Departamento de Geofísica
Facultad de Ciencias Físicas y Matemáticas
Universidad de Chile

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Climate Change Impact upon Hydrological Systems hosting Aquaculture (Salmon farming)

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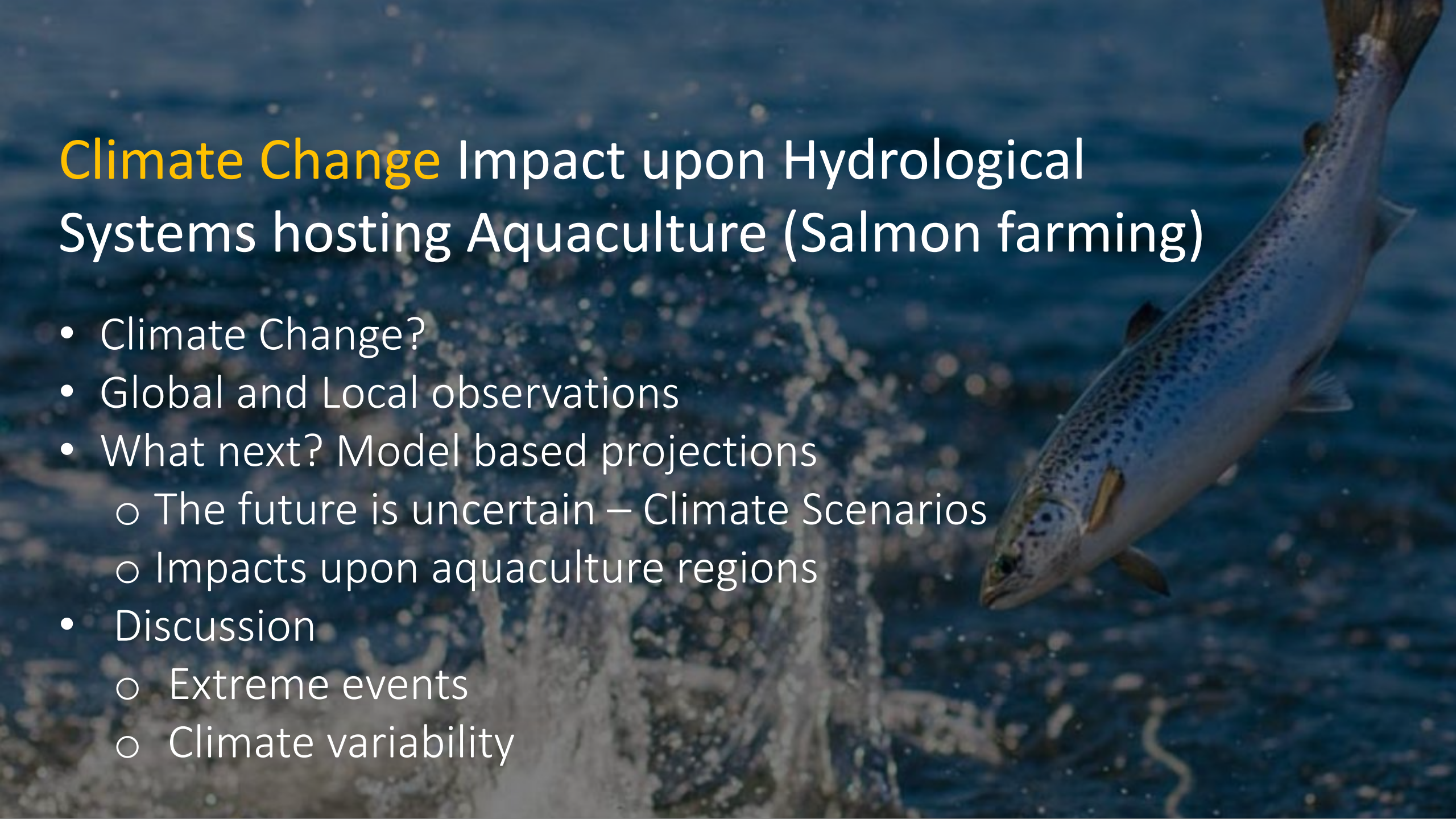
12th International Sea Lice Conference
Nov. 4, 2018 – Punta Arenas, Chile

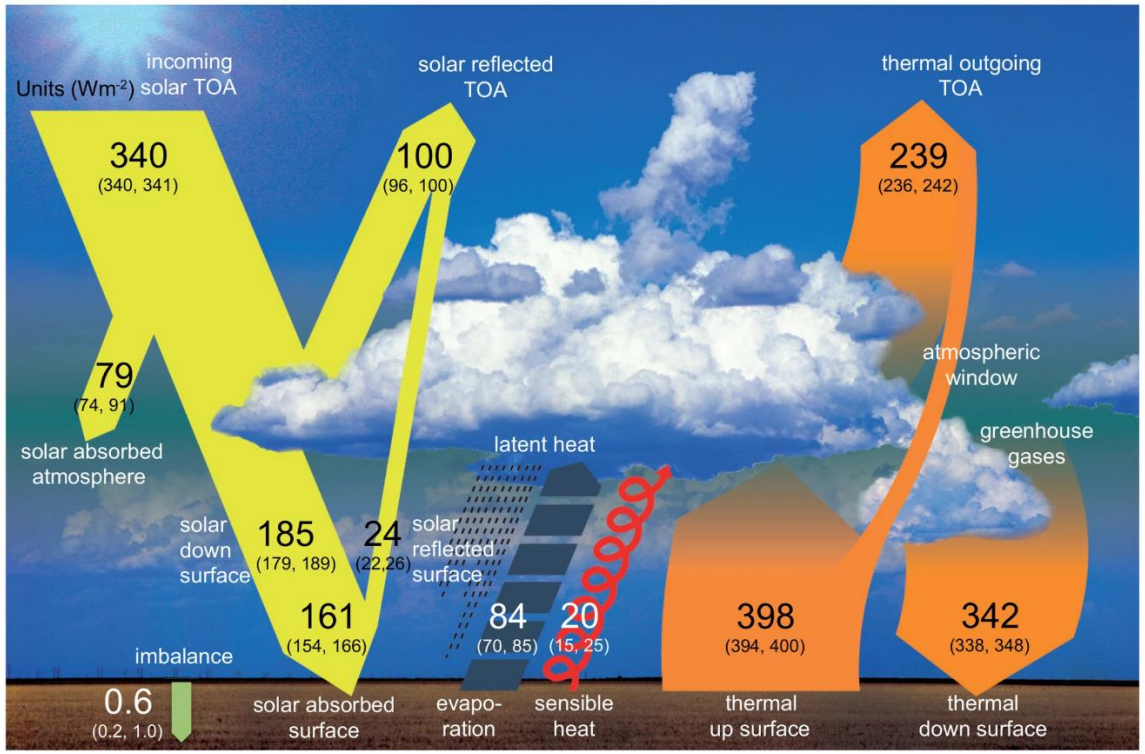


Climate Change Impact upon Hydrological Systems hosting Aquaculture (Salmon farming)

- Climate Change?
- Global and Local observations
- What next? Model based projections
  - The future is uncertain – Climate Scenarios
  - Impacts upon aquaculture regions
- Discussion
  - Extreme events
  - Climate variability

Greenhouse effect and Global Warming

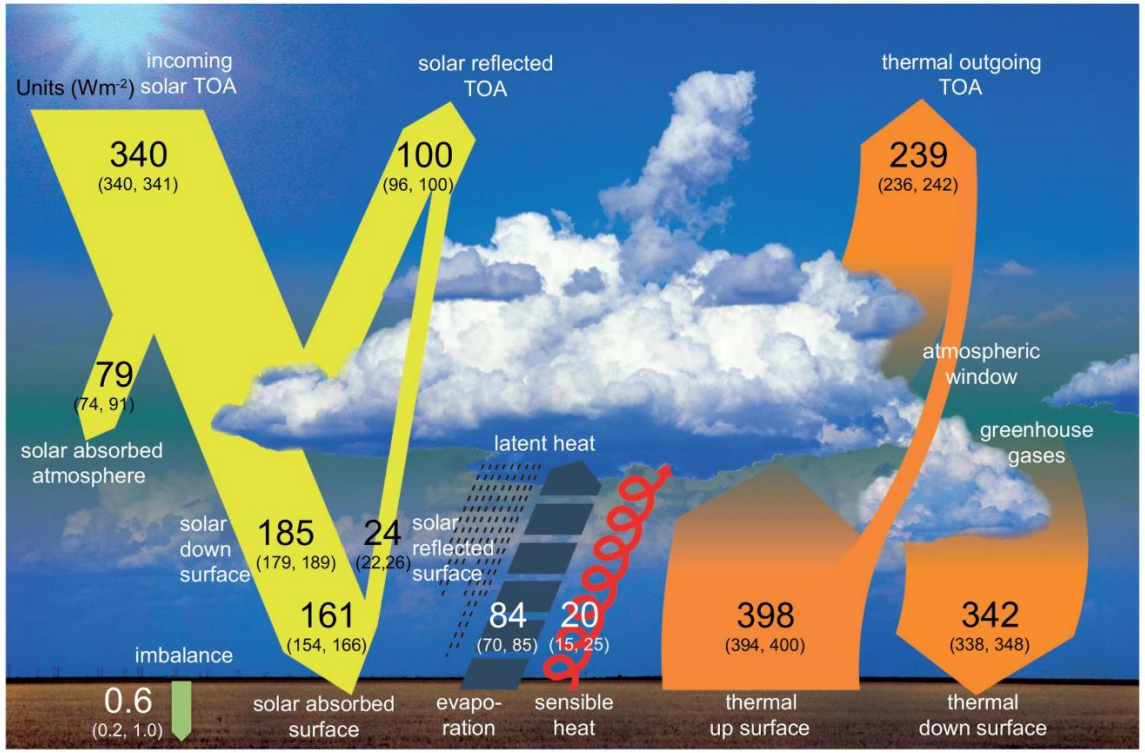
CO2, CH4, H20 and other gasses absorb longwave radiation emitted by the surface….

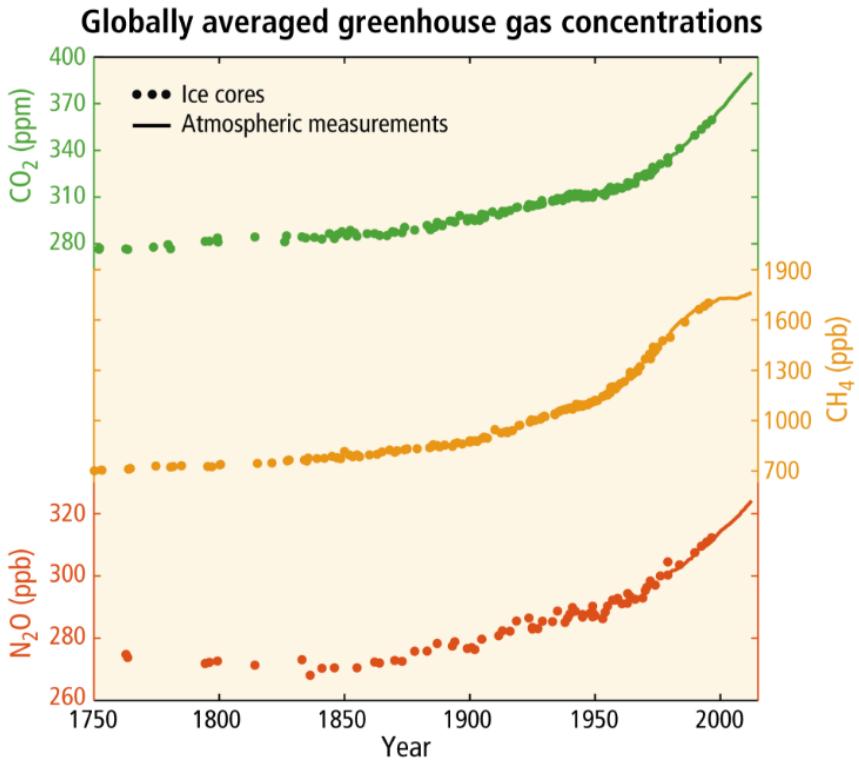


Ruddiman: Earth's Climate, Chapter 4

Greenhouse effect and Global Warming

CO2, CH4, H20 and other gasses absorb longwave radiation emitted by the surface….

