Operational Management of tuna fisheries: from real time to decadal predictions of tuna stocks

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Introduction

anthropogenic climate change

synoptic variability

natural climate variability
seasonal, inter-annual to
decadal modes

time

days to weeks
- harmful algae
- jelly fish
- OA events
- coastal hypoxia
- larval drift

...

seasons to decades
- marine productivity
- biomasses
- fish stocks

...

centennial
projections

Meehl et al. (2009), BAMS

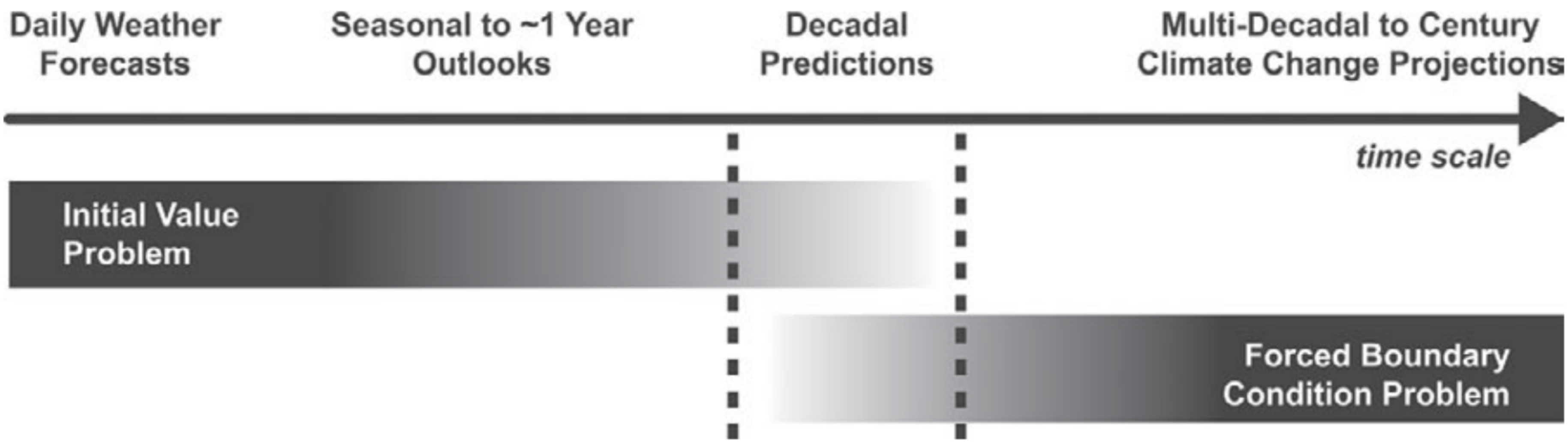

FIG. 2. Schematic illustrating progression from initial value problems with daily weather forecasts at one end, and multidecadal to century projections as a forced boundary condition problem at the other, with seasonal and decadal prediction in between.

a coherent model suites : NEMO/PISCES/SEAPODYM

Forecasting tuna stock dynamics :
Indonesian Seas case study

INDESO

INfrastructure DEvelopment

for Space Oceanography

- Indonesia has the 6th largest EEZ in the world and fisheries generates US$ 3.1 billions revenue and direct employment to 4 millions people (in 2004, source FAO)
- Vessel Monitoring System deployed in 2004; next steps are:
  - Eradicate illegal fishing (IUU)
  - Support sustainable management of stocks
  - Support sustainable development of aquaculture
  - Support coastal environmental protection

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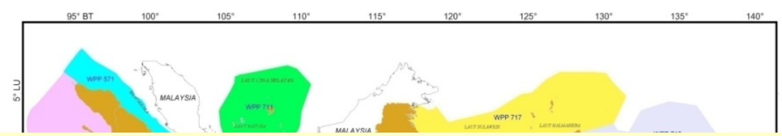
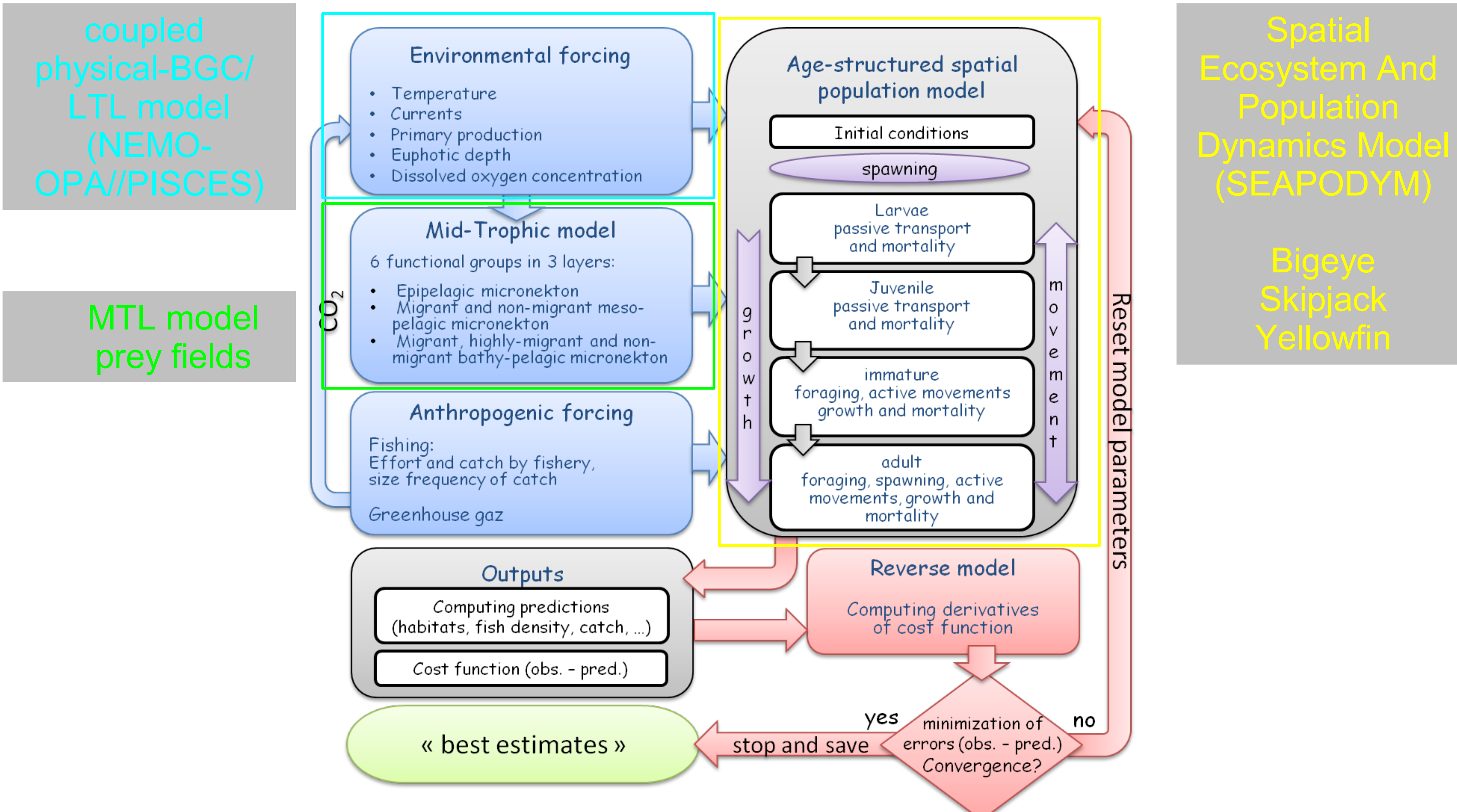


Objective : monitoring tuna stocks and fisheries

=> Indonesian government implements a chain of operational regional models from physics to fish at 1/12° x day resolution

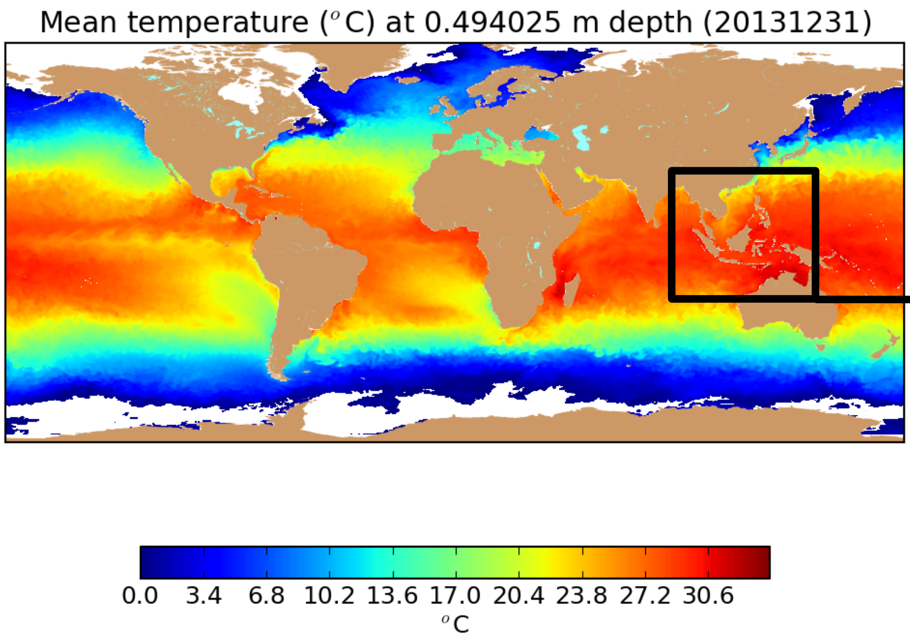
Integrated system for operational modeling of tuna

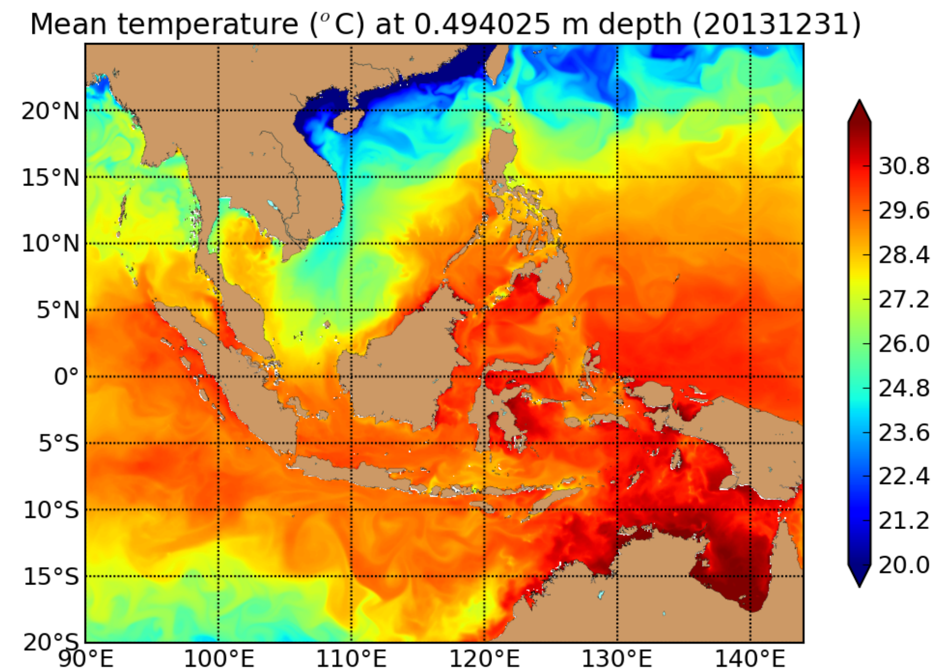


operational global model ¼° weekly forecast (MERCATOR OCEAN) (assim. of physical data)

coupled Physical-biogeochemical/ LTL model (NEMO/PISCES)

