

Future Euro-Mediterranean climate sensitivity to anthropogenic aerosols

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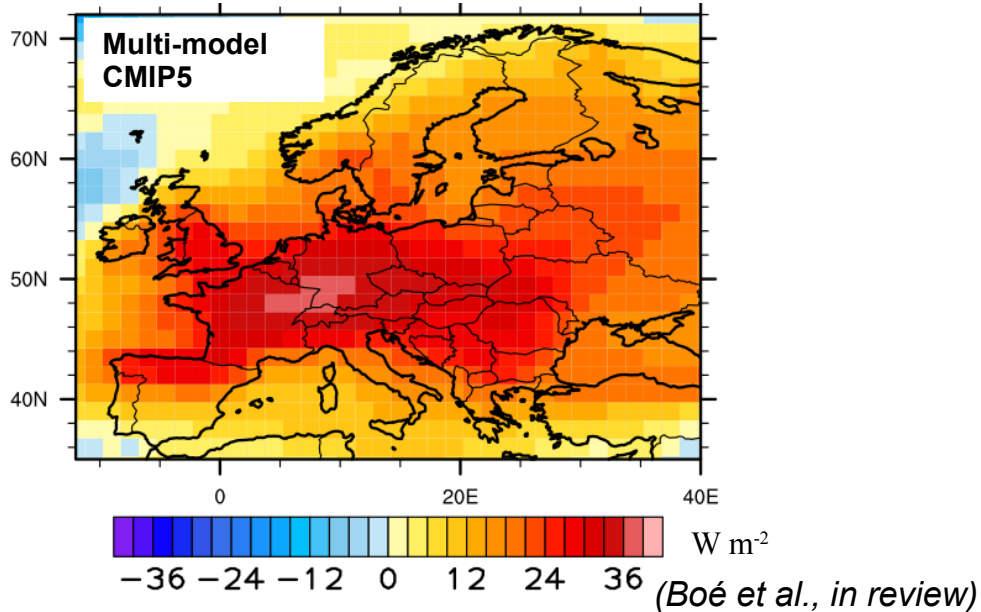
Contact: thomas.druge@meteo.fr

Med-CORDEX Workshop – FPS aerosols – Toulouse – 27th November 2019

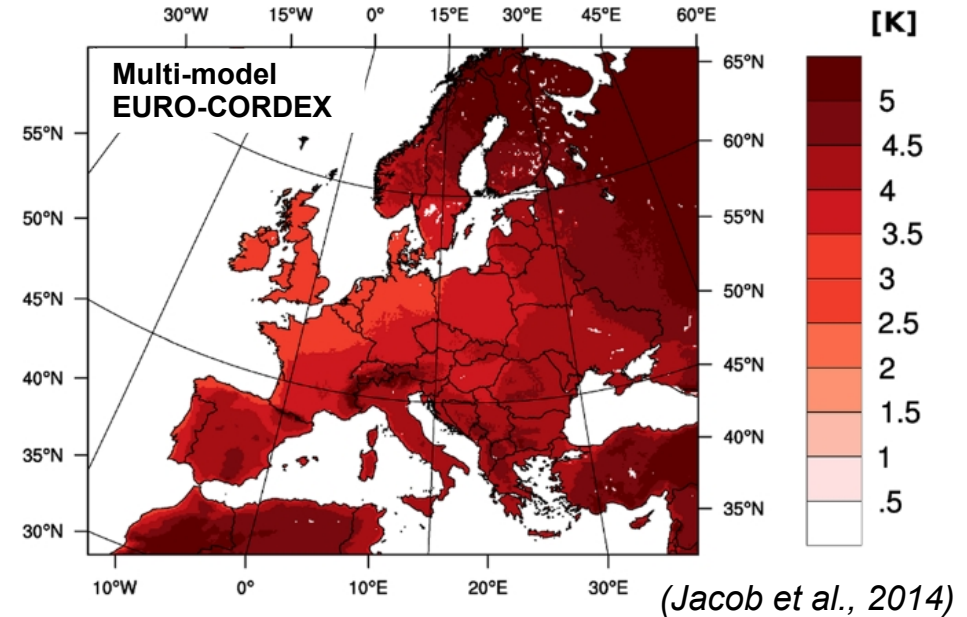


Why should we be interested in the Euro-Mediterranean region?

Surface radiation (2070/2099 - 1970/1999)



Surface temperature (2071/2100 - 1971/2000)

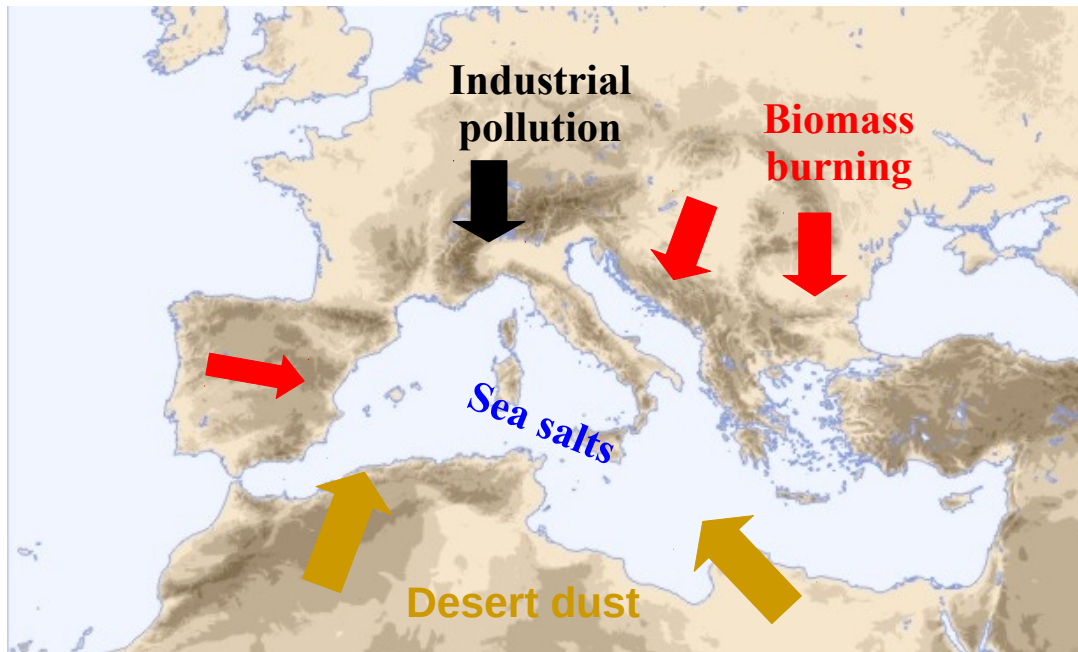


- Future projections (RCP 8.5):
- Increase in surface solar radiation
- Temperature increase

Very sensitive region to
climate change

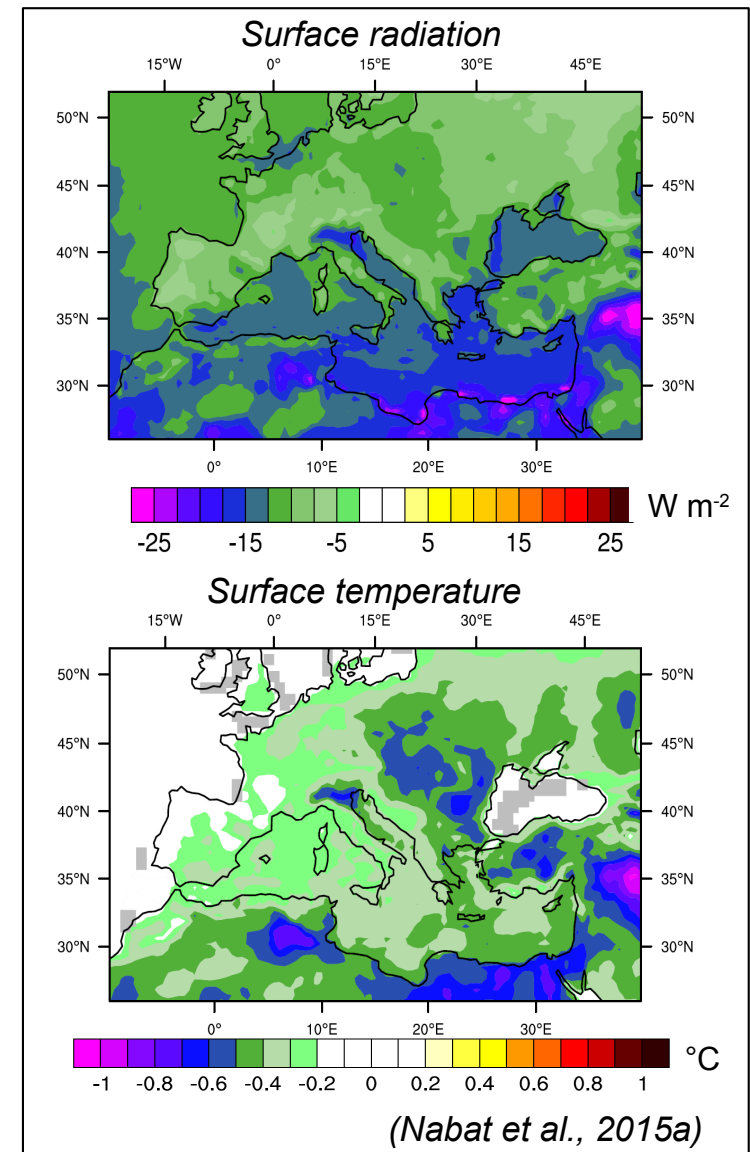
Why should we be interested in the Euro-Mediterranean region?

- Crossroads of various aerosols



Very sensitive region to aerosol content

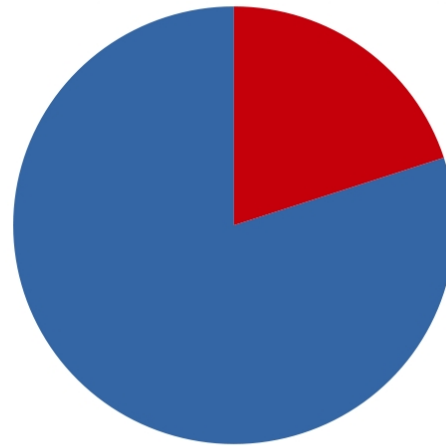
Aerosol impacts (2003-2009)



Regional modelling of aerosol-climate interactions over the Euro-Mediterranean region

- Aerosols = key atmospheric component
- But still represented in a simplified way in regional climate models

*Euro-CORDEX project
(57 simulations)*



• Evolving aerosols (20%)

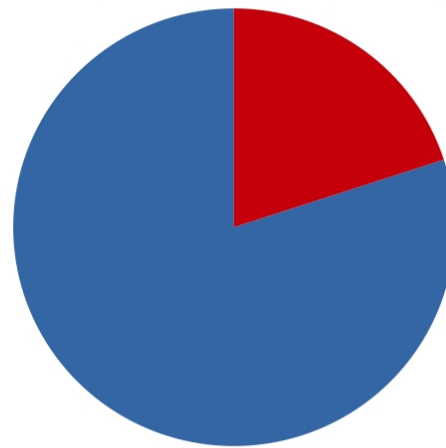
• Constant aerosols (80%)

• No interactive aerosols

Regional modelling of aerosol-climate interactions over the Euro-Mediterranean region

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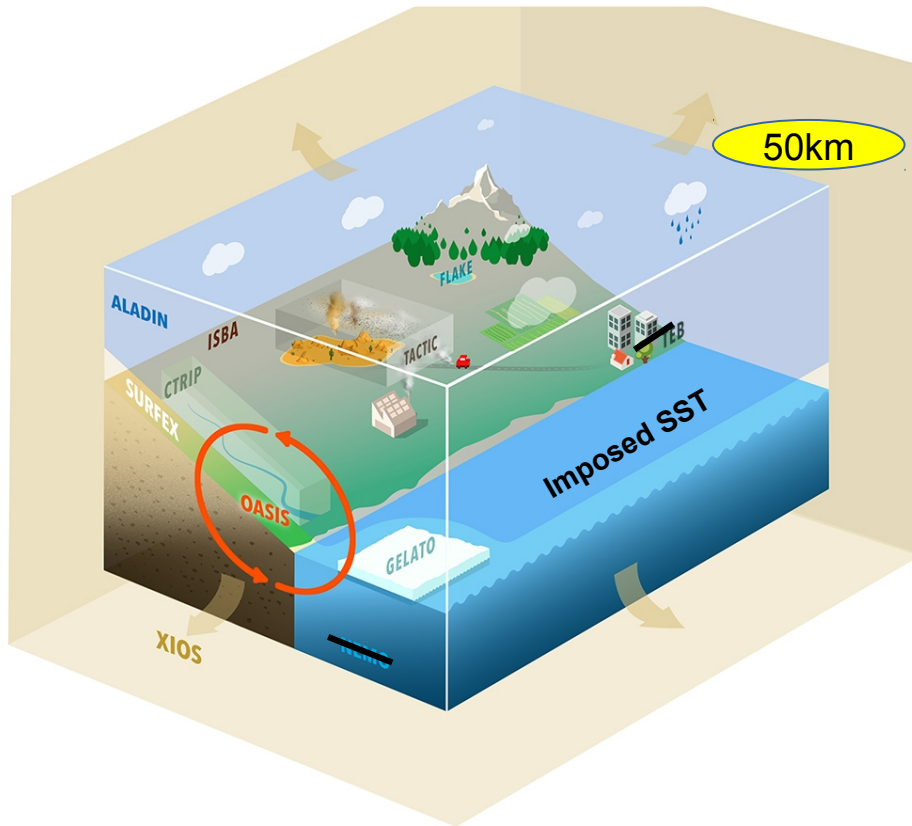
• No interactive aerosols

