A Morphological Algorithm for the Detection of Linear Young Contrails

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1 -Introduction

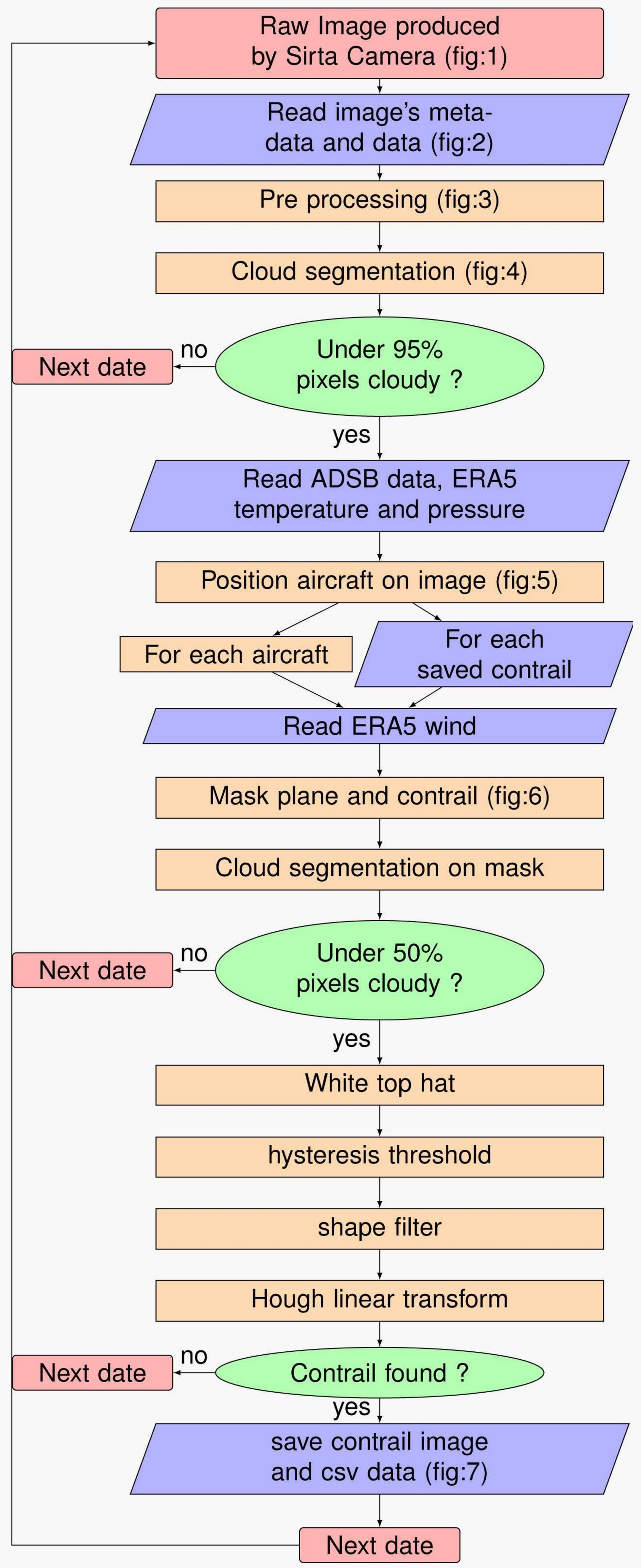
The **climate impact of aviation** can be separated into CO_2 and **non-CO_2 effects,** with the latter being potentially larger than the former. In this context we are more specifically interested in **condensation trails** (hereafter **contrails)** and induced cirrus. Monitoring contrail formation and evolution is necessary to understand their radiative effects and help the aviation industry to transition towards a more sustainable activity. Current research aimed at detecting contrails is mostly based on geostationary satellite images because they allow to follow the contrail over a long period of time. However a major shortcoming is that the formation phase of the contrails cannot be detected and larger, but older, contrails cannot always be attributed to the flights that produced them. To circumvent the problem that satellite images do not have a sufficient resolution to observe the contrail formation phase, we use a **ground-based hemispheric camera** with a two-minute sampling rate as a complementary source of information.

Our aim is to create a database that relates aircraft position, weather conditions, contrail formation and evolution.

The detection process takes advantage of prior knowledge of aircraft trajectories and use morphological operations to detect contrails on images from a ground-based camera. Knowing the aircraft trajectory, we can precisely determine where the contrail may form.

