

Climatological Aspects in Agriculture

FERTASA 65th ANNUAL CONGRESS

Prof Jennifer Fitchett

School of Geography, Archaeology and Environmental Studies

University of the Witwatersrand

Overview

- 1. Clarification of Terminology**
- 2. IPCC 6th Assessment Report – Key Insights**
- 3. Droughts**
- 4. Tropical Cyclones**
- 5. Hail**

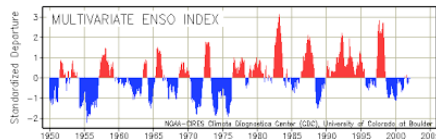
Weather, Climate, Climate Variability and Climate Change



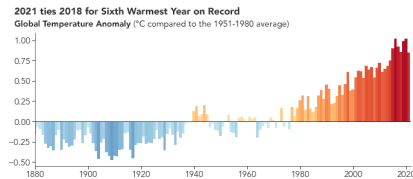
Weather: Day to day meteorological conditions



Climate: Average meteorological conditions over a period of at least 30 years

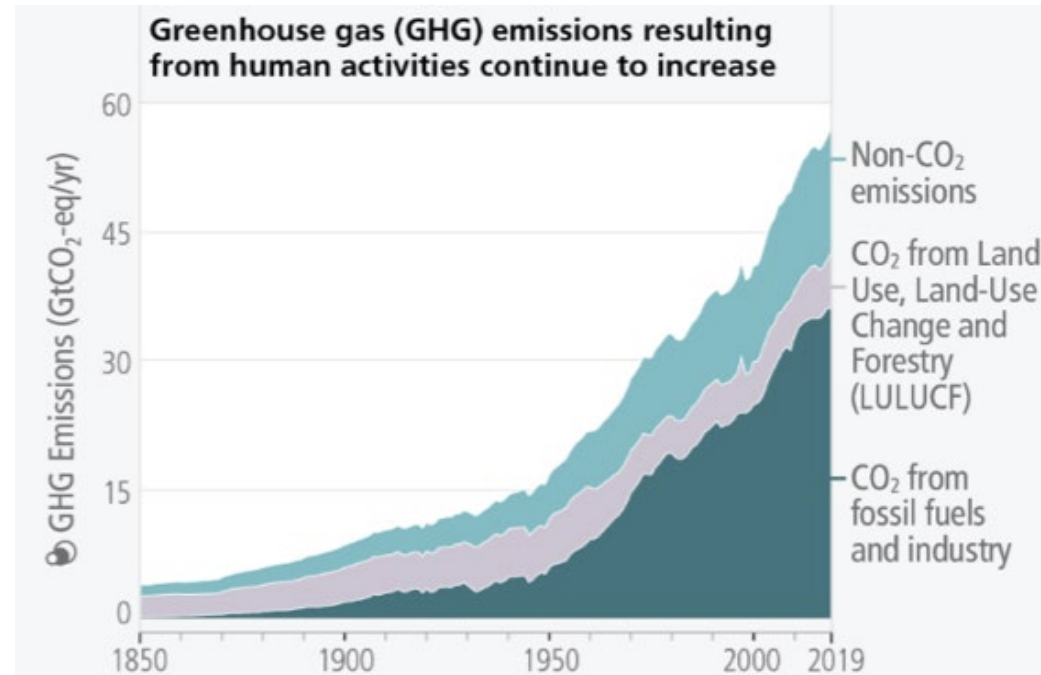
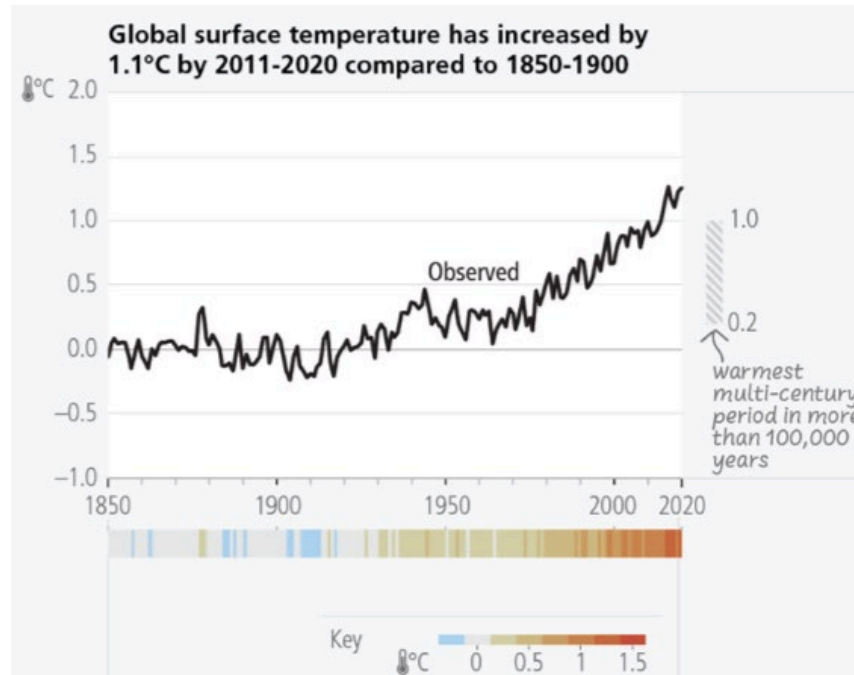


Climate Variability: Cyclical intra- and inter-annual fluctuations in mean meteorological conditions

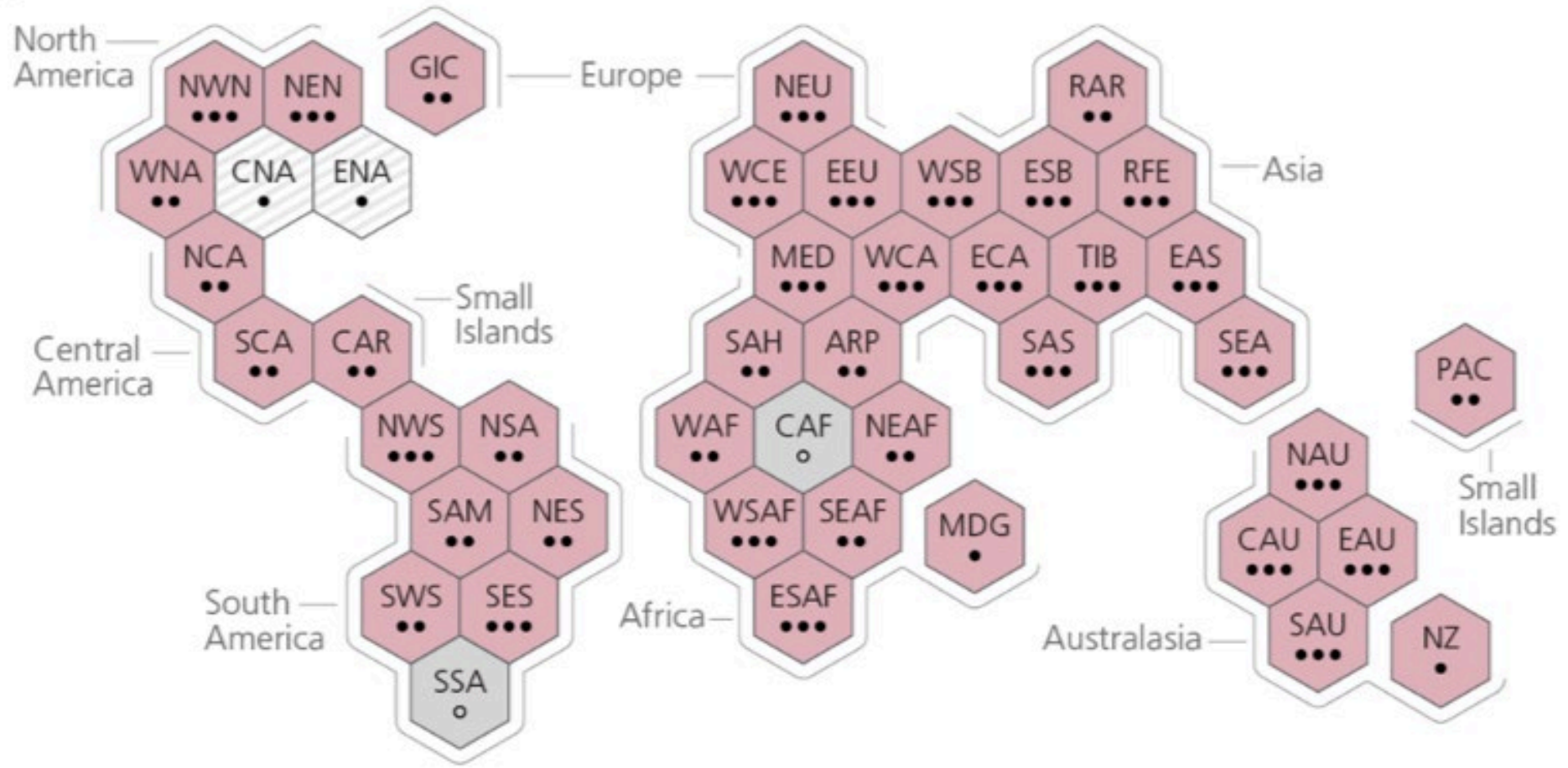


Climate Change: Usually uni-directional inter-annual trends in mean meteorological conditions over periods of at least 30 years

Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850-1900 in 2011-2020. Global greenhouse gas emissions have continued to increase over 2010-2019, with unequal historical and ongoing contributions arising from unsustainable energy use, land use and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and between individuals (*high confidence*). Human-caused climate change is already affecting many weather and climate extremes in every region across the globe. This has led to widespread adverse impacts on food and water security, human health and on economies and society and related losses and damages⁶ to nature and people (*high confidence*). Vulnerable communities who have historically contributed the least to current climate change are disproportionately affected (*high confidence*).



