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Wanli Wang
1, Wuhan University school of resource and environmental science 2,wuhan regional climate center,CMA,

美国气象学会最新“气候变化”报告摘编

（2019 年 04 月 15 日美国气象学会理事会通过）

王万里 [1,2,3]

(1.中国气象局武汉(华中)区域气候中心,湖北武汉,430074。2.武汉大学资源与环境科学学院,湖北武汉,430079。3.云南大学地球科学学院，云南昆明，邮编 650091,)

摘要:

自然变率在量级和空间特征上都不能解释过去几十年地表（ 气温）的平均暖化程度。20 世纪中叶以来观测的地表暖化程度已经超过自然变率的正常水平，超过这部分极有可能由人类活动造成。过去几十年人类活动对气候的突出影响表现在以下几方面：大气层暖化；海洋暖化；大陆上的暴雨增强；海洋上层酸化；日极端平均气温的强度频度都在增加；北半球雪盖冰盖减小；海平面的增高；一些纬度的季节性地表暖化；已观测到对流层整层暖化；平流层降温等。

一， 前言：

2019 年 04 月 15 日美国气象学会理事会通过气候变化报告，其基本要点是承认*当前气候变暖由人类活动引起*。报告开宗明义，称该报告秉承可信，客观，前沿（科学上最新），以通俗方式对公众解释气候变化。尽管报告措词婉转表述方式隐蔽，甚至有些地方还暗地陈述相反观点。但总体来说还是认为今天的全球暖化进度已经超过了自然变率的正常水平，承认超过那部分极可能由人类活动引起。这是个积极的信号，表明美国学界在气候变化问题上能各抒己见，美国气象学会作为一个世界级的专业学会，在美国内和世界上都具有重大影响。其报告能反映全球气候变化方面一些新动态，另外，单从学术层面来讲也能为气候变化这一学科提供更多参考资料，所以具有一定的积极和现实意义。现翻译成文以资借鉴。

二，美国气象学会气候变化主要观点

1， 提供过去 100 多年气候为什么会变化？气候又是怎样变化？以及未来气候又如何变化？特别强调气候近期的年代际变化与人类排放温室气体之间的联系。
2，过去几十年人类活动对气候的影响包括：大气层暖化；海洋暖化；大陆上的暴雨增强；海洋上层酸化；日极端平均气温的强度频度都在增加；北半球雪盖冰盖减小；海平面增高；一些纬度季节性地表暖化；已观测到对流层暖化；平流层降温等。
3，这些变化与增加温室气体的理论预期一致。
4，气候自然变率不能完全解释过去半世纪全球地表气温的增加速度。自然变率如：地球轨

道；太阳活动;火山活动等。

5，另外，用其他的一些“短的”自然变率：如某地到某地 ，从一些年代际到一些年代际的气候自然变率，如厄尔尼若到拉尼娜有 2 年到 7 年尺度的转化；太平洋海洋环流、大西洋海盆洋流的年代际到多年代际尺度变化；把以上这些因素考虑在内，在量级和空间特征上都不能解释过去几十年地表（气温）的平均暖化程度。报告认为 20 世纪中叶以来观测到的地表暖化极有可能由人类活动造成。

6，古气候（代用资料），比如，树木年轮，珊瑚礁，冰心，海和湖的沉积物，石笋等表明：当前地表暖化的尺度和上升速率都突破最近两千年的自然变率水平，前一个间冰期即12.5 万年前全球气温增暖速率就与今天的持平，那时海平面比今天高 6-9 米，预计到下个世纪，全球气温将突破百万年来的地质水平。

气候如何变化？

7，地球气候正在暖化，观测显示绝大多数地区的地表气温、海洋水温都在增高，高纬地区冰雪盖正在萎缩，数据显示地表气温 1901-2017 年间每一百年增加 0.8 度，但 1979-2017年间每一百年增加 1.9 度。除了以上长期暖化趋势外，地表气温在与大气、海洋、陆地、冰雪圈（地球的雪冰转化部分）相互作用过程中显示出年际和年代际波动，这些过程都代表了自然变率。但全球而言不是每年都比它的前一年热，2011 年就冷于它的前 10 年，然而截至 2018 年最热的 4 年是 2015 年,2016 年,2017 年,2018 年，其中 2016 年为最热的一年。

