Hail forecasts in AROME

Y. Seity, S. Riette

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Introduction

- ICE3 OPER AROME 1-moment microphysics scheme uses 5 hydrometeors (cloud, rain, ice, snow, graupel) (Pinty and Jabouille 1998).

- A version with added prognostic hail « ICE4 » (Lascaux et al., 2006) is also available in the code.

Introduction

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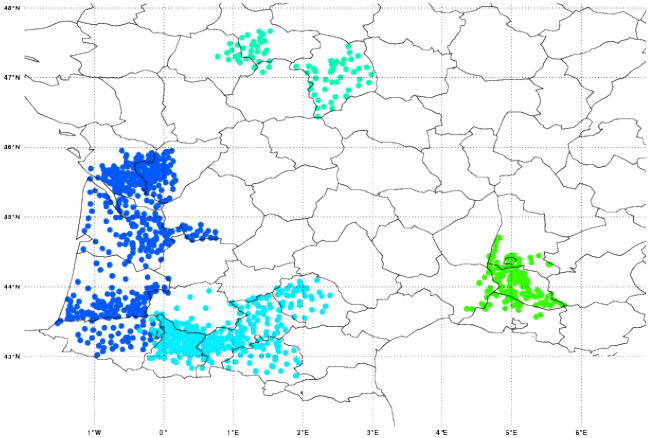
ICE4 was evaluated in 2010 in AROME (comparison with ANELFA hailstones detection network in south-west of France during summer 2009) :

→ not implemented in oper because produces very small hail amounts everywhere there was graupel in altitude.

ANELFA network (1054 « grêlimètres ») :



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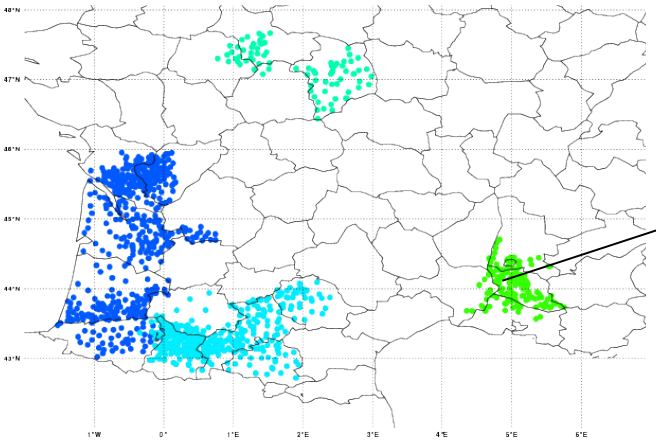

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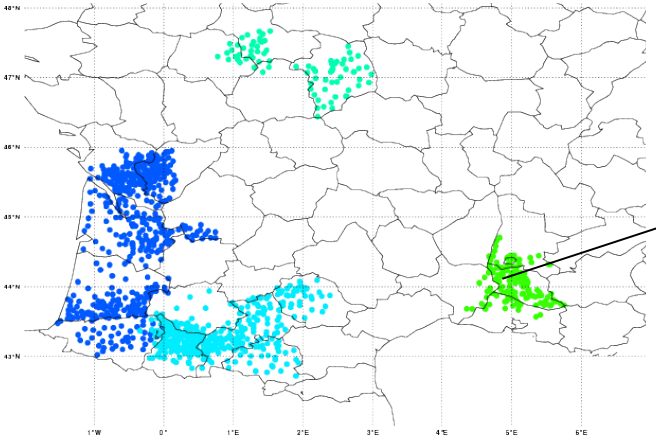
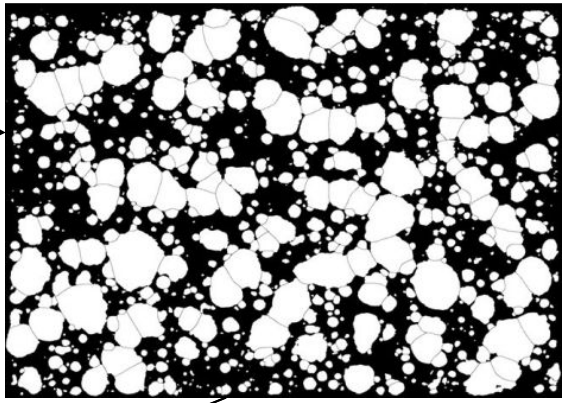


30x40cm polystyrene plates :

covered with ink and scanned



Dmax, Ntot per class, Mtot, Ec tot...

Introduction

Status :

1) => a hail diagnostic was developped for forecasters based on the vertically integrated graupel content (= hourly maximal value)
BUT
Diag understimates in case of tilted ascents / seasonal variation (link with tropopause height)

2) In 2016/2017, ICE3 was modified in order to reduce the sensibility of the scheme to the time-step length (S. Riette)

ICE4 processes were also modified (especially hail formation from graupel)

3) New hail observations available in 2017 based on polar radars

=> Time to test again ICE4 scheme

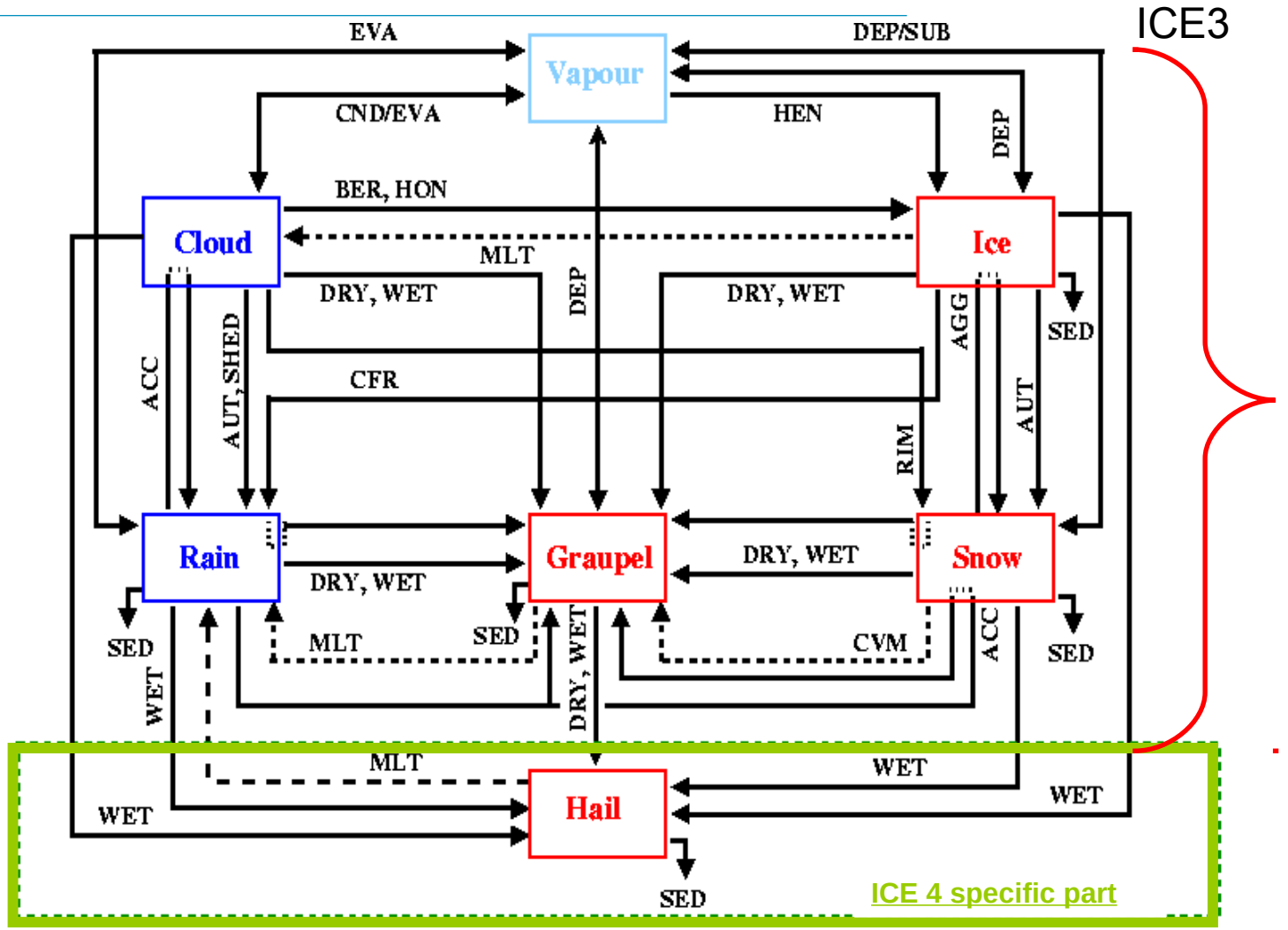
Introduction

warnings:

As all extreme and rare events, validation of hail forecasts not so easy
→ long periods required for statistics
→ Is simulated convection OK ? (not too strong/weak compared with observations)

In this study, we will compare over a 3-months period :
→ ICE4,
→ Hail diagnostic in ICE3
→ Doppler radar hail observations (HYDRE product)

ICE3/ICE4 :



