

HARMONIE-AROME Physics



Emily Gleeson with input from Bjørg Jenny Kokkvoll Engdahl, Marvin Kahnert, Geert Lenderink, , Daniel Martín, Erik van Meijgaard, Charlotte Raven, Wim de Rooy, Eirik Samuelsen, Natalie Theeuwes, Bert van Ulft, Hylke de Vries.

ACC RD

A Consortium for CONvection-scale modelling
Research and Development



HIRLAM countries – HARMONIE-AROME

Model Evaluation

- Gathering case studies
- Observations
- CloudNet data
- Measurement Campaigns
- Tools: DDH, MUSC EMS, scripts

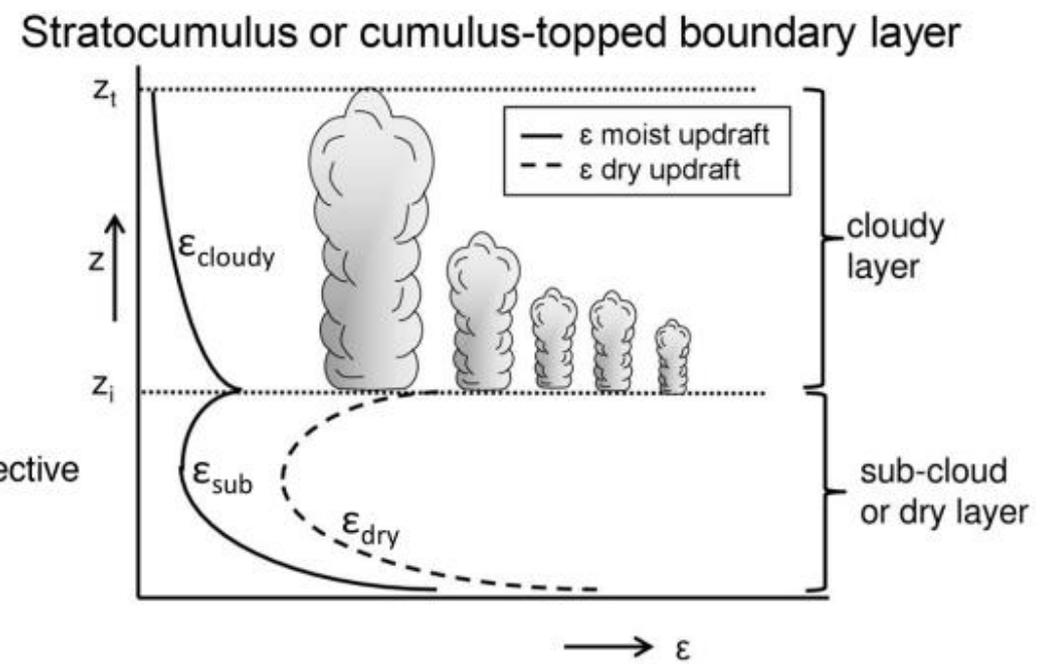
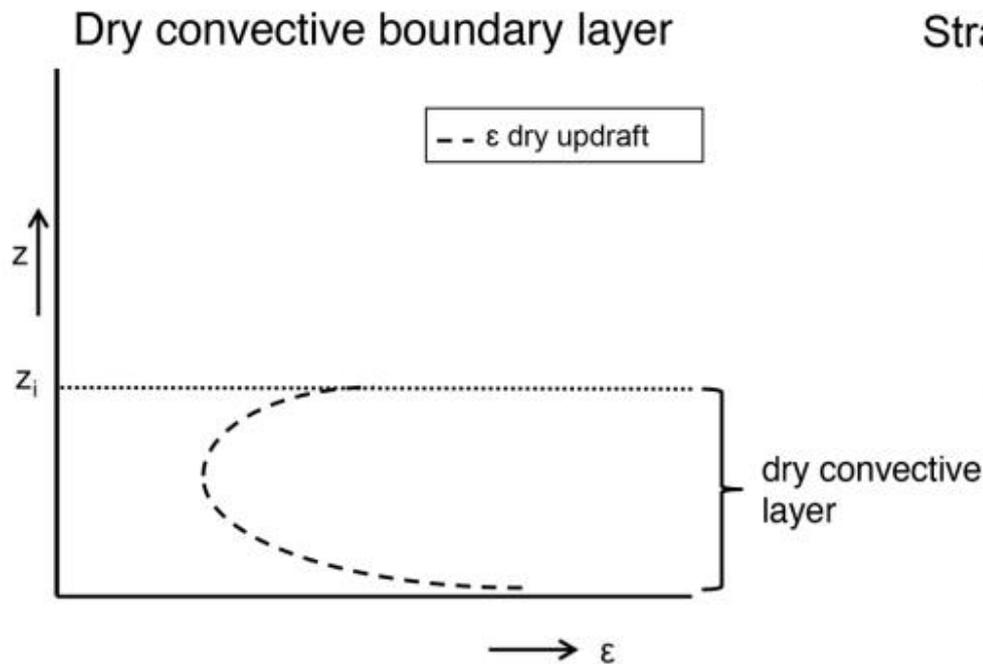
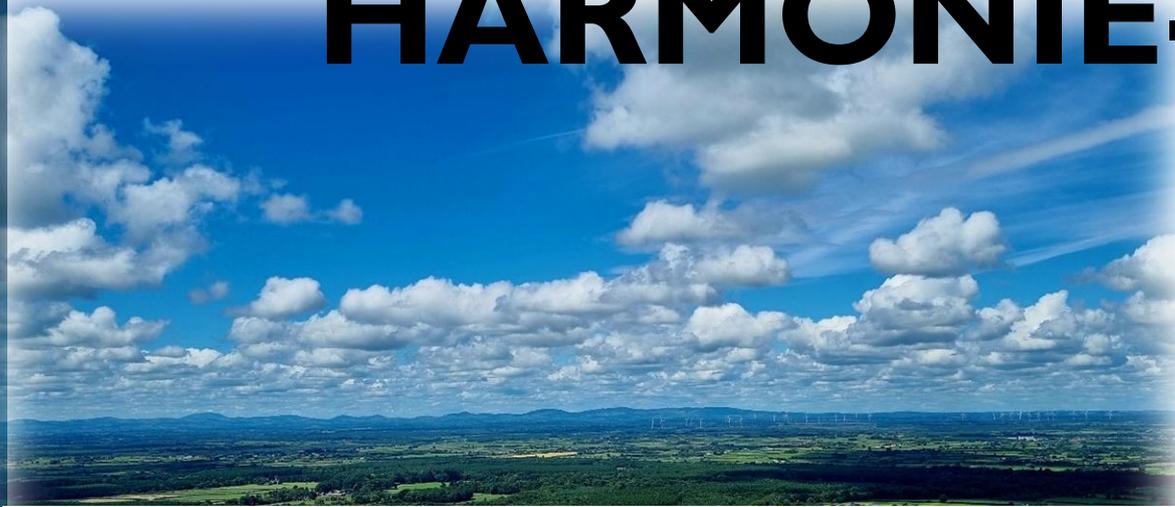


Overview

- Shallow Convection
- Experiments with CAMS NRT aerosols
- ICE-T
- Sandbox Tool



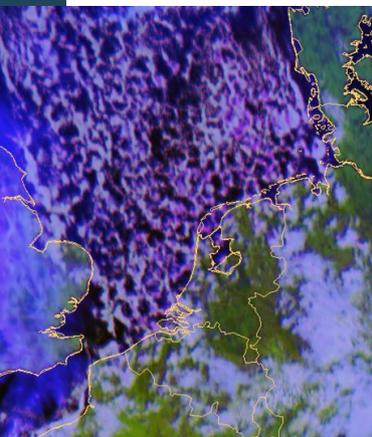
Shallow Convection in HARMONIE-AROME



Shallow Convection

- No shallow convection (no MF)
- Scale-aware shallow convection (SA)
 - built on ideas of Rachel Honnert, based on PBL height
- Scale-aware but using a threshold on w (the resolved vertical velocity) (SAW)
 - w is linked to the model trying to build up convection
 - Use a threshold value for when to shutdown the parametrized shallow convection if the model is building up convection itself (dry+moist, moist)