Hot extremes ← including heatwaves



Type of observed change since the 1950s



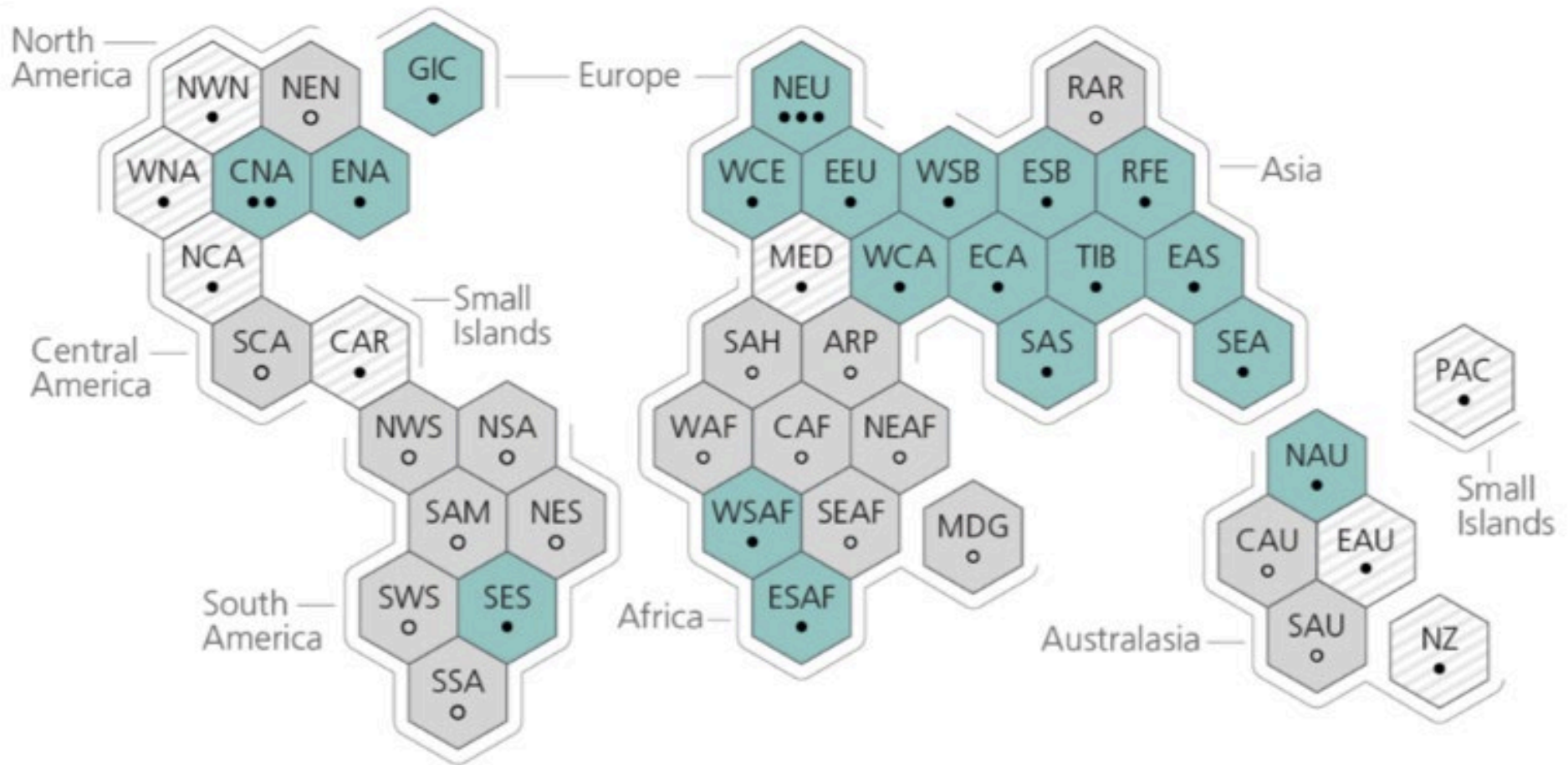
Confidence in human contribution to the observed change

- High
- Medium
- Low due to limited agreement
- Low due to limited evidence

Each hexagon corresponds to a region



Heavy precipitation



Type of observed change since the 1950s



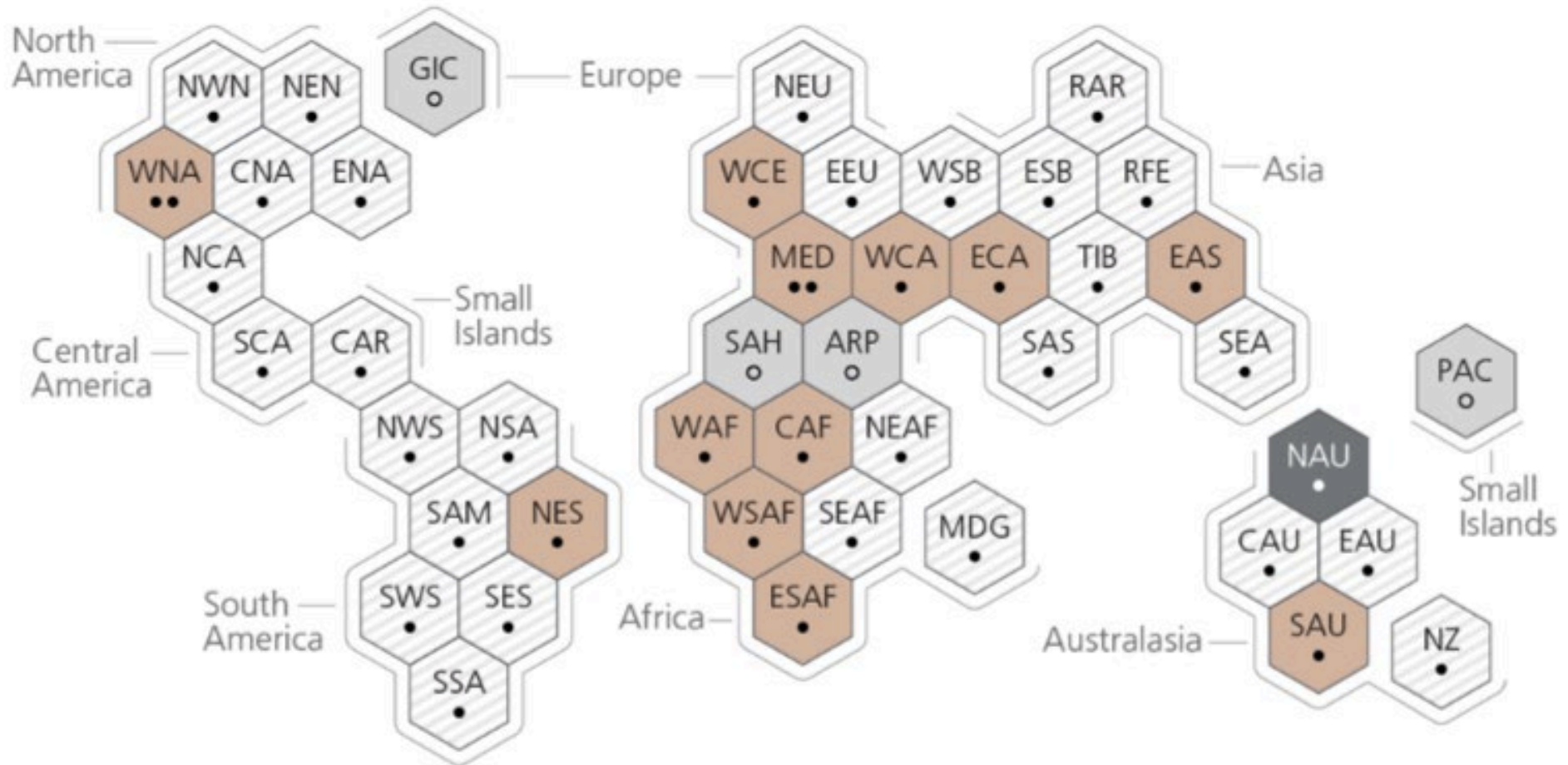
Confidence in human contribution to the observed change

- High (Three dots)
- Medium (Two dots)
- Low due to limited agreement (One dot)
- Low due to limited evidence (Small circle)

Each hexagon corresponds to a region



Agricultural and ecological drought



Type of observed change since the 1950s

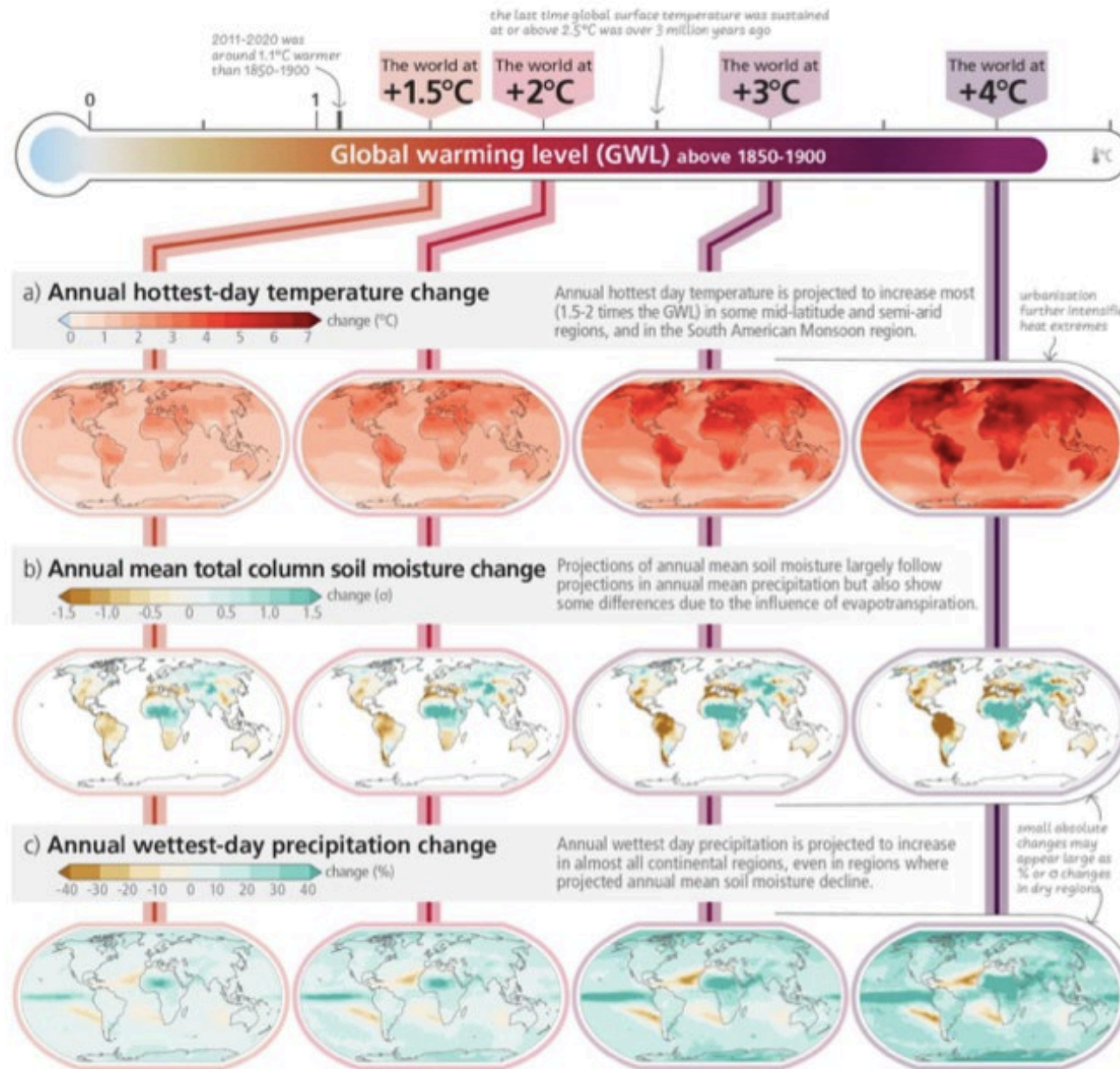


Confidence in human contribution to the observed change













































































































- High
- Medium
- Low due to limited agreement
- Low due to limited evidence

Each hexagon corresponds to a region







c) Observed impacts and related losses and damages of climate change

			Global	Africa	Asia	Australasia	Central & South America	Europe	North America	Small Islands
HUMAN SYSTEMS	Water availability and food production	Physical water availability 								
		Agriculture/crop production 								
		Animal and livestock health and productivity 								
		Fisheries yields and aquaculture production 								
	Health and wellbeing	Infectious diseases 								
		Heat, malnutrition and harm from wildfire 								
		Mental health 								
		Displacement 								
	Cities, settlements and infrastructure	Inland flooding and associated damages 								
		Flood/storm induced damages in coastal areas 								
Damages to infrastructure 										
Damages to key economic sectors 										

