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# Modelling large-scale wetland methane emissions

Nic Gedney (Met Office)

JULES Meeting, 12-13th January 2011



- Motivation
- Model description
- Validation
- Emissions variability
- Conclusions and future work

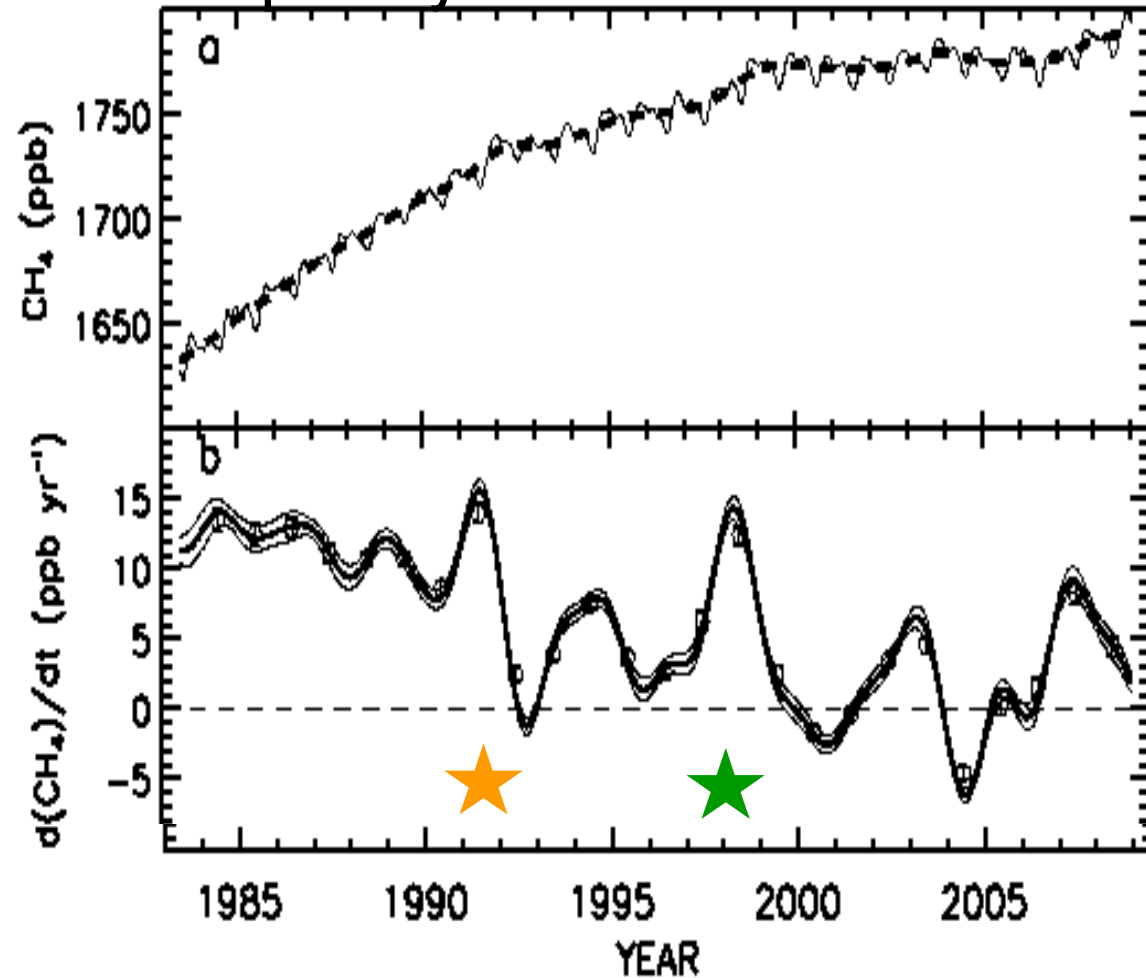
# Motivation

- $\text{CH}_4$  is the second most important anthropogenic greenhouse gas
- Much stronger greenhouse gas than  $\text{CO}_2$
- Wetlands are dominant natural source of  $\text{CH}_4$
- Wetlands contribute ~20%–40% of the global present day atmospheric  $\text{CH}_4$
- Wetland emissions dependent on precipitation and temperature – future feedback?
- Trend and inter-annual variability in  $\text{CH}_4$  growth rate are poorly understood

★ 1991/1992:  
Pinatubo/OH  
Anthro ems  
Wetland ems

★ 1997/1998:  
BB ems  
Wetland ems  
Wildfires

Trend and inter-annual variability in CH<sub>4</sub> growth rate are poorly understood



Dlugokencky et al, 2009

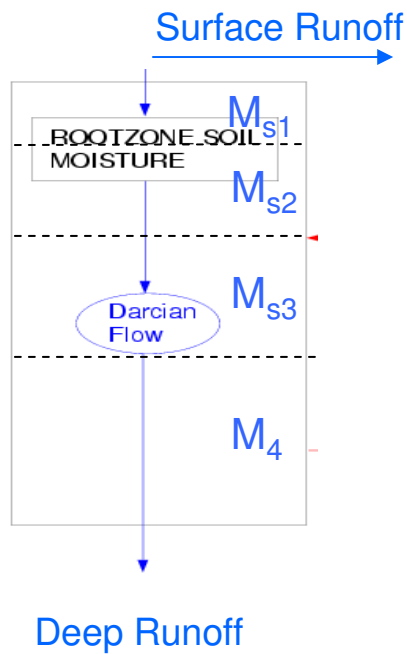


# Wetland hydrology model

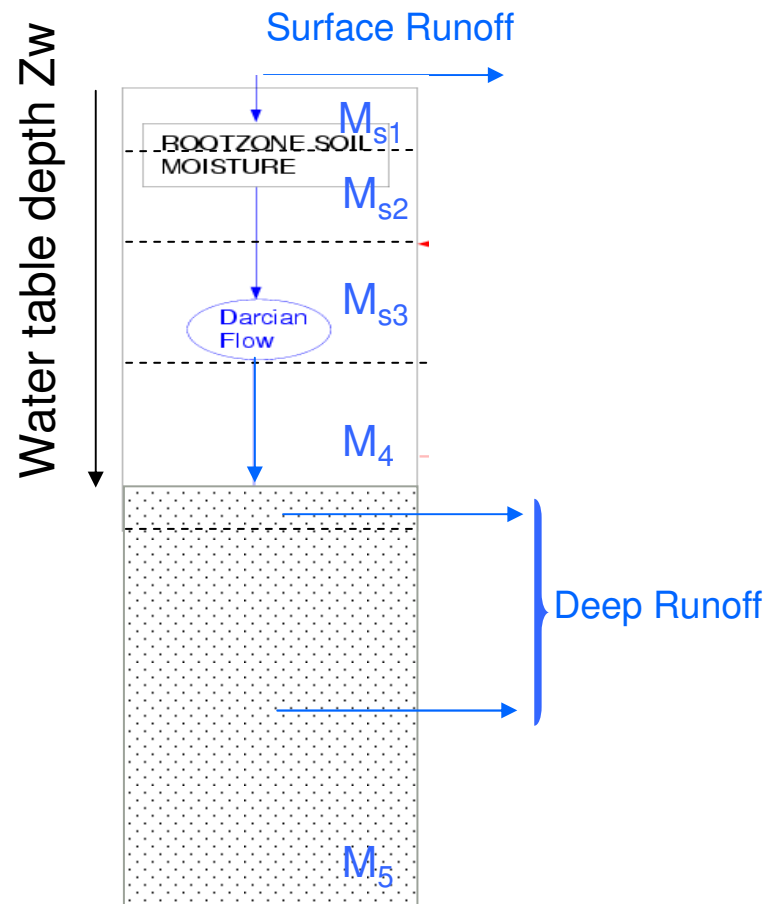
- Wetlands area highly correlated with topography globally
- Wetlands often have peat soils

