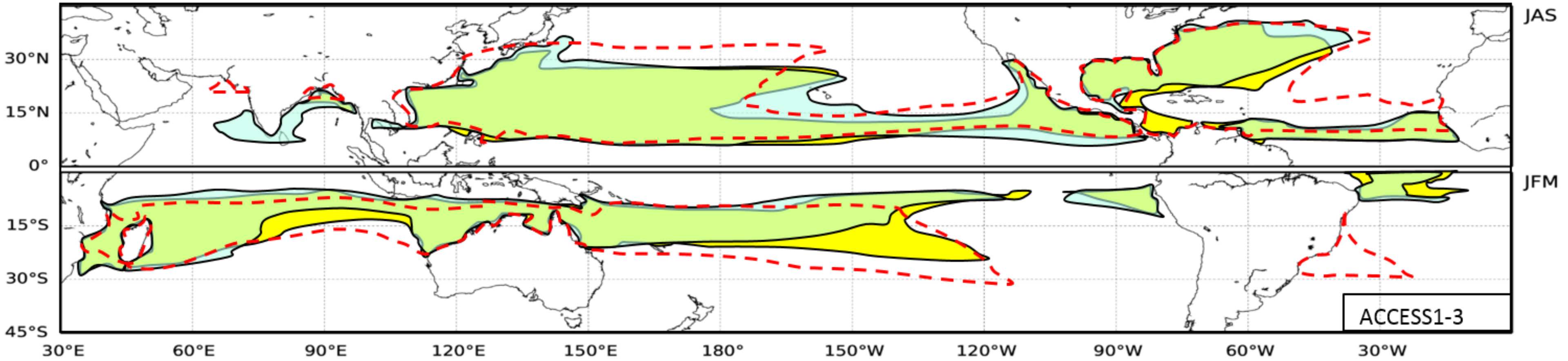

Tropical cyclone formation regions in CMIP5 models

A global performance assessment and projected changes

Kevin Tory, Harvey Ye, Gilbert Brunet

Australian Government

Bureau of Meteorology

Background

- Previously: Developed *method* for identifying TC formation regions in seasonal data

Clim Dyn
DOI 10.1007/s00382-017-3752-4

CrossMark

Understanding the geographic distribution of tropical cyclone formation for applications in climate models

Kevin J. Tory[1] · H. Ye[1] · R. A. Dare[1]

Received: 18 January 2017 / Accepted: 3 June 2017

Abstract Projections of Tropical cyclone (TC) formation under future climate scenarios are dependent on climate model simulations. However, many models produce unrealistic geographical distributions of TC formation, especially in the north and south Atlantic and eastern south Pacific TC basins. In order to improve confidence in projections it is important to understand the reasons behind these model errors. However, considerable effort is required to analyse the many models used in projection studies. To address quantity identify the factors that favour and suppress TC formation throughout the tropics in the real world. This information can be used to understand why TC formation is poorly represented in some climate models, and shows potential for understanding anomalous TC formation behaviour in the real world.

Keywords Tropical cyclone · Tropical cyclone formation · Tropical cyclone climatology · Climate

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Background

- Previously: Developed *method* for identifying TC formation regions in seasonal data
- Recently: Used the *method* to understand TC formation regions in CMIP5 models, and to identify future changes

Climate Dynamics
https://doi.org/10.1007/s00382-020-05440-x

Check for updates

Tropical cyclone formation regions in CMIP5 models: a global performance assessment and projected changes

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Received: 11 April 2020 / Accepted: 23 August 2020

Abstract
Tropical Cyclone (TC) formation regions are analysed in twelve CMIP5 models using a recently developed diagnostic that provides a model-performance summary in a single image for the mid-summer TC season. A subjective assessment provides an indication of how well the models perform in each TC basin throughout the globe, and which basins can be used to determine possible changes in TC formation regions in a warmer climate. The analysis is necessarily succinct so that seven basins in twelve models can be examined. Consequently, basin performance was reduced to an assessment of two common problems specific to each basin. Basins that were not too adversely affected were included in the projection exercise. The North Indian basin was excluded because the mid-summer analysis period covers a lull in TC activity. Surprisingly, the North Atlantic basin also had to be excluded, because all twelve models failed the performance assessment. A slight poleward expansion in the western North Pacific and an expansion towards the Hawaiian Islands in the eastern North Pacific is plausible in the

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Background

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- Recently: Used the *method* to understand TC formation regions in CMIP5 models, and to identify future changes

- The *method*: (*Analogous to Gray's SST threshold determination*.)
  1. Plot ~30 years of summer season TC formation locations
  2. Overlay with various atmospheric/oceanic variables
  3. Choose thresholds for a minimum number of variables that define the formation regions

