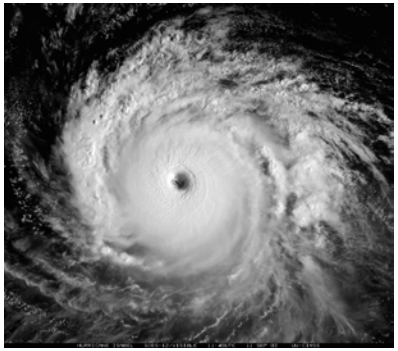

# Tropical Cyclone Climatology in High-Resolution CAM

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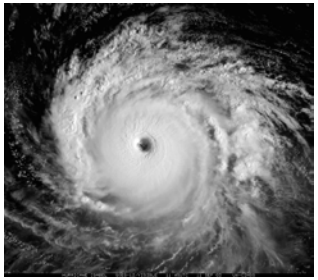
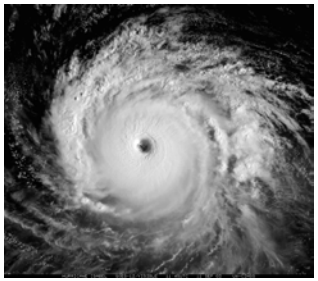


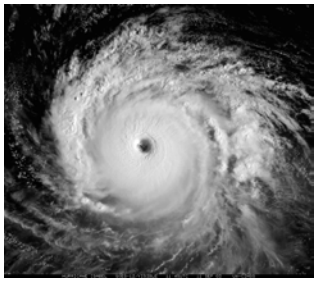
# Overview

- We introduce an idealized vortex into an ideal environment for tropical cyclogenesis in CAM 5.1.
- This configuration is an ideal candidate for a Tropical Cyclone (TC) test case for GCM process studies of:
  - Model resolution - [Reed and Jablonowski 2011, MWR]
  - Model physics - [Reed and Jablonowski 2011, JAMES]
  - Model dynamical core - [Reed and Jablonowski 2012, JAMES]
- Introduce the initial results of decadal climate simulations that are configured in the AMIP manner with prescribed SSTs.
- A select individual storm is chosen for comparison.



# Analytic Initial Conditions

- Use an analytic initialization technique for a single, initially weak vortex.
- The vortex is built upon prescribed analytic 3D moisture, pressure, temperature and velocity fields that are embedded into tropical environmental conditions.
- Vortex is in hydrostatic and gradient wind balance, with $v_0$ = 20 m/s and RMW = 250 km.
- Vortex characteristics:
  - Surface vortex
  - Warm-core
- Favorable environment set by observations from *Jordan 1958*, with 29$^{o}$C SST.



# Analytic Initial Conditions

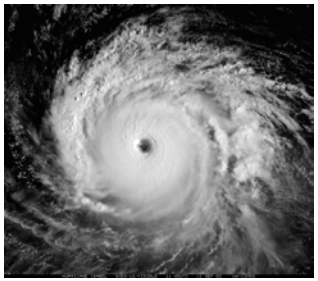
Preview of initial conditions:

$$p(r,z) = \left[p_0 - \Delta p \, \exp\left(-\left(\frac{r}{r_p}\right)^{3/2}\right) \exp\left(-\left(\frac{z}{z_p}\right)^2\right)\right] \left(\frac{T_{v0}-\Gamma z}{T_{v0}}\right)^{\frac{g}{R_d\Gamma}}$$

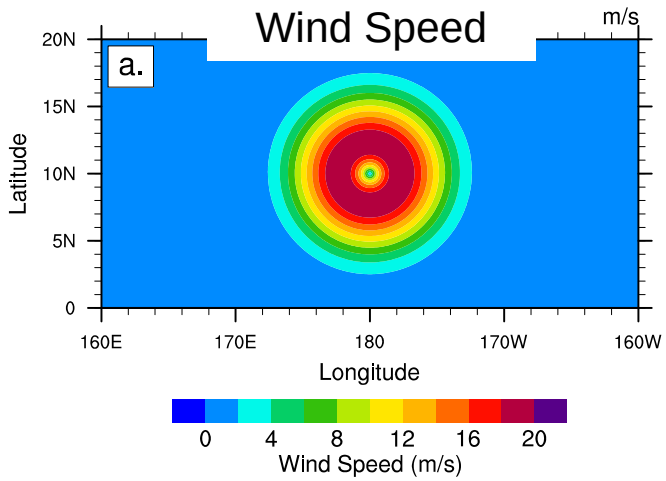
$$p_s(r) = p_0 - \Delta p \, \exp\left(-\left(\frac{r}{r_p}\right)^{3/2}\right)$$

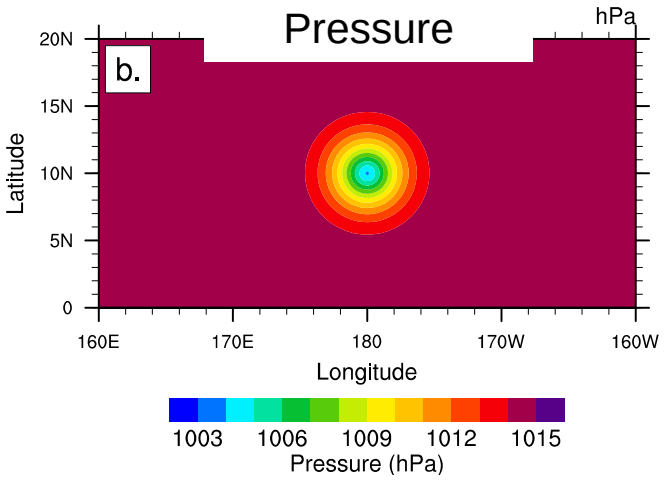
$$T(r,z) = \frac{T_{v0}-\Gamma z}{1+0.608\bar{q}(z)} \left[1 + \frac{2R_d(T_{v0}-\Gamma z)z}{gz_p^2\left[1-\frac{p_0}{\Delta p}\exp\left(\left(\frac{r}{r_p}\right)^{3/2}\right)\exp\left(\left(\frac{z}{z_p}\right)^2\right)\right]}\right]^{-1}$$

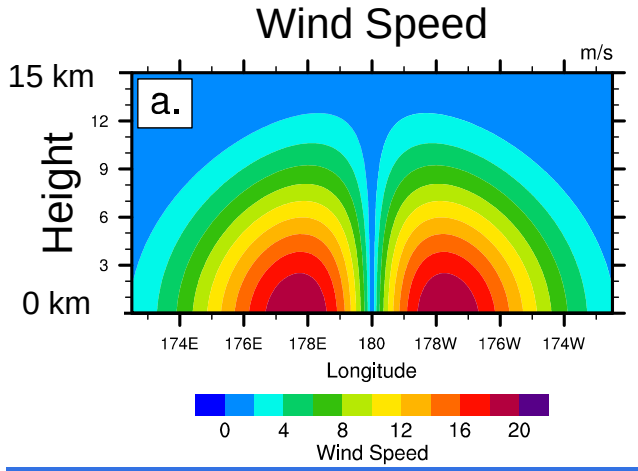
$$v_T(r,z) = -\frac{f_c r}{2} + \sqrt{\frac{f_c^2 r^2}{4} - \frac{\frac{3}{2}\left(\frac{r}{r_p}\right)^{3/2}(T_{v0}-\Gamma z)R_d}{1+\frac{2R_d(T_{v0}-\Gamma z)z}{gz_p^2}-\frac{p_0}{\Delta p}\exp\left(\left(\frac{r}{r_p}\right)^{3/2}\right)\exp\left(\left(\frac{z}{z_p}\right)^2\right)}}$$

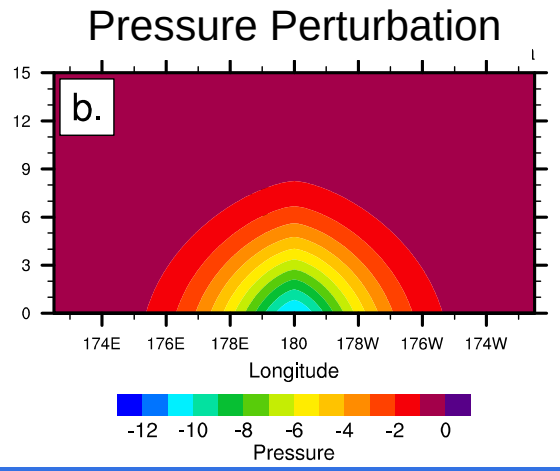


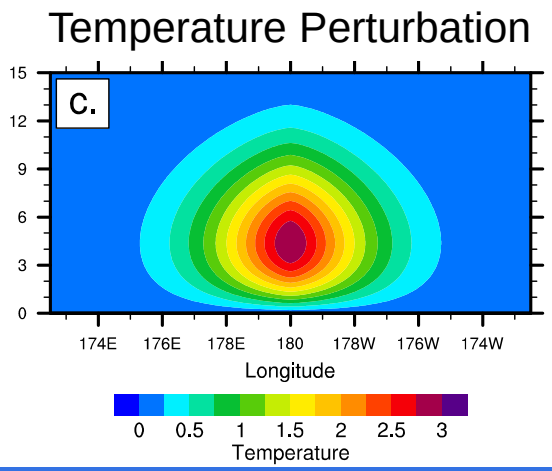
# Analytic Initial Conditions



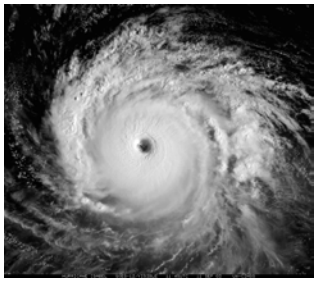



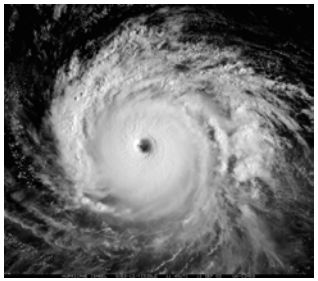



The vortex is centered at $10^{o}$ N and $180^{o}$ E.



