

Climate Change 2022

Impacts, Adaptation and Vulnerability



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Lead Author IPCC Working Group II (Chp. 14, CCP6)



Climate Change

Causes
Drivers

Impacts
Adaptation

Mitigation

WGI

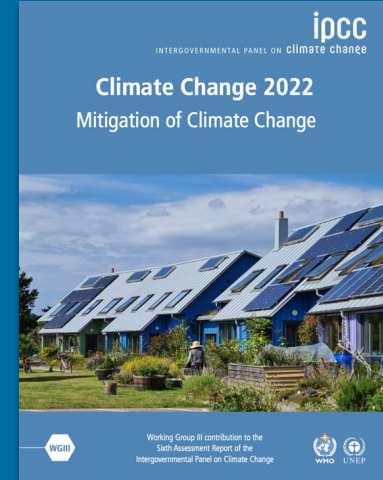
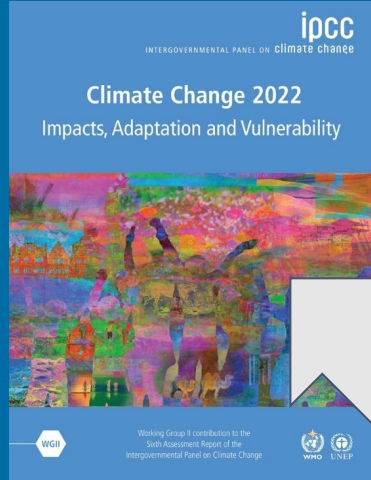
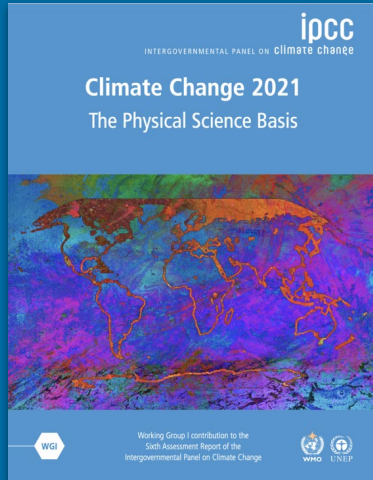
WGII

WGIII

Aug 2021

Feb 2022

Apr 2022





Outline for today

- Part 1: Key WGI findings
- Part 2: Key WGII findings
- Part 3: Relevant findings for Alaska Fisheries
 - Key sections for fisheries
 - Key recommendations for adaptation
- Part 4: WGIII findings relative to 1.5 °C target



How to access the most recent (CMIP6) climate projections

- IPCC Interactive Atlas (explore future variables and scenarios): <https://interactive-atlas.ipcc.ch/>
- PSL Climate Change portal (explore plots from CMIP6; similar to IPCC Atlas): <https://psl.noaa.gov/ipcc/cmip6/>
- ACLIM data portal : explore high res projections for the EBS including krill : <https://data.pmel.noaa.gov/aclim/las/UI.html>
- *Future: EBS Climate Change dashboard (via ACLIM3)*

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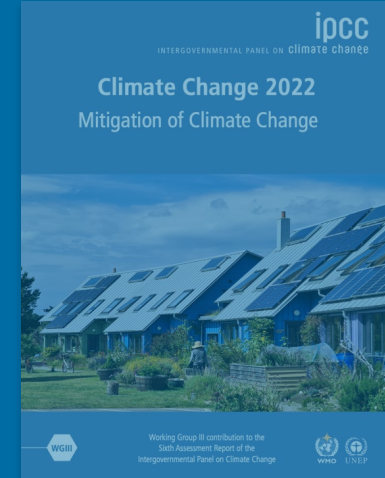
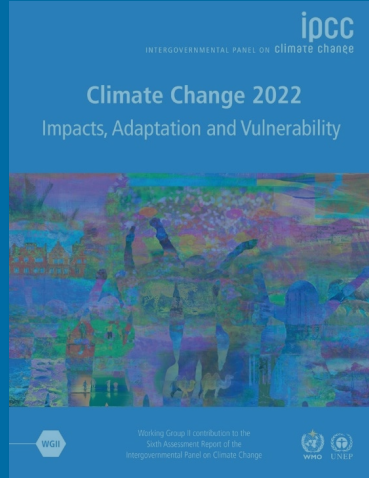
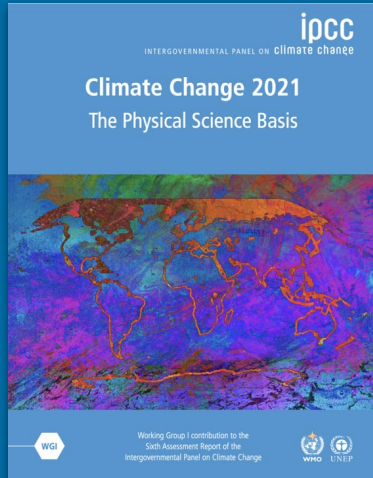
WGII

WGIII

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AR6 WGI : The Physical Basis SPM



A.1 It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred.

A.2 The scale of recent changes across the climate system as a whole – and the present state of many aspects of the climate system – are unprecedented over many centuries to many thousands of years.

A.3 Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5.

Climate change has already warmed the planet

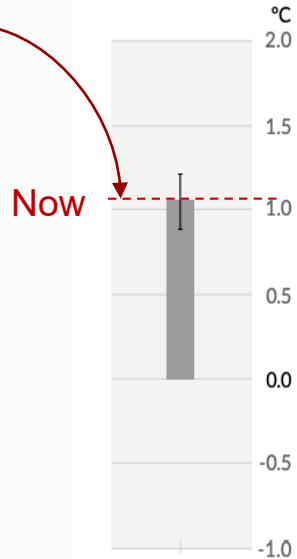
*"The likely range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is **0.8°C to 1.3°C**, with a best estimate of **1.07°C**."*

[IPCC 2021 6th Assessment Report, WG 1, SPM](#)



Observed warming

a) Observed warming
2010-2019 relative to
1850-1900



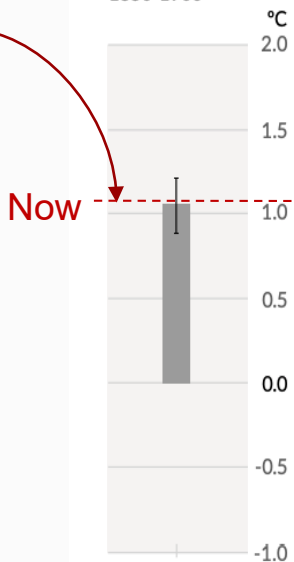
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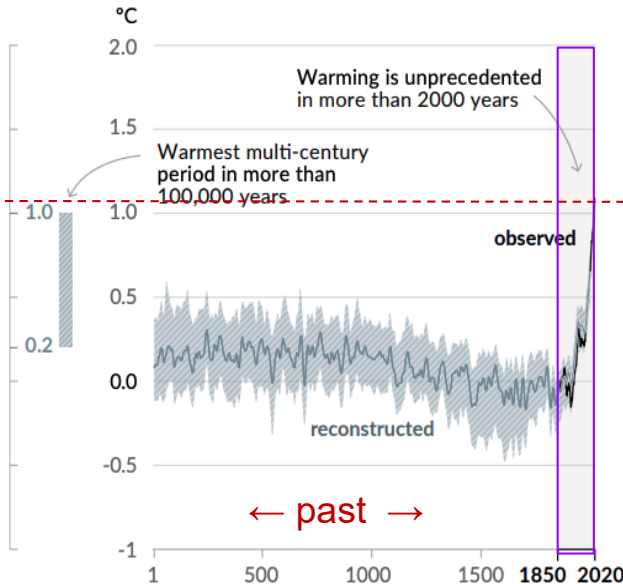
Observed warming

a) Observed warming 2010–2019 relative to 1850–1900



Changes in global surface temperature relative to 1850-1900

a) Change in global surface temperature (decadal average) as reconstructed (1-2000) and observed (1850-2020)



Recent Global Mean Warming is:

- Warmest period in more than 100,000 years
- Unprecedented warming in more than 2,000 years
- CO2 concentrations in 2019 were higher than any time in at least 2 million years.

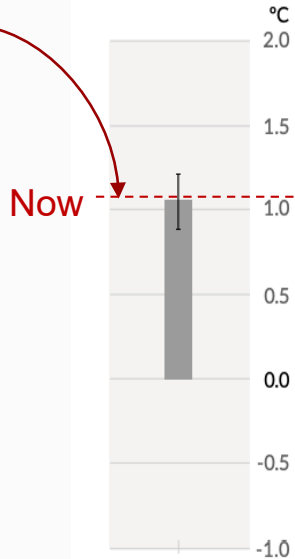
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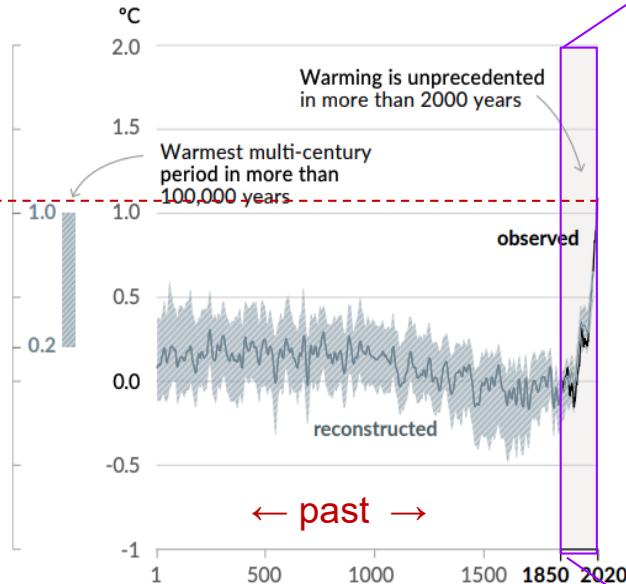
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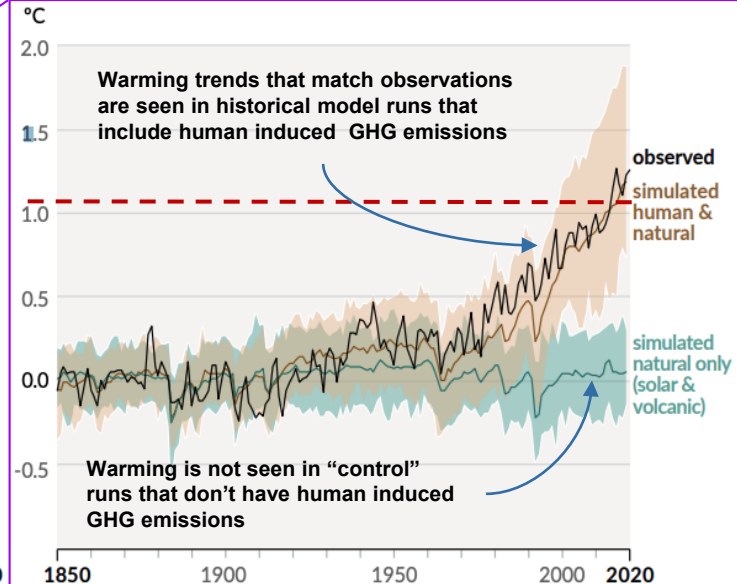


Changes in global surface temperature relative to 1850-1900

a) Change in global surface temperature (decadal average) as reconstructed (1-2000) and observed (1850-2020)



b) Change in global surface temperature (annual average) as observed and simulated using human & natural and only natural factors (both 1850-2020)

