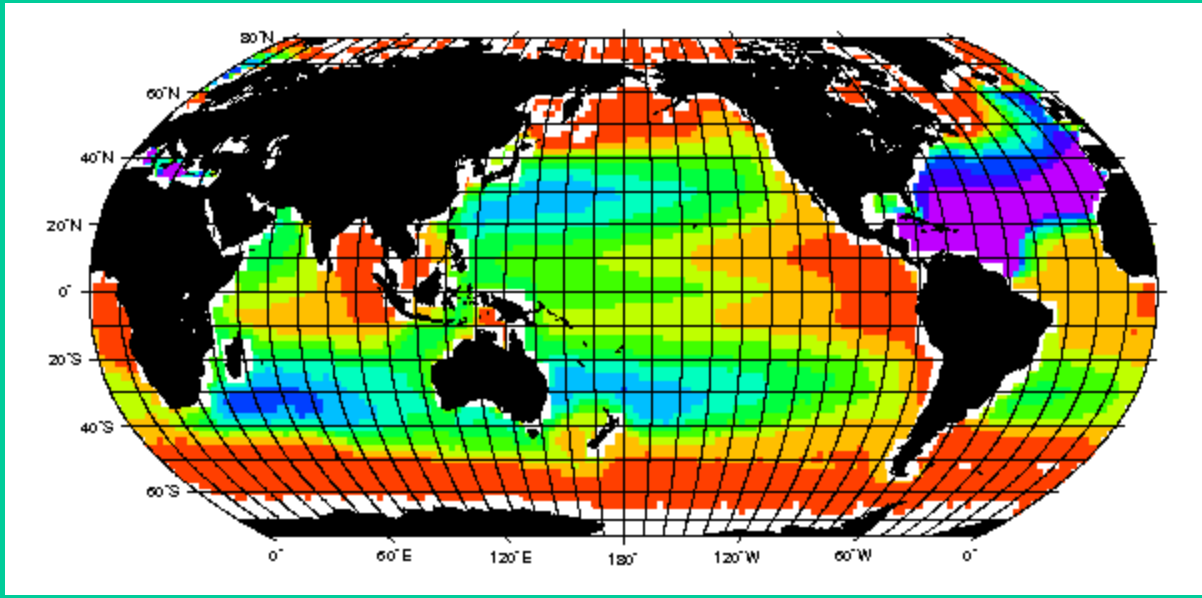
Detection of anthropogenic influences on ocean biogeochemistry



IOS

Fisheries and Oceans Canada | Pêches et Océans Canada

CCCma

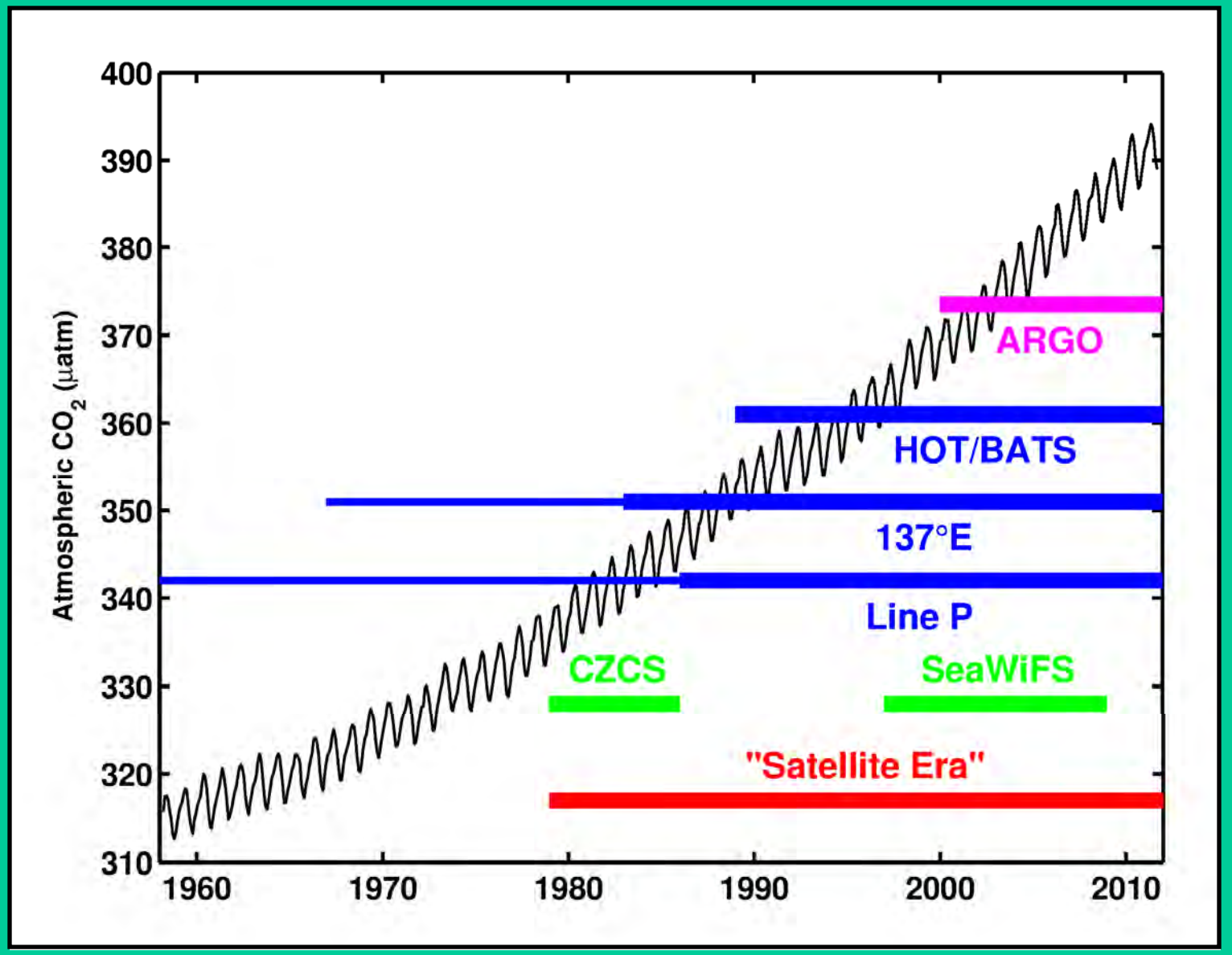
James Christian
Fisheries and Oceans Canada / Canadian Centre for Climate Modelling and Analysis

How do we detect change when we do not have good observations of the 'baseline' state?

How do we distinguish anthropogenic effects from the background of interannual and interdecadal variability?

Baseline H_o (Ockham's Razor): a linear response to atmospheric CO_2 concentration superimposed on a stationary background variability

A brief history of ocean observation



Wally was right, mostly

Greenhouse Bandwagon Rolls On

How much must you know about Earth to predict how mankind's depredations will change it in the next millennium? Should you understand in a general way how the ocean sucks carbon dioxide, a greenhouse gas, out of the atmosphere? Sure. Do you need a research project to learn all the details of how the ocean carries that carbon into the deep sea? Wallace Broecker thinks that's irrelevant to global change, and he is taking the unusual step of telling his colleagues so in the next issue of *Global Biogeochemical Cycles*.

