Linking Terrestrial and Aquatic Ecosystem Models: Recent Development and Future Challenges

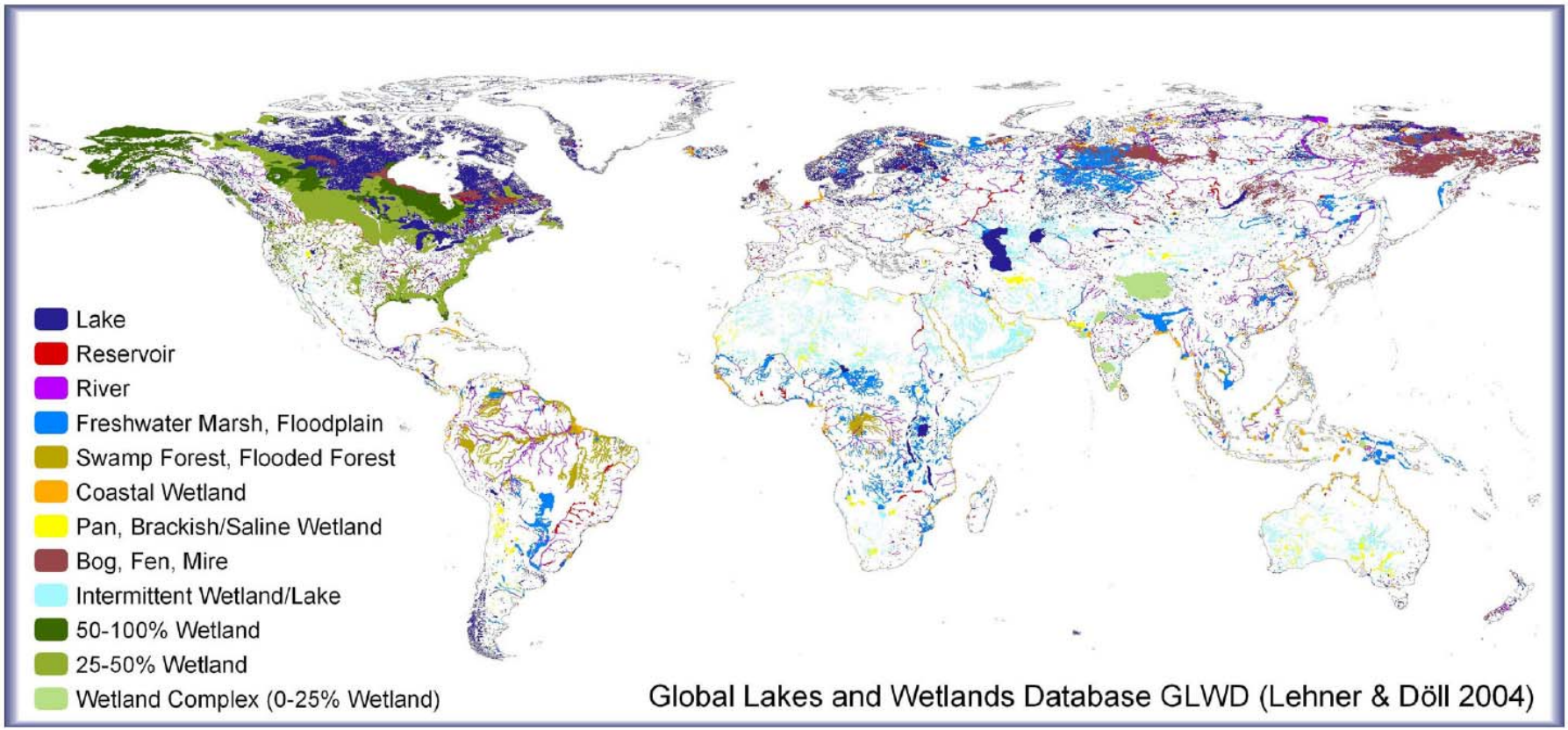
Changhui Peng
University of Quebec at Montreal, Canada

