Evaluation of surface solar irradiance forecasts by the NWP model AROME

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Context

- **Solar energy :**
  - promising source to transit towards a more sustainable energy system

IEA, 2018 ; EDF, 2019

  - intermittent energy source

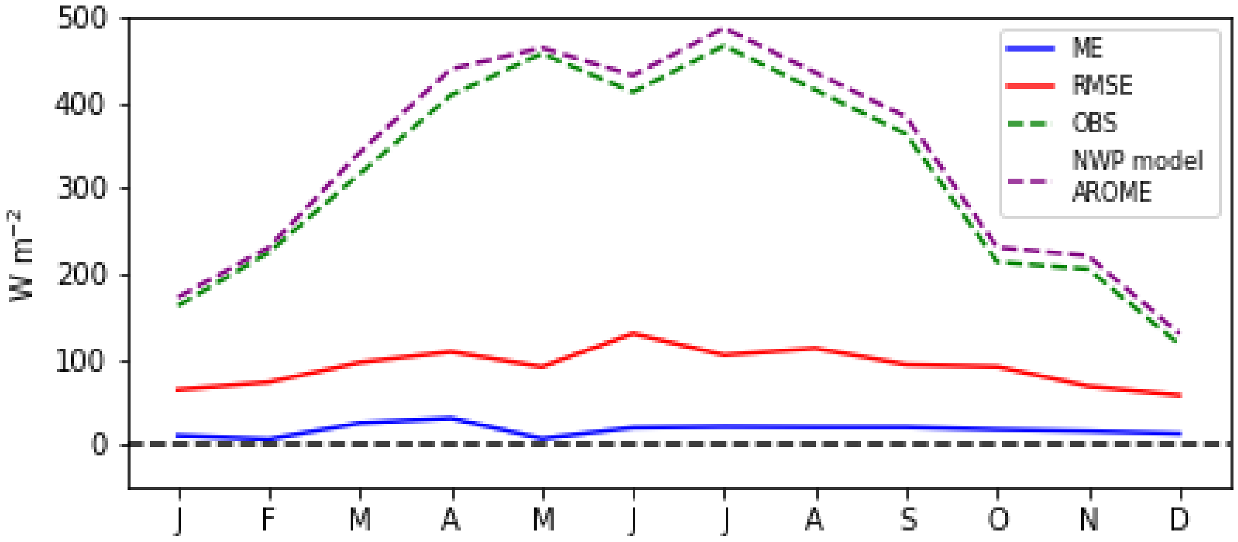
- **NWP models :**
  - are **essential** for a **better incorporation** of solar energy into the electrical grid

Delarue and Morris, 2015

  - have **significant errors** for **surface solar irradiance** (SWD)

- **Illustration for the NWP model AROME :**

Mean flux on year 2020 : 340 W m^{-2}
Bias on year 2020 : 18 W m^{-2}
RMSE on year 2020 : 97 W m^{-2}



Comparison between mean flux observed and in the NWP model AROME on year 2020 over France.

Objective and approach

- **Issues already highlighted :** Morcrette et al, 2002 ; Paquin-Ricard et al., 2009 ; Ahlgrimm and Forbes, 2012 ; Köhler et al., 2017 ; Nielsen and Gleeson, 2018 ; Weverberg et al., 2018 ; Tuononen et al., 2019

- **Several sources of errors already highlighted :** errors in cloud fraction, cloud optical thickness, aerosols, gaz absorption, water vapor, ...

Objective : Evaluation of surface solar irradiance forecasts by the NWP model AROME

Approach :

- Use one full year of AROME hourly forecasts
- Use in-situ SWD measurements from a network of pyranometers over all France
- Use cloud satellite observations to classify the cloud scenes

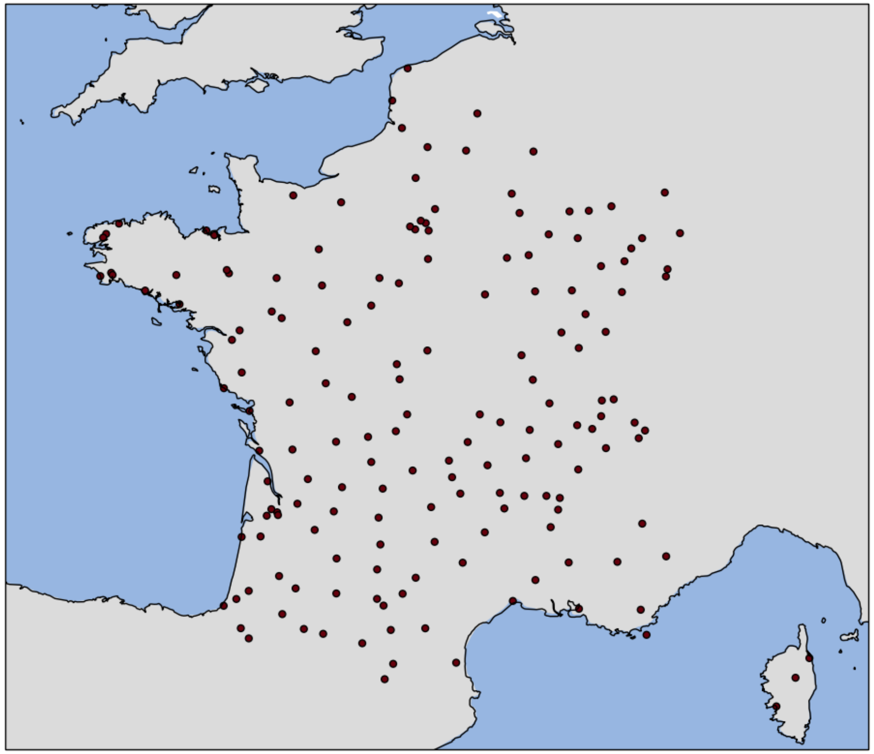
Methodology : model outputs and observations

