LECTURE #22: Wild Fires: The Science & History

Date: 9 April 2025

I. Wild Fires

fire tornado forming

- one of the largest and most expensive hazards
  - in the United States and around the world

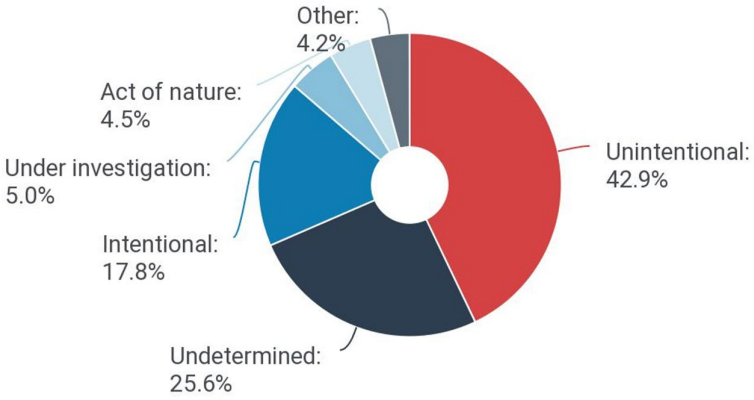
- avg. death toll in the US *(1910 – 2020)*
  - ~11 per year *(wildfires)*
  - compared to ~18 per year since 2000

- average suppression costs:
  - steadily increasing every year

- natural causes (lightning) only ~5% of all fires
- National Interagency Fire Center:
  - http://www.nifc.gov/

- average wildfire statistics from *(last 30 years):*
  - number of fires: ~ 75,000/year
  - acres burned: ~ 5,000,000/year
  - structures burned: ~4,000/year
  - average cost of fire suppression: **$2.9B/yr**
    - estimated to increase **42%** by 2050

- fire statistics (for <u>all</u> fires over the past 10 years):



II. Historic Fires in the US/Canada

- Miramichi Fire
  - October 1825 (Maine & New Brunswick)
    - a summer of sparse rain
    - strong winds spread smaller camp and settler's fires
    - among the worst wildfires in North American history

- burned 3.9 million acres
- killed 160 - 500 people
- left 15,000 homeless

- Hinckley Fire
  - September 1894 (Hinckley, Minnesota)
  - 2-month summer drought
  - several smaller fires combined
  - burned more 200,000 acres
  - killing 418 people *(probably much higher)*
  - completely fire destroyed the town of Hinckley

- Great Fire of 1910
  - Idaho and Montana
  - small blazes plus hurricane-force winds and dry forests combined
  - killed 86 people
  - burned about 3 million acres
    - one of the biggest wildfires ever recorded in North America

- Yellowstone National Park
  - summer, 1988
    - scorched 36% of the park
    - ~ 800,000 acres
    - cost of $120 million
    - causes: 9 fires by humans, 42 by lightning

III. What is Fire??

- rapid combustion
  - combination of O_2 with carbon, hydrogen, and other elements in a chemical reaction that produces light, heat, and flame

- exothermic reaction (releases heat)
  - can think of it as the opposite of photosynthesis

- photosynthesis: **solar energy + $6CO_2$ + $6H_2O$ → $C_6H_{12}O_6$ + $6O_2$**

- fire: **$C_6H_{12}O_6$ + $6O_2$ → CO_2 + $6H_2O$ + heat**

IV. Fire Stages:

- ***pre-heating:***
  - water is expelled from wood/fuel
  - this is accomplished through:
    - flames (nearby fires)
    - long periods of dryness (lack of rain, drought)

- ***pyrolysis:***
  - thermal degradation of the wood cellulose
  - cellulose is stable to about 615°F (325 °C)
  - above that, cellulose breaks down and expands

        - gives off flammable gases & water vapor
        - plus mineral residue, tars, etc. → **ash**

    - gas movement causes cracks in the wood
    - in the presence of O_2 those gases can ignite to form flames

- ***flaming combustion:***
    - pyrolyzed wood burns hot and fast
    - stage of greatest energy release
    - highly efficient and predominates in windy environments
    - wind accelerates fire spread by:
        - bringing in more oxygen
        - heating up air to the point of igniting other fuel
        - spreading material already ignited

    - heat transfer in several ways *(from most to least efficient)*:
        - <u>radiation:</u> energy released directly from flames in the form of radiant heat

        - <u>convection:</u> warming of the air molecules surrounding the wood

        - <u>conduction:</u> heat moves inward through wood by physical contact of wood molecules
            - ➢ inefficient because wood is such a poor conductor

- ***glowing combustion:***
    - after the active flames die off (combustible gas is depleted)
    - coals
        - wood is slowly consumed in an oxidation reaction
        - lower temperature

