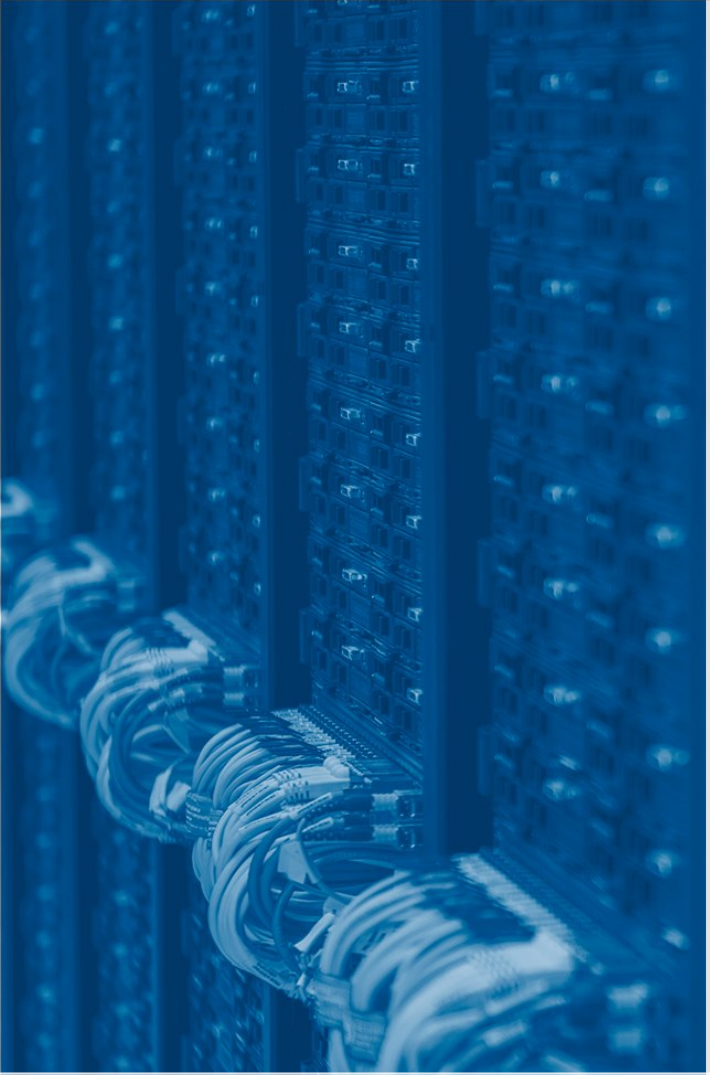


Mixed-phase clouds in EC-Earth3-AerChem: primary and secondary ice production, supersaturation adjustments and model evaluation using satellite observations

BSC: Montserrat Costa Surós, Marios Chatziparaschos, Maria Gonçalves Ageitos, Carlos Pérez-García Pando
EPFL/CSTACC: Paraskevi Georgakaki, Athanasios Nenes
Univ. of Crete/CSTACC: Maria Kanakidou
NOA/CSTACC: Stelios Myriokefalitakis
KNMI: Twan Van Noije, Philippe Le Sager

This project has received funding from Horizon Europe programme under Grant Agreement No 101137680 via project CERTAINTY (Cloud-aERosol inTeractions & their impActs IN The earth sYstem), G.A. No. 773051 (ERC-2017-COG, FRAGMENT project), and from the AXA Research Fund.

19/09/2024

New heterogeneous ice nucleation param.

ICNC estimation

Temperature-sensitive ice nucleation parameterization

Meyers et al. (1992): deposition-condensation freezing

Aerosol-sensitive ice nucleation parameterization

PRIMARY ICE PRODUCTION

Immersion freezing

Atkinson et al. (2013): K-fedlspar
or
Ullrich et al. (2017): soot and dust
or
Harrison et al. (2019): K-feldspar and quartz

