Data assimilation is a power when treated wisely
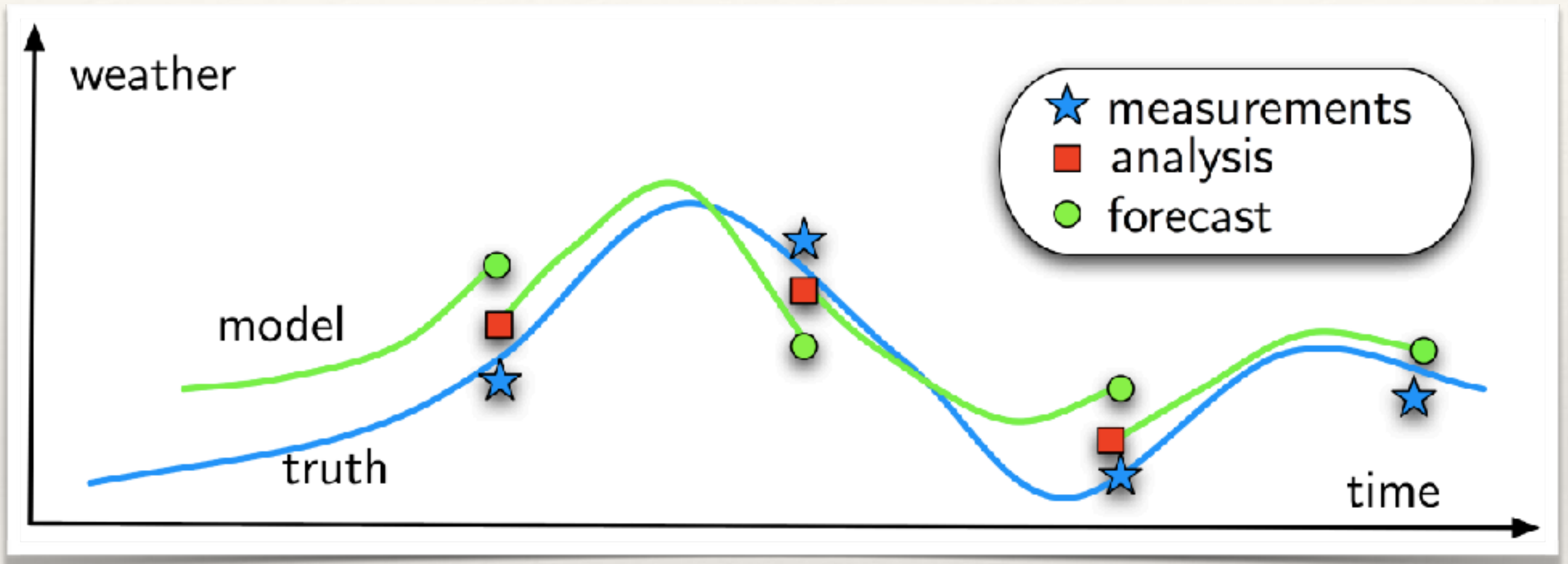
Svetlana Dubinkina (Scientific Computing Group)

Outlook of the talk

- The origin of data assimilation

- My projects

  - Paleo Data Assimilation

  - Subsurface reservoir estimation using data assimilation

  - Influence of a numerical approximation on data assimilation

  - Novel data assimilation for weather predictions

Data assimilation in weather prediction

Data assimilation originates from weather prediction where a physical model is combined with measurements in order to predict more accurate initial conditions.

Emerging Applications of Data Assimilation in the Geosciences

Lorentz center
Workshop @Oort

13 - 17 March 2017, Leiden, the Netherlands

Scientific Organizers

- Svetlana Dubinkina, CWI Amsterdam
- Andreas Fichtner, ETH Zürich
- Hugues Goosse, UC Louvain
- Peter Jan van Leeuwen, U Reading
- Tristan van Leeuwen, U Utrecht

Topics

- Data Assimilation
- Bayesian Statistics
- Seismology
- (Paleo-)Climatology

Invited Speakers

- David Al-Attar, U Cambridge
- Marc Bocquet, EdP ParisTech
- Ebru Bozdag, U Nice
- Stefan Brönnimann, U Bern
- Alberto Carrassi, NERSC Bergen
- Michel Crucifix, UC Louvain
- Ylona van Dinther, ETH Zürich
- Ana Ferreira, UCL London
- Michael Ghil, UCLA
- Arnold Heemink, TU Delft
- Marie-Colette van Lieshout,
  U Twente/CWI Amsterdam
- Gerard van der Schrier,
  KNMI Bilthoven
- Botond Szabo, U Leiden
- Jeannot Trampert, U Utrecht
- Harry van Zanten, U Amsterdam
- Sergiy Zhuk, IBM Dublin