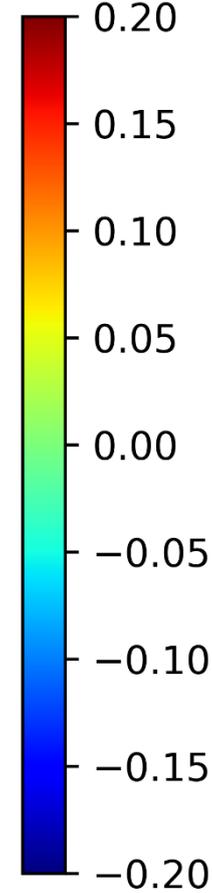
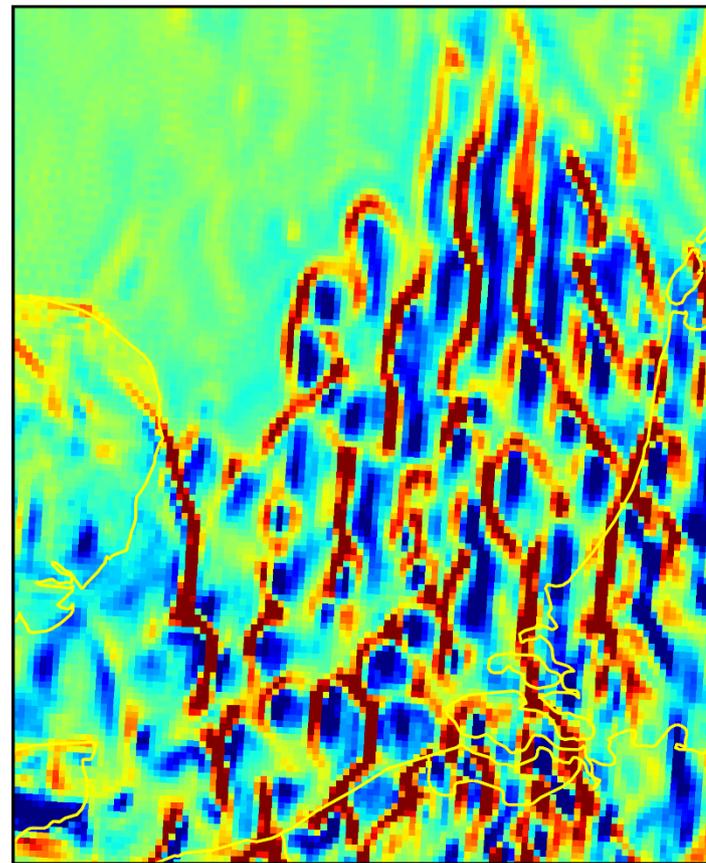
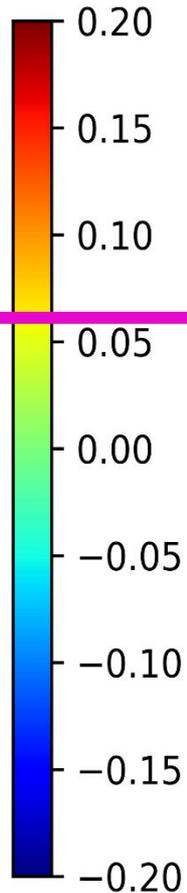
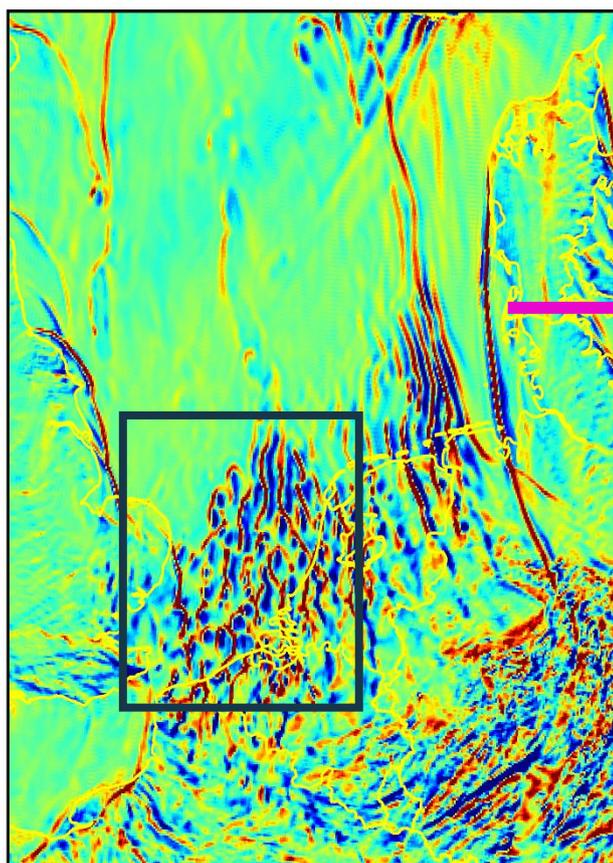
Open Cell Convection Case



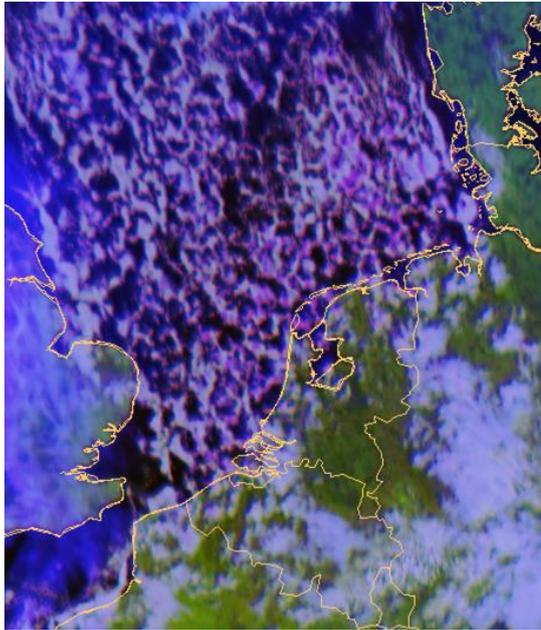
- Vertical (resolved) velocity at 750m height.
- PBL height (h) is small compared to the grid spacing but there are signs of resolved convection - h is not always suitable for determining when to shut down convection.

-HRES_OUT_EZDIAG05_level=048_2017102912_forecast+0021

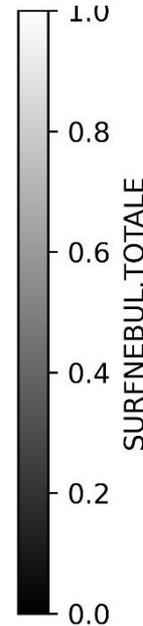
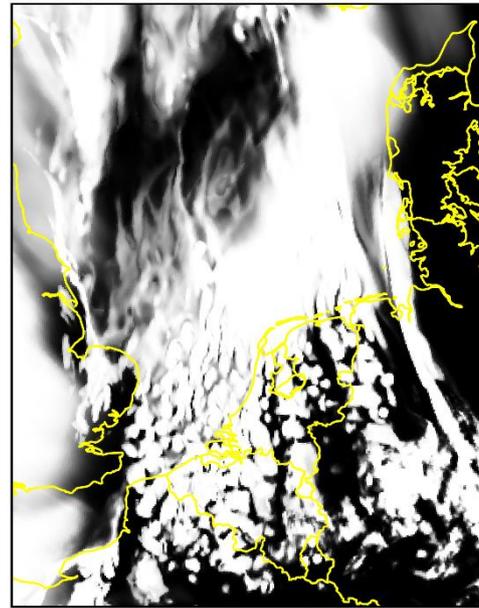
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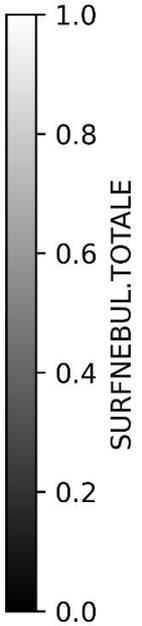
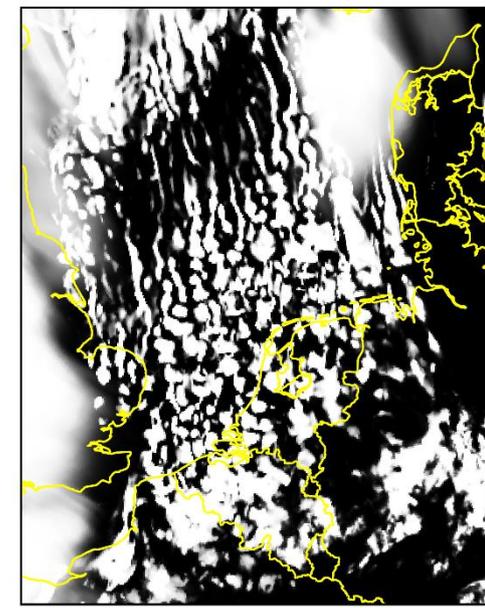
Satellite Cloud