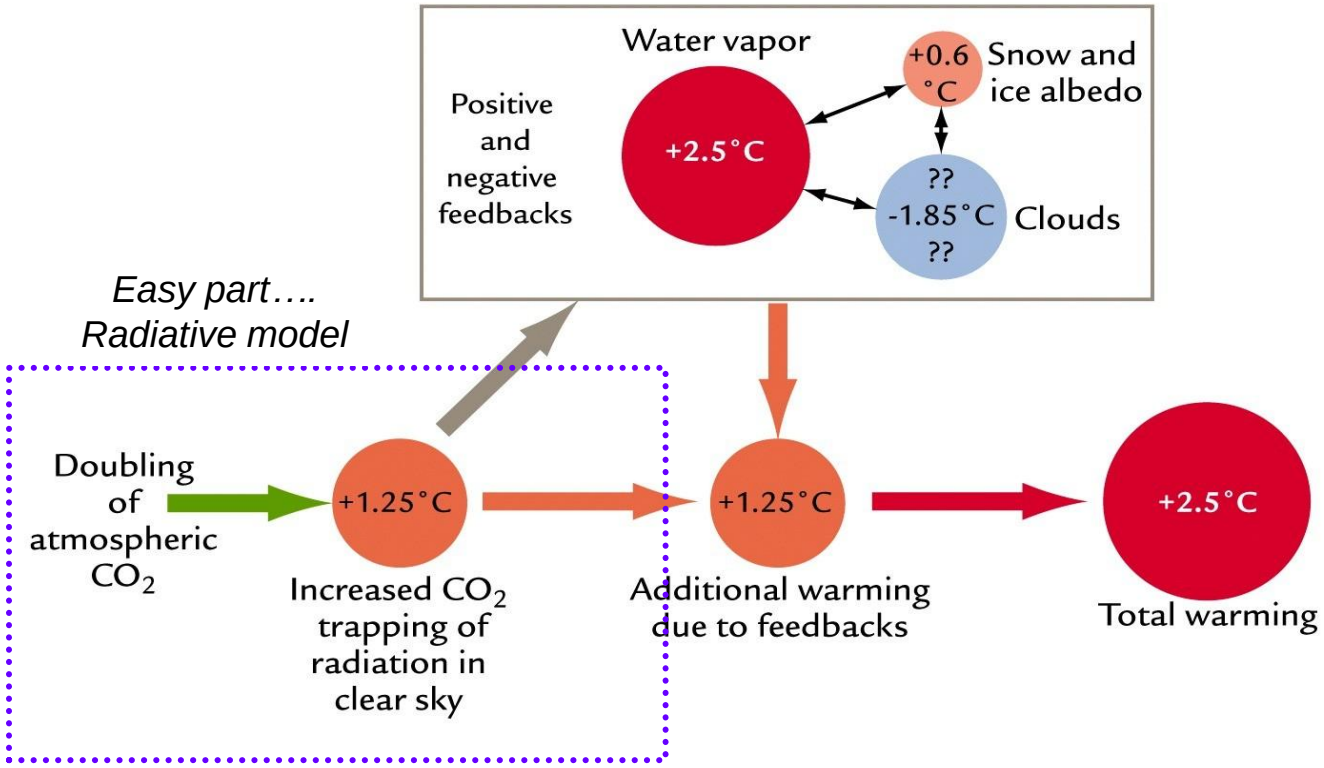


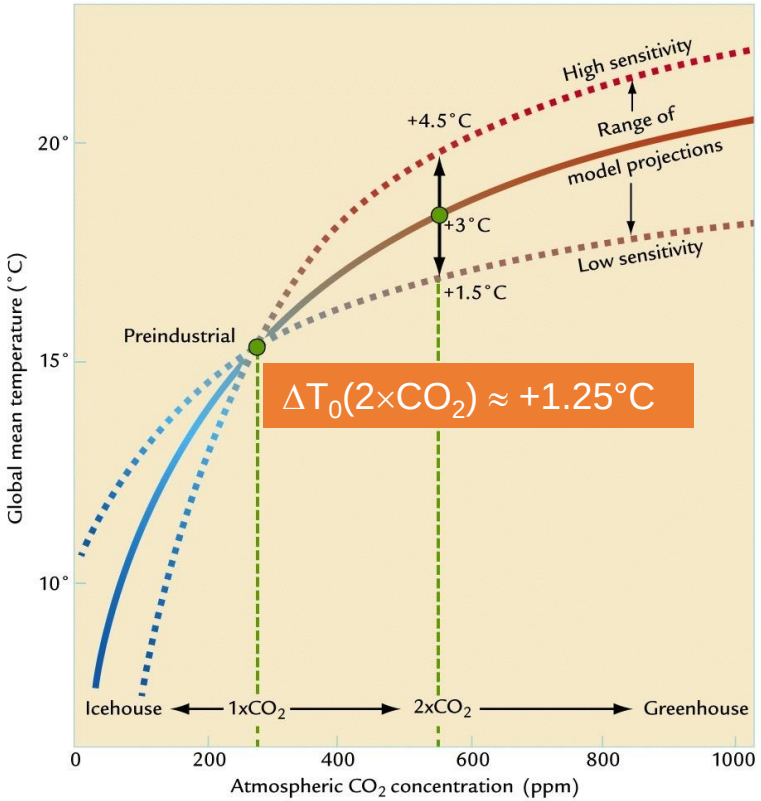


Ruddiman: Earth's Climate, Chapter 4

Greenhouse effect and Global Warming

The direct, radiative effect of increasing CO2 (and other GHG) is well known, but not their feedbacks





Ruddiman: Earth's Climate, Chapter 4

Greenhouse effect and Global Warming

To quantify its effects we use numerical models of the atmosphere/ocean general circulation (GCMs)

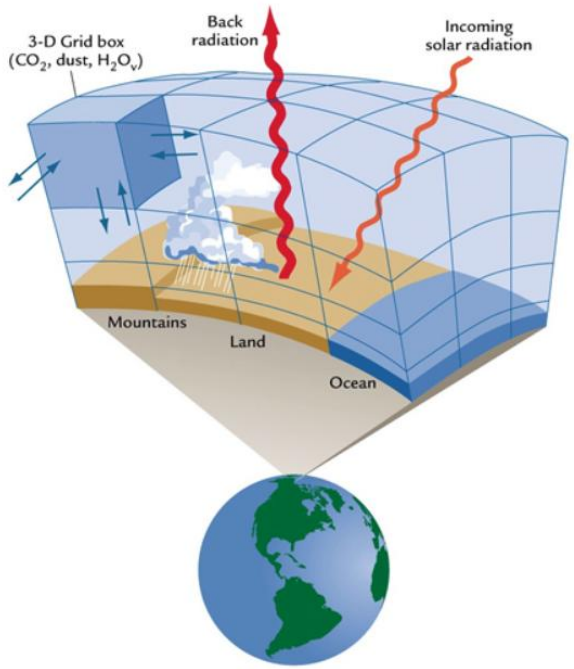
$$\frac{d\vec{V}}{dt} + f\hat{k} \times \vec{V} = -\frac{1}{\rho}\nabla p - \vec{F}_R + \vec{g}$$

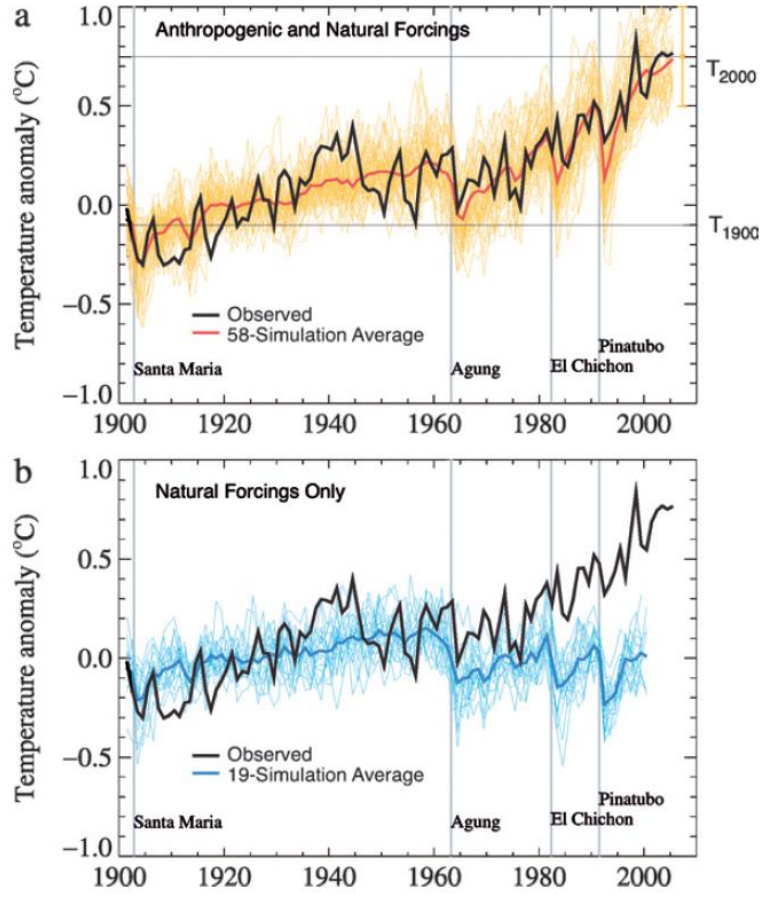
$$\left(\frac{\partial}{\partial t} + \vec{V} \cdot \nabla\right)T - S_p \omega = Q_{RAD} + Q_{Conv} + Q_{Sfc}$$

$$\nabla \cdot \vec{V} + \frac{\partial \omega}{\partial p} = 0$$

$$\frac{\partial (gz)}{\partial p} = -\frac{RT}{p}$$

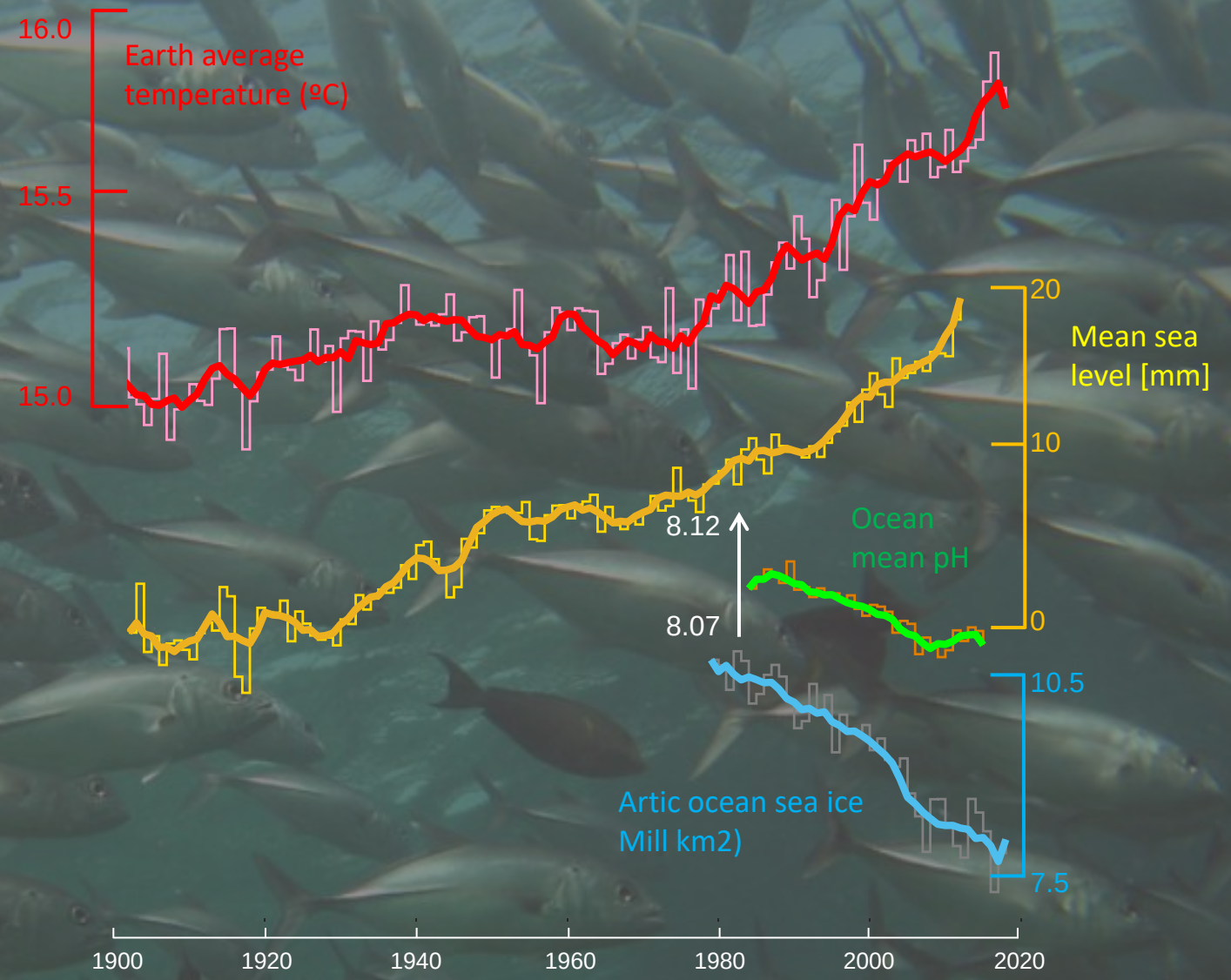
Sub-grid Processes
Highly parameterized
CO2 and other gases





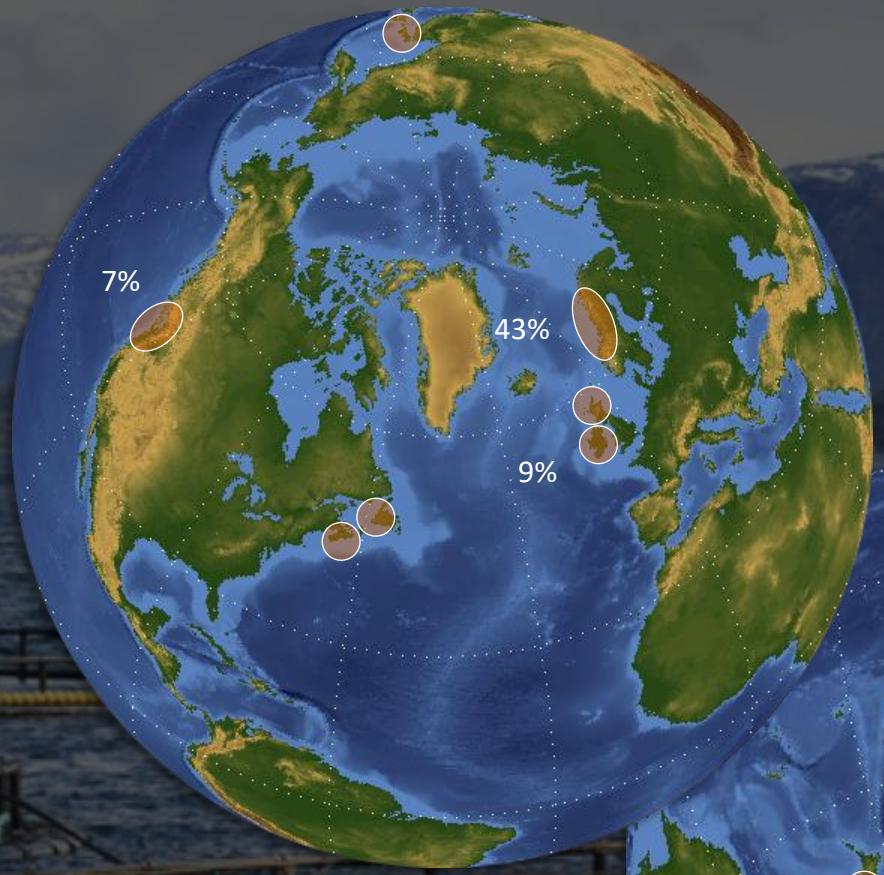
OUR CHANGING CLIMATE

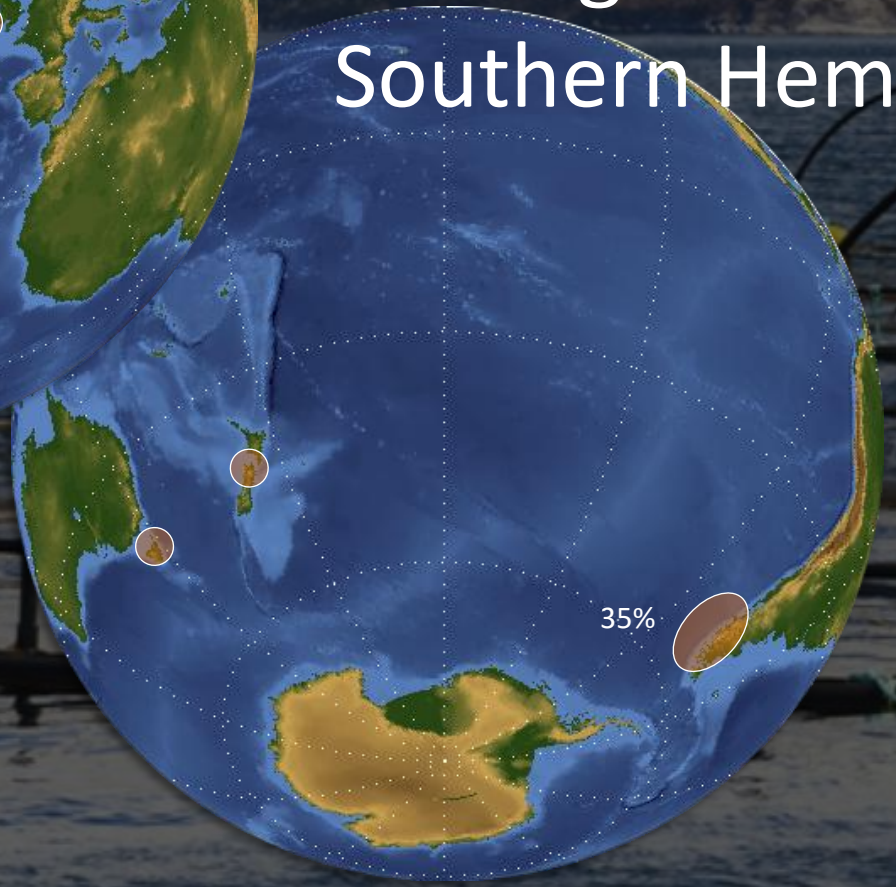
Global signs during the Antropocene

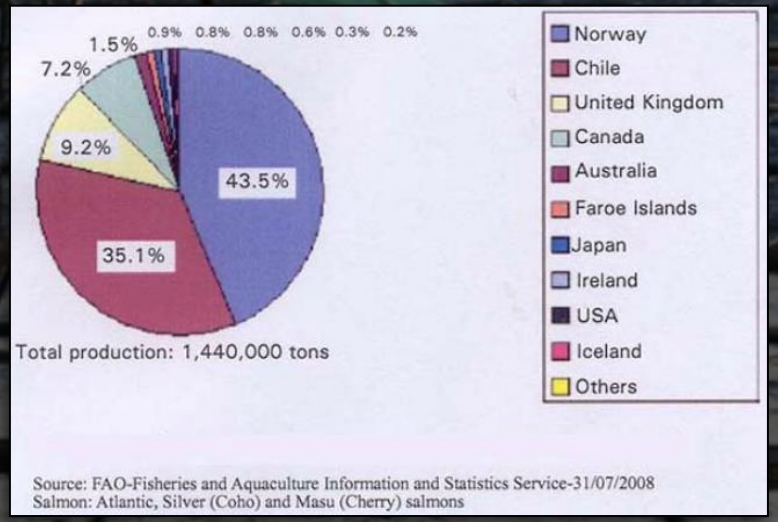


Aquaculture 101

Salmon farm concentrated in just a few regions in the Northern and Southern Hemisphere

