



Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Uncertainty in weather prediction

Where does it come from and what does it look like?

George C. Craig

*Meteorologisches Institut
Fakutät für Physik, LMU München*

Outline

1. A meteorologist's picture of weather
2. Quantitative forecasting
3. Uncertainty and ensembles of forecasts
4. Probabilities and decision making
5. Why we need new ways of looking at data

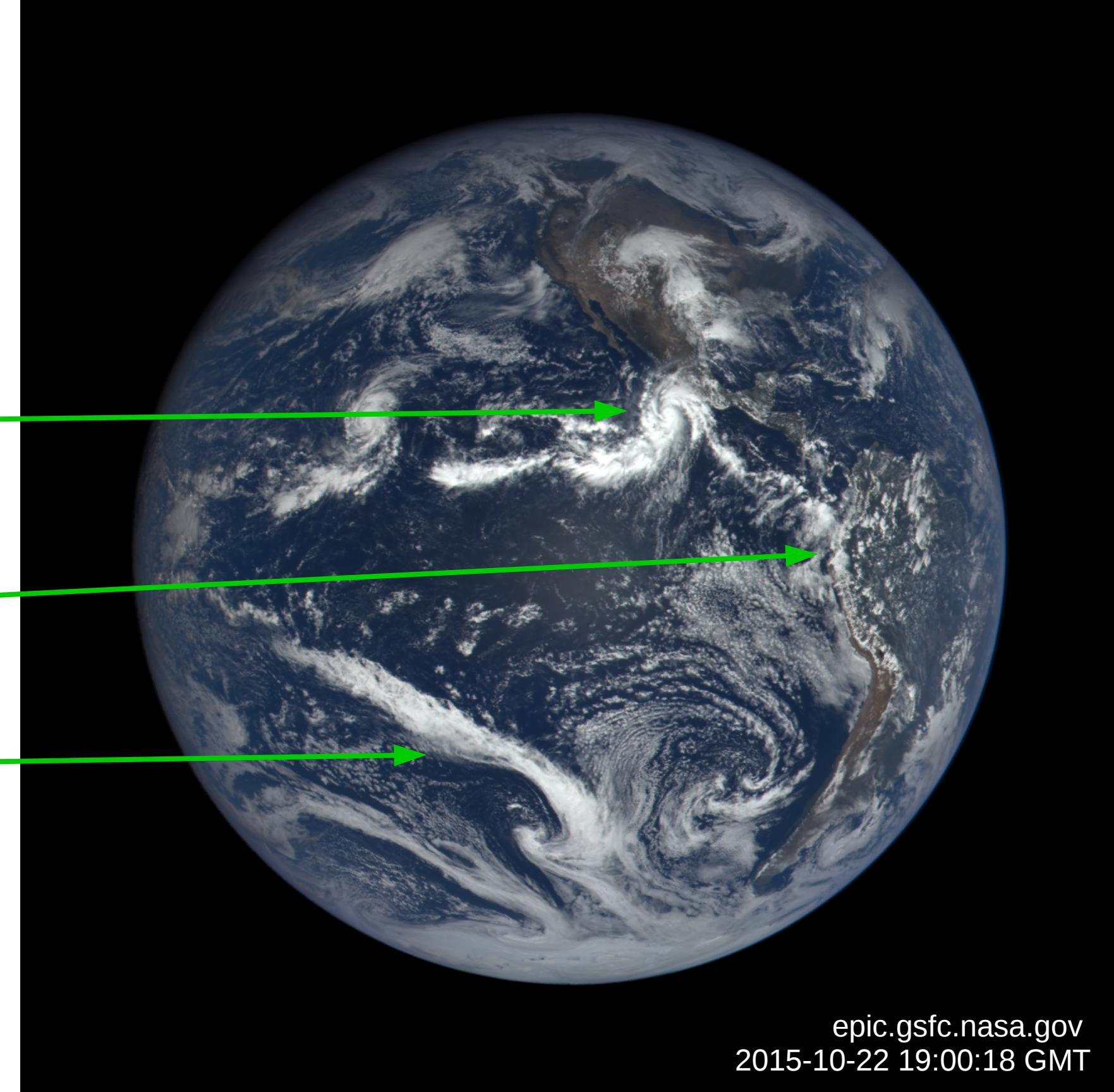
Weather objects

Tropical cyclone Patricia

