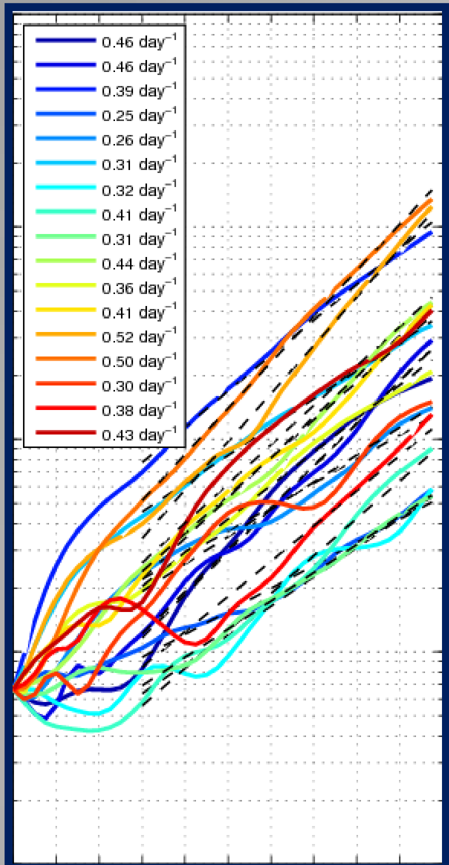

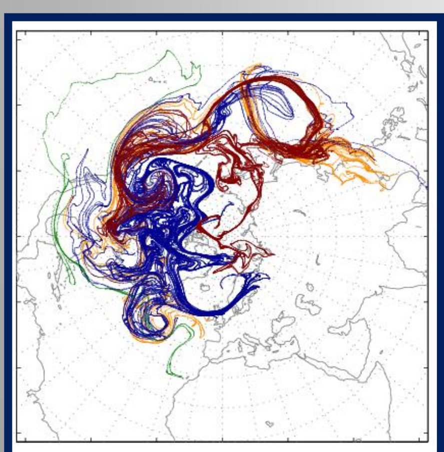

INVESTIGATION OF THE STRETCHING OF POLLUTANT CLOUDS DURING CLIMATE CHANGE IN AN ENSEMBLE APPROACH

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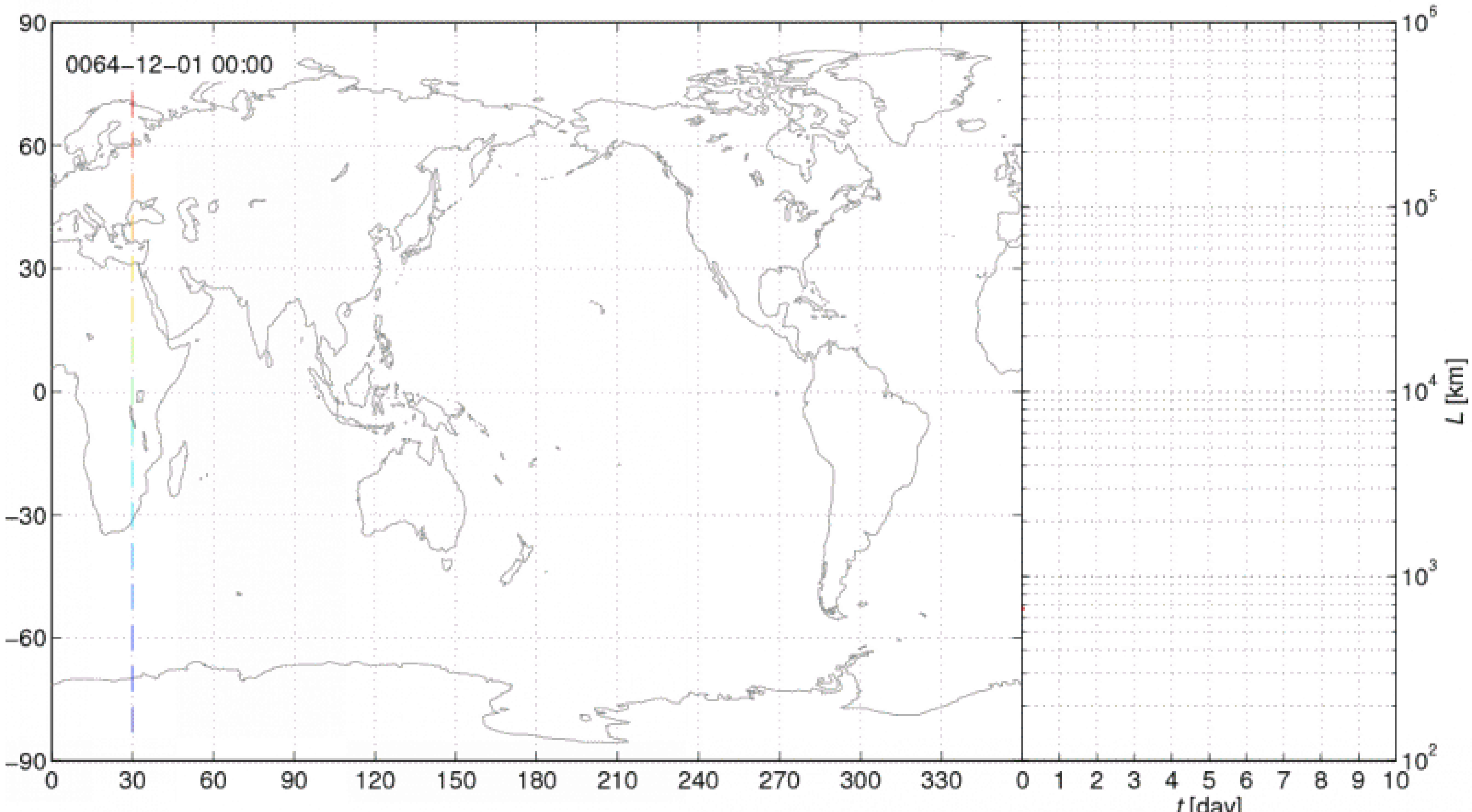
INTRODUCTION