+

Wilson et al. (2015): of marine organic aerosols

SECONDARY ICE PROCESSES

Georgakaki et al. (2024): RaFSIP, considers:
- Hallet-Mossop process
- Droplet shattering during freezing
- Fragmentation due to collisional break-up

v1
v2

Ice crystal growth by vapor deposition

Depositional growth parameterization

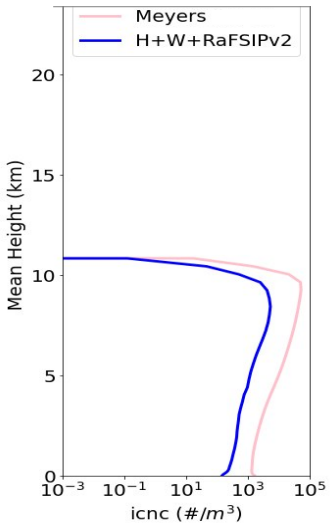
Following Pruppacher and Klett (1997) and Rotstayn et al. (2000)

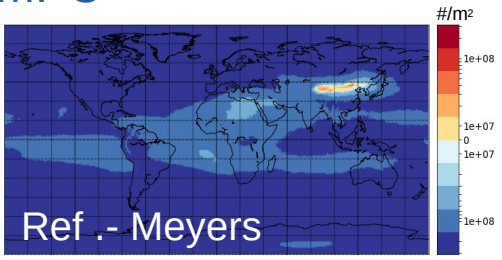
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

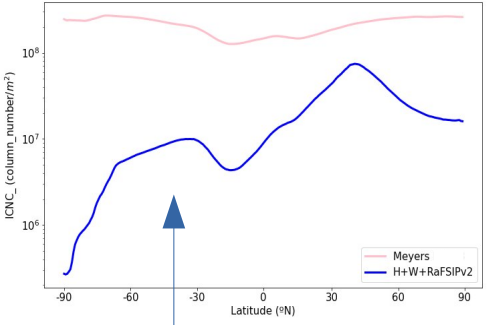
New heterogeneous ice nucleation param.

