Twelve years of forecasting the spring bloom in the Strait of Georgia: Lessons learned

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Experimental Science vs Observational Science

- Formulate a model or hypothesis
- Design an experiment
- Test hypothesis
- Modify model/theory

- Design an observational or analysis project
- Observe ocean (or analyze realistic model)
- Figure out what is happening
- Formulate a explanation/theory

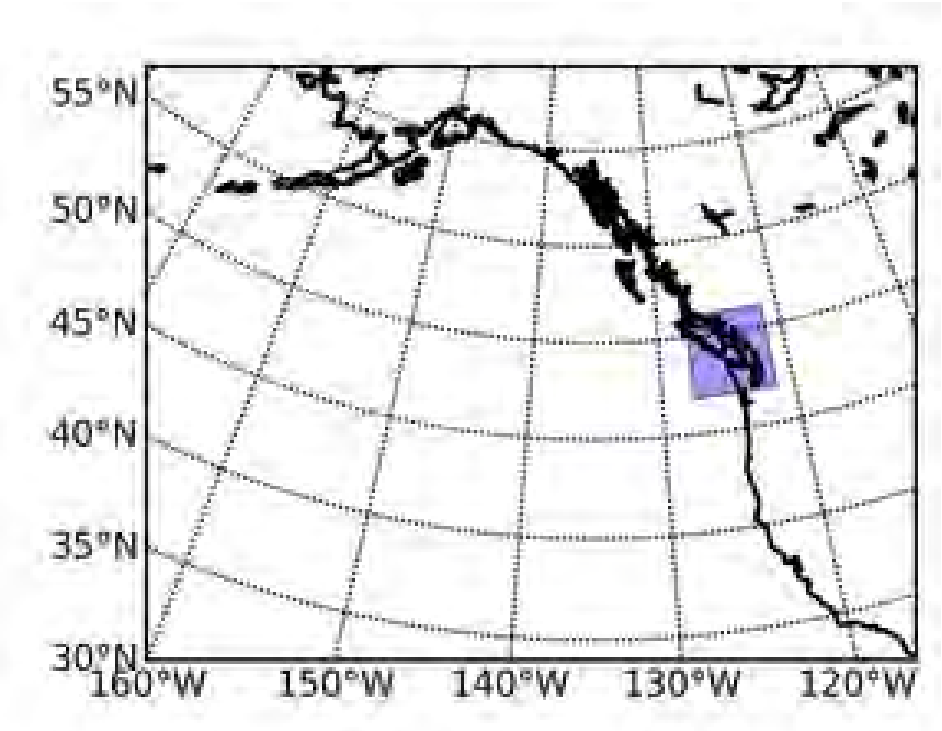
Goal of Science is Prediction

- Formulate a model or hypothesis
- Use it to **predict** result of an experiment
- Test hypothesis
- Modify model/theory

- Formulate a model or hypothesis
- Use it to **Predict** the future
- Wait, observe the future
- Modify model/theory

Outline

Strait of Georgia

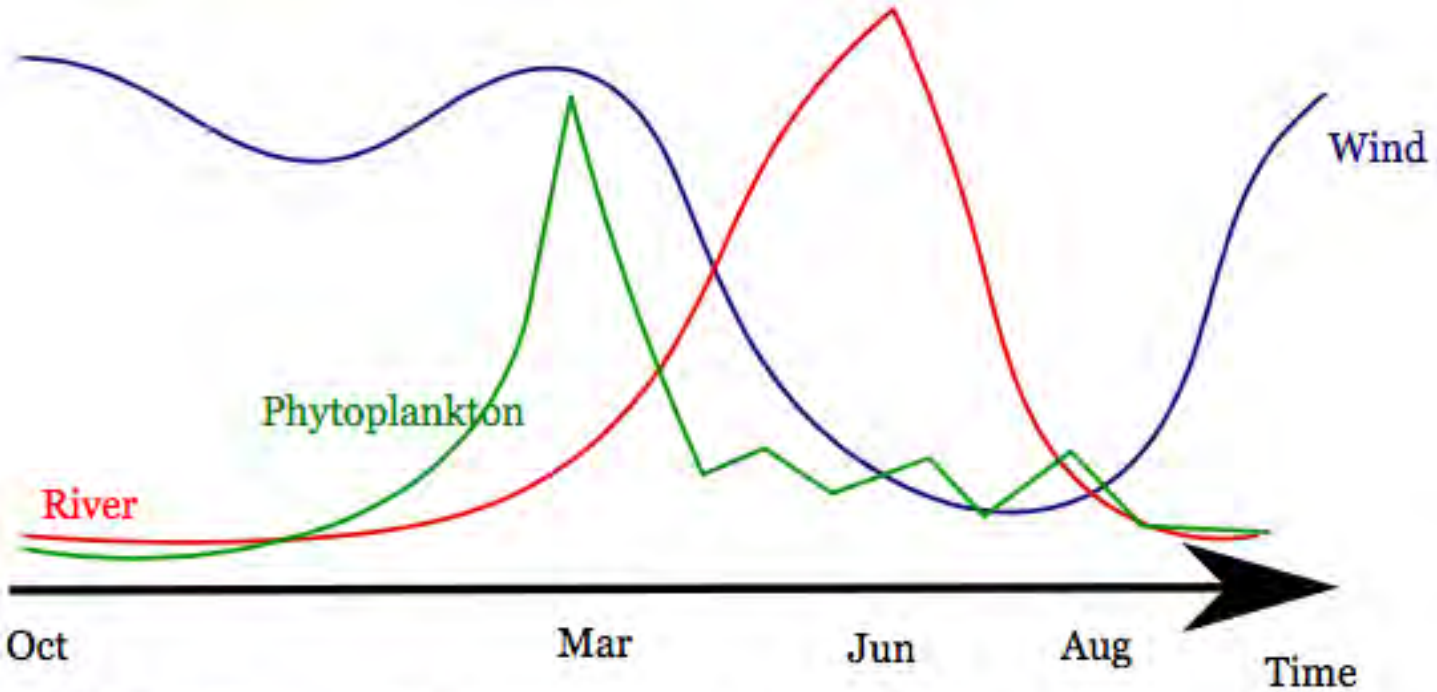


- Home waters for most of the population of BC
- Important habitat for salmon
- Important aquaculture centre

- 400 m deep, 120 km long, 30 km wide
- Significant input of freshwater
- Strongly stratified, often without a surface mixed layer
- Estuarine type circulation
- Biologically productive

NASA

Seasonal Cycle



Fall/Winter: High winds, low light, low phyto.

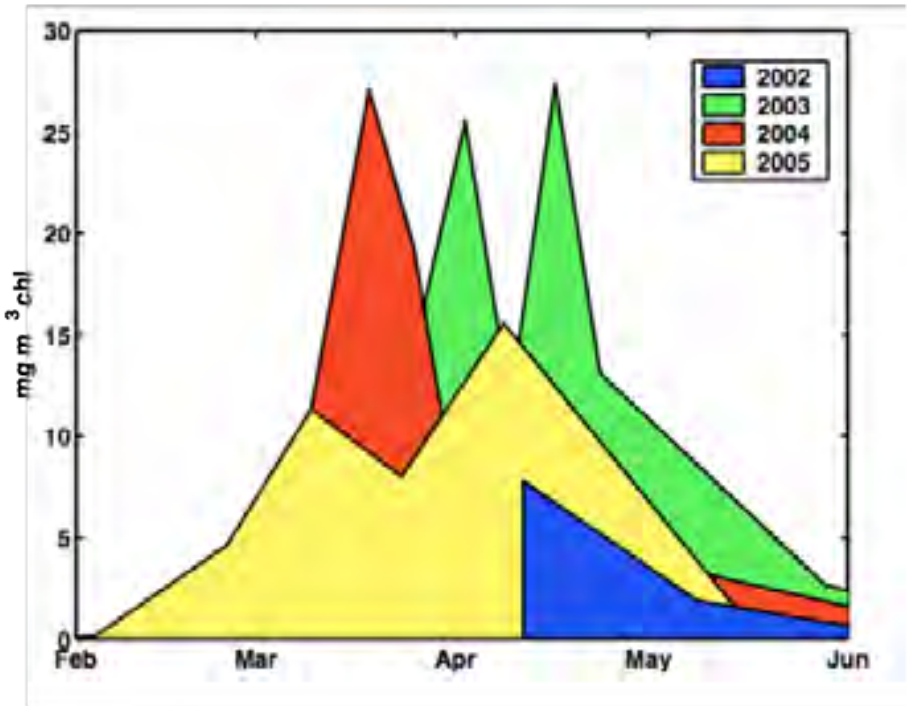
Early spring: Light improves, spring bloom, winds start to decrease

Late spring: Freshet!