December 31, 2013

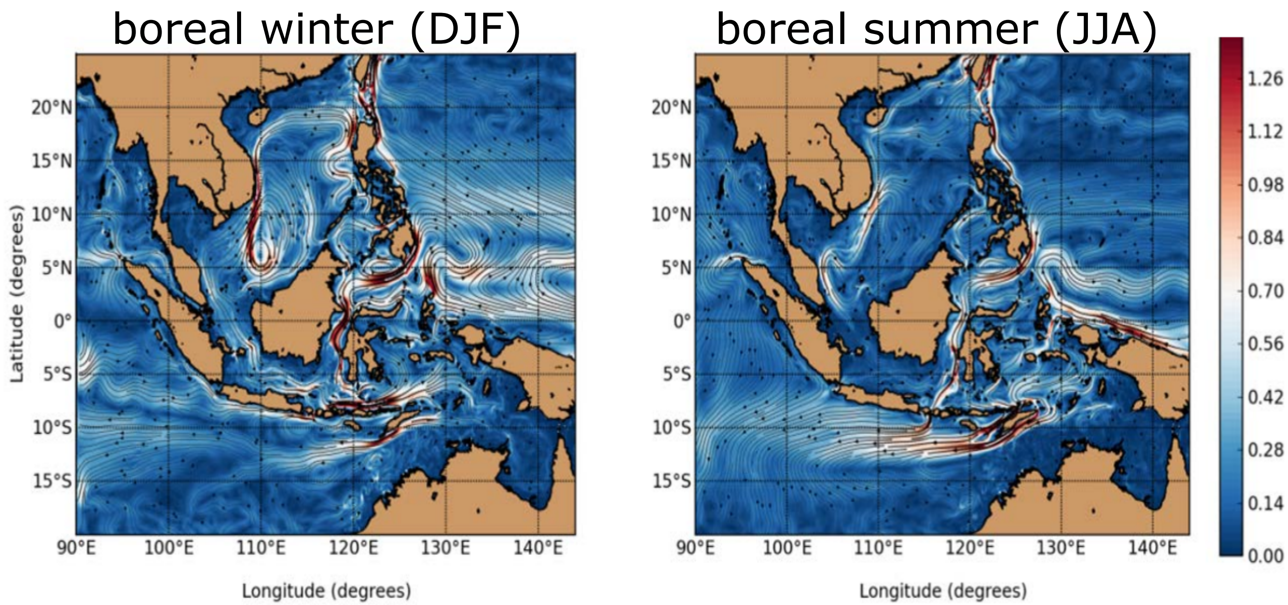




Regional model
1/12° x 1day with Open Boundaries Conditions provided from global model

Tranchant et al., in prep

environmental forcings

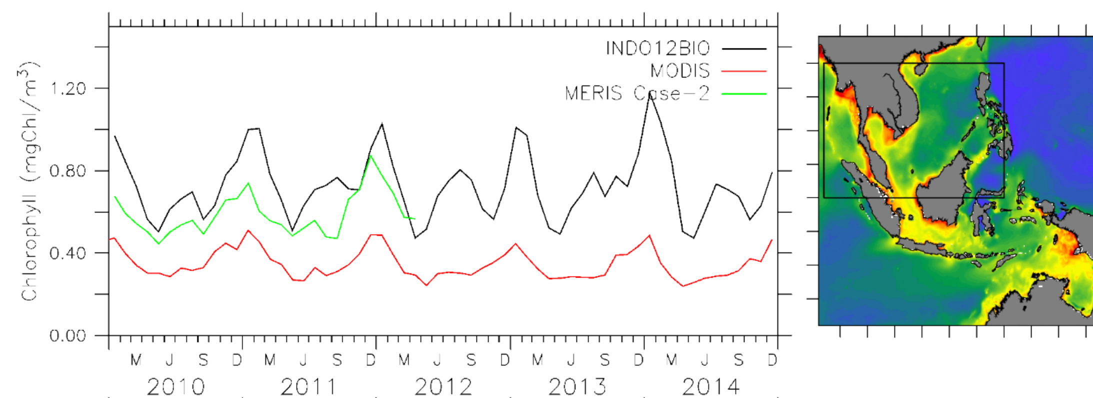


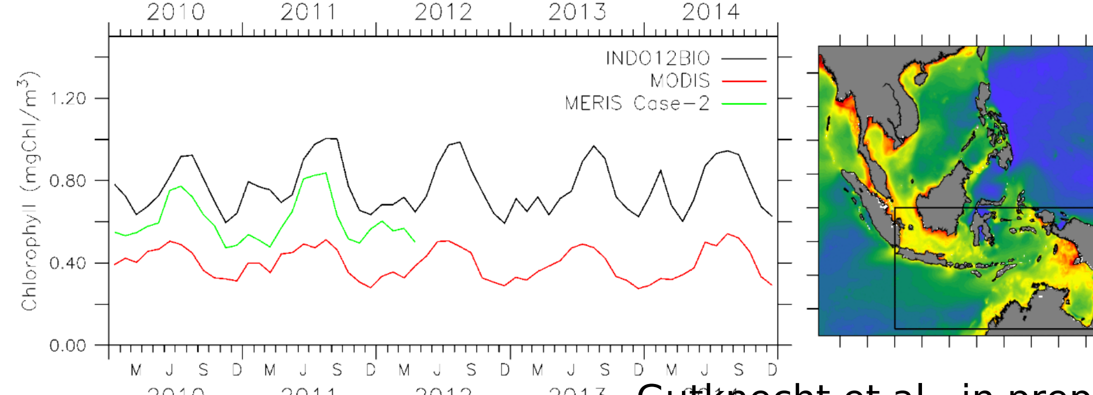
coupled physical-biogeochemical/ LTL model (OPA/PISCES)

Mean Circulation at surface (16 m depth) during 2008-2013 period

Tranchant et al., in prep

Temporal variation of surface chlorophyll-a concentrations (mg Chl m^{-3})





PISCES biogeochemical model (Aumont et al., 2015, GMDD) :

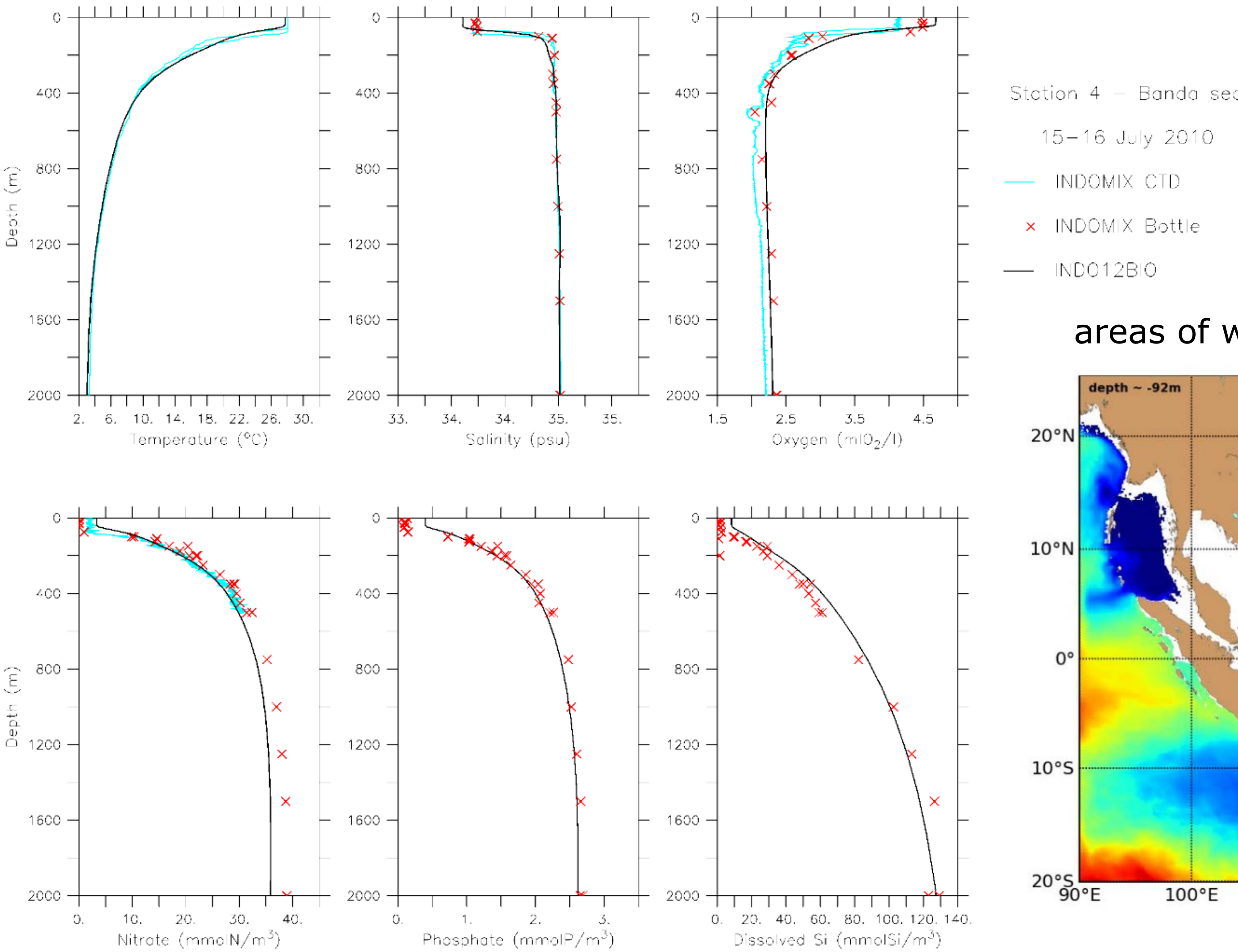
NPP, oxygen, euphotic depth

Gutknecht et al., in prep

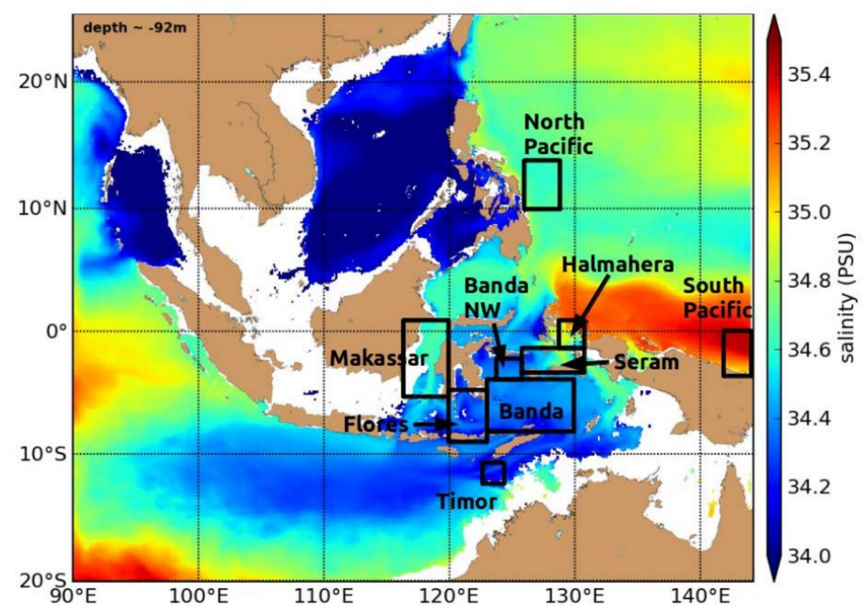
environmental forcings

coupled Physical-biogeochemical/ LTL model (NEMO/PISCES)

