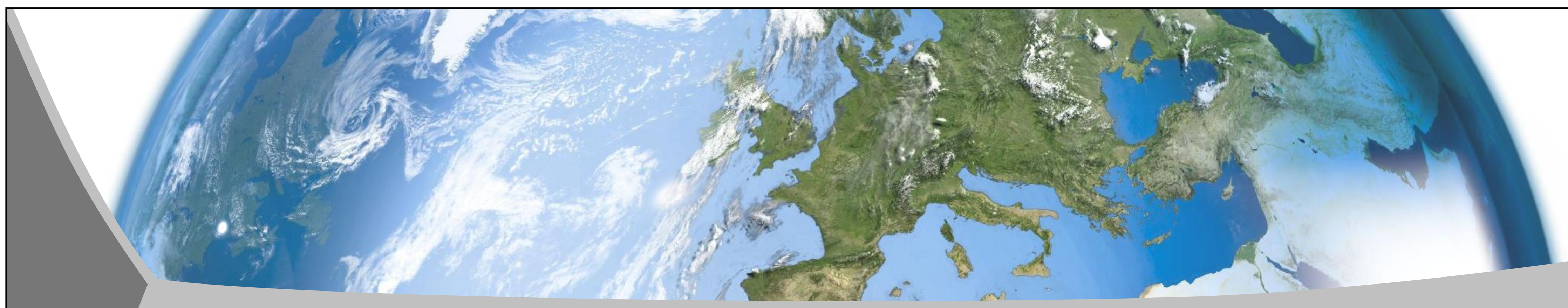

Satellite Based Ice Cloud Detection using Artificial Neural Networks

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Introduction

Ice clouds play an important role in climate as they reflect incoming solar radiation and absorb outgoing thermal radiation. Nevertheless, the understanding of the physical processes that govern their life cycle is still poorly understood, as is their representation in climate models.

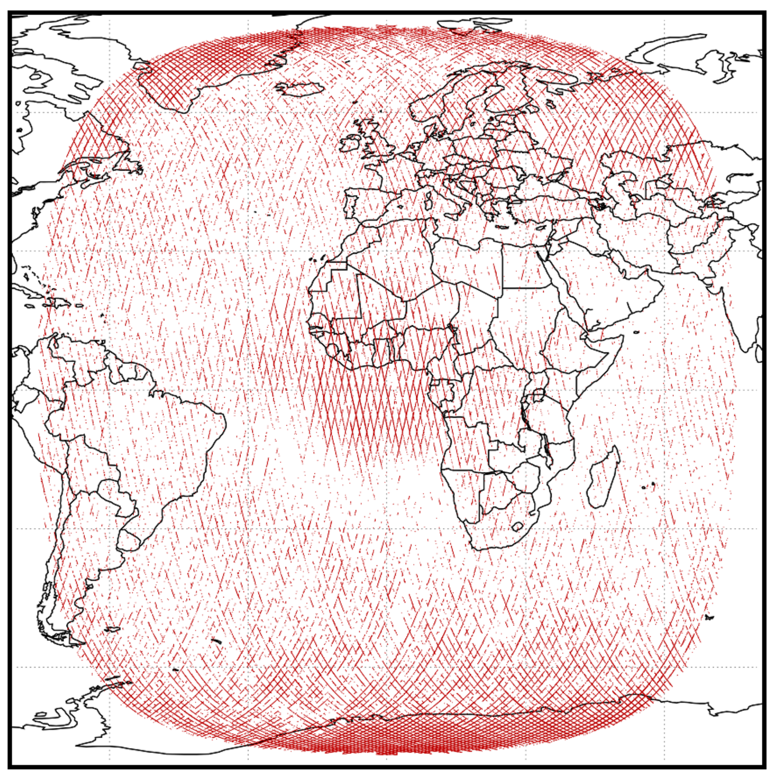
To monitor and better understand the physical and optical properties of ice clouds, an accurate ice cloud detection algorithm is essential.