CY46 REF 2.5 km

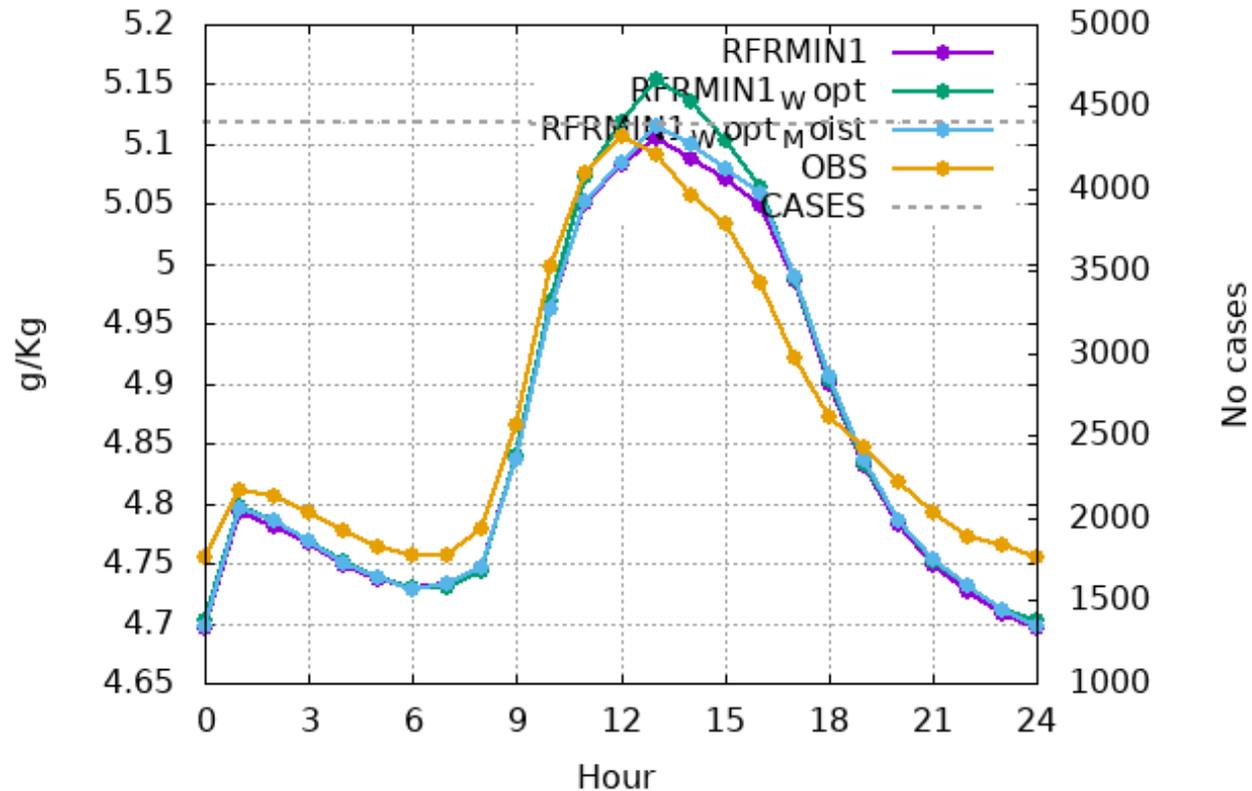


CY46 W-THRESH 2.5 km

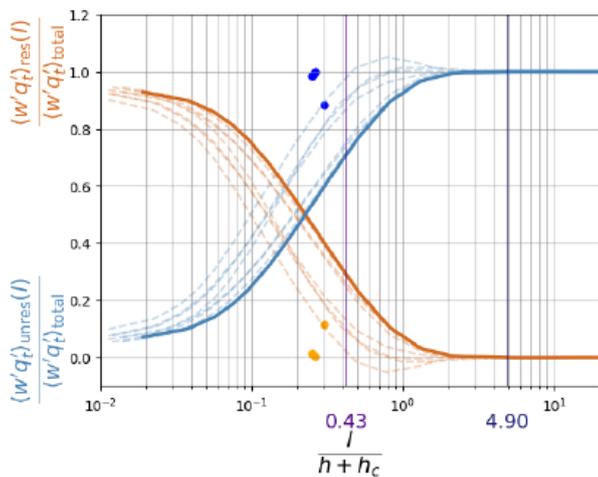


- Too little organisation in the cloud structures (REF) and an underestimation of precipitation.
- Model starts to resolve convection (indicated by resolved vertical velocity) but not enough → continuous leaking of instability by convection scheme.
- Khain et al., 2021 introduced the shutting down of the convection parameterization if $w > w_{\text{threshold}}$.
- Implementation: In every grid cell shut down convection where $|w| > w_{\text{threshold}} = f(\text{grid size})$.
- Clearly more organisation with w-threshold. Also more precipitation, in better agreement with radar

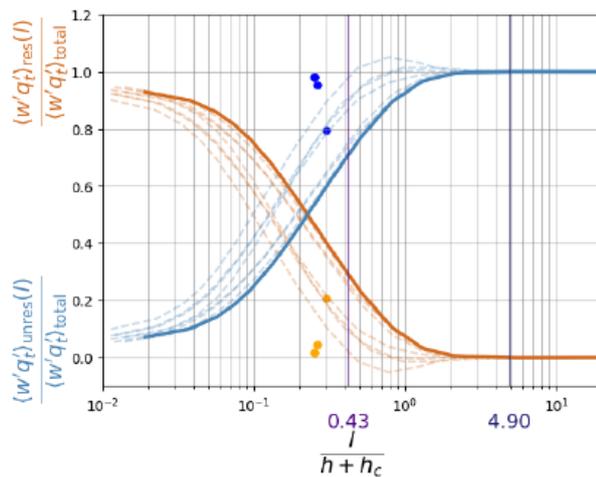
Selection: ALL using 148 stations
 Q2m Period: 20200203-20200217
 Used 00,12 + 01 02 ... 24



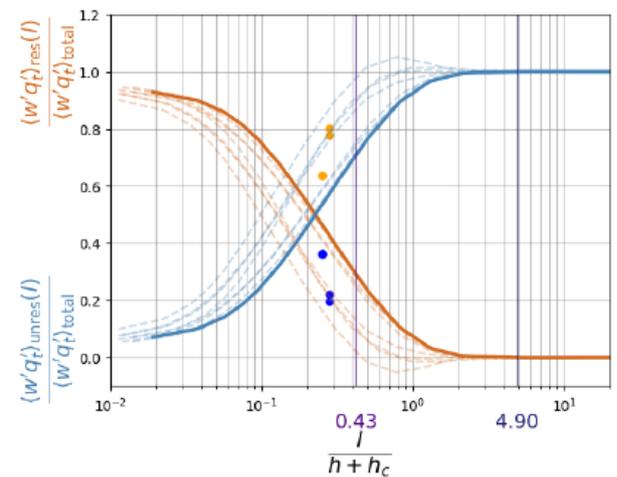
- [Wthreshold_Moist](#), [Wthreshold](#) (both run with Honnert SA also on)
- W-threshold option - underestimation of non-local mixing in dry PBL leading to too much building up of moisture.
- Only shutting down moist convection when wthreshold is met is much better, i.e. [wopt_moist](#).
- Only shutting down the larger sized moist convection, while maintaining dry the convection.



(i) HARMONIE run of the Cabauw case, at 500m resolution, with the original EDMF-scheme.



(ii) HARMONIE run of the Cabauw case, at 500m resolution, with the scale-adaptive MF-scheme.



(iii) HARMONIE run of the Cabauw case, at 500m resolution, with the scale-adaptive MF-scheme, and the w_{max} threshold.

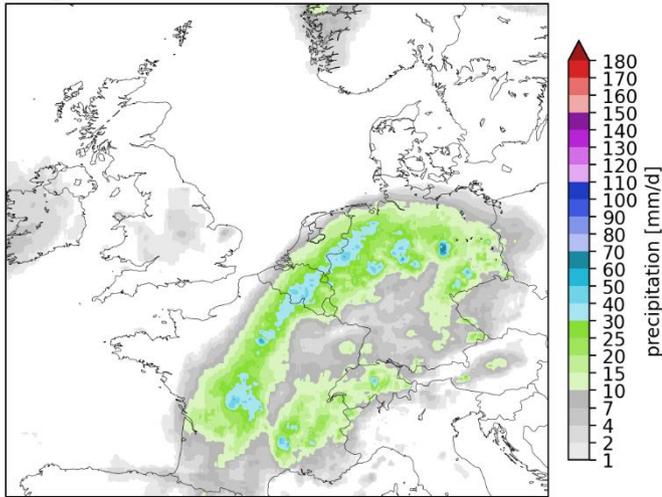
Figure 5.24: The hourly partitions of the resolved (orange markers) and unresolved (blue markers), for the locations in the mixed layer ($h + \frac{1}{4}h_c$, $h + \frac{1}{2}h_c$ and $h + \frac{3}{4}h_c$), plotted on the LES-based partitioning functions of the moisture flux in the cloud layer for the Cabauw case.

- Flux partitioning in LES (.curves) and Harmonie (dots, 500m) for different shallow convection options.
- The partitioning at $h + \frac{1}{4}h_c$ is shown (lower part of the cloud layer).
- This case was also run with LES and the partitioning between resolved and unresolved fluxes determined (orange/blue continuous lines).
- Tested if the partitioning is approximately correct in HARMONIE
- (Left) default (too much parametrized), (centre) scale aware (still too much parametrized) and (right) WTHRESHOLD (too much resolved).