8. 北半球中高纬度陆地暖化得最厉害，这一现象冬春明显而夏秋反而不突出。如北美的阿拉斯加以及加拿大的中北部就是这样，南半球靠南极的南高纬度地区 9-11 月（南半球春季）地表暖化最为凸显。如 1979 年以来的南极洲西部的 ROSS 冰架等。暖化是乎不仅仅是季节气温，美国在日最高气温和日最低气温中从 2000 年进入到 2010 年后期就曾两次刷新“极端值”。

9，对流层暖化：从地表到 10 公里高度都在暖化，暖化程度低层大于中层；中层大于高层，平流层低层（直接连接对流层高层的那一层）随着温室气体的进一步增多将继续变冷。

10，海洋占地表 70%，海表和海洋上层也已暖化，沿北极圈的 Barents 和 Kara、亚洲东海岸、北美北部、赤道印度洋、南半球大陆的周边海洋、南海大部都在以海表年均温度每一百年接近或超过 1℃的速率暖化。相比之下，在很有限的小范围，如靠近格陵兰岛的北大西洋，南极洲西部的冰架 Amundsen 和 bellingshausen 海域有个别冷的趋势。1950年以来，在北大西洋 0-700 米深的海洋上层中海水热量已明显增加，而在 700 至 2000米深的中层海洋海水热量也显增加趋势。

11，除了广泛暖化影响海洋生命外，海水酸化也影响了海洋。由于她吸收过多来自大气中的二氧化碳，酸化后的海洋分解出的氧气数量减少。观测显示比上个 100 年，海洋酸化程度提高 25%， ph 值略减少 0.1，酸化影响了海洋生物，如影响了钙和碳酸盐岩类的构造，包括贝类、珊瑚礁、多系列浮游生物。另外，沿海岸线的污染加上海洋中氧气锐减的共同作用容易形成“海洋死亡带”，从而导致大量鱼类死亡。另外，海洋暖化在量级上的提升和在时间上的延长等极端趋势的频繁出现，严峻威胁当下海洋生态系统安全，如像2015-2016 年间出现的全球性珊瑚礁“漂白或白化”事件。

12，海平面上升，据估计 20 世纪海平面已经上升 17 厘米，1990 年以来还呈加速趋势，经1993 年至今起用的卫星测高技术测量，结果表明海平面每年增高约 2.9 毫米左右，在此基础上具体区域增高程度或大或小，主要取决下面这些大地垂直运动的影响：如地壳活动、地下水流失、洋流低频振荡，冰川调整等。当然海平面即便是小幅上升对小岛国

家和沿岸地区也构成严重威胁。

13，仪器时代以来冰雪圈变化显著、格陵兰岛、南极洲冰架、阿尔卑斯山冰川、冰盖、大陆雪盖以及海冰，2002 至 2016 年经“重力”卫星测算，格陵兰岛流失的冰架相当于每年使海表上升 0.75 毫米；南极洲相当于 0.33 毫米，格陵兰岛的流失率是前 10 年的 3 倍；全球高山冰川按质量平衡计算，过去 100 年相当于使全球海表平均每年上升 1 毫米；季节性减少的大陆雪盖和冰盖虽然对海平面上升没有突出的直接影响，但却影响了对太阳辐射的吸收、也影响了大气边界层的温度湿度以及淡水的存储；多种数据表明晚春北半球大陆雪盖的深度和宽度都有下降趋势，影响了地表径流，这是美国西部重要的水资源。

14，北极海冰，每年 9 月为最小，1979 年到 2018 年每 10 年萎缩 13%，其中面积上较前 40 年减少 50%，超过了自然变率。另外一方面，南极洲的海冰面积在有些地方减少的同时，也有些地区是增加的，这是半球非对称性对温室气体增加的一种响应形式，并非意料之外，主要因为南半球大尺度深水海洋冷水上翻所致，其限制了外强迫对地表变化的影响。

15，降水是地球大气、海洋、陆地、冰雪圈之间的关键环节。目前北半球中高纬度有增加趋势，尤其秋季，就年降雨量在美国西南部是减少的，但在美大平原、 中西部、东北部是增加的。在 1900 以来的近 100 多年里，全美平均降雨量略增加 4%，这 4%多来自秋季降水中的“强降雨或暴雨”比如连续 5 年最大日降水量。1900 年以来“强降雨或暴雨”频度强度两者都是增加的，特别是在美国东部和东北部，一些平常干旱区域中的某些地区的降水量有增加趋势。可是，在另外一些高温和降雨减少的地区中，干旱衍生的相关风险在加大，如全球山火期加长，山火点扩大等。

