RALI: the French radar-lidar airborne platform for cloud dynamics and microphysics studies

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Outline

- RALI?
  - Why radar – lidar?
  - Platform and payload
  - The field campaigns
  - Why is RALI so special?
- Examples of products
- Applications

RALI

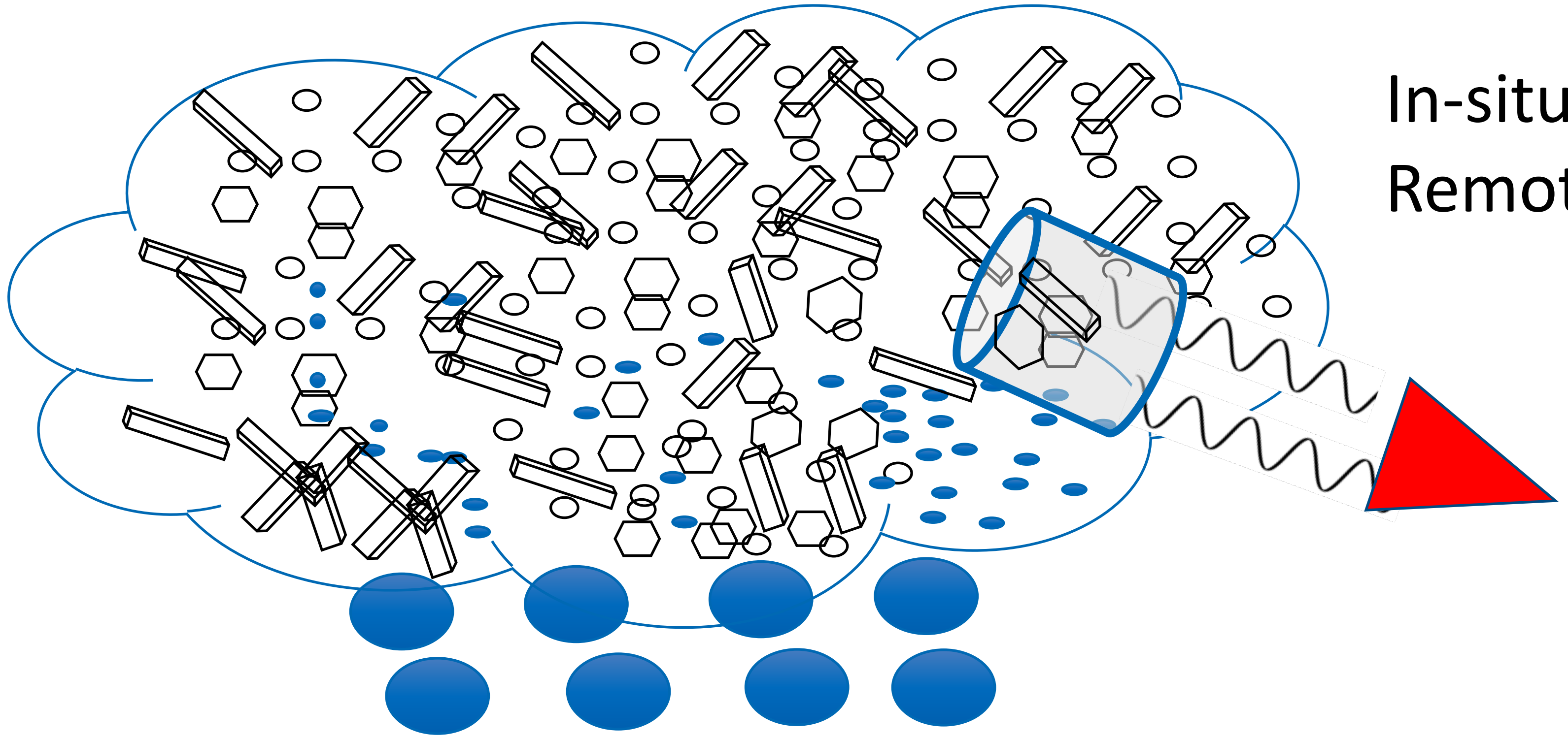
RALI: airborne RAdar- LIdar

An airborne platform dedicated to:

- ✸Cloud, aerosols and precipitation characterisation (Case study) => infer cloud processes and cloud aerosol interaction through their radiative, microphysical and dynamical properties
- ✸Go to locations that ground based systems can't reach and get as close as possible to the targeted area
- ✸Development/Validation of synergistic algorithms/products (associated with in-situ measurements)
- ✸Preparation, Evaluation and Validation of spaceborne instruments and their products (CloudSat-CALIPSO, EarthCare, AEOLUS, MESCAL)

=> Cloud radar, Lidar and Radiometer synergy

Optical and microwave duet…



In-situ: fine description… very local
Remote sensing => sample a distant volume

Interaction depends on wavelength and size/density of hydrometeors

Cloud radar 95 GHz (3.2 mm)

$$Z = \frac{\lambda^4}{|K_W|^2 \pi^5} 10^{18} \int N(D) \sigma_{bsc}(\lambda, D, \rho) dD$$

Assuming no attenuation

$$Z = 10^{18} \int N(D) \boxed{D^6} dD$$

Rayleigh approximation

$\sigma_{bsc}(D, \lambda, \rho)$ scattering coefficients (Mie,1908) or T-matrix…

Radar more sensitive to size
Penetrates larger OD/ less sensitive

Lidar (355nm to 1064 nm)

$$\alpha = 2.10^3 \int N(D) \boxed{A(D)} dD$$

A(D) represents the projected cross sectional area

$$\beta(r) = \frac{\alpha(r)}{S(r)} \exp\left[-2\int_0^r \alpha(r')dr'\right]$$

Assuming no multiple scattering

Lidar more sensitive to concentration
Detects thin cirrus and aerosols/ Strong attenuation

Platform and payload

Aircraft (SAFIRE) :

Dassault Falcon 20

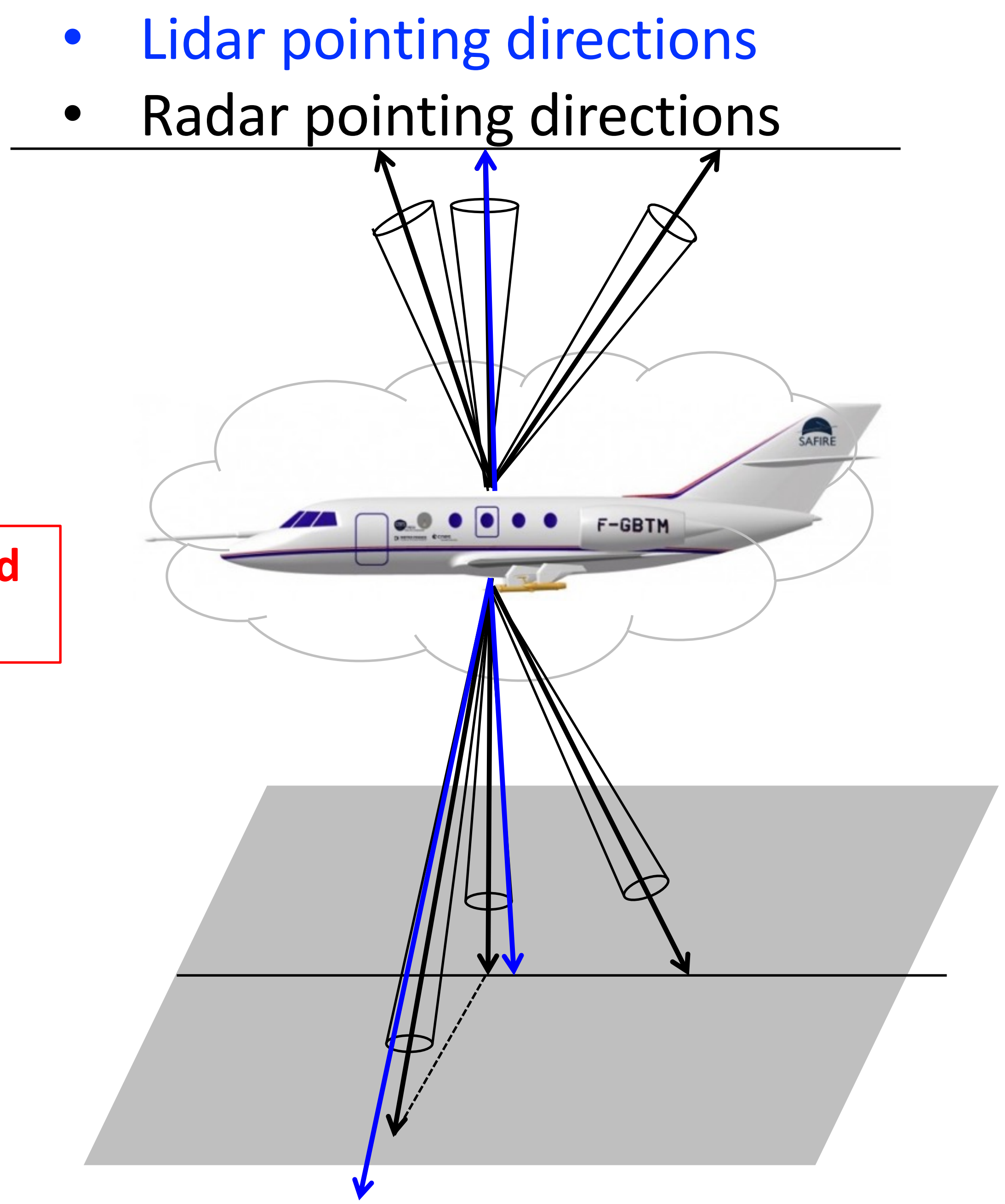
- Endurance: **3.5 flight hours**
- Maximum cruising altitude: **13 km**