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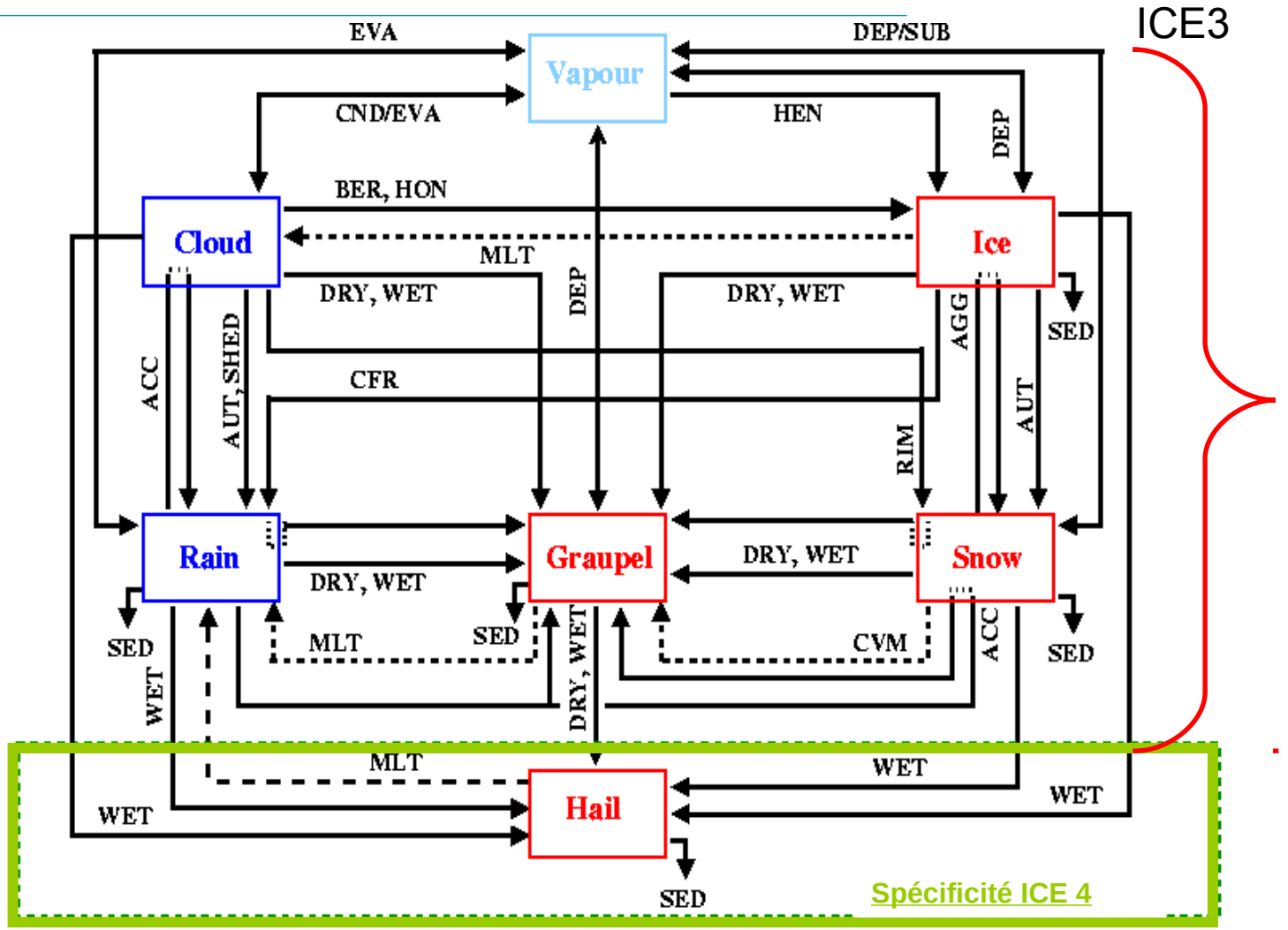

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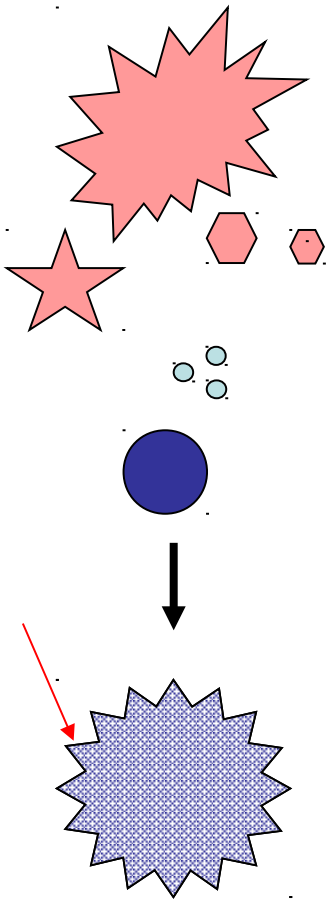
- In ICE4, it is separated (→ higher fall speeds)

Graupel growth modes :



Graupel with
Tsurf < 0°C

Dry growth (→ Graupel)

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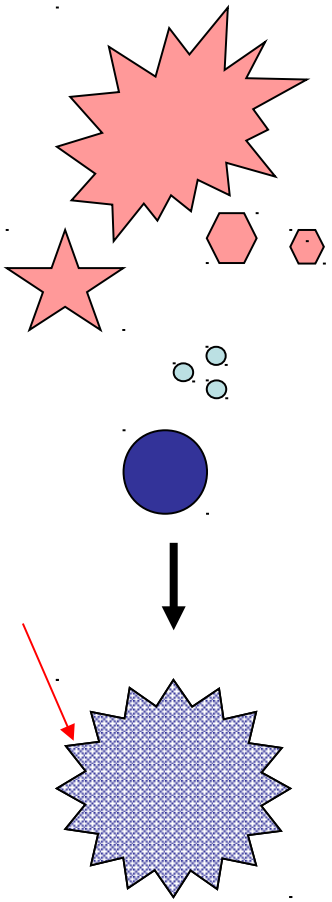

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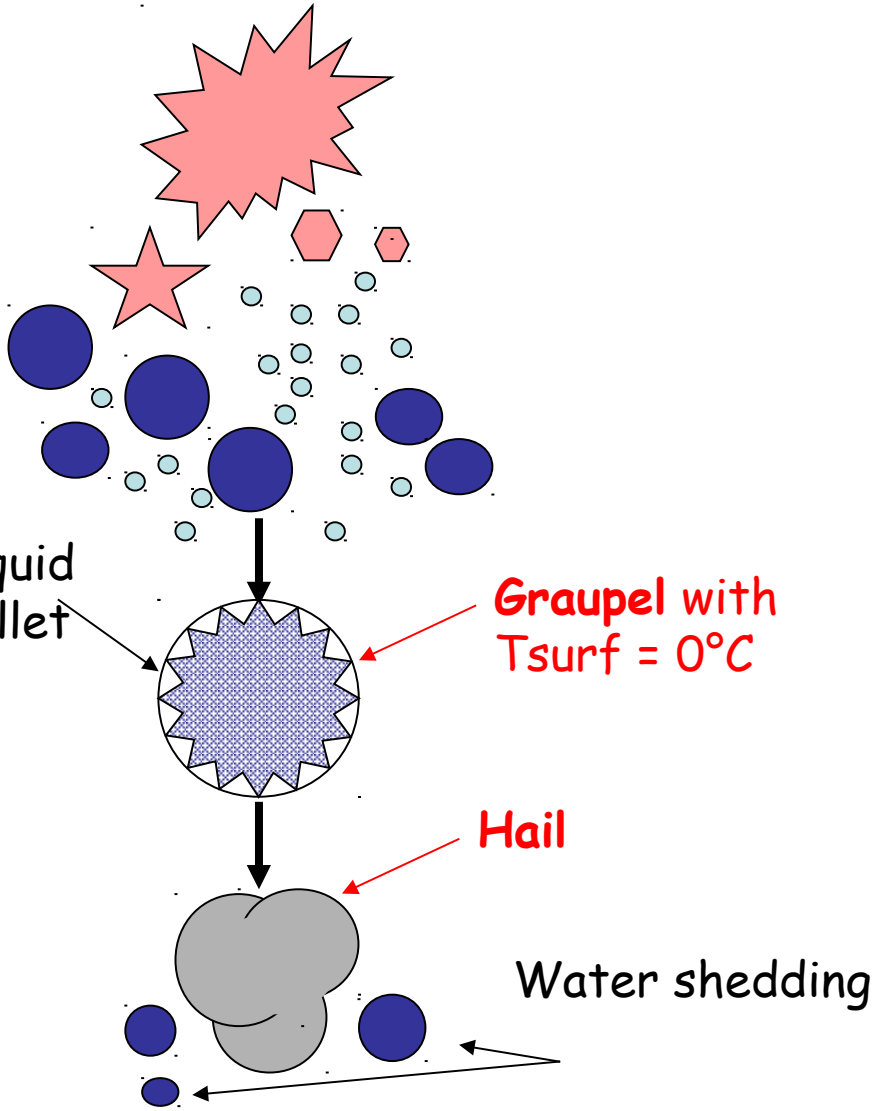

Wet growth (→ Hail)

A few equations :

Graupel growth by collection :

$$\left.\frac{\partial r_g}{\partial t}\right|_g = \sum_y \left[\int_0^\infty \left[\int_0^\infty K(D_g, D_y)\, m_y(D_y)\, n_y(D_y)\, dD_y \right] n_g(D_g)\, dD_g \right]$$

$$K(D_g, D_y) = \frac{\pi}{4}\left(D_g + D_y\right)^2 \left| v_g(D_g) - v_y(D_y) \right| E_{gy}$$

