

# High-Resolution MPAS Simulations for Analysis of Climate Change Effects on Weather Extremes



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**GEWEX CONVECTION-PERMITTING CLIMATE MODELING WORKSHOP II**  
**6 SEPTEMBER 2018**

**NC STATE UNIVERSITY**



# Motivation

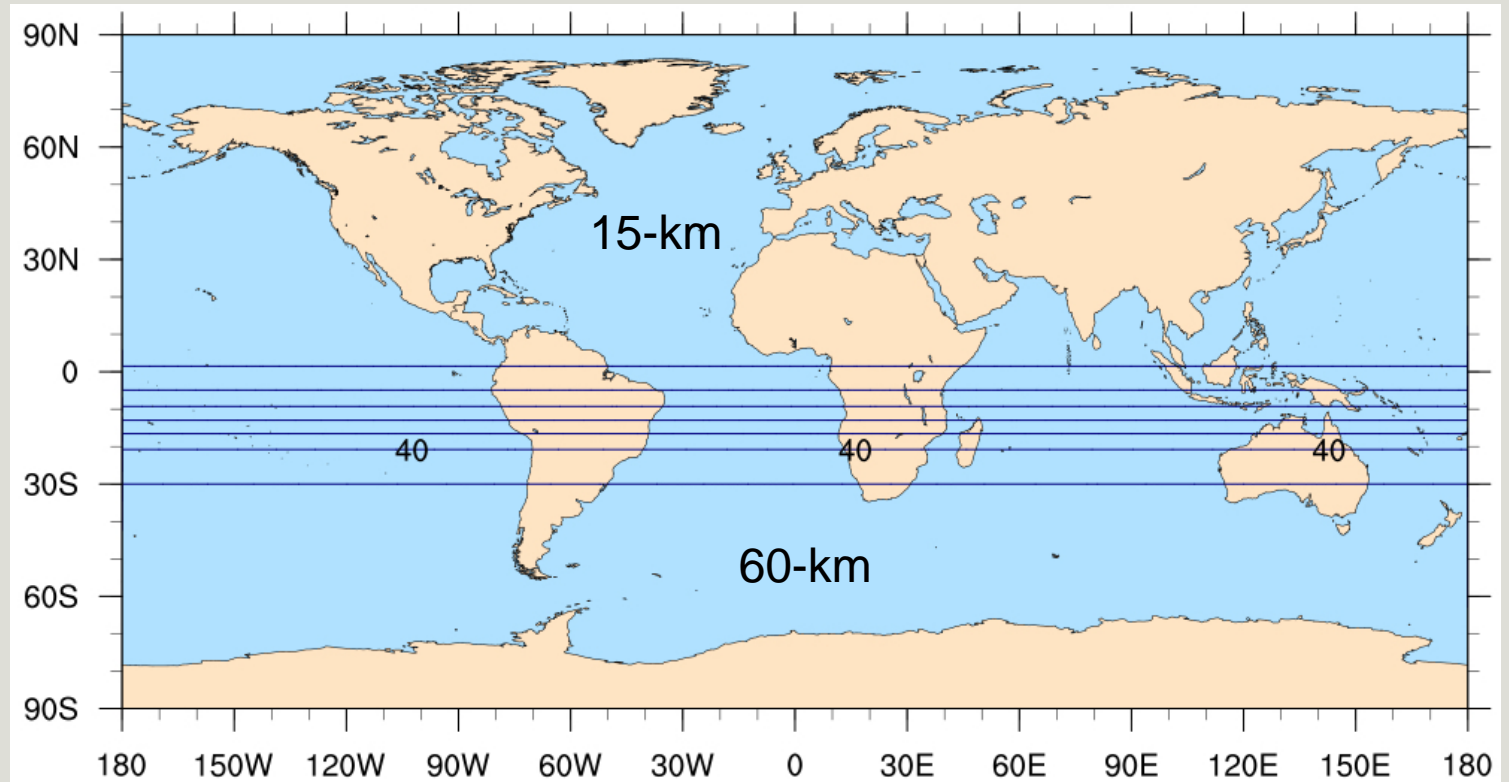


- **Current General Circulation Models (GCMs):**
  - Too coarse for TCs, extreme weather events, issues with blocking
- **Regional Modeling with Pseudo-Global Warming (PGW):**
  - Limited by lateral boundary conditions
- **High-resolution Time Slice Experiments:**
  - Can be limited by SST representation
- **Our Method:**
  - MPAS with high-resolution analyzed SSTs using pseudo-PGW/pseudo-time slice methods

# Model for Prediction Across Scales (MPAS) Simulations

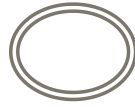


- MPAS v. 5.1
- Variable resolution mesh: 15-km over NH expanding out to 60-km\*
- Physics choices:
  - WSM6 (MP)
  - YSU (PBL)
  - Tiedtke (CP)
  - CAM (radiation)
- Initial conditions and SST field:
  - ERA-Interim Reanalysis



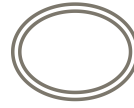
\*Thanks to Michael Duda for creating this mesh

# Model for Prediction Across Scales (MPAS) Simulations

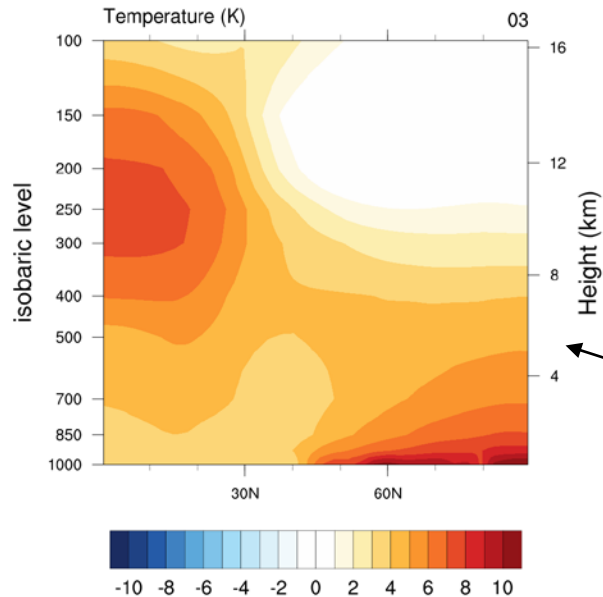
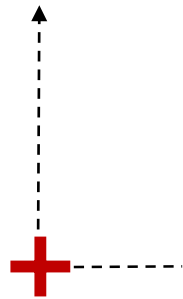
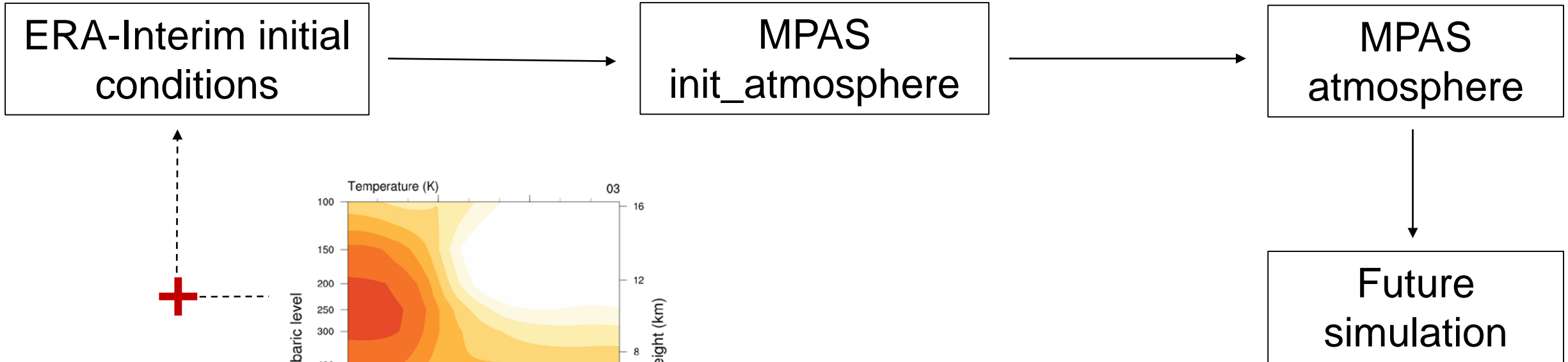


