The State of Global Climate and Hazards posed by Sand and Dust Storms and Wildfires

By Greg Brock, Stéphanie Wigniolle and Chris Hewitt (WMO)

The State of Global Climate

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The State of Global Climate Report 2024[1], published by the World Meteorological Organization (WMO) in March 2025, highlights that 2024 was the warmest year in the 175year observational record, with the annually averaged global mean nearsurface temperature of 1.55 °C ± 0.13 °C above the 1850-1900 average used to represent preindustrial conditions. (Figure 1 below.) This beats the previous record set in 2023. While a single year above 1.5 °C warming does not indicate that the long-term temperature goals of the Paris Agreement are out of reach, it is though a wake-up call. Each of the past ten years (20152024) were individually the ten warmest years on record. (Note, the analysis is based on a synthesis of six global temperature datasets.)

In respect of atmospheric concentrations of the three main greenhouse gases – namely carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) – real-time data

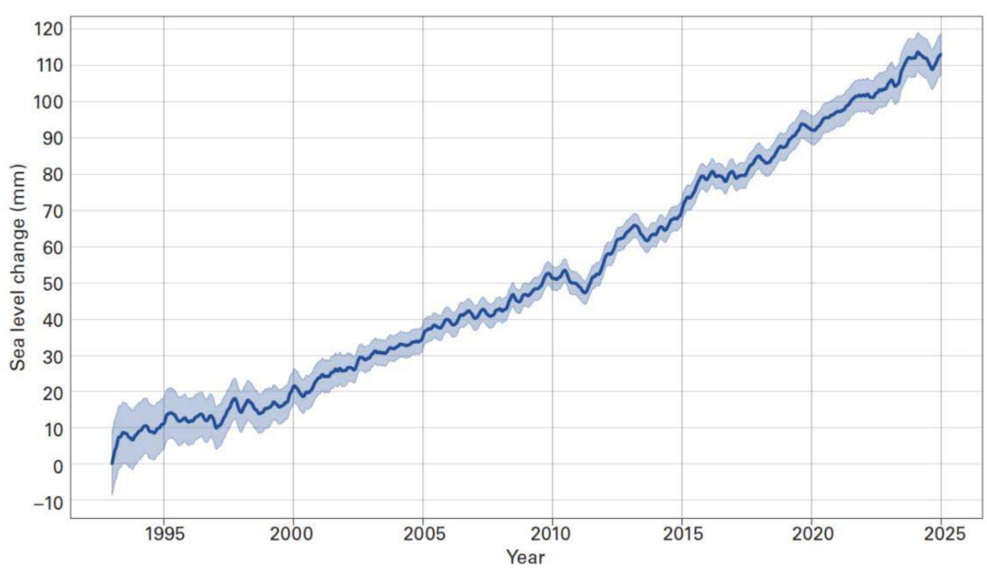

FIGURE 1: Annual global mean temperature anomalies relative to a pre-industrial (1850–1900) baseline shown from 1850 to 2024. Source: Data are from the six datasets indicated in the legend.