Summer; weak winds, lower river, moderate productivity

Large Interannual Variation in Timing of the Spring Bloom

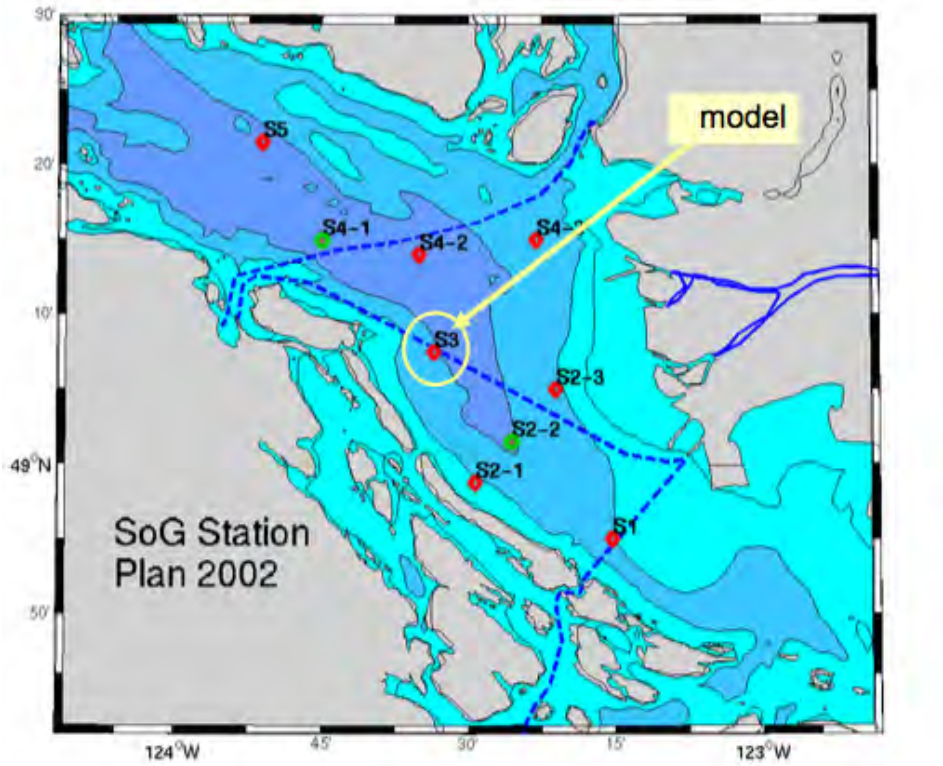
Bloom timing varies by up to 7 weeks



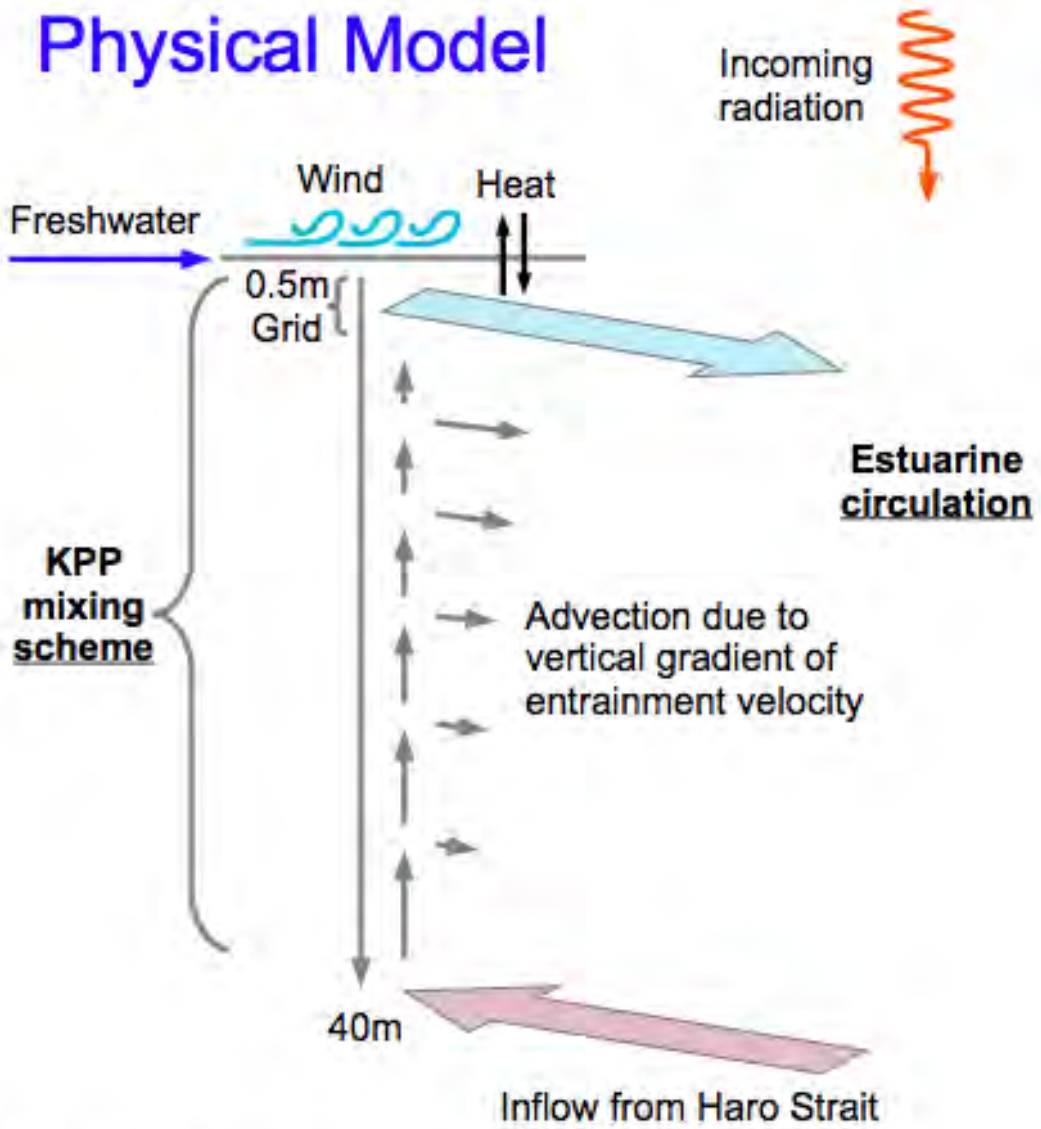
- Spring bloom timing is well defined prediction metric
- Measure of spring time phenology
- Important to zooplankton community succession
- Important to herring recruitment success
- Too early in season to directly relate to salmon juveniles

