Workshop on Global Assessment of the Implications of Climate Change on the Spatial Distribution of Fish and Fisheries

Trying to measure what we don’t know: Examples in ecology and management

Grégoire Certain, post-doc, IMR, Tromsø

Species Distribution Models (SDMs) and associated uncertainties

(sampling)

Species abundance data (Survey)

(model formulation and selection)

Statistical model
(GLM, GAM, BRT, MaxEnt, …)

Environmental Data
(measure, model, satellite)

(scale)

Climate change scenario

Forecasts

Oceanographic, bio-geochemical model

(model formulation and selection)

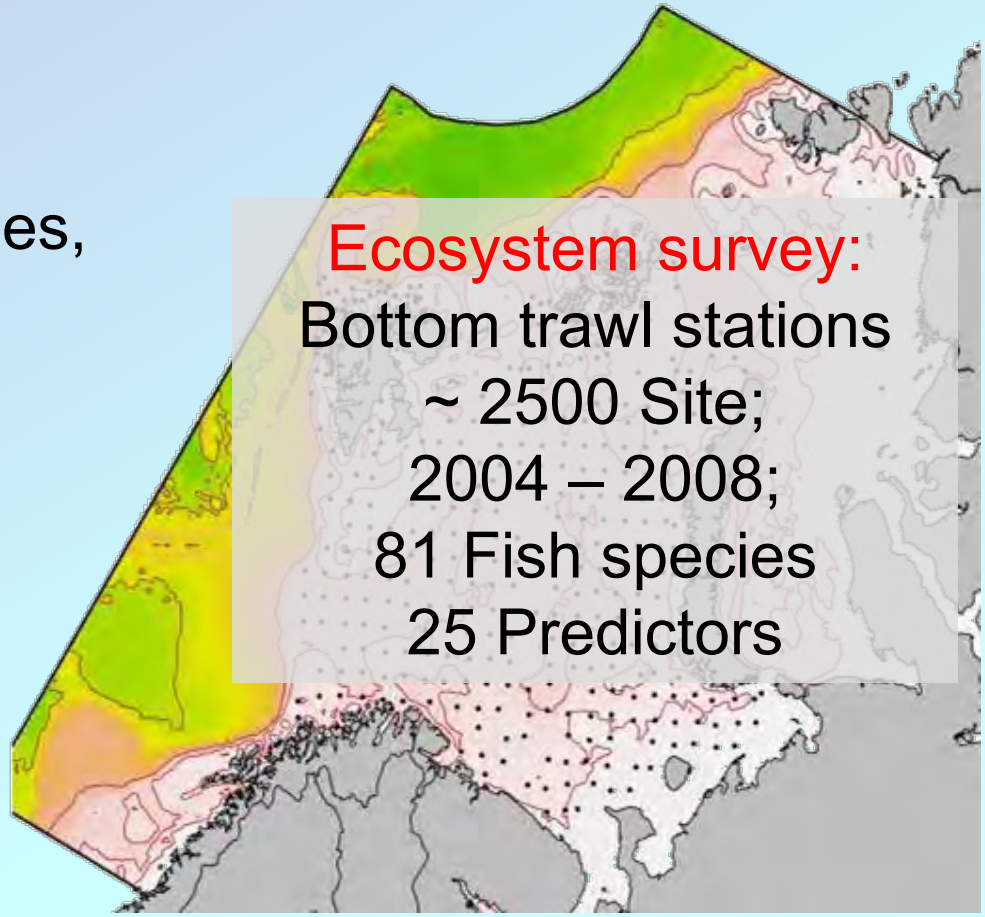
Climatic model

We applied SDMs within the BarEcoRe project

How climate change will affect the spatial distribution of fishes in the Barents Sea?

Build SDM for each species,

Do the prediction.

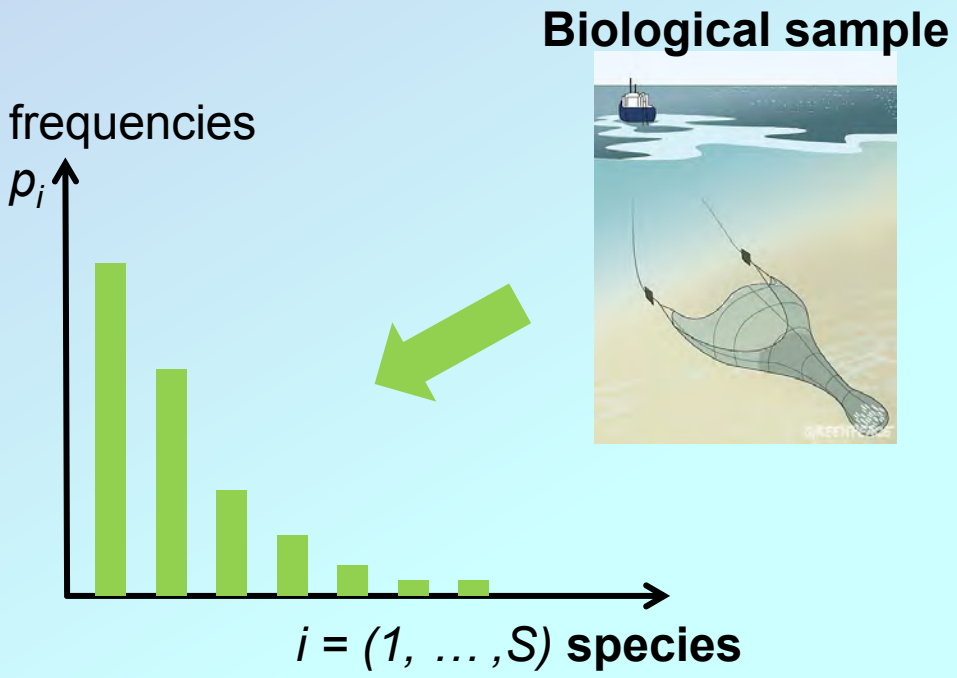


But… many models… and no species interactions… we searched for an alternative approach.