Scale-Aware Shallow Conv

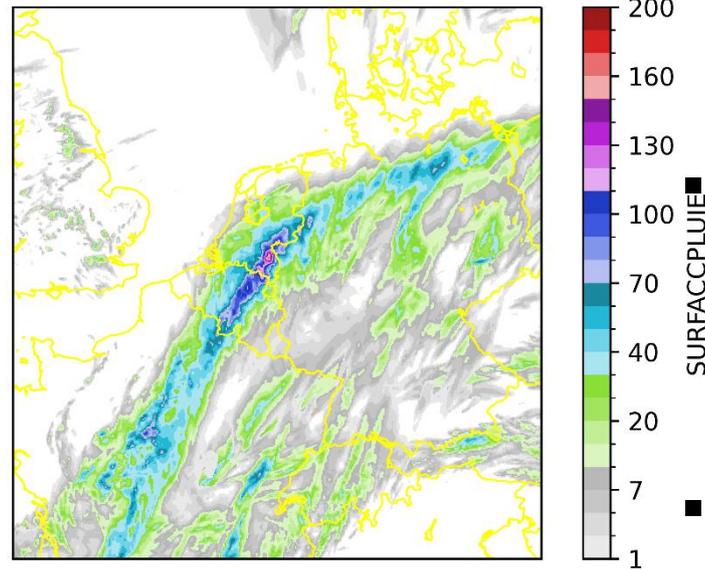
Observations

Case_Germany 20230622 MSWEP



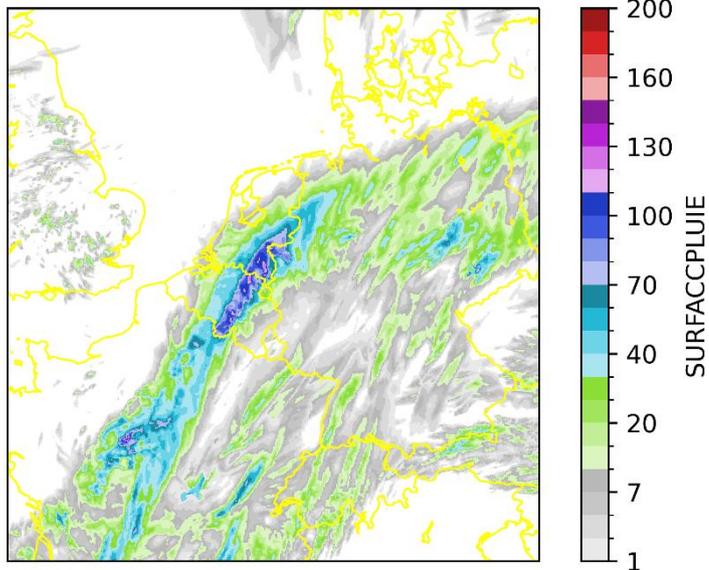
Control

REF_SURFACCPUIE_2023062100_acc_48-24UTC_+



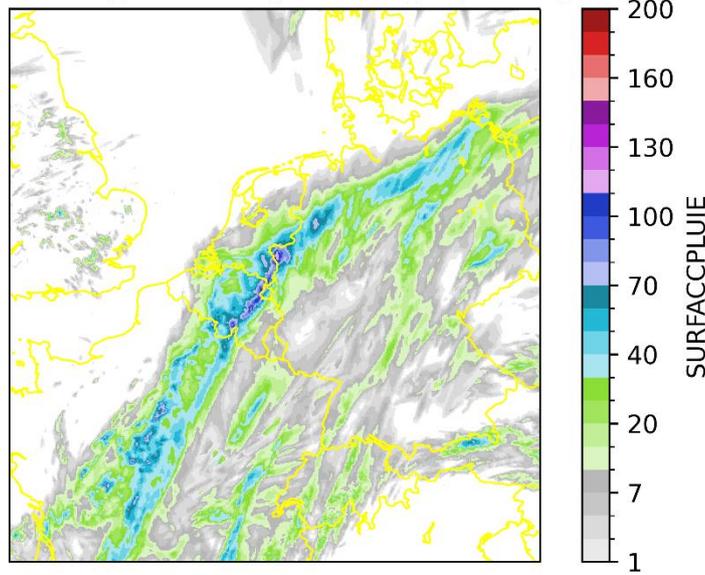
W Threshold

WTHRES_SURFACCPUIE_2023062100_acc_48-24UTC_+



W Threshold (moist)

WTHRESMOIST_SURFACCPUIE_2023062100_acc_48-24UTC_+



Run with HCLIM (HARMONIE-AROME climate model).

Less precip with the W Threshold options – closer to observations.

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- ICE-T
- Sandbox Tool



Article

Use of CAMS near Real-Time Aerosols in the HARMONIE-AROME NWP Model

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² Irish Meteorological Service (Met Éireann), 65/67 Glasnevin Hill, D09 Y921 Dublin, Ireland; emily.gleeson@met.ie

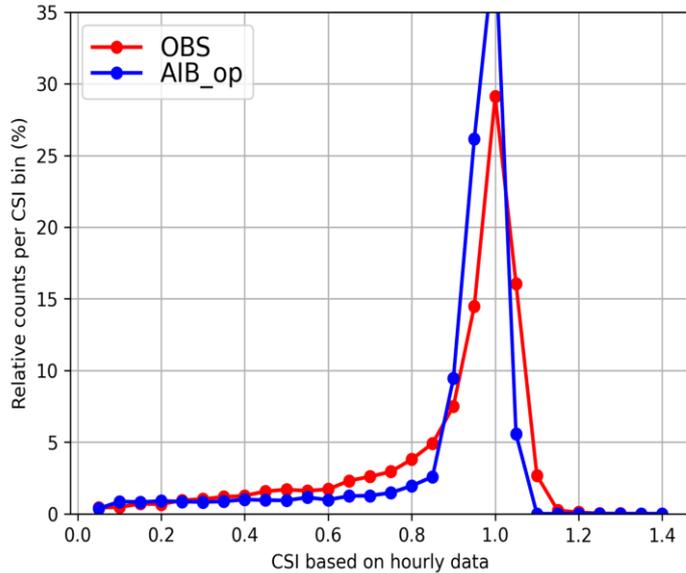
³ Finnish Meteorological Institute (FMI), P.O. Box 503, FI-00101 Helsinki, Finland; panu.maalampi@fmi.fi (P.M.); laura.rontu@fmi.fi (L.R.)

* Correspondence: dmartinp@aemet.es

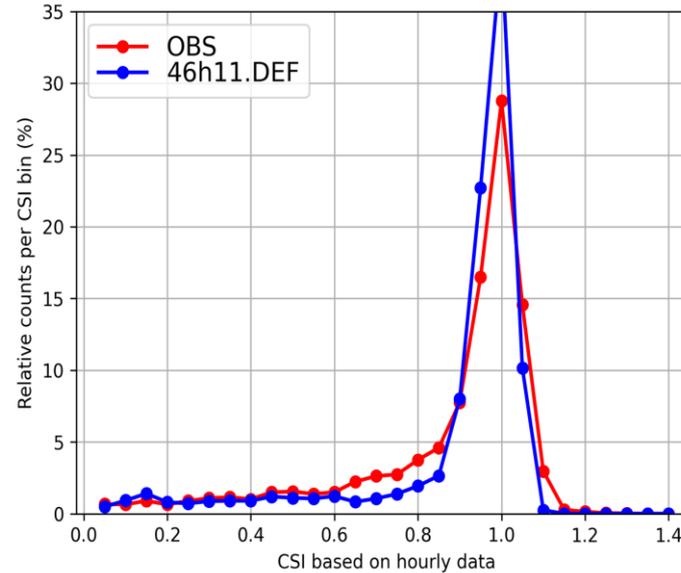
Abstract: Near real-time aerosol fields from the Copernicus Atmospheric Monitoring Services (CAMS), operated by the European Centre for Medium-Range Weather Forecasts (ECMWF), are configured for use in the HARMONIE-AROME Numerical Weather Prediction model. Aerosol mass mixing ratios from CAMS are introduced in the model through the first guess and lateral boundary conditions and are advected by the model dynamics. The cloud droplet number concentration is obtained from the aerosol fields and used by the microphysics and radiation schemes in the model. The results show an improvement in radiation, especially during desert dust events (differences of nearly 100 W/m^2 are obtained). There is also a change in precipitation patterns, with an increase in precipitation, mainly during heavy precipitation events. A reduction in spurious fog is also found. In addition, the use of the CAMS near real-time aerosols results in an improvement in global shortwave radiation forecasts when the clouds are thick due to an improved estimation of the cloud droplet number concentration.

CAMS NRT Aerosols

Operational CY43

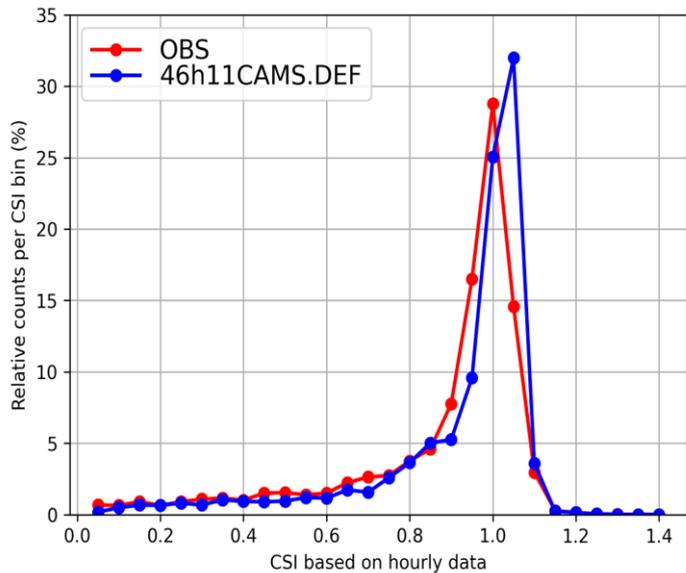


REF CY46

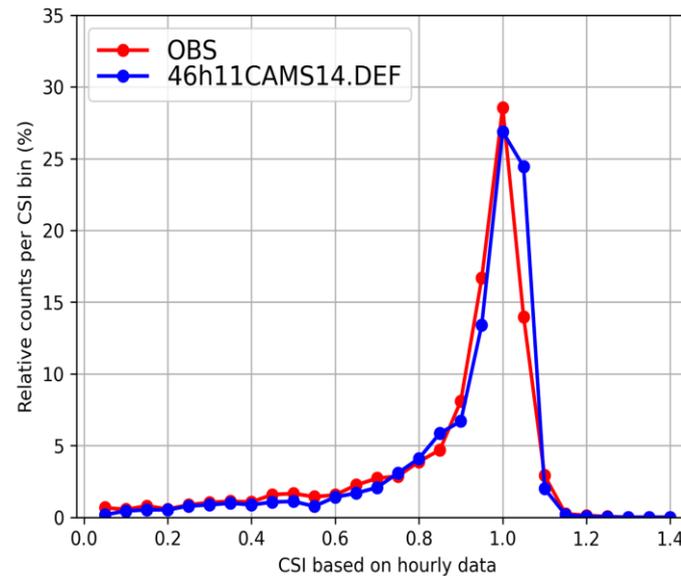


- Clear Sky Index
- SW/SWclear
- July 1-15th 2023
- AEMET stations
- Mostly no clouds

