Dynamical Core Model Intercomparison Project 2016

Introduction and Welcome

June 6^{th} – 17^{th}, 2016

Organized By

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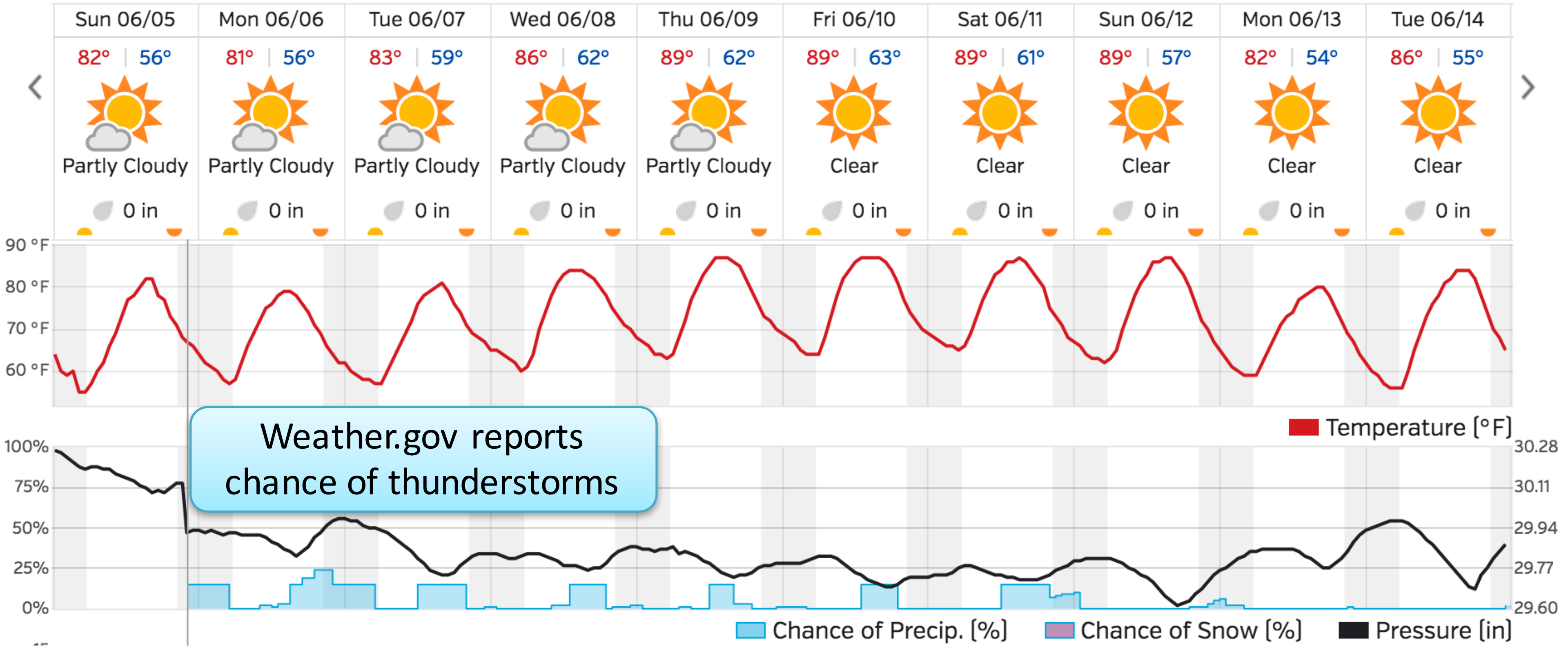
Welcome to Boulder, Colorado

- Boulder lies at 1655m above sea level (5430 feet)
- This week promises to be mostly sunny and dry. The high altitude also tends to lead to more rapid dehydration. If you are going out hiking make sure to bring plenty of water, wear a hat and apply sunscreen.



What is DCMIP?

- The DCMIP2016 summer school and workshop highlights the **newest modeling techniques for climate and weather models**.

- DCMIP2016 emphasizes **non-hydrostatic global models**, physics-dynamics coupling and variable-resolution modeling.

- DCMIP2016 includes:
  - A **morning "summer school"** that incorporates lectures and hands-on sessions for students, postdocs and researchers.
  - An **afternoon "hands-on workshop"** that gives participants the opportunity to work with operational modeling systesm from around the world.
  - An **international dynamical core intercomparison** to quantify difference in modern models.

What is DCMIP?

DCMIP2008: Building a first idealized test case suite for 3D global atmospheric models. Test cases included inertia-gravity waves, baroclinic instability, 3D Rossby-Haurwitz, mountain-induced Rossby gravity wave and solid-body rotation.

DCMIP2012: Focus on non-hydrostatic models. Advanced advection test cases (3D deformational flow, Hadley cell, flow over orography), steady-state orography test, mountain waves, non-hydrostatic gravity waves, baroclinic instability with EPV, idealized tropical cyclone.

What is DCMIP?

