Comparison of WRTDS and GAMs for evaluating long-term trends in chlorophyll

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Since the last call...

- Application of GAMs and WRTDS to 30 year time series of monthly chlorophyll at LE1.2 and TF1.6
- Development of comparable methods for model fitting
- Development of simulated datasets to evaluate flow-normalization
- Comparison of results and conclusions

Model applications

Both models used Vertically-integrated chlorophyll, monthly timestep

LE1.2: lnchla $\sim$ time + ***salinity***

TF1.6: lnchla $\sim$ time + ***flow***

Fits evaluated for whole time series and annual/seasonal/flow aggregations:

- predicted to observed, GAM predicted to WRTDS predicted
- Trends in flow-normalized results (average and % change overall, by time period)

Model applications

For comparing each model's ***predictions to observed***, at both sites:

$$RMSE_{fit} = \sqrt{\frac{\sum_{i=1}^{n} \left(Chl_i - \widehat{Chl}_i\right)^2}{n}}$$

For comparing ***predictions between models***, at both sites:

$$RMSE_{btw} = \sqrt{\frac{\sum_{i=1}^{n} \left(\widehat{Chl}_{WRTDS,\,i} - \widehat{Chl}_{GAM,\,i}\right)^2}{n}}$$

$$\text{Average difference} = \left(\frac{\sum_{i=1}^{n} \widehat{Chl}_{WRTDS,\,i} - \sum_{i=1}^{n} \widehat{Chl}_{GAM,\,i}}{\sum_{i=1}^{n} \widehat{Chl}_{GAM,\,i}} \right) * 100$$

Model fitting and flow-normalization

Objective: compare model fits

Problem: Need methods to prevent over-fitting and to compare apples-to-apples

GAMs - identify optimal degrees of freedom for smoothing parameters

WRTDS - identify optimal window widths for time, discharge (salinity or flow), and season

Existing method for GAMs, k-fold cross-validation and search algorithm ('limited memory BFGS quasi-Newton method') to identify window-widths for WRTDS

Basically, a statistical infrastructure to 'automatically' fit the best model given the dataset

Development of simulated datasets

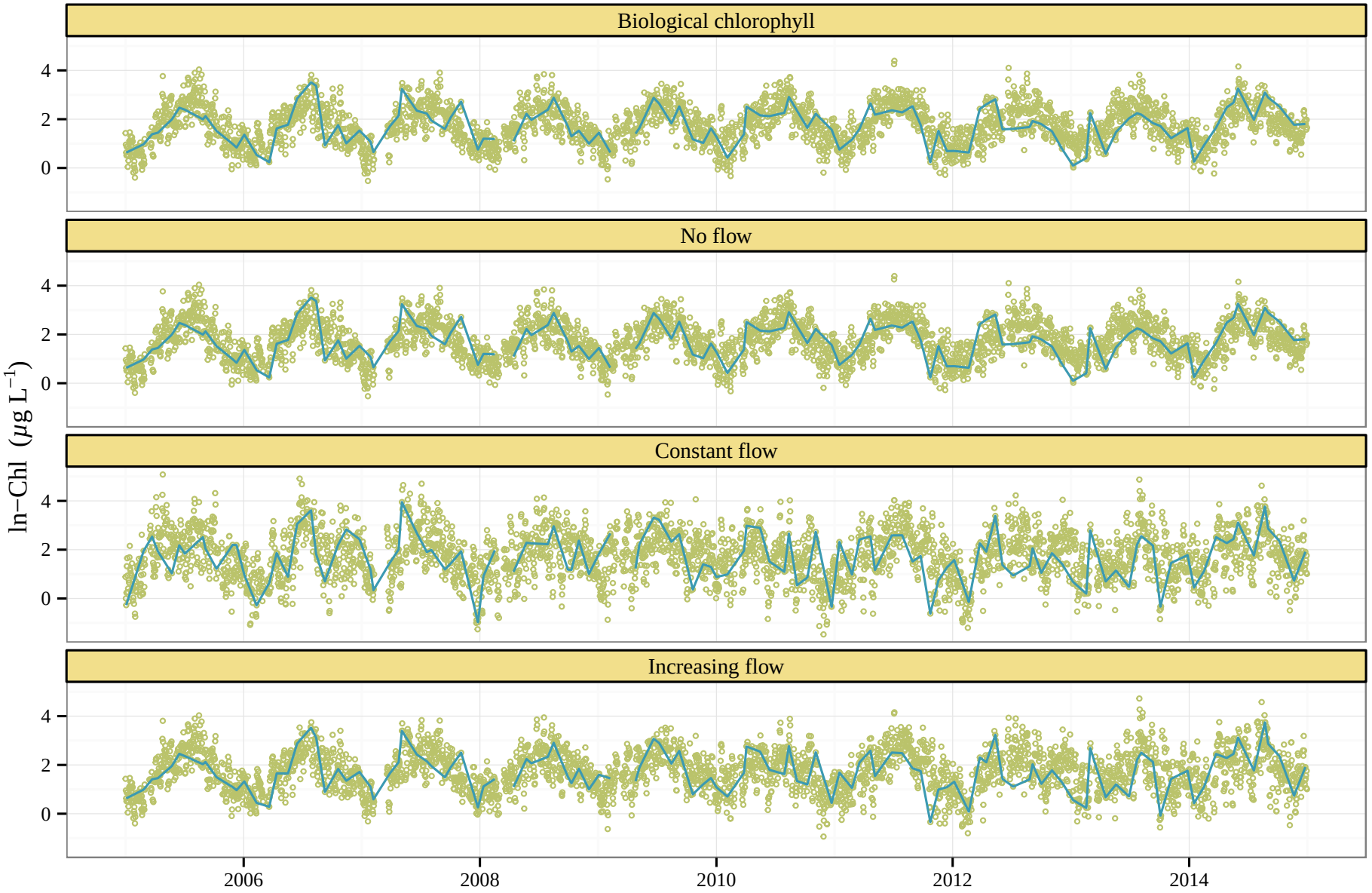
Objective: evaluate ability of each model to reproduce flow-normalized trends

Problem: The true flow-normalized trends are not known and can only be empirically estimated

