Cloud regime analysis over Central Europe based on 14 years of satellite data

V. Tzallas[1], A. Hünerbein[1], H. Deneke[1], M. Stengel[2], J.F. Meirink[3], N. Benas[3], J. Trentmann[2]

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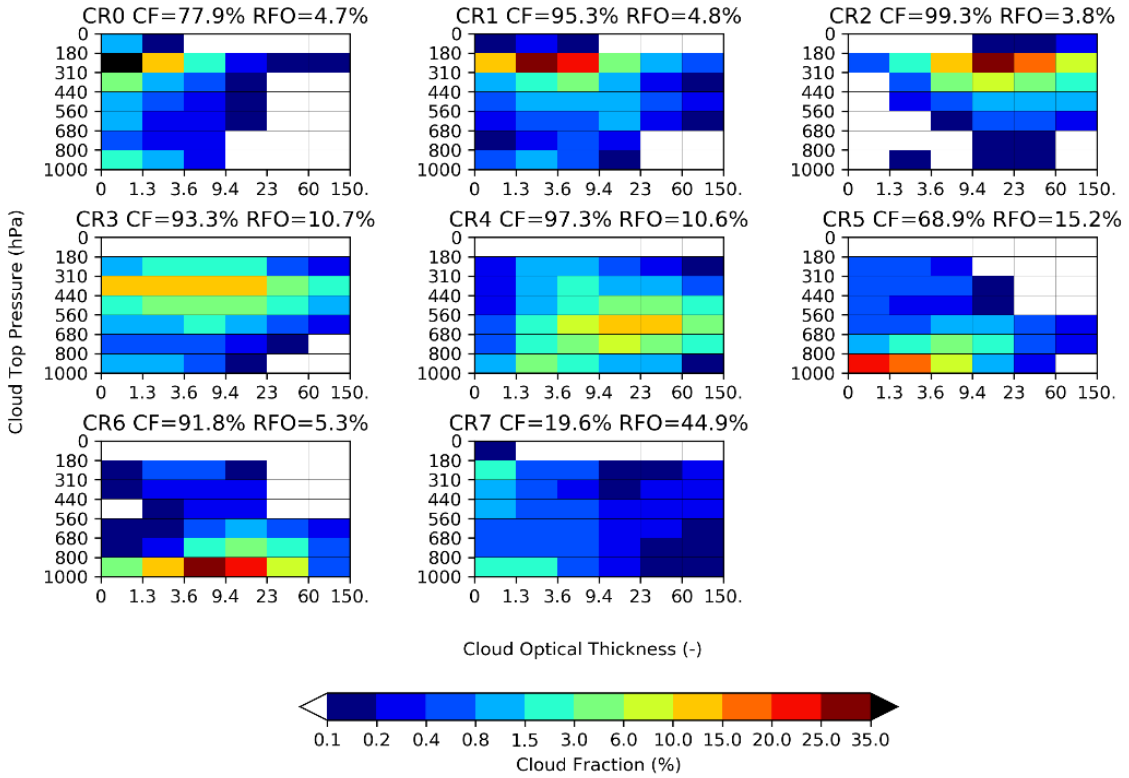
Centroids of the Cloud Regimes



Produced after applying the k-means clustering algorithm to cloud optical property data from the CLAAS-2.1 data record (produced by CM SAF). A methodology similar to Jakob and Tselioudis, 2003, and Oreopoulos et al., 2016 was followed.

The centroids can be considered as the representative 2-D histograms of each cloud regime. The cloud regimes can be associated to specific cloud types as follows:

- CR0 & CR1: Cirrus and some deeper clouds
- CR2: Frontal convection
- CR3: Alto- and nimbo-type clouds
- CR4: Midlevel clouds
- CR5: Shallow cumulus
- CR6: Stratocumulus
- CR7: Clouds with no specific shape / “fair weather” cloud regime