16， 1980 年以来大西洋飓风的强度个数都在增加，但这多数要归为大气和海洋中的自然变化，全球其他大洋中的台风飓风活动没有明显趋势也没有减少活动，如果有目前情况也是不甚明朗。不过海洋暖化可能会给飓风提供更多的能量，使飓风强度增强。

17，没有迹象说明美国最强龙卷（指 EF4 或 EF5 级别）在增加，但年均龙卷活动至 1970 年以来变化很大，要么是强龙卷，要么是中-小强度龙卷，它们之间的转化时间变得更长。因为龙卷、强雷暴及其他局地天气的自然变化范围宽泛，可能需要更长期时期，这些与温室气体有联系的变化才能够被检测出来。

气候为什么会变化？

18，气候是指大气、海洋、陆地、冰雪圈过去几十年的平均与变化的统计描述，以能量收支平衡为主要特征，这些很大程度上依赖于大气构成，人类活动能改变大气构成，如温室气体、气溶胶、地貌改变等。自然变率也影响着气候，这包括海洋环流、大西洋和太平洋海温的年代际或世纪波动。

19，人类导致的气候短期变化趋势并非线性，因为有来自年代际或世纪长度的大西洋太平洋海温自然变化的影响，有时它们并未完成一次完整的循环。然而，自然变率又不能全部解释过去 120 年中许多的上述变化，比如年代际、世纪或千年尺度的洋流或大西洋和太平洋的海温波动。科学证据指出刚刚过去的半个多世纪、气候变暖由人类活动引起，如人类活动导致了大气中的二氧化碳、氯氟碳化合物（氟利昂）、甲烷、臭氧以及氧化亚氮等温室气体含量的明显增加。

20，非水蒸气类的温室气体中，二氧化碳最为突出，主要由石化燃料燃烧、水泥生产、荒漠化等引起其浓度上升。人类产生温室气体总量的近一半停留在大气层中，其余由海洋和陆地生态圈（如大地上的土壤和植被）共同接纳，这是两个主要的二氧化碳收集器，其日常或季节性与大气层进行着大量的二氧化碳交换，二氧化碳一旦驻入大气层的话，大自然自身需要 1000 年或更长时间才能完全消除，期间总量的 50%至少 50 年会停留在大

气中，总量的约 30%驻留期至少也会达到 100 年。

21，水蒸气是另外一种重要的温室气体，但它对气温变化的响应快，因此多被视为一种反馈机制，其放大了气候系统对辐射强迫即变化的响应，可认为它仅放大了像二氧化碳这类"长效"温室气体的温室效应 。

22，甲烷是第三大温室气体，即来源于自然过程也来自人类活动，像湿地、野生动植物排放属于自然过程，而农业、大型填埋场、石化燃料的提取就属人类过程。就甲烷排放总量的大部分而言，今天的人类活动应负主要责任，举一例，从地下利用液压破碎过程抽取石油和天然气将使甲烷进入大气。甲烷生命远远小于二氧化碳，但通过 100 年比较和权重后发现：甲烷每个分子的温室效应或潜在加热能力大于二氧化碳 30 倍 。工业革命前甲烷浓度小于 800/10 亿（800ppb）；而现在超过 1800/10 亿(1800ppb)。随着气候变化，自然界排放的甲烷可能还要增加，比如，由于高纬度大陆地表下冻土层融化，一些在海洋沉积层里富含碳层中，以涵水状态储蓄的甲烷就可能溢出而进入到大气层。

23，悬浮在大气中的固态和液态细小颗粒物（直径见于亿分之一毫米到毫米之间），总体称叫气溶胶，如来自空气污染中的硫酸盐和尘埃等。大气中气溶胶的多寡和物理性质的改变会导致气候变化，具体来讲气溶胶改变了可见光辐射和红外辐射，能影响云和降水的空间分布，人类活动产生的多数气溶胶的**部分功能**与温室气体相反，它们反而使星球变冷，气溶胶在对流层的悬浮时间和跨度远短于像二氧化碳类的长效温室气体，偶然大规模富含硫类的火山爆发会在平流层中产生大量气溶胶，它们反而能降低地球表面温度，为期能达数年。另外，农业、灌溉、荒漠化及城市化也影响了大气层与地表之间水和能量的交换、结果也会促成区域尺度的气候改变。

