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: 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)

\[
Z = \frac{\lambda^4}{K_W} 10^{18} \int N(D) \sigma_{bsc}(\lambda, D, \rho) dD
\]

Assuming no attenuation

\[
\sigma_{bsc}(D, \lambda, \rho)
\]

scattering coefficients (Mie,1908) or T-matrix...

Rayleigh approximation

Radar more sensitive to size
Penetrates larger OD/ less sensitive

Lidar (355nm to 1064 nm)

\[
Z = 10^{18} \int N(D) D^6 dD
\]

\[
\alpha = 2.10^3 \int N(D) A(D) dD
\]

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

11/06/2019
LATMOS 2019
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

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)

Instruments developed by LATMOS/DT-INSU

http://rali.projet.latmos.ipsl.fr
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: EUREC4A (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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Why is RALI so special?

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

Doppler

Doppler (particular)

Atmospheric signal

particles

molecules

Spectral density of energy

Shift from original frequency (GHz)
Why is RALI so special?

• RADAR 3 to 6 antennas @95GHz
• High spectral resolution @ 355 nm

Cloud dynamics at high resolution

Molecular and particular signal are separated

Backscatter (+Doppler) for clouds and aerosols

Example from NAWDEX campaign
RALI and its products
Merge product

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

Radiative

Dynamics

Example from NAWDEX campaign
RALI wind and microphysics retrievals

Example from NAWDEX campaign

11/06/2019

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

Ice crystals sedimentation/aggregation

Example from EXAEDRE campaign

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

Example from NAWDEX campaign
RALI and applications

Cloud processes and model evaluation
Satellite Cal/Val activities
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

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

The different steps:
• RASTA simulator Véronique’s talk
• Method to co-locate Observation and model Véronique’s talk
• Assimilation
• Assessment

Mary Borderies (Borderies et al. 2018, Borderies et al. 2019a et 2019b)
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 – A. Schäfler’s talk)
  ✓ Collaborative radar-lidar synergistic products
  ✓ Duet for many campaigns
Thank you