Thunderstorms

Cold front

Features in space and time



Synoptic Chart

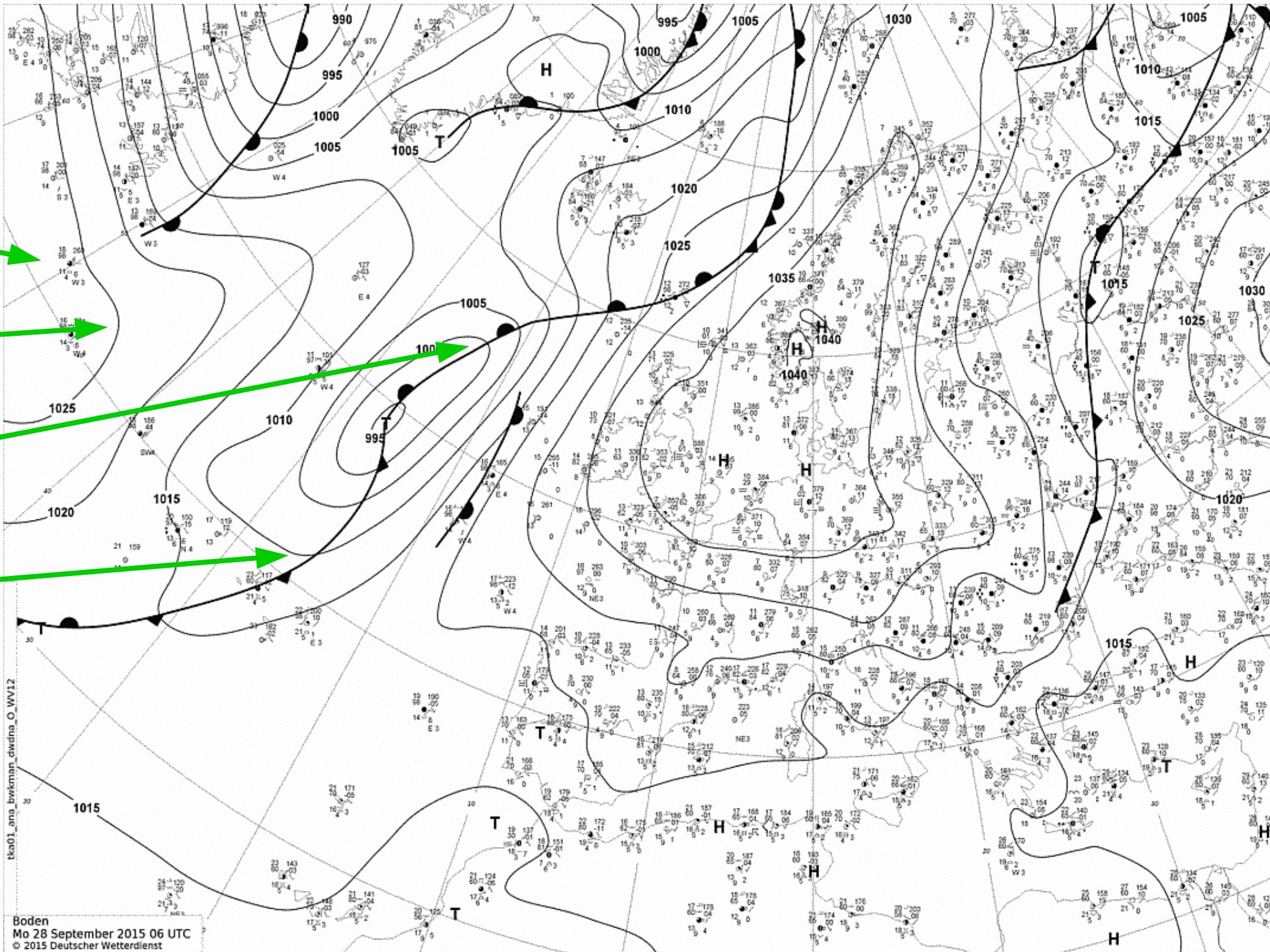
Observations

Isobars

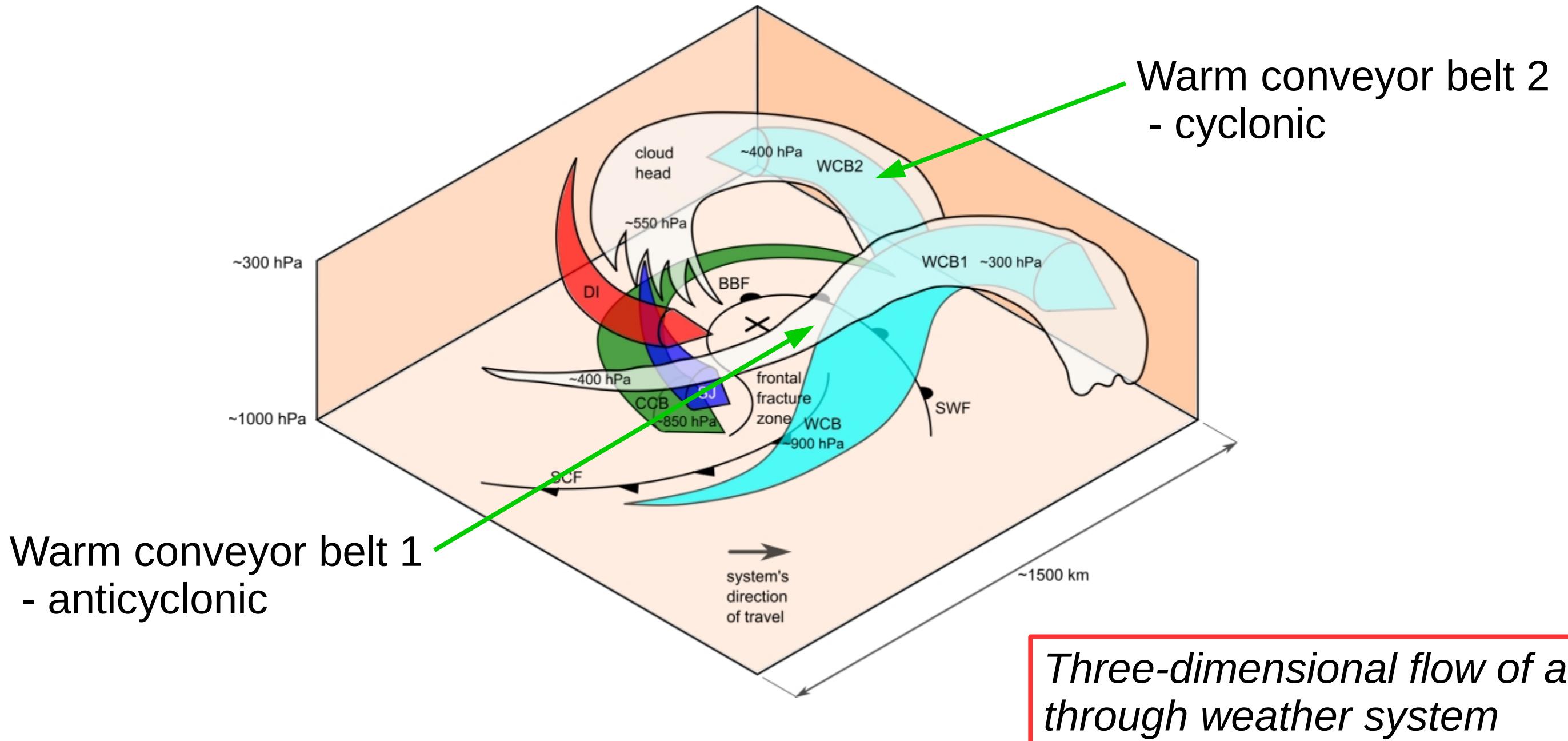
Warm front

Cold front

Conceptual model



A modern conceptual model



Applying the conceptual model

Low pressure center

Cold front

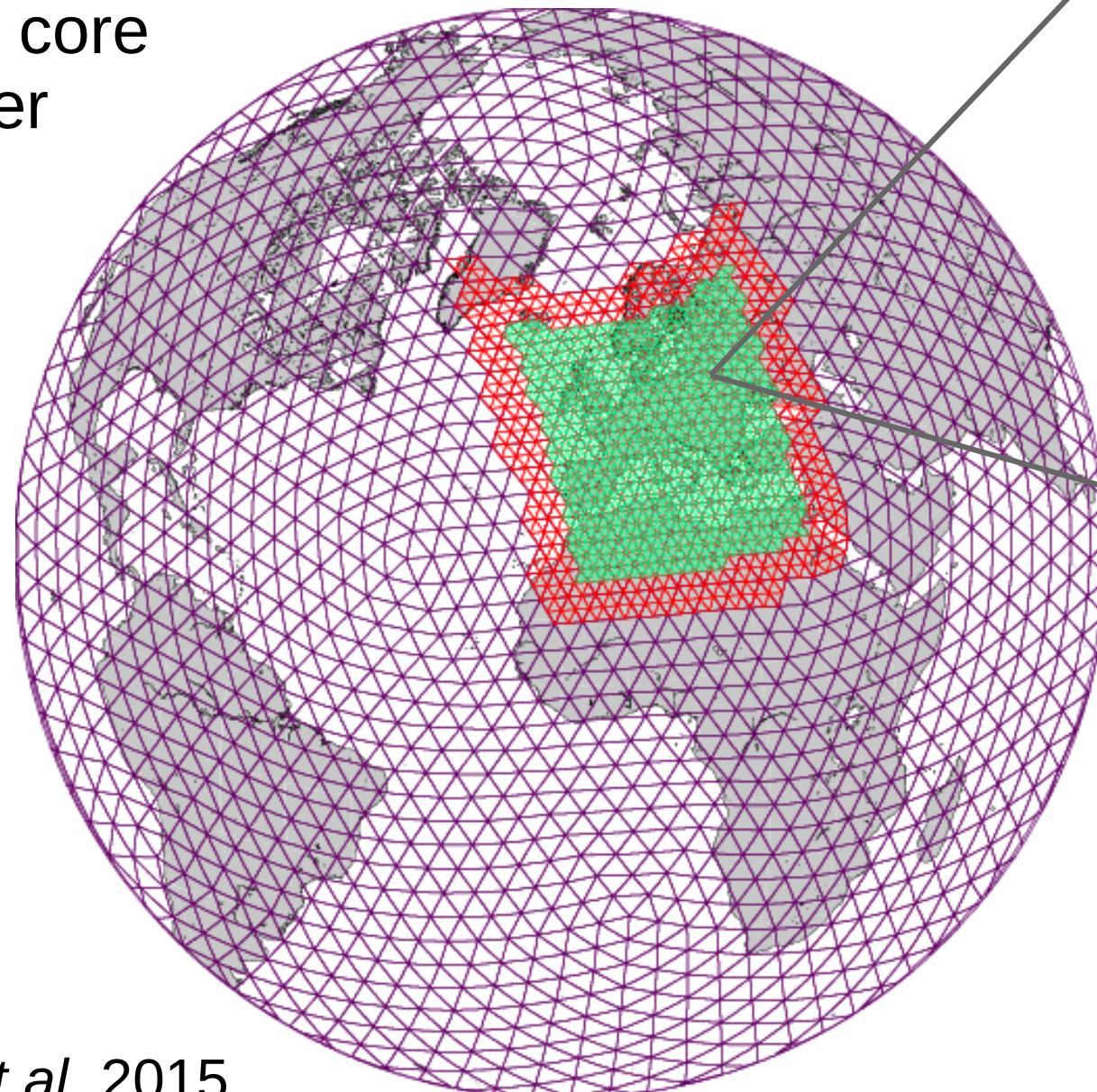
Warm front

Warm conveyor belt outflow

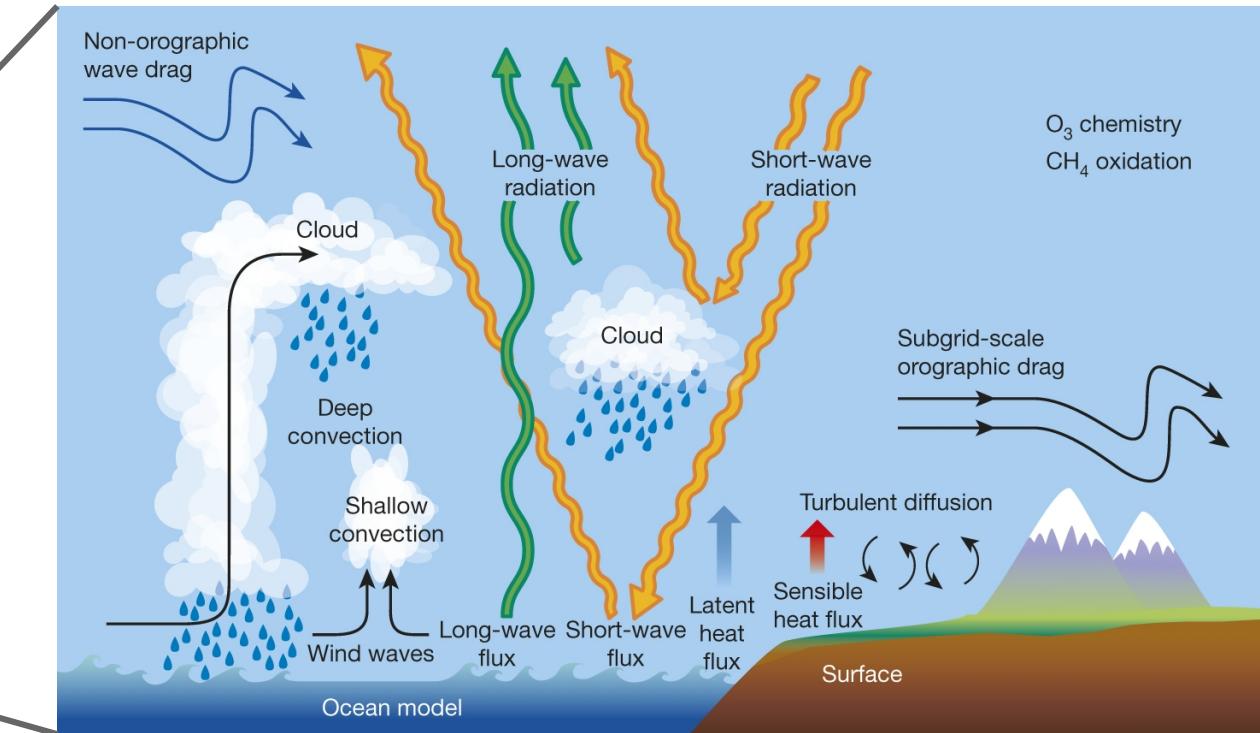
Conceptual models allow us to interpret sparse data