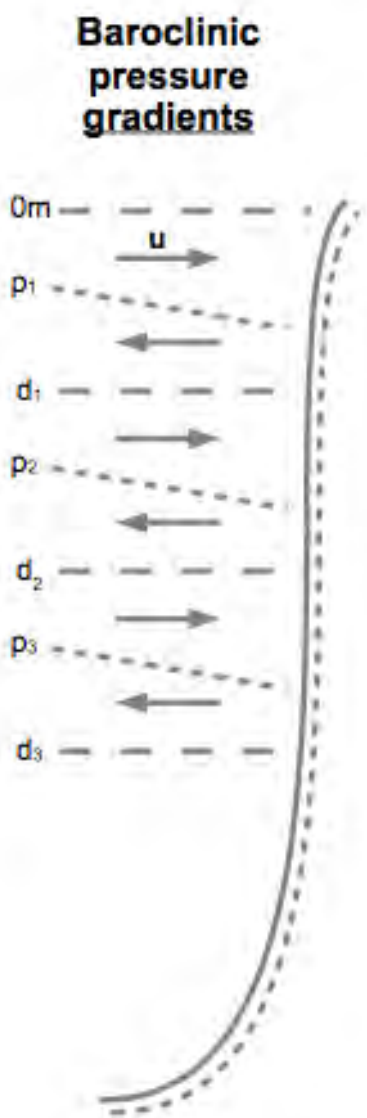
SOG Model

- Vertical one-dimensional model with parameterized two-dimensional processes
- Physical model is based on a 1997 mixing layer model
- Biological model is an Nutrient-Phytoplankton model