Objectives

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

Methodology

ALADIN-Climate regional model

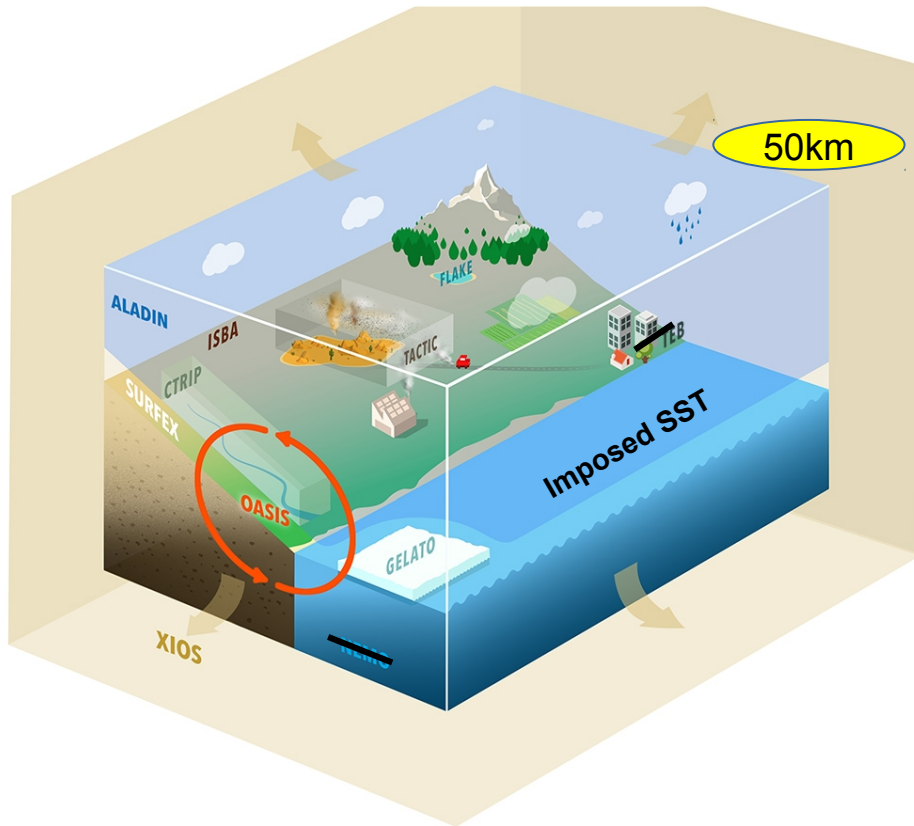


TACTIC (Michou et al., 2015 ; Nabat et al., 2015a)

- 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)
- First indirect aerosol effect for sulfate, sea-salt and organic matter
 - > Simplified scheme to keep a low numerical cost

Methodology

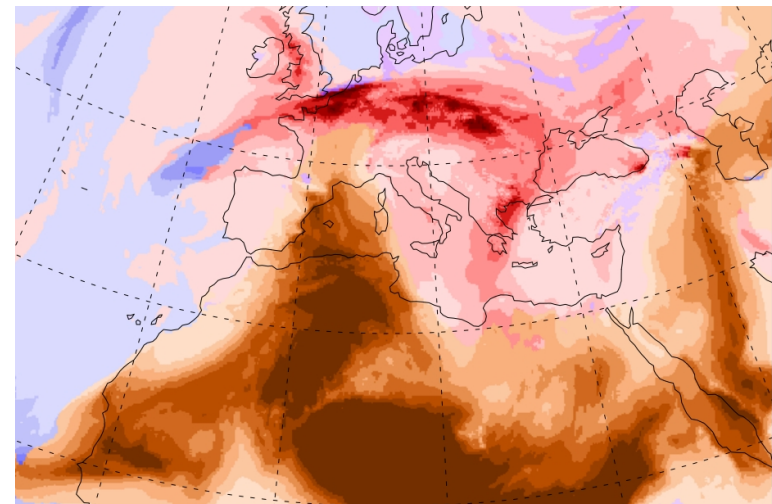
ALADIN-Climate regional model



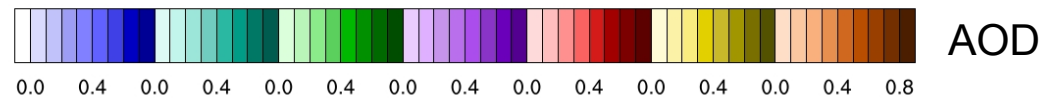
Med-CORDEX extended domain

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

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Sea salts
Ammonium
Organic carbon
Nitrate
Sulfate
Black carbon
Dusts



AOD

0.0 0.4 0.0 0.4 0.0 0.4 0.0 0.4 0.0 0.4 0.0 0.4 0.0 0.4 0.8

Summary

I - Introduction

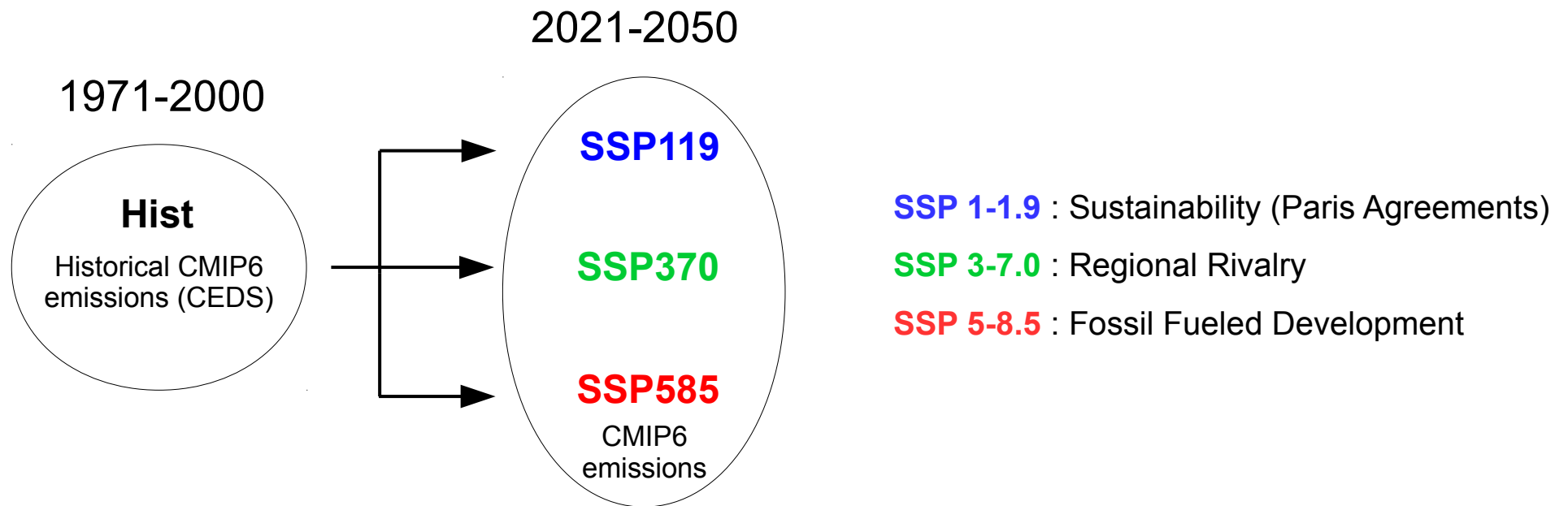
II - Aerosol evolution

III - Future climate sensitivity to aerosols

IV – Conclusion and perspective

Simulations

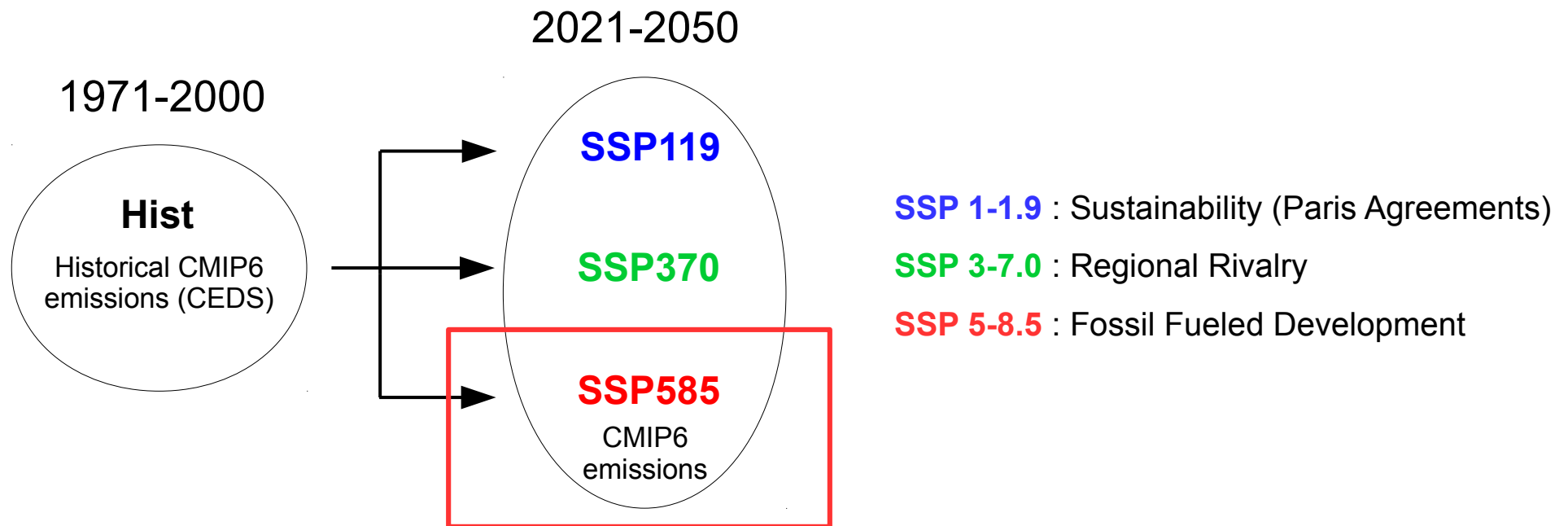
- SSP (Shared Socio-economic Pathways) = combination of radiative forcing and socio-economic scenario



- Simulations forced by the CMIP6 global model CNRM-ESM2-1 (*Séférian et al., 2019*)

Simulations

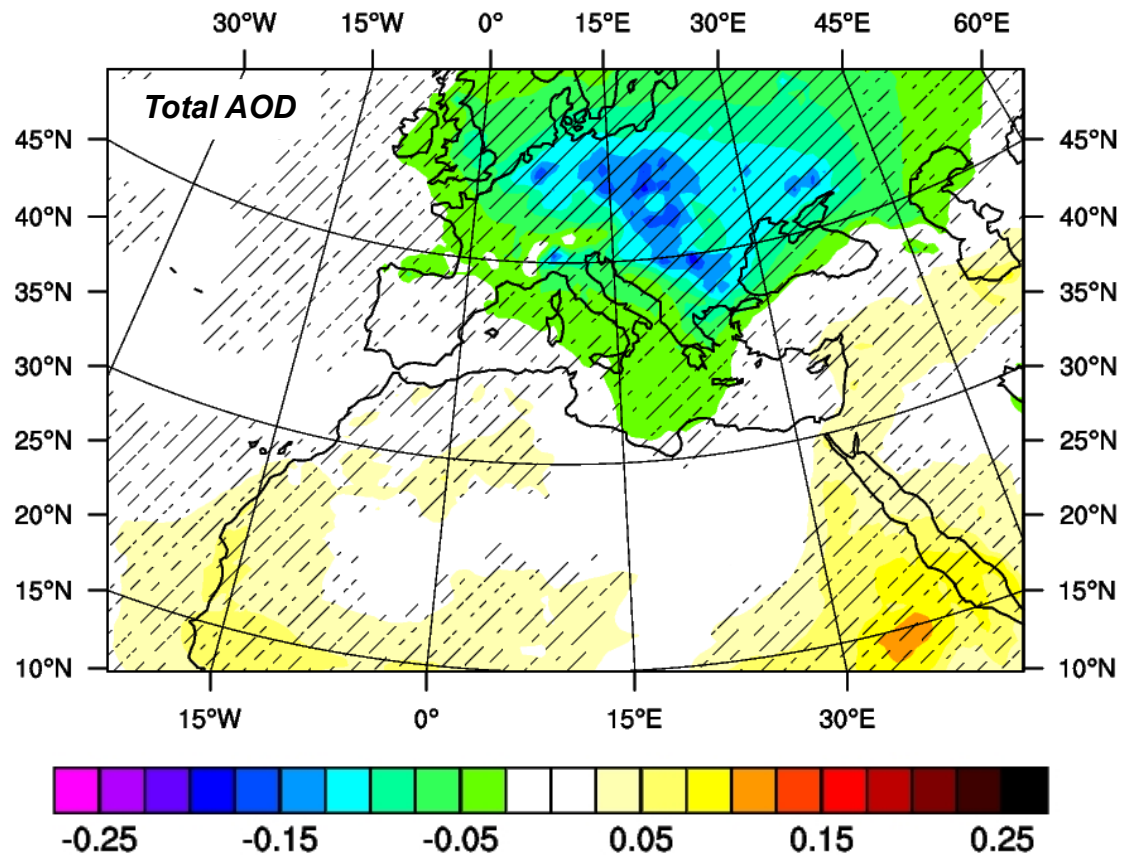
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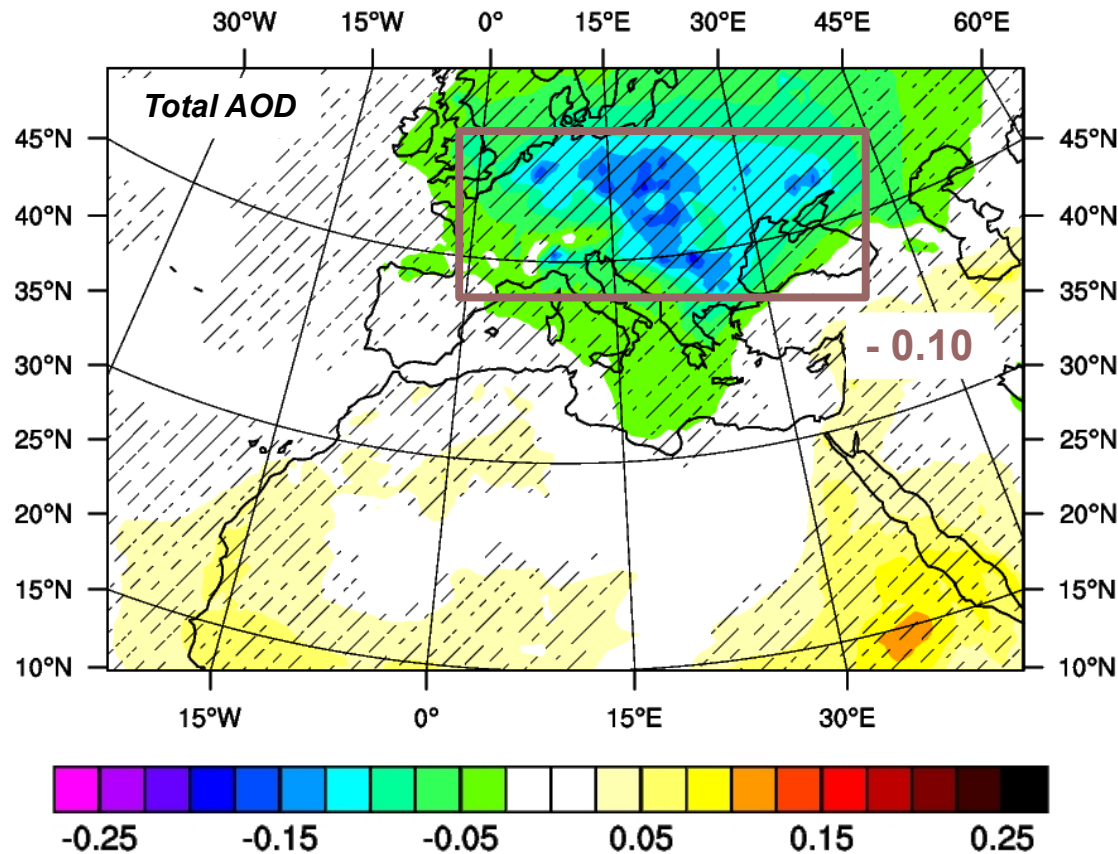
Future total AOD evolution (annual average)

