Non-Hydrostatic Simulations with GEOS-5 and the Cubed-Sphere Finite Volume Dynamical Core

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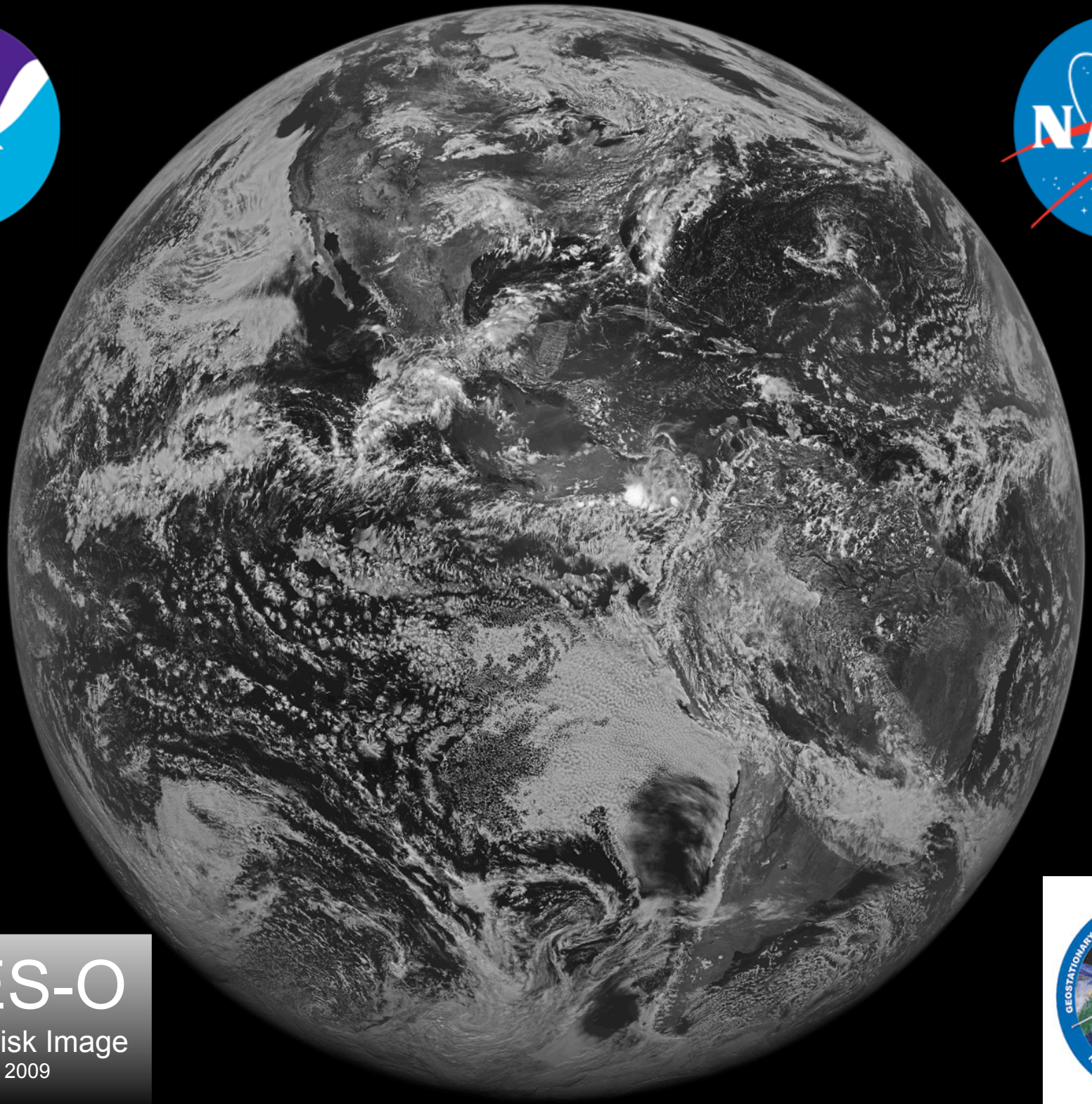
GFDL NOAA

And many others…

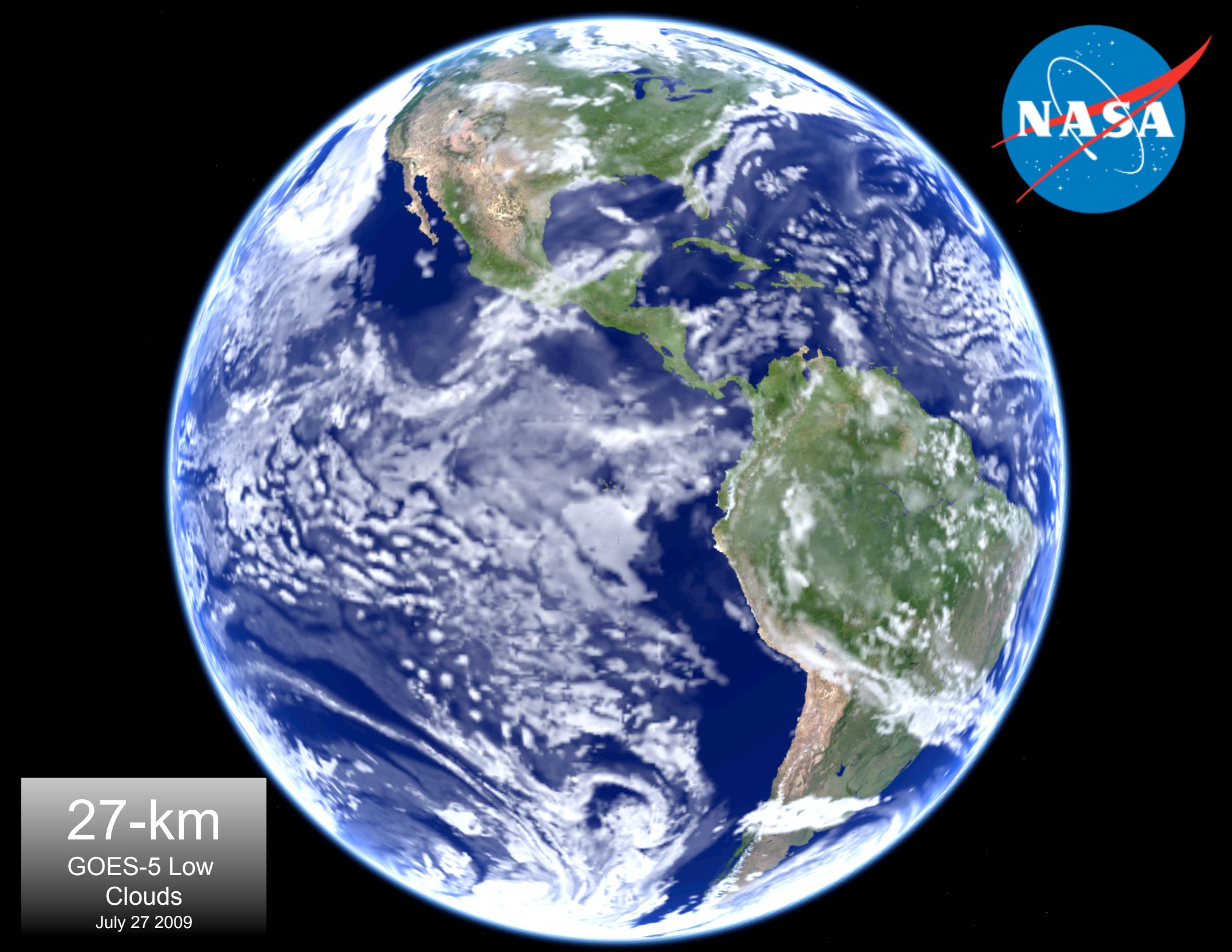


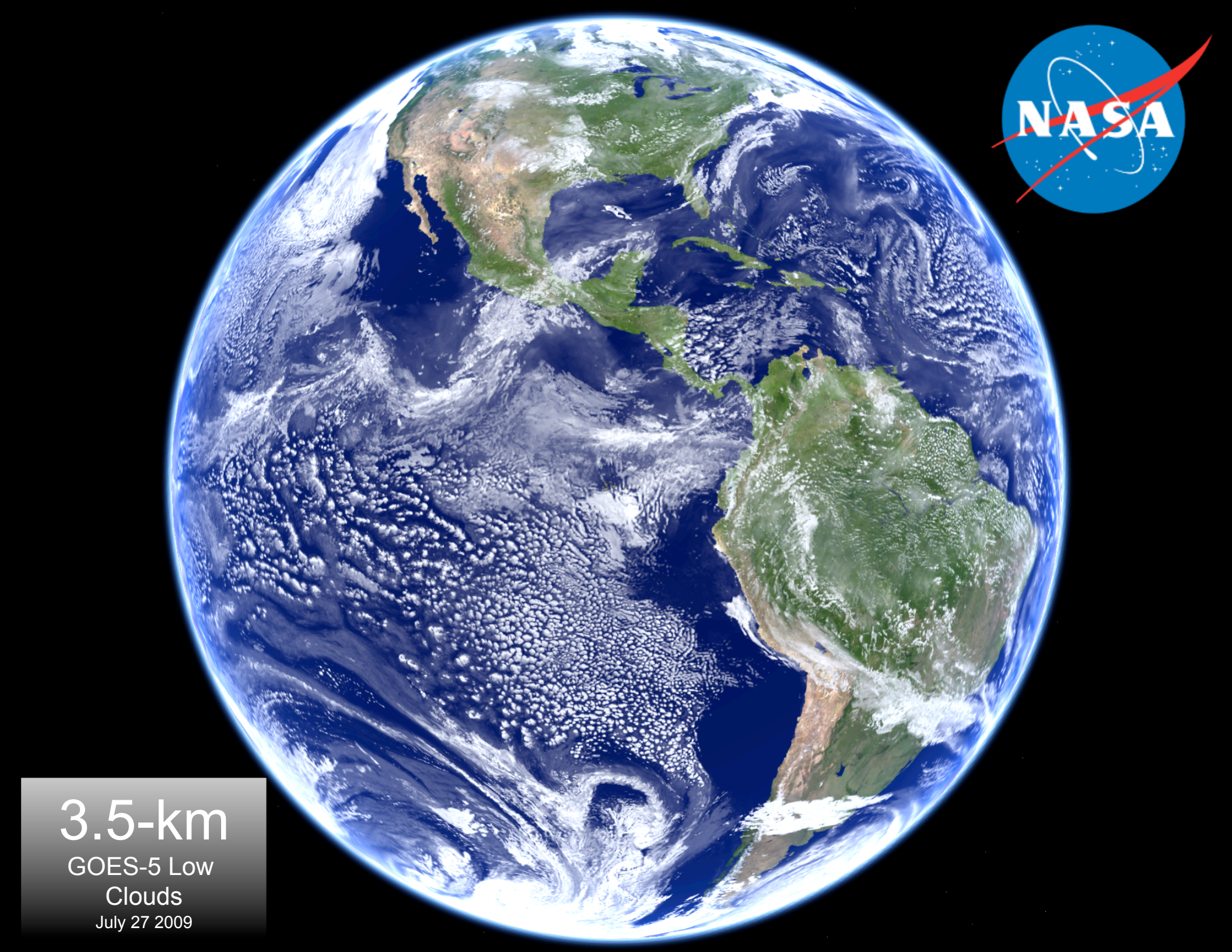
GOES-O

First Full Disk Image

July 27 2009

http://www.nasa.gov/mission_pages/GOES-O/main/index.html


27-km
GOES-5 Low
Clouds
July 27 2009


3.5-km
GOES-5 Low
Clouds
July 27 2009

Global Atmospheric Models: The Next Generation

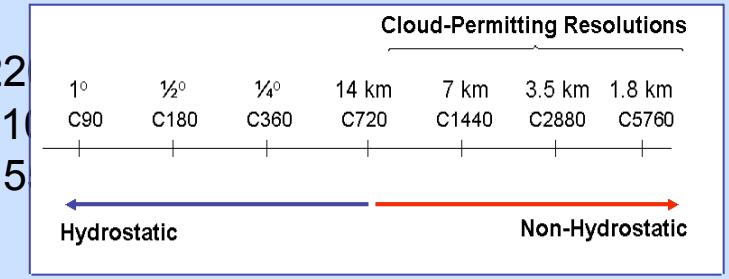
Resolutions of a few kilometers---Cloud Permitting---not quite cloud-resolving---that will require:

- Parameterizations of moist processes that account for the effects of resolved meso-scale organization of convective systems.
- A non-hydrostatic dynamical core capable of running efficiently on the sphere at high resolution
- Quasi-uniform spherical grids (the Cubed-Sphere)
- Massively-parallel (10^4-10^5 processors), peta-flop computers

Weak Scaling

- Computing power is increasing primarily through increased parallelism *(not processor speed)*
- Our models scale badly; adding processors at a fixed problem size does not scale *(Amdahl's Law)*
- If we increase resolution as we add processors, models do fairly well. (*doubling the horizontal resolution*, it will take the same time to do a time step on *four times as many processors*)
- CFL requires *twice as many time steps*.
- So the same forecast will take twice as long. But *better than 8 times as long* on the same number of processors.

C180 (55 km)	500 cores produces	440 d/d	
C360 (27 km)	2000		22
C720 (14 km)	8000		11
C1440 (6.9 km)	32000		5
C2880 (3.4 km)	128000	27.5 d/d	
C5760 (1.7 km)	512000	13.75 d/d	



Current Efforts with NASA GEOS-5 Model

- We now have access to a few large computing systems:

  Discover at NASA NCCS (***10000*** cores)

  Pleiades at NASA NAS (***50000*** cores)

  Jaguar at ORNL (***150000*** cores).

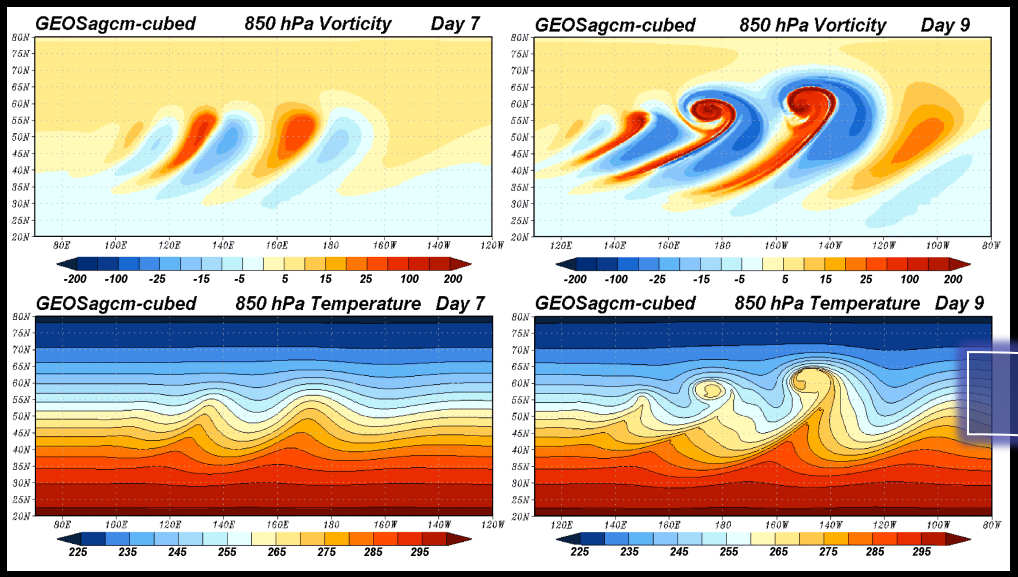
- We were selected as part of team of ~20 groups experimenting with running very large (many cores) jobs on ***Jaguar*** until it was opened to more general use in July 2009.

- We used this time to make forecasts and simulations with the atmospheric model at unprecedented resolutions, pushing both problem size and processor counts.

