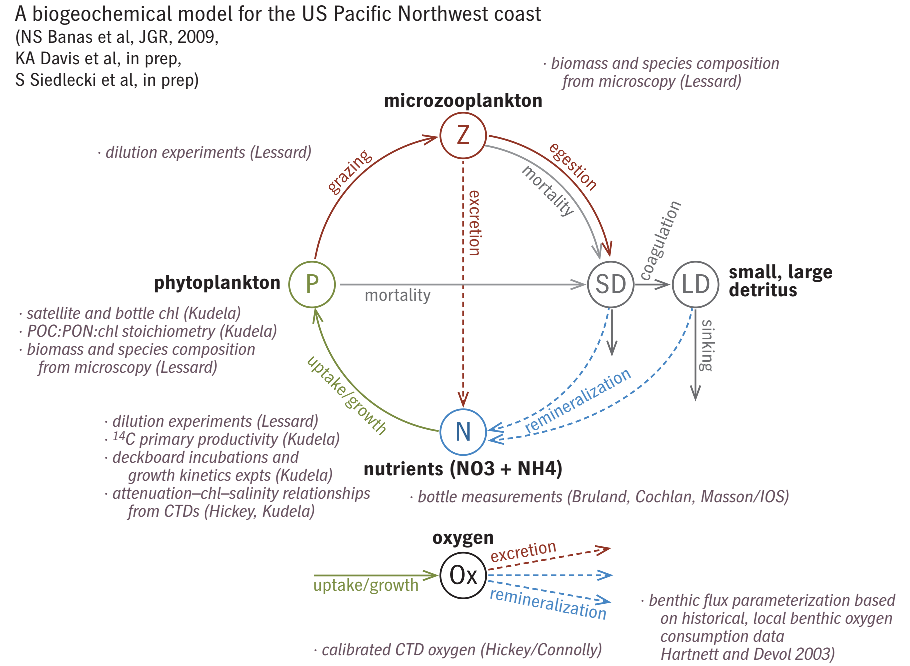
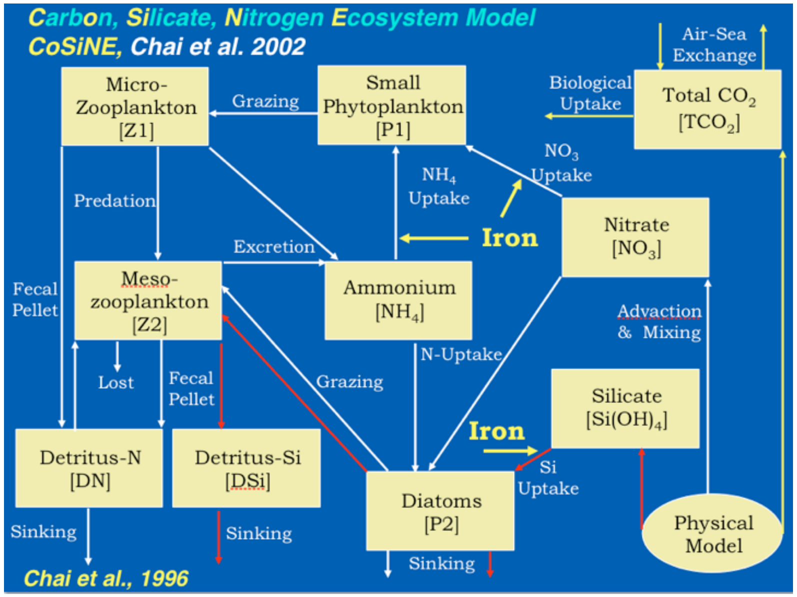
Biological intercomparison in the California Current System: Objective

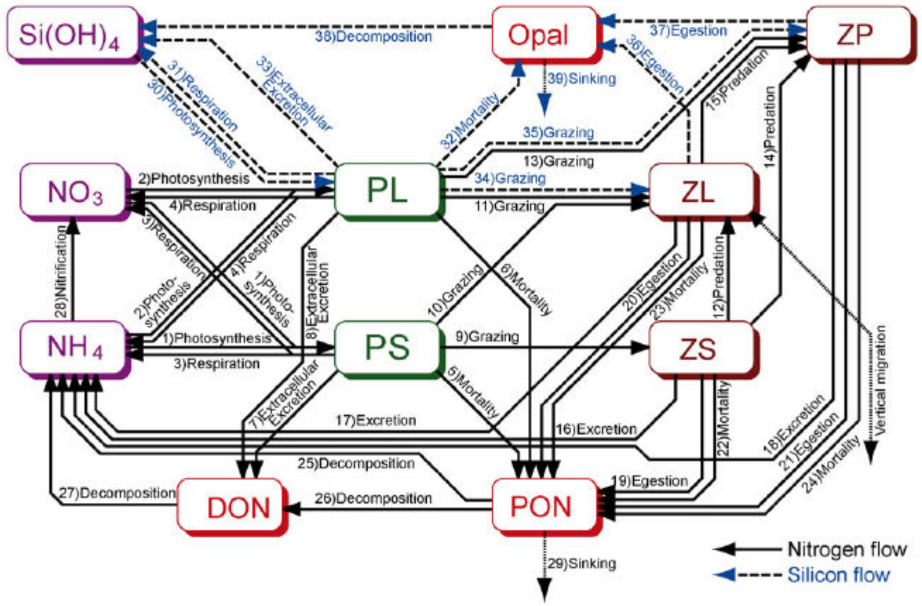
- To compare performance of 3 different established ecosystem models within a single physical circulation system
- Focus on
  - State variables
  - Rate processes
- Approach: A Latin Hypercube sampling of model rate parameters to optimize models to one configuration
- Summary statistics from 1-year (Monte Carlo) and 6-year (rate process) runs
- Collaborations: Edwards, Banas (now MacCready), Chai

3 models

- Cascadia (Banas)
- CoSiNE (Chai)
- NEMURO (Edwards)





