# *An intercomparison and evaluation of modelled trends of nitrogen and sulphur wet deposition in Europe over the period 1990-2010 in the framework of the Eurodelta3/TFMM trend modelling exercise*

*Mark R. Theobald, Marta G. Vivanco, Wenche Aas, Mario Adani, Camilla Andersson, Bertrand Bessagnet, Gino Briganti, Andrea Cappelletti, Giancarlo Ciarelli, Augustin Colette, Florian Couvidat, Kees Cuvelier, Massimo D'Isidoro, Hilde Fagerli, Astrid Manders, Kathleen Mar, Mihaela Mircea, Noelia Otero, Maria-Teresa Pay, Valentin Raffort, Yelva Roustan, Martijn Schaap, Svetlana Tsyro, Peter Wind*

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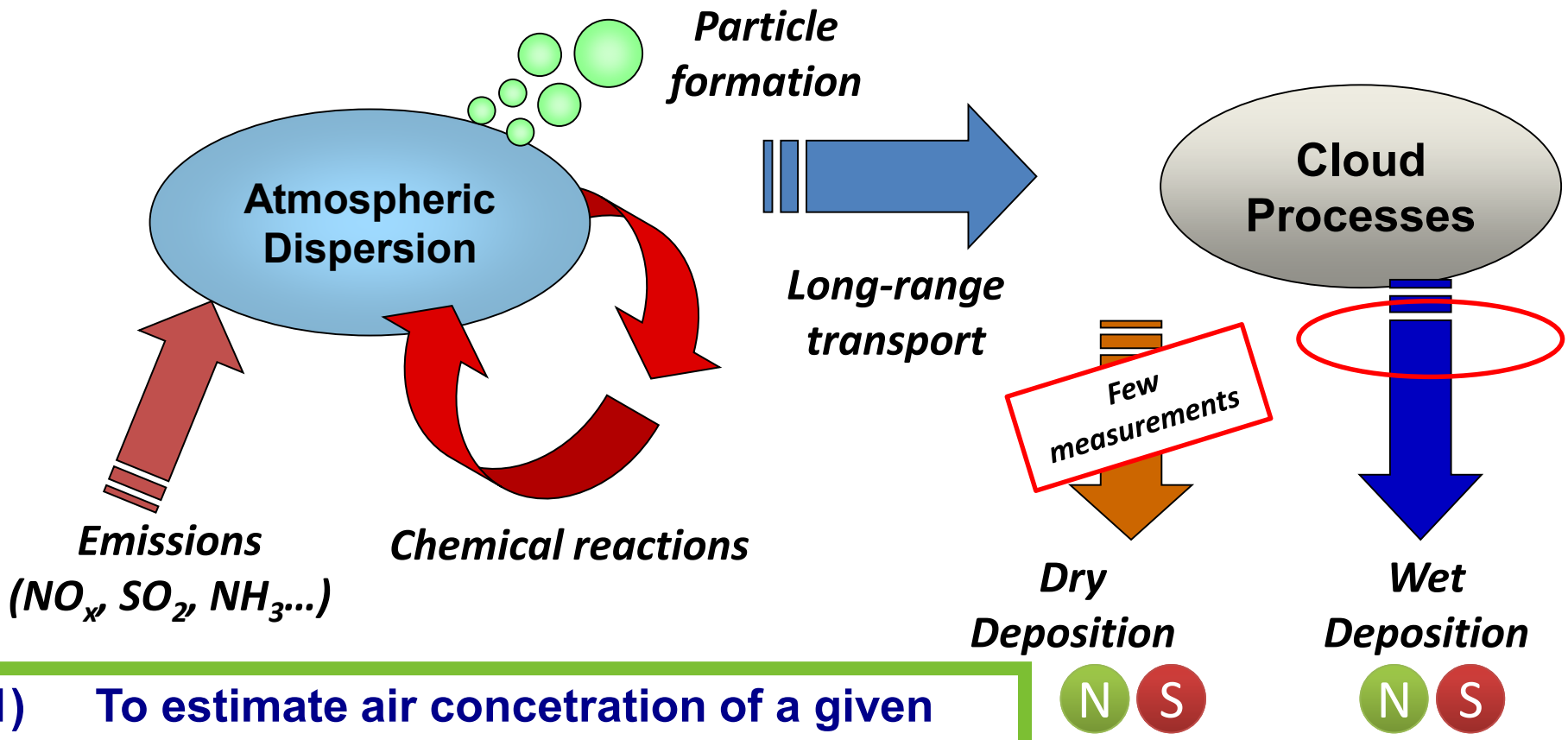
Long-range Transboundary Air Pollution

## *Outline*

- *Why look at deposition?*
- *Datasets*
- *Model performance assessment for wet deposition and precipitation: 1990, 2000, 2010*
- *Analysis of observed/modelled trends in wet deposition for the periods 1990-2000 and 2000-2010*
- *The contribution of dry deposition to total deposition*

# *Why study nitrogen and sulphur deposition?*




1) To estimate air concetration of a given pollutant (deposition as a process in the mass balance)

2) To estimate effects on ecosystems

***Loss of biodiversity***

# *Datasets Used*

## Variables (annual, seasonal)

Wet deposition of oxidised N (**WNOx**)
Wet deposition of reduced N (**WNHx**)
Wet deposition of S (**WSOx**)*
Precipitation

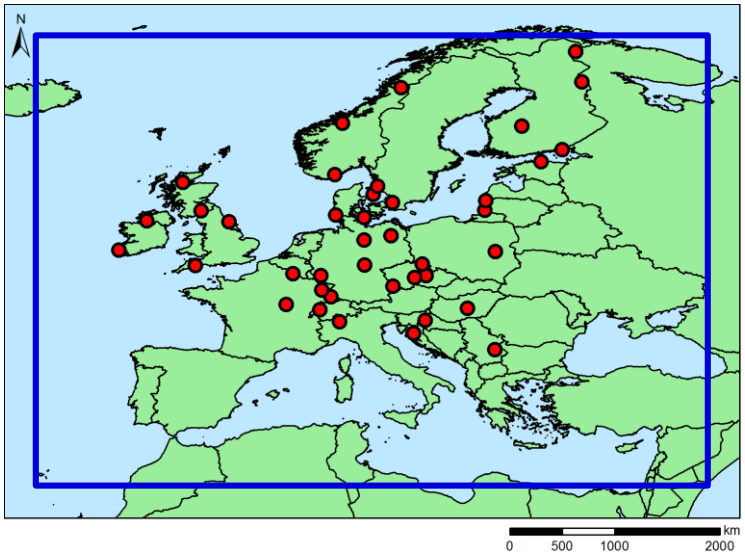
* Not including sea-salt sulphate

## Simulations (1990-2010)

Chimere (**CHIM**)
EMEP MSC-W (**EMEP**)
Lotos-Euros (**LOTO**)
MATCH
MINNI

## Simulations (1990, 2000, 2010)

Chimere (**CHIM**)
EMEP MSC-W (**EMEP**)
Lotos-Euros (**LOTO**)
MATCH
MINNI
CMAQ (**CMAQB**)
Polair3D (**POLR**)
WRF-Chem (**WRFC**)




## Observations (EMEP sites: 1990-2010)

40 Sites

**Criteria: > 75% of year**
**> 75% of years in period**

Colette, A.et al., *Geoscientific Model Development*,*10*(9), 3255.

NILU Norsk institutt for luftforskning Norwegian Institute for Air Research

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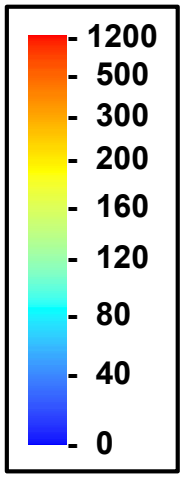
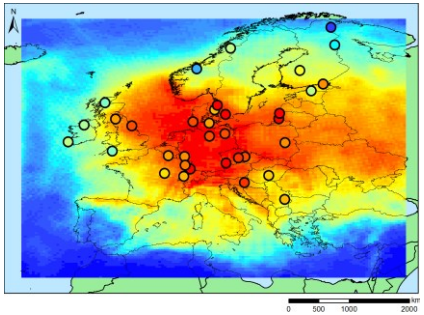
***1990 Base Year***

