Particle Filters
Part II
Demonstrations

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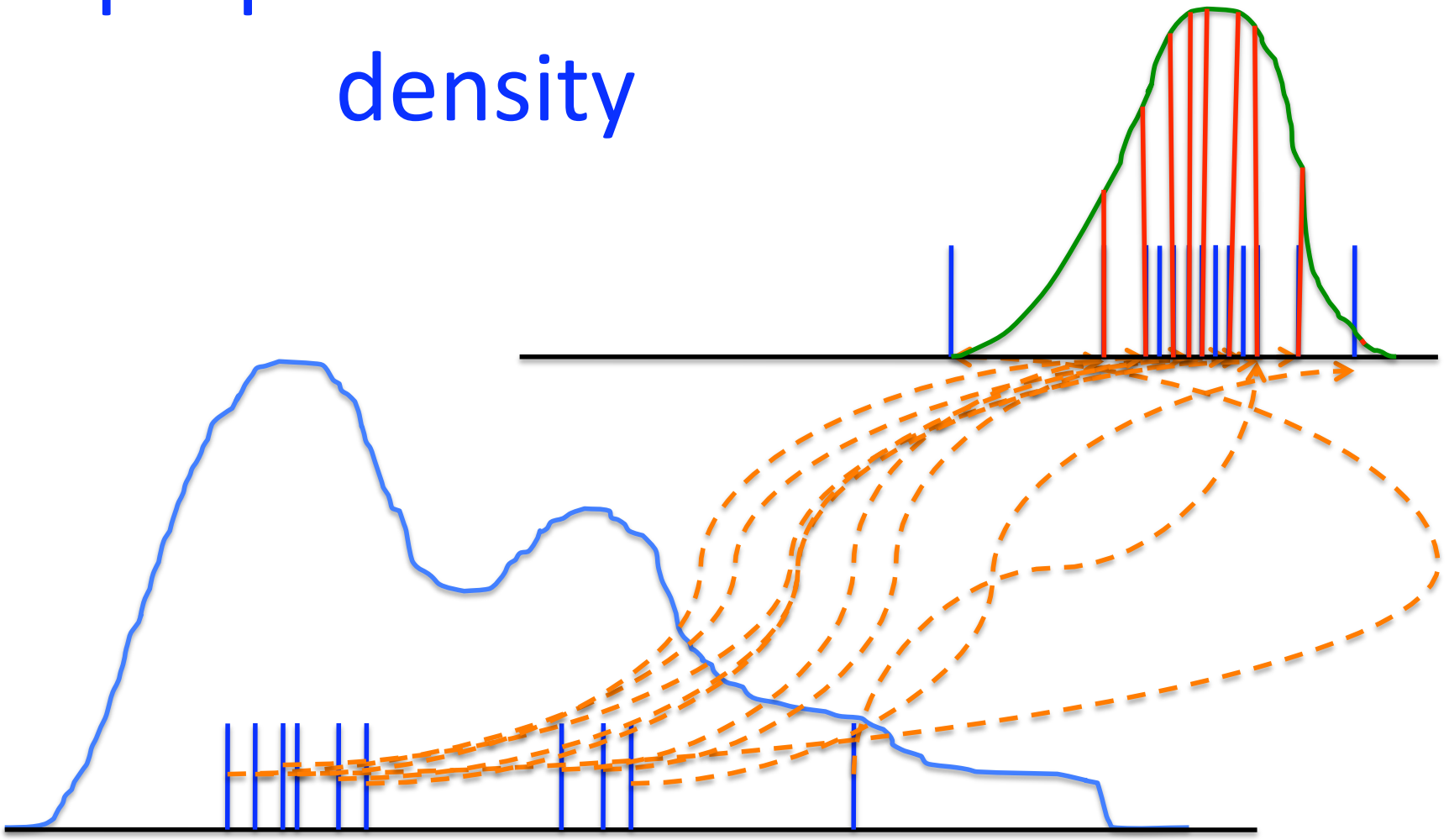
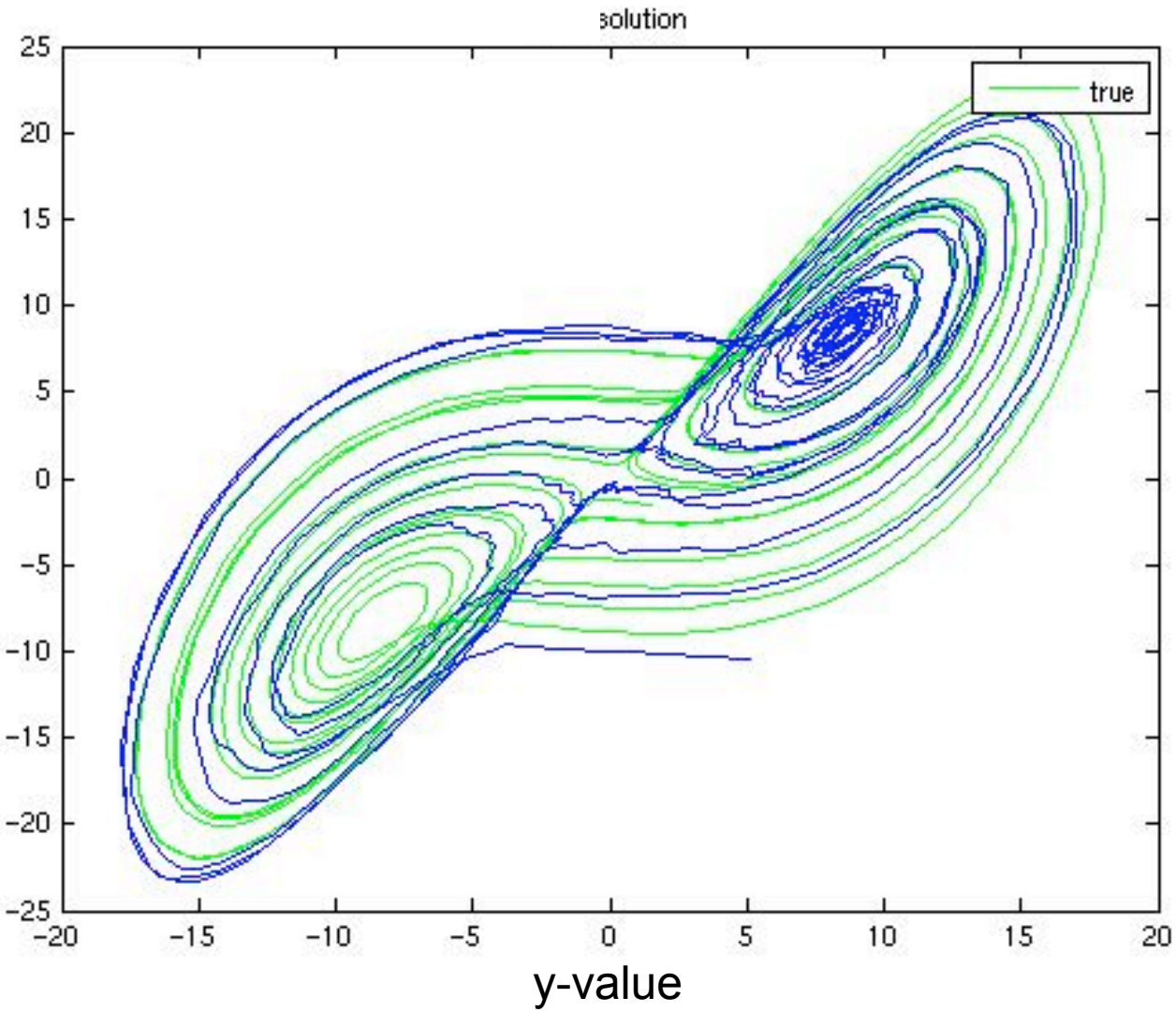
Particle filter with proposal transition density



Experiment: Lorentz 1963 model

(3 variables x,y,z, highly nonlinear)

