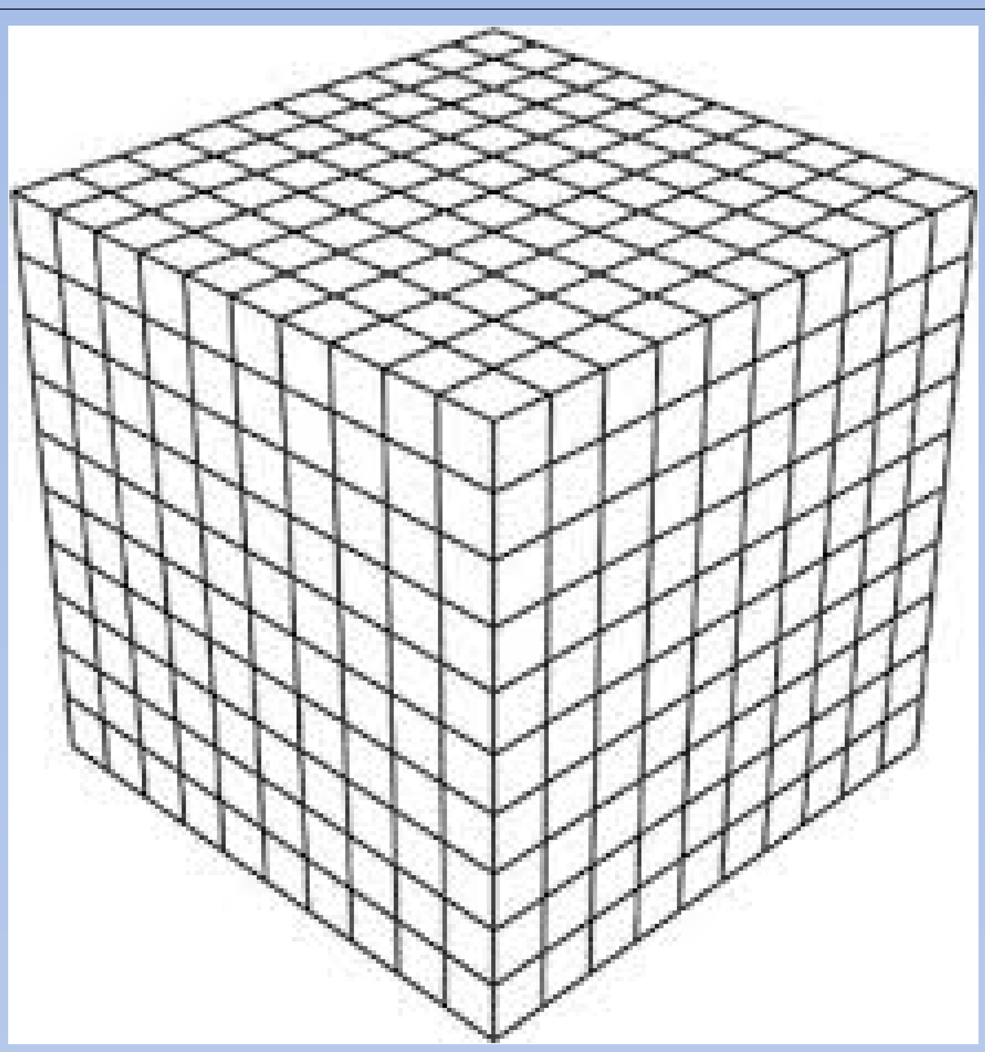
Potential Use of Transport and Dispersion Model Ensembles for Forecasting Applications

Ariel F. Stein[1] and Fantine Ngan[1 2]
[1] NOAA/Air Resources Laboratory, College Park, MD
[2] Cooperative Institute for Climate and Satellites (CICS), University of Maryland, College Park, MD

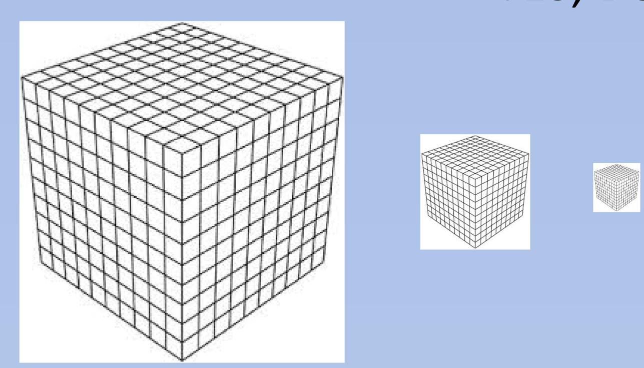
Three main types of uncertainties inherent to dispersion model predictions