Model : AROME 1,3km

- Over France
- Year 2020
- 24h forecasts
- Hourly output

Observations :

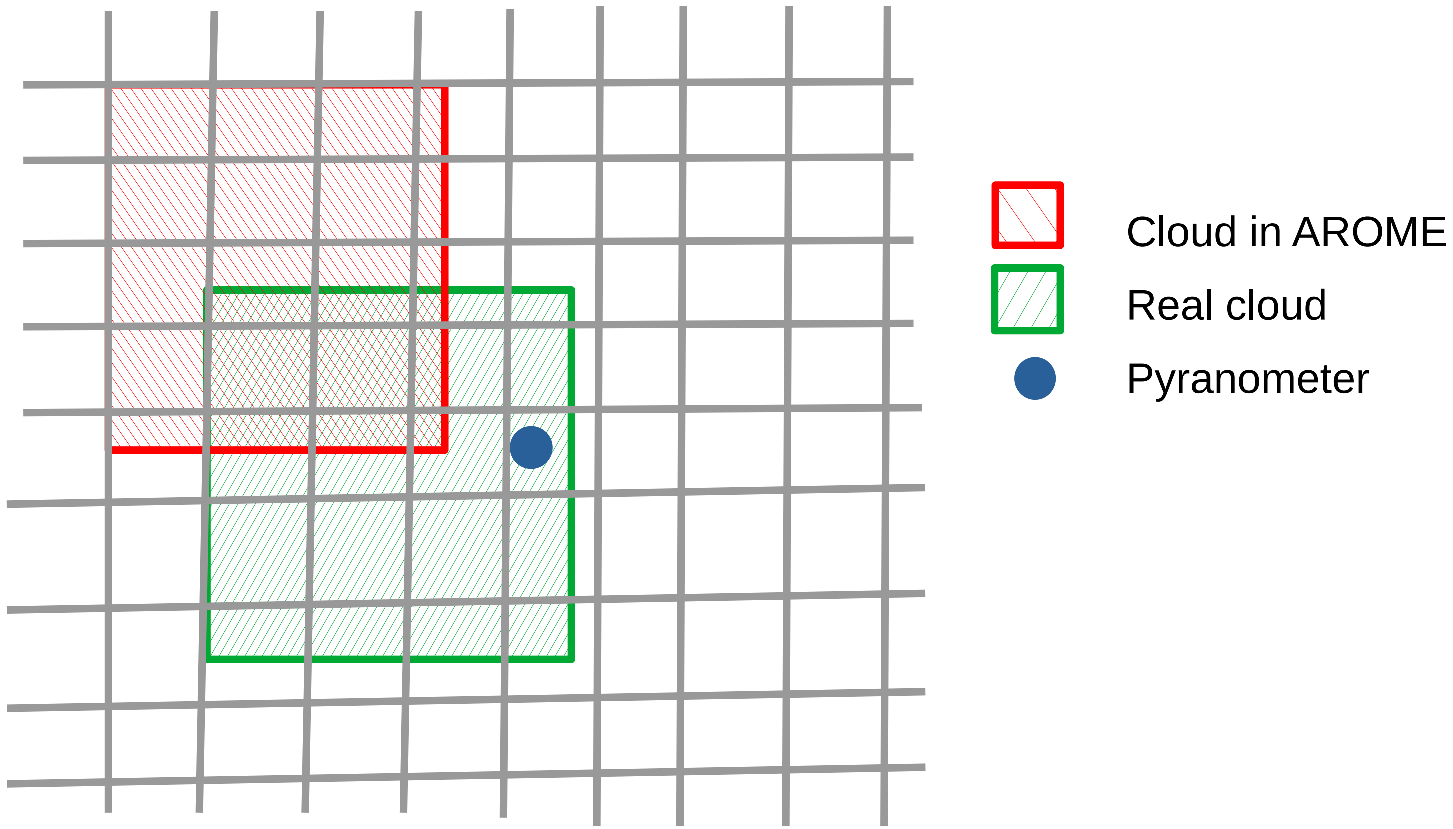
- ~ 180 high-quality pyranometers operated by Météo-France
- Hourly mean measurements



AROME domain and location of pyranometers

Methodology : model/observation comparison strategy

- **Point to point comparison is not adapted** (double penalty)

