Atmospheric rivers causing high accumulation storms in East Antarctica: regional climate model evaluation

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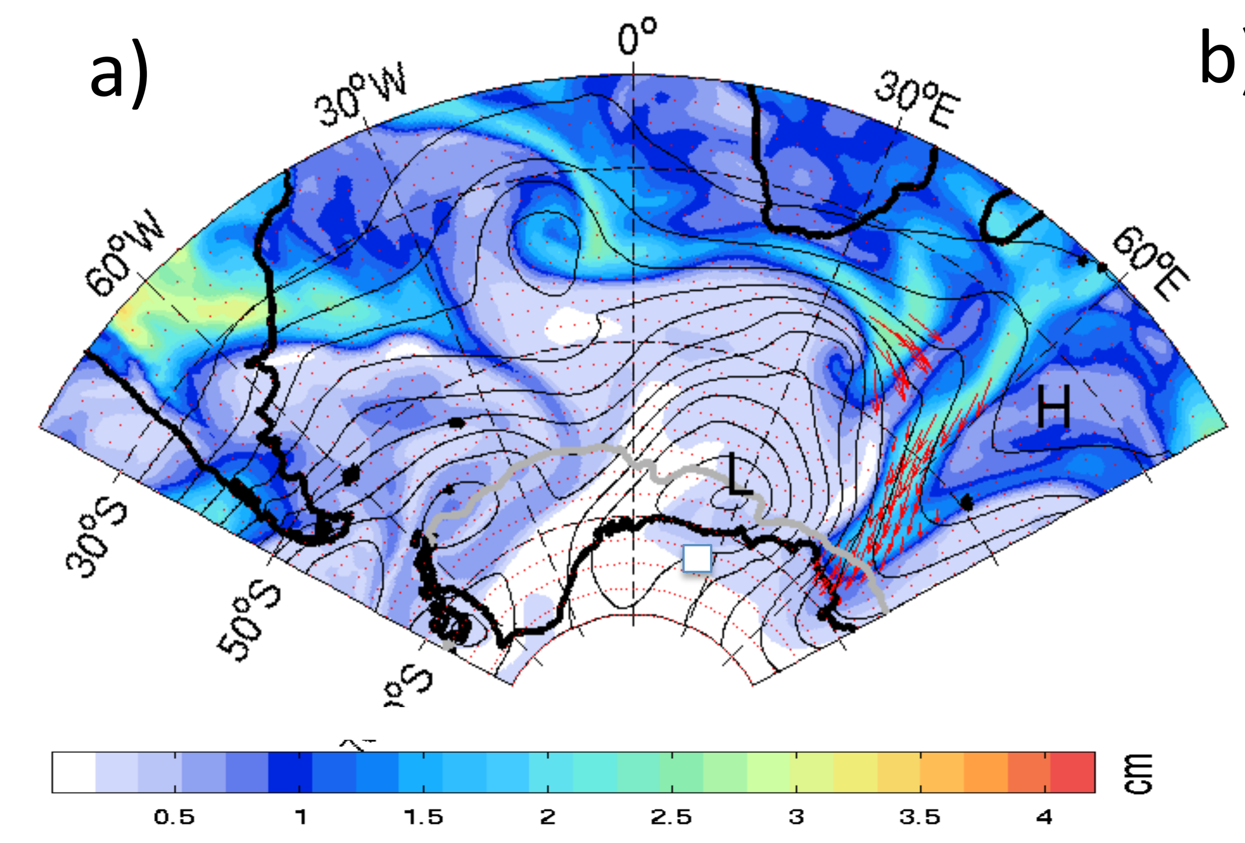
BACKGROUND

Recent studies confirmed that atmospheric rivers (ARs) reach the continent of Antarctica and thus influence the Antarctic accumulation patterns and the ice sheet mass balance (Gorodetskaya et al. 2014, GRL). Similar to mid-latitude ARs, Antarctic ARs are associated with a blocking pattern downstream of a cyclone, which allows channeling of moisture toward the continent. However, due to the extremely cold atmosphere, Antarctic ARs possess some unique features.

- First, the existence of an AR in high latitudes is always associated with warm advection.
- Second, in order for an AR to penetrate the continent, it needs to overcome strong low-level outflow winds – katabatic winds – coming from the interior of the continent
- Thirdly, sea ice surrounding the Antarctic ice sheet introduces an additional "cold barrier" decreasing the tropospheric moisture holding capacity and promoting precipitation before reaching the ice sheet.