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Presentation Plan

- Introduce threshold variables
- Compare with Gray’s TC formation regions
- Apply to CMIP5 models

Boundary variables and thresholds

Poleward boundaries:

- Emanuel's Maximum Potential Intensity: $V_{PI} = 40\ ms^{-1}$
- Relative humidity: $RH_{700} = 40\ \%$
- Vector wind difference magnitude between 850 and 200 hPa: $V_{sh} = 20\ ms^{-1}$

Equatorward boundaries:

- 850 hPa absolute vorticity: $|\eta|_{850}$
- Barotropic instability measure at 700 hPa: $\beta^*_{700} = \frac{\partial \eta}{\partial y}$
- Best result is a hybrid η-β^* quantity: $\xi = \frac{|\eta|_{850}}{\beta^*_{700}(R/2\Omega)} = 2.0 \times 10^{-5} s^{-1}$

  ξ is similar to a Brunet and Haynes (1995) index, which determines if a disturbance in a shear flow will roll-up into a vortex or be sheared apart.

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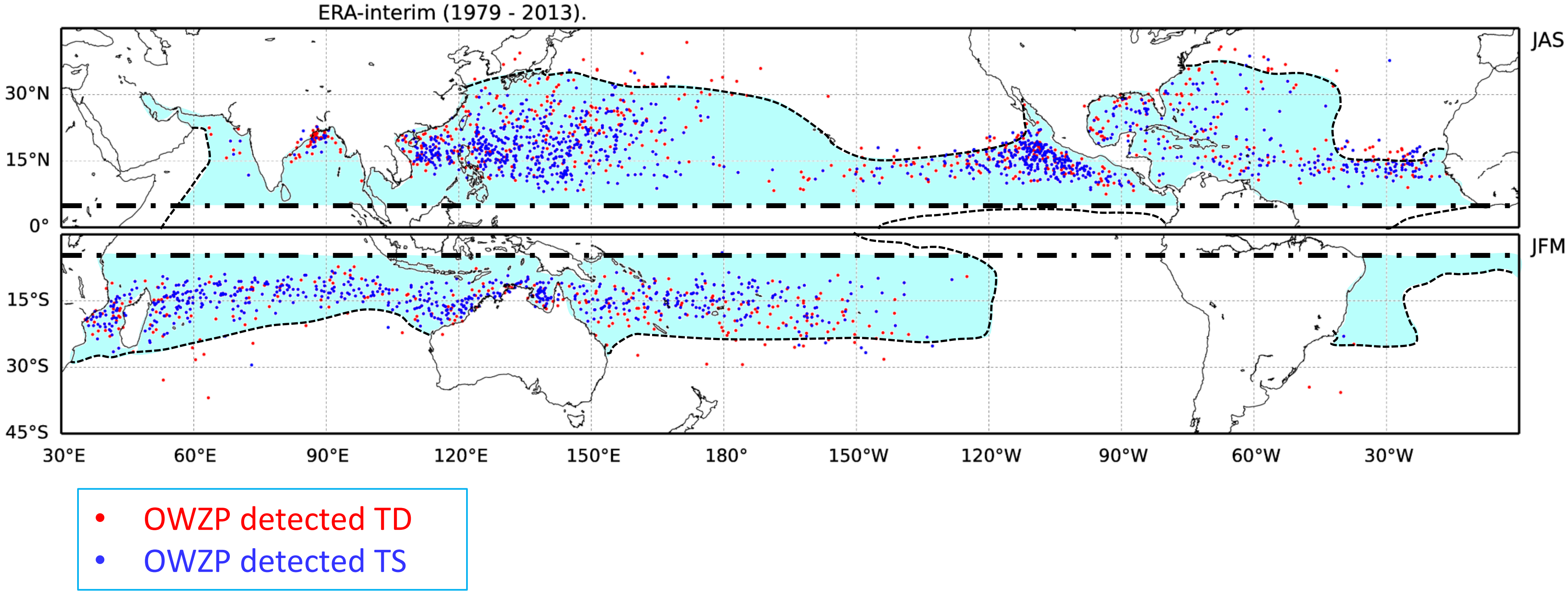
TC formation boundaries: Historical



- SST thresholds: Palmén (1948), 26—27°C; Gray (1968), 26.5°C
- "TCs rarely form within 5° of the equator"
- *Not too bad in the Summer months, but large areas of 'false alarms' in Winter.*

