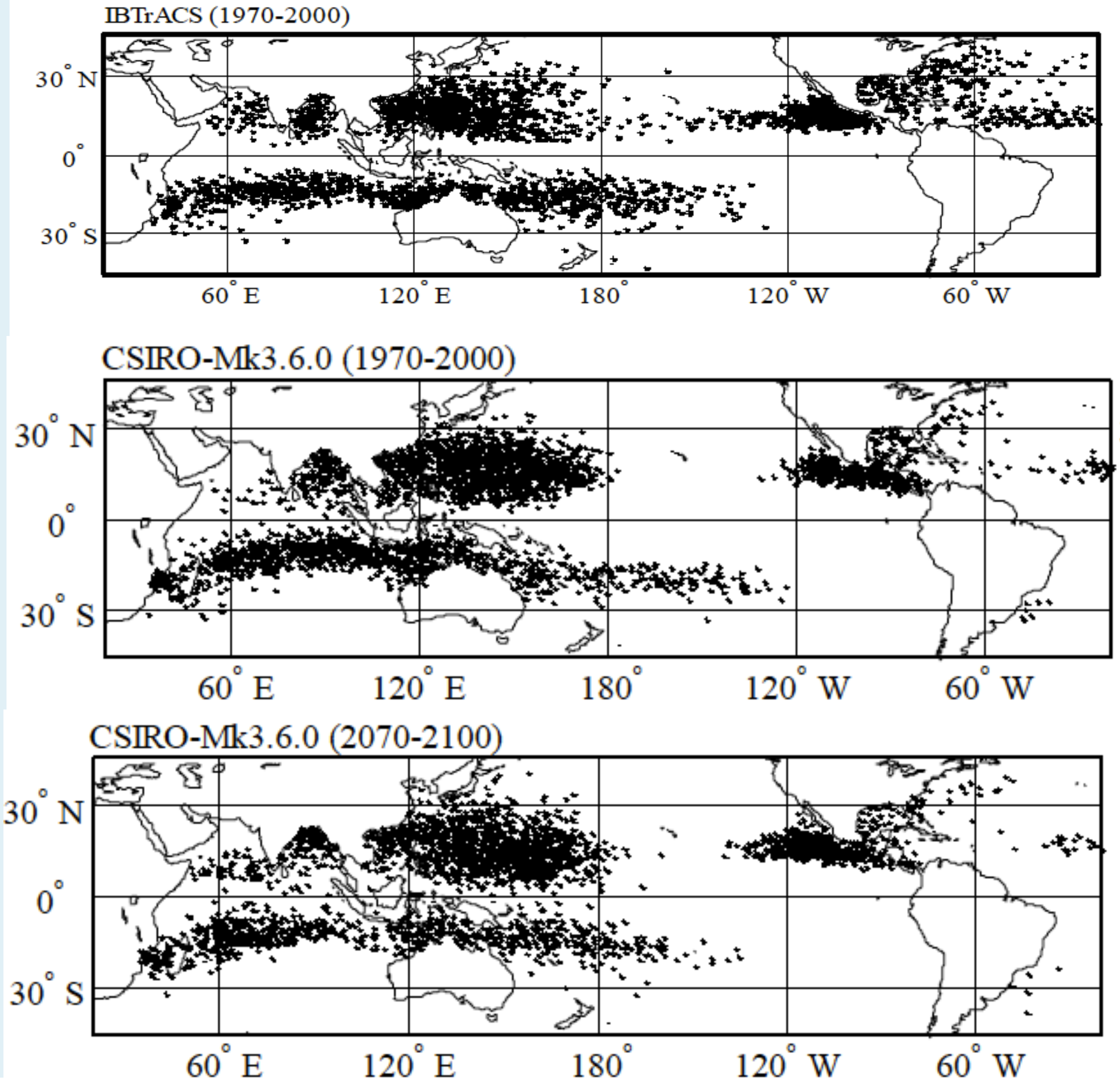

Data
Best Track
1970-2000

Climate model
Historic run
1970-2000

Climate model
Future climate
2070-2100
High emission scenario
Rcp 8.5

Projected changes in late 21st century tropical cyclone frequency in thirteen CMIP-5 coupled climate models

K. J. Tory, S. S. Chand, J. L. McBride, H. Ye and R. A. Dare

Jnl of Climate 2013 In Press

Projected changes in late 21st century tropical cyclone frequency in thirteen CMIP-5 coupled climate models

K. J. Tory, S. S. Chand, **J. L. McBride**, H. Ye and R. A. Dare

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University of Melbourne, Dept of Earth Sciences, Honorary Principal Fellow