These factors contribute to the scarcity of AR events influencing the ice sheet surface mass balance. Nevertheless, their presence is clearly seen in the long-term record. In particular, anomalous accumulation in 2009 and 2011 in Dronning Maud Land (DML) in East Antarctica has been linked to atmospheric rivers.



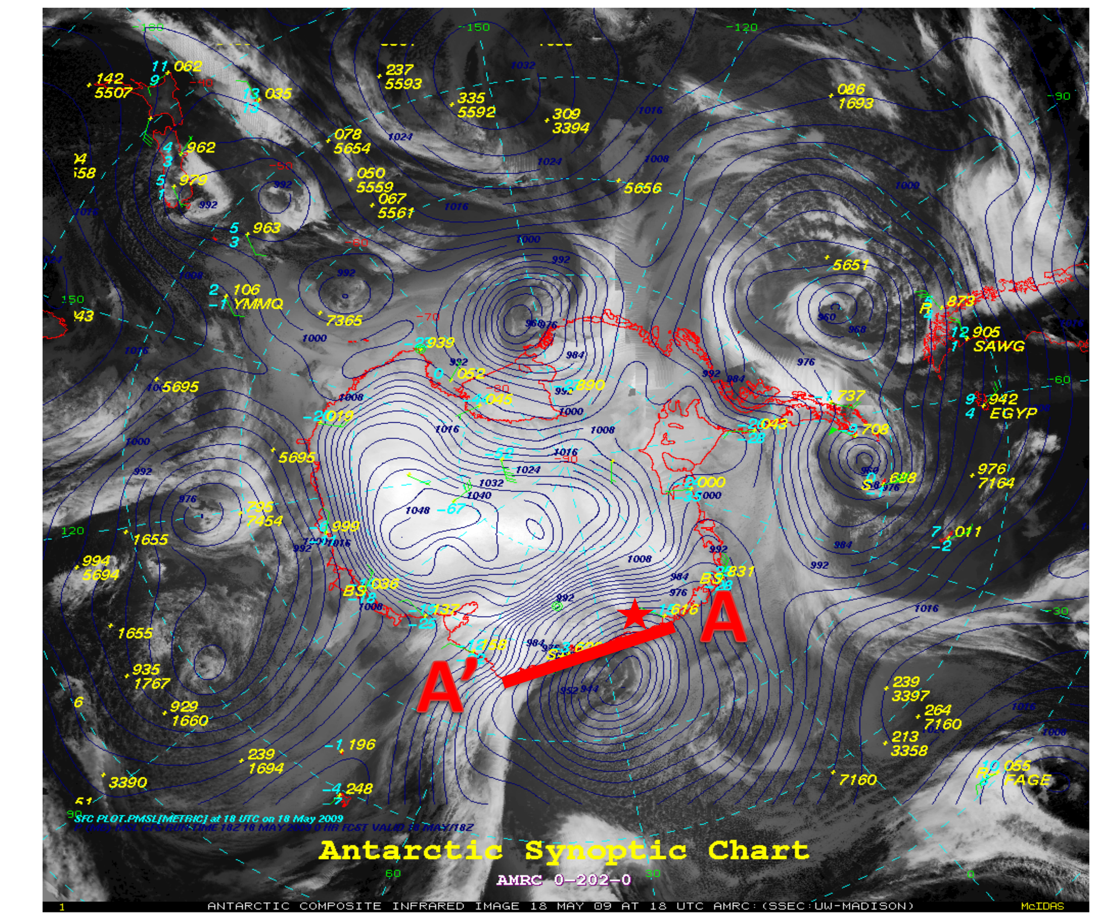


Figure 1. a) Vertically integrated water vapour (colors) and integrated water vapour transport (arrows) influencing DML on 19 May, 2009. Black contours show 500-hPa geopotential heights. Adapted from Gorodetskaya et al (2014, GRL) (b) Antarctic composite Infrared satellite image with synoptic observations & mean sea-level pressure as predicted by the WRF - Antarctic Mesoscale Prediction System (AMPS) (blue contours)

