How well can we model wetlands in tropical and boreal regions?

S Dadson[1], N Gedney[2], G Hayman[1], E Blyth[1], D Clark[1], C Taylor[1], C Prigent[3]

[1] Centre for Ecology and Hydrology (UK); [2] Met Office Hadley Centre (UK); [3] CNRS/Estellus (F)

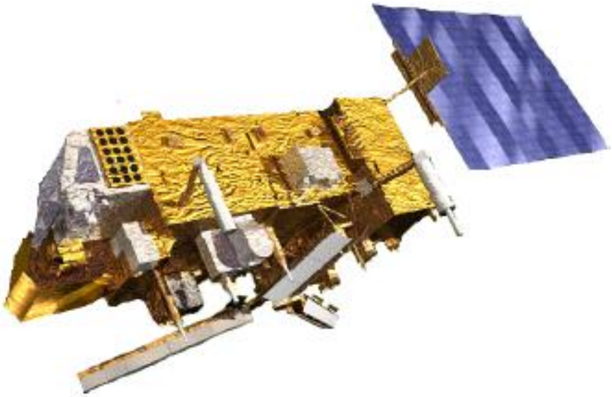
19th September 2011

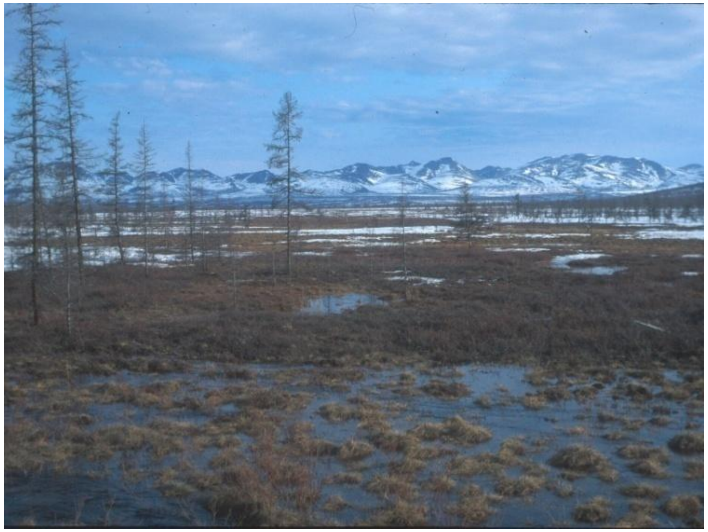
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Scope and Acknowledgements

Scope

- Background
- Boreal wetlands and ALANIS Methane
- Tropical wetlands
- Future activities





Acknowledgements

- European Space Agency
- ALANIS Methane project partners (TU Wien, Bremen)
- iLEAPS

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Background – Methane and wetlands

- CH_4 second most important greenhouse gas after CO_2
- Wetlands are largest natural source but there are large uncertainties
- Subject of recent papers (e.g., Bloom et al., 2010; Ringeval et al., 2010; Bousquet et al., 2011)

Table 2-5. Summary of Estimated Wetland CH_4 Fluxes by Technique (Tg CH_4/Year)

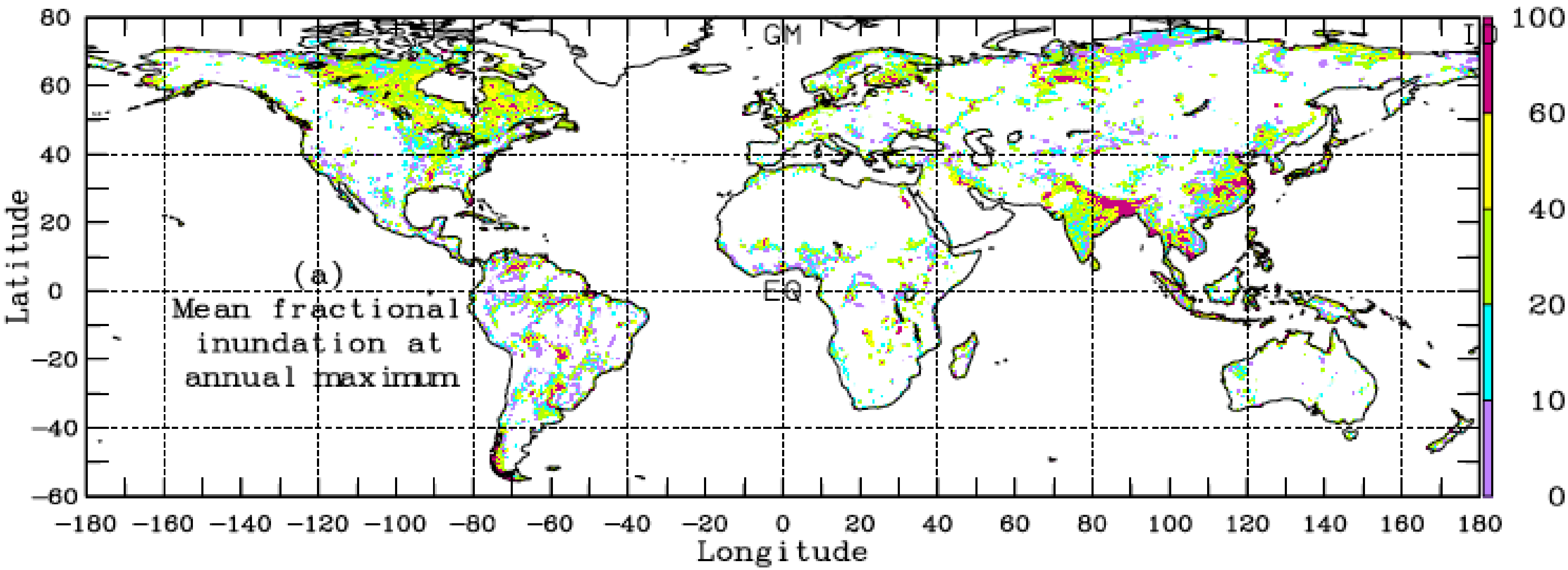
Approach	Northern/Bogs	Tropical/Swamps	Total
Flux extrapolation	31–48[a] avg = 38 (37%)	49–80 avg = 65 (63%)	80–115 sum of avgs = 103 n = 4
Process modeling	20–72[b] avg = 44 (31%)	41–133 avg = 90 (64%)	92–156 sum of avgs = 134 n = 8 (bogs); 5 (swamps)
Inverse modeling	21–47 avg = 36 (20%)	81–206 avg = 144 (78%)	145–237 sum of avgs = 180 n = 6
Current best guess (process and inverse modeling since 2004)	24–72 avg = 42.7 (25%) std. dev. = 16.6; n = 10	81–206 avg = 127.6 (75%) std. dev. = 44.0; n = 8	170.3 range = 105–278 by summing minima and maxima

[a] For flux extrapolation, temperate emissions are split equally between bogs and swamps. Values in parentheses indicate percentage contribution to wetland total emissions.
[b] Walter et al. (2001) estimates excluded.