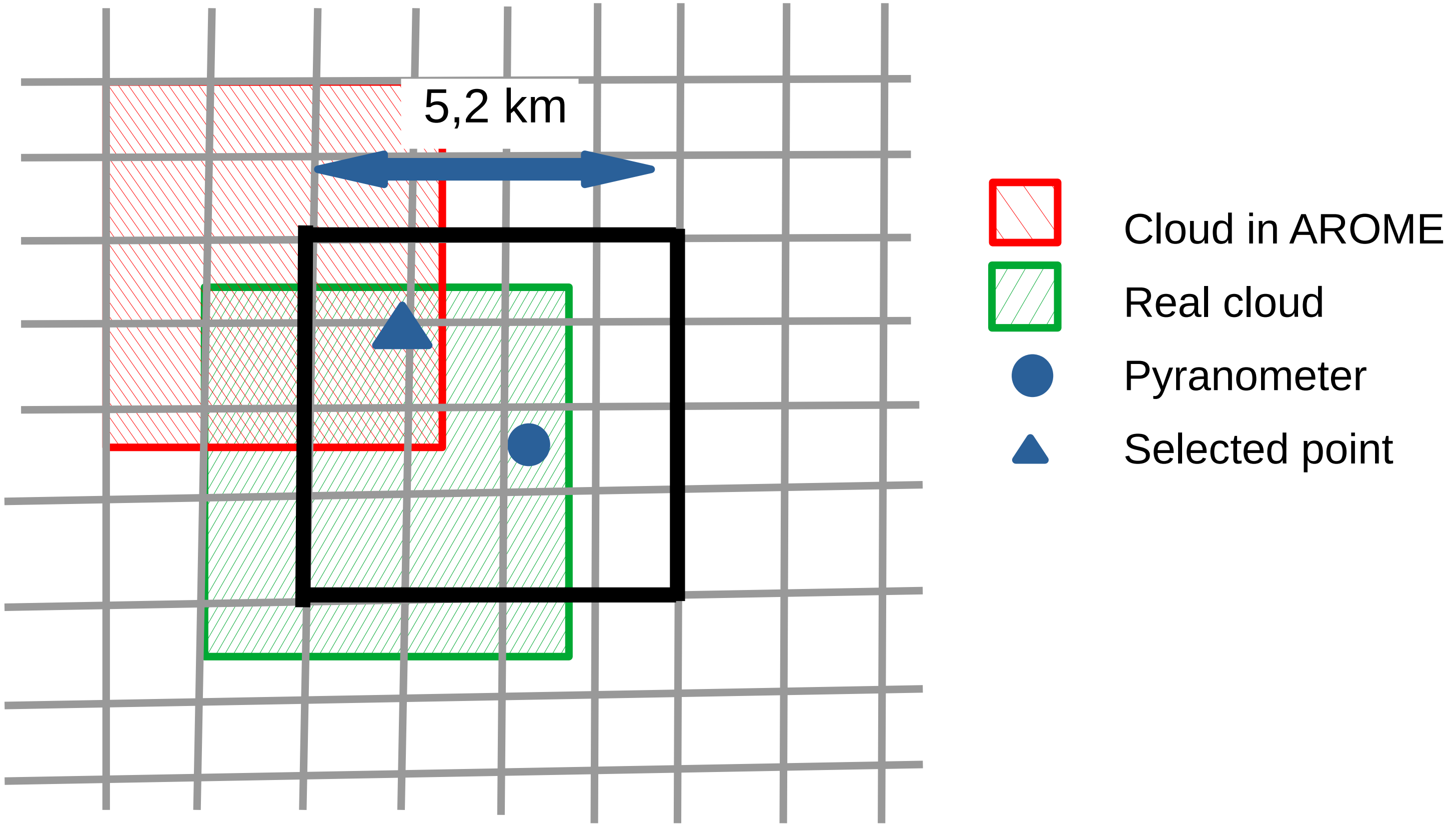


Methodology : model/observation comparison strategy

- **Point to point comparison is not adapted** (double penalty)

➡ Chosen strategy : neighborhood strategy

inspired from Amodei and Stein, 2007 ; Stein and Stoop, 2017



Methodology : defining cloud situations

First classification :

as in Tuononen, 2018

	OBS	AROME
Hit	Cloudy sky	Cloudy sky
False alarm	Clear sky	Cloudy sky
Miss	Cloudy sky	Clear sky
Correct negative	Clear sky	Clear sky

