Cascade effects of global warming 3-12-18 MS

DROUGHT
Atmosphere warms → droughts become longer and more severe → rivers dry up → millions are left without water

Fact box: 40 million people depend on the Colorado River for water[1], and it's already shrinking.[2]

CORALS
Ocean temps rise → photosynthetic algae in coral cannot survive → corals die and reefs bleach → many ocean species lose food and shelter →

Fact box: Three quarters of the world's reef systems have already had severe bleaching events.[3]

SNOW MELT
Glaciers in Himalayas melt → Indus River carries less water → Less water available to irrigate crops → millions in India and Bangladesh cannot grow food.

Fact box: one sixth of the world depends on water from melting snow during the dry seasons.[4]

FOOD SHORTAGES
Droughts and floods reduce harvests, limiting food supply → food prices rise → climate-related shortages have already led to price surges in chocolate, coffee, wheat, rice, corn, and avocados

Fact box: increased droughts could double the price of grain by 2050.

ALLERGIES
Shorter winters → spring arrives earlier → longer pollen season → plant based allergens could double by 2040[5]

HEAT WAVES

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1 Mathez, Ch. 9

2 https://source.colostate.edu/climate-change-shrinking-colorado-river/

3 https://news.nationalgeographic.com/2017/06/coral-reef-bleaching-global-warming-unesco-sites/

4 Mathez ch. 9, citation
e.g. T.M. Shanahan, J.T. Overpeck, K.J. Anchukaitis, J.W. Beck, J.E. Cole, D.L. Dettman, J.A. Peck, C.A. Scholz, and J.W. King, "Atlantic forcing of persistent drought in West Africa," *Science* 324 (2009): 377-380.

5 https://blogs.scientificamerican.com/observations/allergies-from-pollen-projected-to-intensify-with-climate-change/. Citing annual scientific meeting of the American College of Allergy, Asthma and Immunology (ACAAI).

Extreme weather events such as heat waves, floods, and droughts become more frequent and more severe → During the 2003 European heat wave rainfall was reduced by 50% and temperatures were the hottest on record → an estimated 70,000 people died, mostly elderly[6] → the dried out soil produced fewer crops.[7]

Fact box: According to scientists who stucy ancient tree rings The 2003 heat wave in Europe was the hottest in 2,500 years.[8]

PERMAFROST
Ground that is normally frozen year round, called permafrost, is thawing → carbon dioxide and methane frozen into the permafrost is released into the atmosphere → [global warming accelerates, melting more permafrost →] viruses and bacteria stored in the permafrost are released → diseases spread widely because current populations have no immunity to them.

Fact box: There is twice as much carbon stored in the permafrost as in the entire atmosphere.[9]

Fact box: In 2016, anthrax released from thawing permafrost in Siberia sickened dozens of people and thousands of reindeer.

Fact box: Permafrost covers about one quarter of the land in the northern hemisphere.[10]

SNOW MELT
Loss of the snowpack that supplies water the Columbia River could[11]:
→ reduce power to electrical generators
→ prevent salmon from returning to spawn

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[6] Mathez ch. 9, citation
J.-M. Robine, S. K. Cheung, S. Le Roy, H. Van Oyen, C. Griffiths, J.-P. Michel, and F.R. Herrmann, "Death toll exceeded 70,000 in Europe during the summer of 2003" *Comptes Rendus Biologies* 331 (2008): 171-178.

[7] Mathez, Ch. 9, citation
Ciais, P., M. Reichstein, N. Viovy, A. Granier, J. Ogée, V. Allard, M. Aubinet, N. Buchmann, C. Bernhofer, A. Carrara, F. Chevallier, N. De Noblet, A.D. Friend, P. Friedlingstein, T. Grünwald, B. Heinesch, P. Keronen, A. Knohl, G. Krinner, D. Loustau, G. Manca, G. Matteucci, F. Miglietta, J.M. Ourcival, D. Papale, K. Pilegaard, S. Rambal, G. Seufert, J.F. Soussana, M.J. Sanz, E.D. Schulze, T. Vesala, and R. Valentini. "Europe-wide reduction in primary productivity caused by the heat and drought in 2003," *Nature* 437 (2005): 529—533.

