促進氣候變遷調適之風險管理-針對極端事件及災害

Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation

給決策者摘要

Summary for Policymakers

政府間氣候變遷專門委員會特別報告

國家災害防救科技中心　編譯

SPM

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目錄

A. 背景

這份決策者摘要摘錄“「促進氣候變遷調適之風險管理-針對極端事件及災害」特別報告” (Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation，簡稱 SREX) 的重要發現。SREX 檢視科學文獻來探討此議題，包括研究氣候變遷與極端的天氣與氣候事件 (極端氣候) 之間的關係，以及這些極端事件影響社會及永續發展的意涵等相關文獻。研究的重點在於氣候、環境與人文因素的交互作用可能造成衝擊或災害，也可能會影響決策者如何管理極端氣候造成的災害風險，以及非氣候因素在災害衝擊中扮演的重要角色。文字框 SPM.1 為 SREX 特別報告中的專有名詞定義，圖 SPM.1 顯示本報告的核心概念。

極端氣候衝擊的嚴重程度除了取決於極端氣候的本質之外，更取決於暴露量 (Exposure) 及脆弱度 (Vulnerability)。報告中指出，負面的衝擊視為災害，而災害會造成大範圍的損失，並嚴重的影響公眾或社會的正常運作。影響極端氣候、暴露量及脆弱度的因素很多，包括人為造成的氣候變遷，自然氣候變異及社會經濟發展等 (圖 SPM.1)。「災害風險管理」及「氣候變遷調適」主要著重在降低暴露量及脆弱度，並增加回復力 (Resilience) 以因應極端氣候潛在負面衝擊，即使如此，災害風險仍無法被完全消除 (圖 SPM.2)。此外，雖然氣候變遷的減緩不是本報告的重點，但是調適及減緩卻能相輔相成，進而顯著降低氣候變遷帶來的風險。

本報告整合了幾個過去從事氣候科學、氣候衝擊、氣候變遷調適及災害風險管理等不同研究的各種觀點。每一個研究社群各自提出不同的觀點、專業術語、方法及研究目標。這些研究都針對知識基礎及現況缺口提供重要的見解。許多關鍵評估結果來自於不同研究社群間的交集。(如表 SPM.1 所示)。此外，為了能正確地傳達關鍵結果的確定性程度，本報告將一致使用經核定的有關不確定性的名詞 (如文字框 SPM.2)。關於本決策摘要中提及的章節完整內容，請依段落後方括號內的章節編號於 SREX 特別報告全文中參閱。

決定災害風險及其影響的關鍵因素是暴露量與脆弱度 [1.1.2, 1.2.3, 1.3, 2.2.1, 2.3, 2.5] 舉例來說，一個熱帶氣旋可以造成非常不同的衝擊，衝擊程度取決於其登陸地點及時間 [2.5.1, 3.1, 4.4.6]。同樣的，一場熱浪也可以對不同人群造成非常迥異的衝擊，衝擊程度取決於這群人的脆弱度 [文字框 4-4, 9.2.1]。對人類，生態或是自然系統的極端衝擊可來自於個別的極端天氣或氣候事件。極端衝擊亦可能來自於非極端事件，卻處於暴露量及脆弱度皆高的地區 [2.2.1, 2.3, 2.5] 或是多個事件及衝擊的綜合作用 [1.1.2, 1.2.3, 3.1.3]。例如，乾旱伴隨極端高溫及低濕度天氣亦可能增加森林大火的風險 [文字框 4-1, 9.2.2]。

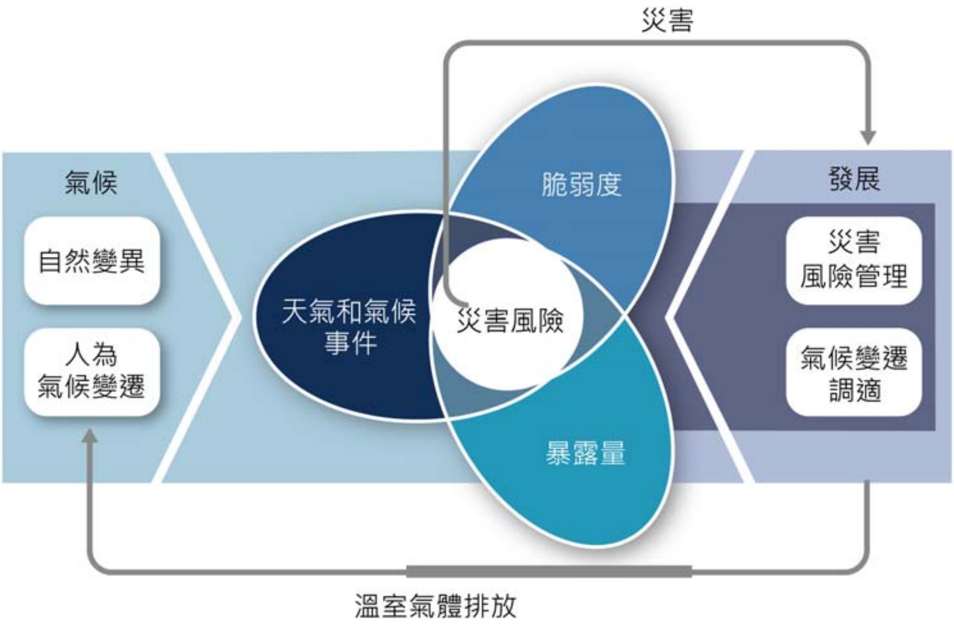

圖 SPM.1 SREX 特別報告核心概念示意圖。本報告評估了天氣及氣候事件的影響下，暴露量及脆弱度如何決定衝擊以及可能的災害 (災害風險)。報告中亦評估自然氣候變異及人為造成的氣候變遷對氣候極端事件所造成的影響，以及對人類社會及自然生態系統的暴露量及脆弱度的影響。此外，此概念考量到社會發展在暴露量及脆弱度變化趨勢裡的角色與作用，災害風險的潛在影響，以及災害與發展之間的交互作用。本報告檢視了災害風險管理及氣候變遷調適如何藉由減低對天氣及氣候事件的暴露量及脆弱度，來降低災害的風險；並針對無法消除的風險提高回復力。其他重要過程則超出本報告的範疇，所以不做深入探討，包括溫室氣體排放及人為氣候變遷影響的發展，以及減緩人為氣候變遷的可能性等問題。

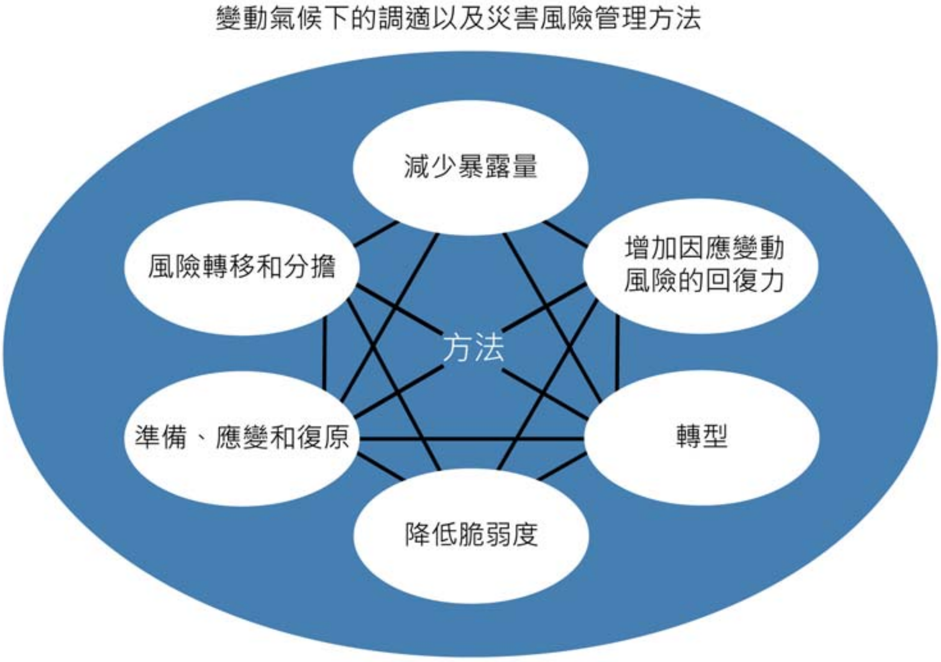

圖 SPM.2 **在氣候變遷的情況下，降低及管理災害風險的調適策略與方法**。這份報告檢視了許多可互補的調適及災害風險管理方法，透過這些方法可以降低極端氣候及災害的風險，並增加回復力以因應不斷改變的風險。這些方法可能重複也可以被同時運用 [6.5, 圖 6-3, 8.6]。

文字框 SPM.1 SREX 特別報告中的專有名詞定義

SREX 報告中使用並在詞彙表[1]中定義的核心概念如下：

氣候變遷 (Climate Change)：當氣候狀態的平均值或是變異特性發生持續性的改變 (通常數十年或是更久)，而且能被確認 (如:使用統計檢定) 稱為氣候變遷。 氣候變遷可能是自然的內部變化或是外力導致，亦或是持續的人為因素改變大氣成分及土地使用所造成。[2]

極端氣候 (極端天氣或氣候事件) (Climate Extreme (extreme weather or climate event))：當一個天氣或氣候的變數的數值高於或低於門檻值，而此門檻值為該變數之觀測數值區間的上限或下限。為求精簡，本報告將極端天氣事件及極端氣候事件統稱為「極端氣候」。

暴露量 (Exposure)：人類生命及其生計、環境服務及資源、基礎建設、或經濟、社會、及文化資產處於有可能受到不利影響的地方。

脆弱度 (Vulnerability)：易受到不利影響的傾向與素質。

災害 (Disaster)：危害性的自然事件與脆弱的社會狀況交互作用後，導致大範圍對人類、物質、經濟及環境的不利影響，進而嚴重影響公眾或社會的正常運作功能，這些影響會需要立即的緊急應變措施去滿足人們需求，並需要有外部支援以利復原。

災害風險 (Disaster Risk)：針對上述所定義之災害在特定時間中發生的可能性／機率。

災害風險管理 (Disaster Risk Management)：一個透過設計、執行及對策略、政策及措施評估的過程去增進對災害風險的瞭解，促進災害風險降低及風險轉移，並推動對災害準備、應變及復原實際作為的持續改進，明確的目標是增進人類安全、福祉、生活品質、回復力及永續發展。

調適 (Adaptation)：是一種調整適應過程。在人類系統中，是針對實際發生或預期會發生的氣候及其所造成的影響所進行的調整適應過程，以便減輕損害及開拓有利的機會。而自然系統的調適，是自身對實際發生的氣候及其所造成影響的調整適應過程，而人類的干預有可能促成因應預期會發生的氣候所進行之調整。

回復力/韌性 (Resilience)：系統或組成單位能及時和有效的預測、吸收、適應及復原災害造成的影響之能力；包括確保基本結構與功能的維護、重建及改進。

轉型 (Transformation)：一個系統根本特性的改變，包括價值系統、法規、立法及官僚體系、金融機構及科技或生物系統等。

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[1] 為反應參與本評估的研究社群多樣性及科學的進步，本報告中使用的數個詞彙定義有別於第四次評估報告及其他政府間氣候變遷專門委員會(IPCC)的報告。

[2] 本定義有別於聯合國氣候變化綱要公約 United Nations Framework Convention on Climate Change (UNFCCC) 中的氣候變遷定義，其定義為「**除了在可觀察到及可比較時期內的自然氣候變異之外，因為人類活動直接或間接造成全球大氣組成的改變，而造成的氣候變化**」，亦即 UNFCCC 在定義氣候變遷時把人類造成的與自然變化的氣候變遷作區別。

極端與非極端的天氣或氣候事件會影響脆弱度，可透過調整回復力、因應能力及調適能力，影響對未來極端事件的脆弱度 [2.4.3]。尤其，地區及地方層級，災害的累積效應會顯著地影響當地的生計選擇、資源及其社會與群眾對未來災害的應變及準備能力。[2.2, 2.7]。

變動的氣候導致極端天氣與氣候事件的變化，包含頻率、強度、空間範圍、持續時間與發生的時間點，以及出現前所未見的極端天氣及氣候事件。極端值的改變可連結到平均值、變異數及機率分配形狀的改變或以上數值皆改變 (圖 SPM.3)。有些極端氣候的形成 (如：乾旱) 可能是多個不被視為極端事件的個別天氣或氣候事件的累積。許多極端天氣及氣候事件是自然的氣候變異造成的，除了人為造成的氣候變遷的因素之外，自然變異將是未來的極端事件形成的另一重要因素。

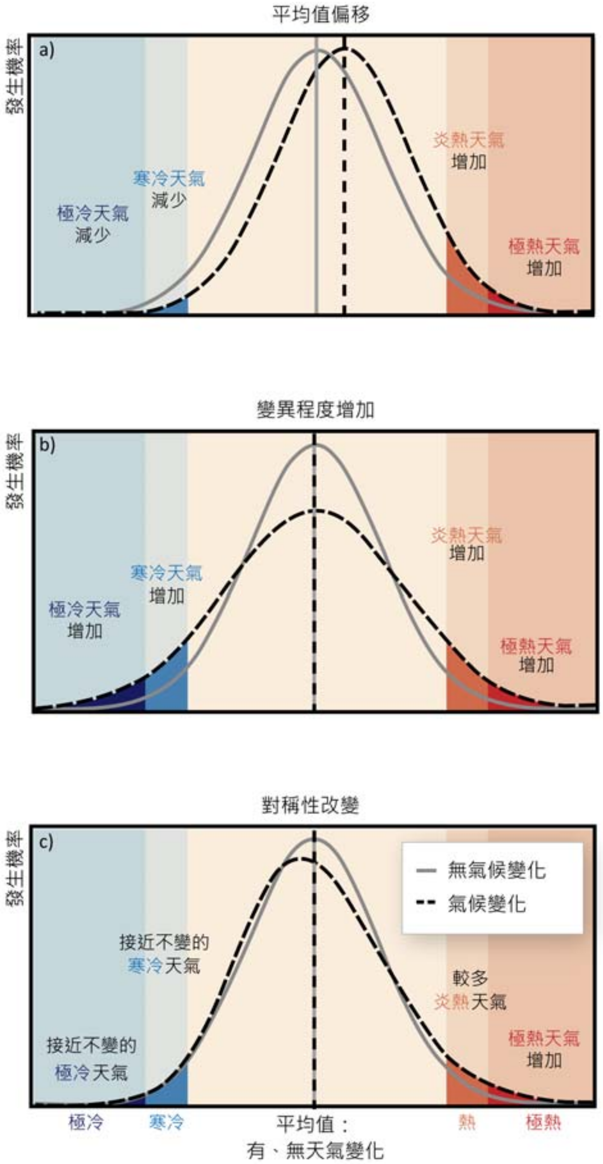

圖 SPM.3　溫度分布變化對極端事件的影響。從過去到未來不同的溫度分布變化及其對分布極端值的影響。
(a)整個分布移動至較暖氣候的影響
(b)溫度變異數增大但平均值不變的影響
(c)分布曲線形狀改變的影響，在這個例子中，整個曲線非對稱性的往較熱區域移動 [圖 1-2, 1.2.2]。

B.　暴露量、脆弱度、極端氣候、衝擊與災害損失的觀測

極端氣候的衝擊與災害發生的可能性除了導因於極端氣候本身，也與人類及自然系統的暴露量及脆弱度有關係。至今觀察到的極端氣候的變化，除了反應出自然氣候變異以外的人為氣候變遷影響之外，亦受到氣候與非氣候因素影響的暴露量與脆弱度變化的影響。

暴露量與脆弱度

暴露量及脆弱度是動態的，會隨著時間及空間尺度不同而改變，並取決於經濟、社會、

地理、人口、文化、制度、治理與環境因素的影響 (高可信度) [2.2, 2.3, 2.5]。基於財富、教育程度、身心障礙及健康程度、性別、年齡、社會階級及其他社會及文化特徵的的不平等，個人和社區的暴露量及脆弱度亦不相同 [2.5]。

居住模式、都市化及社會經濟狀況的改變皆會影響觀察到的極端氣候的暴露量及脆弱度趨勢 (高可信度) [4.2, 4.3.5]。舉例來說，對住在沿海地區包括小島、三角洲，以及與住在山區的居民而言，無論是在開發中或已開發國家，都同樣對極端氣候具有暴露性及脆弱性，但是不同區域及國家程度不同 [4.3.5, 4.4.3, 4.4.6, 4.4.9,4.4.10]。快速都市化及超大城市的急速增加造就了都市社群的高脆弱度，尤其是在開發中國家，最甚者是非正式居民人口多並缺乏土地管理的都市區 (高度共識，證據充分) [5.5.1]。並請參考案例討論 9.2.8 及 9.2.9，脆弱族群亦包括難民，境內流離失所及生活在邊緣區域的人民 [4.2, 4.3.5]。

極端氣候與衝擊

自 1950 年代開始收集到的觀測資料顯示一些極端氣候的變化。這些極端氣候變化的觀測資料之可信度取決於資料的品質與數量，以及分析這些資料的研究可得性，因此，可信度會隨著區域及極端事件的不同而有所不同。當一個在區域或全球尺度上觀察到的極端事件被賦予「低可信度」的時候，並不能意指也不能排除這個極端事件的可能性。極端事件很罕見，意味著可用來評估其頻率及強度改變的資料並不多，越罕見的極端事件就越難去判斷其長期的變化。某一特定極端事件在全球尺度的趨勢與區域尺度的趨勢相比或許可信賴度更高 (例如：極端溫度事件) 或是更低 (例如：乾旱)，這取決於特定極端事件在地理空間一致性的趨勢。以下段落提供從 1950 年代開始對特定極端氣候進一步的觀察內容細節 [3.1.5, 3.1.6, 3.2.1]。

整體來說，在全球尺度下有足夠數據的大陸地區，冷晝及冷夜的數量很有可能減少，而暖晝及暖夜的數量增加了，這些變化可能也發生於北美、歐洲及澳洲地區。亞洲地區的日極端溫度 (日最高溫、日最低溫)趨於暖化是中等可信度，在非洲及南美洲的日極端溫度 (日最高溫、日最低溫) 觀測值的可信度依地區不同，可信度有從低至中等的差異。在許多 (並非全部) 有足夠資料的的區域，暖期與熱浪的持續時間及數量已經增加，此論點具中等可信度[3] [3.3.1, 表 3-2]。

部分區域強降雨事件的數量已經具有統計上顯著的趨勢，雖然有不同區域間的差異，但是多數區域可能面臨強降雨事件數量增加大於減少的趨勢[3.3.2]。

在考慮到過去觀測能力改變的情形下，長期以來觀察到的 (40 年或更久) 熱帶氣旋活動 (強度，頻率，持續時間) 增加的趨勢具有低可信度。在北半球及南半球的溫帶風暴的

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[3] 有關於本段落之冷晝及冷夜、暖晝及暖夜、暖期及熱浪等專有名詞的定義請見 SREX 特別報告的詞彙表。