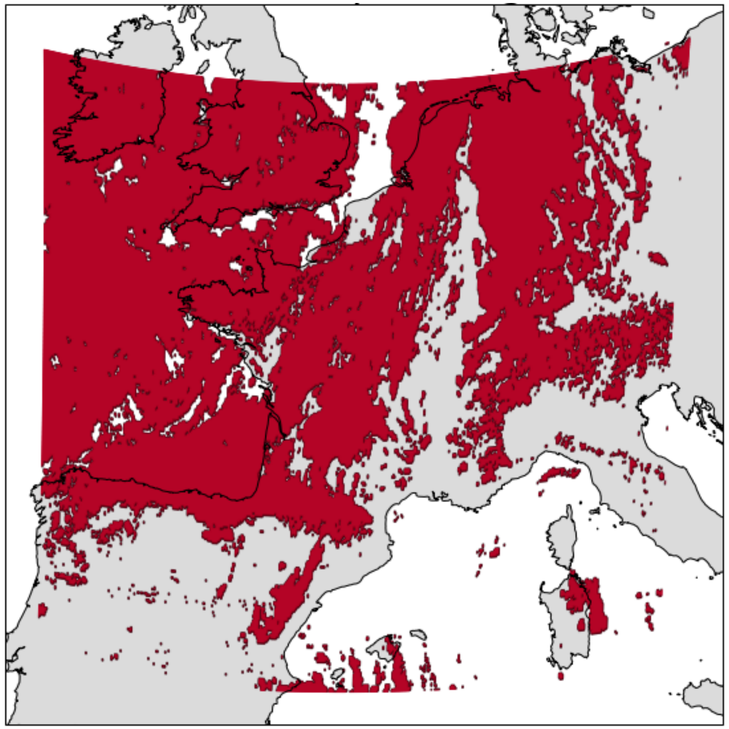
Methodology : identify cloud presence

- **In the observations :** from satellite product

SAF NWC* :

- Cloud mask
- 5km over France,
- Frequency : every 15 minutes
- Clear sky if no clouds during one hour

** http://www.nwcsaf.org*



Example of cloud mask product on AROME domain (the 01/12/2020 at 12 UTC). Clouds in red.

- **In the model :** when total cloud fraction > 2%

Methodology : defining cloud situations

Preliminary results :

	Occurrence (%)	Annual bias (W m^{-2})	STD of errors (W m^{-2})	Contribution to total bias (%)
Hit	66	24	**110**	**89**
False alarm	12	-9	54	**-6**
Miss	5	56	94	**14**
Correct negative	18	3	26	**3**
		Total	**95 W m^{-2}**	**18 W m^{-2}**

Errors mostly occur when clouds are present in the model and in the observations *consistent with Morcrette et al., 2002 ; Paquin-Ricard, 2009 ; Ahlgrimm, 2012 ; Weverberg, 2018 ; Tuononen, 2019*

Methodology : selecting overcast conditions

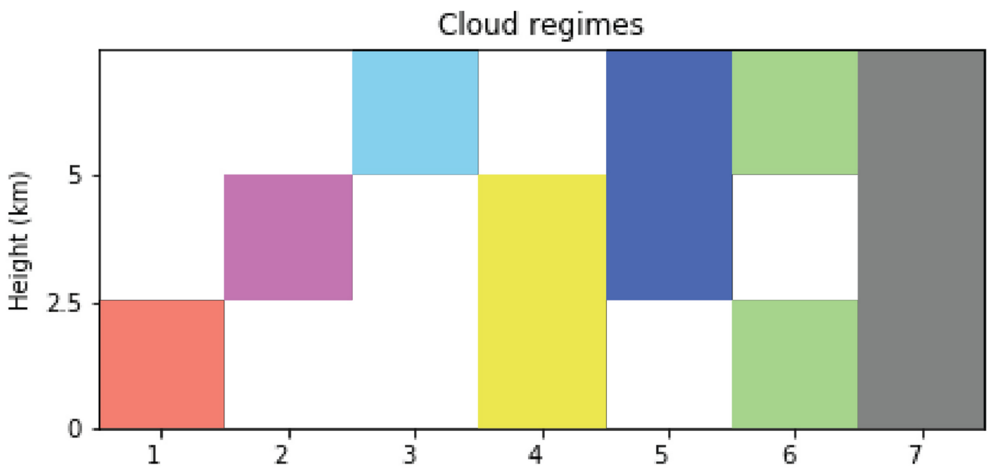
- Errors under cloudy conditions include **cloud fraction errors**
- **Cloud fraction difficult to evaluate** : no reliable observations at high temporal frequency and over a large domain

	Occurrence (%)	Annual bias (W m^{-2})	STD of errors (W m^{-2})
Hit (all cloud fraction)	66	24	**110**
Hit (only cloud fraction >0.95)	28 (43% of cloudy skies)	**1.1**	**101**

➡ **Low bias during overcast conditions** in the model but with persistent errors