- growing interest in the potential consequences of ***climate change***:
  - numerous studies [e.g. Lim and Simmonds, 2007, 2009; Tilinina et al., 2013; Wang et al., 2013] reported: cyclonic activity and the number of cyclones have changed in the last decades.
  - Do quantities that can be related to the cyclones (***intensity of the spreading*** of atmospheric pollutant clouds) also change during climate change?

- **aim**: the change in the intensity of the atmospheric large-scale transport events and their ***relation to the relative vorticity*** are investigated in an ***ensemble approach***.

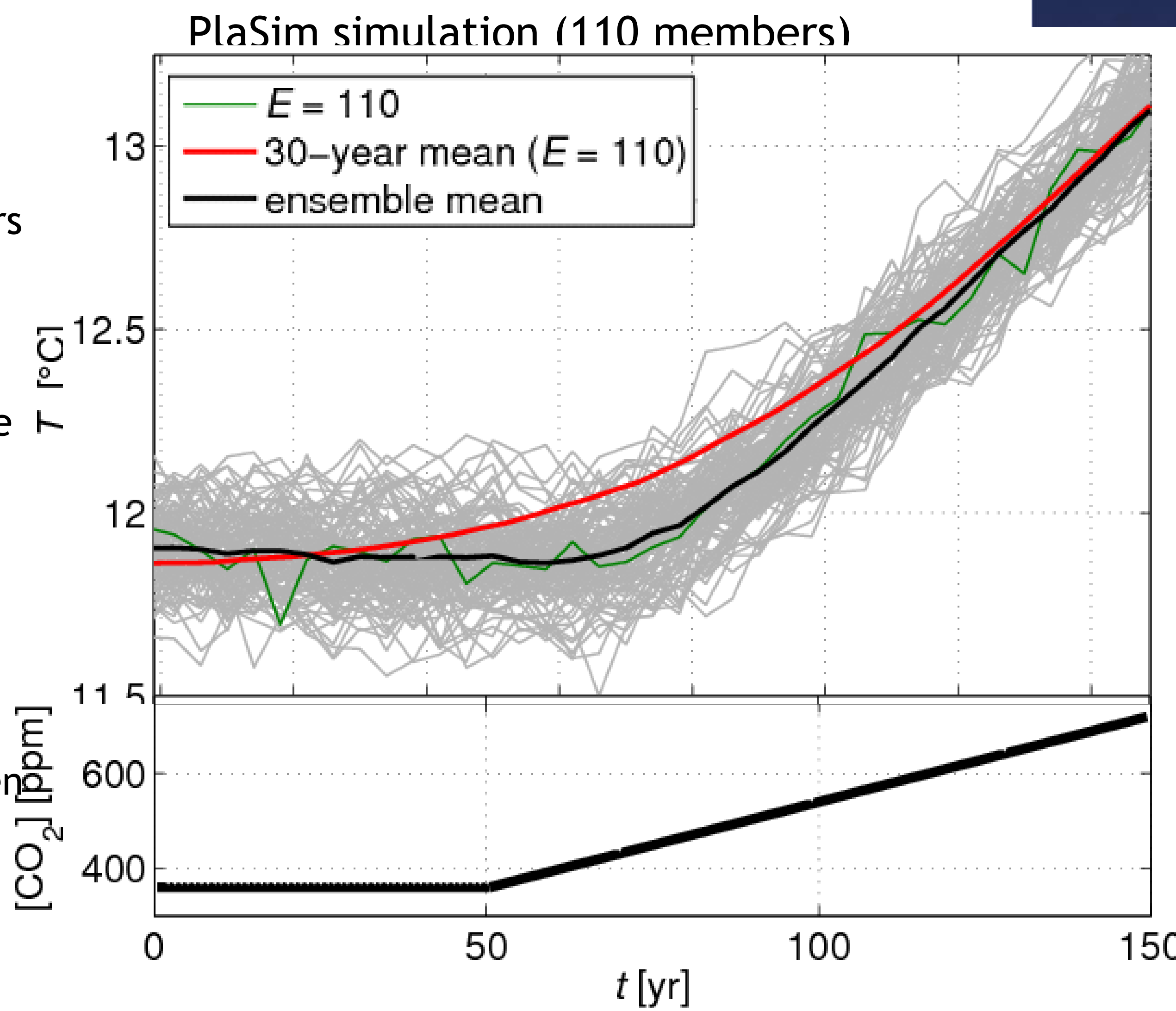
INTENSITY OF THE SPREADING: STRETCHING RATE