Increased climate impacts






HUMAN SYSTEMS

-  Adverse impacts
-  Adverse and positive impacts










ECOSYSTEMS

-  Climate-driven changes observed, no assessment of impact direction

Confidence in attribution to climate change



-  High or very high
-  Medium
-  Low
-  Evidence limited, insufficient
-  Not assessed

c) Observed impacts and related losses and damages of climate change

		Global	Africa	Asia	Australasia	Central & South America	Europe	North America	Small Islands	
ECOSYSTEMS	Changes in ecosystem structure	Terrestrial 	•••	•••	•••	•••	•••	•••	•••	
		Freshwater 	•••	•••	••	-	•••	•••	•••	•••
		Ocean 	•••	•••	•••	•••	•••	•••	•••	•••
	Species range shifts	Terrestrial 	•••	•••	•	•••	•••	•••	•••	•••
		Freshwater 	•••	-	••	-	•••	•••	•••	•••
		Ocean 	•••	•••	-	•••	•••	•••	•••	•••
	Changes in seasonal timing (phenology)	Terrestrial 	•••	-	•	•••	-	•••	•••	•••
		Freshwater 	•••	•	•	-	-	•••	•••	-
		Ocean 	•••	•	••	•	•	•••	•••	••

Increased climate impacts

HUMAN SYSTEMS

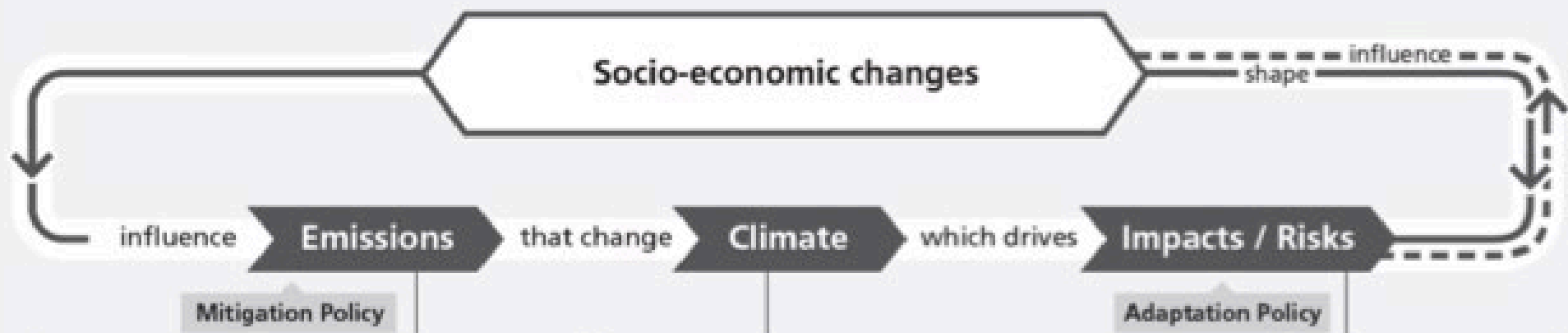
-  Adverse impacts
-  Adverse and positive impacts

ECOSYSTEMS

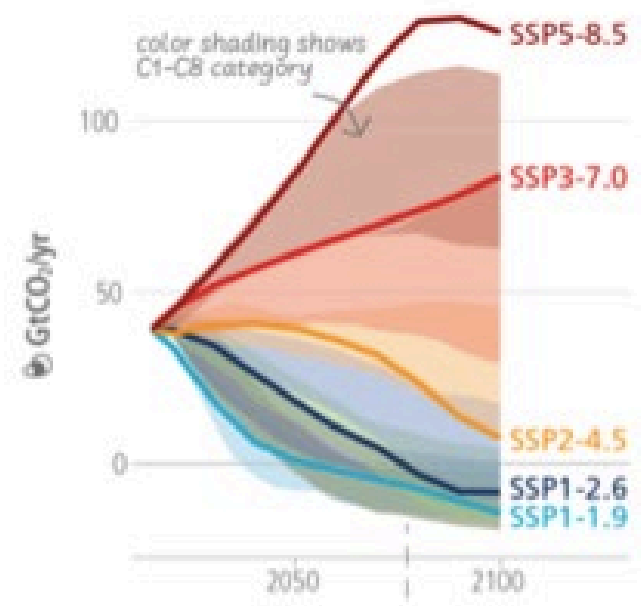
-  Climate-driven changes observed, no assessment of impact direction

Confidence in attribution to climate change

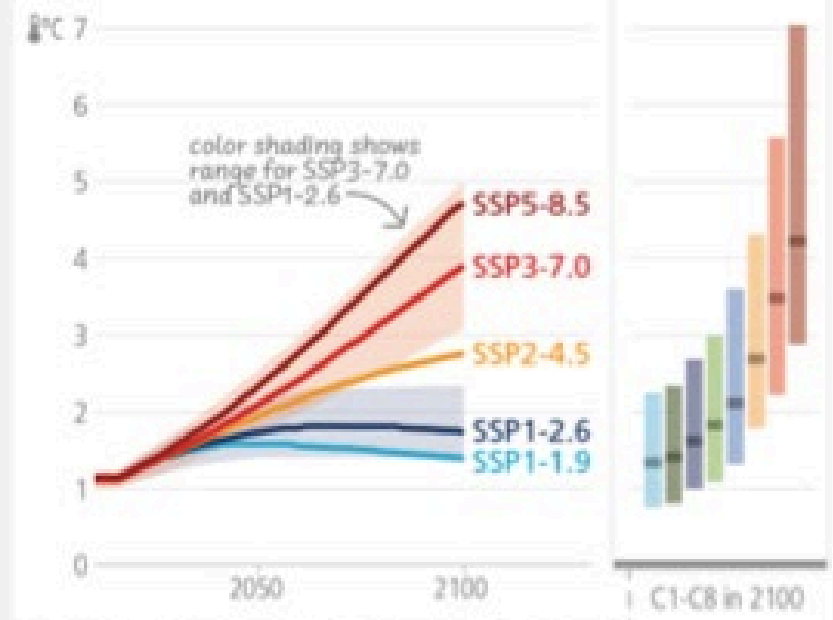
- High or very high
- Medium
- Low
- Evidence limited, insufficient
- / Not assessed



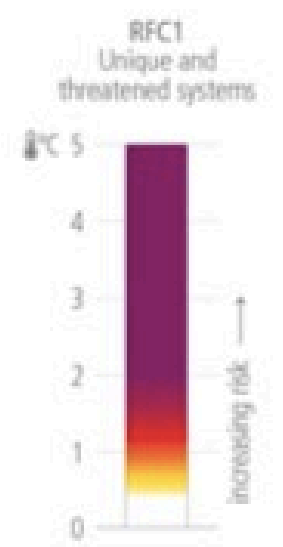
CO₂ emissions for SSP-based scenarios and C1-C8 categories



Temperature for SSP-based scenarios over the 21st century and C1-C8 at 2100

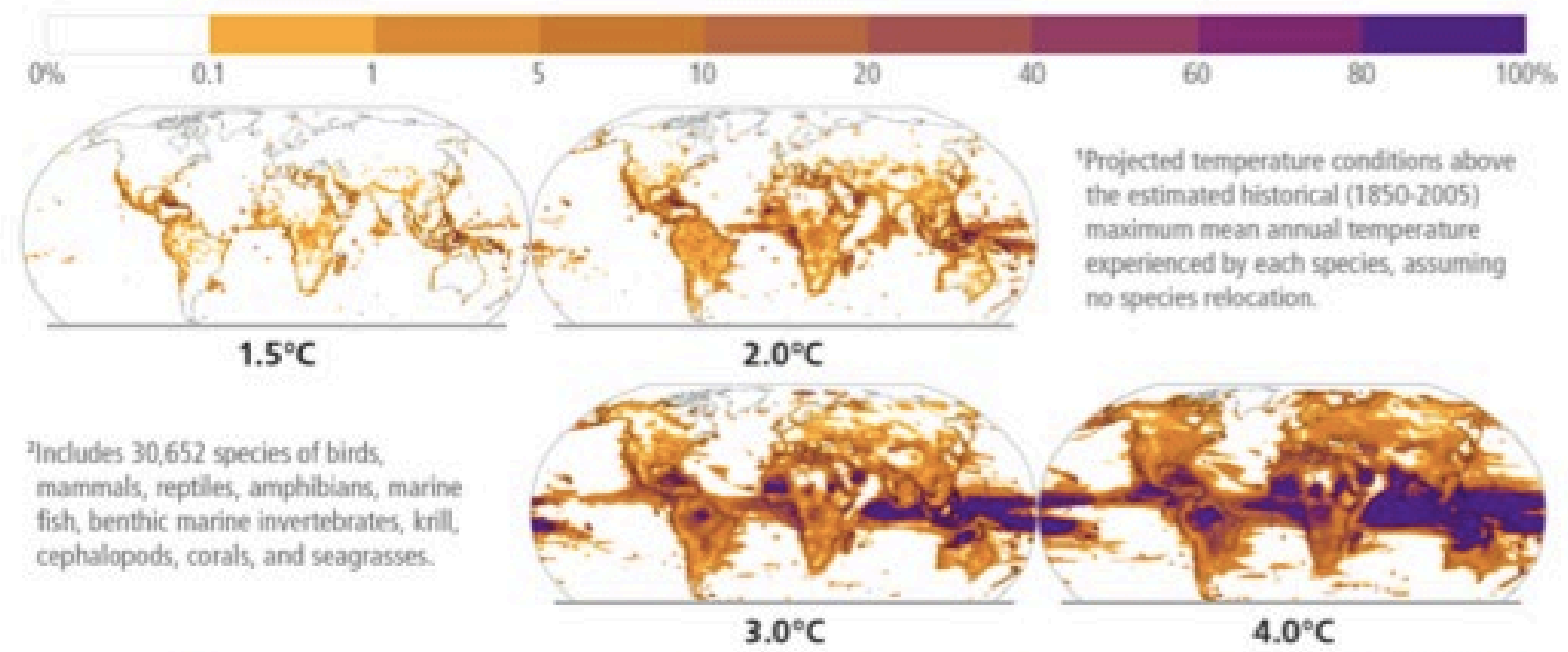


Risks can be represented as "burning embers"



a) Risk of species losses

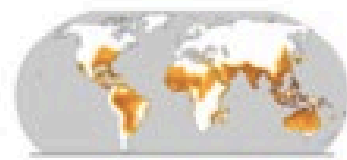
Percentage of animal species and seagrasses exposed to potentially dangerous temperature conditions^{1,2}



¹Projected temperature conditions above the estimated historical (1850-2005) maximum mean annual temperature experienced by each species, assuming no species relocation.