*WNOx (mg N $m^{-2}$)*

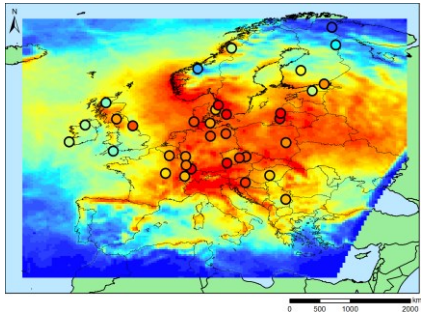
**Legend**



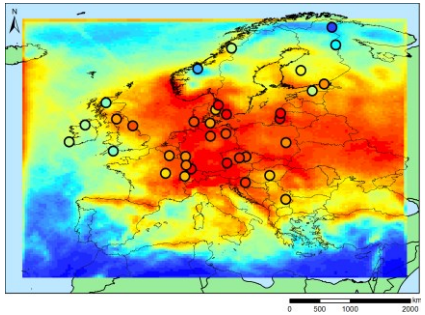

**CHIM**



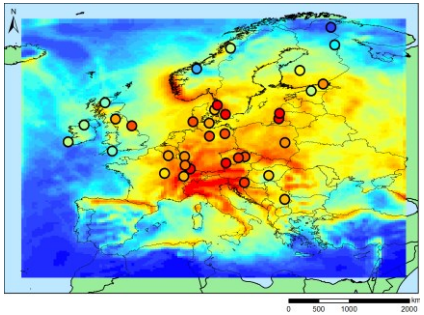
**CMAQB**



**EMEP**



**LOTO**



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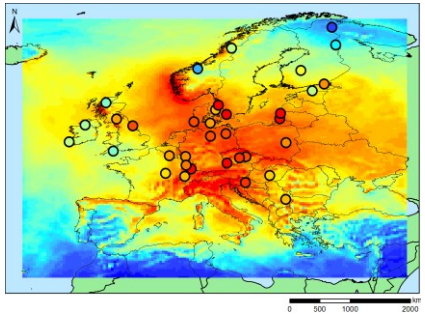
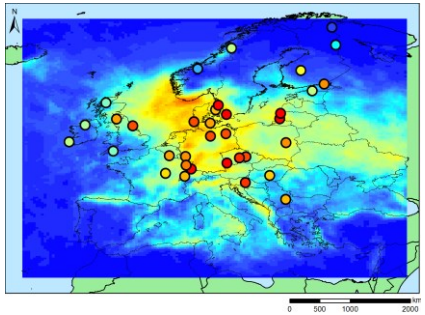
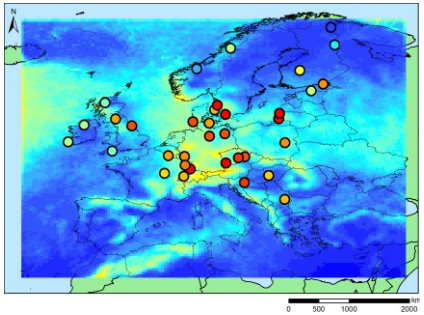


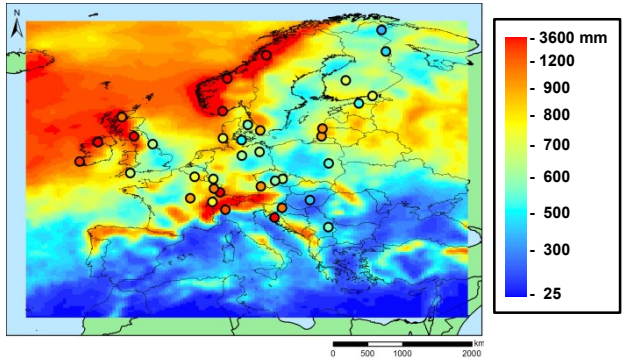
**MINNI**



**POLR**



**Precipitation**

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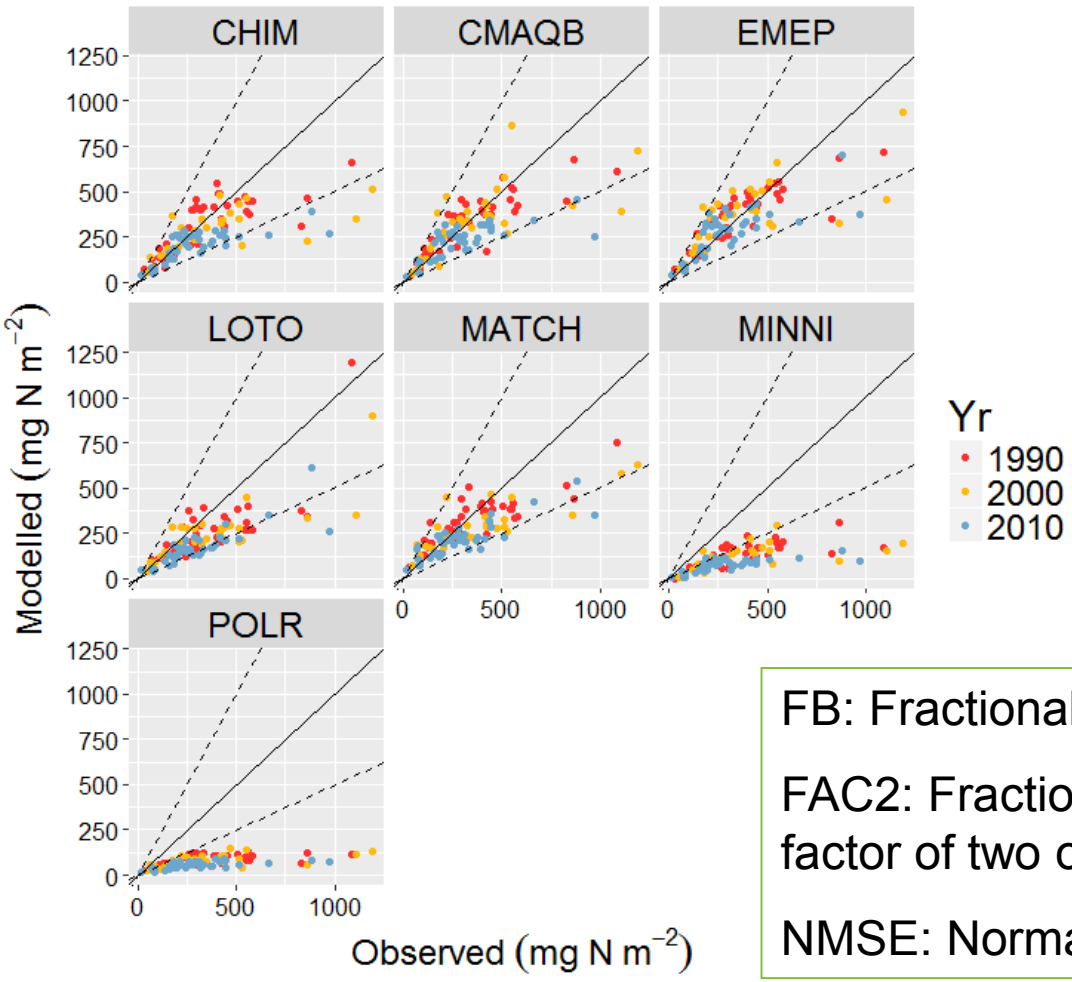
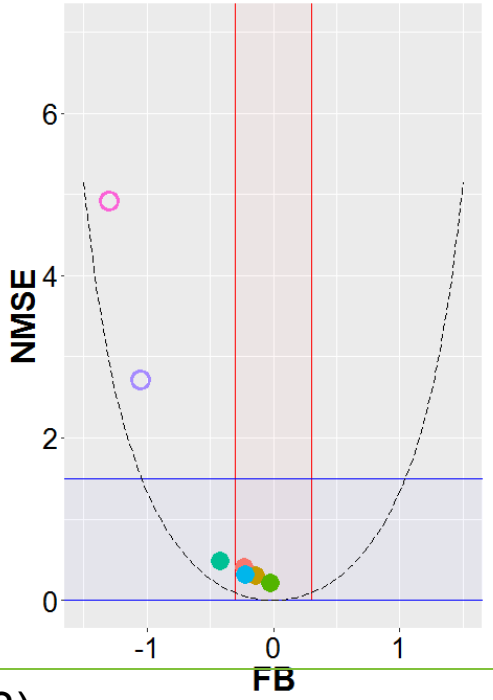
# *Model evaluation – Annual wet deposition*

*WNOx (mg N m$^{-2}$)*








FB: Fractional Bias (+-0.3)

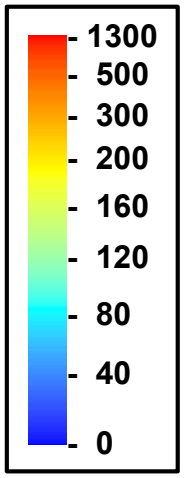
FAC2: Fraction of model estimateswithin a factor of two of the observed values

NMSE: Normalized mean square error (+-1.5)