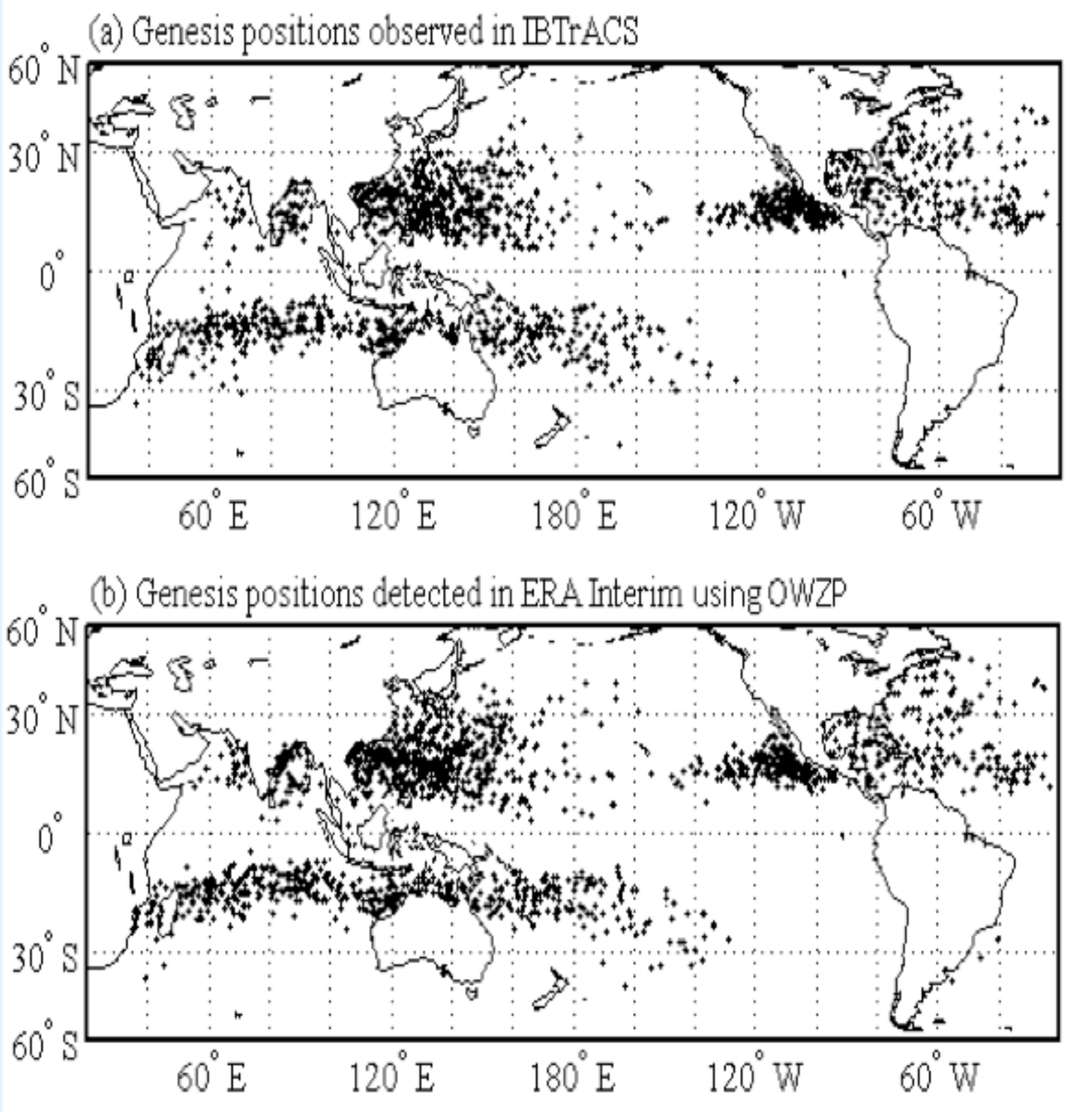
OWZP Direct Detection (Okubo-Weiss-Zeta-Parameter)

- **OWZP DD method tuned and tested in 20 years of ERA-interim reanalysis data (*Tory et al. 2013b*)**

- **Applied to climate models, with no change in algorithm or coefficients. Same algorithm used in every climate models, independent of resolution.**

- **Tested in four CMIP3 models (*Tory et al. 2013c*)**

- **Applied to 13 CMIP5 models (*Tory et al. 2013d*)**



OWZP (Okubo-Weiss-Zeta-Parameter) is a new detection method

- **Developed by Kevin Tory and coauthors**:
- Series of papers in Atmospheric Chemistry and Physics (Tory et al, 2013a) and in Journal of Climate (Tory et al, 2013b, c, d)
- **The name comes from the Okubo-Weiss parameter from studies of 2-dimensional flows and 2-dimensional turbulence. The OW parameter measures the existence of a separate vortex, or rotationally dominated flow regions.**
- Zeta incorporates the absolute vorticity.
- **Key hypothesis is that all tropical cyclone precursors contain enhanced values of OWZ on a scale resolved by climate models (500 to 1000 kM)**

Rationale for the new detection method

- **Other methods :Seasonal Genesis parameter** (downscaling) method does not reproduce interannual variability in current climate
- **Other methods: Normal direct detections** problematic as climate models do not resolve tropical cyclones which have small spatial scale structure: radius of maximum wind, eye-wall etc. 50 km scale or less.
- **New method (OWZP) detects environment in which tropical cyclone develops**
  - well documented as being large scale in nature (back to McBride-Zehr 1981, and many papers since).
  - Depends on transients (monsoon surges, easterly waves etc), so requires daily fields from the climate models
  - Reproduces interannual variability in ERA Interim re-analyses.