[8] Mathez, ch. 9, "at least 2,500 years based on temperature record derived from alpine tree-ring data," Büntgen, U., W. Tegel, K. Nicolussi, M. McCormick, D. Frank, V. Trouet, J.O. Kaplan, F. Herzig, K.-U. Heussner, H. Wanner, J. Luterbacher, and J. Esper. "2500 years of European climate variability and human susceptibility," *Science* 331 (2011): 578-582.

[9] Mathez, Ch. 9

[10] Mathez, ch. 9 (24% per text and fig. 9.21)

[11] Impacts of Climate Change on the Columbia River Basin

www.hydro.washington.edu/.../Presentations/.../hamlet_climate_change_columbia_bas...

→ shorten the skiing season and reduce tourism
→ harm forests due to increased fire, disease, and insect damage
→ affect coldwater trout fishing due to warmer lakes and streams

ELECTRIC SYSTEM UNDER STRESS
(note: multiple effects from same cause, not a chain)
→ Rising tides → flooding of power stations
→ droughts and heat waves overtax grid
→ fires ionize air, shut down power lines
→ storms take out wires and relays
→ droughts reduce hydropower
→ warming water can't be used to cool nuclear reactors (already happened)
→ worst case, flooding of nuclear reactors like Fukushima causes radioactive pollution for thousands of years

Fact box: Over 100 electrical facilities in the U.S. are within 4 feet of local high tide, which is rising due to climate change.[12]]

FIRE
Grass, trees, and shrubs dry out → forest fires become larger and more frequent → loss of ice on mountains increases burning even more

ARCTIC
So far warming worst in Arctic → less ice →less reflected sunlight → water absorbs more sun, warms even further → [feedback loop: even less ice, even more absorption, etc.] →reduced habitat for polar bears → bears come into human communities looking for food → polar bears already declared threatened species because of loss of habitat → ice replaced by plants, also more absorptive than ice
→ some fisheries will move, shrink, or expand → shipping will go through Arctic circle where ice used to be
→ Less arctic ice →more sunlight in shallow arctic seafloor → algae and seaweed choke out invertebrates

WAVES & EROSION
Reduction of sea ice causes waves to increase in size and number in Arctic → coastal erosion → land erodes further because loss of permafrost

WATER QUALITY
Rising sea level affects water quality of Mokong delta (salinization?). Disrupts fishery that 40 millin people depend on for food.[13] [EPA]

[12] https://www.ucsusa.org/global_warming/science_and_impacts/impacts/effects-of-climate-change-risks-on-our-electricity-system.html
[13] https://19january2017snapshot.epa.gov/climate-impacts/international-climate-impacts_.html (footnotes 5, 6)

FOOD SHORTAGES
Increased droughts → less grain → grain prices double by 2050 → also less food for grazing livestock

PRICES OF SPECIFIC FOODS
Flooding in Argentina → damage to soybean crop → increase in price of hummus in America
Drought in 2014 in Brazil, US, Ukraine, Australia → sharp rise in coffee, chocolate, wheat prices[14]; also rice and corn[15]→ Trend toward spending more of total income on food, with less for other things[16] → World has already broken records in food price index[17]

INVASIVE PESTS
Insect ranges change → bark beatle invades, devastates forests

EXTINCTIONS
Habitat changes cause many species to go extinct. Some have already (i.e. golden toad in Costa Rica)

SEASONS
Spring comes earlier → plants bud earlier → insects eat plants earlier → migrating birds arrive at the wrong time, with fewer insects to eat
Also, → plants and animals move to higher higher altitudes and higher latitudes to follow the shifting seasons

SOIL CHANGES
Nutrient mobilization by microbes in forest soil also keyed to temperature and snowpack[18] → affects levels of nitrate, phosphate etc in soil→ already seeing root mortality in sugar maples.