=DRY & WET

Heating budget (Musil 1970, Nelson 1989) : compute mass freezing capacity of the graupel

$$L_m(T_t)\left.\frac{\partial m}{\partial t}\right|_{c+r} - \left.\frac{\partial m}{\partial t}\right|_{i+s} c_{i,s}(T_t - T) =$$

$$4\pi C_g \bar{f}_g \left[k_a(T)(T_t - T) + \frac{L_v D_v(T, P)}{R_v T}\left(e_{vs}(T_t) - e_v\right) \right]$$

=> choice WET or DRY

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=> choice WET or DRY

ICE4 :

$$\left.\frac{\partial r_h}{\partial t}\right|_{g \to h} = \left(\frac{\partial r_g}{\partial t}\right)^* \times \left(\frac{\text{DRY}}{\text{DRY} + \text{WET}}\right)$$

Hail formation

Time step graupel tendency

Weighting factor

Hail processes

Create :

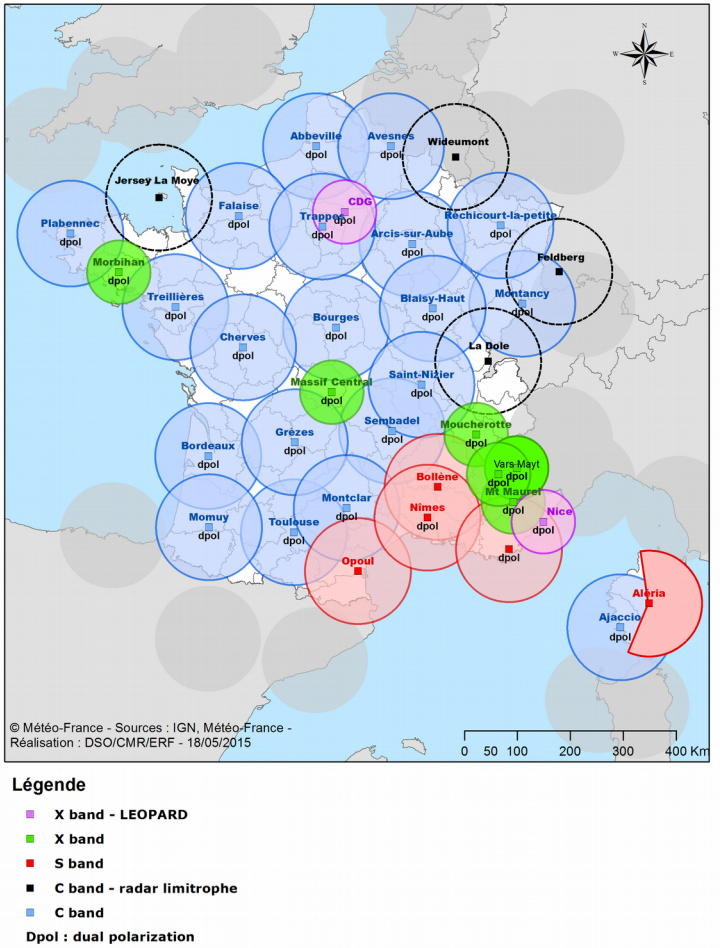
+ : From graupel wet growth (cf previous slide)
+ : Collection of all hydrometeors

Destroy :

- : Back conversion into graupel if arriving in regions less favourable to wet growth
- : Sedimentation
- : Melting

HYDRE

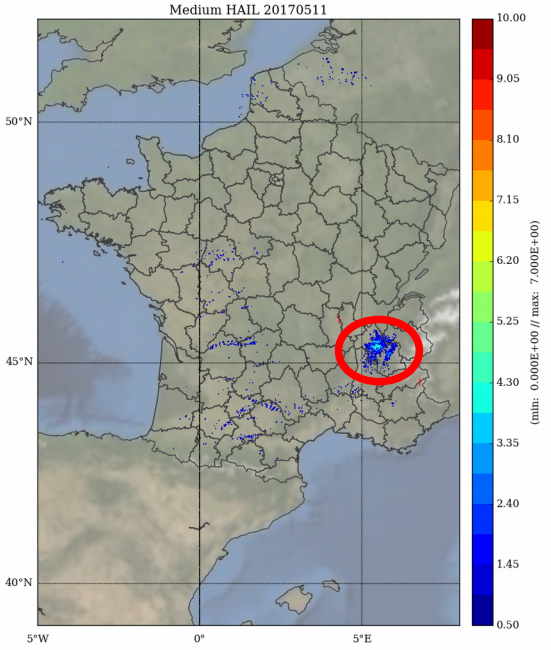
- = a product using radar observation and model forecast to classify hydrometeors reaching ground (wet/dry snow, freezing rain, hail....)
- Algorithm based on NSSL (Schuur et al., 2013) and Canadian Met service (Bourgouin, 2000)
- AROME model profiles (T,Hu) are used for snow, but hail only uses Polar radar observation
- at 1km resolution, hail maps available every 15' (localisation but no quantitative value) :
  - Graupel/small hail (⌀ <5 mm)
  - Medium hail (5 mm <⌀< 2 cm)
  - Large Hail (⌀ > 2cm)



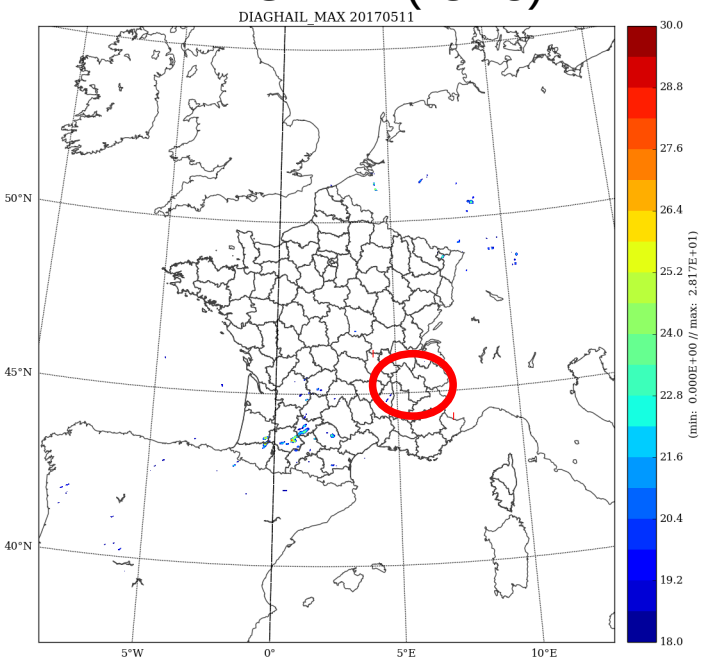
Exemple : 11 May 2017

(accumulated 24h)

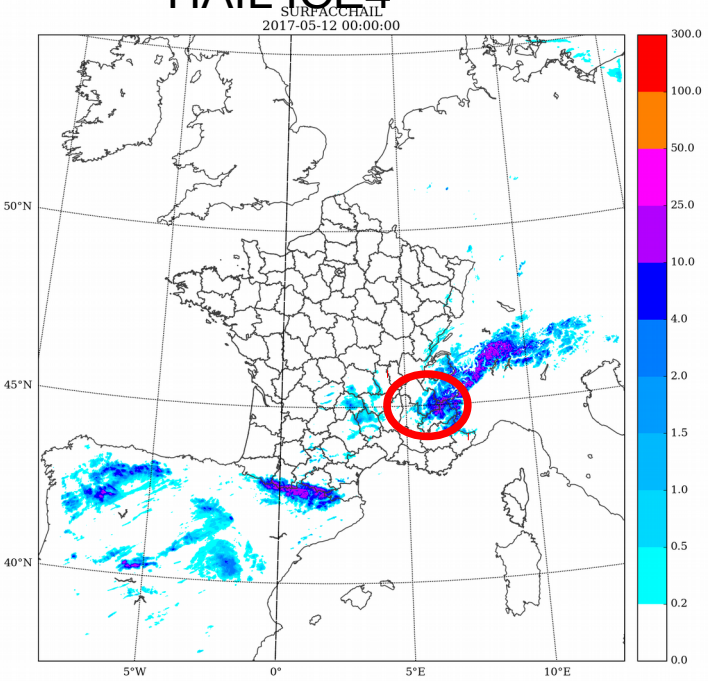
HYDRE



DIAGHAIL (ICE3)



HAIL ICE4



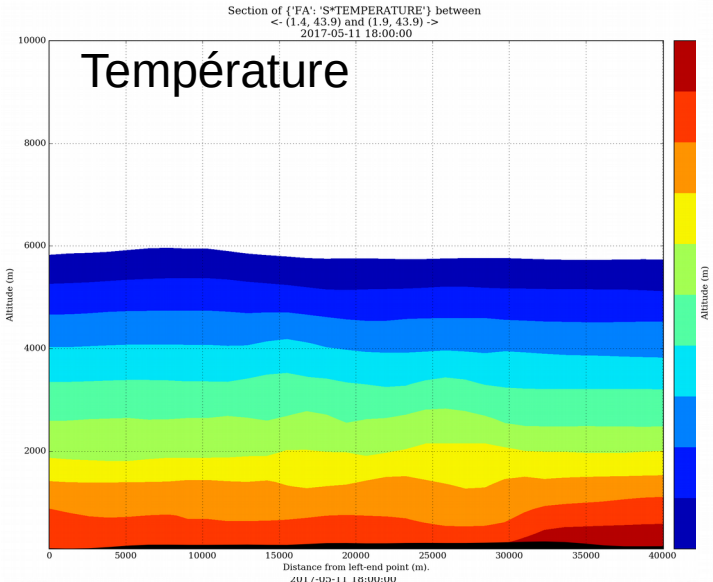
→ ICE4 locally > 0.2 mm in plains, but probably large over-estimation over orography (even if HYDRE may underestimate !).