It's not that the science in that project—the Joint Global Ocean Flux Study (JGOFS)—and others like it isn't worthwhile, Broecker says, it's the trendy, grant-enticing packaging that gets his goat. Too many scientists with too little to contribute to predicting the fate of the planet have discovered the funding benefits of jumping on the global change bandwagon, says the prominent and sometimes cantankerous marine geochemist at Lamont-Doherty Geological Observatory. He sees "a growing tendency for environmental science programs to hitch their wagons to the greenhouse star." He adds "Let's keep global change honest!"

Broecker's concern is that mislabeling will leave policy-makers, rather than scientists, enough to base JGOFS on a single scenario such as Wally's."

Broecker is ready to respond to such arguments with what he considers an even more egregious case, the World Ocean Circulation Experiment (WOCE). A 40-nation effort to understand ocean circulation, WOCE was conceived before global change became popular, says climate modeler Robert E. Dickinson of the University of Arizona. But, he notes, it is "now selling itself in terms of global change, though sometimes it's a little hard to see the connection." Broecker is harsher: "I would give [even] JGOFS a better ranking than WOCE."

Wallace Broecker

But then again, Dickinson isn't convinced that the selling of WOCE is such a bad thing. Who's to say, he asks, that a detailed understanding of ocean currents won't prove vital in an effort to understand the climatic effects of carbon dioxide? "If global change were too focused, we would probably miss things," he says. Modeler Gerald North of Texas A&M also tends to be tolerant of less-than-precise labeling of projects. Giving a fundamental science project a fashionable rubric is sometimes the best way to keep essential money flowing, he says.

In any case, Dickinson says, the trend Broecker deplores is already on the wane. A few years ago, he notes, some researchers hoped public interest in global change would provide an opportunity to stage studies on the grand scale of the International Geophysical Year of 1957-58. Global change, they thought, justified studying everything from Earth's core to its magnetosphere to the surface of the sun. Much of that undiscriminating holistic approach is already gone, Dickinson says, and the weeding continues.

In the most recent budget cycle, for example, the National Science Foundation withdrew its mid-ocean ridge study from the federal global change package and reclassified it as basic science. RIDGE (Ridge Interdisciplinary Global Experiment) will indeed study a source of climate change: variations in the output of carbon dioxide-laden fluids from hot springs on the ocean floor. The only catch is that the resulting climate changes take millions of years. Not quite what's needed to predict the globe's temperature in 2025.

■ RICHARD A. KERR

There is a biological pump for atmospheric CO_2, but there is no biological pump for anthropogenic CO_2 at steady state

Biological pump can become a net sink for anthropogenic CO_2 only if:

- **climate change and/or ocean acidification alters export production**
- **humans alter export production by deliberate fertilization (geoengineering)**
- **other human perturbations (e.g., fishing) alter community structures enough to affect export production globally**

