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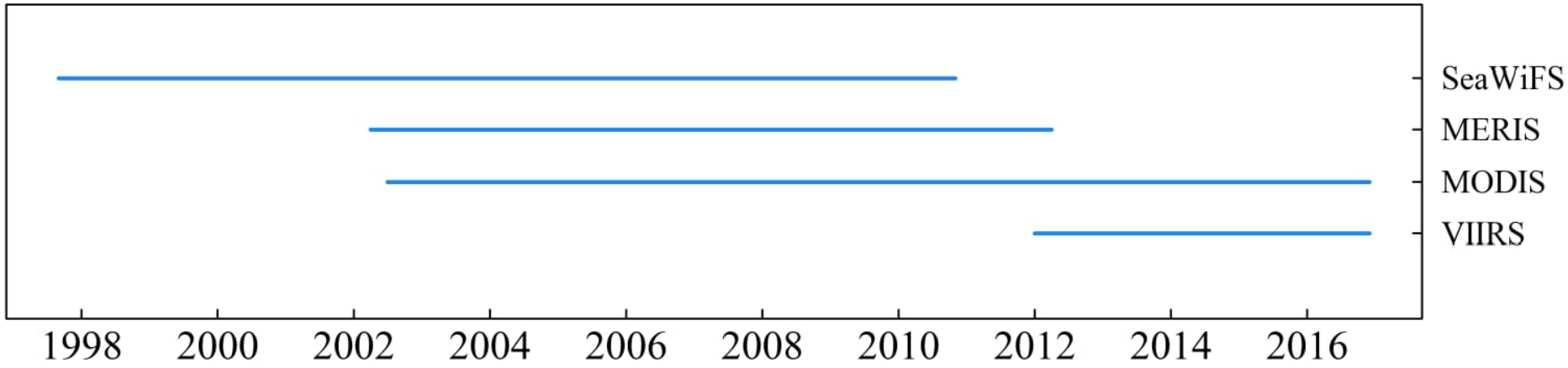
Long-Term Trends in Ocean Chlorophyll: Update from a Bayesian Hierarchical Space-Time Model