- ***stretching rate (h)***: a measure of chaos $L(t) \sim \exp(ht)$
  - measure of the **exponential** stretching of length (L) of pollutant clouds
  - relation: complexity of the structure of pollutant cloud
    unpredictability of the spreading



ENSEMBLE CLIMATE SIMULATIONS

- ***ensemble of parallel climate realizations***
  - realizations slightly differ in their **initial conditions**
  - time interval is long enough for the members to **forget their initial conditions** (transient time)
  - after that the ensemble correctly characterizes the **potential set of typical climate states**
- characterizes more appropriately the mean and the variance at a given time instant
- time-mean ≠ ensemble-mean



ENSEMBLE CLIMATE SIMULATIONS

- using an ***ensemble of parallel climate realizations*** to gain appropriate statistics of variables at given time instants
- precise mathematical background: theory of snapshot attractors [Ghil 2008]

- **advantages:**
  - internal variability of the climate
  - correlation between variables

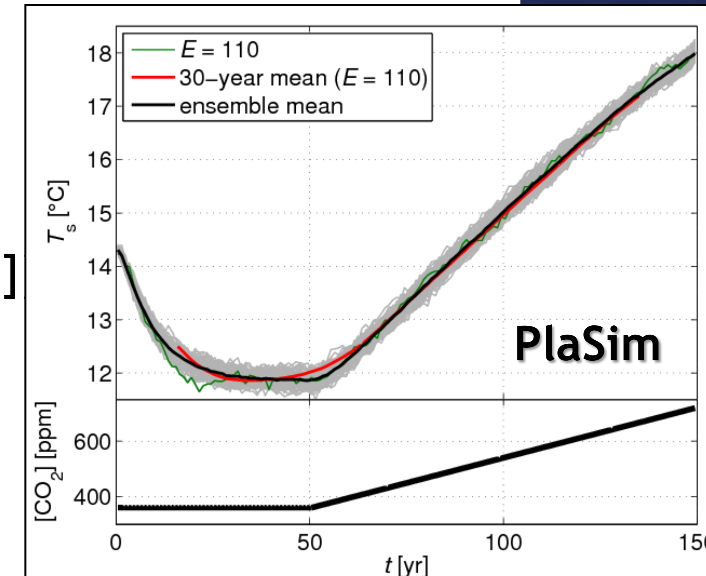
  } can be calculated at given time instant based on the values of the ensemble members

- **aim**: to investigate the intensity of the large-scale atmospheric spreading in an **ensemble approach**

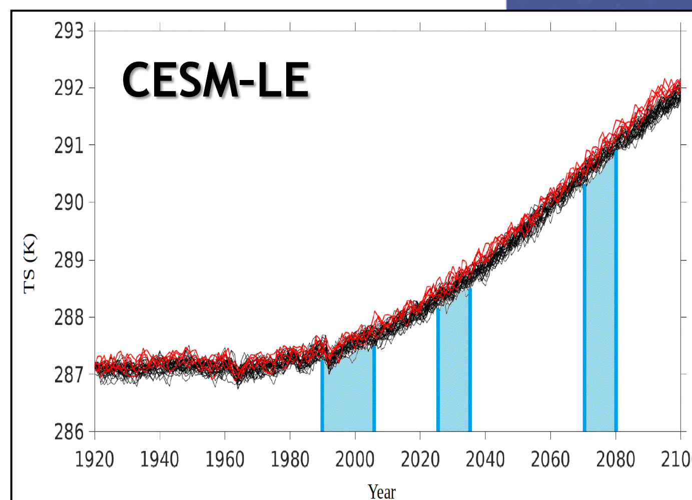
MODELS AND DATA

- **RePLaT** (Real Particle Lagrangian Trajectory Model [Haszpra 2014]) Lagrangian (particle-tracking) dispersion model
  - simulations for **ideal tracers** (corresponding to inert gases)
  - only **advection** is taken into account

- **PlaSim** (Planet Simulator [Fraedrich et al. 2005])
  - intermediate-complexity climate model
  - resolution: T21 (5.6°× 5.6°), 10 levels
  - ensemble: **110 realizations** for a prescribed CO_2 scenario: **360→720 ppm**
  - T_s increases **~6 °C** during 100 years



