HOW GOOD ARE AEROSOL-CLOUD INTERACTIONS IN ONLINE COUPLED MODELS?

R. Baró*, D. Brunner, L. Palacios-Peña, R. Bianconi, G. Curci, M. Hirtl, L. Honzak, R. Forkel, A. Manders, L. Neal, N. Savage, M. Schaap, P. Tuccella, H. Van der Gon, J. Werhahn, R Žabkar and P. Jiménez-Guerrero*

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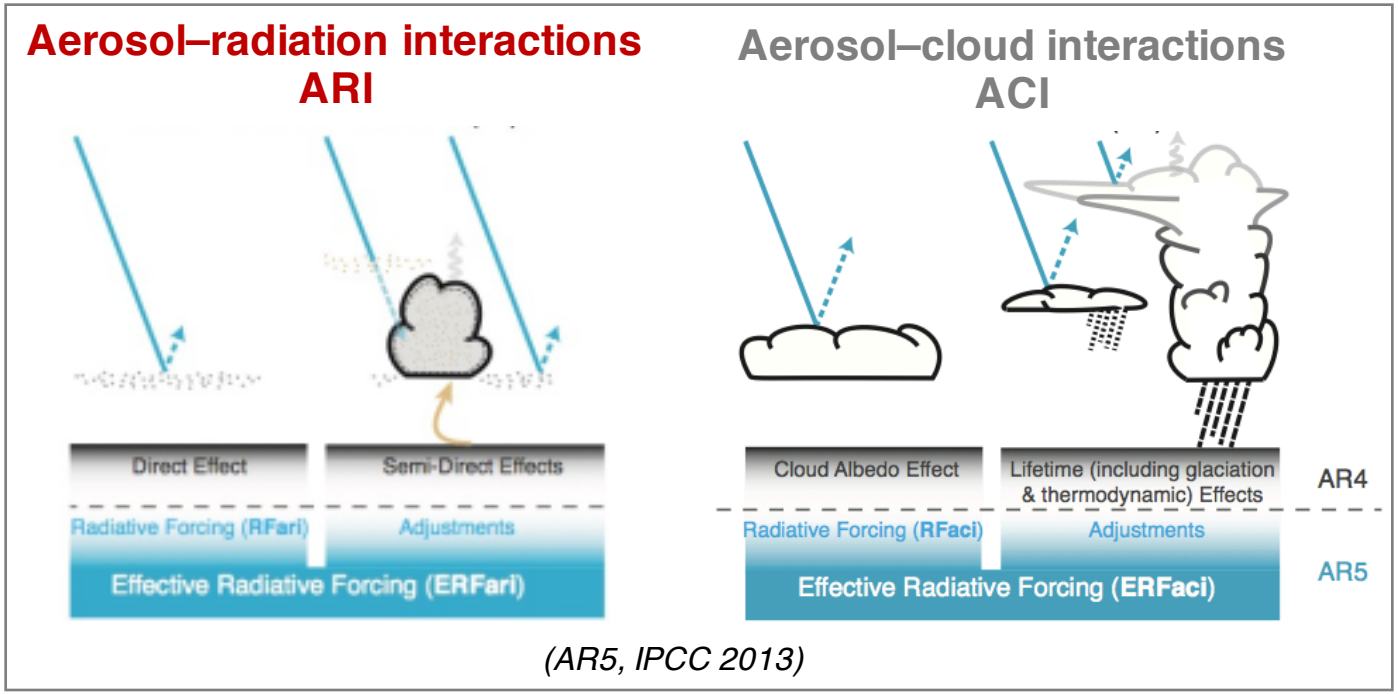
GOBIERNO DE ESPAÑA MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD
FEDER Fondo Europeo de Desarrollo Regional
UNIÓN EUROPEA "Una manera de hacer Europa"

AQMEII
cost ES1004 EuMetChem


WHY STUDY
AEROSOL-CLOUD INTERACTIONS?

MOTIVATION

- Atmospheric aerosols affect air quality and influence the Earth's climate through the **aerosol effects** and **feedbacks**
- Nowadays is one of the most important topics in climate science



(AR5, IPCC 2013)

- Account for these feedback → Fully couped model

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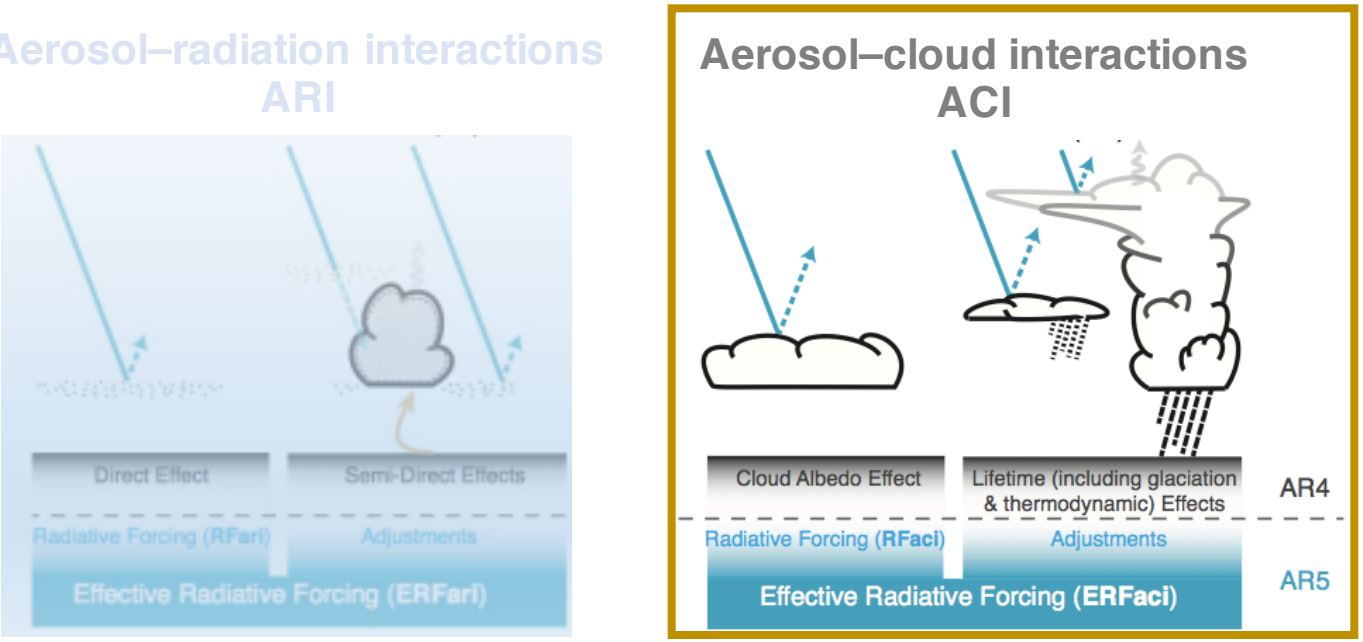

