

Northwest Seaport Alliance Seasonal Hazard Report

Summer and Winter 2022-2023

This report summarizes significant climatic and weather occurrences of the summer and winter seasons to better equip the Northwest Seaport Alliance (NWSA) and its gateway operations. The aim of this report is to document climatic and weather anomalies to create awareness on hazard preparedness, mitigation, and adaptation for the future.



Global Events

The period from June to September in 2022 has been characterized by various climate related disasters that hit many parts of the world. India and Pakistan experienced record-breaking heat waves exceeding 104°F followed by monsoon flooding that devastated a third of Pakistan's landmass, affecting almost 33 million people. In Europe, extreme heat led to the proliferation of wildfires in regions of Spain and Portugal. Reservoirs became arid and empty impacting power generation in France and Germany (1). Heat waves in China dried up parts of the Yangtze River to the lowest levels last seen in 1865, disabling hydroelectric dams and ceasing vessel navigation and cargo supply chains (2).

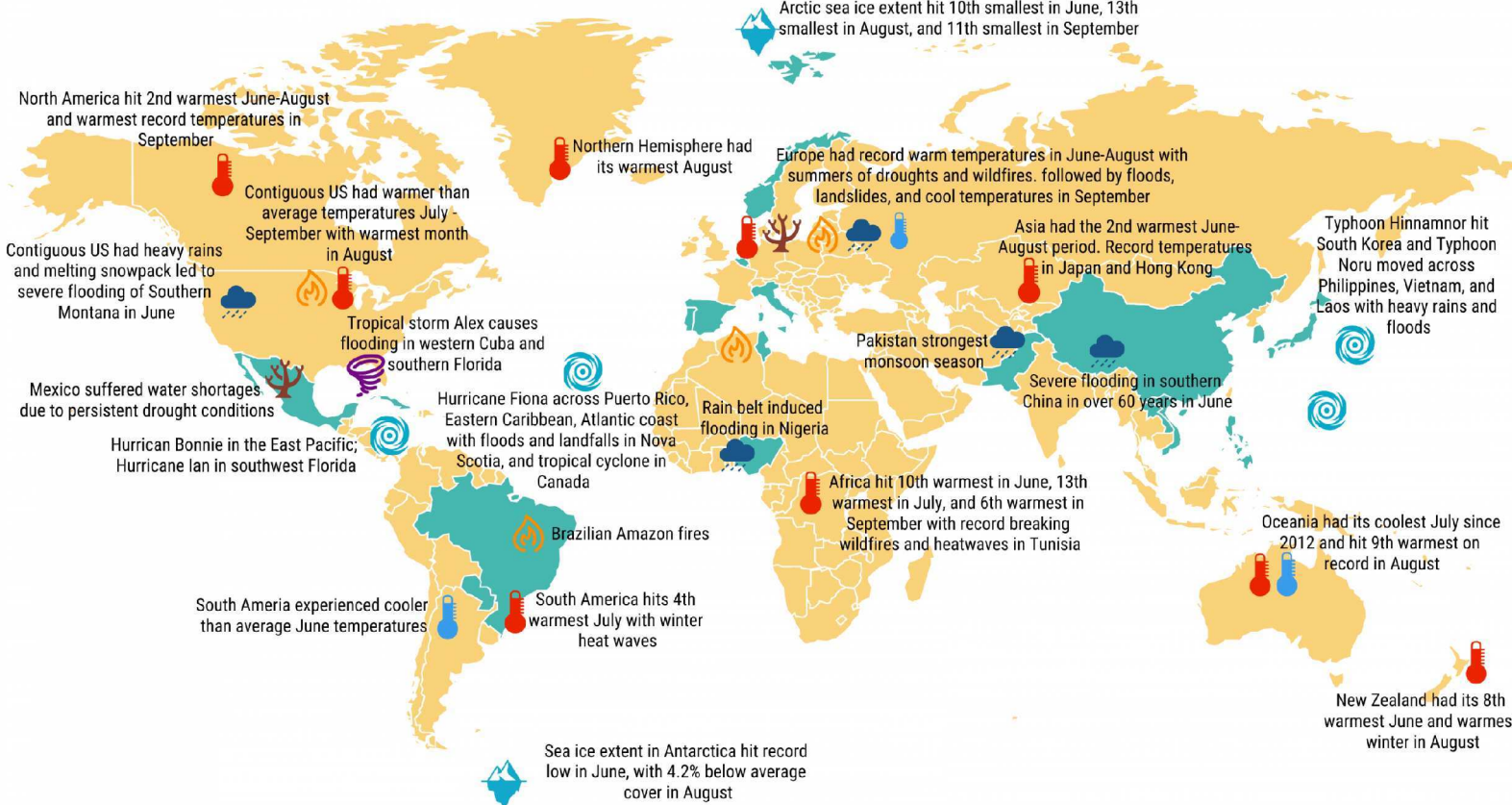


Figure 1: Global Climate and Weather Anomalies and Events for the period June to September 2022 (Adapted from NOAA NCEI Global Climate Reports June -September 2022)

Key Climatic Factors

Temperature

- The Northern Hemisphere was the second warmest on record (after 2020) at temperatures 1.15 °C above average, and winter temperatures in the Southern Hemisphere hit the tenth warmest on record (5).
- Global surface temperature was 0.89°C above the 20th century average of 15.6°C (5).