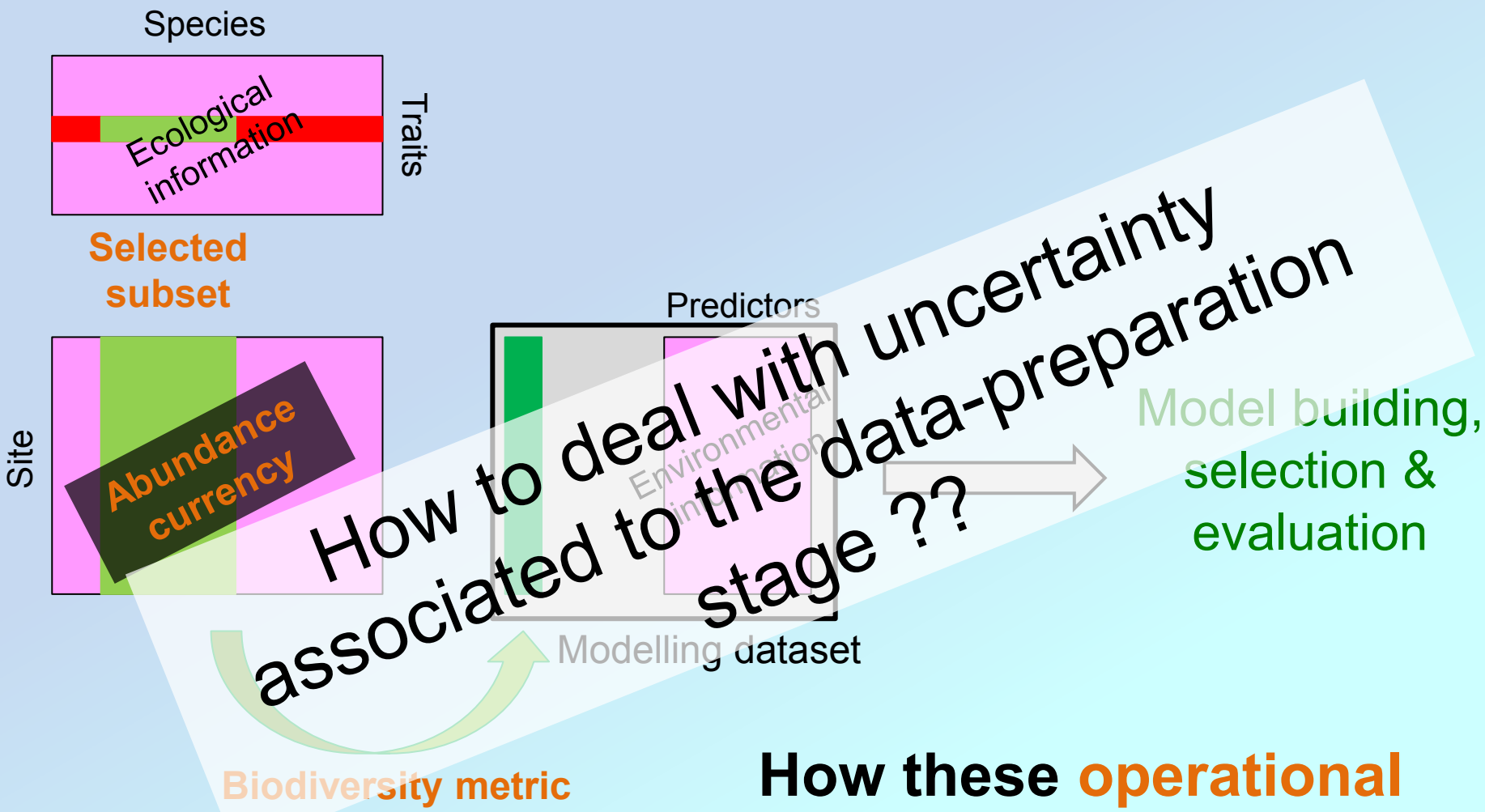
How to account for species interactions whithin SDMs ?

We changed the focus, from species to **Biodiversity.**

The relative frequencies of all species is actually **the output** of these species interactions. We modelled it directly using **diversity indices.**



Building Diversity Models requires several operational choices

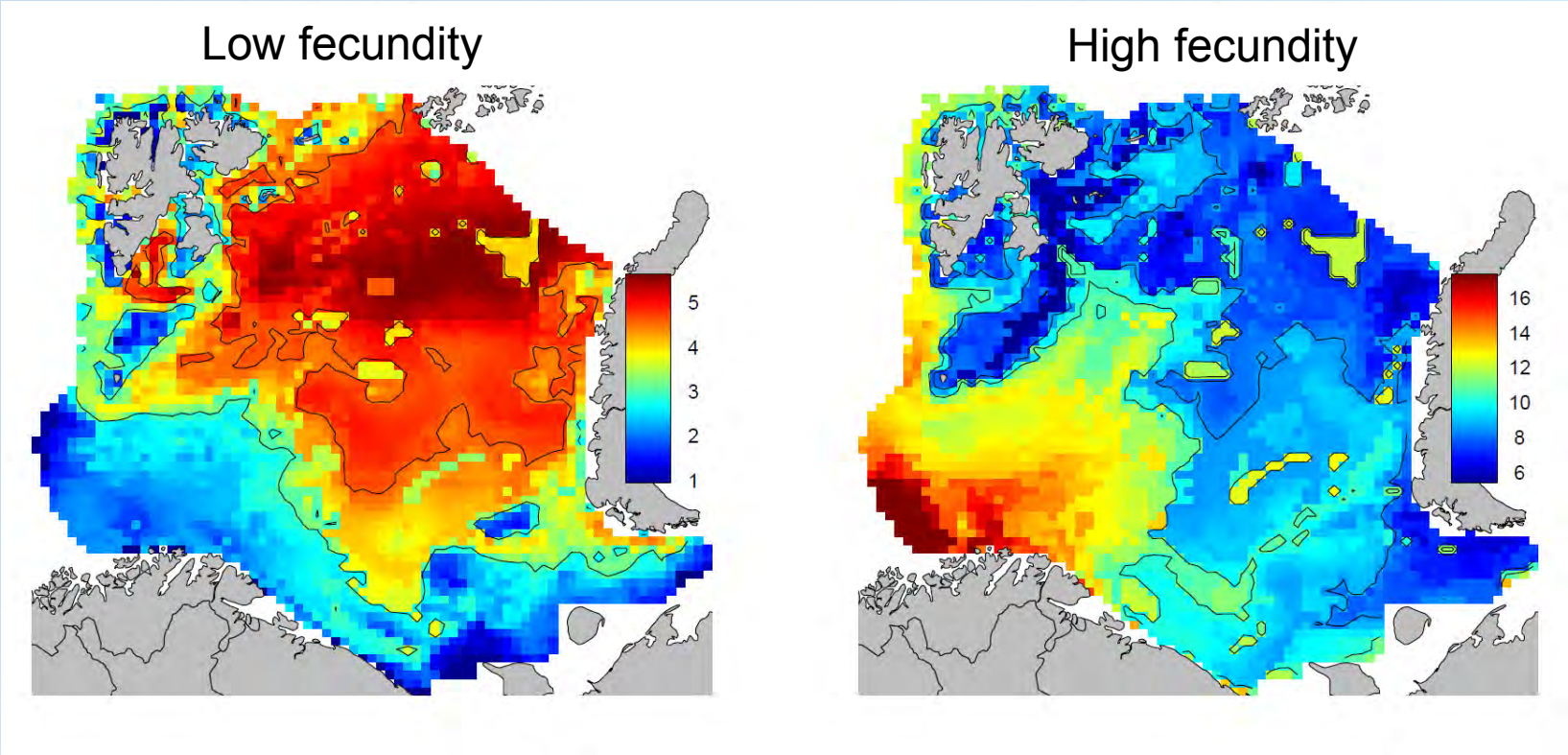


How to deal with uncertainty associated to the data-preparation stage ??