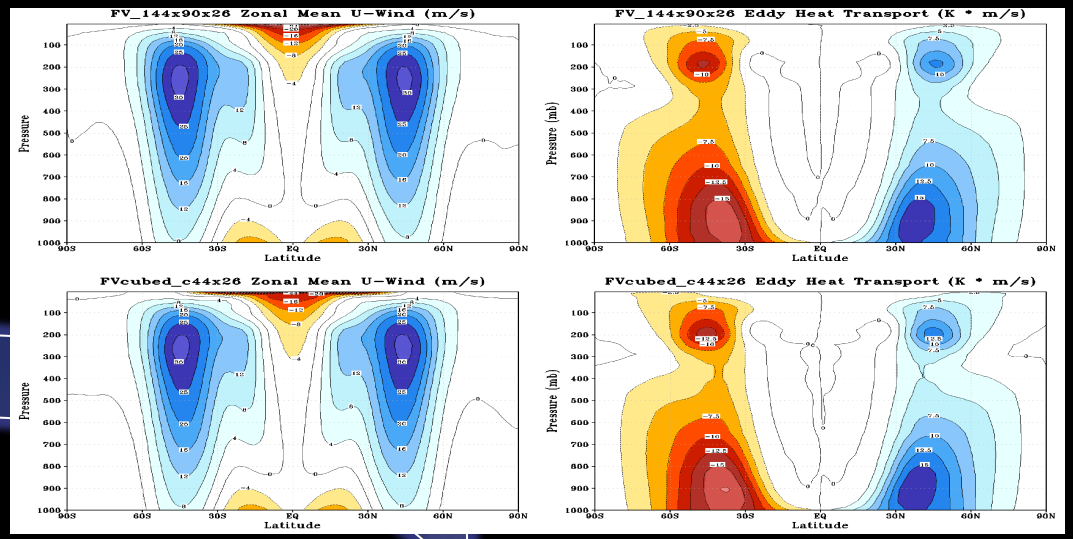
- Today you will see the first results from GEOS on these systems