Numerical weather prediction

Dynamical core
- fluid solver



Zängl et al. 2015



Bauer et al. 2015

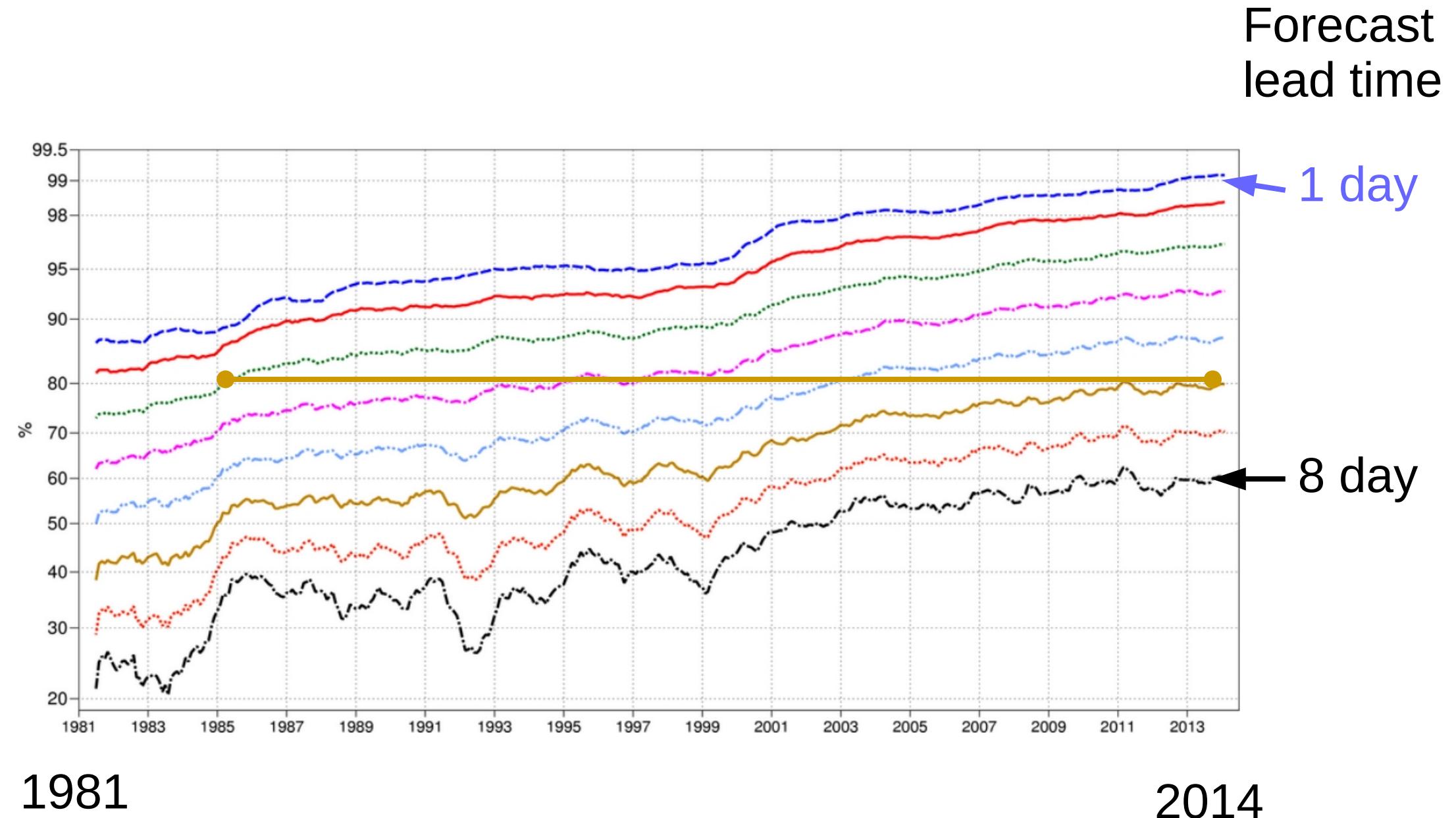
Parameterizations
- additional physical processes

*Complex numerical codes,
based on physical concepts*

Measuring forecast skill

- Root mean square error (here 500 hPa geopotential, NH extratropics)
- Reference forecast - persistence
- Skill score
 - 100% → no error
 - 0% → no better than persistence

*Improvement of
1 day per decade*



A bad forecast!

January 26, 2015

THE HUFFINGTON POST

Edition: U.S. ▾

Search The Huffington Post

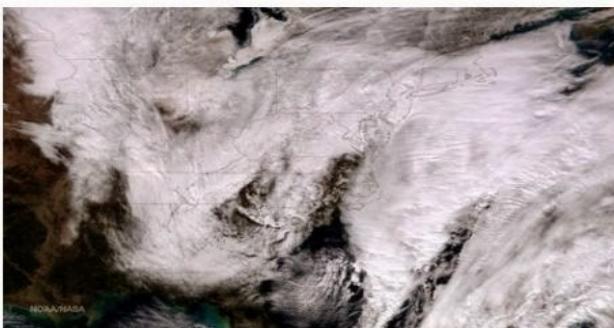
Like 4.7m Follow 3.5M

FRONT PAGE POLITICS BUSINESS ENTERTAINMENT TECH MEDIA WORLDPOST HEALTHY LIVING COMEDY HUFFPOST LIVE ALL SECTIONS

Black Voices • Gay Voices • Sports • Crime • Science • Religion • Celebrity • Green • Style • Horoscopes • Third Metric • OWN • Dr Phil • GPS for the Soul • Davos

WATCH LIVE: Journalist Nicholas Kristof LIVE | Cuff Goldman LIVE COMING UP TUESDAY: Egypt: A New Wave of Dis... Enter email address Subscribe