- Selected 10 simulation years to sample range of ENSO phases
- Simulations run from March 1<sup>st</sup> of year 1 through mid-May of year 2 – first month discarded

# MPAS Simulations – Future



- Simulate same 10 years under future thermodynamic conditions

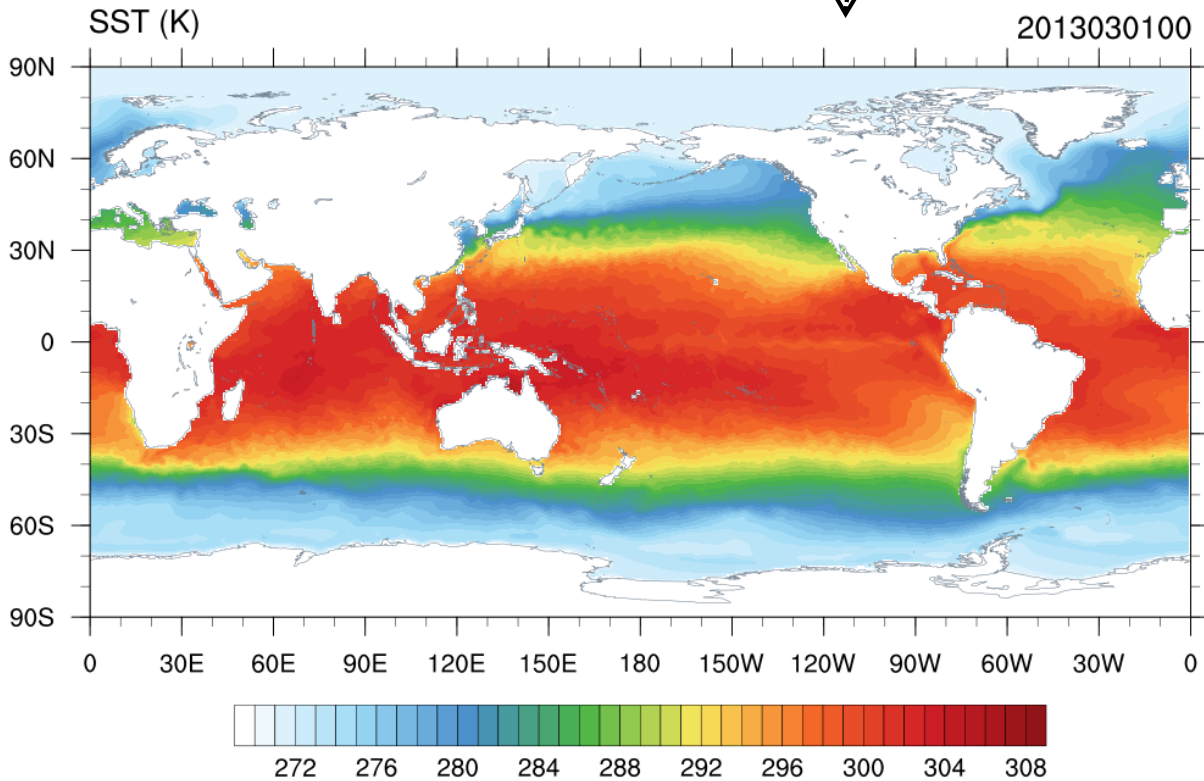
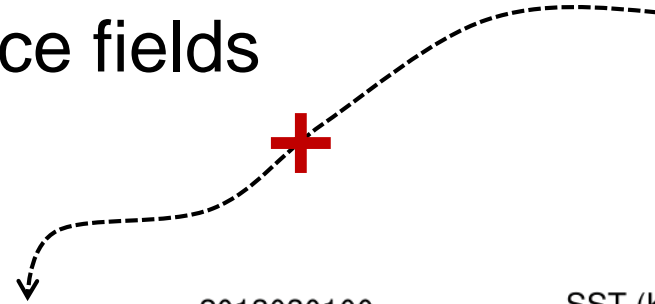
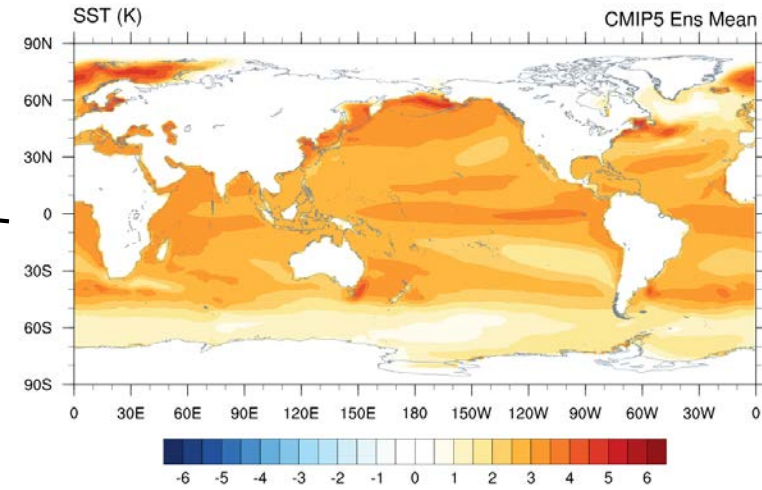


CMIP5 21-member Ensemble  
March Average Temperature Change (K)  
2080–2099 (RCP 8.5) minus 1980–1999