Detections for individual year cyclones in ERA-Interim analyses

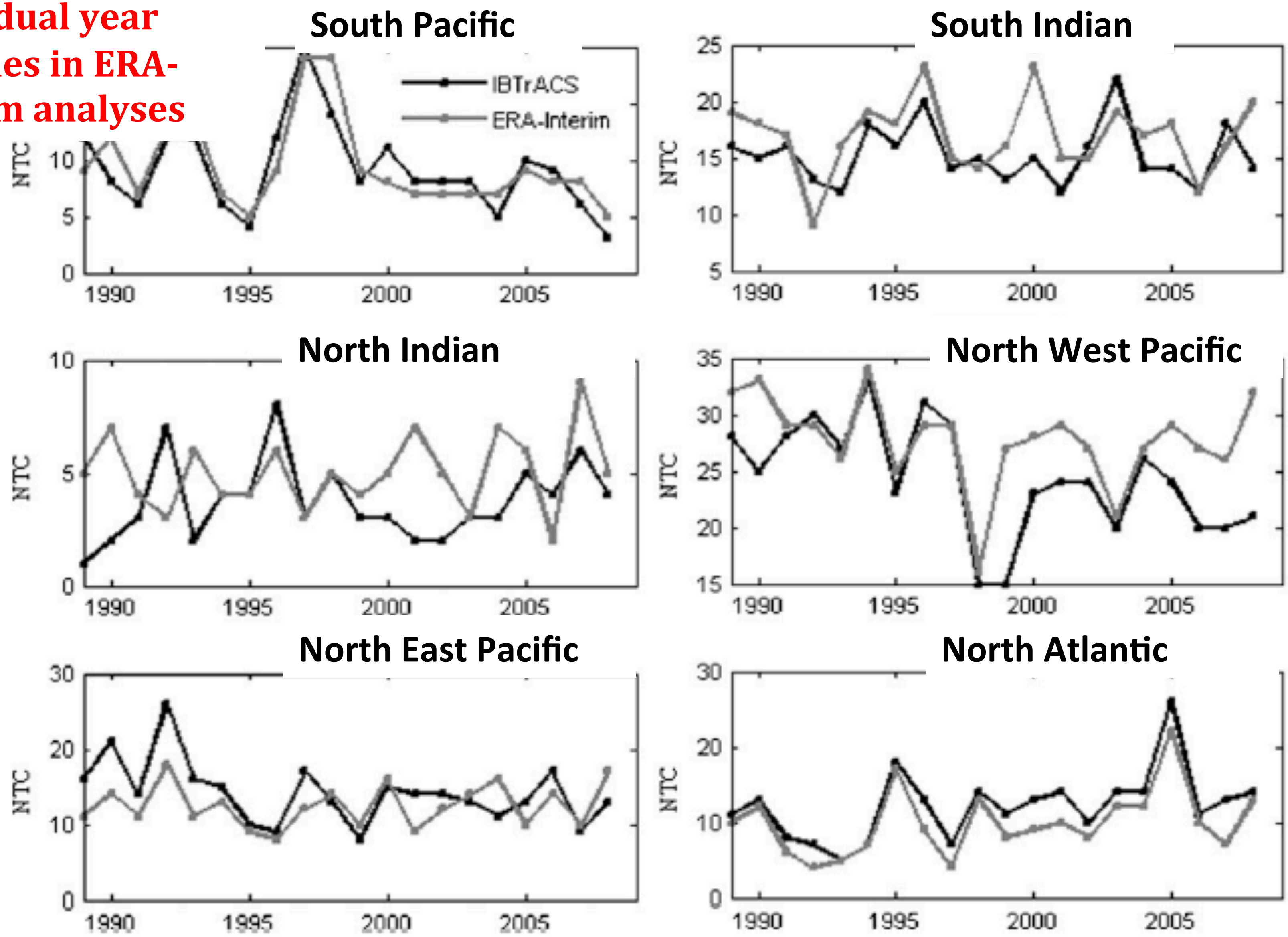


FIG. 5. Interannual variability of the mean annual number of TCs (NTC) in different TC basins. Black lines indicate TCs in the IBTrACS and gray lines indicate TCs detected in the ERA-Interim data.

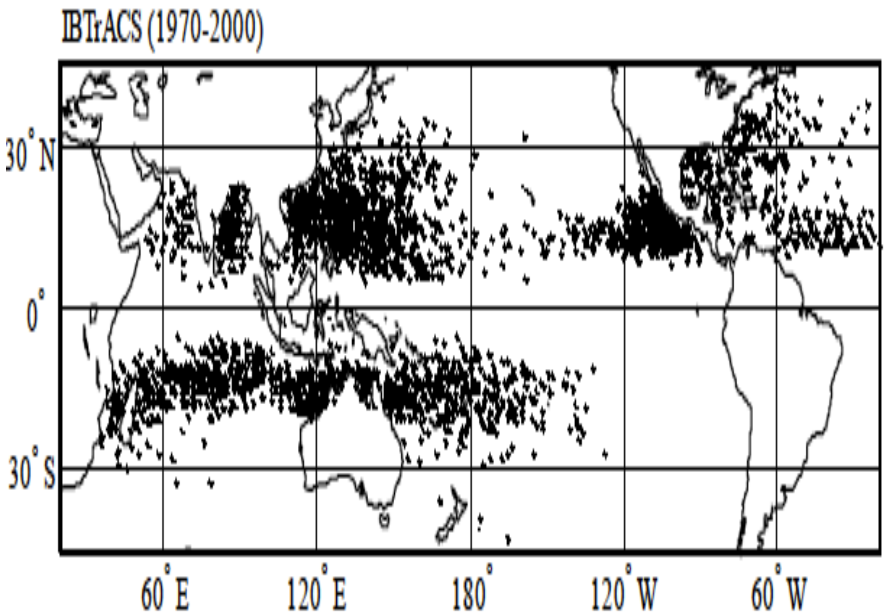
CMIP-5 Study

- Applied OWZP algorithm to 13 CMIP-5 models
- **Historic run** (forced by observed greenhouse gases and volcano activity) 1970-2000 **to see ability to reproduce current Tropical cyclone climatology**
- **Future climate** (high emissions scenario) rcp8.5 **to determine model projections**

Model	Model Institution	Number of lon x lat grid-points
CNRM-CM5	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique	256x128
CCSM4	National Center for Atmospheric Research	288x192
CSIRO-Mk3.6.0	Commonwealth Scientific and Industrial Research Organisation	192x96
NorESM1-M*	Norwegian Climate Centre	144x96
GFDL-CM3	Geophysical Fluid Dynamics Laboratory	144x90
GFDL-ESM2M	Geophysical Fluid Dynamics Laboratory	144x90
GFDL-ESM2G	Geophysical Fluid Dynamics Laboratory	144x90
BCC-CSM1.1	Beijing Climate Center, China Meteorological Administration	128x64
CanESM2*	Canadian Centre for Climate Modelling and Analysis	128x64
FGOALS-g2*	Institute of Atmospheric Physics, Chinese Academy of Sciences; and Tsinghua University	128x60
IPSL-CM5A-LR*	Institut Pierre-Simon Laplace	96x96
IPSL-CM5A-MR*	Institut Pierre-Simon Laplace	144x143
MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	256x128

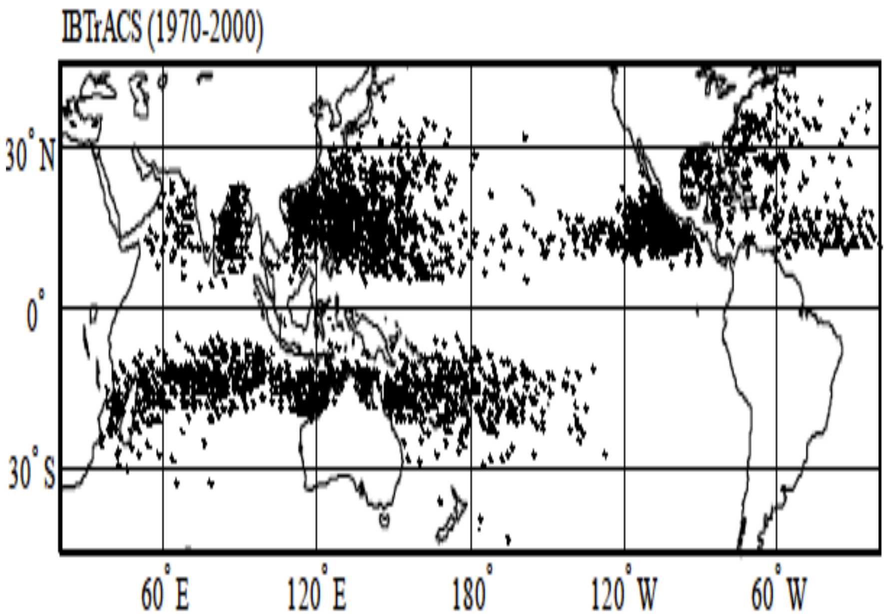
Historic run (1970 – 2000)

Data (Best Tracks)



Of the 13 models, 8 reproduce current climatology to within +/- 50%

Data (Best Tracks)