SSP585 (2021/2050) – Hist (1971/2000)



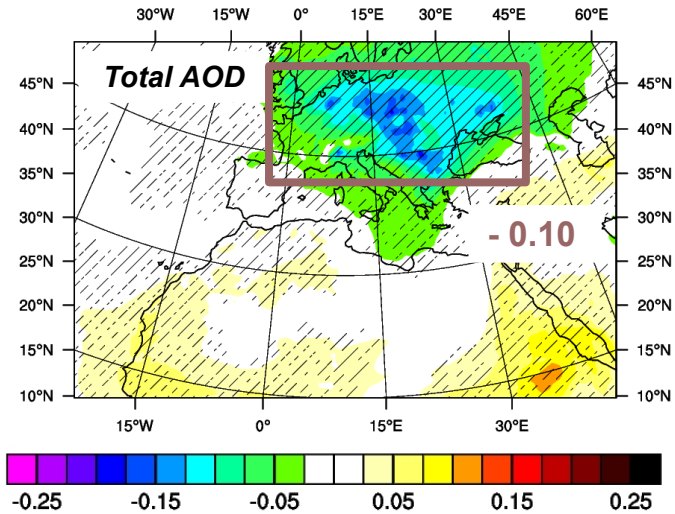
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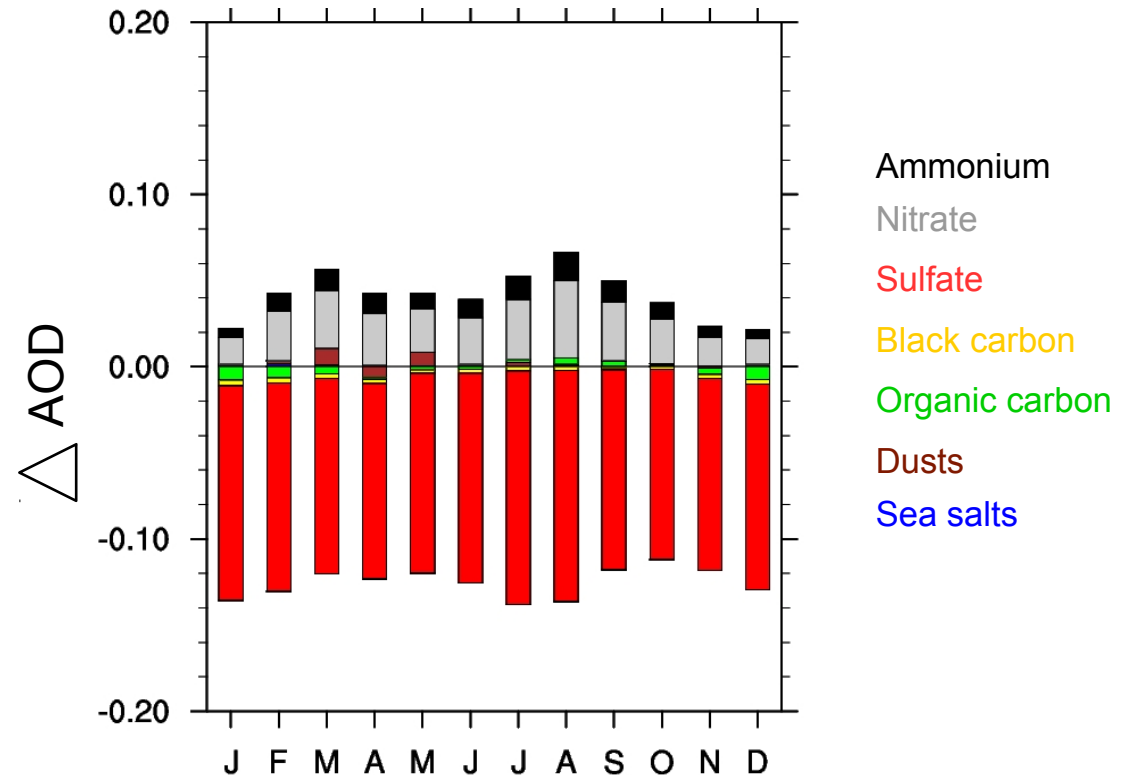
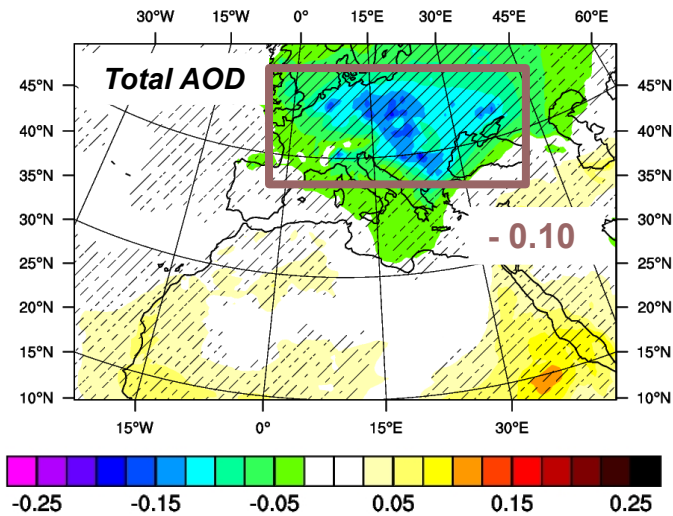
Future total AOD evolution over Europe (annual average)

SSP585 (2021/2050) – Hist (1971/2000)



Future total AOD evolution over Europe (annual average)

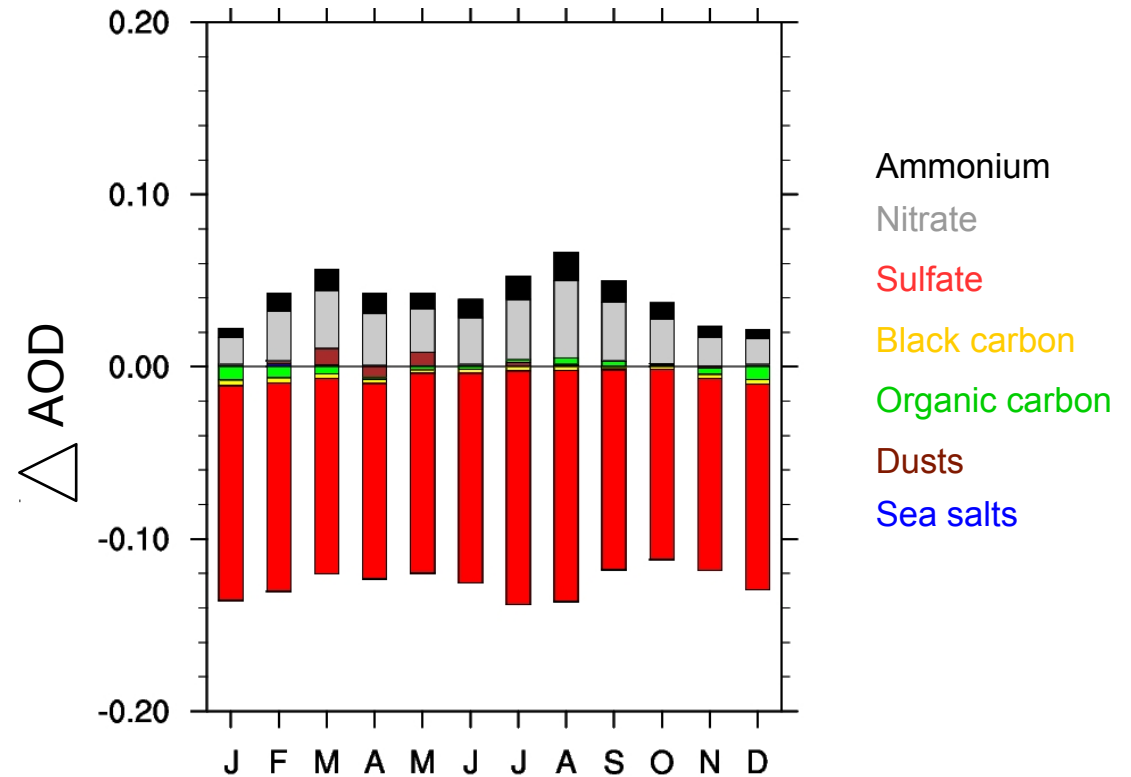
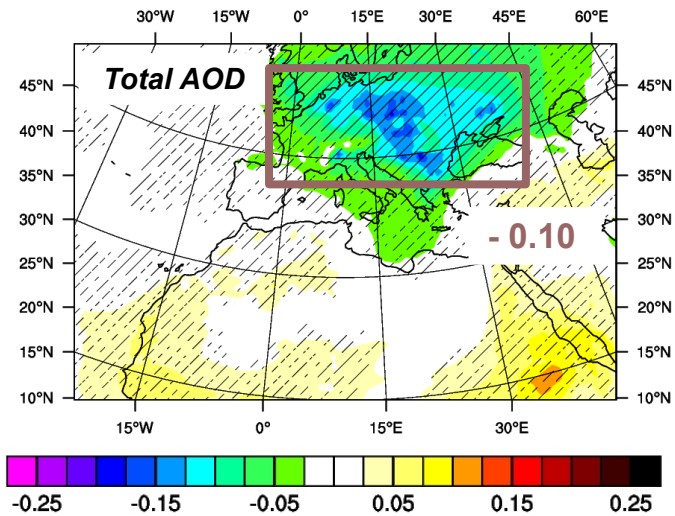
SSP585 (2021/2050) – Hist (1971/2000)



Sulfate aerosols AOD decrease (- 0.13) partially offset by nitrate particles AOD increase (+ 0.03)

Future total AOD evolution over Europe (annual average)

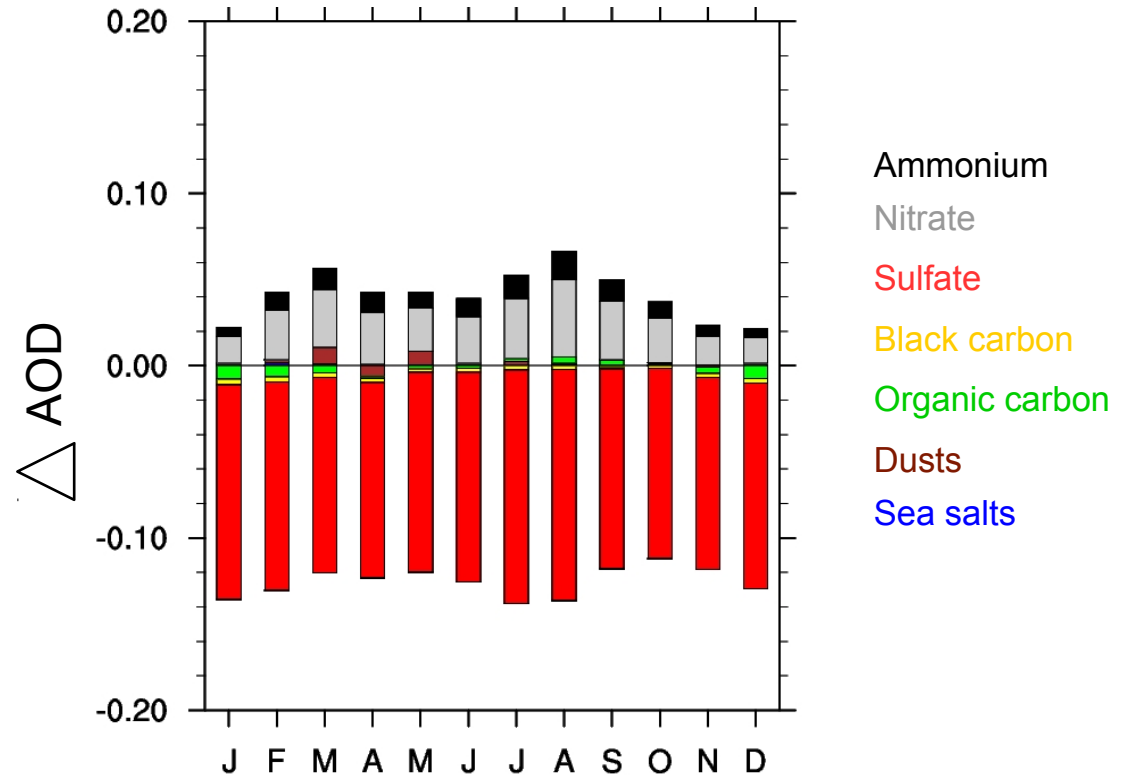
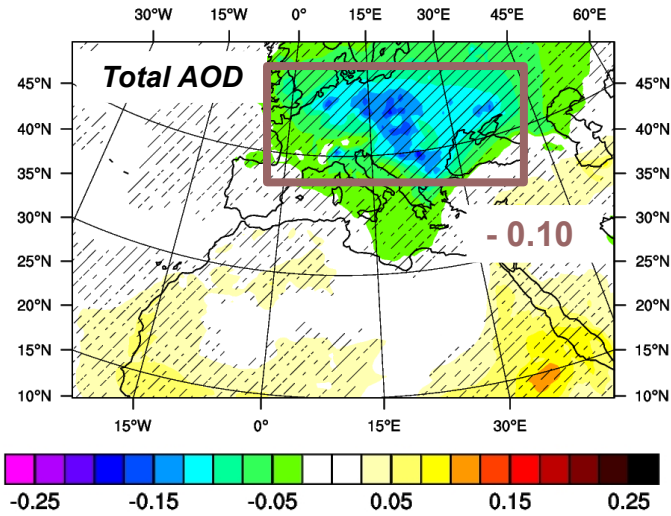
SSP585 (2021/2050) – Hist (1971/2000)