- Sea surface temperatures were high across the northern, western, and southwestern Pacific, the northern and central Atlantic, the Gulf of Mexico, the Mediterranean Sea, and the eastern Indian ocean encompassing 6.1% of the world's surface (6).

Precipitation

- Precipitation levels were 141% relative to "normal" and temperatures averaged 1.4°C above the 1981-2010 average contributing to warmer temperatures on land and providing excess moisture to onshore winds and storms (5).
- In the Southern Hemisphere, the marine heat wave over the South Pacific led to the warmest and wettest meteorological winter (June-August) on record (5).
- The third consecutive La Nina conditions alongside small-scale tropical cyclones led to increased flooding events followed by above average arid conditions (6).

National Events

This past summer, the US has sustained 15 climate and weather-related disaster events with losses of life and property exceeding \$1 billion for each event (7). The distribution of losses was dominated by tropical storm events such as hurricanes, typhoons, and cyclones, alongside extreme heat conditions leading to droughts and wildfires. The western region of the US broke nearly a 1000 heat records with wildfires, persistent heat waves, and drought conditions over many parts of the country setting temperature records. According to the US Climate Extremes Index (USCEI), the January to September 2022 period was estimated to be 26% above average and ranked in the highest one-third of observed climate changes over the 113-year period of records (7).