US EPA, 2010

- Wetland inundation (in Africa) exerts a strong control on fluxes of heat and water at the land surface
- Climate change projections show a 78% increase in methane emissions from x2 CO_2, with both feedbacks and uncertainties greatest in the tropics (Shindell et al., 2004, GRL; IPCC, 2007)

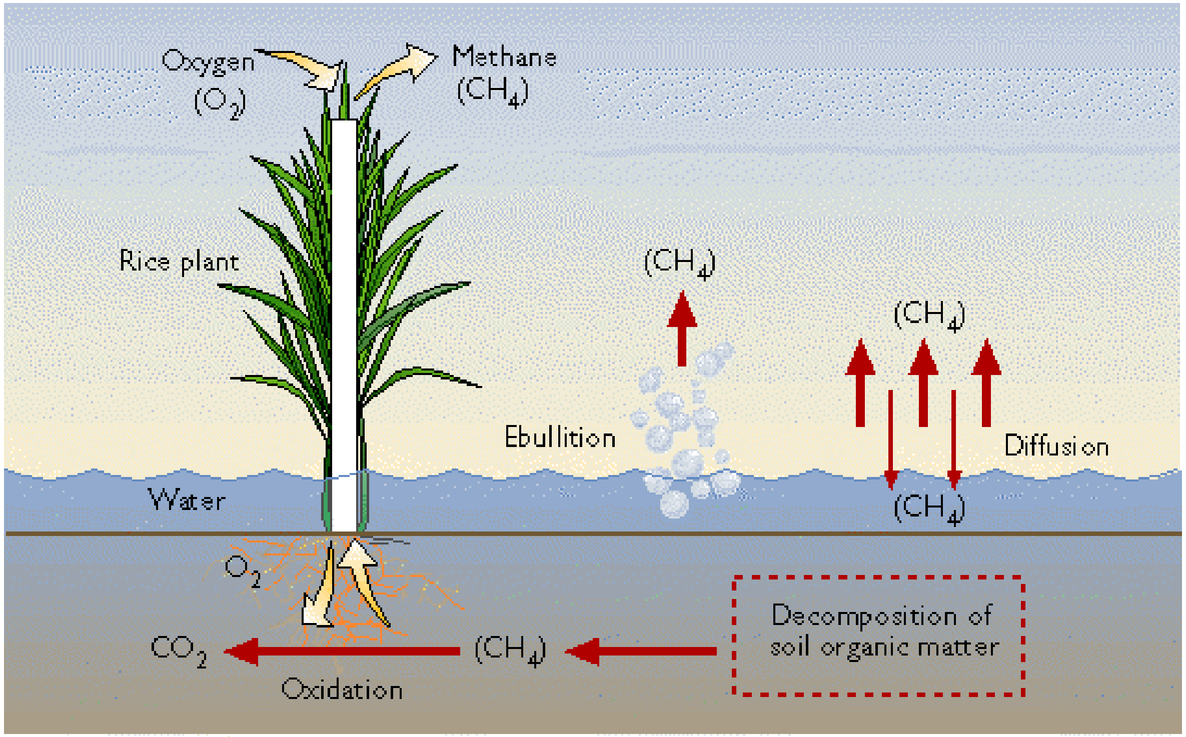
Distribution of wetlands



- Wetland inundation product of Prigent et al.
- Major wetland areas identified (Ob River, Amazon basin, North of Canada, India…)
- Areas of inundation show realistic structures at large scale
- No discrimination between natural wetlands, rice paddies and small lakes

Background – Methane and wetlands

- CH_4 wetland emissions by diffusion across the soil or water interface, by ebullition (bubbling), and by plant-mediated transport
- Parameters for modelling at large scales:
  - Soil temperature (→ soil microbial activity)
  - Water table depth (→ defines the CH_4-generating region
  - carbon content of the decomposable substrate
- Linked to changes in:
  - precipitation, permafrost dynamics, vegetation cover, and topography

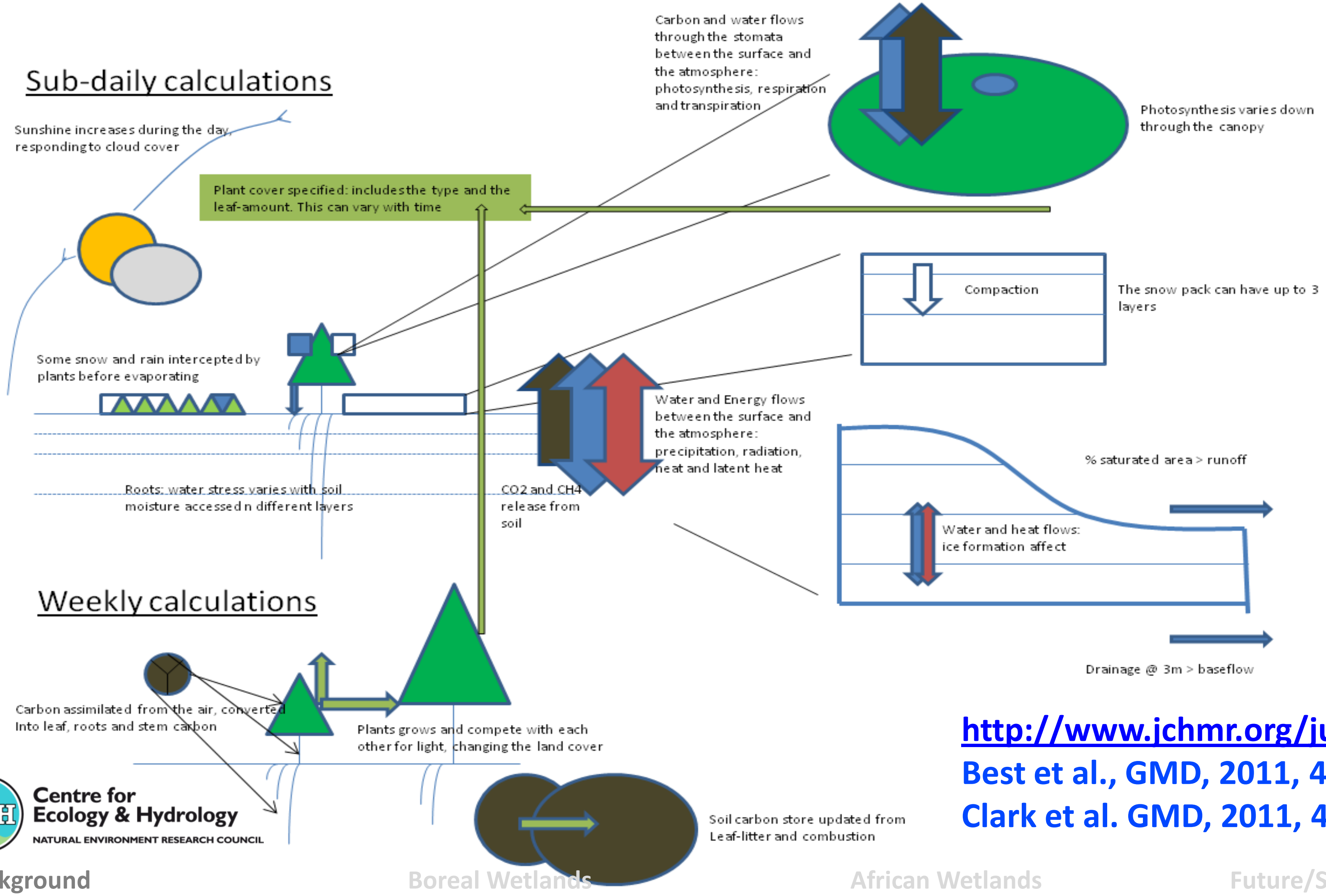


Source: http://www.riceweb.org/reserch/Res.issmethane.htm

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

JULES - Joint UK Land Environment Simulator

- Process-based model of carbon, energy and water exchange between atmosphere and land surface
- CEH lead institute for development of JULES



http://www.jchmr.org/jules/
Best et al., GMD, 2011, 4, 677
Clark et al. GMD, 2011, 4, 701