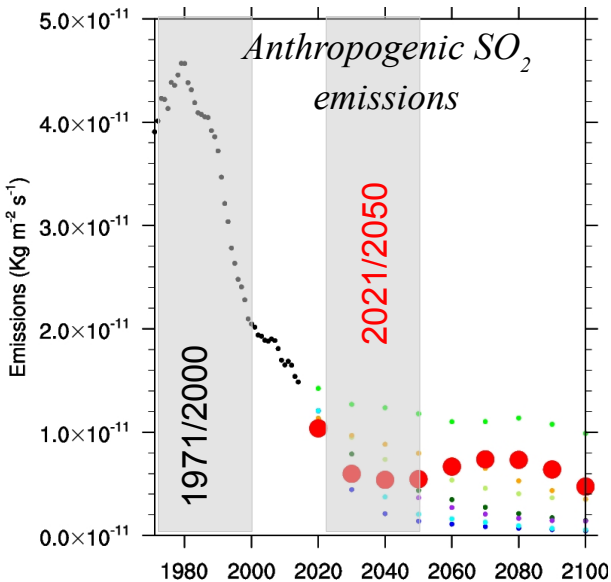
Sulfate aerosols AOD
decrease

Future total AOD evolution over Europe (annual average)

SSP585 (2021/2050) – Hist (1971/2000)



- Ammonium
- Nitrate
- Sulfate
- Black carbon
- Organic carbon
- Dusts
- Sea salts



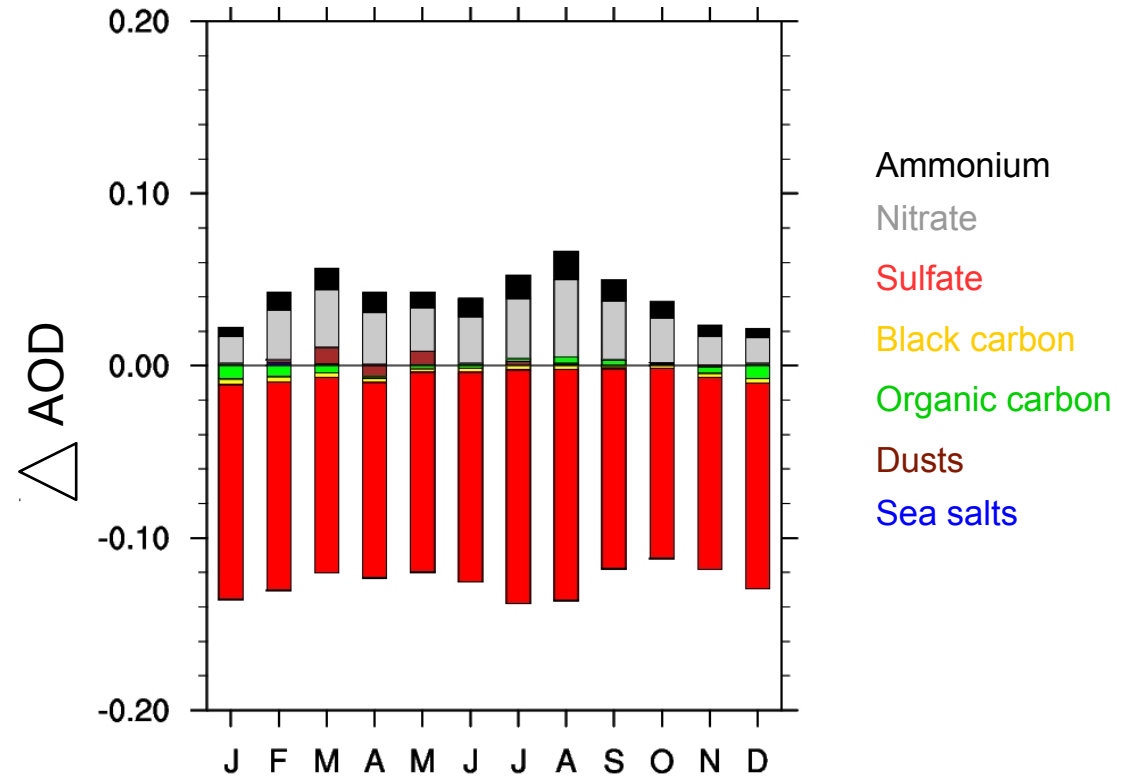
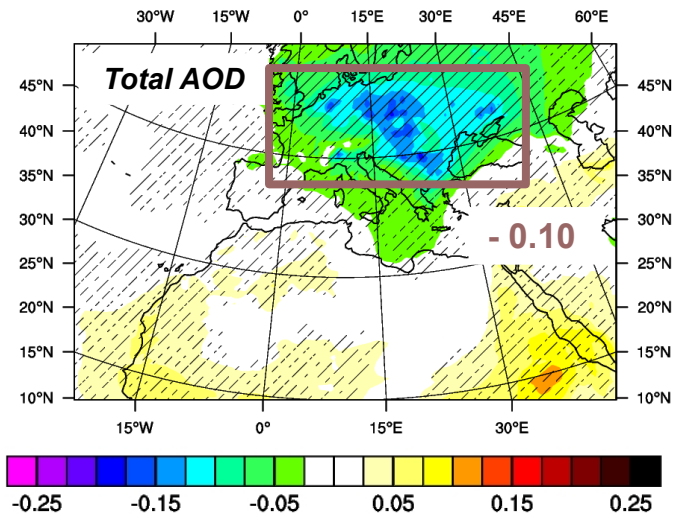
Reduction in sulphur dioxide emissions



Sulfate aerosols AOD decrease

Future total AOD evolution over Europe (annual average)

SSP585 (2021/2050) – Hist (1971/2000)



Reduction in sulphur dioxide emissions

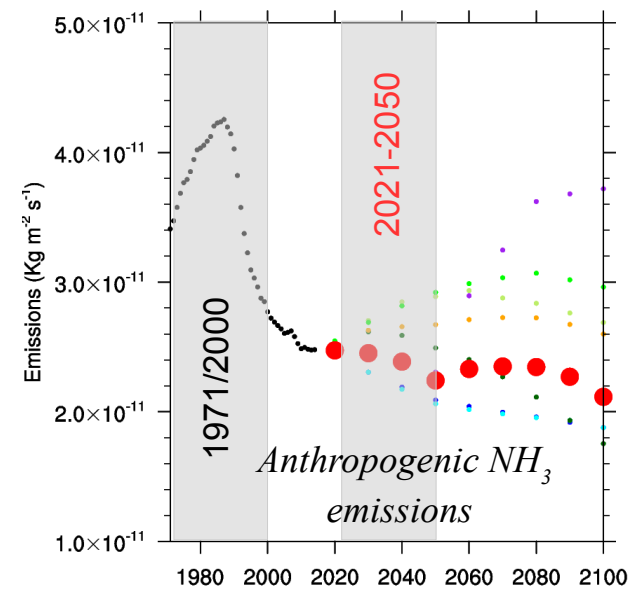
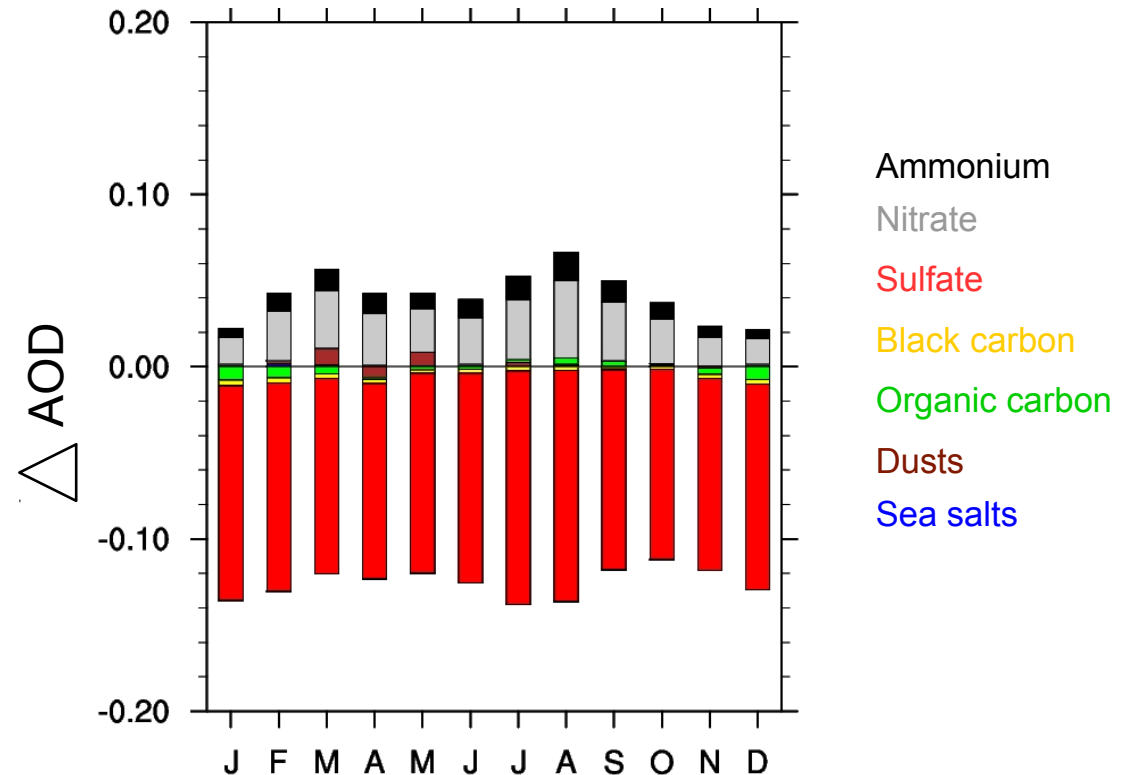
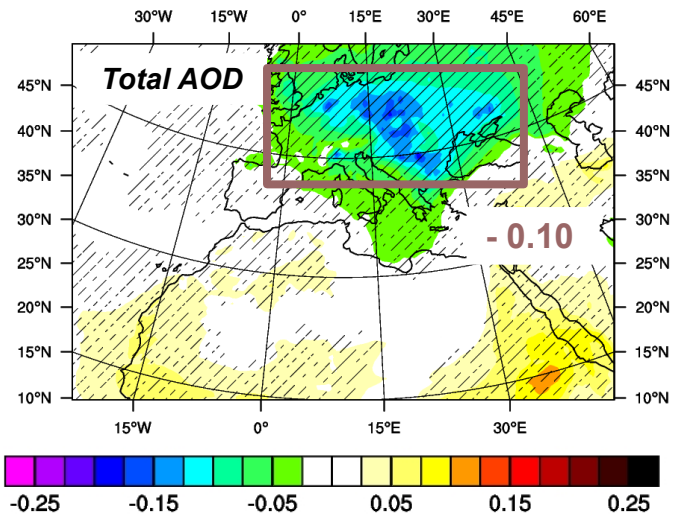


Sulfate aerosols AOD decrease

Nitrate aerosols AOD increase

Future total AOD evolution over Europe (annual average)

SSP585 (2021/2050) – Hist (1971/2000)



Reduction in sulphur dioxide emissions

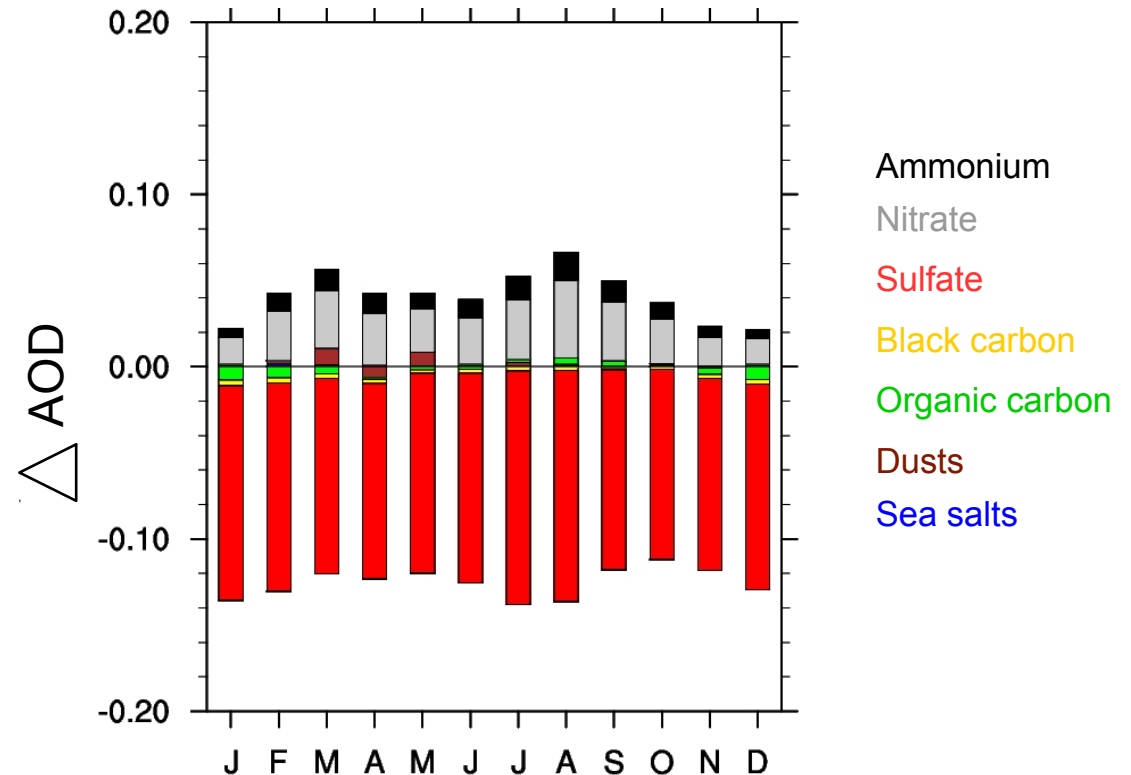
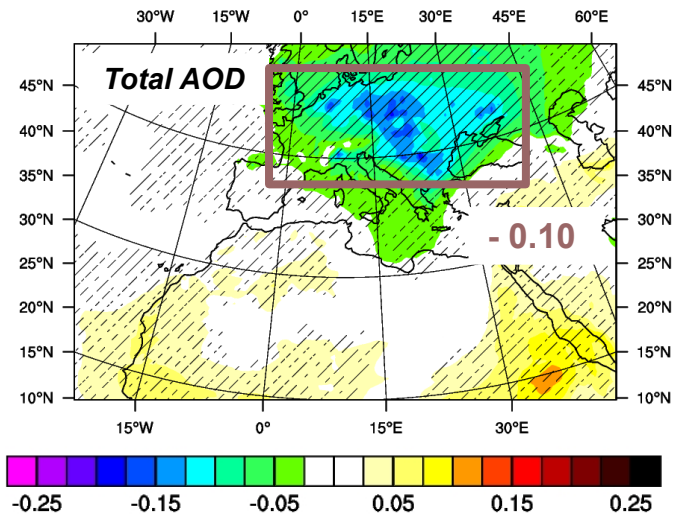
Sulfate aerosols AOD decrease