RESULTS

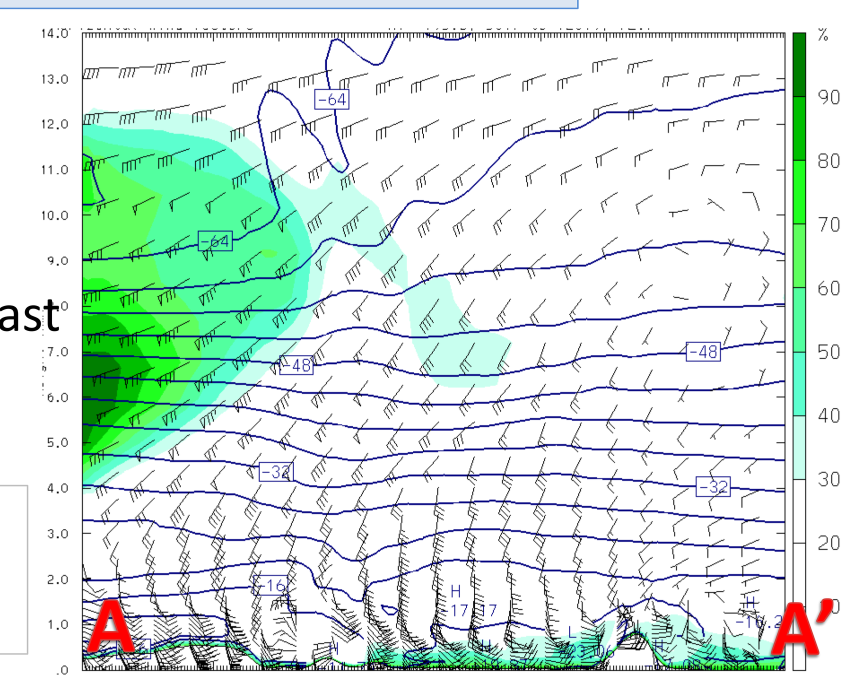
EVOLUTION OF THE VERTICAL PROFILE ALONG THE DRONNING MAUD LAND COAST (10-50ºE)

Below we present the development of meteorological fields (RH wrt ice, temperature, horizontal wind) in the vertical cross-section along the DML coast (as shown on fig. 1b) during the May 18-19, 2009 case when an atmospheric river in the eastern flank of a cyclone made landfall in DML causing extreme snow accumulation (Gorodetskaya et all 2014).

"Typical day" in 2009

- westerly winds aloft
- katabatic winds off the coast
- horizontal isotherms

Horizontal wind
% Relat humid
Temperature

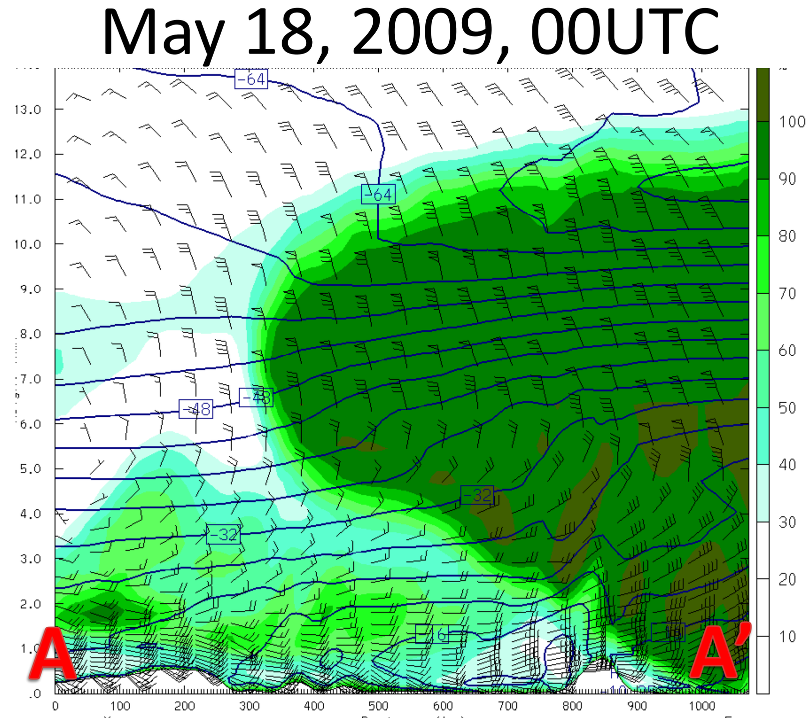


METHODS

Here we present a detailed investigation of the May 2009 AR storm event using the Weather Research and Forecasting (WRF) model simulations for DML region at 15-km horizontal resolution.
The model was initialized on 17 May 2009, 00UTC; Forcing: ERA-Interim reanalysis data (~80km res).
The set up is optimized for the polar regions (Polar WRF) as described by Powers et al (2012).

