Climatology of cloud (radiative) parameters at two stations in Switzerland using hemispherical sky cameras

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Motivation and Objective

- Radiative transfer of energy in the atmosphere and the influence of clouds on the radiation budget remain the greatest sources of uncertainty in the simulation of climate change (IPCC, 2013).
- Depending on the cloud cover and the cloud type, the influence on the shortwave (SW; 0.3 - 3 µm) and longwave (LW; 3 – 100 µm) radiation is different.
- Further parameters (e.g. cloud base height (CBH) and integrated water vapor (IWV)) also have an influence on the magnitude of the cloud radiative effect and thus on the radiative budget of the Earth.
- The objective of this study is to calculate a climatology of cloud radiative effect (CRE), cloud fraction and cloud type at two stations in Switzerland using hemispherical sky cameras.

Data, Sites and Definitions

Measurement sites

- **Davos (DAV)**, in the Alps of Switzerland, 1'594 m asl.
- **Payerne (PAY)**, in the midland of Switzerland, 490 m asl.

Cloud Radiative Effect (CRE)

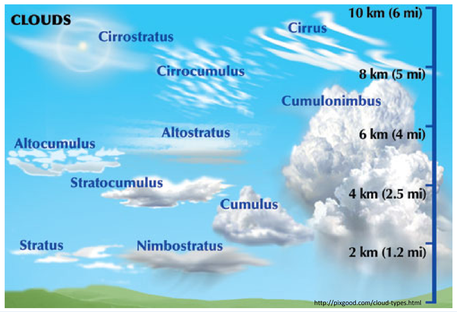
CRE = Measurement – clear sky model

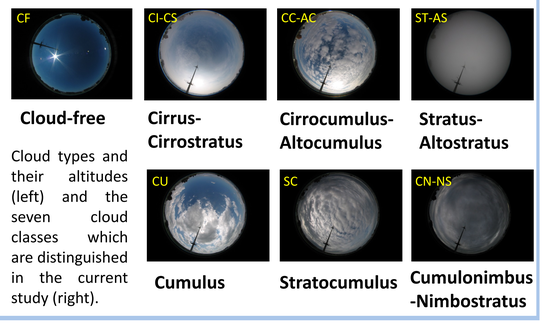
- Shortwave (SW): $SCE = SW_M - SW_{CSM}$
- Longwave (LW): $LCE = LW_M - LW_{CSM}$
- Total: $TCE = CRE_{SW} + CRE_{LW}$

Observational data

- **All-sky visible cloud cameras**
  - DAV: Mobotix Q24M
  - PAY: CMS Schreder VIS-J1006
- **Pyranometers** from Kipp & Zonen CMP22 for SW
  - measurement uncertainty ± 10 W/m²
- **Pyrgeometers** from Kipp & Zonen CG4 for LW
  - measurement uncertainty: ± 5 W/m²
- **Ceilometer** CHM15k for cloud base height (CBH)
- **GPS** for integrated water vapour (IWV)

Cloud types





Cloud types and their altitudes (left) and the seven cloud classes which are distinguished in the current study (right).

Methods

Cloud cover calculation

- Automatic detection and calculation.
- Based on spectral information of the all-sky camera data.

Cloud type determination

- Automatic detection.
- Based on a set of statistical features describing the color (spectral features) and the texture of an image (textural features) (Wacker et al., 2015).

Radiative Transfer Model (RTM)

- Moderate resolution atmospheric transmission model (MODTRAN5).

Clear sky model

- **Shortwave:**
  - Lookup table based on LibRadtran and a standard atmosphere including measured parameters: solar zenith angle, aerosol conditions (angstrom coefficient and aerosol optical depth, both interpolated over one day) and IWV.
- **Longwave:**
  - Empirical model with input of measured surface temperature and IWV values and a climatology of the atmospheric temperature profile [Wacker et al., 2014].
  - Model uncertainty ± 5 - 7 W/m².

Acknowledgement

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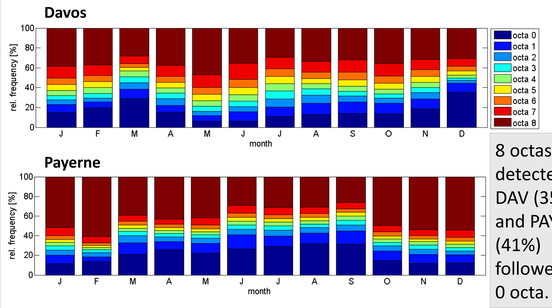
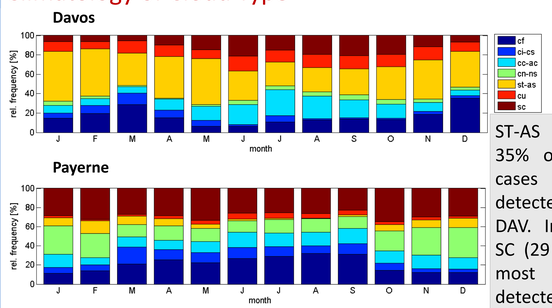
Results