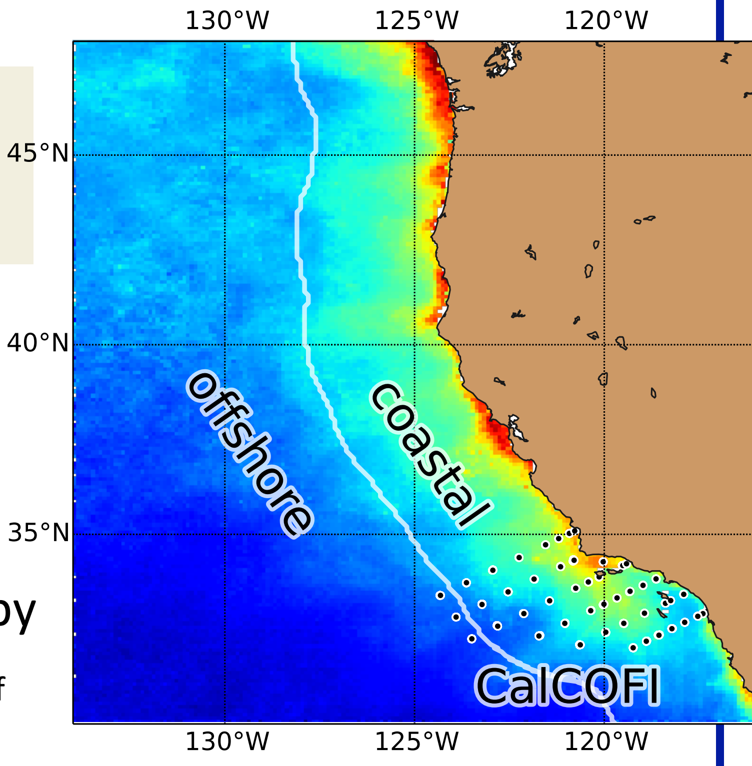


Optimization

- The cost function J(θ) summarizes model performance in one number

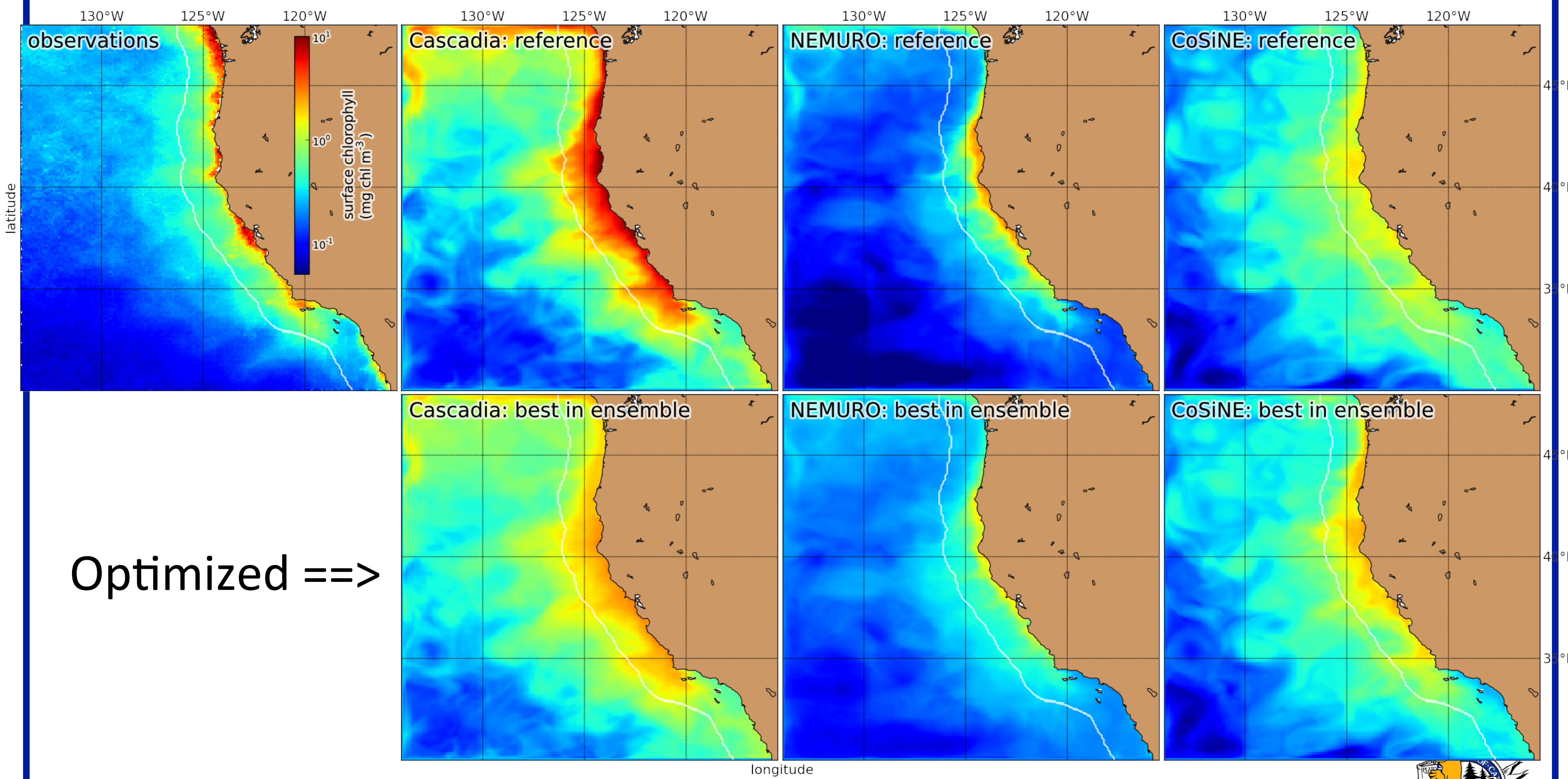
$$J(\theta) = \underbrace{\frac{1}{3}\frac{J_{nut}(\theta)}{J_{nut}(\theta_{\text{ref}})}}_{\text{NO}_3\text{-based}} + \underbrace{\frac{1}{3}\frac{J_{\text{coastal}}(\theta)}{J_{\text{coastal}}(\theta_{\text{ref}})} + \frac{1}{3}\frac{J_{\text{offshore}}(\theta)}{J_{\text{offshore}}(\theta_{\text{ref}})}}_{\text{Chl-based}}$$

- Measures model-observation misfit as a function of select biological parameters θ
- Based on real satellite Chlorophyll and climatological nitrate from WOA
- Individual cost contributions are normalized by the reference simulation with parameters θ_{ref}



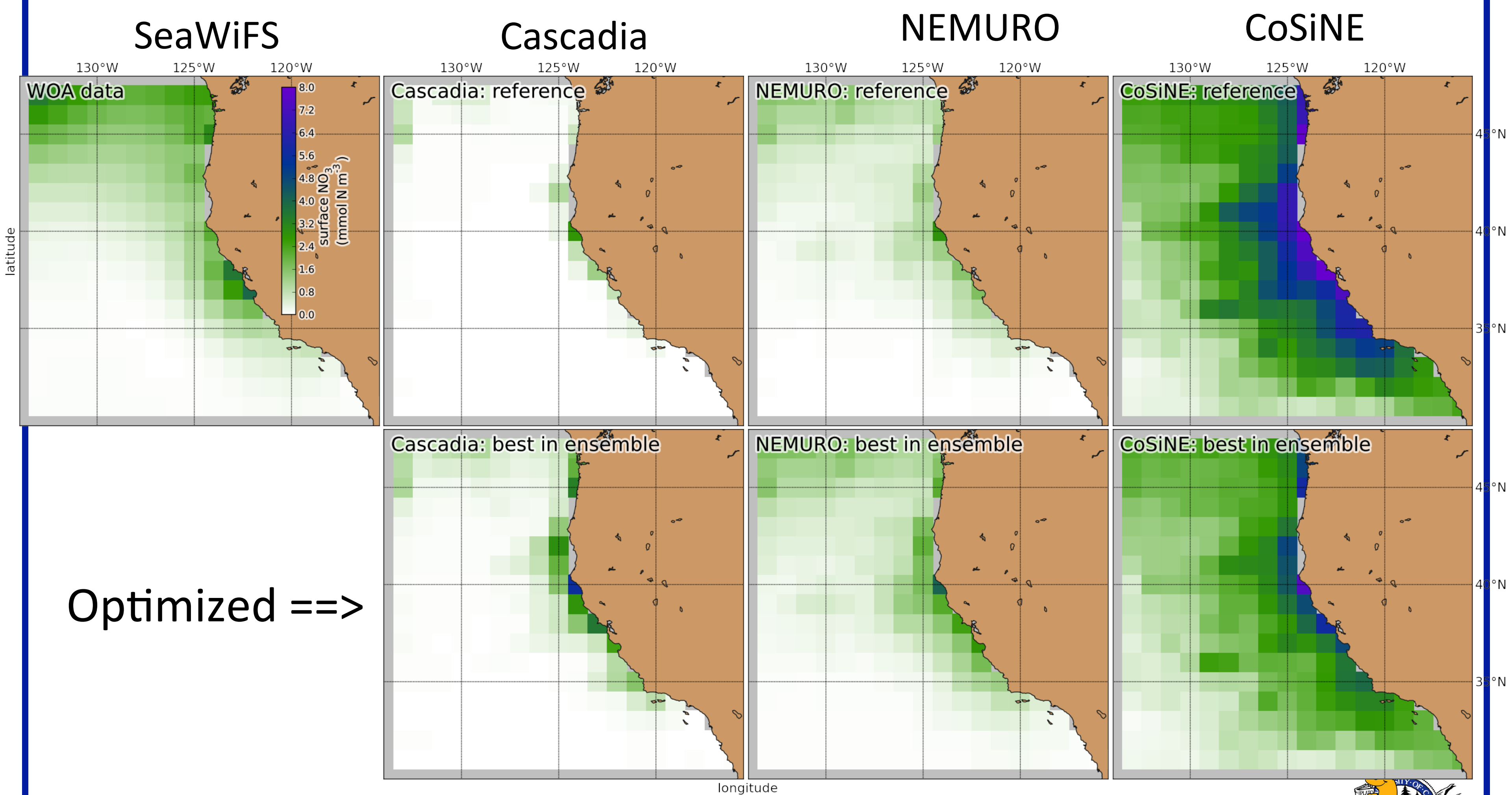
Annual Average performance, Surface Chlorophyll