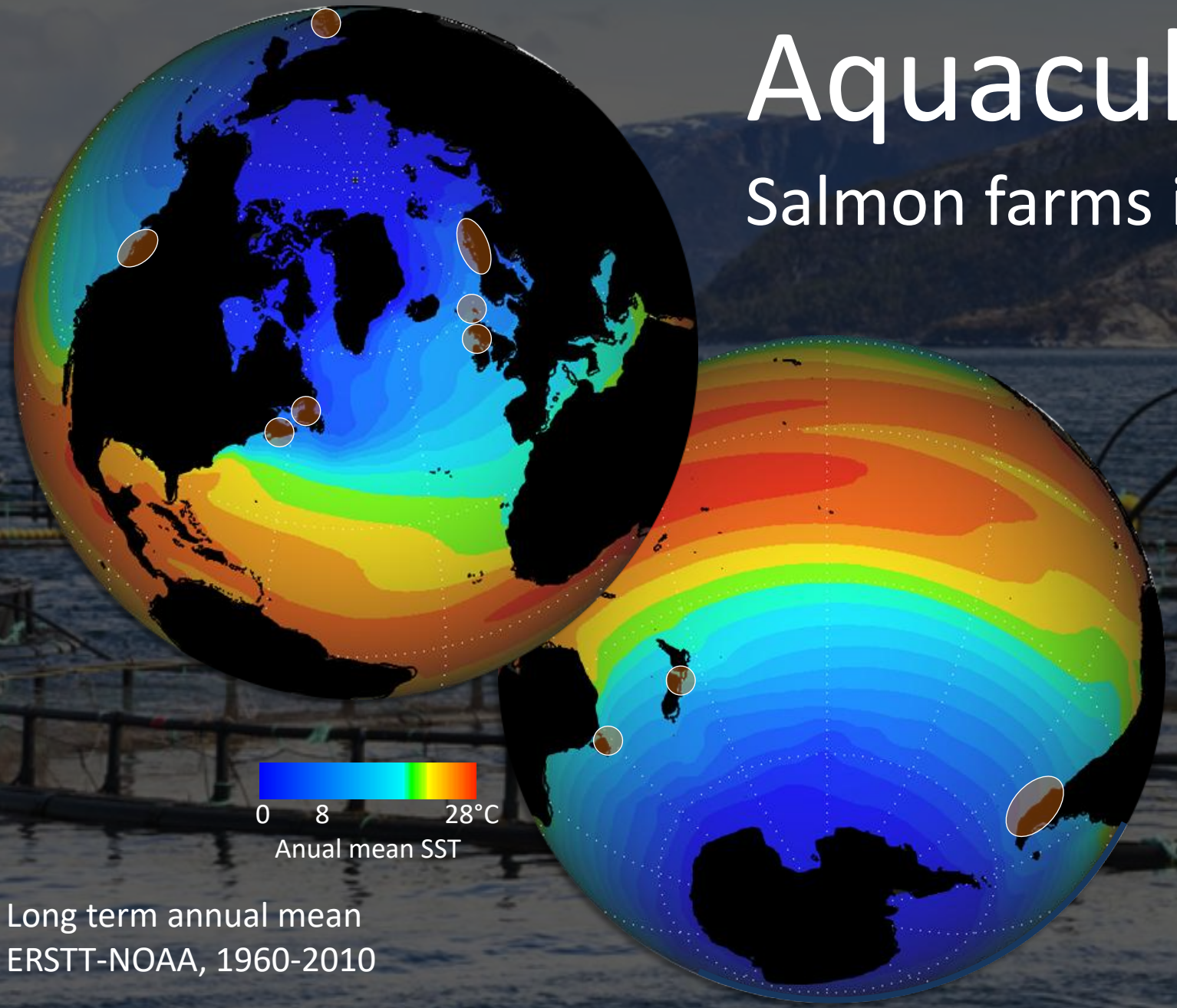






Aquaculture 101

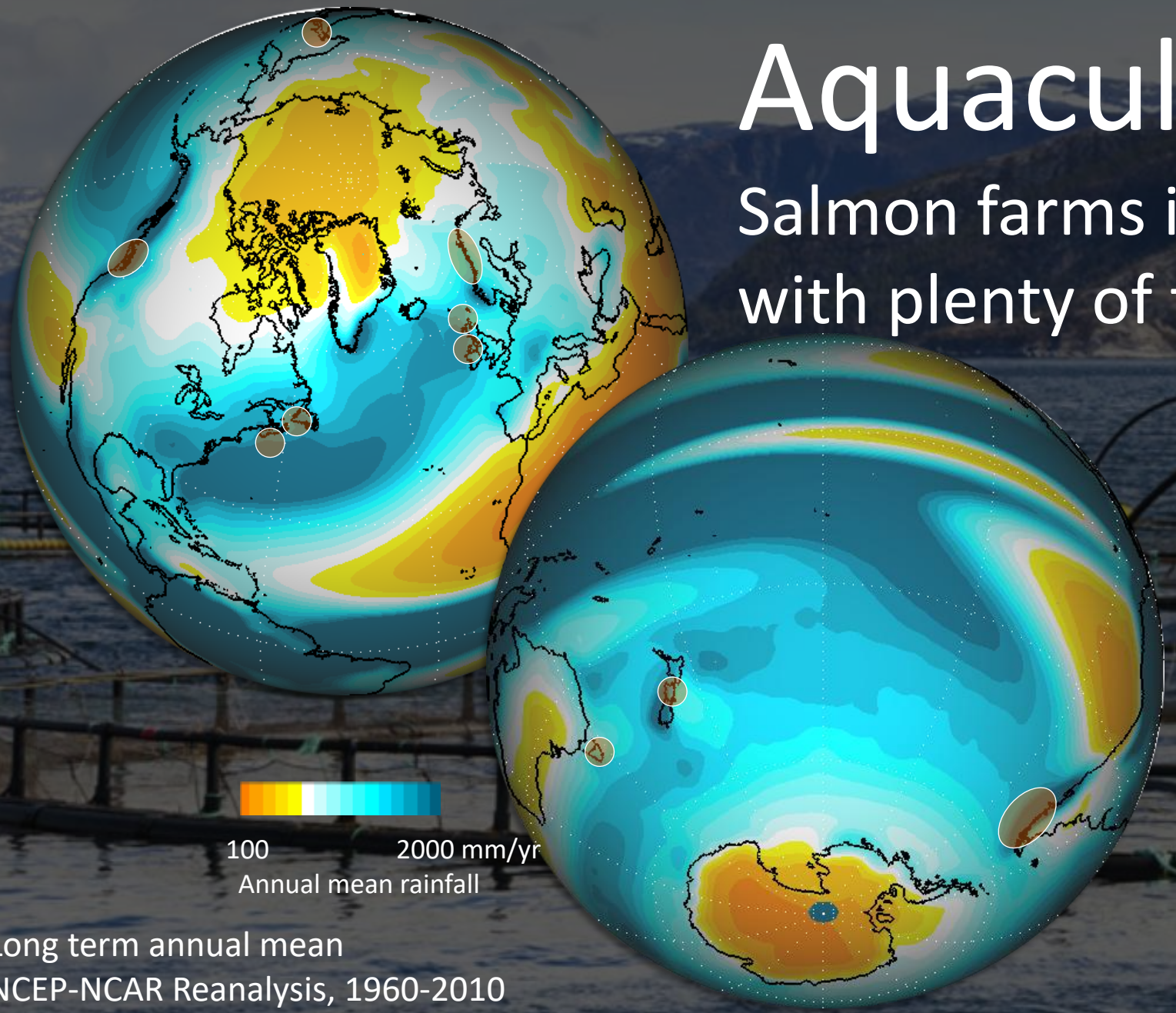
Salmon farms in cool SST regions



Long term annual mean
ERSTT-NOAA, 1960-2010

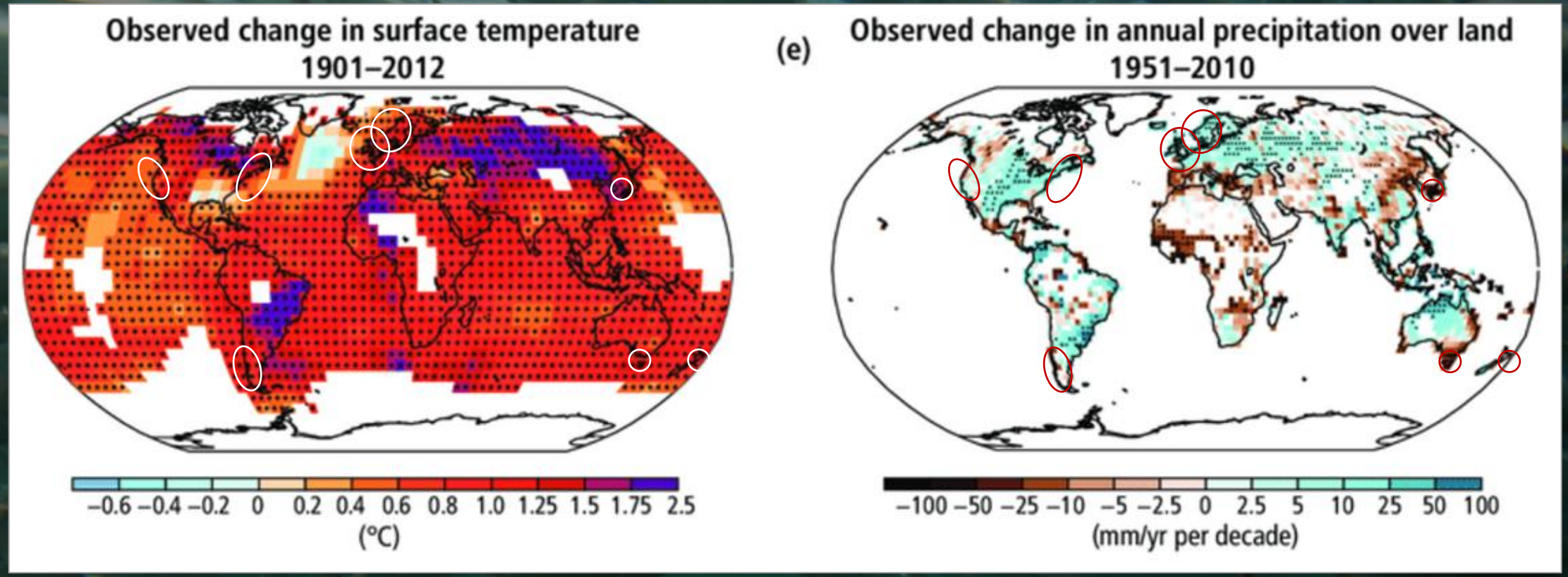
Aquaculture 101

Salmon farms in cool SST regions with plenty of fresh water available



Long term annual mean
NCEP-NCAR Reanalysis, 1960-2010

Observed changes during the 20th Century (IPCC, AR5)

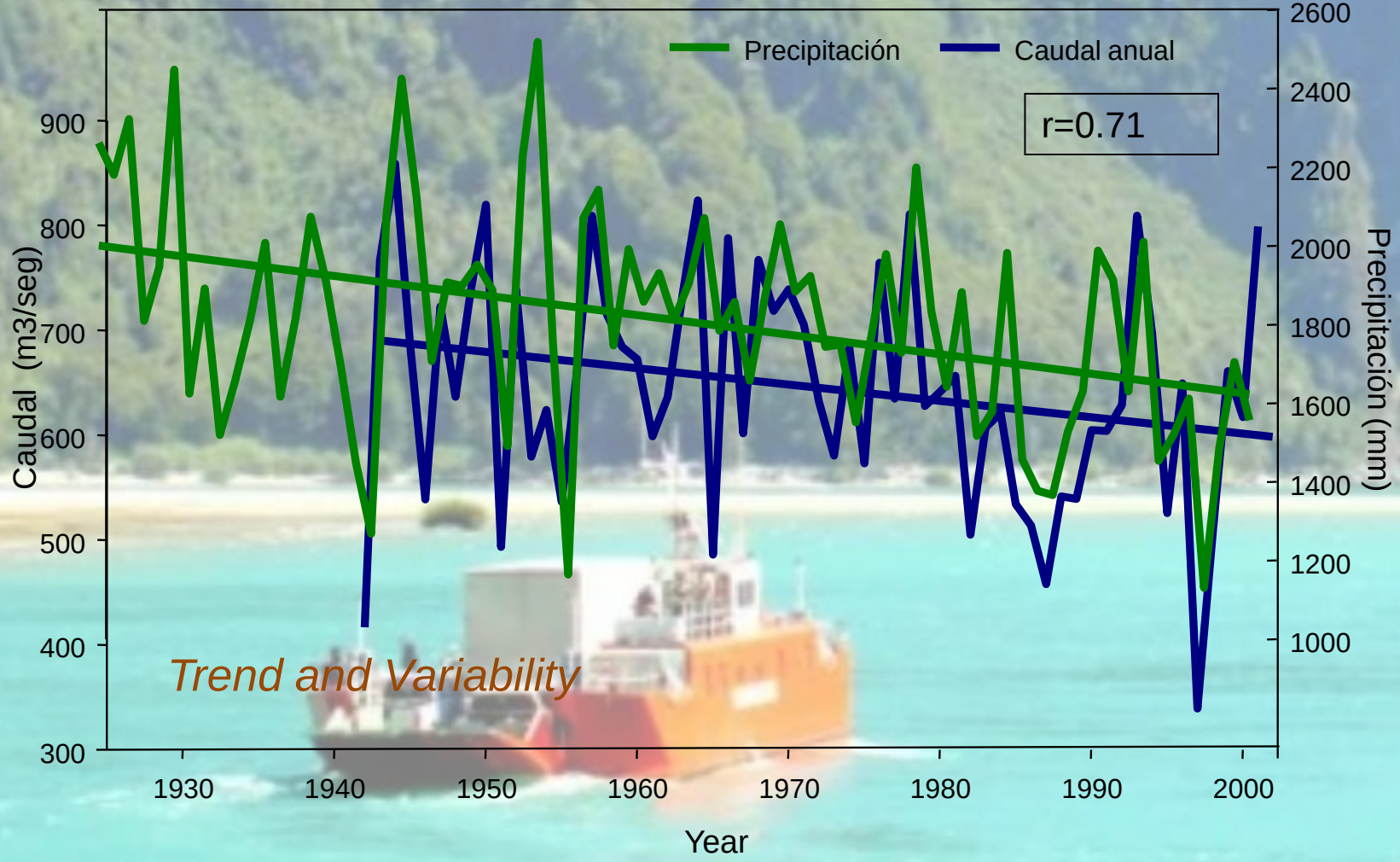


Warming everywhere but variable (0.5-2ºC)

