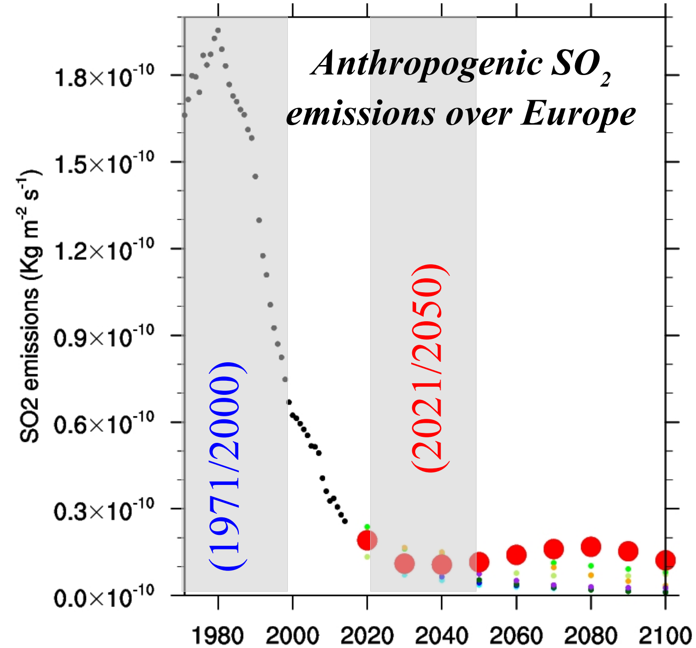
SSP585 (2021/2050) – HIST (1971/2000)




Europe: Total AOD decrease (- 0.10) due to the sufate decrease (- 0.13) and the nitrate compensation (+ 0.03)

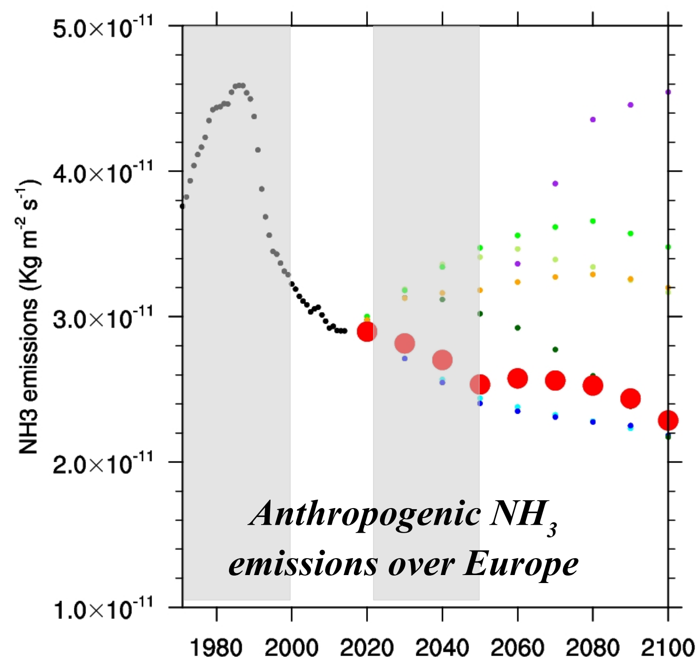
Africa: Total AOD increase on West (+ 0.10) and East (+ 0.25) Africa due to the dust increase (wind rise) and the nitrate contribution

## Aerosol evolution causes?




**Sulfate decrease** due to:

$SO_2$ emissions decline (Europe)




**Nitrate increase** due to:

- sulfate decrease (Europe)
- dust increase (Africa)

