Part II

Butterfly effect and weather forecasting

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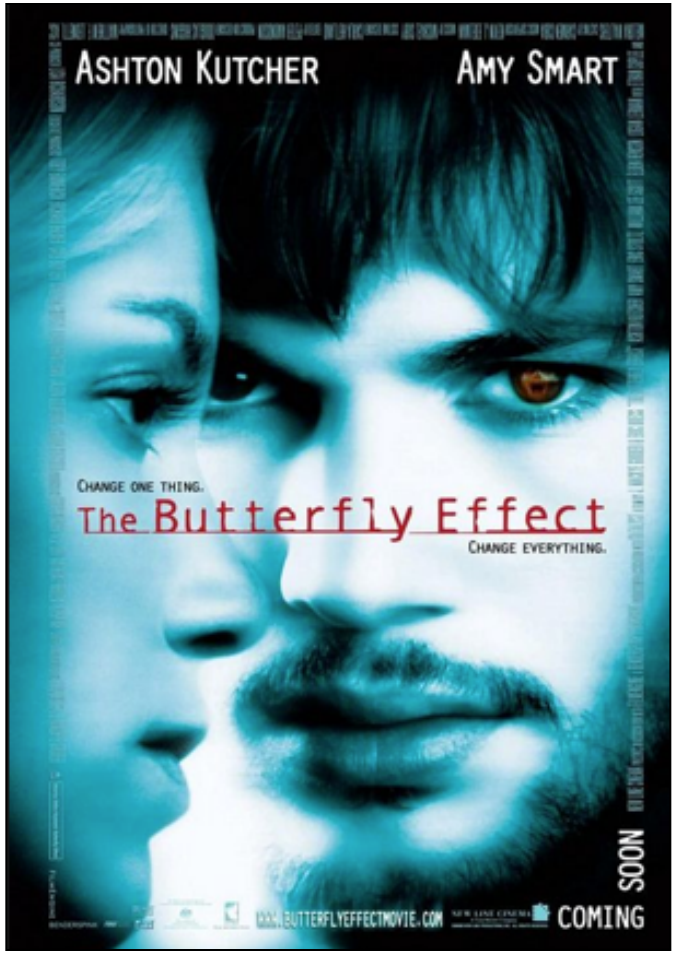
Butterfly effect in popular culture



When a butterfly flaps its wings in one part of the world it can cause a hurricane in another part of the world

http://www.manoneileen.com/2011/03/17/sci-fi-movie-evaluation-the-butterfly-effect/
http://www.technekes.com/blog/category/financial-services-practice

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A metaphor from Edward Lorenz

*One meteorologist remarked that if the theory were correct, one flap of a **seagull's** wings would be enough to alter the course of the weather forever.*

-Lorenz, 1963

*Predictability: Does the Flap of a **Butterfly's** Wings in Brazil set off a Tornado in Texas?*

-Lorenz, 1972

Seagull evolved into the more poetic butterfly

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“Nail effect”: An old poem

http://scottgustafson.com/WN_books_NR7.html

Lessons we learn:

A tiny change can lead to a huge difference in the final results

For want of a nail the shoe was lost,
for want of a shoe the horse was lost;
and for want of a horse the rider was lost;
being overtaken and slain by the enemy,
all for want of care about a horse-shoe nail.

-Benjamin Franklin

Butterfly effect: from the perspective of chaos theory

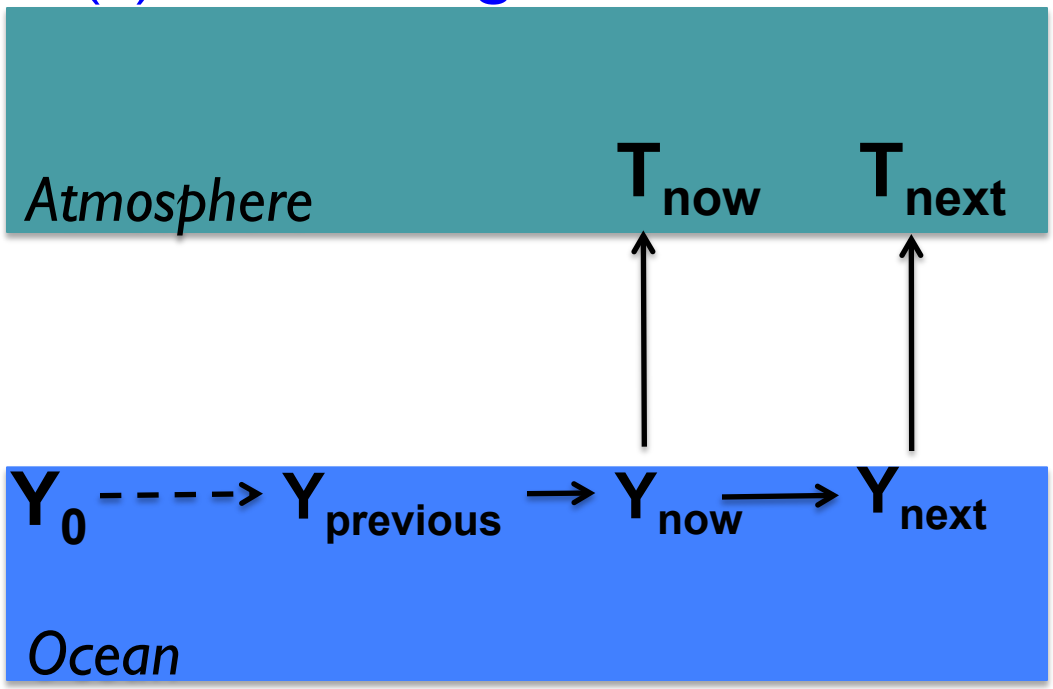
- Sensitivity to the initial conditions
- Every observation has errors
- Propagation of the error through the nonlinear system
- Thus, it's almost impossible to make long time predictions in a nonlinear system