'TOP-FIVE HISTORIC STORM' ~30 MILLION WARNED DRIVING BAN IN NYC



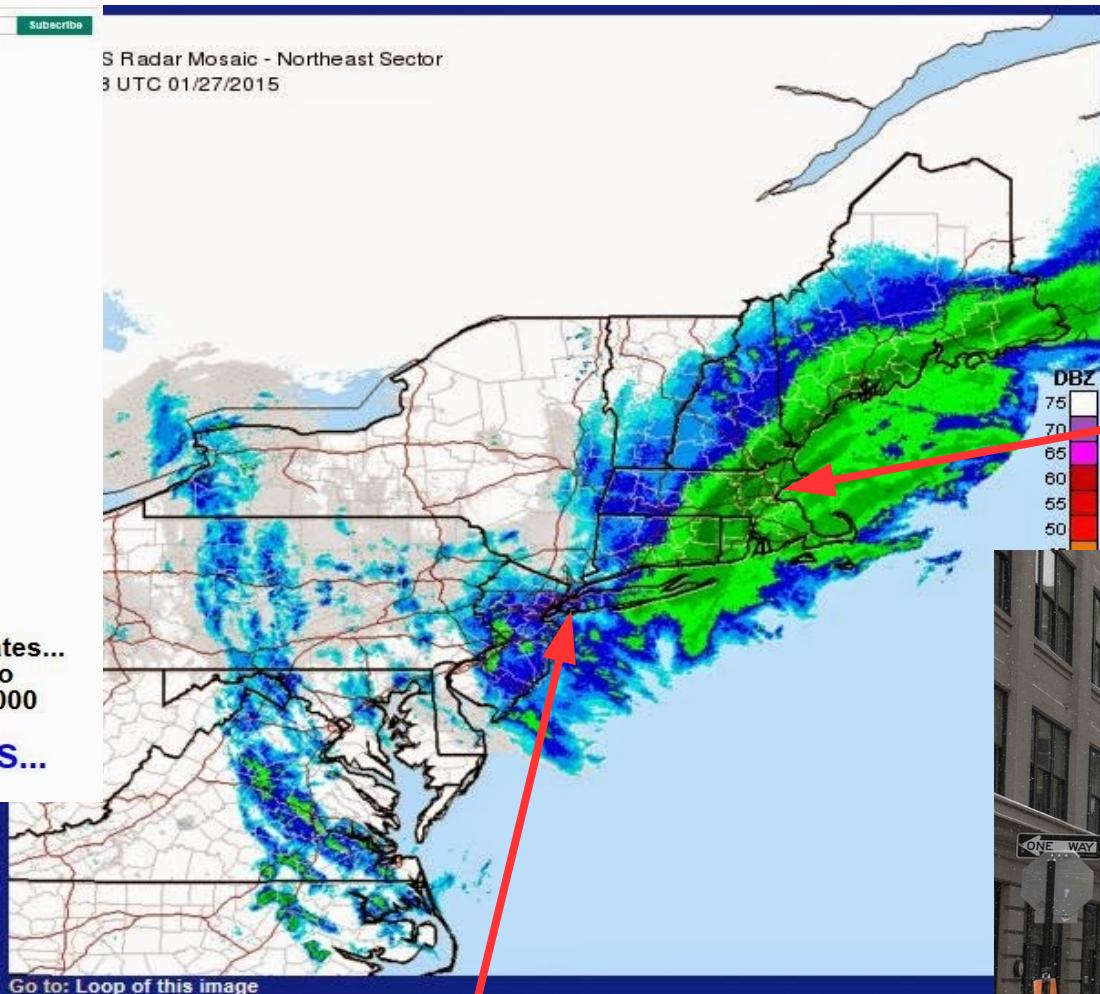
NOAA/NASA

Blizzard Warning For 250-Mile Swath... 2 To 3 Feet Of Snow... 7 States... Region Could Be Shut Down All Week... Residents Scramble To Prepare... NY, NJ, MA, CT Declare State Of Emergency... Over 5,000 Flights Canceled... De Blasio: 'This Is An Emergency...' TRACK STORM... CRISIS MAP... RADAR... HAZARDS...

Comments (426) | Shares (3,173) | Winter

Record winter storm forecast for New York

New York Storm Jan. 27, 2015



Storm missed New York, ...

The Boston Globe

TUESDAY, JANUARY 27, 2015

Healey opposes deal with Partners

AG poised to sue to hospital merger plans

By Priscilla Doyal McCluskey and Michael Abramson GLOBE STAFF

Nearly two weeks ago, General Martin Healey put pressure on a Superior Court judge Monday to accept a proposed financial deal that would allow Partners HealthCare to take over three community hospitals. On Tuesday, a court filing that she would sue to stop the deal if the opportunity arose.

Healey's filing came just a few days after he settled a dispute with his predecessor and former boss, Martha Coakley, and the state's attorney general, which had Coakley's support in rejecting a deal between Partners Hospital in Weymouth and Hallmark Health System's hospital in Braintree, Massachusetts.

Judge Janet L. Sanders is expected to rule on whether to accept the settlement and allow the merger sought by Partners, the largest health care system in the state, to go forward.

"I was very clear to my team we were with this deal. I wanted to be real clear with the court," Healey said in a telephone interview. "My office is prepared to litigate."

Healey's filing comes less than a week after she assumed office.

The storm that rolled in

Atmospheric blend for a behemoth

A satellite image showed the massive scale of the storm bringing snow and high winds to much of the Northeast.

Riding homeless

With beds in short supply, many people are sleeping on the streets. **A6**

The storm that rolled in

... but hit Boston!

... but hit Boston!

Wednesday: Blizzard puts

snow in its wake in the Mid-Atlantic states. Meteorologists say it will be a 'catastrophic' storm for those on the streets. **A6**

Business crunch

The forecast

Tuesday: Heavy, wind-driven snow; high 26-31, low 14-19

Wednesday: Blizzard puts

snow in its wake in the Mid-Atlantic states. Meteorologists say it will be a 'catastrophic' storm for those on the streets. **A6**

Business crunch

The governor called up 500 members of the Massachusetts National Guard to help with damage reports and orders about where to deploy.

Before the storm began

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Brian MacCormac and Leslie Druege GLOBE STAFF

Massachusetts declared Monday for a mammoth storm expected to pummel the state overnight with up to 2 feet of snow, hurricane-force winds and flooding in coastal communities.

The governor declared a state of emergency at noon and banned all but emergency vehicles from state roads beginning at midnight.

Massachusetts drivers avoided parking on major arterials starting at 6 p.m. And the MBTA closed all rail lines, including all bus, commuter rail, and subway lines.

"We are anticipating an historic 'Top 5 snowstorm,'" Baker said. "People are advised to stay at the state emergency bunker in Waltham, and the state's conditions and treacherous roads will make driving anywhere else difficult and dangerous. Please stress this part enough: Please stay home."

The governor called up 500 members of the Massachusetts National Guard to help with damage reports and orders about where to deploy.

Before the storm began

STORM, Page A6

The forecast

Tuesday: Heavy, wind-driven snow; high 26-31, low 14-19

Wednesday: Blizzard puts

snow in its wake in the Mid-Atlantic states. Meteorologists say it will be a 'catastrophic' storm for those on the streets. **A6**

Business crunch

The forecast

Tuesday: Heavy, wind-driven snow; high 26-31, low 14-19

Wednesday: Blizzard puts

snow in its wake in the Mid-Atlantic states. Meteorologists say it will be a 'catastrophic' storm for those on the streets. **A6**