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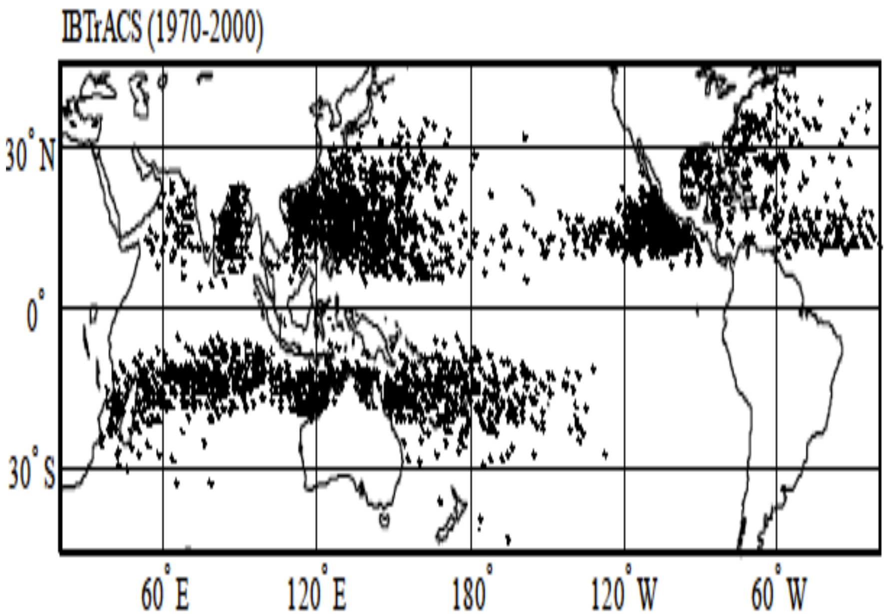
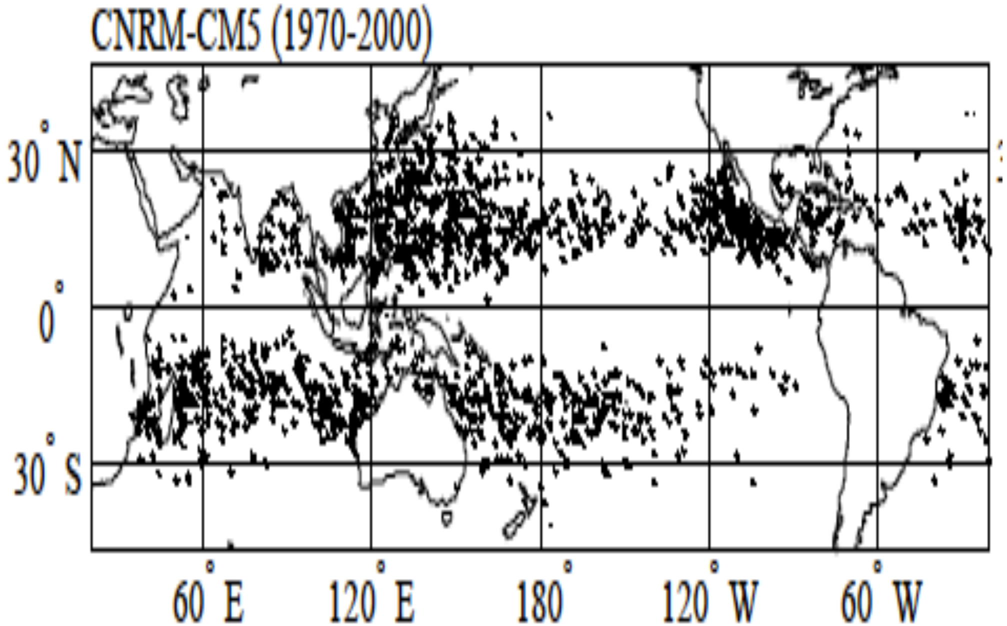
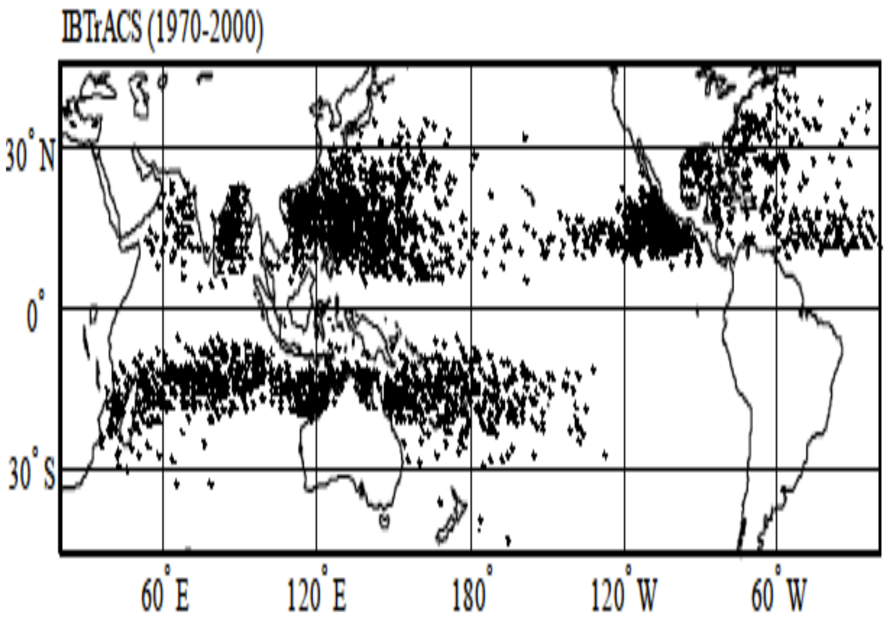


