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Catch your FLIGHT

FIGURE 1: Contrail above Reuniwatt's main facilities center, with several Sky InSight LWIR all-sky imagers being tested, in Toulouse, France

Aviation accounts for approximately 3% of all human-made CO_2 emissions. On top of that, we must now add its non-CO_2 contributions, which have a direct impact on climate. These contributions are mainly due to nitrogen oxide (NO_X) emissions and condensation trails – contrails for short – that sometimes appear behind planes in the sky.

Even if this latter effect seems rather small overall, possibly contributing 0.04°C of the global heating rate by the year 2050, it remains beneficial to mitigate it. This would help the whole aviation community to be more environmentally friendly.

Contrails are artificial ice clouds created at high altitude when an aircraft is crossing an ice super-saturated region (ISSR). Their formation largely depends on the types of clouds, the level of humidity and the efficiency of the plane's engine.

Reuniwatt's all-sky imagers are used by aviation leaders to institute contrail-avoidance strategies

These clouds have a cooling or warming effect depending on their capacity to reflect solar radiation or trap the outgoing infrared radiation coming from the lower atmosphere and the ground. They have a net warming effect, even if its exact impact is currently uncertain. Nonetheless, we consider that the non-CO_2 effect on the climate compared with the direct CO_2 effect of aviation has a factor of 1 to 3.

Every stakeholder in the aviation community – from research labs, institutions such as IATA and SESAR, policymakers and airlines, to national and international traffic agencies such as Eurocontrol – is focusing on the issue and promoting initiatives to take into account the uncertainty regarding the contrail and ice super-saturation modeling; reduce the uncertainty around the radiative effect; create large flight trial campaigns; define new air traffic control (ATC) dispatch protocols and analyze the avoidance benefits; and test new types of fuel (sustainable aviation fuel – SAF) and engine combustion regimes (lean burn versus forced rich burn).

At its 14th conference in September 2023, the International Civil Aviation Organization (ICAO) concluded that there was a need for more scientific proofs before moving to an operational phase and setting up new regulation standards regarding the avoidance of contrail creation. One waypoint is the need to validate tools like the ISSR forecasting model and rerouting algorithms. During this phase – and in the long run – it is necessary to provide 24/7 ground truths from ground-based whole-sky imagers, lidars and satellites.

Fill the gap

Geostationary satellites are among the various techniques that exist to detect contrails. They have the advantage of covering a very large area of the globe. Furthermore, they observe the Earth at several wavelengths, which is a useful benefit to distinguish contrail presence in a scene that includes other types of clouds. However, their coarse spatial and temporal resolutions prevent them from detecting a contrail once it is formed. It is only detected from 20 minutes after its creation. This temporal window is named the appearance lag (see Figure 2).

FIGURE 2

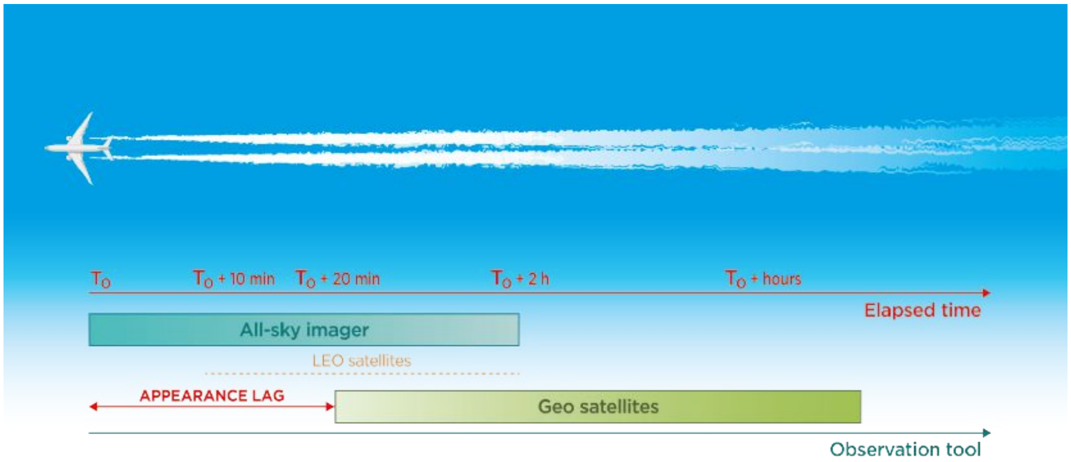

Image: Reuniwatt

FIGURE 2: Schematic view of a contrail's temporal evolution and the various means to observe it. Satellites cannot catch the generation and the first minutes of life of a contrail, making it almost impossible to match it with the plane that created it