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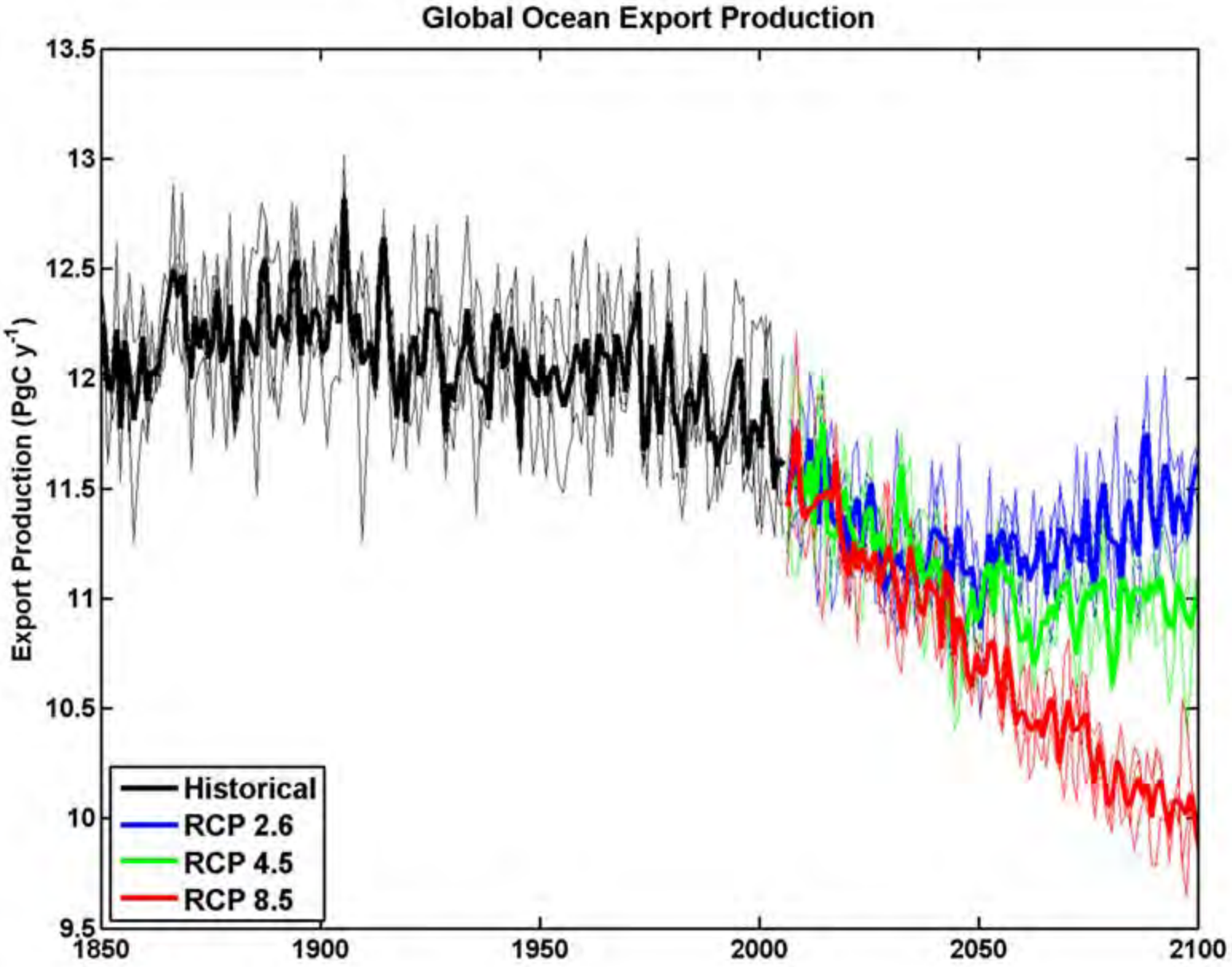
