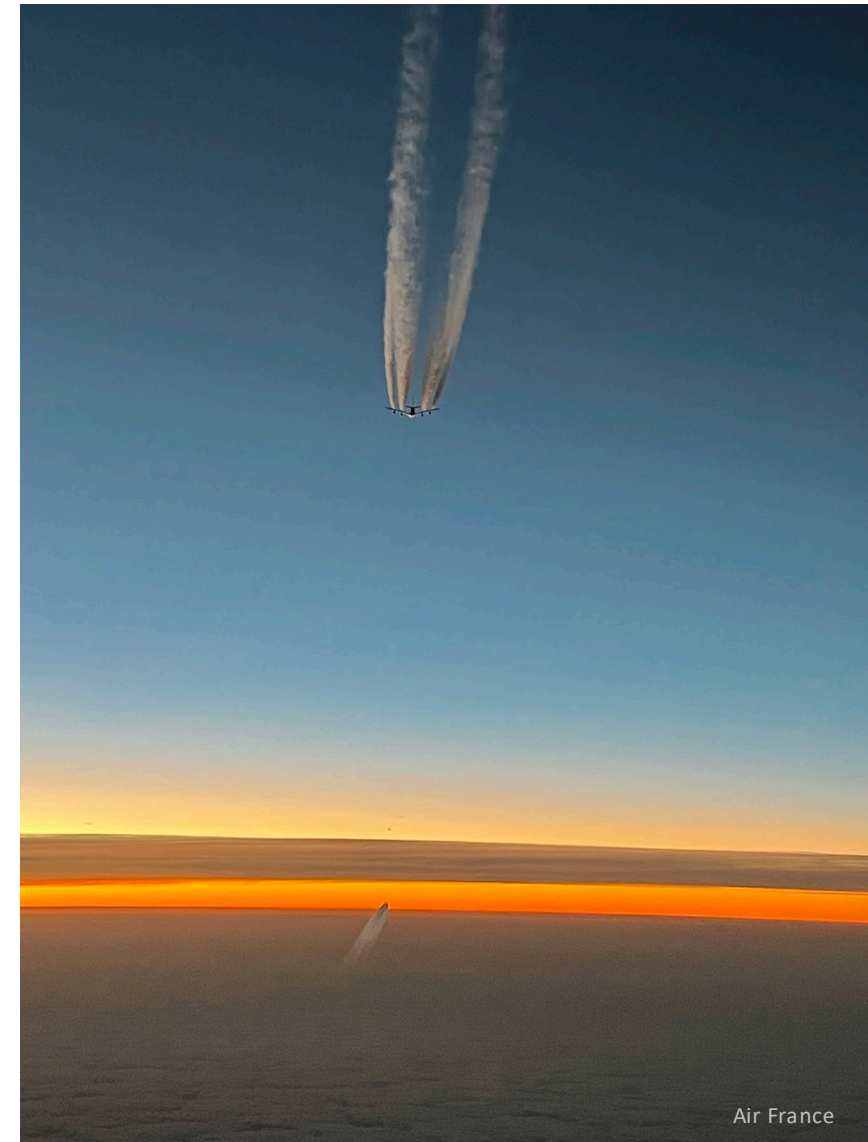


Prediction of contrails formation & Observation process

Météo France – Valentin Curat
Air France – Laure Péchaud



WIMCOT - Technical characteristics

Diagnostic

- Persistent contrails only: ISSR + SAc
- Use of global NWP model with supersaturation ECMWF
- Ensemble forecast

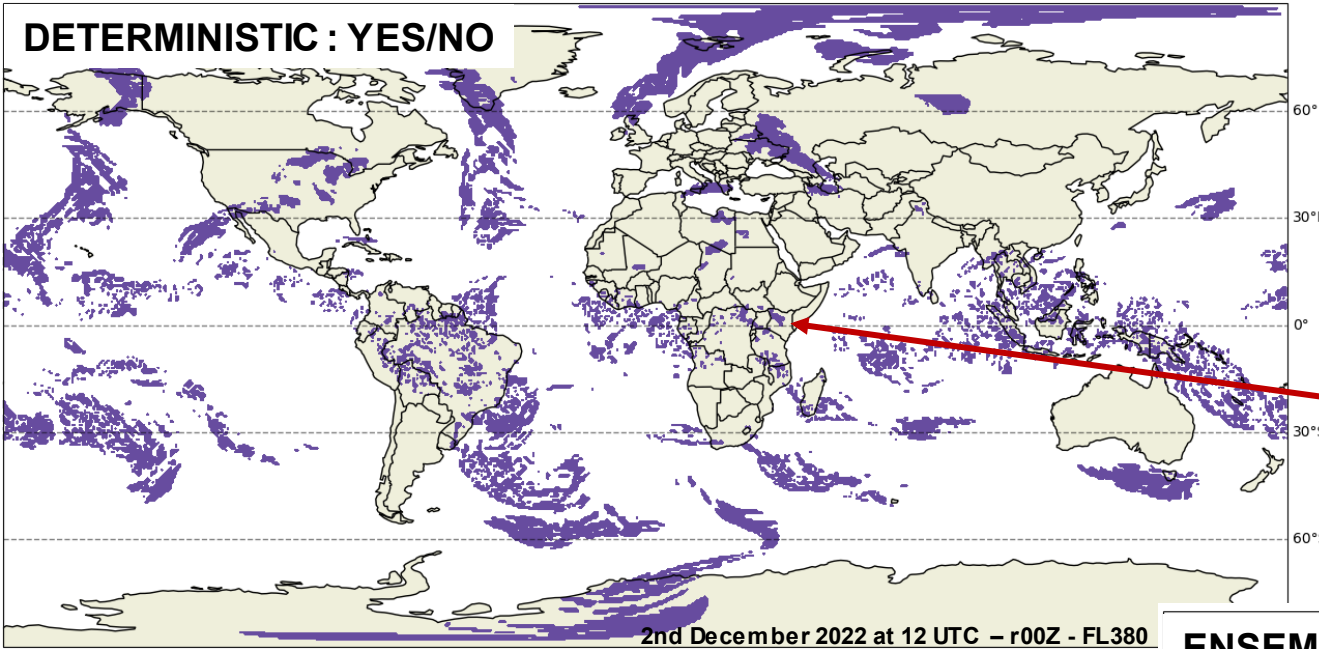
Characteristics

- Time step: hourly
- Horizontal grid: global 0.5° (50km)
- Vertical resolution: 300m
- 4 daily updates