# Short wave direct radiative forcing (W m$^{-2}$)

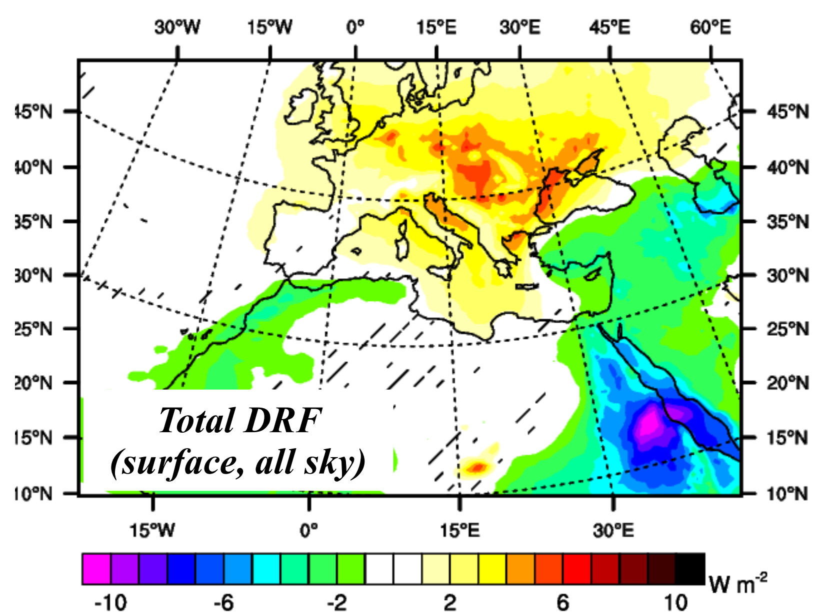
HIST (1971-2000)
SSP585 (2021-2050)

| Europe | | Sulfate + Organics | Nitrate + Ammonium | Black carbon | Total |
|---|---|---|---|---|---|
| All sky | TOA | - 4.3 | - 1.3 | 0.5 | - 5.1 |
| | | - 0.9 | - 3.1 | 0.2 | - 3.8 |
| | Surface | - 5.5 | - 1.6 | - 1.5 | - 8.6 |
| | | - 1.2 | - 4.0 | - 0.9 | - 6.1 |

