Spatio-Temporal Variability Of Clouds And Associated Shortwave Radiative Effects In West Africa With A Satellite-based And Reanalysis Data

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BACKGROUND

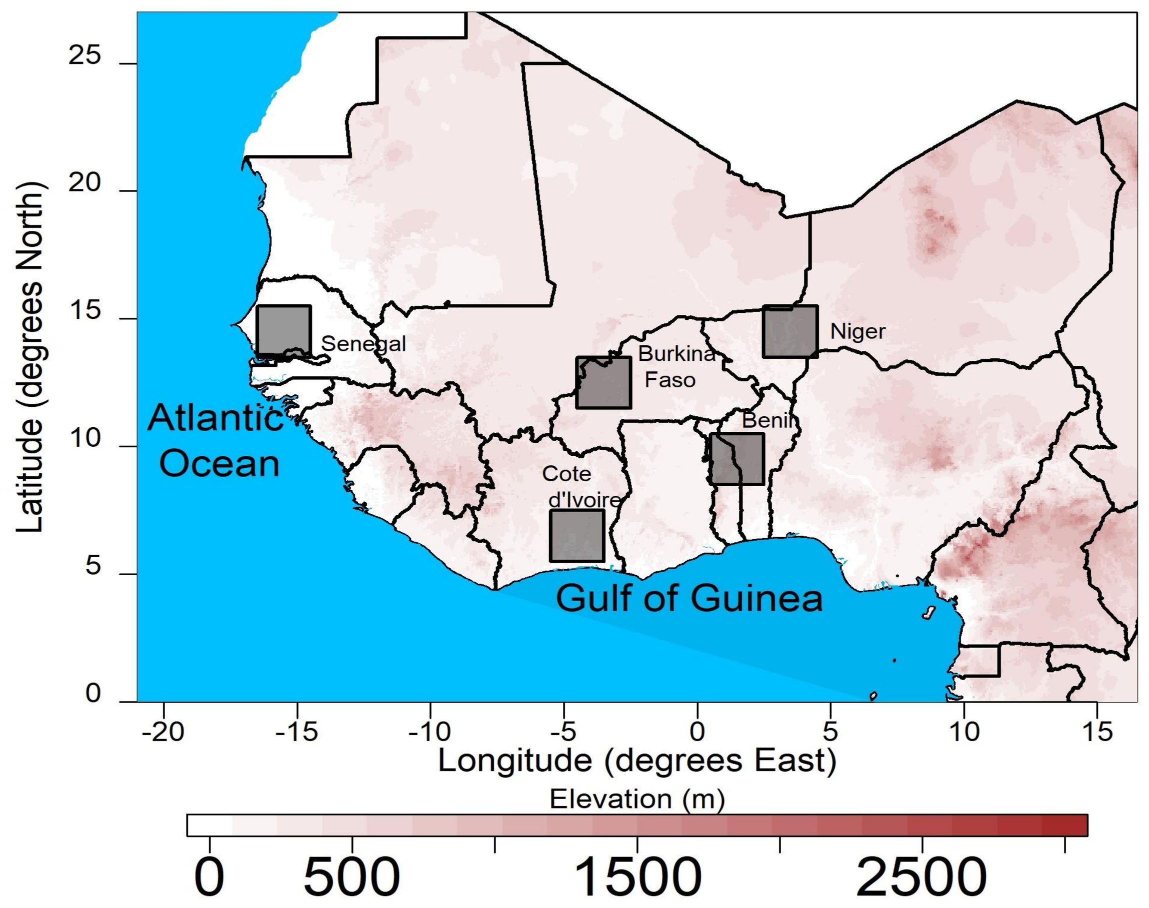
After the Paris Agreement in 2015, many governments and industries have shown great interest in projects dealing with solar photovoltaic (PV) energy and its implementation in West Africa (WA). Nevertheless, many areas in WA present some drawbacks for solar PV energy generation due to intense cloud cover and crustal dust. Cloud cover in particular is highly variable in both space and time, and can significantly decrease the amount of solar radiation received on solar PV panels when in the sun's path. This work presents a climatology of clouds' variability and occurrence frequency in WA essential for assessing feasibility of planned large-scale solar PV energy projects. The annual cycle of lost incoming solar radiation due to clouds is also presented for different areas in WA.