Product status

- Available to Air France since summer 2022 (pre-operational)
- Operational in a few weeks

WIMCOT – Deterministic vs ensemble forecast



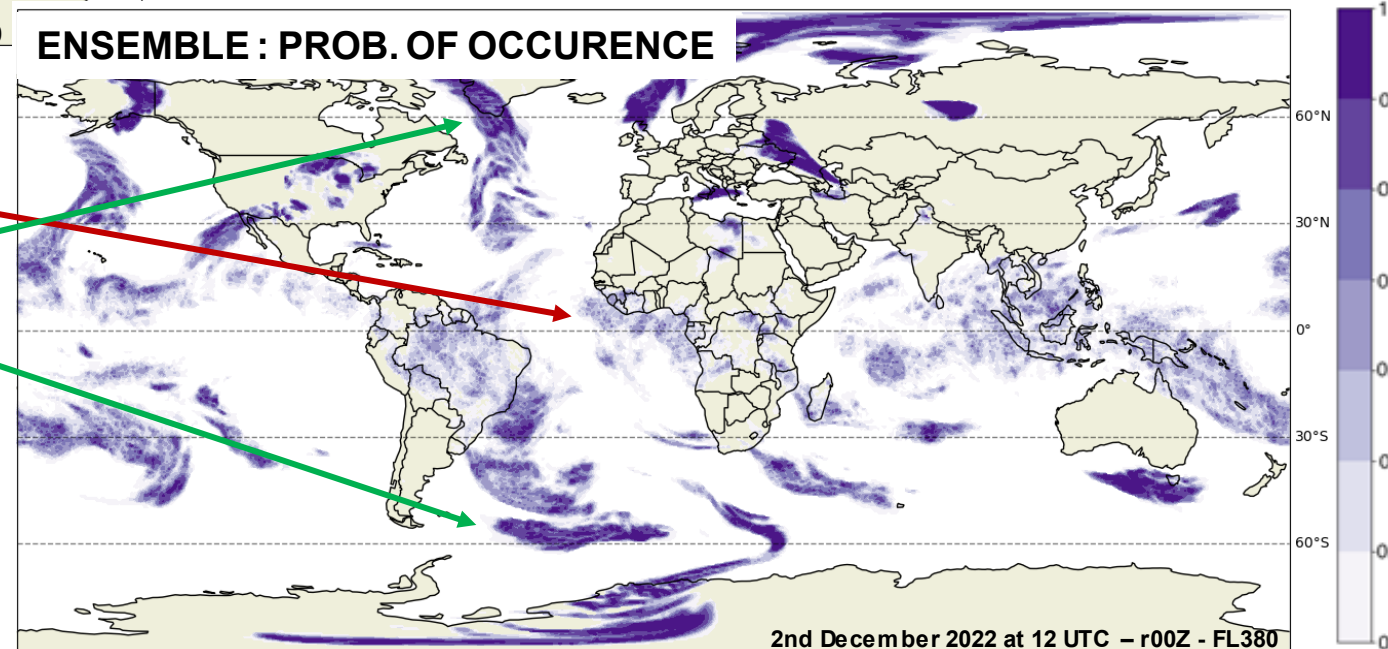
□ No risk area
■ Risk area

Tropics: heterogeneous signal /
not suitable for operations

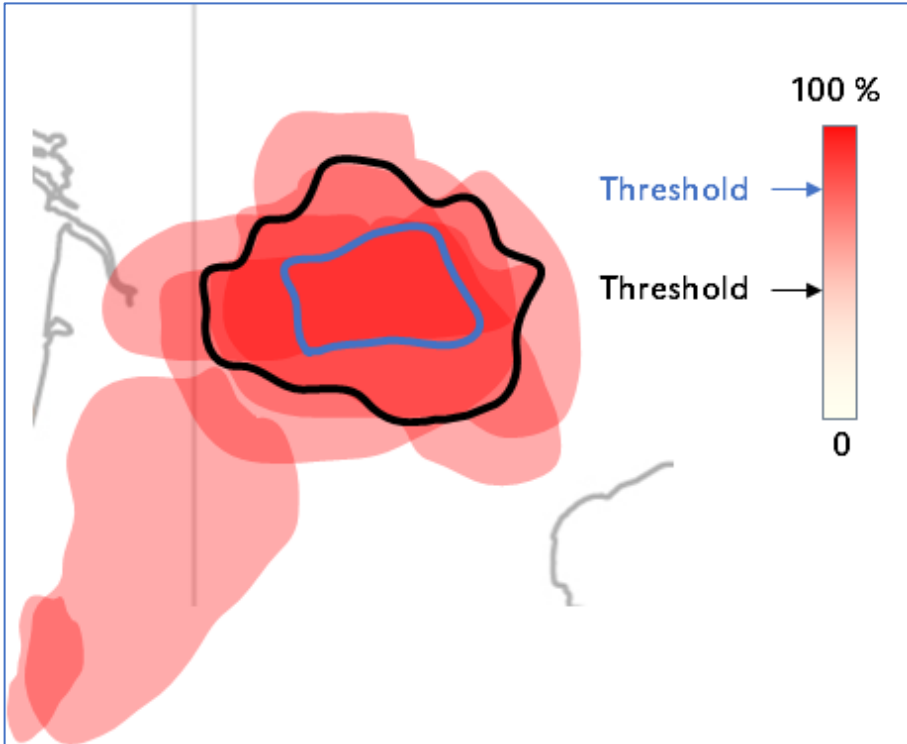
Tropics: lower predictability
Mid-latitudes: higher predictability

