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Supporting Information for

Role of regional wetland emissions in atmospheric methane variability

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Introduction

This supporting information contains four additional figures to the main article. S1 shows a version of JULES with additional wetland processes compared with flux observations. S2 shows TOMCAT comparisons with available TCCON data. S3 and S4 show TOMCAT comparisons with individual NOAA surface observations. S5 provides the respiration rates, which are assumed to be proportional to methanogenesis rate. S6 describes the CH_4 emission scaling.

Text S1.

We have tested several wetland-process additions within the JULES model which are mainly based on previous studies [Gauci et al., 2004; Wania et al., 2010; Riley et al., 2011]. The additions include sulphate suppression, transport mechanisms, a representation of CH_4 pools and, production and oxidation in both saturated and unsaturated regions. For this, parameters from JULES were used where available (e.g. leaf area index). Several soil parameters were fixed in time (e.g. porosity), taken from the Harmonised World Soil Database and sulphate suppression, based on Gauci et al. [2004], used deposition from HadGEM3-UKCA [Turnock et al., 2015]. Sensitivity tests were performed with a range of model parameter values, which were optimised based on flux observations, compiled by Riley et al. [2011]. The ideal model setup was then compared with the original version of JULES, which did not contain the process additions (Fig. S1). The results show that even when the updated model is optimised it still shows a lower correlation with observations in some regions and provides only a small improvement in other regions, for this reason we do not consider that the process additions are well represented and therefore they are

not included in the model simulations in the main paper. Future work to develop model processes is likely to improve the modelled emissions. However, it is currently limited by both process uncertainty and a poor model representation of the variables needed to drive those processes.

Text S2.

Monthly mean column measurements of atmospheric CH_4 using TCCON ground-based Fourier Transform Spectrometers [Wunch et al., 2011] provide XCH_4. Data from 2004 is used from 15 TCCON sites where available to perform comparisons with both simulations (Fig. S2). The results indicate that model data agrees well with observations and that the simulation with the JU wetland inventory performs slightly better than the simulation with BL.

Text S3.

We have used monthly mean surface measurements of atmospheric CH_4 at 19 NOAA observations sites between 1993-2014 [Dlugokencky et al., 2015] to calculate seasonal cycles and compare them with simulations TOMCAT-JU and TOMCAT-BL (Fig. S3). The results indicate that TOMCAT-JU represents the seasonal cycle more realistically than TOMCAT BL at 10 of the 19 sites while TOMCAT-BL is more realistic at 4 of the sites. The remaining 5 sites produce the same correlation values for both simulations.

Text S4.

In addition to the correlation, we calculated the difference in CH_4 concentration at each NOAA site between the TOMCAT simulations (TOMCAT-JU and TOMCAT-BL) and the observations for the period 1993-2014. Fig. S4 shows the mean absolute percentage error (MAPE) at each site calculated using the following equation, where n is the total number of months and CH_{4o} and CH_{4m} are the observed and modelled CH_4 concentrations, respectively:

$$MAPE = \frac{1}{n}\sum \left|\frac{CH_{4o} - CH_{4m}}{CH_{4o}}\right|$$

Several factors beyond the wetland emissions must be noted as caveats when assessing the MAPE, including inaccuracies in non-wetland emissions and potential slow inter-hemispheric mixing within TOMCAT [Wilson et al., 2014]. However, based on Fig. S4 the simulation TOMCAT-JU provides a lower mean absolute percentage error (0.54%) compared with TOMCAT-BL (0.59%).

Text S5.

Respiration values taken from Clark *et al.* [2011] of $3.22 \times 10^{-7} s^{-1}$, $9.65 \times 10^{-9} s^{-1}$, $2.12 \times 10^{-8} s^{-1}$, $6.43 \times 10^{-10} s^{-1}$ for DPM, RPM , BIO and HUM.

Text S6.

A scaling factor is applied to all emission sources so that the 2000-2009 mean annual emissions are equal to top-down estimates provided in Ciais et al. [2014]. The same scaling factor is then applied to emissions pre-2000 and post-2009. The mean emissions for a particular source, e.g. wetlands, will equal Ciais et al. [2014] between 2000-2009; however, the overall mean annual emissions (1993-2014) may differ.

