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NATIONAL INSTITUTE FOR COMPUTATIONAL SCIENCES
NICS

# An International, Dedicated High-End Computing Project to Revolutionize Climate Modeling

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# Collaborators

| | |
|---|---|
| COLA | Center for Ocean-Land-Atmosphere Studies, Calverton, MD, USA |
| ECMWF | European Center for Medium-Range Weather Forecasts, Reading, England |
| JAMSTEC | Japan Agency for Marine-Earth Science and Technology, Tokyo, Japan |
| U of Tokyo | University of Tokyo, Japan |
| NICS | National Institute for Computational Sciences, University of Tennessee, Knoxville, TN, USA |

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# Project objectives

**Use *dedicated* HPC resources – Cray XT4 (Athena) at NICS to**

- **Simulate the mean climate, including all its moments and extremes, at unprecedented high horizontal resolution in an (uncoupled) atmospheric general circulation model**
  - **Forecast intraseasonal climate variability, without parameterization of important physical processes such as cumulus parameterization**
    - **Simulate the effect of increased greenhouse gases on regional aspects of climate, such as precipitation and storminess, and assess the impact of resolution in time-slice mode on depicting the climate change signal**

**Codes**

| | |
|---|---|
| **NICAM (Japan)** | **Nonhydrostatic, Icosahedral, Atmospheric Model** |
| **IFS (Europe)** | **ECMWF Integrated Forecast System** |

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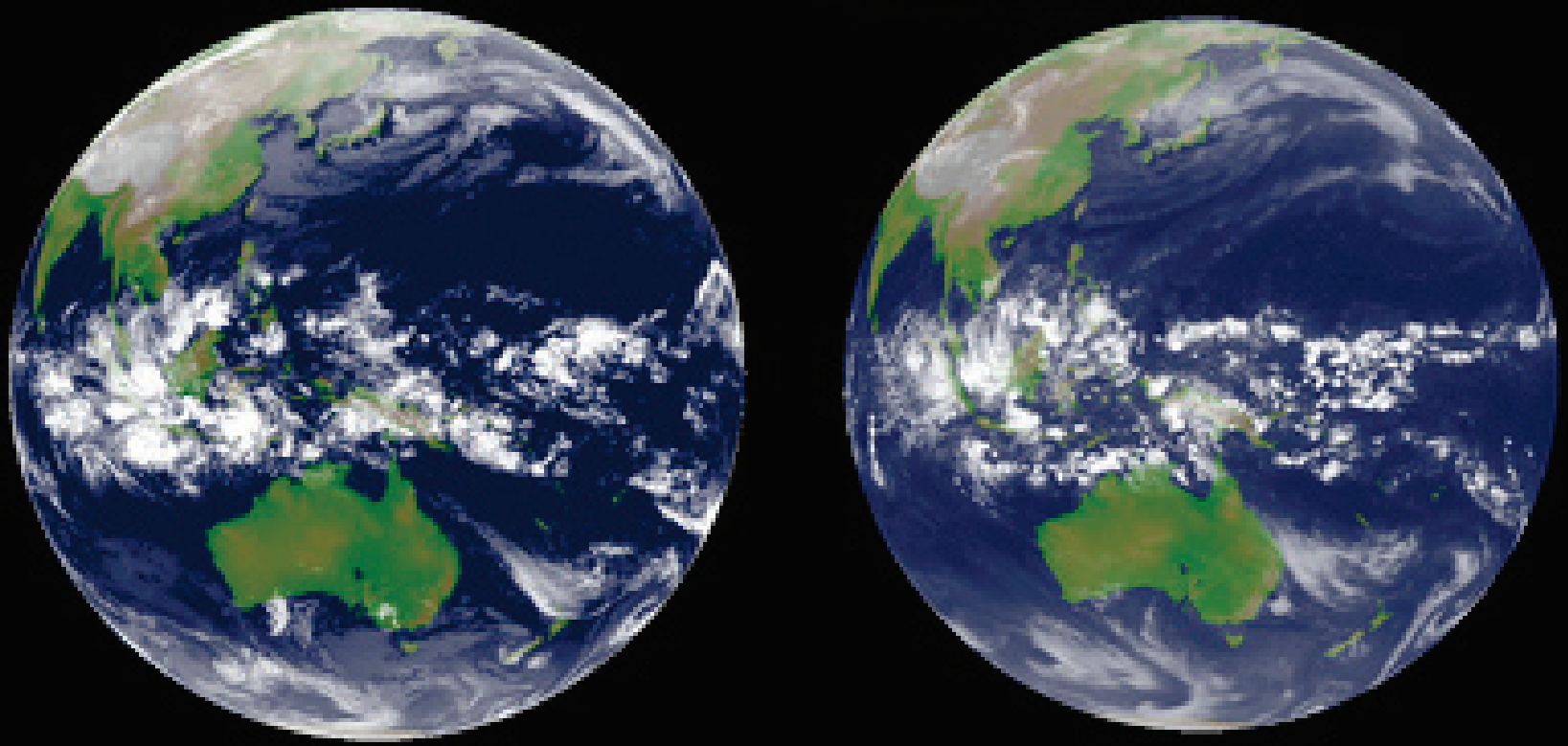
# NICAM