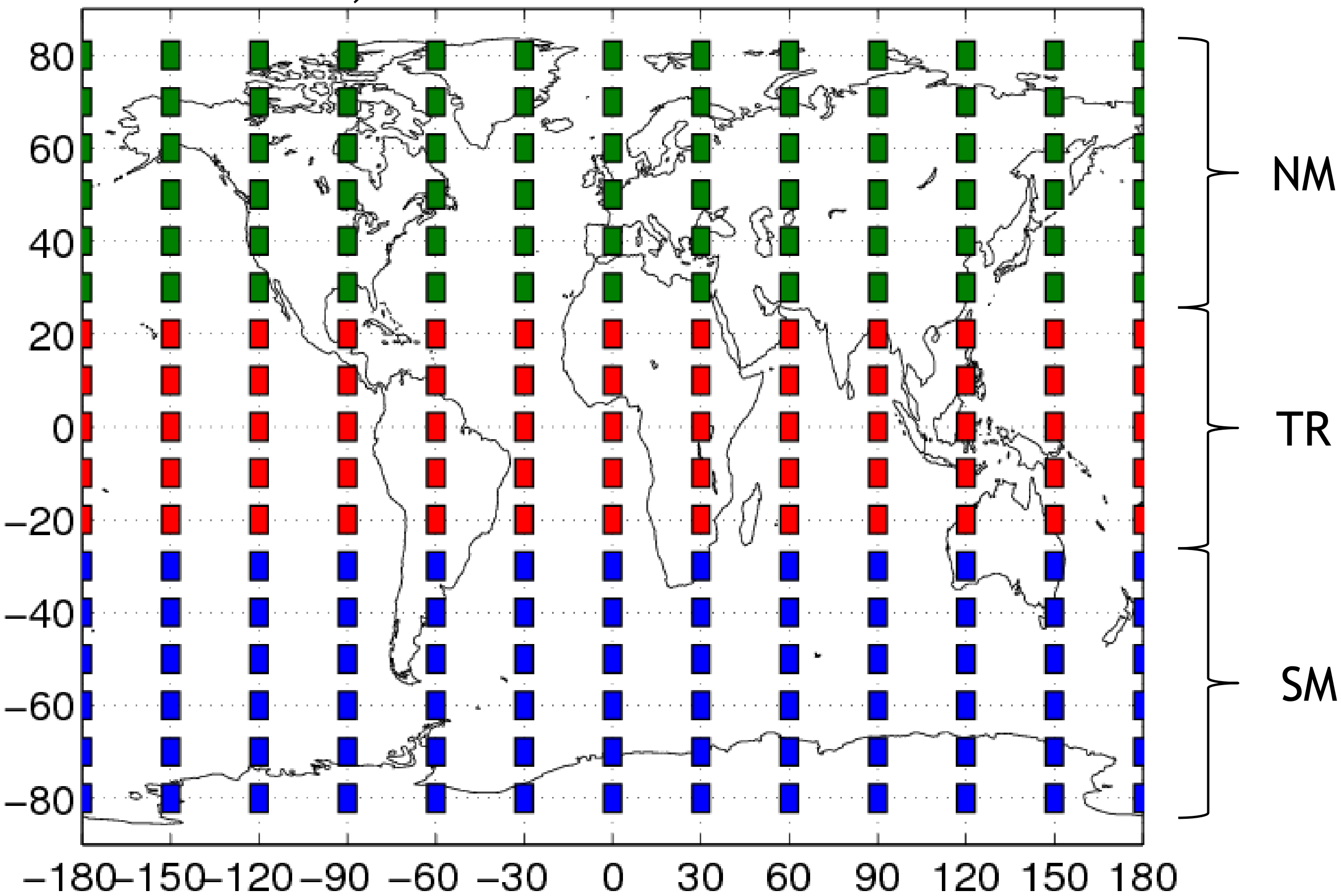
- **CESM-LE** (Community Earth System Model – Large Ensemble Project [Hurrell et al. 2013])
  - resolution: 1.25°× 0.94°, 30 levels
  - ensemble: **35 realizations** with a historical forcing up to 2005 and RCP8.5 thereafter
  - T_s increases ~**3.5 °C** for 1990–2080