DATA AND METHODOLOGY

- **E**uropean **C**entre for **M**edium-Range **W**eather Forecasts **Re**Analysis 5th generation (ERA5)
- **C**louds and the **E**arth's **R**adiant **E**nergy **S**ystem (CERES) SYN1deg passive satellite observations
- Low-, mid- and high-level clouds as well as total clouds cover and incoming downwelling solar radiation (shortwave) are extracted from ERA5 and CERES over the study region.
- Incoming solar radiation ($SW\downarrow$) lost due to clouds (Cloud Shortwave Radiative Effect ($CRE_{SW\downarrow}$)) is computed and expressed as a percentage of the theoretical value for incoming solar radiation when there are no clouds ($SW\downarrow_{CS}$):

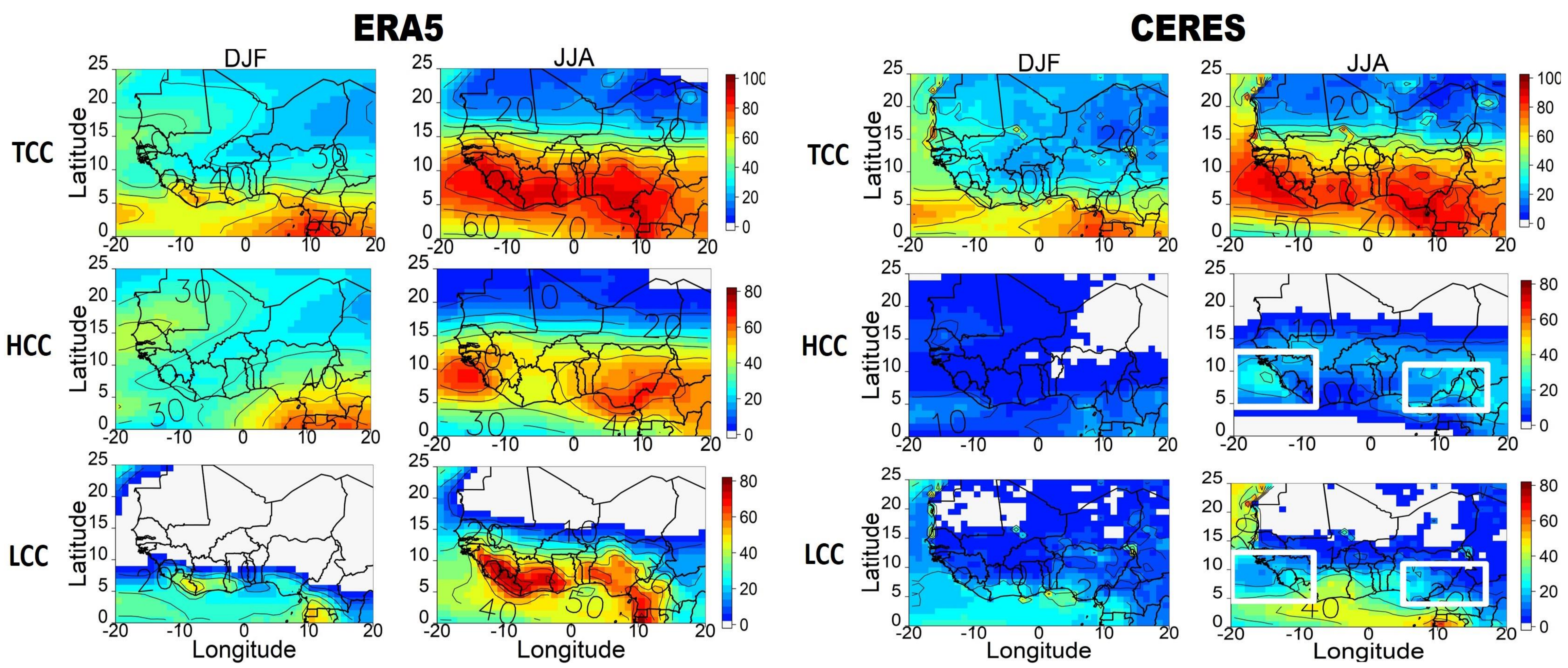
$$CRE_{SW\downarrow} = \frac{1}{n}\sum_{i=1}^{n}\frac{SW\downarrow(t) - SW\downarrow_{CS}(t)}{SW\downarrow_{CS}(t)} \times 100$$