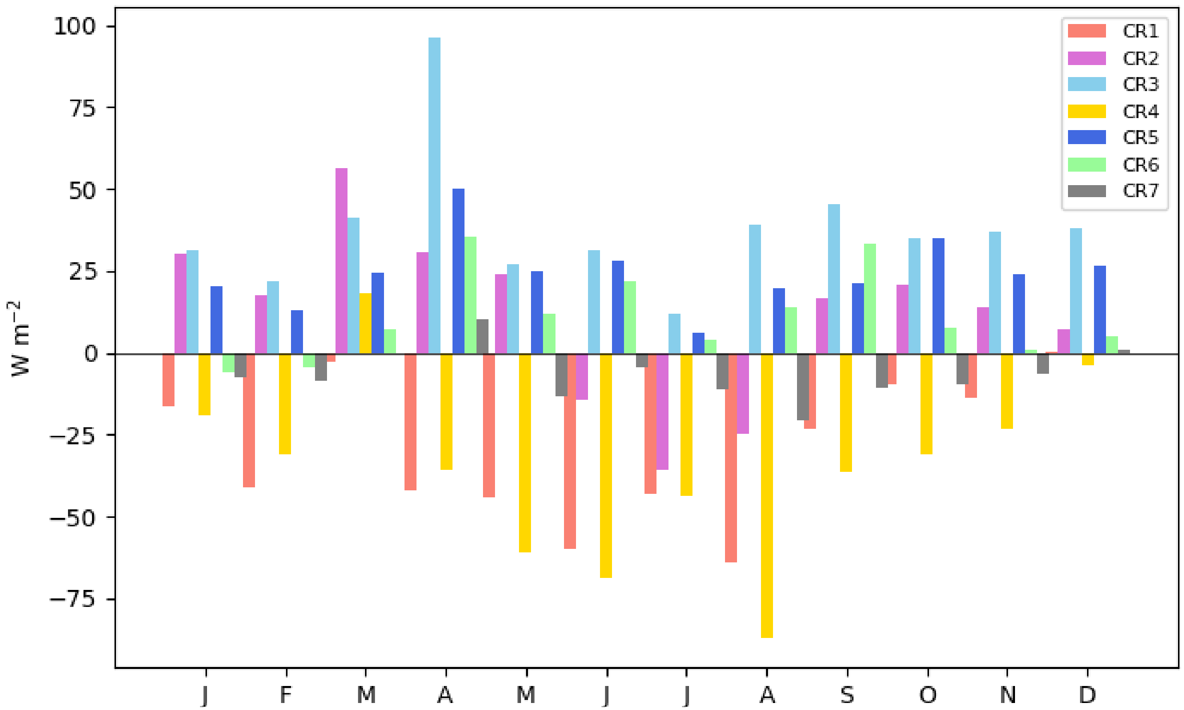
Identifying cloud regime in AROME

Cloud regime classification : *similar to Weverberg, 2018*

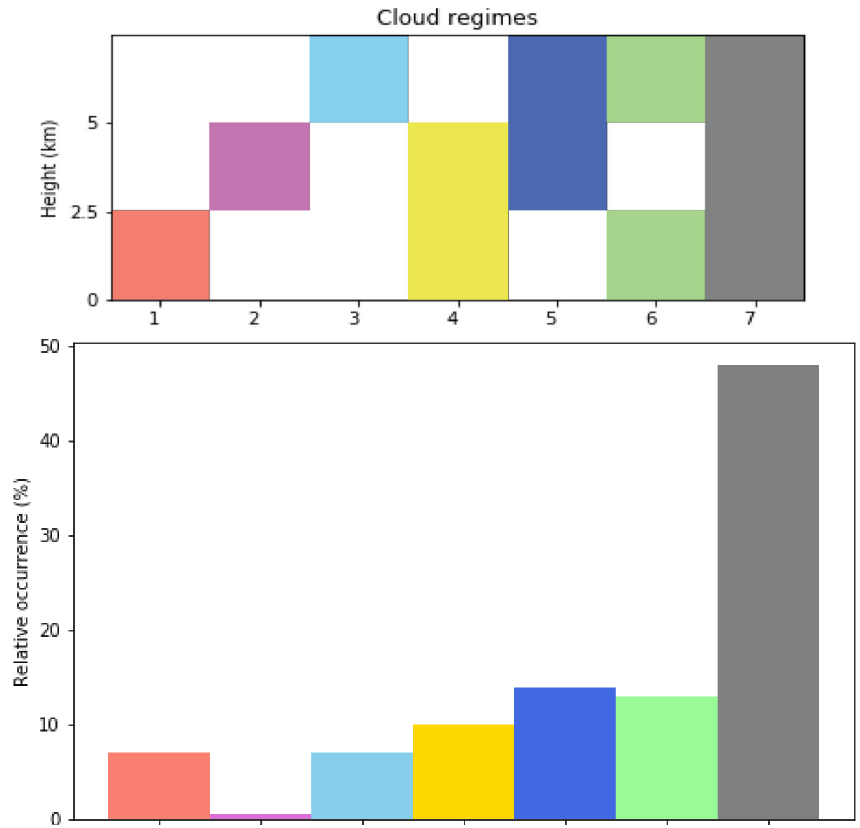


Overview of the cloud regime definitions. 7 cloud regimes based on nonzero cloud fraction in three vertical regions in the NWP model

