# Exploring Constraints on a Wetland Methane Emission Ensemble with GOSAT

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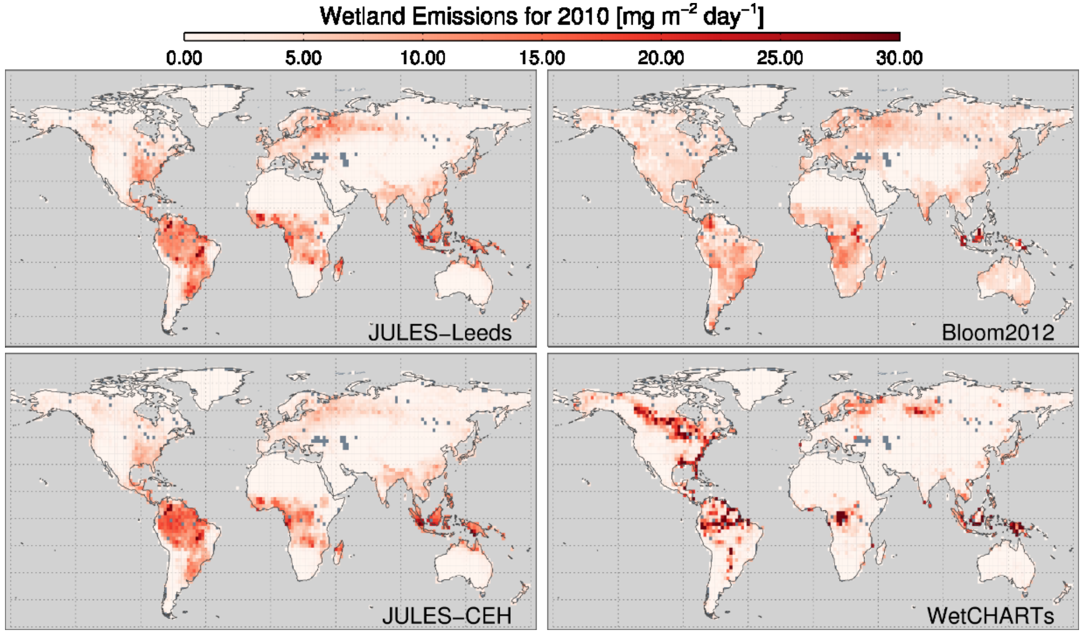
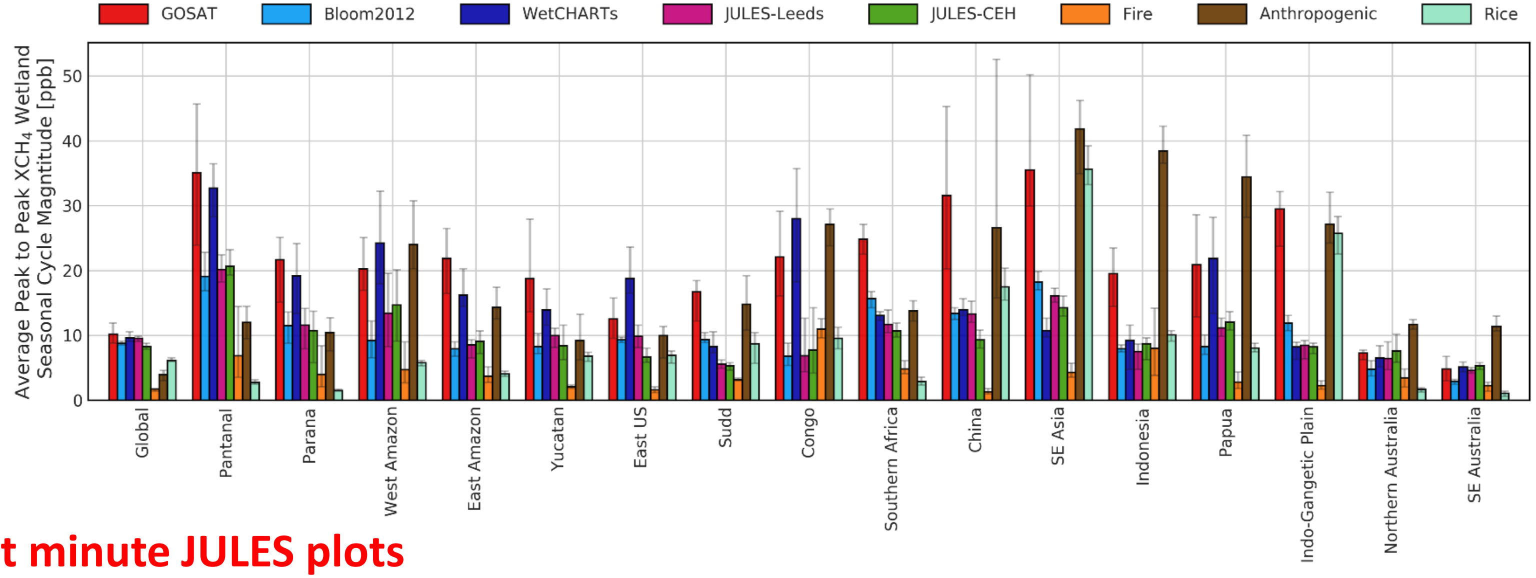
# Motivation

In Parker et al. 2018, *Evaluating year-to-year anomalies in tropical wetland methane emissions using satellite CH$_4$ observations*, we found:

- ☐ Observations show that models **underestimate** tropical seasonal cycle of methane
- ☐ **Large discrepancies** between model and observations over South American wetlands
- ☐ Changes to wetland extent driven by **ENSO** cause large differences
- ☐ Wetland extent changes caused by overbank inundation, a process **missing** in these models
- ☐ This work builds upon this by considering **larger ensembles** of wetland emission datasets (WetCHARTs, JULES) and **evaluates** them against GOSAT CH$_4$ satellite observations
- ☐ Focus of this presentation will be an **initial evaluation of WetCHARTs + some bonus last minute JULES plots**





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# WetCHARTs

- WetCHARTs is an **ensemble** of $CH_4$ emissions produced by A. Bloom (NASA JPL)
- Different constraints on global total, respiration model, temperature dependence and extent parameterisation
- We used the ensemble mean in Parker et al. 2018 but now we want to study the full ensemble and **compare to GOSAT $CH_4$ observations**
- Interested in which ensemble members perform better in which regions to try and understand what factors are important (e.g. temperature vs extent)

**4-digit code describes ensemble member - ABCD**

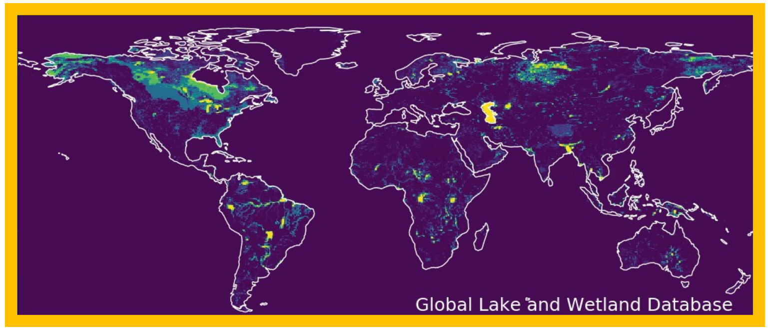
| A | 1 | 2 | 3 |
|---|---|---|---|
| Global Scale Factor (Tg $CH_4$/yr) | 124.5 | 166 | 207.5 |

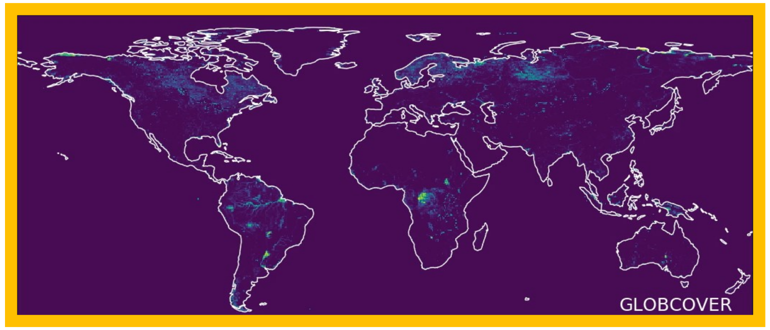
| B | 1-8 | 9 |
|---|---|---|
| Heterotrophic Respiration Model | MsTMIP Models | CARDAMOM |

| C | 1 | 2 | 3 |
|---|---|---|---|
| Temperature Dependence | q10 = 1 | q10 = 2 | q10 = 3 |

| D | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Extent Parameterisation | SWAMPS & GLWD | SWAMPS & GLOBCOVER | PREC & GLWD | PREC & GLOBCOVER |