*Satellite Observation*

*Model Simulation*



The only **global** atmospheric **climate** model capable of resolving cloud systems

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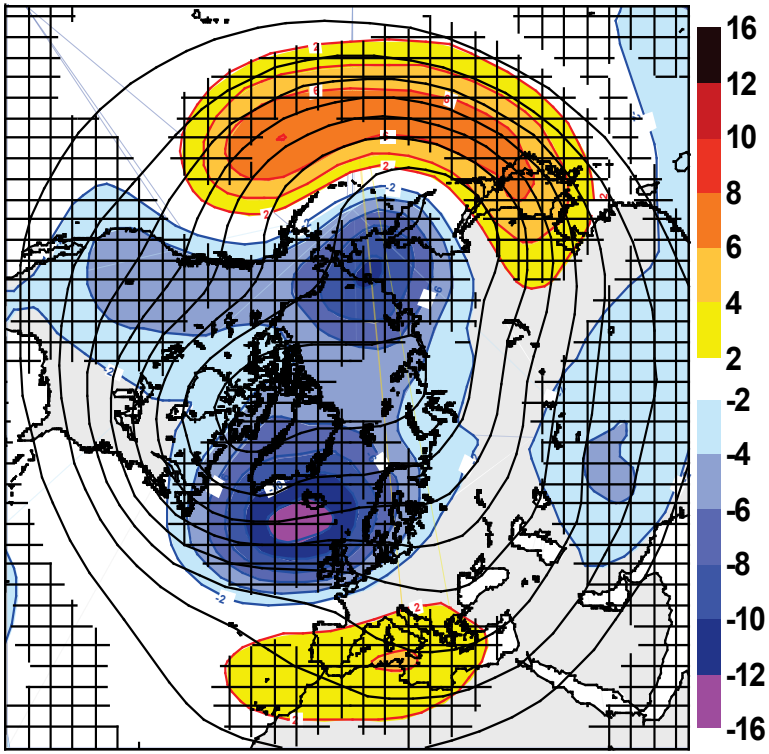
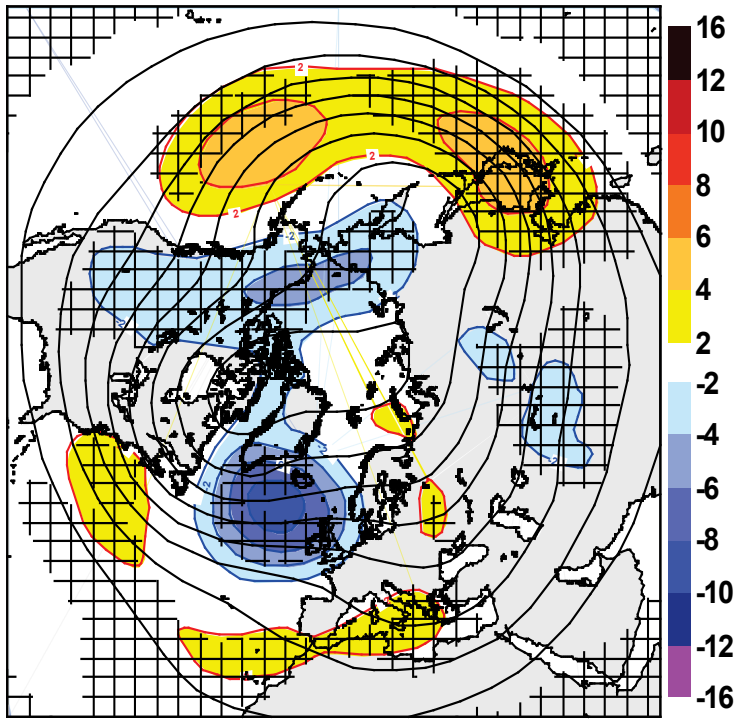
# IFS