12-year nudged simulations

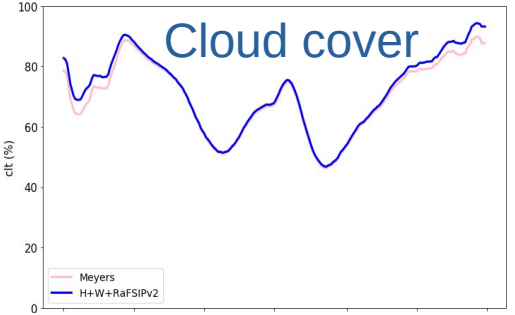
ICNC MPC

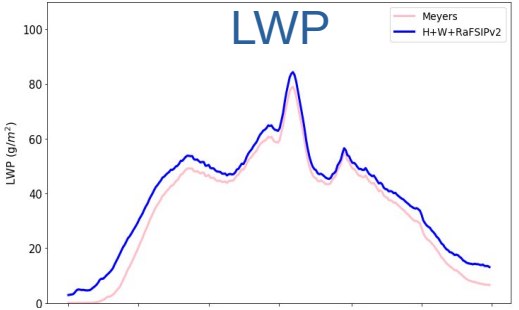


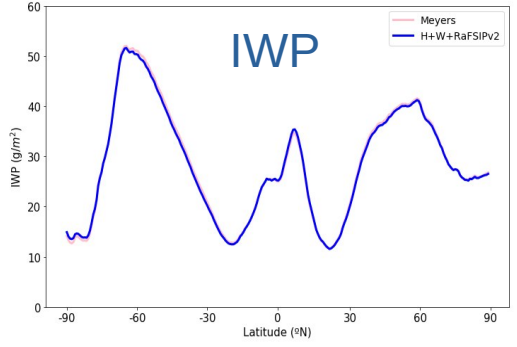


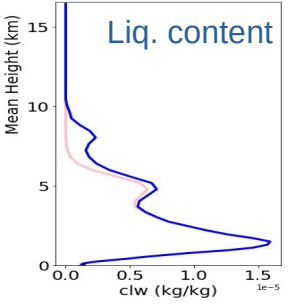


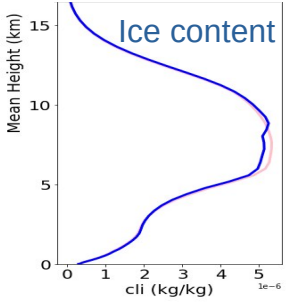
SIP needed
particularly in the SH









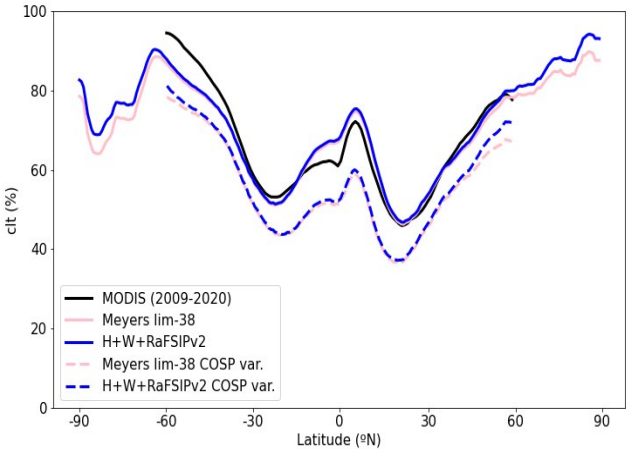


Model evaluation with satellite observations

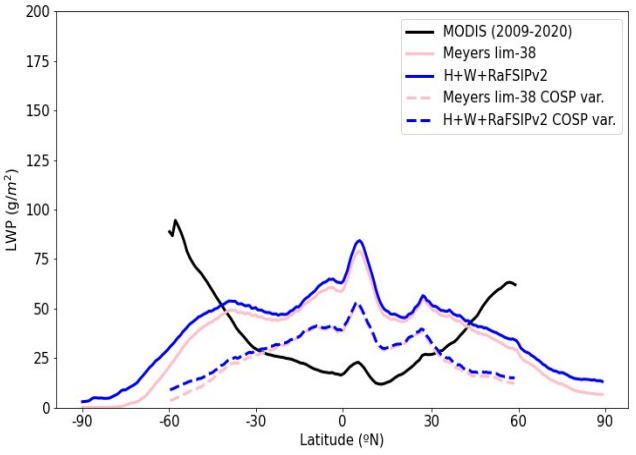
12-year nudged simulations