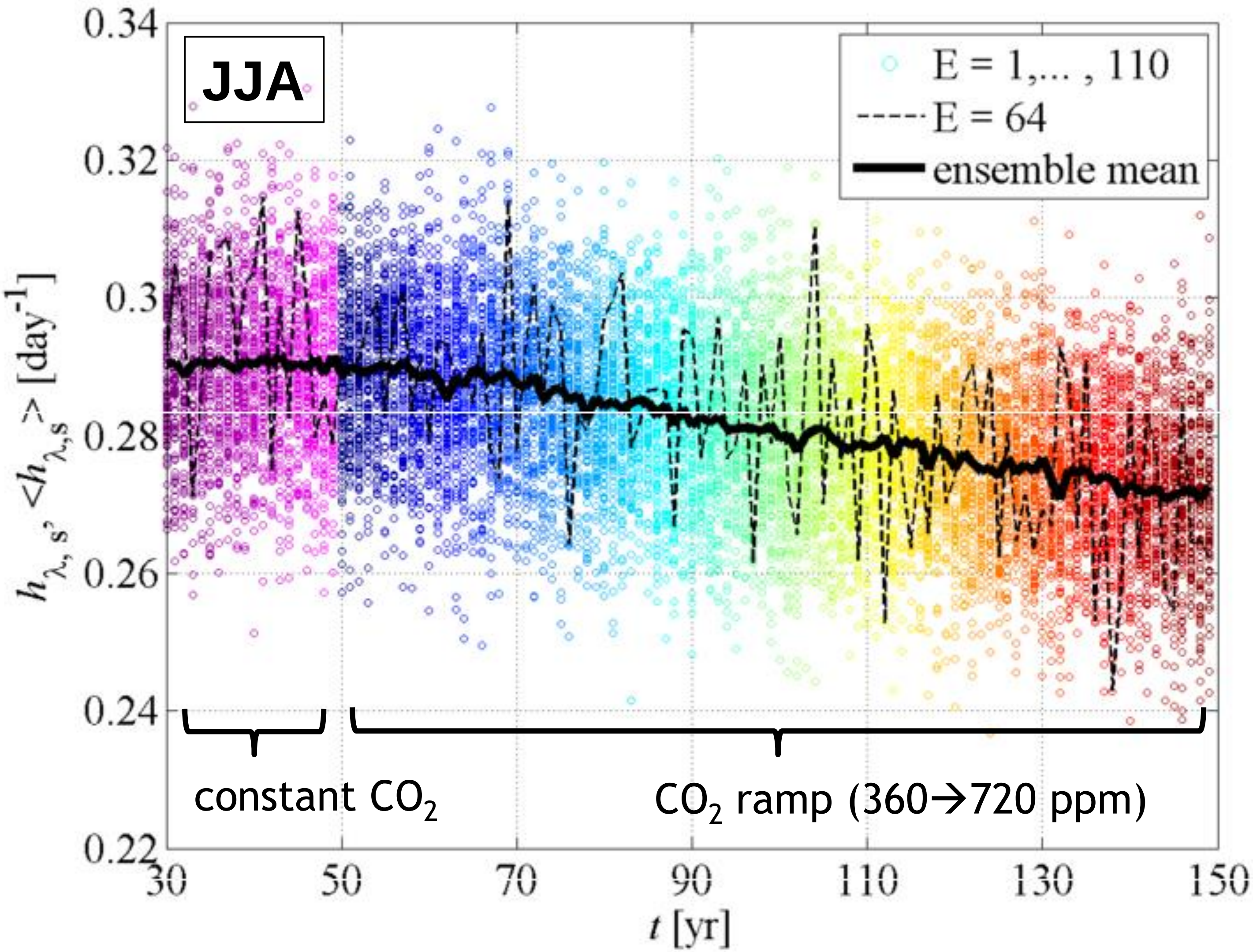
GLOBAL SIMULATIONS

- 12×17 6°-long 1D "pollutant clouds" (filaments) are initialized uniformly distributed over the globe
- in every 10 days for JJA and DJF for the years
  - years 30–150 for PlaSim
  - 1990–2005, 2026-2035 and 2071–2080 for CESM ←