Butterfly effect: An example

How small can you go?

Consider a temperature (F) forecasting model:

$$\begin{cases} Y_0 = 0.33 \\ Y_t = 1.5 \times {Y_{t-1}}^2 - 1 \\ T_t = 30 \times (Y_t + 1) + 60 \end{cases}$$



Butterfly effect: Any pattern?

Can you see any pattern in simulations with different initial conditions?

Consider the simple temperature model again:

Weather forecasting

- Short term forecasting (~12h) is very accurate
- Long term forecasting is impossible.
- But we can predict the probability!

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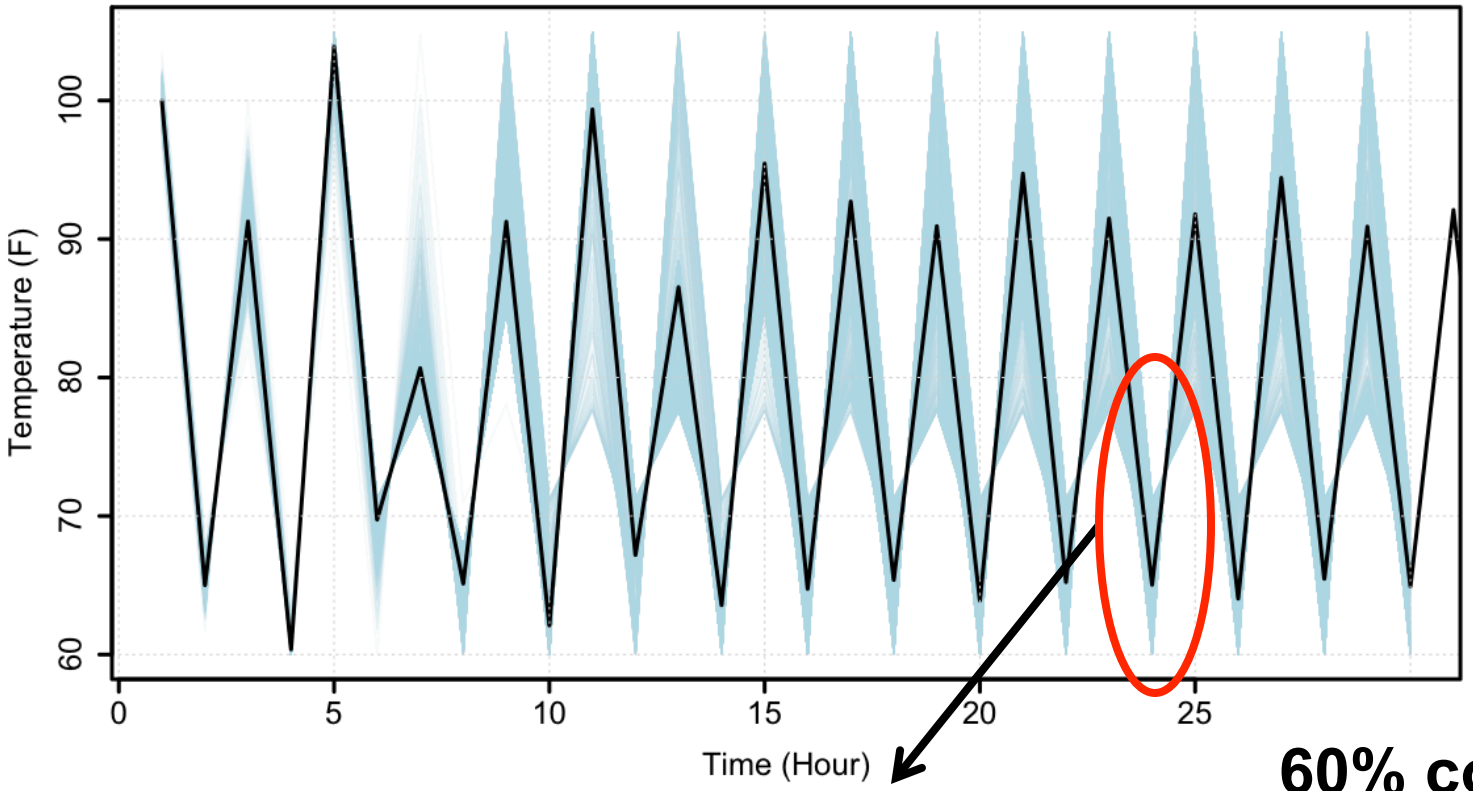
Butterfly effect: Predict the probability

Run the simulation for 1000 times with slightly different initial conditions?