路徑有向極區偏移的可能性。由於監測資料的不均質與不完整，觀測到的小空間尺度現象如龍捲風及冰雹的趨勢為低可信度 [3.3.2, 3.3.3, 3.4.4, 3.4.5]。

部分區域，特別是南歐及西非地區，乾旱的強度變強且持續時間增長，但在部分區域，例如北美洲中部及澳洲西北部，乾旱事件則變得較不頻繁，強度減弱且持續時間減短，此結論具中等可信度 [3.5.1]。

由於從觀測站可得的洪水紀錄在空間廣度及時間尺度是有限的，也因為土地使用及工程改變等干擾因素，目前只有有限到中等程度的證據可評估因氣候造成的區域洪水發生頻率及強度的變化。此外，此項證據的低度共識也使得全球尺度的洪水變化跡象只具有低可信度 [3.5.2]。

與海平面值上升有關的極端海岸高水位事件數量可能已經增加 [3.5.3]。

證據顯示人為因素會影響某些極端事件的改變，包括大氣中溫室氣體濃度的增加。人為因素影響全球的日最低溫及日最高溫的暖化是可能的。人為因素影響全球的極端降雨強度增加具有中等可信度。與海平面平均值上升有關的極端海岸高水位事件有可能因為人為因素而增加。因為熱帶氣旋歷史紀錄的不確定性、缺乏對熱帶氣旋度量與氣候變遷之間的物理機制關聯的完整知識、熱帶氣旋的變異性等三項考量，將可偵測到的熱帶氣旋活動變化歸因於人為因素影響的推論僅有低可信度。將單一極端事件歸因於人為造成氣候變遷的論點具挑戰性 [3.2.2, 3.3.1, 3.3.2, 3.4.4, 3.5.3, 表 3-1]。

災害損失

天氣及氣候造成的災害的經濟損失逐漸增加，但其中存在顯著的空間及不同年際間的歧異 (高可信度，基於高度共識、中等證據量)。過去幾十年間記錄全球天氣與氣候相關的災害損失主要反映在可貨幣化的資產直接毀損，這些損失分布並不平均。

從 1980 年代開始預估年度損失區間從幾十億美金到超過 2000 億美金 (以 2010 年幣值)，其中 2005 年為最高損失金額的一年 (卡翠娜颶風發生的那一年)。損失估計值是估計值的下限，因為許多衝擊，例如生命、文化遺產及生態系統服務的損失是難以貨幣化並衡量價值的，因此很難從預估損失中反應出來。對於某些地區及產業中，非正規及無正式記錄的經濟體的衝擊，以及間接的經濟影響亦可能非常重要，但是一般在預估損失時不會採計 [4.5.1, 4.5.3, 4.5.4]。

在已開發國家，與天氣、氣候及地球物理事件有關的經濟損失(包括保險損失)更高。而在開發中國家，死亡率及經濟損失佔國內生產總值的比例較高 (高可信度)[4]。從 1970 年

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[4] 本段落中所指的經濟損失及死亡率為所有與天氣、氣候及地球物理有關的災害事件。

代到 2008 年間，超過 95%的天然災害死亡人數發生在開發中國家。資產快速擴充的中等收入國家所承擔的負擔最大，根據有限證據量指出，在 2001 至 2006 年間，損失約佔中等收入國家國內生產總額的 1%，相較於低收入國家中佔國內生產總額的 0.3%，以及已開發中國家國內生產總額不到 0.1%。在暴露量較小的國家中，尤其是開發中的小島國家，損失佔國內生產總額的比率特別高 (採 1970 至 2010 災害及非災害年的平均值)，這些損失常常超過 1%，甚至在最極端案例中達到 8% [4.5.2, 4.5.4]。

天氣及氣候災害經濟損失長期增加的主要原因是人類及經濟資產的暴露量增加(高可信度)。災害經濟損失的長期增加趨勢(考量財富及人口調整後)，並沒有完全歸因於氣候變遷，但也不排除氣候候變遷所扮演的角色(高度共識、中等證據量)。這些結論取決於目前研究的一些侷限。脆弱度是造成災害損失的一個重要因素，卻尚未被充分重視。其他侷限在於 (1) 資料取得：大部分可得資料是從已開發國家的經濟部門取得；(2) 災害的種類：大部分研究著重在氣旋，而觀測結果能將氣旋歸因於人類影響的可信度偏低。第二個結論還有其他侷限：(3) 損失資料隨時間調整的過程；及 (4) 紀錄的長度 [4.5.3]。

C. 災害風險管理與氣候變遷調適：極端氣候的歷史經驗

過去在極端氣候的經驗可以幫助我們了解有效的災害風險管理及管理風險的調適策略

極端氣候的衝擊嚴重性主要取決於對這些極端事件的暴露及脆弱的程度 (高可信度) [2.1.1, 2.3, 2.5]。

災害風險變化的主要驅使因素是暴露量及脆弱度的趨勢 (高可信度) [2.5]。要先了解暴露量與脆弱度的多面性，才能去決定天氣及氣候事件如何促使災害發生，並設計且執行有效的災害風險管理與調適策略[2.2, 2.6]。降低脆弱度是災害風險管理與調適的共同核心議題 [2.2, 2.3]。

形成災害風險的關鍵是發展實務、政策及成果，風險可能因為發展過程的缺失而增加 (高可信度) [1.1.2, 1.1.3]。高暴露量與脆弱度通常是發展過程失衡的結果，例如環境惡化、危險地區無規劃的急速都市化、失敗的治理以及窮困人口缺乏生計選項 [2.2.2, 2.5]。逐漸增加的全球經濟與生態系統的互賴性及互聯性有時會減少或是增加災害風險與脆弱度 [7.2.1]。如果能在進行國家發展及產業規劃時將災害風險納入考量，或是採取氣候變遷調適策略並針對脆弱區域及族群加以實施相關行動方案，國家將能更有效管理災害風險 [6.2, 6.5.2]。

地方層級因為缺乏災害及災害風險降低方面的數據，而使降低地方脆弱度的改善空間受限 (高度共識、中等證據量) [5.7]。在國家層級的災害風險管理系統及相關風險管理措施

中明確整合暴露量、脆弱度、及極端氣候的知識及不確定性的案例很少 [6.6.2, 6.6.4]。

各種不平等現象影響地方的因應及調適能力，並成為地方及國家層級對災害風險管理與調適的挑戰 (高度共識，證據充分)。這些不平等反應出社會經濟、人口、健康、政府治理、生計資源取得、權利及其他因素的不同 [5.5.1, 6.2]。不同國家間也存在不平等:相較於開發中國家，已開發國家通常在財政及體制上較能採取明確措施，並能更有效的對暴露量、脆弱度及極端氣候的推估變化做因應。然而，所有的國家都同樣面臨到對這些推估變化進行評估、了解與因應的挑戰 [6.3.2, 6.6]。

當減災措施缺乏或不足時，往往會需要人道救援 (高度共識、證據充分) [5.2.1]。較小或是經濟發展較不多元的國家會在幾個特定方面面臨挑戰: 提供災害風險管理相關的公共物資，吸收極端氣候及災害帶來的損失，提供救援與協助重建 [6.4.3]。

災後復原與重建提供一個機會去降低天氣氣候相關的災害風險以及加強調適能力 (高度共識、證據充分)。過份強調快速重建房屋、基礎設施及生計活動卻經常導致原有的脆弱度再現，甚至惡化，並因此妨礙對加強災後復原及永續發展的長期規劃與政策修訂 [5.2.3]。相關評估請見 [8.4.1] 及 [8.5.2]。

建立地方、國家、區域甚至全球的風險分擔及轉移機制可以增加對極端氣候的回復力 (中等可信度)。這些機制包括非正式的或是傳統的風險分擔機制，例如：小額保險、保險、再保險及國家、區域甚至全球的共同責任基金 [5.6.3, 6.4.3, 6.5.3, 7.4]。這些機制提供資助救援及生計恢復、重建等方法去降低脆弱度，及提供知識與動機去降低風險，透過這些方法降低災害風險並適應氣候變遷 [5.5.2, 6.2.2]。然而，在某些情況下，這些機制可能會對降低災害風險有反效果 [5.6.3, 6.5.3, 7.4.4]，這些正式的風險分擔及轉移機制按照不同災害種類在不同區域呈現不平衡分布狀態 [6.5.3]。請見案例討論 9.2.13.

調適與災害風險管理策略與政策的設計及執行在短期內可降低風險，但卻可能增加長期的暴露量及脆弱度；因此，考量暴露量及脆弱度的時間及空間動態變化尤其重要 (高度共識、中等證據量)。舉例來說，河堤、攔砂壩等水利設施可以提供立即的防護去減低對洪水的暴露量，但就長期而言可能會助長增加風險的居住模式 [2.4.2, 2.5.4, 2.6.2]。另請參閱 1.4.3, 5.3.2 及 8.3.1.

國家系統是國家應對能力的核心，以應對已觀察到及推估的暴露量、脆弱度、及天氣與氣候極端事件的趨勢 (高度共識，證據充分)。有效的國家系統包括多個行動者：國家政府、地方政府、私有企業、研究機構及公民社會包括社區組織，根據他們的功能及能力各自在風險管理上扮演著不同但互補的角色 [6.2]。

將災害風險管理與氣候變遷調適更緊密的整合，再將其與地方、次國家、國家甚至國際的發展政策與操作結合，可在各個層級帶來效益 (高度共識，中等證據量) [5.4, 5.5, 5.6,

6.3.1, 6.3.2, 6.4.2, 6.6, 7.4]。國際間逐漸認知到將社會福利、生活品質、基礎建設、生計與多重災害策略融入短期防災規劃與行動中，可以促進長期對極端氣候的調適 [5.4, 5.5, 5.6, 7.3]。策略與政策若能考量多重壓力、不同的優先價值以及相互競爭的政策目標的才會更有效 [8.2, 8.3, 8.7]。

D. 未來極端氣候、衝擊與災害損失

因自然氣候變異、人為導因的氣候變遷，以及社會經濟的發展境況所造成的未來的暴露量、脆弱度及極端氣候的變化，會導致極端氣候對自然與人類系統的衝擊改變，甚而有災害發生的可能性。

極端氣候與衝擊

氣候變遷趨勢及幅度的推估可信度取決於許多因素，包括極端氣候的種類、區域、季節、觀測資料的數量及品質、對基本過程的了解程度、以及模式模擬的可靠性。不同排放情境下[5]的極端氣候變異推估在未來的20至30年間不會有太大的不同，但是這些徵象相較於同一段時間的自然氣候變異較小，甚至有些極端氣候推估變化在這段時間的徵象呈現不確定情形。至於到21世紀末的推估變化，依極端事件本身的不同，這些模式或排放情境的不確定性逐漸明顯。因為氣候系統具有瞬變及複雜的特性，加上我們對氣候門檻值不了解，所以即使推估結果是低機率、高衝擊的氣候變遷現象，並不能因此排除其發生的可能性。即使對某一個極端事件的推估值賦予「低可信度」，並不能意指也不能排除這個極端事件會變化的可能性。以下是對21世紀末並相對於20世紀末的氣候推估所做的可能性與可信度的評估 [3.1.5, 3.1.7, 3.2.3, 文字框 3-2]。

推估模式的結果顯示21世紀末時極端氣溫會顯著上升。實質上可以肯定的是21世紀全球日極端最高溫事件的發生頻率及幅度會增加，日極端最低溫事件發生頻率及幅度會減少；非常有可能在大部分的陸地區域暖期及熱浪發生的頻率、持續時間及強度都會增加。基於A1B 及 A2 排放情境，在大多數區域，原本20年頻率 (統計結果顯示平均每二十年發生一次) 的高溫事件到21世紀末可能變成2年頻率，例外的是在北半球高緯度地區可能會變成5年頻率的事件 (請見圖 SPM.4A)。而在B1情境下，20年頻率的事件有可能會變成5年頻率的事件 (北半球高緯度地區則變成10年頻率的事件)。此外，20年頻率的日最高溫 (1981到2000年間只發生過一次超過平均值的值) 將可能在21世紀中葉上升攝氏1到3度，在21世紀末上升2到5度，這些改變幅度取決於區域及排放情境 (B1,A1B,A2情境) [3.3.1,

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[5] 這些會對輻射量起重要作用的物質的排放情境是根據社會經濟與科技發展情況去設定的。這份報告使用政府間氣候變遷專門委員會排放情境特別報告 (IPCC Special Report on Emissions Scenarios, SRES) 中，描述的至2100年的40個排放情境下的子情境 (B1, A1B, A2)，這其中並不包括其他氣候相關的行動計劃。這三種情境被廣泛地運用在氣候變遷推估上，以及包含各種二氧化碳當量濃度，但沒有包含 SRES 裡描述到的所有情境。

3.1.6,表 3-3,圖 3-5]。

在 21 世紀全球許多地區強降水頻率或強降雨占總雨量的比例可能增加，尤其在高緯度及熱帶地區，還有北半球中緯度地區的冬季時期。與熱帶氣旋相關的強降雨可能隨著氣溫持續暖化而增加。在某些地區即使推估總降雨量是減少的，但強降雨發生頻率依然會增加，此論點具有中等可信度。根據排放情境的範圍 (B1, A1B, A2)，在許多地區一個原本 20 年頻率的年最大日降雨量到 20 世紀末可能變成 5 年至 15 年頻率，而且在大部分地區，越高的排放情境 (A1B 及 A2) 會導致在重現期內預估的降水減少幅度更大。請參考圖 SPM.4B [3.3.2, 3.4.4, 表 3-3, 圖 3-7]。

熱帶氣旋的平均最大風速可能會增加，雖然這種情況不會出現在所有的海洋盆地。以全球來說，熱帶氣旋的發生頻率可能會減少或是維持不變 [3.4.4]。

具有中等可信度的是在各半球的的溫帶氣旋數量會減少。雖然對溫帶氣旋活動的詳細地理位置推估是低可信度，但是對溫帶氣旋路徑向極區移動的推估具有中等可信度。對小空間尺度現象 (例如龍捲風或是冰雹) 的推估僅具低可信度，一方面因為其中的互相抵消或影響的物理過程，另一方面是因為目前的氣候模式無法模擬這種小尺度的氣候現象 [3.3.2, 3.3.3, 3.4.5。

21 世紀將因為降雨量的減少及蒸發散量的增加導致部分地區部分季節乾旱的強度增強，此論點具有中等可信度。這個狀況適用於南歐、地中海地區、中歐、北美洲中部、中美洲、墨西哥、巴西東北部及非洲南部地區。對於其他地區的推估因為對於乾旱變化的推估不一致 (根據模式及乾旱指標) 所以是低可信度。定義上的問題、缺乏觀測數據以及模式無法涵蓋所有影響乾旱形成的因子使得乾旱推估的可信度只具有中等可信度。請參考圖 SPM.5 [3.5.1, 表 3-3, 文字框 3-3]。

雖然整體而言對河川洪水的推估僅具低可信度，降雨量及溫度變化的推估還是表示出洪水可能的變化。儘管這個論點有一些例外情況，但此論點僅具低可信度是因為證據有限以及區域性的變化原因很複雜。具中等可信度的是 (根據物理推理) 推估強降雨的增加會促使部分流域或區域的局部洪水增加 [3.5.2]。

平均海平面上升在未來很有可能會促使海岸極端高水位有上升的趨勢。具有高可信度的是目前已面臨海岸侵蝕或洪水氾濫等負面衝擊的地區在其他影響因素不變的情況下，會因為海平面的上升使得這些負面衝擊未來會持續發生。很有可能發生的平均海平面上升促使極端沿岸高水位，若與有可能增加的熱帶氣旋最大風速耦合在一起，對小型海島國家而言是很重要的議題 [3.5.3, 3.5.5, 文字框 3-4]。

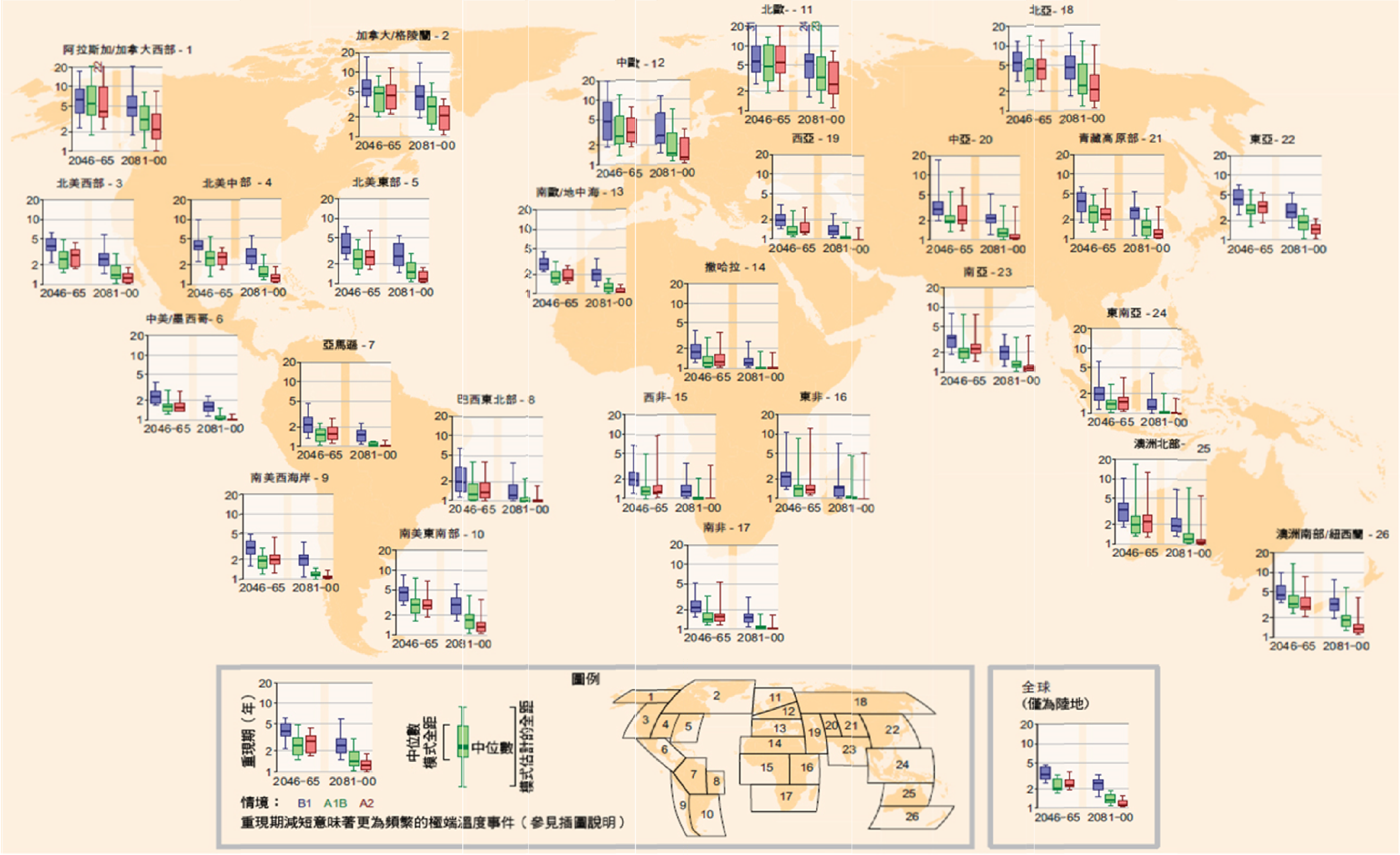


圖 SPM.4A 當日平均最高溫的重現期推估在 20 世紀末期的 20 年中(1981-2000)只超過平均值一次。重現期的縮短代表極端溫度事件更頻繁地發生(例如：前後事前中間的平均間隔時間縮短)。盒鬚圖表示與 20 世紀末相比，兩個時期從 2046 到 2065 以及從 2081 到 2100，根據三個 SRES 的不同排放情境，各區域平均的推估值（請見上框圖例）。這些結果是根據耦合模式比較計畫(Coupled Model Intercomparison Project,CMIP3)—階段 3 中的 14 個 全球氣候模式(global climate models, GCM) 的數據來做的分析。顏色框的大小用來表示模式間的共識(包含了 50%的模式推估值)，針狀線的長短則代表各模式預估值的最大值與最小值。請參照圖例中所定義的區域範圍。這些數值僅針對陸地上的收集點， 插入框“全球”標示的數值來自於所有陸地收集點的值 [3.3.1, 圖 3-1, 圖 3-5]