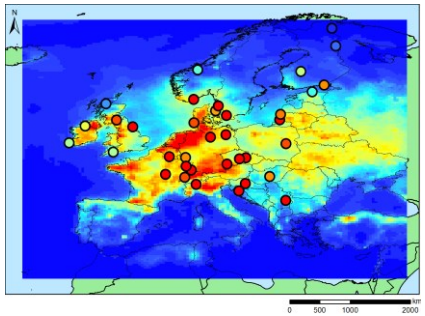
***1990 Base Year***

*WNHx (mg N $m^{-2}$)*

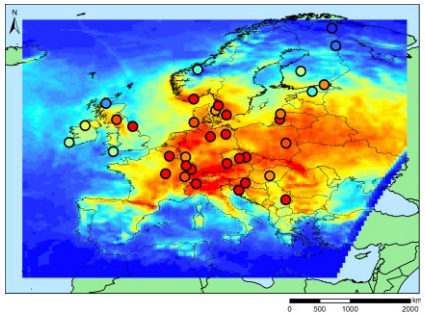
**Legend**



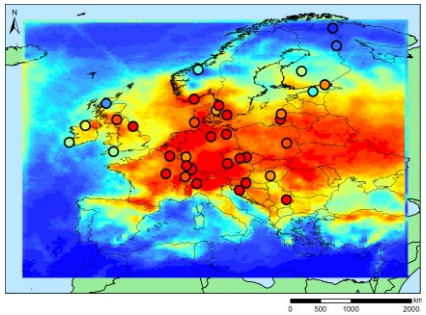

**CHIM**



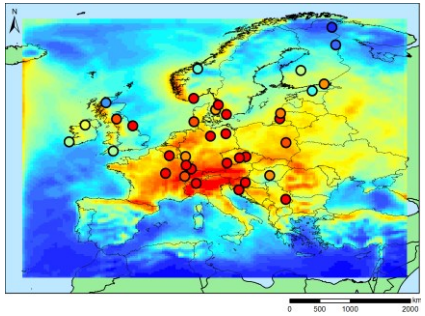
**CMAQB**



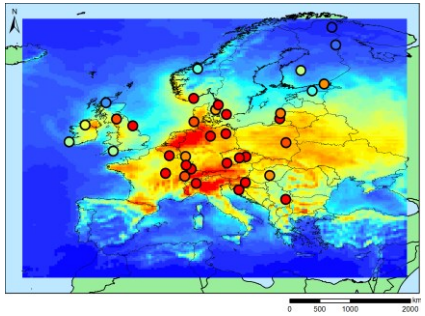
**EMEP**



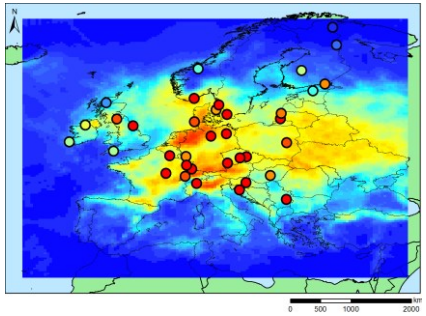
**LOTO**



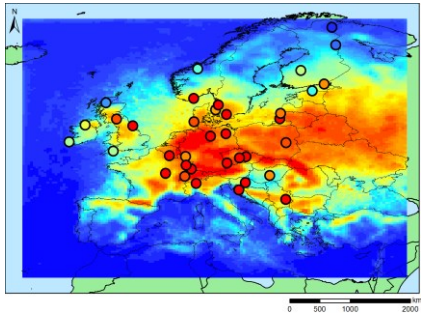
**MATCH**



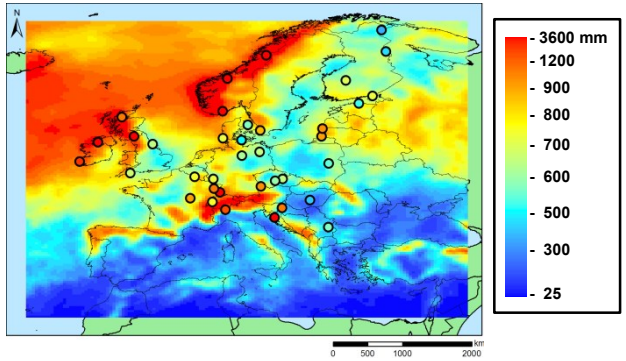
**MINNI**



**POLR**



**Precipitation**

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# *Model evaluation – Annual wet deposition*

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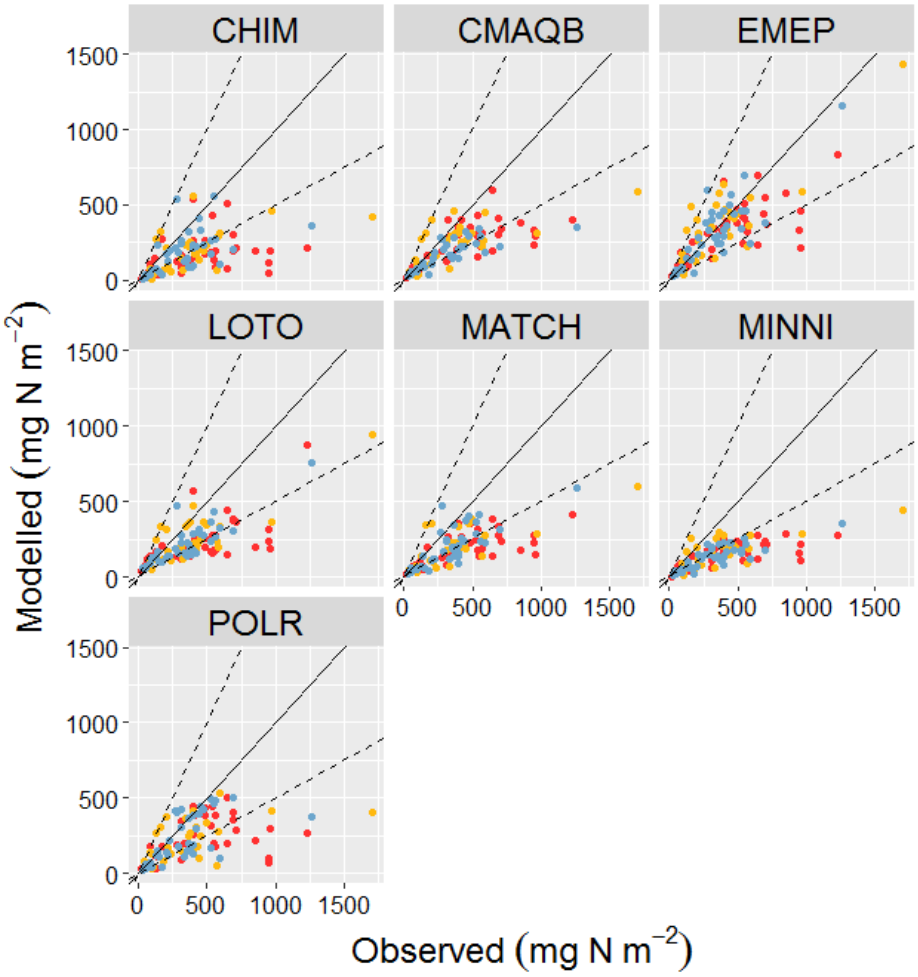
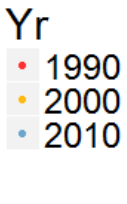
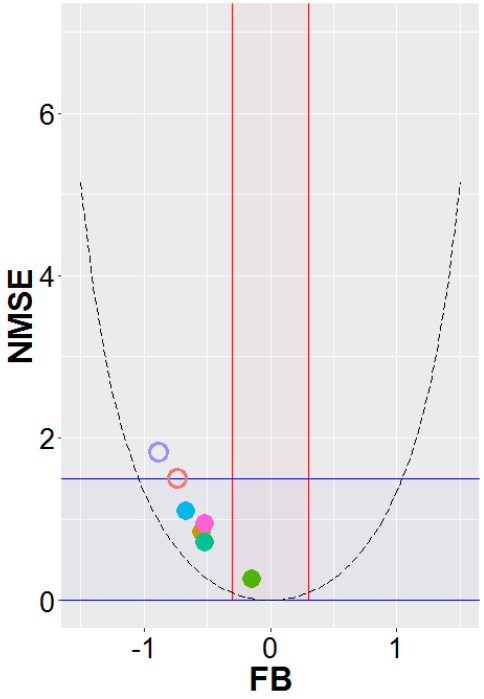