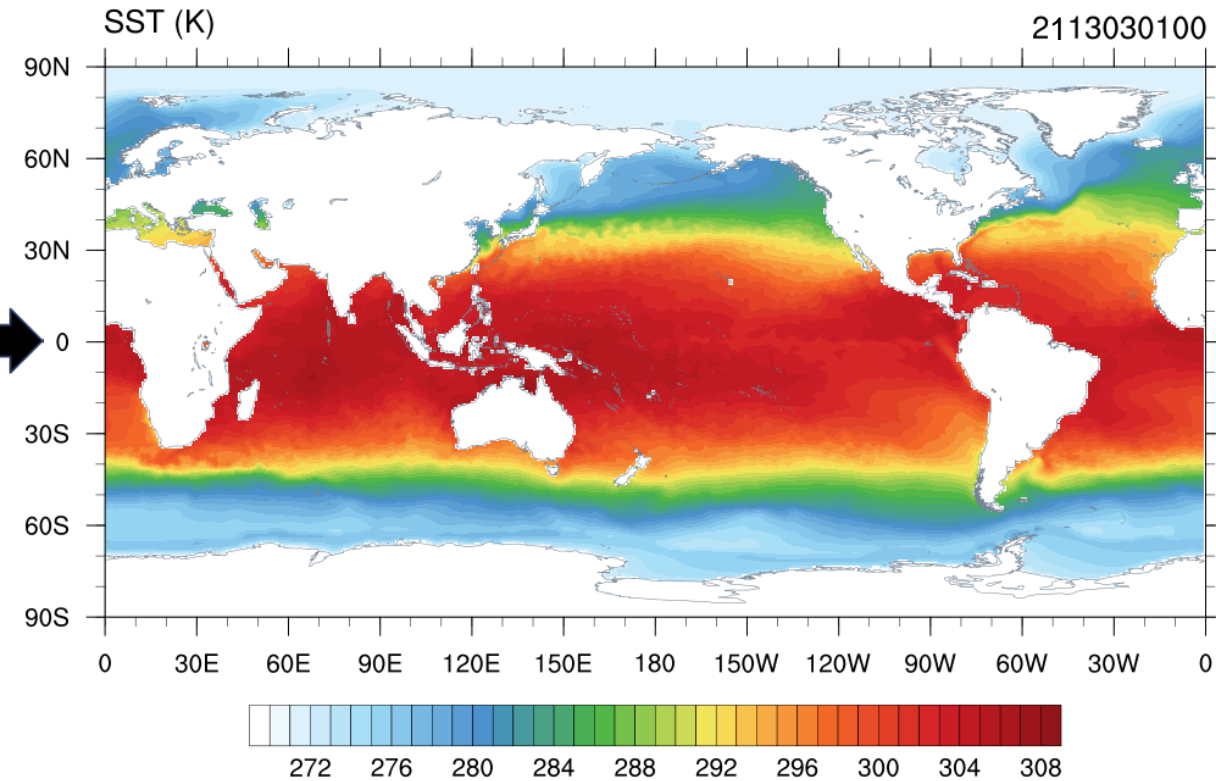
\*CO<sub>2</sub> adjusted to  
936 ppm

# MPAS Simulations – Future

- Future SST and sea ice fields



Current

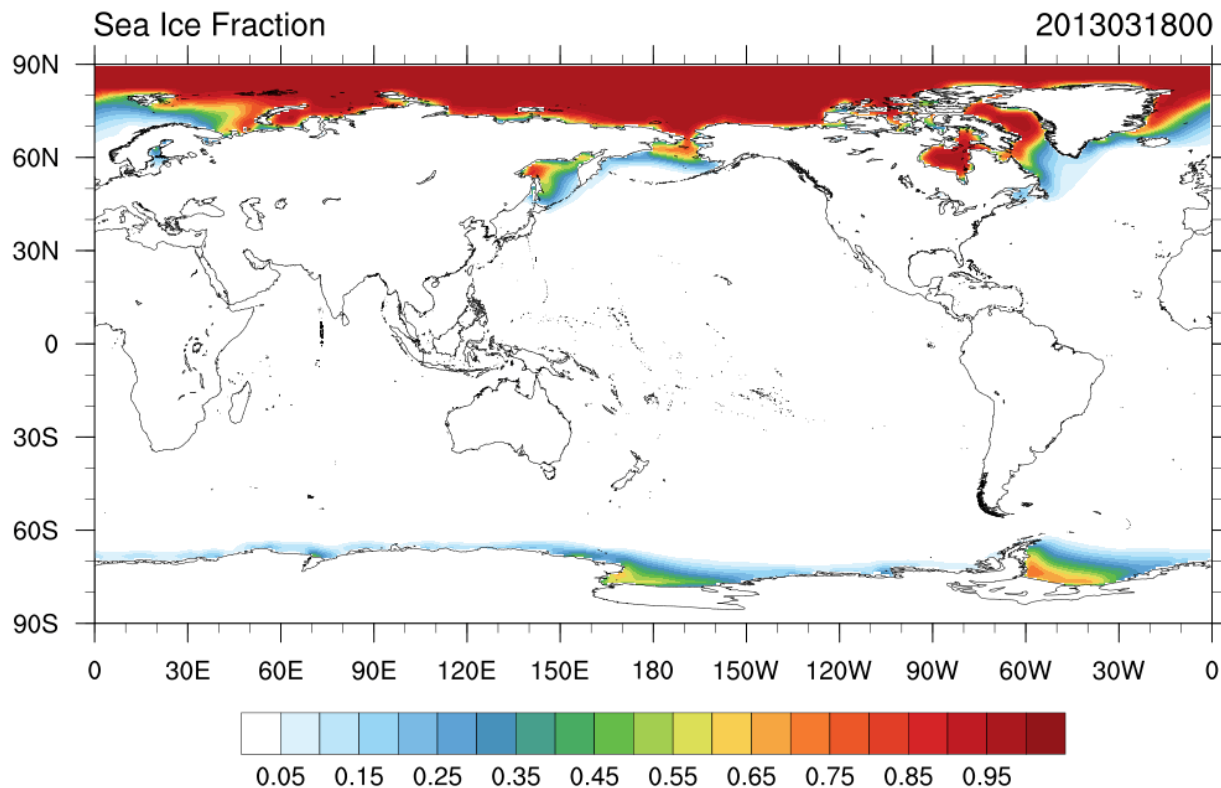


Future

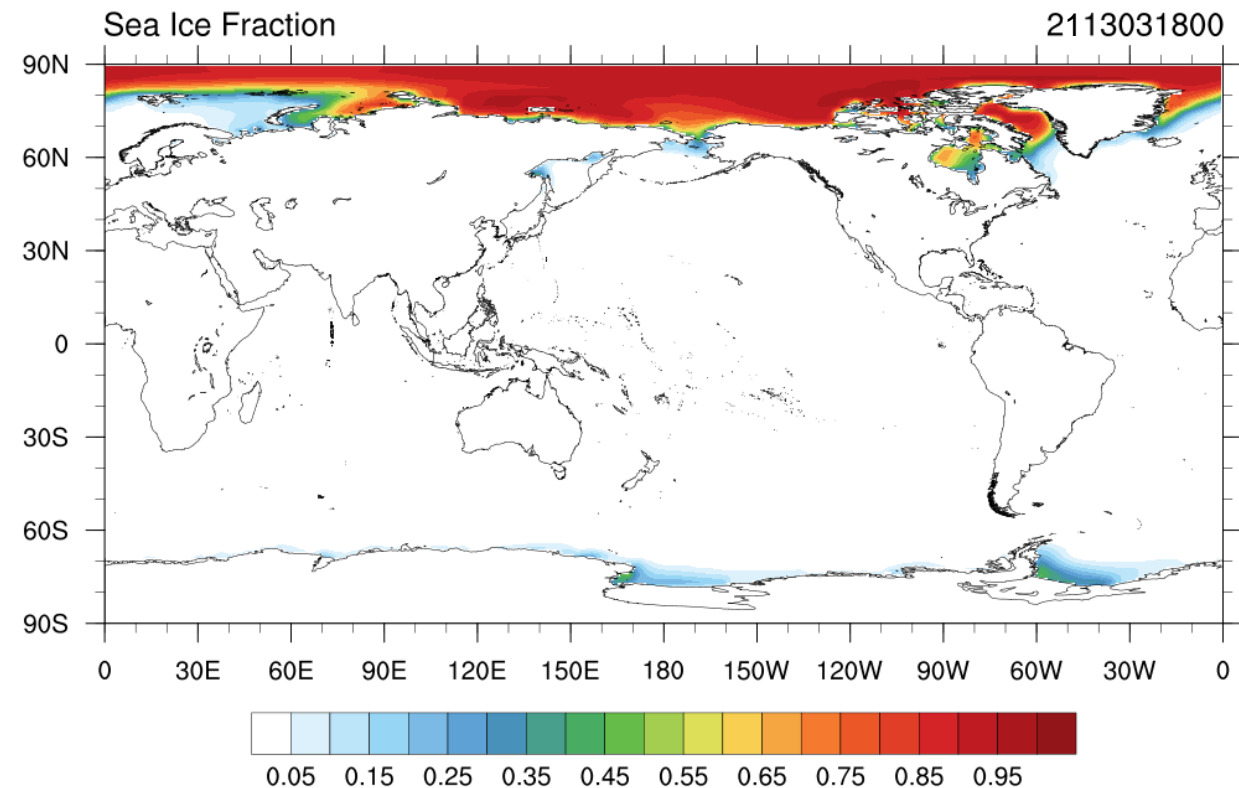
# MPAS Simulations – Future

- Future SST and sea ice fields

- Create pseudo-daily sea ice fields from monthly average CMIP5 ensemble mean – historical and RCP 8.5 future emissions scenario