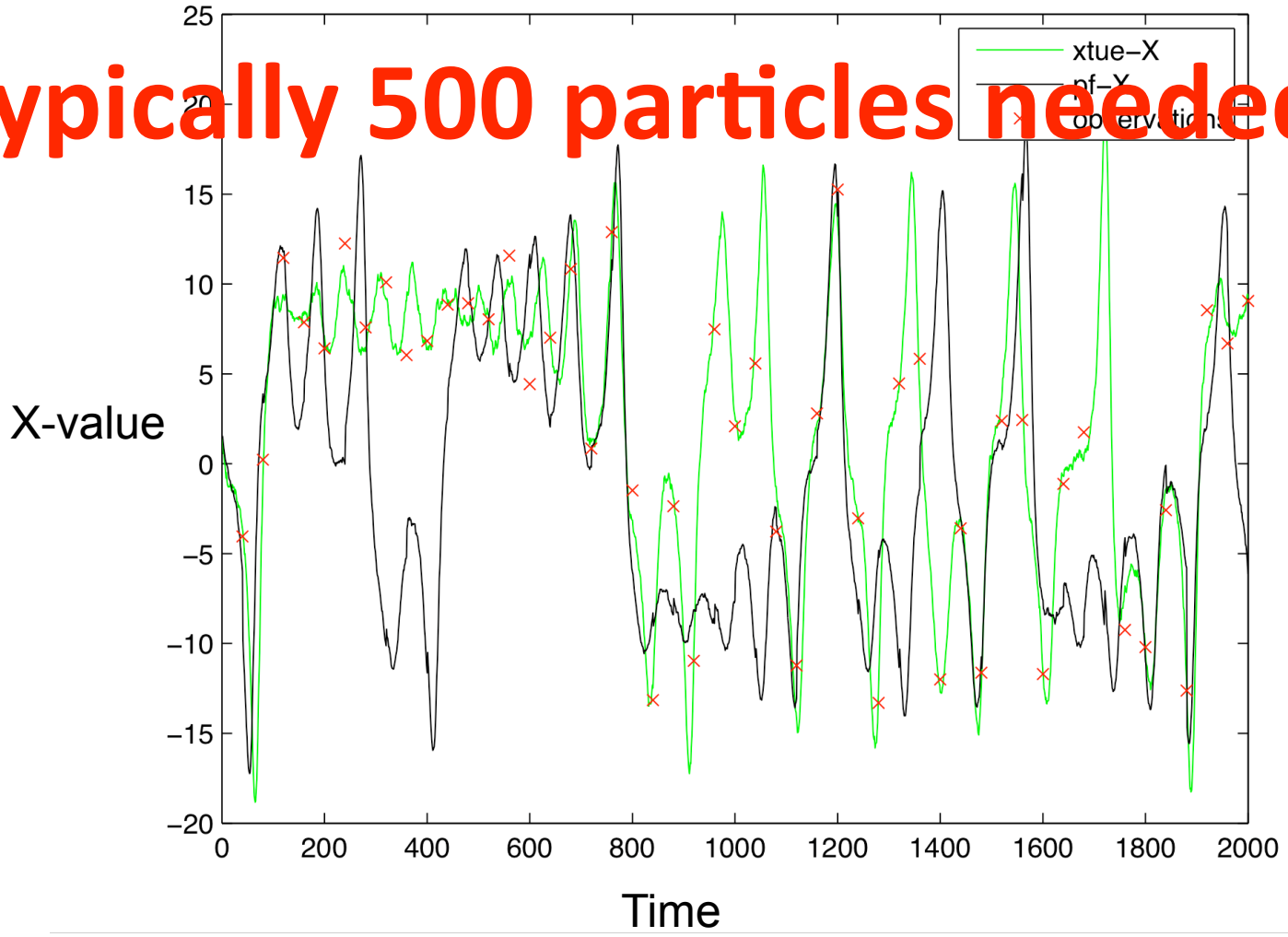
Measure only X-variable



Standard Particle filter with resampling

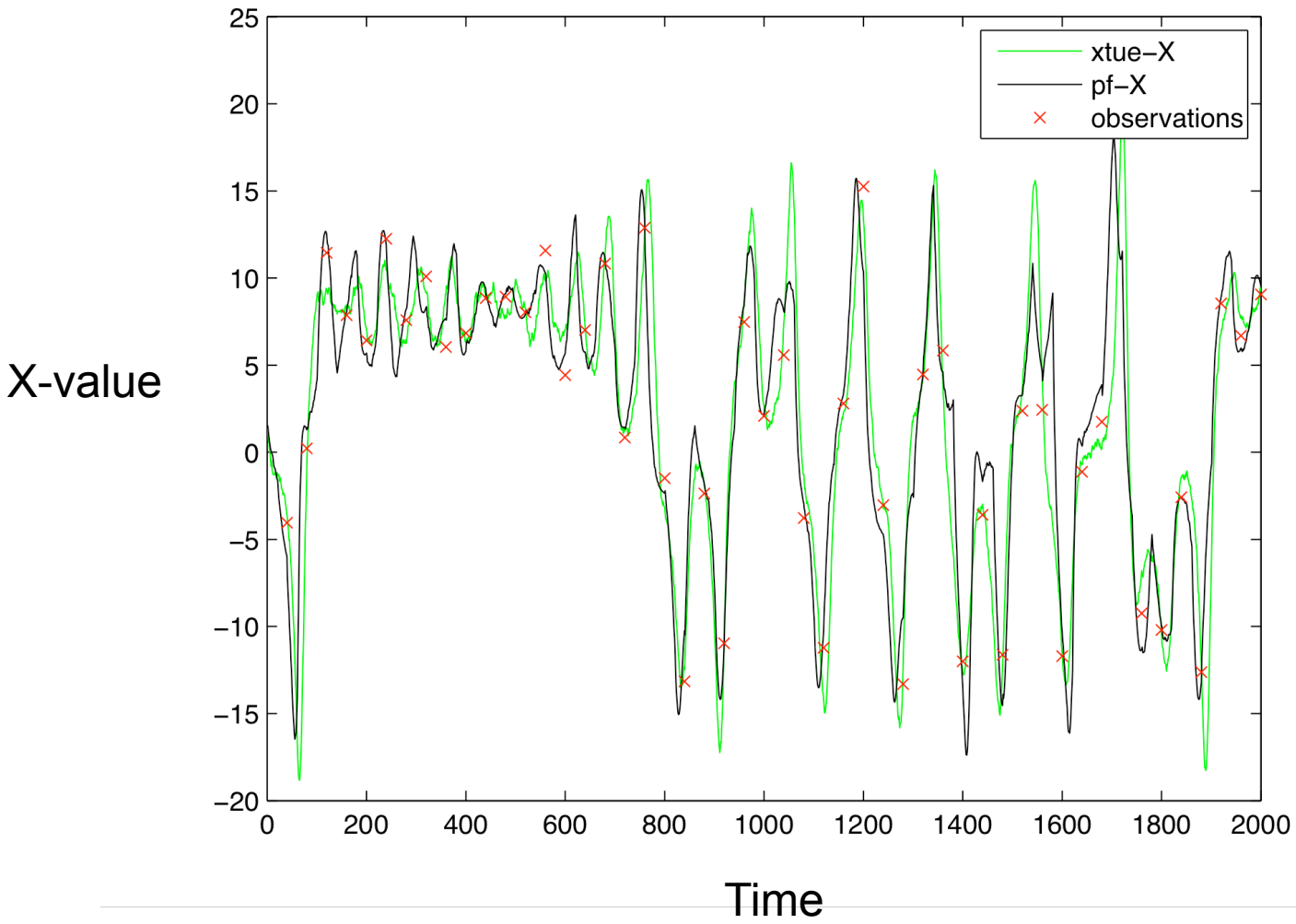
20 particles

Typically 500 particles needed !



