# 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



Acknowledgements: Contribution to ESA Alanis-Methane

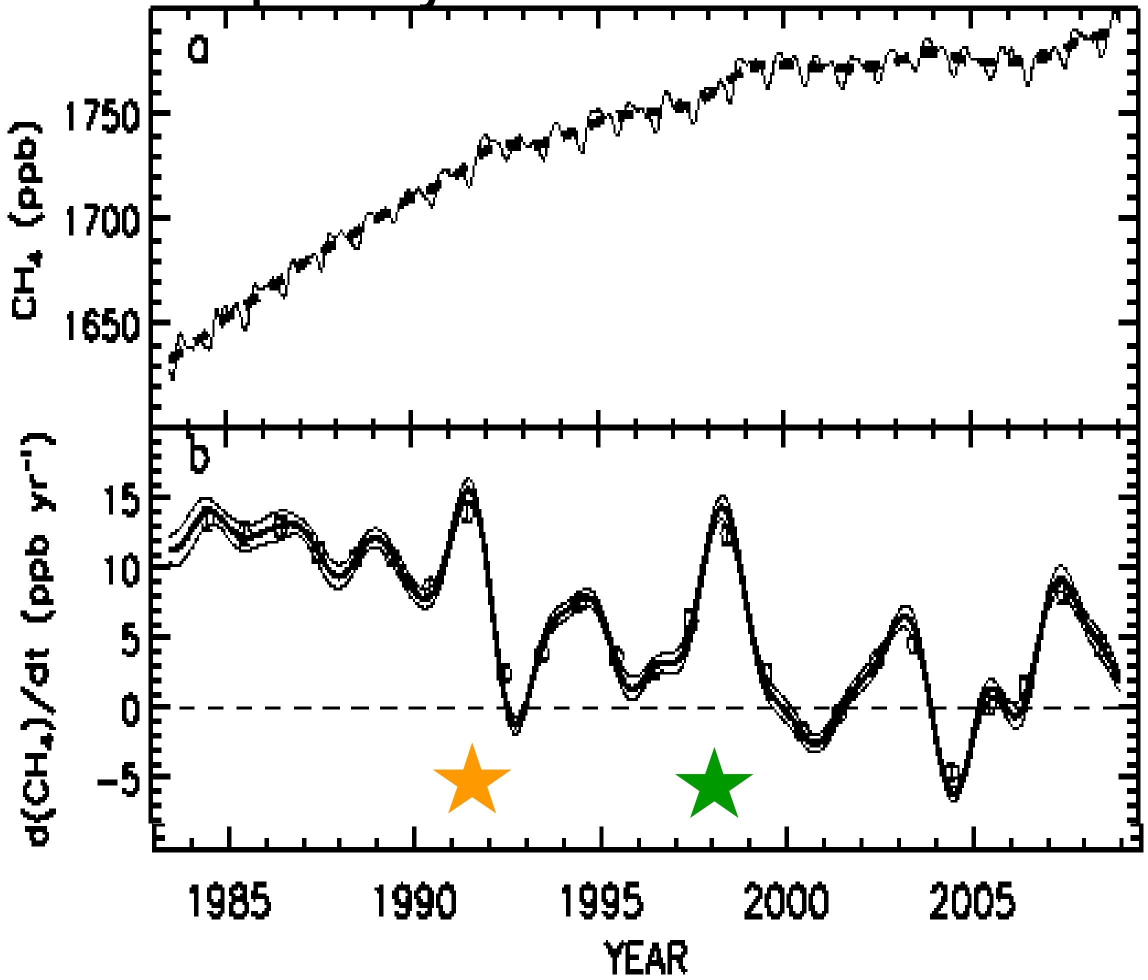
# Motivation

- $CH_4$ is the second most important anthropogenic greenhouse gas
- Much stronger greenhouse gas than $CO_2$
- Wetlands are dominant natural source of $CH_4$
- Wetlands contribute ~20%–40% of the global present day atmospheric $CH_4$
- Wetland emissions dependent on precipitation and temperature – future feedback?
- Trend and inter-annual variability in $CH_4$ growth rate are poorly understood

# Trend and inter-annual variability in $CH_4$ growth rate are poorly understood

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

★ 1997/1998:
BB ems
Wetland ems
Wildfires




Dlugokencky et al, 2009

# Wetland hydrology model

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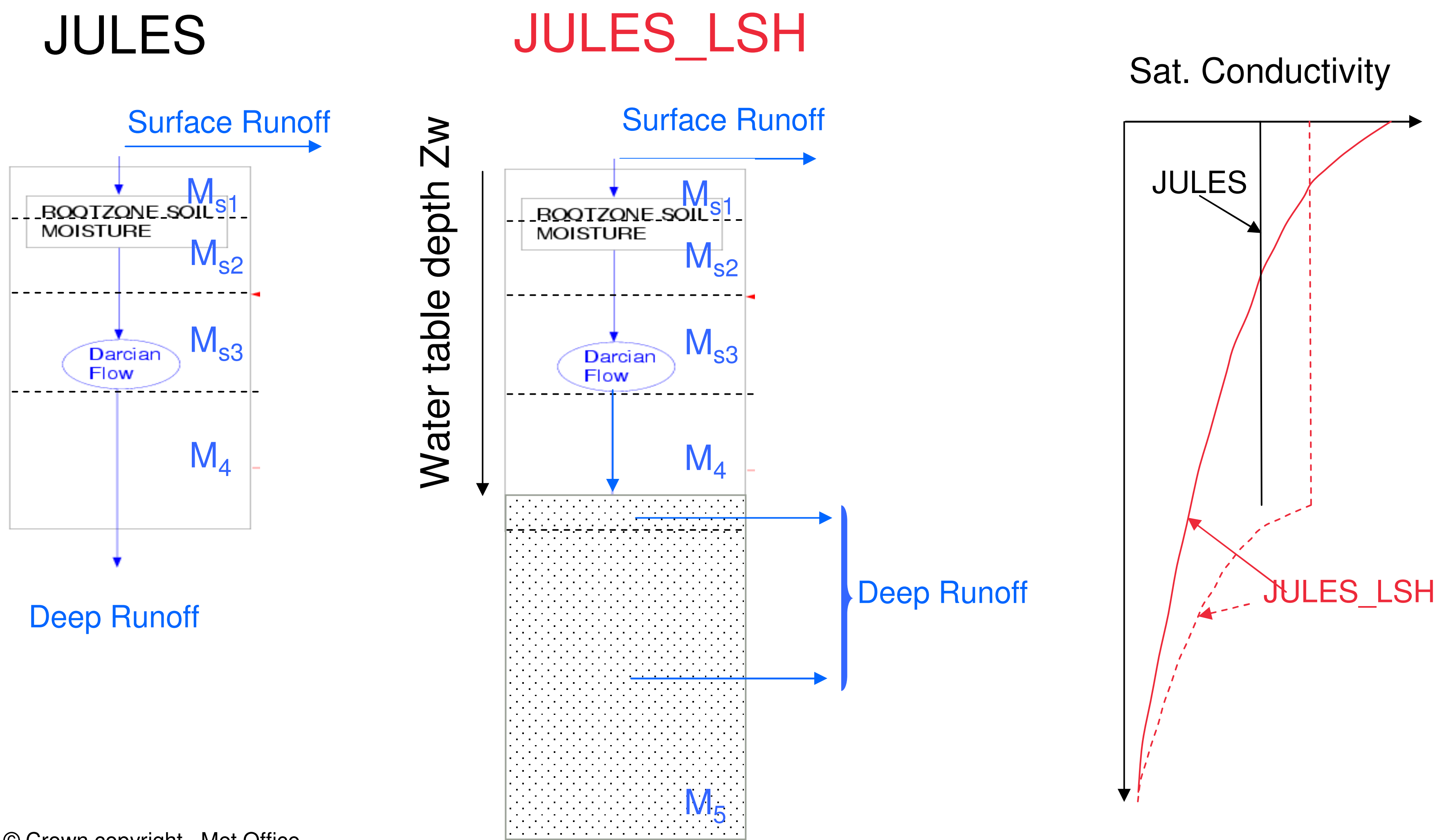
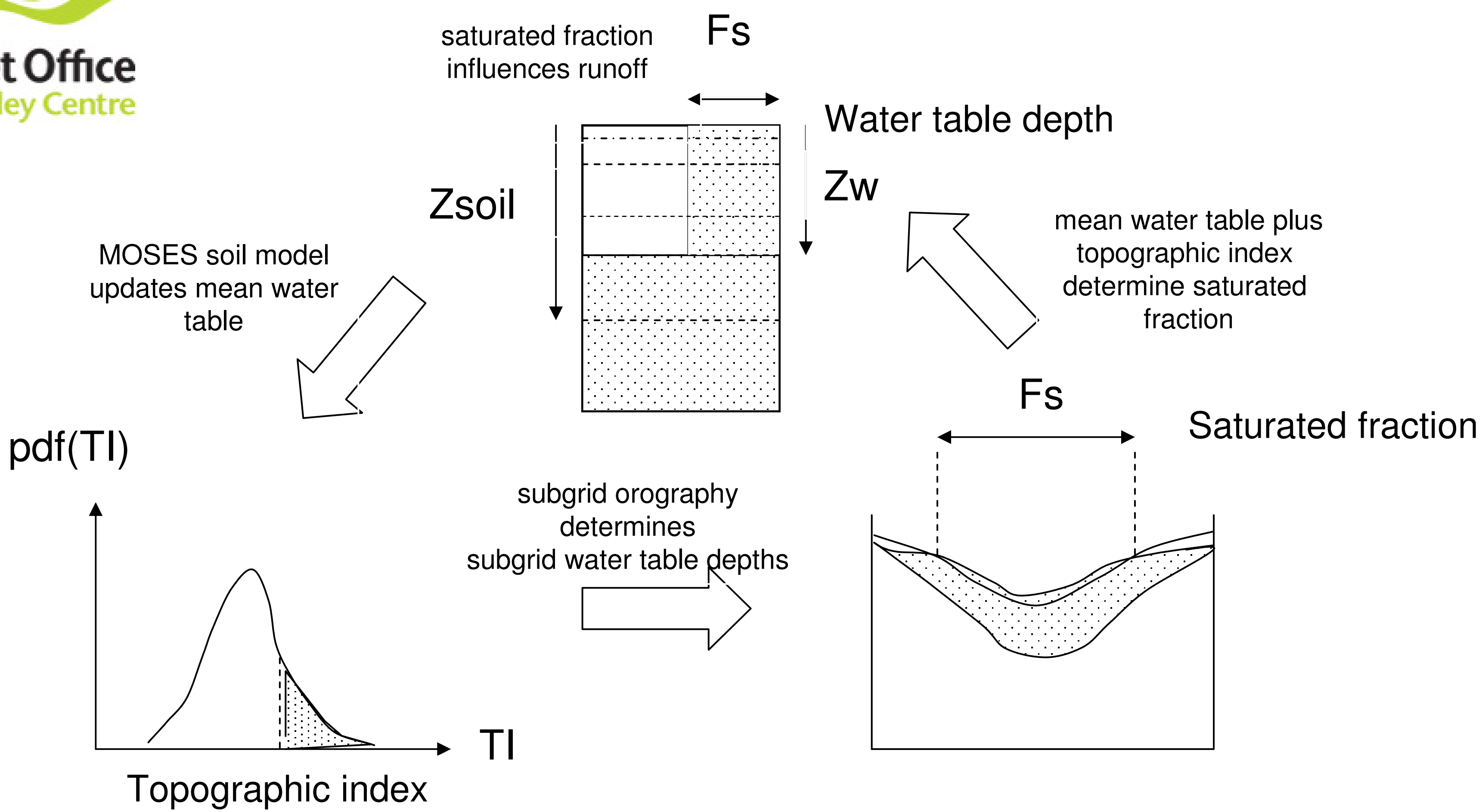
- Wetlands area highly correlated with topography globally
- Wetlands often have peat soils