Matthew Hammond, Claudie Beaulieu, Stephanie Henson, & Sujit Sahu

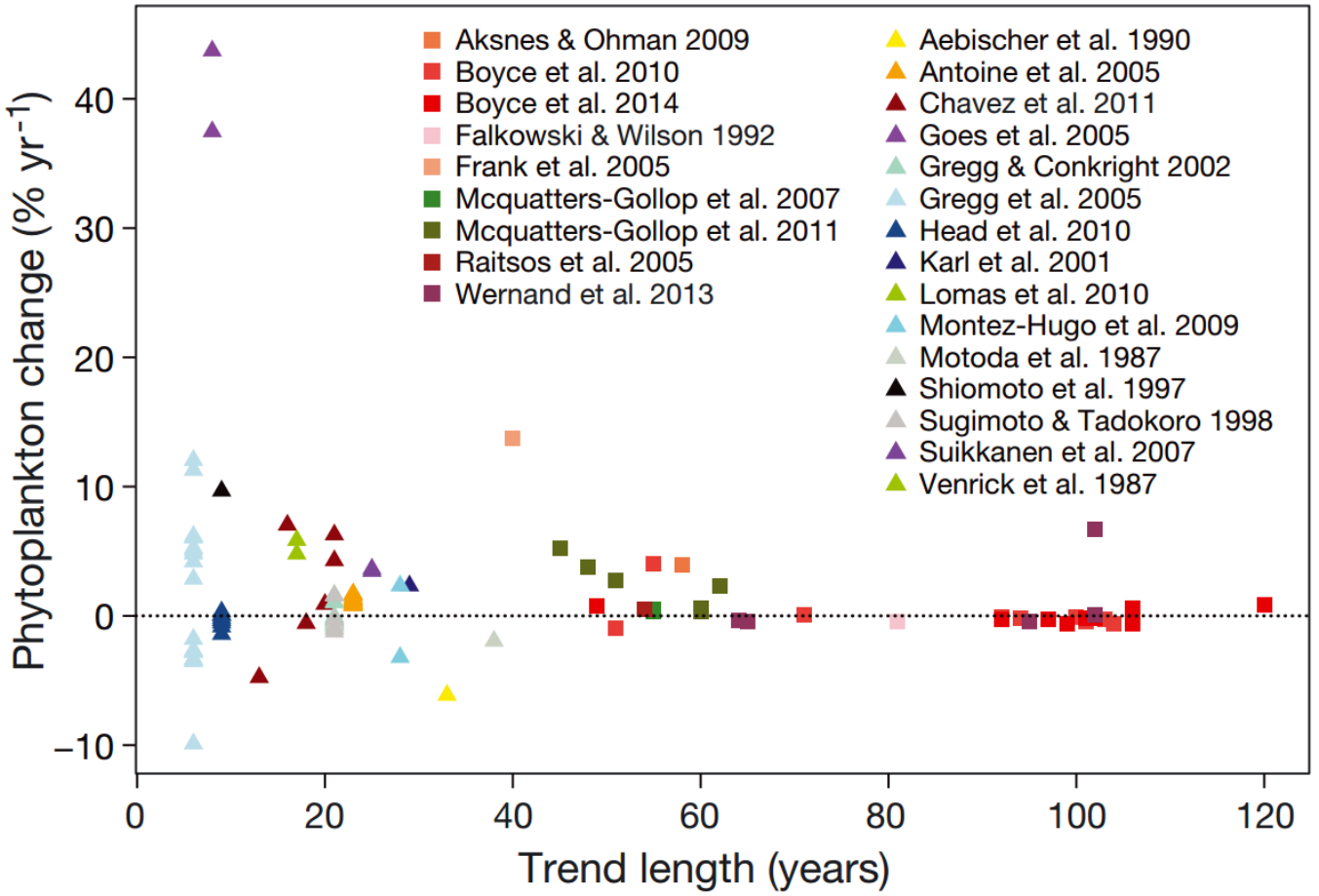
Ocean Colour

- Phytoplankton are responsible for ~50% total biospheric production
- Chlorophyll is a phytoplankton pigment that can be remotely sensed
  - Thus is listed as an essential climate variable (Bojinski et al., 2014)
- Continuous satellite ocean colour record ~22 years



Phytoplankton Trend Studies

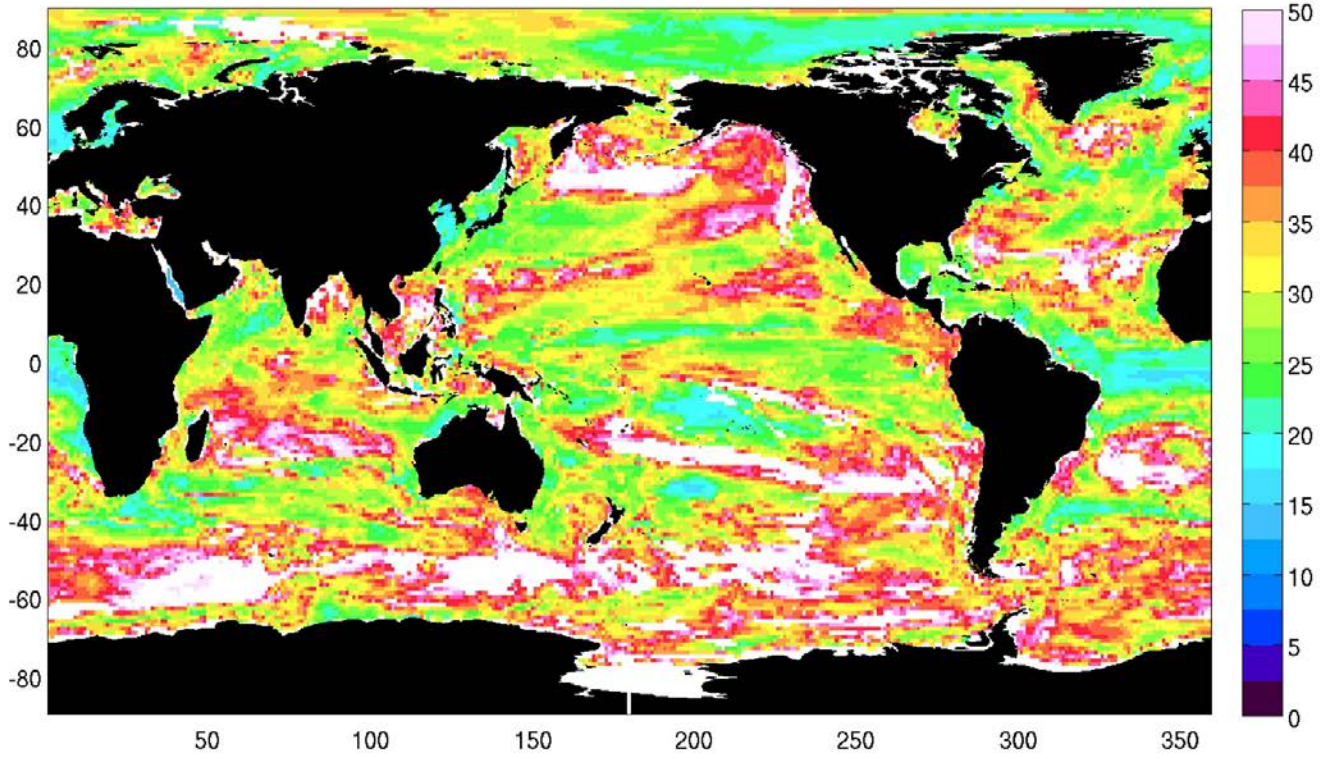
- There are conflicting trends in observational studies
- Arising due to
  - Differences in technique
  - Short record length
  - Large interannual variability



Boyce & Worm (2015)