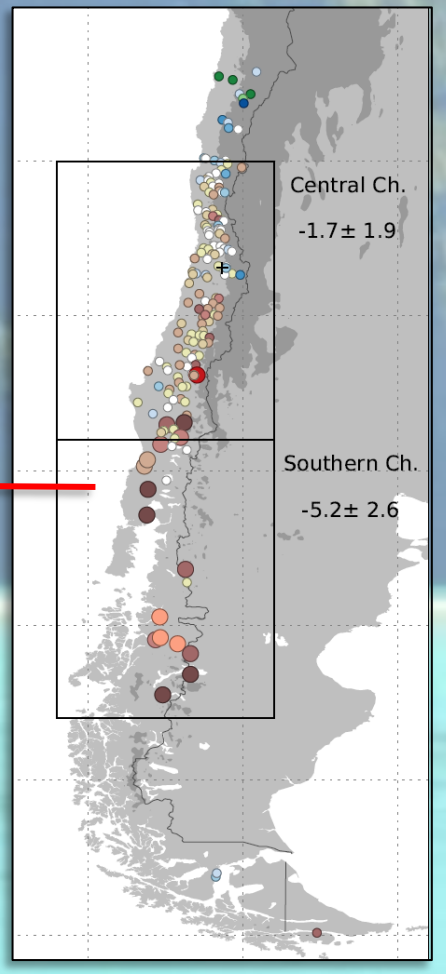
Mixed signal (dry/wet)

Drying in central-southern Chile (GHG+O3+Nat Variability)

Puerto Montt annual rainfall and Puelo mean discharge
(Fuente: Antonio Lara, UACH)



Rainfall trend 1960-2016
Boisier et al. 2018



Just in case you are interested in **Central Chile**

SANTIAGO

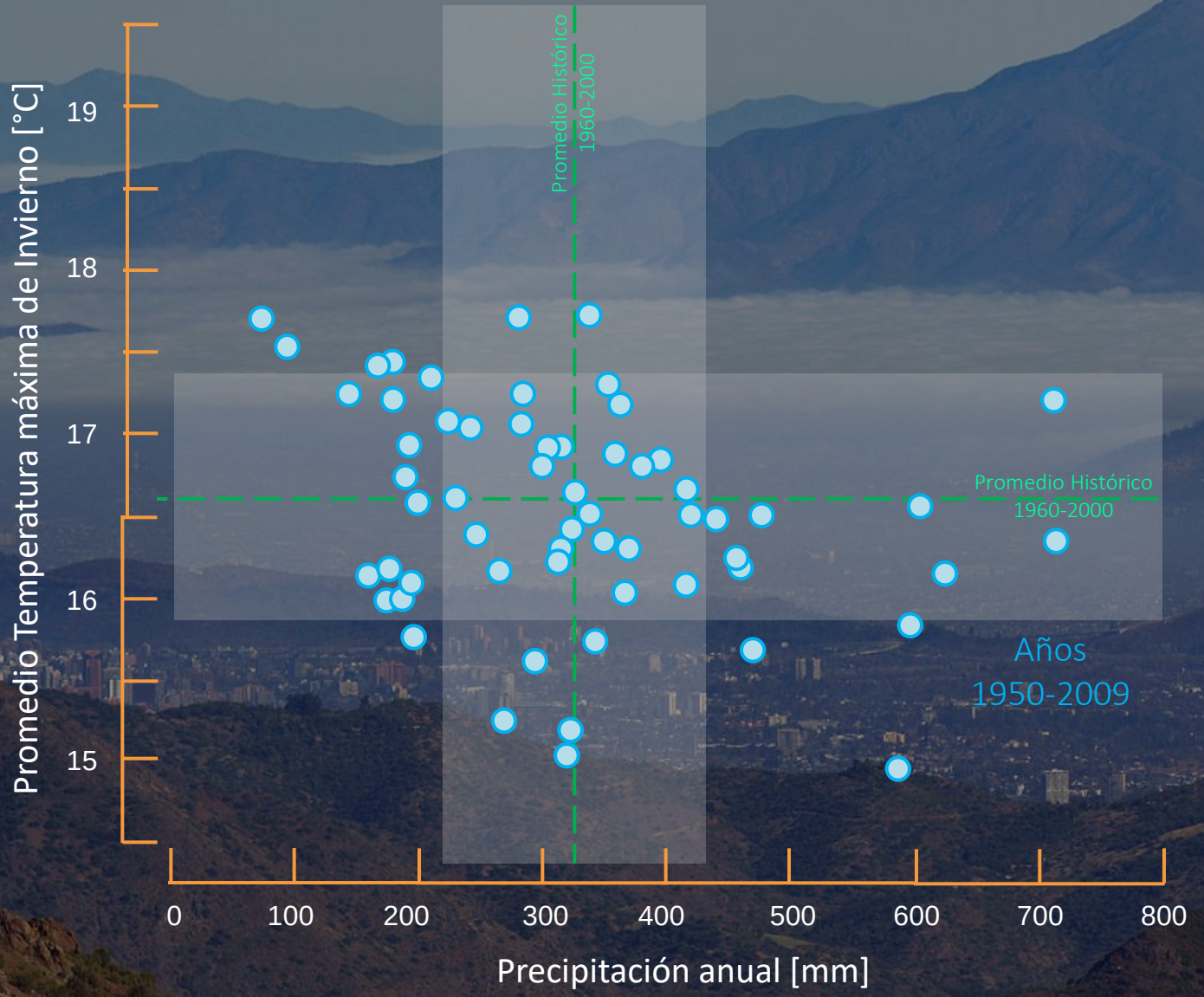
Estación Quinta Normal

Fuente: DMC

Templado

Semiárido

Mediterráneo



Just in case you are interested in **Central Chile**

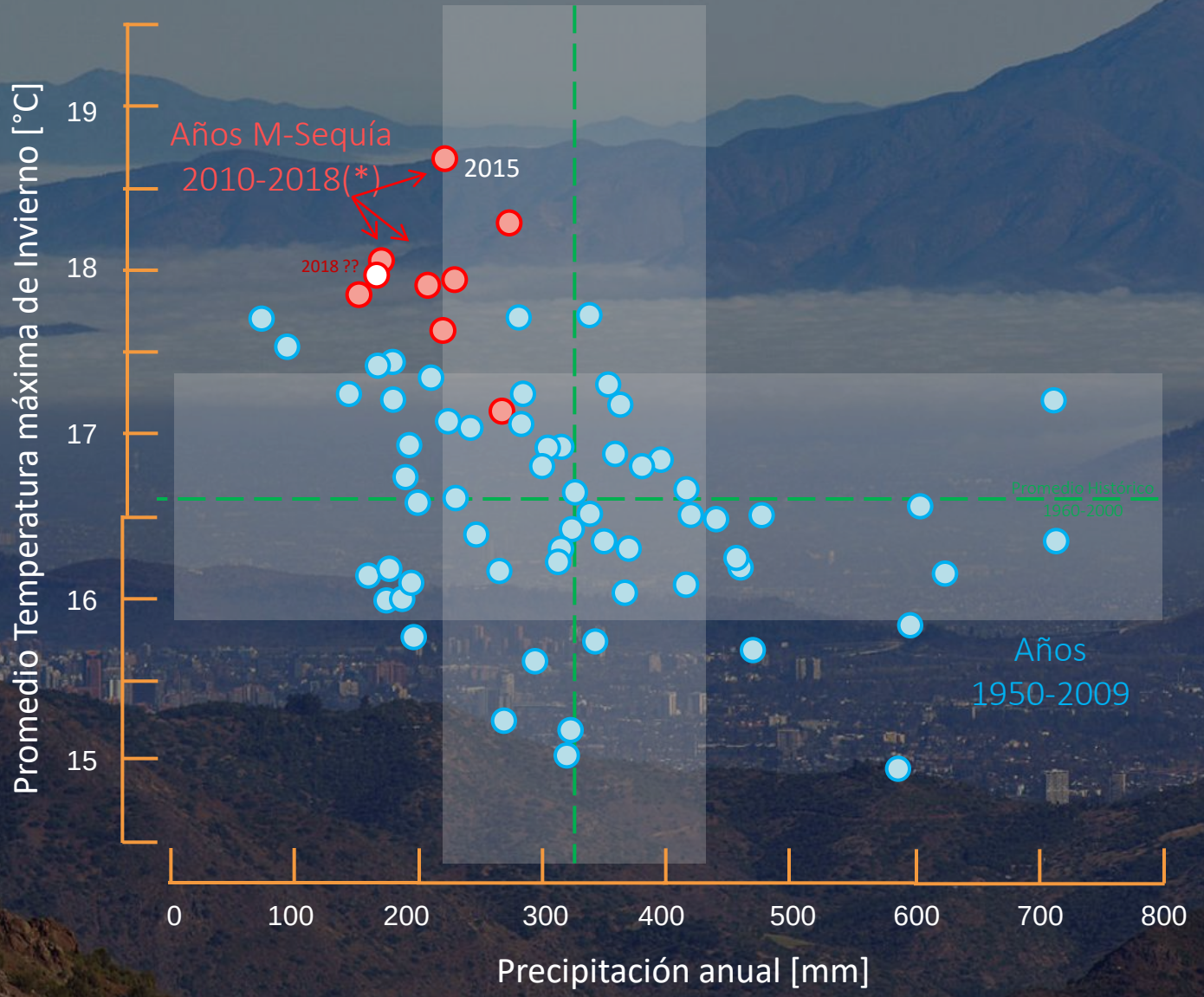
SANTIAGO

Estación Quinta Normal

Fuente: DMC

La Mega Sequia

2010-201X

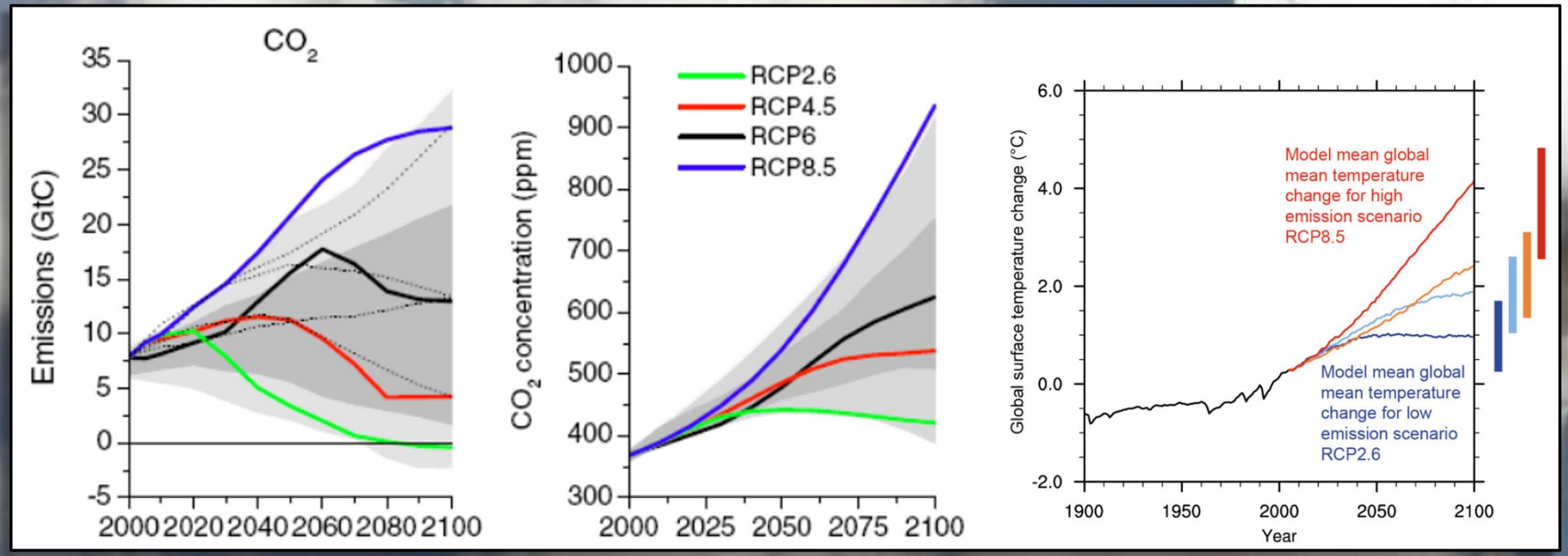



And What Next?
The major source of uncertainty
How much CO2 will be emitted in the future ?

How much CO2 will be emitted in the future ?