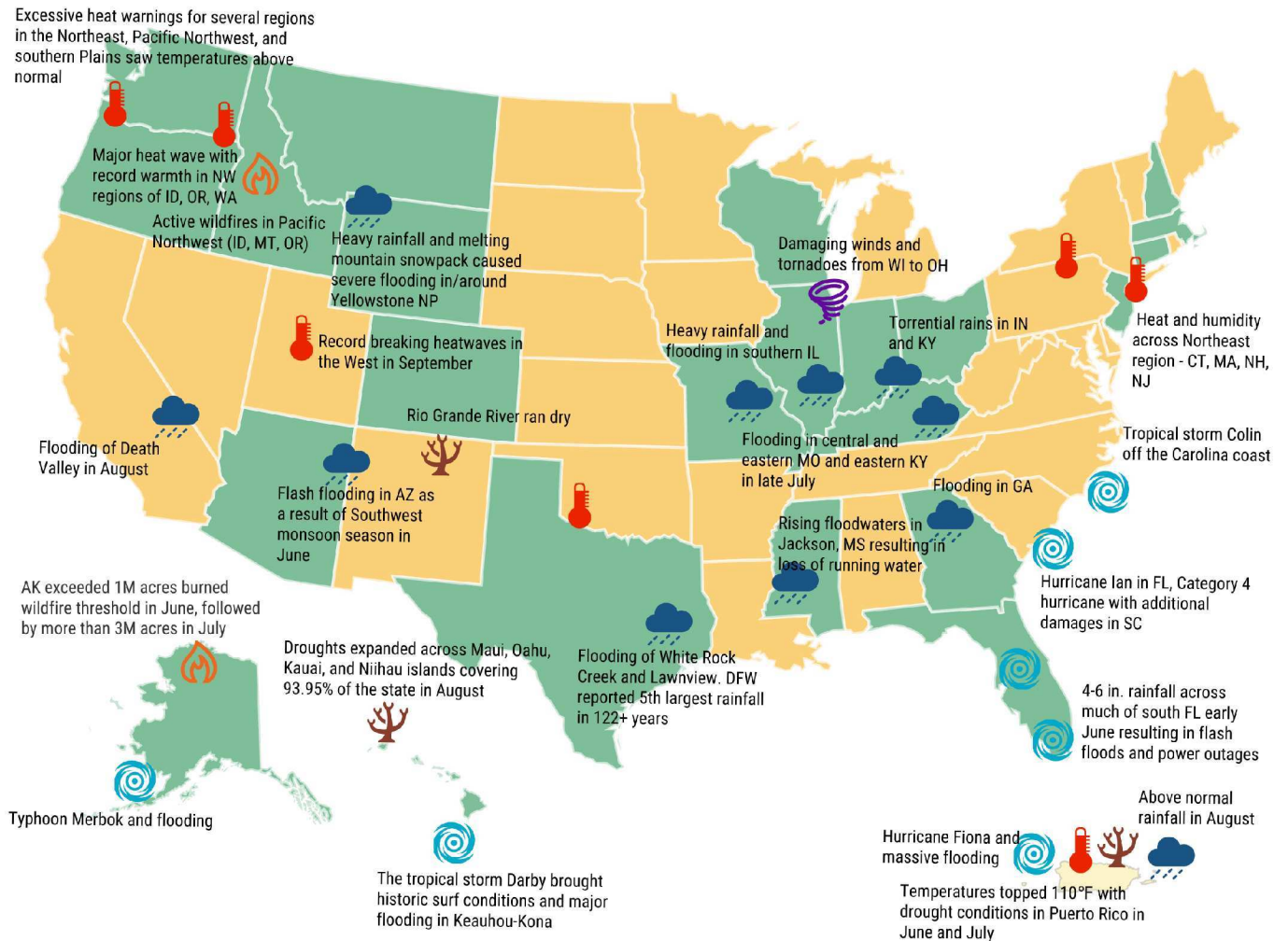


Figure 2: US Climate and Weather Anomalies and Events for the period June to September 2022 (Adapted from NOAA NCEI National Climate Reports June -September 2022)

Key Climatic Factors

Temperature





- The average temperature across the contiguous US was 73°F, 2.8°F above the 1981-2010 baseline average ranking as the warmest on record for this period (8).
- The average maximum (daytime) temperature during this period was 85.2°F, 2.5°F higher than the 20th century average and average minimum (nighttime) temperature was 59.7°F, 2.9°F higher than the 20th century average (7).

Precipitation

- Precipitation levels were below average across much of the Pacific Northwest, Plains to Mississippi Valley, Great Lakes, upper Midwest, parts of the Southeast, and northern Atlantic coastline (8).
- The total precipitation levels recorded from January to September was 1.67 inches below average, ranking as the 3rd driest period relative to the historical record (8).

Regional Events: Washington State

The summer season sustained unusually long-lasting heat waves that began at the end of July. Temperature departures above average hit record breaking values 13 times during the season with temperatures 90°F or higher (14). The frequency of warm temperatures across maximum daily temperatures and minimum daily temperatures broke records, with persistent heat waves.