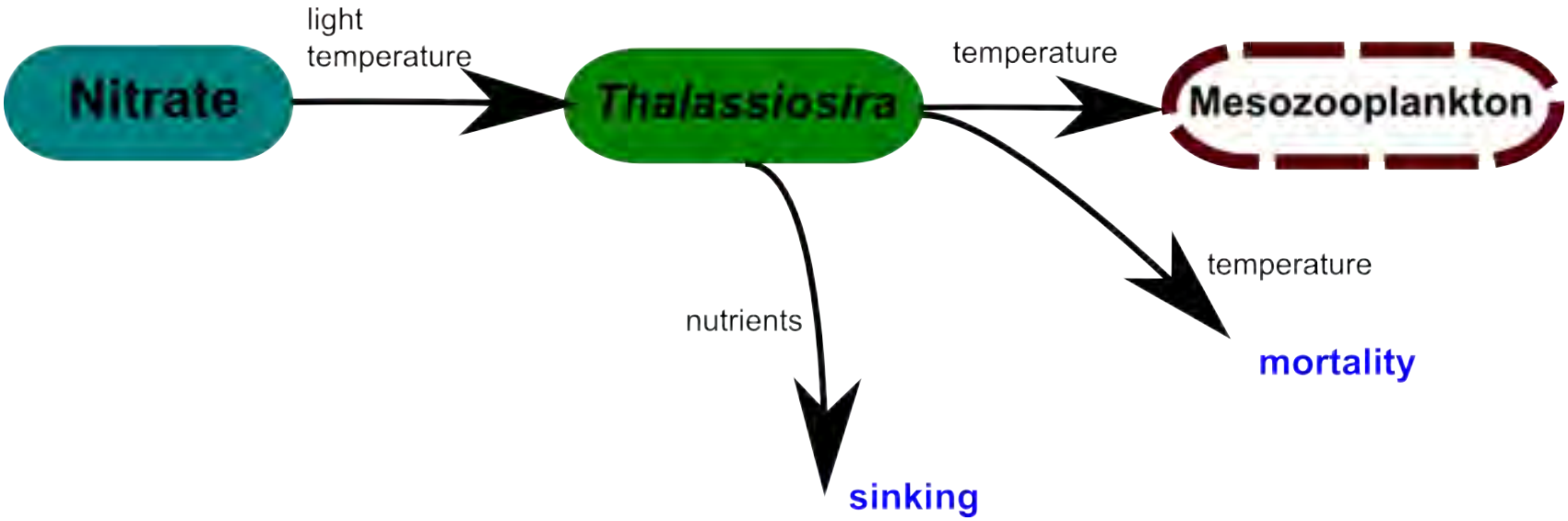
Physical Model





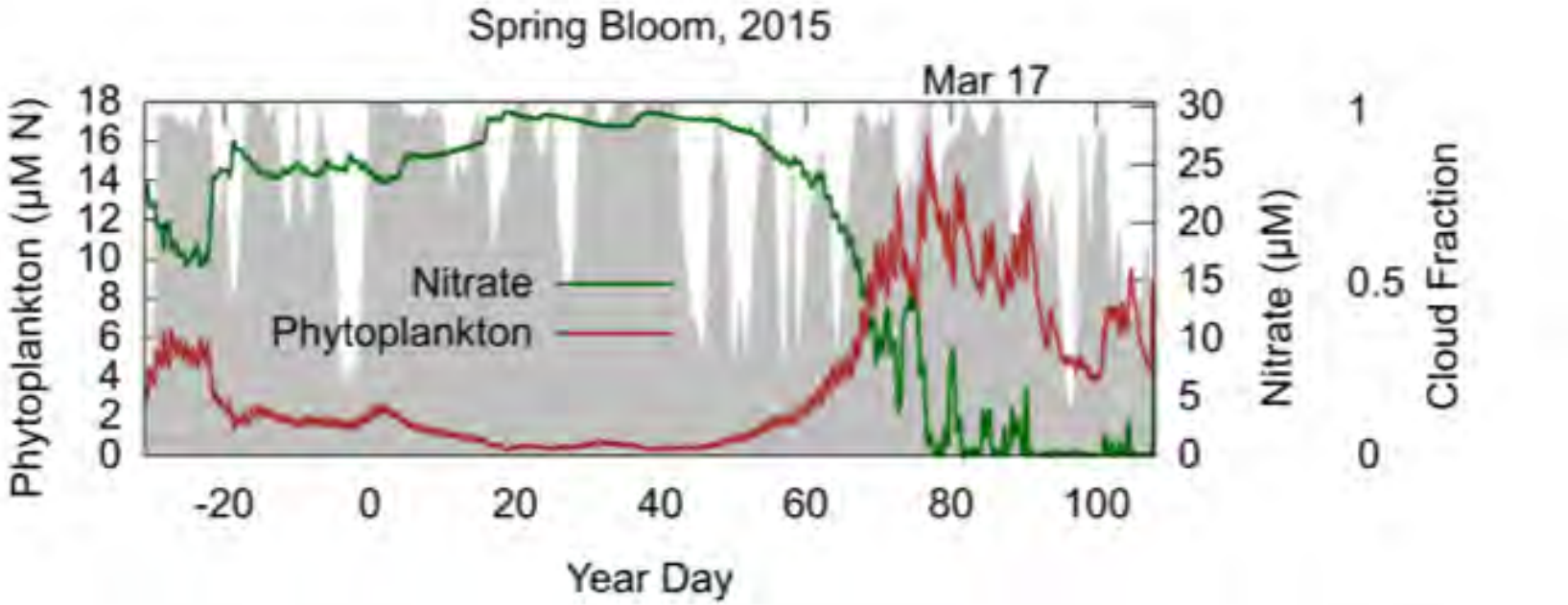
Ben Moore-Maley

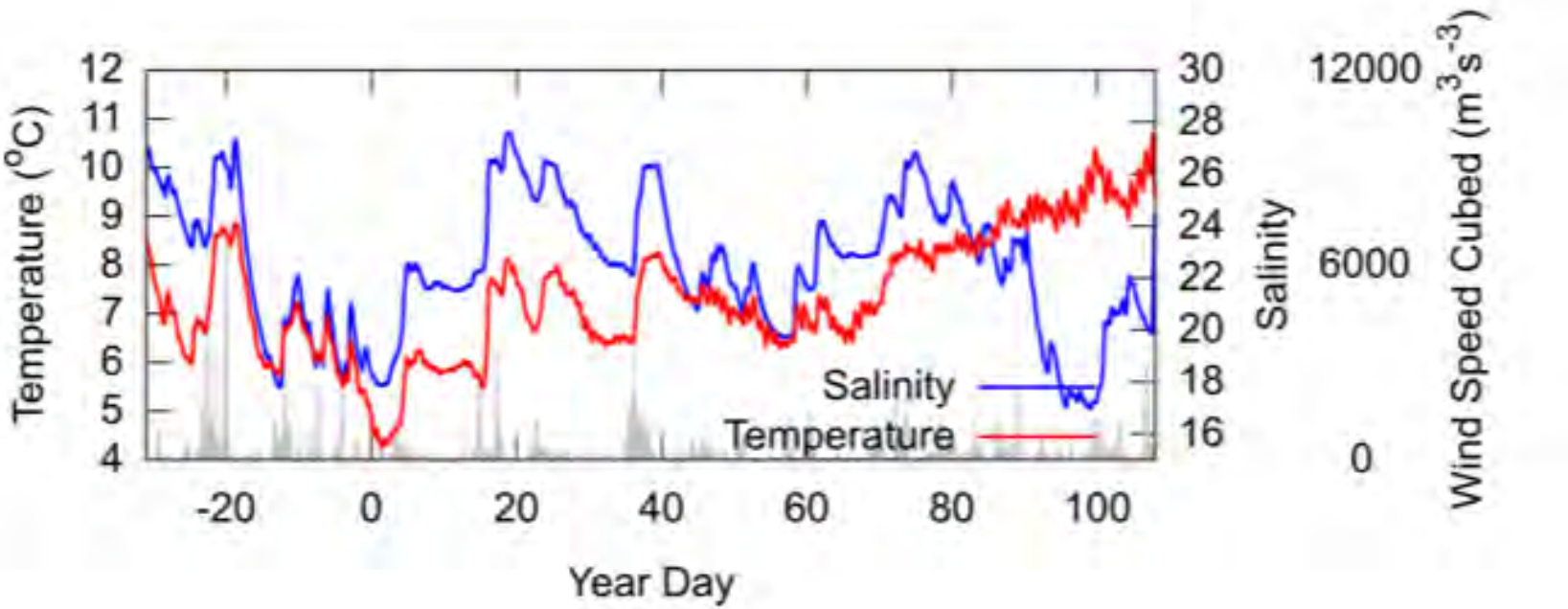
Spring Bloom Model



$$\partial P/\partial t = growth - mortality - grazing - sinking + physics$$

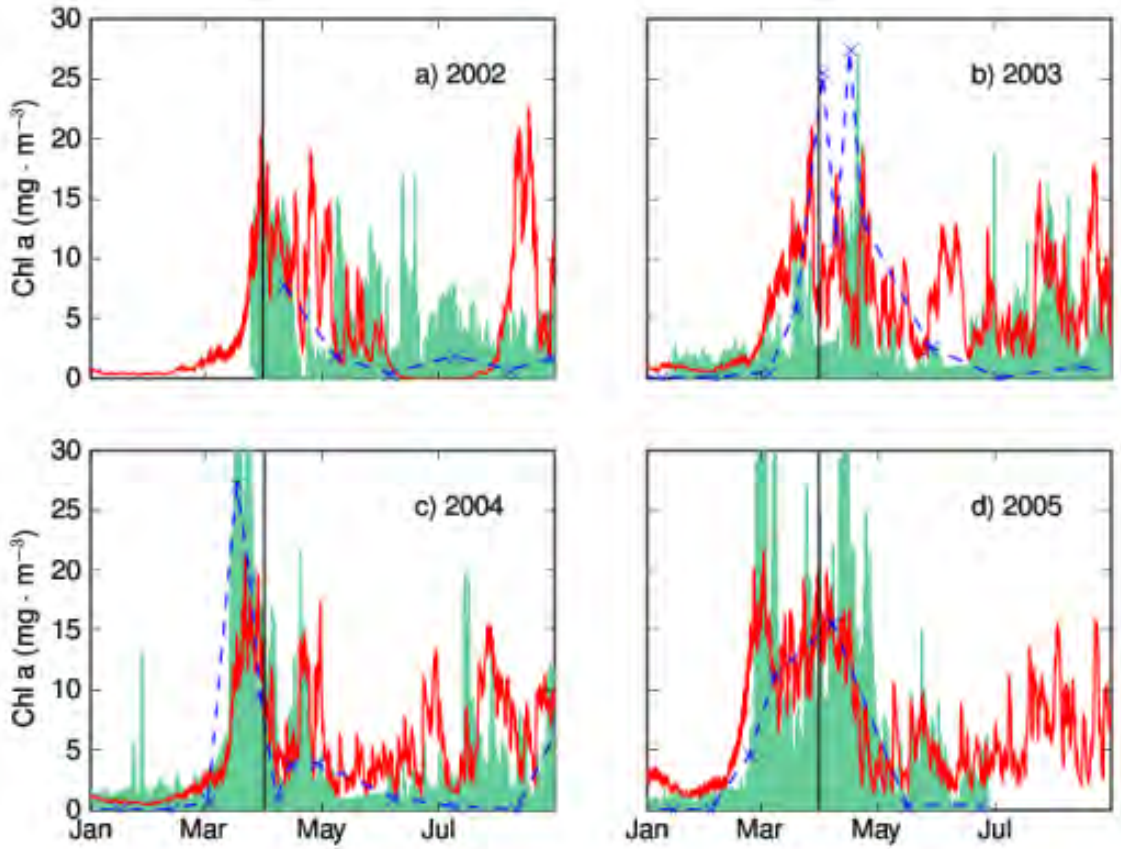
- Growth: Needs nitrate and light
- Mortality: Temperature dependent
- Grazing: A function of observed zooplankton biomass
- Sinking: Diatoms heavy
- Physics: Mixing and advection


Spring Bloom, 2015
Mar 17
Phytoplankton (µM N)
Nitrate (µM)
Cloud Fraction
Nitrate
Phytoplankton
Year Day


Temperature (°C)
Salinity
Wind Speed Cubed (m³s⁻³)
Salinity
Temperature
Year Day

Tuning

Parameter	Impact
Fresh water flux	surface salinity
Fresh water depth	halocline depth
Internal wave mixing	halocline strength
Diatom growth rate	timing of spring bloom