(AR5, IPCC 2013)

ACIs constitute one of the most important uncertainties in anthropogenic climate perturbations

MOTIVATION

In order to build confidence in air quality-climate interaction studies, an evaluation of integrated meteorology-atmospheric chemistry models is needed

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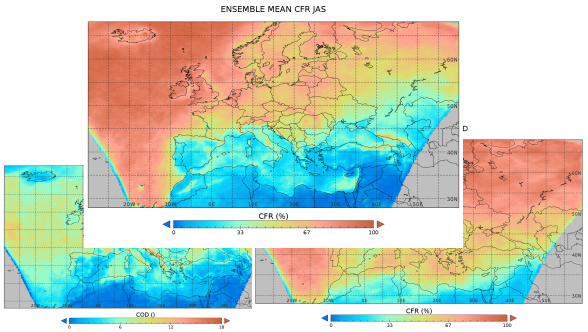
Model output



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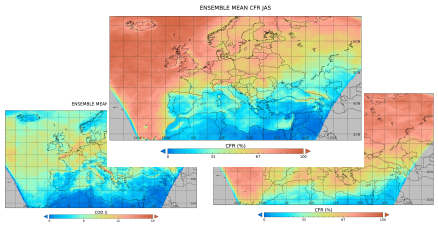
Observational data

To study the improvements of modelling the aerosol interactions

MOTIVATION

Air Quality 2016

Model output



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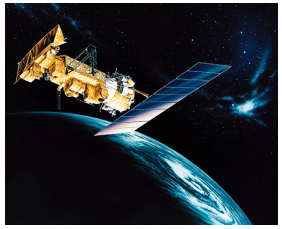
Satellite data



AQMEII-Phase 2

Air Quality Model Evaluation International Initiative

- Joint effort of different european and american groups
- Focus on online coupled meteorology-chemistry models.
- Assess how well coupled regional AQ models simulate aerosols feedbacks
- Years 2006 and 2010

MOTIVATION

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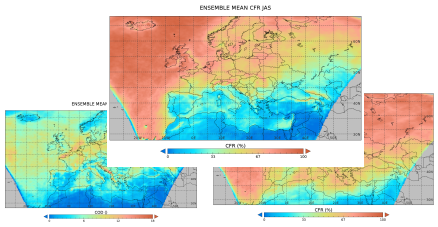

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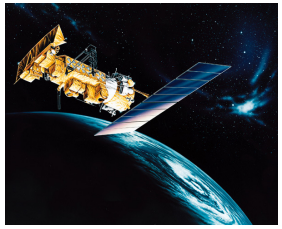

esa climate change initiative

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ESA CLOUD CCI Project

European Space Agency, Climate Change Initiative

- **Phase 1** (2010-2013) data sets from 2007-2009
- **Phase 2** (2014-2016) with sensors:

  1. **AVHRR/MODIS/(A)ATSR** data from 1982-2014

  2. **MERIS/AATSR** time series from 2002 to 2012, extended by **OLCI/SLSTR** on-board Sentinel-3.

OBJECTIVES

MAIN OBJECTIVE

To assess whether the inclusion of ACIs in regional-scale, integrated models improves the simulation of the climate-chemistry-cloud-radiation system over Europe

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To assess whether the inclusion of ACIs in regional-scale, integrated models improves the simulation of the climate-chemistry-cloud-radiation system over Europe

- ✓ Test the Cloud CCI preliminar data and provide feedbacks to the CCI people
- ✓ To study the relationship between Aerosol Optical Depth (AOD) and several cloud variables in online coupled models

METHODOLOGY

- One year simulations for 2010 conducted with several different models under the umbrella of AQMEII-2.

	Model	Microphysics	Gas Phase	SW radiation	LW radiation	Aerosol	Aerosol feedbacks
1	WRF Chem	Lin	RADM 2	RRTM	Goddard	MADE SORGAM	Yes
2		Morrison	RADM 2 integ1				
3			RACM	RRTMG	RRTMG	MADE VBS	
4*			RADM 2			MADE SORGAM	No
5	RACMO LOTOS-EUROS	Tiedtke, Tompkins Neggers	CB-IV	RRTM	RRTM	ISORROPIA II 2 bins	Yes
6	METUM UKCA	Wilson & Ballard	RAQ	Edwards-Slingo		Classic	

No Feedbacks

- 5 simulations with ACIs and one without

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STUDIED VARIABLES →

Cloud Fraction → CFR
Cloud Optical Depth → COD
Cloud Liquid Water Path → CWP
Cloud Ice Water Path → CIP

METHODOLOGY

Model Evaluation

- Satelite data : AVHRR NOAA-19 (equator crossing time of 1:30 to 2:00PM- local solar time)
- Mean BIASerror (MBE)

$$MBE = \frac{1}{n}\sum_{i=1}^{n} e_i = \bar{P} - \bar{O}$$

- Model Ensemble vs NoFeedback model

AOD vs Cloud variables relationship

- Correlation over time

$$o(1,x) = \frac{\sum_{t \in S(x)} i_1(t,x) i_2(t,x) - n\ \overline{i_1(t,x)}\ \overline{i_2(t,x)}}{\sqrt{\left(\sum_{t \in S(x)} i_1(t,x)^2 - n\ \overline{i_1(t,x)}^2\right)\left(\sum_{t \in S(x)} i_2(t,x)^2 - n\ \overline{i_2(t,x)}^2\right)}}$$

RESULTS

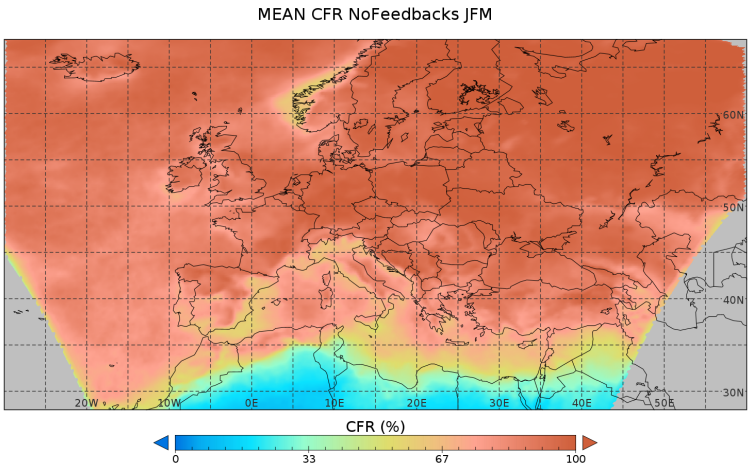
MODEL EVALUATION using preliminar Cloud cci data.