IFS vs COSP output variables

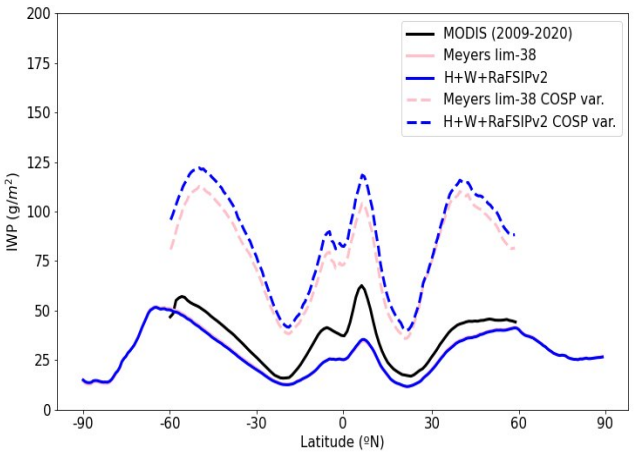
Cloud cover



LWP



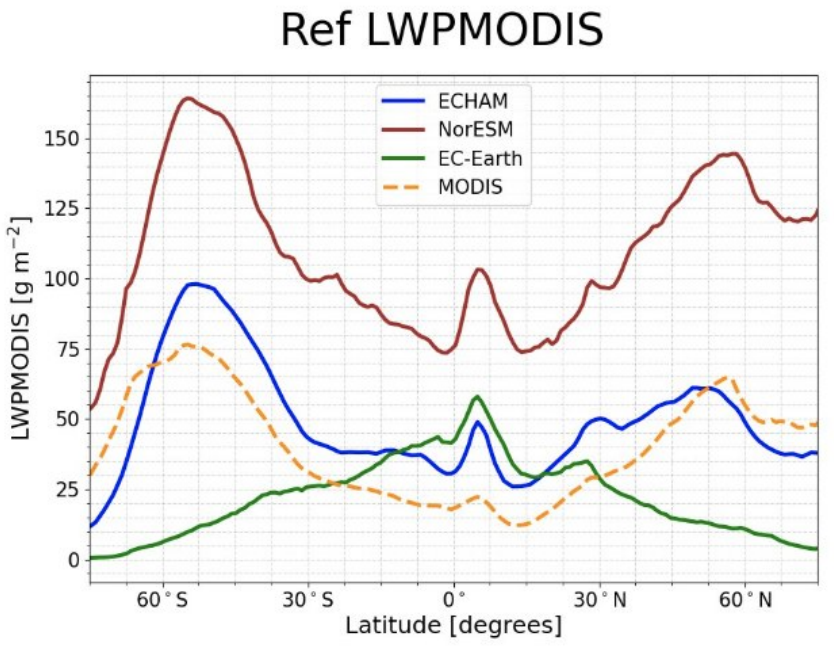
IWP

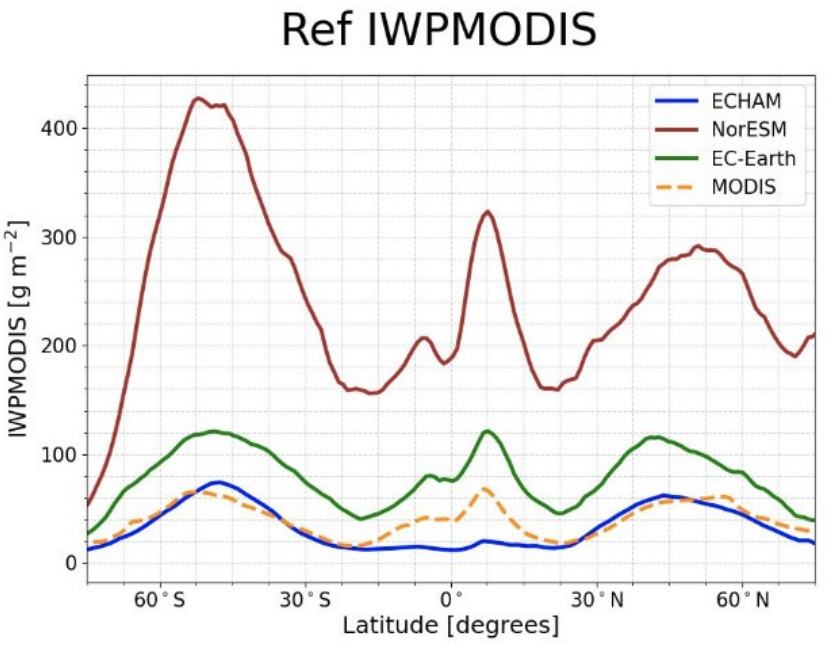


→ Uncertainties are linked to COSP assumptions.
→ Uncertainties in the MODIS observations (differ considerably from other satellite data, e.g. CloudSat)

Model evaluation with satellite observations

1-year nudged simulations (FOR-ICE project, preliminary resuts)

