How well does LMDZ6 represent the physical processes of the Stalactite Cyclone (NAWDEX IOP6) ?

2 Oct 2016, 13 UTC

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1. LMD-ENS
2. LMD-Sorbonne Université
3. Météo France
4. LATMOS
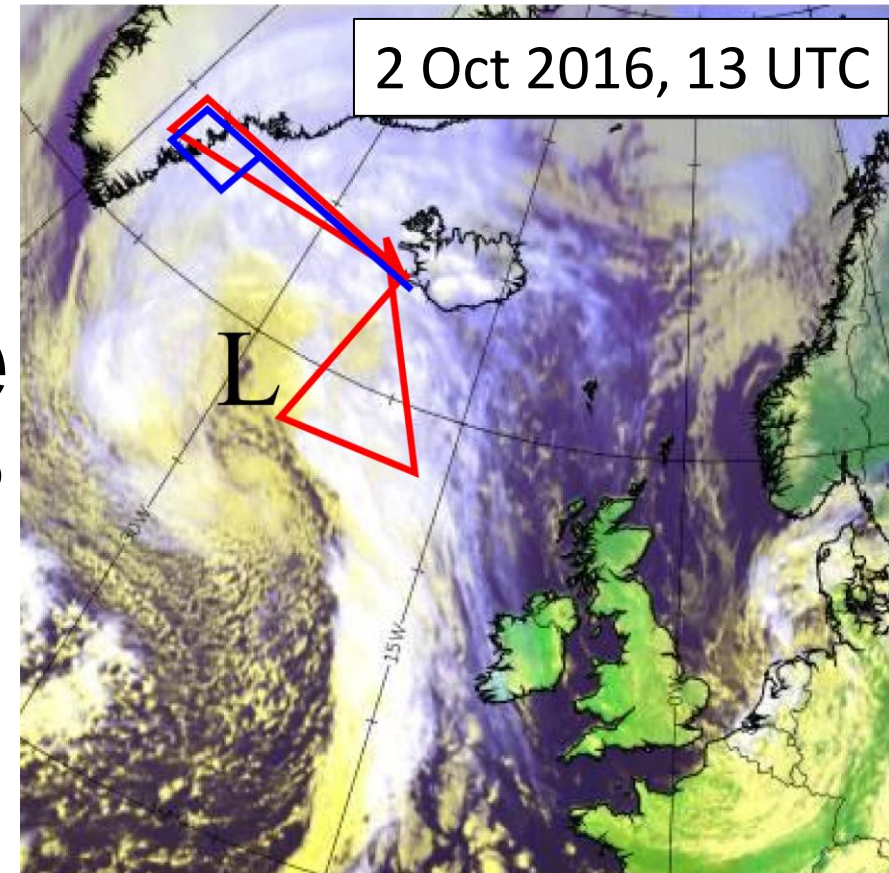
# Running a climate model in a weather forecast mode (T-AMIP exp): comparison between LMDZ6 et Arpege-Climat

	ARPEGE-Climat (run by R. Roehrig)	LMDZ6 (run by I. Musat)
CMIP 6	T127 (~1.1°)	2.5° x 1.7°
HRES	T359 (~0.5°)	zoom to 0.5° over N Atlantic; rest of domain 1.1°
Physics	CMIP 6	CMIP 6
Hindcast initiation dates	27, 28, **29 Sep** and 1, **2 Oct** 2016 at 00 UTC	27, 28, **29 Sep** and 1, **2 Oct** 2016 at 00 UTC
Initial Conditions	ECMWF analysis	ECMWF analysis
Hindcast length	10 days	10 days
Vertical output	Pressure levels every 25 hPa	Pressure levels every 25 hPa
Temporal output	3 h	3 h
Data considered after	T + 18 h	T + 18 h