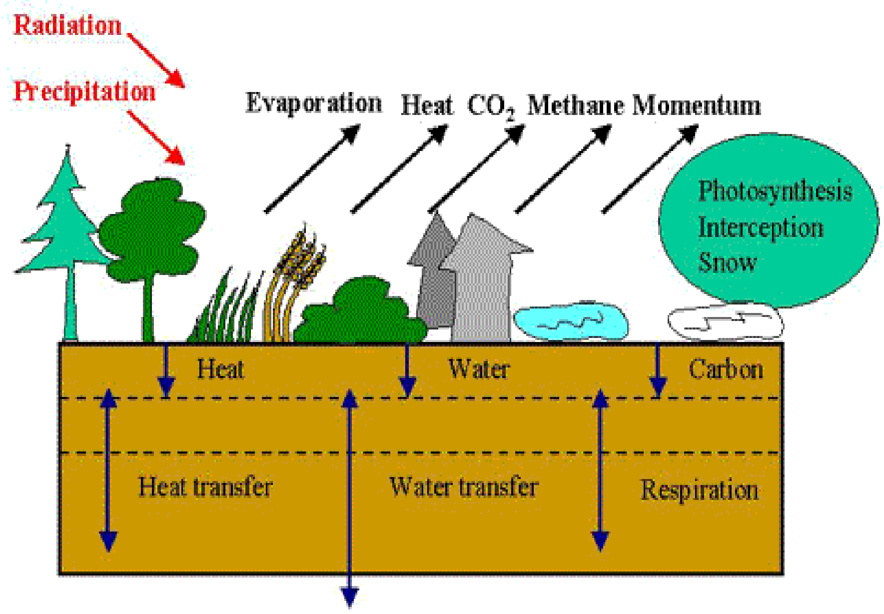
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

JULES – Modelling methane emissions from wetlands

- Gedney et al [2003, 2004] parameterisations of large-scale hydrology and wetland biogeochemistry
- Modelled wetland fraction is based on soil moisture saturation
- Current version has no overbank inundation
- Can be used in different configurations:
  a. Point/Offline
  b. Gridded/Offline
  c. Coupled into atmospheric chemistry model

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

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

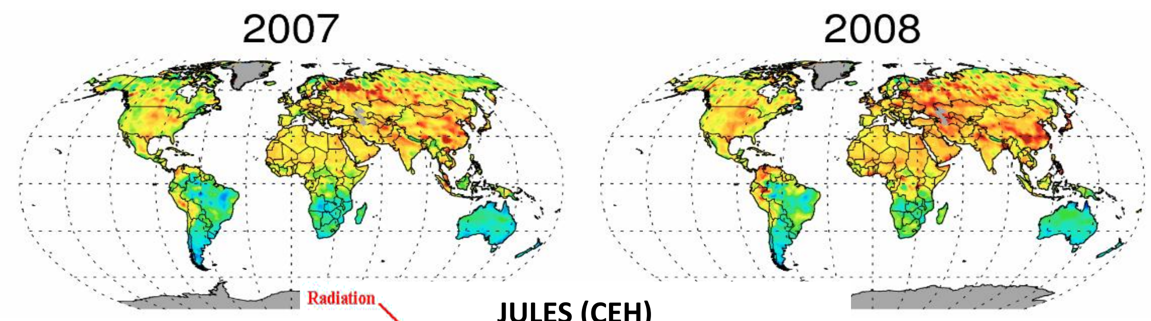


http://www.jchmr.org/jules/

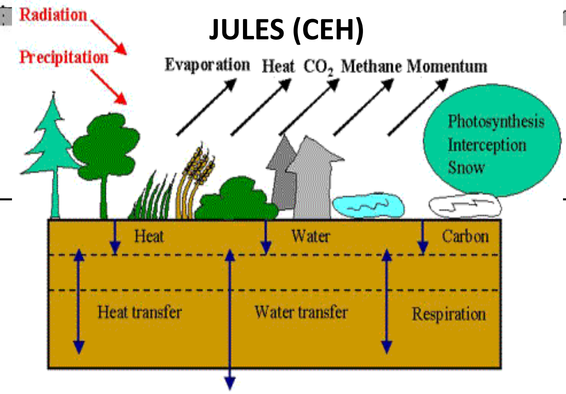
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

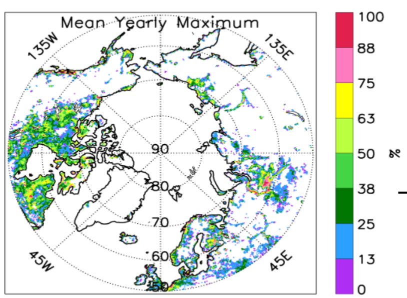
ESA ALANIS Methane

- Producing EO products relevant to large-scale land surface modelling
- Presentation on ALANIS Methane (Bartsch, Wednesday)

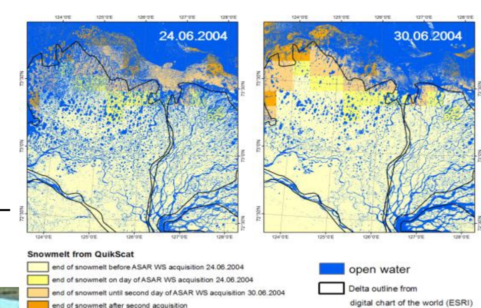


Column CH_4
(Bremen)





Wetland Extent
(Estellus)



Snowmelt
(Vienna)

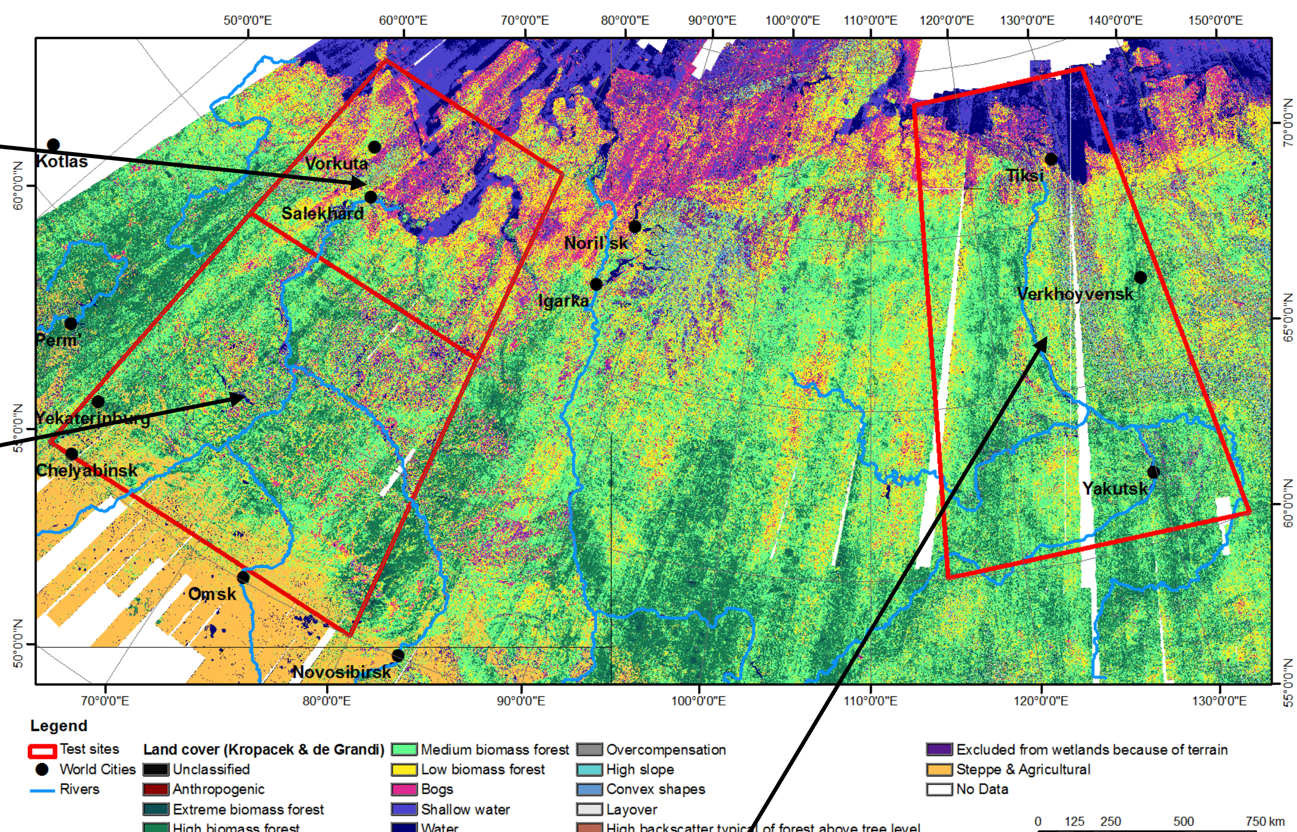
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

