



Sustainable Skies Conference: Contrails in Focus

A Linear Contrail Detection, Tracking and Matching Algorithm

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Motivations on Contrails Observation



Contrail models validation



Contrail models improvement



Maybe a future monitoring of contrails

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Contrail models validation



Contrail models improvement

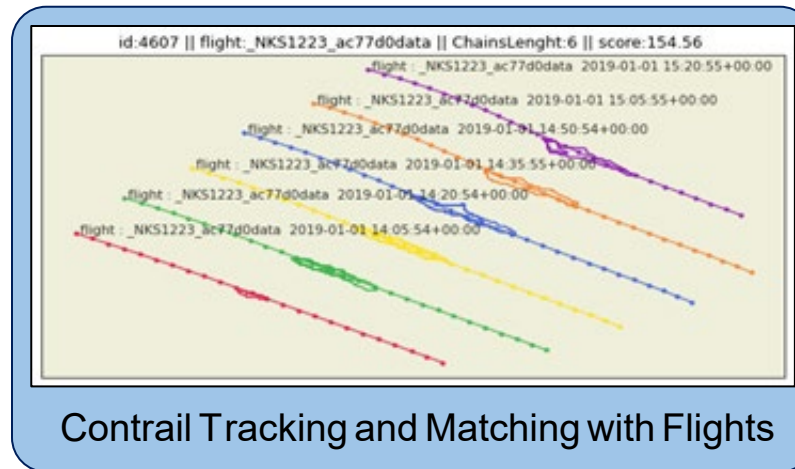
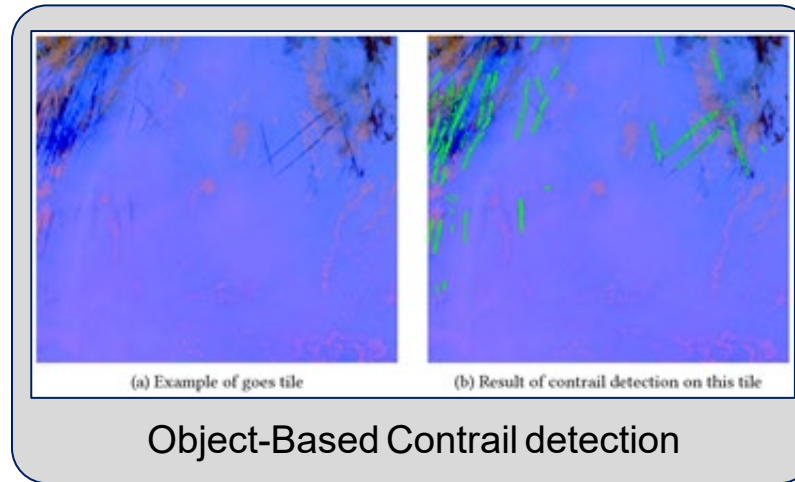
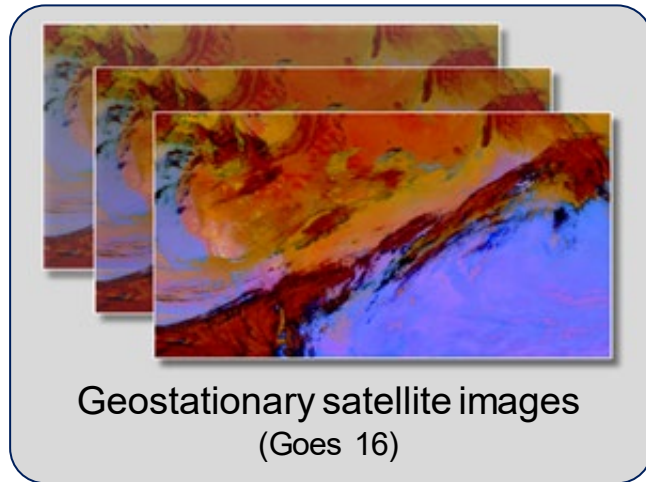


Maybe a future monitoring of contrails



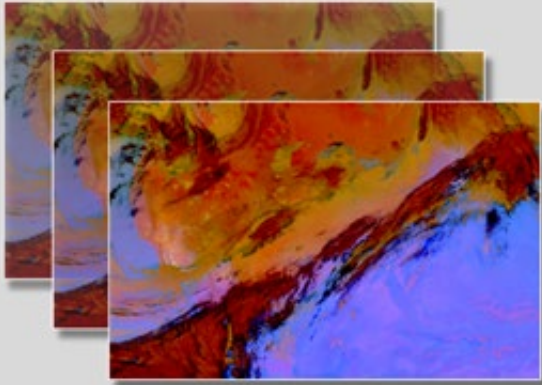
Focus : Building a contrail observation dataset

