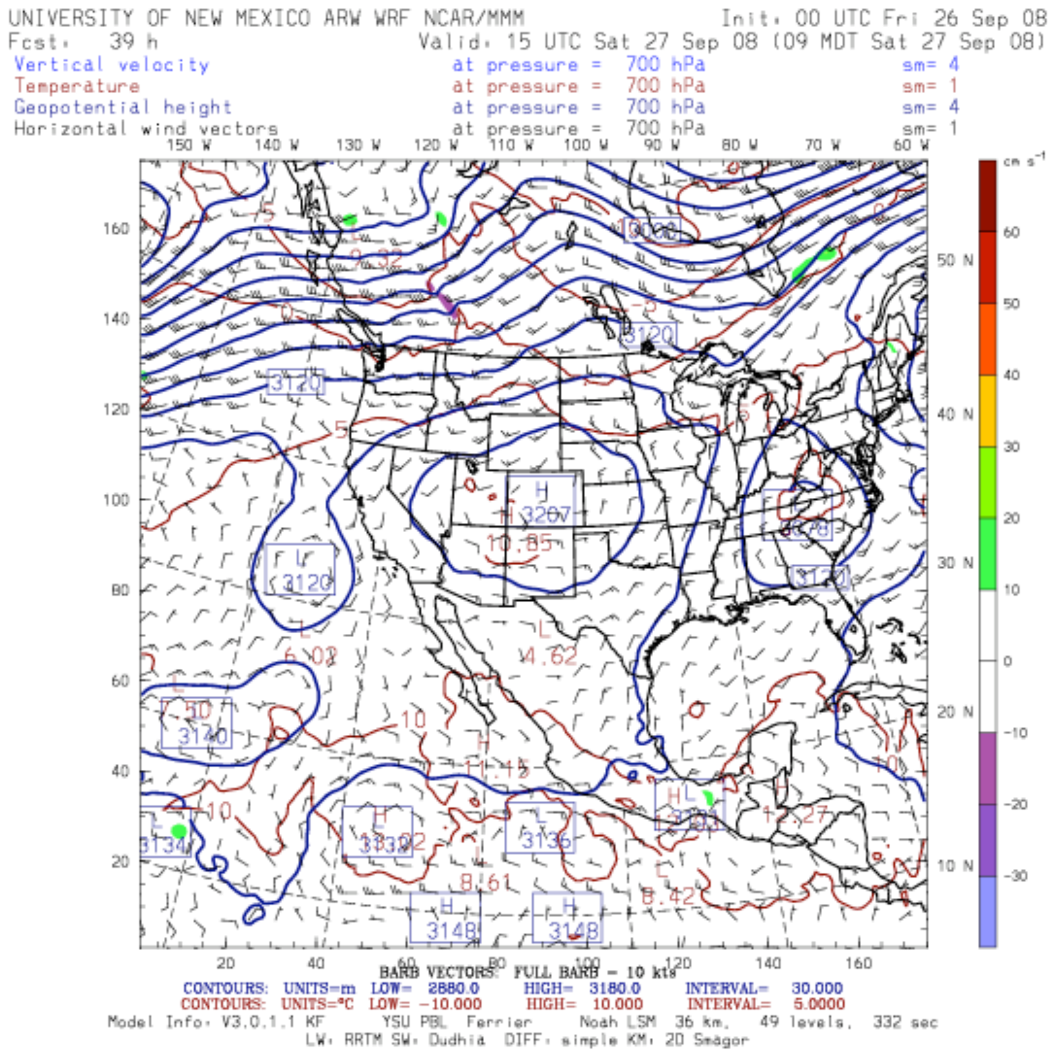

Transitioning to HPC: Experiences from the Atmospheric Sciences

Dr. Joe Galewsky

Department of Earth and Planetary Sciences

University of New Mexico

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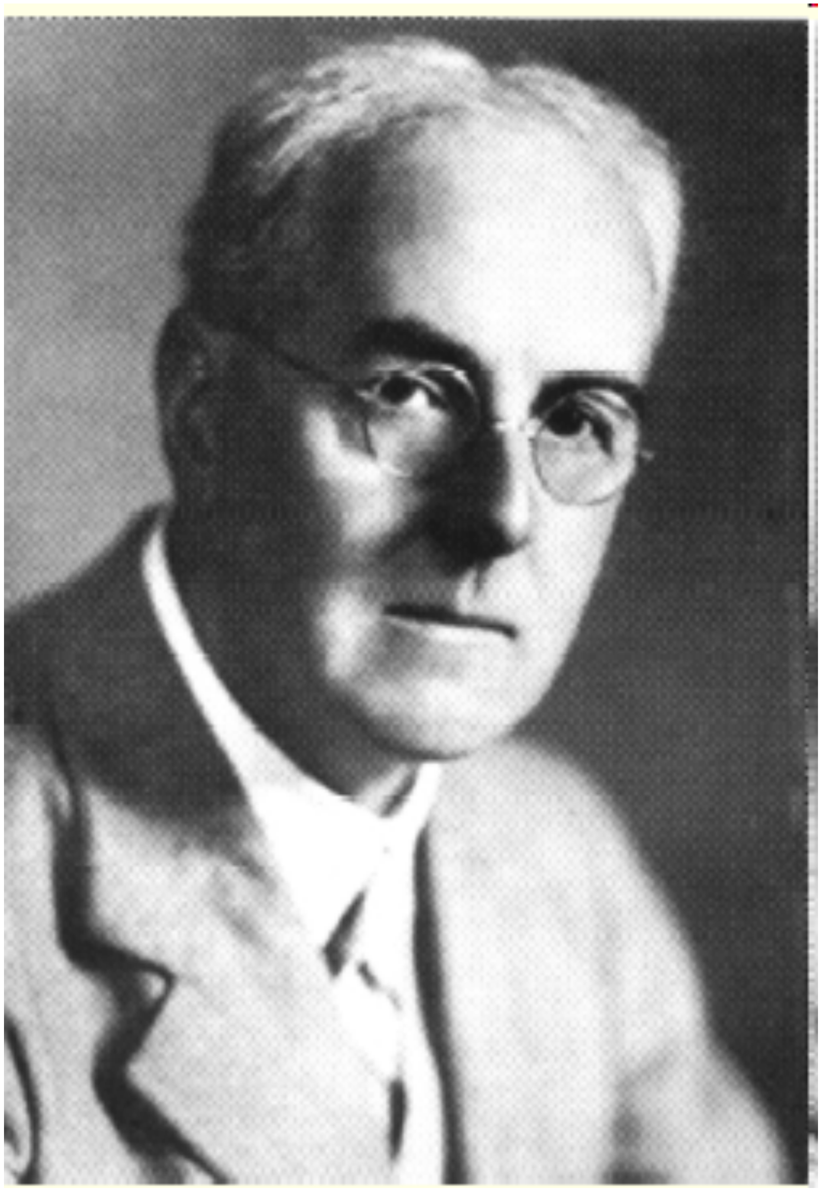
http://www.hpc.unm.edu/wrf/