Socio-economic development pathways

Climate Scenarios

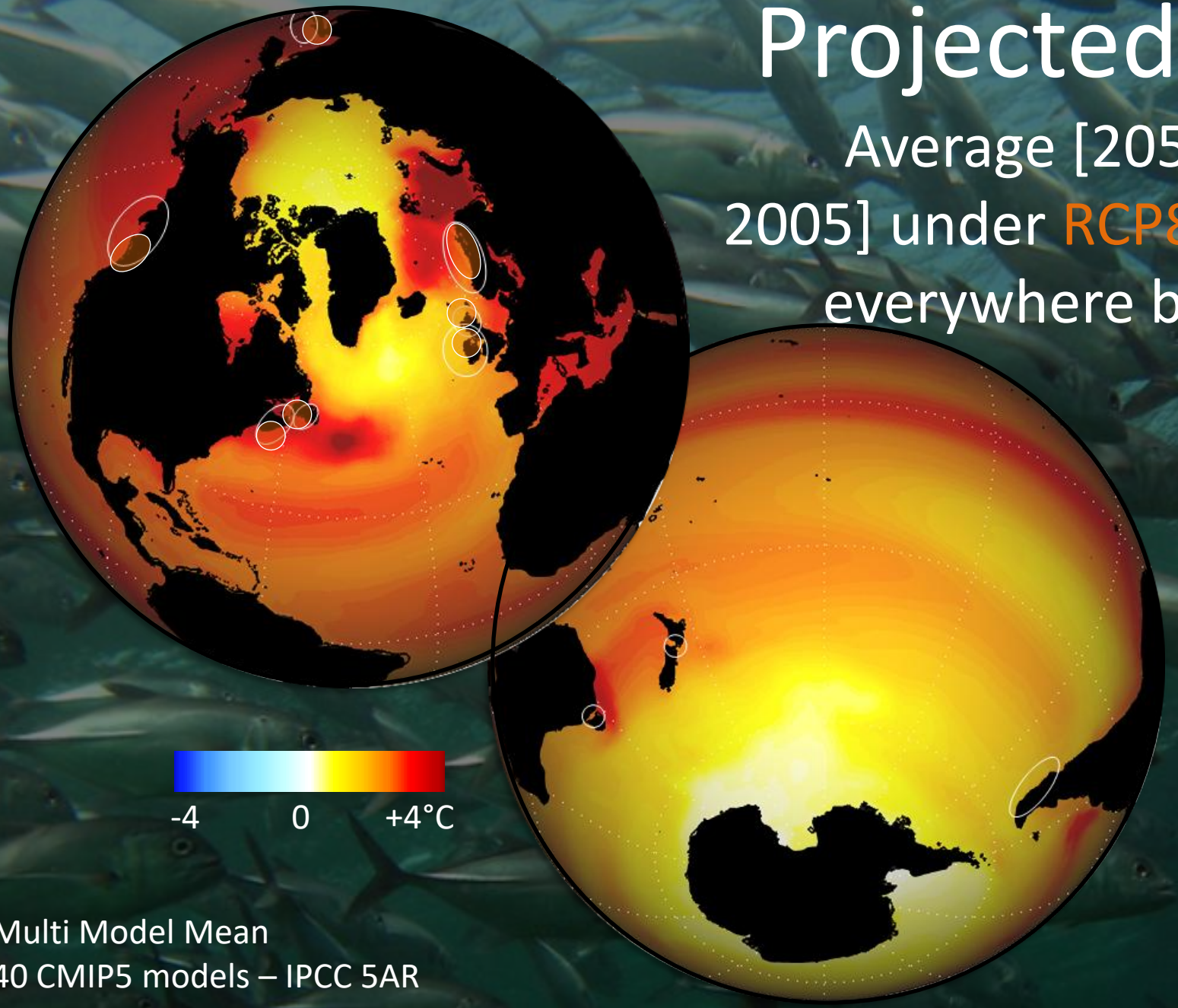


Balance De Masa

GCMs (more than 40)

Projected Changes SST

Average [2050-2100] minus [1960-2005] under RCP8.5 scenario. Warming everywhere but stronger in the NH, weaker in Patagonia



Multi Model Mean
40 CMIP5 models – IPCC 5AR

Regional sea level rise by the end of the 21st century

RCP8.5

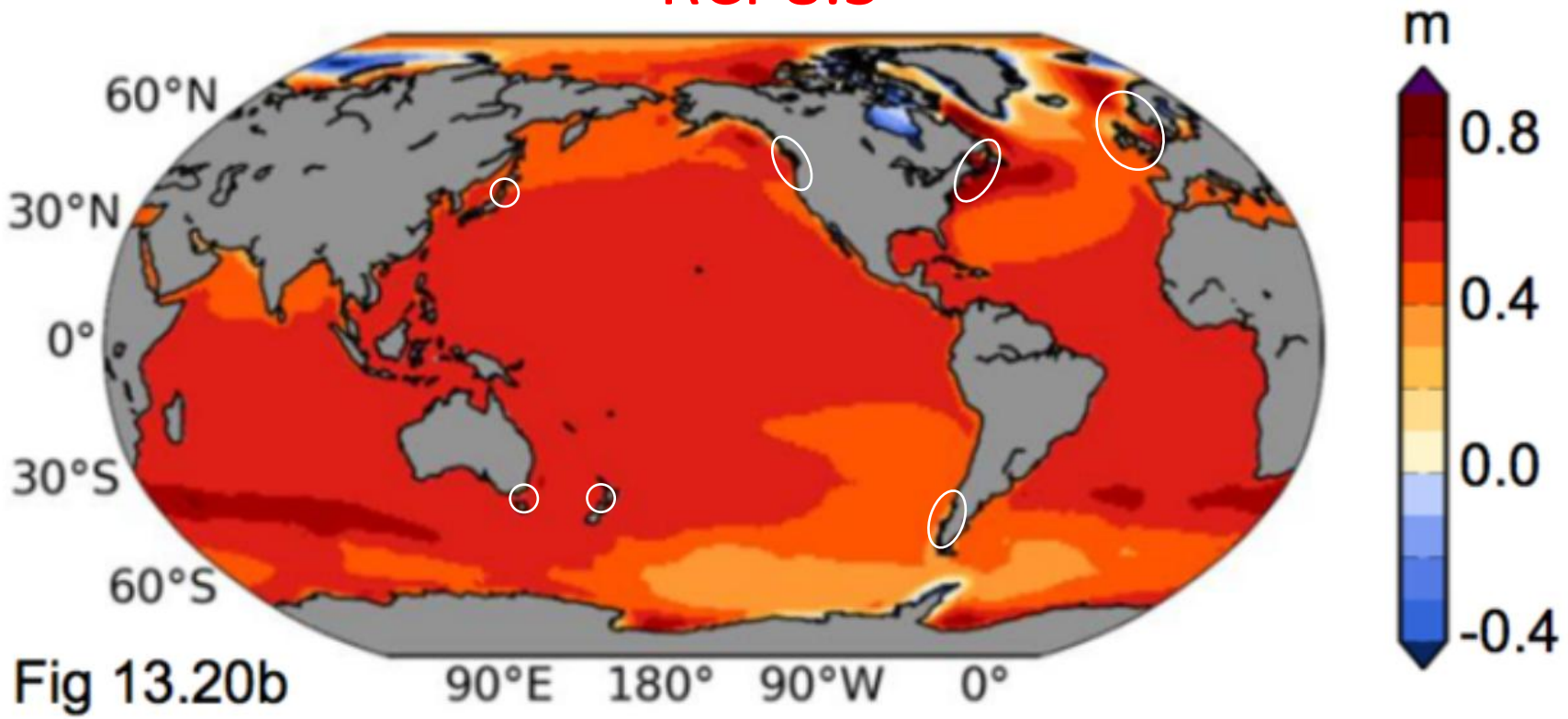
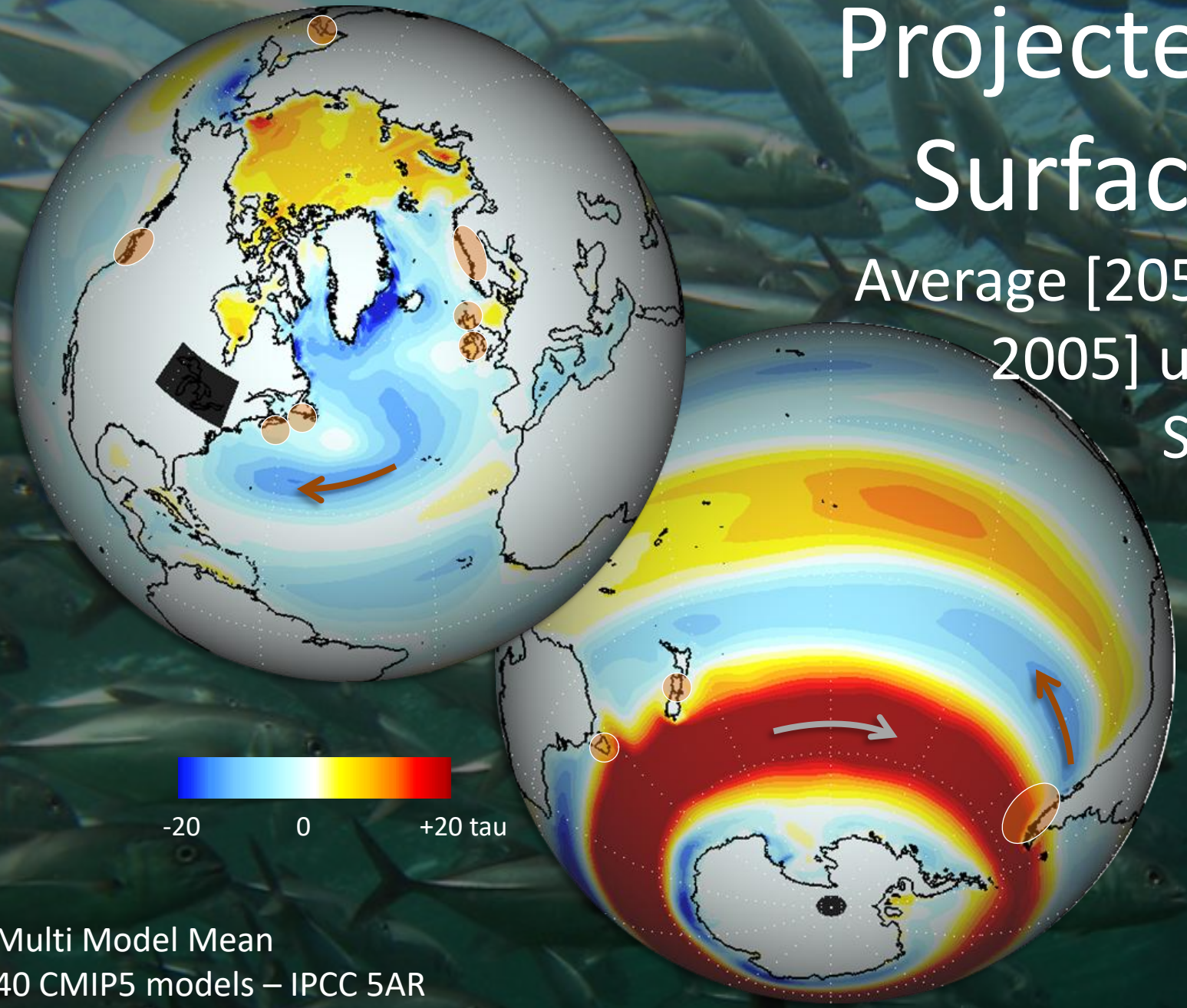


Fig 13.20b

Regions in dark red will see the greatest rise in sea levels by the year 2100, while areas in blue will see a local decrease. IPCC

Projected Changes in Surface wind stress

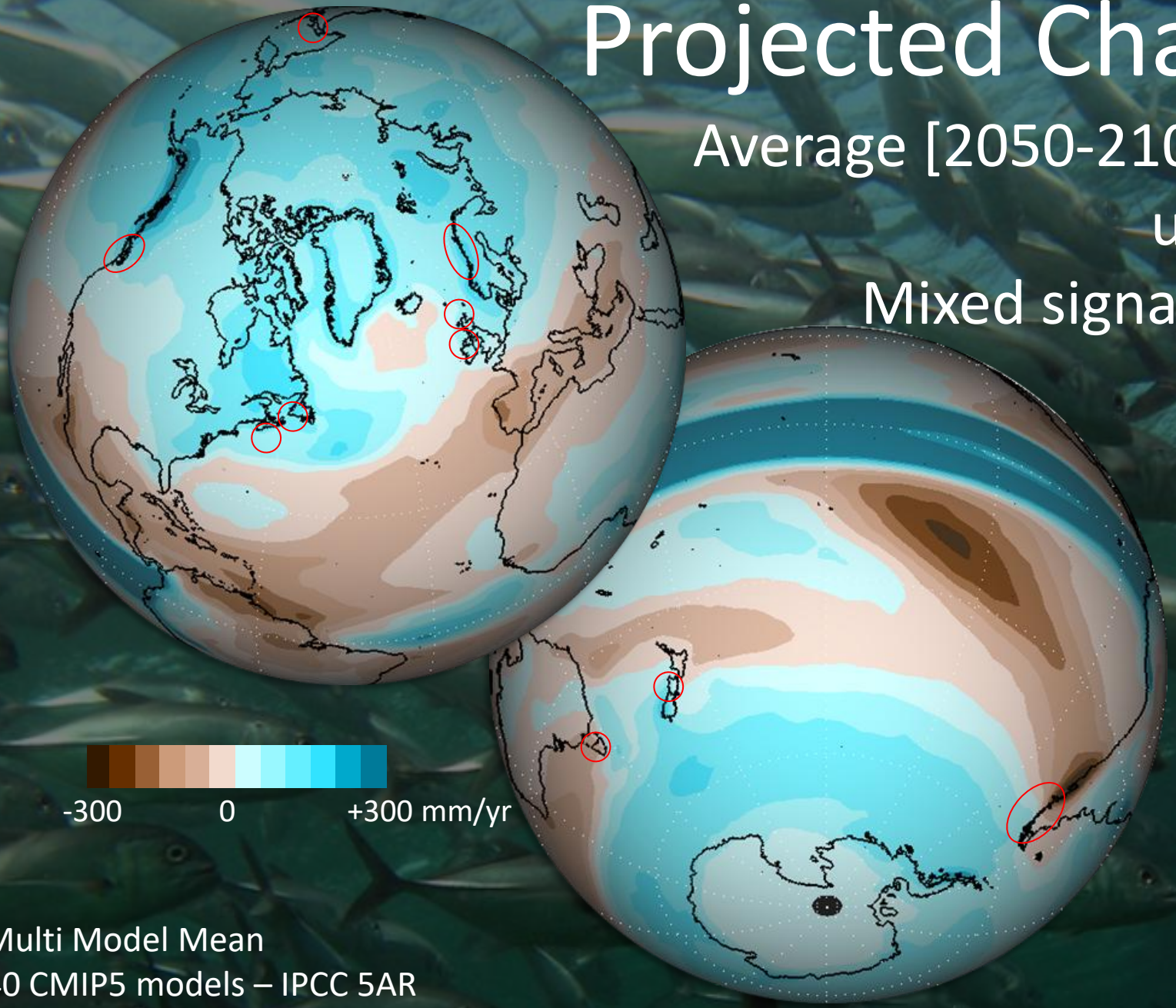
Average [2050-2100] minus [1960-2005] under RCP8.5 scenario.
Strong signal in the SH.



