HARMONIE-AROME Physics

Emily Gleeson on behalf of the HIRLAM Physics Team

ACCORD

A Consortium for COnvection-scale modelling Research and Development

HIRLAM countries – HARMONIE-AROME

High Resolution Hirlam Limited Area Model

Overview

- Shallow convection testing
- ecRad optimization
- Impact of CDNC on snow
- Near real-time aerosols
- Other physics updates




Shallow Convection

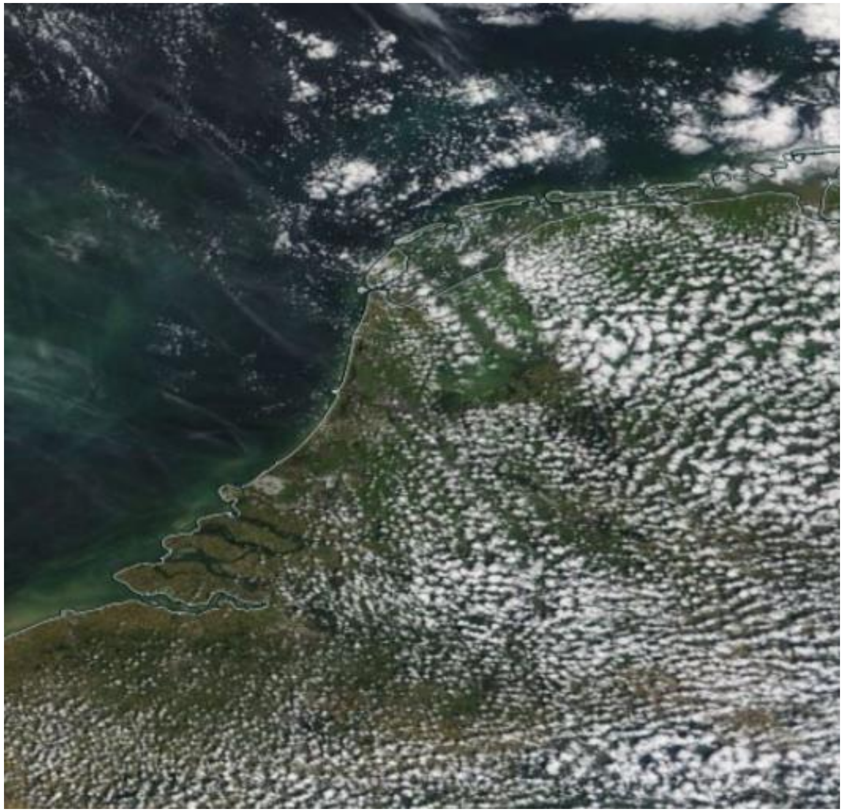
- No shallow convection (no MF)
- Scale-aware shallow convection (SA)
  - built on ideas of Rachel Honnert
- Scale-aware but using a threshold on w (the resolved vertical velocity) (SAW)
  - w is linked to the model trying to build up convection
  - Use a threshold value for when to shutdown the parametrized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

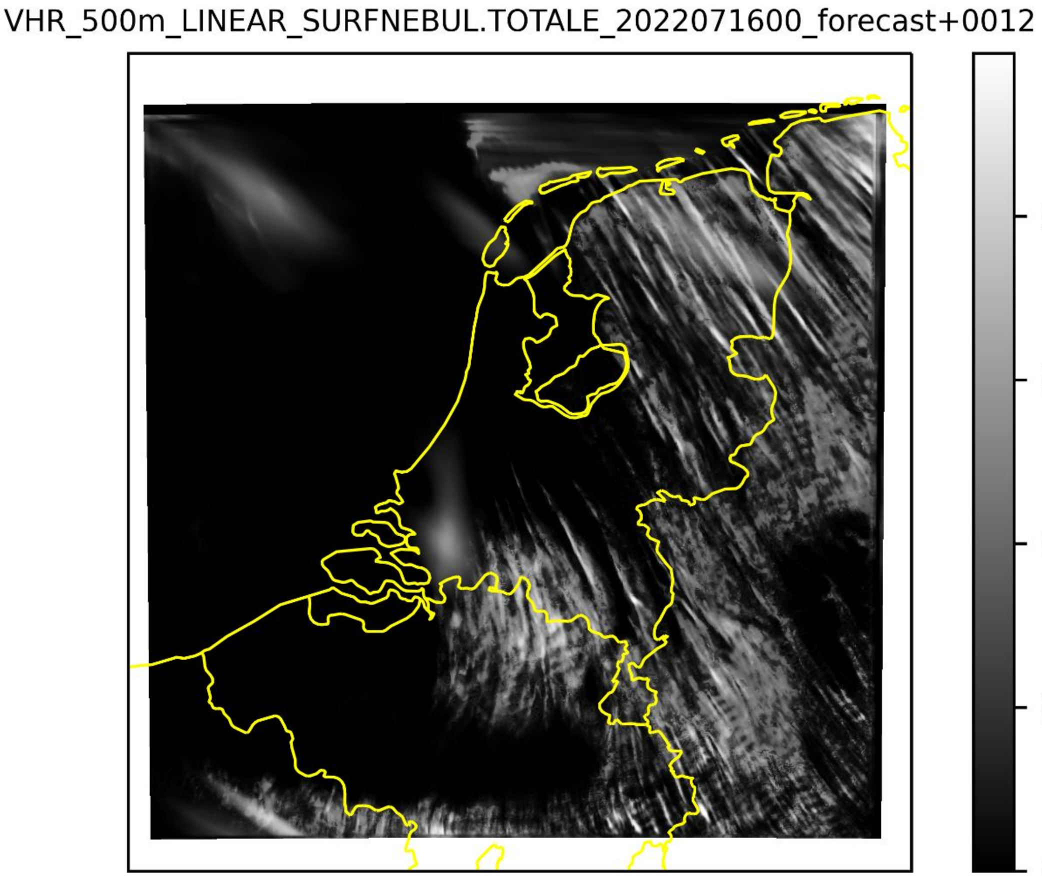
Wim de Rooy, Natalie Theeuwes, Bert van Ulft, KNMI

Shallow Convection

- Shallow Cumulus case 2022071600 +12h 500 m forecast.

Full MF scheme on



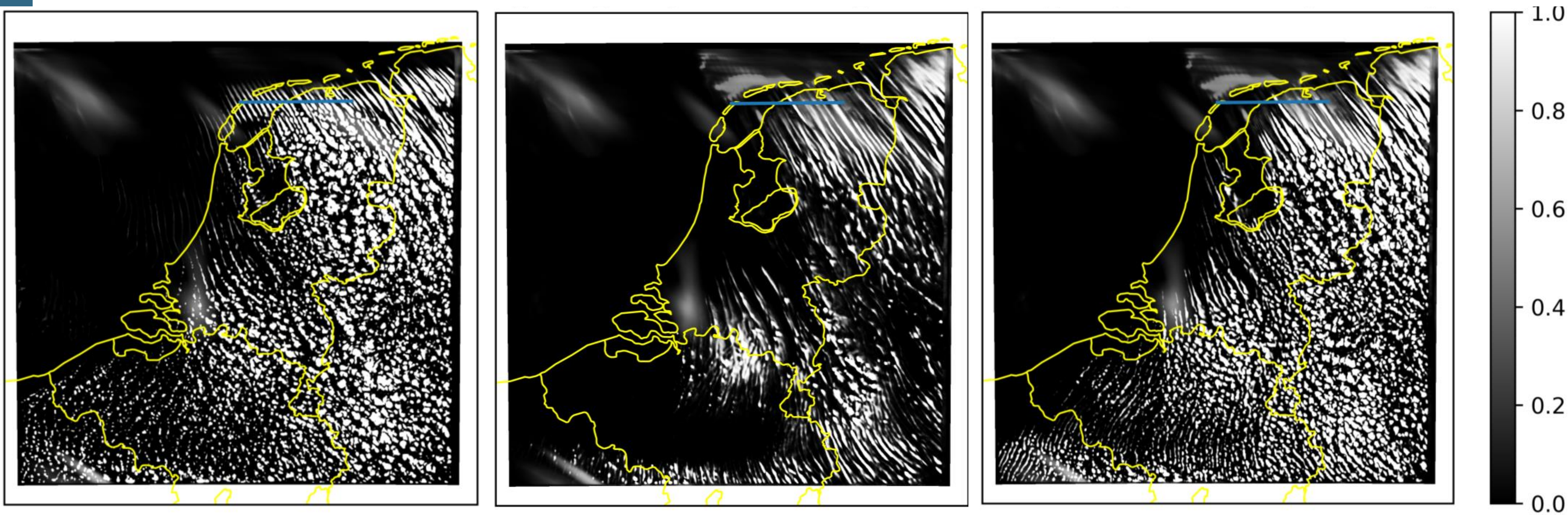


Wim de Rooy, Natalie Theeuwes, Bert van Ulft, KNMI

Shallow Convection

- Shallow Cumulus case 2022071600 +12h 500 m forecast.

No MF | **Scale aware** | **Scale aware w**



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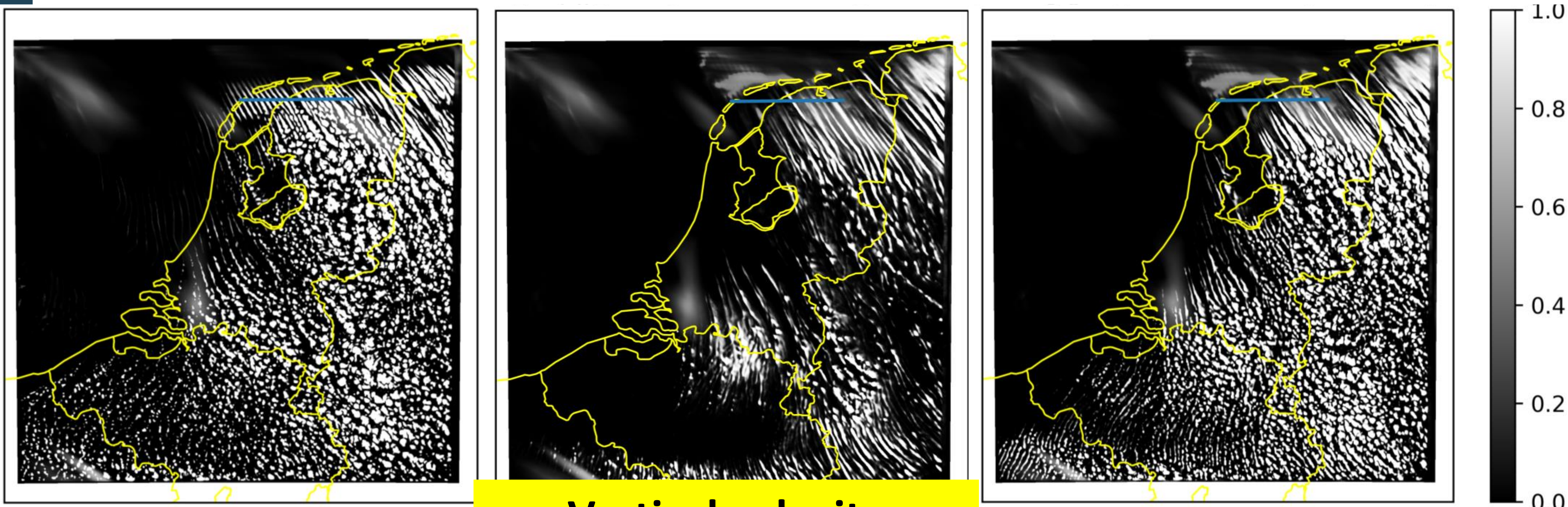
Shallow Convection