- Daytime hours only (06h to 17h)



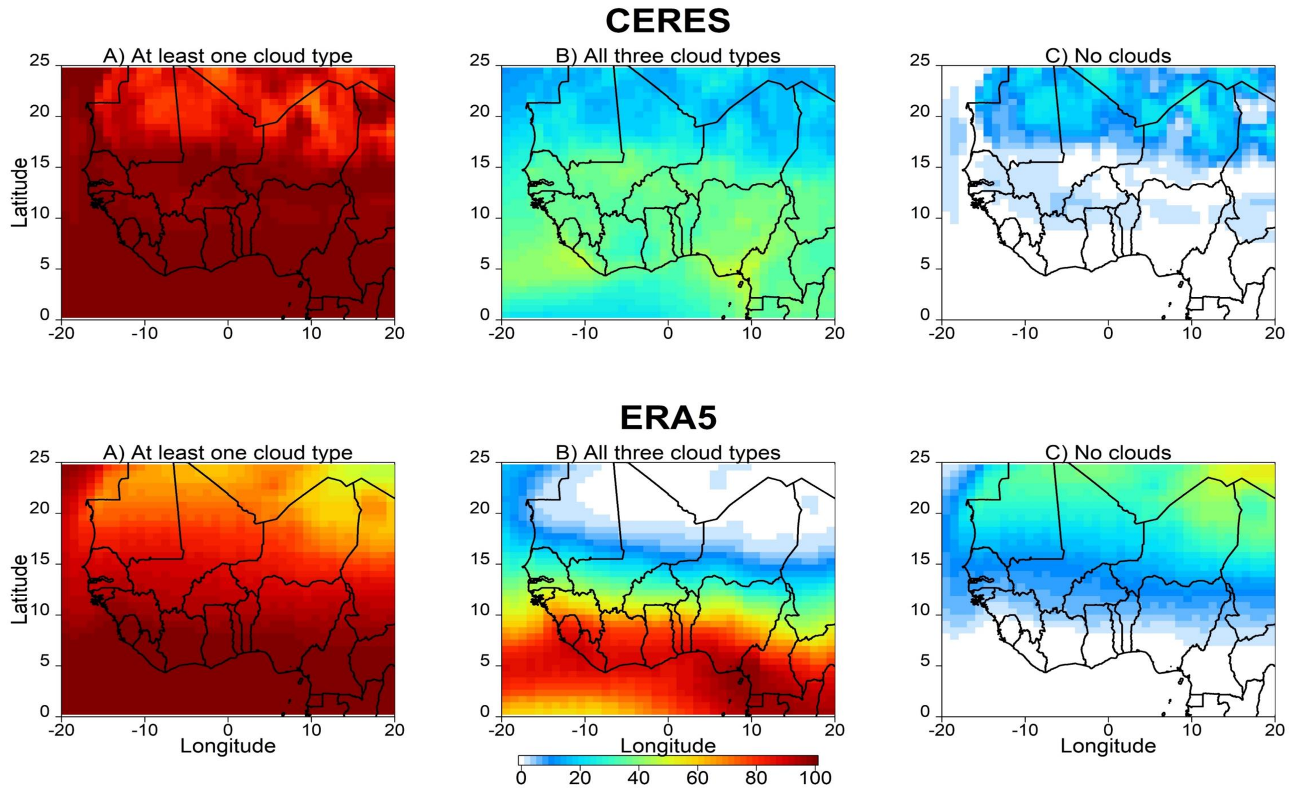
Map of West Africa with locations of 5 grid boxes selected for the estimation of CRE.