Decrease in ammonia emissions

Nitrate aerosols AOD increase

Future total AOD evolution over Europe (annual average)

SSP585 (2021/2050) – Hist (1971/2000)



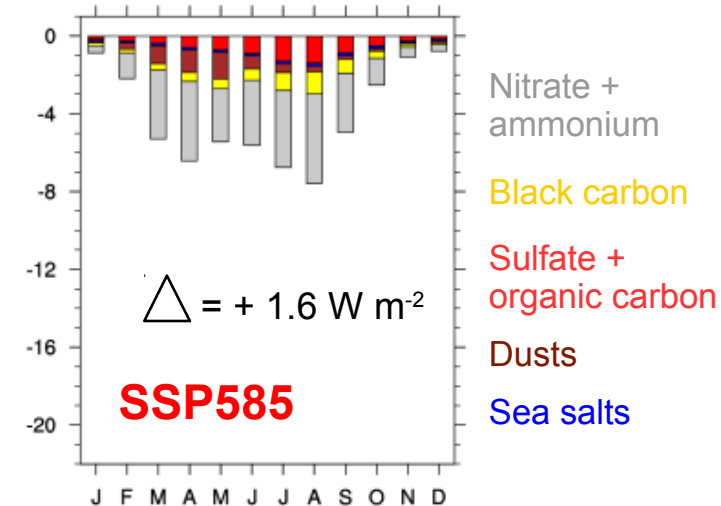
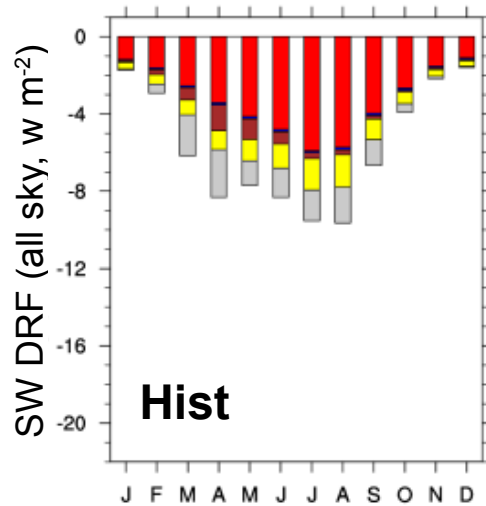
Reduction in sulphur dioxide emissions

Sulfate aerosols AOD decrease

Less ammonia consumed

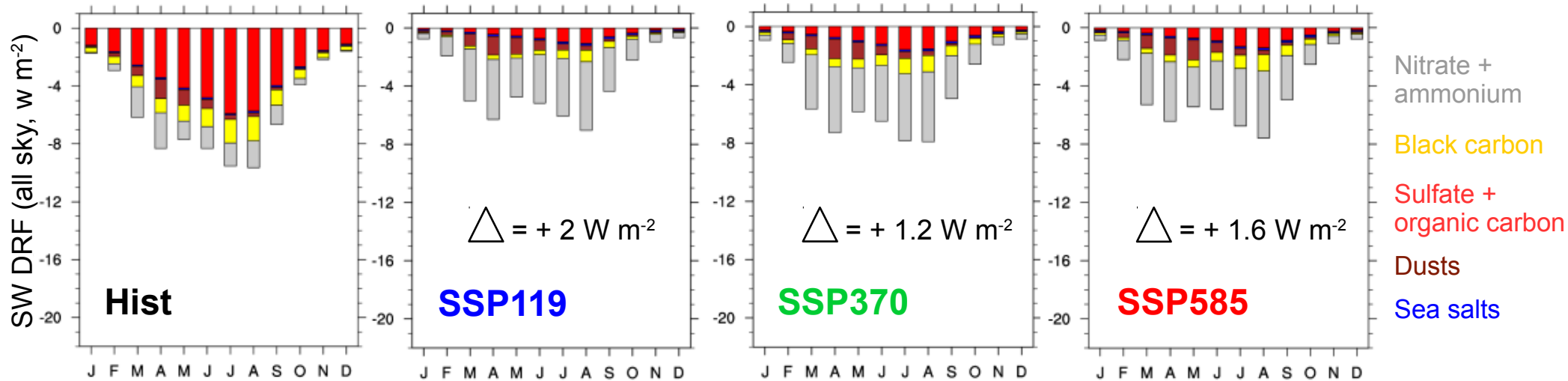
Nitrate aerosols AOD increase

Direct radiative forcing evolution over Europe



- Relative forcing decrease of sulfate, organic carbon and black carbon aerosols
- Relative forcing increase of nitrate and ammonium aerosols
- Consistent with AOD results
- Lower decrease in total aerosols radiative forcing at the top of the atmosphere (+ 1 W m⁻²)

Direct radiative forcing evolution over Europe



- Relative forcing decrease of sulfate, organic carbon and black carbon aerosols
- Relative forcing increase of nitrate and ammonium aerosols
- Consistent with AOD results
- Lower decrease in total aerosols radiative forcing at the top of the atmosphere ($+ 1 \text{ W m}^{-2}$)
- Total aerosol radiative forcing decrease between 1.2 and 2 W m^{-2}

Summary

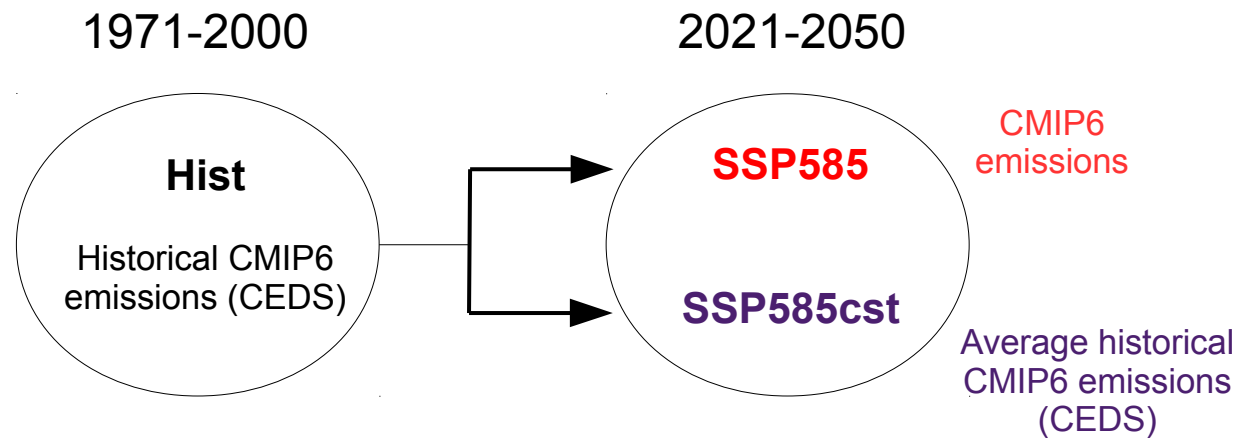
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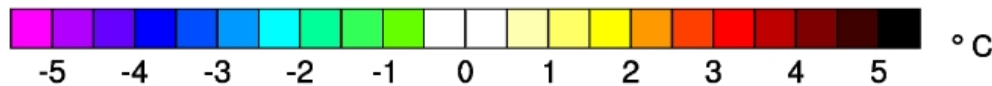
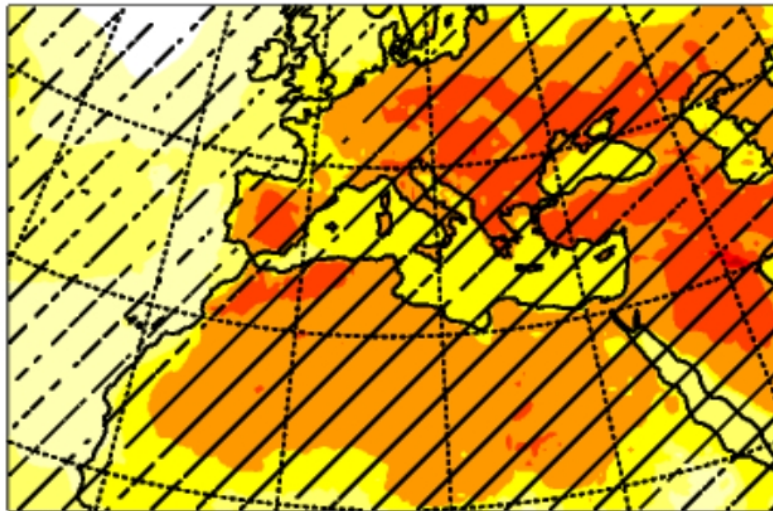


- Two twin simulations with and without evolution of anthropogenic aerosol emissions
- SSP585cst: isolates the anthropogenic aerosols effect of on the various climatic parameters

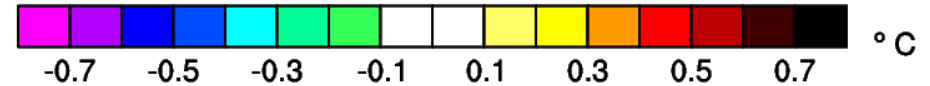
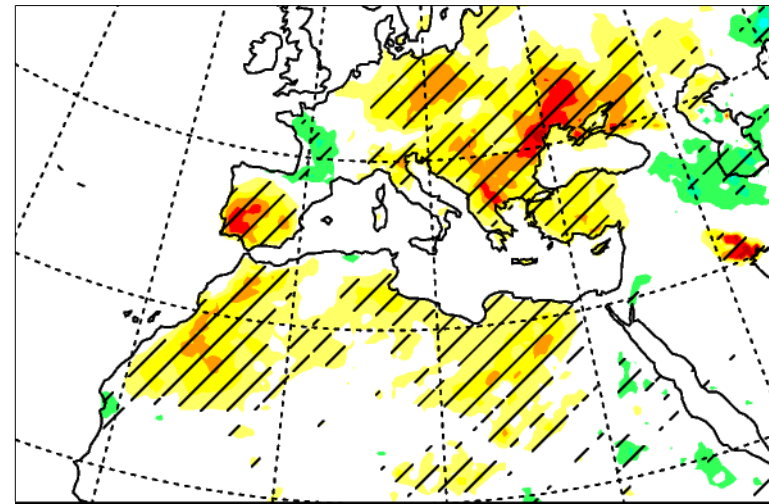
Impact of anthropogenic aerosols on future temperature over Europe (JJA)

Surface temperature

SSP585 – Hist



SSP585 – SSP585cst

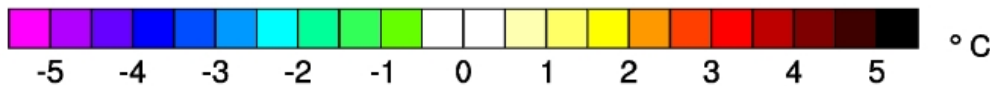
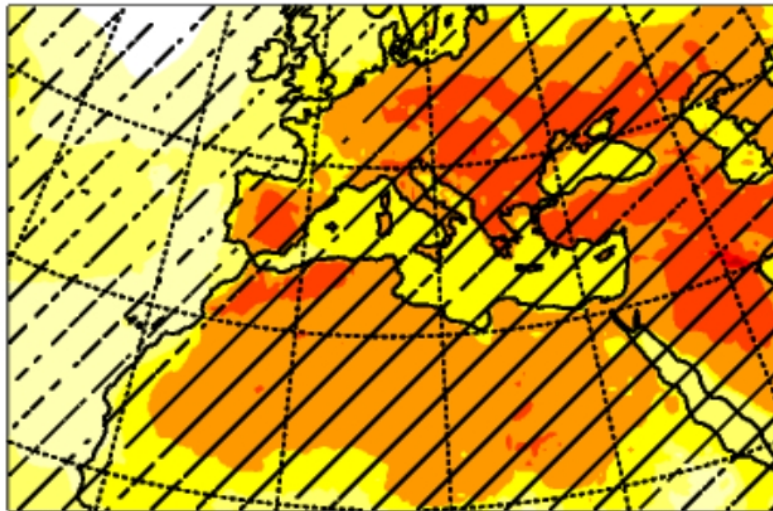


- Anthropogenic aerosols = 10 % of the expected warming over Europe

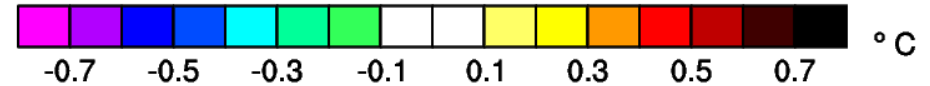
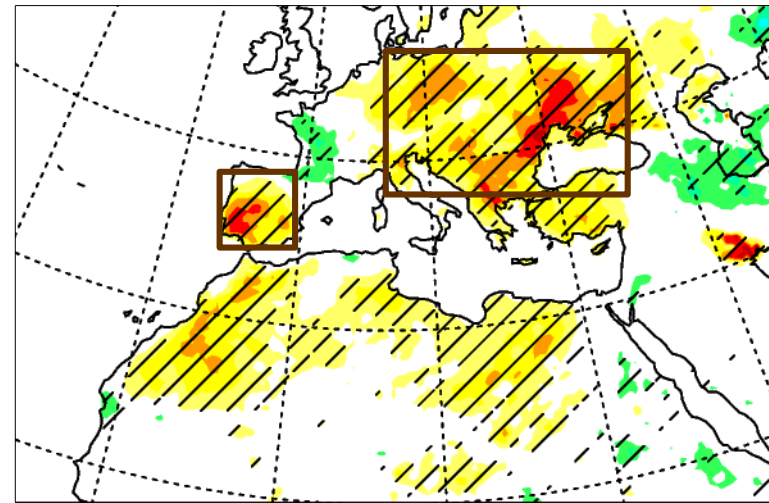
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SSP585 – Hist