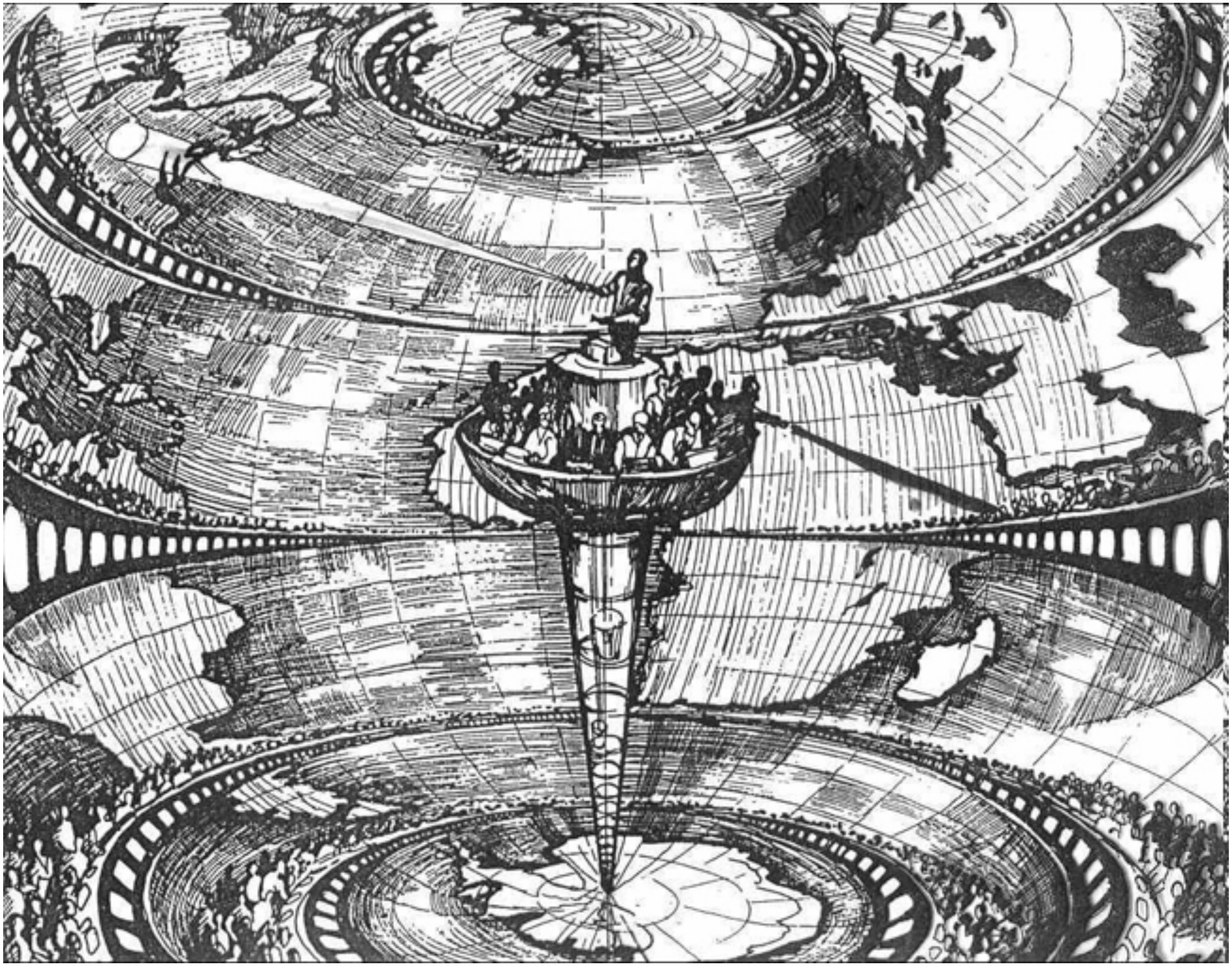
Lewis Fry Richardson

1881-1953

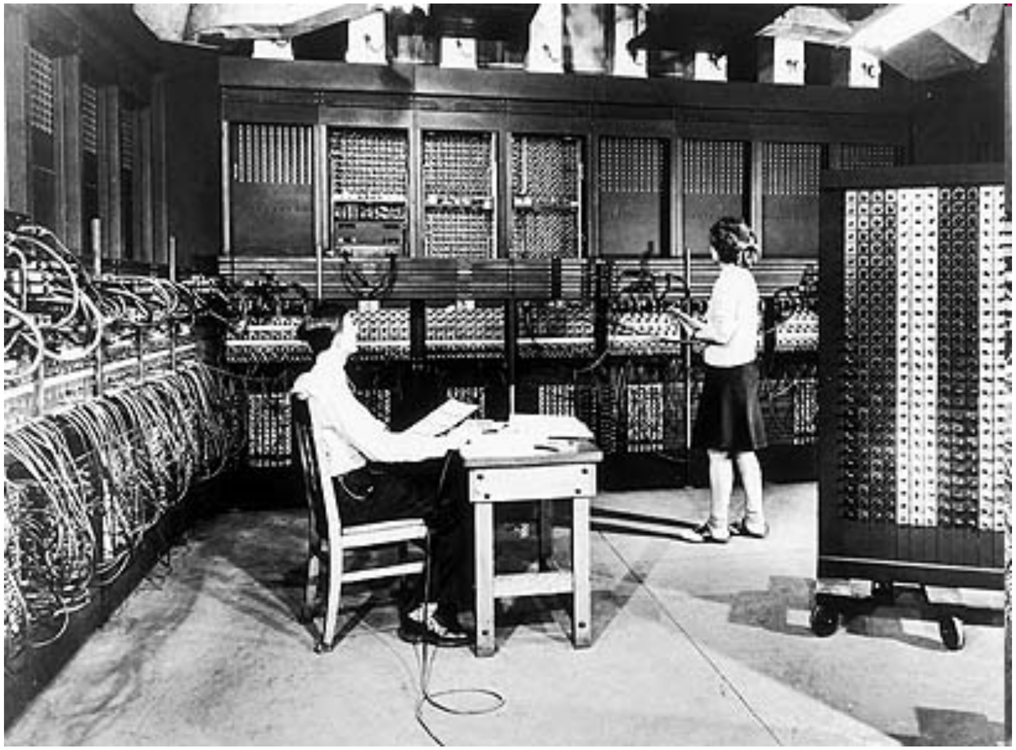
May 20, 1910:

First numerical weather forecast by direct integration of the equations of atmospheric motion.

It failed because of numerical instability.



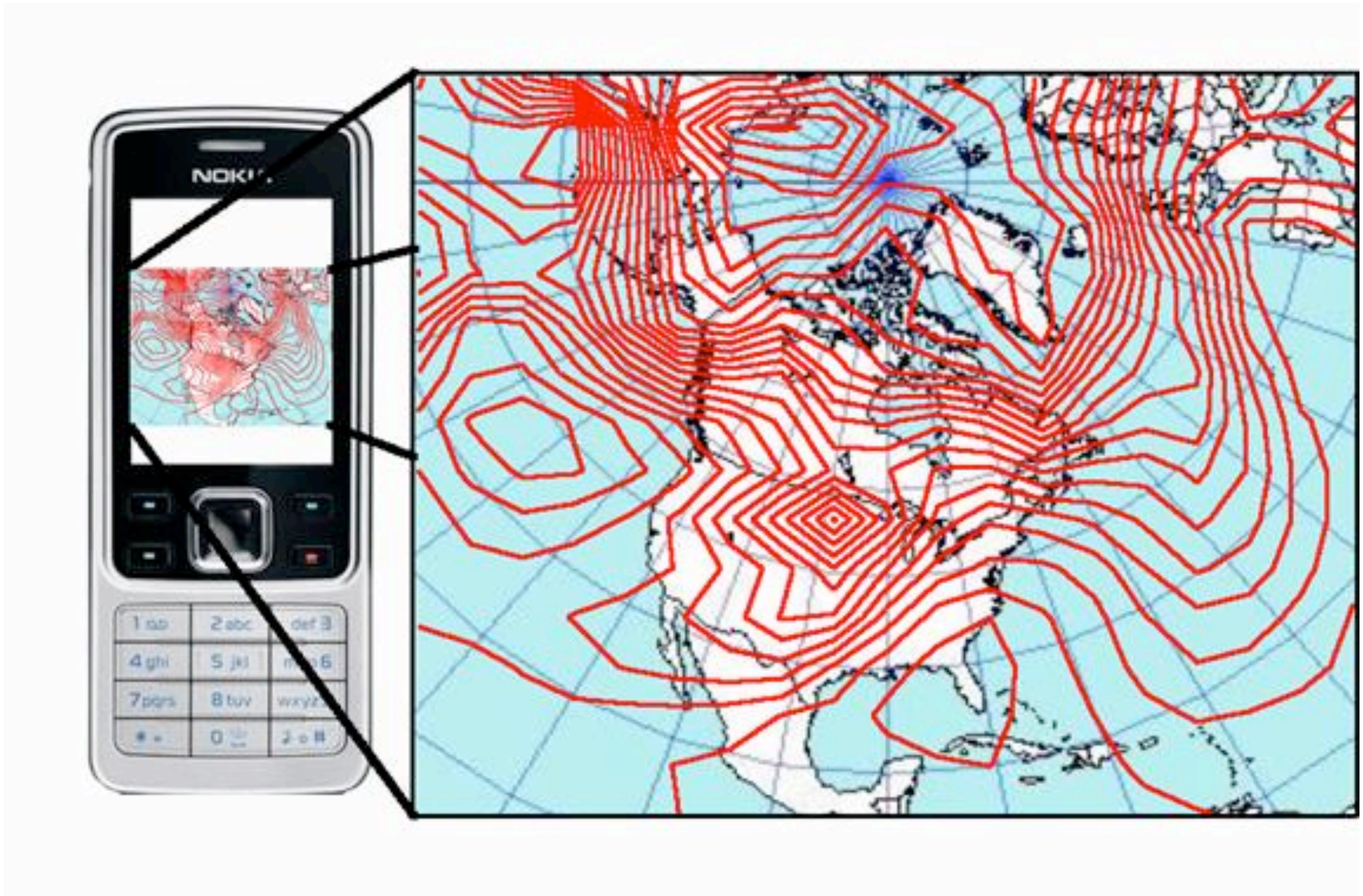
Richardson’s Forecast Factory

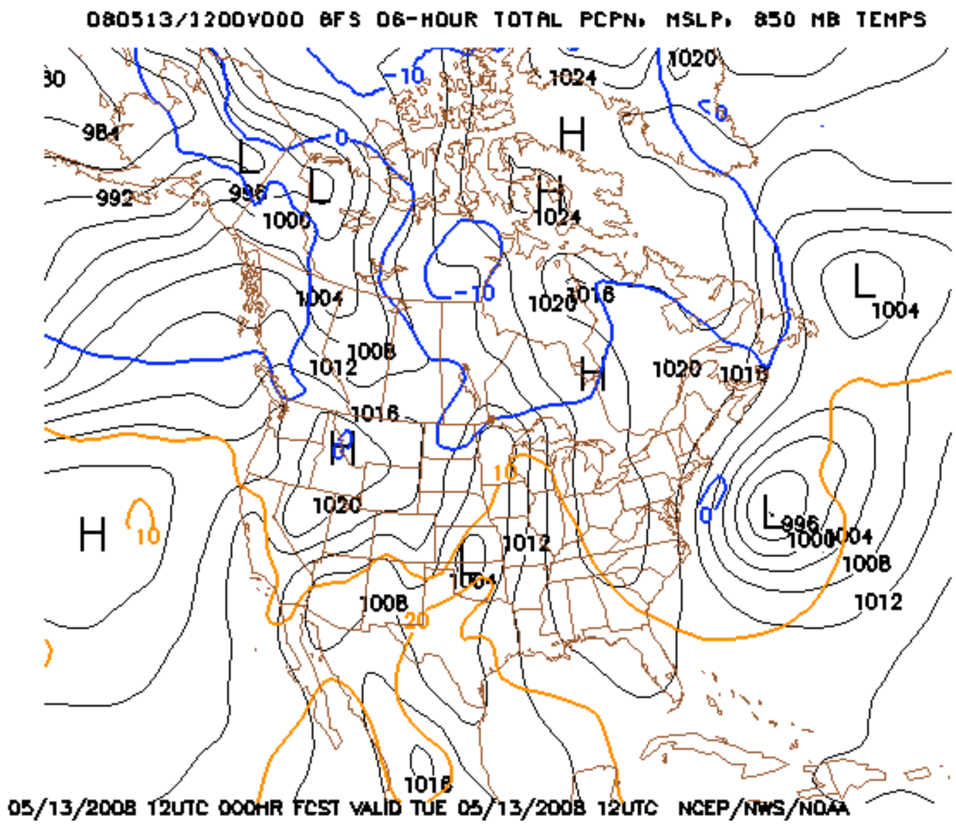


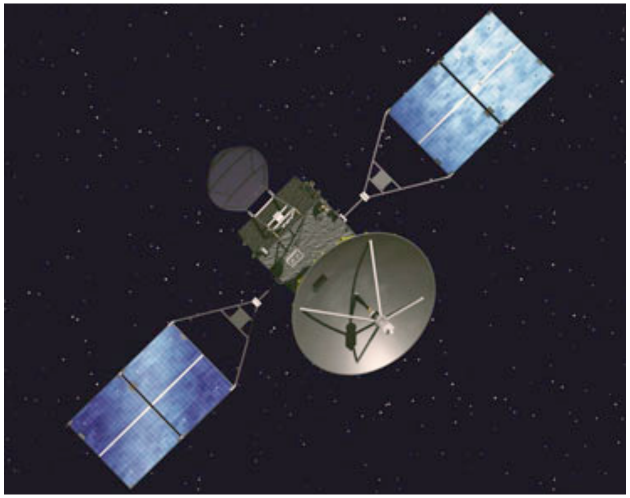
John von Neumann and ENIAC

The first successful numerical
weather forecast on March 5, 1950
Operational numerical weather forecasting begin in 1954

Yes, you can run the first weather forecast on your cell phone!







Creating the initial conditions:
The data assimilation problem


NSF
NCAR
IBM
575

Deterministic Nonperiodic Flow[1]

EDWARD N. LORENZ

Massachusetts Institute of Technology

(Manuscript received 18 November 1962, in revised form 7 January 1963)