CY46 + CAMS NRT



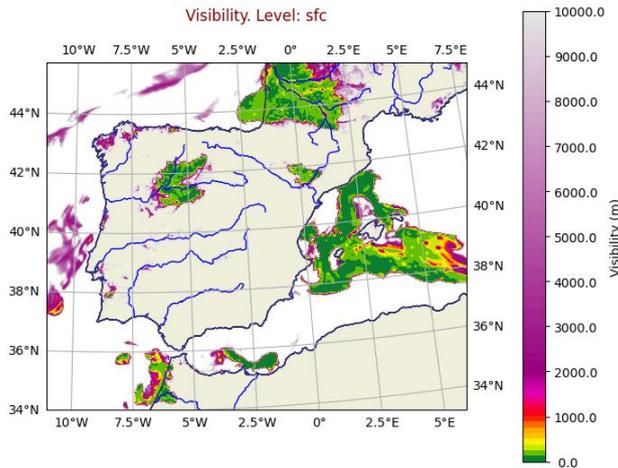
CY46+CAMS NRT + Nitrates/Ammonia



Fog Case - Spain

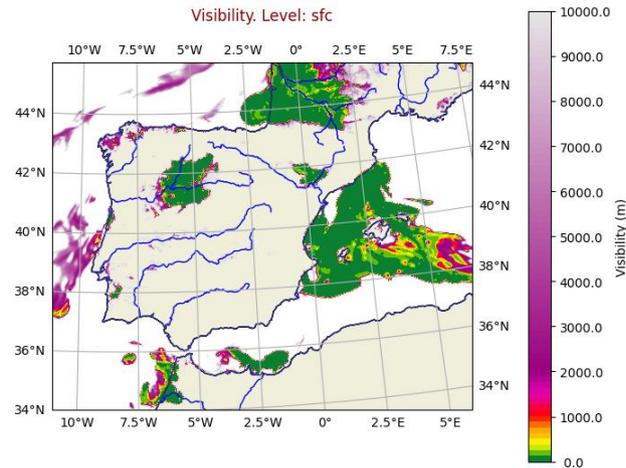
- Modification of the CDNC (Cloud Droplet Number Concentration)
- Experiments: (Warm Start)
 - **46h I I.DEF**: Reference (reduction in the CDNC in the lowest level)
 - **46h I I.SFC**: No reduction of CDNC in lowest level
 - **46h I I_cams.DEF**: CDNC based on CAMS aerosols

AIBC_46h11_ddh.DEF. 2024012600 + 009



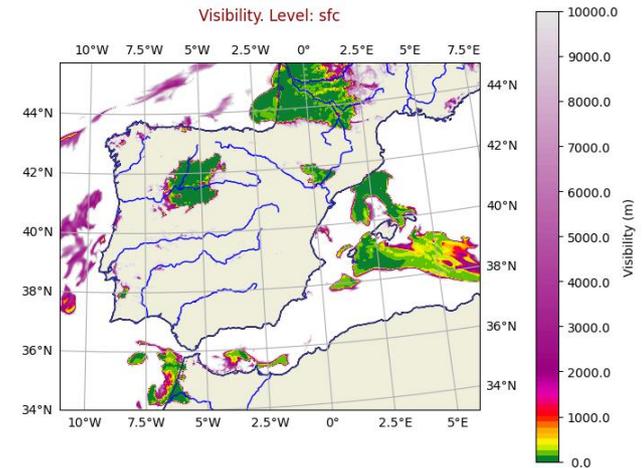
46h I I.DEF

AIBC_46h11_ddh.SFC. 2024012600 + 009



46h I I.SFC

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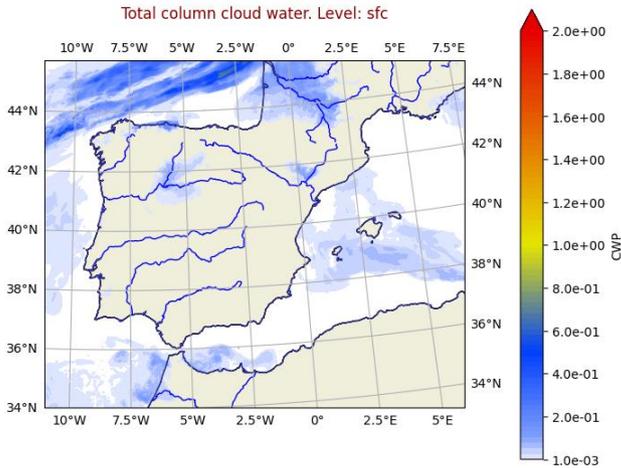


46h I I_cams.DEF

Fog Case - Spain

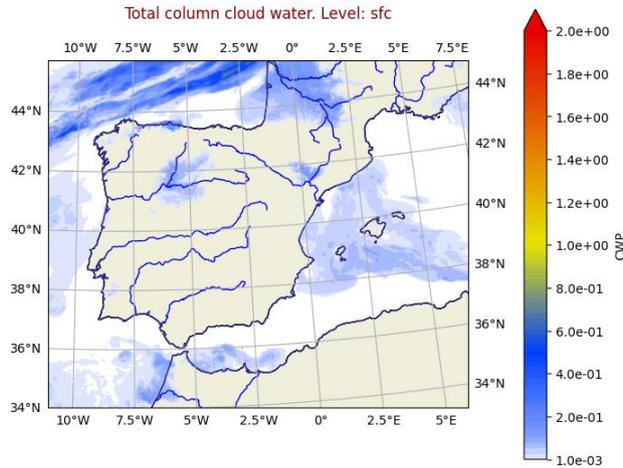
■ Liquid Water Content at 09H

AIBC_46h11_ddh.DEF. 2024012600 + 009



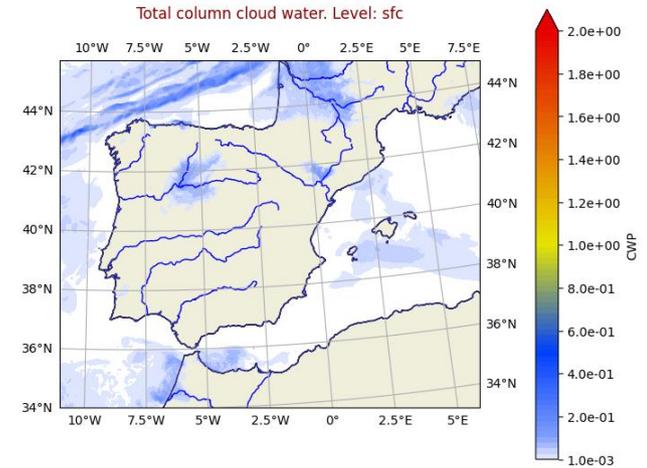
46h I I.DEF

AIBC_46h11_ddh.SFC. 2024012600 + 009



46h I I.SFC

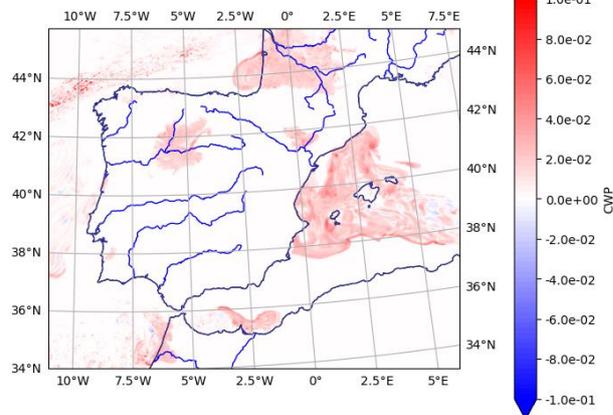
AIBC_46h11_cams_ddh.DEF. 2024012600 + 009