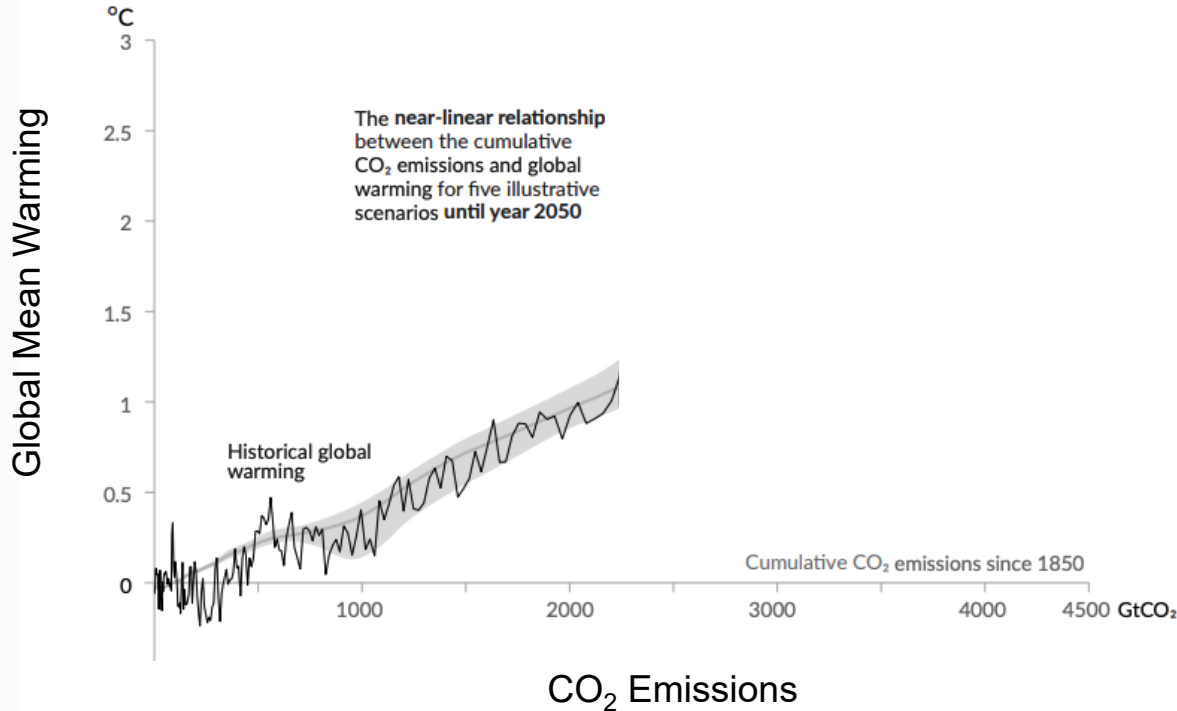


Near linear relationship between temperature & CO₂ emissions



Every tonne of CO₂ emissions adds to global warming

Global surface temperature increase since 1850–1900 (°C) as a function of cumulative CO₂ emissions (GtCO₂)

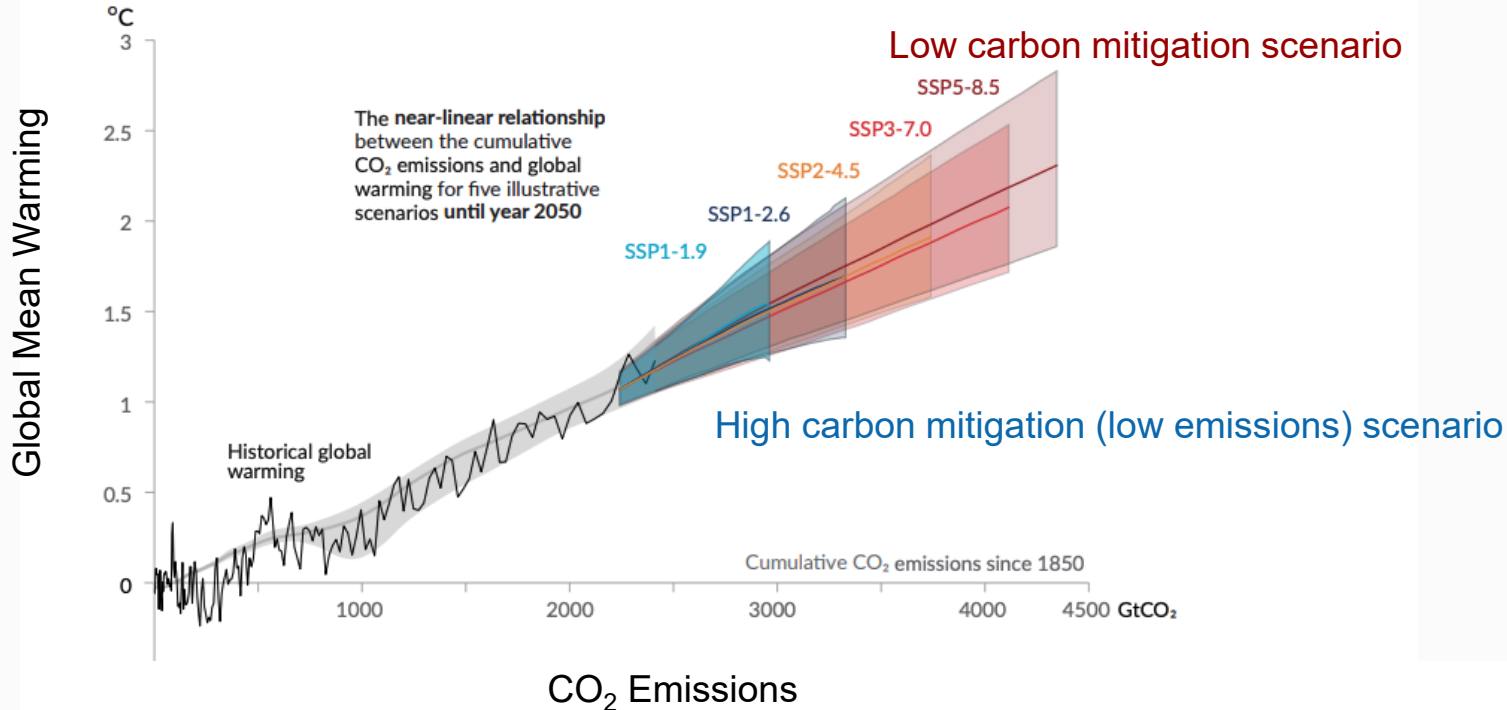


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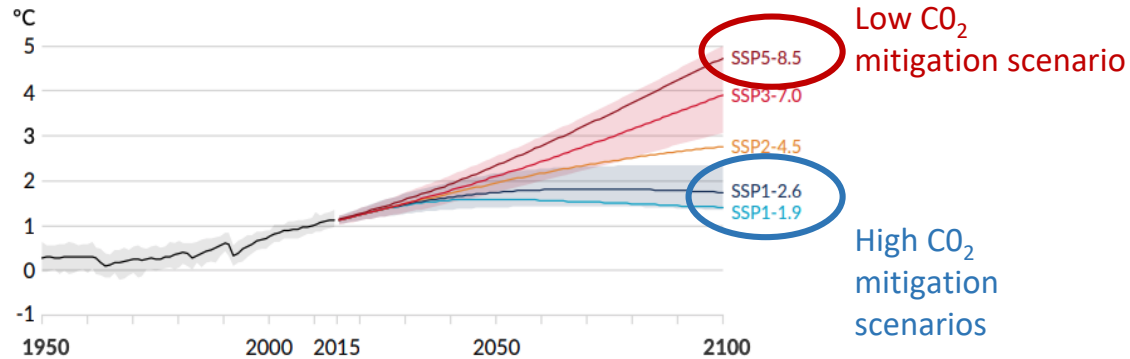
Global surface temperature increase since 1850–1900 (°C) as a function of cumulative CO₂ emissions (GtCO₂)



Climate change is expected to continue to impact AK Ecosystems & Fisheries



a) Global surface temperature change relative to 1850-1900



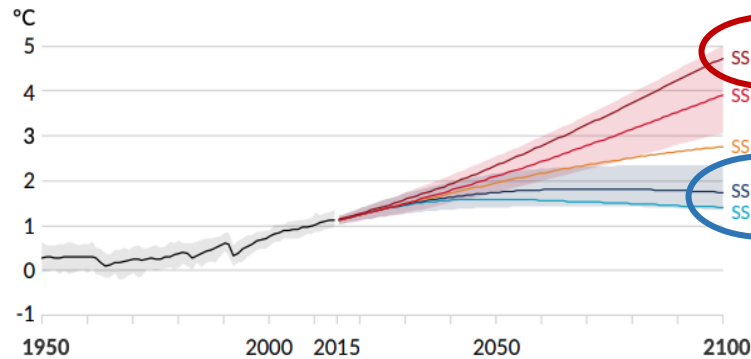
Carbon Emission Scenarios

“plausible descriptions of how the future may evolve with respect to a range of variables... **they are not meant to be policy prescriptive**, (i.e. no likelihood or preference is attached to any of the individual scenarios of the set)”
van Vuuren et al. 2011

Climate change is expected to continue to impact AK Ecosystems & Fisheries



a) Global surface temperature change relative to 1850-1900

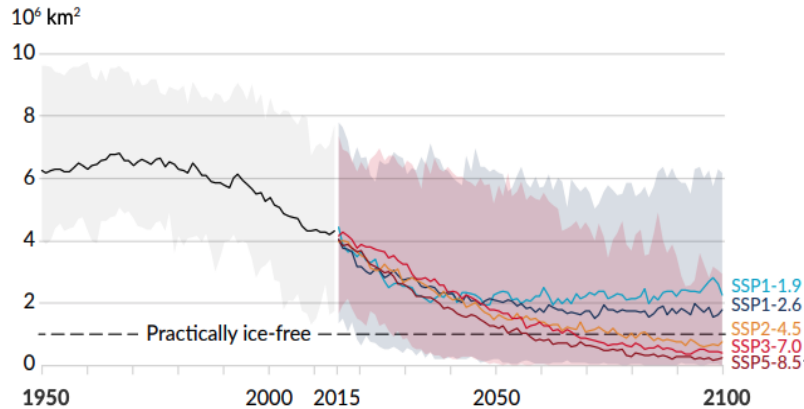


Low CO₂ mitigation scenario

High CO₂ mitigation scenarios

Warming will continue and is greater in scenarios with low CO₂ mitigation

b) September Arctic sea ice area



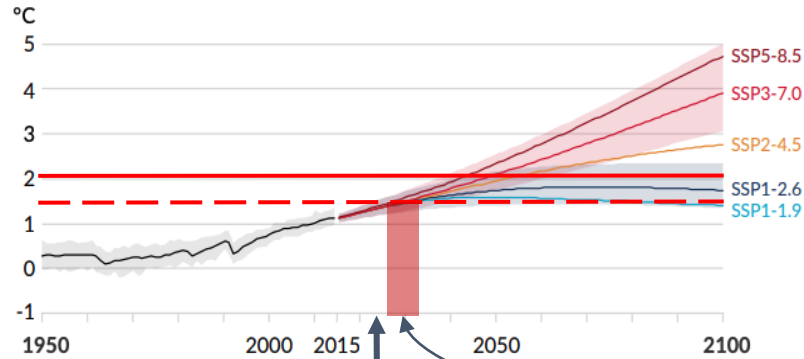
Sea Ice will continue to decline, more so under scenarios with high global warming and low CO₂ mitigation

Figures from the IPCC AR6 WGI Summary for Policymakers: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPC_C_AR6_WGI_SPM.pdf