+ 2.5

Less effect

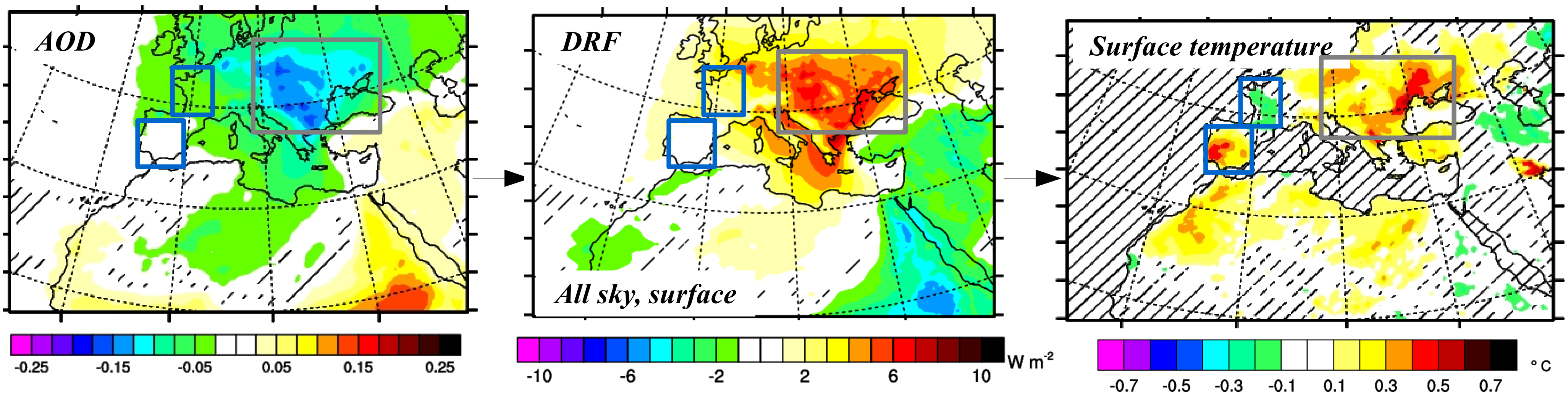
More effect




– > Consistent with previous results

# Anthropogenic aerosols impact on the future Europe climate

SSP585 - SSP585avg

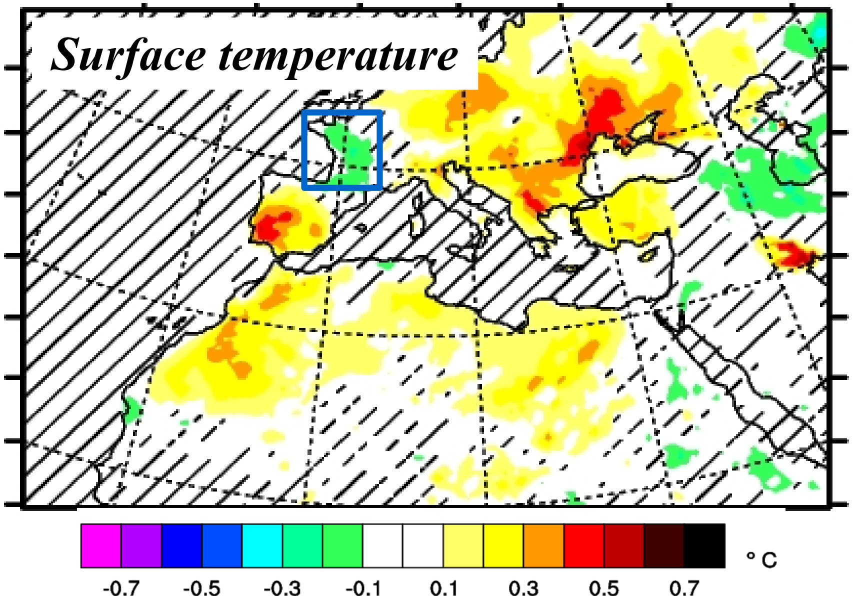


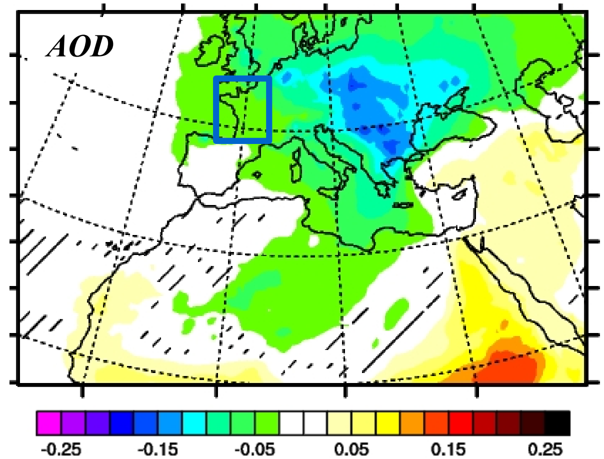

**High regional temperature variability**

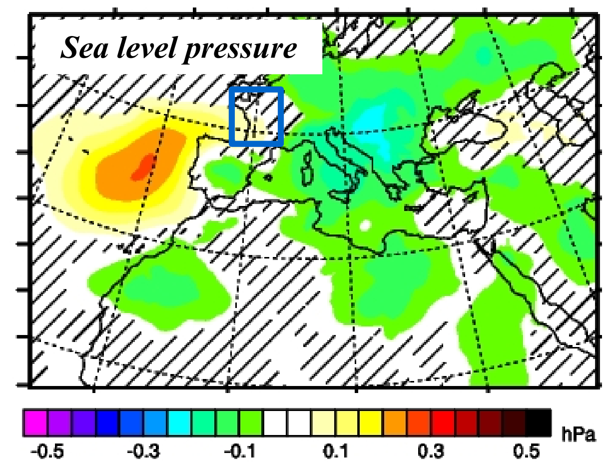