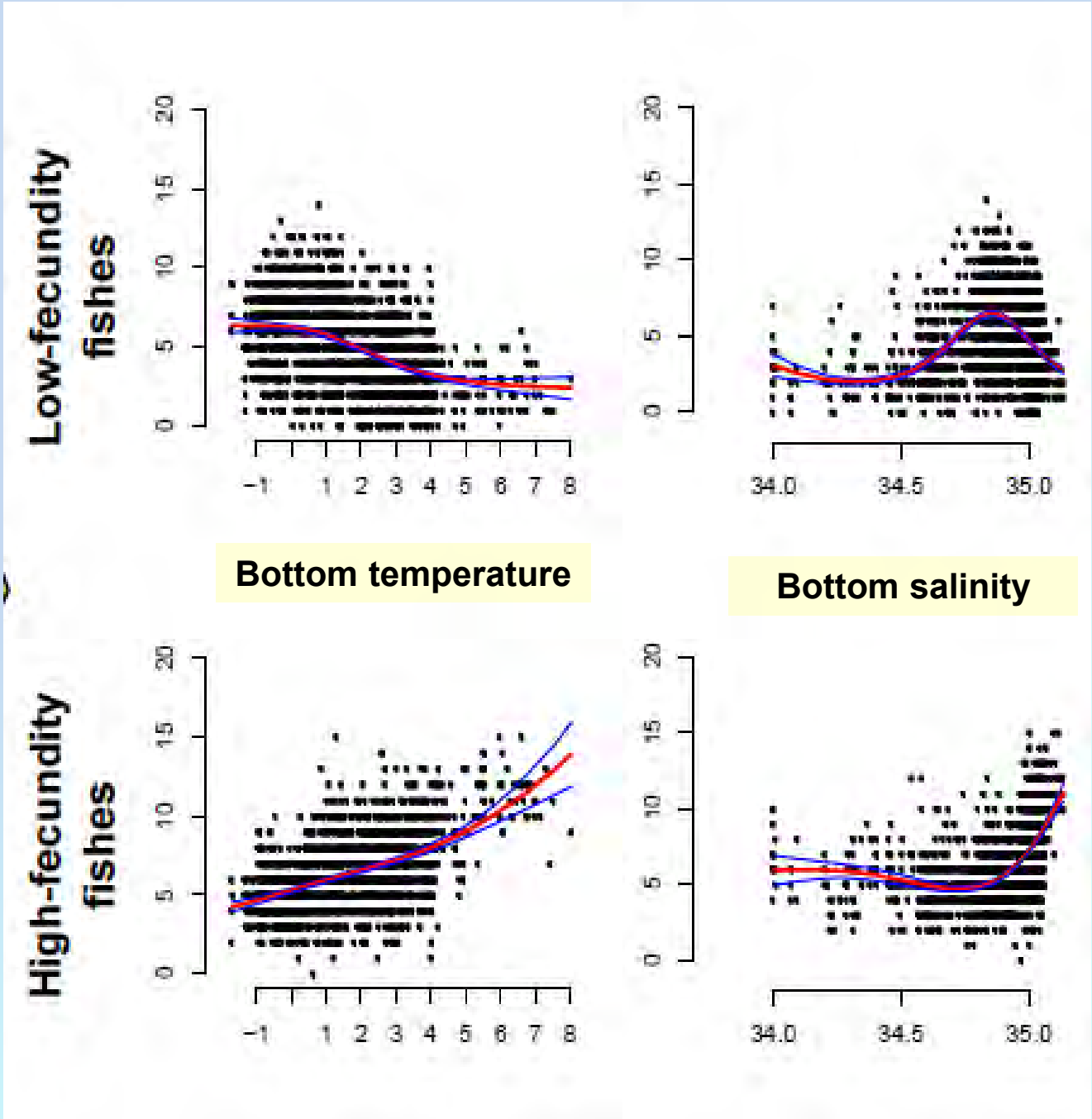
How these operational choices affects predictive power ??

We constructed 220 modelling scenarios by combining different operational choices and we compared their predictive power.

Among the 220 modelling options considered, only a few led to high predictive power (~0.5-0.6 Pearson's correlation with "independent" dataset).



Intermediate level between modelling all species separately and all at once (e.g. "fish species richness")


Low-fecundity fishes
High-fecundity fishes
Bottom temperature
Bottom salinity
0
5
10
15
20
−1
1
2
3
4
5
6
7
8
34.0
34.5
35.0

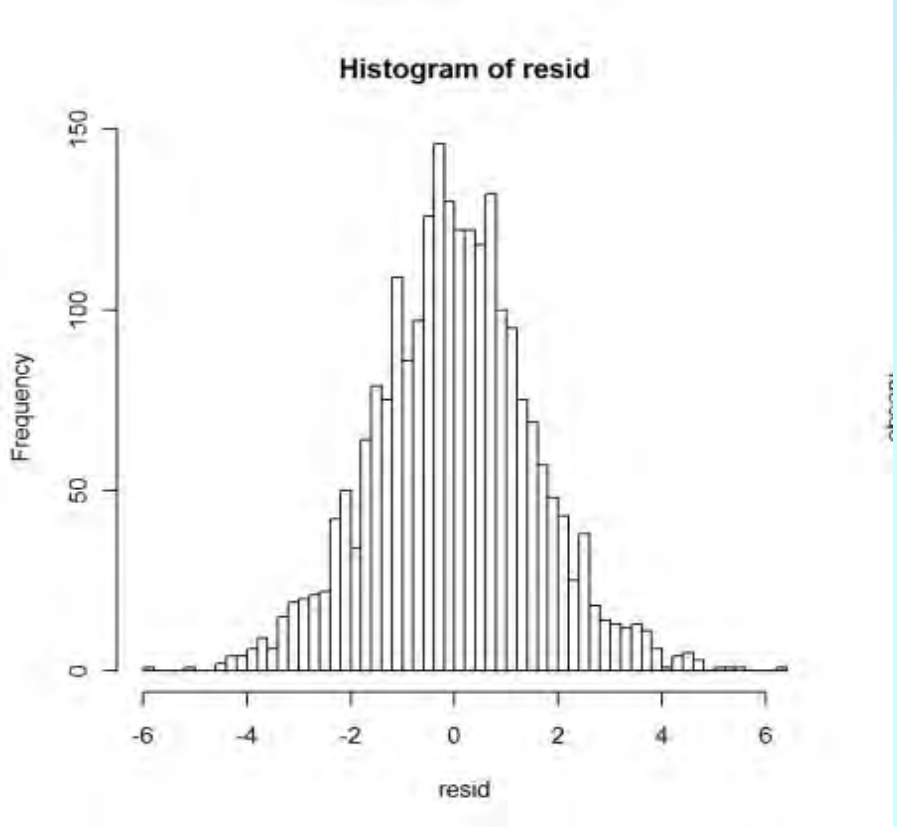
What does the model explains, and what it is not explaining ?

```
R-sq.(adj) =  0.435   Deviance explained = 45.1%
GCV score = 2.4941  Scale est. = 2.4238    n = 2316
```