未来气候能预计吗？

24，通过建立在物理基础定理和已知物理原理基础上的大气-海洋-陆地-冰圈地球多圈层系统模式，未来几十年的气候将被模拟出来，这些模式详尽的制作出未来 100 公里分辨率的大尺度海洋大气的运动形态。随着温室气体和其他强迫的变化，同时考虑其浓度在假设排放情景前提下的演变，未来气候对这些大气构成变化的响应是能够模拟出来的，这样计算得到的未来气候强调的是大气海洋的平均态和极端态，集中于几十年尺度到百年尺度，而非整个气候系统的未来瞬时态，这样的预计完全依据能量收支平衡的演变以及在气候系统变化中的诸如海洋、陆地、冰雪圈等慢变量的变化估计，以及它们之间的相互作用过程。

25，自然变率会模糊人类活动对多年代际尺度气候变化的贡献，这包括 20 世纪头几十年大气的慢速暖化， 以及 21 世纪初期的快速暖化，这类暖化速度的变化在对未来气候的预计中是能够看得到的。

26，气候模式优点缺点并存，比如它们的可靠性指能代表多种基础物理过程，这些过程产生了天气气候，这包括中纬度风暴、热浪、干旱、和极端季节降雨量，结果很多模式都有能力模拟出 20 世纪气候的广泛特征，然而，一些关键的物理过程诸如云、对流、海洋涡旋、深水海洋，碳循环等目前都很粗放并不精细，这些缺陷也是这类模式模拟当今气候、自然变率、以及近期气候演变中产生错误的基本根源。

27，区域尺度是模拟和预计未来气候中的一大难题，这一尺度密切联系着人类对气候变化的适应实践。不过有些模式也能成功地模拟出 20 世纪的暖化，这与未来气候变化也一致，这个世纪的其他全球性区域性变化特征也能够期待，而且，近期发展出的高分辨气候模式，也有利于改进和提高对区域尺度未来气候的模拟能力。

未来气候

28，建立在对过去变化的认识和对今后人类活动预计的基础上，预计未来 100 年地表将继续暖化，程度至少像过去 100 年的那样，或是过去的 2-6 倍。进一步而言，人类活动产生的气溶胶，虽然目前减缓了暖化程度，但未来这样的减缓也会受到削弱。

29，即便大气温室气体浓度某一程度保持今天的水平，全球暖化、海平面上升等气候变化现象，下一个几十年也将继续，这样的延续主要源于海洋极地冰架对环境温度、热量输入、以及空气海洋中化学变化的内在慢速响应。

30，预计未来排放情景，相对于 1850-1900 年预计到本世纪末气候模式预计全球海平面将上升 0.3-1.2 米，平均全球表层温度一般将上升 1.5 度，最高也能到 4 度。但如排放限制在国际协议的水平上的话，未来地球表层温度上升区间将收窄 2.6 度到 3.1 度；海洋将更加酸化，ph 值再减 0.3 到 0.4 或酸化度将提高 150%。

31，就区域尺度而言，气候模式预计副热带降雨一般而言是减少的，结合气温增高降水减少将加重副热带地区的干旱，高纬度地区降雨增多并伴有极端降雨事件，北冰洋海冰预计将变成季节性海冰，或在某些地方整体消失。北极地区大陆边沿地带更易受到风暴海浪的侵扰，美国阿拉斯加地区的暖化快于美国其他地区，且将继续并伴随地下冻土层的进一步融化。

32，总之，减少温室气体排放、将温室气体移出大气层，少些的大规模火山活动、让太阳能返回太空都是避免进一步暖化、避免全球性海平面进一步上升，避免极端降水极端热浪，以及确保地球生态系统安澜的唯一途径，适应至少能减缓或降低气候变化对全球经济和人类健康的某些负面影响。

二，　结语

气候变化问题是一个非常复杂的科学问题，因为它几乎涵盖了所有的自然科学学科和工程技术学科以及部分文化学科，由于作者水平有限，成文仓促，对一些专业把握不一定很准确，所以错误在所难免。但正如报告内容多种多样，但不掩盖其主题和主要结论一样：**今天的全球变暖已经超过了自然变率的正常水平，超过那部分极有可能是人类活动所造成**。作者也力求在翻译中不走大样不走大题，力求保持原报告的基本主线。

译者：王万里，1961 年-，男，河南登封人，出生地贵州安顺市，1982 年 2 月本科毕业于云南大学地球物理系气象专业。L 概率分布函数及相关系列理论发现人和创始人；　主要研究方向：气候动力；天气动力。美国气象学会（AMS）会员；美国地球物理学会（AGU）会员；伦敦数学学会（LMS）会员；英国皇家统计学会（RSS）会员。国际气候、气候变化、水、能源、海洋、森林、生物多样性通讯成员。庞加莱研究所（ihp）索邦（巴黎）大学（sorbonne university）访问学者(配办公室)，国际学术识别码 orcid.org/0000-0002-4265-5158。