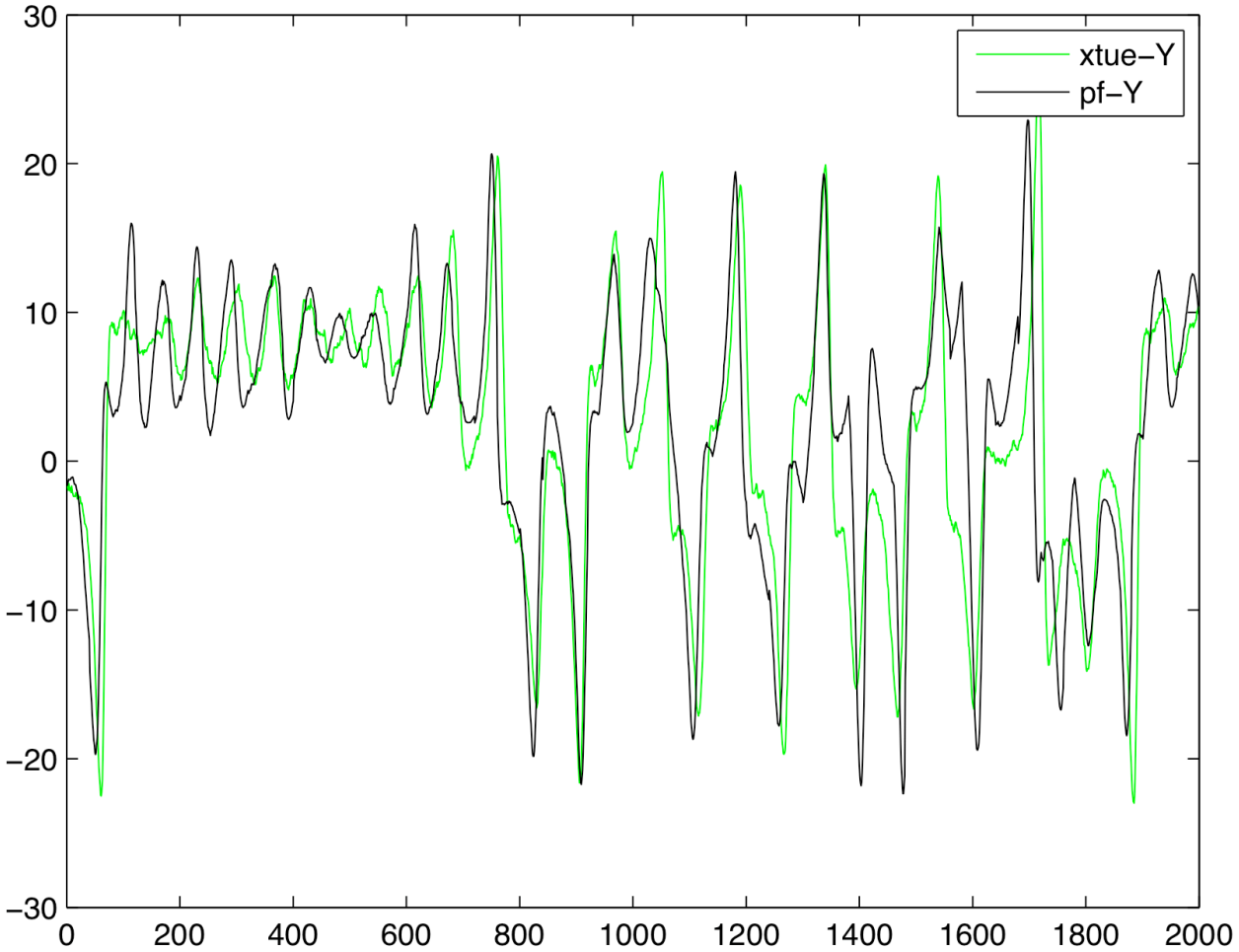
Particle filter with proposal transition density

3 particles

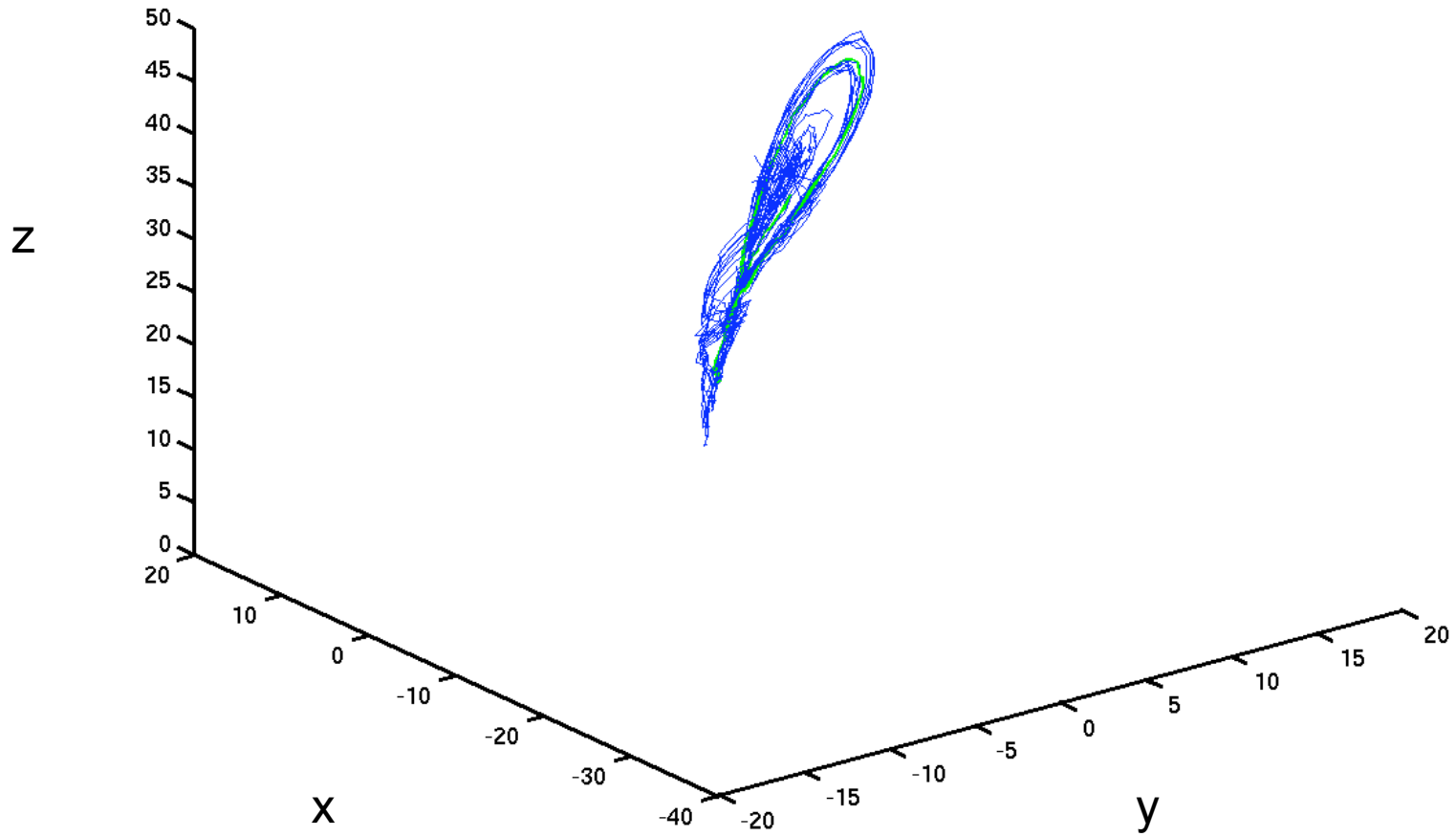


Particle filter with proposal transition density 3 particles

Y-value
(not observed)



Application: Lorenz 1963



What about high-dimensional systems?

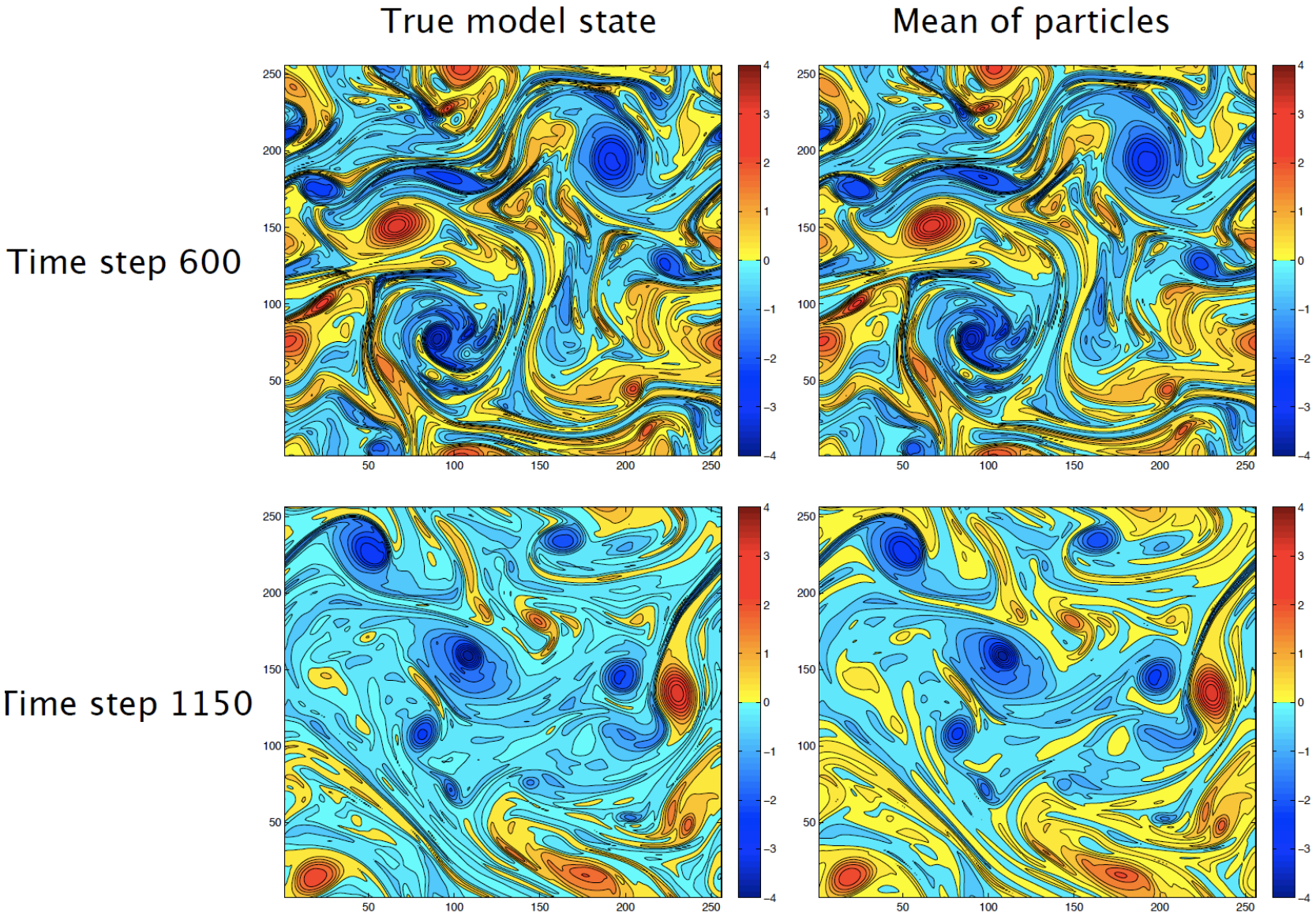
Application: the barotropic vorticity equation