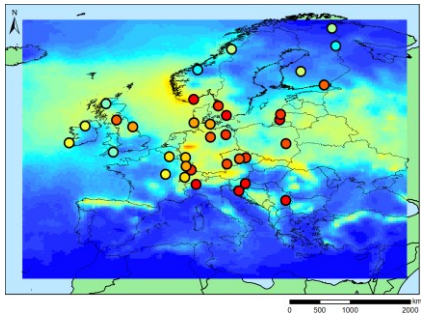
***1990 Base Year***

*WSOx (mg S $m^{-2}$)*

**Legend**

1500
700
500
400
300
200
150
75
0

**CHIM**



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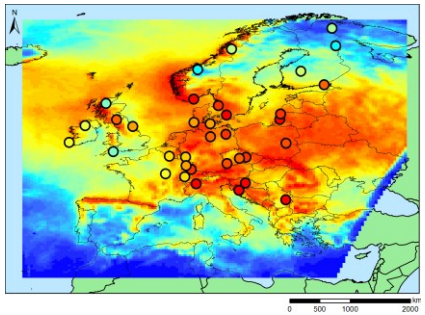
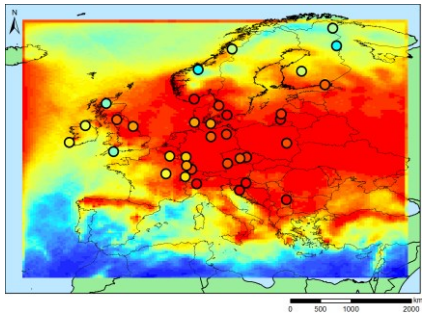
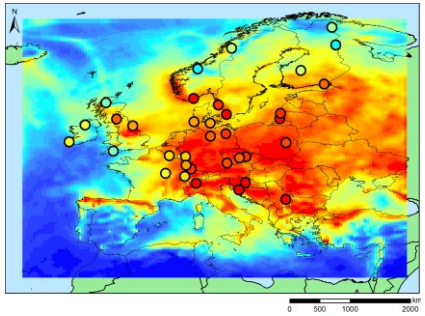


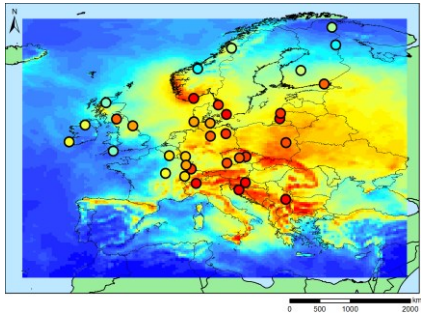
**EMEP**



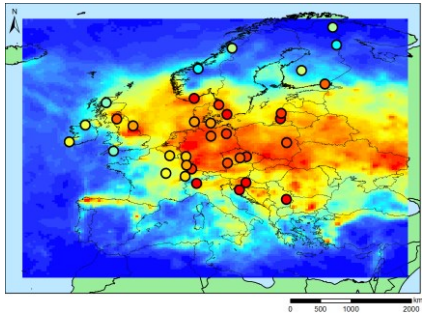
**LOTO**



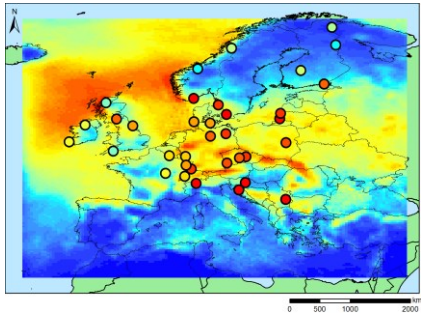
**MATCH**



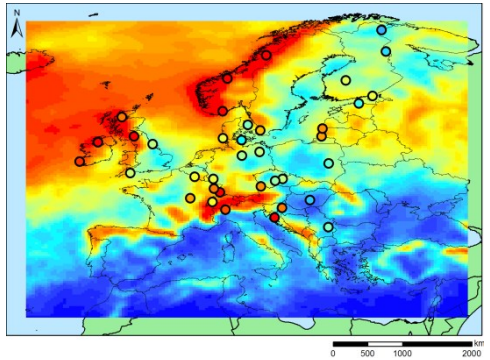
**MINNI**



**POLR**



**Precipitation**



3600 mm
1200
900
800
700
600
500
300
25

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# *Model evaluation – Annual wet deposition*

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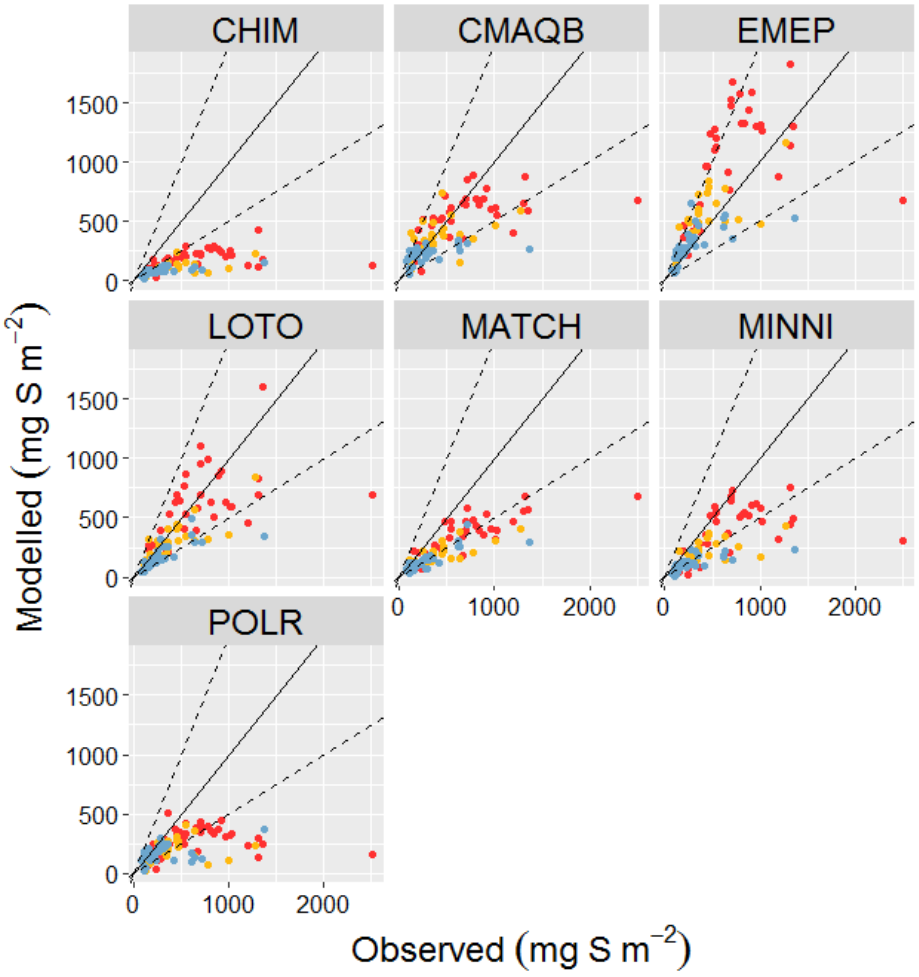
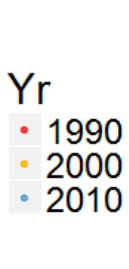
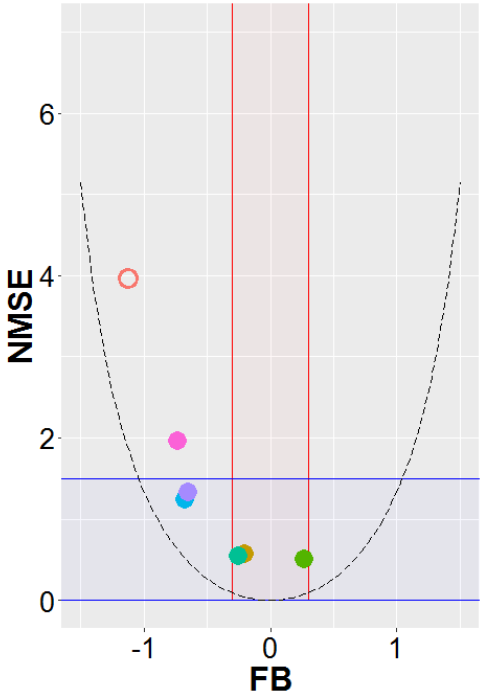