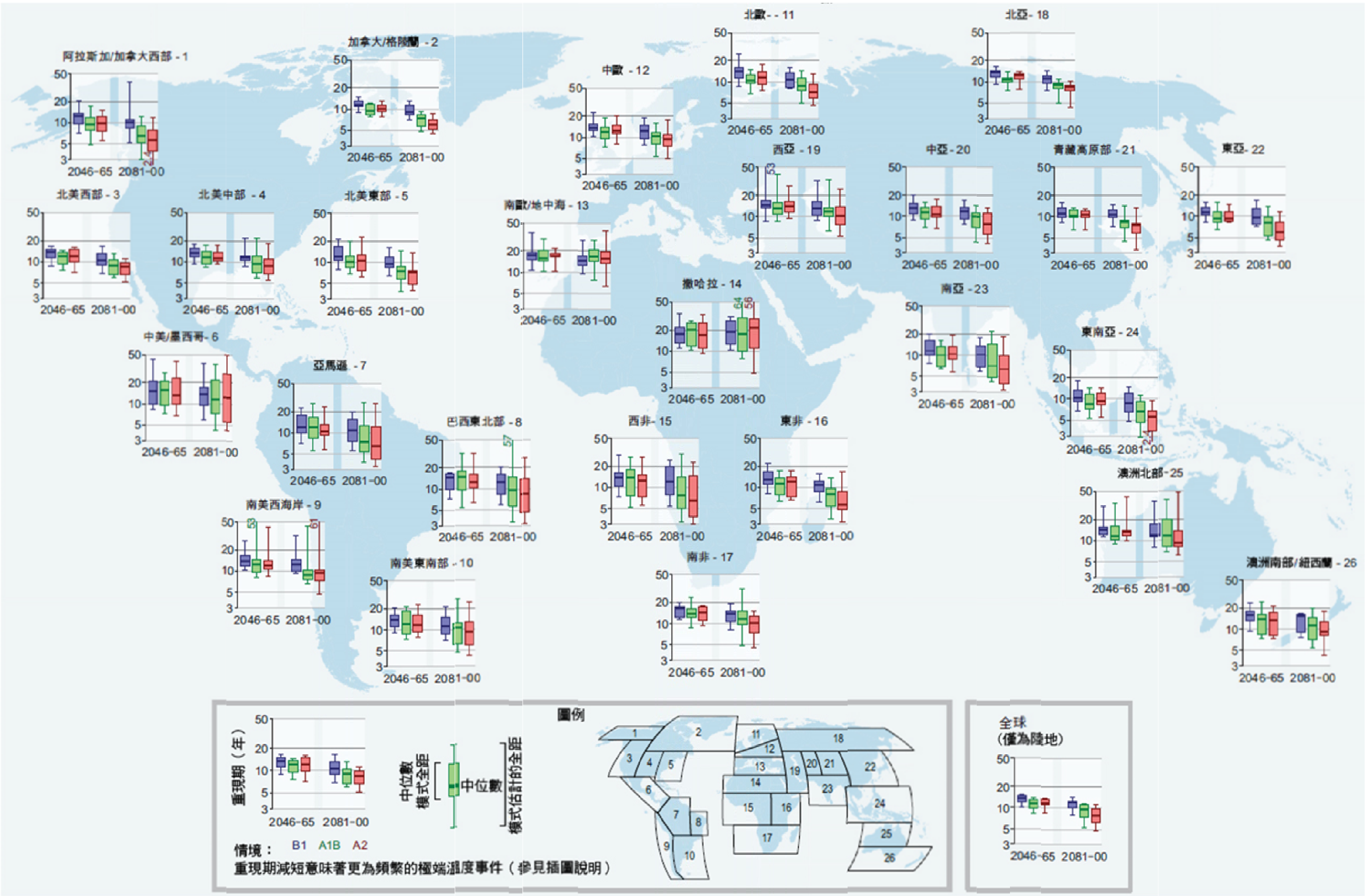


圖 SPM 4B. 在 20 世紀末的 20 年(1981-2000)週期中，日降雨量重現期的推估僅超過平均值一次。重現期的縮短表示極端降雨事件發生頻率的增加(例如前後事件平均相隔時間縮短) 圖中的盒鬚圖表示：與 20 世紀末相比，兩個時期從 2046 到 2065 以及從 2081 到 2100，根據三個 SRES 的不同排放情境(B1,A1B,A2)，各區域平均的推估值 (請見上框圖例)。 這些結果是根據耦合模式比較計畫—階段 3 (CMIP3) 中的 14 個 全球氣候模式 (GCM) 的數據來做的分析。顏色框的大小 (其中包含其各模式的中間預估值) 及針狀線的長短 (代表各模式預估值的最大值與最小值) 用來表示模式間的共識。請參照圖例中所定義的區域範圍。這些數值僅針對陸地上的收集點，插入框“全球”標示的數值來自於所有陸地收集點的值 [3.3.2, 圖 3-1, 圖 3-7]

具有高可信度的是熱浪、冰川後退、凍土退化的變化將影響高山現象，例如：斜坡不穩定、大規模土層移動、以及冰湖潰決的洪水。強降雨的變化在某些區域會影響土石流也具有高可信度 [3.5.6]。

對大規模的自然氣候變異的推估僅具低可信度。對季風變化 (降雨、環流) 的推估是低可信度，因為各模式在季風的未來變化徵象上未能達成共識。模式對聖嬰南方振盪現象變數及聖嬰事件發生的頻率的推估不一致，所以對這種現象的推估僅具低可信度 [3.4.1, 3.4.2, 3.4.3]。

人類衝擊與災害損失

極端事件將對與氣候相關的領域 (例如：水資源、農業、糧食安全、林務、健康及旅遊) 造成更大衝擊。舉例來說，雖然目前還未能可靠的推估流域尺度的具體變化，但具有高可信度的是氣候變遷很有可能對水資源管理系統產生嚴重影響。然而，氣候變遷在許多情況下可能只是未來變化的其中一個驅動因子，在地區尺度下也不見得是最重要的驅動因子。此外，氣候相關的極端事件也被認為會對基礎設施造成重大衝擊，不過目前對其推估出及潛在的損壞的詳細分析還僅限於少數國家、少數基礎設施種類及領域 [4.3.2, 4.3.5]。

在許多區域，部分極端氣候事件造成未來經濟損失的增加的主要原因是社會經濟的本質(中等可信度，基於中度共識，有限證據)。極端氣候雖然只是影響風險的其中一項因素，但將人口變化、人類及資產暴露量及脆弱度作為決定性因素予以量化的研究還是不足。不過現有的少數研究普遍有強調推估面臨風險的人口及資產變化 (增加) 的重要性 [4.5.4]。

在暴露量增加的情況下，熱帶氣旋會造成更多的直接經濟損失，這些損失也取決於未來熱帶氣旋發生頻率及強度的改變 (高可信度)。溫帶氣旋造成的總損失也會增加，不過有些地區可能會減少或維持不變 (中等可信度)。雖然未來許多地區因為洪水造成的損失會隨著缺少額外保護措施而增加 (高度共識，中等證據量)，但是，因為不同區域、不同氣候情境、及評估河川逕流量及洪水發生衝擊時所用的方法不同，預測的變化量變異度高 [4.5.4]。

與極端氣候相關的災害會影響人口的流動及遷移，並同時影響當地及原本的社群 (中度共識，中等證據量)。如果災害發生的頻率增加，及／或強度增強，部分當地地區將會變得更不適合居住並維持生計。在這種情況下，遷移及改變居住地可能變成永久性的，這可能會對遷入地區形成新的壓力。在某些地區 (如環礁) 的某些情況下，有時候許多居民不得不遷移 [5.2.2]。

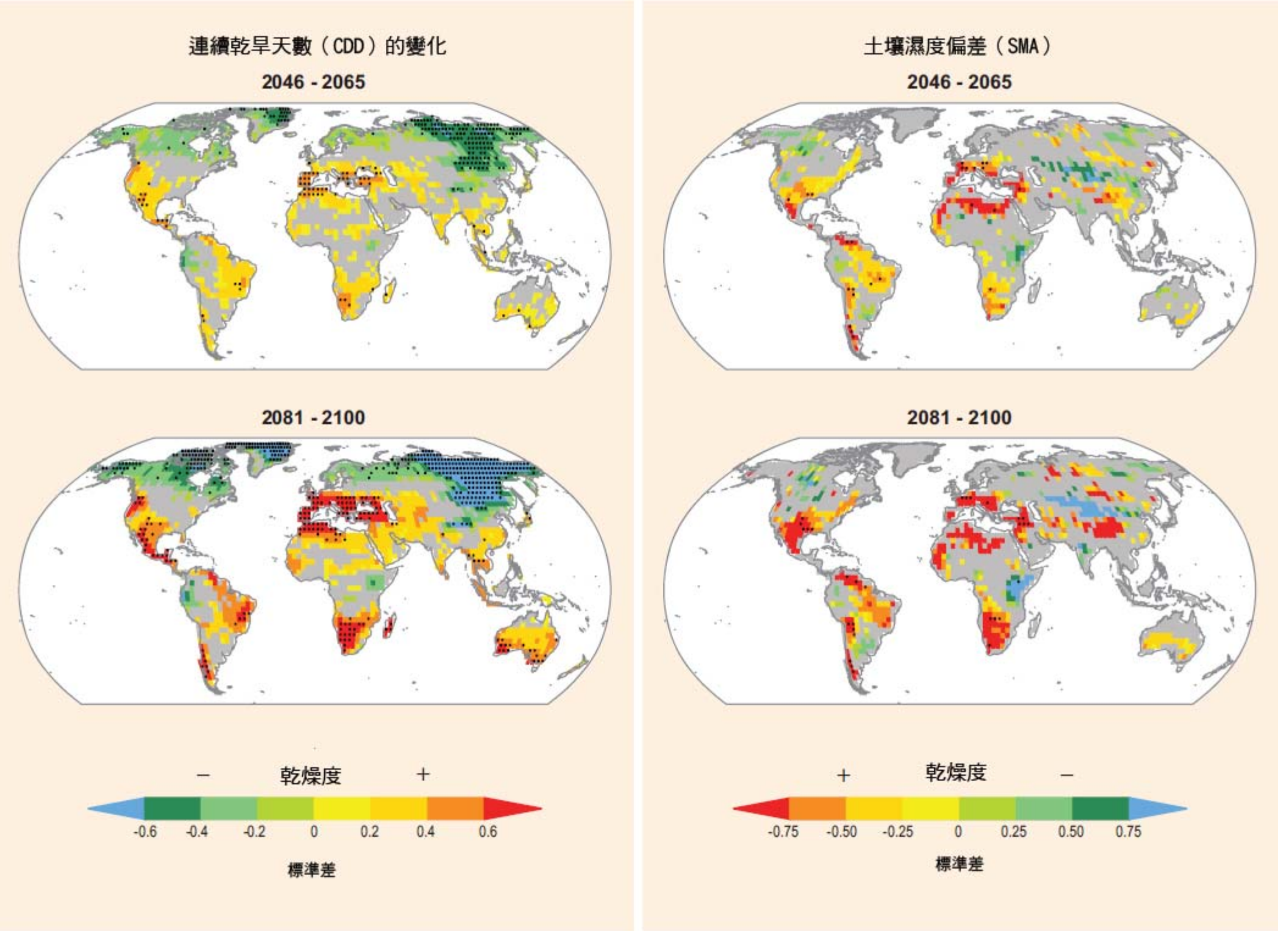


圖 SPM.5 根據兩個指數評估年際乾旱變化 左欄: 每年最長連續乾旱天數 (CDD: 降雨量<1mm 的天數) 右欄: 土壤濕度變化 (SMA: 土壤溼度異常指數) 乾旱加劇用黃到紅表示;乾旱減緩用綠到藍表示。推估的變化以三段各 20 年的時期(1980–1999, 2046–2065, 及 2081–2100)的年際變化的標準差單位來表示，本圖表示兩個時期 2046–2065 and 2081–2100 與 20 世紀末 (1980–1999) 的數值相比的變化,這是基於 SRES A2 情境下的全球氣候模式模擬，相對於 20 世紀末的環境所做的模擬。 結果是根據 CMIP3 中的 17 個 CDD 及 15 個 SMA (來自於 GCM) 有顏色的區域表示至少有 66% (17 個 CDD 中的 12 個, 15 個 SMA 中的 10 個) 的模式對此變化有共識，黑點區域表示至少 90% (17 個 CDD 中的 16 個, 15 個 SMA 中的 14 個) 的模式對此變化有共識，灰色陰影部分表示模式共識不足 (<66%)。[3.5.1,圖 3-9]

E. 管理極端氣候及災害的變動風險

氣候變遷調適與災害風險管理提供了一個互補性的方法以管理氣候變遷及災害的風險(如圖 SPM.2 所示)。將更廣的挑戰納入考量 (如永續發展)，更將有助於有效地結合並實踐不同的方法。

有利於當前氣候及未來氣候變遷情境的措施被稱作-低後悔措施，低後悔措施是開始面對暴露量、脆弱度、極端氣候等推估趨勢的起始點。這些措施很可能在現在帶來助益，並為應對推估變化奠定基礎 (高可信度，中等證據量)。許多低後悔措施能產生共生效益，有

助於完成其他發展目標，例如改善民生、人類福祉，生物多樣性保育，並盡可能縮減調適不良的範圍 [6.3.1, 表 6-1]。

潛在的低後悔措施包括早期預警系統、決策者與當地民眾的風險溝通、永續土地資源管理 (包括土地利用規劃) 及生態系統管理與重建。其他低後悔措施包含改善衛生監控、供水、環境衛生及灌溉排水系統、防氣候衝擊的基礎設施、建築法規的發展與執法及更完好的教育與意識 [5.3.1, 5.3.3, 6.3.1, 6.5.1, 6.5.2]。案例探討請見 9.2.11 及 9.2.14 詳細評估內容請見章節 7.4.3。

有效的風險管理通常包含一系列減低與轉移風險、對事件及災害的行動，而非只專注於單項行動或特定一類的行動 (高可信度) [1.1.2, 1.1.4, 1.3.3]。這種整合性的策略如果能夠因應當地環境加以客製化會變得更有效 (高共識，證據充分) [5.1] 成功的策略要能夠結合硬體上相關基礎設施的配合，以及軟實力的建立(例如:個人或是體制上的能力建構，以及生態系統為基礎的因應) [6.5.2]。

複合型災害風險管理方法是減少複雜及複合災害的契機(高度共識，證據充分)。將所有減低風險的努力集中在一種災害上將增加當前及未來對其他災害的暴露量及脆弱度，因此，考量多種類型的災害的管理方法將降低此種可能性 [8.2.5, 8.5.2, 8.7]。

國際金融體制尚未被完全體認到有為災害風險管理與氣候變遷調適產生綜效的機會(高可信度)。與國際人道救援相比，降低災害風險的國際基金依然持續偏低。[7.4.2] 降低災害風險及氣候變遷調適相關的技術轉移合作非常重要，但是，這兩個領域間技術轉移合作的協調尚嫌不足，並因此造成實際執行的分裂 [7.4.3]。

國際層級的努力不一定能為地方層級帶來實質並快速的成果 (高可信度)。在跨層級(從國際到在地) 上的整合還有進步的空間 [7.6]。

整合在地知識與額外的科學與技術知識能促進降低災害風險及氣候變遷調適 (高度共識，證據確定)。當地居民運用許多不同的方法去記錄他們應對多變氣候的經驗(尤其是極端天氣事件)，這些自發性的知識可顯示出社區既有的能力及不足之處 [5.4.4]。在地參與以社區為基礎的調適方法能對災害風險及極端氣候的管理有所助益。然而，加強管理災害風險的人力及金融資源的可得性與建立專屬在地利益相關者的氣候資訊都有助於以社區為基礎的調適 (中等共識，中等證據量) [5.6]。

為達到有效的調適及災害風險管理，適當且即時的風險溝通是非常重要的 (高可信度)。明確的闡述不確定性及複雜性能夠強化風險溝通 [2.6.3]。有效的風險溝通建立在交流、分享及整合來自各種不同的利益相關者的氣候風險相關的知識。不同的利益相關者及團體對災害風險的認知來自於心理及文化因素、價值觀及信仰 [1.1.4, 1.3.1, 1.4.2] 相關評估可參考章節 7.4.5。

反覆的監測、研究、評估、學習及創新能減少災害的風險並促進在極端氣候情況下的調適性管理 (高度共識，證據充分) [8.6.3, 8.7]。因為氣候變遷本質上的複雜性、不確定性、及長期性，反覆性風險管理策略有助於調適方法的建構 (高可信度) [1.3.2]，透過強化觀測及研究來回應知識缺口的問題、降低不確定性，並有助於設計有效的調適與風險管理策略。[3.2, 6.2.5, 表 6-3, 7.5, 8.6.3] 相關評估可參考章節 6.6。

表 SPM.1 呈現了幾個例子，這些例子為如何將暴露量、脆弱性及極端氣候的觀測及推估趨勢作為制定風險管理及調適策略、政策及措施的依據。這些趨勢對決策者的重要性在於在時間及空間尺度下被管理的風險強度與確定性的程度，以及執行風險管理選項的可行能力。

表 SPM.1 暴露量、脆弱度、極端氣候事件與調適策略。

在每個範例中，資訊是按照決策相關的空間尺度分類。從觀測及推估到的全球或區域尺度下的極端氣候變異可以看出，這些變化的確定性的程度、級數、及方向都可能隨著不同的空間尺度而改變。

