

The graphic features a green and blue background with a stylized globe on the left and a smaller globe on the right. An airplane is shown flying over the globe on the left, with yellow wavy arrows indicating emissions. Another airplane is shown flying over the globe on the right. The sun is visible in the top left corner. The text is centered in white.

ICAO Symposium on Non-CO₂ Aviation Emissions

16 — 18 September 2024
Montréal, Canada

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Speaker

Session 2: Enhancing Scientific Knowledge
Part II - Contrails

Contrail simulation: from near field to global climate impact

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Institut Pierre-Simon Laplace (IPSL)

Sciences du climat

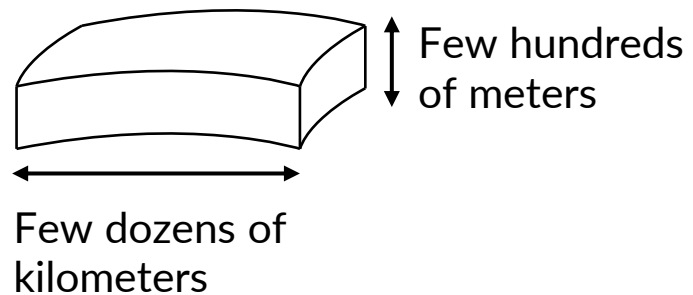
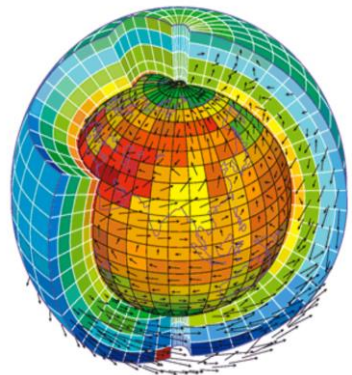
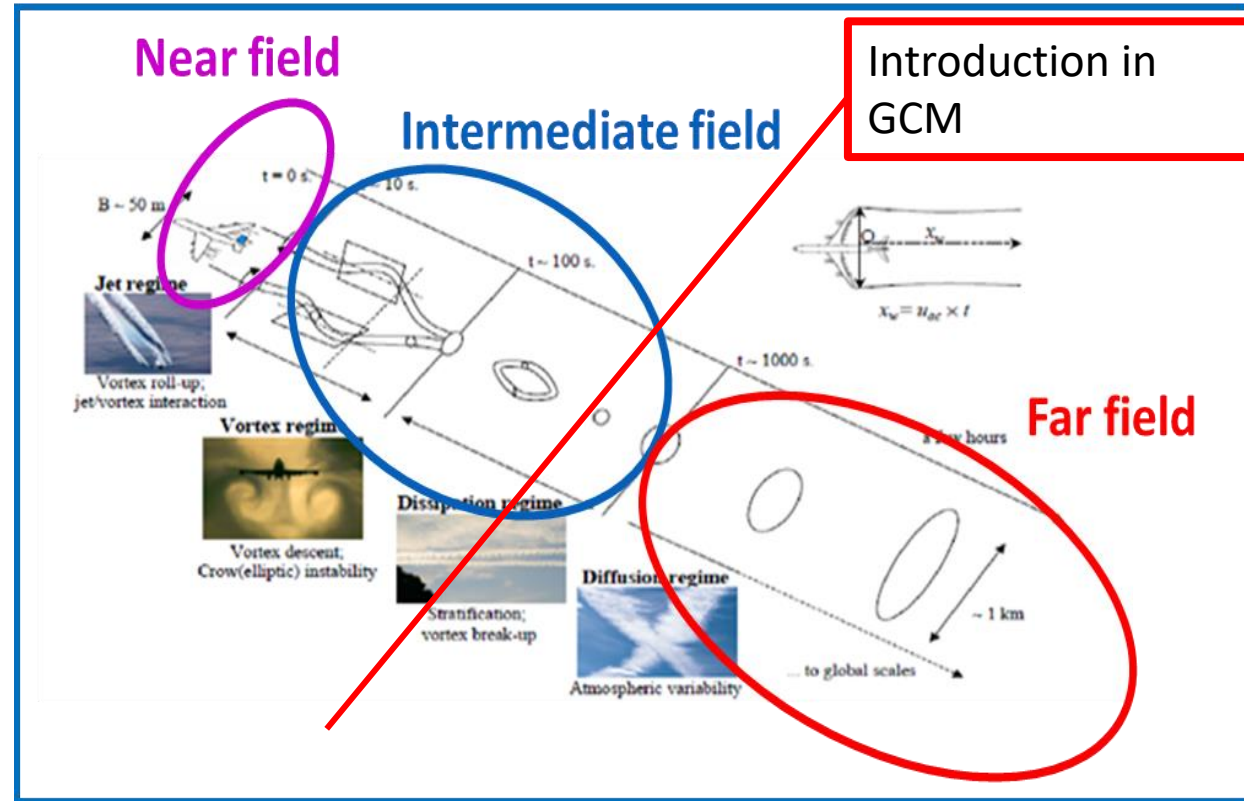