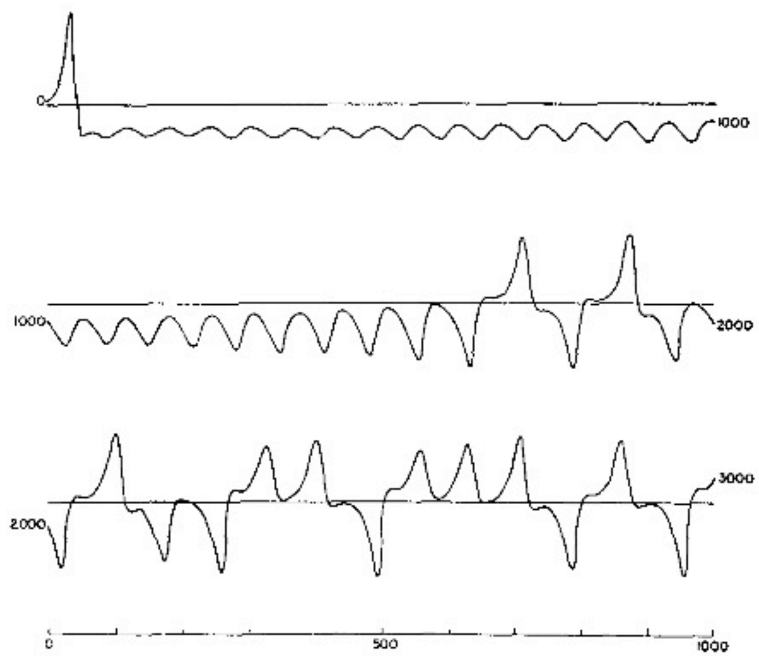
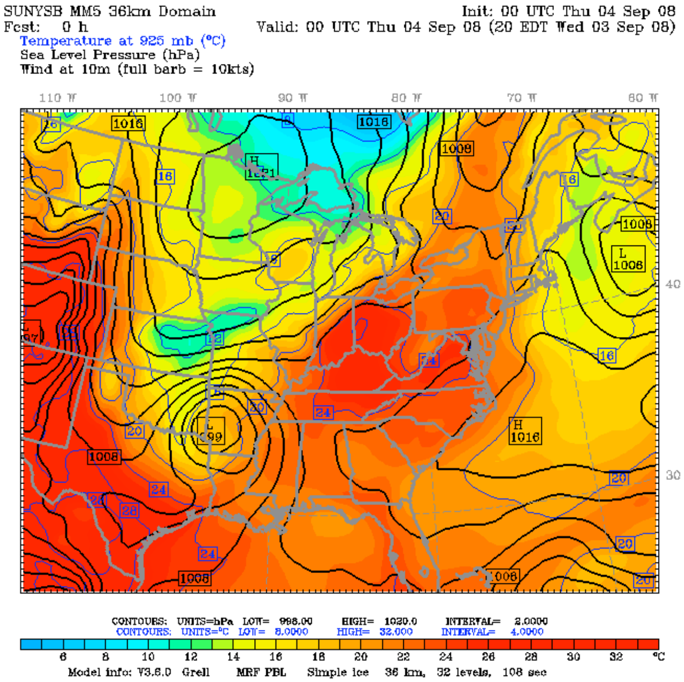
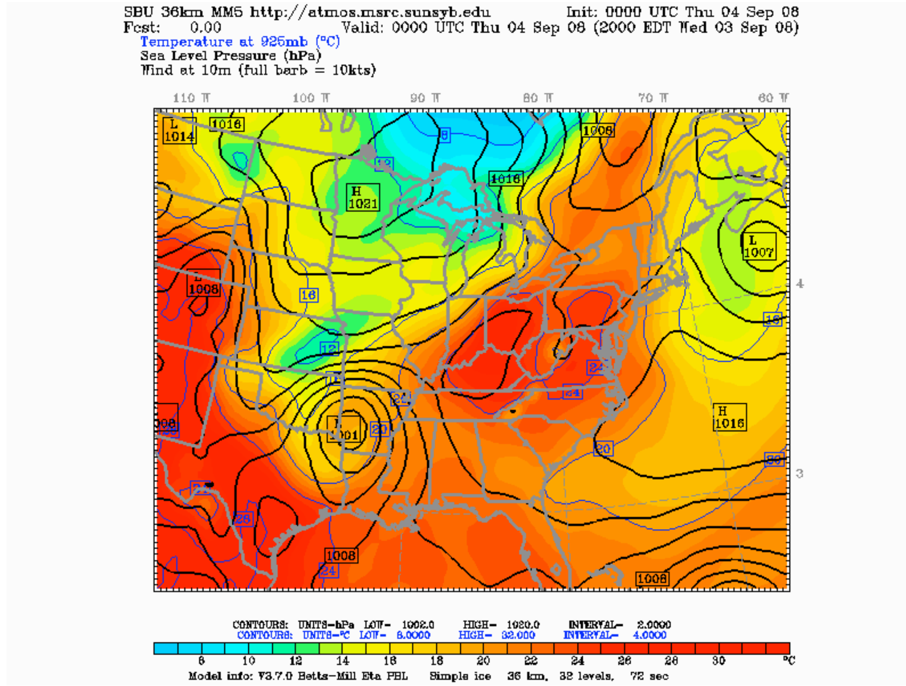
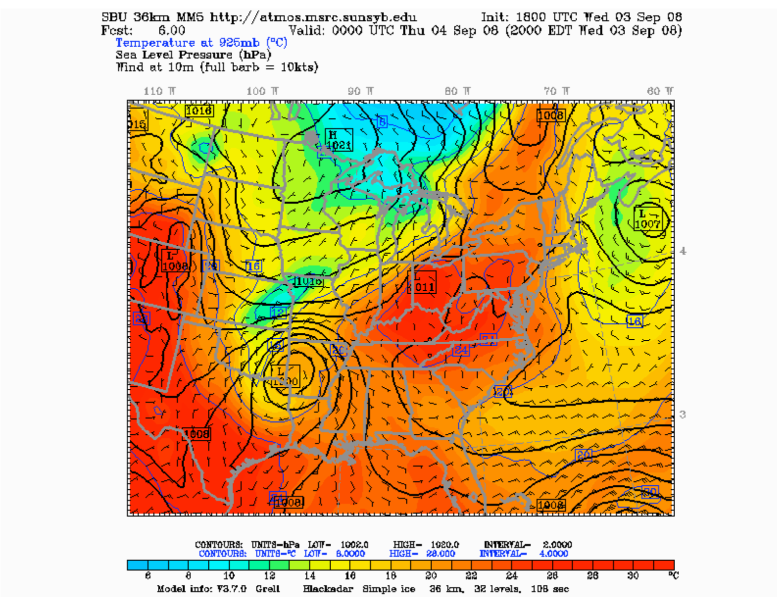
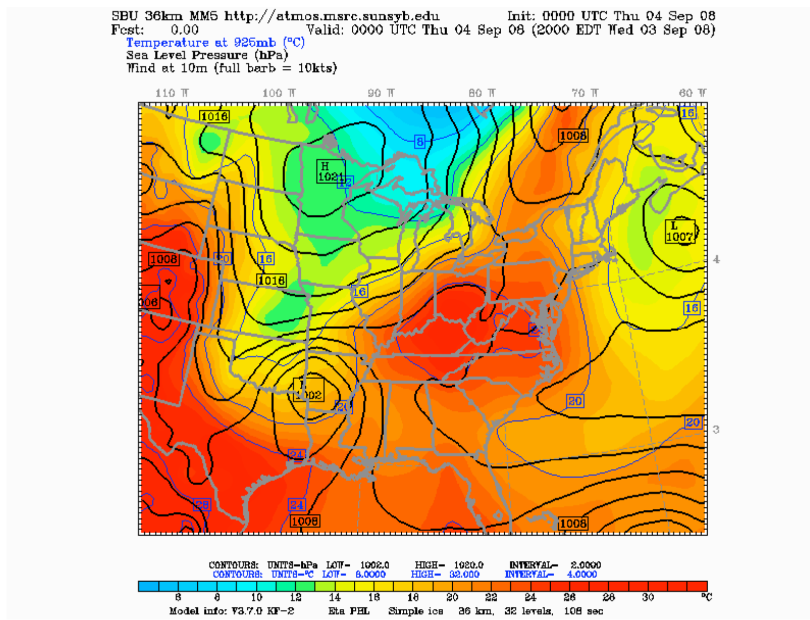


FIG. 1. Numerical solution of the convection equations. Graph of Y as a function of time for the first 1000 iterations (upper curve), second 1000 iterations (middle curve), and third 1000 iterations (lower curve).