SEASONAL MEAN CLOUD COVER FRACTION

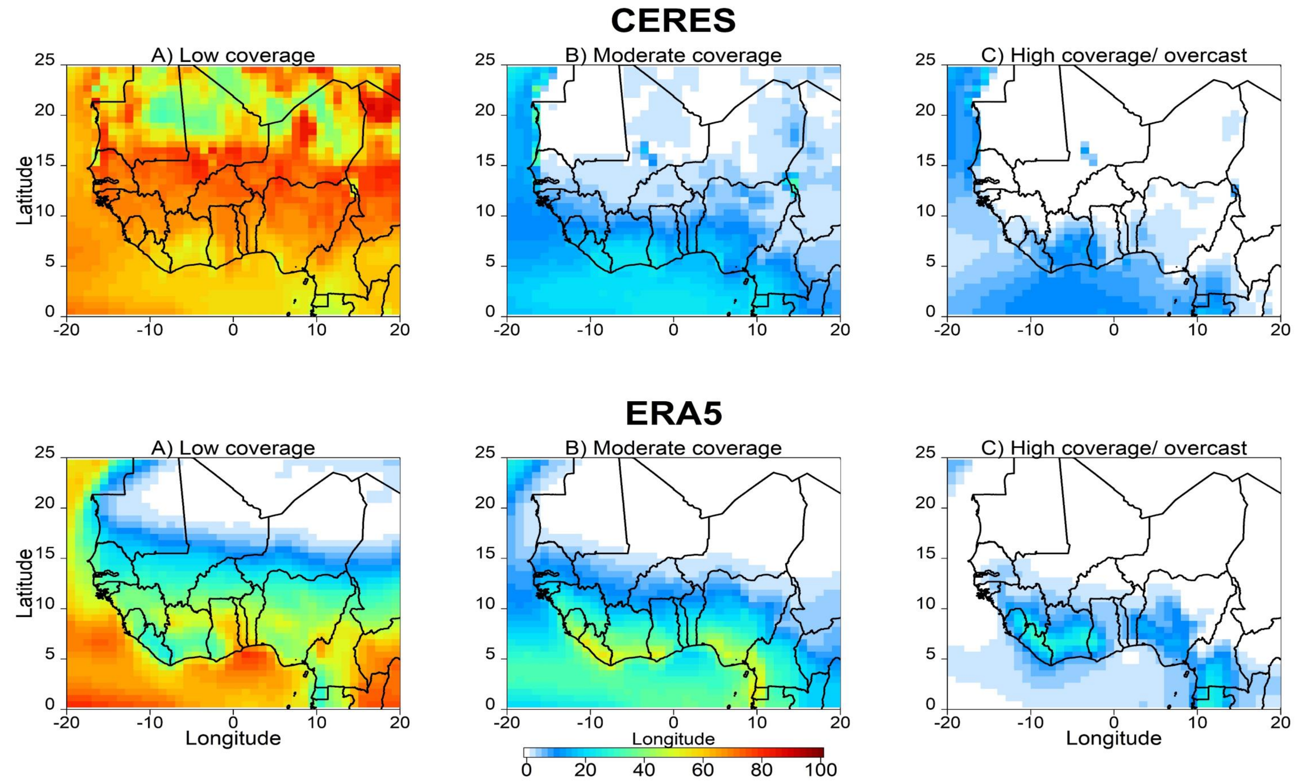


- Clouds strengthen in JJA (monsoon) over southern WA (both ERA5 and CERES).
- Strong N-S LCC gradient in ERA5 (seasonal evolution appears to follow ITCZ evolution) but not in CERES.
- Low values of HCC by CERES linked to the instruments' difficulty to detect optically thin clouds in the atmosphere.
- LCC over Sahara/Sahel region even in DJF in CERES: Possibly due to misinterpretation of Saharan dust as low clouds by the CERES instruments.