COCS (Cirrus Optical properties derived from CALIOP and SEVIRI, Kox et al. 2014) is an artificial neural network trained with coincident CALIPSO/CALIOP version 2 data and MSG/SEVIRI thermal observations in order to detect ice clouds and derive ice optical thickness and ice top height. Using this approach, the high sensitivity to ice clouds of the polar orbiting LIDAR (CALIOP) is combined with the high temporal resolution and large spatial coverage from the geostationary imager (SEVIRI).

COCS-2 is based on the heritage of COCS, but several improvements have been made to overcome some shortcomings of COCS. Additionally a new output variable, ice water path, is introduced.

Motivation

A recent validation of COCS using seven months of CALIOP version 3 data revealed a higher probability of false detection at small satellite viewing angles, high latitudes and over regions like Russia, Scandinavia and the southern Atlantic Ocean than expected. Following the validation results, COCS-2 is developed.



Geographical distribution of all points falsely classified as ice clouds by COCS. The **probability of false detection** is

- 23% for VZA < 15°
- 33% for |latitude| > 65°
- 7.8% on average

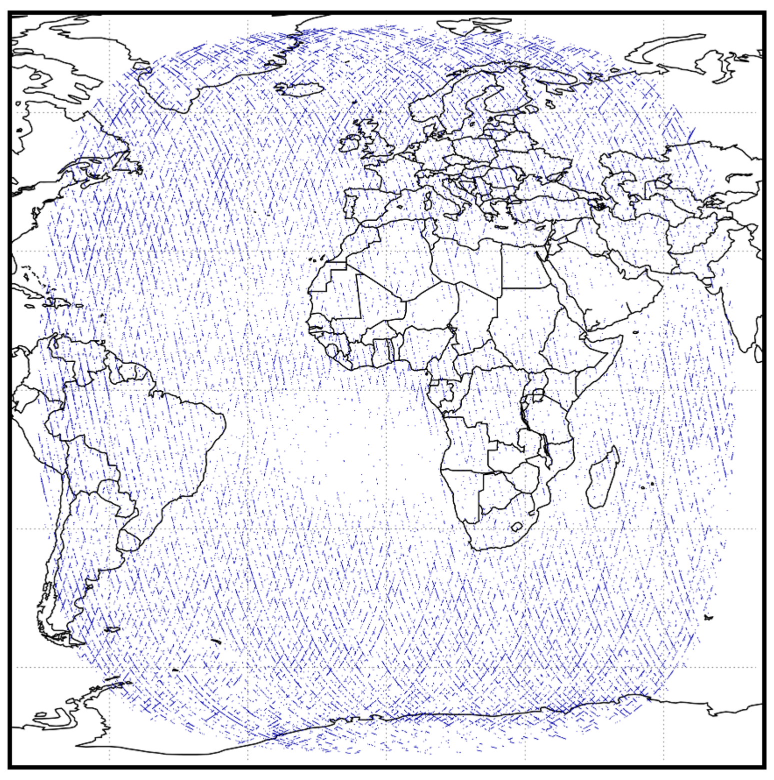
COCS uses an IOT threshold of 0.1 for ice cloud detection, meaning that all false detections will have a retrieved IOT ≥ 0.1.

Method

To improve the performance of COCS, COCS-2 implements several relevant changes:

- Training and retrieval are divided into **multiple networks**
  - **Ice cloud detection** (presented here)
  - Optical thickness and ice water path retrieval
  - Top height retrieval
- Separate neural networks are used for the **tropical/subtropical** and **temperate/polar** regions respectively
- The more accurate CALIOP **version 3** products are used for training
- More **precise collocations** between SEVIRI and CALIOP are used
- The neural network structure and training procedure are optimized