UQÀM

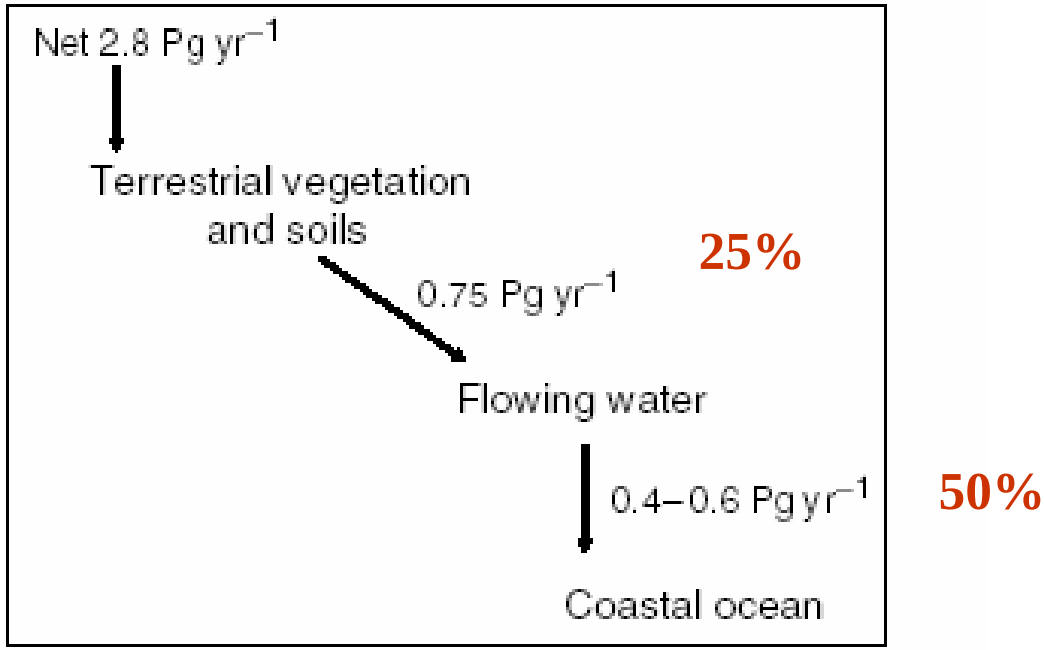
Lab website: www.crc.uqam.ca

Background:

Lake: **304 million lakes, 4.2 million km^2 in area, >3% the earth's land surface.**