Contrail detection, tracking and matching

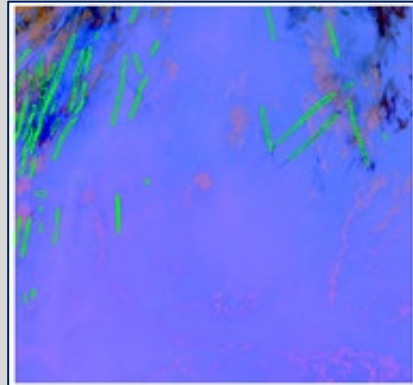


Detection, tracking and matching, but still subject to several limitations

Adding data from other sensors



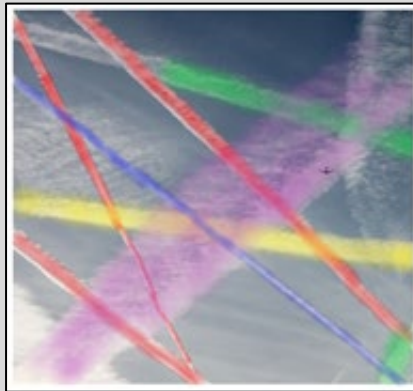
Geostationary satellite images



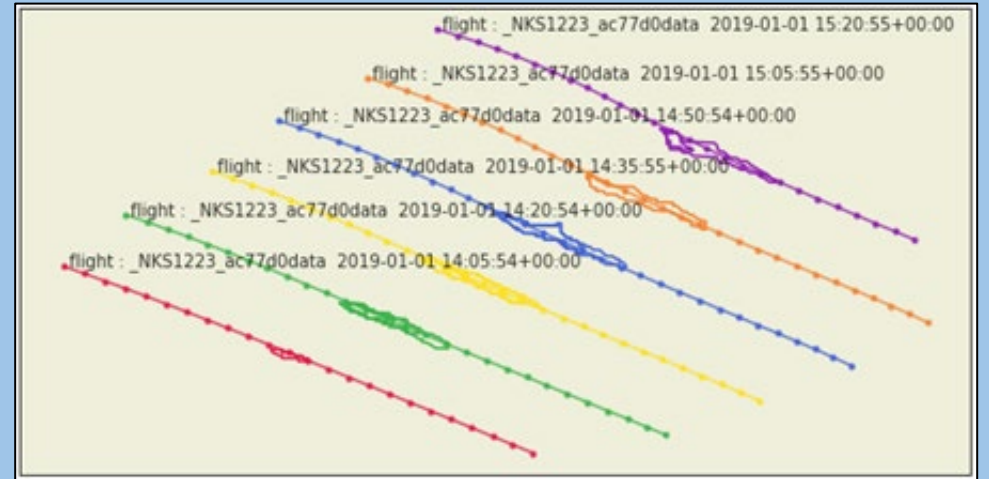
Object-Based Contrail detection



Ground based images

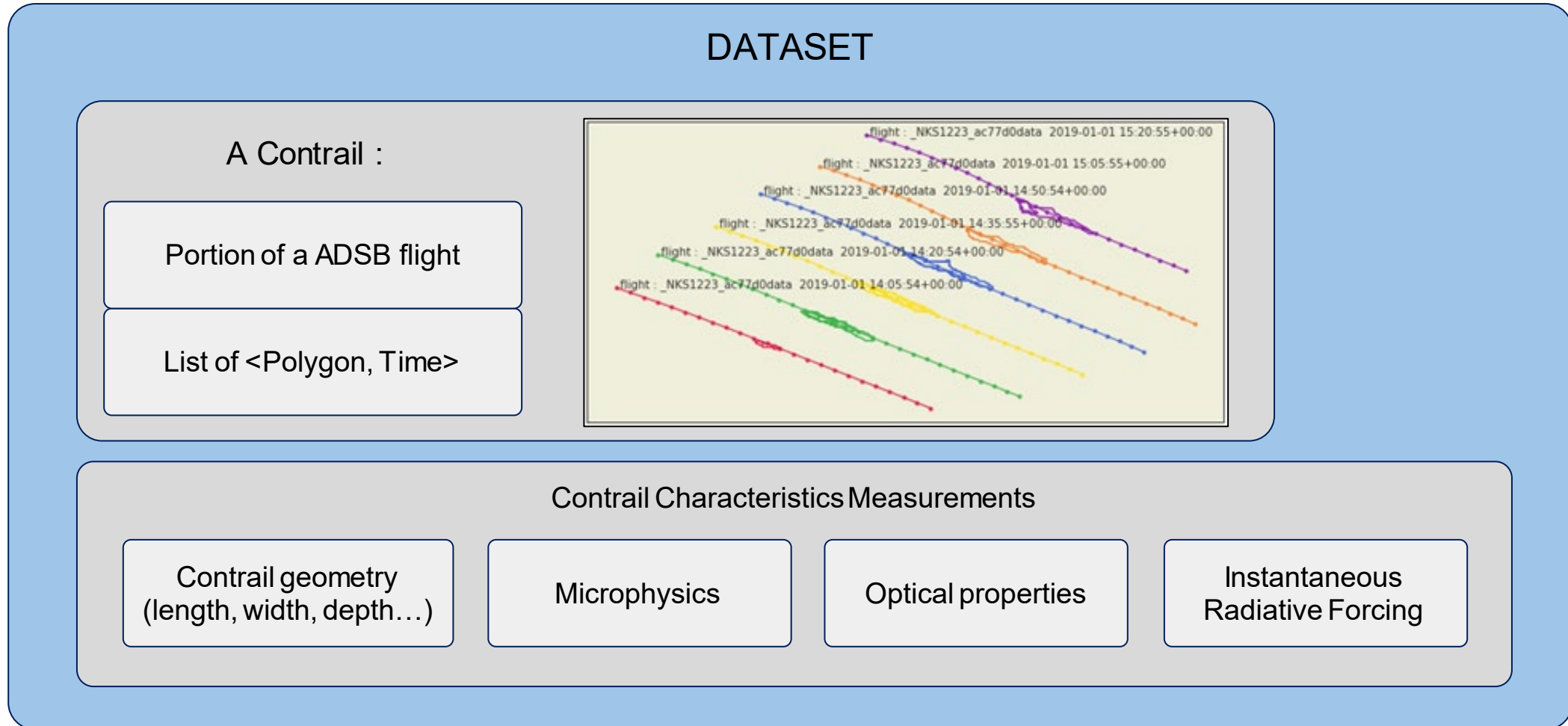


Object-Based Contrail detection



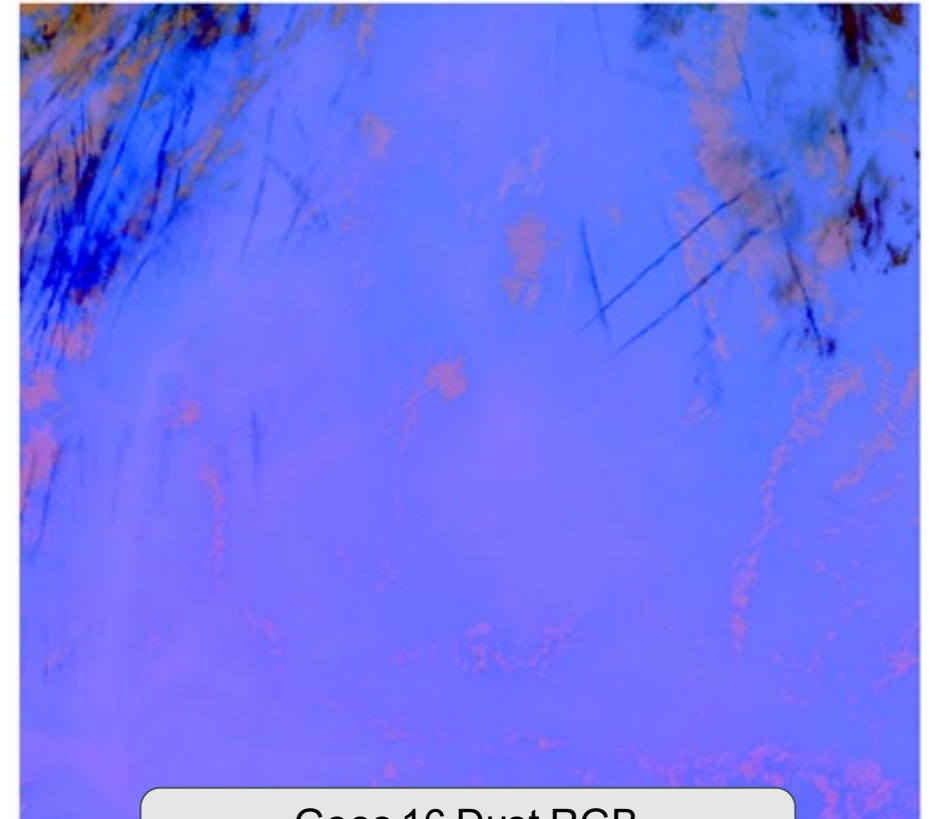
Contrail Tracking and Matching with Flights
Sensor Agnostic

Structure of a Contrail Dataset



Geostationary Satellites

- ✓ Temporal resolution 10-15 min
- ✗ Low spatial resolution
- ⚠ → Contrails are not visible until they are sufficiently thick and wide
- ✓ Great spatial coverage



Goes 16 Dust RGB
(combination of infrared channels)

Low orbit satellite



Good lateral resolution



One shot image (time of revisit is usually larger than the lifetime of the contrails)

Ground Cameras



Great temporal resolution



Good lateral resolution above the camera, decreasing with the angle with respect to vertical

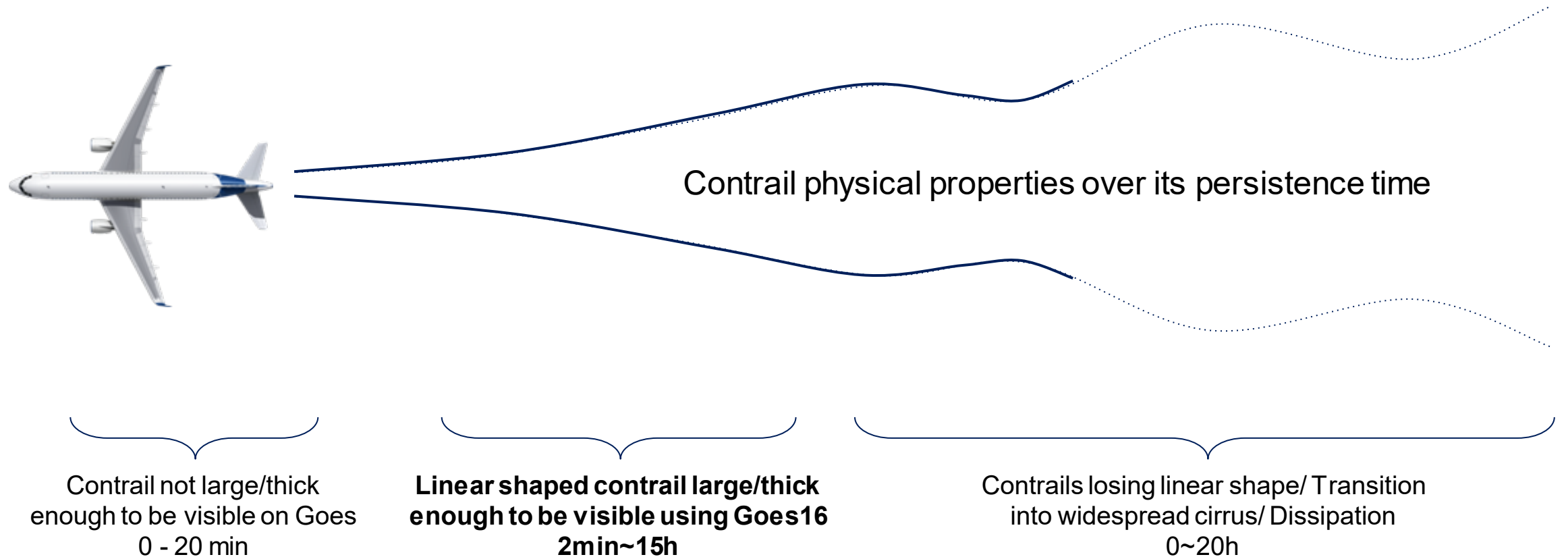
⇒ Small spatial coverage



Low clouds could be a problem to observe the contrails.

Night observation



Contrail Observation






Difficult to observe all these phases from a single mean of observation

Solution : Combining observation methods ?

Low level satellites/ground cameras :

-  Detect and match young contrails
-  Detect and match older contrails

Geostationary Satellites :

-  Detect and match young contrails
-  Detect and match older contrails
-  Match with flights

Different aspects to implement



Detect the contrails



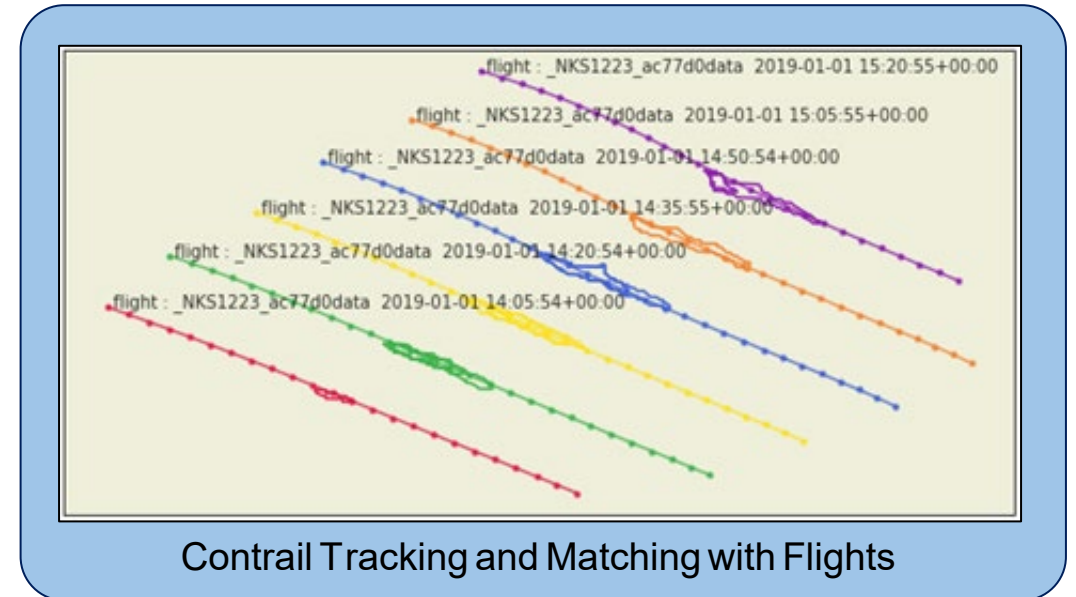
Track the contrails



Identify the Aircraft (Match)



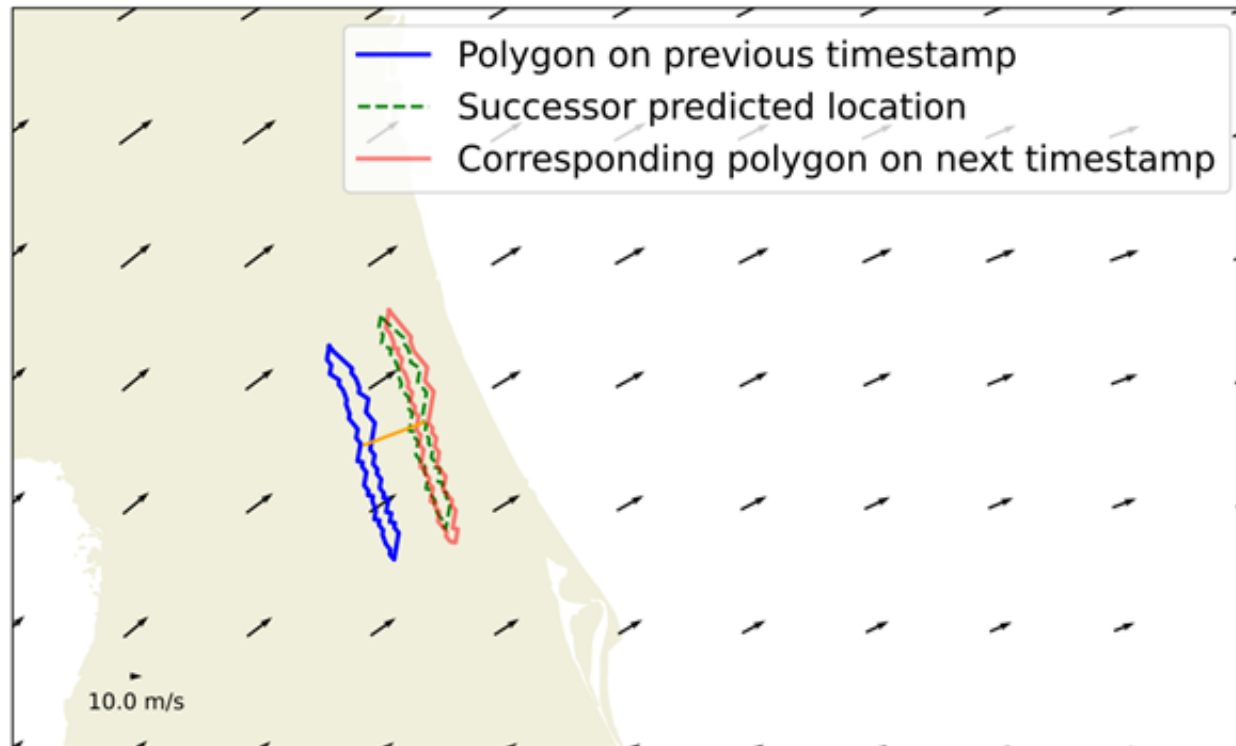
Measure Contrail characteristics (microphysics, shape, etc)



Contrail tracking



Difficult with 10-15 min between images, tracking deforming and/or overlapping objects