intervals when met. fields in 6h of time resolution are available

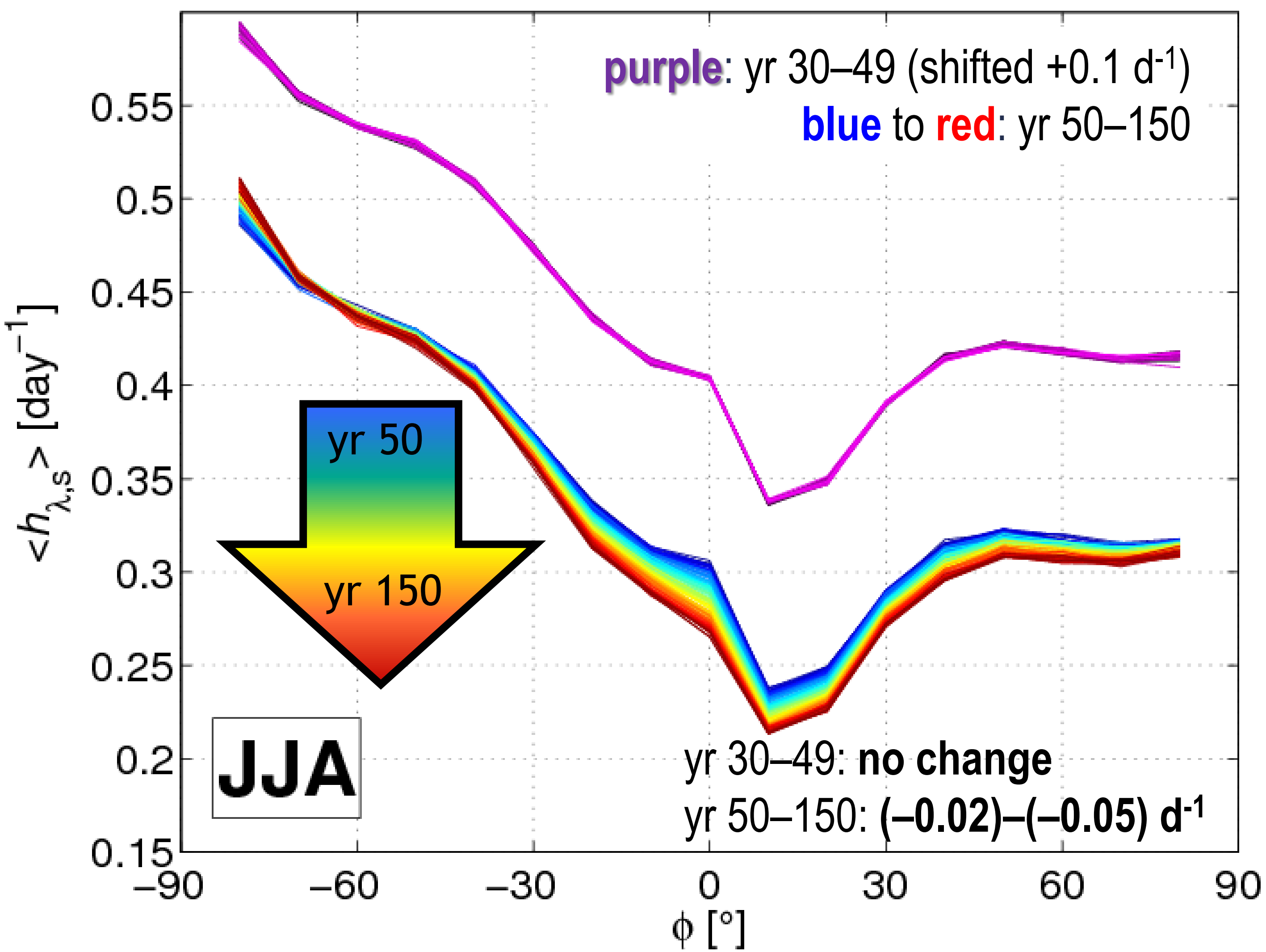


STRETCHING RATE (PLASIM, YRS 30-49 AND 50-150)

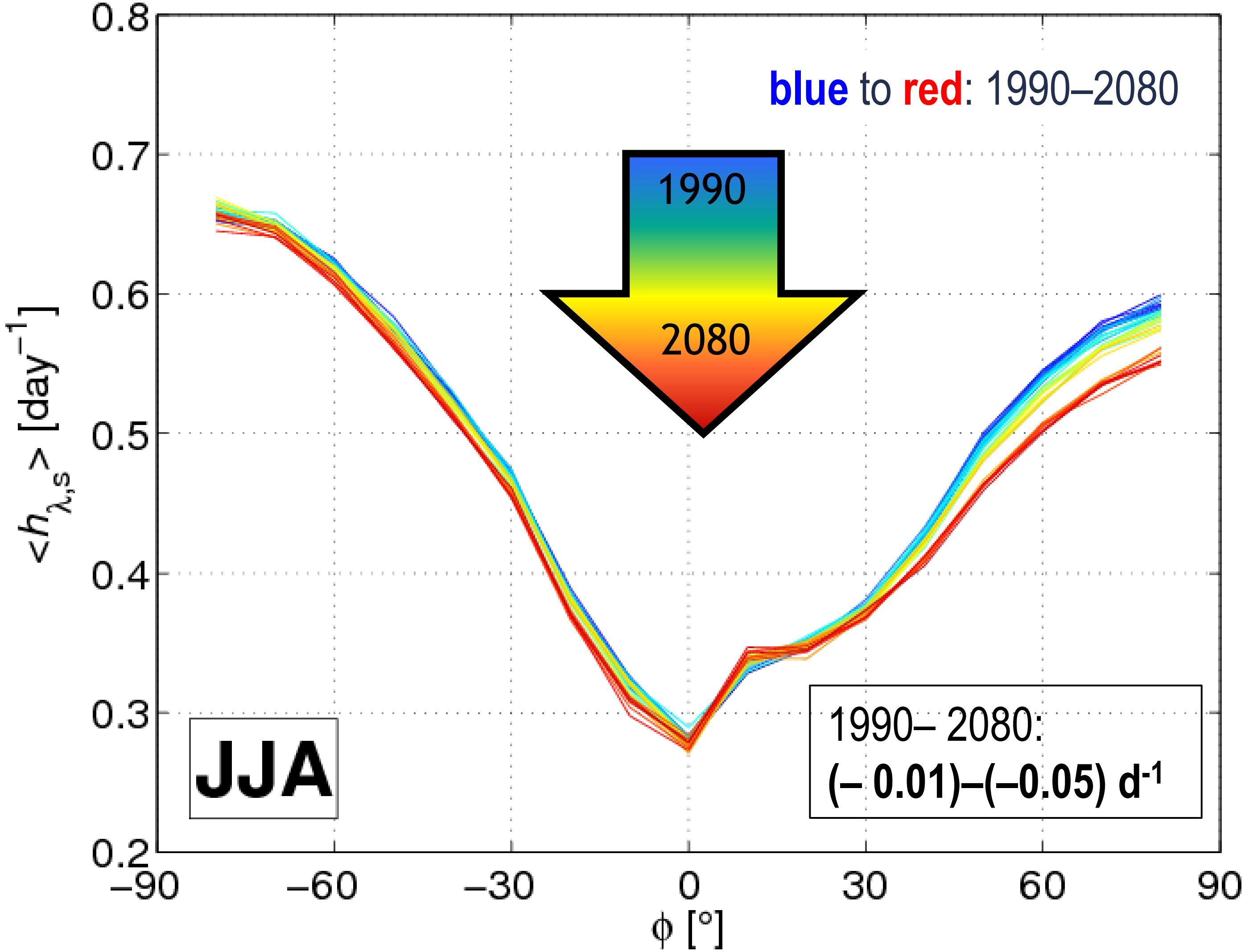


30° N

STRETCHING RATE - ZONAL DISTR. ENSEMBLE MEAN (PLASIM)