Major advantage

Encompasses uncertainty for a
better route optimization



WIMCOT - Ensemble forecast display threshold



Currently : 67% of members



Forecast for 04/09/2023 at 10UTC
From 03/09/2023 12UTC
Risk of contrail persistence between FL300 and FL450

■ Risk area

Operational thresholds under discussion

WIMCOT - Demonstration



 Risk area

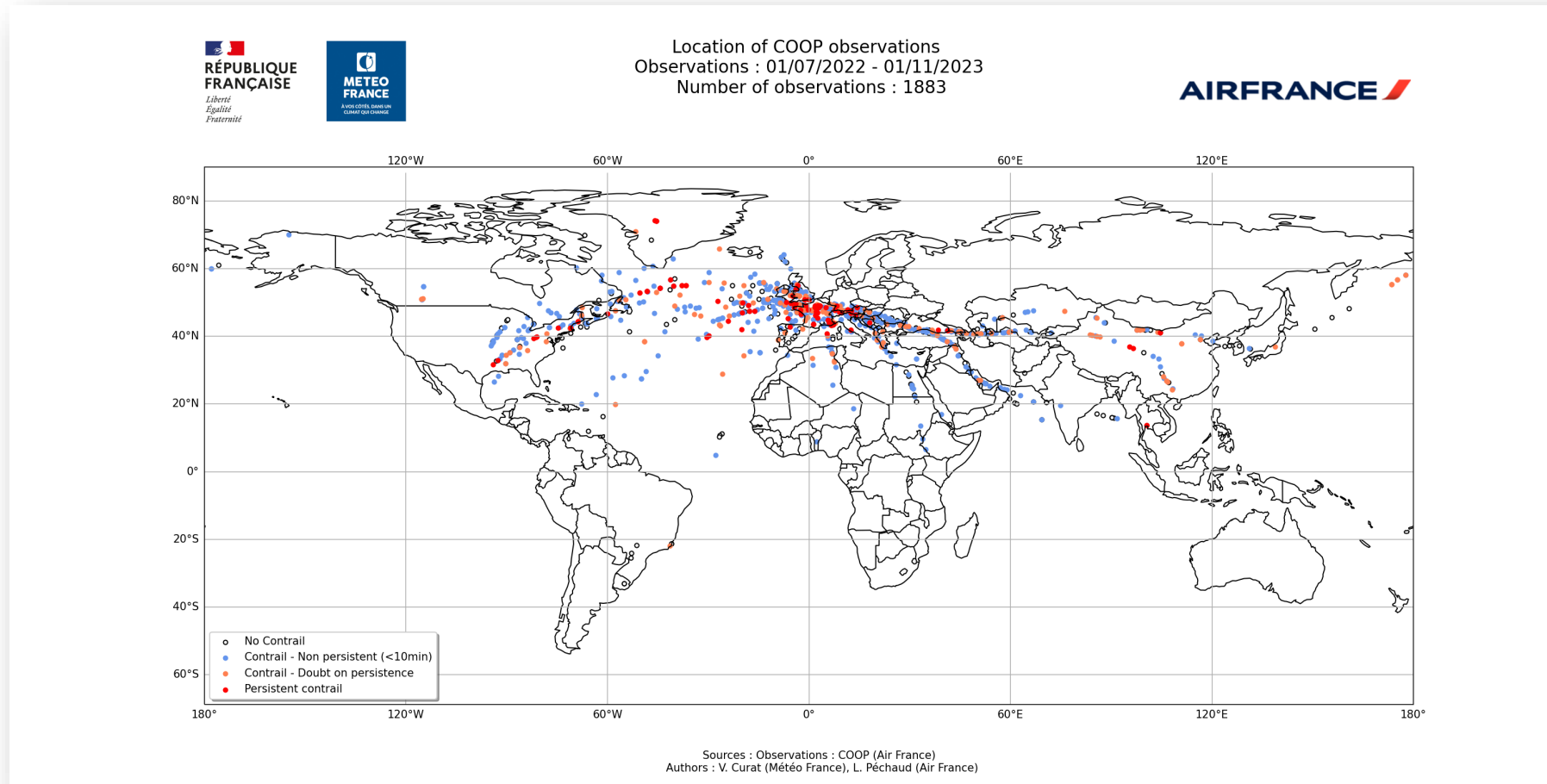
Forecast for 04/09/2023 at 10UTC
From 03/09/2023 12UTC

