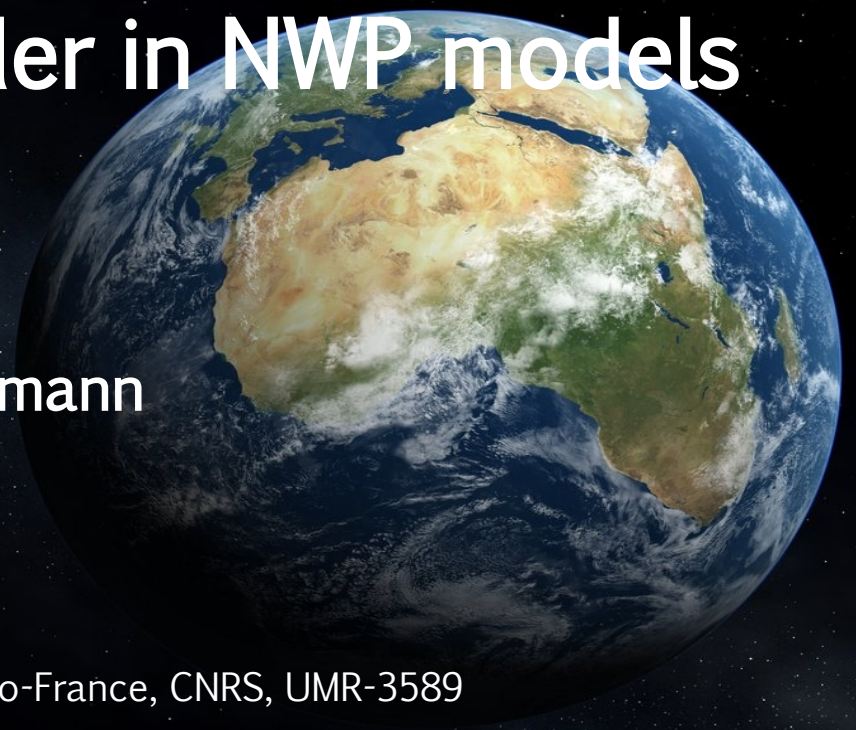
First steps in the preparation for the assimilation of the future IRS sounder in NWP models



Olivier Coopmann

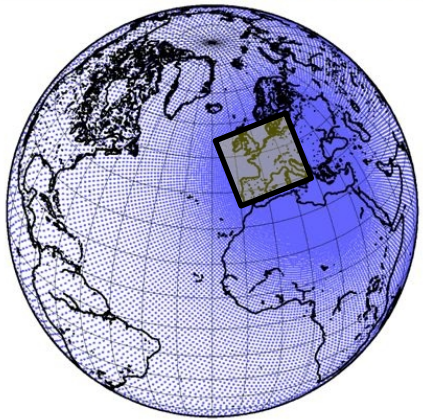
CNRM, Université de Toulouse, Météo-France, CNRS, UMR-3589

Supervisor: **Nadia FOURRIÉ**

With the participation of **Philippe Chambon** and **Pierre Brousseau**

FellowDay – EUMETSAT – Darmstadt – March 01, 2021

ARPEGE global model



- Variable horizontal resolution from 5.0 km to 25 km
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AROME and ARPEGE models at Météo-France

ARPEGE global model

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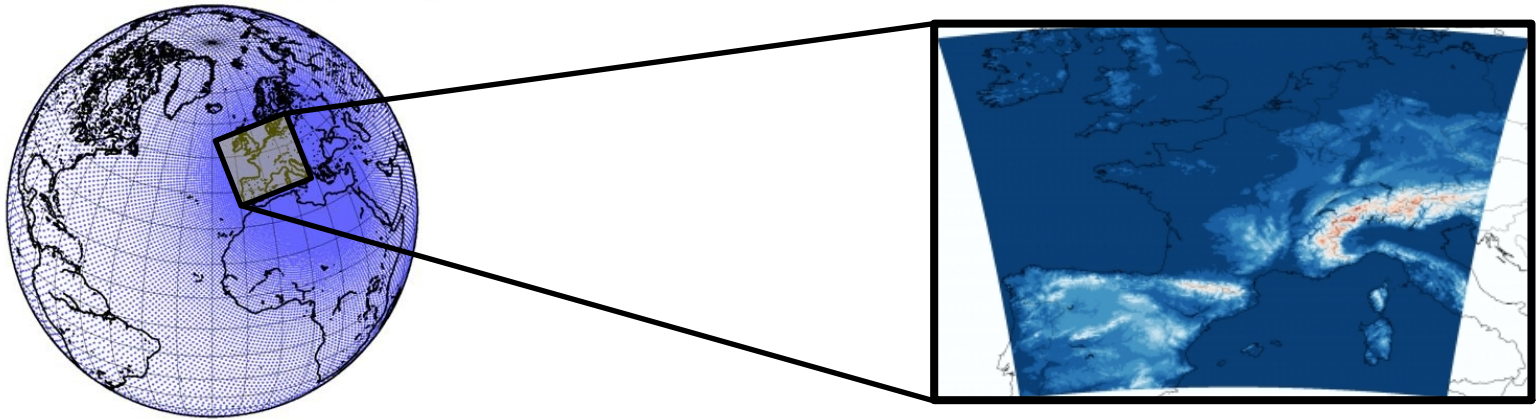

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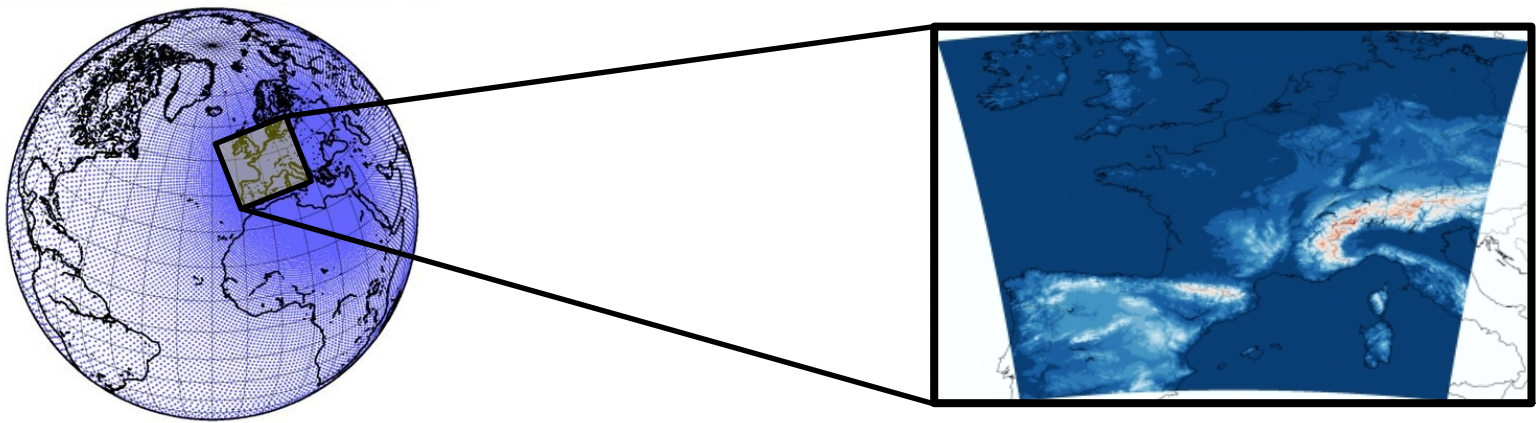

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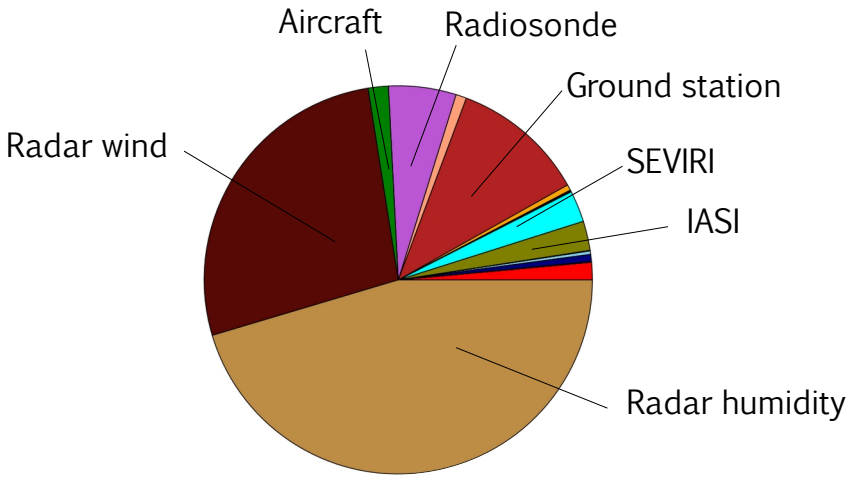
AROME

- Fine scale NWP model characterized by a non-hydrostratic dynamical core
- High skill short range forecasts of severe events such as intense Mediterranean precipitation, severe storms…

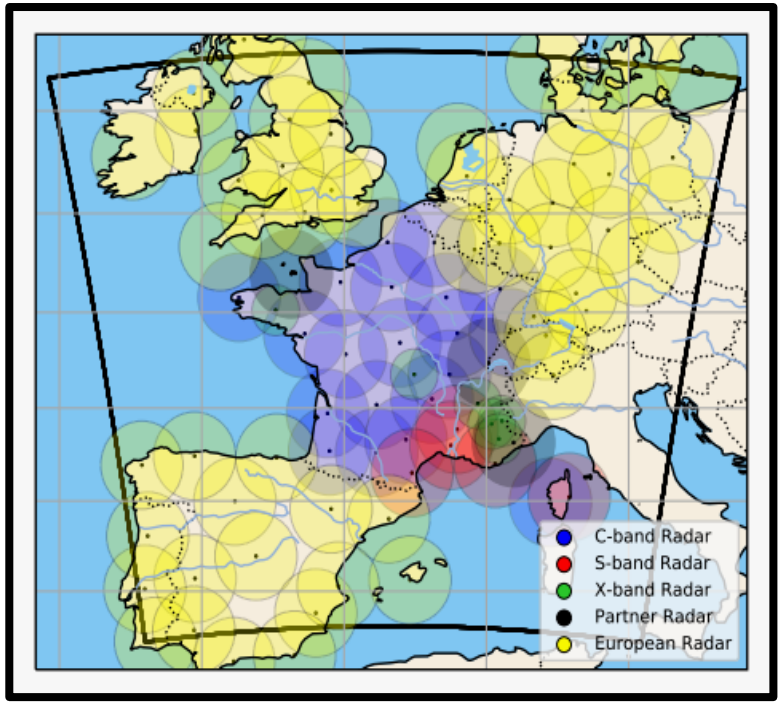
AROME 3D-Var data assimilation system

- AROME forecasts are initialized using analyses from a 3D-Var data assimilation system with 1h cycling
- Radar data represent 75% (France + Europe) of the observations assimilated mainly on land
- Infrared observations represent only 5% of the assimilated data for a rainy day



Ratio of the number of observations used in AROME (January 2021)

The Météo-France radar network



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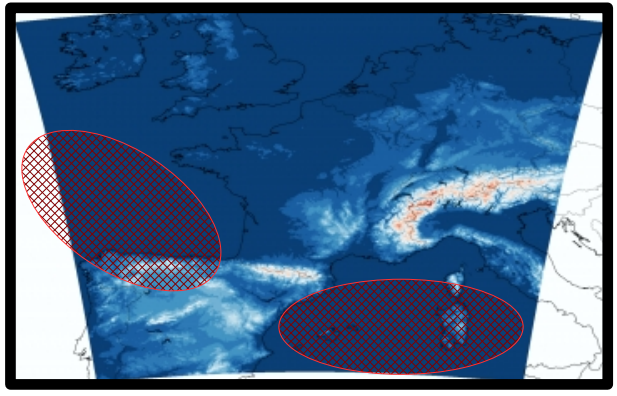

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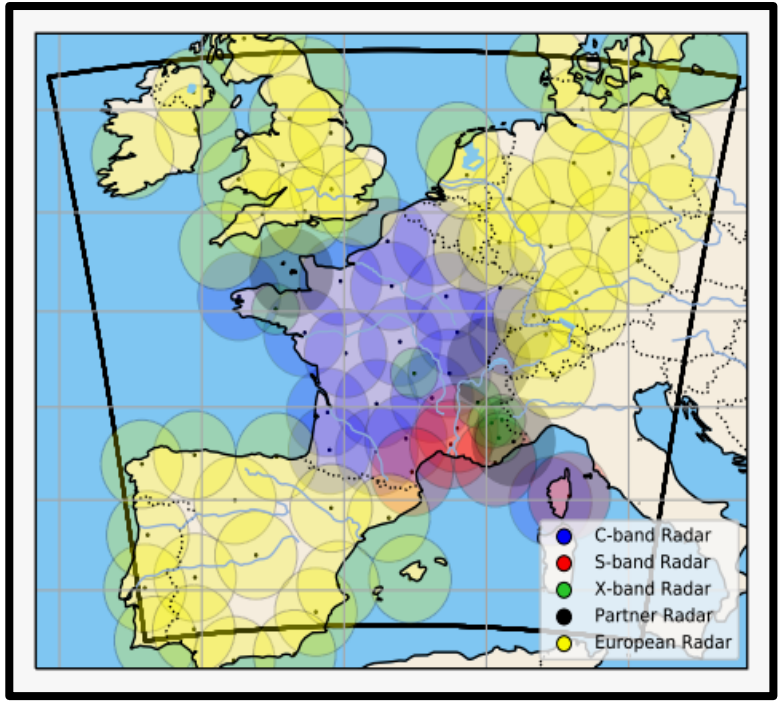

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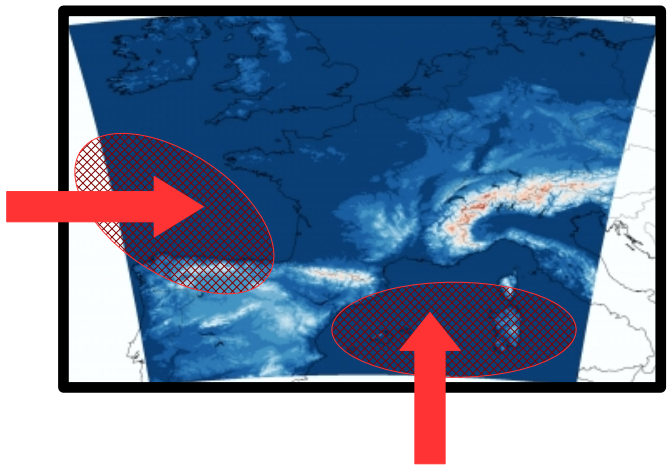