ATR42

- Endurance: **5 flight hours**
- Maximum cruising altitude: **7.5 km**

F20 SAFIRE / ATR42

Instruments developed by LATMOS/DT-INSU



http://rali.projet.latmos.ipsl.fr

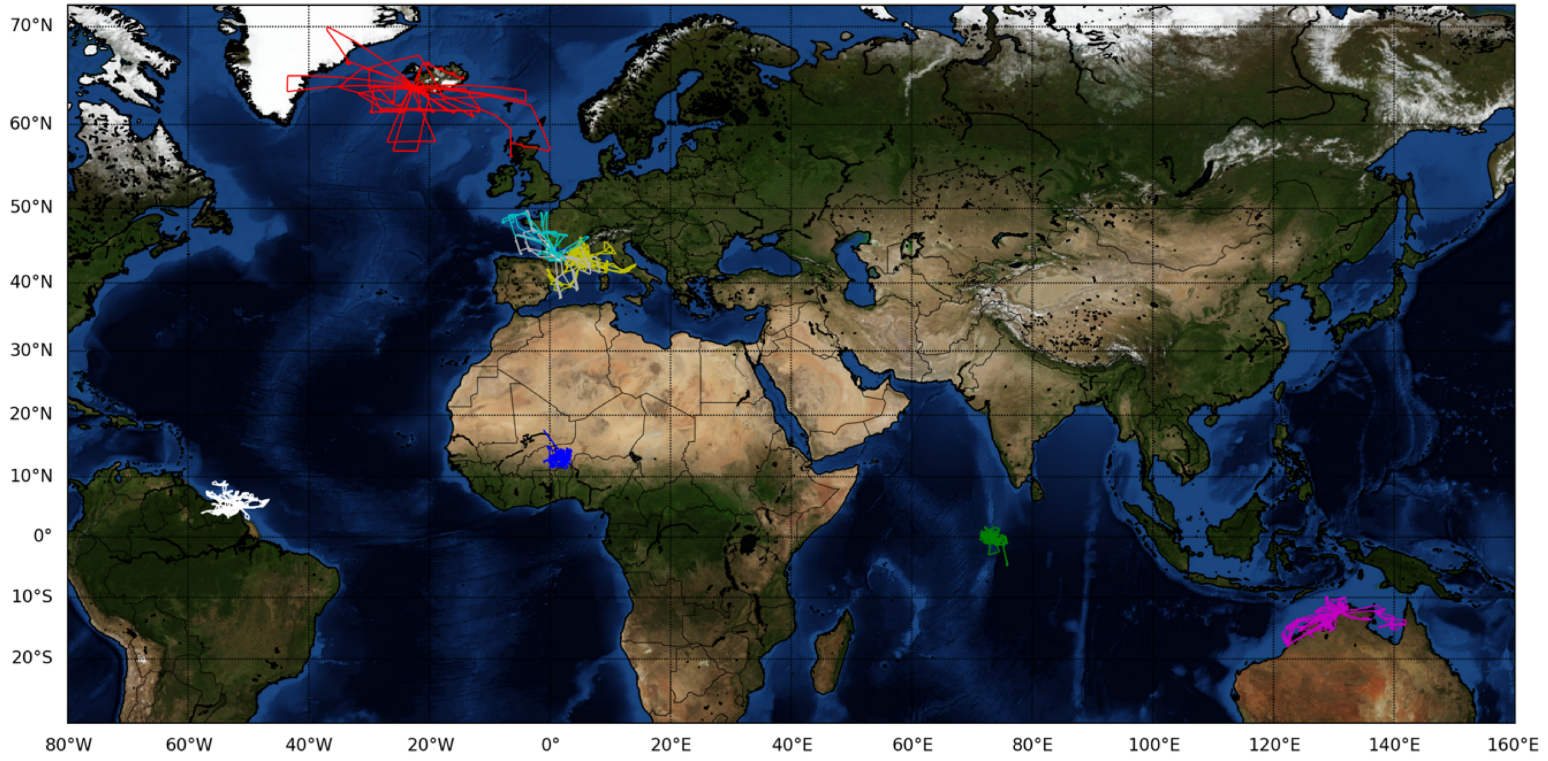
Payload:

- **LNG High spectral resolution Doppler lidar** (355 nm), 532 and 1064 nm
- **RASTA Doppler cloud Radar** (95 GHz) – up to 6 antennas
- IR radiometer CLIMAT (brightness temperature 8-10-12 micron)
- L/S fluxes
- Dropsonde launching (profiles of T, p, hum, u, v)

RALI around the world

RALI Campaigns

- 2006 : AMMA, CAL/VAL CALIPSO-CloudSat (West Africa)
- 2007 : CIRCLE II (Europe)
- 2008: POLARCAT (Polar region)
- 2010: CloudSat/CALIPSO (France)
- 2016: NAWDEX (Iceland) => G. Riviere & A. Schäfler's talks
- 2019: AEOLUS CAL/VAL (France)
- 2020: EUREC^{4}A (Barbados) => S. Bony's talk
- 2020: ASKOS-CADDIWA (Cape Verde) => P. Knippertz /C. Flamant's talk



LI only

- 2011: FENNEC (Western Sahara)
- 2013: CHARMEX (Mediterranean region)
- 2017: AEROCLO-SA (South Africa)

RA only

- 2010 and 2011: Megha-Tropique (West Africa and Maldives)
- 2012: HYMEX (Mediterranean region) => V. Ducrocq's talk
- 2014 and 2015: HAIC (Darwin and French Guiana)
- 2018: EXAEDRE (Corsica) => E. Defer's poster

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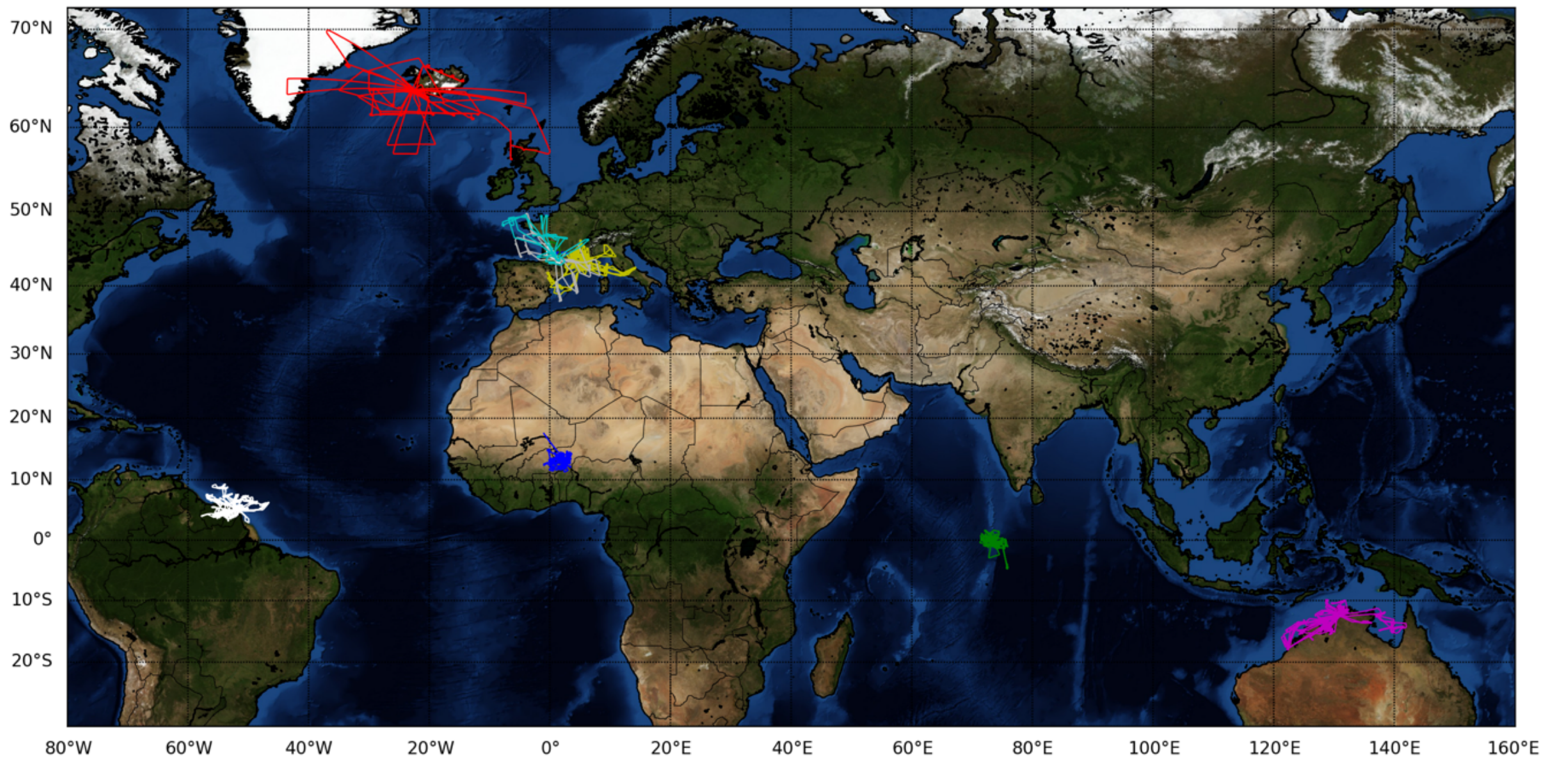