ESA ALANIS Methane – Areas of interest

Focus on Northern Eurasia, 2007-2008

Test Site #1: Western Siberia (N)
- Subarctic-Arctic
- continuous to discontinuous permafrost
- hotspot of lake change

Test Site #2: Western Siberia (S)
- Boreal
- Ob river floodplains
- sporadic to discontinuous permafrost
- extensive peatlands

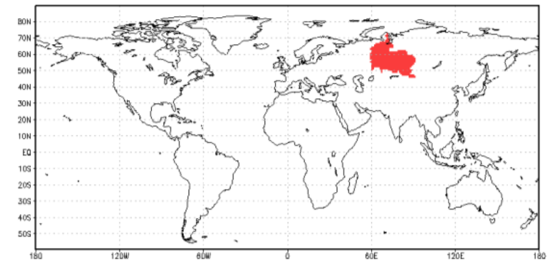


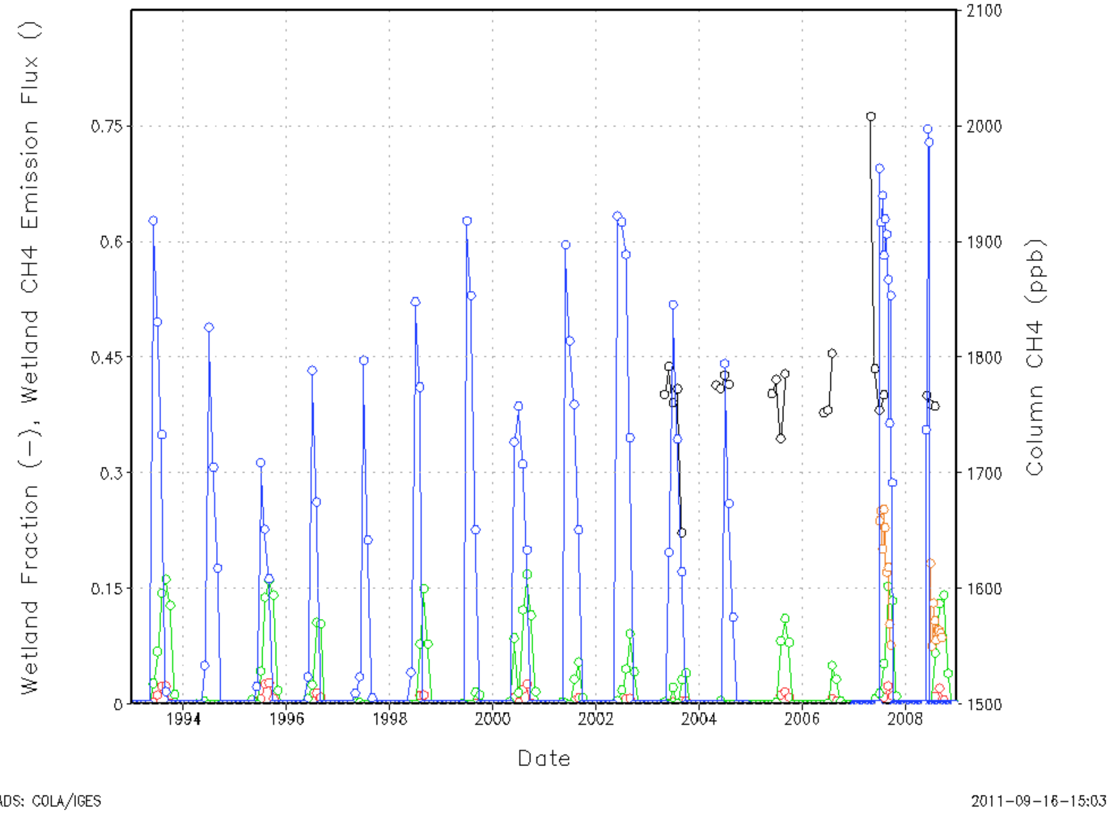
Test Site #3: Lower Lena River floodplain and delta
- Subarctic to High Arctic lowlands
- key region for understanding the basic processes of the dynamic and development of permafrost in the Siberian Arctic
- upstream basin with flood plains
- extensive delta area with several terraces

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

JULES – Comparison with EO products for Ob river

- Standard version of JULES
- Model run to 1.0° x 1.0° global grid for 1975-2010 using CRU-NCEP driving met data
- Time series at point of high inundation (66.5° E, 66.5° N)
  - Blue - EO 'wetland' fraction (Prigent)
  - Orange - EO 'wetland' fraction (TU Wien)
  - Green – JULES 'wetland' fraction
  - Red – JULES CH_4 emission flux
  - Black – Sciamachy column CH_4
- Further assessment of hydrology as part of ALANIS Methane