Cubed Sphere Implementation Path

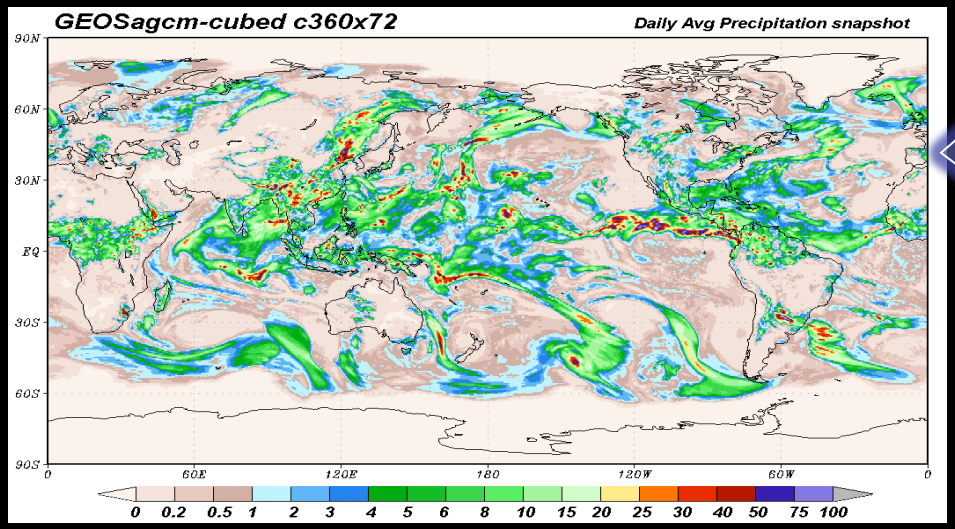
Idealized waves



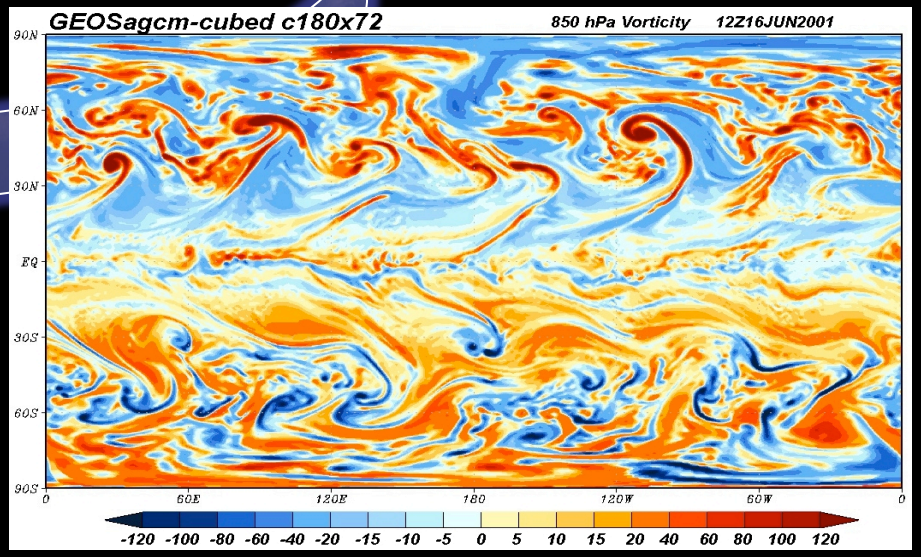
Held-Suarez



GEOS-5



Aqua

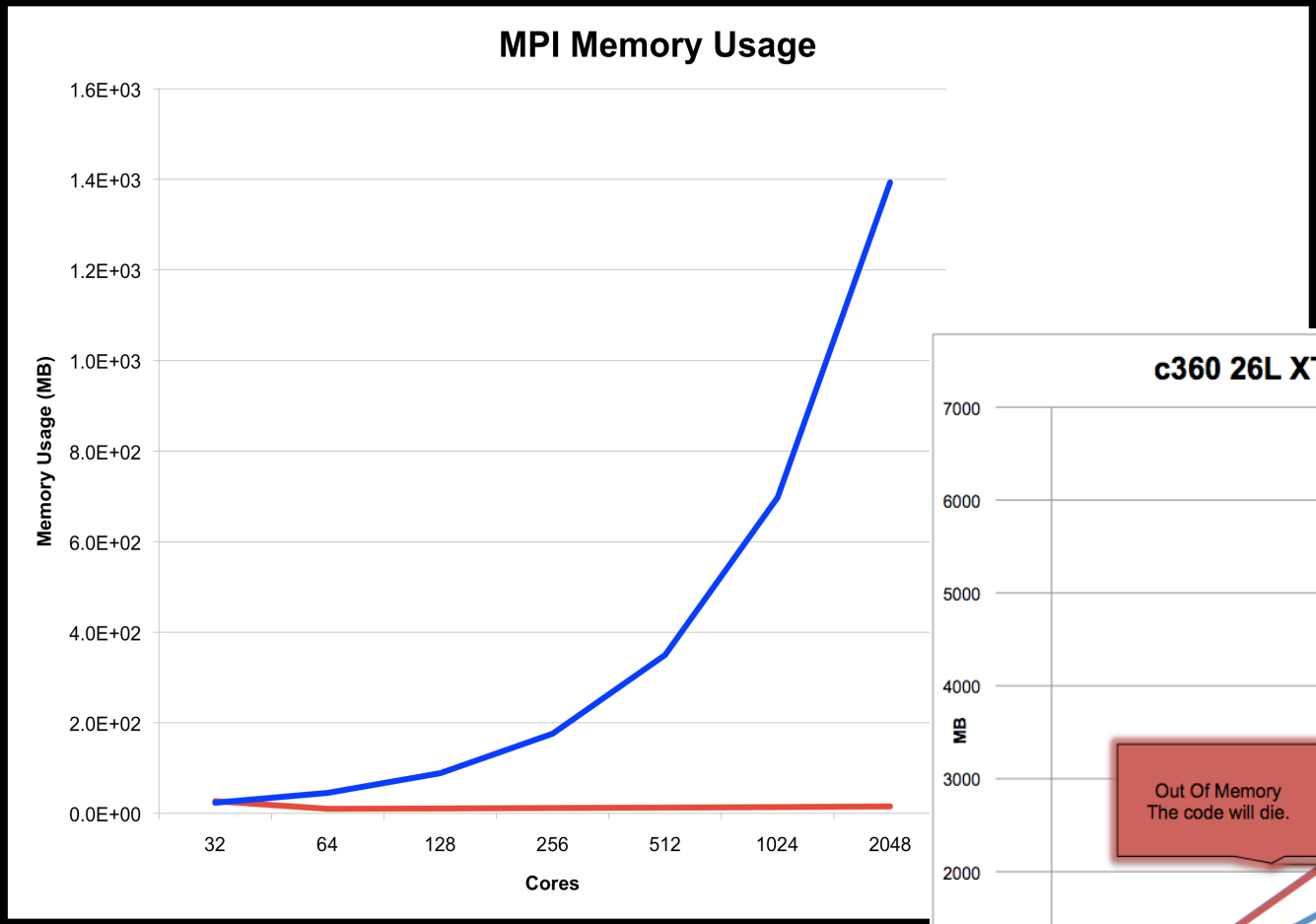


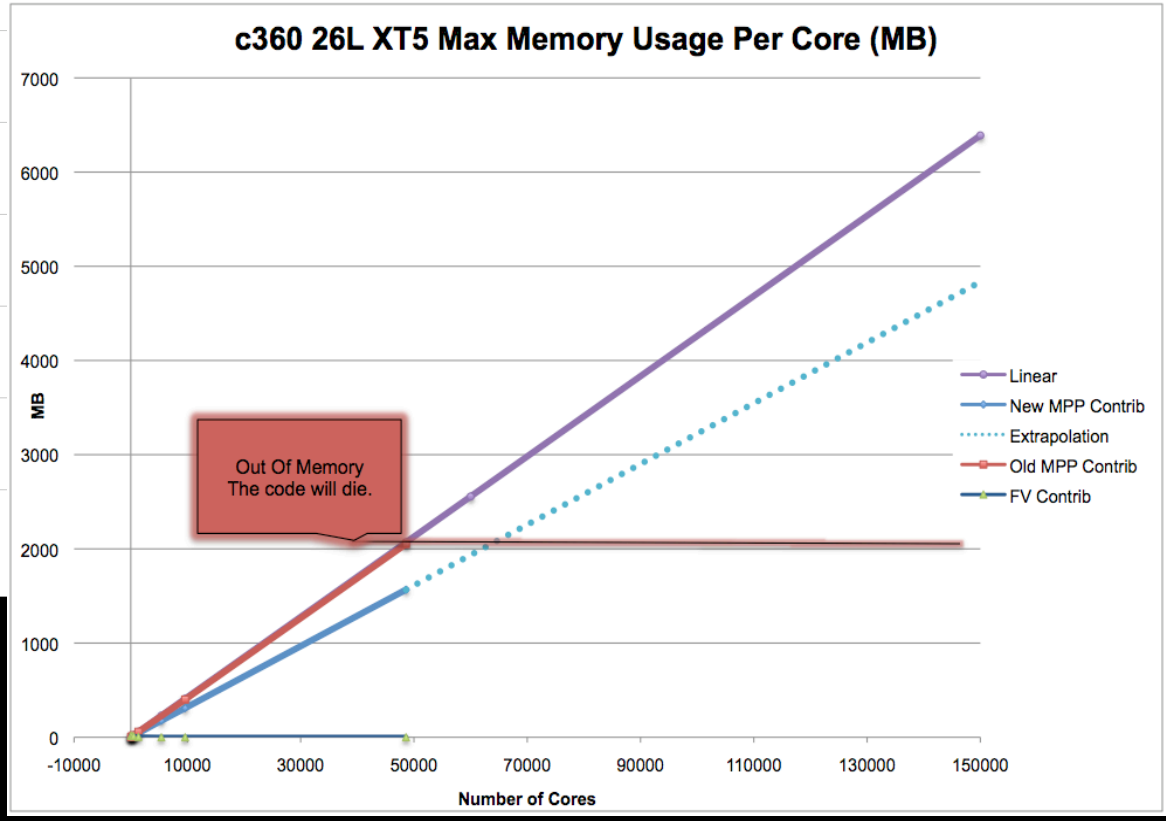
Scaling Climate/Weather Applications

MEMORY

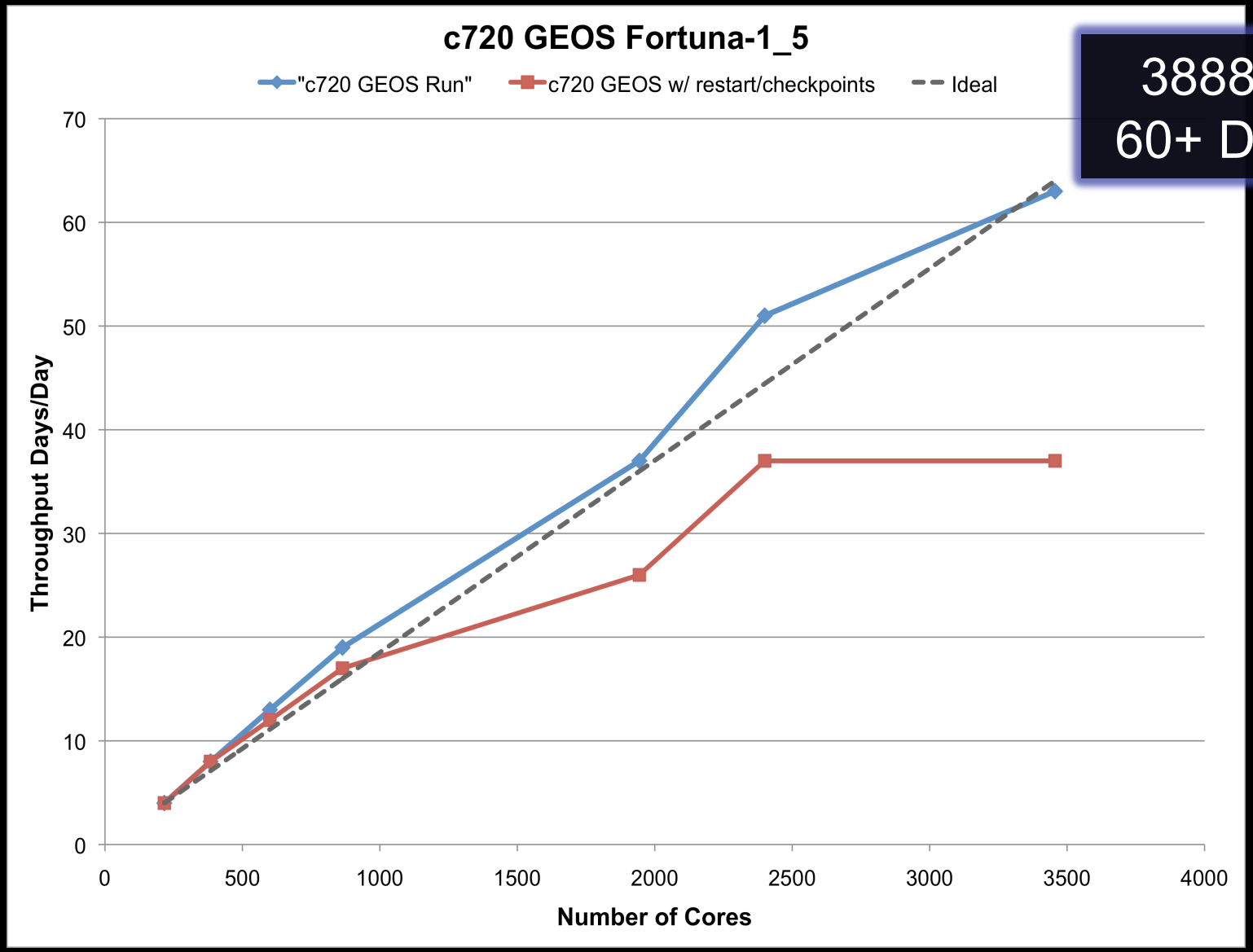
Parallel I/O

IntelMPI & FMS
Memory Scaling



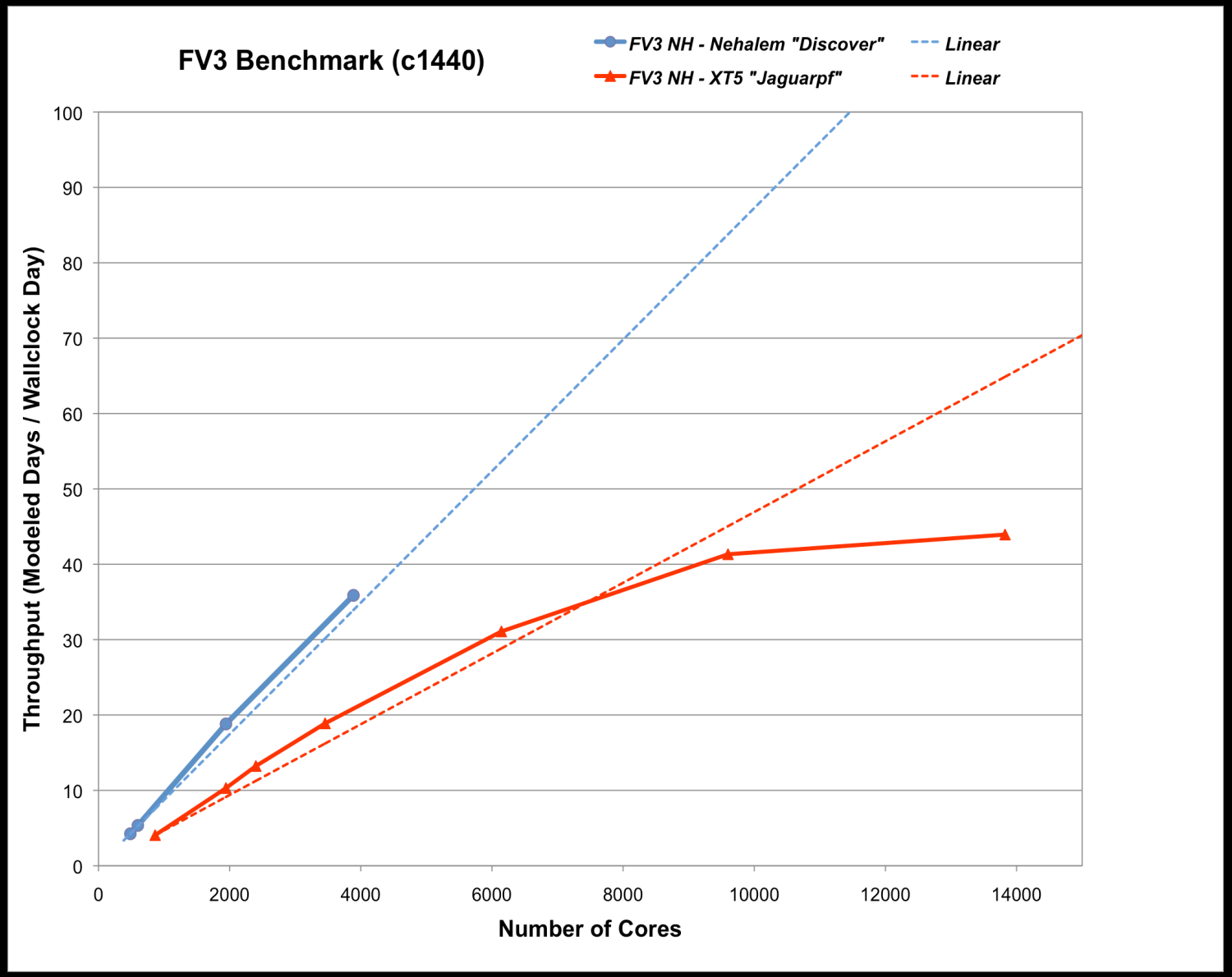


GEOS/FV^3 Scaling