46h I I_cams.DEF

AIBC_46h11_ddh.SFC. 2024012600 + 009
AIBC_46h11_ddh.DEF. 2024012600 + 009

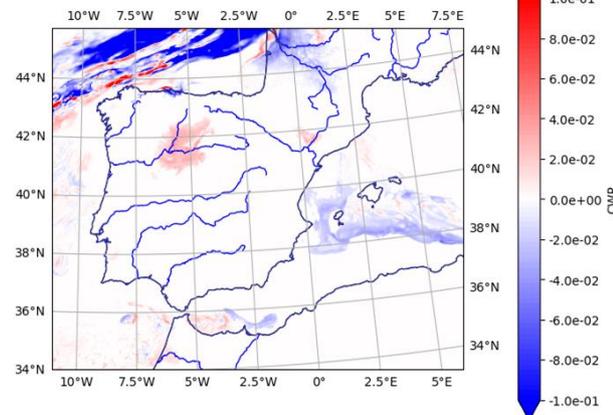
Total column cloud water. Level: sfc



46h I I.SFC
minus
46h I I.DEF

AIBC_46h11_cams_ddh.DEF. 2024012600 + 009
AIBC_46h11_ddh.DEF. 2024012600 + 009

Total column cloud water. Level: sfc

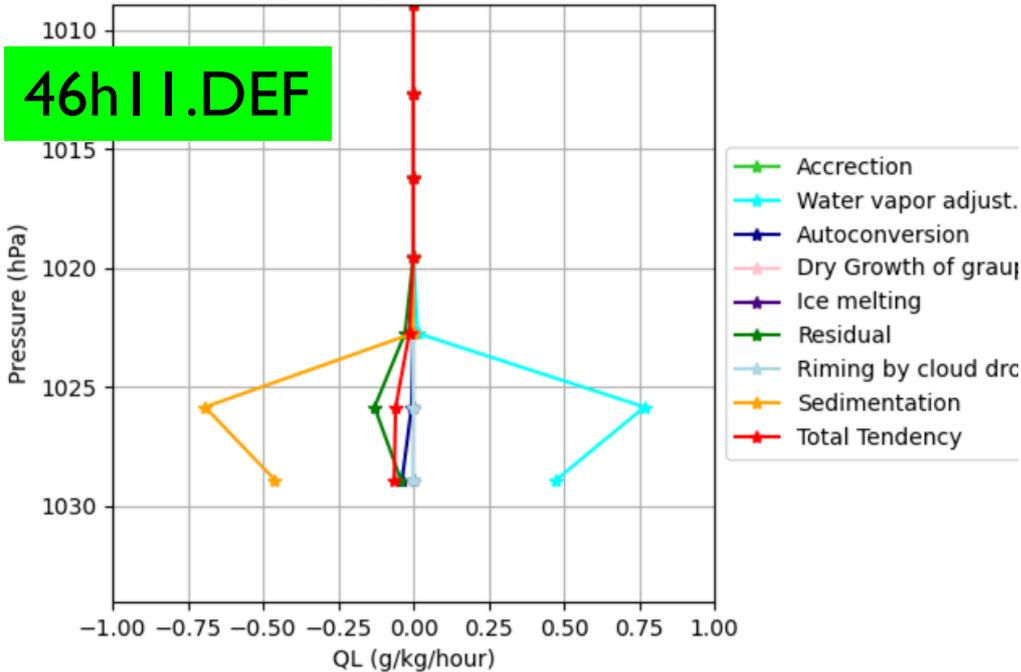


46h I I.SFC
minus
46h I I.DEF

Fog Case - Spain

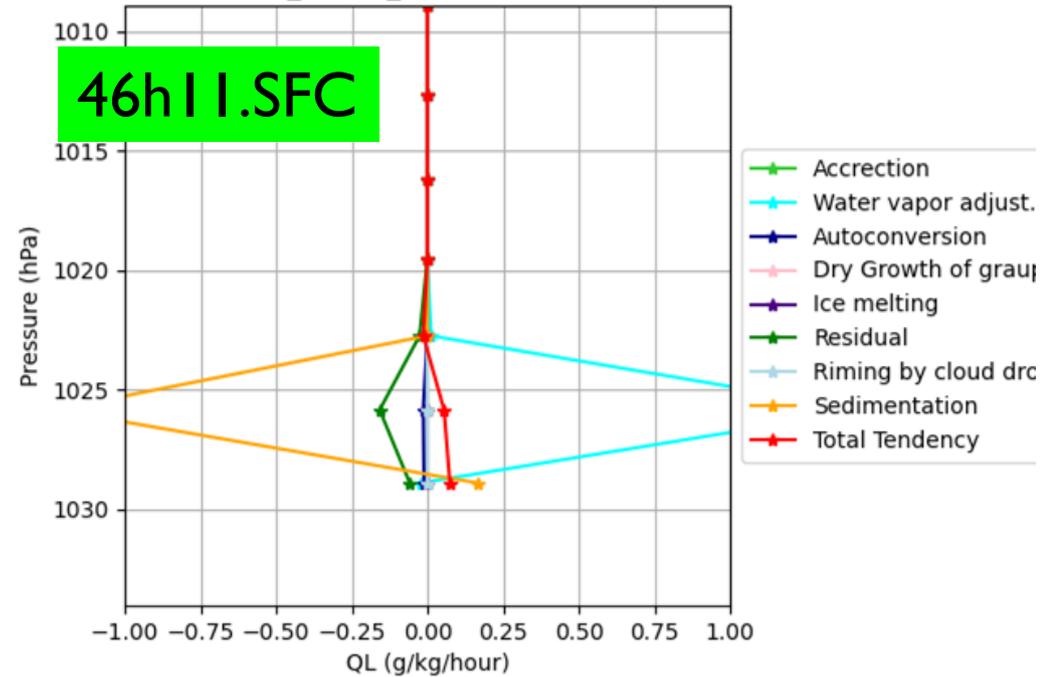
QL DOM03 AIBC_46h11_ddh.DEF 2024012600+0001

46h I I.DEF



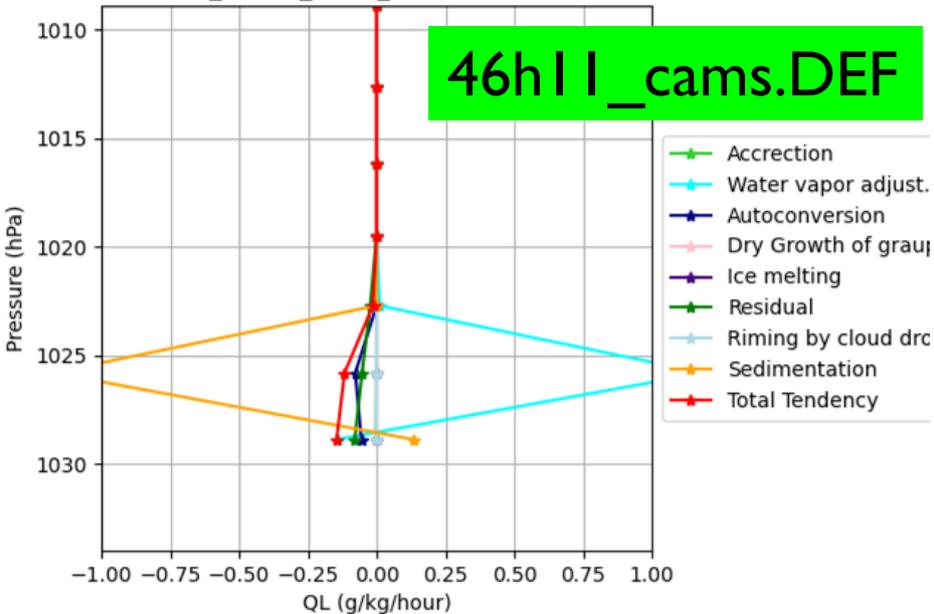
QL DOM03 AIBC_46h11_ddh.SFC 2024012600+0001

46h I I.SFC



QL DOM03 AIBC_46h11_cams_ddh.DEF 2024012600+0001

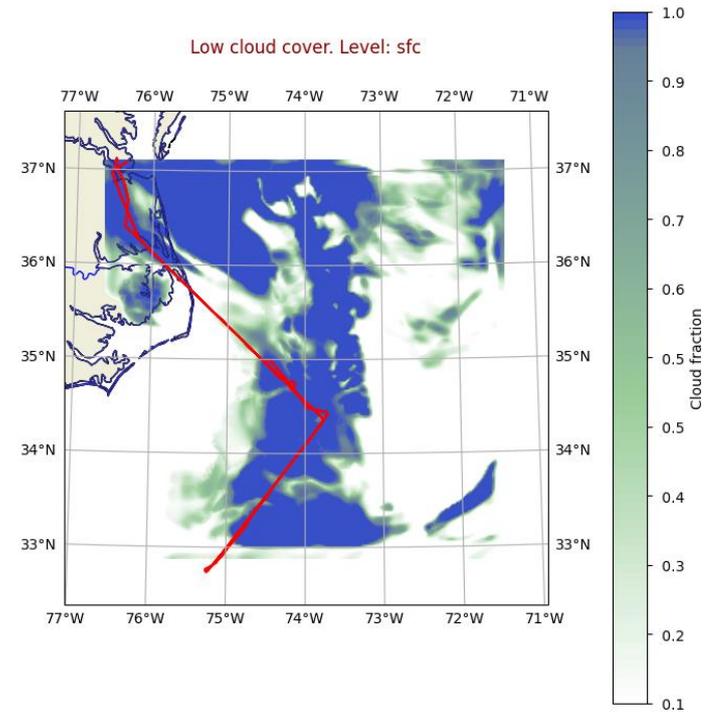
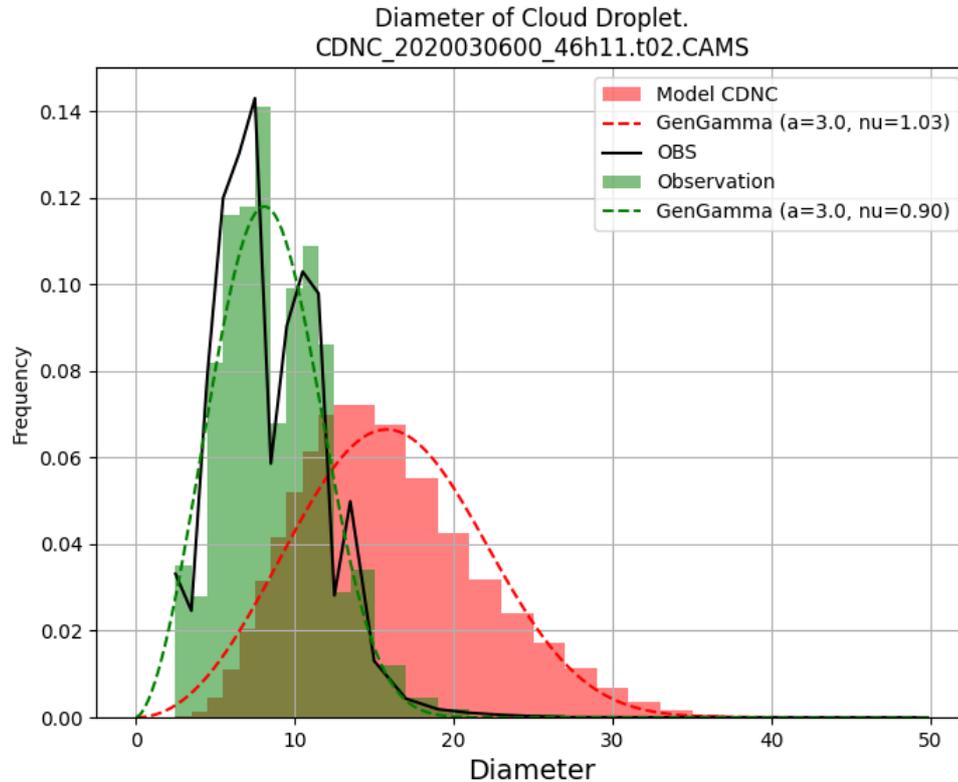
46h I I_cams.DEF



- QL – cloud water tendency
- Considering a point over the sea
- **Total tendency**
- **Sedimentation** and **condensation** patterns are different.
- The **autoconversion** (conversion of cloud water to rain) is important only for **46h11_cams.DEF**.

