Improved navigation of AVHRR data at high latitudes

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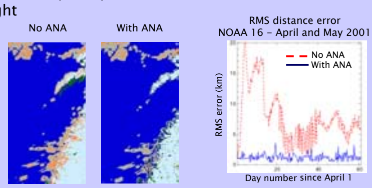
Objective

Improve the automatic navigation of AVHRR data as provided by AAPP and the Automatic Navigation Adjustment (ANA) software package (Brunel & Marsouin, 2002) at night with particular emphasis on high latitude conditions.

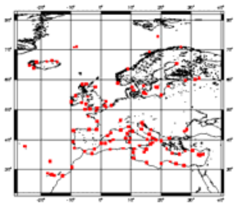
Motivation

- Inaccurate navigation may impose serious problems when data are used as input to a geophysical retrieval, like e.g. an objective cloud classification scheme
- ANA frequently fails to make an attitude correction at night

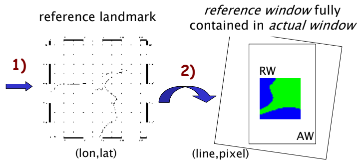


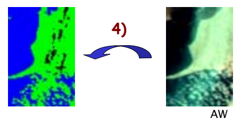
What is ANA?

The Automatic Navigation Adjustment (ANA) technique (Brunel and Marsouin, 2000) combines a physical image deformation model and automatic adjustment on coastal landmarks. The navigation adjustment is done in satellite co-ordinates allowing interpreting the landmark navigation errors in terms of satellite attitude: yaw, pitch and roll.

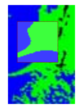


The ANA software version 3.1 integrates with AAPP.





1) **Generation of reference landmarks**
2) **Landmark location:** Deformation model + Nominal attitude
3) Cloud Mask (optional)
4) **Binary land-sea mask:** Channel 1&2 daytime and channel 4&5 nighttime
5) **Calculation of similarity coefficient:** between moving and reference windows for all possible displacements
6) **Attitude estimation**

5)  The displacement corresponding to the maximum of the similarity coefficient gives the landmark navigation error expressed in line and pixel numbers.

6) Assuming the attitude error is constant over the whole image, it can be estimated by the rms resolution of a system involving the measured landmarks position in the image and their true latitudes and longitudes.

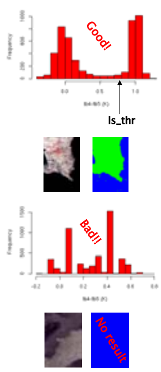
ANA nighttime land-sea mask

The landmark detection algorithm applied at night is detailed in Brunel and Marsouin (2002):

- Calculates AVHRR Tb4-Tb5 histogram (assuming cloudfree)
- Search for two peaks and computes a threshold: **ls_thr**
- Assigns all pixels with **Tb4-Tb5 < ls_thr** to land and all others to sea

Weaknesses!

- Assumes that Tb4-Tb5 is always greater over sea than over land.
- Even though the Tb4-Tb5 is rarely greater over land than over sea, it happens quite frequently that there is no clear separation of the land and sea peaks. In those cases no threshold is found and no separation is attempted, and the landmark is rejected.
- The algorithm is based on empirical parameters tuned for mid latitude conditions only

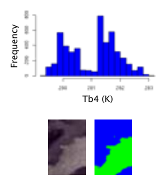


A new nighttime algorithm

A classical automatic k-means clustering method with two clusters using all available spectral channels.

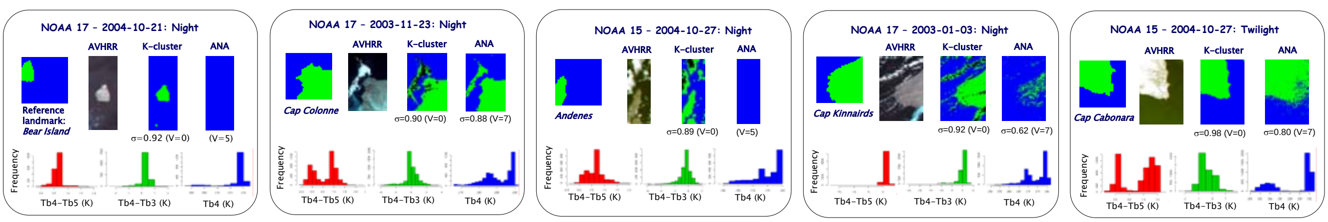
Algorithm steps:

- **Gross cloud screening**: Dynamic thresholding using RTM and NWP information, as in the *NWCSAF AVHRR cloudmask* (Dybbroe et al., 2005), however, using only the three IR channels. In addition a dynamic threshold for Tb4 using statistics on the observed data is derived.
- **k-means clustering** on all cloudfree pixels.
- **Quality checking**
  - High cloud cover and poor cluster separation
  - Very small clusters not allowed
  - Cloud contamination according to Tb4-Tb3 (only performed if the probability of sunglint is low)
  - Cloud contamination according to Tb4-Tb5
  - Cloud contamination according to Tb4



The aim is to only filter out the pixels where there is severe alteration of the TOA radiance due to cloud contamination, allowing for partially filled cloud pixels and thin and highly transparent clouds. We rather want to let cloudy pixels get undetected than mistake cloud free pixels for clouds.

Results

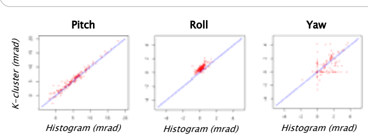


σ: Similarity coefficient
V: Validity code

V=5: T4-T5 land-sea mask failure

V=7: Similarity lower than threshold (0.9)

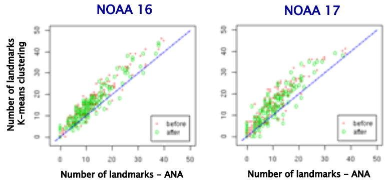
Do the two methods result in comparable attitude errors?



Yes

Comparing NOAA 17 attitude errors as estimated using the *histogram* and the *k-means clustering* methods

Number of valid landmarks before and after attitude estimation



205 NOAA 17, 174 NOAA 16 and 36 NOAA 15 overpasses, November to March (2003 and 2004):

10179 viewed landmarks (NOAA17 night):
- New method: 2529 (24.8%) valid
- Histogram method: 1749 (17.2%) valid

Number of overpasses for which a pitch error is derived:
- NOAA 15: 92% → 97%
- NOAA 16: 91% → 94%
- NOAA 17: 74% → 82%

References

Brunel, P. and Marsouin, A., 2000: Operational AVHRR navigation results. *Int. J. of Remote Sensing*, **21**, 951-972.

Brunel, P. and Marsouin, A., 2002: ANA-3 User's Manual. Available from Météo France, Centre de Météorologie Spatiale, Avenue de Lorraine, Bp 147, 22302 Lannion Cédex.

Dybbroe, A., Brunel, P., Marsouin, A., and Thoss, A., 2003: Accurate real-time navigation of AVHRR data at high latitudes. "XII International TOVS Study Conference", Lorne, Australia, 27 February - 5 March 2002.

Dybbroe, A., Karlsson, K.-G. and Thoss, A., 2005: NWCSAF AVHRR cloud detection and analysis using dynamic thresholds and radiative transfer modelling - part one: Algorithm description, *J. Appl. Meteor.*, Vol 44, No 1, pp 39-54.

Acknowledgement

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Conclusion

A new nighttime landmark detection algorithm for ANA has been developed. This new method is an improvement over the existing histogram based method:

- The rate of success in the landmark detection increase significantly
- The number of overpasses for which a pitch error is derived increase
- The attitude errors estimated with the two methods are in good agreement

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