Assessment of model responses' sensitivity to emission changes in support of local emission reduction strategies: The FAIRMODE CT9 platform

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Active modelling participants (11 groups)

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- ***Angelos Violaris, Jonilda Kushta****; The Cyprus Institute, Climate and Atmosphere Research Center, Cyprus*
- ***Bruce R. Denby, Qing Mu****,* ***Eivind G****. Wærsted; Norwegian Meteorological Institute, Norway*
- ***Marta García Vivanco, Mark R. Theobald, Victoria Gil;*** *Atmospheric Modelling Unit. Environment Department, CIEMAT, Spain*
- ***Ranjeet S Sokhi, Kester Momoh, Ummugulsum Alyuz, Rajasree VPM, Saurabh Kumar****; Centre for Climate Change Research (C3R) and Centre for Atmospheric and Climate Physics (CACP), Department of Physics, Astronomy and Mathematics, University of Hertfordshire, United Kingdom*
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- ***Arineh Cholakian, Romain Pennel, Sylvain Mailler, Laurent Menut****; Laboratoire de Météorologie Dynamique (LMD), Ecole Polytechnique, IPSL Research University, Ecole Normale Supérieure, Université Paris-Saclay, Sorbonne Universités, UPMC Univ Paris 06, CNRS, France*
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- ***Claudia Flandorfer, Kathrin Baumann-Stanzer****; Zentralanstalt für Meteorologie und Geodynamik (ZAMG), Austria*
- ***Virginie Hutsemékers, Elke Trimpeneers****; Belgian Interregional Environment Agency, Belgium*
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FAIRMODE CT9 OBJECTIVES

- For a given mitigation scenario (**scen**) and a base case (**bc**), models (**M**) provide different absolute results C_{scen}^{M}
- **BUT, HOW DO THEY BEHAVE ON DELTAS?**

$$\Delta = C_{scen}^{M} - C_{bc}^{M}$$

- What is the order of magnitude of differences? How to evaluate these differences? Which indicators?
- Can we explain the differences, what are the main drivers?

Policy Implication:

It is important to assess the robustness of deltas for urban air quality policies!

Models and teams involved - Overview

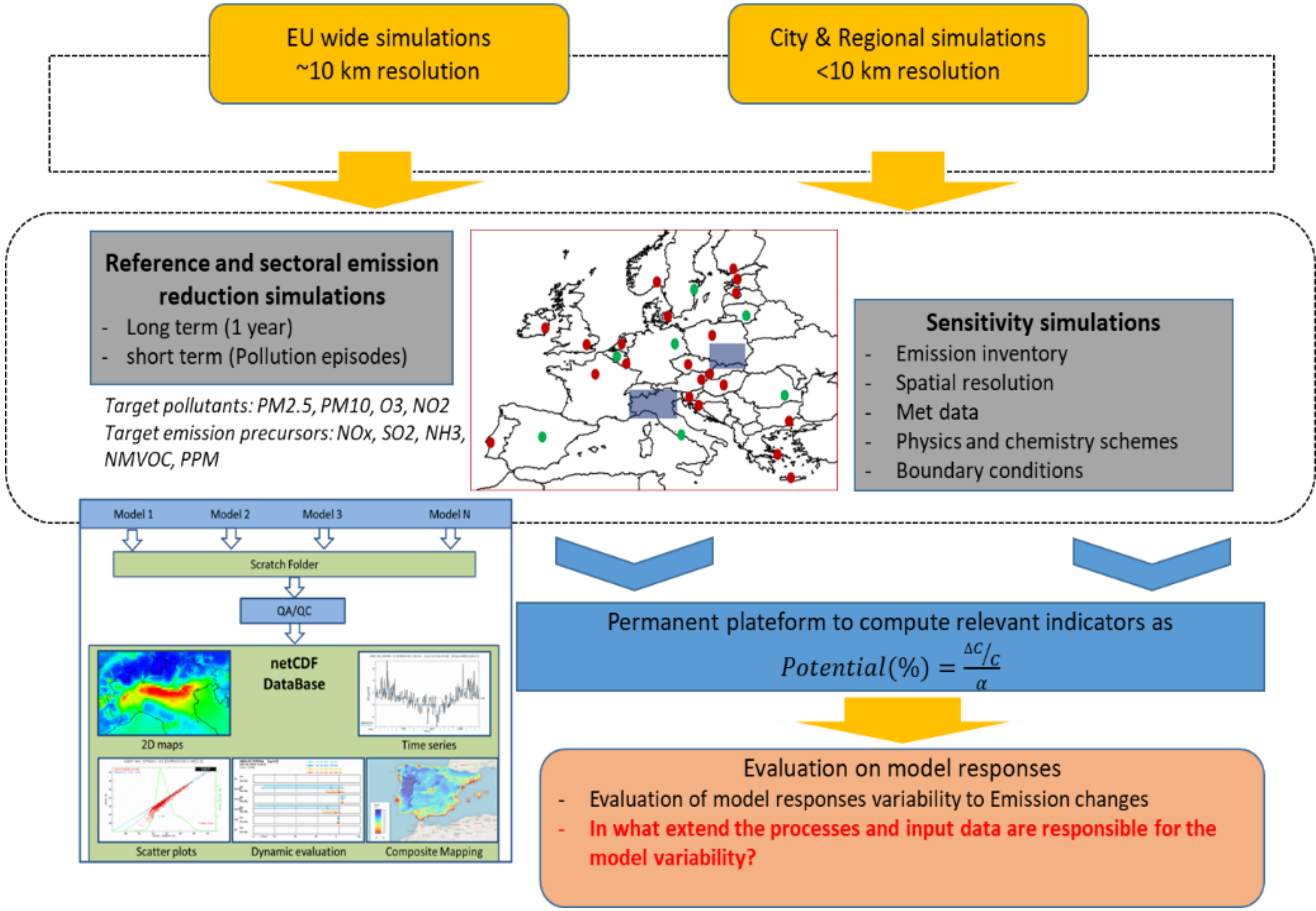
Constraints:

-Meteorology 2015

-Emission reductions 25 and 50%

-Target domains, periods (episodes)