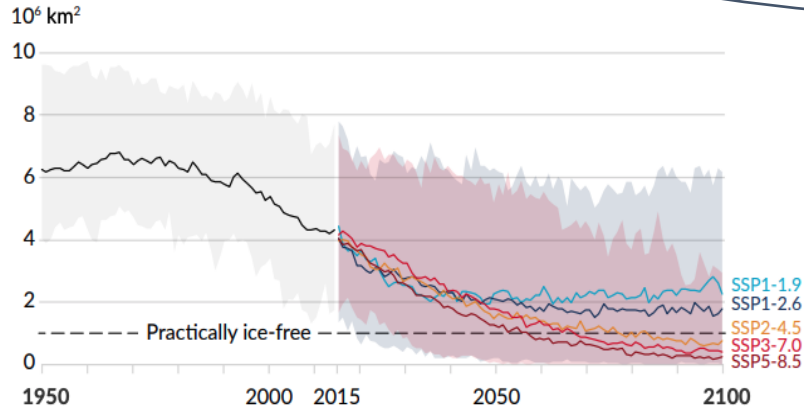
Climate change is expected to continue to impact AK Ecosystems & Fisheries



a) Global surface temperature change relative to 1850-1900



b) September Arctic sea ice area



WGI TECHNICAL SUMMARY

*“In AR6, combining the larger estimate of global warming to date and the assessed climate response to all considered scenarios, **the central estimate of crossing 1.5°C of global warming (for a 20-year period) occurs in the early 2030s, ten years earlier than the midpoint of the likely range assessed in the SR1.5, assuming no major volcanic eruption.**”*

*Figures from the IPCC AR6 WGI Summary for Policymakers:
https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPC_C_AR6_WGI_SPM.pdf*

Warming in the Arctic is 2-3 x global average



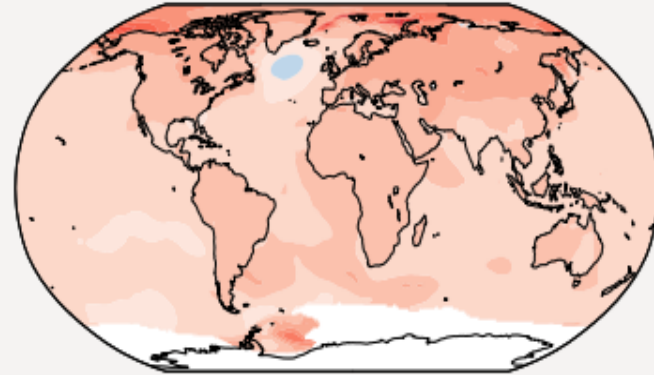
1.07°C of “Global mean warming” = Warming of 2-3°C in the Arctic

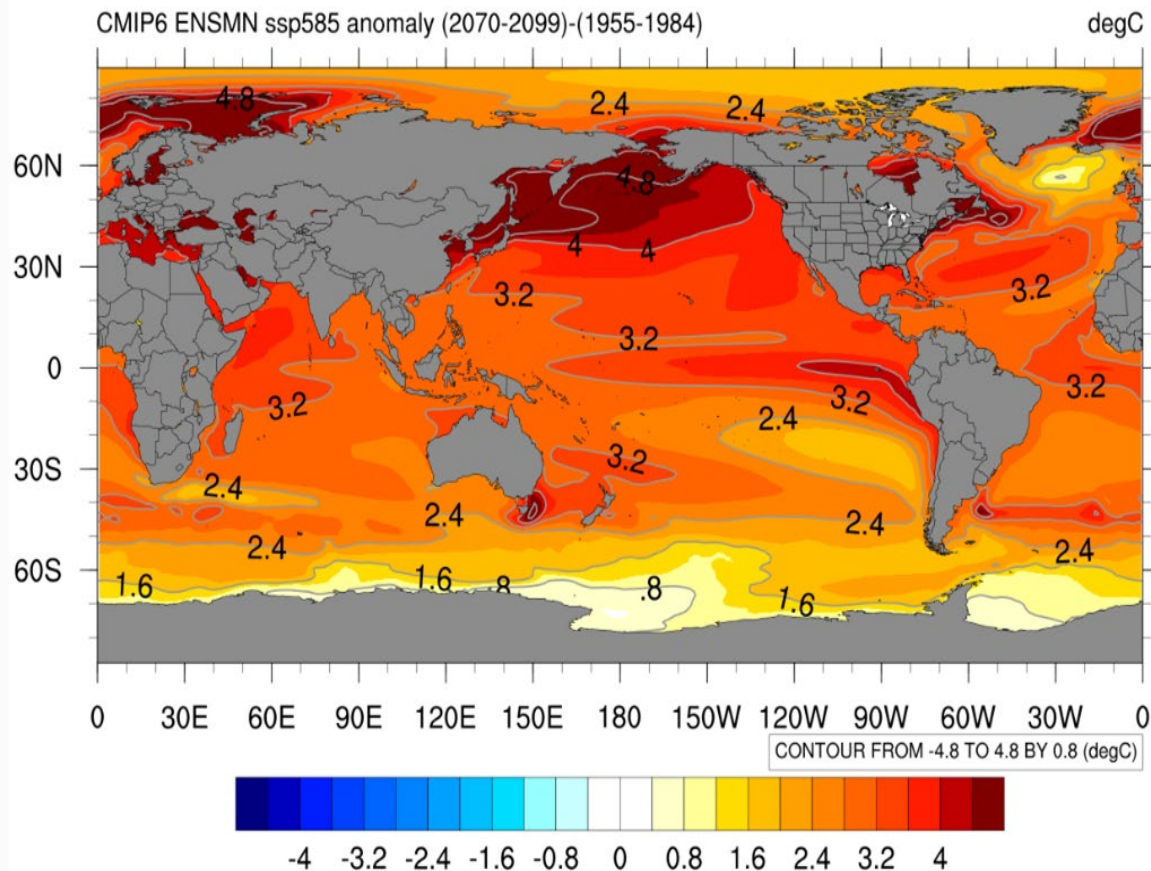
“Arctic Amplification”

a) Annual mean temperature change (°C)
at 1 °C global warming

Warming at 1 °C affects all continents and is generally larger over land than over the oceans in both observations and models. Across most regions, observed and simulated patterns are consistent.

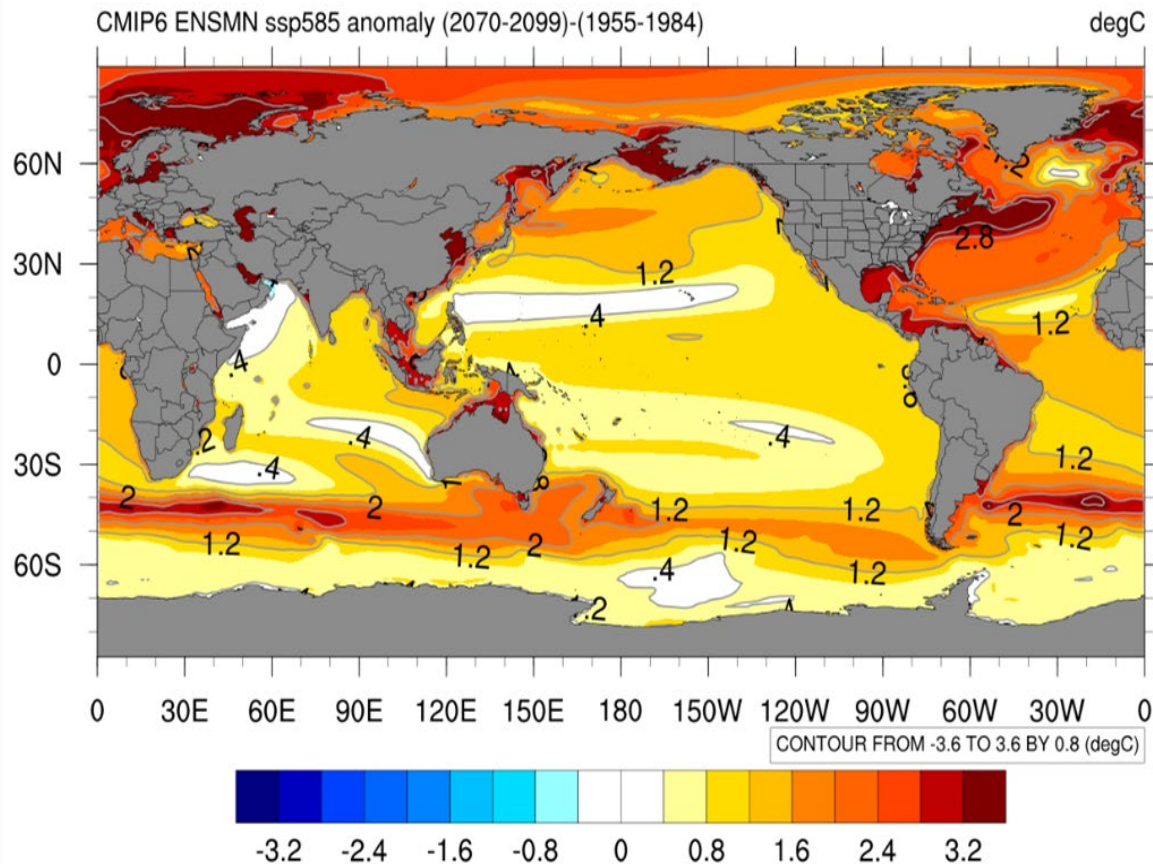
Observed change per 1 °C global warming





**High Emissions
(SSP585)**

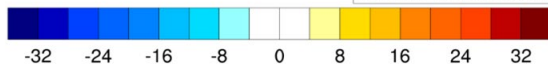
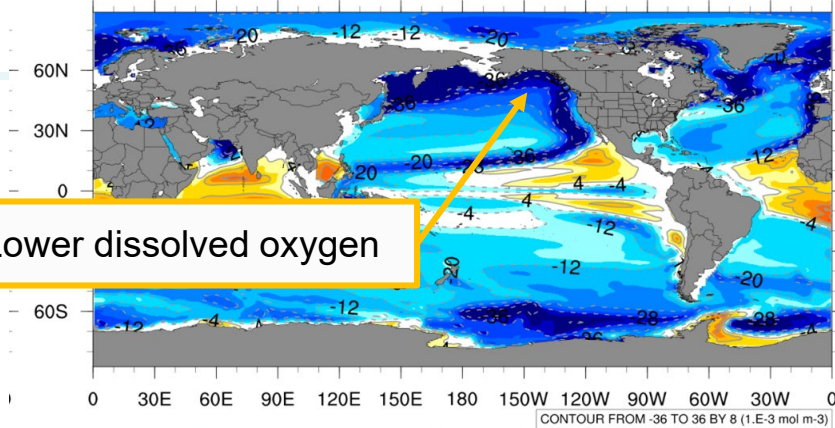
**End of Century
Change in
Sea Surface
Temperature (°C)**



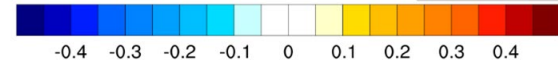
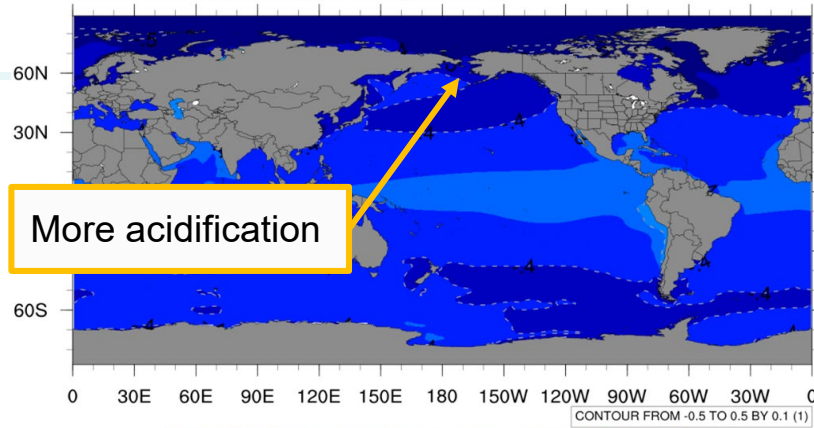
High Emissions (SSP585)