CLOUD OCCURRENCE FREQUENCY

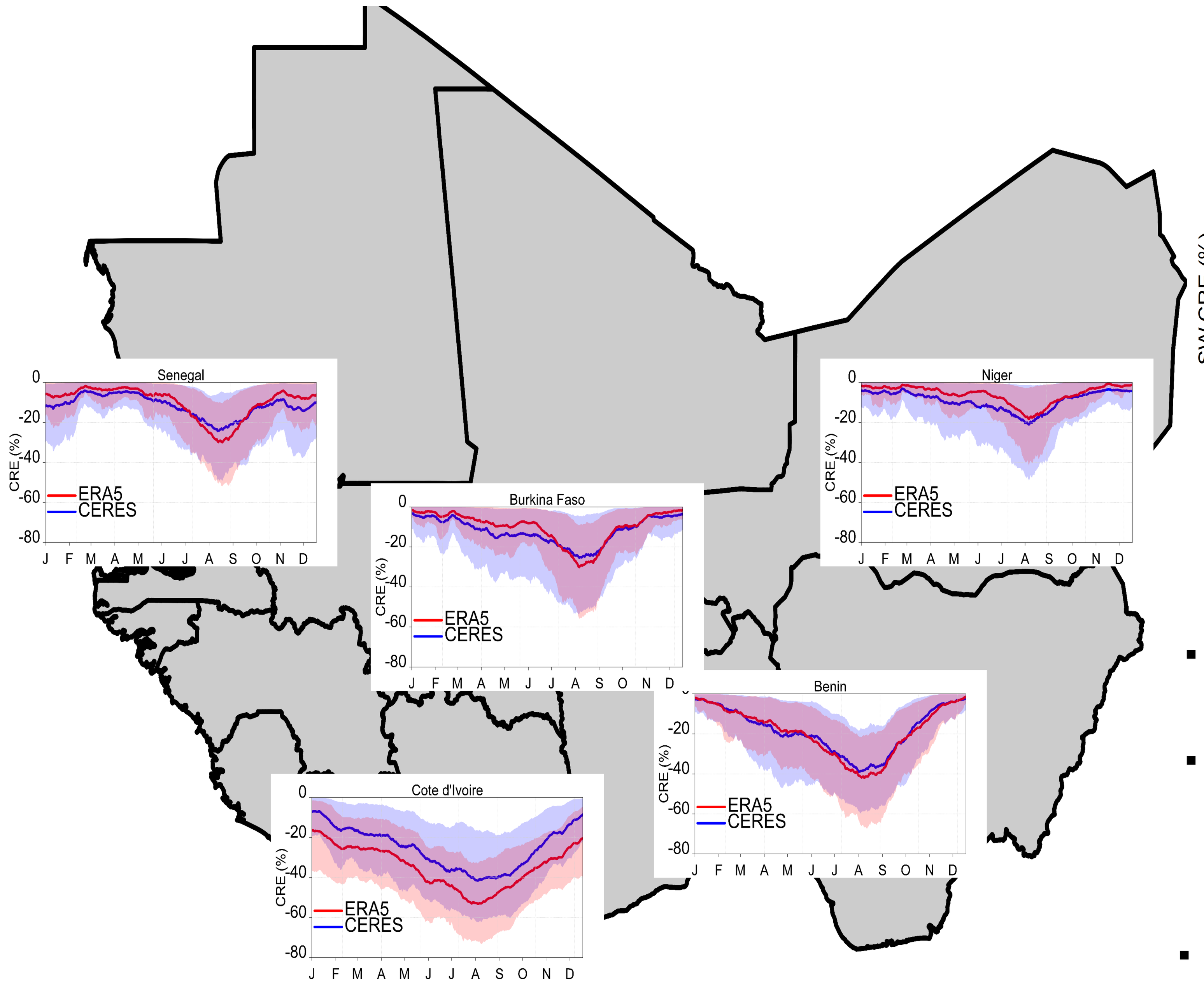


Climatologies of occurrence frequency (percentage of events out of total observations) for (a) at least one cloud type presence, (b) all three cloud types presence and (c) no cloud presence, over WA. Computed with ERA5