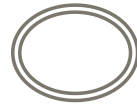


Current

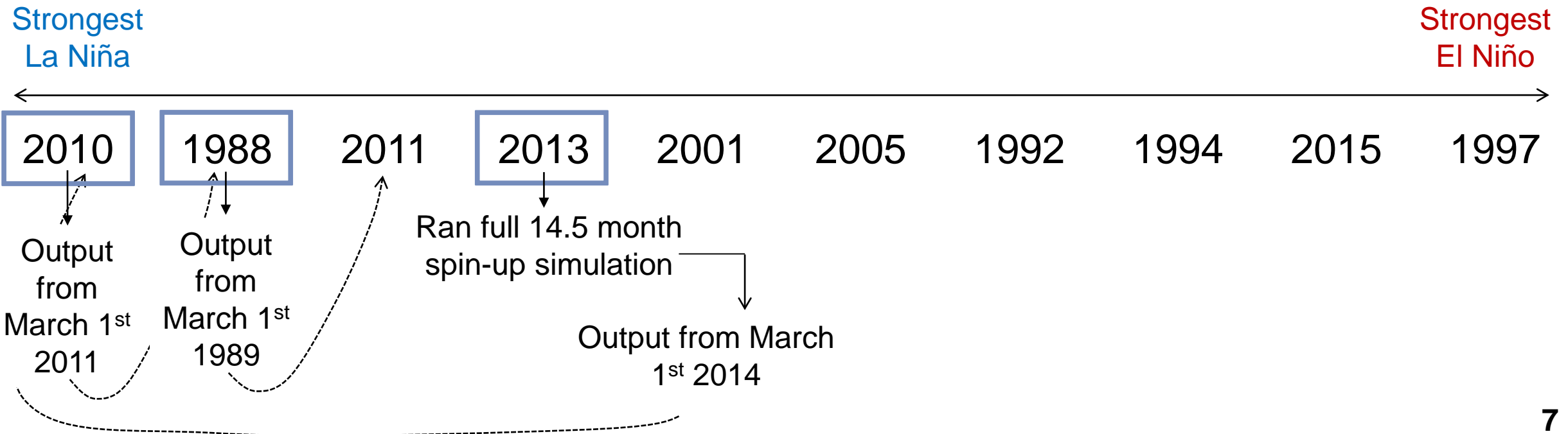


Future

# Model for Prediction Across Scales (MPAS) Simulations



- Selected 10 simulation years to sample range of ENSO phases
- Simulations run from March 1<sup>st</sup> of year 1 through mid-May of year 2 – first month discarded





# MPAS Simulations

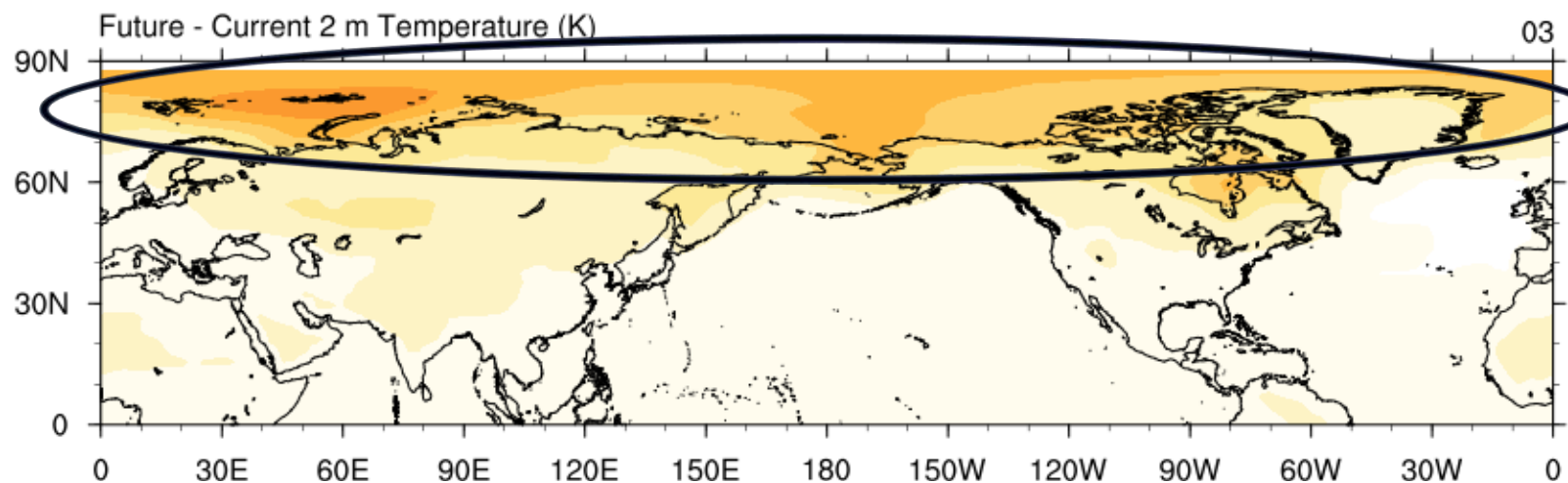


- Completed 10 sets (current and future) of simulations
  - 2010, 1988, 2011, 2013, 2001, 2005, 1992, 1994, 2015, 1997
- Output has been post-processed
  - Interpolate fields (temperature, height, winds, etc.) to pressure levels
  - Interpolate output to a  $0.15^\circ \times 0.15^\circ$  lat-lon grid
    - ✦ Saving output for Northern Hemisphere only
- Select results shown today from (mostly) present-day simulations
  - 2-m temperature, zonal mean temperature
  - Midlatitude jet features, tropical precipitation
  - Tropical cyclones