**End of Century Change in
Bottom Temperature (°C)**

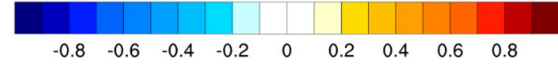
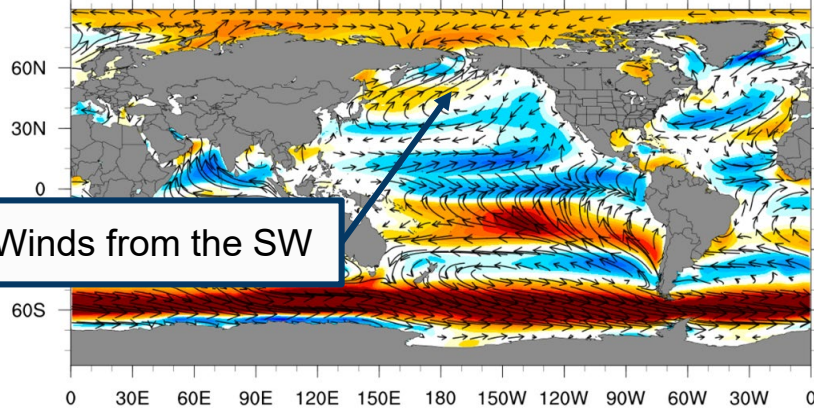
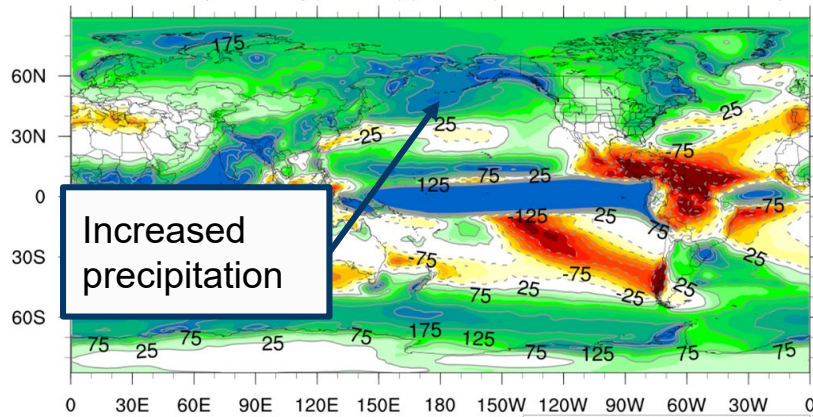
CMIP6 ENSMN ssp585 anomaly (2070-2099)-(1955-1984) 1.E-3 mol m-3



CMIP6 ENSMN ssp585 anomaly (2070-2099)-(1955-1984) 1



CMIP6 ENSMN ssp585 anomaly (2070-2099)-(1955-1984) mm/year



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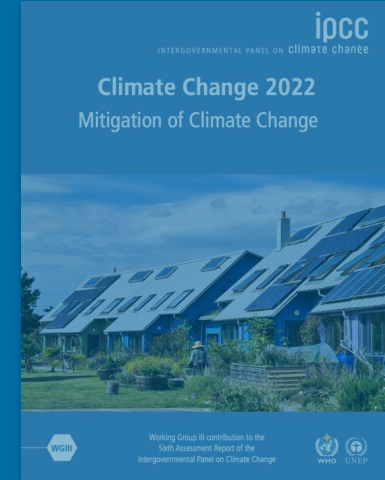
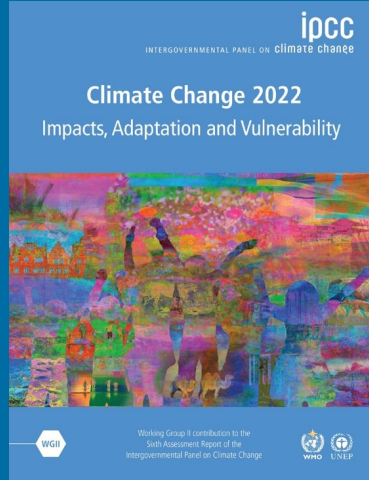
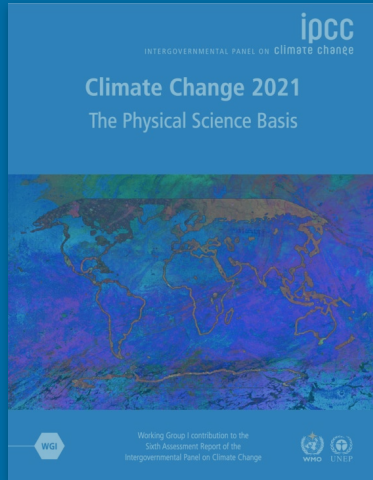
WGII

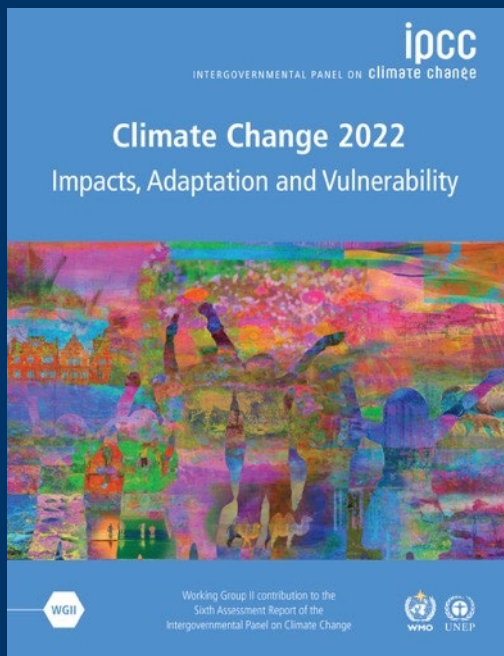
WGIII

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The science is clear.

Any further delay in concerted global action will miss a brief and rapidly closing window to secure a liveable future.

This report offers solutions to the world.

IPCC AR6 WGII Report by numbers



270 Authors



67 Countries



43 % Developing countries
57 % Developed countries



41 % Women / 59 % Men



675 Contributing authors



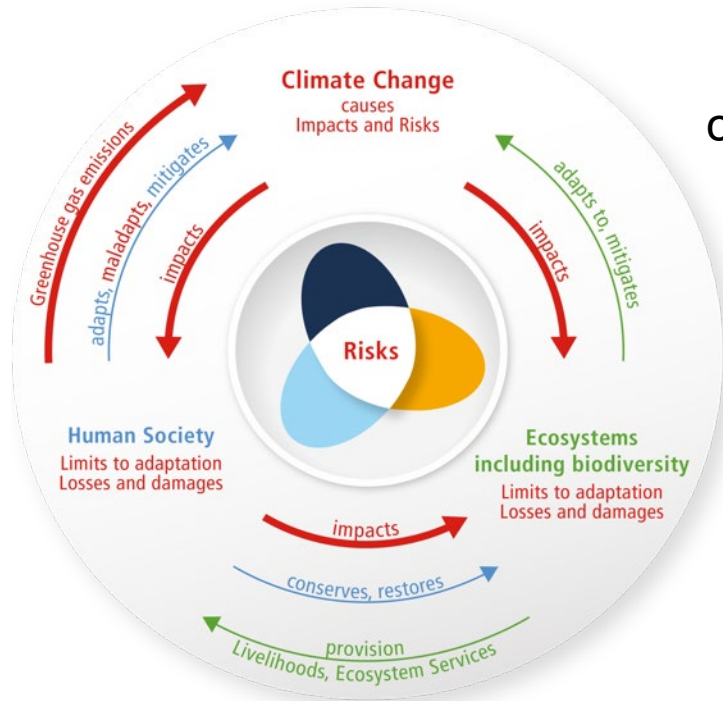
More than
34,000 scientific papers



62,418
Review comments

**Growing scientific
knowledge gives us our
best understanding yet**

New understanding of interconnections



Consider coupled
climate-ecological-social
systems

The risk propeller shows that risk emerges from the overlap of:

- Climate hazard(s)
 - Vulnerability
 - Exposure
- ...of human systems, ecosystems
and their biodiversity



Global warming
has caused dangerous and
widespread disruption in nature...

...and climate change is affecting the lives of billions of people, despite efforts to adapt.





Action on adaptation has increased but progress is uneven and we are not adapting fast enough.



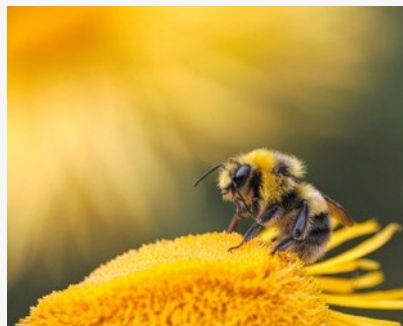
ipcc

INTERGOVERNMENTAL PANEL ON climate change



Every small increase in warming
will result in increased risks.

Nature's crucial services at risk in a warming world



Pollination



Coastal protection



Tourism / recreation



Food source



Health



Water filtration

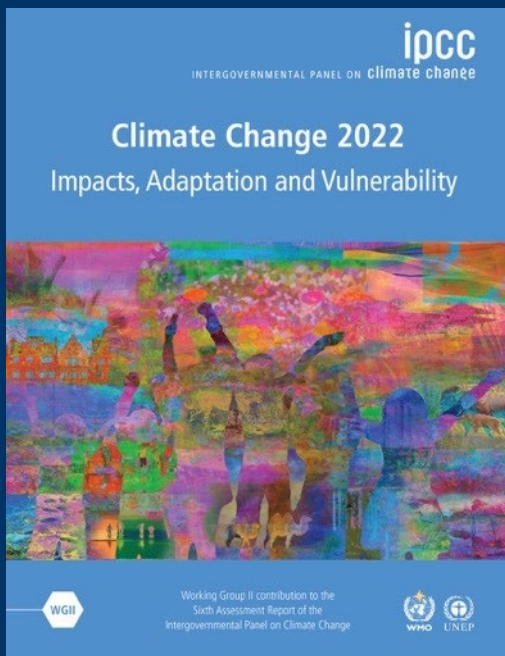


Clean air



Climate regulation

Fisheries and Alaska



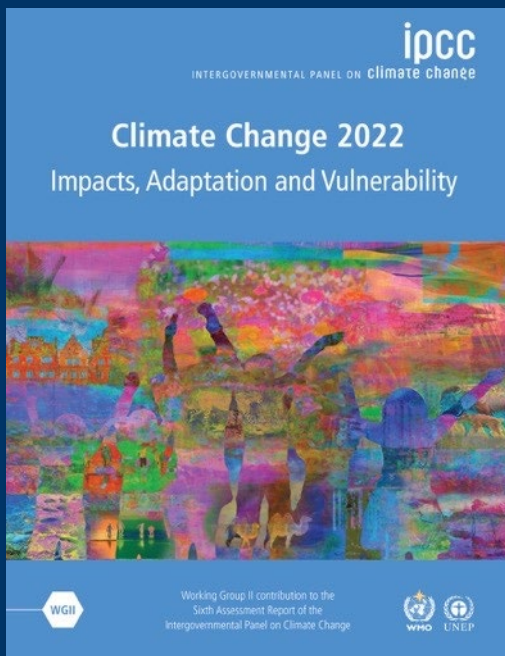
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CCP6 : Polar Regions

Chapter 3: Oceans

Chapter 5: Food and Fibre

Chapter 14: North America



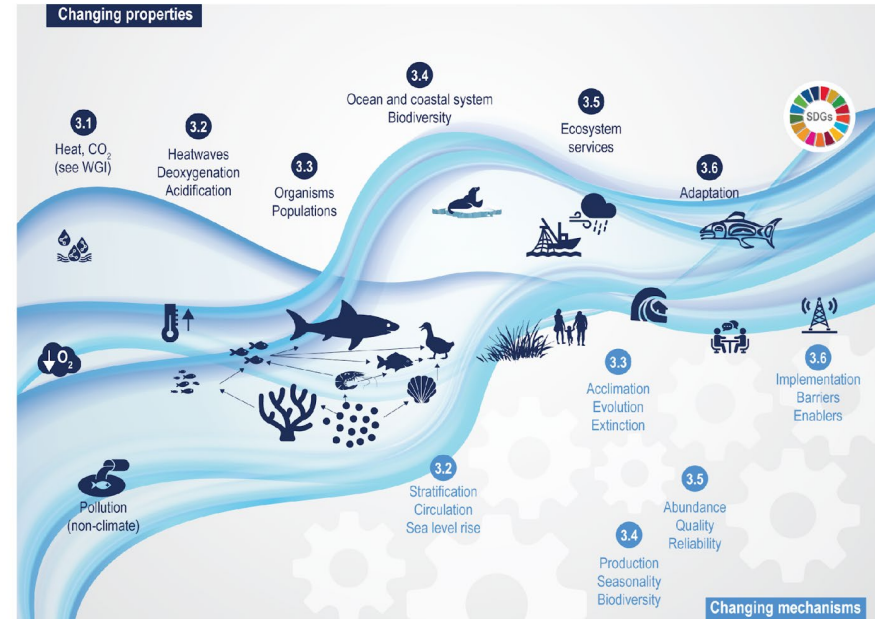
“

Long-term loss and degradation of marine ecosystems compromises the ocean's role in cultural, recreational, and intrinsic values important for human identity and well-being.