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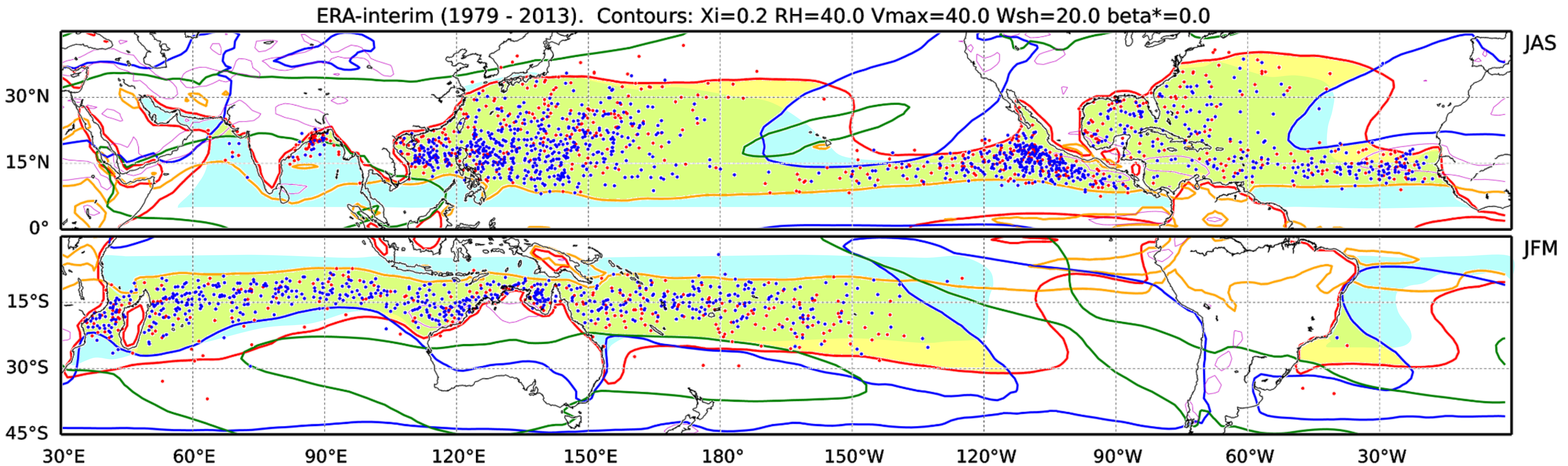
TC formation boundaries



- OWZP detected TD
- OWZP detected TS

- Palmén/Gray Boundaries replaced with V_{PI} and ξ thresholds
- Additional RH_{700} and V_{sh} thresholds added.

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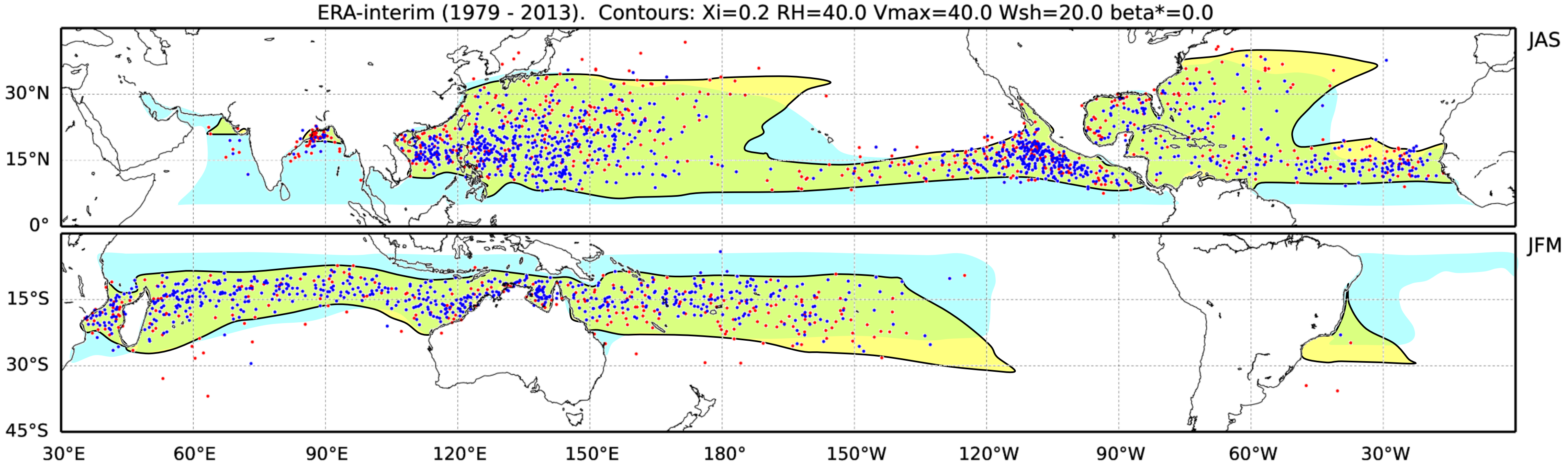
TC formation boundaries: Improved



- OWZP detected TD
- OWZP detected TS

- Palmén/Gray Boundaries replaced with V_{PI} and ξ thresholds
- Additional RH_{700} and V_{sh} thresholds added.
- Improved boundaries
- Much improved in Winter (not shown).