# JULES schematic of soil moisture flow



# LSH (Gedney and Cox 2003)

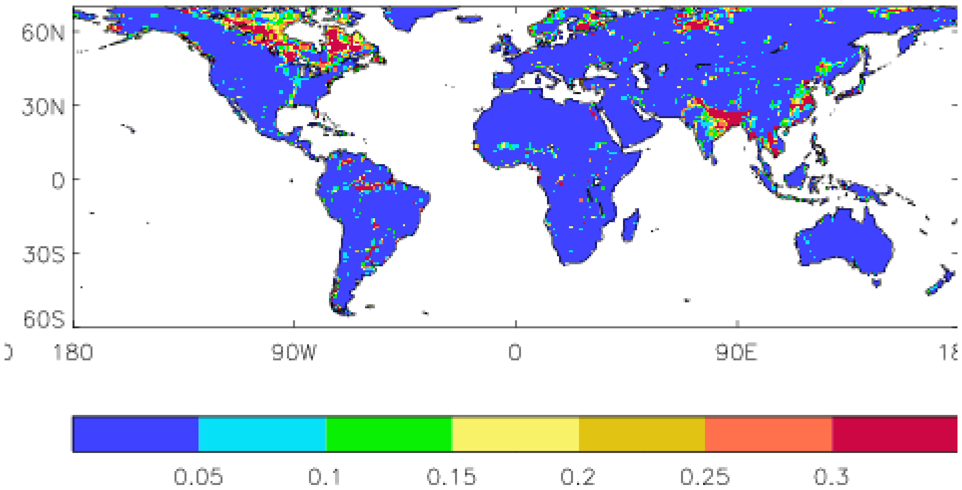



Predicts the distribution of sub-grid scale water table depth and wetland fraction from the overall soil moisture and the sub-grid scale topography

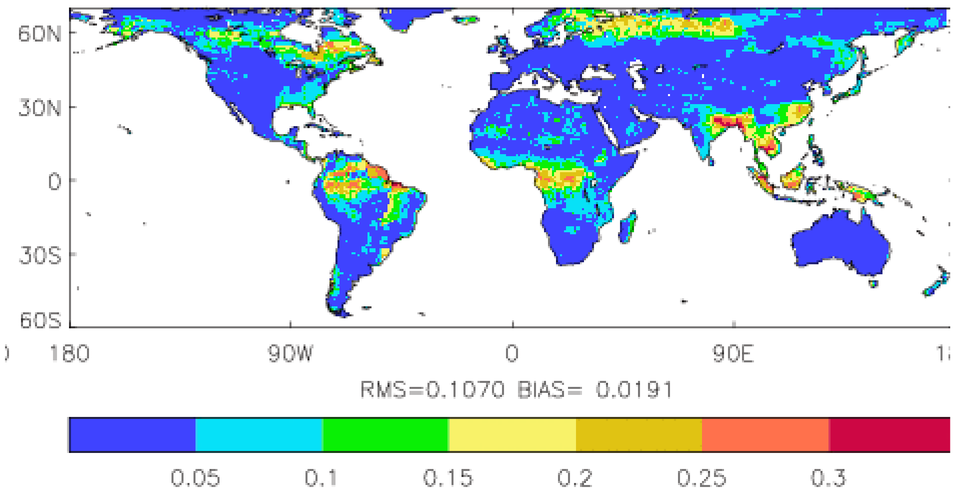
# Modelled global wetland fraction

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

“Obs” (Prigent et al., 2007)

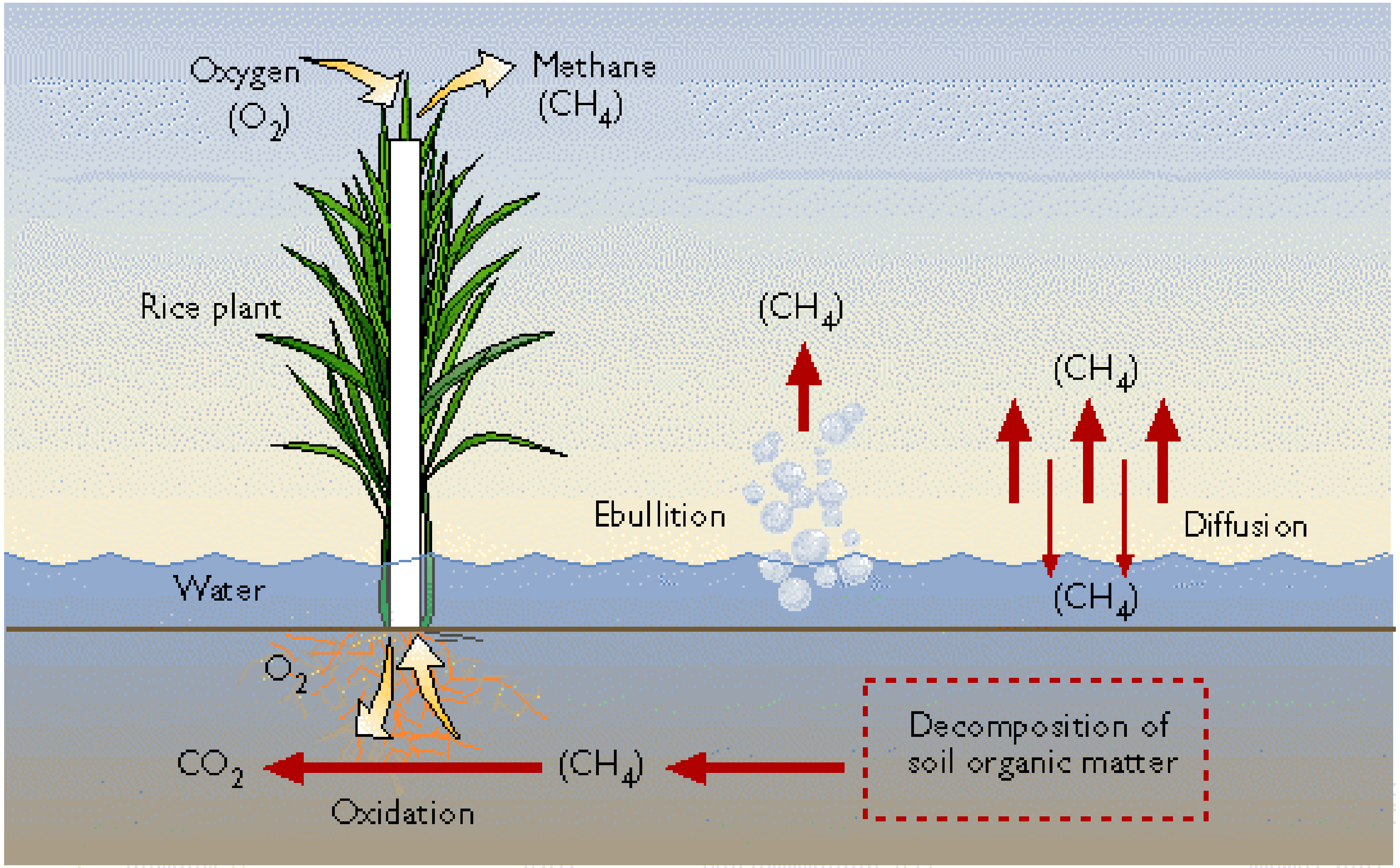



JULES_LSH (corrected Amazon)