Risk of contrail persistence at
different levels



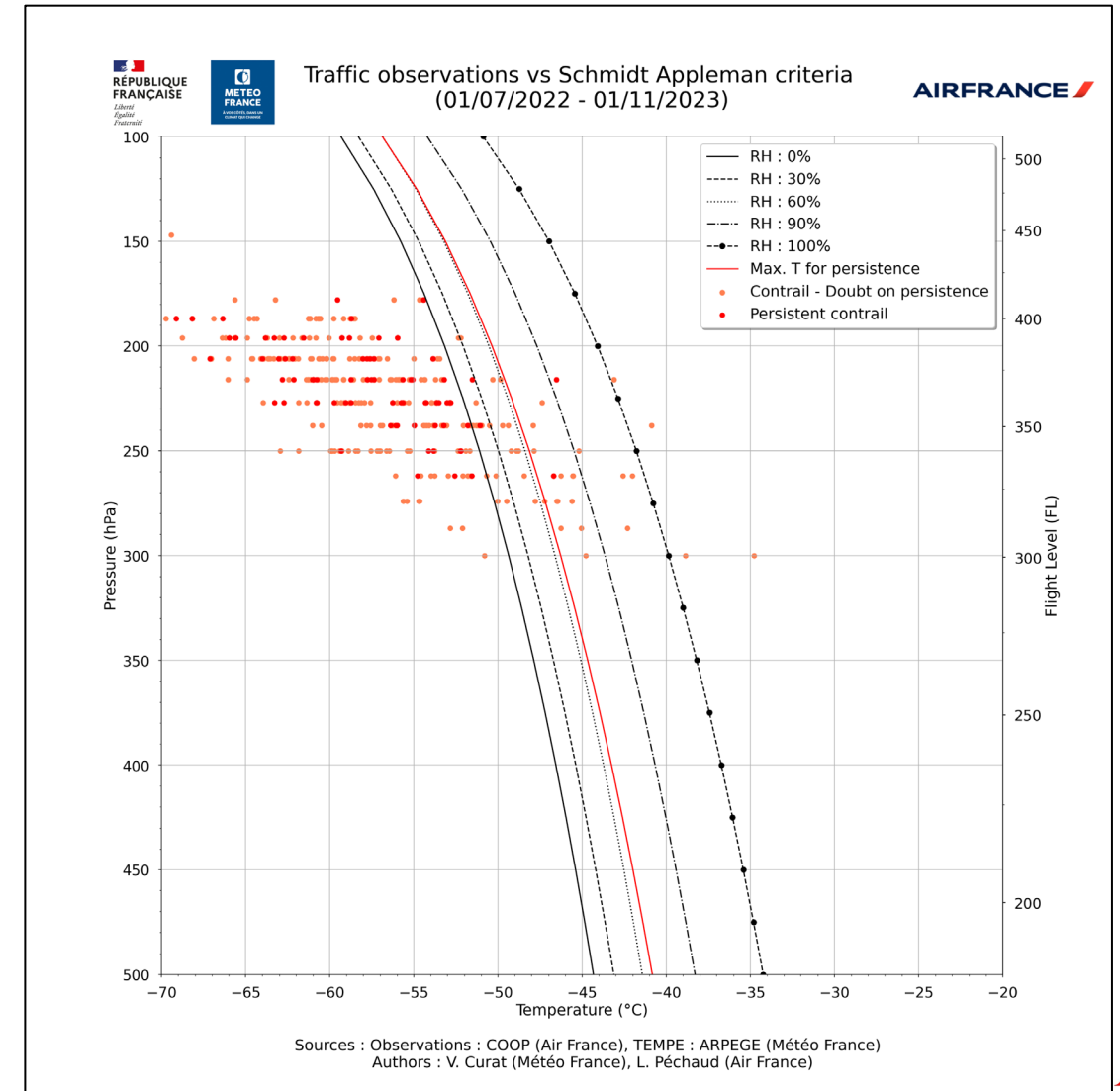
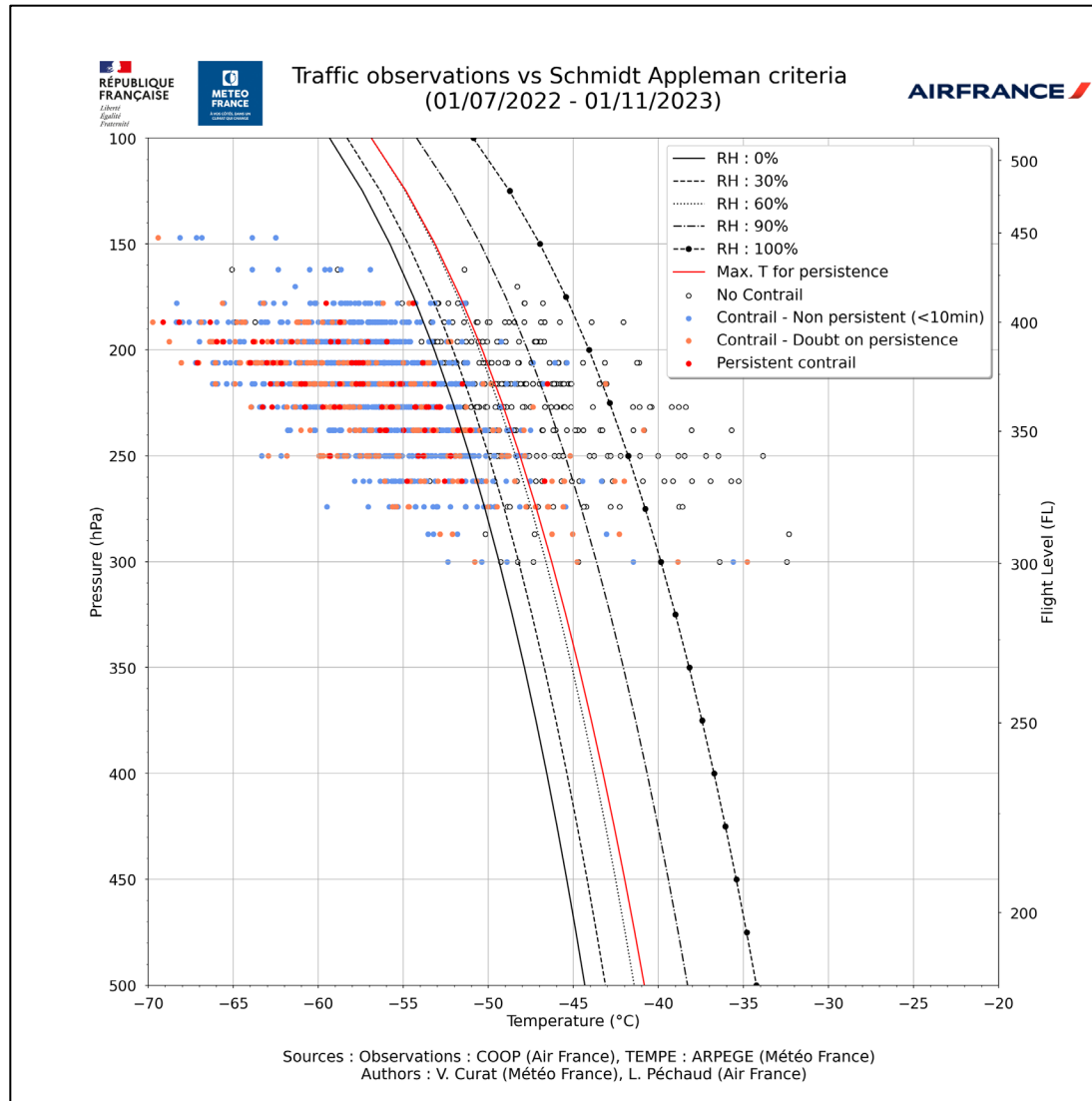
COOP – COntrail Observation Program