SeaWiFS | Cascadia | NEMURO | CoSiNE

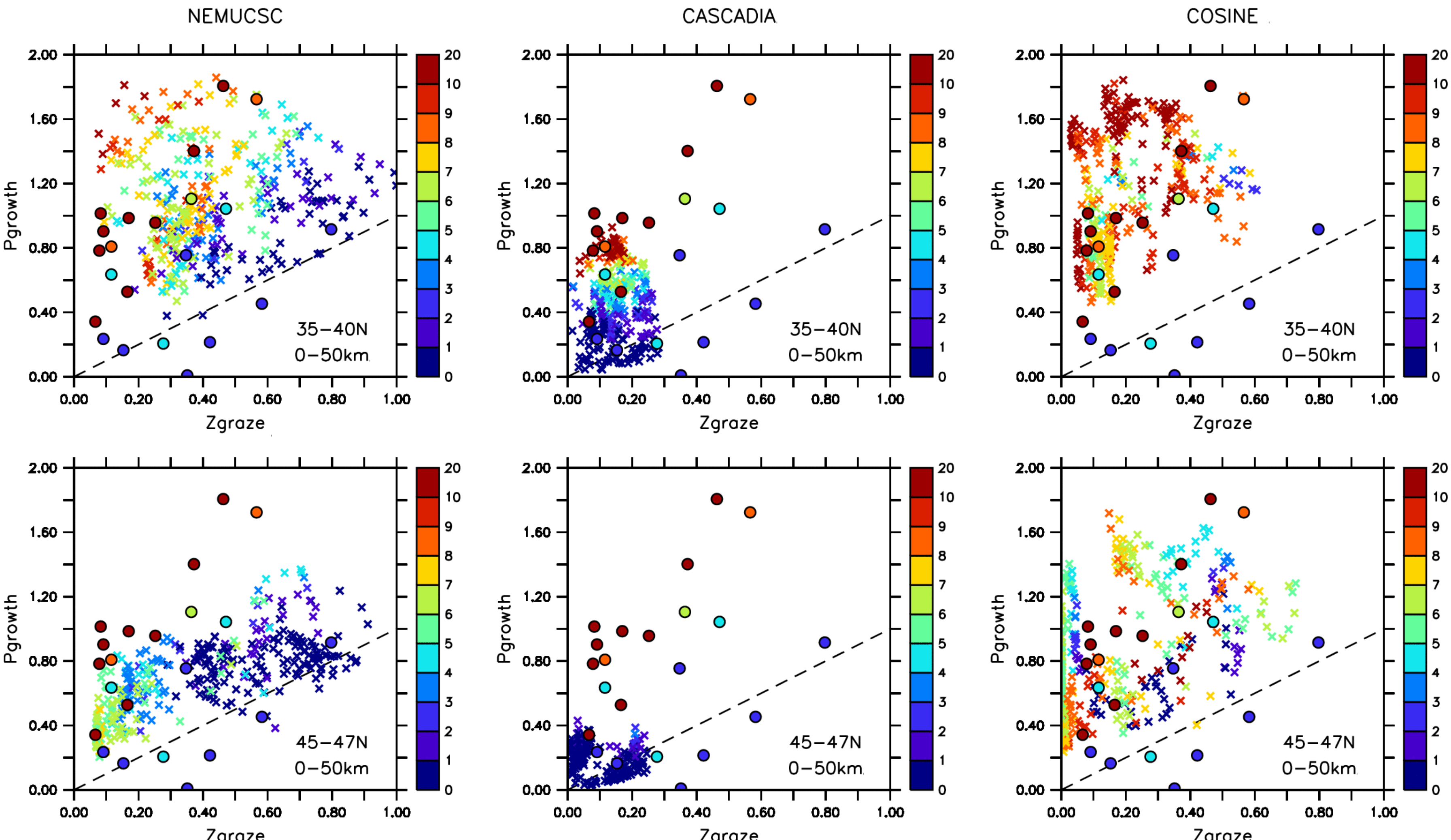


Optimized ==>

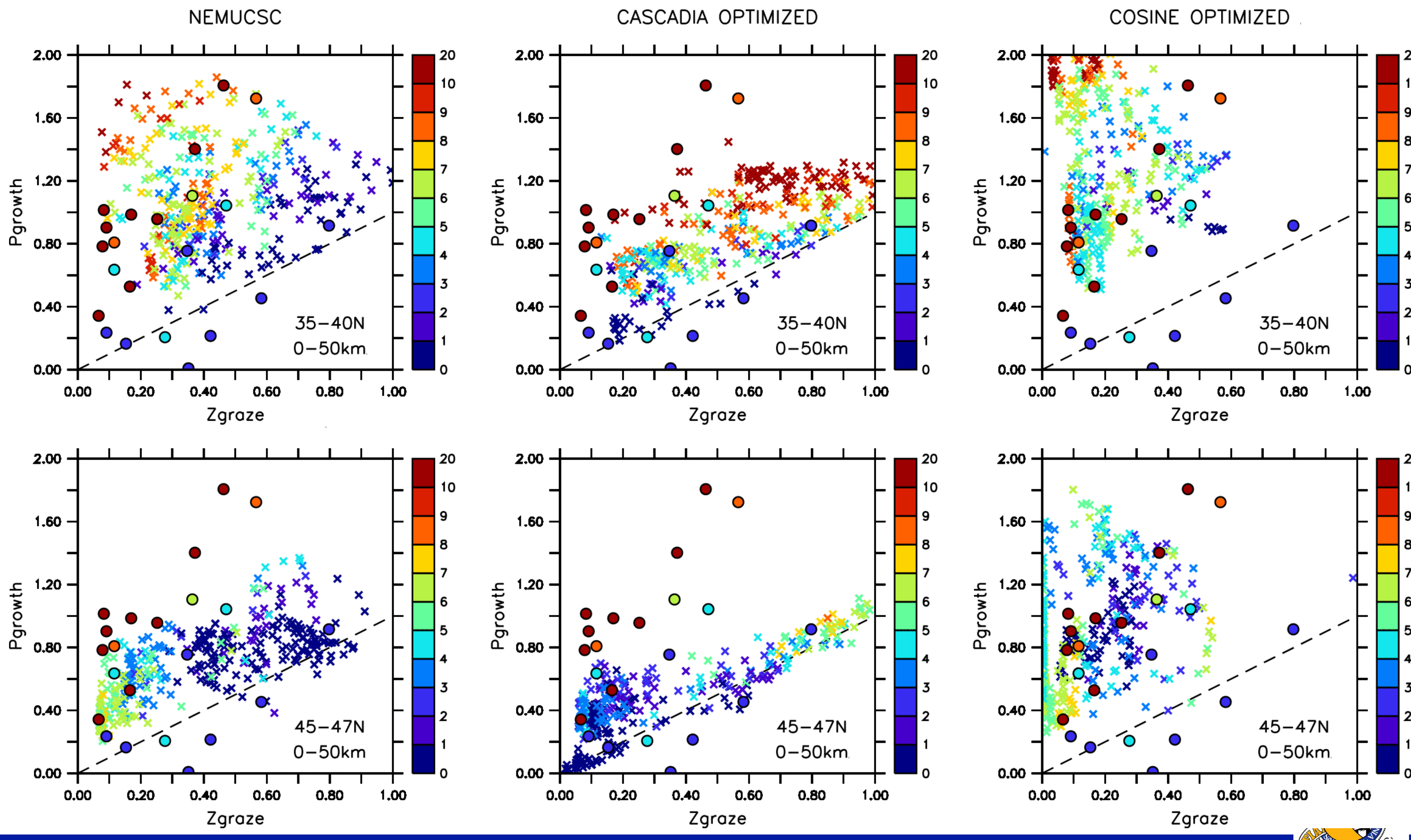
Average Annual Performance, Surface Nitrate



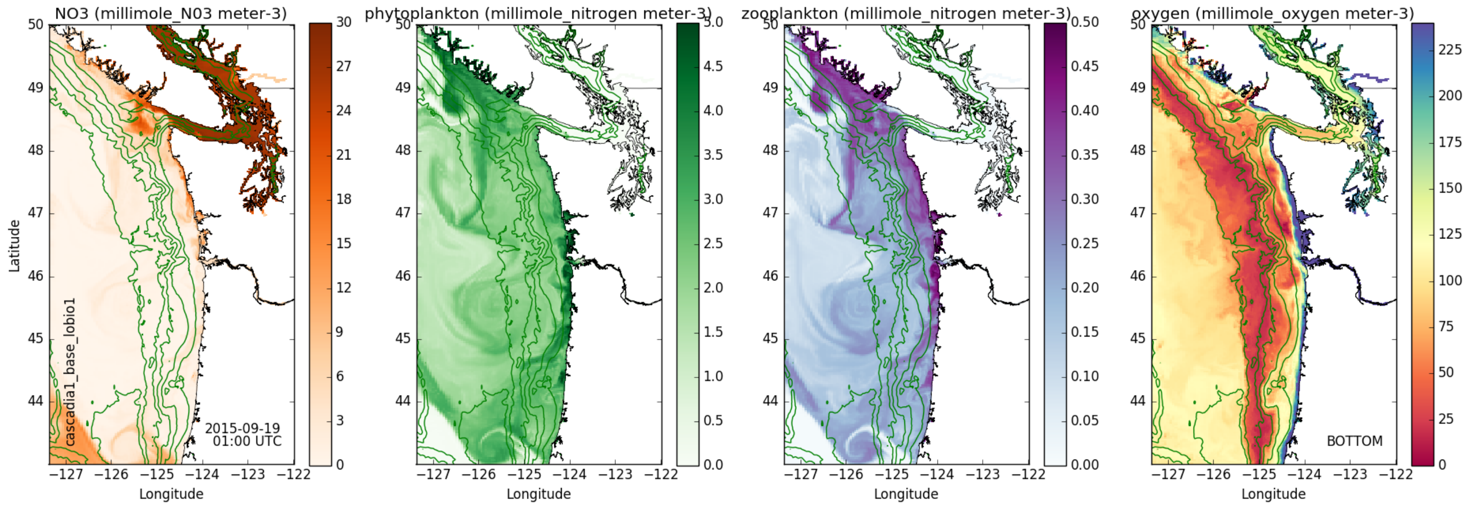
Rate process comparison (1 of 2)
Pgrowth/P vs Zgraze/P, models and observations together, Original parameters, Data from Banas et al. (2008)



