DE LA RECHERCHE À L'INDUSTRIE

Simulation of the ^{133}Xe background at the global scale:

Use of NCEP ensemble data to factor in meteorological uncertainties

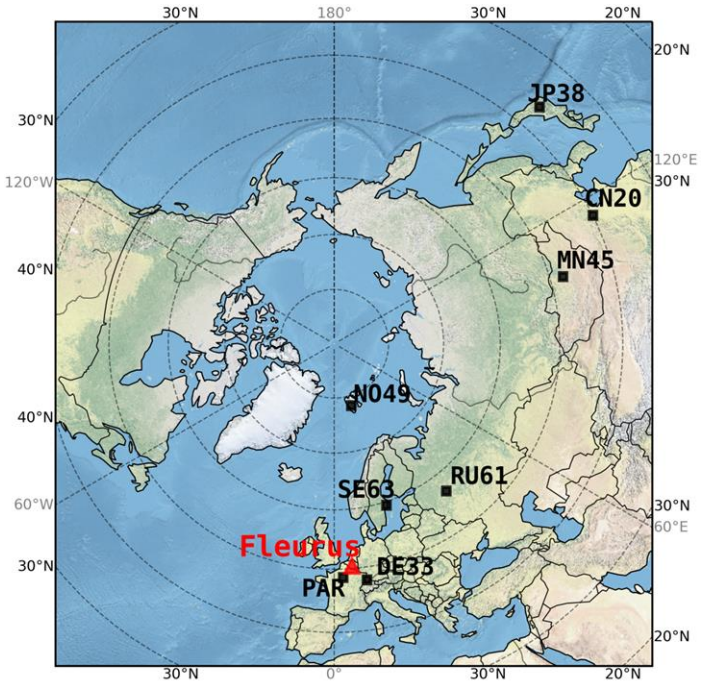
Generoso S., Achim P., Morin M., Gross P., Douysset G.

Commissariat à l'énergie atomique et aux énergies alternatives - www.cea.fr

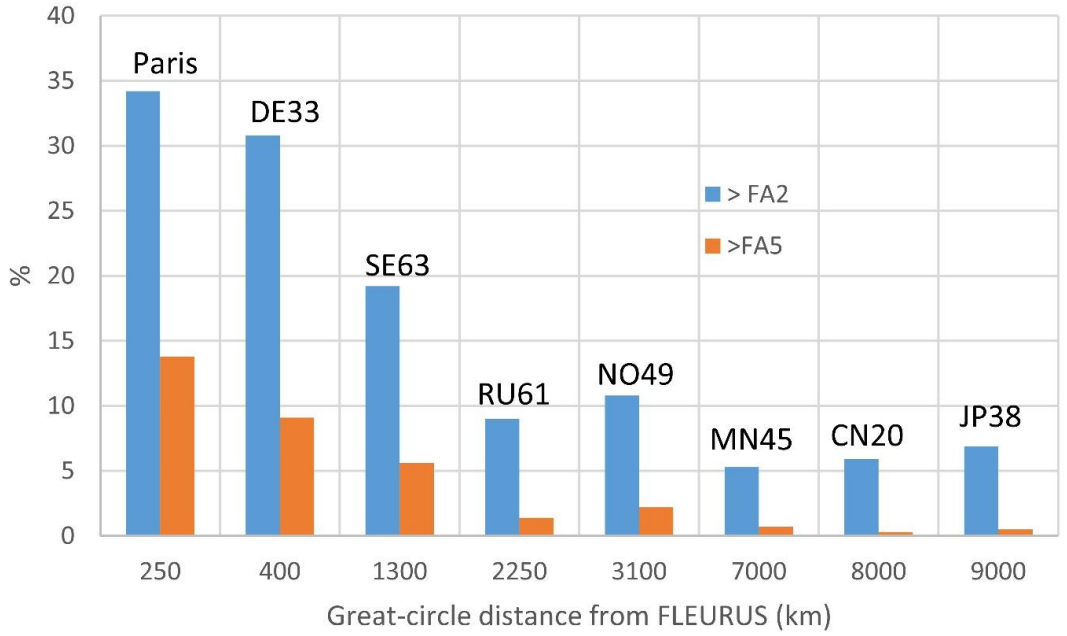
- **Use of STAX data** [WOSMIP 2021]
  - Implementation of STAX data from IRE (Fleurus, Belgium) in our automated simulation of the radioxenon background
  - Summary of lessons learned from analysis of a 1-year simulation dataset

- **Use of STAX data & NCEP GEFS meteorological data**
  - Simulations conducted with a method similar to our automated process, for a 1 year period (Nov. 2020 – Nov. 2021), and only with IRE emissions (Belgium)
    - with NCEP / GFS data (deterministic)
    - with NCEP / GEFS data (Ensemble)
  - Results compared to measurements at Paris (France) and DE33-Freiburg (Germany)
  - Share feedbacks from a National Data Center perspective on using ensemble meteorological data compared to deterministic data

Use of STAX data (versus a constant a priori) [WOSMIP 2021]



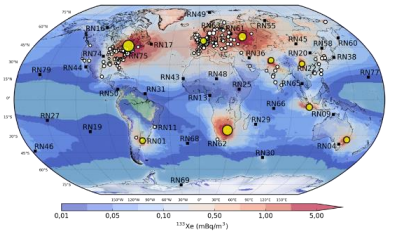
Percent of simulation results that differ by a factor of more than 2 (blue) and 5 (red) between the "A PRIORI" and "STAX" simulations.



- Notable differences in simulations < 1 500-2 000 km from Fleurus
  No detectable differences > 2 000 km
- Simulations improved notably with respect to timings of peaks
- However, STAX data alone are not sufficient to fully reproduce the day-to-day variability → other uncertainties in ATM
- Results in agreement with other studies and National Data Centers

Generoso et al., submitted to JER special issue, 2021

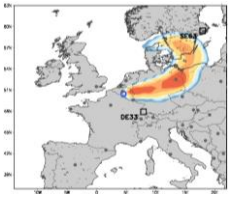
STAX data are implemented in CEA automated daily simulations



NCEP GFS and GEFS (*Global Ensemble Forecast System*)

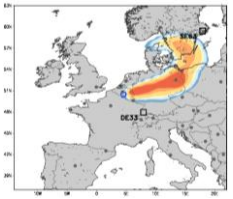
❑ Concretely, for the ATM:

GFS | **Deterministic** ⟶ Flexpart



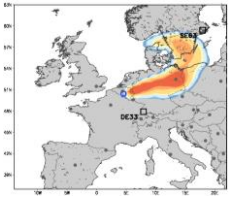
GEFS (31 **perturbed** members)

Control c00 ⟶ Flexpart



Perturbed

p01 ⟶ Flexpart



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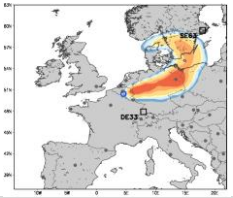
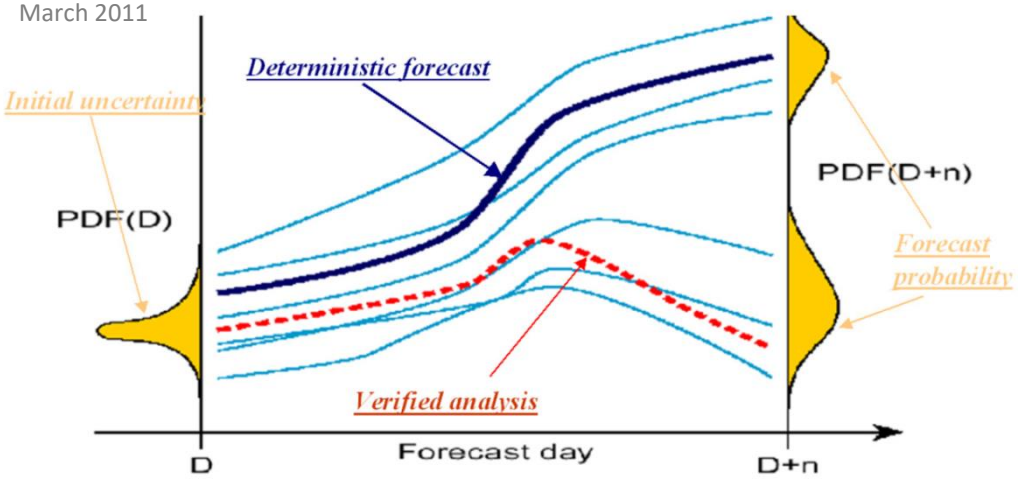
p30 ⟶ Flexpart