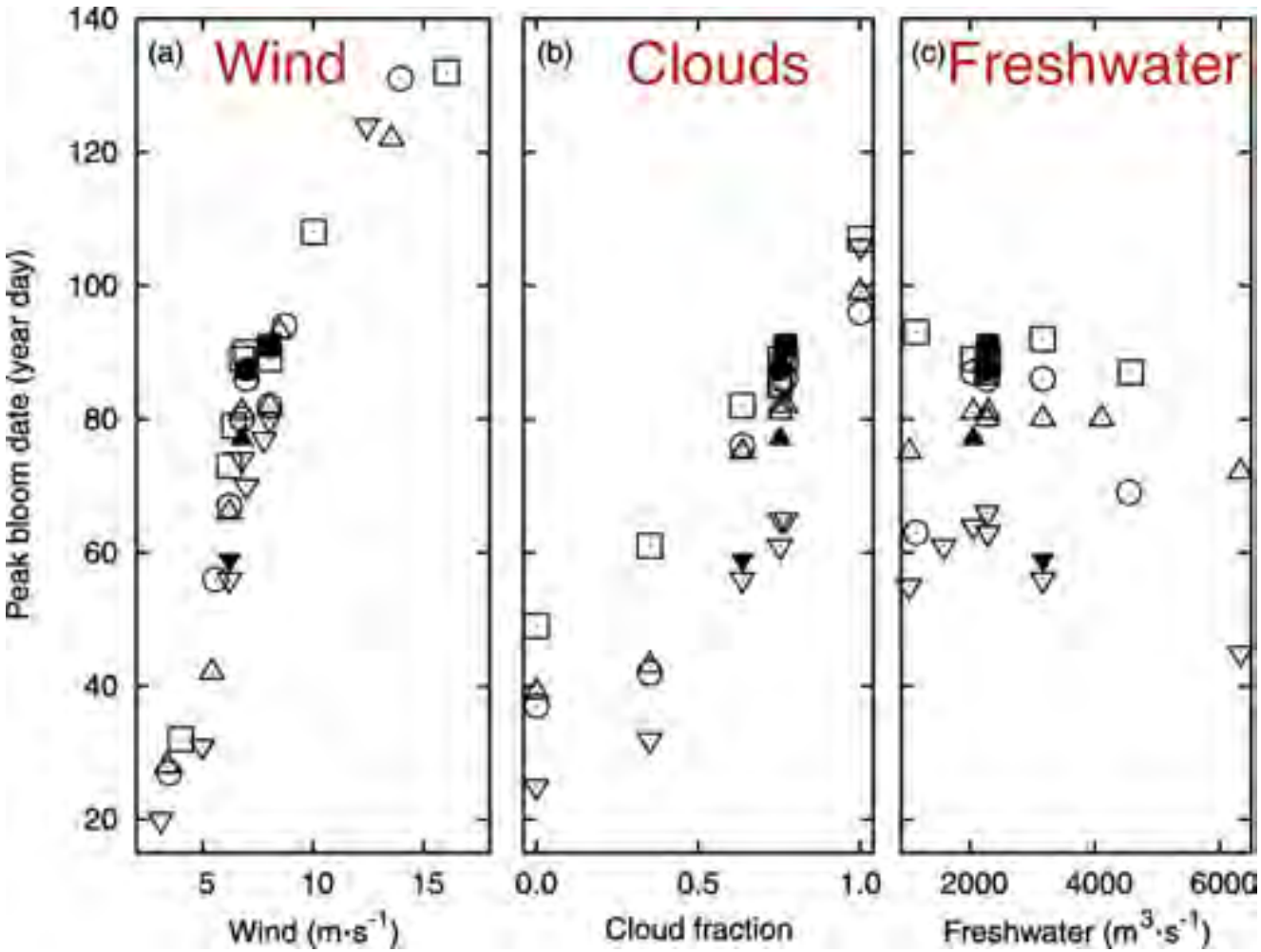


Green: ferry observations Red: model

Collins et al, 2009

Sensitivity

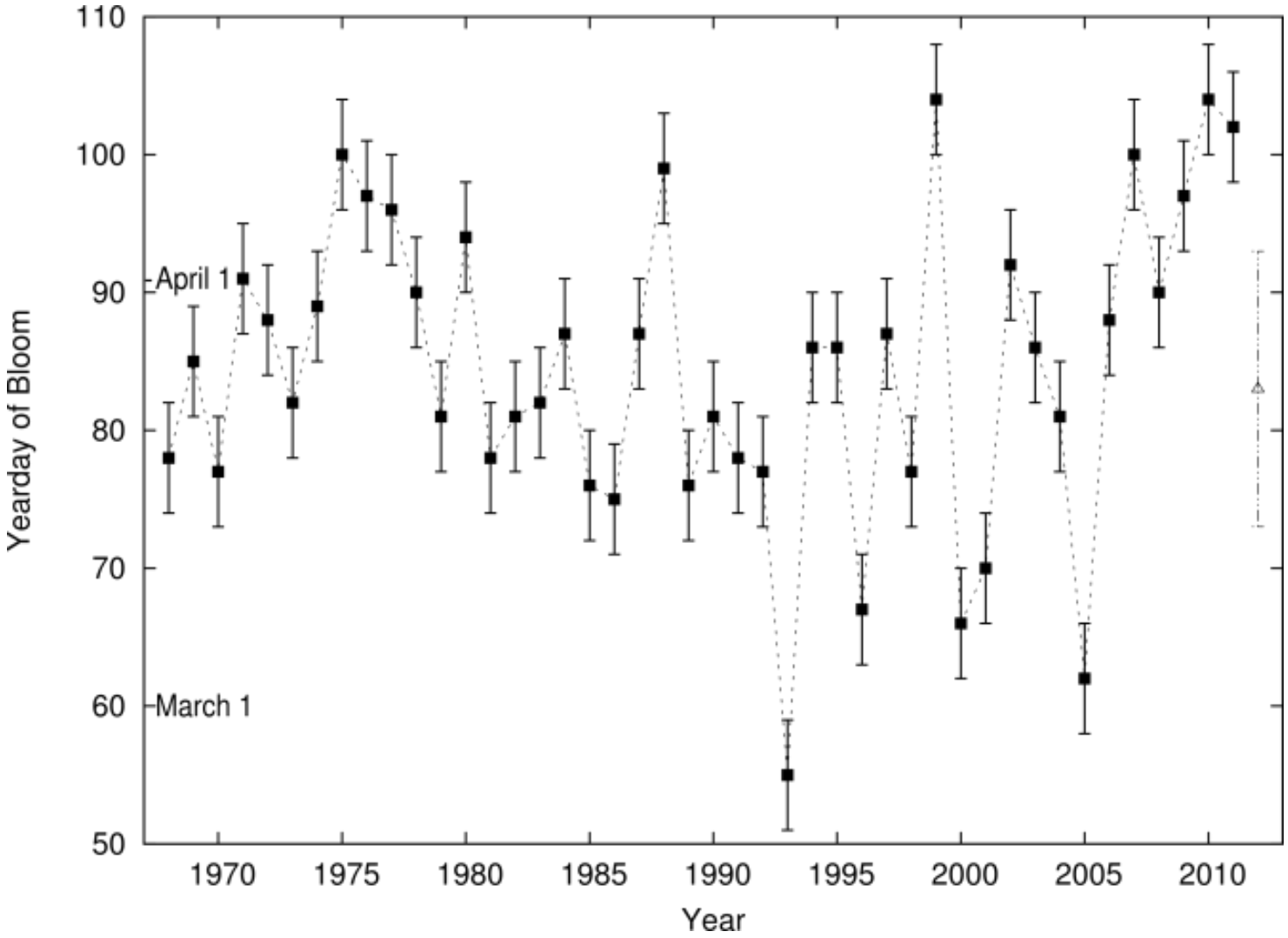
Run many simulations varying wind, Fraser River flow and cloud cover.
Spring bloom is strongly dependent on the average winds and cloud cover and weakly dependent on the fresh water flux.



Collins et al, 2009

Long Model Hindcast

Since the start of good wind data (aka Sand Heads Station)