- Stochastic barotropic vorticity equation:

$$\frac{\partial q}{\partial t} + u \cdot \nabla q = F$$

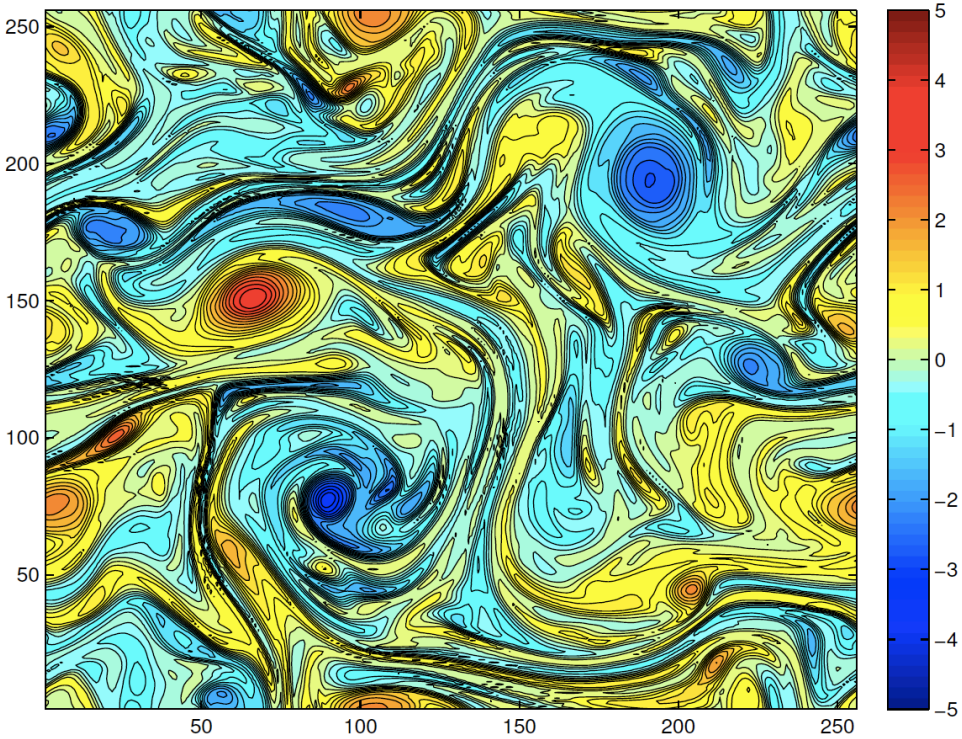
- 256 by 256 grid - 65,536 variables
- Double periodic boundary conditions
- Semi-Langrangian time stepping scheme
- Twin experiments
- Observations every 50 time steps – decorrelation time of 42
- 32 particles