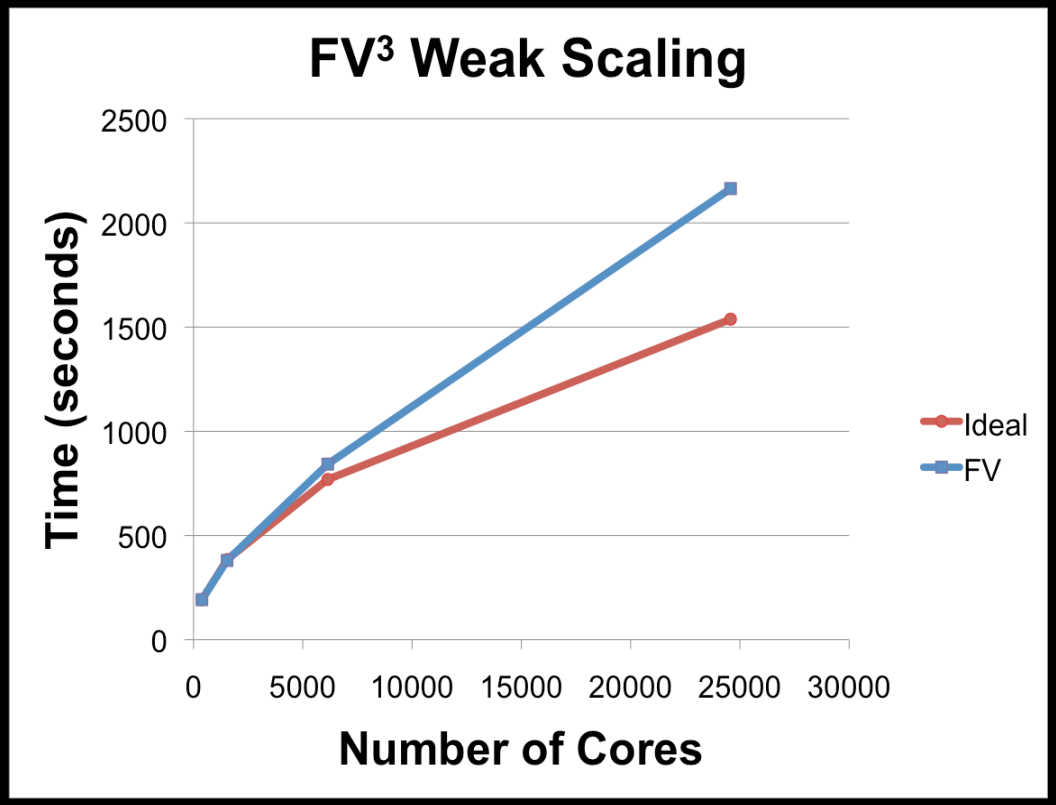
3888 Cores
60+ Days/day

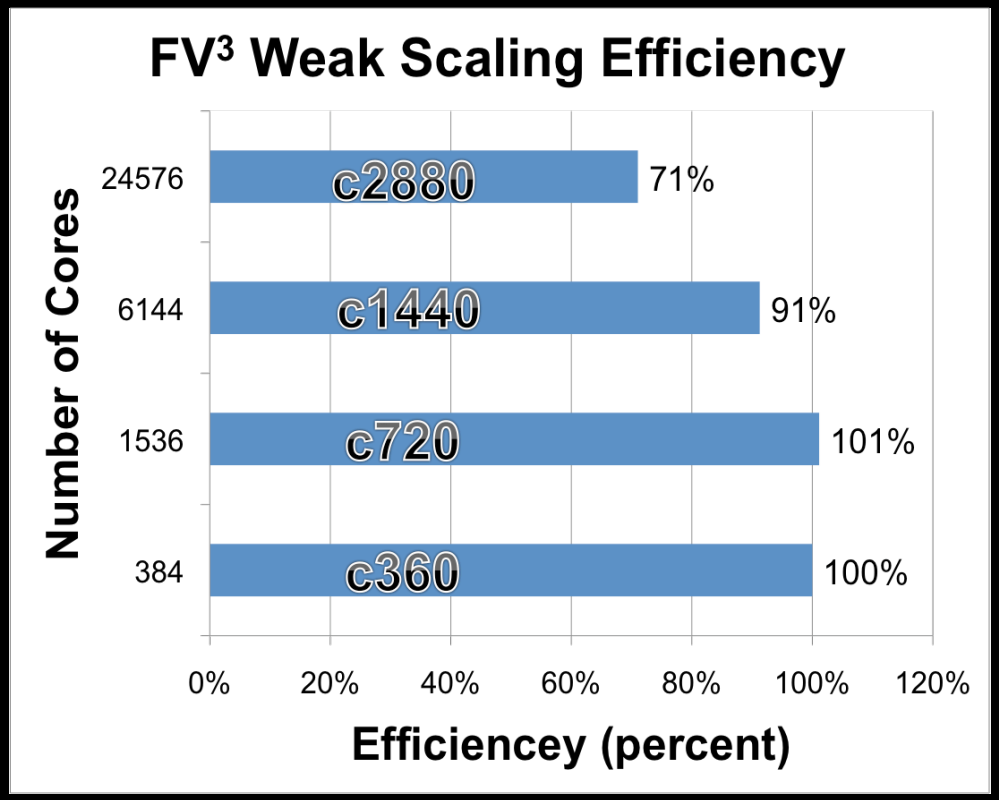
GEOS/FV^3 Strong Scaling

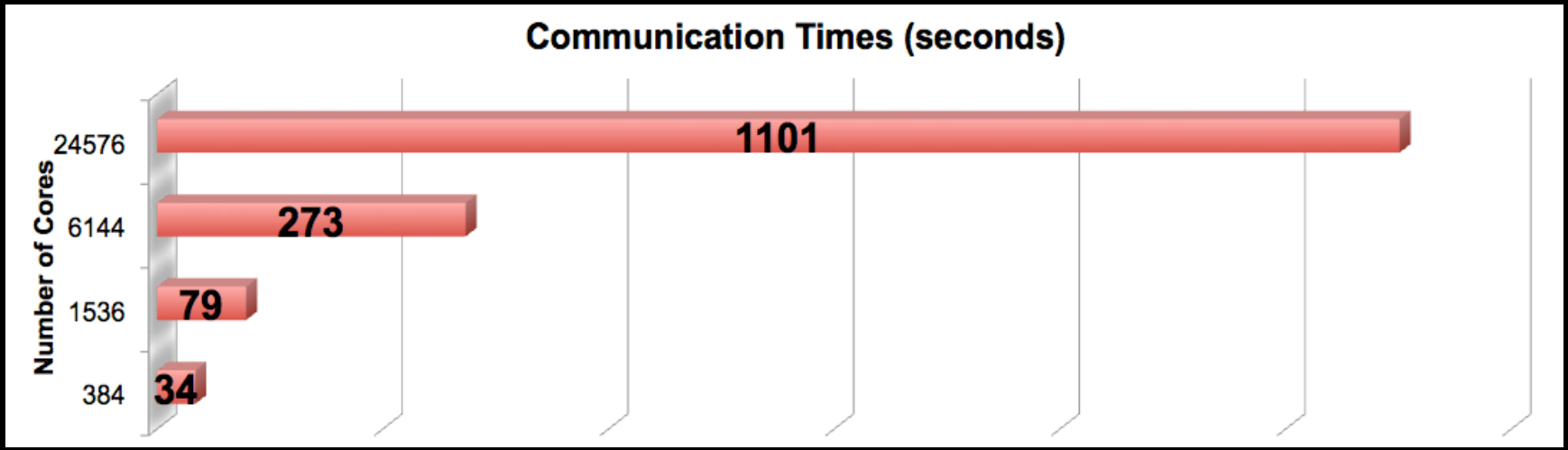


GEOS/FV^3 Weak Scaling

SCIENCE MISSION DIRECTORATE

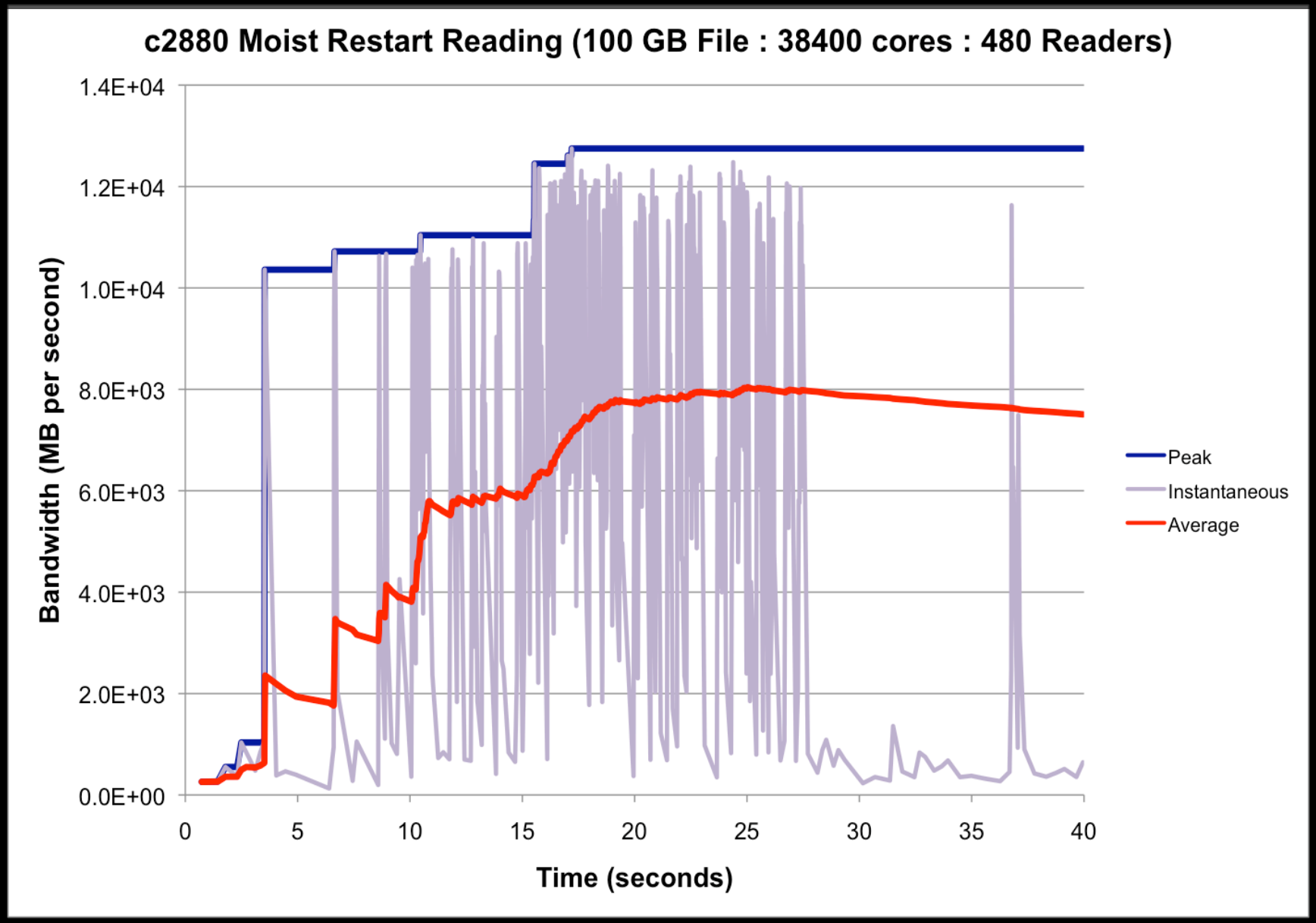


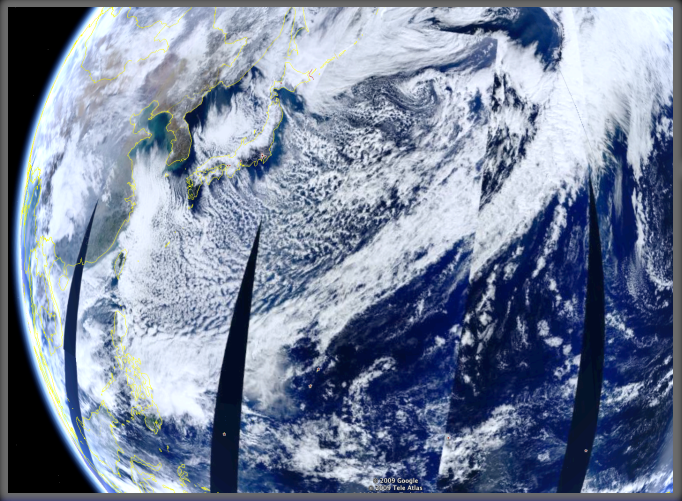




GEOS I/O Scaling

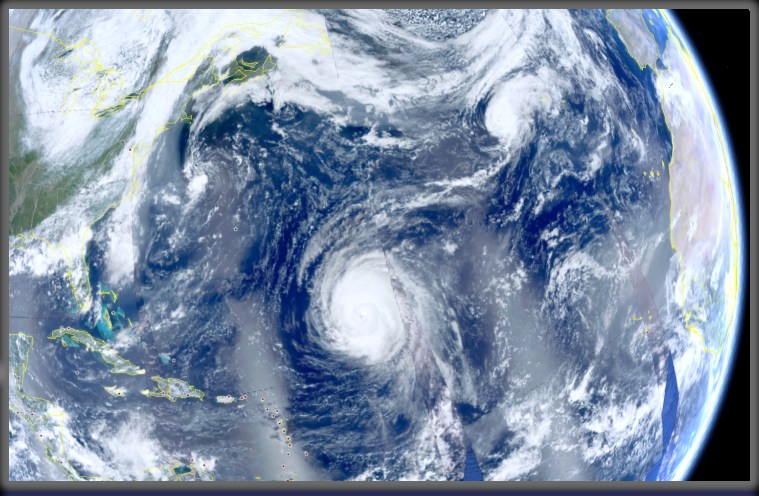
Serial Read at 200 MB/s took 30 minutes
A **48x** Improvement !





