



REPLAT-CHAOS: A SOFTWARE FOR EDUCATIONAL PURPOSES TO ILLUSTRATE THE CHAOTIC BEHAVIOR OF THE ADVECTION OF VOLCANIC ASH CLOUDS

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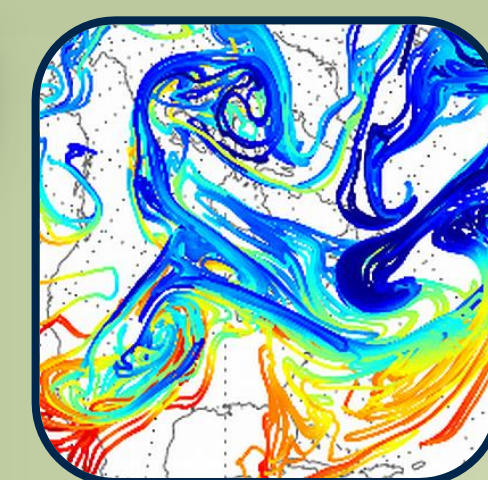
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1. Motivation

In everyday life we often read about hazards due to volcanic ash clouds and other atmospheric pollutants.



A questionnaire revealed that students are **typically unaware** that **pollutant clouds do not disperse** in the atmosphere **like dye blobs** on clothes, rather an initially compact pollutant cloud becomes soon **strongly stretched**, while becoming **filamentary and folded**.

In 3-D flows, such as the atmosphere, the **advection of pollutants is chaotic**: the advection dynamics exhibits the typical characteristics of chaos:

- sensitivity to initial conditions,
- irregular motion,
- complicated but well-organized (fractal) structures.

Aim: to create a **software (RePLaT-Chaos)** → students / curious people can investigate the characteristics of the atmospheric dispersion in an **easy and interactive way** in reanalysis wind fields.

2. RePLaT-Chaos

- Based on the previously developed **RePLaT** (Real Particle Lagrangian Trajectory) Lagrangian (particle-tracking) dispersion model [Haszpra and Tél, 2013]
- The **simulations** utilize real atmospheric meteorological data and follow the time evolution of pollutant clouds consisting of a **large number of individual particles**.
- It is also a suitable tool for studying the **chaotic features of the advection**.
- **Student / full version** is available.
- The software was tested at the Berzsenyi Dániel Grammar School (Budapest, Hungary) by 7th and 12th grade (13- and 18-year-old) students.



