Ensemble Calibration for Uncertainty Estimation

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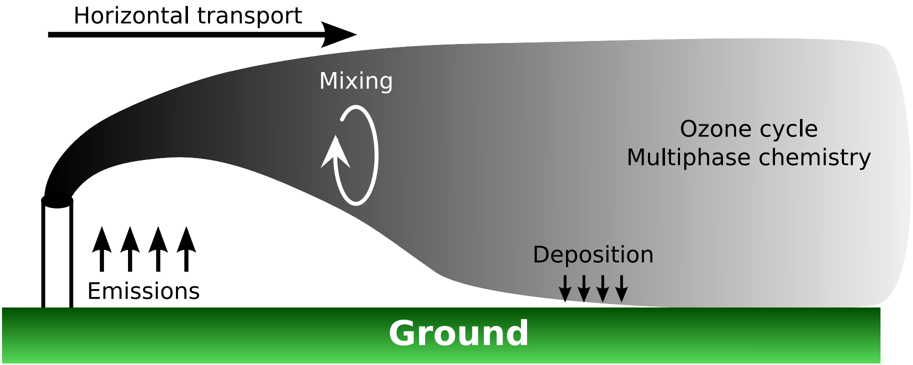
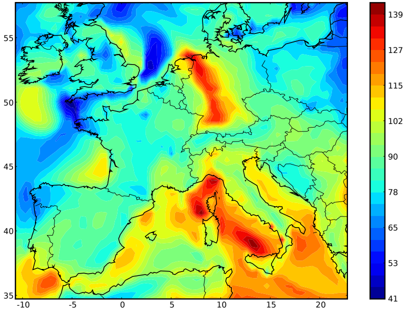
Introduction to Air Quality

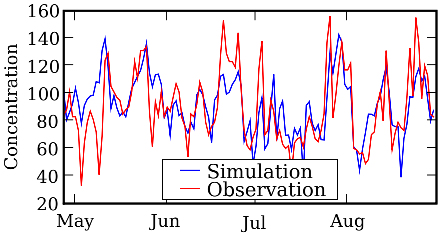


$$\frac{\partial c_i}{\partial t} = -\mathrm{div}(V c_i) + \mathrm{div}\left(\rho K \nabla \frac{c_i}{\rho}\right) + \chi_i(c, t) + S_i - P_i$$

Air Quality Forecast



Ozone map ($\mu g\,m^{-3}$)



Ozone daily peak concentration

Uncertainty Sources

Input Data

- Emission data
- Meteorological fields

Physical Parameterizations

- Chemical mechanism
- Vertical diffusion coefficient

Numerical Approximations

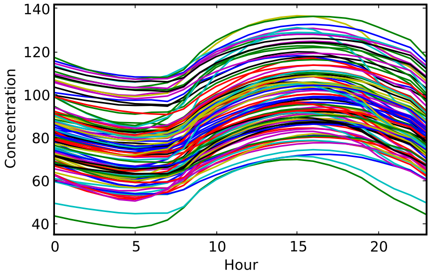
- Time step
- Vertical resolution
- Schemes

Ensemble Approach

Different alternatives

- Kz : T&M or Louis
- Chemical mechanism: RACM ou RADM2
- Numerical approximations: Δt, Nz, ...
- Perturbations: winds, emissions, boundary conditions...

Large dispersion



Ozone daily profiles from 101 members ($\mu g\, m^{-3}$)

$$\frac{\partial c_i}{\partial t} = -\mathrm{div}(V c_i) + \mathrm{div}\left(\rho K \nabla \frac{c_i}{\rho}\right) + \chi_i(c, t) + S_i - P_i$$

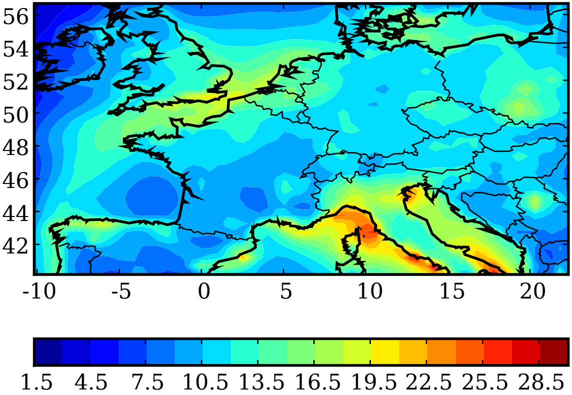
Uncertainty Estimation

- Concentration: random vector — a normal distribution for instance $\mathcal{N}(\mu, \Sigma)$
- Measure example: standard deviation (Σ)

Why is it important?