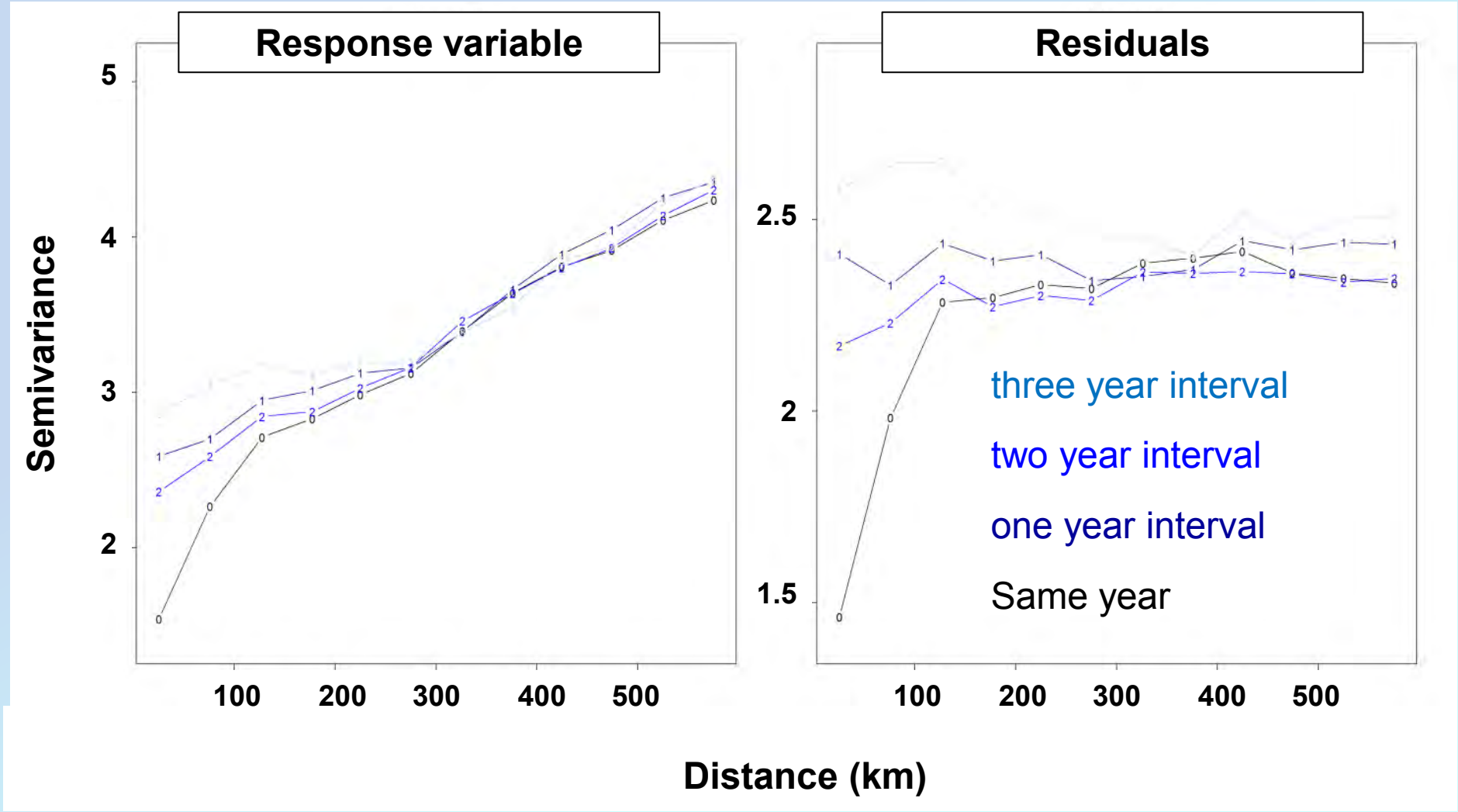
The model is not explaining *everything*

Check the residuals ! This is good statistical practice… and this is also a good way to 'look' at uncertainty…

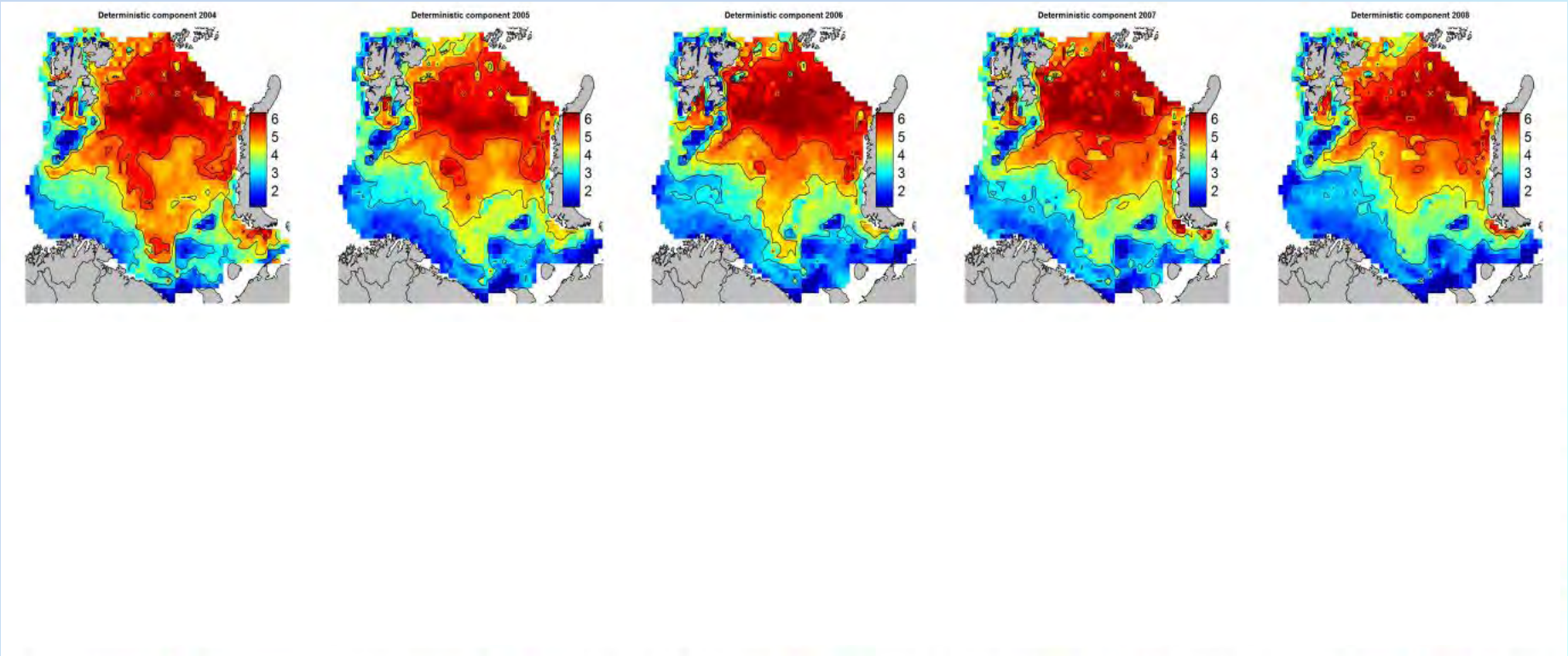
Statistical Distribution



Spatio-temporal correlation in the residuals (variograms)