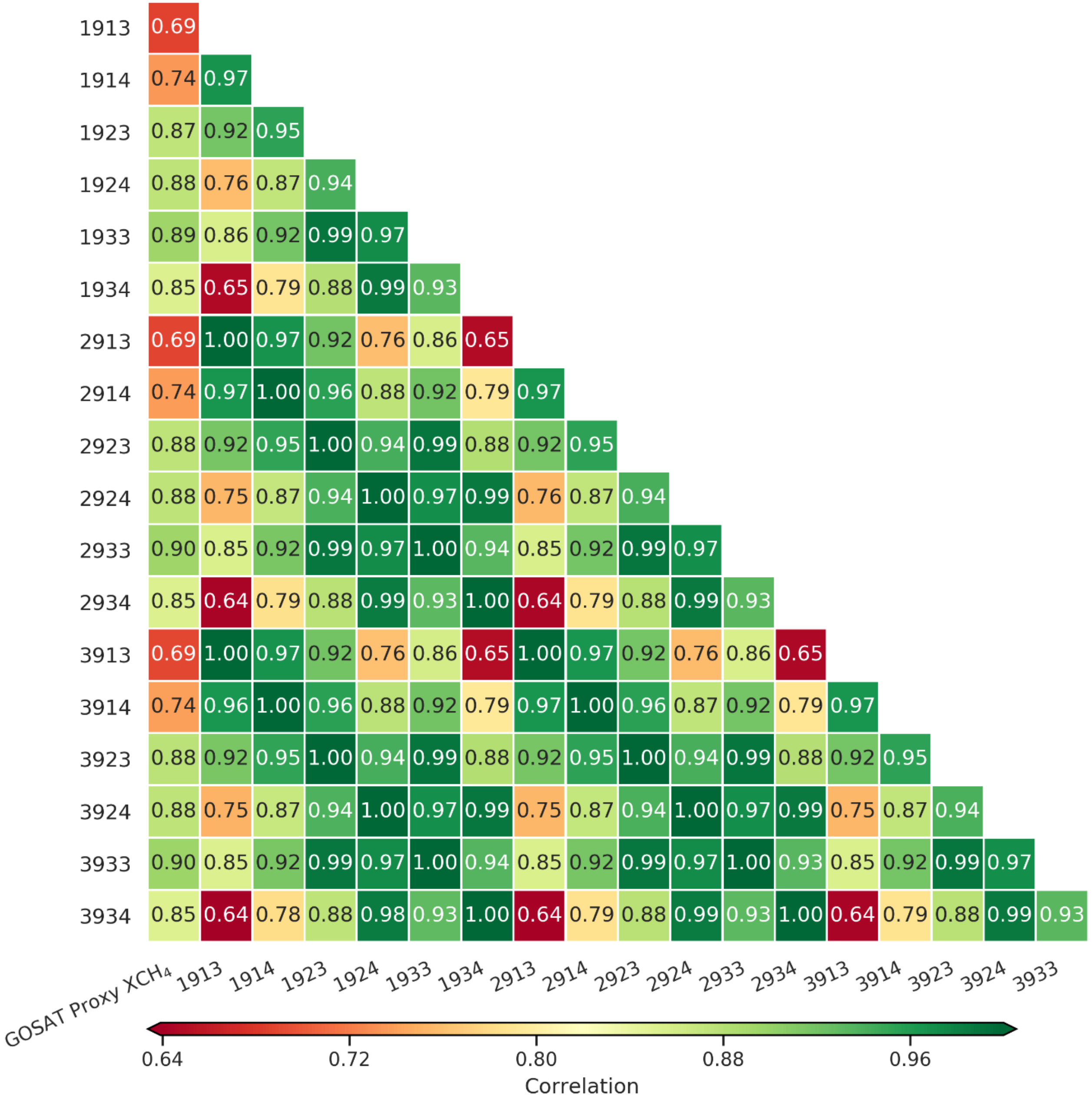
January 2001





# Global Correlation Between GOSAT and Different Ensemble Members

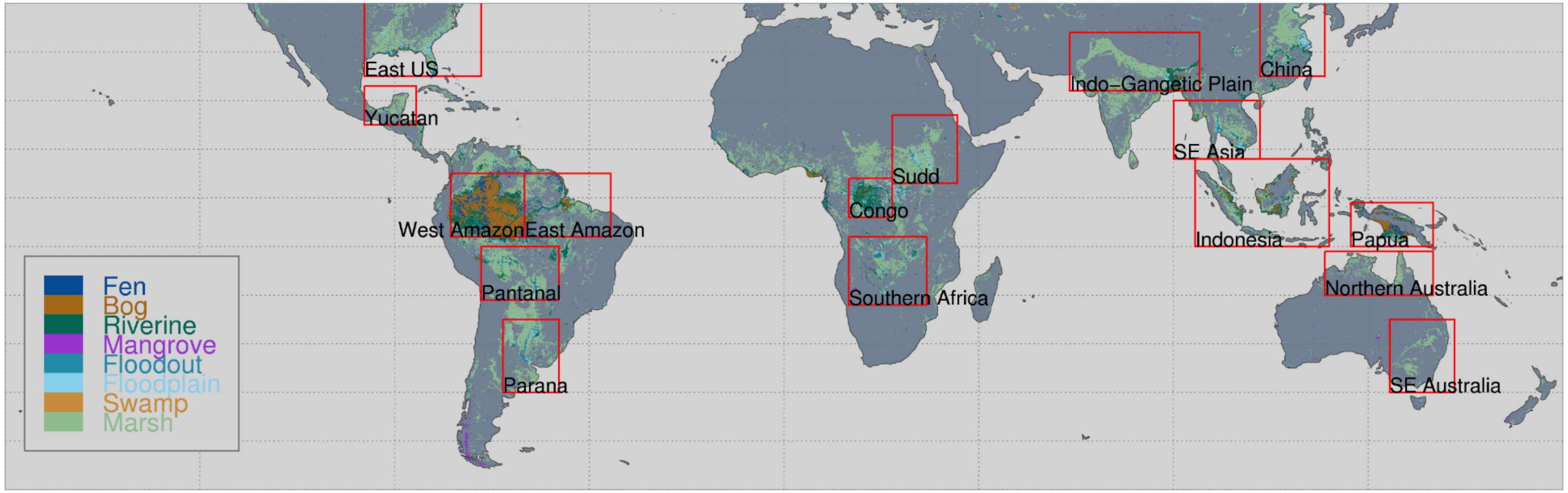
- Correlation shows GOSAT vs each ensemble member (left-most column)
- Temperature dependence important
  - Low $Q_{10}$ (=1, i.e. no dependency) **does poorly**
- Significant **variability** in inter-ensemble correlations
- Correlation of ensemble members against each other is useful for determining **sensitivity** to different constraints
- Very **low correlation** (0.64) between extreme ensemble members (i.e. when $Q_{10}$ and extent are most different)

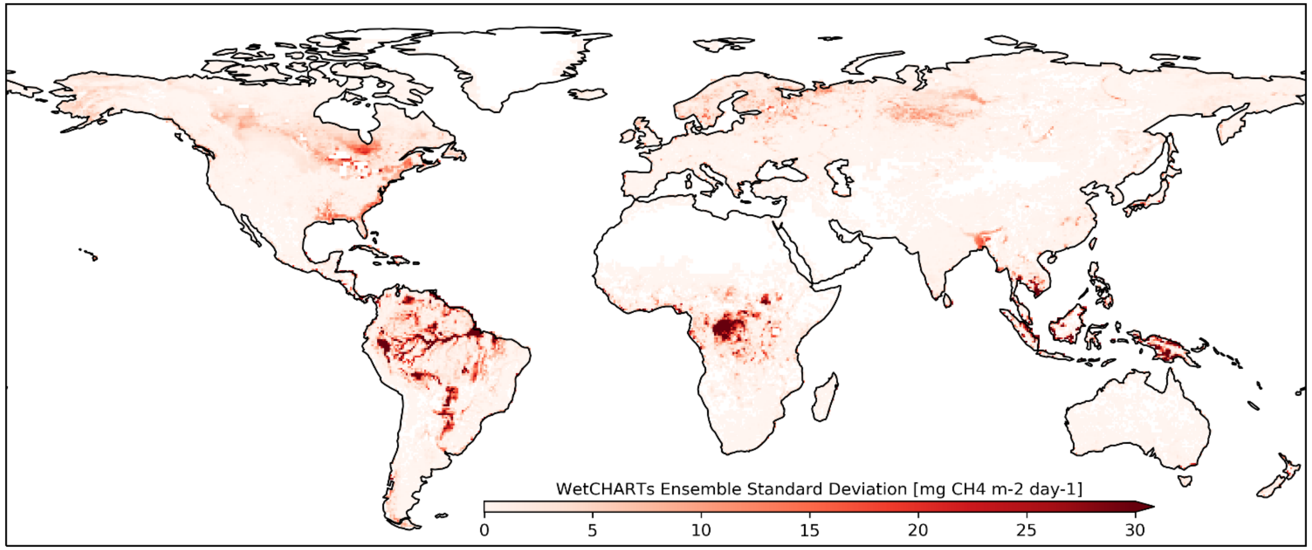


| | GOSAT Proxy XCH₄ | 1913 | 1914 | 1923 | 1924 | 1933 | 1934 | 2913 | 2914 | 2923 | 2924 | 2933 | 2934 | 3913 | 3914 | 3923 | 3924 | 3933 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1913 | 0.69 | | | | | | | | | | | | | | | | | |
| 1914 | 0.74 | 0.97 | | | | | | | | | | | | | | | | |
| 1923 | 0.87 | 0.92 | 0.95 | | | | | | | | | | | | | | | |
| 1924 | 0.88 | 0.76 | 0.87 | 0.94 | | | | | | | | | | | | | | |
| 1933 | 0.89 | 0.86 | 0.92 | 0.99 | 0.97 | | | | | | | | | | | | | |
| 1934 | 0.85 | 0.65 | 0.79 | 0.88 | 0.99 | 0.93 | | | | | | | | | | | | |
| 2913 | 0.69 | 1.00 | 0.97 | 0.92 | 0.76 | 0.86 | 0.65 | | | | | | | | | | | |
| 2914 | 0.74 | 0.97 | 1.00 | 0.96 | 0.88 | 0.92 | 0.79 | 0.97 | | | | | | | | | | |
| 2923 | 0.88 | 0.92 | 0.95 | 1.00 | 0.94 | 0.99 | 0.88 | 0.92 | 0.95 | | | | | | | | | |
| 2924 | 0.88 | 0.75 | 0.87 | 0.94 | 1.00 | 0.97 | 0.99 | 0.76 | 0.87 | 0.94 | | | | | | | | |
| 2933 | 0.90 | 0.85 | 0.92 | 0.99 | 0.97 | 1.00 | 0.94 | 0.85 | 0.92 | 0.99 | 0.97 | | | | | | | |
| 2934 | 0.85 | 0.64 | 0.79 | 0.88 | 0.99 | 0.93 | 1.00 | 0.64 | 0.79 | 0.88 | 0.99 | 0.93 | | | | | | |
| 3913 | 0.69 | 1.00 | 0.97 | 0.92 | 0.76 | 0.86 | 0.65 | 1.00 | 0.97 | 0.92 | 0.76 | 0.86 | 0.65 | | | | | |
| 3914 | 0.74 | 0.96 | 1.00 | 0.96 | 0.88 | 0.92 | 0.79 | 0.97 | 1.00 | 0.96 | 0.87 | 0.92 | 0.79 | 0.97 | | | | |
| 3923 | 0.88 | 0.92 | 0.95 | 1.00 | 0.94 | 0.99 | 0.88 | 0.92 | 0.95 | 1.00 | 0.94 | 0.99 | 0.88 | 0.92 | 0.95 | | | |
| 3924 | 0.88 | 0.75 | 0.87 | 0.94 | 1.00 | 0.97 | 0.99 | 0.75 | 0.87 | 0.94 | 1.00 | 0.97 | 0.99 | 0.75 | 0.87 | 0.94 | | |
| 3933 | 0.90 | 0.85 | 0.92 | 0.99 | 0.97 | 1.00 | 0.94 | 0.85 | 0.92 | 0.99 | 0.97 | 1.00 | 0.93 | 0.85 | 0.92 | 0.99 | 0.97 | |
| 3934 | 0.85 | 0.64 | 0.78 | 0.88 | 0.98 | 0.93 | 1.00 | 0.64 | 0.79 | 0.88 | 0.99 | 0.93 | 1.00 | 0.64 | 0.79 | 0.88 | 0.99 | 0.93 |