Example Impacts & Risks

- Shifting distributions & altered access
- Shifts in trophic pathways & size spectra
- Phenological mismatches & changes in productivity
- Reductions in fishery & subsistence resources
- Future risk to food & nutritional security
- Geopolitical, survey, stock boundary challenges
- Increased interactions between protected species & fisheries (e.g., pot fisheries)
- Compound multiple climate impacts (MHW, HABs, and low DO) & non-climate pressures (e.g., pollution, shipping)
- Increasing fishery emergencies & economic losses
- Reduced confidence in management
- Supply chain disruption (e.g., ports)
- Changes in safety & security
- Changes in markets & demand (interactions with agriculture)

WGII AR6 Chapter 3 concept map



Climate change has already caused: US Fishery impacts



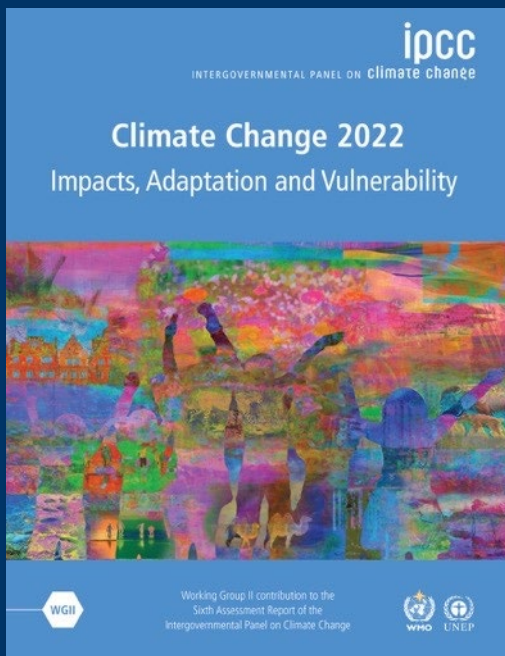
PeerJ

“Nationwide, 84.5% of fishery disasters were either partially or entirely attributed to extreme environmental events.”

Table 2 Total U.S. Congressional fishery disaster assistance (2019 USD) by cause and by federal fisheries management region. One additional disaster had an allocation amount that was not reported, but the request letter cited economic impacts of \$53.8-94.2M. Anthropogenic causes include pollution and overfishing; environmental causes include marine heatwaves, harmful algal blooms, hurricanes, extreme drought, etc.; and a combination includes both anthropogenic and environmental causes. Examples of fisheries being impacted by a combination of causes can be found in some Pacific northwest salmon fishery disasters, which were caused by low returns that resulted from marine heatwaves, drought, disease, habitat impacts, mismanagement, and overfishing.

Cause	Alaska	Greater Atlantic	Pacific Islands	Southeast	West Coast	To be determined	Total
Anthropogenic	\$82,000,000	\$132,996,669		\$30,940,000	\$7,600,000		\$253,536,669
Environmental	\$174,292,189	\$41,572,622	\$1,140,000	\$505,938,343	\$170,723,211		\$893,666,365
Combination of Both	\$75,588,349	\$36,600,000		\$37,098,200	\$281,802,589		\$431,089,138
To be determined						\$414,103,069	\$414,103,069
Total	\$331,880,538	\$211,169,291	\$1,140,000	\$573,976,543	\$460,125,800	\$414,103,069	\$1,992,395,241

Bellquist et al. 2021. The rise in climate change-induced federal fishery disasters in the United States. <https://peerj.com/articles/11186/>



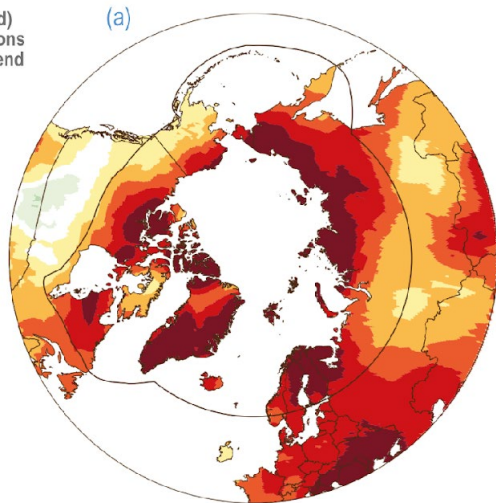
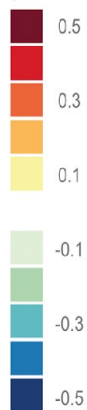
Contractions of the polar climate zones lead to distribution shifts and changes in food webs, induce declines in many species (*medium confidence*)

with impacts on subsistence harvests and commercial fisheries, and threaten global dependence on polar regions for substantial marine food production (*high confidence*).

Projected Impacts: Arctic

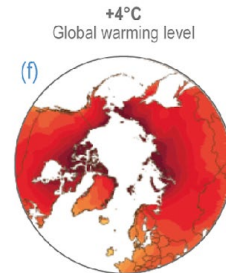
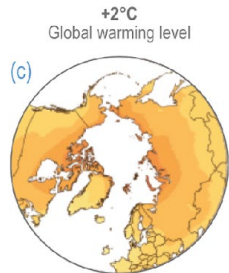
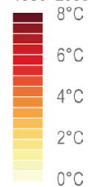
Warming to date

W5E5 (ERA5 adjusted)
1980–2015 observations
mean temperature trend
(°C decade⁻¹)



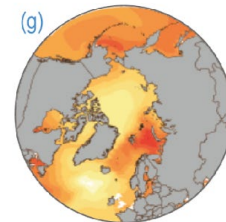
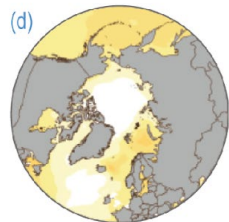
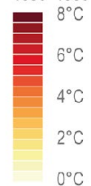
Future conditions

ΔT °C
relative to
1986–2005



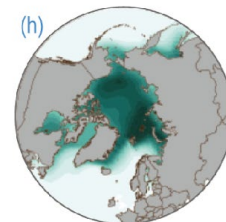
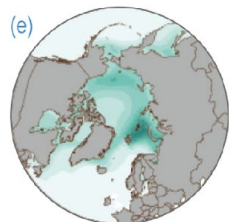
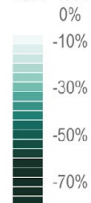
Land Temp.

ΔSST °C
relative to
1850–1900



Sea Surface
Temp.

ΔSI %
relative to
1850–1900



Sea Ice Loss

<https://interactive-atlas.ipcc.ch/>

Example Impacts & Risks

Disappearing sea ice

Winter ice cover in the Bering Sea has diminished faster than scientists expected. The record for the least amount of ice since 1850 was set in 2018, and 2019 came close to breaking that record.



Sources: Esri, NOAA

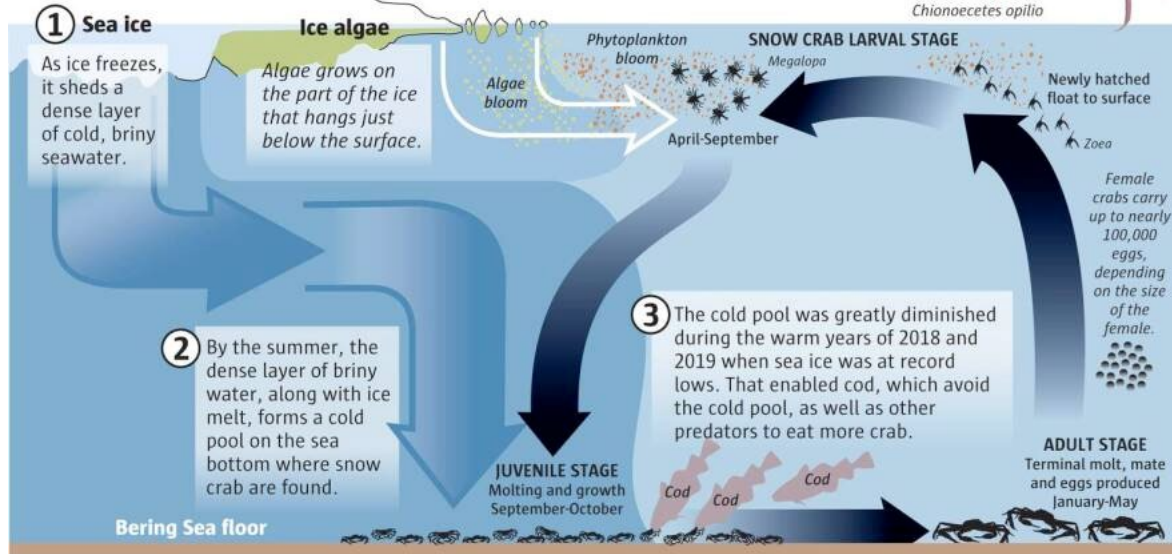
MARK NOWLIN / THE SEATTLE TIMES

<https://www.noaa.gov/stories/unprecedented-2018-bering-sea-ice-loss-repeated-in-2019>
<https://www.seattletimes.com/seattle-news/as-bering-sea-ice-melts-nature-is-changing-on-a-massive-scale-and-alaska-crab-pots-are-pulling-up-cod/>

Example Impacts & Risks

How sea ice helps sustain Bering Sea snow crab

Snow crab typically dwell in a bottom layer of cold water that provides protection from predators. That cold pool shrank drastically during recent warming.