	JUNE	JULY	AUGUST	SEPTEMBER
TEMPERATURE 	<p>Below normal temperatures were predominant in eastern WA and above normal temperatures were prevalent across Puget Sound and southwestern WA</p>	<p>Average temperatures were above normal statewide and broke historical records. Maximum daily records set at 108°F. Minimum daily records set at 73°F.</p>	<p>August 2022 was warmest on record, 4 to 6°F above the 1991-2020 normal. Average minimum temperatures were also the warmest on record.</p>	<p>Average temperatures were above normal statewide. September 2022 was 5th warmest on record, 3.3°F above the 1991-2020 normal.</p>
PRECIPITATION 	<p>Eastern WA values exceeded 200% of normal in contrast to Western WA values that ranged between 110-225% of normal.</p>	<p>Deficits observed in generally wetter portions of the state whereby July average precipitation was drier than normal.</p>	<p>Precipitation levels were below normal statewide. August was the 16th driest on record since 1974.</p>	<p>Precipitation levels were below normal statewide with some exceptions along the WA/ID border.</p>
STREAMFLOW 	<p>Above normal levels due to melting of low and middle elevation snowpack alongside wetter conditions with record high streamflow in southeastern WA.</p>	<p>Normal to above normal across WA state as a result of complete melt of higher elevation snowpacks.</p>	<p>Normal to above normal for majority of the state with some exceptions in western and eastern WA.</p>	<p>Average streamflow was at record lows for some rivers across western WA.</p>
DROUGHT 	<p>"Moderate drought to "Abnormally dry" conditions reflective of cool and wet conditions.</p>	<p>Regions categorized as "Moderate" and "Abnormally dry" saw decline in conditions.</p>	<p>"Abnormally dry" conditions began to intensify across the state.</p>	<p>Dry and warm conditions alongside low streamflow prompted expansion of drought conditions with all of WA in at least "abnormally dry" and "moderate drought" conditions.</p>
CLIMATE AND WEATHER PATTERNS 	<p>La Nina accompanied by cooler than normal temperatures in WA led to reduced sea surface temperatures and mixed precipitation levels with drier conditions in the eastern side.</p>	<p>Heat waves begun end of the month and "La Nina Advisory" remained in effect with increases in sea surface temperatures.</p>	<p>Several heat waves occurred throughout the month with record daily high temperatures followed by thunderstorms across the Puget Sound region. "La Nina Advisory" remained in effect.</p>	<p>Dry and windy conditions alongside gusty downslope flow from the east paved way for fire weather conditions. "La Nina Advisory" remained in effect.</p>

Local Climate Factors

In relation to temperature, June to September saw higher temperatures than average with the period ranked as the warmest in the 128-year record with anomalies 3-5°F above normal statewide. The minimum daily temperatures (nighttime) were warmest on record for the month of August at 3-4°F above normal (15). Although precipitation anomalies were more variable, a general pattern of below normal levels was observed statewide. For the purpose of this report, the primary local regions discussed in Washington include Seattle and Tacoma which are locations of the homeports of the NWSA.

Seattle

Climate Factors	Key Takeaways
Temperature	<ul style="list-style-type: none">Increases in the intensity and frequency of warmer temperaturesMaximum and minimum temperature departures from normalWarm temperatures extended into fall with record values in August and early October
Precipitation	<ul style="list-style-type: none">Summer 2022 in Seattle was officially the driest summer on record with only 0.5 inches of rain recorded between June to September

Tacoma

Climate Factors	Key Takeaways
Temperature	<ul style="list-style-type: none">Daily average high temperatures increased by 7°F from 68°F to 75°F this past summer rarely falling below 59°FThe highest daily average maximum temperature was 85°F alongside an extreme value of 90°F recorded in AugustAverage daily low temperatures increased by 4°F from 50°F to 55°F
Precipitation	<ul style="list-style-type: none">Precipitation levels were recorded at 0.5 inches in total for the summer season, lower than the seasonal average

The most recent international climate assessment from the United Nations' Intergovernmental Panel on Climate Change found significant increases in both the frequency and intensity of extreme temperature and precipitation events leading to series of climate events.

As the polar regions begin to warm at higher rates than the equator, the temperature differences cause reduced winds and more meandering jet streams. These changes create high pressure systems and atmospheric blocking that favor the frequency and intensity of heat waves amplified through positive feedback loops. Frequent and persistent heat waves alongside reduced precipitation in some regions cause more severe droughts and conditions suitable for wildfires. The next section discusses summer hazards observed in Washington in 2022 and its impacts to the NWSA and its gateway.

Summer Hazards and Impacts

Washington's summer season comprised warnings of record-breaking heat waves exacerbated by drought conditions that paved way for wildfires, increased smoke exposure, alongside declining air quality across the state. Exposure and vulnerabilities to these conditions are the consequences of natural variabilities and anthropogenic pressures leading to increased intensities, rapid, and widespread changes in climate, increasing the onset of climate related disasters and hazards.