# Global Wetland Locations

- ☐ We choose geographic areas to concentrate on based on a static wetland database (SWAMP)
- ☐ The standard deviation of the 18-member WetCHARTs ensemble shows (as expected) that many of these regions have a large spread across the ensemble
- ☐ The **objective** is to begin investigating these regions and to **diagnose what is driving this variability** within the ensemble and to **evaluate which members perform best against observations**





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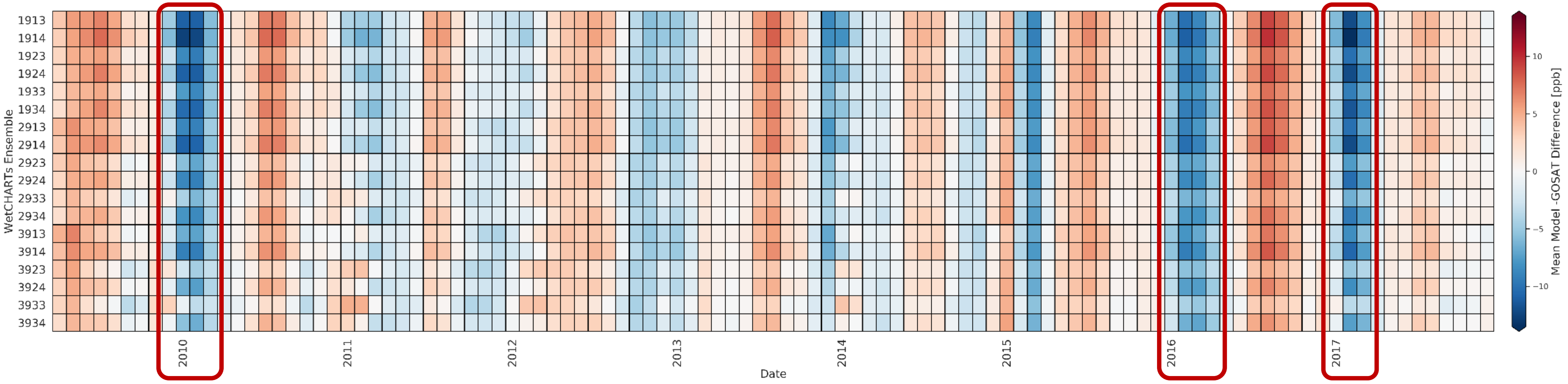
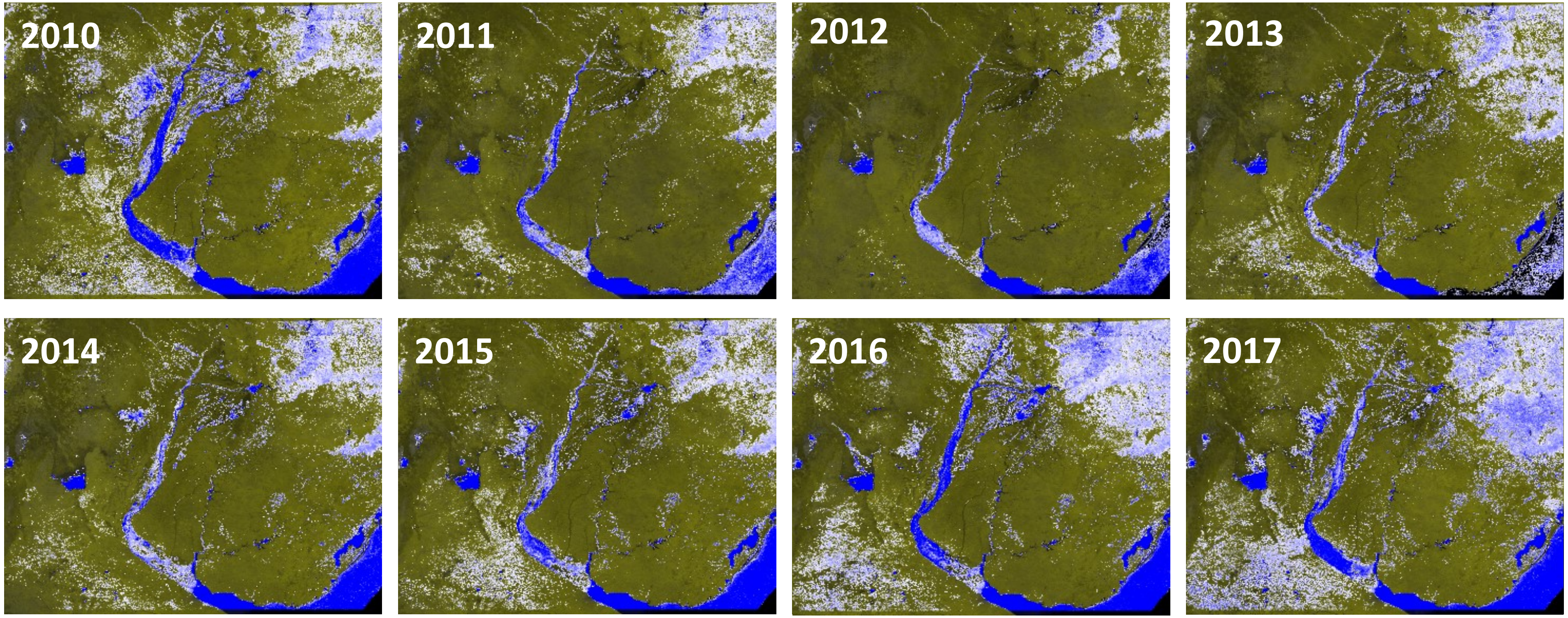
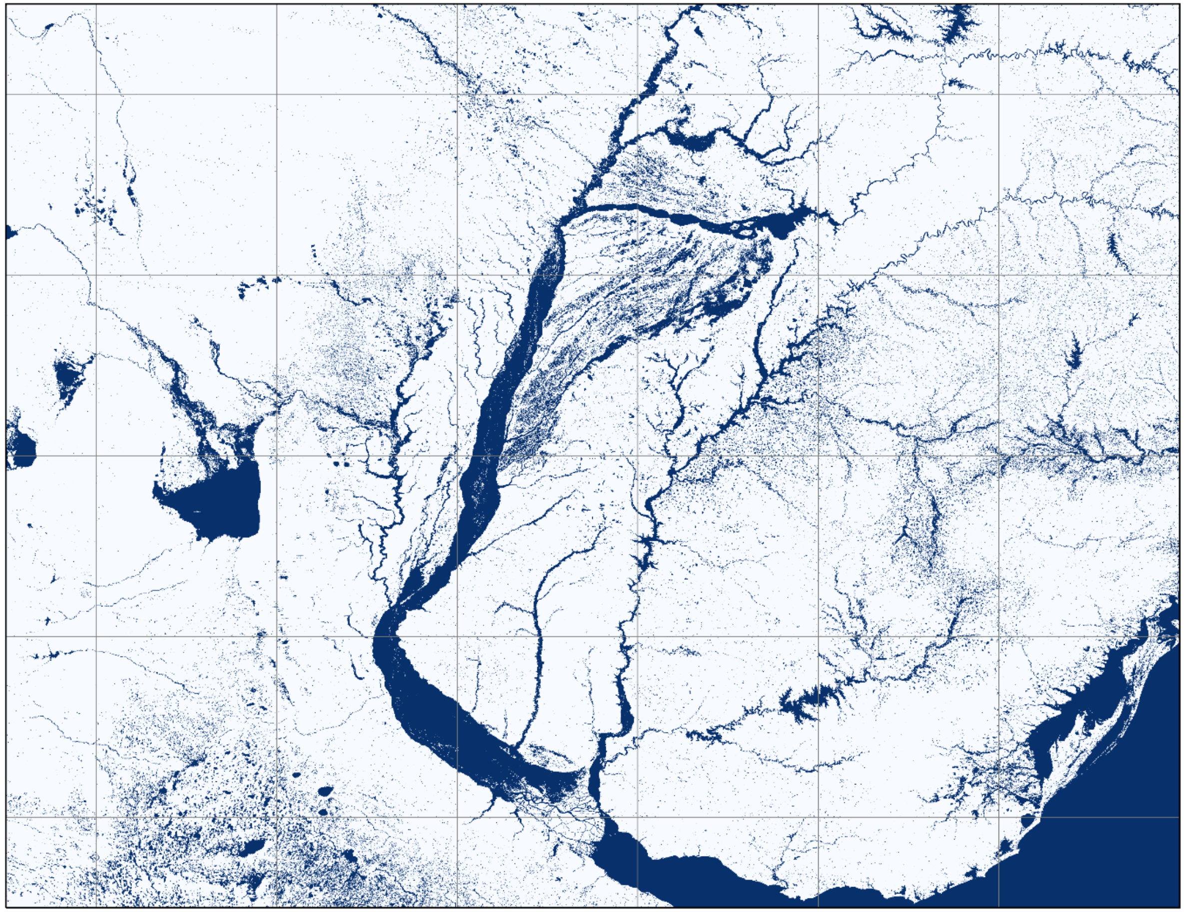
# Paraná River

- Previous study (Parker et al., 2018) saw **big discrepancy in early 2010** but data stopped in 2015
- Attributed to **overbank inundation** driven by ENSO
- Can we explain 2016/2017?
- MODIS imagery shows **very significant** flooding in 2016
- Behaviour in 2017 is slightly different in the visible but **significantly increased wetland extent** clearly apparent in NDWI