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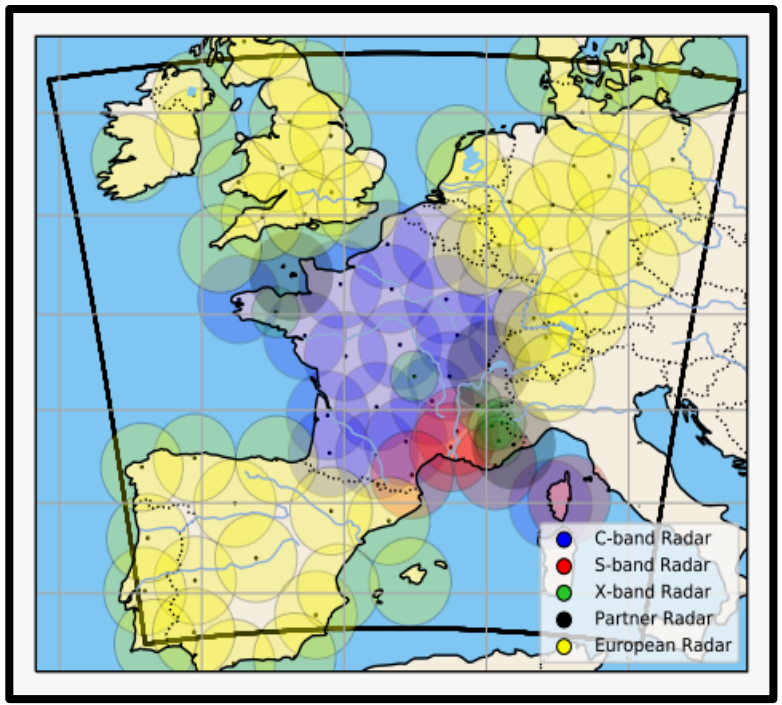

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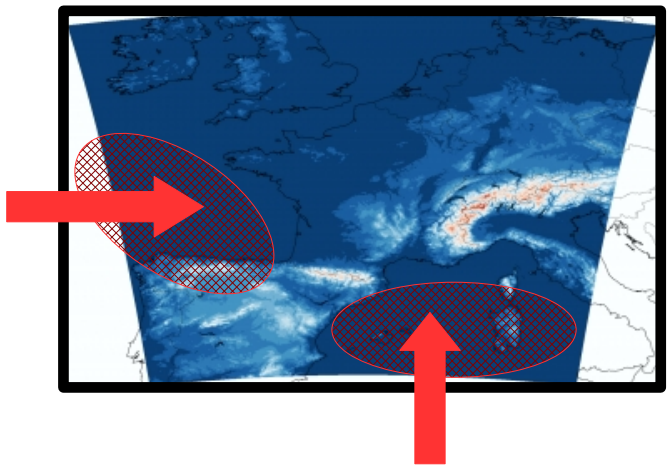

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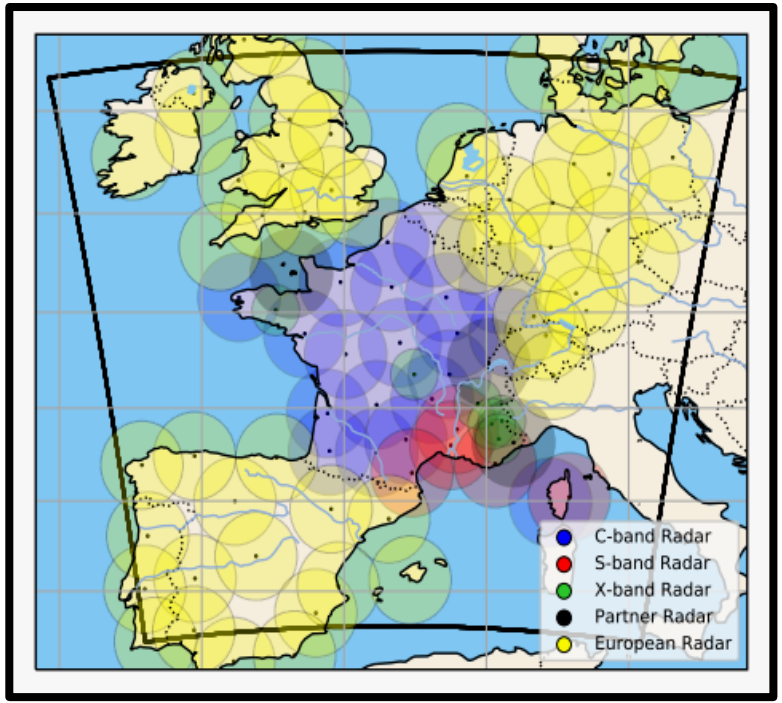

The observations made by the IRS sounder could make up for the lack of observations in these maritime areas and provide additional information on the full AROME domain

Objectives, tools and actions

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- Preparation of the assimilation of IRS for AROME
- Assessing the impact of IRS in addition to radars
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Outlook:

(1) Details on the Observing System Simulation Experiment framework

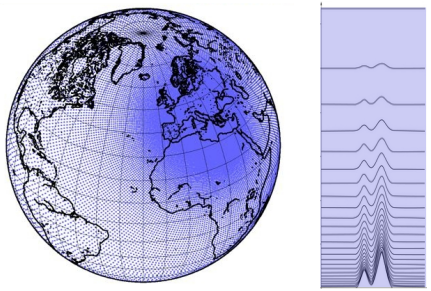
(2) Preparation and Validation of the Nature Runs

(3) General IRS channel selection for NWP

(4) Conclusions & Future work

(1) Observing System Simulation Experiment framework

Nature Run ARPEGE model
(5km – 105L up to 0.1 hPa)



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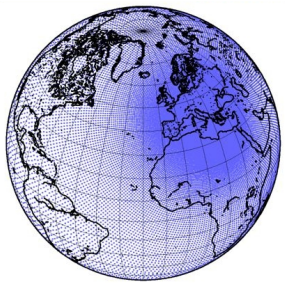
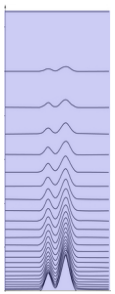
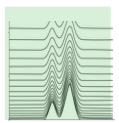
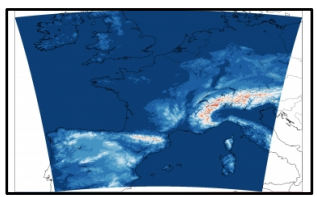




Nature Run AROME model
(2.5km – 105L up to 0.1 hPa)





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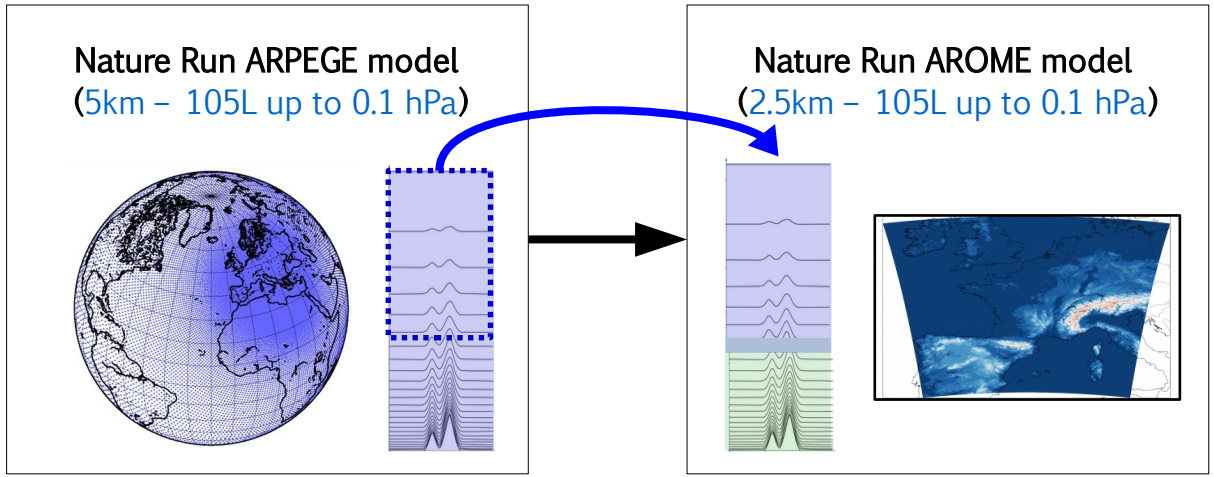

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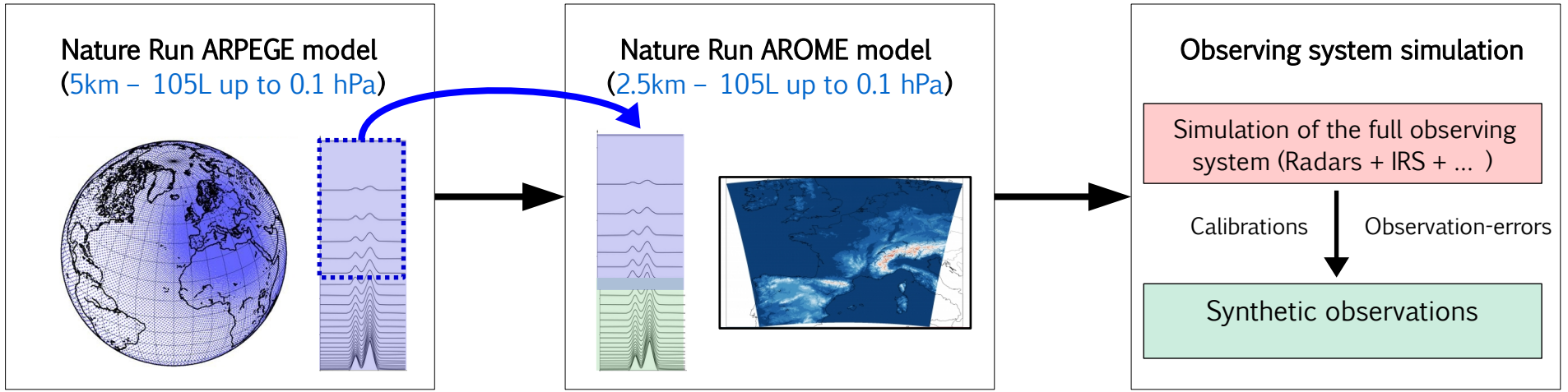

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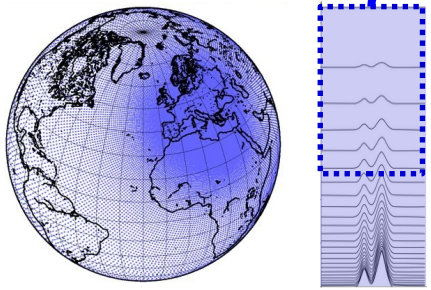

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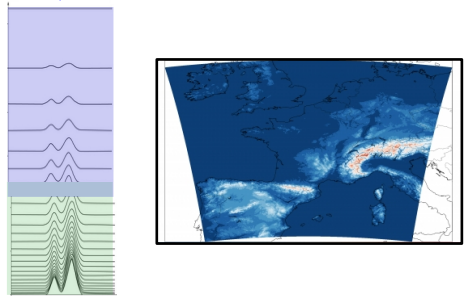


Observing system simulation

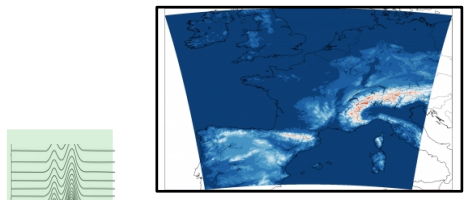
Simulation of the full observing system (Radars + IRS + …)

Calibrations

Observation-errors

Synthetic observations

AROME model 3D-Var Data Assimilation
(1.3km – 90L up to 10 hPa)



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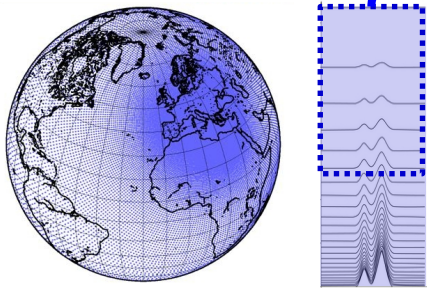

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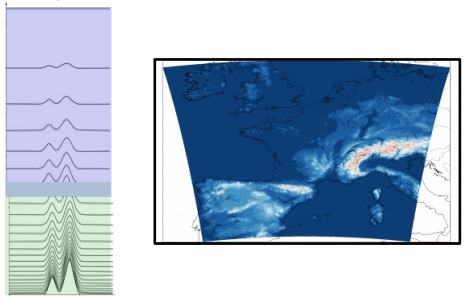

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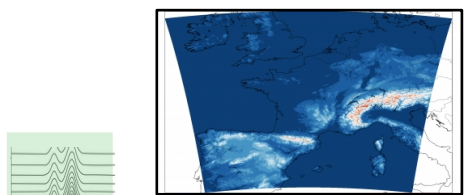

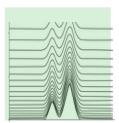

Experiments with & without IRS

Analysis

Forecast

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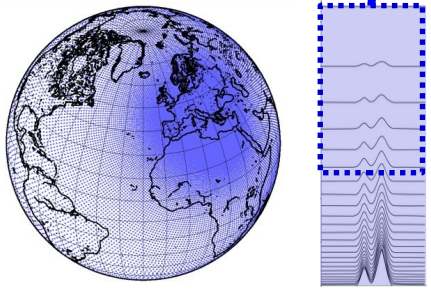

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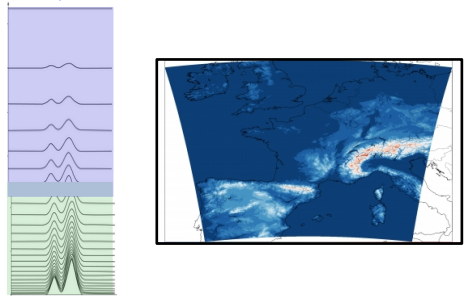

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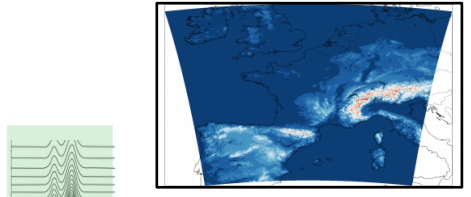

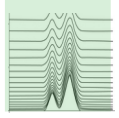

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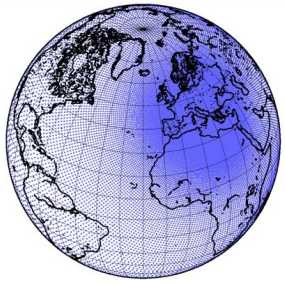

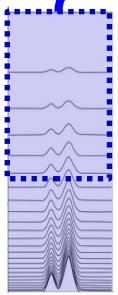

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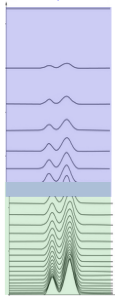

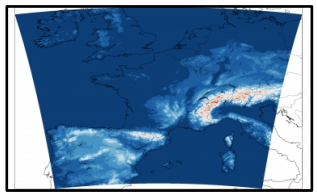

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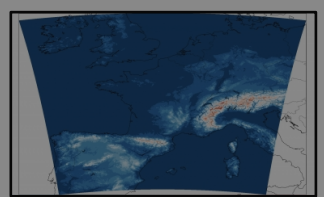