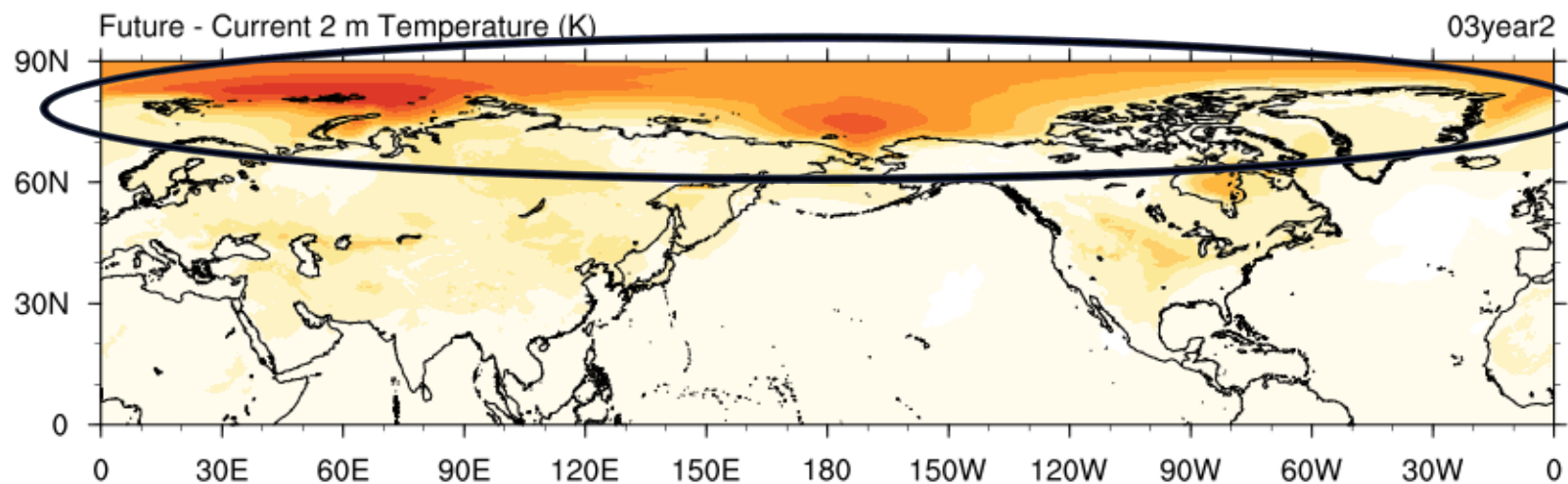
# 2-m Temperature (K) – March



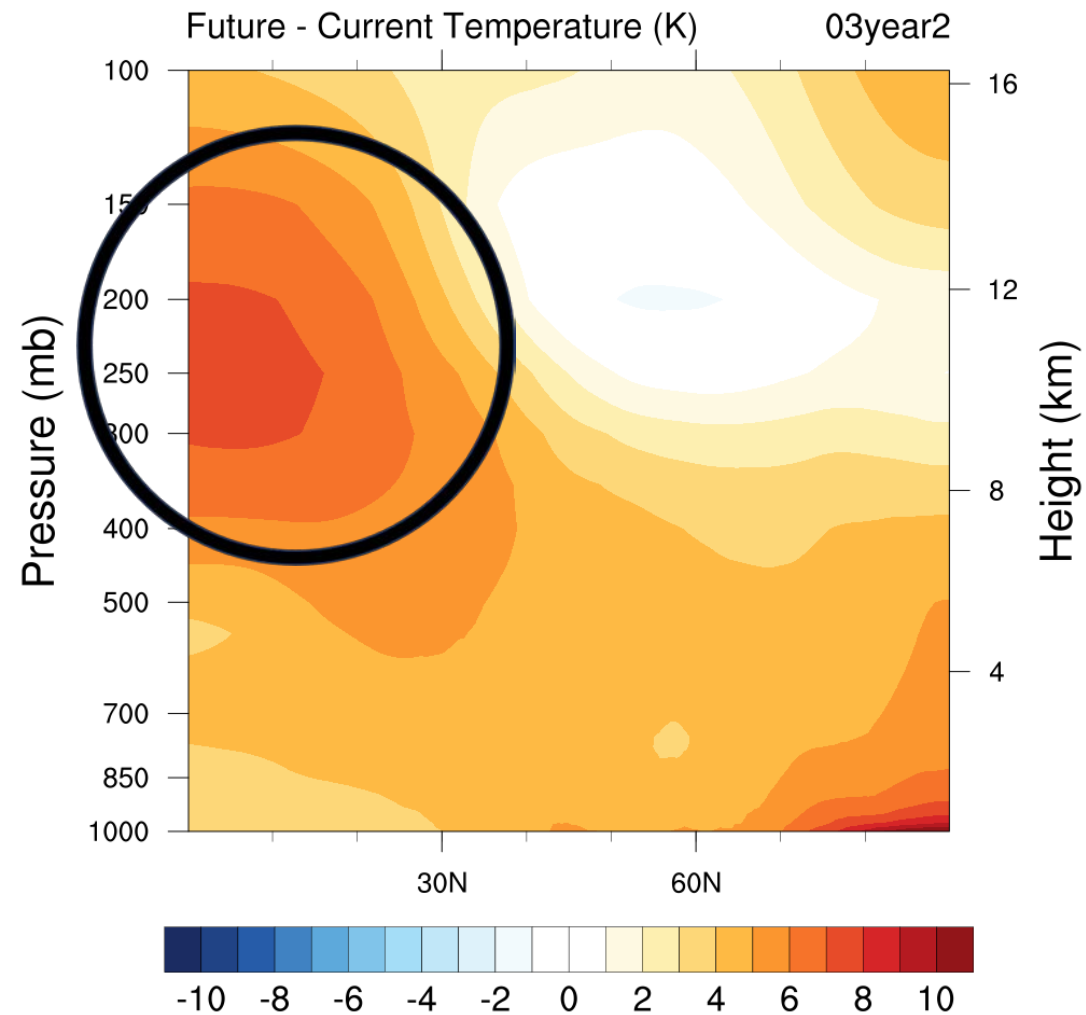
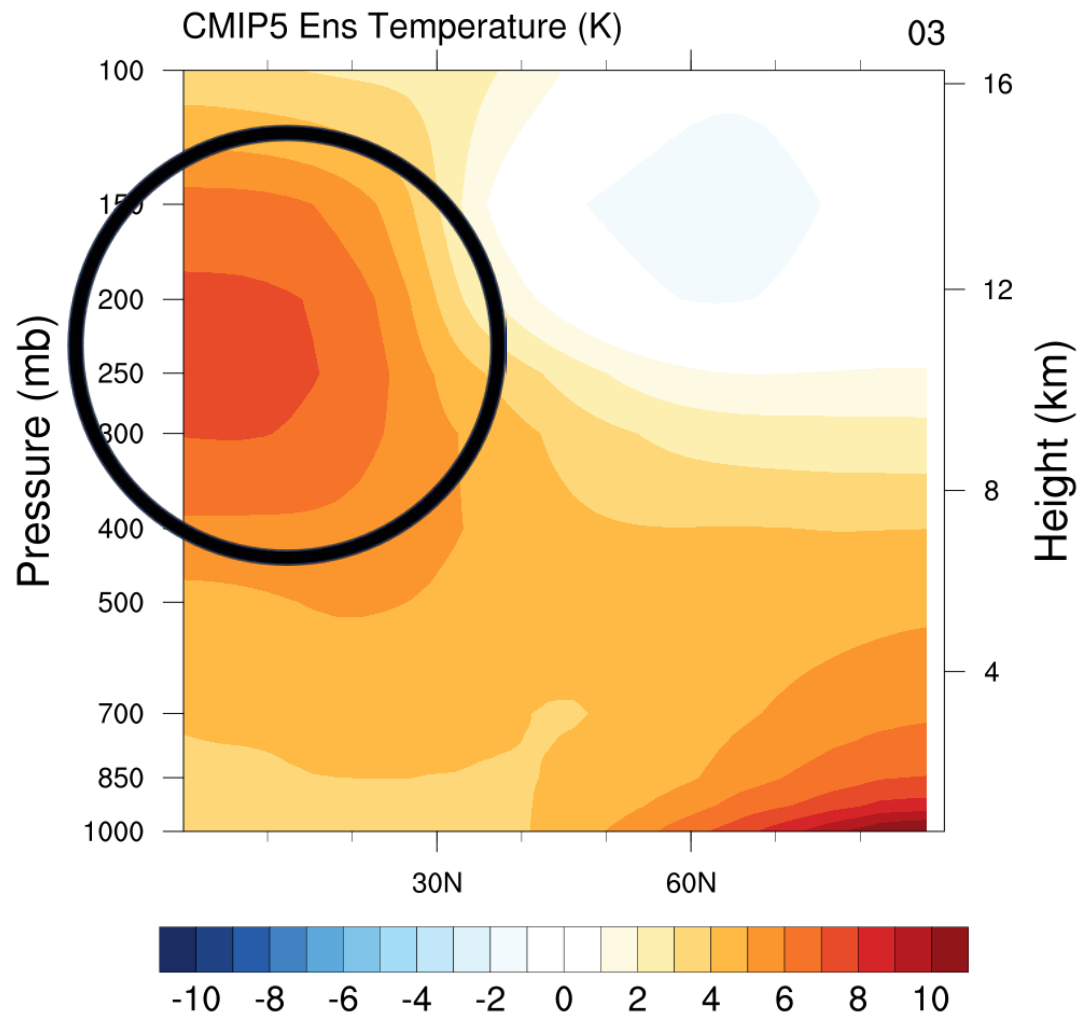
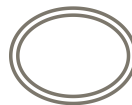
CMIP5 Ensemble Mean  
(20 year mean of 21 ensemble members)