Allen and Wolfe, 2013

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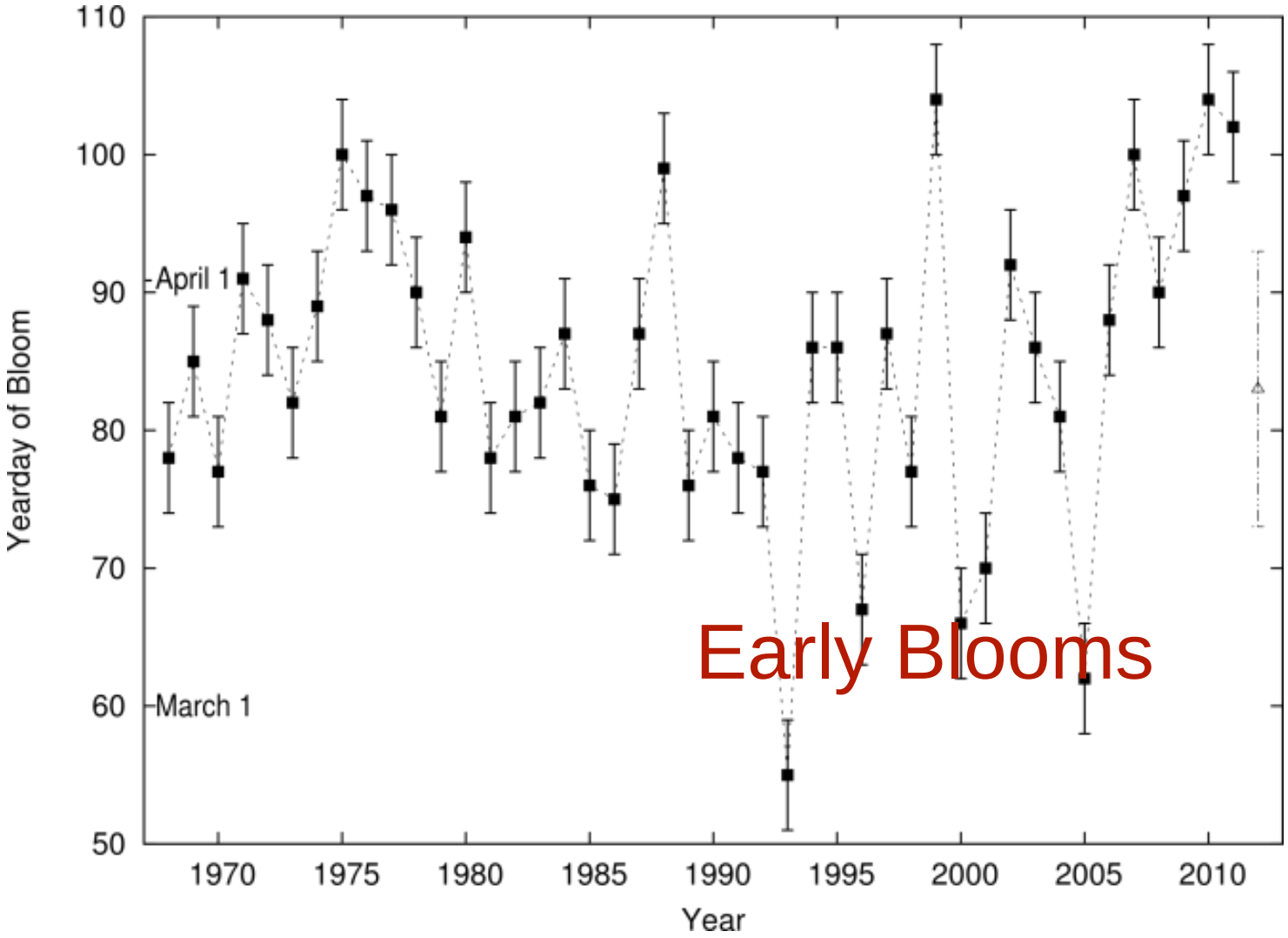


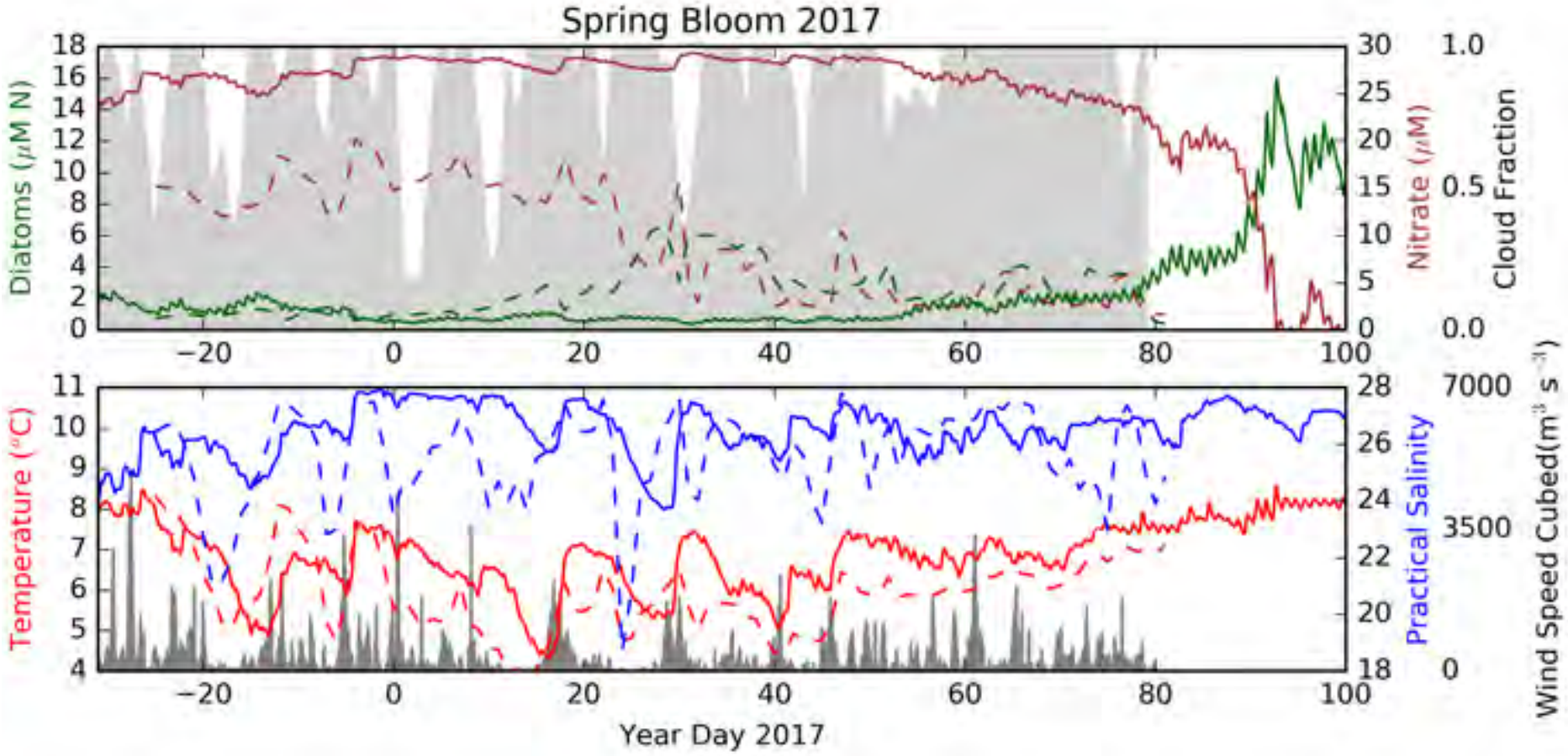
Allen and Wolfe, 2013

Automate Prediction

A script is configured to run each day, it:

- Downloads up to yesterday's wind, meteorology including cloud fraction and river flows
- Runs to yesterday with that data
- Rusn forward with data from each year 1981-2010 to produce an ensemble of runs
- Chooses the median spring bloom as the best prediction and first 5% and last 5% as error bounds.

Plots and charts the results on a webpage.

