Internship August 2021

Mini-Project

TREND ANALYSIS OF GLOBAL CLOUD COVERAGE

By using the CM SAF R-Toolbox

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1. Different levels of clouds

1.1 Definition of cloud heights

The definition of cloud types is based on cloud top pressure and optical thickness. They are differentiated into low, middle and high level clouds. Concerning the cloud top pressure, low clouds range from 1000hPa to 680hPa. At pressure levels of 680hPa to 440hPa clouds are classified as middle high, while high clouds cover pressure levels from 440hPa to 50hPa. Regarding the cloud optical thickness, low clouds for example, are categorized into Cumulus, Stratocumulus and Stratus (ISCCP, 2017).

1.2 Importance of observing different cloud levels

In general, clouds affect the current climate by reflecting and absorbing solar radiation. A cooling effect is due to the reflection of incoming shortwave radiation, while a warming effect is caused by the absorption of outgoing longwave radiation. However, in total, the cloud coverage leads to a negative net radiative impact. With a global mean record of -20 W/m^2, clouds definitely play an important role. Moreover, it is relevant to distinguish between low, middle and high clouds as they generally show different effects on the interaction with solar radiation. While high and optical thin clouds cause rather warming effects, low and generally thicker clouds, lead to cooling effects through a high reflection of solar radiation (Marsh & Svensmark, 2000).

1.3 Project outline

As described above, depending on their height, clouds effect the climate in separate ways, which makes it interesting to analyze how the cloud coverage of different cloud levels changes over time (30 years). The purpose is to test the possibilities of the CM SAF R-Toolbox and to illustrate and describe positive, negative or no trends on a global scale and initiate more profound scientific research.

2. Global trend analysis using the R-Toolbox

2.1 Trend analysis of global cloud coverage of low, middle and high clouds in comparison to the long-term mean of the respective cloud coverage

Linear trends of global cloud coverage were calculated over the period from 1991 to 2020. Therefore, the cloud coverage was differentiated into low, middle and high clouds. When observing low clouds, it is noticeable, that trends in cloud coverage are strongly positive above the Arctic and the Pacific Ocean. The Arctic seems to be a region, which responds very sensitive on changes in climate (Vavrus et al., 2008). The increase of the cloud coverage is highest at low cloud levels, followed by high cloud levels and is lowest at middle cloud levels. Negative trends can be seen above Alaska, Australia and West Asia. Regarding the coverage of middle clouds, almost only negative trends are visible everywhere. Above Antarctica, they are particularly negative. Linear trends in high cloud coverage are also strongly negative above Antarctica and strongly positive above Southeast Asia. In general, maximum linear trends are specifically visible above the oceans and the polar ice caps, whereas minimum linear trends are detected especially over land. Additionally, the long-term means of the cloud coverage in all different cloud levels were created to provide a better view on their global distribution and frequency as well as a comparison to the corresponding linear trend maps. Regarding low clouds for example, it is now possible to compare regions in which they reside more frequently to their trends in the same region within the same period of time (see fig. 1).