Fully observed system

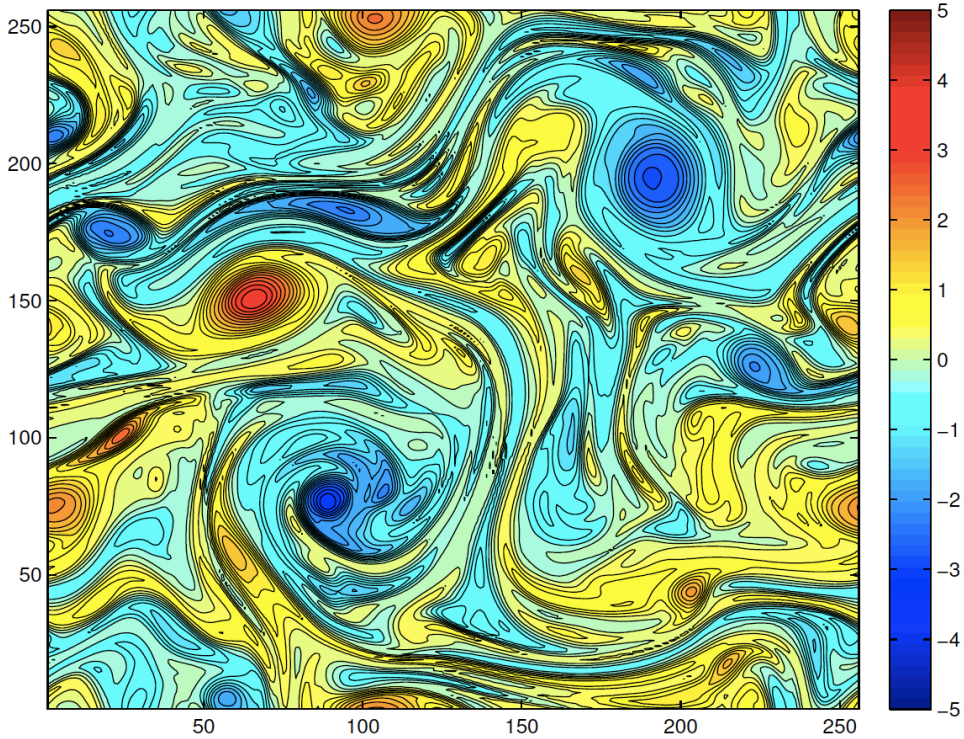


Every 4th variable observed, 600 time steps

4096 of the 65,536 variables



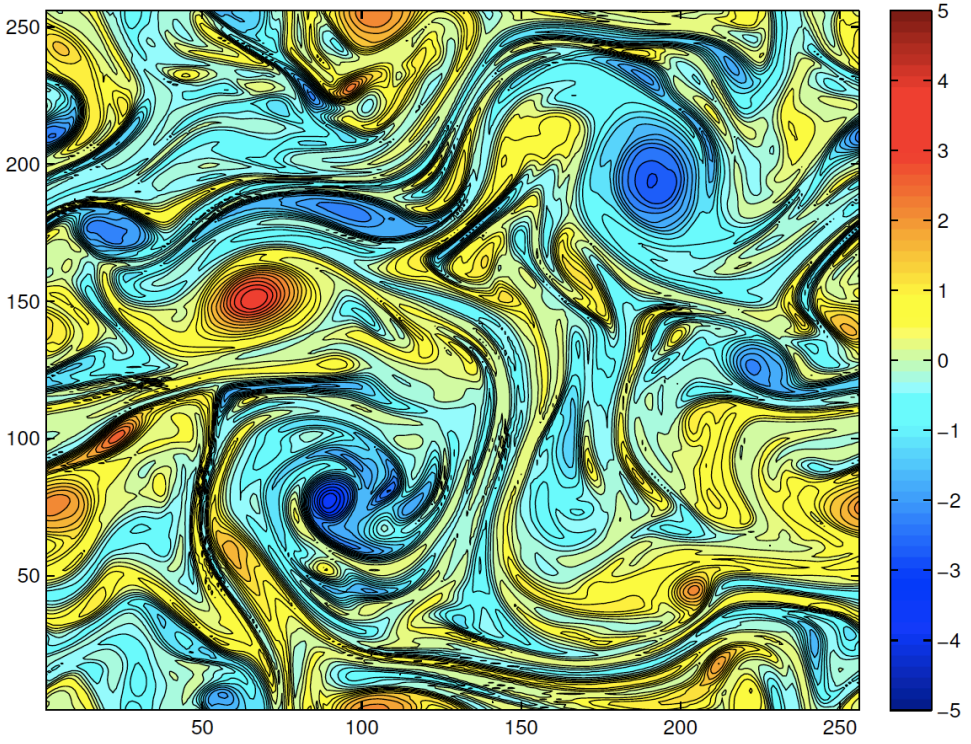
(a) truth



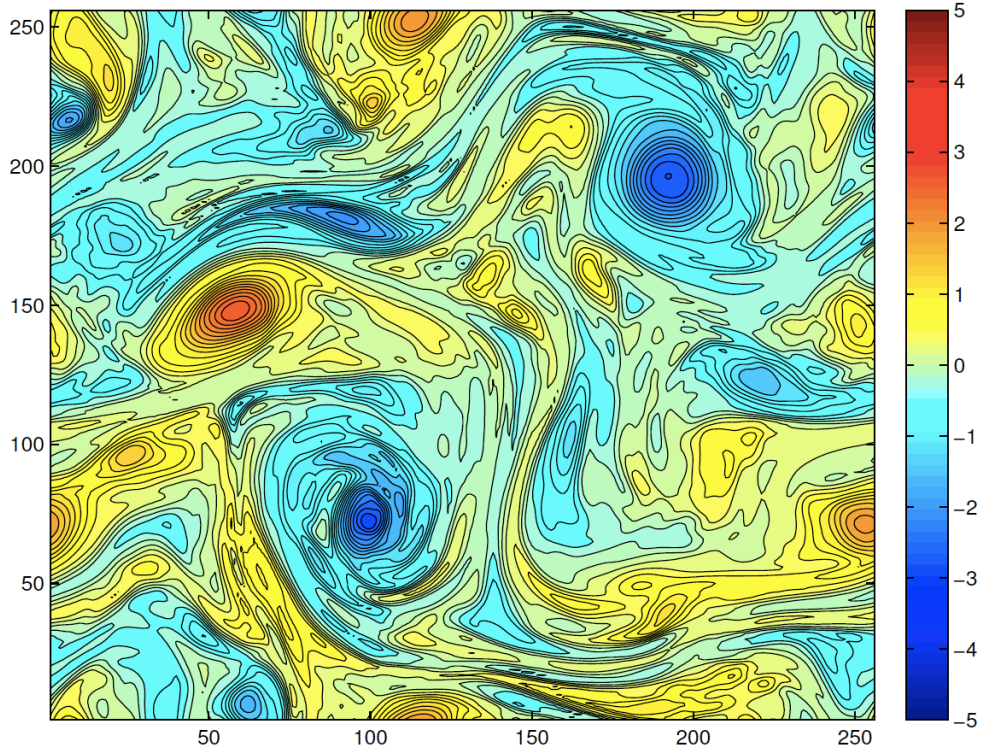
(b) Every 4th variable observed

Every 8th variable observed, 600 time steps

1024 of the 65,536 variables



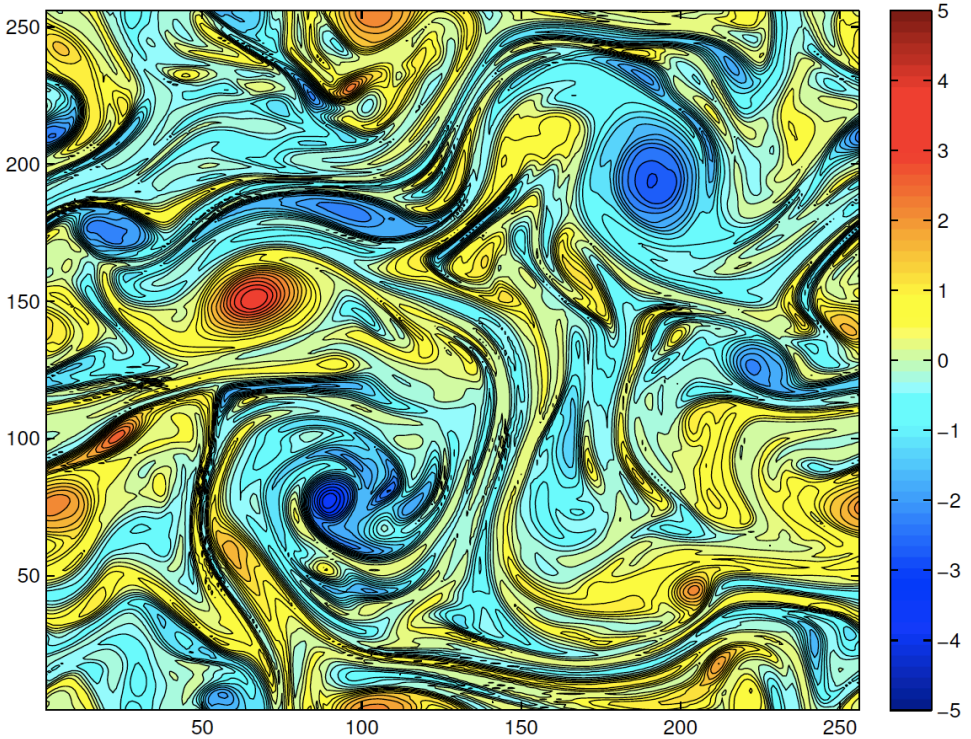