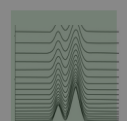

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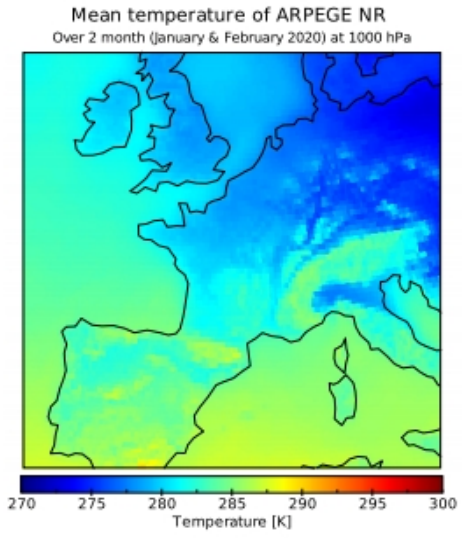
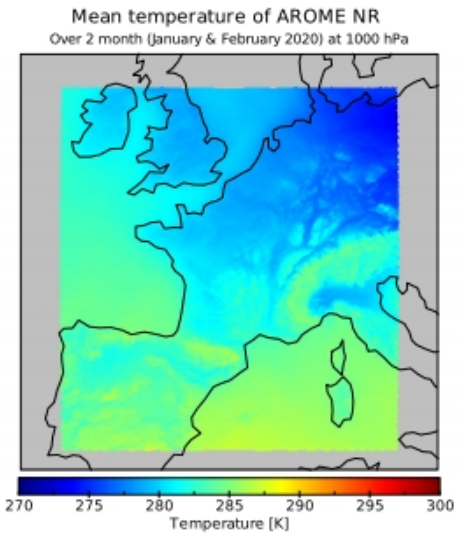
(2) Preparation and Validation of the Nature Runs

Mean T (24h forecast range) over Winter period (January & February 2020) at 1000 hPa

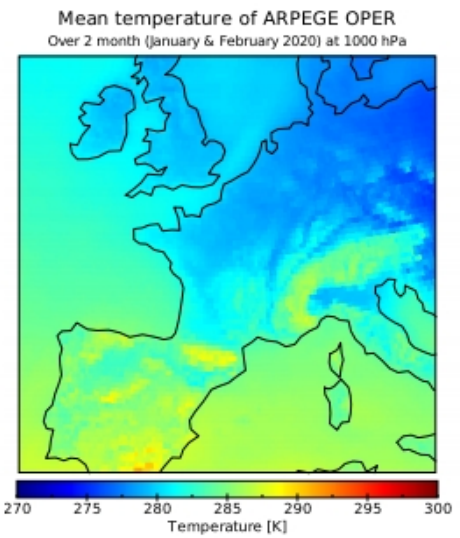
ARPEGE NR



AROME NR



ARPEGE OPER



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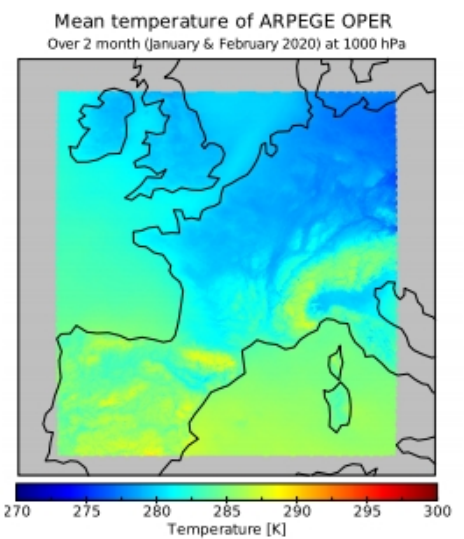
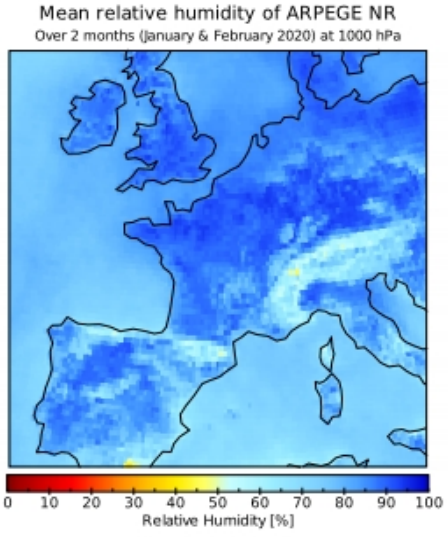


- Consistent structures, no time drift, no unrealistic regional effects
- On mean, no difference in temperature for the AROME NR in the winter period compared to the OPER
- On mean, AROME NR is 2K warmer in the summer period (not shown)

Mean q (24h forecast range) over Winter period (January & February 2020) at 1000 hPa

ARPEGE NR



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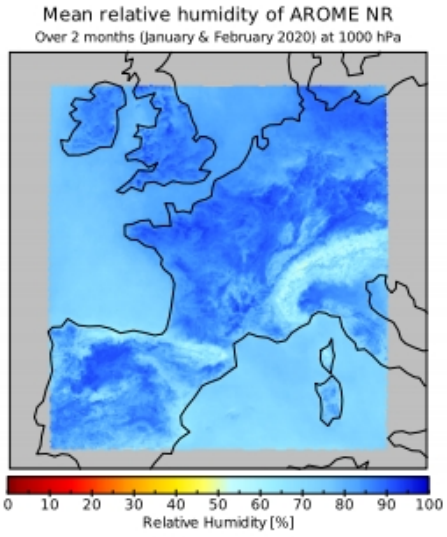

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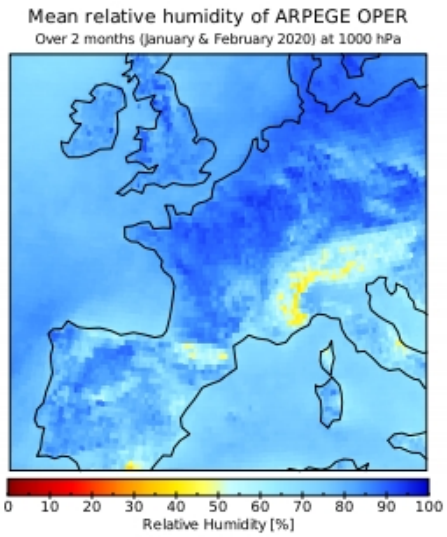

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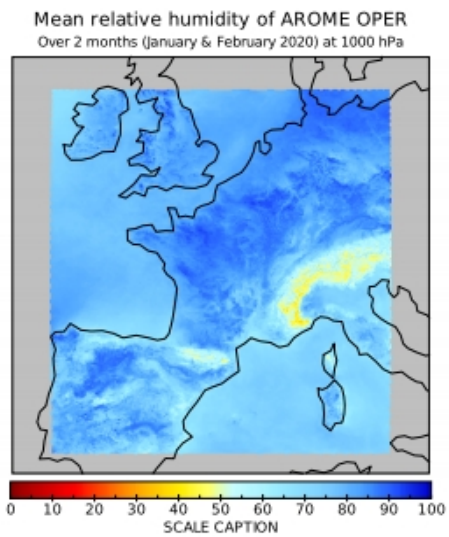
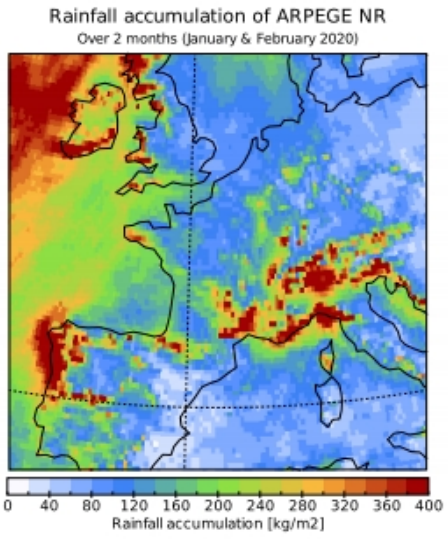


- Consistent structures, no time drift, no unrealistic regional effects
- On mean, AROME NR is 2% wetter in the winter period than OPER
- On mean, AROME NR is 9% drier in the summer period (not shown)

(2) Preparation and Validation of the Nature Runs

Rainfall accumulation (24h forecast range) over Winter period (January & February 2020) at 1000 hPa

ARPEGE NR



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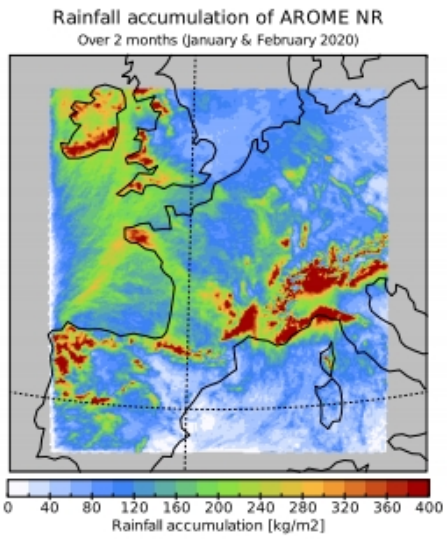
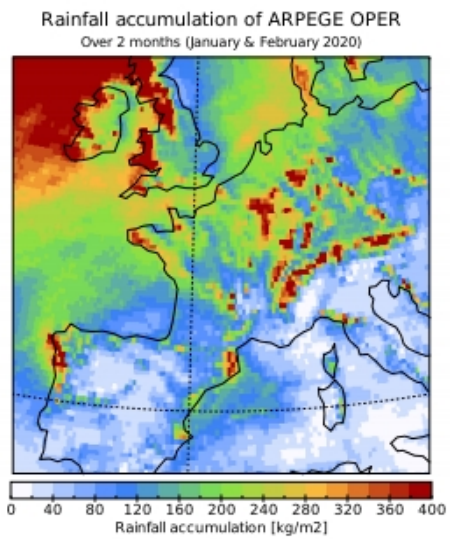
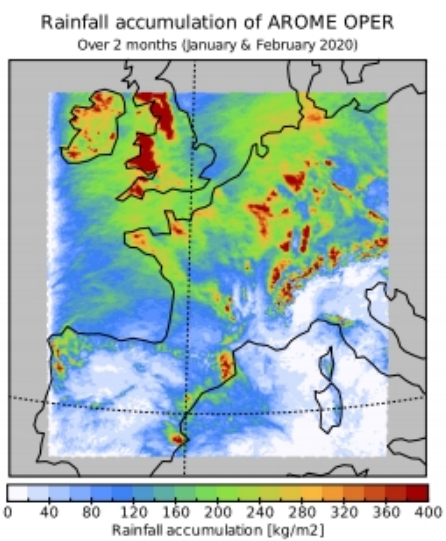


ARPEGE OPER

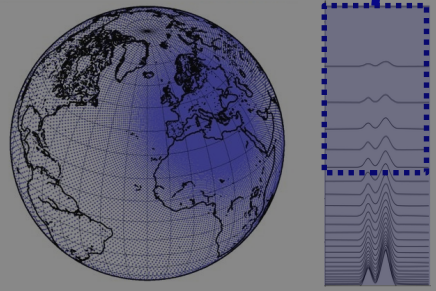


AROME OPER

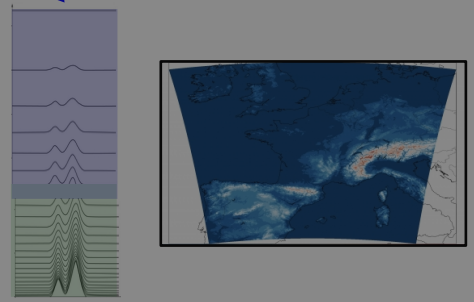


- Consistent structures, no time drift, no unrealistic regional effects
- Winter NRs are less rainy in the north-east of the domain and more in the southern half of the domain
- Summer NRs are generally less rainy (not shown)

Nature Run ARPEGE model
(5km – 105L up to 0.1 hPa)



Nature Run AROME model
(2.5km – 105L up to 0.1 hPa)



Observing system simulation

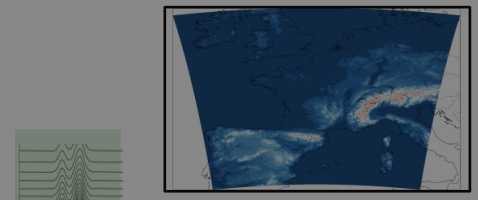
Simulation of the full observing system (Radars + IRS + …)

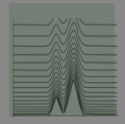
Calibrations

Observation-errors

Synthetic observations

AROME model 3D-Var Data Assimilation
(1.3km – 90L up to 10 hPa)





Experiments with & without IRS

Analysis

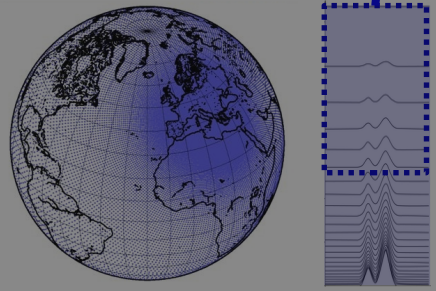
Forecast

Evaluations

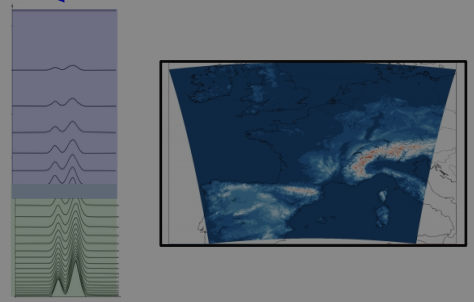
Forecast with IRS

Forecast without IRS

Nature Run ARPEGE model
(5km – 105L up to 0.1 hPa)



Nature Run AROME model
(2.5km – 105L up to 0.1 hPa)

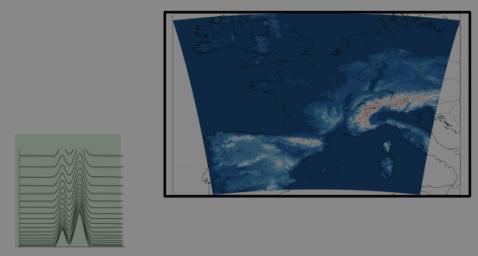


Observing system simulation

Simulation of limited number of IRS channels

→ General Selection of information among the 1960 IRS channels for NWP

AROME model 3D-Var Data Assimilation
(1.3km – 90L up to 10 hPa)



Experiments with & without IRS

Analysis

Forecast

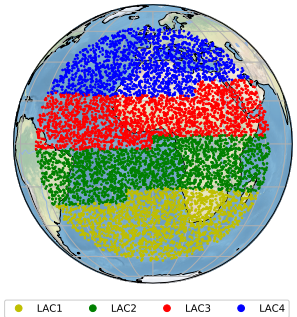
Evaluations

Forecast with IRS

Forecast without IRS

(3) General IRS channel selection for NWP

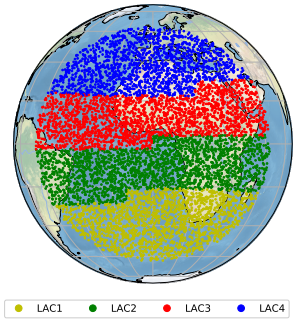
Creation of a database



- 7500 synthetic IRS observations
- 7500 background profiles (T, q, O_3, surface parameters)
- Observation errors matrix from the converted NEΔT(T) for the corresponding scene temperature T for each pixel

