Bayesian Cloud Mask

Title: Development of a Bayesian Cloud Mask for All GOES-R Applications

Authors and Affiliations

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Topics: Other

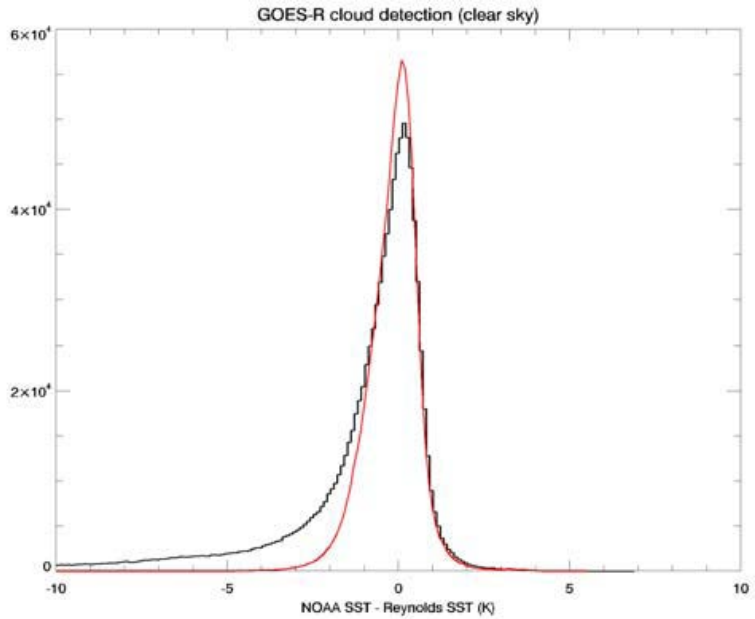
Program: GOES-R3

Introduction

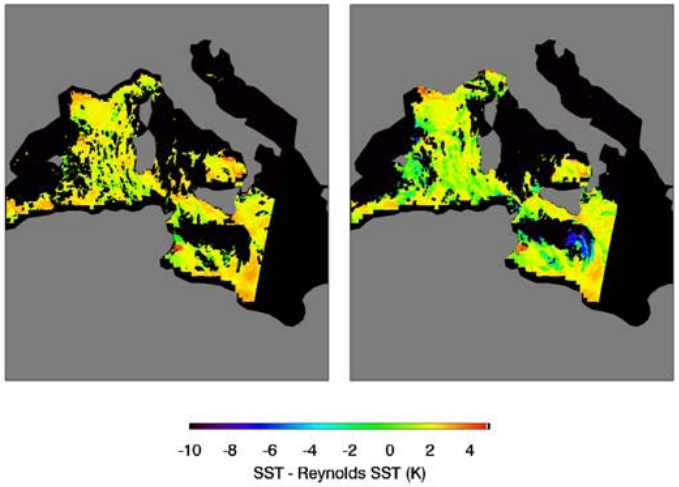
- The aim of this project is to develop and test an alternative cloud detection methodology for GOES-R which is based on forward modeling and Bayes' theorem over both land and ocean.
- This will be an improved version similar to the Bayesian algorithm running on the operational GOES sea surface temperature processing system at NOAA/NESDIS.
  - Provides continuity for users between Geo-SST cloud masks and GOES-R
- The Bayesian technique delivers a cloud mask of probability of clear-sky rather than a binary mask with arbitrary levels of clear or cloudy designations.
- This allows each user to choose the threshold of probability that defines valid pixels most appropriate for their application.
- This project offers an improved cloud mask which uses a common approach into which maintenance and improvement resources can be focused and also meets the needs of a variety of downstream users.

Introduction (Cont)

- Preliminary ocean cloud mask using Geo-SST PDFs
  - Does better than GOES-R cloud mask even now
  - Does not include any of the improvements/extra channels which will be added in Year 3 work based on the land cloud mask work



Histograms of SEVIRI-retrieved SST minus Reynolds Daily-OI SST. The black line shows the distribution obtained using the current GOES-R cloud mask while the red line is the result of applying our Bayesian scheme from the Geo-SST PDFs.



Comparison of part of the SEVIRI minus Daily-OI SST. LH image shows a Bayesian mask, RH image shows a GOES-R cloud mask. Cloud contamination is seen for the GOES-R mask

Methodology/Expected Outcomes

- The detection of cloud over land is significantly more difficult than that over ocean.
  - First 2 years have been dominated by investigations in the problem of cloud detection over land than ocean
- The Bayesian approach depends on the accurate modeling of top of atmosphere radiances. For land we have determined how best to
  - Model the Bidirectional Reflectance Distribution Functions (BRDFs) for land
    - Investigate different BRDFs
  - Obtain optimum cloudy/textural probability density functions (PDFs) based on SEVIRI data
  - Best practice RTM/RTM use methodology for visible channel data
- The ocean component will be investigated in Year 3 by
  - Deriving improved cloudy/textural PDFs over ocean
  - Incorporate the improvements derived during the land segment for ocean
- Combine both land and ocean parts into a single algorithm
  - Incorporate into modified GEO-SST system as a baseline
  - Show improvement over current GOES-R cloud mask methods with test cases
  - Generate best practices for developing a GOES-R Bayesian cloud mask