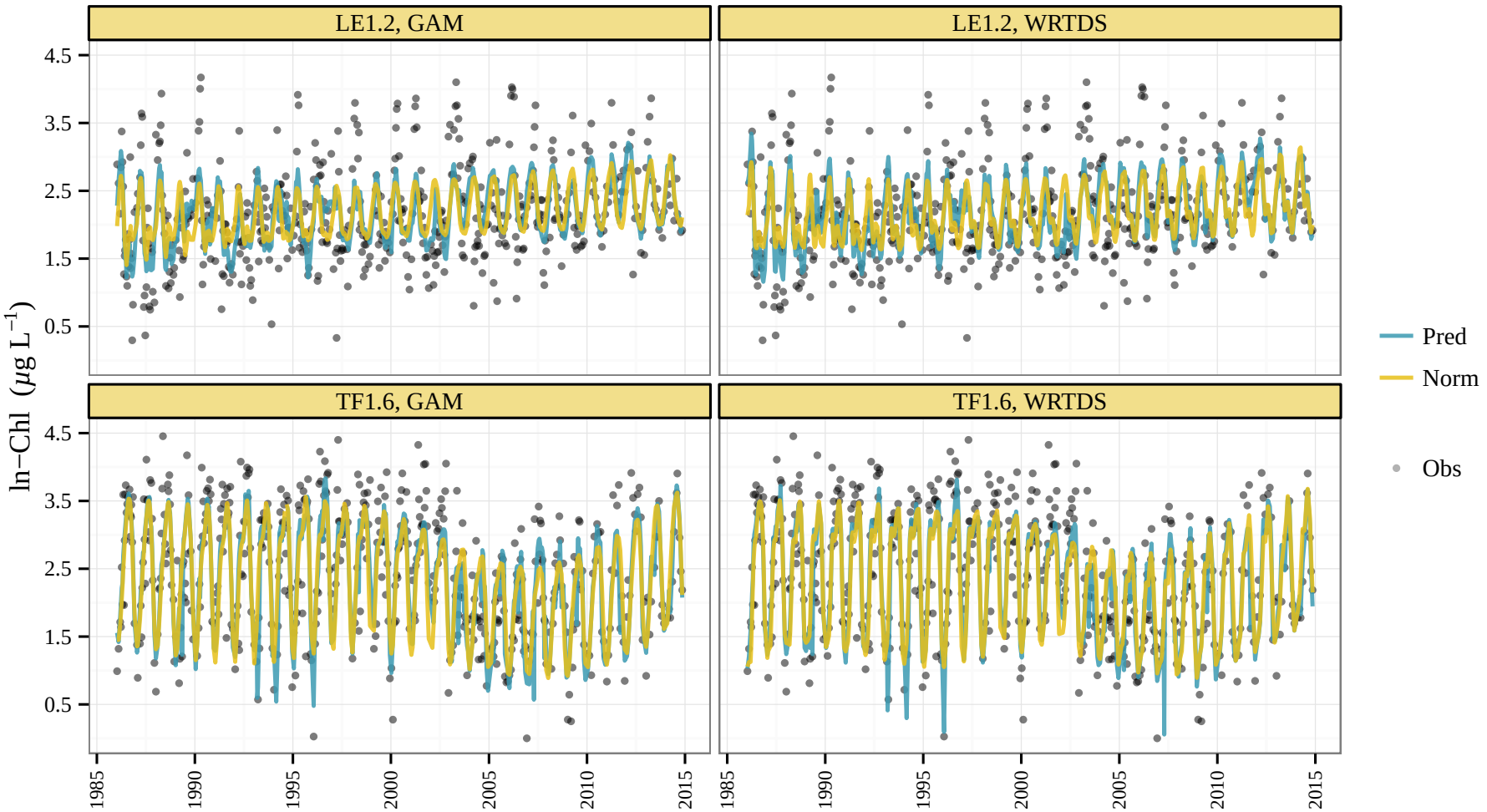
We created monthly simulated datasets following the general technique in Hirsch et al. 2015 (sec. 4, MC simulations)

- Actual daily time series: discharge from Bowie gage, Jug Bay fluorescence
- Overall: $Chl_{obs} = Chl_{flo} + Chl_{bio}$
- From discharge: $Chl_{flo} = I\left(\widehat{Q}_{seas} + \sigma \cdot \varepsilon_{Q,\,sim}\right)$
- From fluorescence: $Chl_{bio} = \widehat{Chl}_{seas} + \sigma \cdot \varepsilon_{Chl,\,sim}$
- indicator I changes to simulate changing flow component

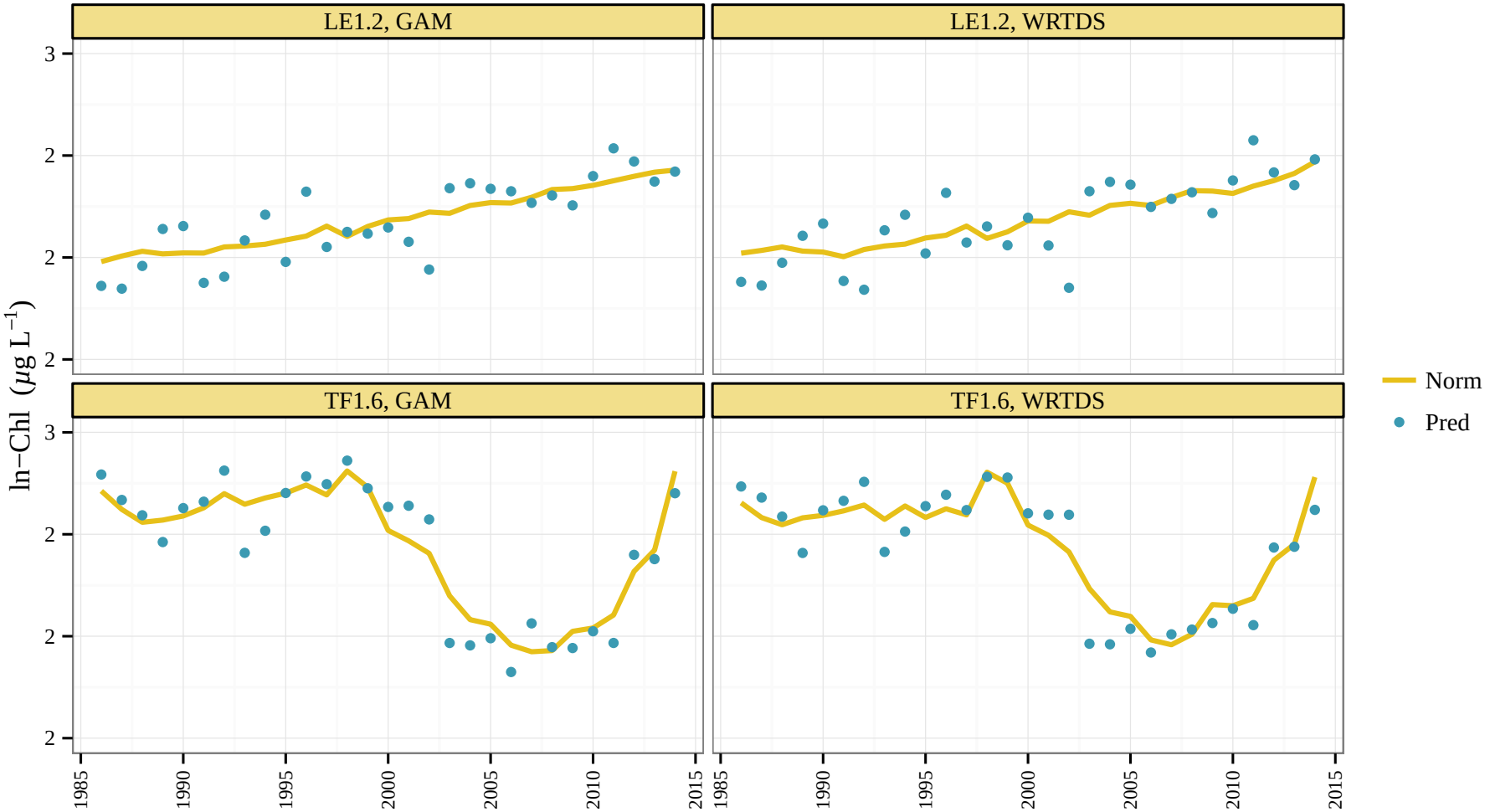
Development of simulated datasets



Results


LE1.2, GAM
LE1.2, WRTDS
TF1.6, GAM
TF1.6, WRTDS
ln–Chl (μg L⁻¹)
4.5
3.5
2.5
1.5
0.5
1985
1990
1995
2000
2005
2010
2015
Pred
Norm
Obs

Results


LE1.2, GAM
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ln−Chl (μg L−1)
3
2
2
2
3
2
2
2
1985
1990
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2000
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2010
2015
Norm
Pred

Results

Table : RMSE of observed to predicted ln-chlorophyll.