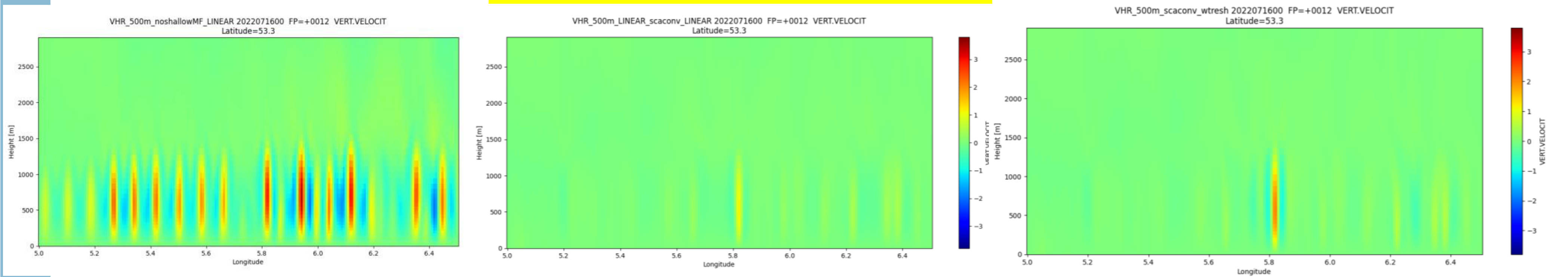
No MF

Scale aware

Scale aware w



Vertical velocity



Wim de Rooy, Natalie Theeuwes, Bert van Ulft, KNMI

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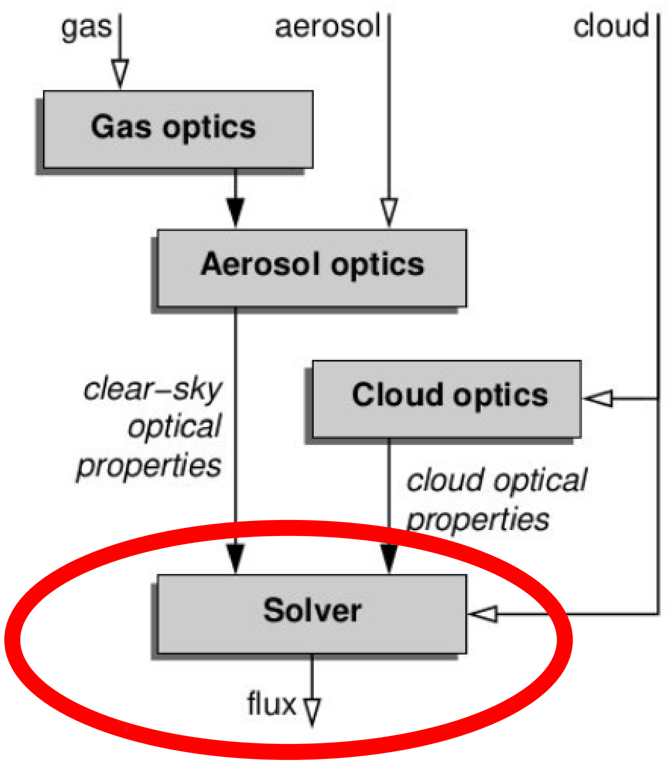
Radiation: ecRad

The ecRad scheme



ecRad is a modular, highly configurable radiation scheme developed at ECMWF https://github.com/ecmwf-ifs/ecrad

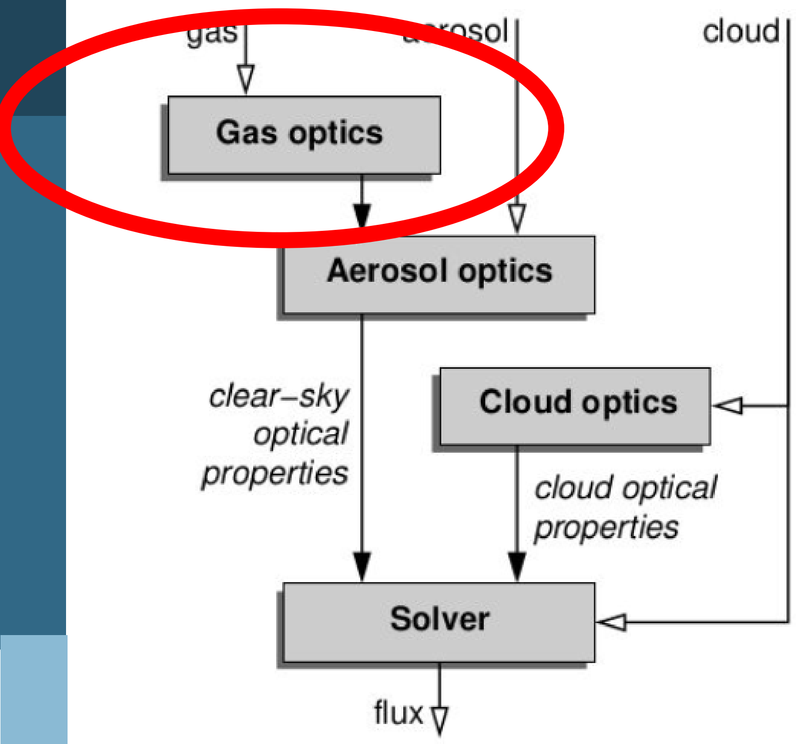
Several solvers available:

- **McICA** - used operationally. Samples sub-grid clouds stochastically in spectral space
- **TripleClouds** - treats sub-grid cloud structure deterministically by dividing each level into a clear-sky and two cloudy regions (optically thin and thick) *Planned for future ECMWF cycle*
- **SPARTACUS** - similar to TripleClouds but accounts for the lateral flow of radiation from cloud sides (cloud 3D radiative effects). Longwave solver still under development

Peter Ukkonen, DMI

Radiation: ecRad

The ecRad scheme



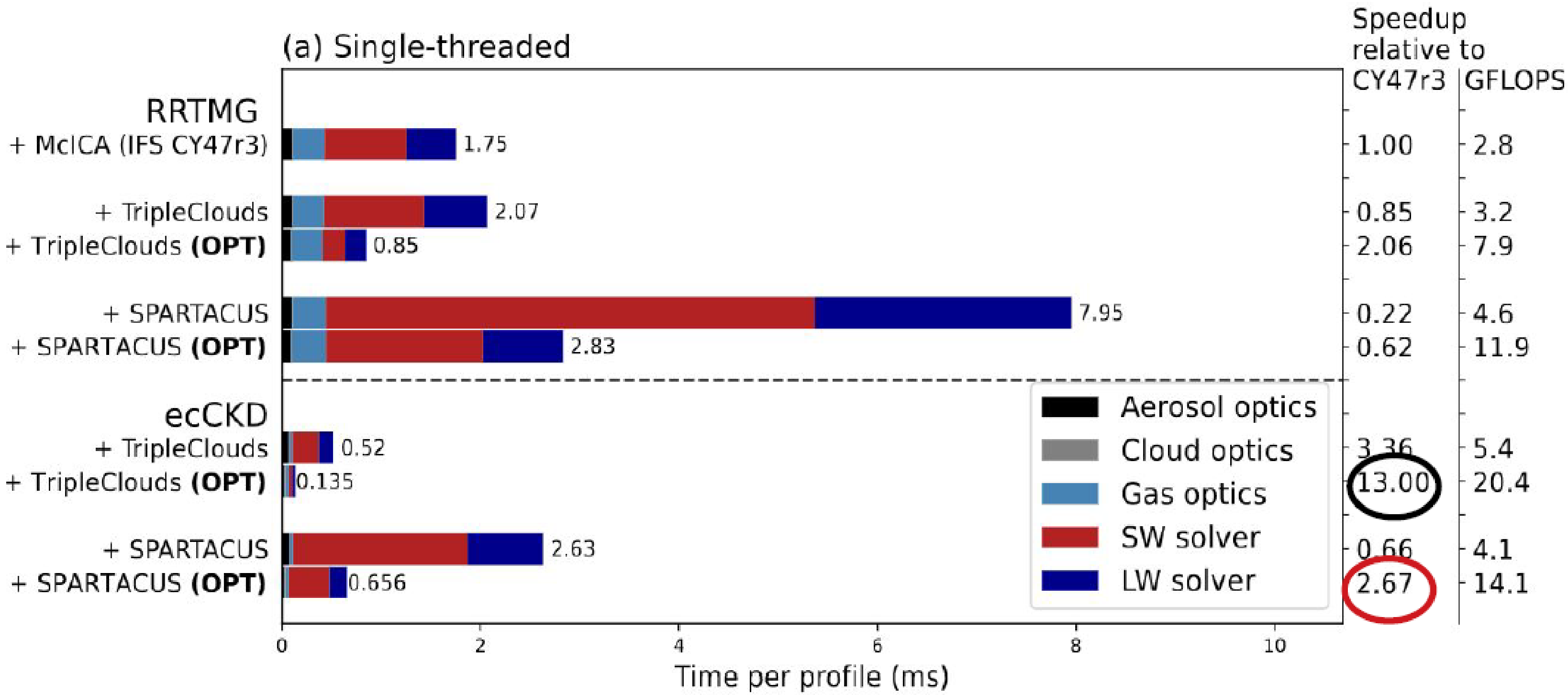
The gas optics scheme is crucial as it determines the spectral resolution and therefore the cost. Four gas optics schemes now available

- **RRTMG**: Used operationally, has 112/124 (ShortWave/LongWave) “g-points”. A few decades old, outdated spectroscopy and solar irradiance (biases in stratosphere and mesosphere)
- **RRTMGP**: Successor to RRTMG, 224/256 g-points by default but reduced distributions available (112/124)
- **RRTMGP-NN:** Neural network version of RRTMGP by me, ~3x faster gas optics
- **ecCKD**: recently developed tool by Robin & Matricardi. Can generate gas optics schemes that are accurate with only 32/32 g-points

Peter Ukkonen, DMI

Radiation: ecRad

A new state-of-the-art in speed/accuracy by combining spectral and code optimization



TripleClouds + ecCKD: similar or better accuracy than operational schemes and **13X faster**

SPARTACUS + ecCKD: **accounts for previously ignored 3D cloud radiative effects, 2.6X faster than operational scheme**

- SPARTACUS (OPT) – refactored code

Peter Ukkonen, DMI

Radiation: ecRad

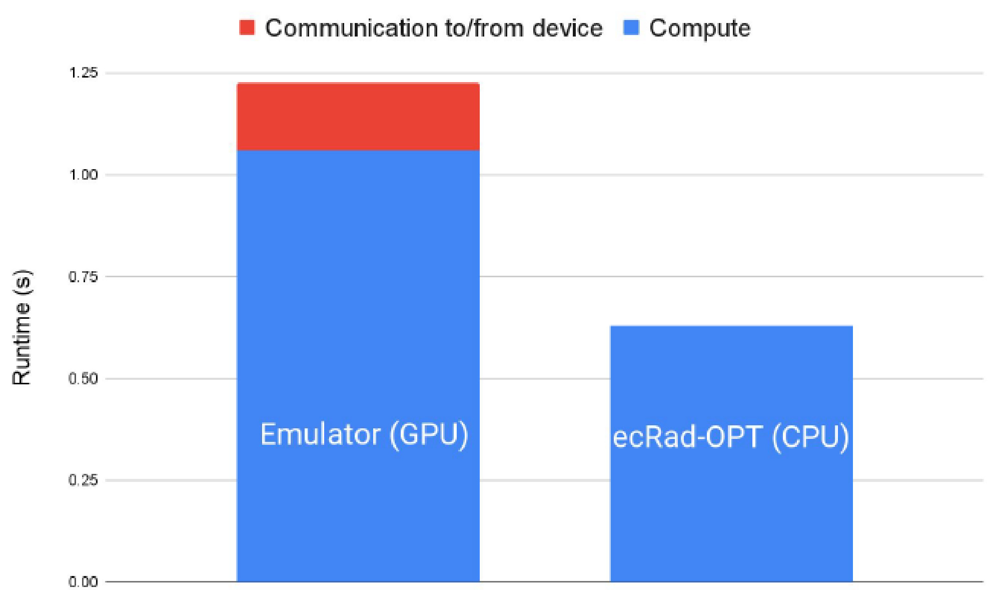
- ecRad-OPT running on a full AMD node is almost twice as fast as emulators (done with RNNs) running on GPU!
- Working on merging ecRad-OPT into AROME cy49.
- Robin Hogan (ECMWF) has added most of the optimisations into the develop branch of IFS cy49,

Performance comparison: RNN-based emulators on GPU vs optimized TripleClouds on CPU

Time to solution for 400,000 columns (lower is better)

bi-LSTM, 64 neurons
Offline setup with little overhead, ONNX runtime
Large batch size (40k)