## Numerical Weather Prediction Model being used for climate simulation

*200 km resolution*




*40 km resolution*




**Systematic error with respect to observations of geopotential height over North Pacific and North Atlantic viewed from above the North Pole**

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# Computational challenges

- General Circulation Models (GCMs) are both highly computing- and data-intensive applications
- GCMs have frequent I/O accesses, large memory requirements, and intensive data flow
- Climate science experiments generate large output that requires long-term storage

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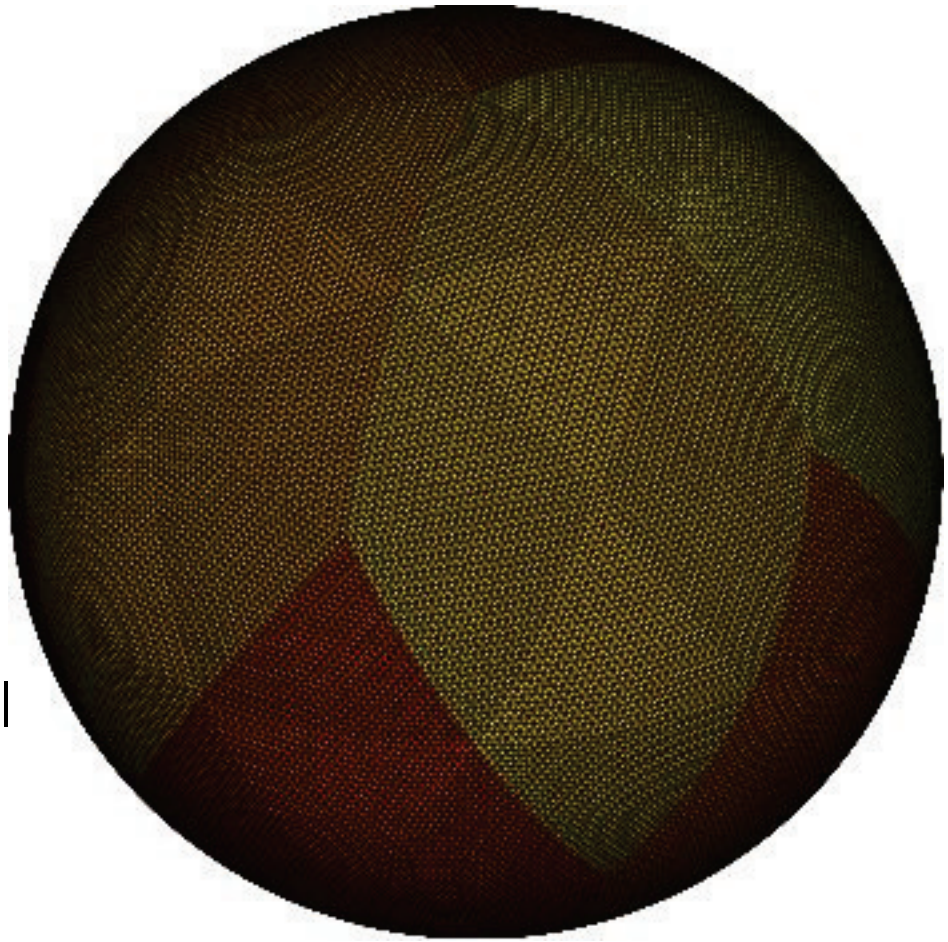
# Computational challenges NICAM

- 2D domain decomposition on an icosahedral grid
- 10×211+2 grid points for 3.5 km resolution
- MPI parallelization
- Sustained performance, TFLOPS, memory, archival