DCMIP2016: Focus on non-hydrostatic models, physics-dynamics coupling and variable-resolution modeling systems. Three "core" test cases:

- **Test 1:** Moist baroclinic instabiltiy with "toy" Terminator chemistry
- **Test 2:** Moist tropical cyclone test
- **Test 3:** Moist mesoscale storm test

"Living" Test case document:

https://github.com/ClimateGlobalChange/DCMIP2016

More on this later…

DCMIP2016 Organizers

Paul Ullrich

Kevin Reed

James Kent

Christiane Jablonowski

Peter Lauritzen

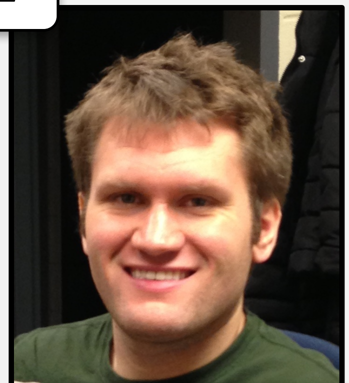
Ram Nair

Colin Zarzycki

DCMIP2016 Model Mentors

HOMME-NH/CAM-SE

David Hall



Colin Zarzycki

NEPTUNE

Kevin Viner

Alex Reinecke

UZIM (CSU)

David Randall

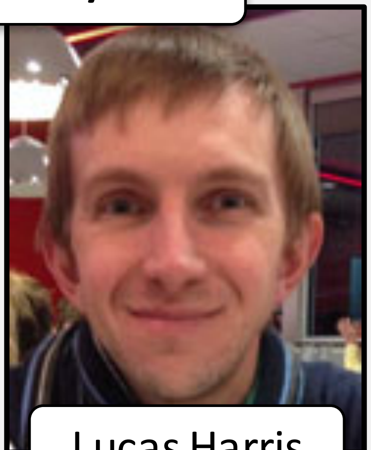
Don Dazlich

Celal Konor

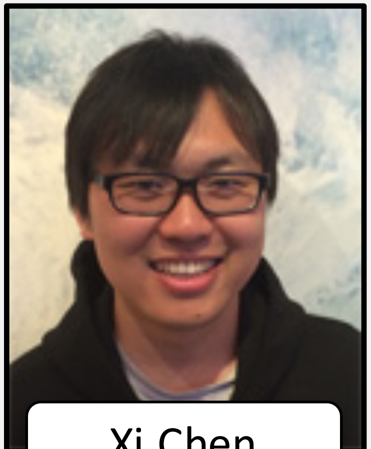
Ross Heikes

DCMIP2016 Model Mentors

GFDL/FV3



Lucas Harris



Xi Chen

ICON

Daniel Reinert

Marco Giorgetta

IFS/FVM (ECMWF)

Christian Kuehnlein

OLAM

Bob Walko

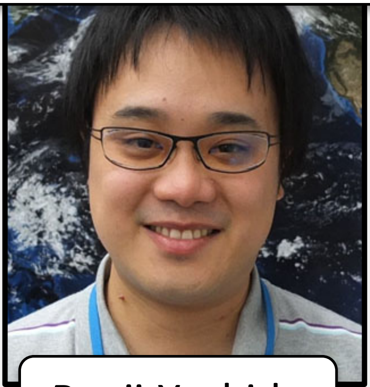
GEM

Vivian Lee

Abdessamad Qaddouri

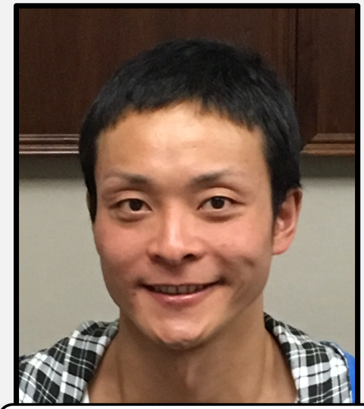
DCMIP2016 Model Mentors

NICAM



Ryuji Yoshida

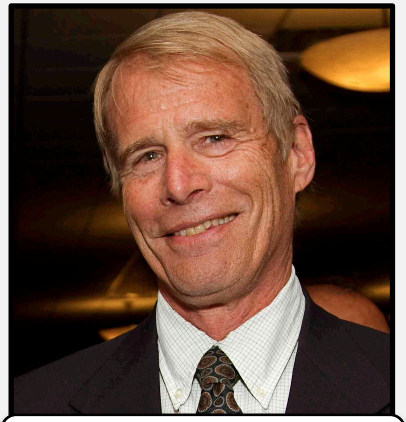
Hiroaki Miura



Tomoki Ohno

MPAS

William Skamarock



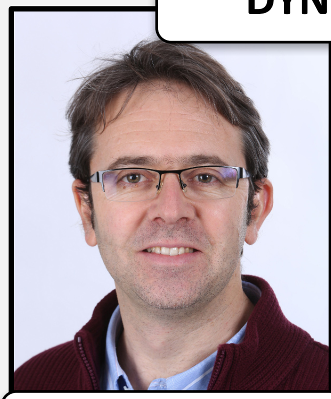
Joseph Klemp

Sang-Hun Park

Michael Duda

DCMIP2016 Model Mentors
(Intercomparison Only)