- Central Europe: temperature increase of about 0.3°C due to anthropogenic aerosols drop (direct aerosol effect)

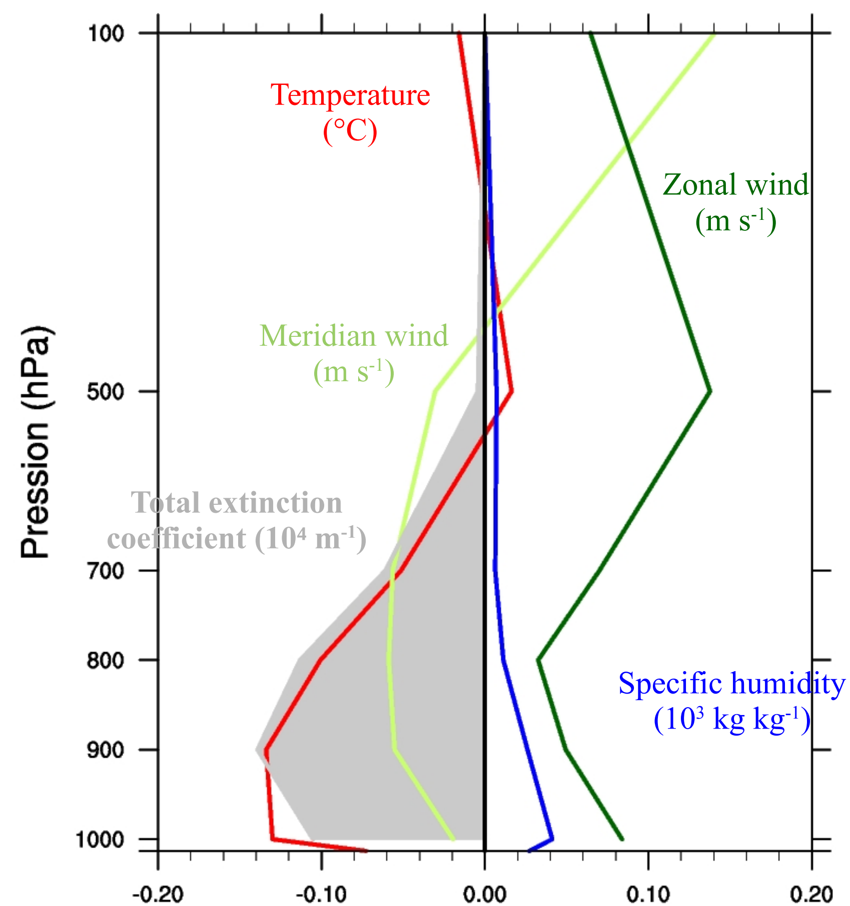
- Two special cases: western France (temperature decrease of about – 0.1°C) and Iberian Peninsula (temperature increase of about 0.2°C)