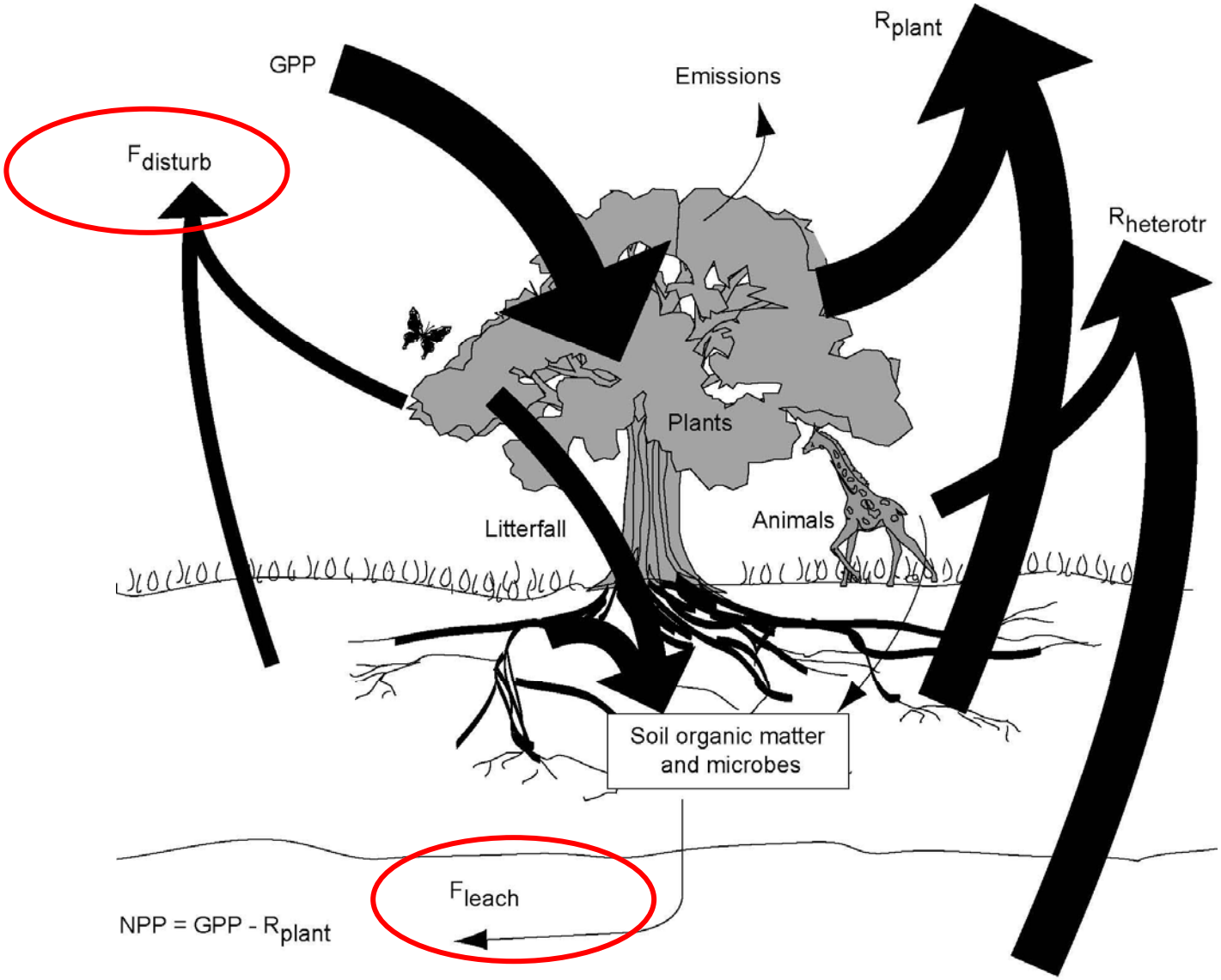


Estimated global fluxes of organic carbon from terrestrial to aquatic systems:



(Summarized from Lal, 2003; Schimel et al., 2001)

Uncertainty in Ecosystem Carbon Budget



$NPP = GPP - R_{plant}$

$NEP \approx GPP - (R_{plant} + R_{heterotr} + F_{disturb} + F_{leach})$

Leaching

leaching of dissolved organic carbon (DOC) and dissolved inorganic carbon (DIC) to groundwater and stream is an important avenue of carbon loss from some terrestrial ecosystems.

Abut 20% of CO_2 produced in artic soils, for example, leaches to groundwater and is released from lakes and streams (Kling et al. 1991, *Science*).

Despite their importance. Leaching losses of carbon to groundwater are seldom measured and therefore frequently ignored in ecosystems carbon budgets

DOC is still missing in current ecosystem carbon budget

DOC is poorly represented in most terrestrial carbon models

Within forested ecosystem, DOC leaching from the forest floor and organic soil horizons ranges from **10 to 85 g m^{-2} yr^{-1}** (Neff and Asner, 2000)