Team name - Country		Model Name
JRC	(EU)	EMEP
JRC	(EU)	EMEP
JRC	(EU)	EMEP
JRC	(EU)	EMEP
ZAMG	(AT)	WRF-Chem
Met Norway	(NO)	EMEP
Met Norway	(NO)	EMEP + uEMEP
CyI	(CY)	WRF-Chem
NKUA	(GR)	WRF-Chem
DHMZ	(HR)	ADMS-Urban
DHMZ	(HR)	LOTOS-EUROS
LMD/IPSL	(FR)	WRF-CHIMEREv2020r1
UH-CACP	(UK)	WRF-CMAQ
CIEMAT	(ES)	IFS-CHIMEREv2017r4
ENEA	(IT)	WRF-MINNI
IRCELINE	(BE)	CHIMERE + RIO + ATMOSTREET

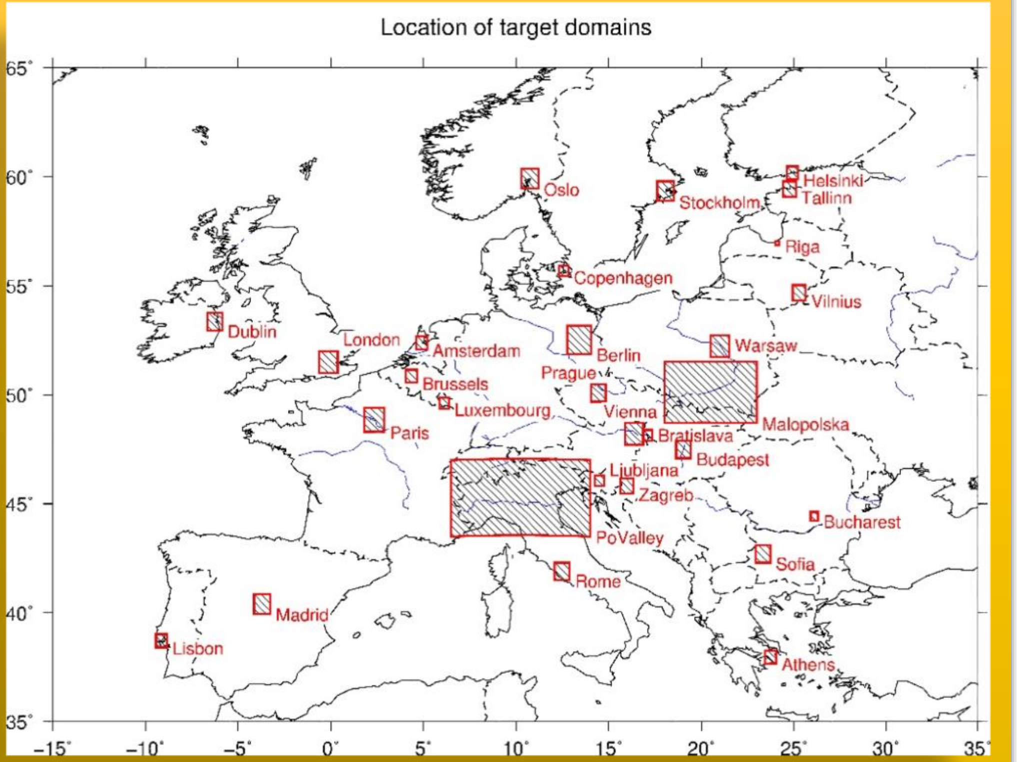


The overall framework

Set-up

- Short term (ST) on episodes
  - *Emissions reduced only during 2015 episodes from 00:00 to 23:00*
- Long term (LT) simulations
  - *Emissions reduced for the whole year 2015*
- Two reductions so far:
  - 25% and 50% from a base case (BC)
- Reduced species depends on target pollutants
  - ***PM10**: PPM, NOx, VOC, NH3, SO2, **ALL** (All together)*
  - ***Ozone**: NOx, VOC, **ALL** (All together)*