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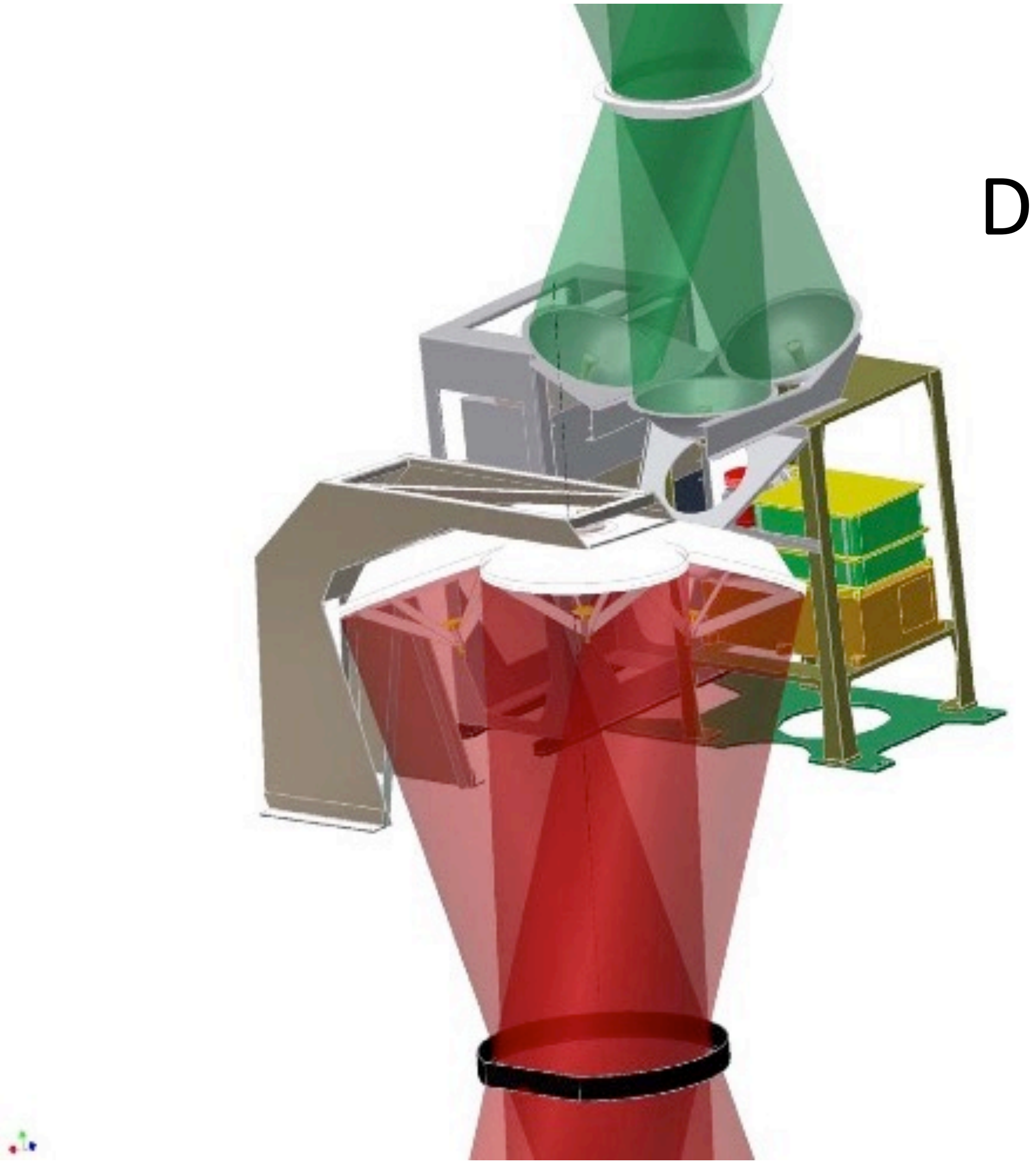
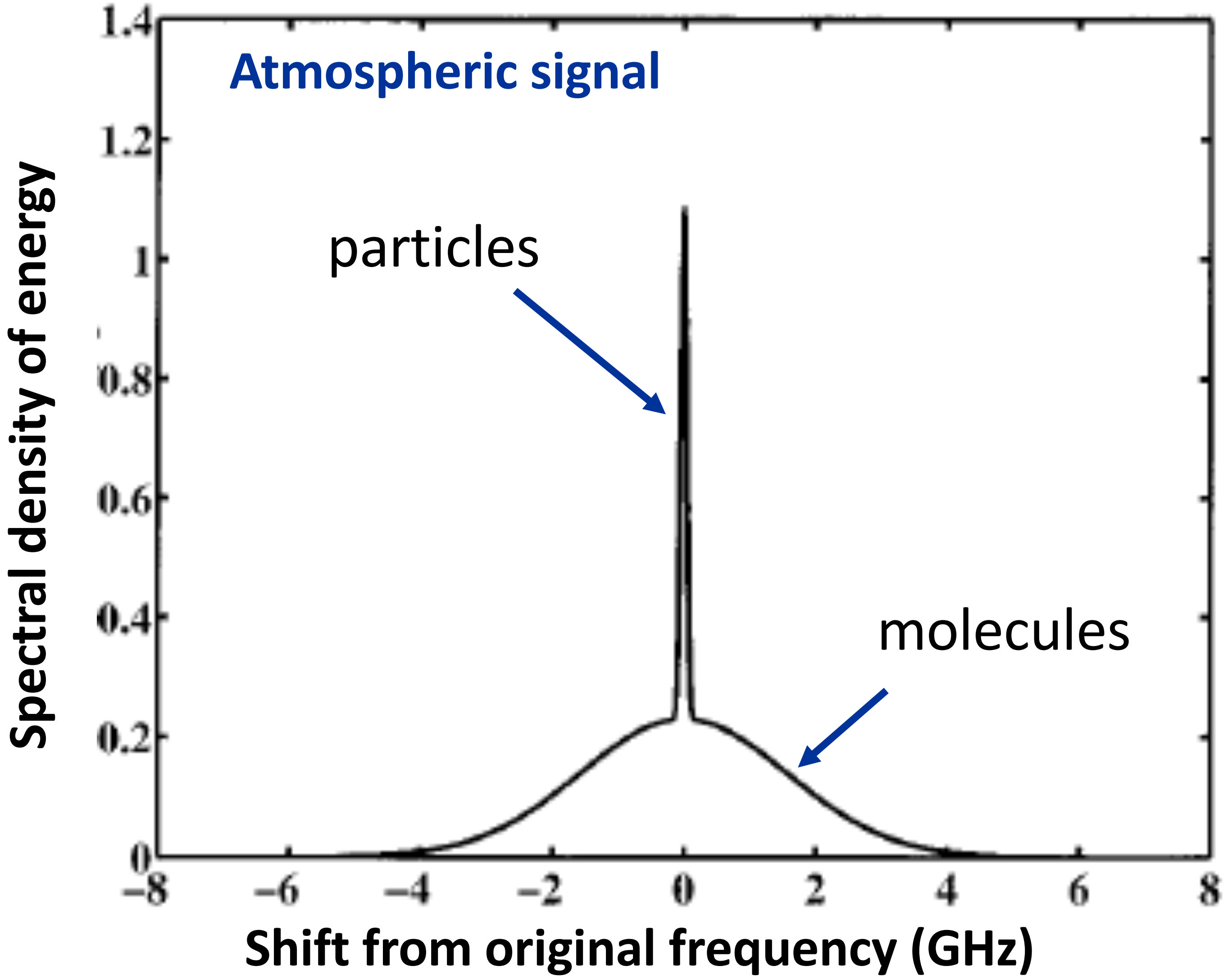
Why is RALI so special?