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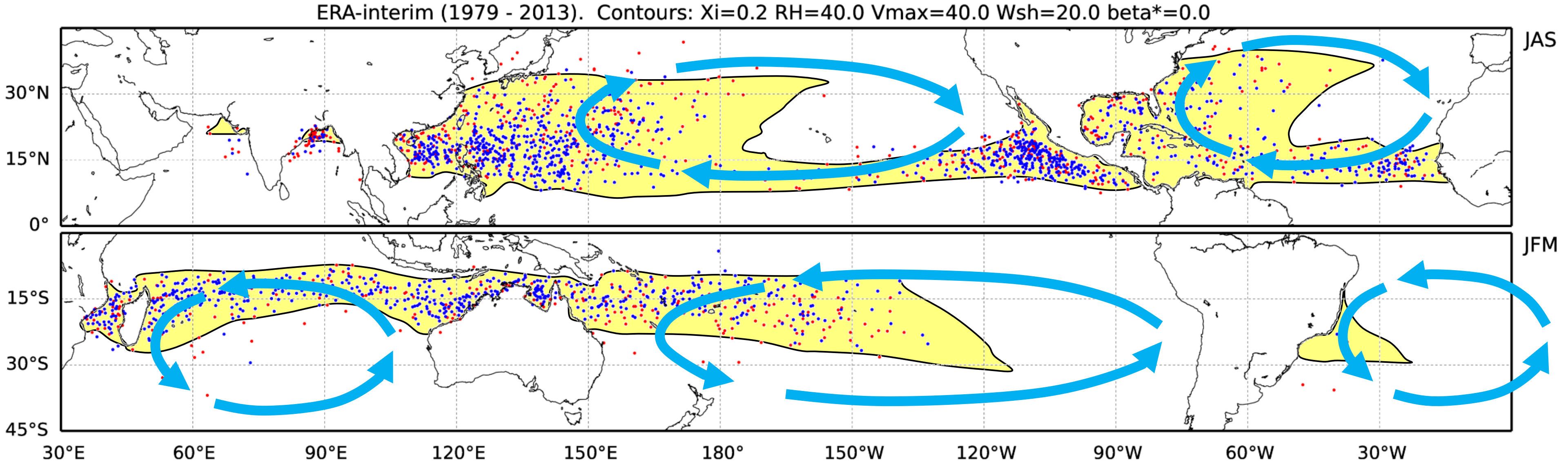
TC formation boundaries: Why this shape?



- All ocean basins (except NI) influenced by oceanic and atmospheric anticyclones
- Cold upwelling in the eastern basins
- Eastern basins: Cool/dry air and cold SST advected equatorward and westward.
- Western basins: Warm/moist air and warm SST advected poleward
- Relative size, strengths of upwelling, anticyclones etc. determines the east/west asymmetry