Cloud Droplet Size Distributions

46h11.t02.CAMS. 2020030600 + 018



- Cloud droplet size distribution. **red: model**, **green: observations**,
- With generalized gamma function fitting the data.
- Displacement of maximum but similar parameter ν for the distribution
- NASA Langley Aircraft and State Data (2020 ACTIVATE) field campaign
- PLATFORM: NASA HU-25 aircraft
- <https://asdc.larc.nasa.gov/soot/power-user/ACTIVATE/2022>



Overview

- Shallow Convection
- Experiments with CAMS NRT aerosols
- **ICE-T**
- Sandbox Tool



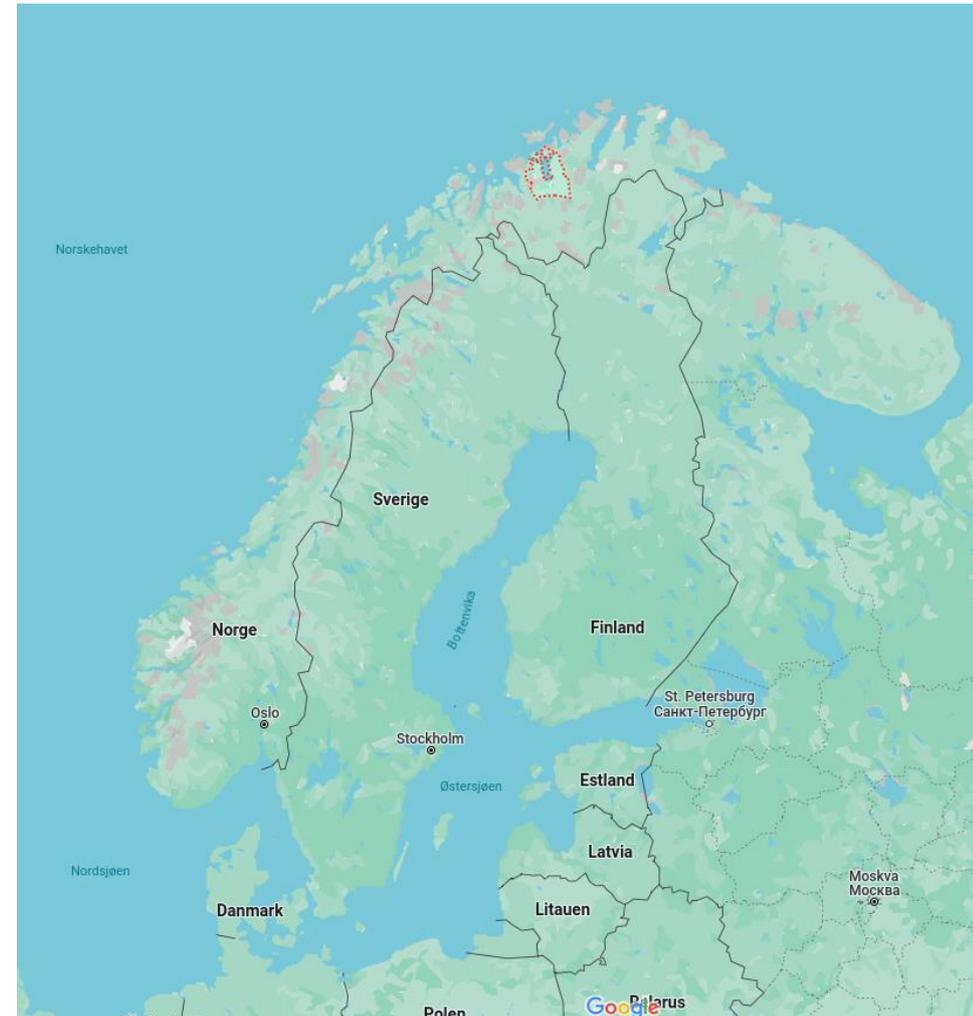
ICE-T

- ICE-T = ICE3 with elements from the Thompson Scheme (particularly concerning supercooled liquid)



Airbus Helicopter campaign in Alta

- April 18 - 19, 2023
- Testing new anti-icing equipment on H175 Airbus
- Cloud droplet probe to measure liquid water content (LWC) on the aircraft
- Encountered quite different icing conditions on the two days



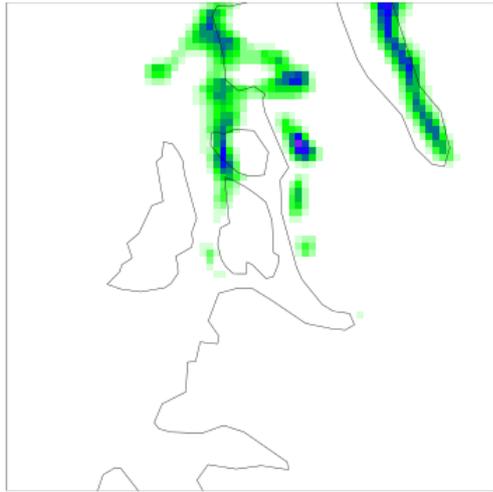
Airbus Helicopter campaign in Alta

- April 19th 2023
- Strong westerly winds, mountain waves, lenticular clouds
- Morning and afternoon flight encountered heavy icing
- LWC as high as 1.3 g/m^3

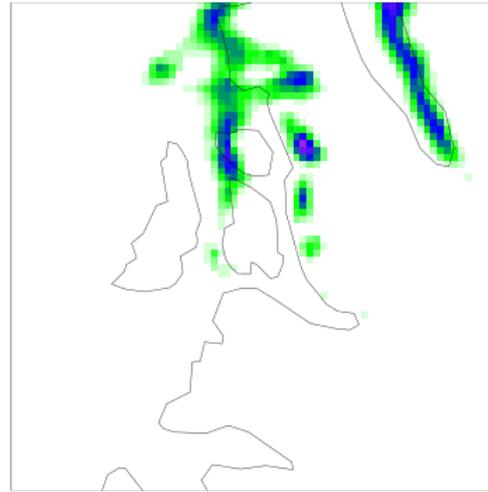


Airbus Helicopter campaign in Alta

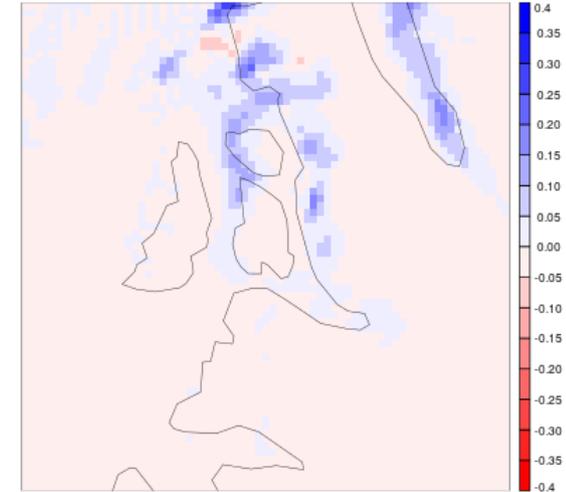
CLW in model level 41 (~830hPa) [g/m³], DEF
April 19 2023 1400UTC



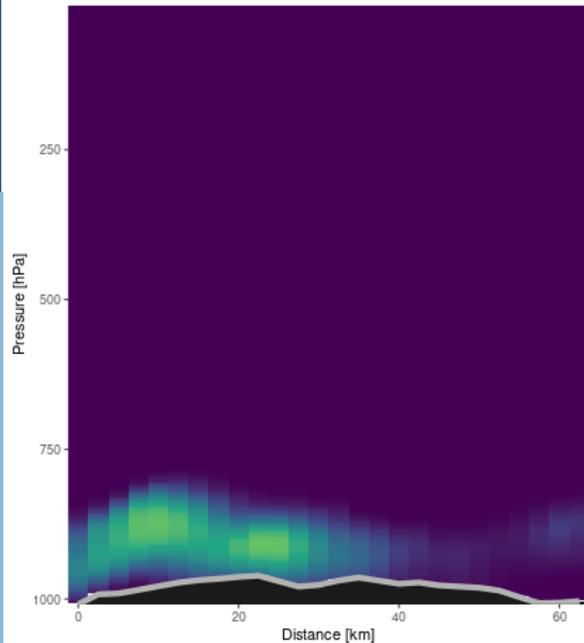
CLW in model level 41 (~830hPa) [g/m³], ICE-T
April 19 2023 1400UTC



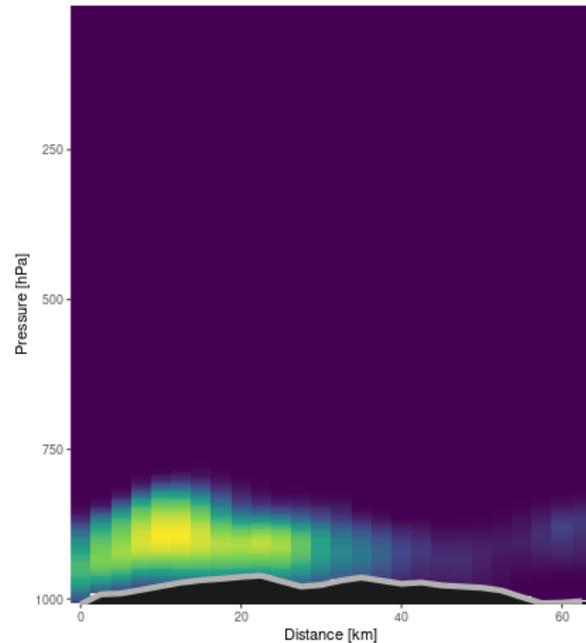
Diff CLW model level 41 (~830hPa) [g/m³], ICE-T-DEF
April 19 UTC 2023