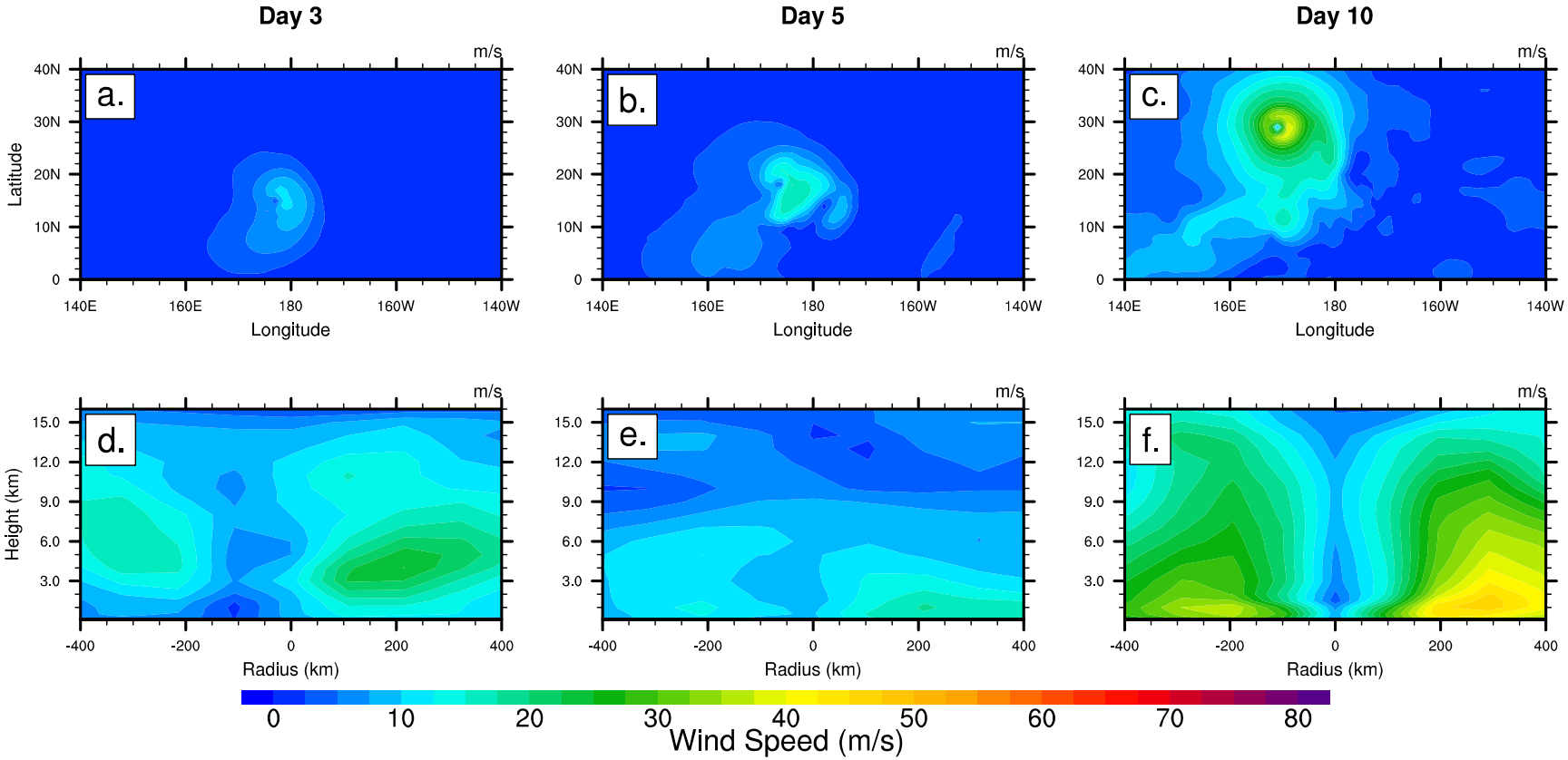
# Design of Experiments

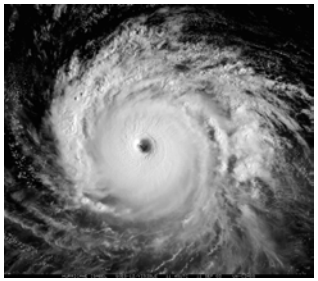
- National Center for Atmospheric Research's (NCAR) Community Atmosphere Model (CAM).
- Use physics version:
  - CAM 5.1 – CESM 1
- The Finite-Volume (FV) dynamical core with 30 vertical levels is used at horizontal resolutions of:
  - $1.0^{o}$ by $1.0^{o}$ [~110 km]
  - $0.5^{o}$ by $0.5^{o}$ [~55 km]
  - $0.25^{o}$ by $0.25^{o}$ [~28 km]
- Full physics in Aquaplanet mode is used, with a simplified ocean covered Earth and constant SST.
  - Parameters are set to the FV dynamical core $1.0^{o}$ resolution tuning set.



# CAM 5.1

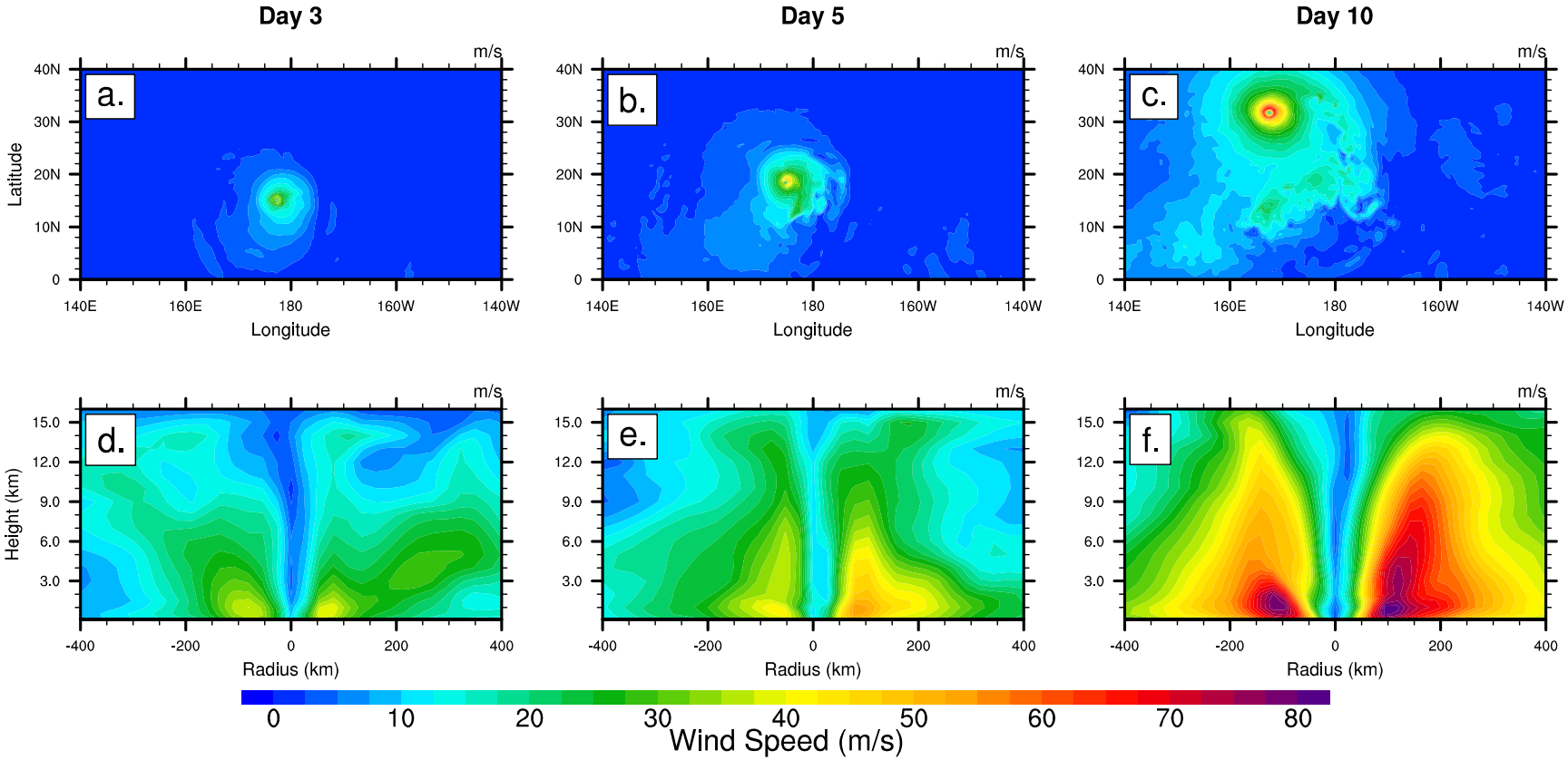
## Wind Speed for 1.0$^o$ by 1.0$^o$ Simulation