Source: Aug. 23, 2019, presentation by Janet Duffy-Anderson, NOAA/Alaska Fisheries Science Center

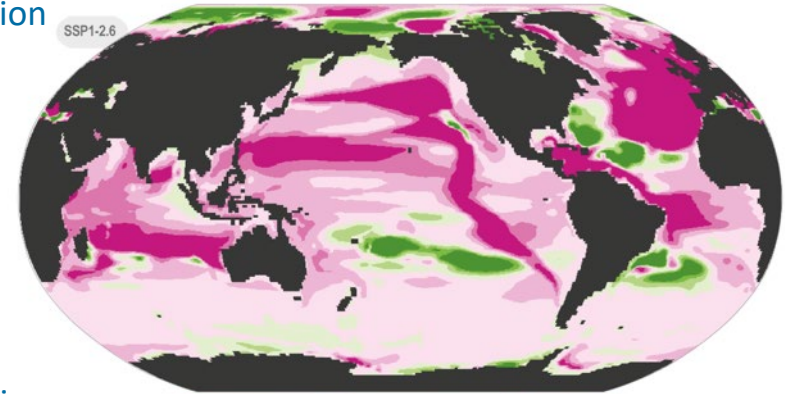
MARK NOWLIN / THE SEATTLE TIMES

Projected Impacts

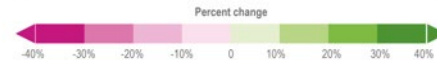
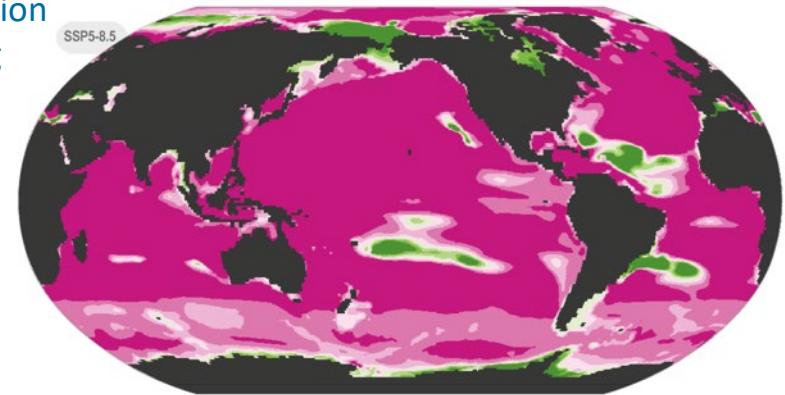
Declines in benthic biomass projected for most regions

Projected change in marine benthic animal biomass
Simulated change averaged over 2090–2099, relative to 1990–1999

High CO₂ Mitigation
Less warming
(SSP1 2.6)



Low CO₂ Mitigation
High warming
(SSP5 8.5)



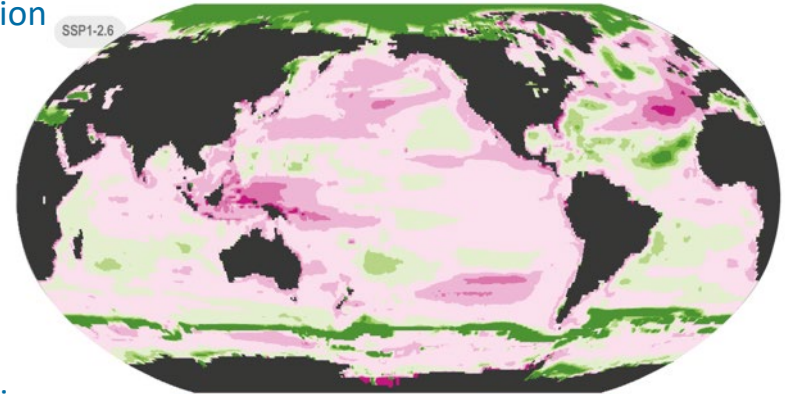
Projected Impacts

Declines in fish biomass projected for most regions

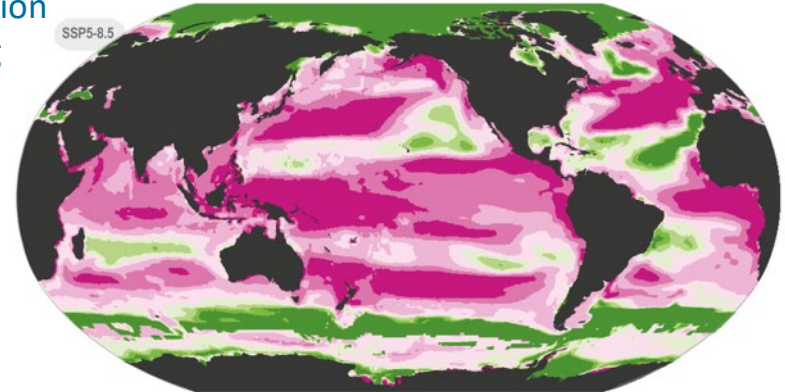
Adaptation planning needed to minimize impacts

High CO₂ Mitigation
Less warming
(SSP1 2.6)

Projected change in marine fish biomass
Simulated change averaged over 2090–2099, relative to 1990–1999



Low CO₂ Mitigation
High warming
(SSP5 8.5)





There are options we can take
to reduce the risks to people and nature.

Adaptation can reduce risks if coupled with CO₂ Mitigation

Urgent need for:

“ Implementation of adaptive management that is closely linked to monitoring, research, and low cost and inclusive public participation”

Impact: Changes to cold water habitats & critical refugia
Adaptation: Spatial management of climate refugia, EBM

Impact: Permafrost loss, erosion, loss of ice & snow routes impact homes, buildings, & critical infrastructure
Adaptation: Co-management agreements and shared leadership approaches to managing self-determined sustainable development

Impact: Alterations to bio-psycho-social conditions & cultural continuity negatively disrupt mental health
Adaptation: Place-specific mental health resources & training and infrastructure and incorporating a climate-sensitive mental health lens into climate change adaptation

Impact: Climate impacts on caribou & reindeer subsistence resources
Adaptation: Indigenous co-management, protect & enhance grazing habitats, enhance forage



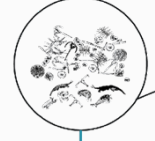
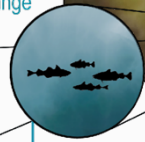
Impact: Sea ice mobility & near-term shipping navigational hazards
Adaptation: Improved charting, enhanced local search & rescue, technological developments in ship-design



Impact: Loss of multiyear ice, early break up, thinner more hazardous ice, loss of ice dependent species, shipping interactions
Adaptation: Nowcasting & real time observations of ice conditions, communication, sea ice mapping, data sharing, Indigenous co-management & oversight, enhanced search & rescue capacity, conservation



Impact: Loss of productivity in polar fisheries with impacts on food & nutritional security within & beyond polar regions
Adaptation: Diversify harvest portfolios, provide climate informed advice with EBM, nowcasts, & seasonal to decadal forecasting to improve harvest recommendations



Impact: Changes to lower trophic pathways, ecosystem linkages, and carrying capacity
Adaptation: Climate-informed Ecosystem Based Management (EBM), measures to reduce pressure

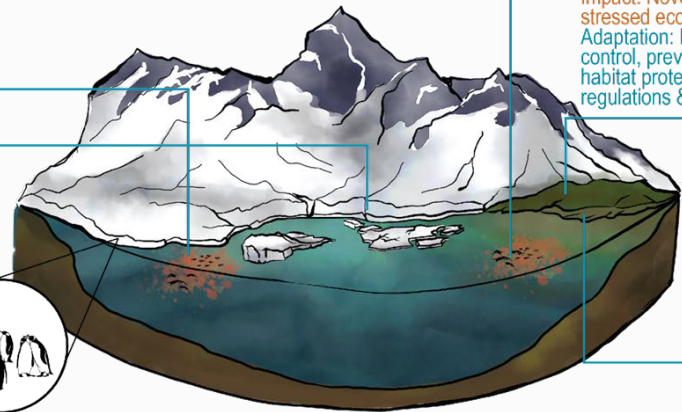
Impact: Novel conditions, increased activity, & stressed ecosystems favor invasive species
Adaptation: Increased detection, reporting, & control, preventative measures to reduce vectors, habitat protection to increase biotic resistance, regulations & quarantine to reduce introductions

Impact: Changes to cold water habitats and critical refugia
Adaptation: Spatial management of climate refugia, EBM, conservation Marine Protected Areas (MPAs)

Impact: decline in coastal ice habitats for Emperor penguins
Adaptation: Protection of important prey fields & ice-habitats to reduce interference and increase resilience of the species.



Impact: Coastal erosion impacts coastal infrastructure
Adaptation: Infrastructure reinforcement, research & development on climate resilient infrastructure, climate informed planning and relocation



Ocean adaptation

IPCC AR6 WGII
Figure 3.23

Categories

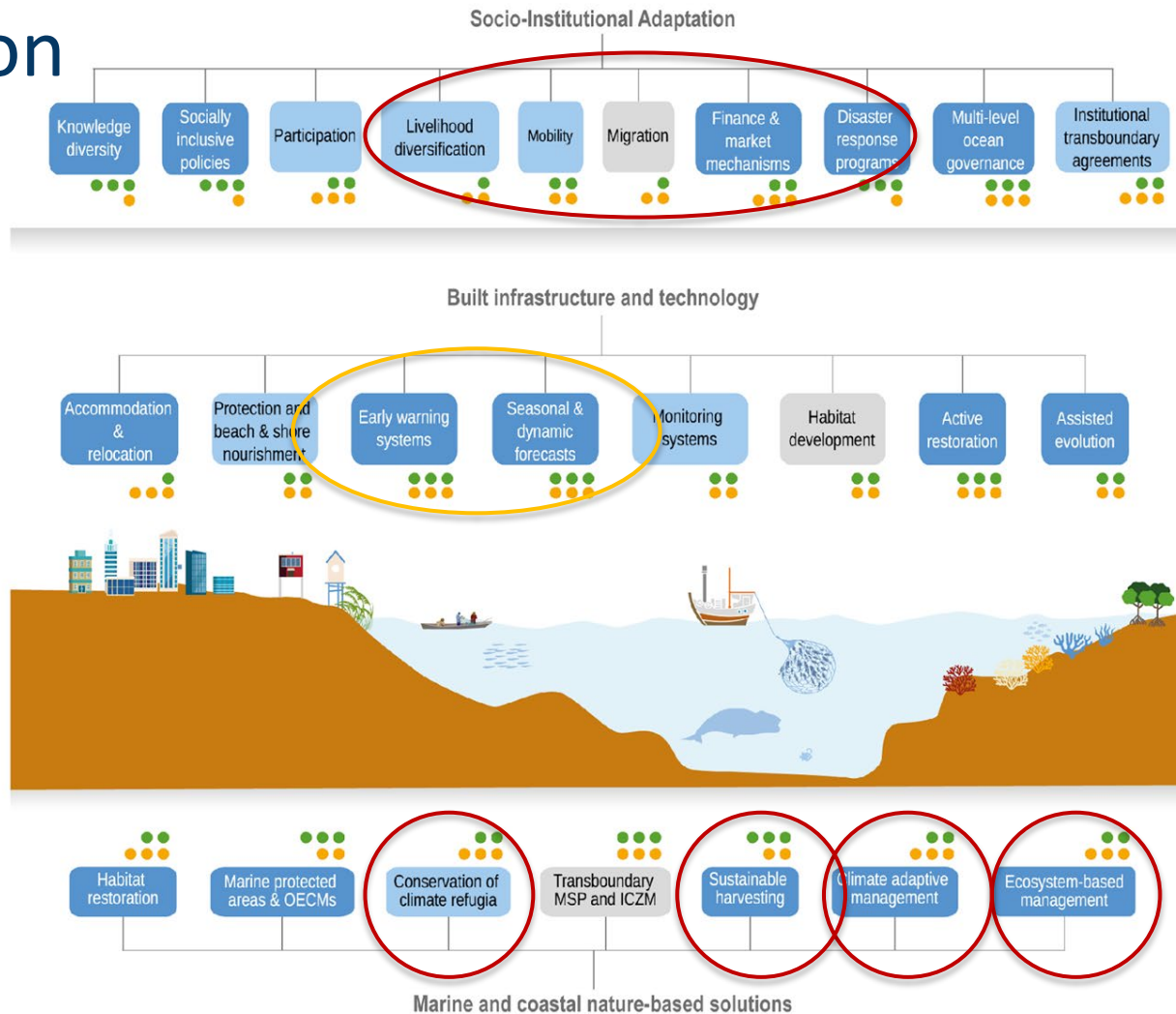
- Feasibility
- Effectiveness to reduce climate risks

Level

- High
- Medium
- Low

Confidence in solution

- High
- Medium
- Low



Key Aspects of Fisheries Adaptation

- Inclusive, participatory, & equitable decision making
- Responsive & flexible management
- Ecosystem Based Management
- Diversity in harvest options & livelihoods
- Ecological redundancy & high biodiversity
- Preserve ecosystem function & climate refugia
- Climate change planning & preparation
- Increased foresight & climate informed advice
- Monitoring & rapid response
- Emergency response



Steve Ringman / The Seattle Times



There are limits to adaptation

“ To avoid mounting losses, urgent action is required to adapt to climate change.