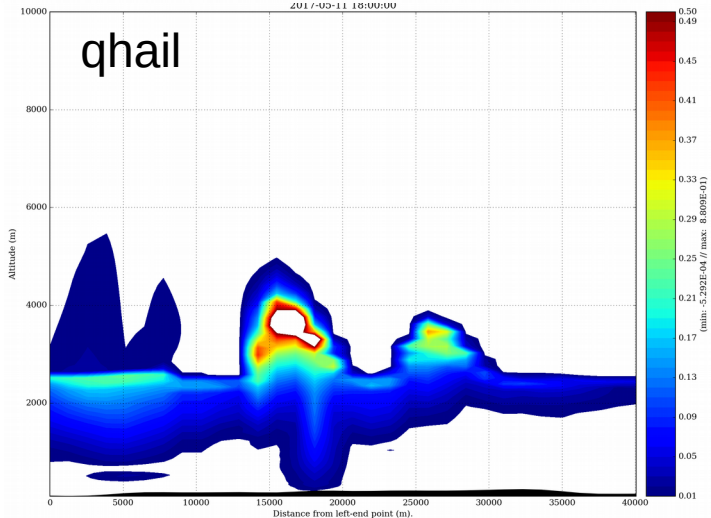
→ ICE3 DIAGHAIL does not over-estimate over orography but misses the max.

Exemple : 11 May 2017

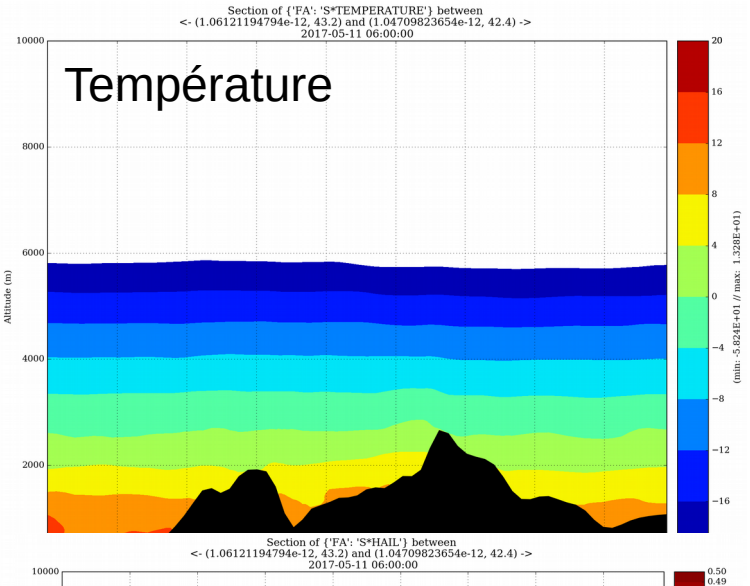
(Vertical cross sections inside convective cells)

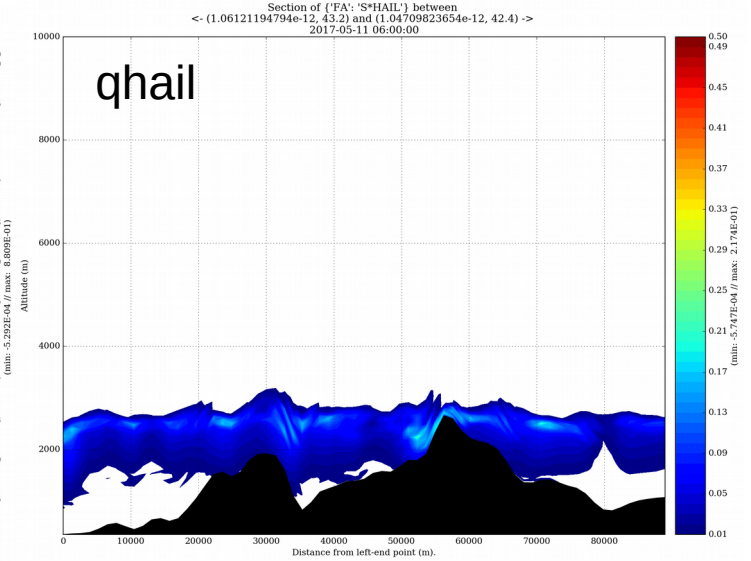
Plain around Toulouse :





Over Pyrenees :





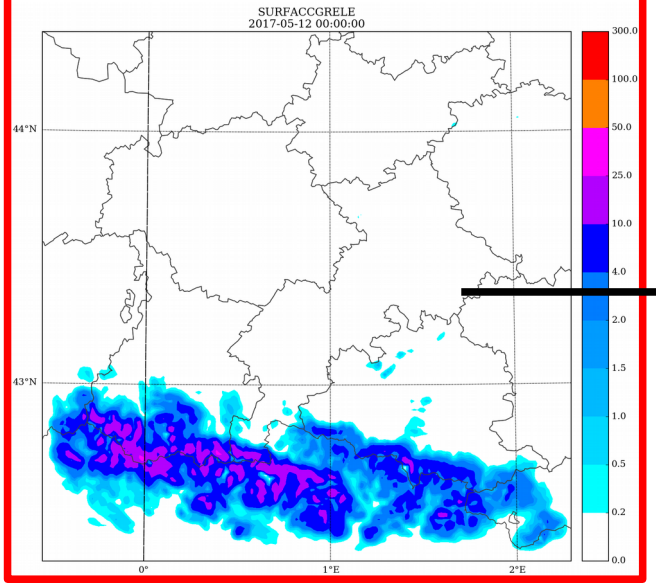
→ Over pyrenees, hail appears near 0°C, whereas over plain, it is observed at much higher altitude.

→ Explanation : In ICE3, snow melting creates graupel (which can next be used to create hail in ICE4)

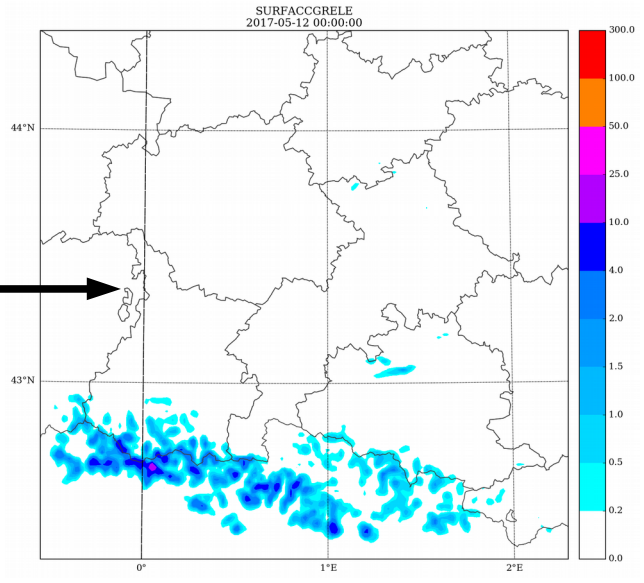
Exemple : 11 May 2017

(tests to reduce strong hail accumulations over orography)

ICE4 : HAIL 24h accumulated



ICE4_test : 24h acc. Hail :



All that is not wet growth has been removed from graupel content which can be converted into hail (snow melting for instance)

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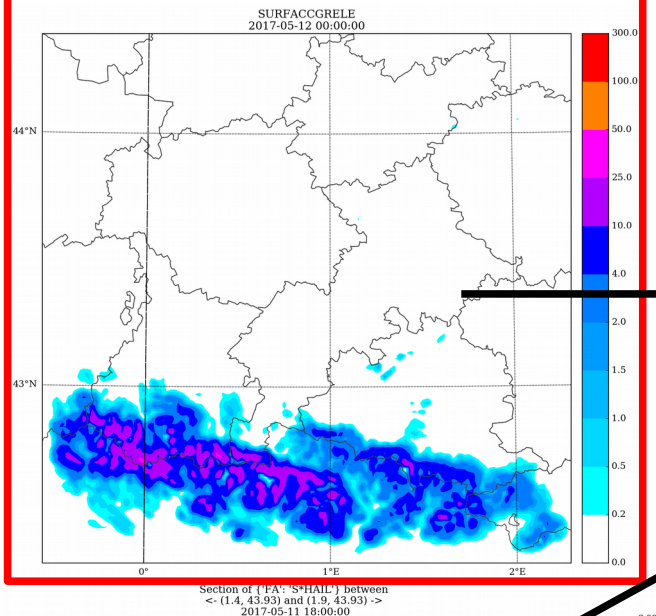