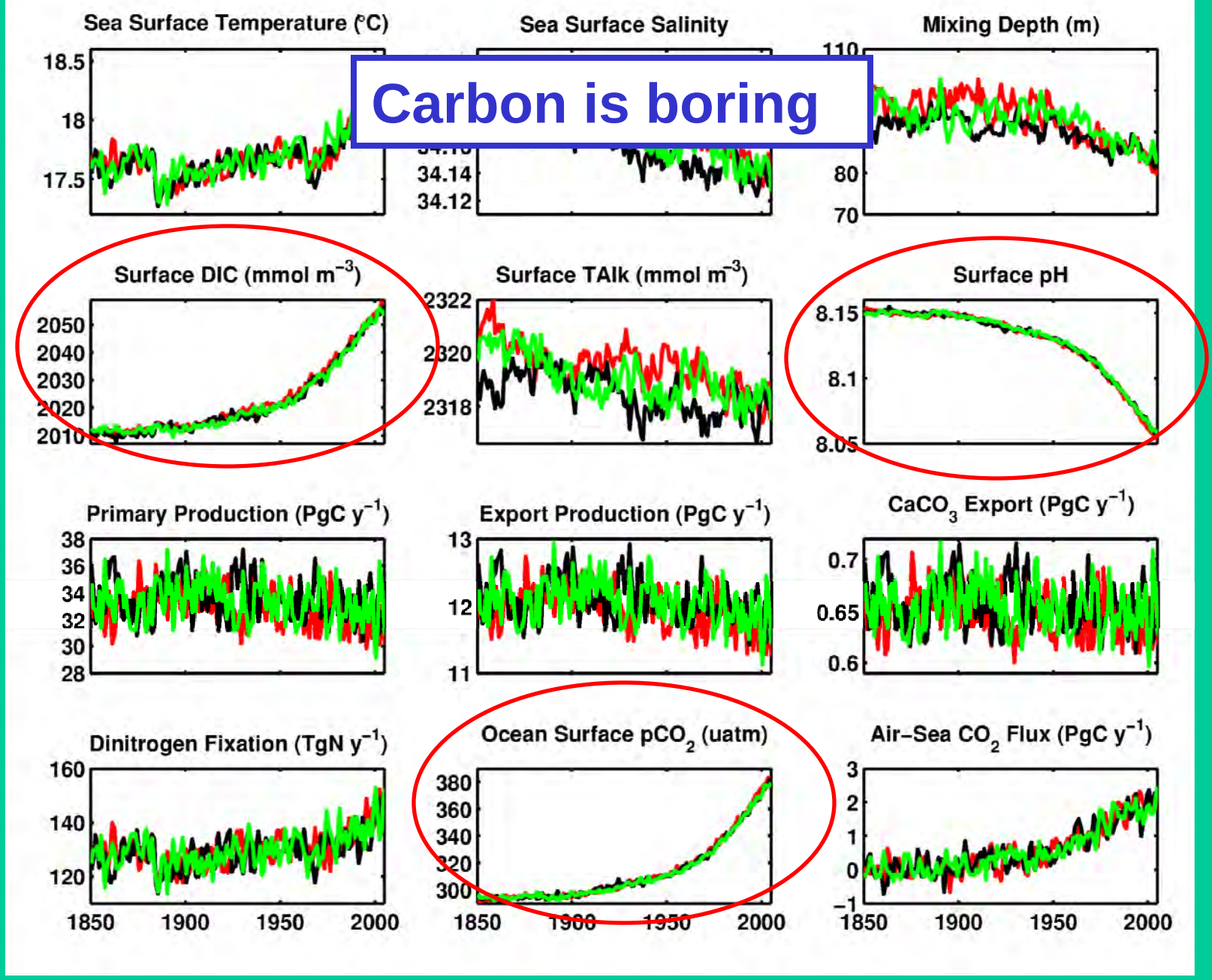
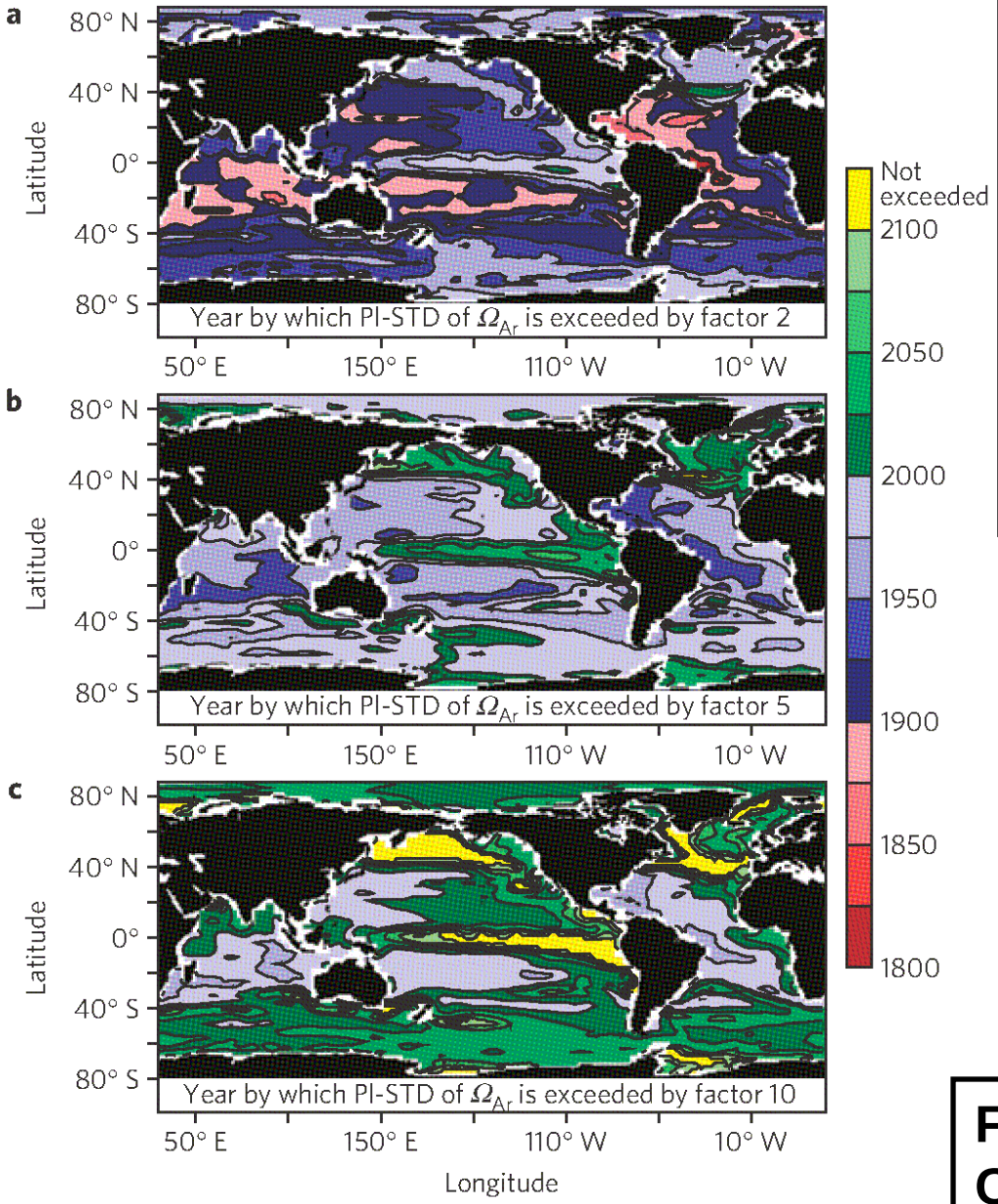
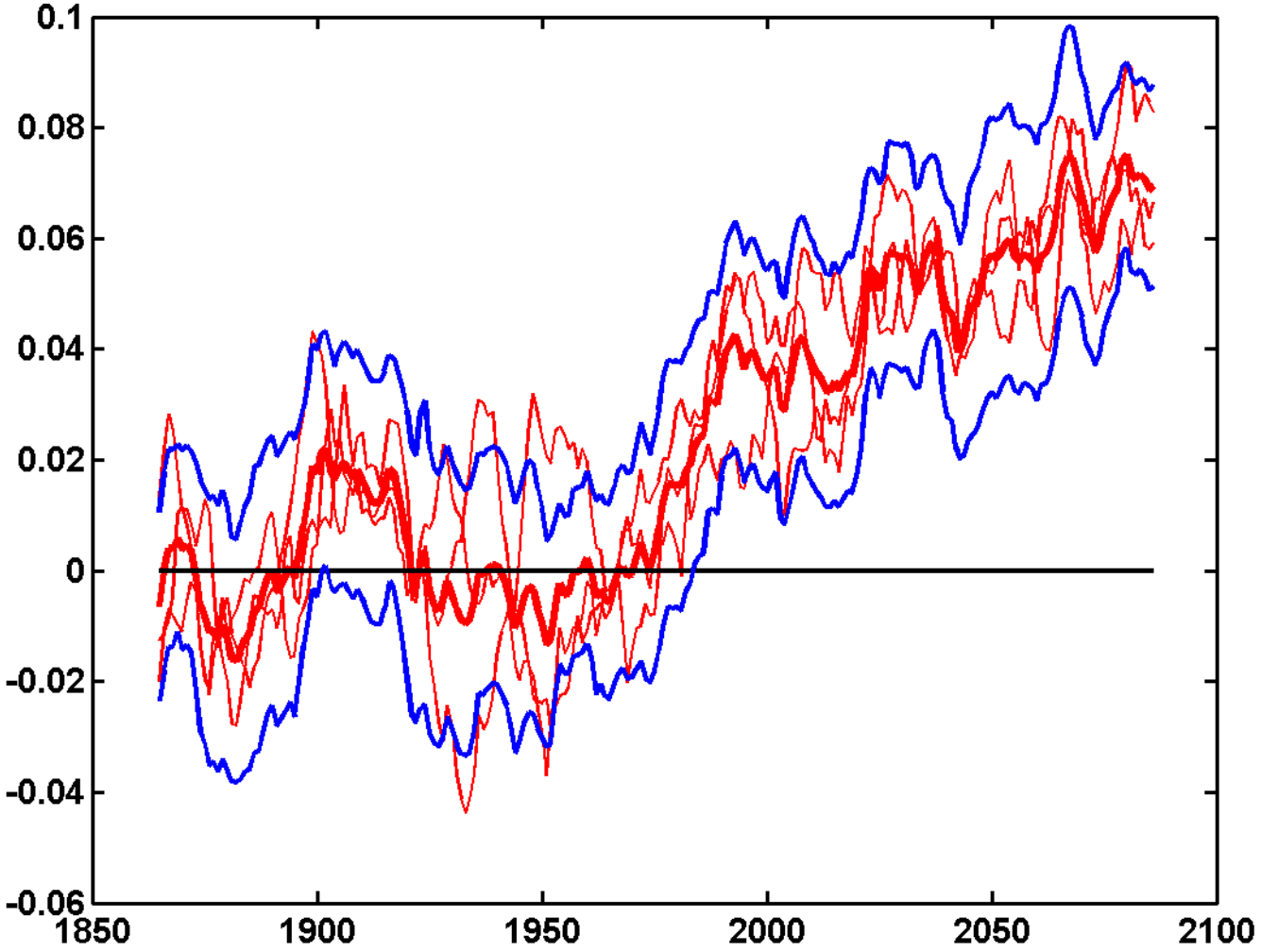

