Cloud Radiative Effect in dependence on Cloud Type

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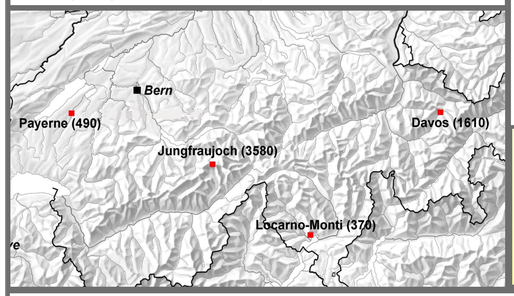
Motivation and Objective

- **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 **shape, altitude and the type of cloud**, the **influence** on the **shortwave (0.3 - 3 µm)** and **longwave (3 – 100 µm)** radiation is **different**.
- **Further parameters** (e.g. temperature and integrated water vapor (IWV)) also have an influence on the development of the clouds and thus on the radiative budget of the Earth.
- The **objective** of this study is to calculate the **Cloud Radiative Effect (CRE)** depending on cloud cover and cloud type.
- So far, the **study** has been performed at two different sites in Switzerland (a low level and a high level station) and for **different cloud types separately**.

Data, Sites and Definitions

Measurement sites

- **Payerne (PAY)**, in the midland of Switzerland, 490 m asl
- **Jungfraujoch (JFJ)**, in the Alps of Switzerland, 3’580 m asl



Observational data

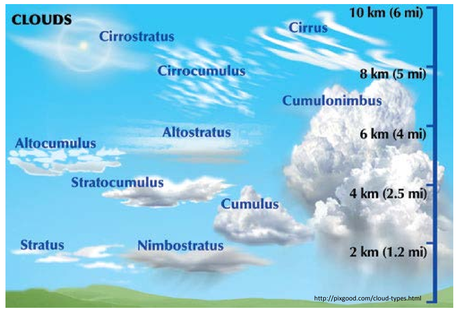
- **All-sky visible cloud cams**
  - JFJ: Mobotix Q24M
  - PAY: CMS Schreder VIS-J1006
- **Pyranometers** from Kipp & Zonen CMP22
  - measurement uncertainty +/- 10 W/m²
- **Pyrgeometers** from Kipp & Zonen CG4
  - measurement uncertainty: +/- 5 W/m²

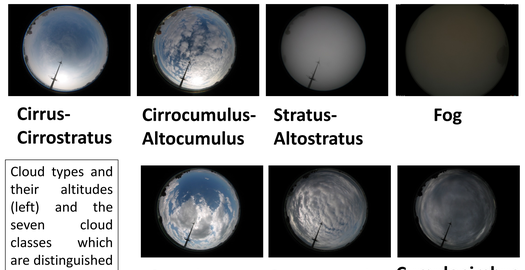
Cloud Radiative Effect (CRE)

CRE = Measurement – clear sky model

- Shortwave (SW): $CRE_{SW} = SW_m - SW_{cs}$
- Longwave (LW): $CRE_{LW} = LW_m - LW_{cs}$
- Total: $CRF_{total} = CRE_{SW} + CRE_{LW}$

Cloud types





Cirrus-Cirrostratus | Cirrocumulus-Altocumulus | Stratus-Altostratus | Fog

Cumulus | Stratocumulus | Cumulonimbus-Nimbostratus

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

Methods

Cloud cover calculation

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

Cloud type determination

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

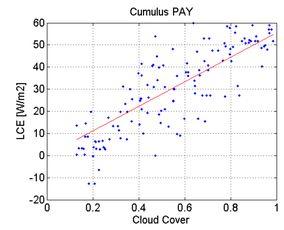
Clear sky model

- **Shortwave:**
  - Lookup table based on LibRadtran plus input parameters (solar zenith angle, total ozone content, integrated water vapor , aerosols).
- **Longwave:**
  - Empirical model plus climatologies of water vapor and lapse rate temperature (Wacker, 2013).
  - Model uncertainty +/- 5 W/m²

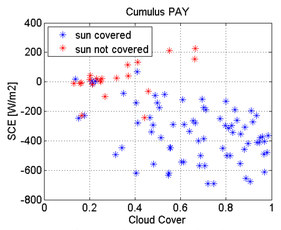
Acknowledgement

Ch. Aebi is financed through the GAW-CH project «Comprehensive Radiation Flux Assessment (CRUX)» by MeteoSwiss.

Results



Correlation between cloud and longwave cloud effect (LCE); blue: single events with cumulus clouds in PAY, red: linear fit.

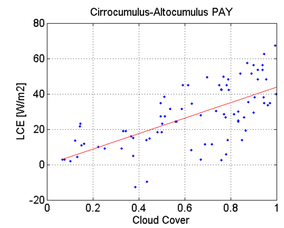


Correlation between cloud cover and shortwave cloud effect (SCE); blue: single events and sun covered by cumulus clouds in PAY; red: single events and sun visible.