From NCEP Global Ensemble Forecast System (GEFS) – Review, Y. Zhu, NCEP/NWS/NOAA, March 2011



❑ GEFS data come at a cost of a lower resolution than the deterministic run

GFS (interpolated at 0.5°)
Initial model :
~13km → 10 days,
~34km from 10 to 16 days
64 vertical layers

GEFS V12 since Sep. 2020 (interpolated at 0.5°)
Initial model :
~25km -> 16 days,
64 vertical layers

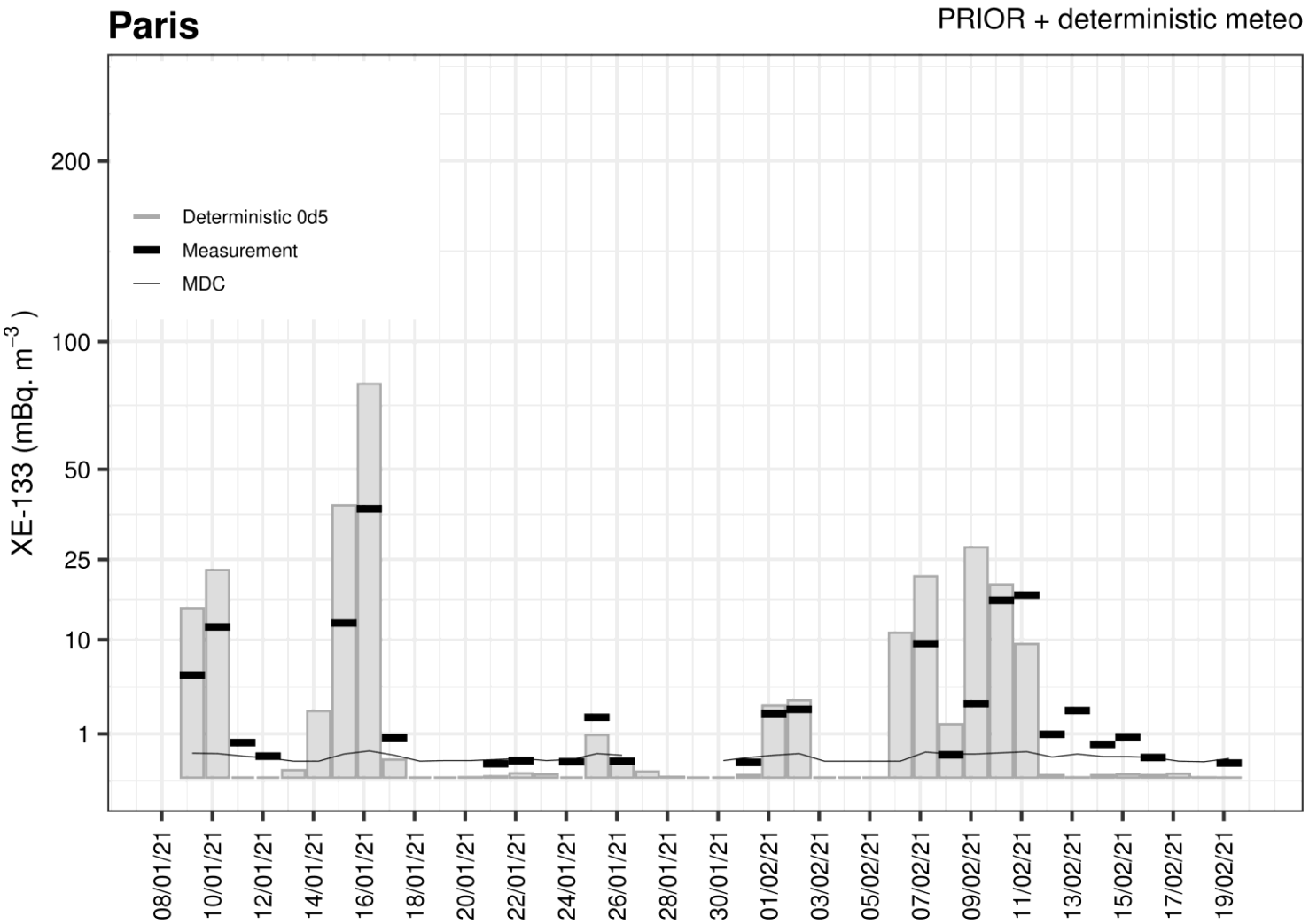
❑ General Features

- "Deterministic runs (e.g., GFS) usually have more skill than any *individual ensemble member* due to superior resolution"

- "Ensemble mean can be more skillful than a *higher-resolution deterministic run*, especially beyond ~3 days"

Ensemble Prediction System,
E. S. Blake and M. J. Brennan,
National Hurricane Center, March 2016

Time series at station location – Zoom in January 2021



FLEXPART v9.02
GFS / GEFS 0.5° / 6 hr
Output 0.5°x0.5 / 12 hr
CTL=1

24 hour average from 17h to 17h as measurements

Only emissions from IRE

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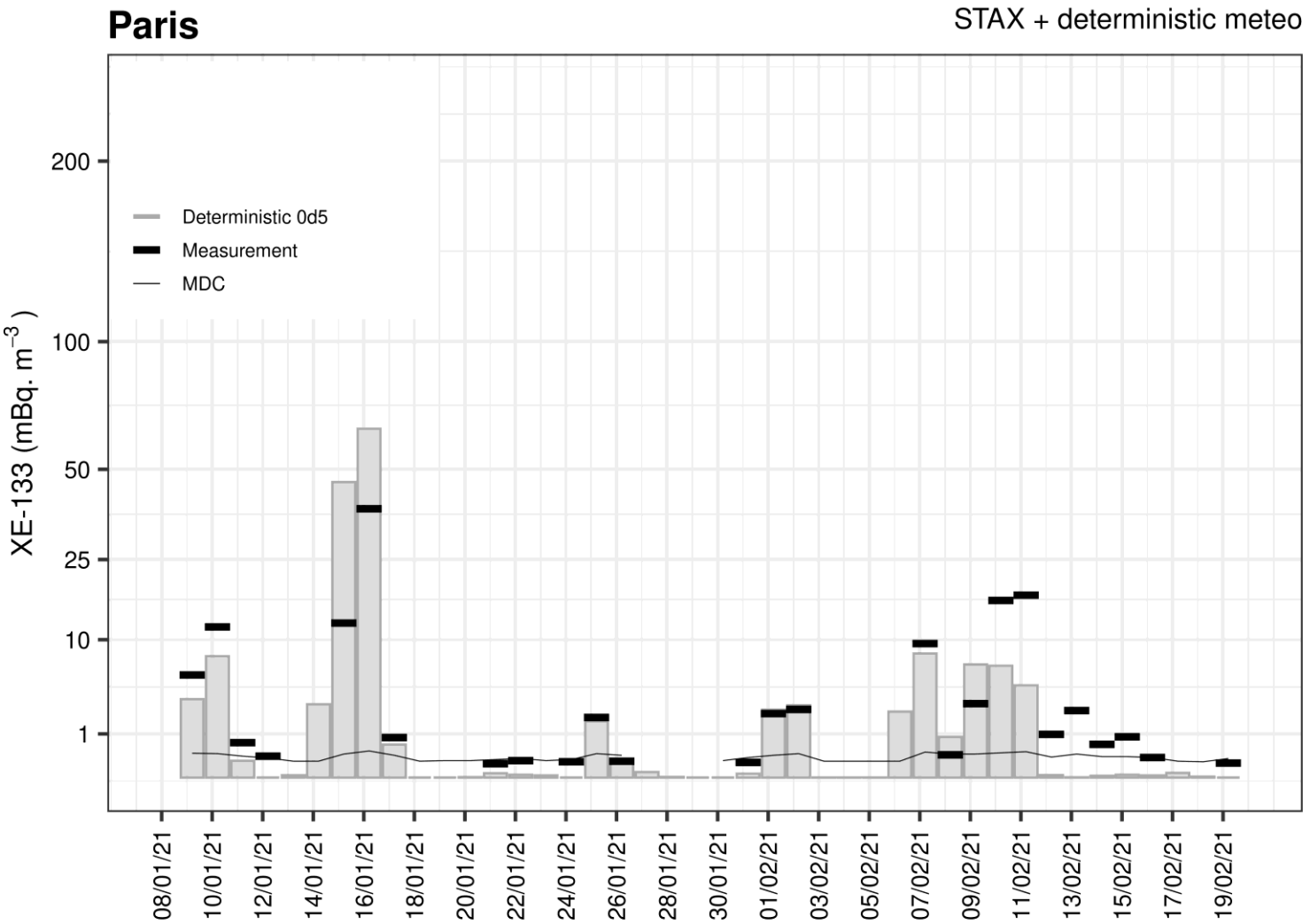