- 2700 ground & flight worldwide observations over almost 2 years
- Focus: Meteorological model validation (persistence: 10 min)
- Questionnaire developed by Air France with Météo France and Climaviation



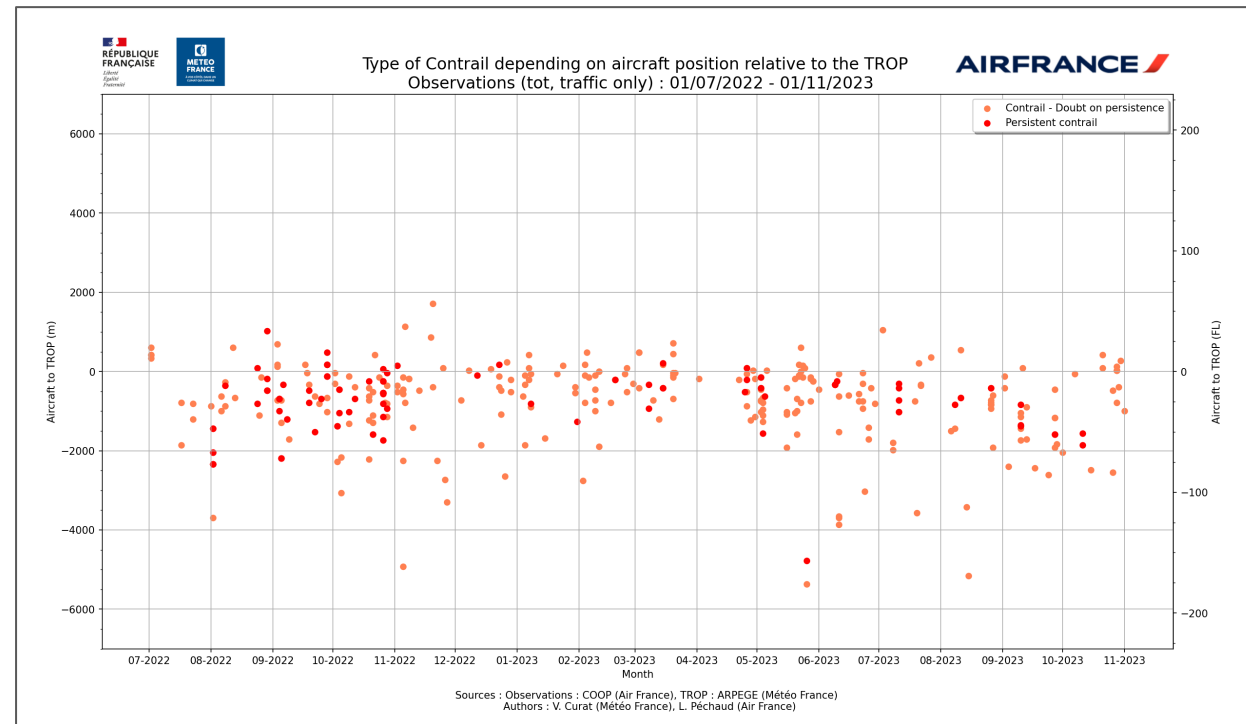
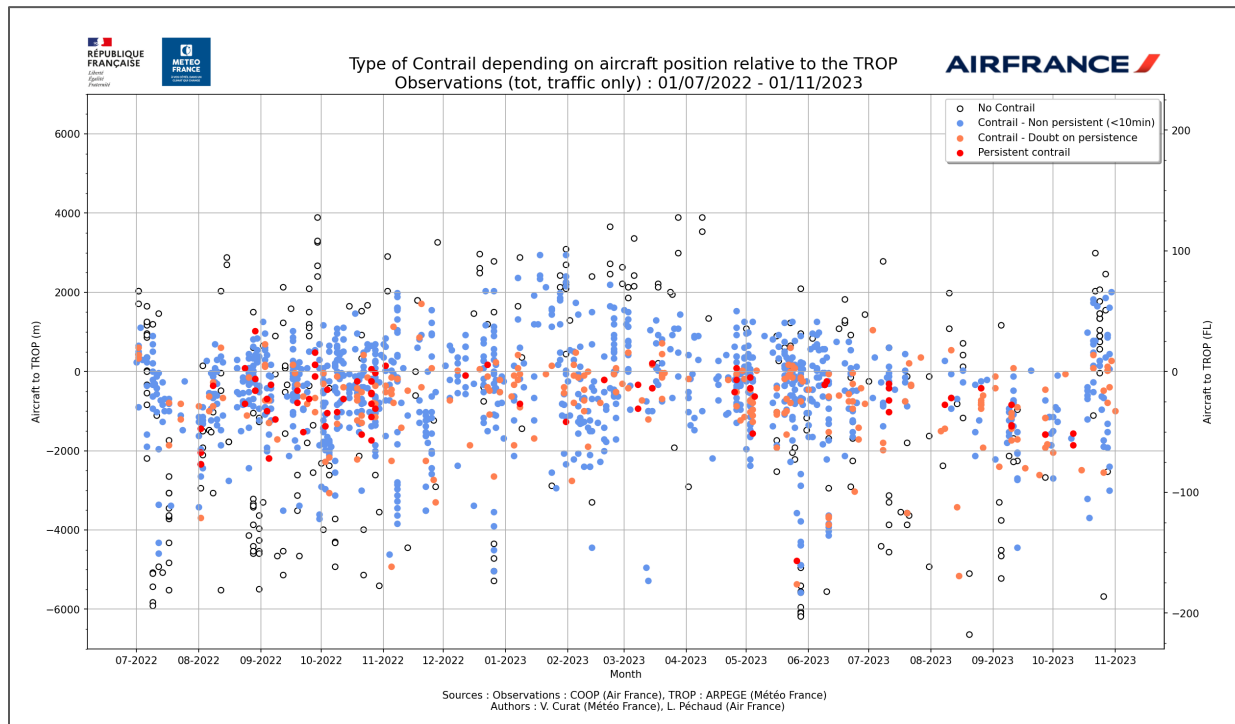
COOP – COntrail Observation Program