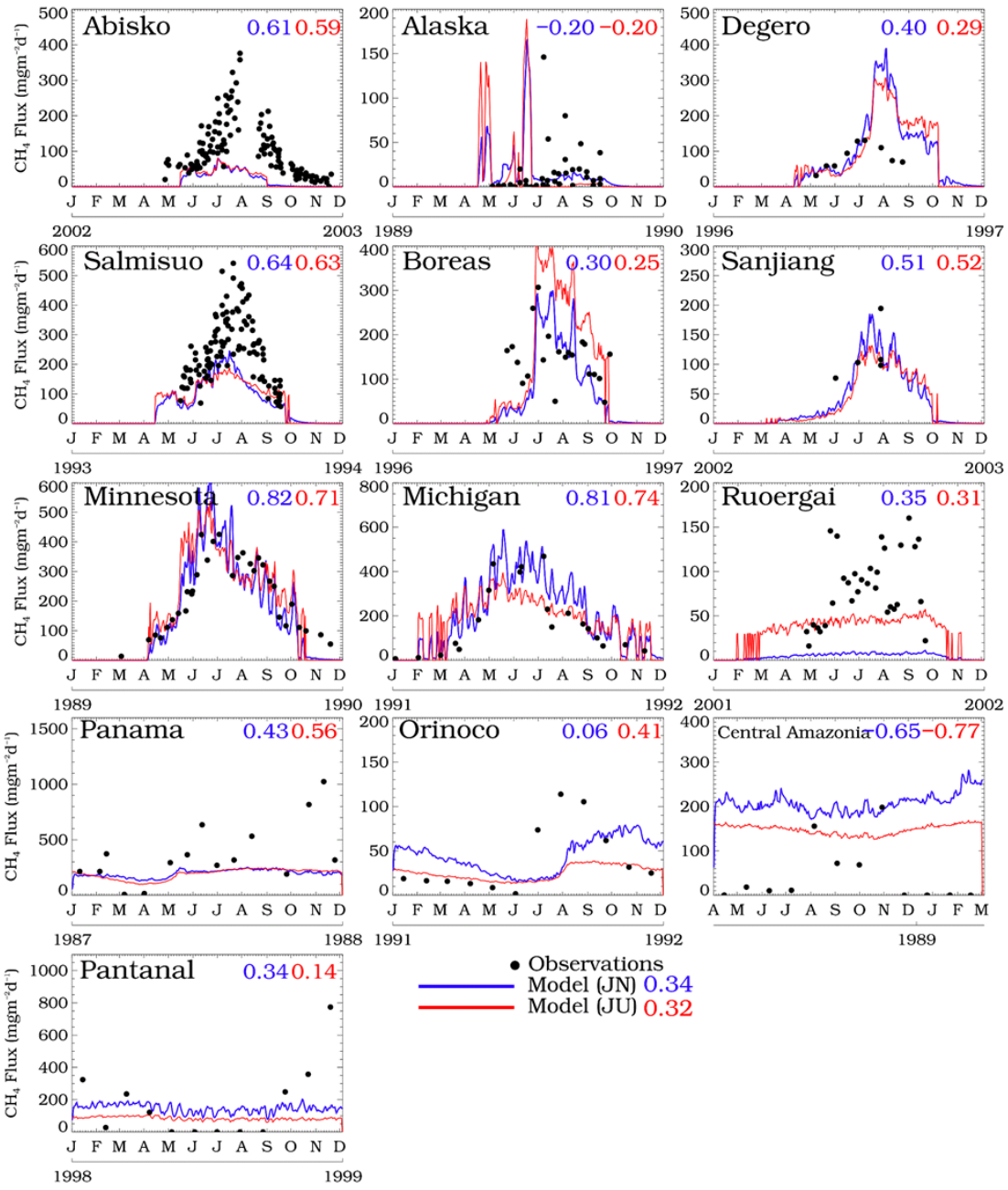

Figure S1. CH_4 flux ($mgCH_4$ m-2 day-1) from 13 measurement sites when data are available (black circles), compiled by Riley et al. [2011]. Also shown are daily results from a JULES simulation with additional processes included (JN), for the parameter configuration that provides the lowest mean RMSE over all sites (blue line), and emissions from the standard JULES configuration (JU) (red line). Correlation coefficients for JN (blue) and JU (red) compared with observations are displayed for each site and as an all-site mean.