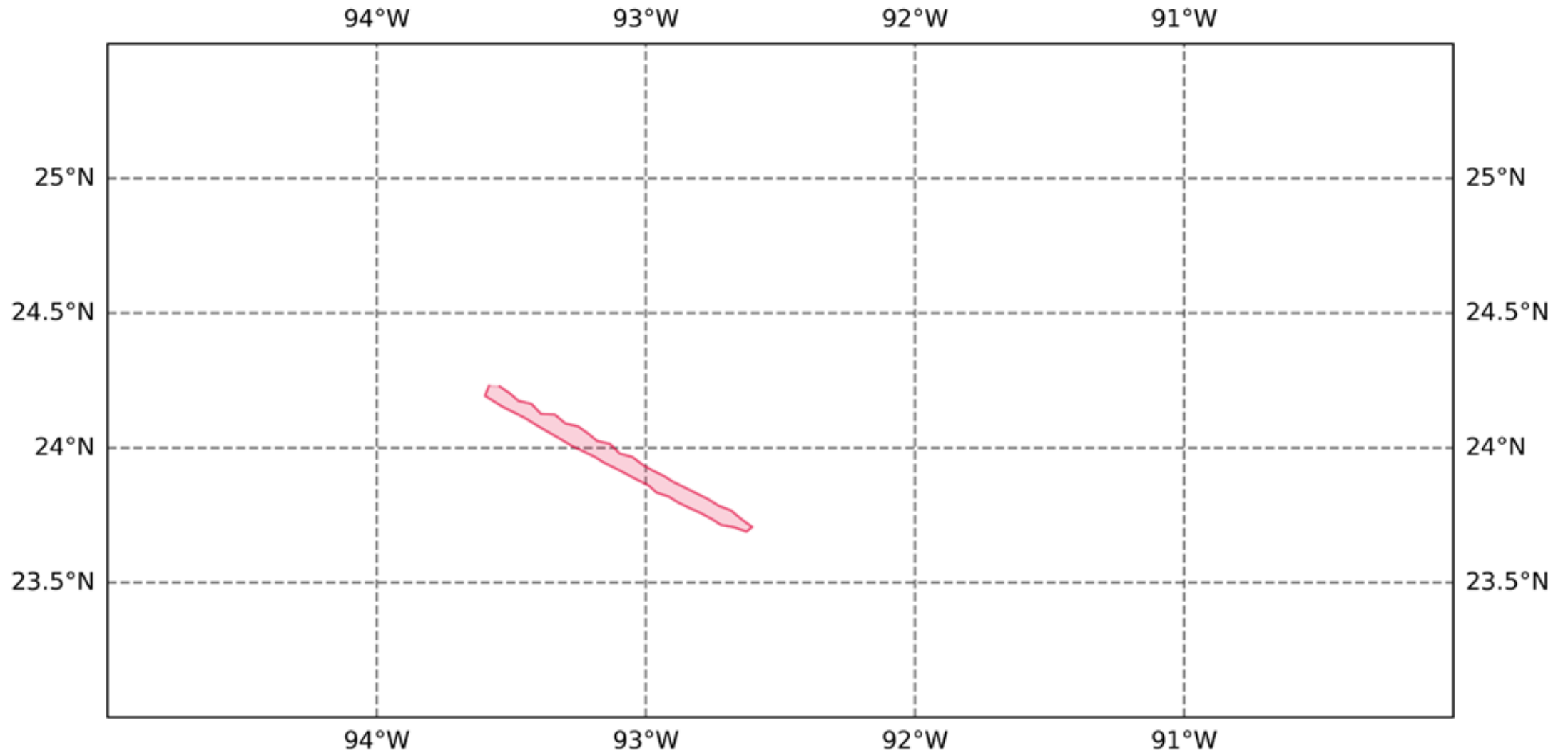


Use wind field

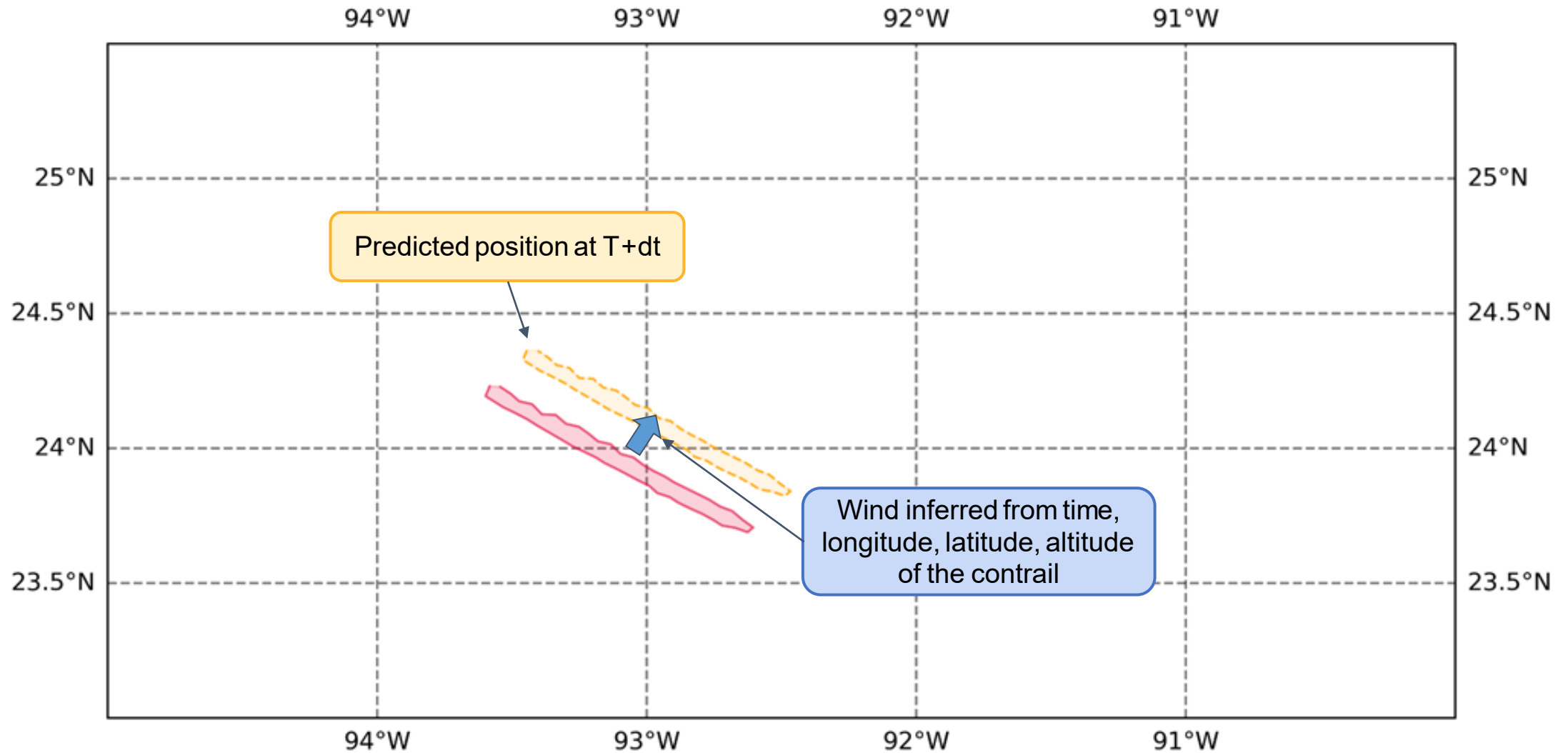


Difficult without any altitude information

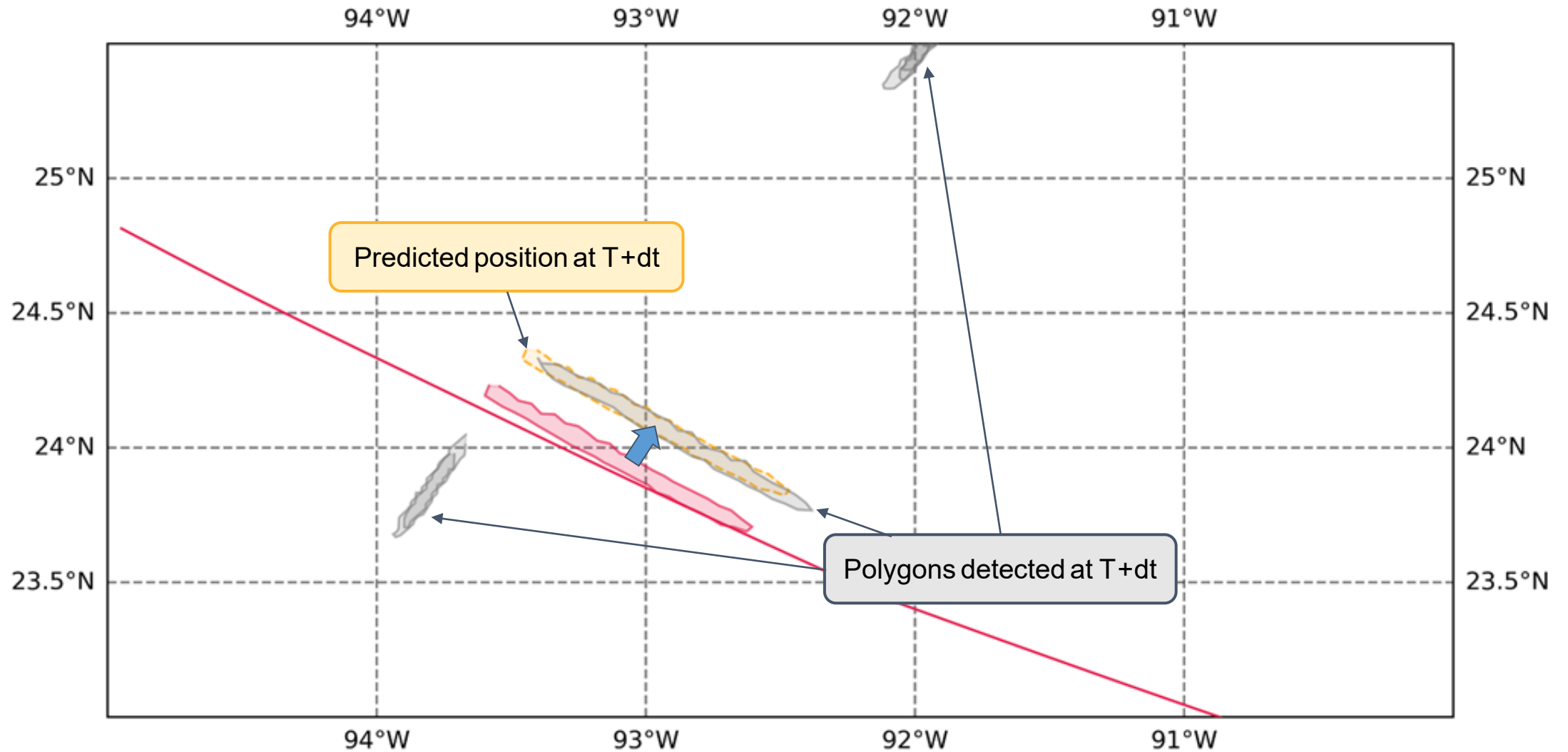
Contrail tracking process