- Data or parameter uncertainty, which comes from errors or uncertainties in the meteorological data that are driving the dispersion model, or in various parameters (e.g. emissions) or initial and boundary conditions.
- Model or structural uncertainty, arising from approximations of physical processes and imperfect numerics within the dispersion model.
- Stochastic uncertainty, which is associated with atmospheric turbulence.

Improving the model can minimize the first two types of uncertainty, but not the third type, although it can be quantified **statistically**.

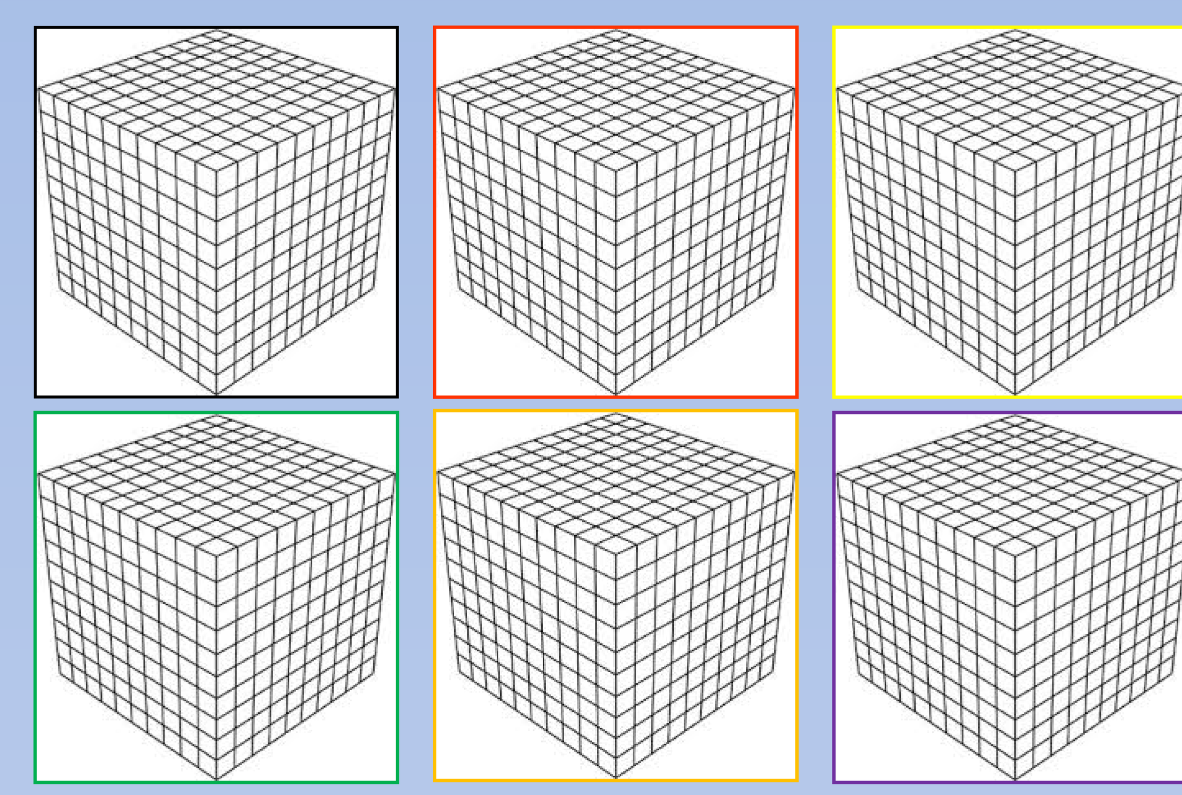


Increase spatial and temporal resolution?
Improve physical parameterizations?
In-line?
Data assimilation?



YES, BUT ALSO....

Ensembles



How is a dispersion ensemble created ??

- Available model outputs from different research groups regardless of the model characteristics (e.g. Potempski and Galmarini, 2009).
- Performing an arbitrary number of runs with different configurations by individual researchers.