Author
Wanli Wang (1961-), or w.-l. Wang (1961-), or w.w(1961-). Man, Orcid.org/0000-0002-4265-5158;
ScholarID: CN-BU74675J; The Discoverer of L Probability Distribution Function; The founder of the theory

system of L probability distribution ; The inventor of L probability distribution. Major in climate dynamics, meteorological dynamics and L probability distribution function;

Email:xiaowanw2002@yahoo.com；xiaowanw@aliyun.com；642177543@qq.com；xiaowanw2002@gmail.com ；17787954998@189.cn

Mobile：008613658898898；008618986211996；008617787954998; 008602787410611(home)；0086087163347998(home)；Passport: eg5780283 or g36272099；Chinese id: 510102196102051614；

Address: 302 room-3 door-25 building-tiaoyuan residential area-hubei meteorological bureau-3 number-dong hu dong street- hong shang district- wuhan city –china, zip code: 430074

Climate Change

An Information Statement of the American Meteorological Society

(Adopted by the AMS Council on 15 April 2019)

The AMS Information Statement seeks to provide a trustworthy, objective, and scientifically up-to-date explanation of climate change to the public using easily understood language.

Background

This statement provides an overview of how and why global climate has changed over the past century and why it will continue to change in the future. It is based on peer-reviewed scientific literature and reflects current scientific understanding. A particular focus is on climate change in recent decades and its connection to human-produced greenhouse gases.

Executive Summary

Research has found a human influence on the climate of the past several decades. Its manifestation includes the warming of the atmosphere and oceans, intensification of the heaviest precipitation over continental areas, increasing upper-ocean acidity, increasing frequency and intensity of daily temperature extremes, reductions in Northern Hemisphere snow and ice, and rising global sea level. The latitudinal and seasonal observations of the surface warming and the observed warming of the troposphere and cooling of the stratosphere are consistent with theoretical expectations from increased concentrations of greenhouse gases.

The increase in global average surface temperature over the past half-century cannot be fully explained by natural climate variability, e.g., responses to Earth's orbital changes over thousands of years, or natural climate forcing such as from solar or volcanic variability. The observed warming rate varies from place to place and from decade to decade because of natural climate variations, such as natural swings between El Niño and La Niña on time scales of two to seven years, and variations in ocean circulation in the Pacific and Atlantic basins on decadal to multi-decadal timescales. The influence of these relatively short-period fluctuations is factored into climate change analyses. These natural fluctuations have neither the magnitude nor the spatial characteristics to explain the observed warming of Earth's average surface temperature over the past several decades. The IPCC (2013), USGCRP (2017), and USGCRP (2018) indicate that it is extremely likely that human influence has been the dominant cause of the observed warming since the mid-twentieth century.

Proxies, which are indirect measurements of past temperature obtained from archives, such as tree rings, corals, ice cores, lake and marine sediments, and cave stalagmites, reveal that the rate and magnitude of the current global temperature change is likely exceptional in the context of the last two thousand years. Global temperatures were last on par with the present ones in the previous Interglacial Period (125,000 years ago), when sea level was 6–9 m (20–30 ft) higher than today. Projected warming over the next century will likely place global temperatures in a range not seen in millions of years of geologic history.

How is climate changing?

Earth’s climate is warming. Observations show increasing surface air and ocean temperatures over most regions and diminishing snow and ice cover at high latitudes. Global surface temperature has increased at an average rate of 0.8°C (1.4°F) per century over the period 1901–2017, and 1.9°C (3.4°F) per century during 1979–2017. In addition to this long-term warming, the global surface temperature fluctuates from year to year and decade to decade from interactions of the atmosphere, ocean, land surface, and cryosphere (the snow and ice-covered portions of Earth); these processes represent natural climate variability. Consequently, not every year is warmer than the preceding one, globally: For example, 2011 was cooler than the ten previous years. However, the four warmest years on record through 2018 are the four most recent ones—2015, 2016, 2017, and 2018—with 2016 being the warmest.

The surface warming over northern continents is largest in the middle to high latitudes; it is pronounced in winter–spring and notably smaller in summer–autumn. Over North America, the winter–spring surface warming is largest in Alaska and central-northern Canada. The surface warming in the high southern latitudes is largest in spring (September–November), with warming over West Antarctica and the Ross Ice Shelf since 1979. The warming is apparent not just in seasonal temperatures: The United States has had twice as many record daily high maximum temperatures as record daily low minimum temperatures from 2000 into the late 2010s.