Truth



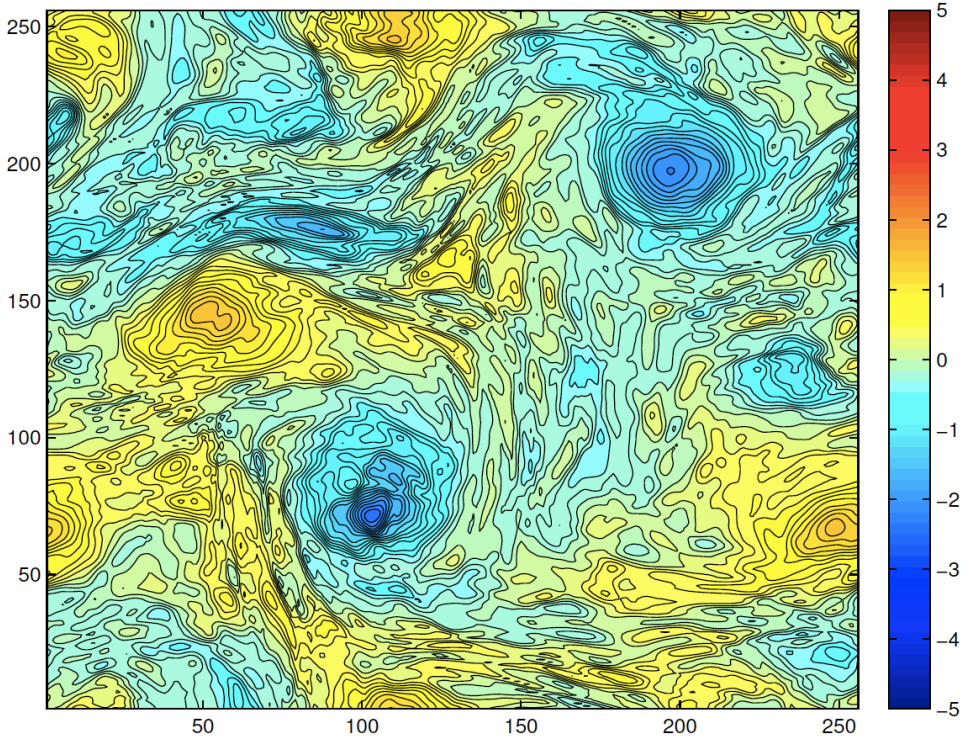
(c) Every 8th variable observed

Every 16th variable observed, 600 time steps

256 of the 65,536 variables

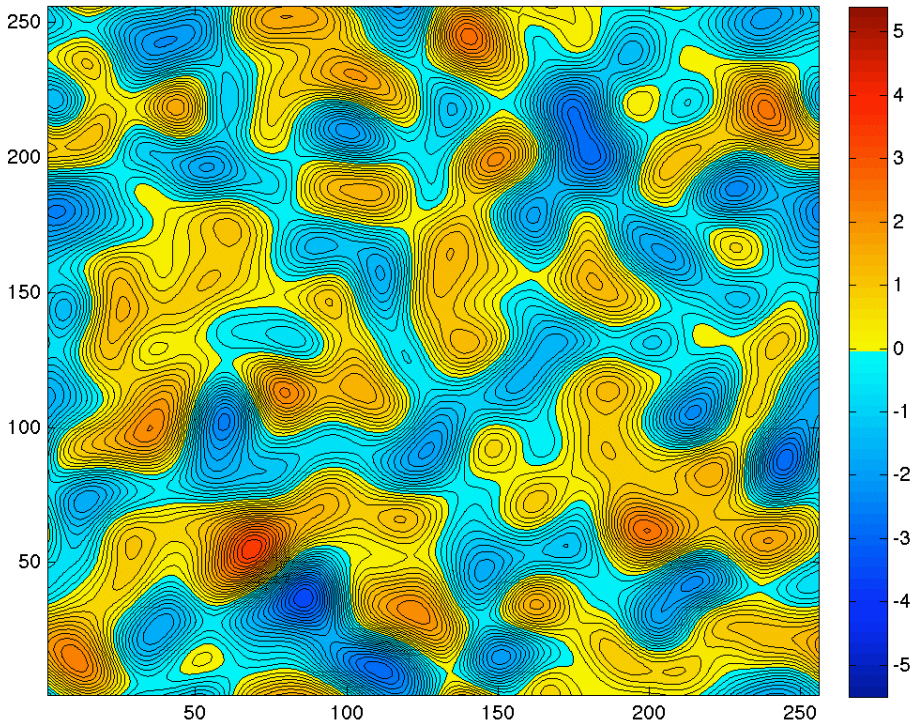


Truth

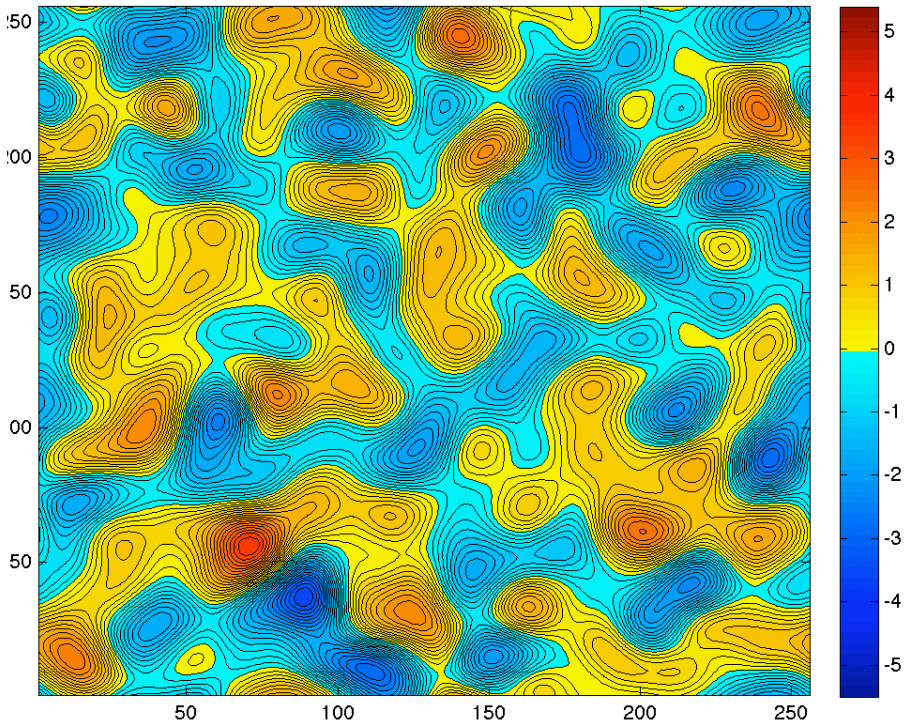


(d) Every 16th variable observed

¼ Observations over half of state

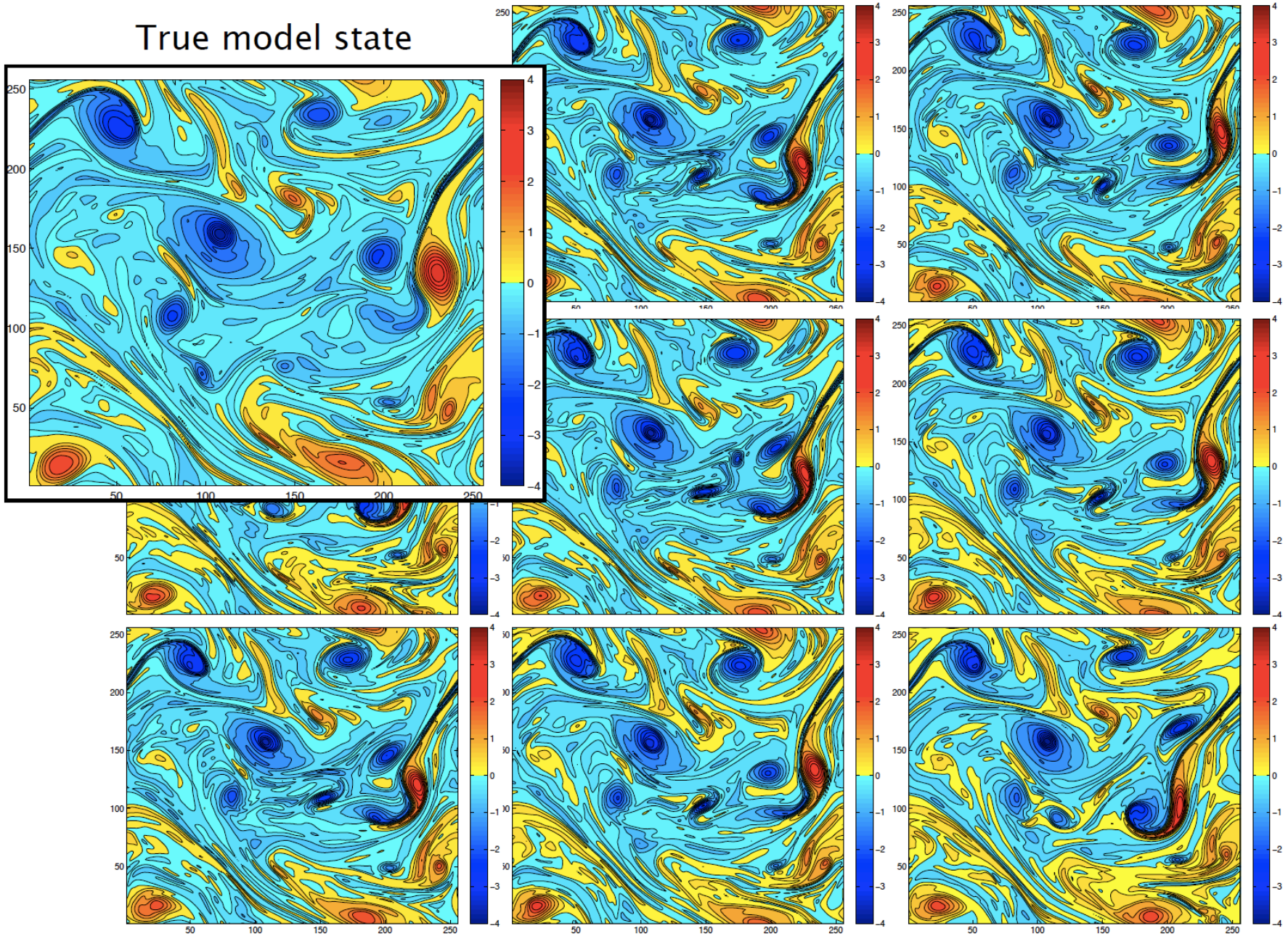


