Regional Contrail Coverage Estimated from AVHRR Data

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ABSTRACT

Knowledge on the changes in cloud coverage and cloud properties is essential for the modeling of future climates. A direct human influence on cloud coverage is given by the contrails produced from air-traffic, which is currently increasing at approximately 7%/year. The infrared channels of the Advanced Very High Resolution Radiometer (AVHRR) on board of the weather satellites of the NOAA series are used for the automated detection of linear contrails. Results from studies on contrail coverage and the resulting radiative impact over Europe, the continental USA, SE and E-Asia will be presented in this paper.

1 Introduction: The global view

A first global estimate of contrail coverage was performed by Gierens, Ponater and Sausen ([11, 12, 2]) and used in many further calculations of the impact of contrails on global climate ([8]). This estimate is based on ECMWF reanalysis data covering the years 1983 to 1993 and an air traffic fuel consumption inventory for the years 1991 and 1992. The potential contrail coverage is estimated using the Schmidt-Appleman criterion, which relates the possibility of contrail formation to ambient temperature and humidity, and the cloud coverage analyzed in the ECMWF 'initialized reanalysis' data. The parameterization used to estimate the potential contrail coverage is shown in fig. 2. Details and the derivation of this parameterization are given in [12]. This potential contrail coverage is folded with the air traffic fuel consumption data.

The resulting contrail index is related to reality using the regional determination of contrail coverage over (western) Europe performed visually by Bakan and Betancor([1]). It should be noted, that the chosen parameterization of potential contrail coverage refers to the resolution of the meteorological data of 2.8°x 2.8°. Sub grid-cell sized phenomena such as convective events, fronts and thunderstorms are smoothed out. The meteorological data is taken from

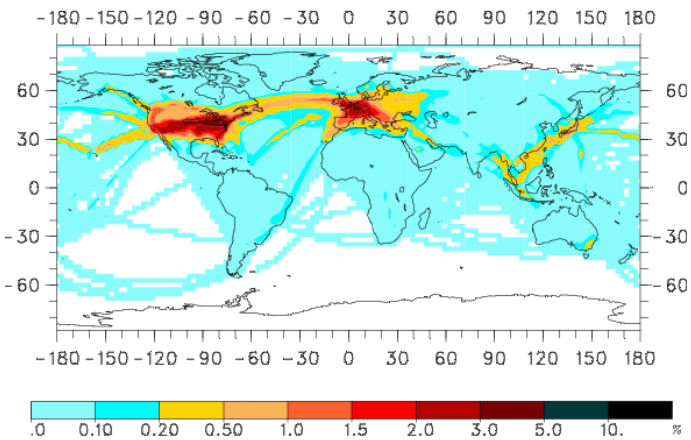

Figure 1: Global contrail coverage estimated from the air traffic data of 1992.

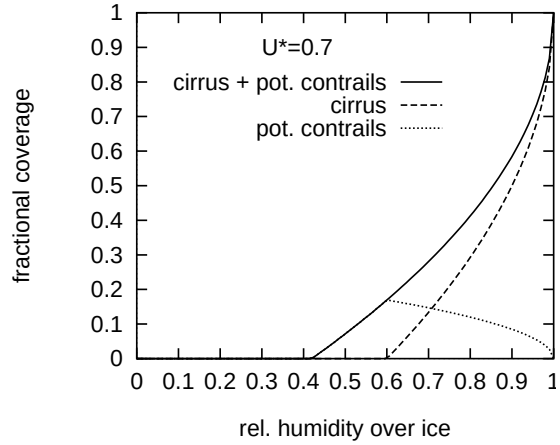

Figure 2: Parameterization of contrail and cirrus coverage used in Figure 1 .

1200UT for the whole globe, the air traffic data describes the daily mean. Thus the influence of the daily variation of meteorological parameters is distributed around the world, the influence of daily variations in air traffic density is neglected.