The Lorentz Center organizes international workshops for researchers in all scientific disciplines. Its aim is to create an atmosphere that fosters collaborative work, discussions and interactions.
For registration see: www.lorentzcenter.nl

We learn more about the earth and its climate by integrating data from different sources, such as volcanic eruptions and the movement of ice sheets. Poster design: SuperNova Studios .NL
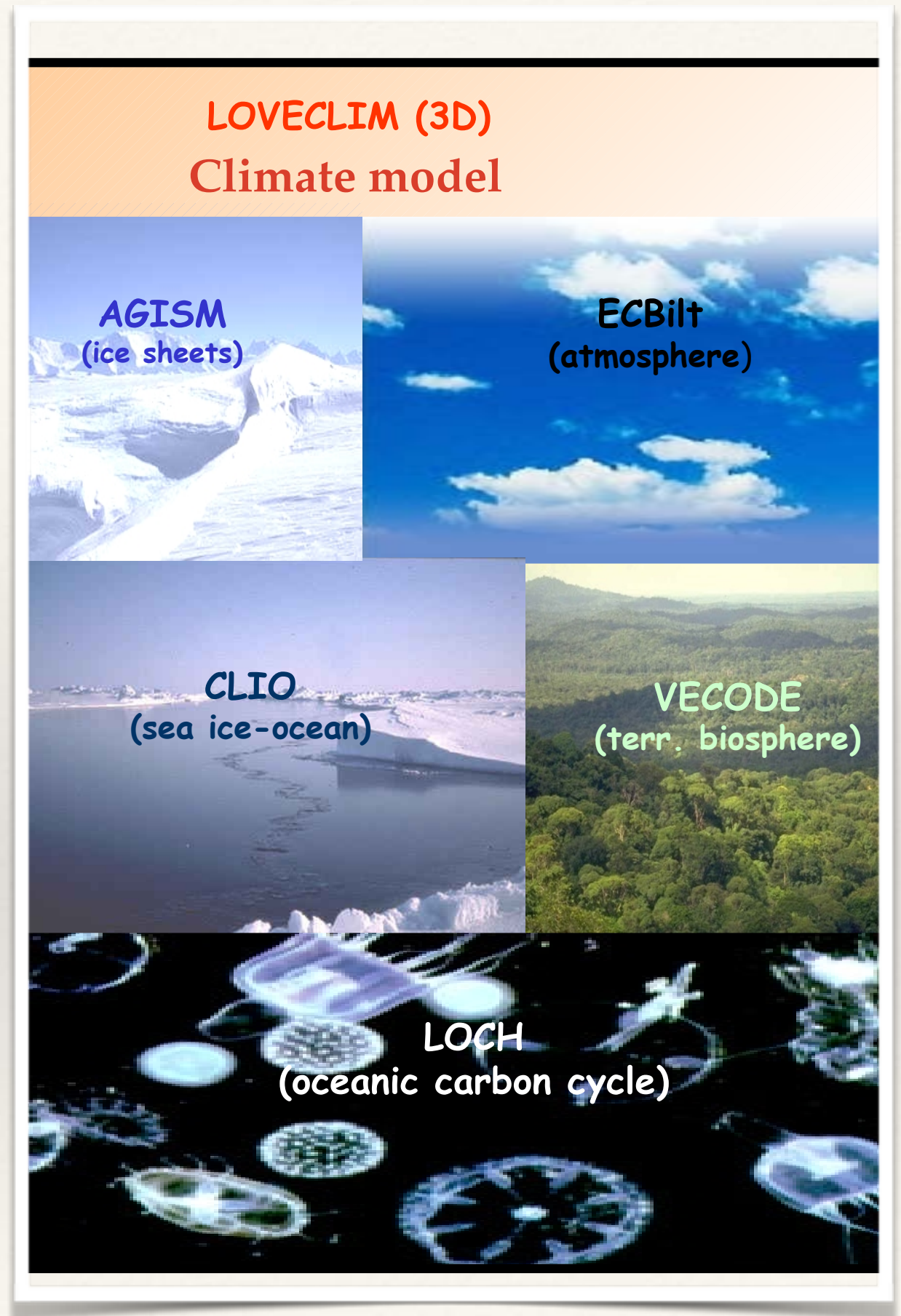
Universiteit Leiden The Netherlands · FOM · STW connecting innovators · **S**tochastics - **T**heoretical and **A**pplied **R**esearch · NDNS+ · NWO Netherlands Organisation for Scientific Research Earth and Life Sciences · NWO Netherlands Organisation for Scientific Research Physical Sciences

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In collaboration with Hugues Goosse (UCL, Belgium)

I. Paleo Data Assimilation

In order to predict the future one needs to understand the past.

