HARMONIE-AROME Radiation Experiments and Developments

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1. Summary

- This poster contains a summary of current or recently completed work using different versions of the HARMONIE-AROME configuration of the shared ALADIN-HIRLAM system.
- Topics include:
  - **Evaluation of solar irradiance using observations**
  - **Shortwave (SW) indices as a cloud evaluation tool**
  - **Aerosol climatologies**
  - **Comparison of SW radiation schemes**
  - **Improvements to snow and ice albedos**
  - **Consistency in cloud condensate effect radii used by the cloud microphysics and radiation schemes**

2. SW irradiance *vs* Observations

- **Datasets:**

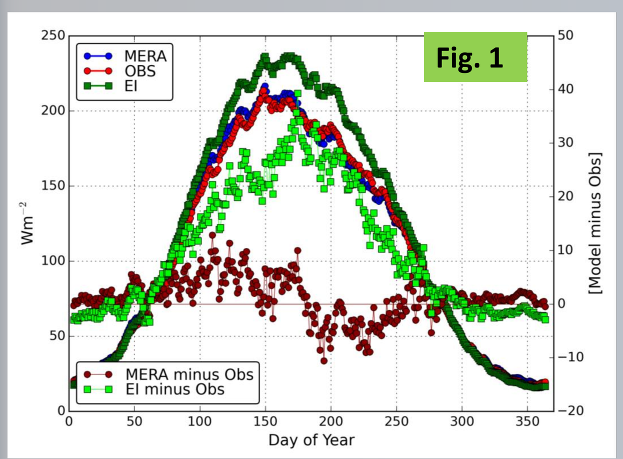
- Irish & Danish global radiation networks (20/26 stations)
- MÉRA 2.5 km reanalysis for Ireland (1981-present) **[1]**
- DMI NEA domain operational runs (June-Dec. 2017)

- **MÉRA versus NEA (model differences):**

- **MÉRA:** cycle 38h1.2, IFS SW radiation scheme based on cy25r, SW inhomogeneity factor of 0.7, 3DVar – conventional observations.

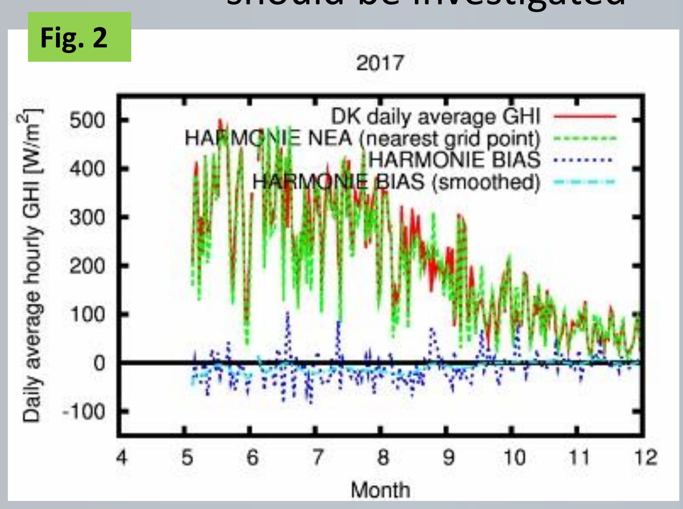
- **DMI NEA:** cycle 40h1.1, Nielsen cloud liquid optical property scheme, SW inhomogeneity factor of 1, significantly more observations than used in MÉRA's 3DVar.

- Main physics differences are: SURFEX version (7.2 vs 7.3), inhomogeneity factor (0.7 vs 1.0) and turbulence scheme (CBR vs RACMO).



- Daily mean global horizontal irradiance (GHI) by day of year.
- High resolution MÉRA has much lower bias than ERA-Interim
- Mostly (+) bias
- Monthly climatological fields in the model should be investigated

- (-) bias of 10-20 Wm^{-2} for June-Sept. in NEA.
- Change in sign of the bias between MÉRA and DMI runs may be related to the inhomogeneity factor as shown in Section 3.