2 The algorithm

The contrail detection algorithm used for these studies is based on line detection filters applied to the IR split window channels of the AVHRR on-board of the satellites of the NOAA series. It is described in [4] and [5]. This algorithm detects only linear shaped contrails and is tuned

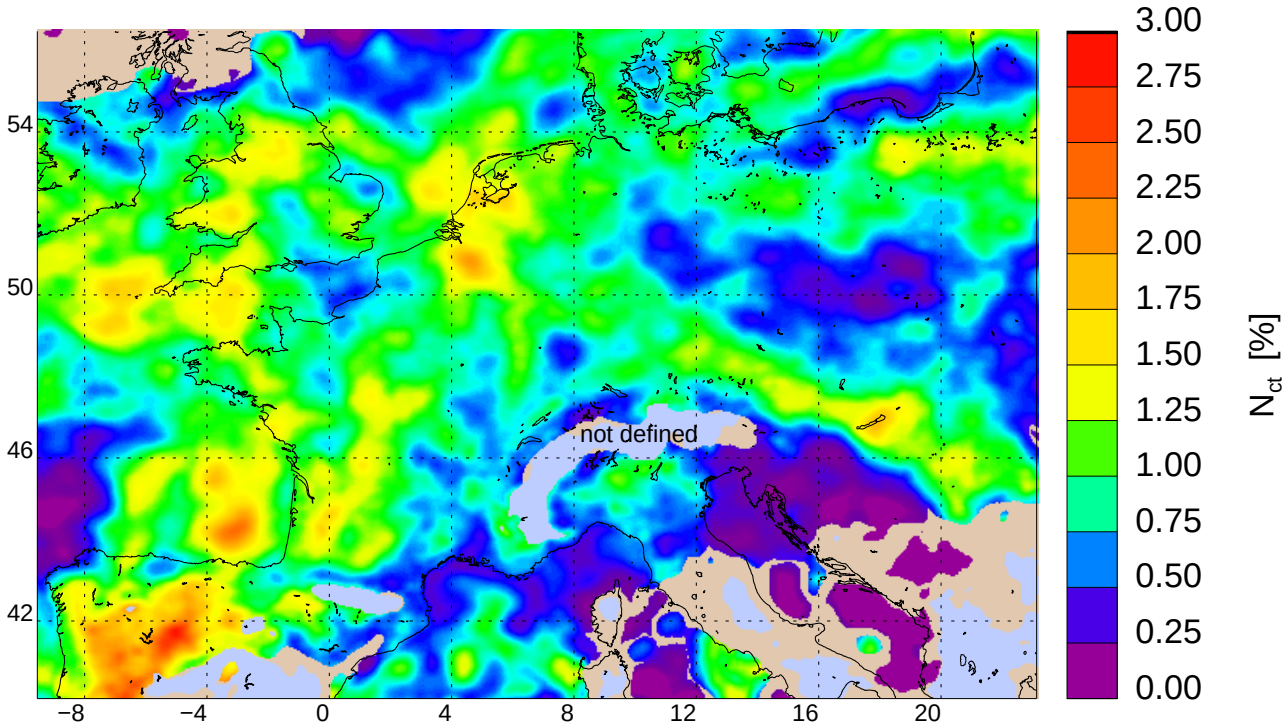

Figure 3: Daytime contrail coverage over Europe, March 1995 to Feb. 1997

to have a very low false alarm rate, as the contrail coverage itself has values in the order of 1%. A false alarm rate of 0.1 % for NOAA14 is determined from AVHRR data from Newsealand, where we found nearly no real contrails. Due to the tuning of the algorithm to reach this low false alarm rate the detection efficiency is far from being perfect.

A precise determination of the detection efficiency is impossible as the truth (i.e. the contrail coverage at the time of the satellite overpass) is not very well defined and no independent measurement of contrail converge is known. The transition from a well marked, linear contrail to a fuzzy cirrus cloud that might have been triggered by an airplane can only be followed using highly resolved time series. Usually it is not possible to discriminate aged contrails from natural cirrus clouds without measuring the composition of the ice particle residuals or knowing the history of this cloud.