We have prediction for different years, and we now that…



They are likely to be modified by a gaussian random field of mean 0, temporally independent, and spatially autocorrelated up to 100km scale

Predicting under climate change scenario

Climatic models, coupled with bio-geochemical model may provide much detailed predictions that can be used as input for forecast when available:

For example:

Progress in Oceanography 90 (2011) 117–131

Contents lists available at ScienceDirect

Progress in Oceanography

journal homepage: www.elsevier.com/locate/pocean

Evaluating primary and secondary production in an Arctic Ocean void of summer sea ice: An experimental simulation approach

D. Slagstad [a,*], I.H. Ellingsen [a], P. Wassmann [a,b]

Classical Bio-geochemical model structure

Slagstad et al. 2011: Biogeochemical model for the Arctic

Atmospheric & oceanic forcings

Hydrodynamic model

Ice

Open water

3D, nested architecture, T°, S‰ currents, stratification, light

Geochemical model

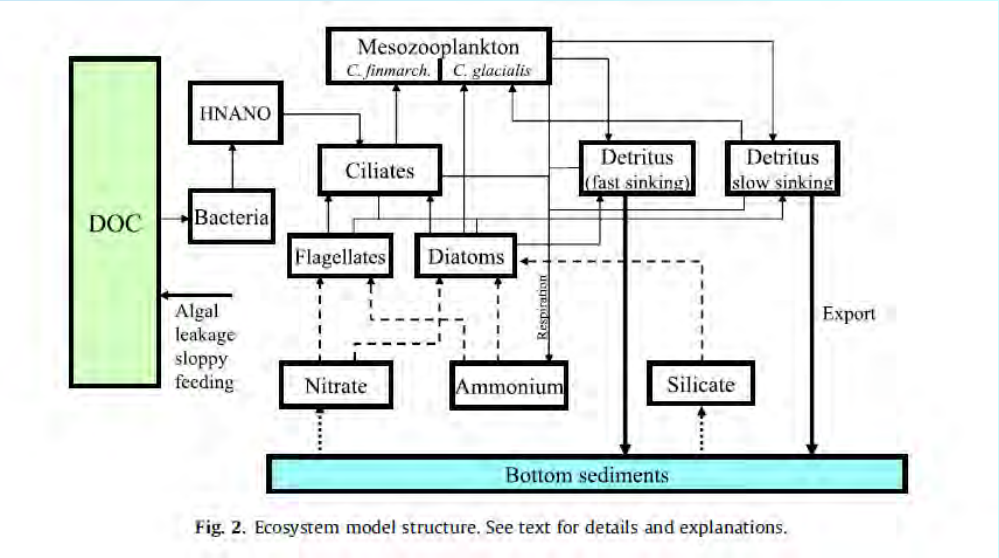
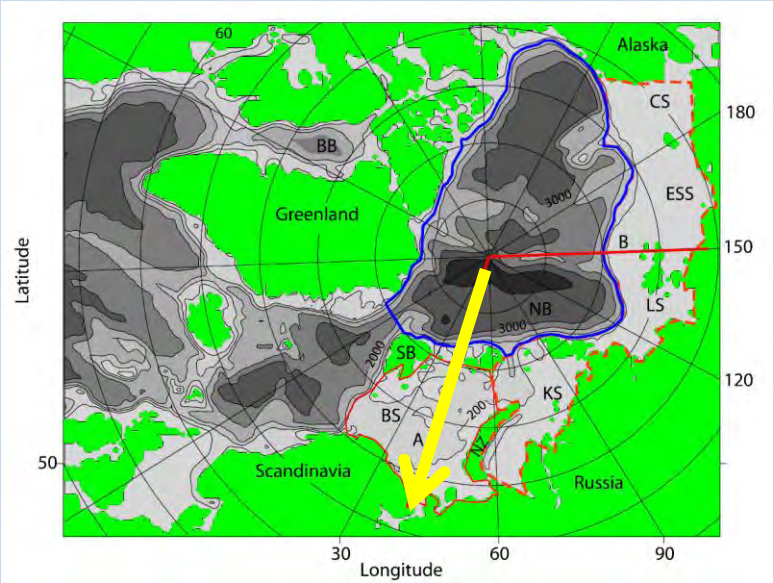
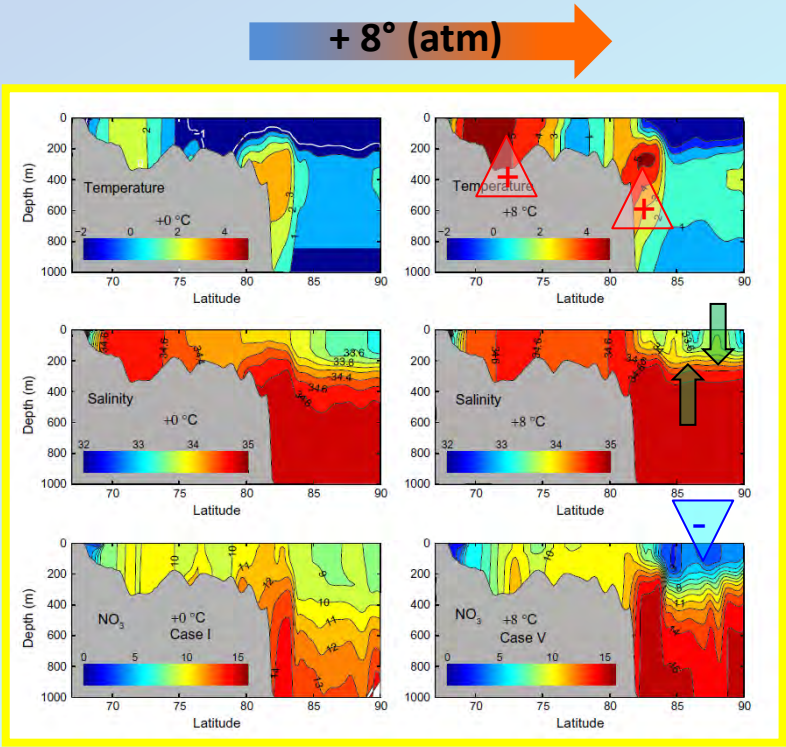


Fig. 2. Ecosystem model structure. See text for details and explanations.