(3) General IRS channel selection for NWP

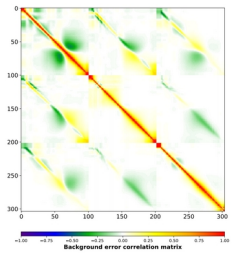
Creation of a database



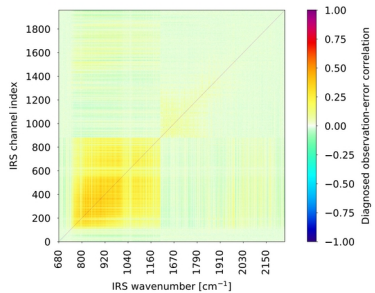
- 7500 synthetic IRS observations
- 7500 background profiles (T, q, O_3, surface parameters)
- Observation errors matrix from the converted NEΔT(T) for the corresponding scene temperature T for each pixel

Errors

- Use of a multi-variate background error covariance matrix **B** (T, q, O_3, T_{skin})

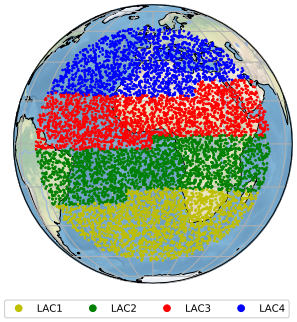


- Use of a diagnosed observation error covariance matrix **R** with the Desroziers method



(3) General IRS channel selection for NWP

Creation of a database



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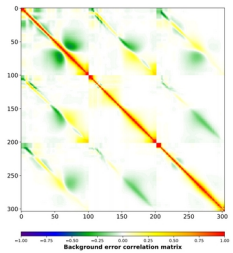

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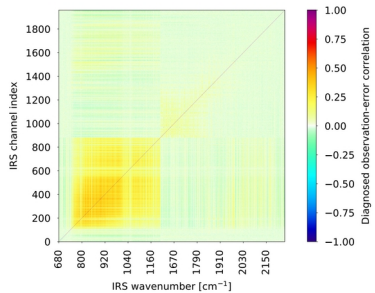
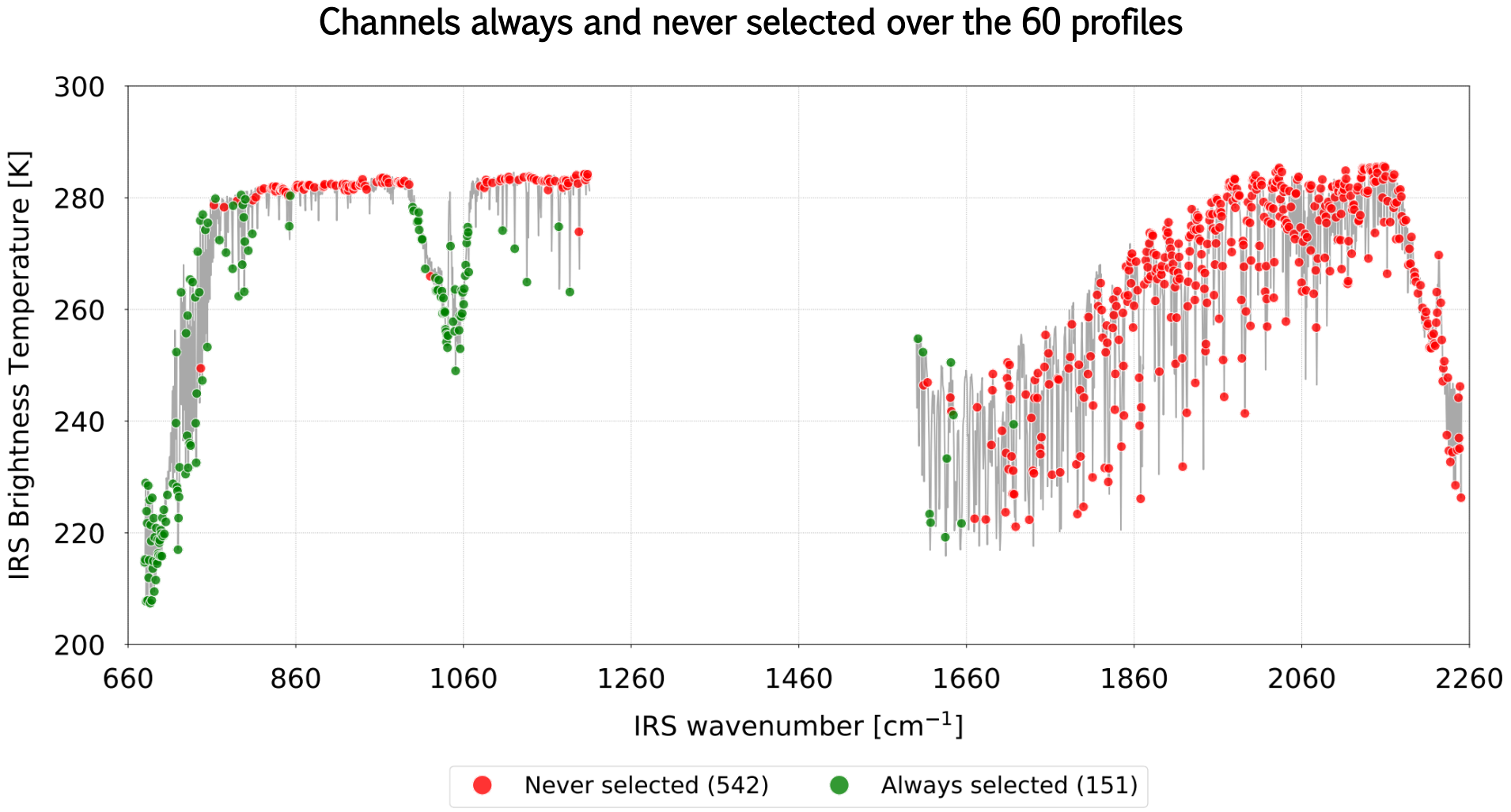


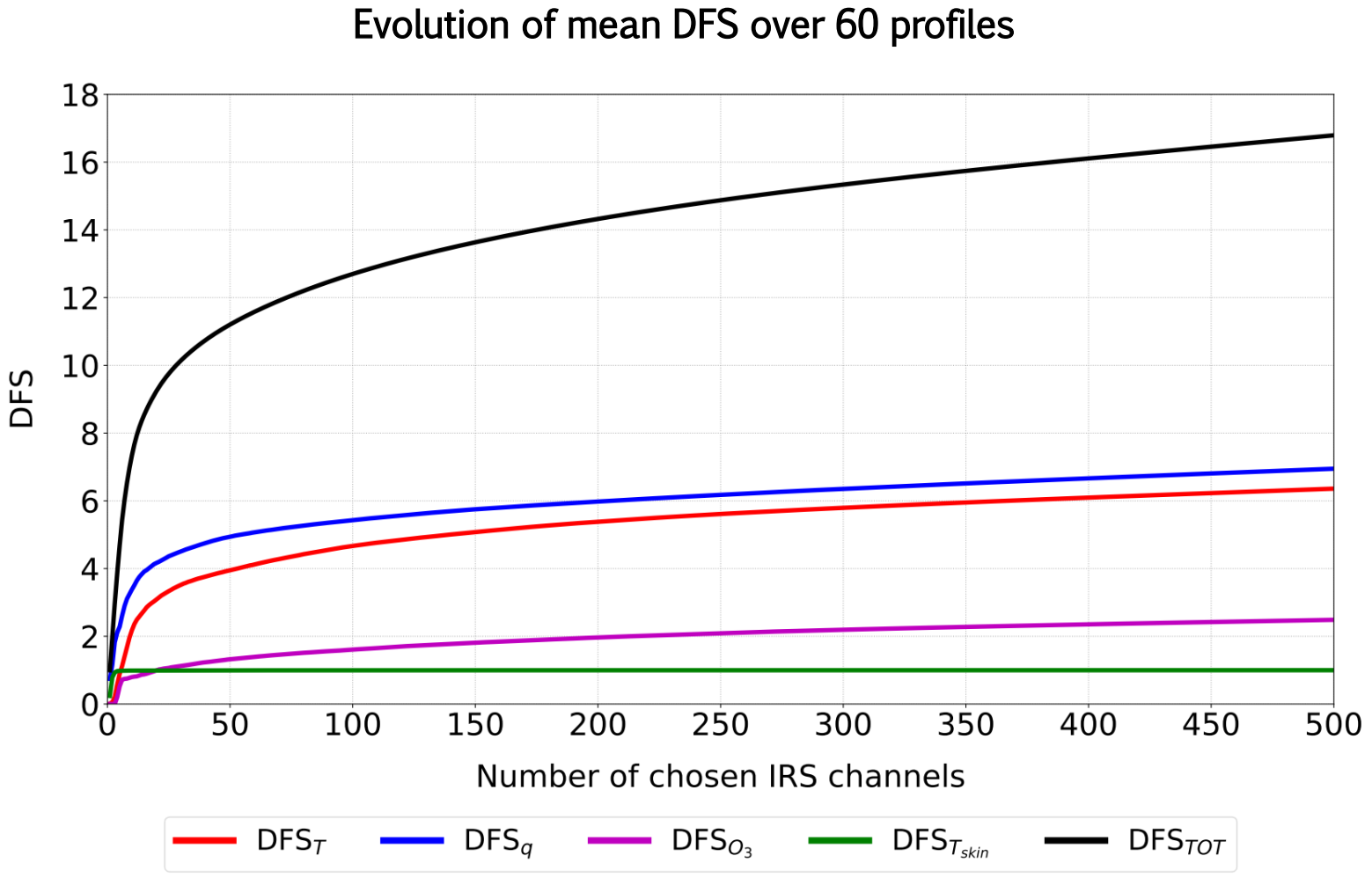
Channel selection method

- Selection among 60 profiles representative of the atmospheric variability
- Use of the information content method (Degree of Freedom for Signal)

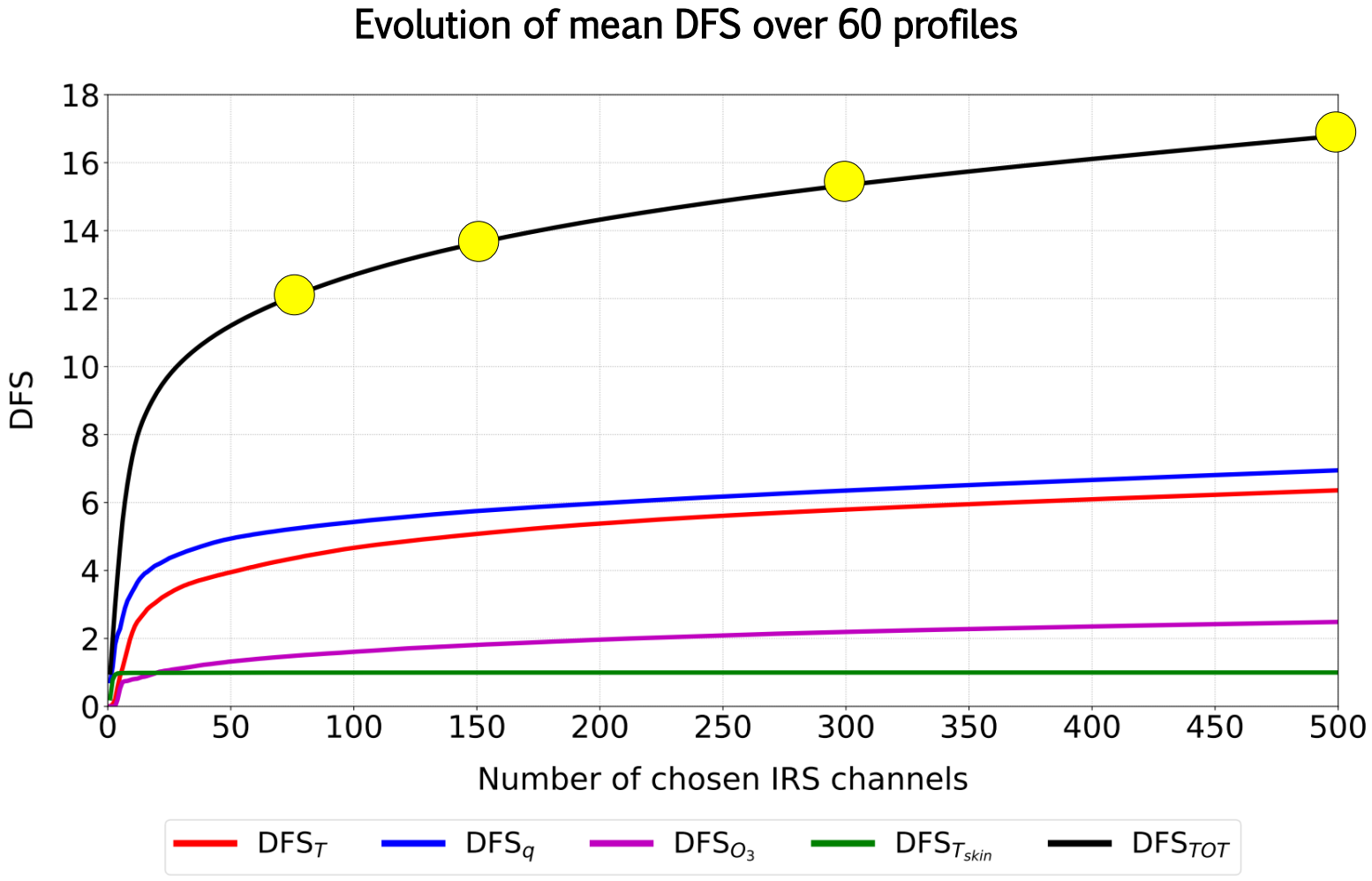
  DFS = Tr (**I** – **AB**$^{-1}$)
- Total DFS including the DFS of T, q, O_3 and Tskin as a figure of merit


Channels always and never selected over the 60 profiles
IRS Brightness Temperature [K]
300
280
260
240
220
200
660
860
1060
1260
1460
1660
1860
2060
2260
IRS wavenumber [cm^{-1}]
Never selected (542)
Always selected (151)