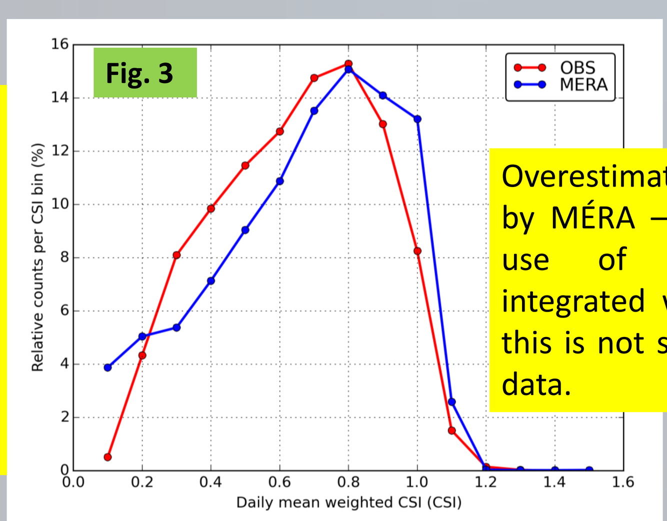


- See **[2]** for the more detail on the analysis presented in this section and Section 3.

3. Indices for Evaluating SW Irradiance/clouds

- GHI provides an objective and quantitative measure for evaluating cloud forecasts during daylight hours.
- We used a clear sky index (CSI) **[3]** and a variability index (VI) **[4]**.
- CSI involves the ratio of GHI and the theoretical GHI during clear sky conditions; we used the clear sky model of **[5]**.
- Model integrated water vapour was used in the DMI calculations; for MÉRA a typical mid-latitude value of 2.5 gcm^{-2} was assumed.
- A frequency distribution of daily mean CSI weighted using GHI (computed using hourly CSI and GHI) using MÉRA and Irish observations is shown in Fig. 3.

MÉRA has more cases of low CSI than observed – likely to be related to the thickest clouds having too high a cloud water content.



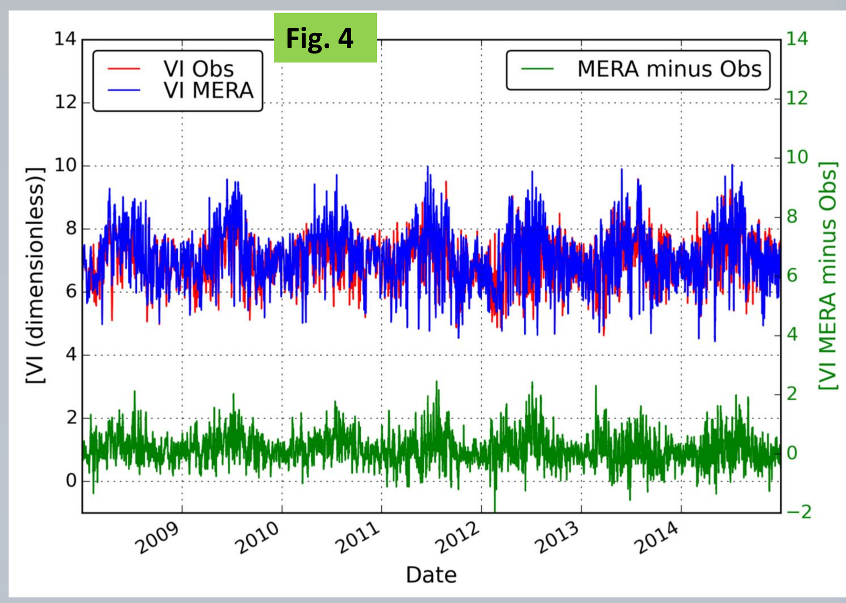
Overestimation of high CSI by MÉRA – related to the use of 2.5g/cm^2 for integrated water vapour – this is not seen in the DMI data.

- A variability index by Stein et al., 2012 was also computed for both the MÉRA and DMI datasets.
- VI is defined as follows where *k* = hour of day and *SBOA* is the GHI under clear-sky conditions.