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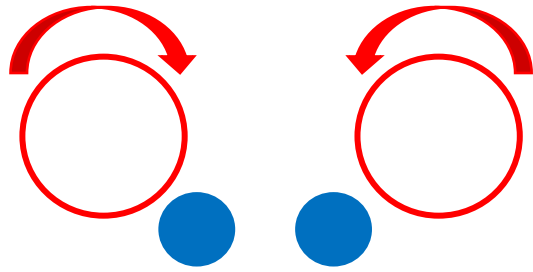


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- Global climate model or modeler CoCip (Schumann 2012) need to initialise a contrail considering
 - high
 - width
 - Ice Water Content
 - ice crystal number (at least for CoCip)
- Usually based on fixed initial width (Burkardt 2009) of on a dilution law (Schumann 2012)
- What if we introduce a parametrisation based on detailed simulation?
- What degree of detail is required to get a good representation of contrails?



$$\text{Contrail} = f \left(\frac{\partial T}{\partial z}, \tau_{atmo}, \text{Wind shear}, RH, T, \text{fuel}, \text{aircraft} \right)$$



Usual initialisation

- Most approaches do not represent the influence of aircraft aerodynamic on plume dilution and initial crystal formation
 - Simulation started downstream when vortices are established
 - Jet computed by LES or box model with no interaction with vorticity sheet
 - **Vortices : initialized based on aircraft span and weigh ("ideal vortices")**
- **Can we neglect the early interaction with vorticity sheet ?**