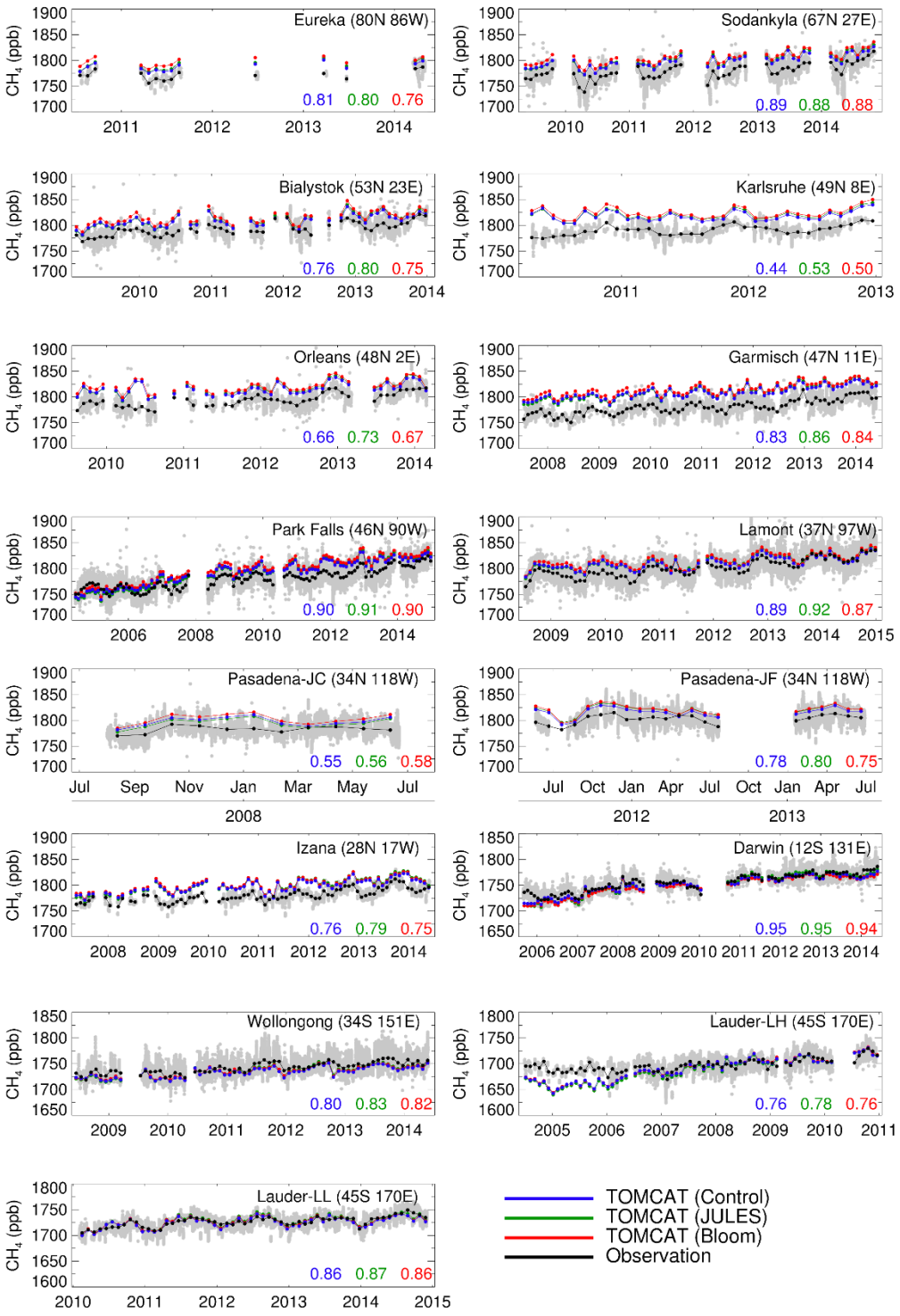

Figure S2. Monthly mean XCH_4 concentrations (ppb) from 15 TCCON sites when data are available (black). Individual observations are shown in grey. Also shown are concentrations from TOMCAT simulations using repeating (blue), JULES (green) and Bloom et al. [2012] (red) wetland emissions, with TCCON averaging kernels applied. Correlation coefficients of model and observations are displayed for both simulations.