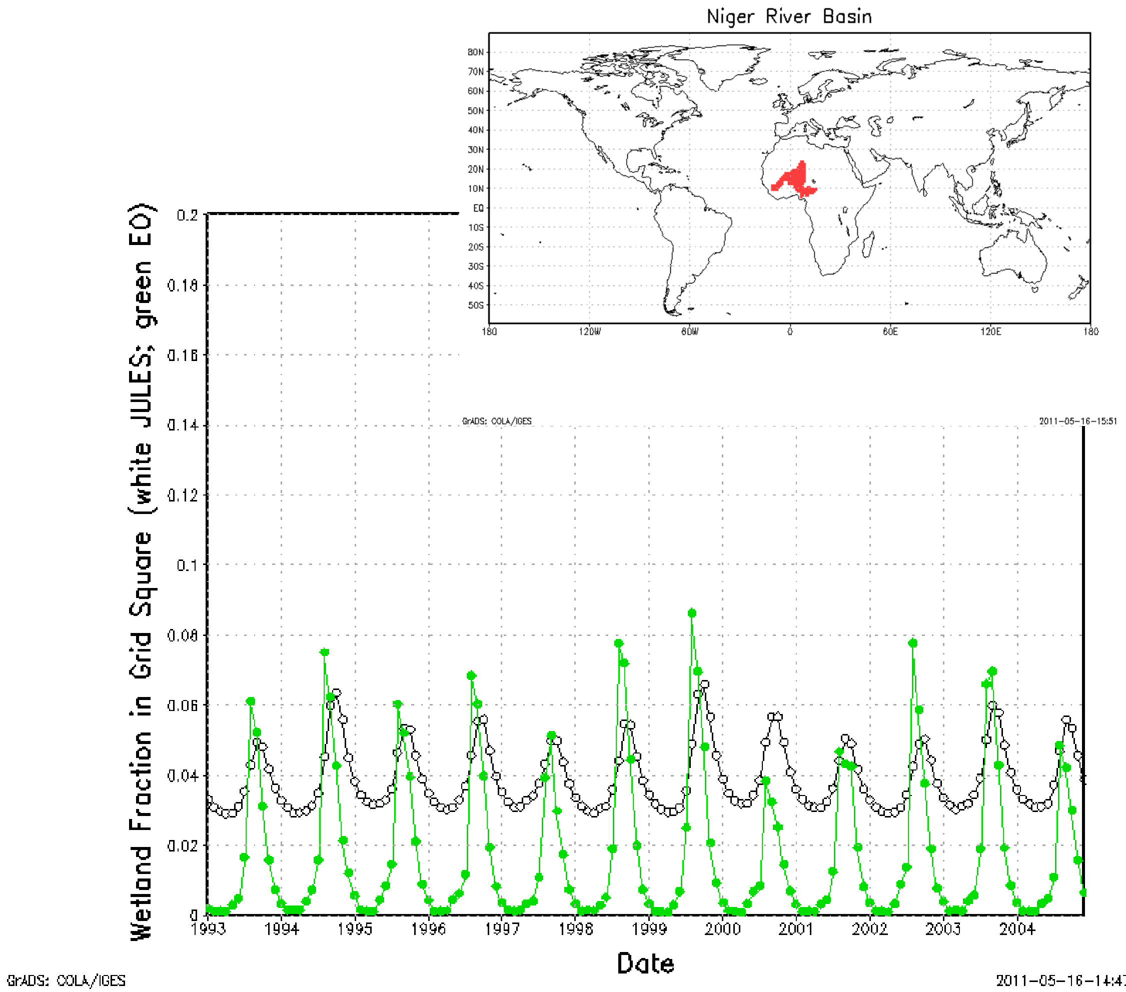




Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

JULES – Comparison with EO products for Niger Inland Delta

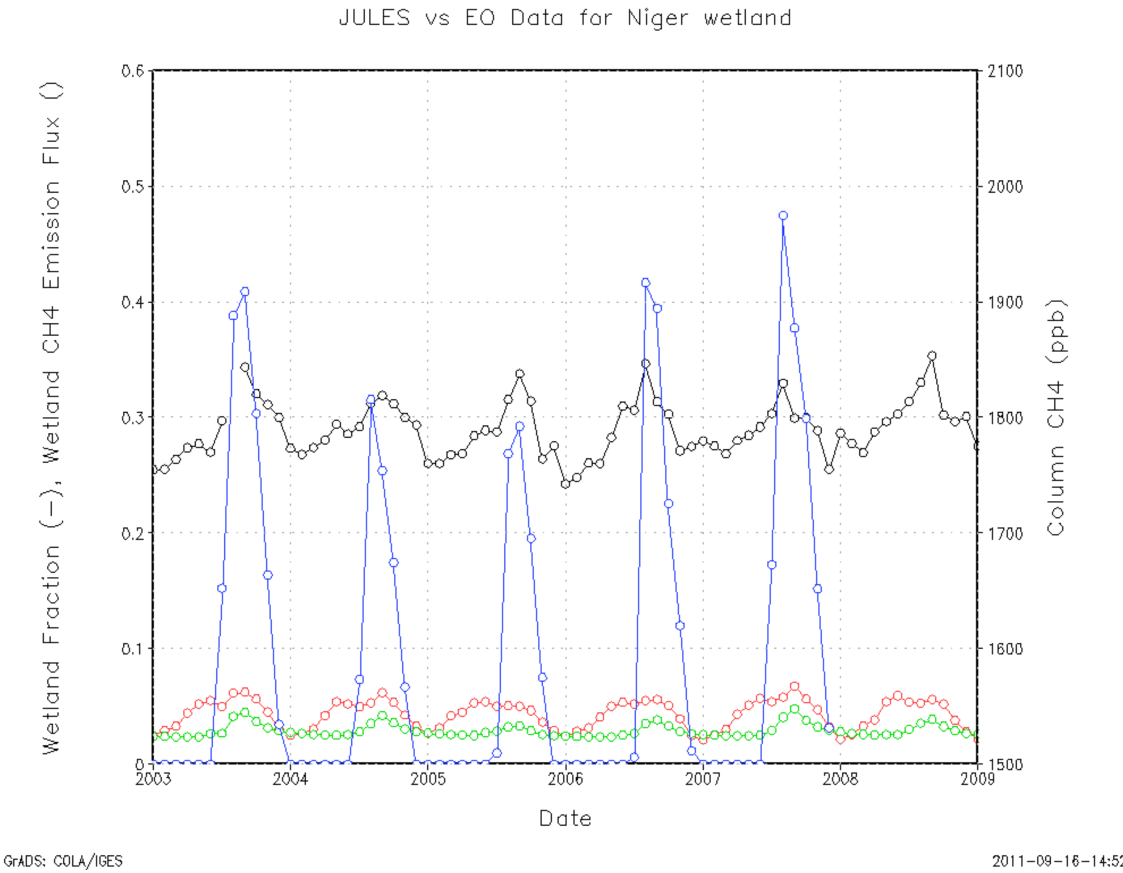
- Standard version of JULES
- Model run to 1.0° x 1.0° global grid for 1975-2010 using CRU-NCEP driving met data
- EO products reprocessed to same output grid as JULES
- Time series as average over Niger river basin
  - Green – EO 'wetland' fraction (Prigent)
  - Black – JULES 'wetland' fraction
- Underestimates magnitude of inundation and suggestion that the model does not dry out



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

JULES – Comparison with EO products for Niger Inland Delta

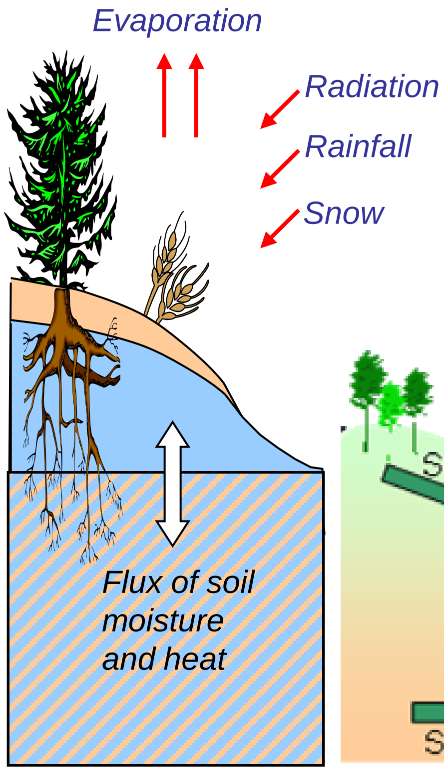
- Standard version of JULES
- Model run to 1.0° x 1.0° global grid for 1975-2010 using CRU-NCEP driving met data
- EO products reprocessed to same output grid as JULES
- Time series at point (~4° W, ~14° N)
  - Blue - EO 'wetland' fraction (Prigent)
  - Orange - EO 'wetland' fraction (TU Wien)
  - Green – JULES 'wetland' fraction
  - Red – JULES CH_4 emission flux
  - Black – Sciamachy column CH_4



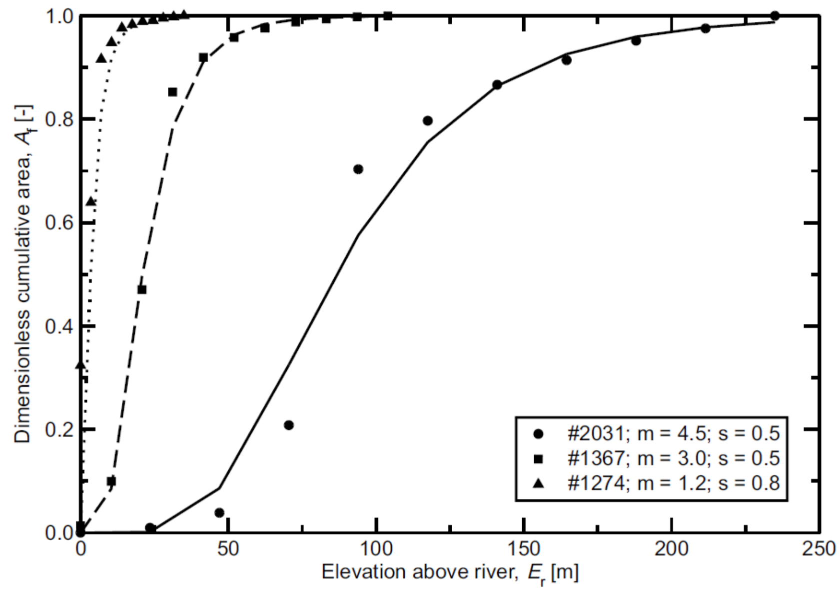
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