Another source of ambiguity is given by ambient cirrus clouds. Quite often contrails form in regions where there is already a thin cirrus cloud. These contrails add no additional cloud coverage, but alter the cloud optical and macro physical properties.

Two of the three studies presented here use only NOAA14, as we noticed a stronger then expected dependency of the performance of the algorithm on the actual instrument of the satellite. As the algorithm uses the calibrated blackbody temperatures of the AVHRR either the small differences in the spectral sensitivity of the channels 4 and 5 or varying misalignments of these channels might be the reason for this behavior.

3 Europe

A first analysis of contrail coverage was presented by Mannstein and Meyer [4], giving a mean daytime (12:30 UT ± 70 min) contrail coverage for Central Europe (between 5°W and 22°E, 43°N and 57°N) of 0.5 % ± 0.25 % for the year 1996. Nighttime coverage was estimated to be 0.2 %.

A wider area was analyzed by Meyer ([6, 7]) for the period March 1995 to February 1997. Further data (continuing until now) are already processed, but still not evaluated. For the region between 8°W and 23°E, 41°N and 56°N Mayer gives as best estimate a contrail coverage of 0.75%, assuming an overall detection efficiency for linear shaped contrails of 0.4.

4 Continental USA

Palikonda et al. ([9, 10]) used NOAA11 and NOAA12 data covering the mid-season months of 1993 to analyze the contrail coverage over the continental USA (Fig. 4) To give reasonable results, the tuning of the algorithm had to be changed. Thus the results for continental US are not directly comparable to those for Europe and SE Asia. The mean contrail coverage is apr. 1.7 % with a yearly cycle (minimum in summer) and a low daily variation (see Fig. 5). More contrails are detected with the noon (and midnight)- satellite NOAA11 than with the morning satellite NOAA12. This seems to indicate different performance of the algorithm with different satellites.

5 SE-Asia

The area between 90°E and 126.4 °E, 0°N and 25.2°N was analyzed [3] using data received at the Asian Center for Research an Remote Sensing (ACRoRS) in January, April, July and October 1998. The amount of data (480 NOAA14 overpasses from the four mid-season months

