Special Report on the Ocean and Cryosphere in a Changing Climate

Chapter 6: Extremes, Abrupt Changes and Managing Risks

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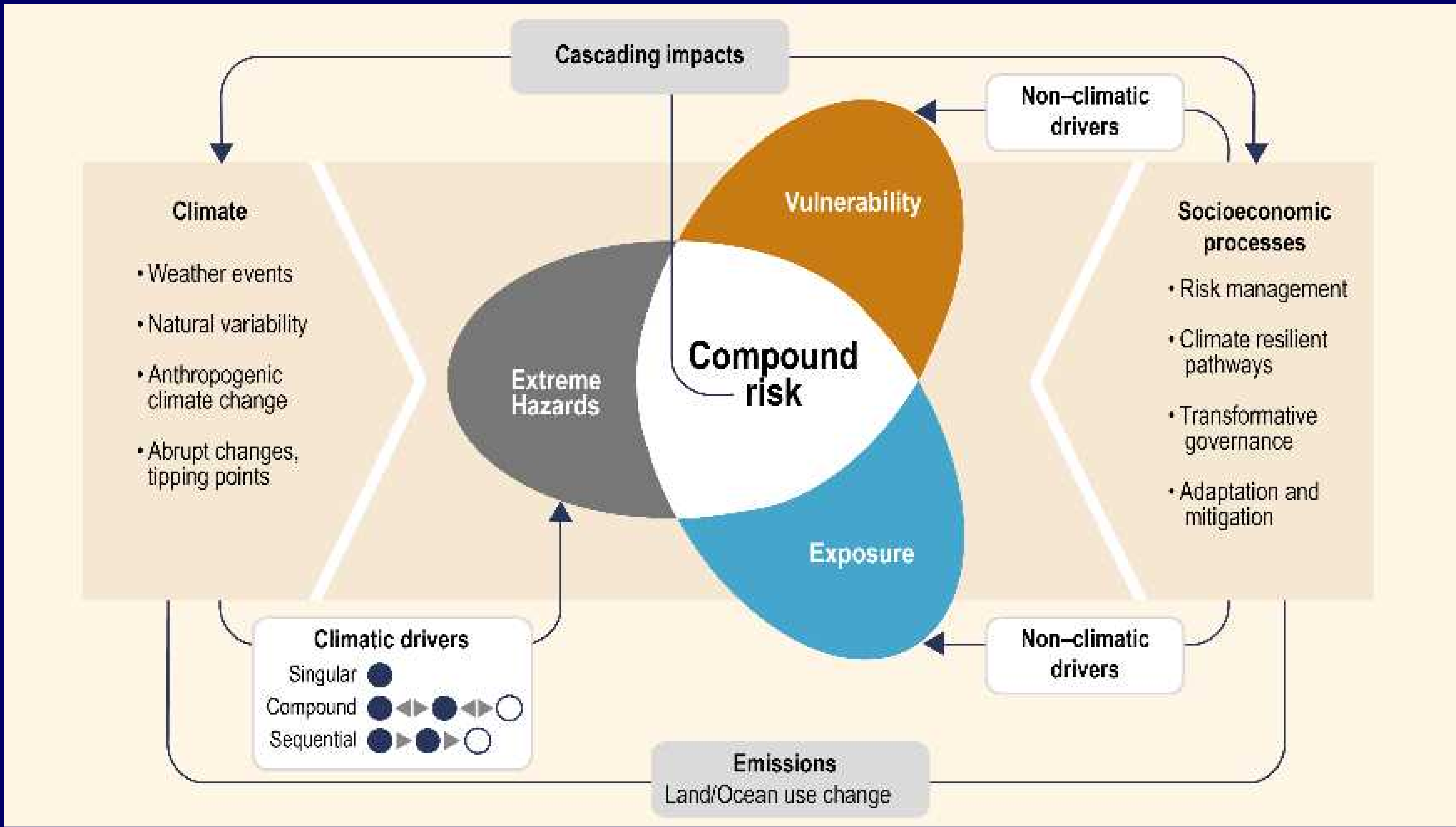
This chapter assesses extremes and abrupt or irreversible changes in the ocean and cryosphere in a changing climate, to identify regional hot spots, cascading effects, their impacts on human and natural systems, and sustainable and resilient risk management strategies.

Definition

- **Extreme weather/climate event:** An event that is rare (10^{th} pdf) at a particular place and time of year.
- **Abrupt climate change:** A large-scale change in the climate system (a few decades or less), persists (a few decades), and causes substantial disruptions in human and natural systems.
- **Compound events** refer to the combination of multiple drivers and/or hazards that contribute to societal or environmental risks.

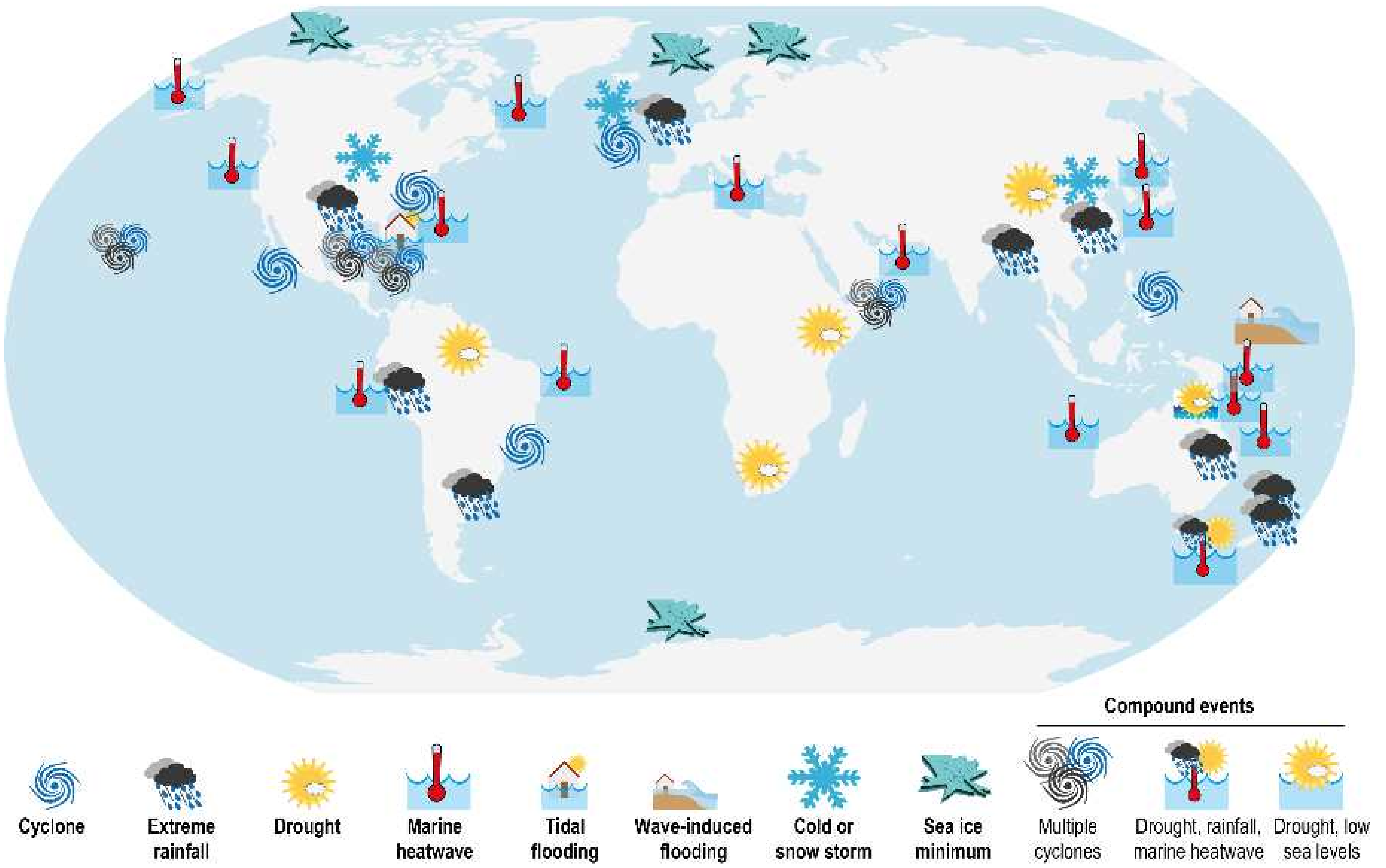


- Tropical and Extra Tropical Cyclone
- Sea level
- Marine Heatwave
- Extreme El Niño and La Niña
- Extreme ocean decadal variability
- AMOC, subpolar gyres