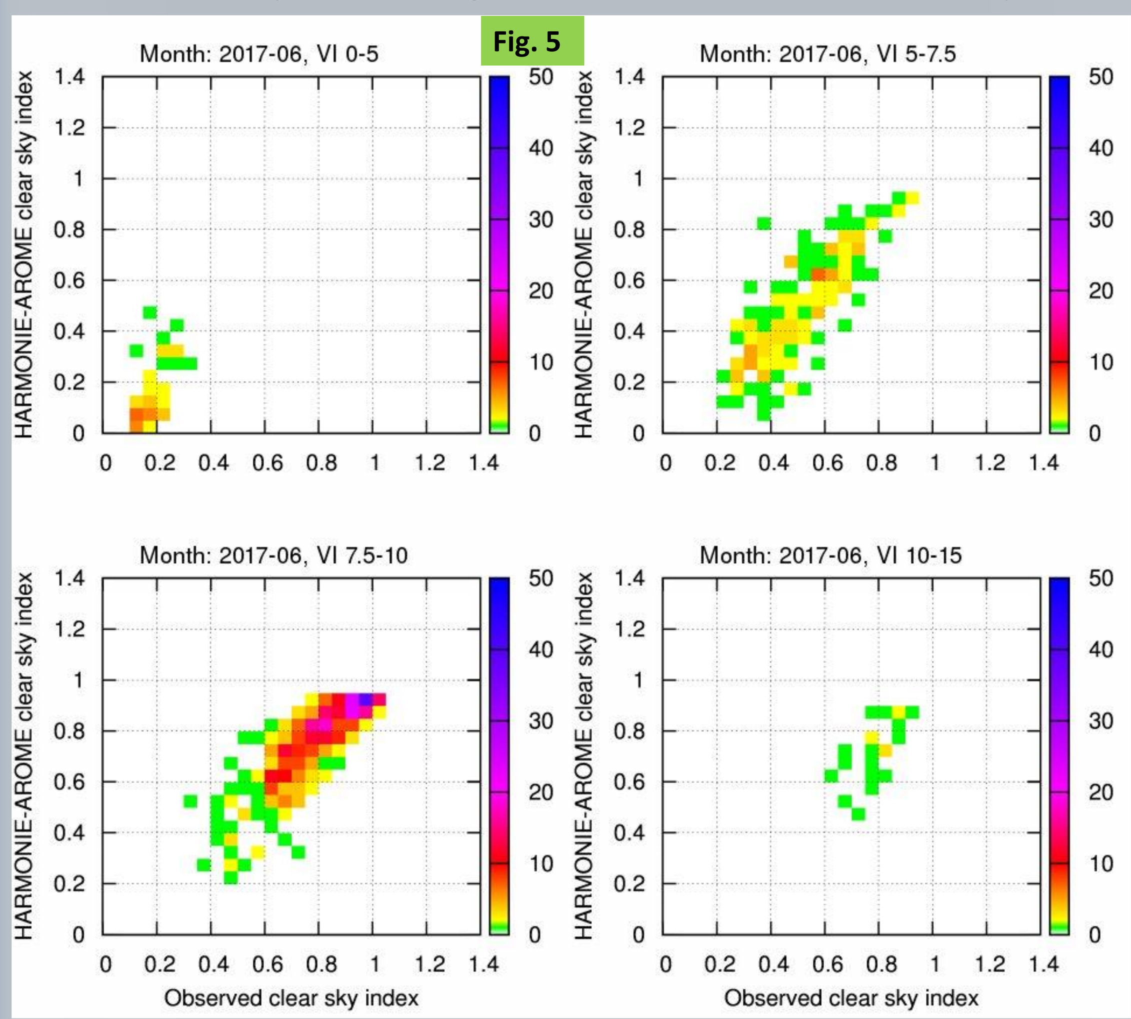
$$VI = \frac{\sum_{k=2}^{n}\sqrt{(GHI_k - GHI_{k-1})^2 + \Delta t^2}}{\sum_{k=2}^{n}\sqrt{(SBOA_k - SBOA_{k-1})^2 + \Delta t^2}}$$

- VI provides a method of classifying cloud situations.
- VI is high for subgrid scale variability that is unresolved by the models.