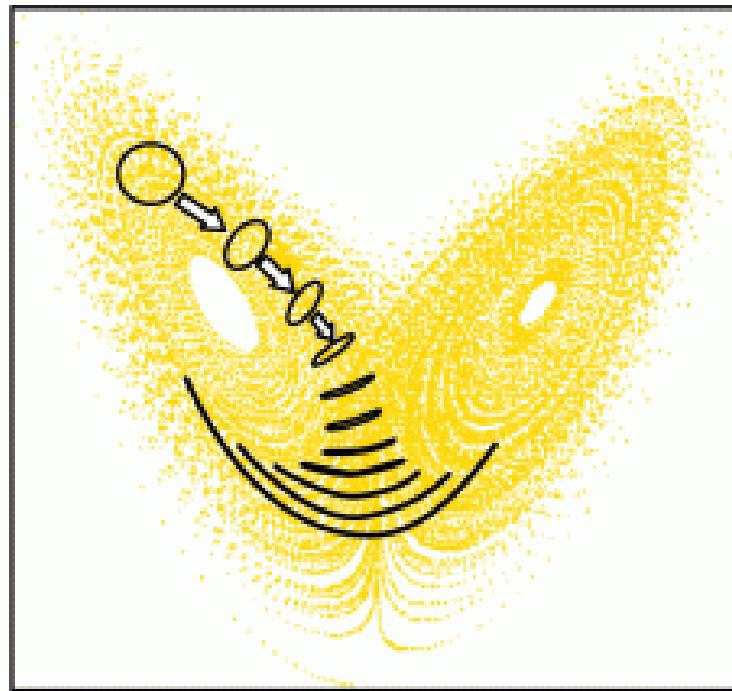
Business crunch



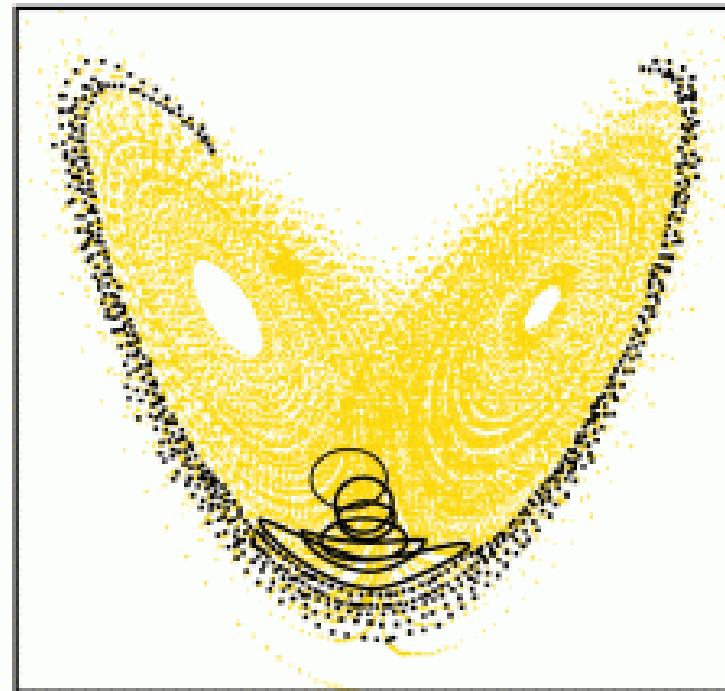
Predictability and chaos

Simple dynamical system with three degrees of freedom
... but nonlinear

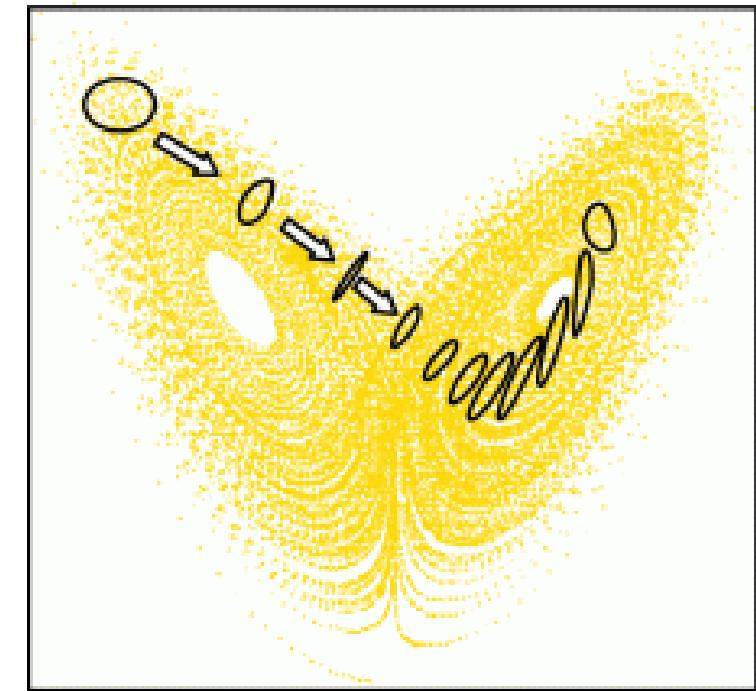
Lorenz (1963)