DYNAMICO



Thomas Dubos

Yann Meurdesoif

TEMPEST

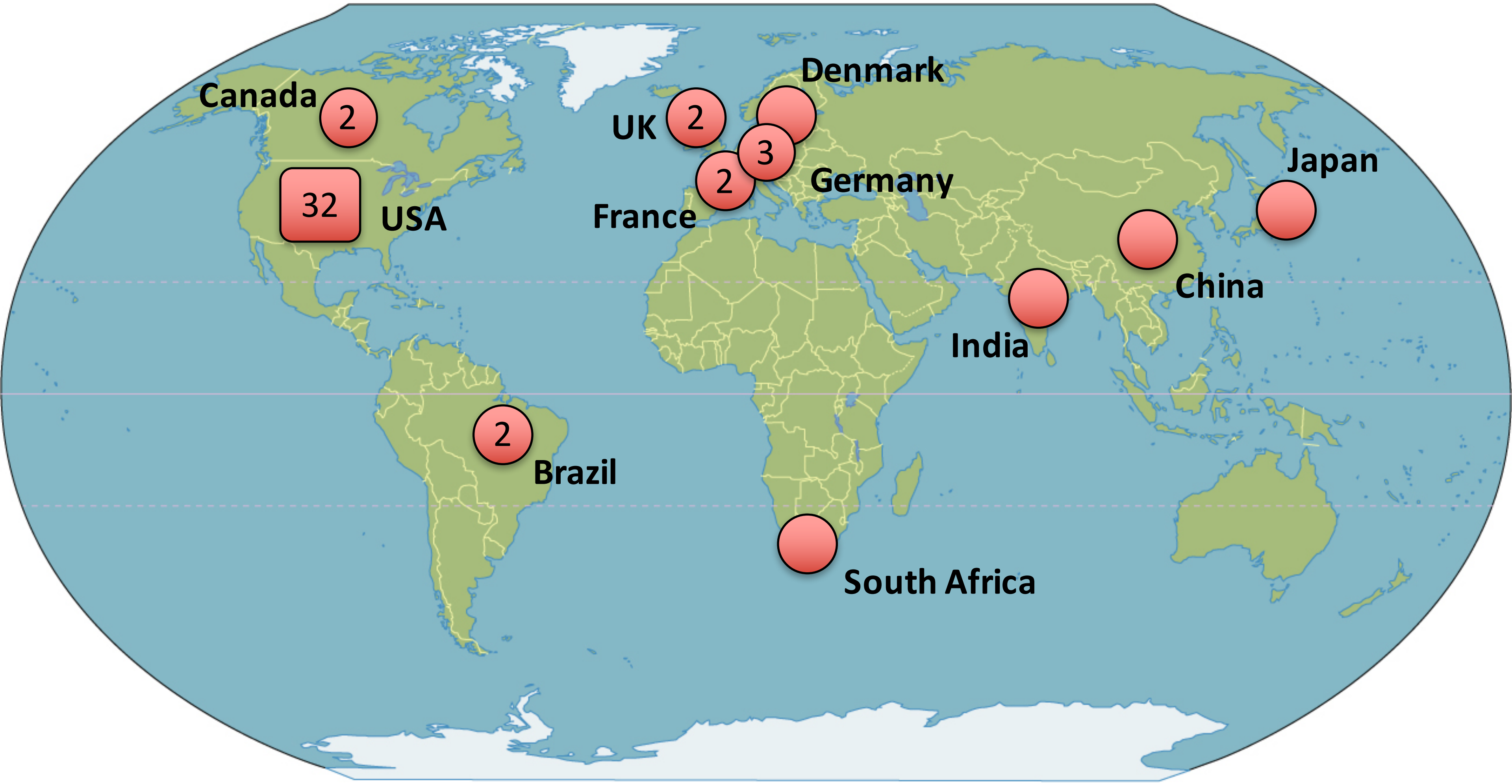
Paul Ullrich

ENDGame

Thomas Melvin

DCMIP Participants (48 Total)

Countries with representation at DCMIP2016



DCMIP Sponsors

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NCAR

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NOAA
U.S. DEPARTMENT OF COMMERCE

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Special thanks to…

Our NCAR Hosts

- Richard Loft (Director of NCAR CISL's Technology Development Division)
- Cecilia Banner (NCAR CISL Administrator)
- Dave Hart (NCAR CISL User Services Manager)
- Michelle Smart and the NCAR CISL data base services team
- Eric Nienhouse (NCAR, Software Applications)
- Siddhartha Ghosh, Rory Kelly and Patrick Nichols (NCAR)
- Kristine Grosland (CU Boulder Housing Coordinator)
- Cheri Johnson (University of Michigan Administrator)
- Gina Skyberg (University of California Davis Administrator)

Logistics: How does this work?

Daily Agenda (Days 1-9)

8:00am	Bus pickup at CU Dorms
8:30am – 9:30am	Lecture 1
9:30am – 10:30am	Lecture 2
10:30am – 11:00am	Break
11:00am – 12:00pm	Lecture 3
12:00pm – 12:20pm	Model mentor presentation 1
12:20pm – 12:40pm	Model mentor presentation 2
12:40pm – 1:40pm	Lunch
1:40pm – 3:00pm	Workshop
3:00pm – 3:30pm	Afternoon science session
3:30pm – 3:45pm	Discussion and break
3:45pm – 5:00pm	Workshop
5:15pm	Bus pickup at CG

Daily Themes

Day 1	*Earth System Modeling and the Role of the Atmospheric Component Model*
Day 2	*Numerical Methods in Dynamical Cores*
Day 3	*High-Resolution Atmospheric Modeling*
Day 4	*Tracers in Atmospheric Models*
Day 5	*Physical Parameterizations*
Day 6	*Dynamics-Physics Coupling*
Day 7	*Evaluating Global Atmospheric Models*
Day 8	*Emerging computational aspects*
Day 9	*Informing the science*
Day 10	*Dynamical Core Model Intercomparison, what did we learn?*

DCMIP2016 Model Presentations…

Tuesday, June 7th
12:00pm **NICAM**
12:20pm **GFDL/FV3**

Wednesday, June 8th
12:00pm **NEPTUNE**
12:20pm **GEM**

Thursday, June 9th
12:00pm **HOMME**
12:20pm **TEMPEST**

Friday, June 10th
12:00pm **DYNAMICO**
12:20pm **FV-IFS / ECMWF**

Monday, June 13th
12:00pm **CSU**
12:20pm **MPAS**

Tuesday, June 14th
12:00pm **OLAM**
12:20pm **ICON**

Wednesday, June 15th
12:00pm **Chombo**
12:20pm **ENDGame**

Total: 14 Models

More information on the workshop and summer school after the break.

In the mean time...