Global Ocean Export Production
Export Production (PgC y-1)
13.5
13
12.5
12
11.5
11
10.5
10
9.5
1850
1900
1950
2000
2050
2100
Historical
RCP 2.6
RCP 4.5
RCP 8.5


Carbon is boring
Sea Surface Temperature (°C)
18.5
18
17.5
Sea Surface Salinity
34.14
34.12
Mixing Depth (m)
110
80
70
Surface DIC (mmol m^{-3})
2050
2040
2030
2020
2010
Surface TAlk (mmol m^{-3})
2322
2320
2318
Surface pH
8.15
8.1
8.05
Primary Production (PgC y^{-1})
38
36
34
32
30
28
Export Production (PgC y^{-1})
13
12
11
CaCO$_3$ Export (PgC y^{-1})
0.7
0.65
0.6
Dinitrogen Fixation (TgN y^{-1})
160
140
120
Ocean Surface pCO$_2$ (uatm)
380
360
340
320
300
Air–Sea CO$_2$ Flux (PgC y^{-1})
3
2
1
0
−1
1850
1900
1950
2000

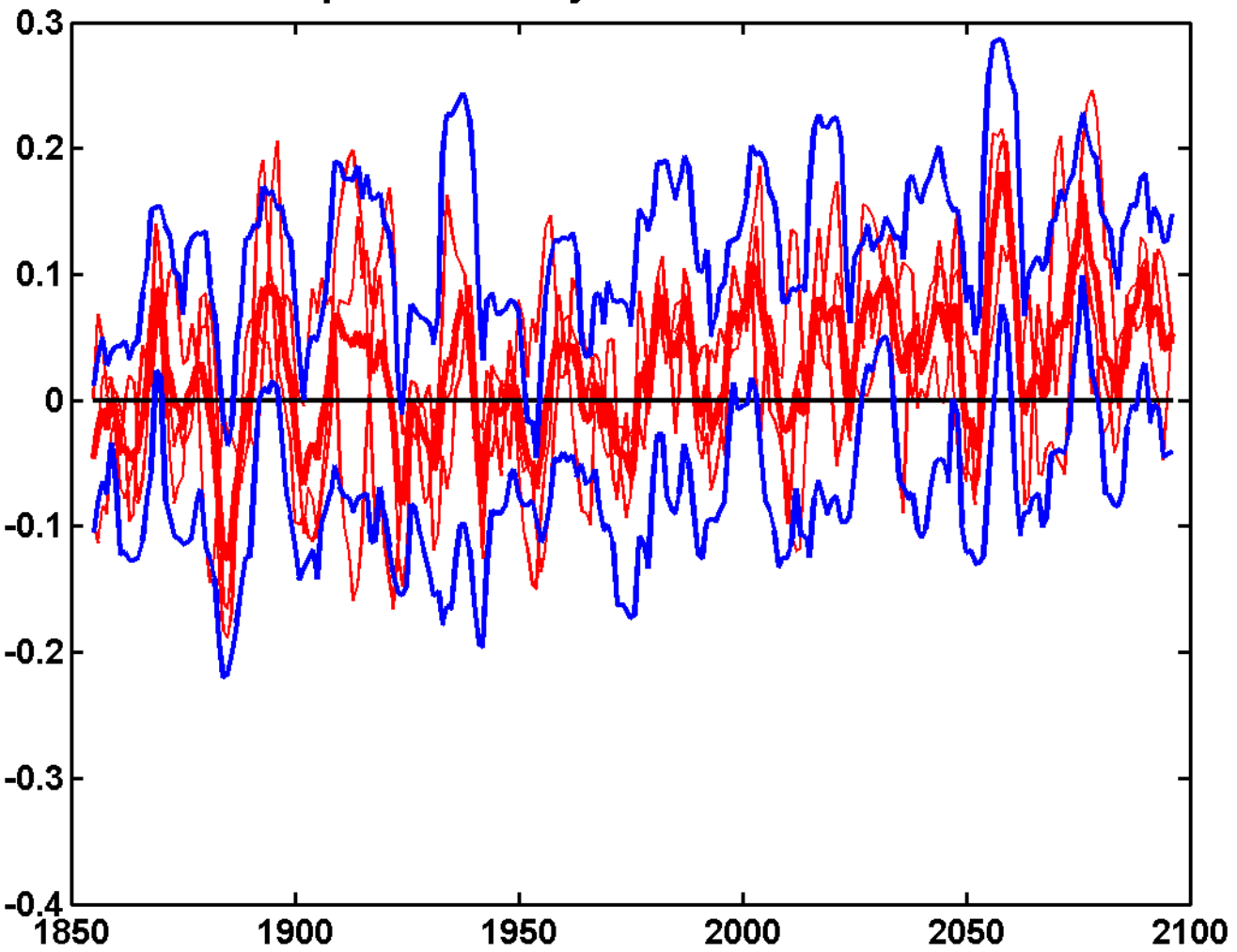


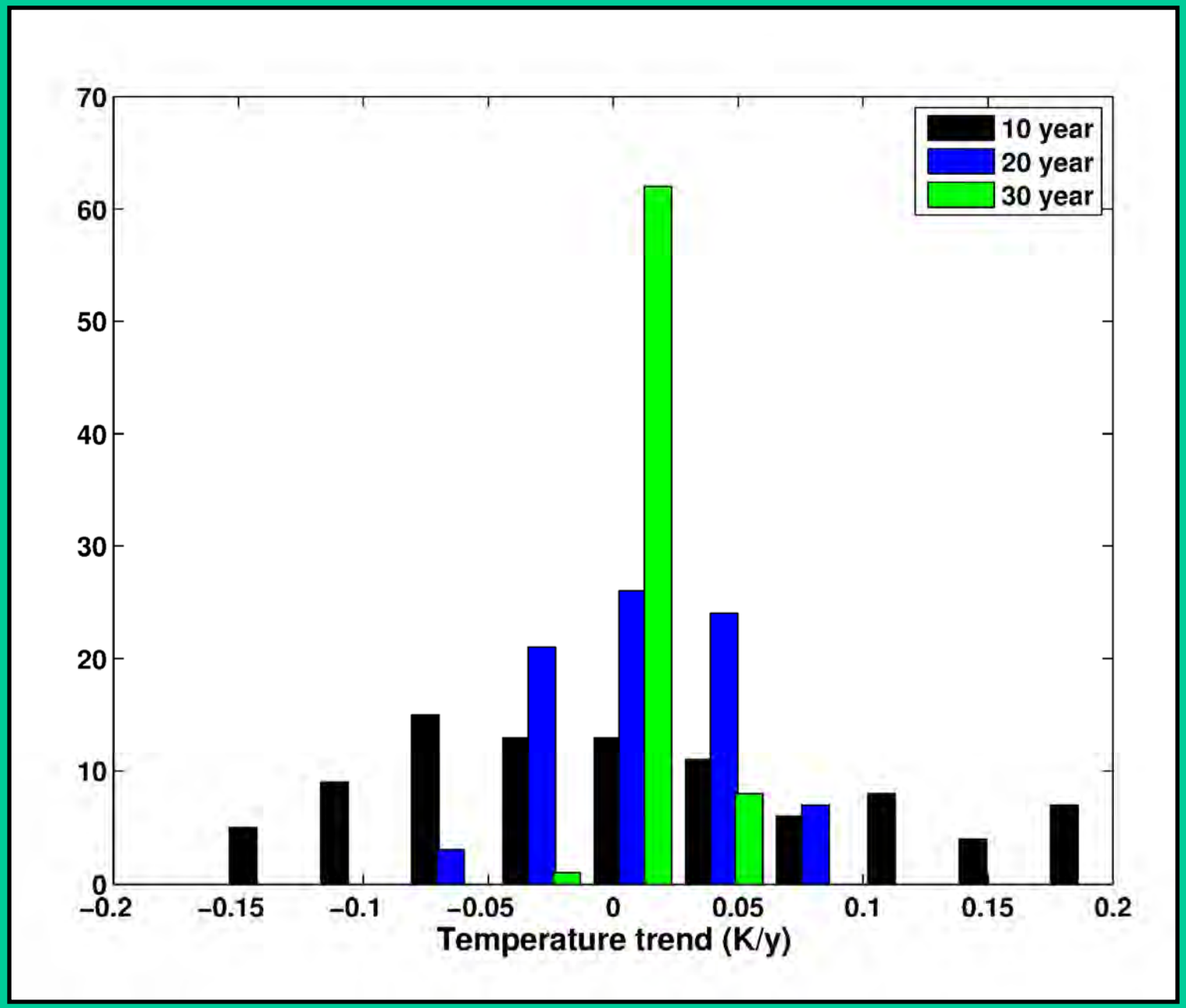
"the current anthropogenic trend in ocean acidification already exceeds the level of natural variability by up to 30 times"