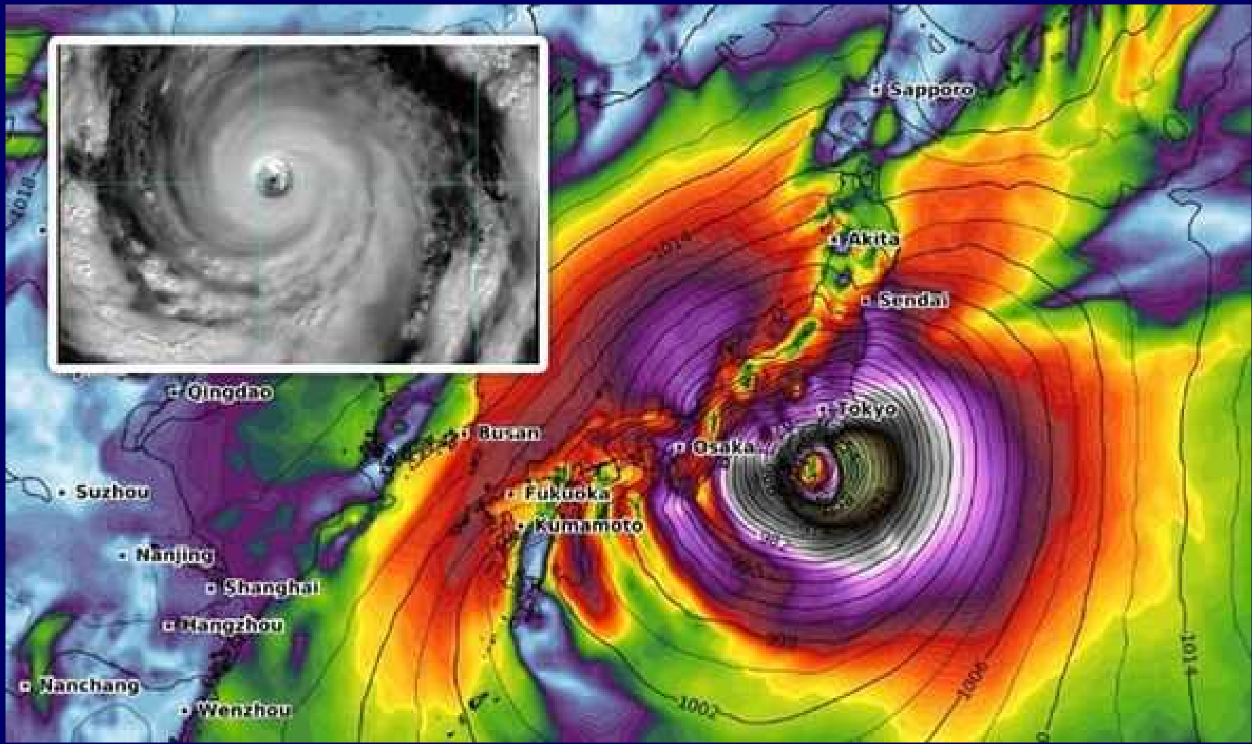
Outline

- Introduction
- Ongoing and projection changes in Ocean & Cryosphere & Impacts
    - ✓ Cyclones (tropical and extra-tropical)
    - ✓ Marine Heatwaves
    - ✓ Extreme El Niño/La Niña
    - ✓ Inter-Ocean Exchange/Decadal Variability
    - ✓ AMOC (Atlantic Meridional Overturning Circulation)
- Strengthening Responses, Risk Management & Resilient Development pathways
- Executive Summary

Locations where extreme events with an identified link to ocean changes



Typhoon HAGIBIS Oct 12, 2019



https://www.express.co.uk/news/world/1188313/typhoon-hagibis-path-course-map-forecast-japan-tokyo-jtwc-jma-latest

https://asia.nikkei.com/Economy/Natural-disasters/In-pictures-Typhoon-Hagibis-tears-Japan-apart

https://www.straitstimes.com/asia/east-asia/typhoon-hagibis-shuts-down-tokyo

Tropical and Extra-tropical cyclones & Sea Surface dynamics

- Ongoing:

✓ Increased precipitation, winds and extreme sea level (ESL), a number of observed tropical tropical/extra-tropical cyclones (*h.c) and poleward extension in western Pacific (l.c).*

✓ Wave power increased at rate 0.41% globally, extreme wave height increased (5%).

- Projections:

✓ An increase: TCs (cat. 4-5) intensity, precipitation (assumed 2'C global temperature rise) (*mc*), although *low confidence* in future frequency changes at the global scale.

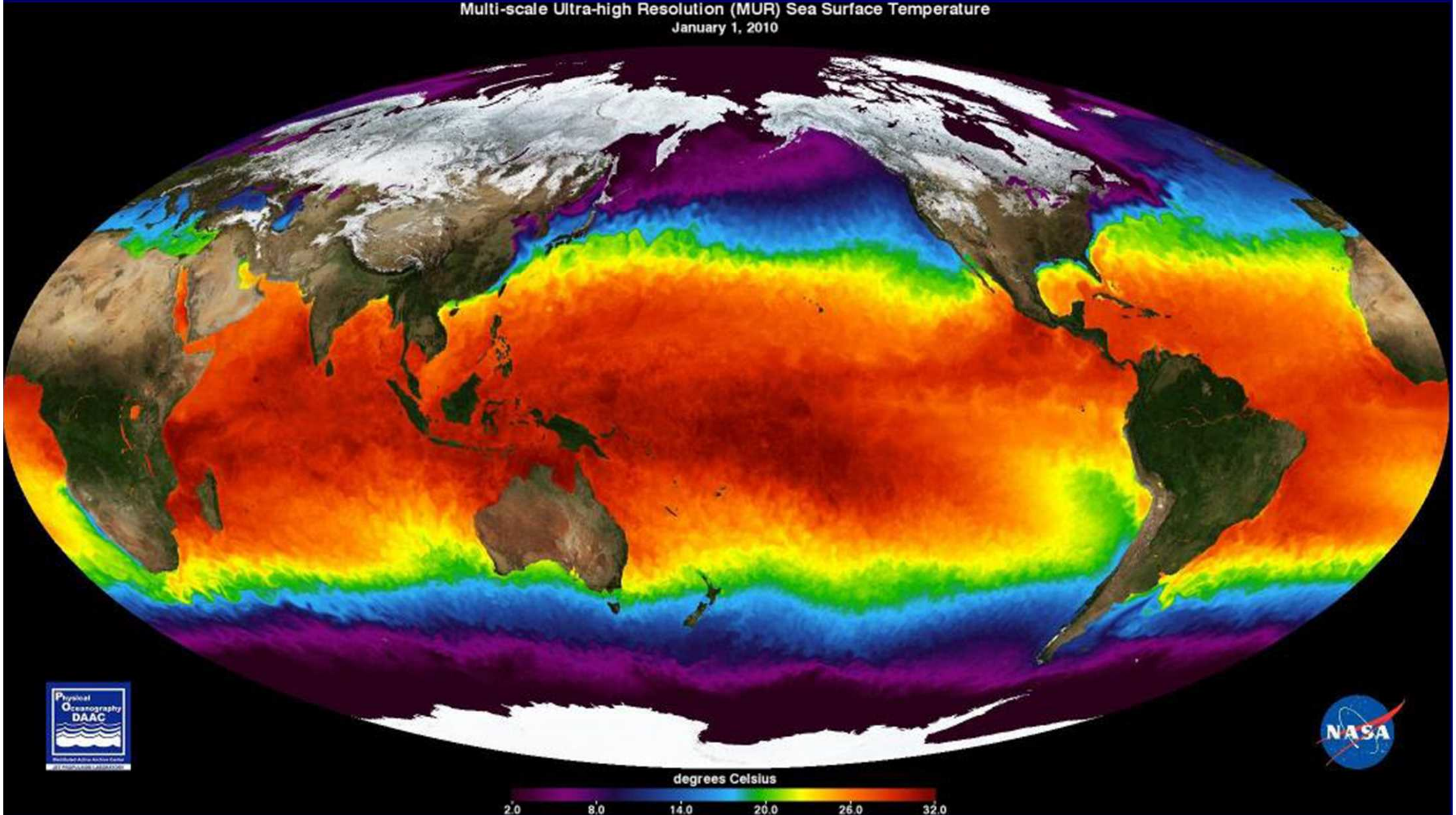
✓ Rising sea levels will contribute to higher ESLs associated with TCs in the future (*vhc*). Global average 100-year extreme sea level is likely to increase by 34-76 cm (RCP4.5) and 58-172 cm (RCP8.5) from 2000-2100.

✓ NH extra-tropical cyclone changes in storm track *(lc),* SH ETCs strengthening and shift poleward.