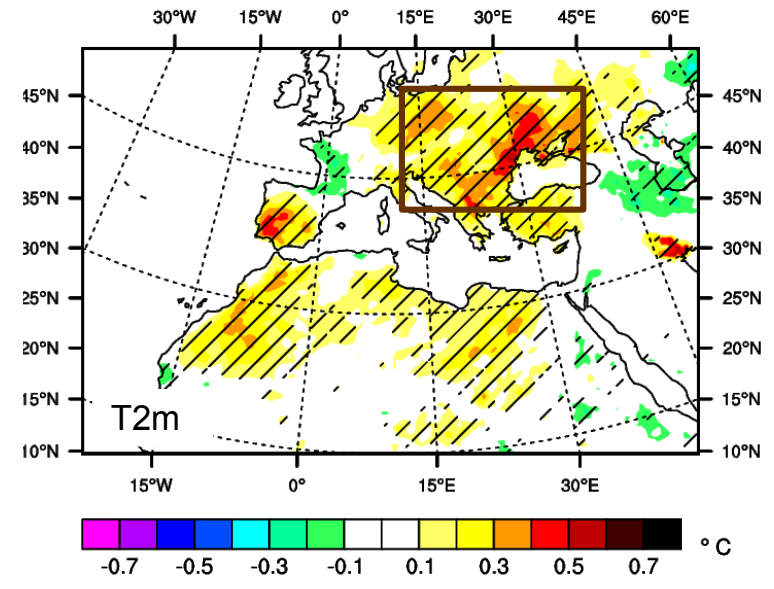
SSP585 – SSP585cst



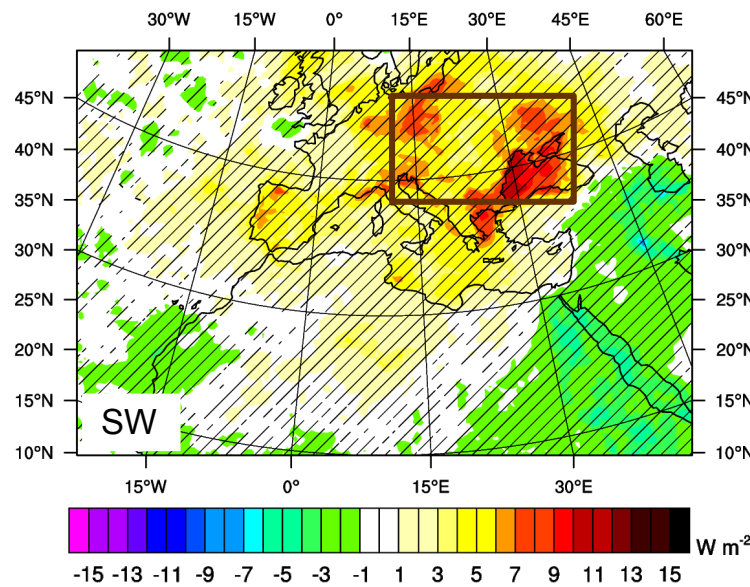
- Anthropogenic aerosols = 10 % of the expected warming over Europe
- Two temperature maximum increases due to anthropogenic aerosols evolution (Central Europe and Iberian Peninsula)

Central Europe case (SSP585 – SSP585cst)

Surface temperature
increase over
Central Europe



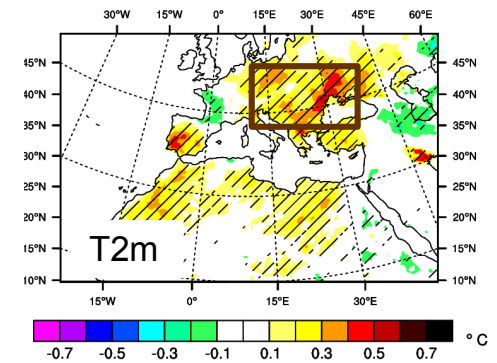
Central Europe case (SSP585 – SSP585cst)



Surface radiation increase



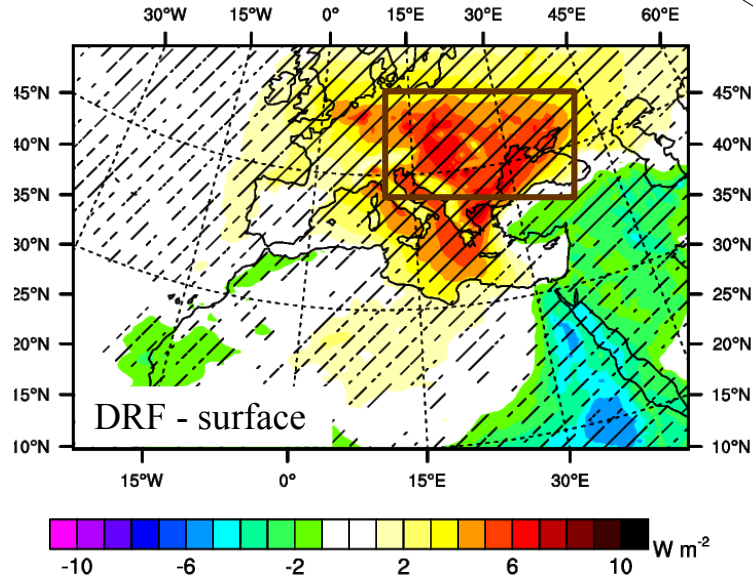
Surface temperature increase over Central Europe



Central Europe case (SSP585 – SSP585cst)

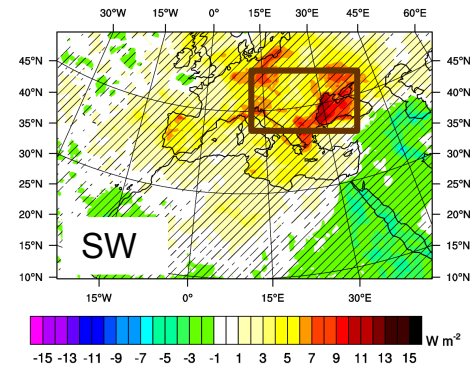
Direct effect

Direct aerosols radiative forcing decrease



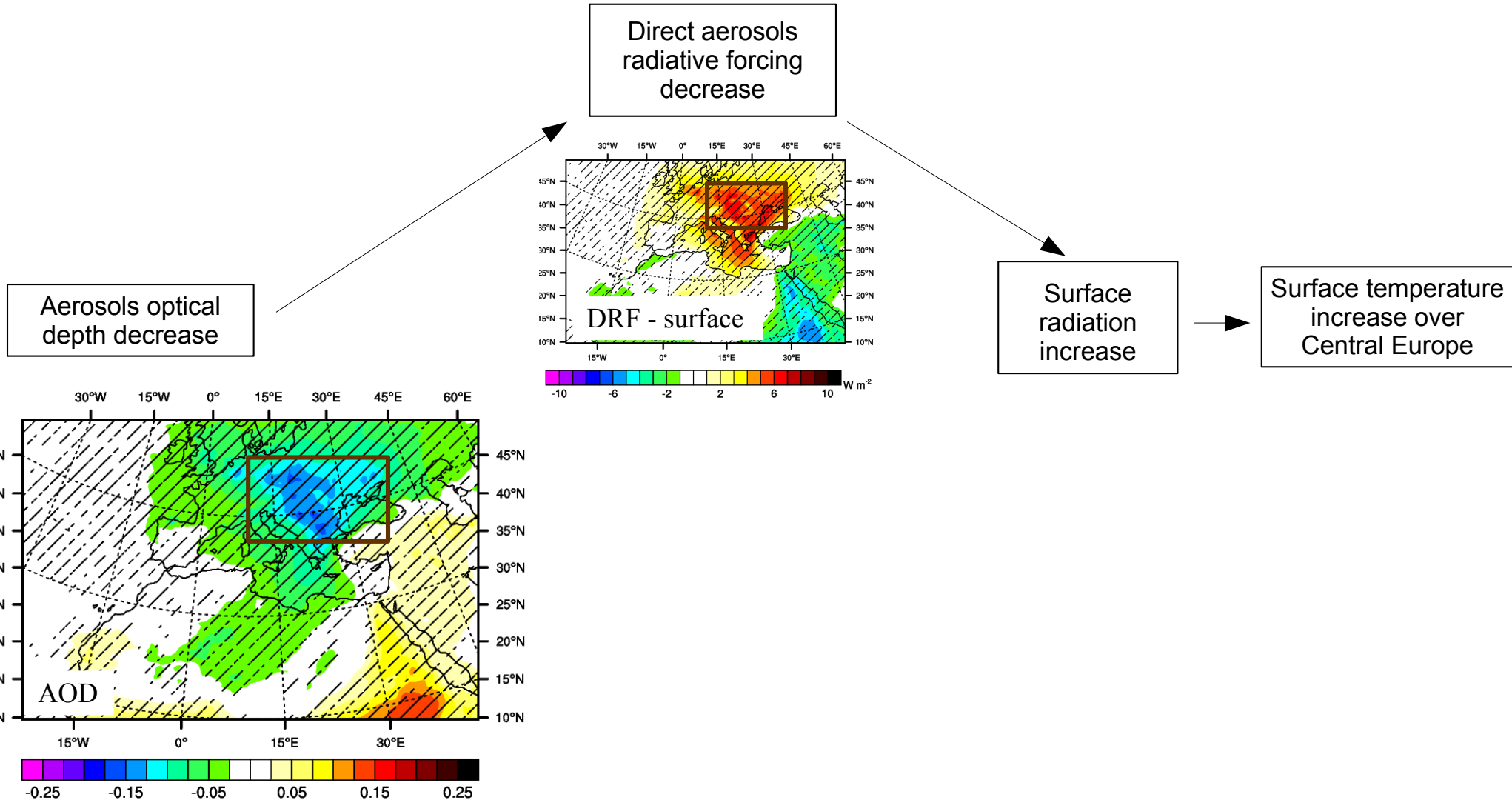
Surface radiation increase

Surface temperature increase over Central Europe



Central Europe case (SSP585 – SSP585cst)

Direct effect



Central Europe case (SSP585 – SSP585cst)

Direct effect

Direct aerosols radiative forcing decrease

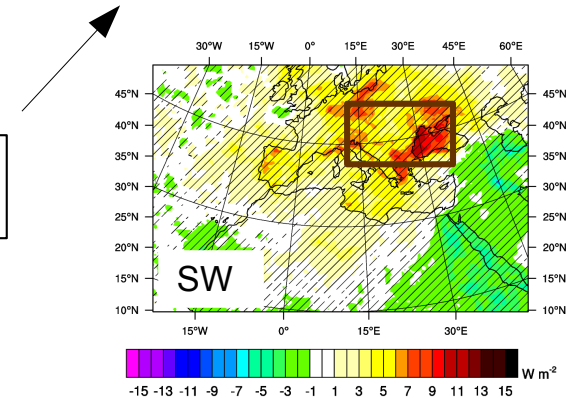
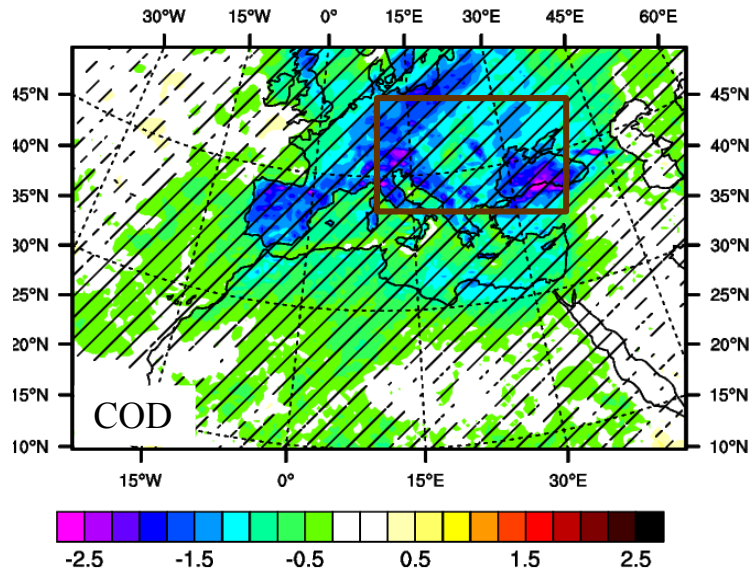
Aerosols optical depth decrease

Surface radiation increase

Surface temperature increase over Central Europe

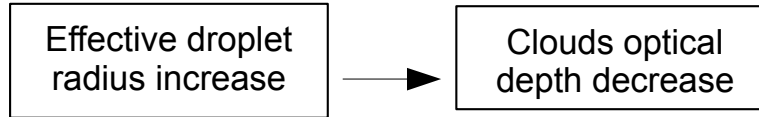
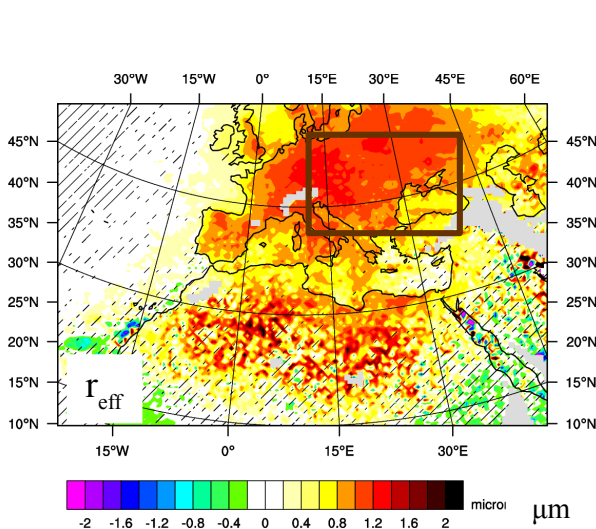
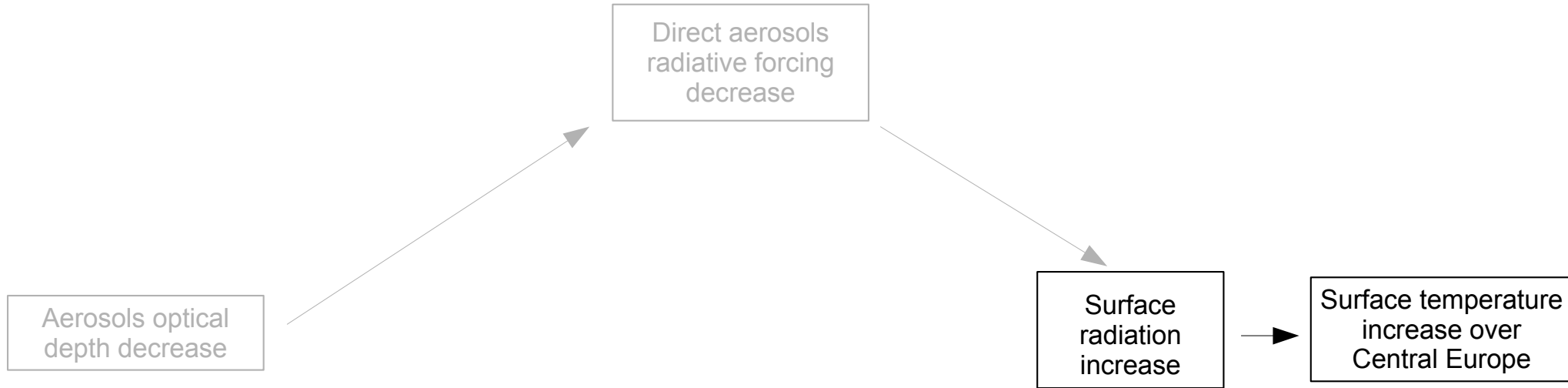
Clouds optical depth decrease