Friedrich et al 2012 – Nature Climate Change

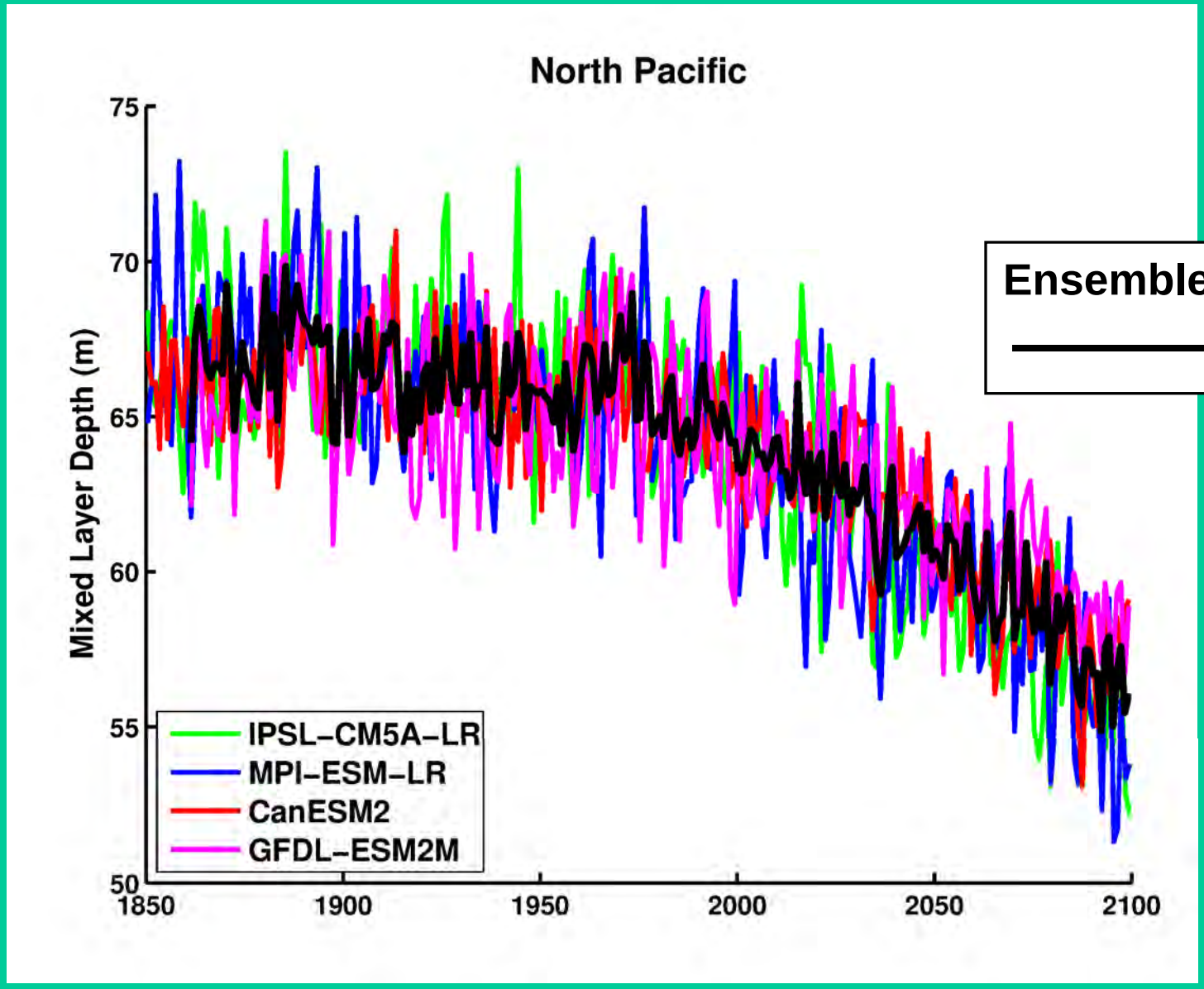

Sea Surface Temperature - 30 year trend - Ocean Station P - RCP85
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
1850
1900
1950
2000
2050
2100

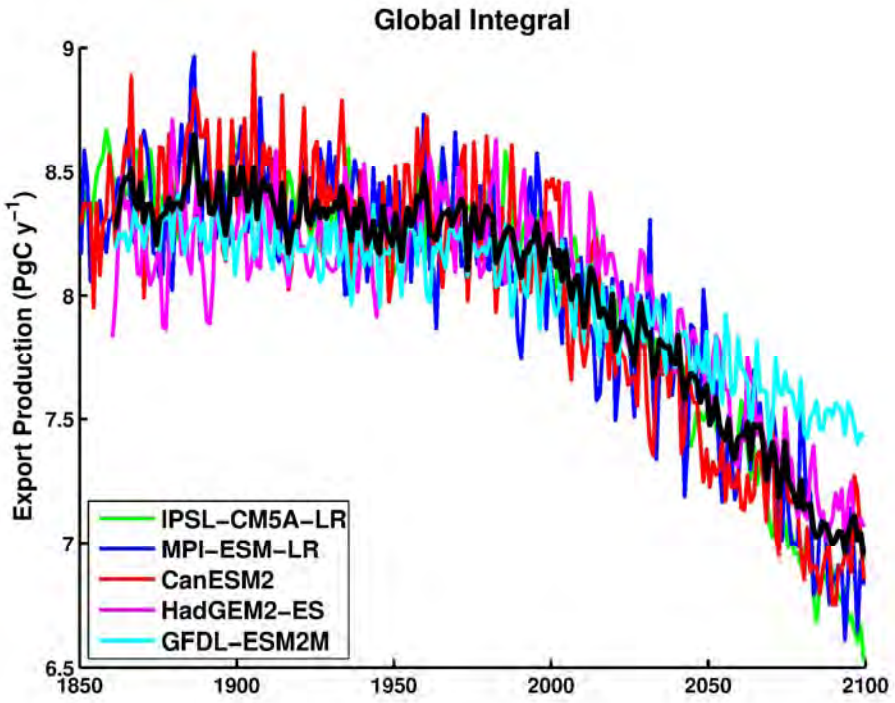
10 year trends are rarely significant




10 year
20 year
30 year
70
60
50
40
30
20
10
0
−0.2
−0.15
−0.1
−0.05
0
0.05
0.1
0.15
0.2
Temperature trend (K/y)