Impacts & managing risks:

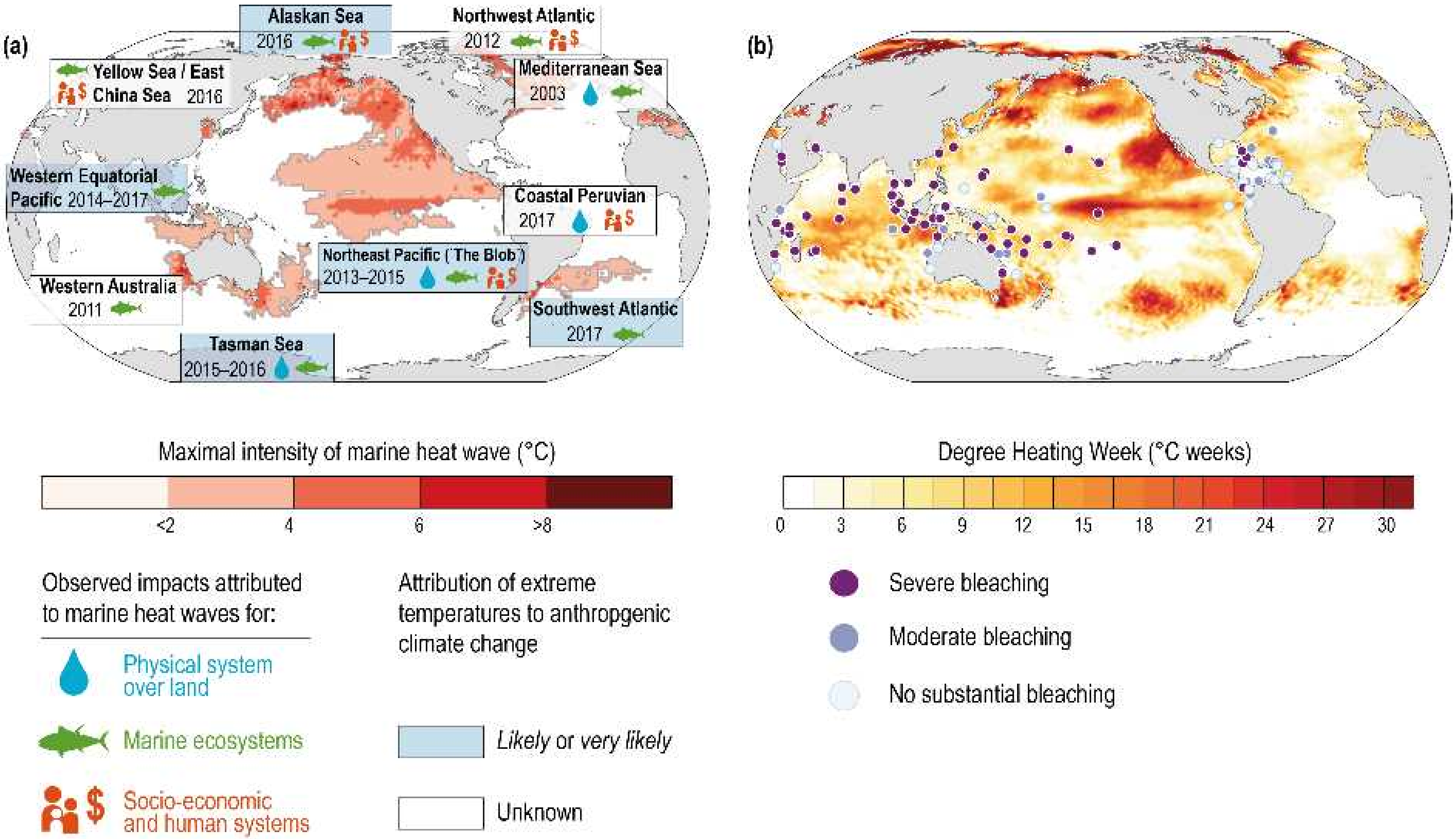
Investment in disaster risk reduction, flood management and early warning systems decreases economic loss (mc), but may be hindered by limited local capacities, such as increased losses and mortality from extreme winds and storm surges in less-developed countries despite adaptation efforts.

Marine heat waves

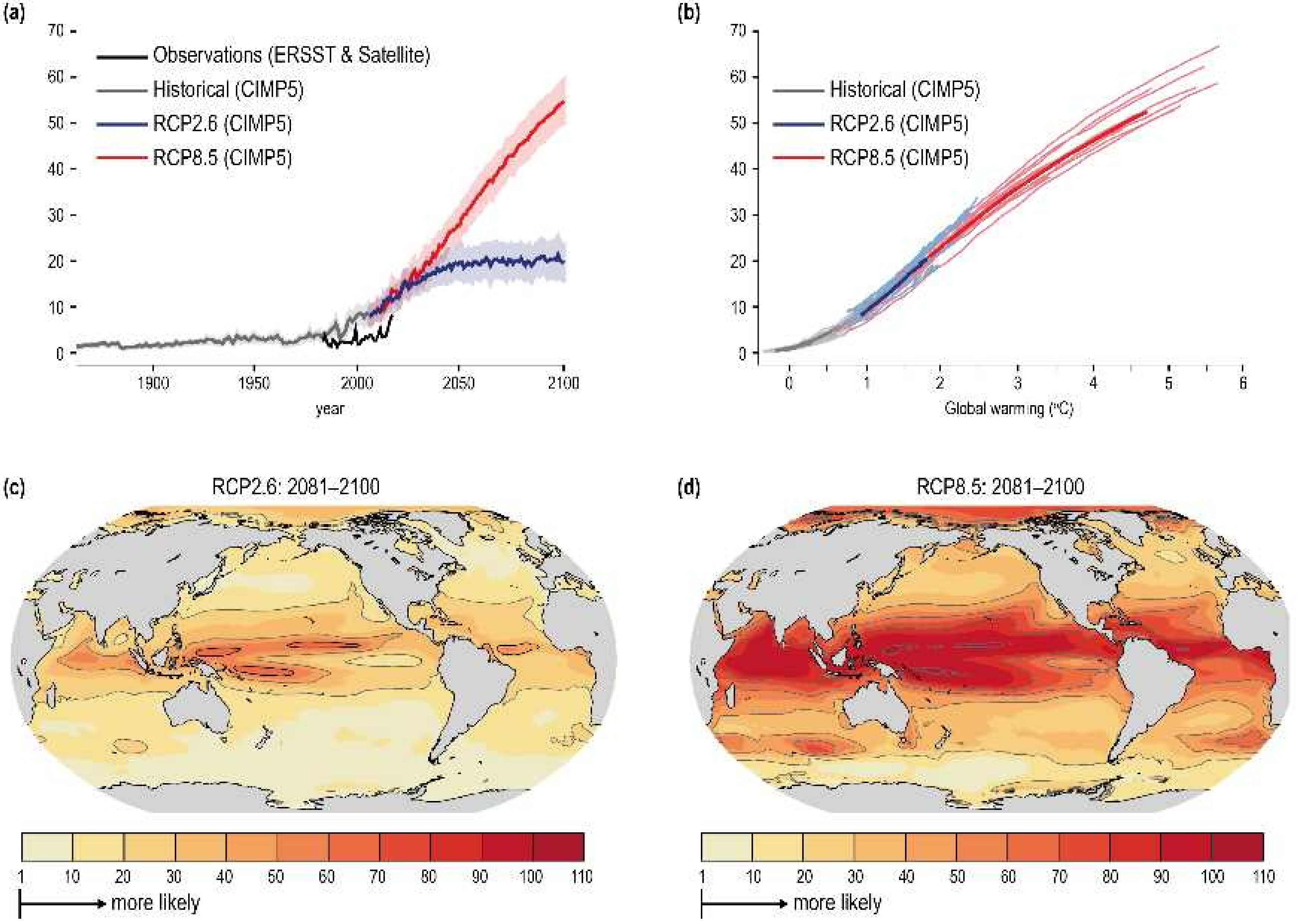


MHW: extremely high ocean temp. that persist for days to months, >1000km, penetrate > 100 m depth

Example of marine heatwave and its impact



Projections of Marine Heatwave



Marine Heatwaves

- Ongoing:

✓ Marine heatwaves, periods of extremely high ocean temperatures, have negatively impacted marine organisms and ecosystems in all ocean basins over the last two decades (vhc).