# JULES schematic of soil moisture flow

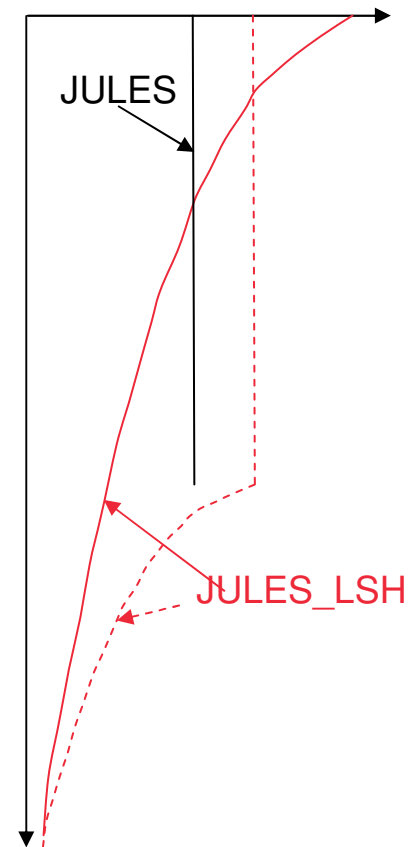
## JULES



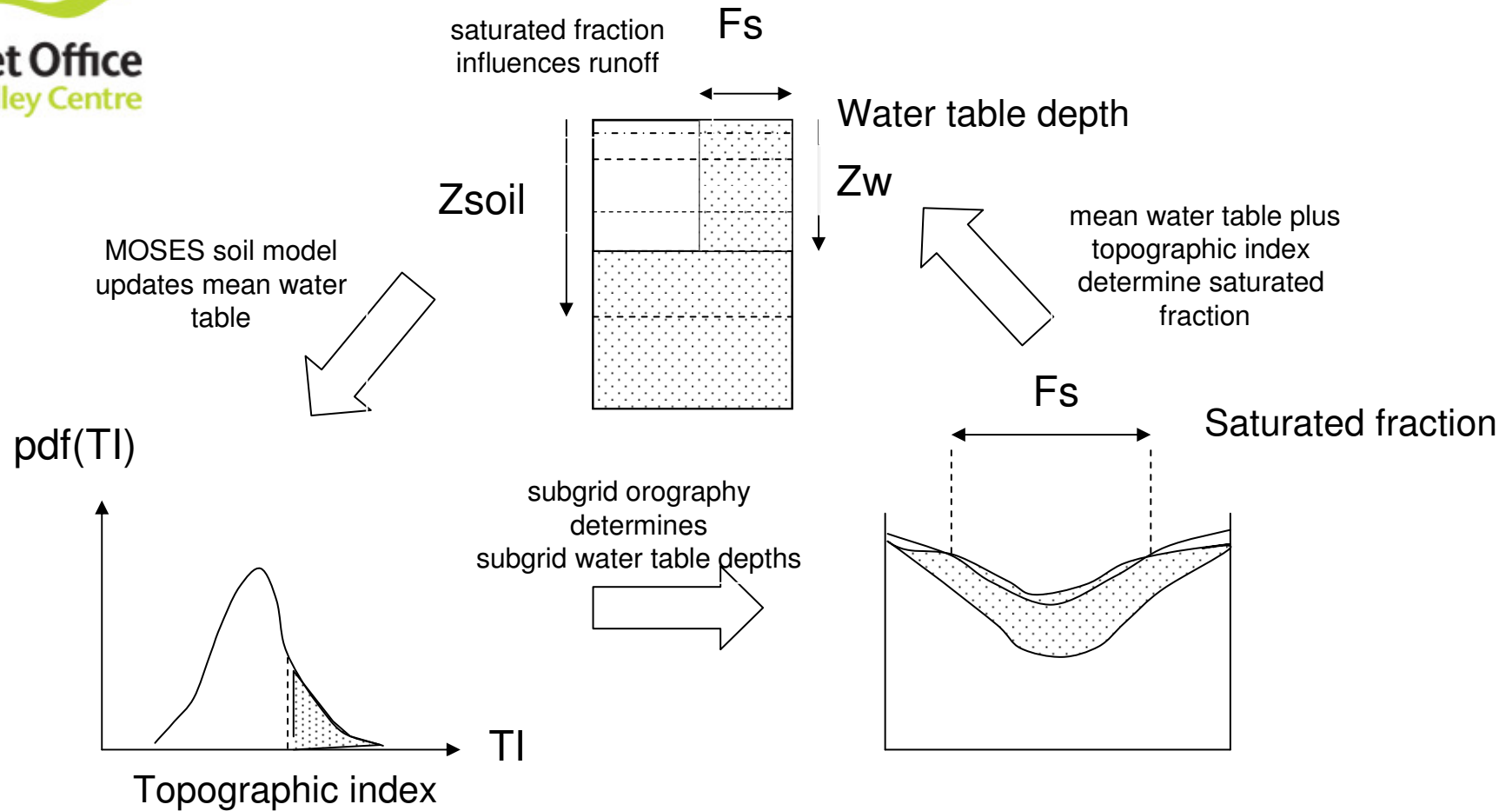
## JULES\_LSH



## Sat. Conductivity



# LSH (Gedney and Cox 2003)

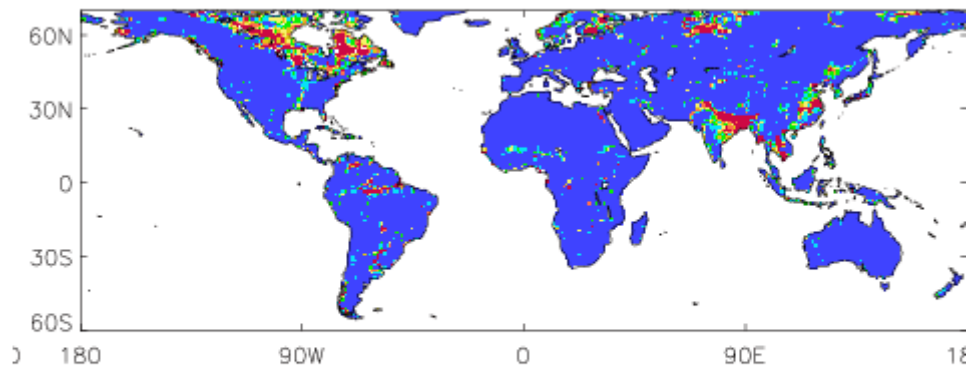


Predicts the distribution of sub-grid scale water table depth and wetland fraction from the overall soil moisture and the sub-grid scale topography

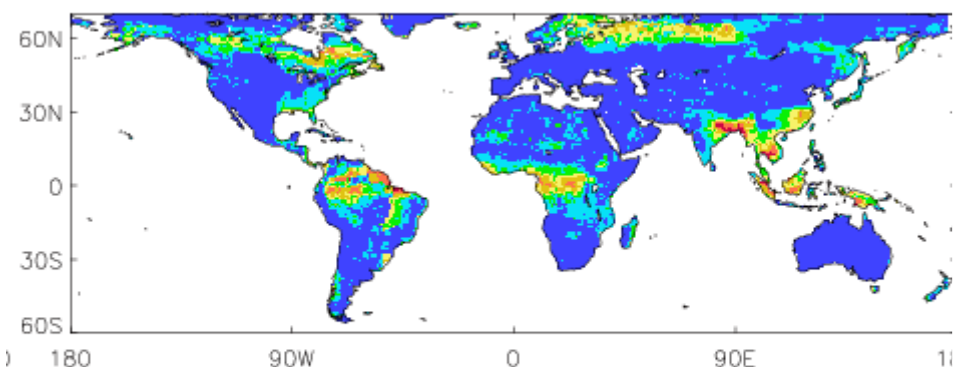
# Modelled global wetland fraction

- Global temporal inundation estimates using multiple satellite data (Prigent et al., 2007)
- JJA Fractional inundation extent:

“Obs” (Prigent et al., 2007)



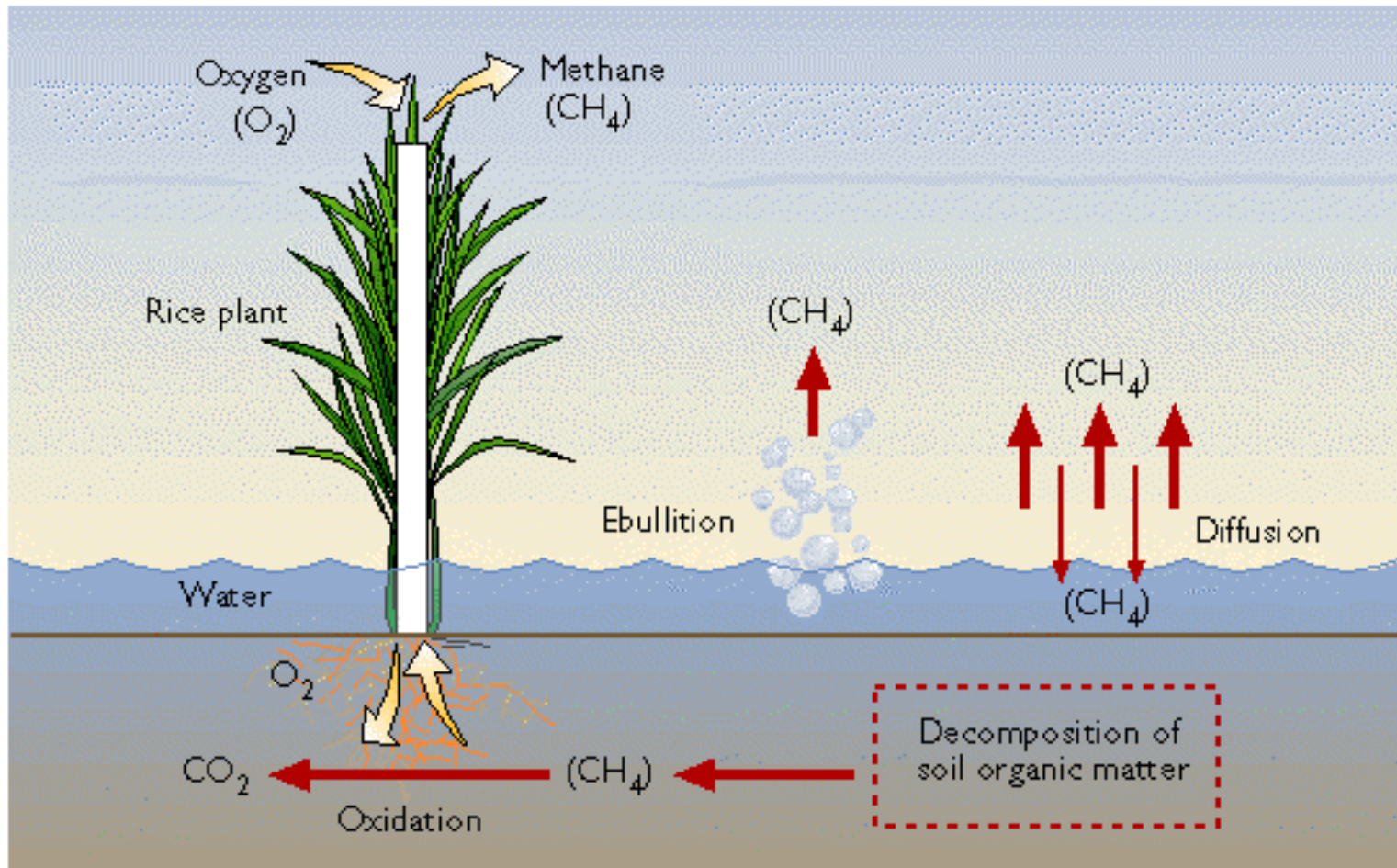
JULES\_LSH (corrected Amazon)