New flow routing and overbank inundation scheme for JULES

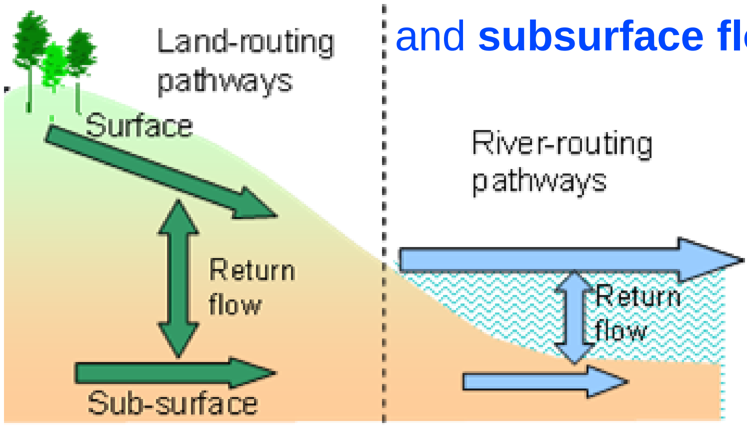
JULES takes **temperature**, **wind speed**, **humidity**, **LW** & **SW radiation** and **precipitation** from RCM;



Diagnose state of **soil moisture** by using a Pareto distribution of soil moisture store sizes;



Convert to **surface** and **subsurface flow.**

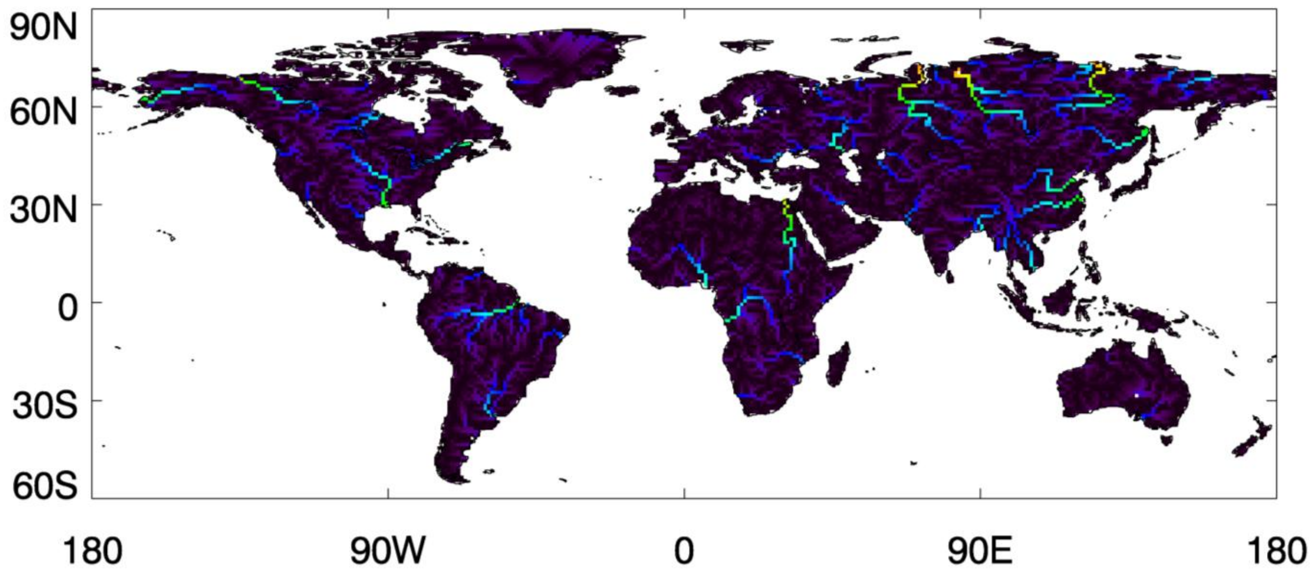


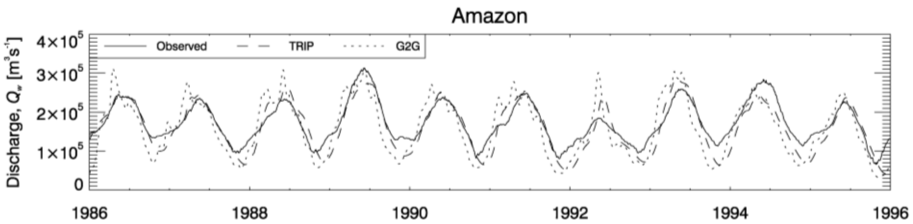
Inundated wetland area calculated using sub-grid elevation data

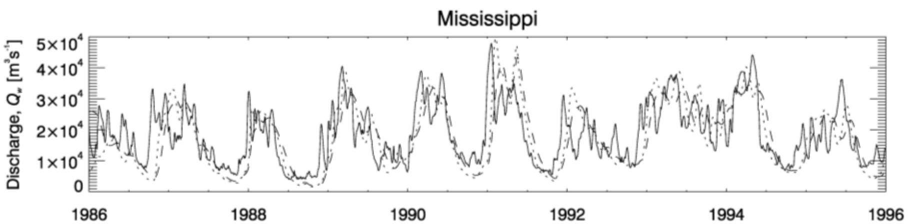
Bell *et al.*, 2007; Dadson *et al.*, 2010

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Global Applications: Major Rivers



