FLIRt: Flow by Infra-Red Tandem

An ESA EE9 proposal

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Mission Overview

Cloud dynamics and their interplay with aerosols (Aerosol Cloud Interactions, ACI) and the effect on atmospheric circulation represent the greatest uncertainty in climate forecasting. The development of Clouds and ACI, in turn, are governed predominately by convective vertical velocities.

The Flow by IR tandem mission (FLIRt) will use a unique combination of Sentinel-3 and dual/tandem satellites dedicated to thermal IR wind retrieval to produce winds 24 hours per day with a wide swath (1500km) at high horizontal resolution (down to 0.5km) by tracking clouds and simultaneously retrieving their height to ≤150m vertical accuracy and their advective and vertical updraft wind-fields to ≤1.0 m/s by combining several simultaneous views at each location.

Measurements of cloud-top updraft speeds are highly correlated with "within-cloud" updrafts (see fig 1) such that typically they are half the maximum "within-cloud" speed. This means that within-cloud dynamics can be retrieved from cloud-top surface measurements, a critical factor for the use of passive remote sensing. These measurements will therefore address the most significant remaining uncertainties left in both NWP forecast improvement and the prediction of climate change.

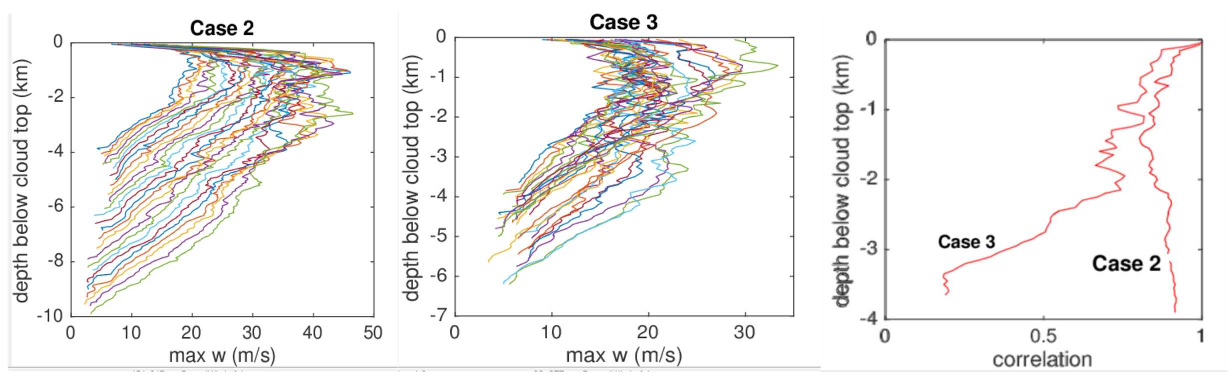

Fig 1. The maximum updraft speed as a function of distance below cloud top for strong (left) and moderate (middle) convective clouds at various time steps during their growth . The correlation between the rising rate and maximum updraft speeds at various depth below cloud tops for the two cases (right). The clouds were simulated by the System for Atmospheric Modelling (SAM) at a grid resolution of 50 m. The only difference between the simulations was aerosol concentrations, low in Case 2 and high in Case 3, demonstrating the strong sensitivity of the storms to CCN aerosols.

Mission objectives

Our scientific objectives are to

- Understand the nature of the interactions in vertical convective updrafts between aerosols, cloud microphysics and dynamics and the impacts on cloud radiative forcing, at scales from individual clouds to whole synoptic systems
- Develop improved parameterisation of clouds within GCMs by quantifying the convective mass flux and mixing as a function of thermal buoyancy, vertical winds, wind shear and precipitation forming processes.

In addition to addressing these Grand Scientific Challenges, **FLIRt** will deliver

- Direct impact in NWP by assimilation of advective wind-fields with better height assignment than can be obtained with existing AMVs.
- Stereo heights allowing for an independent assessment of cloud heights from traditional AMVs, providing a useful tool in assessing AMV sources of error
- Global coverage for dataset intercomparisons, validation, and operational satellite product improvement
- Higher resolution horizontal winds than can be obtained with existing AMVs. These will allow for improved understanding of severe weather systems, such as hurricanes, tornado-generating systems, polar lows and Mesoscale Convective Systems (MCS). These also have the potential to be used for severe weather nowcasting and forecasting