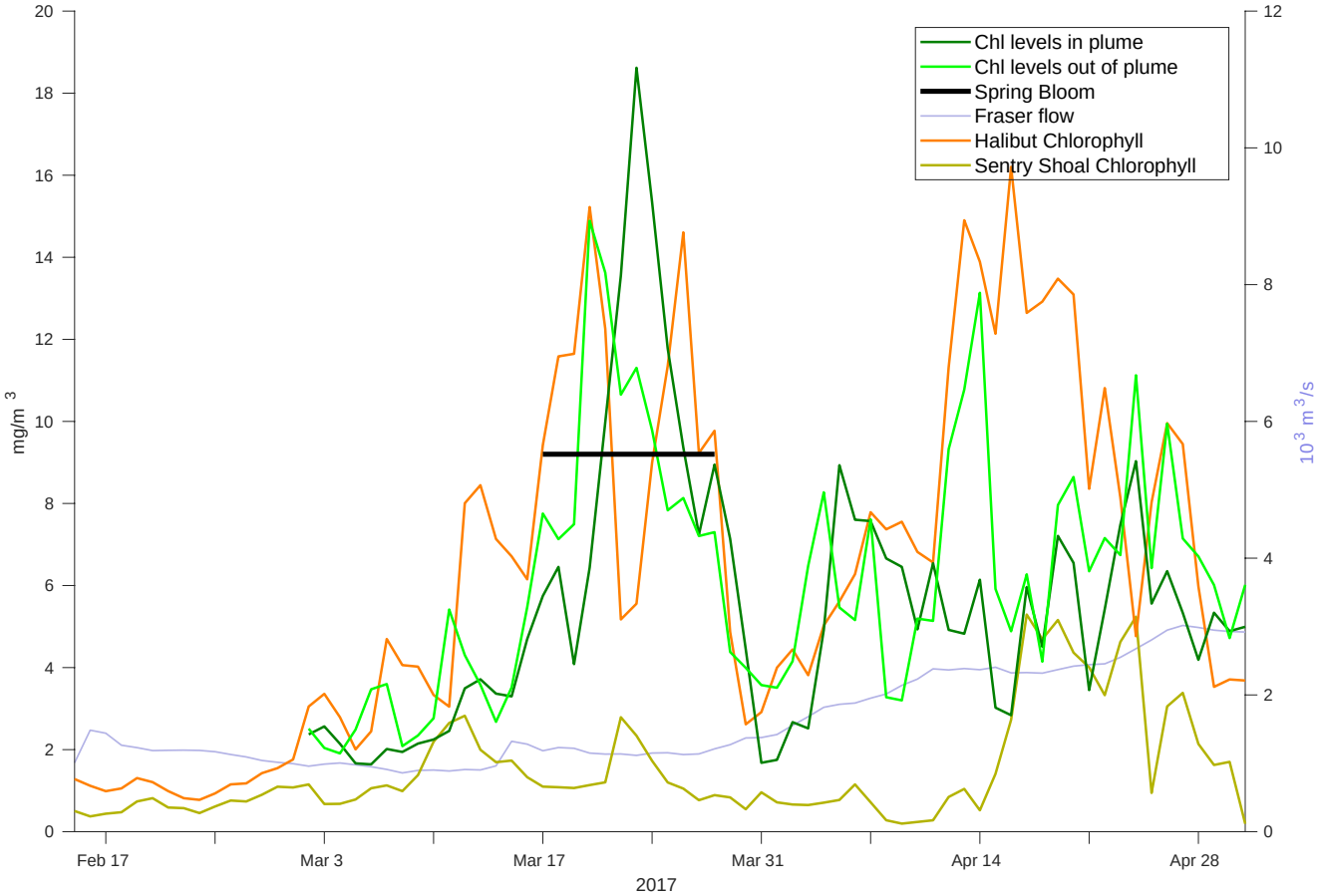


As of March 22, 2017:

Median prediction: median of using, after today, all historical weathers from 1981-2010.

Current prediction: Between March 26 and April 14 with Median Date **April 1**

2017 Spring Bloom : Observations



Observations from ferries and buoys.
Green: central Strait,
Orange: northern Strait.
In Central Strait of Georgia Bloom was March 18-28.

Feb 17

Apr 28

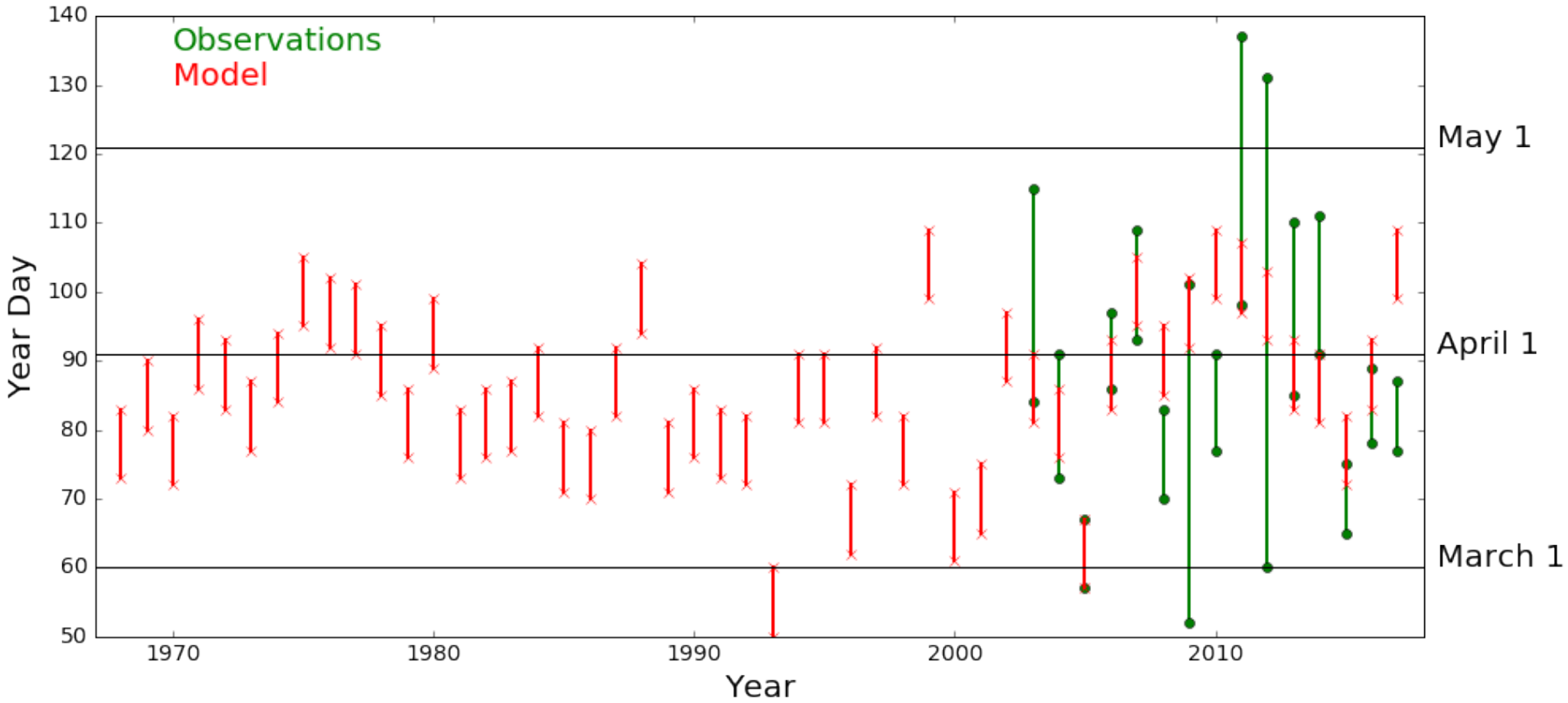
Allen et al, 2018

Observations

- Combination of all ferry systems
  1: STRATOGEM/Pawlowicz
  2: IOS/Gower
  3: ONC

  1 and 3 on Tsawwassen/Duke Point run, 2 on Tsawwassen/Swartz Bay.
- Data extracted and averaged for in and out-of-plume for 1 and 3. Bloom timing in and out-of plume is THE SAME for all years (when both are available; to the resolution we see). In and out of plume matters more in the summer.
- For 2: averaged over southern SoG.

Observation/SOG Model Comparison and Interannual Variability



Mostly the model agrees with the observations (success).
In 2008 and 2017 the model does not agree (useful).
(In 2010 the data is not really clear).