1x NVIDIA A100 40 GB
Released: May 2020
MSRP: ?
Price: $6800 - $10000
TDP: 400W



Opt. TripleClouds + ecCKD
GCC 9.3, -O3
128 cores = threads
Batch size 8

2x AMD EPYC 7H12
Released: September 2019
MSRP: ??
Price: $7600 - $14000
TDP: 560W

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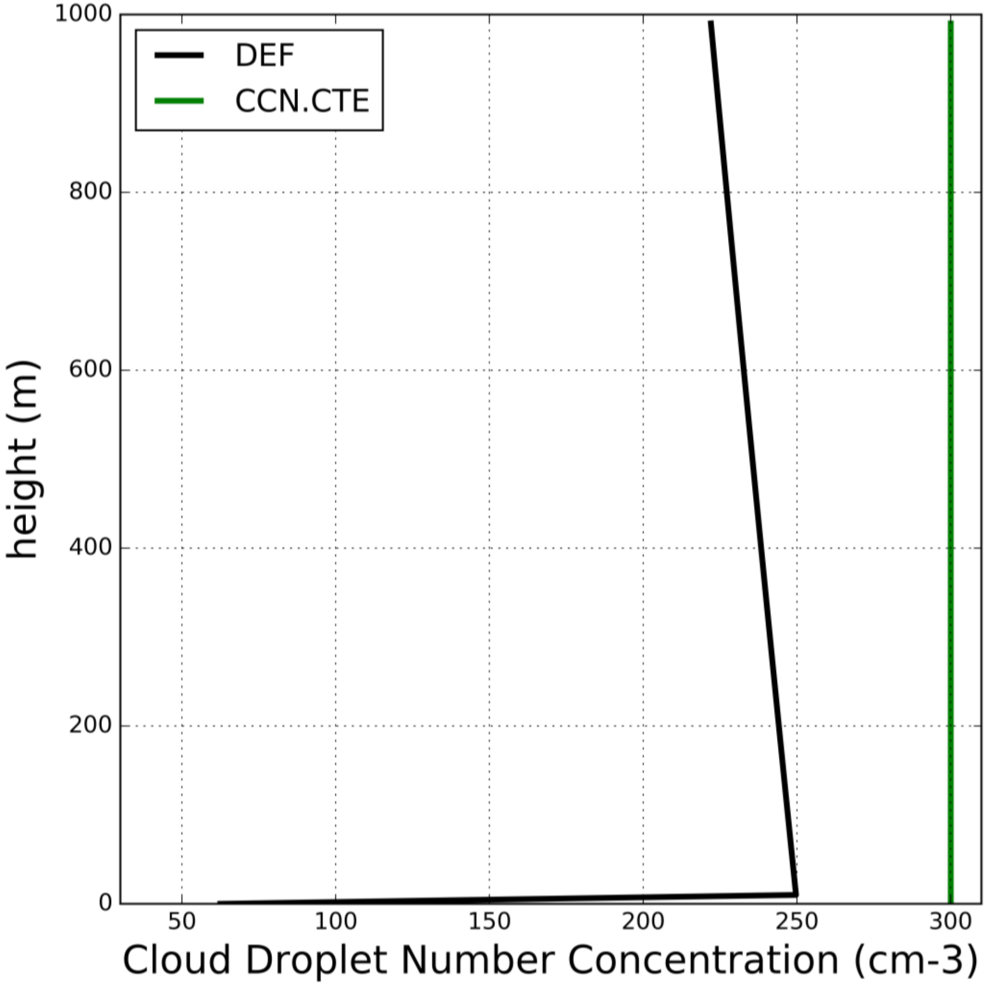
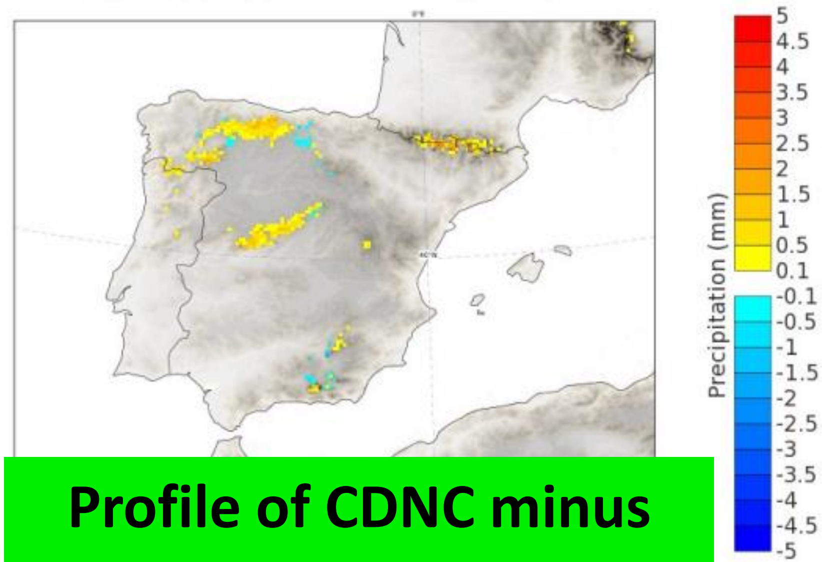
Cloud Droplet Number Concentration *vs* Snowfall



Profile of CDNC



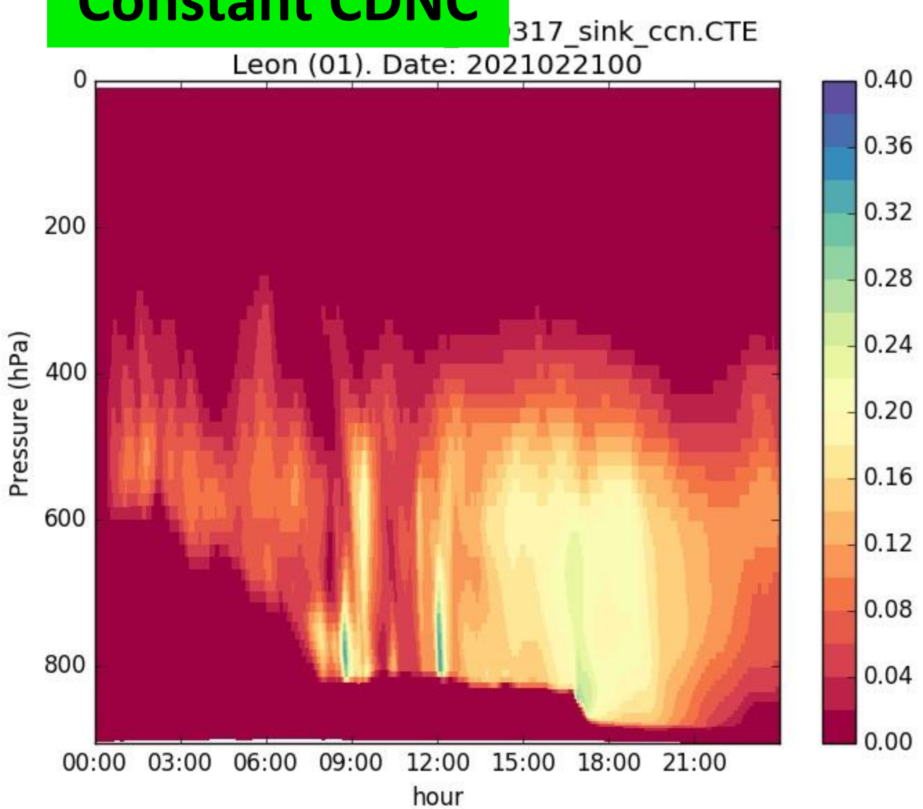
Profile of CDNC minus Constant CDCN

Daniel Martín, AEMET

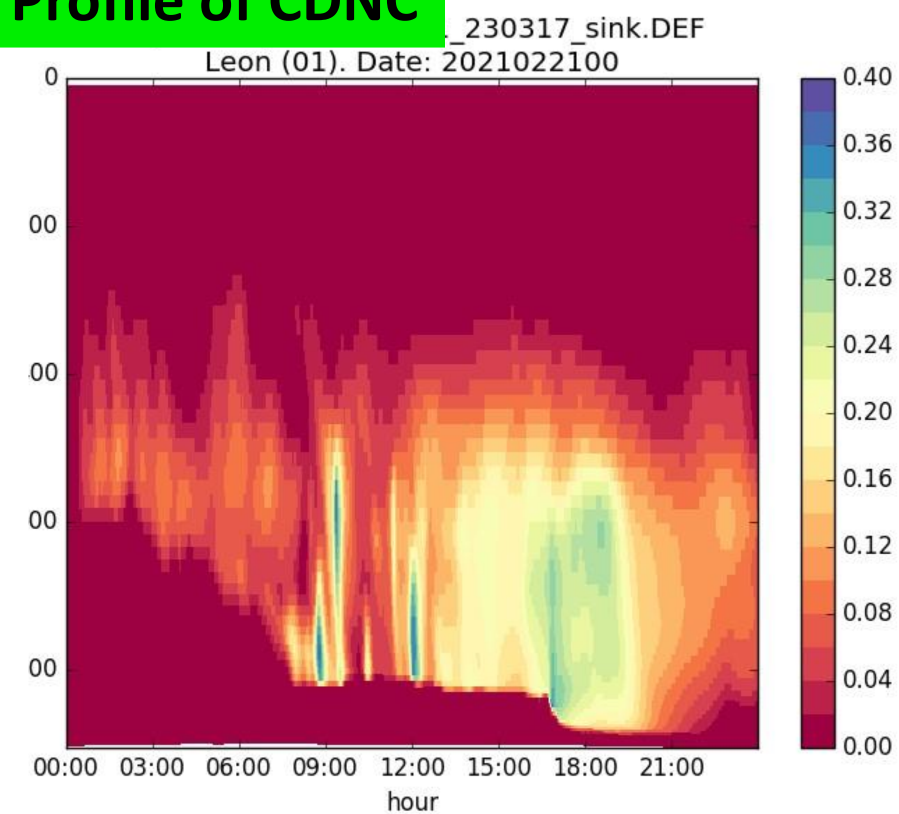
Snow Precipitation

- Impact of constant cloud droplet number concentration (CDNC, 300cm^{-3}) vs a height-dependent profile of CDNC on intensity of snowfall (VQS1).