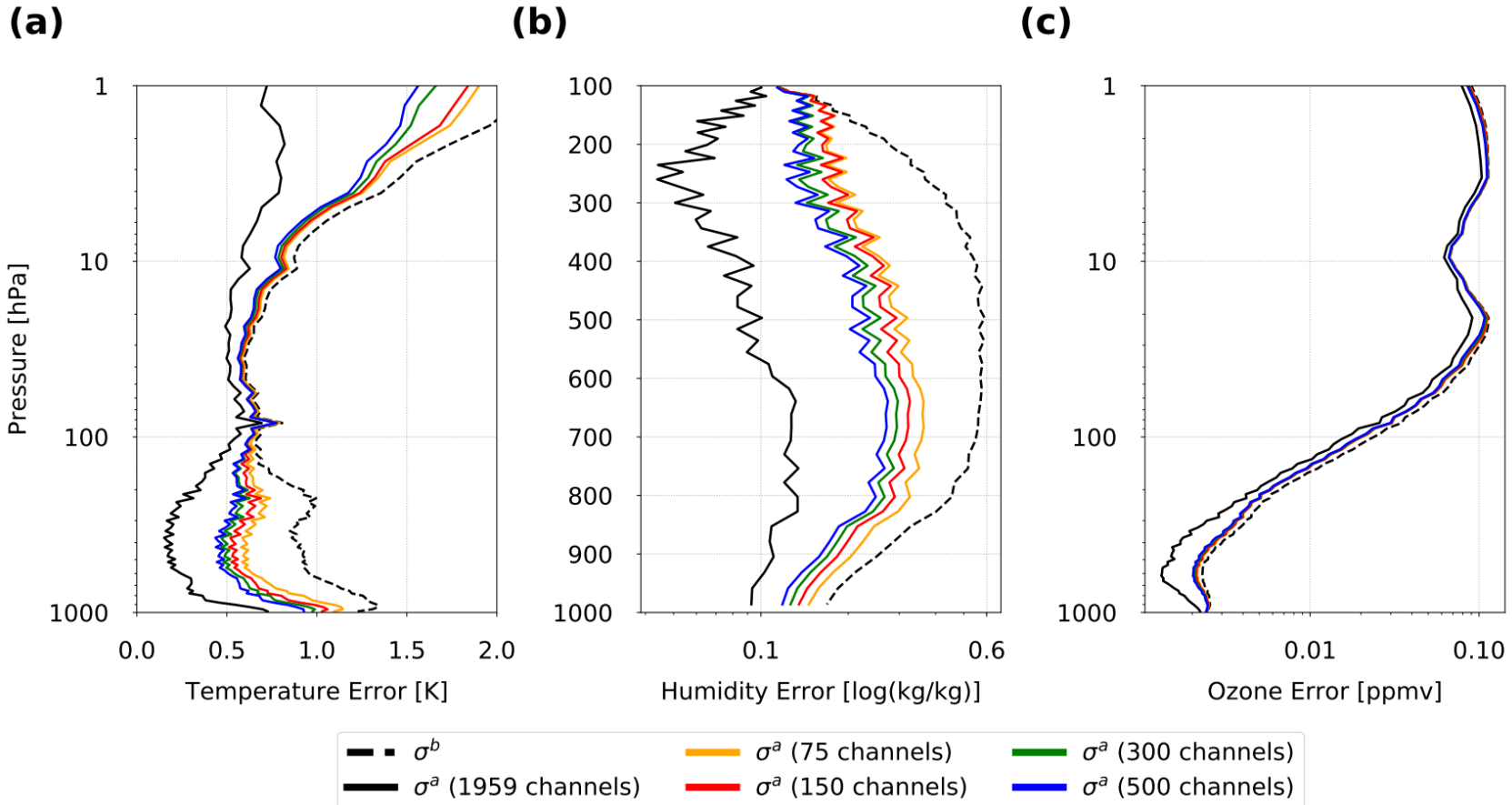
(3) General IRS channel selection for NWP



(3) General IRS channel selection for NWP

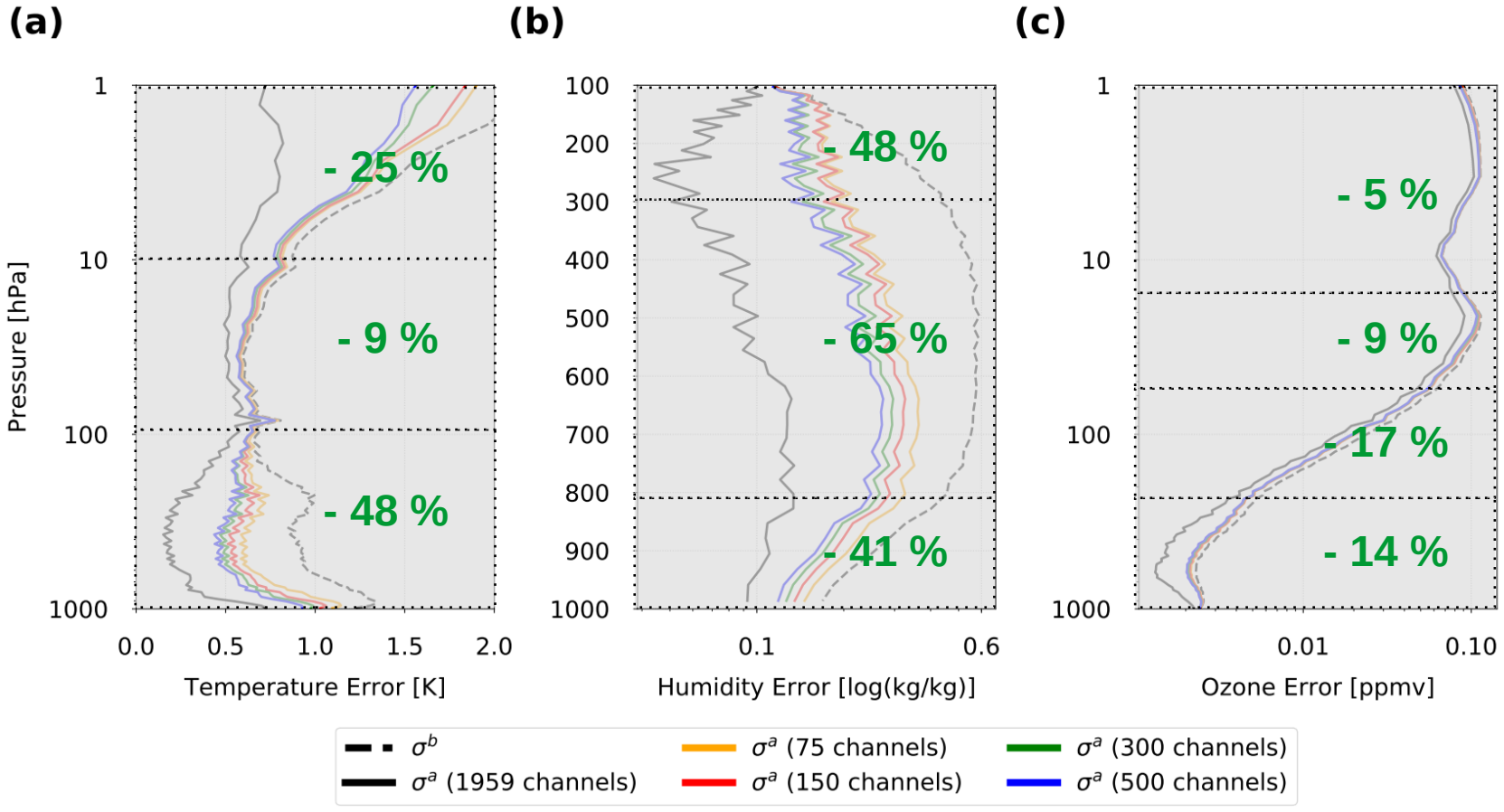


Error profiles (over 1700 profiles considered clear)

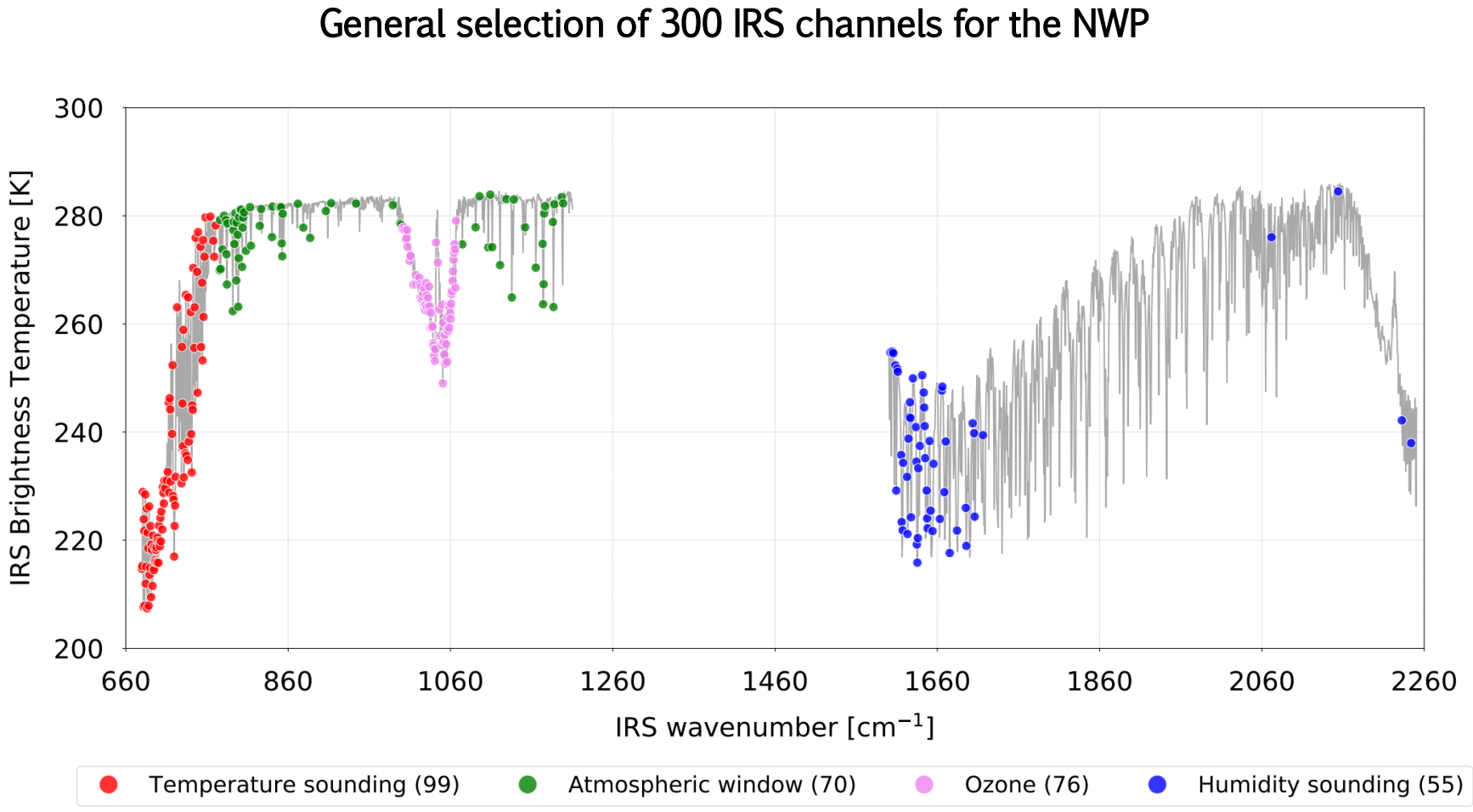


(3) General IRS channel selection for NWP

Relative Analysis-errors reduction for the 300 selected channels



(3) General IRS channel selection for NWP



(4) Conclusion

Channel selection:

- General selection of **300** IRS channels for NWP
- Analysis error reduction of up to **48%** for temperature, **65%** for humidity and **17%** for ozone
- Article in preparation

OSSE framework:

- The NR ARPEGE and AROME show realistic forecasts compared to the operational forecasts
- The summer NR is rather hot, dry and not very rainy and the winter NR is rather cold, wet and rainy

(4) Future work

Channel selection:

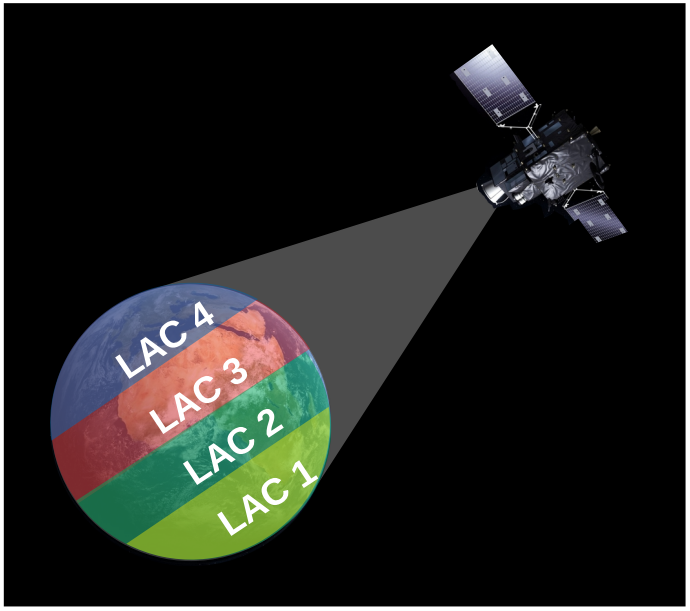
- Specific selection for AROME
- Selection with reconstructed radiances (**waiting for the PCs information**)
- Selection with real observations (new R-matrix) after MTG launch

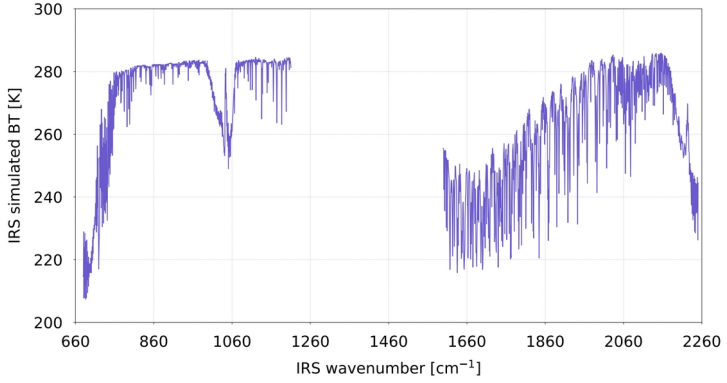
OSSE framework:

- Simulation of the AROME observation system and creation of synthetic observations (**including radars for the first time**)
- Calibration and adjustment to get closer to the real assimilation system
- Evaluation of the assimilation of IRS in AROME and use of the specific selected channels adapted for a regional model