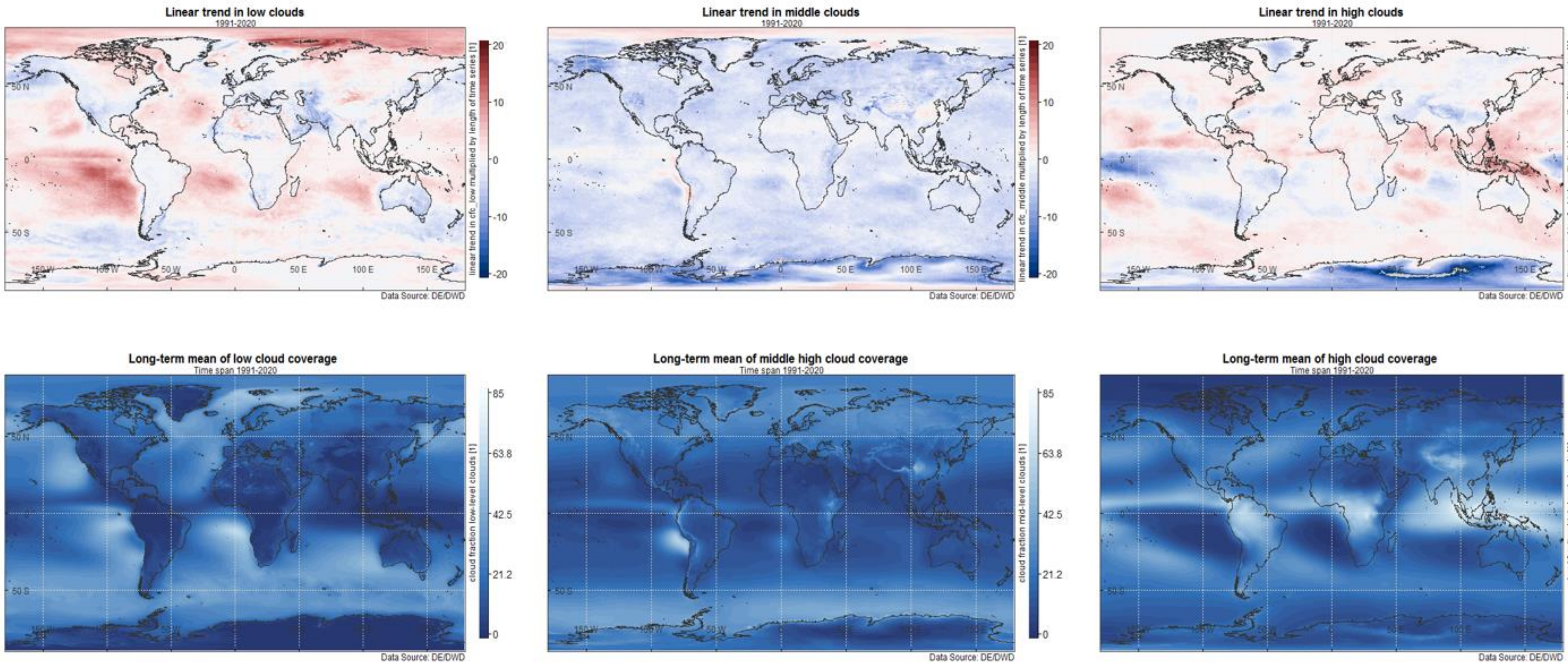

Fig. 1: “Maps of linear trends in low, middle and high clouds (at the top) and maps of the long-term mean cloud coverage of low, middle and high clouds (below) within the time span 1991-2020”

2.2 Comparison of the global trend analysis map to the corresponding global time series of cloud coverage regarding different cloud levels

The global time series of the cloud coverage of low clouds shows a slightly positive trend. Compared to the map of the global trend analysis below, mainly positive trends are recognized as well. Illustrating the linear trends as a global map makes it easy to locate regions in which trends appear to be extremely high or low. Regarding low clouds, the trends are very high in regions near the Arctic. The time series of the cloud coverage of middle high clouds shows a negative trend, which can also be seen in the map. The strength of the trend is the same almost everywhere, but with a minimum above Antarctica. There is almost no trend in the cloud coverage of high clouds regarding the global spatial mean, whereas in this case the map shows a strong positive trend above Southeast Asia and a strong negative trend above Antarctica.