# Wetland methane model

# Schematic representation of Methane from Wetlands





# Wetlands CH<sub>4</sub> Emissions Scheme

$$F_{\text{CH}_4}^{\text{w}} = k_{\text{CH}_4} * f_{\text{w}} * C_{\text{s}} * Q_{10}(T_{\text{soil}})^{(T_{\text{soil}} - T_0)/10}$$

$F_{\text{CH}_4}^{\text{w}}$  = methane flux from wetlands

$k_{\text{CH}_4}$  = scaling factor

$f_{\text{w}}$  = wetland fraction

$C_{\text{s}}$  = “substrate”: **fixed** soil carbon content

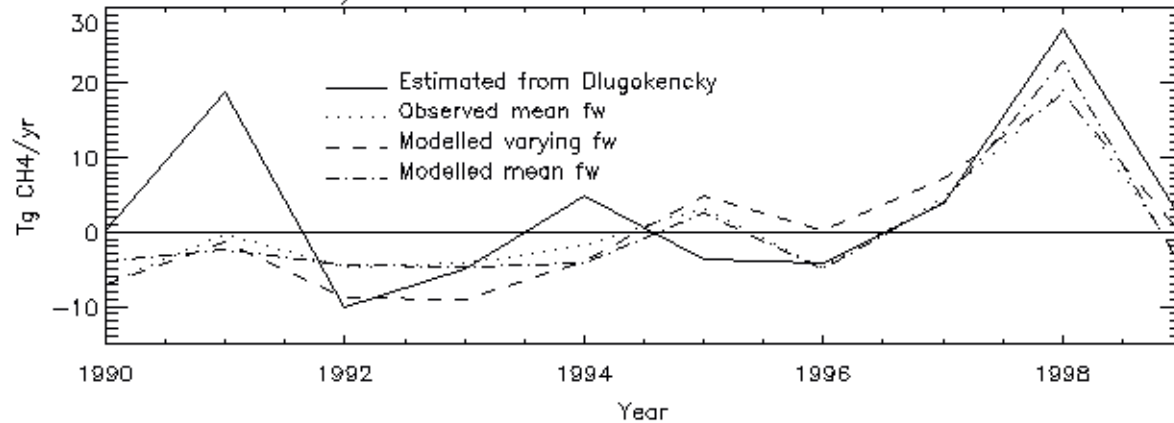
$Q_{10}$  = temperature sensitivity

**Interactive CH<sub>4</sub> emissions from wetlands  
coupled to UKCA**



# Calibrating the wetland CH4 parameterisation from global inter-annual variability (Gedney et al, 2004)

b) Methane Anomalies over Observed Wetland

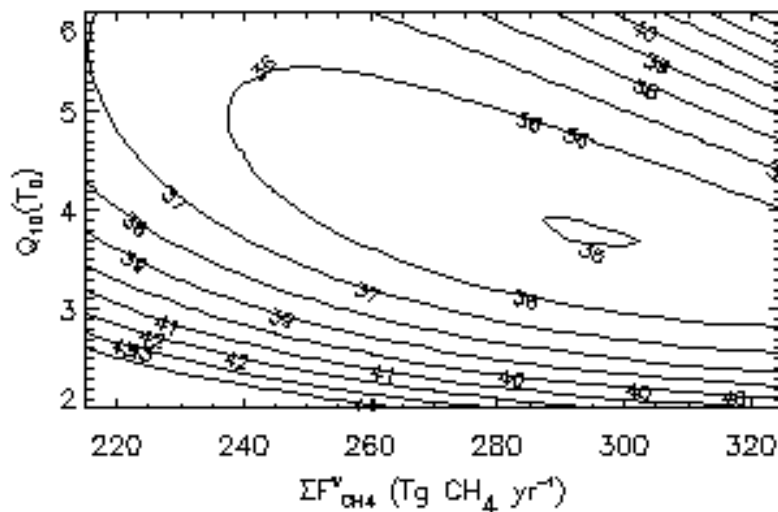


CH4 flux derived from atmos CH4 conc data: Dlugokencky (pers com)

Force with observed T and precip.

Simple global atmos chem model:

$$d(\text{CH}_4)/dt = \Sigma F_{\text{CH}_4} - \text{CH}_4/\tau$$

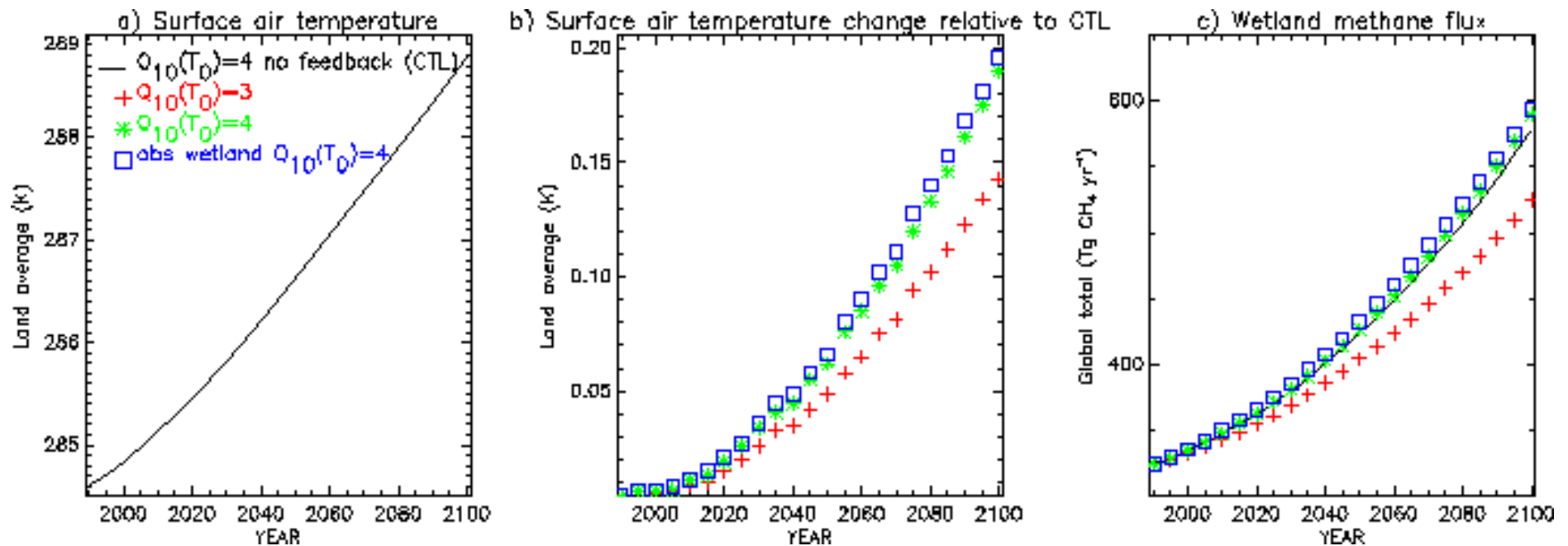


Minimum RMS Error:

$$\Sigma F_{\text{CH}_4} = 295 - 325 \text{ Tg CH}_4 \text{ yr}^{-1}, Q_{10}(T_0) = 3.2 - 3.8$$

# Transient climate change predictions (climate analogue model)

IMOGEN, IS92A: Annual mean, land average



3-5% increase in radiative forcing



# Model Limitations

- Hydrology model had poor sub-annual variability
- Amalgamation of physical processes
- No explicit model of substrate availability
- No validation against local flux measurements
  - (only global and regional)



# NEW Wetland CH<sub>4</sub> Emission Schemes

## New Simple model:

$$F_{\text{CH}_4}^{\text{wet}} = k_{\text{CH}_4} * f_w * S * Q_{10}(T_{\text{soil}})^{(T_{\text{soil}}-T_0)/10}$$

$k_{\text{CH}_4}$  = scaling factor

$f_w$  = modelled wetland fraction

$S$  = “substrate”: **weighted soil carbon pools  
or NPP**

$Q_{10}$  = temperature sensitivity

“Complex” model (simplified Whyme model (Wania 2010):