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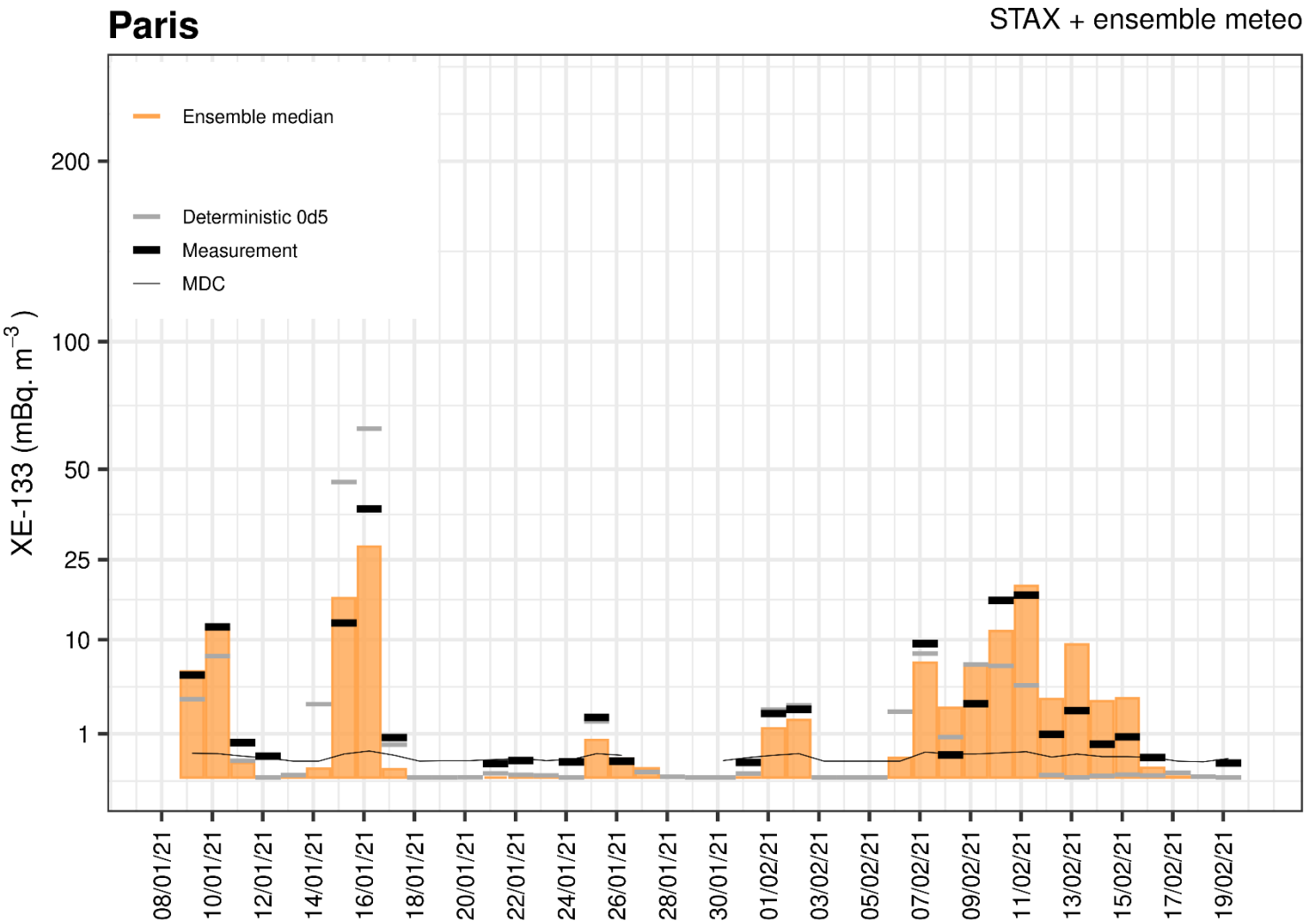

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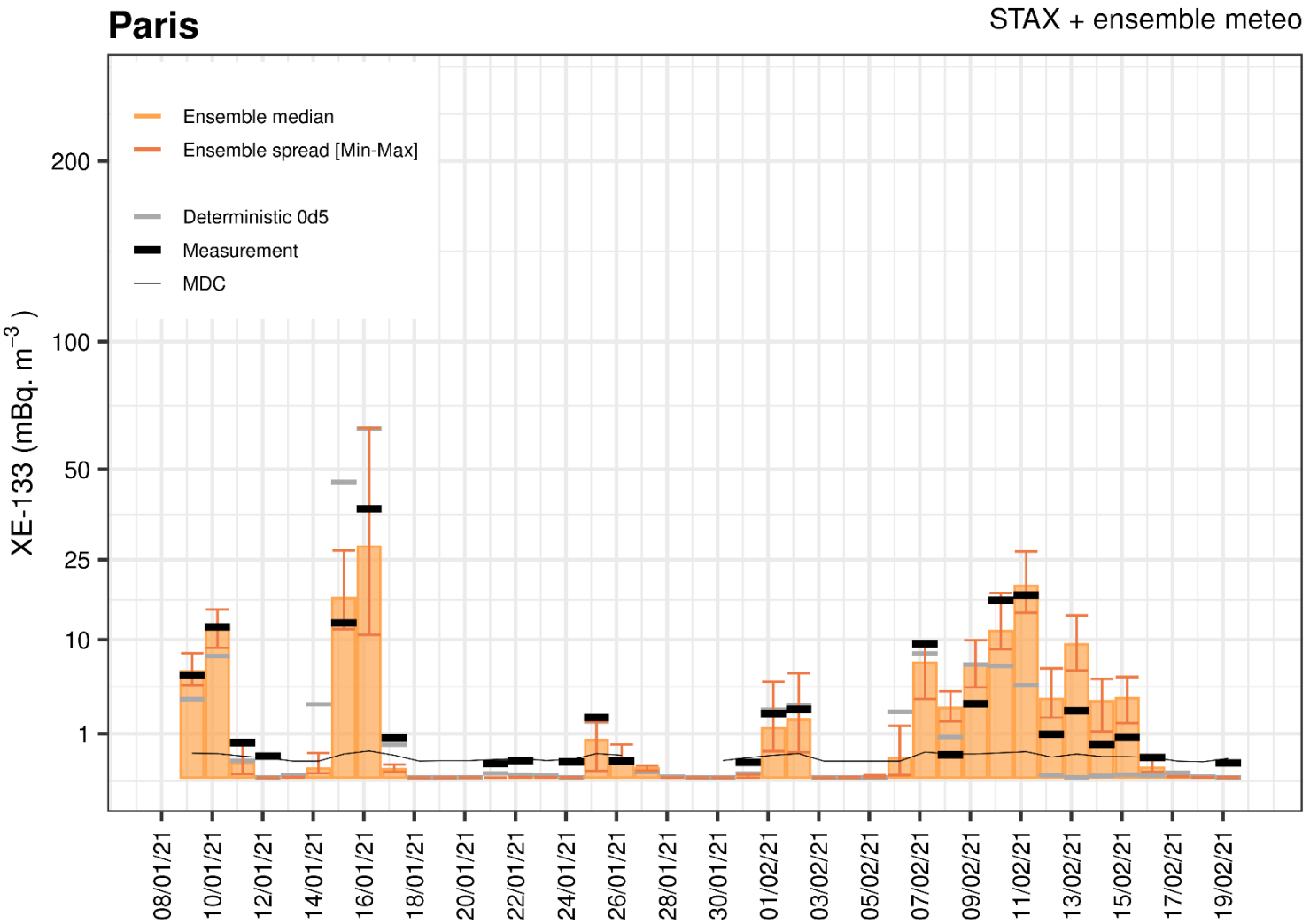

