Near-field modelling of contrails microphysics

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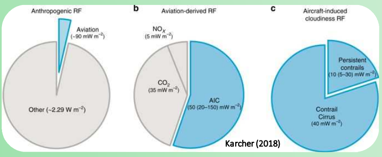
CONTEXT

- Increasing **societal pressure** around the environmental impact of aviation.
- Contrail is the dominant component of the aviation climate impact with **56 (29-65) %** of the global impact of aviation (Lee et al., 2020).
- Contrail cirrus represents **4/5 of the Aircraft Induced Cloud** (ACI) climate impact (Karcher (2018).
- Uncertainty remains one of **highest** among climate forcers.



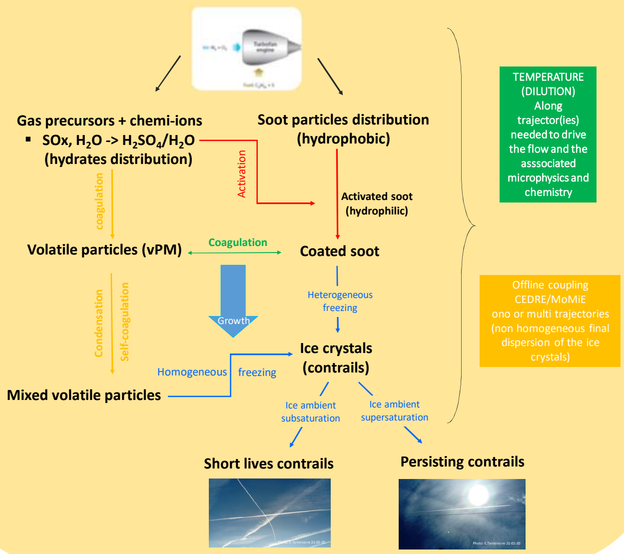
APPROACH

- CFD codes give robust information of the wake dynamics but use a simplified description of microphysics and chemistry within the plume.
- Microphysical box models generally use simple parametrized dilution along with a detailed description of the plume microphysics.
- Hybrid approach based on the use of fluid dynamics trajectories extracted from the CFD CEDRE (ONERA) code coupled to the microphysical trajectory box model MoMiE (ONERA).
- Access details **crystals characteristics** associated to contrails

METHODOLOGY

- Fluid dynamics and associated temperature (dilution) from CEDRE or from experimental data derived parametrizations.
- Using MoMiE (Vancassel et al., 2014) relevant microphysics processes of the plume is modelled such as:
  - ✓ initial soot distribution (size and number), Fuel Sulphur Content (FSC), water emission index, chemi-ions;
  - ✓ Formation and growth of volatile particles based on collision-aggregation;
  - ✓ Condensation/evaporation of water onto nvPM and vPM;
  - ✓ heterogeneous ice nucleation of the activated soot particles.
- Outputs include volatile particles, activated soot and ice crystals distributions (size and concentration) between nozzle exit and several seconds after exit.

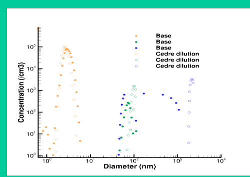
Schematic of the processes include in MoMiE (after Vancassel et al.)



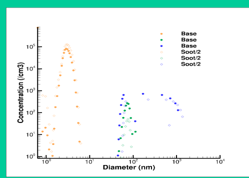
RESULTS

- Sensitivity analysis performed using the MoMiE particles trajectory code coupled to a mean CEDRE (CFD) trajectory:

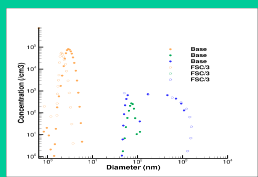
Name	Dilution	Distribution	Soot (number/cm3)	FSC (ppm)
Base	*Parametrized*	*Lognormal*	*10^{12}*	*350*
RUN 2	CEDRE	Lognormal	10^{12}	350
RUN 3	Parametrized	Lognormal	5.10^{11}	350
RUN 4	Parametrized	Lognormal	10^{12}	100
RUN 5	Parametrized	Mono	10^{12}	350
CEDRE	CFD/RANS	Mono	10^{12}	350



Using the higher CEDRE dilution
=
Larger ice crystals



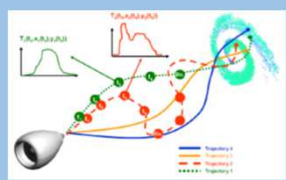
Number of soot emitted divided by a factor 2
=
Less ice crystals but larger



FSC divided by a factor 3
=
Larger ice crystals

PERSPECTIVES

- Adapt the multiple trajectories offline coupling approach (MoMiE/CEDRE) to accurately represent the ice crystals characteristics within the plume up to 100 spans.
- Test the influence of alternative fuel such biofuel and hydrogen on contrails characteristics (ice crystals distributions)
- Test the influence of plane geometry (e.g. engines position) using the multiple trajectories approach.
- Developed a parametrization to modelled ice crystals distributions (e.g. as a function of ambient temperature and relative humidity, soot emission index, FSC and fuel type) suitable for global climate model.



Example of a multiple trajectories approach (Vancassel et al., 2014)

References

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