***** Important to remember that all these stages are ongoing at once in different parts of the fire***

V. Factors Controlling Wildfire Propagation:

- wind speed/direction/strength
- fuel type
    - some species have a lower threshold of ignition
    - varies with world climate and elevation
    - example:
        - Eucalyptus trees have high oil contents

    - other species rely on fire to propagate their seeds
    - example:
        - Ponderosa Pine trees in the western US
            - ➢ cones don't open until a certain temperature is reached

Ponderosa pine

- topography
  - factor in plant distribution, growth patterns, and burning
  - steep slopes promote convective heat transfer
    - funneling a lot of air up slope
    - chimney effect

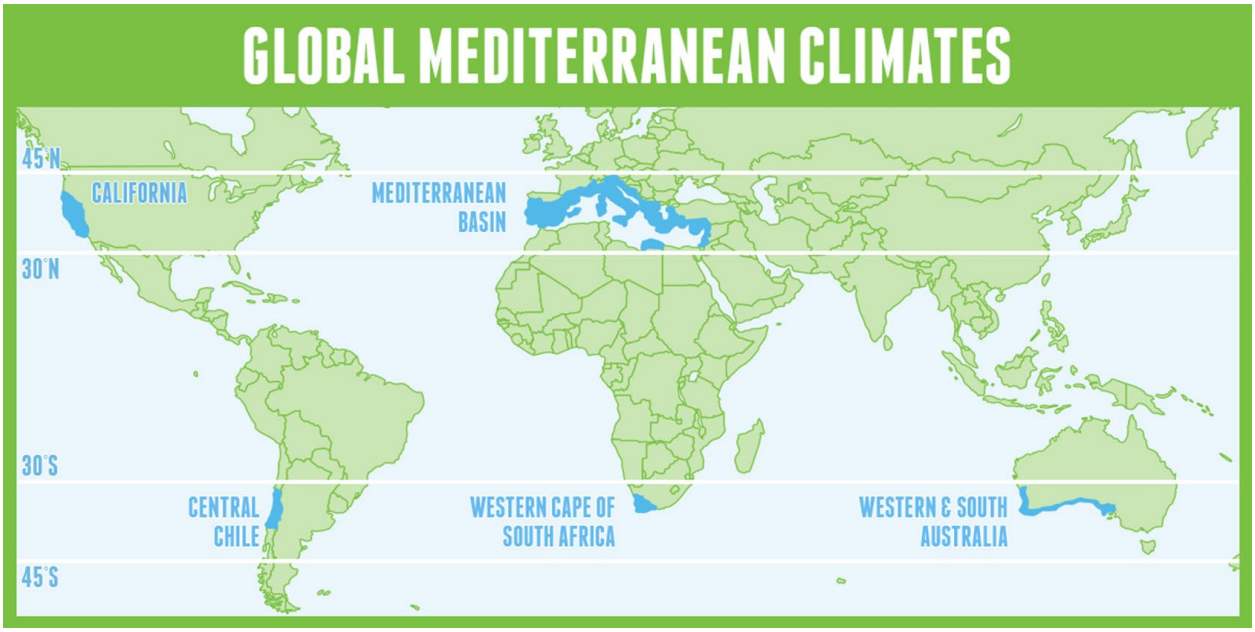
  - deep canyons can cause turbulent air flow
    - even higher convective heat transfer

  - rugged topography also can hinder firefighting efforts

- climate
  - most at-risk is the *Mediterranean climate*
  - located in several regions of the world:
    - the southern Mediterranean and Middle East
    - coastal California
    - southwestern coast of Australia

  - characterized by a very brief wet season
    - high growth rates of vegetation

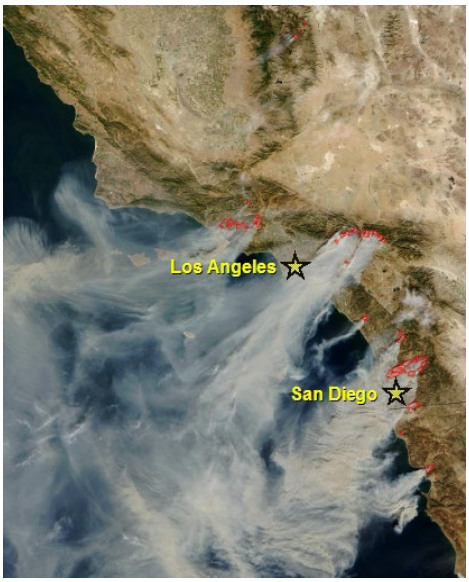
  - followed by a longer, protracted dry season
    - very susceptible to lightning and strong winds