Ocean Colour Trend Studies

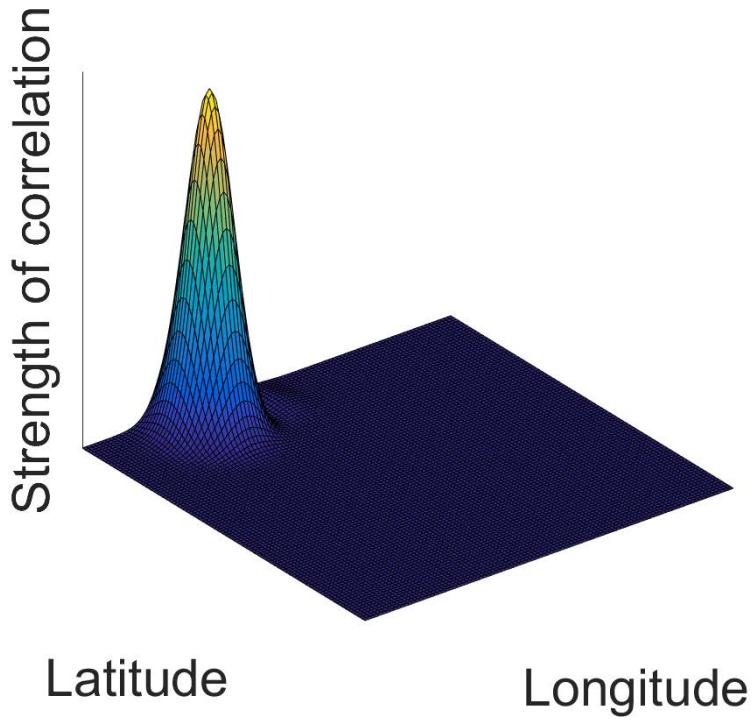
- Studies suggest average of ~32 years of record required
  - Albeit region dependent
- Although this uses a linear regression technique



Henson et al. (2016)

Limitations of Previous Studies

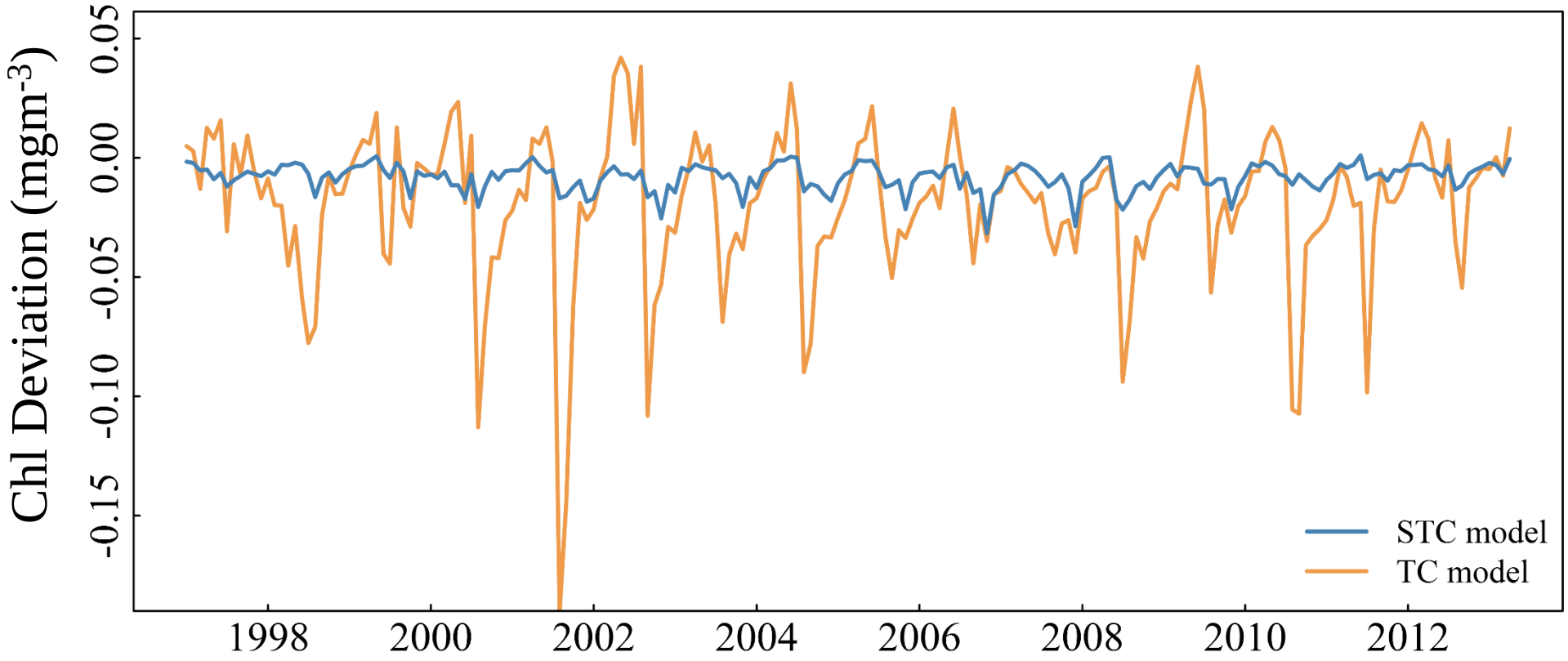
- Linear regression approach considers individual grid cells independently
- Incorporating spatial correlation should improve ability to detect trends
- We also use a Bayesian framework so we can quantify uncertainty



Spatio-Temporal Model

- 3 level hierarchical model
  - Data level
  - Process level: Regression coefficients, Temporal and Spatial Correlation
  - Prior level: Uninformative - as preliminary
- 2 models to show effects of spatial correlation
- ESA OC-CCI v3.1 dataset
- Trend determined in individual Longhurst regions