這些範例是根據後面相關章節現有證據提出的，其中包括暴露量、脆弱度、氣候資訊、風險管理及調適選項。相較於比較各區域間不同的脆弱度與風險管理經驗，這些實例更傾向於反映與風險管理相關的主題與尺度。地區尺度下的極端氣候變異的推估可信度比區域尺度或全球尺度的推估可信度更有限，正因如此，政策制定重點會著重在低後悔措施，期望能加強對無法完全消除的風險的回復力並降低暴露量及脆弱度。反之，較高可信度的推估值能夠在制定調適或風險管理策略、政策及措施時，提供更多資訊去做更具體的調整 [3.1.6, 文字框 3-2, 6.3.1, 6.5.2]。

案例	在風險管理尺度下暴露量及脆弱度實例	不同空間尺度下的極端氣候資料			案例採用的風險管理及調適選項 (在一定範圍內的災害變化趨勢下，用以降低暴露量及脆弱度的低後悔措施)
		全球 (自 1950 年以來已發生；推測至 2100 可能發生)	區域 (自 1950 年以來已發生；推測至 2100 可能發生)	可供風險管理與決策參考資訊	
發展中熱帶島嶼國家，因為平均海平面上升而導致海岸溢淹	位於太平洋、印度洋及大西洋上的小型島嶼國家通常由於海拔低，對海平面上升及相關衝擊(如海岸侵蝕、洪水、海岸線後退、海水入侵沿岸蓄水池等)時，尤為脆弱。這些衝擊會造成生態環境失衡、降低農業生產力、疾病分布改變、經濟損失(例如: 旅遊業)、及人口遷移， 這些都凸顯小型島嶼國家對極端天氣	**已發生:** 平均海平面上升之沿海地區，極端高水位事件有可能增加。 **未來可能發生:** 平均海平面上升很有可能會促使沿海極端水位事件有上升的趨勢。 具高可信度的是目前正面臨沿岸侵蝕及洪水的地區在其他因素不變的情況下，會因為持續上升的海平面而繼續受影響。 全球熱帶氣旋發生頻率可能減少或基	**已發生:** 近年來，潮汐及聖嬰南方震盪現象使得沿岸極端高水位及洪水事件在部分太平洋島嶼的發生頻率增加。 **未來可能發生:** 對熱帶小型島嶼國家而言，平均海平面上升很有可能促使沿岸極端高水位事件增加，伴隨著可能增加的熱帶氣旋最大風速，都是這些小島面臨的特定問題。關於	過去觀測受限於陸地上觀測網絡區域覆蓋率及時間覆蓋率低，以及海上觀測網路分布有限；近幾十年來由於加入衛星觀測而有顯著進步。 風暴的變化也許會影響沿岸的極端高水位，但目前研究的地理範圍有限，伴隨著風暴變化的不確定性， 整體來說關於風暴變化對暴潮的評估	• 排水系統的維護 • 控制海水汙染地下水的水井工程技術 • 早期預警系統的改進 • 區域風險分擔機制 • 紅樹林保育與復育 具體的調適選項包括: 降低國家經濟對氣候的依賴性、從歷史經驗反覆學習的調適管理。某些情況下應考慮遷移，如會被暴潮完全淹沒的環礁。[4.3.5, 4.4.10, 5.2.2, 6.3.2, 6.5.2, 6.6.2, 7.4.4, 9.2.9, 9.2.11, 9.2.13]

案例	在風險管理尺度下暴露量及脆弱度實例	不同空間尺度下的極端氣候資料			案例採用的風險管理及調適選項 (在一定範圍內的災害變化趨勢下，用以降低暴露量及脆弱度的低後悔措施)
		全球 (自 1950 年以來已發生；推測至 2100 可能發生)	區域 (自 1950 年以來已發生；推測至 2100 可能發生)	可供風險管理與決策參考資訊	
	事件的脆弱度。[3.5.5, 文字框 3-4, 4.3.5, 4.4.10, 9.2.9]	本上維持不變。熱帶氣旋平均最大風速可能增加，但不會發生在所有海洋盆地。[表 3-1, 3.4.4, 3.5.3, 3.5.5]	熱帶氣旋推估請參考全球變化欄位 [文字框 3-4, 3.4.4, 3.5.3]	目前還不可能做到。[文字框 3-4, 3.5.3]	
在肯亞(奈若比)暫時安置區發生暴洪	在肯亞奈若比地區，因為貧窮人口快速擴張，使用脆弱建材並在河流鄰近地區隨意建屋，導致天然排水系統阻塞，增加當地的暴露量及脆弱度。[6.4.2, 文字框 6-2]	**已發生:** 洪水強度與發生頻率的變化僅具低可信度。 **未來可能發生:** 對洪水的變化推估因為有限的證據量及區域變化的成因複雜，所以僅具低可信度。強降雨的增加會導致部分流域因降雨過多發生洪澇，此推估具中等可信度(基於物理解釋)。[表 3-1, 3.5.2]	**已發生:** 東非強降雨的觀測變化值因證據量不充足所以尚未確認。 **未來可能發生:** 東非的強降雨可能增加。	對當地發生洪水的推估能力有限。[3.5.2]	• 強化建築設計相關法規 • 降低貧窮人口的相關計畫 • 改善城市排水與汙水處理系統 奈若比河整治與重建計畫包括設置河岸緩衝區、河渠、排水系統及清理現有排水管；以調適氣候多樣性變化的原則去設計符合當地條件的汙水處理基礎設施，並建立防治洪水的環境監測系統。
熱浪對歐洲城市的衝擊	影響暴露量及脆弱度的因素如年齡、既有健康狀況、戶外活動量、社會經濟因素(如貧困及社會孤立等), 空調的取得難易度、人為調適措施如空調設施，以及都市基礎設施等。[2.5.2, 4.3.5, 4.3.6, 4.4.5, 9.2.1]	**已發生:** 從 20 世紀中以後開始，暖期及熱浪的持續時間及數量在許多區域(並非全部區域)增加；暖晝及暖夜數量與強度很有可能增加。此論點具中等可信度。 **未來可能發生:** 大多數陸地地區域暖期及熱浪持續的時間、發生頻率及強度很有可能增加。暖晝及暖夜數量與強度幾乎確定會增加。[表 3-1, 3.3.1]	**已發生:** 從 20 世紀中以後開始，暖期及熱浪的持續時間及數量在許多區域增加；暖晝及暖夜數量與強度很有可能增加。此論點具中等可信度。 **未來可能發生:** 在歐洲地區熱浪及暖期的持續的時間、發生頻率及強度很有可能增加。暖晝及暖夜數量與強度幾乎確定會增加。[表 3-2, 表 3-3, 3.3.1]	觀測及推估的變化可對歐洲地區特定都市區提供資訊；預估會因為都市熱島效應及區域發展的趨勢而使得熱浪增加 [3.3.1, 4.4.5]。	• 可傳達至社會弱勢團體(如老年人)的預警系統。 • 製作脆弱度地圖及採取因應措施。 • 提供熱浪發生時的應變資訊，包括民眾應對行為諮詢。 • 採用能夠接觸到弱勢團體的社會服務網路 根據熱浪的趨勢對策略、政策、及措施進行具體調整，其中包括:透過公共議題的提出與討論，提高民眾對熱浪的意識；變更都市基礎建設及土地規劃(例如增加都市綠地)；改善公共設施的降溫方法，調整能源生產及傳輸的基礎設施等。[表 6-1, 9.2.1]
在美國及加勒比海地區	人口數持續成長及財產價值增加造成暴露量及脆弱度提高，在美國大西洋沿岸及	**已發生:** 考慮到從過去至今觀測能力的改變，對長期以來(40 年或更長時間)熱帶氣	請參考左欄。	由於目前尚無法精確模擬熱帶氣旋生成、路徑及強度變化等因素，因此針	• 採用並落實執行更完善的建築法規 • 改善天氣預報能力及運用改良後的警報系統(包括疏散計畫及基

案例	在風險管理尺度下暴露量及脆弱度實例	不同空間尺度下的極端氣候資料			案例採用的風險管理及調適選項 (在一定範圍內的災害變化趨勢下，用以降低暴露量及脆弱度的低後悔措施)
		全球 (自 1950 年以來已發生；推測至 2100 可能發生)	區域 (自 1950 年以來已發生；推測至 2100 可能發生)	可供風險管理與決策參考資訊	
颶風造成的損失持續增加	墨西哥灣地區尤其明顯。建築法規的改善有助於降低脆弱度及暴露量。[4.4.6]	旋逐漸增加的觀測僅具低可信度。 **未來可能發生:** 熱帶氣旋發生頻率可能減少或原則上維持不變。熱帶氣旋最大平均風速可能增加，不過不會發生在所有海洋盆地。熱帶氣旋造成的強降雨可能會增加。推估模式結果顯示未來海平面會上升，亦可能加劇熱帶氣旋引發的暴潮所帶來的衝擊。[表 3-1, 3.4.4]		對特定區域及居住區的推估模擬能力有限。[3.4.4]	礎設施調配) - 區域風險分擔機制 在相關趨勢充滿高不確定性及多樣性的前提下，所採取的措施應該強調持續學習及靈活度(例如開曼群島國家颶風委員會)的調適管理。[5.5.3, 6.5.2, 6.6.2, 文字框 6-7, 表 6-1, 7.4.4, 9.2.5, 9.2.11, 9.2.13]
從糧食安全角度看西非的乾旱	隨著季節性的降雨、乾旱及極端氣候事件增加，相對原始的農業活動反映地區的脆弱度。人口數量增加、生態環境退化、過度使用自然資源、及衛生、教育、政府治理的水準低落都加劇當地的脆弱度。[2.2.2, 2.3, 2.5, 4.4.2, 9.2.3]	**已發生:** 具中等可信度的是某些地區乾旱的強度變強且持續時間變長，但有些地區乾旱發生頻率則是減少、強度減弱且持續時間縮短。 **未來可能發生:** 具中等可信度的是在某些季節及某些地區乾旱強度增加。其他區域的推估結果因為缺乏共識所以僅具低可信度。 [表 3-1, 3.5.1]	**已發生:** 具中等可信度的是乾燥程度的增加。最近幾年年際的變率大於過去四十年，西薩哈勒(Sahel)地區乾燥程度維持不變，而東薩哈勒(Sahel) 地區則逐漸回復為較潮溼的氣候。 **未來可能發生:** 因為模式推估的信號不一致，所以結果僅具低可信度。[表 3-2, 表 3-3, 3.5.1]	在長時間尺度下，次季節、季節及年際間預報的不確定性增加。預警系統的監測、設備及資料品質已改善，但對面臨風險的人口的參與度及訊息傳播效果仍有限。[5.3.1, 5.5.3, 7.3.1, 9.2.3, 9.2.11]	- 傳統的雨水及地下水收集及儲水系統 - 水需求管理及提高灌溉措施的效率 - 保育性農業、作物輪作及民生生計多樣性。 - 增加耐旱作物品種的使用。 - 整合乾旱推估訊息與季節預報的預警系統，並加強關於其他延伸服務的溝通。 國家層級或區域間的風險分擔機制。 [2.5.4, 5.3.1, 5.3.3, 6.5, 表 6-3, 9.2.3, 9.2.11]

對永續發展的影響

從強化作為 (incremental steps) 到轉換式變革 (transformational changes) 的各項行動對減低極端氣候帶來的風險至關重要 (高度共識，證據充分)。強化作為試圖在目前的科技水準、政府治理及價值系統中改善效率；而轉換式變革有可能會對這些原有系統的屬性帶來根本上的改變。被要求進行變革的對象，可通過持續地強調調適管理與學習而達成。當脆弱度高而調適能力低落時，若不採取轉換性變革，將會讓該系統持續地對極端氣候做

調適。脆弱度通常在較低收入國家或團體間比較明顯，儘管較高收入國家或團體面對極端氣候也是脆弱的，但脆弱度通常集中在較低收入國家或團體 [8.6, 8.6.3, 8.7]。

社會、經濟及環境的永續性可通過災害風險管理及調適方法而得到強化。在氣候變遷的前提下，其中一個實現永續發展的條件是強調並解決脆弱度的成因，包括結構上的不平等所造成的持續性貧窮及資源取得的限制 (中度共識，證據充分)。這個解決方案必須將災害風險管理及調適措施與社會經濟及環境政策充分整合 [8.6.2, 8.7]。

最有效的調適及減低災害風險的方法是能在短時間能呈現出發展的效益，長期下來又能降低脆弱度 (高度共識，中等證據量)。目前的決策可能會在不同的價值、利益及優先順序上與長期的規劃考量有衝突。對氣候變遷的災害風險管理與調適在短期與長期的觀點上因此變得很難去調和。這種調和更牽涉到克服當地風險管理經驗與國家體制、法律架構、政策及規劃之間的不連貫 [8.2.1, 8.3.1, 8.3.2, 8.6.1]。

在極端氣候不斷變化的情況下，持續的質疑假設、案例及模擬方式的創新能進一步鼓勵新的應對方法並增加回復力及永續發展 (中度共識,證據充分)。能成功地強調災害風險、氣候變遷及其他壓力因素的方法通常包括廣泛參與策略研發、結合多重觀點的能力以及組織社會關係的各種方法 [8.2.5, 8.6.3, 8.7]。

氣候變遷減緩、調適及災害風險管理之間的互動可能會對創造一個具回復力且永續的解決途徑產生重大影響(高度共識，低等證據量)。在特定項目中，減緩與調適目的間的互動雖然是局部地展開，但會有全域 (球) 性的結果 [8.2.5, 8.5.2]。

通往永續發展並具有回復力的未來之途徑有很多 [8.2.3, 8.4.1, 8.6.1, 8.7]。然而，當策略執行時超過了社會或是自然系統的門檻值及臨界點時，防災能力會面臨各種限制，並使得建立長期調適能力面臨嚴峻挑戰 [8.5.1]。氣候事件的調適行動之選項及預期效果必須要反映出多樣化的能力、資源及多重的互動過程。這些調適行動要在各種價值及目標之間權衡取捨，並提供各種能隨時間不同而改變的發展願景。當風險內容、評估方法及察覺及認知都會隨著時間進化，互動式的方法能夠讓災害管理與發展途徑相融合，並提供多樣性的政策選項 [8.2.3, 8.4.1, 8.6.1, 8.7]。

文字框 SPM.2 | 對不確定性的處理

根據 IPCC 第五次不確定性處理評估報告的指導說明，這份決策者摘要依據兩個衡量標準來表達重要發現的不確定程度，這些標準是由本報告的作者團隊基於科學的評估所提出:

- 對證據可信度 (Validity) 的信心 (Confidence)，根據其類型、數量、品質及共識 (例如機械觀、理論、數據、模式、專家意見) 給予信心程度，信心程度以定性 (Qualitatively) 表示。
- 量化不確定性的研究結果並以機率的方式表示 (根據觀測值、模式模擬結果或專家意見去做統計分析)。

這份指導說明對 IPCC 第三次及第四次的評估報告的指導說明做了一些改善。直接比較這份報告的不確定評估及第四次評估報告的不確定性評估非常艱難，但不是不可能；因為採用不同的方法，以及取得更多新的資料、對科學認識的進步、對數據及模式的持續分析，還有在評估研究中採用不同方法。在某些極端事件當中，已針對不同的方面去做評估，所以兩者直接做比較是不適當的。

每項主要發現的可信度都是根據作者團隊針對此發現的相關證據及共識所做的評量結果。信心程度是作者團隊對一項發現所作的定性綜合評估，其判斷是透過對證據量及共識程度的評估。如果不確定性可以用機率量化，作者團隊就可以用校正過的可能性或更精準的機率去表達此發現的特色。除非另有說明，高可信度，或非常高可信度，這些都是作者團隊們對某些發現經過評量後的結果，並代表著一個機率數值。

以下是針對證據的可取得性 (availability) 所做的定性描述:有限、中等或證據充分；而共識程度則是用: 低、中等、高。信心程度的定性描述: 非常低、低、中等、高及非常高。下圖對證據的共識程度及信心程度的關係做詳細說明。共識程度和可信度的關係是有彈性的，在評估一項證據的共識程度後，可以給予不同程度的信心程度，不過信心程度的提高會提高證據的共識程度。

不確定之質化定義:

高度共識 有限證據量	高度共識 中等證據量	高度共識 證據充分
中度共識 有限證據量	中度共識 中等證據量	中度共識 證據充分
低度共識 有限證據量	低度共識 中等證據量	低度共識 證據充分

作者團隊們對證據量的共識程度與信心度的關係。信心程度用顏色深淺表示，越往右上角顏色越深表示可信度越高。一般來說，當有最大量證據，共識程度最高及可信度最高時表示證據最充分。

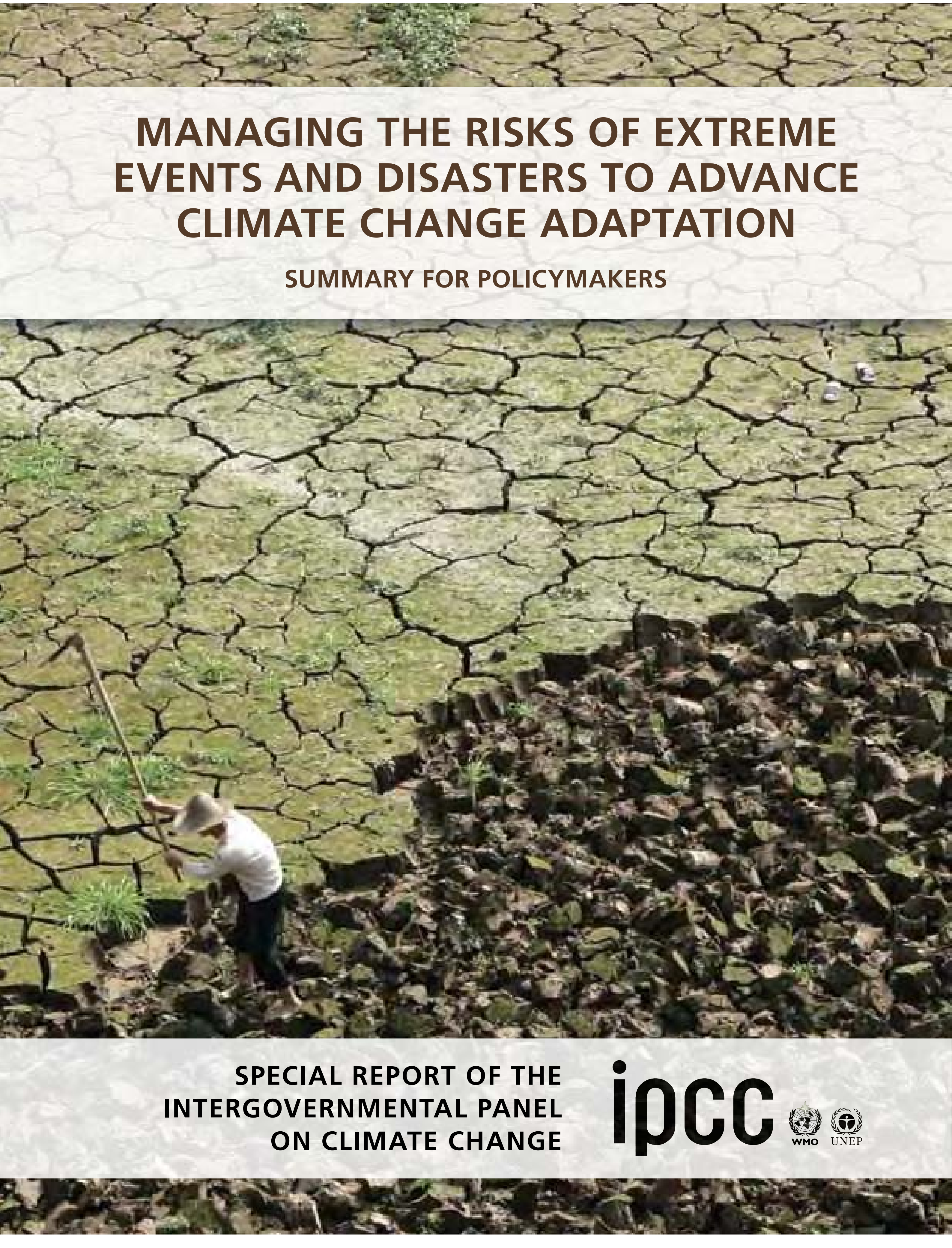
下列術語用來表示評估的可能性:

專門用語	結局/結果之發生機率
幾乎確定	發生機率 99% -100%
非常可能	發生機率 90 – 100%
可能	發生機率 66 – 100%
或許可能	發生機率 33 – 66%
不可能	發生機率 0 – 33%
非常不可能	發生機率 0 – 10%
幾乎不可能	發生機率 0 - 1%

第四次評估報告中不常使用到的敘述 (極有可能，發生機率為 95%-100%, 應該可能，發生機率為 95% -100%, 極不可能，發生機率為 0%-5%) 在本報告中會可能會斟酌使用。

MANAGING THE RISKS OF EXTREME EVENTS AND DISASTERS TO ADVANCE CLIMATE CHANGE ADAPTATION

SUMMARY FOR POLICYMAKERS



SPECIAL REPORT OF THE
INTERGOVERNMENTAL PANEL
ON CLIMATE CHANGE

SPM

Summary for Policymakers

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A. Context

This Summary for Policymakers presents key findings from the Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX). The SREX approaches the topic by assessing the scientific literature on issues that range from the relationship between climate change and extreme weather and climate events ('climate extremes') to the implications of these events for society and sustainable development. The assessment concerns the interaction of climatic, environmental, and human factors that can lead to impacts and disasters, options for managing the risks posed by impacts and disasters, and the important role that non-climatic factors play in determining impacts. Box SPM.1 defines concepts central to the SREX.