Period	LE1.2		TF1.6	
	GAM	WRTDS	GAM	WRTDS
All				
	0.54	0.51	0.54	0.52
Annual				
1986-1993	0.54	0.50	0.53	0.49
1994-2000	0.52	0.50	0.58	0.58
2001-2007	0.63	0.60	0.54	0.53
2008-2014	0.39	0.36	0.49	0.44
Seasonal				
JFM	0.61	0.58	0.53	0.49
AMJ	0.69	0.64	0.60	0.58
JAS	0.38	0.35	0.48	0.46
OND	0.41	0.38	0.55	0.54
Flow				
1 (Low)	0.40	0.36	0.48	0.46
2	0.47	0.42	0.56	0.54
3	0.61	0.57	0.56	0.52
4 (High)	0.64	0.63	0.56	0.54

Results

Table : Comparison of predicted results between models.

Period	LE1.2		TF1.6	
	Ave. diff.	RMSE	Ave. diff.	RMSE
All				
	-0.11	0.15	0.01	0.17
Annual				
1986-1993	0.18	0.16	-0.78	0.17
1994-2000	0.53	0.15	-1.09	0.19
2001-2007	-0.95	0.14	0.48	0.14
2008-2014	-0.18	0.14	3.12	0.18
Seasonal				
JFM	2.91	0.14	-5.02	0.22
AMJ	-3.42	0.17	0.93	0.14
JAS	5.03	0.14	-0.10	0.17
OND	-5.25	0.14	2.08	0.17
Flow				
Flow 1 (Low)	0.19	0.16	-0.09	0.12
Flow 2	-0.83	0.16	0.73	0.15
Flow 3	0.19	0.15	0.84	0.20
Flow 4 (High)	0.03	0.13	-1.62	0.20

Results

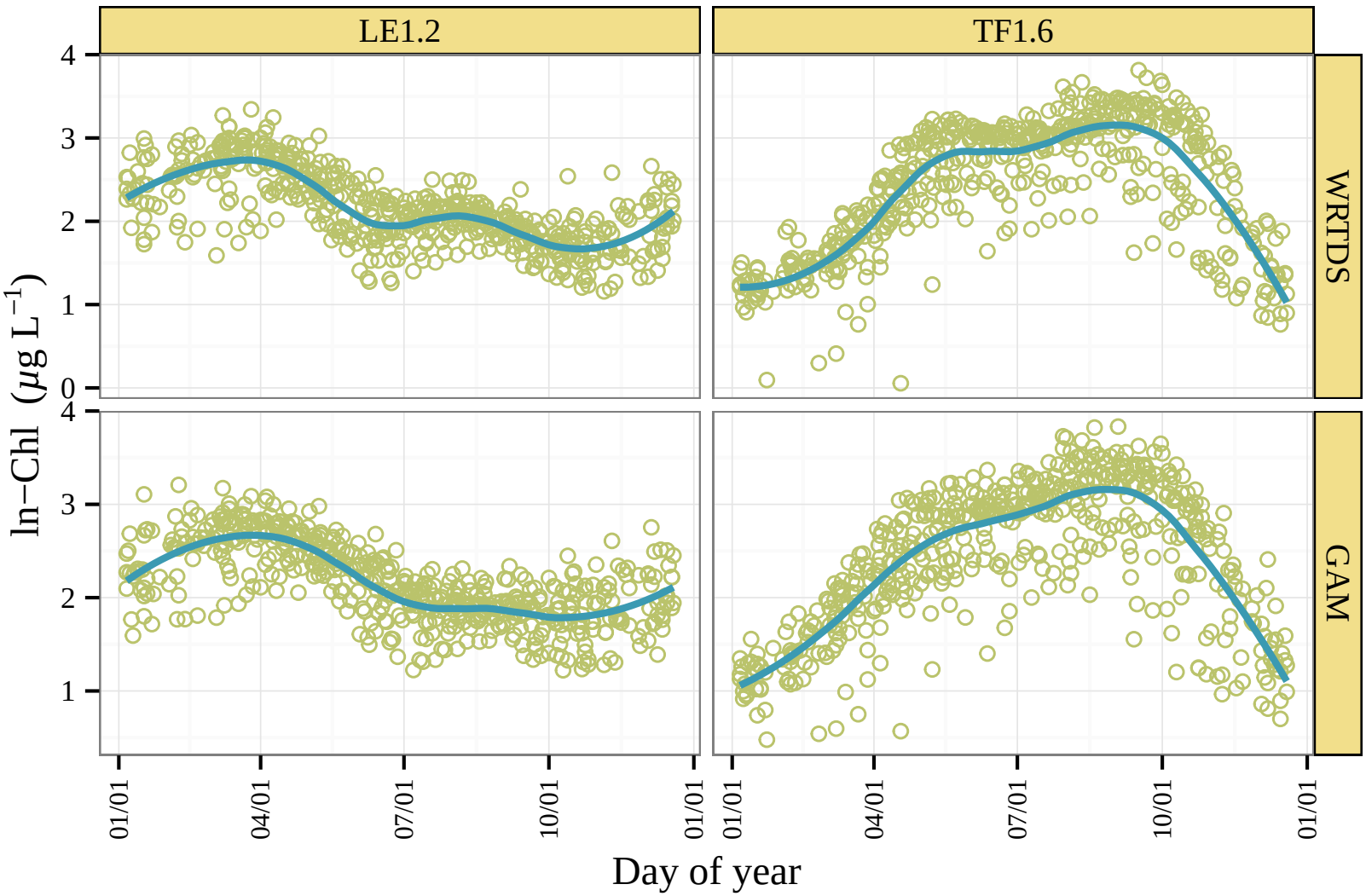

Figure : Seasonal variation from model predictions.