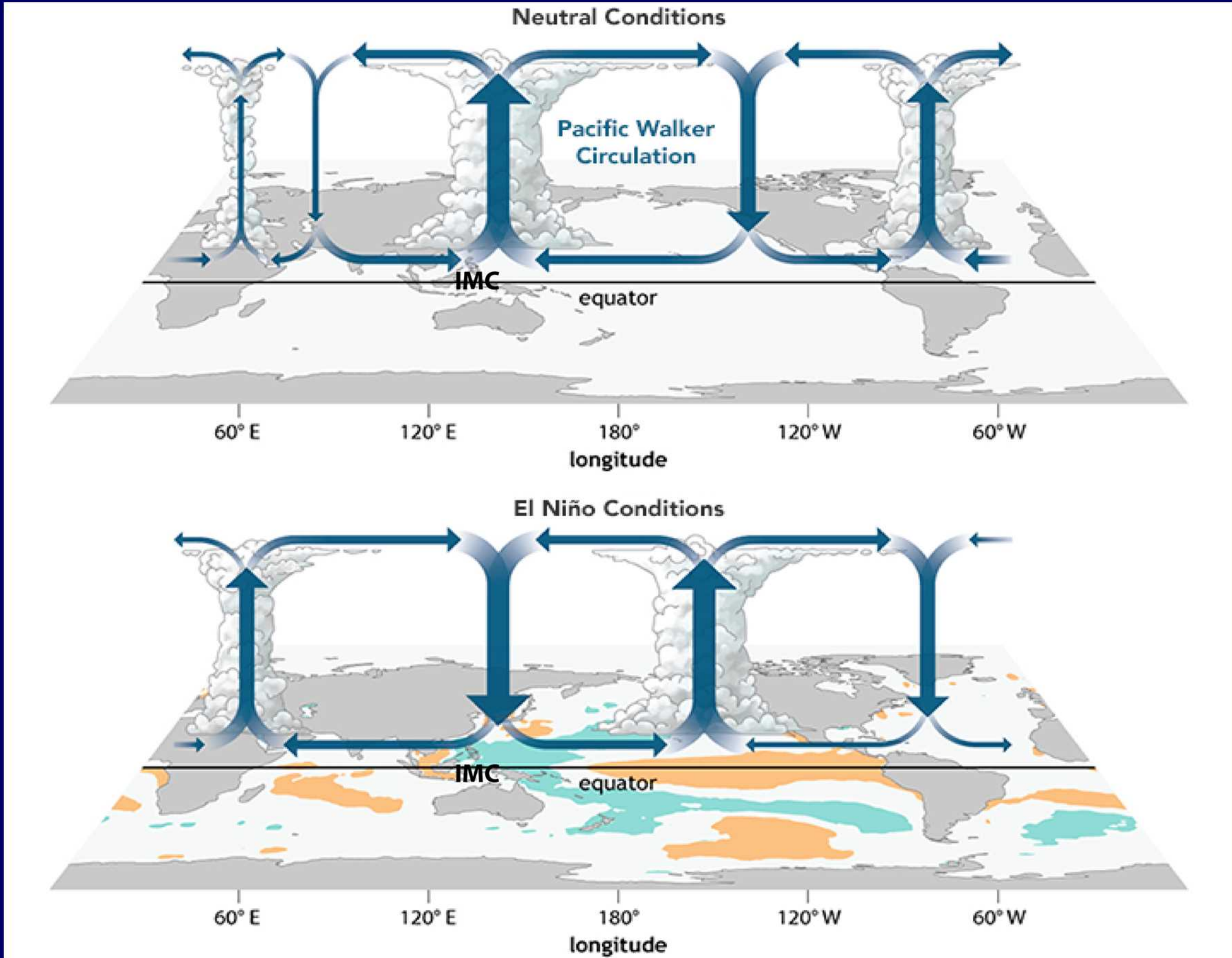
- Projection

✓ Marine heatwaves will further increase in frequency, duration, spatial extent and intensity under future global warming (vhc) pushing some marine organisms, fisheries and ecosystems beyond the limits of their resilience, with cascading impacts on economies and societies (hc).

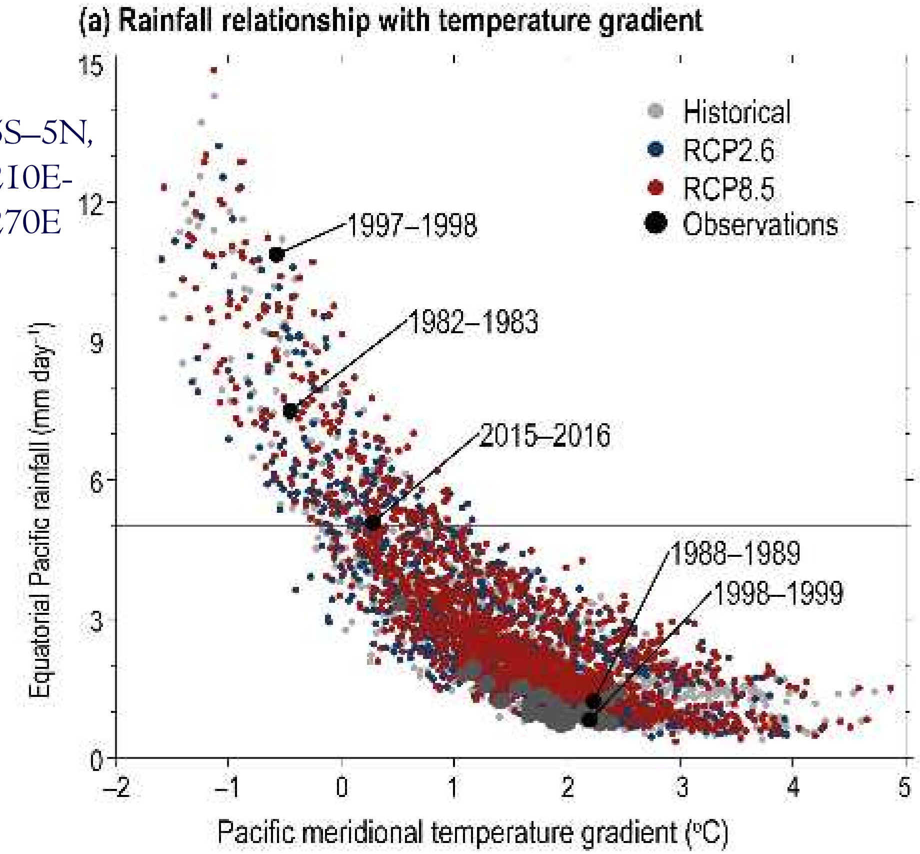
Managing risks:

✓ **Include early warning systems as well as seasonal and multi-annual prediction systems as well as "degree heating weeks" as metric for regions conducive to coral bleaching.**