NH Winter

NH Summer



2008-12-31 21z
27-km GEOS DAS as IC
10-day Forecasts

2006-09-12 00z
54-km GEOS DAS as IC
10-day Forecasts

27-km
Hydrostatic

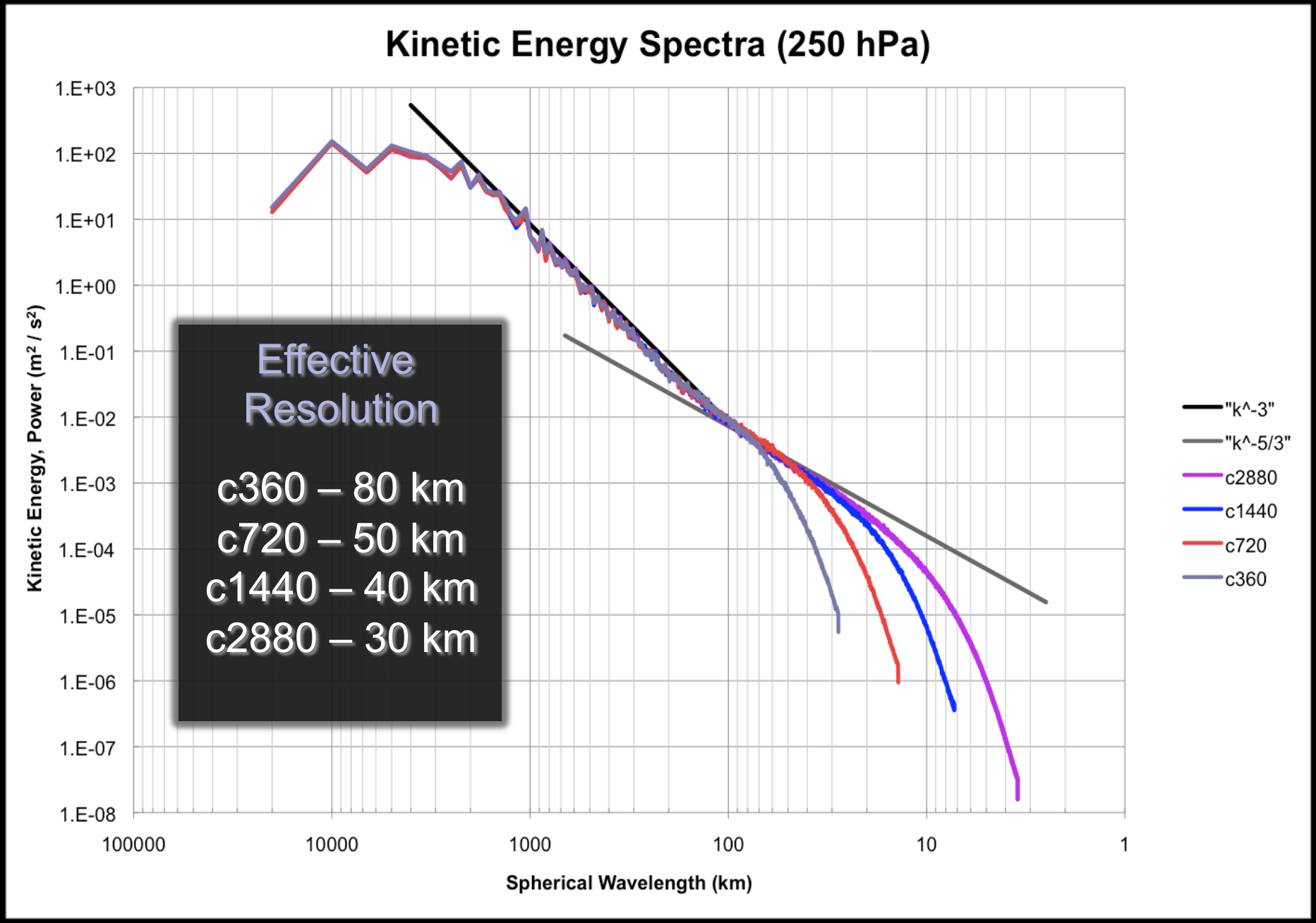
With RAS

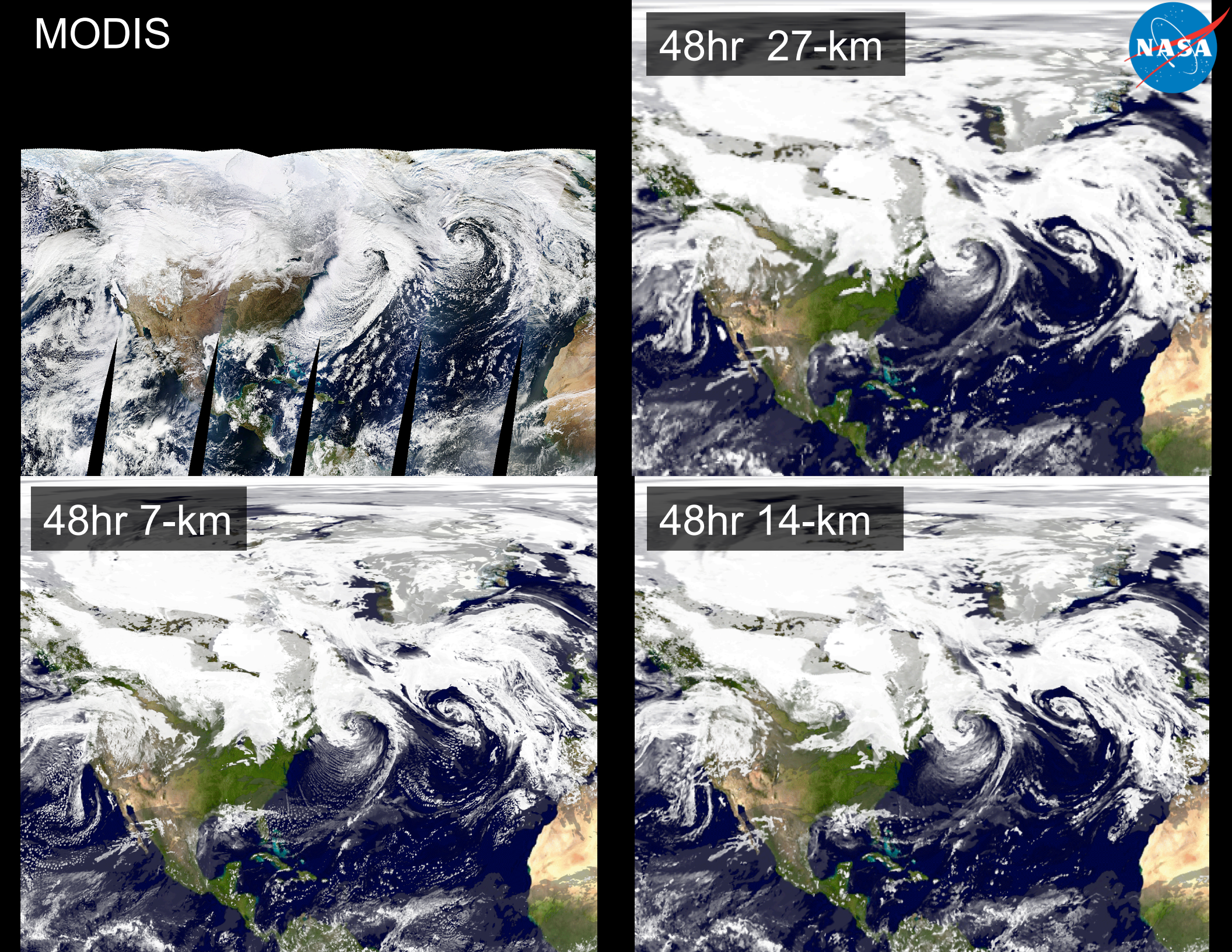
14-km
Hydrostatic &
Non-Hydrostatic

Without RAS

7-km & 3.5-km
Non-Hydrostatic

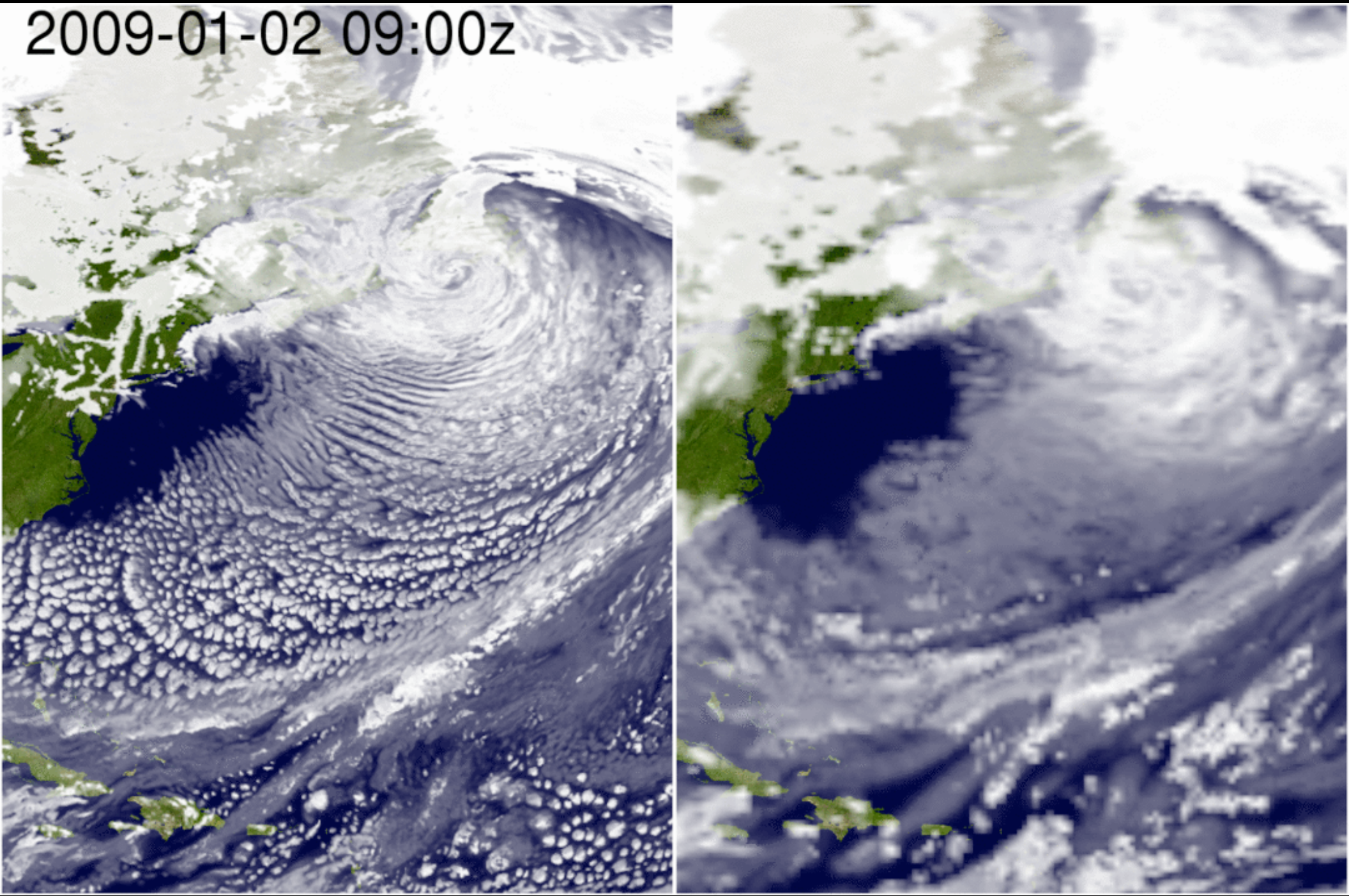
Kinetic Energy Spectra




MODIS
48hr 27-km
48hr 7-km
48hr 14-km

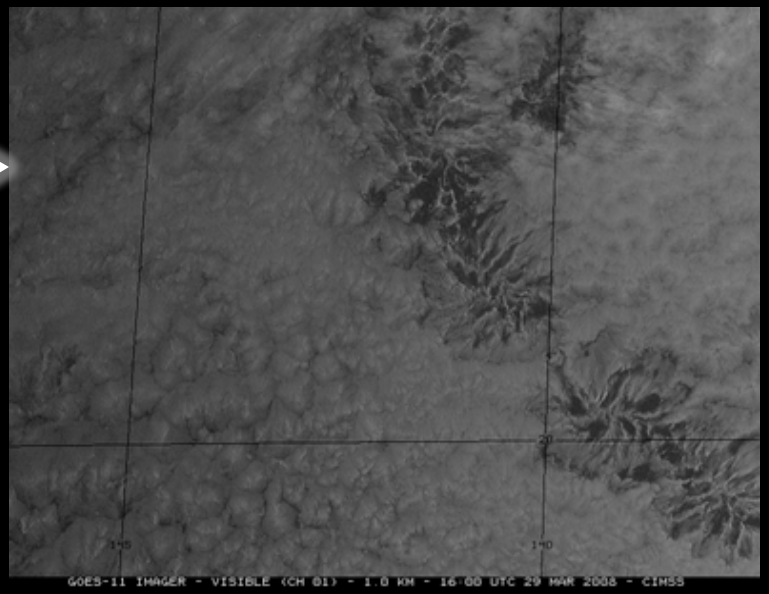
Cloud Streets Animation

7-km 10-day forecast 27-km



Pacific Marine Stratocumulus Clouds

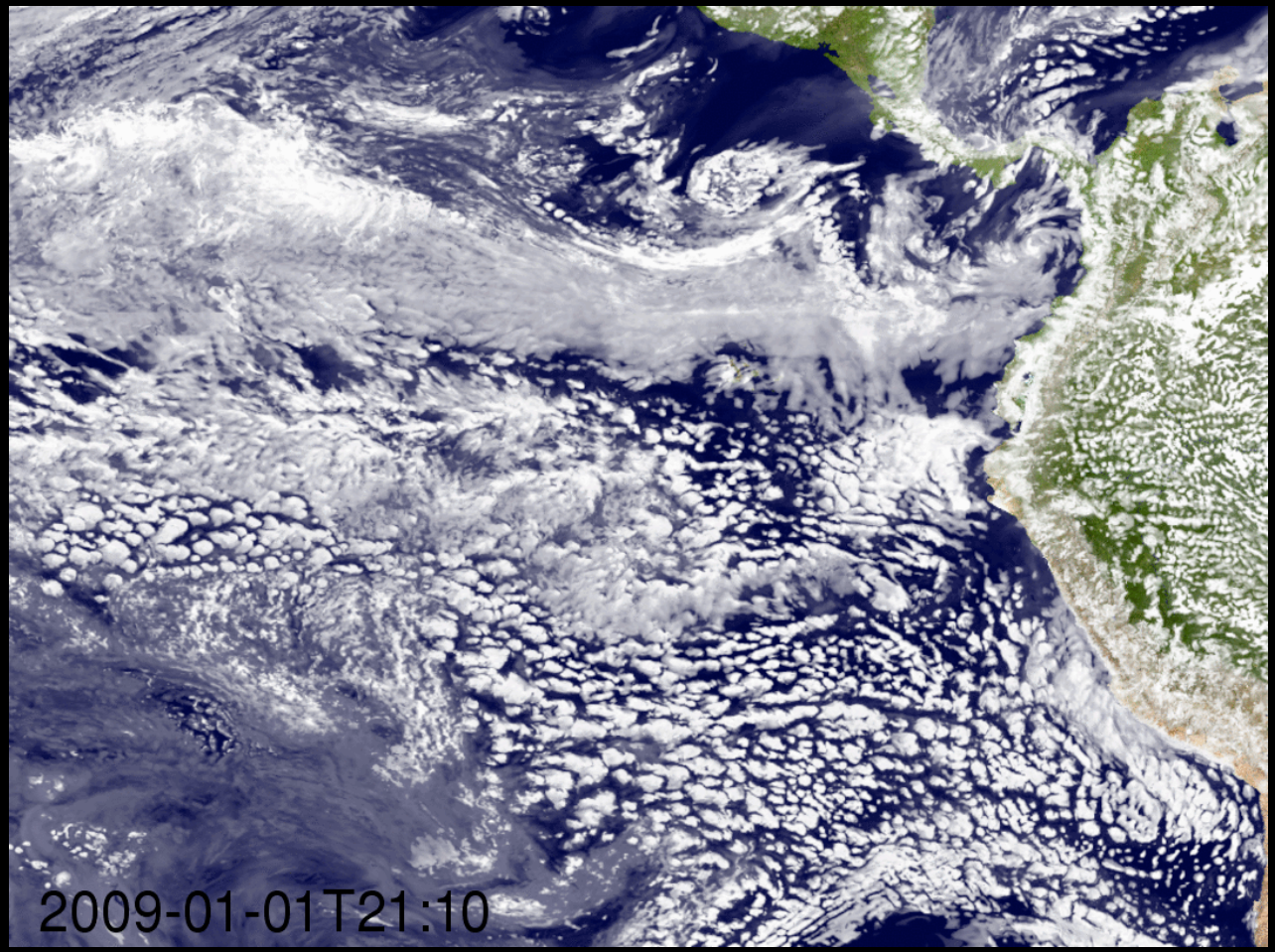
GOES-11



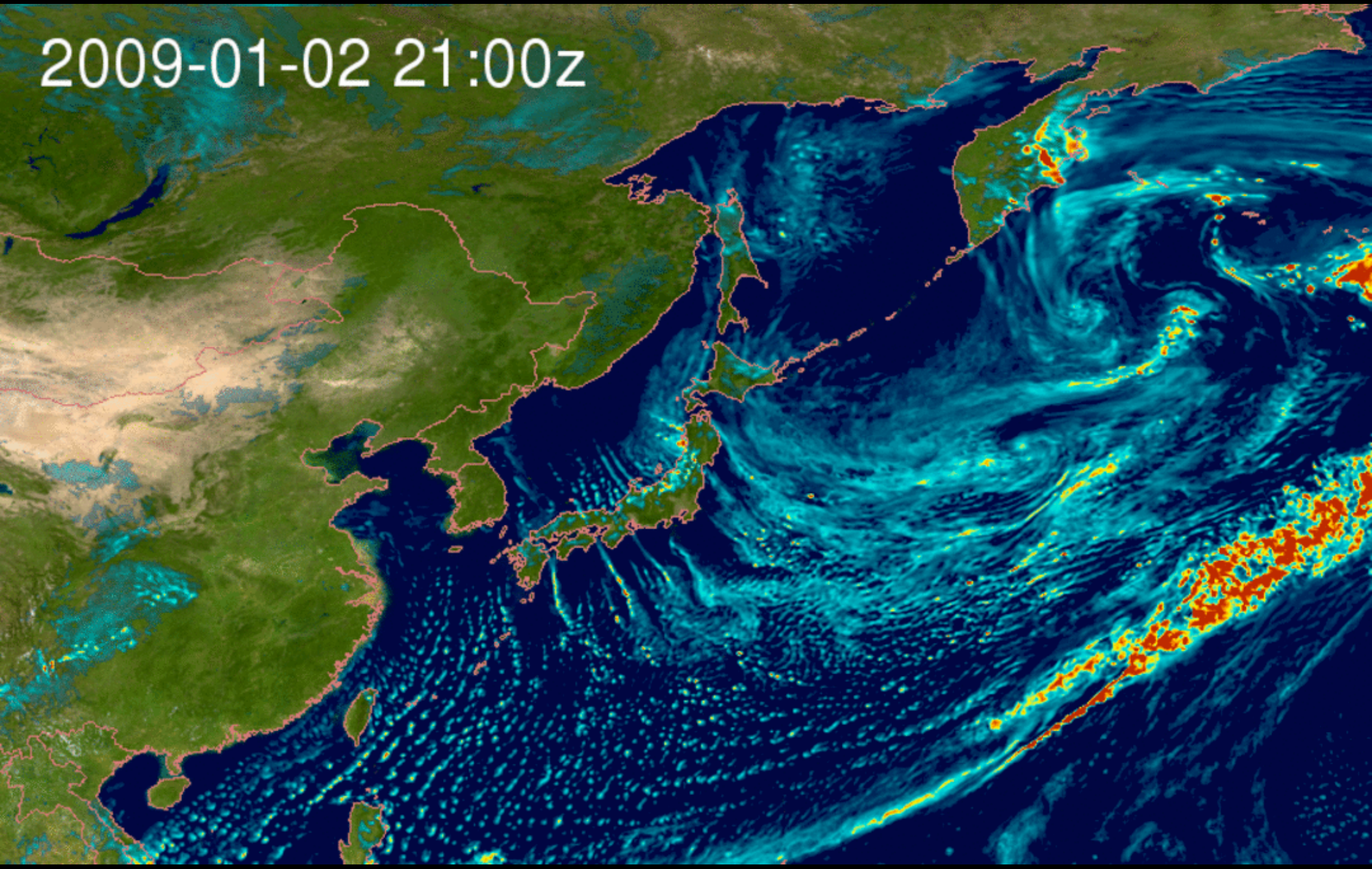
embedded
Gravity
Waves

3.5-km

1-day simulation



Orographic Influences on Precipitation



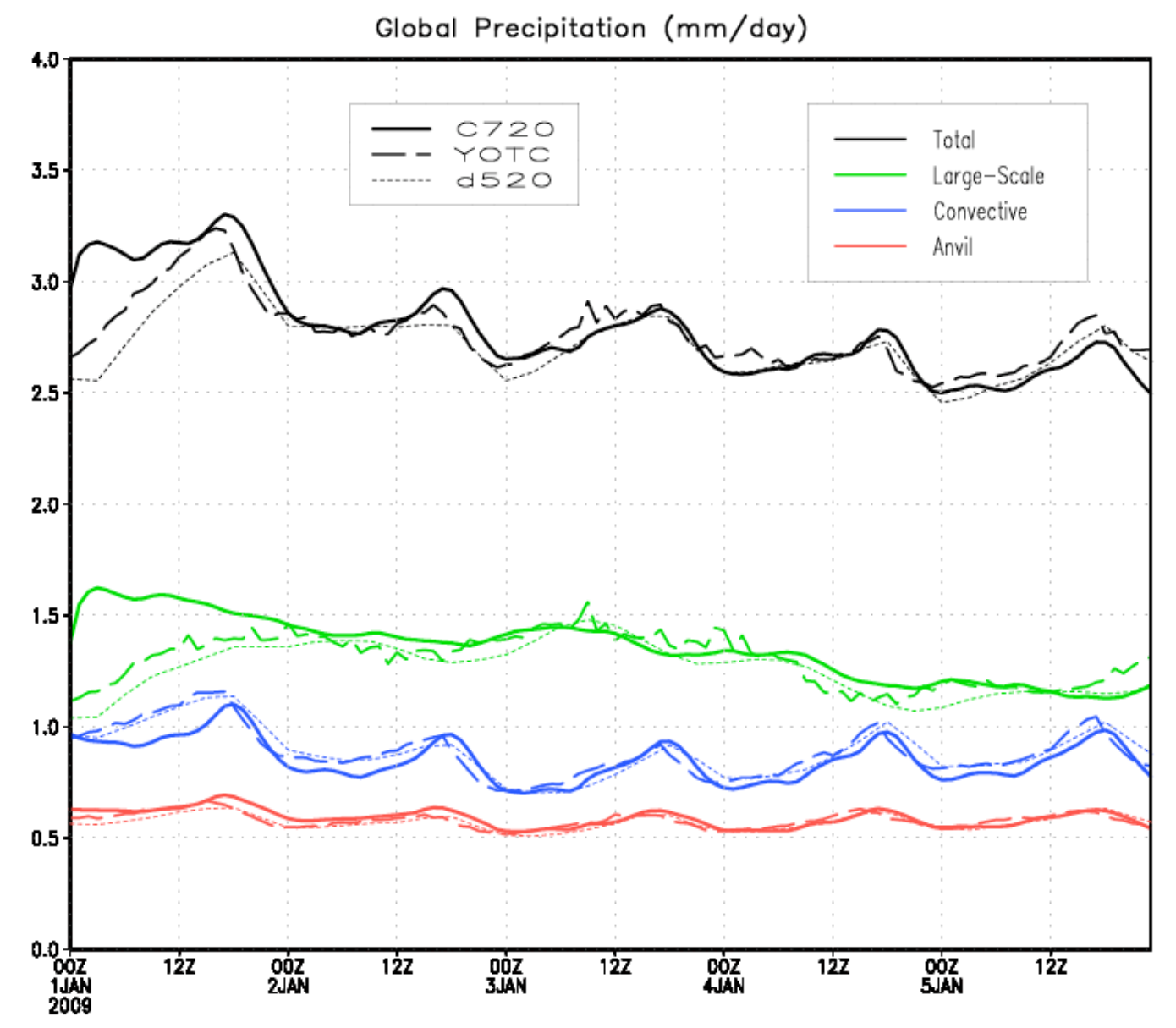
7-km

Total Precipitation (kg m^{-2} s^{-1})

0 0.0005 0.001

10-day Forecast

c720 Precipitation Global Average



Saharan Air Layer

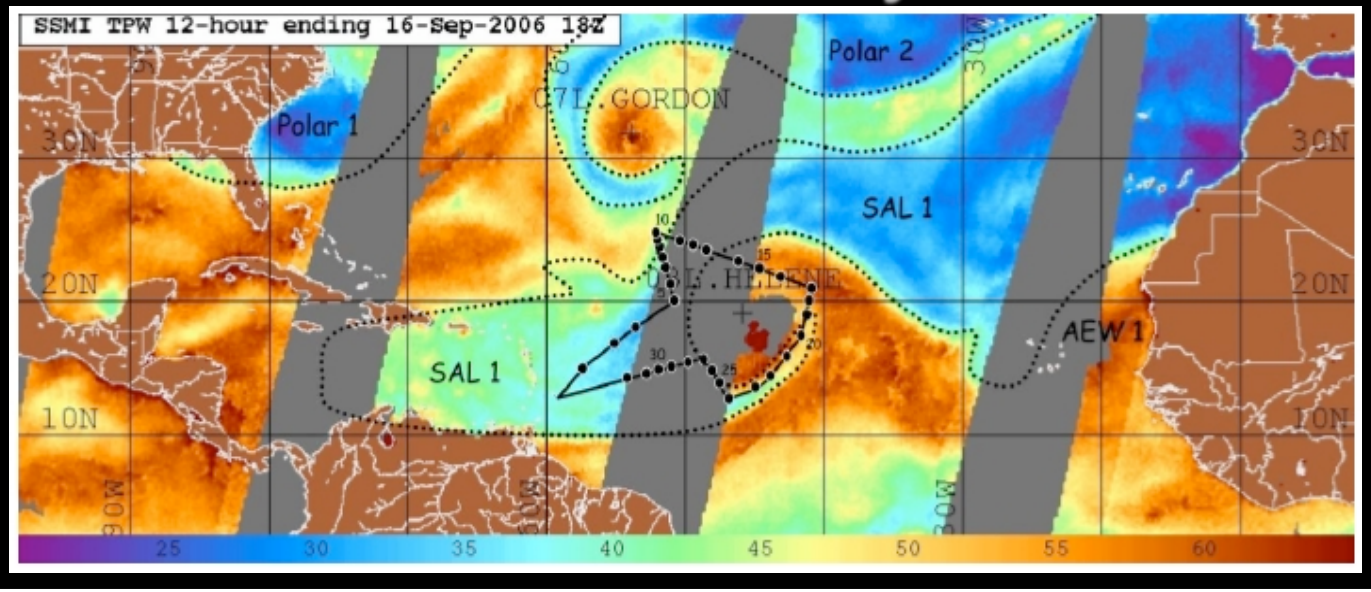
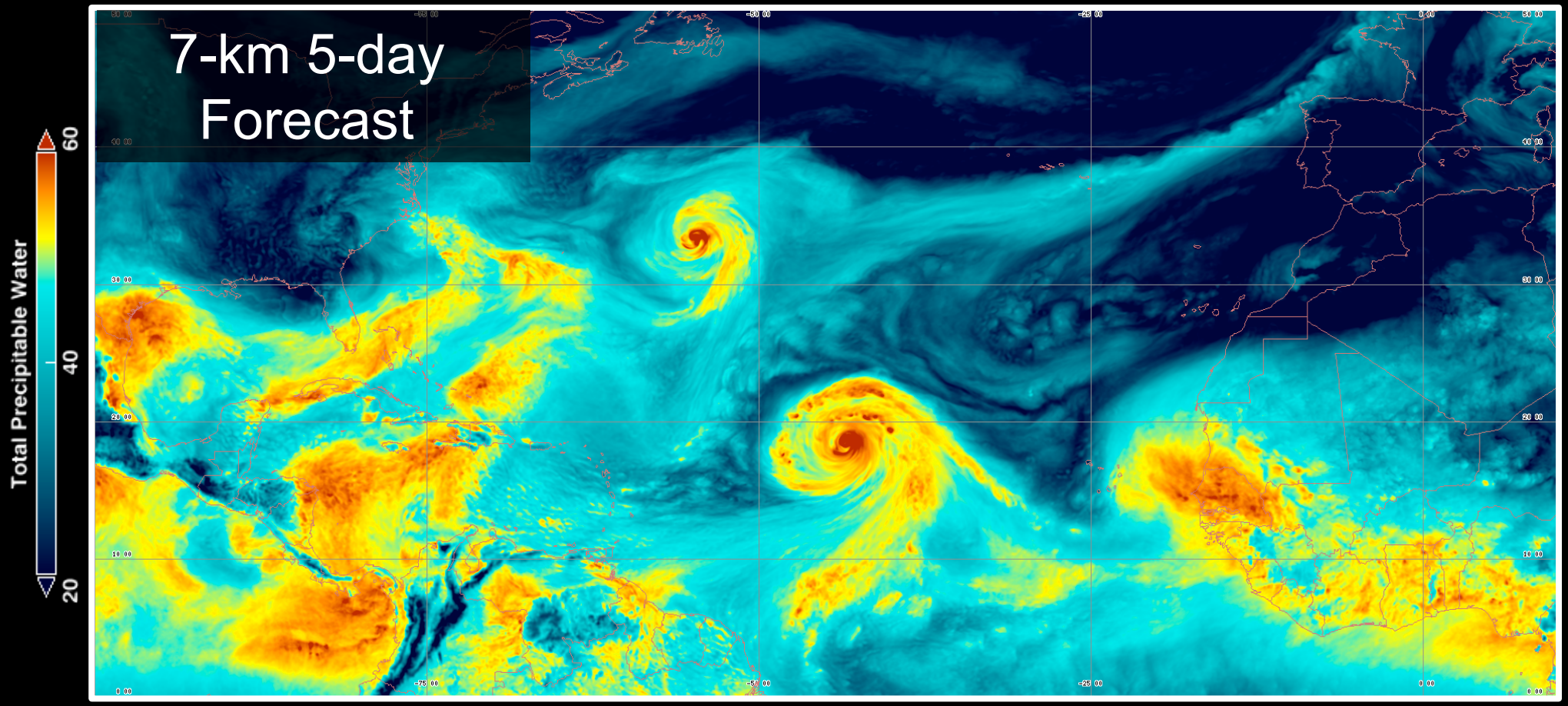


Image courtesy of NOAA/AOML
http://www.aoml.noaa.gov/hrd/Storm_pages/helene2006/20060916N1.html