ACT NOW

At the same time, it is essential to make rapid, deep cuts in greenhouse gas emissions to keep the maximum number of adaptation options open.

Climate Change

Causes
Drivers

Impacts
Adaptation

Mitigation

WGI

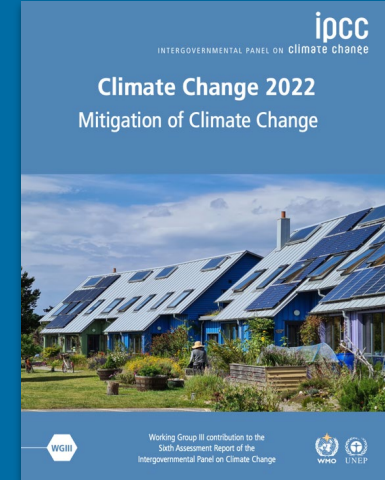
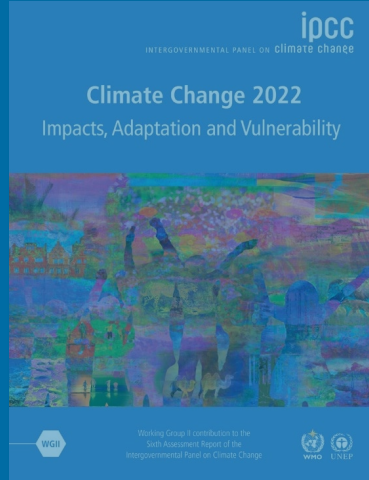
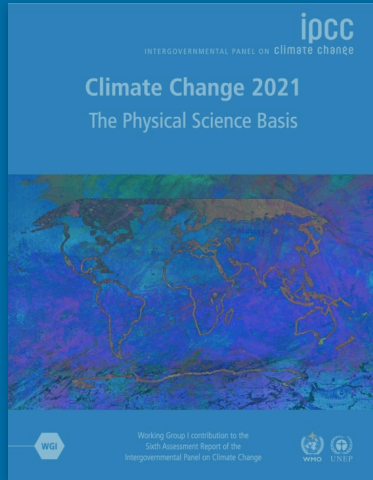
WGII

WGIII

Aug 2021

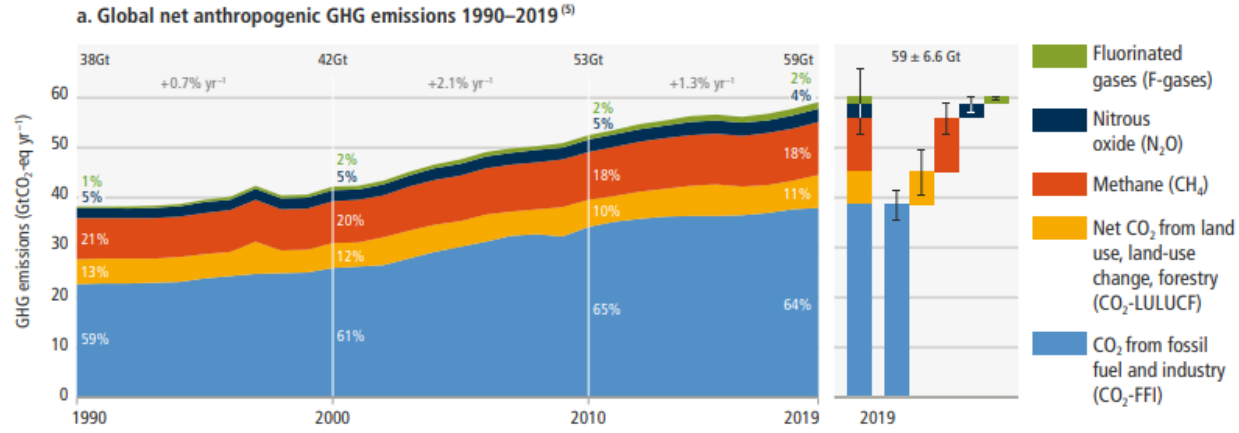
Feb 2022

Apr 2022



AR6 WGIII : Mitigation of Climate Change

Global net anthropogenic emissions have continued to rise across all major groups of greenhouse gases.



2019 total net anthropogenic GHG emissions

- 34% Energy Supply
- 24% Industry
- 22% Agriculture, forestry & land use
- 15% Transport
- 6% Buildings

AR6 WGIII : Mitigation of Climate Change

C.1 Global **GHG emissions are projected to peak between 2020 and at the latest before 2025 in global modelled pathways that limit warming to 1.5°C (>50%)** with no or limited overshoot and in those that limit warming to 2°C (>67%) and assume immediate action...

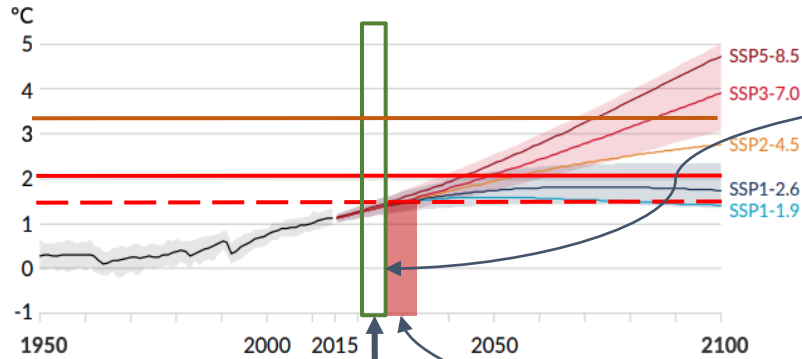
...Without a strengthening of policies beyond those that are implemented by the end of 2020, GHG emissions are projected to rise beyond 2025, **leading to a median global warming of 3.2 [2.2 to 3.5] °C** by 2100.

C.3 All global modelled pathways that limit warming to 1.5°C (>50%) with no or limited overshoot, and those that limit warming to 2°C (>67%), involve **rapid and deep, and in most cases, immediate GHG emission reductions in all sectors.**

Climate change is expected to continue to impact AK Ecosystems & Fisheries



a) Global surface temperature change relative to 1850-1900



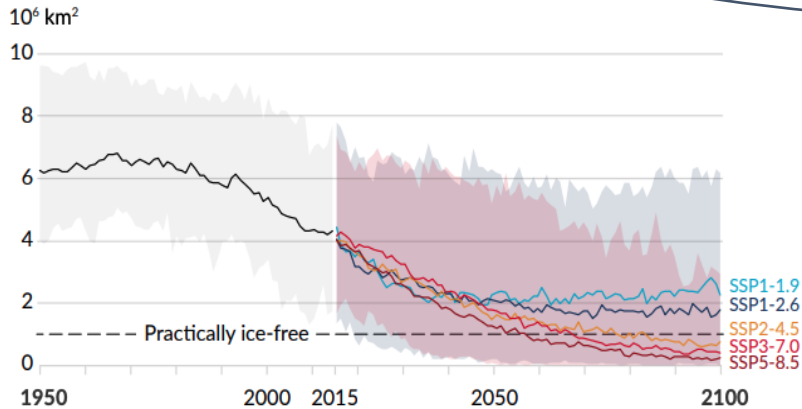
WGIII SPM

Range of action to remain below 1.5 °C
GMW (2020-2025; emissions must peak
now to limit warming to 1.5 °C)

WGI TECHNICAL SUMMARY

“In AR6, combining the larger estimate of global warming to date and the assessed climate response to all considered scenarios, **the central estimate of crossing 1.5°C of global warming (for a 20-year period) occurs in the early 2030s, ten years earlier than the midpoint of the likely range assessed in the SR1.5, assuming no major volcanic eruption.**”

b) September Arctic sea ice area



Figures from the IPCC AR6 WGI Summary for Policymakers:
https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPC_C_AR6_WGI_SPM.pdf

This is solvable!

ACT NOW

Overall, the latest studies on the net economic implications of decarbonisation – which also account for avoided climate damages – **point to overall benefit from the transition.**

-Prof Valentina Bosetti

If people are provided with opportunities to make choices supported by policies, infrastructure and technologies, there is an untapped mitigation potential to **bring down global emissions by between 40 and 70% by 2050** compared to a baseline scenario.

-Prof Joyashree Roy

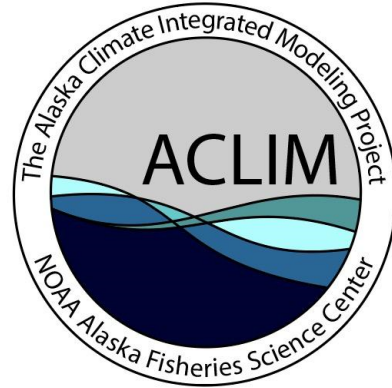
The evidence is clear: there are now mitigation options available in all sectors that could together **halve global greenhouse gas emissions by 2030.**

-Dr Céline Guivarch

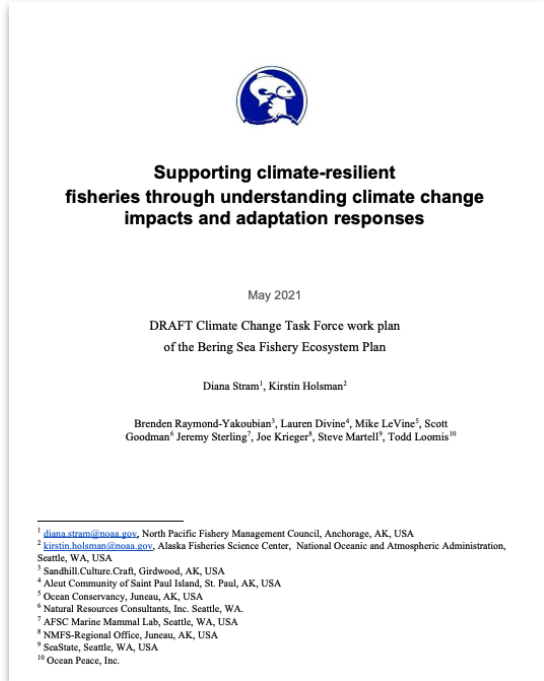
ACLIM & Climate informed advice



Dr. Kirstin K. Holsman
NOAA AFSC, Seattle
kirstin.holsman@noaa.gov

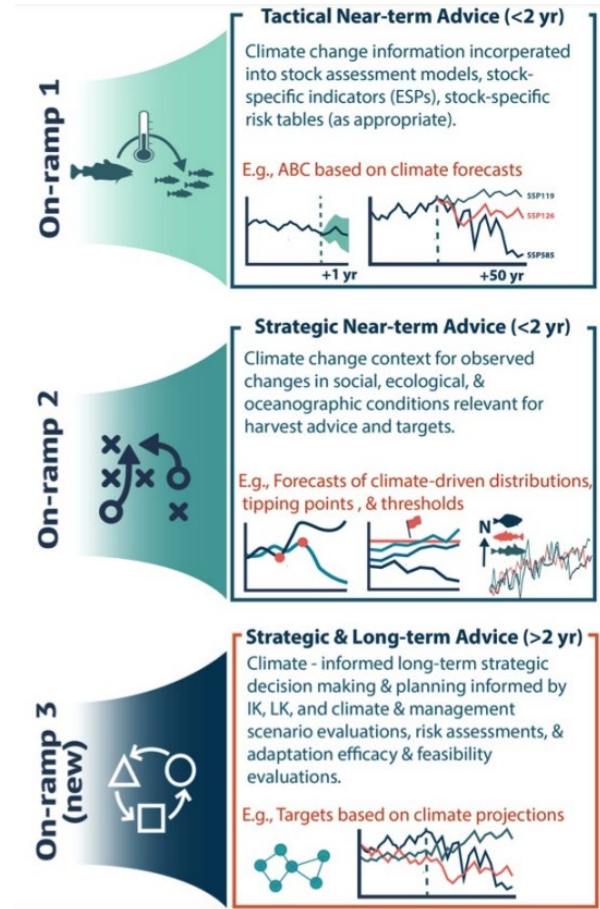


Provide tools and approaches to support climate informed management decisions



[https://www.npfmc.org/climatechangetaskforce/Stram et al. 2021](https://www.npfmc.org/climatechangetaskforce/Stram%20et%20al.%202021)