Identifying cloud regime in AROME : results



Biais for each cloud regime on year 2020

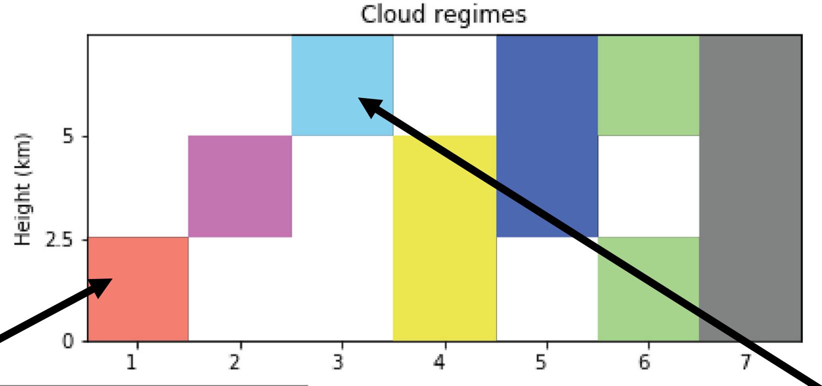


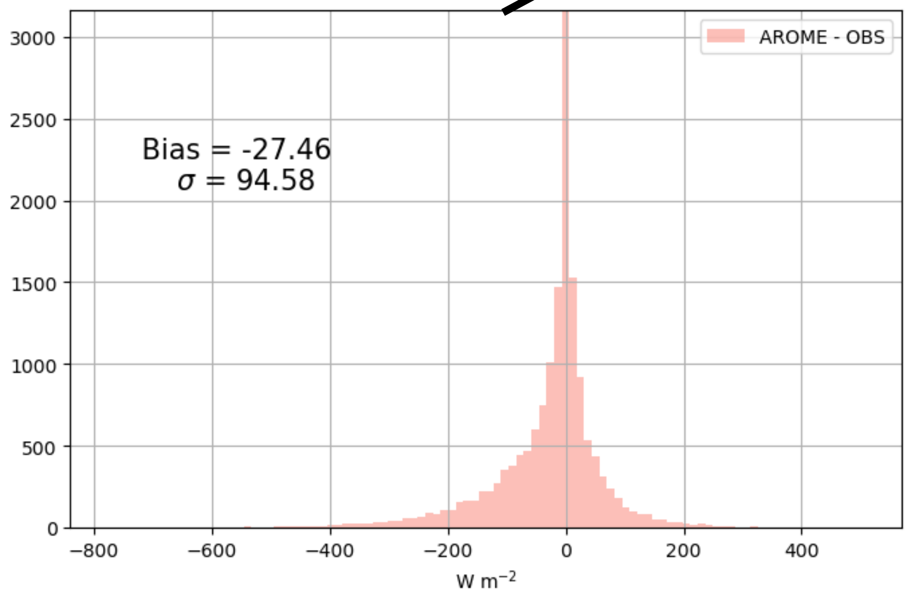
Relative occurrence for each cloud regime on year 2020

Large contribution to SWD errors when **high clouds** are simulated by AROME with a positive bias over the year (CR3, CR5, CR6)

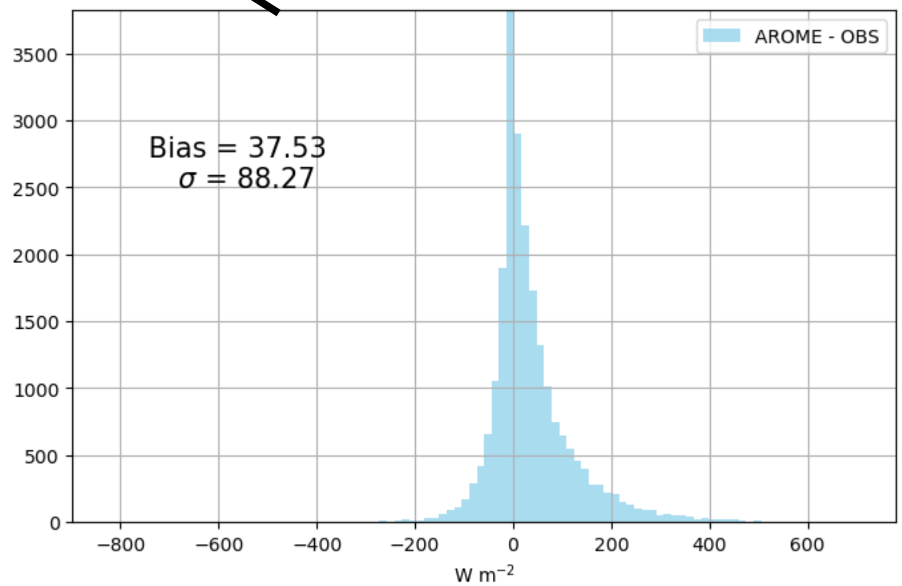
Negative bias during low clouds (CR1, CR4) with a pronounced seasonal cycle

Identifying cloud regime in AROME : results





Distribution of errors AROME – OBS on year 2020 for CR1



Distribution of errors AROME – OBS on year 2020 for CR3

➡ **Large standard deviation of errors** σ for each cloud regimes

Conclusion and perspectives

- **Low overall slightly positive bias in overcast** conditions but resulting **from significant compensating errors** (sign of bias depending on cloud regime : positive for high clouds and negative for low clouds)

- **Significant RMSE in all cloud conditions :** critical for the energy sector which needs hourly or day-ahead forecasts

- **Next step : focusing on high clouds**
  - High clouds largely contribute to errors
  - Potentials sources of errors :
    - ➡ **Not accounting for snow** in the radiation scheme of AROME
      shown by Li et al, 2014 ; Li et al., 2022
    - ➡ Too low total IWP in AROME (**crystals sediment too quickly**)
      shown by Wurtz et al., 2022

- **Extending methodology** to other classification based on observations, to go further in the cloud regime classification, ...

Thank you for your attention !