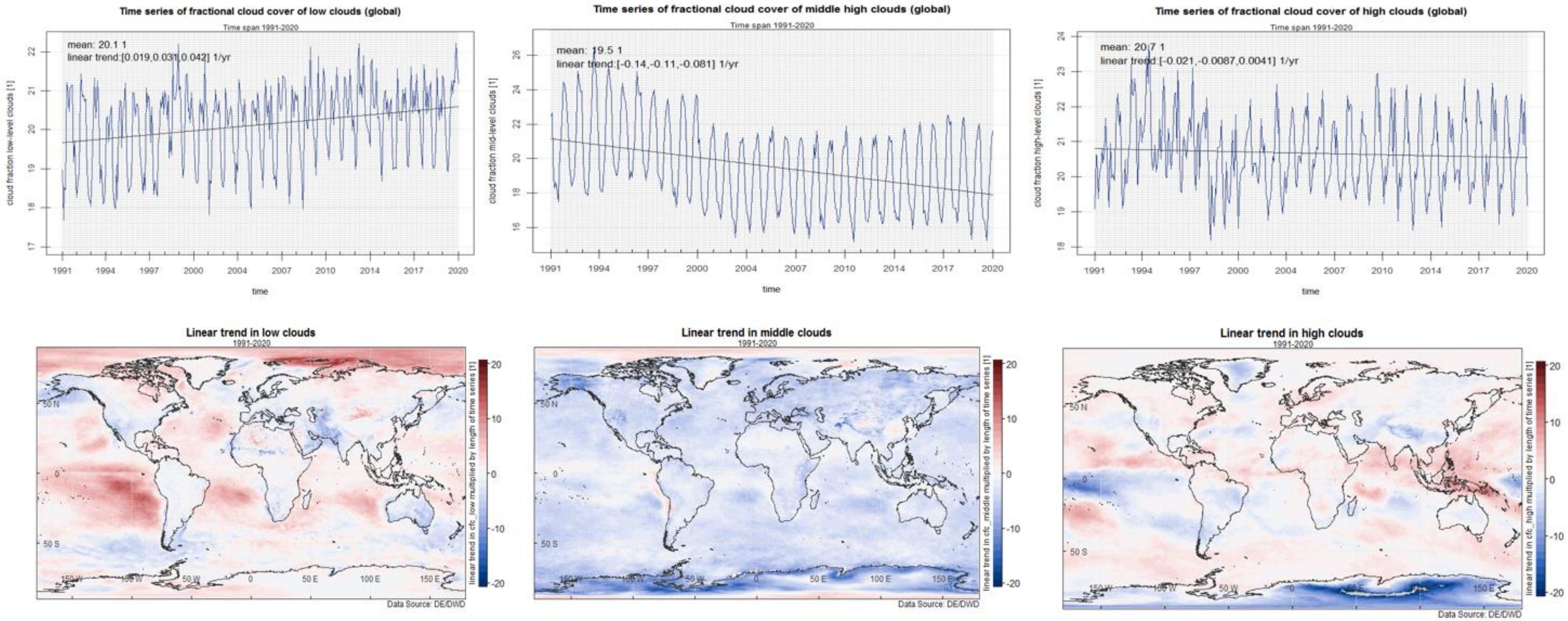

Fig. 2: “Global time series of cloud coverage of low, middle and high clouds (at the top) compared to the global maps of linear trends in the different cloud coverages (below) within the time span 1991-2020”

2.3 Significance

Furthermore, it is possible to verify the significance of the created linear trends. In this example, the significance is based on the 95% confidence interval, which means that the significance level amounts to 5%. Values of 1 indicate that positive trends are significant, values of 0 mean no significant trends and values of -1 imply that negative trends are significant. It is noticeable, that strongly positive and negative trends are mostly significant.