Rate process comparison (2 of 2)
Pgrowth/P vs Zgraze/P, models and observations together
Optimized parameters, Data from Banas et al. (2008)

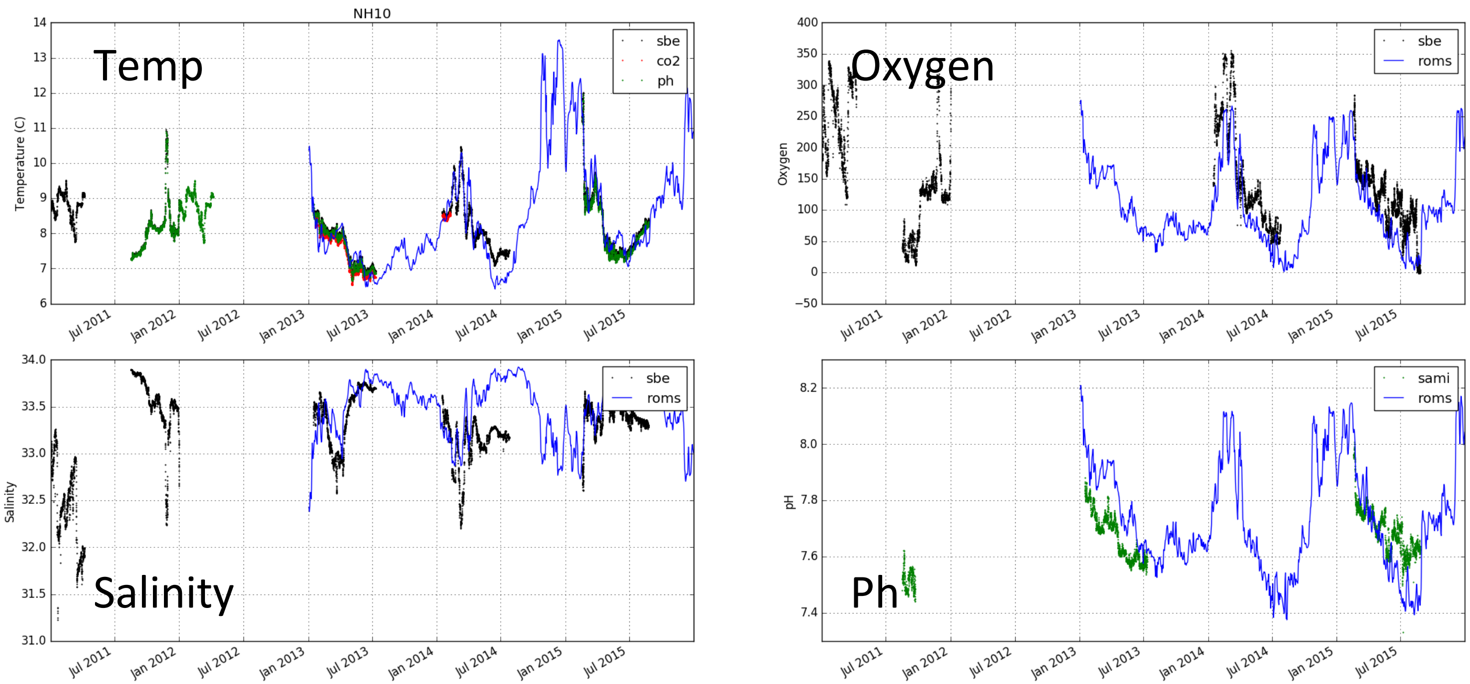


Cascadia is at presently used in UW forward model system



P. MacCready

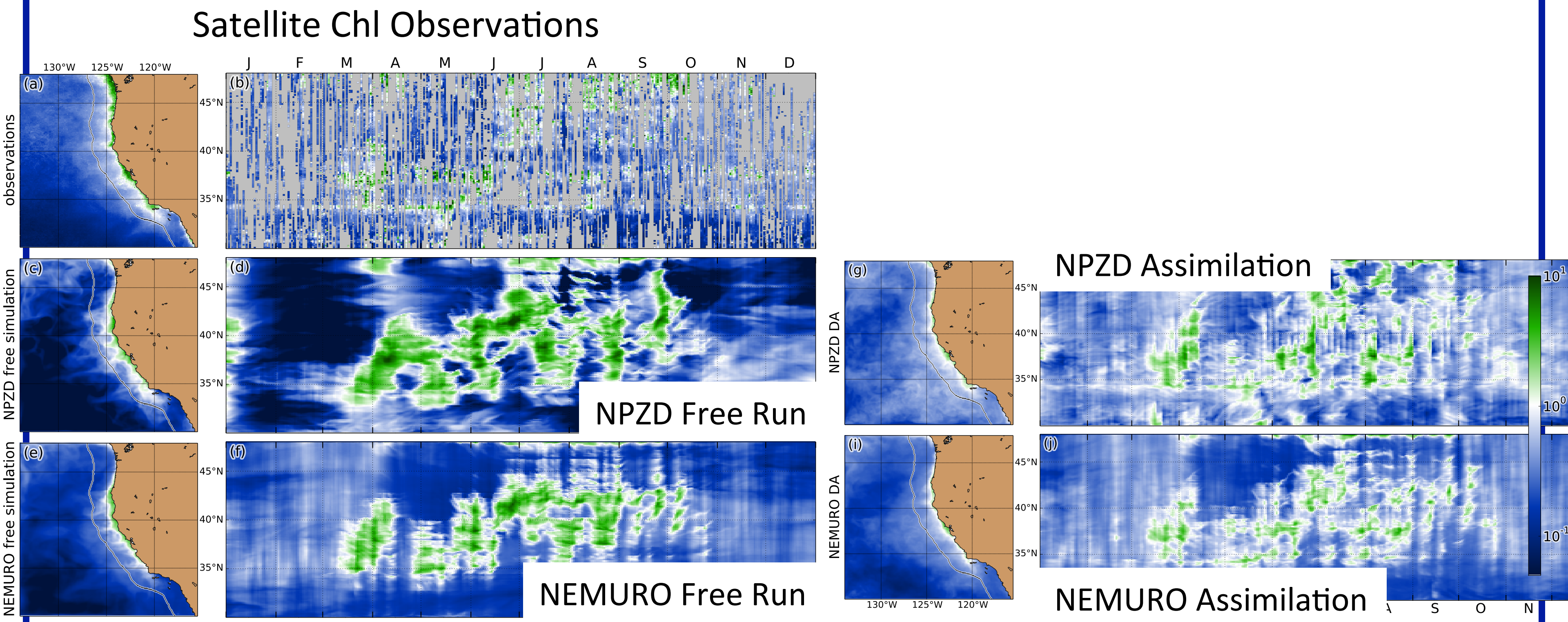
Performance of forward Cascadia run against Newport Time-series (2011-2015)



P. MacCready

Adjoint and Tangent linear models for both NPZD and NEMURO have been written and tested for 4D-Var Assimilation.

Evaluation for Year 2000



Song et al. (2015a,c), Mattern et al. (submitted)

Summary: Intercomparison of Cascadia, NEMURO and CoSiNE within UCSC CCS model

- State variables:
  - NEMURO has lowest RMS error against satellite-derived chl and climatological nitrate
  - CoSiNE leaves high nitrate near surface, cannot be removed through optimization
  - Cascadia arguably suffers in terms of state-variable metric due to only one phytoplankton

- Rate process investigation reveals
  - CoSiNE exhibits grazing-limited production, limiting nitrate uptake
  - NEMURO and Cascadia are more consistent with observations, showing a shift from high phytoplankton growth in nutrient-replete conditions, shifting to a growth/grazing balance in low nutrient conditions
  - NEMURO rate processes reasonably span range of available observations
  - Cascadia does not yield high phytoplankton growth portion found in observations

- Cascadia is functioning in non-data-assimilative mode at UW in hindcast and forecast studies.

- 4D-Var assimilation demonstrated for both NPZD and NEMURO.