Multi Model Mean
40 CMIP5 models – IPCC 5AR

Projected Changes Rainfall

Average [2050-2100] minus [1960-2005]
under RCP8.5 scenario.
Mixed signals between and within
salmon farm regions

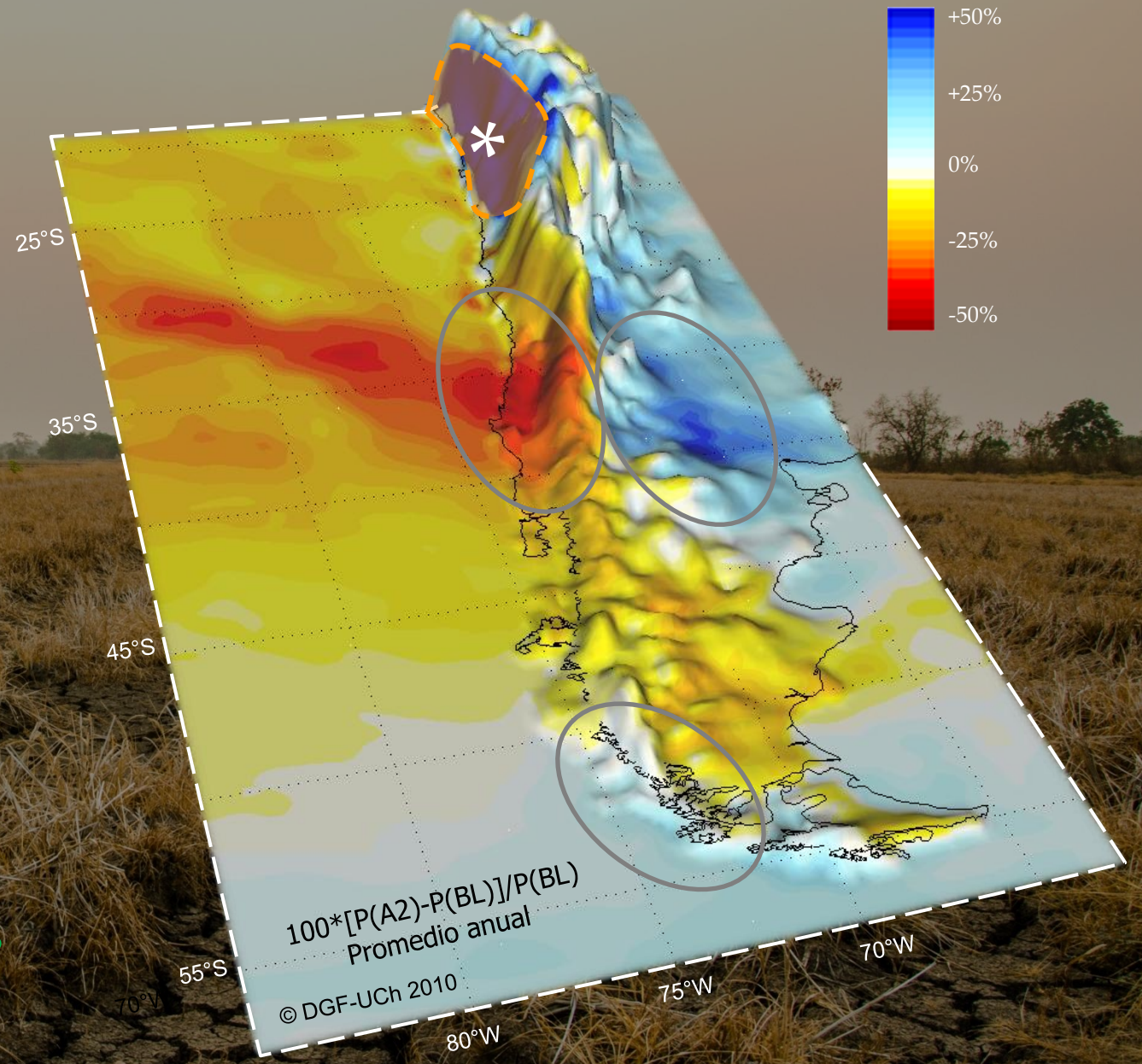


Multi Model Mean
40 CMIP5 models – IPCC 5AR

Climate Projections for continental Chile

End of century (2070-2100) under heavy GHG scenario (A2 / RCP8.5)

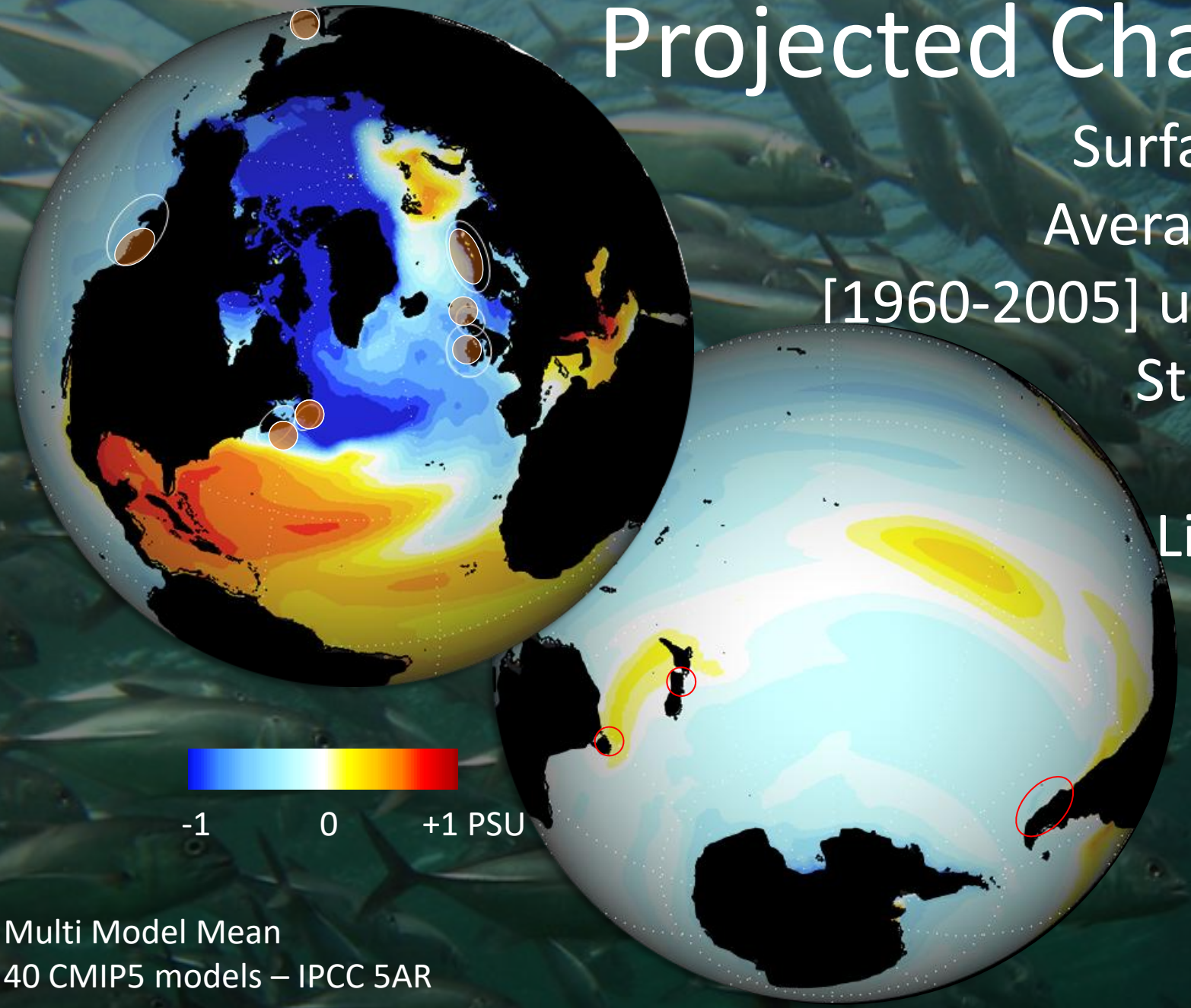
Central Chile
Surface temperatura increase: 2.5-3.5°C
Rainfall deficit 25-35%
– rain + temperature = hydrological changes



Estudio DGF/UCh-CONAMA 2007 empleando PRECIS

Projected Changes Salinity

Surface value-open ocean.
Average [2050-2100] minus [1960-2005] under RCP8.5 scenario.
Strong freshening in the North Atlantic.
Little changes in the SH



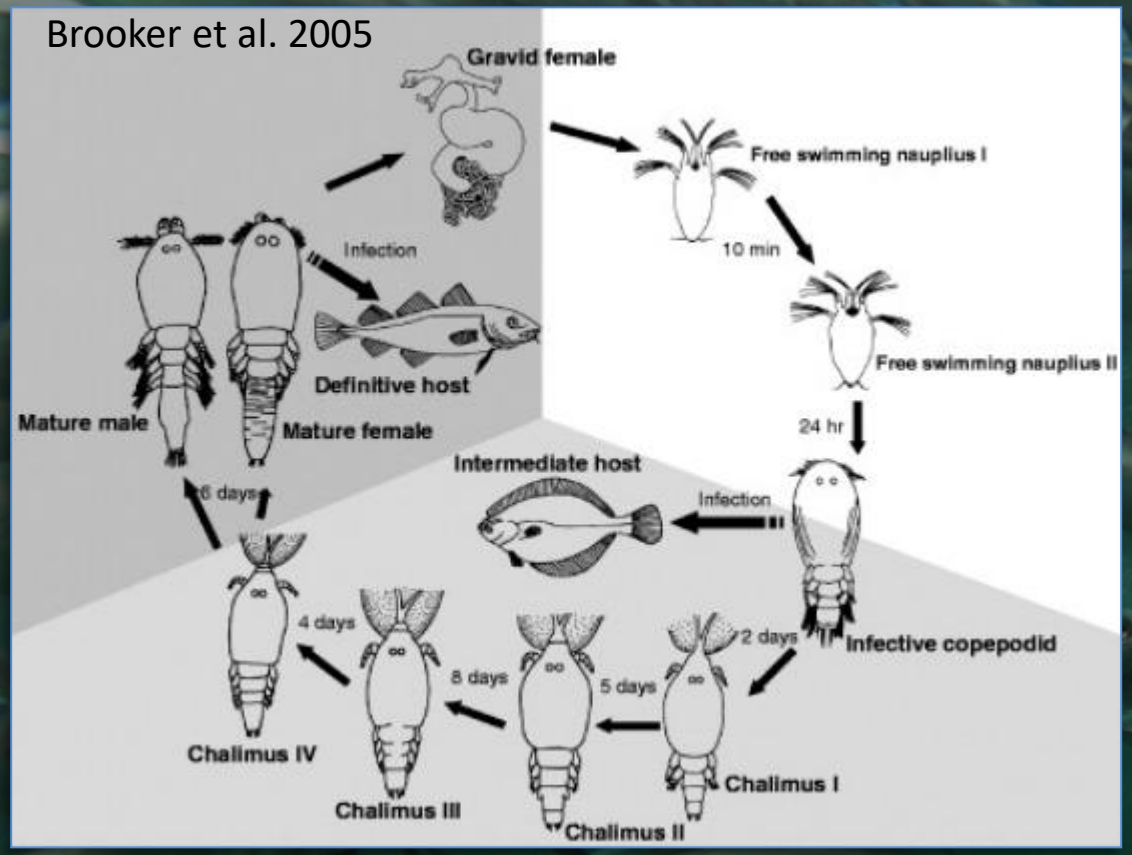
Multi Model Mean
40 CMIP5 models – IPCC 5AR

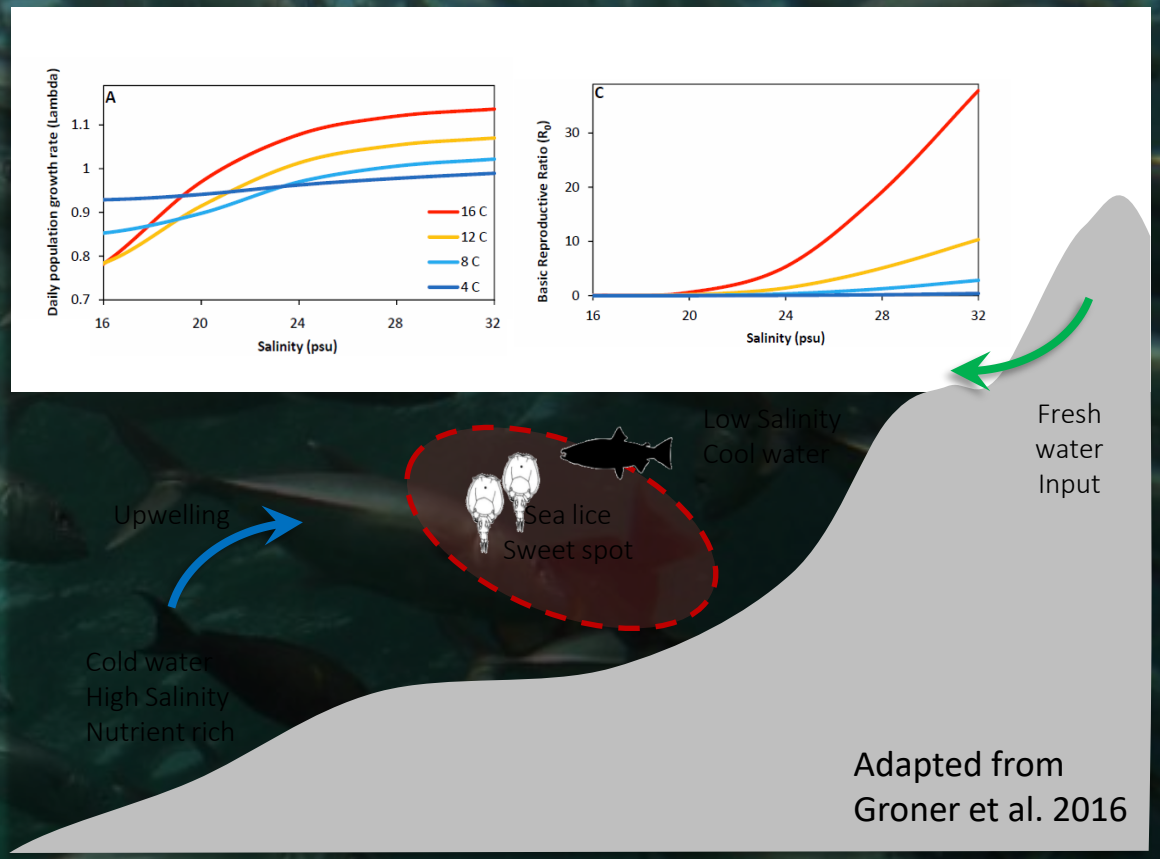
Summary of Climate Change Impact upon main Salmon farming regions. End of 21st Century under Heavy GHG scenario

Region	Offshore SST (ºC)	Off. Surface Salinity (PSU)	Rainfall (mm/yr)	Sea level (m)
Southern Chile (Los Lagos)	1.5	< +0.2	-250	0.2
Southern Chile (Magallanes)	1.0	< +0.1	+50	0.2
Norway	2.3	-0.5	+70	0.5
UK + Faroe Island	2.0	-0.4	+50	0.5
Canada (BC)	2.7	-0.6	+90	0.3
United States (East coast)	2.7	±0.4	+70	0.6
Japan	2.8	-0.2	+40	0.5
Australia + New Zealand	1.8	~ 0	+70(?)	0.5