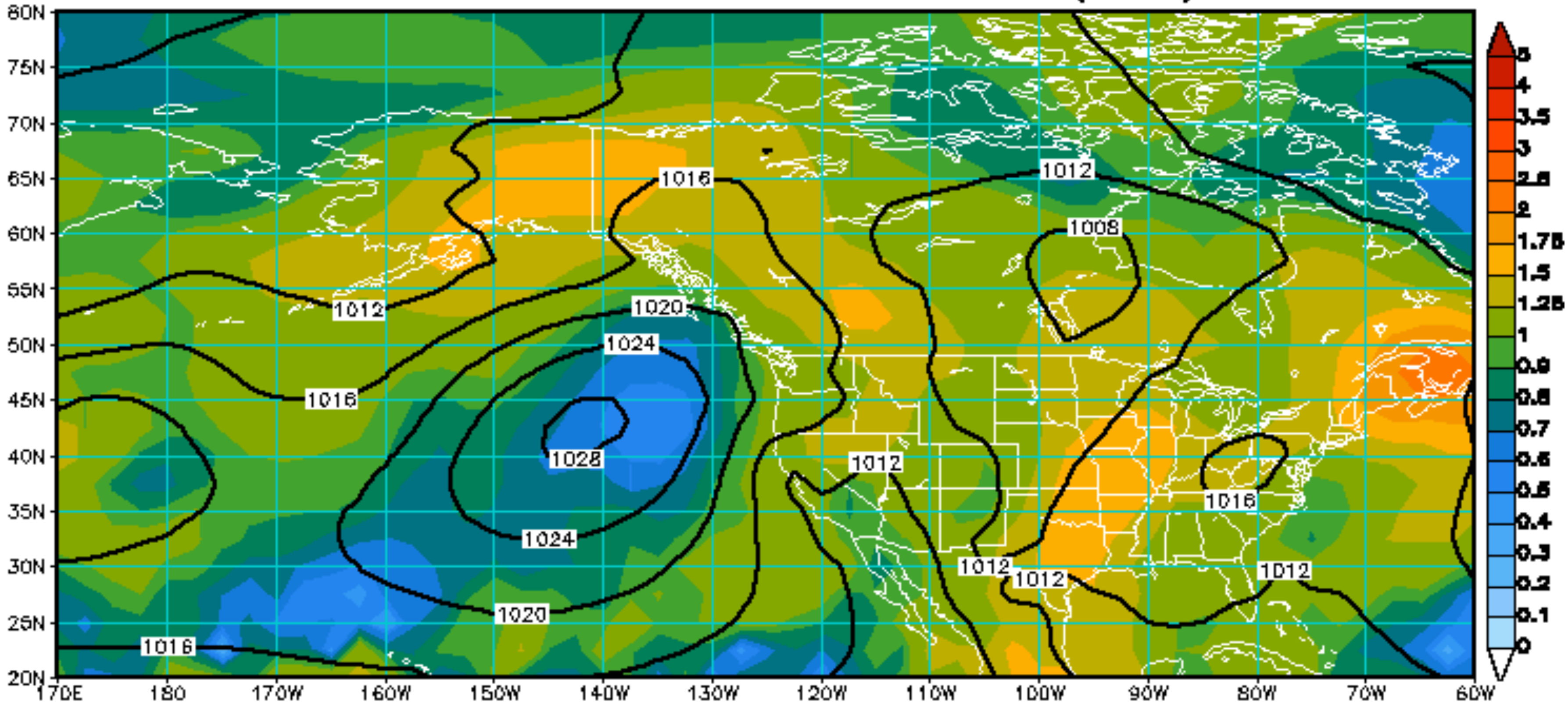

SUNYSB MM5 36km Domain
Init: 00 UTC Thu 04 Sep 08
Fcst: 0 h
Valid: 00 UTC Thu 04 Sep 08 (20 EDT Wed 03 Sep 08)
Temperature at 925 mb (°C)
Sea Level Pressure (hPa)
Wind at 10m (full barb = 10kts)
CONTOURS: UNITS=hPa LOW= 998.00 HIGH= 1020.0 INTERVAL= 2.0000
CONTOURS: UNITS=°C LOW= 8.0000 HIGH= 32.000 INTERVAL= 4.0000
Model info: V3.6.0 Grell MRF PBL Simple ice 36 km, 32 levels, 108 sec


SBU 36km MM5 http://atmos.msrc.sunysb.edu
Init: 0000 UTC Thu 04 Sep 08
Fcst: 0.00
Valid: 0000 UTC Thu 04 Sep 08 (2000 EDT Wed 03 Sep 08)
Temperature at 925mb (°C)
Sea Level Pressure (hPa)
Wind at 10m (full barb = 10kts)
CONTOURS: UNITS=hPa LOW= 1002.0 HIGH= 1020.0 INTERVAL= 2.0000
CONTOURS: UNITS=°C LOW= 8.0000 HIGH= 32.000 INTERVAL= 4.0000
Model info: V3.7.0 Betts-Mill Eta PBL Simple ice 36 km, 32 levels, 72 sec


SBU 36km MM5 http://atmos.msrc.sunysb.edu
Init: 1800 UTC Wed 03 Sep 08
Fcst: 6.00
Valid: 0000 UTC Thu 04 Sep 08 (2000 EDT Wed 03 Sep 08)
Temperature at 925mb (°C)
Sea Level Pressure (hPa)
Wind at 10m (full barb = 10kts)
CONTOURS: UNITS=hPa LOW= 1002.0 HIGH= 1020.0 INTERVAL= 2.0000
CONTOURS: UNITS=°C LOW= 8.0000 HIGH= 28.000 INTERVAL= 4.0000
Model info: V3.7.0 Grell Blackadar Simple ice 36 km, 32 levels, 108 sec


SBU 36km MM5 http://atmos.msrc.sunysb.edu
Init: 0000 UTC Thu 04 Sep 08
Fcst: 0.00
Valid: 0000 UTC Thu 04 Sep 08 (2000 EDT Wed 03 Sep 08)
Temperature at 925mb (°C)
Sea Level Pressure (hPa)
Wind at 10m (full barb = 10kts)
CONTOURS: UNITS=hPa LOW= 1002.0 HIGH= 1020.0 INTERVAL= 2.0000
CONTOURS: UNITS=°C LOW= 8.0000 HIGH= 32.000 INTERVAL= 4.0000
Model info: V3.7.0 KF-2 Eta PBL Simple ice 36 km, 32 levels, 108 sec