13 state variables, fluxes in N (convertible to C)

Model predictions: Water masses





Temperature: increase (S, shelf break)
Salinity: thinning of the halocline (N)
Nutrient: decrease in the North, surface

Model predictions: Primary Production

A General increase with regional differences

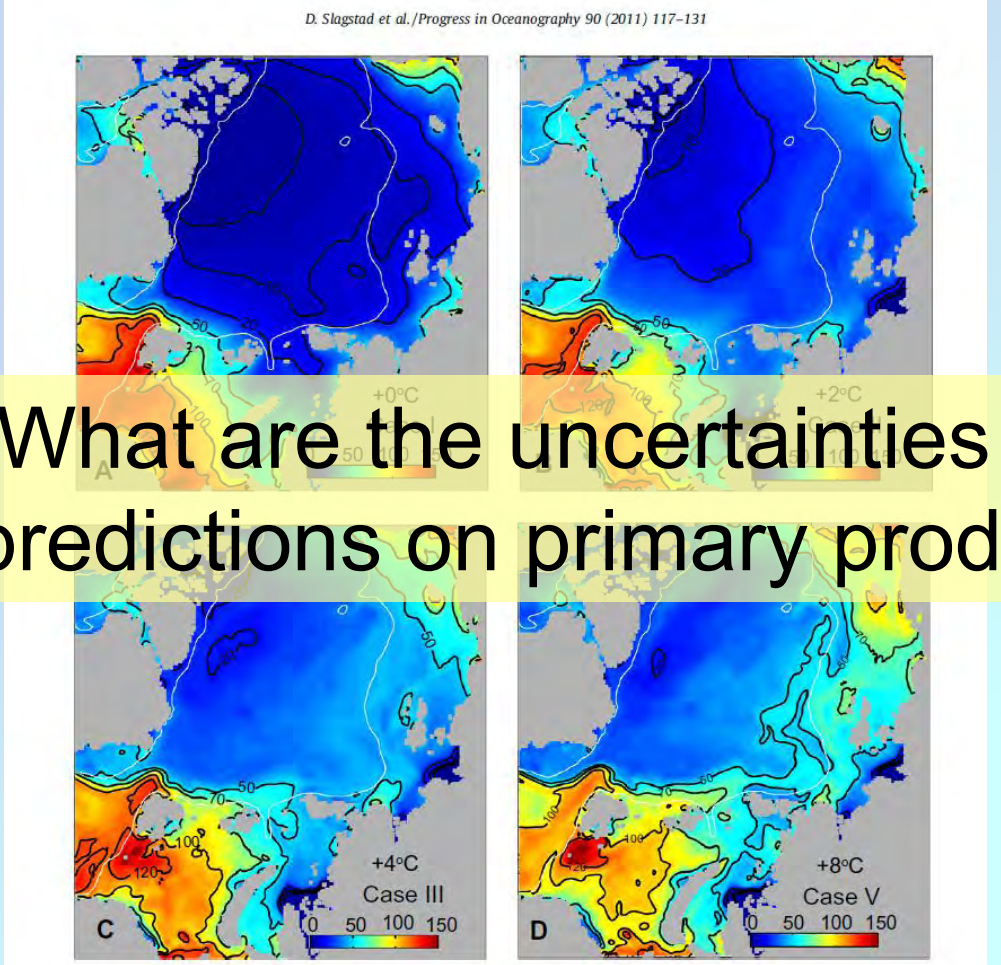


Fig. 7. Simulated annual gross primary production (g C m^{-2}) in the Arctic Ocean in Case I (A), Case II (B), Case III (C) and Case V (D).

+2

+4

+8

But… What are the uncertainties around these predictions on primary production ?

Discrepancies in model predictions.

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, C00D12, doi:10.1029/2011JC007112, 2012

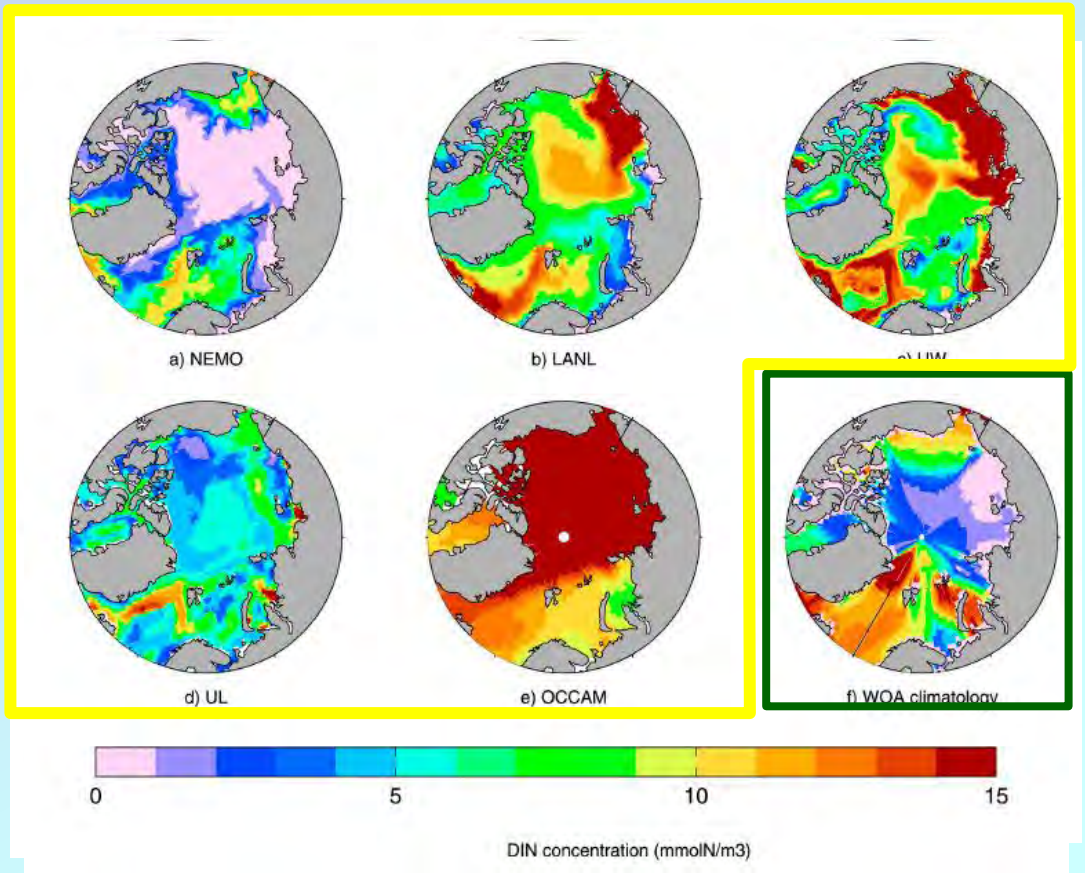
What controls primary production in the Arctic Ocean? Results from an intercomparison of five general circulation models with biogeochemistry

Ekaterina E. Popova,[1] Andrew Yool,[1] Andrew C. Coward,[1] Frederic Dupont,[2] Clara Deal,[3] Scott Elliott,[4] Elizabeth Hunke,[4] Meibing Jin,[3] Mike Steele,[5] and Jinlun Zhang[5]

Outputs of 5 different models are compared for the year 1998

Dispelled by model (the stratification)

Model outputs



Observations

Keeping track of uncertainty: Ensemble forecasting

esa ECOSPHERE

SYNTHESIS & INTEGRATION

Managing uncertainty in climate-driven ecological models to inform adaptation to climate change

Jeremy S. Littell,[1,†] Donald McKenzie,[2] Becky K. Kerns,[3,5] Samuel Cushman,[4] and Charles G. Shaw[2]