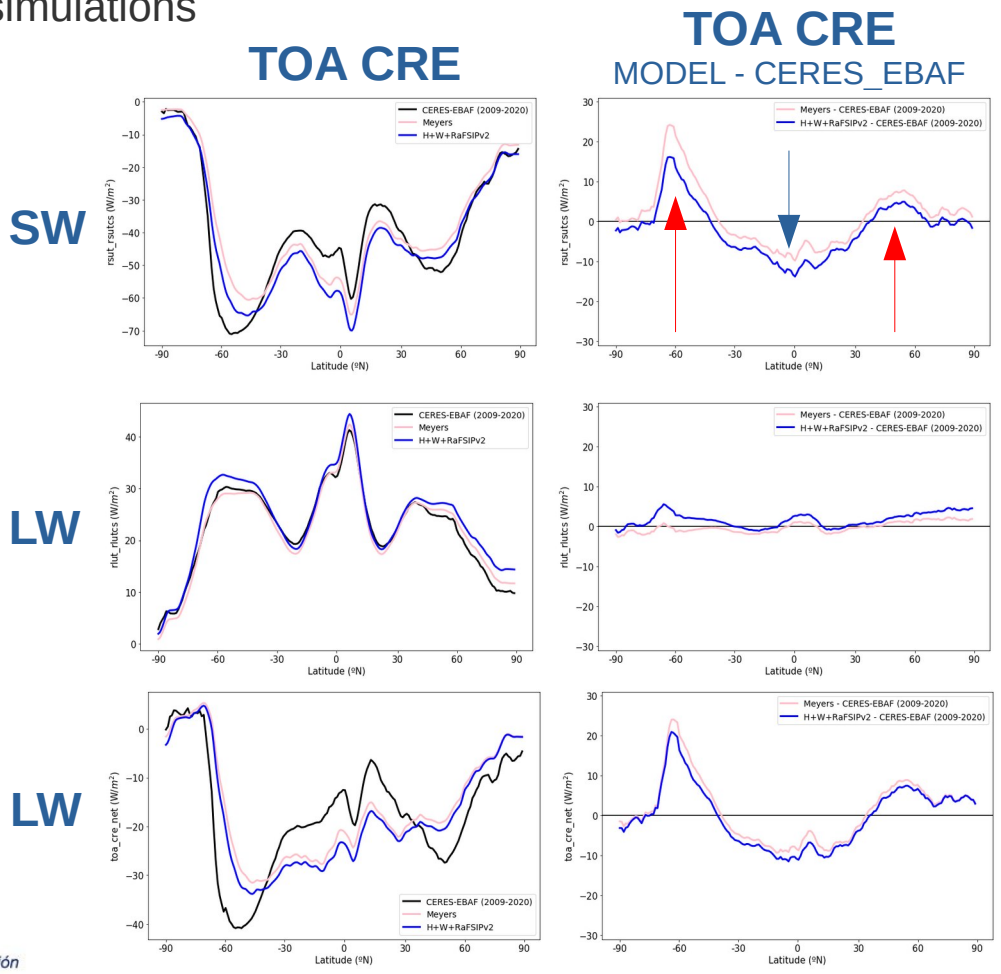




Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Model evaluation with satellite observations

12-year nudged simulations



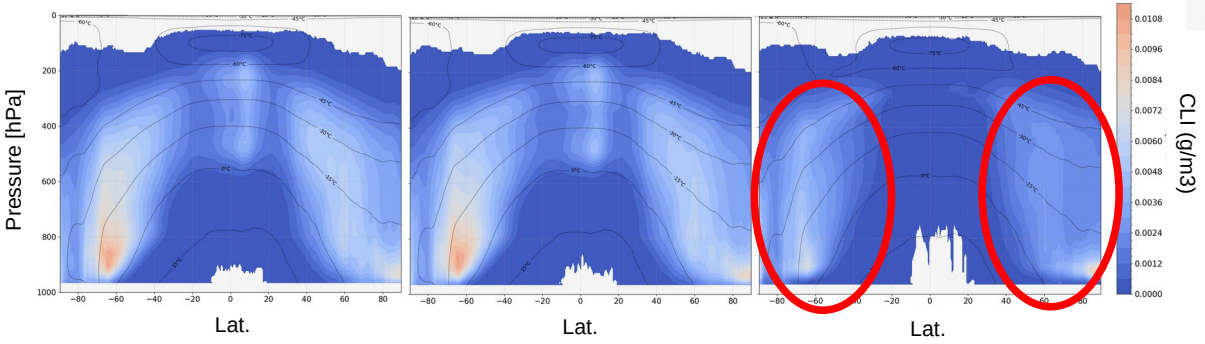
Refining the supersaturation adjustments

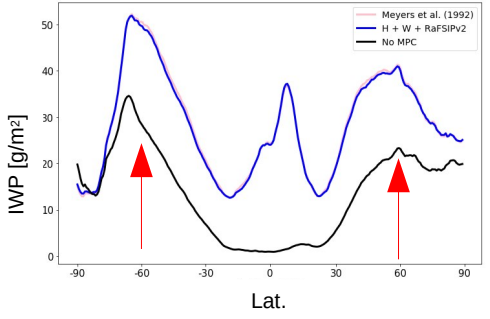
FOR-ICE experiments with ECE3-AerChem (IFS Cy36r4)

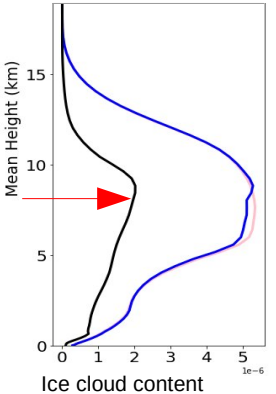
Zonal cross sections of ice cloud content [g/m^3] (1-year nudged sim.):