Mediterranean climate zones

VI. Brief Case Studies:

- Southern California fires
  - October 2003
    - burned about 800,000 acres
    - killing 22 people
    - destroying more than 3,400 homes
    - thousands evacuated
      - later in the year: deadly mudslides from heavy rainfall
  - October 2007
    - burned area: 500,000 acres
    - killing 14 people / ~ 200 serious injuries
    - destroying more than 1,500 homes
    - evacuations displaced more than 900,000 people
      - *largest peacetime movement of Americans since the Civil War*



26 October 2003

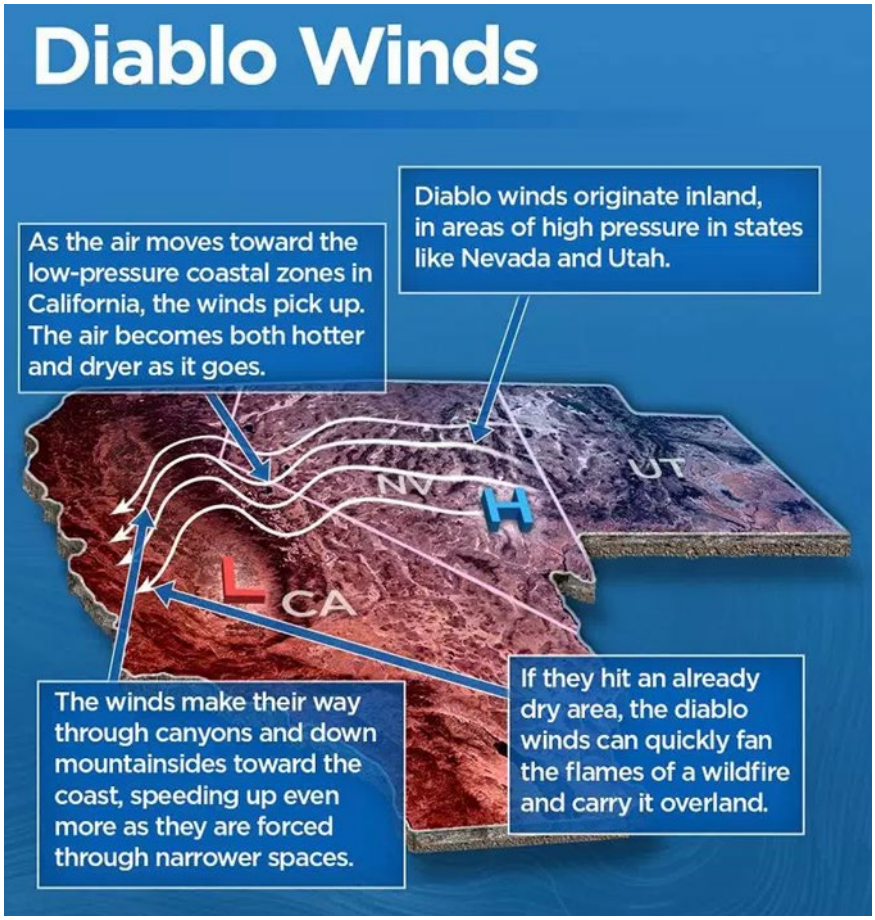
- Mediterranean: 2007 fires in Greece
  - 23-27 August
  - 3 consecutive heat waves of over 40°C (105 °F)
    - severe drought in 2007
  - wildfires tore through many of villages and olive groves
    - killed 84 people
    - destroyed ~10 % of Greece's tree cover
    - 670,000 acres of forest, olive groves and scrub vegetation


25 August 2007

- Northern California fires in 2018
  - facts & statistics for the entire 2018 CA fire season
    - total number of fires: 8,527
    - total acres burned: 1,893,913
      - Mendocino Complex Fire: burned more than 459,000 acres
      - *the largest complex fire in the state's history*
      - Camp Fire: killed 86 people
      - destroying > 18,000 homes including most of Paradise, CA
    - cost: >$3.5 billion *(2018 USD)*
      - $1.8 billion in fire suppression costs
    - injuries:
      - fatalities: 98 civilians and 6 firefighters killed
      - non-fatal injuries: at least 80 total

- factors leading up to the fires
  - extreme droughts in the years prior
    - in 2016, only 3% of the state was free from drought conditions

  - red flag warning by the National Weather Service
    - high winds expected ("Diablo winds") just prior to large fires
      - conditions were expected to become extremely volatile
      - winds expected to be gusting between 25 and 35 mph



  - Pacific Gas and Electric (PG&E)
    - faced lawsuits and fines for its role in causing devastating wildfires
    - owned the transmission lines that caused the Camp Fire
    - pled guilty in 2020
    - fine of $3.5 million
    - a $25.5 billion settlement that will compensate victims