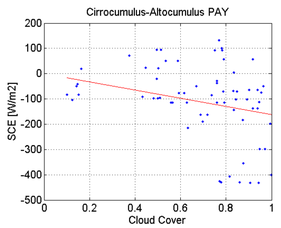
Picture taken by the visible all-sky camera in PAY on July 30, 2011 12:05 UTC. Cloud type: cumulus; cloud cover = 55 %; LCE = 25 W/m²; SCE = -620 W/m².

Picture taken by the visible all-sky camera in PAY on May 16, 2012 13:30 UTC. Cloud type: cumulus; cloud cover = 55 %; LCE = 25 W/m²; SCE = 213 W/m².

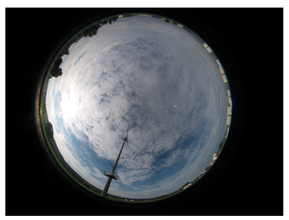
Cumulus



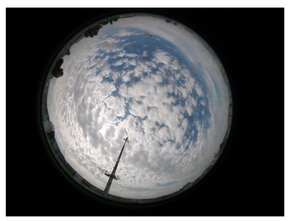
Correlation between cloud cover and longwave cloud effect (LCE); blue: single events with cirrocumulus-altocumulus clouds, red: linear fit. Top: PAY; Bottom: JFJ.



Correlation between cloud cover and shortwave cloud effect (SCE); blue: single events with cirrocumulus-altocumulus clouds, red: linear fit. Top: PAY; Bottom: JFJ.

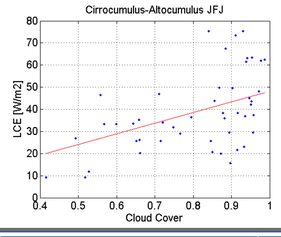


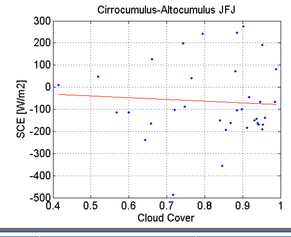
Picture taken by the visible all-sky camera in PAY on August 5, 2011 6:55 UTC. Cloud type: cirrocumulus-altocumulus; cloud cover = 78 %; SCE = 101 W/m².



Picture taken by the visible all-sky camera in PAY on August 3, 2011 9:20 UTC. Cloud type: cirrocumulus-altocumulus; cloud cover = 78 %; SCE = -431 W/m².

Cirrocumulus -Altocumulus





Discussion

- The study has been performed for cases with only one cloud type.
- Case studies help to understand the large spread in the CRE when the same fractional cloud cover is present.
- The main effect on SCE spread is whether the sun is covered by a cloud or not.
- Several possible sources of uncertainty: model, instrument, cloud cover detection and cloud type algorithms.

Cloud type	# cases	PAY: LCE [W/m²]	PAY: SCE [W/m²]	# cases	JFJ: LCE [W/m²]	JFJ: SCE [W/m²]
Cirrus-Cirrostratus	172	22 (20, 24)	-113 (-131, -94)	91	19 (17, 21)	-42 (-66, -18)
Cirrocumulus-Altocumulus	88	44 (40, 48)	-162 (-209, -115)	54	48 (43, 53)	-79 (-149, -9)
Stratus-Altostratus	76	81 (80, 83)	-270 (-277, -262)	88	61 (57, 64)	-196 (-230, -163)
Cumulus	132	56 (53, 59)	-431 (-490, -372)	-	Not defined	Not defined
Stratocumulus	123	66 (62, 70)	-211 (-228, -194)	-	Not defined	Not defined
Cumulonimbus-Nimbostratus	227	54 (53, 55)	-501 (-535, -466)	-	Not defined	Not defined
Fog	-	Not defined	Not defined	101	79 (78, 81)	-352 (-412, -292)

CRE per cloud class

Overview of the CRE in SW (SCE) and LW (LCE) depending on the cloud type for PAY and JFJ. In brackets are the 95 % confidence boundaries of the respective CRE.

In general, the LCE results are more significant than the SCE.

Conclusions and Outlook

- First approach to calculate the longwave and shortwave cloud effect dependent on cloud cover and cloud type for two different sites in Switzerland.
- To get more significant results the data set has to be increased.
- More parameters which may have an influence on the cloud radiative effect have to be analysed.
- The study will also be performed in Davos, Switzerland (1’560 m asl).
- A thermal infrared camera system is in developement in order to perform the study also at night.

References

Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.), IPCC 2013, Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, (2013).

Wacker, S., J. Groebner and L. Vuilleumier, A method to calculate cloud-free long-wave irradiance at the surface based on radiative transfer modeling and temperature lapse rate estimates, Theoretical and Applied Climatology, (2013).

Wacker, S., J. Gröbner, C. Zysset, L. Diener, P. Tzoumanikis, A. Kazantzidis, L. Vuilleumier, R. Stöckli, S. Nyeki, and N. Kämpfer (2015) Cloud observations in Switzerland using hemispherical sky cameras, Journal of Geophysical Research.