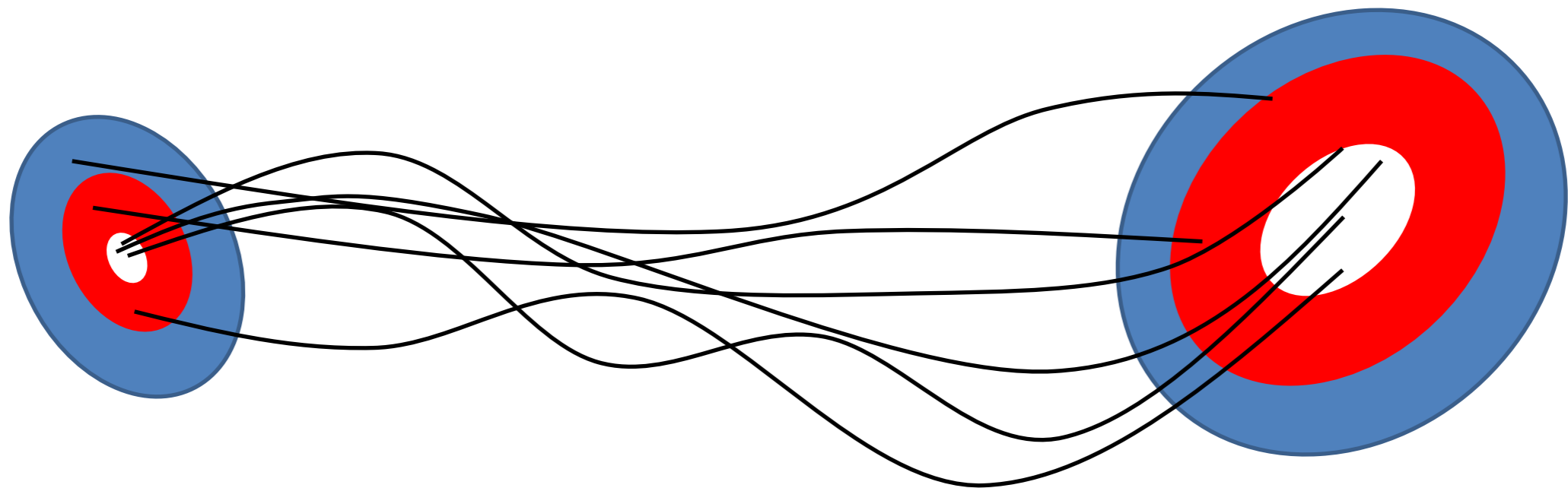


The Ensemble Kalman filter

PRACTICAL

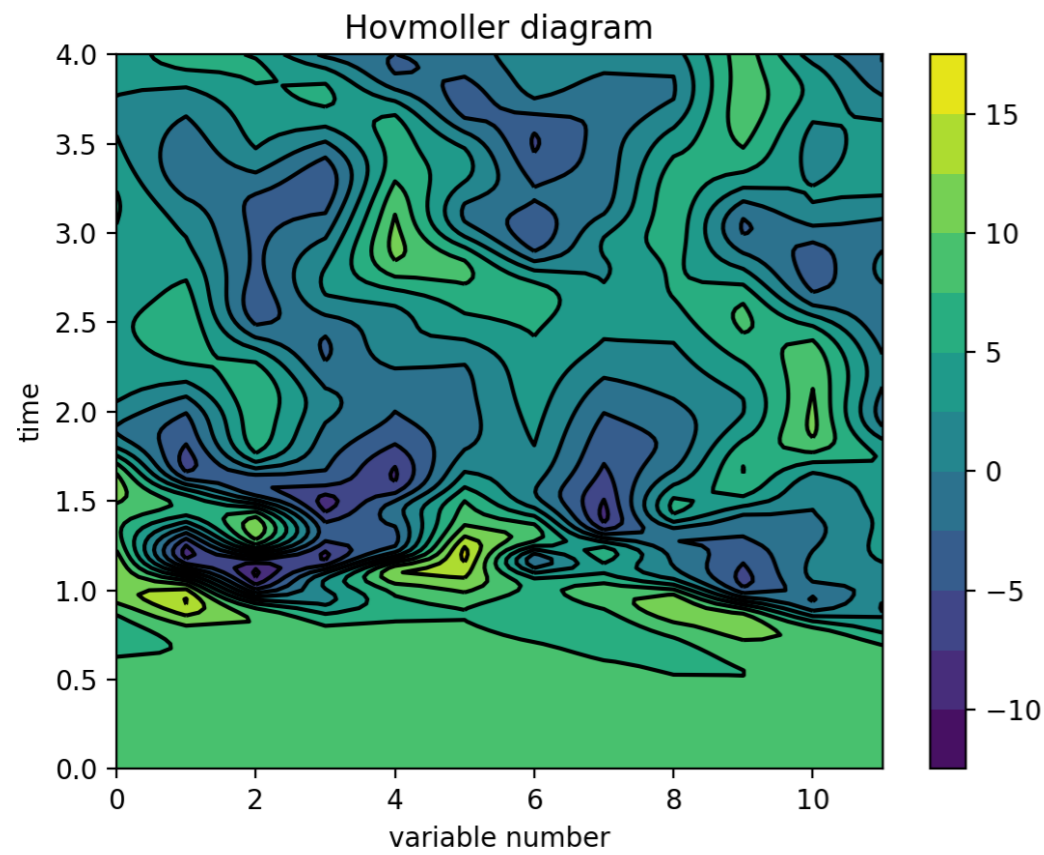