- 30-day running mean
- Clear seasonal cycle
- Spring/Summer – more variable – convection more likely



- We also did analysis using both CSI and VI to test HARMONIE-AROME under specific cloud conditions.
- Daily mean weighted CSI is plotted for different VI bins (for MÉRA 3 VI bins were used 0-5, 5-10 and 10-15; the middle bin was split in two for the DMI data (5-7.5 and 7.5-10)).
- MÉRA agrees well with observations for the most variable days (10-15 range for VI); the lowest range shows a negative bias consistent with Fig. 3 – suggesting that cloud water loads are too high in the thickest clouds
- The DMI results are shown below – there are negative deviations in the model data for low CSI, low VI (upper left) and similarly for the high CSI values in the lower left panel.



4. Aerosols: Tegen vs CAMS

- Aerosol concentrations and inherent optical properties (IOPs) are needed for atmospheric radiative transfer calculations in NWP.
- The Tegen **[6]** and CAMS **[7]** climatologies differ in concentrations and IOPs. The difference in IOPs is illustrated in Fig. 6 and 7 which show the ratio of IFS AOD (aerosol optical depth) to AOD at 550 nm at a range of wavelengths for 4 aerosol categories, and the corresponding ratio of CAMS mass extinction (ME) to ME at 550 nm.

Fig. 6 – Tegen – default in HARMONIE-AROME

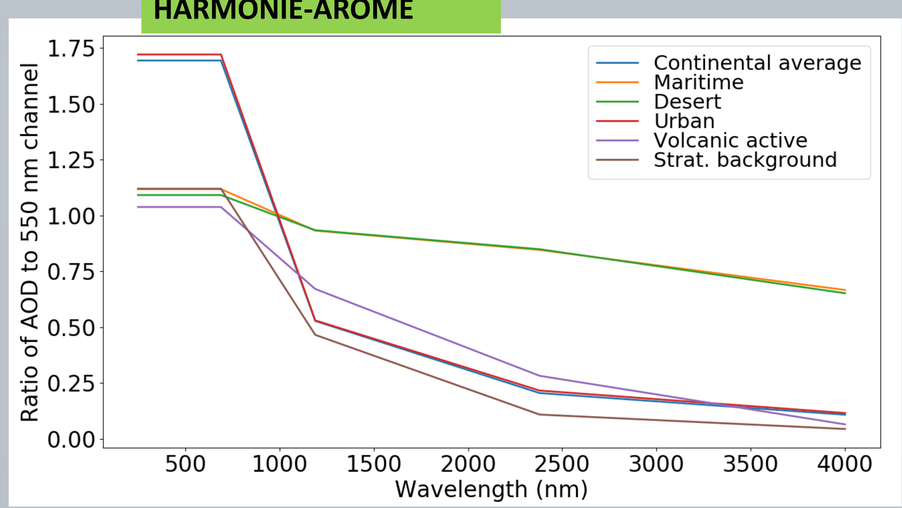
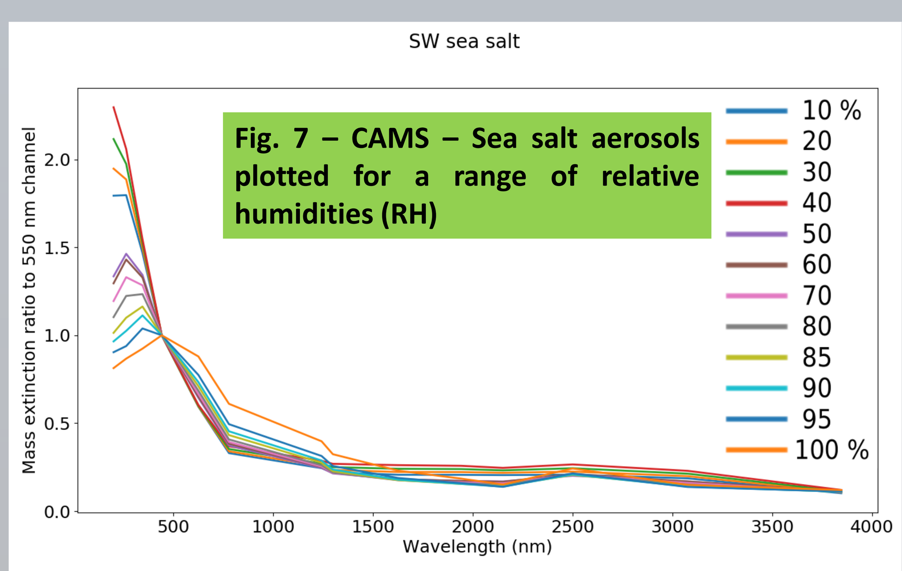