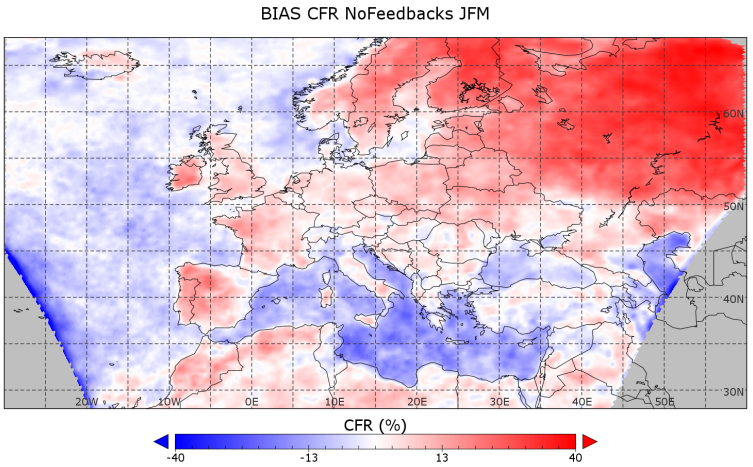
Comparison of the NoFeedback simulation BIAS and the ENSEMBLE (w Feedbacks) BIAS

CLOUD FRACTION -CFR

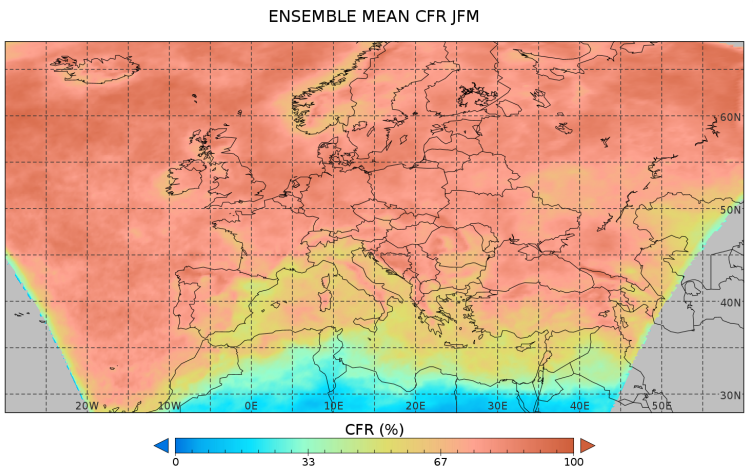
Winter months

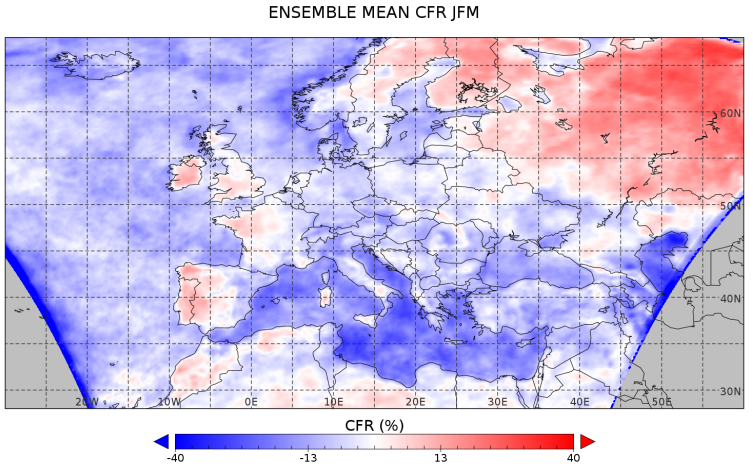
BIAS NoFeedbacks





BIAS ENSEMBLE w Feedbacks



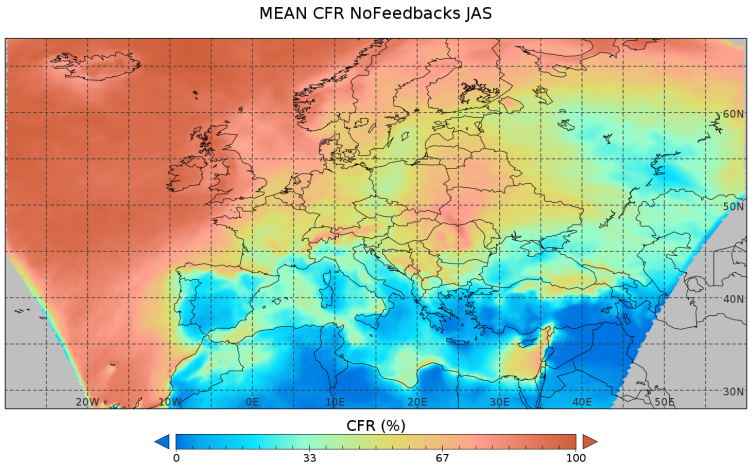


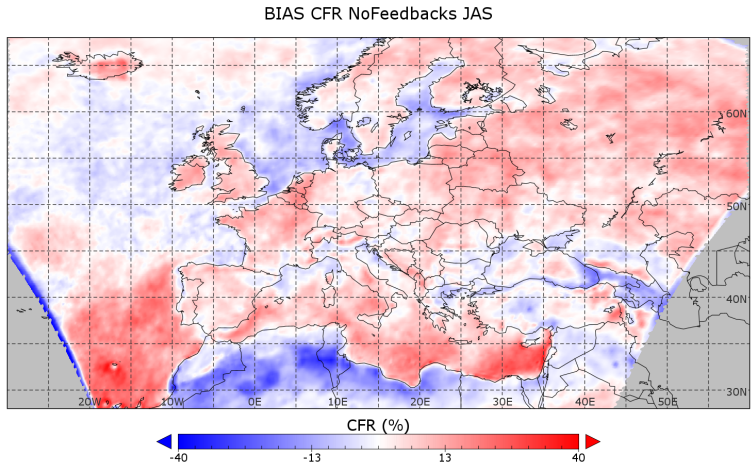
- The same BIAS response, negative BIAS over the Sea and positive BIAS over land
- The inclusion of the ACIs imply a lower positive BIAS over land and negative BIAS is slightly higher