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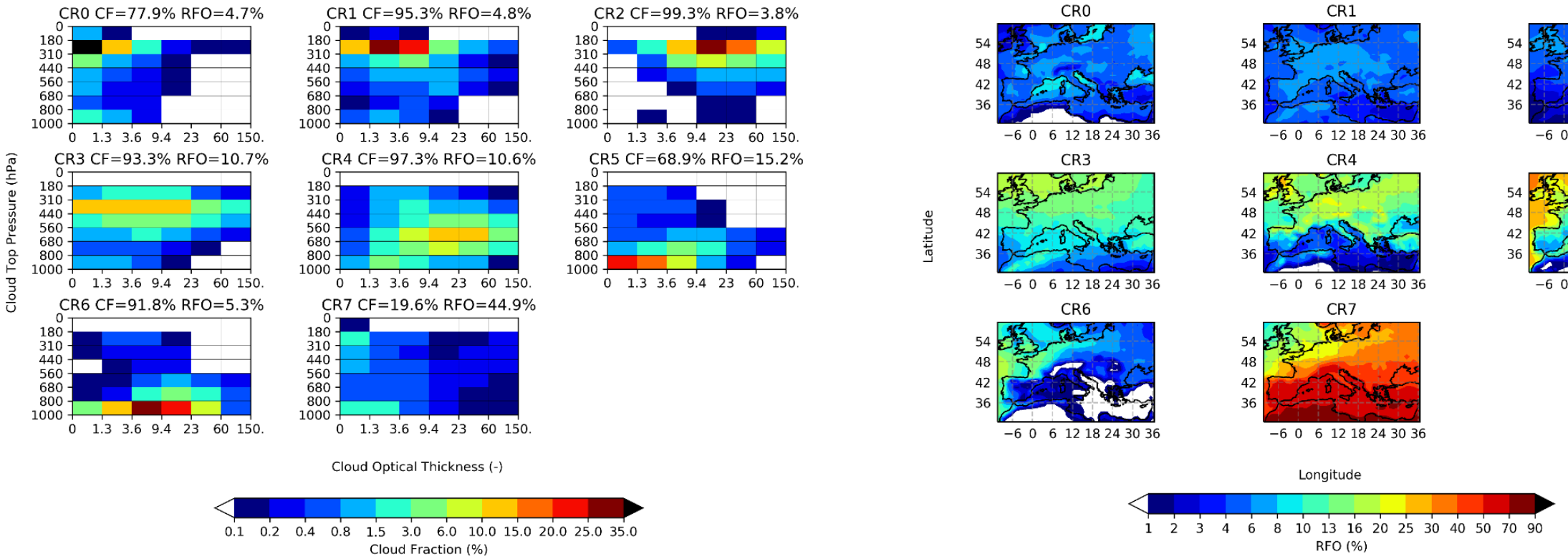
Cloud Regime Relative Frequency of Occurrence



- On the right, next to the corresponding centroids of the 8 cloud regimes, the geographical variability of the multiannual (2004-2017) mean RFO is shown.