Uncertainty in initial
conditions grows
rapidly

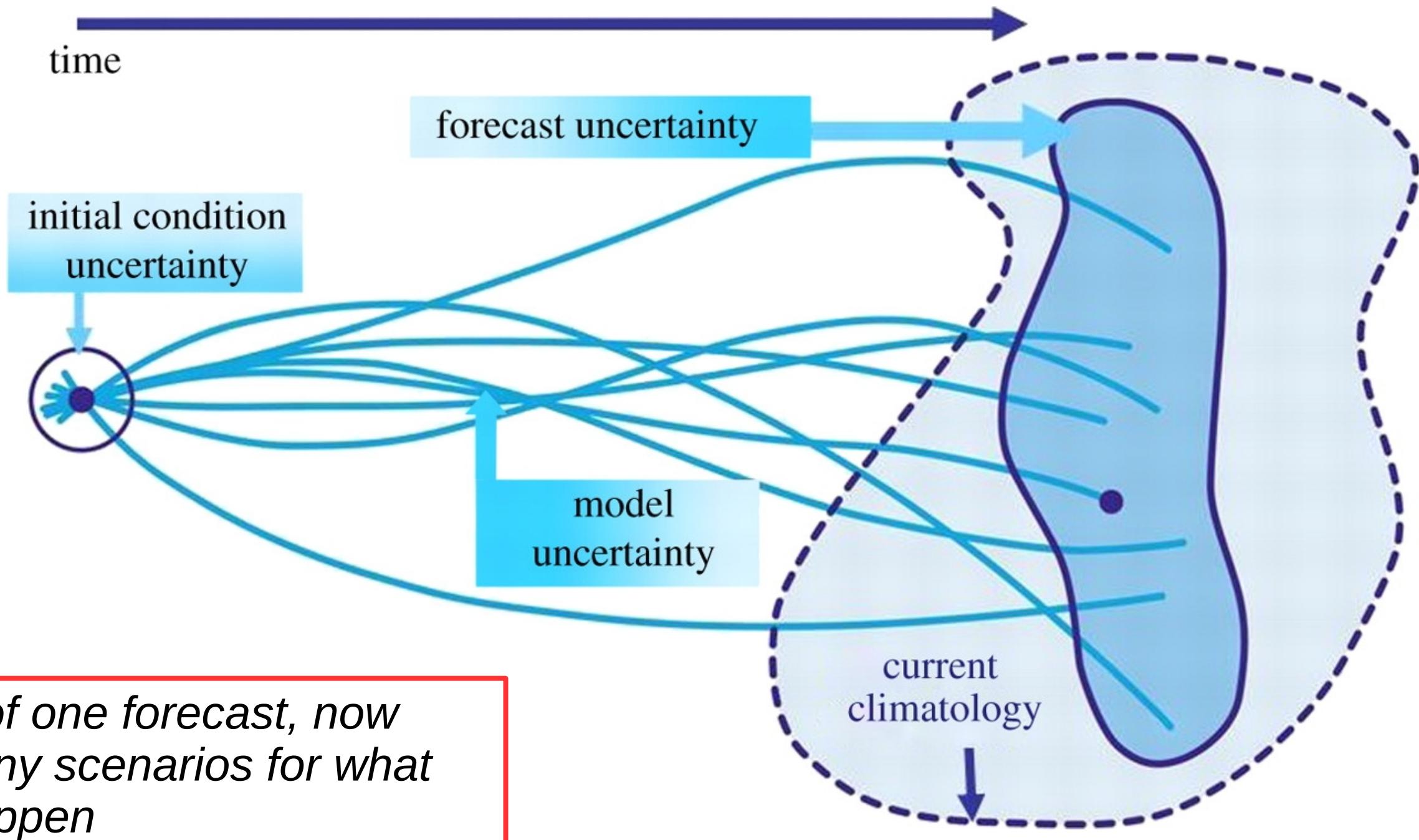


can lead to complete
loss of predictability in
finite time

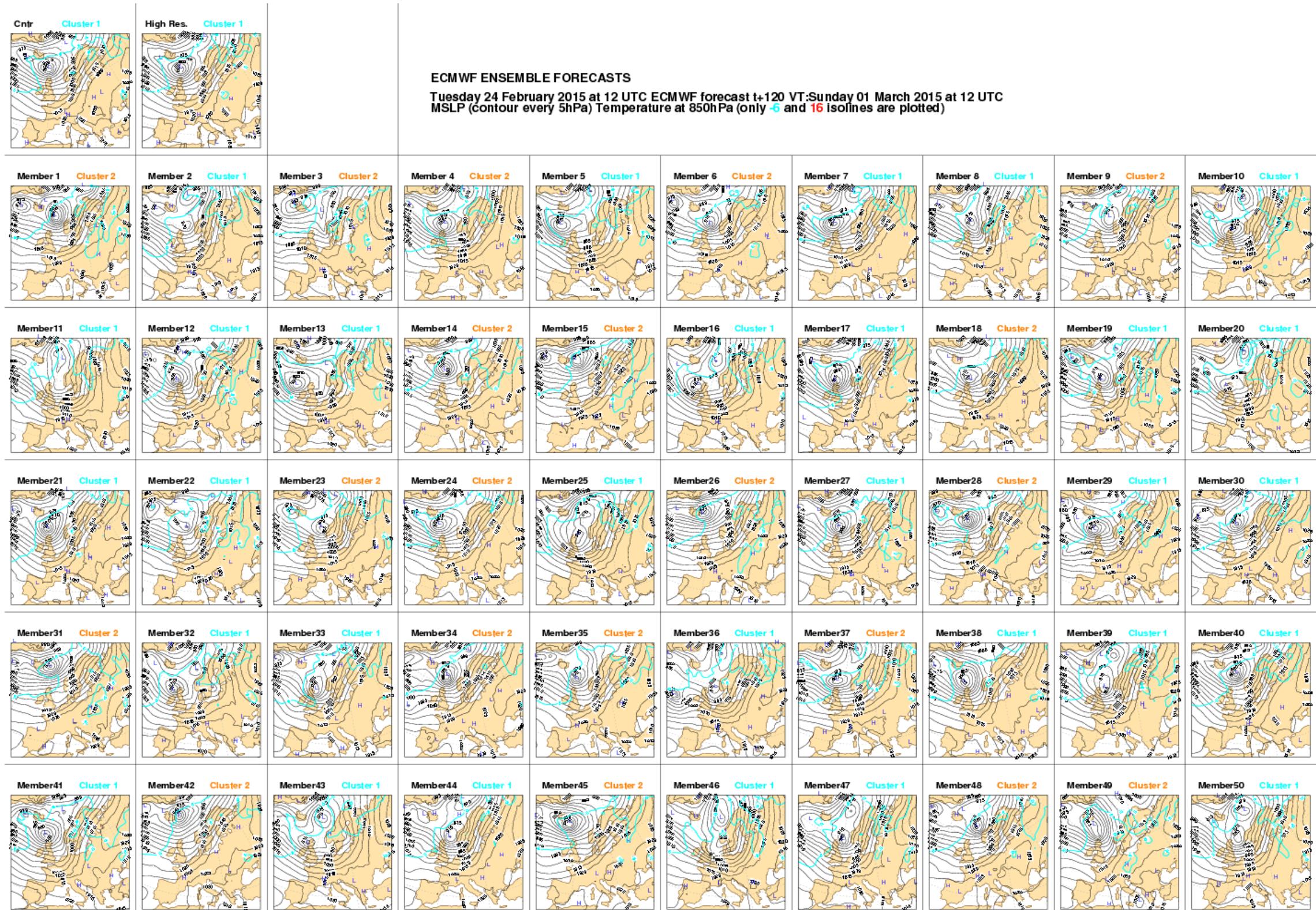


... but not always

Ensemble prediction systems



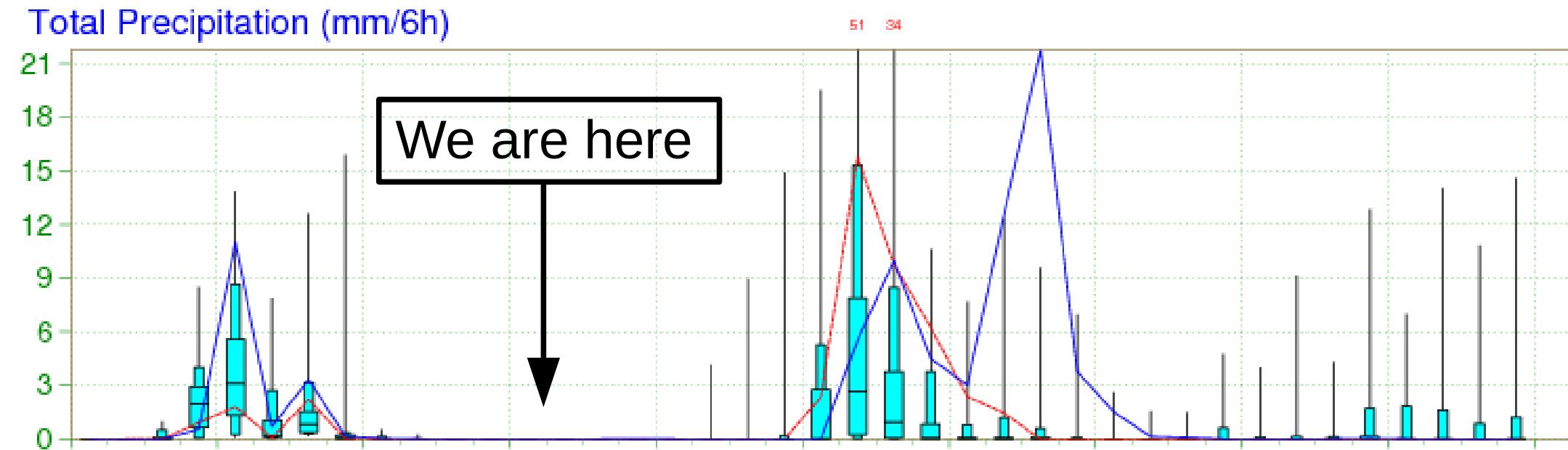
50 forecasts from ECMWF



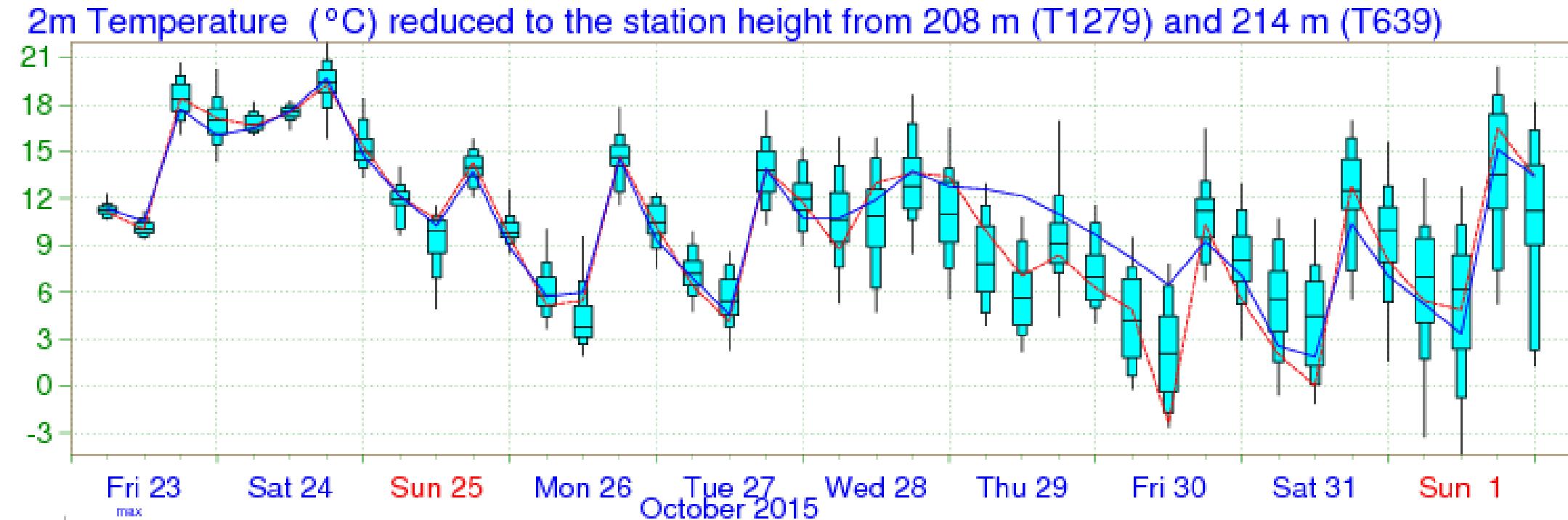
Meteogram

Forecast for Chicago
from Friday

Precipitation
- scenarios



Temperature
- spread increases
with time

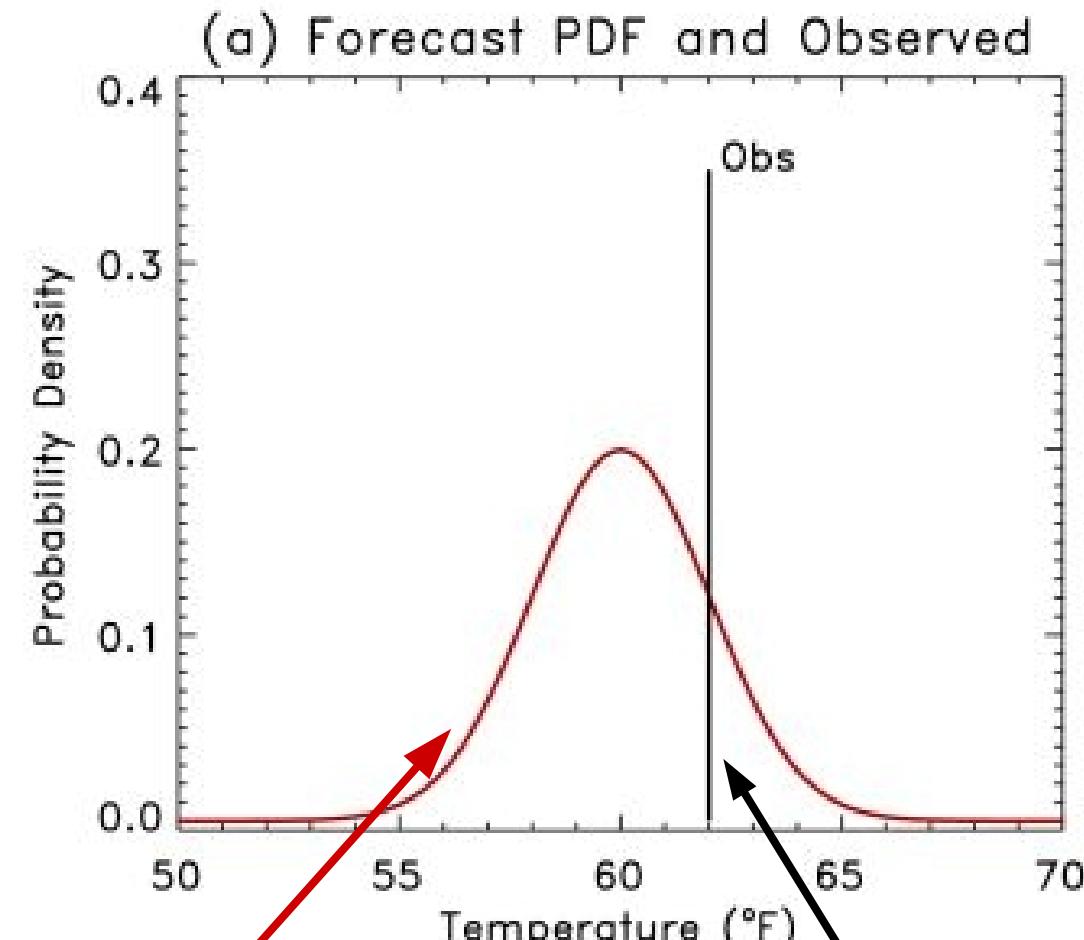


Forecast is the
probability of an
event

What is a good probabilistic forecast?