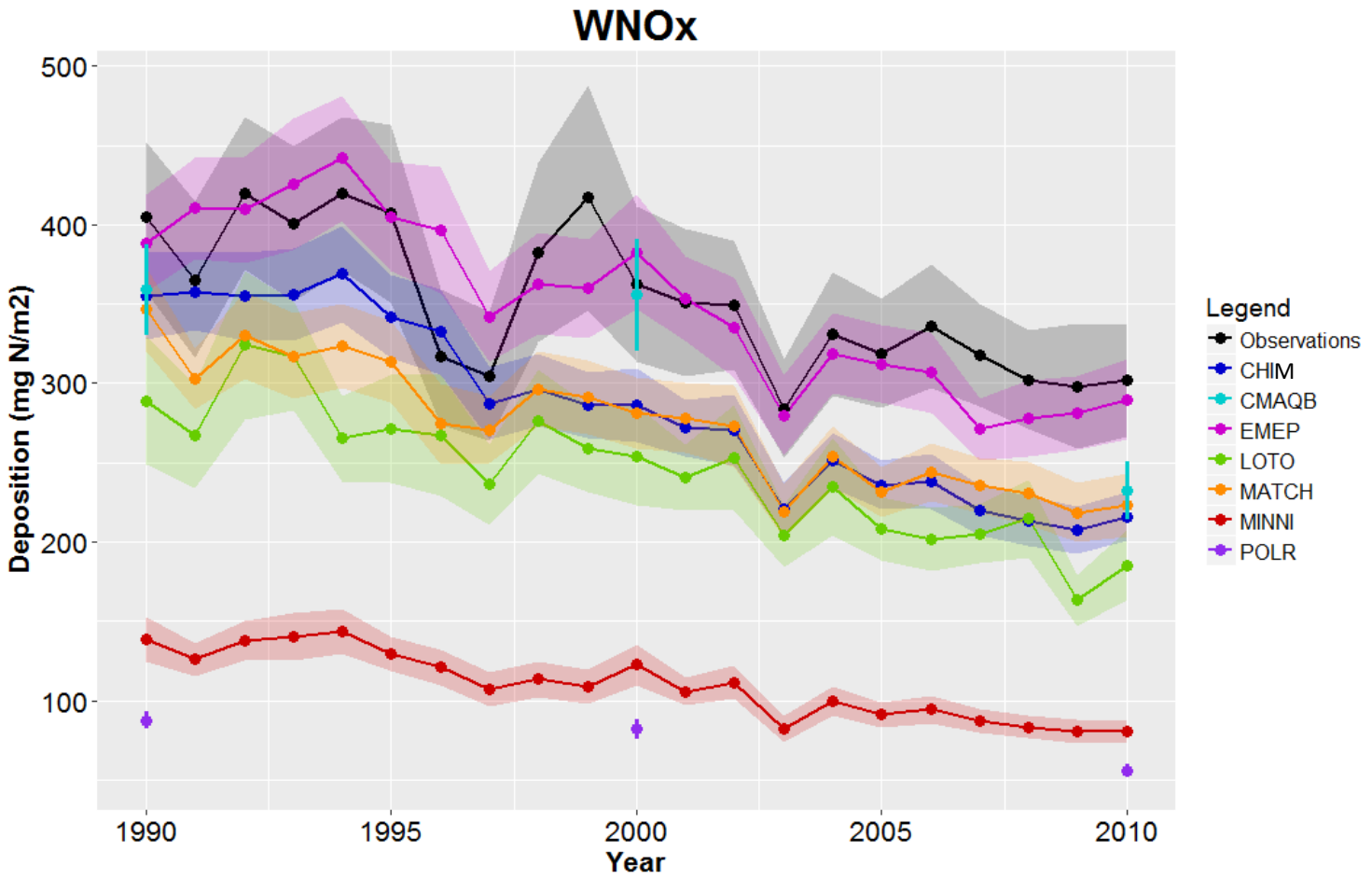







# *21 year time series (1990-2010) – Mean of all sites (plus Std. Error)*

*WNOx (mg N $m^{-2}$ $yr^{-1}$)*



# *21 year time series (1990-2010) – Mean of