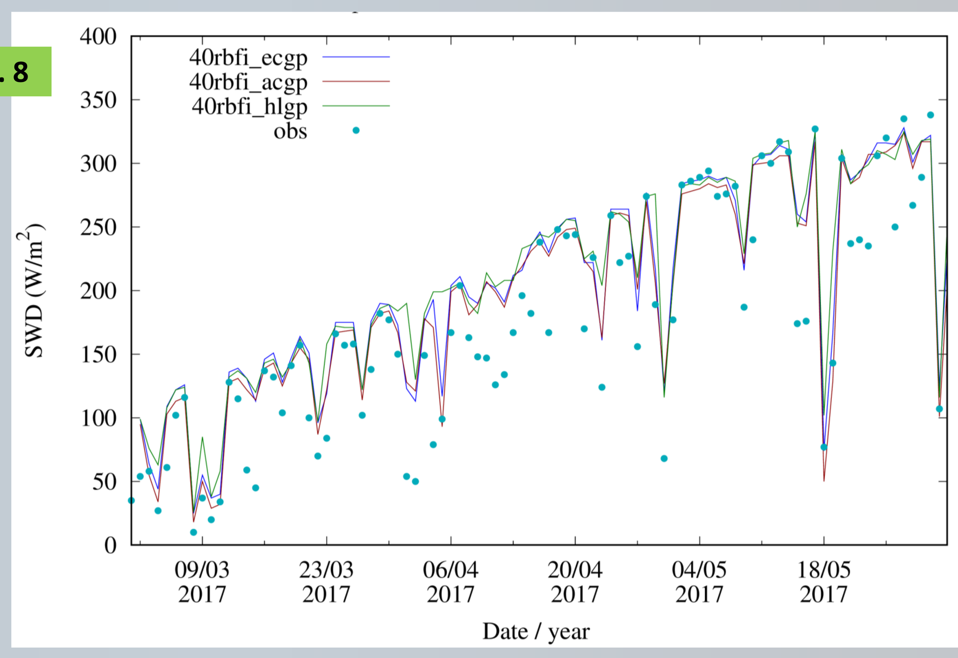
Fig. 7 – CAMS – Sea salt aerosols plotted for a range of relative humidities (RH)



- The notable difference in the behaviour of AOD indicates a need to improve the assumed IOPs in HARMONIE-AROME, in addition to updating the aerosol concentrations.