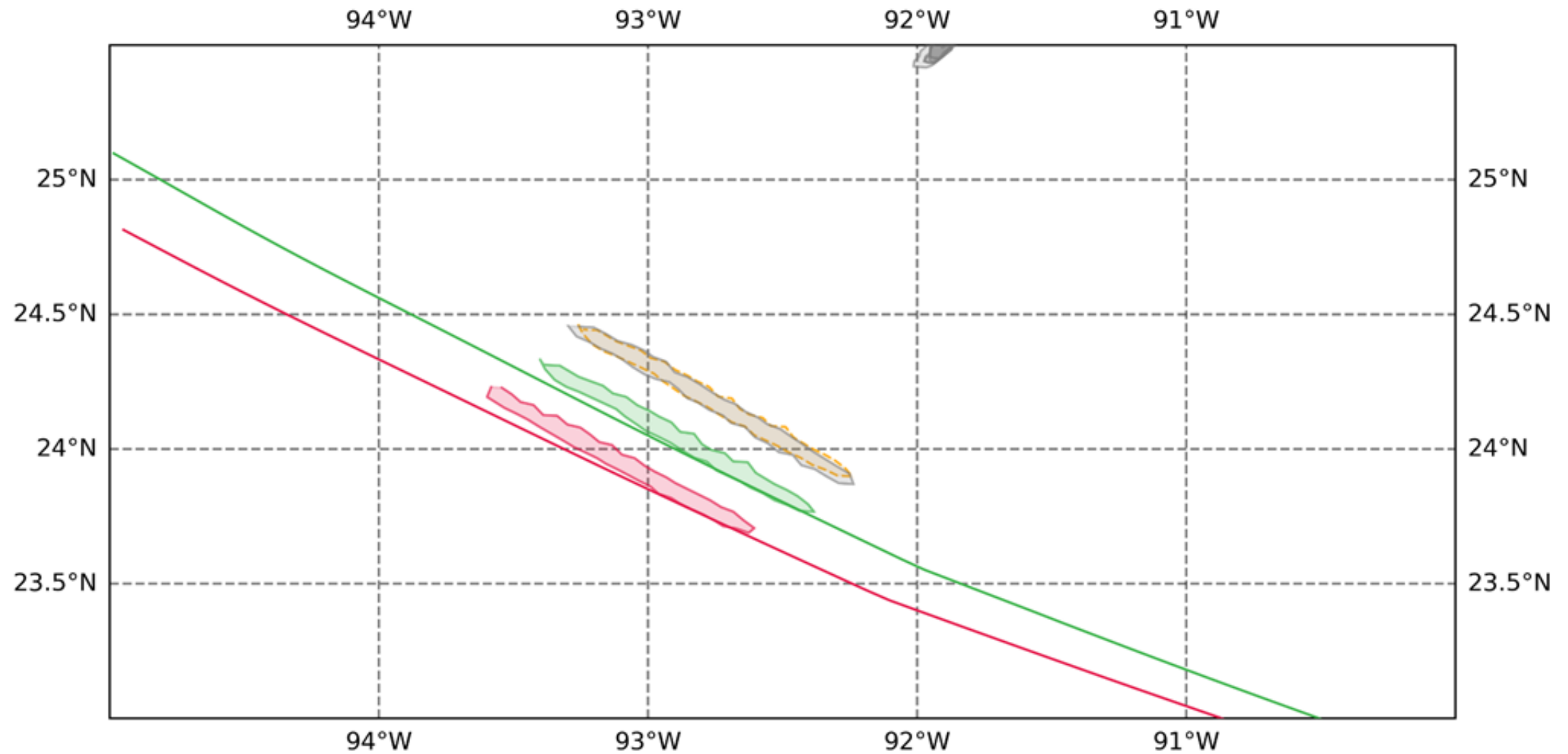
Contrail tracking process



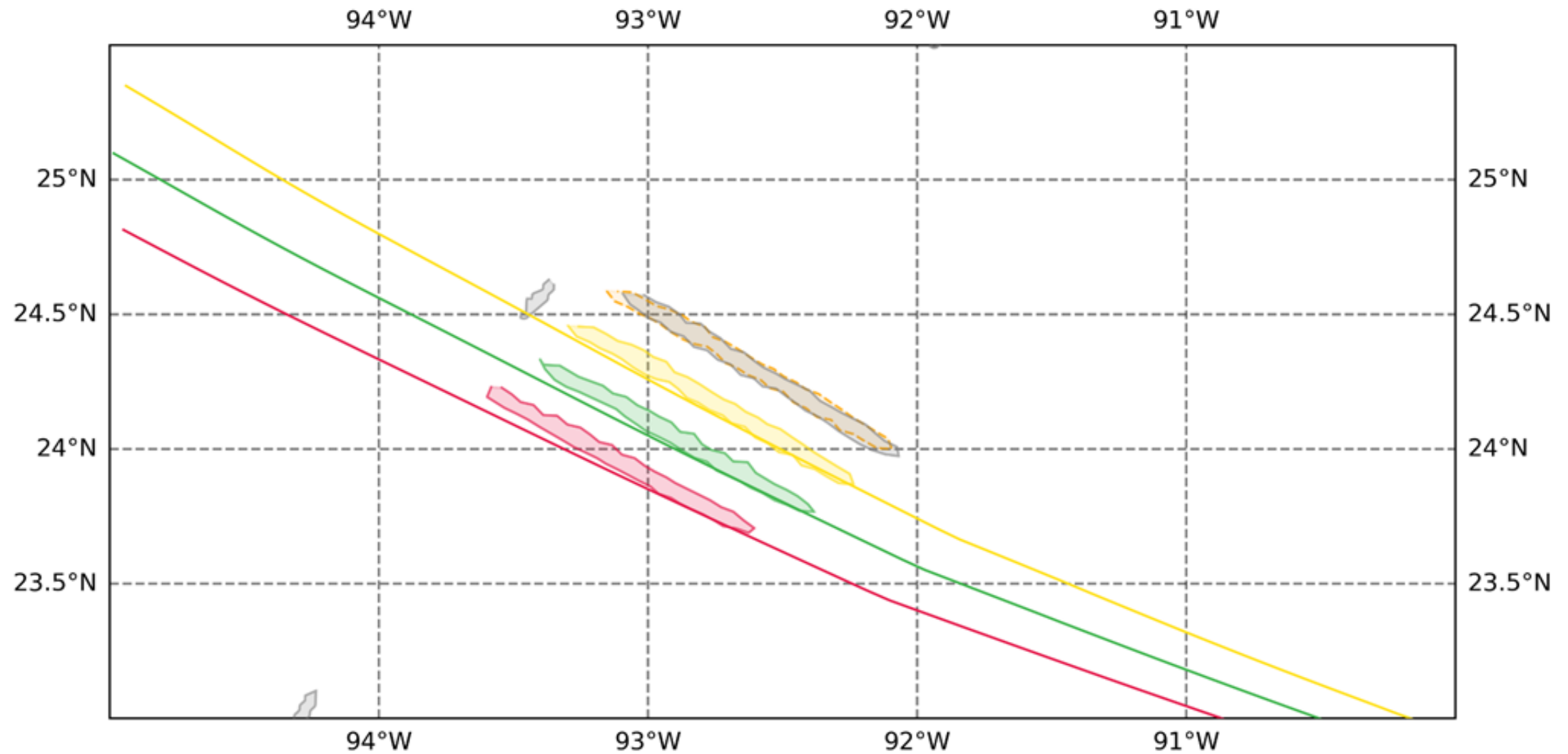
Contrail tracking process



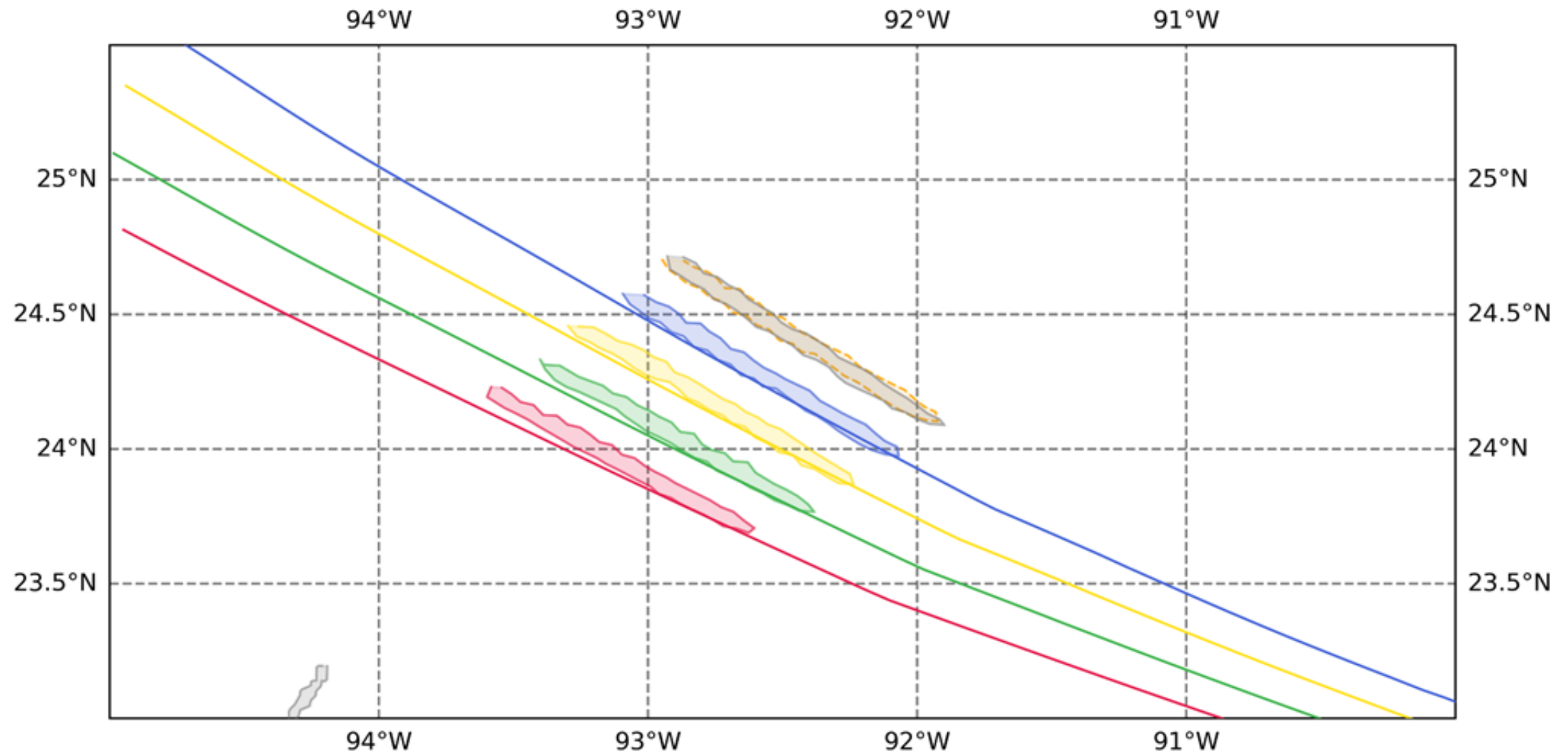