True evolution

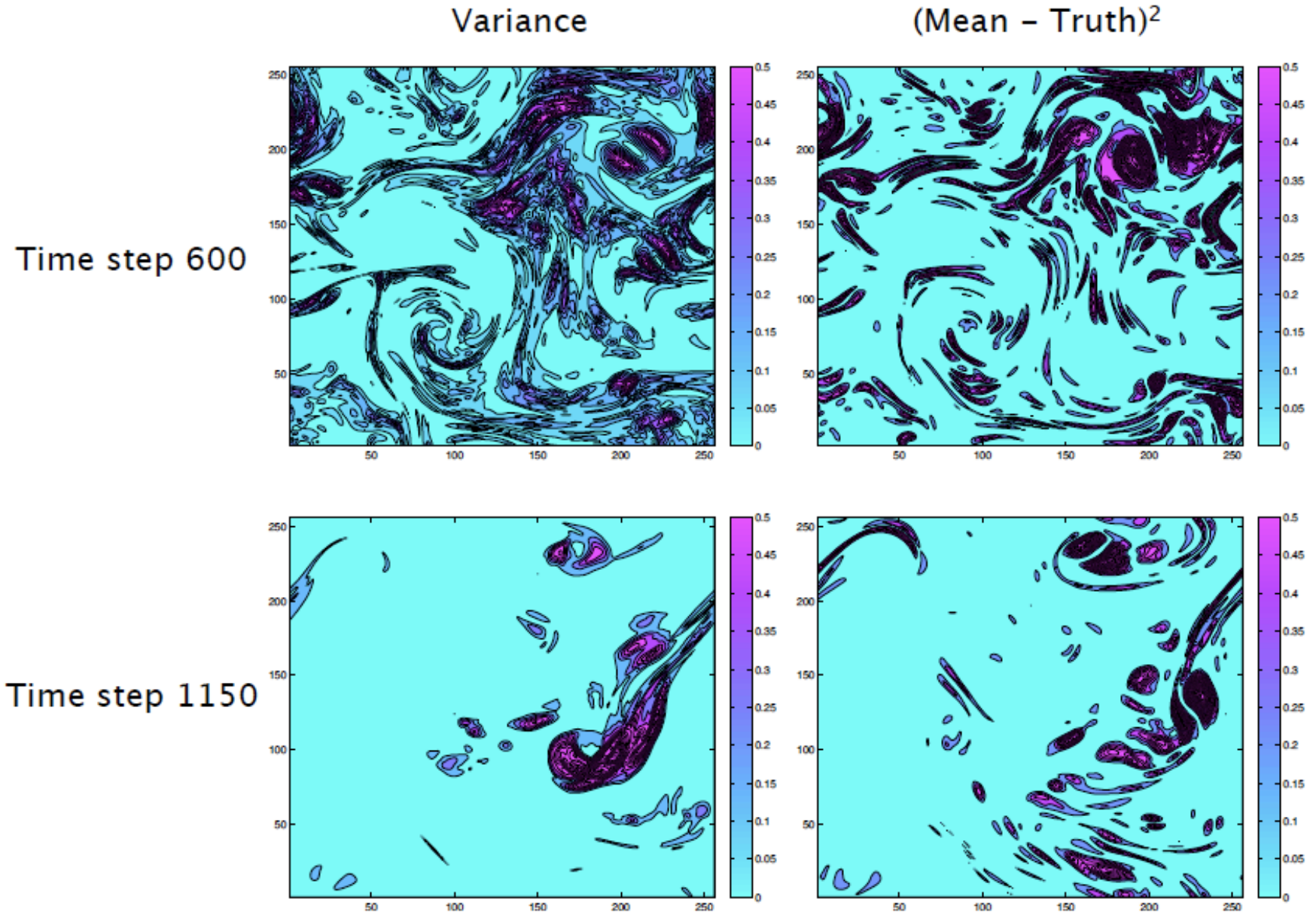


Mean of EW Particle filter

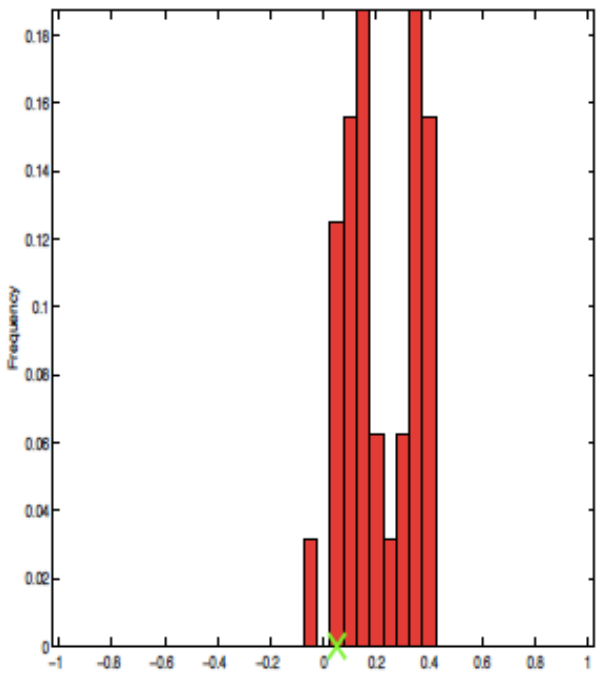
1/4 observations over half the state – time 1150



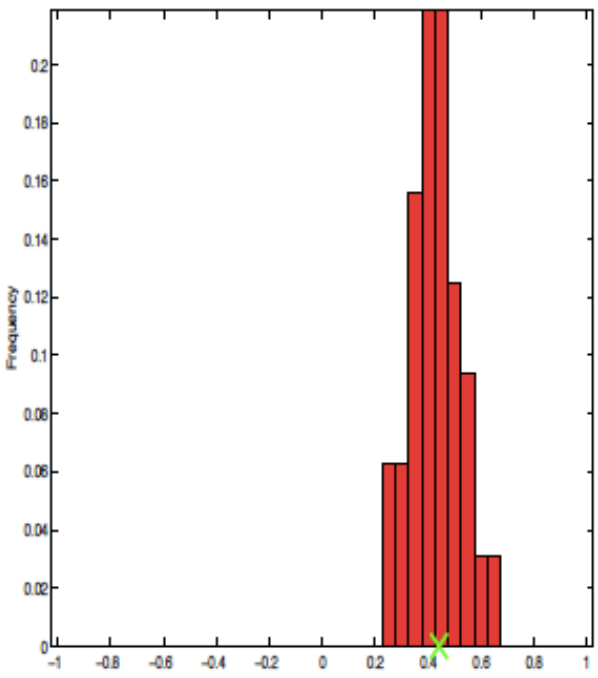
¼ observations over half of state



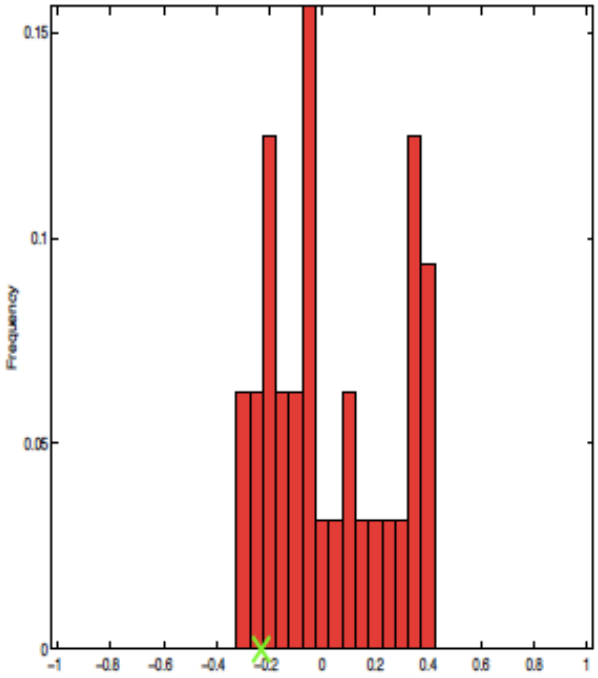
Marginal posterior probability densities



variable (20,64)