A Brief History of Atmospheric Modeling

Ancient Times

- Before the invention of modern meteorological devices, weather prediction techniques were limited to sky observations.

> "When evening comes, you say,
> 'It will be fair weather: for the sky is red.'
> And in the morning,
> 'Today it will be stormy, for the sky is red and overcast.' "
>
> *Matthew 16:2-3*

- Other weather "lore" was discovered, of course.

> *Seagull, seagull sit on the sand.*
> *It's never good weather when you're on the land.*

The 1600s

1643

Evangelista Torricelli invents the **barometer**, able to measure the pressure of the air.

He observed that the pressure of the air is highly correlated with the weather.

For example, he observed that a drop in air pressure often signaled a coming storm.

1664

Francesco Folli invents the first "practical" **hygrometer**, capable of determining the humidity of the air.

Evangelista Torricelli

The 1700s

1709 German physicist and engineer Daniel Gabriel Fahrenheit develops the **alcohol thermometer**, and later the mercury thermometer.

(Surprise!) He's also responsible for the Farenheit scale, which he proposed in 1724.

Daniel Gabriel Farenheit

1765 French chemist Antoine-Laurent de Lavoisier begins making daily measurements of **air pressure**, **moisture content**, **wind speed** and **direction**.

> "It is almost possible to predict one or two days in advance, within a rather broad range of probability, what the weather is going to be; it is even thought that it will not be impossible to publish daily forecasts, which would be very useful to society."
>
> *- Antoine-Laurent de Lavoisier*

The 1700s

Antoine-Laurent de Lavoisier was also responsible for several other notable discoveries:

- He stated the first version of the law of conservation of mass.
- He was involved with the invention of the metric system.
- He wrote the first exhaustive list of chemical elements and was involved heavily in discoveries that led to the development of modern chemistry.

Antoine-Laurent de Lavoisier: "The father of modern chemistry."

The 1800s

1837

With the invention of the electric telegraph at last there was a mechanism for communicating weather conditions over a vast geographical area.

1849

Under the leadership of Joseph Henry, the Smithsonian began to establish an observation network across the US.

However, the idea of a national system for predicting the weather was slow to take off in both Europe and America

Joseph Henry

The 1800s

1854

The advent of modern meteorology started with a disaster…

In 1854, a French warship and 38 merchant vessels sank in a violent storm in the northwest of the Black Sea.

The director of the Paris Observatory, Urbain Le Verrier, was directed to investigate…

He discovered that the storm had formed two days earlier in the southeast. If a tracking system had been in place, it could have given prior warning to the ships.

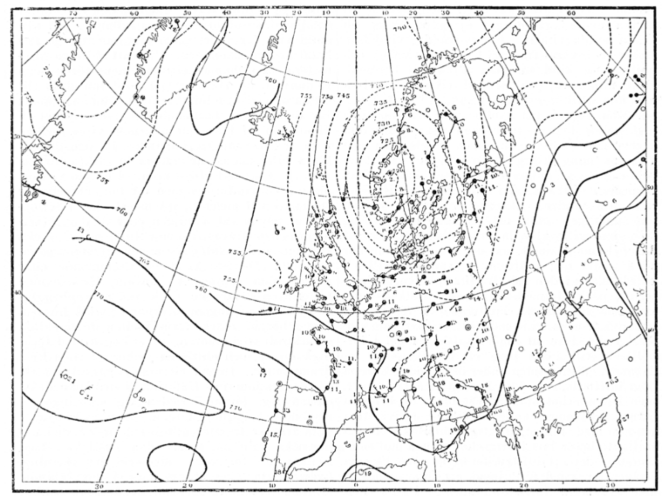
Urbain Le Verrier

The 1800s

1855 A year later, a national storm warning service was established in France.

1860 Robert FitzRoy uses the new telegraph system to produce the first synoptic charts in England. He coins the term “weather forecast” and publishes the first ever forecasts of this type.

1873 The International Meteorological Organization is formed in Vienna.



Väderlekskarta på morgonen den 22 oktober 1874.

Early synoptic chart.

The US Army Signal Corp, forerunner to the National Weather Service, issues its first hurrican warning.

Early 1900s

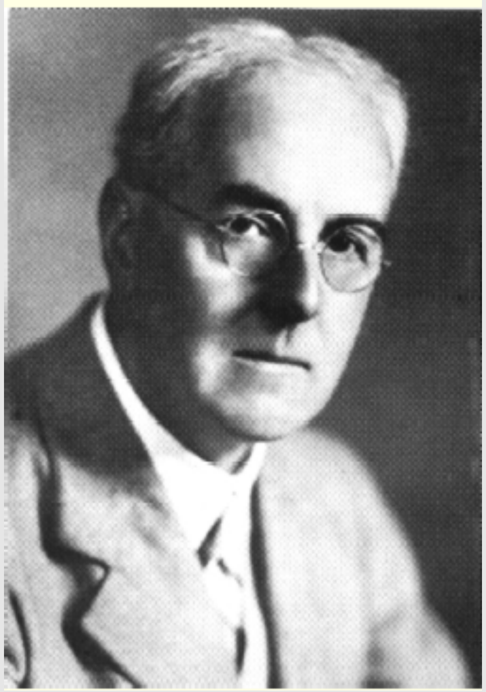
Well into the 1900s meteorologists constructed their forecasts exclusively via historical weather patterns.

1916

Norwegian meteorologist Vilhelm Bjerknes introduces the first set of equations of motion for the atmosphere using the theory of fluids.

1922

Enter: British meteorologist Lewis Fry Richardson. His work *Weather Prediction by Numerical Process* was published in 1922, proposing a mathematical technique for systematic forecasting.