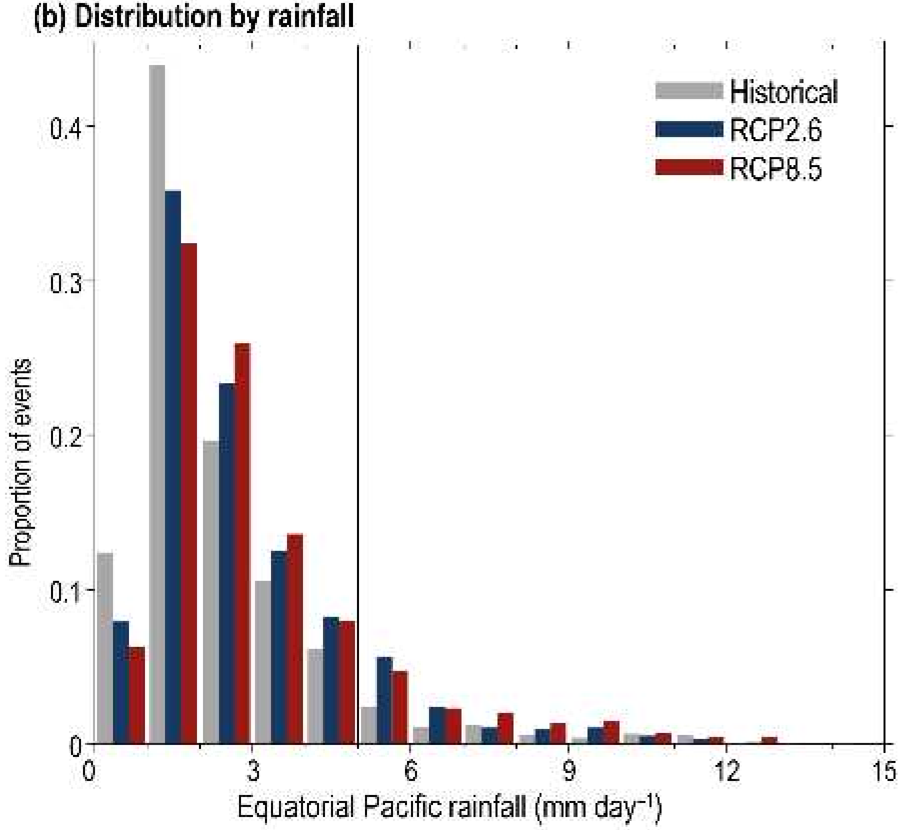
Extreme El Niño and La Niña



5S–5N,
210E-
270E



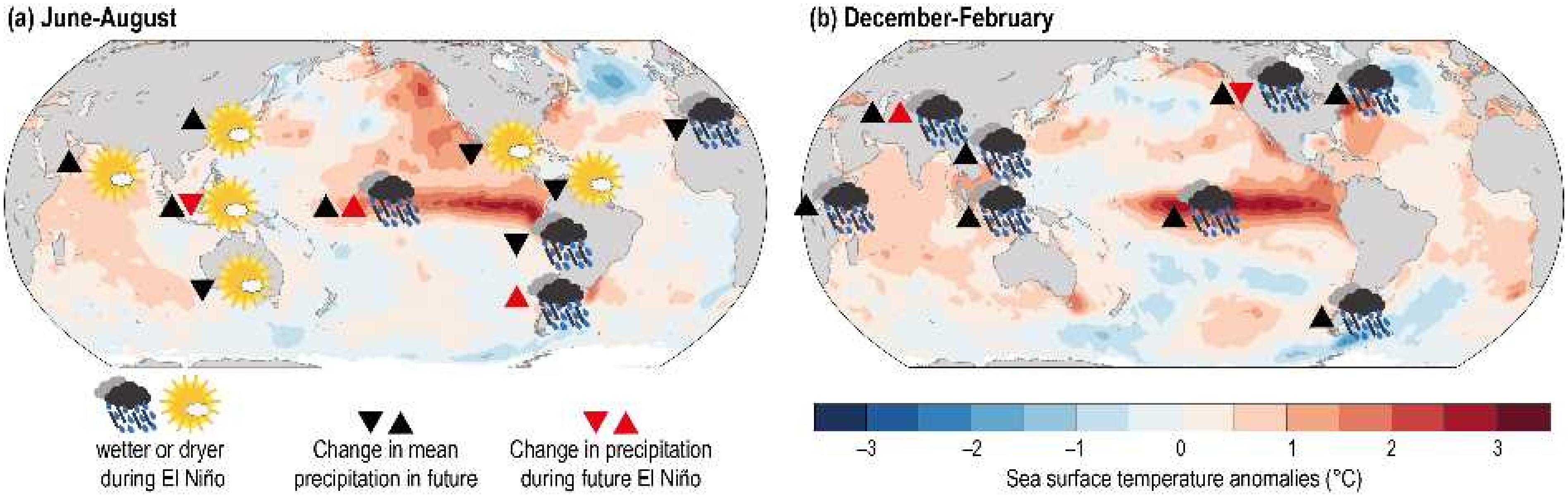
5N–10N, 210E–270E minus 2.5S–2.5N, 210E–270E)



Frequency of extreme El Niño Southern Oscillation (ENSO) events, adapted from Cai et al. (2014a).

> 5mm/day rainfall during Dec – Feb in Niño3 region

Histogram showing the relative frequency of rainfall rates. The vertical line denotes the 5 mm per day threshold. Higher counts of extreme events under the RCP8.5 scenario suggest an increase in the frequency of extreme El Niño under global warming.



Schematic figure indicating future changes in El Niño teleconnections based on the study of Power and Delage (2018).

Extreme ENSO

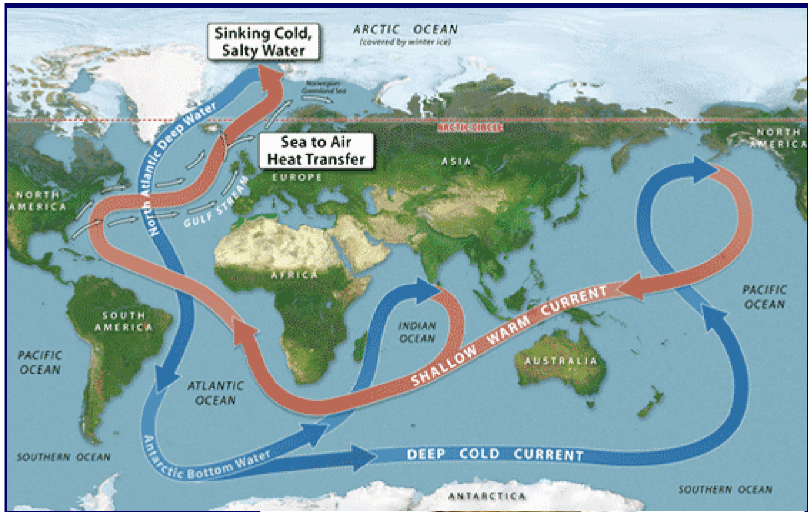
Ongoing :

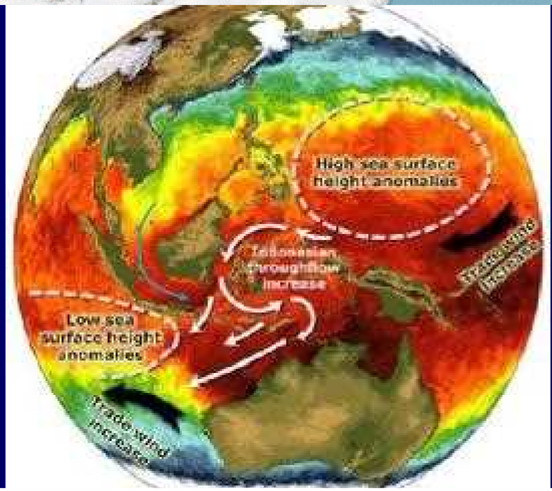
- The strongest El Niño and La Niña events since the pre-industrial have occurred during the last fifty years (*mc*).

Projections :

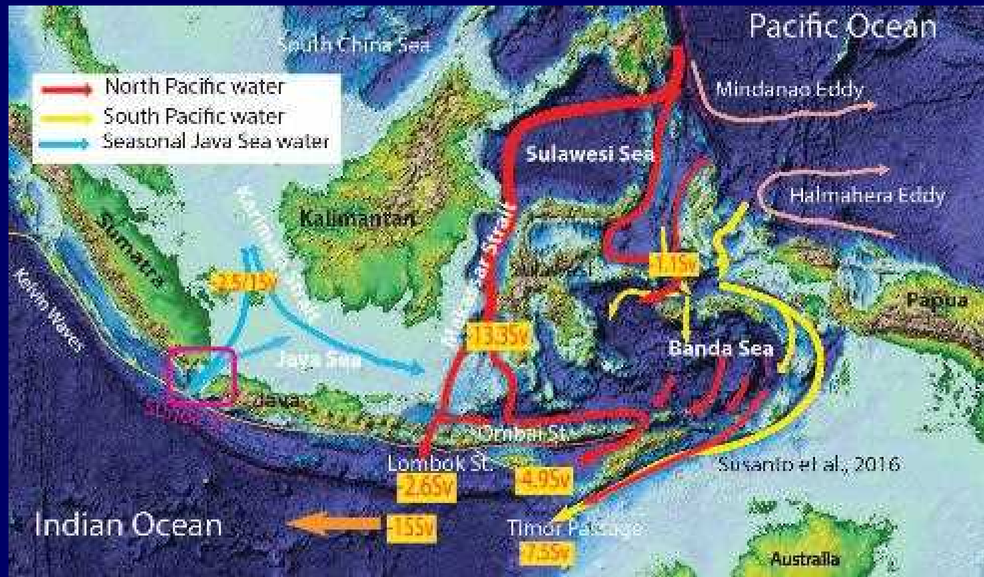
- Extreme El Niño and La Niña events are *likely* to occur more frequently with global warming and are *likely* to intensify existing impacts, with drier or wetter responses in several regions across the globe, even at relatively low levels of future global warming (*mc*).