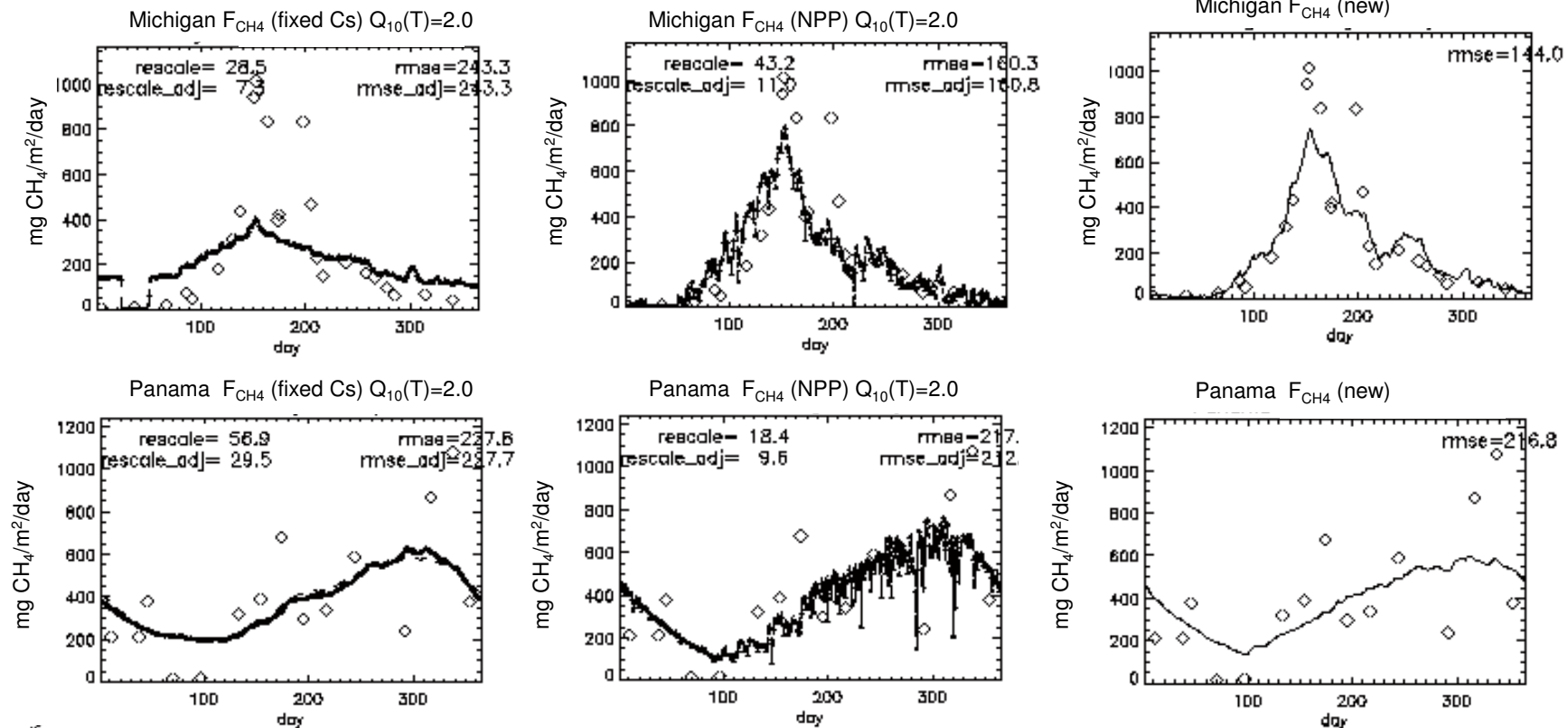
Single CH<sub>4</sub> store in saturated soil.

Transport to atmosphere by:

Diffusion, ebullition, vascular plants

# Models compared against flux sites

- 5 mid-high latitude sites, 1 tropical (Panama)
- 4 sites have some water table depth information



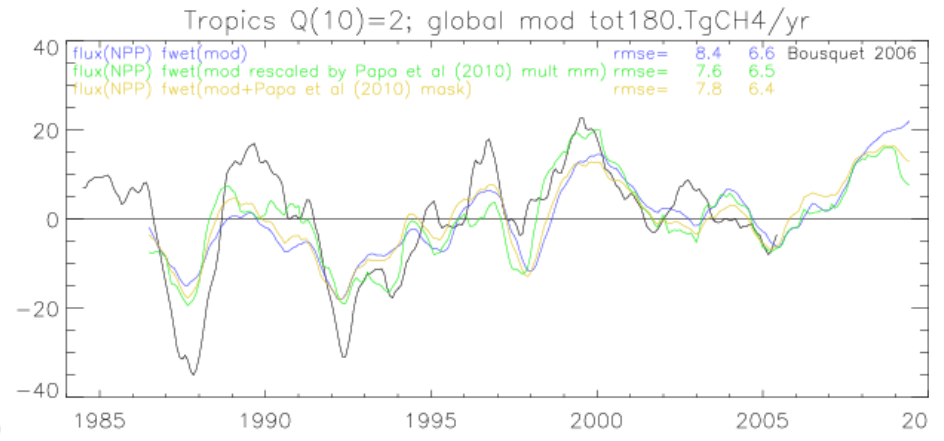
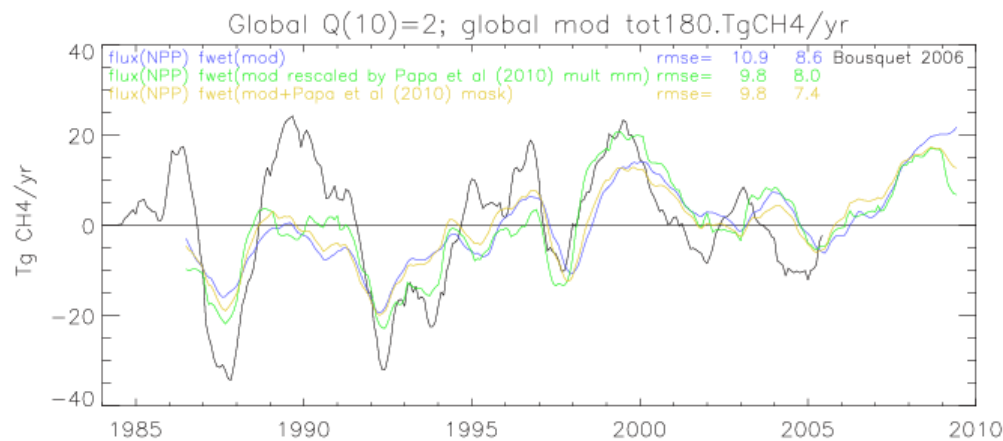
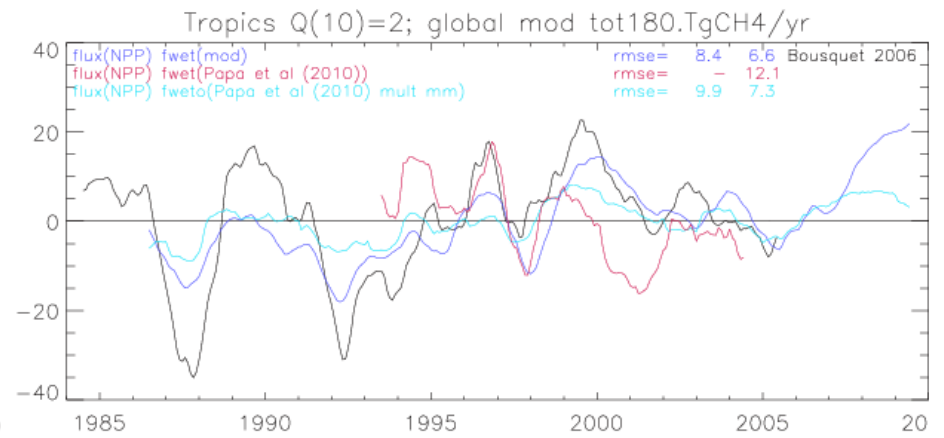
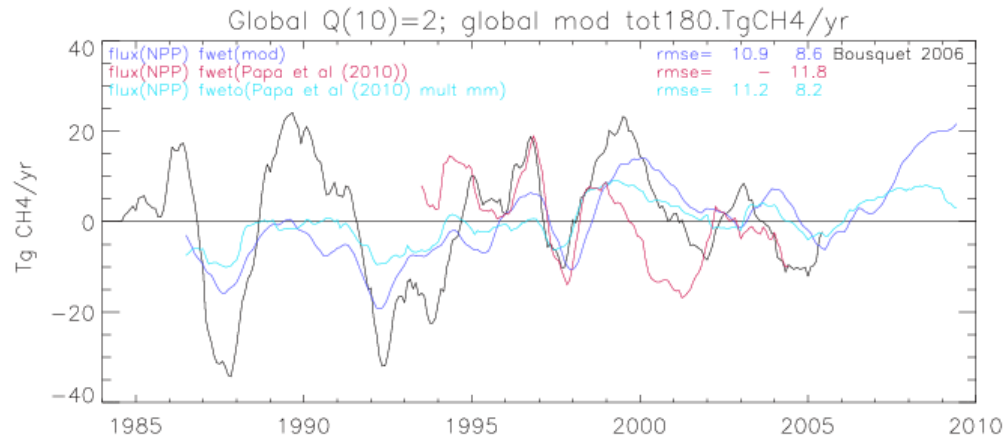


# Overall results

- All models ~reproduce seasonality
- No clear best model
- When optimising parameters:
  - $Q_{10}(T) \sim 3.5$  for fixed soil carbon based  $CH_4$  model
  - $Q_{10}(T) \sim 2$  for NPP & soil resp based  $CH_4$  models



# Comparing modelled regional fluxes against inversion estimates (Bousquet et al, 2006)





# Conclusions

Can ~reproduce site obs even with relatively simple model

Gross interannual variability in line with inversion study

Hydrology important in interannual variability



# Future work

Improve seasonal inundation

Compare models against more recent and alternative inversion data

Interactive methane model run in UKCA chemistry model – comparison with:

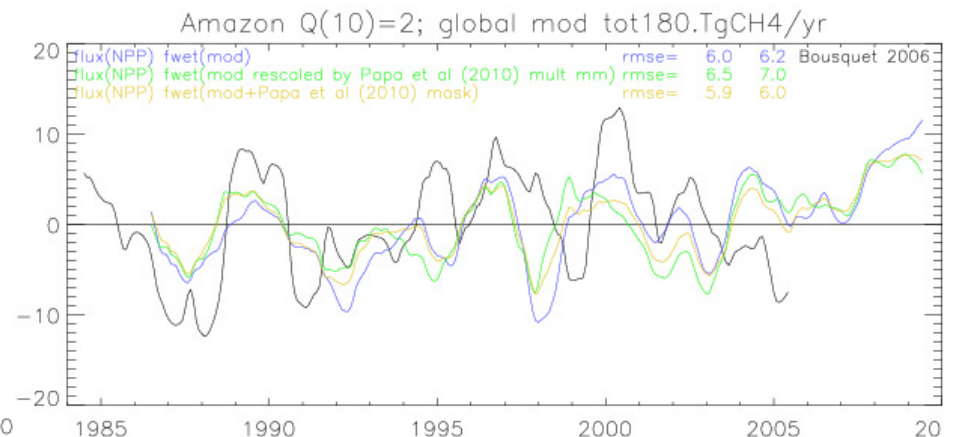
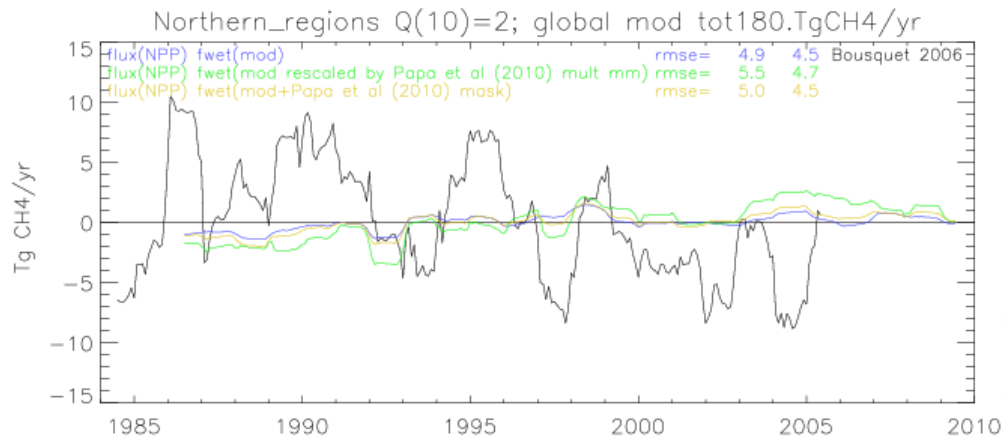
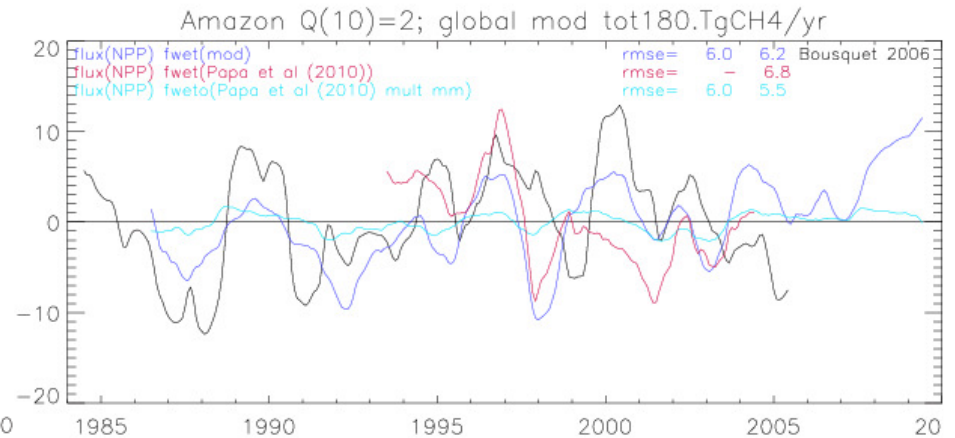
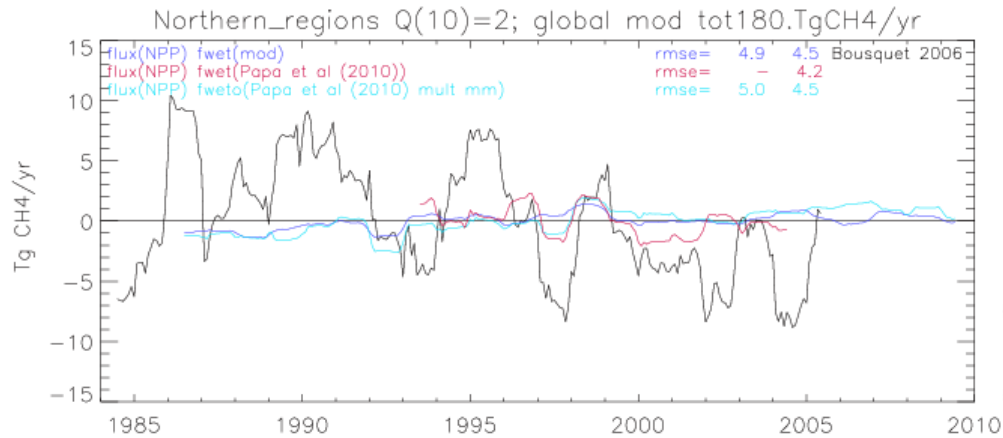
Atmospheric measurements

EO Sciamachy data

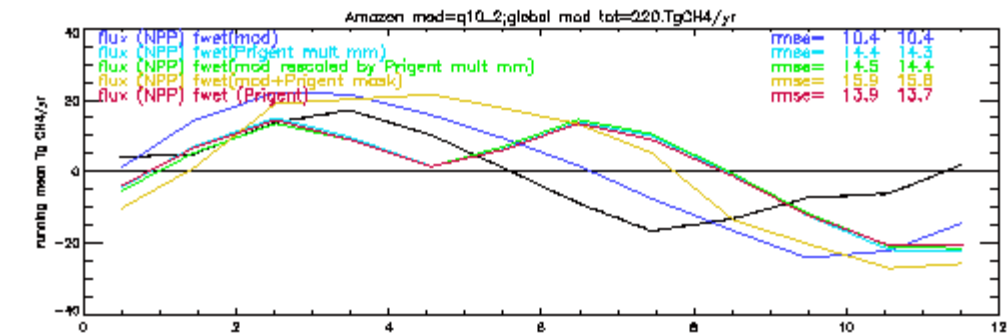
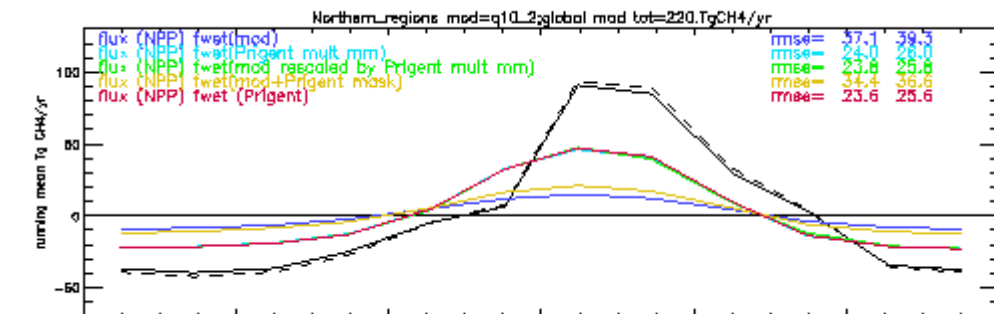
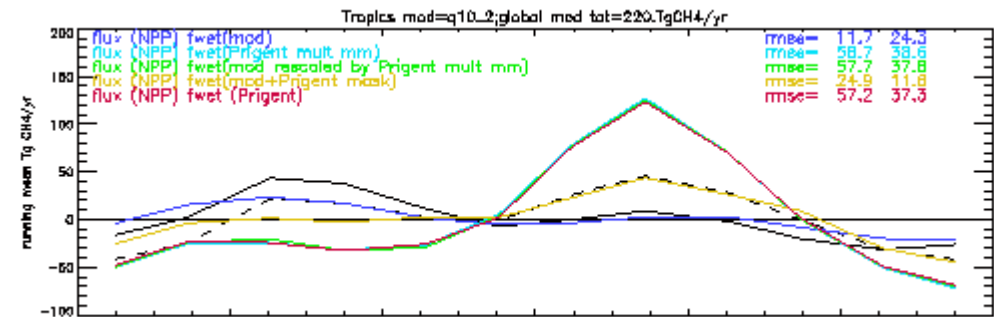
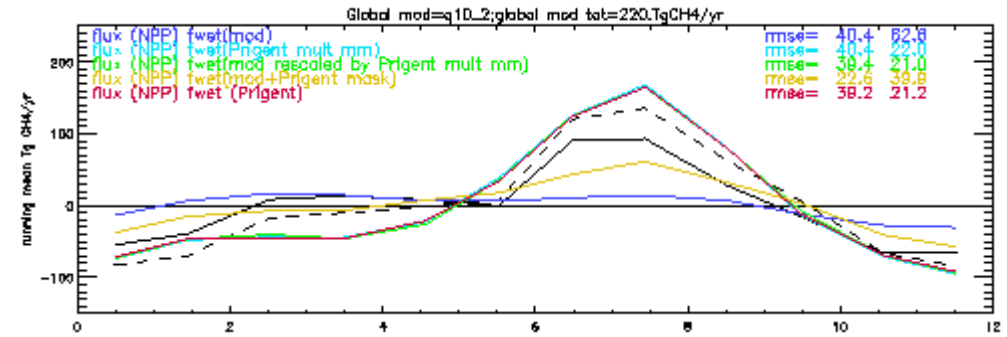