Figure 1: Image of the Sirta camera

3-Workflow algorithm



4-Illustration of the processing stages

A-Example of an image from the Sirta

Figure 2: Raw image 1024*768 pixels

- The camera is located at the Sirta supersite in Palaiseau (near Paris in France)
- RGB camera with fish eye lens
- Resolution is 1024*768 pixels
- Images are stored every two minutes from sunrise to sunset since 2014

B-Pre-processing step

Figure 3: Image after pre-processing

- Image is cropped beyond 60° zenith angle
- Image is re-projected onto a plane to straighten lines
- Final resolution is 901*901 pixels

C-Cloud screening

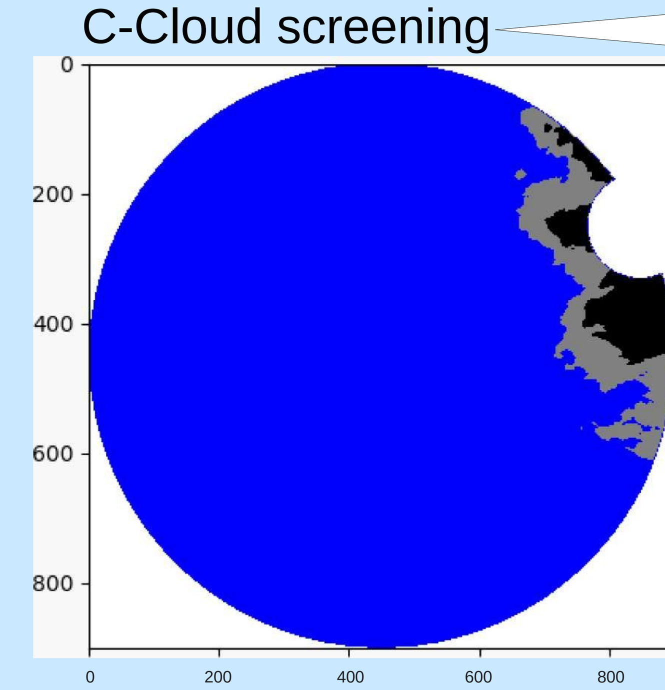


Figure 4: Cloud screening based on red/blue ratio

- We follow Lothon et al(2019). and apply a Red on Blue ratio to screen clouds
- Pixel class as blue sky if the ratio is under 0.75
- Pixel class as sure cloudy if the ratio is over 0.85.

D-Projection of aircraft positions

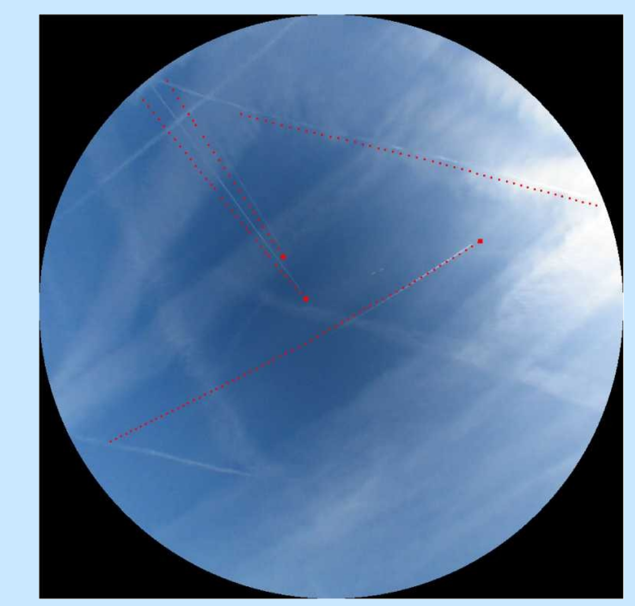


Figure 5: Aircraft projection on image space

The last 3-minute aircraft positions are projected using an angular calibration model (Jeanne et al(2019).) consisting of :

- A rotation (3 parameters)
- A radial distorsion (5 parameters)
- An azimutal distorsion (2 parameters)
- A conversion from polar to Cartesian coordinates (2 parameters)

E-Aircraft masking

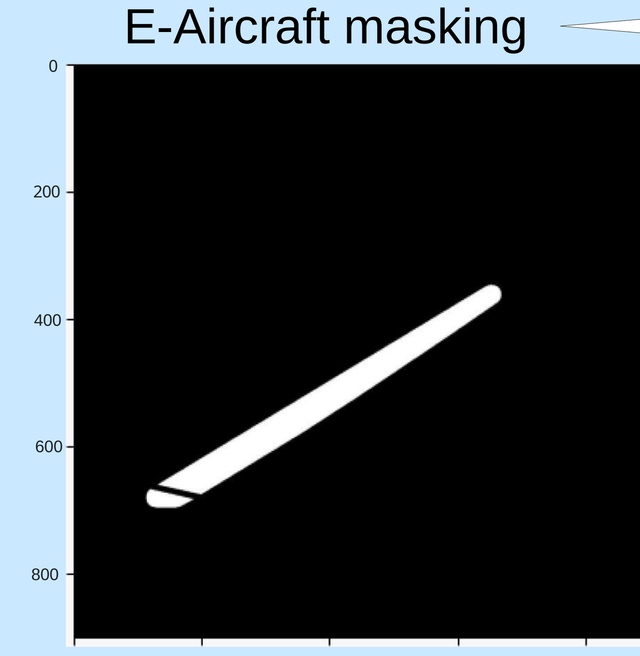


Figure 6: One Mask on each aircraft trajectory

- A mask is created around the trajectory
- The mask is translated according an estimate of the wind
- Each aircraft is process separately