Results

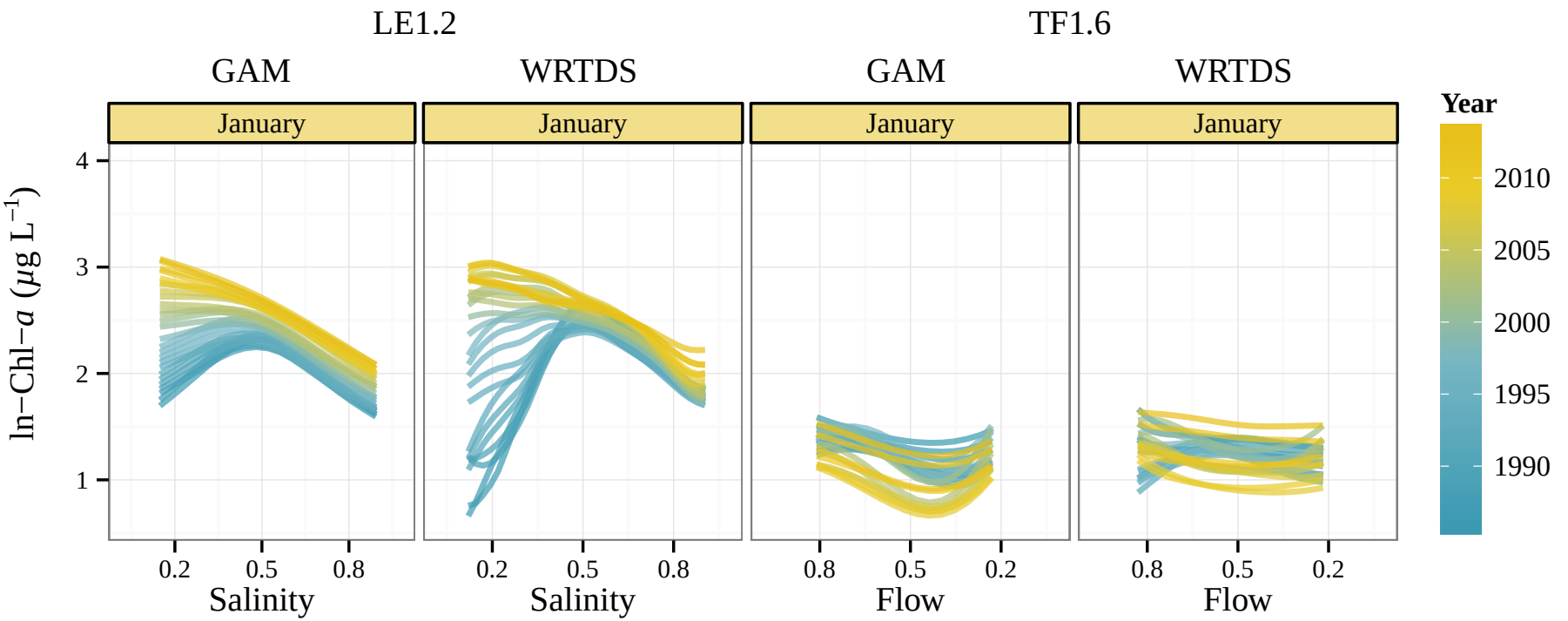

Figure : Changes in the relationship between chlorophyll and flow across the time series, seaprate plots by month, model, and station. The scales of salinity and flow are reversed for comparison of trends. Units are proportions of the total range in the observed data with values in each plot truncated by the monthly 5^{th} and 95^{th} percentiles.

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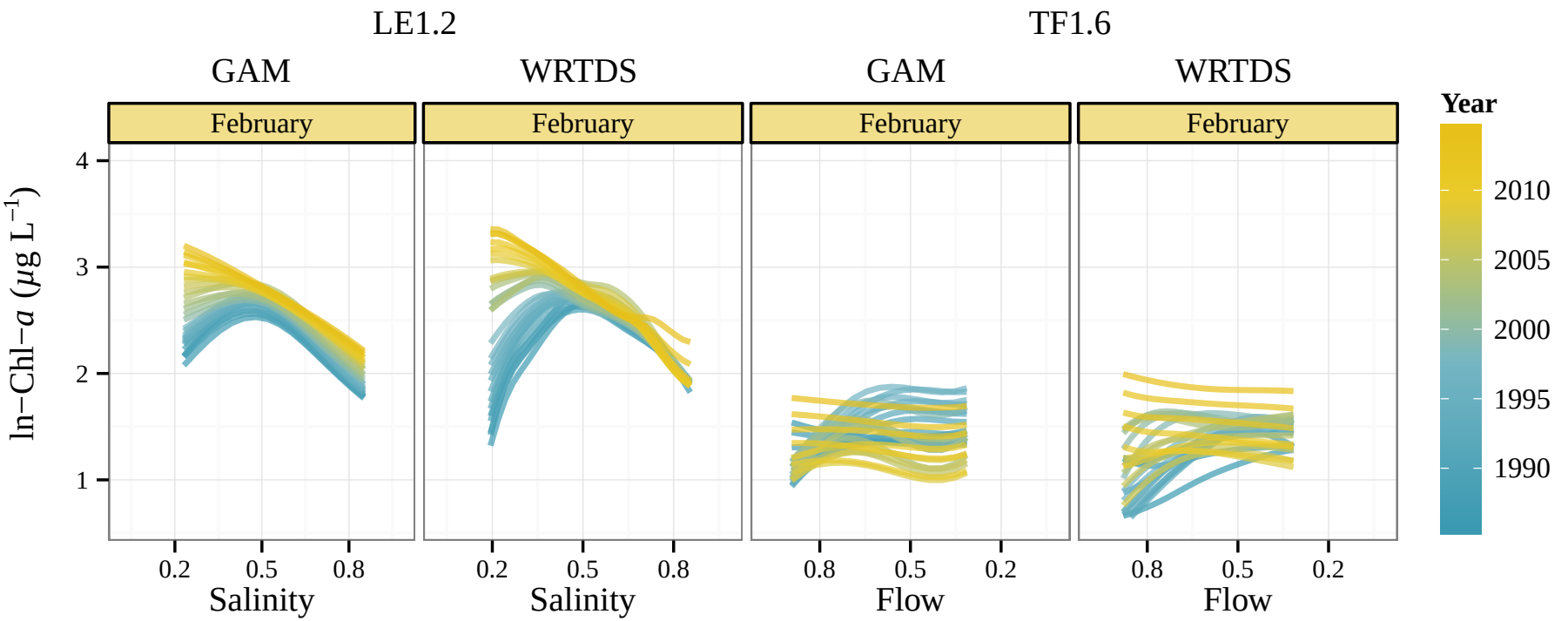

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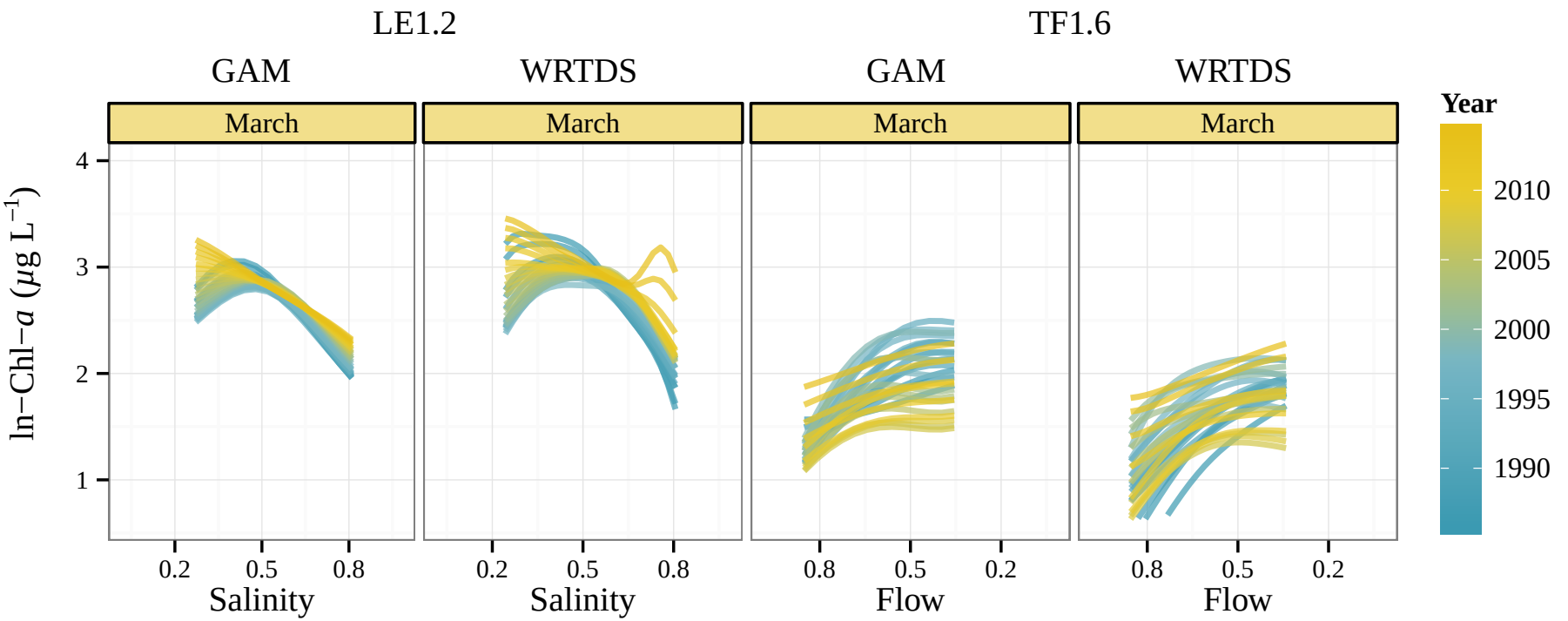