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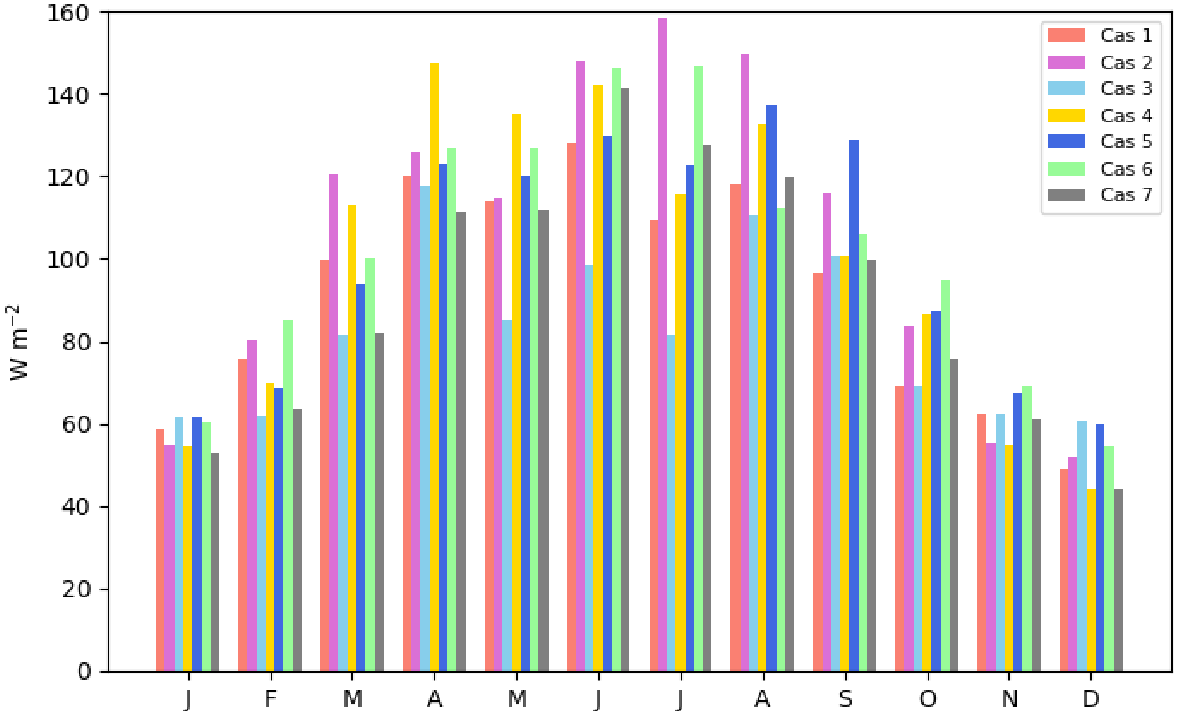
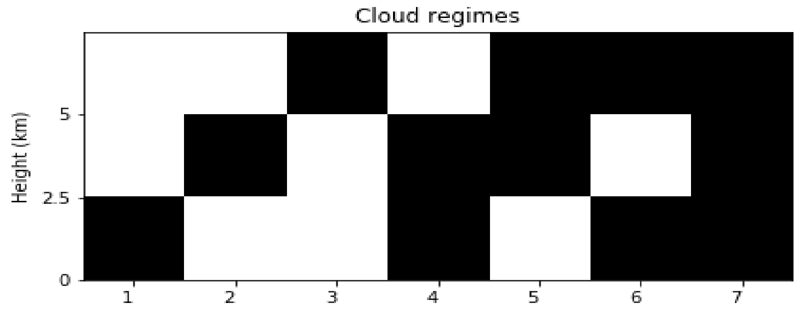
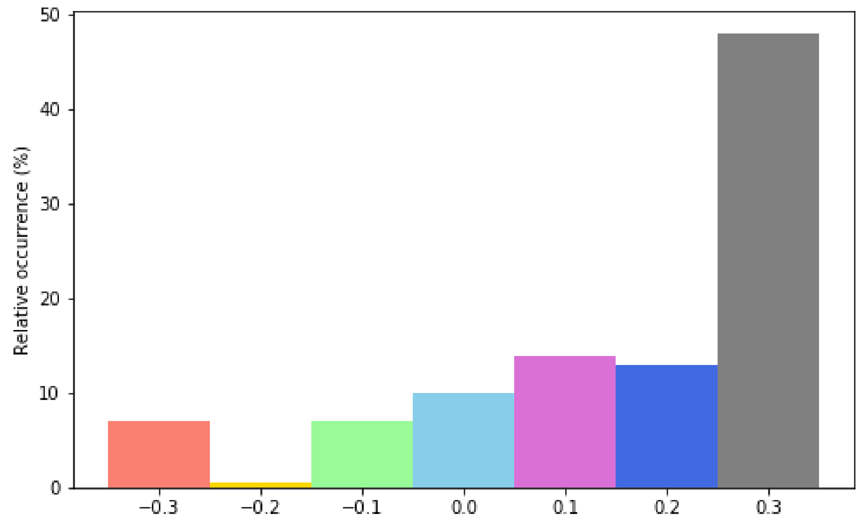
Annexe