Constant CDNC



Profile of CDNC

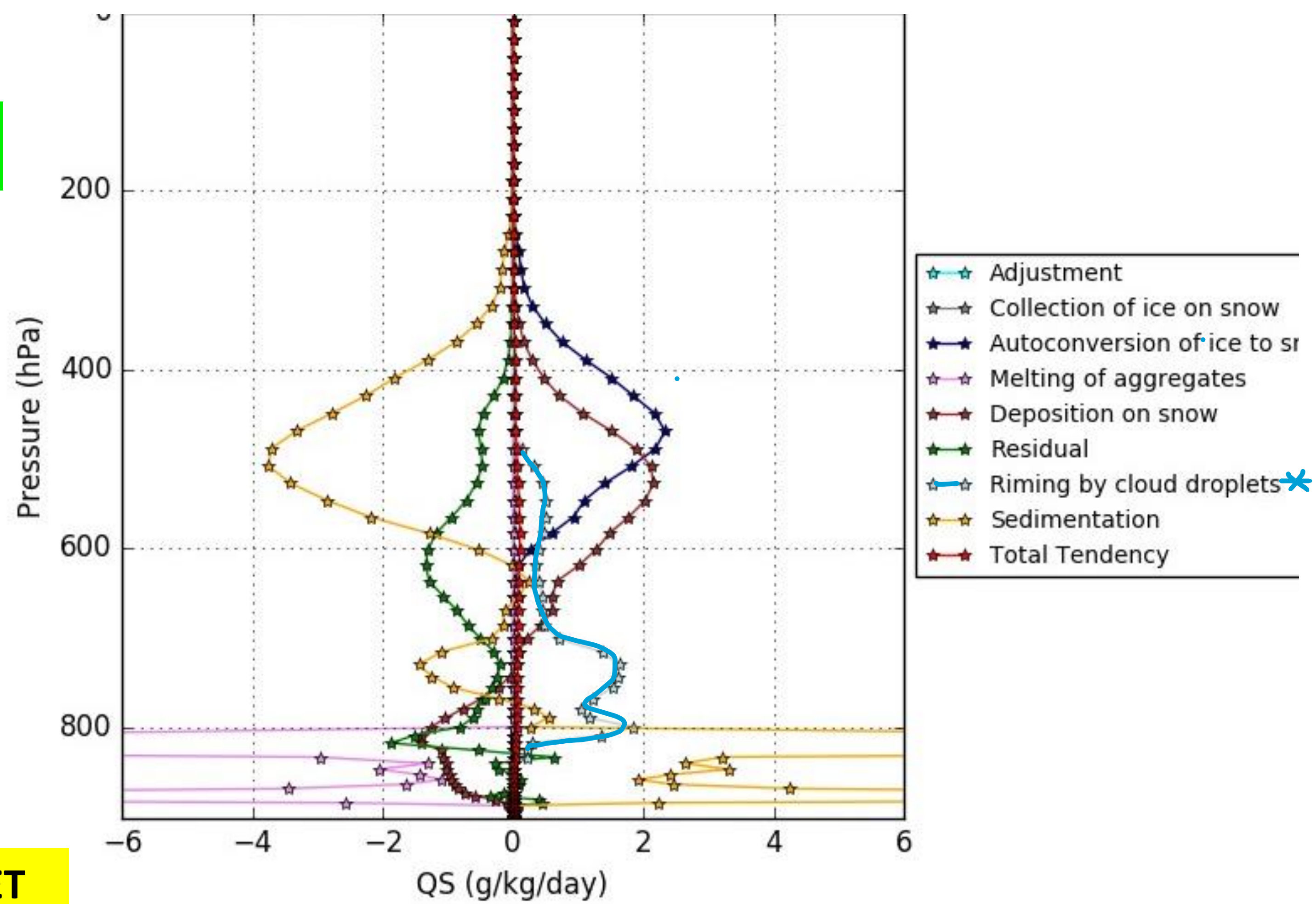


Daniel Martín, AEMET

Snow Budget Tendancy

- DDH tool shows that the riming process is responsible.
- Collision efficiency of snowflakes with cloud droplets increases with droplet size (as collision efficiency of snowflakes and cloud droplets depends on the terminal velocity of the cloud droplets in the OCDN2 option)

Constant CDNC



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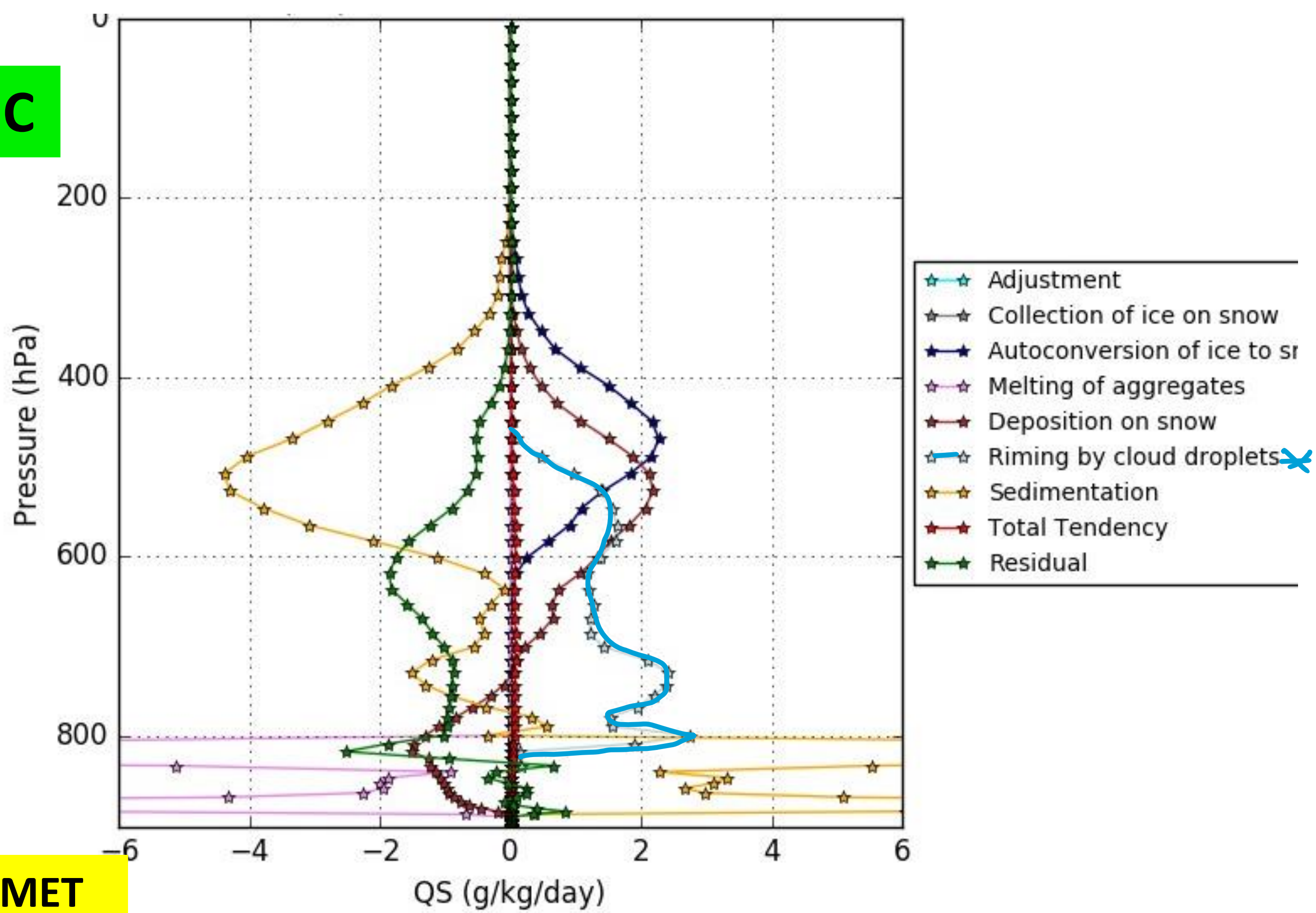
Profile of CDNC



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Aerosols - Tiny Particles Big Impact

- Tegen Climatology
- CAMS Climatology
- CAMS Near Real Time

Credit: NASA

Emily Gleeson, Karl-Ivar Ivarsson, Daniel Martin,
Laura Rontu, Wim de Rooy,

Aerosols - Tiny Particles Big Impact

- ## Tegen Climatology
  - **Radiation:** Sea, Land, Soot, Desert climatologies (Background statrospheric)
  - Optical Properties: AOD at 550nm, single scattering albedo, asymmetry factor
  - **Microphysics**: Profiles of cloud droplet number concentration

- ## CAMS Climatology
  - Change to the climatology as used by radiation (no change re micro. CAMS AOD replaces TEGEN AOD)

- ## CAMS Near Real Time
  - Changes re radiation (MMRs to AODs) and microphysics (MMRs to CCNs/IFNs)
  - 14 aerosol types (11 in radiation by default) – sea salt, dust, organic matter, black carbon, sulfates, nitrates, ammonia



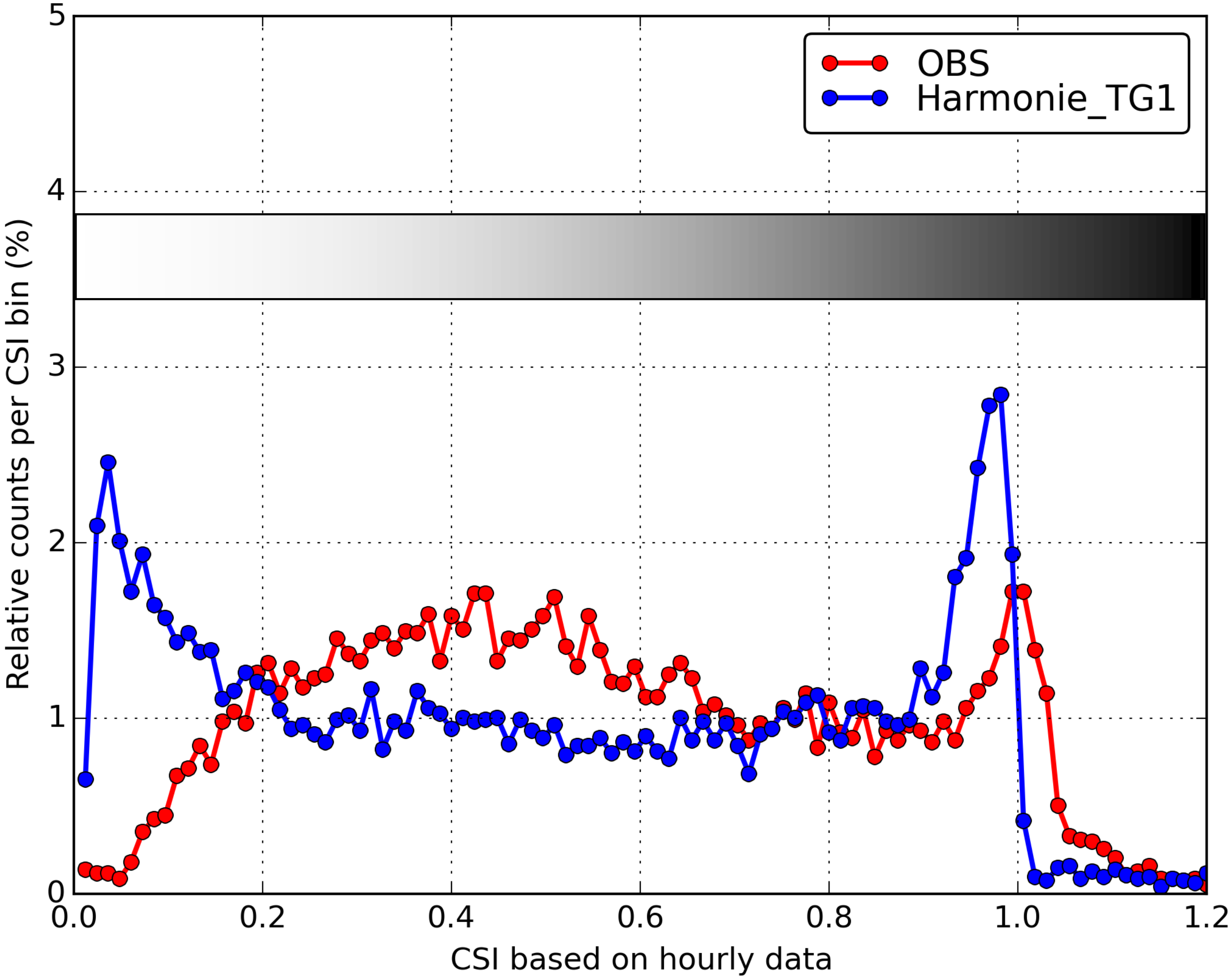

Credit: NASA

Wim's Experiments

Time Period	Aerosol Info	Other Physics
Summer 2018	Tegen, CAMS climatological, CAMS NRT	RFRMIN(24)=1
Winter 2020	Tegen, CAMS climatological, CAMS NRT	RFRMIN(24)=1