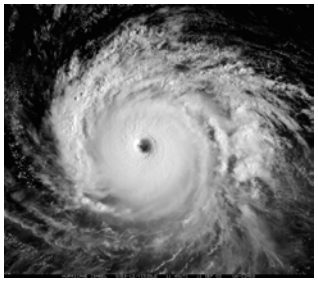




# CAM 5.1

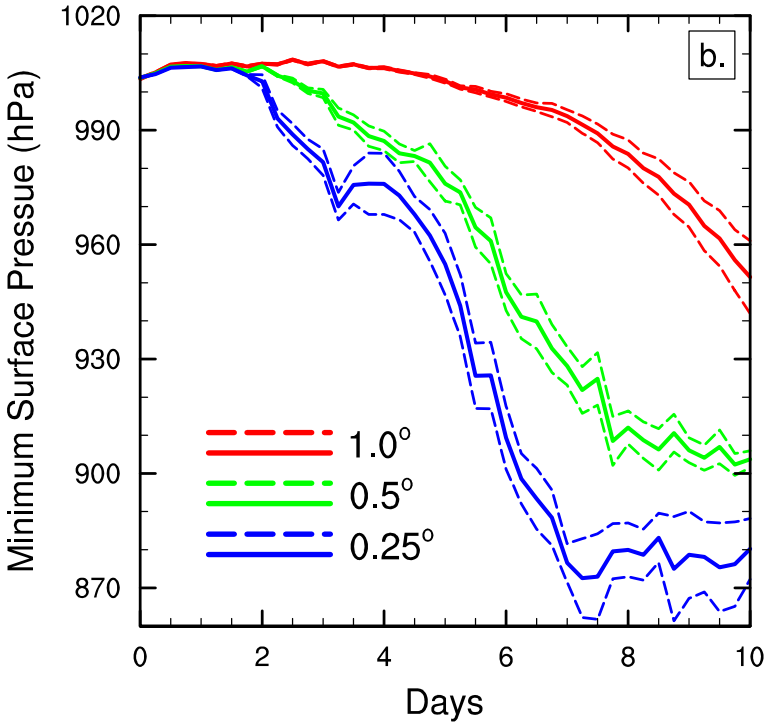
## Wind Speed for 0.25$^o$ by 0.25$^o$ Simulation

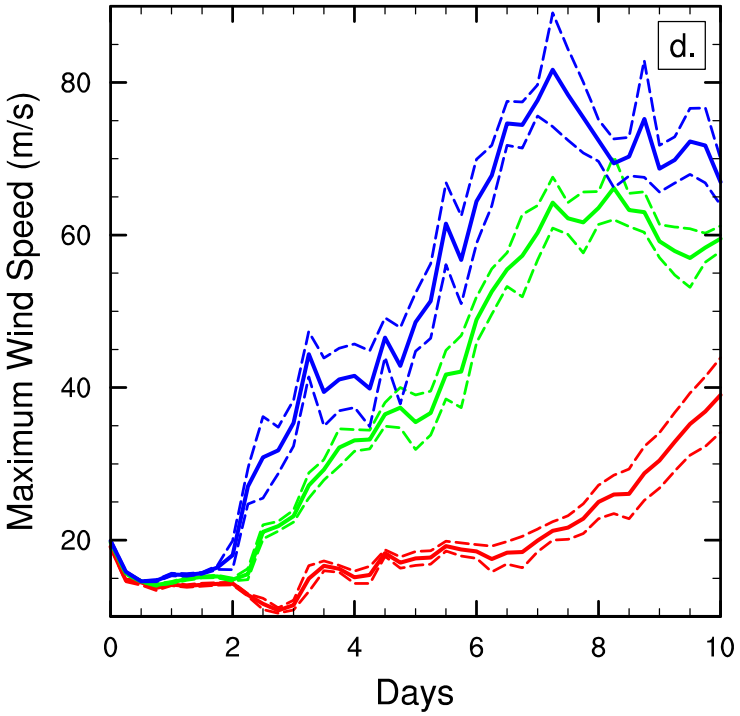


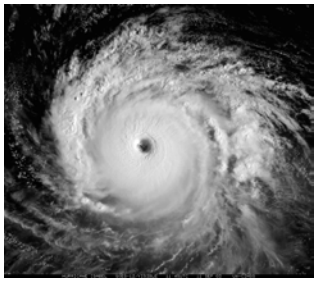


# CAM 5.1 Comparison

## Assess initial data and model uncertainties

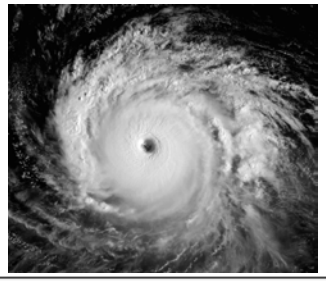


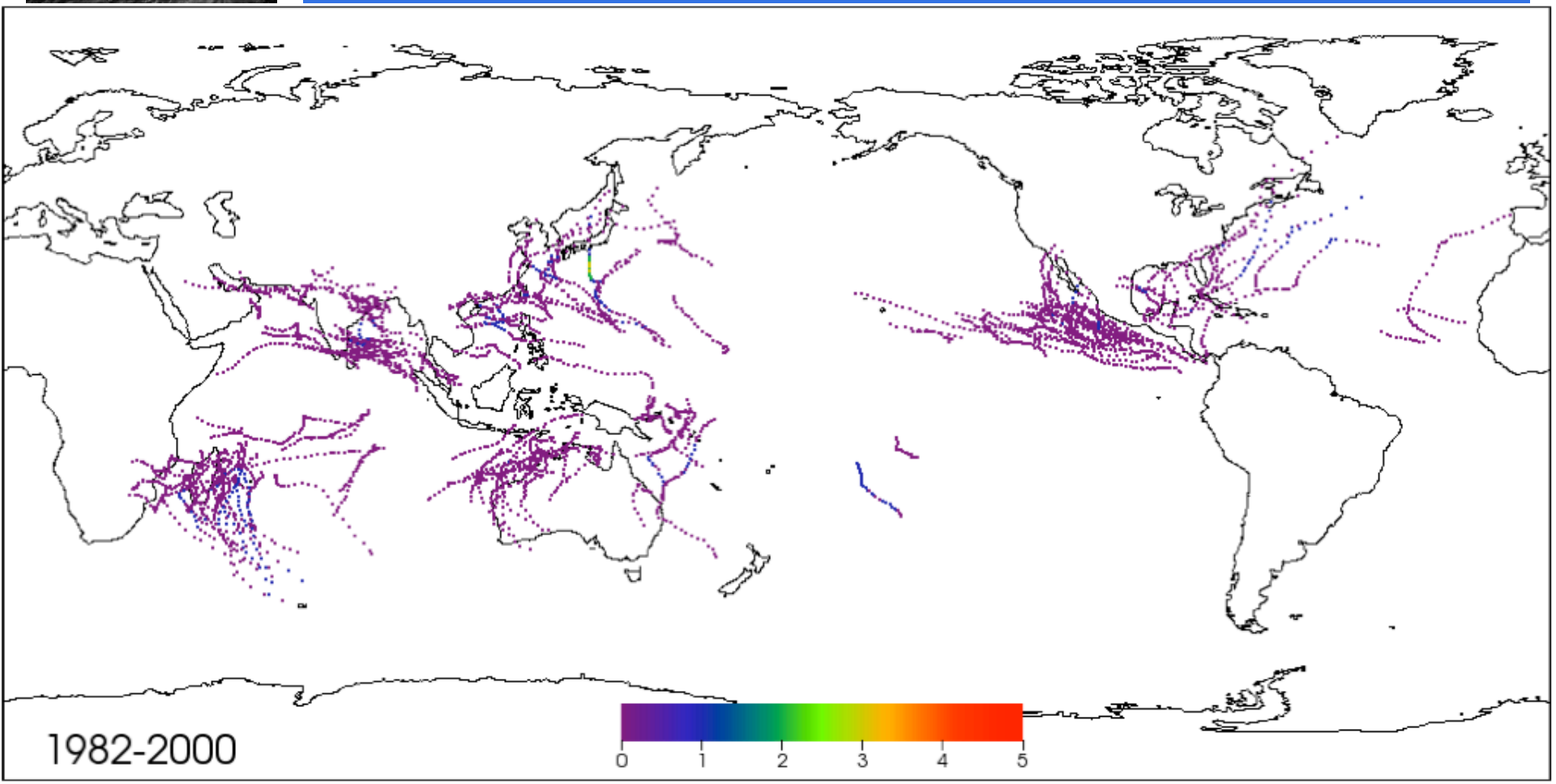


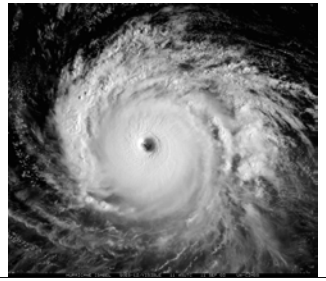
# Design of Decadal Experiments

- National Center for Atmospheric Research's (NCAR) Community Atmosphere Model version 5.1 (CAM 5.1).
- The FV dynamical core with 30 vertical levels is used at the horizontal resolutions of:
  - $0.9^{o}$ by $1.25^{o}$
  - $0.23^{o}$ by $0.31^{o}$
  - Full CAM 5.1 physics with Atmospheric Model Intercomparison Project (AMIP) protocols (with prescribed aerosol forcing).
  - Observed ozone, $CO_2$, solar forcing, etc.
  - LBNL has rewritten the GFDL tracking code (C++/mpi).
  - Completed 1979-2005.
  - ***Preliminary Results***