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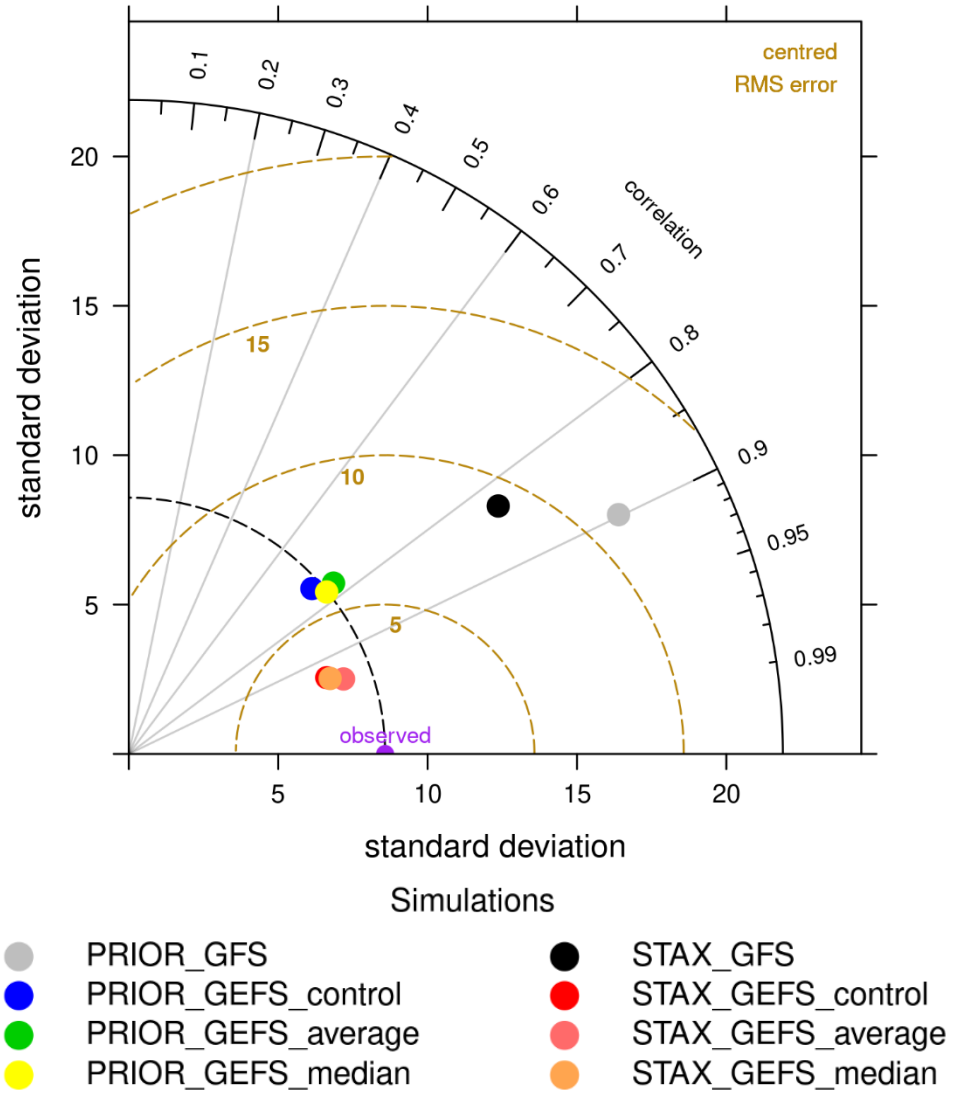
Taylor diagram at station location – Zoom in January 2021

- STAX+GEFS performs best
- Results from the ensemble are close (control, average and median)
- The ensemble performs better than the deterministic run in this case



Paris

January 21

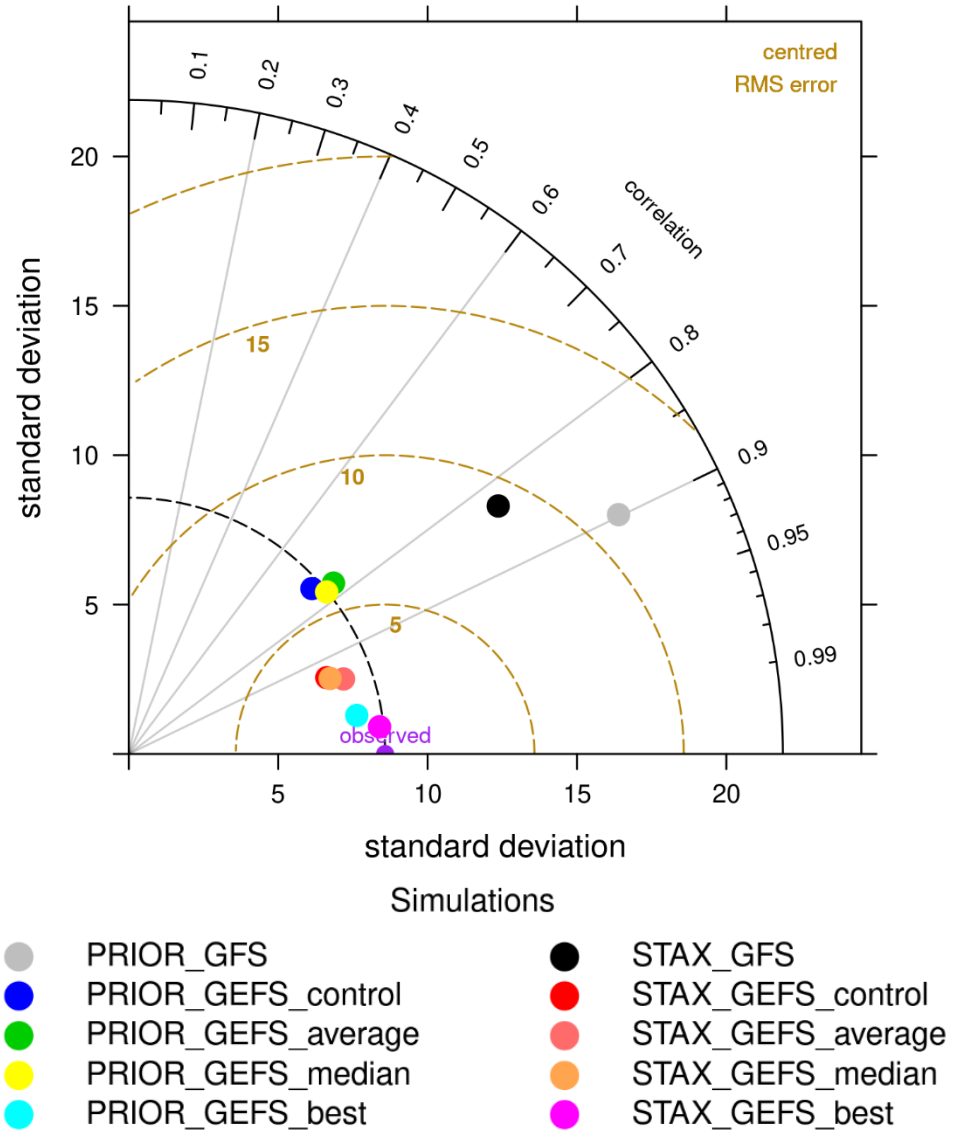
Taylor, K., 2001, Summarizing multiple aspects of model performance in a single diagram, JGR, 106, D7.

Maurer, C. et al., 2021, Evaluating the added value of multi-input atmospheric transport ensemble modeling for applications of the CTBTO, JER, 237, 106649.