The character and severity of impacts from climate extremes depend not only on the extremes themselves but also on exposure and vulnerability. In this report, adverse impacts are considered disasters when they produce widespread damage and cause severe alterations in the normal functioning of communities or societies. Climate extremes, exposure, and vulnerability are influenced by a wide range of factors, including anthropogenic climate change, natural climate variability, and socioeconomic development (Figure SPM.1). Disaster risk management and adaptation to climate change focus on reducing exposure and vulnerability and increasing resilience to the potential adverse impacts of climate extremes, even though risks cannot fully be eliminated (Figure SPM.2). Although mitigation of climate change is not the focus of this report, adaptation and mitigation can complement each other and together can significantly reduce the risks of climate change. [SYR AR4, 5.3]

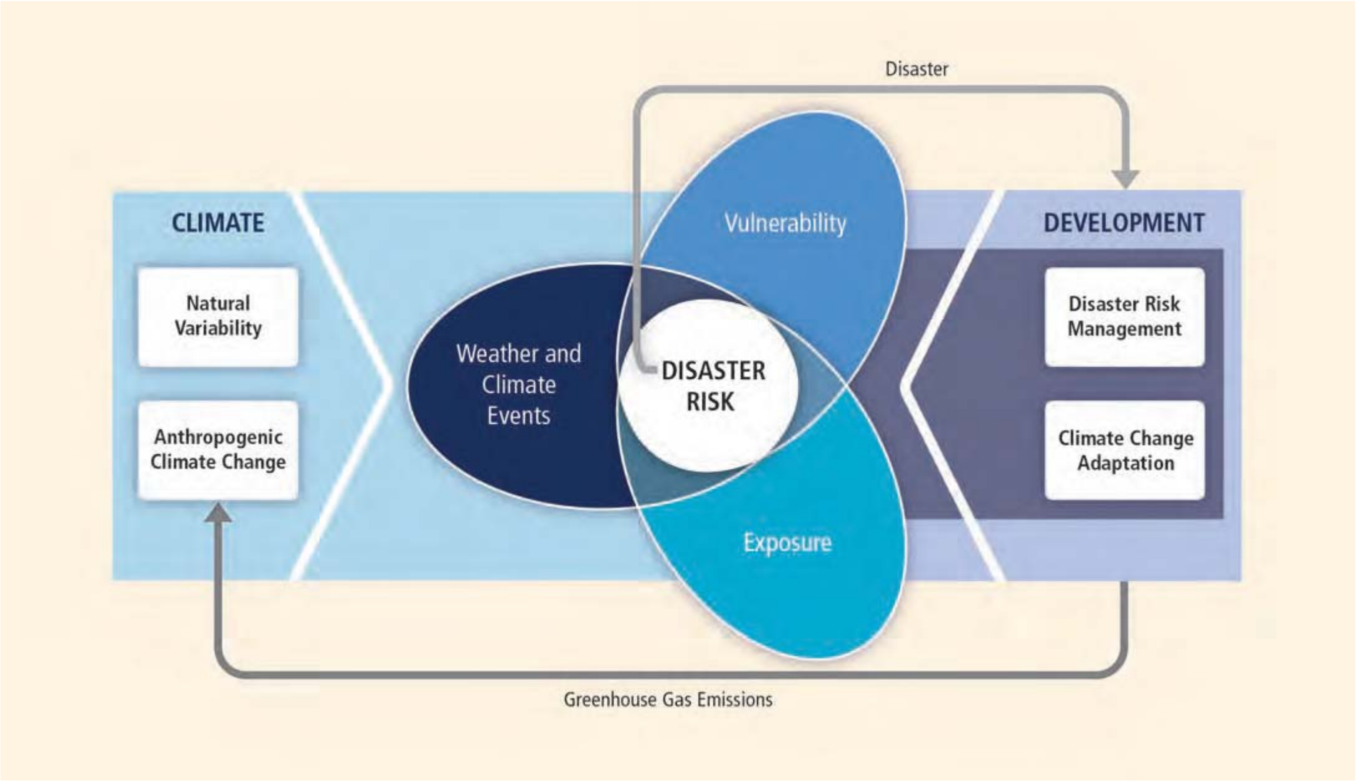

Figure SPM.1 | Illustration of the core concepts of SREX. The report assesses how exposure and vulnerability to weather and climate events determine impacts and the likelihood of disasters (disaster risk). It evaluates the influence of natural climate variability and anthropogenic climate change on climate extremes and other weather and climate events that can contribute to disasters, as well as the exposure and vulnerability of human society and natural ecosystems. It also considers the role of development in trends in exposure and vulnerability, implications for disaster risk, and interactions between disasters and development. The report examines how disaster risk management and adaptation to climate change can reduce exposure and vulnerability to weather and climate events and thus reduce disaster risk, as well as increase resilience to the risks that cannot be eliminated. Other important processes are largely outside the scope of this report, including the influence of development on greenhouse gas emissions and anthropogenic climate change, and the potential for mitigation of anthropogenic climate change. [1.1.2, Figure 1-1]

Box SPM.1 | Definitions Central to SREX

Core concepts defined in the SREX glossary[1] and used throughout the report include:

Climate Change: A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.[2]

Climate Extreme (extreme weather or climate event): The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. For simplicity, both extreme weather events and extreme climate events are referred to collectively as 'climate extremes.' The full definition is provided in Section 3.1.2.

Exposure: The presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected.

Vulnerability: The propensity or predisposition to be adversely affected.

Disaster: Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.

Disaster Risk: The likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.

Disaster Risk Management: Processes for designing, implementing, and evaluating strategies, policies, and measures to improve the understanding of disaster risk, foster disaster risk reduction and transfer, and promote continuous improvement in disaster preparedness, response, and recovery practices, with the explicit purpose of increasing human security, well-being, quality of life, resilience, and sustainable development.

Adaptation: In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate.

Resilience: The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.

Transformation: The altering of fundamental attributes of a system (including value systems; regulatory, legislative, or bureaucratic regimes; financial institutions; and technological or biological systems).

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[1] Reflecting the diversity of the communities involved in this assessment and progress in science, several of the definitions used in this Special Report differ in breadth or focus from those used in the Fourth Assessment Report and other IPCC reports.

[2] This definition differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change is defined as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

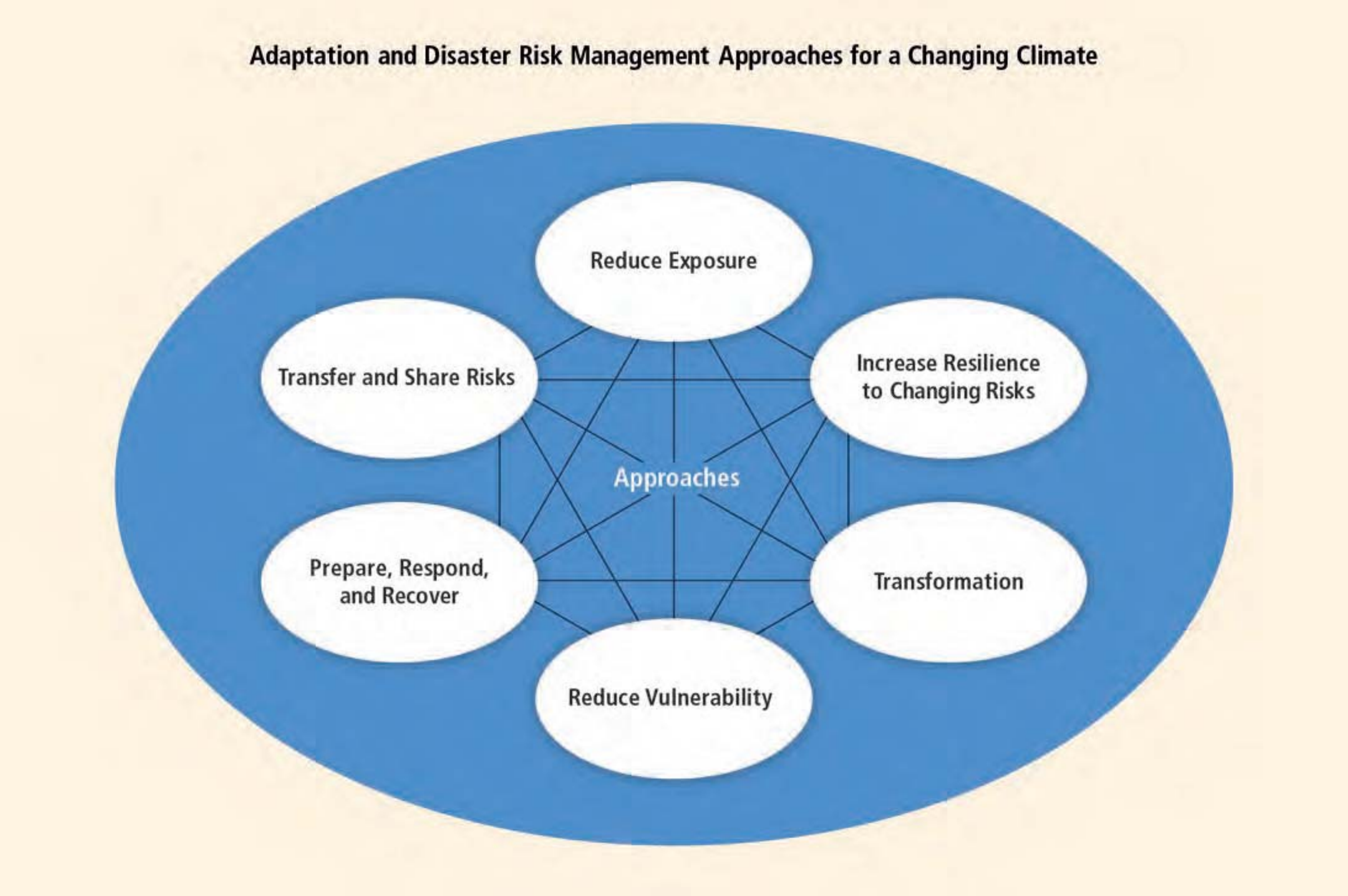

Figure SPM.2 | Adaptation and disaster risk management approaches for reducing and managing disaster risk in a changing climate. This report assesses a wide range of complementary adaptation and disaster risk management approaches that can reduce the risks of climate extremes and disasters and increase resilience to remaining risks as they change over time. These approaches can be overlapping and can be pursued simultaneously. [6.5, Figure 6-3, 8.6]

This report integrates perspectives from several historically distinct research communities studying climate science, climate impacts, adaptation to climate change, and disaster risk management. Each community brings different viewpoints, vocabularies, approaches, and goals, and all provide important insights into the status of the knowledge base and its gaps. Many of the key assessment findings come from the interfaces among these communities. These interfaces are also illustrated in Table SPM.1. To accurately convey the degree of certainty in key findings, the report relies on the consistent use of calibrated uncertainty language, introduced in Box SPM.2. The basis for substantive paragraphs in this Summary for Policymakers can be found in the chapter sections specified in square brackets.

Exposure and vulnerability are key determinants of disaster risk and of impacts when risk is realized. [1.1.2, 1.2.3, 1.3, 2.2.1, 2.3, 2.5] For example, a tropical cyclone can have very different impacts depending on where and when it makes landfall. [2.5.1, 3.1, 4.4.6] Similarly, a heat wave can have very different impacts on different populations depending on their vulnerability. [Box 4-4, 9.2.1] Extreme impacts on human, ecological, or physical systems can result from individual extreme weather or climate events. Extreme impacts can also result from non-extreme events where exposure and vulnerability are high [2.2.1, 2.3, 2.5] or from a compounding of events or their impacts. [1.1.2, 1.2.3, 3.1.3] For example, drought, coupled with extreme heat and low humidity, can increase the risk of wildfire. [Box 4-1, 9.2.2]

Extreme and non-extreme weather or climate events affect vulnerability to future extreme events by modifying resilience, coping capacity, and adaptive capacity. [2.4.3] In particular, the cumulative effects of disasters at local or sub-national levels can substantially affect livelihood options and resources and the capacity of societies and communities to prepare for and respond to future disasters. [2.2, 2.7]

A changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events, and can result in unprecedented extreme weather and climate events. Changes in extremes can be linked to changes in the mean, variance, or shape of probability distributions, or all of these (Figure SPM.3). Some climate extremes (e.g., droughts) may be the result of an accumulation of weather or climate events that are not extreme when considered independently. Many extreme weather and climate events continue to be the result of natural climate variability. Natural variability will be an important factor in shaping future extremes in addition to the effect of anthropogenic changes in climate. [3.1]

B.

Observations of Exposure, Vulnerability, Climate Extremes, Impacts, and Disaster Losses

The impacts of climate extremes and the potential for disasters result from the climate extremes themselves and from the exposure and vulnerability of human and natural systems. Observed changes in climate extremes reflect the influence of anthropogenic climate change in addition to natural climate variability, with changes in exposure and vulnerability influenced by both climatic and non-climatic factors.

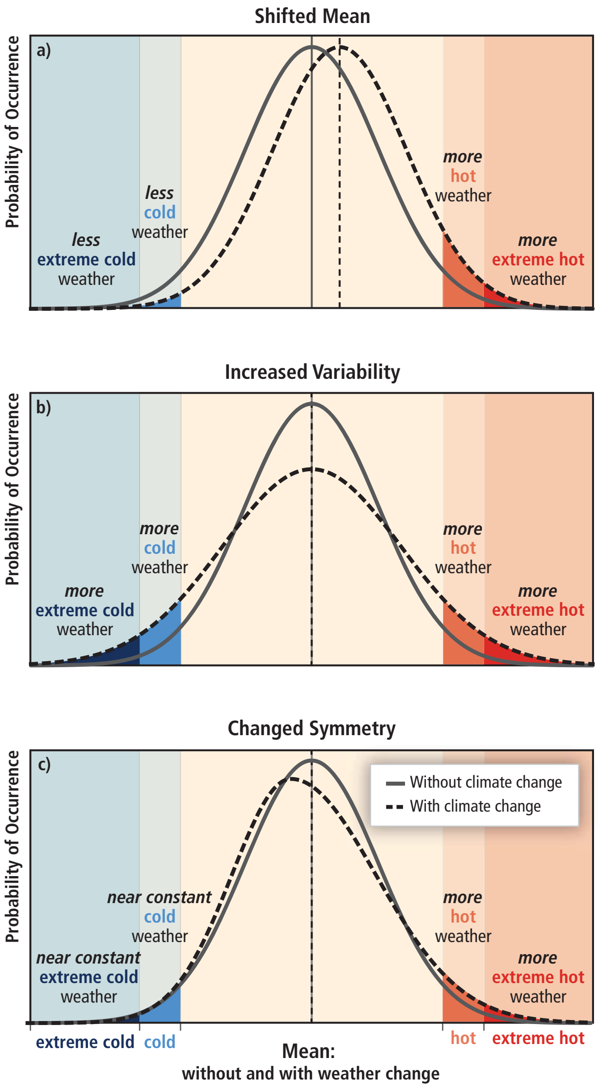

Figure SPM.3 | The effect of changes in temperature distribution on extremes. Different changes in temperature distributions between present and future climate and their effects on extreme values of the distributions: (a) effects of a simple shift of the entire distribution toward a warmer climate; (b) effects of an increase in temperature variability with no shift in the mean; (c) effects of an altered shape of the distribution, in this example a change in asymmetry toward the hotter part of the distribution. [Figure 1-2, 1.2.2]

Exposure and Vulnerability

Exposure and vulnerability are dynamic, varying across temporal and spatial scales, and depend on economic, social, geographic, demographic, cultural, institutional, governance, and environmental factors (*high confidence*). [2.2, 2.3, 2.5] Individuals and communities are differentially exposed and vulnerable based on inequalities expressed through levels of wealth and education, disability, and health status, as well as gender, age, class, and other social and cultural characteristics. [2.5]