CLOUD FRACTION -CFR

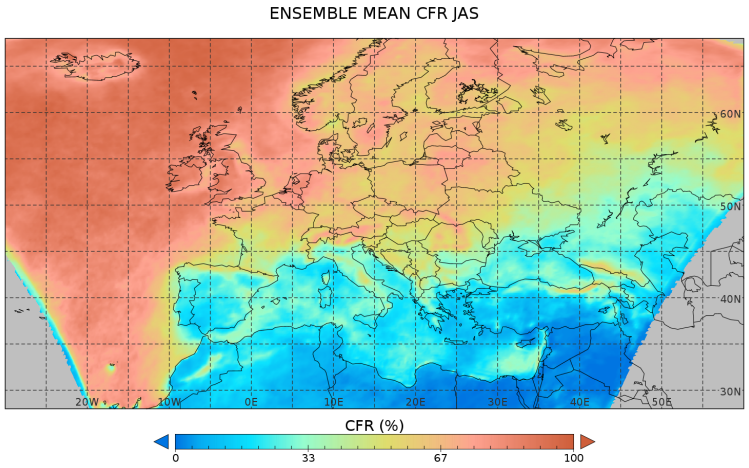
Summer months

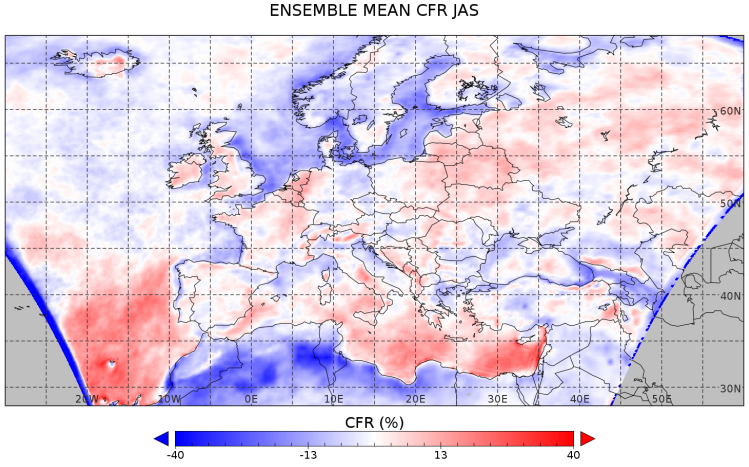
BIAS NoFeedbacks





BIAS ENSEMBLE w Feedbacks

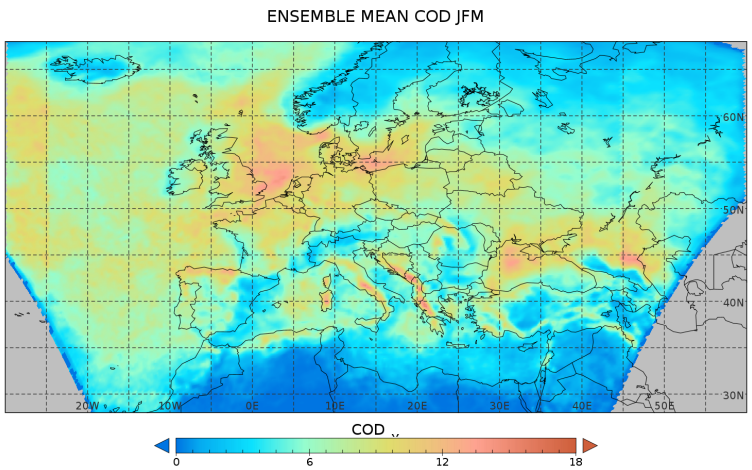


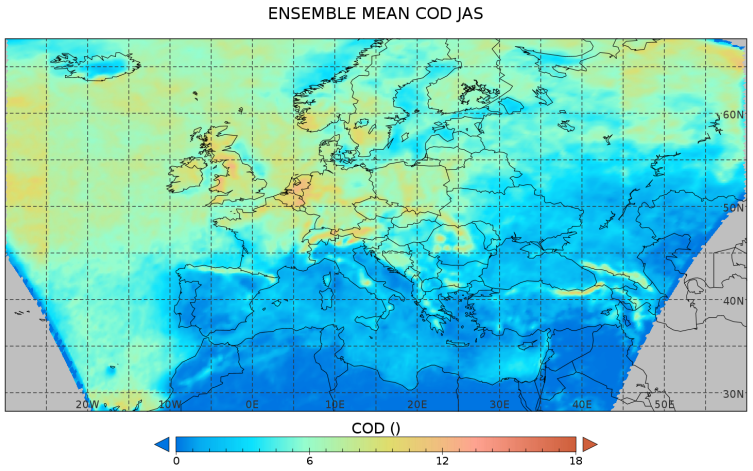


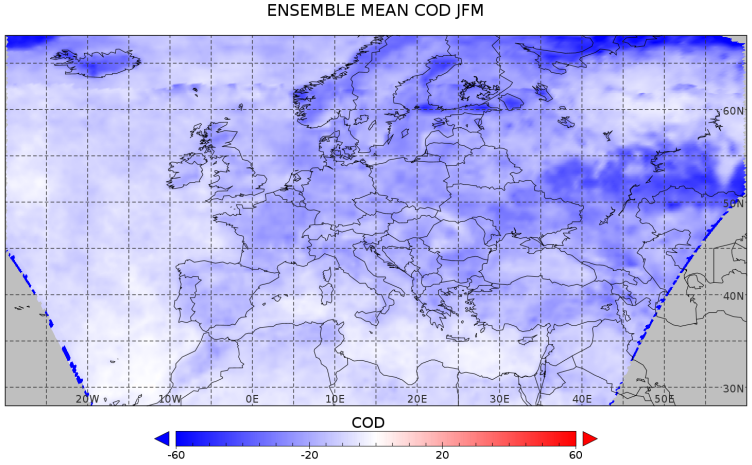
- The same BIAS response, negative BIAS over the Noth Sea and North Africa and positive BIAS over the Mediterranean Sea and land.
- The inclusion of the ACIs imply a lower positive BIAS over land and negative BIAS is slightly higher