Redundancy: ensemble members may not be much different from each other

Overemphasis on certain transport and dispersion features that can be inaccurate.

Inaccurate ensemble

Independence: ensemble members are different

Does not necessarily imply that the independent reduced group of runs will be more accurate than the full ensemble if, by chance, the latter could be also over emphasizing redundant members that happen to be more accurate.

What is the optimum number of members to obtain accurate results??

Solazzo and Galmarini (2014): an ensemble can be reduced by optimizing the skills of the mean taken among all the possible subsets of ensemble members.

Methodology:

Calculate the average of all the possible model combinations composed by an increasing number of sub ensemble members up to M (total number of ensemble members) and estimate their mean square error (MSE). Furthermore, if n is the number of sub ensemble members, then the number of possible combinations is given by $M!/(n!*(M-n)!)$. For instance, we combine the 24 model outputs in 276 pairs, 2024 trios, 10626 quartets, etc. and determine which combination provides the minimum MSE.

Big problem: not many datasets available to construct ensembles ➔ TRACER EXPERIMENTS

Cross-Appalachian Tracer Experiment (CAPTEX)

Dayton, Ohio, USA starting on:
September 18 at 1700 UTC (CAPTEX #1)
September 25 at 1700 UTC (CAPTEX #2)
October 2 at 1900 UTC (CAPTEX #3)
October 14 at 1600 UTC (CAPTEX #4)
Sudbury, Ontario, Canada starting on:
October 26 at 0345 UTC (CAPTEX #5)
October 29 at 0600 UTC (CAPTEX #7)

- Releases lasted three hours
- Samples were collected at 84 different measurement sites distributed from 300 to 800 km downwind of the emission source.
- Samples were collected as either 3- or 6-hour averages up to 60 hours after each release.