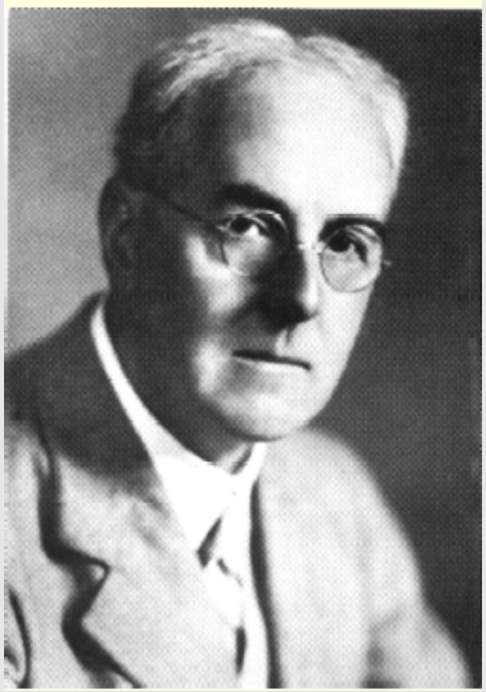


Lewis Fry Richardson

Early 1900s: Lewis Fry Richardson

Richardson made the first attempt at mathematically (using primitive numerical methods) to forecast the weather during a single day – 20 May 1910, using initial data at 7am to predict the next six hours.

This calculation took roughly 3 months to complete, and predicted a huge rise in pressure (145 mbars)…



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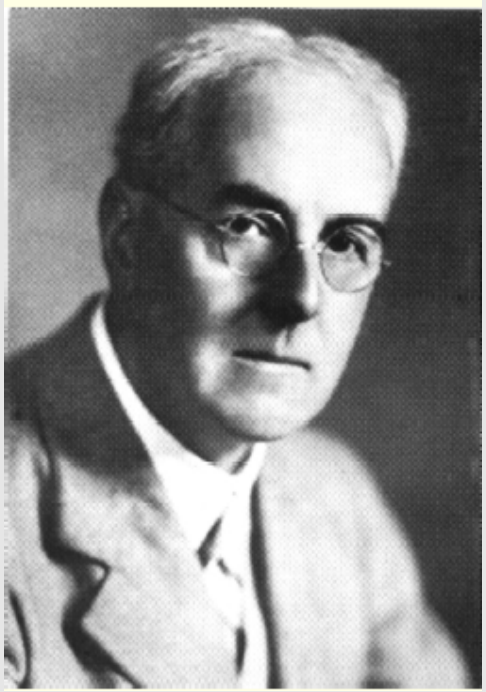
However, observations showed that pressure remained more or less static…



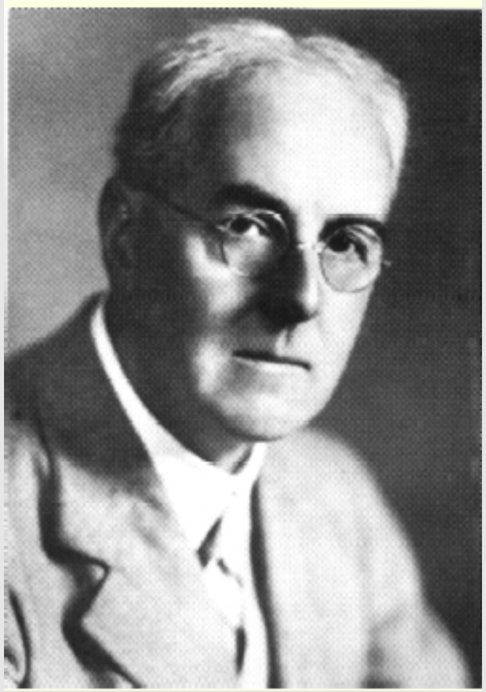
Lewis Fry Richardson

Early 1900s: Lewis Fry Richardson

Consequently, his calculation was considered a "dramatic failure."

A detailed analysis tracked the problem to a failure to use smoothing (essentially he was using an unstable numerical technique that seemed reasonable at the time).

…After making appropriate corrections, his forecast was essentially accurate!



Lewis Fry Richardson

Early 1900s: Lewis Fry Richardson

"After so much hard reasoning, may one play with a fantasy? Imagine a large hall like a theatre, except that the circles and galleries go right round through the space usually occupied by the stage. The walls of this chamber are painted to form a map of the globe. The ceiling represents the north polar regions, England is in the gallery, the tropics in the upper circle, Australia on the dress circle and the Antarctic in the pit.

A myriad computers are at work upon the weather of the part of the map where each sits, but each computer attends only to one equation or part of an equation."

Keep in mind that when Richardson described "computers" he referred to actual people performing computations by hand.

Mid 1900s: Advent of Computation

Richardson's formulas were so complicated that, on working them out by hand, nobody could predict the weather in time.

1940s

John von Neumann is successful in computing the behavior of explosions using numerical methods. Seeing the parallels with numerical weather prediction, he advocates for using computers to model the atmosphere.

John von Neumann

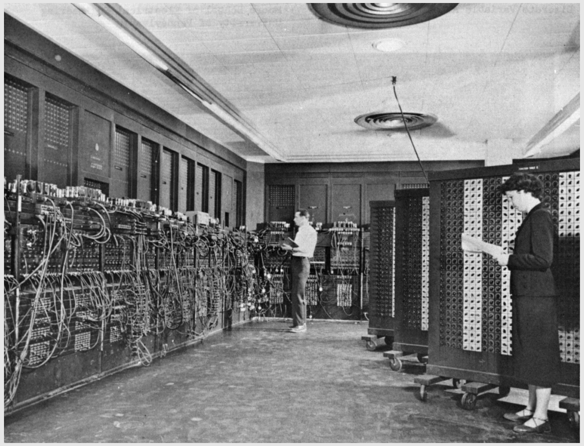
Mid 1900s: Advent of Computation

1950

Von Neumann recruits **Jule Gregory Charney** (from Carl-Gustaf Rossby's lab at the University of Chicago) to develop a numerical framework for weather prediction. The first successful experiment finally came about in 1950 (at Princeton, on the ENIAC computer).