Heat waves and Droughts

Wildfires

- June-September 2022 season marks the third historic heat event on record with increasing temperature ranges
- The Pacific Northwest region was issued heat warnings during the season as temperatures hit triple digits



BACKGROUND

- Severe drought conditions and extreme heat provided favorable conditions for another wildfire season in the US across New Mexico, California, Oregon, Washington, Idaho, Montana, and Alaska with over 6.9 million acres of land burned nationally in 2022

- Warm air and easterly winds cause warm, dry air to descend from the mountains creating temperature increases
- Dry/warm conditions, reduced streamflow, and arid soil pave way for droughts



CONDITIONS

- A total of 140,000 acres of land have been burned and 1370 separate fires have been recorded (23)
- Increasing warm temperatures, low humidity, below average precipitation, and winds fueled fires. Most fires began in the end of August with significant fire activity into mid-October

- Low winter precipitation
- Dry summer
- Warm winter temperatures



TYPES

- Ground fires
- Surface fires
- Crown fires

- **Temperature:** US National Weather Service
- **Drought forecast:** US Drought Monitor (USDM) NOAA National Integrated Drought Information System (NIDIS), Office of Washington State Climatologist



RESOURCES

- **National Wildfire Risk Maps:** InciWeb, National Interagency Fire Center
- **State Wildfire Risk Map and Information:** Washington State Department of Natural Resources
- **Air Quality:** Air Now (National), Washington State Department of Ecology (State) (Fire and Smoke maps)

- The **USDM five-category system** - Abnormally Dry or D0, (a precursor to drought, not actually drought), and Moderate (D1), Severe (D2), Extreme (D3) and Exceptional (D4) Drought relative to dryness and how much water is available in streams, lakes, and soils compared to usual for the same time of year.



THRESHOLD

- **National Park Service Wildfire Preparedness Levels 1-5**
- Washington State Department of Ecology **Industrial Fire Precaution Levels I-IV**

- **Risk** - increased incidents of heatwaves, bushfires, air and water temperatures
- **Roads** - road surface degradation, road melts, reduced accessibility
- **Rail** - electrical/mechanical failures, high energy costs
- **Seaport assets** - high energy costs (terminals, operations, cargo handling equipment), power overload/system failure, pipe leaks
- **Operations** - worker health and safety incidents, reduced/changing work hours, inadequate emergency routes/access, delays/cancellations,



NWSA IMPACTS

- **Risk** - increased incidents of heatwaves, bushfires, air and water temperatures and quality
- **Roads** - road surface degradation, road melts, reduced accessibility, closures
- **Rail** - electrical/mechanical failures, high energy costs, closures
- **Seaport assets** - high energy costs (terminals, operations, cargo handling equipment, infrastructure), power overload/system failure, contamination
- **Operations** - worker health and safety incidents, reduced/changing work hours, inadequate emergency routes/access, delays/cancellations

- **Environment** - air quality, water quality, early snowmelt, low soil moisture, invasive species, reduced streamflow, ecosystem changes
- **Operations** - vessel navigation, berthing, increased transportation costs, delays/cancellations
- **Community** - human health/safety/illness/diseases/injuries/fatalities, decreased water quantity and quality, economic loss, disparities
- **Economy** - supply chain disruptions, loss of livelihoods, delay/cancellations



GATEWAY IMPACTS

- **Environment** - air quality, water quality, invasive species, ecosystem changes, stream diversions, pollution, sedimentation, debris flow, increased turbidity
- **Operations** - vessel navigation/access, freight disruptions (road, rail, waterways), delays/cancellations/closures
- **Community** - human safety/health/illness/diseases/injuries/fatalities, decreased water quantity and quality, economic loss, disparities
- **Economy** - supply chain disruptions, loss of livelihoods, delay/cancellations

Winter Hazards and Impacts

The winter season is heavily influenced by La Nina conditions returning for the third consecutive year. In Washington, this translates into below than normal temperatures with precipitation levels wetter than average conditions. This paves way for winter hazards such as flooding, landslides, and extreme weather events.