SLP minimum and tracks
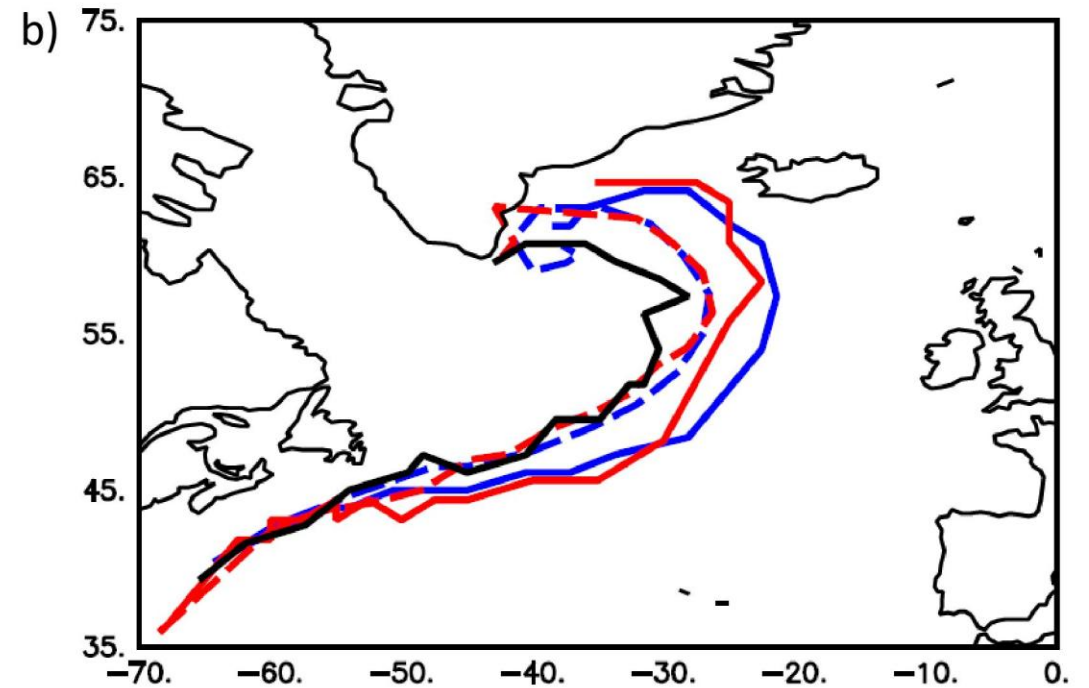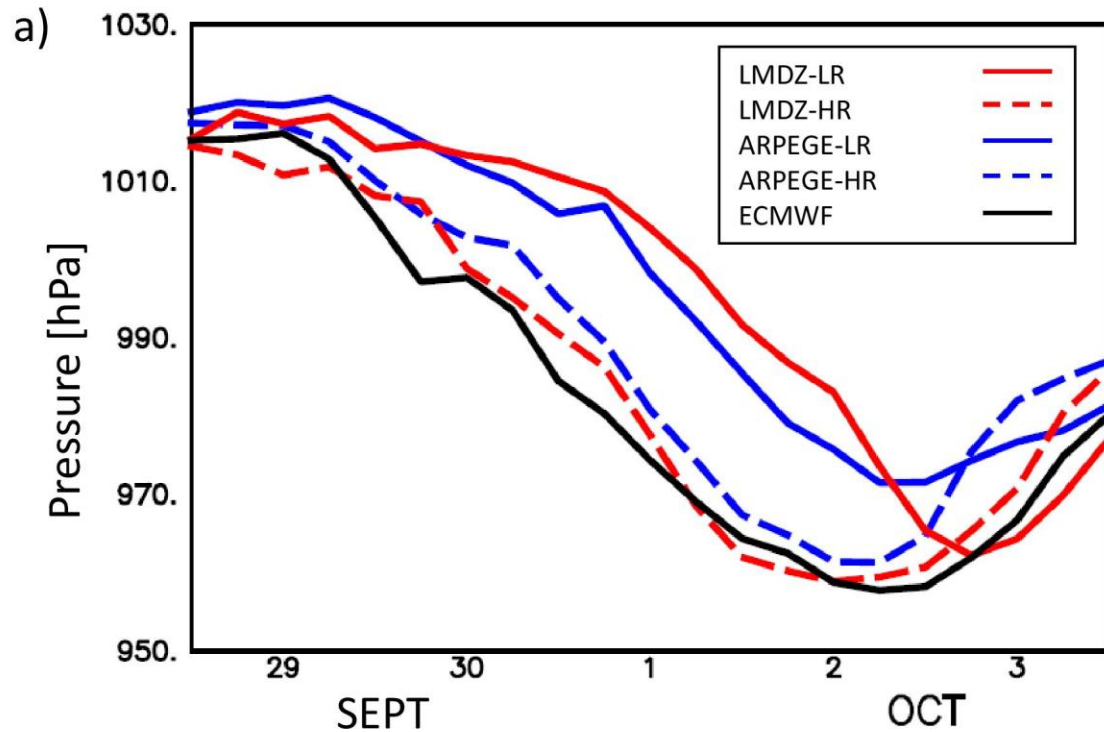
- In LRES, delayed deepening and track too much eastward
- HRES: rather good scenario in track and