Name of research institute or organization:

Institute for Atmospheric and Climate Science, ETH Zürich

Title of project:

Assessment of high altitude aerosol and cloud characteristics by remote sensing techniques

Project leader and team:

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Project description:

Using a Leosphere Lidar ALS 450, we measure aerosols and clouds over Jungfraujoch. Since September 12, 2013 the Lidar is back operating at Jungfraujoch after a major laser repair in France.

Our main interest is the measured cirrus clouds. One part of the project is to establish a climatology of the properties of mid-latitude cirrus clouds.

These properties are compared with Lidar measurements using the same kind of Lidar instrument in Zürich and Jülich. Table 1 displays the Lidar data available to date at the different measurement sites. From Jungfraujoch, already a large amount of data has been collected.

	Jungfraujoch	**Zürich**	**Jülich**
Days of measurement	73	83	37
Cirrus cloud coverage	23 %	16 %	14 %

Table 1. Lidar measurements from different measurement sites and their corresponding cirrus cloud coverage.

The Lidar data are automatically evaluated using a cloud detection scheme (see report 2012) coupled to the Lidar inversion. Cloud properties such as optical depth, cloud base, cloud top and ice water content are estimated for the detected clouds. In Fig. 1, the retrieved cloud bases and cloud heights at the different measurement sites are displayed in comparison to the long time series above Salt Lake City by Sassen and Comstock [2001]. The cirrus clouds measured at the different measurement sites show consistent values of cloud base and cloud top at the different mid-latitude measurement sites.

In the evaluation algorithm, the optical depth τ of the detected cirrus clouds is calculated. The calculated optical depths are divided into three categories as described in Sassen & Cho [1992] and listed in Table 2. We observe that a larger fraction of the measured and detected cirrus clouds at Jungfraujoch are subvisible as compared to Zürich and Jülich. The mean optical depth is lower at Jungfraujoch as well. As Jungfraujoch is situated at 3580 m asl and above the planetary boundary layer, these results are what we expected. Assuming similar properties of the cirrus clouds above the three measuring sites, we presume that we are able to measure a larger amount of subvisible cirrus clouds at Jungfraujoch in comparison to Zürich and Jülich.

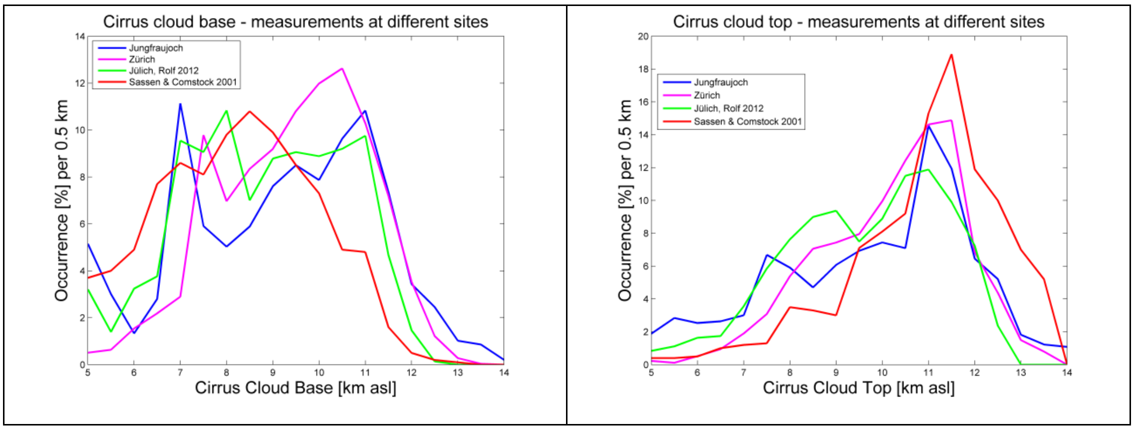

Figure 1. Retrieved cirrus cloud base and height from Jungfraujoch (blue line), Zürich (magenta line), Jülich (green line) and Salt Lake City (red line). The figures show consistent properties of cirrus cloud altitude at mid-latitudes. Please note that the data from Salt Lake City were processed by Sassen and Comstock and therefore may show different properties than if they had been processed by our algorithm.

	Jungfraujoch	**Zürich**	**Jülich**
Subvisible cirrus ($\tau < 0.03$)	44.0 %	39.7%	38.4%
Thin cirrus ($0.03 < \tau < 0.3$)	47.4 %	50.0%	43.4 %
Thick cirrus ($0.3 < \tau \leq 3$)	8.6 %	10.2 %	18.2 %
Mean τ	0.10	0.14	0.19

Table 2. Categorization of retrieved cirrus clouds as described in Sassen & Cho [1992] and mean optical depth τ *for the different measurement sites.*

The distribution of the retrieved optical depths is displayed in Fig. 2. The retrieved optical depths in this figure are normalized to all-sky to show how the absolute cloud fraction is distributed over the different retrieved optical depths.