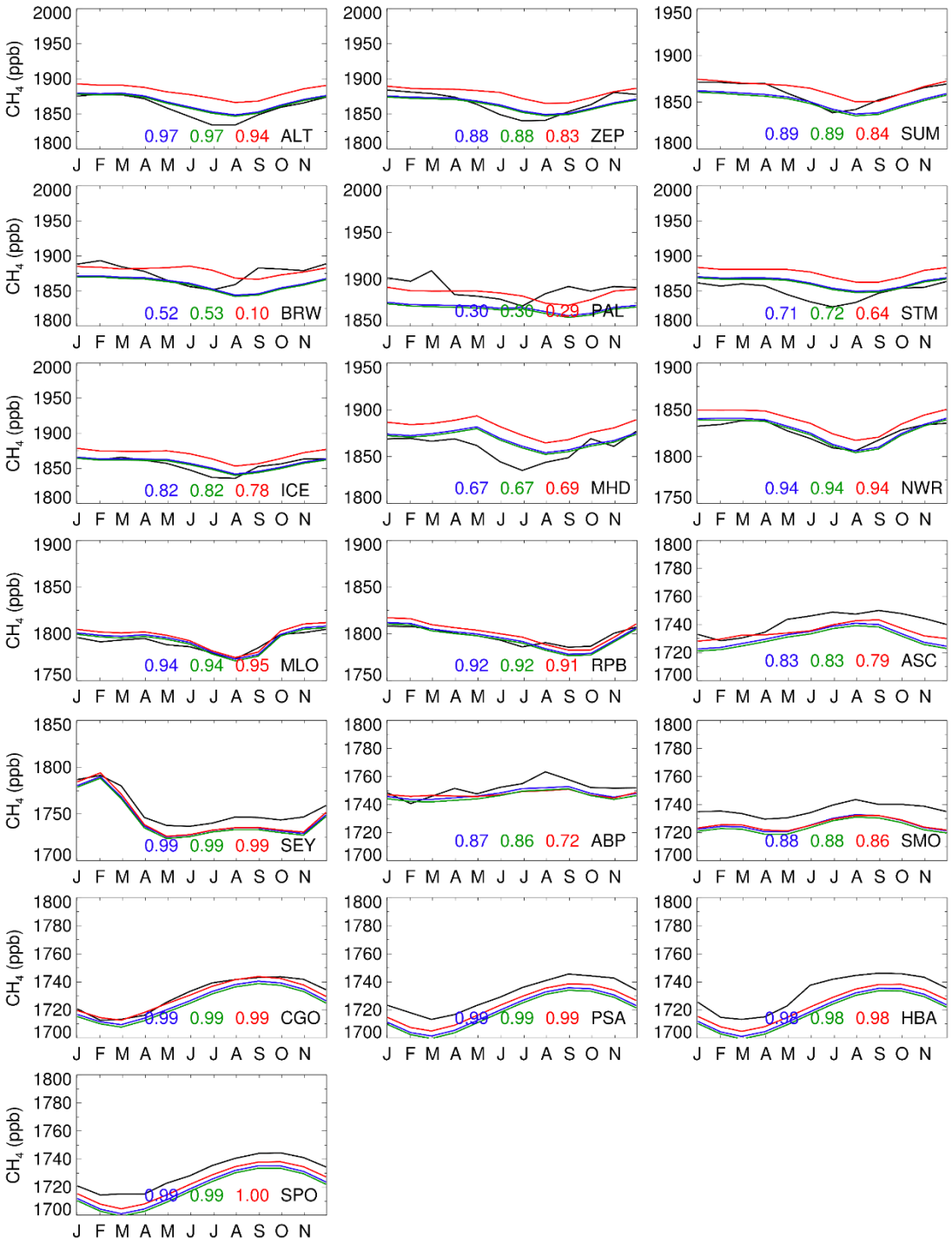

Figure S3. Seasonal cycle of monthly mean surface CH_4 (ppb) from 19 NOAA observation sites (black) from 1993 to 2014, where data are available. The site is indicated by its 3-letter code in each panel. Also shown are concentrations from TOMCAT simulations using repeat (blue), JULES (green) and Bloom et al. [2012] (red) wetland emissions. Values denote correlation coefficients for each model simulation compared with observations.