Settlement patterns, urbanization, and changes in socioeconomic conditions have all influenced observed trends in exposure and vulnerability to climate extremes (*high confidence*). [4.2, 4.3.5] For example, coastal settlements, including in small islands and megadeltas, and mountain settlements are exposed and vulnerable to climate extremes in both developed and developing countries, but with differences among regions and countries. [4.3.5, 4.4.3, 4.4.6, 4.4.9, 4.4.10] Rapid urbanization and the growth of megacities, especially in developing countries, have led to the emergence of highly vulnerable urban communities, particularly through informal settlements and inadequate land management (*high agreement, robust evidence*). [5.5.1] See also Case Studies 9.2.8 and 9.2.9. Vulnerable populations also include refugees, internally displaced people, and those living in marginal areas. [4.2, 4.3.5]

Climate Extremes and Impacts

There is evidence from observations gathered since 1950 of change in some extremes. Confidence in observed changes in extremes depends on the quality and quantity of data and the availability of studies analyzing these data, which vary across regions and for different extremes. Assigning 'low confidence' in observed changes in a specific extreme on regional or global scales neither implies nor excludes the possibility of changes in this extreme. Extreme events are rare, which means there are few data available to make assessments regarding changes in their frequency or intensity. The more rare the event the more difficult it is to identify long-term changes. Global-scale trends in a specific extreme may be either more reliable (e.g., for temperature extremes) or less reliable (e.g., for droughts) than some regional-scale trends, depending on the geographical uniformity of the trends in the specific extreme. The following paragraphs provide further details for specific climate extremes from observations since 1950. [3.1.5, 3.1.6, 3.2.1]

It is *very likely* that there has been an overall decrease in the number of cold days and nights,[3] and an overall increase in the number of warm days and nights,[3] at the global scale, that is, for most land areas with sufficient data. It is *likely* that these changes have also occurred at the continental scale in North America, Europe, and Australia. There is *medium confidence* in a warming trend in daily temperature extremes in much of Asia. Confidence in observed trends in daily temperature extremes in Africa and South America generally varies from *low* to *medium* depending on the region. In many (but not all) regions over the globe with sufficient data, there is *medium confidence* that the length or number of warm spells or heat waves[3] has increased. [3.3.1, Table 3-2]

There have been statistically significant trends in the number of heavy precipitation events in some regions. It is *likely* that more of these regions have experienced increases than decreases, although there are strong regional and subregional variations in these trends. [3.3.2]

There is *low confidence* in any observed long-term (i.e., 40 years or more) increases in tropical cyclone activity (i.e., intensity, frequency, duration), after accounting for past changes in observing capabilities. It is *likely* that there has been a poleward shift in the main Northern and Southern Hemisphere extratropical storm tracks. There is *low confidence* in observed trends in small spatial-scale phenomena such as tornadoes and hail because of data inhomogeneities and inadequacies in monitoring systems. [3.3.2, 3.3.3, 3.4.4, 3.4.5]

There is *medium confidence* that some regions of the world have experienced more intense and longer droughts, in particular in southern Europe and West Africa, but in some regions droughts have become less frequent, less intense, or shorter, for example, in central North America and northwestern Australia. [3.5.1]

There is *limited* to *medium evidence* available to assess climate-driven observed changes in the magnitude and frequency of floods at regional scales because the available instrumental records of floods at gauge stations are limited in space and time, and because of confounding effects of changes in land use and engineering. Furthermore, there is *low agreement* in this evidence, and thus overall *low confidence* at the global scale regarding even the sign of these changes. [3.5.2]

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[3] See SREX Glossary for definition of these terms: cold days / cold nights, warm days / warm nights, and warm spell – heat wave.

It is *likely* that there has been an increase in extreme coastal high water related to increases in mean sea level. [3.5.3]

There is evidence that some extremes have changed as a result of anthropogenic influences, including increases in atmospheric concentrations of greenhouse gases. It is *likely* that anthropogenic influences have led to warming of extreme daily minimum and maximum temperatures at the global scale. There is *medium confidence* that anthropogenic influences have contributed to intensification of extreme precipitation at the global scale. It is *likely* that there has been an anthropogenic influence on increasing extreme coastal high water due to an increase in mean sea level. The uncertainties in the historical tropical cyclone records, the incomplete understanding of the physical mechanisms linking tropical cyclone metrics to climate change, and the degree of tropical cyclone variability provide only *low confidence* for the attribution of any detectable changes in tropical cyclone activity to anthropogenic influences. Attribution of single extreme events to anthropogenic climate change is challenging. [3.2.2, 3.3.1, 3.3.2, 3.4.4, 3.5.3, Table 3-1]

Disaster Losses

Economic losses from weather- and climate-related disasters have increased, but with large spatial and interannual variability (*high confidence*, based on *high agreement*, *medium evidence*). Global weather- and climate-related disaster losses reported over the last few decades reflect mainly monetized direct damages to assets, and are unequally distributed. Estimates of annual losses have ranged since 1980 from a few US$ billion to above 200 billion (in 2010 dollars), with the highest value for 2005 (the year of Hurricane Katrina). Loss estimates are lower-bound estimates because many impacts, such as loss of human lives, cultural heritage, and ecosystem services, are difficult to value and monetize, and thus they are poorly reflected in estimates of losses. Impacts on the informal or undocumented economy as well as indirect economic effects can be very important in some areas and sectors, but are generally not counted in reported estimates of losses. [4.5.1, 4.5.3, 4.5.4]

Economic, including insured, disaster losses associated with weather, climate, and geophysical events[4] are higher in developed countries. Fatality rates and economic losses expressed as a proportion of gross domestic product (GDP) are higher in developing countries (*high confidence*). During the period from 1970 to 2008, over 95% of deaths from natural disasters occurred in developing countries. Middle-income countries with rapidly expanding asset bases have borne the largest burden. During the period from 2001 to 2006, losses amounted to about 1% of GDP for middle-income countries, while this ratio has been about 0.3% of GDP for low-income countries and less than 0.1% of GDP for high-income countries, based on *limited evidence*. In small exposed countries, particularly small island developing states, losses expressed as a percentage of GDP have been particularly high, exceeding 1% in many cases and 8% in the most extreme cases, averaged over both disaster and non-disaster years for the period from 1970 to 2010. [4.5.2, 4.5.4]

Increasing exposure of people and economic assets has been the major cause of long-term increases in economic losses from weather- and climate-related disasters (*high confidence*). Long-term trends in economic disaster losses adjusted for wealth and population increases have not been attributed to climate change, but a role for climate change has not been excluded (*high agreement, medium evidence*). These conclusions are subject to a number of limitations in studies to date. Vulnerability is a key factor in disaster losses, yet it is not well accounted for. Other limitations are: (i) data availability, as most data are available for standard economic sectors in developed countries; and (ii) type of hazards studied, as most studies focus on cyclones, where confidence in observed trends and attribution of changes to human influence is *low*. The second conclusion is subject to additional limitations: (iii) the processes used to adjust loss data over time, and (iv) record length. [4.5.3]

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[4] Economic losses and fatalities described in this paragraph pertain to all disasters associated with weather, climate, and geophysical events.

C. Disaster Risk Management and Adaptation to Climate Change: Past Experience with Climate Extremes

Past experience with climate extremes contributes to understanding of effective disaster risk management and adaptation approaches to manage risks.

The severity of the impacts of climate extremes depends strongly on the level of the exposure and vulnerability to these extremes (*high confidence*). [2.1.1, 2.3, 2.5]

Trends in exposure and vulnerability are major drivers of changes in disaster risk (*high confidence*). [2.5] Understanding the multi-faceted nature of both exposure and vulnerability is a prerequisite for determining how weather and climate events contribute to the occurrence of disasters, and for designing and implementing effective adaptation and disaster risk management strategies. [2.2, 2.6] Vulnerability reduction is a core common element of adaptation and disaster risk management. [2.2, 2.3]

Development practice, policy, and outcomes are critical to shaping disaster risk, which may be increased by shortcomings in development (*high confidence*). [1.1.2, 1.1.3] High exposure and vulnerability are generally the outcome of skewed development processes such as those associated with environmental degradation, rapid and unplanned urbanization in hazardous areas, failures of governance, and the scarcity of livelihood options for the poor. [2.2.2, 2.5] Increasing global interconnectivity and the mutual interdependence of economic and ecological systems can have sometimes contrasting effects, reducing or amplifying vulnerability and disaster risk. [7.2.1] Countries more effectively manage disaster risk if they include considerations of disaster risk in national development and sector plans and if they adopt climate change adaptation strategies, translating these plans and strategies into actions targeting vulnerable areas and groups. [6.2, 6.5.2]

Data on disasters and disaster risk reduction are lacking at the local level, which can constrain improvements in local vulnerability reduction (*high agreement, medium evidence*). [5.7] There are few examples of national disaster risk management systems and associated risk management measures explicitly integrating knowledge of and uncertainties in projected changes in exposure, vulnerability, and climate extremes. [6.6.2, 6.6.4]

Inequalities influence local coping and adaptive capacity, and pose disaster risk management and adaptation challenges from the local to national levels (*high agreement, robust evidence*). These inequalities reflect socioeconomic, demographic, and health-related differences and differences in governance, access to livelihoods, entitlements, and other factors. [5.5.1, 6.2] Inequalities also exist across countries: developed countries are often better equipped financially and institutionally to adopt explicit measures to effectively respond and adapt to projected changes in exposure, vulnerability, and climate extremes than are developing countries. Nonetheless, all countries face challenges in assessing, understanding, and responding to such projected changes. [6.3.2, 6.6]

Humanitarian relief is often required when disaster risk reduction measures are absent or inadequate (*high agreement, robust evidence*). [5.2.1] Smaller or economically less-diversified countries face particular challenges in providing the public goods associated with disaster risk management, in absorbing the losses caused by climate extremes and disasters, and in providing relief and reconstruction assistance. [6.4.3]

Post-disaster recovery and reconstruction provide an opportunity for reducing weather- and climate-related disaster risk and for improving adaptive capacity (*high agreement, robust evidence*). An emphasis on rapidly rebuilding houses, reconstructing infrastructure, and rehabilitating livelihoods often leads to recovering in ways that recreate or even increase existing vulnerabilities, and that preclude longer-term planning and policy changes for enhancing resilience and sustainable development. [5.2.3] See also assessment in Sections 8.4.1 and 8.5.2.

Risk sharing and transfer mechanisms at local, national, regional, and global scales can increase resilience to climate extremes (*medium confidence*). Mechanisms include informal and traditional risk sharing mechanisms, micro-insurance, insurance, reinsurance, and national, regional, and global risk pools. [5.6.3, 6.4.3, 6.5.3, 7.4] These mechanisms are linked to disaster risk reduction and climate change adaptation by providing means to finance relief, recovery of livelihoods, and reconstruction; reducing vulnerability; and providing knowledge and incentives for reducing risk. [5.5.2, 6.2.2] Under certain conditions, however, such mechanisms can provide disincentives for reducing disaster risk. [5.6.3, 6.5.3, 7.4.4] Uptake of formal risk sharing and transfer mechanisms is unequally distributed across regions and hazards. [6.5.3] See also Case Study 9.2.13.

Attention to the temporal and spatial dynamics of exposure and vulnerability is particularly important given that the design and implementation of adaptation and disaster risk management strategies and policies can reduce risk in the short term, but may increase exposure and vulnerability over the longer term (*high agreement, medium evidence*). For instance, dike systems can reduce flood exposure by offering immediate protection, but also encourage settlement patterns that may increase risk in the long term. [2.4.2, 2.5.4, 2.6.2] See also assessment in Sections 1.4.3, 5.3.2, and 8.3.1.

National systems are at the core of countries' capacity to meet the challenges of observed and projected trends in exposure, vulnerability, and weather and climate extremes (*high agreement, robust evidence*). Effective national systems comprise multiple actors from national and sub-national governments, the private sector, research bodies, and civil society including community-based organizations, playing differential but complementary roles to manage risk, according to their accepted functions and capacities. [6.2]

Closer integration of disaster risk management and climate change adaptation, along with the incorporation of both into local, sub-national, national, and international development policies and practices, could provide benefits at all scales (*high agreement, medium evidence*). [5.4, 5.5, 5.6, 6.3.1, 6.3.2, 6.4.2, 6.6, 7.4] Addressing social welfare, quality of life, infrastructure, and livelihoods, and incorporating a multi-hazards approach into planning and action for disasters in the short term, facilitates adaptation to climate extremes in the longer term, as is increasingly recognized internationally. [5.4, 5.5, 5.6, 7.3] Strategies and policies are more effective when they acknowledge multiple stressors, different prioritized values, and competing policy goals. [8.2, 8.3, 8.7]

D. Future Climate Extremes, Impacts, and Disaster Losses

Future changes in exposure, vulnerability, and climate extremes resulting from natural climate variability, anthropogenic climate change, and socioeconomic development can alter the impacts of climate extremes on natural and human systems and the potential for disasters.

Climate Extremes and Impacts

Confidence in projecting changes in the direction and magnitude of climate extremes depends on many factors, including the type of extreme, the region and season, the amount and quality of observational data, the level of understanding of the underlying processes, and the reliability of their simulation in models. Projected changes in climate extremes under different emissions scenarios[5] generally do not strongly diverge in the coming two to three decades, but these signals are relatively small compared to natural climate variability over this time frame. Even the sign of projected changes in some climate extremes over this time frame is uncertain. For projected changes by the end of the 21st century, either model uncertainty or uncertainties associated with emissions scenarios used becomes dominant, depending on the extreme. Low-probability, high-impact changes associated with

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[5] Emissions scenarios for radiatively important substances result from pathways of socioeconomic and technological development. This report uses a subset (B1, A1B, A2) of the 40 scenarios extending to the year 2100 that are described in the IPCC Special Report on Emissions Scenarios (SRES) and that did not include additional climate initiatives. These scenarios have been widely used in climate change projections and encompass a substantial range of carbon dioxide equivalent concentrations, but not the entire range of the scenarios included in the SRES.

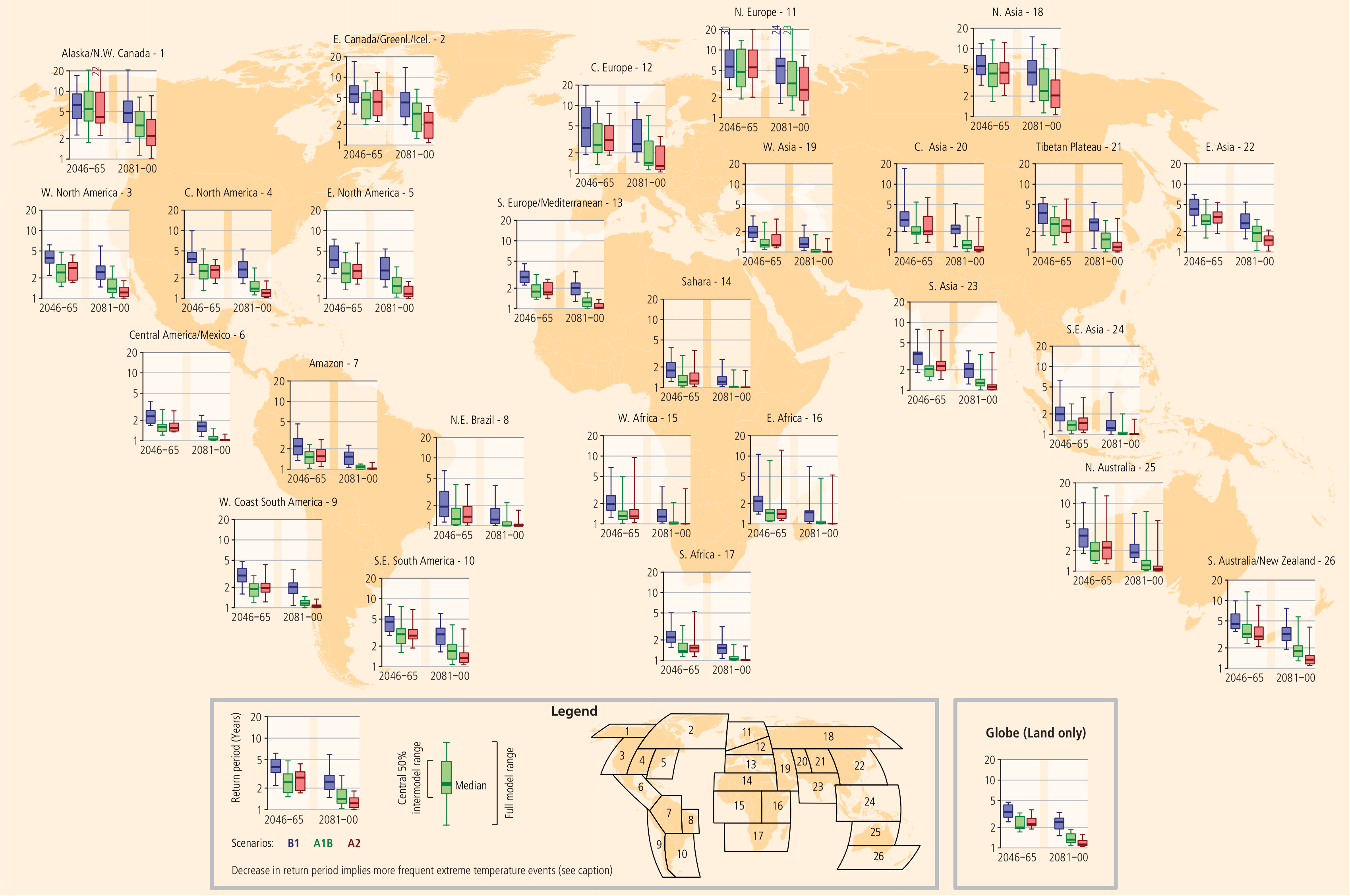


Figure SPM.4A | Projected return periods for the maximum daily temperature that was exceeded on average once during a 20-year period in the late 20th century (1981–2000). A decrease in return period implies more frequent extreme temperature events (i.e., less time between events on average). The box plots show results for regionally averaged projections for two time horizons, 2046 to 2065 and 2081 to 2100, as compared to the late 20th century, and for three different SRES emissions scenarios (B1, A1B, A2) (see legend). Results are based on 12 global climate models (GCMs) contributing to the third phase of the Coupled Model Intercomparison Project (CMIP3). The level of agreement among the models is indicated by the size of the colored boxes (in which 50% of the model projections are contained), and the length of the whiskers (indicating the maximum and minimum projections from all models). See legend for defined extent of regions. Values are computed for land points only. The 'Globe' inset box displays the values computed using all land grid points. [3.3.1, Figure 3-1, Figure 3-5] the crossing of poorly understood climate thresholds cannot be excluded, given the transient and complex nature of the climate system. Assigning 'low confidence' for projections of a specific extreme neither implies nor excludes the possibility of changes in this extreme. The following assessments of the likelihood and/or confidence of projections are generally for the end of the 21st century and relative to the climate at the end of the 20th century. [3.1.5, 3.1.7, 3.2.3, Box 3-2]