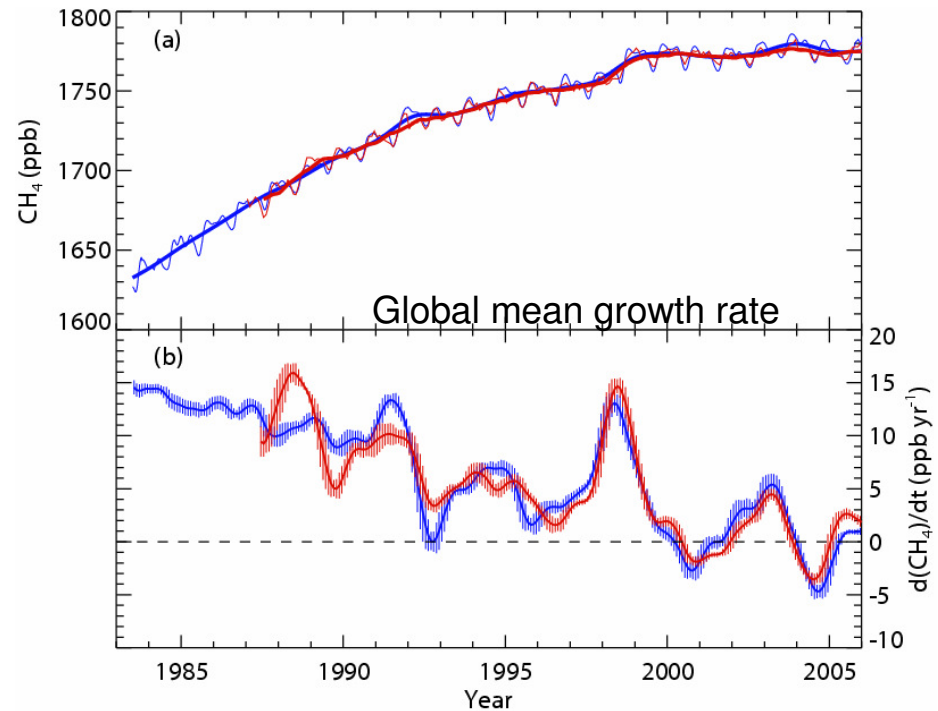
# Comparing modelled regional fluxes against inversion estimates (Bousquet et al, 2006)



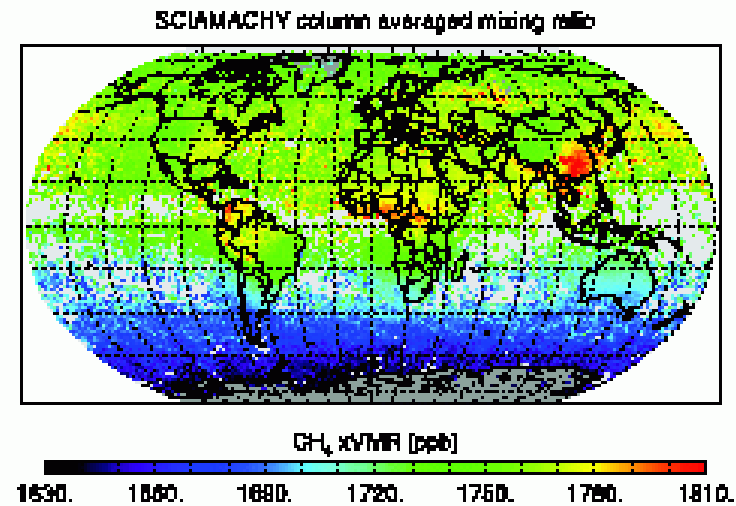
# Seasonal anomalies



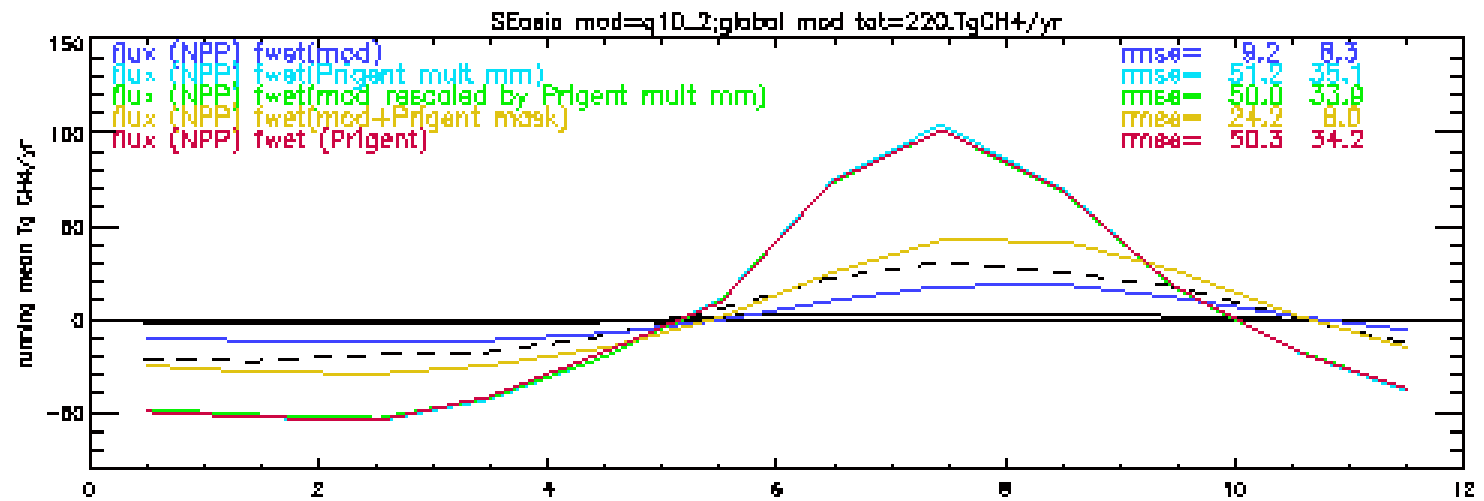
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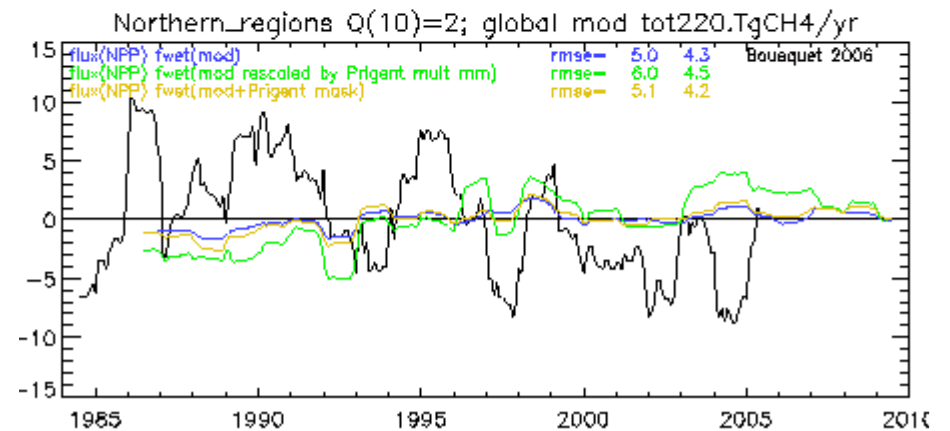
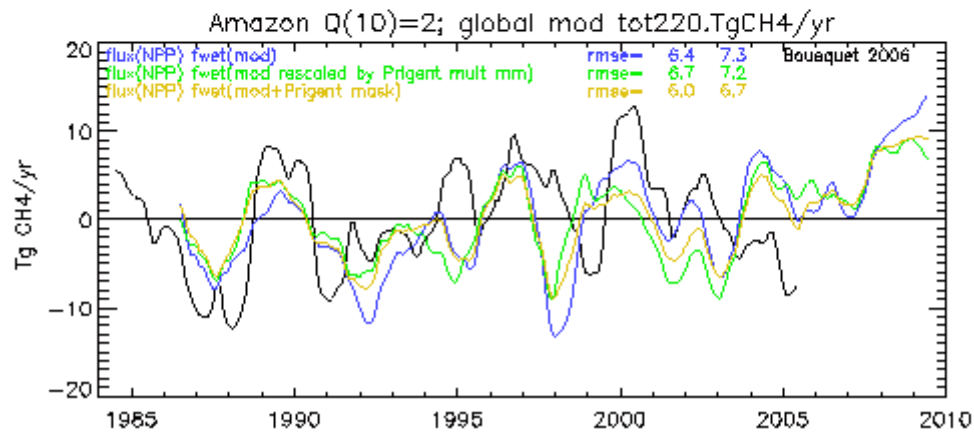
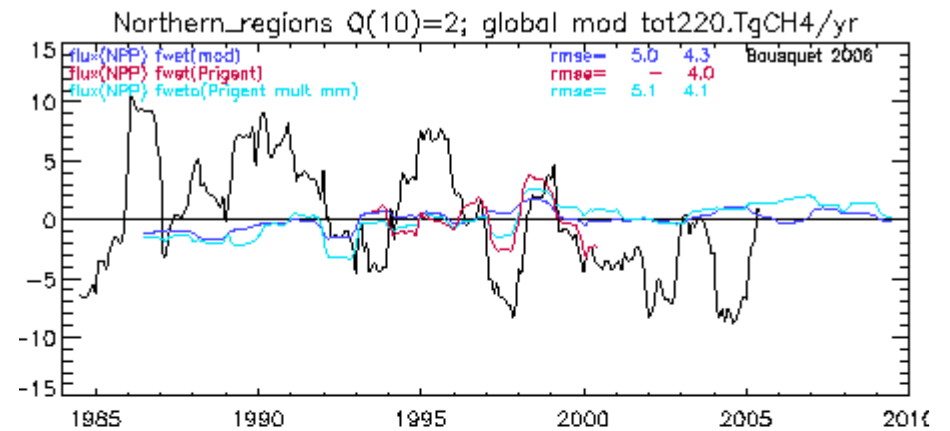
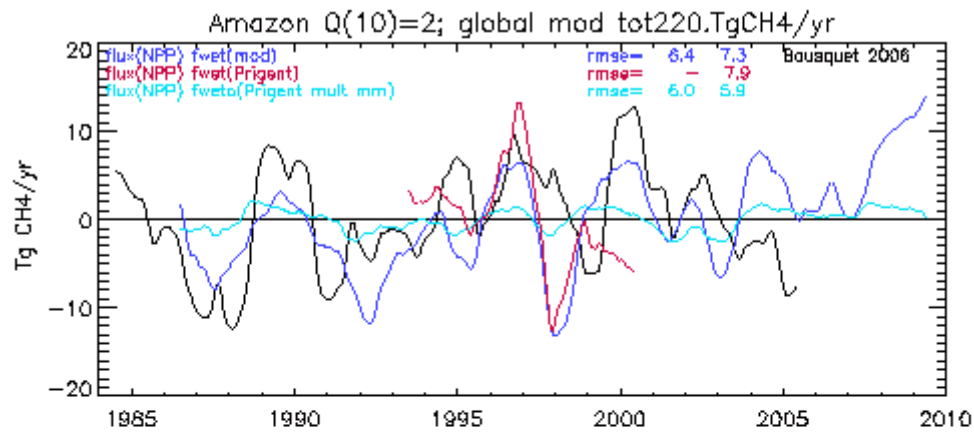