Thank you for your attention

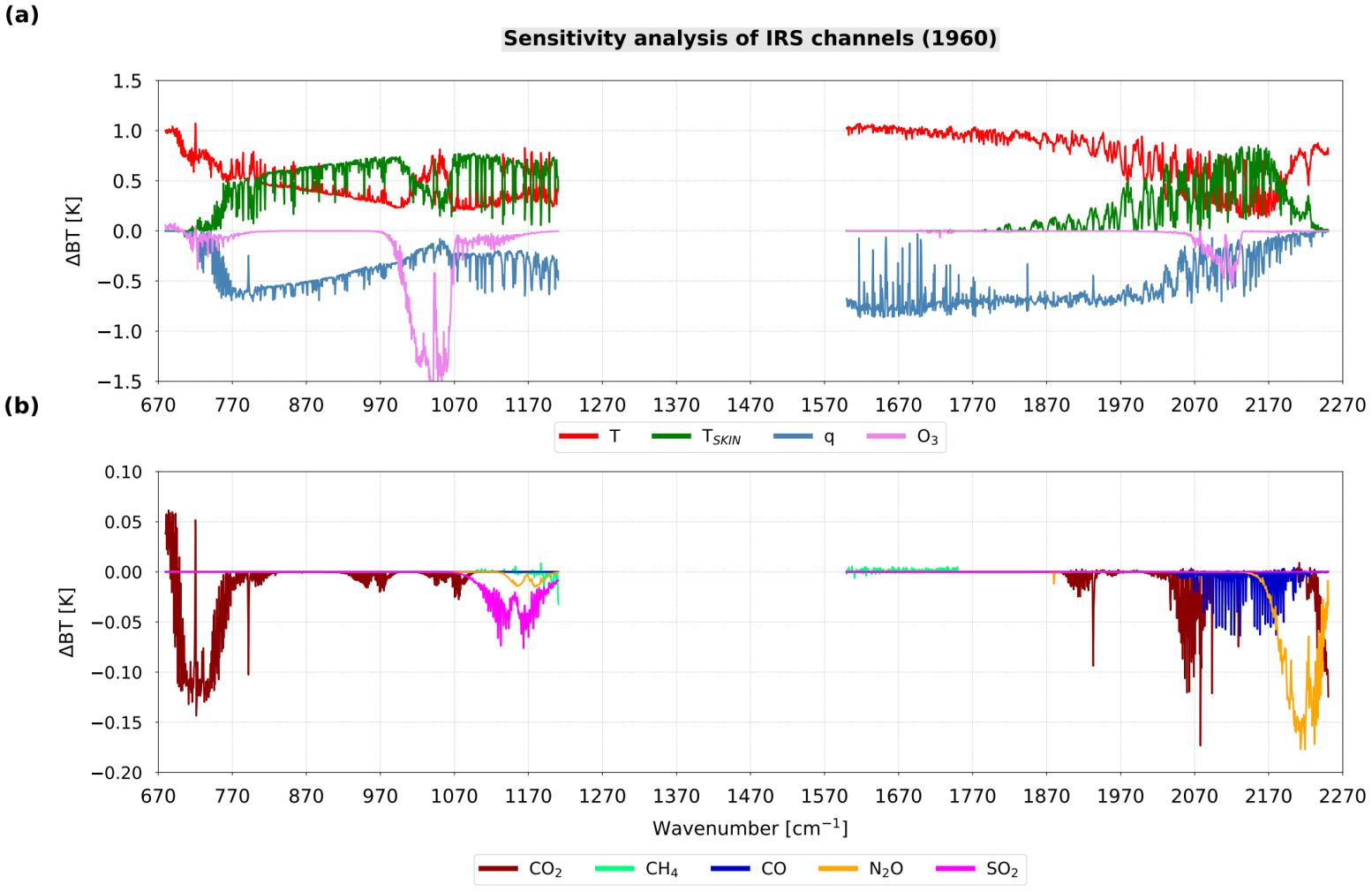
The IRS infrared sounder



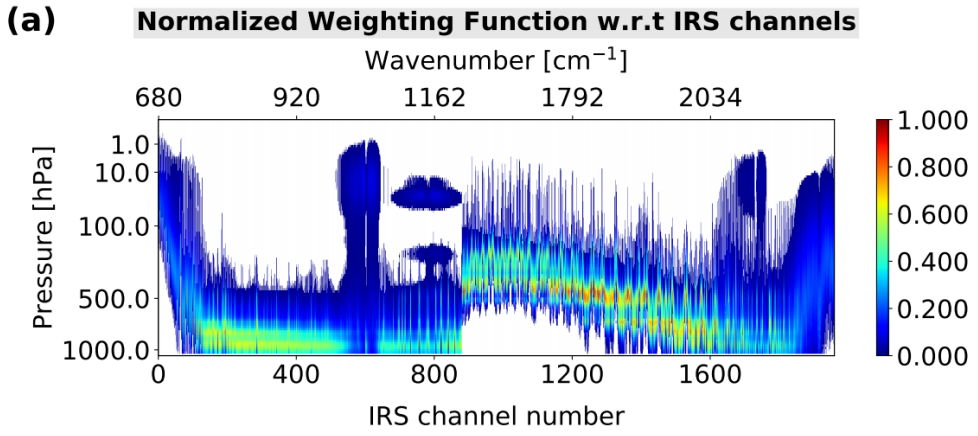


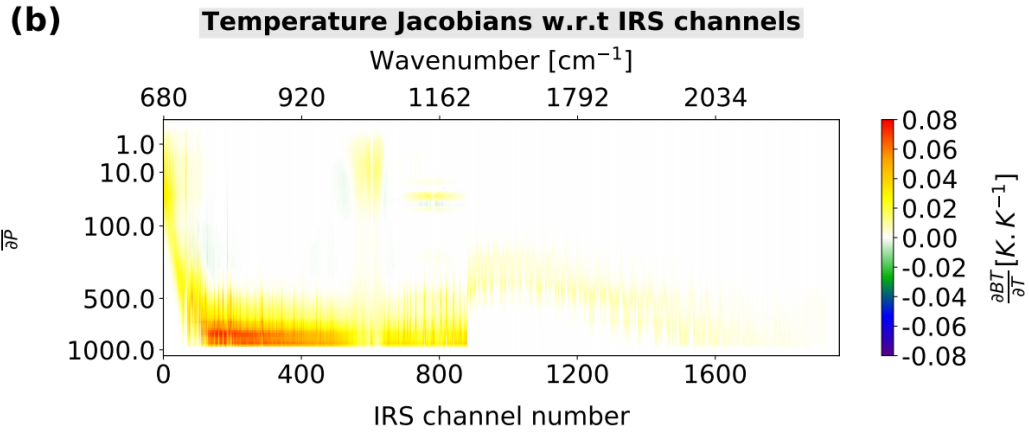
- Planned launch in 2024 onboard geostationary sounding satellite **MTG-S**
- Measurement with 4 Local Area Coverage (**LAC**) zones and Earth disc covered with ~ 313 Dwells
- **LAC 4** covering Europe every 30 minutes
- Each Dwell is taken in **10 s** and covers about **640 x 640** km² at nadir with **160 x 160** spatial samples
- Each Pixel covers ~ **6 x 6 km²** over Europe (4 x 4 km² at nadir)
- **1960** channels between **680 - 1210 cm^{-1}** and **1600 - 2250 cm^{-1}**
- Spectral sampling of ~ 0.6 cm^{-1} for both bands
- Measurements in CO_2, O_3, H_2O absorption bands and atmospheric windows

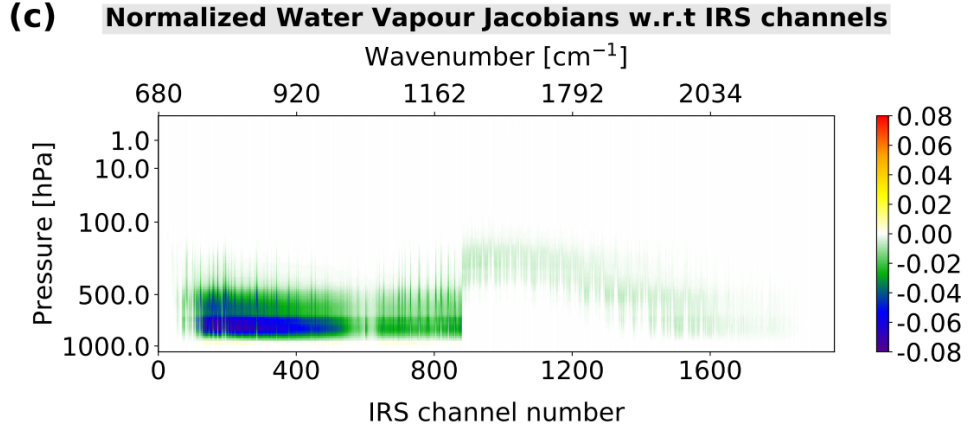
IRS sensitivity analysis

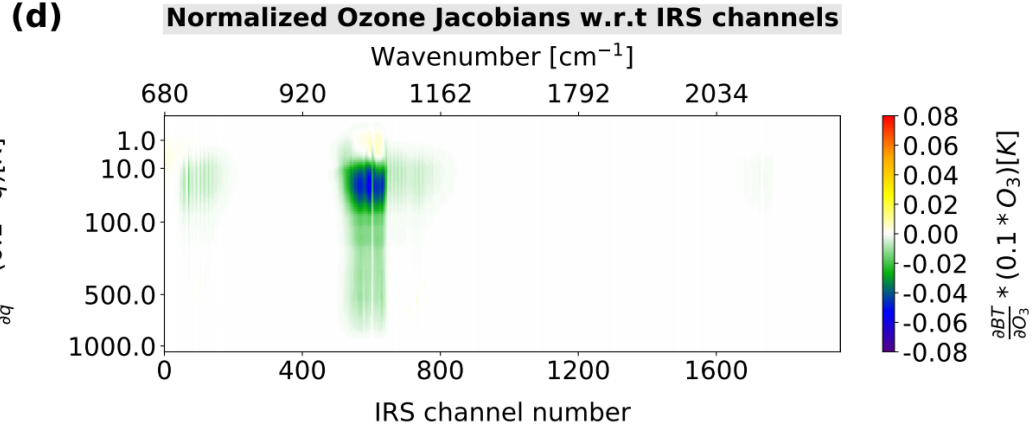


IRS Weighting Function and Jacobians









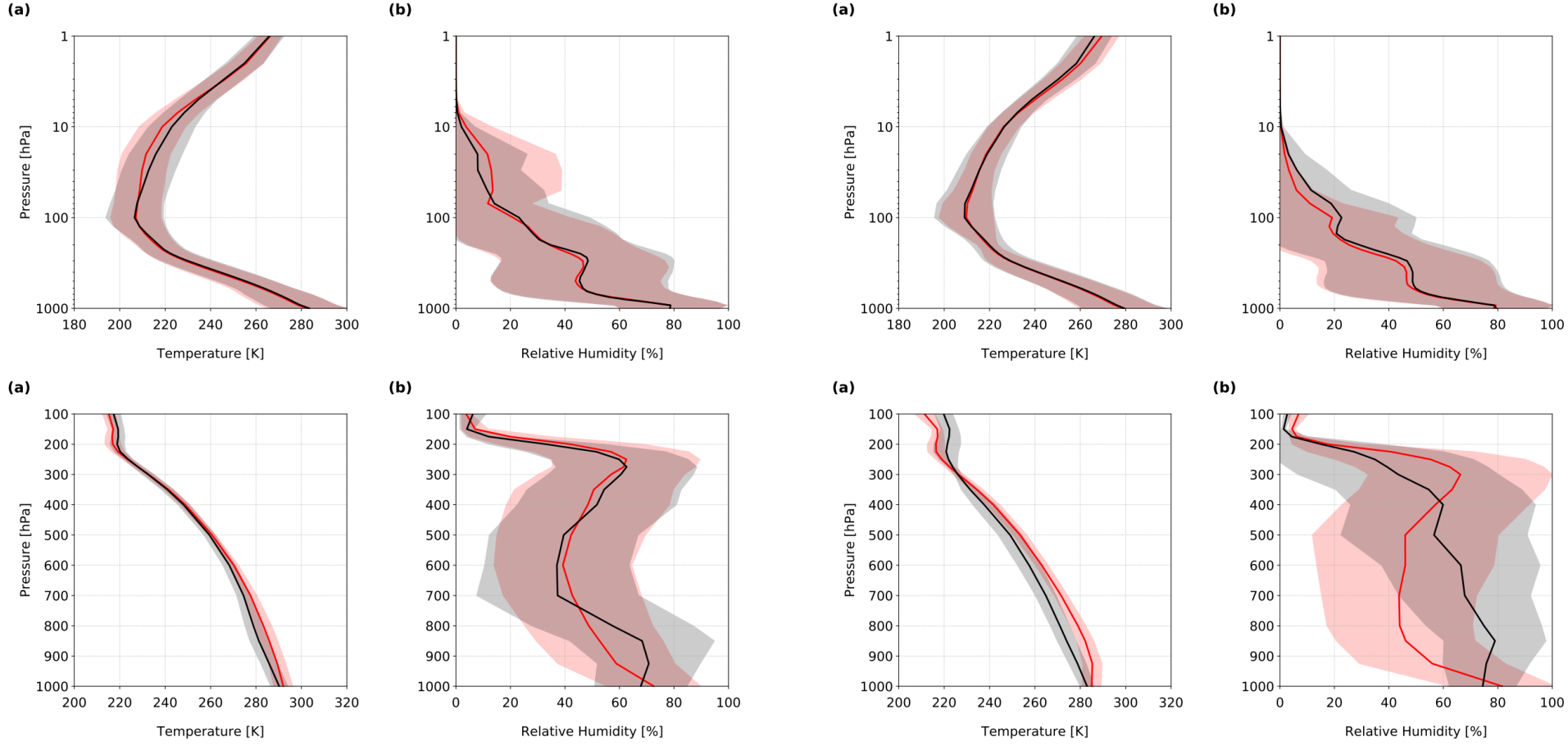
(3) Preparation and Validation of the Nature Runs

Mean T & q (24h forecast range) over Summer period (JA)

Mean T & q (24h forecast range) over Winter period (JF)

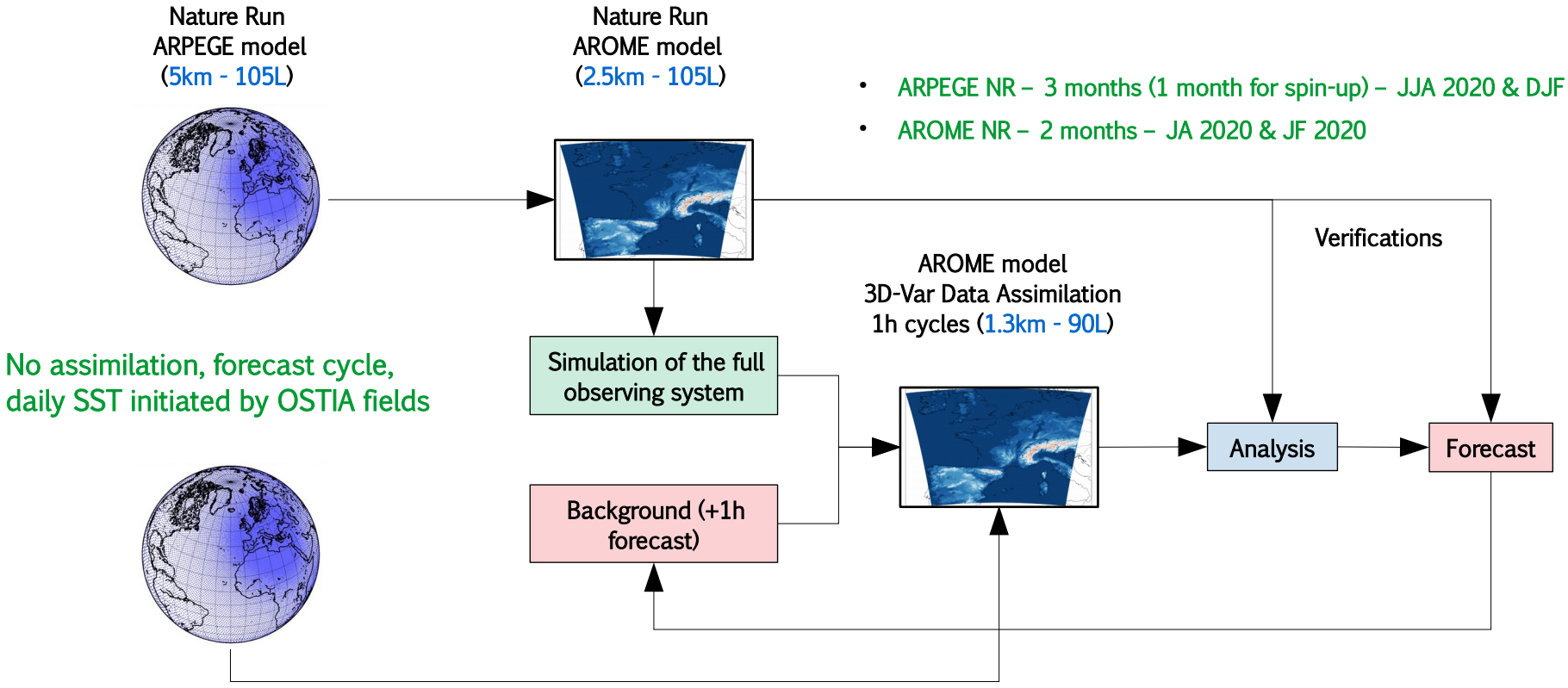
ARPEGE

AROME



(2) Details on the OSSE framework – Objectives & method

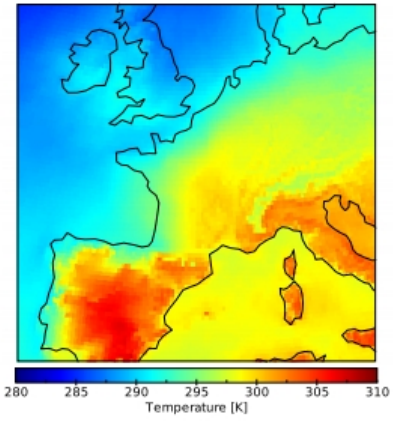
- Prepare the assimilation system and data flow for IRS observations for AROME NWP
- Simulation of the full Observing System including Radar data to assess the future impact of the IRS on top of the full set observation
- Assess the contribution of IRS observations to weather analysis and forecasts