Allen et al, 2018

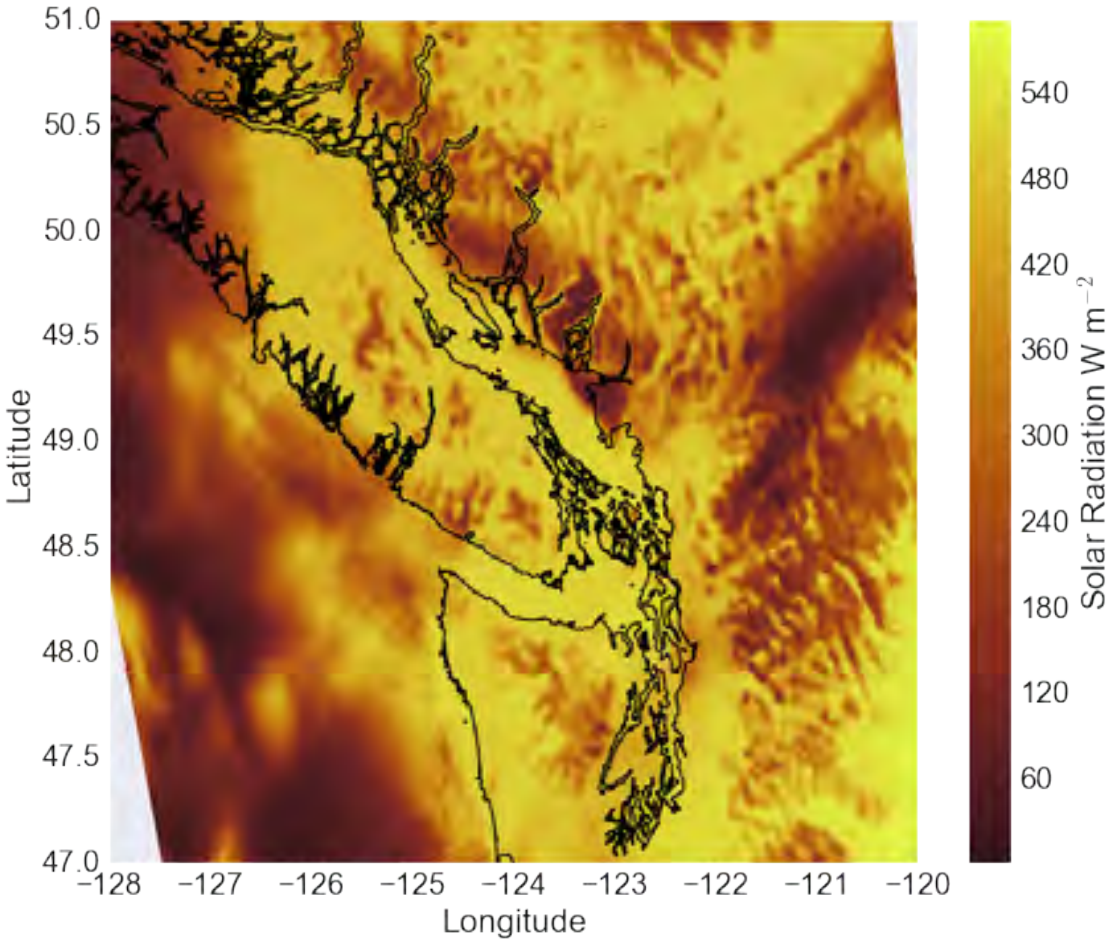
2017 Spring Bloom : SOG Model

SOG predicted a very late bloom (April 14) in 2017 compared to the typical bloom timing observed.

Which assumption/limitation of the SOG model failed in 2017?

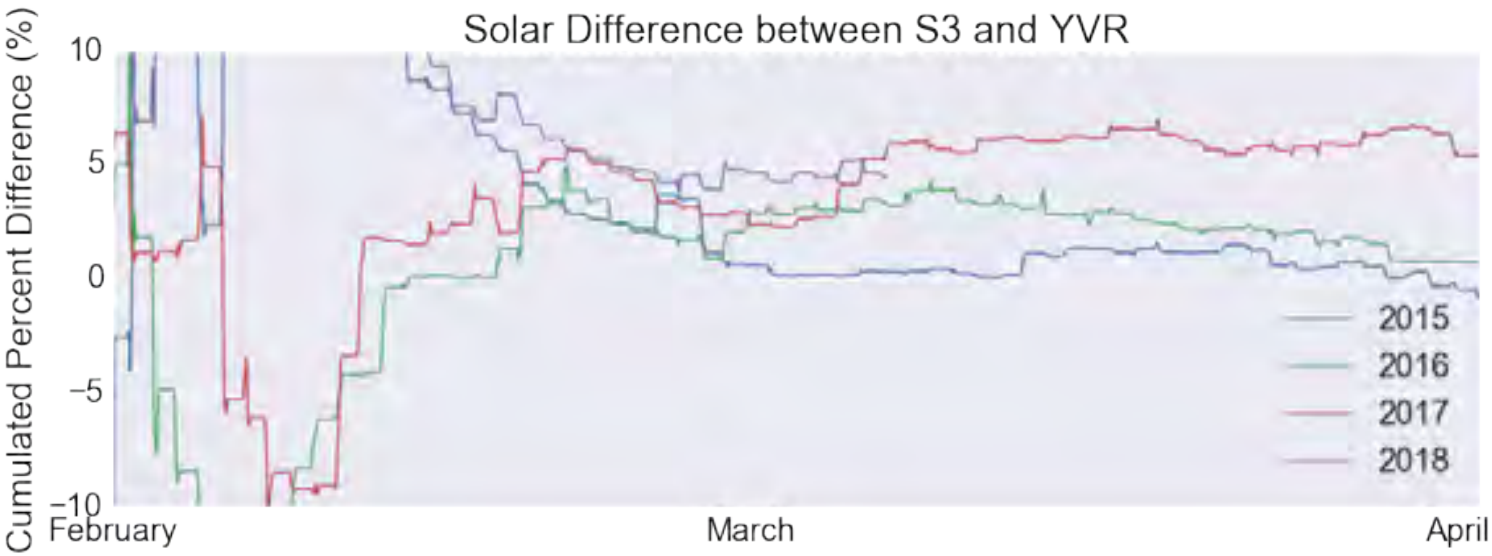
- spatial uniformity – NO, observations show bloom throughout southern SoG
- mesozooplankton less numerous – possible
- different faster growing phytoplankton – NO, observations show *Thalassiosira*
- problem with the forcing
  - wind: observations, over water
  - light: observations, at airport
  - rivers: Fraser River and Englishman, latter could be a problem as it is to represent all other rivers: however, impact on bloom timing is small
  - temperature – possible

2017 Spring Bloom : Light



Light from HRDPS weather model (2.5 km from Environment and Climate Change Canada). An example from spring 2017.

Cumulative Light difference: Station S3 vs YVR



Unlike in other years, in 2017, the cumulative light at Station S3 was consistently 7% higher than the airport through March.
Given the sensitivity of the spring bloom to the light, this is sufficient to explain the discrepancy.

Allen et al, 2018

Summary

- SOG spring bloom timing depends primarily on winds and cloud cover with impacts of temperature on year-to-year variation
- Most years the SOG model accurately predicts/nowcasts the time of the peak spring bloom
- SOG model is incorrect in years where YVR clouds are different than those over the Central Strait of Georgia (we can monitor and flag)
- Starting in January each year follow updates at : `http://salishsea.eos.ubc.ca/bloomcast/spring_diatoms.html`

Conclusions : Predictions

- Predictions, particularly short-term, allow us to test our models/theory
- Continuing predictions (even an old model) are useful
- Poor predictions are opportunities to learn
- Automation is necessary as funding cycles end

Science Challenge: Predict!

and make your predictions public

Our latest model is SalishSeaCast with predictions (today and tomorrow) published daily `salishsea.eos.ubc.ca/nemo`