Understand wetland contribution through EO (Sciamachy) and atmospheric chemistry model (UKCA)

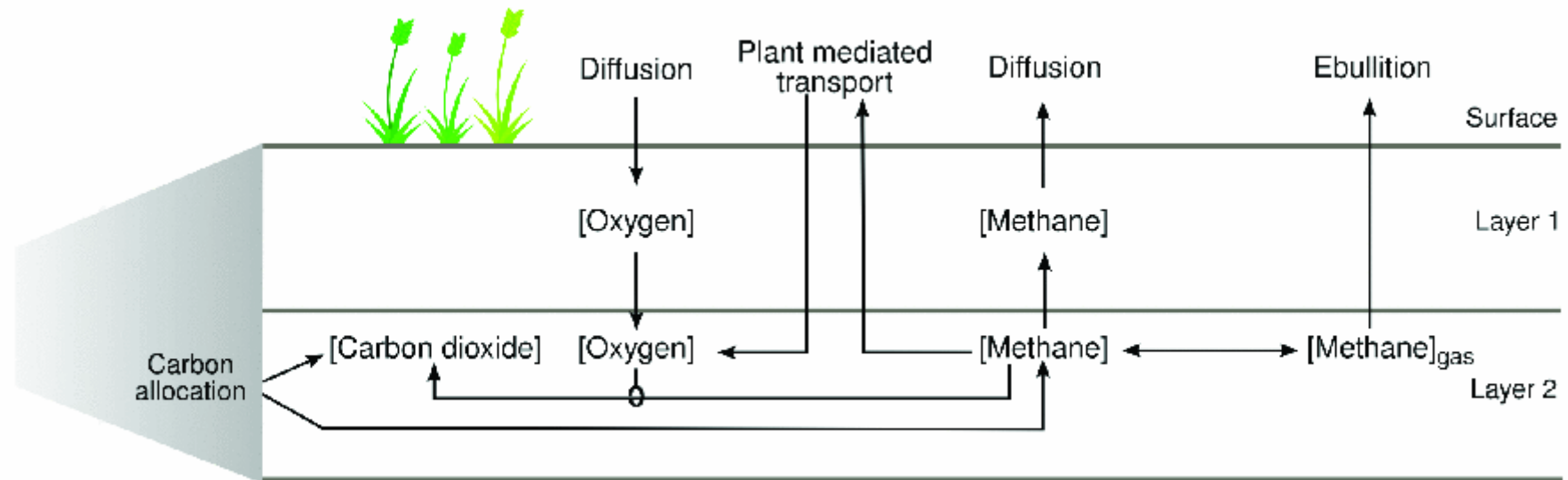


Frankenberg et al, 2008





# Schematic representation of the LPJ-WHyMe methane model



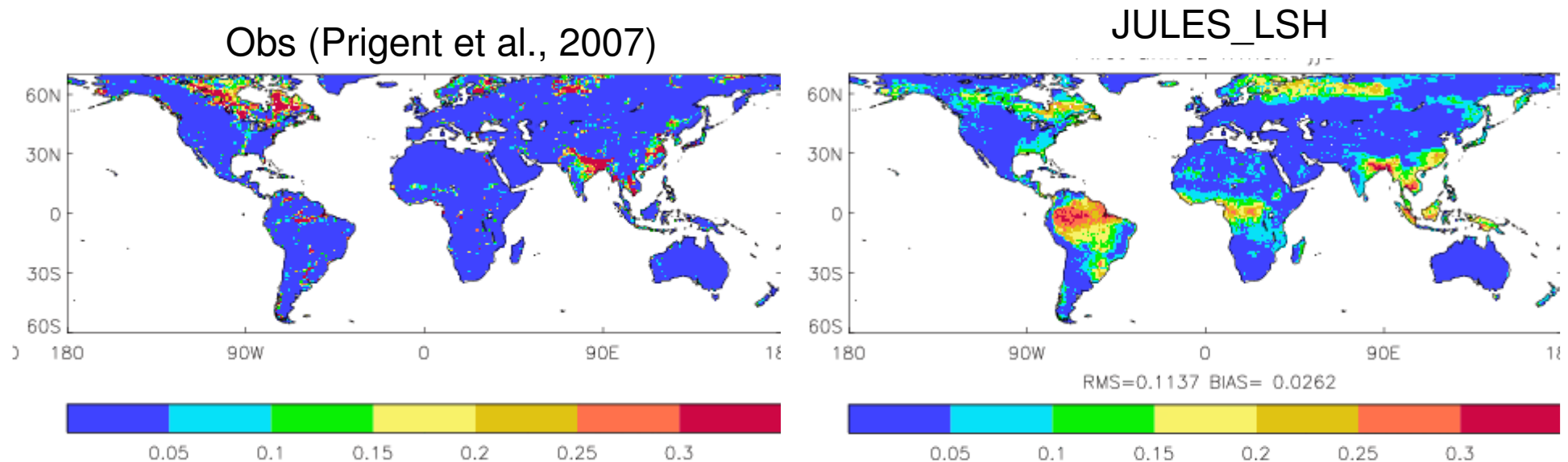
Wania et al, 2010



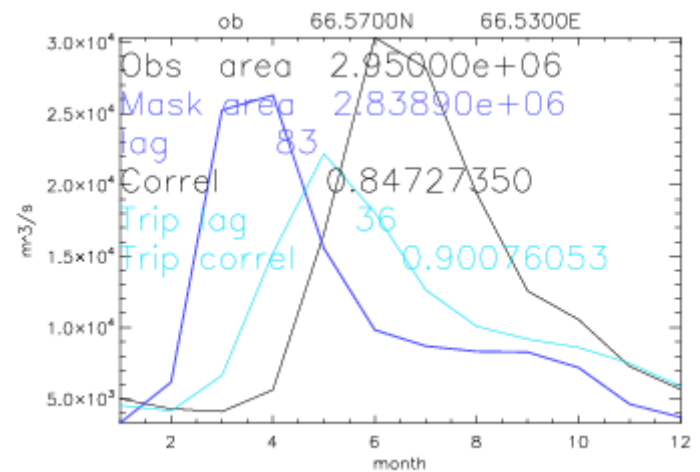
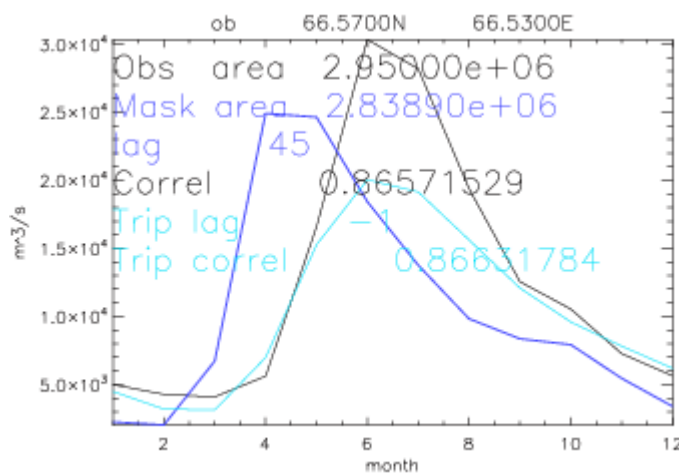
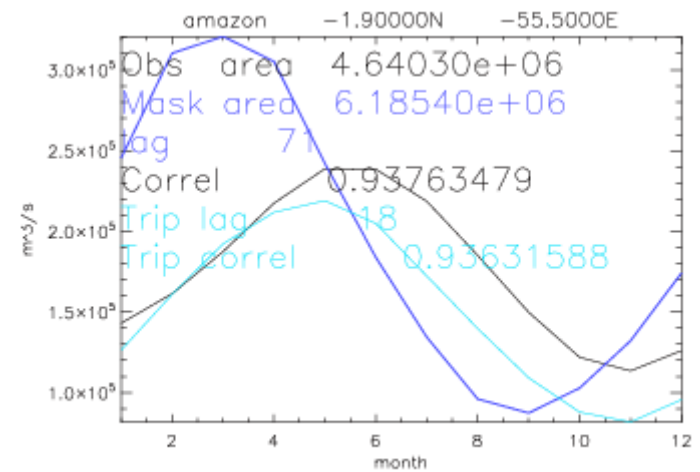
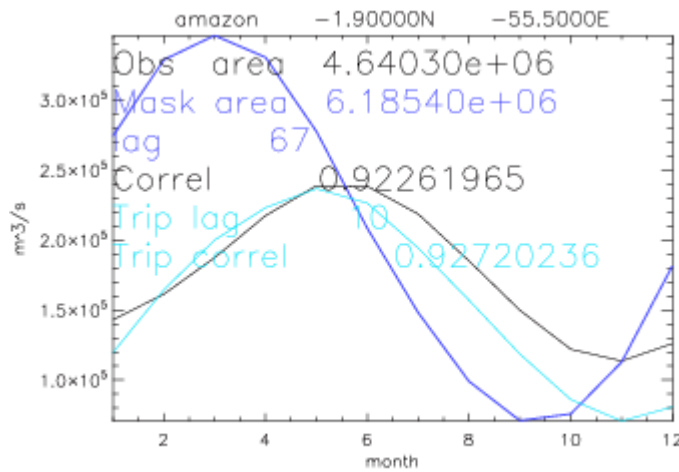
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- Microwave remote sensing soil moisture products
  - Top few cms
- Global temporal inundation estimates using multiple satellite data (Prigent et al., 2007)
  - JJA Fractional inundation extent:

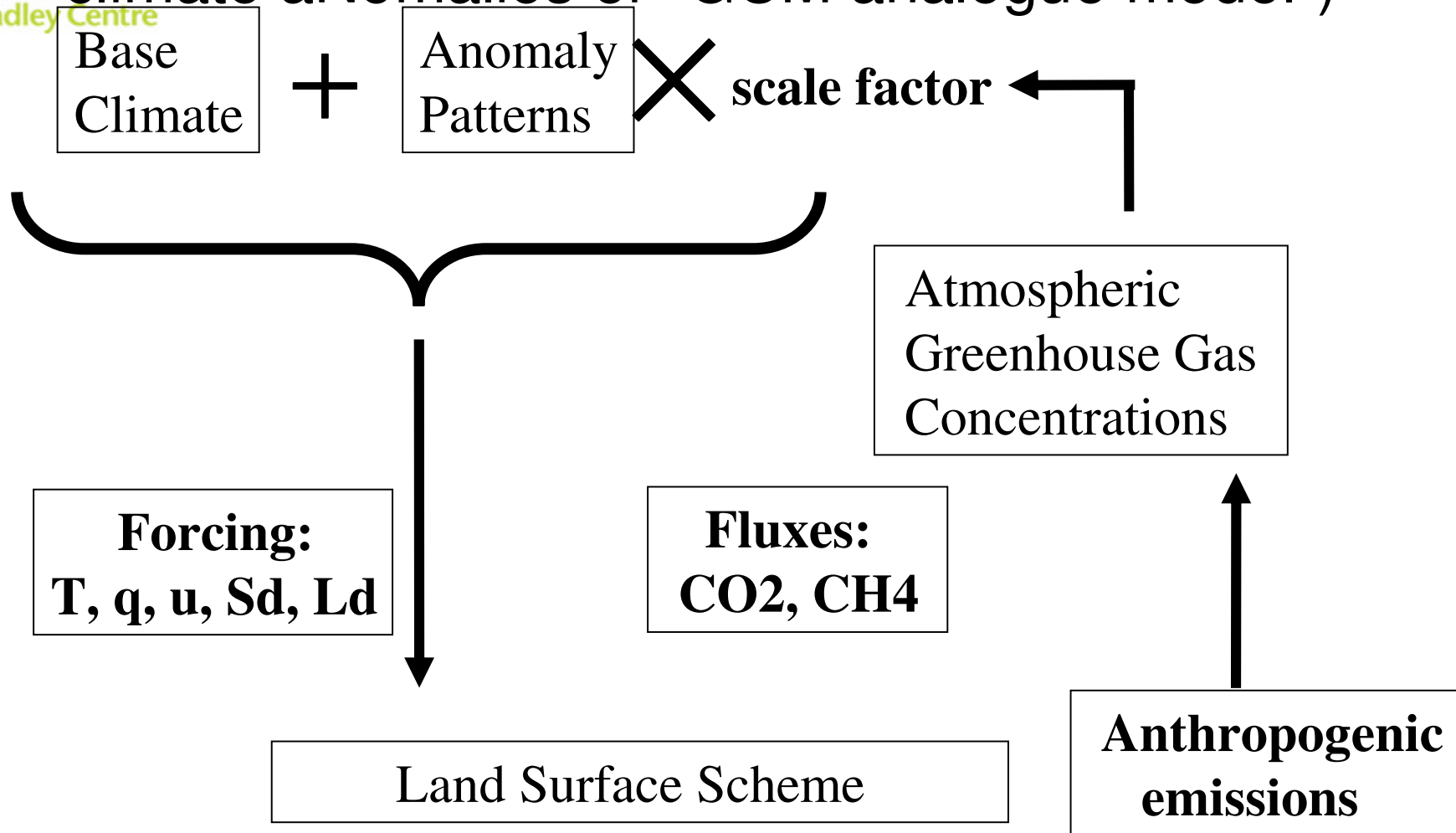


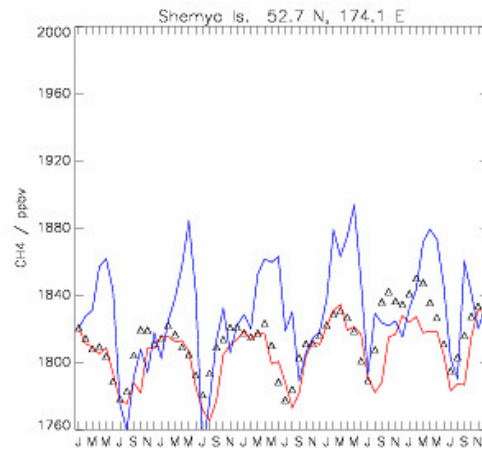
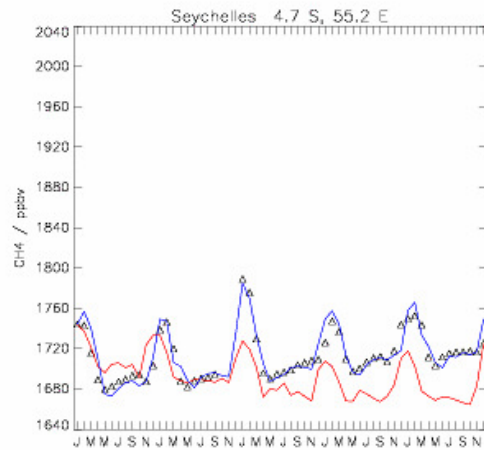
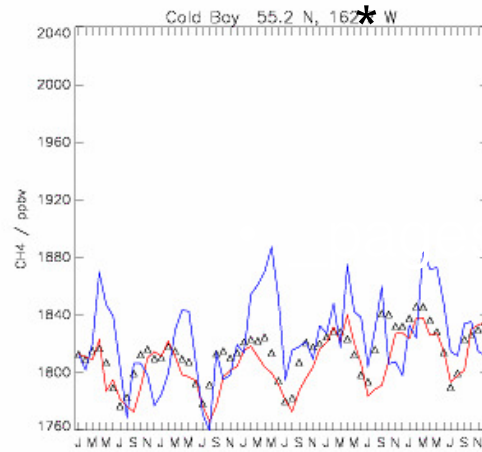
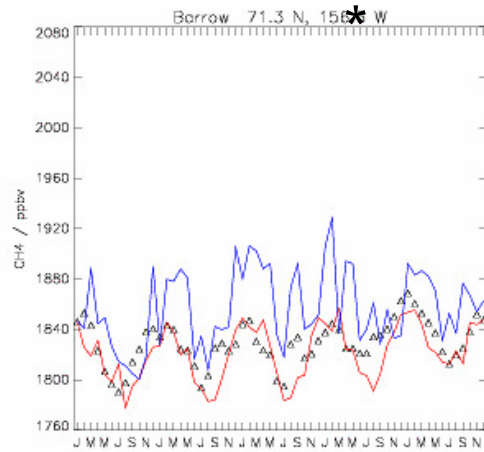
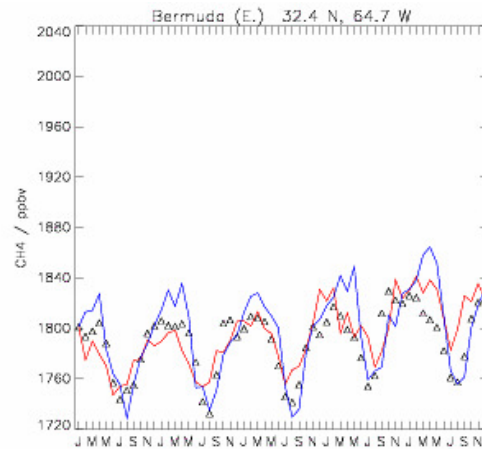
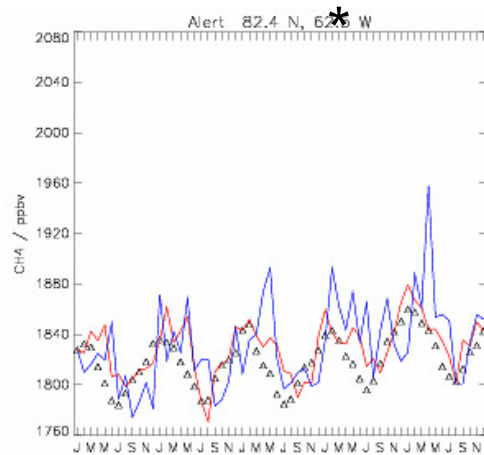
# Modelled river flow



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# Schematic diagram of IMOGEN (Integrated Model Of the Global Effects of Climate anomalies or “GCM analogue model”)





**Regional validation:**  
 Simulating monthly mean surface methane levels using STOCHEM atmospheric chemistry model.  
 (Mike Sanderson)

red: interactive wetland CH<sub>4</sub> emissions  
 blue: constant wetland CH<sub>4</sub> emissions  
 triangles: NOAA/CMDL