First indirect effect

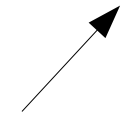
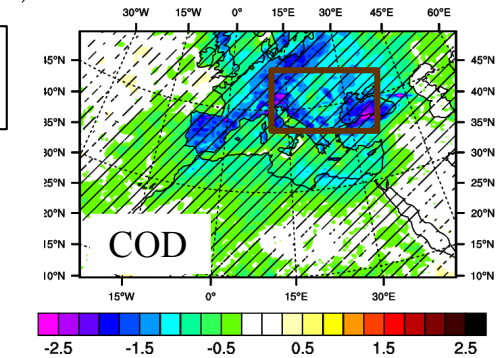


Central Europe case (SSP585 – SSP585cst)

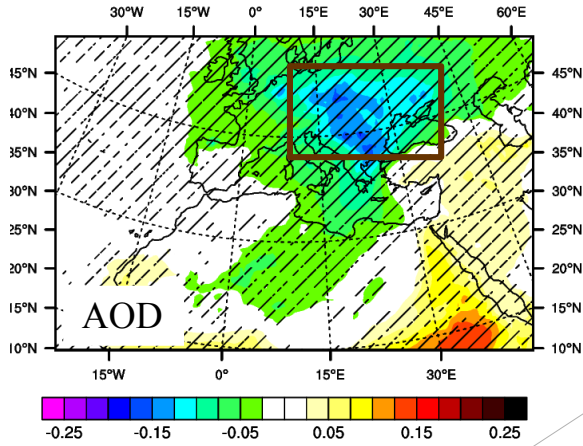
Direct effect



First indirect effect



Central Europe case (SSP585 – SSP585cst)



Aerosols optical depth decrease

Direct effect

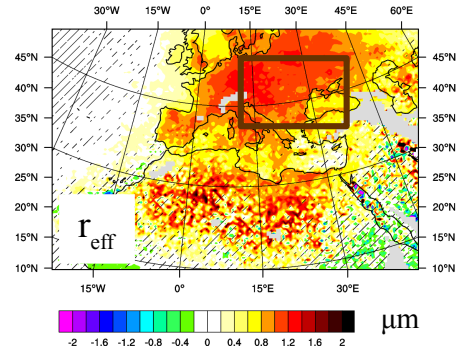
Direct aerosols radiative forcing decrease

Surface radiation increase

Surface temperature increase over Central Europe

Effective droplet radius increase

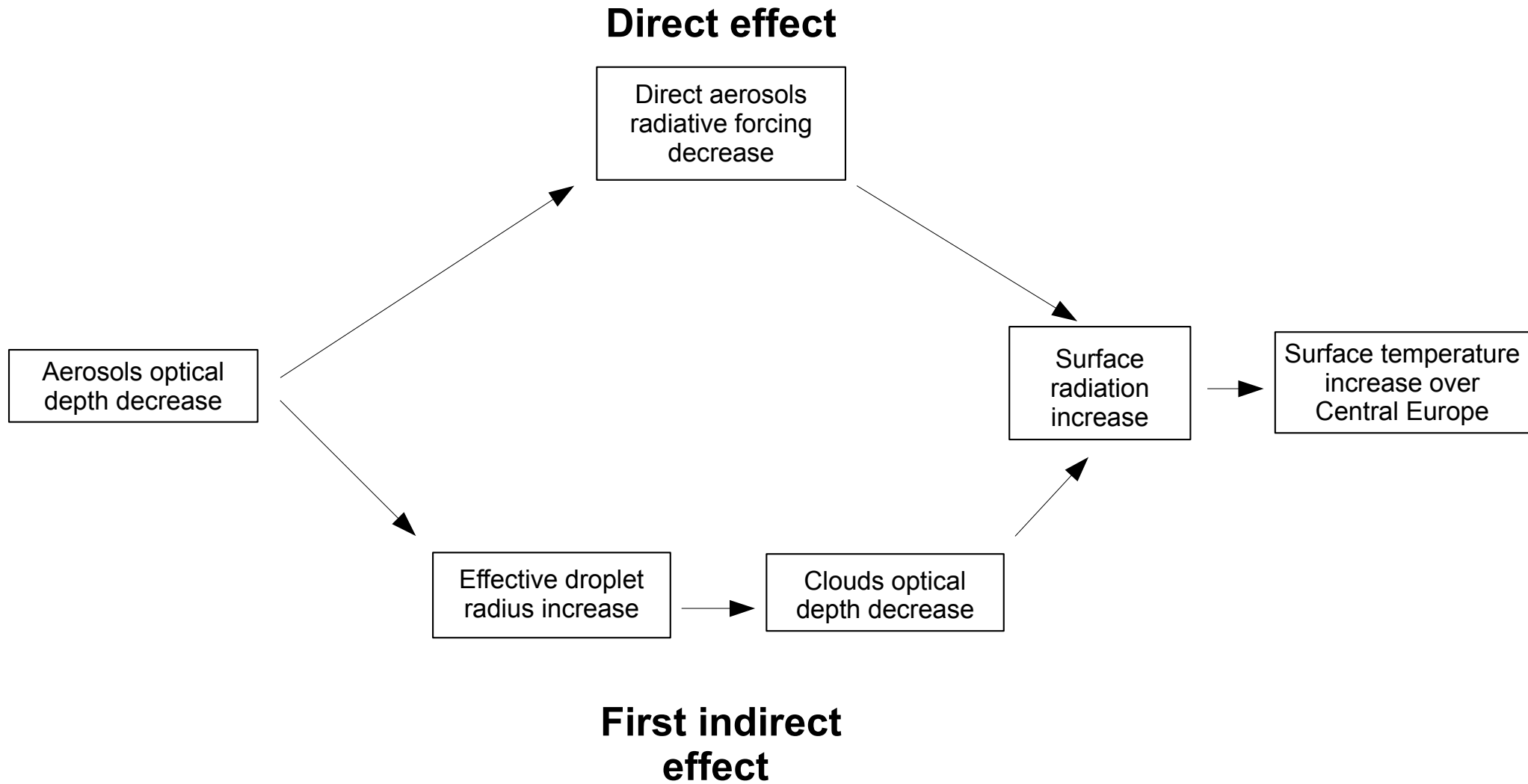
Clouds optical depth decrease



First indirect effect

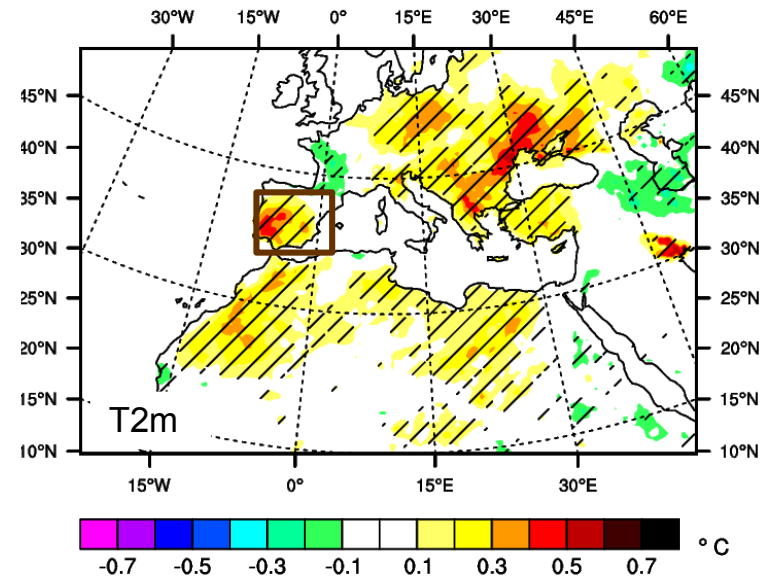
-2 -1.6 -1.2 -0.8 -0.4 0 0.4 0.8 1.2 1.6 2 μm

Central Europe case (SSP585 – SSP585cst)



Iberian Peninsula case (SSP585 – SSP585cst)

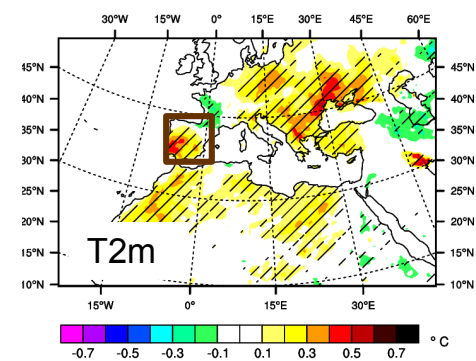
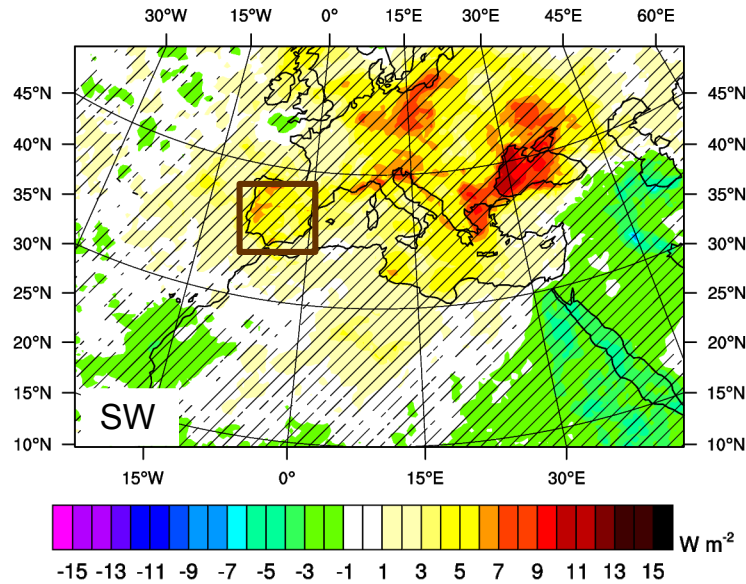
Surface temperature increase over the Iberian Peninsula



Iberian Peninsula case (SSP585 – SSP585cst)

Surface radiation increase

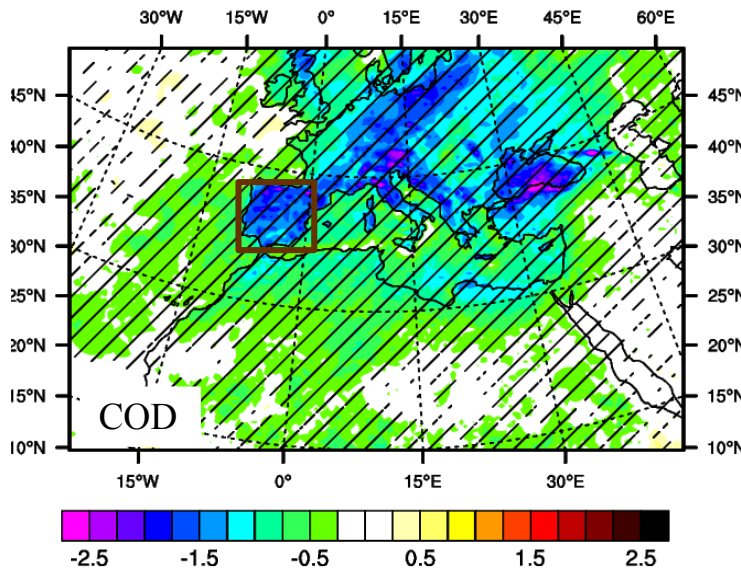
Surface temperature increase over the Iberian Peninsula



Iberian Peninsula case (SSP585 – SSP585cst)

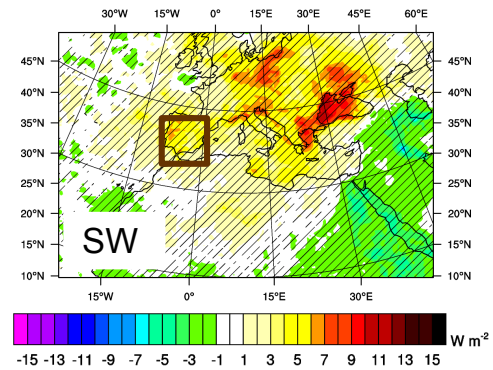
First indirect effect

Clouds optical depth decrease



Surface radiation increase

Surface temperature increase over the Iberian Peninsula

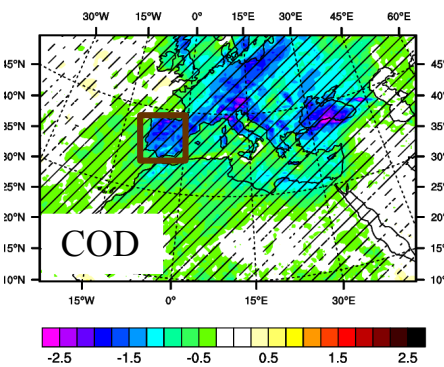
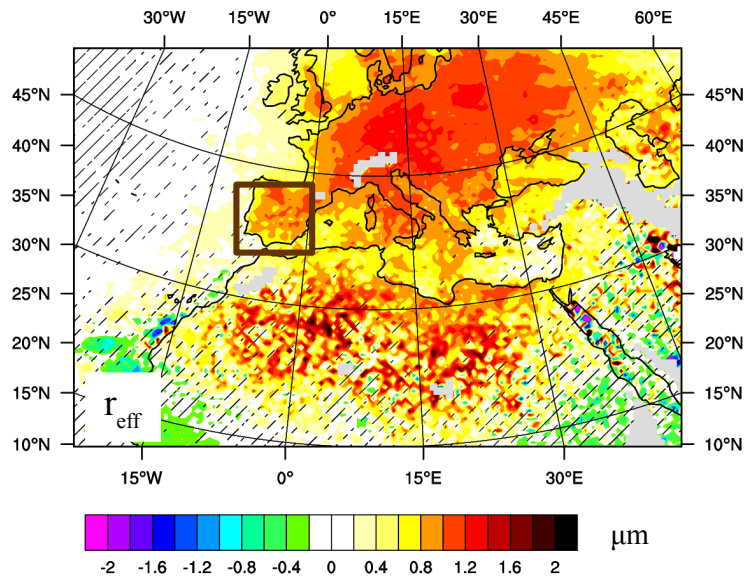