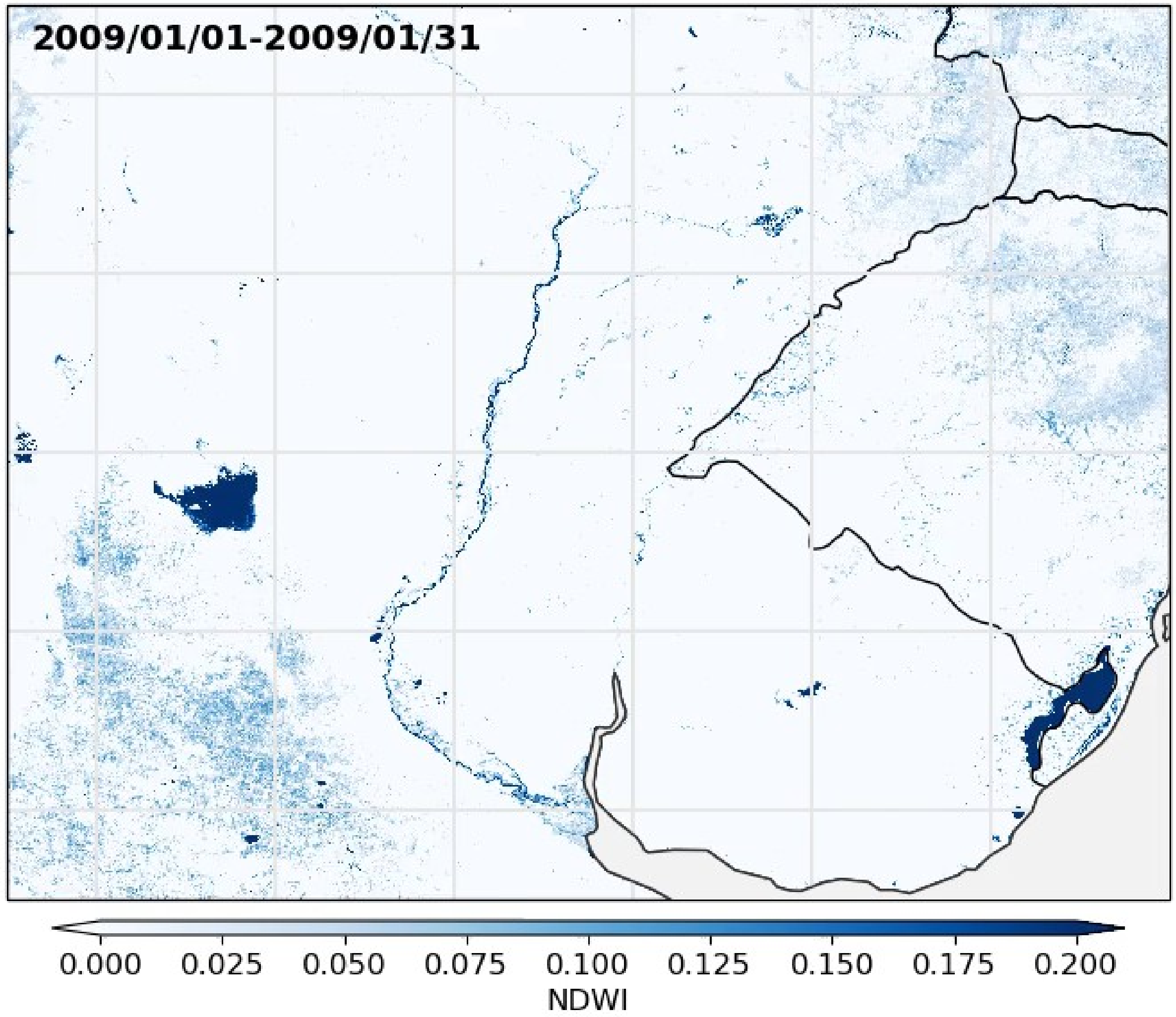




# Paraná River – Surface Water



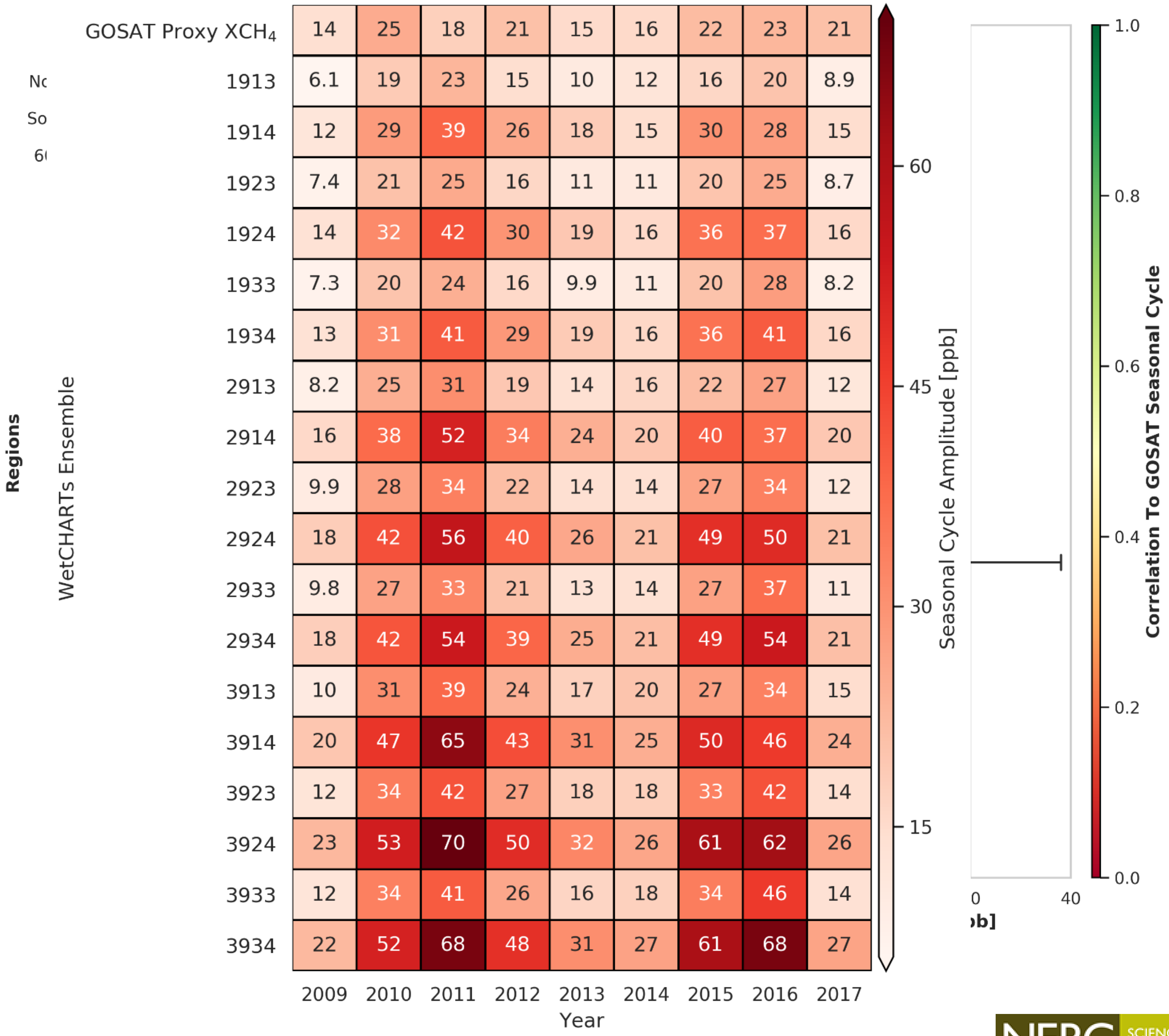
JRC Surface Water Maximum Extent (1984-2018)



- ☐ Complex seasonal hydrology that drives wetland extent and subsequent $CH_4$ emissions

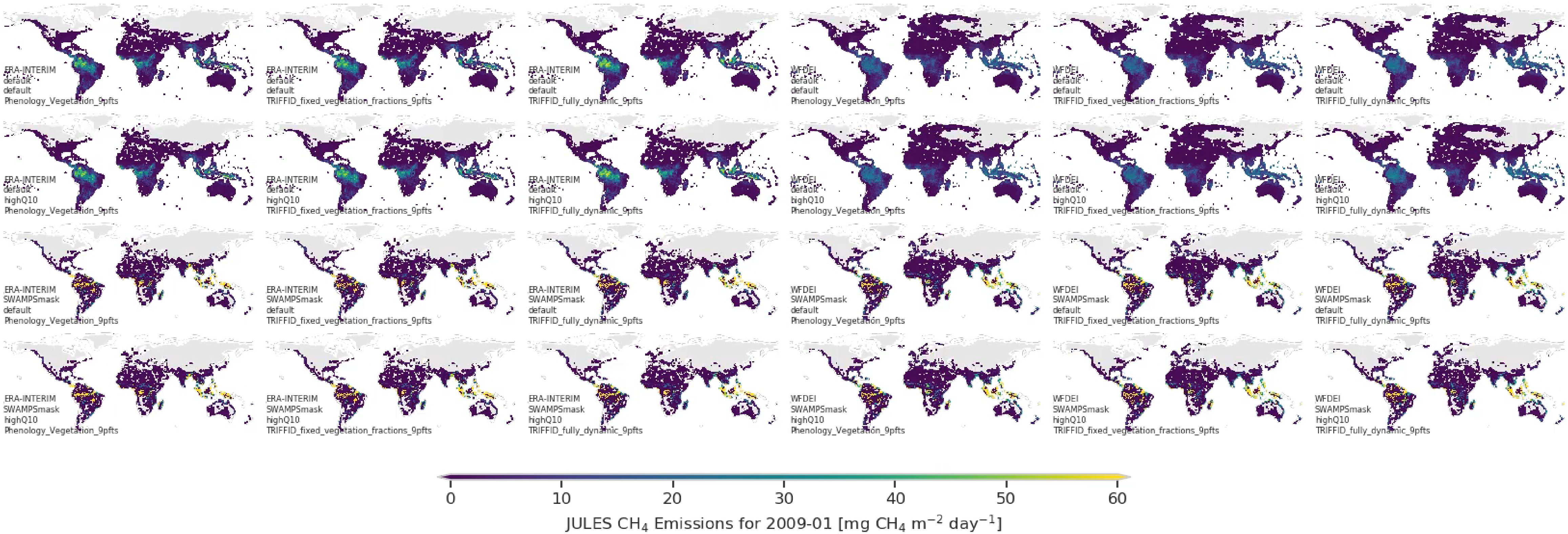
# Wetland Seasonal Cycle Amplitude Difference to Observations