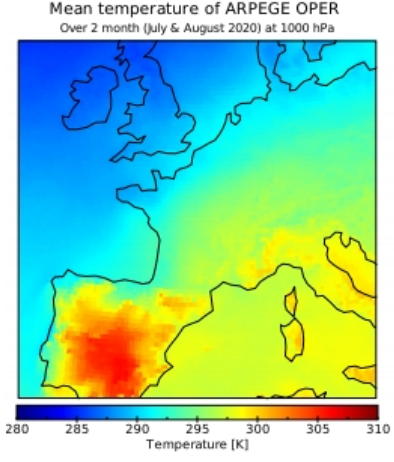


(3) Preparation and Validation of the Nature Runs

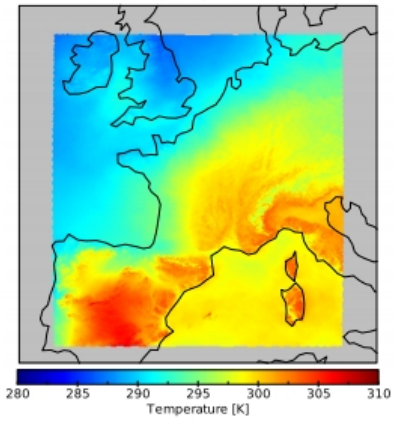
Mean T (24h forecast range) over Summer period (JA)

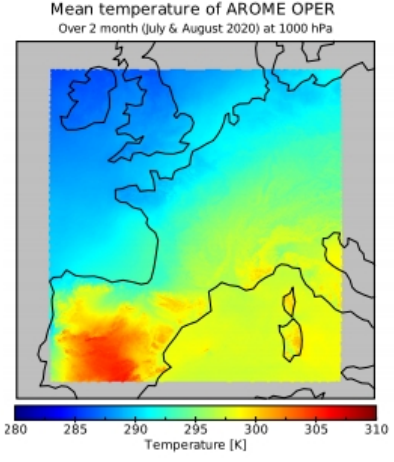
ARPEGE





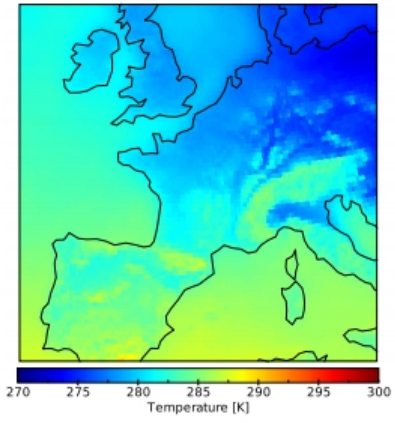
AROME

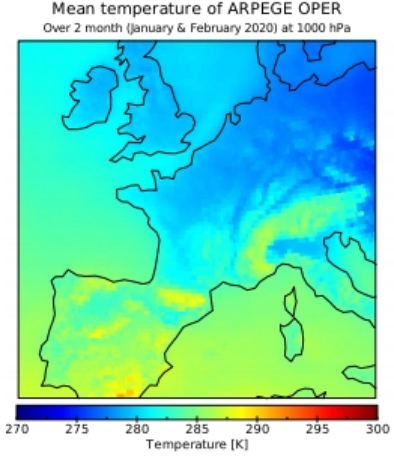




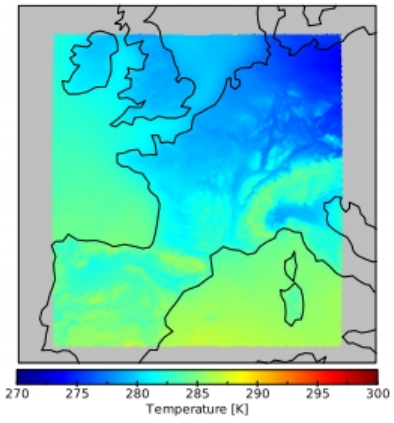
Mean T (24h forecast range) over Winter period (JF)

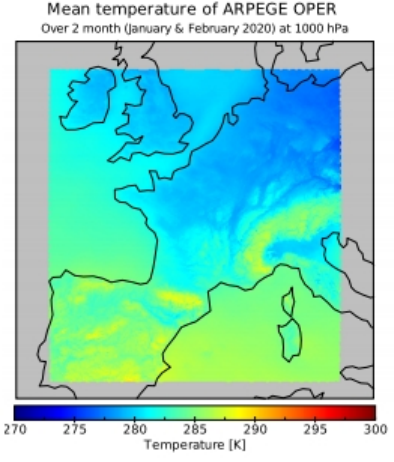
ARPEGE





AROME





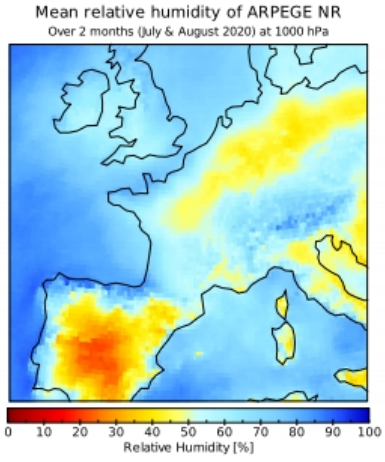
Nature Run

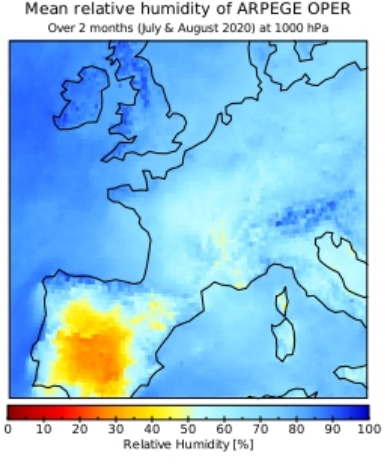
OPER

(3) Preparation and Validation of the Nature Runs

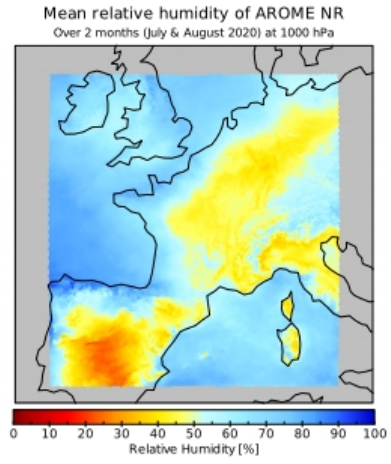
Mean q (24h forecast range) over Summer period (JA)

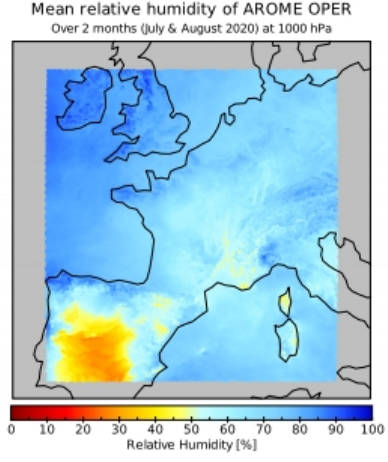
ARPEGE





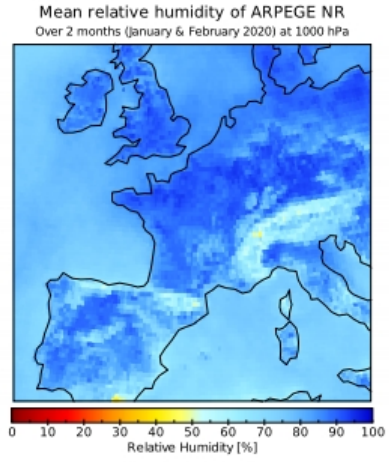
AROME

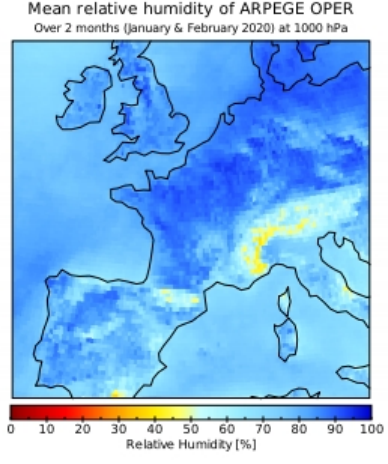




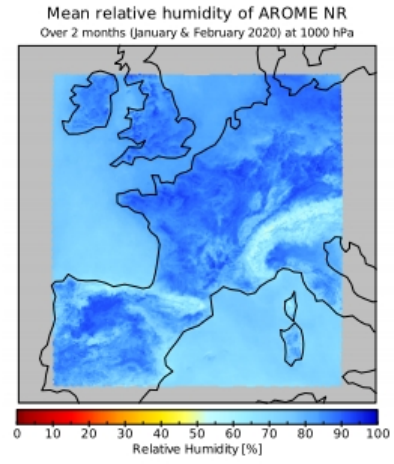
Mean q (24h forecast range) over Winter period (JF)

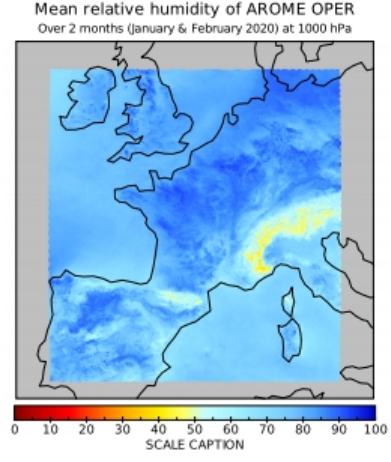
ARPEGE





AROME





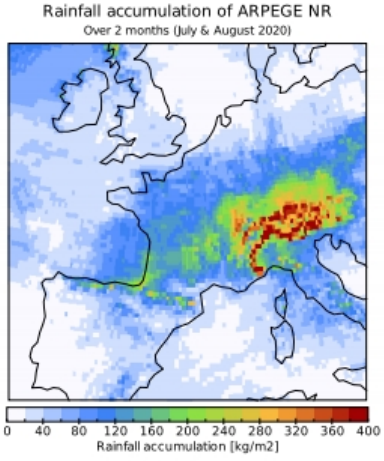
Nature Run

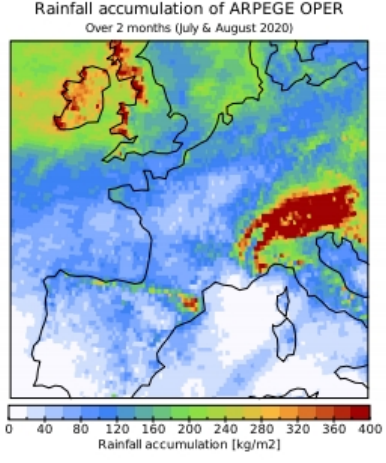
OPER

(3) Preparation and Validation of the Nature Runs

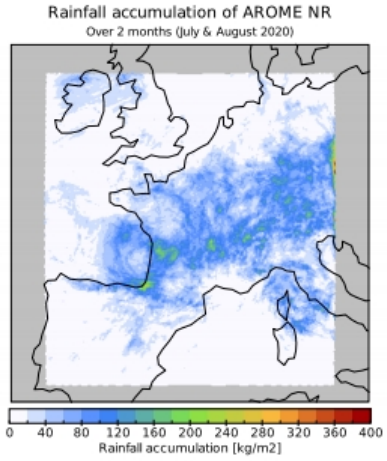
Rainfall accumulation over Summer period (JA)

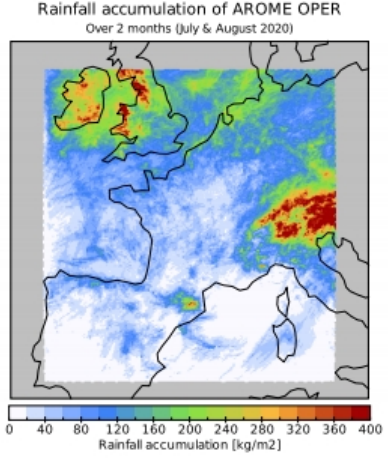
ARPEGE





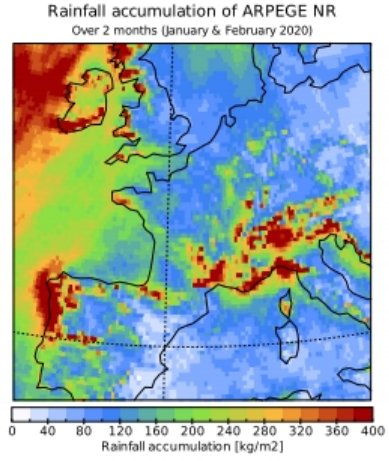
AROME

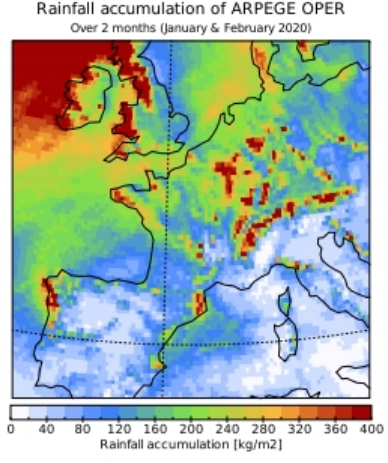




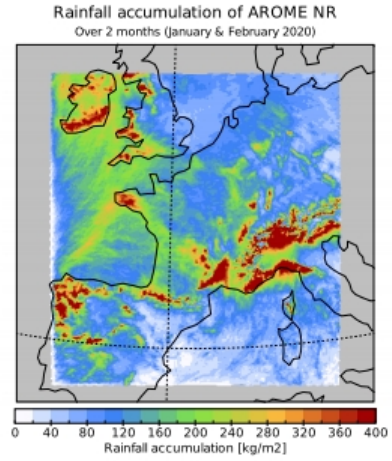
Rainfall accumulation over Winter period (JF)