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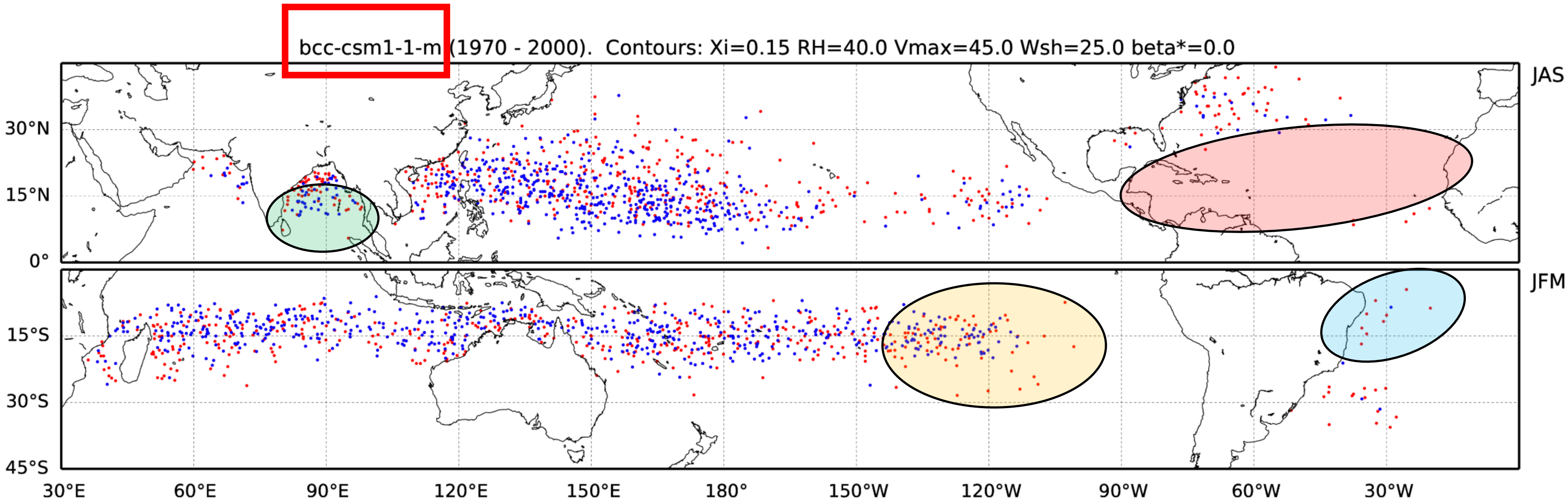
Application to CMIP5 models

- Add boundaries to CMIP5 models with OWZ detections overlaid
- Use to: Understand TC formation errors

  Eliminate poorly performing models

  Formulate projections from common patterns

Example: Understand TC formation errors



- Why are there no TCs in the central NA?
- Why do the TCs extend so far east in the SP?
- Why are there low latitude TCs in the SA?
- Why are there TCs in the NI, equatorward of 15°?

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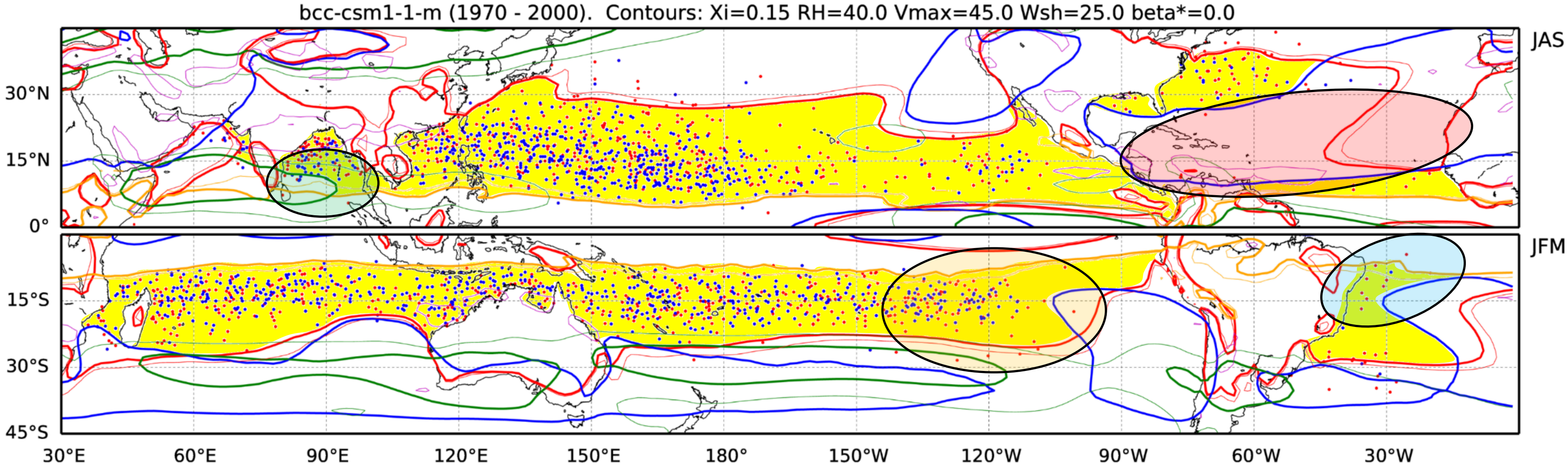
Example: Understand TC formation errors



Original thresholds: fine lines

- Why are there no TCs in the central NA? — Too dry.
- Why do the TCs extend so far east in the SP? — Too warm and moist.
- Why are there low latitude TCs in the SA? — Too warm and moist.
- Why are there TCs in the NI, equatorward of 15°? — Monsoon shear too weak.