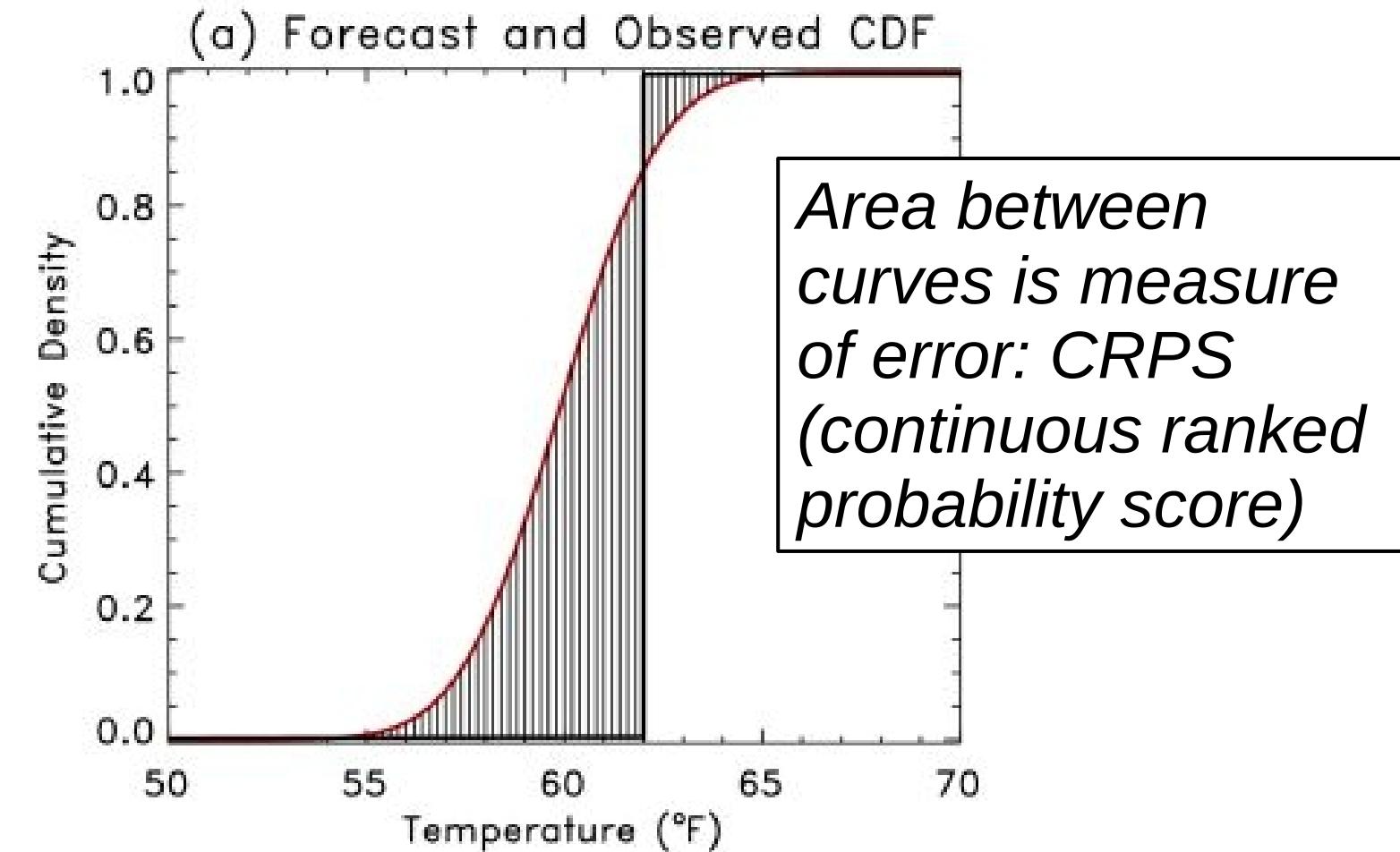
Probability density

Will this temperature occur?



Cumulative density

Will this temperature be exceeded?



Forecast
probability

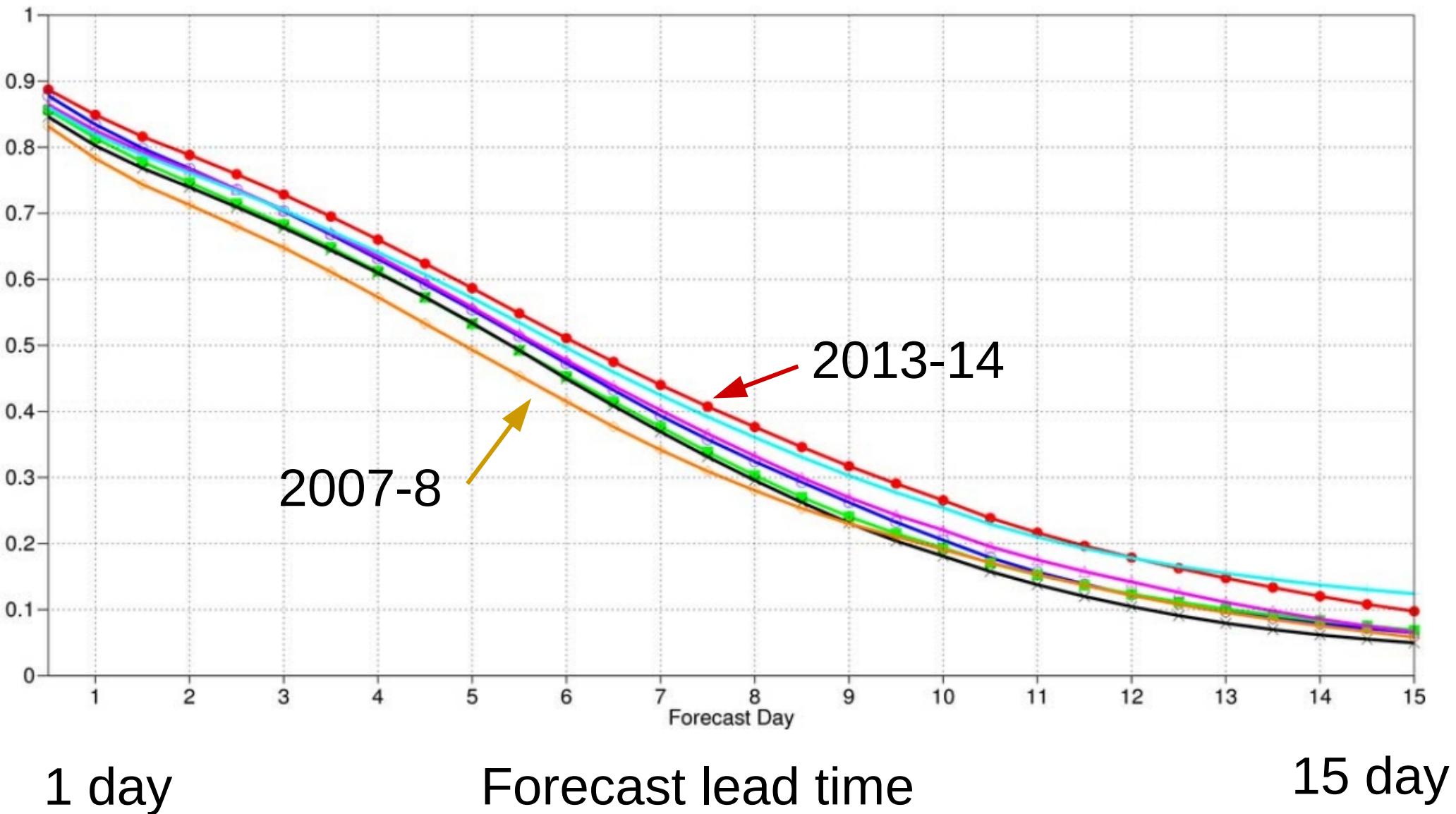
Observation

Forecast errors - too low (*reliability*)
- too vague (*sharpness*)

Measuring probabilistic forecast skill

- CRPS (here 850 hPa temperature, NH extratropics)
- Reference forecast - persistence
- Skill score
 - 1 → no error
 - 0 → no better than persistence

*Rapid improvement
– but is it useful?*



1 day

Forecast lead time

15 day

A toy decision model

A static cost-loss model

- L: Loss due to an adverse event
- C: Cost of an action protecting against the loss. Arises whether or not event occurs
- $C < L$ (or never take action!)