- RASTA 3 to 6 antennas @95GHz
- LNG High spectral resolution @ 355 nm



Doppler

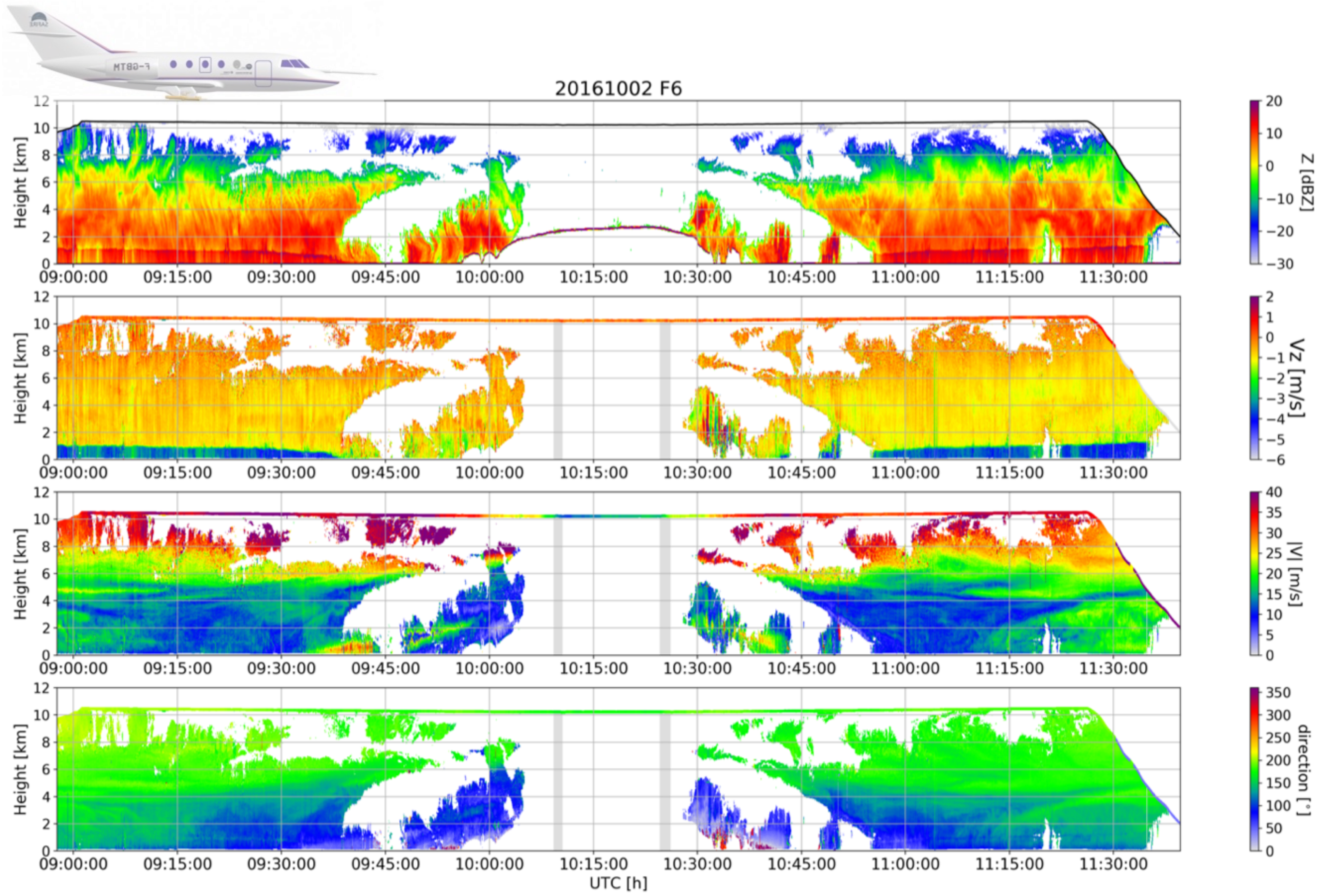
Doppler (particular)



Why is RALI so special?