MPAS 10-yr Mean



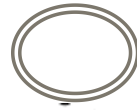
# Zonal Mean Temperature (K) – March



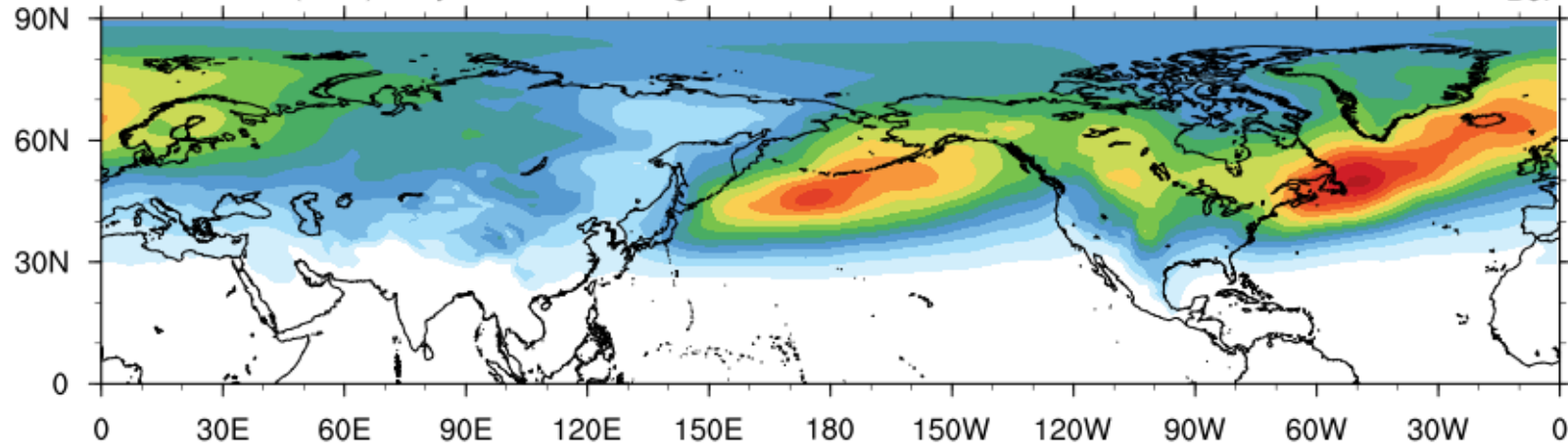
CMIP5 Ensemble Mean

MPAS 10-yr Mean

# Sea-Level Pressure Variance (hPa<sup>2</sup>) – DJF

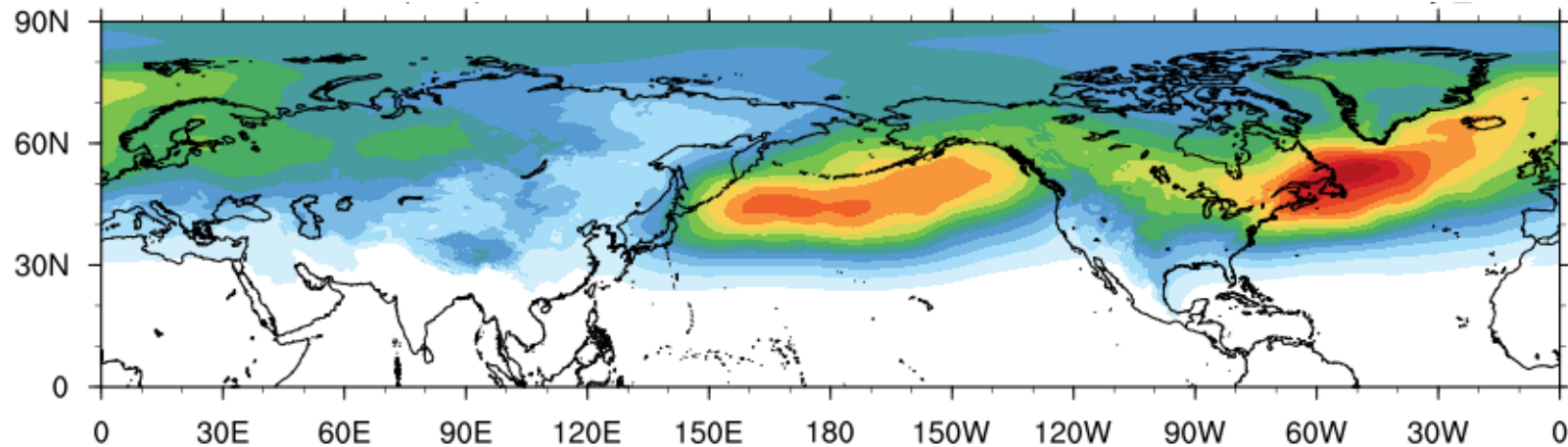


ERA-Interim 10-yr  
Climatology

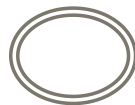


$r > 0.95$

MPAS 10-yr  
Mean

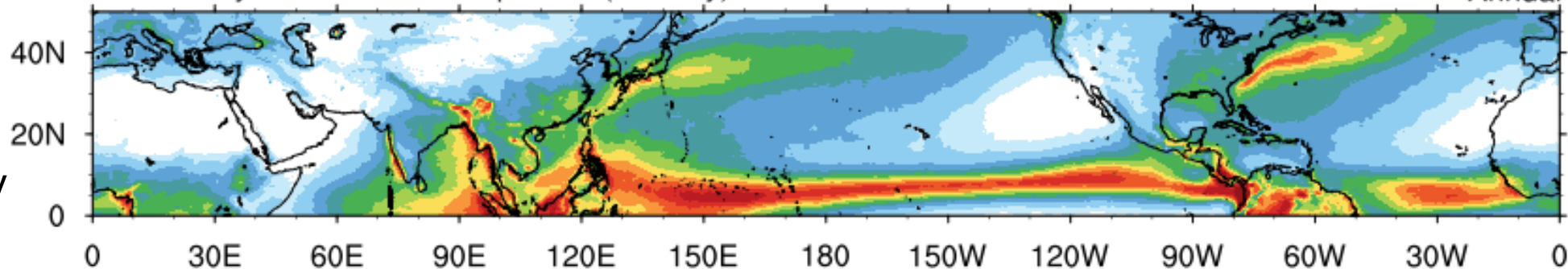


# Tropical Precipitation (mm/day) – Annual



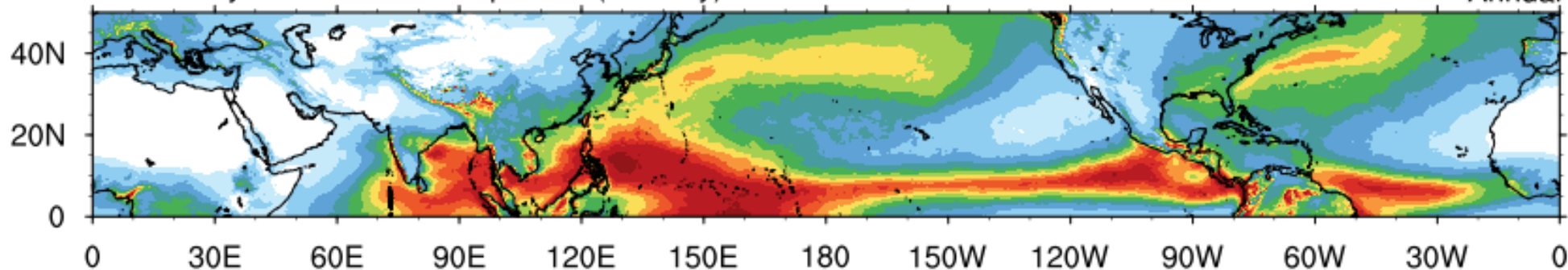
TRMM  
19-yr  
Climatology

TRMM 19-yr Mean Total Precipitation (mm/day)



MPAS  
10-yr  
Mean

MPAS 10-yr Mean Total Precipitation (mm/day)



# Tropical Cyclone Tracking



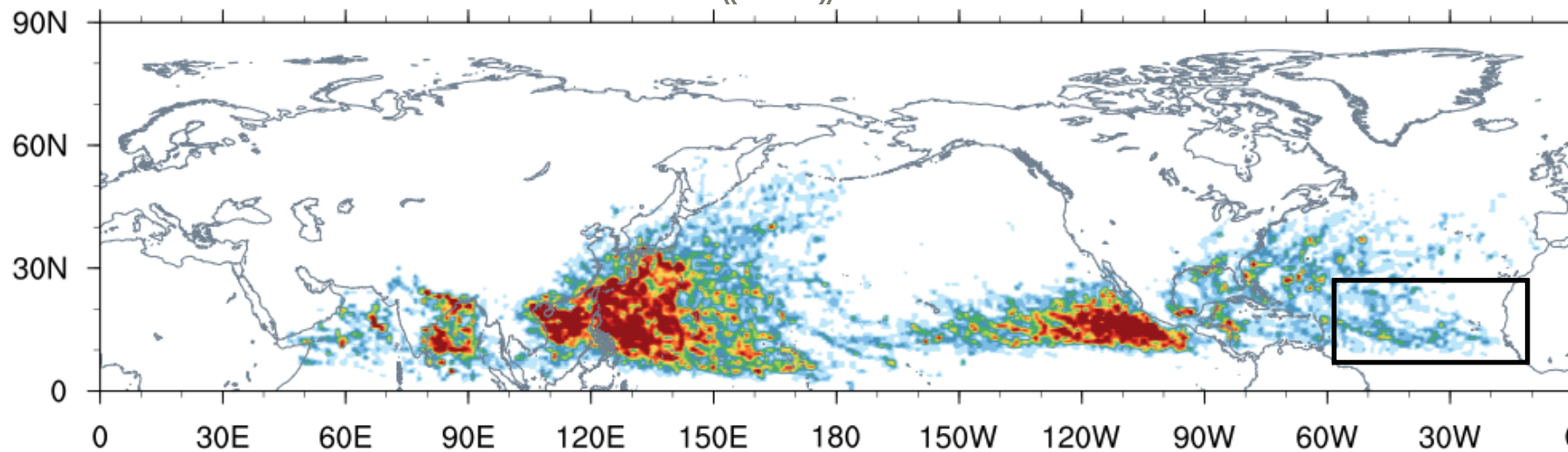