CRM + 2 engines



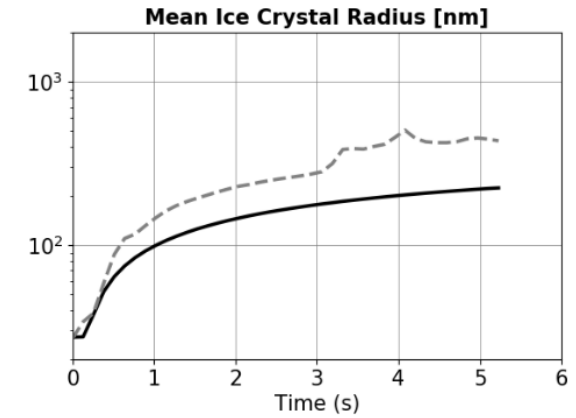
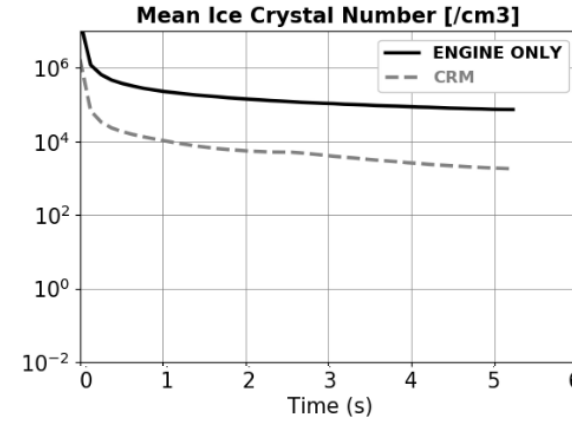
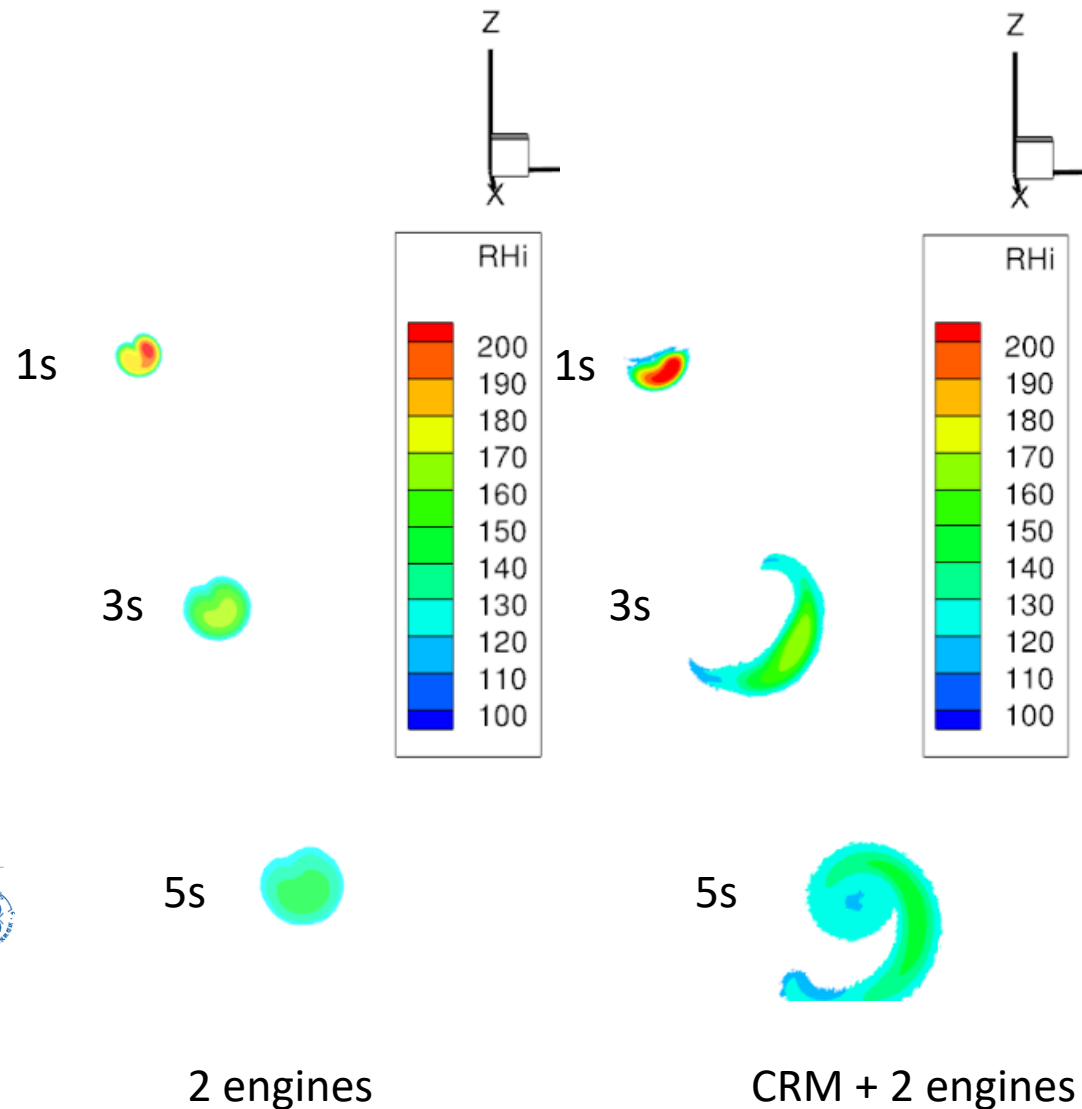
2 engines