# Wetland methane model

# Schematic representation of Methane from Wetlands






source: Riceweb.org

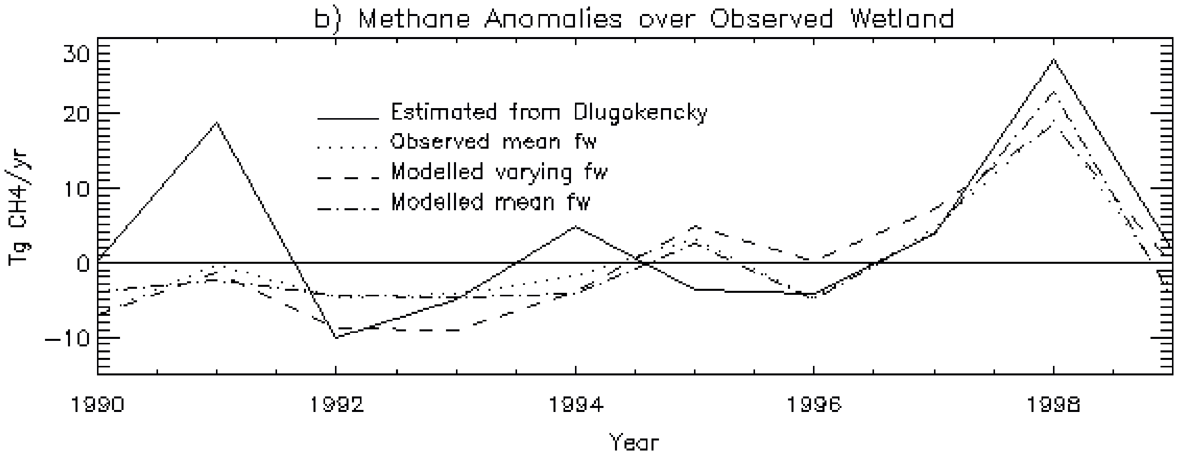
# Wetlands $CH_4$ Emissions Scheme

$$F^{w}_{CH4} = k_{CH4} * f_w * C_s * Q_{10}(T_{soil})^{(T_{soil}-T_0)/10}$$

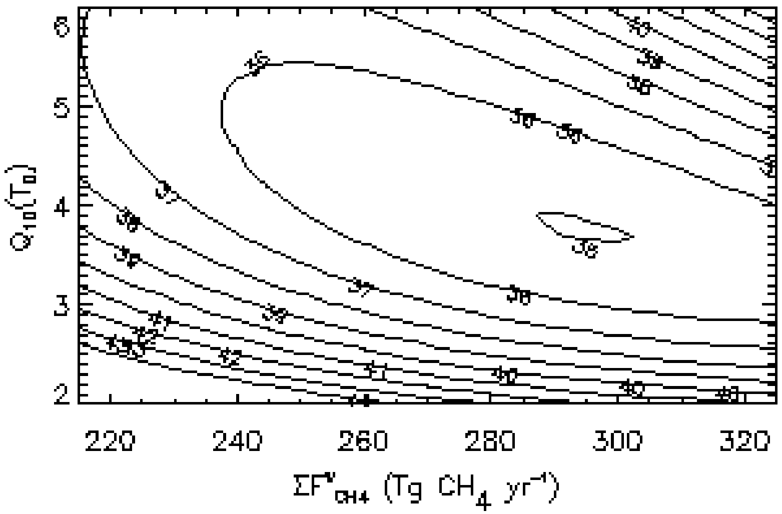
$F^{w}_{CH4}$ = methane flux from wetlands
$k_{CH4}$ = scaling factor
$f_w$ = wetland fraction
$C_s$ = "substrate": fixed soil carbon content
$Q_{10}$ = temperature sensitivity

**Interactive $CH_4$ emissions from wetlands coupled to UKCA**

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




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




Force with observed T and precip.

Simple global atmos chem model:

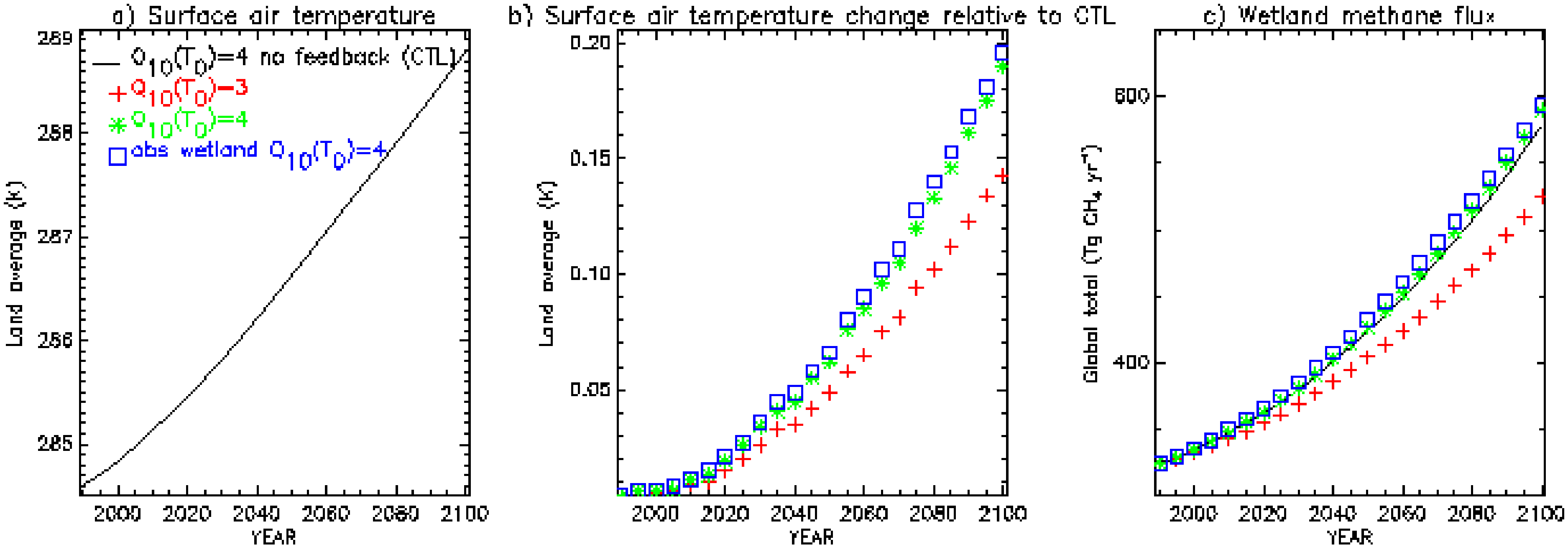
$$d(CH4)/dt = \Sigma\ FCH4 - CH4/\tau$$

Minimum RMS Error:

$\Sigma F_{CH4}$=295-325Tg$CH_4yr^{-1}$, $Q_{10}(T_0)$=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 $CH_4$ Emission Schemes

**New Simple model:**

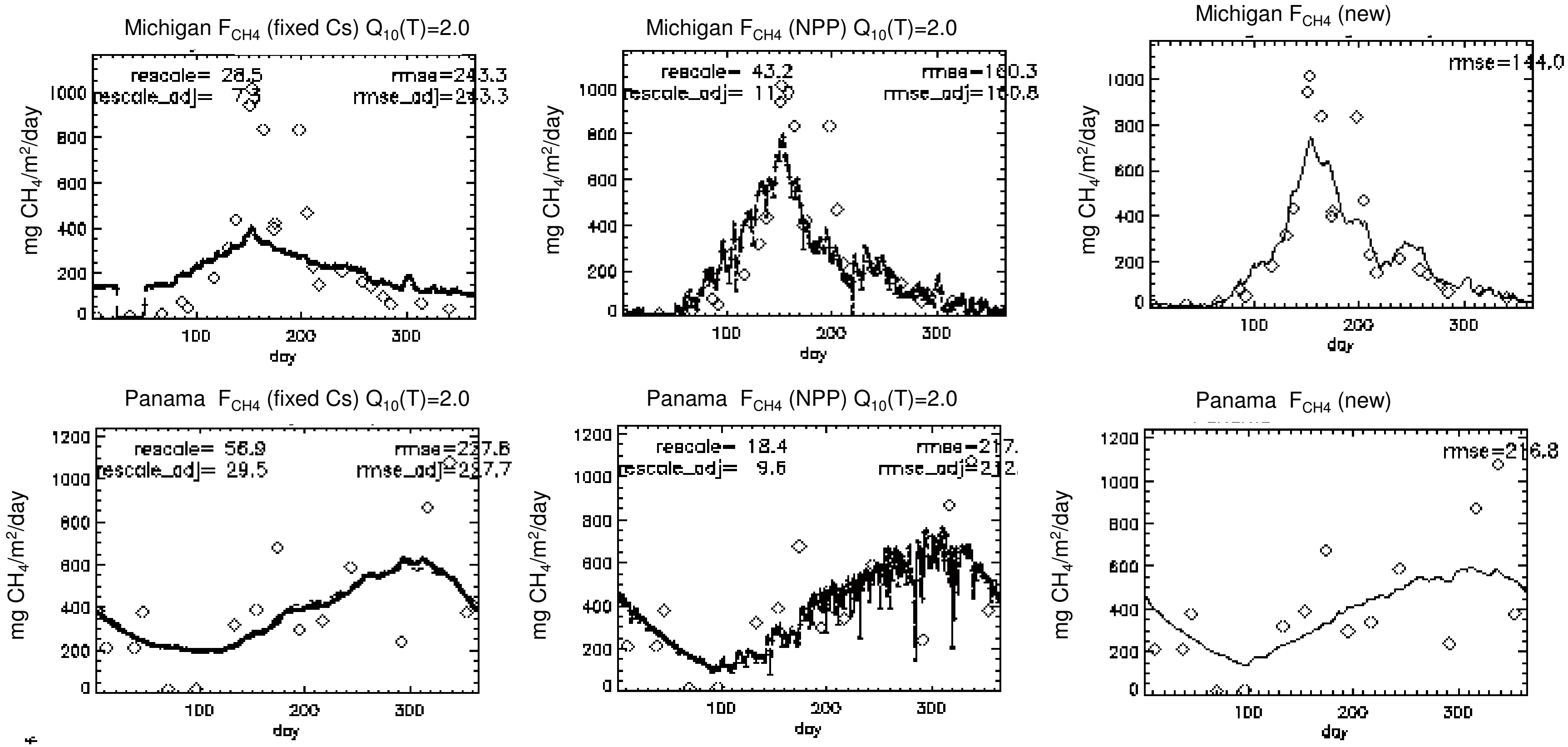
$$F^{wet}_{CH4} = k_{CH4} * f_w * S * Q_{10}(T_{soil})^{(T_{soil}-T_0)/10}$$