- Consistency with Schmidt Appleman criteria ($\eta = 0.3$)



COOP – COntrail Observation Program

- Tropopause analysis (TROP)
- Outcomes:
 - Above the TROP: Preliminary results confirm low risk of Persistent contrails
 - Below the TROP: Further observations are needed to characterize a potential risk area



WIMCOT – Validation

- First results on 1566 observations (ground and flight observations from COOP, nearest run)

MOD	OBS	COTRA	NO COTRA
COTRA	tp 168	fp 60	
NO COTRA	fn 46	tn 1292	

Contingency table

Hit Rate : 78.5%

FA_obs : 4.4%

FA_forecast : 26.3%

Accuracy : 93.2%

- Following analyses will be conducted:
 - Non-matching cases to improve the model & the observation process
 - Sensitivity analysis to optimize operational thresholds

Definitions:

$$\text{Hit Rate} = \frac{\text{tp}}{\text{COTRA obs}} = \frac{\text{tp}}{\text{tp} + \text{fn}}$$

$$\text{Accuracy} = \frac{\text{tp} + \text{tn}}{\text{total}}$$

$$\text{FA}_{\text{obs}} = \frac{\text{fp}}{\text{NO COTRA obs}} = \frac{\text{fp}}{\text{fp} + \text{tn}}$$

$$\text{FA}_{\text{forecast}} = \frac{\text{fp}}{\text{COTRA model}} = \frac{\text{fp}}{\text{fp} + \text{tp}}$$

Complementary sources of observations

	FLIGHT - COOP	GROUND - COOP
Device required	Phone or tablet	Phone or tablet
Nb of positions	Unlimited	Unlimited
Availability over oceans	Yes	Limited
Accuracy of position	Approximate	Precise
Duration	Short term	Short term
A/C origin of Persistent contrail	Not available	Available
Characteristics of the contrail (Optical Depth, width.....)	Not available	Not available
Nighttime	Rarely available	Not Available
Cloudy day	Available	Not available
Transmission of observation	Differed	Differed
Validation of observer	Picture	Picture
Atmospheric data (Humidity, wind, temperature...)	Limited & approximate	Not available

EVOLUTIONS WITH CICONIA

- Satellite observations
- Flight observations:
 - Development of ACARS forms
 - A/C equipped with IAGOS equipment will perform some trials
- Ground observations
 - Ground cameras network
 - LIDAR

Extension of COOP to other airlines under discussion

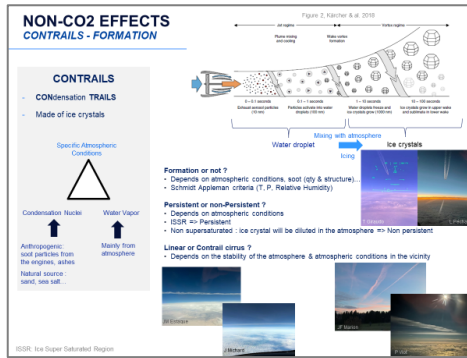
Way forward for Météo France - CICONIA

- Use additional observational data to continue the validation of WIMCOT
- Use of ARPEGE, the Météo France global model: evaluation of ISSR (using observations) and improvements of ISSR forecasting
- Propose products for representation and dealing with uncertainty

The Skyteam Flight Challenge 2023

- « Support to R&D for Non-CO₂ effects » challenge won by Air France with METEO FRANCE, PACE & GOOGLE RESEARCH