intensity compared to ECMWF analysis
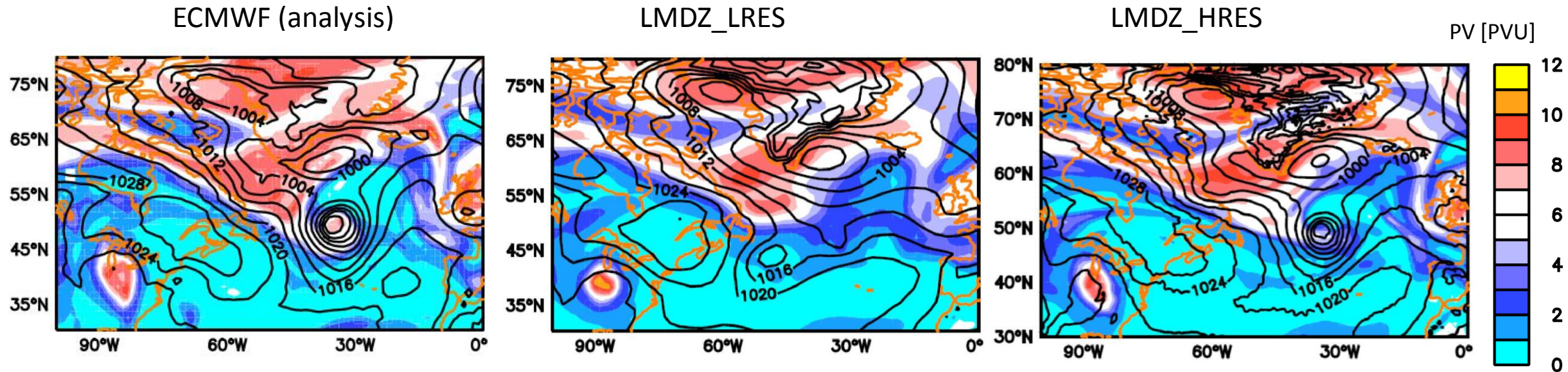
Cyclogenesis stage
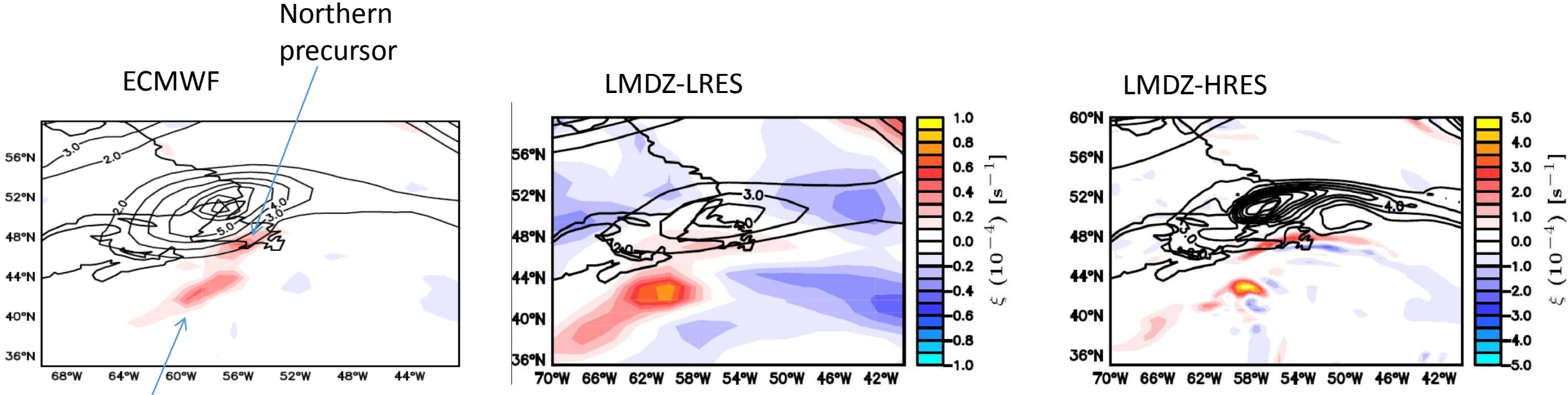
Relative vorticity at 850 hPa (shadings); PV>2PVU at 300 hPa (contours)