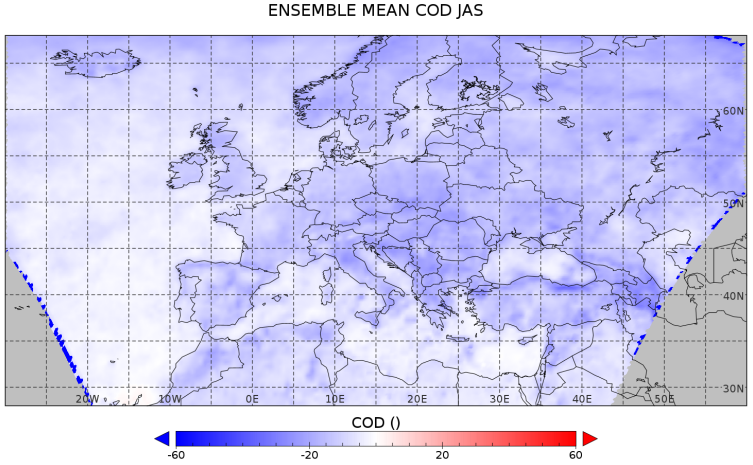
CLOUD OPTICAL DEPTH- COD

BIAS ENSEMBLE w Feedbacks





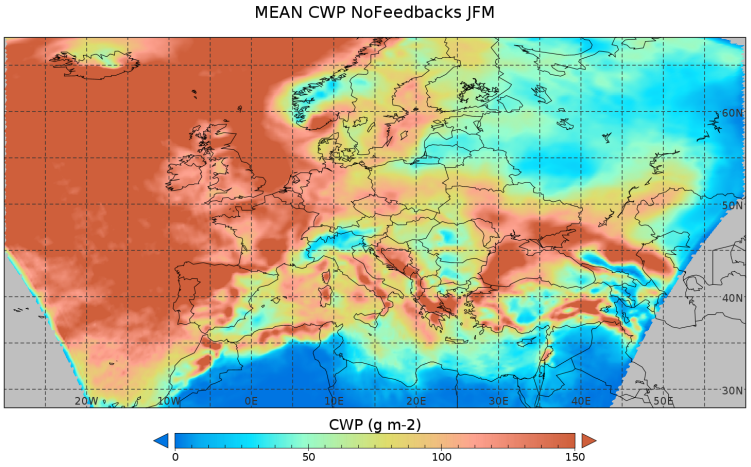


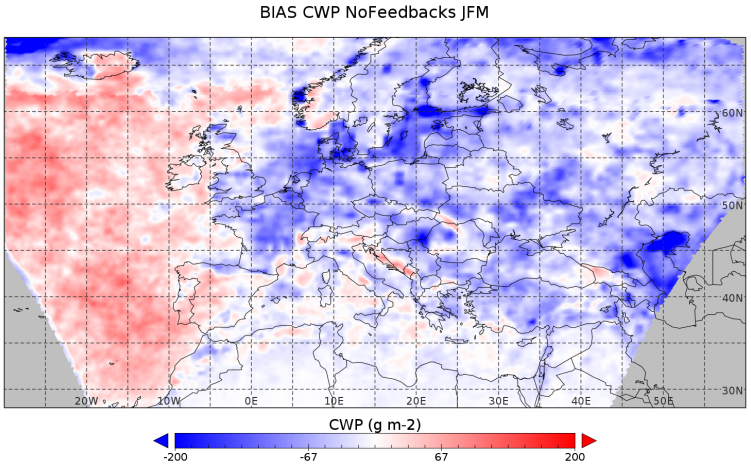


- The Ensemble Mean understimates the Cloud Optical Depth during all 2010
- Higher understimation is found during winter months

CLOUD LIQUID WATER PATH- CWP Winter months

BIAS NoFeedbacks





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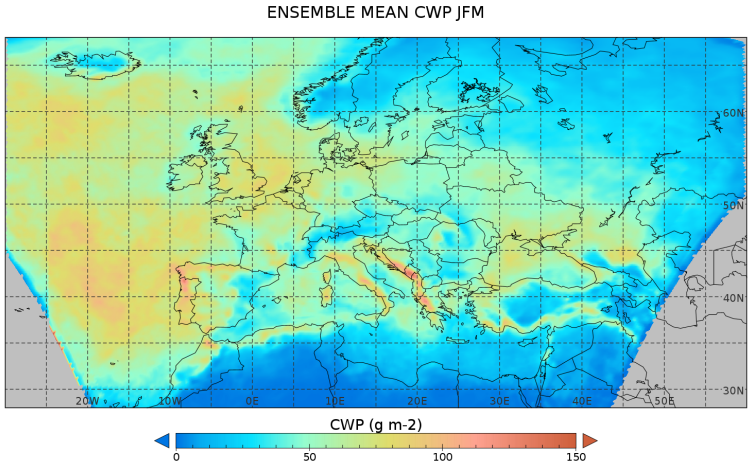
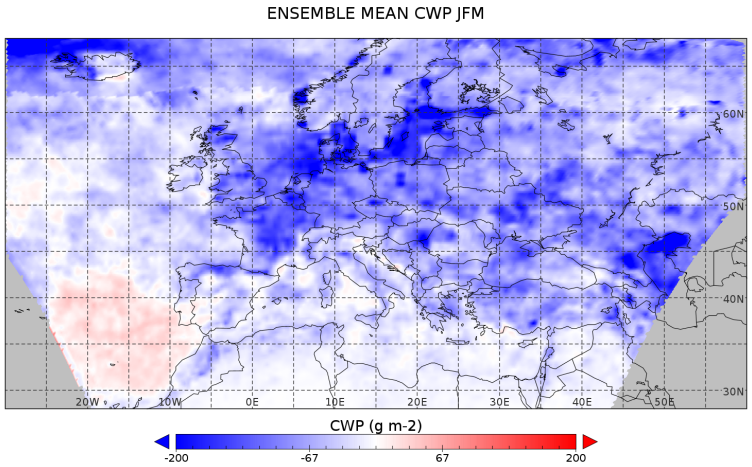
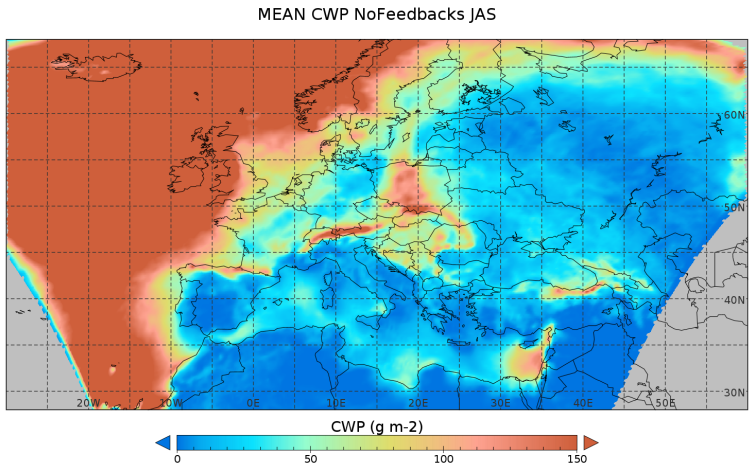