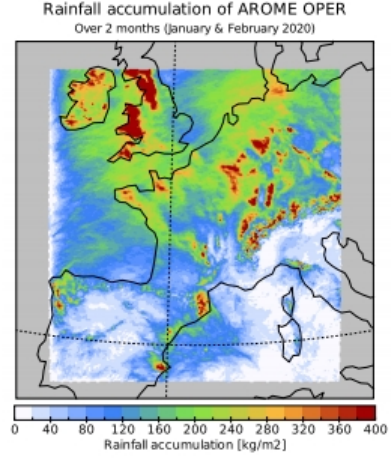
ARPEGE





AROME





Nature Run

OPER

(4) IRS channel selection – 1D framework

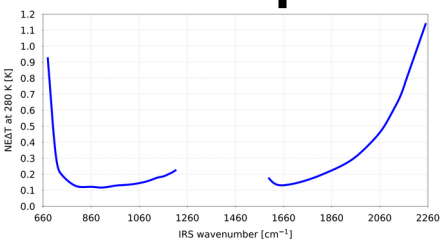
Creation of a 1D database with the Synthetic Observations method - General selection for the NWP ARPEGE (a more specific selection for the regional AROME model will be made later)

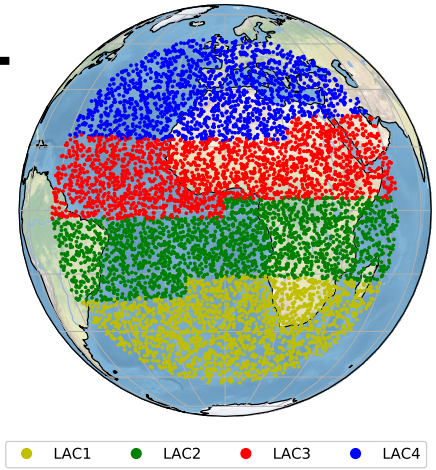
Simulation of IRS observations (1960 channels) for 7500 pixels

Realistic atmospheric profiles (7500) x^t (T, q, O_3, surfaces) extracted from the ARPEGE model (Research experience) and colocated to the IRS pixel geometry

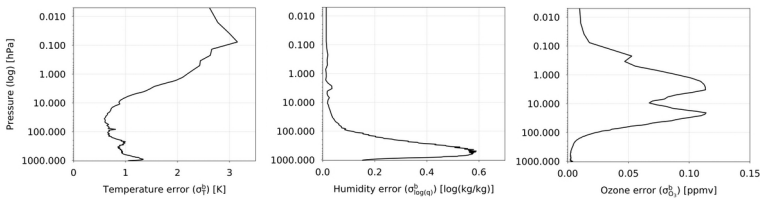
RTTOV v12

$$y = H(x^t) + R_{NE\Delta T}^{1/2} \cdot \eta^o$$





$$x^b = x^t + B^{1/2} \cdot \eta^b$$



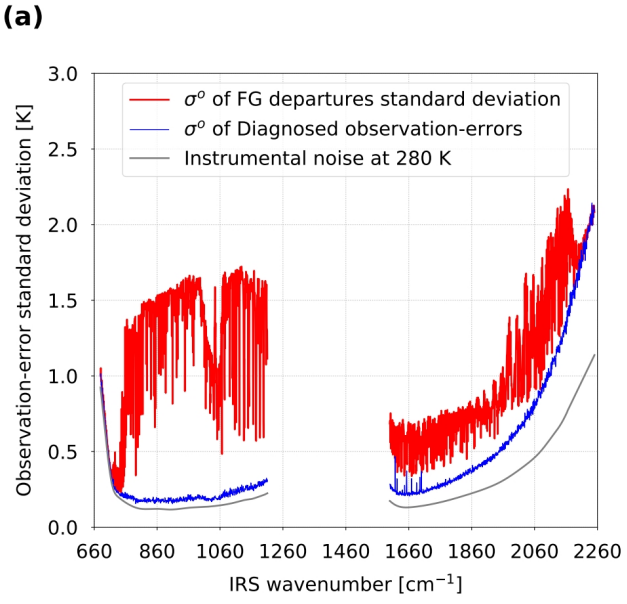
R from the converted NEΔT(T) for the corresponding scene temperature T for each pixel

B from multi-variate background-error covariance matrix for T, q, O_3 and Tskin

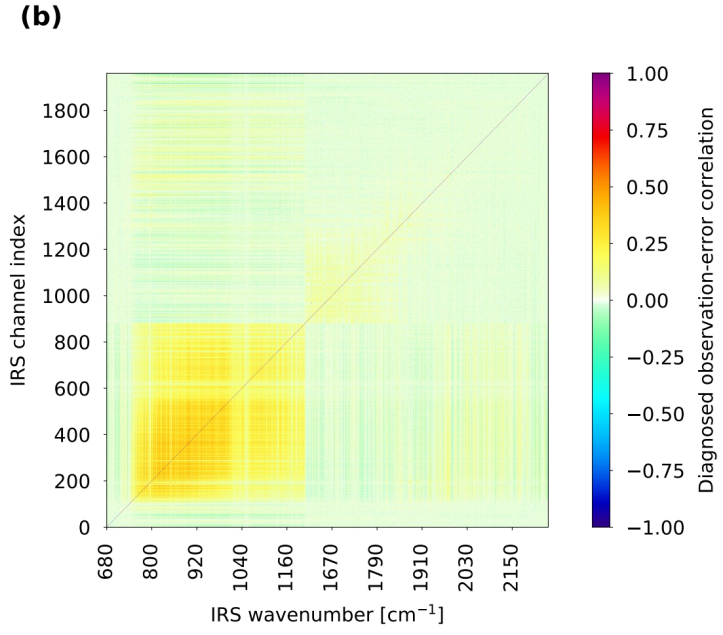
(4) IRS channel selection – Diagnosed **R** Matrix

- Clear pixel identification using the McNally & Watts algorithm (1700 pixels)
- Use of 1D-Var data assimilation with synthetic observations **y** and background $\mathbf{x}^b$
- Minimisation on T, q, O_3 and Tskin
- Use of **R** (FG departures standard deviation) and **B** (multi-varied T, q, O_3 and Tskin) matrices
- Statistical estimation of the full **R** matrix using the Desroziers method

Observation-error standard deviation

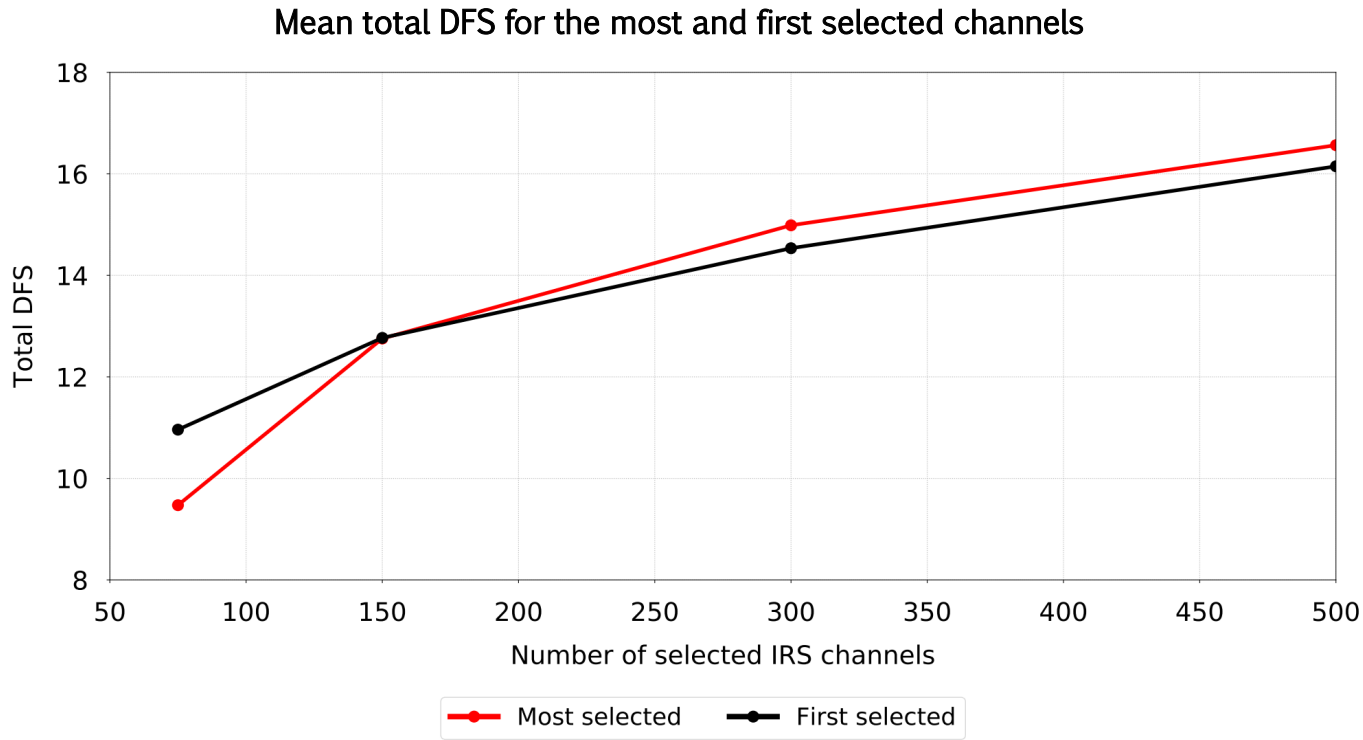


Diagnosed observation-error correlation



(4) IRS channel selection – Two selection methods

- After the pre-selection of 500 channels, two selection methods are used: the most selected channels and the channels selected first
- Sorting of selections by packages of **75**, **150**, **300** and **500** channels
- Calculation of the total DFS for each of these selections

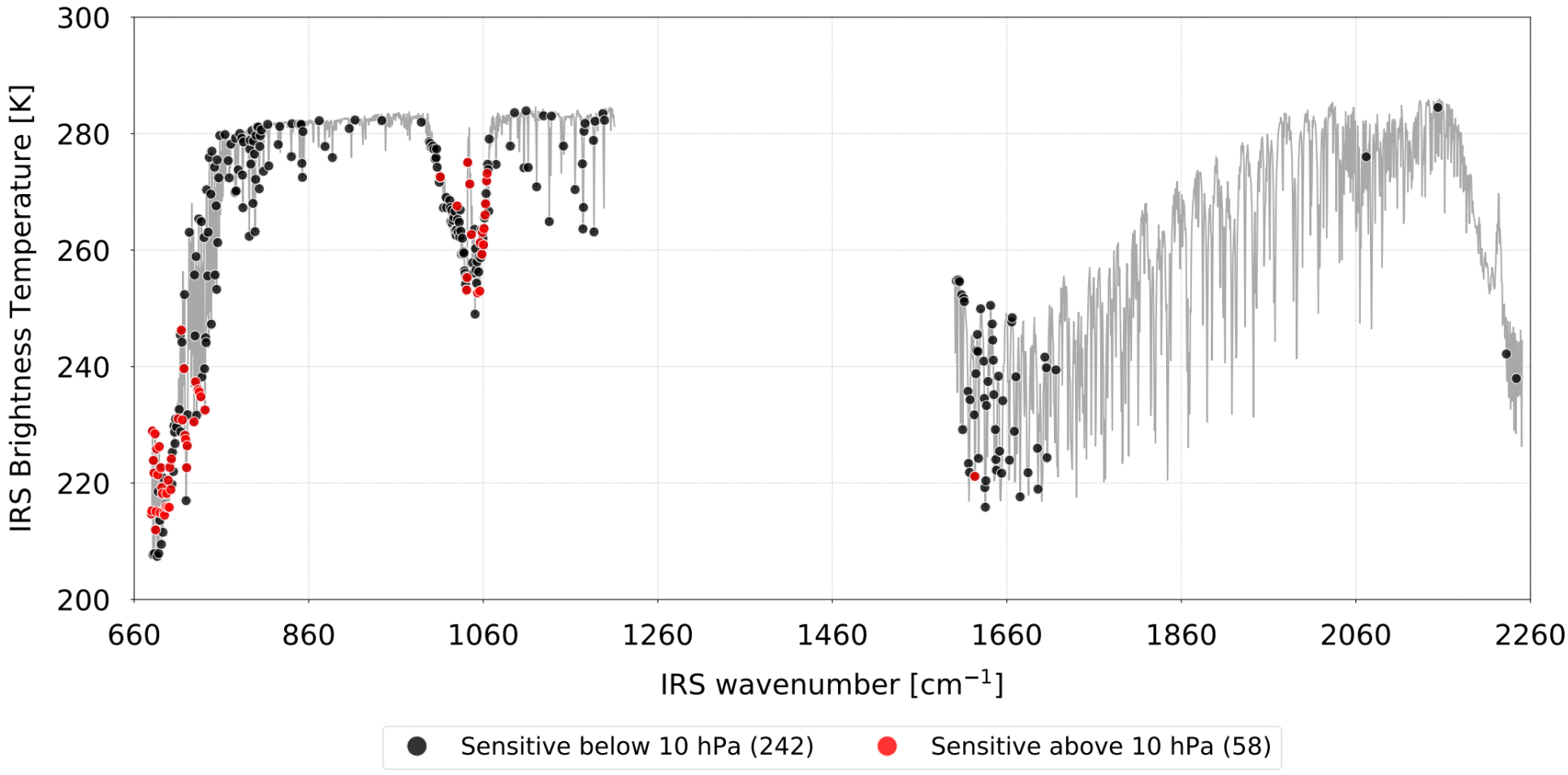


DFS Results

Mean of DFS and percentage of available mean DFS for the 75, 150, 300, 500 most selected channels and all channels

	DFS T	DFS q	DFS O_3	DFS $_{Tskin}$	Total DFS
75	3,44 (27.7%)	3.50 (25.0%)	1.55 (22.2%)	0.98 (98%)	9.47 (26.4%)
150	4.98 (35.8%)	5.01 (35.8%)	1.78 (25.5%)	0.99 (99%)	12.76 (35.6%)
300	5.71 (41.0%)	6.12 (43.7%)	2.16 (30.9%)	1.00 (100%)	14.99 (41.8%)
500	6.29 (45.2%)	6.79 (48.5%)	2.48 (35.5%)	1.00 (100%)	16.56 (46.2%)
All channels	13.91	13.99	6.98	1.00	35.88

IRS channels sensitive above 10 hPa



IRS channels sensitive above 10 hPa