1. Bayesian Cloud Mask

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

Authors and Affiliations

Eileen Maturi, NOAA/NESDIS, eileen.maturi@noaa.gov

Jonathan Mittaz, University of MD, CICS, jon.mittaz@noaa.gov

Christopher Merchant, University of Edinburgh, Edinburgh, U.K., c.merchant@ed.ac.uk

Topics: Other

Program: GOES-R3

2. Introduction

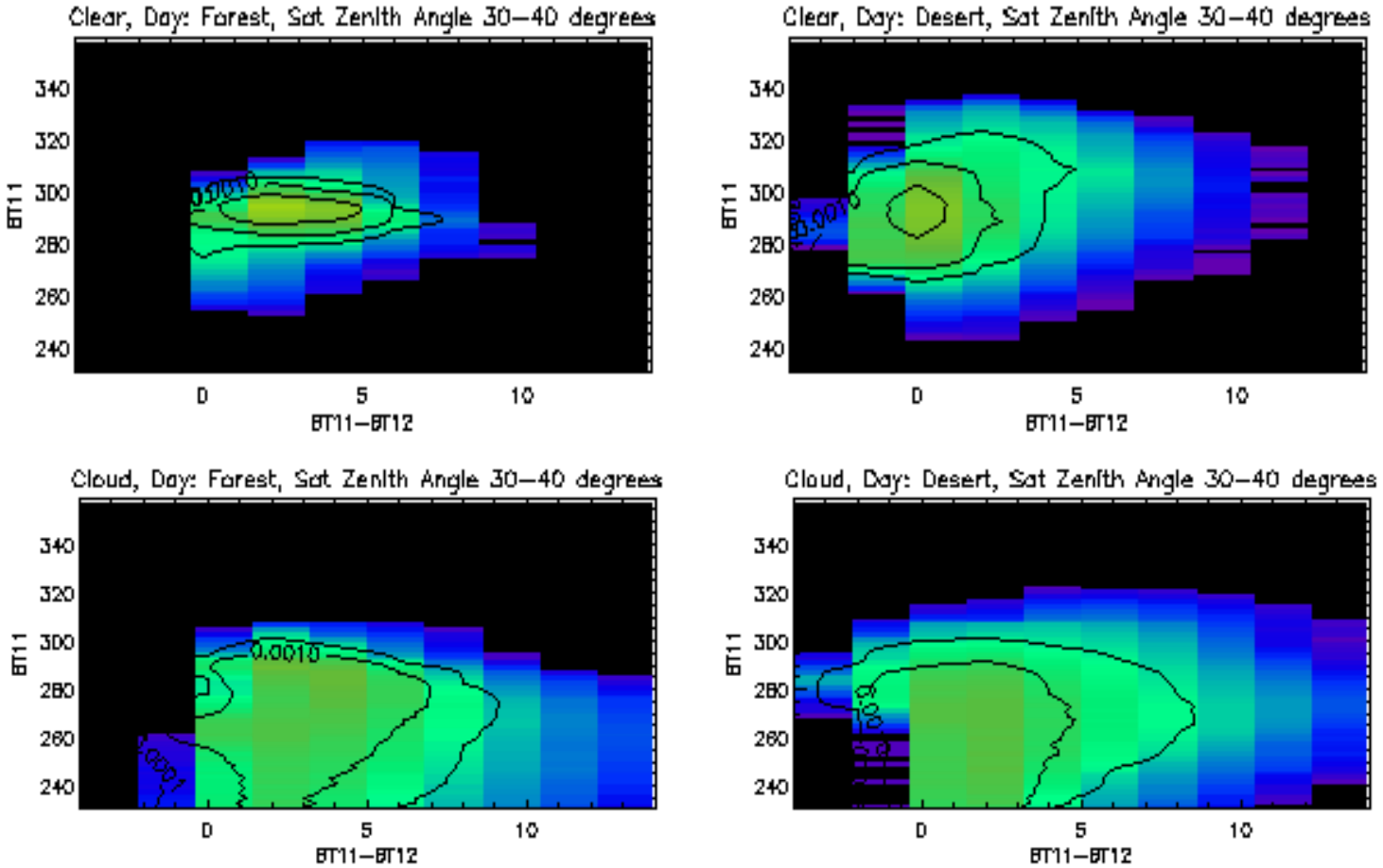
- The aim of this project is to develop and test an alternative cloud detection methodology for GOES-R which is based on forward modeling and Bayes' theorem over both land and ocean.
- This will be an improved version similar to the Bayesian algorithm running on the operational GOES sea surface temperature 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.