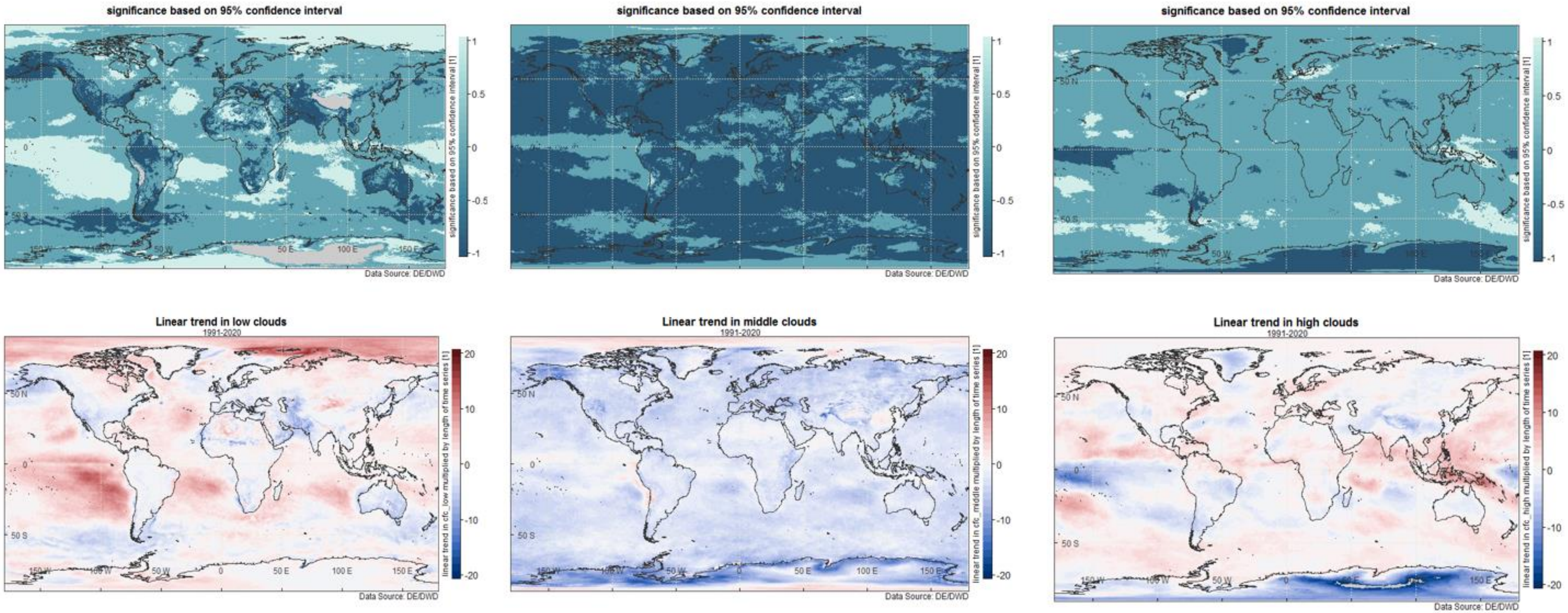

Fig. 3: “Significance of the linear trends presented in maps (at the top) in comparison to the global maps of linear trends in the different cloud coverages (below) within the time span 1991-2020”

2.4 Seasonal analysis of linear trends in cloud coverage of low, middle and high clouds

Another option is to analyze linear trends during the summer and winter season. The summer season refers to the months June, July and August, the winter season to the months December, January and February. When observing the low cloud coverage, negative trends are visible above the Arctic during the summer season, whereas the trends are strongly positive during the winter season. Overall, the seasonal changes in cloud coverage are largest at low level compared to the coverage at middle and high levels. The trends in cloud coverage of middle high clouds during the summer and winter period are nearly similar. The trends are predominately negative, except near the Arctic where slightly positive trends can be detected. On the other hand, the trends in cloud coverage of high clouds during the summer and winter months are once again quite different above the Arctic. During the summer months, the cloud coverage of high clouds increases, whereas during the winter months the cloud coverage decreases. In addition, there are strong positive trends above Southeast Asia in summer and strong negative trends above the Pacific in winter visible.

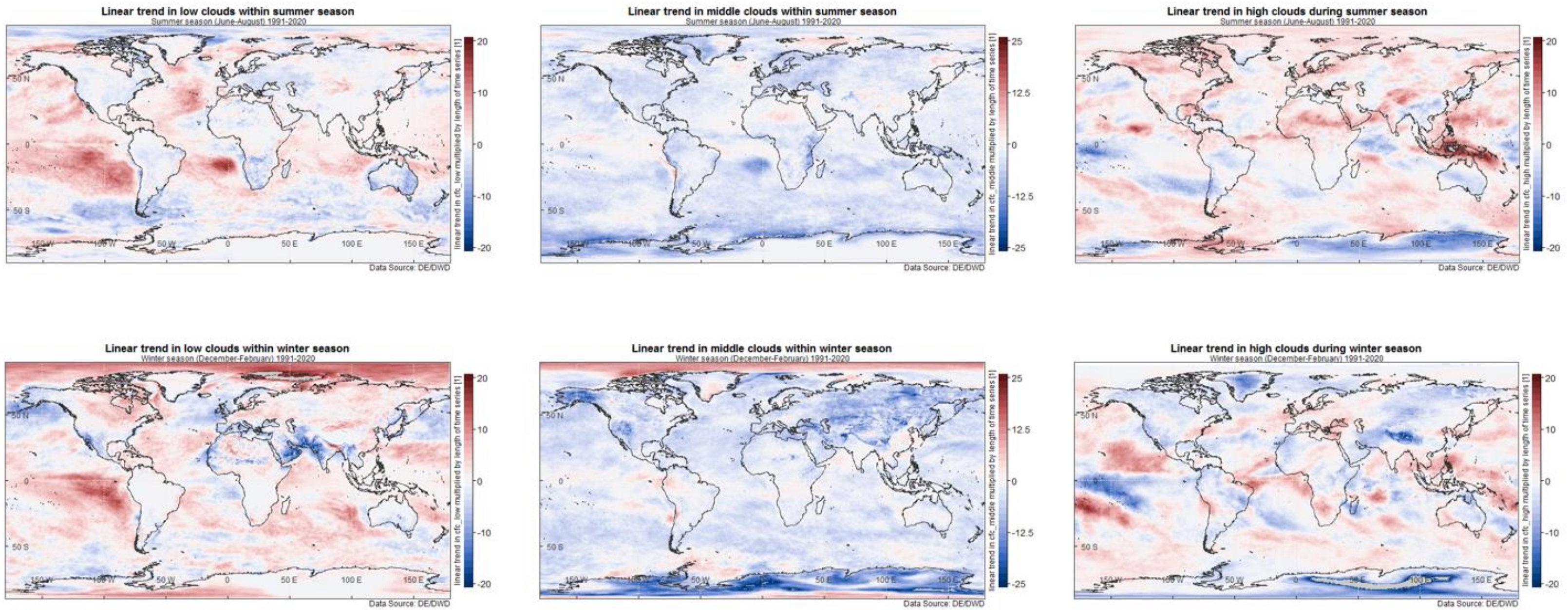

Fig. 4: "Linear trends in cloud coverage of low, middle and high clouds during summer (JJA) (at the top) and winter (DJF) (below) season during 1991-2020"