Flooding

TYPES

- **Coastal Flooding:** High tides and winds during storms push water into coastal areas eroding the coastal bluffs and can potentially lead to landslides
- **Riverine Flooding:** Heavy precipitation events cause river or streams to overflow its banks into adjoining floodplains
- **Urban Flooding:** Occurs suddenly when severe precipitation events swell and overwhelm the capacity of drainage and stormwater systems

Excess runoff into the Duwamish increases risks of flooding and low elevations of the Tacoma tide flats alongside the Puyallup river makes it susceptible to flooding from high tides and wind driven waves.

RESOURCES

- King County Flood Risk Map
- United States Geological Survey River Gage Data - **The Duwamish and Puyallup river gage data depict higher water levels relative to 2021 levels**
- Washington State Department of Ecology Flood Hazard Maps and Information for Preparedness
- Federal Emergency Management Agency Mapping and Preparedness
- Washington State Department of Health Preparedness Information
- NOAA Tides and Currents Tidal Tables for Seattle (9447130) and Tacoma (9446484) stations

KING TIDES

Flooding from king tides prevail during extreme weather events such as severe storm activity and associated wave run ups. The emerging threat of sea level rise as a result of climate change can amplify the magnitude and frequency of flooding events.

- **Seattle:** NOAA tidal tables predict a height range of 12.9 to 13.1 ft for king tides in the period of November to January 2022-2023. In the last week of December, preliminary height was recorded at 15.1 ft relative to the predicted 12.8 ft.
- **Tacoma:** NOAA tidal tables predict a height range of 12.9 to 13.4 ft for king tides in the period of November to January 2022-2023. During the first week of January 2022, the Tacoma station broke the 15ft mark for the first time in quarter of a century historical data. In the last week of December, preliminary height was recorded at 15.58 ft relative to the predicted 13.1 ft.

FLOODING CHARACTERISTICS

CONDITIONS

- La Nina conditions
- Low pressure systems
- Precipitation volumes
- Snow melt
- Water depth
- Water velocity
- Time water stays above flood level
- Elevation levels
- Shape of floodplains
- Storm surges

NWSA IMPACTS

- **Roads** - inundation, delays, damages, sediment drift, increased costs
- **Rail** - inundation, delays, damages, sediment drift, increased costs
- **Seaport assets** - Inundation and wind damage to infrastructure and equipment (terminals, operations, etc.), saltwater intrusion, sediment drift, mechanical/electrical/communications failures, increased costs, corrosion, changes to vessel clearance
- **Operations** - delays, closures, increased costs

GATEWAY IMPACTS

- **Environment** - debris flow, sedimentation, contamination, increased turbidity, pollution, slope destabilization
- **Community** - Injuries, fatalities, economic and societal loss, reduced accessibility, worker safety, service disruptions
- **Operations** - utility disruptions, service interruptions, reduced accessibility, freight disruptions, repair and maintenance costs
- **Economy** - supply chain disruptions, loss of livelihoods, economic loss

Most casualties occur when floods develop at a rapid pace within enclosed structures or flash flood events. Floods can impact vital infrastructure such as transportation routes and pipelines vital to the NWSA gateway. Secondary impacts include hazardous material spills and consequent wildfires.

The prevalence of storms and surges amplified by climate change can create floods as high as 23 ft in conjunction with tropical storms. Storm surges have a high destructive potential as a result of waves pushed ashore at high velocities. Strong structures such as port facilities, warehouses, and bridges are vulnerable to coastal floods with increased susceptibility during high tides. According to the Washington Climate Change Impacts Assessment, flooding hazard trends are shifting towards significant short duration and high intensity events with increases in extreme high precipitation events in and around the Puget Sound region over the next half century.

Winter Hazards and Impacts

Extreme Weather

The winter season in the Puget Sound region can expect extreme weather events characterized by damaging winds, heavy precipitation, and below average temperatures. The climatic factors and associated weather events are heavily dependent on La Nina entering its third consecutive year. This year La Nina conditions have surpassed threshold values creating ocean anomalies within the equatorial Pacific with direct implications for climate in North America. Some secondary hazards in the winter season as a result of extreme weather conditions include flooding, landslides, avalanches, post wildfire debris flow, increased erosion, sedimentation, and so forth.