FIGURE 3

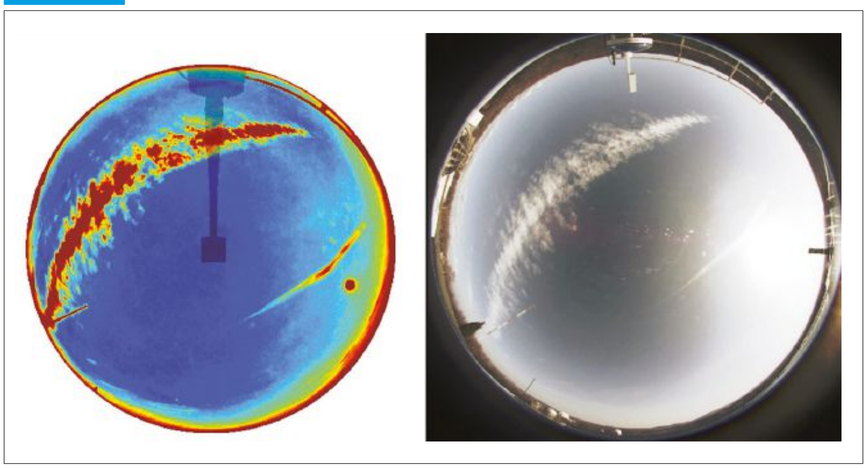

Image: Reuniwatt

FIGURE 3: Images taken above the Observatory of Haute Provence in Manosque, France, with co-located Sky InSight LWIR imager (left image) and Sky Cam Vision visible imager. The images show the presence of a newly generated contrail in the right bottom quadrant of the image, and an older, persistent contrail on the upper left side of the image

Low Earth orbit (LEO) satellites can bring a better spatial resolution to the previous observation. Still, they only observe a scene during a very short period of time and do not always follow the same path. Therefore, they are not very useful for detecting and tracking a contrail, unless using a large LEO constellation. Ground-based all-sky imagers, in the solar spectrum or long-wave infrared (LWIR) spectrum, are the only observation tools able to detect, charaterize and track a contrail from its creation. Using these instruments, it is also possible to pair a contrail with the plane that has created it (see Figure 3).

Furthermore, LWIR in the 8-14μm atmospheric window is the most efficient way to detect the clouds at night, and the only tool that can provide validation data at the ground level, complementing satellite information for radiative models.

Pairing with planes

Several American and European airlines have begun exploring the possibility of modifying airplane routes to avoid contrail formation and reduce the global CO_2 equivalent impact.

Large uncertainties still exist regarding the signature of each contrail, but most have a very limited effect. And as the ISSR forecasts are still not accurate enough to precisely predict the creation and persistence of the big hitters (the contrails with the highest potential to warm the atmosphere) it is necessary to push toward a general avoidance strategy within the full fleet. This is a very tricky issue, as it depends heavily on air traffic management protocols and airspace capacity. For example, in Southern Europe the summer sky is typically too crowded to reasonably propose any avoidance strategy during the day. Some corridors may still exist in Northern Europe, and thankfully at night and during the winter season. Furthermore, the net radiative effect of contrails is most noticeable at night, which may match nicely with the possibility of rerouting flights.

Several solutions are currently under evaluation, with options for pre-flight/inflight

FIGURE 4

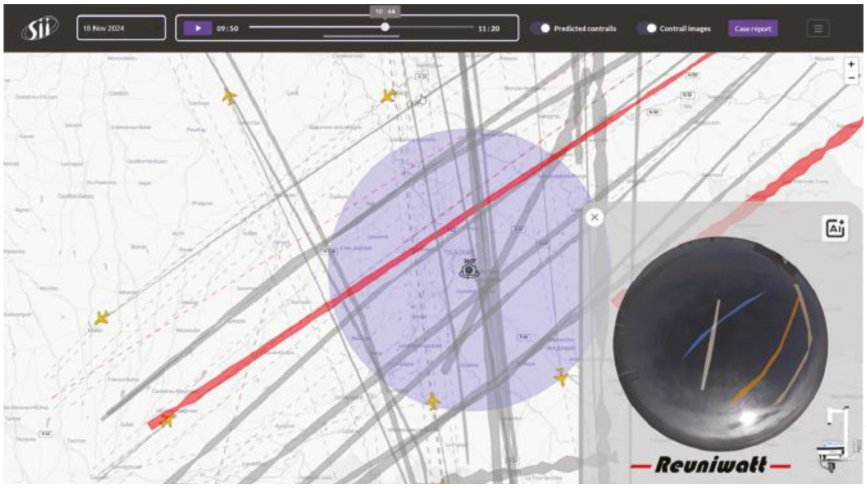

Image: SII

FIGURE 4: SII's Contrail Tracker interface depicting observed and modeled contrail signatures on a window of several minutes, using Reuniwatt Sky InSight imagers in Toulouse. The tool can show the newly generated contrails and follow their evolution over time once advected

modes proposed to pilots. Companies including American Airlines, Delta Air Lines, Icelandair, easyJet, TUI, Lufthansa, Swiss and Amelia are intensively testing rerouting procedures to optimize their flights in terms of non-CO_2 impacts.