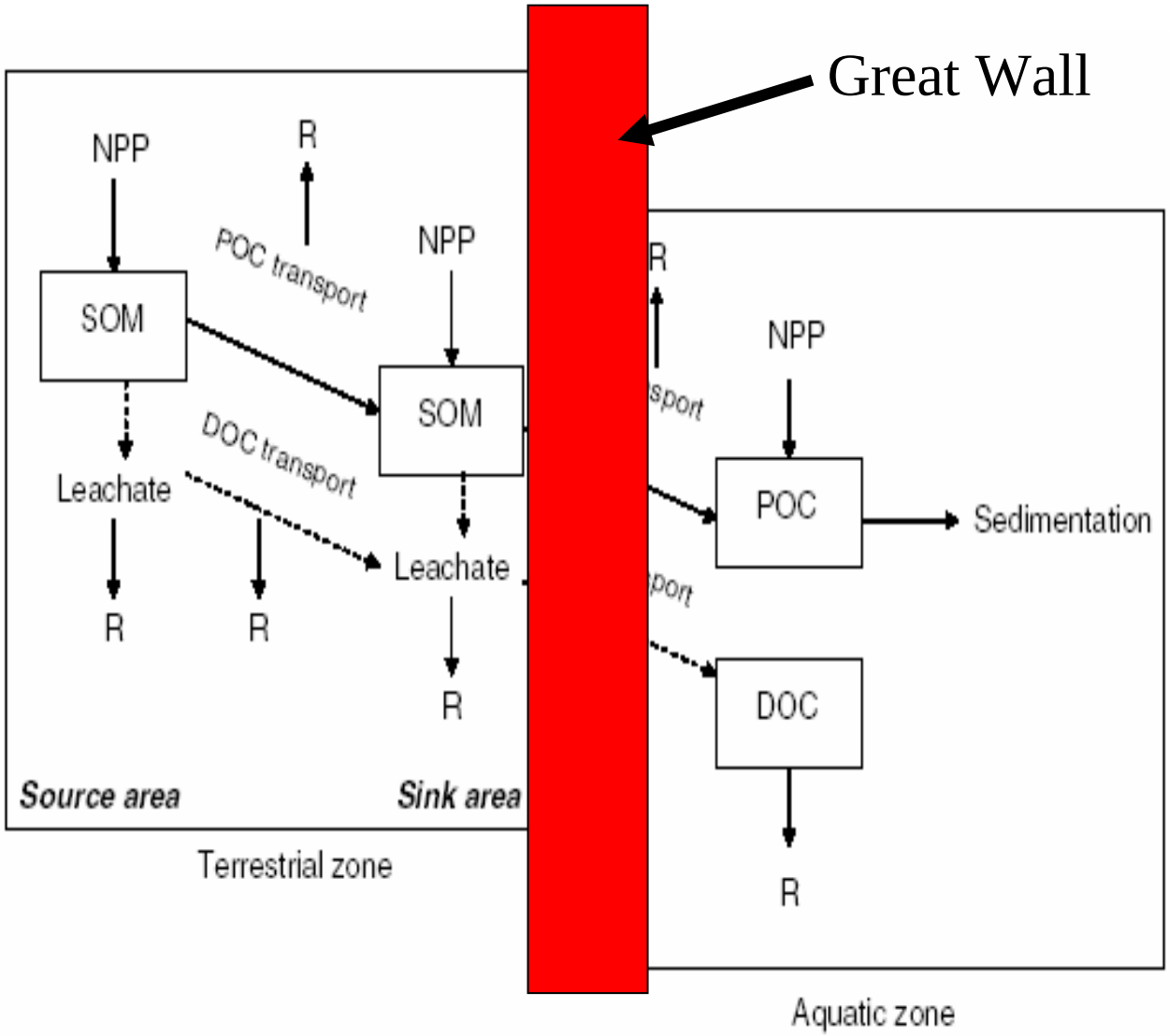


Fig. 3 Hydrologic-induced differential transport and processing of material throughout the landscape. NPP, net primary production; R, respiration; SOM, soil organic matter; POC, particulate organic carbon; DOC, dissolved organic carbon.