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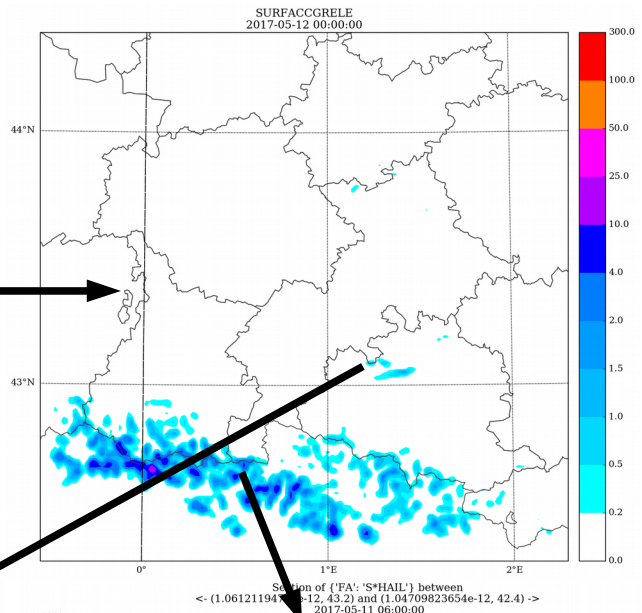

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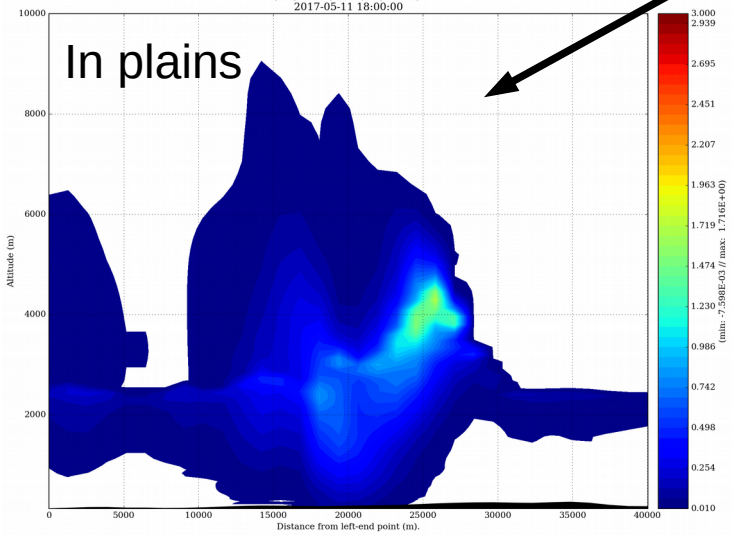
In plains



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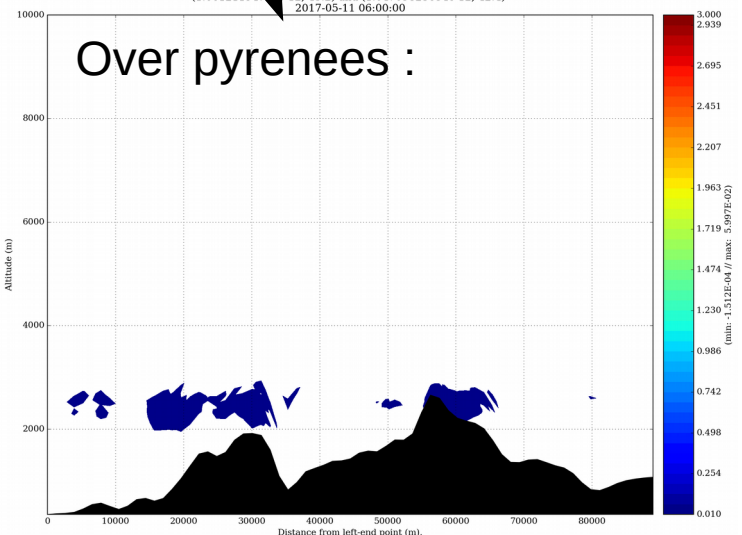


→ Reduced accumulation over orography, similar in plains.

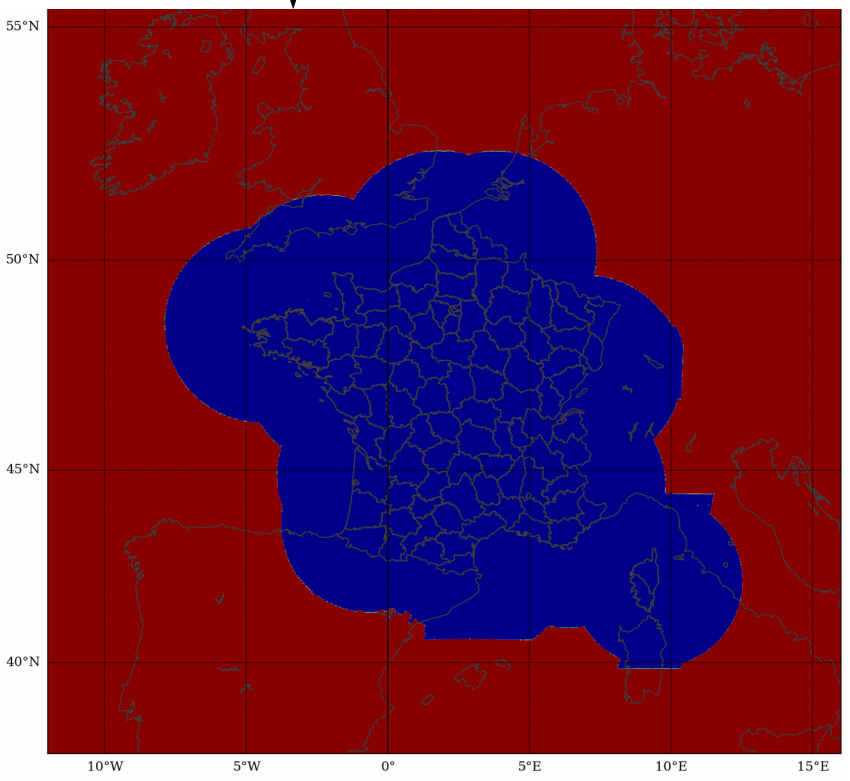
This test version will now be evaluated on a longer period.

3-months evaluation

(1-05-2017 au 31-07-2017)

Comparison or surface areas with hail.

Masks applied on datas : 1) remove > 1000m (radar detection / over-estimation of ICE4)
2) HYDRE detection mask applied on model datas



Daily accumulation :

3 thresholds for ICE3 diagnostic 20,25,30 kg/m² :
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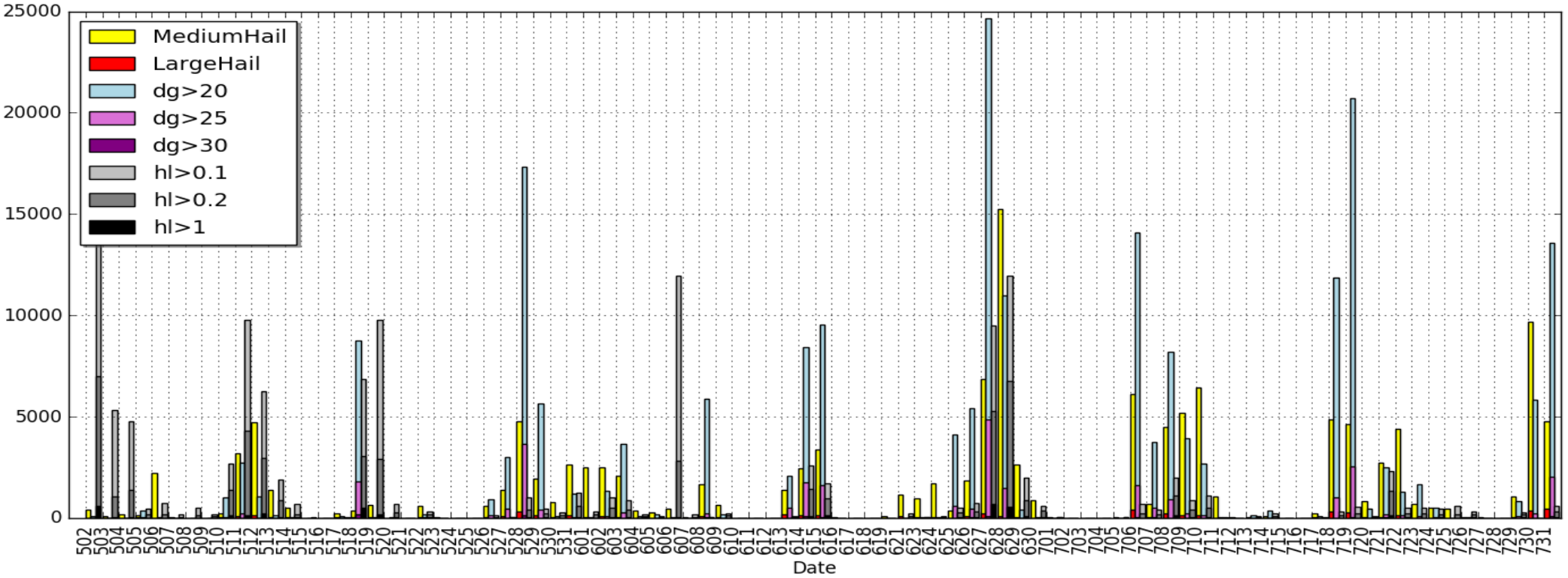
Surface area in km² :