Domains of emission reductions

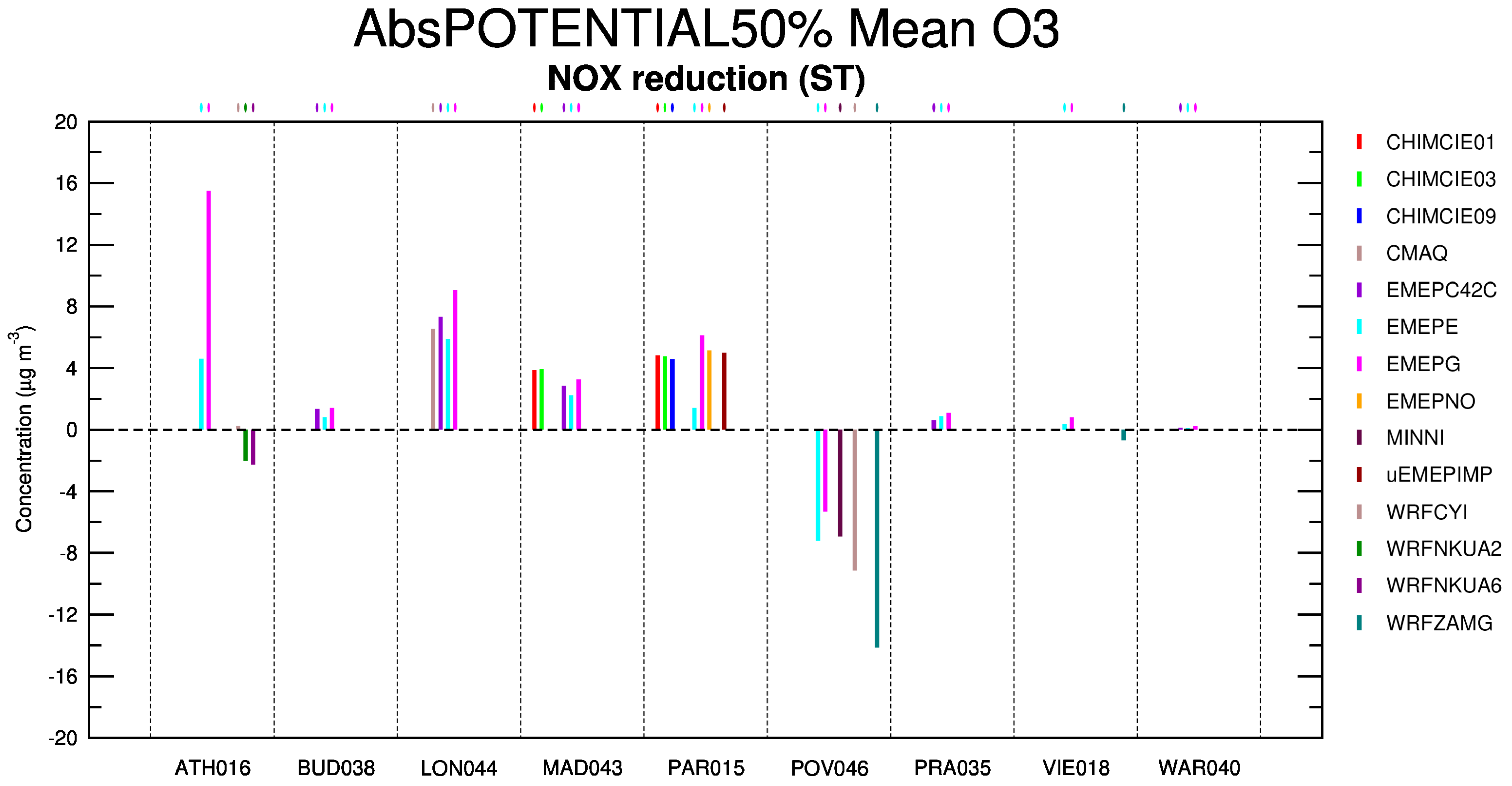


The overall framework

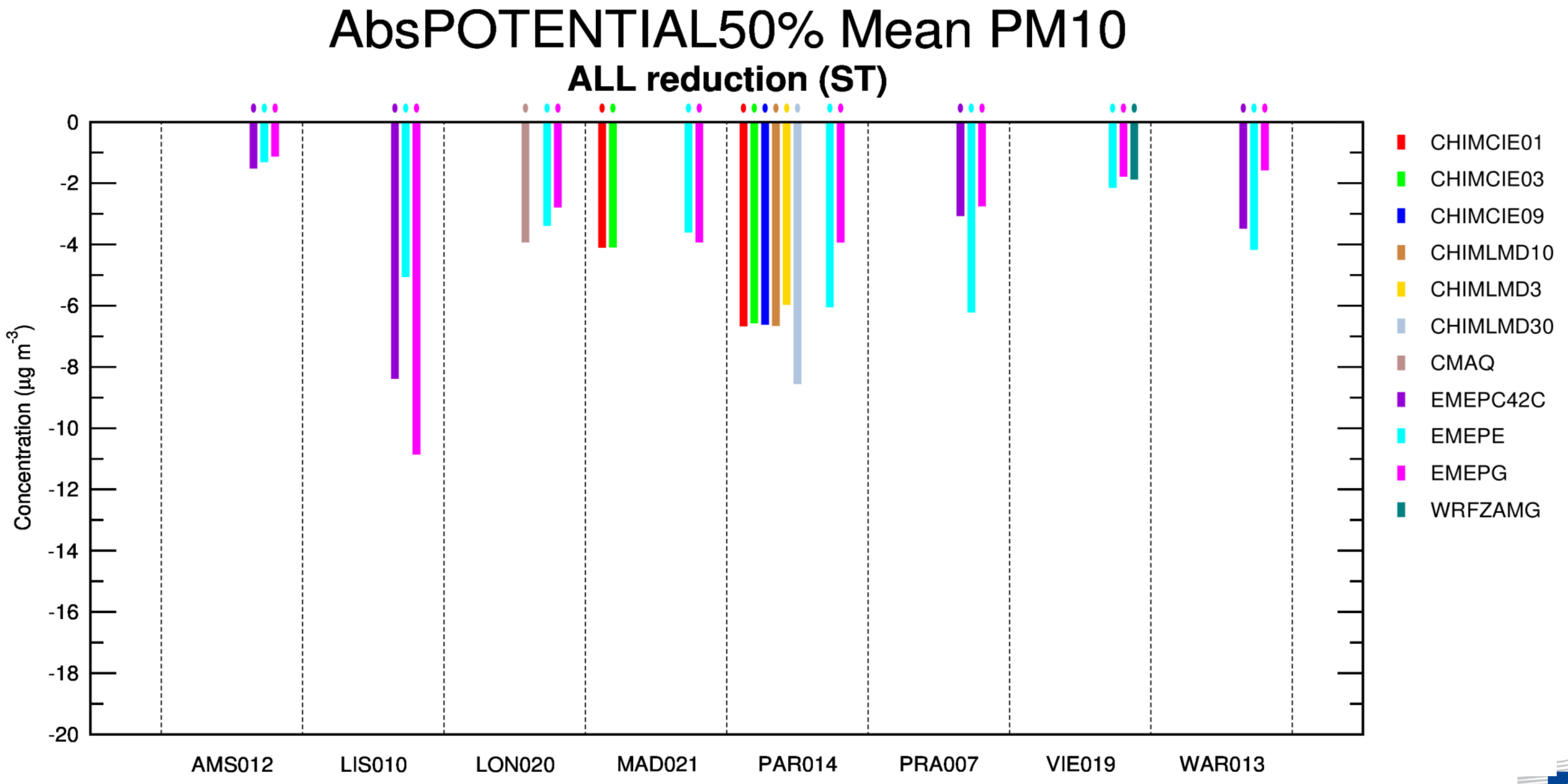
Basis Indicators

- **Absolute Potential** defined as the reduction in µg/m³ scaled by the reduction α of the scenario (25 or 50%) of a precursor from base case BC
  - $APl = (C_{SCEN} - C_{BC})/(\alpha\ )$ ($APl \times \alpha$ is the delta of concentrations)
- **Relative Potential** defined as the reduction in % scaled by the reduction α of the scenario (25 or 50%) of precursor *n* from base case BC and by the BC concentrations.
  - $RPl = (C_{SCEN} - C_{BC})/(\alpha \times C_{BC})$
- **Absolute Potency** in µg/m³/(ton/day) defined as the derivative of the concentration with respect to the emissions density E of a precursor or in other words the rate with which the concentrations (*C*) will change as a result of an emission density E)
  - $APy = (C_{SCEN} - C_{BC})/(\alpha \times E_{BC})$

Absolute Potential for O3 for NOx reduction



Absolute Potential for PM10 with ALL pollutant reductions



Other indicators

- **Variability** for each indicator
  - IND = API, RPI, APY

Variability from models M assessed by Norm. Std. Dev.