(Jenerette and Lal, 2005)

© 2005 Blackwell Publishing Ltd, *Global Change Biology*, **11**, 1873–1882

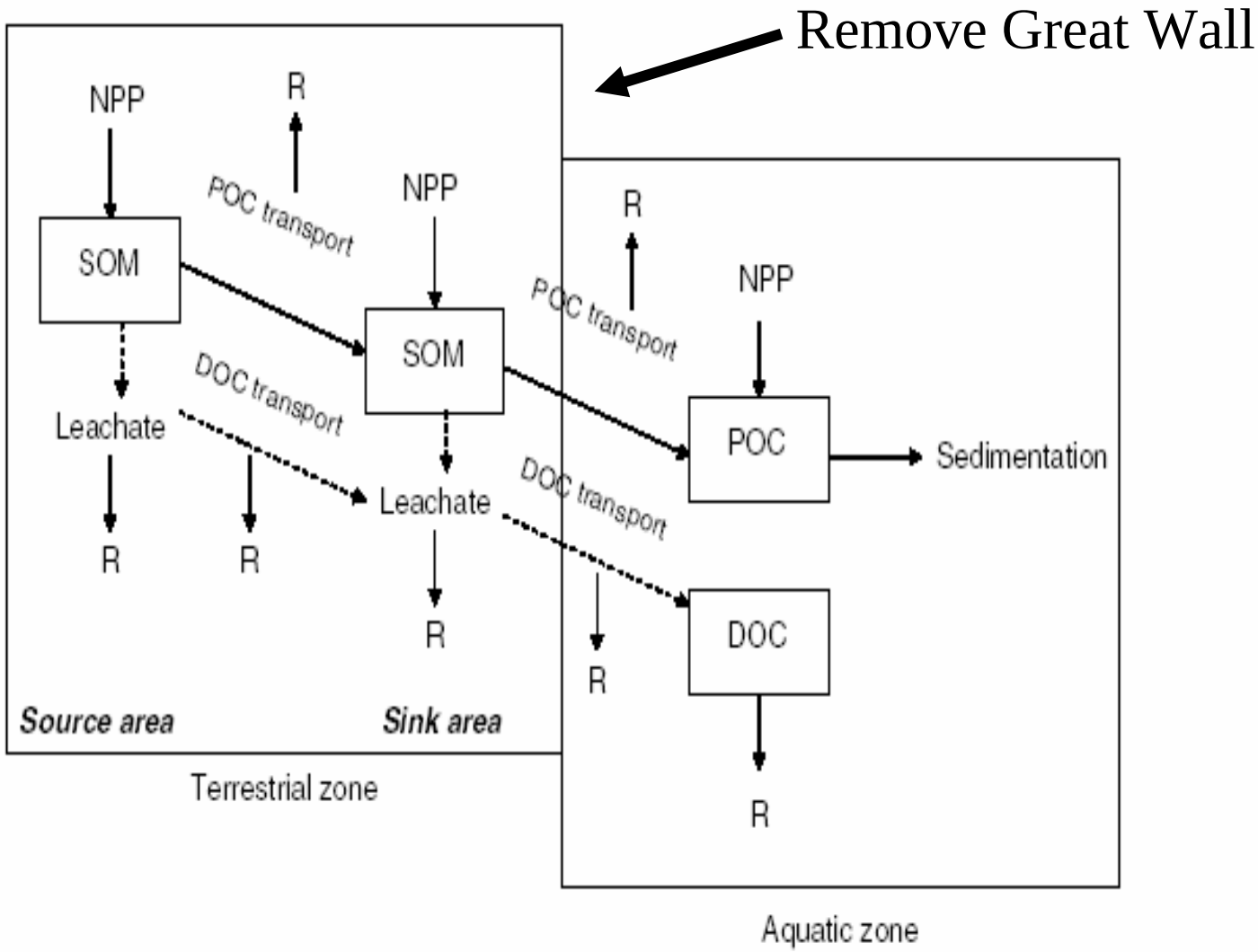


Fig. 3 Hydrologic-induced differential transport and processing of material throughout the landscape. NPP, net primary production; R, respiration; SOM, soil organic matter; POC, particulate organic carbon; DOC, dissolved organic carbon.