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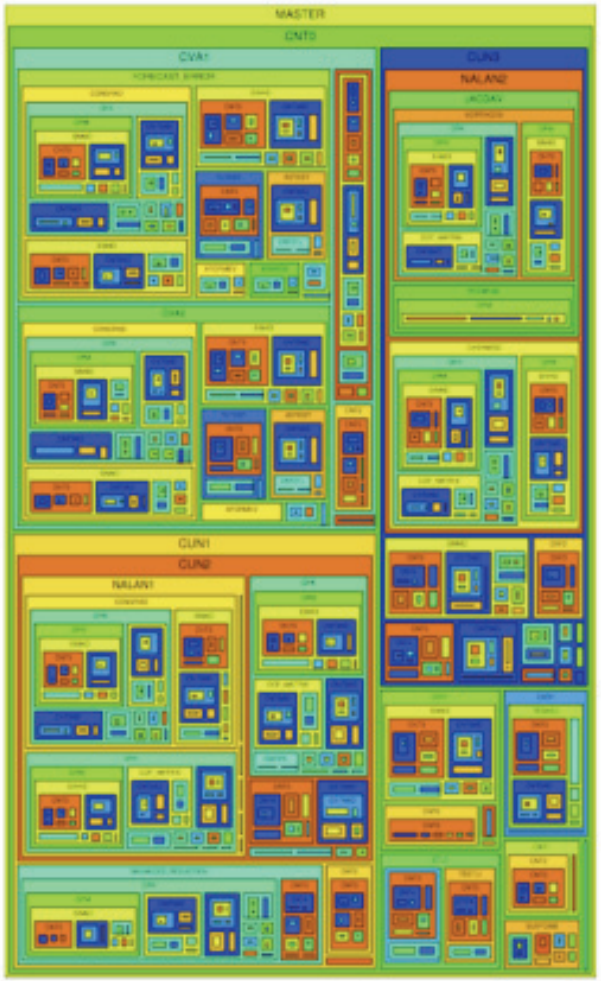
# Computational challenges IFS

## Calling Tree

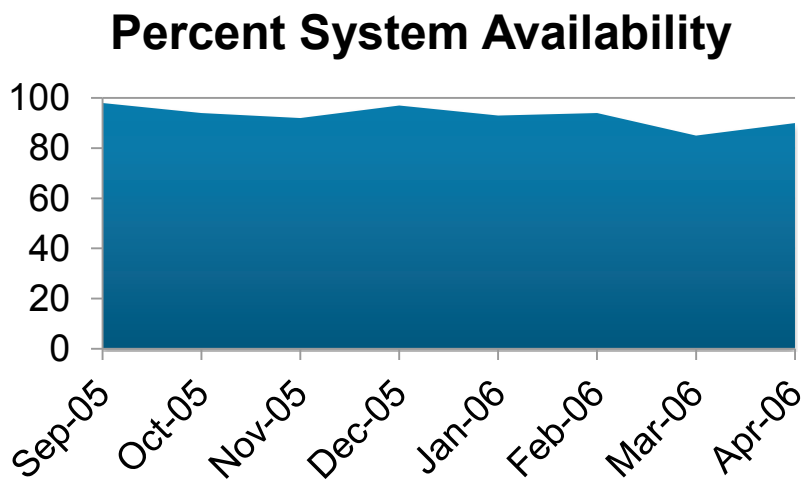



## Variable grid point decomposition

# Athena utilization

- Athena has been very reliable
- System utilization was ~95% for the 6 month period (includes scheduled and unscheduled downtime)
- The project used ~70M hours over 6 months on Athena, out of a total of ~78M hours available in the 6 months; 90% utilization by COLA

| | |
|---|---|
| Oct-09 | 98% |
| Nov-09 | 94% |
| Dec-09 | 92% |
| Jan-10 | 97% |
| Feb-10 | 93% |
| Mar-10 | 94% |