Inter-Ocean Exchange/Decadal Change

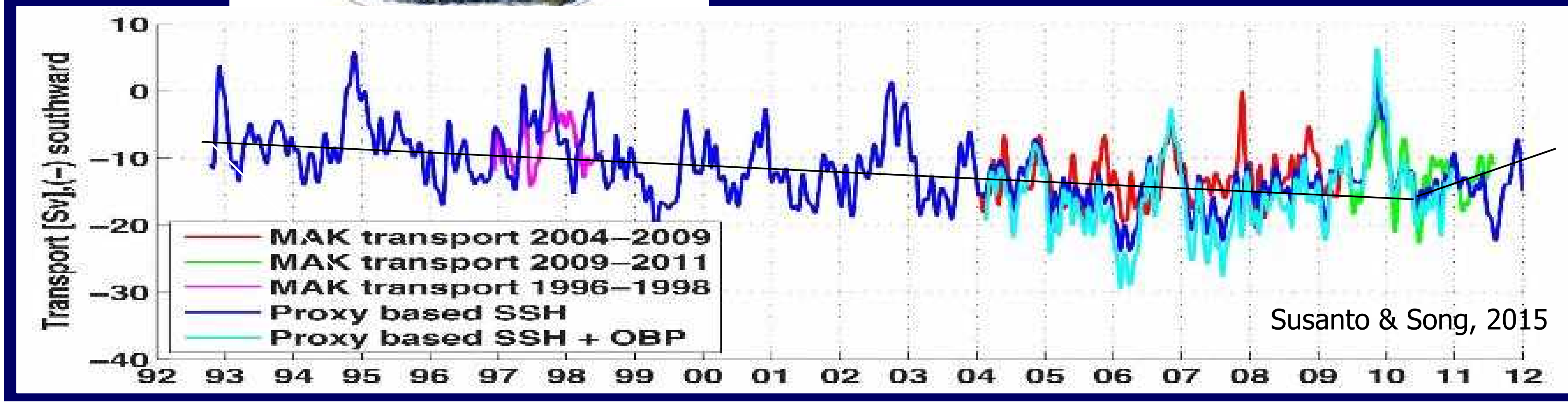


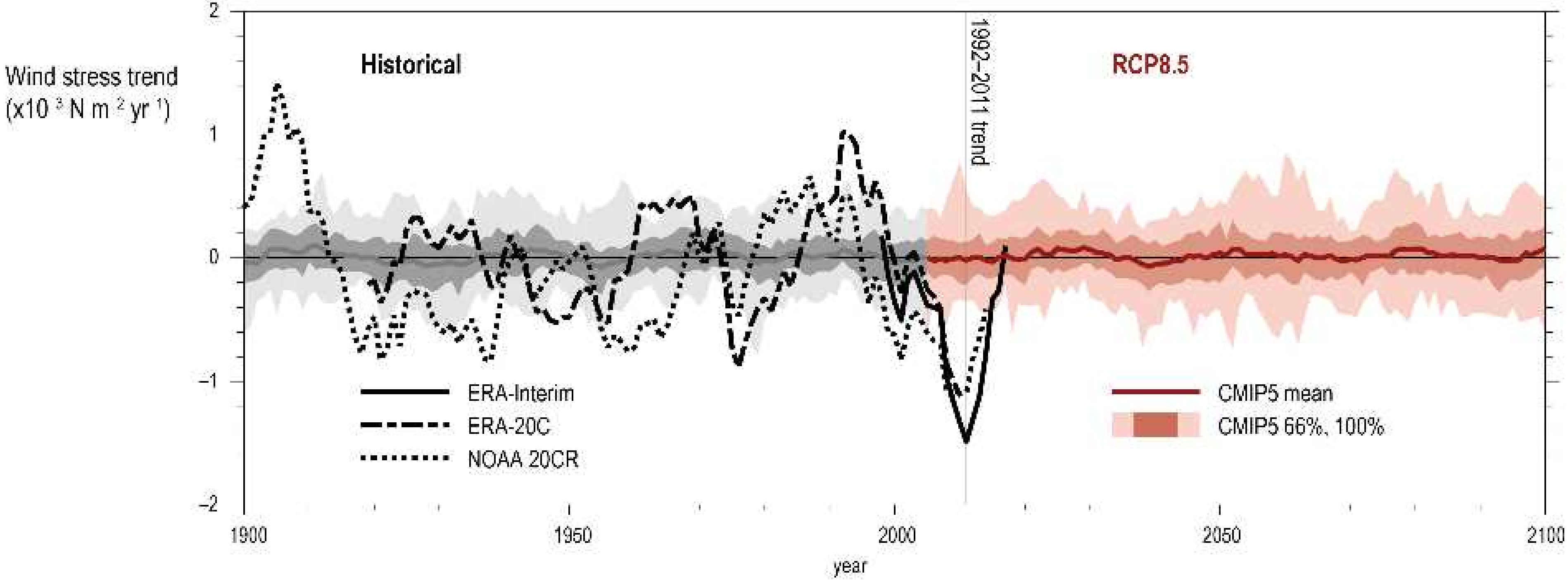


Pacific to Indian Ocean Exchange (Indonesian throughflow; ITF)



Susanto et al., 2016





Running twenty-year trends of zonal wind stress over the central Pacific (area-averaged over 8°S–8°N and 160°E–150°W) in Coupled Model Intercomparison Project Phase 5 (CMIP5) models and three reanalyses. The 66% and 100% ranges of all available CMIP5 historical simulations with Representative Concentration Pathway (RCP)8.5 extension are shown.

Inter-Ocean Exchange

Ongoing :

- The equatorial Pacific trade wind system experienced an unprecedented intensification during 2001–2014, resulting in enhanced ocean heat transport from the Pacific to the Indian Ocean, influencing the rate of global temperature change (*mc*).
- In the last two-decades, ITF increased attributed to Pacific cooling and basin-wide warming Indian Ocean.
- An abrupt increase in the Indian Ocean upper 700 m ocean heat content (OHC) after 1998, contributing to more than 28% of the global ocean heat gain (IO is only 12% of global ocean).

Projections :

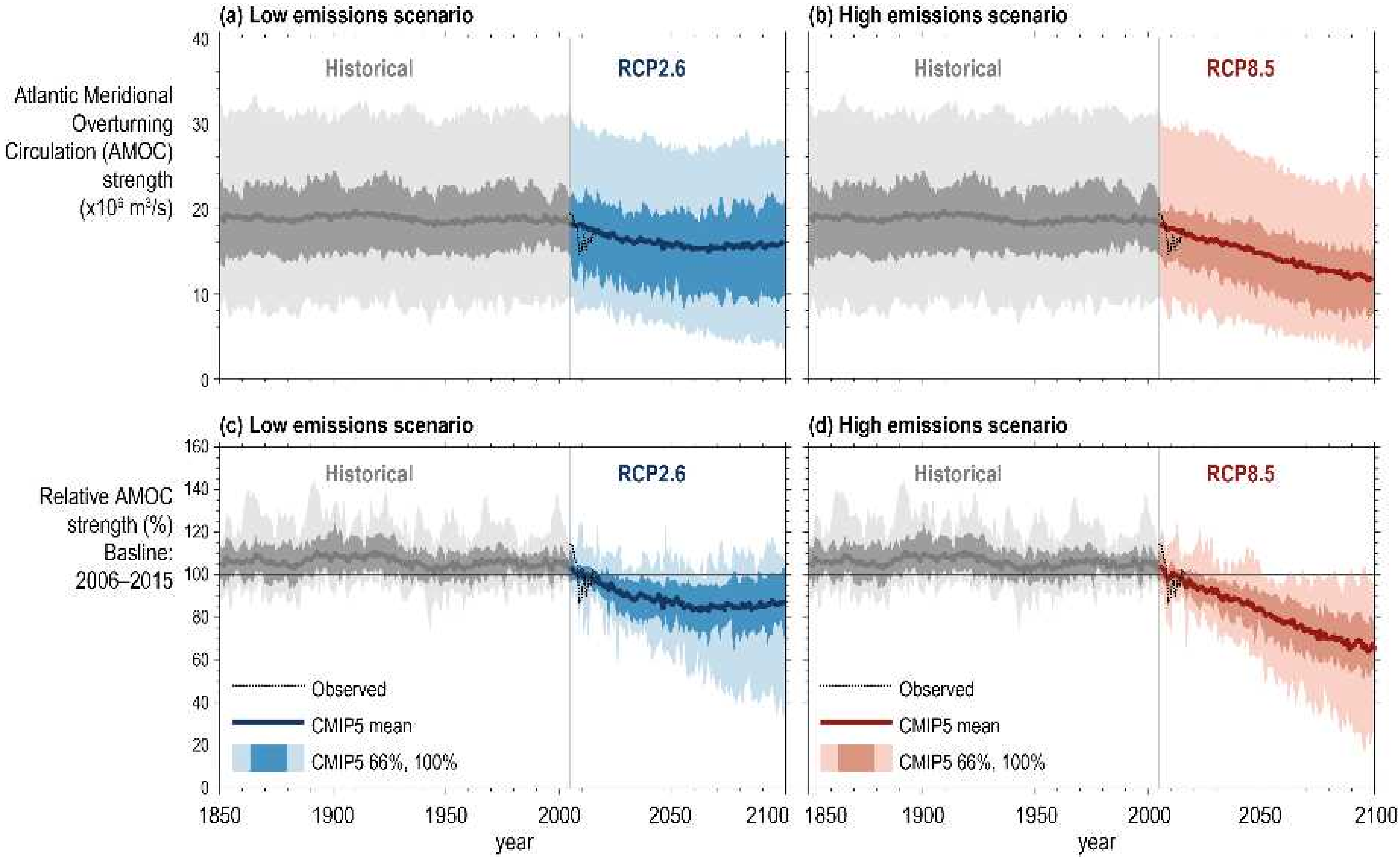
- Extreme +IOD events increase by ~3x (1/17years in 20th to 1/6 years in 21st century, lc)
- It is likely that ITF will decrease, reduces Indian – Atlantic Ocean transport, which is likely contributed to AMOC slowdown.