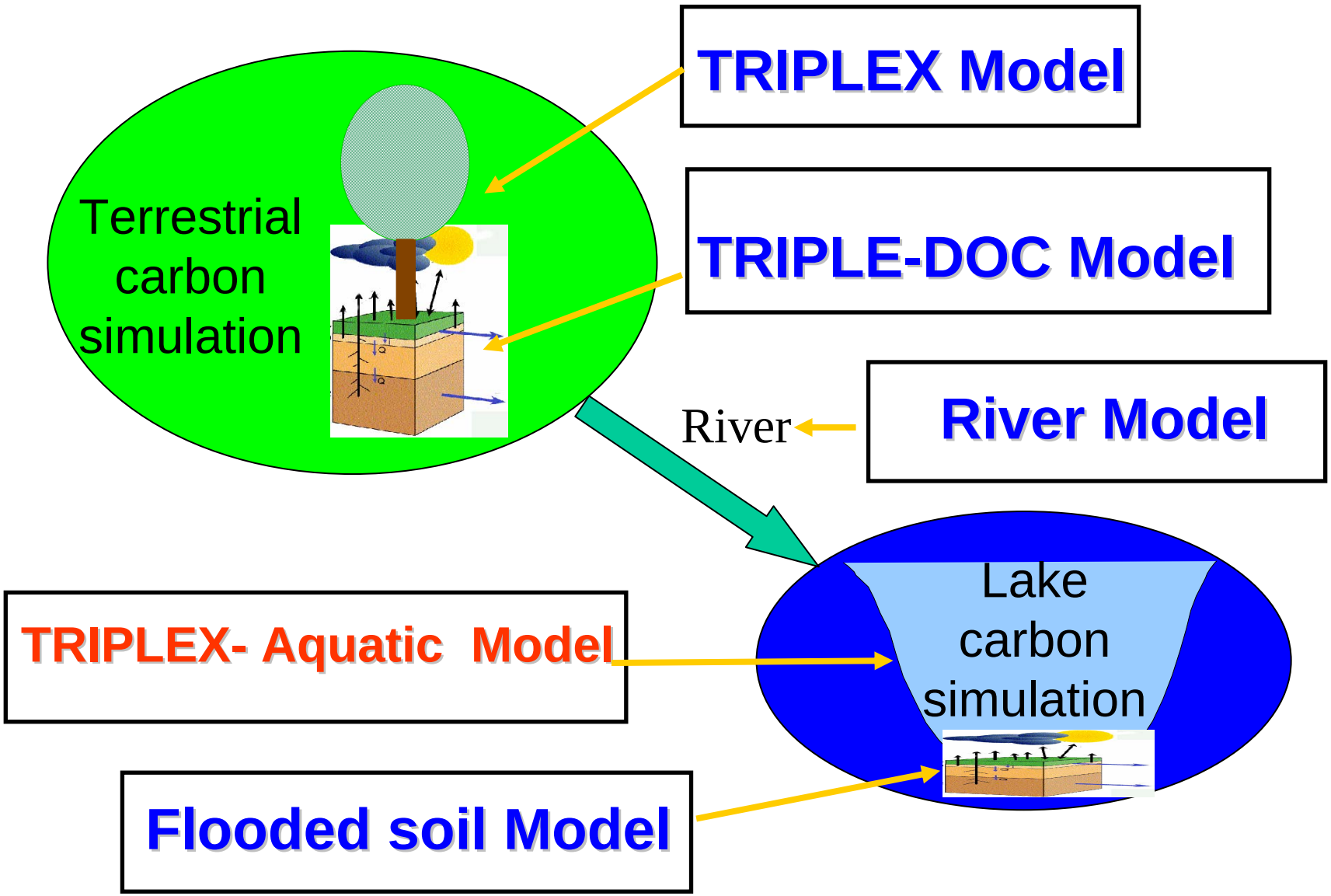
(Jenerette and Lal, 2005)