Models project substantial warming in temperature extremes by the end of the 21st century. It is *virtually certain* that increases in the frequency and magnitude of warm daily temperature extremes and decreases in cold extremes will occur in the 21st century at the global scale. It is *very likely* that the length, frequency, and/or intensity of warm spells or heat waves will increase over most land areas. Based on the A1B and A2 emissions scenarios, a 1-in-20 year hottest day is *likely* to become a 1-in-2 year event by the end of the 21st century in most regions, except in the high latitudes of the Northern Hemisphere, where it is *likely* to become a 1-in-5 year event (see Figure SPM.4A). Under the B1 scenario, a 1-in-20 year event would *likely* become a 1-in-5 year event (and a 1-in-10 year event in Northern Hemisphere high latitudes). The 1-in-20 year extreme daily maximum temperature (i.e., a value that was exceeded on average only once during the period 1981–2000) will *likely* increase by about 1°C to 3°C by the mid-21st century and by about 2°C to 5°C by the late 21st century, depending on the region and emissions scenario (based on the B1, A1B, and A2 scenarios). [3.3.1, 3.1.6, Table 3-3, Figure 3-5]

It is *likely* that the frequency of heavy precipitation or the proportion of total rainfall from heavy falls will increase in the 21st century over many areas of the globe. This is particularly the case in the high latitudes and tropical regions, and in winter in the northern mid-latitudes. Heavy rainfalls associated with tropical cyclones are *likely* to increase with continued warming. There is *medium confidence* that, in some regions, increases in heavy precipitation will occur despite projected decreases in total precipitation in those regions. Based on a range of emissions scenarios (B1, A1B, A2), a 1-in-20 year annual maximum daily precipitation amount is *likely* to become a 1-in-5 to 1-in-15 year event by the end of the 21st century in many regions, and in most regions the higher emissions scenarios (A1B and A2) lead to a stronger projected decrease in return period. See Figure SPM.4B. [3.3.2, 3.4.4, Table 3-3, Figure 3-7]

Average tropical cyclone maximum wind speed is *likely* to increase, although increases may not occur in all ocean basins. It is *likely* that the global frequency of tropical cyclones will either decrease or remain essentially unchanged. [3.4.4]

There is *medium confidence* that there will be a reduction in the number of extratropical cyclones averaged over each hemisphere. While there is *low confidence* in the detailed geographical projections of extratropical cyclone activity, there is *medium confidence* in a projected poleward shift of extratropical storm tracks. There is *low confidence* in projections of small spatial-scale phenomena such as tornadoes and hail because competing physical processes may affect future trends and because current climate models do not simulate such phenomena. [3.3.2, 3.3.3, 3.4.5]

There is *medium confidence* that droughts will intensify in the 21st century in some seasons and areas, due to reduced precipitation and/or increased evapotranspiration. This applies to regions including southern Europe and the Mediterranean region, central Europe, central North America, Central America and Mexico, northeast Brazil, and southern Africa. Elsewhere there is overall *low confidence* because of inconsistent projections of drought changes (dependent both on model and dryness index). Definitional issues, lack of observational data, and the inability of models to include all the factors that influence droughts preclude stronger confidence than *medium* in drought projections. See Figure SPM.5. [3.5.1, Table 3-3, Box 3-3]

Projected precipitation and temperature changes imply possible changes in floods, although overall there is *low confidence* in projections of changes in fluvial floods. Confidence is *low* due to *limited evidence* and because the causes of regional changes are complex, although there are exceptions to this statement. There is *medium confidence* (based on physical reasoning) that projected increases in heavy rainfall would contribute to increases in local flooding in some catchments or regions. [3.5.2]

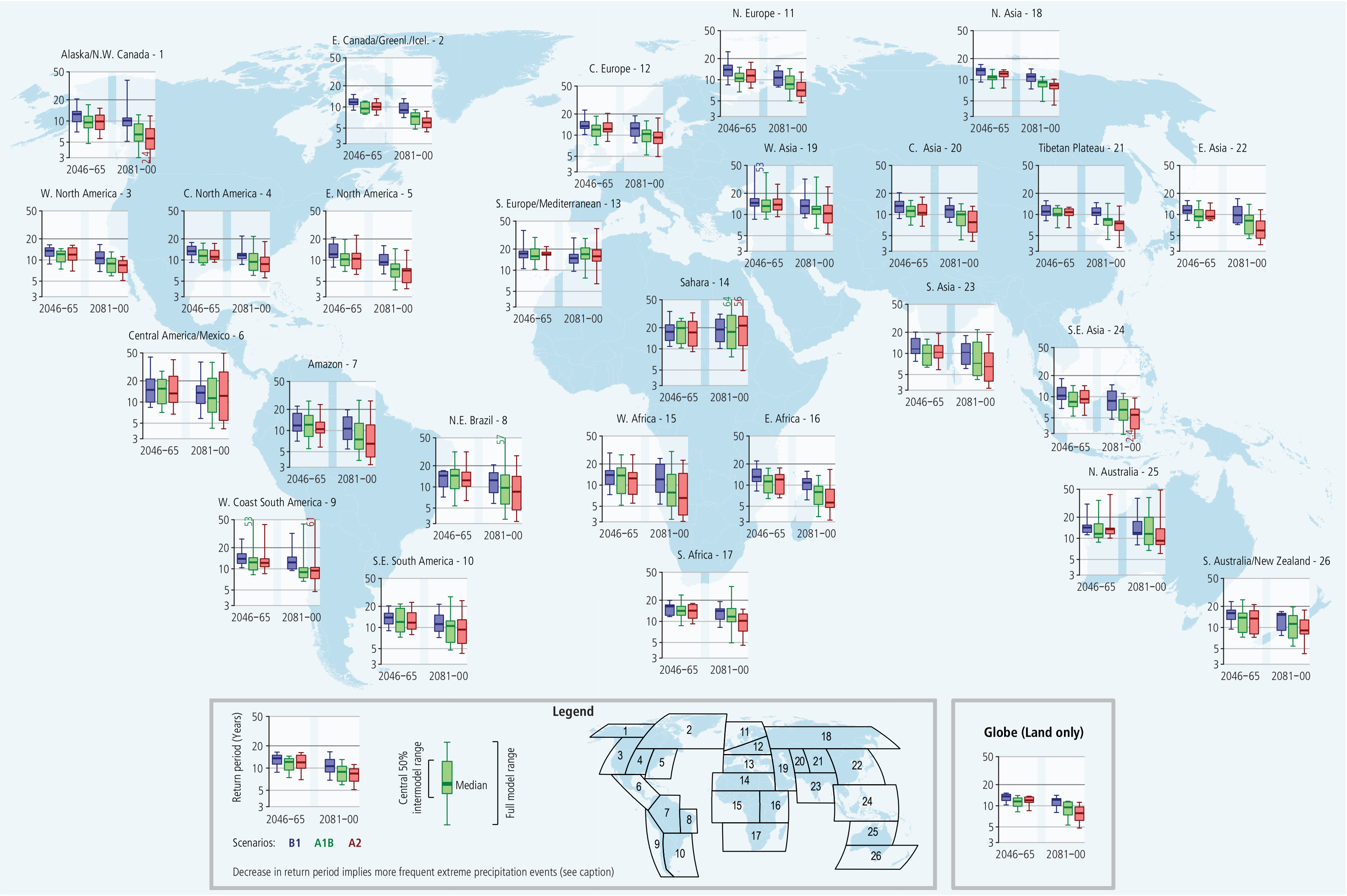


Figure SPM.4B | Projected return periods for a daily precipitation event that was exceeded in the late 20th century on average once during a 20-year period (1981–2000). A decrease in return period implies more frequent extreme precipitation events (i.e., less time between events on average). The box plots show results for regionally averaged projections for two time horizons, 2046 to 2065 and 2081 to 2100, as compared to the late 20th century, and for three different SRES emissions scenarios (B1, A1B, A2) (see legend). Results are based on 14 GCMs contributing to the CMIP3. The level of agreement among the models is indicated by the size of the colored boxes (in which 50% of the model projections are contained), and the length of the whiskers (indicating the maximum and minimum projections from all models). See legend for defined extent of regions. Values are computed for land points only. The 'Globe' inset box displays the values computed using all land grid points. [3.3.2, Figure 3-1, Figure 3-7]

It is *very likely* that mean sea level rise will contribute to upward trends in extreme coastal high water levels in the future. There is *high confidence* that locations currently experiencing adverse impacts such as coastal erosion and inundation will continue to do so in the future due to increasing sea levels, all other contributing factors being equal. The *very likely* contribution of mean sea level rise to increased extreme coastal high water levels, coupled with the *likely* increase in tropical cyclone maximum wind speed, is a specific issue for tropical small island states. [3.5.3, 3.5.5, Box 3-4]

There is *high confidence* that changes in heat waves, glacial retreat, and/or permafrost degradation will affect high mountain phenomena such as slope instabilities, movements of mass, and glacial lake outburst floods. There is also *high confidence* that changes in heavy precipitation will affect landslides in some regions. [3.5.6]

There is *low confidence* in projections of changes in large-scale patterns of natural climate variability. Confidence is *low* in projections of changes in monsoons (rainfall, circulation) because there is little consensus in climate models regarding the sign of future change in the monsoons. Model projections of changes in El Niño–Southern

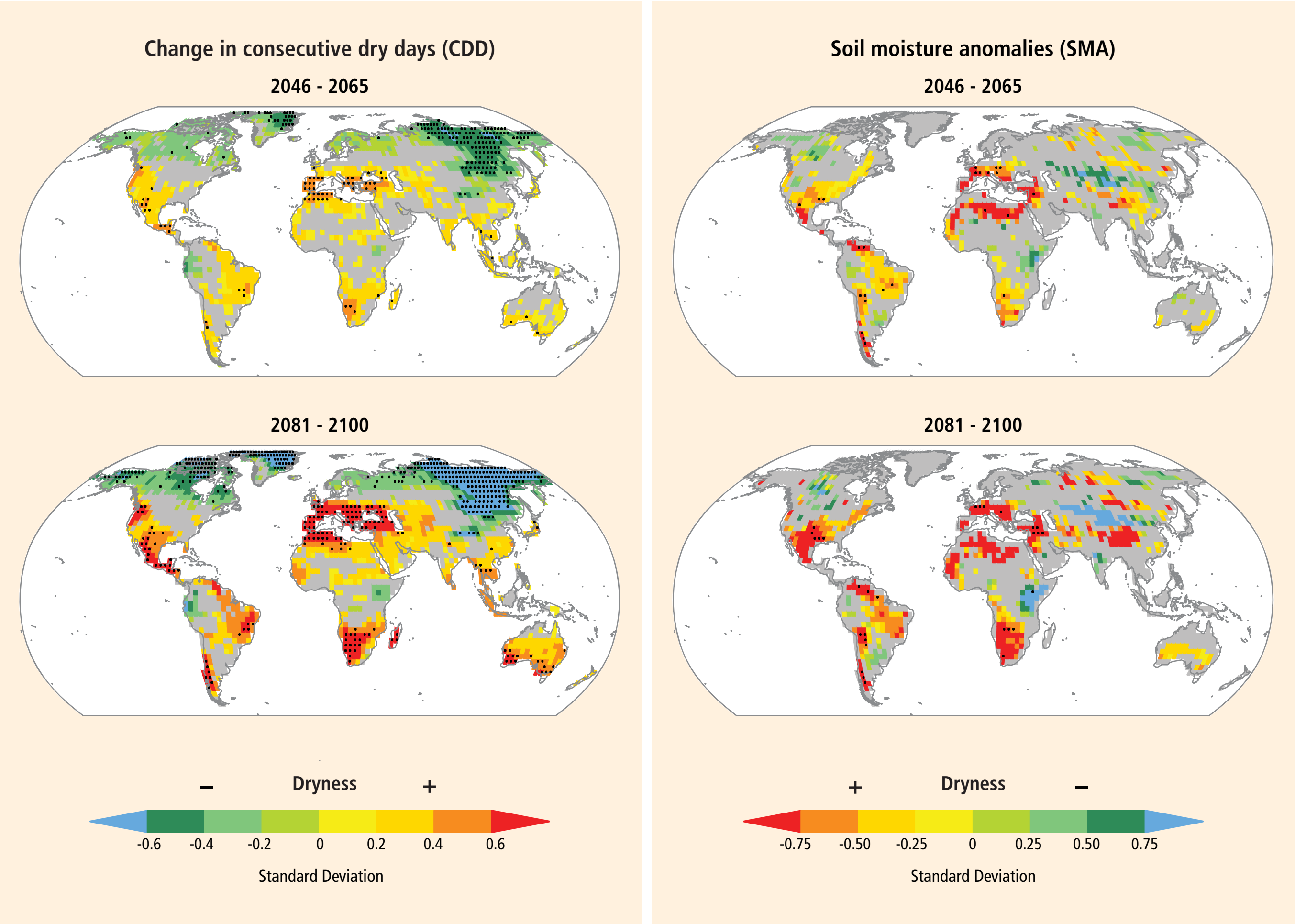


Figure SPM.5 | Projected annual changes in dryness assessed from two indices. Left column: Change in annual maximum number of consecutive dry days (CDD: days with precipitation <1 mm). Right column: Changes in soil moisture (soil moisture anomalies, SMA). Increased dryness is indicated with yellow to red colors; decreased dryness with green to blue. Projected changes are expressed in units of standard deviation of the interannual variability in the three 20-year periods 1980–1999, 2046–2065, and 2081–2100. The figures show changes for two time horizons, 2046–2065 and 2081–2100, as compared to late 20th-century values (1980–1999), based on GCM simulations under emissions scenario SRES A2 relative to corresponding simulations for the late 20th century. Results are based on 17 (CDD) and 15 (SMA) GCMs contributing to the CMIP3. Colored shading is applied for areas where at least 66% (12 out of 17 for CDD, 10 out of 15 for SMA) of the models agree on the sign of the change; stippling is added for regions where at least 90% (16 out of 17 for CDD, 14 out of 15 for SMA) of all models agree on the sign of the change. Grey shading indicates where there is insufficient model agreement (<66%). [3.5.1, Figure 3-9]

Oscillation variability and the frequency of El Niño episodes are not consistent, and so there is *low confidence* in projections of changes in this phenomenon. [3.4.1, 3.4.2, 3.4.3]

Human Impacts and Disaster Losses

Extreme events will have greater impacts on sectors with closer links to climate, such as water, agriculture and food security, forestry, health, and tourism. For example, while it is not currently possible to reliably project specific changes at the catchment scale, there is *high confidence* that changes in climate have the potential to seriously affect water management systems. However, climate change is in many instances only one of the drivers of future changes, and is not necessarily the most important driver at the local scale. Climate-related extremes are also expected to produce large impacts on infrastructure, although detailed analysis of potential and projected damages are limited to a few countries, infrastructure types, and sectors. [4.3.2, 4.3.5]

In many regions, the main drivers of future increases in economic losses due to some climate extremes will be socioeconomic in nature (*medium confidence*, based on *medium agreement*, *limited evidence*). Climate extremes are only one of the factors that affect risks, but few studies have specifically quantified the effects of changes in population, exposure of people and assets, and vulnerability as determinants of loss. However, the few studies available generally underline the important role of projected changes (increases) in population and capital at risk. [4.5.4]

Increases in exposure will result in higher direct economic losses from tropical cyclones. Losses will also depend on future changes in tropical cyclone frequency and intensity (*high confidence*). Overall losses due to extratropical cyclones will also increase, with possible decreases or no change in some areas (*medium confidence*). Although future flood losses in many locations will increase in the absence of additional protection measures (*high agreement, medium evidence*), the size of the estimated change is highly variable, depending on location, climate scenarios used, and methods used to assess impacts on river flow and flood occurrence. [4.5.4]

Disasters associated with climate extremes influence population mobility and relocation, affecting host and origin communities (*medium agreement, medium evidence*). If disasters occur more frequently and/or with greater magnitude, some local areas will become increasingly marginal as places to live or in which to maintain livelihoods. In such cases, migration and displacement could become permanent and could introduce new pressures in areas of relocation. For locations such as atolls, in some cases it is possible that many residents will have to relocate. [5.2.2]

E. Managing Changing Risks of Climate Extremes and Disasters

Adaptation to climate change and disaster risk management provide a range of complementary approaches for managing the risks of climate extremes and disasters (Figure SPM.2). Effectively applying and combining approaches may benefit from considering the broader challenge of sustainable development.

Measures that provide benefits under current climate and a range of future climate change scenarios, called low-regrets measures, are available starting points for addressing projected trends in exposure, vulnerability, and climate extremes. They have the potential to offer benefits now and lay the foundation for addressing projected changes (*high agreement, medium evidence*). Many of these low-regrets strategies produce co-benefits, help address other development goals, such as improvements in livelihoods, human well-being, and biodiversity conservation, and help minimize the scope for maladaptation. [6.3.1, Table 6-1]

Potential low-regrets measures include early warning systems; risk communication between decisionmakers and local citizens; sustainable land management, including land use planning; and ecosystem management and restoration.

Other low-regrets measures include improvements to health surveillance, water supply, sanitation, and irrigation and drainage systems; climate-proofing of infrastructure; development and enforcement of building codes; and better education and awareness. [5.3.1, 5.3.3, 6.3.1, 6.5.1, 6.5.2] See also Case Studies 9.2.11 and 9.2.14, and assessment in Section 7.4.3.

Effective risk management generally involves a portfolio of actions to reduce and transfer risk and to respond to events and disasters, as opposed to a singular focus on any one action or type of action (*high confidence*). [1.1.2, 1.1.4, 1.3.3] Such integrated approaches are more effective when they are informed by and customized to specific local circumstances (*high agreement, robust evidence*). [5.1] Successful strategies include a combination of hard infrastructure-based responses and soft solutions such as individual and institutional capacity building and ecosystem-based responses. [6.5.2]

Multi-hazard risk management approaches provide opportunities to reduce complex and compound hazards (*high agreement, robust evidence*). Considering multiple types of hazards reduces the likelihood that risk reduction efforts targeting one type of hazard will increase exposure and vulnerability to other hazards, in the present and future. [8.2.5, 8.5.2, 8.7]

Opportunities exist to create synergies in international finance for disaster risk management and adaptation to climate change, but these have not yet been fully realized (*high confidence*). International funding for disaster risk reduction remains relatively low as compared to the scale of spending on international humanitarian response. [7.4.2] Technology transfer and cooperation to advance disaster risk reduction and climate change adaptation are important. Coordination on technology transfer and cooperation between these two fields has been lacking, which has led to fragmented implementation. [7.4.3]

Stronger efforts at the international level do not necessarily lead to substantive and rapid results at the local level (*high confidence*). There is room for improved integration across scales from international to local. [7.6]

Integration of local knowledge with additional scientific and technical knowledge can improve disaster risk reduction and climate change adaptation (*high agreement, robust evidence*). Local populations document their experiences with the changing climate, particularly extreme weather events, in many different ways, and this self-generated knowledge can uncover existing capacity within the community and important current shortcomings. [5.4.4] Local participation supports community-based adaptation to benefit management of disaster risk and climate extremes. However, improvements in the availability of human and financial capital and of disaster risk and climate information customized for local stakeholders can enhance community-based adaptation (*medium agreement, medium evidence)*. [5.6]

Appropriate and timely risk communication is critical for effective adaptation and disaster risk management (*high confidence*). Explicit characterization of uncertainty and complexity strengthens risk communication. [2.6.3] Effective risk communication builds on exchanging, sharing, and integrating knowledge about climate-related risks among all stakeholder groups. Among individual stakeholders and groups, perceptions of risk are driven by psychological and cultural factors, values, and beliefs. [1.1.4, 1.3.1, 1.4.2] See also assessment in Section 7.4.5.