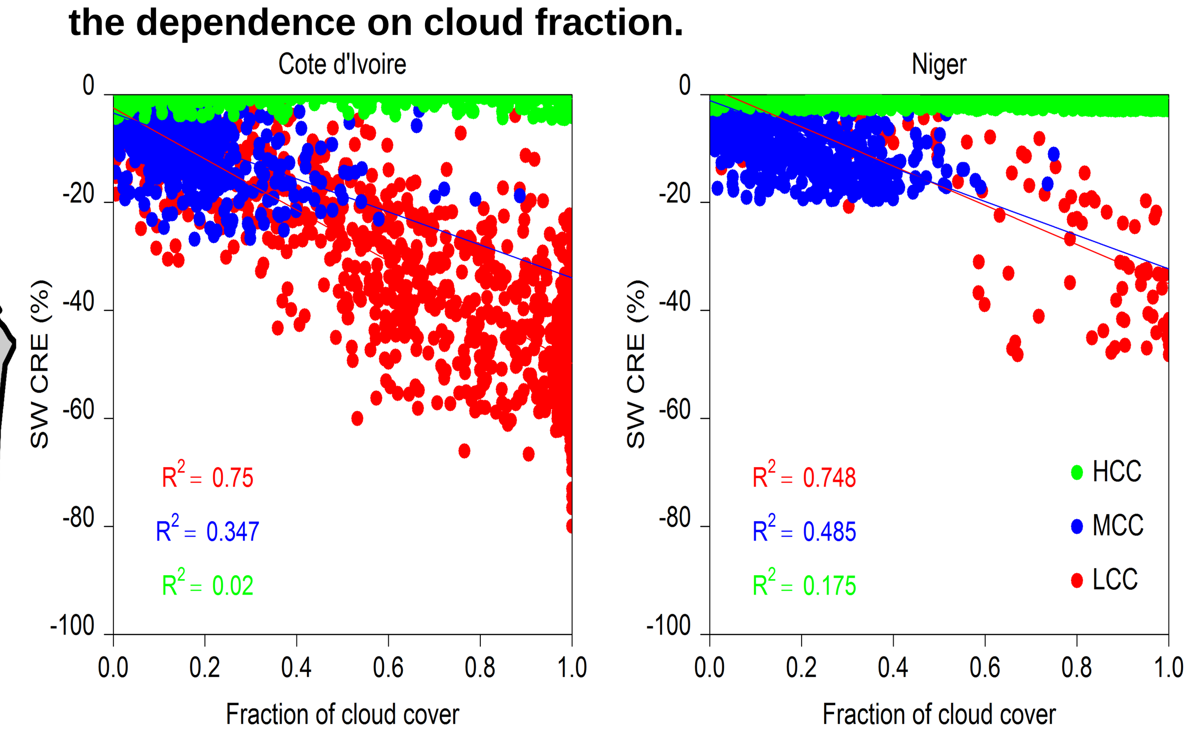
Climatologies of occurrence frequency of LCC with respect to cloud fraction (CF).
[Low coverage = CF < 40%, Moderate coverage = 40% ≤ CF < 80%, High coverage = CF ≥ 80%].

CLOUD SHORTWAVE RADIATIVE EFFECT IN WA



Average annual cycle of percentage of incoming solar radiation lost due to clouds in selected windows (upper and lower bounds of the shaded areas represent the 90th and 10th percentiles of the percentage losses).

Percentage of lost incoming solar radiation by cloud types and the dependence on cloud fraction.



- Low-level clouds lead to the highest losses of incoming solar radiation followed by mid-level clouds.
- Incoming solar radiation loss dependence on cloud fraction is:
  - higher in low-level clouds.
  - non-existent for high-level clouds.
- Largest losses of incoming solar radiation experienced in JJAS (monsoon) season in all windows.
- Losses of incoming solar radiation are higher in southern WA due to intense cloudiness.

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