$$VAR_{IND} = \sqrt{\frac{\sum_{m=1}^{M}(IND_m - \overline{IND})^2}{(\overline{IND})^2}}$$

- Test of linearity using the 50% and 25% runs. **Deviation to linearity for API**

$$100 \times \left(\frac{API50\% - API25\%}{API25\%}\right)$$

- Test of additivity using the ALL scenarios and "ADD" as the sum of individual precursors reductions. **Deviation to additivity for API, RPI**

$$100 \times \left(\frac{IND_{ADD} - IND_{ALL}}{IND_{ALL}}\right)$$

European Commission

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  - IND = API, RPI, APY

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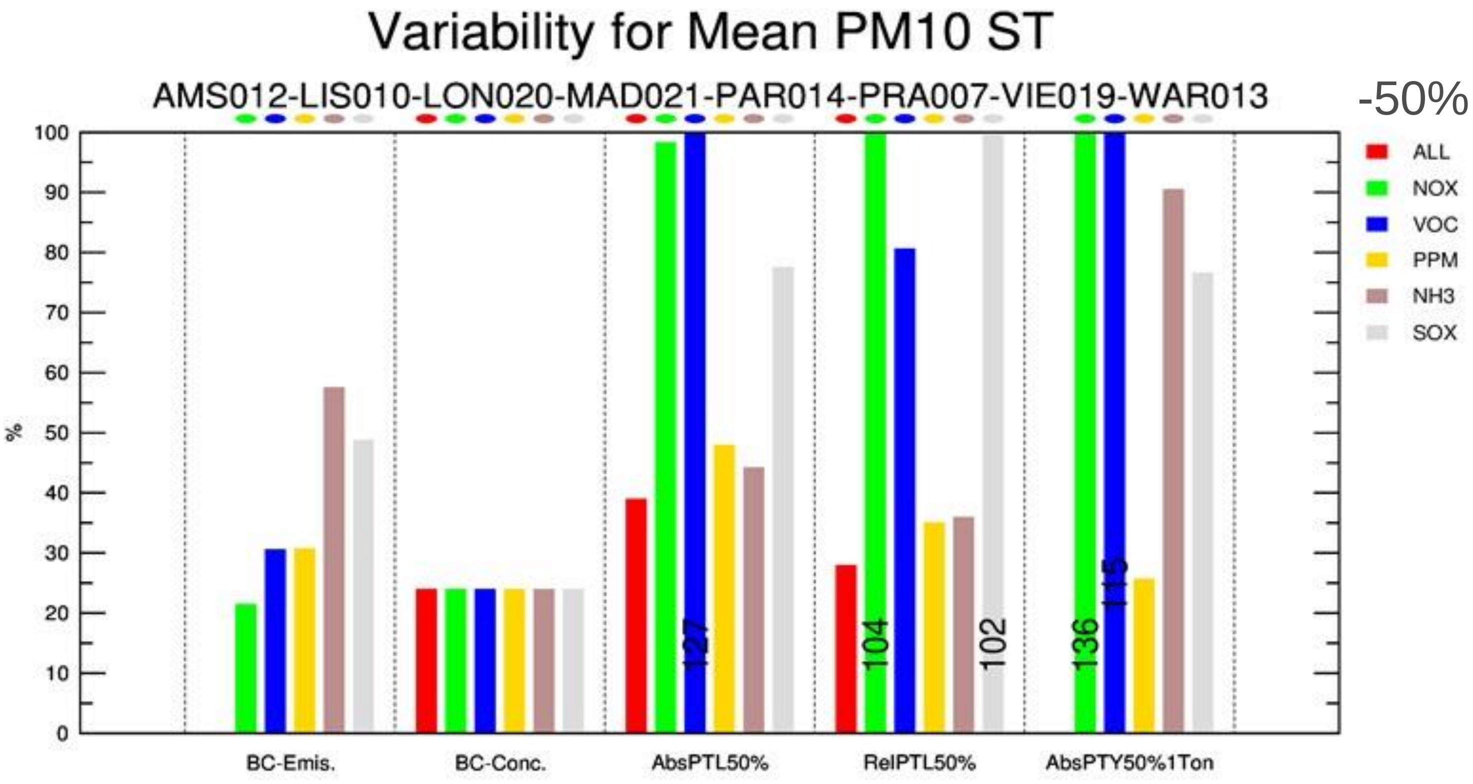