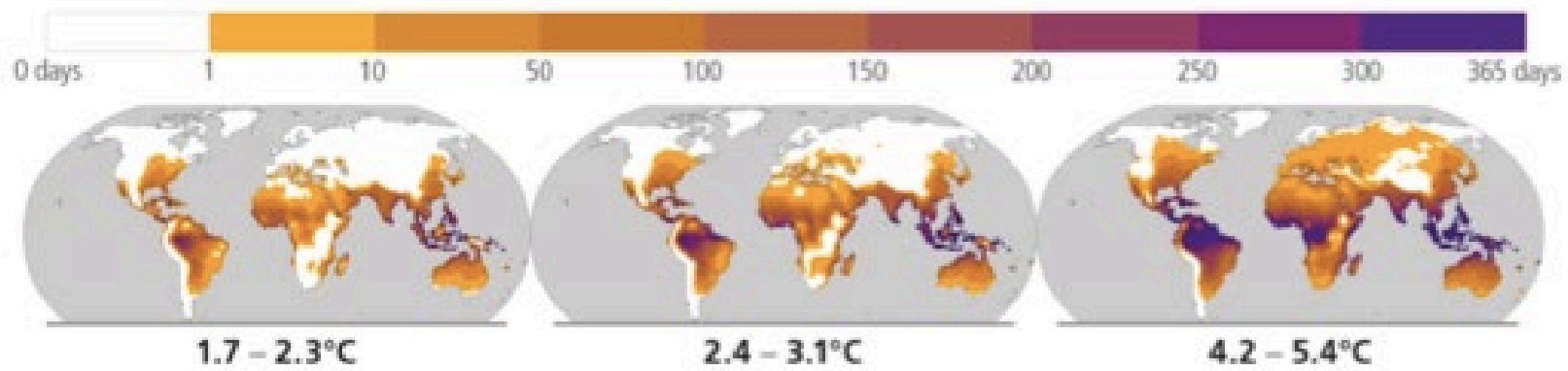
²Includes 30,652 species of birds, mammals, reptiles, amphibians, marine fish, benthic marine invertebrates, krill, cephalopods, corals, and seagrasses.

b) Heat-humidity risks to human health



Historical 1991-2005

Days per year where combined temperature and humidity conditions pose a risk of mortality to individuals³



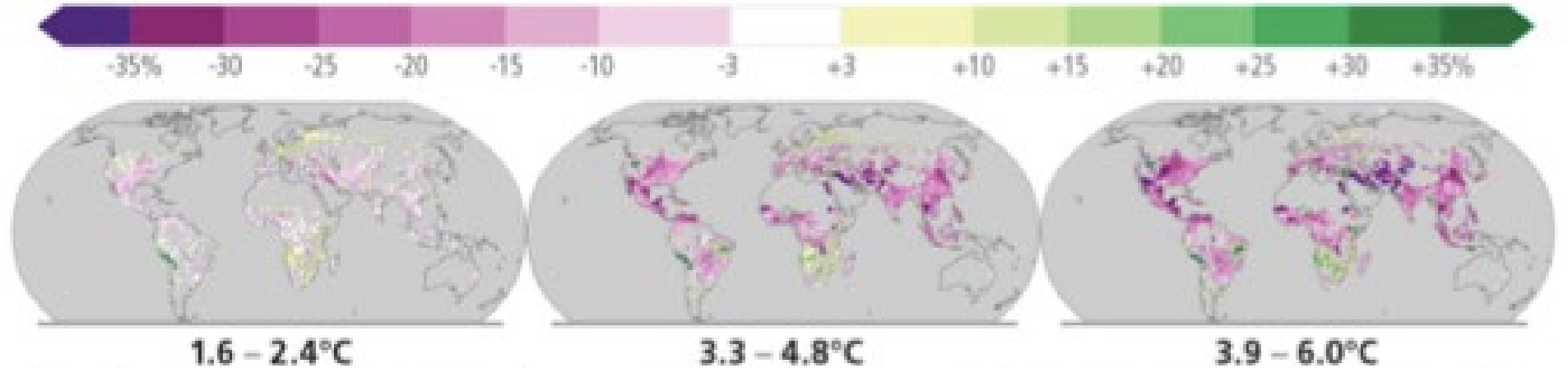
³Projected regional impacts utilize a global threshold beyond which daily mean surface air temperature and relative humidity may induce hyperthermia that poses a risk of mortality. The duration and intensity of heatwaves are not presented here. Heat-related health outcomes vary by location and are highly moderated by socio-economic, occupational and other non-climatic determinants of individual health and socio-economic vulnerability. The threshold used in these maps is based on a single study that synthesized data from 783 cases to determine the relationship between heat-humidity conditions and mortality drawn largely from observations in temperate climates.

c) Food production impacts



c1) Maize yield⁴

Changes (%) in yield

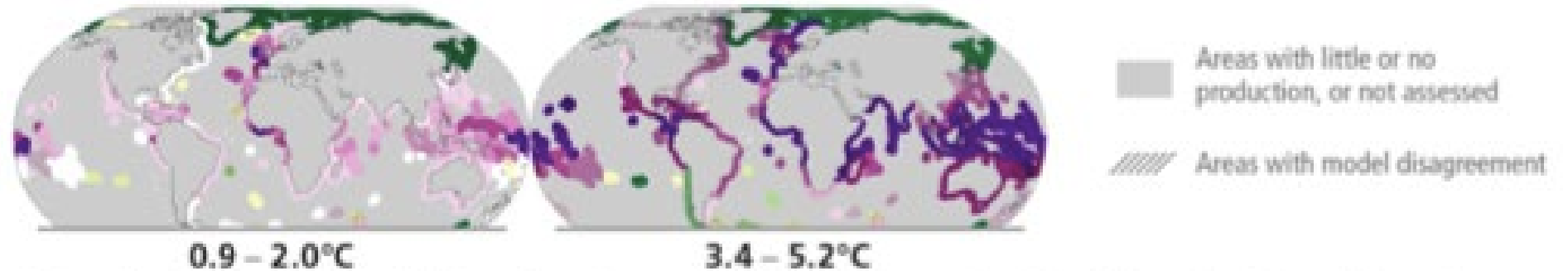


⁴Projected regional impacts reflect biophysical responses to changing temperature, precipitation, solar radiation, humidity, wind, and CO₂ enhancement of growth and water retention in currently cultivated areas. Models assume that irrigated areas are not water-limited. Models do not represent pests, diseases, future agro-technological changes and some extreme climate responses.



c2) Fisheries yield⁵

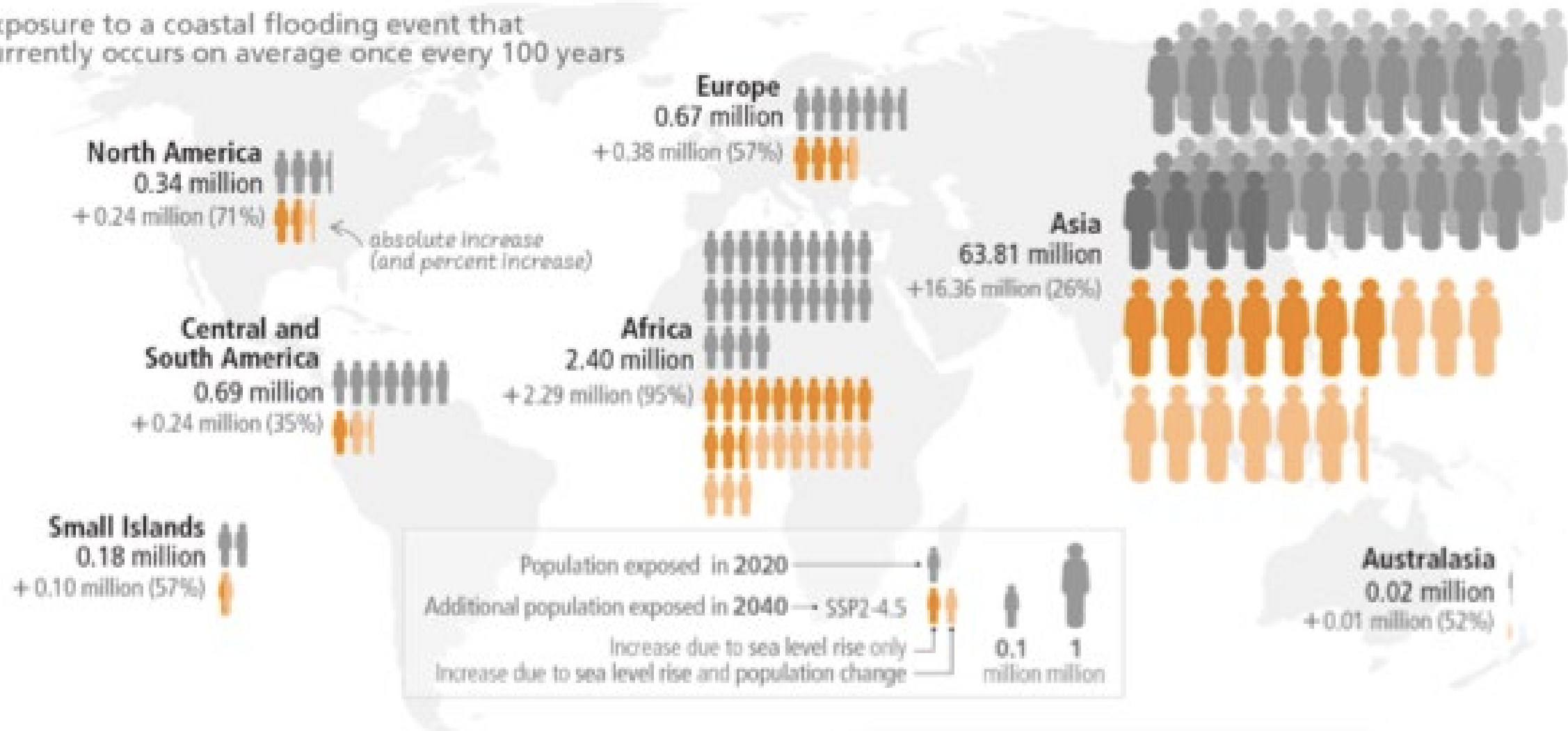
Changes (%) in maximum catch potential



⁵Projected regional impacts reflect fisheries and marine ecosystem responses to ocean physical and biogeochemical conditions such as temperature, oxygen level and net primary production. Models do not represent changes in fishing activities and some extreme climatic conditions. Projected changes in the Arctic regions have low confidence due to uncertainties associated with modelling multiple interacting drivers and ecosystem responses.