The warming is not confined to Earth’s surface: The troposphere—the region extending upward from the surface to about 10 km (30,000 ft) altitude—has also warmed. Although tropospheric temperature records are not as long or spatially dense as those at the surface—limiting the ability to characterize long-term trends—both the lower and middle troposphere have warmed, with the former warming more than the latter. Importantly, cooling is present in the stratosphere (the region directly above the troposphere)—which together with surface warming is consistent with the predicted response to increasing greenhouse gas concentrations.

The oceans, which cover about 70% of Earth’s surface, have warmed both at the surface and in the upper subsurface layers. Annual sea surface temperature has warmed notably (i.e., approaching or exceeding 1.0°C or 1.8°F per century) in the Barents and Kara Seas along the Arctic Rim, off the east coasts of Asia and northern North America, in the equatorial Indian Ocean, around the Southern Hemisphere continents, and across large stretches of the Southern Ocean. The cooling trends, in contrast, are small and spatially limited, confined to the North Atlantic near Greenland and the Amundsen and Bellingshausen Seas off the West Antarctic Ice Sheet. The heat content in the upper ocean (0–700 m; 0–2,300 ft) has also increased, notably in the North Atlantic, since at least the 1950s. There is also a strong positive heat content trend at middle oceanic depths (700–2,000 m; 2,300–6,500 ft).

In addition to the widespread warming, the oceans are becoming more acidic and the amount of dissolved oxygen is decreasing, impacting marine life. These changes are consequences of well-understood chemical and physical processes. Seawater becomes more acidic when it absorbs some of the excess carbon dioxide that has accumulated in the atmosphere. Observations show that the oceans have become 25% more acidic (0.1 pH decrease) over the last century. Ocean acidification affects marine organisms, notably those that build calcium carbonate structures, including shellfish, corals, and many species of marine plankton. Pervasive surface warming has led to reduced ocean oxygen levels that, when combined with coastal pollution, contribute to ocean “dead zones” and massive fish kills. An increase in the magnitude and duration of ocean temperature extremes represent an acute near-term threat to many marine ecosystems, including coral reefs, as apparent from the global-scale coral bleaching event of 2015–2016.

Globally averaged sea level is estimated to have risen by about 17 cm (6.7 in) during the twentieth century, with an acceleration evident since the early 1990s. The climate change–driven rate of sea level rise over the satellite altimeter era (1993–present) is about 2.9 mm/yr (0.1 in/yr). Regionally, the sea level rise can be larger or smaller depending on a number of factors, including vertical motion of the land itself (e.g., from tectonic activity, removal of groundwater, low-frequency changes in ocean circulation patterns, and adjustment due to past glaciations). Even small rises in sea level can be consequential for coastal communities and small island nations.

The cryosphere—regions on Earth where water is in the form of ice or snow—has changed significantly during the period of the instrumental record, including the large ice sheets on Greenland and Antarctica, alpine glaciers and small ice caps, terrestrial snow, and sea ice. Gravity-based satellite measurements of the 2002–2016 loss in ice sheet mass show that Greenland contributed to an equivalent sea level rise of about 0.75 mm/yr, and Antarctica to about 0.33 mm/yr; the loss rate for Greenland is more than three times larger than for the preceding decade. The global trend in the mass balance of alpine glaciers over the last century is equivalent to about 1 mm/yr of sea level rise. The loss of seasonal terrestrial snow (and ice), while not contributing significantly to sea level rise, influences the absorption of solar radiation, atmospheric boundary layer temperature and humidity, and freshwater storage. Multiple data sources indicate downward trends in Northern Hemisphere terrestrial snow cover extent and depth in late spring, which impact runoff—a key source of water in the western United States.

Arctic sea ice at its seasonal minimum in September has declined by about 13% per decade during 1979–2018, i.e., a 50% decline in extent over the preceding four decades, well beyond what can be expected from natural variability. On the other hand, Antarctic sea ice extent has increased in some regions while it has decreased in others. This hemispheric asymmetry in the response to rising greenhouse gases is not unexpected due to the large-scale upwelling of colder deep waters in the Southern Ocean, which limit the effects of surface-forced change.