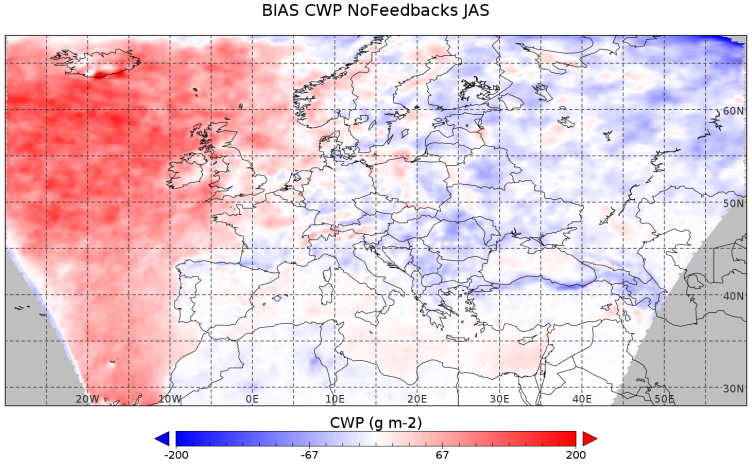


- The inclusion of the ACIs imply a lower positive BIAS over Atlantic Sea and negative BIAS is slightly higher in Center Europe.

CLOUD LIQUID WATER PATH- CWP Summer months

BIAS NoFeedbacks





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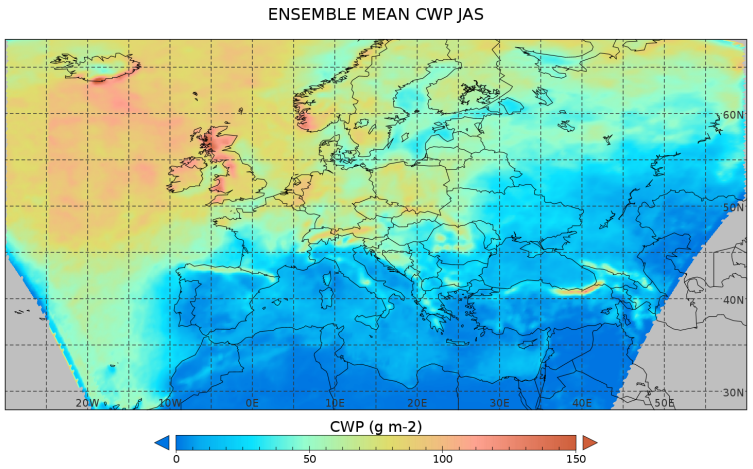

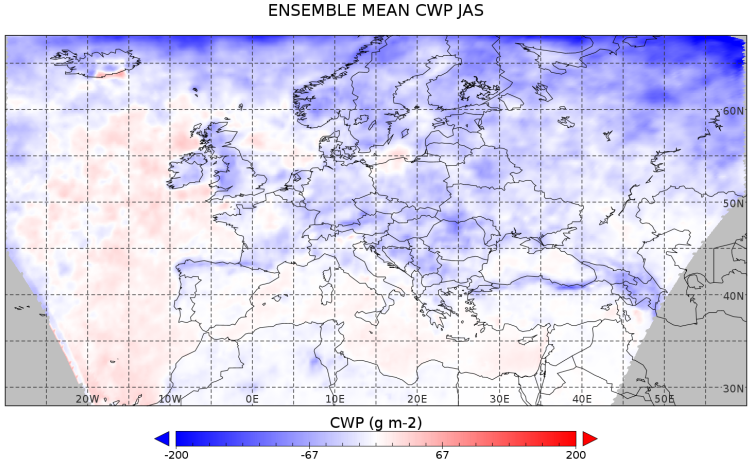

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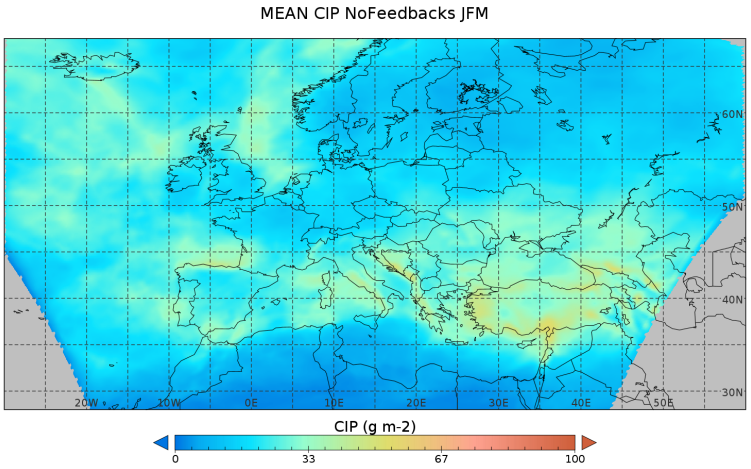
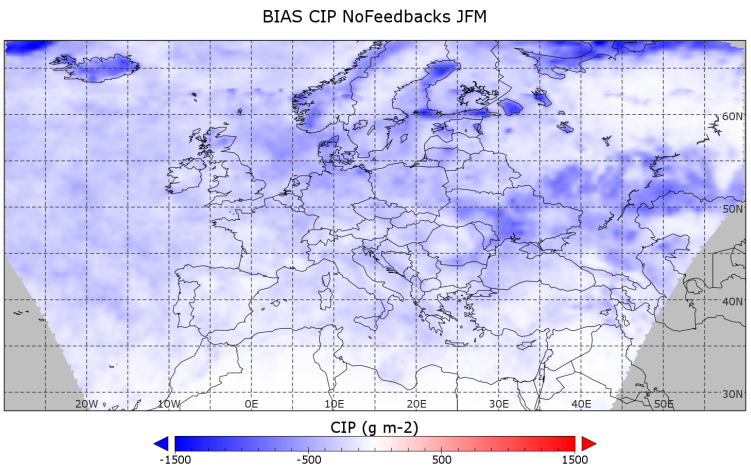
CLOUD LIQUID ICE PATH- CIP