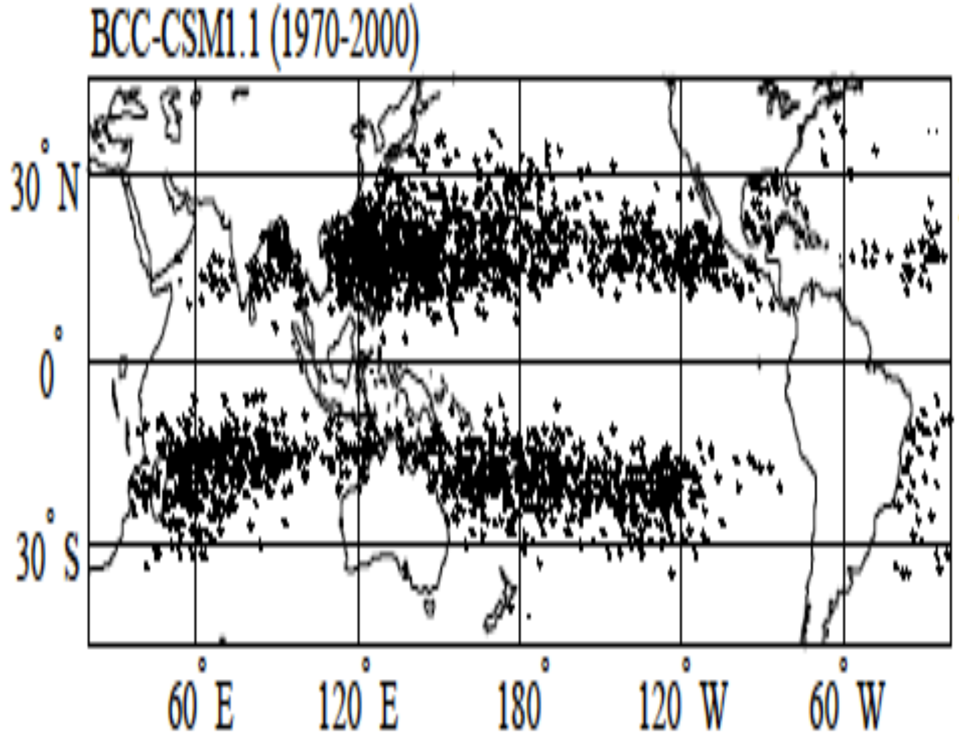


High resolution model CNMR-CM5

Of the 13 models, 8 reproduce current climatology to within +/- 50%

Data (Best Tracks)

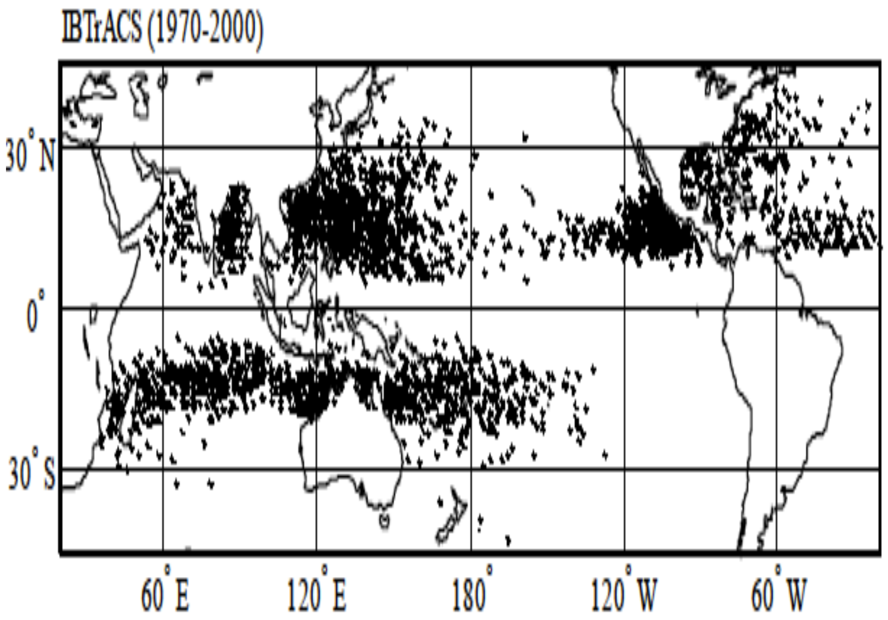


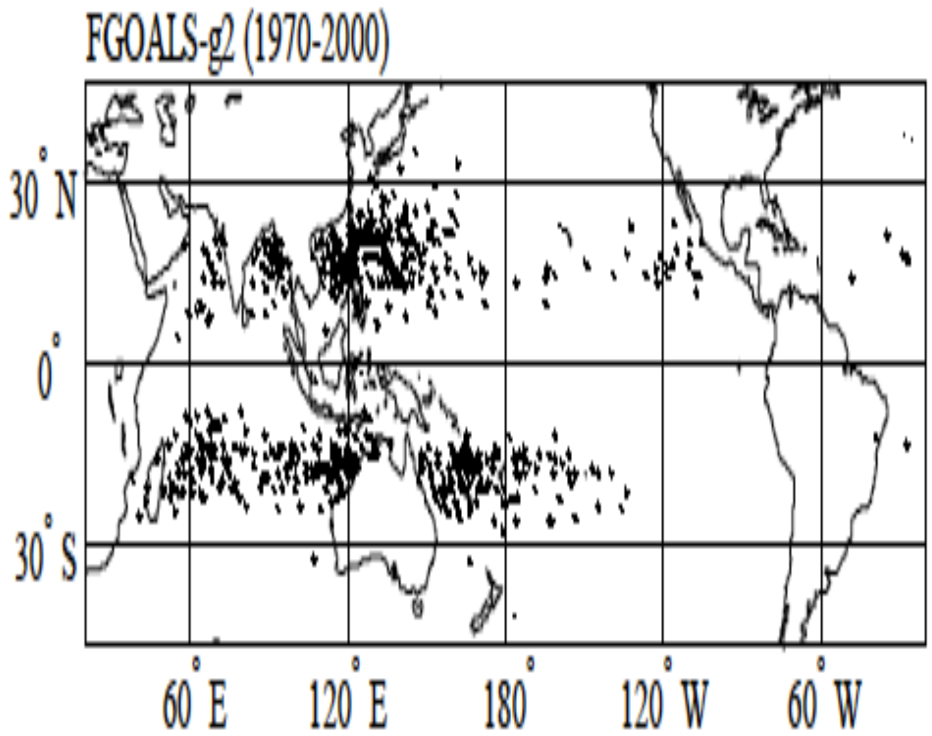


Low resolution model BCC-CSM1

Of the 13 models, **5 do not reproduce current climatology**

Data (Best Tracks)