Vertical profiles of temperature at Station 4 of INDOMIX cruise (Banda Sea; 15 - 16 July 2010), CTD and bottle measurements model output as 2-day averages (co-located in time and space)

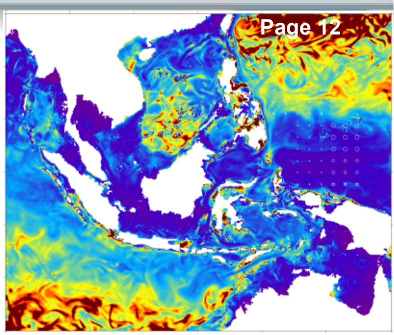


areas of water masses transformation



Gutknecht et al., in prep

Spatial Ecosystem And POpulation DYnamics Model



SEAPODYM

Though based on the same population dynamics equations SEAPODYM is different from classical fish population dynamics models:

- Fully explicit spatial representation (Eulerian approach)
- Includes fish movement
- Representing Population, not only « stock », meaning it includes spawning and larval stages
- Based on mechanisms relying on the environment (ecosystem) that control life stage dynamics
- Allowing to predict fish distribution even where there is no catch information
- Using all detailed spatially disaggregated data in parameter optimization
- Search for overall species parameterization, ie valid everywhere at basin-scale or even globally

Spatial Ecosystem And POpulation DYnamics Model

Lehodey et al. (2003,2008)
Senina et al (2008)
www.spc.int/ofp/seapodym/

Model parameter Estimation (MLE) (catch, size, acoustic and tagging data)

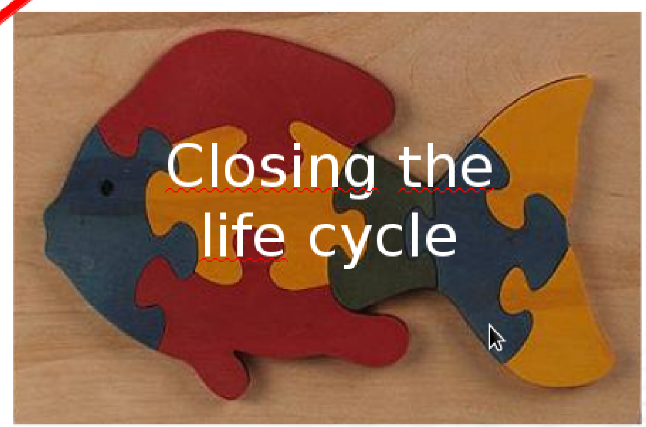
+++ + -

Active movement to feeding areas

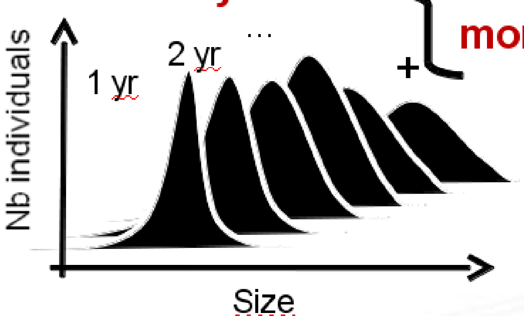
Mortality

Feeding habitat = Abundance of prey (micronekton) x accessibility ($T°$, O_2)

Age structured population



By cohort
Growth
mortality



Spawning success

Recruitment (passive drift)

Spawning habitat =
Temperature
Prey (zoopl.)
Predators (micronekton)

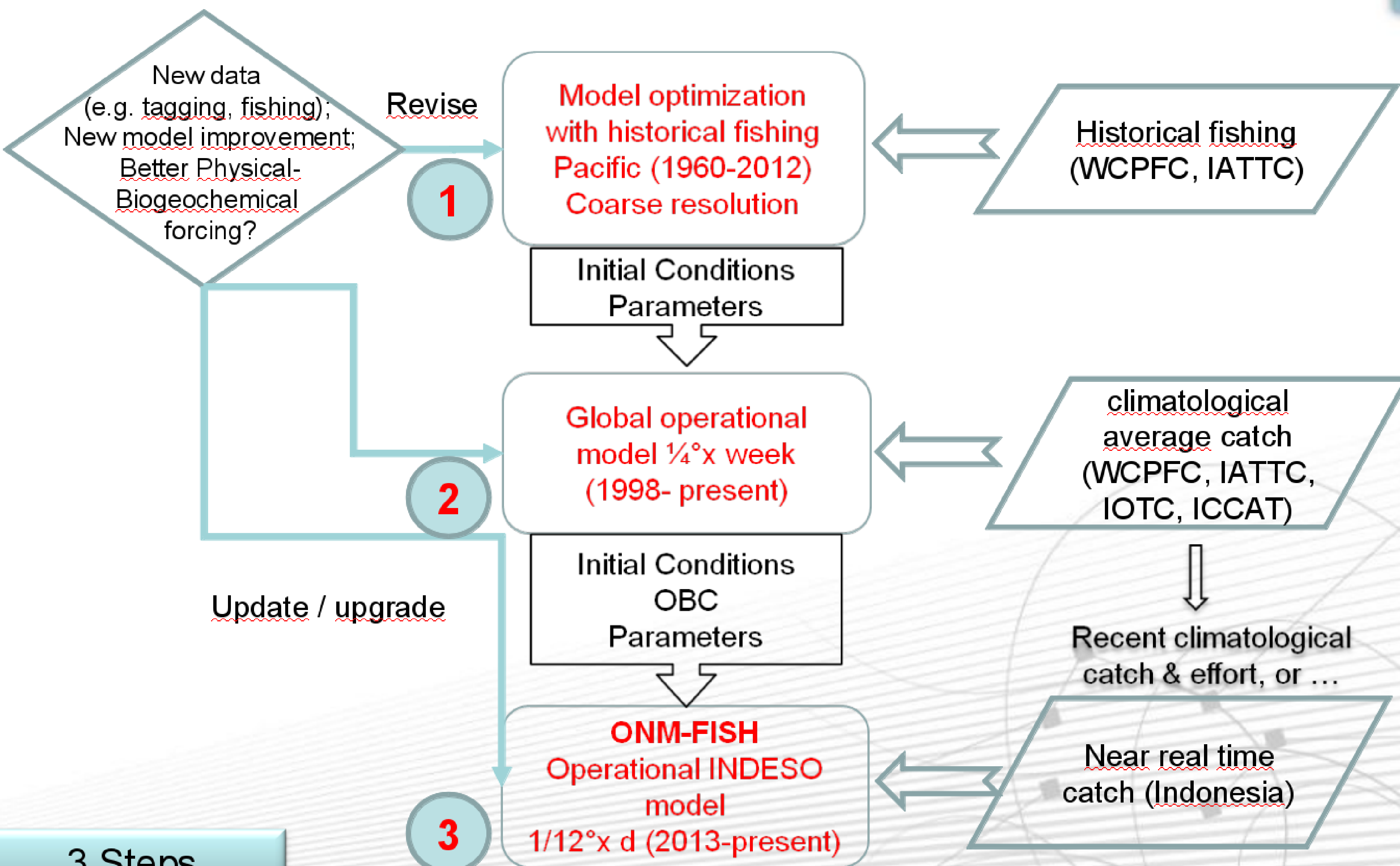
Active movement to Spawning areas

Fishing (catch; effort; size)

2 types of forcings of SEAPODYM

T, O2, PP, currents, mnk

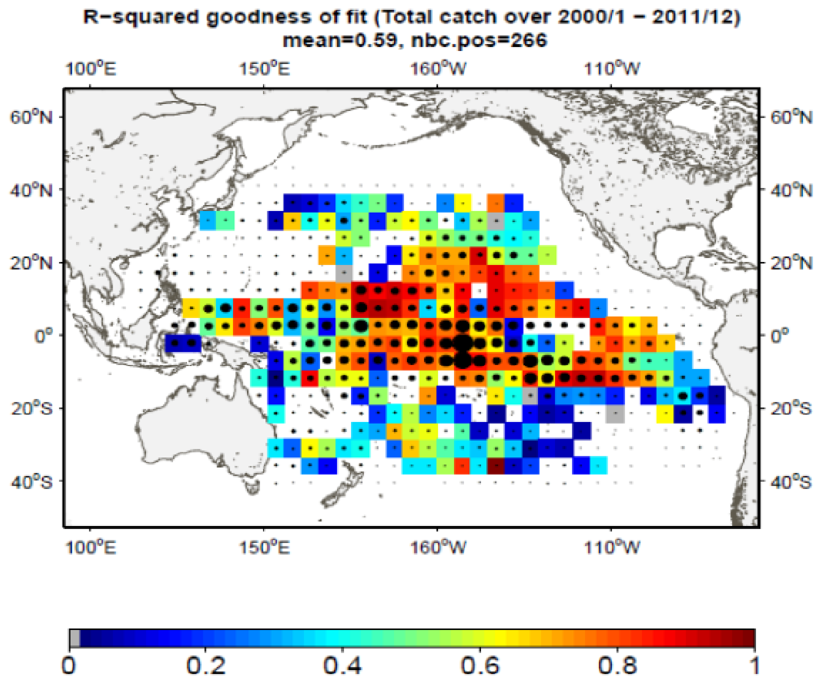
Process for operational regional modeling of tuna