Precipitation—a key link between the atmosphere, oceans, land surface, and the cryosphere—is increasing over the northern middle–high latitudes, especially in autumn. Over the United States, annual precipitation has decreased in the Southwest but increased over the Great Plains, Midwest, and the Northeast; U.S.-averaged precipitation has increased by about 4% since 1900, mostly from the increase in autumn precipitation. Heavy precipitation (e.g., maximum daily precipitation in consecutive 5-year segments) has increased in both intensity and frequency since 1900, especially in the eastern half of the United States and notably in the Northeast. Areas that receive limited precipitation, sometimes called drylands, are increasing in area. The combination of warmer temperature and reduced precipitation in some regions has increased the risk of drought and drought-related impacts. There is evidence that wildfire seasons are increasing globally and areas where wildfires occur are expanding.

The number and intensity of Atlantic hurricanes have both increased since the early 1980s, but much of this increase may be due to natural variability of the atmosphere and ocean. Furthermore, there is little trend or even a decrease in hurricane activity in other ocean basins, so the global trend, if there is one, is not clear. There is evidence that ocean warming is providing more energy to make hurricanes more intense.

There is no sign of an increase in the most violent U.S. tornadoes (those rated EF4 or EF5 on the Enhanced Fujita Scale). However, there is evidence that annual U.S. tornado activity has become more variable since the 1970s, with larger tornado outbreaks separated by longer periods of below-average tornado frequency. Because of the wide range of natural variability in tornadoes, severe thunderstorms, and other localized weather events, it may take longer for any persistent changes related to human-produced greenhouse gases to become detectable.

Why is climate changing?

Climate—the statistical description (both mean and variability) of the atmosphere–ocean–land–cryosphere system over a few decades—is characterized by the balance of incoming and outgoing energy, which strongly depends on the composition of the atmosphere. Consequently, climate can be affected by human-induced changes in atmospheric composition (greenhouse gases and aerosols) and land surface use/cover. Climate is also influenced by natural variability, which includes decadal to multi-decadal fluctuations of ocean circulation and temperature in the Atlantic and Pacific basins.

Anthropogenic (i.e., human-induced) climate change cannot be accurately characterized from linear trends over short periods, as these trends will likely have contributions from the incomplete cycles of natural decadal to multi-decadal variability. However, many of the above-noted changes in the past 120 years cannot be fully accounted for by natural climate variability such as the decadal to multi-decadal fluctuations of ocean circulation and temperature in the Atlantic and Pacific basins. Scientific evidence indicates that the leading cause of climate change in the most recent half century is the anthropogenic increase in the concentration of atmospheric greenhouse gases, including carbon dioxide (CO_2), chlorofluorocarbons, methane, tropospheric ozone, and nitrous oxide.

Other than water vapor, the most prevalent greenhouse gas is CO_2, whose concentration is rising mainly from fossil fuel combustion, cement production, and deforestation. About half the anthropogenic CO_2 input into the atmosphere has remained in the atmosphere, and the rest has been taken up by the oceans and terrestrial biosphere (i.e., soil and plants on land)—the two CO_2 reservoirs with which the atmosphere routinely exchanges large amounts of CO_2, seasonally. Once introduced, the CO_2 can reside in the atmosphere for 1000 years or more before it is removed by natural processes, with more than 50% of the introduced CO_2 remaining in the atmosphere for at least 50 years and roughly 30% remaining for at least 100 years.

Water vapor is another important greenhouse gas, but unlike CO_2, it responds quickly to temperature change. For this reason, it mostly acts as a feedback, amplifying the response of the climate system to changes in radiative forcing, for instance from long-lived greenhouse gases like CO_2.

A third important greenhouse gas is methane, which is produced both naturally, primarily by emissions from wetlands and wildlife, and from human activities such as agriculture, landfills, and fossil fuel extraction processes, with the human activities responsible for the majority of emissions today. For example, methane is a by-product of the hydraulic fracturing (fracking) process for extracting oil and natural gas from underground. Methane is shorter-lived and much less abundant than CO_2 but a much more effective greenhouse gas per molecule, with more than 30 times the warming potential of CO_2 by weight when compared over a 100-year period. The concentration of methane in the atmosphere was less than 800 parts per billion before the industrial revolution and is now measured at over 1,800 parts per billion. As the climate changes, the production of natural methane will likely increase, for example, due to melting of previously frozen carbon-rich soils in the permafrost zones of the high-latitude continents and the possible mobilization of methane trapped in hydrate form in oceanic sediment.