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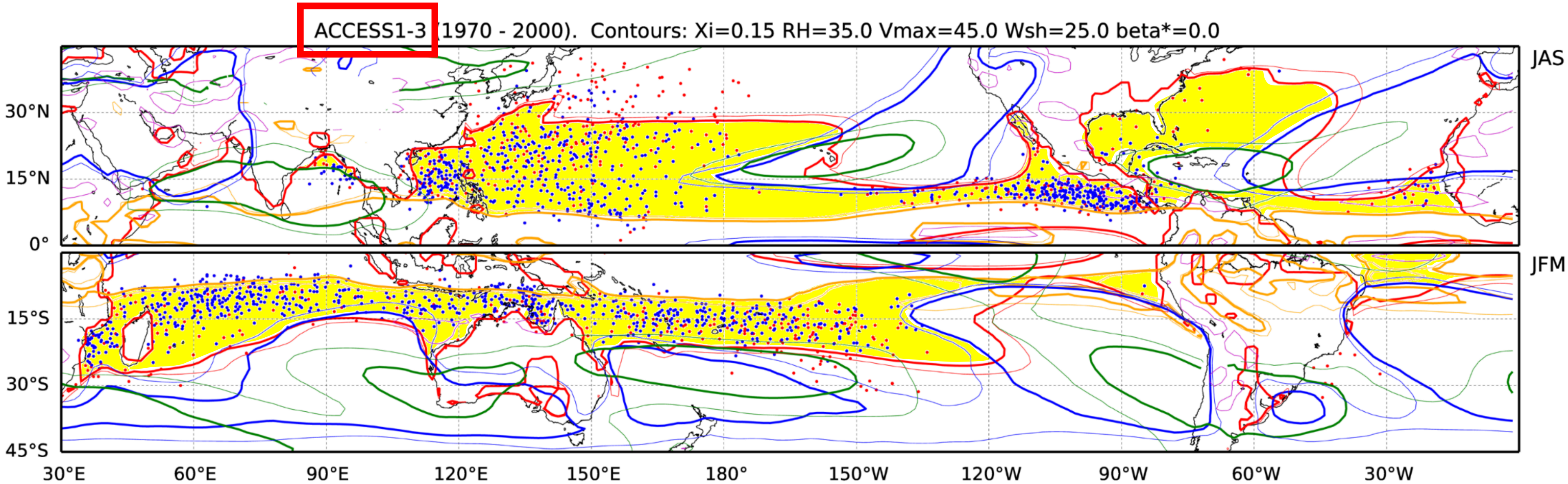
Example: Inform projections



- Historical scenario: Model performs reasonably well.
- Too few TCs in the NA: Too dry and shear too strong.
- Other basins are good and can be used in projection study.

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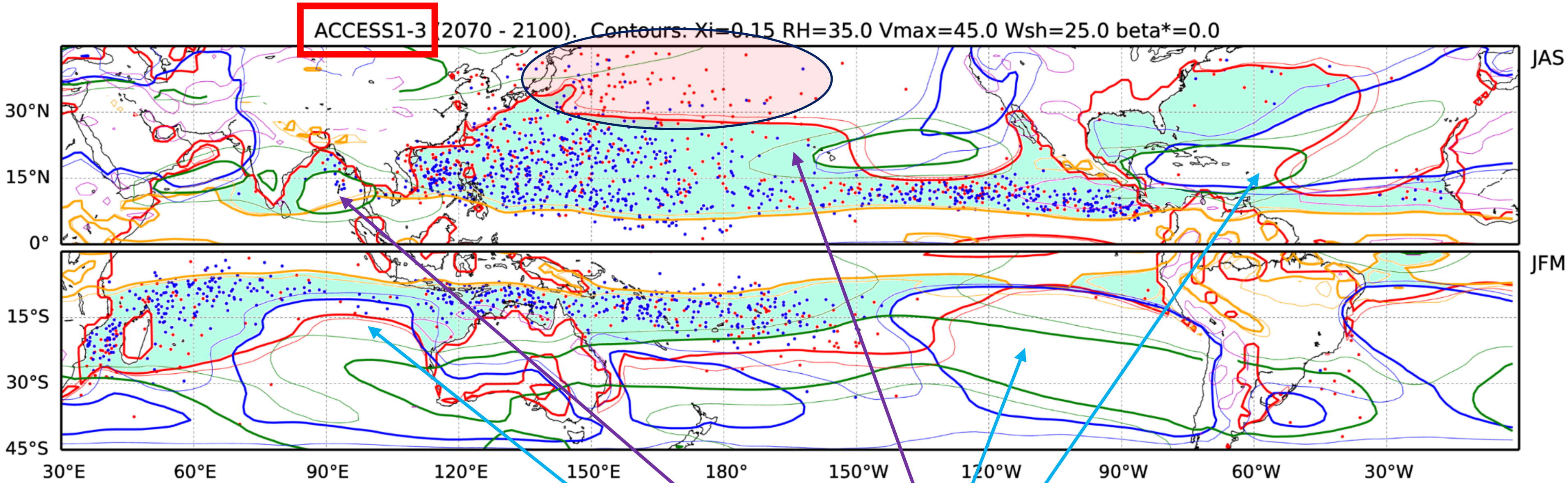
Example: Inform projections