- ☐ We compare the wetland seasonal cycle amplitude between the observations and all ensemble members
- ☐ Example (right) for Congo shows that majority of ensemble members overestimate the observed seasonal cycle (especially for 2010-2012, 2015-2016)
- ☐ Switching between wetland masks can account for almost a doubling of seasonal cycle amplitude
- ☐ The distribution of the differences to the observed seasonal cycle are calculated for each region (right)
- ☐ Also coloured by the correlation coefficient between the observations and the mean WetCHARTs seasonal cycle



| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|
| GOSAT Proxy $XCH_4$ | 14 | 25 | 18 | 21 | 15 | 16 | 22 | 23 | 21 |
| 1913 | 6.1 | 19 | 23 | 15 | 10 | 12 | 16 | 20 | 8.9 |
| 1914 | 12 | 29 | 39 | 26 | 18 | 15 | 30 | 28 | 15 |
| 1923 | 7.4 | 21 | 25 | 16 | 11 | 11 | 20 | 25 | 8.7 |
| 1924 | 14 | 32 | 42 | 30 | 19 | 16 | 36 | 37 | 16 |
| 1933 | 7.3 | 20 | 24 | 16 | 9.9 | 11 | 20 | 28 | 8.2 |
| 1934 | 13 | 31 | 41 | 29 | 19 | 16 | 36 | 41 | 16 |
| 2913 | 8.2 | 25 | 31 | 19 | 14 | 16 | 22 | 27 | 12 |
| 2914 | 16 | 38 | 52 | 34 | 24 | 20 | 40 | 37 | 20 |
| 2923 | 9.9 | 28 | 34 | 22 | 14 | 14 | 27 | 34 | 12 |
| 2924 | 18 | 42 | 56 | 40 | 26 | 21 | 49 | 50 | 21 |
| 2933 | 9.8 | 27 | 33 | 21 | 13 | 14 | 27 | 37 | 11 |
| 2934 | 18 | 42 | 54 | 39 | 25 | 21 | 49 | 54 | 21 |
| 3913 | 10 | 31 | 39 | 24 | 17 | 20 | 27 | 34 | 15 |
| 3914 | 20 | 47 | 65 | 43 | 31 | 25 | 50 | 46 | 24 |
| 3923 | 12 | 34 | 42 | 27 | 18 | 18 | 33 | 42 | 14 |
| 3924 | 23 | 53 | 70 | 50 | 32 | 26 | 61 | 62 | 26 |
| 3933 | 12 | 34 | 41 | 26 | 16 | 18 | 34 | 46 | 14 |
| 3934 | 22 | 52 | 68 | 48 | 31 | 27 | 61 | 68 | 27 |

# JULES Ensemble



- Ensemble of JULES runs provided by Eddy (CEH)
- **ERA-Interim** vs **WFDEI met**, **default** vs **high Q10**, **default** vs **mask extent**, **phenology** vs **TRIFFID fixed** vs **TRIFFID dynamic veg**
- 2 x 2 x 2 x 3 = **24** ensemble members
- Have now run these emissions through same TOMCAT model as WetCHARTs (huge time and data storage requirements)
- Analysis just beginning (as of last week!)

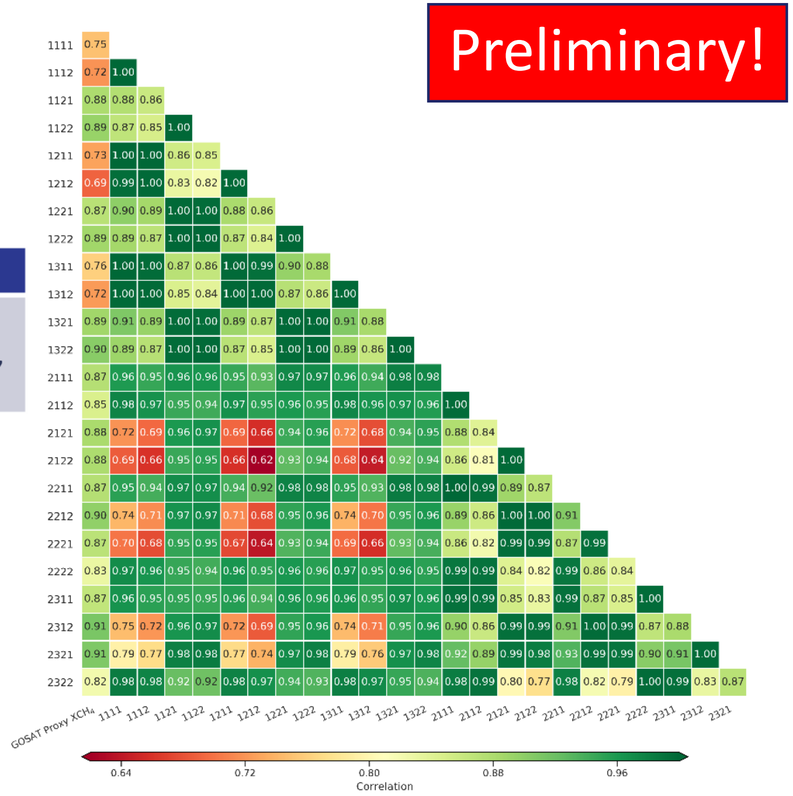
# JULES

Preliminary!

- ☐ Higher temperature dependency performs better for ERA-Interim but less impact for WFDEI
- ☐ WFDEI correlates better in general to observations globally
- ☐ The different extent masking does not cause large differences on a global scale (it does have a very large effect over some regions though!)

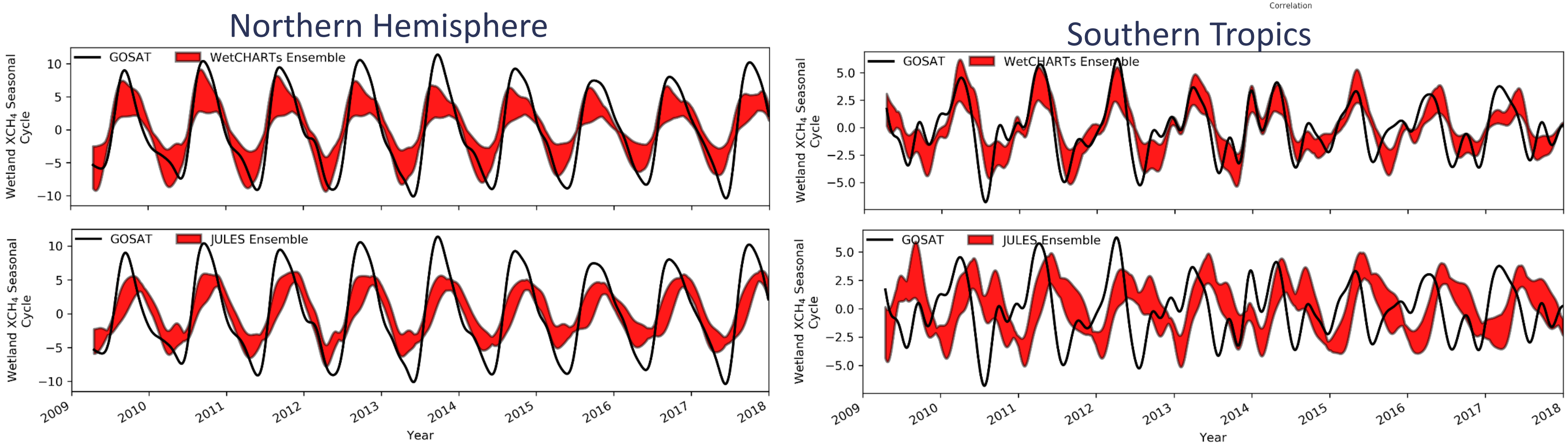
**4-digit code describes ensemble member - ABCD**

| **A** | **1** | **2** | |
|---|---|---|---|
| Met Driving Data | ERA-Interim | WFDEI | |
| **B** | **1** | **2** | **3** |
| Vegetation | Phenology, 9pfts | TRIFFID Fixed, 9pfts | TRIFFID Dynamic, 9pfts |
| **C** | **1** | **2** | |
| Temperature Dependence | q10 = 3.7 | q10 = 5.0 | |
| **D** | **1** | **2** | |
| Extent Parameterisation | JULES | JULES with SWAMPS mask | |