# Western France (SSP585 – SSP585avg)



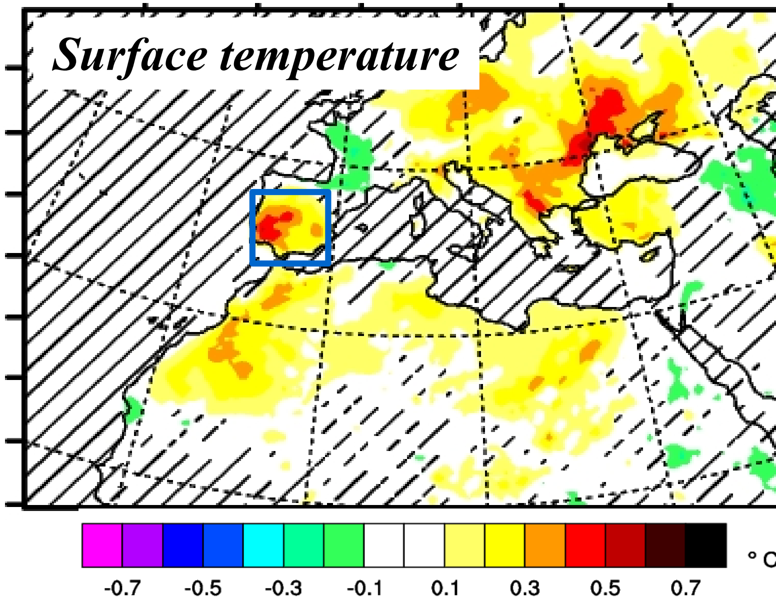



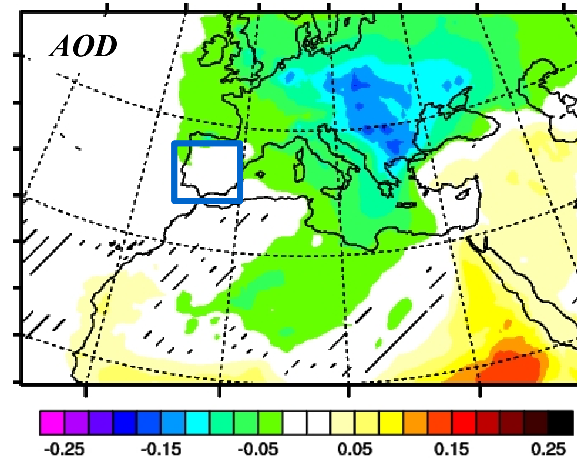

Cold air arrival from the ocean over western France

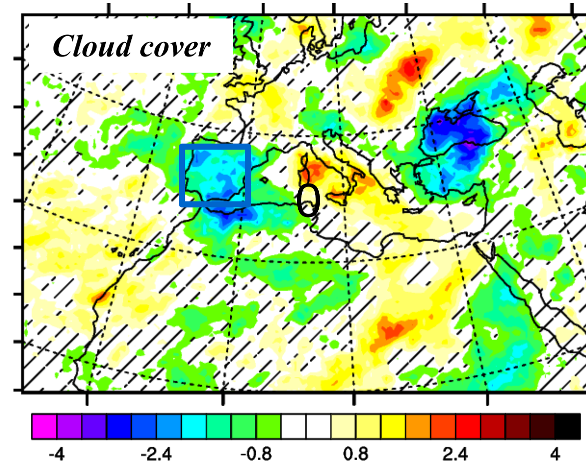
↓

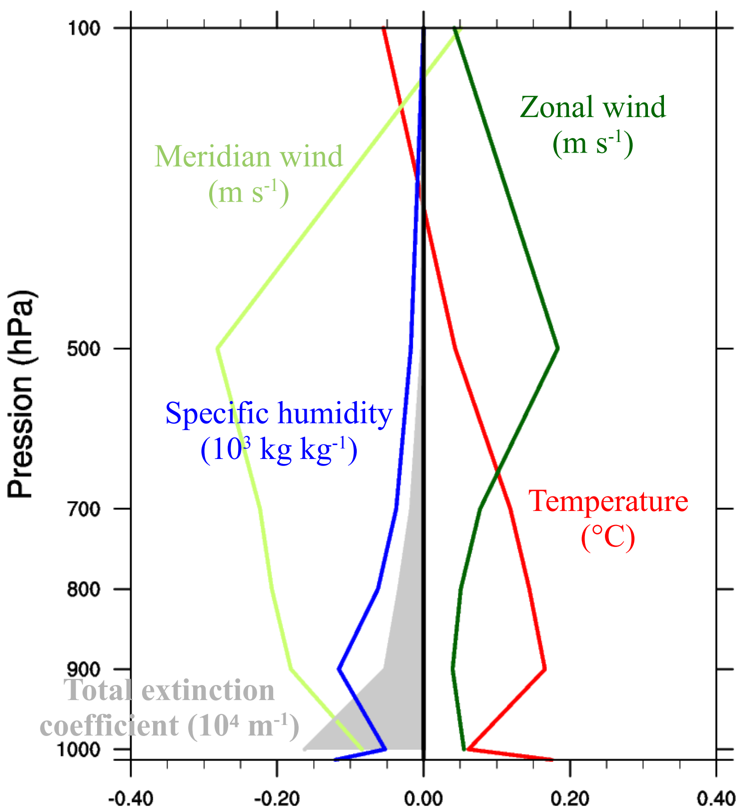
**Dynamic modification**
(semi-direct aerosol effect)

Iberian Peninsula
(SSP585 – SSP585avg)



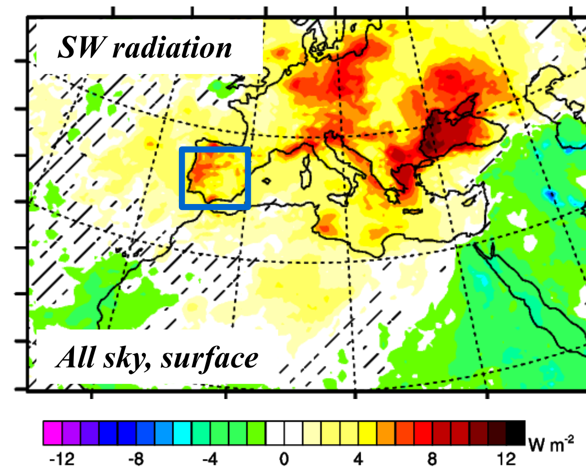




SW radiation increase and drier continental air supply

**Dynamic modification**
(semi-direct aerosol effect)



# Conclusion

*During the summer (June, July and August)*

**Aerosols evolution**

SSP585 - HIST

- Strong AOD sulfate decline (- 0.13) over Europe partly offset by nitrate aerosols (+ 0.03)

**Future mediterranean climate sensitivity to anthropogenic aerosols**

SSP585 - SSP585avg

- Direct aerosol effect: temperature increase over Central Europe (+ 0.3°C) due to sulfate decrease

  **– > Over Central Europe, the aerosols are responsible of about 10% of the warming**

- Semi-direct aerosol effect: temperature increase over the Iberian Peninsula (+ 0.2°C) and temperature decrease over western France (- 0.1°C)

# Discussion

- Use of a single scenario (SSP 5-8.5)
- Model not coupled to the ocean (ocean feedbacks not considered)
- Not taking into account secondary aerosol indirect effect

Thank you for your attention !

# Wind speed (JJA)

SSP585 - HIST