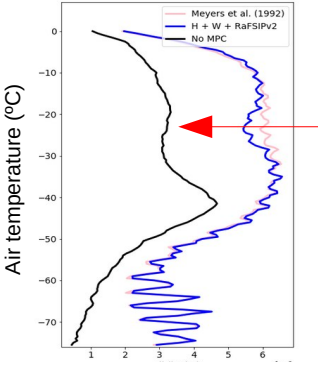
Meyers H+W+RaFSIPv2 No MPC

No PIN, no SIP, no ice SED, no TRA (includes ice-detrainment and all ice tendencies =0, including those for the vertical diffusion)





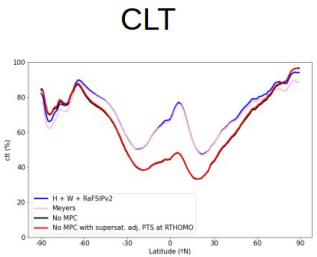


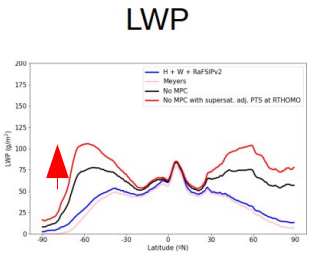


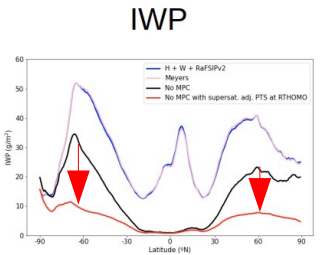
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

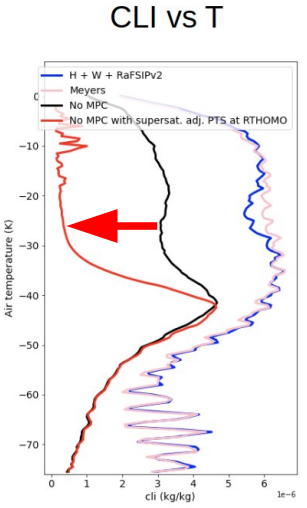
Refining the supersaturation adjustments