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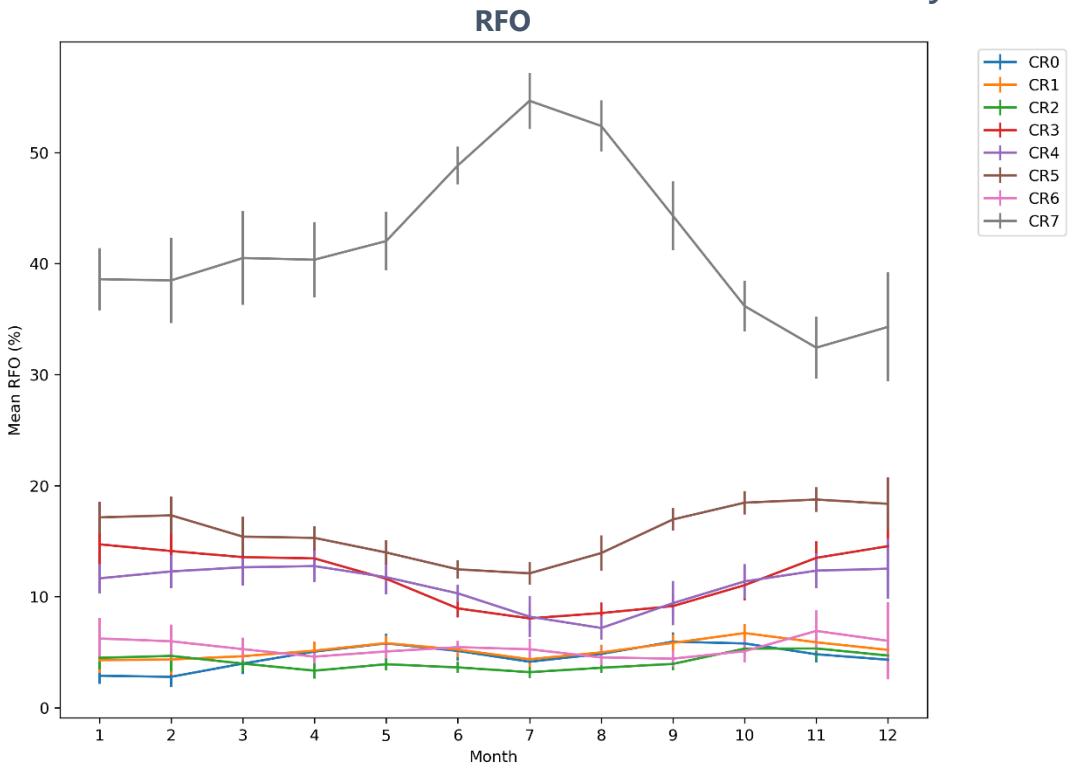
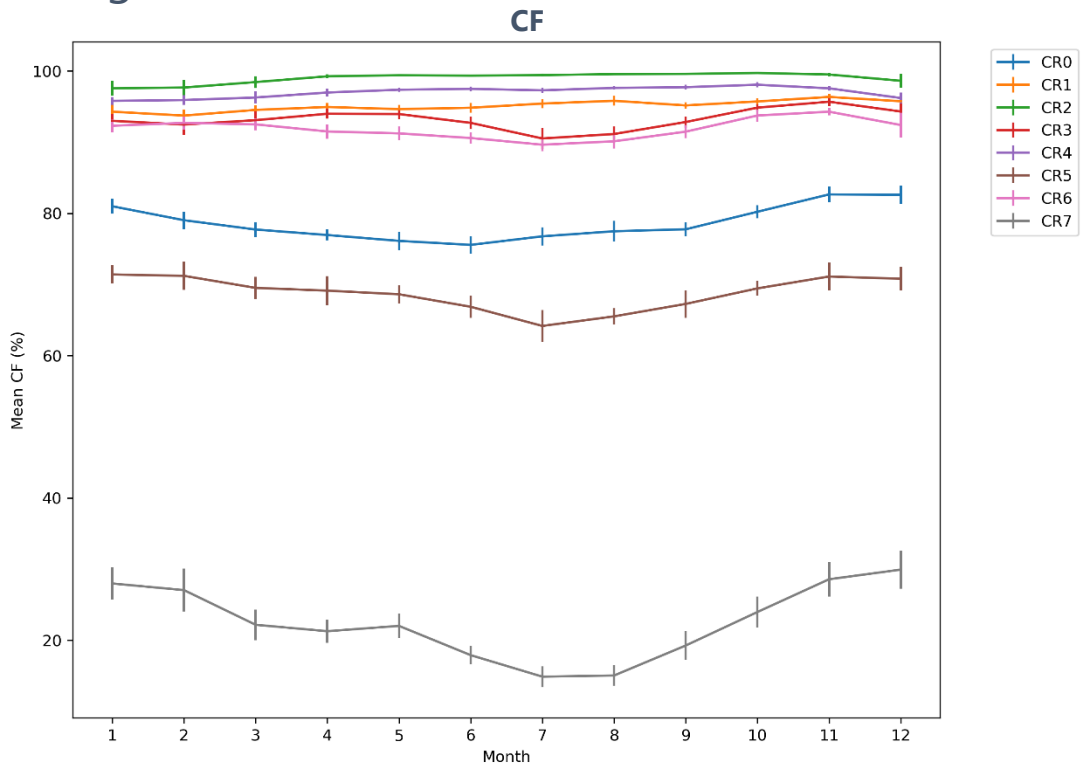
Annual cycle of the Cloud Regimes





- The Relative Frequency of Occurrence is dominated by CR7, which has a very pronounced annual cycle reaching up to ~55% in summer and decreasing during winter. The other cloud regimes have a considerably smaller RFO and most of them have a less strong annual variability.