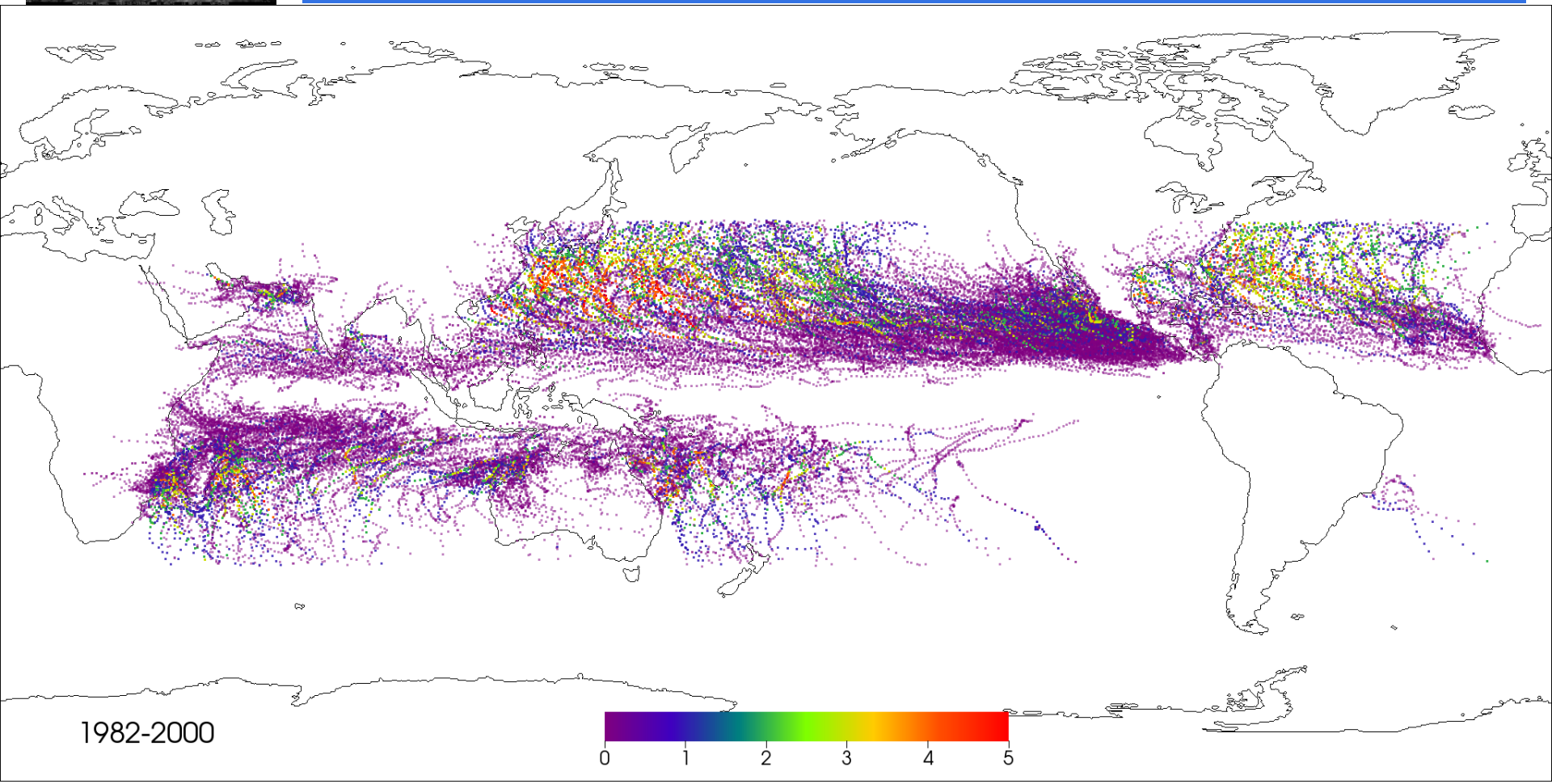


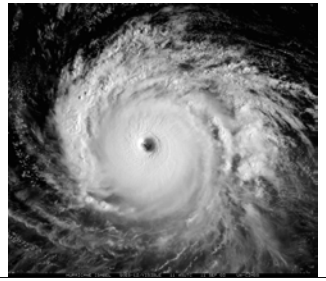
# 0.9º by 1.25º Storm Tracks



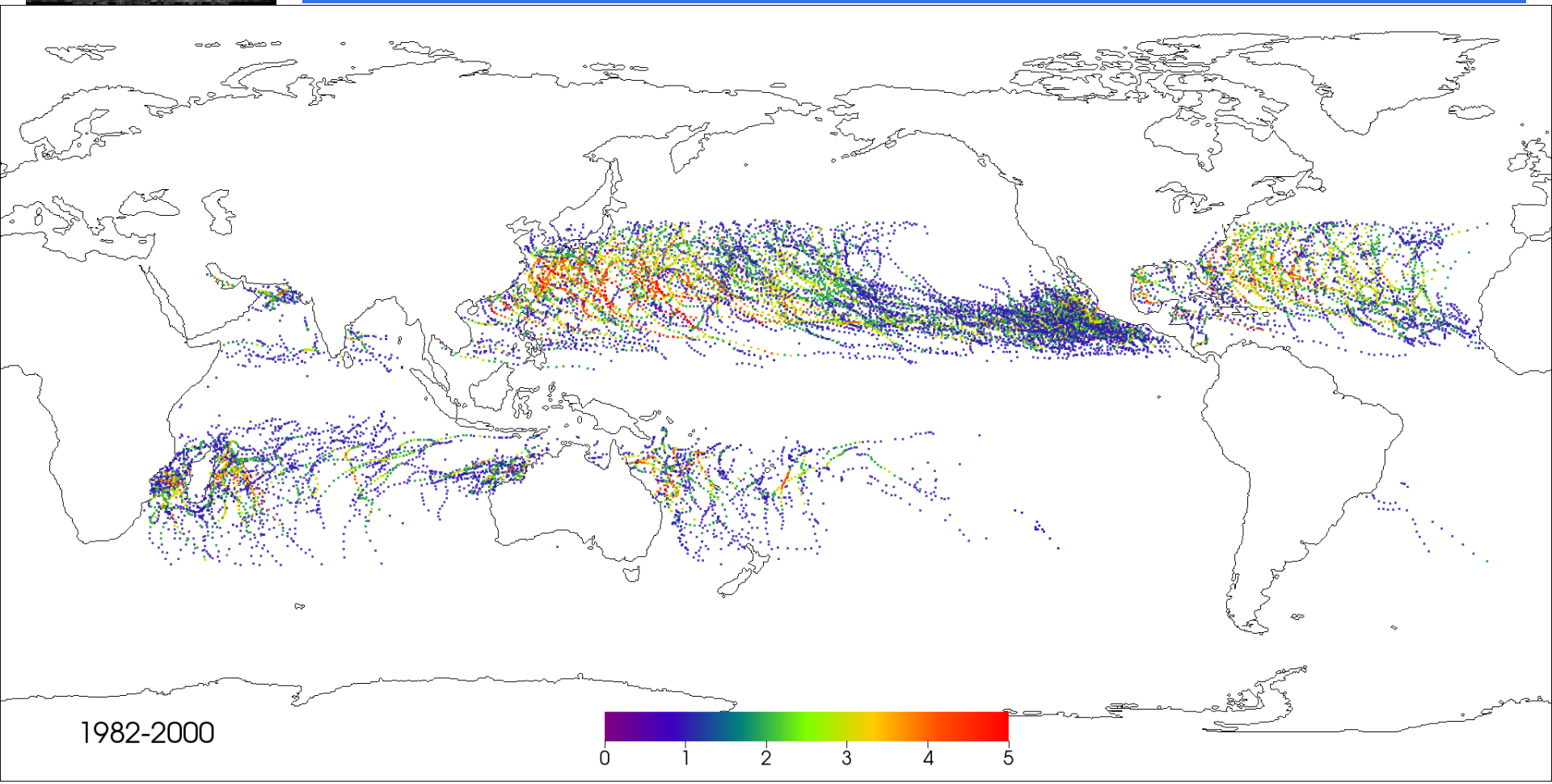


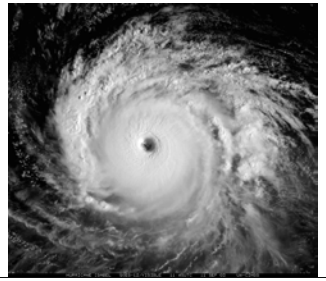
# 0.23° by 0.31° Storm Tracks





# Categories 1 - 5





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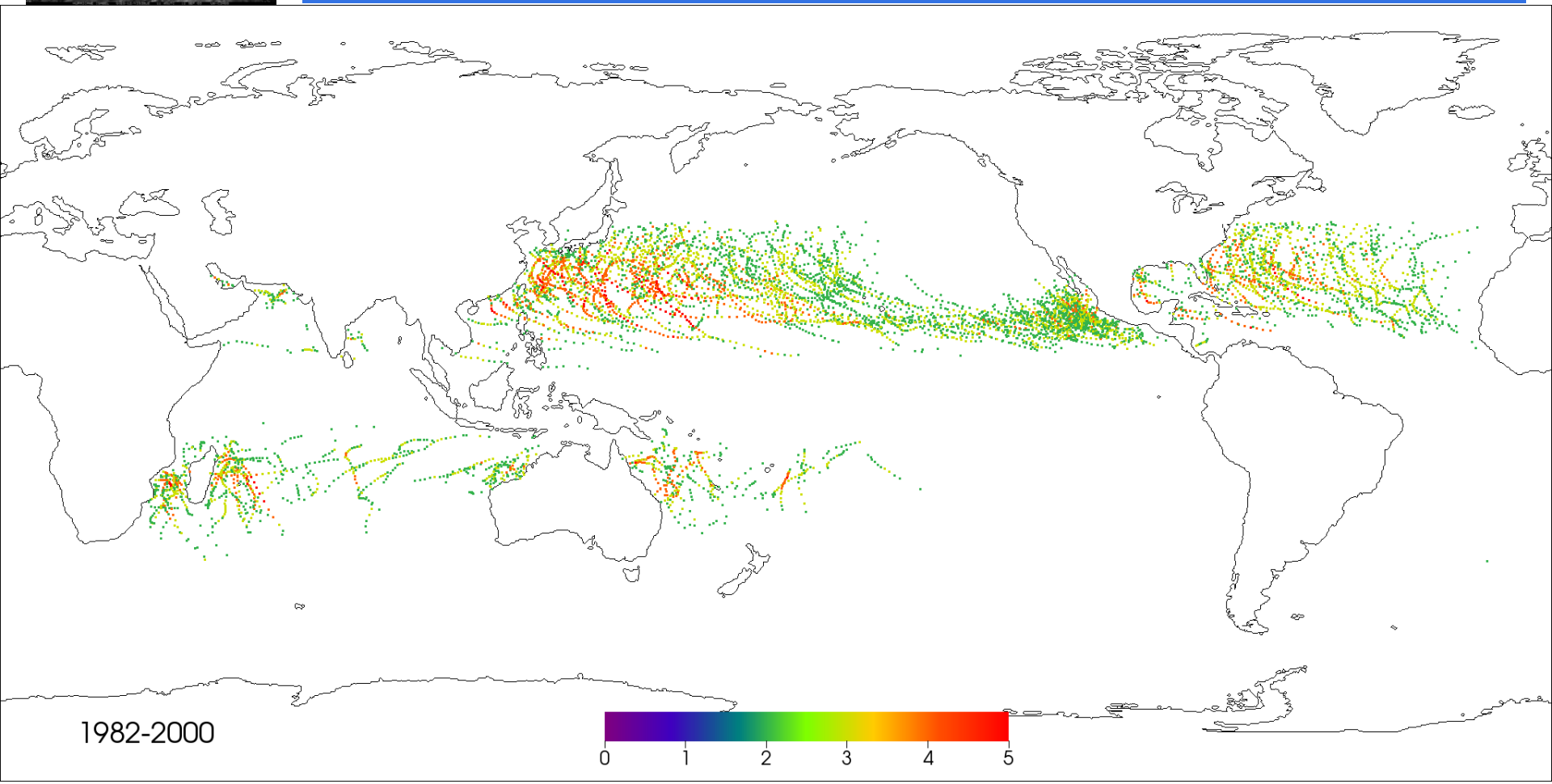