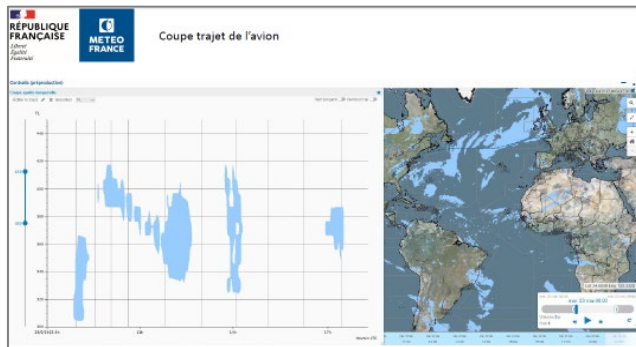
1. SHARE KNOWLEDGE on NON-CO2 EFFECTS with FUTURE KEY PLAYERS



2. ROUTE ANALYSIS BASED ON DISPATCH TOOL (Contrail risk areas)

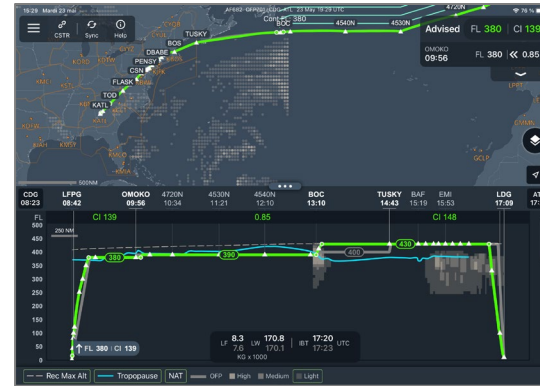
Constraints: equivalent CO₂ emissions for alternate routes
(High level of uncertainty on contrails climate impact &

No political consensus on priority between short term & long term)