Impacts & Risk management and adaptation :

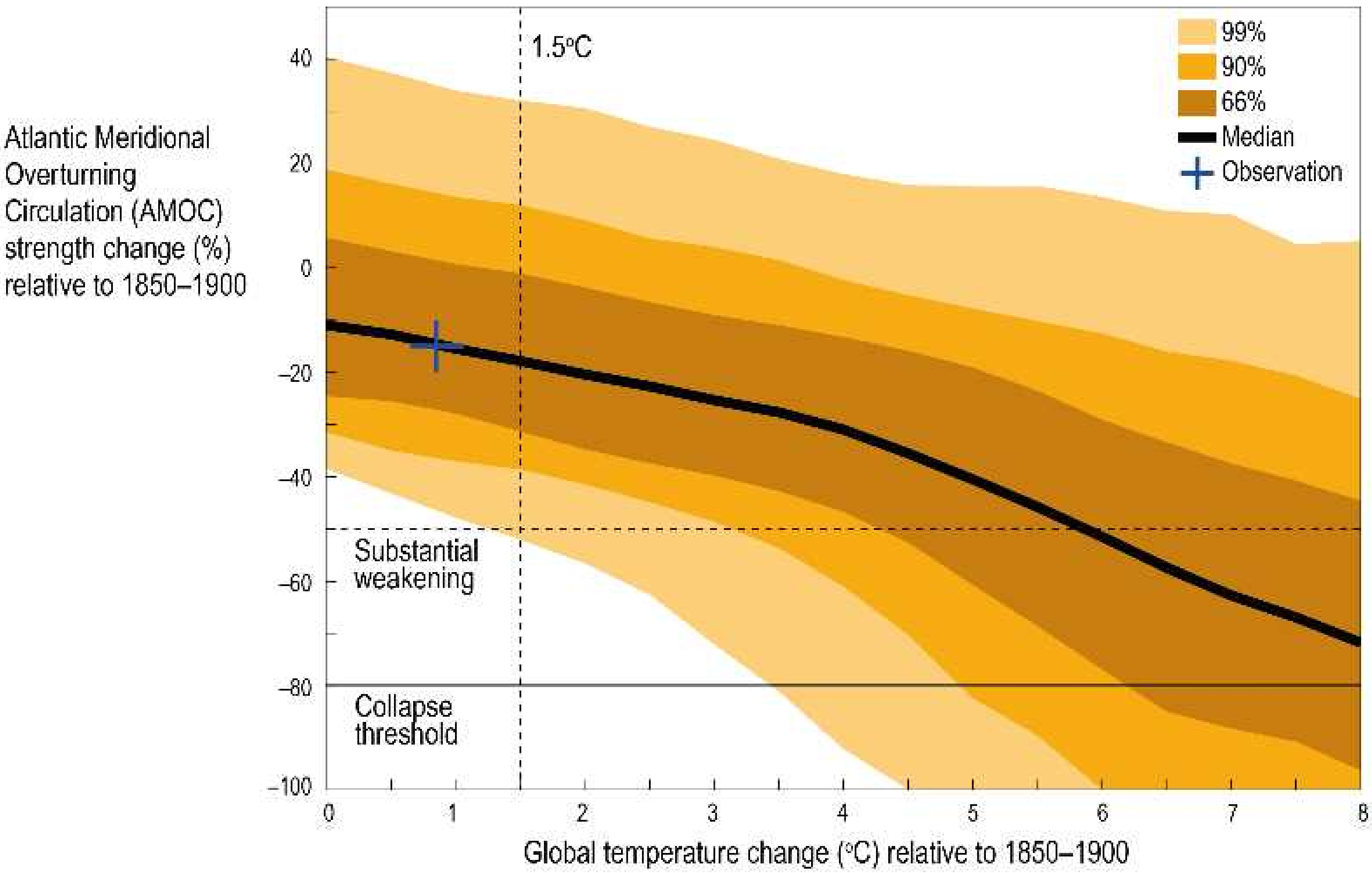
✓ Increasing frequency of extreme ENSO and IOD events have the potential to have widespread impacts on natural and human systems in many parts of the globe.

✓ Sustained long-term monitoring and improved forecasts and early warning can be used in managing the risks of extreme events (human health, agriculture, fisheries, coral reefs, aquaculture, wildfire, drought and flood management) (*hc*).

AMOC: Atlantic Meridional Overturning Circulation

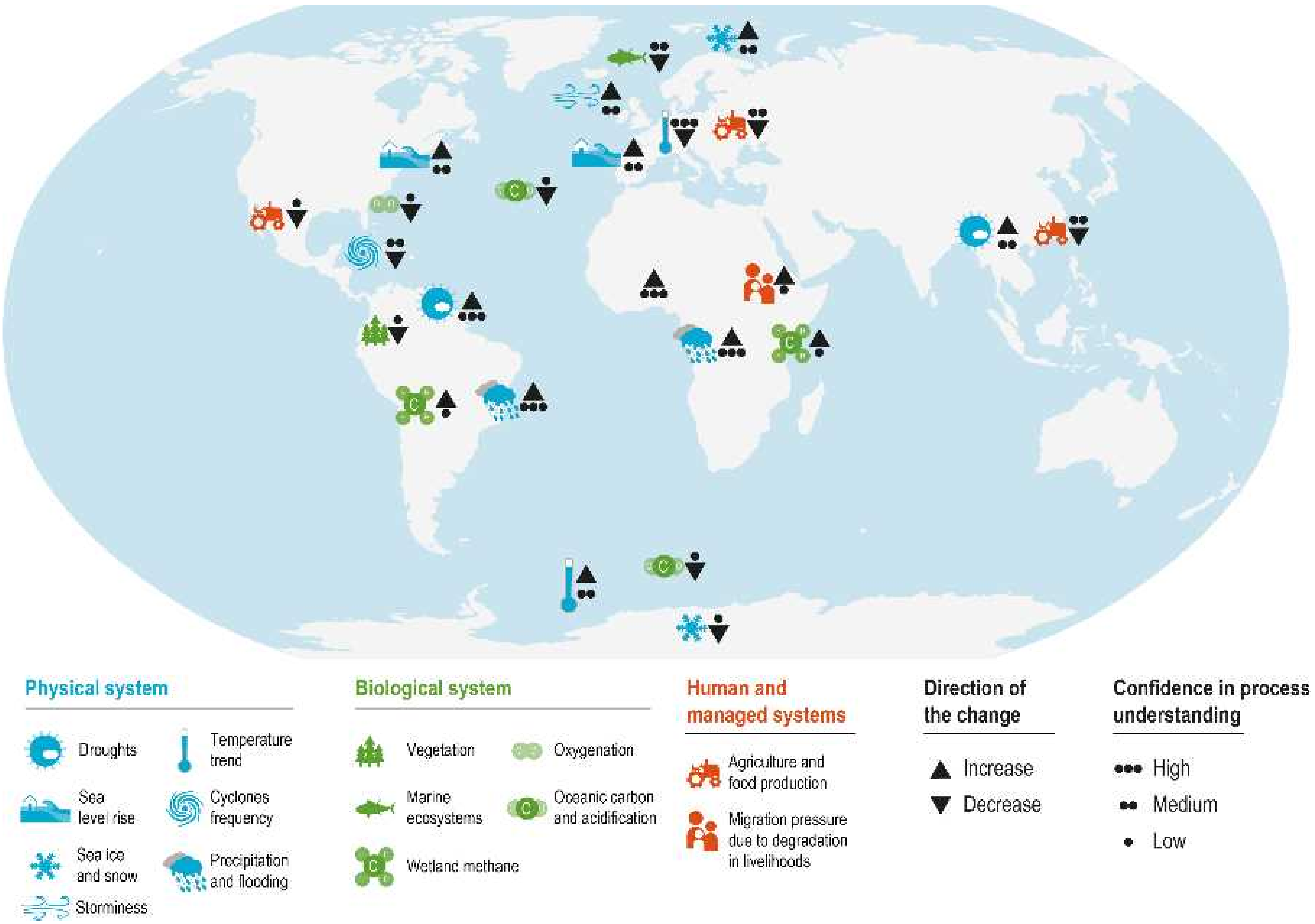


Atlantic Meridional Overturning Circulation (AMOC) changes at 26°N as simulated by 27 models (only 14 were shown in the IPCC 5th Assessment Report (AR5); IPCC, 2013).



The changes in the Atlantic Meridional Overturning Circulation (AMOC) strength as a function of transient changes in global mean temperature for projections from RCP4.5 and RCP8.5 scenario.

The ranges (66%, 90% and 99%) correspond to the amount of simulations that are within each envelope.



Infographic on teleconnections and impacts due to AMOC collapse or substantial weakening.