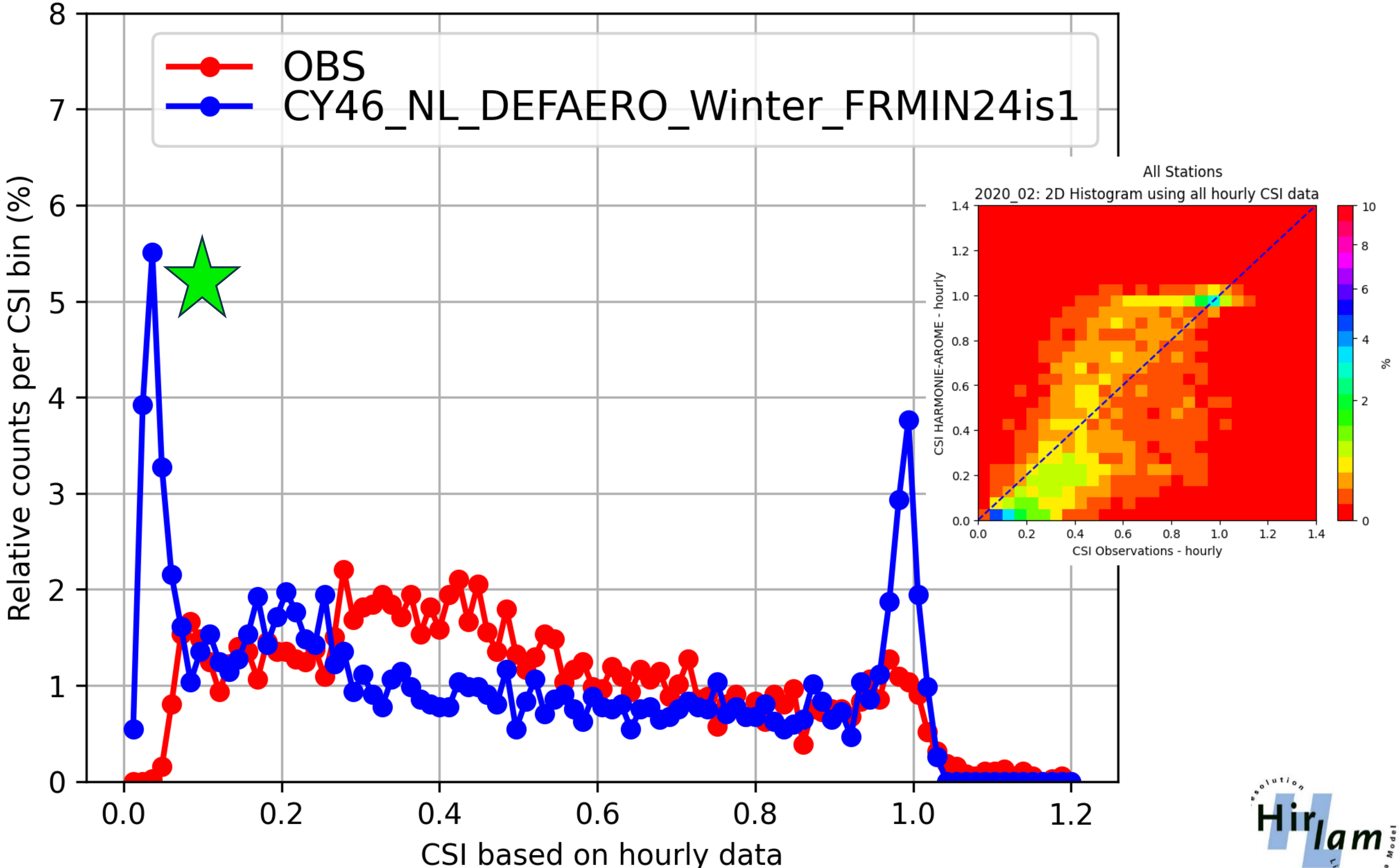
- 50 measurement stations

Clear Sky Index (SW/SW_{clear})