Model FGOALS-g2

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CNRM-CM5	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique	256x128
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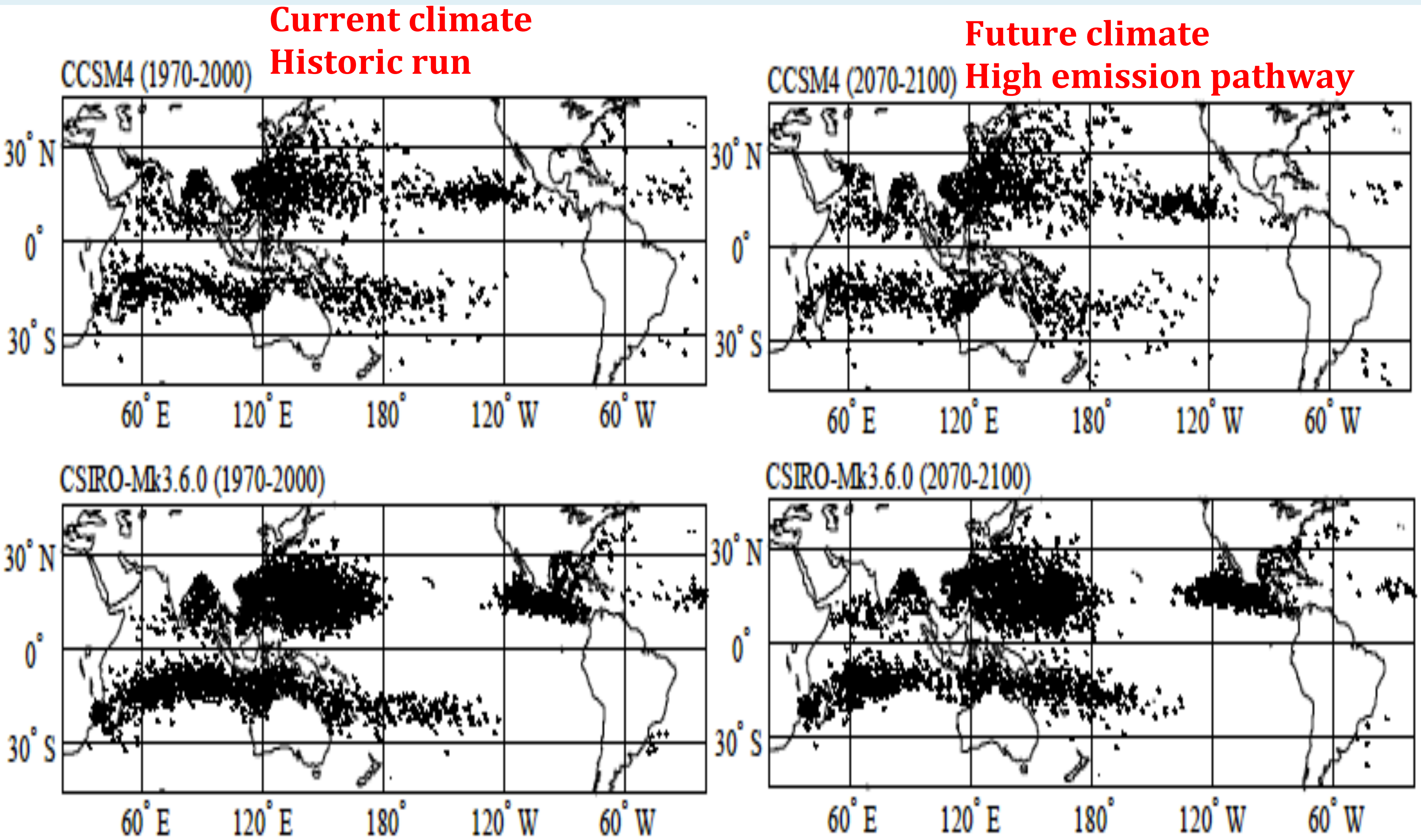
CMIP-5 Projections rcp8.5 2070-2100



CMIP-5 Projections rcp8.5
2070-2100

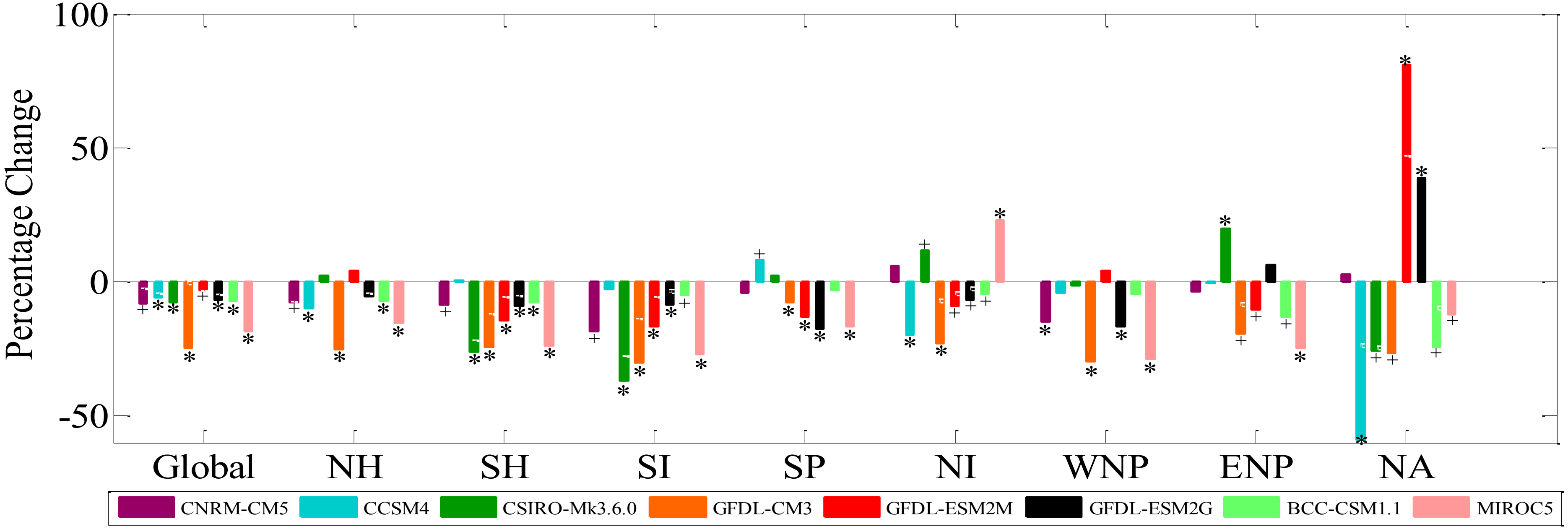
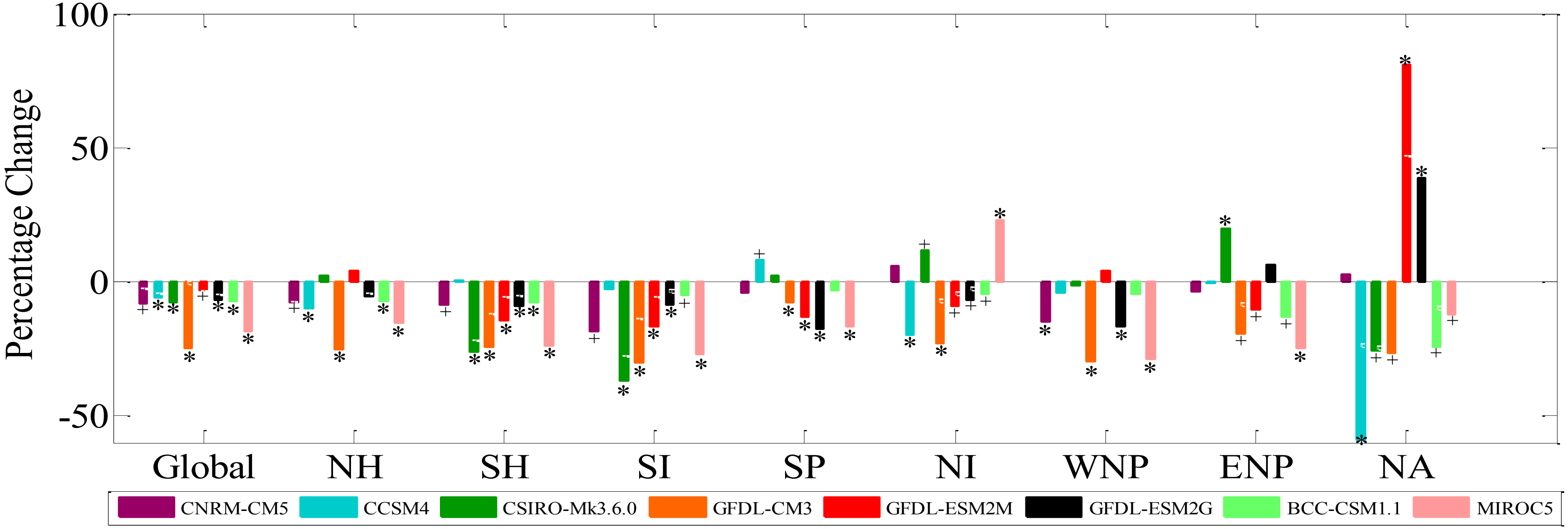