all sites (plus Std. Error)*

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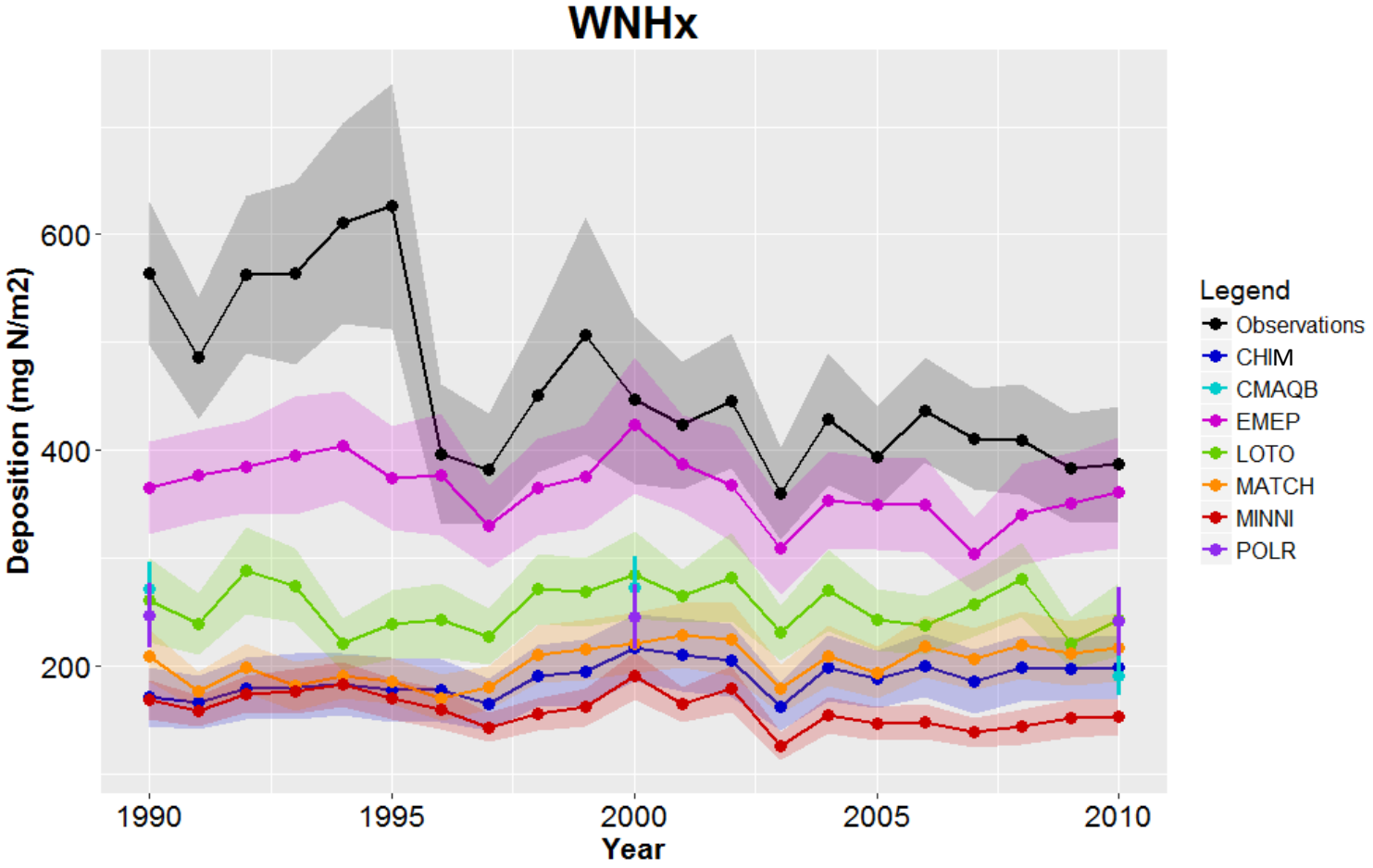
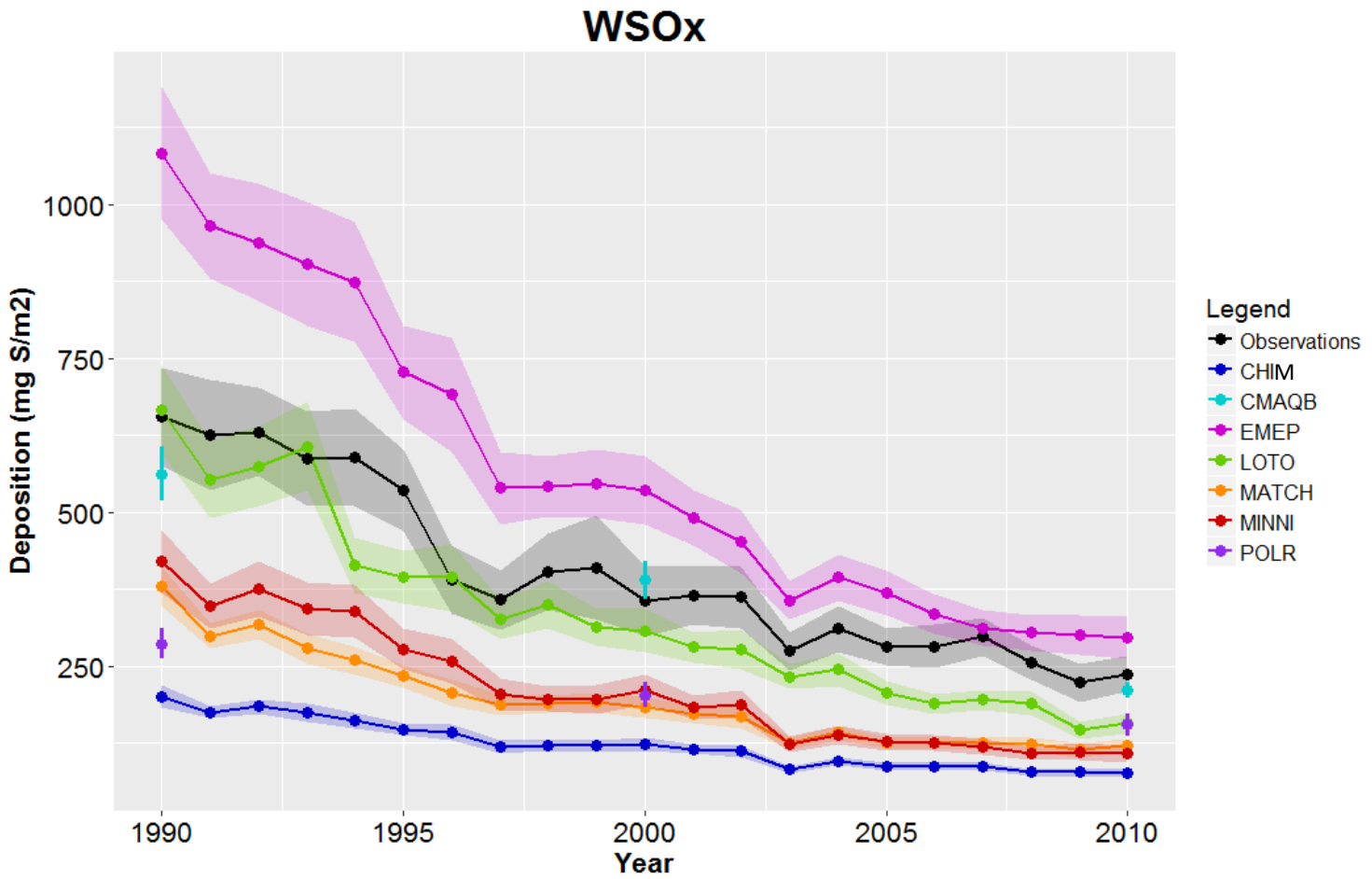
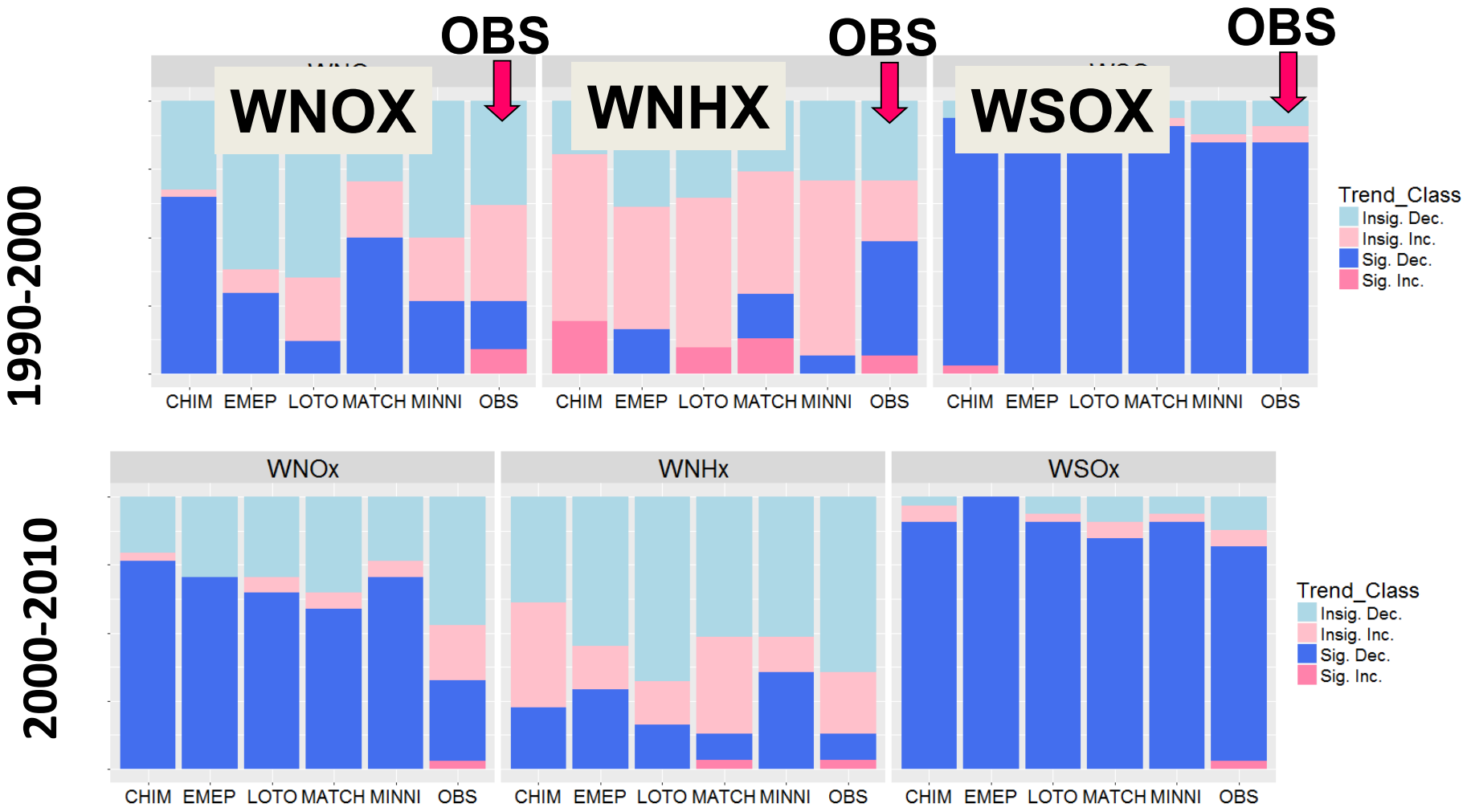