$k_{CH4}$ = 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 $CH_4$ store in saturated soil.**
**Transport to atmosphere by:**
**Diffusion, ebullition, vascular plants**

# Models compared against flux sites

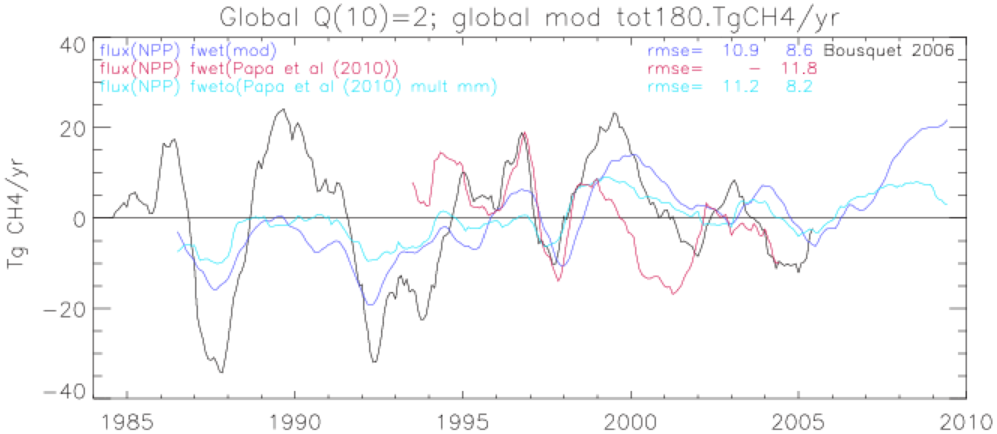
- 5 mid-high latitude sites, 1 tropical (Panama)
- 4 sites have some water table depth information

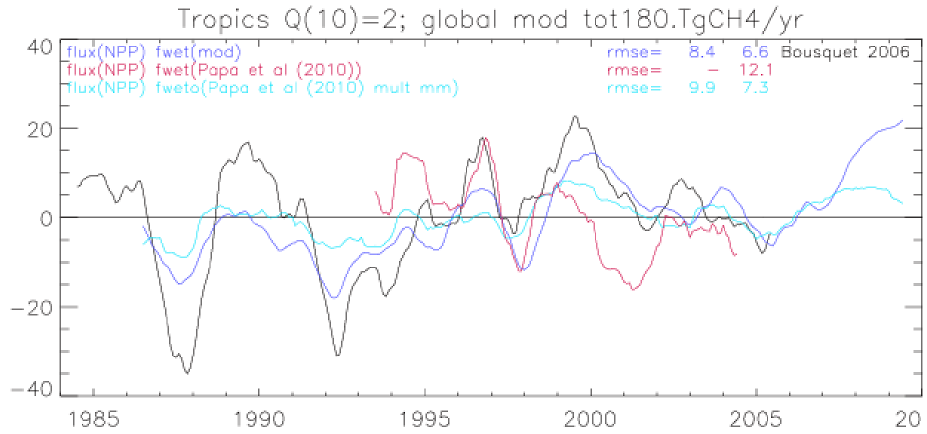


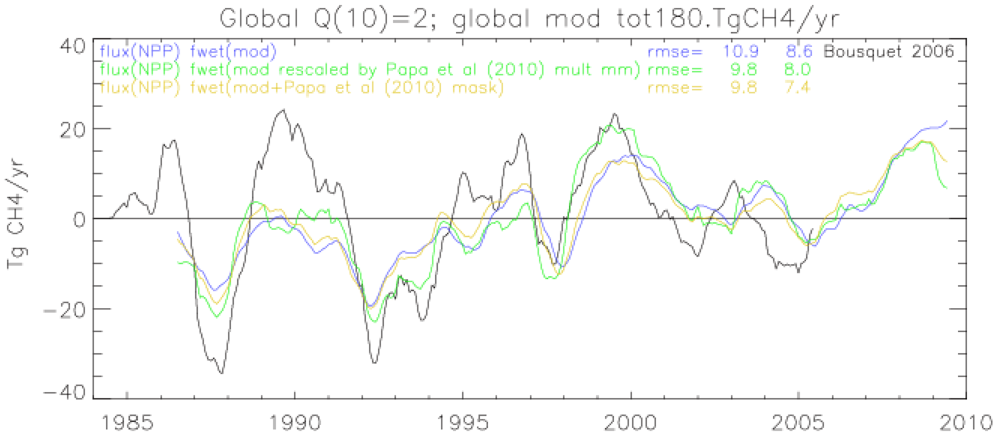
# Overall results

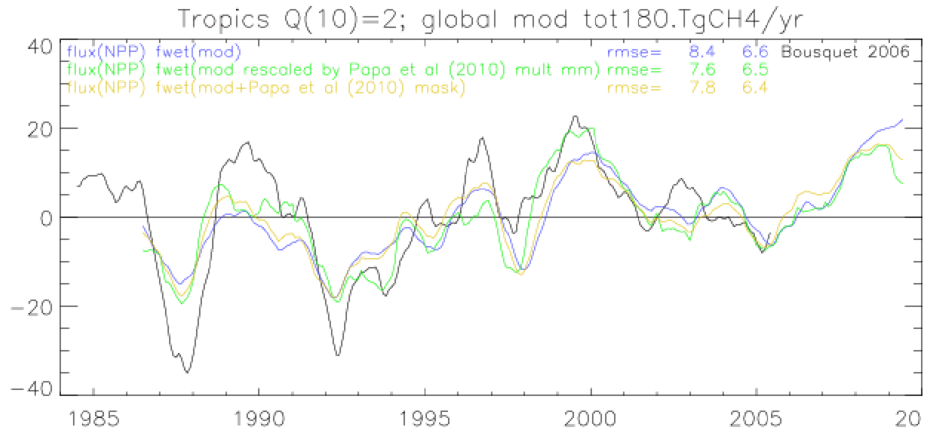
- All models ~reproduce seasonality
- No clear best model
- When optimising parameters:
  - **$Q_{10}$(T)~3.5 for fixed soil carbon based $CH_4$ model**
  - **$Q_{10}$(T)~2 for NPP & soil resp based $CH_4$ models**