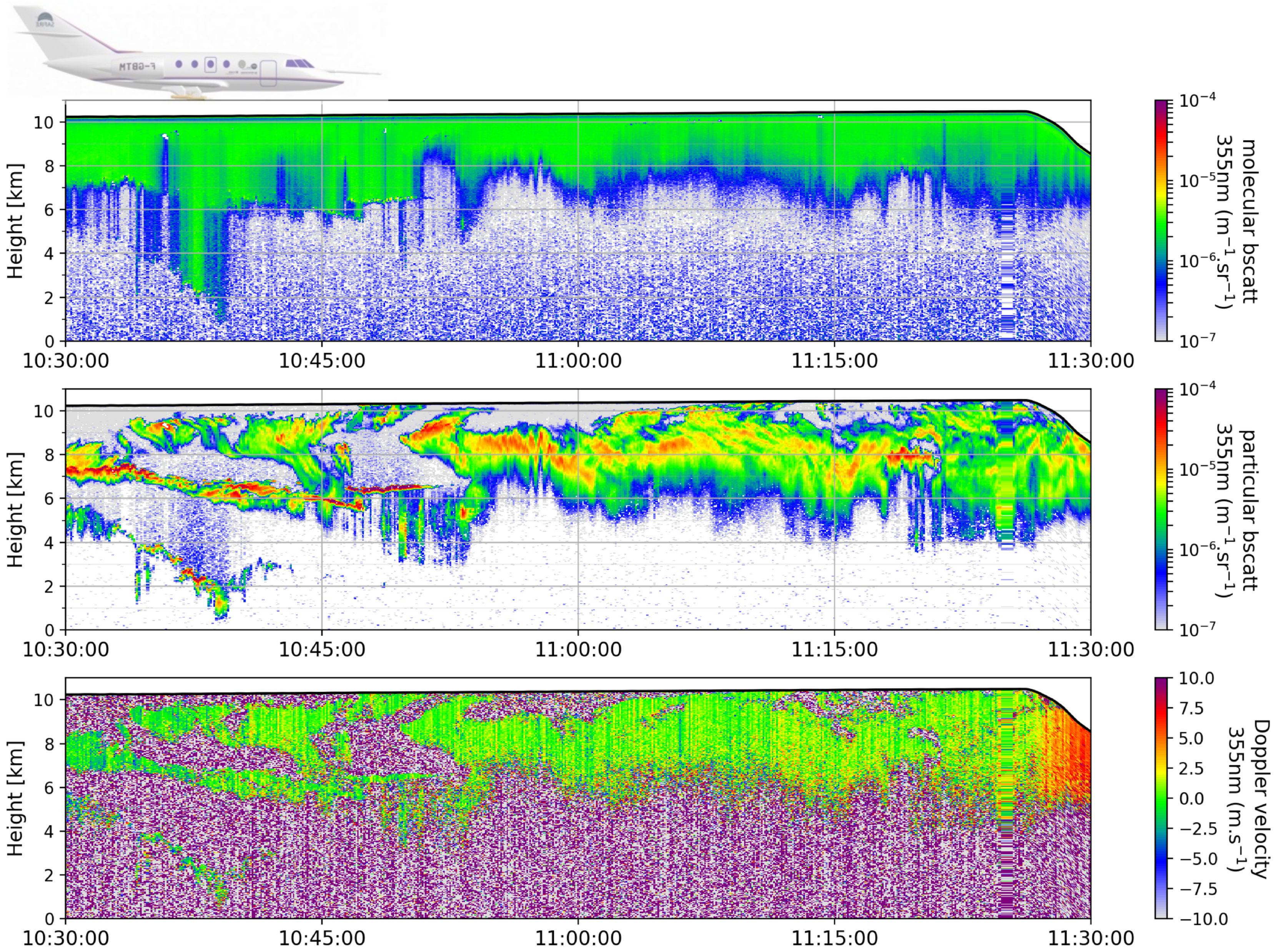
- RADAR 3 to 6 antennas @95GHz

Cloud dynamics at high resolution



- High spectral resolution @ 355 nm

Molecular and particular signal are separated



Example from NAWDEX campaign

Backscatter (+Doppler) for clouds and aerosols

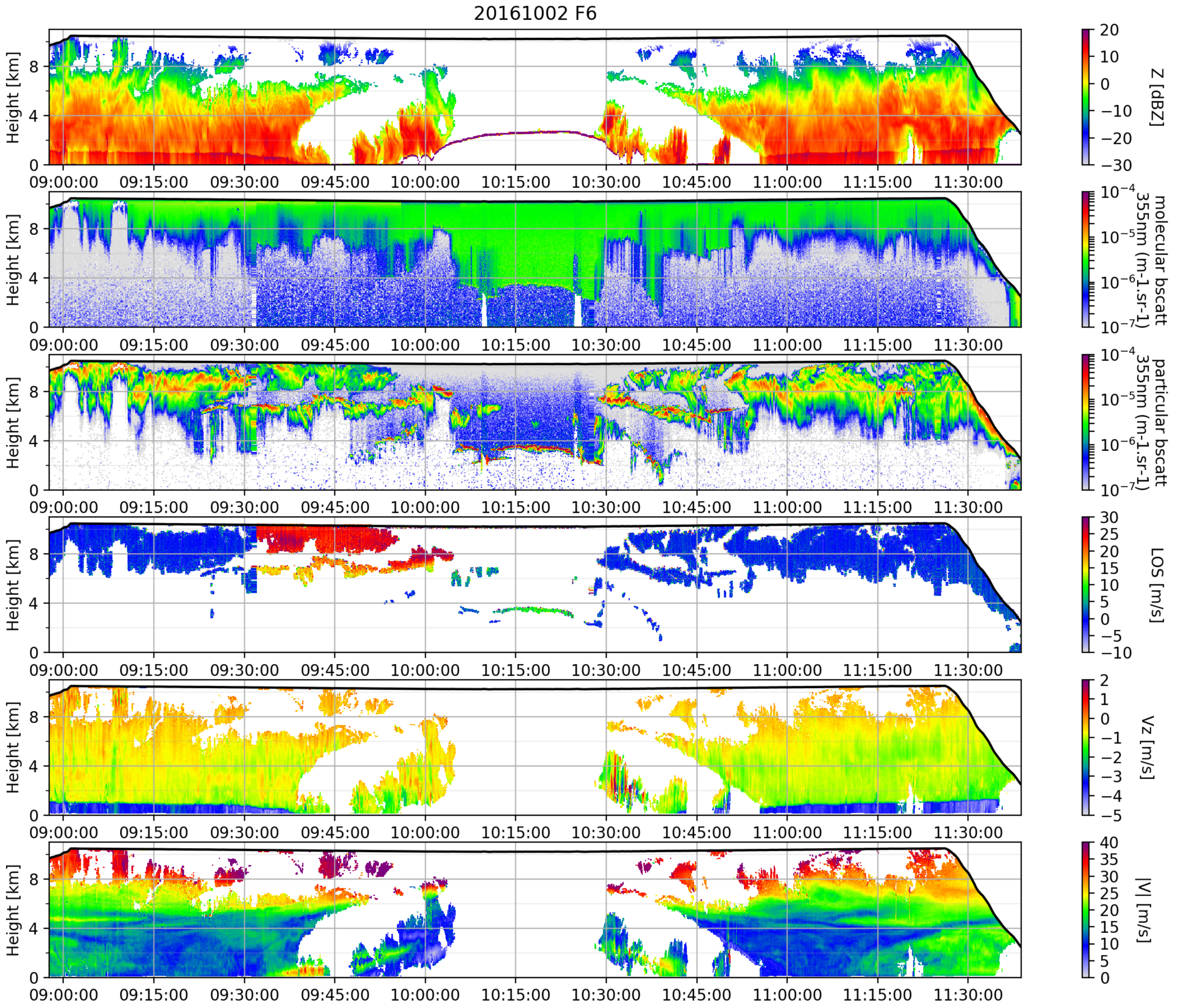
RALI and its products

Merge product

Radiative

RASTA and LNG measurements/retrievals
⇒Same grid (5s, 60m)
⇒Co-located in space and time