Météo France Dispatch tool, Source Valentin Curat

3. SHARE CONTRAILS RISK AREAS WITH PILOTS



PACE FPO application, GOOGLE RESEARCH data

4. FLIGHT OBSERVATIONS:

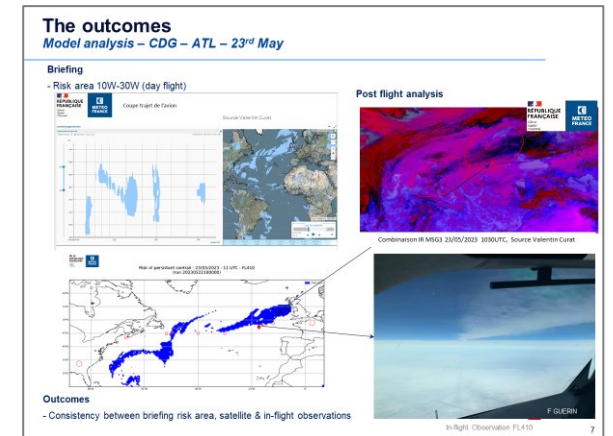
COOP : Contrail Observation Program



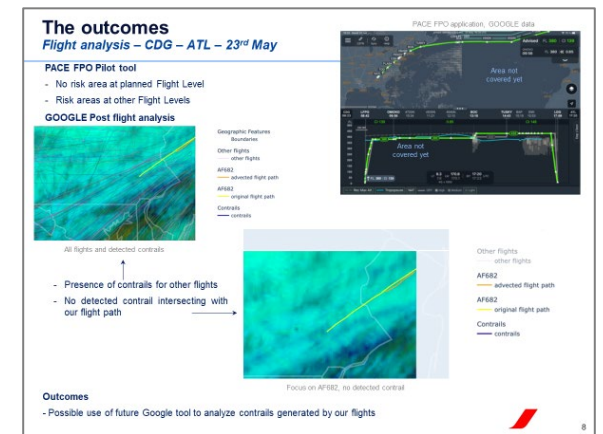
F Guérin, Air France

5. POST FLIGHT ANALYSIS

Positive results



Météo France Dispatch tool, briefing & IR Imagery, Source Valentin Curat

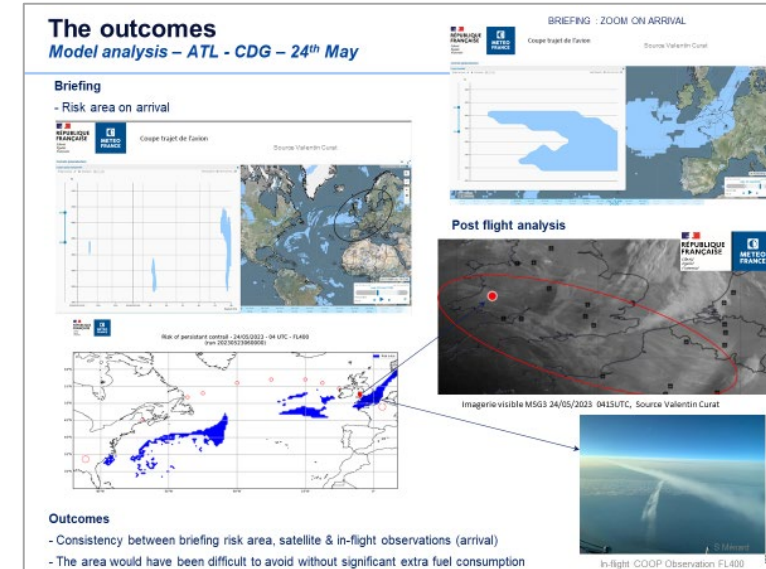


Satellite Imagery analysis & AI by GOOGLE RESEARCH

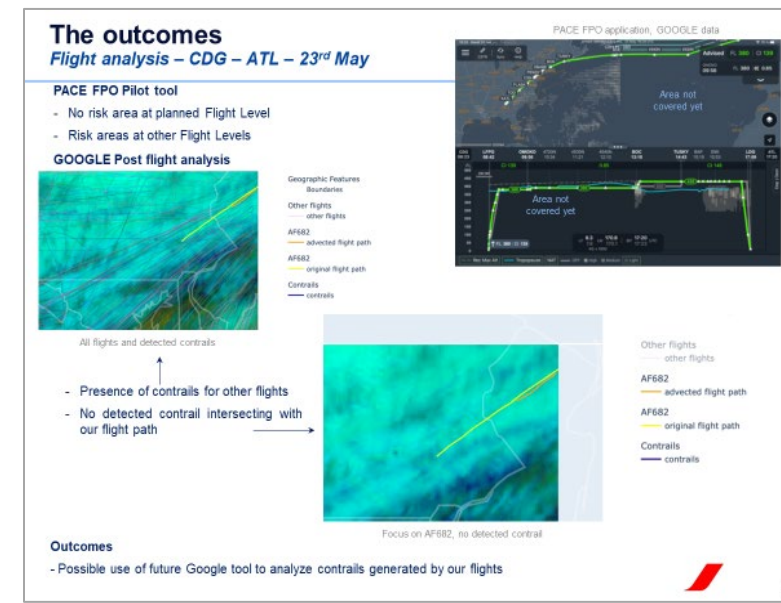
The Skyteam Flight Challenge 2023

- Satisfactory results
 - Consistency of forecasts with satellite /images and flight observations
 - Consistency of contrail risk areas forecasts by MÉTÉO FRANCE & GOOGLE RESEARCH
 - Stability of MÉTÉO FRANCE diagnostic through multiple runs

- Future exploration
 - Need to explore other solutions for contrail risk areas that could not be avoided
 - Need for integrated tools providing accurate computation of CO₂/Non-CO₂ climate impact
 - Need for clear instructions for dispatchers and pilots concerning the priority CO₂ vs Non-CO₂
 - Interest in future GOOGLE RESEARCH tool for analyzing contrails generated by our flights

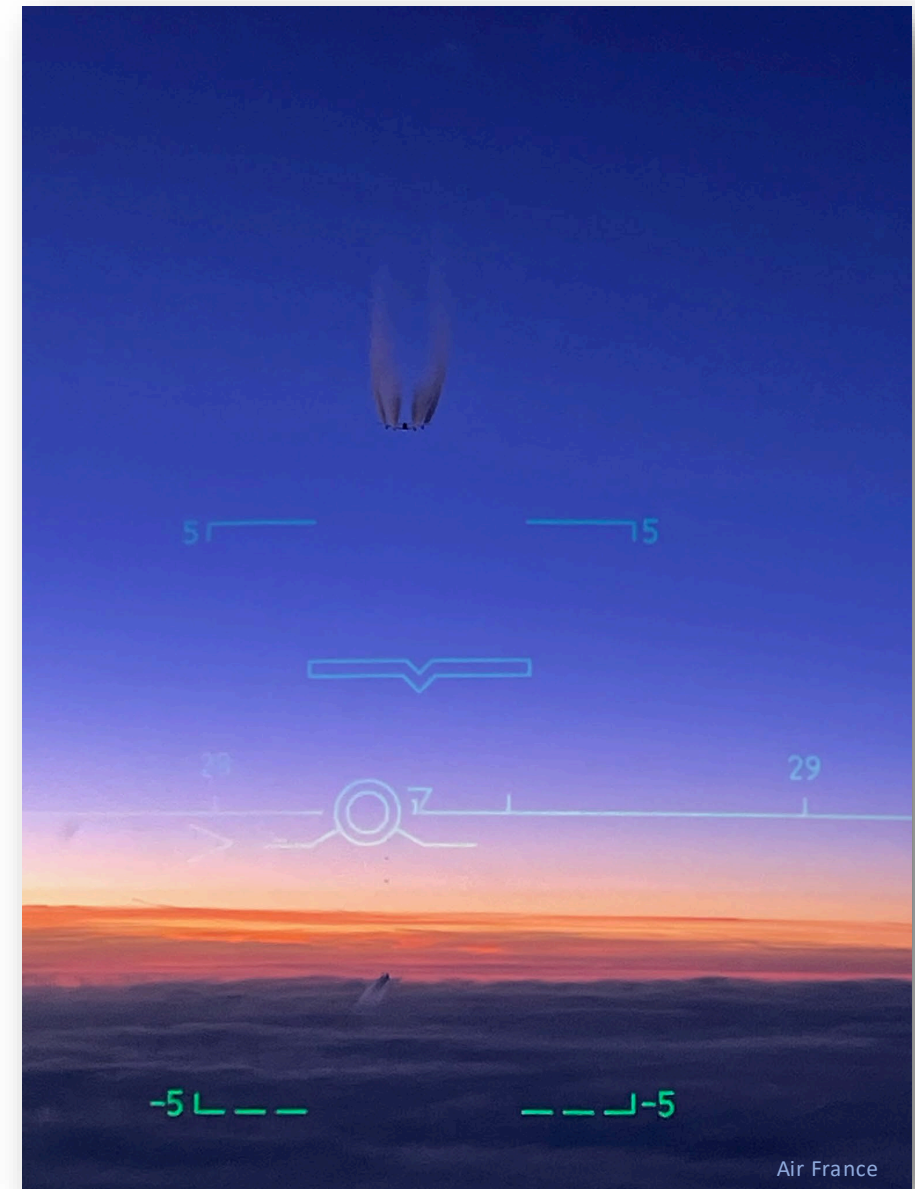


Briefings & satellite images by V Curat, Météo France



PACE FPO application,
GOOGLE RESEARCH data & Post flight analysis

Thank you for your attention





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