Contrail tracking process



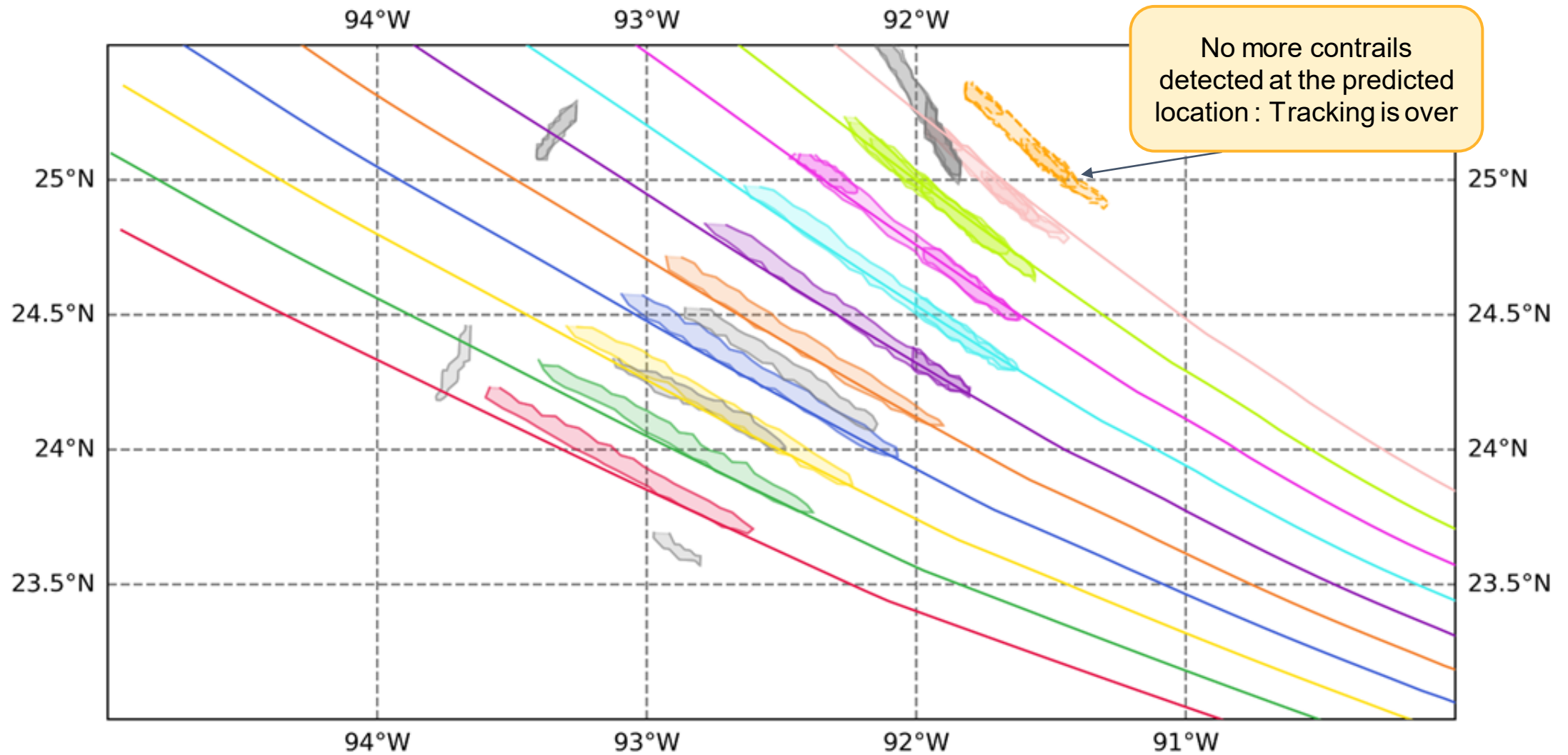
Contrail tracking process



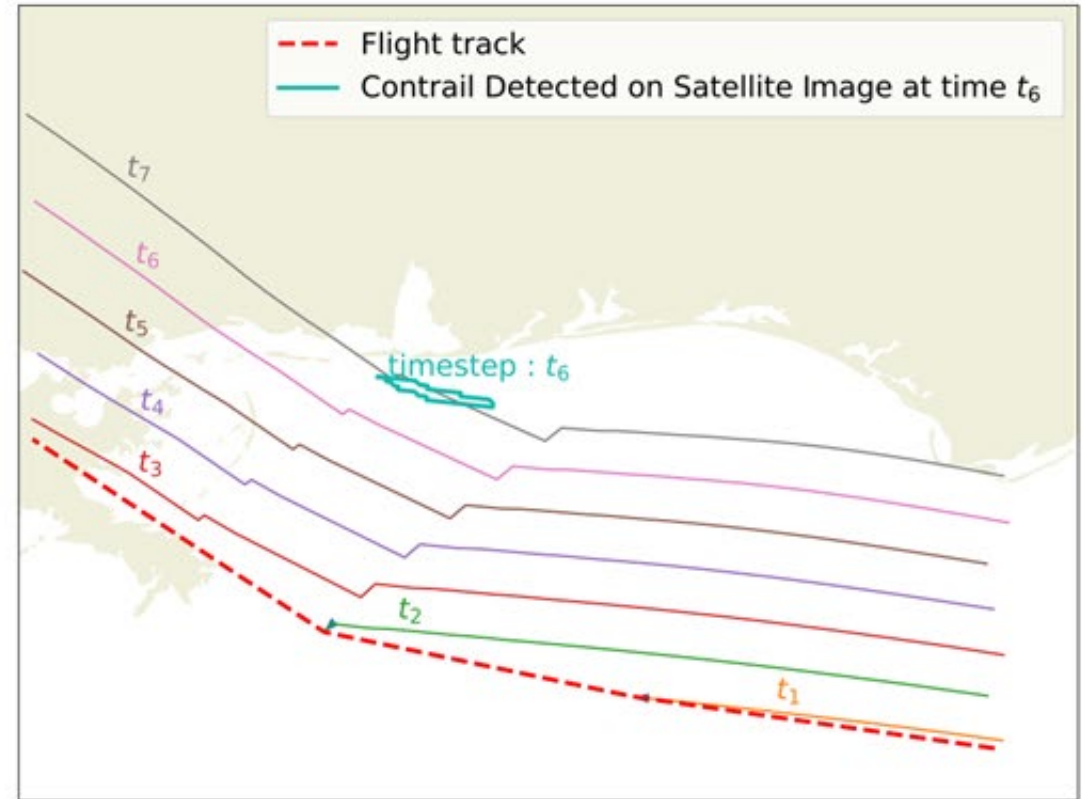
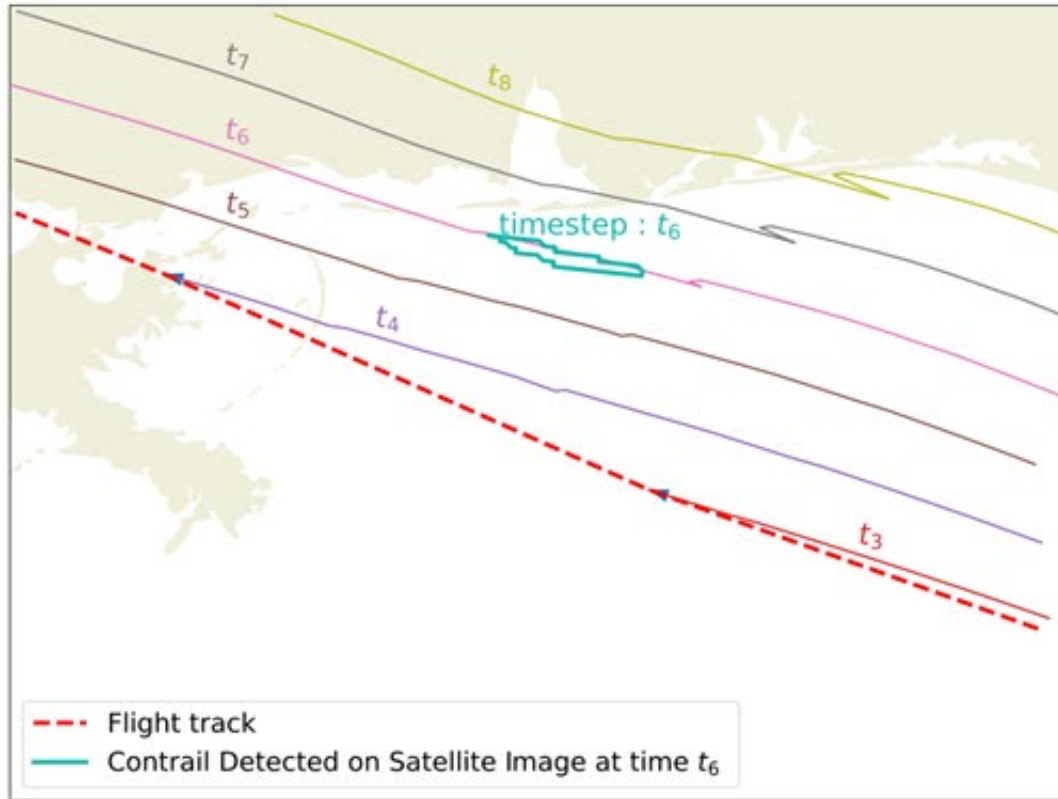
Contrail tracking process