FIG. 4. Percentage change in mean TC frequency between the late twentieth and late twenty-first centuries for the CMIP5 models deemed to have reasonable global TC climatology (i.e., within 50% of that observed) . Changes that are significant at 95% and 90% confidence levels are indicated by asterisk and plus symbols respectively.

CMIP-5 Projections rcp8.5
2070-2100



All 8 models show a reduction for the globe: -3% (GFDL-ES2M) to -15% (GFDL-CM3)
Seven models show reduction for Southern Hemisphere
Northern Hemisphere ranges from -25% (decrease) GFDL-CM3 to +4% (increase) % (GFDL-ES2M)
Wide inter-model response in individual basins, particularly Northern Hemisphere basins

Context of the study

- CMIP-3 and earlier generation results summarised by WMO Expert team on TC and Climate change: (Knutson et al, 2010)

nature geoscience

REVIEW ARTICLE

PUBLISHED ONLINE: 21 FEBRUARY 2010 | DOI: 10.1038/NGEO779

Tropical cyclones and climate change

Thomas R. Knutson[1]*, John L. McBride[2], Johnny Chan[3], Kerry Emanuel[4], Greg Holland[5], Chris Landsea[6], Isaac Held[1], James P. Kossin[7], A. K. Srivastava[8] and Masato Sugi[9]

Whether the characteristics of tropical cyclones have changed or will change in a warming climate — and if so, how — has been the subject of considerable investigation, often with conflicting results. Large amplitude fluctuations in the frequency and intensity of tropical cyclones greatly complicate both the detection of long-term trends and their attribution to rising levels of atmospheric greenhouse gases. Trend detection is further impeded by substantial limitations in the availability and quality of global historical records of tropical cyclones. Therefore, it remains uncertain whether past changes in tropical cyclone activity have exceeded the variability expected from natural causes. However, future projections based on theory and high-resolution dynamical models consistently indicate that greenhouse warming will cause the globally averaged intensity of tropical cyclones to shift towards stronger storms, with intensity increases of 2–11% by 2100. Existing modelling studies also consistently project decreases in the globally averaged frequency of tropical cyclones, by 6–34%. Balanced against this, higher resolution modelling studies typically project substantial increases in the frequency of the most intense cyclones, and increases of the order of 20% in the precipitation rate within 100 km of the storm centre. For all cyclone parameters, projected changes for individual basins show large variations between different modelling studies.

The challenge for climate change detection and attribution research with regard to tropical cyclones is to determine whether an observed change in tropical cyclone activity

coastal areas. In developing countries, in particular, the movement of the population to the coast is the result of social factors that are not easily countered. Climate change is hence one of several factors likely

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REVIEW A

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For all cyclone parameters, projected changes for individual basins show large variations between different modelling studies.

Context of the study

- Purpose of our CMIP-5 study: To determine the robustness of the results from CMIP-3 and earlier generations:
  - Reduced global average frequency of tropical cyclones,
  - but large inter-model variations between frequency projections for individual basins
- Results: verify this…. **The global frequency reduction is a robust result, in that it is also true for CMIP-5 projections.**