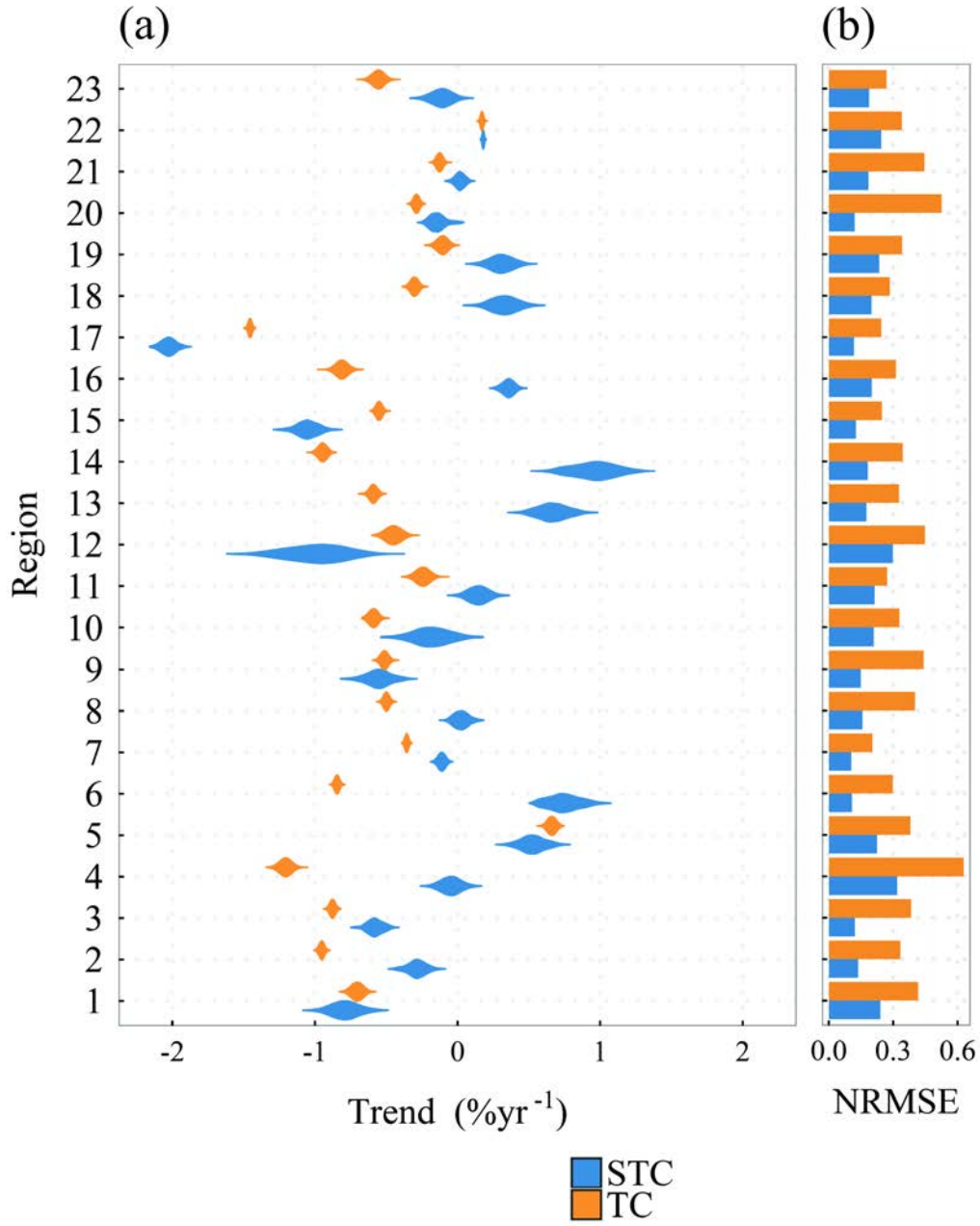
Initial Model Comparison



Hammond et al. (2017)

Model Comparison

- Spatial correlation consistently leads to improved accuracy
- Up to 2 %yr^{-1} difference between the models
- Including spatial correlation leads to realistic assessment of uncertainty



Hammond et al. (2017)