Aquaculture 102: Sea Lice

Brooker et al. 2005





Adapted from
Groner et al. 2016

Summary of Climate Change Impact upon main Salmon farming regions. End of 21st Century under Heavy GHG scenario

Region	Offshore SST (ºC)	Off. Surface Salinity (PSU)	Rainfall (mm/yr)	Sea Lice growth
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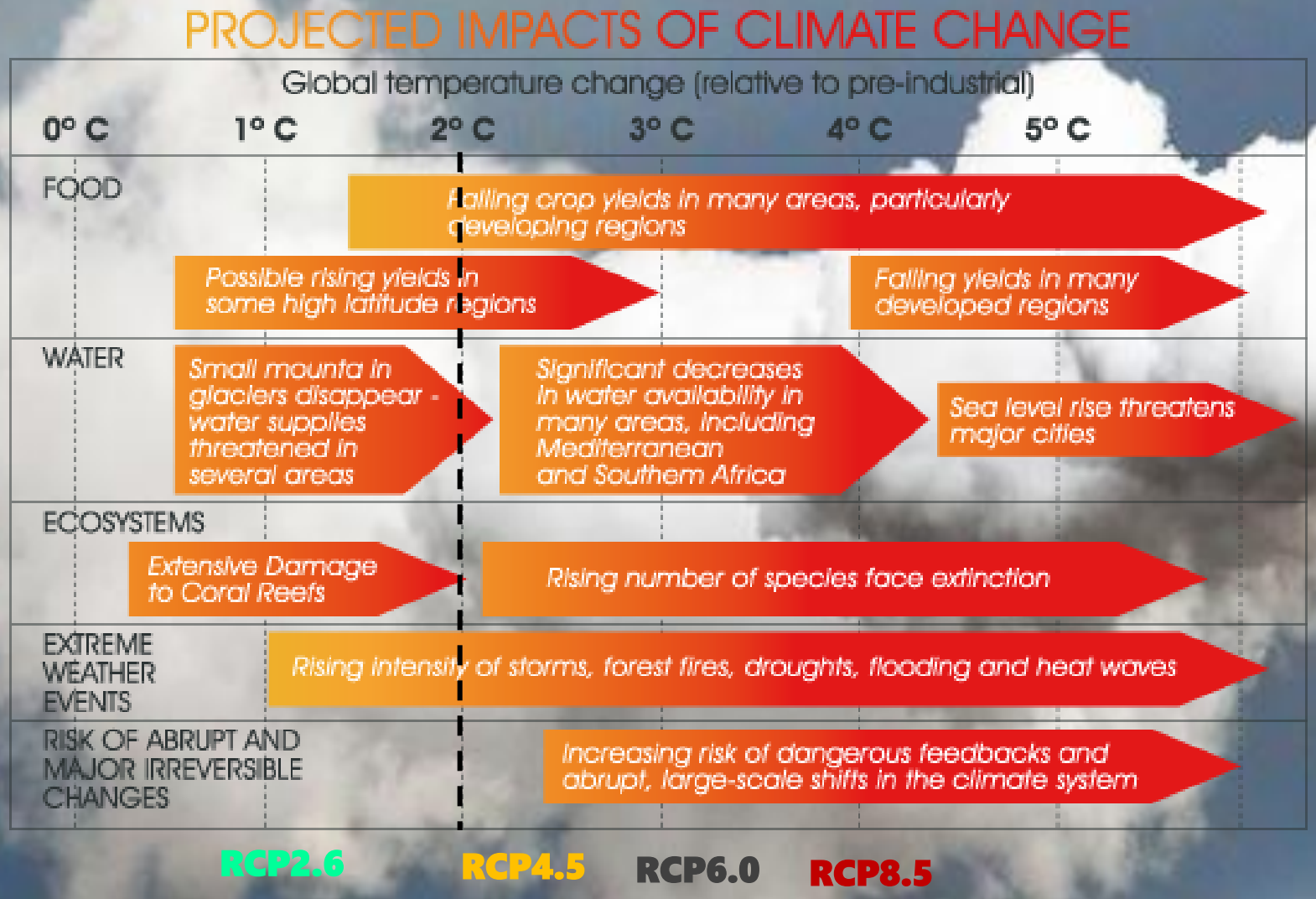
UK + Faroe Island	2.0	-0.4	+50	+
Canada (BC)	2.7	-0.6	+90	++
United States (East coast)	2.7	±0.4	+70	++
Japan	2.8	-0.2	+40	++
Australia + New Zealand	1.8	~ 0	+70(?)	+

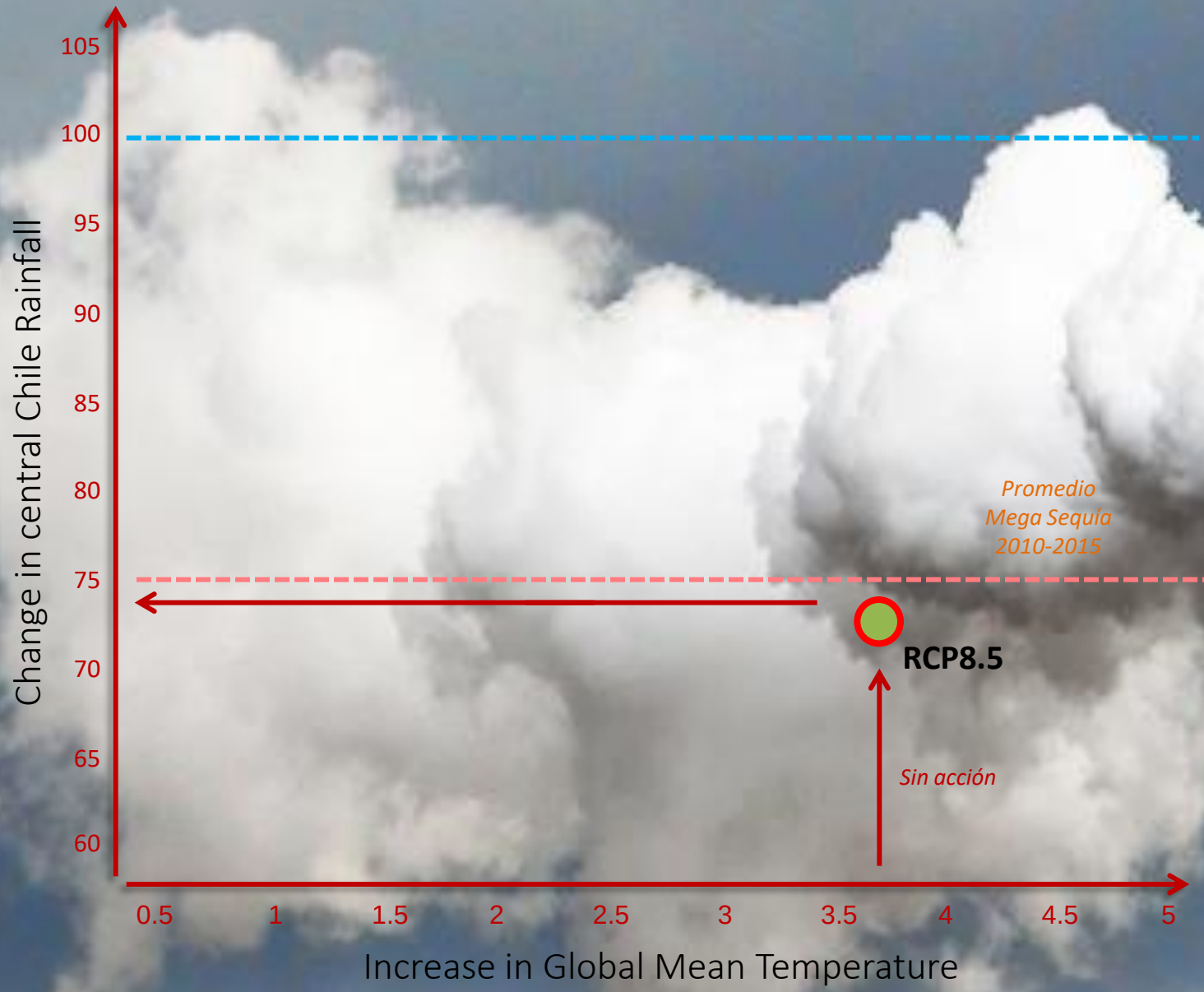
But Remember: **The future is open**



But Remember: **The future is open**

Cambio de precipitación y aumento de temperatura a fines de siglo (2070-2100) con respecto a clima actual (1970-2000).

Círculos indican promedio multi-modelo para cada escenario (32 modelos). Barras de error indican desviación estándar entre modelos .



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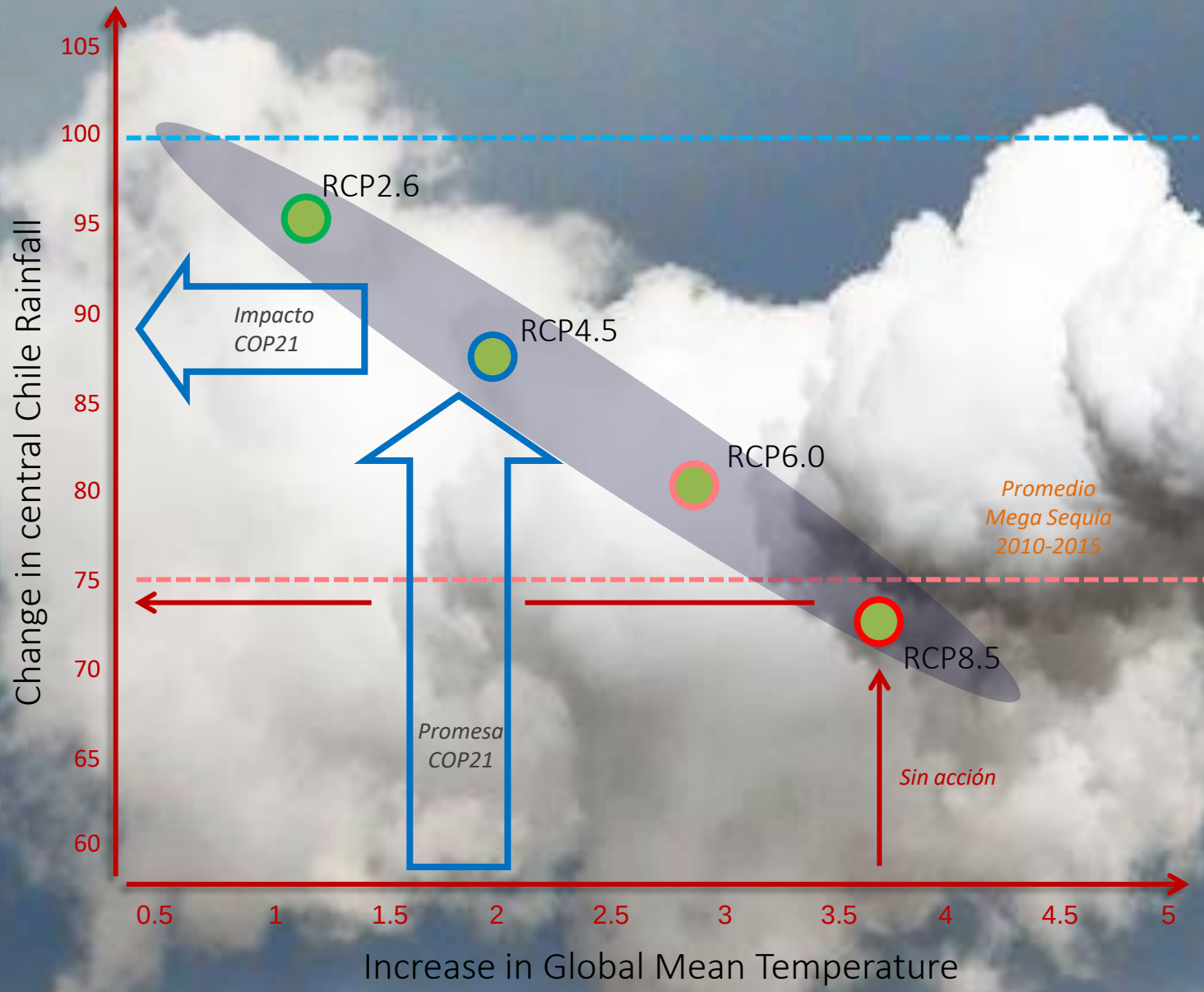
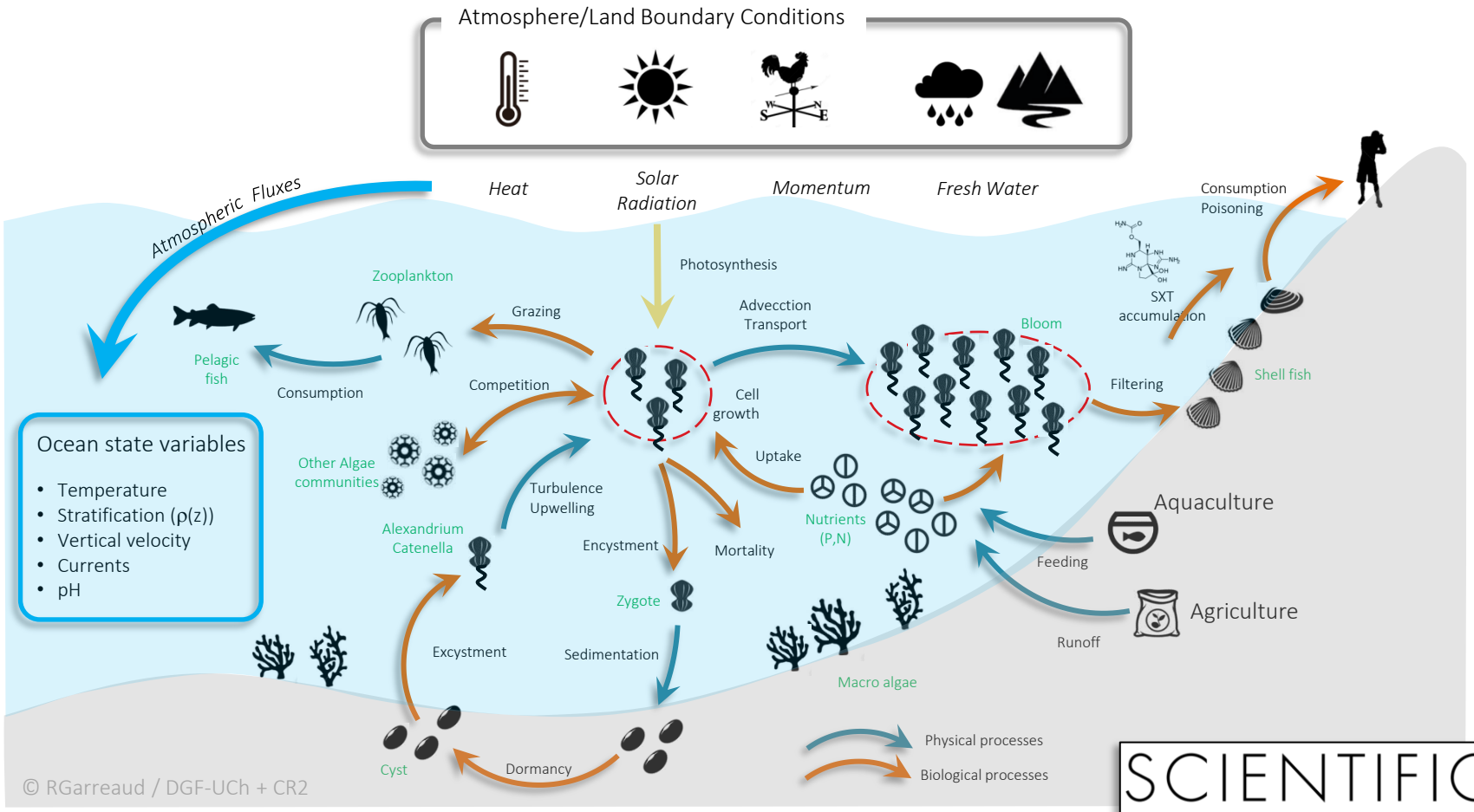


What about extreme events?