1954

The first real-time numerical weather prediction experiments are performed by the Royal Swedish Air Force Weather Service.



ENIAC

Mid 1900s: The First Global Models

1955

The first atmospheric **general circulation model (GCM)** is developed by **Norman Phillips**, Princeton University. His computer held 5 kilobytes of memory plus 10 kilobytes of data storage, and successfully modeled a two-layer atmosphere on a **cylinder** 17 cells high and 16 cells in circumference.

1958 → 1965

Joseph Smagorinsky (US Weather Bureau) and **Syukuro Manabe** develop the first three-dimensional atmosphere model built from the primitive equations. This led to the Geophysical Fluid Dynamical Laboratory (GFDL, Princeton) family of GCMs.

1956 → 1964

Motivated by **Phillips'** paper, **Yale Mintz** recruited **Akio Arakawa** to develop a two-layer model with realistic topography. This led to the UCLA family of models, and this work was incorporated into later work by the European Center for Medium Range Weather Forecasting (ECMWF)

The 1900s

GFDL: Geophysical Fluid Dynamics Laboratory (Manabe)

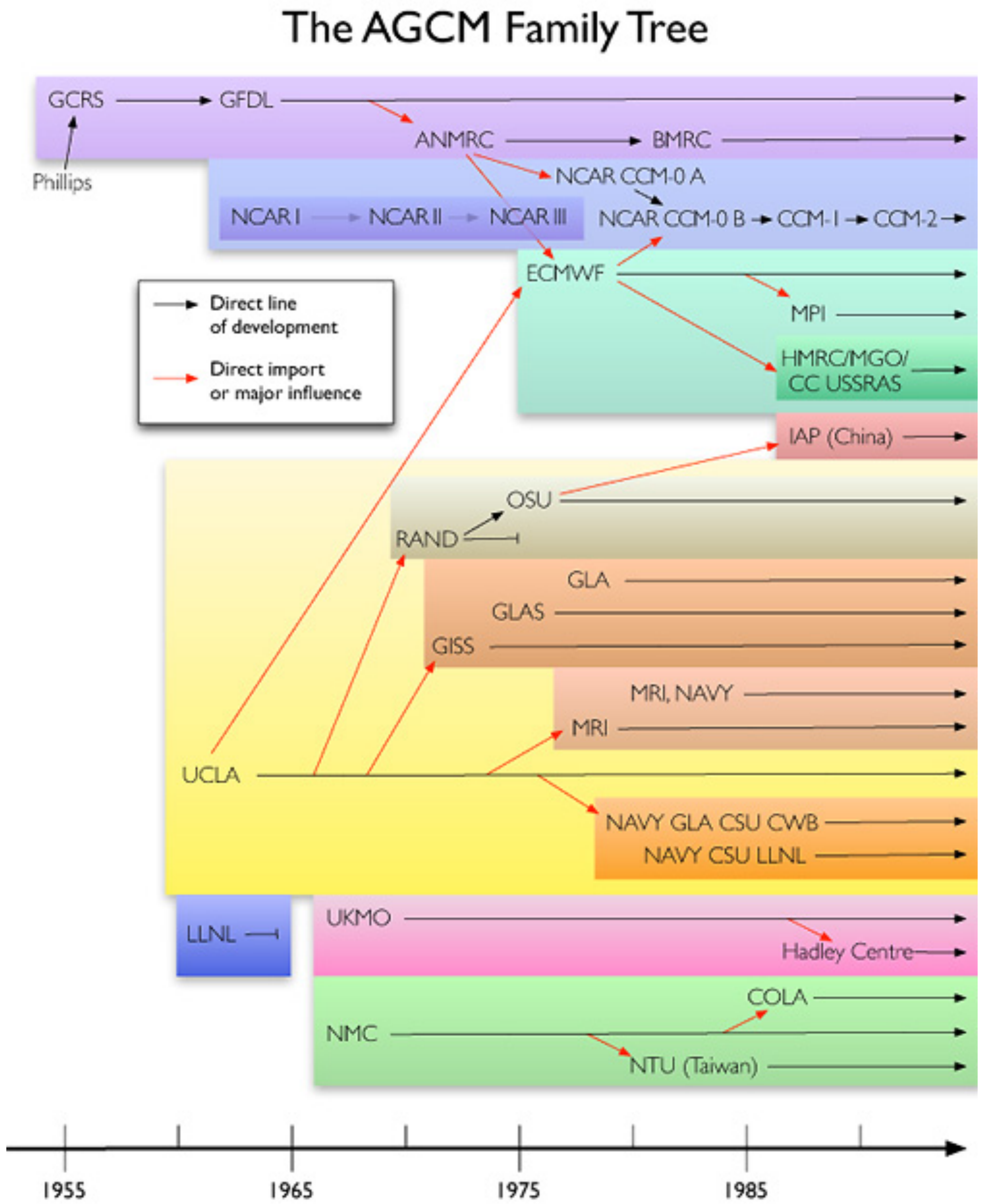
NCAR: National Center for Atmospheric Research

CCM: NCAR's Community Climate Model

ECMWF: European Centre for Medium-Range Weather Forecasts

GISS: Goddard Institute for Space Sciences (Hansen)

UCLA: University of California, Los Angeles (Mintz, Arakawa).