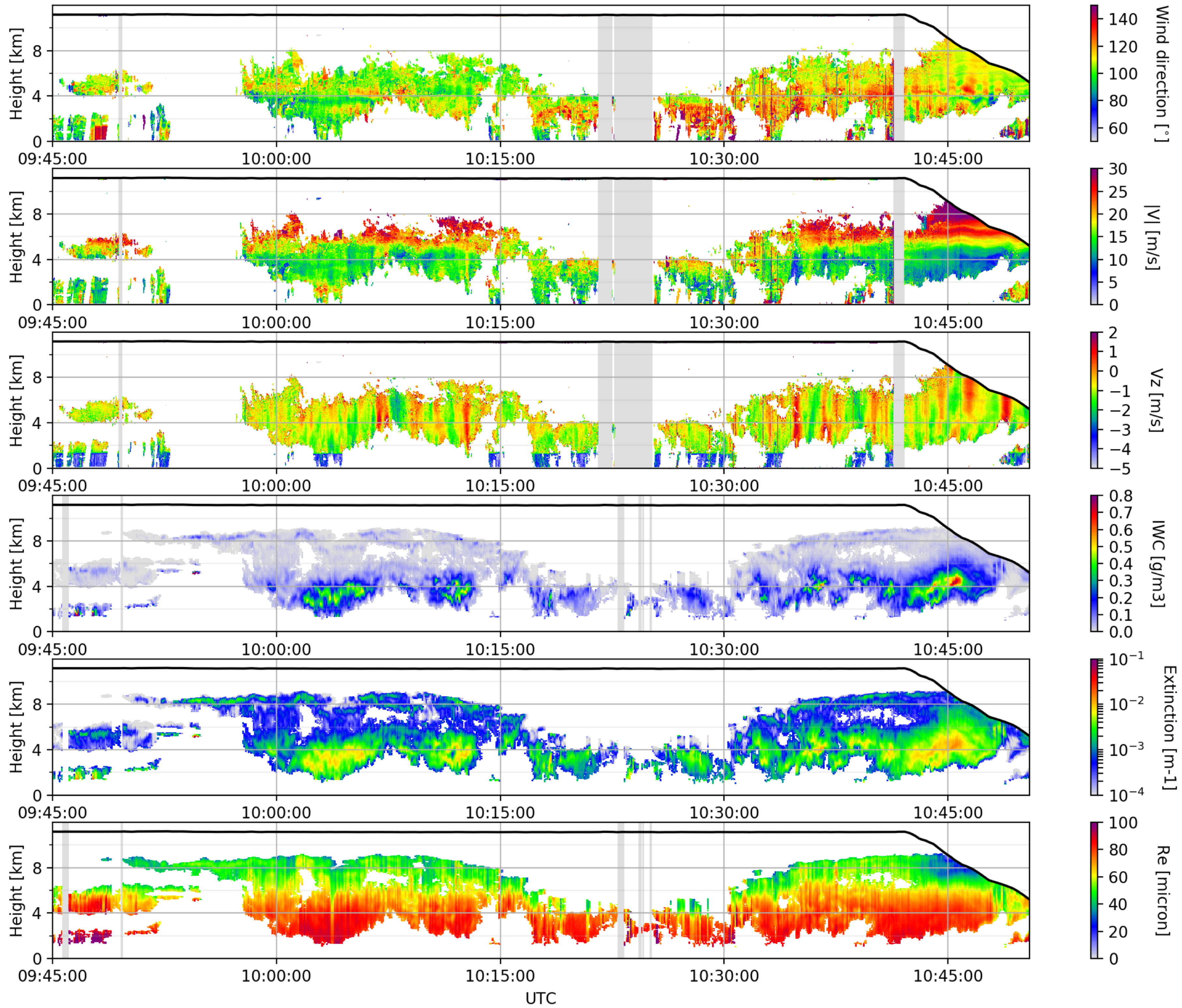
Dynamics



Example from NAWDEX campaign

RALI wind and microphysics retrievals

Example from NAWDEX campaign



Horizontal cloud wind direction

Horizontal cloud wind speed

Vertical cloud wind

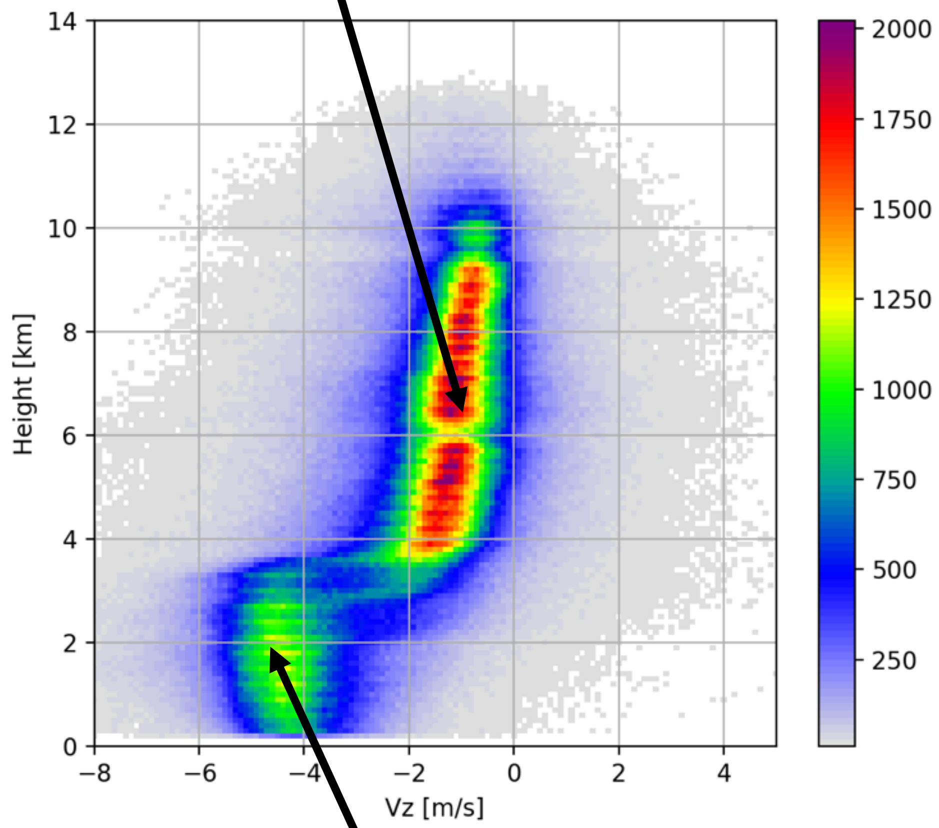
IWC from radar-lidar retrieval

Extinction from radar-lidar retrieval

Re from radar-lidar retrieval

Example from EXAEDRE campaign

Ice crystals sedimentation/aggregation

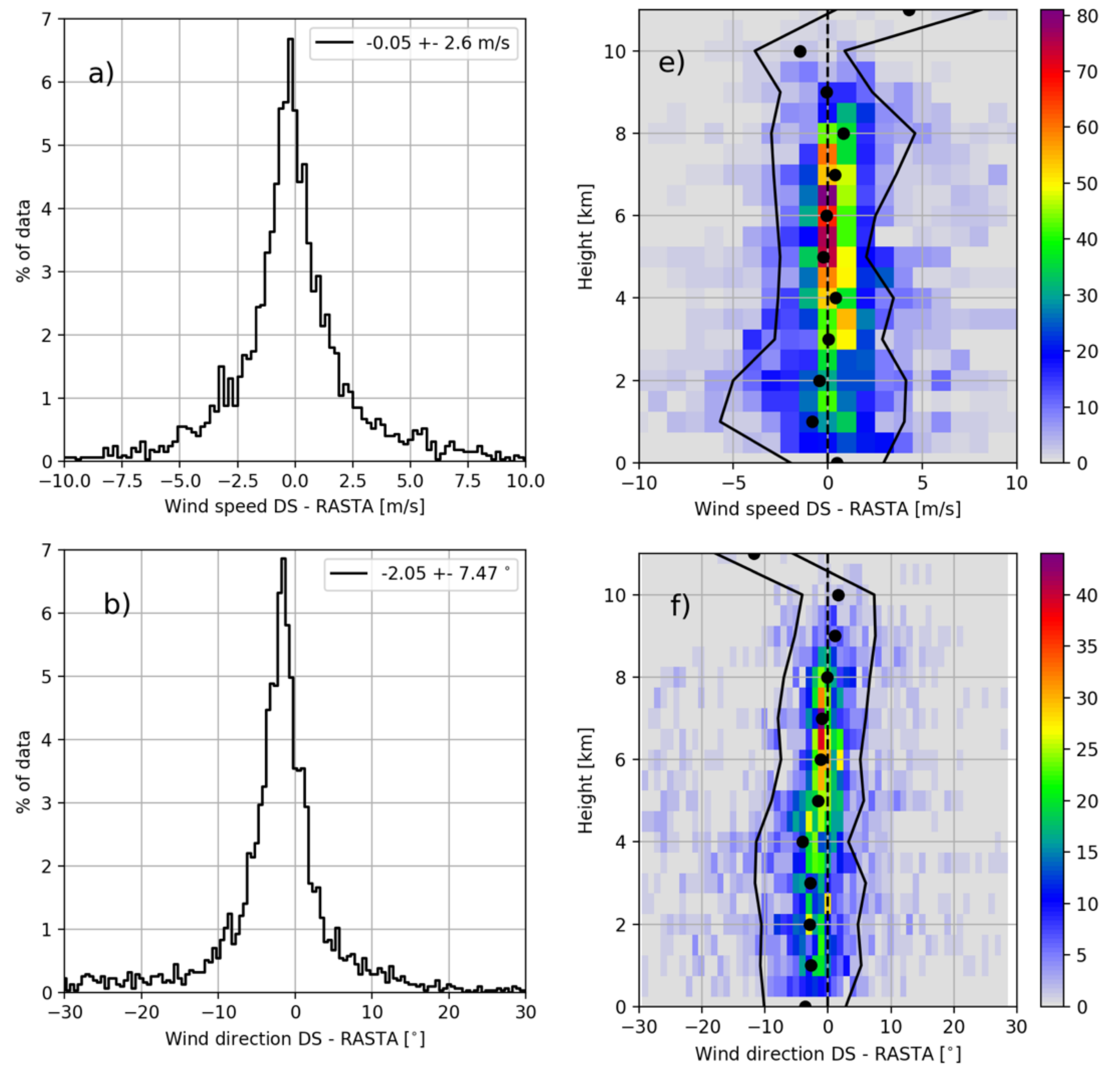


Rain

Varcloud: Delanoë and Hogan 2008
Similar to DARDAR

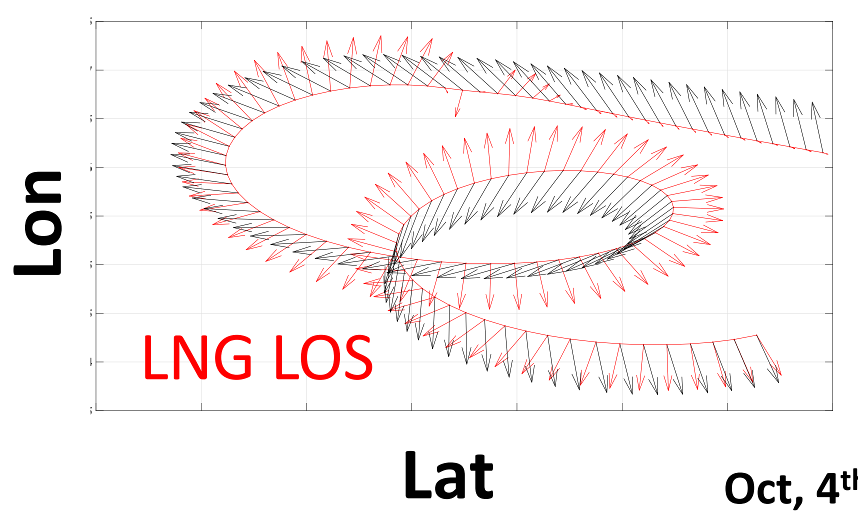
RALI WIND retrieval assessment

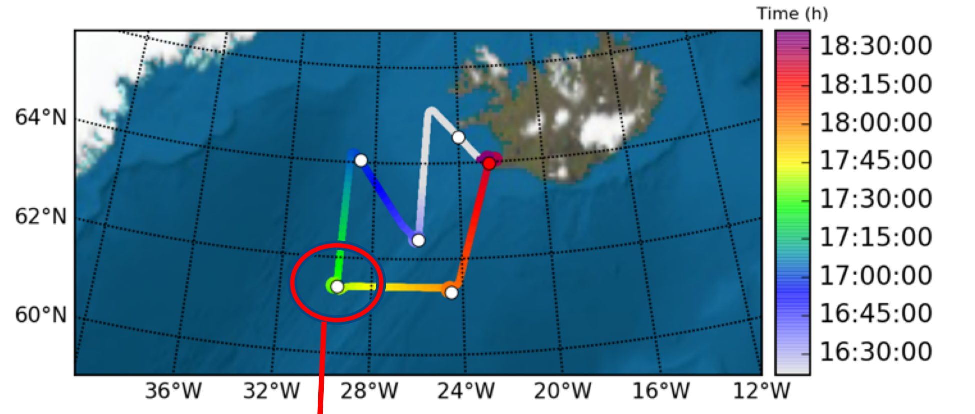
RASTA against DS (all flights)



Wind speed: 0.05 +- 2.6 m/s
Wind direction: -2.05 +- 7.47°

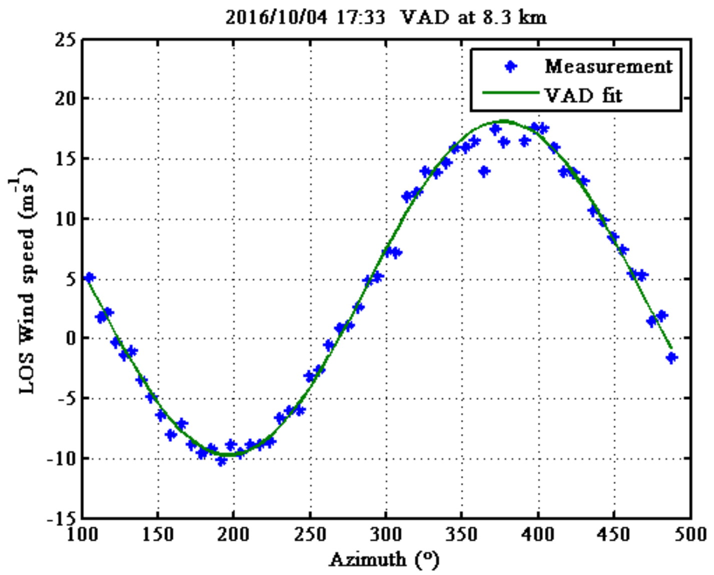
Dropsonde launch time with a 10s window for RASTA measurements