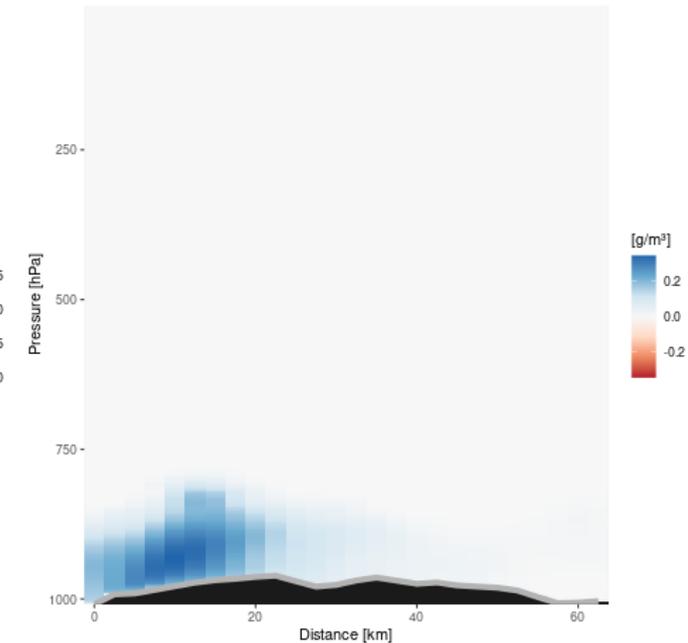
LWC DEF April 19 2023 1400UTC



LWC ICE-T April 19 2023 1400UTC

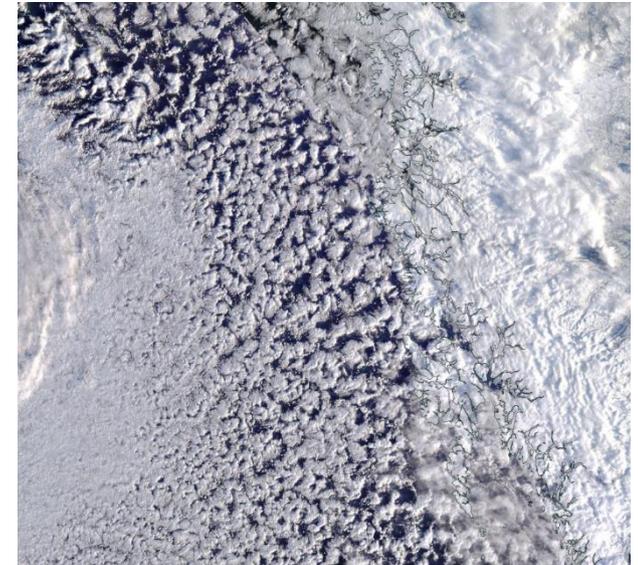


Diff. (ICE-T - DEF) in LWC April 19 2023 1400UTC

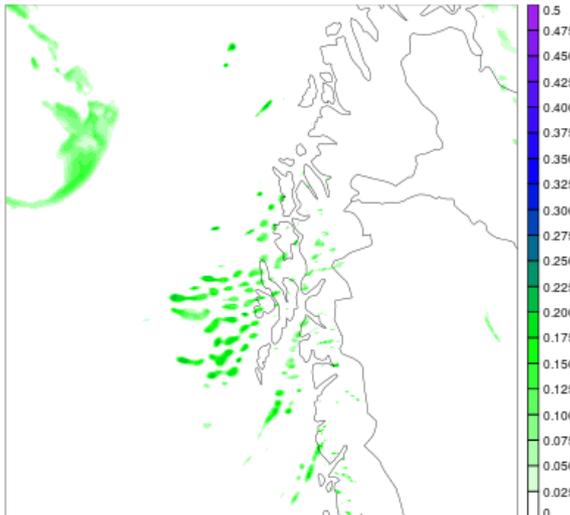


MC2-ICEPACKS Campaign

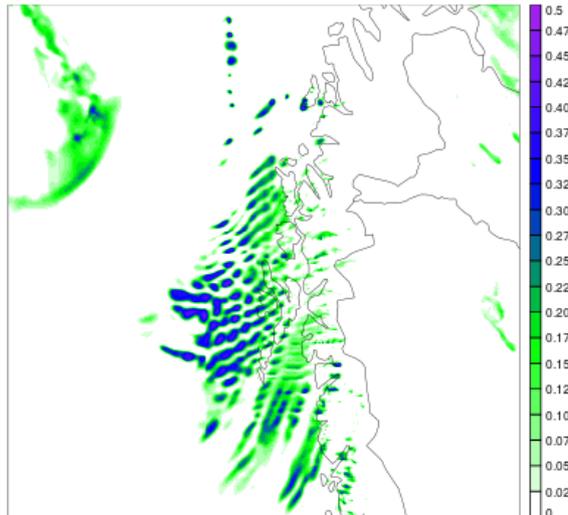
- Launched from Andøya, Norway
- Lead by the University of Oslo
- Feb-march 2023
- Target: Cold air outbreaks



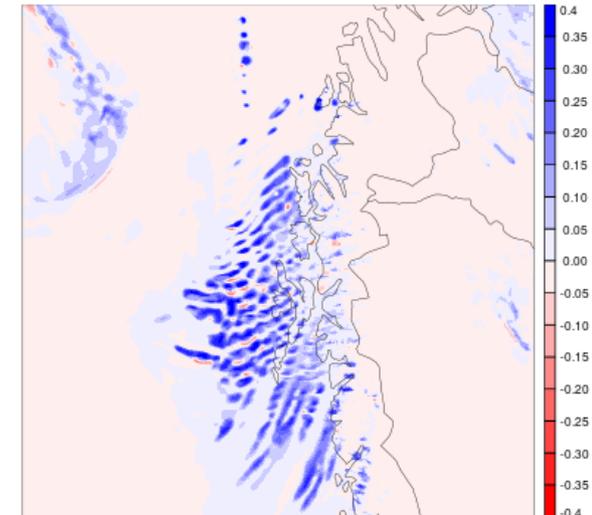
Cloud water in model level 35 (~730hPa) [g/m³], DEF
Feb 24 2023 1500UTC



Cloud water in model level 35 (~730hPa) [g/m³], ICE-T
Feb 24 2023 1500UTC



Diff CLW model level 35 (~730hPa) [g/m³], ICE-T-DEF
Feb 24 1500UTC 2023



Overview

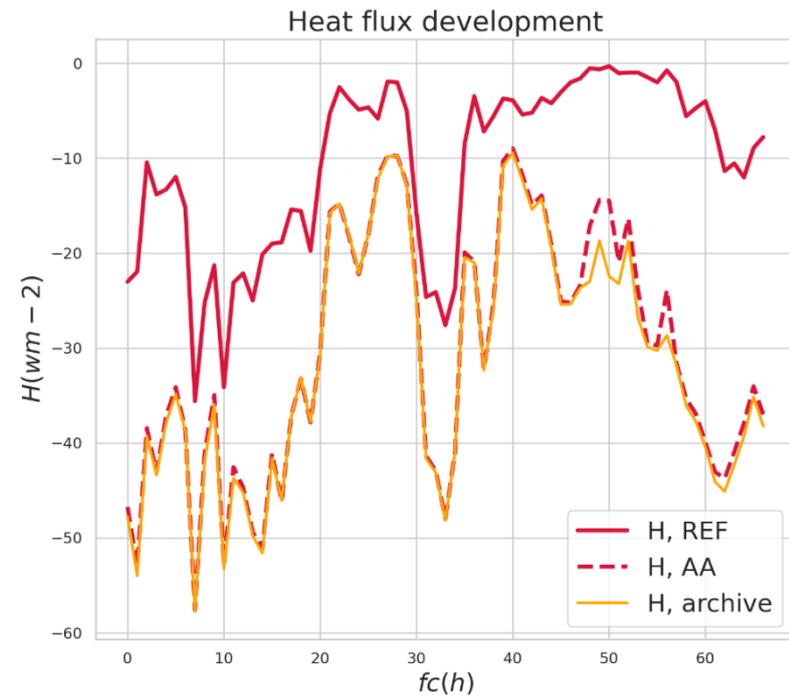
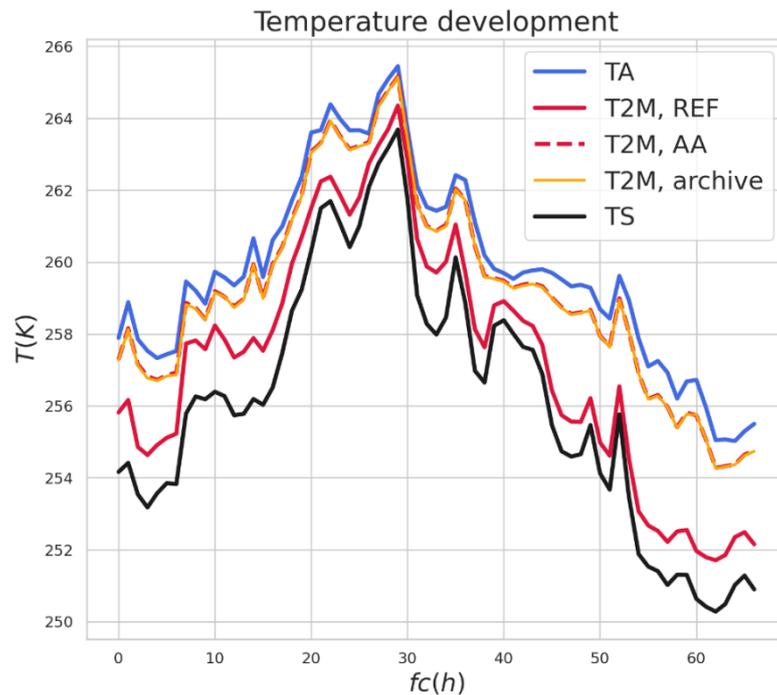
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Sandbox Tool

- Python-based emulator of the calculation of T2m, Q2m, RH2m, and H as is done in our model (CY43/CY46)
- https://github.com/MetNoMarvinK/T2M_HARMONIE_AROME_sandbox.git



Radiation WW in 2014!