- TempestExtremes tracking algorithm (Ullrich and Zarzycki 2017)
- Tunable Parameters:
  - 2 hPa closed SLP contour within  $2^\circ$  of center
  - -15 m closed 300–500-hPa thickness contour within  $6^\circ$  of center
    - ✦ Maximum offset from SLP minimum:  $1.1^\circ$
  - Maximum search latitude for candidate storms:  $60^\circ\text{N}$
  - Maximum travel distance within 6-h:  $6^\circ$
  - Minimum lifetime: 2 days
  - Allows for up to 12-h gaps in trajectories
  - Must be over water for at least 12-h
  - Must have at least 2 (non-consecutive) days of 10-m winds  $\geq 14$  m/s ( $\sim 31$  mph)



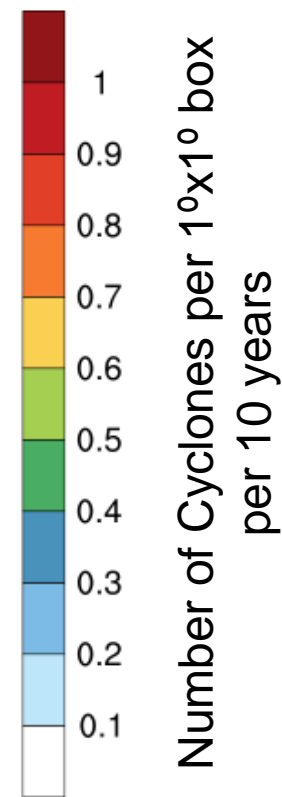
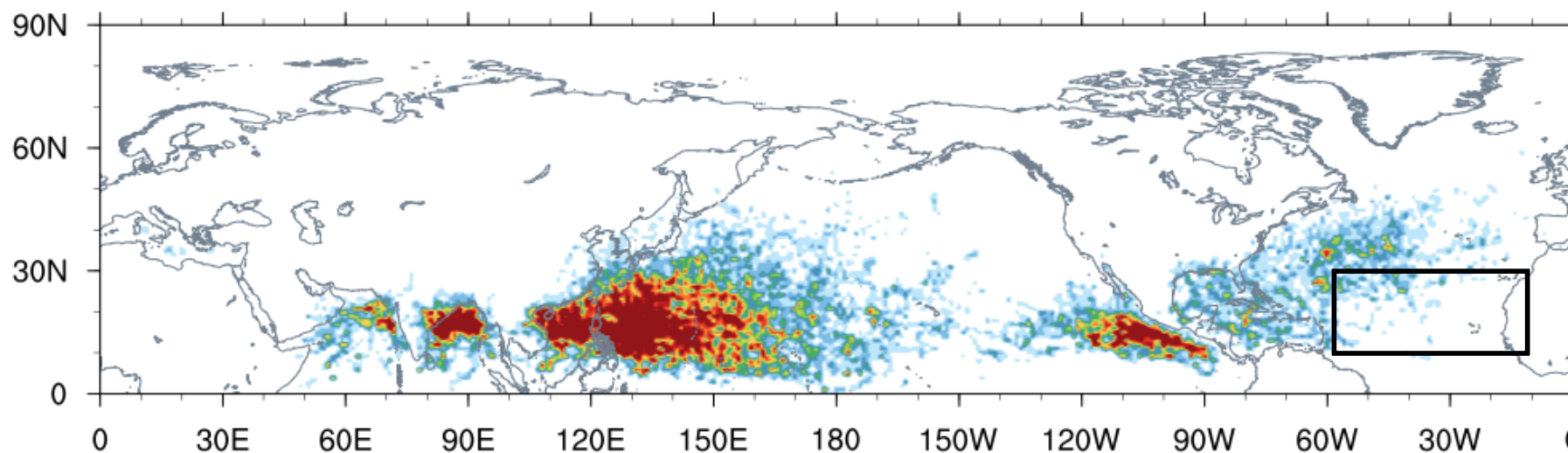
# Tropical Cyclone Density