HOWEVER

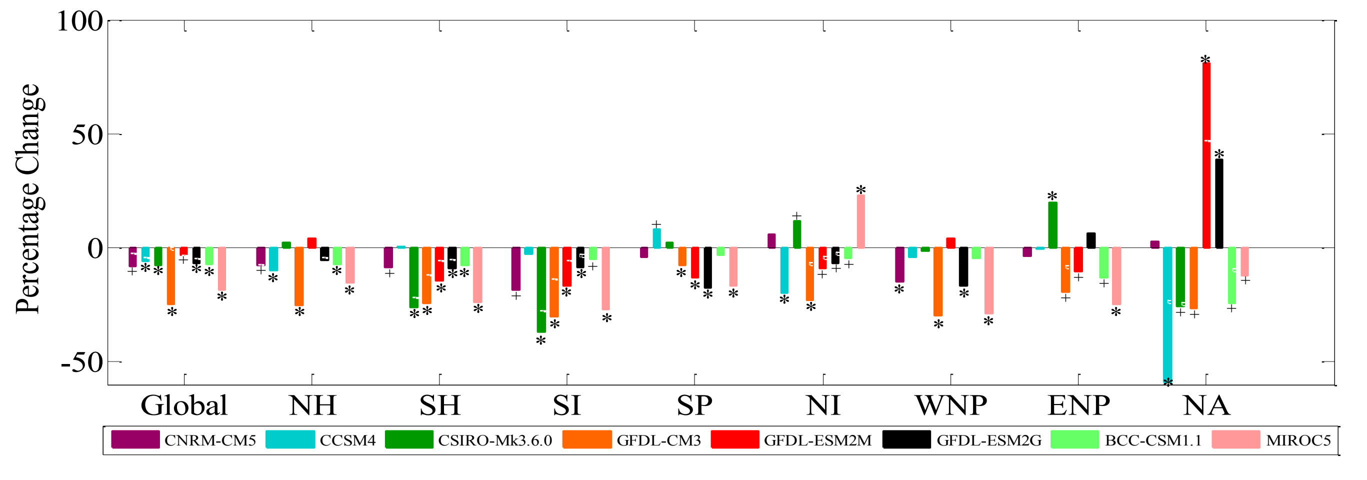
HOWEVER

- To date, three papers published on global tropical cyclone projections from CMIP-5
  - Our paper, Tory et al, J Climate 2013 in press. CMIP-5 results same as CMIP-3.. **Reduction in global frequency consistent across CMIP-5 models**
  - Emanuel, PNAS 2013, downscale model (runs idealised dynamical TC model offline from CMIP-5 model fields – **reports global increase in TC frequency** (opposite to his CMIP-3 results)
  - Camargo, J Climate 2013, in Press. Direct detection technique, 14 CMIP-5 models. Found all models badly underestimate cyclone frequency in current climate. Found "**no robust signal across CMIP-5 models in global and regional changes in TC activity for future scenarios**"

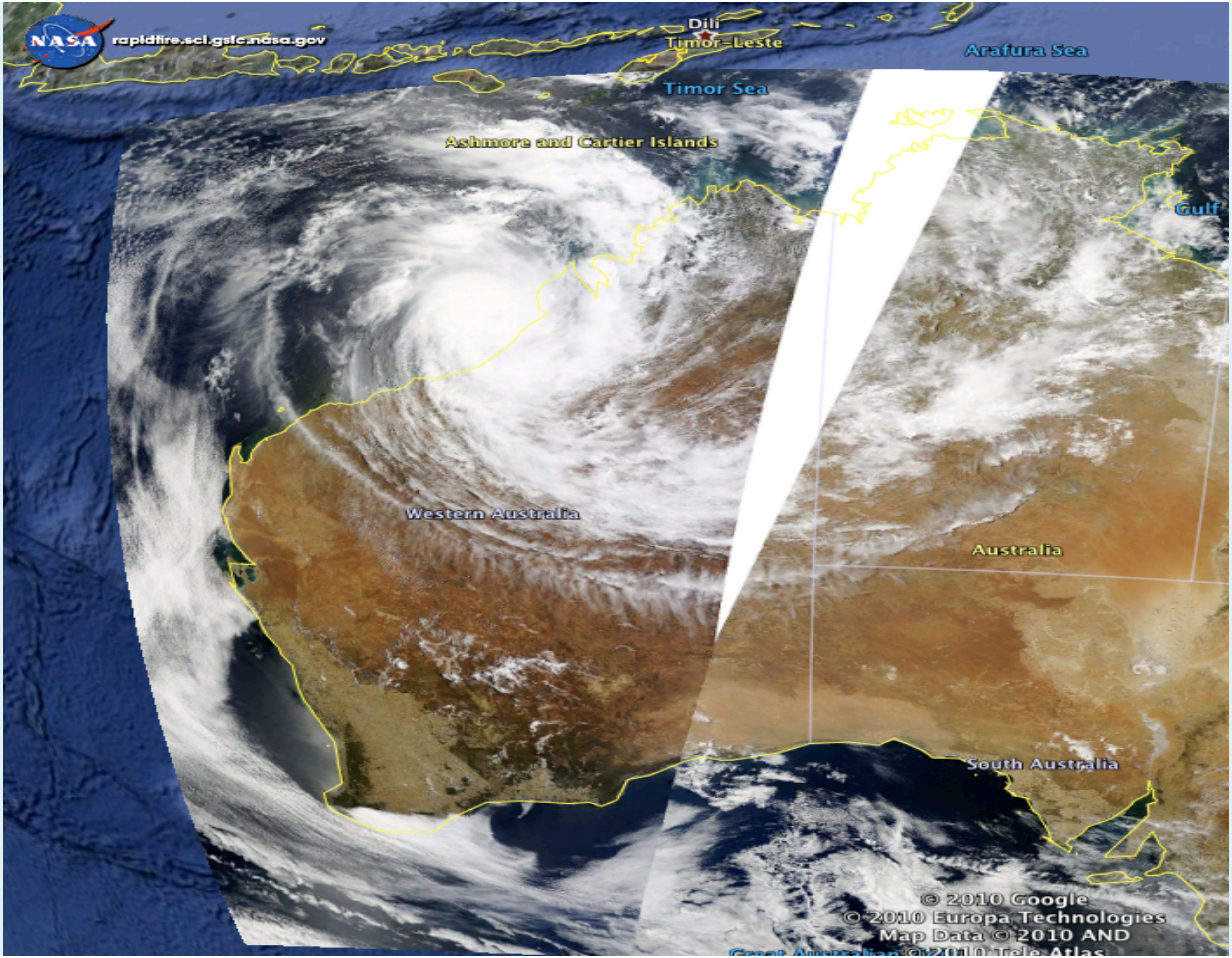
Summary

- New detection technique: OWZP detects large scale structure leading to tropical cyclogenesis – reproduces current climatology and inter-annual variability in ERA-interim re-analyses
- Reproduces current climate in CMIP-5 historic run for 8 of 13 CMIP-5 climate models
- Inverse result – 5 of 13 CMIP models (mainly low resolution) do not reproduce environment supporting TC development

Summary-II



- Our method gives reduction in global frequency, robust across CMIP-5 models, consistent with CMIP-3 results (Expert Team, Knutson et al)
- The two other global peer-reviewed CMIP-5 papers give different results (global increase, and no robust signal)
- So, despite the consistent, robust signal from CMIP-3 we have taken a temporary step backwards in CMIP-5
- These things are being investigated.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