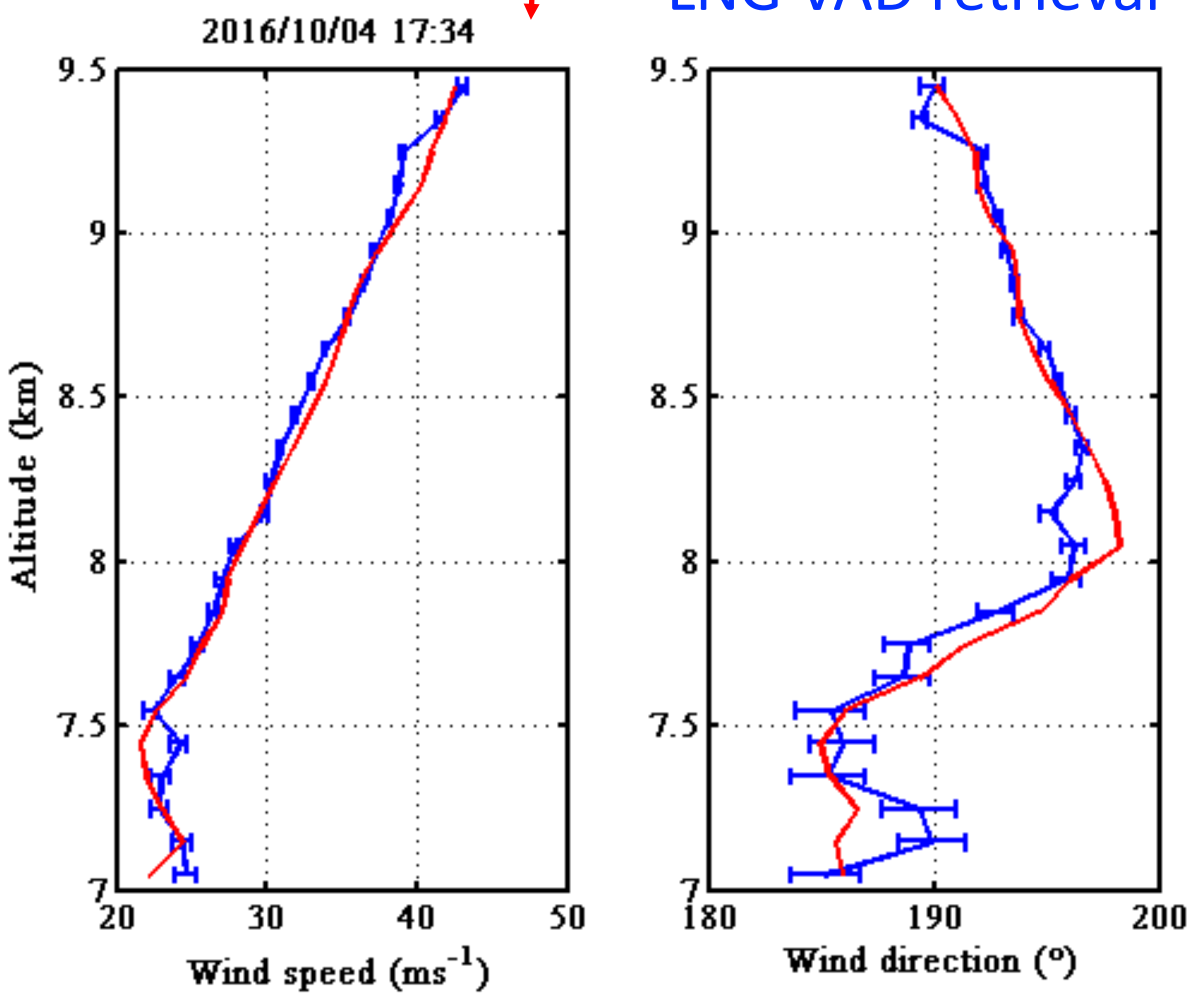




Oct, 4th 2016

Dropsonde
LNG VAD retrieval





Example from NAWDEX campaign

RALI and applications

Cloud processes and model evaluation

Satellite Cal/Val activities

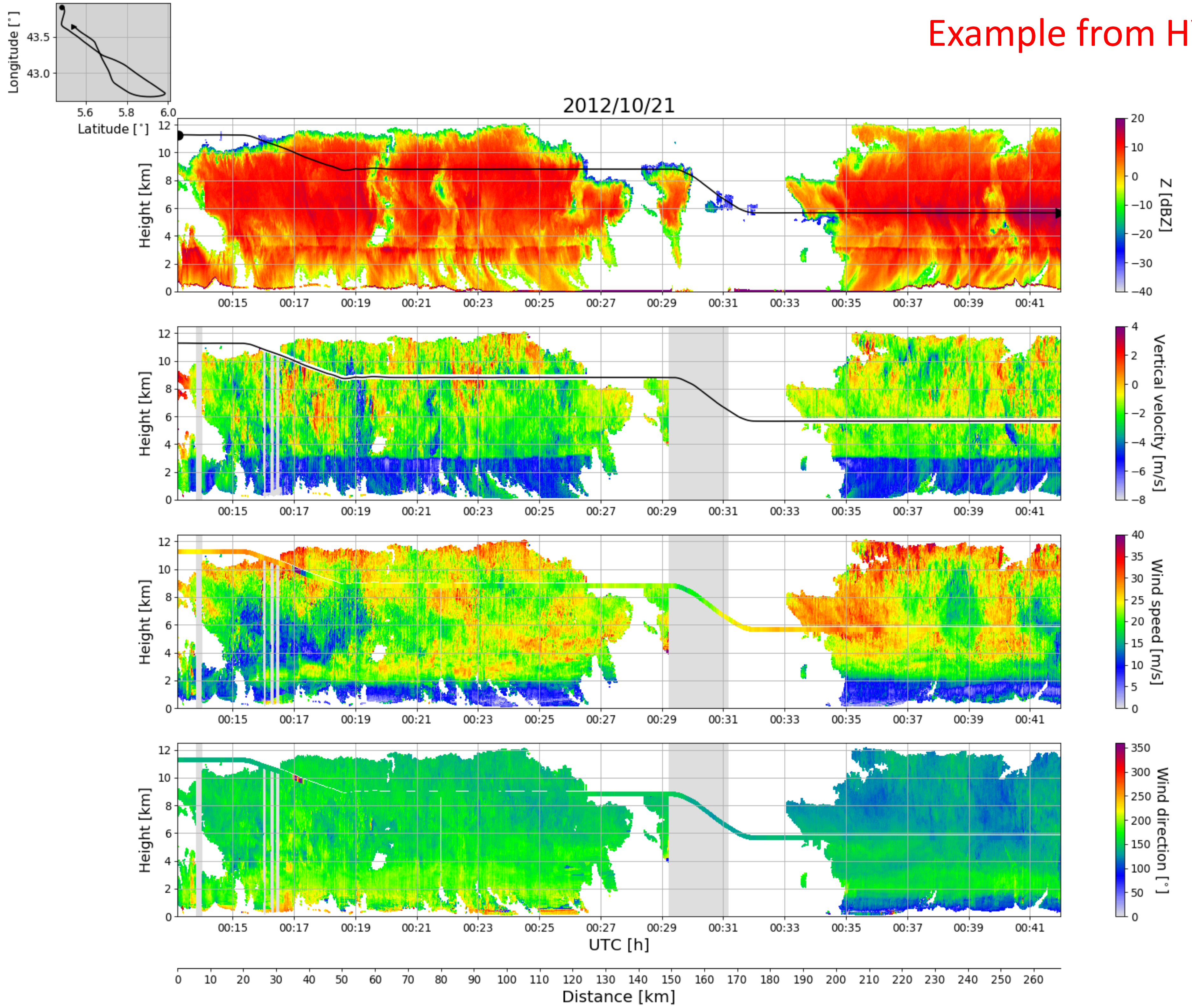
LATMOS

RALI and a few applications

- ✓Process studies or aircraft regulation (numerous field campaigns with in-situ data – HAIC… see EXAEDRE poster for lightning studies)
- ✓Cloud and climate (see S. Bony's presentation)
- ✓GCM evaluation (see G. Riviere's presentation)
- ✓Cloud schemes evaluation (Ice3 vs LIMA – Taufour and Vié CNRM, Taufour et al. 2018)
- ✓Turbulence (RASTA's Doppler spectrum => Eddy dissipation rate, D. Ricard CNRM)
- ✓Satellite Cal/Val (CloudSat-CALIPSO/ESA-EPATAN for EarthCare / AEOLUS)
- ✓DATA assimilation (HYMEX)

DATA assimilation in forecast model

Example from HYMEX campaign



RASTA reflectivity and horizontal wind have been assimilated in AROME (Météo-France) with 3DVar during HyMeX-SOP1

The different steps:

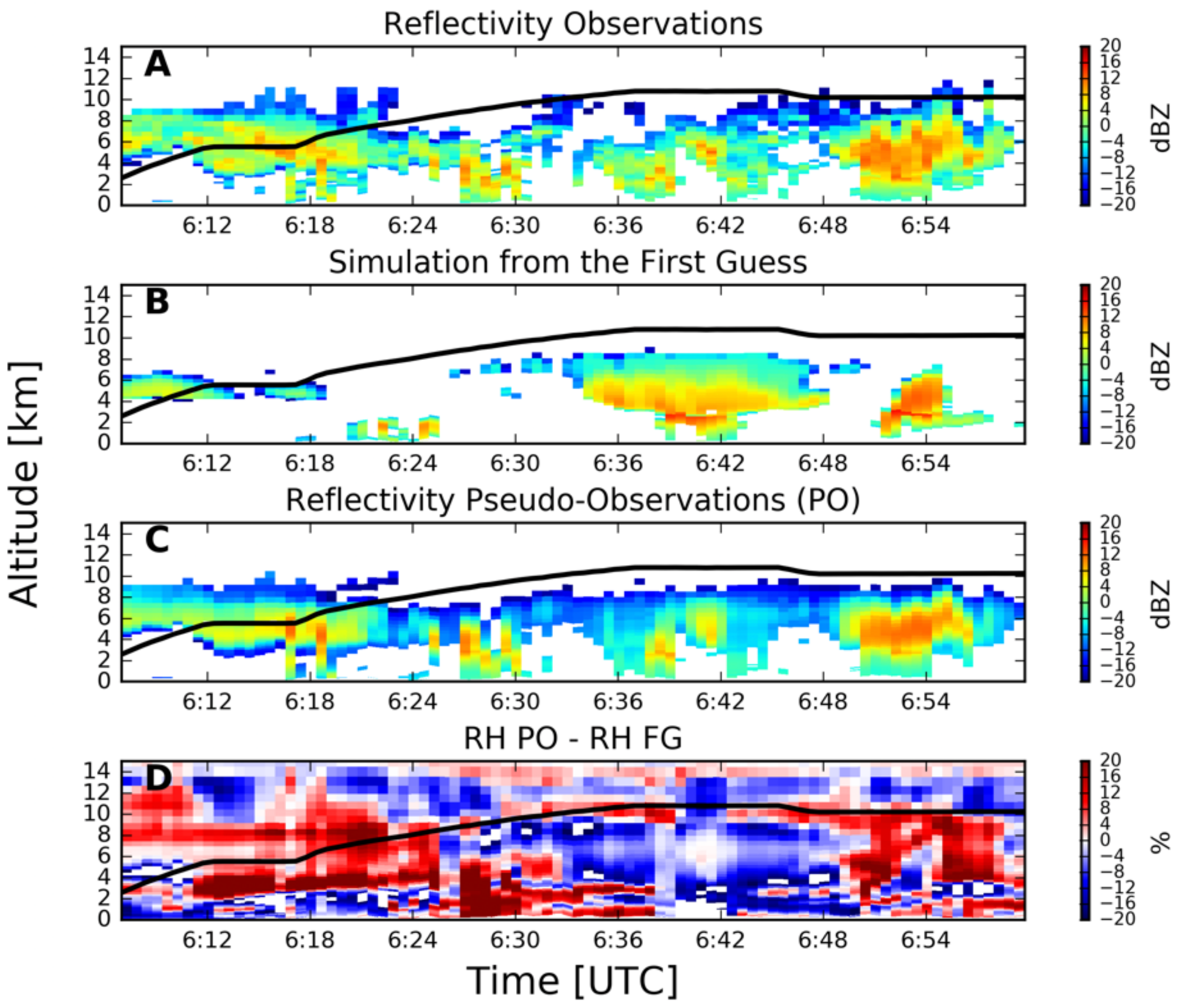
- RASTA simulator <u>Véronique's talk</u>
- Method to co-locate Observation and model <u>Véronique's talk</u>
- Assimilation
- Assessment

Mary Borderies (Borderies et al. 2018, Borderies et al. 2019a et 2019b)

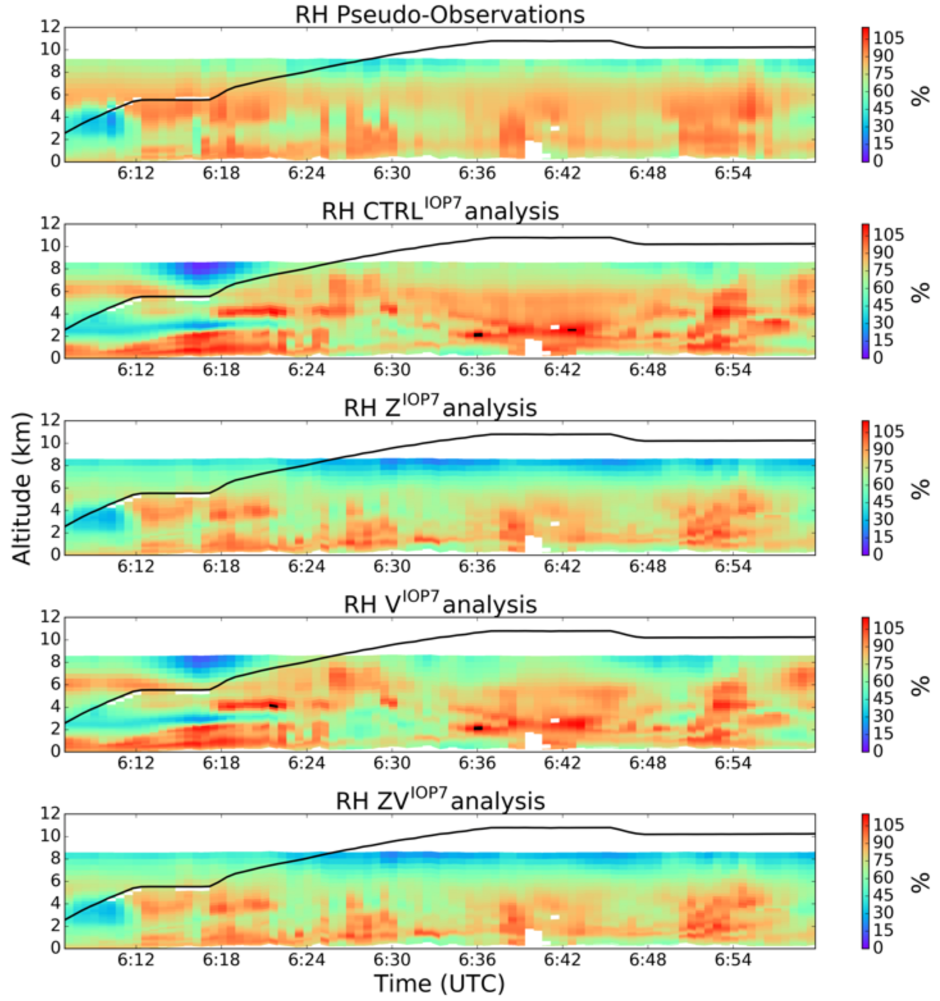
DATA assimilation in forecast model

RASTA data have been assimilated in AROME (Météo-France) with 1D+3DVar during HyMeX-SOP1

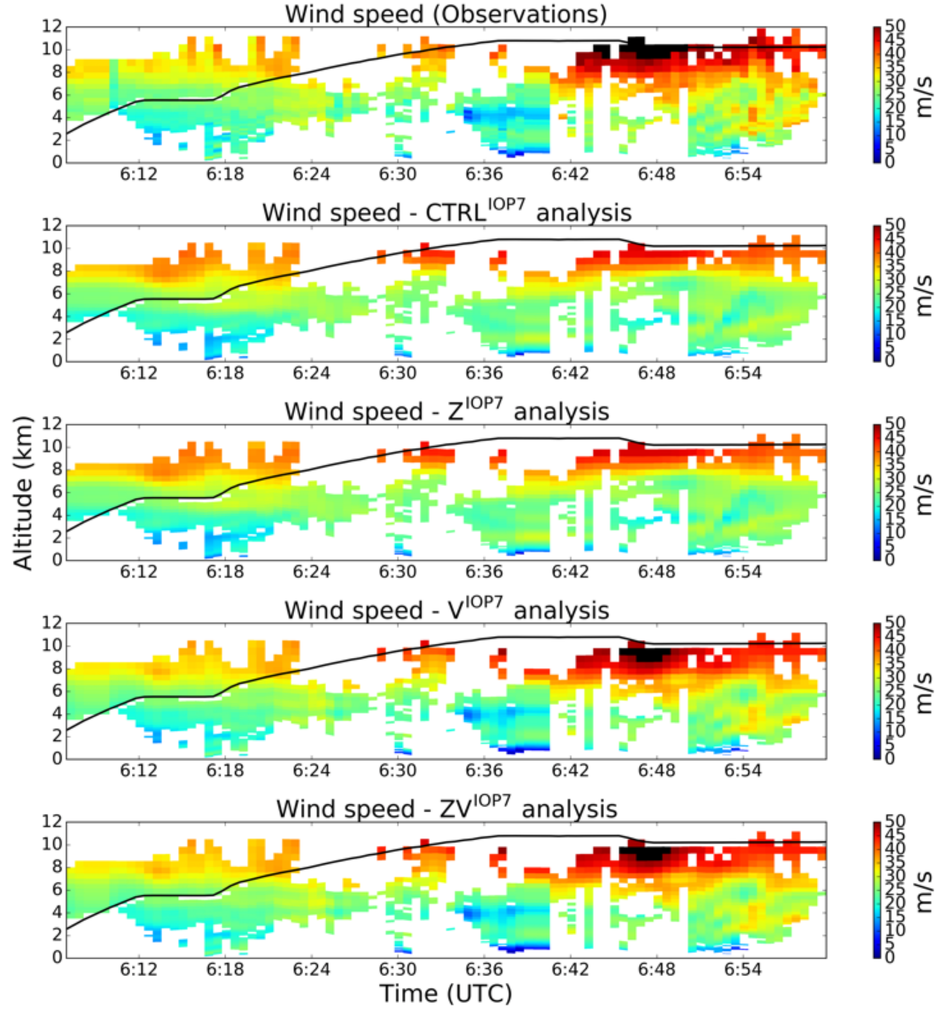
- 1D Bayesian retrieval : pseudo RH obs
- 3D VAR: Horiz wind / RH pseudo obs are assimilated



Impact on RH
Evaluated using independent in-situ measurements (aircraft)



Impact on wind speed



=> Assimilating reflectivity and wind (Z and V) slightly improved humidity forecast and precipitation

Mary Borderies CNRM (Borderies et al. 2018, Borderies et al. 2019a et 2019b)

What’s next… and collaborations

- ✓RALI will be deployed in several field campaigns

- ✓Radar RASTA and lidar LNG to be upgraded (R&D activities)

- ✓RALI has friends! Tight collaborations with the German platform HALO with complementary instruments (MIRA, WALES and SpecMacs – <u>A. Schäfler’s talk</u>)
  - ✓Collaborative radar-lidar synergistic products
  - ✓Duet for many campaigns

Thank you

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