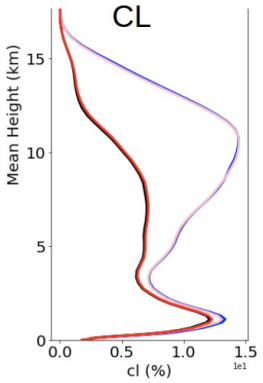
1-year nudged simulations

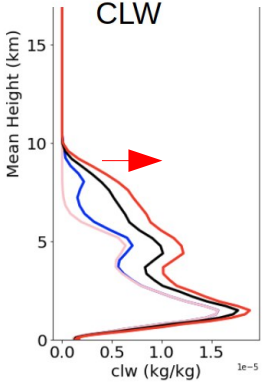


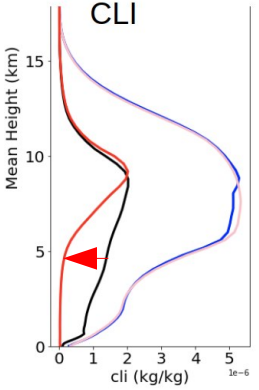




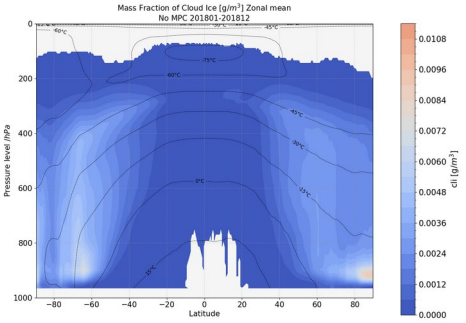




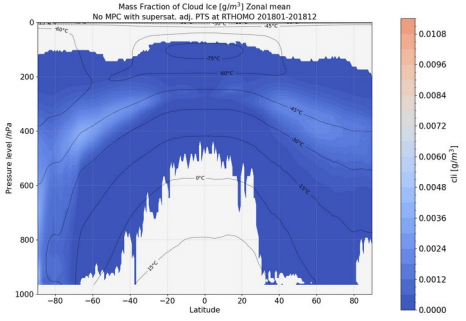




NoMPC



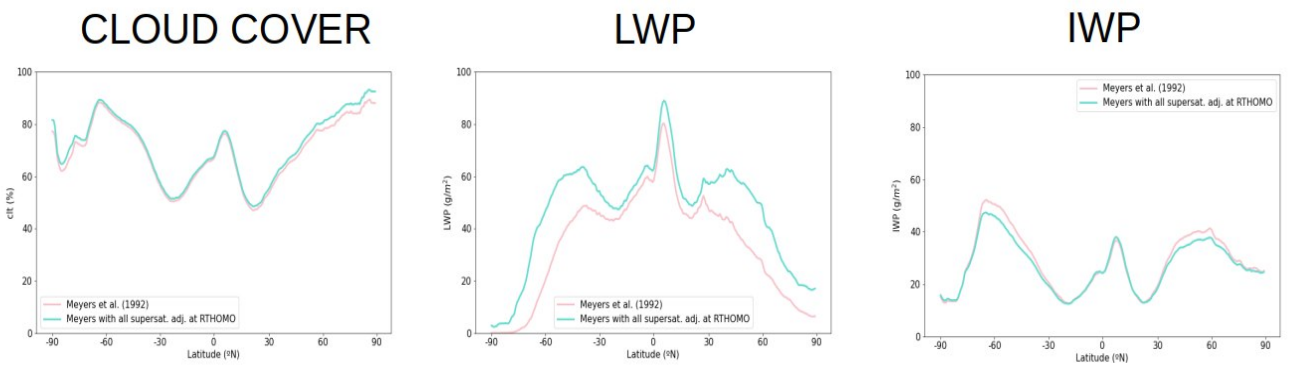
NoMPC + supersat. adjustment PTS RTHOMO



https://dev.ec-earth.org/issues/1352

Refining the supersaturation adjustments

1-year nudged simulations



The change improves LWP and IWP in the mid to high latitudes relative to observations, but it further overestimates LWP in the low latitudes, and the underestimation of LWP at high latitudes remains substantial.

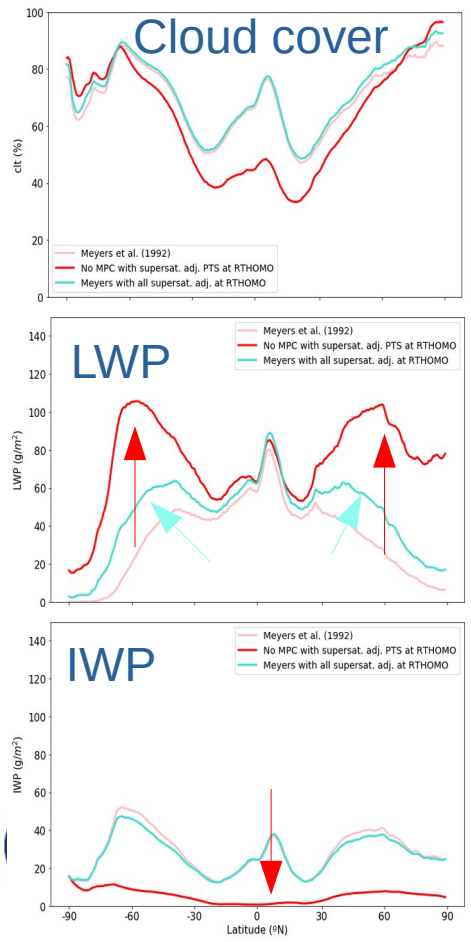
Model version	TOA net SW	TOA net LW
CMIP6 (Meyers)	241	-240
Meyers with all saturation adjustments at RTHOMO (-38ºC)	236	-238

In later IFS cycles (**CY37r3**), ECMWF corrected this issue, significantly increasing supercooled liquid water at cloud tops and improving SW radiation biases. In **CY47r3** and **OIFS-48r1**, cloud saturation adjustment was further improved, with the *PSUPSAT* term removed and the process moved to the *CLOUD_SATADJ* subroutine, incorporating *RTHOMO* (-38 ºC).