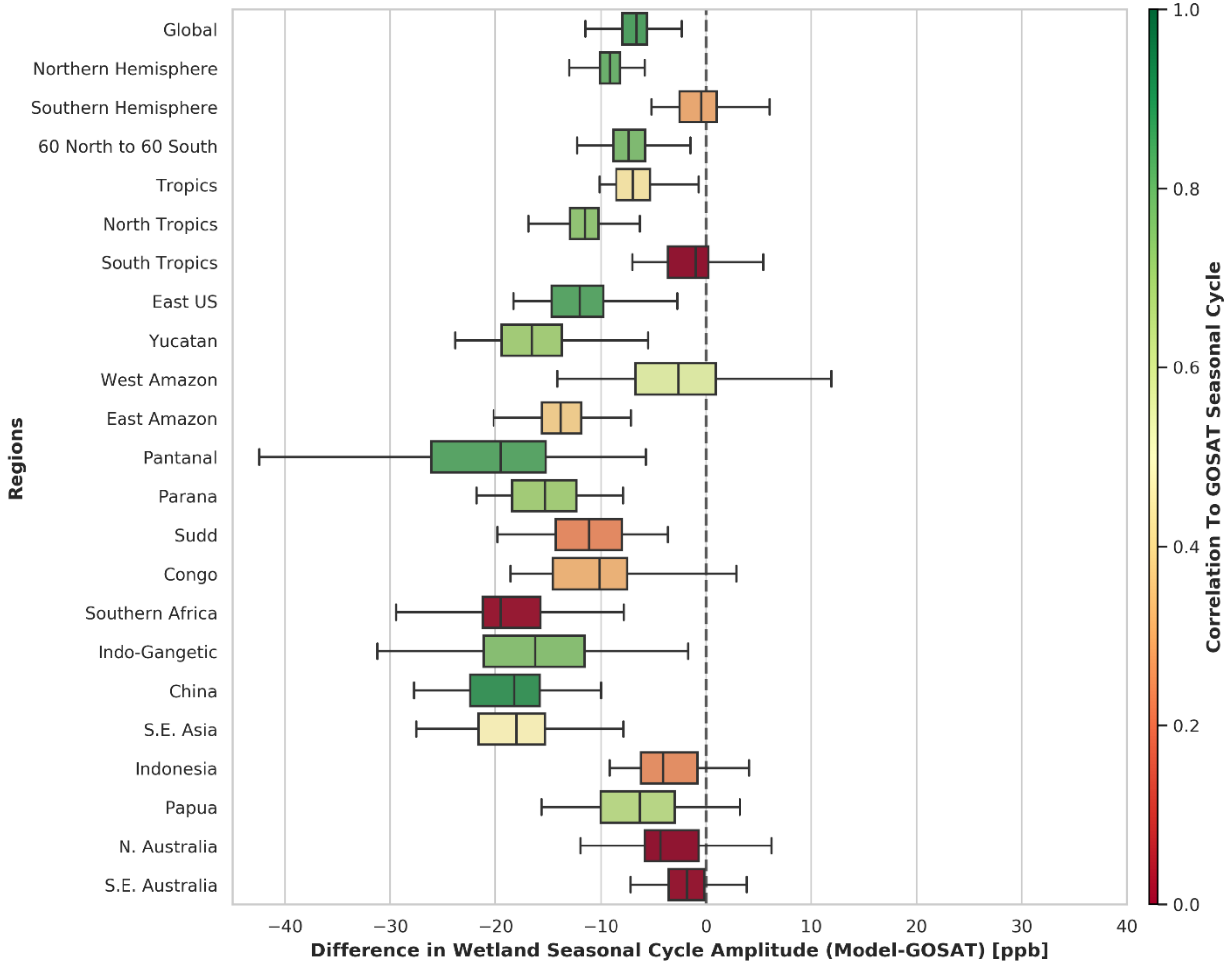
| | GOSAT Proxy $XCH_4$ | 1111 | 1112 | 1121 | 1122 | 1211 | 1212 | 1221 | 1222 | 1311 | 1312 | 1321 | 1322 | 2111 | 2112 | 2121 | 2122 | 2211 | 2212 | 2221 | 2222 | 2311 | 2312 | 2321 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1111 | 0.75 | | | | | | | | | | | | | | | | | | | | | | | |
| 1112 | 0.72 | 1.00 | | | | | | | | | | | | | | | | | | | | | | |
| 1121 | 0.88 | 0.88 | 0.86 | | | | | | | | | | | | | | | | | | | | | |
| 1122 | 0.89 | 0.87 | 0.85 | 1.00 | | | | | | | | | | | | | | | | | | | | |
| 1211 | 0.73 | 1.00 | 1.00 | 0.86 | 0.85 | | | | | | | | | | | | | | | | | | | |
| 1212 | 0.69 | 0.99 | 1.00 | 0.83 | 0.82 | 1.00 | | | | | | | | | | | | | | | | | | |
| 1221 | 0.87 | 0.90 | 0.89 | 1.00 | 1.00 | 0.88 | 0.86 | | | | | | | | | | | | | | | | | |
| 1222 | 0.89 | 0.89 | 0.87 | 1.00 | 1.00 | 0.87 | 0.84 | 1.00 | | | | | | | | | | | | | | | | |
| 1311 | 0.76 | 1.00 | 1.00 | 0.87 | 0.86 | 1.00 | 0.99 | 0.90 | 0.88 | | | | | | | | | | | | | | | |
| 1312 | 0.72 | 1.00 | 1.00 | 0.85 | 0.84 | 1.00 | 1.00 | 0.87 | 0.86 | 1.00 | | | | | | | | | | | | | | |
| 1321 | 0.89 | 0.91 | 0.89 | 1.00 | 1.00 | 0.89 | 0.87 | 1.00 | 1.00 | 0.91 | 0.88 | | | | | | | | | | | | | |
| 1322 | 0.90 | 0.89 | 0.87 | 1.00 | 1.00 | 0.87 | 0.85 | 1.00 | 1.00 | 0.89 | 0.86 | 1.00 | | | | | | | | | | | | |
| 2111 | 0.87 | 0.96 | 0.95 | 0.96 | 0.96 | 0.95 | 0.93 | 0.97 | 0.97 | 0.96 | 0.94 | 0.98 | 0.98 | | | | | | | | | | | |
| 2112 | 0.85 | 0.98 | 0.97 | 0.95 | 0.94 | 0.97 | 0.95 | 0.96 | 0.95 | 0.98 | 0.96 | 0.97 | 0.96 | 1.00 | | | | | | | | | | |
| 2121 | 0.88 | 0.72 | 0.69 | 0.96 | 0.97 | 0.69 | 0.66 | 0.94 | 0.96 | 0.72 | 0.68 | 0.94 | 0.95 | 0.88 | 0.84 | | | | | | | | | |
| 2122 | 0.88 | 0.69 | 0.66 | 0.95 | 0.95 | 0.66 | 0.62 | 0.93 | 0.94 | 0.68 | 0.64 | 0.92 | 0.94 | 0.86 | 0.81 | 1.00 | | | | | | | | |
| 2211 | 0.87 | 0.95 | 0.94 | 0.97 | 0.97 | 0.94 | 0.92 | 0.98 | 0.98 | 0.95 | 0.93 | 0.98 | 0.98 | 1.00 | 0.99 | 0.89 | 0.87 | | | | | | | |
| 2212 | 0.90 | 0.74 | 0.71 | 0.97 | 0.97 | 0.71 | 0.68 | 0.95 | 0.96 | 0.74 | 0.70 | 0.95 | 0.96 | 0.89 | 0.86 | 1.00 | 1.00 | 0.91 | | | | | | |
| 2221 | 0.87 | 0.70 | 0.68 | 0.95 | 0.95 | 0.67 | 0.64 | 0.93 | 0.94 | 0.69 | 0.66 | 0.93 | 0.94 | 0.86 | 0.82 | 0.99 | 0.99 | 0.87 | 0.99 | | | | | |
| 2222 | 0.83 | 0.97 | 0.96 | 0.95 | 0.94 | 0.96 | 0.95 | 0.96 | 0.96 | 0.97 | 0.95 | 0.96 | 0.95 | 0.99 | 0.99 | 0.84 | 0.82 | 0.99 | 0.86 | 0.84 | | | | |
| 2311 | 0.87 | 0.96 | 0.95 | 0.95 | 0.95 | 0.96 | 0.94 | 0.96 | 0.96 | 0.96 | 0.95 | 0.97 | 0.96 | 0.99 | 0.99 | 0.85 | 0.83 | 0.99 | 0.87 | 0.85 | 1.00 | | | |
| 2312 | 0.91 | 0.75 | 0.72 | 0.96 | 0.97 | 0.72 | 0.69 | 0.95 | 0.96 | 0.74 | 0.71 | 0.95 | 0.96 | 0.90 | 0.86 | 0.99 | 0.99 | 0.91 | 1.00 | 0.99 | 0.87 | 0.88 | | |
| 2321 | 0.91 | 0.79 | 0.77 | 0.98 | 0.98 | 0.77 | 0.74 | 0.97 | 0.98 | 0.79 | 0.76 | 0.97 | 0.98 | 0.92 | 0.89 | 0.99 | 0.98 | 0.93 | 0.99 | 0.99 | 0.90 | 0.91 | 1.00 | |
| 2322 | 0.82 | 0.98 | 0.98 | 0.92 | 0.92 | 0.98 | 0.97 | 0.94 | 0.93 | 0.98 | 0.97 | 0.95 | 0.94 | 0.98 | 0.99 | 0.80 | 0.77 | 0.98 | 0.82 | 0.79 | 1.00 | 0.99 | 0.83 | 0.87 |

- ☐ JULES seasonal cycle in Northern Hemisphere is reasonable
- ☐ JULES seasonal cycle in Southern Tropics is out of phase with observations and far worse than WetCHARTs

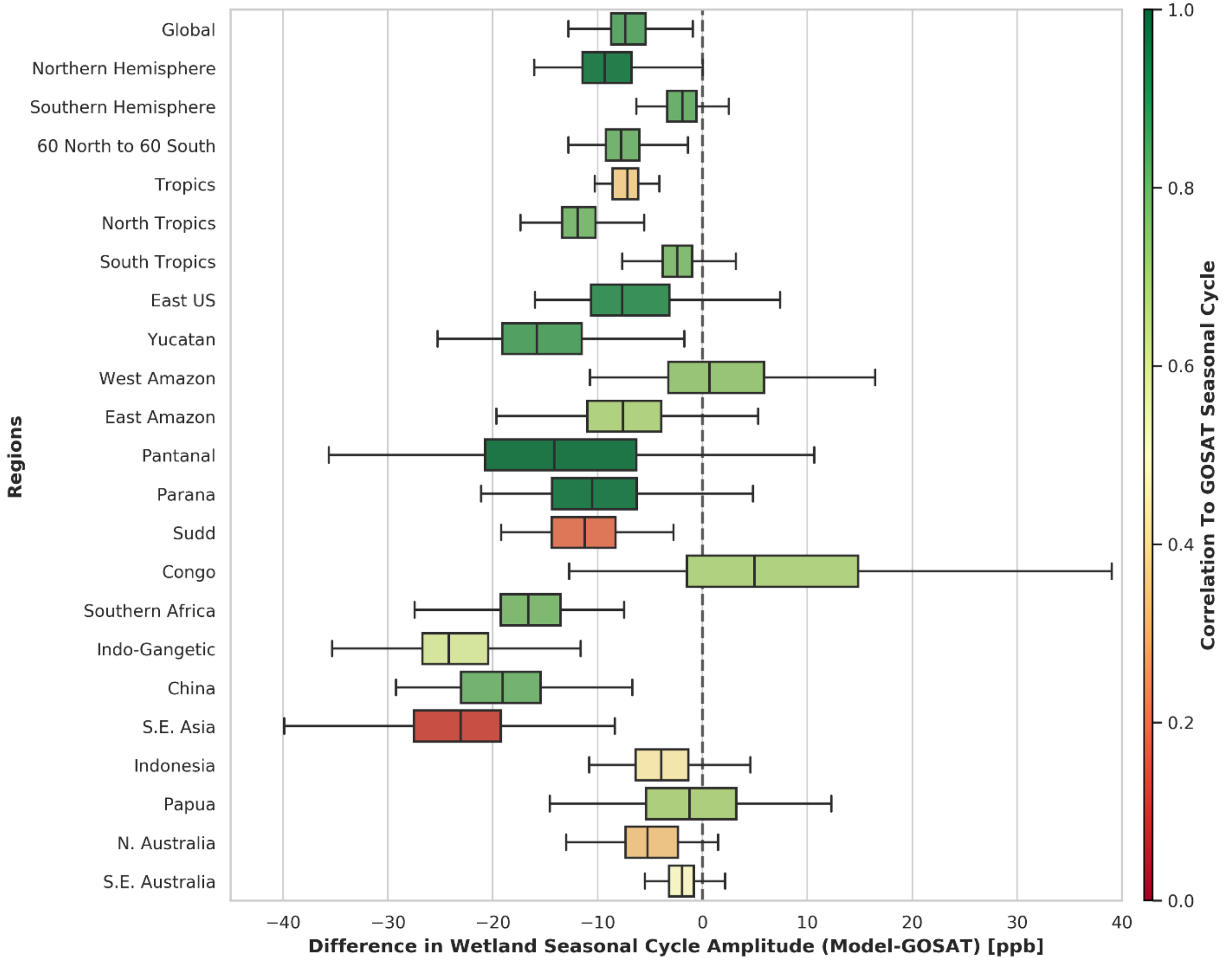


# Seasonal Cycle Amplitude and Correlation

## JULES Ensemble



## WetCHARTs Ensemble



- Things of note: Overall pattern similar, Congo spread much reduced in JULES, JULES has much poor correlation in general (especially S. Tropics) BUT better over India/China/S.E. Asia