On the weather agencies' side, the German weather service (DWD), in partnership with the DLR (German aerospace center), has developed a specific forecast output along the flight paths to be evaluated. However, there are still many hurdles to overcome before contrail-avoidance solutions are routinely instituted.

Confirming the contrail modeling

French company SII, in partnership with Reuniwatt, has developed a specific interface, called Contrail Tracker. It enables users to show modeled contrails, predicted with the CoCiP (Contrail Cirrus Prediction) model developed by DLR, and compare them with the truly identified contrails observed by Reuniwatt's all-sky imagers (see Figure 4).

Reuniwatt's ground data has already been used to verify several companies' rerouting strategies, checking their flights above numerous locations in Europe. Among them, Amelia, in collaboration with Thales Green Operations, conducted a successful proof of concept to validate the effect of changing the route of its flights from Paris in France to Valladolid in Spain by changing one flight level to another to reduce ISSRs on the path, thus reducing the climate impact of its flights by a mean value of 40% (see Figure 5).

With SII – and in cooperation with Swiss – Reuniwatt conducted other successful contrail-avoidance validation solutions over Toulouse, France, in autumn 2024, showing the capacities and limitations of CoCiP models.

The airlines plan to extend their validation plan to hundreds of their flights over France in 2025, and will use Reuniwatt's data services (ground instruments and datasets).

FIGURE 5: Thales' tool used by Amelia to choose the optimal route for the most eco-efficient flight, avoiding ISSR areas provoking contrail creation. The images taken with Sky InSight (circular images on the right) are used to validate the choice above the Bordeaux area with a 30km radius at 10km altitude

FIGURE 5

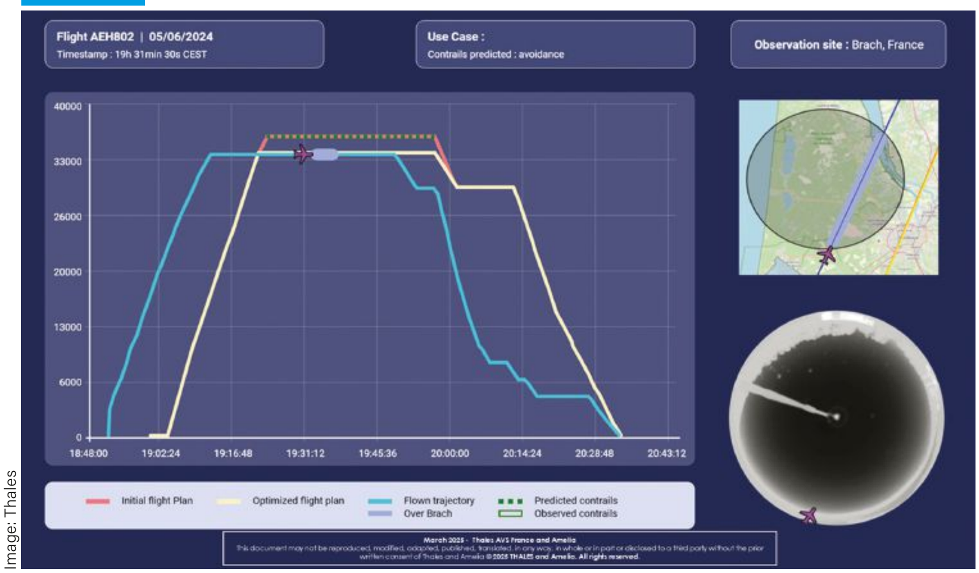

Image: Thales

Conclusion

Reuniwatt plays a critical role in the taskforces of several airlines, helping them evaluate new protocols of contrail mitigation and choose more eco-friendly routes for their flights. By losing 1-2% of flight time and maintaining optimal fuel consumption, they may diminish their climate contribution by 80%, greatly improving the global CO_2 equivalent footprint, whatever metric is used for calculation.

The next step in this global aviation effort is to define and evaluate European air traffic operational protocols to consider contrail avoidance in a systematic manner in air traffic planning. It is a very difficult challenge that might involve considering the true warming effect of some contrails, either from their geometrical extent or microphysics characteristics, in order to pinpoint the worst potential contributors and identify a more optimal cruising altitude. Reuniwatt's Sky InSight LWIR imagers will be key to validating this future step. ∎