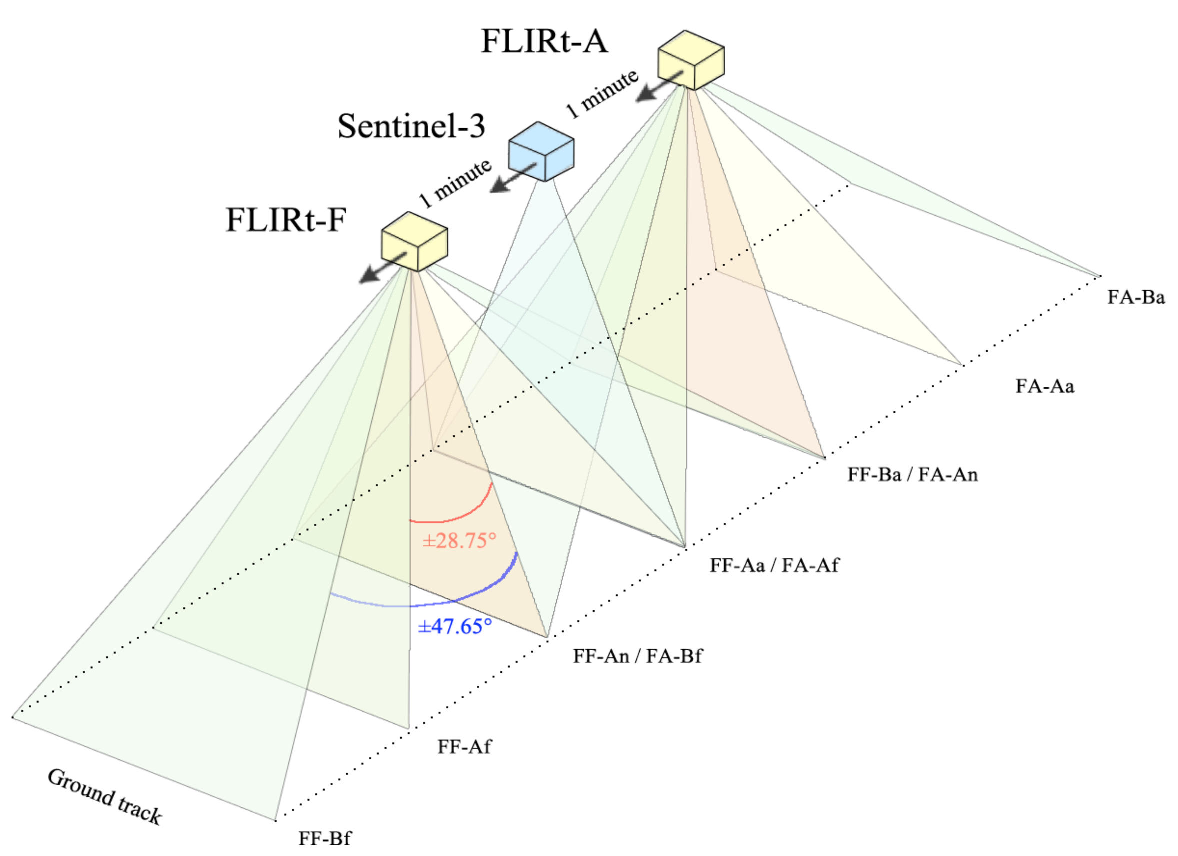

Fig 2. Proposed FLIRt configuration with Sentinel-3. Based on ESA Study contract on MetOp-SG (courtesy of Ad Stoffelen, KNMI; Karl Atkinson, Airbus DS, Amanda Regan, ESA-ESTEC)

Mission implementation

FLIRt aims to address the retrieval of the 3D wind-field (u,v,w) along with brightness temperatures in the thermal IR using space-qualified European uncooled microbolometer arrays operating in Time Delay Integration (TDI) mode on two spacecraft (a tandem) positioned 60 s ahead of and 60 s behind Sentinel-3 (see fig 2). The synergy between the retrieval of cloud and aerosol microphysical properties from SLSTR and OLCI on S3 and the extremely accurate temperature calibration of SLSTR to cross-calibrate the **FLIRt** cameras will allow atmospheric dynamics to be coupled to thermodynamics and cloud microphysics for the first time ever.

- The **FLIRt** tandem will allow geometric cloud-top heights (CTHs) to be retrieved from stereo machine vision at a single time instance, thus avoiding cloud dynamics to degrade cloud height estimates, as is the case for the single MISR satellite (see fig 3 and 4).
- Multiple simultaneous stereo views allow observing the time variation of CTHs, such that the vertical velocity can be retrieved, alongside the change in temperature of the cloud-tops at resolutions from 150m, that can then be converted into very fine vertical displacement of the cloud top.
- Cloud thermal buoyancy can be obtained and related to updraft speed and to the extent of cloud mixing with ambient air.
- Better determined heights lead, in addition, to more accurate cloud-top advective winds and vertical temperature profiles.
- Near cloud base updrafts along with cloud drop concentrations as obtained from S3 can be used to infer the concentrations of cloud condensation nuclei aerosols and the supersaturation at which they form the cloud droplets.