CHARACTERISTICS

- Jet streams as a result of La Nina conditions creates a powerful blocking high pressure system within the North Pacific redirecting the polar jet stream over the northern US (43).
- The displaced jet stream brings colder temperatures and storms from polar areas down into northern and northwestern US (43).
- Conditions comprising long, and wide plumes of moisture and snowfall can lead to Atmospheric River storms and chances of bigger snowstorms during the second half of the season.
- Seattle can probably expect twice as much snow than usual in a La Nina winter with greater projections expected for a third year La Nina relative to the previous year.



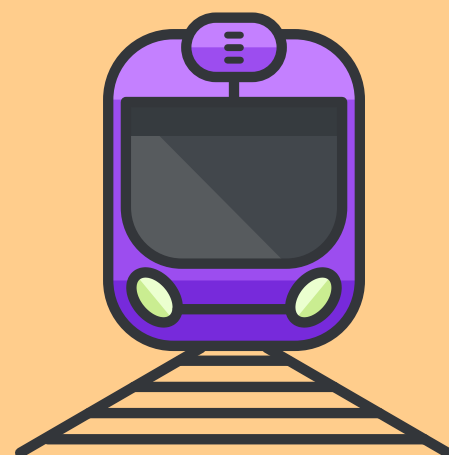
NWSA IMPACTS

- **Roads** - inundation, delays, closures, damages, sediment drift, increased costs
- **Rail** - inundation, delays, closures, damages, sediment drift, increased costs
- **Seaport assets** - Inundation and wind damage to infrastructure and equipment (terminals, operations, etc.), saltwater/freshwater intrusion, sediment drift, mechanical/electrical/communications failures, increased costs, corrosion, changes to vessel clearance, service interruptions
- **Operations** - delays, closures, increased costs, worker health and safety

GATEWAY IMPACTS

Freight Networks: Washington State Department of Transportation (WSDOT) expects longer road closures in winter; some roads and passes will not get the same level or service due to limited equipment for snow and ice removal, highway lane accessibility may be reduced, lower speed limits will likely be enforced, alongside slower emergency response times having significant implications for gateway production, consumption, and distribution. According to the US Department of Agriculture's current snow and precipitation reports recorded in Stevens and Stampede pass have surpassed historical median levels.

Other Impacts: service disruptions, economic loss, societal loss, ecosystem changes



Winter Hazards and Impacts

Landslides and Associated Hazards

The likelihood of landslides increases in the winter season with greater storm activity specifically rain or snow events. Washington is one of the most landslide prone states in the country due to its geological landscape (comprised of mountains, coastal luffs, valley slopes), with hundreds to thousands of events each year.

Background



- Landslides typically occur in the winter months in western Washington and during the summer months in eastern Washington but are possible at any time with many of them typically exhibiting a mixture of different materials and slides. They also have the potential to create their own secondary hazards such as tsunamis, floods, and underwater landslides.
- The most common landslides near homeports are shallow (less than 6-10 ft) and fast moving (up to 60 km/hour) that occur on undeveloped slopes. Risk factors are particularly associated with coastal bluffs, stability disruptions, and pressure.
- Although landslides do not pose a direct threat to NWSA homeports and its facilities, they can disrupt key freight channels.

Post Wildfires



- The shift from a wildfire summer season to above average rainfall in winter increases the potential for post-wildfire hazards such as erosion, flash floods, debris flow, and alluvial fans.
- The burning of vegetation and other forms of ground over or forest floors produce water repellent soils which double the rate of waterflow. These areas are prone to increased erosion due to vegetative loss.
- According to the US Forest Services (USFS), 16% of landcover was marked by high burn severity and 32% as moderate burn severity following the Bolt Creek Fire. The impacts of post wildfire hazards and associated landslides to infrastructure is available in reports published by the Washington State Department of Natural Resources.

Avalanches



- Similar to landslides, avalanches are high probability hazard events in Washington. They are a regular occurrence during the winter months through early spring but can also occur year around in higher alpine areas.
- Several critical freight corridors for the gateway include roadways and railroads that pass-through avalanche prone areas. For roadways these include the I-90 Snoqualmie Pass and Stampede Pass.
- Unstable snow paths are predominantly evident during or immediately after a storm; on steep wind loaded slopes; and in higher elevation terrain where the snowpack may be much deeper.