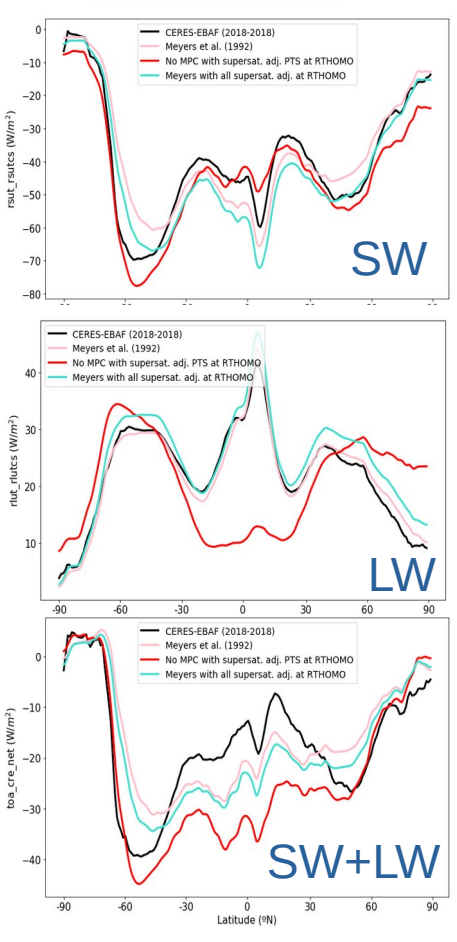
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Refining the supersaturation adjustments

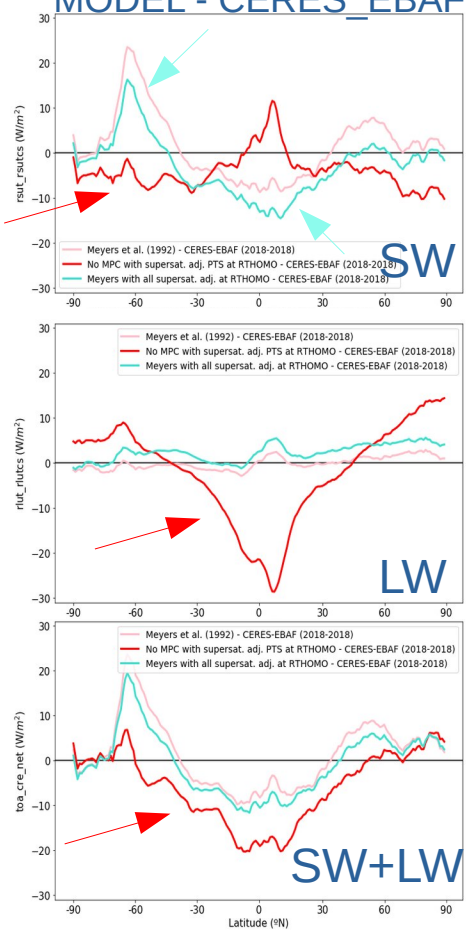
1-year nudged simulations



TOA CRE



TOA CRE
MODEL - CERES_EBAF



Supersat. adjustment test: The increase in LWP at the expense of IWP brings the CRE at TOA closer to CERES observations in mid to high latitudes, as more SW is reflected. However, the comparison to observations worsens at low latitudes (the effect on the LW is small in comparison).

“No MPC” sensitivity test: Suppressing MPC ice and increasing LWP lead to an overall cooling effect in the net TOA CRE, with more SW reflected (except in the intertropical latitudes) and less LW trapped in the atmosphere.

Conclusions and outlook

- Should we incorporate the changes in the supersaturation adjustments into our next simulations with EC-Earth3-AC, taking into account that the model is tuned for the CMIP6 version?
- COSP limitations:
  - Should we use COSP results or rely on IFS variables? (E.g. Fiddes et al. (2022) opted not to use COSP variables, instead comparing the MODIS retrievals directly to model outputs)
  - Feedback, opions, experiences with COSP evaluation, or any recommendations?
  - Consider trying COSP v2?
- Compare results with other satellite observations (e.g. CloudSat, CALIPSO, ISCCP).
- Conduct intercomparisons with the current state of the art and evaluate alongside other models (e.g., FOR-ICE).
- Transition to ECE4

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

CERTAINTY
CLOUD–AEROSOL INTERACTIONS & THEIR IMPACTS IN THE EARTH SYSTEM

montserrat.costa@bsc.es

Royal Netherlands Meteorological Institute
Ministry of Infrastructure and Water Management

Special acknowledgements:
Atmospheric Composition
EC-Earth3 Working Group

This project has received funding from Horizon Europe programme under Grant Agreement No 101137680 via project CERTAINTY (Cloud-aERosol inTeractions & their impActs IN The earth sYstem), G.A. No. 773051 (ERC-2017-COG, FRAGMENT project), and from the AXA Research Fund.