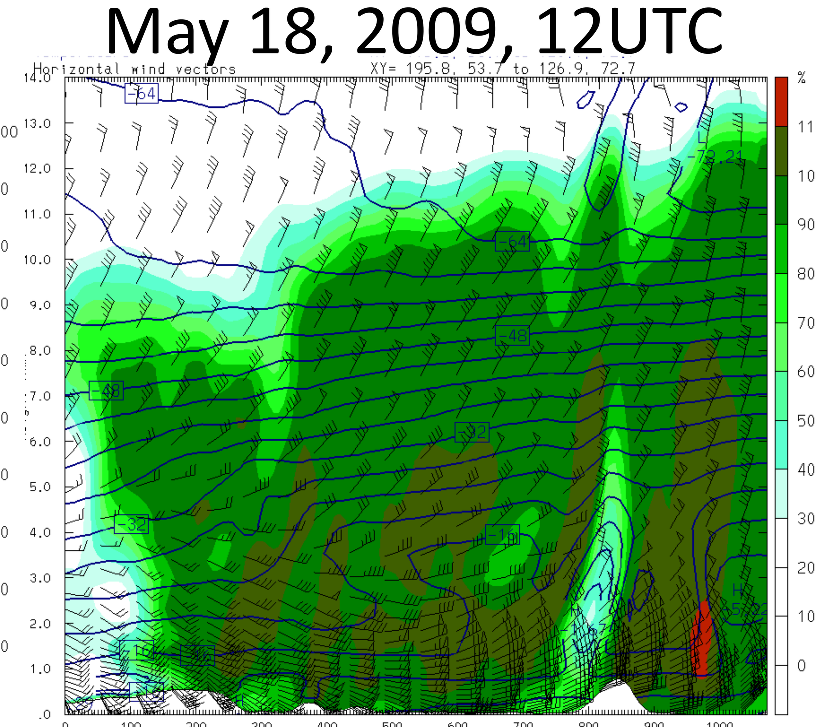
Atmospheric river development in meteorological fields

May 18, 2009, 00UTC



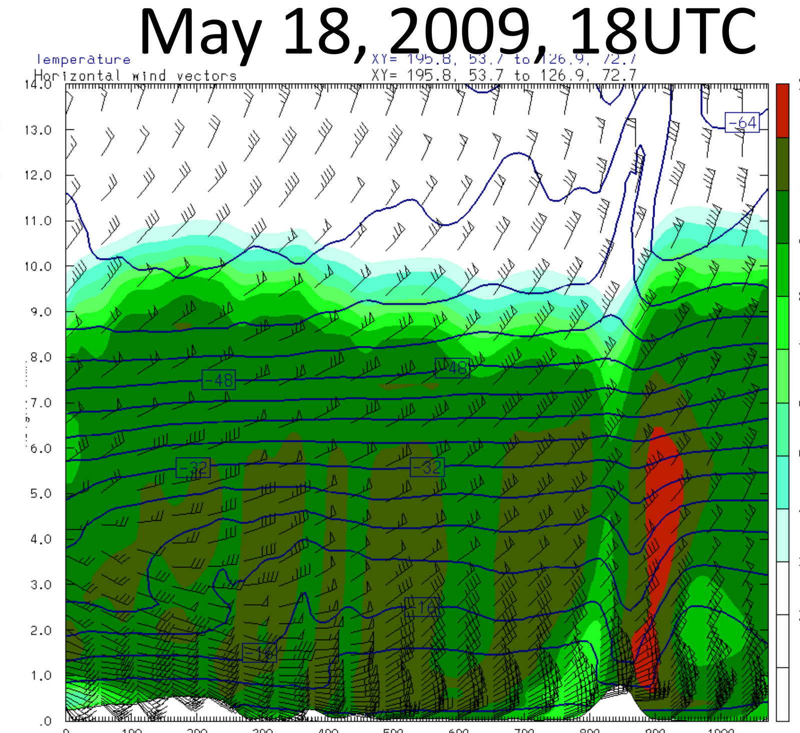
- Approaching storm
- Heat and moisture advection
- Saturated air
- Snowfall starts reaching the surface
- Easterly flow along the coast and N-NE flux aloft