a) Increase in the population exposed to sea level rise from 2020 to 2040

Exposure to a coastal flooding event that currently occurs on average once every 100 years



c) Example of complex risk, where impacts from climate extreme events have cascading effects on food, nutrition, livelihoods and well-being of smallholder farmers

Multiple climate change risks will increasingly compound and cascade in the near term



a) Observed widespread and substantial impacts and related losses and damages attributed to climate change

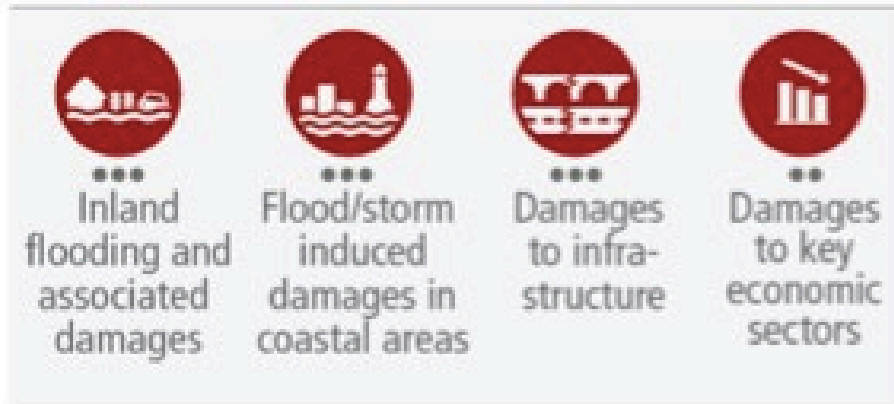
Water availability and food production



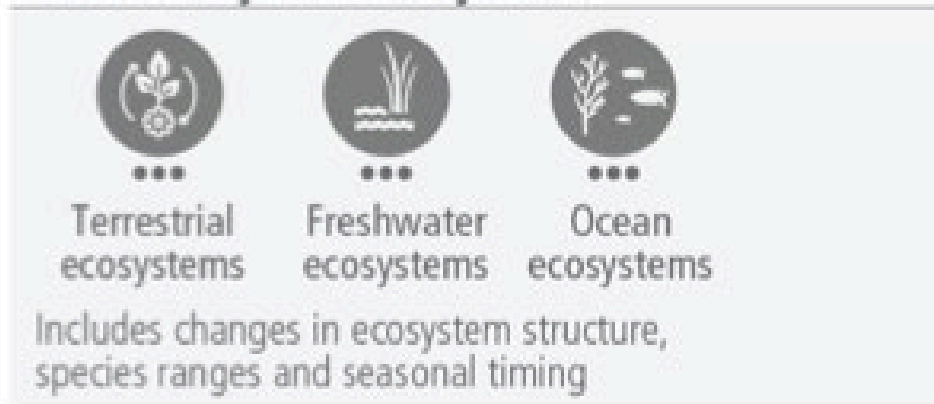
Health and well-being



Cities, settlements and infrastructure



Biodiversity and ecosystems



- Adverse impacts
- Adverse and positive impacts
- Climate-driven changes observed, no global assessment of impact direction

- Confidence in attribution to climate change
- *** High or very high confidence
 - ** Medium confidence
 - Low confidence

b) Impacts are driven by changes in multiple physical climate conditions, which are increasingly attributed to human influence

Attribution of observed physical climate changes to human influence:

Medium confidence



Increase in agricultural & ecological drought



Increase in fire weather



Increase in compound flooding

Likely



Increase in heavy precipitation

Very likely



Glacier retreat



Global sea level rise




Virtually certain






Upper ocean acidification



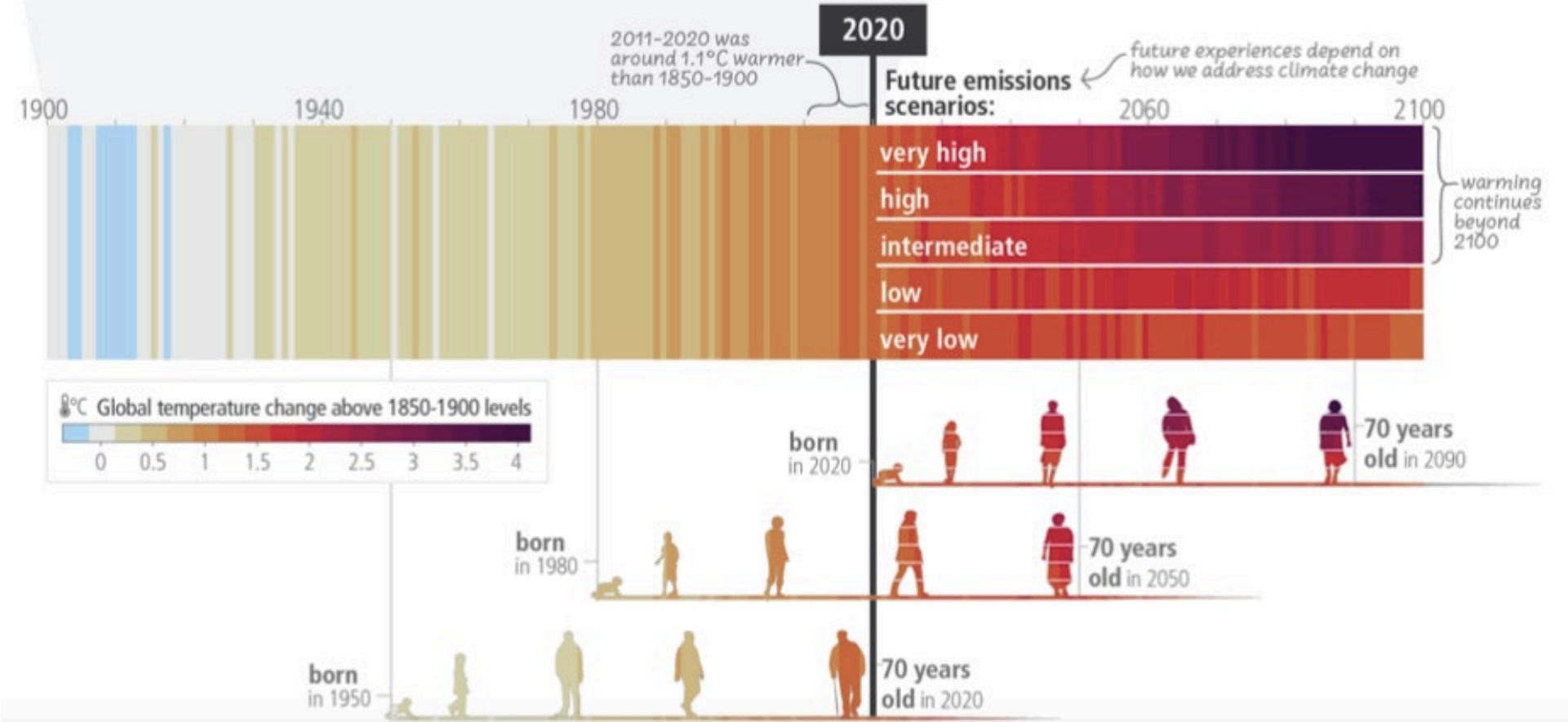
Increase in hot extremes

-  Adverse impacts
-  Adverse and positive impacts
-  Climate-driven changes observed, no global assessment of impact direction

Confidence in attribution to climate change

-  High or very high confidence
-  Medium confidence
-  Low confidence

c) The extent to which current and future generations will experience a hotter and different world depends on choices now and in the near-term



- Adverse impacts
- Adverse and positive impacts
- Climate-driven changes observed, no global assessment of impact direction

- Confidence in attribution to climate change
- High or very high confidence
 - Medium confidence
 - Low confidence



4 TYPES OF DROUGHT

AGRICULTURAL DROUGHT

Agricultural Droughts occur when there is not enough moisture in the soil to sustain the growth of crops.

SOCIOECONOMIC DROUGHT

Socioeconomic Droughts occur when the water supply is too low to support human and environmental needs

HYDROLOGICAL DROUGHT

Hydrological Droughts occur when there is a lack of surface and subsurface water supply.