Late 1900s: Algorithmic Development

1965

A panel of the US National Academic of Sciences reported that: "Although global models were largely successful at reproducing gross features of the atmosphere, there were significant shortfalls in these models that could only be addressed by substantially increased computational power."

1970s → Today

Algorithmic developments from computational fluid dynamics (generally Aerospace) have led to dramatic advancements in the quality of GCMs.

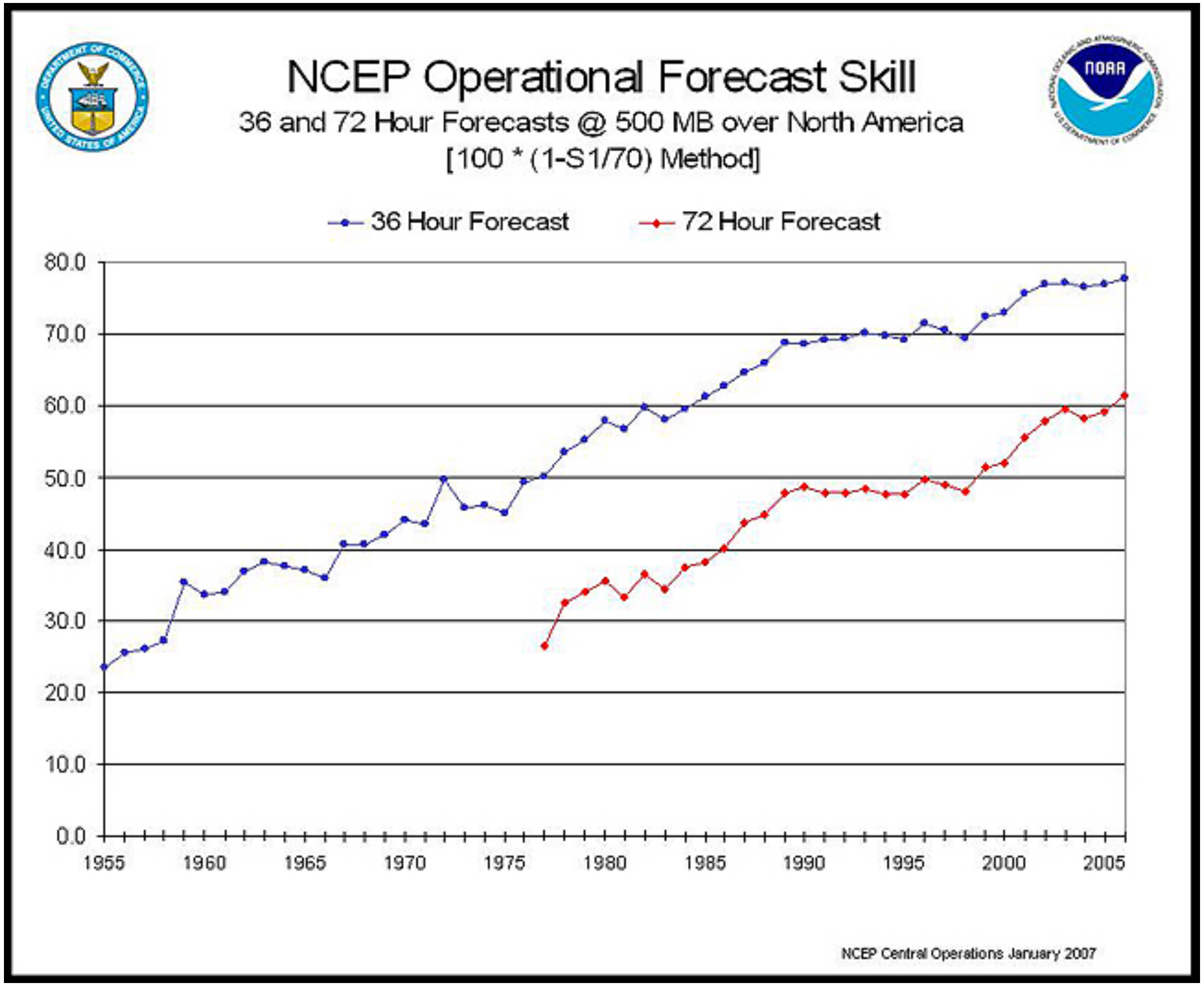
The number of general circulation models has exploded: There are more than 17 operational GCMs today being maintained by atmospheric modeling centers around the world.

Global model resolution has reached as low as 800m globally.

Late 1900s: Algorithmic Development

Computer power and time versus model accuracy as defined by the S1 score (a measure of the skill of the forecast) of 36- and 72-hour NCEP 500-millibar forecasts.