An iterative process of monitoring, research, evaluation, learning, and innovation can reduce disaster risk and promote adaptive management in the context of climate extremes (*high agreement*, *robust evidence*). [8.6.3, 8.7] Adaptation efforts benefit from iterative risk management strategies because of the complexity, uncertainties, and long time frame associated with climate change (*high confidence*). [1.3.2] Addressing knowledge gaps through enhanced observation and research can reduce uncertainty and help in designing effective adaptation and risk management strategies. [3.2, 6.2.5, Table 6-3, 7.5, 8.6.3] See also assessment in Section 6.6.

Table SPM.1 presents examples of how observed and projected trends in exposure, vulnerability, and climate extremes can inform risk management and adaptation strategies, policies, and measures. The

Table SPM.1 | Illustrative examples of options for risk management and adaptation in the context of changes in exposure, vulnerability, and climate extremes. In each example, information is characterized at the scale directly relevant to decisionmaking. Observed and projected changes in climate extremes at global and regional scales illustrate that the direction of, magnitude of, and/or degree of certainty for changes may differ across scales.

The examples were selected based on availability of evidence in the underlying chapters, including on exposure, vulnerability, climate information, and risk management and adaptation options. They are intended to reflect relevant risk management themes and scales, rather than to provide comprehensive information by region. The examples are not intended to reflect any regional differences in exposure and vulnerability, or in experience in risk management.

The confidence in projected changes in climate extremes at local scales is often more limited than the confidence in projected regional and global changes. This limited confidence in changes places a focus on low-regrets risk management options that aim to reduce exposure and vulnerability and to increase resilience and preparedness for risks that cannot be entirely eliminated. Higher-confidence projected changes in climate extremes, at a scale relevant to adaptation and risk management decisions, can inform more targeted adjustments in strategies, policies, and measures. [3.1.6, Box 3-2, 6.3.1, 6.5.2]

Example	Exposure and vulnerability at scale of risk management in the example	Information on Climate Extreme Across Spatial Scales			Options for risk management and adaptation in the example
		GLOBAL Observed (since 1950) and projected (to 2100) global changes	REGIONAL Observed (since 1950) and projected (to 2100) changes in the example	SCALE OF RISK MANAGEMENT Available information for the example	
Inundation related to **extreme sea levels** in tropical small island developing states	Small island states in the Pacific, Indian, and Atlantic Oceans, often with low elevation, are particularly vulnerable to rising sea levels and impacts such as erosion, inundation, shoreline change, and saltwater intrusion into coastal aquifers. These impacts can result in ecosystem disruption, decreased agricultural productivity, changes in disease patterns, economic losses such as in tourism industries, and population displacement – all of which reinforce vulnerability to extreme weather events. [3.5.5, Box 3-4, 4.3.5, 4.4.10, 9.2.9]	**Observed:** *Likely* increase in extreme coastal high water worldwide related to increases in mean sea level. **Projected:** *Very likely* that mean sea level rise will contribute to upward trends in extreme coastal high water levels. *High confidence* that locations currently experiencing coastal erosion and inundation will continue to do so due to increasing sea level, in the absence of changes in other contributing factors. *Likely* that the global frequency of tropical cyclones will either decrease or remain essentially unchanged. *Likely* increase in average tropical cyclone maximum wind speed, although increases may not occur in all ocean basins. [Table 3-1, 3.4.4, 3.5.3, 3.5.5]	**Observed:** Tides and El Niño–Southern Oscillation have contributed to the more frequent occurrence of extreme coastal high water levels and associated flooding experienced on some Pacific Islands in recent years. **Projected:** The *very likely* contribution of mean sea level rise to increased extreme coastal high water levels, coupled with the *likely* increase in tropical cyclone maximum wind speed, is a specific issue for tropical small island states. See global changes column for information on global projections for tropical cyclones. [Box 3-4, 3.4.4, 3.5.3]	Sparse regional and temporal coverage of terrestrial-based observation networks and limited in situ ocean observing network, but with improved satellite-based observations in recent decades. While changes in storminess may contribute to changes in extreme coastal high water levels, the limited geographical coverage of studies to date and the uncertainties associated with storminess changes overall mean that a general assessment of the effects of storminess changes on storm surge is not possible at this time. [Box 3-4, 3.5.3]	Low-regrets options that reduce exposure and vulnerability across a range of hazard trends: • Maintenance of drainage systems • Well technologies to limit saltwater contamination of groundwater • Improved early warning systems • Regional risk pooling • Mangrove conservation, restoration, and replanting Specific adaptation options include, for instance, rendering national economies more climate-independent and adaptive management involving iterative learning. In some cases there may be a need to consider relocation, for example, for atolls where storm surges may completely inundate them. [4.3.5, 4.4.10, 5.2.2, 6.3.2, 6.5.2, 6.6.2, 7.4.4, 9.2.9, 9.2.11, 9.2.13]
Flash floods in informal settlements in Nairobi, Kenya	Rapid expansion of poor people living in informal settlements around Nairobi has led to houses of weak building materials being constructed immediately adjacent to rivers and to blockage of natural drainage areas, increasing exposure and vulnerability. [6.4.2, Box 6-2]	**Observed:** *Low confidence* at global scale regarding (climate-driven) observed changes in the magnitude and frequency of floods. **Projected:** *Low confidence* in projections of changes in floods because of limited evidence and because the causes of regional changes are complex. However, *medium confidence* (based on physical reasoning) that projected increases in heavy precipitation will contribute to rain-generated local flooding in some catchments or regions. [Table 3-1, 3.5.2]	**Observed:** *Low confidence* regarding trends in heavy precipitation in East Africa, because of insufficient evidence. **Projected:** *Likely* increase in heavy precipitation indicators in East Africa. [Table 3-2, Table 3-3, 3.3.2]	Limited ability to provide local flash flood projections. [3.5.2]	Low-regrets options that reduce exposure and vulnerability across a range of hazard trends: • Strengthening building design and regulation • Poverty reduction schemes • City-wide drainage and sewerage improvements The Nairobi Rivers Rehabilitation and Restoration Programme includes installation of riparian buffers, canals, and drainage channels and clearance of existing channels; attention to climate variability and change in the location and design of wastewater infrastructure; and environmental monitoring for flood early warning. [6.3, 6.4.2, Box 6-2, Box 6-6]

Continued next page →

Table SPM.1 (continued)

Example	Exposure and vulnerability at scale of risk management in the example	Information on Climate Extreme Across Spatial Scales			Options for risk management and adaptation in the example
		GLOBAL Observed (since 1950) and projected (to 2100) global changes	REGIONAL Observed (since 1950) and projected (to 2100) changes in the example	SCALE OF RISK MANAGEMENT Available information for the example	
Impacts of **heat waves** in urban areas in Europe	Factors affecting exposure and vulnerability include age, pre-existing health status, level of outdoor activity, socioeconomic factors including poverty and social isolation, access to and use of cooling, physiological and behavioral adaptation of the population, and urban infrastructure. [2.5.2, 4.3.5, 4.3.6, 4.4.5, 9.2.1]	**Observed:** *Medium confidence* that the length or number of warm spells or heat waves has increased since the middle of the 20th century, in many (but not all) regions over the globe. *Very likely* increase in number of warm days and nights at the global scale. **Projected:** *Very likely* increase in length, frequency, and/or intensity of warm spells or heat waves over most land areas. *Virtually certain* increase in frequency and magnitude of warm days and nights at the global scale. [Table 3-1, 3.3.1]	**Observed:** *Medium confidence* in increase in heat waves or warm spells in Europe. *Likely* overall increase in warm days and nights over most of the continent. **Projected:** *Likely* more frequent, longer, and/or more intense heat waves or warm spells in Europe. *Very likely* increase in warm days and nights. [Table 3-2, Table 3-3, 3.3.1]	Observations and projections can provide information for specific urban areas in the region, with increased heat waves expected due to regional trends and urban heat island effects. [3.3.1, 4.4.5]	Low-regrets options that reduce exposure and vulnerability across a range of hazard trends: • Early warning systems that reach particularly vulnerable groups (e.g., the elderly) • Vulnerability mapping and corresponding measures • Public information on what to do during heat waves, including behavioral advice • Use of social care networks to reach vulnerable groups Specific adjustments in strategies, policies, and measures informed by trends in heat waves include awareness raising of heat waves as a public health concern; changes in urban infrastructure and land use planning, for example, increasing urban green space; changes in approaches to cooling for public facilities; and adjustments in energy generation and transmission infrastructure. [Table 6-1, 9.2.1]
Increasing losses from **hurricanes** in the USA and the Caribbean	Exposure and vulnerability are increasing due to growth in population and increase in property values, particularly along the Gulf and Atlantic coasts of the United States. Some of this increase has been offset by improved building codes. [4.4.6]	**Observed:** *Low confidence* in any observed long-term (i.e., 40 years or more) increases in tropical cyclone activity, after accounting for past changes in observing capabilities. **Projected:** *Likely* that the global frequency of tropical cyclones will either decrease or remain essentially unchanged. *Likely* increase in average tropical cyclone maximum wind speed, although increases may not occur in all ocean basins. Heavy rainfalls associated with tropical cyclones are *likely* to increase. Projected sea level rise is expected to further compound tropical cyclone surge impacts. [Table 3-1, 3.4.4]	See global changes column for global projections.	Limited model capability to project changes relevant to specific settlements or other locations, due to the inability of global models to accurately simulate factors relevant to tropical cyclone genesis, track, and intensity evolution. [3.4.4]	Low-regrets options that reduce exposure and vulnerability across a range of hazard trends: • Adoption and enforcement of improved building codes • Improved forecasting capacity and implementation of improved early warning systems (including evacuation plans and infrastructures) • Regional risk pooling In the context of high underlying variability and uncertainty regarding trends, options can include emphasizing adaptive management involving learning and flexibility (e.g., Cayman Islands National Hurricane Committee). [5.5.3, 6.5.2, 6.6.2, Box 6-7, Table 6-1, 7.4.4, 9.2.5, 9.2.11, 9.2.13]
Droughts in the context of food security in West Africa	Less advanced agricultural practices render region vulnerable to increasing variability in seasonal rainfall, drought, and weather extremes. Vulnerability is exacerbated by population growth, degradation of ecosystems, and overuse of natural resources, as well as poor standards for health, education, and governance. [2.2.2, 2.3, 2.5, 4.4.2, 9.2.3]	**Observed:** *Medium confidence* that some regions of the world have experienced more intense and longer droughts, but in some regions droughts have become less frequent, less intense, or shorter. **Projected:** *Medium confidence* in projected intensification of drought in some seasons and areas. Elsewhere there is overall *low confidence* because of inconsistent projections. [Table 3-1, 3.5.1]	**Observed:** *Medium confidence* in an increase in dryness. Recent years characterized by greater interannual variability than previous 40 years, with the western Sahel remaining dry and the eastern Sahel returning to wetter conditions. **Projected:** *Low confidence* due to inconsistent signal in model projections. [Table 3-2, Table 3-3, 3.5.1]	Sub-seasonal, seasonal, and interannual forecasts with increasing uncertainty over longer time scales. Improved monitoring, instrumentation, and data associated with early warning systems, but with limited participation and dissemination to at-risk populations. [5.3.1, 5.5.3, 7.3.1, 9.2.3, 9.2.11]	Low-regrets options that reduce exposure and vulnerability across a range of hazard trends: • Traditional rain and groundwater harvesting and storage systems • Water demand management and improved irrigation efficiency measures • Conservation agriculture, crop rotation, and livelihood diversification • Increasing use of drought-resistant crop varieties • Early warning systems integrating seasonal forecasts with drought projections, with improved communication involving extension services • Risk pooling at the regional or national level [2.5.4, 5.3.1, 5.3.3, 6.5, Table 6-3, 9.2.3, 9.2.11]

importance of these trends for decisionmaking depends on their magnitude and degree of certainty at the temporal and spatial scale of the risk being managed and on the available capacity to implement risk management options (see Table SPM.1).

Implications for Sustainable Development

Actions that range from incremental steps to transformational changes are essential for reducing risk from climate extremes (*high agreement, robust evidence*). Incremental steps aim to improve efficiency within existing technological, governance, and value systems, whereas transformation may involve alterations of fundamental attributes of those systems. Transformations, where they are required, are also facilitated through increased emphasis on adaptive management and learning. Where vulnerability is high and adaptive capacity low, changes in climate extremes can make it difficult for systems to adapt sustainably without transformational changes. Vulnerability is often concentrated in lower-income countries or groups, although higher-income countries or groups can also be vulnerable to climate extremes. [8.6, 8.6.3, 8.7]

Social, economic, and environmental sustainability can be enhanced by disaster risk management and adaptation approaches. A prerequisite for sustainability in the context of climate change is addressing the underlying causes of vulnerability, including the structural inequalities that create and sustain poverty and constrain access to resources (*medium agreement, robust evidence*). This involves integrating disaster risk management and adaptation into all social, economic, and environmental policy domains. [8.6.2, 8.7]

The most effective adaptation and disaster risk reduction actions are those that offer development benefits in the relatively near term, as well as reductions in vulnerability over the longer term (*high agreement, medium evidence*). There are tradeoffs between current decisions and long-term goals linked to diverse values, interests, and priorities for the future. Short- and long-term perspectives on disaster risk management and adaptation to climate change thus can be difficult to reconcile. Such reconciliation involves overcoming the disconnect between local risk management practices and national institutional and legal frameworks, policy, and planning. [8.2.1, 8.3.1, 8.3.2, 8.6.1]

Progress toward resilient and sustainable development in the context of changing climate extremes can benefit from questioning assumptions and paradigms and stimulating innovation to encourage new patterns of response (*medium agreement, robust evidence*). Successfully addressing disaster risk, climate change, and other stressors often involves embracing broad participation in strategy development, the capacity to combine multiple perspectives, and contrasting ways of organizing social relations. [8.2.5, 8.6.3, 8.7]

The interactions among climate change mitigation, adaptation, and disaster risk management may have a major influence on resilient and sustainable pathways (*high agreement, limited evidence*). Interactions between the goals of mitigation and adaptation in particular will play out locally, but have global consequences. [8.2.5, 8.5.2]

There are many approaches and pathways to a sustainable and resilient future. [8.2.3, 8.4.1, 8.6.1, 8.7] However, limits to resilience are faced when thresholds or tipping points associated with social and/or natural systems are exceeded, posing severe challenges for adaptation. [8.5.1] Choices and outcomes for adaptive actions to climate events must reflect divergent capacities and resources and multiple interacting processes. Actions are framed by tradeoffs between competing prioritized values and objectives, and different visions of development that can change over time. Iterative approaches allow development pathways to integrate risk management so that diverse policy solutions can be considered, as risk and its measurement, perception, and understanding evolve over time. [8.2.3, 8.4.1, 8.6.1, 8.7]

Box SPM.2 | Treatment of Uncertainty

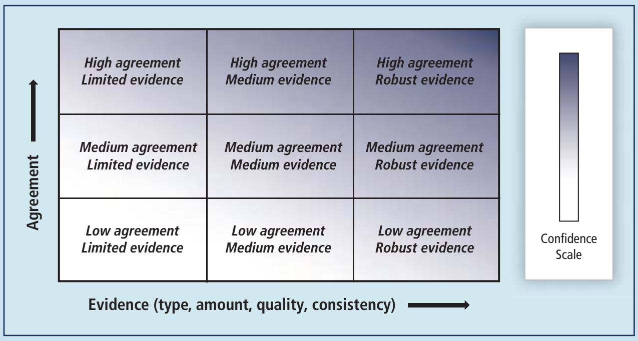
Based on the Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties,[6] this Summary for Policymakers relies on two metrics for communicating the degree of certainty in key findings, which is based on author teams' evaluations of underlying scientific understanding:

- Confidence in the validity of a finding, based on the type, amount, quality, and consistency of evidence (e.g., mechanistic understanding, theory, data, models, expert judgment) and the degree of agreement. Confidence is expressed qualitatively.
- Quantified measures of uncertainty in a finding expressed probabilistically (based on statistical analysis of observations or model results, or expert judgment).

This Guidance Note refines the guidance provided to support the IPCC Third and Fourth Assessment Reports. Direct comparisons between assessment of uncertainties in findings in this report and those in the IPCC Fourth Assessment Report are difficult if not impossible, because of the application of the revised guidance note on uncertainties, as well as the availability of new information, improved scientific understanding, continued analyses of data and models, and specific differences in methodologies applied in the assessed studies. For some extremes, different aspects have been assessed and therefore a direct comparison would be inappropriate.

Each key finding is based on an author team's evaluation of associated evidence and agreement. The confidence metric provides a qualitative synthesis of an author team's judgment about the validity of a finding, as determined through evaluation of evidence and agreement. If uncertainties can be quantified probabilistically, an author team can characterize a finding using the calibrated likelihood language or a more precise presentation of probability. Unless otherwise indicated, *high* or *very high confidence* is associated with findings for which an author team has assigned a likelihood term.

The following summary terms are used to describe the available evidence: *limited*, *medium*, or *robust*; and for the degree of agreement: *low*, *medium*, or *high*. A level of confidence is expressed using five qualifiers: *very low*, *low*, *medium*, *high*, and *very high*. The accompanying figure depicts summary statements for evidence and agreement and their relationship to confidence. There is flexibility in this relationship; for a given evidence and agreement statement, different confidence levels can be assigned, but increasing levels of evidence and degrees of agreement are correlated with increasing confidence.



High agreement *Limited evidence*	*High agreement* *Medium evidence*	*High agreement* *Robust evidence*
Medium agreement *Limited evidence*	*Medium agreement* *Medium evidence*	*Medium agreement* *Robust evidence*
Low agreement *Limited evidence*	*Low agreement* *Medium evidence*	*Low agreement* *Robust evidence*

A depiction of evidence and agreement statements and their relationship to confidence. Confidence increases toward the top-right corner as suggested by the increasing strength of shading. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality evidence.

The following terms indicate the assessed likelihood:

Term*	**Likelihood of the Outcome**
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability

* Additional terms that were used in limited circumstances in the Fourth Assessment Report (*extremely likely:* 95–100% probability, *more likely than not:* >50–100% probability, and *extremely unlikely:* 0–5% probability) may also be used when appropriate.

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[6] Mastrandrea, M.D., C.B. Field, T.F. Stocker, O. Edenhofer, K.L. Ebi, D.J. Frame, H. Held, E. Kriegler, K.J. Mach, P.R. Matschoss, G.-K. Plattner, G.W. Yohe, and F.W. Zwiers, 2010: *Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties*. Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland, www.ipcc.ch.