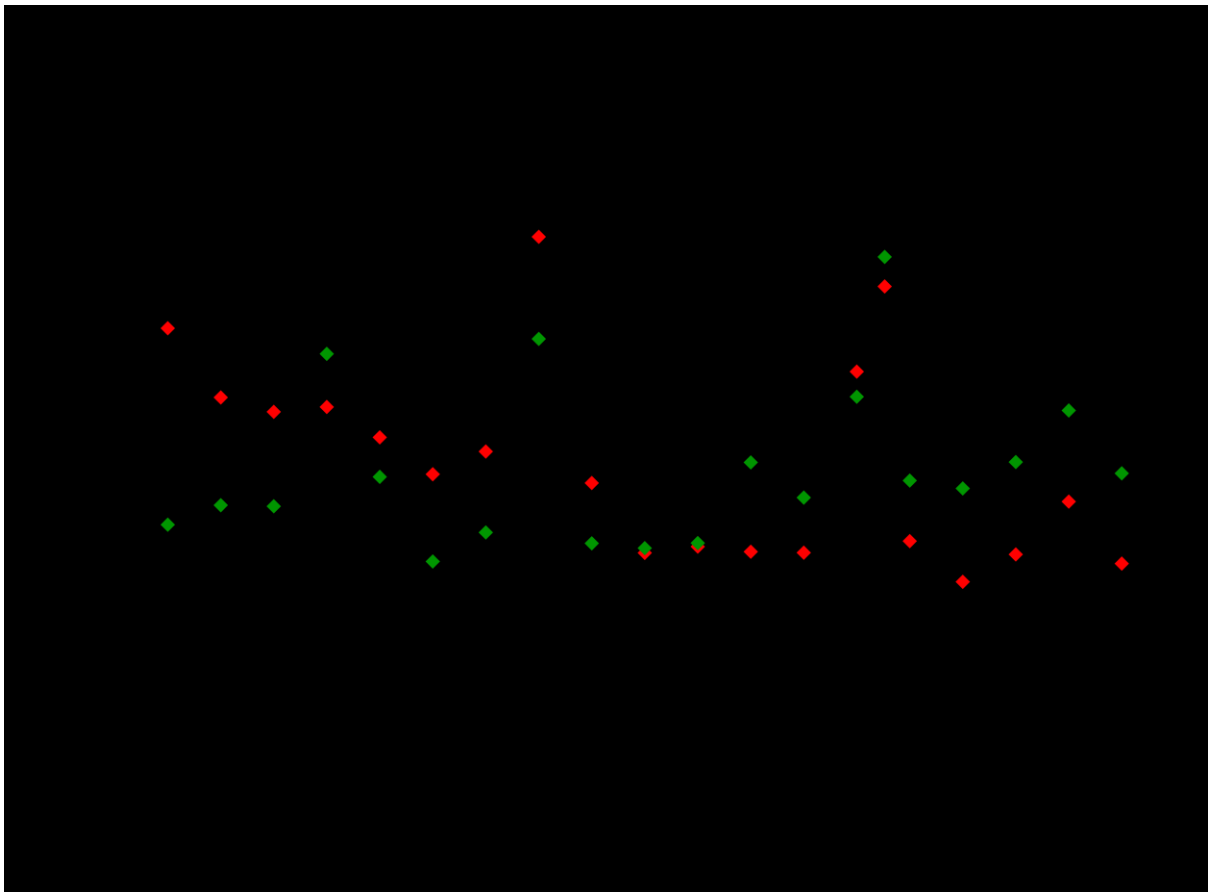

Figure S3. Mean absolute percentage error calculated from the two TOMCAT simulations compared with monthly mean surface CH_4 (ppb) from 19 NOAA observation sites from 1993 to 2014, where data are available. The observations are sorted by latitude from north to south and indicated by their site code.