2.5 Time series of monthly means in selected regions in the northern and southern hemisphere

Due to strong positive and negative trends in the northern and southern regions of the hemispheres plus huge influence of polar clouds on the current climate (Vavrus et al., 2008), regions near the Arctic and Antarctic will be examined more closely in the following. Therefore, certain areas in the north (lat.: 5.38°-120.38°; lon.: 78.38°-89.62°) and south (lat.: 10.38°-115.38°; lon.: -89.62°- -73.62°) are selected. The Antarctic shows slightly positive trends in the low cloud coverage and slightly negative trends in the middle and high cloud coverage. Besides, figure 5 shows a large increase of the cloud coverage of low clouds in 2018. Linear trends in middle and high cloud coverage are mildly to moderately negative. In contrast, the time series of low cloud coverage in the arctic region shows a relatively strong positive trend, which underscores the theory, that the Arctic is expected to become cloudier (Vavrus et al., 2008). The high cloud coverage increases as well, but only slightly. The mid-level cloud coverage shows almost no trend as expected, when looking at the linear trend maps.

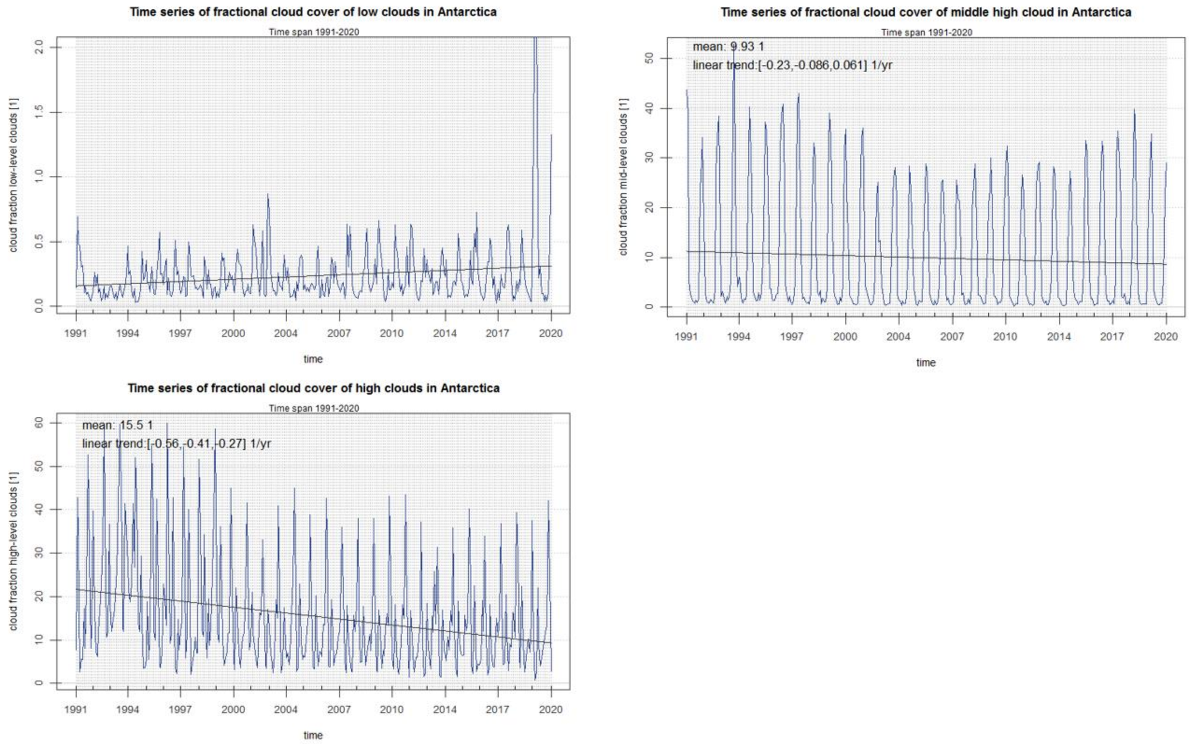

Fig. 5: “Time series of cloud coverage of low, middle and high clouds in Antarctica during 1991-2020”