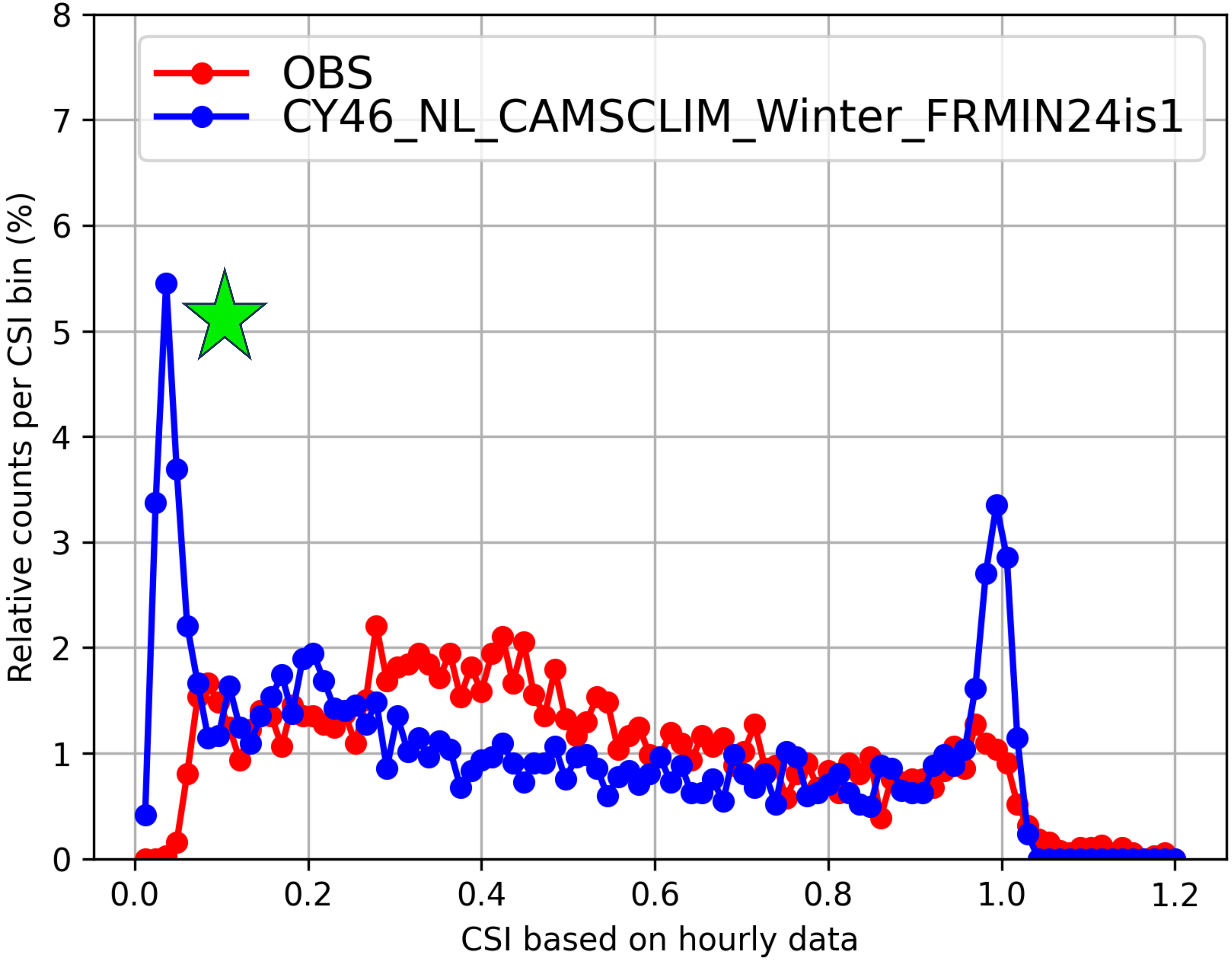
NL Domain – Winter 2020

TEGEN



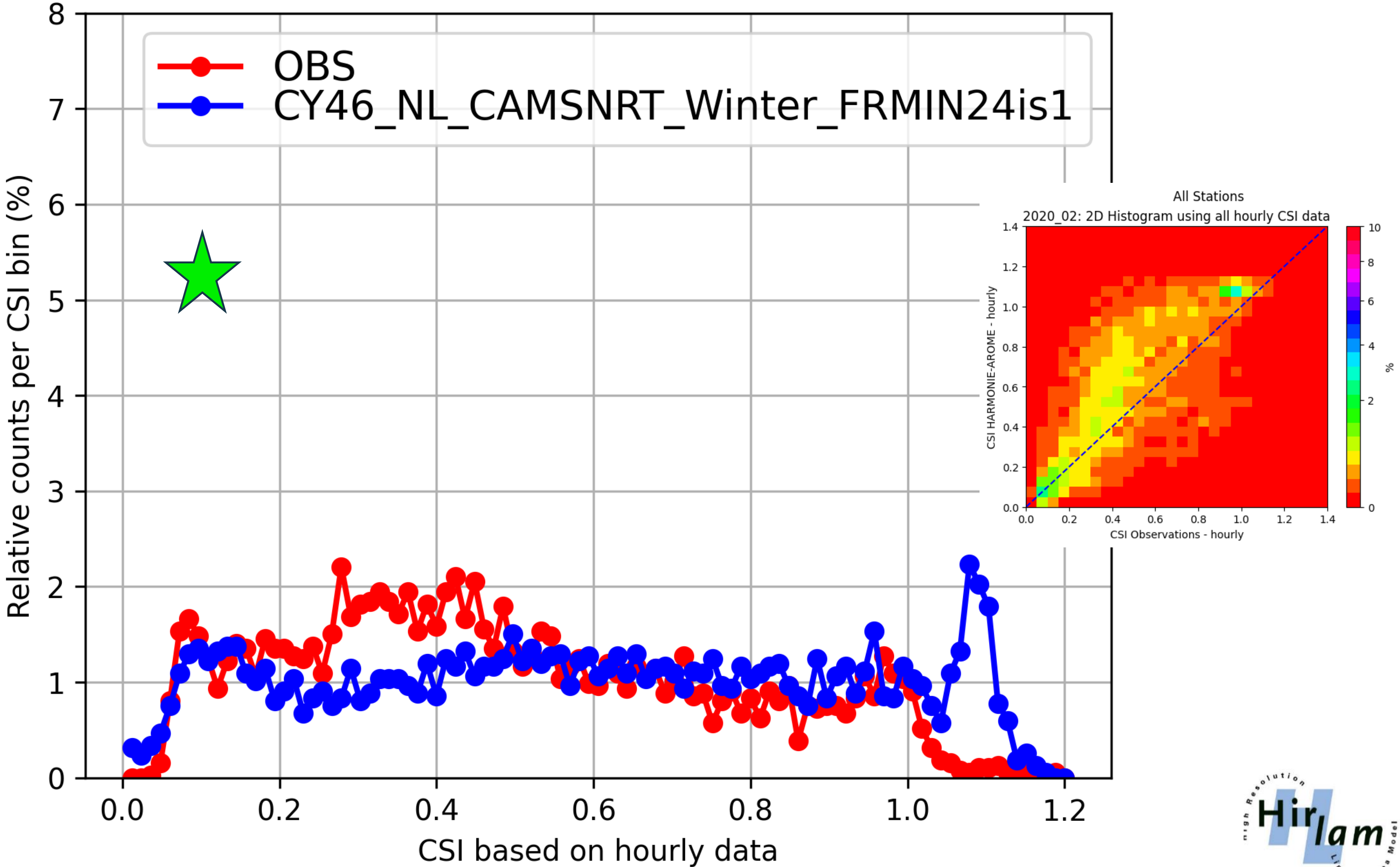
NL Domain – Winter 2020

CAMSCLIM



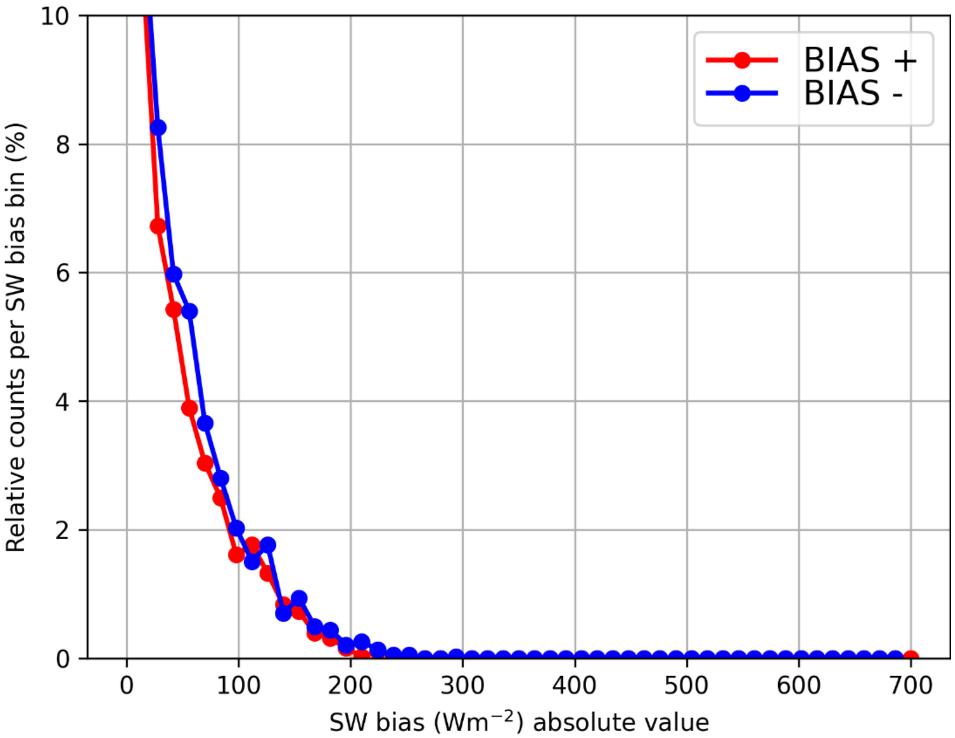
NL Domain – Winter 2020

CAMSNRT

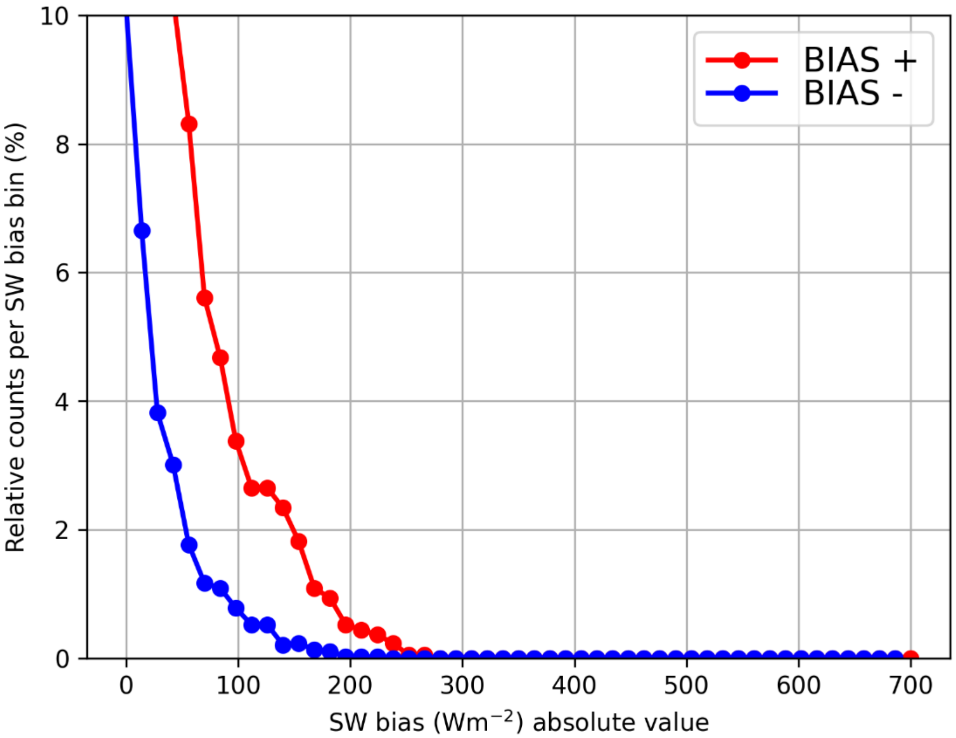


SW Biases (+/- on same axis)