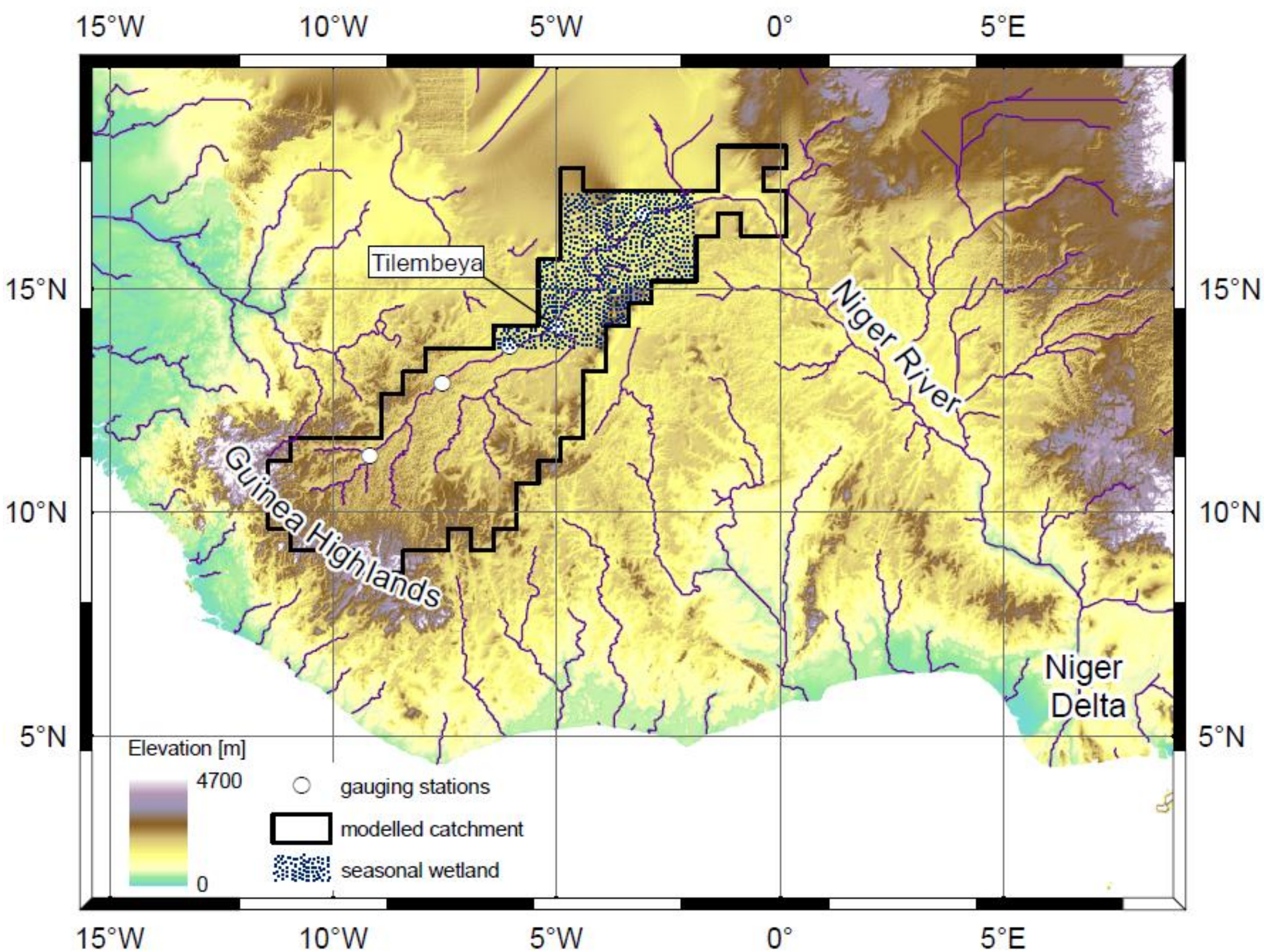




- Use of gridded spatial data reduces the need to calibrate the model for each catchment
- Generic modelling capability -> Hadley Centre Regional Model (PRECIS)
- Joint project with Hadley Centre to evaluate river flows in new AR5 model (HadGEM)

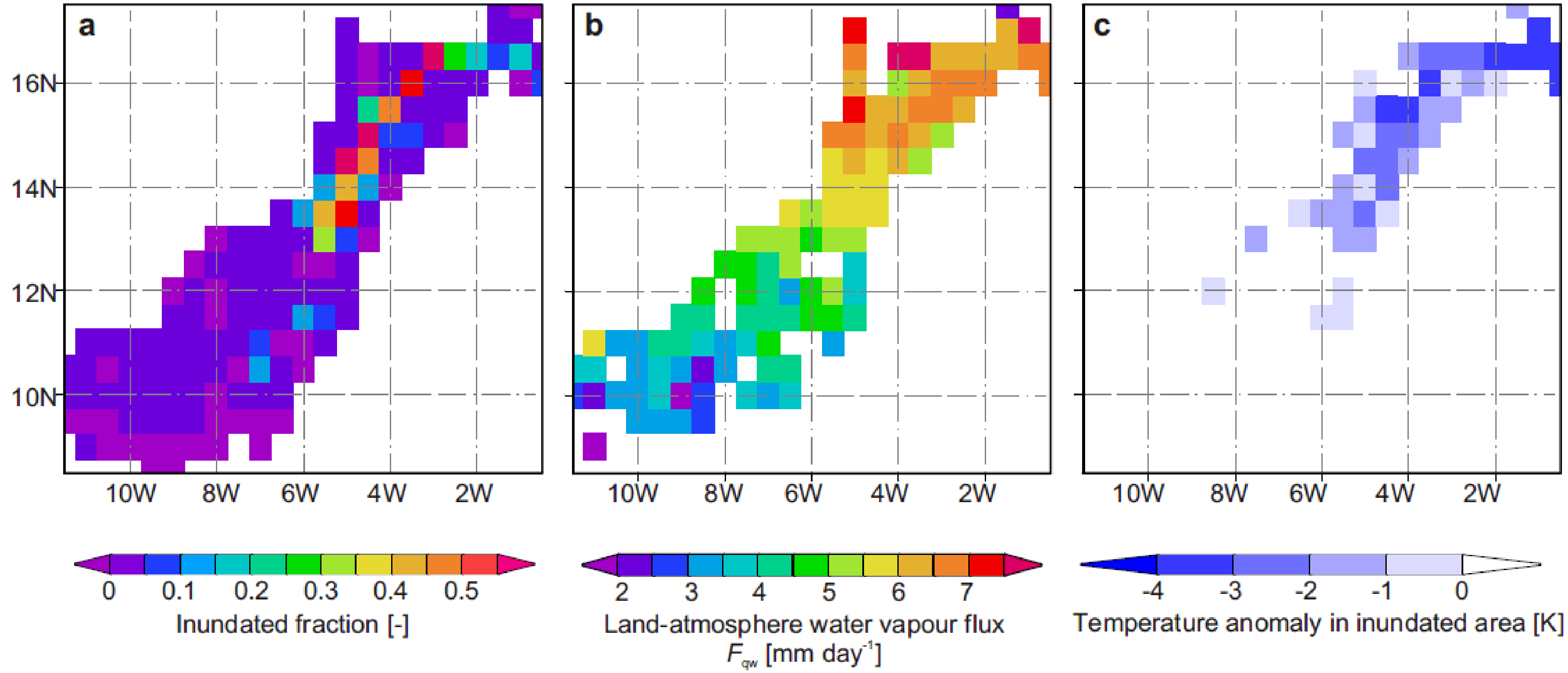
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Niger Inland Delta, MALI



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

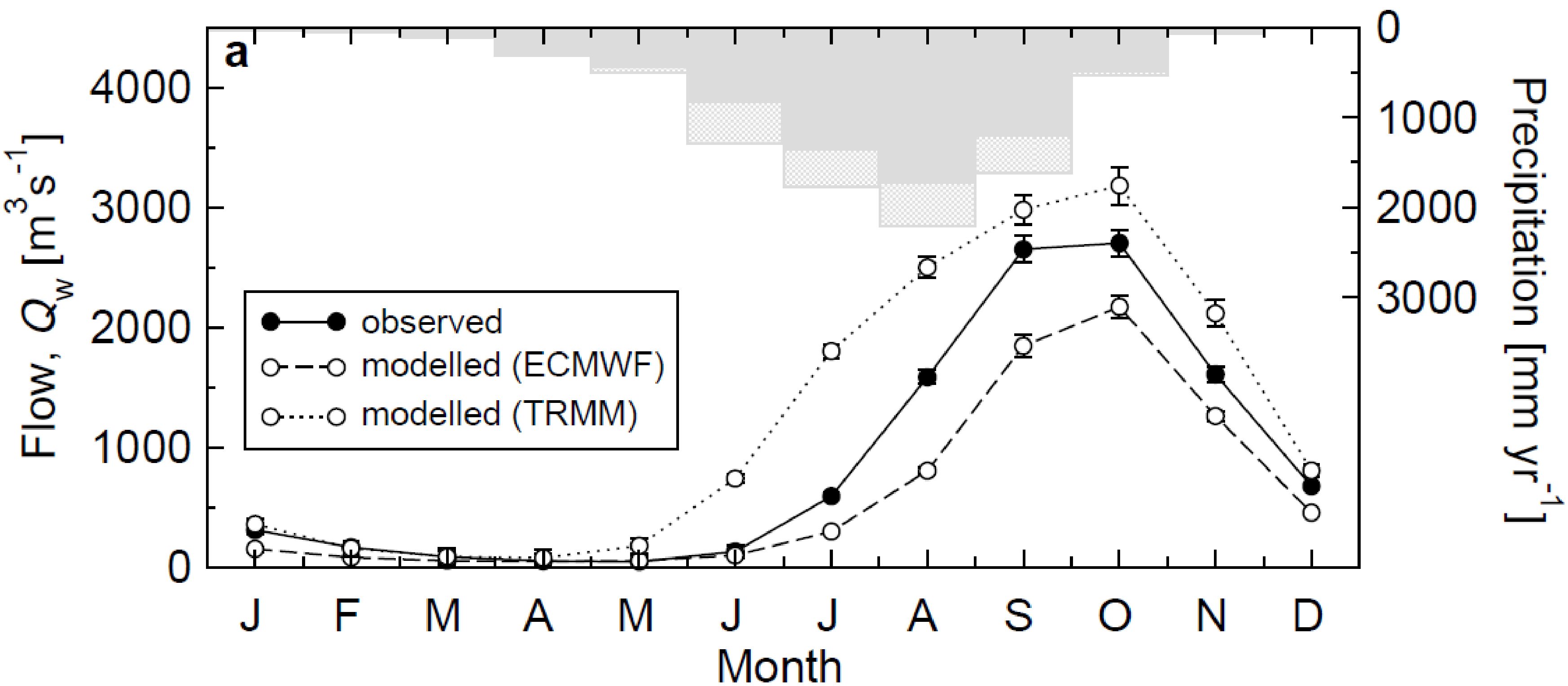
Modelled river flows and evaporation using new scheme