Taylor diagram at station location – Zoom in January 2021

- STAX+GEFS performs best
- Results from the ensemble are close (control, average and median)
- The ensemble performs better than the deterministic run in this case
- « GEFS Best » :
  A reconstructed series with, for each detection, the result of the closest perturbed member (not the same all along)

➔ *The ensemble carries a valuable information (thanks to the range of the members)*



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Paris

- January and June show different patterns

- The deterministic run performs better than the ensemble in June, and over the full period

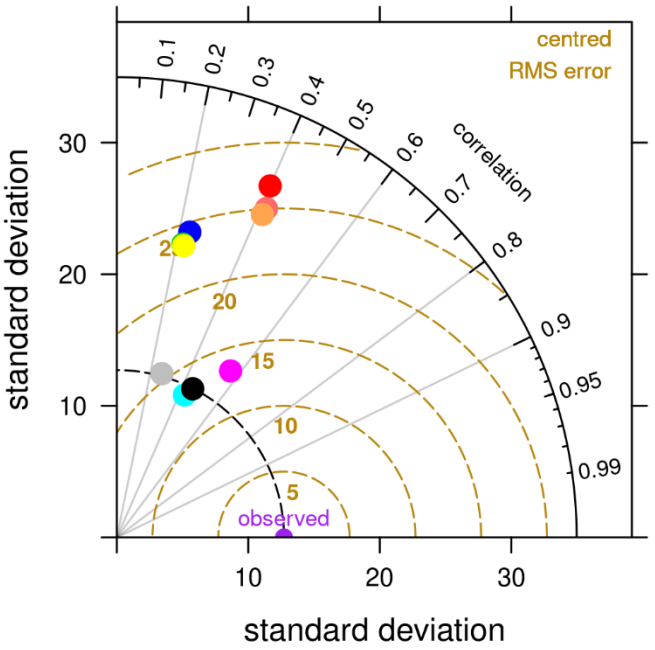
➔ *The cost of the lower resolution of the ensemble members ?*

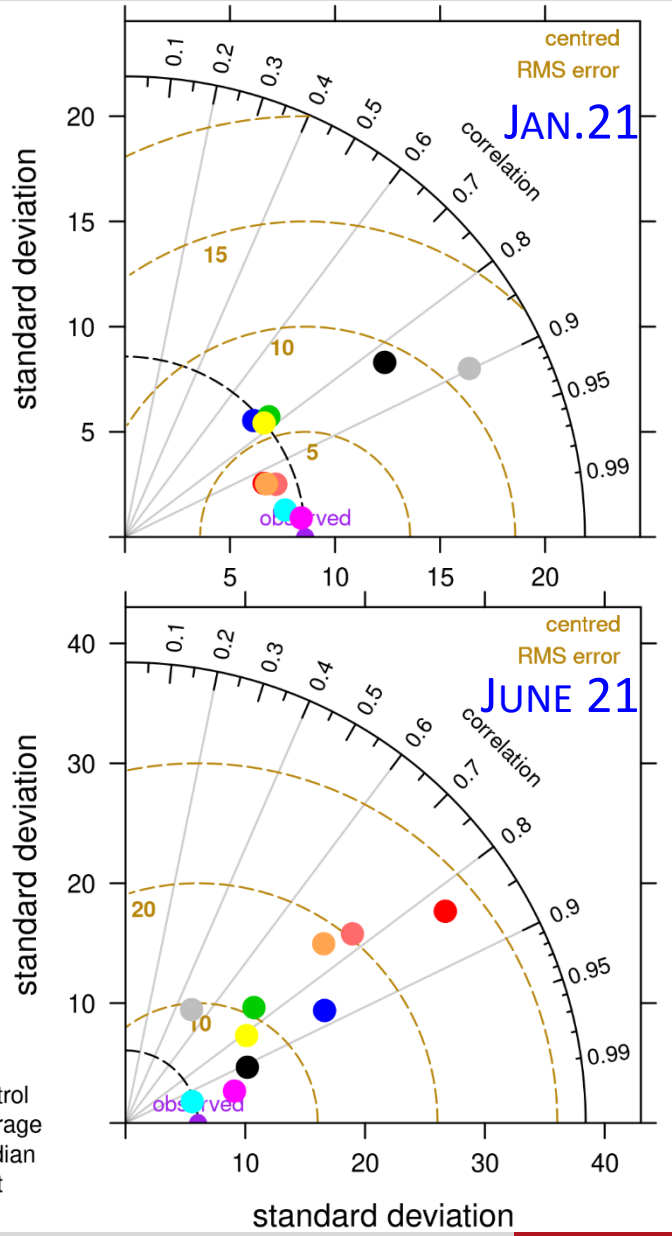
➔ *Not yet enough statistics (longer period of comparisons would be needed)*

- However, overall "GEFS best" performs better

➔ *The ensemble carries a valuable information thanks to its spread : one of the member is the closest to the measurements*

NOV 20 – JUNE 21 "FULL PERIOD"