TEGEN

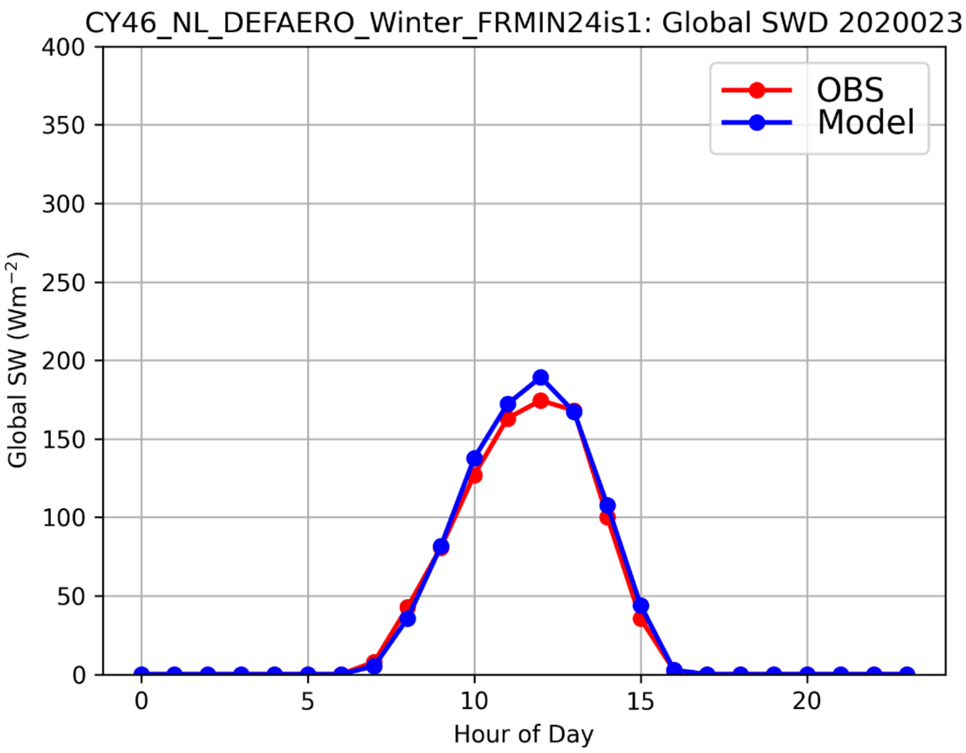


CAMSNRT

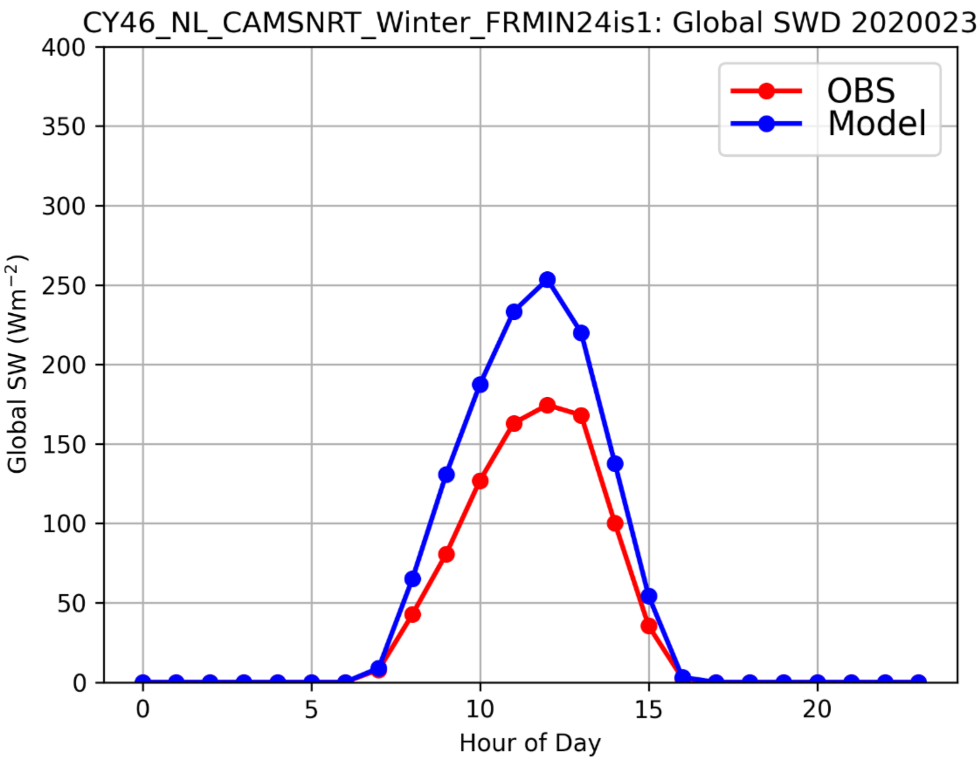


Sample Daily Cycle Global SW

TEGEN

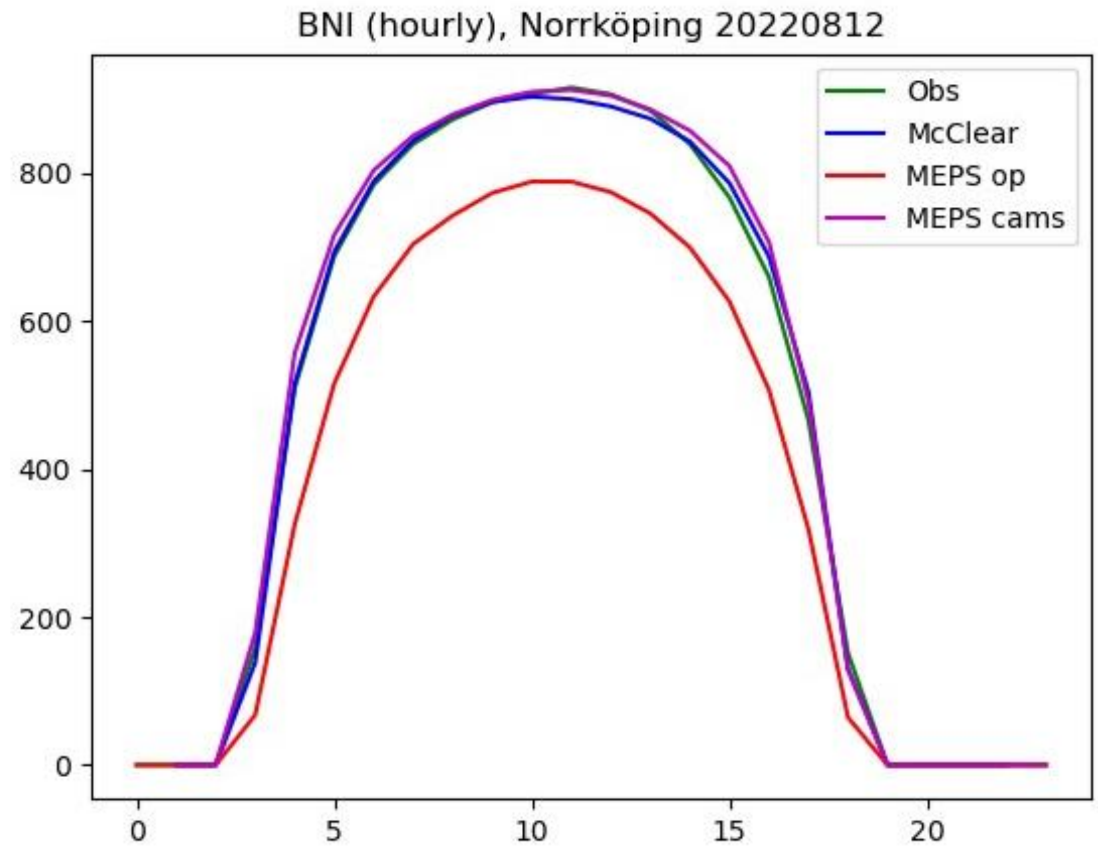


CAMSNRT



Direct SW Radiation -SMHI

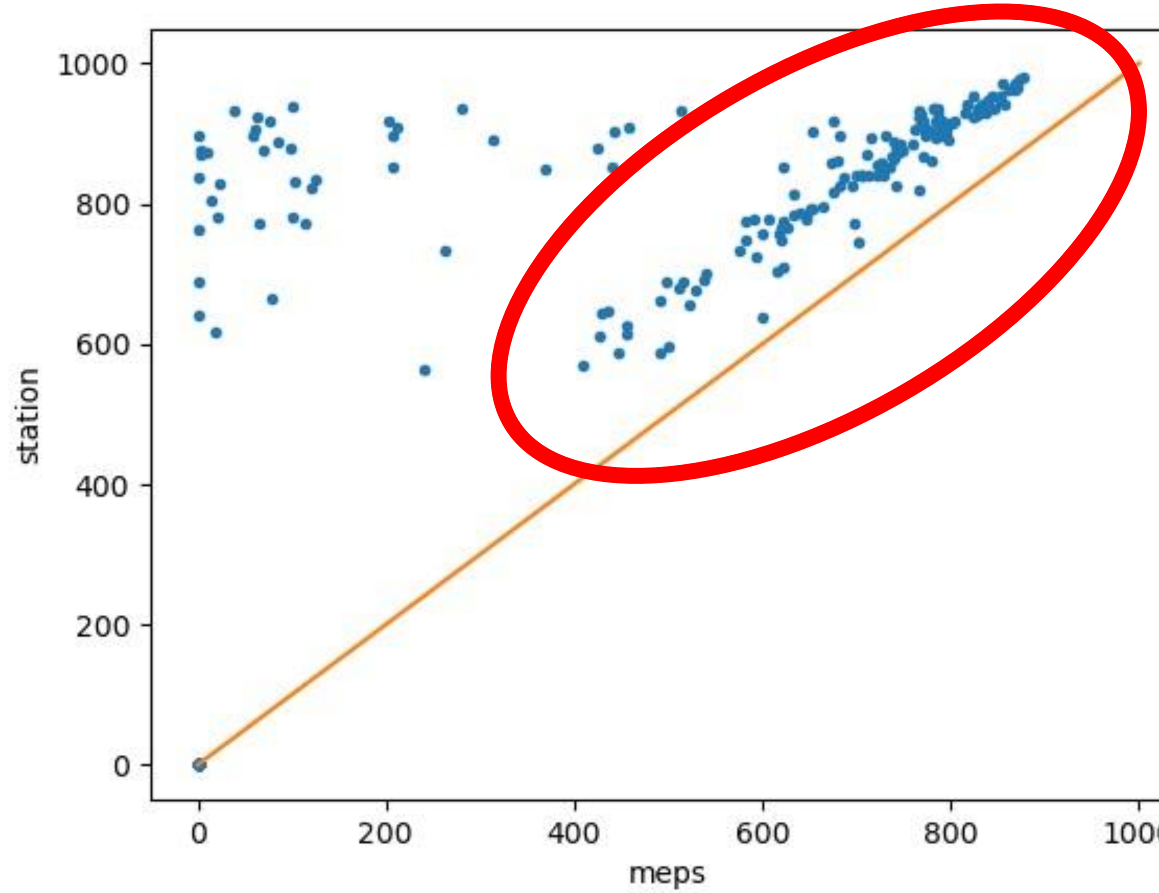
- Operationally over Sweden there's a negative bias in Direct SW Radiation compared to observations.
- Tested with CAMS NRT aerosols and also compared to the McClear Clear Sky Model using CAMS NRT.



Tomas Landelius, SMHI

Direct SW Radiation -SMHI

- April to October 2022 Norrköping - DNI
- Observations from clear hours *vs* MEPS
- Cases where obs are clear but model is not (LHS)
- Can also see clear underestimation of the model (red oval!)



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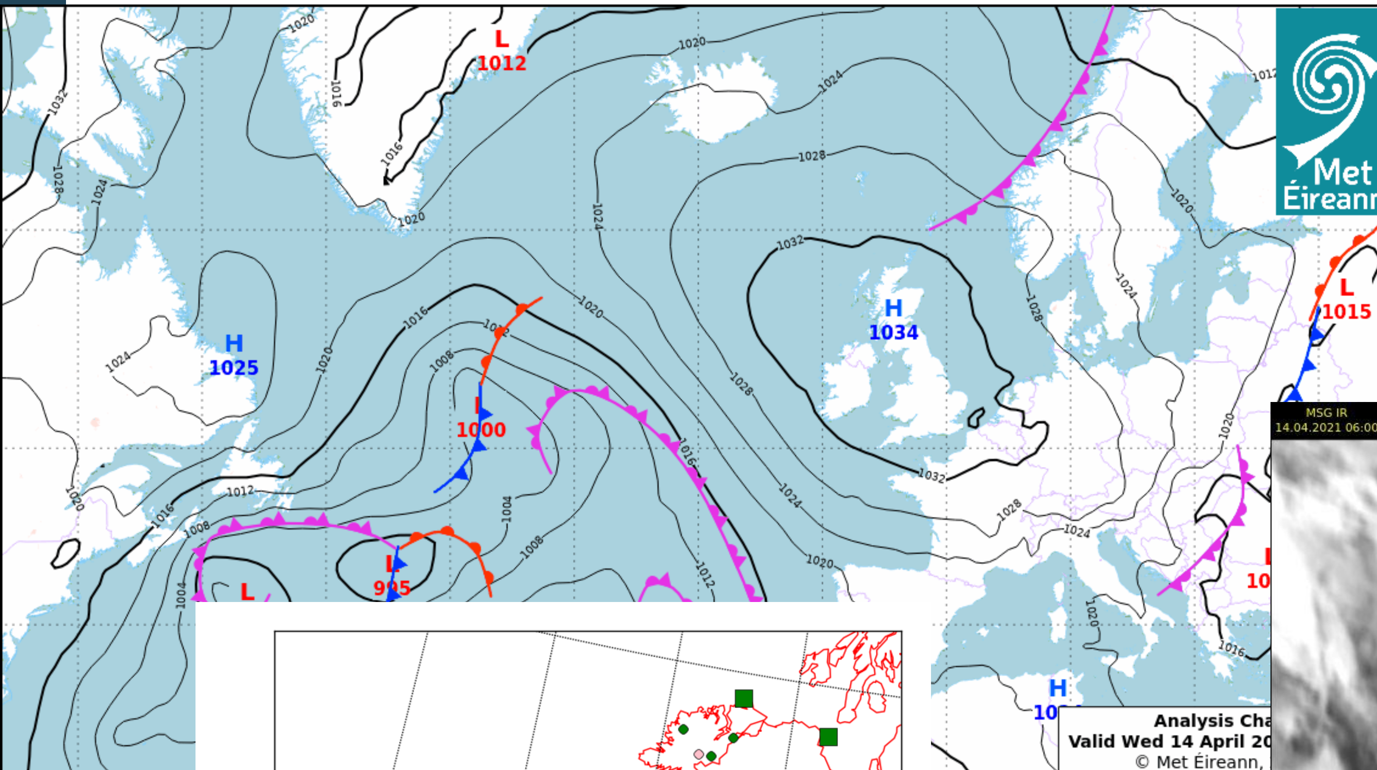
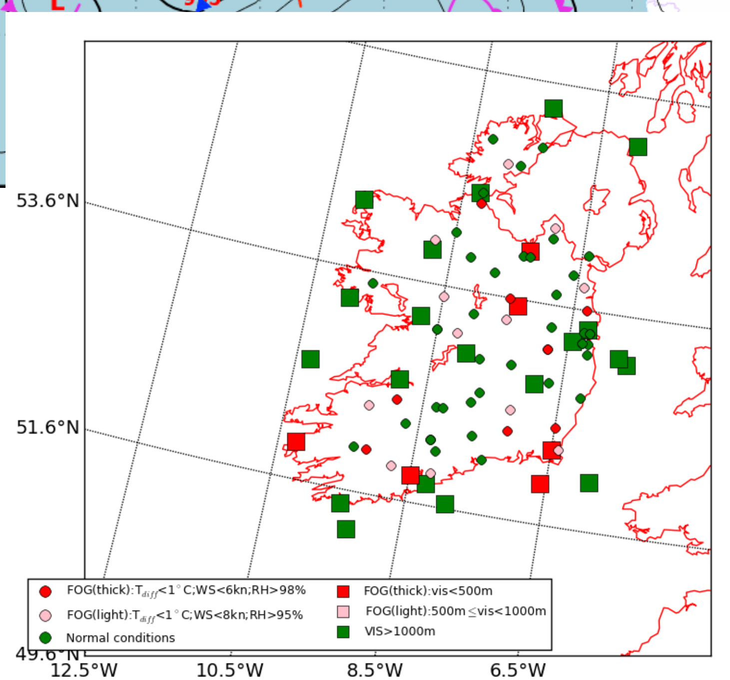
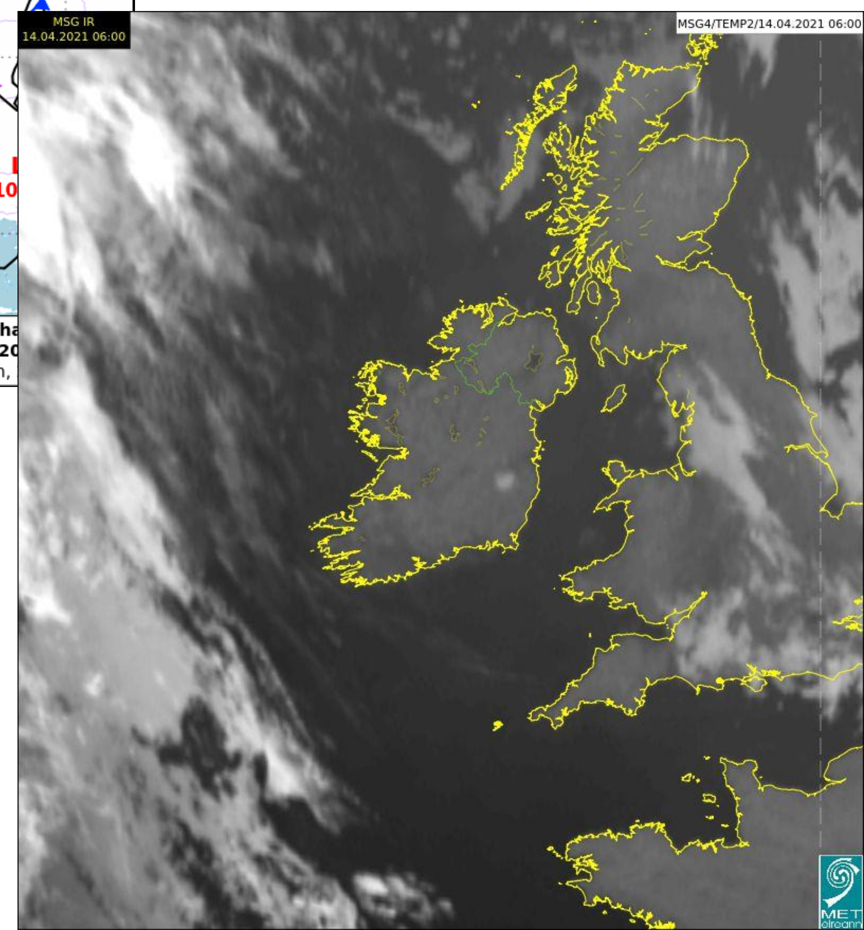
Two Fog Cases