Winter months

BIAS NoFeedbacks





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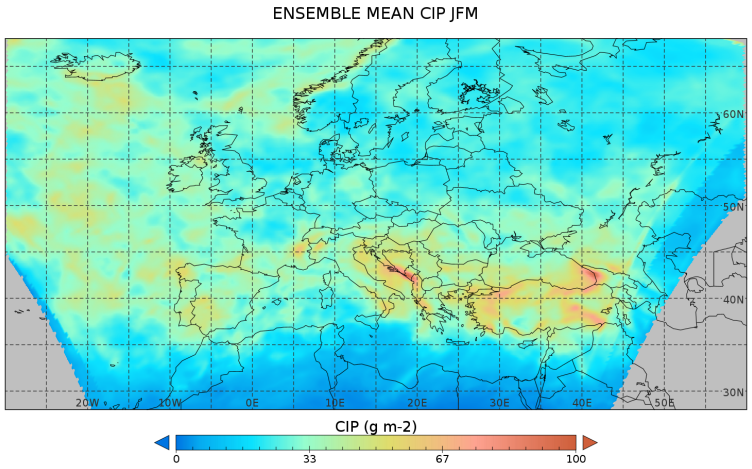
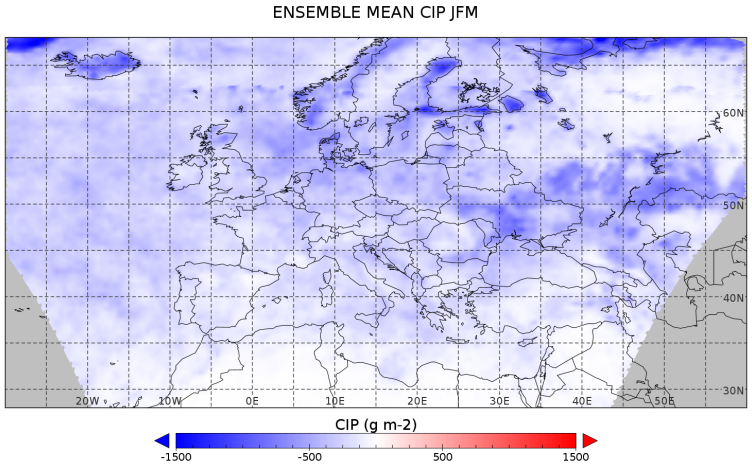


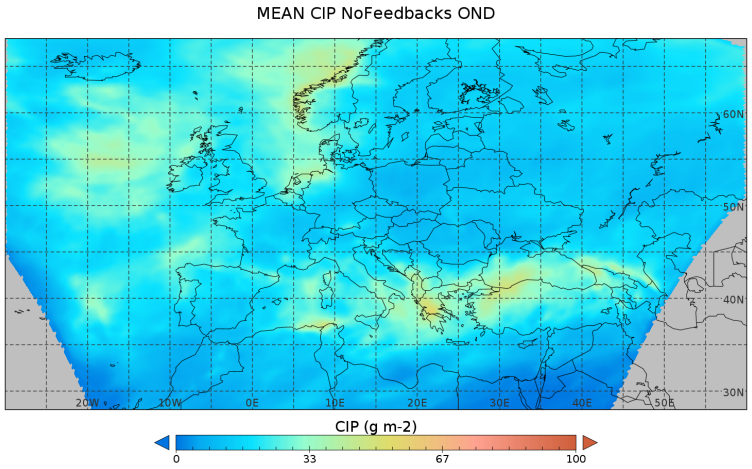


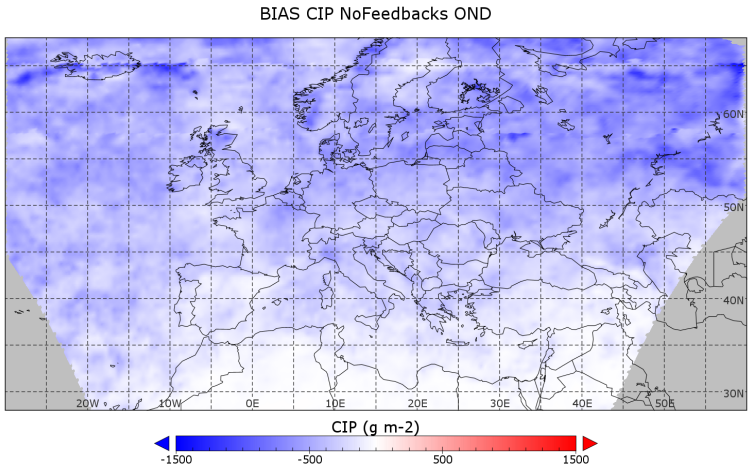
- For NoFeedback case and the Ensemble Mean CIP is understimated, with same values

CLOUD LIQUID ICE PATH- CIP

Winter months

BIAS NoFeedbacks





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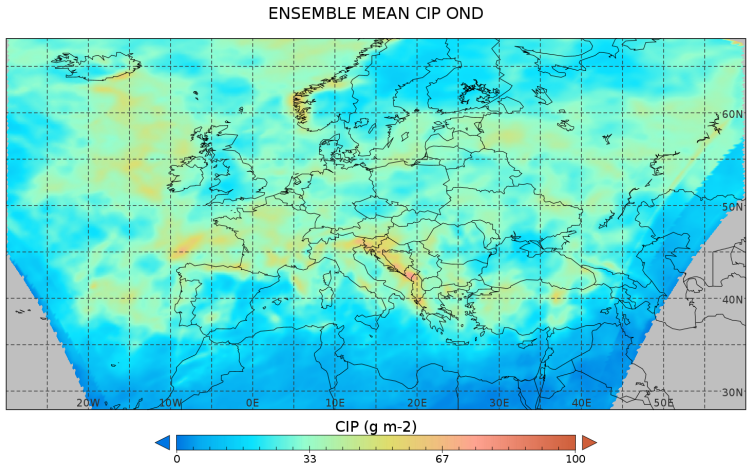

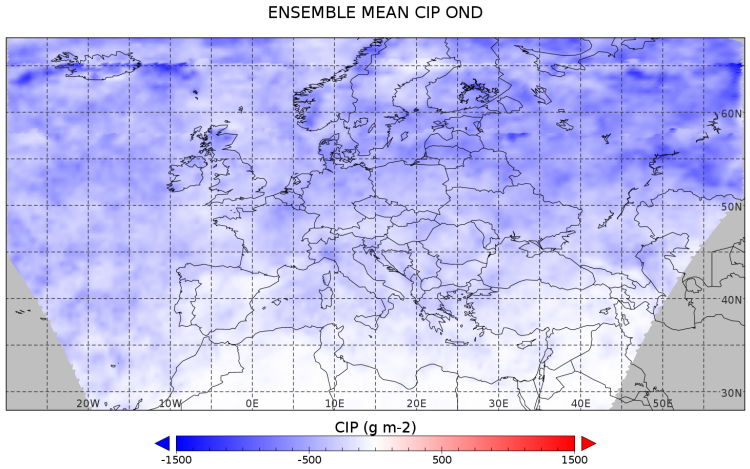

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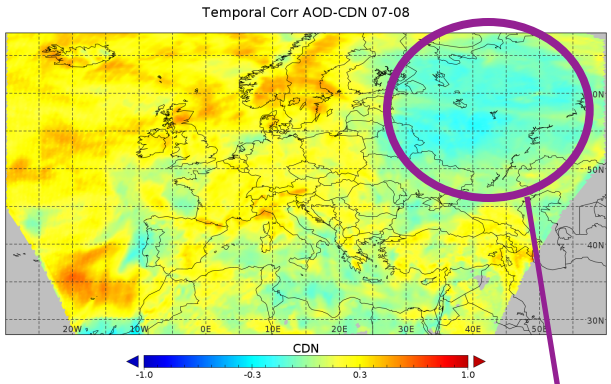
AOD vs Cloud Variables