-50% scenario

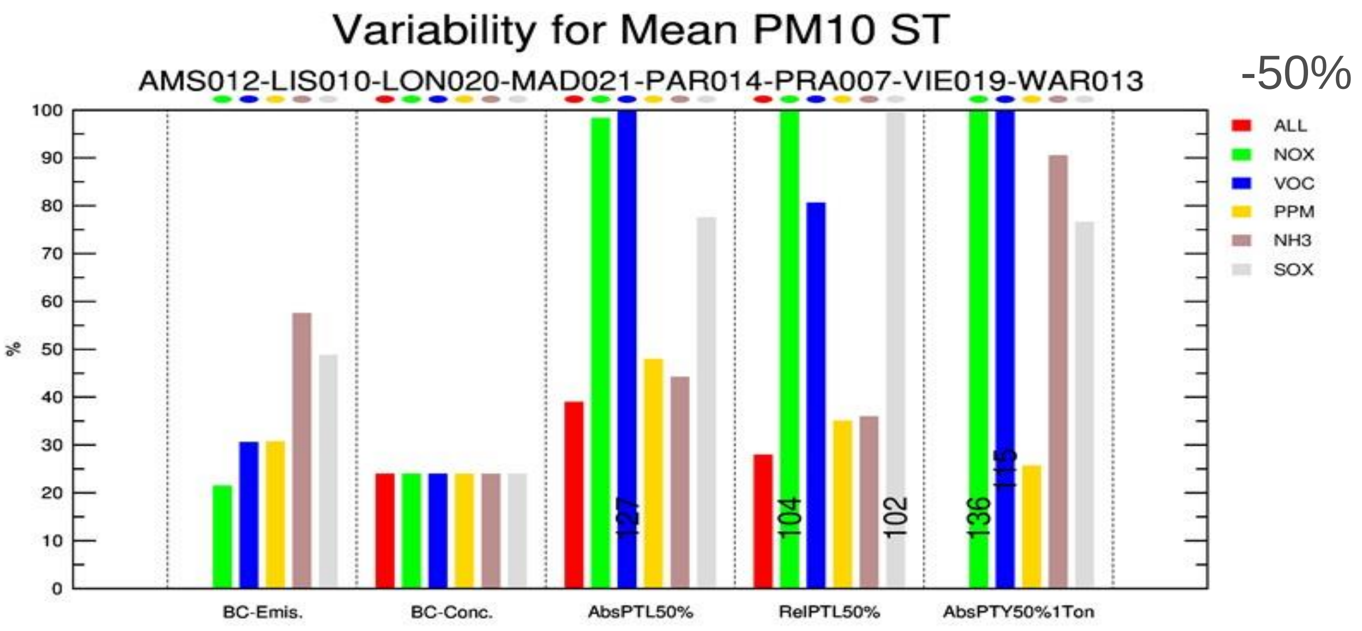
European Commission

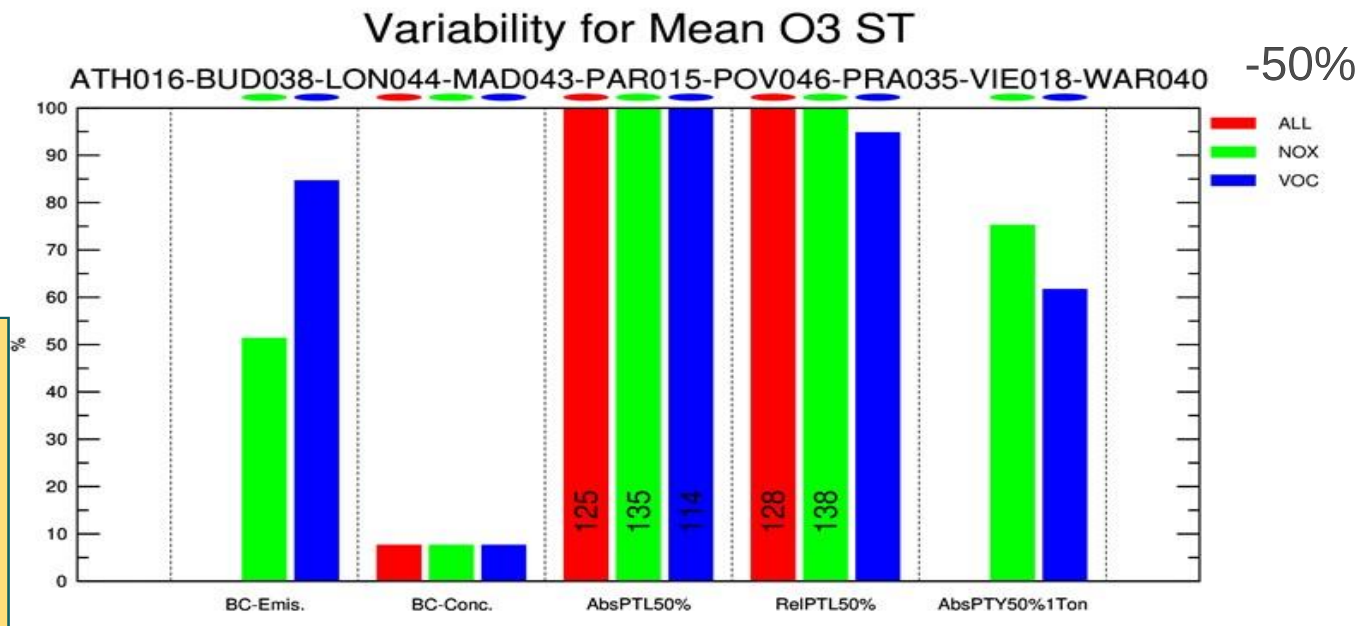
Results on variability

- Less variability on O3 BC Mean than PM10 BC Mean
  - 6% versus 22%
- Variability of indicators
  - Very high, depending on the indicator
  - Lower variability on Potency (PTY)

Variability from models M assessed by Norm. Std. Dev.

$$NSD_{IND} = \sqrt{\frac{\sum_{m=1}^{M}(IND_m - \overline{IND})^2}{(\overline{IND})^2}}$$