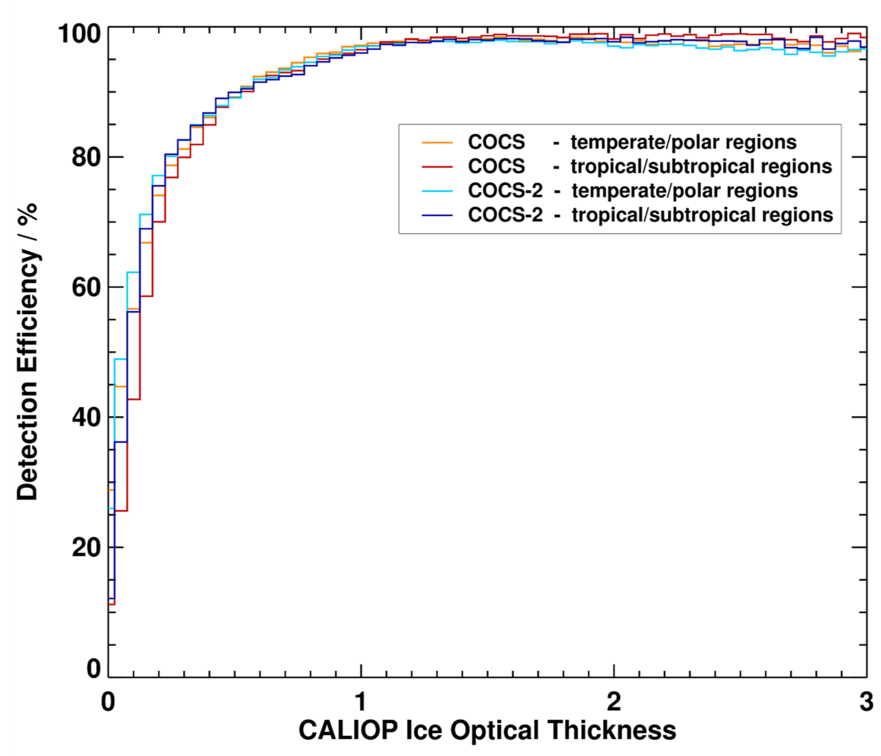
Results – Validation against CALIPSO/CALIOP



Geographical distribution of all points falsely classified as ice clouds by COCS-2. The **probability of false detection** has been reduced to