Human activity also affects climate through changes in the number and physical properties of tiny (nano- to micrometer diameter) solid particles and liquid droplets suspended in the atmosphere, known collectively as atmospheric aerosols, e.g., dust and sulfates from air pollution. Aerosols modify both visible and infrared radiation and can influence the spatial distribution of clouds and precipitation. Most aerosols originating from human activity act to cool the planet, partly counteracting the greenhouse warming. However, the time span in which aerosols remain suspended in the troposphere is much shorter than for greenhouse gases such as CO_2. Stratospheric aerosols generated by occasional large sulfur-rich volcanic eruptions can reduce the global surface temperature for a few years.

Changes in land surface use from agriculture, irrigation, deforestation, and urbanization also influence the surface exchange of water and energy with the atmosphere, generating regional climate change.

How can climate change be projected into the future?

Climate projections for decades into the future are made using computer programs that model the atmosphere–ocean–land surface–cryosphere system, based largely on fundamental physical laws and well-understood physical principles. These models explicitly simulate the large-scale [approximately 100 km (60 miles) or larger] motions of the atmosphere and ocean. By subjecting these models to time-dependent greenhouse gas concentrations and other forcings, with concentrations allowed to evolve in the future based on emission hypotheses (or “scenarios”), the simulated climate responds to such changes in atmospheric composition. Climate projections from such calculations focus on identifying the average (mean) state and extreme states of the atmosphere and ocean, summarized on the time scales of decades, rather than an instantaneous future state of the entire system. The projections depend on the evolution of the energy budget and its influence on the climate system's slowly varying system components—ocean, land surface, and the cryosphere—and their interactions.

Natural variability can obscure anthropogenic influences on climate at the multidecadal scale. Examples include a slower pace of atmospheric warming during the first decade of the twenty-first century and a more rapid pace during the mid-2010s. Such changes in the pace of warming are also seen in projections of future climate.

Climate models have both strengths and weaknesses. For example, they reliably represent many of the fundamental processes that govern weather and climate, including midlatitude storms, heat waves, droughts, and extreme seasonal precipitation. As a result, many models are able to simulate the broad features of the twentieth-century climate. However, some crucial processes like clouds and convection, ocean eddies, deep water formation, and carbon cycle remain crudely represented. These deficiencies are thought to underpin model errors in the representation of the present climate, its modes of natural variability, and its recent evolution. Climate simulations and projections are especially challenged on the regional scale—the scale of relevance in adaptation efforts. However, climate models successfully replicate the global warming of the twentieth century, and they agree that further warming and other global and regional changes can be expected this century. Furthermore, there are recent developments of higher-resolution climate models that can be used to project regional-scale changes.

How is the climate projected to change in the future?

Based on understanding of past changes and projections of future human activities, it is projected that over the next 100 years Earth’s surface will warm at least as much as it did in the past 100 years, and perhaps 2–6 times more. Further, the proportion of global warming that is offset by cooling from human sources of aerosols may diminish in the future.

Global warming and sea level rise would continue during the next few decades even if atmospheric greenhouse gas concentrations could somehow be held constant at their present levels. This decades-long delay is because of the inherent slowness with which the oceans and polar ice sheets respond to surrounding temperature, the input of heat, and changes in the chemistry of the air and oceans.

Climate models project the global average sea level to be 0.3–1.2 m (1.0–4.0 ft) higher, and the global average surface temperature to be warmer by more than 1.5°C (and up to 4.0°C depending on future emission scenarios) at the end of the twenty-first century relative to the 1850–1900 period. A narrower range for the global surface temperature increase (2.6°–3.1°C) is obtained in scenarios where emissions are restricted to the level of current international agreements. Oceans are also projected to be significantly more acidic (an additional 0.3–0.4 pH decrease, or +150% more acidic) by the end of this century.

At regional scales, climate models project a general reduction of precipitation in the subtropics, which, together with warmer temperatures, will have the effect of intensifying drought. An increase of precipitation in the high latitudes is also projected, with associated increasing extreme precipitation events. The sea ice in the Arctic Ocean is projected to become seasonal or disappear entirely from some places, making the continental margins of the Arctic more prone to damaging storms and ocean waves. Warming in Alaska, which is faster than in other parts of the United States, will continue, with likely further melting of permafrost.

Barring large increases in volcanic activity or decreases in solar energy output, reducing the amount of greenhouse gas emitted by human activity and/or accelerating the removal of these gases from the atmosphere is the only way to avoid much of the projected warming and its associated global-scale effects on sea level rise, precipitation and heat extremes, and ecosystem health. Adaptation could ameliorate at least some of the impacts of projected climate change on economies and human health.

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[This statement is considered in force until April 2024 unless superseded by a new statement issued by the AMS Council before this date.]