# *21 year time series (1990-2010) – Mean of all sites (plus Std. Error)*

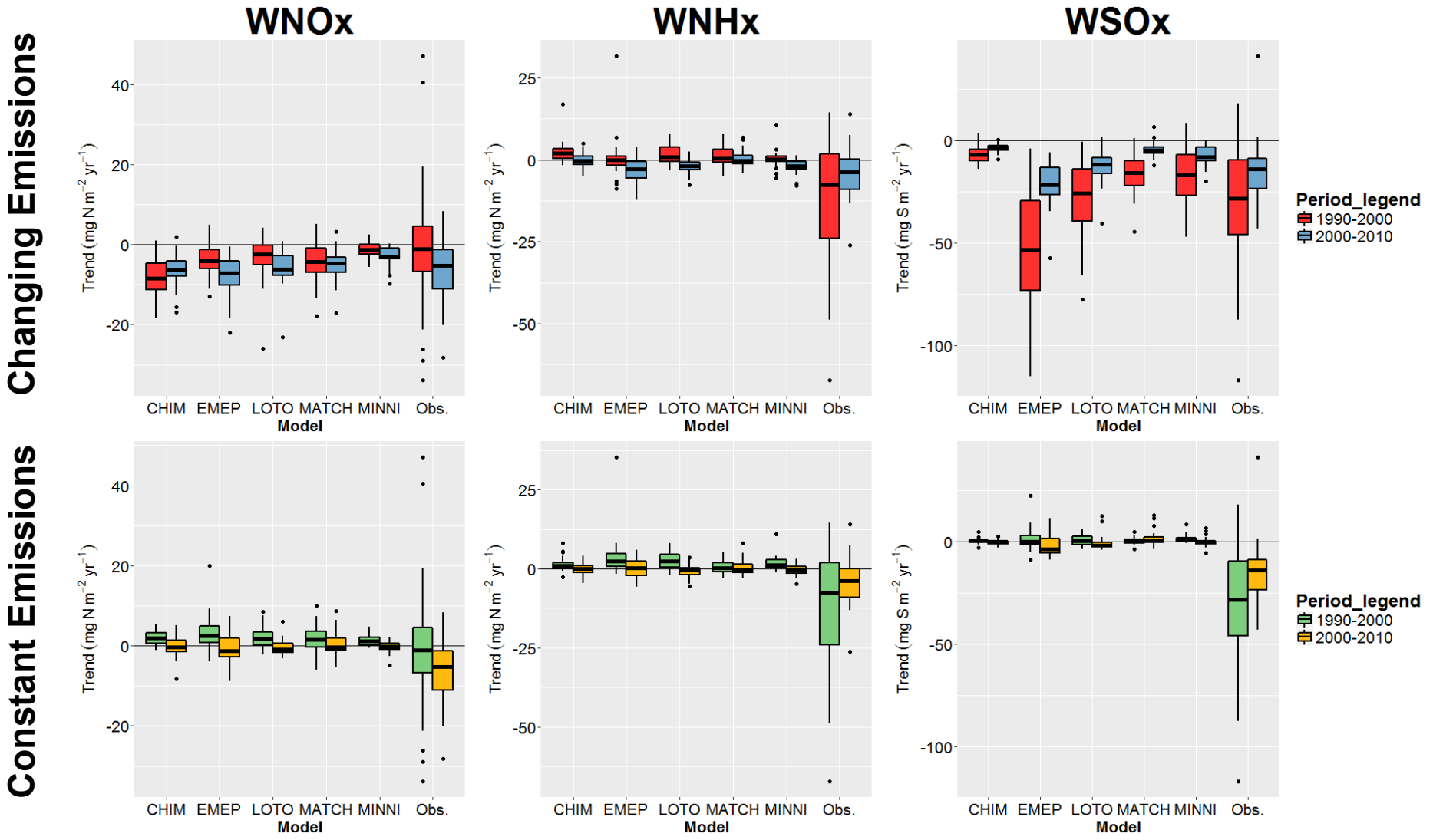
*WSOx (mg S $m^{-2}$ $yr^{-1}$)*



# *Trend magnitude: Sen's method, Trend Significance: using the partial seasonal Mann-Kendall test*



# *Trend distributions (changing and constant emissions)*

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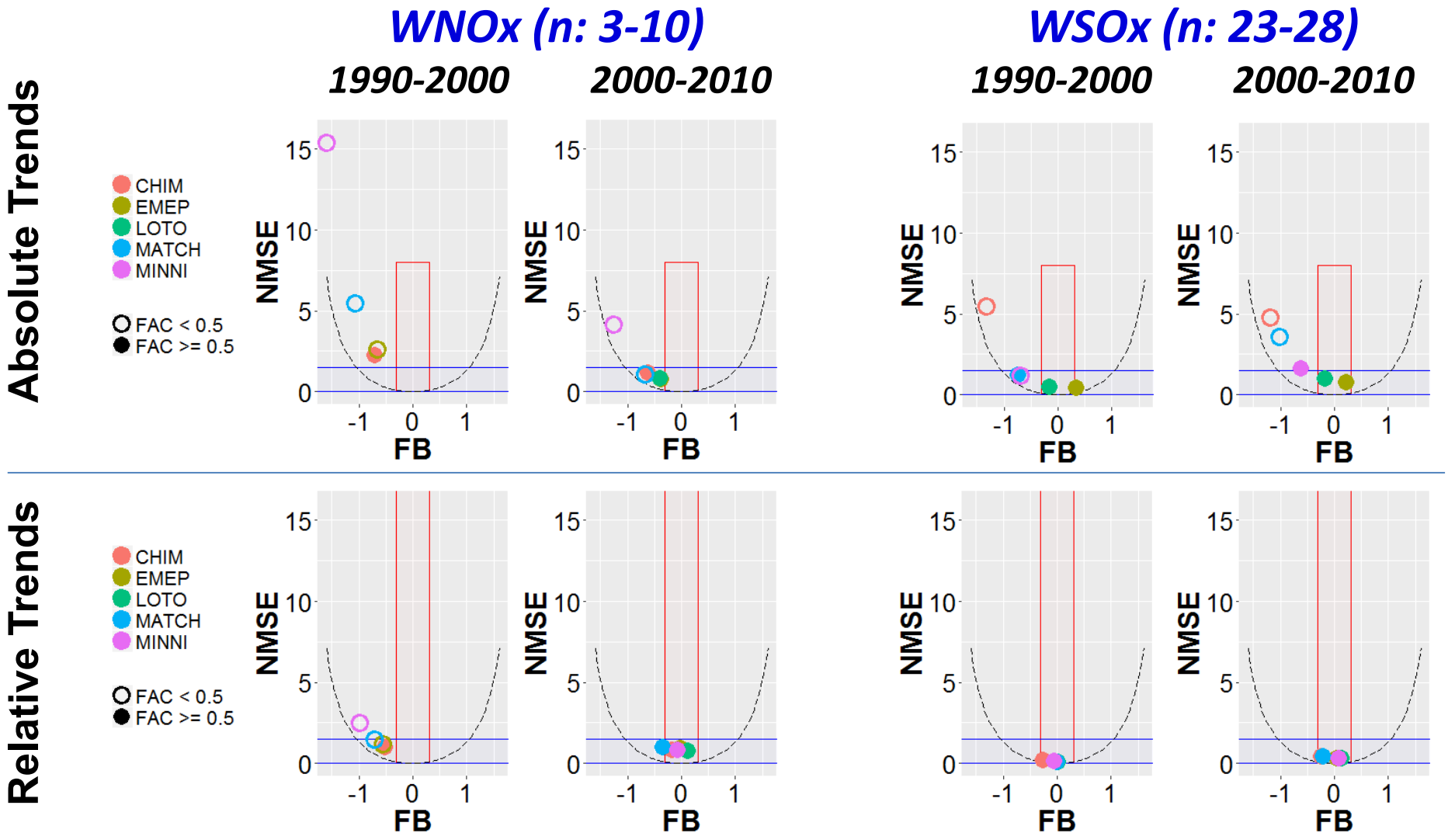
# *Evaluation of modelled significant trends (WNOx and WSOx)*

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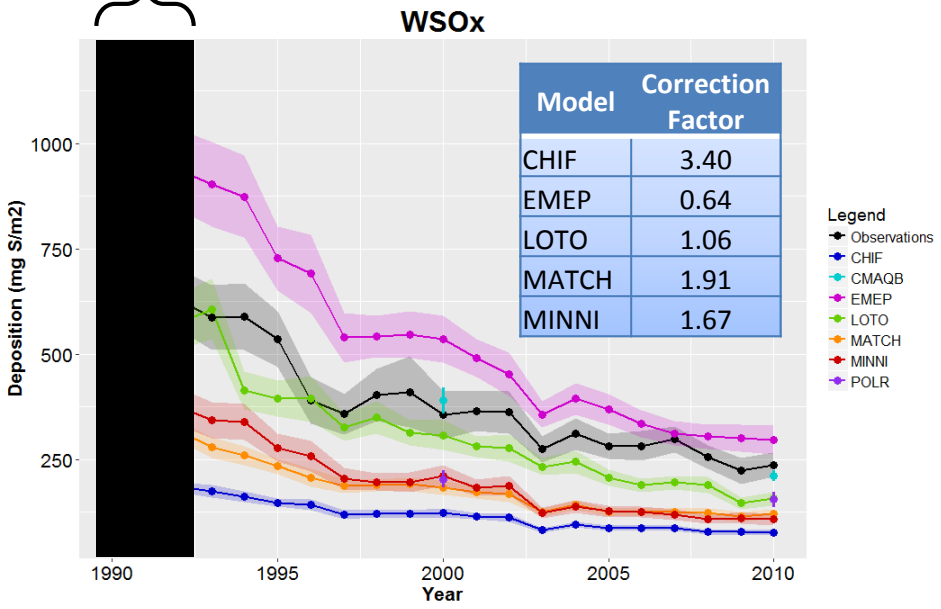
# *Obtaining more robust time series through measurement-model fusion*

*"If the models are better at estimating relative changes in deposition then maybe we can obtain more reliable estimates of future deposition by correcting the models for an initial period for which measurements exist"*