- Confidence in forecasts
- Risk prediction ($[\mathrm{O}_3] \geq 240\ \mu\mathrm{g\,m}^{-3}$)
- Economic and health issues
- Data assimilation (matrix **B**)

Uncertainty Example



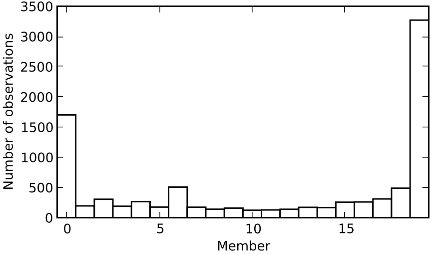
Standard deviation ($\mu g\, m^{-3}$)

Strategy

1. List all possible alternatives and so available models (150 billion)
2. Sample possible model space efficiently in order to obtain a smaller space (100 models)
3. Select according to an objective criterion (30–50 models)

Ensemble Assessment

Rank Histogram



Brier Score

Assessment for a given event.
$c \geq 240 \mu\text{g}\,\text{m}^{-3}$

$BS = \frac{1}{N} \sum_{i=1}^{N} (p_i - o_i)^2$.

p_i : probability for the date i.

o_i : observed probability for the date i.

The best Brier Score is 0.

Objective Criterion and Method

Rank Histogram Variance

$$\mathcal{S} \subseteq \mathcal{E}$$

Cost function:

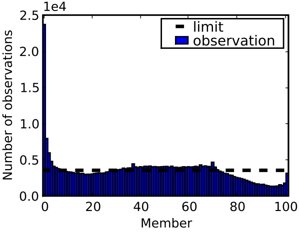
$$J(\mathcal{S}) = \sum_{i=0}^{N_{\mathcal{S}}} (b_i - \hat{b}_{\mathcal{S}})^2$$

$$\min_{\mathcal{S} \subseteq \mathcal{E}} J(\mathcal{S})$$

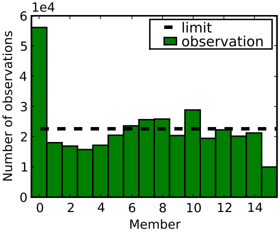
Genetic Algorithm

1. Population $\{\mathcal{S}_1, \mathcal{S}_2, \ldots, \mathcal{S}_K\}$
2. Assessment and selection $\{\mathcal{S}_i / J(\mathcal{S}_i) \leq \delta\}$
3. Crossover $(\mathcal{S}_a, \mathcal{S}_b) \rightarrow (\mathcal{S}_c, \mathcal{S}_d)$
4. Mutation $\mathcal{S}_i \rightarrow \mathcal{S}'_i$
5. New population of K subensembles

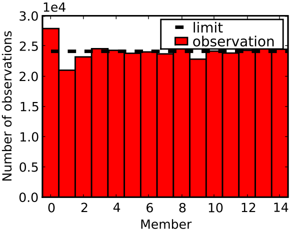
Rank Histograms



Large ensemble

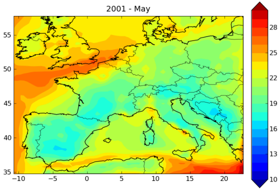


Random subensemble

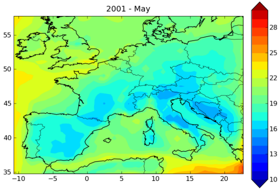


Calibrated subensemble

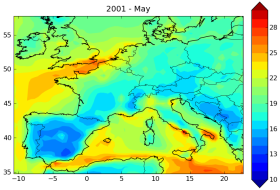
Uncertainty Maps



Large ensemble

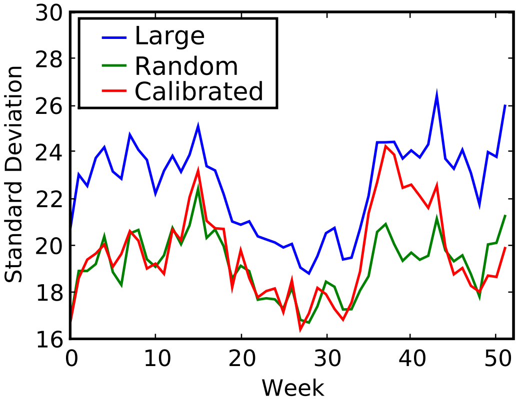


Random subensemble



Calibrated subensemble

Time series



Weekly standard deviation ($\mu g\, m^{-3}$)

Conclusion

- Ensemble calibration to estimate uncertainty
- D.Garaud and V.Mallet. **Automatic generation of a large ensemble for air quality forecasting using the Polyphemus system**. *Geoscientific Model Development Discussion*, 2, 889-933, 2009
- Comparison with other ensembles
- Other pollutants (aerosols, NO, . . .)
- Risk prediction