- RCP85 scenario:
- Most changes are subtle.
- More TDs outside the boundaries in NP
- General drying and increase in shear here:
- General moistening and/or reduction of shear here:
- *Best way to compare is to overlay the boundaries.*

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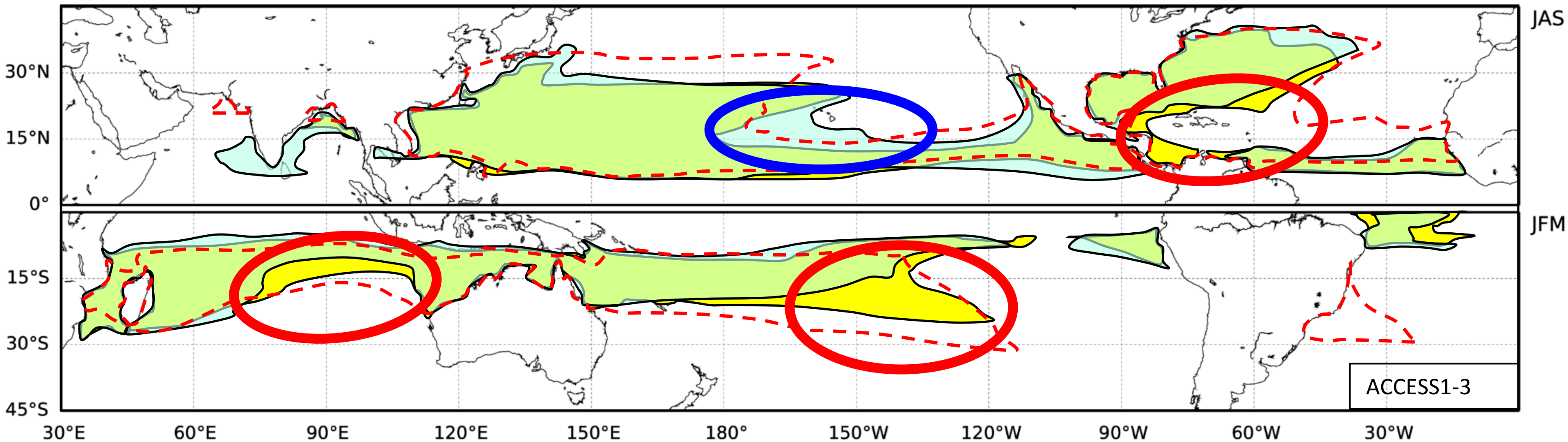
Example: Inform projections



- Central NA becoming less favourable: Drying, increased wind shear
- Central NP becoming more favourable: Moistening, reduced wind shear
- Narrowing of favourable zone in SI: Drying
- Central SP becoming less favourable: Increased wind shear

- Australian region sees a narrowing of the favourable formation region

These changes are common to many models.