Weak surface Northern precursor in LRES – stronger in HRES as in ECMWF analysis

Mature Stage of the Cyclone

12 UTC 1 Oct 2016

ECMWF (analysis)   LMDZ_LRES   LMDZ_HRES   PV [PVU]

Potential vorticity at 850 hPa (shadings); SLP (contours)

Delayed interaction of the surface cyclone with high stratospheric PV air in LRES.
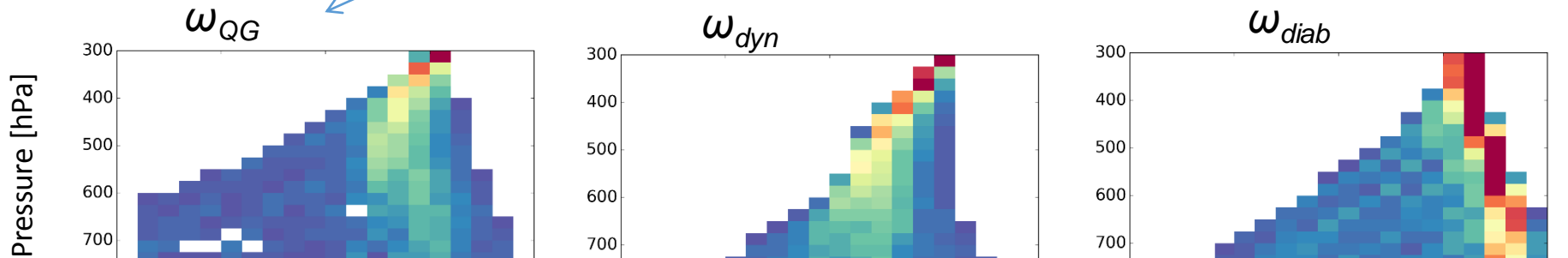
Vertical velocity statistics across the cyclone

Quasi-geostrophic omega equation

$$\left(\sigma \nabla_p^2 + f_0^2 \frac{\partial^2}{\partial p^2} \right) \omega_{QG} = -2\left(\nabla \cdot \mathbf{Q} \right) - \frac{R}{p} \nabla^2 \mathbf{J} \qquad \mathbf{Q} = -\frac{R}{p} \begin{pmatrix} \frac{\partial \mathbf{u}_g}{\partial x} \cdot \nabla_p T \\ \frac{\partial \mathbf{u}_g}{\partial y} \cdot \nabla_p T \end{pmatrix}$$
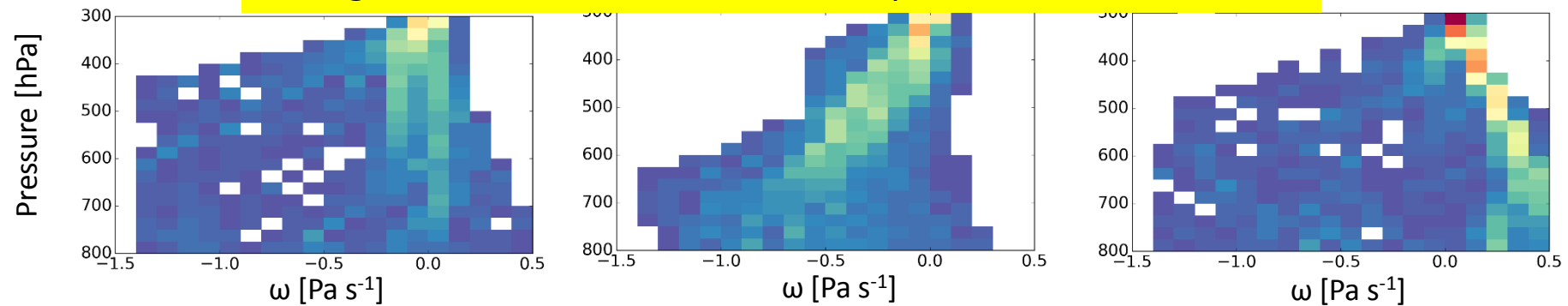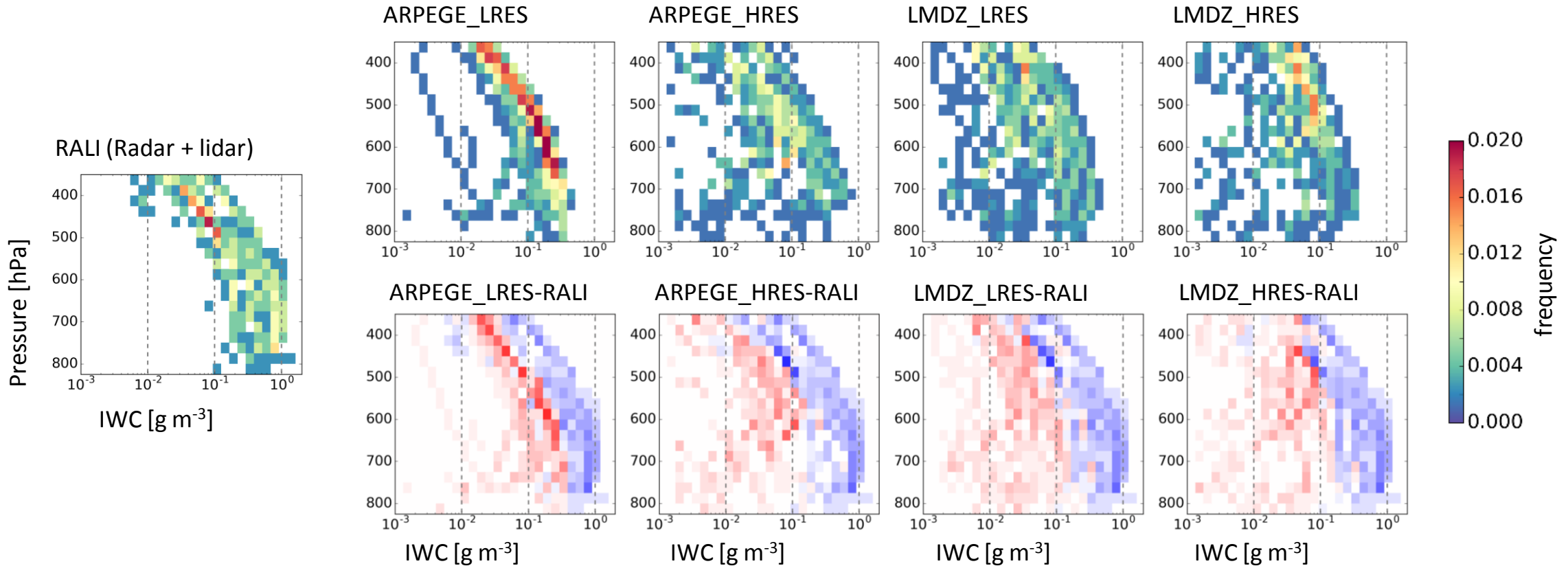
Total heating