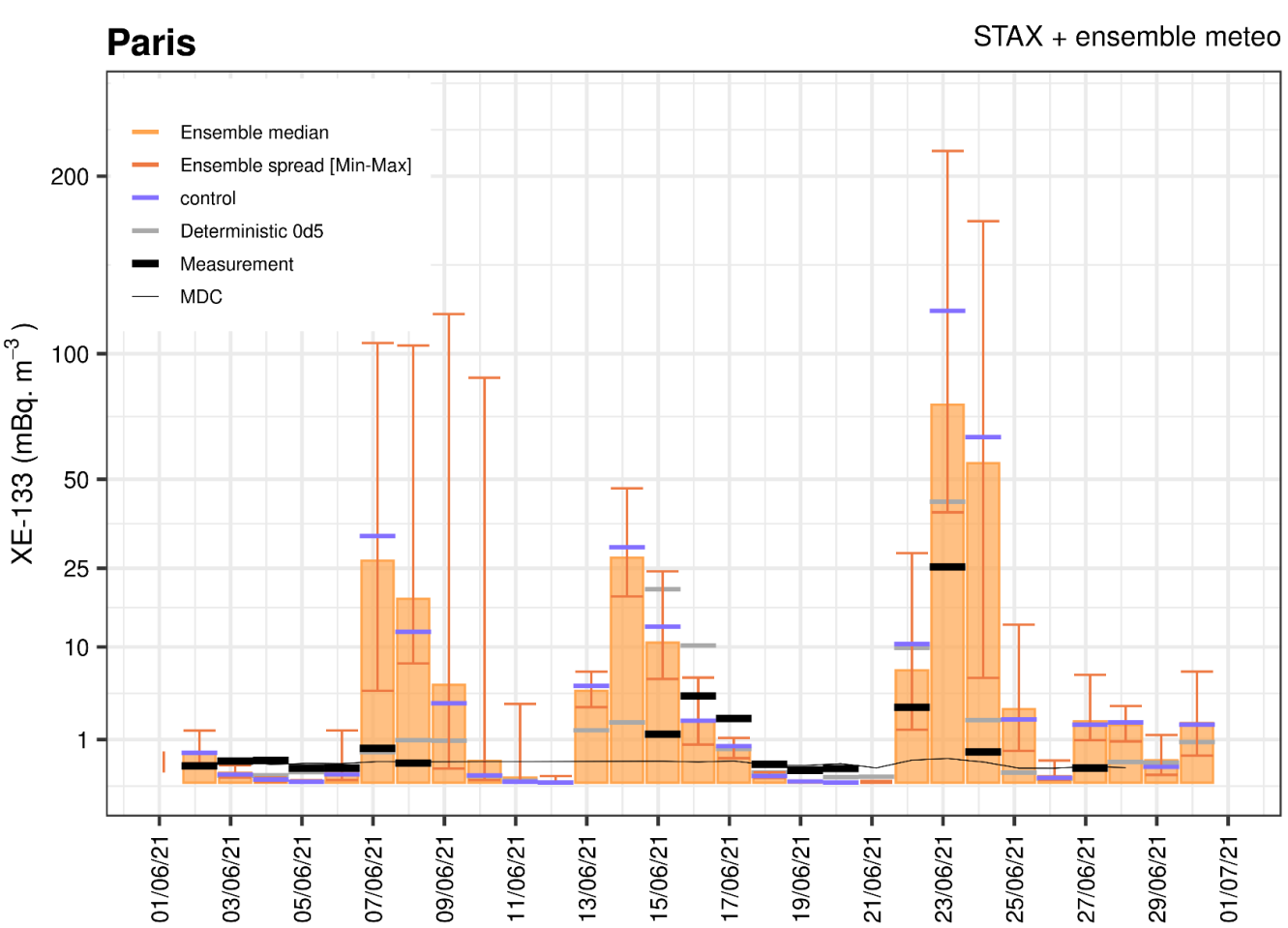


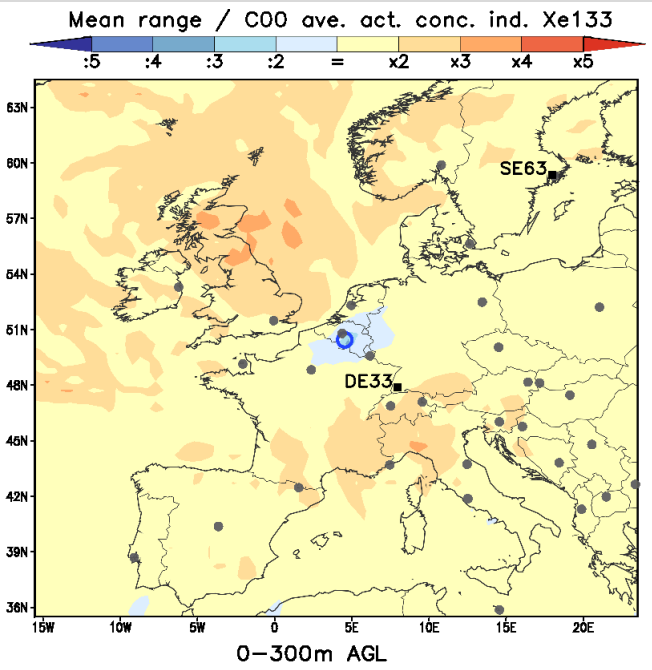
Simulations

PRIOR_GFS	STAX_GFS
PRIOR_GEFS_control	STAX_GEFS_control
PRIOR_GEFS_average	STAX_GEFS_average
PRIOR_GEFS_median	STAX_GEFS_median
PRIOR_GEFS_best	STAX_GEFS_best

Time series at station location

Zoom in June 2021





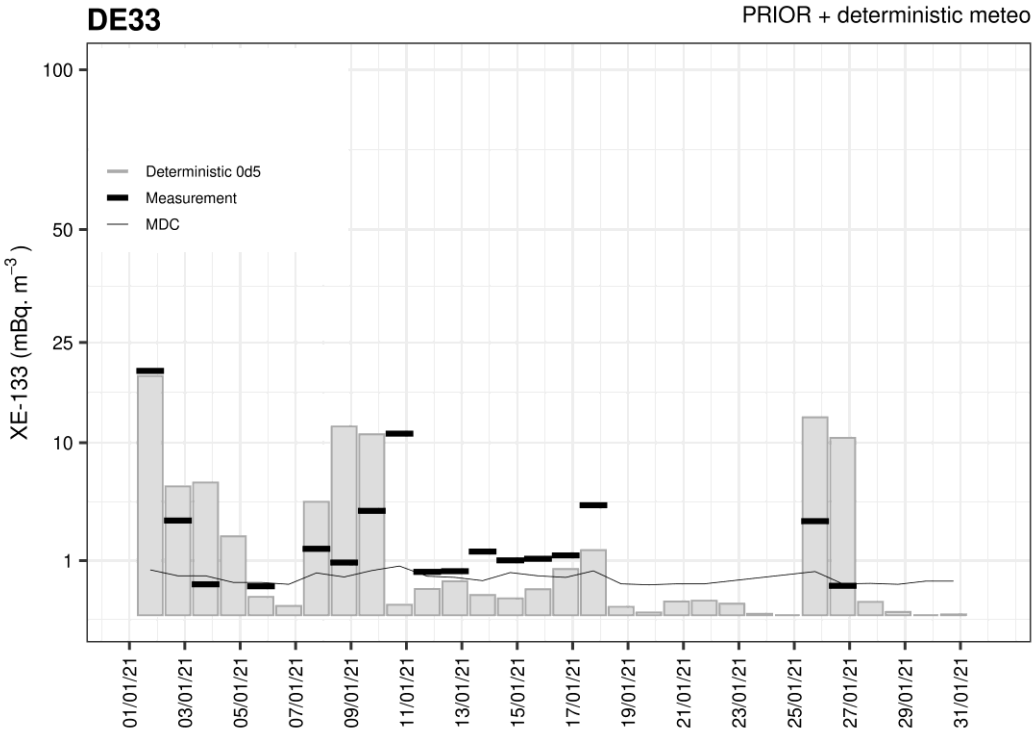
In June, the range of the ensemble is covering up to > 100 mBq/m^3

On average, over one year, the mean range / control ~ 2 x control result (-> map)

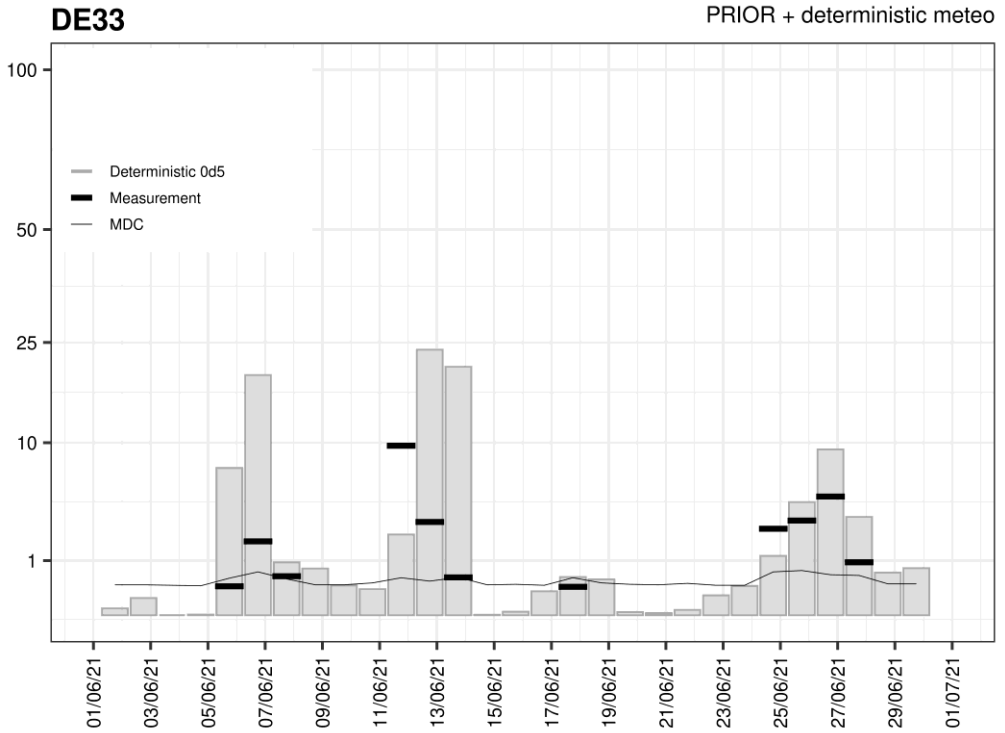
➔ *The range of the ensemble (relatively to e.g. the control run) might carry an indication on a degree of confidence*