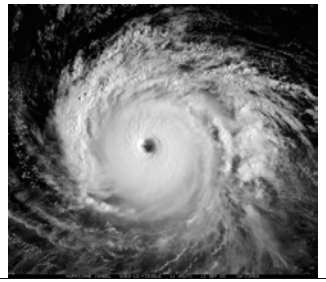

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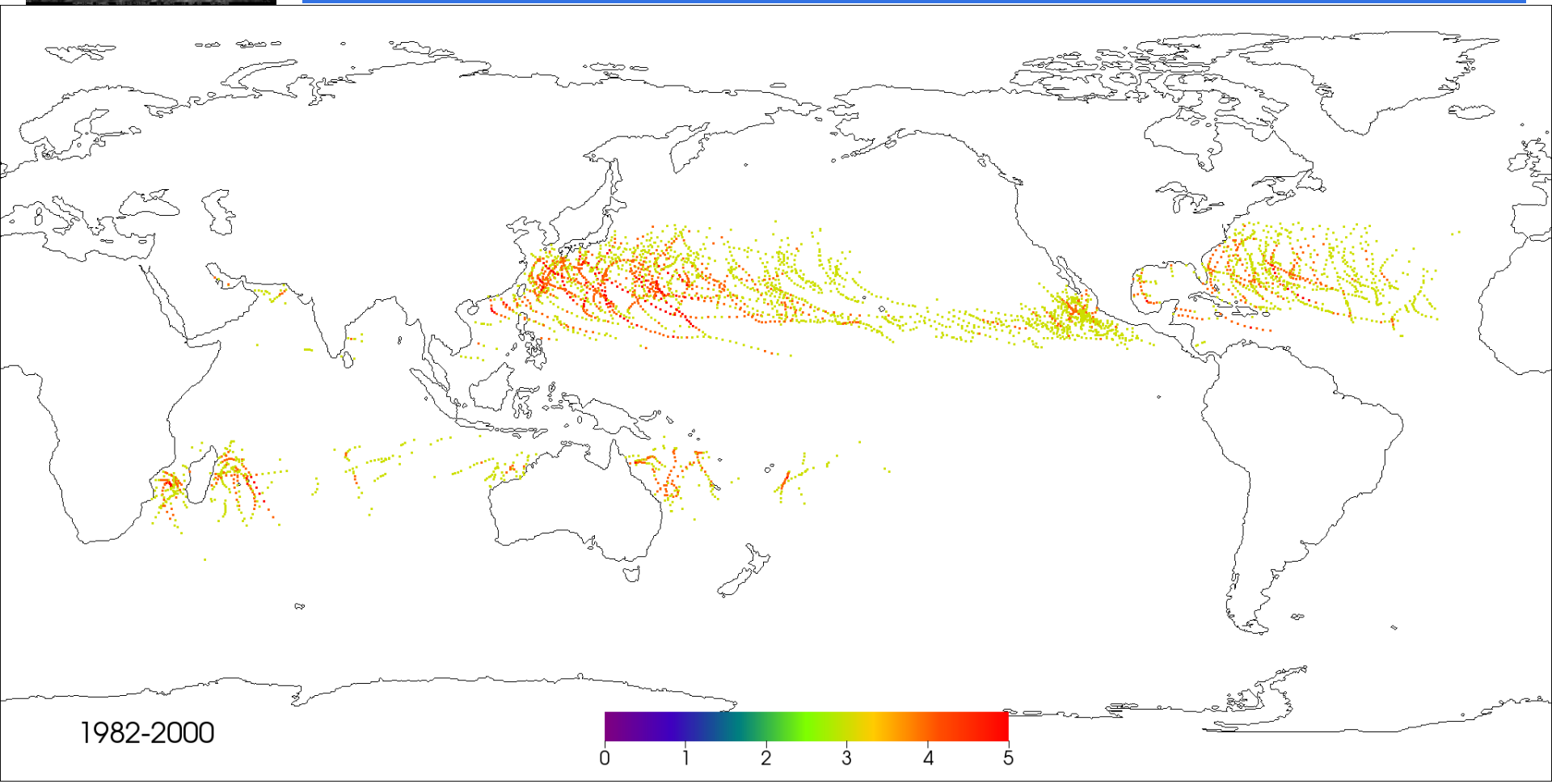

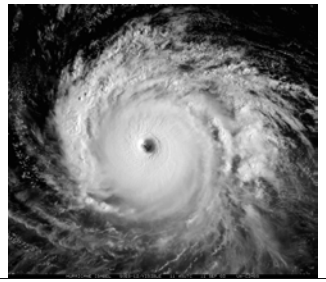

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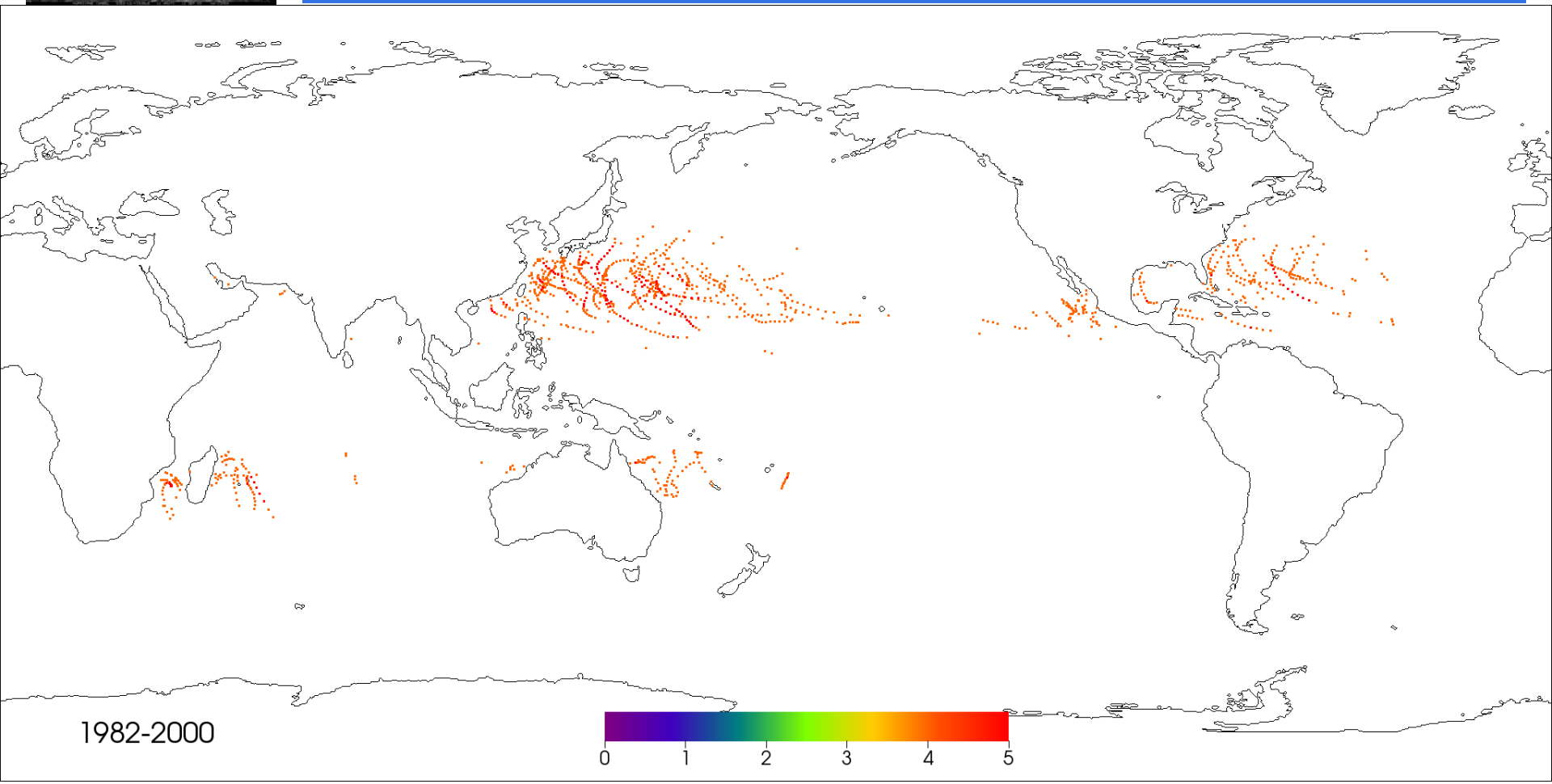