Executive Summary

- **Developed a methodology for applying Bayesian cloud screening over land using MSG-2 SEVIRI data as a proxy to ABI to be flown on the new GOES-R satellite.**
- **Completed the software to implement this methodology for land-only processing**
  - **based on the GOES Bayesian Cloud Screening framework used for the current GOES operational cloud screening over the ocean.**
- **Completed the relevant modules for cloud screening over the land to integrate easily with the existing Bayesian software.**
- **Tested this methodology against the OSI SAF* cloud mask for the SEVIRI imagery supplied by Meteo-France**.**
- **The optimised Bayesian cloud screening over land shows a high skill compared with the EUMETSAT OSI SAF cloud mask**
  - **the skill may be underestimated as the OSI SAF cloud mask is not perfect.**
  - **identified the key factors that affect the skill of the Bayesian cloud screening over land.**
- **Delivered software and Algorithm Theoretical Basis Document to STAR/SOCD.**

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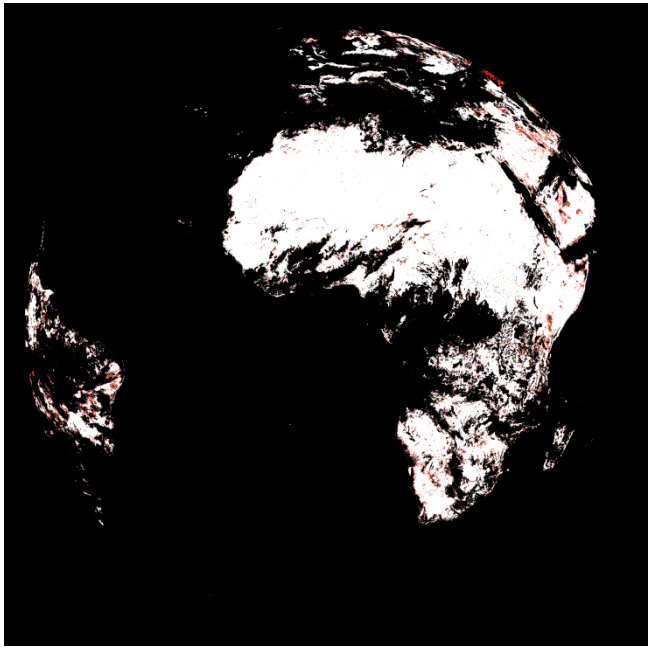
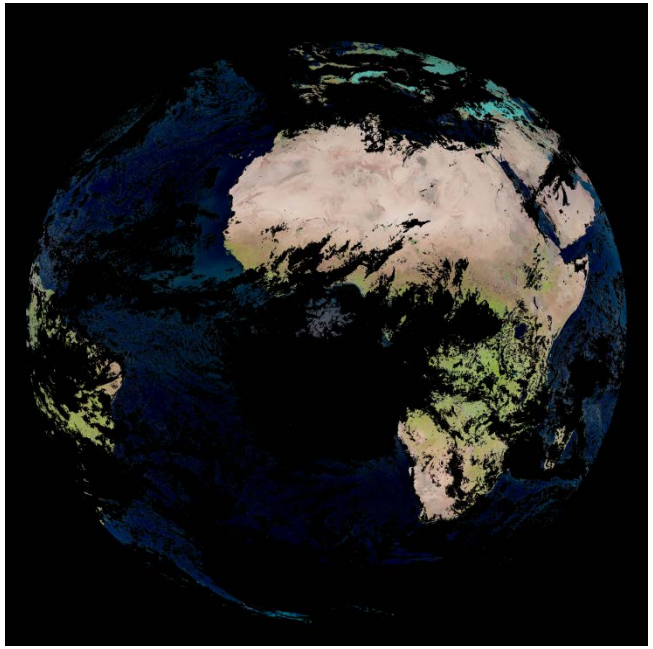
Example – Land Mask