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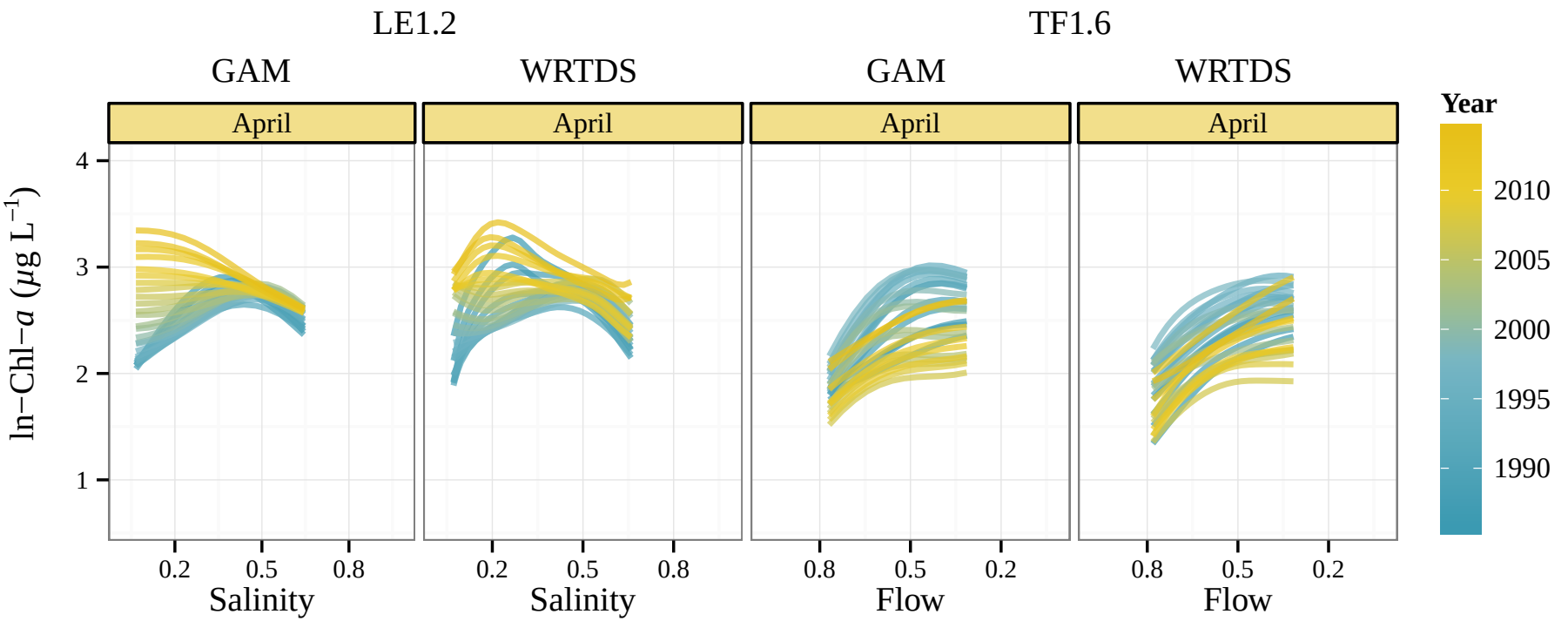

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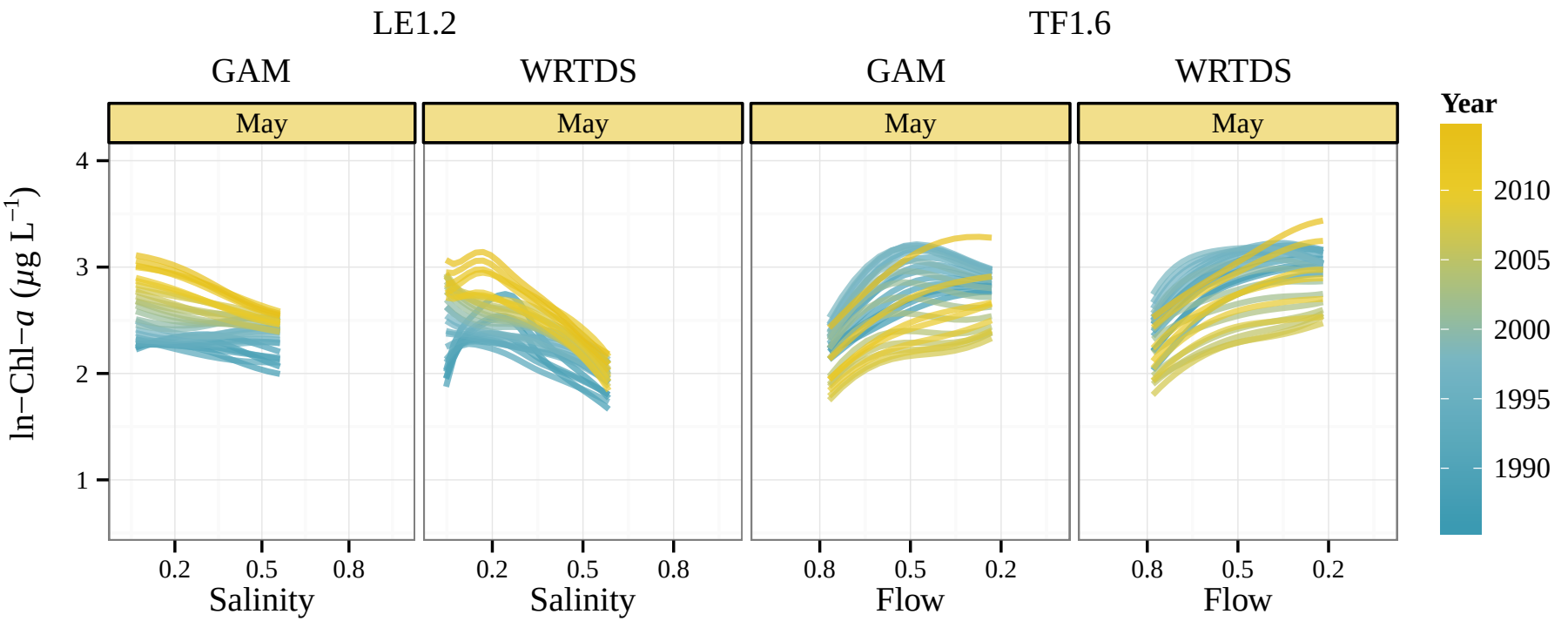