<http://theorphys.elte.hu/fiztan/volcano/index.html>

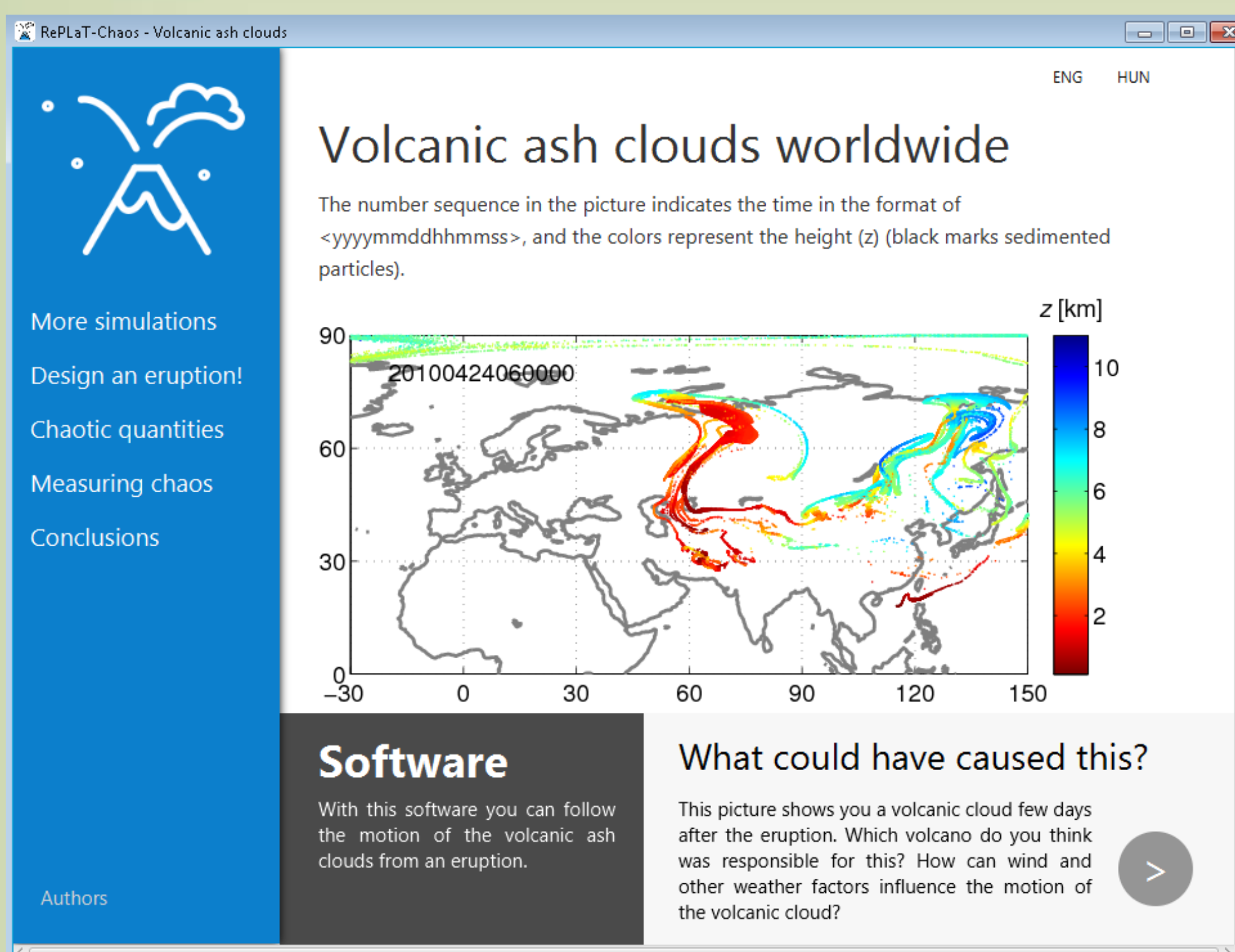
3. RePLaT-Chaos – student version

User interface is adapted by: **Mária Kiss** (Berzsenyi Dániel Grammar School, 12th grade, Budapest, Hungary)



Welcome page

- **Language** can be chosen (currently: English, Hungarian)
- Due to "dictionary files" **it is easy to add other languages** to the software.



Volcanic ash clouds worldwide

- example of the advection of a volcanic ash cloud from the Eyjafjallajökull (2010)
- main aim: **to show the nature of advection**

More simulations

- includes animations of further, hypothetical eruptions

Design eruption & Measuring chaos

- eruption location can be assigned by **clicking on the map**
- altitude and size of the volcanic ash cloud, the number of the particles and the particle properties can be entered in the textboxes