April 2021 Fog

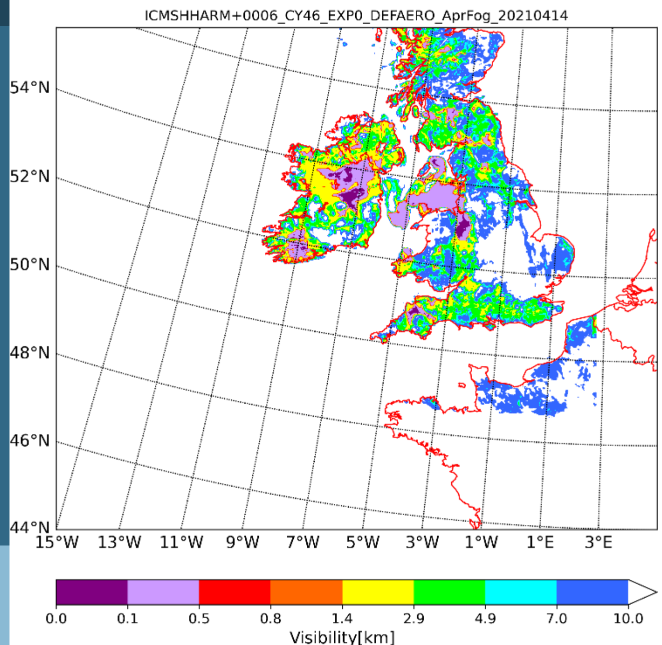


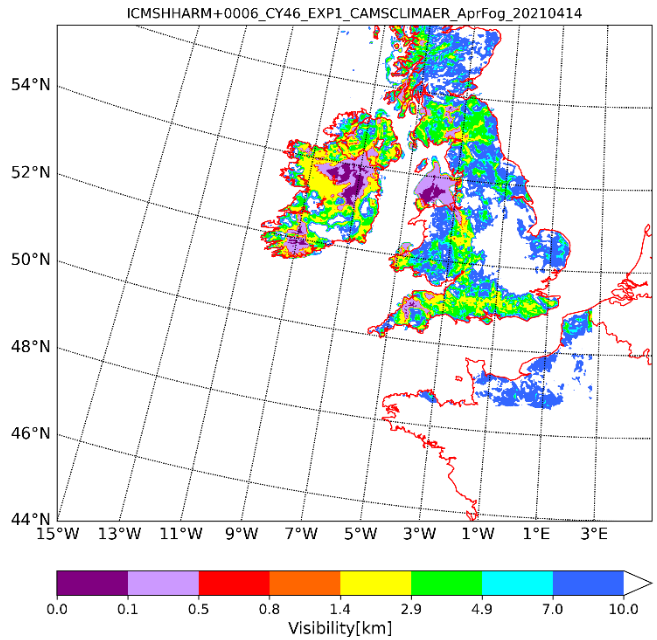


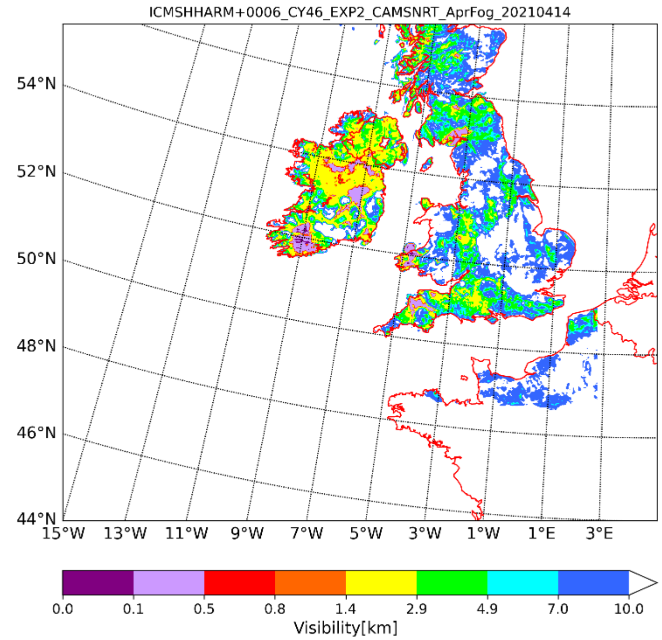


Tegen vs CAMS clim vs CAMS nrt

(for nrt used min CDCN etc of 10 as is default)

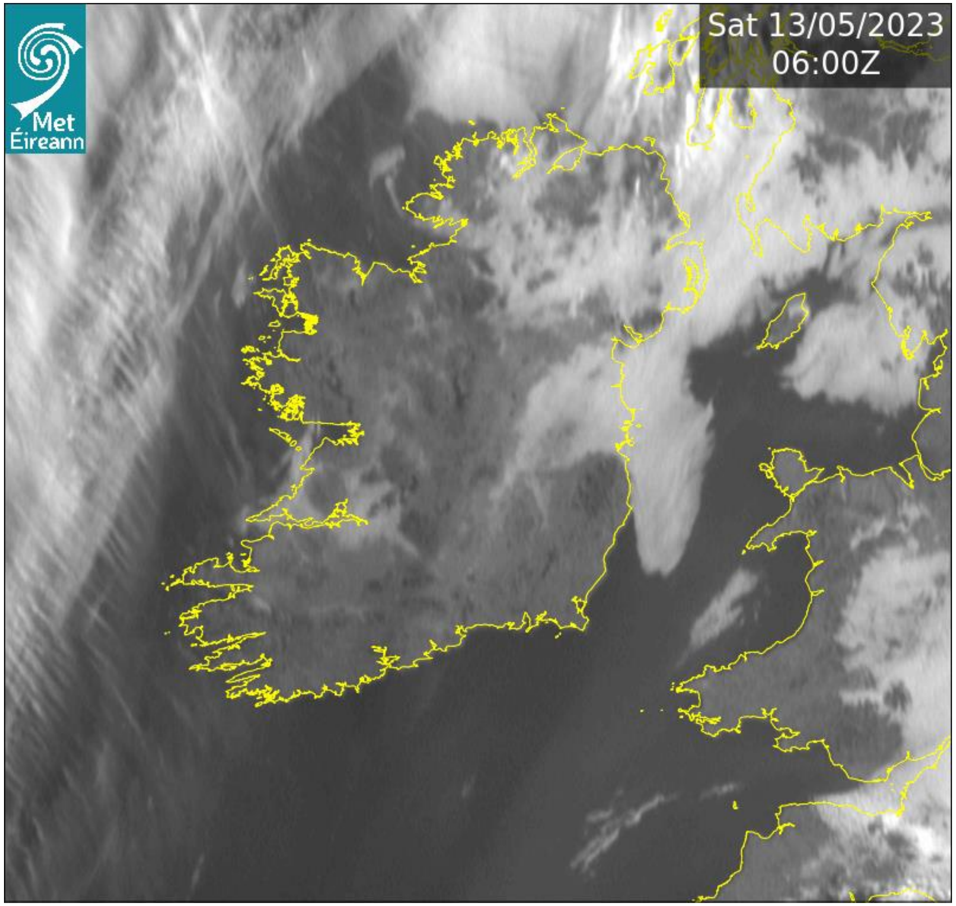


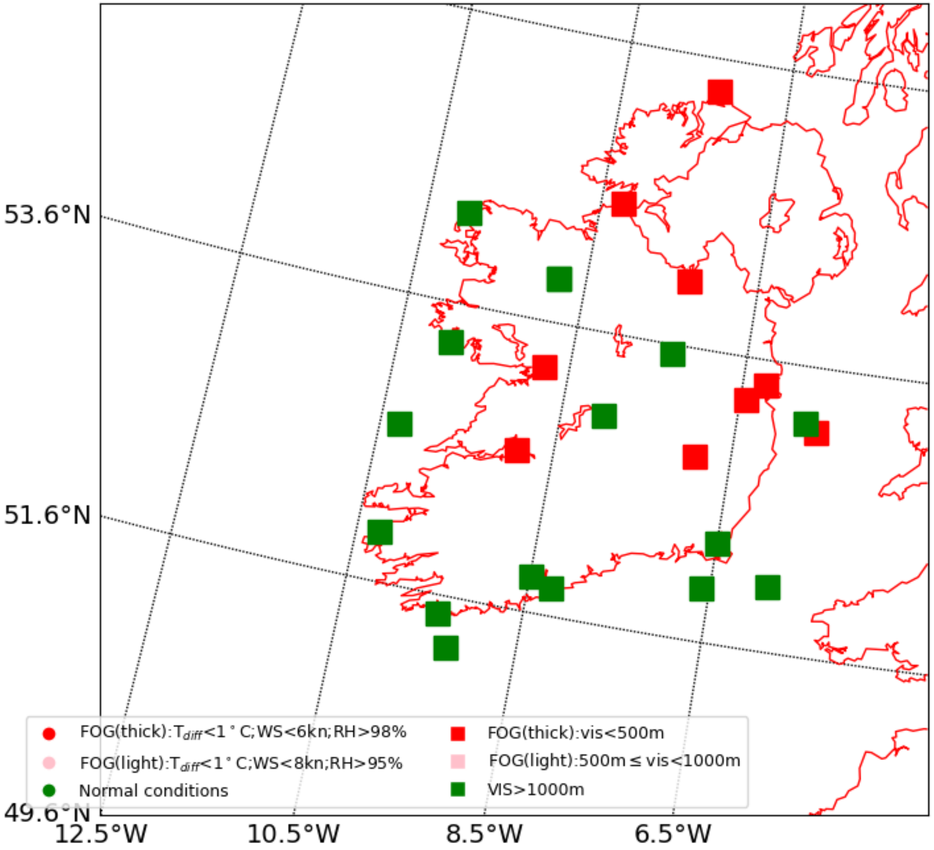




CAMS nrt gets rid of most of the erroneous fog over the sea near the UK and the extent of the fog over Ireland looks more realistic.

May 13th 2023: 06Z





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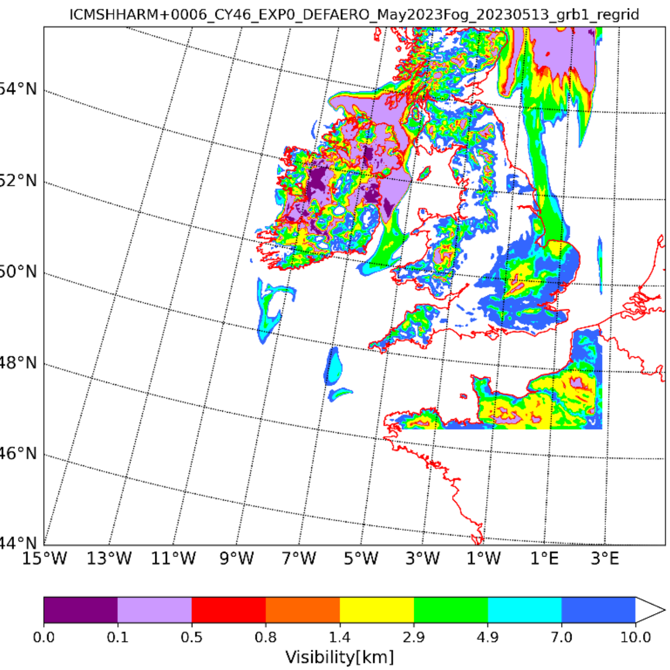

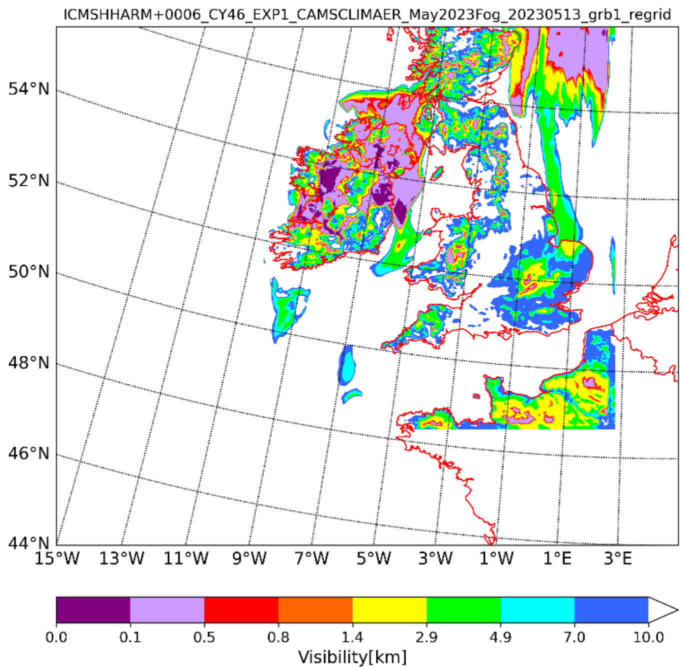

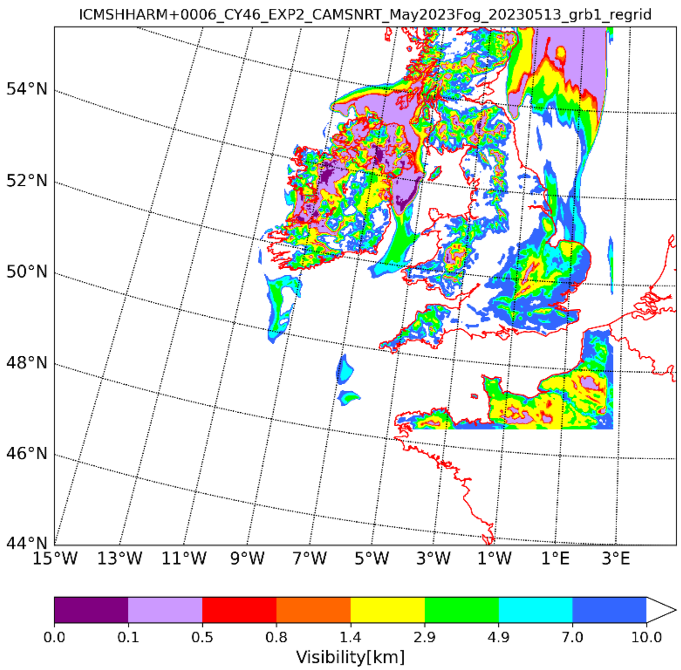

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Sodankylä 2023

- Physics Working Week last week – Stable Boundary Layer
- Common version of MUSC – interoperability of physics components