Extra slides

In case people are curious about individual cost function components

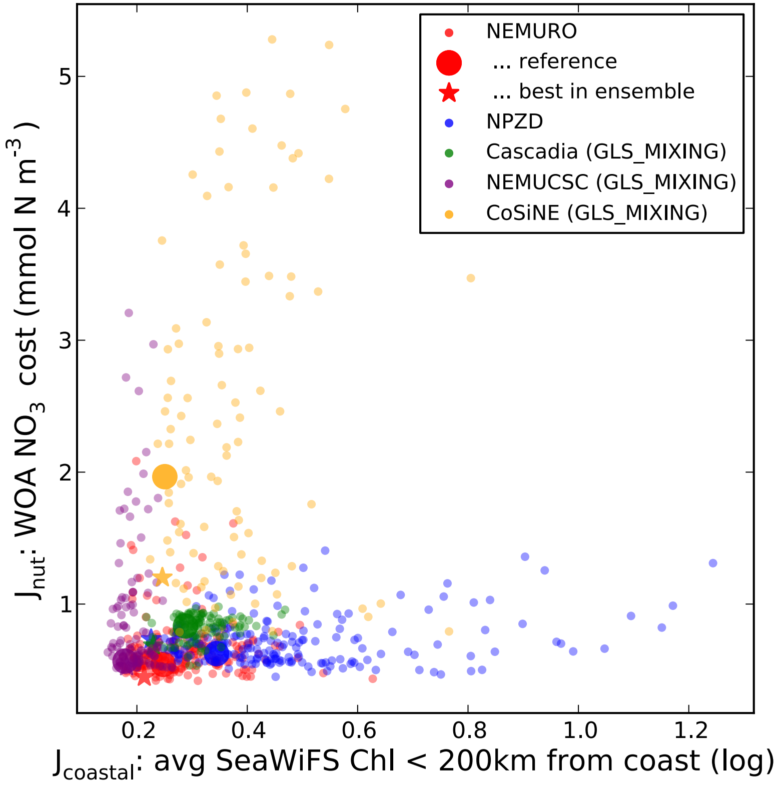
$$J_{nut}(\theta) = \frac{1}{4} \sum_{t \in \{\mathrm{JFM},\mathrm{AMJ},\mathrm{JAS},\mathrm{OND}\}} \frac{1}{2} \left(\frac{1}{n_t} \left| \sum_{i=1}^{n_t} \bar{m}_{i,t}^{\mathrm{NO_3}}(\theta) - \sum_{i=1}^{n_t} \bar{o}_{i,t}^{\mathrm{NO_3}} \right| + \sqrt{\frac{1}{n_t} \sum_{i=1}^{n_t} \left(\bar{m}_{i,t}^{\mathrm{NO_3}}(\theta) - \bar{o}_{i,t}^{\mathrm{NO_3}} \right)^2} \right)$$

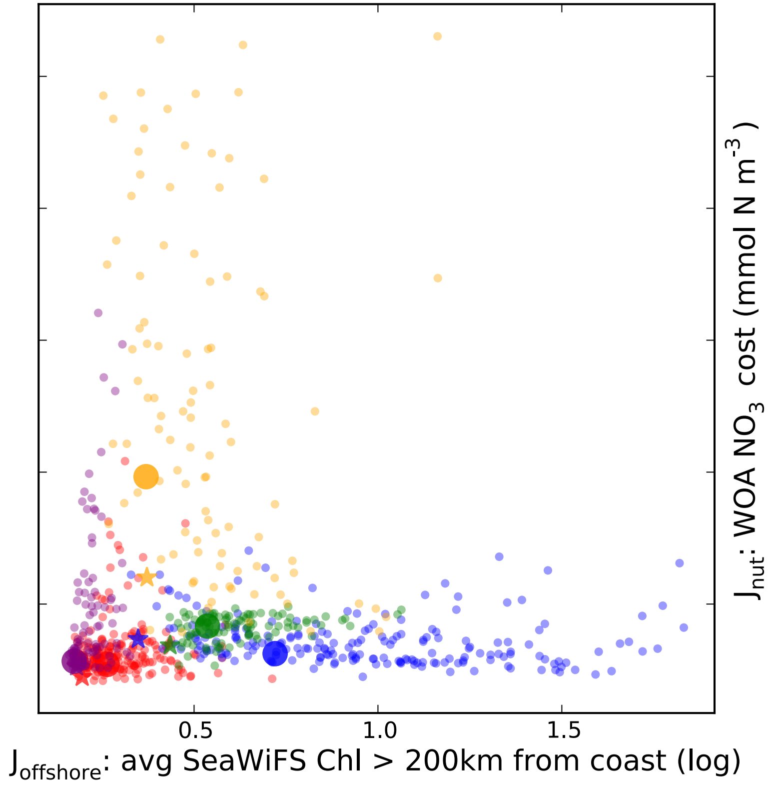
$$J_{\mathrm{coastal}}(\theta) = \sqrt{\frac{1}{\# G_{\mathrm{coastal}}} \sum_{x \in G_{\mathrm{coastal}}} \frac{1}{12} \sum_{t=1}^{12} \log \left(\bar{m}_{x,t}^{\mathrm{chl}}(\theta) / \bar{o}_{x,t}^{\mathrm{chl}} \right)^2}$$

$$J_{\mathrm{offshore}}(\theta) = \sqrt{\frac{1}{\# G_{\mathrm{offshore}}} \sum_{x \in G_{\mathrm{offshore}}} \frac{1}{12} \sum_{t=1}^{12} \log \left(\bar{m}_{x,t}^{\mathrm{chl}}(\theta) / \bar{o}_{x,t}^{\mathrm{chl}} \right)^2}$$

- Chlorophyll is in log-space and relative to satellite observations
- Nitrate is using seasonal and 1°x1° spatial averages relative to WOA