3. 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 tin 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

4. Results(1)

- Preliminary cloudy PDFs over different land surface types have been generated



4. Results(2)

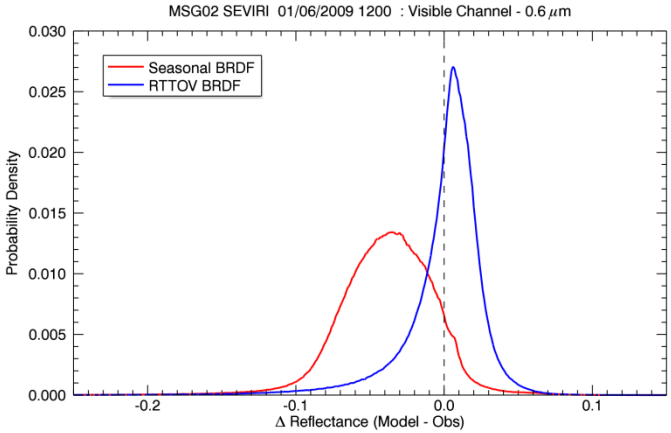
- BRDF generation for visible channels
  - SEVIRI used as a proxy
  - Comparison between UoE* and RTTOV12 BRDF
    - RTTOV is better is the baseline

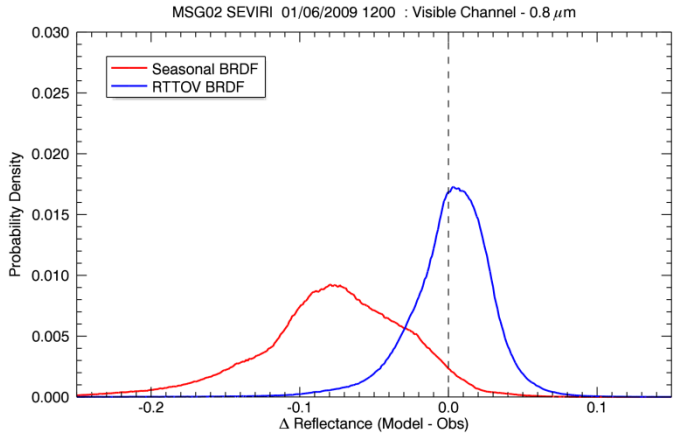
Red curve - UoE seasonal BRDF atlas

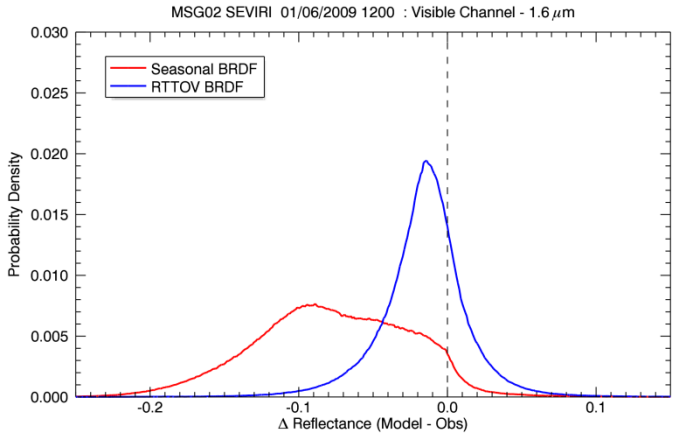
Blue curve - RTTOV monthly BRDF atlas

Positive difference = Model over-estimating

Negative difference = Model under-estimating







*UoE- University of Edinburgh

4. Results(3)

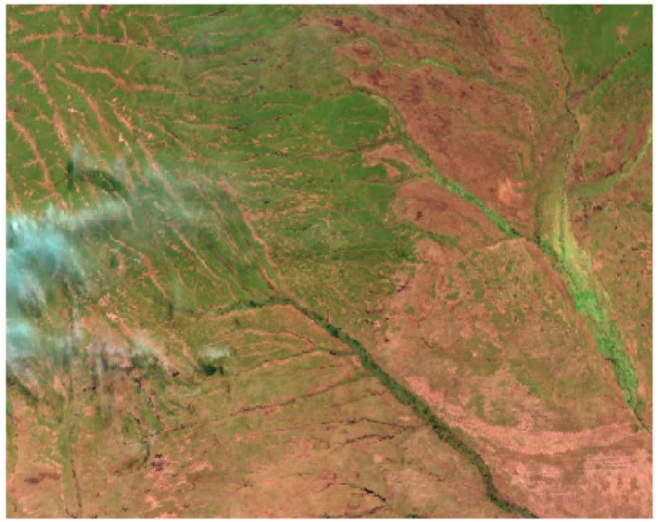
- Investigation of per-profile or per-location RTM
  - per-profile uses less RTM runs and can use RTTOV/CRTM
  - Per-location needs very fast RTM – can't use RTTOV/CRTM - use local UoE model
  - Little difference between per-profile or per-location RTM runs
    - RTTOV includes Rayleigh scattering for visible channel so would be preferred