AMOC

Ongoing :

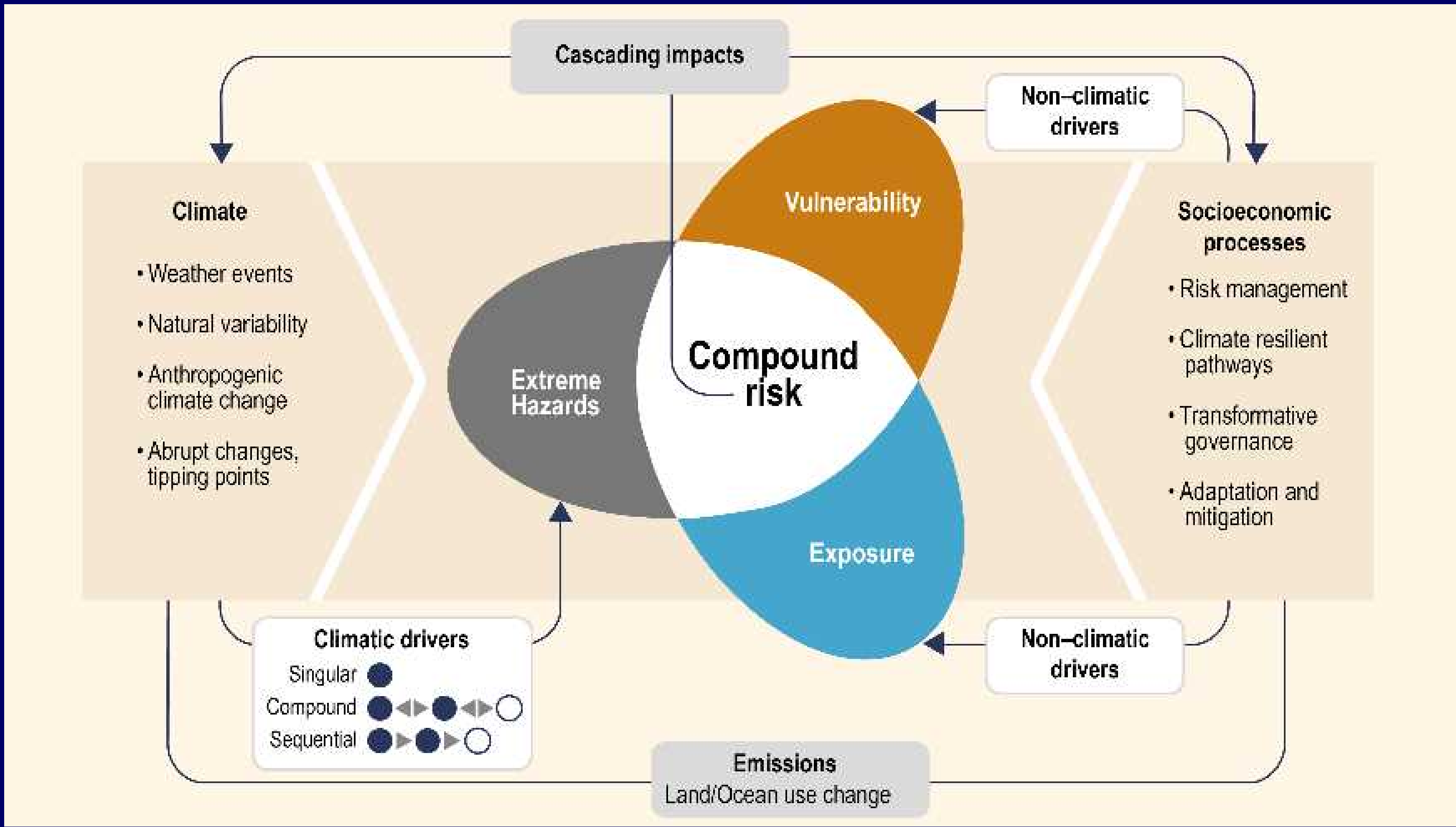
- Modern observations, climate simulations and palaeoclimate reconstructions suggest that the AMOC has weakened since the pre-industrial (*mc*).

Projections :

- The AMOC will *very likely* weaken over the 21st century (*hc*), although a collapse is *very unlikely* (*mc*). Nevertheless, a substantial weakening of the AMOC remains a physically plausible scenario.

Risk management and adaptation :

✓ Sustained long-term monitoring and improved forecasts and early warning system can be used in managing the risks and adaptation.



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Compound Events and Cascading Impacts

- Compound events refer to the combination of multiple drivers and/or hazards that contribute to societal or environmental risks.
- Cascading impacts from extreme weather/climate events occur when an extreme hazard generates a sequence of secondary events in natural and human systems that result in physical, natural, social or economic disruption, whereby the resulting impact is significantly larger than the initial impact.
- Examples:

✓ Tasmania in southeast Australia experienced multiple extreme climate events in 2015–2016, driven by the combined effects of natural modes of climate variability and anthropogenic climate change, with impacts on the energy sector, fisheries and emergency services.

✓ The Coral Triangle is under the combined threats of mean warming, ocean acidification, temperature and sea-level variability (often associated with both El Niño and La Niña), coastal development and overfishing, leading to reduced ecosystem services and loss of biodiversity.

✓ The above-average hurricane activity of the 2017 season led to the sequential occurrence of Hurricanes Harvey, Irma and Maria on the Caribbean and southern US coasts collectively causing USD 265 billion damage and making 2017 the costliest hurricane season on record.

Governance and Policy Options, Risk Management, DRR

- Inclusion of, and coordination between, different stakeholders is a key component for managing risks of extreme events, including in a changing climate.
- **Limiting the risk from the impact of extreme events and abrupt changes leads to successful adaptation to climate change with the presence of well-coordinated climate-affected sectors and disaster management relevant agencies (*hc*).**
- **Transformative governance inclusive of successful integration of disaster risk management (DRM) and climate change adaptation, empowerment of vulnerable groups, and accountability of governmental decisions promotes climate-resilient development pathways (*hc*).**

→ the Sendai Framework for Disaster Risk Reduction 2015–2030

- Priority 1: Understanding disaster risk.
- Priority 2: Strengthening disaster risk governance to manage disaster risk.
- Priority 3: Investing in disaster risk reduction for resilience.
- Priority 4: Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction.

Executive Summary

Ongoing and Emerging changes of OC and their impacts

- Anthropogenic climate change has increased precipitation, winds and extreme sea level (ESL), a number of observed tropical/extra tropical cyclones (*h.c) and poleward extension in western Pacific (l.c)*
- Extreme wave heights across the globe have increased by around 5% over the past three decades (m.c)
- Increased (frequency, intensity, duration) of Marine heatwaves (MHWs), (*vhc*).
- The strongest El Niño and La Niña events during the last fifty years (*mc*).
- Unprecedented intensification equatorial Pacific trade wind system 2001–2014, -> increase ITF & OHC transport to the Indian Ocean (by 28% of global), influencing the rate of global temperature change (*mc*).
- AMOC has weakened since the pre-industrial (*medium confidence*).
- Climate change is modifying multiple types of climate-related events or hazards in terms of occurrence, intensity and periodicity. It increases the likelihood of compound hazards that comprise simultaneously or sequentially occurring events to cause extreme impacts in natural and human systems. Compound events in turn trigger cascading impacts (*hc*).

Projections of OC change under low and high emissions

- An increase: TCs intensity, precipitation, a 2'C global temperature rise (*mc*), although *low confidence* in future frequency changes at the global scale. Rising sea levels will contribute to higher ESLs associated with TCs in the future (*vhc*).
- MHWs will further increase in frequency, duration, spatial extent and intensity (*vhc*) pushing some marine organisms, fisheries and ecosystems beyond the limits of their resilience, with cascading impacts on economies and societies *(hc*).
- Increase in frequency and intensity of Extreme El Niño and La Niña events
- *Low confidence (lack obs. and* inadequacies ability climate model) in future projections of the trade wind system and their link to inter-ocean variability and its impacts.
- The AMOC will *very likely* weaken over the 21st century (*hc*), although a collapse is *very unlikely (mc)*. Nevertheless, a substantial weakening of the AMOC remains a physically plausible scenario.
- Impacts from further changes in TC and ETCs, MHWs, extreme El Niño and La Niña events and other extremes will exceed the limits of resilience and adaptation of ecosystems and people, leading to unavoidable loss and damage (*mc*).

Strengthening Responses (SGD) & Resilient Development pathways

- Extremes and abrupt changes leads to a several-fold increase in the cost of carbon emissions (*mc*). If carbon emissions decline, the risk of extremes and abrupt changes are reduced, creating co-benefits.
- Investment in disaster risk reduction, flood management and early warning systems decreases economic loss (*mc*), but such investments may be hindered by limited local capacities in less developed countries despite adaptation efforts.
- Limiting global warming would reduce the risk of impacts of MHWs, but critical thresholds for some ecosystems will be reached at relatively low levels of future global warming (*hc*).
- Sustained long-term monitoring and improved forecasts can be used in managing the risks of extreme El Niño and La Niña events associated with human health, agriculture, fisheries, coral reefs, aquaculture, wildfire, drought and flood management (*hc*).
- Climate change adaptation and disaster risk reduction require capacity building and an integrated approach (*hc*).
- The ratio between risk reduction investment and reduction of damages of extreme events varies. Investing in preparation and prevention against the impacts from extreme events is *very likely* less than the cost of impacts and recovery (*mc*).
- Extreme change in the trade wind system and its impacts on global variability, biogeochemistry, ecosystems and society have not been adequately understood and represent significant knowledge gaps.

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ありがとうございました

Thank You