Chaotic quantities & Conclusions

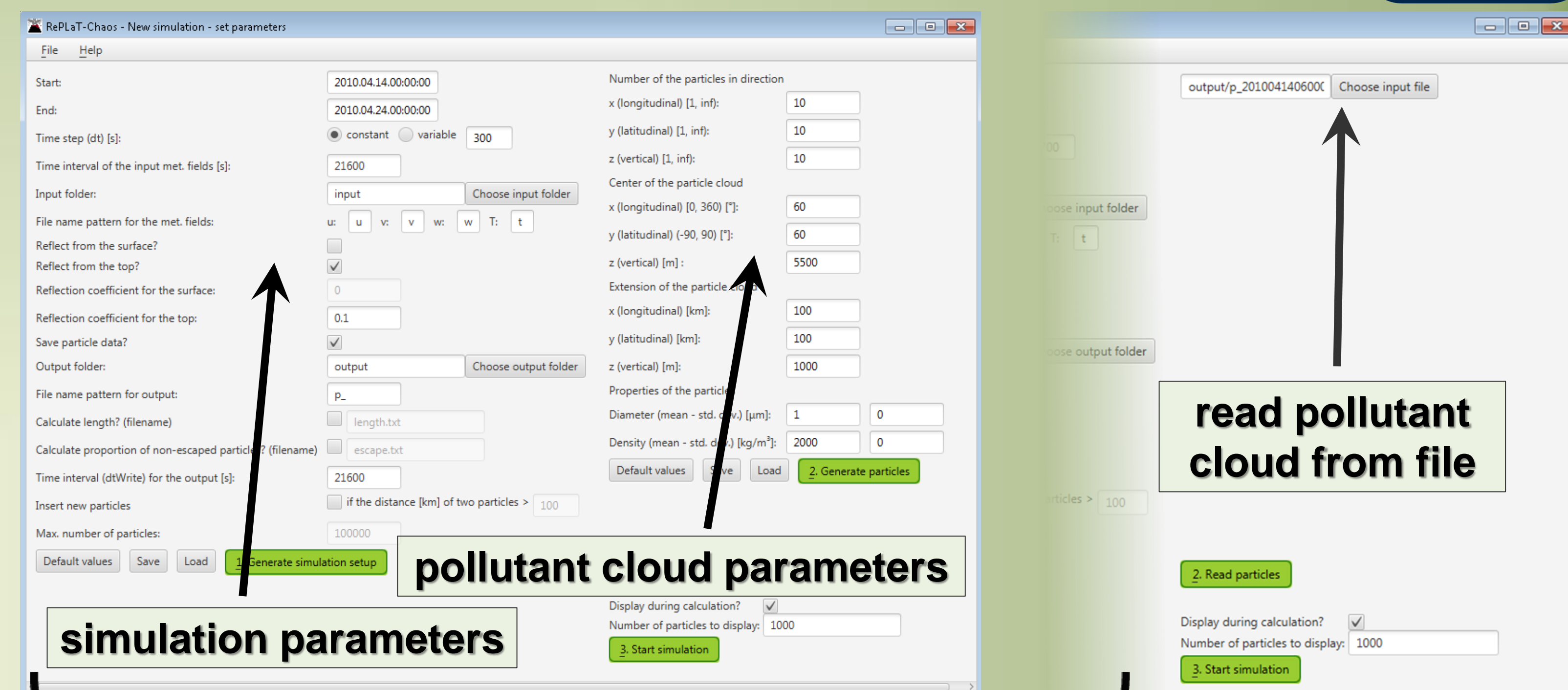
- summarizes the main chaotic features of the advection of pollutant clouds, and provides a brief overview of two chaotic measures
- **Stretching rate** h : quantifies the complexity and irregularity of the motion. The shape of the ash clouds becomes soon distorted into a thin, folded line whose **length grows exponentially**: $L(t) \sim \exp(ht)$.
- **Life time** τ : characterizes the rapidity by which particles leave the atmosphere. The ratio $n(t)/n(0)$ of the non-escaped particles starts to **decay exponentially** after a certain time: $n(t)/n(0) \sim \exp(-t/\tau)$.