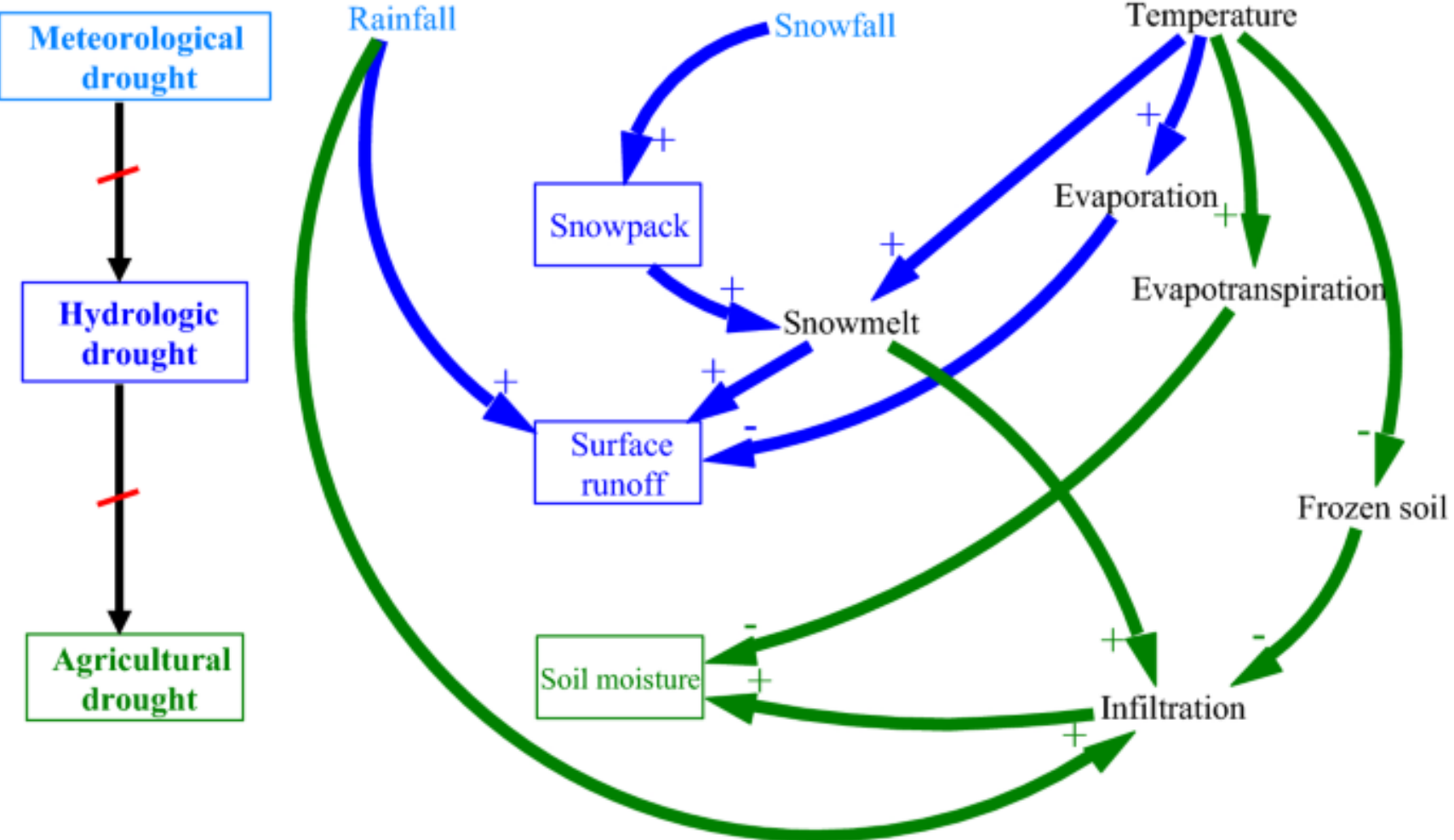
METEOROLOGICAL DROUGHT

Meteorological Droughts are region-specific; they occur when an area receives less rainfall than it normally should.

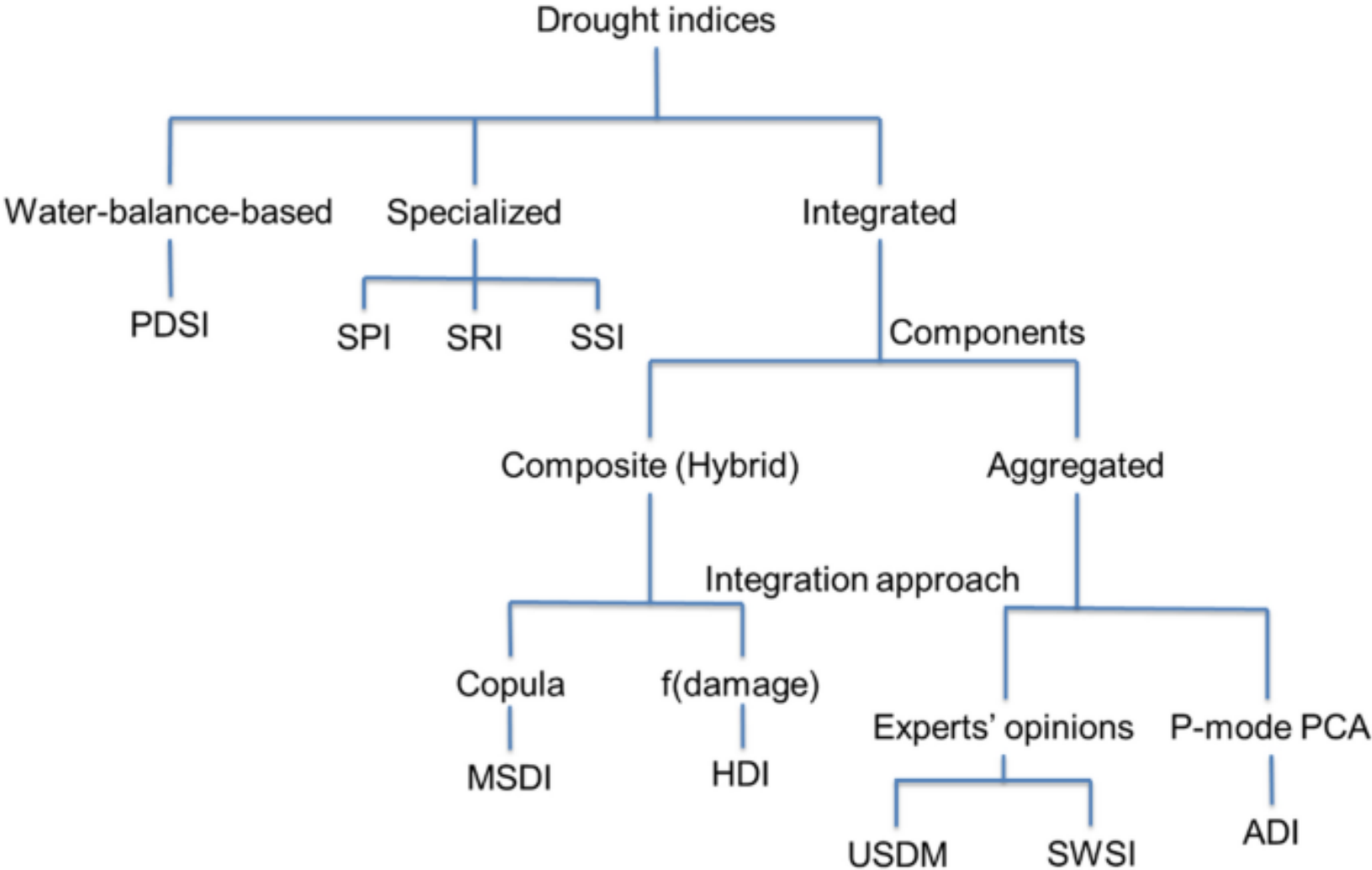
Rough estimates of drought:

- Comparing rainfall total of a given period, in a given area, to the long-term mean for that location, to determine whether there is less rainfall than would normally be expected
- Measuring dam levels, and identifying critical limits
- Farm reporting on yields and quality
- Exploring pricing fluctuations, and supply issues for locally produced crops

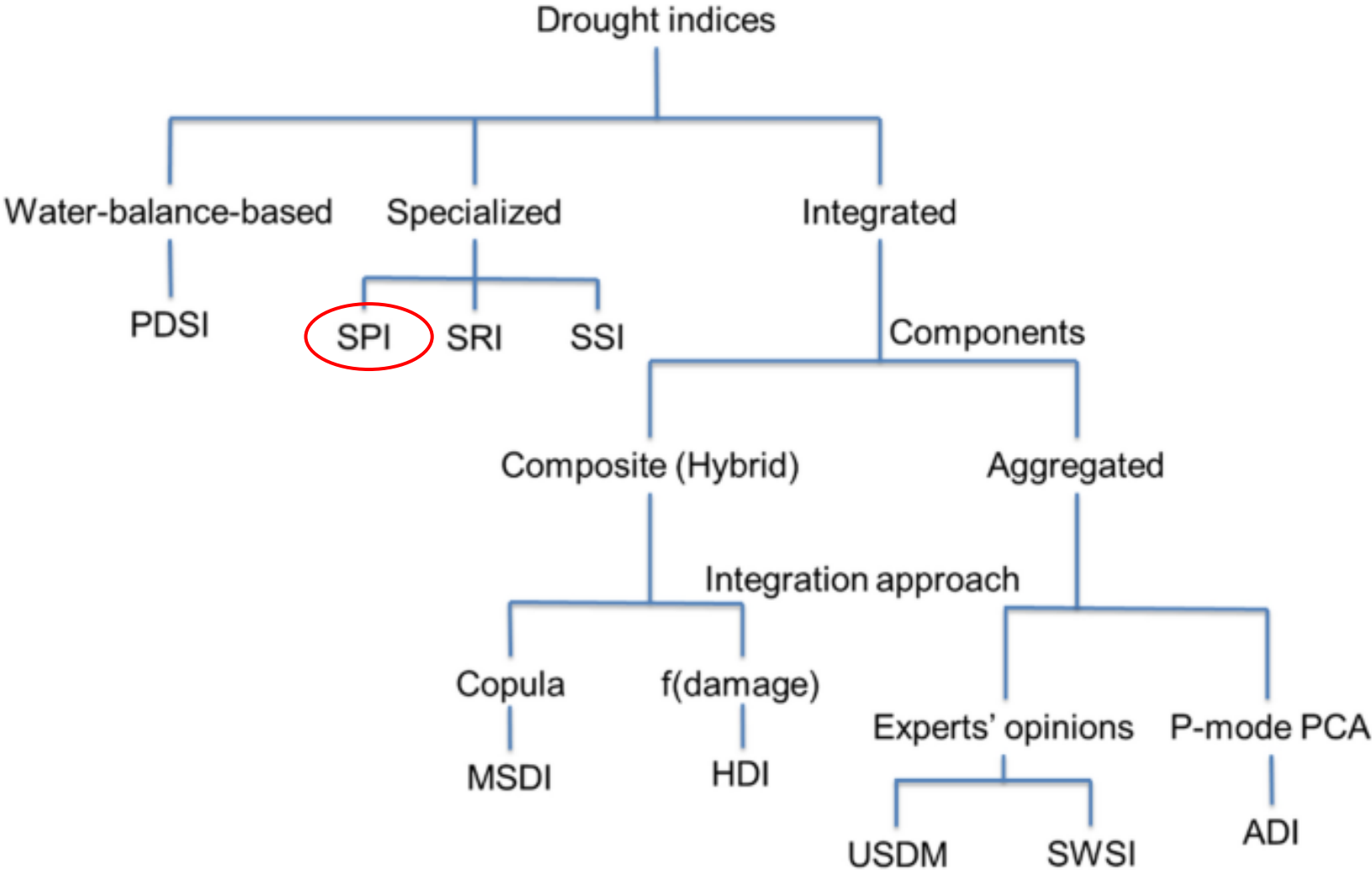
Indices for Drought Classification



Indices for Drought Classification



Indices for Drought Classification



Indices for Drought Classification

$$SPI_{ijk} = \frac{P_{ijk} - \overline{P_{ij}}}{\sigma_{ij}}$$

Table 1: *WMO SPI User Guide*^(p.4) standardised precipitation index (SPI) value classifications

SPI value	Classification
2.0+	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2.0 and less	Extremely dry

Indices for Drought Classification

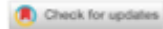
$$SPI_{ijk} = \frac{P_{ijk} - \overline{P_{ij}}}{\sigma_{ij}}$$

Table 1: WMO SPI User Guide^(p.4) standardised precipitation index (SPI) value classifications

SPI value	Classification
2.0+	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2.0 and less	Extremely dry

Drought

Indices for Drought Classification



AUTHOR:
Jennifer M. Fitchett¹

AFFILIATION:
¹School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand, Johannesburg, South Africa

CORRESPONDENCE TO:
Jennifer Fitchett

EMAIL:
Jennifer.Fitchett@wits.ac.za

HOW TO CITE:
Fitchett JM. On defining droughts: Response to 'The ecology of drought – a workshop report'. *S Afr J Sci*. 2019;115(3/4), Art. #5910, 2 pages. <https://doi.org/10.17159/sajs.2019/5910>

ARTICLE INCLUDES:
 Peer review
 Supplementary material

KEYWORDS:
Lincoln Declaration; standardised precipitation index

PUBLISHED:
27 March 2019

On defining droughts: Response to 'The ecology of drought – a workshop report'

Situated between the subtropics and the mid-latitudes, South African climate is dominated by persistent anticyclonic conditions year round.^{1,2} As a consequence, the region is relatively water scarce by global standards.^{2,3} During years of below-average rainfall, significant biometeorological impacts are felt by natural systems and human populations, yet often these are under-researched and under-reported, particularly in developing regions.⁴ Efforts to bring together interdisciplinary teams to collaborate in quantifying the impacts of adverse climatic conditions on ecosystem function are thus tremendously valuable. Swemmer et al.⁵ report on one such workshop, presenting important insights into the detriments, and in some cases benefits, of the below-average rainfall experienced in 2015–2016.