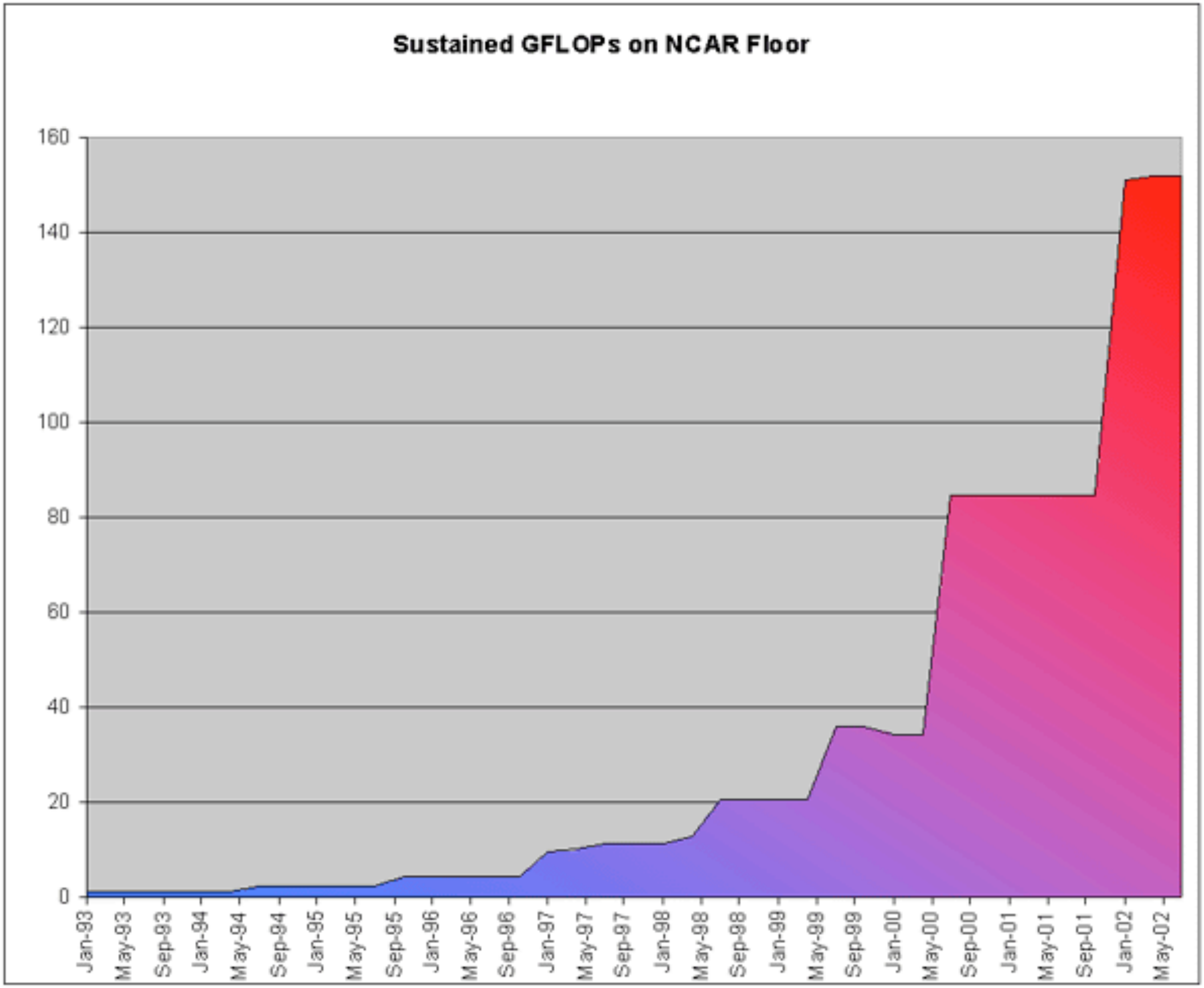
NCEP MSLP Normalized Ensemble Spread (shaded)
Ensemble Mean MSLP Forecast(contours, mb)
it: 2008090412 vt: 2008091412 (240h)



The ensemble mean gives a better forecast(on average) than any ensemble member. The ensemble spread *may* give a measure of forecast skill . . . But that’s still unclear.

Ensemble forecasting

- How do we generate ensemble members with sufficient spread?
- How do we use ensembles to generate probability forecasts?
- How do we take advantage of petascale computing?


Sustained GFLOPs on NCAR Floor
160
140
120
100
80
60
40
20
0
Jan-93
May-93
Sep-93
Jan-94
May-94
Sep-94
Jan-95
May-95
Sep-95
Jan-96
May-96
Sep-96
Jan-97
May-97
Sep-97
Jan-98
May-98
Sep-98
Jan-99
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02

Gordon Bell Prize - The Association for Computing Machinery

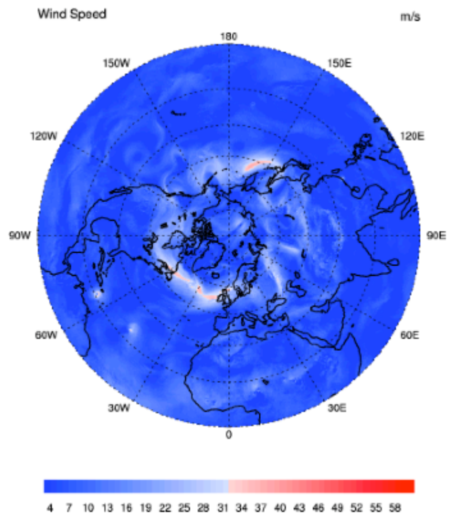
The Gordon Bell Prizes are awarded each year to recognize outstanding achievement in high-performance computing. The purpose of the award is to track the progress over time of parallel computing, with particular emphasis on rewarding innovation in applying high-performance computing to applications in science. Prizes are awarded for peak performance as well as special achievements in scalability and time-to-solution on important science and engineering problems and low price/performance. Financial support of the $10,000 award is provided by Gordon Bell, a pioneer in high-performance and parallel computing

Nature Run: Methodology

- Configuration and Domain
  - Idealized (no terrain) hemispheric domain
    - 4486 x 4486 x 100 (2 billion cells)
    - 5KM horizontal resolution, 6 second time step
    - Polar projection
  - Mostly adiabatic (dry) processes
  - Forced with Held-Suarez climate benchmark
  - 90-day spin-up from rest at coarse resolution (75km)