EL NINOS
More and more extreme El Nino events[19] → will increase for next 100 years even if meet targets → more floods, droughts, etc

ACIDIFICATION
CO2 is absorbed by oceans Ocean acidification → forms carbonic acid → acid makes it harder for animals to make shells → microscopic shelled organisms are base of food

[14] https://www.ft.com/content/5c4500fc-a518-11e3-8988-00144feab7de
[15] http://blogs.ei.columbia.edu/2011/03/22/climate-change-to-exacerbate-rising-food-prices/
[16] https://www.csmonitor.com/Business/The-Bite/2016/1217/How-climate-change-could-affect-food-prices
[17] http://blogs.ei.columbia.edu/2011/03/22/climate-change-to-exacerbate-rising-food-prices/
[18] https://academic.oup.com/bioscience/article/62/12/1056/230680
[19] https://www.washingtonpost.com/news/energy-environment/wp/2017/07/24/it-was-really-a-surprise-even-minor-global-warming-could-worsen-super-el-ninos-scientists-find/?utm_term=.2a25d952dc31

chain for larger animals → ability to support life jeopardized, including larger animals humans eat
→ also cannot support photosynthetic microbes, which produce our oxygen → so life on Earth threatened as well

DISEASE
warming changes seasons → plants and animals' ranges shift → animals out of synch with plants and prey
→ spread of diseases[20], including malaria and dengue fever by mosquito range moving
→ waterborn diseases increase as rain and runoff contaminate water supplies[21], including cholera[22]
→ lime disease as ticks range spreads
→ algal blooms and contaminated seafood[23]
also yellow fever, Chagas's disease, schistosomiasis, and salmonella[24]

TOXINS
warming oceans →growth of phytoplankton that produce toxins → toxins accumulate in seafood and sicken humans[25]

DESERT ECOSYSTEMS
→Desert bacteria die → loss of biocrust → more erosion → damage entire ecosystem

GLACIERS & VOLCANOES→Loss of glaciers → changing pressure on crust → more volcanoes (probably thousands of years away though,

SPECIES BALANCES
More rain → more silt runoff into oceans → ocean water gets darker → more fish, less jellyfish

FINANCIAL
Effects on insurance industry:[26]
Increased disease and property damage → huge costs for insurers → collapse of businesses and expensive government bailouts → massive premium increases for consumers and tax increases → some insurers are investing in businesses that provide mitigation strategies[27]

MILITARY BASES

[20] https://chge.hsph.harvard.edu/climate-change-and-infectious-disease
[21] https://chge.hsph.harvard.edu/climate-change-and-infectious-disease
[22] https://www.ipcc.ch/ipccreports/sres/regional/144.htm
[23] https://www.ipcc.ch/ipccreports/sres/regional/144.htm
[24] https://www.ipcc.ch/ipccreports/sres/regional/144.htm
[25] https://www.ipcc.ch/ipccreports/sres/regional/144.htm
[26] http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=328
[27] https://www.theguardian.com/environment/2016/dec/07/climate-change-threatens-ability-insurers-manage-risk

Rising sea levels → coastal flooding → Destruction of 18 military bases on US Atlantic Coast[28] (Naval and Marines).
[Double the floods by 2050, daily flooding by 2070, up to 50% underwater by 2100.]

POLITICAL INSTABILITY
drought, famine, loss of water, floods, hurricane damage → mass migration → resistance to refugees → political instability & collaps of governments → rise of radicals and violence → regional hostility and war[29]

WATER SHORTAGES
Drought, reduced snow melt, reduced aquifers →water shortages → disputes over water rights lead to warfare (middle east, Bolivia, etc)

[28] https://www.ucsusa.org/global-warming/science-and-impacts/impacts/sea-level-rise-flooding-us-military-bases
[29] https://cfrd8-files.cfr.org/sites/default/files/report_pdf/ClimateChange_CSR32%20%281%29.pdf