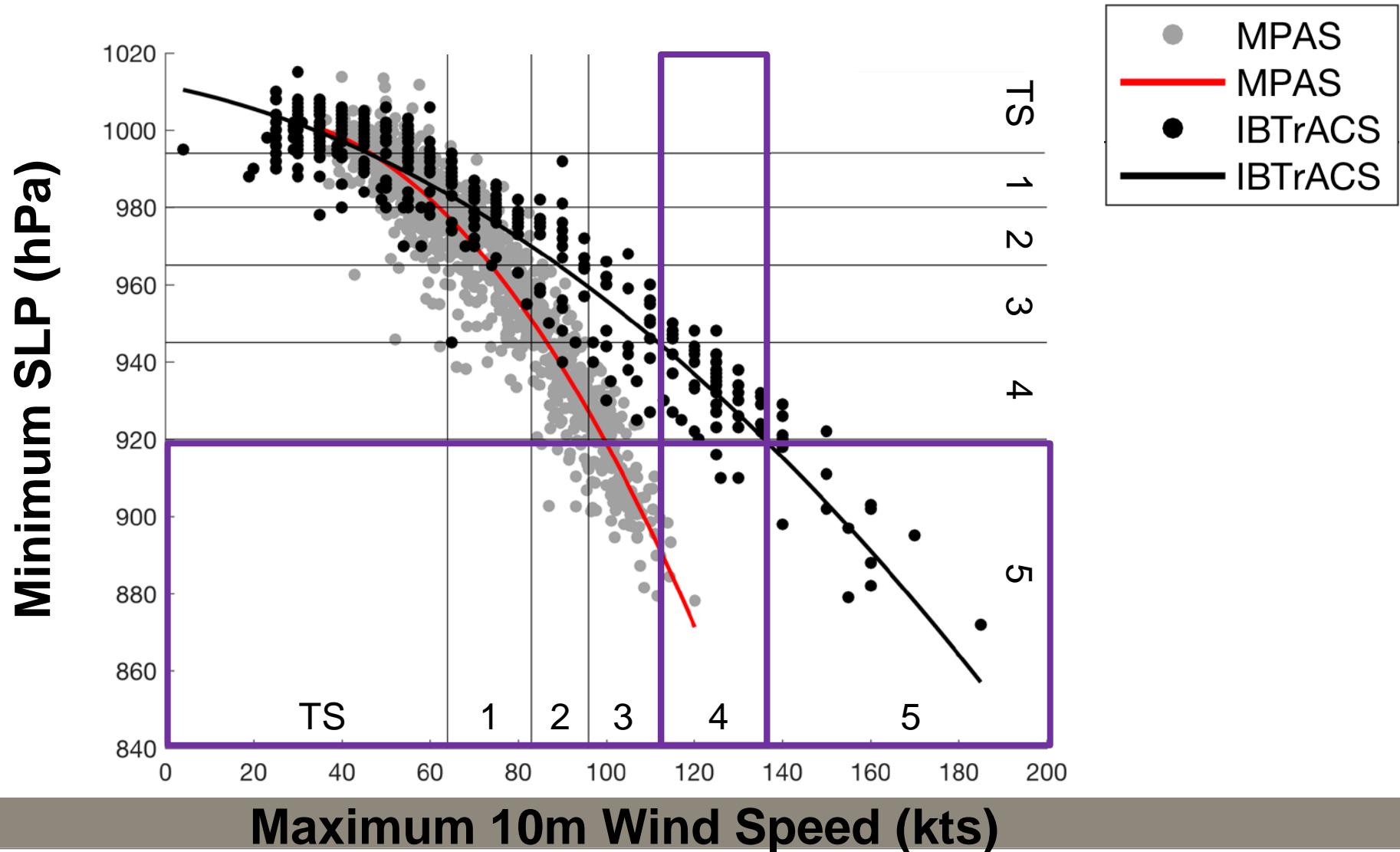
IBTrACS  
10-yr  
Climatology



MPAS 10-yr  
Mean



# Tropical Cyclone Strength



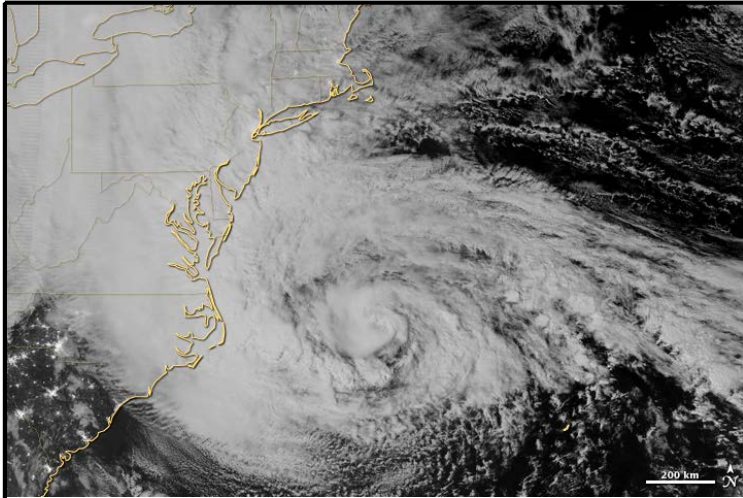


# Summary



- Future MPAS simulations reproduce two key warming signatures
  - Arctic amplification and tropical upper-tropospheric warming
- Large-scale, seasonal mean fields realistically represented in MPAS simulations
  - e.g., midlatitude storm tracks, tropical precipitation
- TC activity generated in all Northern Hemispheric basins
  - Storms simulated across full intensity spectrum

# Ongoing Projects

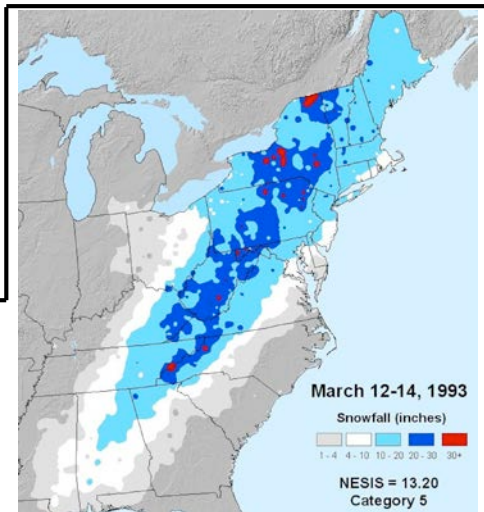


Extratropical Transition of TCs



TC Seasonality

Persistent Anomalies



Extreme Precipitation along US East Coast