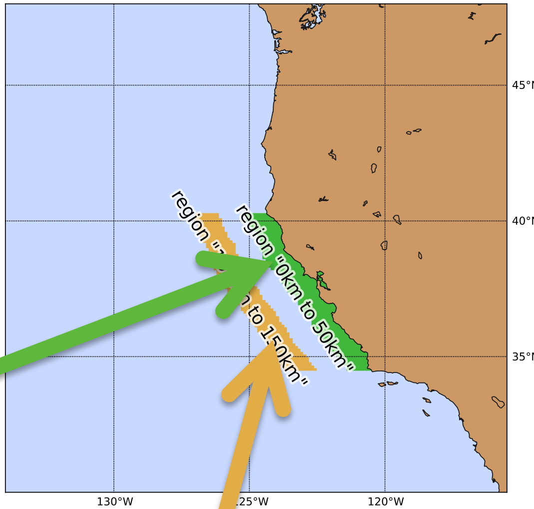
Cost-function scatterplots

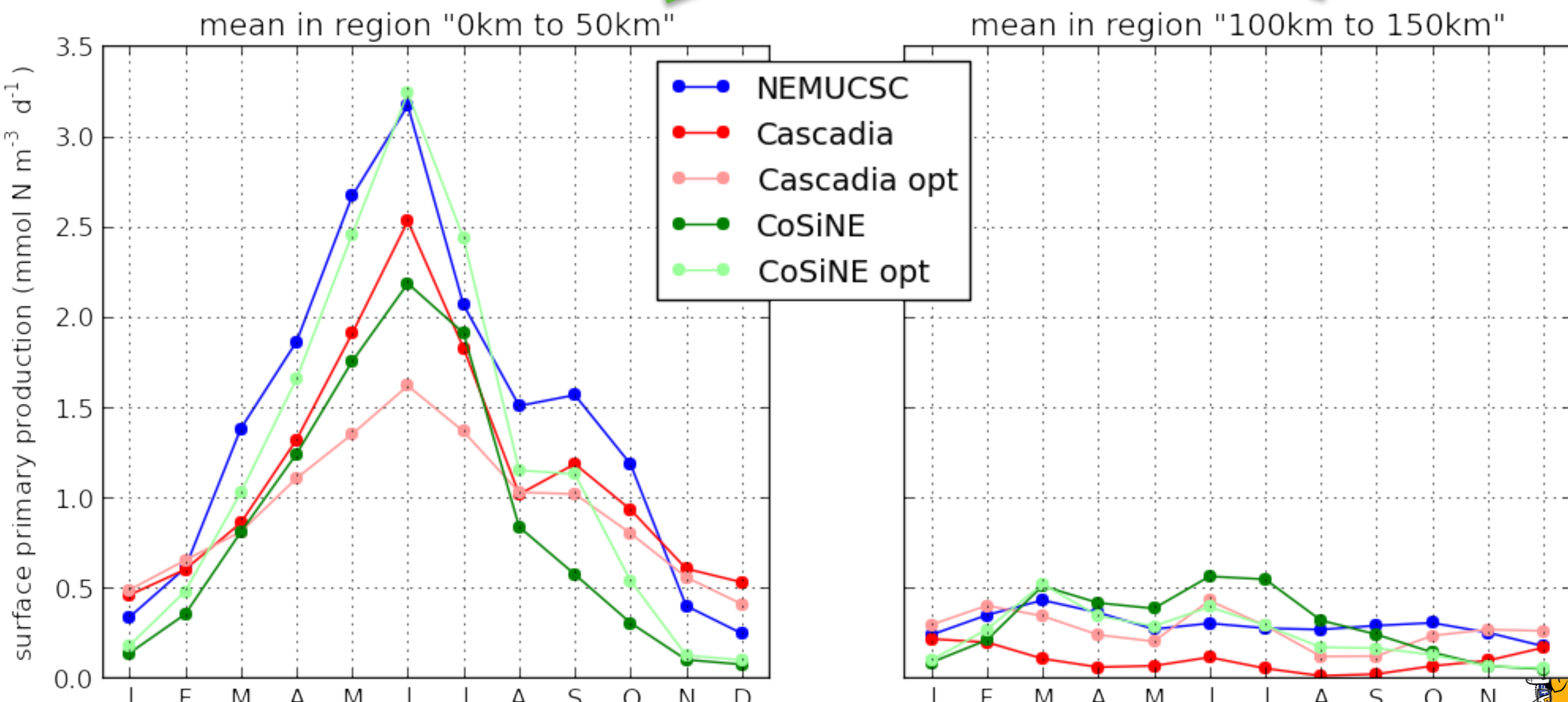




Climatological cycle of rate processes
Primary production

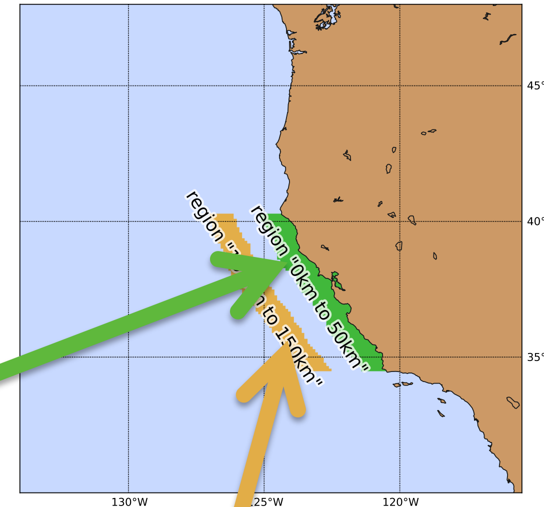
- Similar seasonal cycle of processes
- Magnitudes differ by factors 2-5 in different times of year and locations

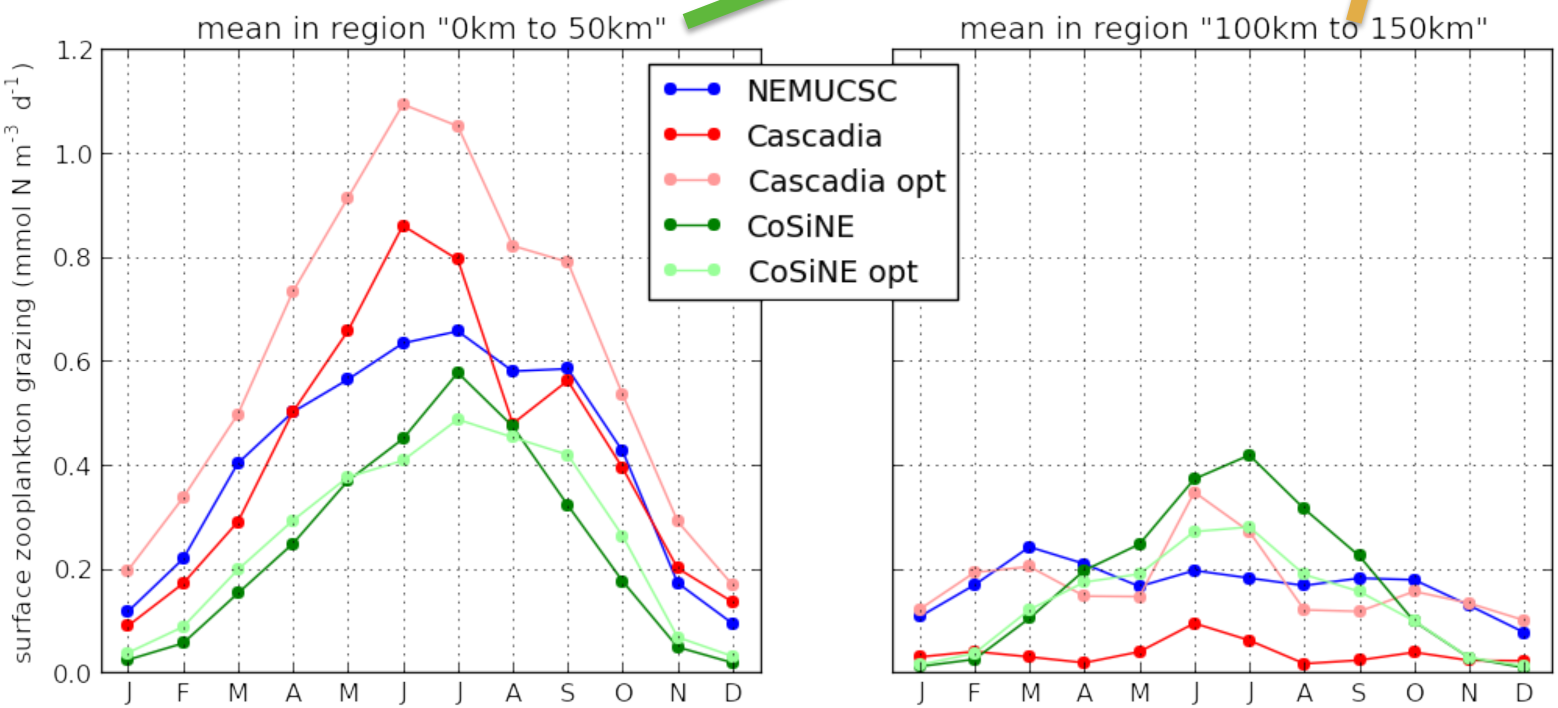




Climatological cycle of rate processes
Zooplankton grazing

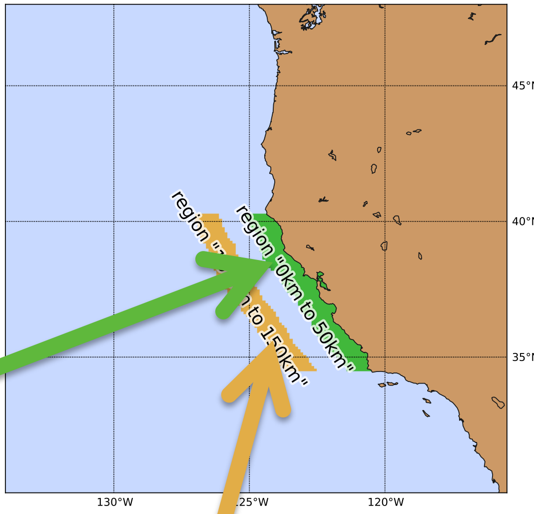
- Similar seasonal cycle of processes
- Magnitudes differ by factors 2-5 in different times of year and locations