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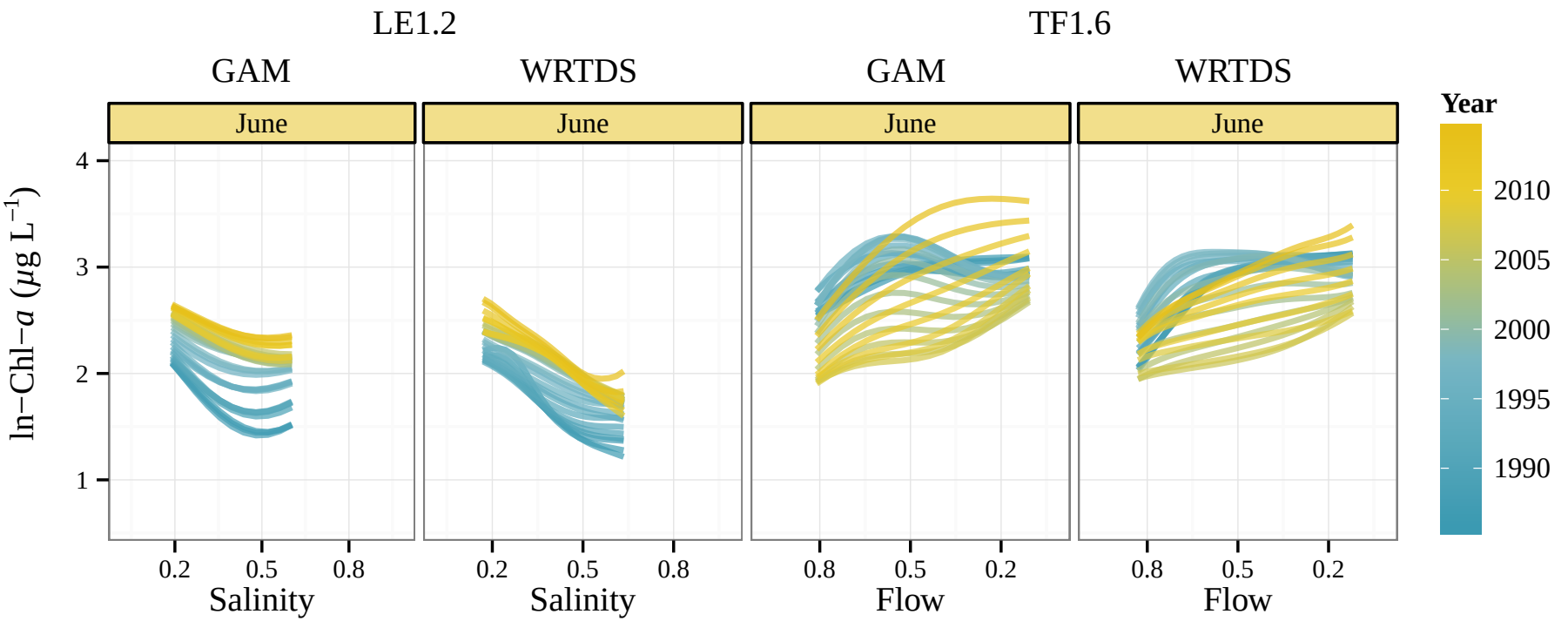

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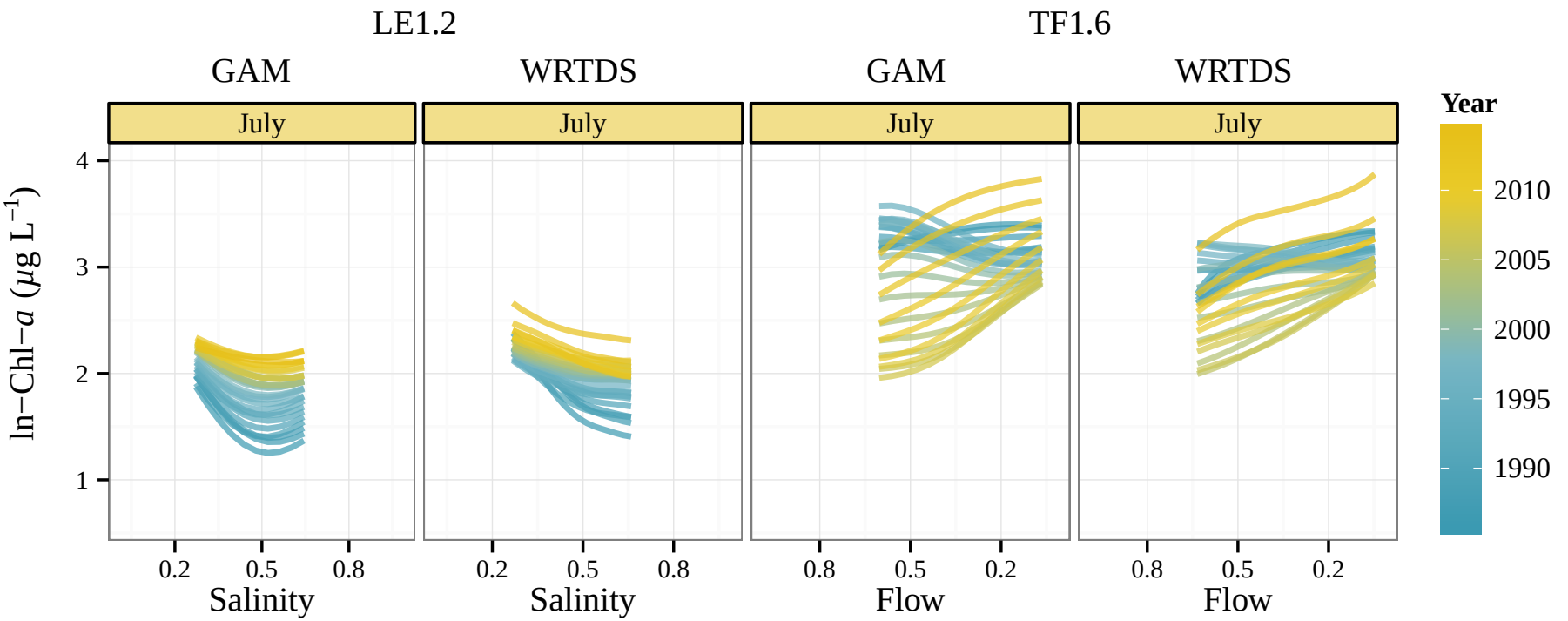