- 2.1% for VZA < 15°
- 5.1% for |latitude| > 65°
- 2.8% on average

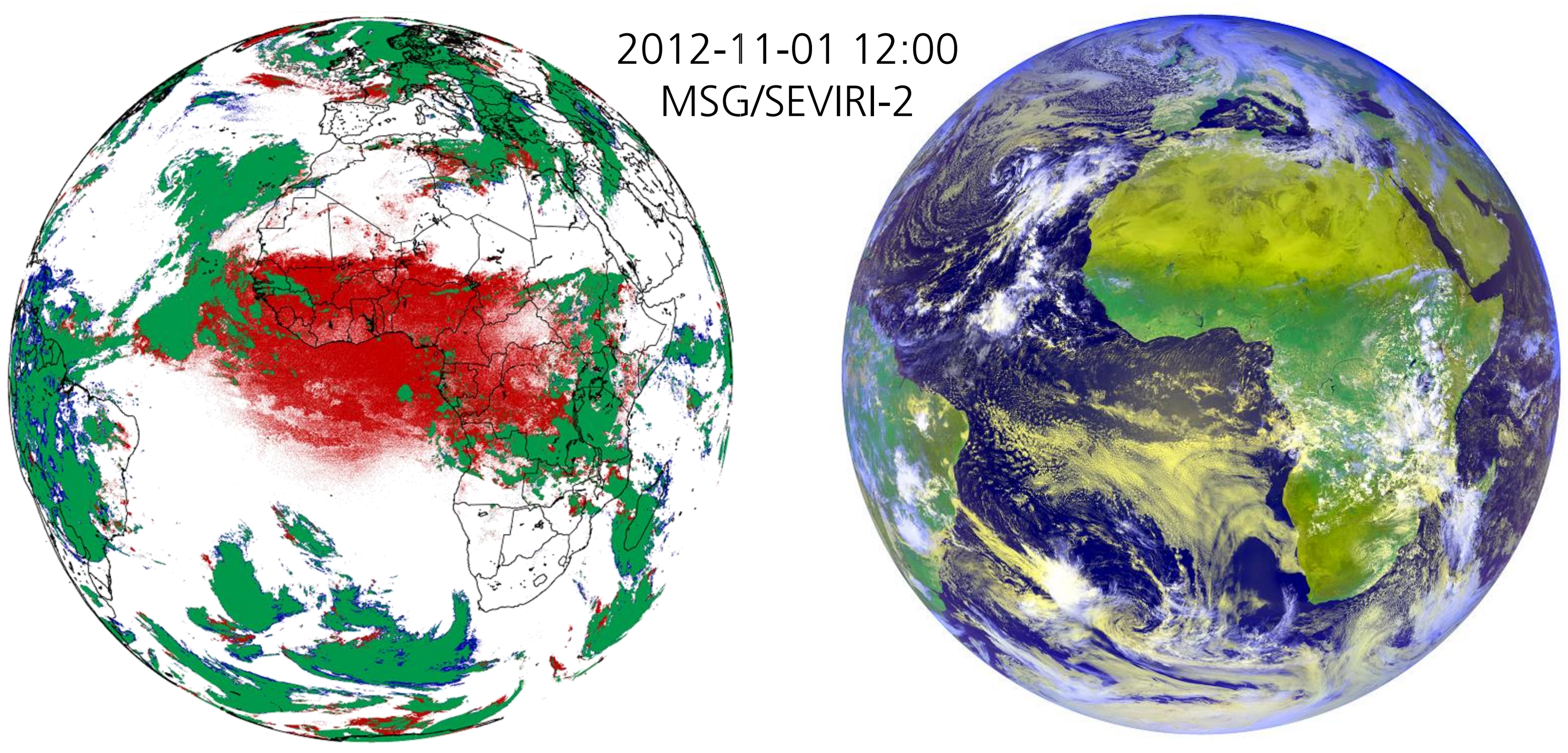
Since COCS-2 includes a pure ice cloud detection algorithm, there is no minimum IOT value for the false detections.



Ice cloud **detection efficiency** as a function of optical thickness

- COCS-2 shows an increased detection efficiency for thin ice clouds
- For optically thicker clouds, COCS shows a slightly higher detection efficiency

Results - Application to real MSG/SEVIRI Data



Left:

Ice cloud mask comparison:

Green – classified as ice cloud by COCS and COCS-2
Red – classified as ice cloud by COCS only
Blue – classified as ice cloud by COCS-2 only

Right:

A corresponding false color RGB composite. Ice clouds are recognized as white or bluish, whereas liquid water clouds are recognized as yellowish.

The reduced probability of false detection near the sub-satellite point is clearly visible as is the improved detection efficiency of thin clouds at the ice cloud edges.

Conclusions

- Artificial neural networks are a powerful tool for ice cloud detection from MSG/SEVIRI
- The shortcomings of COCS have been overcome with the new algorithm COCS-2
  - Generally reduced probability of false detection with major improvements for certain regions where COCS had problems
  - Increased detection efficiency for thin ice clouds, which is an important improvement for a future study of the ice cloud life cycle
  - In contrast to COCS, COCS-2 requires no minimum IOT threshold for the ice cloud detection

Outlook

The next steps are to train additional neural networks for the retrieval of ice cloud optical thickness, top heigth and ice water path. Furthermore a more comprehensive validation will be performed in order to evaluate the performances for different vertical cloud profiles.

References

Kox, S., Bugliaro, L. and Ostler, A. (2014). Retrieval of cirrus cloud optical thickness and top altitude from geostationary remote sensing. *Atmos. Meas. Tech.*, 7, pp. 3233-3246.

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