The findings regarding the impacts on herbivore mortality, migration and the utilisation of artificial waterholes, and the spatial heterogeneity in vegetation changes including grass and forb growth patterns and tree deaths⁶, are valuable in tracking the impacts of regional-scale water scarcity during events of below-average rainfall. These findings are not disputed. Rather, this Commentary reflects on issues surrounding the definition of a drought event, and in particular the use of a drought classification scale that discriminates exclusively between 'wet' and 'drought' conditions. It must be stated outright that the definition of drought does not affect the veracity of the workshop report by Swemmer et al.⁵ pertaining to the impacts of a rainfall reduction on herbivores and vegetation, nor do I contest that below-average rainfall occurred during this period.

Swemmer et al.⁵ present a map demonstrating 24-month standardised precipitation index (SPI) scores for an end run-date of May 2016. On the basis of this map, the authors argue that a severe to extreme drought 'appears' to have been experienced in northeastern Mpumalanga, the eastern half of the Free State and northern KwaZulu-Natal.⁵ It is curious that the authors use such tentative language, when the occurrence of a drought formed the primary basis of their workshop. It is also curious that they did not perform independent climatological analysis, nor present the methodology for SPI calculation conducted by the ARC or justification for the use of a 24-month SPI plot (as opposed to 6- or 12-month plots which are also produced by ARC in their UMLUNDI newsletters).

The SPI is one of the most widely used measures of meteorological drought conditions globally⁷, and, following the Lincoln Declaration⁸, it has been formally adopted by the World Meteorological Organization (WMO) as the formal metric on which drought conditions should be classified and quantified, with a WMO SPI User Guide published to standardise calculation and interpretation of SPI score⁹. It is therefore highly appropriate to use the SPI in a workshop on drought and any publications that follow, but such use of the SPI should follow WMO conventions to facilitate comparison of results across WMO member countries. The WMO SPI User Guide groups SPI scores into seven discrete classifications ranging from extremely dry, with scores < -2 , to extremely wet, with scores $> +2$, and with scores ranging from $+0.99$ to -0.99 classified as near normal (Table 1⁹). A drought event is thereafter declared on the basis of SPI scores of < -1.5 , i.e. severely dry conditions.⁹ The map presented by Swemmer et al.⁵ is not consistent with the WMO SPI User Guide classifications. The plot discriminates eight rather than seven classifications which span 'extremely wet' to 'extreme drought'.⁵ There are no SPI values assigned to any of these classifications, so it is not possible to determine whether the upper boundary of 'mild drought' is associated with an SPI score of -1.5 , or whether it refers to all SPI scores of less than zero. The plot also contains no classification for normal conditions.



Commentary
Page 1 of 3

AUTHORS:
Anthony M. Swemmer¹
William J. Bond^{1,2}
Jason Donaldson²
Gareth P. Hempton¹
Johan Malherbe¹
Izak P.J. Smidt^{1,3}

AFFILIATIONS:
¹South African Environmental Observation Network, Phalaborwa, South Africa
²Department of Biological Sciences, University of Cape Town, Cape Town, South Africa
³School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, Johannesburg, South Africa
⁴Natural Resources and the Environment, Council

The ecology of drought – a workshop report

The 2014–2016 drought experienced across the summer rainfall region of South Africa brought a range of social and economic impacts, with regular coverage in the public media. However, little has been reported on the ecological impacts of the drought in the rural rangelands and protected areas of the country. To address this issue a workshop on the ecology of drought was organised by the South African Environmental Observation Network (SAEON), a facility of the National Research Foundation, in November 2017. The event brought together researchers active in savannas (bushveld) of the northeastern part of the country, including the Kruger National Park (KNP) and adjacent Lowveld, and in savannas and grasslands of KwaZulu-Natal. The land uses in these areas varied from conservation to densely populated communal rangelands.

Drought impacts on commercial farmers are relatively straightforward to assess through quantification of crop yields. Ecological impacts are less tangible, particularly as many of these may only manifest years after the drought has ceased. Furthermore, while drought impacts are invariably negative in agriculture, they may have some positive impacts in ecosystems, such as reducing herbivore numbers (thus preventing overgrazing in the long term), reducing the densities of trees (thus combating bush encroachment) and providing an opportunity for 'drought adapted' flora and fauna to thrive. The primary aim of the workshop was to assess evidence available for testing the divergent predictions of drought impacts on natural systems. A key question was how severely livestock and wildlife populations were affected. On the topic of vegetation, some argued that droughts open up savannas by killing trees, others that droughts promote the seedling recruitment of trees (as a consequence of reduced competition from grasses and less fire) leading to bush encroachment. Many questions exist around recovery following the drought. Some argued that grasses take decades to recover their productive potential, others that recovery is very rapid once the drought breaks. How does the pattern of recovery vary with the ecological status preceding droughts and actions after it? And, most ominously, does each successive drought transform an ecosystem, pushing it

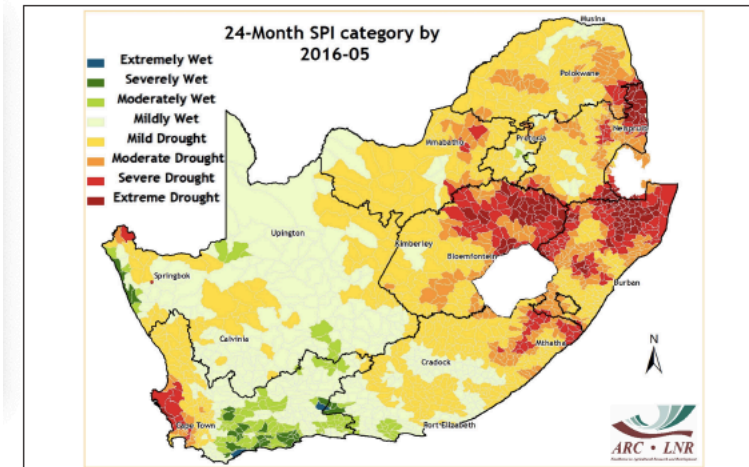


Figure 1: The Standardised Precipitation Index for South Africa over a 2-year period, as of May 2016, indicating which parts of the country experienced the most severe rainfall deficits.



Indices for Drought Classification

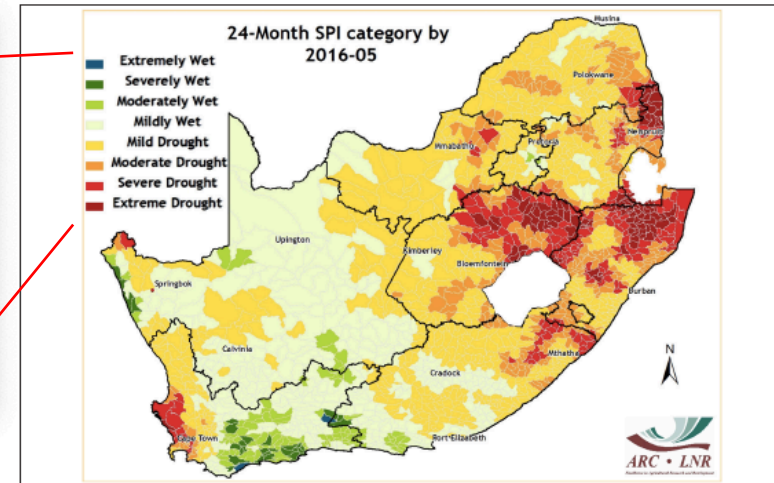


Figure 1: The Standardised Precipitation Index for South Africa over a 2-year period, as of May 2016, indicating which parts of the country experienced the most severe rainfall deficits.

Table 2: Initial standardised precipitation index (SPI) value classifications by McKee et al.^{10(p.2)}

SPI value	Drought category
0 to -0.99	Mild drought
-1.00 to -1.49	Moderate drought
[-*]1.5 to -1.99	Severe drought
≤-2.00	Extreme drought

*In the McKee et al. paper this is presented as 1.5 to -1.99, but is no doubt a typo.

Indices for Drought Classification

*Eighth Conference on Applied Climatology,
17–22 January 1993, Anaheim, California*

THE RELATIONSHIP OF DROUGHT FREQUENCY AND DURATION TO TIME SCALES

Thomas B. McKee, Nolan J. Doesken and John Kleist

Department of Atmospheric Science
Colorado State University
Fort Collins, CO 80523

1.0 INTRODUCTION

The definition of drought has continually been a stumbling block for drought monitoring and analysis. Wilhite and Glantz (1985) completed a thorough review of dozens of drought definitions and identified six overall categories: meteorological, climatological, atmospheric, agricultural, hydrologic and water management. Dracup et al. (1980) also reviewed definitions. All points of view seem to agree that drought is a condition of insufficient moisture caused by a deficit in precipitation over some time period. Difficulties are primarily related to the time period over which deficits accumulate and to the connection of the deficit in precipitation to deficits in usable water sources and the impacts that ensue.

Usable water sources include soil moisture, ground water, snowpack, streamflow and reservoir storage. Any impacts of drought associated with water demand exceeding water supply originate with one or more of these five usable supplies. The time period from the arrival of precipitation until water is available in each useable form differs greatly. Water uses also have characteristic time scales. Consequently, the impacts of a water deficit are a complex function of water source and water use. The time scale over which precipitation deficits accumulate becomes extremely important and functionally separates different types of drought. Agricultural (soil moisture) droughts, for example, typically have a much shorter time scale than hydrologic (groundwater, streamflow and reservoir) droughts.