The goal of Paleo Data Assimilation is to estimate past climate states using climate models and indirect measurements obtained from tree rings, ice cores, sediments, etc.

By combining those using efficient data assimilation methods we aim at better reconstructions of the past climate states.

LOVECLIM (3D)
Climate model

AGISM
(ice sheets)

ECBilt
(atmosphere)

CLIO
(sea ice-ocean)

VECODE
(terr. biosphere)

LOCH
(oceanic carbon cycle)

Ocean heat content reconstruction

The ocean is the largest solar energy collector on Earth. Not only does water cover more than 70% of our planet's surface, it can also absorb large amounts of heat without a large increase in temperature. This ability to store and release heat over decades and centuries makes the correct estimation of the ocean heat content essential for quantifying the human impact on global warming.
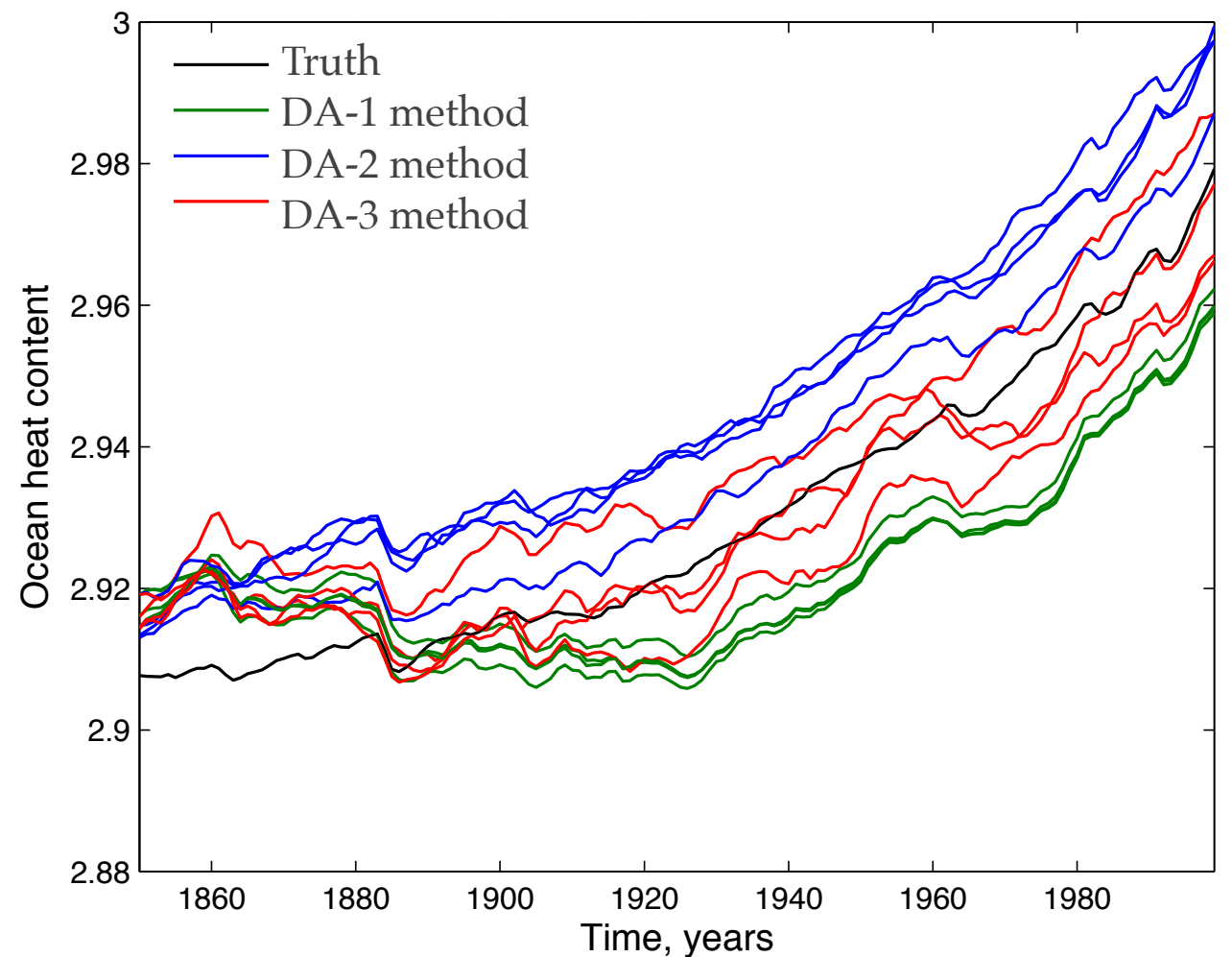
Conclusion: ocean heat content is well estimated only by one data assimilation method.