Dr Sanita Vetra-Carvalho, Dr Javier Ameczua, Dr Natalie Douglas

DA Toy Models

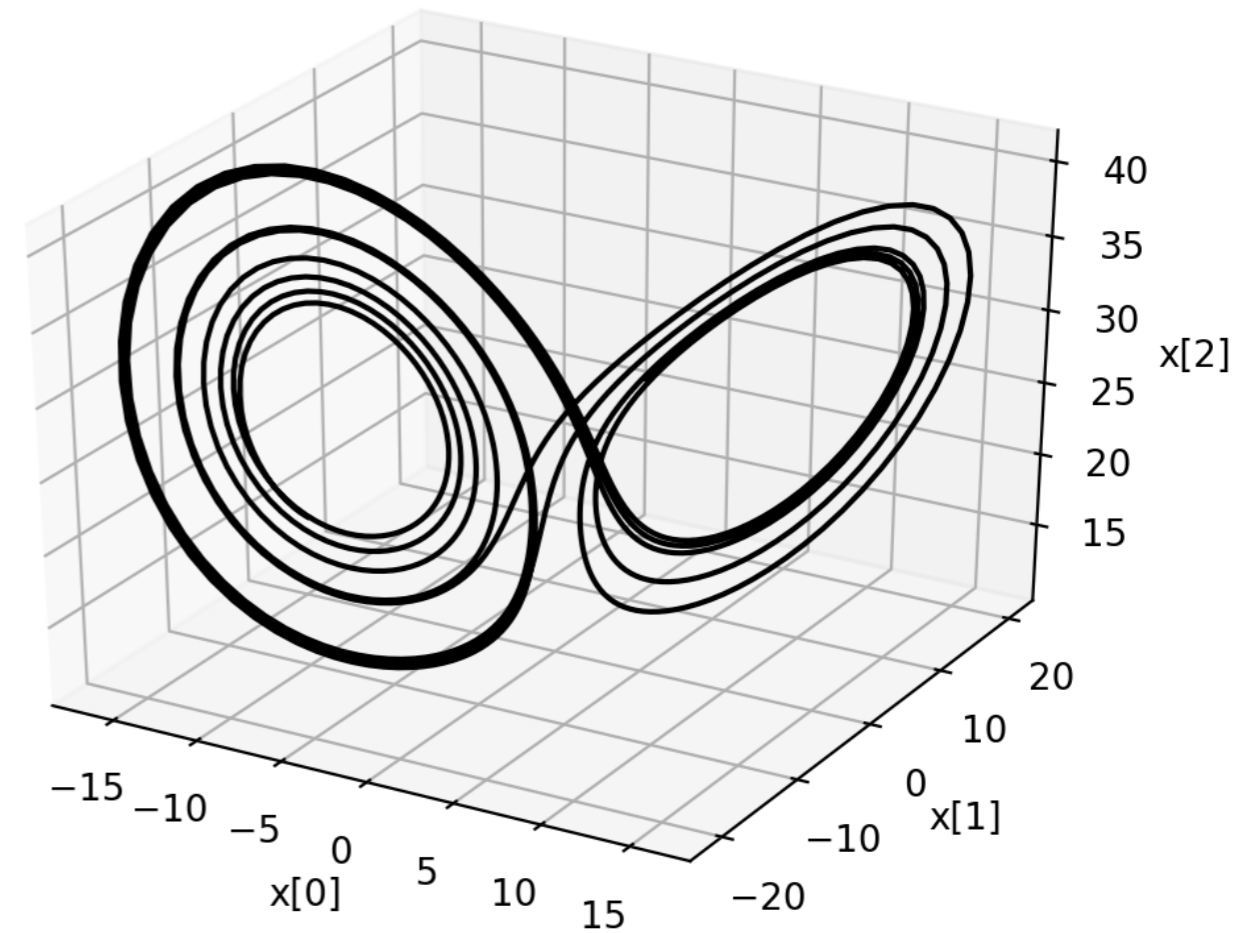
We will use two toy models:

- Lorenz '63 with 3 variables
- Lorenz '96 with 12 variables



Lorenz96

Lorenz63



DA Toy Models: L63

$$\frac{dx}{dt} = \sigma(y - x),$$

$$\frac{dy}{dt} = x(\rho - z) - y,$$

$$\frac{dz}{dt} = xy - \beta z.$$

The constants:

$$\sigma = 10,$$

$$\rho = 8/3,$$

$$\beta = 28$$

are the system parameters, chosen such that we have a chaotic system.

The equations relate the properties of a two-dimensional fluid layer uniformly warmed from below and cooled from above. In particular, the equations describe the rate of change of three quantities with respect to time:

- x is proportional to the rate of convection,
- y to the horizontal temperature variation,
- and z to the vertical temperature variation.

DA Toy Models: L96

For $i = 1, \dots, N$:

$$\frac{dx_i}{dt} = (x_{i+1} - x_{i-2})x_{i-1} - x_i + F$$

where it is assumed that

$$x_{-1} = x_{N-1}, x_0 = x_N \text{ and } x_{N+1} = x_1$$

Here, x_i is a system variable and $F = 8$ is a forcing term.

How to run the models

Lorenz '63

- **ControlL63Enkf.py**

This is the control file, and it is the one which you will be running and modifying.

- **L63model.py**

This file contains all the instructions to run the L63 model.

- **L63misc.py**

This file generates different observation operators, creates the observations, and generates a simple background error covariance matrix.

- **L63kfs.py**

This file contains the routines to perform SEnKF and ETKF.

- **L63plots.py**

This file has instructions for different plots.

Lorenz '96

- **ControlL96EnKF.py**

This is the control file, and it is the one which you will be running and modifying.

- **L96model.py**

This file contains all the instructions to run the L96 model.

- **L96misc.py**

This file generates different observation operators, creates the observations, and generates a simple background error covariance matrix.

- **L96kfs.py**

This file contains the routines to perform SEnKF, ETKF.

- **L96plots.py**

This file has instructions for different plots.

How to run the models

You will run different sections of the file *ControlL63EnKF.py*.

The sections are enumerated as comments of the file (recall that in python # is used for comments).

To run only a section of a file you can highlight the desired instructions with the mouse, and then press F9.

How to run the models

- **Section 1** generates the nature run of the experiment, i.e. what we consider to be the true system. You can change the system parameters if you want to.
- **Section 2** is related to the observations. You can select which variables to observe, how frequently and with what variance.
- **Section 3** contains the DA experiments using ETKF, SEnKF and L-SEnKF for the L96. Here you can vary the size of the ensemble, inflation, localisation (for L96), and DA method.
- **Section 4** allows you to perform parameter estimation (L63 only).

Output

A number of plots will be generated by the code including:

- nature run or truth
- observations
- ensemble forecast and analysis mean
- forecast and analysis ensemble
- RMSE vs Ensemble Spread