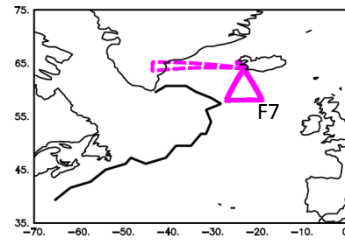ω_{QG} ω_{dyn} ω_{diab}

ARPEGE (HRES)

Stronger diabatic heating aloft in LMDZ compared to ARPEGE
Stronger vertical motion in LMDZ compared to ARPEGE

LMDZ (HRES)

Pressure [hPa] — ω [Pa s^{-1}]

Observations: Ice Water Content: F7

Ice Water Content retrieved from radar/lidar using the variational algorithm
of Delanoë and Hogan (2008) with adaptations from Cazenave (2019).

- Large underestimation of IWC whatever the resolution / model
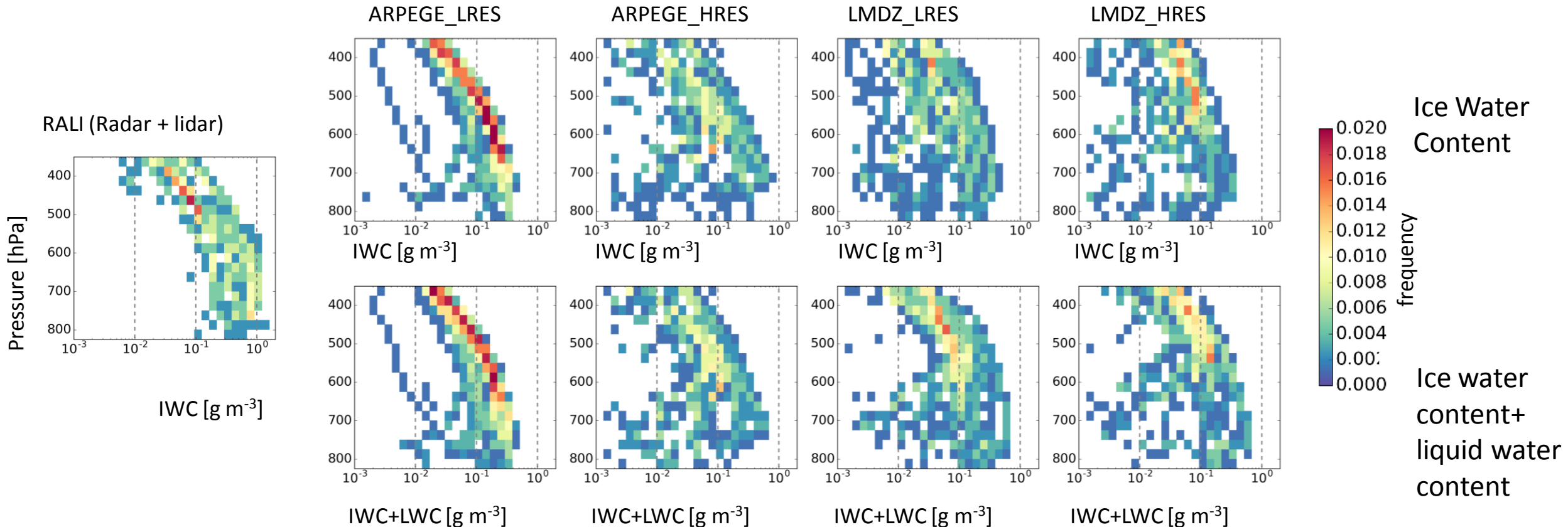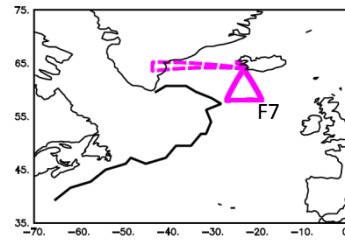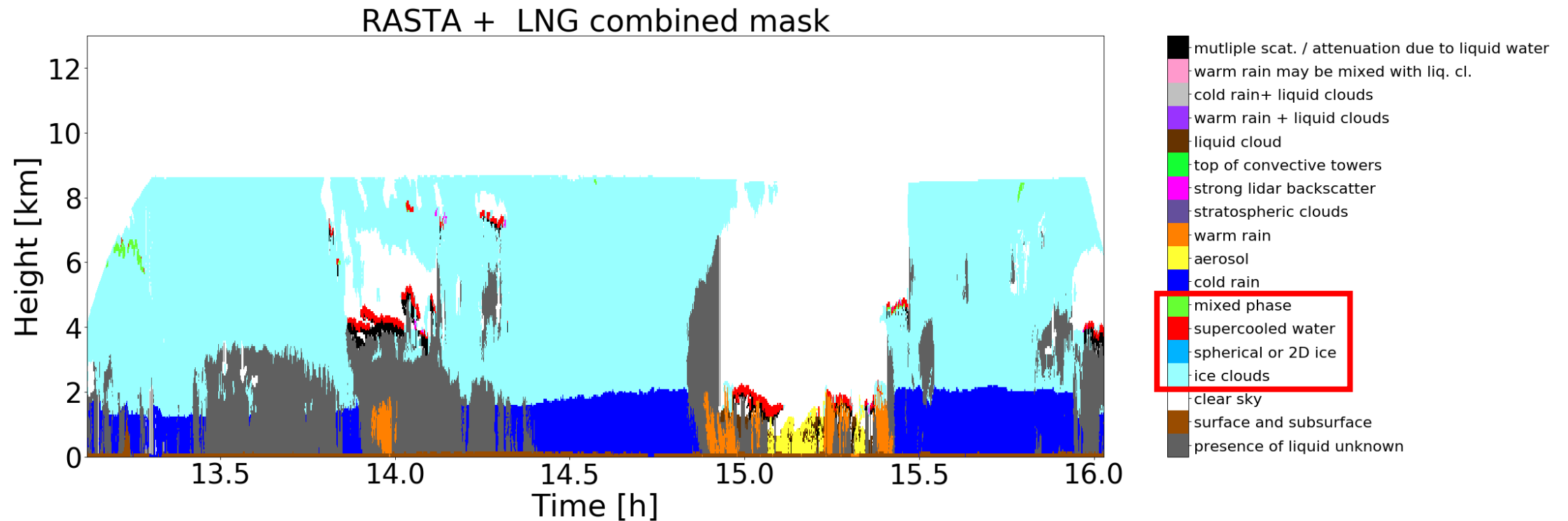
Observations: Ice Water Content: F7

Ice Water Content retrieved from radar/lidar using the variational algorithm
of Delanoë and Hogan (2008) with adaptations from Cazenave (2019).

• Improvement of the shape and intensity of the PDF in LMD6 by adding the liquid water content, while there is almost no change for Arpege-CM6

With combined radar-lidar data we can determine if the particles are ice, super-cooled liquid and mixed phase

RASTA + LNG combined mask

Legend:
- mutliple scat. / attenuation due to liquid water
- warm rain may be mixed with liq. cl.
- cold rain+ liquid clouds
- warm rain + liquid clouds
- liquid cloud
- top of convective towers
- strong lidar backscatter
- stratospheric clouds
- warm rain
- aerosol
- cold rain
- mixed phase
- supercooled water
- spherical or 2D ice
- ice clouds
- clear sky
- surface and subsurface
- presence of liquid unknown