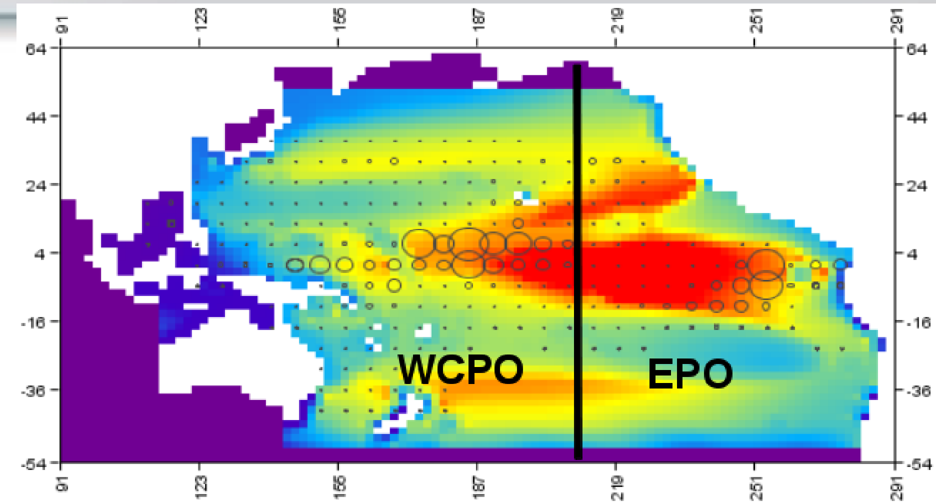


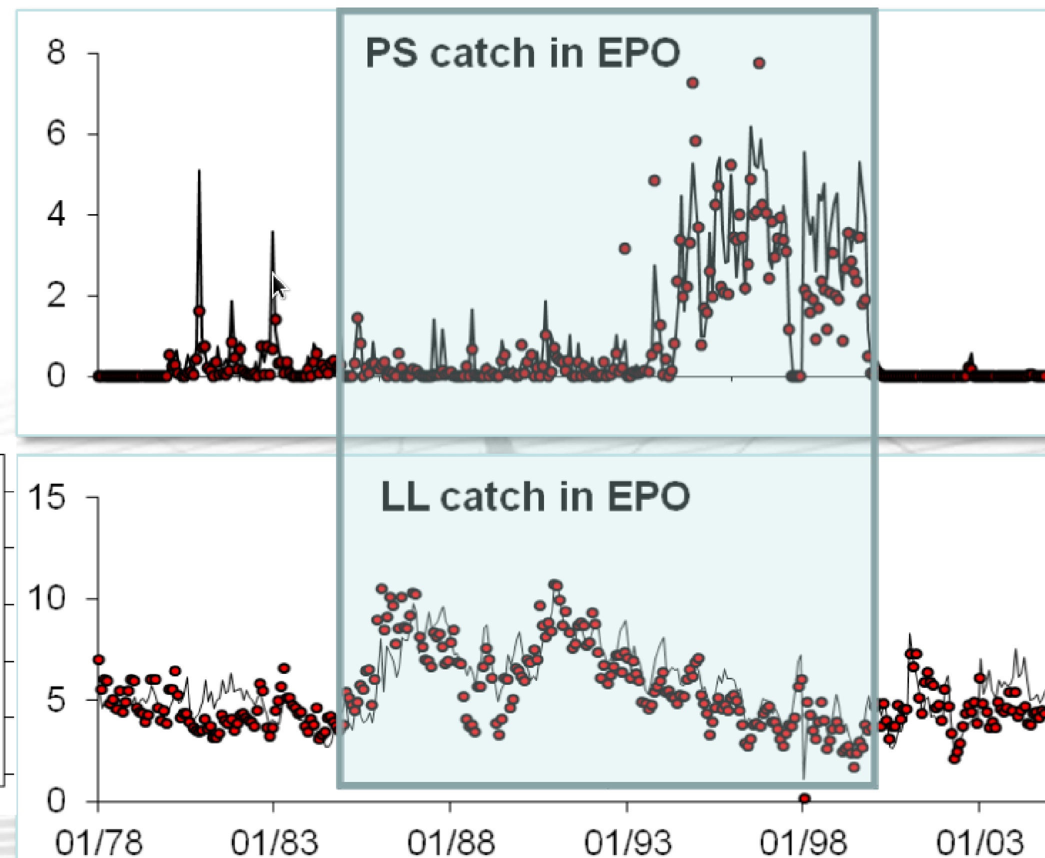
3 Steps

Step 1: Reconstructing population history

Ex: Pacific Bigeye tuna

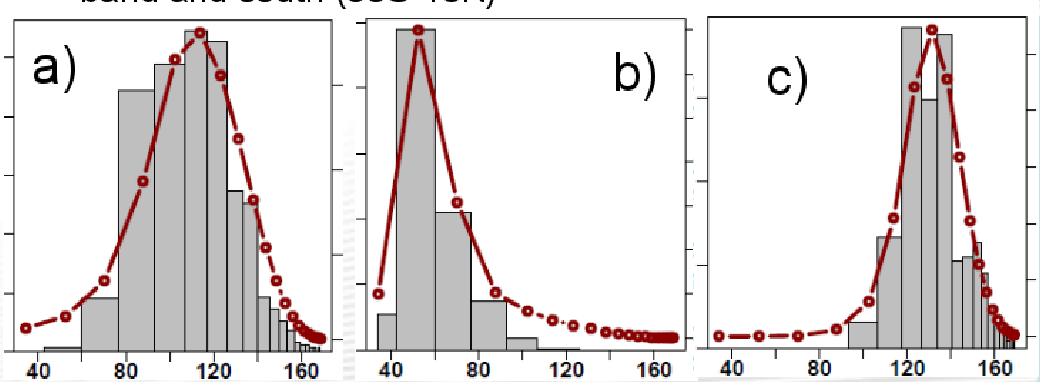






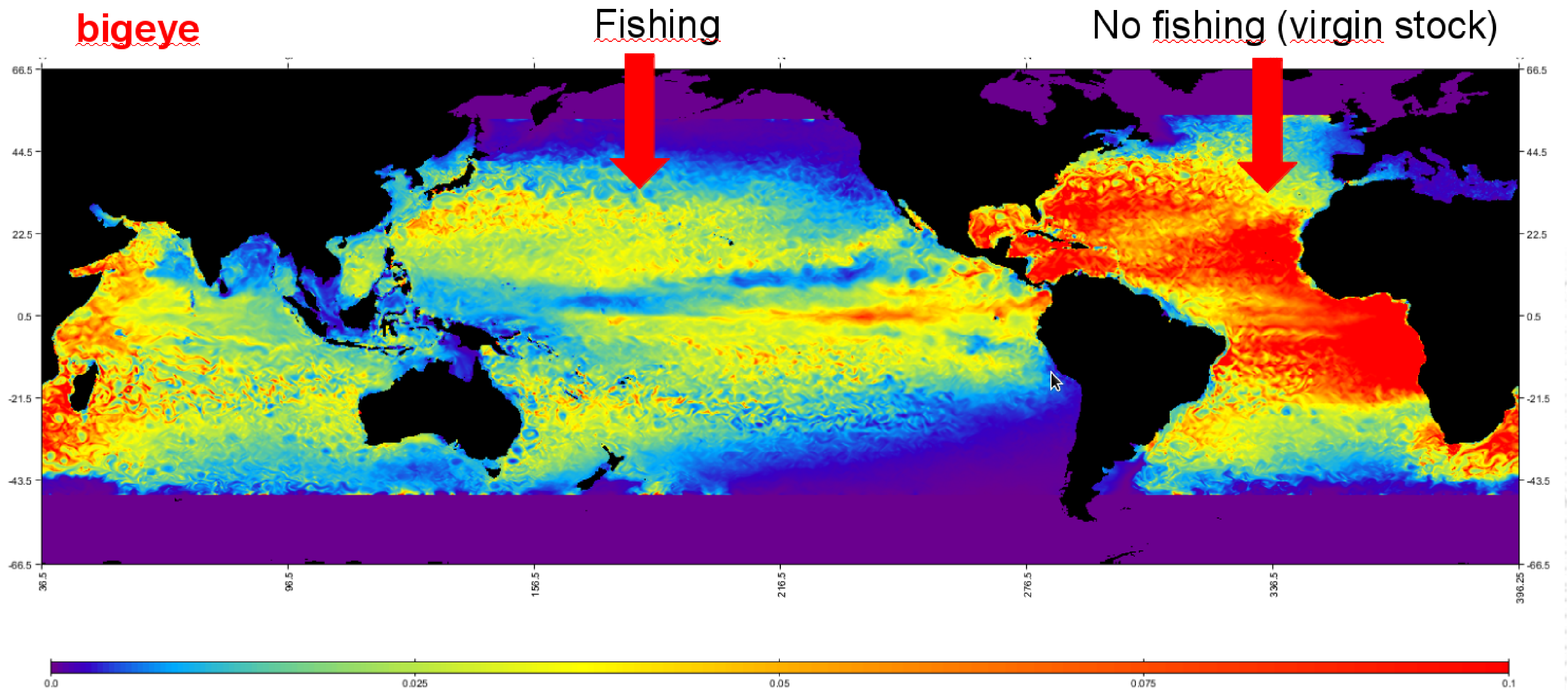
Size distributions by fishery type and region

a) WCPO traditional LL; b) WCPO PS; c) EPO LL equatorial band and south (50S-10N)



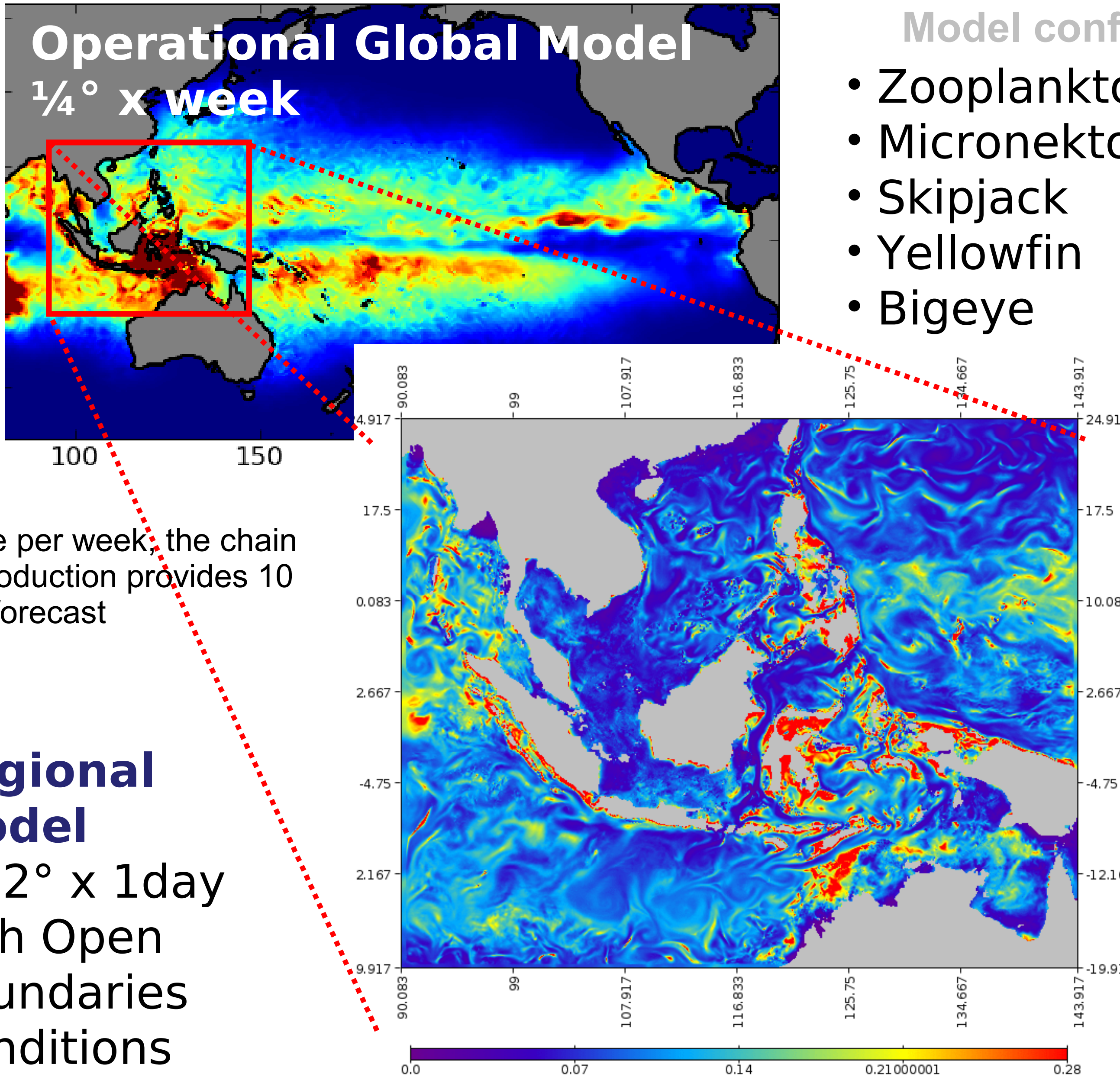
Step 2: Global operational model

Initial conditions (biomass and size structure distribution) including the **historical impact of fishing** are critical!