- **Area of greatest inundation follows topographic low;**
- **Inundation drives water vapour flux and temperature anomaly;**
- **Seasonal flooding provides up to 50 percent of water vapour to atmosphere.**

Dadson et al., (2010). Journal of Geophysical Research, 115, D23114.

Modelled and observed flows

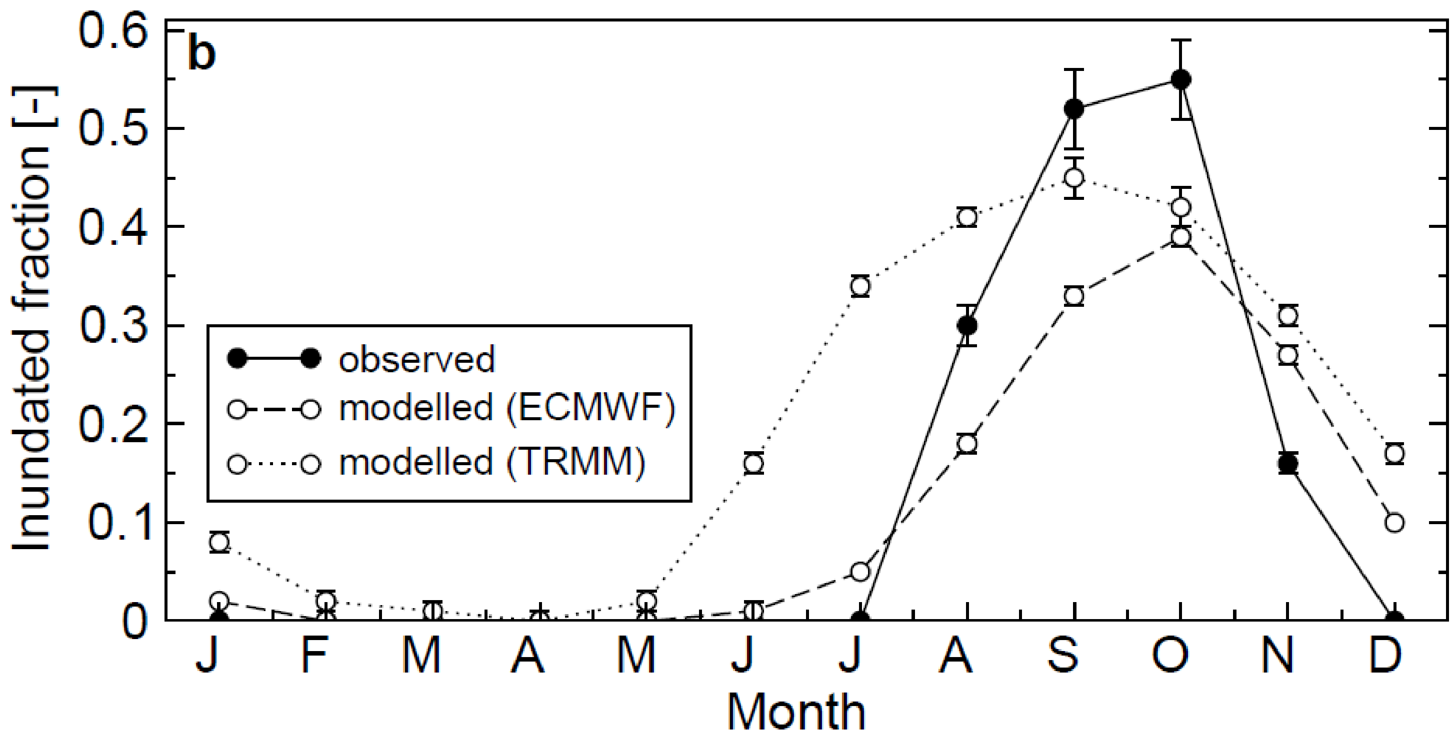


- **Timing of flows accurately reproduced by the model;**
- **ECMWF forcing gives 31% underestimate of flow (limited penetration inland of W. African Monsoon) R^2 = 0.79;**
- **TRMM-corrected forcing gives 41% overestimate of flow R^2 = 0.70.**

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Dadson et al., (2010). Journal of Geophysical Research, 115, D23114.

Modelled and observed inundation



- **Satellite observations of inundation fraction from Prigent *et al.*, 2007 (passive & active microwave, near infra-red);**
- **ECMWF forcing gives better match with timing R^2 = 0.79, but peak inundation is 29 % lower than observed;**
- **TRMM forcing gives better peak inundation, but timing is worse.**

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Dadson et al., (2010). Journal of Geophysical Research, 115, D23114.

Future work

- **Boreal wetlands (ALANIS Methane)**
  - Development, application and evaluation of JULES in different configurations , including as LSM in HADGEM3 climate model
  - Generation and dissemination of products
  - Ongoing interaction with iLEAPS community
- **African wetlands**
  - Extend and test inundation model on other African wetlands (Lake Chad, Sudd, Okavango)
- **Benchmarking of wetlands in land surface models (GEWEX-GLISS)**

Summary

- Wetlands are the largest natural source of methane but the emission estimates have large uncertainties
- Boreal wetlands
  - ALANIS methane project developing novel EO products relevant for land surface modelling
  - The standard version of JULES does not represent the area of inundation of boreal wetlands well
- African wetlands
  - Overbank inundation scheme developed for Niger Inland Delta
  - Will be extended and tested on other wetlands in Africa (and globally)

Related presentations and posters

- **Integrating Earth observation data and a land-surface model to better understand high northern latitude phenology** by R Ellis [Oral: Next presentation]
- **Novel Earth Observation Products to Characterise Wetland Extent and Methane Dynamics: the ESA ALANIS-methane Project** by G Hayman, E Blyth, D Clark, A Bartsch, S Schlaffer, C Prigent, F Aires, M Buchwitz, J Burrows, O Schneising, F O'Connor and N Gedney [Oral Presentation - Wednesday]
- **Land-atmosphere feedbacks in a semi-arid environment: what we've learnt from AMMA** by C Taylor [Oral Presentation – Thursday]
- **Variability and long-term trends of carbon dioxide and methane column-averaged mole fractions retrieved from SCIAMACHY onboard ENVISAT** by O Schneising, M Buchwitz, M Reuter, J Heymann, H Bovensmann and J Burrows [Poster presentation]
- **Active microwave satellite data in support of methane modeling at high latitudes**. A Bartsch, S Schlaffer, C Paulik, D Sabel, V Naeimi, G Hayman, W Wagner [Poster presentation]