1 https://library.wmo.int/records/item/69455-state-of-the-global-climate-2024

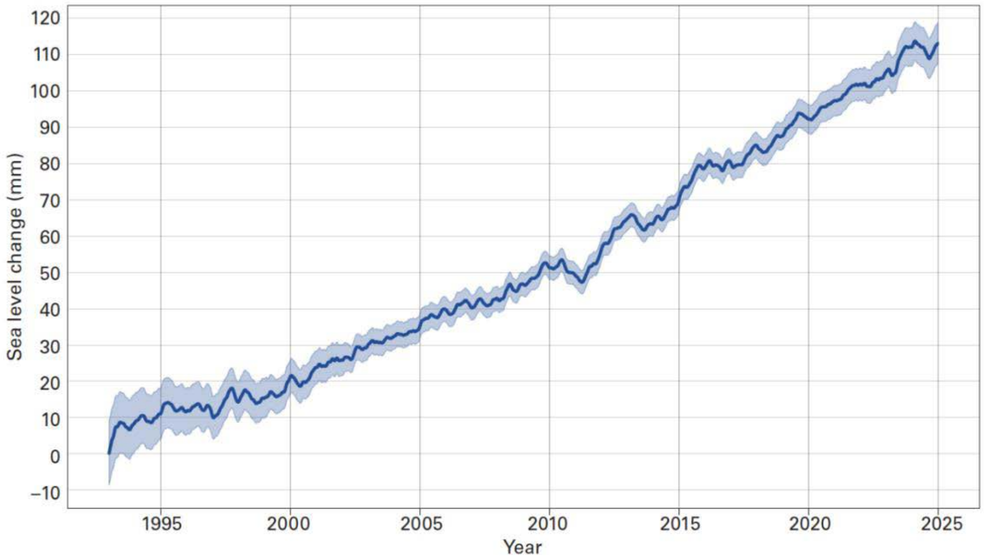

FIGURE 2: Seasonal global mean sea level change from 1993 shown for 1993–2024. The seasonal cycle has been removed from the data. The shaded area indicates the uncertainty. Source: Data from AVISO CNES.

from specific locations show that levels continued to increase in 2024. Moreover, in 2023 (the most recent year for which consolidated global annual figures are available), atmospheric concentrations of CO_2, CH_4 and N_2O were at their highest levels in the last 800,000 years. In calendar year 2023, for example, the concentration of CO_2 increased by 2.8 parts per million (ppm), representing the fourth largest within-year change since modern CO_2 measurements started in the 1950s. (Note, the rate of growth is typically higher during El Niño conditions due to an overall increase from fire emissions and reduced net terrestrial carbon sinks.) And concentration of CH_4 reached 1 934 ± 2 parts per billion (ppb), which is 265% of pre-industrial levels, while N_2O reached 336.9 ± 0.1 ppb, which is 125% of pre-industrial levels.

In respect of other climate change indicators of interest to aviation:

- The global mean sea level reached a record high in the satellite record (1993 to present). (Figure 2 above.) The rate of global mean sea-level rise in the past 10 years (20142025) was more than twice that recorded in the first decade of the satellite recorded (19932002), increasing from 2.1 mm per year between 1993 and 2002 to 4.7 mm per year between 2015 and 2024. In an aviation context, if the sea-level rise trend continues and without any adaptation or mitigation to build resilience, coastal and low-lying airports will be particularly vulnerable to an increased risk of flooding and storm surges.

- Most land areas in 2024 were warmer than the 30-year long-term average (19912020), with limited areas of below-average temperatures around Iceland, parts of Antarctica and the southern tip of South America. Record or near-record high annual mean temperatures were observed across large areas of the tropics from South and Central America east to the western Pacific. Other land areas outside of the tropics also experienced exceptionally high annual temperatures, including eastern North America, North Africa and Europe, and southern and eastern Asia. In an aviation context, warmer near-surface temperatures and extreme heat can negatively affect aircraft take-off performance and fuel efficiency, airport runway conditions and throughput, and may result in the imposing of more stringent weight restrictions.

- Unusually dry or unusually wet conditions were experienced across continents in 2024. In Africa, for example, drier than average (1991–2020) conditions were observed over much of Southern Africa, some locations in coastal West Africa and along the North

African coast, while parts of the Sahel region and parts of Central and southern East Africa were wetter than normal. Meanwhile, in South America, the Amazon lowlands and northern Andes to the Pantanal wetlands were drier than normal. And, in large parts of North-east, East and Central Asia and to a smaller extent also in South-east, South and South-west Asia, higher than normal precipitation totals were observed. Variance in the distribution of precipitation, i.e. lower than normal and higher than normal, was experienced elsewhere across the globe too. In an aviation context, unusually dry conditions can create an environment favourable to sand and dust storms, which may cause disturbances, including safety concerns, to air and ground operations.