INDESO

Step 3: Regional operational model



skj_totbm.dym
2010 October 01
Total skipjack tuna biomass

Once per week, the chain of production provides 10 day forecast

Regional model
1/12° x 1day with Open Boundaries Conditions provided from global model

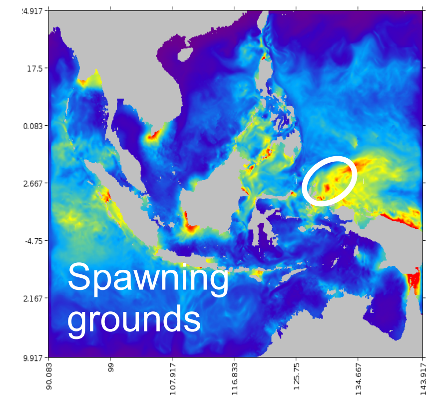
Model configuration

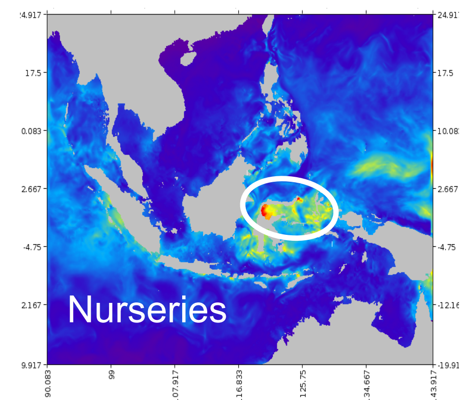
- Zooplankton
- Micronekton
- Skipjack
- Yellowfin
- Bigeye

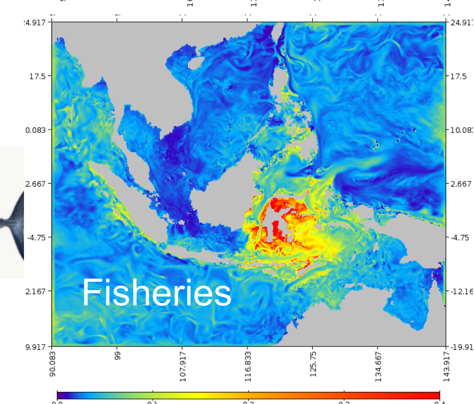

Larvae


juveniles


Adults

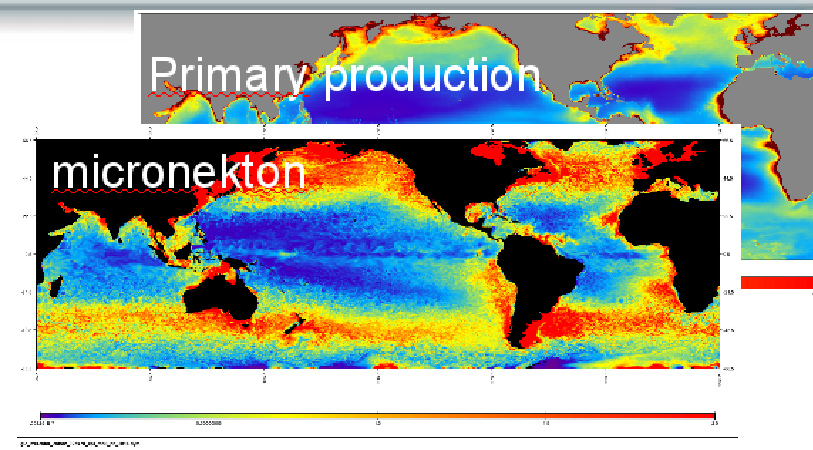






Step 4, 5, 6…

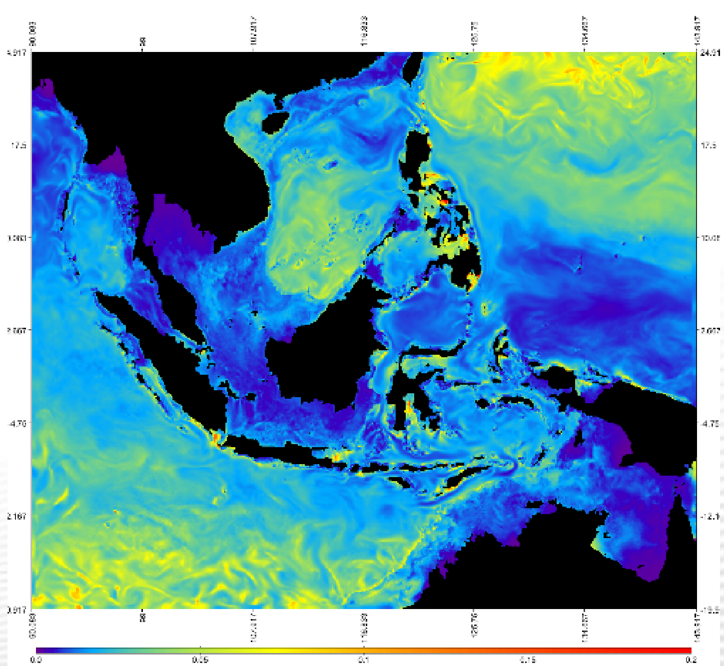
- Improved environmental forcings for both operational and historical simulations;
- Longer & better time series of catch data (catch, effort, LF) for optimisation and fishing mortality
- Improved mechanisms in the model
- New independent data (eg tagging data)



Global scale

Continuous PROGRESS in SEAPODYM-INDESO

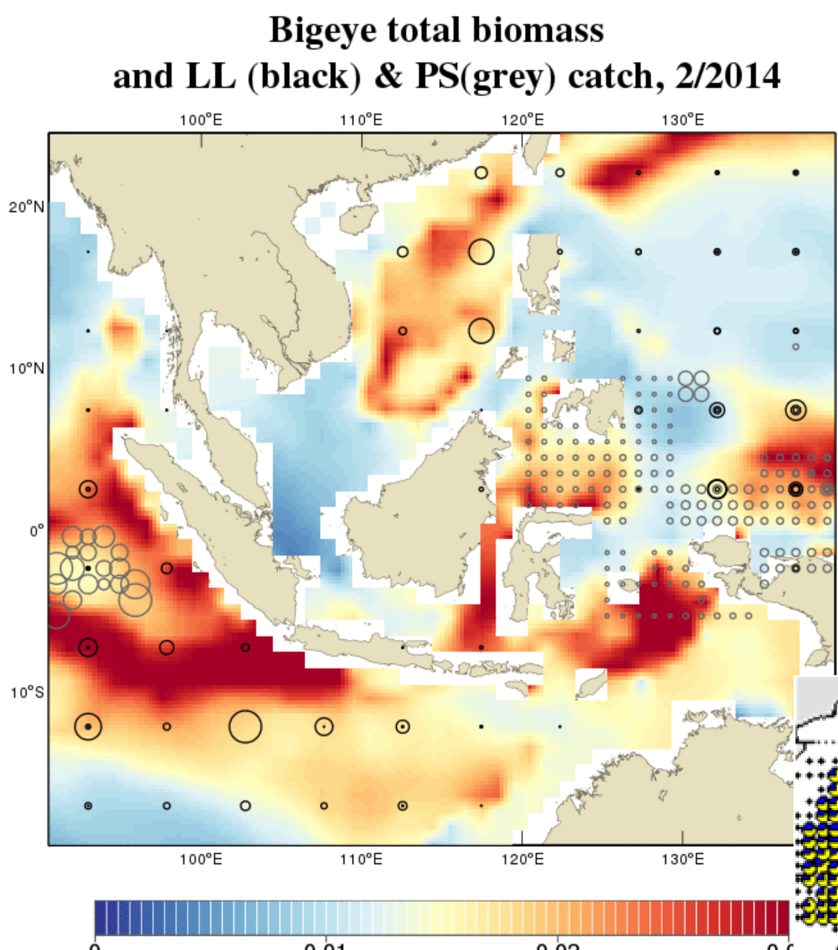
Regional Scale (INDESO)



- Still using crude average catch for historical period;
- Climatological (average over last few years) data for operational model
- Limited amount of length frequency data
- No catch data to validate high resolution outputs
- Fishing effort is unknown or roughly estimated

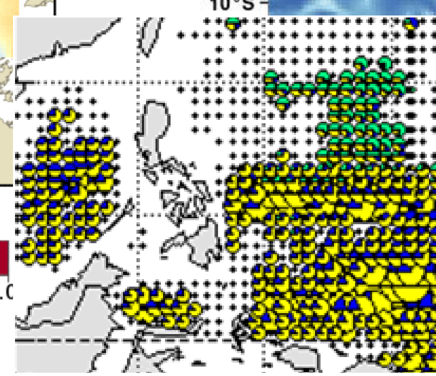
SEAPODYM-INDESO VALIDATION

Average distribution in INDESO region from ECCO 1 degree and ONM 1/12 degree

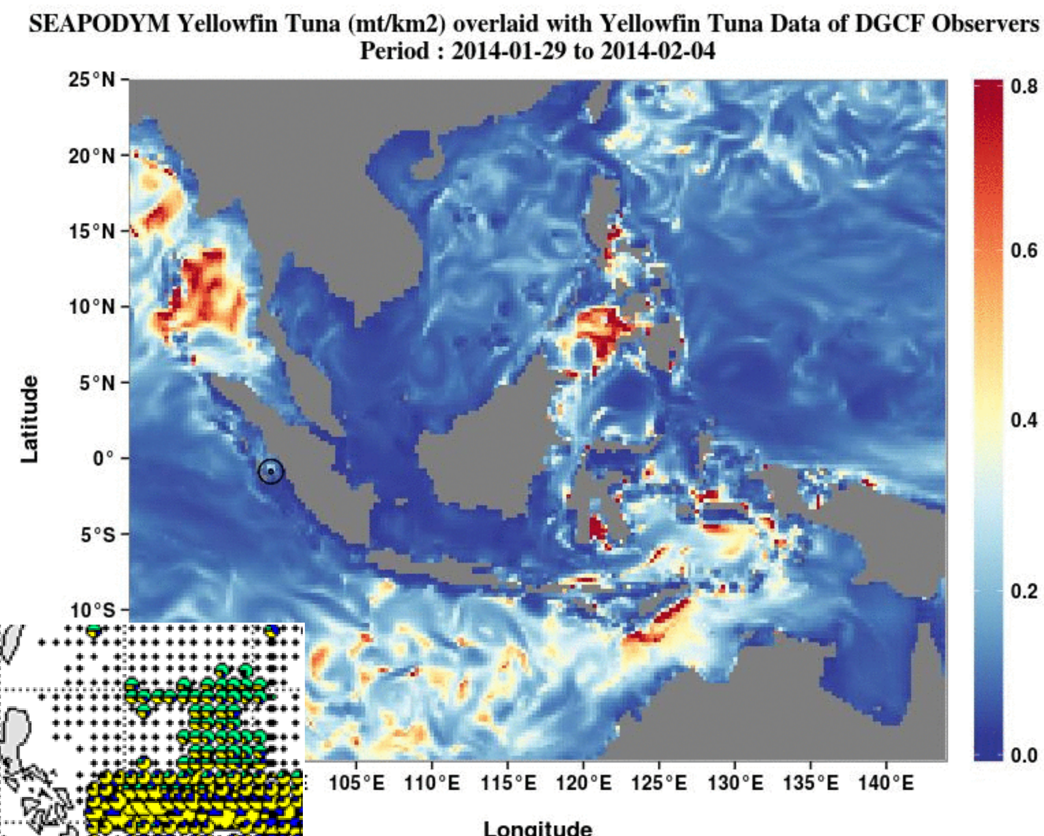


ECCO 1 degree (historical fishing)

Bigeye Optimization Version 2



Historical 1° resol. Jap. longline catch (yellow =yellowfin; blue = bigeye)