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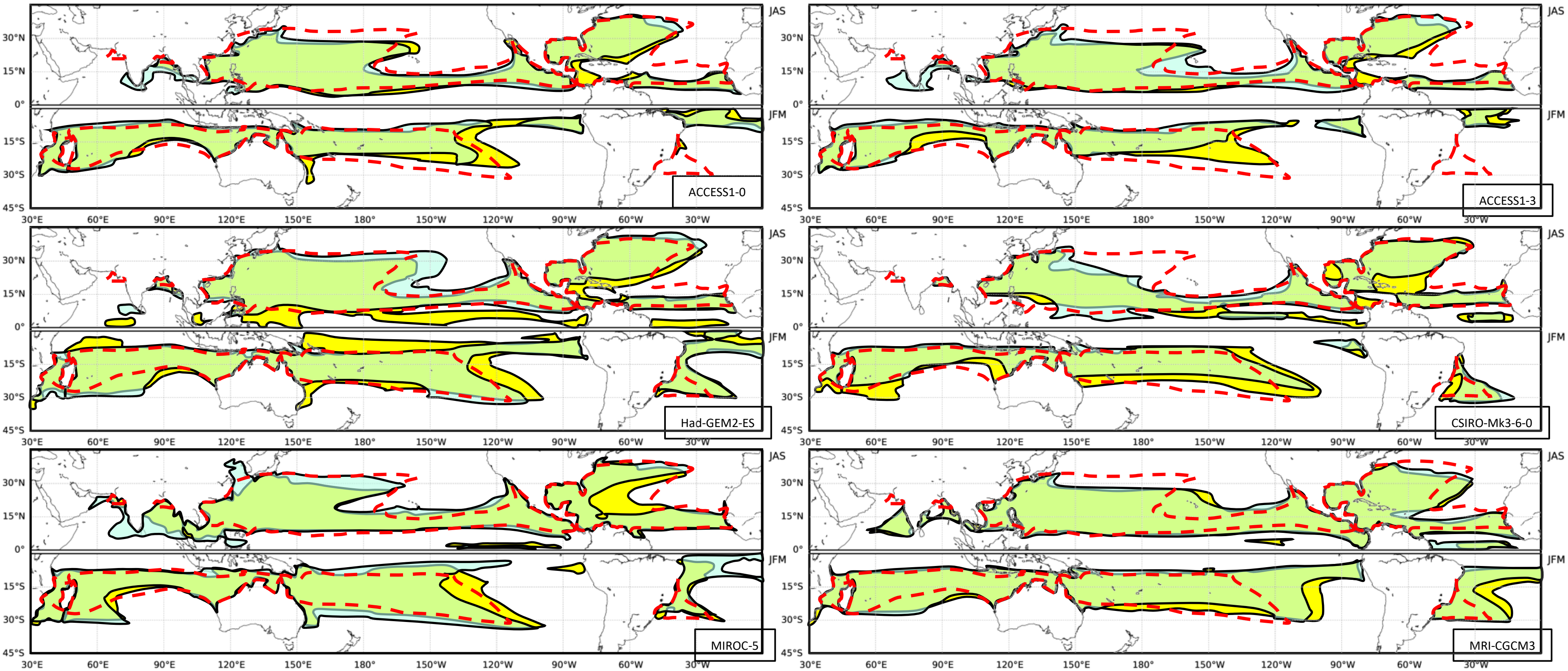
Formulate projections from common patterns



Dashed lines: ERA-interim boundaries

- Six models show results consistent with the previous slide
- Australian region sees a narrowing of the favourable formation region

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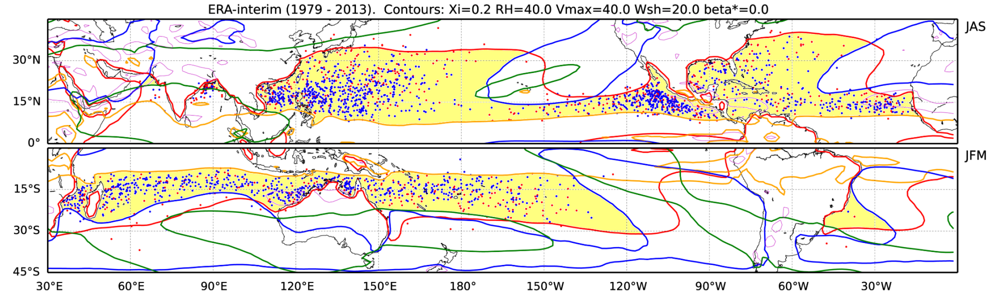
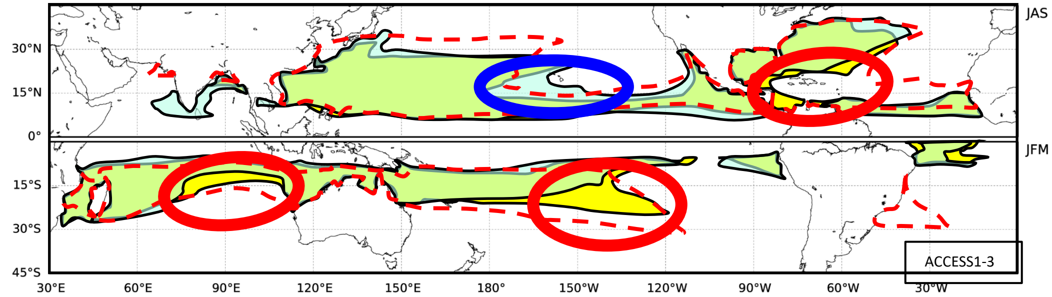
Summary



- Previously: Developed method for identifying TC formation regions in seasonal data
- The method is used to understand TC formation regions in CMIP5 models, and to identify future changes



- Selected results:

Central NA and central SP becoming less favourable

Central NP becoming more favourable

Narrowing of favourable zone in SI

Australian region is becoming less favourable

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