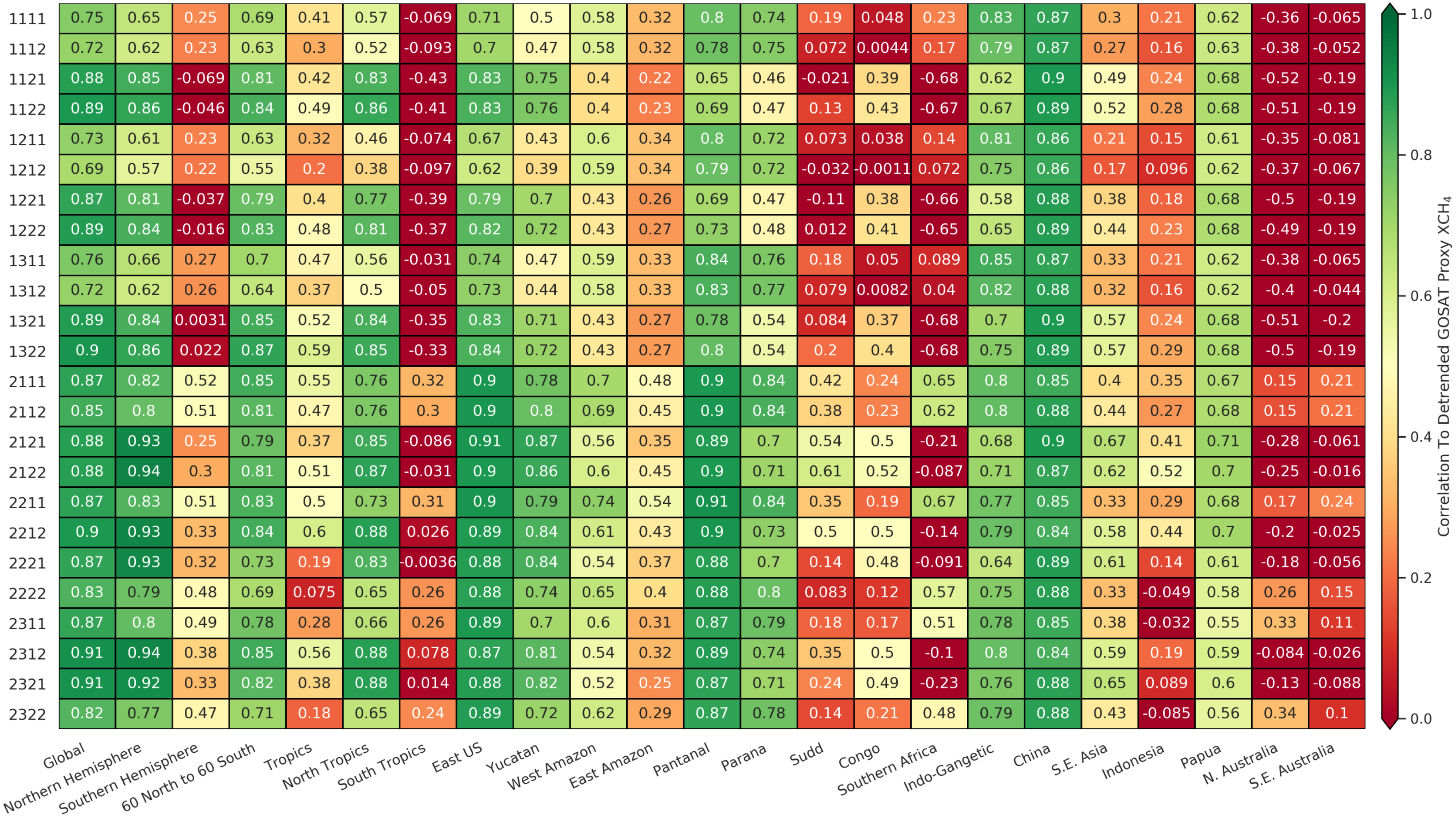
Preliminary!

# Summary

- ☐ We now have a really interesting dataset of Global Chemistry Transport model simulations driven by a large ensemble of WetCHARTs and JULES $CH_4$ emission data
- ☐ Starting to exploit this dataset by comparing to GOSAT observations to evaluate which factors are **most important in matching the observed $CH_4$ distributions**
- ☐ WetCHARTs could be viewed as a very basic data-driven implementation of JULES $CH_4$ parameterisation and so comparisons of performance against observations vs JULES can be useful
- ☐ In general WetCHARTs **performs very well**, capturing the **correct phase and magnitude** of wetland $CH_4$ emissions over many regions
- ☐ Ensemble member using **highest $Q_{10}$** value and **GLWD** wetland masking seems to perform the best against observations globally
- ☐ The Paraná river region which we focused on heavily in Parker et al., 2018 continues to be of interest as 2016/2017 show **strong anomalies consistent with increased wetland extent**
- ☐ The wetland mask (GLWD vs GLOBCOVER) makes a big difference to how well the emissions can match observations with **GLWD performing much better**
- ☐ However, WetCHARTs relies on precipitation to drive wetland extent and has **no knowledge of hydrology** (i.e. input from upstream) and hence even with a good wetland mask it will **struggle to reproduce anomalous events** (such as those observed in 2010, 2016, 2017) over the Paraná
- ☐ Extending this analysis to **JULES** ensemble is just beginning but already some interesting results
- ☐ Extension of existing satellite-based surface inundation datasets **critical** for determining role of inundation in atmospheric $CH_4$ observations

# Extra Slides

# JULES Correlation to Observed Wetland Seasonal Cycle



| | Global | Northern Hemisphere | Southern Hemisphere | 60 North to 60 South | Tropics | North Tropics | South Tropics | East US | Yucatan | West Amazon | East Amazon | Pantanal | Parana | Sudd | Congo | Southern Africa | Indo-Gangetic | China | S.E. Asia | Indonesia | Papua | N. Australia | S.E. Australia |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1111 | 0.75 | 0.65 | 0.25 | 0.69 | 0.41 | 0.57 | -0.069 | 0.71 | 0.5 | 0.58 | 0.32 | 0.8 | 0.74 | 0.19 | 0.048 | 0.23 | 0.83 | 0.87 | 0.3 | 0.21 | 0.62 | -0.36 | -0.065 |
| 1112 | 0.72 | 0.62 | 0.23 | 0.63 | 0.3 | 0.52 | -0.093 | 0.7 | 0.47 | 0.58 | 0.32 | 0.78 | 0.75 | 0.072 | 0.0044 | 0.17 | 0.79 | 0.87 | 0.27 | 0.16 | 0.63 | -0.38 | -0.052 |
| 1121 | 0.88 | 0.85 | -0.069 | 0.81 | 0.42 | 0.83 | -0.43 | 0.83 | 0.75 | 0.4 | 0.22 | 0.65 | 0.46 | -0.021 | 0.39 | -0.68 | 0.62 | 0.9 | 0.49 | 0.24 | 0.68 | -0.52 | -0.19 |
| 1122 | 0.89 | 0.86 | -0.046 | 0.84 | 0.49 | 0.86 | -0.41 | 0.83 | 0.76 | 0.4 | 0.23 | 0.69 | 0.47 | 0.13 | 0.43 | -0.67 | 0.67 | 0.89 | 0.52 | 0.28 | 0.68 | -0.51 | -0.19 |
| 1211 | 0.73 | 0.61 | 0.23 | 0.63 | 0.32 | 0.46 | -0.074 | 0.67 | 0.43 | 0.6 | 0.34 | 0.8 | 0.72 | 0.073 | 0.038 | 0.14 | 0.81 | 0.86 | 0.21 | 0.15 | 0.61 | -0.35 | -0.081 |
| 1212 | 0.69 | 0.57 | 0.22 | 0.55 | 0.2 | 0.38 | -0.097 | 0.62 | 0.39 | 0.59 | 0.34 | 0.79 | 0.72 | -0.032 | -0.0011 | 0.072 | 0.75 | 0.86 | 0.17 | 0.096 | 0.62 | -0.37 | -0.067 |
| 1221 | 0.87 | 0.81 | -0.037 | 0.79 | 0.4 | 0.77 | -0.39 | 0.79 | 0.7 | 0.43 | 0.26 | 0.69 | 0.47 | -0.11 | 0.38 | -0.66 | 0.58 | 0.88 | 0.38 | 0.18 | 0.68 | -0.5 | -0.19 |
| 1222 | 0.89 | 0.84 | -0.016 | 0.83 | 0.48 | 0.81 | -0.37 | 0.82 | 0.72 | 0.43 | 0.27 | 0.73 | 0.48 | 0.012 | 0.41 | -0.65 | 0.65 | 0.89 | 0.44 | 0.23 | 0.68 | -0.49 | -0.19 |
| 1311 | 0.76 | 0.66 | 0.27 | 0.7 | 0.47 | 0.56 | -0.031 | 0.74 | 0.47 | 0.59 | 0.33 | 0.84 | 0.76 | 0.18 | 0.05 | 0.089 | 0.85 | 0.87 | 0.33 | 0.21 | 0.62 | -0.38 | -0.065 |
| 1312 | 0.72 | 0.62 | 0.26 | 0.64 | 0.37 | 0.5 | -0.05 | 0.73 | 0.44 | 0.58 | 0.33 | 0.83 | 0.77 | 0.079 | 0.0082 | 0.04 | 0.82 | 0.88 | 0.32 | 0.16 | 0.62 | -0.4 | -0.044 |
| 1321 | 0.89 | 0.84 | 0.0031 | 0.85 | 0.52 | 0.84 | -0.35 | 0.83 | 0.71 | 0.43 | 0.27 | 0.78 | 0.54 | 0.084 | 0.37 | -0.68 | 0.7 | 0.9 | 0.57 | 0.24 | 0.68 | -0.51 | -0.2 |
| 1322 | 0.9 | 0.86 | 0.022 | 0.87 | 0.59 | 0.85 | -0.33 | 0.84 | 0.72 | 0.43 | 0.27 | 0.8 | 0.54 | 0.2 | 0.4 | -0.68 | 0.75 | 0.89 | 0.57 | 0.29 | 0.68 | -0.5 | -0.19 |
| 2111 | 0.87 | 0.82 | 0.52 | 0.85 | 0.55 | 0.76 | 0.32 | 0.9 | 0.78 | 0.7 | 0.48 | 0.9 | 0.84 | 0.42 | 0.24 | 0.65 | 0.8 | 0.85 | 0.4 | 0.35 | 0.67 | 0.15 | 0.21 |
| 2112 | 0.85 | 0.8 | 0.51 | 0.81 | 0.47 | 0.76 | 0.3 | 0.9 | 0.8 | 0.69 | 0.45 | 0.9 | 0.84 | 0.38 | 0.23 | 0.62 | 0.8 | 0.88 | 0.44 | 0.27 | 0.68 | 0.15 | 0.21 |
| 2121 | 0.88 | 0.93 | 0.25 | 0.79 | 0.37 | 0.85 | -0.086 | 0.91 | 0.87 | 0.56 | 0.35 | 0.89 | 0.7 | 0.54 | 0.5 | -0.21 | 0.68 | 0.9 | 0.67 | 0.41 | 0.71 | -0.28 | -0.061 |
| 2122 | 0.88 | 0.94 | 0.3 | 0.81 | 0.51 | 0.87 | -0.031 | 0.9 | 0.86 | 0.6 | 0.45 | 0.9 | 0.71 | 0.61 | 0.52 | -0.087 | 0.71 | 0.87 | 0.62 | 0.52 | 0.7 | -0.25 | -0.016 |
| 2211 | 0.87 | 0.83 | 0.51 | 0.83 | 0.5 | 0.73 | 0.31 | 0.9 | 0.79 | 0.74 | 0.54 | 0.91 | 0.84 | 0.35 | 0.19 | 0.67 | 0.77 | 0.85 | 0.33 | 0.29 | 0.68 | 0.17 | 0.24 |
| 2212 | 0.9 | 0.93 | 0.33 | 0.84 | 0.6 | 0.88 | 0.026 | 0.89 | 0.84 | 0.61 | 0.43 | 0.9 | 0.73 | 0.5 | 0.5 | -0.14 | 0.79 | 0.84 | 0.58 | 0.44 | 0.7 | -0.2 | -0.025 |
| 2221 | 0.87 | 0.93 | 0.32 | 0.73 | 0.19 | 0.83 | -0.0036 | 0.88 | 0.84 | 0.54 | 0.37 | 0.88 | 0.7 | 0.14 | 0.48 | -0.091 | 0.64 | 0.89 | 0.61 | 0.14 | 0.61 | -0.18 | -0.056 |
| 2222 | 0.83 | 0.79 | 0.48 | 0.69 | 0.075 | 0.65 | 0.26 | 0.88 | 0.74 | 0.65 | 0.4 | 0.88 | 0.8 | 0.083 | 0.12 | 0.57 | 0.75 | 0.88 | 0.33 | -0.049 | 0.58 | 0.26 | 0.15 |
| 2311 | 0.87 | 0.8 | 0.49 | 0.78 | 0.28 | 0.66 | 0.26 | 0.89 | 0.7 | 0.6 | 0.31 | 0.87 | 0.79 | 0.18 | 0.17 | 0.51 | 0.78 | 0.85 | 0.38 | -0.032 | 0.55 | 0.33 | 0.11 |
| 2312 | 0.91 | 0.94 | 0.38 | 0.85 | 0.56 | 0.88 | 0.078 | 0.87 | 0.81 | 0.54 | 0.32 | 0.89 | 0.74 | 0.35 | 0.5 | -0.1 | 0.8 | 0.84 | 0.59 | 0.19 | 0.59 | -0.084 | -0.026 |
| 2321 | 0.91 | 0.92 | 0.33 | 0.82 | 0.38 | 0.88 | 0.014 | 0.88 | 0.82 | 0.52 | 0.25 | 0.87 | 0.71 | 0.24 | 0.49 | -0.23 | 0.76 | 0.88 | 0.65 | 0.089 | 0.6 | -0.13 | -0.088 |
| 2322 | 0.82 | 0.77 | 0.47 | 0.71 | 0.18 | 0.65 | 0.24 | 0.89 | 0.72 | 0.62 | 0.29 | 0.87 | 0.78 | 0.14 | 0.21 | 0.48 | 0.79 | 0.88 | 0.43 | -0.085 | 0.56 | 0.34 | 0.1 |