Contrail tracking process

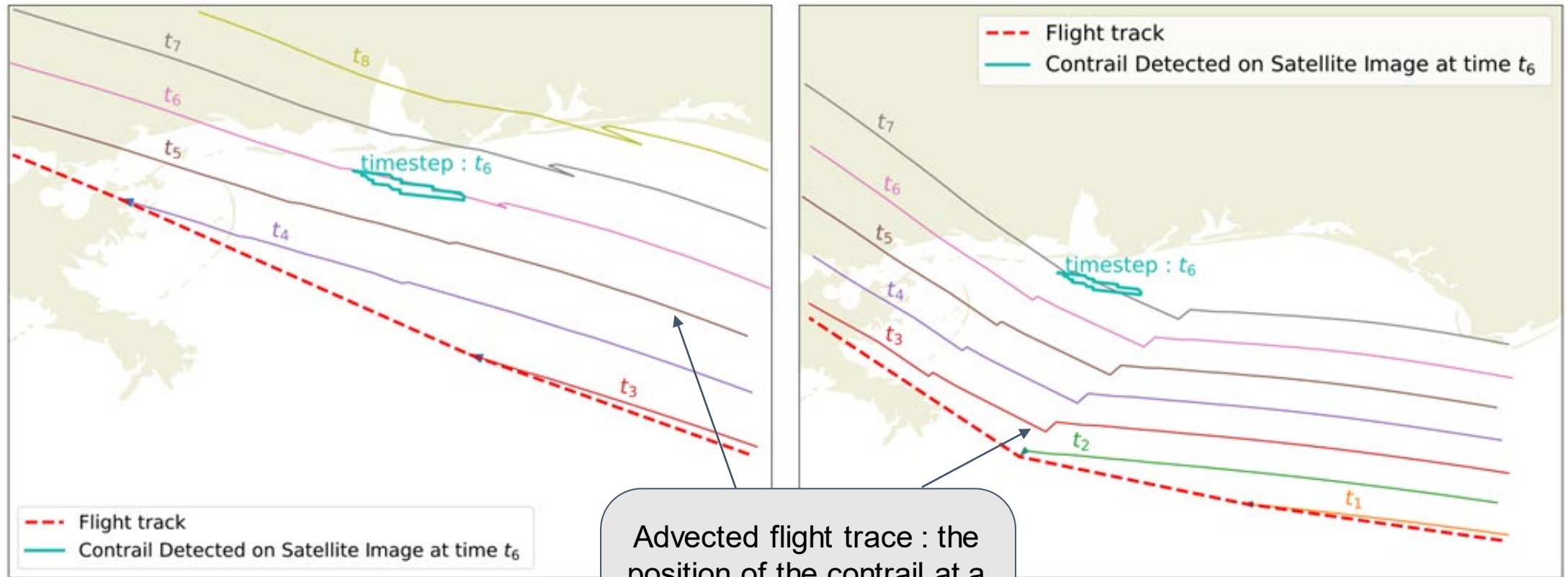


Contrail matching



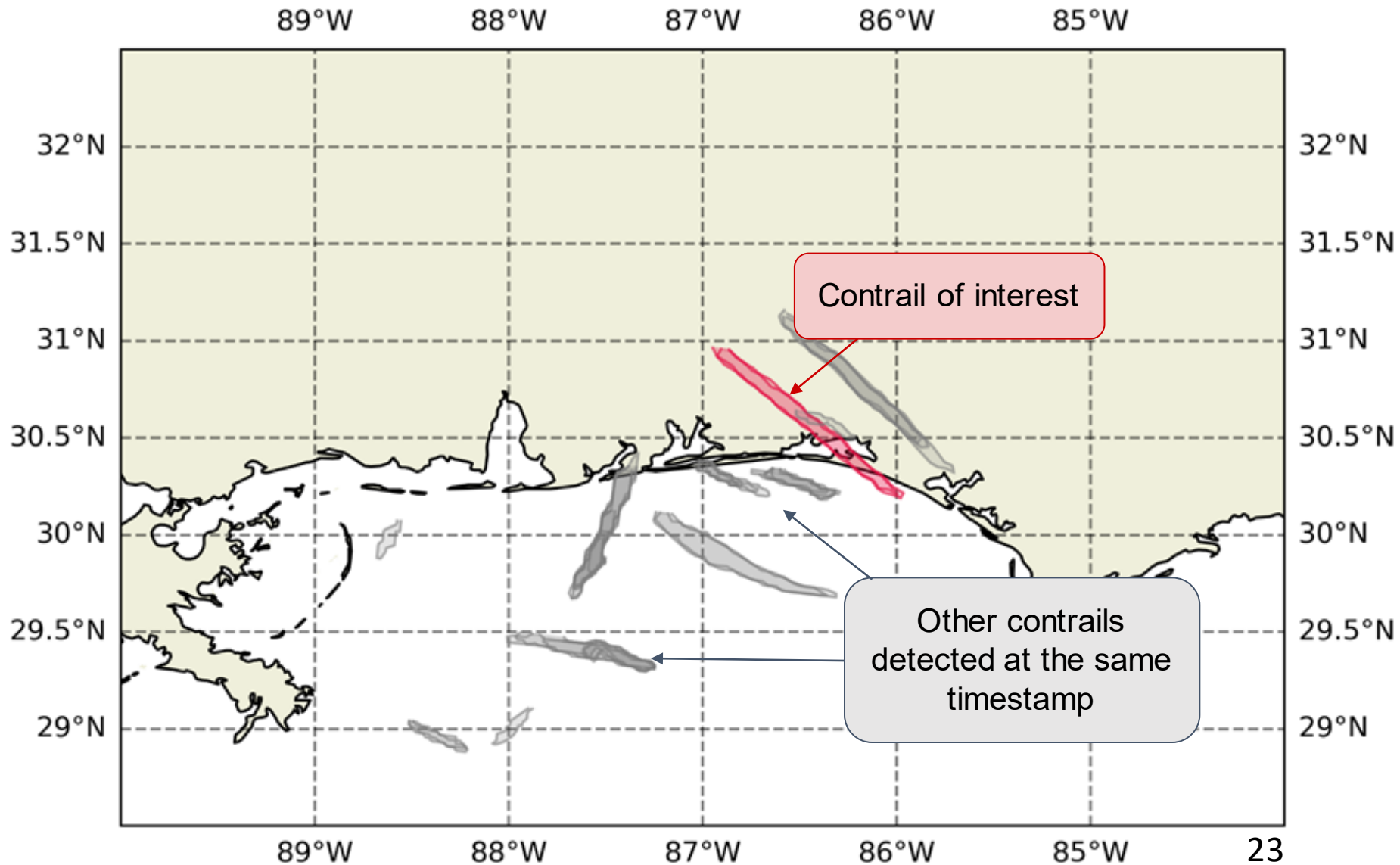
Which flight was at the right time at the right place so that if it had created a contrail and said contrail had persisted, it would match the position of the real world detected contrail

Contrail matching

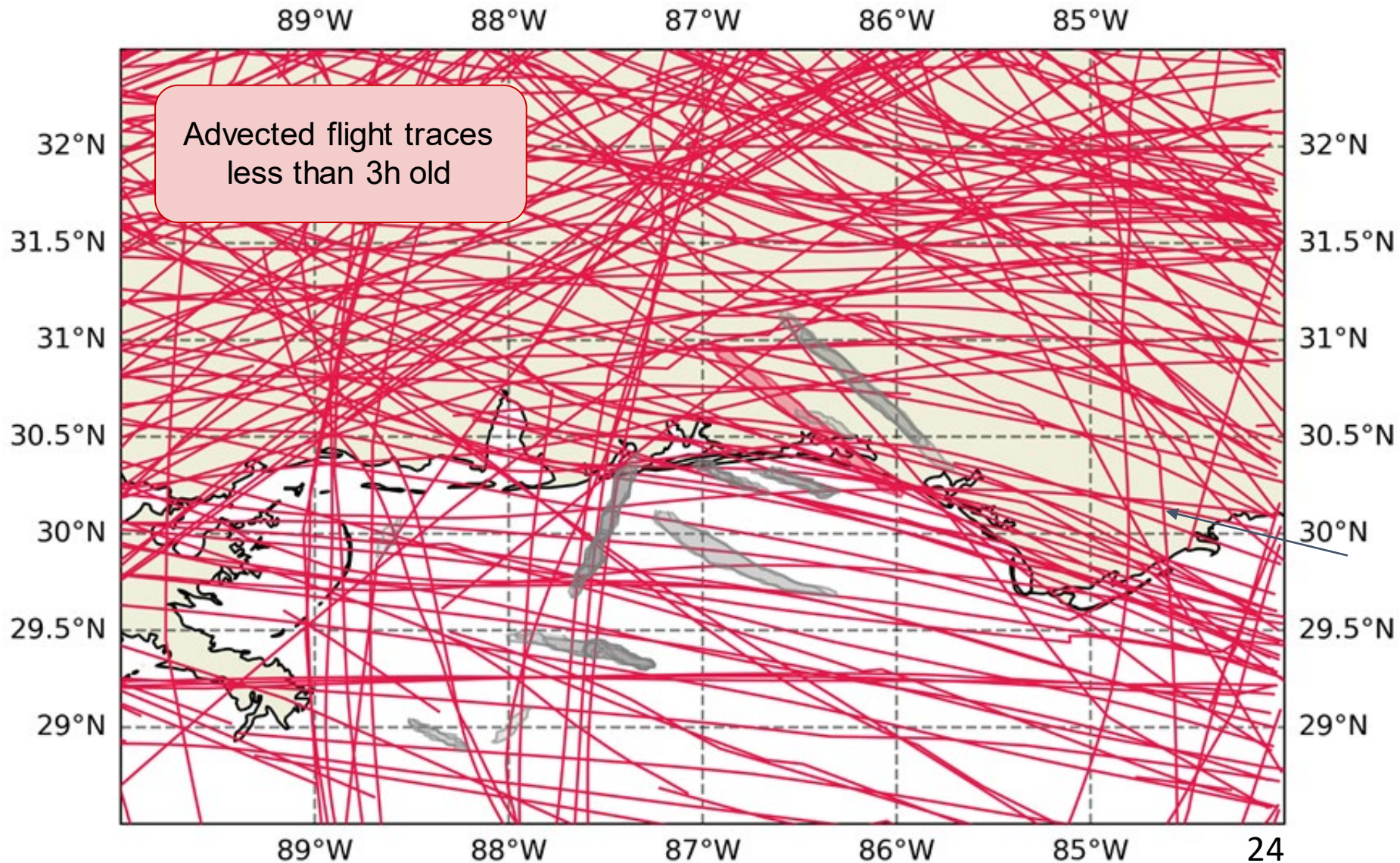


Advected flight trace : the position of the contrail at a certain time if the flight had produced a contrail and if it had persisted

