Non-local metrics applied to the comparison of CO_2 plumes and their sensitivities to mesoscale meteorology

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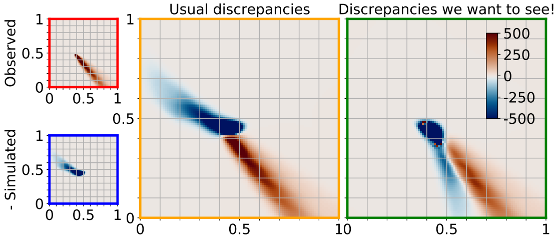
IWGGMS-18 2022-07-14

Example: Case of a German power plant.

Experimental set-up:

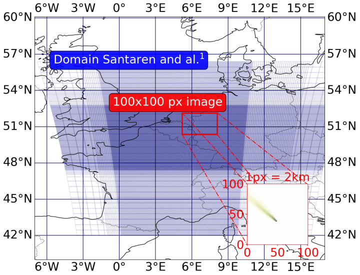
- Both images result from simulations.
- Same source location.
- Same emission rate.
- Same simulation period.
- Different meteorology.

Example:



Simulated CO_2 plumes:

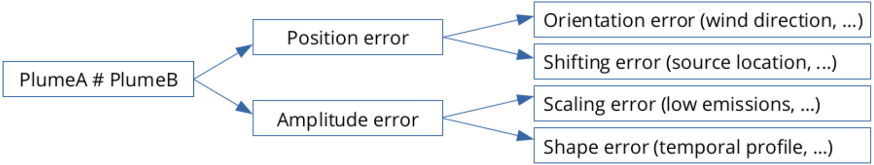
- No background concentrations.
- Images of 100x100 pixels.
- Resolution of 4 km^2.
- Hourly output.



[1]: https://doi.org/10.5194/amt-14-403-2021

Strategy

- **Matching errors decomposition:**



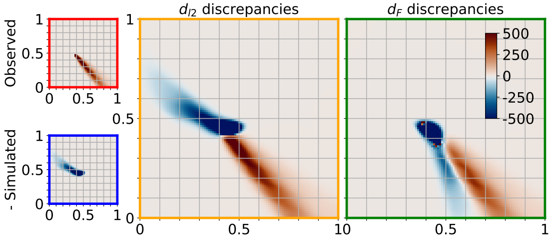
- **Assumption:**
  - The position error is mainly driven by errors in the mesoscale wind field.
- **Aim for the new metrics:**
  - Avoid the double penalty issue (transform position error into amplitude error).
  - Segregate the position error.

New metrics

- **Baseline $\mathscr{L}_2$ metric (d_{l2}):**
  - (+) Easy to compute.
  - (-) double penality issue.
- **New local metric (d_F) freed from position error:**
  - (+) Keep $\mathscr{L}_2$ formalism while addressing double penalty issue.
  - (-) Add a local minimisation process.
- **Non-local Wasserstein metric (w):**
  - (+) Separation of the errors sources.
  - (-) Loose of the scale information.
- **Non-local Hellinger metric (w_F):**
  - (+) Cheap and freed of position error.
  - (-) Ground on Gaussian puff assumption.

Some results

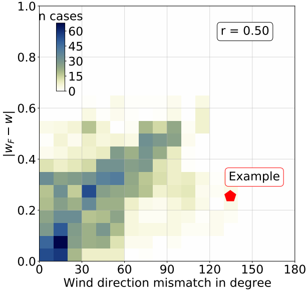
- **Back to our example:**



d_{l2}	w	d_F	w_F
388.6	0.3376	371.36	0.0830

Both d_F and w_F lead to lower values, and comparison with less position error.

- **Results on ≈2000 different comparisons:**



The shifting error is correlated to mesoscale wind direction changes.

Discussions

- **What we learnt?**
  - To separate the position error from the amplitude error by using smarter metrics.
  - The shifting error is mainly driven by mismatch in the wind direction.
  - Remove the position error lead to a decrease in the sensitivity of the comparison with respect to changes in the wind field.
  - The new metrics has to be tuned.
  - Optimal transport metrics required the addition of a "mass" term to keep the scaling error.

- **To go further!**
  - The double penalty issue is addressed, but it creates an issue between orientation error and shape.
  - Introduce these metrics in an assimilation process.
  - Optimize the computation of Wasserstein distance.
  - Get the sensitivities (Sobol index) according either meteorology or source profile.

- **Supplementary information:** article will be submitted soon to AMT journal.