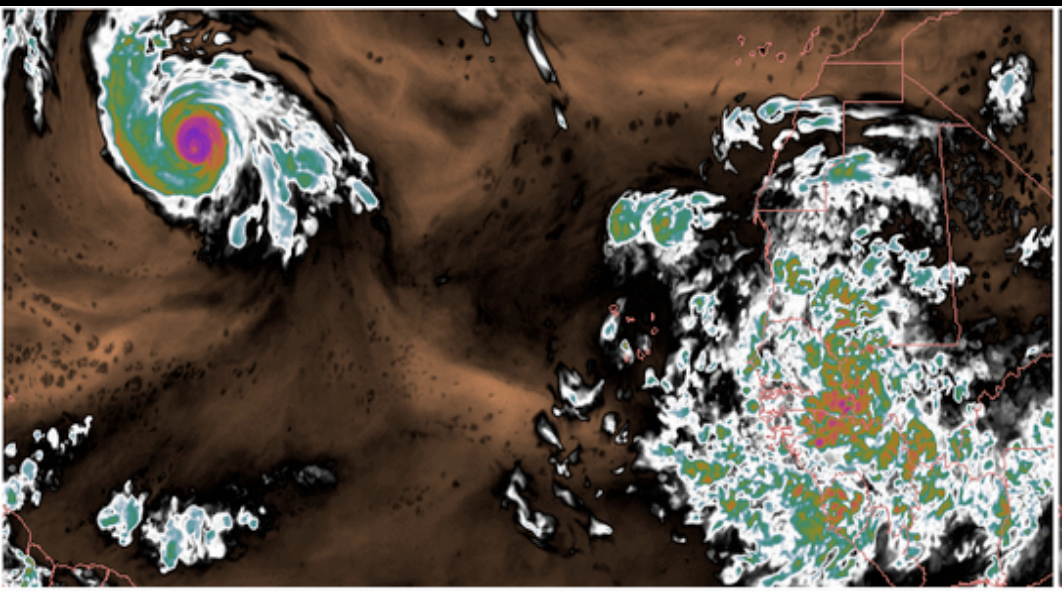


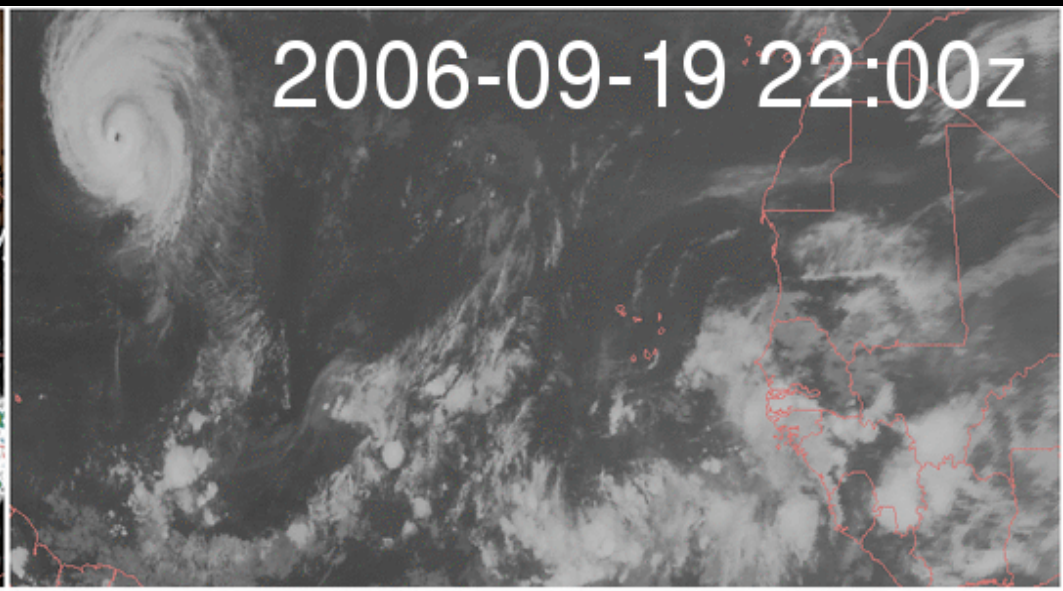
The Development of Hurricane Helene

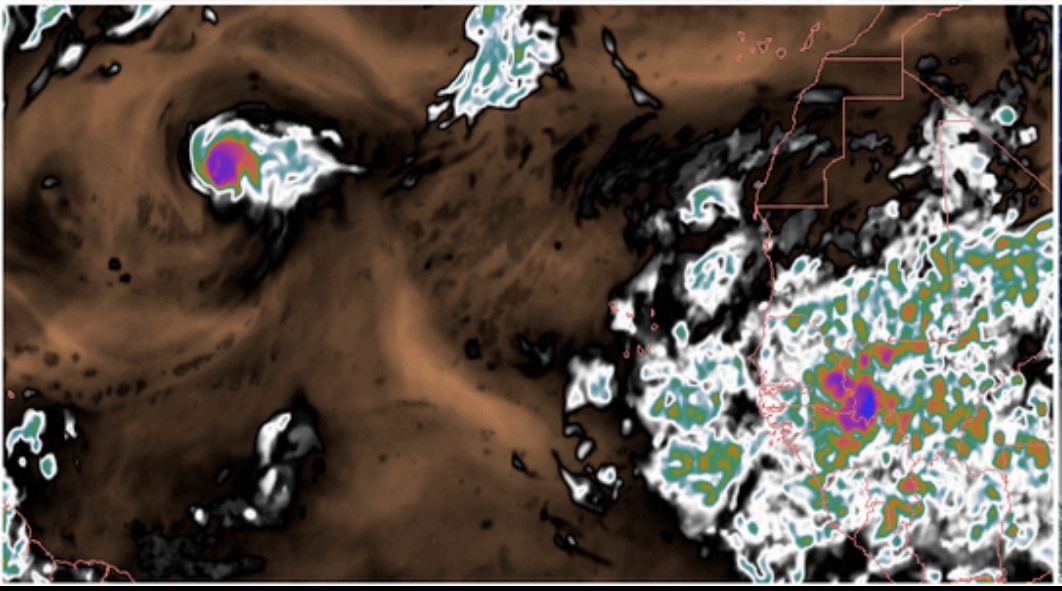
8-day Forecast

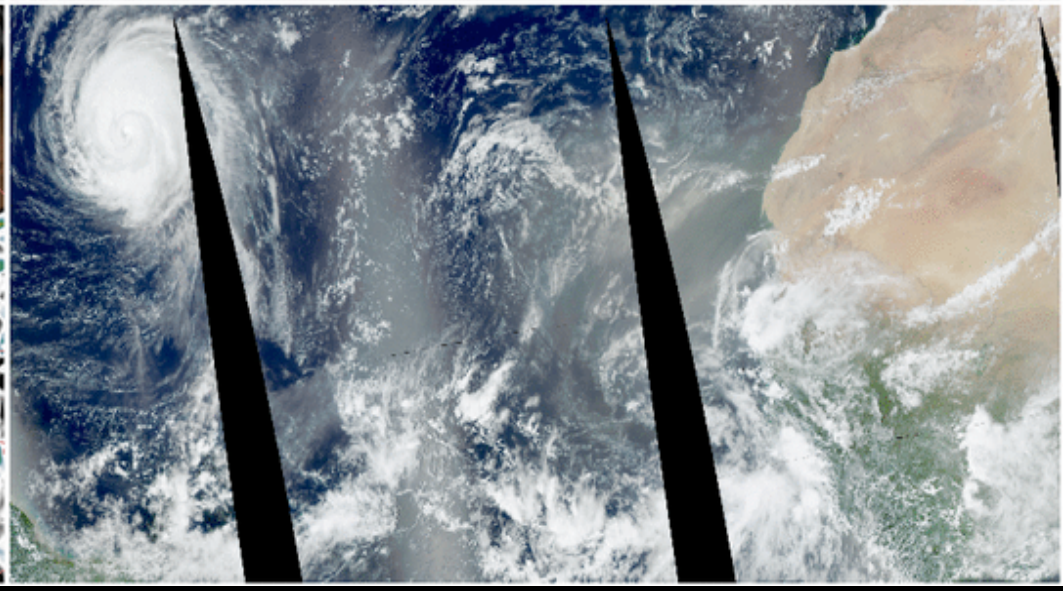
7-km

GCPC









14-km

MODIS

7-km Gordon 5-day Forecast Accuracy

Observed Position 31.9N 53.8W; 120-h Forecast 34.1N 54.1W

Track error: 130 nm

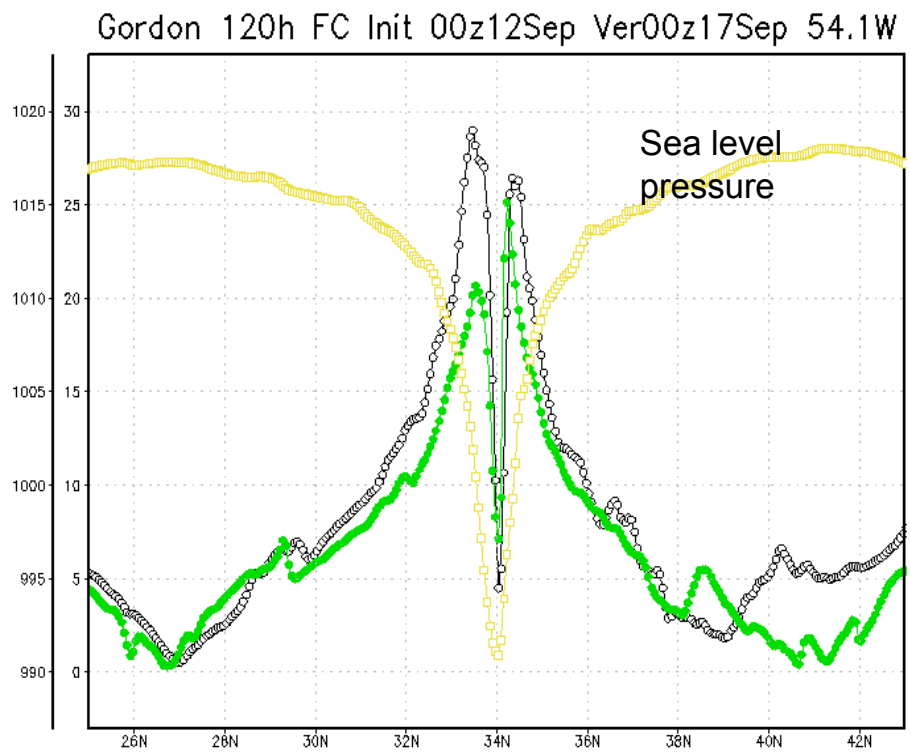
NHC official (consensus) error: 361 nm

Observed Center Pressure 987 hPa; 120-h Forecast 990 hPa

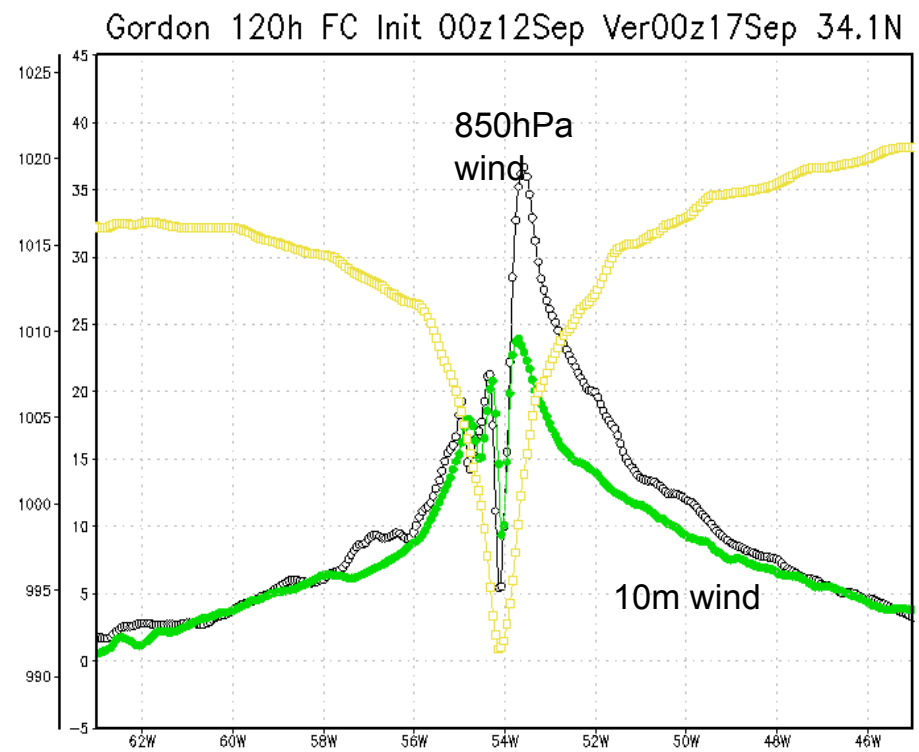
Observed Max wind 65 kt; 120-h Forecast 10m-850hPa 50-72 kt

NHC Official intensity (consensus) error: 21 kt

North-South Cross Section



East-West Cross Section



7-km Helene 5-day Forecast Accuracy

Observed Position 19.4N 47.1W; 120-h Forecast 18.9N 43.7W

Track error: 195 nm

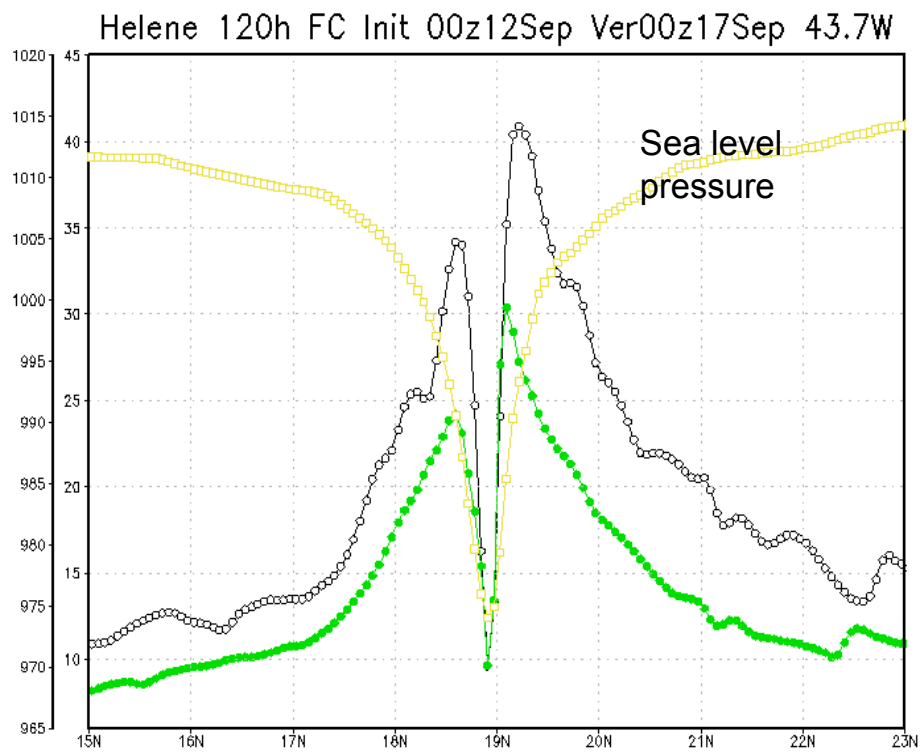
NHC official track (consensus) error: 192 nm

Observed Center Pressure 983 hPa; 120-h Forecast 970 hPa

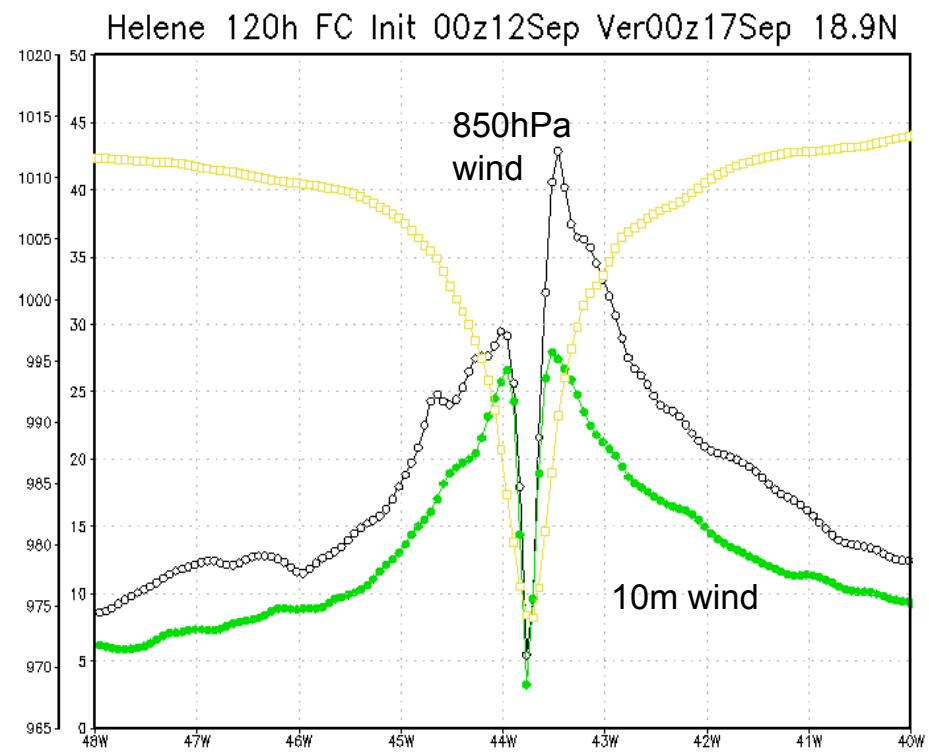
Observed Max wind 70 kt; 120-h Forecast 10m-850hPa 60-85 kt