NWSA and Gateway Impacts



- **Freight Networks:** roadways, rail corridors near sloped terrains and loose material, repair and maintenance costs, sediment drift
- **Infrastructure:** areas susceptible to land subsidence and slope destabilization can impact facilities such as sinkholes, seawalls, terminals, wharfs, cargo handling equipment, and reduce vessel berths, repair and maintenance costs
- **Operations:** service disruptions, mechanical/electrical/power failures, source-based delivery systems, access restrictions, delays, closures, workforce safety, economic loss, repair and maintenance costs
- **Community:** health and safety (injuries/fatalities), loss of livelihood, societal disruptions, property damage, increased costs
- **Environment:** reduced habitat connectivity, sedimentation, contamination, ecosystem shifts, reduced resource quality

Resources



- Washington State Department of Natural Resources
- US and Washington Geological Survey - information, homeowner preparedness, maps
- King County Landslides Hazard Maps
- Washington State Department of Transportation - road closures, avalanche prone areas and control measures
- Northwest Avalanche Center

Conclusion

2022 has been one marked by climate disasters globally, nationally, and regionally. As some regions experienced extreme heat, rising temperatures, droughts, and wildfires, others suffered severe floods, tropical storms, and hurricanes. Although global warming is undoubtedly a factor, the changing flow of energy through the climate system have been exacerbated by additional anthropogenic pressures. Globally, the northern hemisphere saw its second hottest meteorological summer on record with the onset of numerous hazards devastating natural and human systems. Moving into the winter season, the first half saw cold and relatively dry conditions while second half expects intense rainfall and major storms exacerbating king tides and flooding, that can increase the potential for landslide associated hazards to occur. Increasing awareness and documenting these occurrences can aid in hazard preparedness, and consequently enhance resilience of the NWSA and its gateway across socio-economic and environmental assets.



Climate Trends

- June to September saw higher than average maximum and minimum daily temperatures
- June to September precipitation was generally below normal, but variable
- La Nina conditions return for its third consecutive year
- Winter temperatures dropped 10-15°F below average seasonal temperatures
- Winter precipitation was generally above normal relative to rainfall and snow accumulation



Summer Hazards

- **Heat waves and Droughts:** June to September observed "abnormally dry to moderate dry" conditions due to increasing temperature ranges, reduced streamflow, and arid soils
- **Wildfires:** 1370 fires were recorded in Washington state that burned 140,000 acres of land
- **Seaport Impacts:** infrastructure damage/degradation (roads, rails, terminals, cargo handling equipment), utilities failure (electric/mechanical), high energy costs, worker health and safety, reduced accessibility/routes, operational delays/cancellations/closures, reduced air and water quality, ecosystem shifts, contamination/pollution, economic and health disparities, supply chain disruptions



Winter Hazards

- **Flooding:** coastal, riverine, and urban flooding; king tide induced storm surge and wave run can have high exposure to NWSA facilities and its gateway operations
- **Landslides:** associated hazard include post wildfire risks and avalanches; generally low exposure to NWSA facilities but high exposure to seaport associated freight assets impacting gateway operations
- **Extreme weather:** Characteristics prevalent in Washington include strong winds, above average precipitation (rain and snow), and below average temperature ranges
- **Seaport Impacts:** Freight damage/degradation/disruptions, infrastructure and equipment damage (terminals, cargo handling equipment), utilities failures, increased costs, operational delays/closures, reduced accessibility, worker safety, service disruptions, economic loss, saltwater/freshwater intrusion, corrosion, sedimentation, slow destabilization, supply chain disruptions

Planning and Preparedness Resources

- Washington State Drought Contingency Plan - Washington State Department of Ecology
- US Drought Monitor
- Air Now - Air quality map
- Cybersecurity and Infrastructure Security Agency
- American Planning Association
- Washington State Department of Natural Resources Wildfire Information and Preparedness
- National Interagency Fire Center
- InciWeb Portal - Active wildfires map
- US Climate Resiliency Toolkit
- Flood risk maps - King County, FEMA, Washington State Department of Ecology
- NOAA Tide and Currents tables
- United States and Washington Geological Survey - hazard exposure maps, river gage data, information, etc.
- Washington State Department of Natural Resources Landslides Information and Preparedness
- Washington State Department of Transportation
- Northwest Avalanche Center
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