Consider the simple temperature model again:

Butterfly effect: Predict the probability

Time series for 1000 simulations



60% confidence

600 of the 1000 simulations:
Range from 60.9-68.3 F

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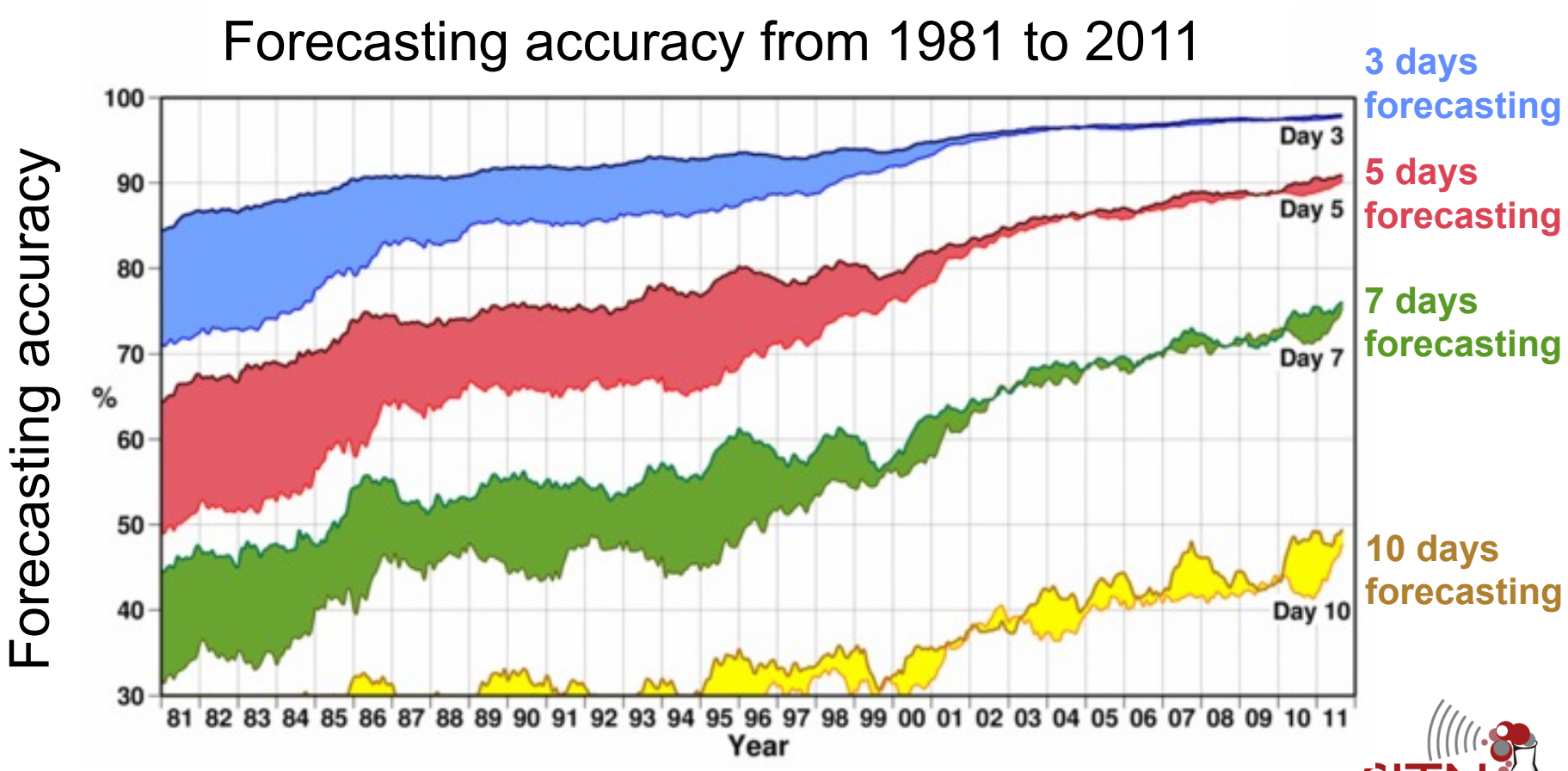
Weather forecasting

- What improves our prediction capabilities?



Summary

- Use and misuse of butterfly effect
- Why long term weather forecasting is impossible
- There is a general pattern/rule/structure in a chaotic system

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