# 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

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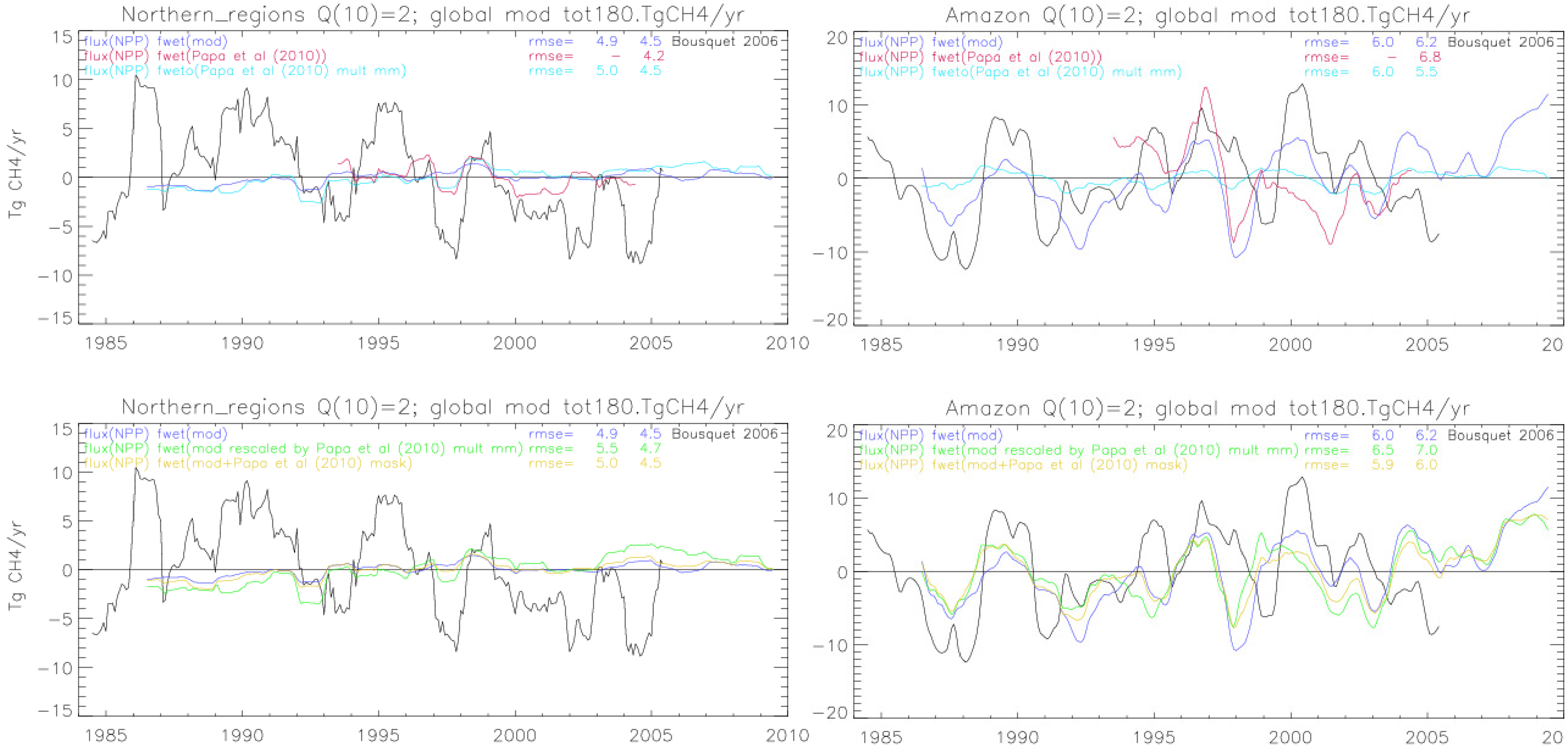
Hadley Centre

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



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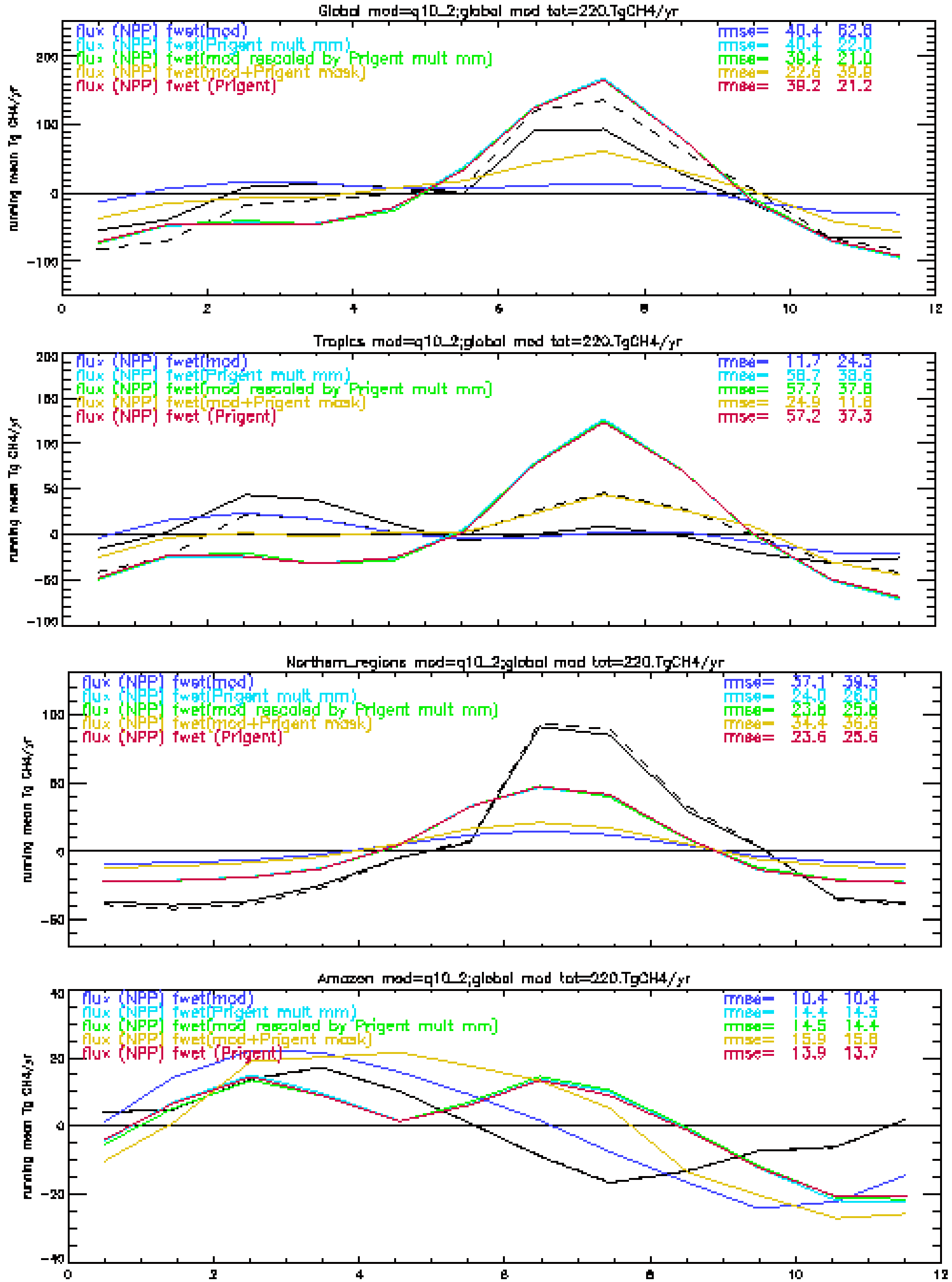
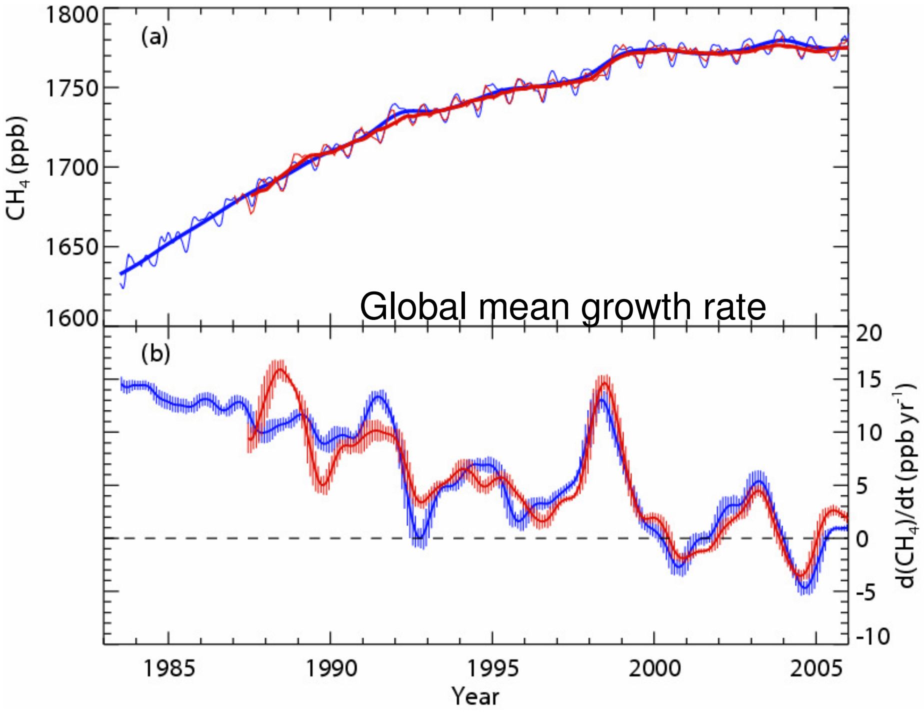
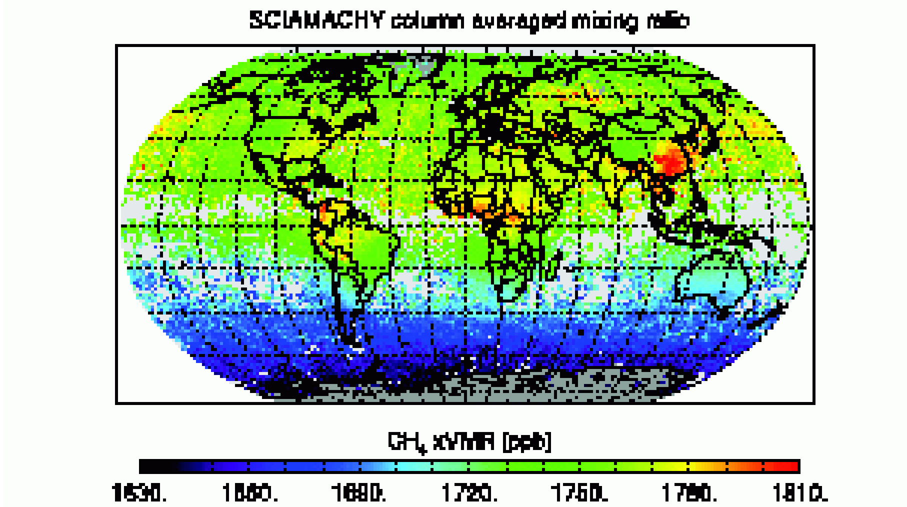
# Seasonal anomalies