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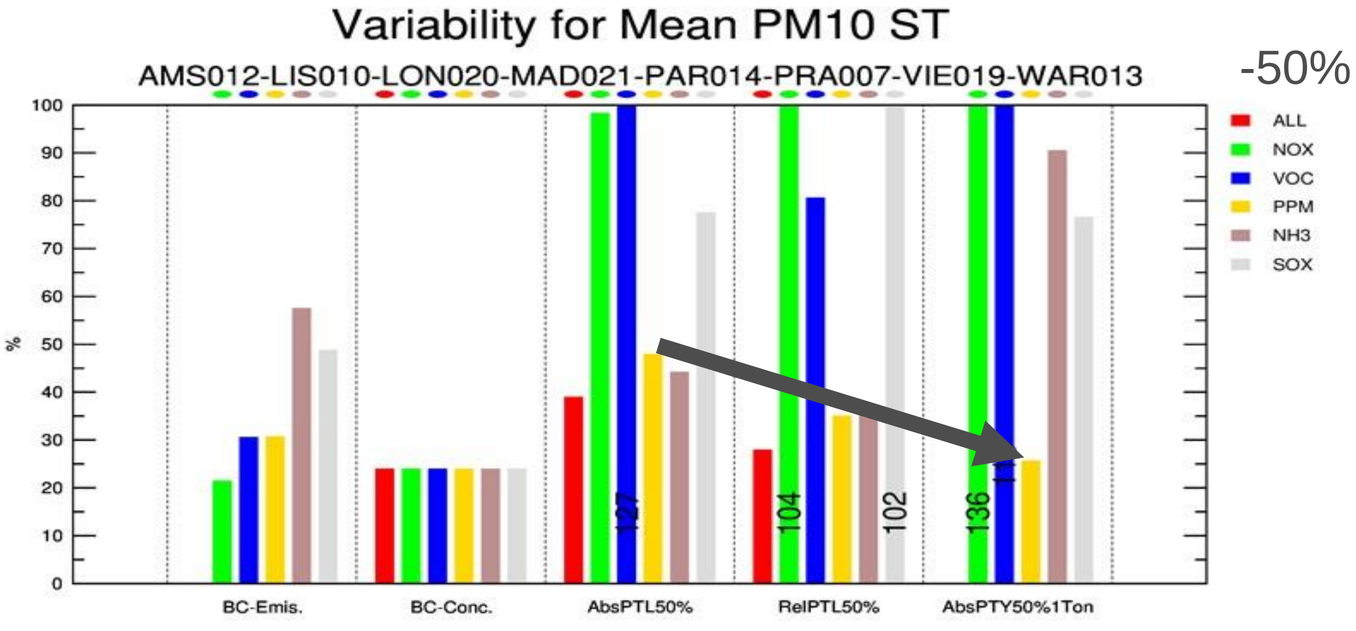
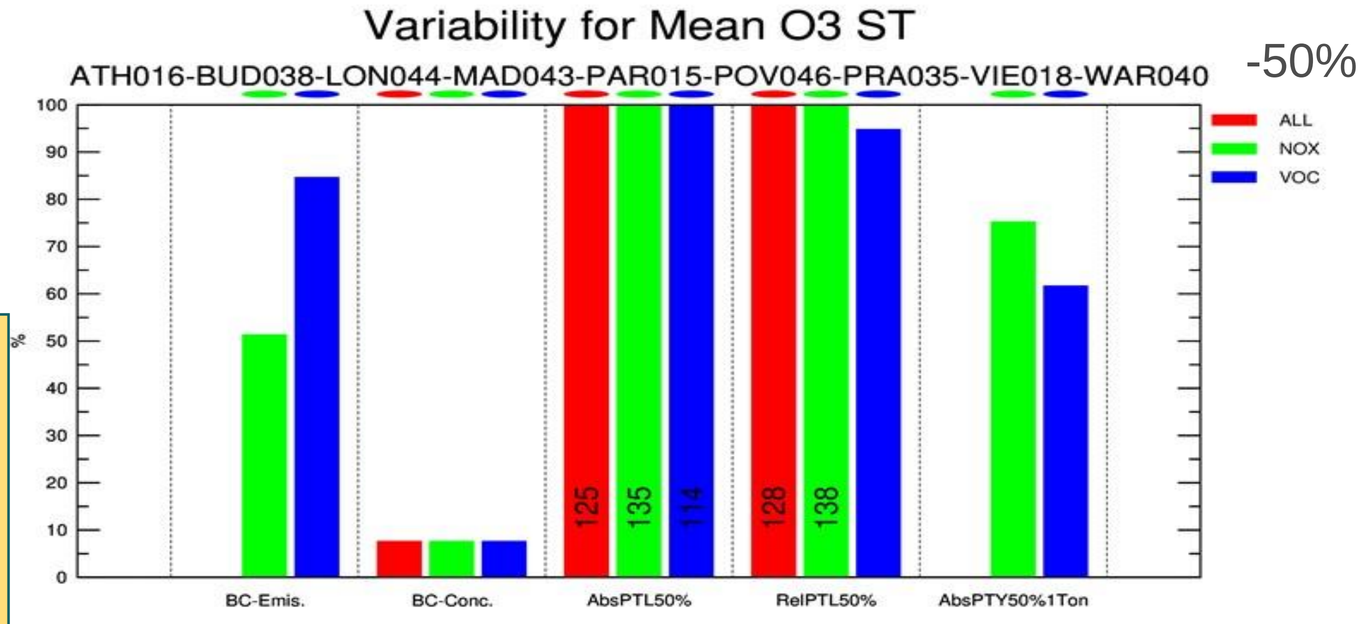
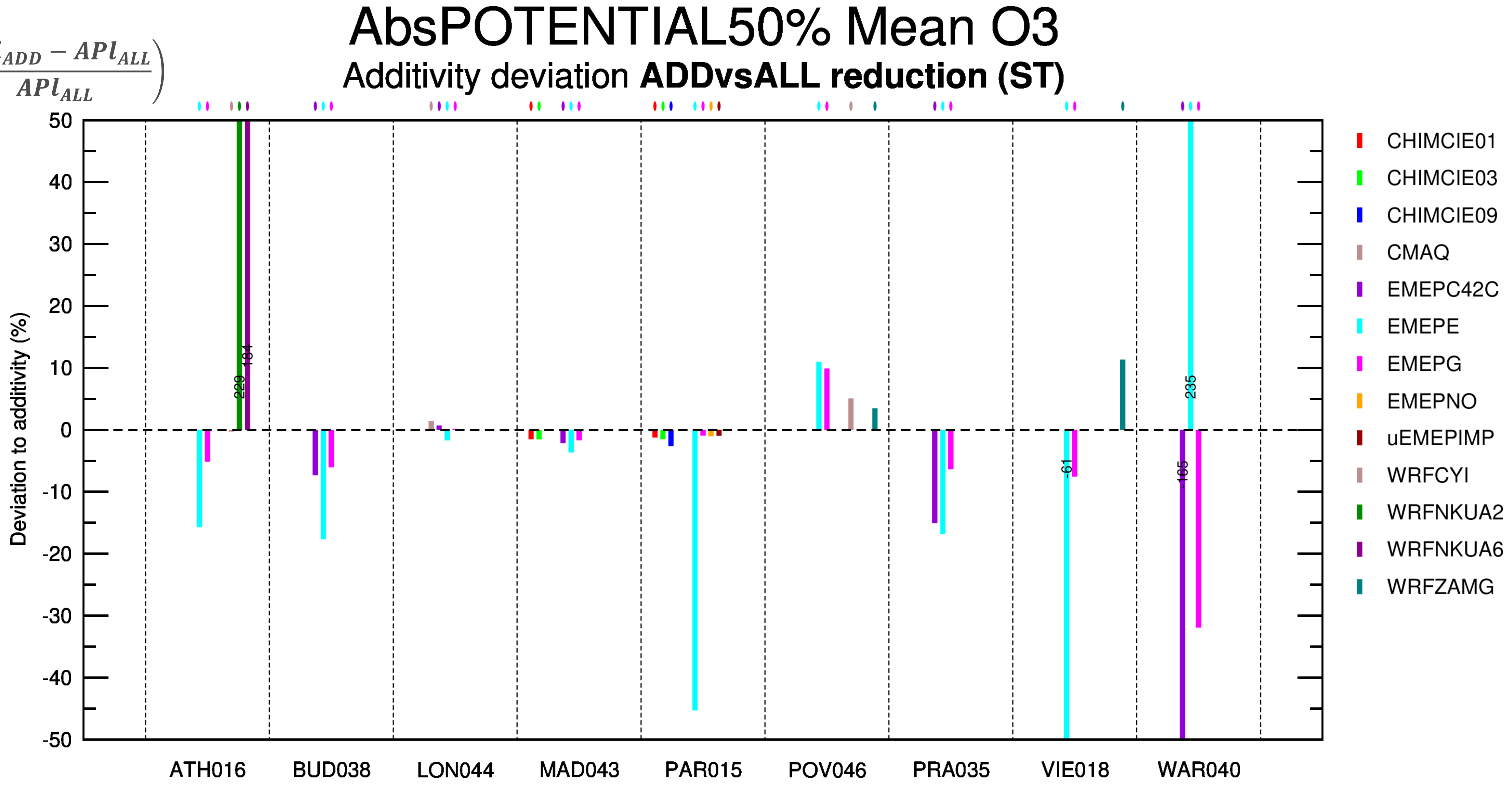