Temporal Correlations

Ensemble Model Mean during July and August
Russian and Portugal Fires

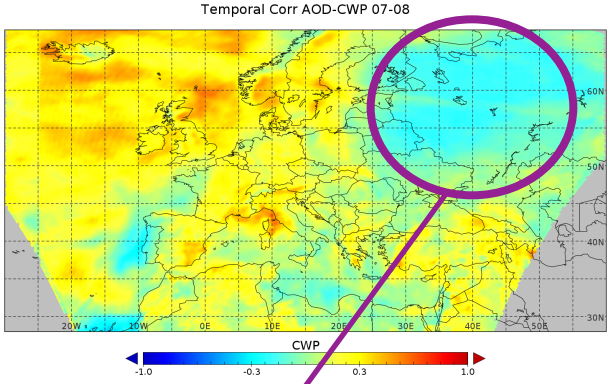
RESULTS

AOD vs CDNC



Cloud Droplet Number concentration

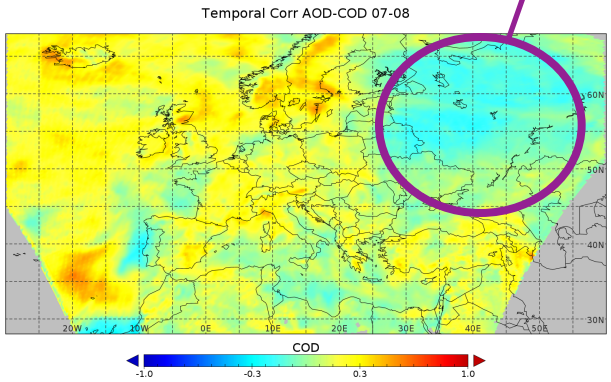
AOD vs CLWP



Cloud Liquid Water Path

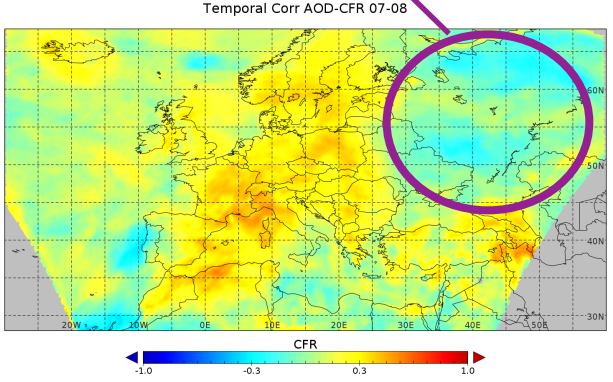
Slighlty negative correlated, -0.2/-0.3

AOD vs COD



Cloud Optical Depth

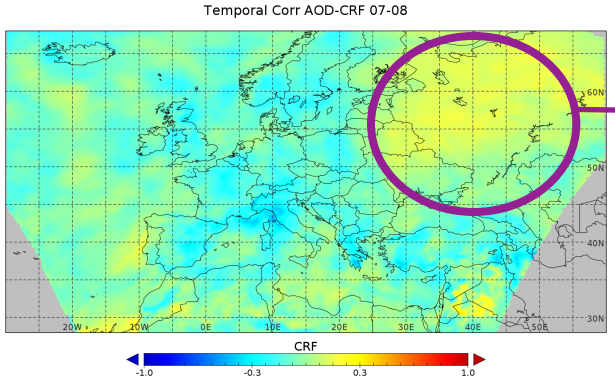
AOD vs CFR



Cloud Fraction

RESULTS

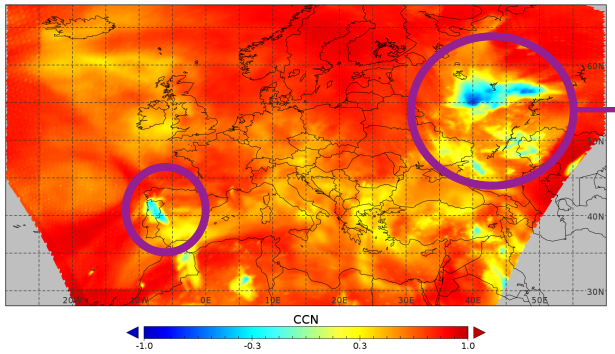
AOD vs CRF



Cloud Radiative Forcing

Positive correlated: extinction due to Biomass Burning aerosol is mostly absorbing

AOD vs CCN



Cloud Condensation Nuclei

We expected a positive correlation with the CCN….

We think that..

These quantities refer to different volumes of air. (CCN most relevant to ACI are located at the cloud base altitude, the AOD entire vertical column)

Any suggestions ?

CONCLUSIONS

- ✓ Cloud Fraction, negative BIAS over the Sea and positive BIAS over land is found.
- ✓ The Ensemble mean BIAS tends to underestimate the cloud optical depth over the entire domain and year, being higher during winter months.
- ✓ For the CWP inclusion of the ACIs imply a lower positive BIAS over The Atlantic Sea and negative BIAS is slightly incresased.
- ✓ CIWP is underestimated for both cases and there is no change when taking into account the ACIs.
- ✓ In general it is observed that the inclusion of the ACIs imply a lower positive BIAS and negative BIAS is slightly higher

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- ✓ CIWP is underestimated for both cases and there is no change when taking into account the ACIs.
- ✓ In general it is observed that the inclusion of the ACIs imply a lower positive BIAS and negative BIAS is slightly higher
- ✓ We will investigate the anticorrelation found between AOD-CCN simulated by all the models.
- ✓ We provided feedback to the Cloud CCI people and are in contact for the final dataset that we will test again in order to see if there are improvements.

THANK YOU
FOR YOUR ATENTION

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