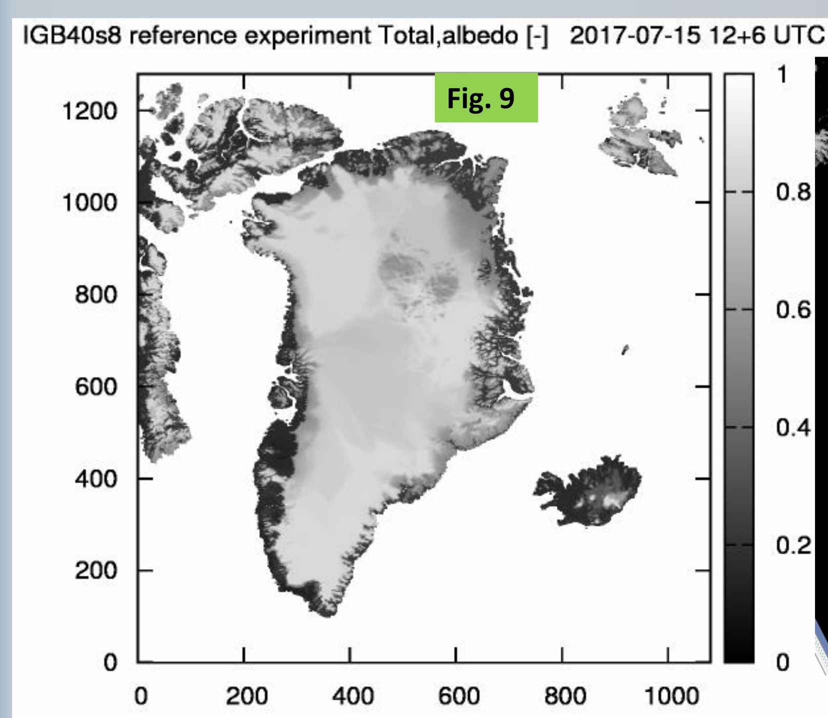
5. Radiation Scheme Comparison

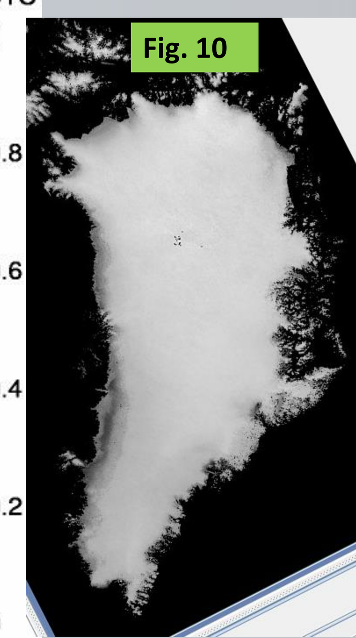
- HARMONIE-AROME run for Spring 2017 using the IFS cy25r (ec), ACRANEB2 (ac) and HLRADIA (hl) radiation schemes.
- Fig. 8 shows observed and modelled GHI at Utö in Finland, a station that represents open sea conditions.
- The forecasts using each scheme follow each other more closely than they follow the observed values. Observed daily averages tend to be lower than forecast, especially when the fluxes are small due to clouds or low solar elevation.
- Under clear skies the differences are small, with a slight underestimation of GHI by each scheme compared to observations.



6. Snow and Ice Albedo

- Since autumn 2016 DMI and IMO have initiated glaciers in their domains with 10000 kg/m^2 of snow on Sept. 1st.
- This is the recommended way for the ECOCLIMAP glacier cover type: "Permanent snow", and it removes the previously exposed glacier errors **[8]**.
- An example of the current HARMONIE "IGB" Greenland albedos in mid July is shown in Fig. 9, and can be compared with the MODIS July albedos shown in Fig. 10.





- It can be seen that the large dark exposed glacier ice area in Western Greenland is too bright in HARMONIE-AROME.
- Also, the dark patches on the interior ice sheet are not seen in the satellite-derived albedos. Here the aging effect on the snow albedo assumed in the D95 scheme **[9]** is clearly too high.
- The snow albedo aging effects for glacier snow are better in the CROCUS/ES **[10]** scheme, but these albedos are also too low (not shown).

7. Radiation / Microphysics Consistency in HARMONIE-AROME

- In IFS cy25r the scheme in [11] is used to parametrize the effective radius of cloud liquid particles. This scheme assumes CCN of 50 and 900 for marine and land aerosols.
- The microphysics parametrization assumes CCN of 100 and 300 for the same aerosol types. Such difference influence the effective radii of cloud liquid particles.
- Subgrid scale fractions of cloud water/ice are also inconsistent between the radiation and microphysics parametrizations.
- Testing is underway to harmonise what is used/available in each scheme.

References: **[1]** Gleeson & Whelan, ASR, 2017 **[2]** Nielsen & Gleeson, Atmosphere, 2018 **[3]** Perez et al., Solar Energy, 1990 **[4]** Stein et al., WREF Conference, 2012 **[5]** Savijarvi et al., J. Appl. Met. 1990 **[6]** Tegen et al., J. Geophys. Res. Atmos., 1997 **[7]** Bozzo et al., ECMWF, 2017 **[8]** Mottram et al., ASR, 2017 **[9]** Douville et al., Climate Dynamics, 1995 **[10]** Vionnet et al., GMD, 2012 **[11]** Martin et al., J. Atmos. Sci., 1994