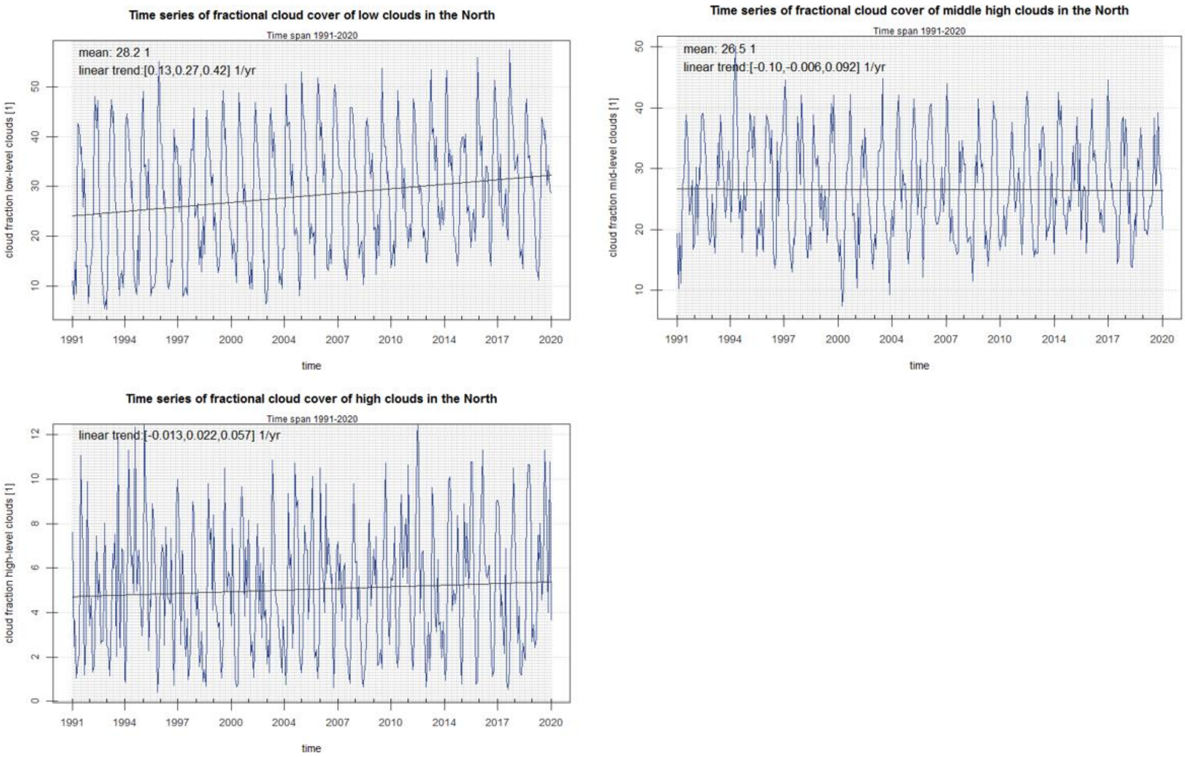

Fig. 6: "Time series of cloud coverage of low, middle and high clouds near the Arctic during 1991-2020"

3. Accessed Data

- EUMETSAT CM SAF data on: https://wui.cmsaf.eu/

- Data names:
  - Monthly data 1991-2018 (TCDR) „1991-01-01 2019-06-01, CFC - Fractional cloud cover, AVHRR on polar orbiting satellites, Monthly, Mean, Global"
  - Monthly data 2019-2020 (ICDR) „2019-07-01 2020-12-01, CFC - Fractional cloud cover, AVHRR on polar orbiting satellites, Monthly, Mean, Global"

4. References

- Vavrus, S., Waliser, D., Schweiger, A., & Franics, J. (2008): Simulations of 20th and 21st century Arctic cloud amount in the global climate models assessed in the IPCC AR4, DOI: 10.1007/s00382-008-0475-6
- Marsh, N. & Svensmark, H. (2000): Cosmic rays, clouds and climate, Danish Space Research Institute, Copenhagen
- ISCCP (2017): ISCCP definition of cloud types, Cloud parameter definitions and measurement methods, access at 23.08.2021 on: https://isccp.giss.nasa.gov/cloudtypes.html