ONM 1/12 degree

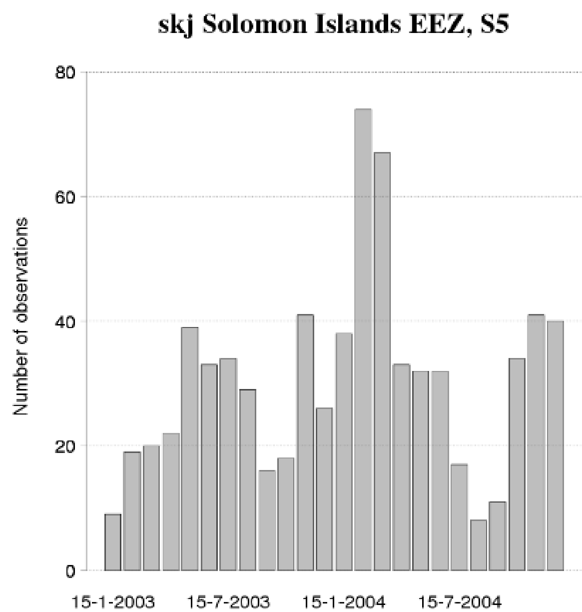
Yellowfin Optimization Version 1

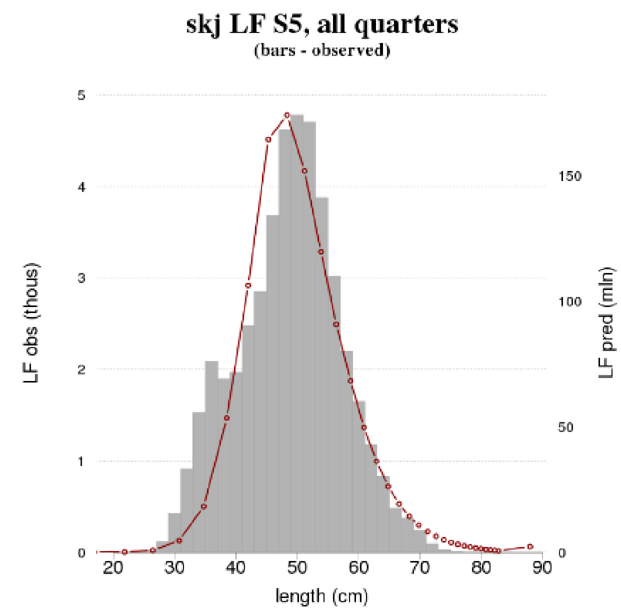
INDESO long-term metrics

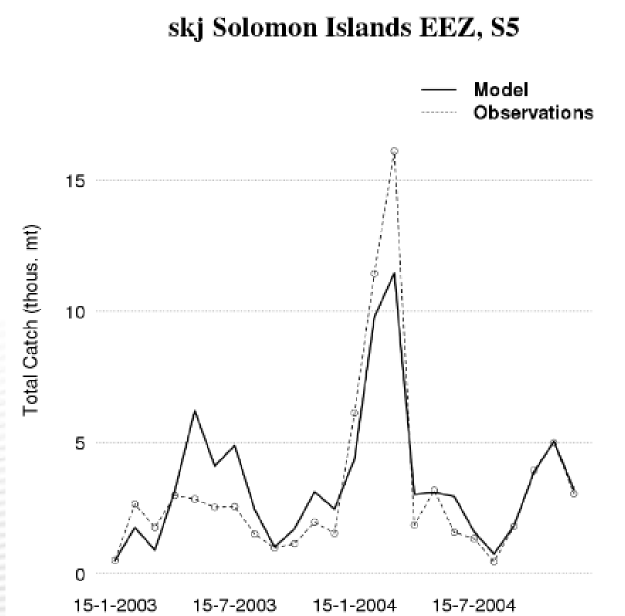
Automatic production of metrics are included in the operational chain of production to monitor the fisheries.

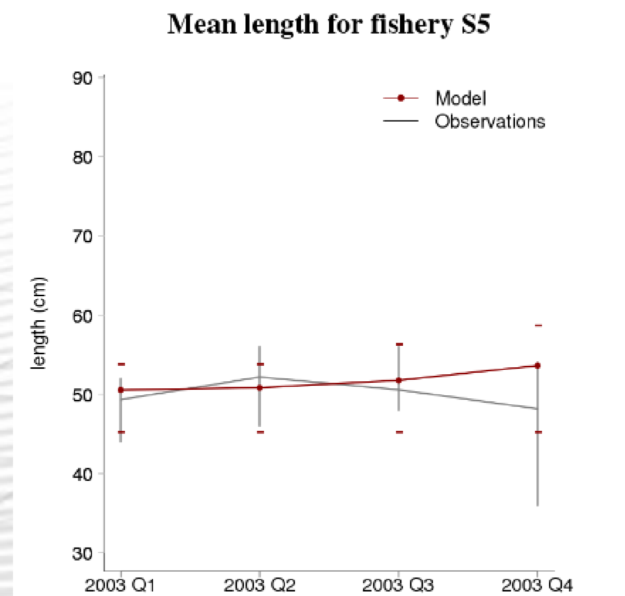
However, for Indonesia there is no data available. The Government is now developing the network.

The Vessel Monitoring System should help to rapidly improve catch and effort data collection.







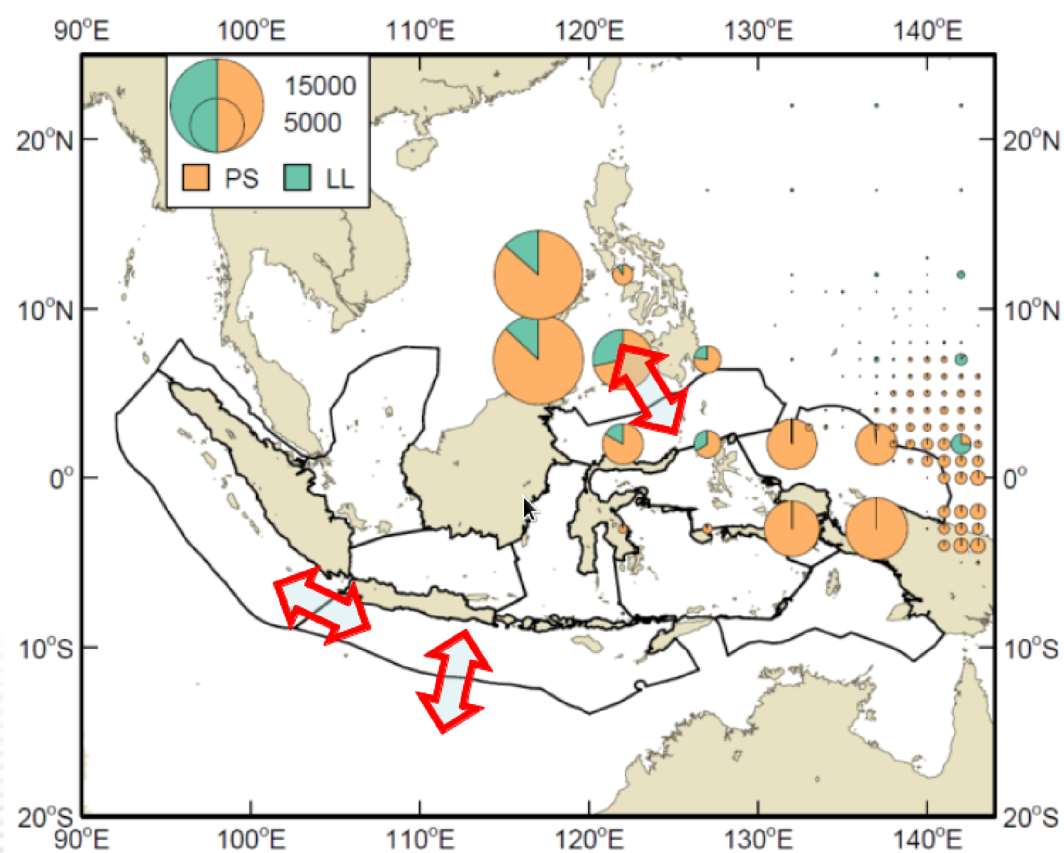


Regional Management of tuna stocks

The Model can be also used to answer key management questions:

- What is the total allowable sustainable catch (TAC) by species in each Fishing Marine Area?
- What is the Maximum fishing effort (fishing licenses) that can be allocated for a given species in each FMA?
- What is the local status of stock?
- How are these estimates above dependent of:
  i) fishing in other FMA?
  ii) fishing outside of Indonesia?