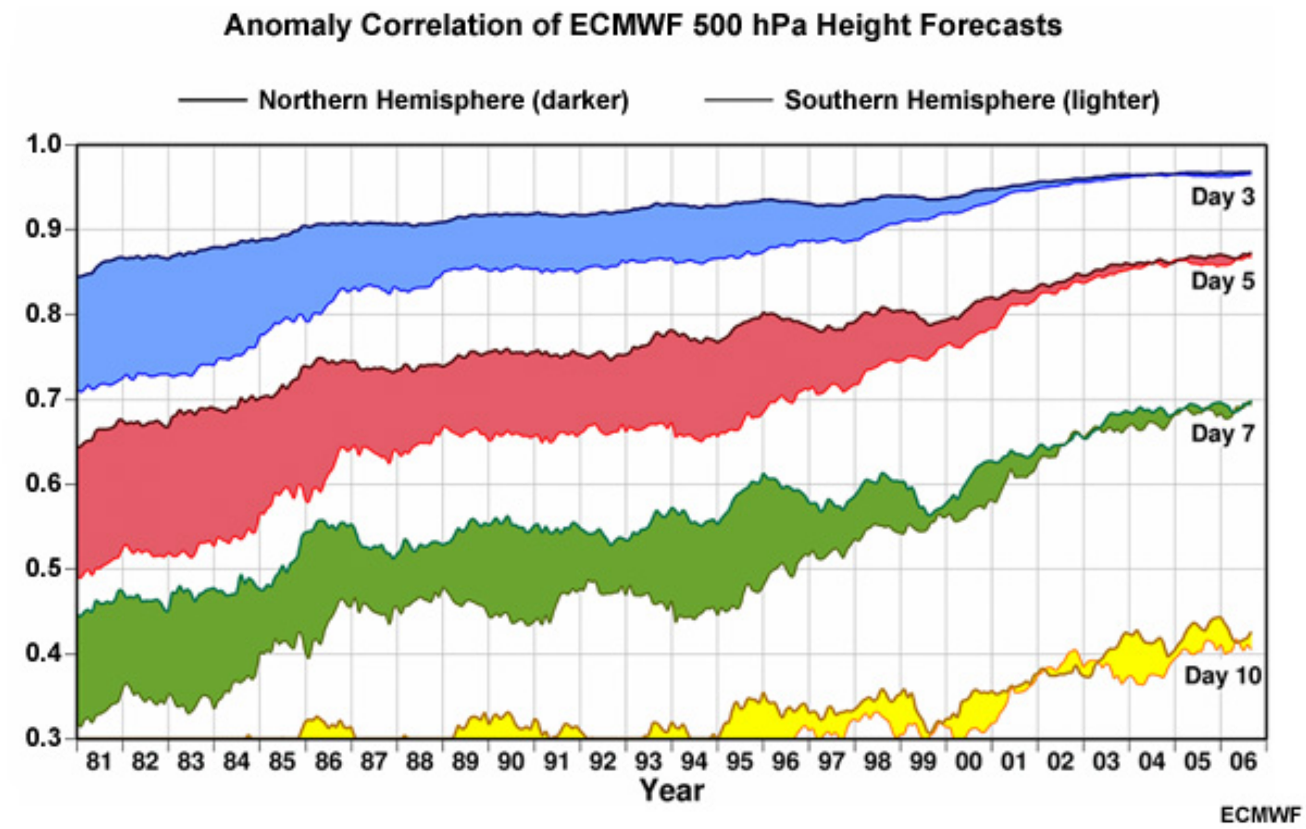
(Source: NOAA)



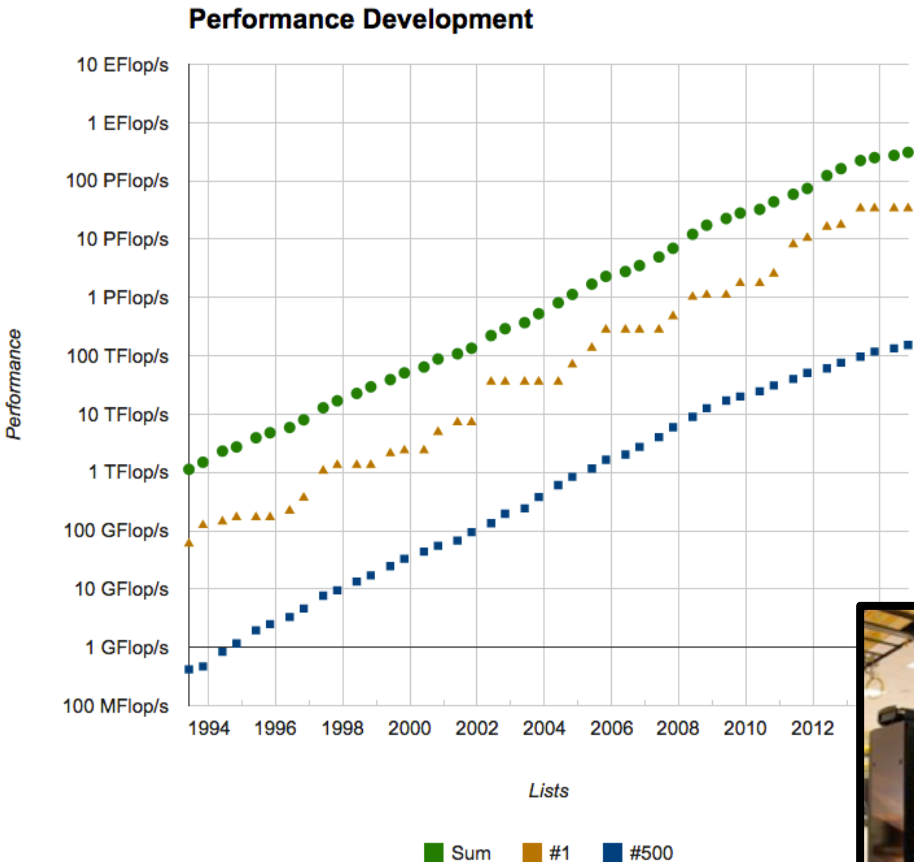
Late 1900s: Algorithmic Development

Forecast skill (measured by the anomaly correlation) for 500 hPa height forecasts using the ECMWF short-term forecasting model.

(Source: ECMWF)



The 21st Century: A New Era for GCMs



The power of supercomputing systems continues to grow at an exponential pace.

The Yellowstone supercomputer (NCAR) is a cutting-edge platform for Earth-system modeling.

The 21st Century: A New Era for GCMs