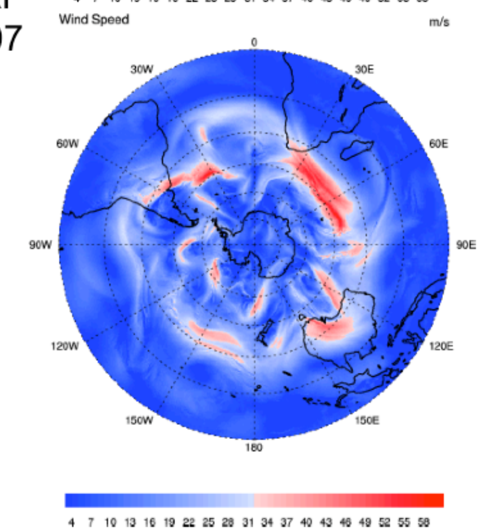
Initial simulation results

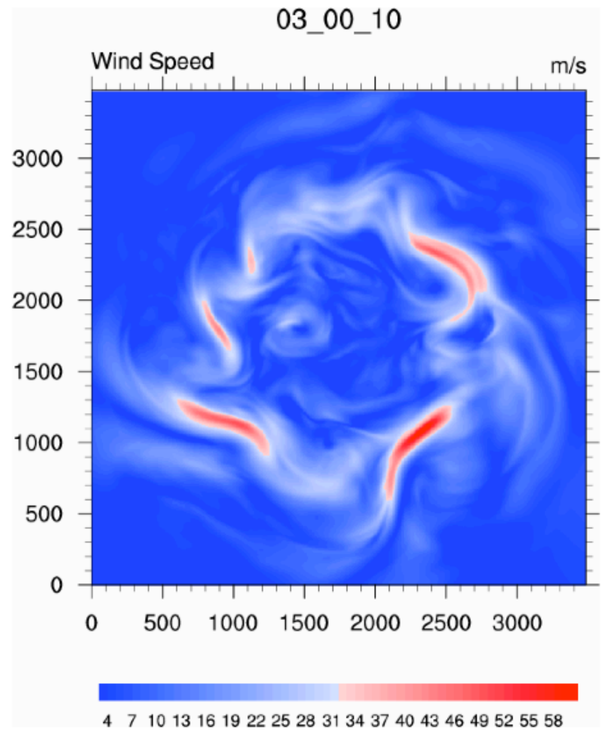
N.H.



Real Data Forecast
20km Global WRF
July 22, 2007

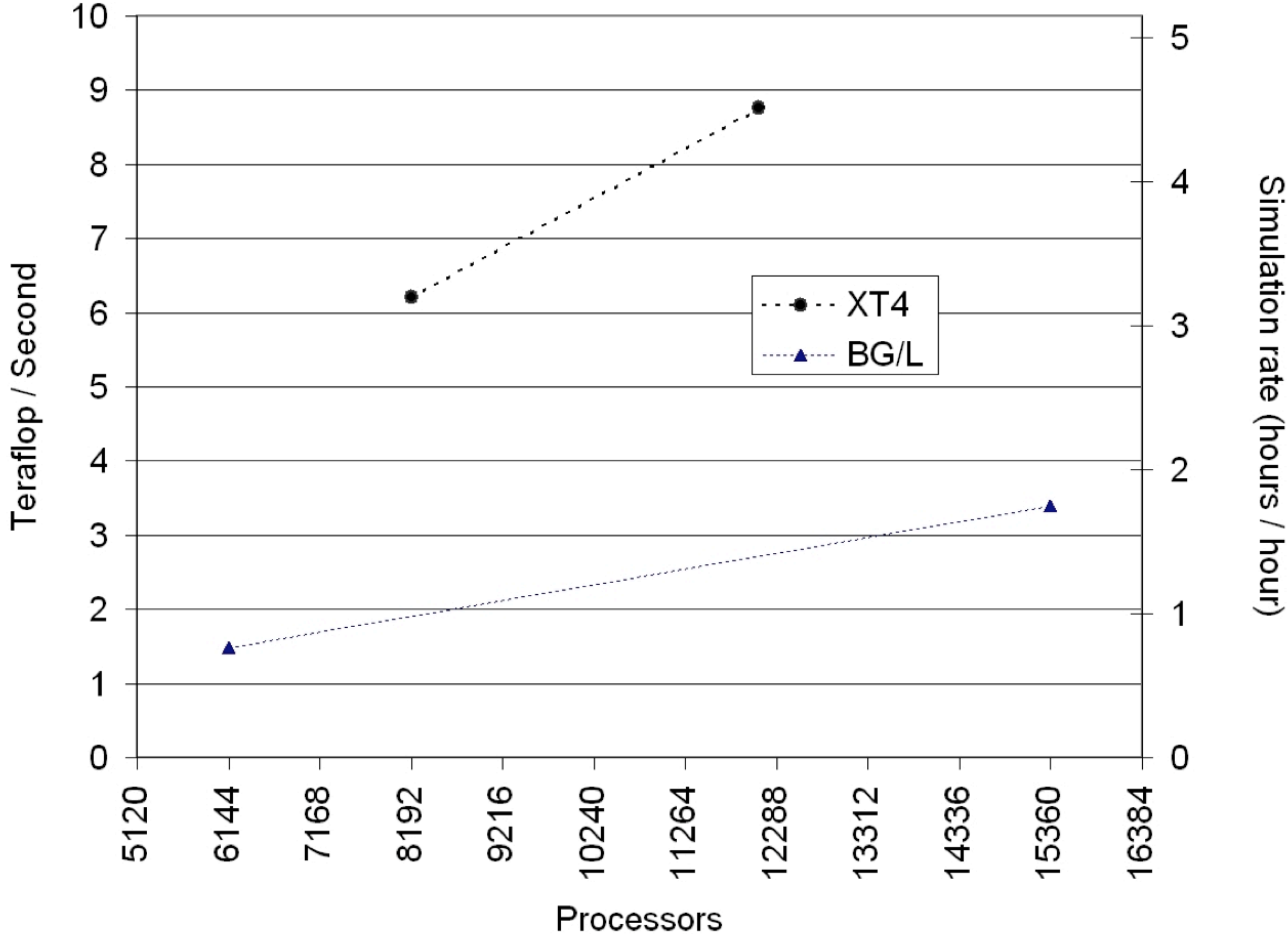
S.H.





WRF Nature Run
5km (idealized)
Capturing large scale structure already
(Rossby Waves)
Small scale features spinning up (next slide)

Floating Point Rate



Surface process modeling

- Diverse range of governing equations for surface processes/geomorphology modeling.

- The need for decision support (e.g. forecasting) is not as well established.

- How can the basic science be advanced by transitioning to parallel architectures?

- Let's build it and see what happens . . .