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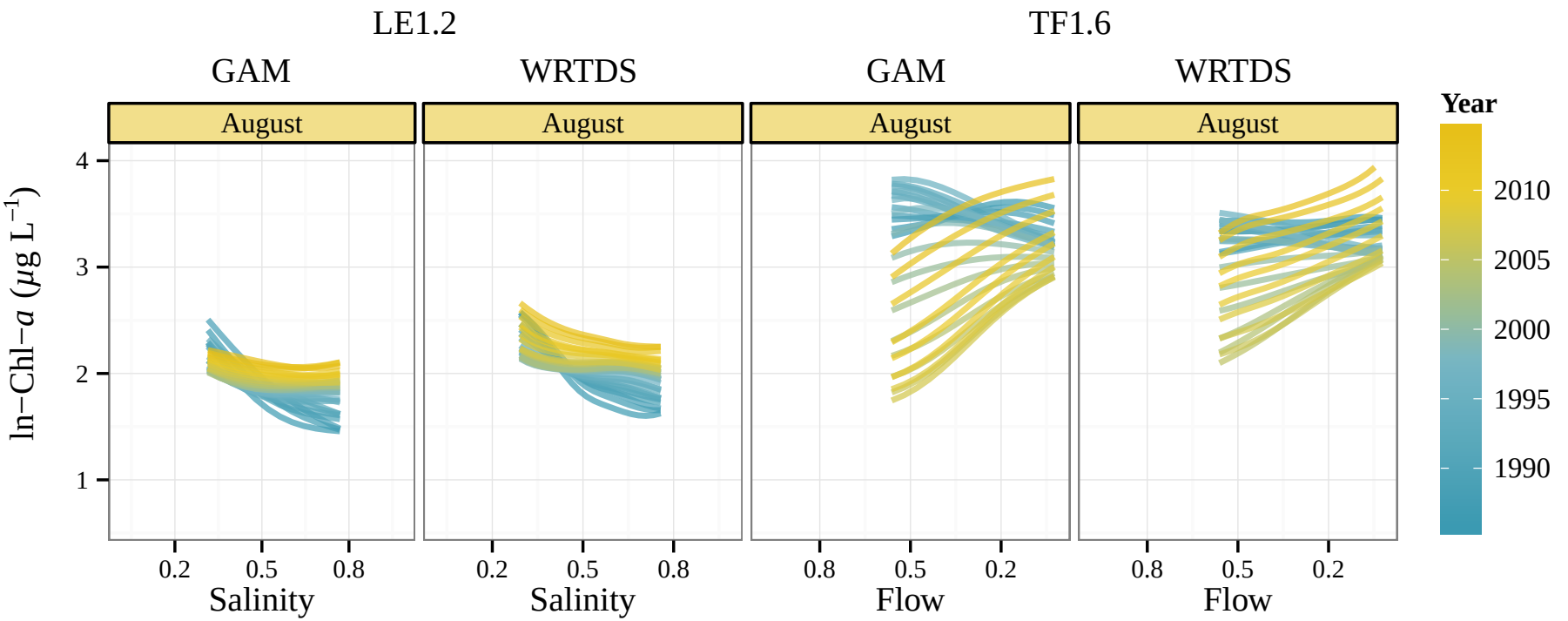

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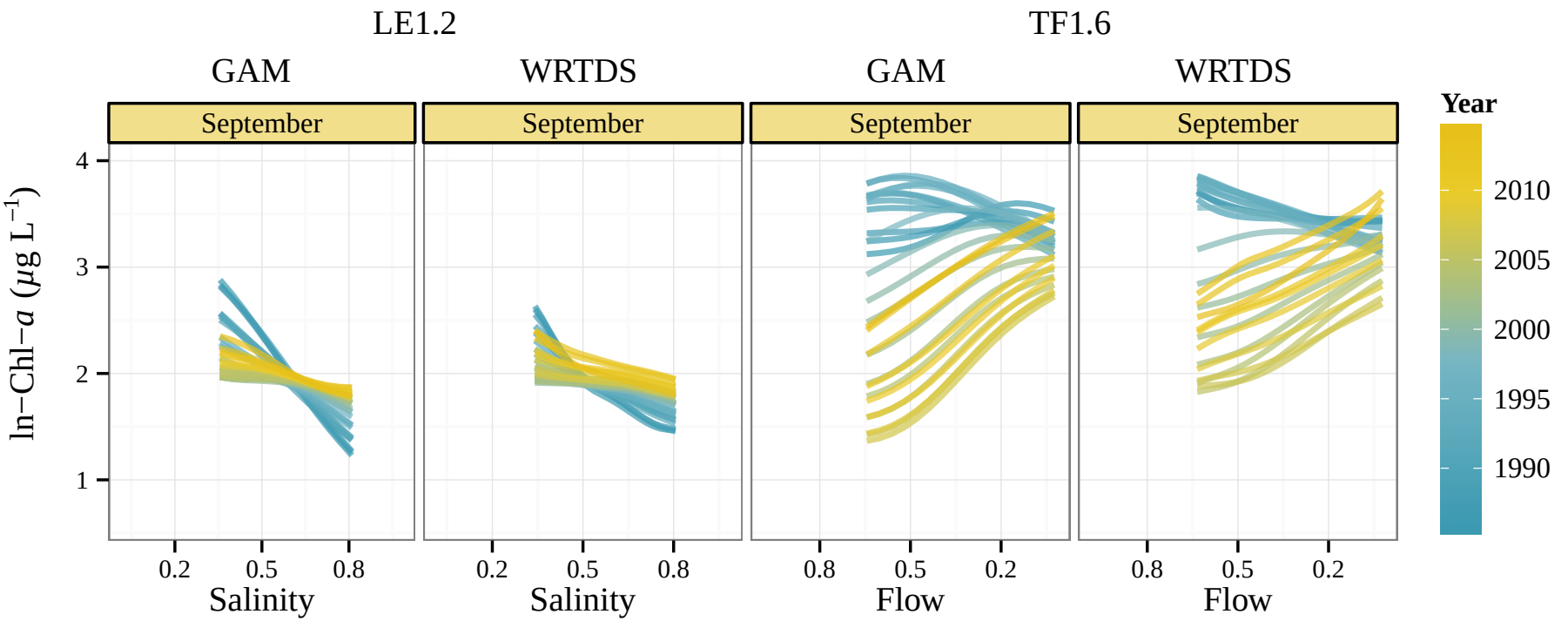

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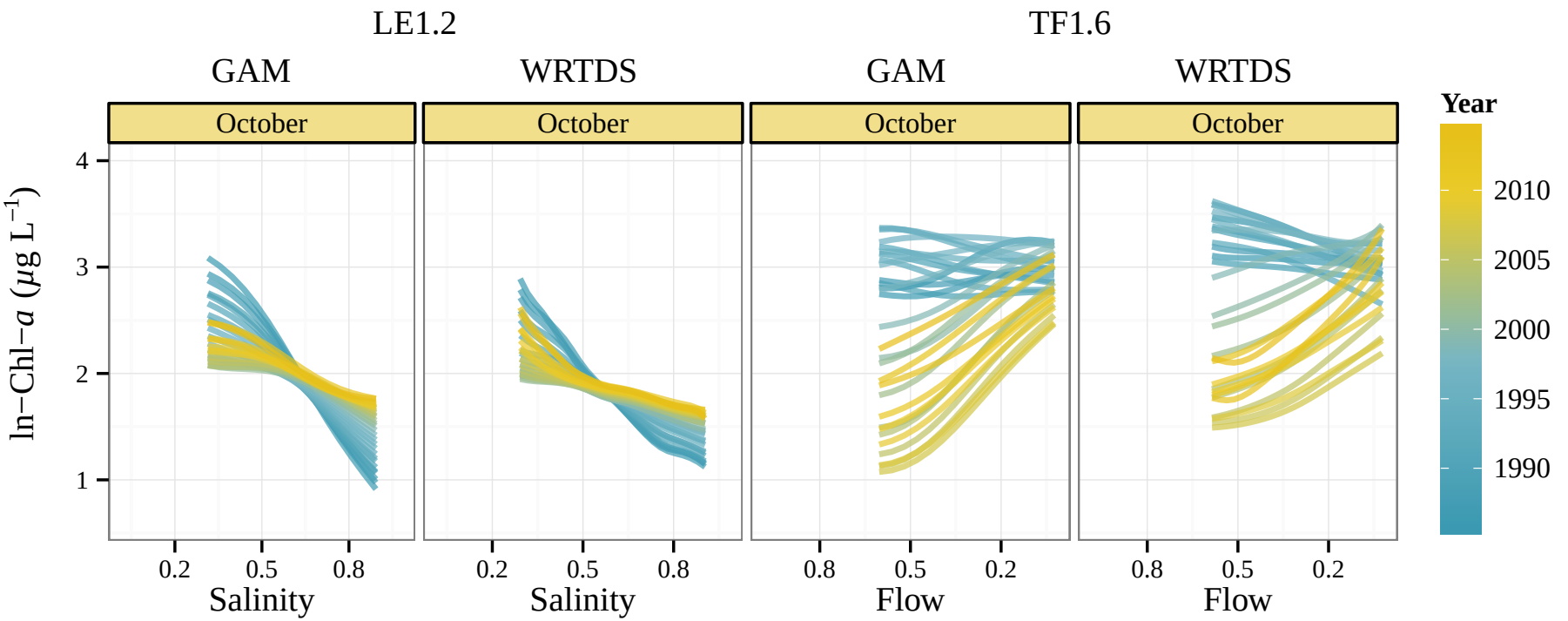