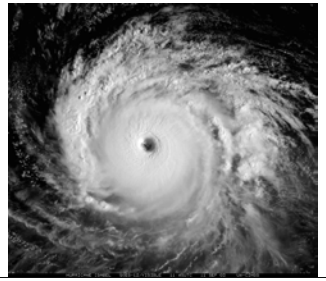

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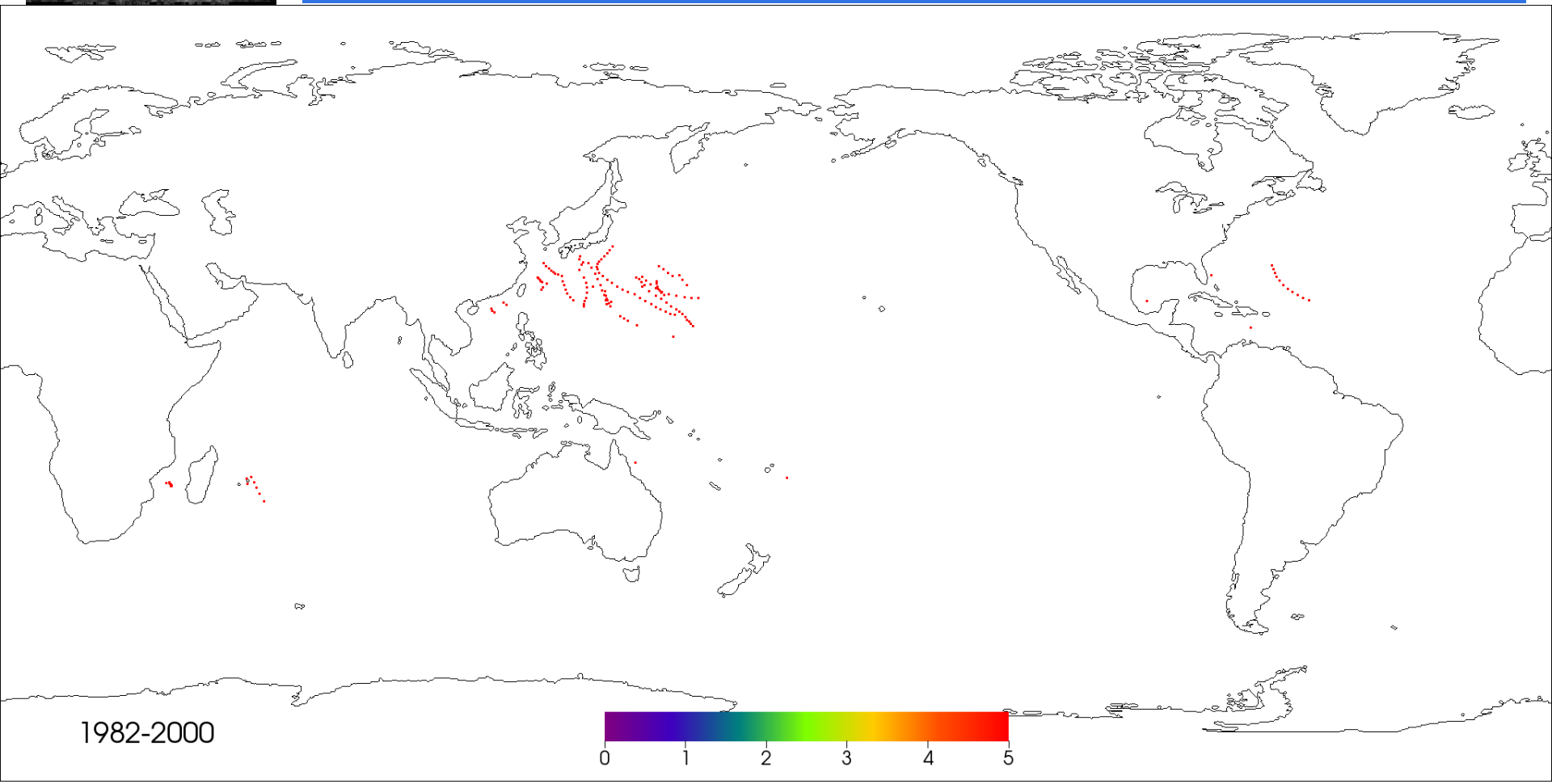
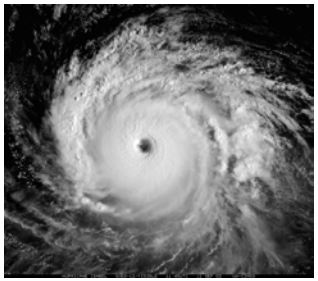




# Global average / year

Total TC

–Observations **87±8**

–CAM 5.1:

– 0.9º by 1.25º **9±3**

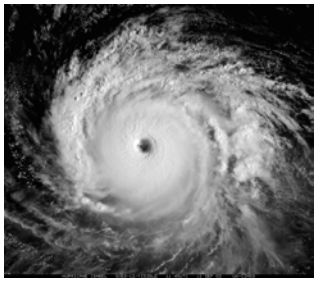
– 0.23º by 0.31º **84±9**

Total Hurricanes

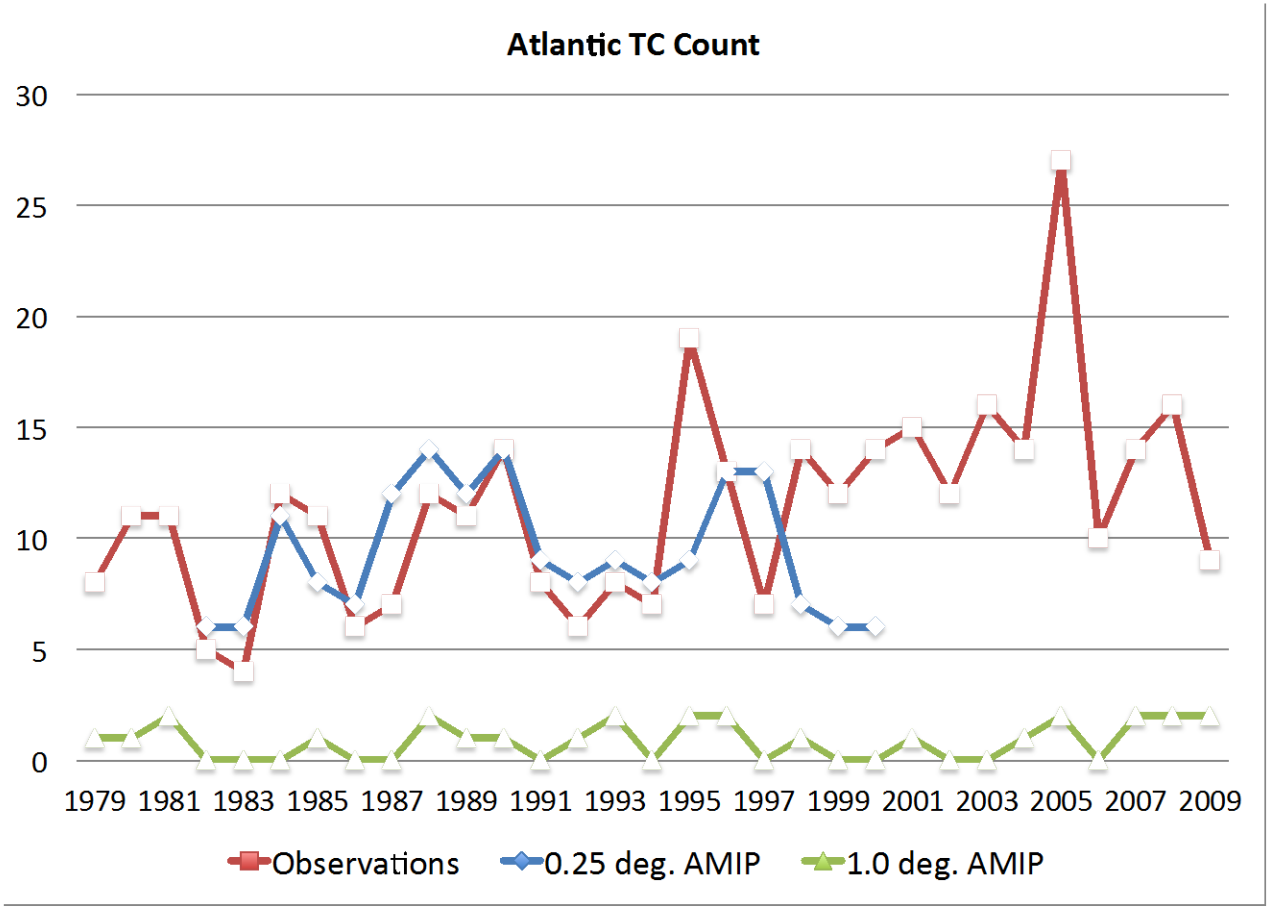
–Observations **49±7**

–CAM 5.1 0.23º by 0.31º **52**

- cat1 **21**
- cat2 **5**
- cat3 **12**
- cat4 **7**
- cat5 **1.5**

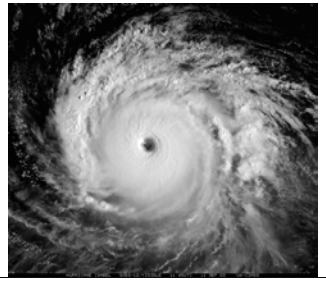


# Atlantic TCs per year

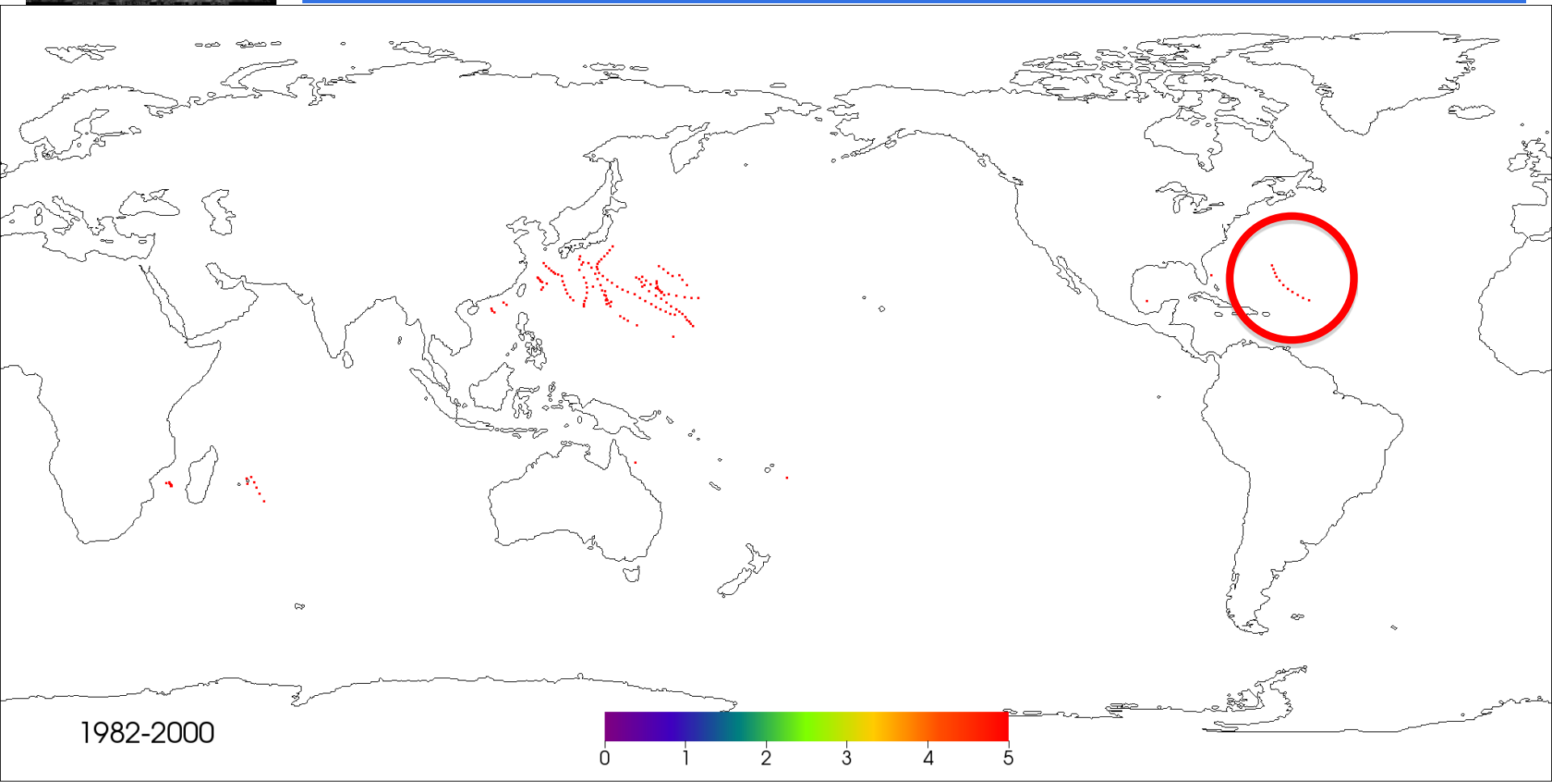


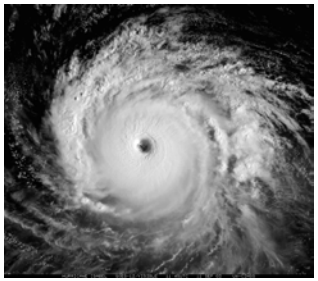

1982-2000 Mean:

- Observations 10
- 0.9° by 1.25° <1
- 0.23° by 0.31° 9.4



# Select A Storm



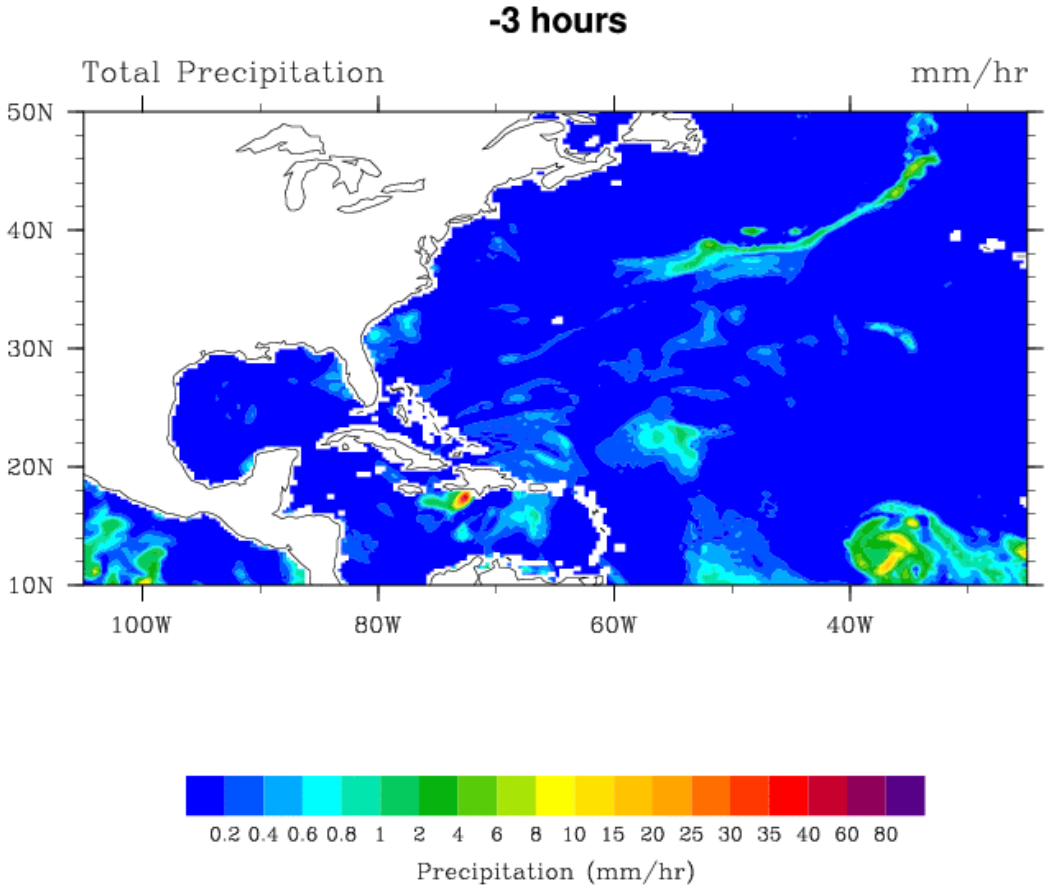


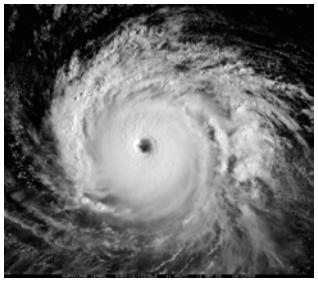
# AMIP Tropical Cyclone

Total Precipitation Rate (mm/hr)