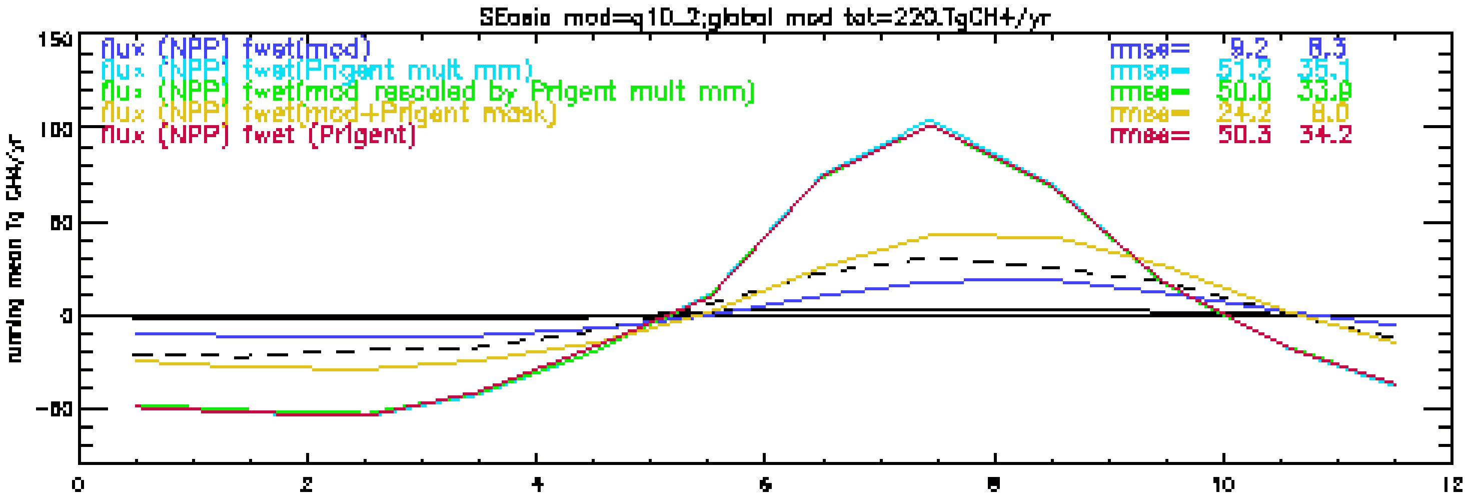
Historical trend and inter-annual variability in $CH_4$ growth rate are poorly understood



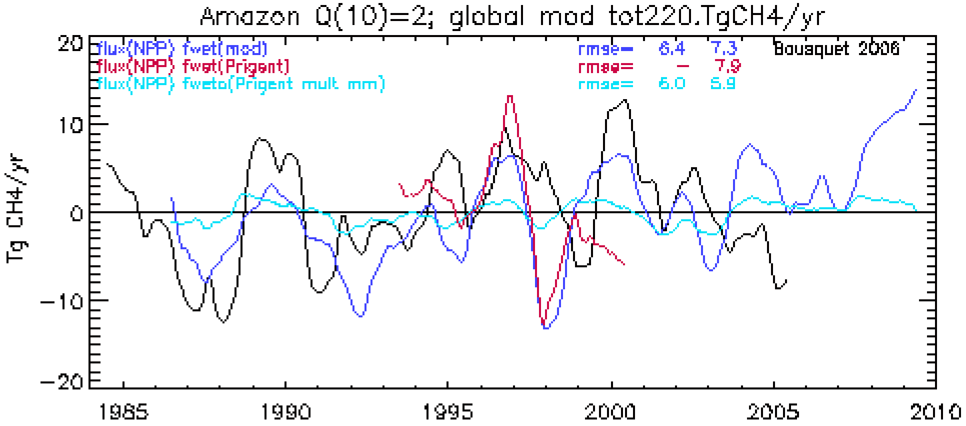

Understand wetland contribution through EO (Sciamachy) and atmospheric chemistry model (UKCA)

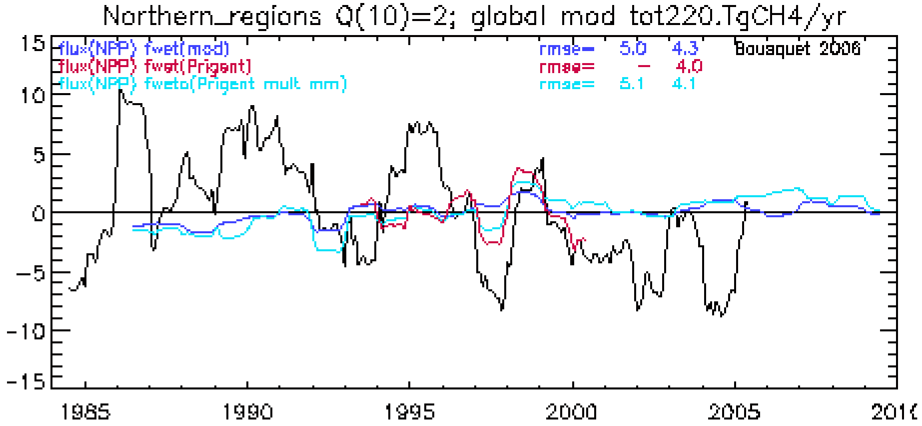


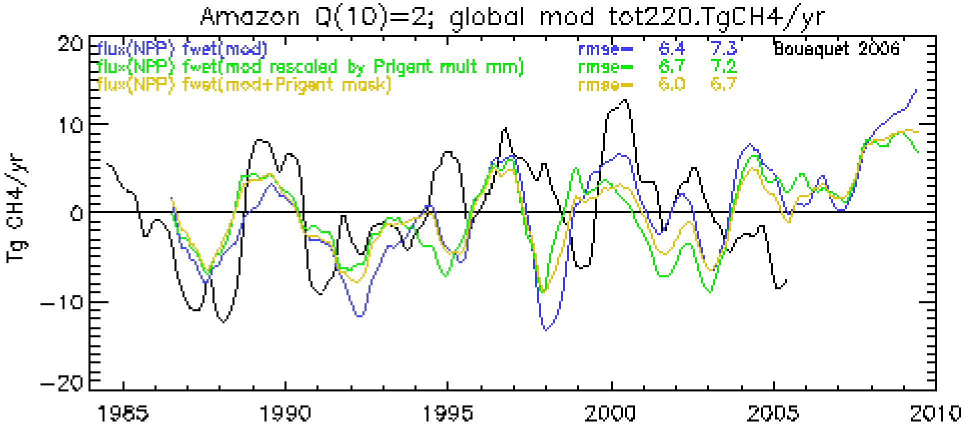

Frankenberg et al, 2008

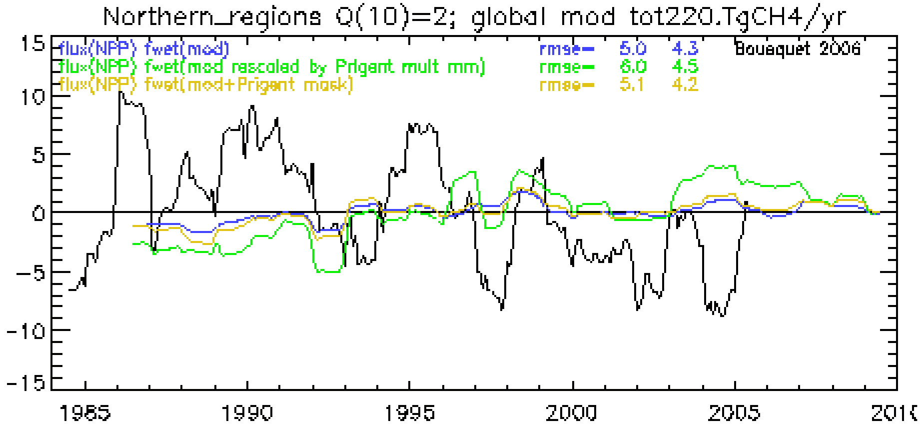


SEasia mod=q10_2;global mod tot=220.TgCH4/yr
flux (NPP) fwet(mod)
flux (NPP) fwet(Prigent mult mm)
flux (NPP) fwet(mod rescaled by Prigent mult mm)
flux (NPP) fwet(mod+Prigent mask)
flux (NPP) fwet (Prigent)
rmse= 9.2 8.3
rmse= 51.2 35.1
rmse= 50.0 33.9
rmse= 24.2 8.0
rmse= 50.3 34.2
running mean Tg CH4/yr
150
100
50
0
-50
0
2
4
6
8
10
12