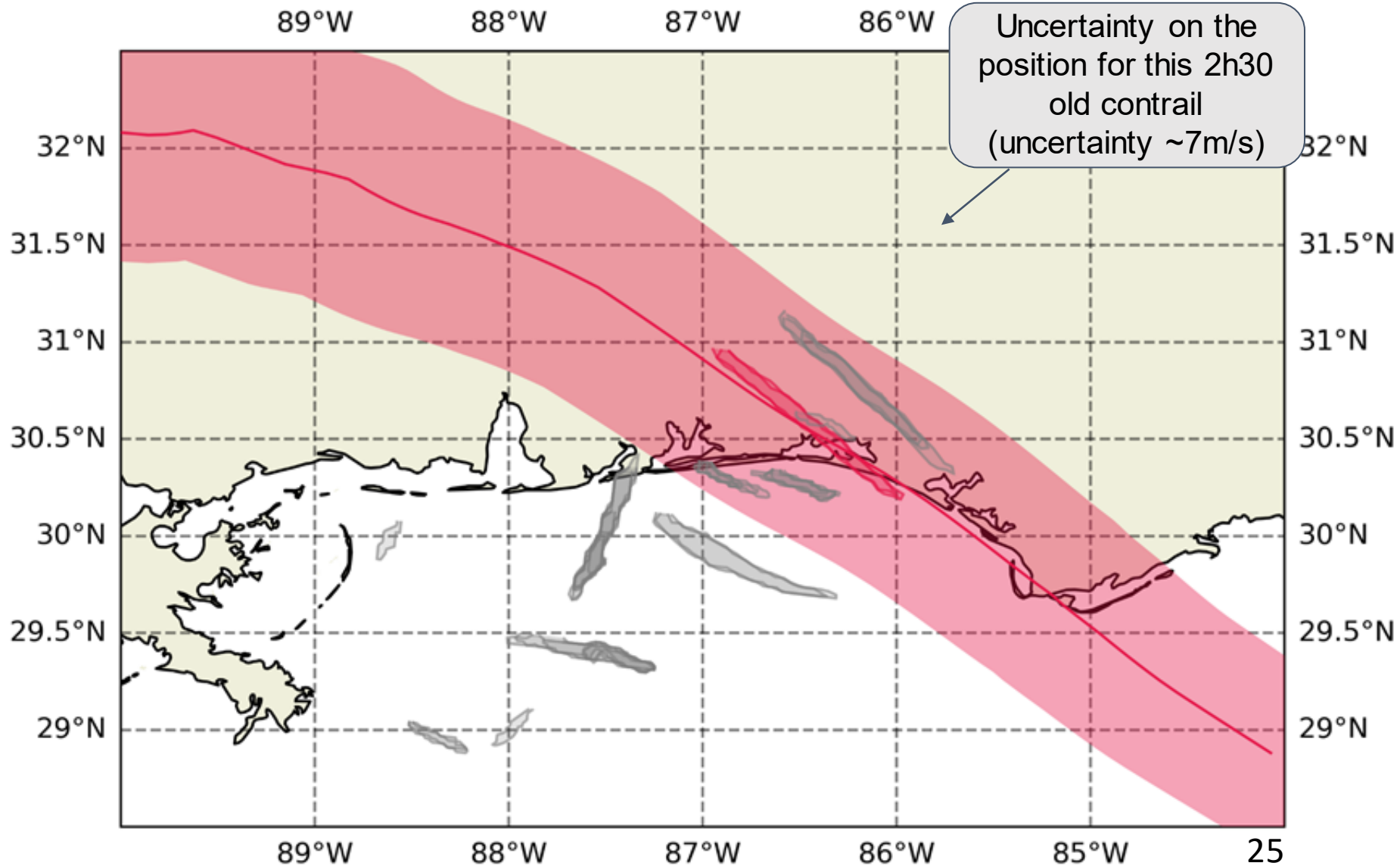
Contrail matching



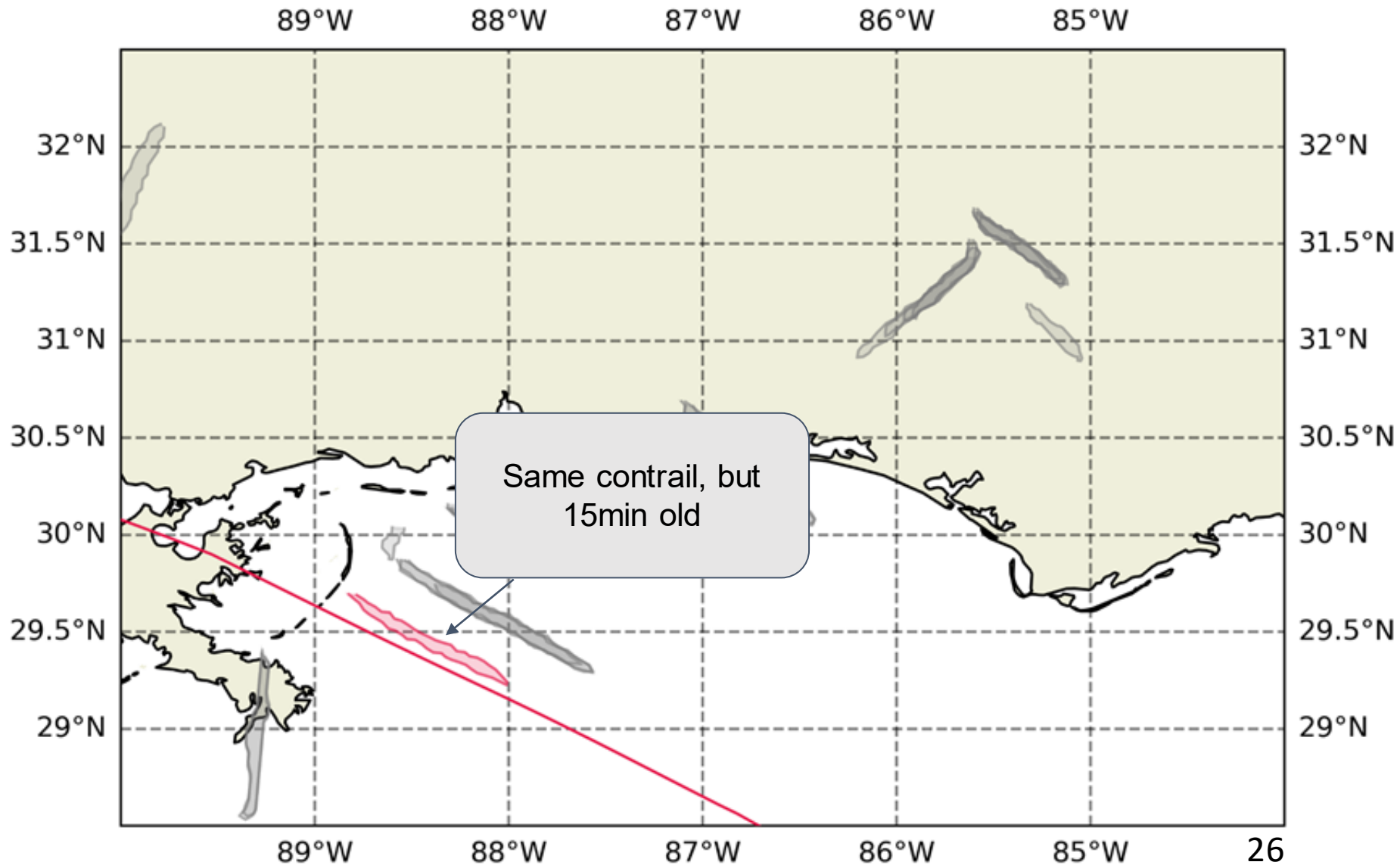
Contrail matching



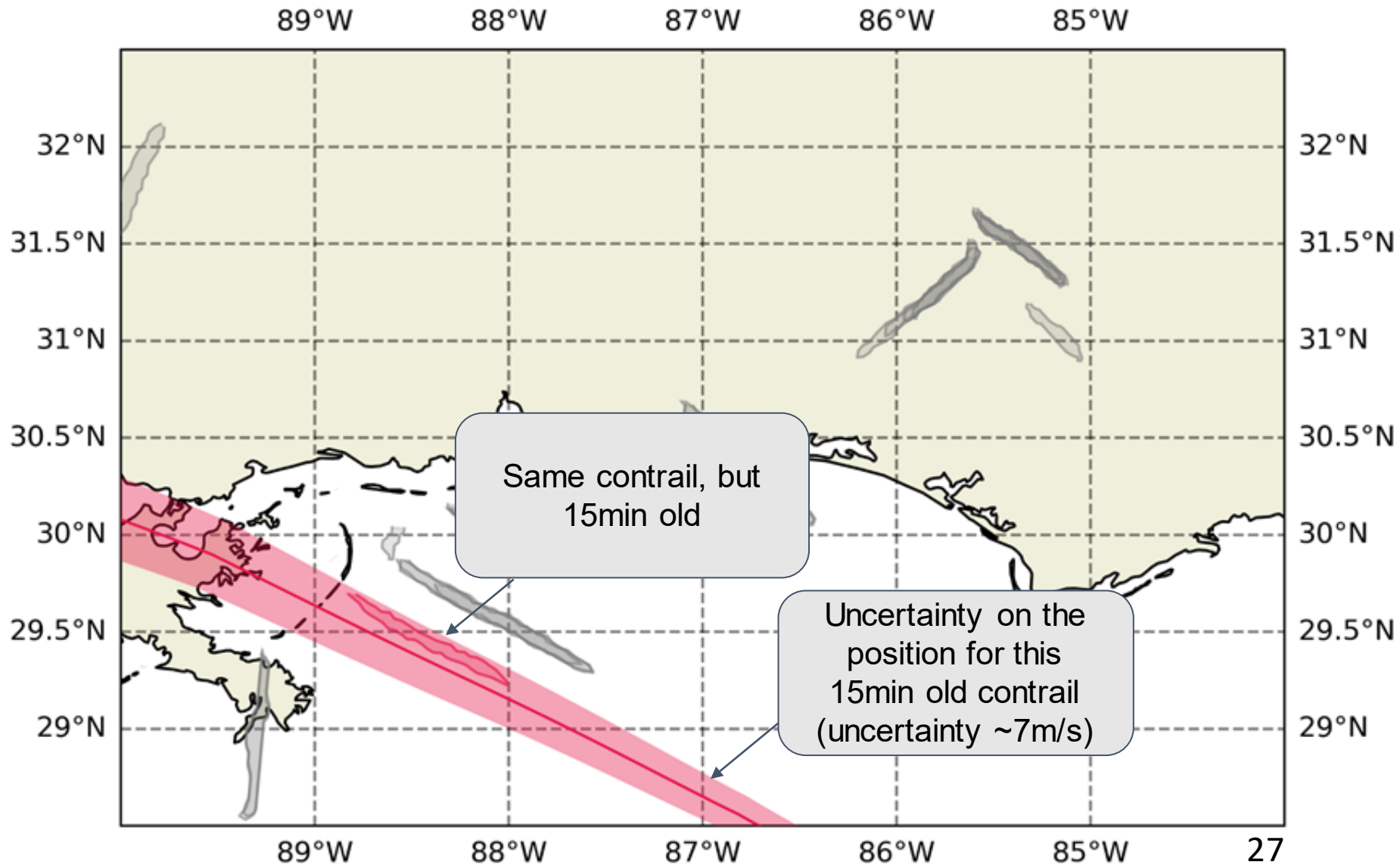
Contrail matching



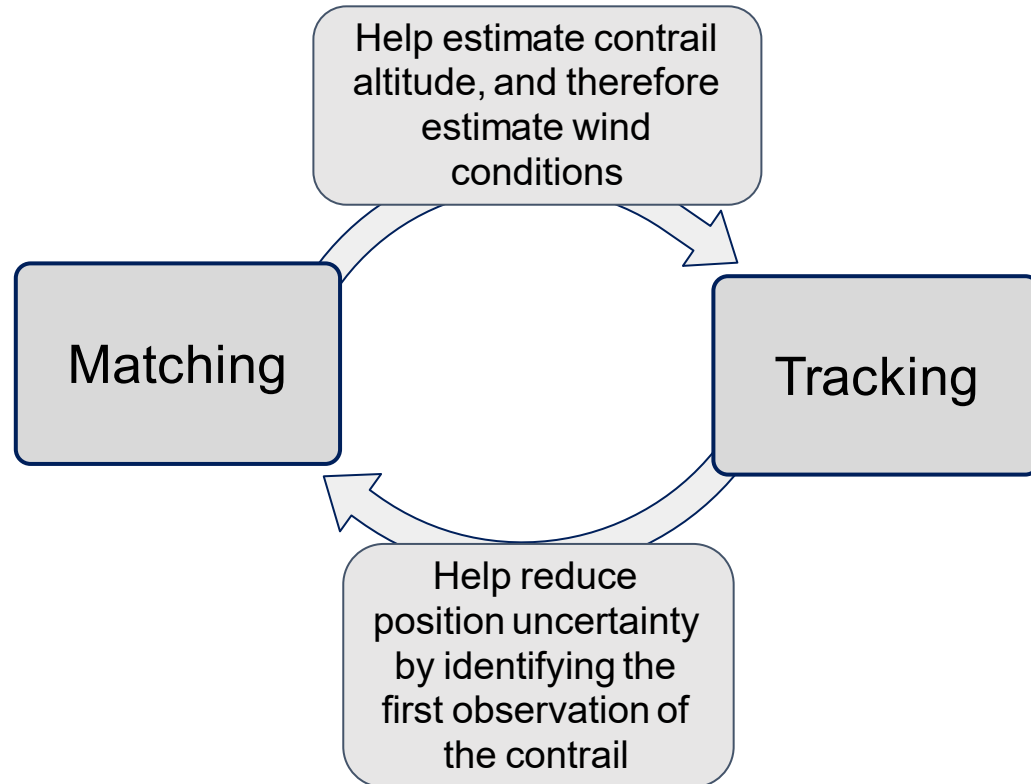
Contrail matching



Contrail matching



Matching and Tracking at the same time :