Model Information as Prior

- Biogechemical models can compensate for the shortness of the observed record

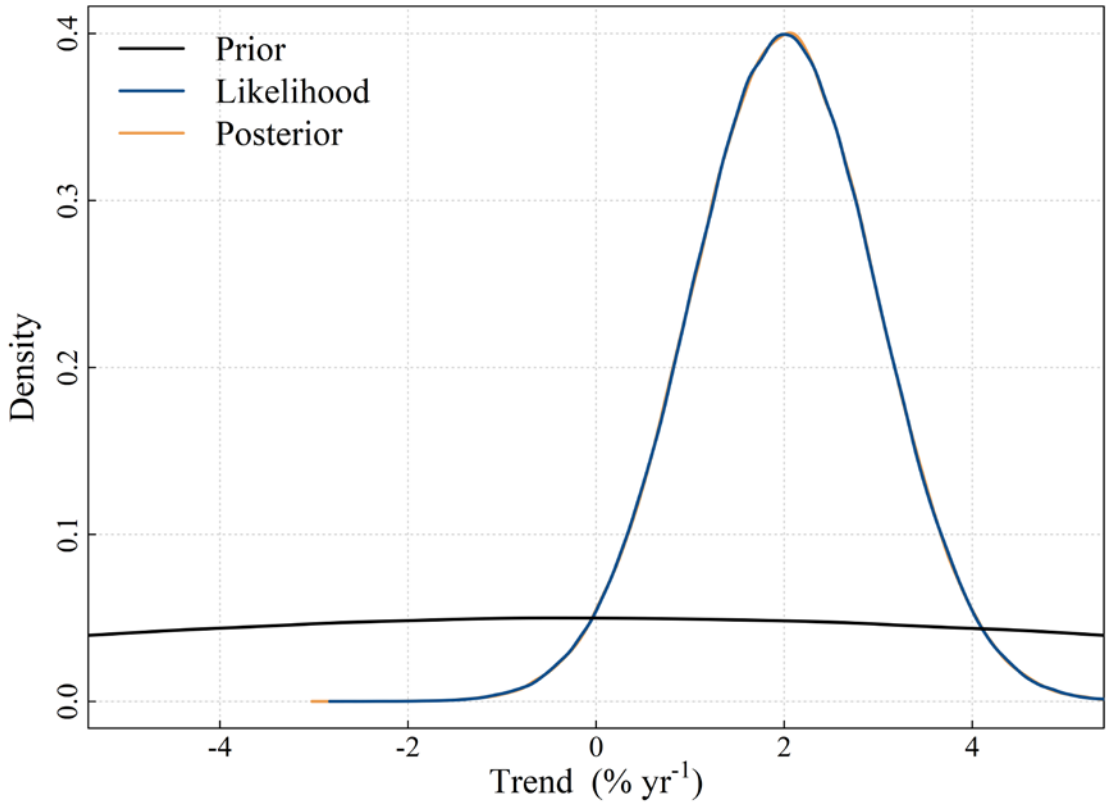
- We use information from the analysis of CMIP5 models
  - 14 Models
  - Up to 6 ensembles per model
  - Period covering 1997-2039 combining RCP 8.5 and historical scenarios

- We analyse trends in each model and ensemble to get a multi-model mean and variance