Identifying cloud regime in AROME : results



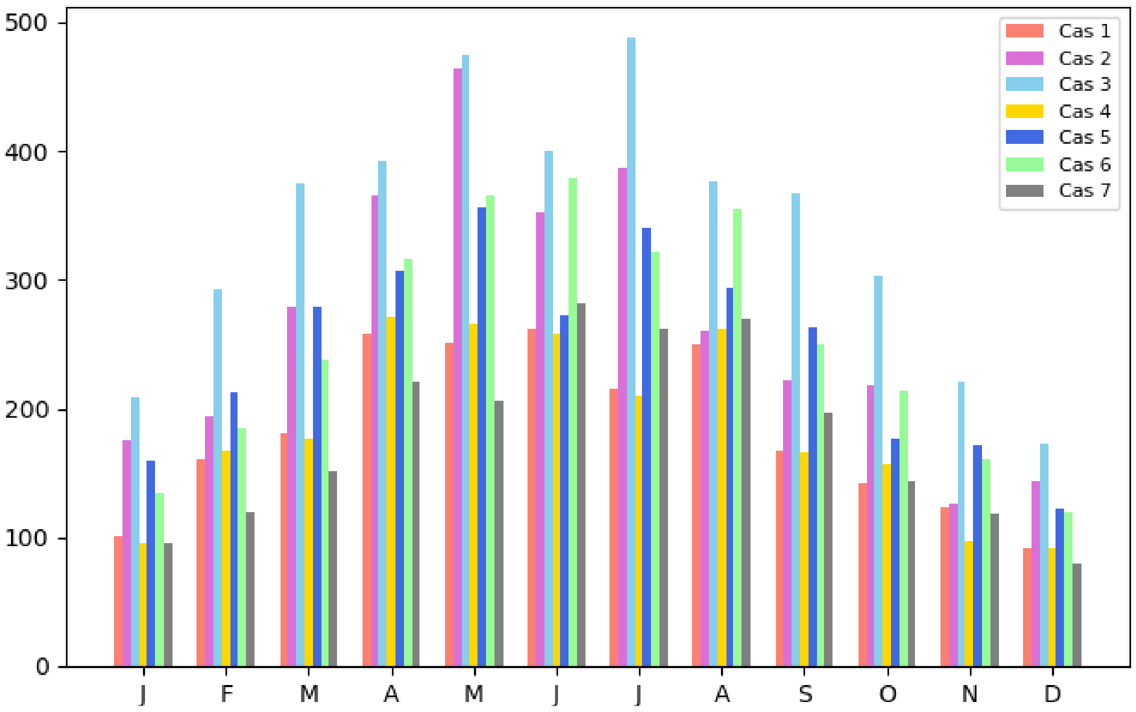
STD of errors for each cloud regime on year 2020



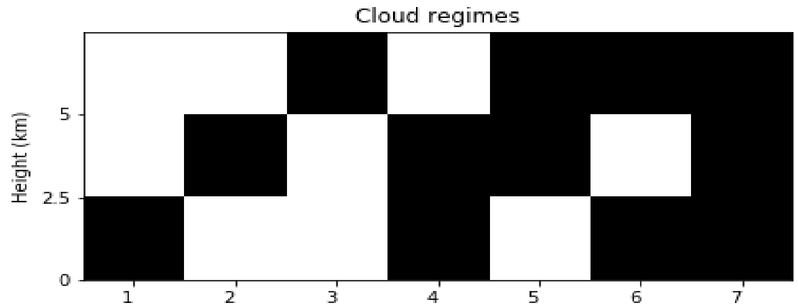


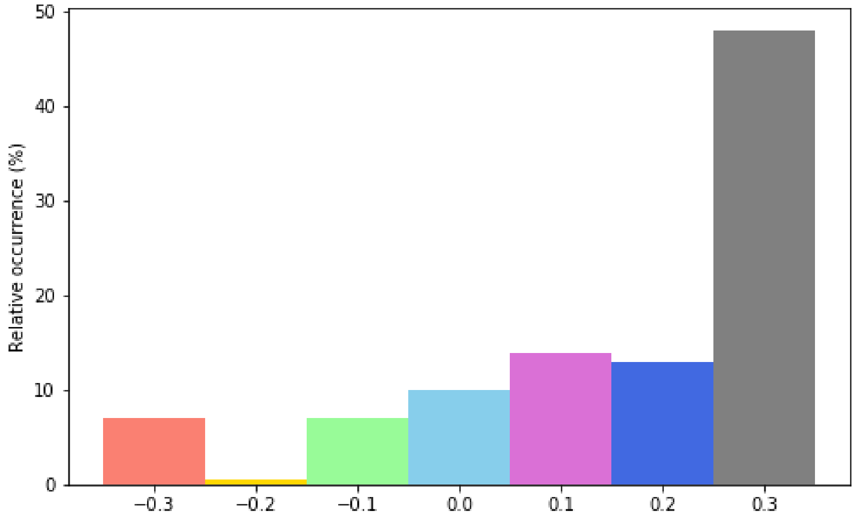
Relative occurrence for each cloud regime on year 2020

Identifying cloud regime in AROME : results



Mean observed flux for each cloud regime on year 2020





Relative occurrence for each cloud regime on year 2020