Iberian Peninsula case (SSP585 – SSP585cst)

First indirect effect

Effective droplet
radius increase

Couds optical
depth decrease



Surface
radiation
increase

Surface temperature
increase over the
Iberian Peninsula

Iberian Peninsula case (SSP585 – SSP585cst)

First indirect effect

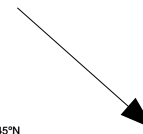
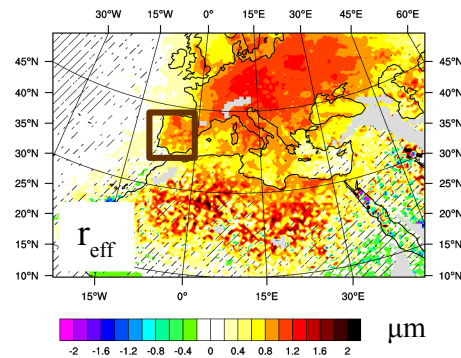
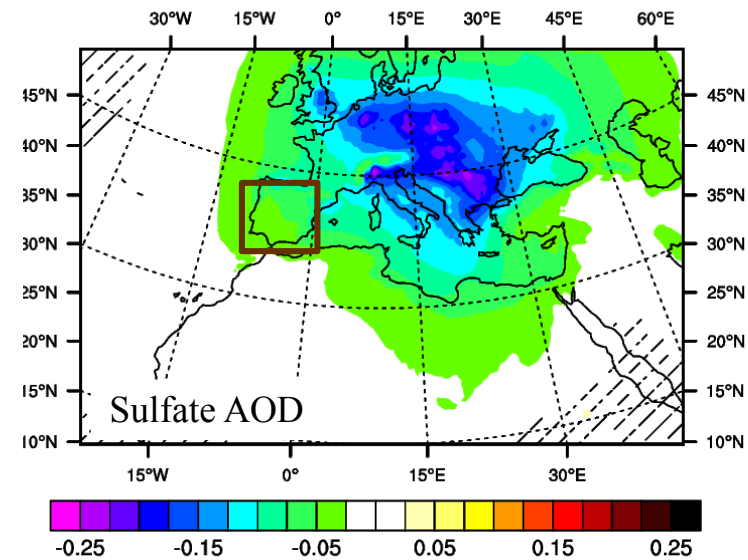
Sulfate aerosols
optical depth
decrease

Effective droplet
radius increase

Couds optical
depth decrease

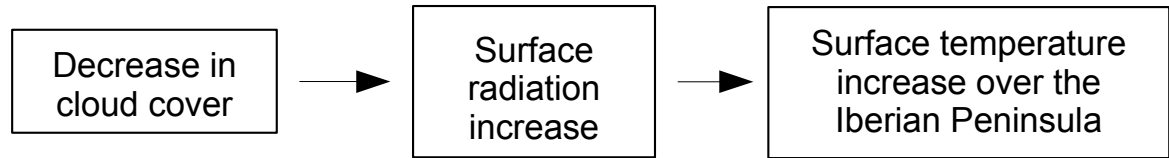
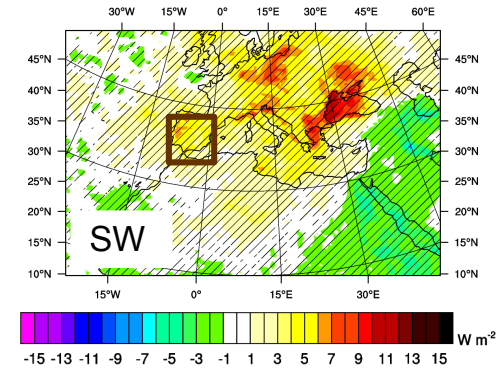
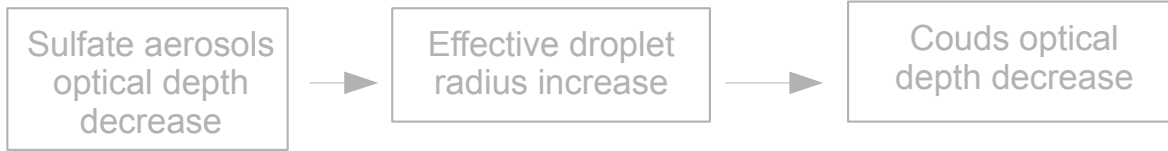
Surface
radiation
increase

Surface temperature
increase over the
Iberian Peninsula

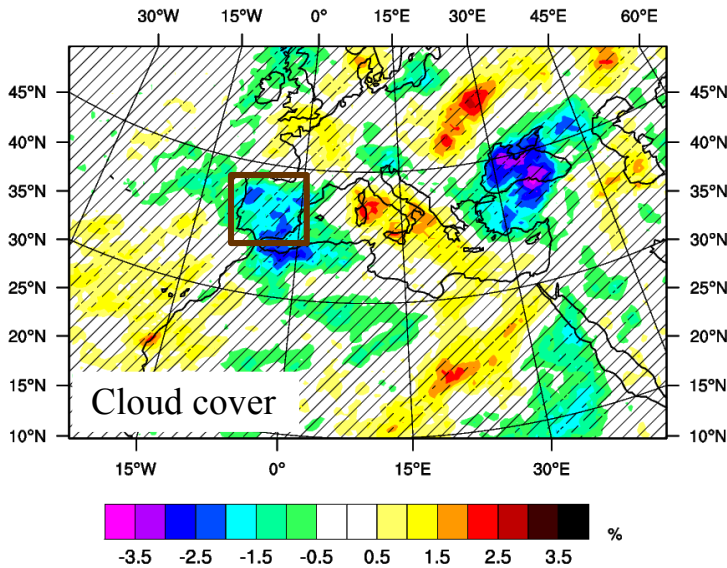


Iberian Peninsula case (SSP585 – SSP585cst)

First indirect effect

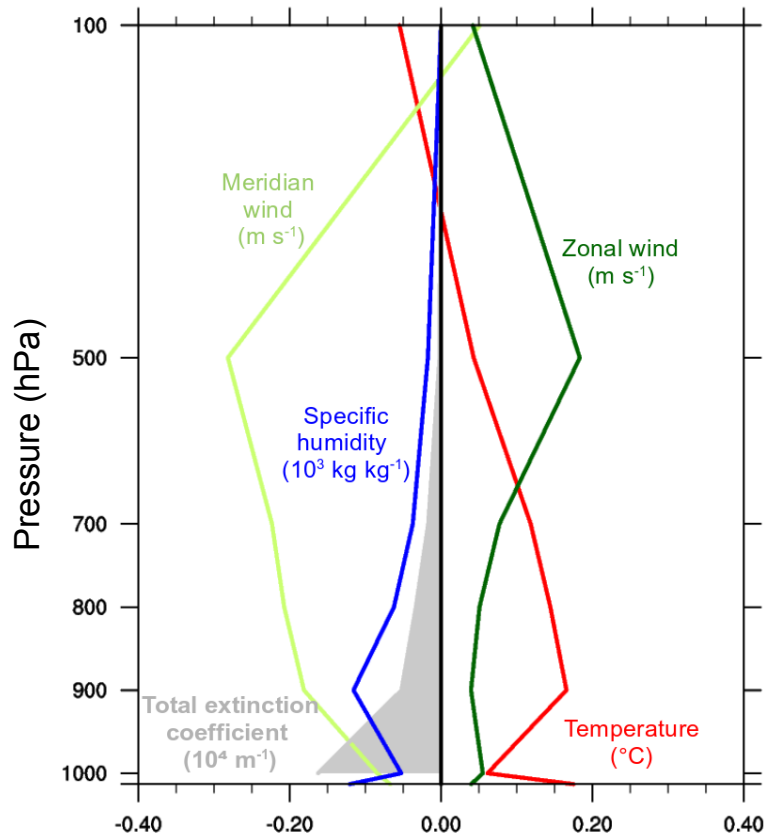
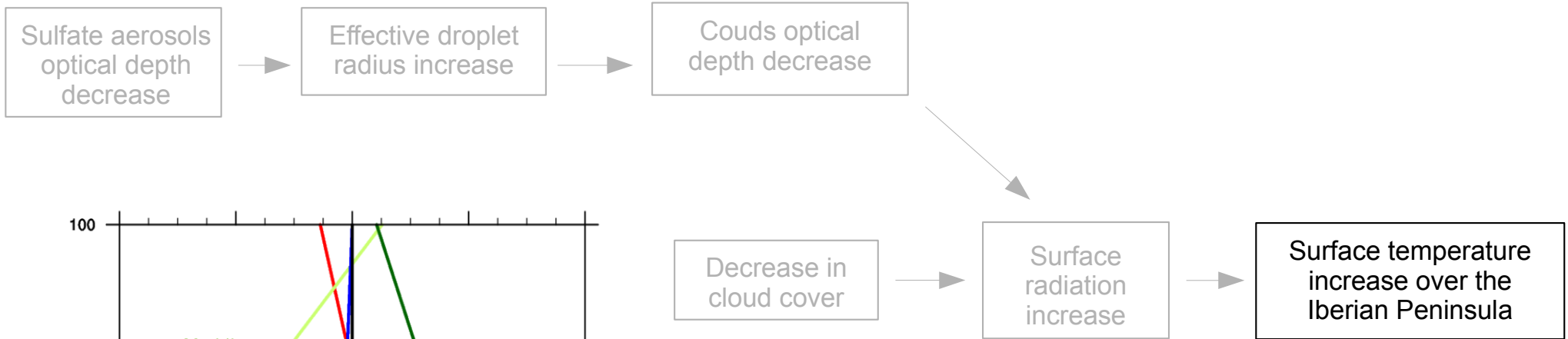


Semi-direct effect



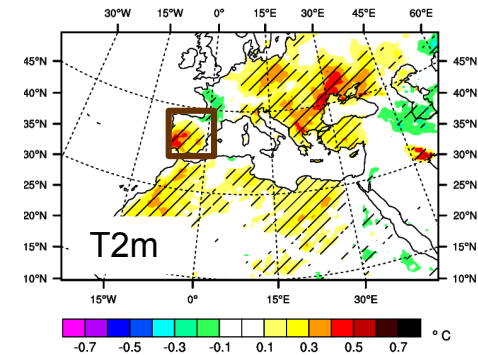
Iberian Peninsula case (SSP585 – SSP585cst)

First indirect effect



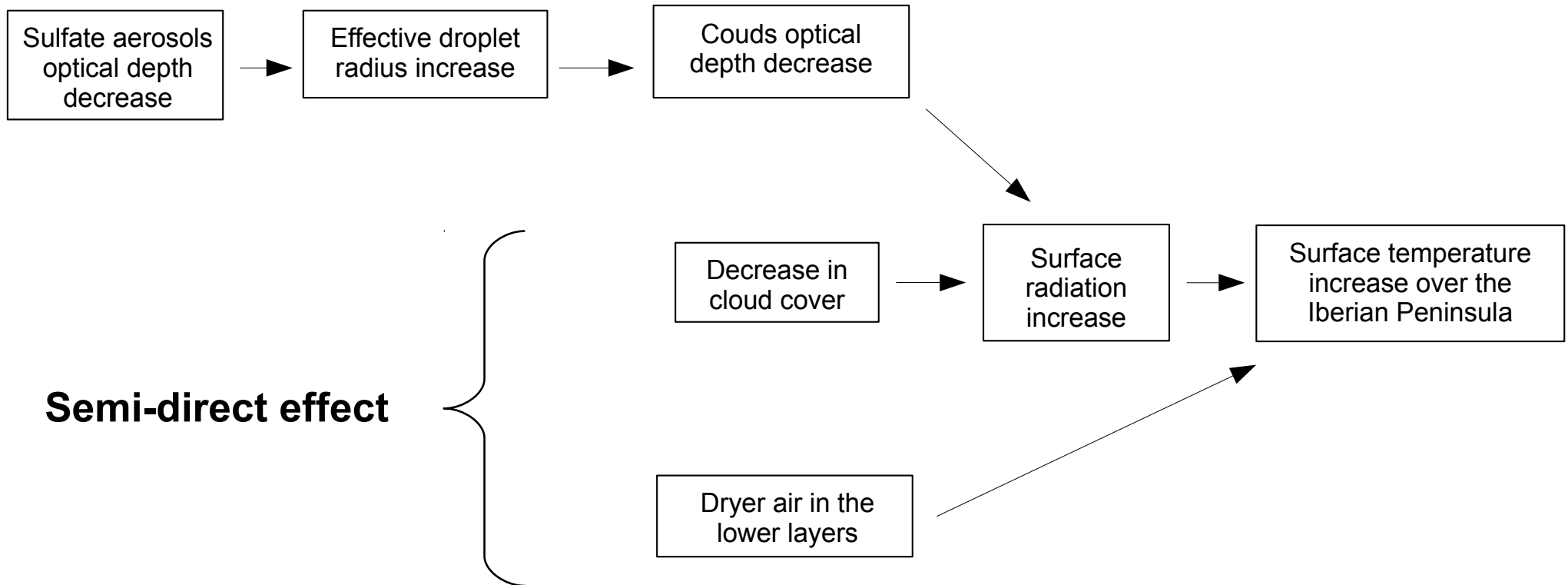
Semi-direct effect

Dryer air in the lower layers



Iberian Peninsula case (SSP585 – SSP585cst)

First indirect effect



Summary

I - Introduction

II - Aerosol evolution

III - Future climate sensitivity to aerosols

IV – Conclusion and perspective

Conclusion

Aerosols evolution

SSP585 - HIST

- Shows a strong AOD sulfate decline over Europe partly offset by nitrate aerosols
- Is essential to understand the past and future climate of the Euro-Mediterranean region

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SSP585 - SSP585avg

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Regional climate modelling approach with interactive aerosols well adapted to this type of study

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Perspective

A regional multi-models exercise ?

Thank you for your attention!