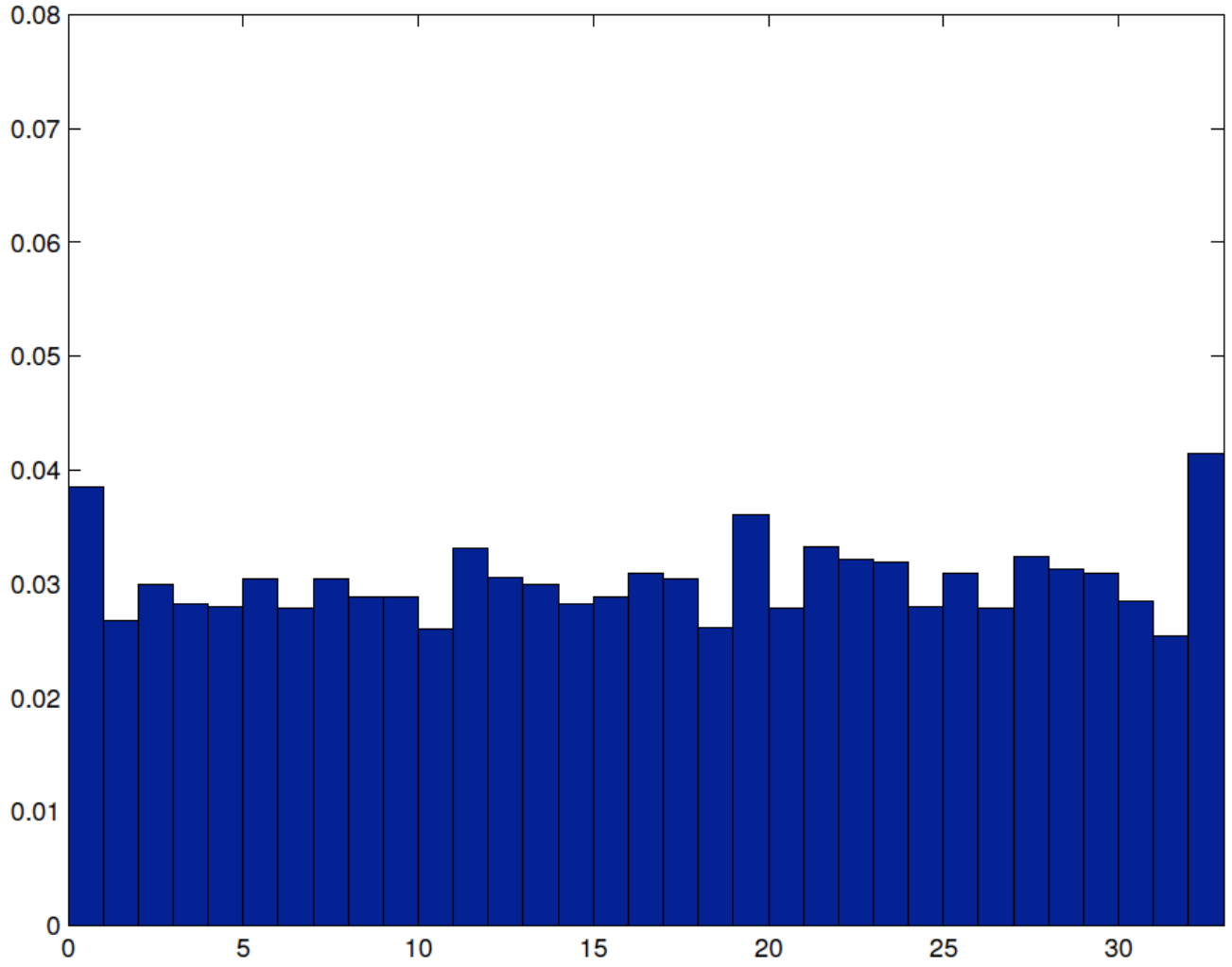


variable (56,64)



variable (197,64)

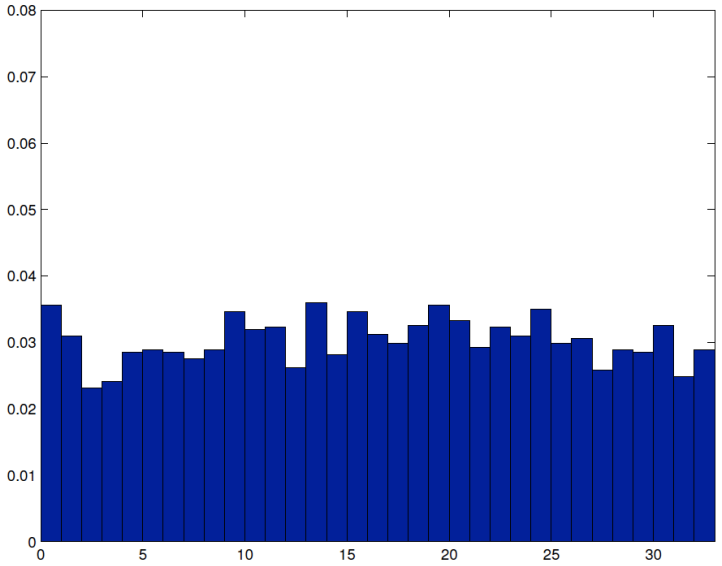
Rank histograms

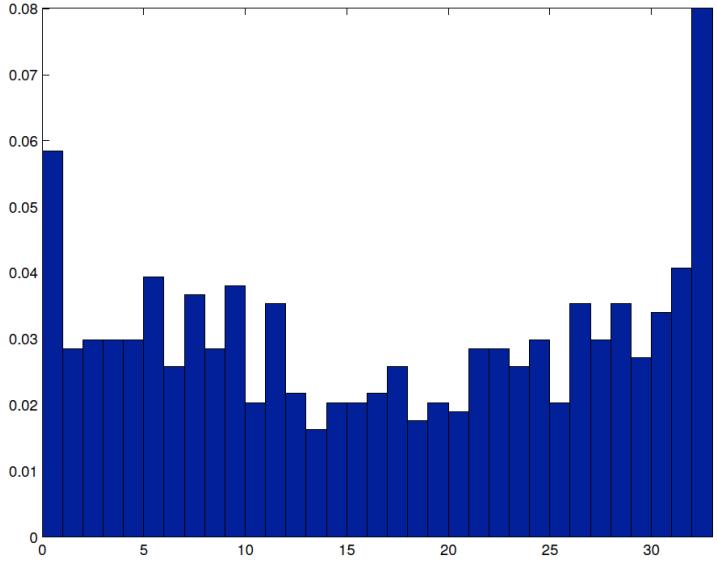


Full state observed

Histograms

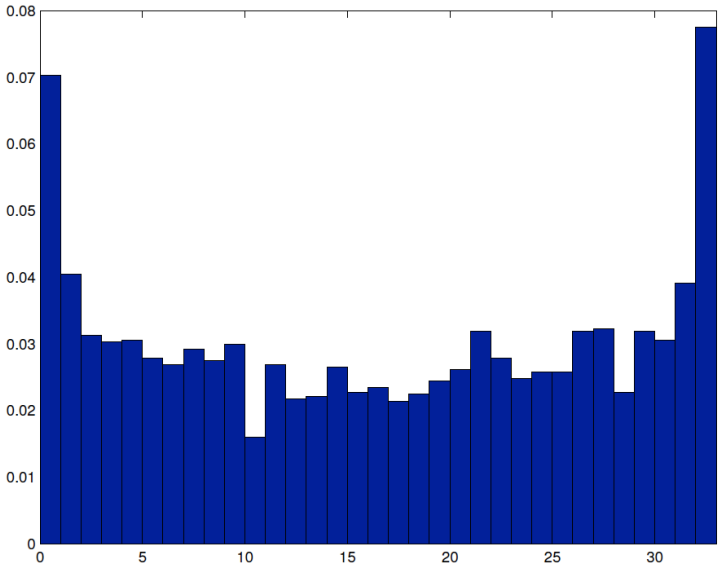
1/4
of obs

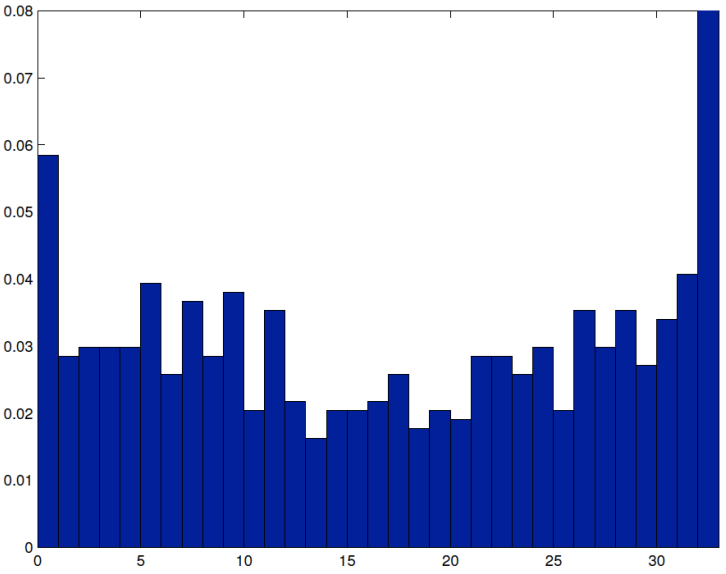




1/16
of obs

1/4 of
obs for
half state





1/4 of
obs from
middle
half state

Conclusions

- Particle filters do not need state covariances.

- Degeneracy is related to number of observations, not to size of the state space.

- Proposal density allows enormous freedom

- Almost-equal-weight scheme is scalable => high-dimensional problems.

- Other efficient schemes are being derived.

- Applications to ECMWF system and HadCM3 climate model