Sangeetika Ruchi (PhD candidate)

II. Subsurface reservoir estimation

- Estimation of gas and petroleum reservoir structure is an example of a problem with uncertain physical parameters. The parameters could be estimated using available measurements, thus data assimilation could be applied.
- Measurements of pressure at well locations are available.
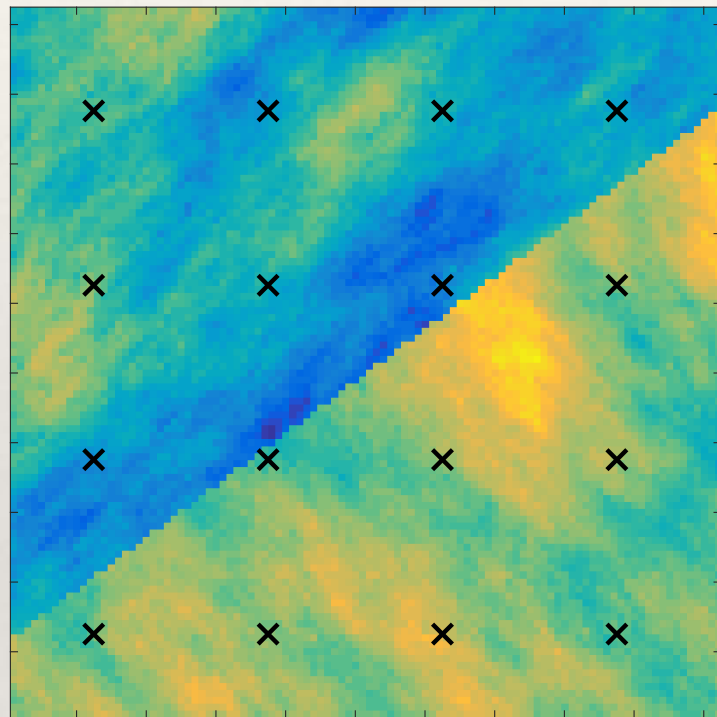- A physical parameter such as permeability needs to be estimated.
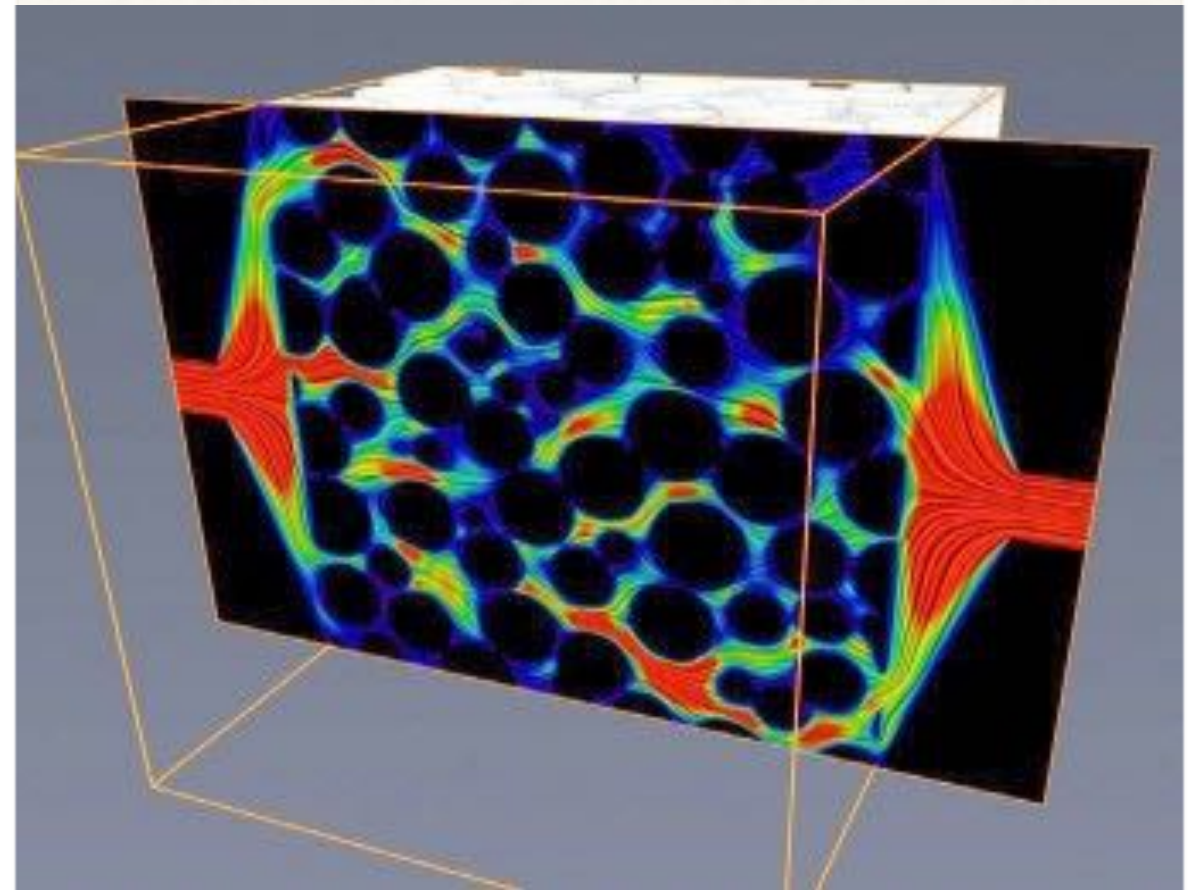
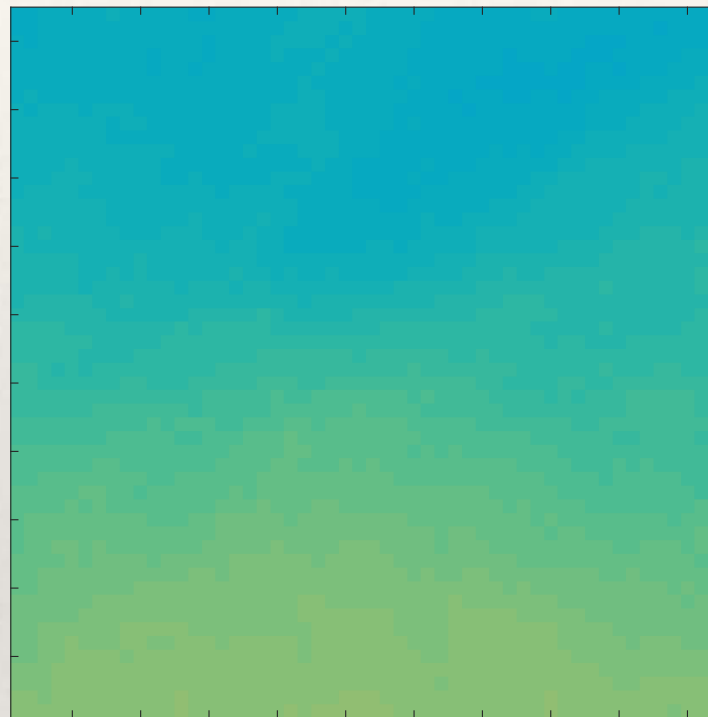Permeability of a rock is a measure of the resistance to the flow of a fluid through a rock.
We work on estimations of permeability (high dimensional problem) given a few observations of pressure.