Time series at station location – Zoom in January and June 2021

January 21



June 21



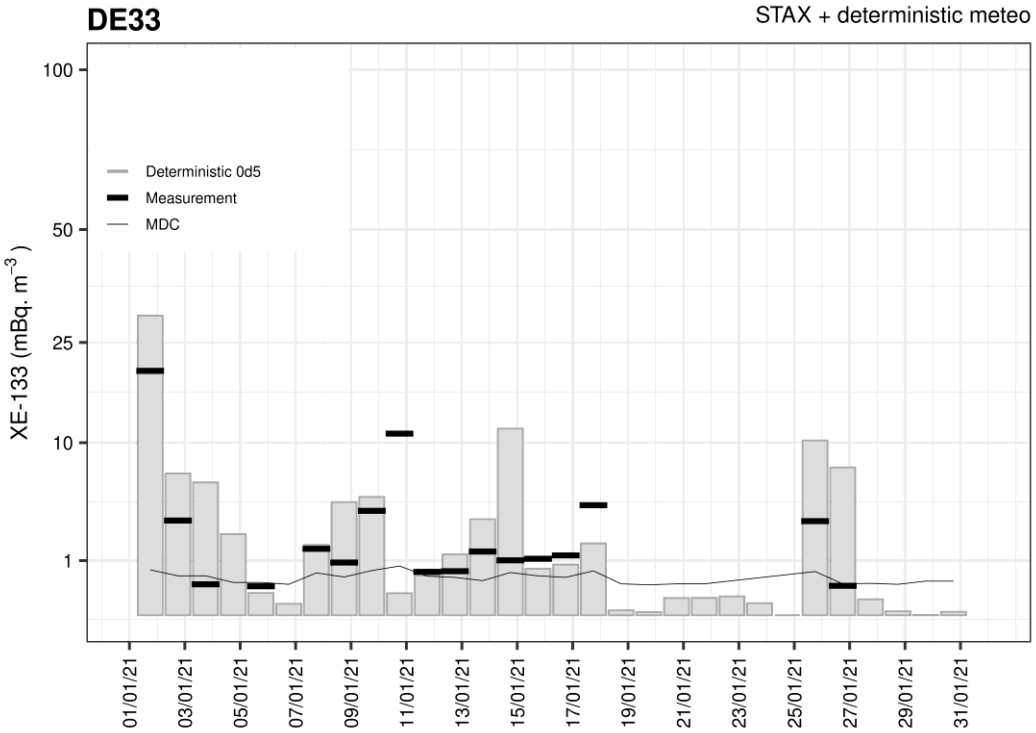
FLEXPART v9.02
GFS / GEFS 0.5° / 6 hr
Output 0.5°x0.5 / 12 hr
CTL=1

24 hour average
from 06h to 06h as
measurements

<u>Only emissions from IRE</u>

Time series at station location – Zoom in January and June 2021

January 21



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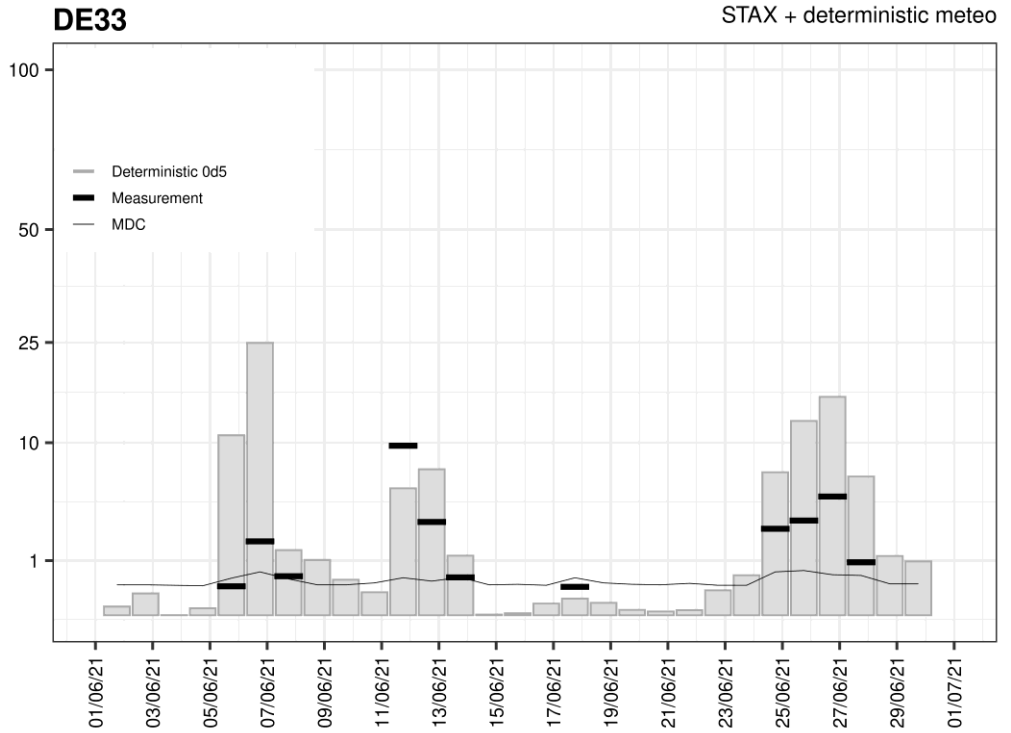

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Time series at station location – Zoom in January and June 2021

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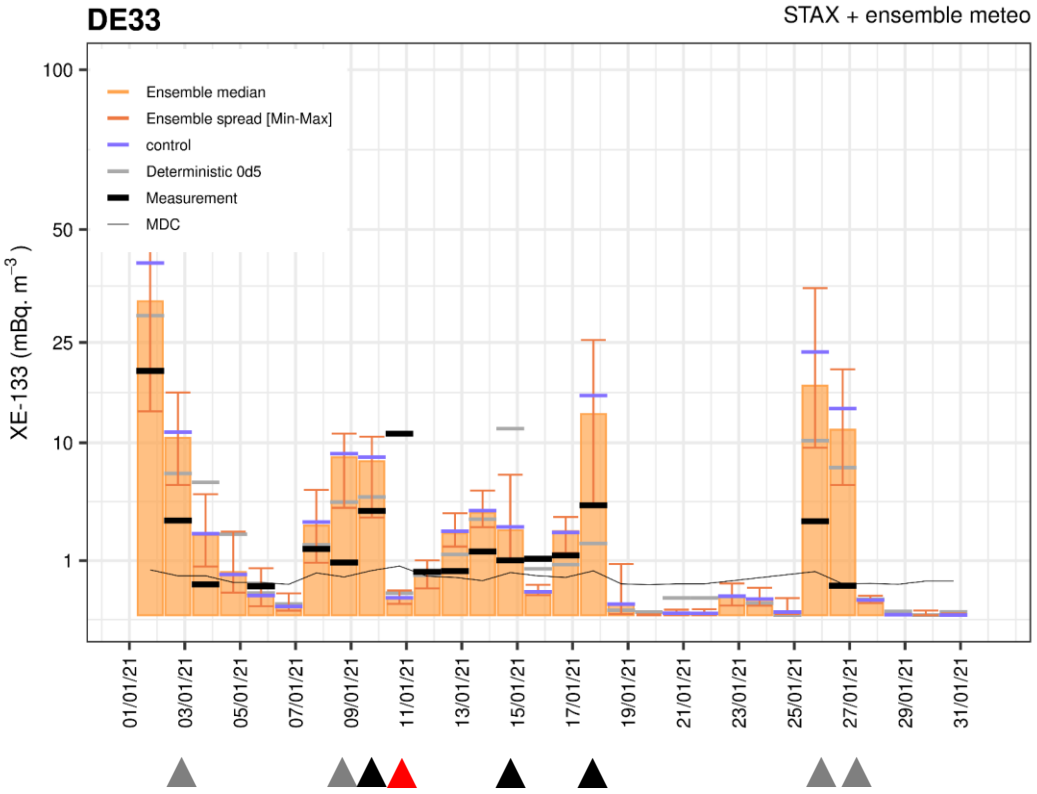