- Example of a Bayesian derived land cloud mask

The left hand panel shows an image from Mongu, Zambia on 09/07/03 with some thin cirrus seen as a blue haze. For the right hand panels
• Top panel: Cloud mask derived from the optical data
• Bottom panel: Cloud mask derived from thermal infrared imaging along using the Bayesian technique.

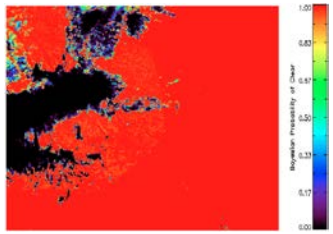
The Bayesian cloud mask captures more of the thin cirrus and is expected to work even better when the optical data is also included.

Optical image



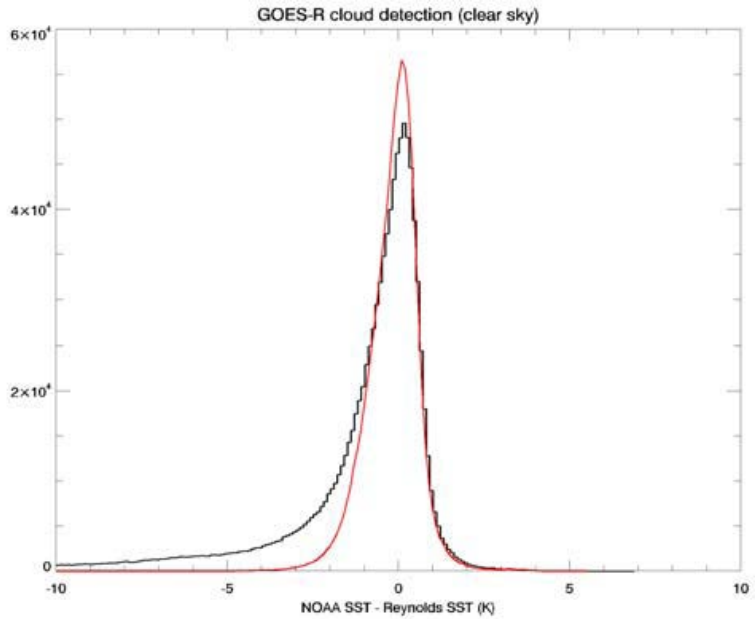
Optical cloud mask

Bayesian cloud mask

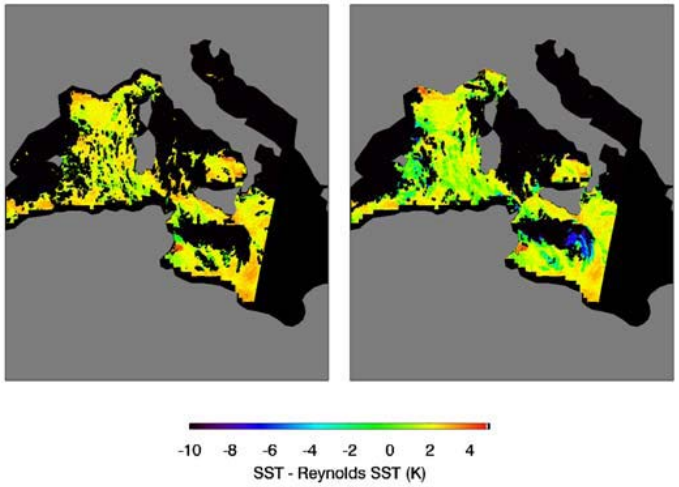


4. Results(4)

- 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

5. Possible 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

6. Future Plans

- Complete the land cloud mask work
  - Expected to be delivered by UoE in June 2013
- 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

7. Publication List

- References

- Mackie, S., O. Embury; C. Old; C. J. Merchant; P. Francis, Generalized Bayesian cloud detection for satellite imagery. Part 1: Technique and validation for night-time imagery over land and sea, *International Journal of Remote Sensing,* ***31, 2573-2594, 2010***
- Merchant, C.J., Harris A.R., Maturi E., and MacCallum, S., Probabilistic physically-based cloud screening of satellite infra-red imagery for operational sea surface temperature retrieval, *Quart. J. Royal Met. Soc.,* ***131,*** 2735-2755, 2005