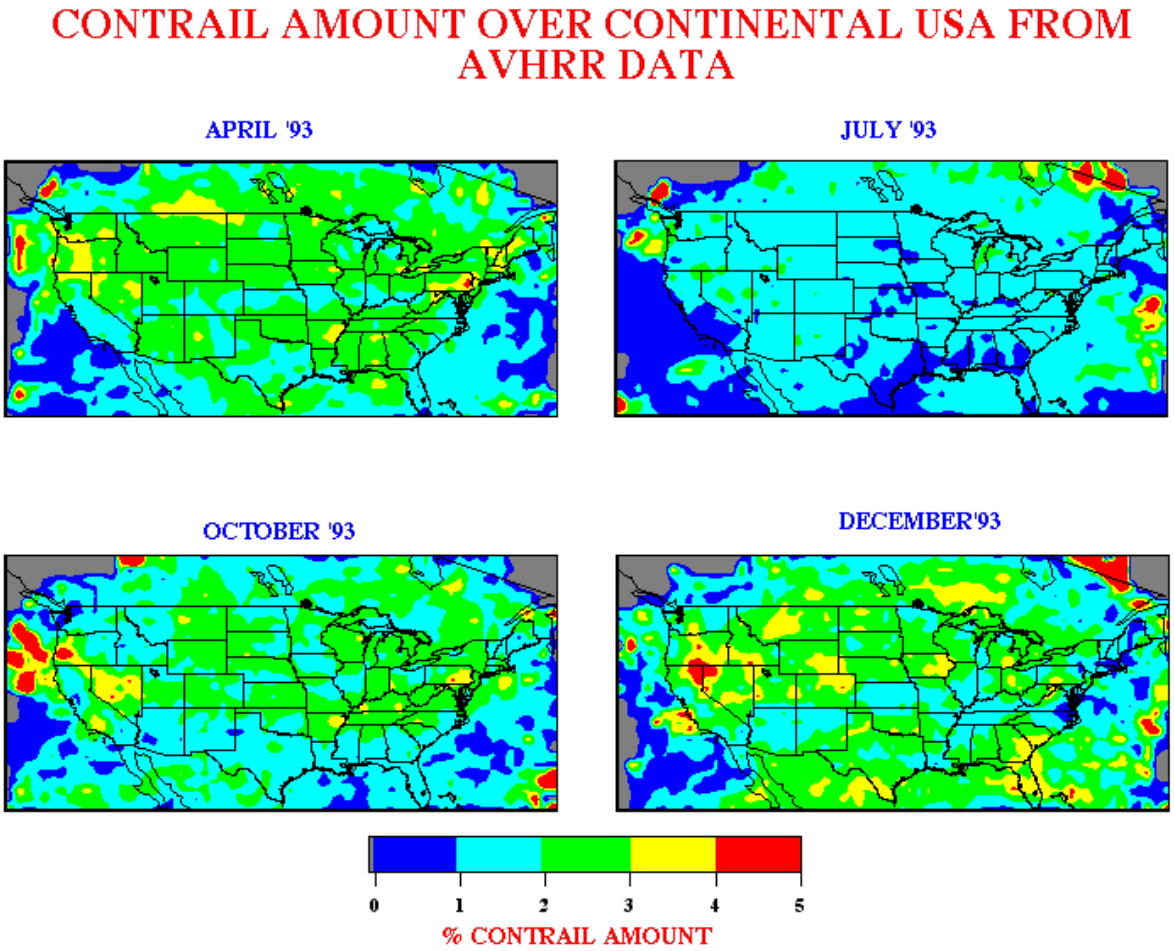

Figure 4: Contrail amount over continental USA from AVHRR data

of 1998) is a compromise between data handling effort and the significance of the results. The results show a yearly cycle with higher values in the dry season (January and April) and a daily variation with (except from January) higher values of contrail coverage at nighttime. According to air traffic data from March 1992 nighttime air traffic in this region is, like in Europe, 1/3 of daytime air traffic. Obviously there is at least in tropical regions a marked daily variation of the meteorological parameters of the upper troposphere which is not accounted for in the model estimate.

6 Results

The following table gives an overview on the main results of the regional studies of contrail coverage using AVHRR HRPT data. The order of magnitude of global contrail coverage as estimated by [12] and their regional distribution is supported by the regional studies.