NHC official intensity (consensus) error: 29 kt

North-South Cross Section



East-West Cross Section

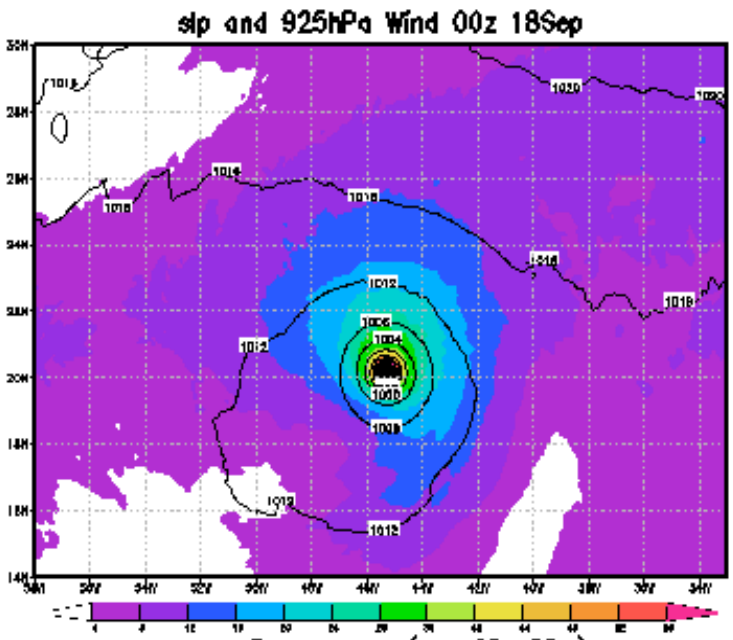


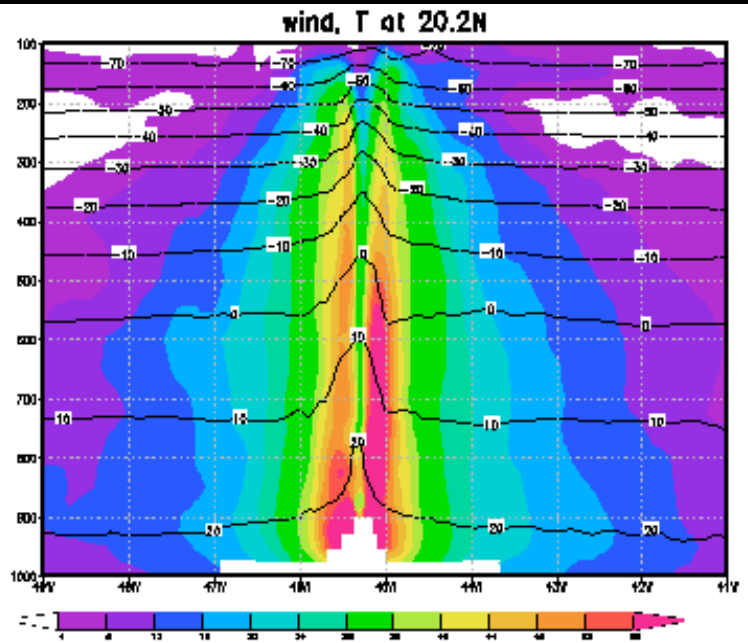
7-km Helene 6-day Forecast

Verification 00z 18 September

Horizontal and vertical structure

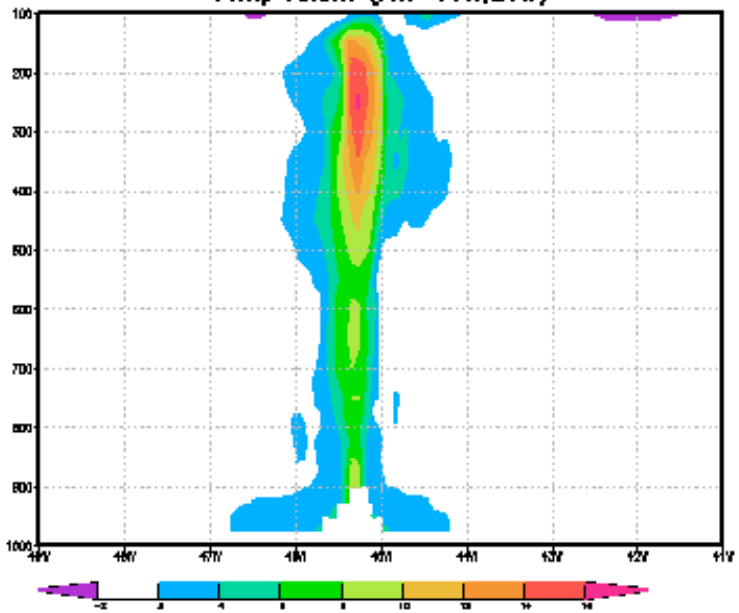
Slp & 925 hPa Wind

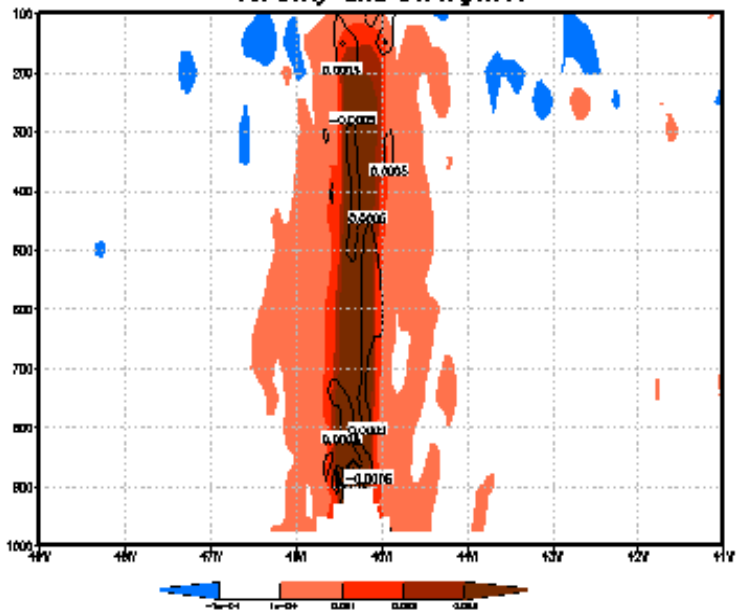




Wind & Temp

Temp Anom

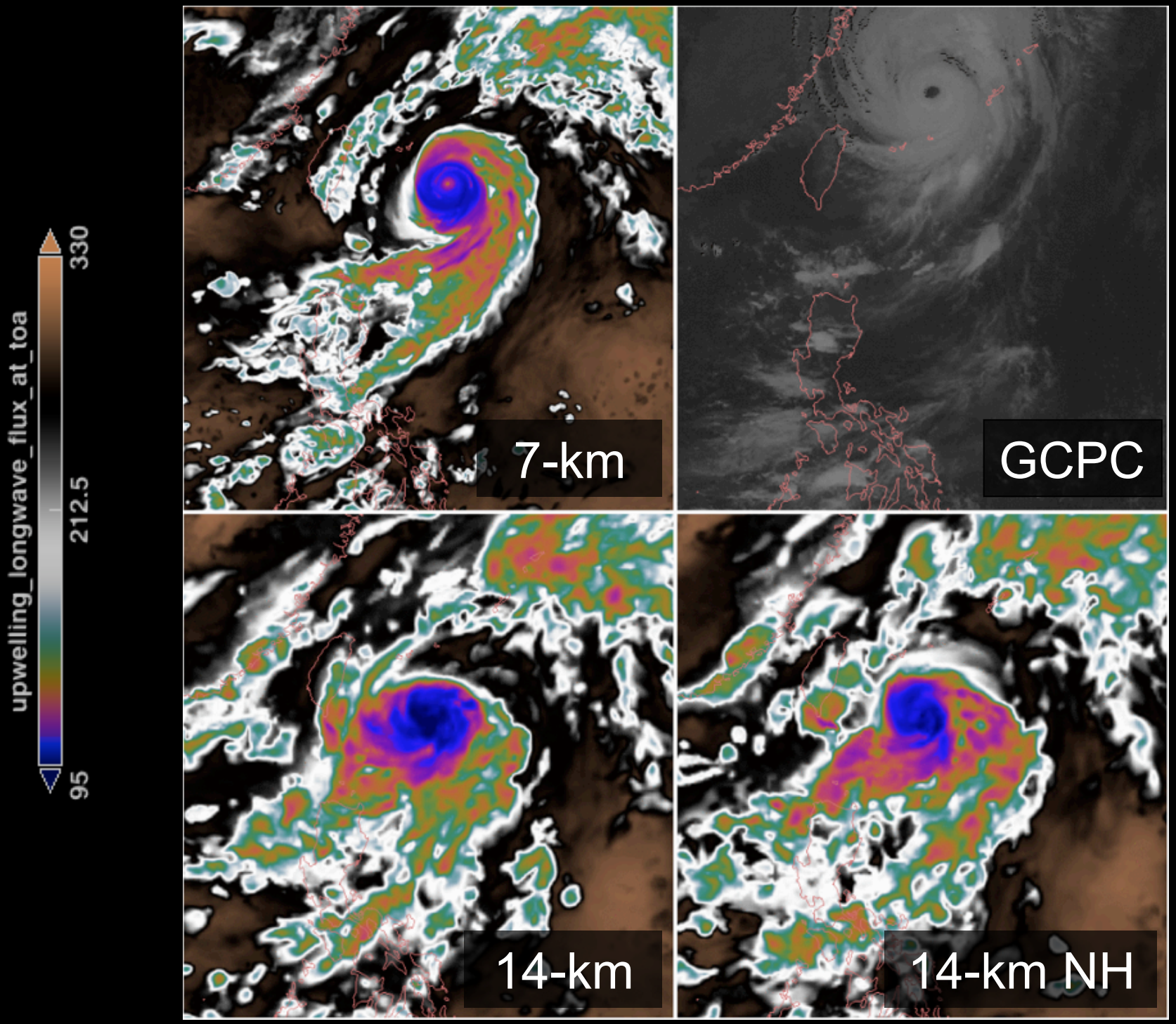




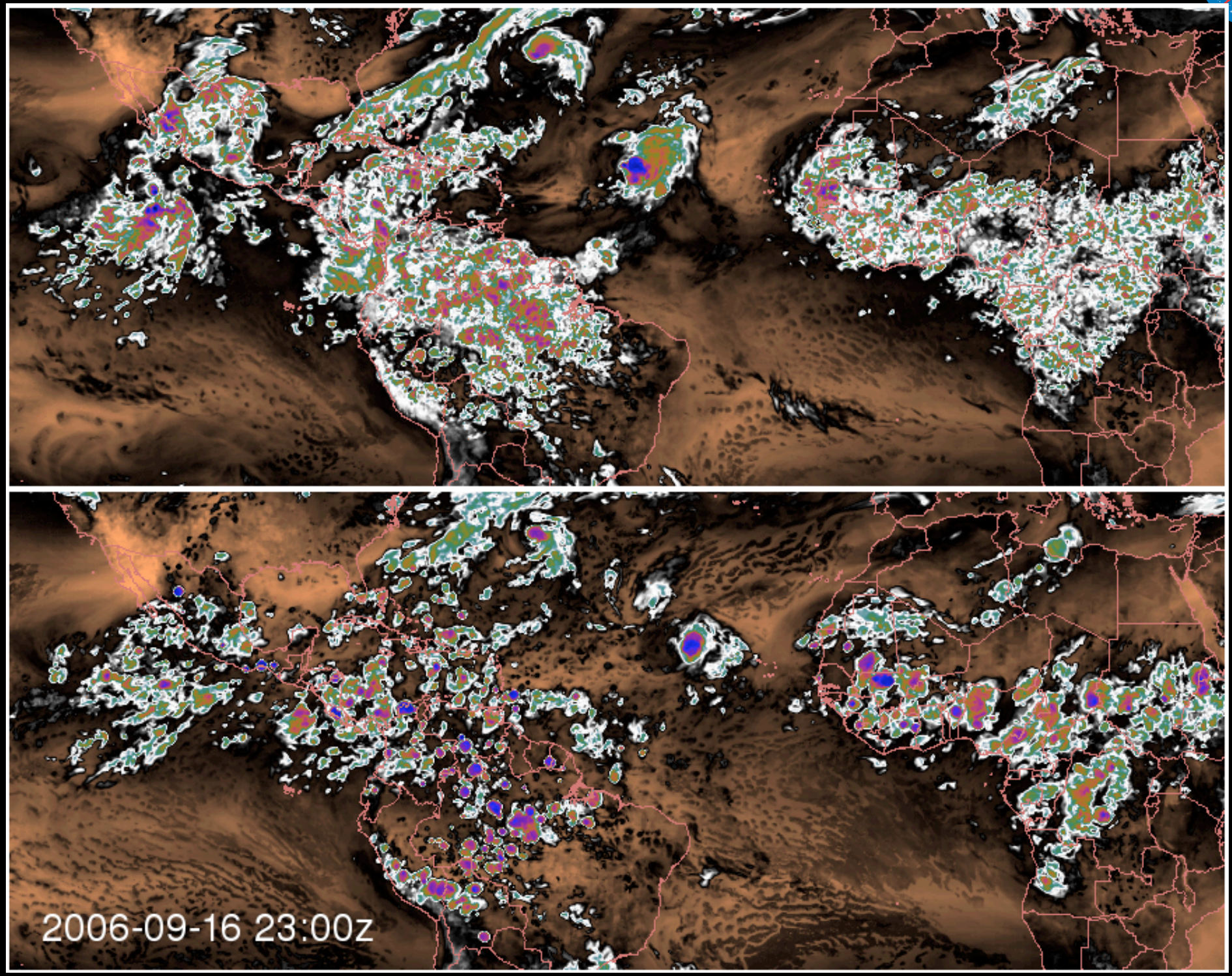
Vort & Div

The Eye-Wall of Typhoon Luis