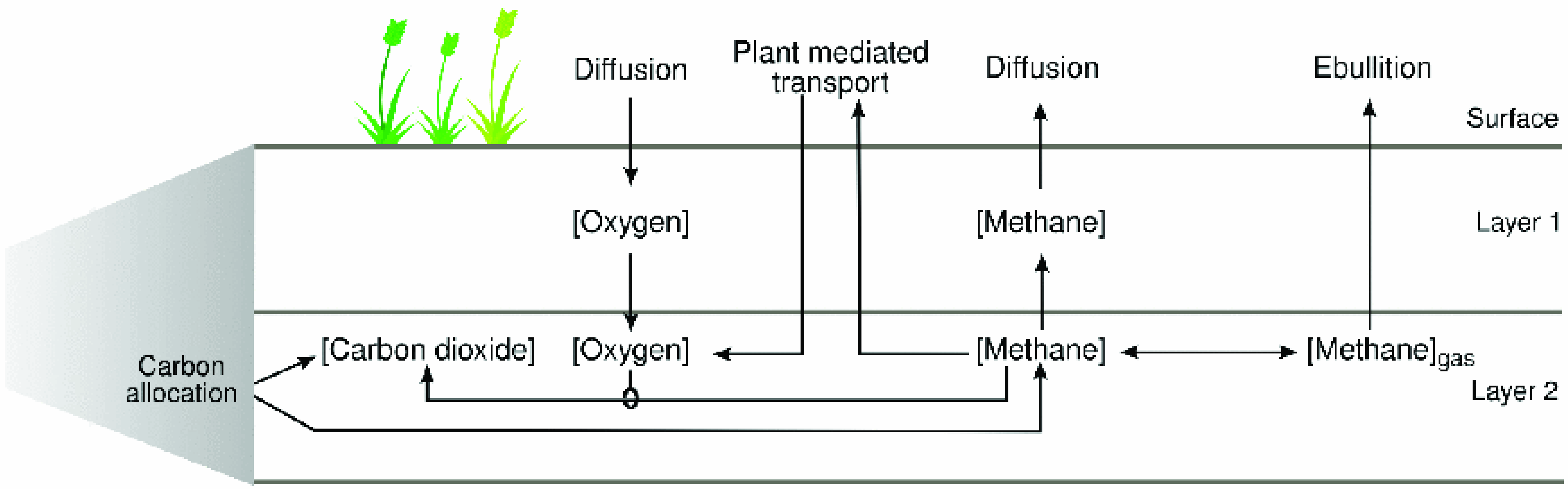

Amazon Q(10)=2; global mod tot220.TgCH4/yr
flux(NPP) fwet(mod)
flux(NPP) fwet(Prigent)
flux(NPP) fweto(Prigent mult mm)
rmse= 6.4 7.3
rmse= – 7.9
rmse= 6.0 5.9
Bousquet 2006
Tg CH4/yr
20
10
0
−10
−20
1985
1990
1995
2000
2005
2010


Northern_regions Q(10)=2; global mod tot220.TgCH4/yr
flux(NPP) fwet(mod)
flux(NPP) fwet(Prigent)
flux(NPP) fweto(Prigent mult mm)
rmse= 5.0 4.3
rmse= – 4.0
rmse= 5.1 4.1
Bousquet 2006
15
10
5
0
−5
−10
−15
1985
1990
1995
2000
2005


Amazon Q(10)=2; global mod tot220.TgCH4/yr
flux(NPP) fwet(mod)
flux(NPP) fwet(mod rescaled by Prigent mult mm)
flux(NPP) fwet(mod+Prigent mask)
rmse= 6.4 7.3
rmse= 6.7 7.2
rmse= 6.0 6.7
Bousquet 2006
Tg CH4/yr
20
10
0
−10
−20
1985
1990
1995
2000
2005
2010


Northern_regions Q(10)=2; global mod tot220.TgCH4/yr
flux(NPP) fwet(mod)
flux(NPP) fwet(mod rescaled by Prigent mult mm)
flux(NPP) fwet(mod+Prigent mask)
rmse= 5.0 4.3
rmse= 6.0 4.5
rmse= 5.1 4.2
Bousquet 2006
15
10
5
0
−5
−10
−15
1985
1990
1995
2000
2005

# Schematic representation of the LPJ-WHyMe methane model

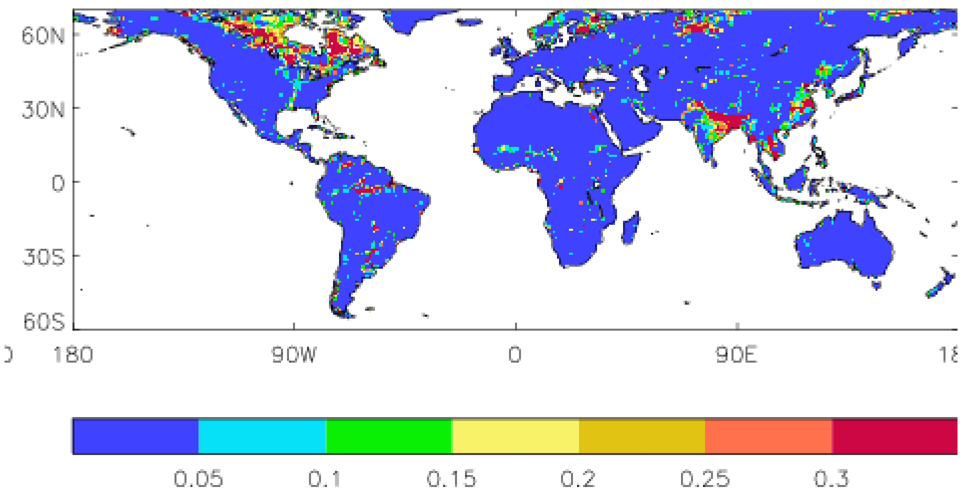



Wania et al, 2010

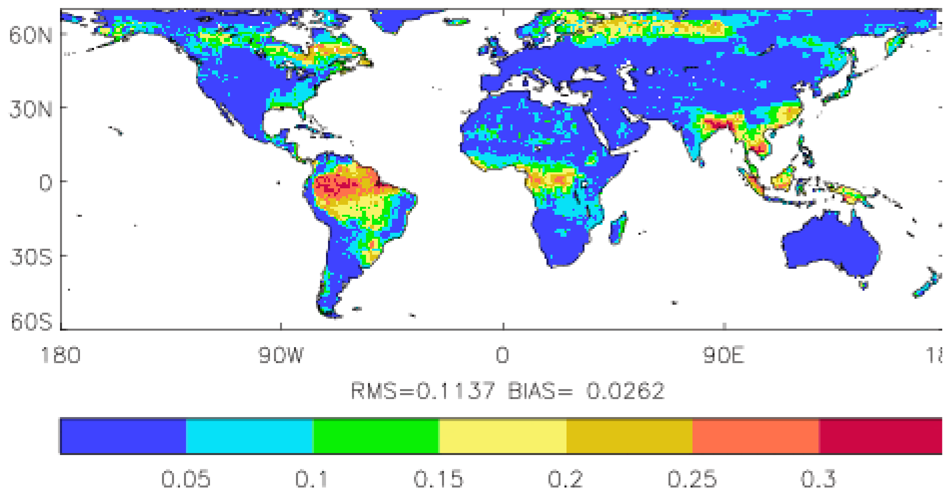
- Microwave remote sensing soil moisture products
  - Top few cms

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

Obs (Prigent et al., 2007)




JULES_LSH



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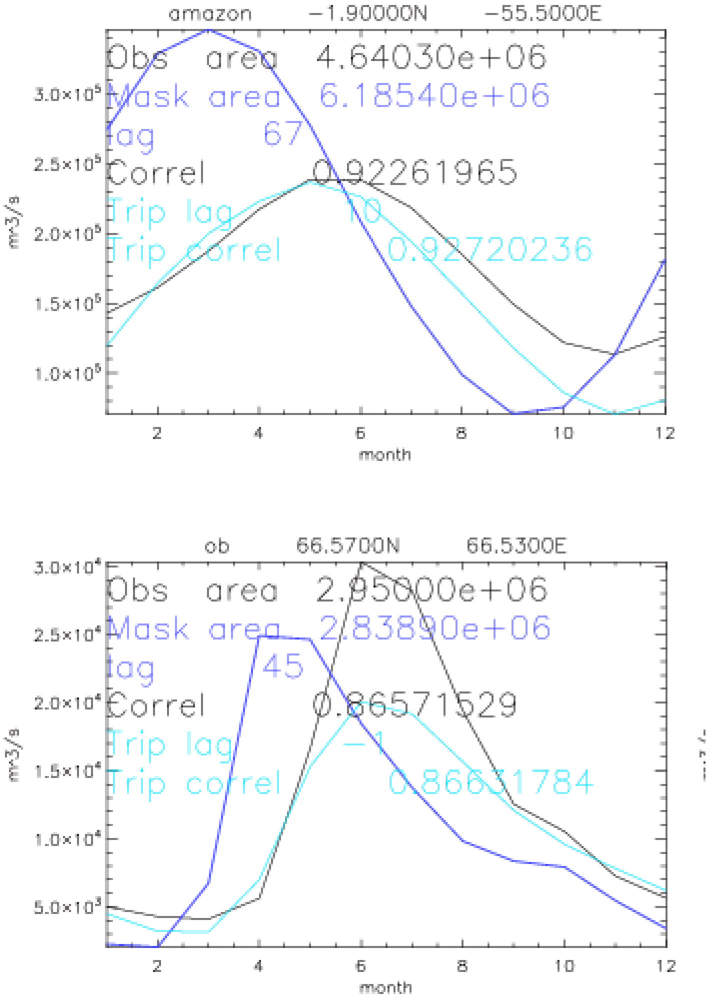
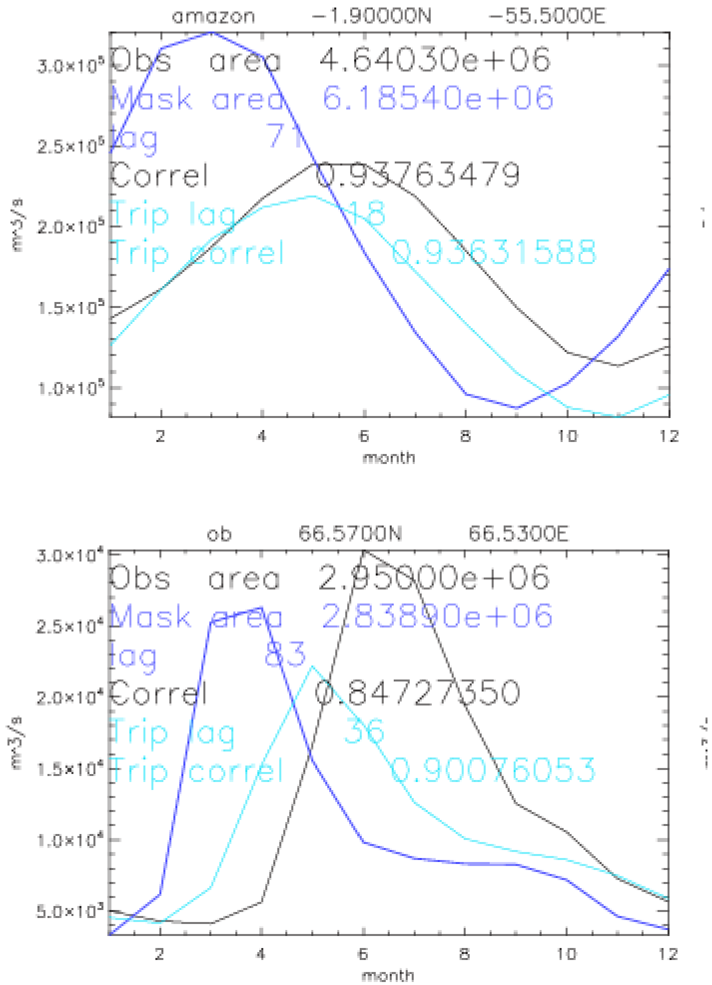
# Modelled river flow