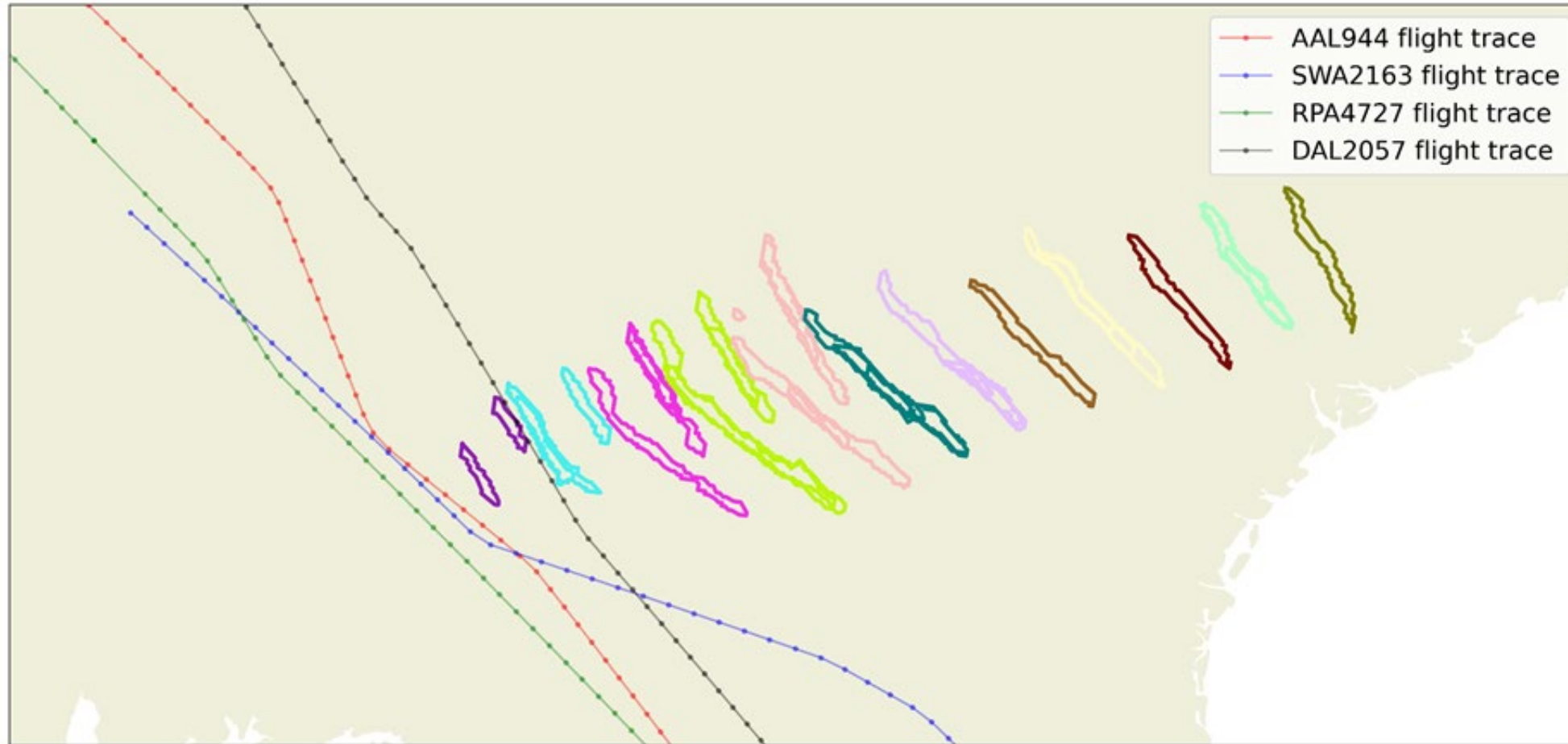


Each process benefit from the other's result

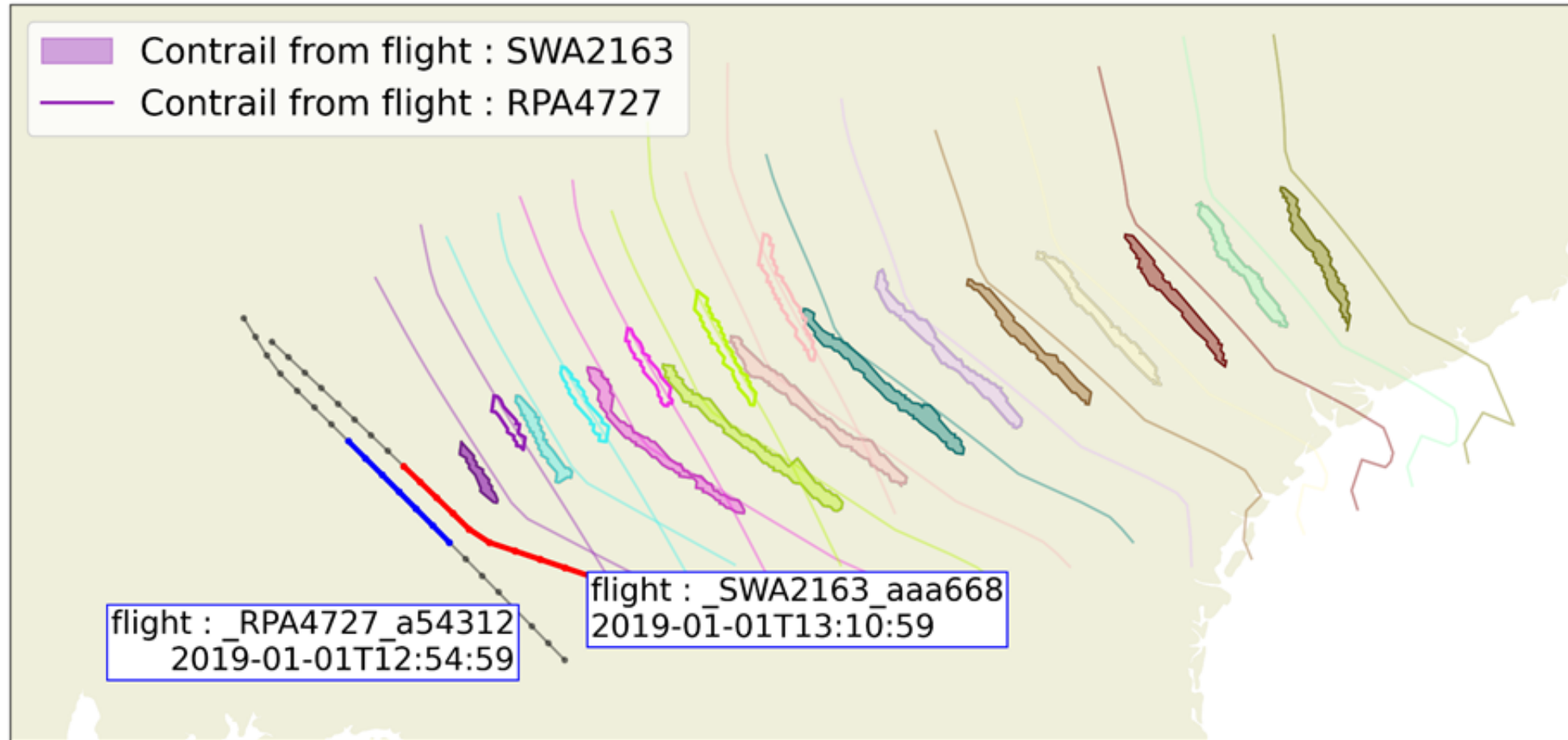
Make assumptions on the matching, generate all the possible solutions

Let an optimization method choose the best set of solutions

Matching and Tracking at the same time :



Results :



Limitations



Low confidence in crowded area

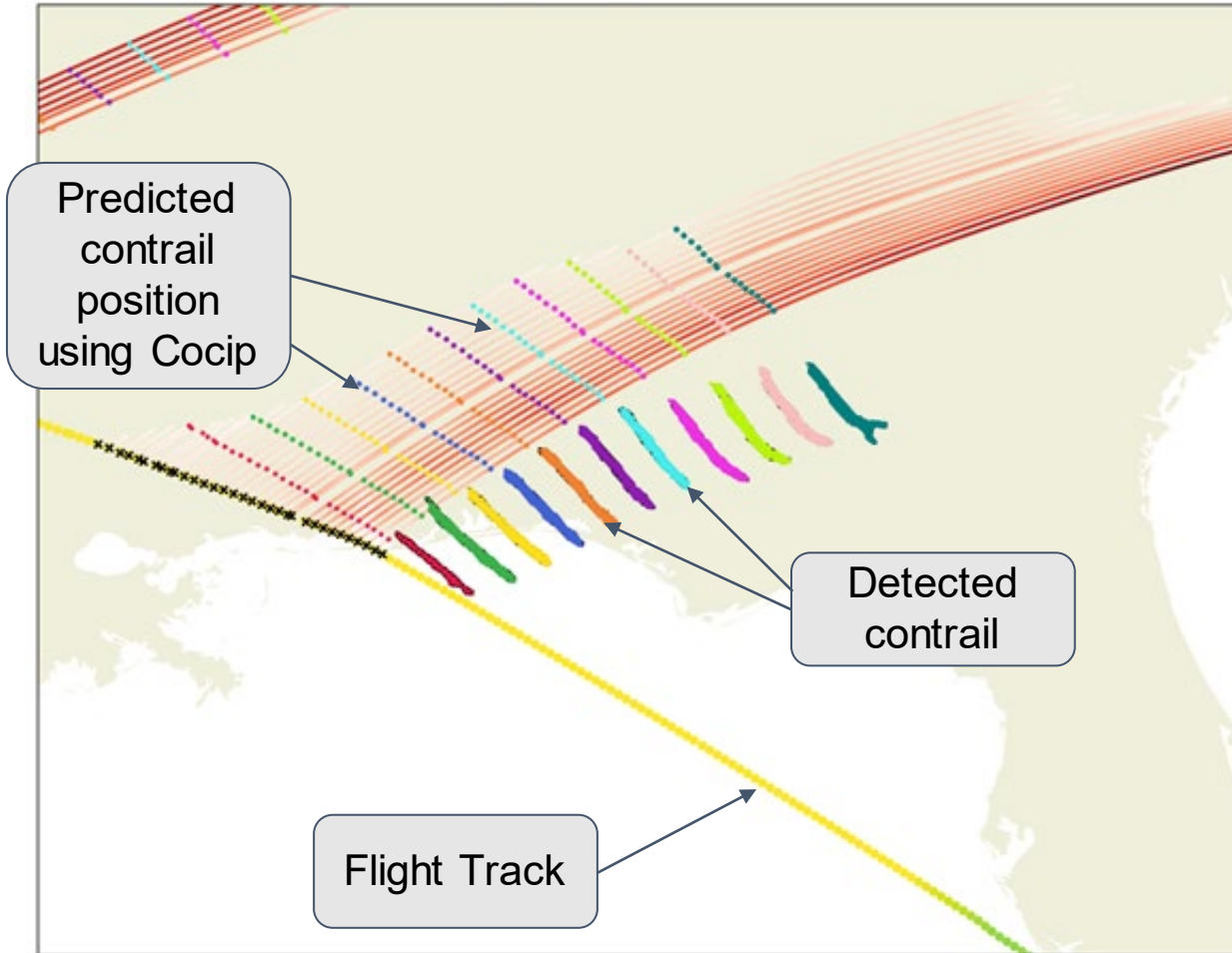
⇒ Wind uncertainties

⇒ Detection could be more difficult



Unable to track a contrail that would have lost its linear shape/ mixed with other clouds

Example of use case : Comparison with CoCip



This is only a case study, and has not enough sample to be statistically relevant



We need to perform large-scale studies to understand under what conditions the predictions are accurate and where there might be room for improvement.
(weather data, ...)

Conclusion



Detecting, tracking and matching is possible using geostationary satellite images, but still subject to several limitations.



Combining geostationary satellite data with other means of observation to overcome these limitations look promising.



Comparison with contrail prediction models is important to identify in which situation these models are suitable for operational use.