RANS simulations

Test case : simulation aircraft vs engines alone

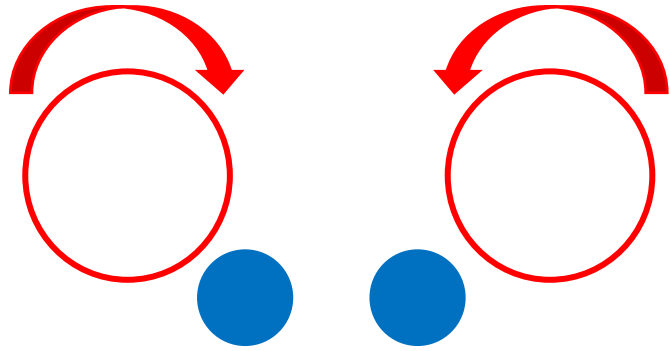
- If interaction is weak enough, early phase of contrail formation shall be the same
- 3D RANS
- Microphysical scheme:
 - Activation of soot by sulfuric acid
 - Condensation on activated soot

Influence of aircraft aerodynamic in contrail formation(2/2)

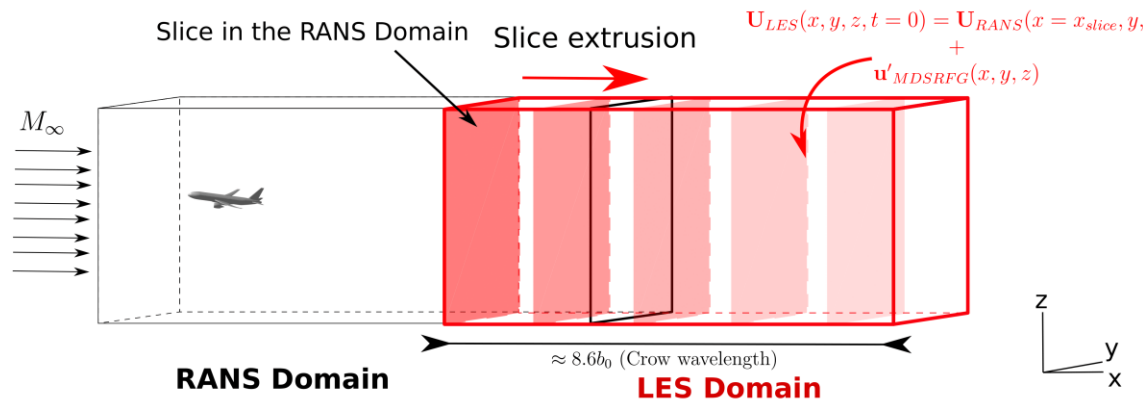


- The relative humidity with respect to ice inside the jet is modified due to the presence of the aircraft geometry
 - The concentration of ice crystal as well due to differences in the dilution
 - As a consequence the radius of ice crystals is different
- => For the nucleation process the interaction jet/vortex is important at least up to 5s

Importance of aircraft geometry up to dissipation phase (1/2)