Climatology of Cloud Coverage



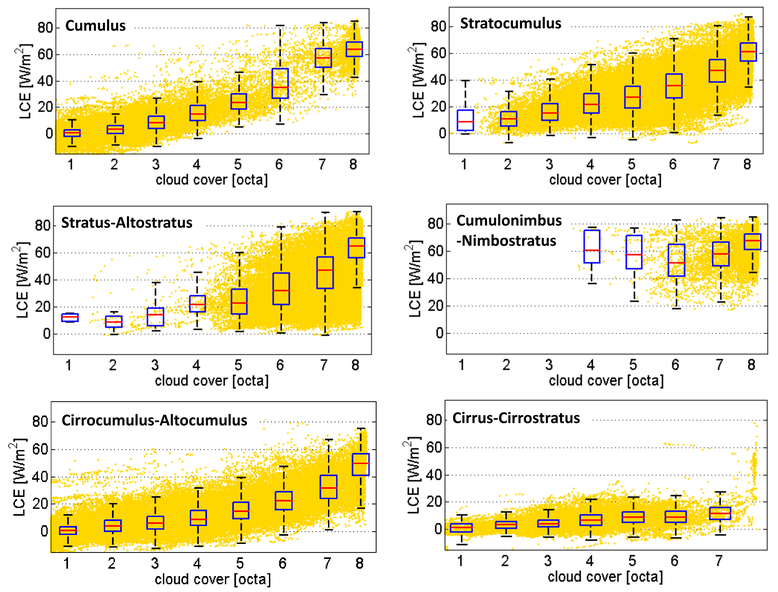
8 octas most detected in DAV (35%) and PAY (41%) followed by 0 octa.

Climatology of Cloud Type



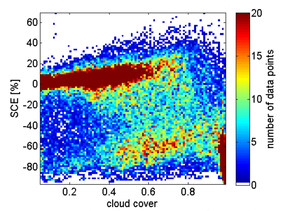
ST-AS with 35% of the cases most detected in DAV. In PAY SC (29 %) is most detected.

Climatology of Longwave Cloud Radiative Effect (LCE)

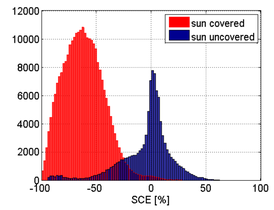


Dependence of LCE on cloud coverage for Davos for different cloud classes. Data points (yellow dots) and box plots per octa with median (red line), interquartile range (blue box) and spread without outliers.

Climatology of Shortwave Cloud Radiative Effect (SCE)



Density distribution of the dependence of SCE on cloud coverage for Davos for mid-level clouds (CC-AC). The density color distribution represents the number of data points.



Distribution of SCE values for Davos for low-level clouds (CU, SC, ST-AS, CN-NS).

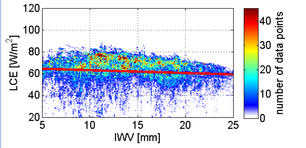
Sun coverage is important factor deciding about magnitude of SCE.

Cloud enhancement

- SW radiation cloud enhancement events have been observed in 14 % and 8 % of cloud cases in Davos and Payerne respectively.
- Cloud enhancement event defined as SW measurement larger than 5 %.

Sensitivity Analysis

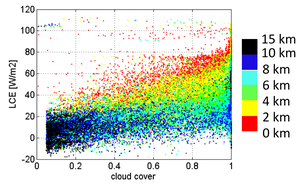
Integrated Water Vapour (IWV)



Dependence of LCE on IWV for Davos and cloud coverage of 8 octas for low-level clouds (CU, SC, ST-AS, CN-NS) shown as a density plot. Red line: linear regression.

Slightly negativ trend: the more IWV, the smaller the LCE (observed and modelled).

Cloud Base Height (CBH)



Dependence of LCE on cloud coverage for Payerne for the following lowest measured CBH ranges.

The lower the CBH, the higher the LCE.

Discussion and Conclusions

- LCE values for low-level clouds (CU, SC, ST-AS, CN-NS) and 8 octas cloud coverage are between 58 and 72 Wm^{-2} with the highest values for CN-NS.
- LCE values for the mid-level cloud class CC-AC and 8 octas are with 49 Wm^{-2} clearly lower.
- There is a mean difference of LCE between the two stations from 6 Wm^{-2} (8 octas) up to 13 Wm^{-2} (4 octas).
- The large spread in LCE values can be explained by other parameters like integrated water vapour or cloud base height.
- The relative values of the shortwave cloud radiative effect (SCE) for low-level clouds and a cloud coverage of 8 octas are between -88 to -62 %.
- The magnitude of the SCE values are influenced by cloud fraction, cloud type and whether the sun is directly covered by a cloud or not.
- To complete the surface radiation budget analysis nighttime measurements are needed as well.

References

Aebi, C., J. Gröbner, N. Kämpfer and L. Vuilleumier, Climatology of cloud radiative effect, cloud fraction and cloud type at two stations in Switzerland using hemispherical sky cameras, to be submitted.

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