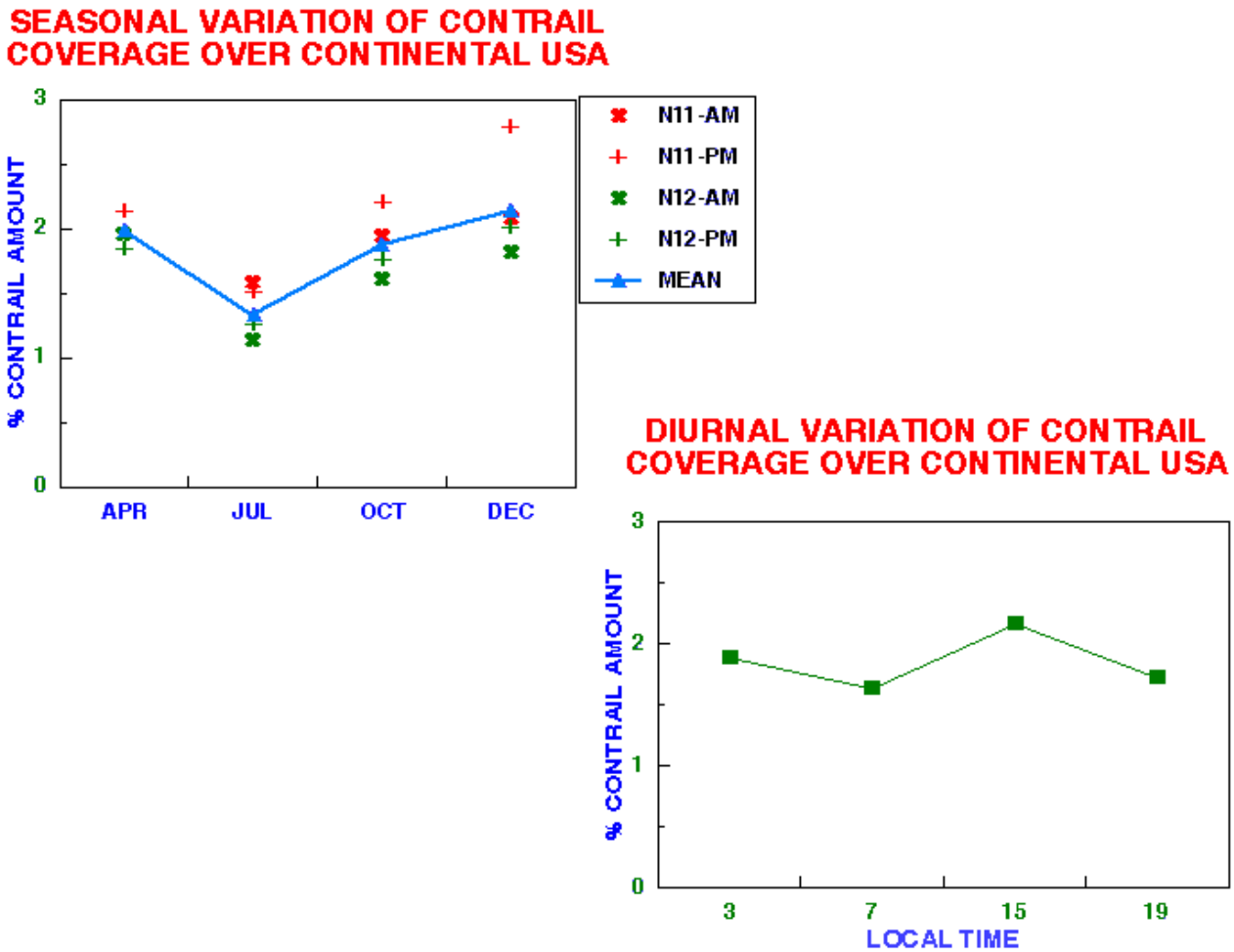

Figure 5: Diurnal and seasonal variation of contrail coverage over continental USA

Area	Sausen et al.	Satellite	remarks
Europe 30W-30E,35N-75N 8W-23E,41N-56N	 0.5 1.33	 0.75	 per definition- Bakan et al. Meyer(2000)
SE-Asia, all (90E-126E,0N-25N) North (11N-25N) South (0N-11N)	0.14 0.18 0.10	0.13 0.17 0.09	high nighttime values
Continental USA	1.44	1.7	NOAA11+NOAA12, different tuning of algorithm

An important finding of the SE-Asia study is the relatively high amount of contrails at nighttime. This indicates, that the model approach misses at least in the tropics the description if