Many examples are available where quantitative links have been established between precipitation deficits and drought impacts in particular water use areas. These use-specific relationships will likely continue to be expanded to assist in crop yield predictions, hydroelectric power projections and in many other drought-sensitive fields. However, the importance of monitoring and assessing water supply from a general climate perspective harmonizes with

Five practical issues become important in any analysis of drought. These include: 1) time scale, 2) probability, 3) precipitation deficit, 4) application of the definition to precipitation and to the five water supply variables, and 5) the relationship of the definition to the impacts of drought. Frequency, duration and intensity of drought all become functions that depend on the implicitly or explicitly established time scales. Our experience in providing drought information to a collection of decision makers in Colorado is that they have a need for current conditions expressed in terms of probability, water deficit, and water supply as a percent of average using recent climatic history (the last 30 to 100 years) as the basis for comparison. No single drought definition or analysis method has emerged that addresses all these issues well. Of the variety of definitions and drought monitoring methods used in the past, by far the most widely used in the United States is the Palmer Drought Index (Palmer, 1965), but its weaknesses (Alley, 1984) frequently limit its wise application. For example, time scale is not defined for the Palmer Index but does inherently exist.

The purpose of the following discussion is to propose an indicator and definition of drought which could serve as a versatile tool in drought monitoring and analysis. This indicator requires only one input variable, could be applied in a similar way to precipitation, snowpack, streamflow, reservoir storage, soil moisture, and ground water, recognizes a variety of time scales, and provides information on precipitation deficit, percent of average and probability.

2.0 A FUNCTIONAL DEFINITION OF DROUGHT

The definition of drought proposed here is based on standardized precipitation. Standardized precipitation is simply the difference of precipitation from the mean for a specified time period divided by the standard deviation where the mean and standard deviation are determined from past records. This same method can also be used to evaluate variations in any



Indices for Drought Classification

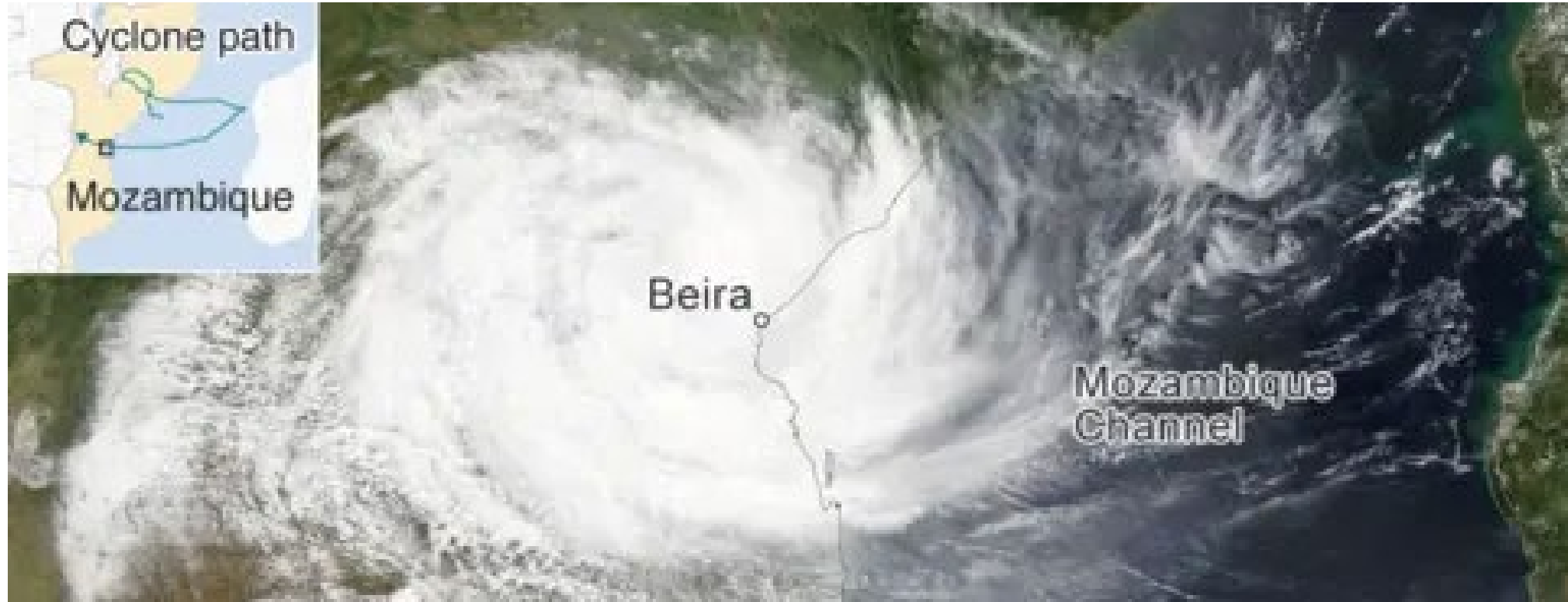
$$SPI_{ijk} = \frac{P_{ijk} - \overline{P_{ij}}}{\sigma_{ij}}$$

Table 1: WMO SPI User Guide^(p.4) standardised precipitation index (SPI) value classifications

SPI value	Classification
2.0+	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2.0 and less	Extremely dry

Drought

Risk of Tropical Cyclones



It is *likely* that the global proportion of Category 3–5 tropical cyclone instances ² has increased over the past four decades. The average location where TCs reach their peak wind intensity has *very likely* migrated poleward in the western North Pacific Ocean since the 1940s, and TC translation speed has *likely* slowed over the conterminous USA since 1900. Evidence of similar trends in other regions is not robust. The global frequency of TC rapid intensification events has *likely* increased over the past four decades. None of these changes can be explained by natural variability alone (*medium confidence*).

Risk of Tropical Cyclones

- Decrease in number
- Increase in intensity
- Poleward migration of storms

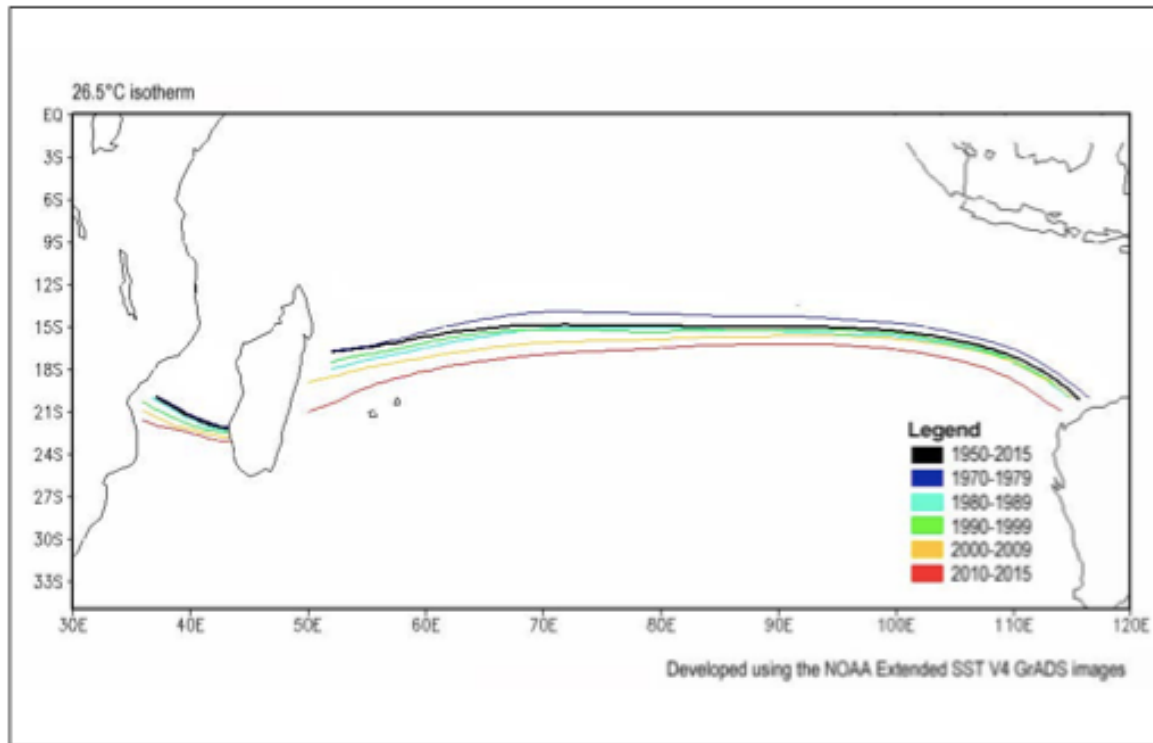


Table 1: Summary of the GAT5 tropical cyclones recorded in the IBTrACS storm track database

Year	Storm name	Date of conversion	Date of dissipation	Lowest central pressure	Highest speed
2015	Eunice	2015-01-30	2015-01-30	910 mb	140 kts
2015	Bansi	2015-01-13	2015-01-13	915 mb	140 kts
2013	Bruce	2013-12-21	2013-12-22	920 mb	140 kts
2010	Edzani	2010-01-08	2010-01-09	910 mb	140 kts
2004	Gallo	2004-03-06	2004-03-07	895 mb	140 kts
2004	Bento	2004-11-23	2004-11-24	915 mb	140 kts
2003	Kalunde	2003-03-08	2003-03-08	910 mb	140 kts
2002	Hary	2002-03-10	2002-03-10	905 mb	140 kts
1999	Evrina	1999-03-31	1999-03-31	920 mb	140 kts
1996	Itelle	1996-04-14	1996-04-14	935 mb	140 kts
1995	Agnielle	1995-11-21	1995-11-21	927 mb	150 kts
1994	Geralda	1994-02-01	1994-02-01	905 mb	145 kts

Risk of Tropical Cyclones

- Impacts not only experienced at the location of landfall
- Impacts are not only experienced for the duration of landfall
- Influence of tropical cyclones on the synoptic systems of adjacent regions
- Uncertainty in storm path forecasting

Risk of Hail



Risk of Hail

- Less clear historical trends and future projections
- Very difficult to forecast even at short-time periods
- Hail damage partly a factor of the size and density of the hail stones, which is determined by the amount of time circulating in convective clouds
- Typically an afternoon occurrence, but increasingly inconsistent
- Risk to plants, animals and to vehicles

Concluding Remarks

- As the climate is becoming increasingly unpredictable, access to high quality information is essential
- Great value in reading the IPCC summary reports
- Tracking shifting weather patterns at farm level is very valuable in understanding how climate change is influencing you at a microclimate scale

Questions?

Jennifer.Fitchett@wits.ac.za