F-Segmentation

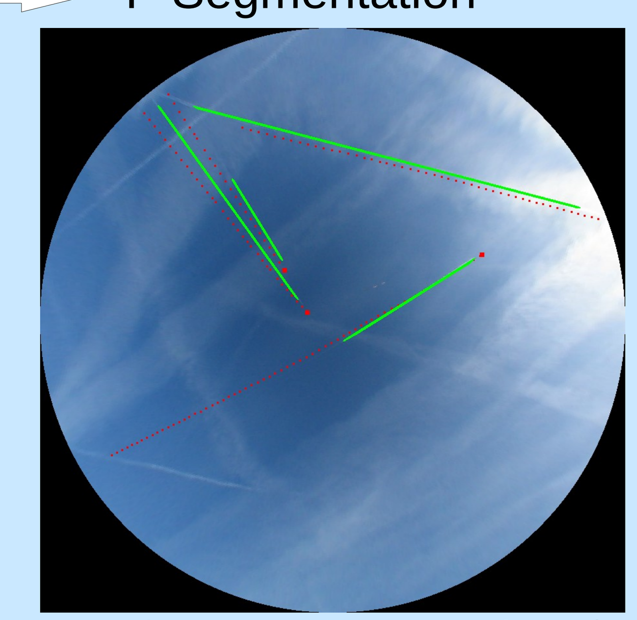


Figure 7: Output image with segmentation for visualization

- Aircraft trajectories are shown in red
- Contrail pixels from the segmentation are shown in green

2-Ground-based sky images

Advantages

- Easy to detect young contrails
- Easy to attribute a contrail to a particular aircraft
- Potential to link to satellite data

Disadvantages

- Difficult to follow contrail beyond a few minutes
- Image deformation because of fish eye lens (solve in processing step to straighten images)

5-Metric Evaluation

Segm : Segmentation by algorithm
Annot : Annotation by human with polygons

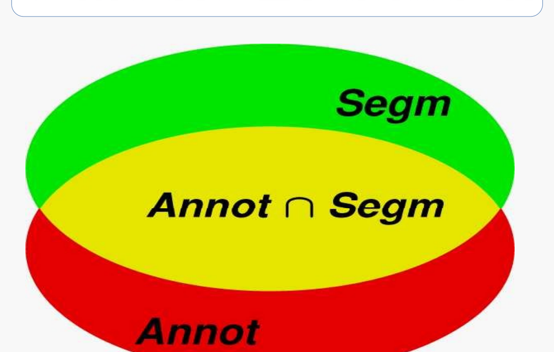


Figure 8: Intersection on Union

Score Binary
True positive : cases with intersection
True negative : cases with no Annot and no Segm
False positive : cases with Segm but no Annot
False negative : cases with Annot but no Segm

$$\text{Score on True Positif} = \frac{\text{inter section}}{\text{union}}$$

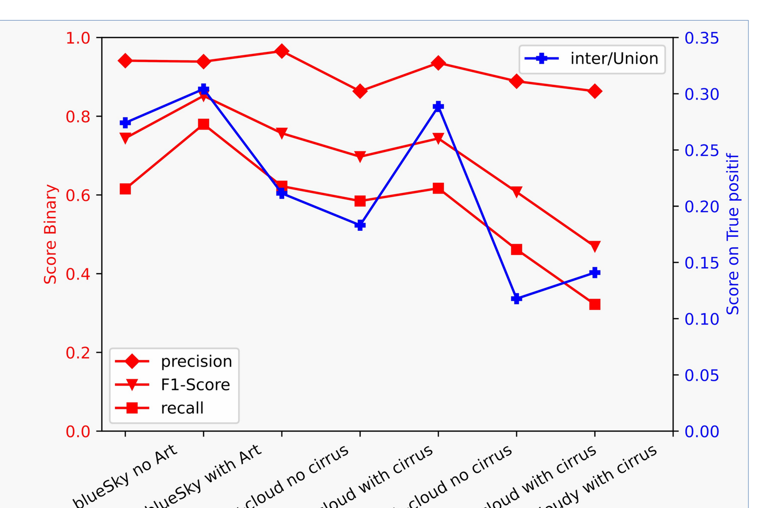


Figure 9: Score in red where the intersection is considered a true positive. Score in blue where we consider in the true positive cases the intersection on the union .

6- Conclusions

- The algorithm makes it easy to process and analyze thousands of images
- There are structural limits with positioning the aircraft on the image and with the Hough transform
- The performance of the segmentation algorithm decreases as the cloud cover increases
- Thin clouds decreases the contrast of the image and decreases the performance of the segmentation

7- Acknowledgments

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8-References

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[2] S. Jeanne et al. "Calibration of fish-eye lens and error estimation on fireball trajectories: application to the FRIPON network." In: *Astronomy & Astrophysics* 627 (2019): A78. DOI: 10.1051/0004-6361/201834990. URL: https://www.aanda.org/articles/aa/pdf/2019/07/aa34990-18.pdf

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