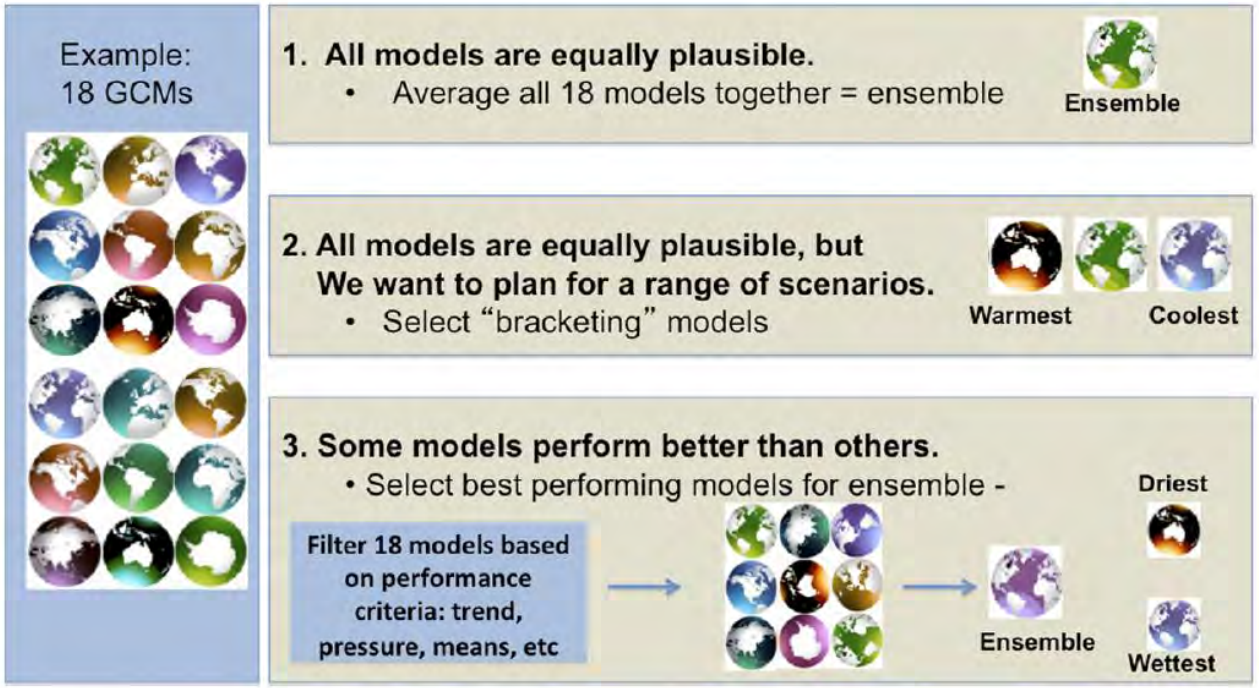


Fig. 2. One approach to limiting uncertainty about future climate is choosing relevant subsets of global climate models (1), using ensemble means and (2) bracketing scenarios for downscaling (e.g., "delta" method) (3), and combining these approaches for a filtered subset of models. Planet image modified from original online at ⟨www.psdgraphics.com⟩.

Up to which point can we push up the ”prediction cascade” ?

Predictions on climate (IPCC)

?

Prediction on water masses

??

(Biogeo-chemical models)

Prediction on primary production

???

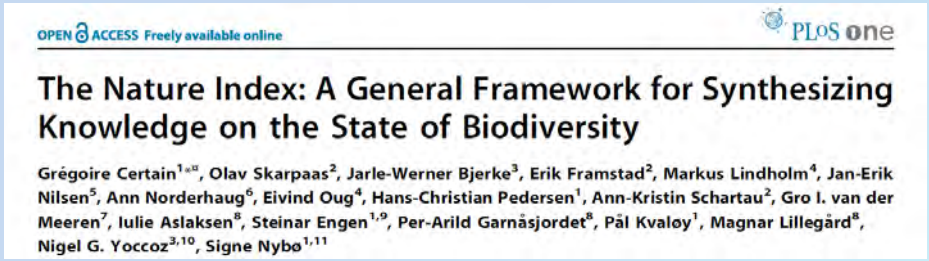
Prediction on fish distribution

When uncertainty can’t be quantified: Expert elicitation

In many situation, we don’t know how to quantify uncertainty. Ex: Differences in knowledge in the biology of species.

Elicitation is the process through which **you extract and organize information from expert’s head…**

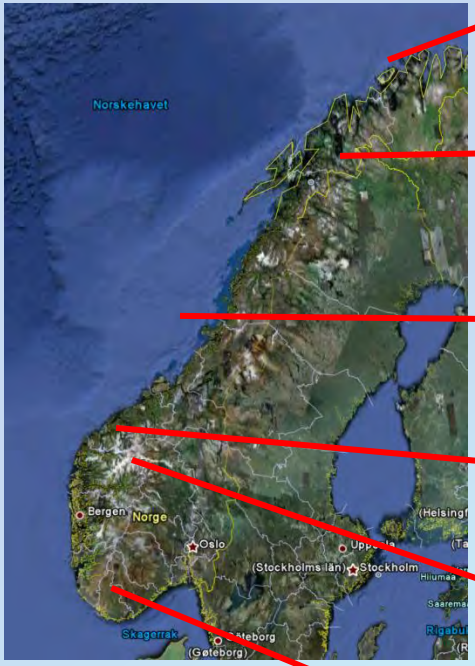
without opening.


OPEN ACCESS Freely available online PLoS one

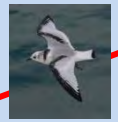
The Nature Index: A General Framework for Synthesizing Knowledge on the State of Biodiversity

Grégoire Certain[1*¤], Olav Skarpaas[2], Jarle-Werner Bjerke[3], Erik Framstad[2], Markus Lindholm[4], Jan-Erik Nilsen[5], Ann Norderhaug[6], Eivind Oug[4], Hans-Christian Pedersen[1], Ann-Kristin Schartau[2], Gro I. van der Meeren[7], Iulie Aslaksen[8], Steinar Engen[1,9], Per-Arild Garnåsjordet[8], Pål Kvaløy[1], Magnar Lillegård[8], Nigel G. Yoccoz[3,10], Signe Nybø[1,11]

Detailed information on natural systems



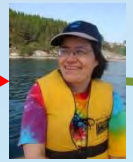
Norwegian nature






Natural metrics (indicators)






Scientists (experts)