- Medium hail is observed 57 over 90 days (64%)
- ICE4 : Large variability of the results (cases with overestimation : begining of May, 7 June, good estimation : end of June, and under-estimation : end of May, begining of June)

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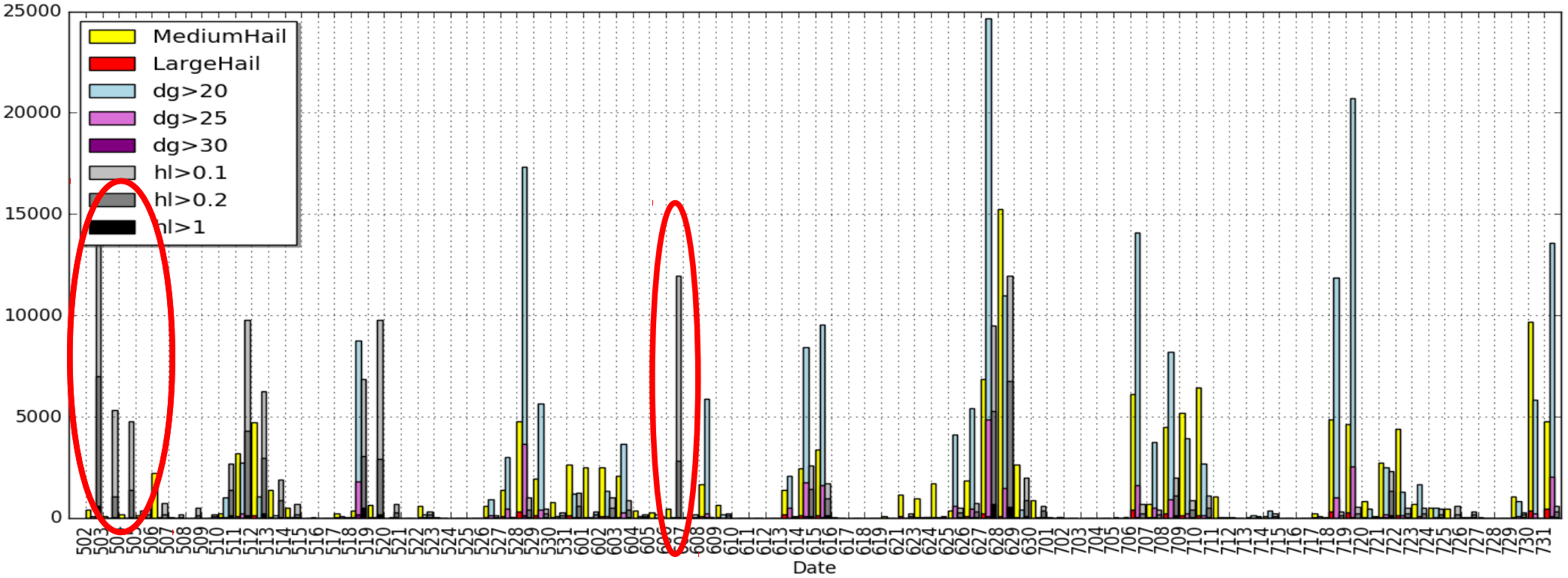

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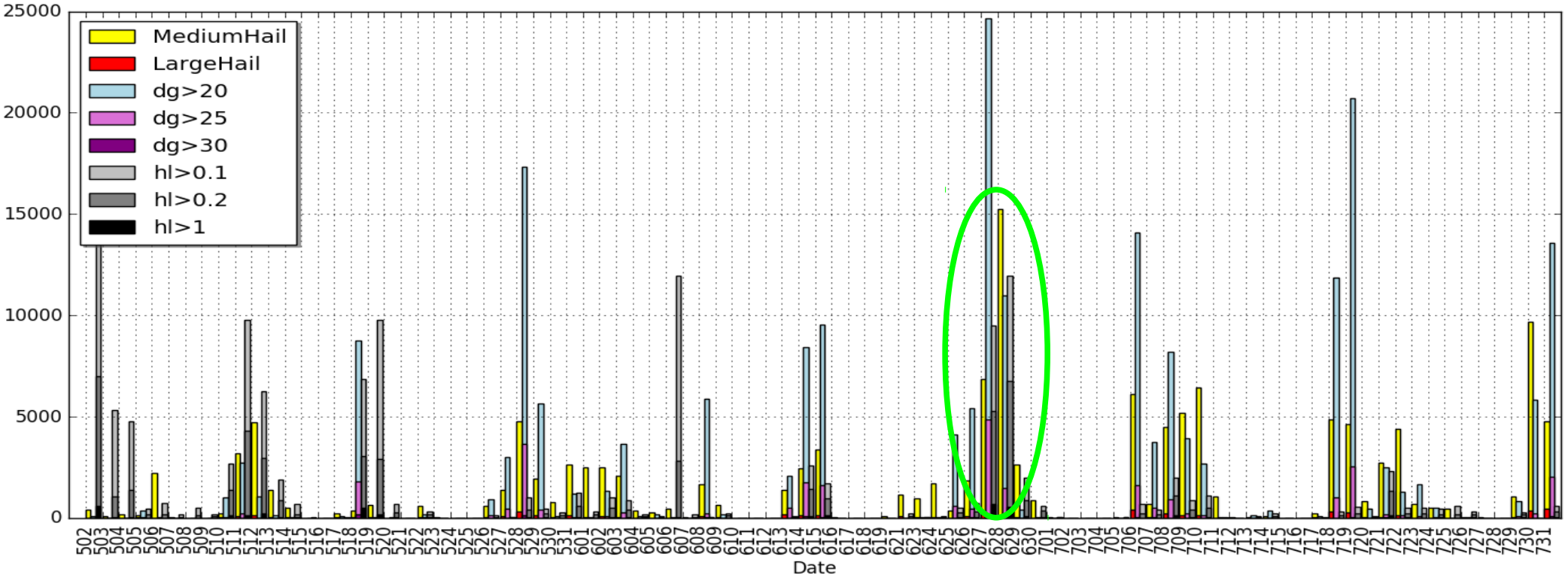

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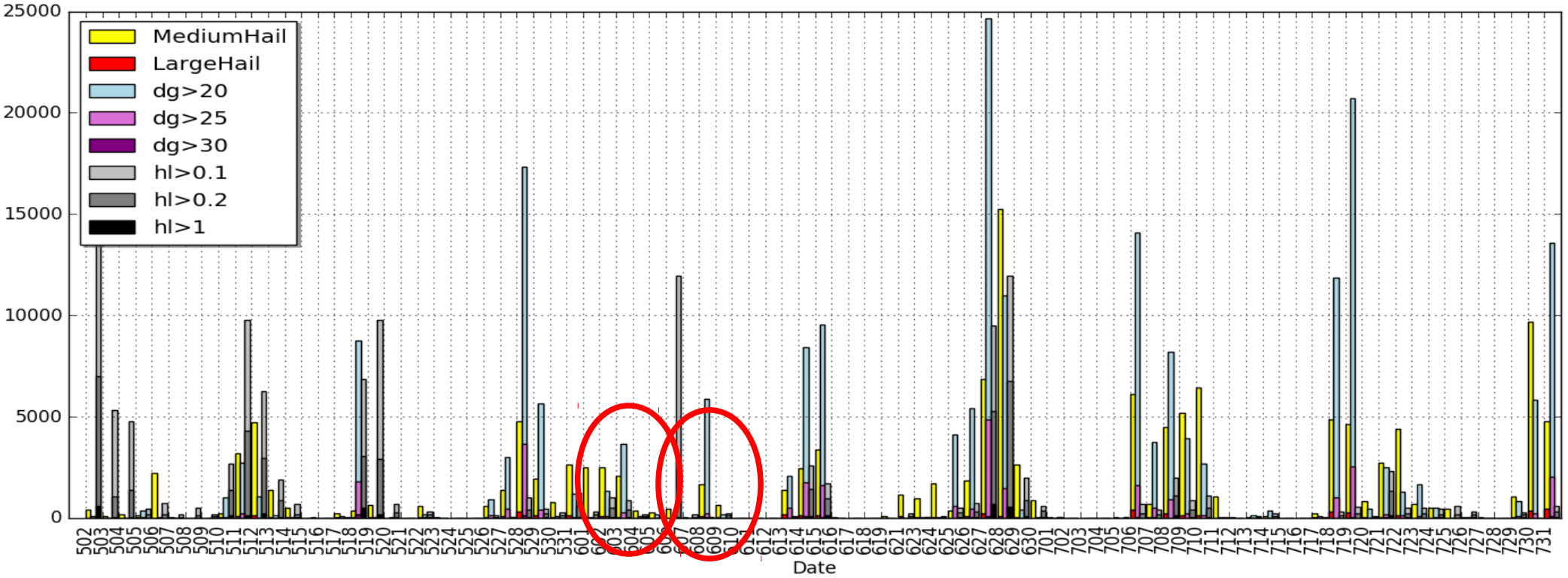