We see a larger amount of thinner cirrus clouds measured at Jungfraujoch as compared to Zürich and Jülich. This supports the assumption that we are able to measure thinnest cirrus clouds at Jungfraujoch. In Jülich, less cirrus clouds are detected than in Zürich. We observe the same amount of thinnest cirrus clouds ($\tau < 5 \cdot 10^{-3}$) in Jülich as in Zürich. In Jülich, a larger amount of thicker cirrus clouds ($\tau > 0.3$) are observed than in Zürich and at Jungfraujoch.

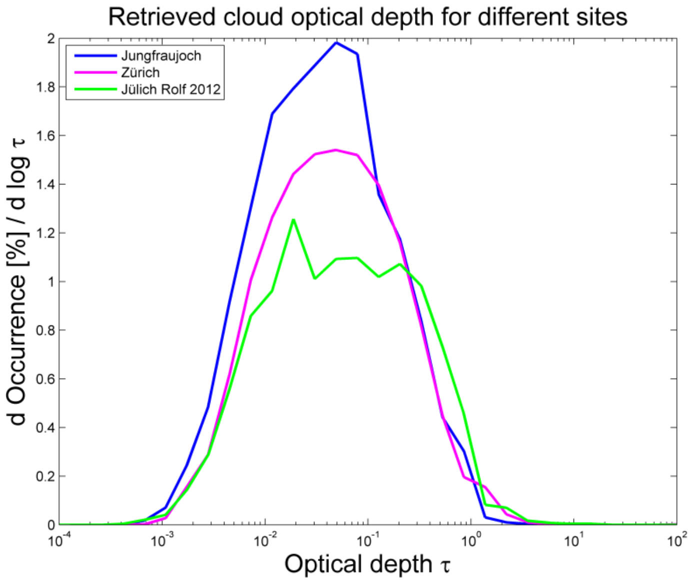

Figure 2. Retrieved optical depth normalized to all-sky at the different measurement sites. It is clearly observable that a larger amount of optically thinner clouds were measured at Jungfraujoch than in Zürich and Jülich.

The retrieved cloud properties from the algorithm can be used to calculate the influence of the detected clouds on the radiation budget. Cirrus clouds may cool or warm, depending on the microphysical properties of the cloud [Fu & Liou, 1993]. A warming effect takes place due to the absorption of outgoing longwave radiation by the cloud. On the other hand, a cirrus cloud may reflect the incoming solar radiation and thus produce a cooling effect.

To assess the cloud radiative effect at the top of atmosphere, the radiation model of Corti and Peter [2009] is used. This model requires input values such as cloud optical depth, cloud top temperature, ground temperature and ground albedo. Cloud optical depth is calculated in the retrieval while cloud top and ground temperature are taken from COSMO2-Analysis data [Consortium for Small Scale Modeling, 2014]. The model of Corti & Peter is suitable for radiation calculations of Lidar data as no information on ice particle size and ice crystal number density is needed. For all radiative effect calculations, an albedo of 0.3 was assumed. The calculated forcings are listed in Table 3.

	Jungfraujoch	**Zürich**	**Jülich**	**Chen et al. 1999**
CRF NET subvisual	0.61	1.00	1.02	-
CRF NET thin	4.20	7.86	8.75	-
CRF NET thick	21.26	37.44	37.01	-
CRF NET overcast	**4.09**	**8.16**	**10.92**	**5.4**
CRF NET all sky	**0.67**	**1.11**	**1.47**	**1.3**

Table 3. Cloud Radiative Forcing (CRF) in Wm-2 for different cloud types and different measurement sites. The CRF NET for each cloud type is calculated for overcast sky, i.e. only when a cirrus cloud of the respective category is present.

We find that the measured cirrus clouds display an overall warming effect. Our results can be compared to the values by Chen et al. [1999]. Using satellite data they find a globally averaged net cloud radiative forcing for overcast sky of 5.4 Wm^{-2} and an all-sky net cloud radiative forcing of 1.3 Wm^{-2}. These values are comparable with the values retrieved through our analysis (bold in Table 3). It has to be noted that there is a weaker longwave effect at Jungfraujoch since, due to its high altitude location, lower ground temperatures are present than in Zürich and Jülich.

To further improve the statistics of the cirrus cloud properties, we aim to continue our measurements at Jungfraujoch in 2014.

References:

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