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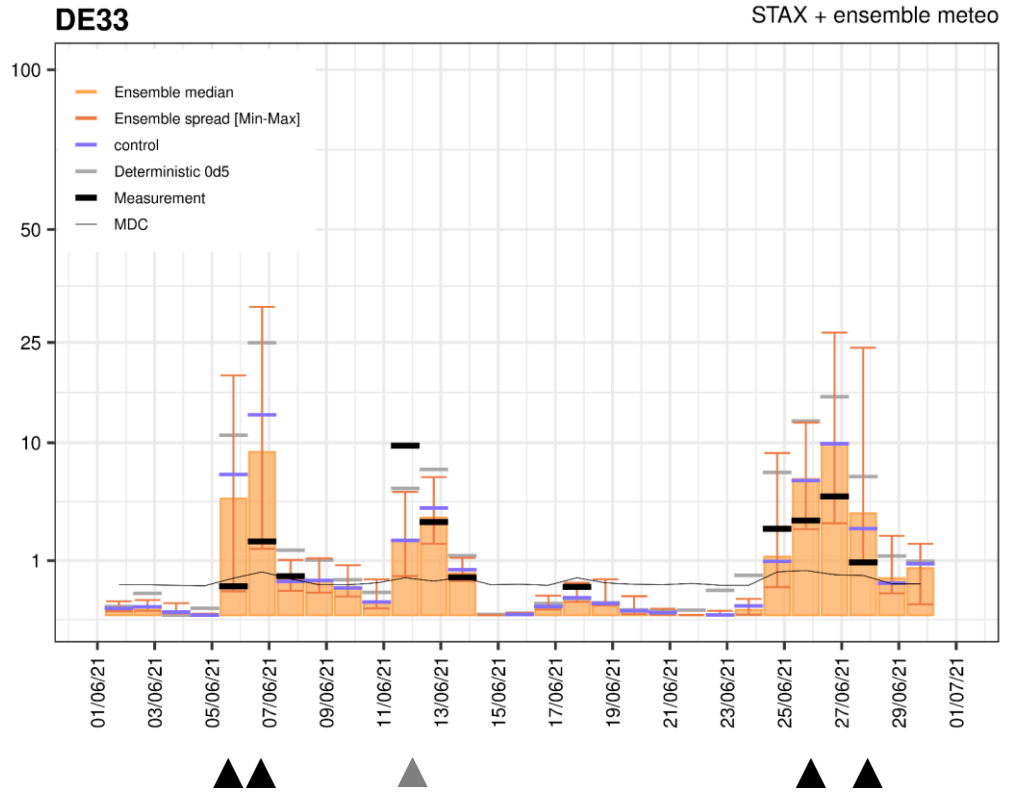


Extreme outlier ensemble member can carry the best forecast

Some detection can still be out of the range of the ensemble (but still “not too far” from IRE)

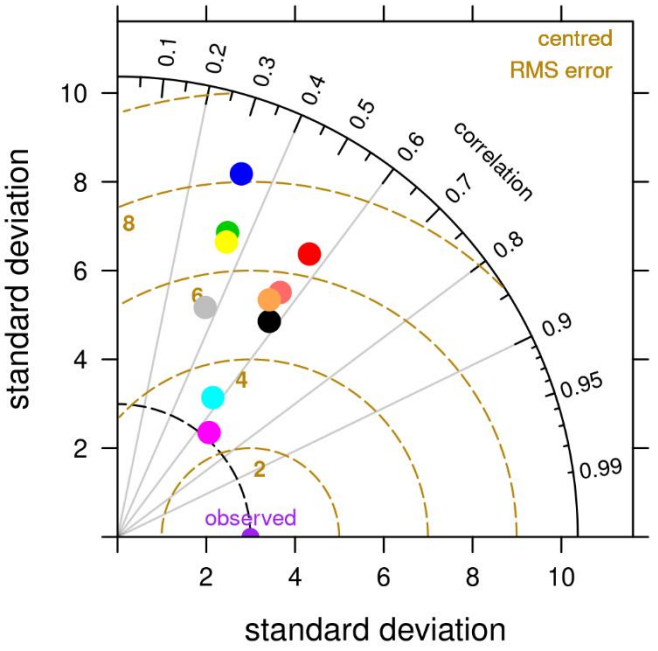
1 detection = No ensemble member and not the deterministic predict a contribution from IRE > MDC =>
Backtracking to MIP in Russia ➔ The simulation correctly plays its part of flagging a detection from another source

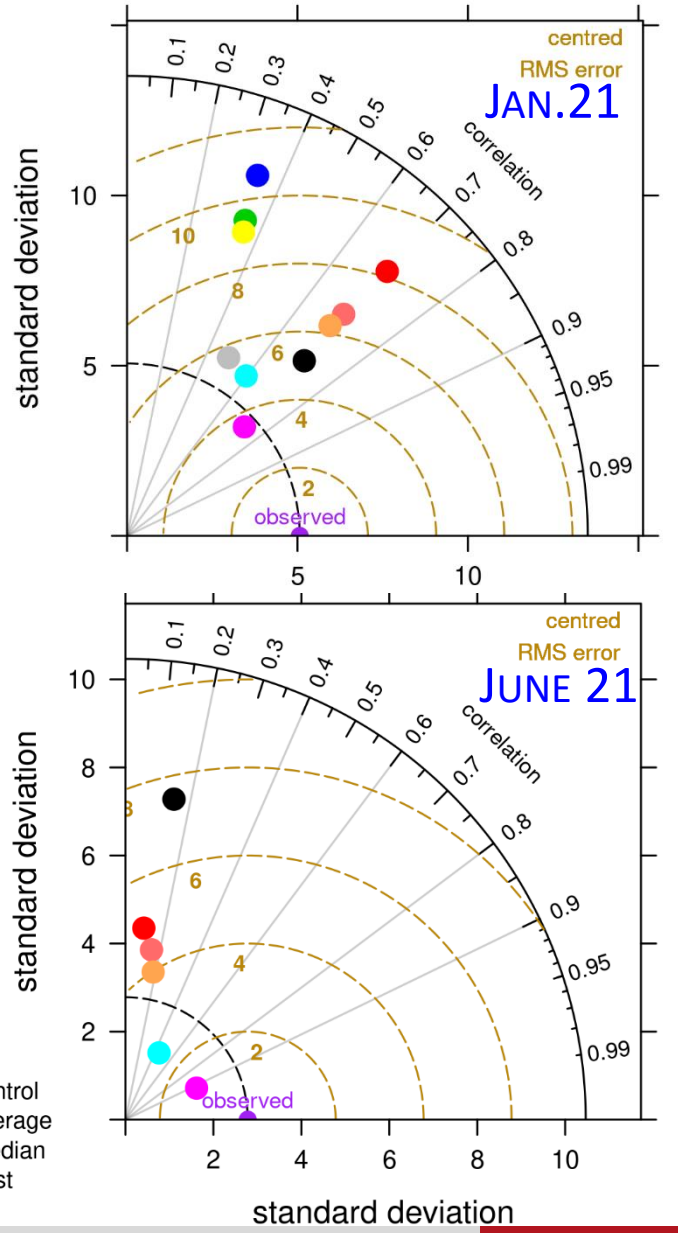
DE33

- Clearly the use of STAX + the GEFS ensemble improves simulations at DE33
- The control run is quite different than the deterministic run (worse in January and overall, better in June)
- The ensemble (average and median) partly compensates for the loss of performance of the control compared to the deterministic run
- "GEFS best" performs better than the rest

➔ *The ensemble carries a valuable information thanks to its spread*

NOV 20 – JUNE 21 "FULL PERIOD"





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Conclusions

A few feedbacks from the use of STAX data (from IRE, Fleurus) and NCEP ensemble meteorological data in ATM :

- Clearly the use of STAX + the ensemble improves simulations at Paris and DE33 (250 and 400 km from Fleurus)
- At this distance and in these cases, the ensemble (control, average and median) do not always performs better than the deterministic run (e.g., Paris)
- However, overall the ensemble carries the best forecast through at least one of its member
- Extreme outlier ensemble member can carry the best forecast => The valuable information lies in the average/median, but also in the spread and minimum/maximum of the members

In agreement, e.g., with De Meutter et al. [2016], Maurer et al. [2021], De Meutter and Delcloo [2022]

A few other feedbacks from daily operational analysis of simulation versus IMS data :

- The day-to-day variability is not always captured by the simulations (even large peaks), even with the use of STAX and ensemble meteorological data ➔ *day-to-day remains a challenge*
- Even with uncertainties and many challenges ahead to perfect the results, the simulation already plays its role to pointing to detections from other sources ➔ *The analysis is consolidated as the data useful for interpretation are "piling up" (emissions, ensemble meteorological data)*

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