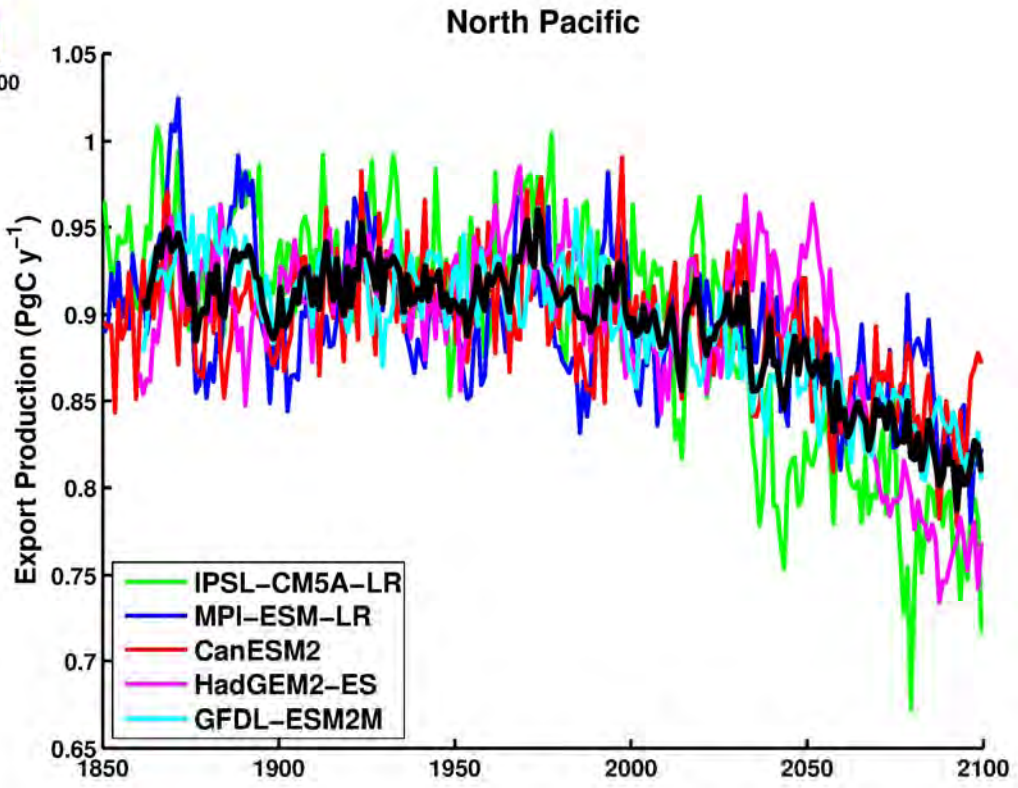
CMIP5 models now online



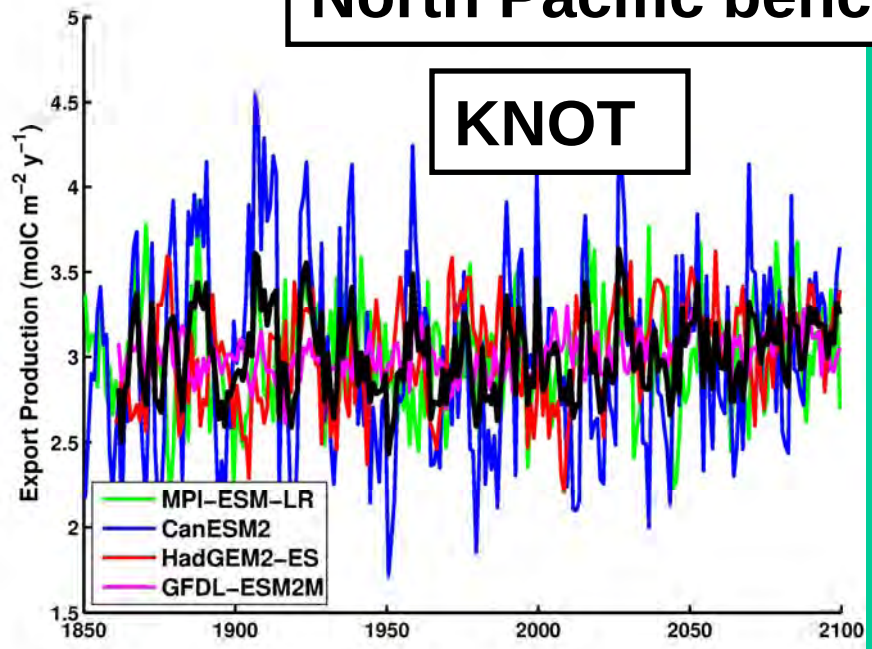


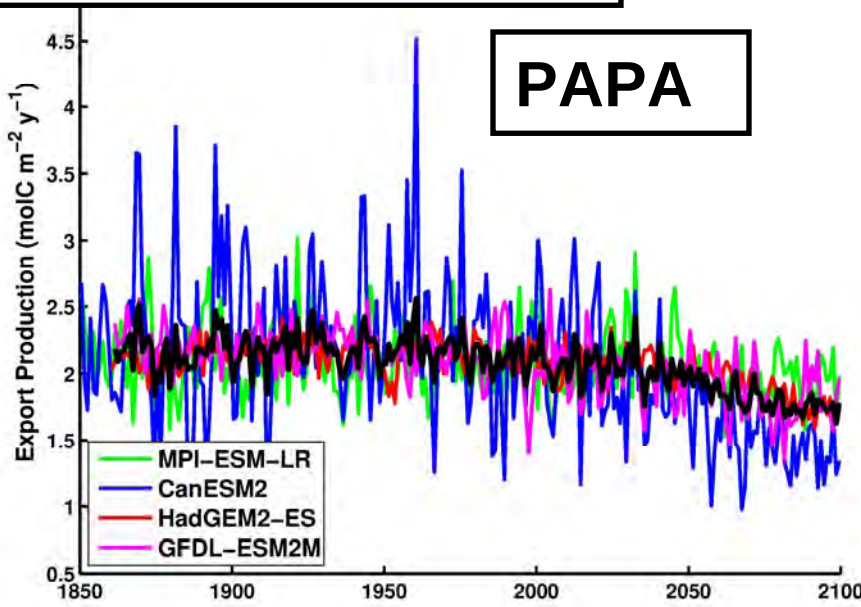
Global and North Pacific integral export production (normalized)