Decision strategy

Take decisions so that expenses are minimized over the long term

Cost-loss ratio determines how to react to a forecast

Expenses:

| | | event occurs | |
|-------------------|-----|--------------|-----|
| | | yes | no |
| Decision is taken | yes | C | C |
| | no | L | 0 |

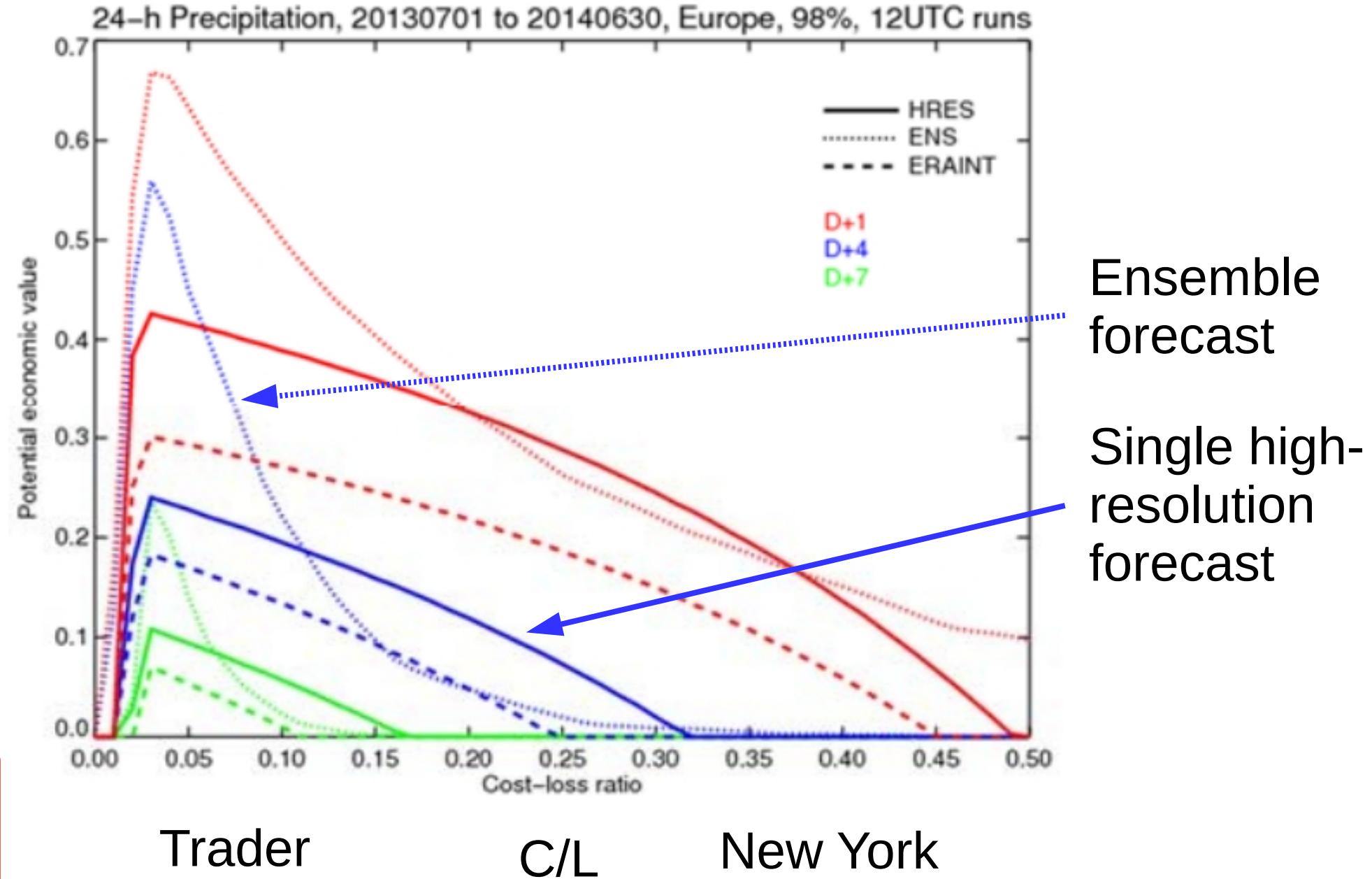
Different users have different cost-loss ratios

- Low C/L, e.g. energy trader
- High C/L, e.g. Mayor of New York

Potential economic value

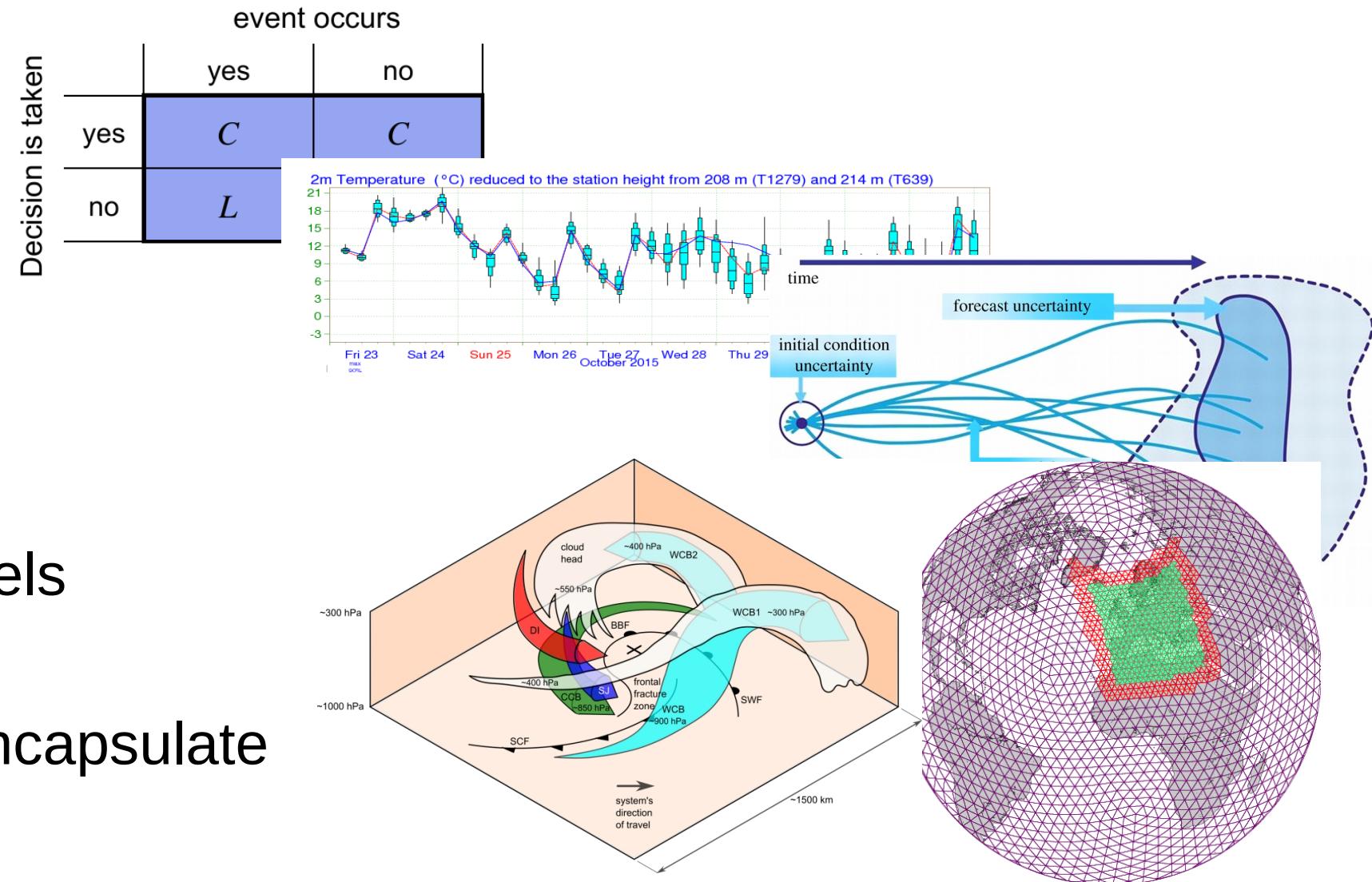
- PEV for extreme precipitation (24 hr accumulation for Europe above 98th percentile)
- Reference forecast - climatology
- Skill score
 - 1 → expenses as low as for perfect forecast
 - 0 → no better than climatology

For some users, a deterministic forecast gives the best probabilities



The need for new ways of looking at data

- Decision making
... *based on*
- Probabilistic forecasts
... *based on*
- Ensembles of scenarios
... *based on*
- Numerical prediction models
... *based on*
- Conceptual models that encapsulate physical understanding



How can we understand probabilistic and ensemble information using physically-based concepts and conceptual models?