Permeability estimation using data assimilation
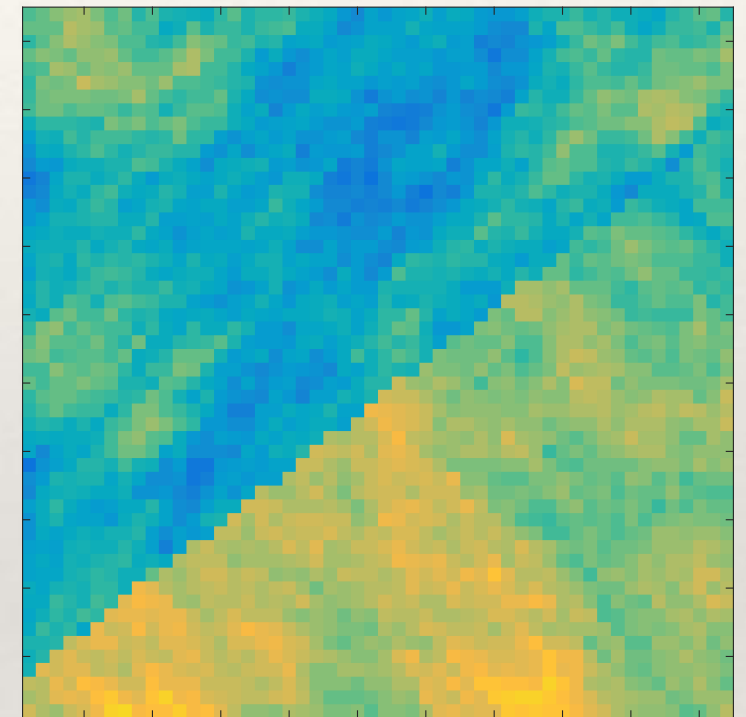
True permeability

Permeability
before Data Assimilation

Permeability
after Data Assimilation

Crosses denote locations
of pressure observations

Conclusion: we are able to estimate high dimensional permeability (2500) given only 16 observations of pressure.