Additivity on O3

Deviation=0% means perfect additivity

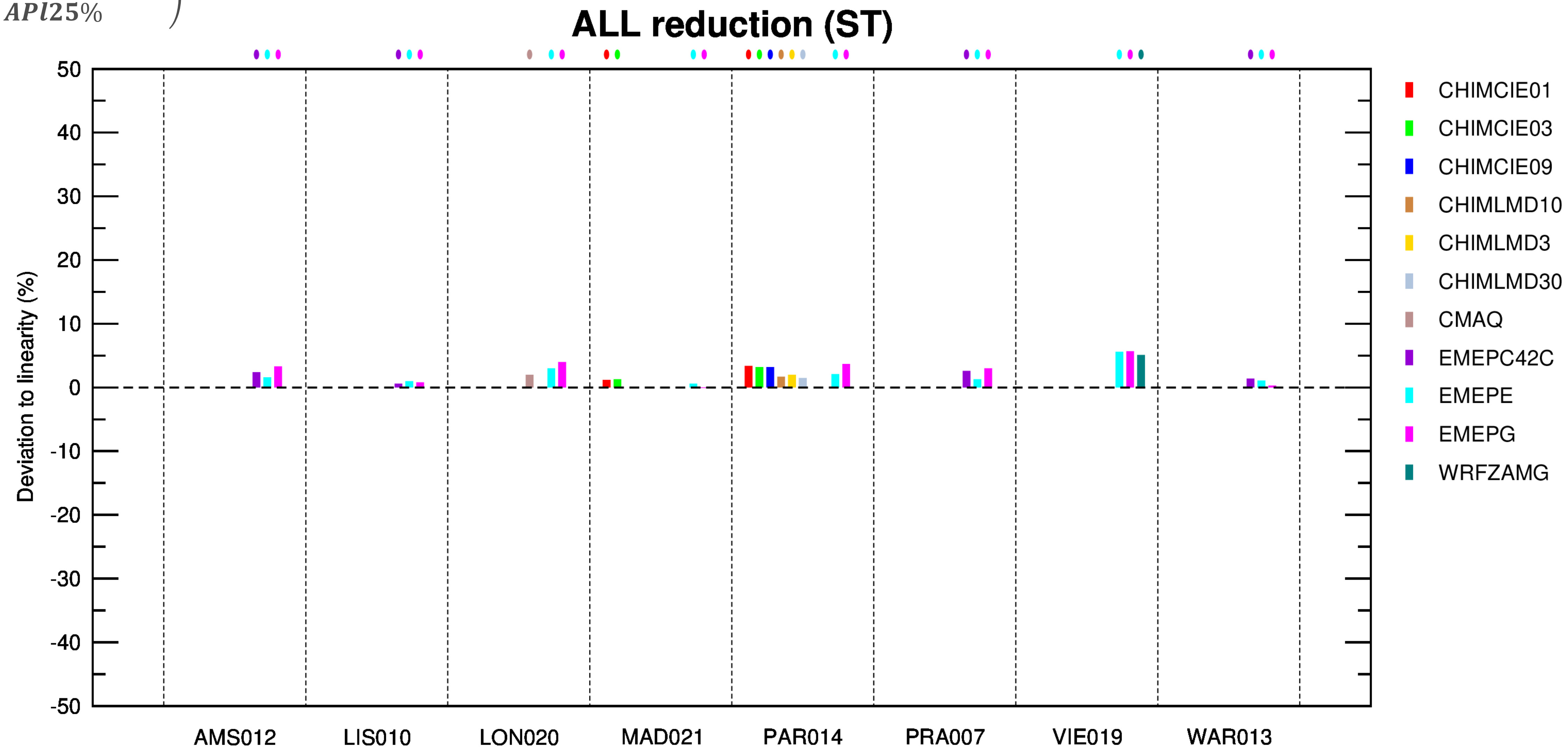
$$100 \times \left(\frac{APl_{ADD} - APl_{ALL}}{APl_{ALL}}\right)$$