STRETCHING RATE - ZONAL DISTR. ENSEMBLE MEAN (CESM)



Δh = —0.05 day^{-1}

t = 10 day:

L_2/L_1 =
= exp(Δh*t) =
= exp(—0.5) =
= **0,61**

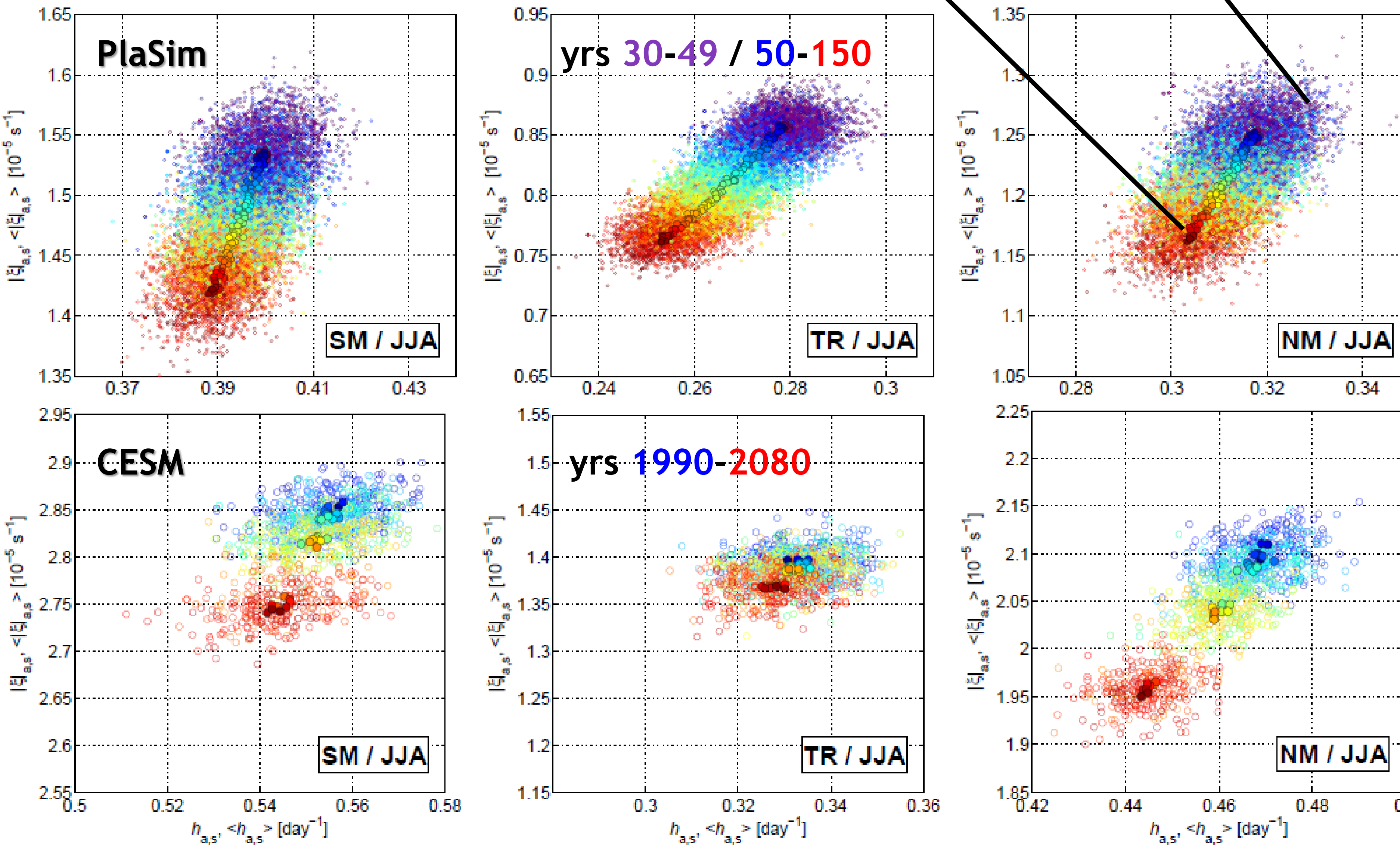
STRETCHING RATE - RELATIVE VORTICITY

- the position of the particles of the filament is determined by the local velocity field at each time instant →
- **stretching rate is also determined by the velocity values**