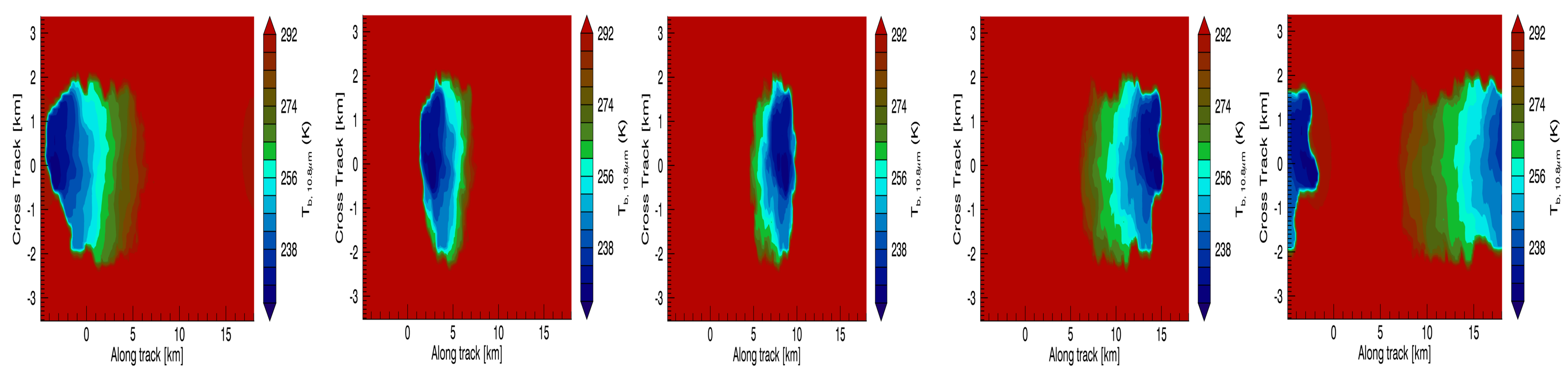

Fig 3. An example of Forward calculated IR images at 10.8 μm. The image are collocated in space and time adopting the 5 angles to be used in the FLIRt configuration . Note that the forward view at +47.65° appears on the left due to the cyclic boundary condition used to minimize calculation time. All images have a noise level between 30 and 40mK.

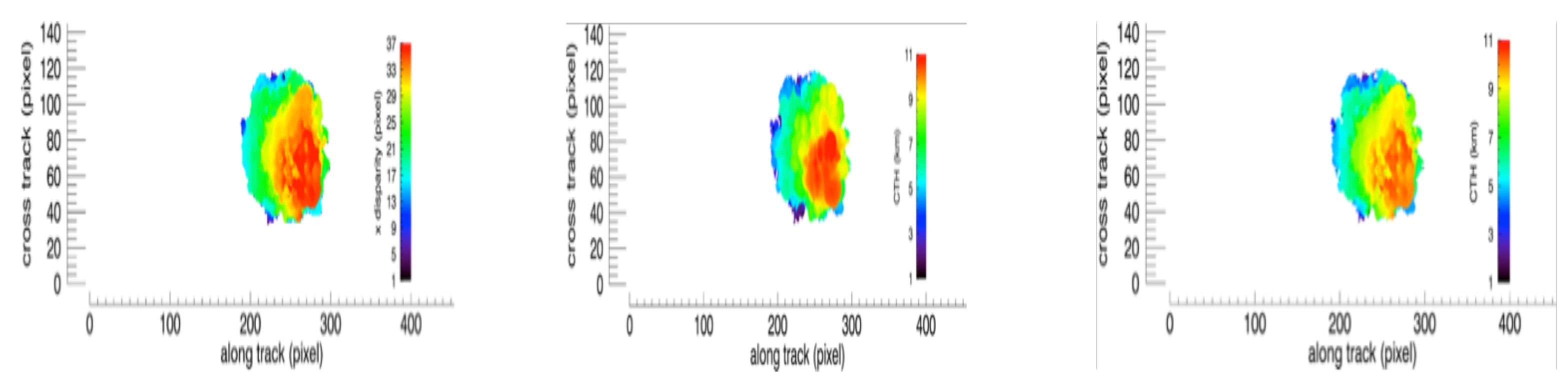

Fig 4. Example of along-track disparities produced from the stereo matching system with the inputs from Fig 2 (left). Model (middle) and retrieved (right) cloud-top height, calculated from the nadir-oblique image along-track disparities.

Summary

FLIRt will provide crucial measurements of cloud top velocities, to allow for advances in our understanding of cloud aerosol interactions.

FLIRt has a long and distinguished heritage based on the measurement concept exploiting the visible/NIR pushbroom sensors of the NASA MISR instrument and the thermal, SWIR and visible along-track (A)ATSR(2) sensors and the AirMISRlite demonstrator.

FLIRt will measure accurate, high resolution cloud top 4D-winds over a wide swath. This can be compared to Earthcare, which will be able to measure the velocity of hydrometeors (indirectly related to vertical updrafts) through a slice of the depth of most clouds, due to its relatively high sensitivity of -35dBZ. However, Doppler velocities will only be available in areas which have at least a radar reflectivity of -20dBZ, which excludes most of the top of the ice clouds and low liquid water clouds without precipitation. As such, FLIRt and Earthcare will be truly complimentary.