Mean climatological effort of skipjack

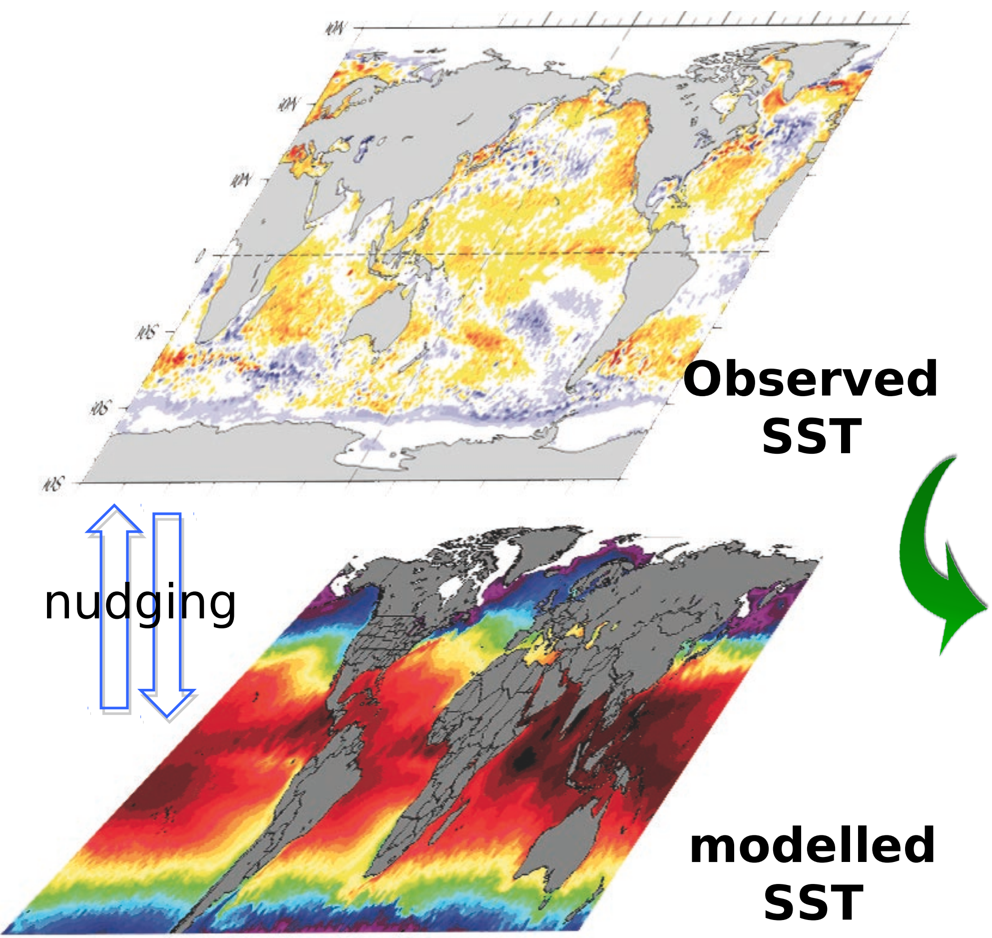


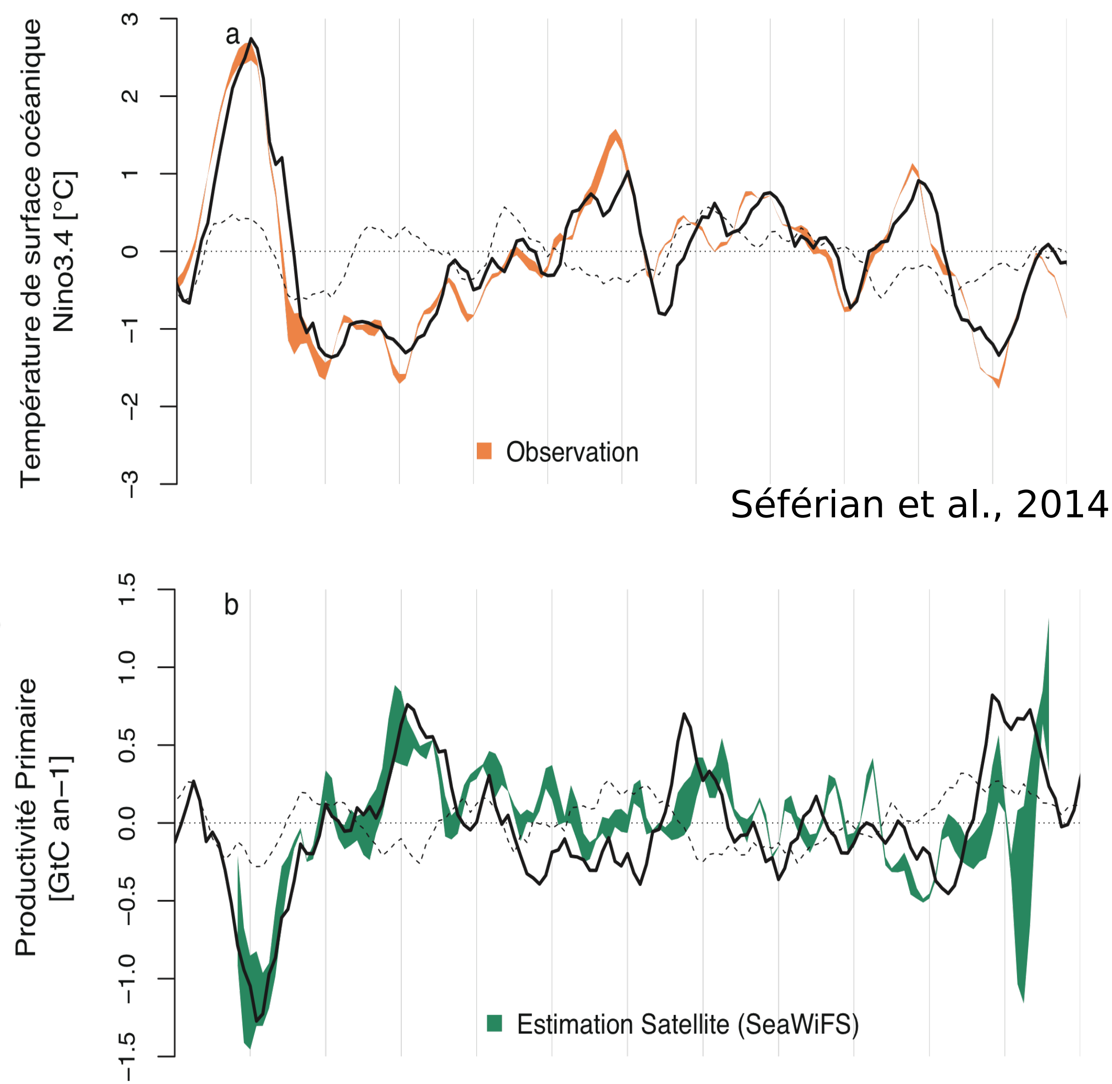
Moving down the time line :

Pluri-annual to decadal

Decadal approach applied to biogeochemistry

Initialization: guiding the model along the trajectory of observed natural variability





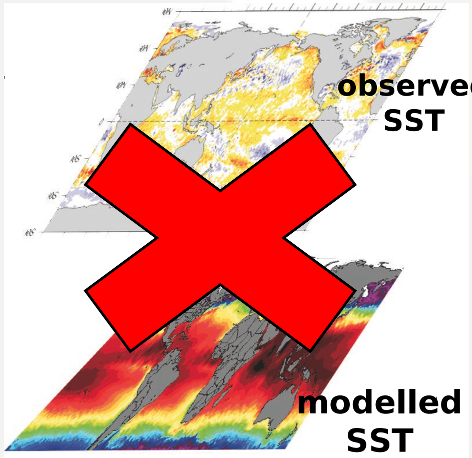
Séférian et al., 2014

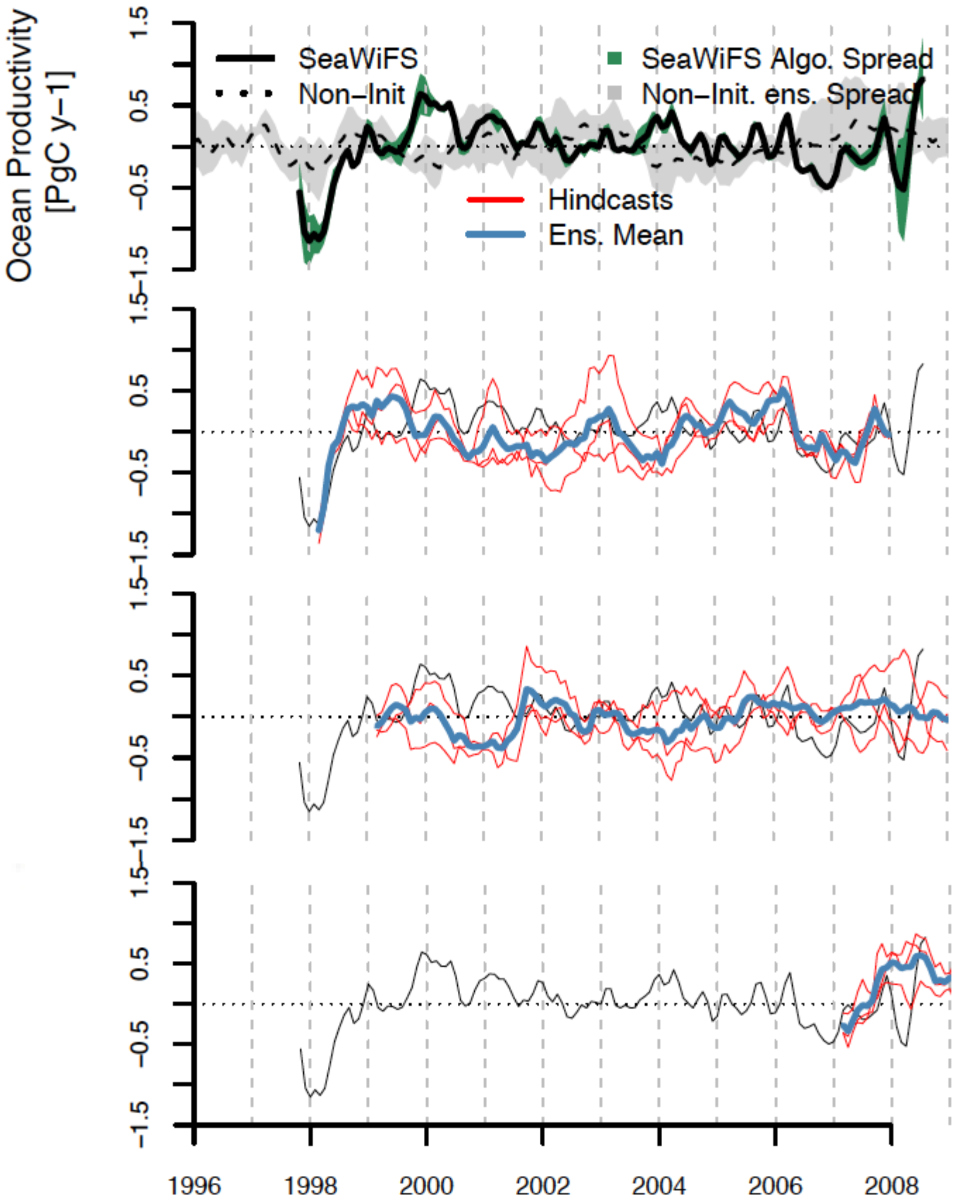
over 60% of observed NPP variability is reproduced by the model

Prediction of NPP

Retrospective forecasting period:
1997 to 2012.
Observations:
-SeaWiFS: 1997-2008
-MODIS : 2002-2012

Prediction :
- each year
- ensemble of 3 members
- for 10 years
- no nudging



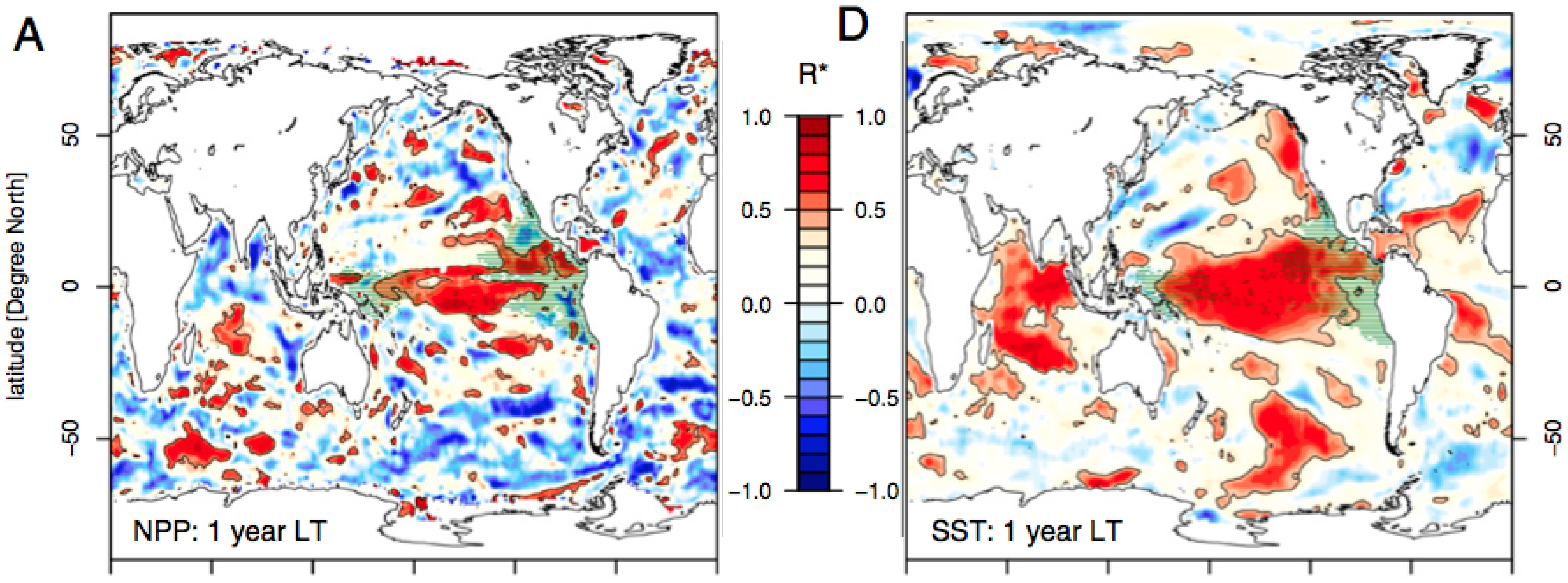


Séférian et al., 2014

Prediction of NPP

1-year predictability (from correlation)