In terms of impacts, extreme weather events in 2024 led to the highest number of new displacements recorded in a year since 2008. New, onward and protracted displacements affected significant numbers of people in fragile, and conflict affected contexts. Alongside the destruction of homes, critical infrastructure, forests, farmland and biodiversity, such extreme weather events can undermine resilience and pose significant risks to people on the move and those already living in displacement.

Tropical cyclones were responsible for many of the highest-impact events of 2024. Other high-impact events included abnormal cold and snowfall, extreme rainfall, severe flooding including flash flooding, an abnormally active monsoon season, exceptionally dry or severe drought conditions, and heatwaves.

Aviation was not immune to the impacts of extreme or high-impact weather events in 2024. In April 2024, the United Arab Emirates was affected by an extreme rainfall event, which led to flash flooding at Dubai international airport and the reported cancellation of several hundreds of flights and delays to the travel plans of thousands of passengers. A few months later, in July 2024, Houston international airport in the United States of America was affected by Hurricane Beryl, reportedly resulting in the cancellation of nearly a thousand flights. These are just a couple of examples, among many, of how aviation can be impacted by extreme or high-impact weather events. While caution should be exercised to link such events to climate change, changes in the frequency and/or intensity of weather events, and where they occur, requires aviation to be proactive in its preparedness and response, through the building climate adaptation, mitigation and resilience and the appropriate use of meteorological and climatological information from authoritative sources, including national meteorological and hydrological services of WMO Members.

Hazards posed by sand and dust storms and wildfires

By Sara Basart (WMO

Atmospheric composition-related hazards — such as sand and dust storms (SDS) and smoke from vegetation fires — pose increasing safety and operational risks to international civil aviation. These hazards can cause severely reduced visibility, strong gusty winds, turbulence and wind shear, all of which have contributed to aviation incidents and accidents. Dust-induced icing has also been linked to fatal occurrences (Scherllin-Pirscher et al, 2025)[2]. In addition to immediate flight safety concerns, prolonged exposure to airborne dust and smoke accelerates corrosion, causes surface abrasion, and leads to molten particle ingestion in engine hot-section components — compromising aircraft airworthiness, heightening maintenance needs, and increasing lifecycle ownership costs.

The frequency and severity of SDS and wildfires are expected to rise in many regions due to the impacts of climate change (WMO State of the Global Climate, 2024)[3]. These changes contribute to both the expansion of arid regions and the growing vulnerability of ecosystems to fire, amplifying the scale and frequency of dust and smoke events that may affect aviation.

To address these evolving risks, the World Meteorological Organization (WMO), continues to support the integration of specialized hazard monitoring systems into national meteorological and hydrological services, including those that provide service for aviation. The WMO Sand and Dust Storm Warning Advisory and Assessment System

2 https://journals.ametsoc.org/view/journals/bams/106/1/BAMS-D-23-0311.1.xml
3 https://library.wmo.int/records/item/69455-state-of-the-global-climate-2024

(SDS-WAS)[4] and the Vegetation Fires and Smoke Pollution Warning Advisory and Assessment System (VFSP-WAS)[5], for example, provide essential regional and global forecasting, advisory and observational products to support flight planning and hazard avoidance. Nevertheless, gaps remain in data resolution, coverage and real-time availability, particularly in data-sparse regions.

Enhanced collaboration among ICAO, WMO, national meteorological and hydrological services and the scientific community is critical to improving aviation resilience to atmospheric composition hazards, consistent with the needs of ICAO Annex 3 – *Meteorological Service for International Air Navigation* and the broader global climate adaptation efforts.

4 https://community.wmo.int/en/activity-areas/gaw/science-for-services/sds-was
5 https://community.wmo.int/en/activity-areas/gaw/science/modelling-applications/vfsp-was