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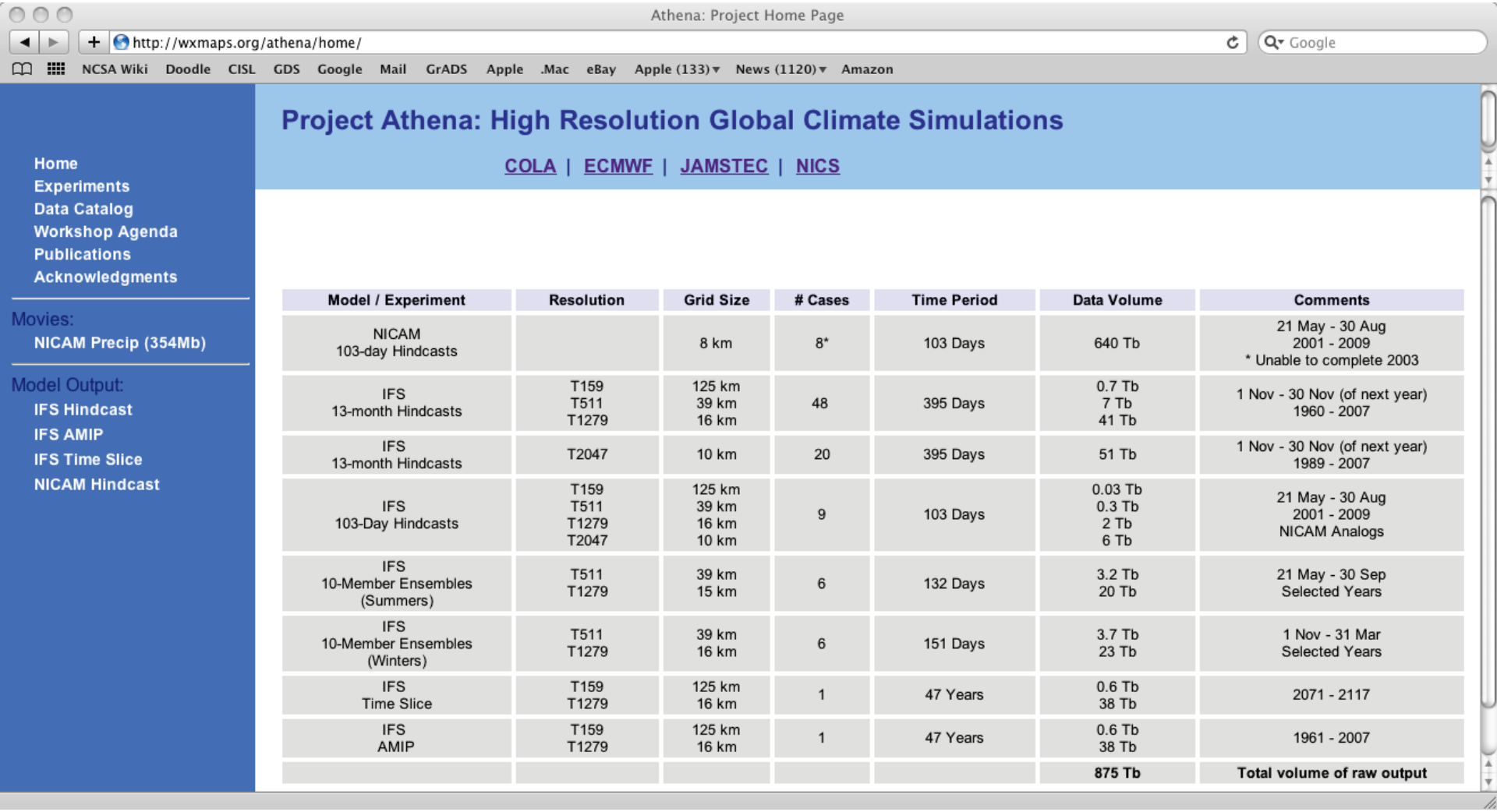
# Experiments catalog




| Model / Experiment | Resolution | Grid Size | # Cases | Time Period | Data Volume | Comments |
|---|---|---|---|---|---|---|
| NICAM<br>103-day Hindcasts | | 8 km | 8* | 103 Days | 640 Tb | 21 May - 30 Aug<br>2001 - 2009<br>* Unable to complete 2003 |
| IFS<br>13-month Hindcasts | T159<br>T511<br>T1279 | 125 km<br>39 km<br>16 km | 48 | 395 Days | 0.7 Tb<br>7 Tb<br>41 Tb | 1 Nov - 30 Nov (of next year)<br>1960 - 2007 |
| IFS<br>13-month Hindcasts | T2047 | 10 km | 20 | 395 Days | 51 Tb | 1 Nov - 30 Nov (of next year)<br>1989 - 2007 |
| IFS<br>103-Day Hindcasts | T159<br>T511<br>T1279<br>T2047 | 125 km<br>39 km<br>16 km<br>10 km | 9 | 103 Days | 0.03 Tb<br>0.3 Tb<br>2 Tb<br>6 Tb | 21 May - 30 Aug<br>2001 - 2009<br>NICAM Analogs |
| IFS<br>10-Member Ensembles<br>(Summers) | T511<br>T1279 | 39 km<br>15 km | 6 | 132 Days | 3.2 Tb<br>20 Tb | 21 May - 30 Sep<br>Selected Years |
| IFS<br>10-Member Ensembles<br>(Winters) | T511<br>T1279 | 39 km<br>16 km | 6 | 151 Days | 3.7 Tb<br>23 Tb | 1 Nov - 31 Mar<br>Selected Years |
| IFS<br>Time Slice | T159<br>T1279 | 125 km<br>16 km | 1 | 47 Years | 0.6 Tb<br>38 Tb | 2071 - 2117 |
| IFS<br>AMIP | T159<br>T1279 | 125 km<br>16 km | 1 | 47 Years | 0.6 Tb<br>38 Tb | 1961 - 2007 |
| | | | | | **875 Tb** | **Total volume of raw output** |