(a) Probability of cloud-free

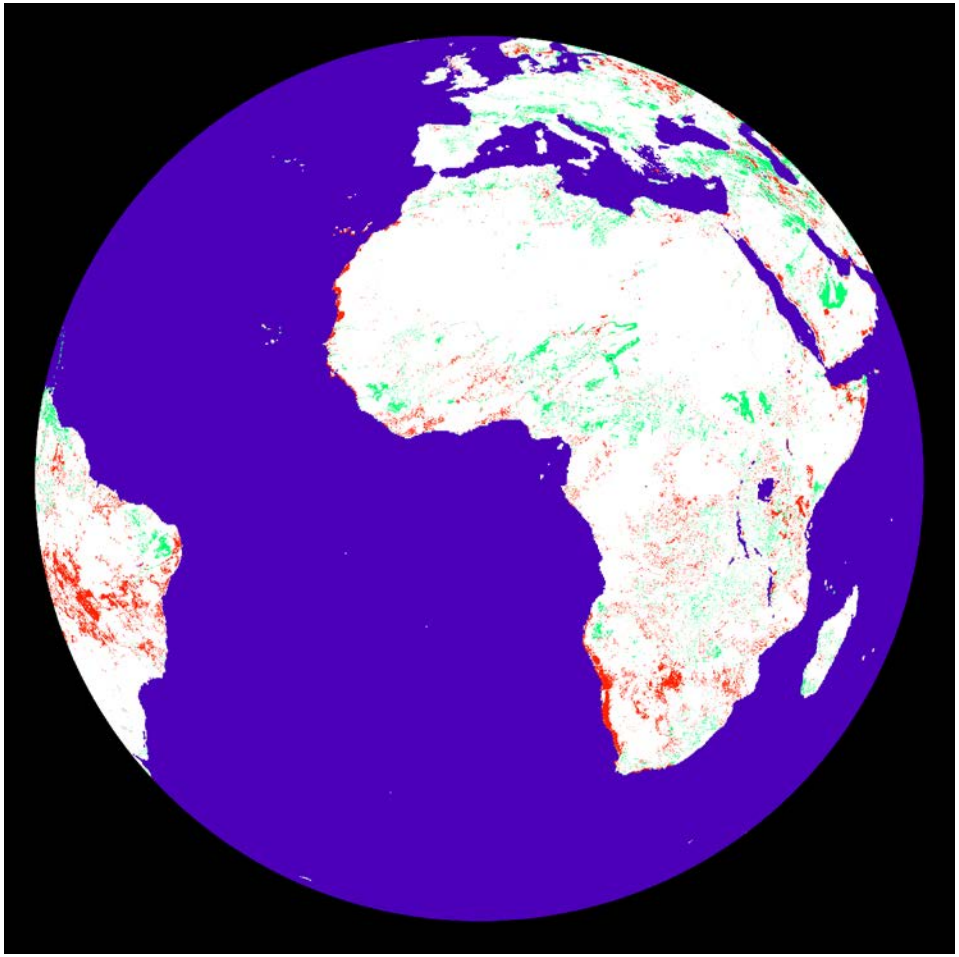


(b) Bayesian cloud mask (Pclr > 0.9)



An example of the Land Bayesian cloud screening on a mid-day image. (a) The probability of clear scene (white = 1.0, black = 0.0, red = 0.8). (b) The cloud mask defined using a threshold of Pclr > 0.9 overlaid on a false color image of the full disk.

TESTED METHODOLOGY



The location of the false alarms (red points) and missed cloud (green points) when compared with the OSI SAF cloud mask.

Path to Operations

- The development of an alternative cloud detection methodology is essential in order to mitigate the risk to many products posed by their dependency on a single cloud mask algorithm for GOES-R.
- A Bayesian framework should not require significant post-launch tuning due to its reliance on well-established forward models and real-time numerical weather prediction data so transition to GOES-R should be relatively easy.
- The current project will provide methodologies/recommendations for the implementation of a GOES-R Bayesian cloud mask after launch

Conclusions –Land Mask

- **The key modifications to the Bayesian cloud clearing scheme**
  - **the implementation of bias corrections to the modelled top of atmosphere reflectance and brightness temperatures**
  - **a correction applied to the background surface temperature over land that accounts for differences in elevation between the spatial locations of the pixel and the background state vector data**
- **Testing the methodology against the OSI SAF cloud mask supplied with the MSG-2 SEVIRI data**
  - **indicates that modifications produce a fairly high skill at cloud clearing over land.**
- **The scheme was most successful during day time where the use of the visible channel data leads to a distinct separation in the cloudy and cloud-free probabilities.**
  - **the scheme can be further optimized for night time scenes**
  - **the Bayesian scheme is potentially doing better than the statistics suggest given that the OSI SAF cloud mask is not perfect.**
- **This methodology can be adapted operationally to the ABI on the GOES-R satellite.**

General Conclusions

- The development of an alternative cloud detection methodology is essential in order to mitigate the risk to many products posed by their dependency on a single cloud mask algorithm for GOES-R.
- A Bayesian framework should not require significant post-launch tuning due to its reliance on well-established forward models and real-time numerical weather prediction data so transition to GOES-R should be relatively easy.
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Future Plans

- Develop GOES-R cloud mask methods over ocean
  - Leverage off UoE land cloud mask work and GeoSST experience
  - Develop PDFs for ocean
- Combine land and ocean components into a unified scheme
  - Compare with GOES-R cloud mask for certain test cases