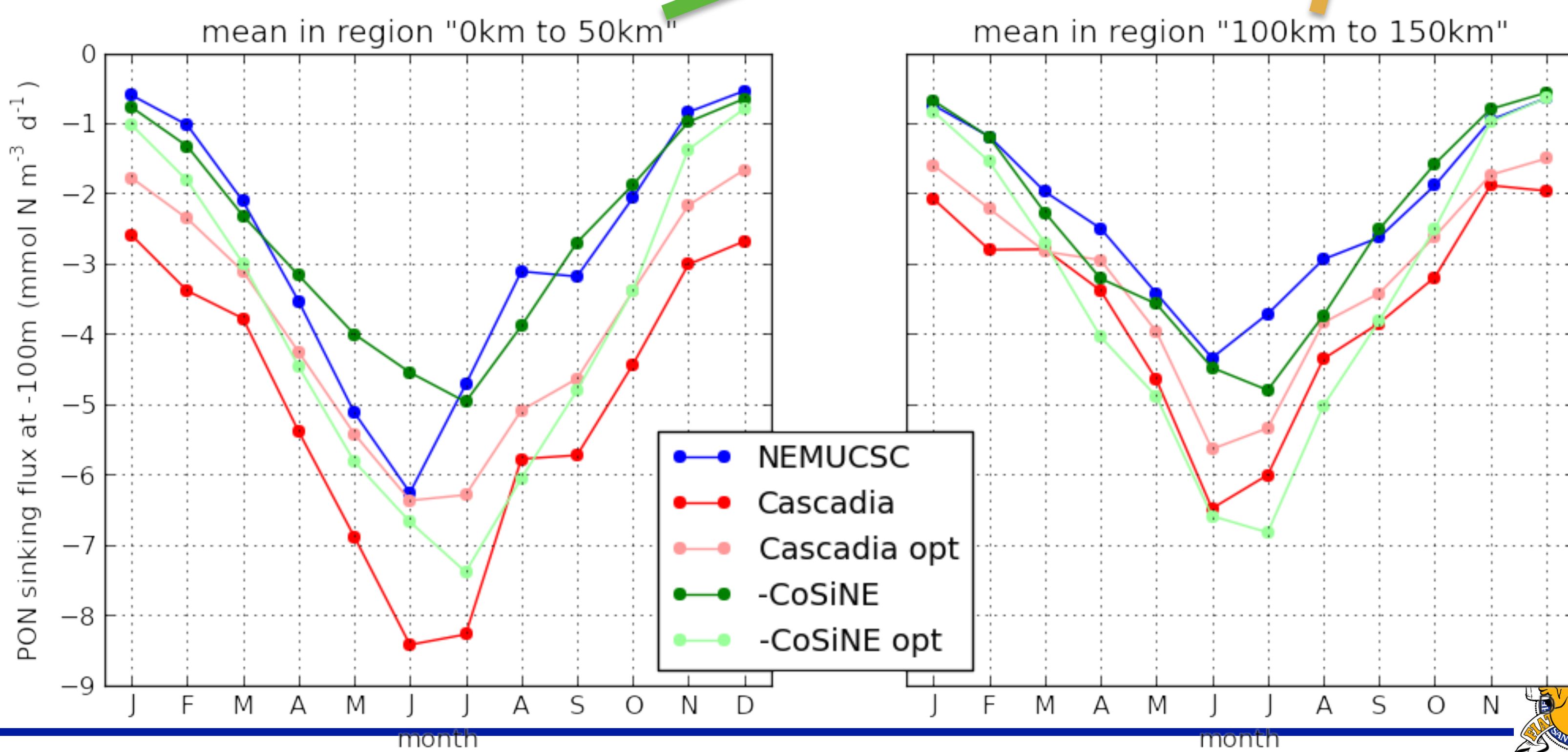




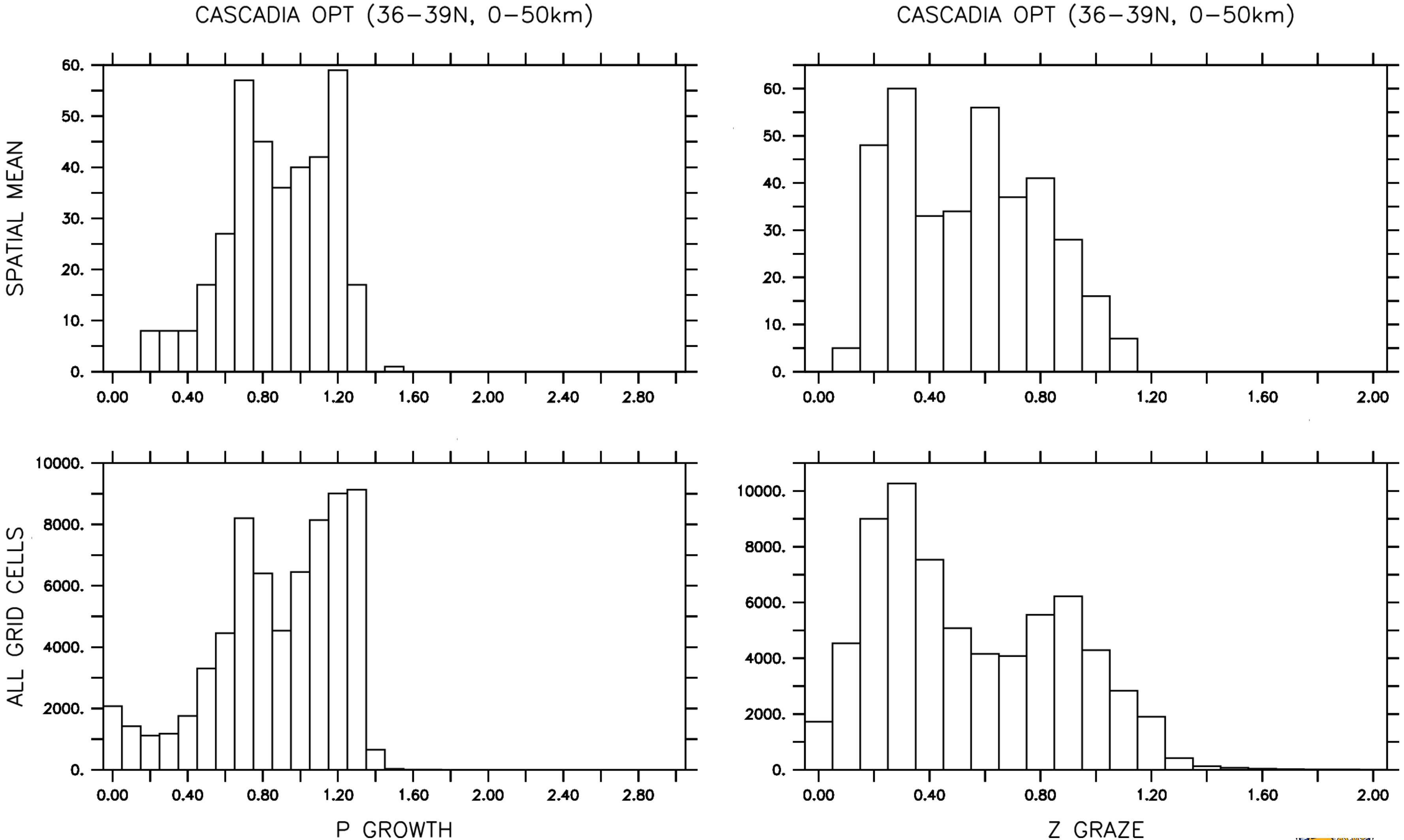
Climatological cycle of rate processes
Vertical export

- Similar seasonal cycle of processes
- Magnitudes differ by factors 2-5 in different times of year and locations