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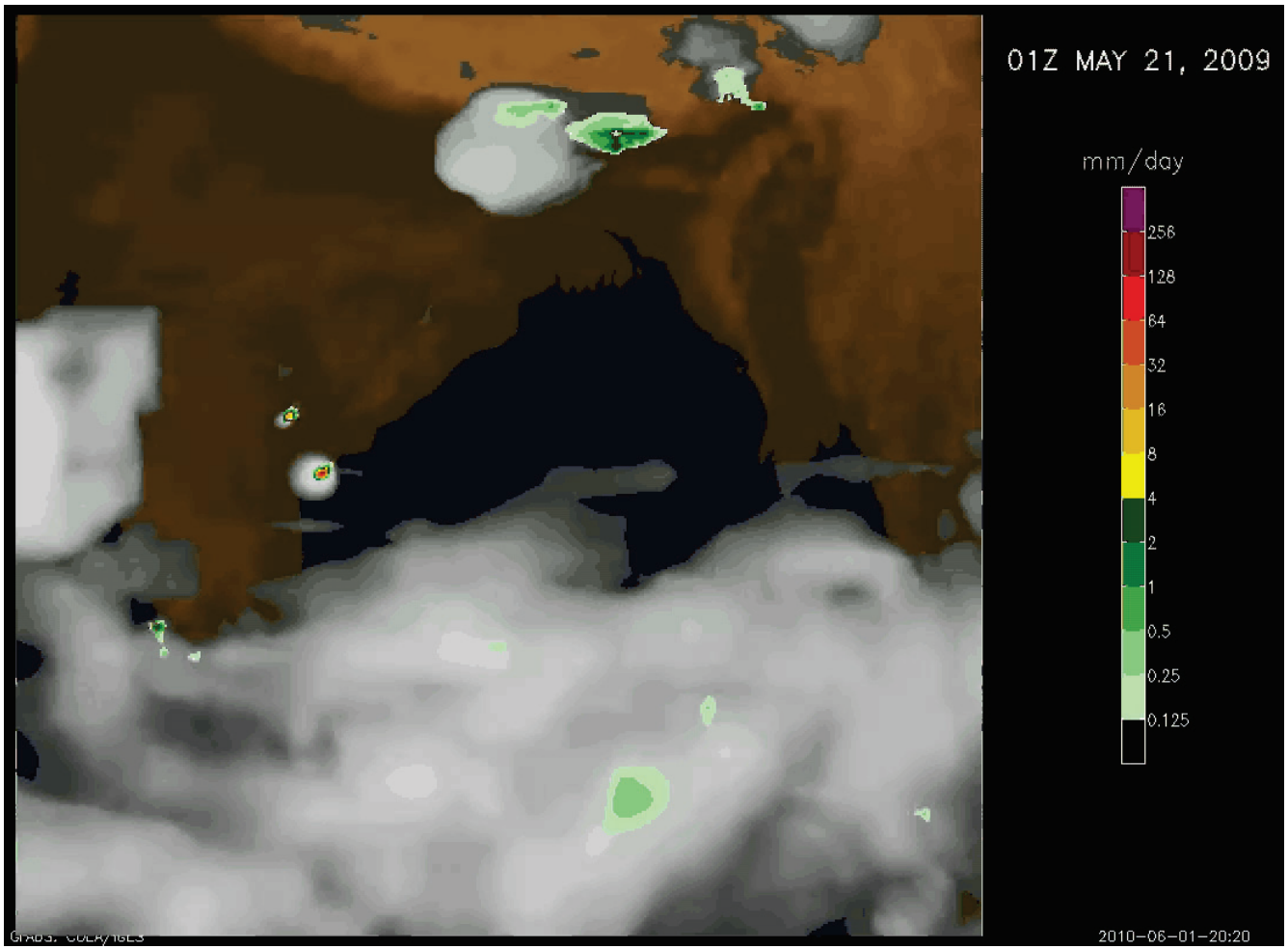
# Results




NICAM
Hourly simulation of precipitation and clouds during May–August 2009

Courtesy:
Brian Doty, COLA

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**COLA – Center for Ocean-Land-Atmosphere Studies, USA**

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