- This is then incorporated into our model as an informative Bayesian prior

Bayesian Inference

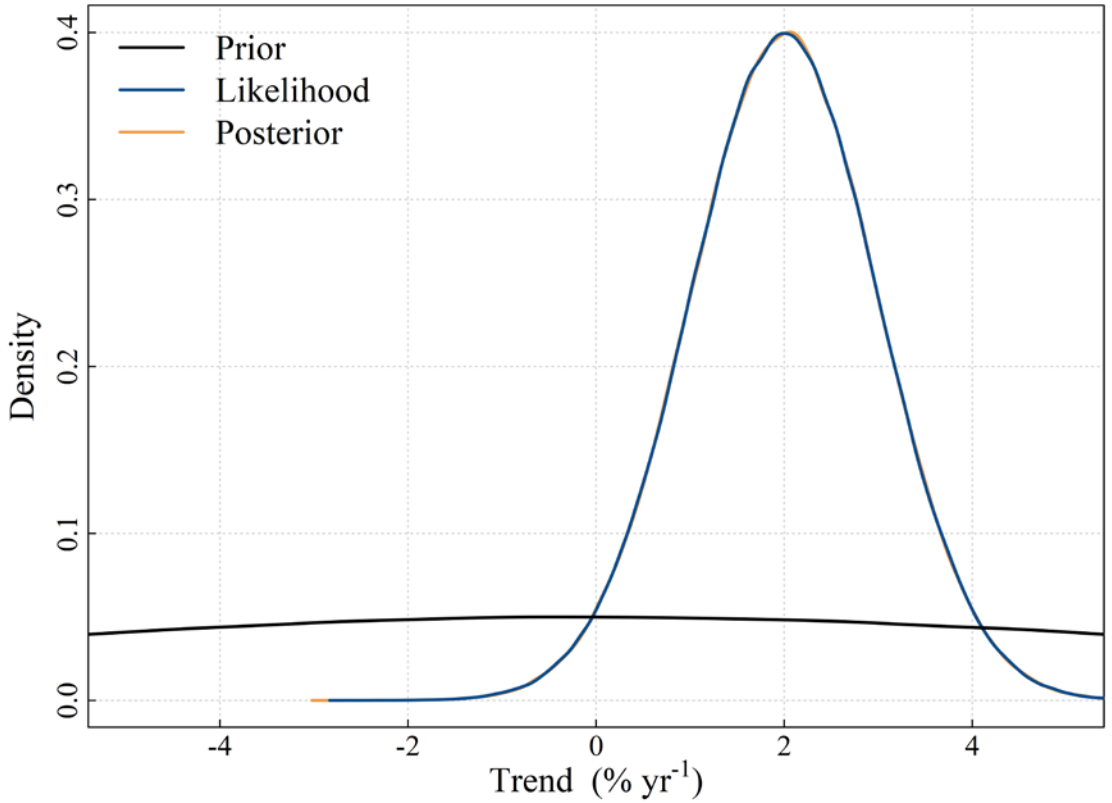
Vague Prior



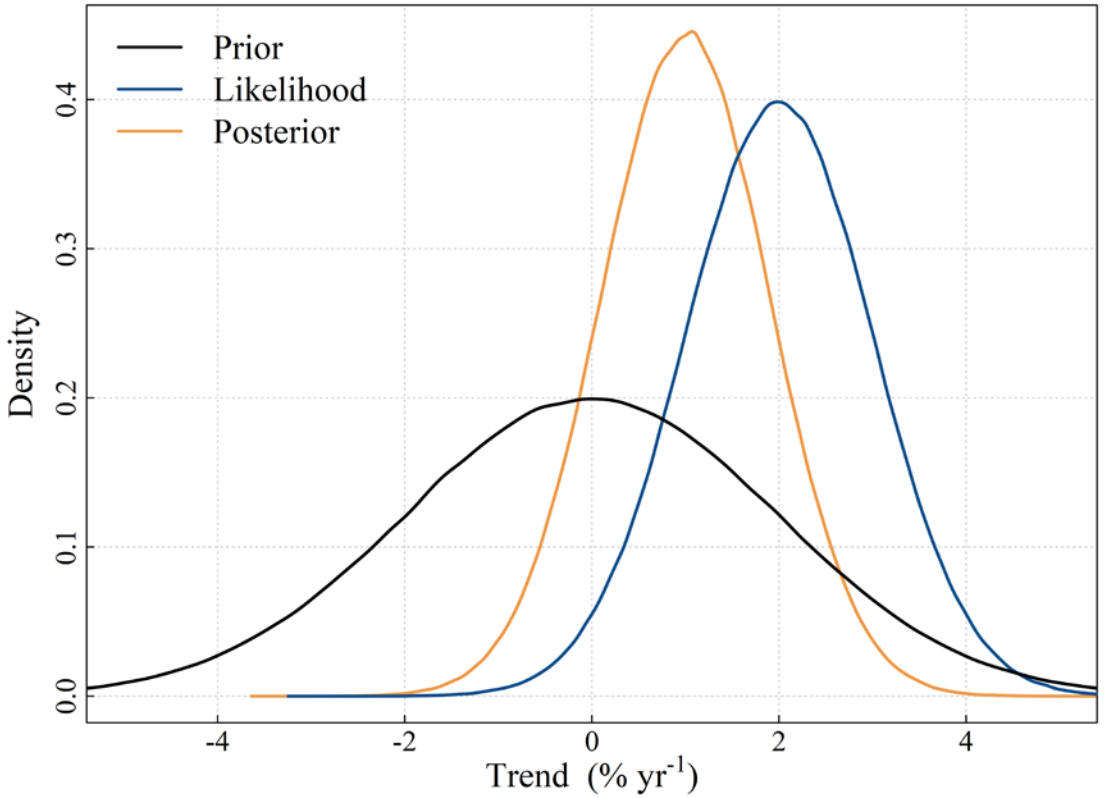
$$Posterior \propto Likelihood \times Prior$$