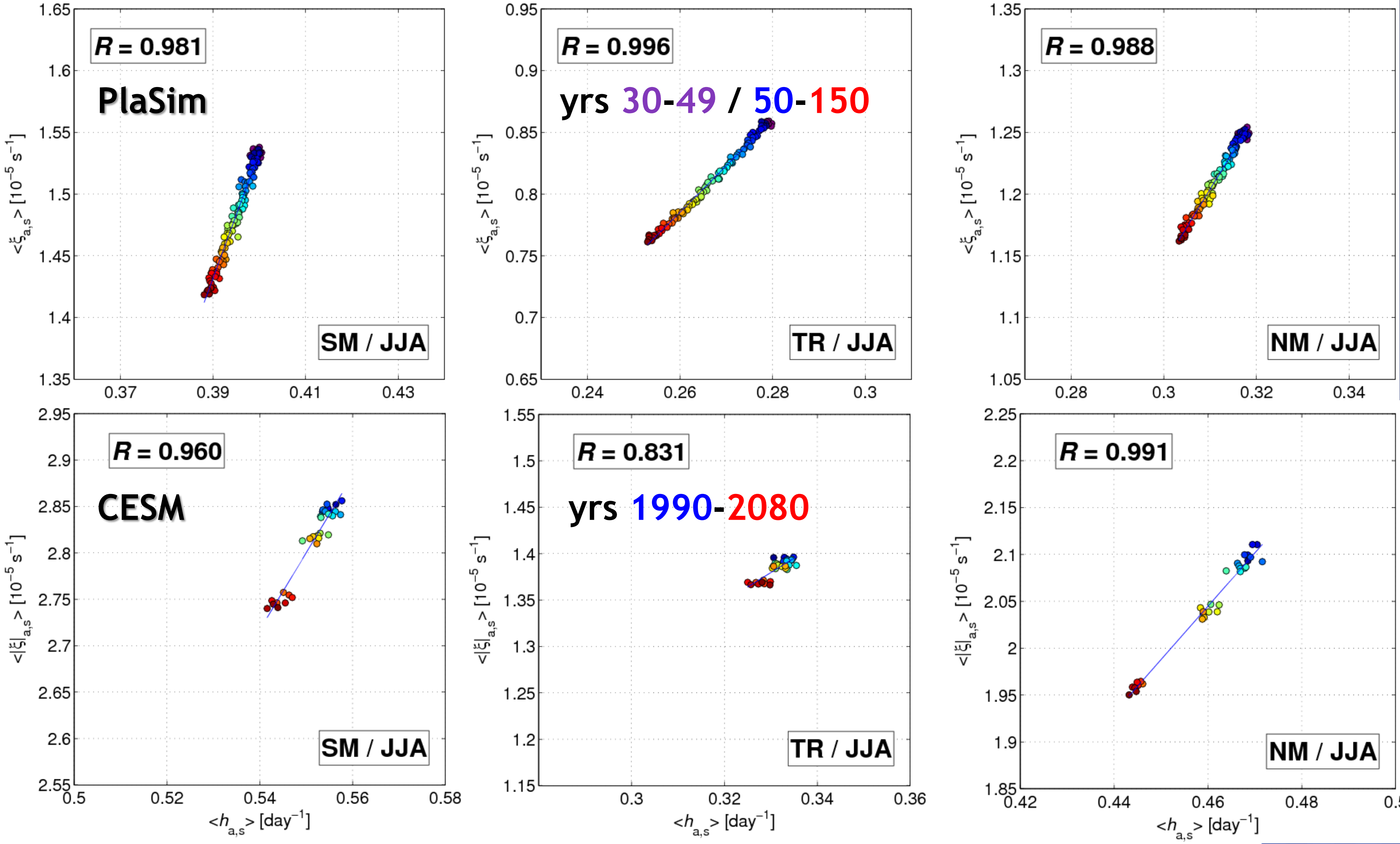
- aim: to estimate the change in the intensity of large-scale spreading based on only the meteorological fields of a climate realization (**without transport simulations**)

- **absolute value of the relative vorticity** $|\xi|$: directly linked to the velocity differences that cause the stretching

STRETCHING RATE – RELATIVE VORTICITY



STRETCHING RATE – RELATIVE VORTICITY CORRELATION



SUMMARY

- stretching rate: **zonal distribution**
  - tropical region: smaller values → slower stretching
  - extratropics: larger values → faster stretching

- in contrast to single time-series, in the **ensemble approach** the **trends in the stretching rate** can be more appropriately determined
- the stretching rate (→ the intensity of the spreading) **decreases** almost everywhere in the globe →
- typical extension of a polluted region from a pollution event decreases → might cause **larger pollutant concentration**

- **stretching rate ~ |relative vorticity|**
- **The relationship may help estimate the changes in the intensity of spreading utilizing only met. variables operationally computed by climate models**, without carrying out numerous computationally demanding dispersion simulations.

Haszpra and Herein: Ensemble-based analysis of the pollutant spreading intensity induced by climate change. Submitted to Sci. Rep.

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Thank you for your attention!