- The opposite applies for the mean Cloud Fraction. CR7 has much lower values compared to the other cloud regimes, which decrease during summer and increase during winter.

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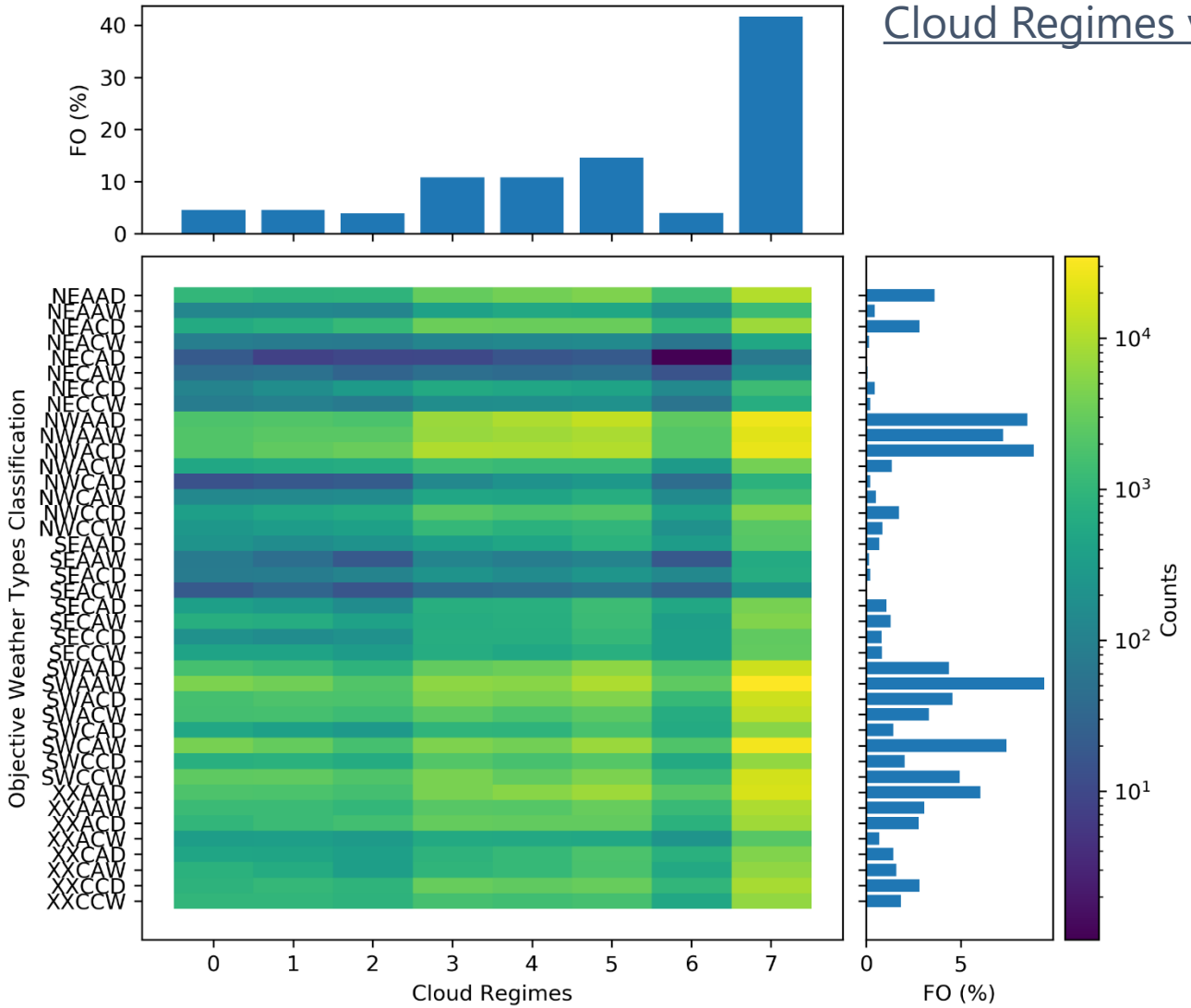

Cloud Regimes vs Weather Types

Focusing over Germany, the produced Cloud Regimes are compared against the 40 Weather types of the Objective Weather Types Classification (produced by DWD). Each weather type is represented by 5 letters. The first two stand for the wind index, the following two indicate the cyclonality index for 950 hPa and 500 hPa, and the last letter represents the humidity index.