III. Influence of a numerical approximation on data assimilation

❖ Data assimilation needs to be computationally cheap, fast, and independent of a physical model (black-box model approach).

❖ An example of such a data assimilation methodology is a <u>well-known</u> Ensemble Kalman Filter.

❖ Ensemble Kalman Filter though has a major shortcoming of violating conservation laws.

❖ Thus one might assume that a numerical approximation of the physical model does not need to possess conservation laws, since those will be violated by data assimilation anyway.

❖ We investigate how a numerical approximation of a physical model influences the data assimilation estimation depending on the conservation laws it possesses.

Relevance of a conservative numerical approximation for an Ensemble Kalman Filter
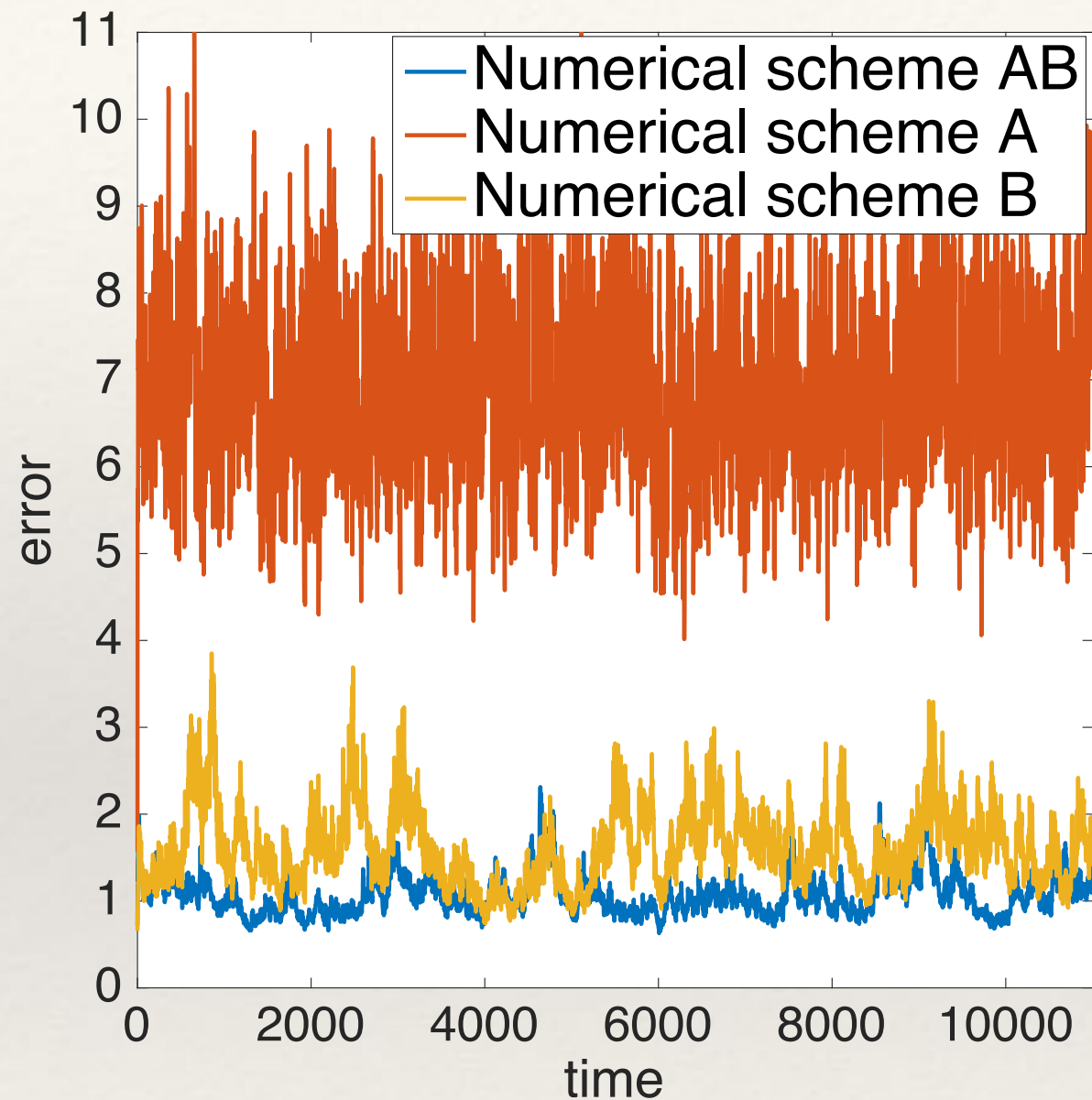
As a physical model we consider a model that is used to describe flow in the ocean and atmosphere.