5-day Forecast

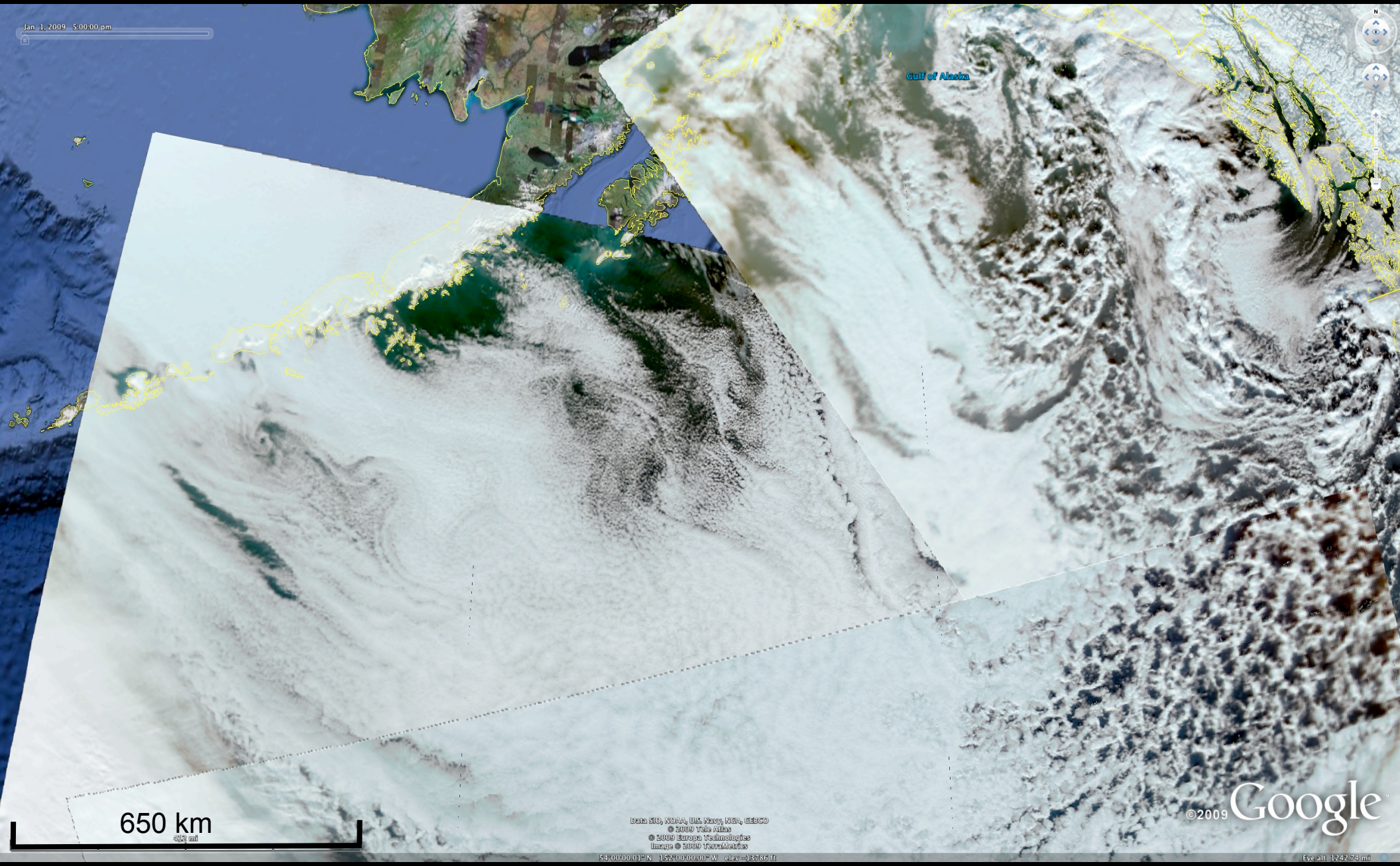


14-km Disabling Convective Parameterization



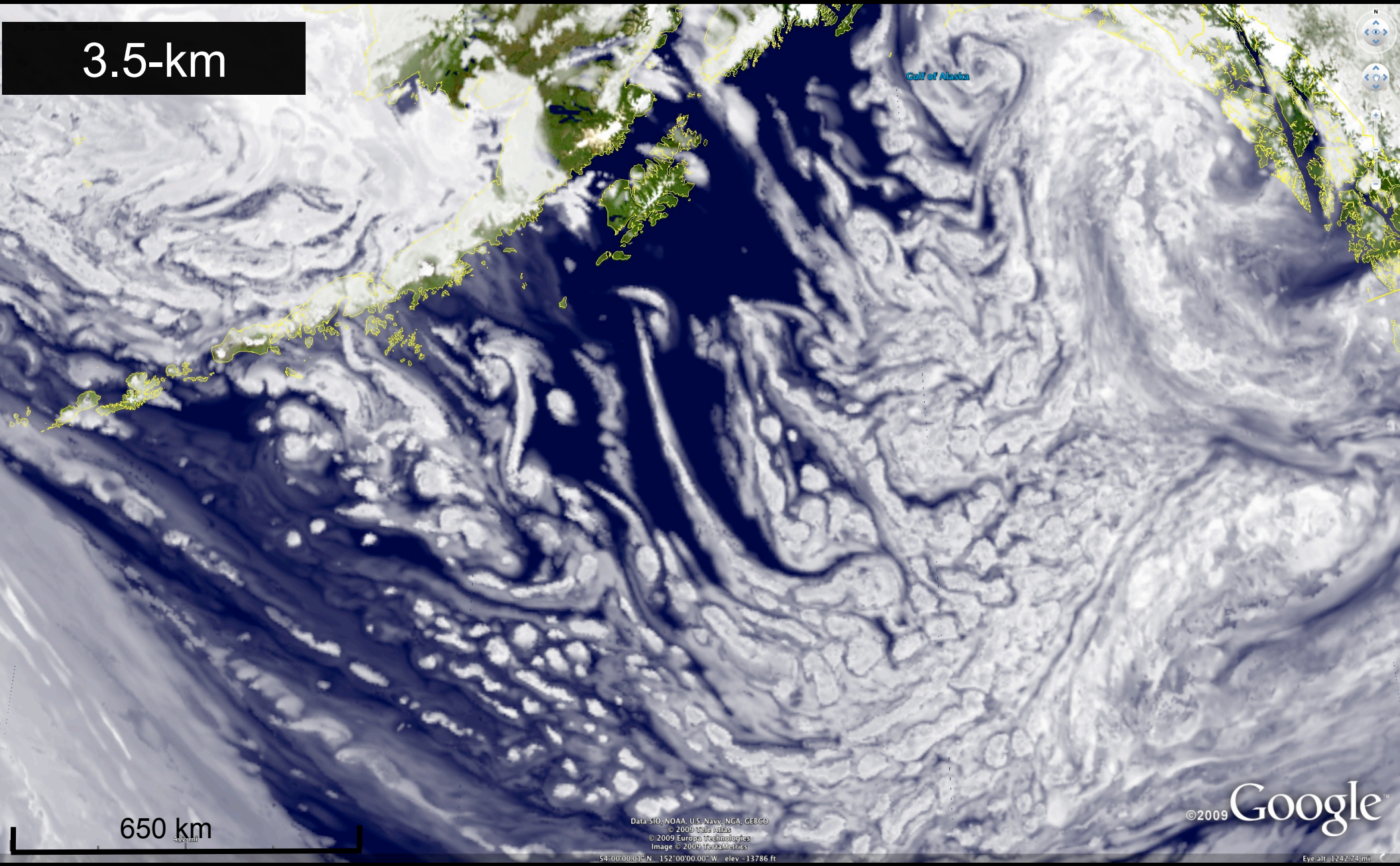
von Karman Vortex Streets

MODIS – January 1, 2009



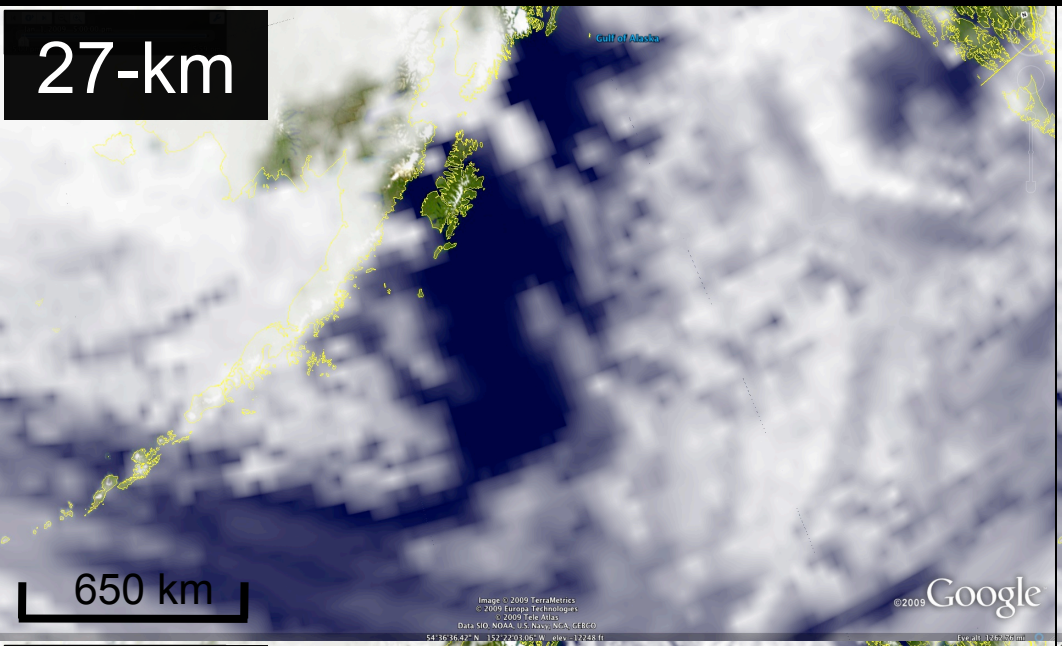
von Karman Vortex Streets

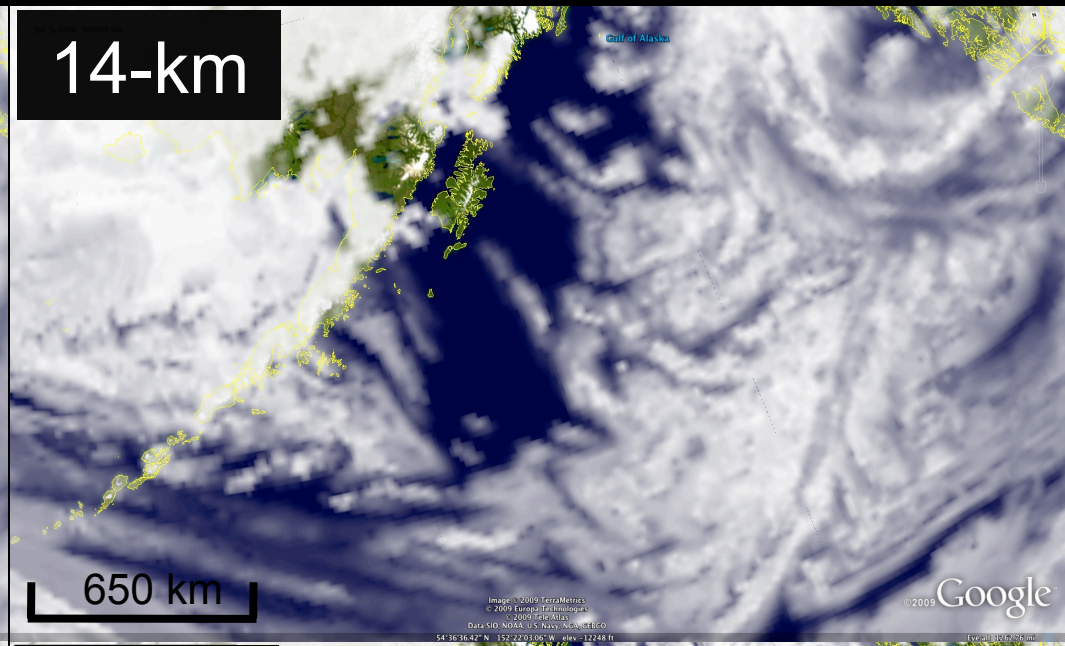
24-hr Forecast

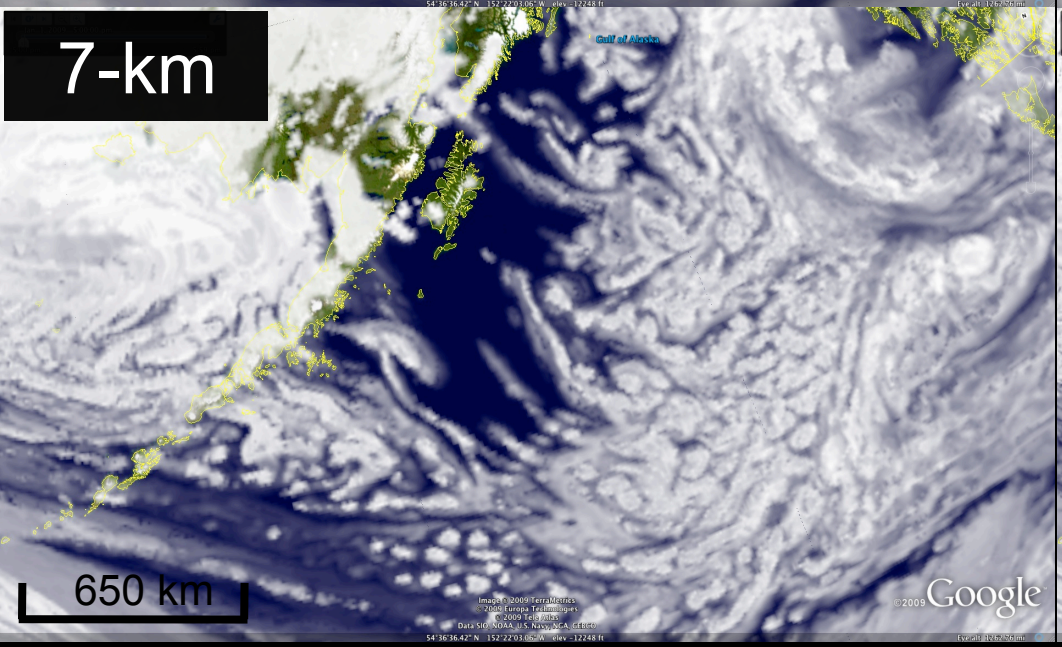


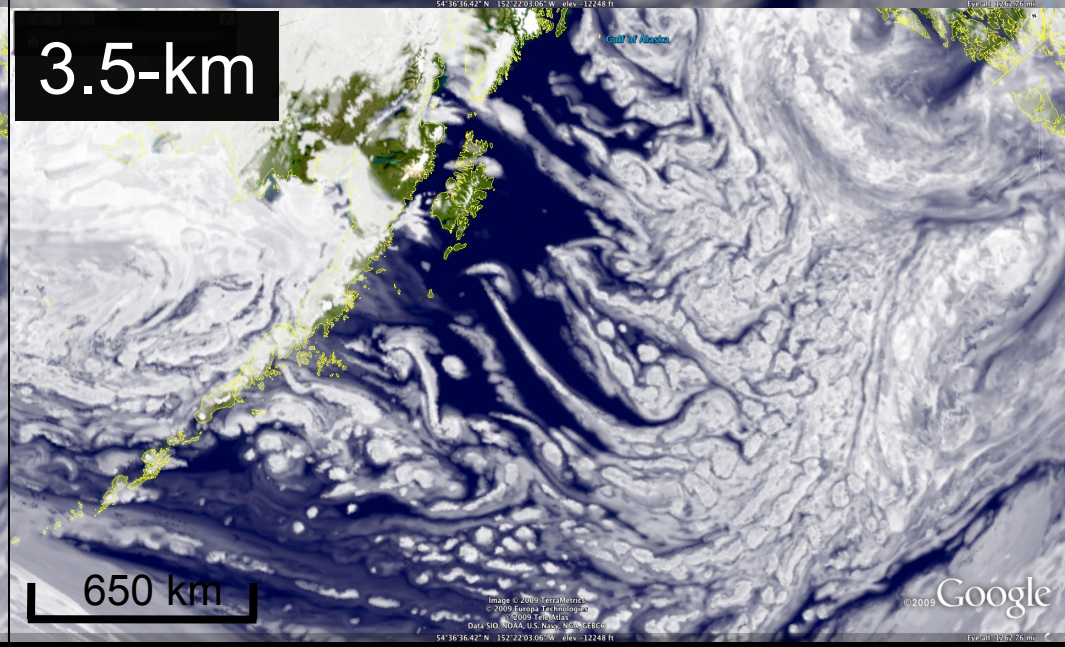
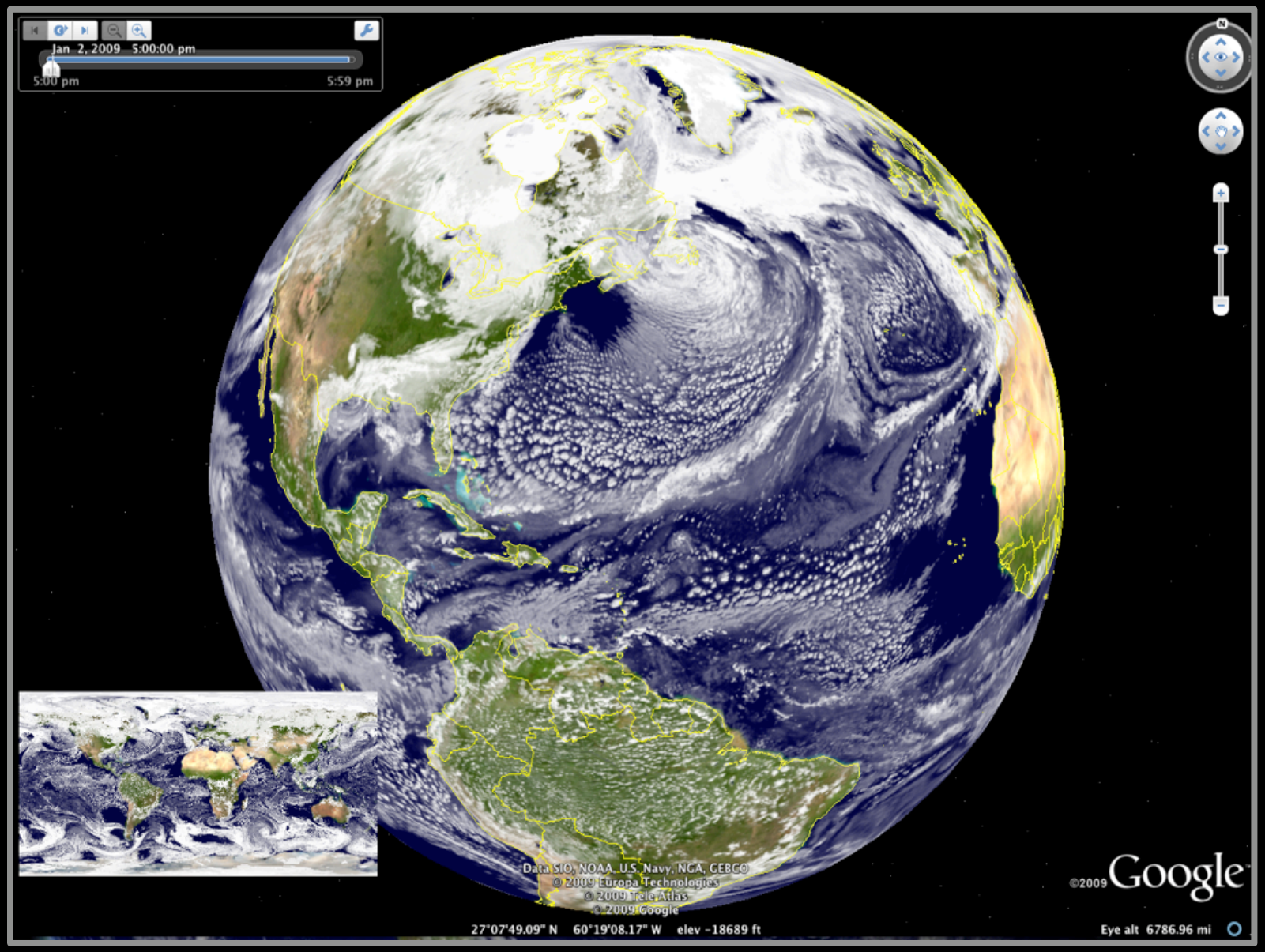
von Karman Vortex Streets

24-hr Forecast









Google Earth