4. RePLaT-Chaos – full version

- several parameters can be changed to study the advection in detail

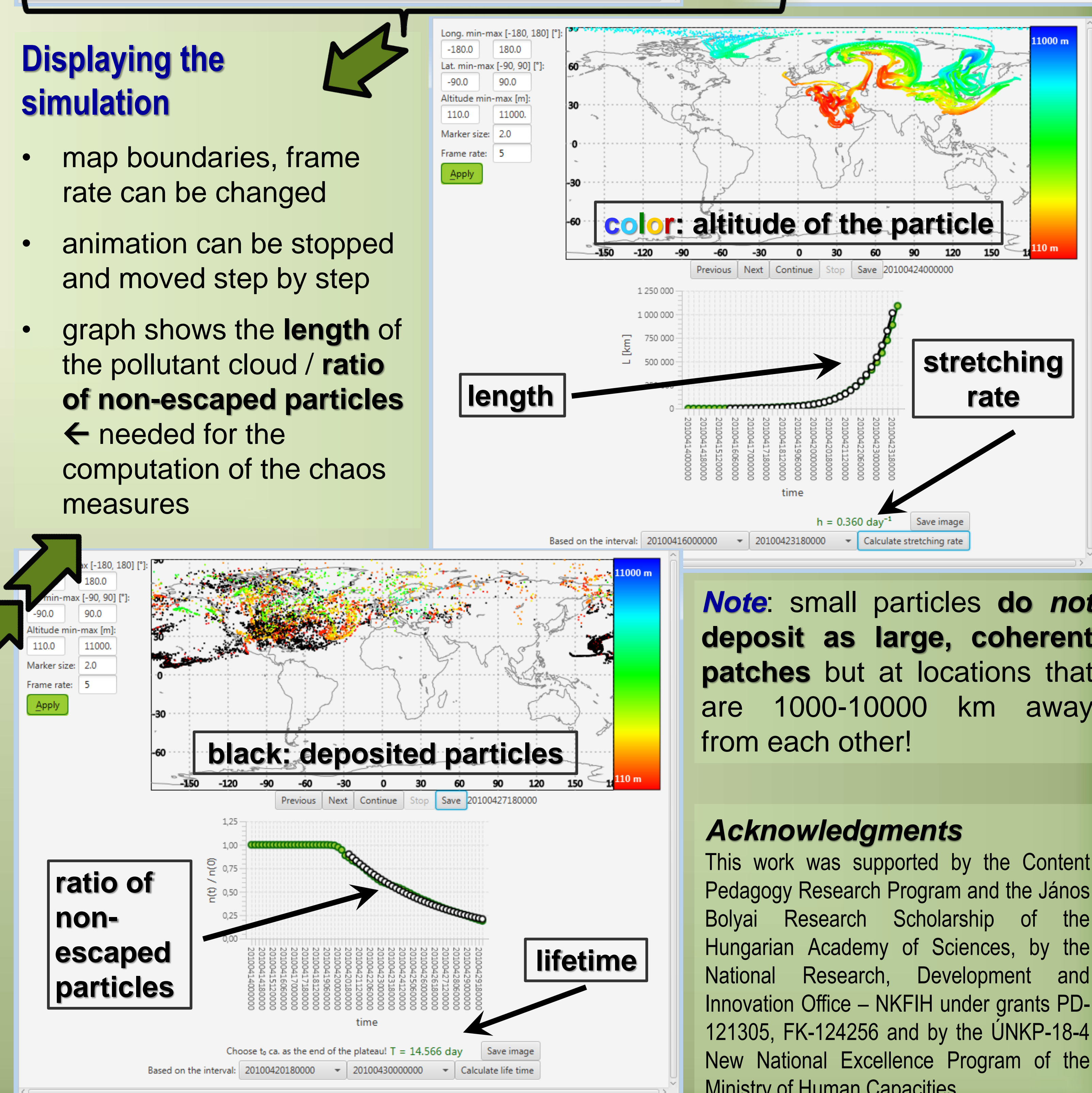


Design eruption



Displaying the simulation

- map boundaries, frame rate can be changed
- animation can be stopped and moved step by step
- graph shows the **length of the pollutant cloud / ratio of non-escaped particles** ← needed for the computation of the chaos measures



Note: small particles do **not** deposit as large, coherent patches but at locations that are 1000-10000 km away from each other!

Acknowledgments

This work was supported by the Content Pedagogy Research Program and the János Bolyai Research Scholarship of the Hungarian Academy of Sciences, by the National Research, Development and Innovation Office – NKFIH under grants PD-121305, FK-124256 and by the ÚNKP-18-4 New National Excellence Program of the Ministry of Human Capacities.