As a numerical approximation we consider 3 classical schemes:

- ❖ Numerical scheme AB that preserves two quantities A and B

- ❖ Numerical scheme A that preserves only one quantity A

- ❖ Numerical scheme B the preserves only one quantity B

Results

**Conclusion**: conservation properties of a numerical approximation strongly influence the results of data assimilation.

Bart de Leeuw (PhD candidate)

IV. Novel data assimilation method for weather predictions

The current data assimilation method used for weather predictions suffers from the limitation of number of observations it can take into account.
Intuitively, one could guess that by taking more observations into account the estimation would be better. Therefore we introduce a novel data assimilation method that can handle more observations than the "classical" one.
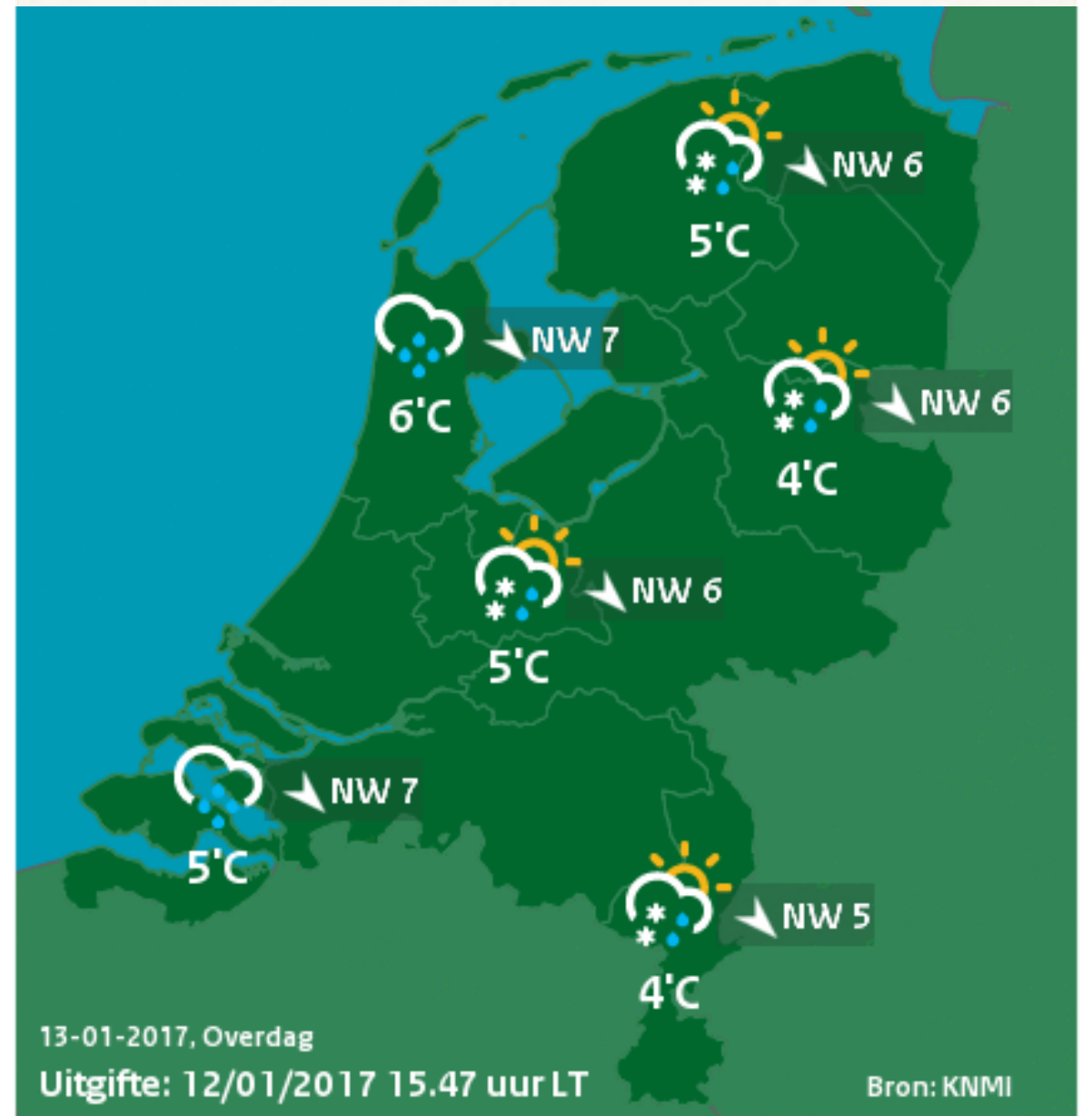
Results for a toy model of the atmosphere
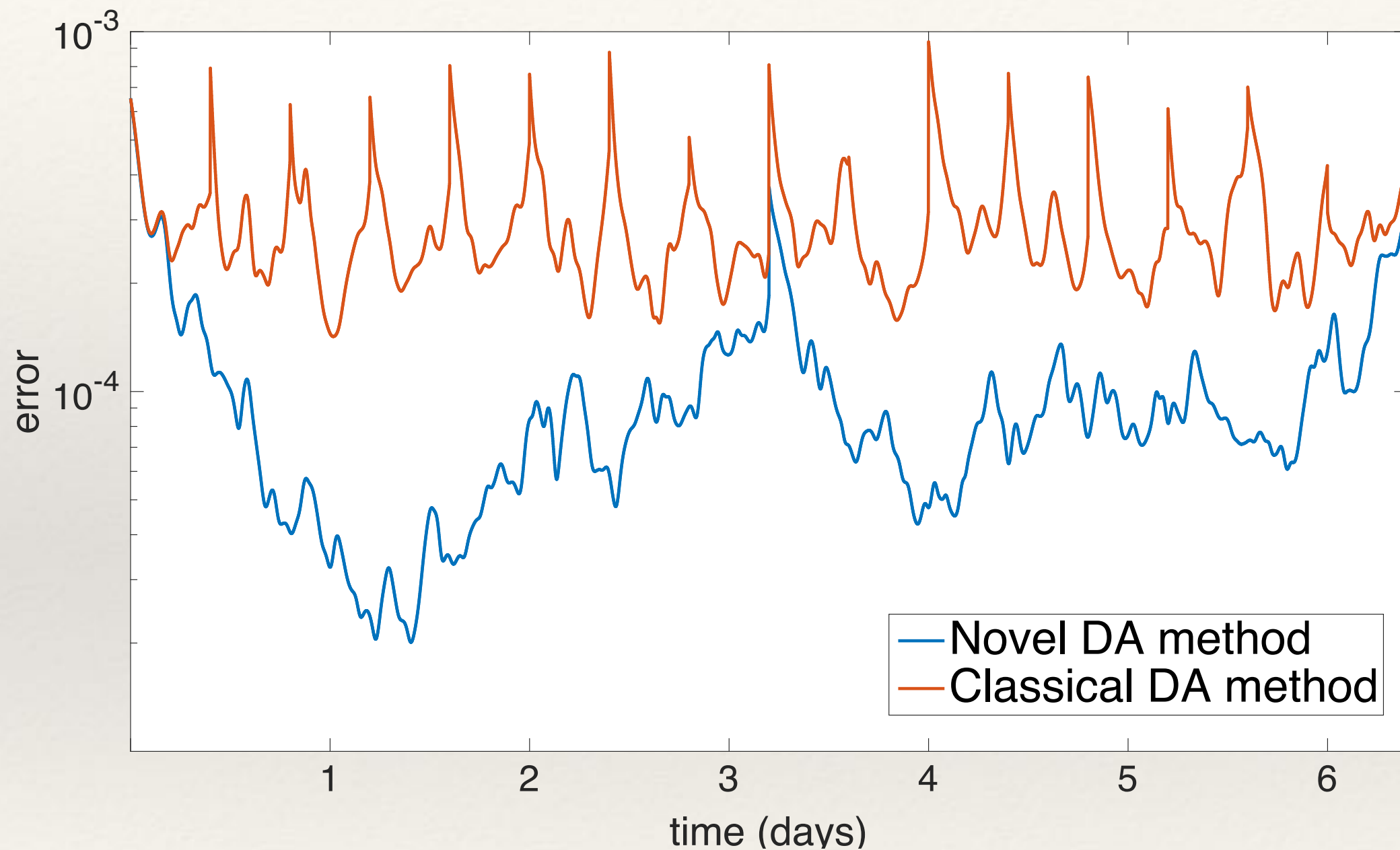
Conclusion: our new data assimilation method decreases the error.

Conclusions of the talk

❖ Data assimilation can prove to be useful in any application where models are uncertain but measurements are available.

❖ However, one needs to keep in mind that data assimilation is a power only when it is treated wisely.

❖ Thus many more interesting and challenging problems lie ahead.