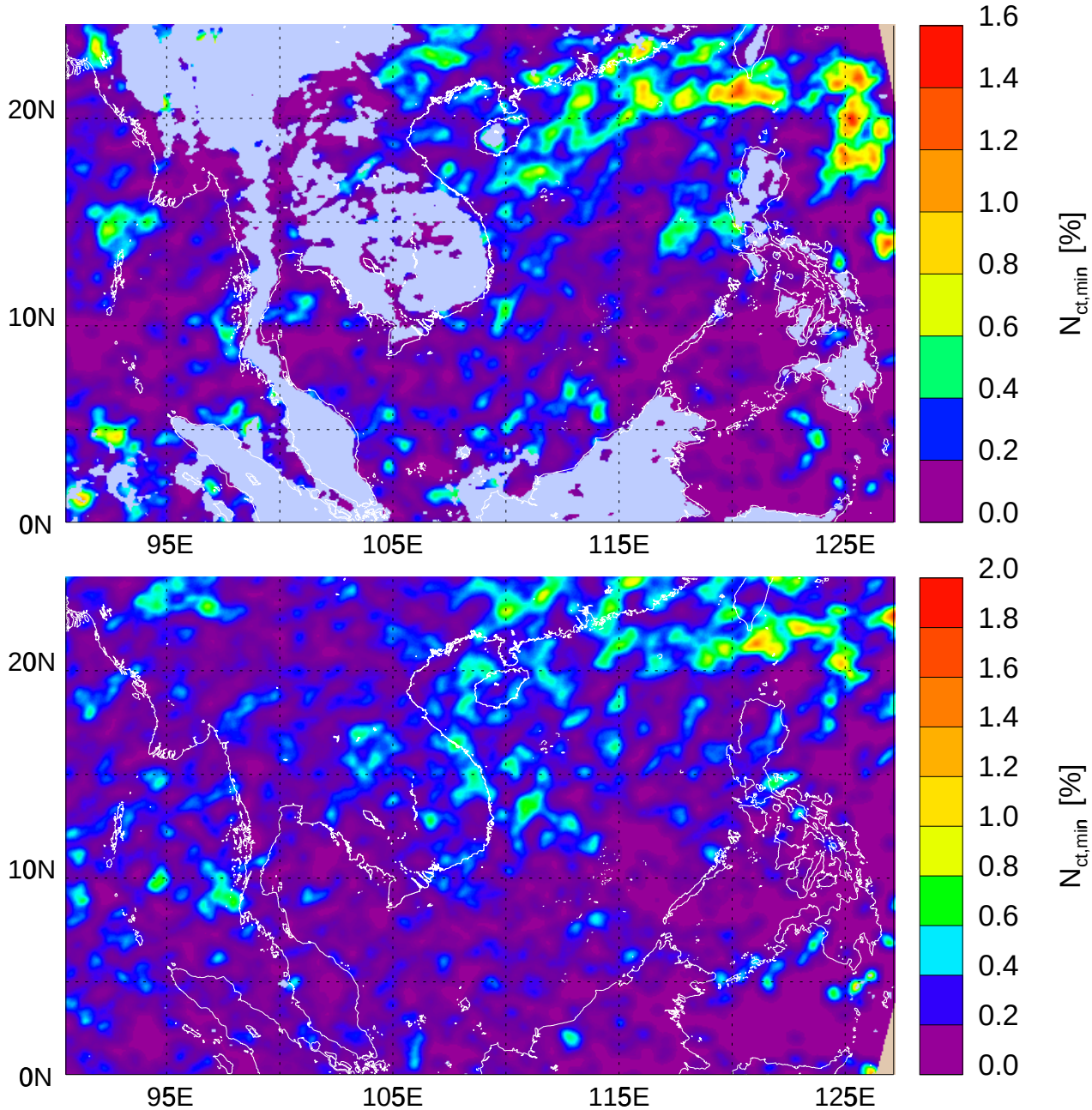

Figure 6: Contrail coverage January, April, July and October 1998. Top image shows daytime, bottom image nighttime data. The grey areas in the daytime image over land depict regions, where the algorithm is unable to detect the majority of contrails due to the thermal inhomogeneity of the background.

daily variation in weather and air-traffic. As the energetic impact of contrails on the earth-atmosphere system depends strongly on solar zenith angle and therefore on daytime both, the daily variation of weather parameters and air traffic, should be considered in future model estimates.

A further study of regional contrail coverage is planned for the East-Asian region. The study of the European region will be extended to a small climatology of at least 5 years. The extension of the studies to other satellites necessitates a characterization of the performance of the algorithm on the different satellites.

The main problems with the interpretation of the results of the regional studies arose from the following two points:

- Different time period:
  Sausen et al: Air traffic data from 1992, Meteorological data 1983-1993.
  Satellite data: Europe 1995-1997, SE-Asia 1998, USA 1993

- Different times of the day:
  Sausen et al: Air traffic - daily mean, weather 12UT
  Satellite data: Europe daytime (noon), SE-Asia day + nighttime, USA 4 overpasses per day

In further model studies on contrail coverage the daily variation of contrail coverage should be addressed, resulting in better possibilities for comparisons. The performance of the contrail detection scheme will be compared for different satellites.

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