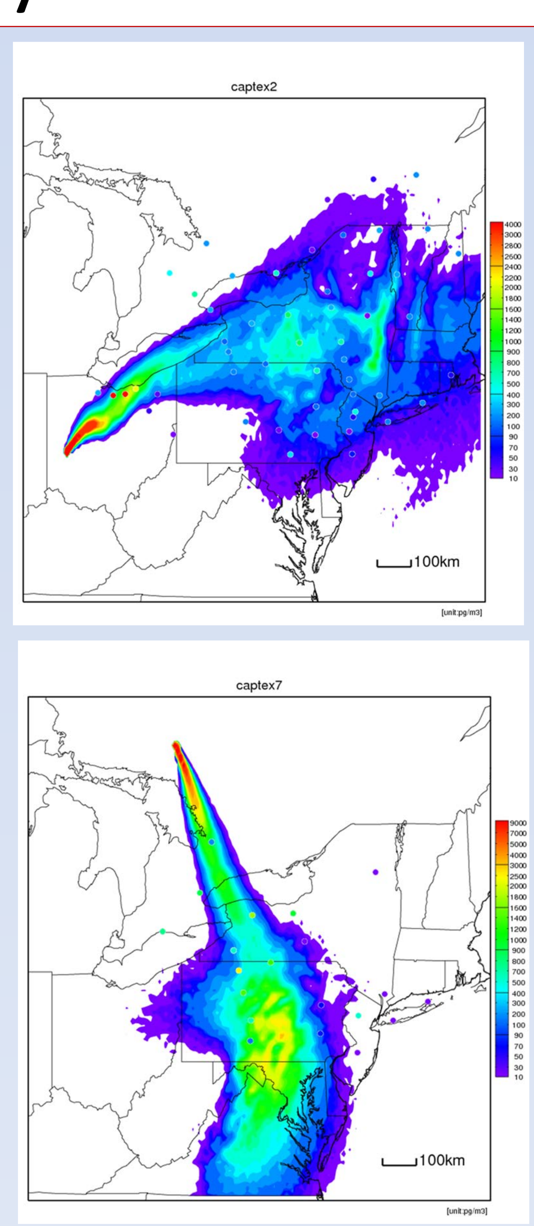


Figure 1: modeled and measured tracer concentrations

Ensemble member #	PBL parameterization	Min PBL [m]	Wind field	TKE	TLvs/TLvu [s] /[s]
1	YSU	250	INS	NO	200/200
2	MYJ	250	INS	NO	200/200
3	YSU	250	FLX	NO	200/200
4	MYJ	250	FLX	NO	200/200
5	MYJ	250	INS	YES	200/200
6	MYJ	250	INS	YES	5/200
7	MYJ	50	INS	YES	200/200
8	YSU	250	INS	NO	5/200
9	MYJ	250	INS	NO	5/200
10	YSU	50	INS	NO	200/200
11	MYJ	50	INS	NO	200/200
12	YSU	250	FLX	NO	5/200
13	MYJ	250	FLX	NO	5/200
14	YSU	50	FLX	NO	200/200
15	MYJ	50	FLX	NO	200/200
16	MYJ	250	FLX	YES	5/200
17	MYJ	250	FLX	YES	200/200
18	MYJ	50	FLX	YES	200/200
19	MYJ	50	FLX	YES	5/200
20	YSU	50	INS	NO	5/200
21	MYJ	50	INS	NO	5/200
22	YSU	50	FLX	NO	5/200
23	MYJ	50	FLX	NO	5/200
24	MYJ	50	INS	YES	5/200

Table 1: Description of HYSPLIT ensemble members.

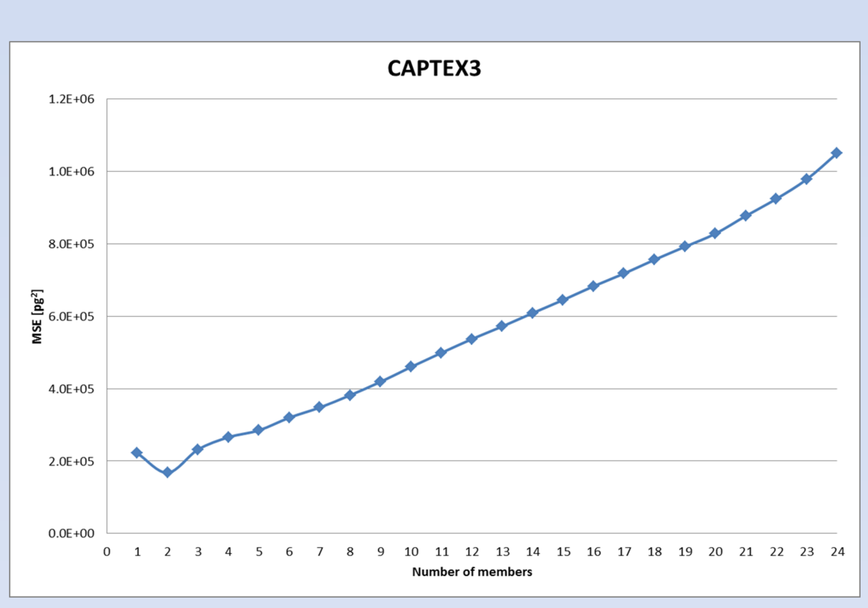


Figure 2: Minimum MSE as a function of the number of ensemble members corresponding to CAPTEX #3.

$Rank = R^2 + 1-|FB/2| + FMS/100 + (1-KSP/100)$

	Full Ensemble	Reduced ensemble minimizing MSE (Ensemble member #)
Rank		
Captex-1	2.43	2.76 (5,18)
Captex-2	3.06	3.49 (12,13,23)
Captex-3	1.79	1.93 (13,23)
Captex-4	2.36	2.37 (9,13)
Captex-5	2.65	2.80 (12,18)
Captex-7	2.50	2.99 (14,12)

Table 2: Statistical performance measures corresponding to the full ensemble and the reduced ensembles..

Conclusions

- Reduced model groups perform as well or better than the 24-member ensemble.
- Technique selects different members for different releases, indicating the possible influence of meteorological conditions on the determination of the model groups.
- The process of creating an ideal ensemble for transport and dispersion of pollutants still remains an open research topic.

References:

Solazzo, E. and Galmarini, S., 2014. The Fukushima-137Cs deposition case study: properties of the multi-model ensemble. Journal of Environmental Radioactivity, 139, 226–233, 2015.
Potempski, S., and S. Galmarini, 2009. Est modus in rebus: Analytical properties of multi-model ensembles, Atmos. Chem. Phys., 9 (24), 9471–9489, doi:10.5194/acp-9-9471-2009.