May 18, 2009, 12UTC



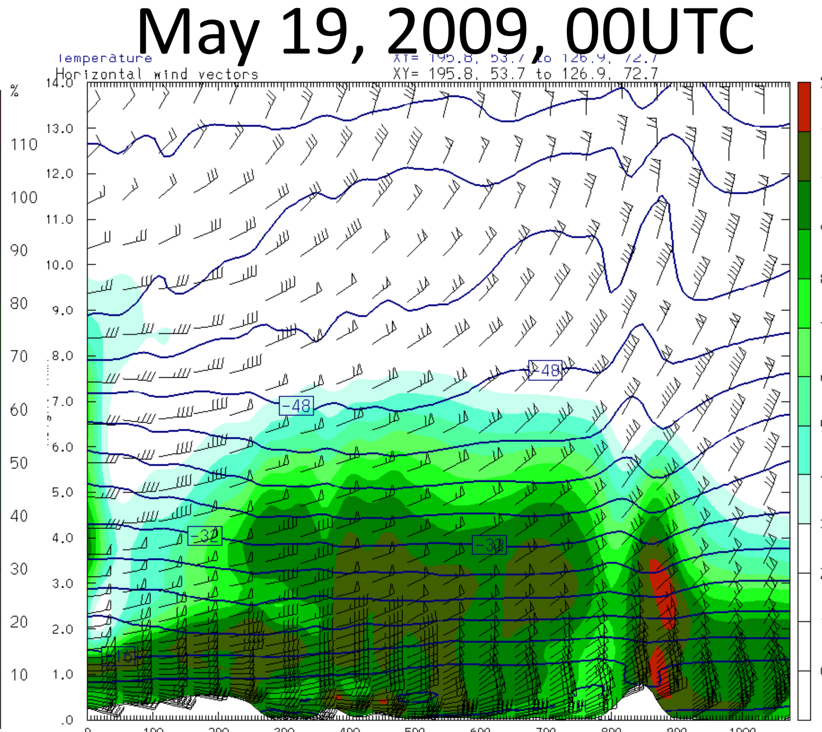
- Warm temperature advection at low and mid tropospheric levels
- High moisture content and snowfall
- Flow intensification below 3km in the east of the cross-section (eastern flank of the cyclone) – low level jet?

May 18, 2009, 18UTC



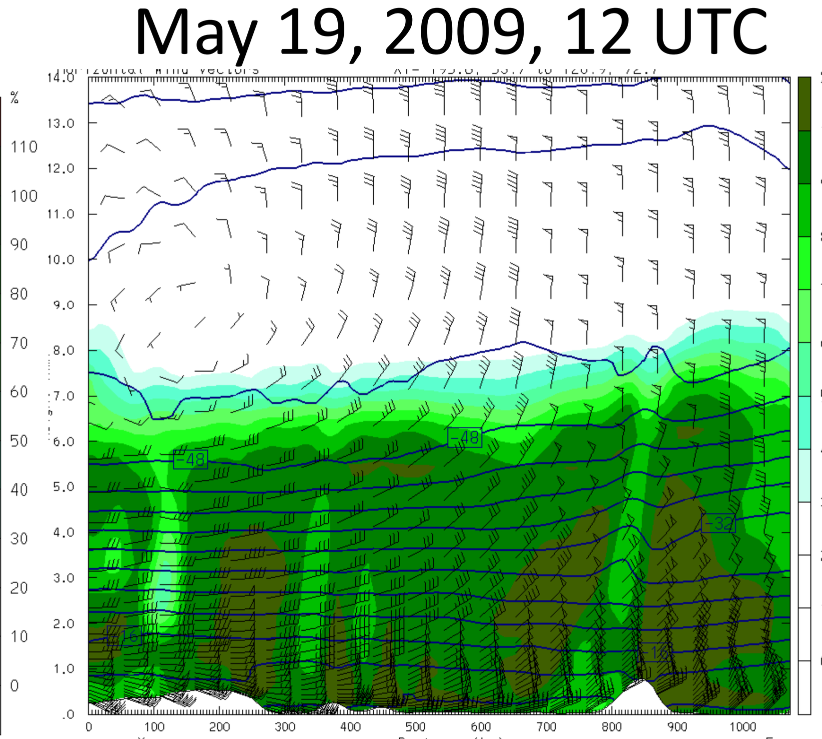
- Strongest winds in the cross-section E and LLJ with northerly component coincide with highest moisture contents – AR signature