***Very simple example:***

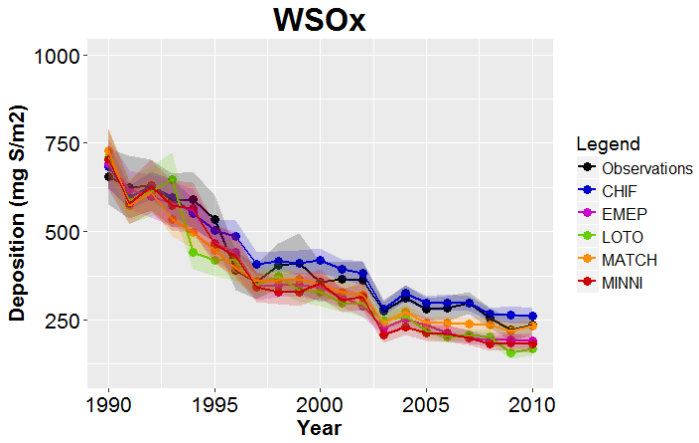
***Initial period***



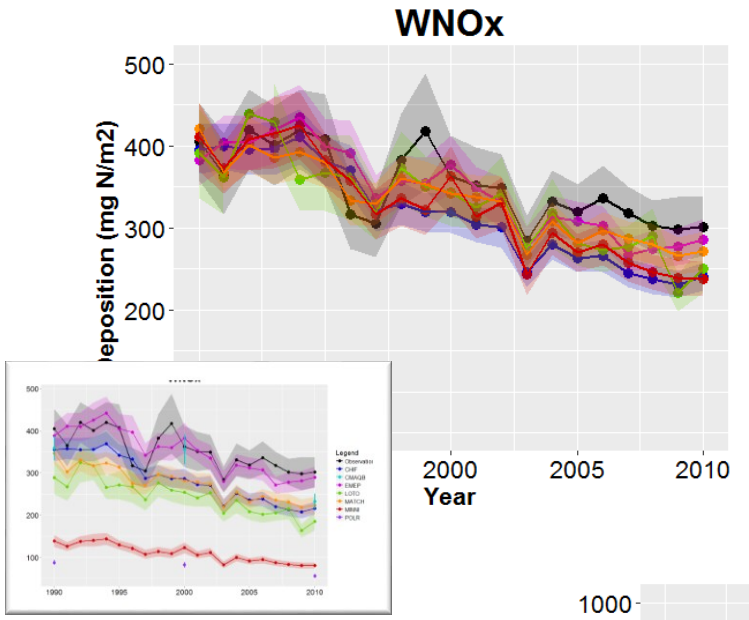

| Model | Correction Factor |
|---|---|
| CHIF | 3.40 |
| EMEP | 0.64 |
| LOTO | 1.06 |
| MATCH | 1.91 |
| MINNI | 1.67 |

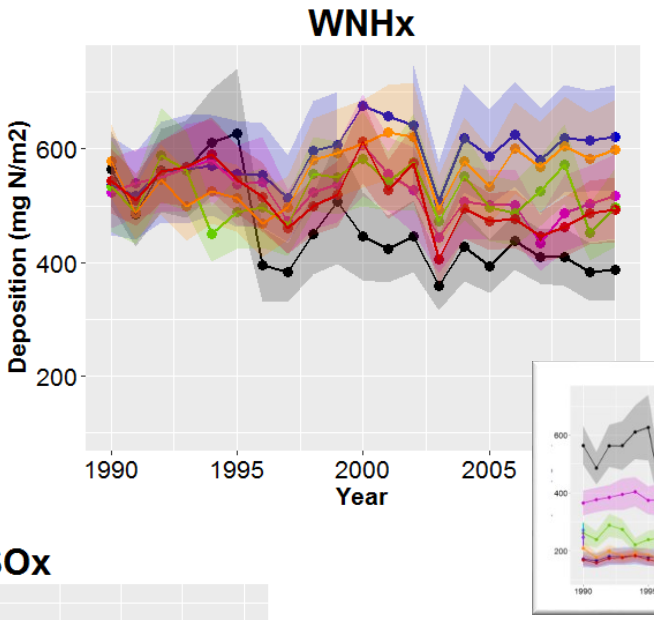
*1) Calculate the model correction (e.g. bias correction) for the initial period (3 years, in this example)*

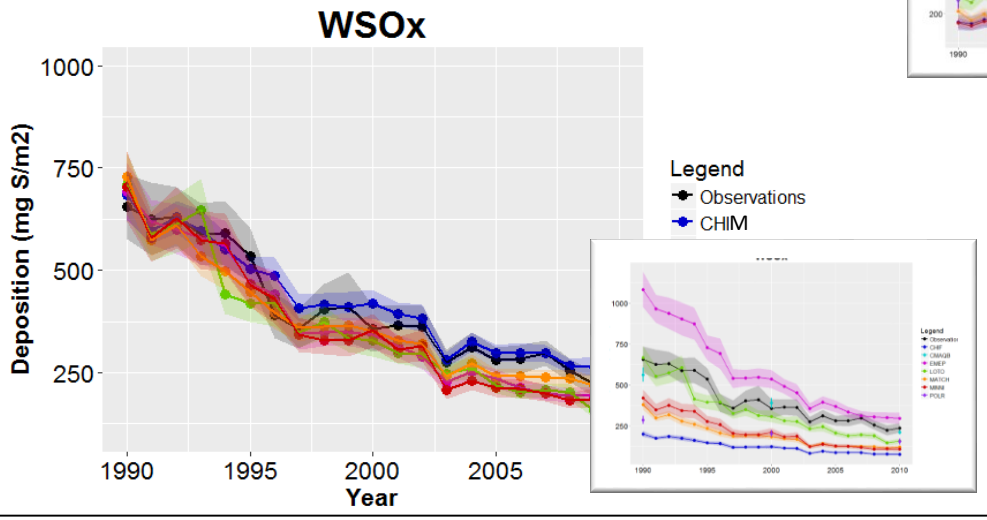
*2) Apply the correction to the rest of the time series*



# *Time series of bias-corrected models*

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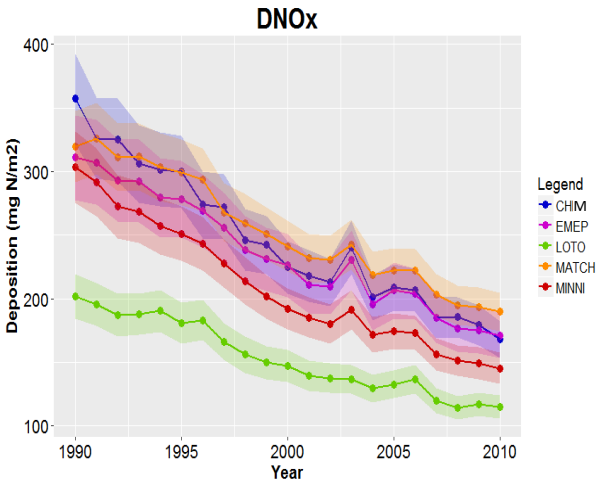
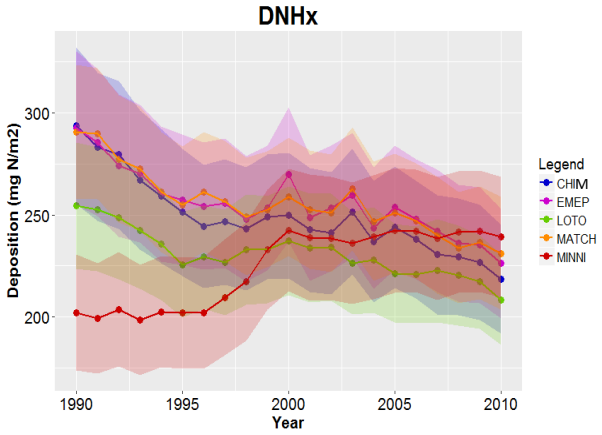
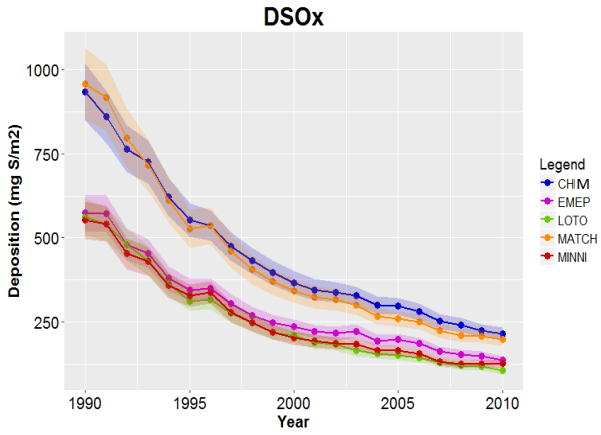
Long-range Transboundary Air Pollution

# *Time series of dry deposition (no observations)*




**DNOx:** most of the models estimate similar mean dry deposition rates (with the exception of LOTO, with substantially lower values; not reflected in the estimates of WNOx.

Contribution to total oxidised N deposition: **35-70%**

**DNHx:** More agreement between the models for the second half of the time series. For the 1990-2000 period, MINNI estimates smaller deposition rates with an increasing trend (the others: decreasing trend). LOTO estimated the lowest rates for the period 2000-2010.

Contribution to total reduced N deposition: **35-60%**

**DSOx:** two groups of models: CHIM and MATCH estimating higher dry deposition rates than the other three models.

Contribution to total S deposition: **35-60%**

*The contribution of dry deposition to the total is substantial and varies widely between models (mean contributions of 30 – 80%). It would be necessary to find a way to evaluate dry deposition*

*Thank you very much!!*