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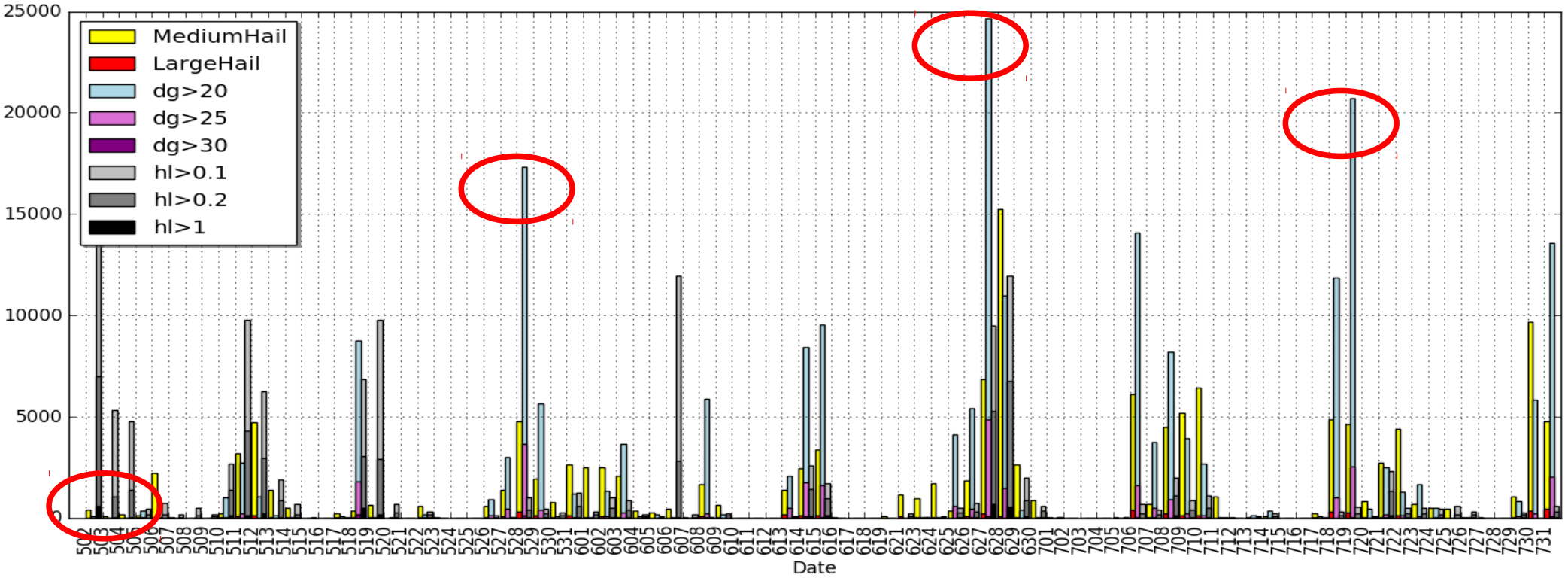

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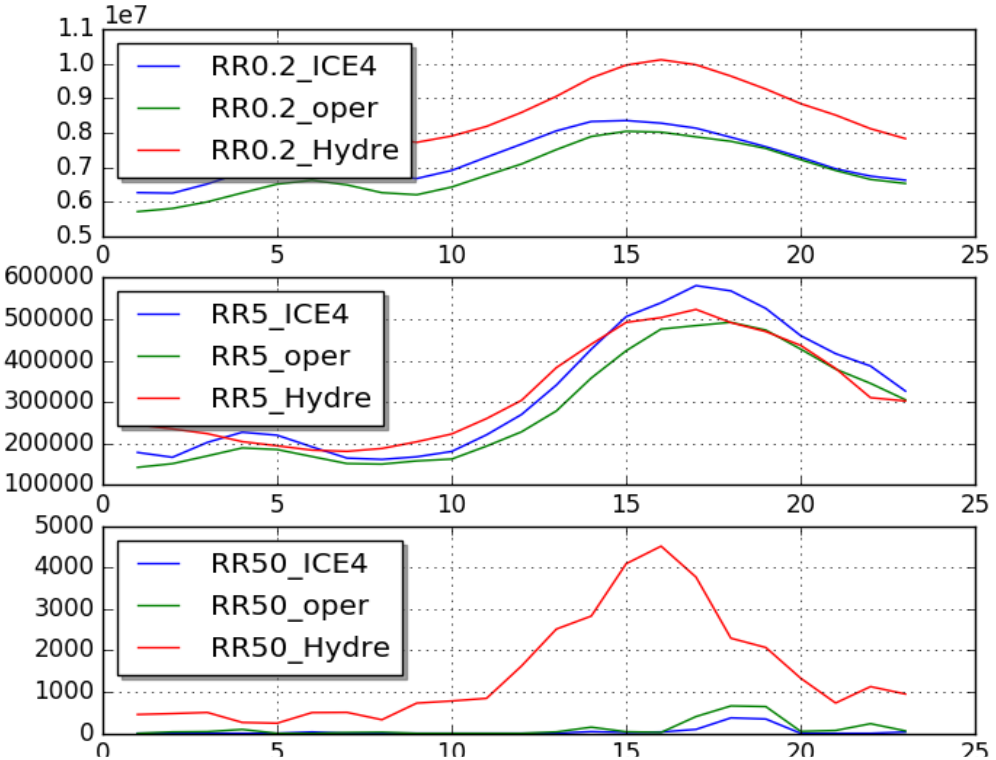
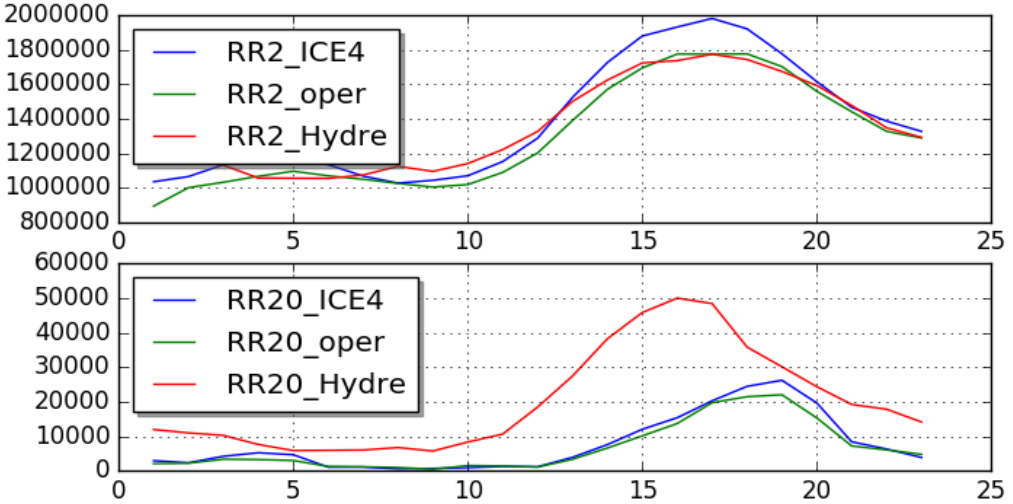
- ICE3 diagnostic : 20 kg/m² is too much in begining of may, overstimates later.

Diunal cycle :





- Model underestimation surface of RR > 20mm. ICE4 > oper for RR < 50 mm

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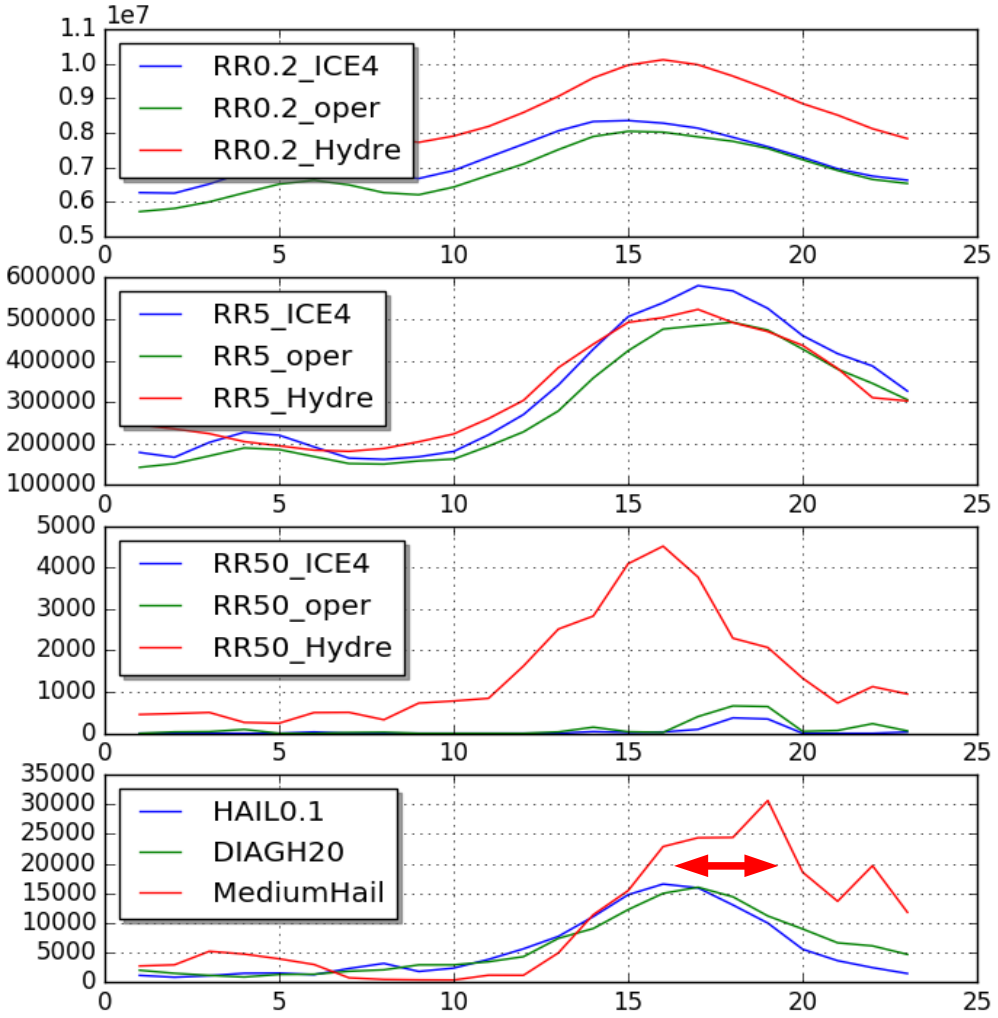