Let's consider the terrible summer-fall 2016 when the worst ever recorded Harmful Algal Bloom (*Pseudochattonella cf. verruculosa + Alexandrium catenella*) affected southern Chile, decimating 10% of the Chilean Salmon production and causing social unrest and economic losses.

Aquaculture 103: HAB




SCIENTIFIC REPORTS

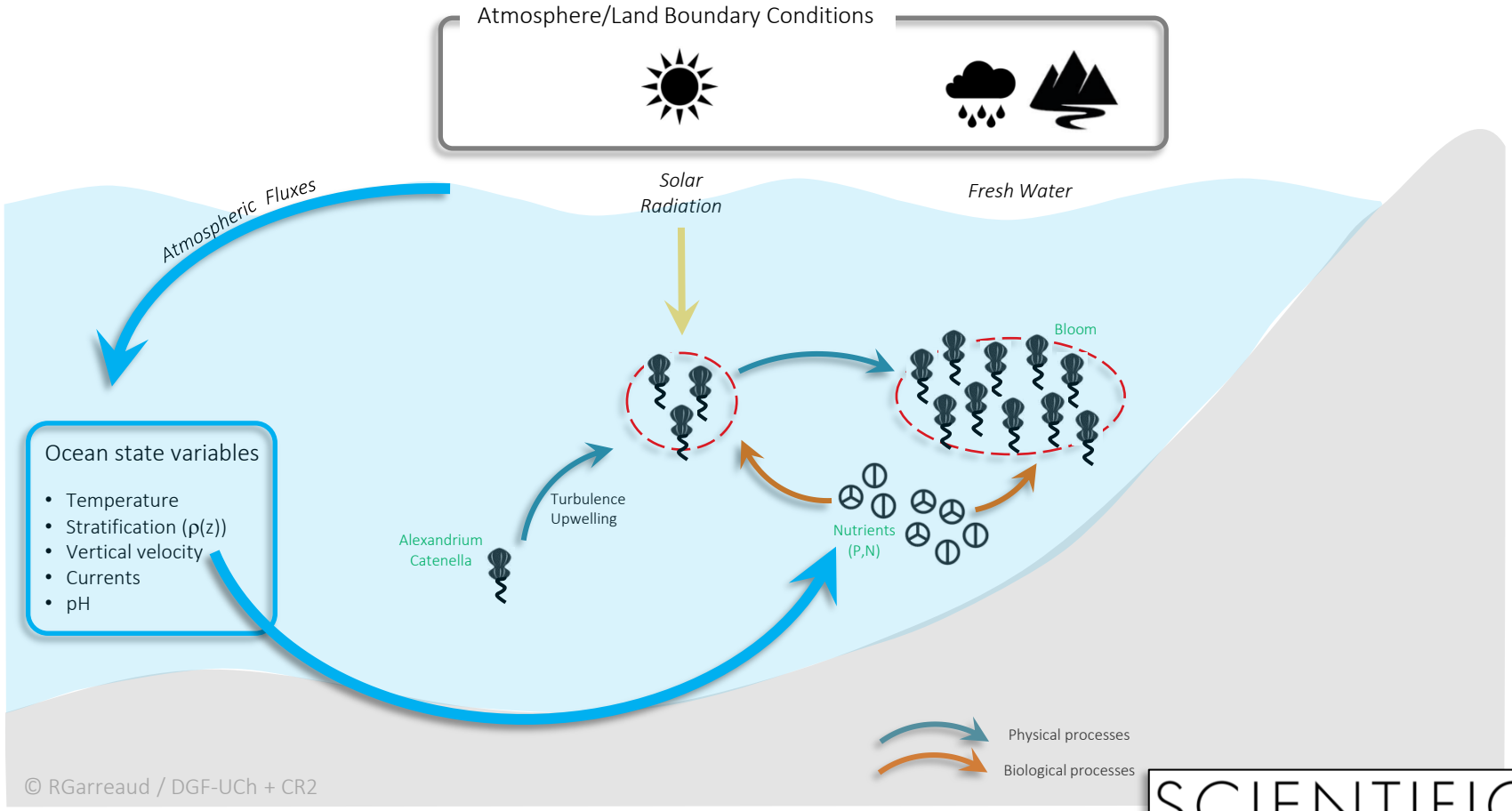
OPEN

Hydroclimatic conditions trigger record harmful algal bloom in western Patagonia (summer 2016)

Jorge León-Muñoz[1], Mauricio A. Urbina[2], René Garreaud[3,4] & José Luis Iriarte[5,6,7]

d: 26 April 2017

Aquaculture 103: HAB

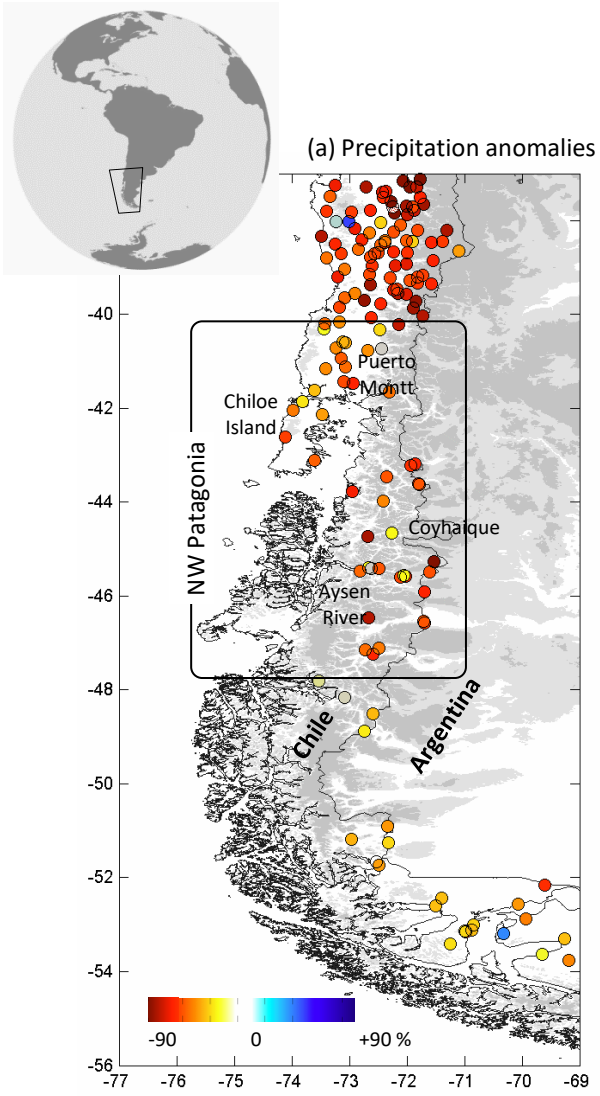


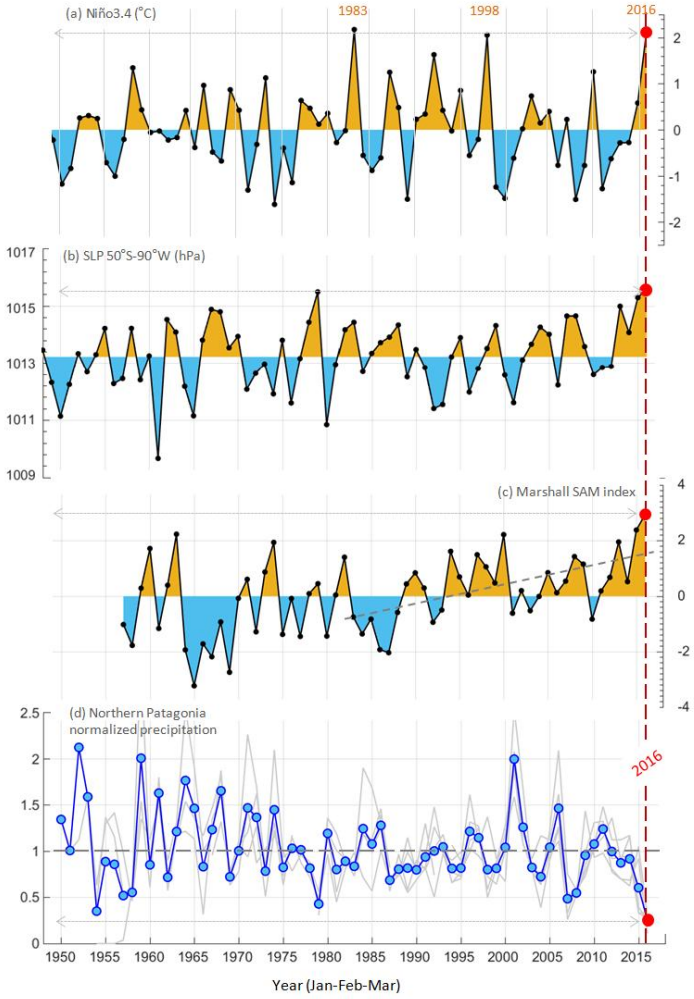
What about extreme events?

The drought of summer 2016, as most climate extreme, occurred by the superposition of natural variability (e.g. ENSO) upon climate change.

Record-breaking climate anomalies lead to severe drought and environmental disruption in western Patagonia in 2016

R. D. Garreaud[1,2,*]



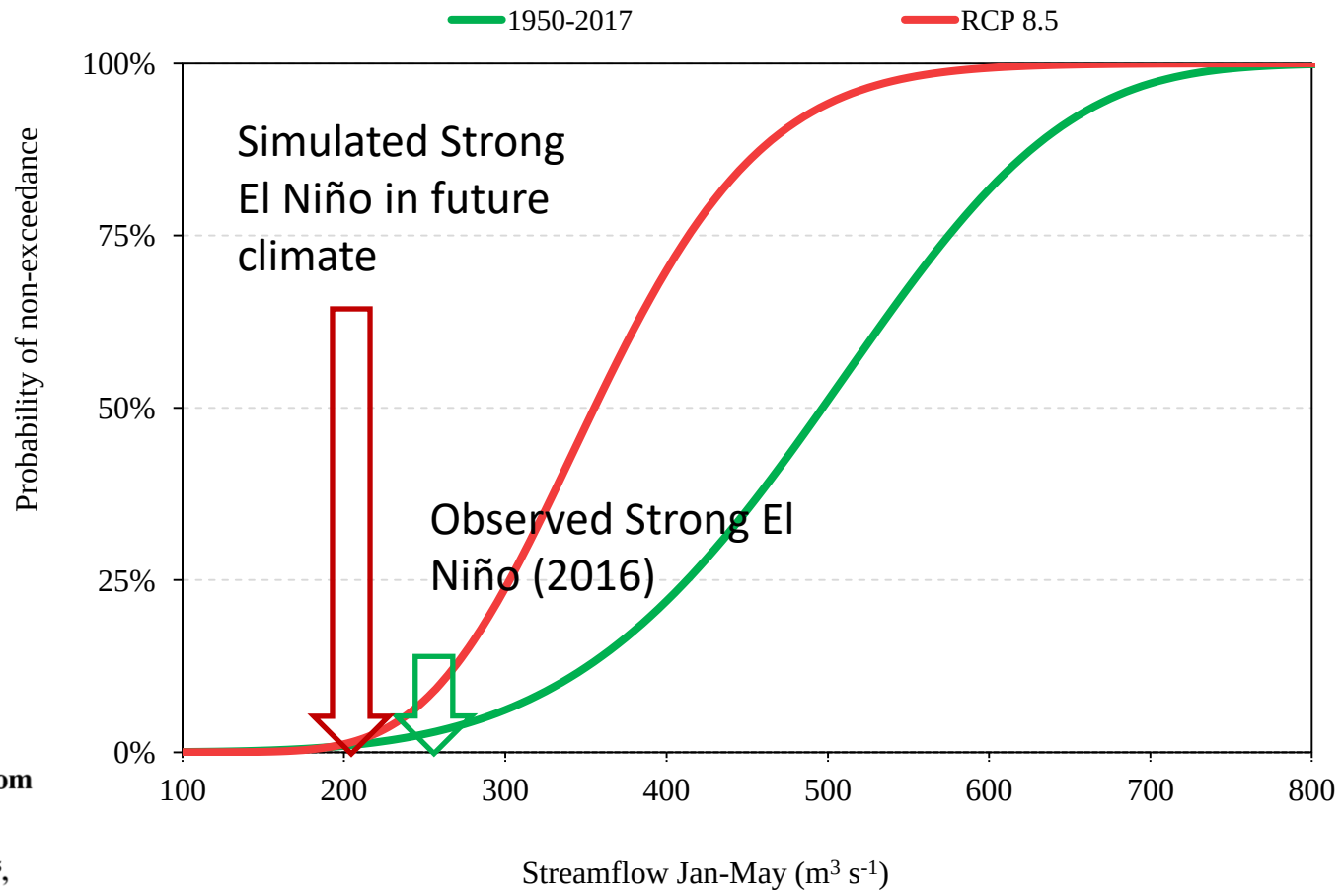


El Niño! Natural….

Antrophogenic SAM!

What about extreme events?

Thus, extreme events may be more frequent and/or intense in the future, but the change depend on the region and the phenomena in play.



The Glass Half-Empty: Climate Change Drives Shortage in Freshwater Inputs from a Trans-Andean Basin to the Coastal System of Chilean Northern Patagonia

Rodrigo Aguayo[1], Jorge León-Muñoz[2,3]*, José Vargas-Baecheler[1], Aldo Montecinos[4,5], René Garreaud[6,7], Mauricio Urbina[8,9], Doris Soto[3], José Luis Iriarte[10,11]

CONCLUSIONS

01 Temperature and precipitation trends forced by GHG/O3 have began to emerge at the global and local scale

02 Climate models indicate that such trends will continue during the 21st century, possibly causing an increase in sea lice (expansion? Intensity? Seasonality?)

03 The magnitude and timing of the global climate change effects depends on the emission rate of GHG (and hence of the socio-economic development pathways)

04 Local impacts (e.g., upon salmon production on a specific region) require further analyses of the climate-environment-industry relationships.

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