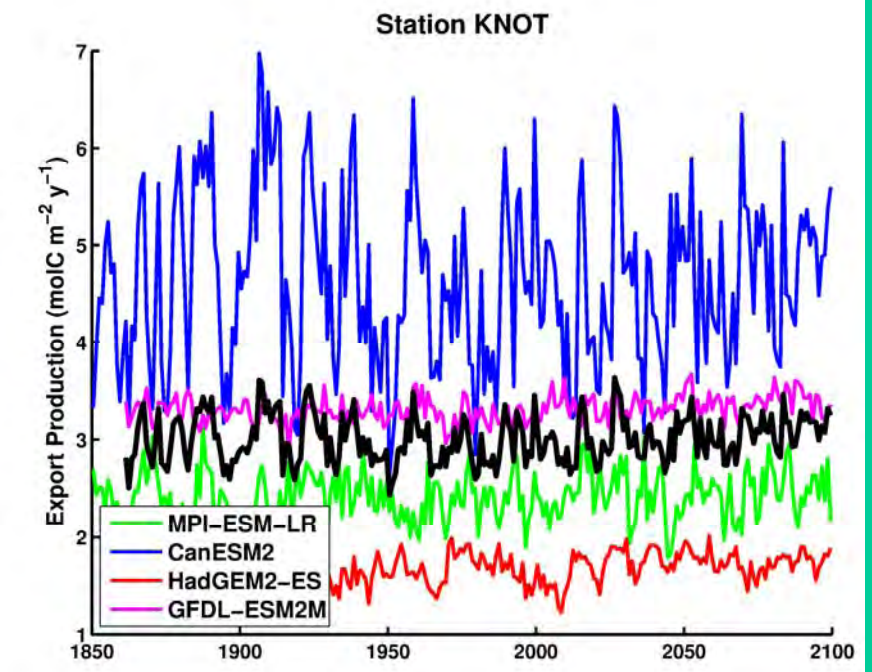
Trend is consistent across models

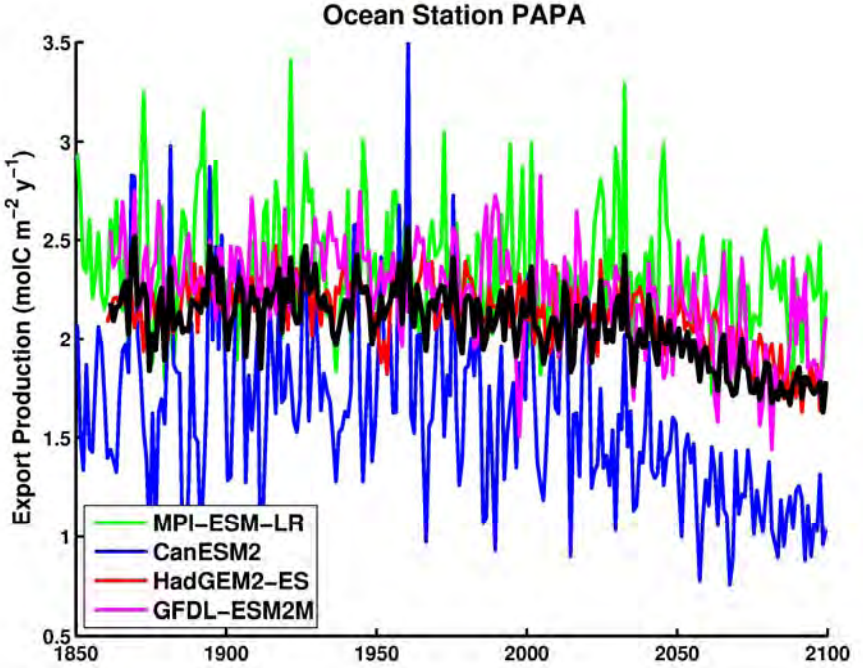


North Pacific benchmark observing stations

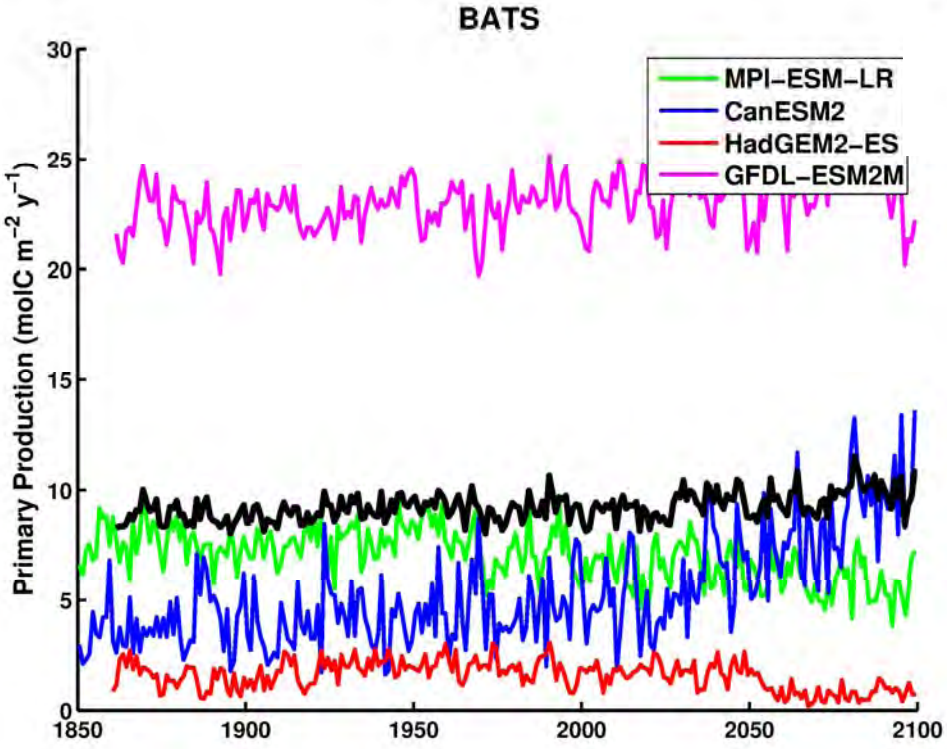


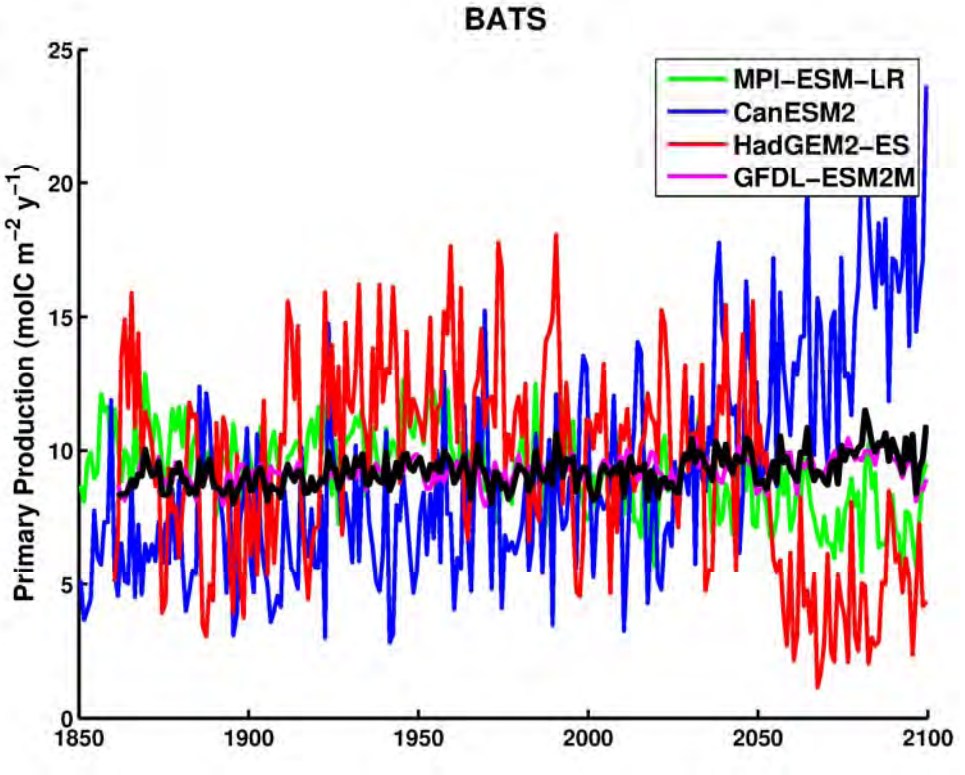






Primary production at BATS (subtropical Atlantic)





Inconsistent trends, and highly variable baseline values

Ensemble mean value is quite reasonable

Conclusions

- anthropogenic impact has existed throughout the modern era of ocean observation; we are entering the era when the anthropogenic transient will likely be the largest component of variability in many ocean bgc fields

- 10 years is rarely enough to detect a secular trend because of internal variability; 20-30 years may be, but whether the models have a realistic amount of internal variability at longer timescales is unknown

- trends are fairly consistent across models in some cases, but differences in baseline values among models can be large