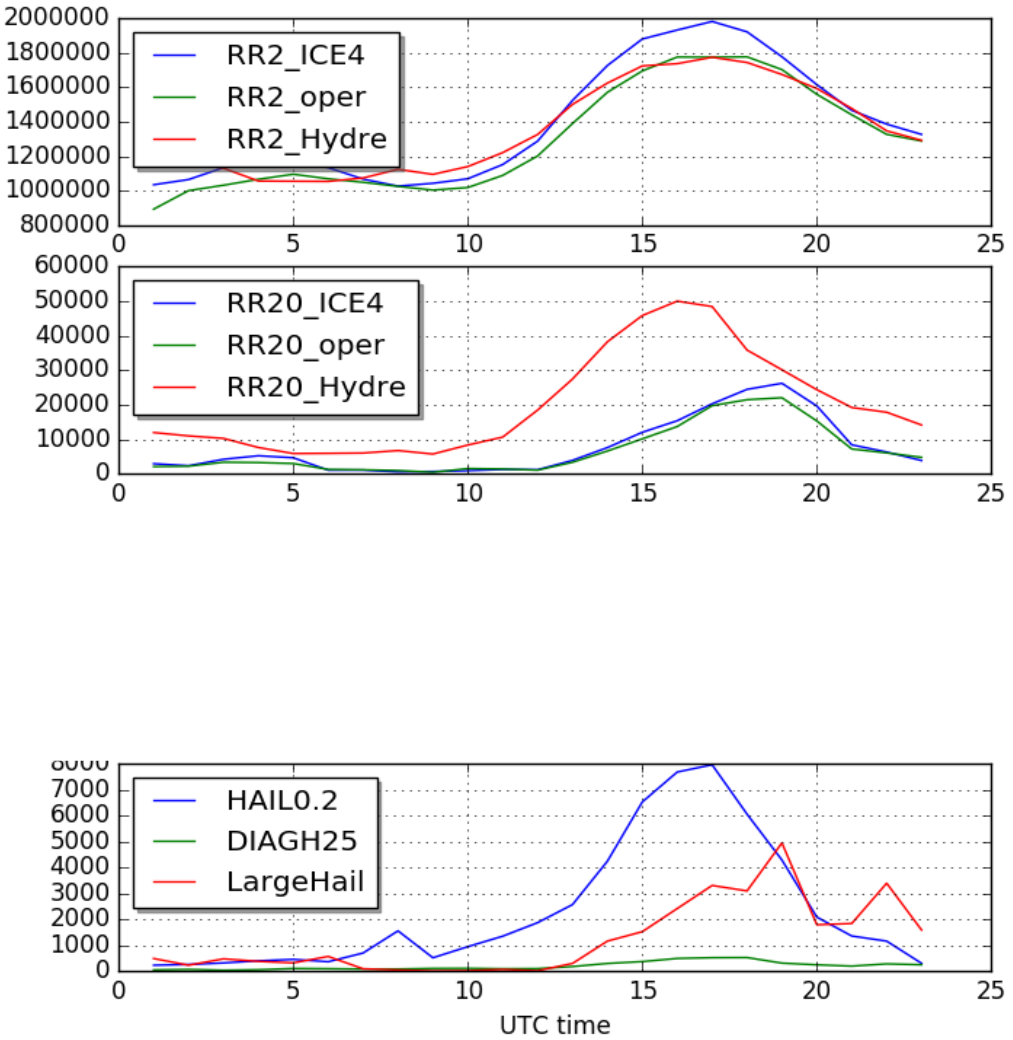

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- In ICE4, hail maximum appears at the same time as the one of high RR. In observation, or in ICE3 diagnostic, it appears later (3h in HYDRE, 1h in ICE3). → life cycle of convection not well simulated in ICE4.

Subjective evaluation

- Over the 90 days period, 19 are removed (8 without convection, 11 with clear pbs in AROME simulation of convection)

- Over remaining 71 days, contingency tables are slightly in favour of ICE3-OPER : (78 % / 74 % good forecasts)

ICE3 OPER	Hail observed	No Hail observed
Hail forecasted	47 %	4 %
No Hail forecasted	18 %	31 %

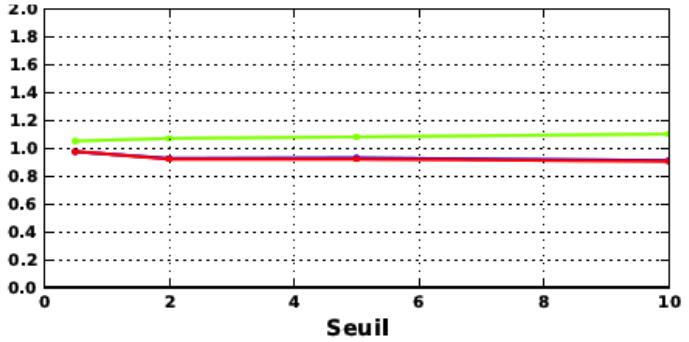
ICE4	Hail observed	No Hail observed
Hail forecasted	44 %	15 %
No Hail forecasted	11 %	30 %

Scores of ICE4/ICE3 ...

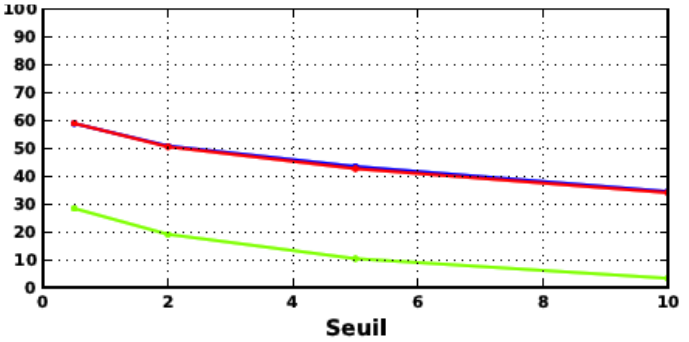
- Neutral scores (T2m/Hu2m, V10m, Pmer, RR6, RR24, profiles...)

RR6

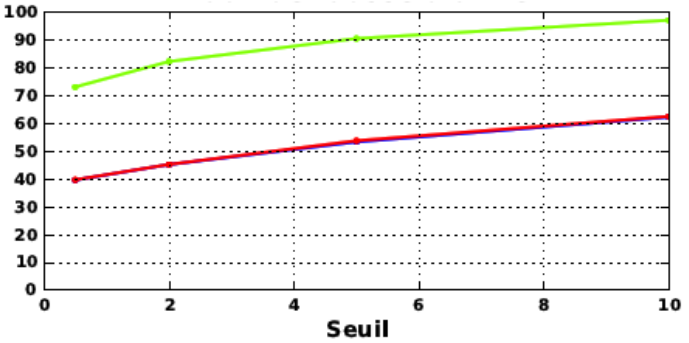
Bias :

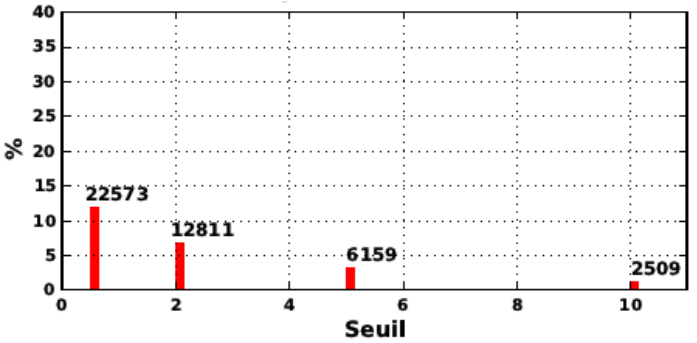


Detection rate :



False alarms rate :





Summary

- ICE4 1-moment hail scheme has been improved
- May be still an over-estimation over orography
- Still not better than ICE3 hail diagnostic (with +6 % CPU time).

→ Not so easy to beat a diagnostic with a more complex physical scheme !!

Outlook

- Validation with scores (BSS or other ...)
- Comparison HYDRE / ANELFA observations
- Detailed case studies.

Announcement ...

- Météo-France will organise by 2020 an international field campain devoted to fog (observation / high resolution modeling). Location not yet defined.

  If interested, for more information contact thierry.bergot@meteo.fr

Thank you for your attention !

Y. Seity, S. Riette (CNRM)

EWGLAM Meeting
Reading, October 2017