Linearity on PM10

Deviation=0% means perfect linearity

$$100 \times \left(\frac{API50\% - API25\%}{API25\%}\right)$$



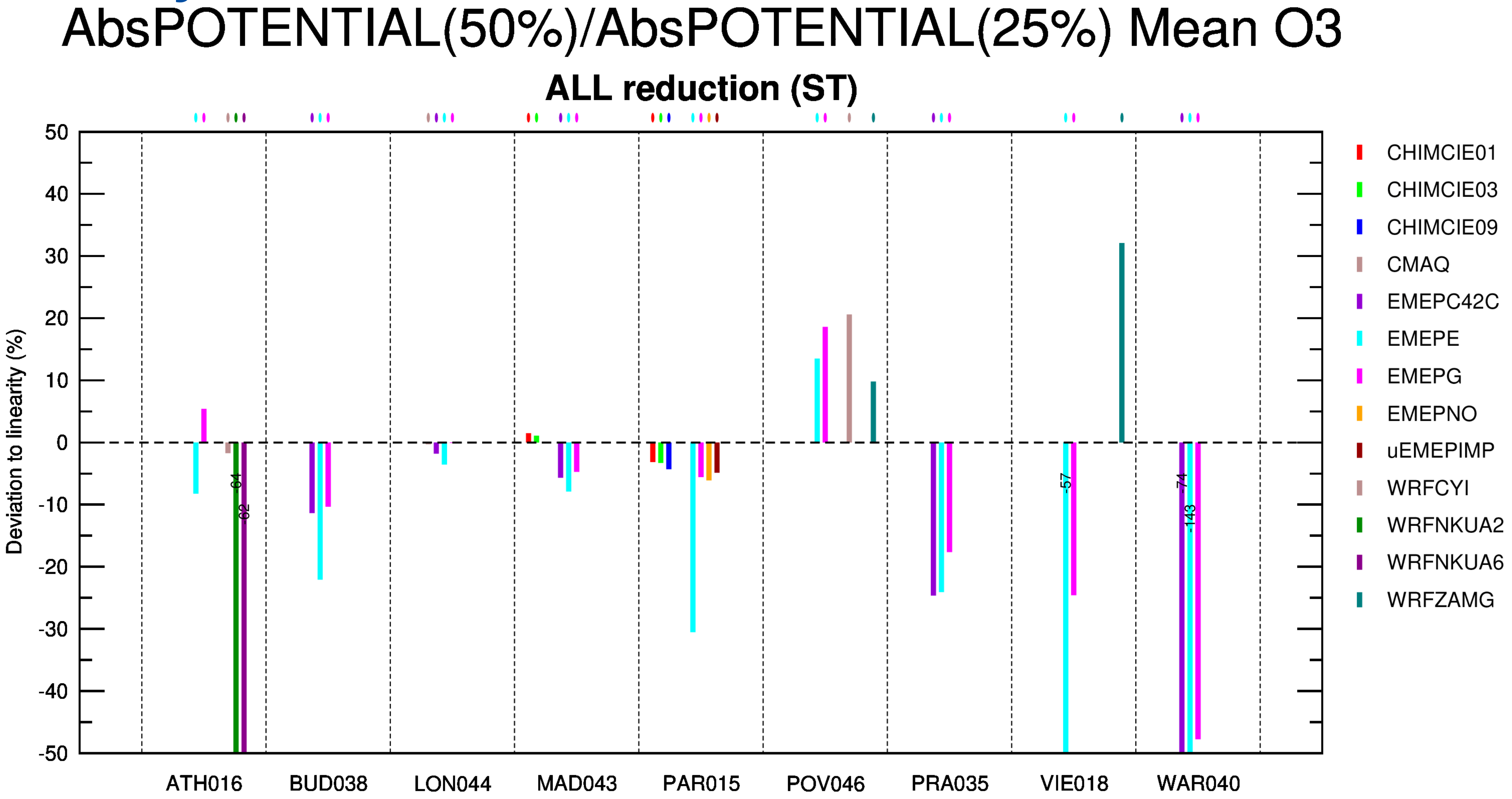
Conclusions

- **High variability of indicators observed in our first results**
  - Larger variability on model responses to emission reduction than for absolute values!
  - Less variability between models for the Potency compare to Potential
- **Next steps**
  - ✓ FAIRMODE meeting in Oslo (18-20th October 2022)
  - ✓ Rough analyses and paper I (presentation of the exercize)
  - ✓ In depth work in sub groups on the impact of:
    - *Resolution (CIEMAT, LMD, NKUA)*
    - *Chemistry (CIEMAT, NKUA)*
    - *Emissions on LT (Alexander de Meij – METCLIM/JRC) → **Presentation by Kees Cuvelier***
  - ✓ Possible extention investigating the impact on threshold exceedances using observations
    - Impact at stations applying an absolute or relative delta
- **Other modelling groups are welcome!**

END

Thank you for your attention

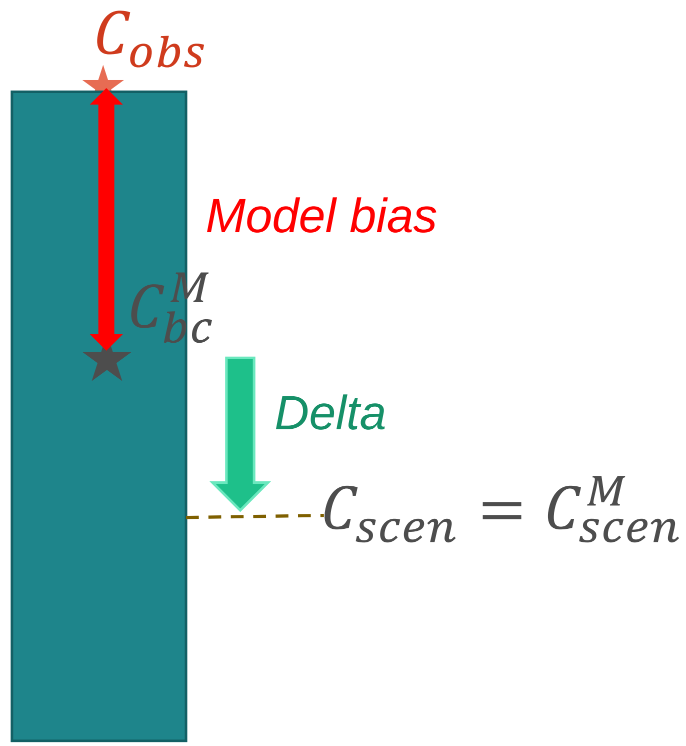
Linearity on O3



FAIRMODE CT9 CONTEXT

- Many inter-comparison exercises of air quality models
- No recent exercises to assess the capacity of models to simulate “delta” (Formerly CityDelta, EURODELTA) particularly at more local sacle
- **Need to have a long term inter-comparison platform to continually assess model responses**

Mod. only based method



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- A Model Concentration Delta can be applied to an observation C_{obs} to evaluate a scenarios based on ‘*bc*’ reference and ‘*scen*’ simulations:
  - Absolute (for O3?): $C_{scen} = C_{obs} + \overbrace{\left(\boldsymbol{C^{M}_{scen} - C^{M}_{bc}}\right)}^{delta}$
  - Relative (for NO2 or PM?): $C_{scen} = C_{obs} \times \left(\boldsymbol{C^{M}_{scen} - C^{M}_{bc}}\right)/\boldsymbol{C^{M}_{bc}}$
  - ***Techniques often used but rarely assessed***

Mod.+obs only based method