NPP **SST**

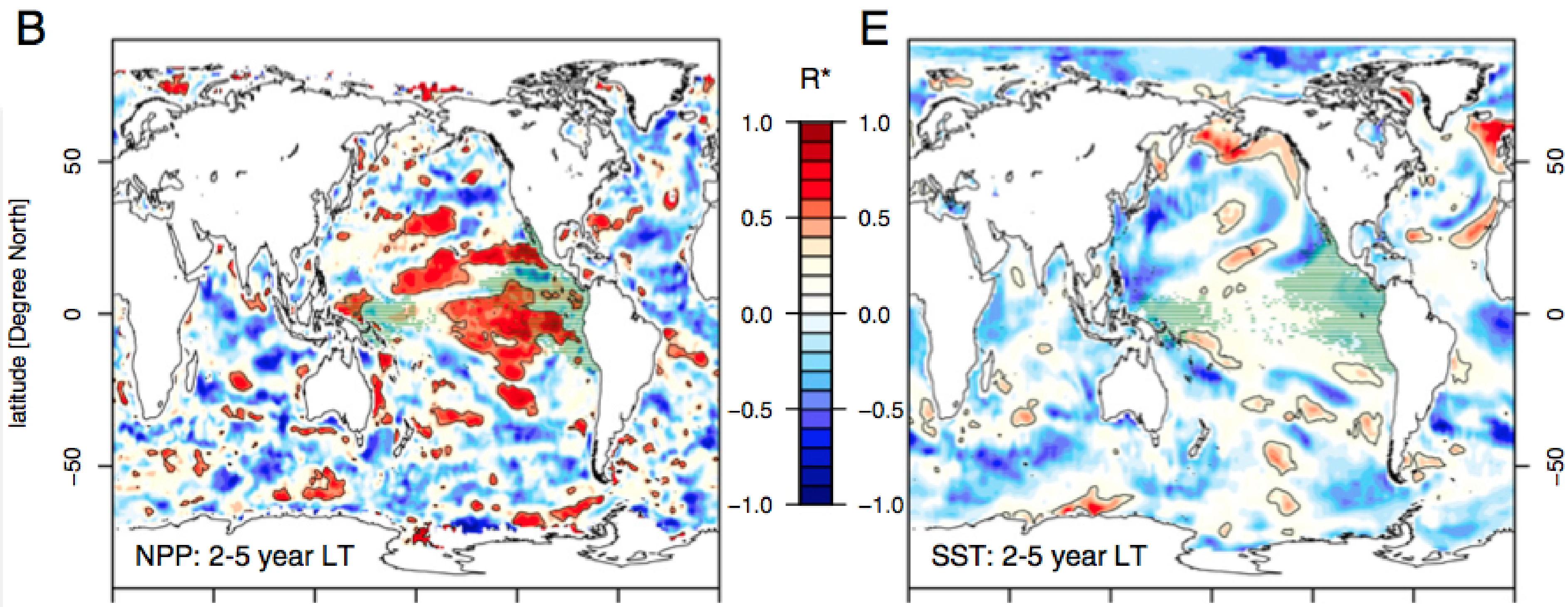


Séférian et al., 2014

Prediction of NPP

2 to 5 year predictability **(from correlation)**

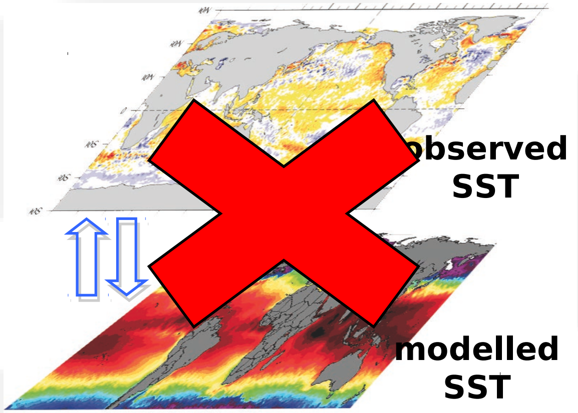
NPP **SST**



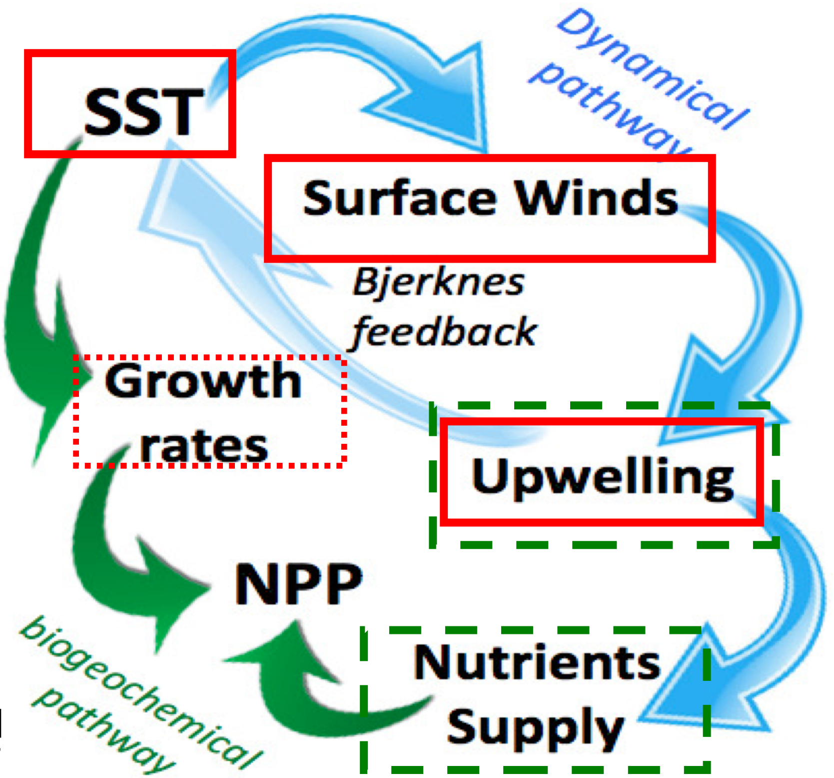
SST is predicted up to 1 year
NPP is predicted from 2 up to 5 years !

Séférian et al., 2014

Prediction of NPP: explanation

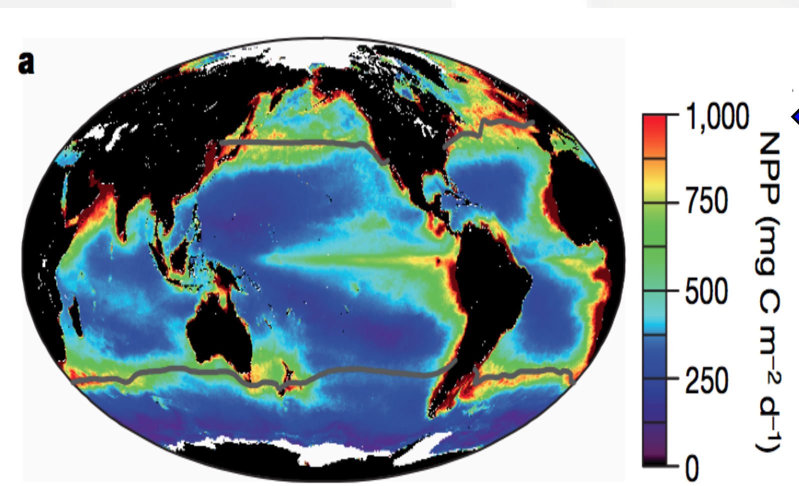


Fast dynamic adjustment for SST



Slow dynamic
adjustment fo BGC

Primary production



Séférian et al., 2014

Forecasting/predicting ocean biogeochemistry for marine ressource management

The capacity for forecasting/predicting marine biogeochemistry and ecosystems for ressource management requires :

integrated model system

- significant progess, coherent modeling systems for applications across time scales

but :

- complexity of biogeochemical component
- need for improved integration of physics/ biogeochemistry-LTL/mid- & upper TL
- bridging of spatial scales global 2 regional
- predictability of key physical/chemical/biological variables beyond short-term forecasts ?

The capacity for forecasting/predicting marine biogeochemistry and ecosystems for ressource management requires :

2) data assimilation schemes

- need to be revisited for coupling to BGC

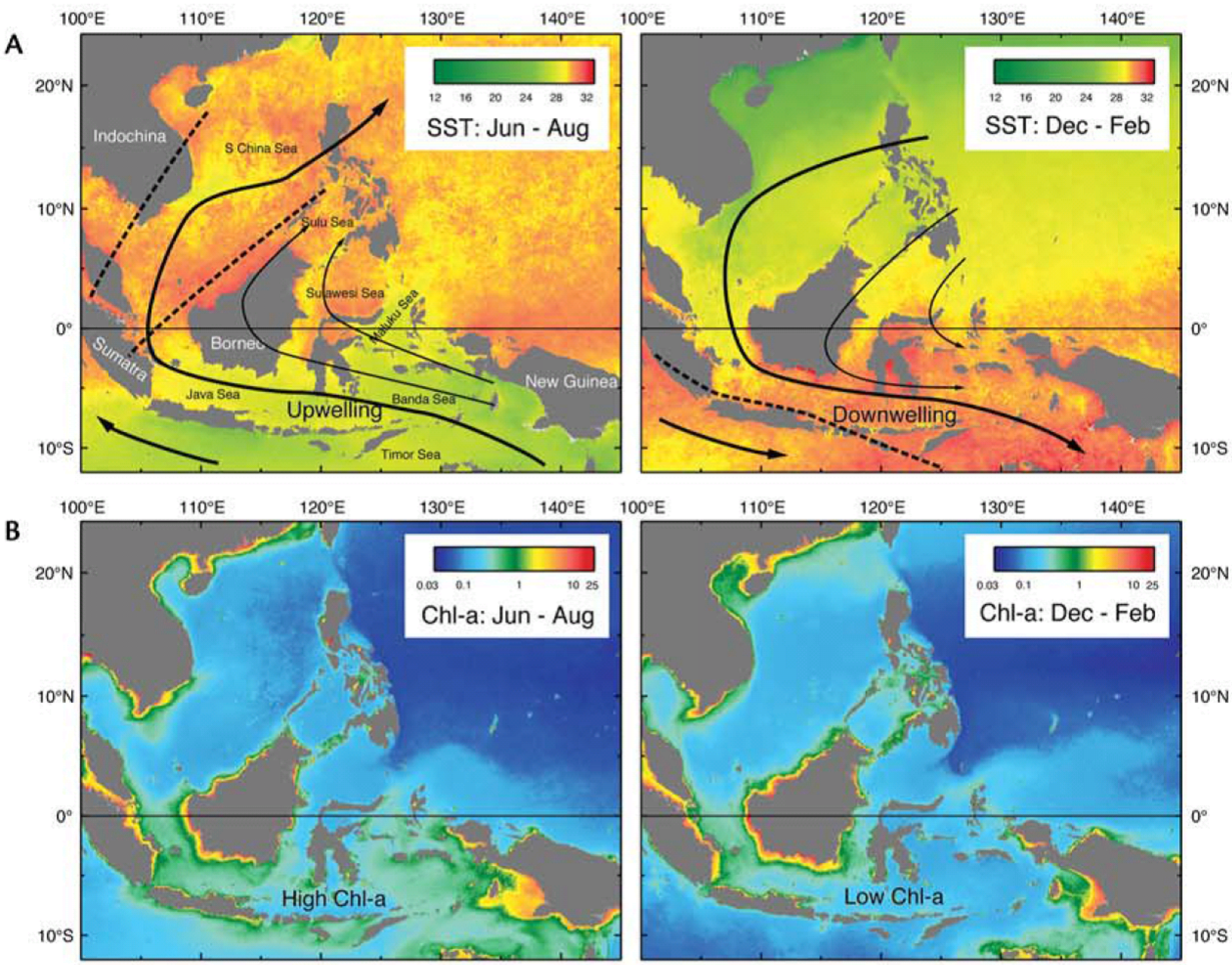
3) observations

- need of a sustained effort
- access to fishing data

contribution of long-term global ocean observing systems ?

=> demonstration of usefulness of systems for real world applications


Thank you for your attention !
GREENPEACE


A
B
SST: Jun - Aug
SST: Dec - Feb
Chl-a: Jun - Aug
Chl-a: Dec - Feb
Indochina
S China Sea
Sulu Sea
Sulawesi Sea
Maluku Sea
Borneo
Sumatra
Java Sea
Banda Sea
New Guinea
Timor Sea
Upwelling
Downwelling
High Chl-a
Low Chl-a
100°E
110°E
120°E
130°E
140°E
20°N
10°N
0°
10°S
12 16 20 24 28 32
0.03 0.1 1 10 25