For example, the weather type "NECAD" has a Northeast wind direction, a cyclonic index for 950 hPa, an anticyclonic index for 500 hPa, and a Dry humidity index.

The contingency table along with the corresponding Frequency of Occurrence values for each classification is shown on the left.

- There are Weather Types with a very low Frequency of occurrence.
- Highest co-occurrence values are found for CR7 with SWAAW and SWCAW.
- It is relatively hard to distinguish patterns because of the very dominant (in terms of FO) CRs and WTs.

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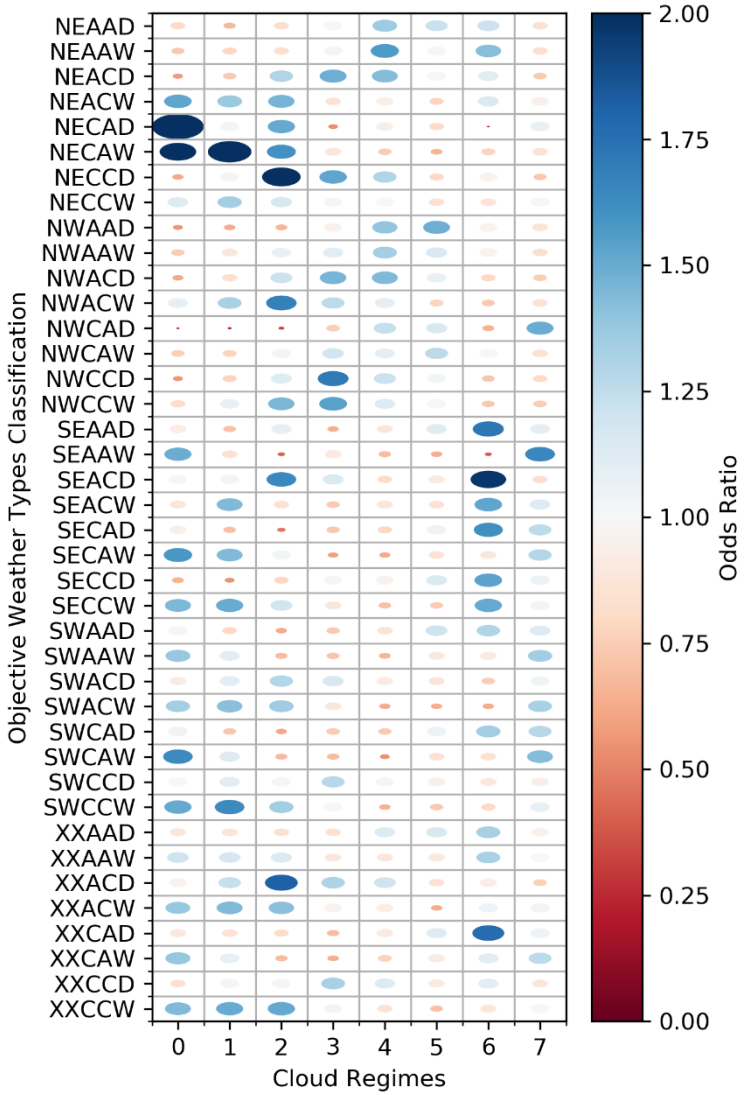

Cloud Regimes vs Weather Types

In order to better identify patterns between the cloud regimes and the weather types, the odds ratio (OR), which quantifies the strength of the association between two events, was calculated.

- OR=1: events are independent
- OR>1: events are correlated
- OR<1: events are anti-correlated

- CR0 shows a strong correlation with NECAD and NECAW, while it is mainly anti-correlated with NW flows.
- CR1 is strongly correlated with NECAW and is anti-correlated with NWCAD.
- CR2 shows its highest correlation with NECCD and XXACD.
- One of the main features for CR3 and CR4 is that they are mainly correlated with weather types that have a north component in their wind index, and they are mostly anti-correlated with weather types that have a south wind direction.
- CR5 has a more mixed pattern with not very strong associations.
- CR6 is widely correlated with weather types consisting of a SE wind index.
- Weather types with a south wind direction present a correlation with CR7.