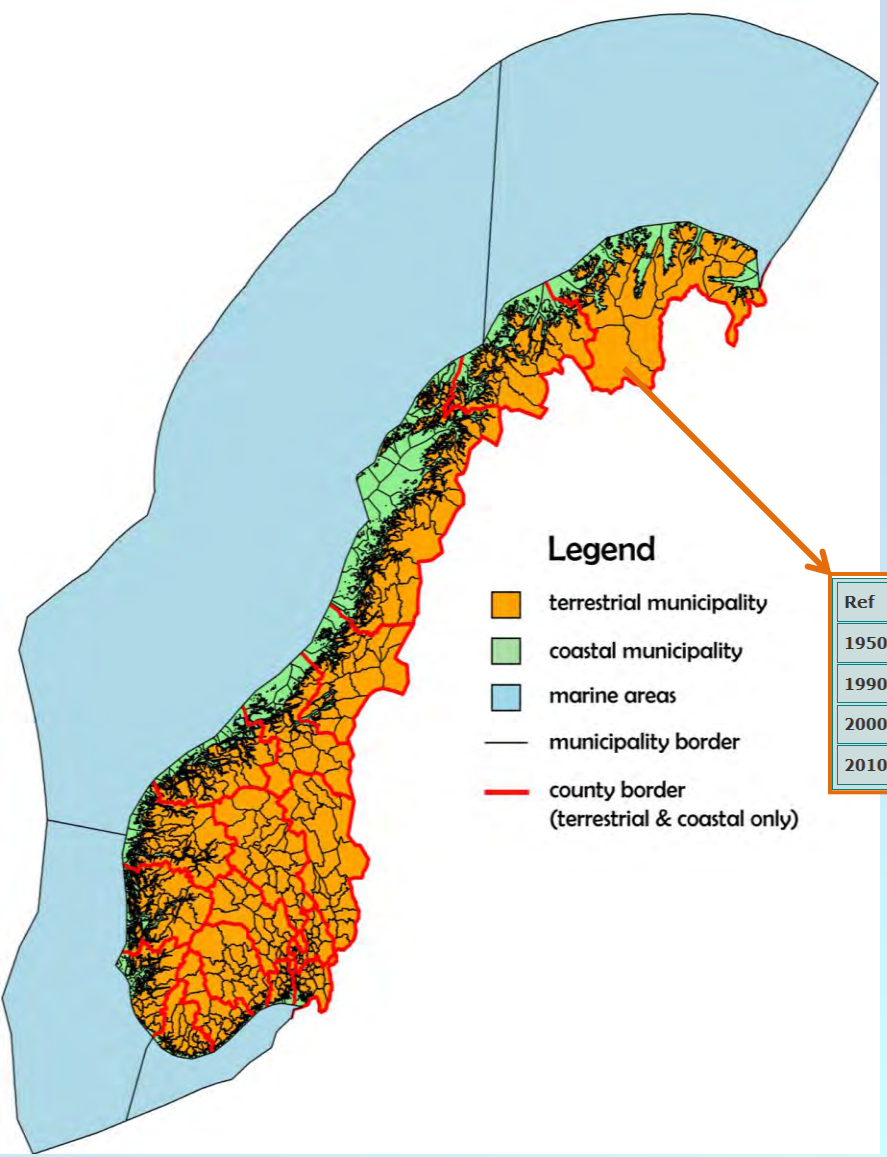
Nature Index Framework

$$NI_{tn} = \sum_{ijk} S_{ijktn} W_{ijkt}$$

Information for the public

Tool for environmental management

Data collection through a website:



At the municipality scale, each expert should enter data on their respective indicators…

(1) Selecting a **subset of** municipality

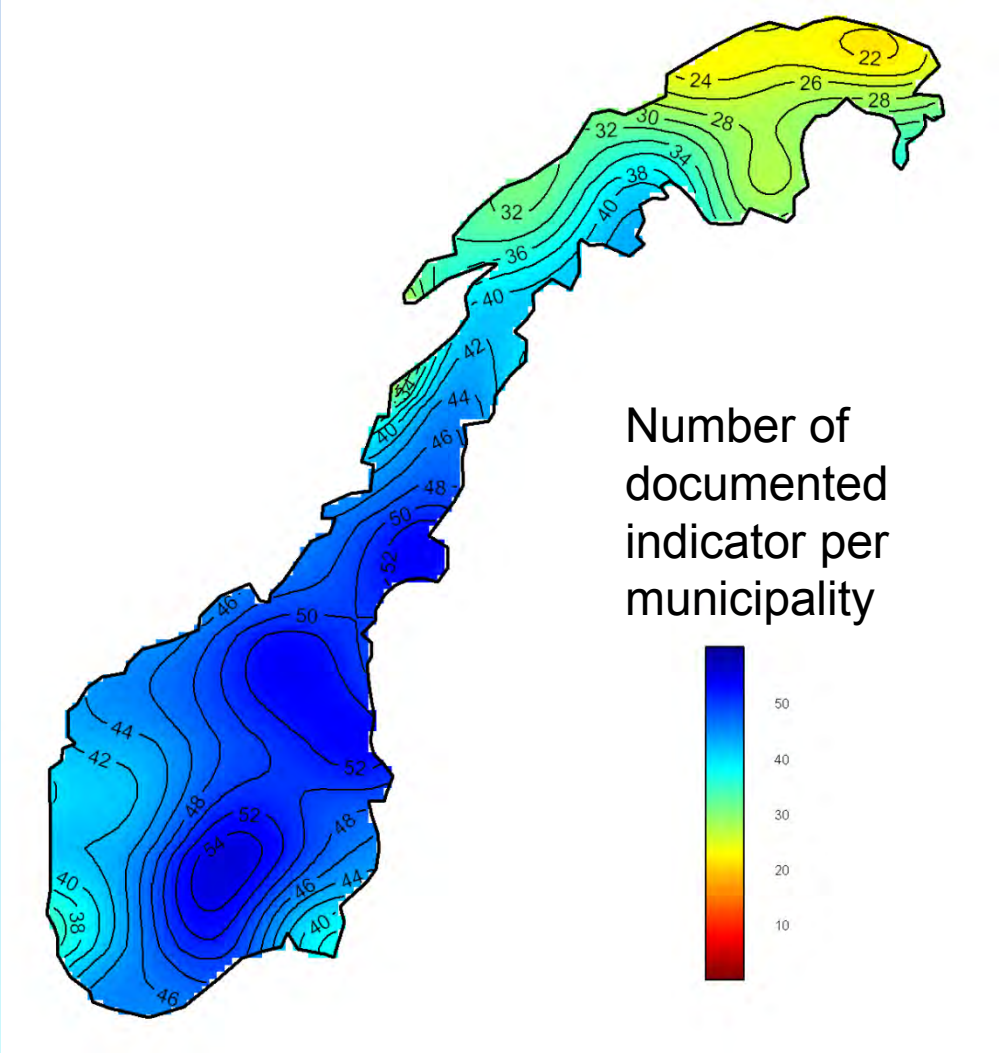
(2) **Entering data:**

Ref	Verdi		Nedre verdi (25%)		Øvre verdi (75%)		Datatype	Ekspertvurdering
1950	Verdi		Nedre verdi (25%)		Øvre verdi (75%)		Datatype	Ekspertvurdering
1990	Verdi		Nedre verdi (25%)		Øvre verdi (75%)		Datatype	Ekspertvurdering
2000	Verdi		Nedre verdi (25%)		Øvre verdi (75%)		Datatype	Ekspertvurdering
2010	Verdi		Nedre verdi (25%)		Øvre verdi (75%)		Datatype	Ekspertvurdering

A set of **310 indicators** covering **both terrestrial and marine systems**

This data collection process allowed us to know where information was available:

Ex for forest: **Regional contrast in the documentation of indicators**



Time to conclude:

Many types of uncertainty, many ways of quantifying/qualifying it, and also **many ways of forgetting i**t.

Trying to **propagate all kind of uncertainties together may be an endless exercise**… We should be explicit about which source of uncertainty we wish to address and which we don't.

”after science” uncertainty: what's the fate of the forecast ?

Thanks for your attention !