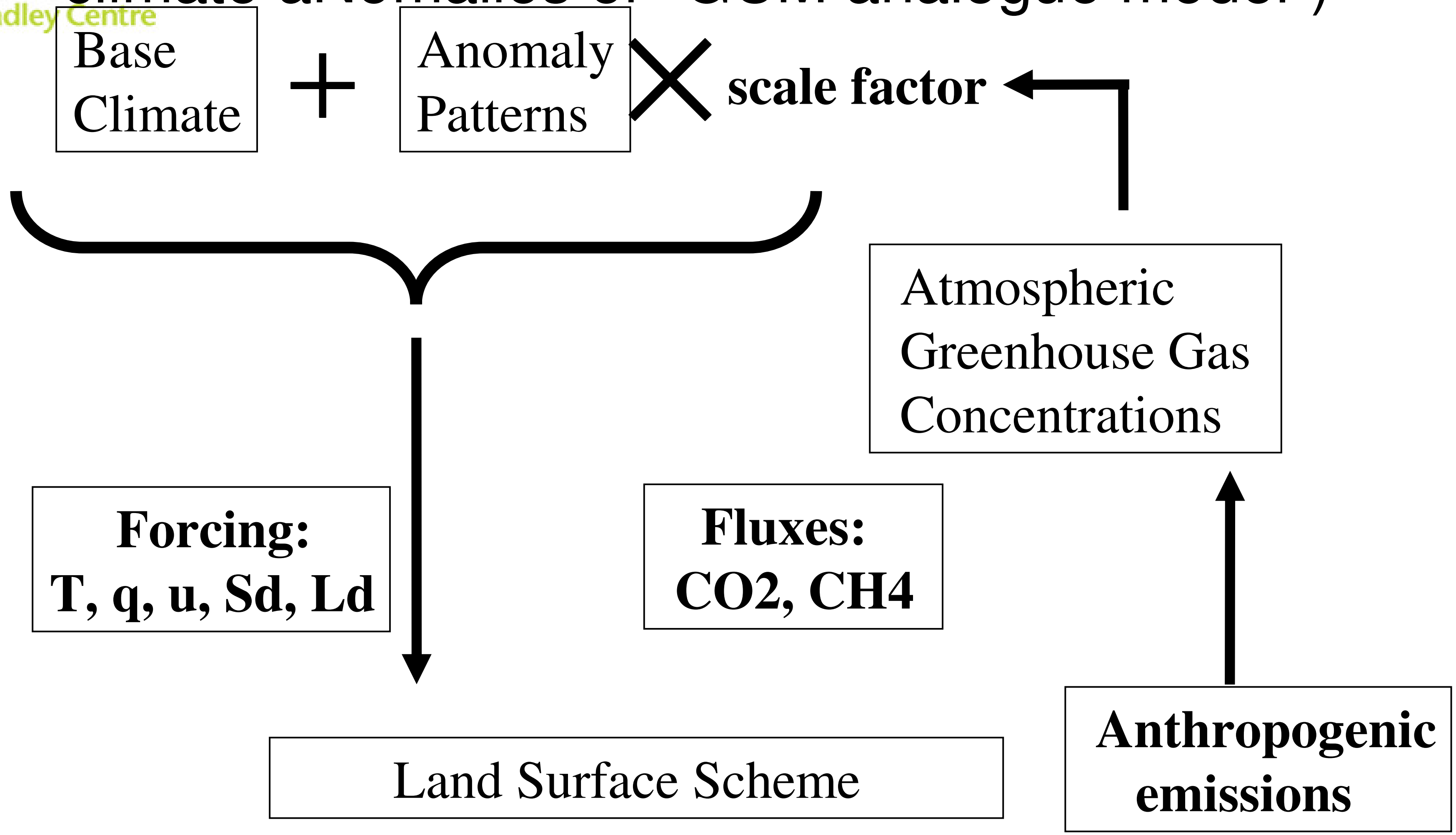


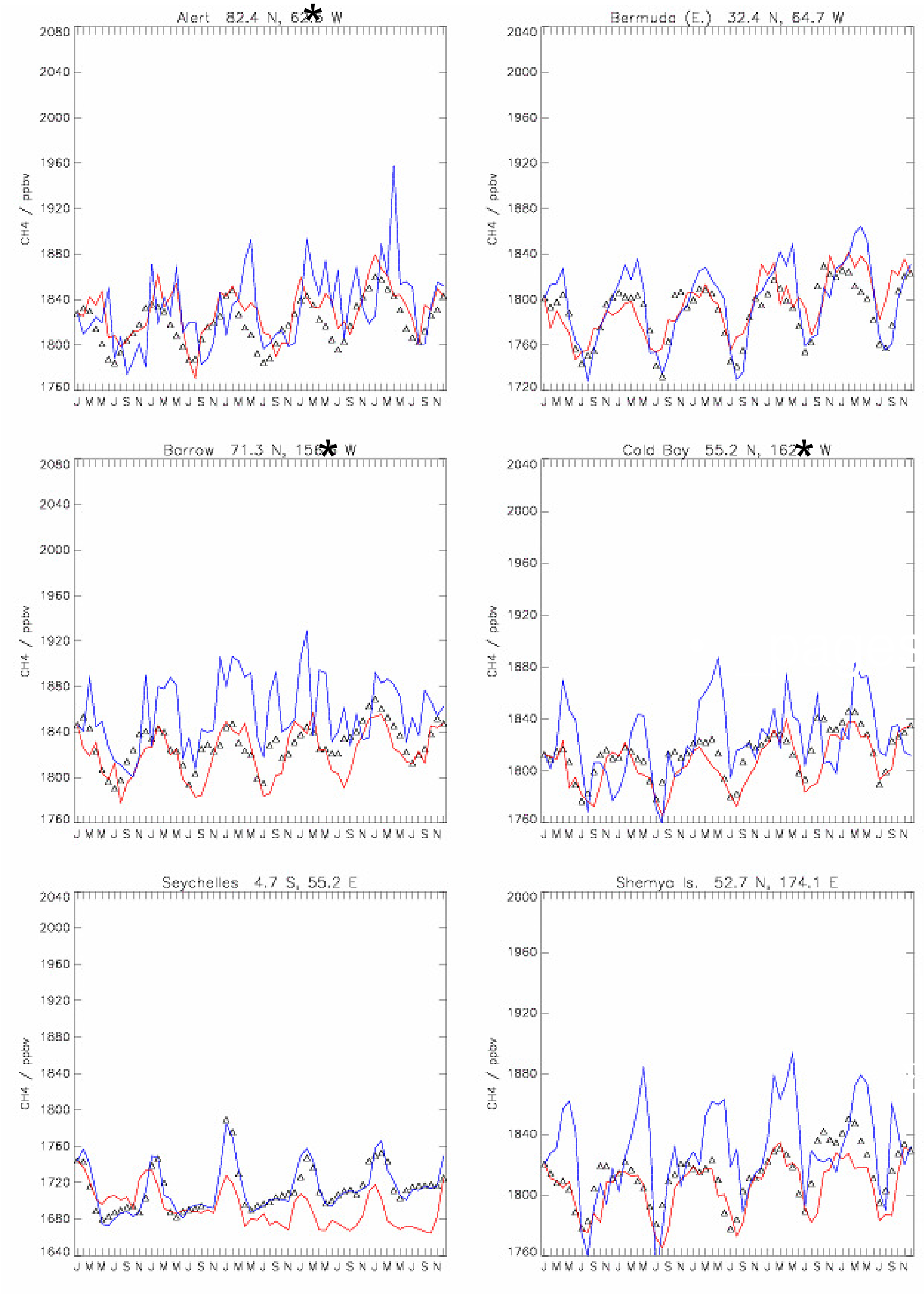

JULES




JULES-LSH

# 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 CH4 emissions
blue: constant wetland CH4 emissions
triangles: NOAA/CMDL