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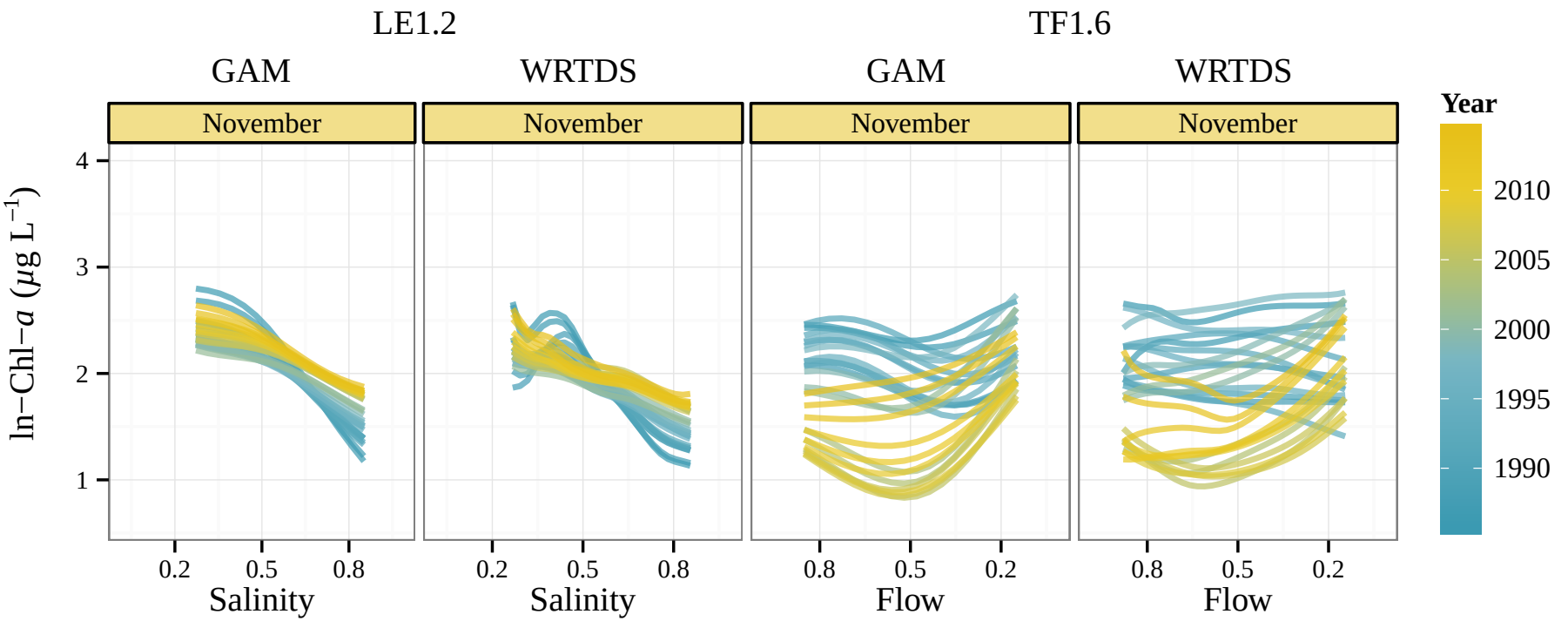

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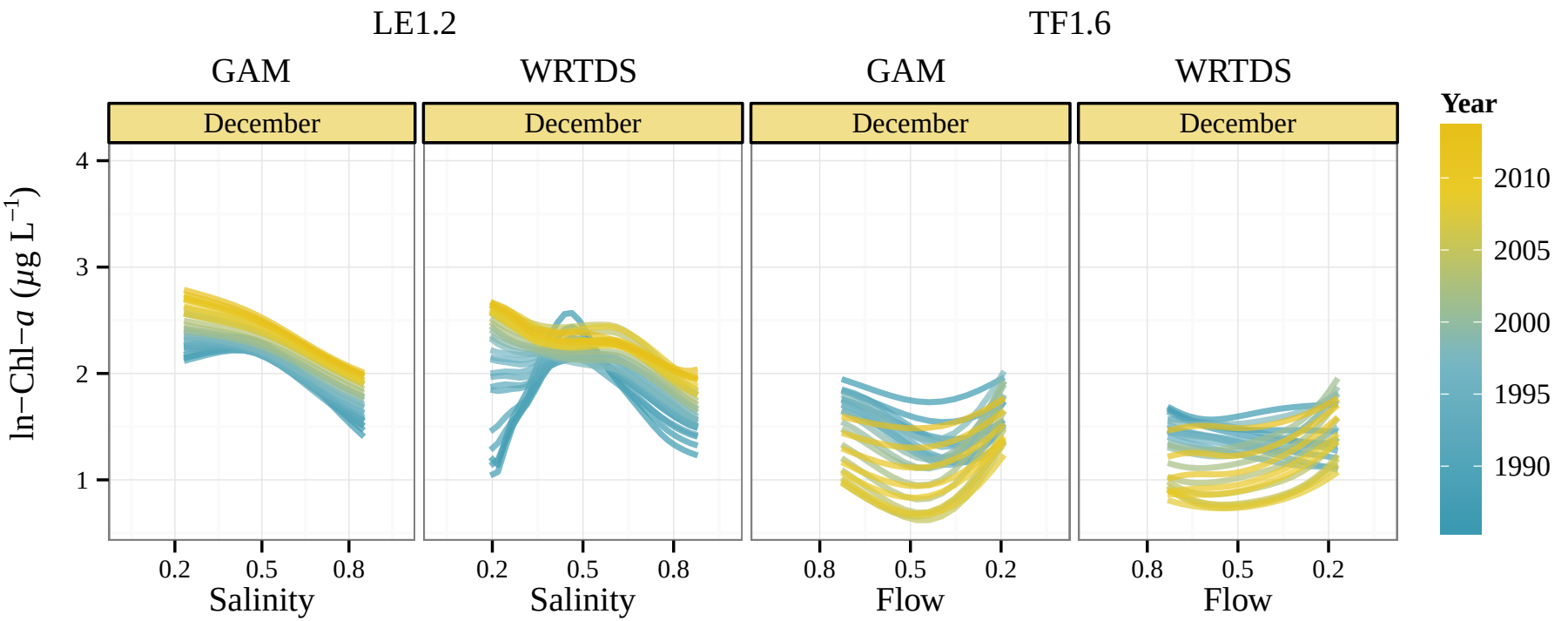

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