May 19, 2009, 00UTC

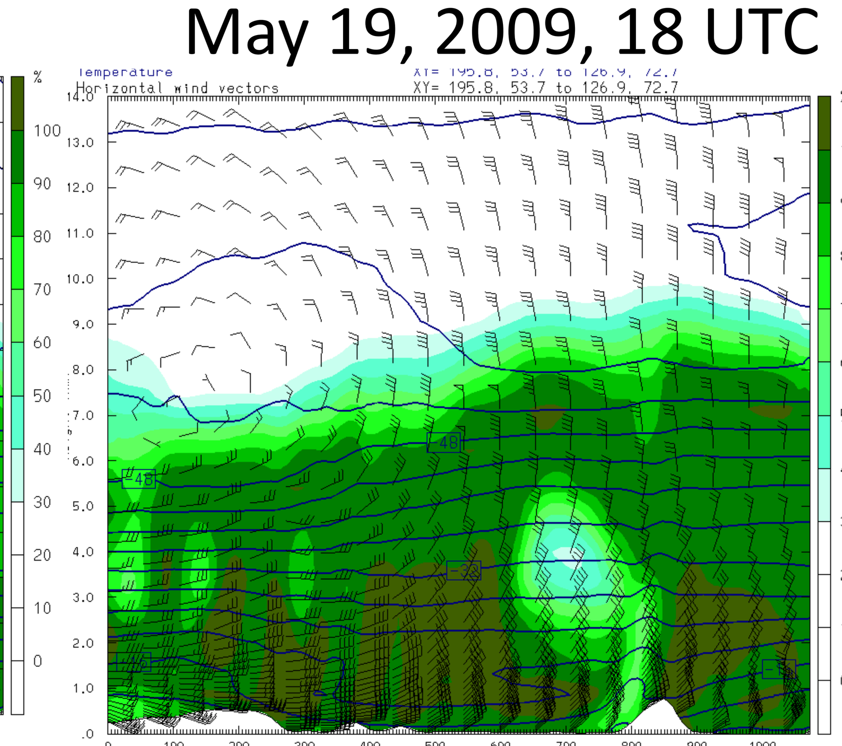


- Decrease in humidity aloft
- Isotherms stratified, although near surface layers are still saturated (snowfall)

May 19, 2009, 12 UTC



May 19, 2009, 18 UTC



- Low-level jet (heights<3km) is still strong but humidity has decreased
- Snowfall continues and troposphere stays saturated near the surface and at mid levels
- Storm dissipating

CONCLUSIONS AND FURTHER RESEARCH

- Limited area model WRF is used to examine the vertical structure of meteorological fields within a cross-section along DML coast during an atmospheric river case on 18-19 May 2009
- AR reaching the DML coast causes abundant moisture and heat advection at mid levels followed by the entire tropospheric RH_{ice} reaching saturation and snowfall
- Presence of the low level jet in the eastern flank of the cyclone coincident with highest RH

REFERENCES

Gorodetskaya, I. V., M. Tsukernik, K. Claes, M. F. Ralph, W. D. Neff, and N. P. M. Van Lipzig (2014), The role of atmospheric rivers in anomalous snow accumulation in East Antarctica, *Geophys. Res. Lett.*, *41*, 6199–6206.
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ACKNOWLEDMENTS

We thank NCAR/UCAR and Byrd Polar Research Center (OSU) for the AMPS/WRF model development and technical support; The European Centre for Medium-range Weather Forecasts for providing reanalysis data. Thanks to the National Science Foundation Grants ANT-1246178 & ANT-1244924 supporting MT and ML; CESAM grant, FCT, MCTES and COMPETE 2020 supporting IG.