Ice Water fraction compared to Liquid Water fraction

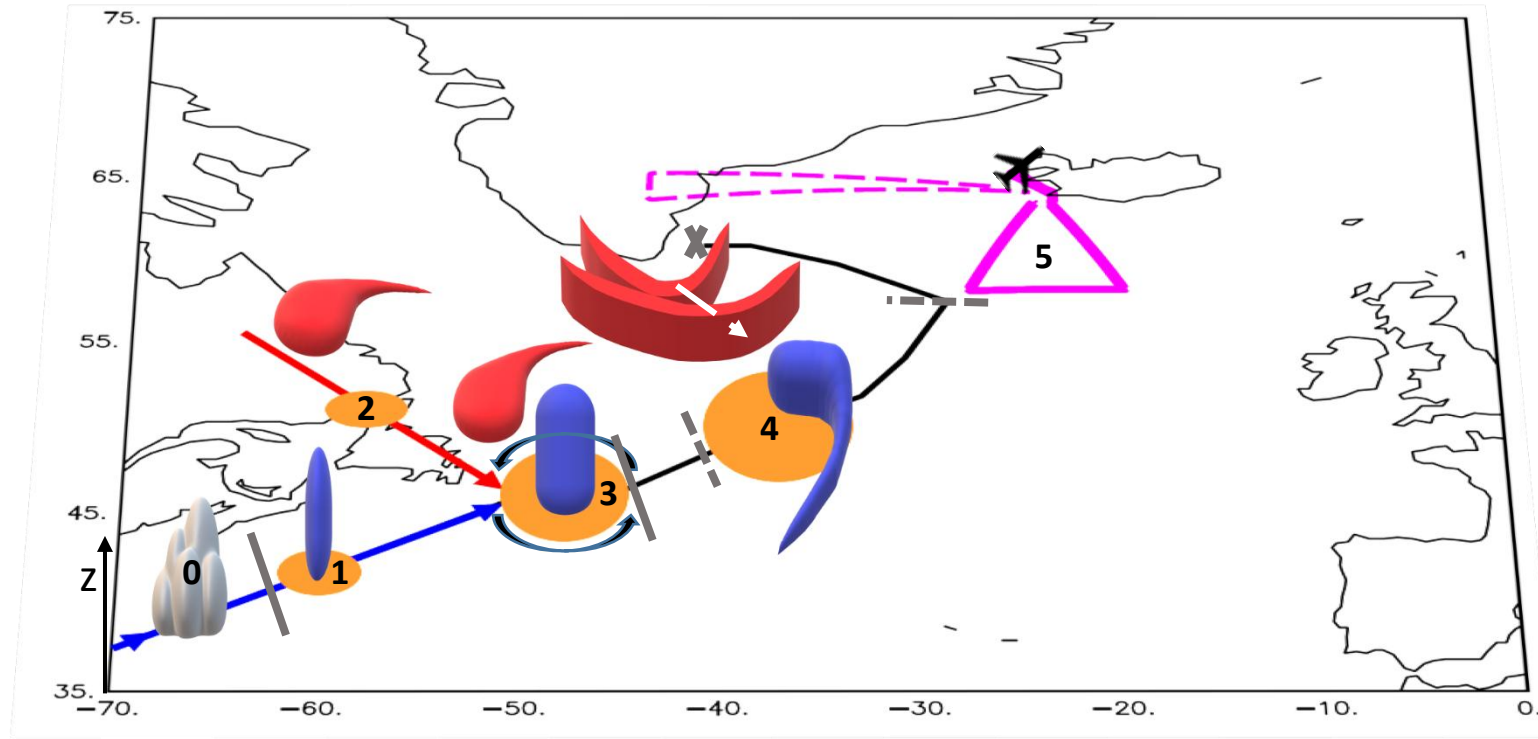|	Observations	LMDZ-LR	LMDZ-HR	ARPEGE-LR	ARPEGE-HR
Super-cooled liquid [LWC > 0.99(TOTAL)]	1.5 %	1.2 %	0.5 %	0.0 %	0.0 %
Mixed phase [0.01(TOTAL) < LWC < 0.99(TOTAL)]	0.2 %	72.8 %	79.7 %	41.4 %	61.6 %
Ice [LWC < 0.01(TOTAL)]	98.3 %	26.0 %	19.8 %	58.6 %	38.4 %

Where TOTAL = ICE + SNOW + LIQUID

There is less water in ARPEGE compared to LMDZ, and too much water in LMDZ compared to the observations, regardless of threshold used to identify ice.
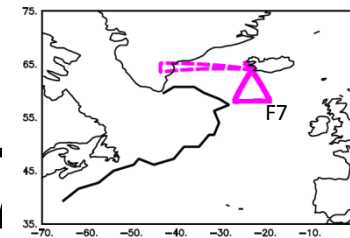
Summary

- How well do LMDZ6 and Arpege-CM6 represent the two stages of the Stalactite Cyclone?
  - 0.5° (HRES) can represent the dynamics well
  - CMIP6 resolution can do the mature stage but not cyclogenesis
- What is the main difference between LMDZ6 and Arpege-CM6 in the representation of the Stalactite Cyclone?
  - LMDZ6 creates a deeper cyclone, because of a stronger heating rate.
- What information did we gain from the observations?
  - The sum of ice water content and liquid water content is higher in LMDZ6 than Arpege-CM6 and in that sense closer to observations in terms of the amount of condensates.
  - However, LMDZ6 strongly overestimates the fraction of supercooled liquid water compared to observations