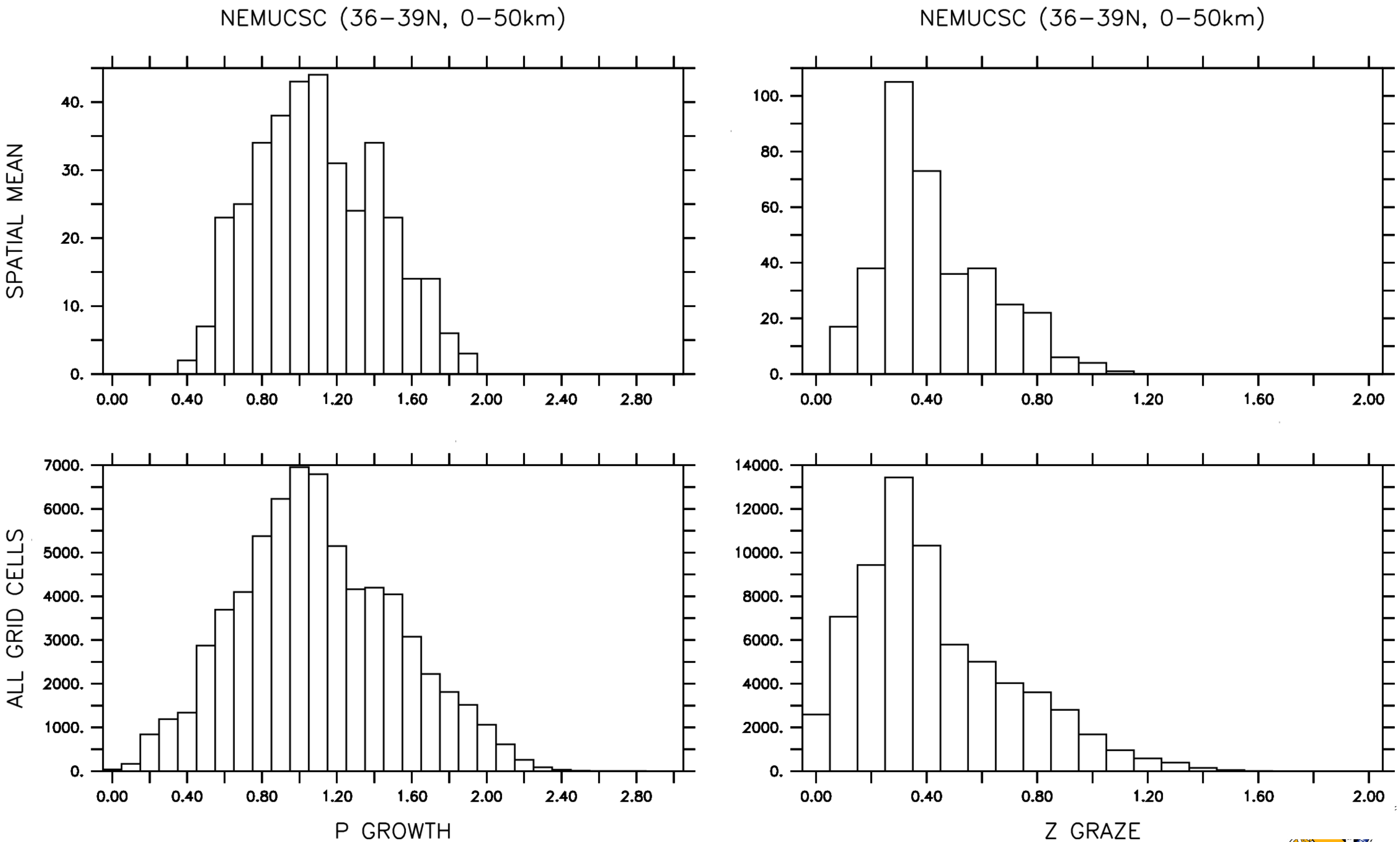




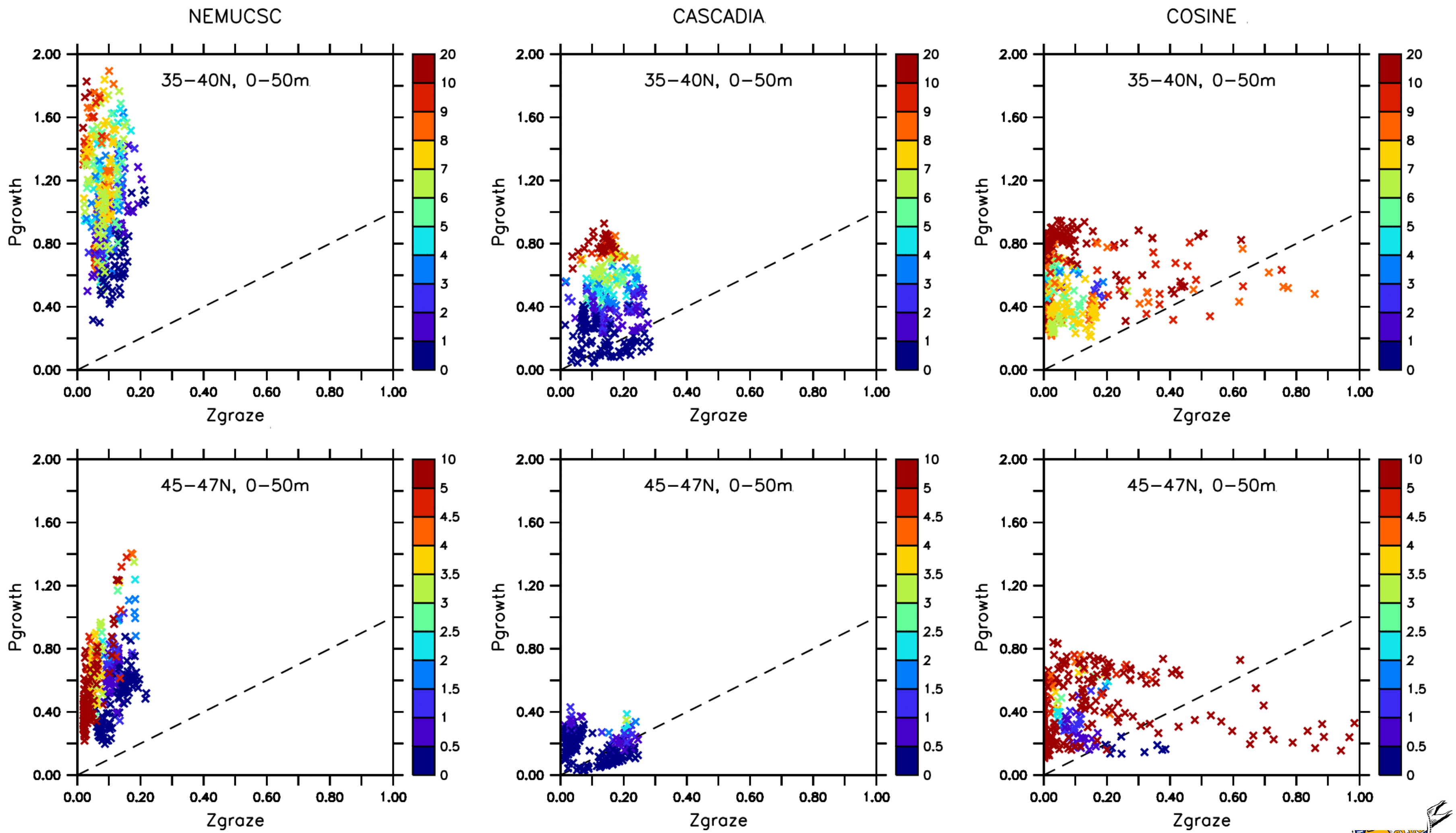
NPZD rate statistics
Spatial mean vs. every point



NEMURO rate statistics
Spatial mean vs. every point



Rate process comparison (3 of 3)
Diatoms only



Evaluation of rate processes against observations (sorry, must flip axes)

- Dilution experiments from Oregon (E. Lessard) suggests that region experiences specific growth and grazing rates mostly between 0 and 1 /d.
- This suggests that NEMURO (and optimized Cascadia) exhibit somewhat higher rates than measured.
- Must be added to constrain optimization.

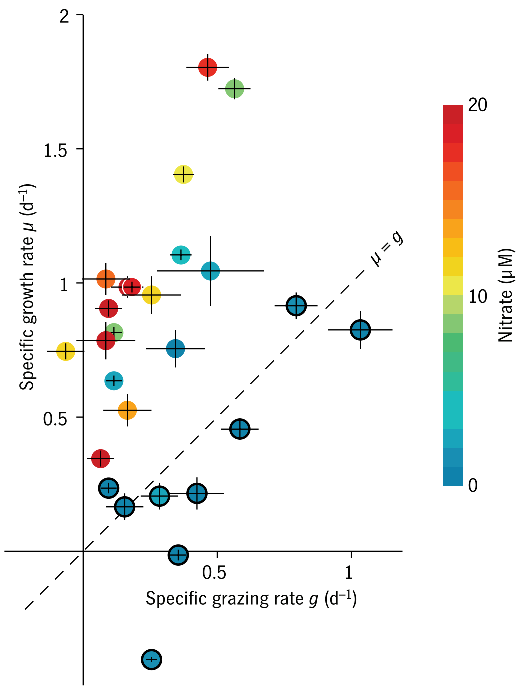
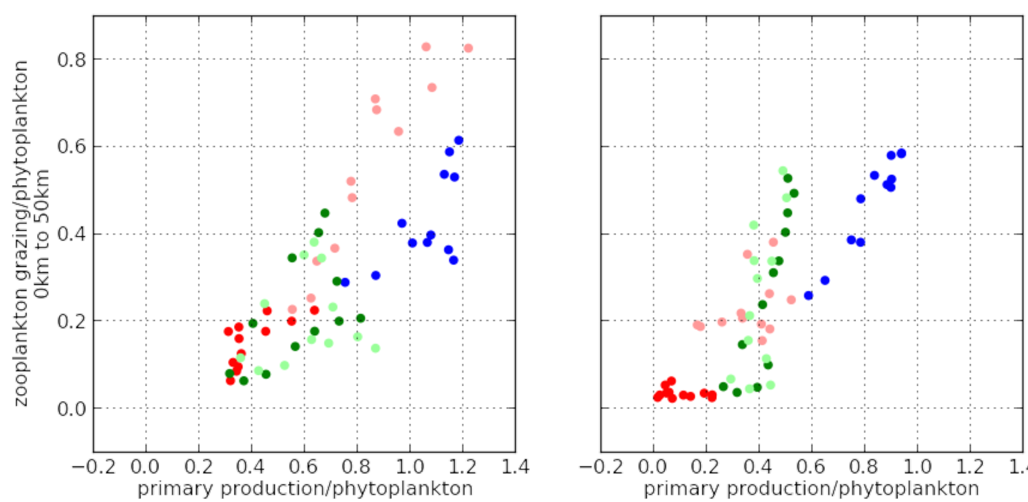


Figure 2. Overview of results from dilution experiments used in this study. Each point represents one experiment. Low-nutrient, near-equilibrium points used to diagnose zooplankton rate parameters are marked with black circles. Standard errors are indicated with vertical and horizontal bars.



Banas et al. (2009)

Climatological cycle of rate processes
Primary production versus grazing

- Total grazing and production between models (not shown) does not look that different (overall magnitudes vary between factor of 2-5, but along straight lines showing that growth and grazing vary proportionally to one another).

- When normalized by phytoplankton concentration (shown), differences between models are more clear.
- NEMURO is high growth/high grazing Cascadia is low growth/low grazing
- Optimization shifts Cascadia toward the NEMURO dynamics (red->pink)
- As nutrients diminish (offshore) CoSiNE shows low growth (but still high grazing), which is the cause for the high nutrients left at the surface in CoSiNE simulations.