Bayesian Inference

Vague Prior



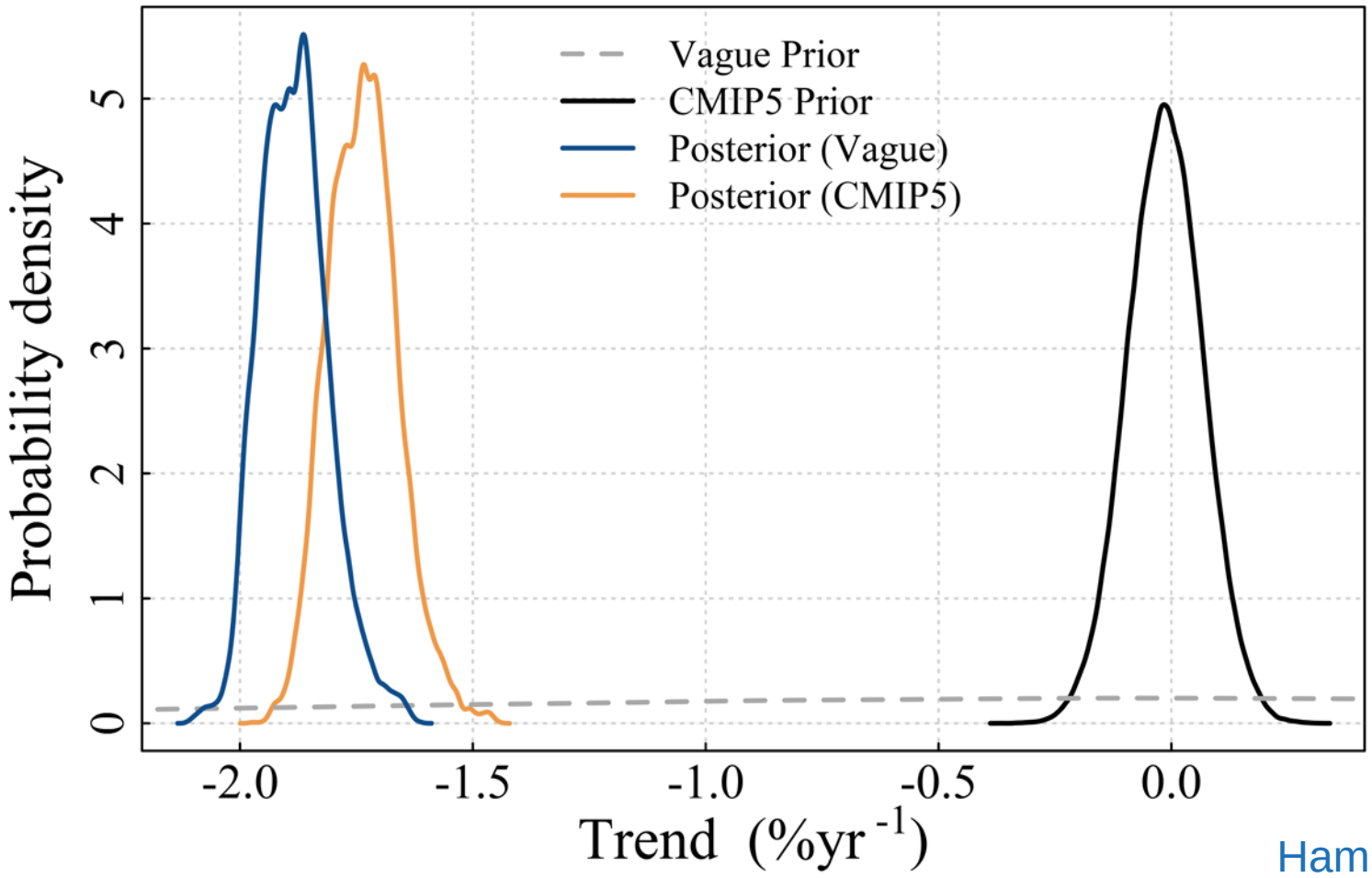
Specific Prior



$$Posterior \propto Likelihood \times Prior$$

Impact of Priors

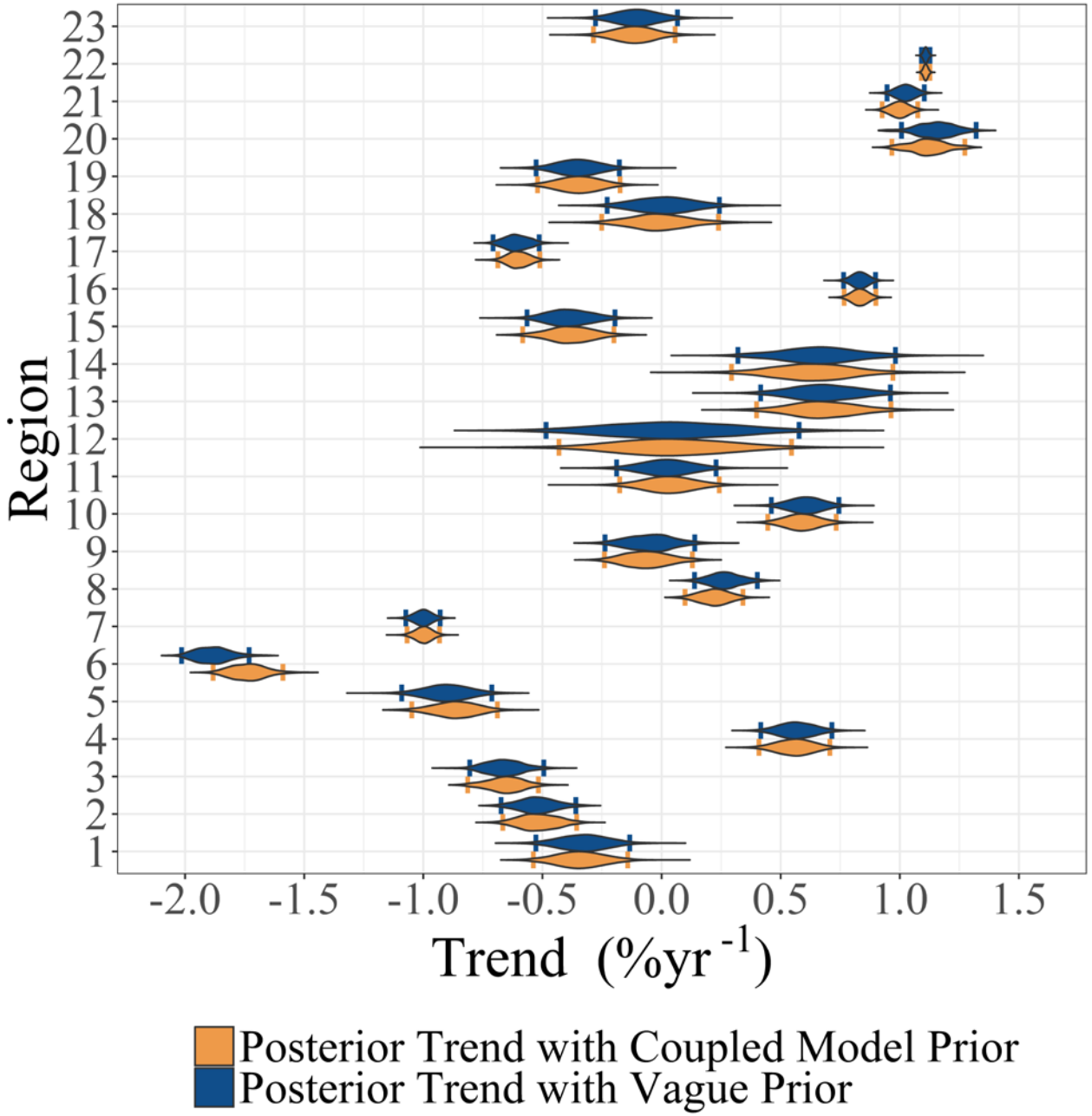
North Pacific Tropical Gyre Province



Hammond et al. (In Review)