Supplementary Slides
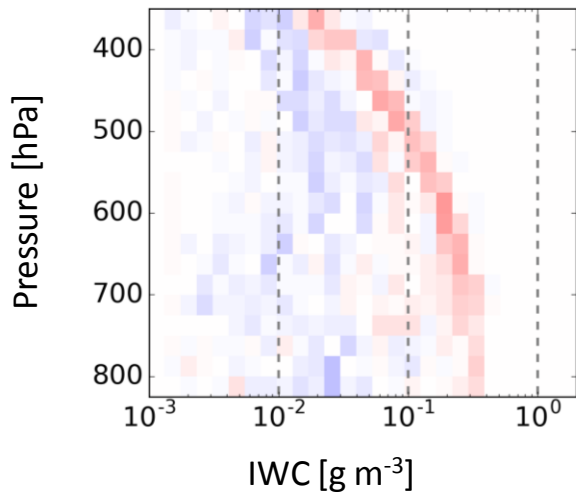
The Stalactite Cyclone

Legend:
- Mesoscale Convective System
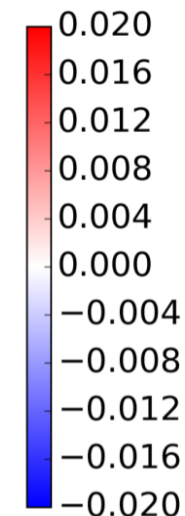- Upper-level dynamical forcing
- ECMWF (analysis) track
- Location limits of cyclogenesis phase
- X Location of cyclolysis
- Vortex Roll-up
- Diabatic heating
- Low-level relative vorticity maximum
- Flight tracks
- Location limits of explosive deepening phase
- Base of SAFIRE Falcon

IWC differences: ARPEGE - LMDZ: F7
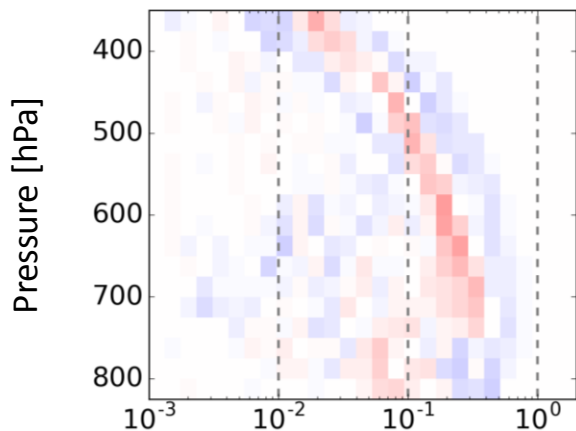
More ice LMDZ is associated with stronger diabatism at all resolutions

Radar CFADs: F7

Observations | ARPEGE (CMIP 6) | ARPEGE (HRES) | LMDZ (CMIP 6) | LMDZ (HRES)
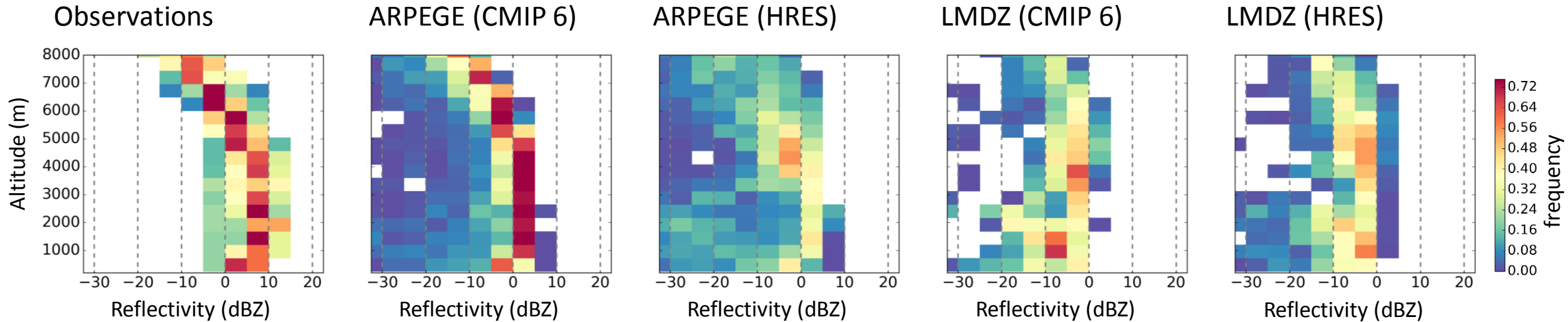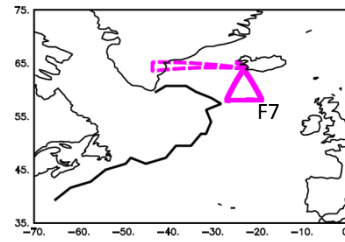
ARPEGE has better representation of reflectivity as it is more sensitive to the larger ice particles compared to the smaller liquid particles which are more numerous in LMDZ