Climate information on ramps for fisheries management



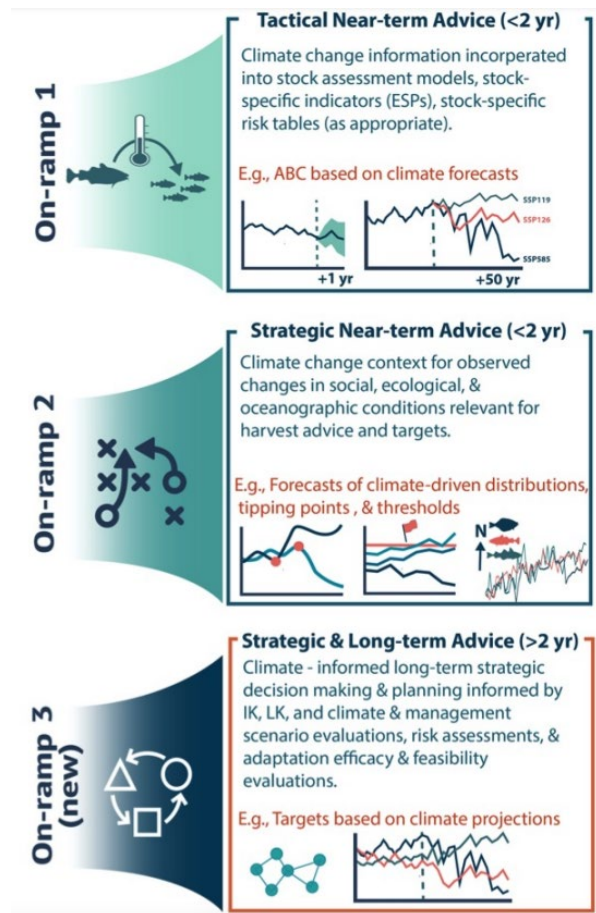
Provide tools and approaches to support climate informed management decisions

Climate informed annual* stock assessments & advice

Climate information in near-term management targets

Climate information in long-term management targets and design

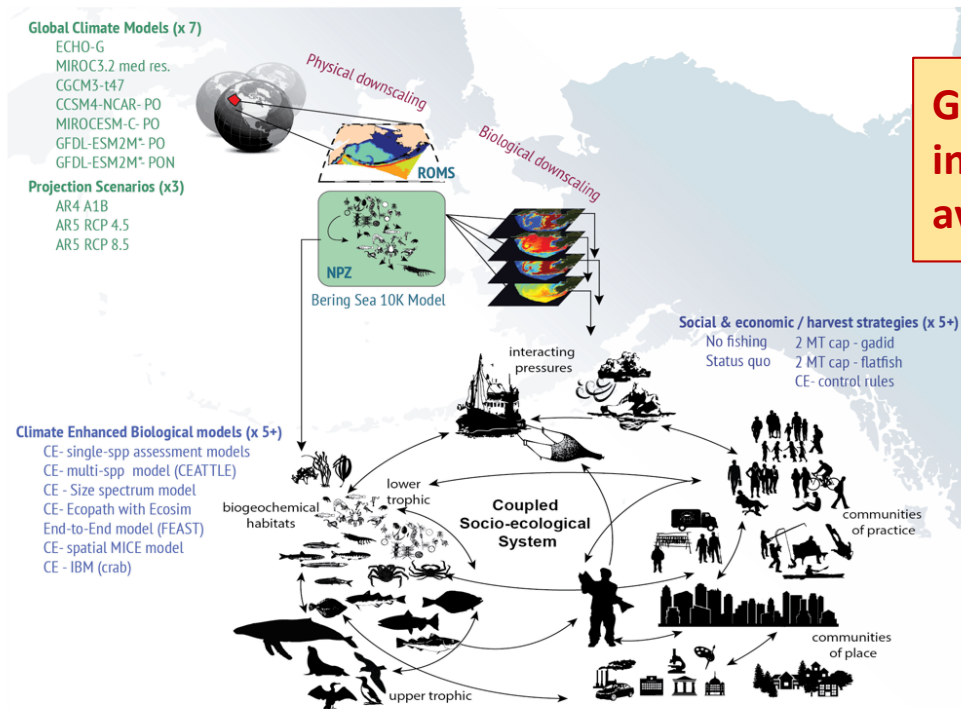
Climate information on ramps for fisheries management



The Alaska Climate Integrated Modeling Project



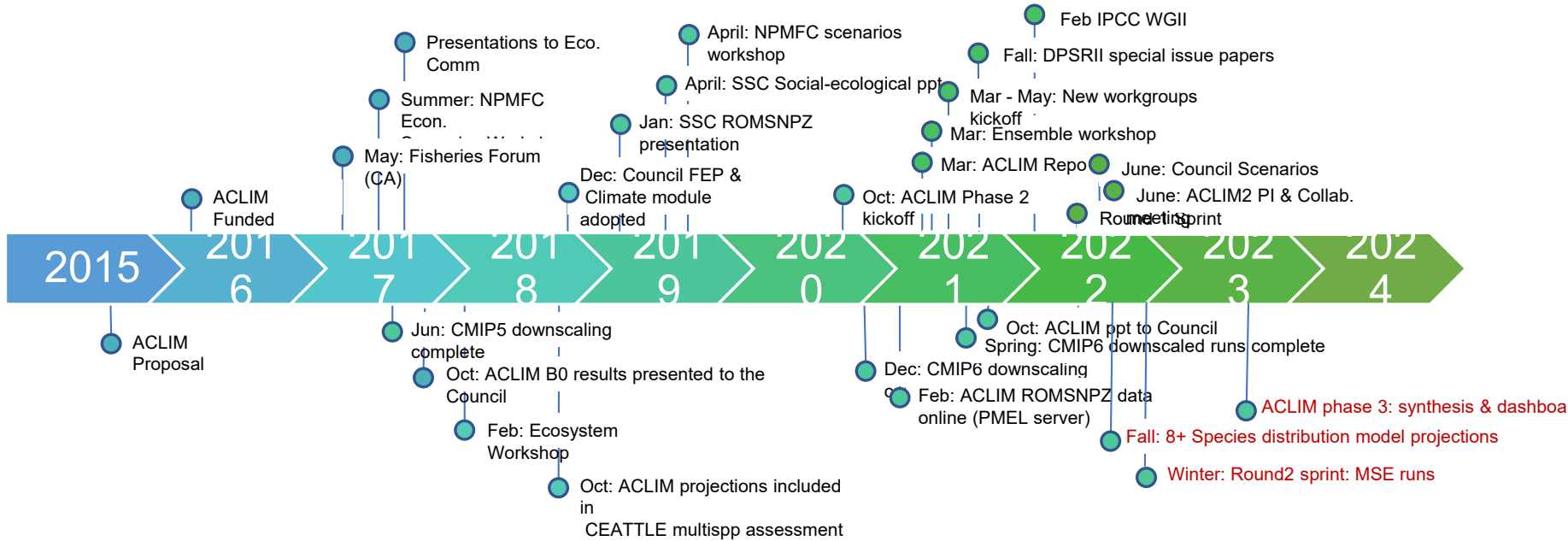
www.fisheries.noaa.gov/alaska/ecosystems/alaska-climate-integrated-modeling-project



Goal: To address climate information needs with best available science & tools



ACLIM Timeline





Key elements of climate ready advice

Rapid response



Plan & predict, near-real time alerts, emergency aid, triage impacts, enable individual adaptation

\$ e.g., Emergency relief

Ecosystem foresight



Social-ecological system forecasts & projections, tipping points & early warnings

Climate smart decision support tools

Climate enhanced stock assessments, climate informed advice & tools, dynamic management

Coordinated science & advice

Inter- & intra-agency coordination, Indigenous partnerships, national strategies aligned with regional priorities, efficient information sharing, reduced redundancy

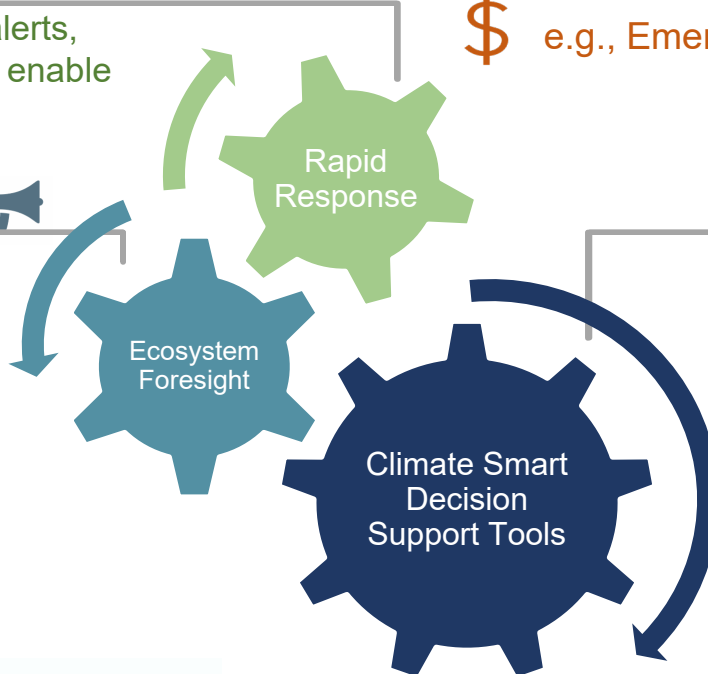


Effective monitoring & research

Improved research & climate-ready survey design, increased speed of response



e.g., Risk assessment & probability of increase or decrease



Climate, Ecosystems, & Fisheries Initiative (CEFI)

National Marine Fisheries Service | NOAA CLIMATE, ECOSYSTEMS, AND FISHERIES INITIATIVE

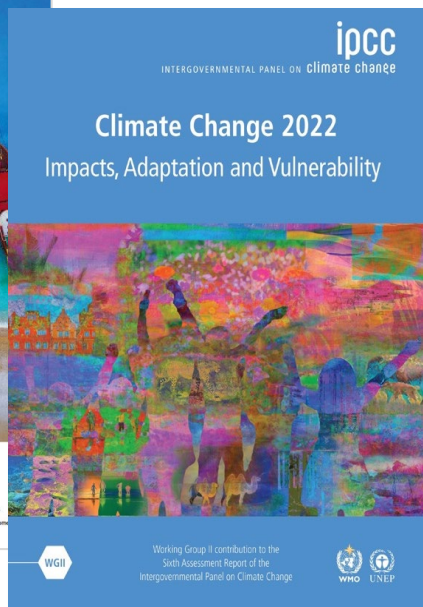
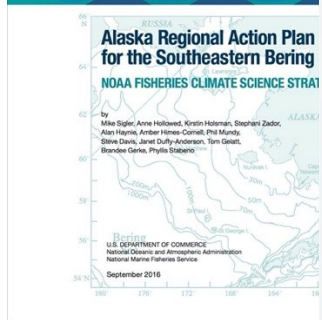
CEFI Integrated Ocean Modeling and Decision Support System



Operational support for Climate-informed fisheries & ecosystem management advice

<https://www.fisheries.noaa.gov/topic/climate-change/climate,-ecosystems,-and-fisheries>

Two way information exchange: regional, national, & International Advice



- Food & nutritional security
- Adaptation
- Social-ecological system risk