Impact of Priors

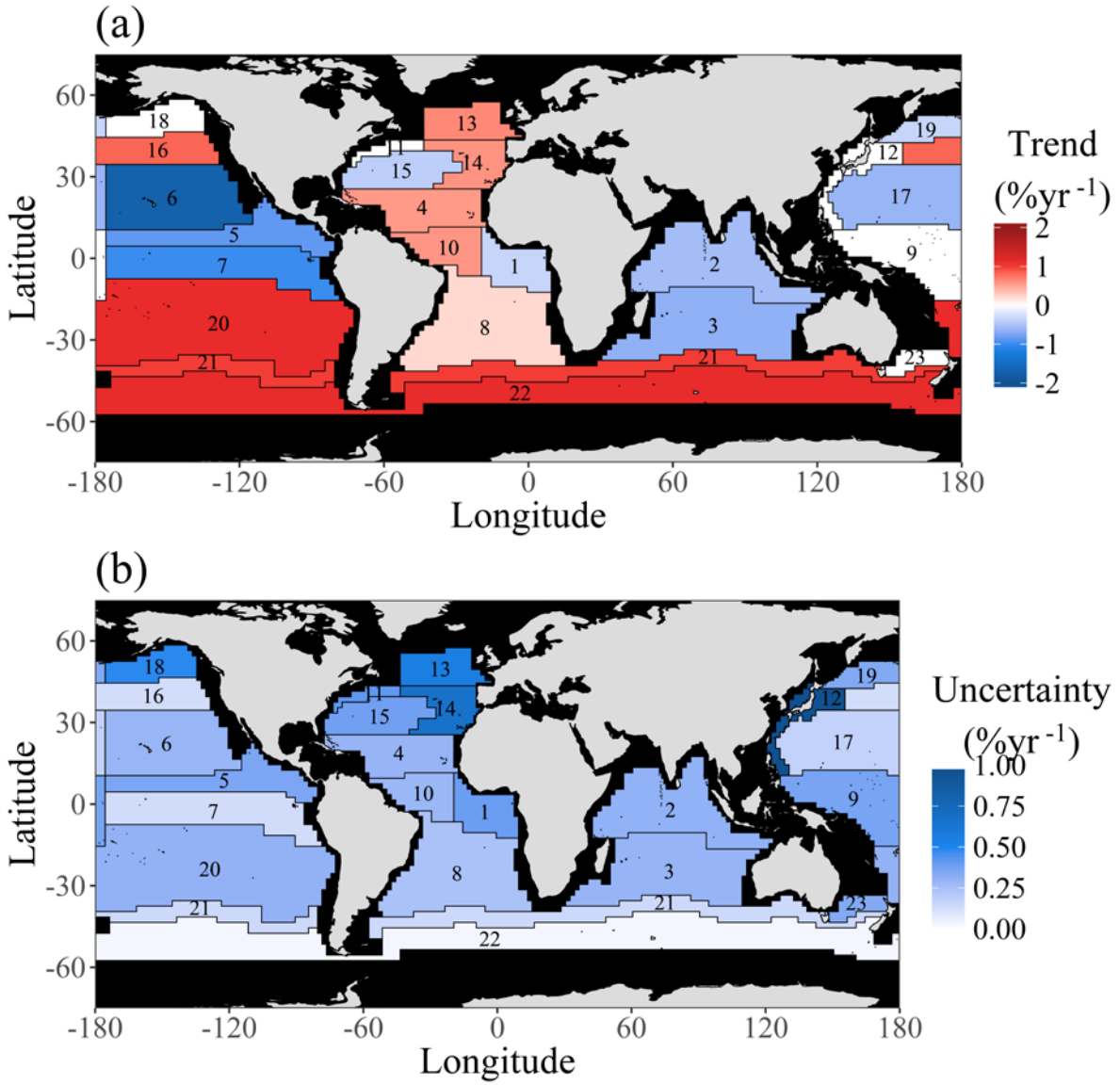
- Slight reduction in uncertainty in the majority of regions
  - 15/23 regions
- General biasing effect towards zero
- Effect in most cases fairly small
  - Large range of model projections?
  - Priors for other parameters?



Hammond et al. (In Review)

Global Outlook

- Trends generally positive in the Southern Ocean and Atlantic
  - Up to 1.5%yr^{-1}
- Global average small net positive trend
  - 0.08 %yr^{-1}
- Most uncertainty in trend estimates in the North Atlantic and Kuroshio Current regions



Hammond et al. (In Review)

Conclusions

- We find greatly improved accuracy in estimating chl trends when using spatial correlation terms

- Using prior information from CMIP5 models helps to constrain trends and their uncertainties, particularly important while the observational record is still short

- The statistical model used here provides a robust framework for incorporating all available information and can be applied to improve understanding of global change in a range of key climate variables

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Thank you

Hammond, Beaulieu, Sahu, and Henson. (2017) - "*Assessing Trends and Uncertainties in Satellite-Era Ocean Chlorophyll Using Space-Time Modeling*". Global Biogeochemical Cycles.

Hammond, Beaulieu, Henson, and Sahu. (2018) – "*Assessing the presence of discontinuities in the ocean color satellite record and their effects on chlorophyll trends and their uncertainties".* Geophysical Research Letters.

Hammond, Beaulieu, Henson, and Sahu. (In review) - "*Updated Global Ocean Color Trends and Uncertainties Constrained Using Biogeochemical Models*".