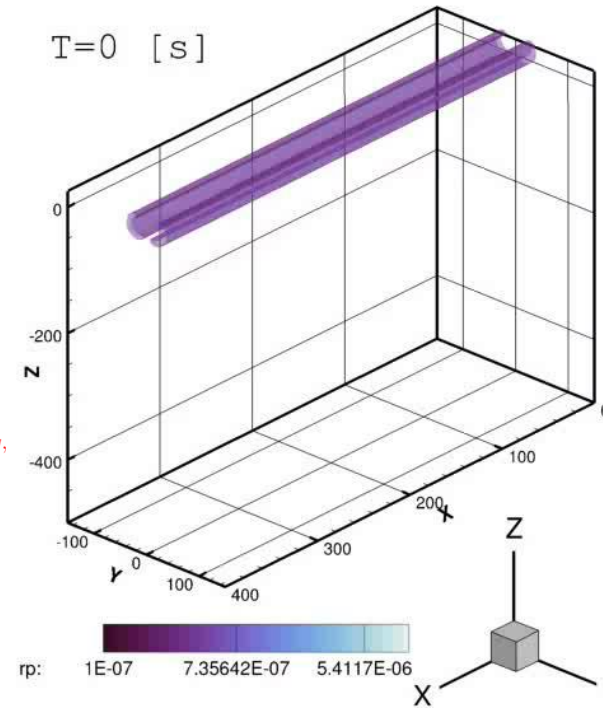


Analytical initialisation

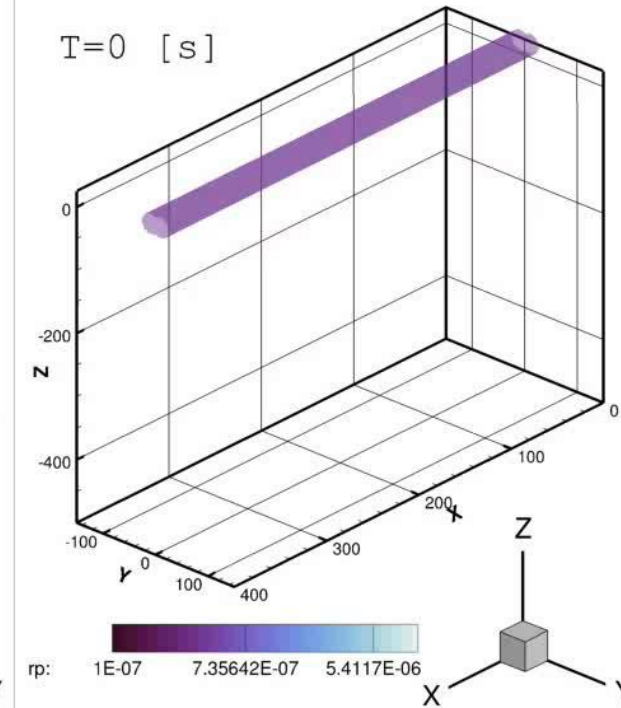


RANS based initialisation

RANS based intialisation



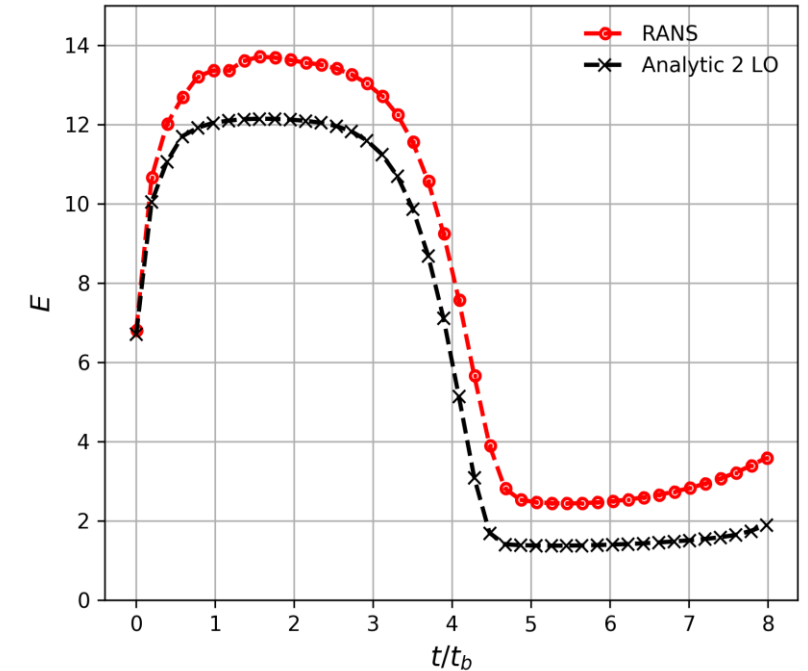
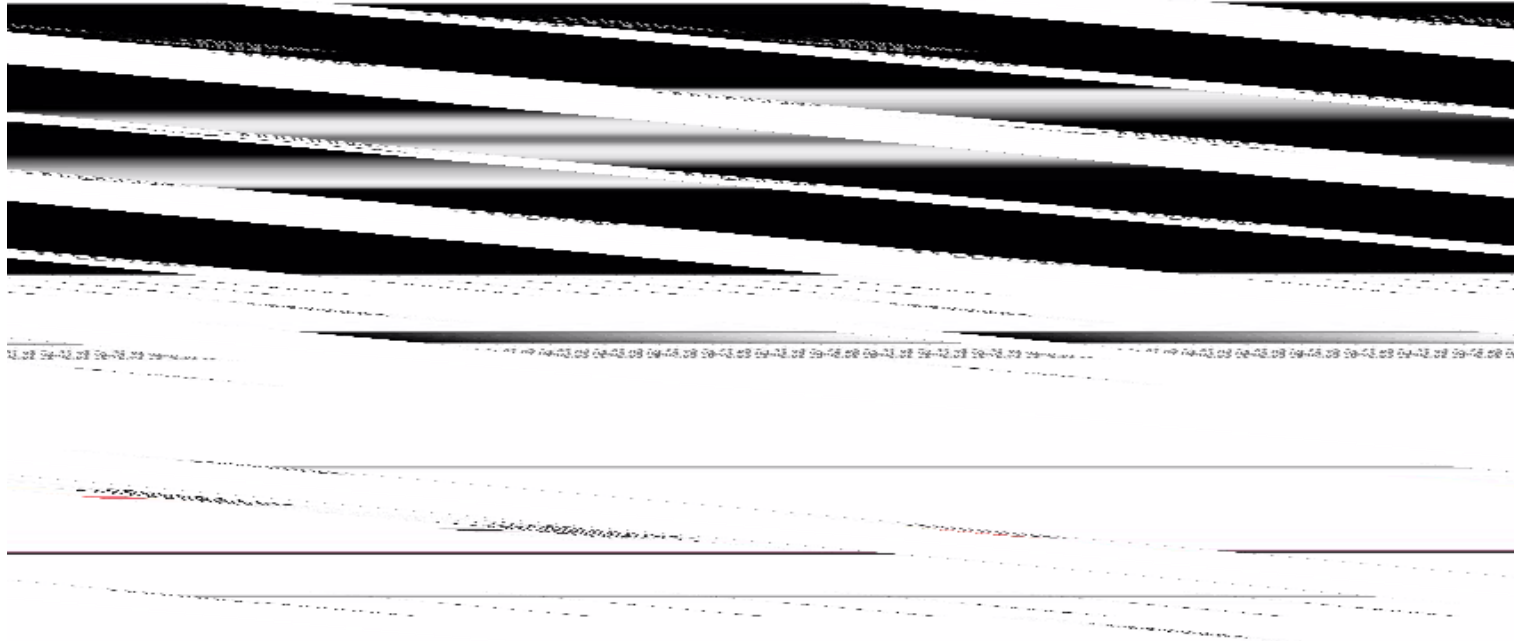
Analytical initialisation



Importance of aircraft geometry (2/2)

RANS base initialisation

Analytical initialisation



- The differences in contrail spreading leads to a change on its extinction coefficient
- Almost a factor of 2 at 220s
- **Work to be pursued to determine the impact on contrail modelling in in GCM or Cocip like model**
- *Question also for "unconventional" configurations (e.g. open-fan)*

- Burkhardt, U., & Kärcher, B. (2009). Process-based simulation of contrail cirrus in a global climate model. *Journal of Geophysical Research: Atmospheres*, 114(D16).
- Schumann, U. (2012). A contrail cirrus prediction model. *Geoscientific Model Development*, 5(3), 543-580.

Thank You