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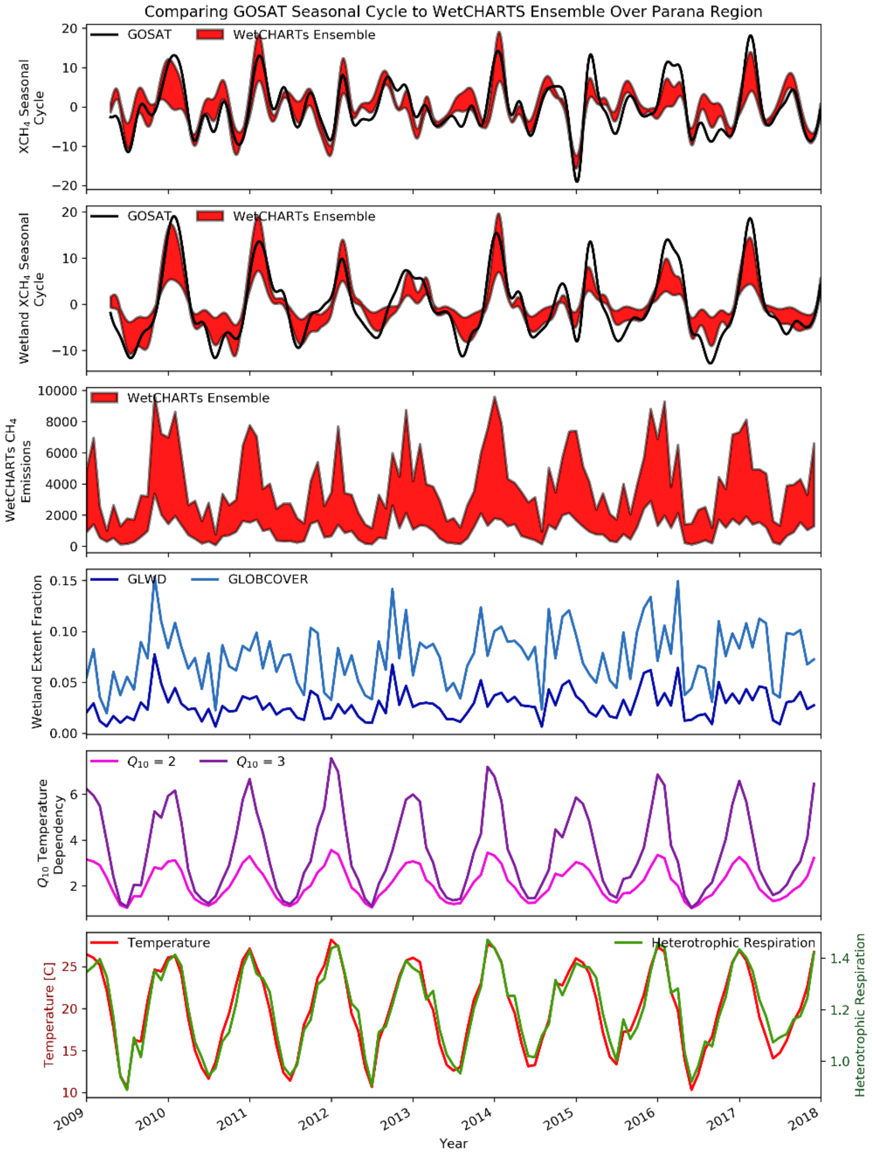
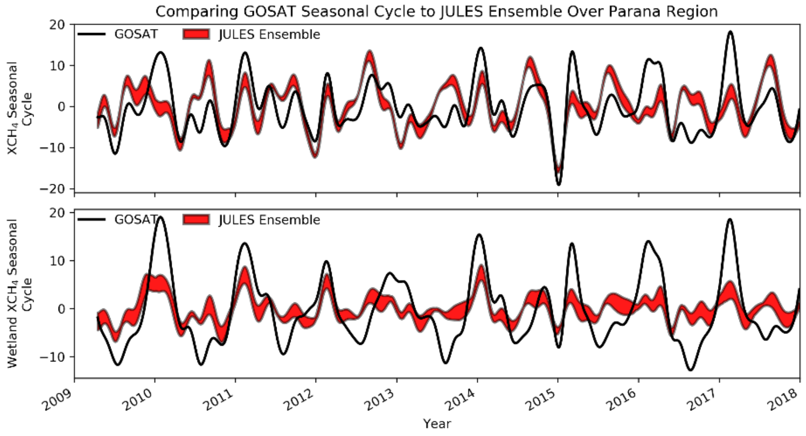
# Paraná Timeseries

- ❑ Some WetCHARTs ensemble members can get close to observed wetland seasonal cycle (albeit still underestimating the strong peaks)
- ❑ JULES does a much poorer job here and although it broadly captures the seasonality, the magnitude it far too small

## WetCHARTs Ensemble

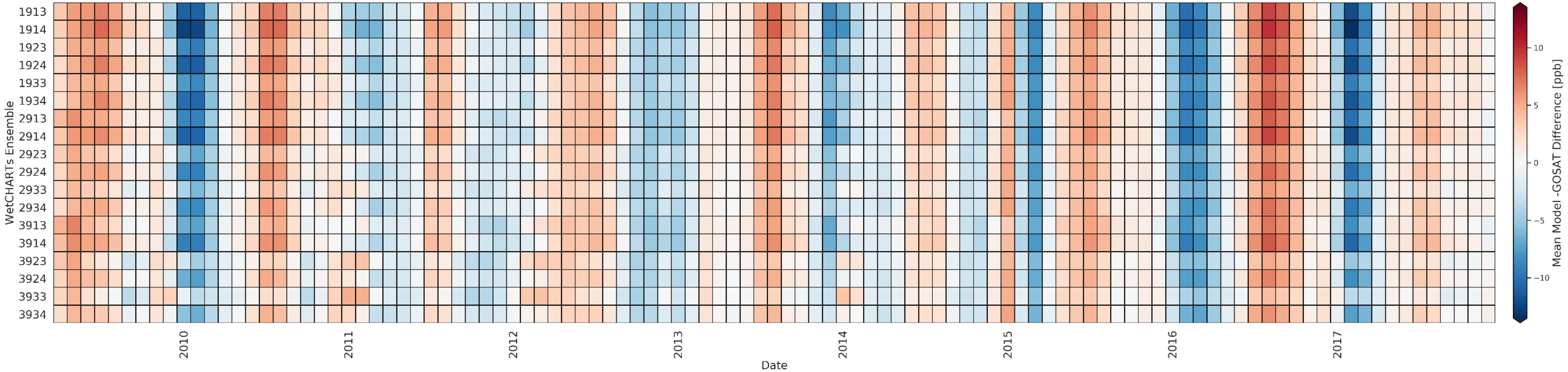


## JULES Ensemble



# Paraná Timeseries

WetCHARTs Ensemble



JULES Ensemble