CAM 5.1 - FV
0.23$^{o}$ by 0.31$^{o}$

Cat. 5 Storm



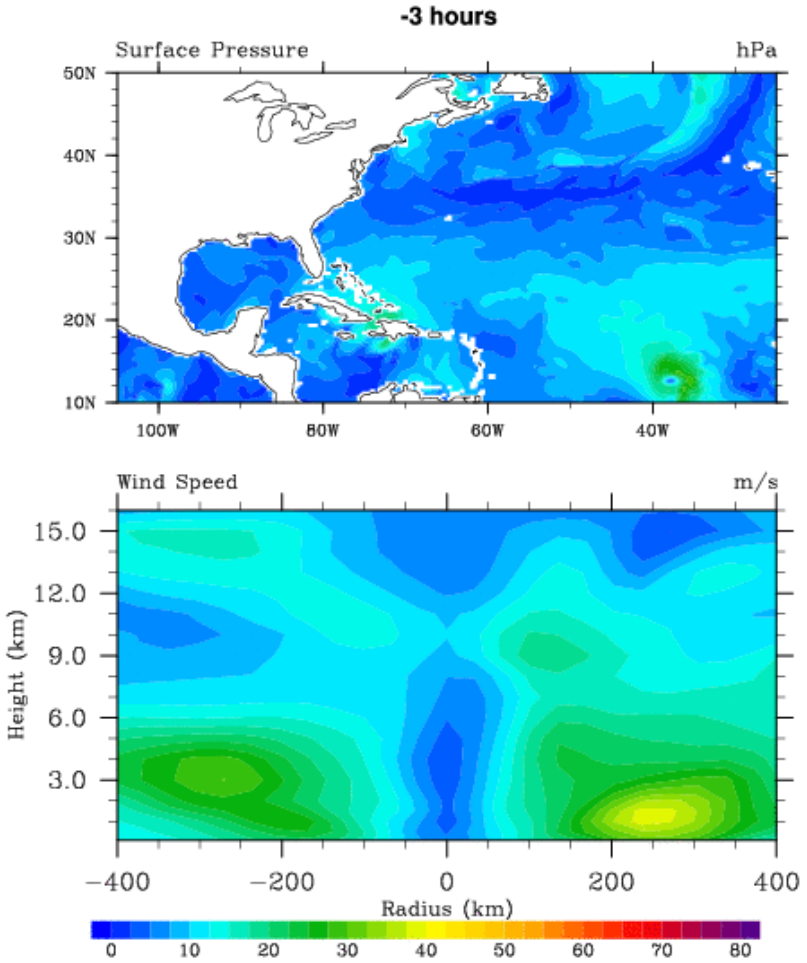


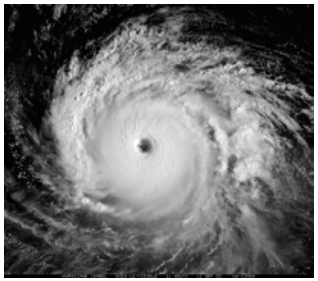
# AMIP Tropical Cyclone

Wind Speed
(m/s)

CAM 5.1 - FV
0.23º by 0.31º

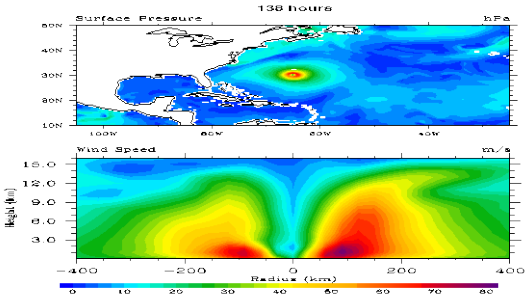
Cat. 5 Storm

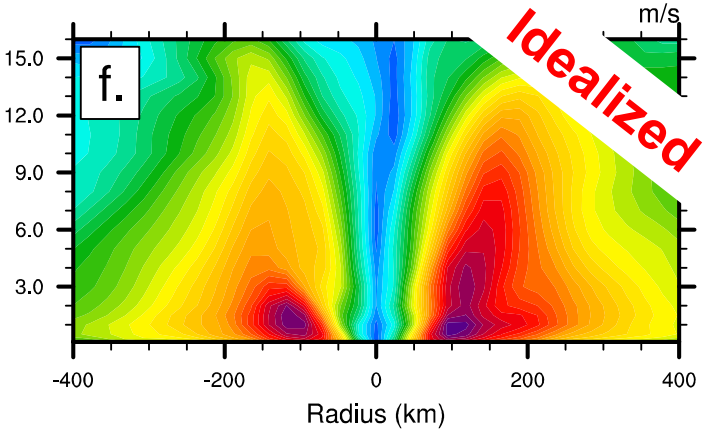


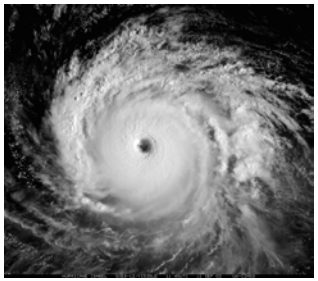


# AMIP Tropical Cyclone

**Wind Speed (m/s)**

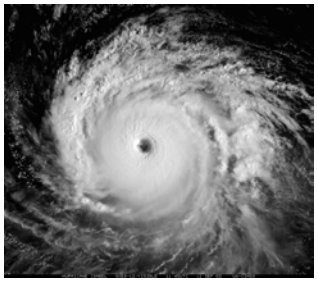


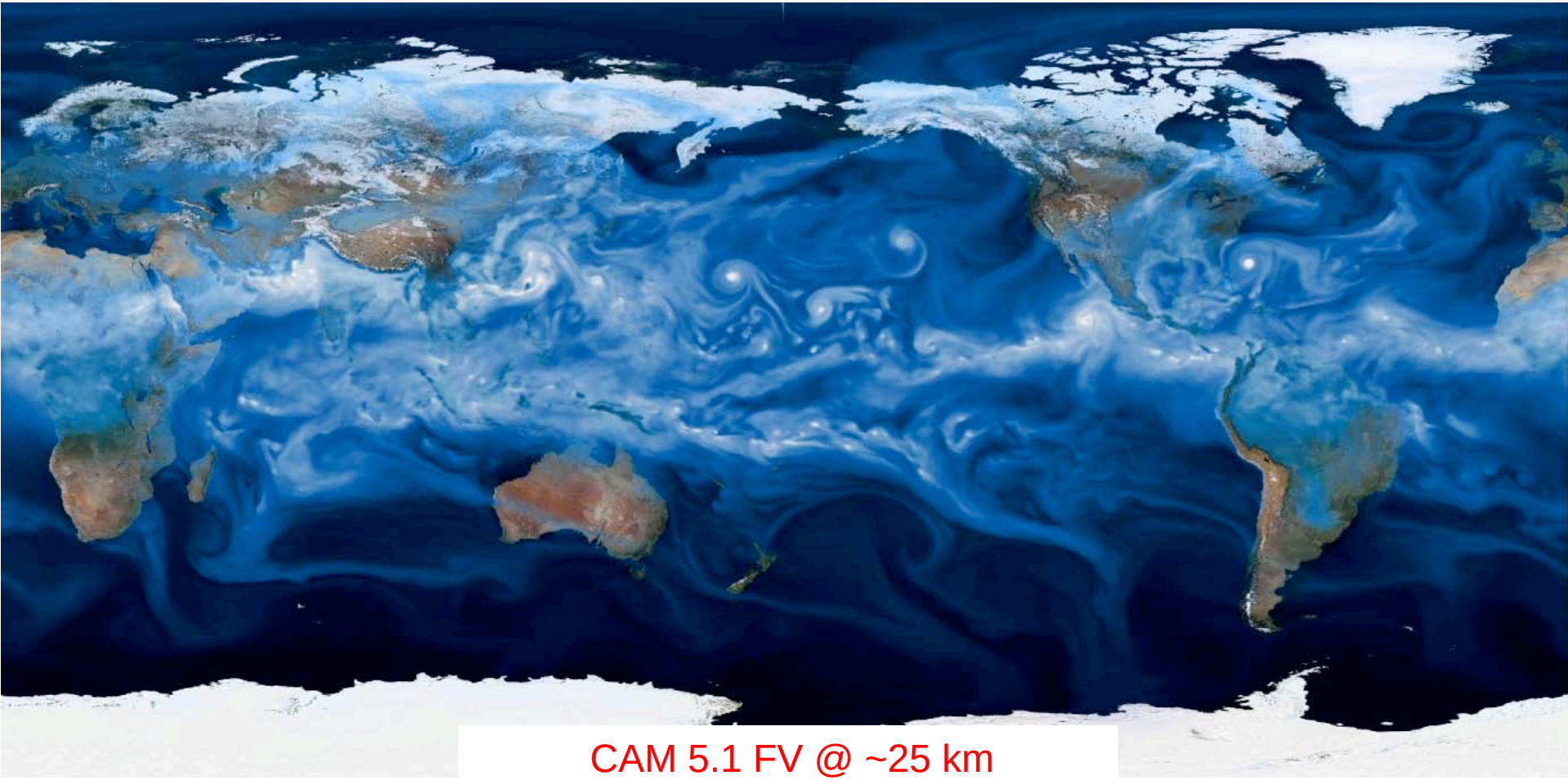


# Final Thoughts

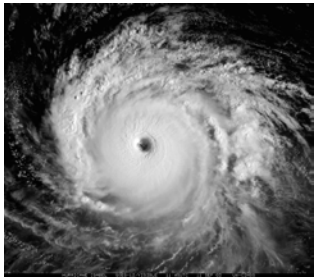
- CAM 5.1 has shown the ability to simulate TCs (especially at ~0.25$^{o}$).
- The 0.23$^{o}$ by 0.31$^{o}$ AMIP simulation compares reasonably well to Global and Atlantic TC counts, as well as capturing some of the interannual variability.
- The idealized results compare reasonably well with the structure of individual storms in the decadal (AMIP) simulations.
- The idealized test seems to be a decent indicator of the TC activity in the AMIP simulations.
- Future work:
  - Investigate other basins
  - Additional simplified climatology studies



# Thank You



CAM 5.1 FV @ ~25 km



# References


- Jordan, C. L., 1958: Mean Soundings for the West Indies Area. Journal of the Atmospheric Sciences, 15, 91-97, doi:10.1175/1520-0469(1958)015.
- Reed, K. A., and C. Jablonowski (2011a), An analytic vortex initialization technique for idealized tropical cyclone studies in AGCMs, Mon. Wea. Rev., 139, 689–710, doi:10.1175/2010MWR3488.1.
- Reed, K. A., and C. Jablonowski (2011b), Assessing the Uncertainty of Tropical Cyclone Simulations in NCAR's Community Atmosphere Model, J. Adv. Model. Earth Syst., 3, M08002, 16, doi:10.1029/2011MS000076.
- Reed, K. A., and C. Jablonowski (2012), Idealized tropical cyclone simulations of intermediate complexity: a test case for AGCMs, *J. Adv. Model. Earth Syst.*, 4, M04001, doi:10.1029/2011MS000099.



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