© 2005 Blackwell Publishing Ltd, *Global Change Biology*, **11**, 1873–1882

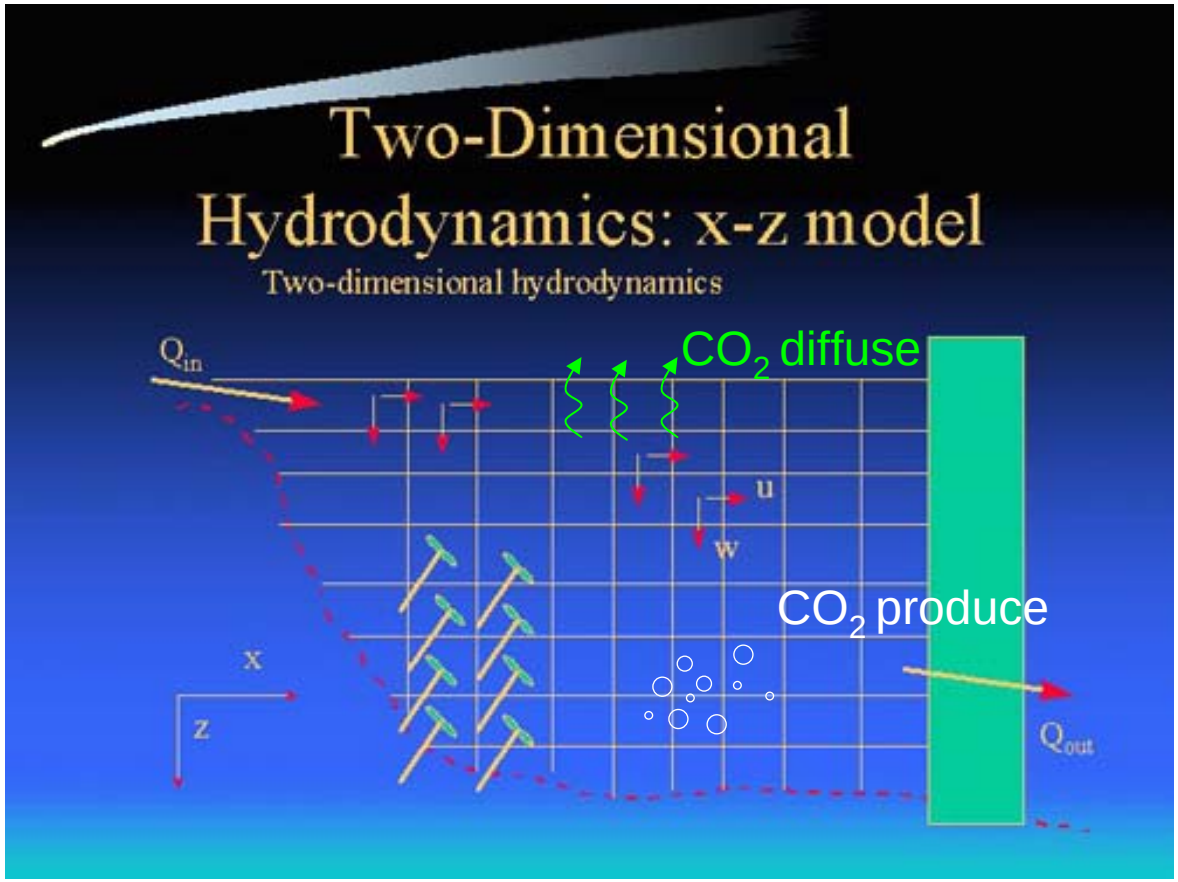
Model Framework

Empirical model + Process-based model

Coupled model



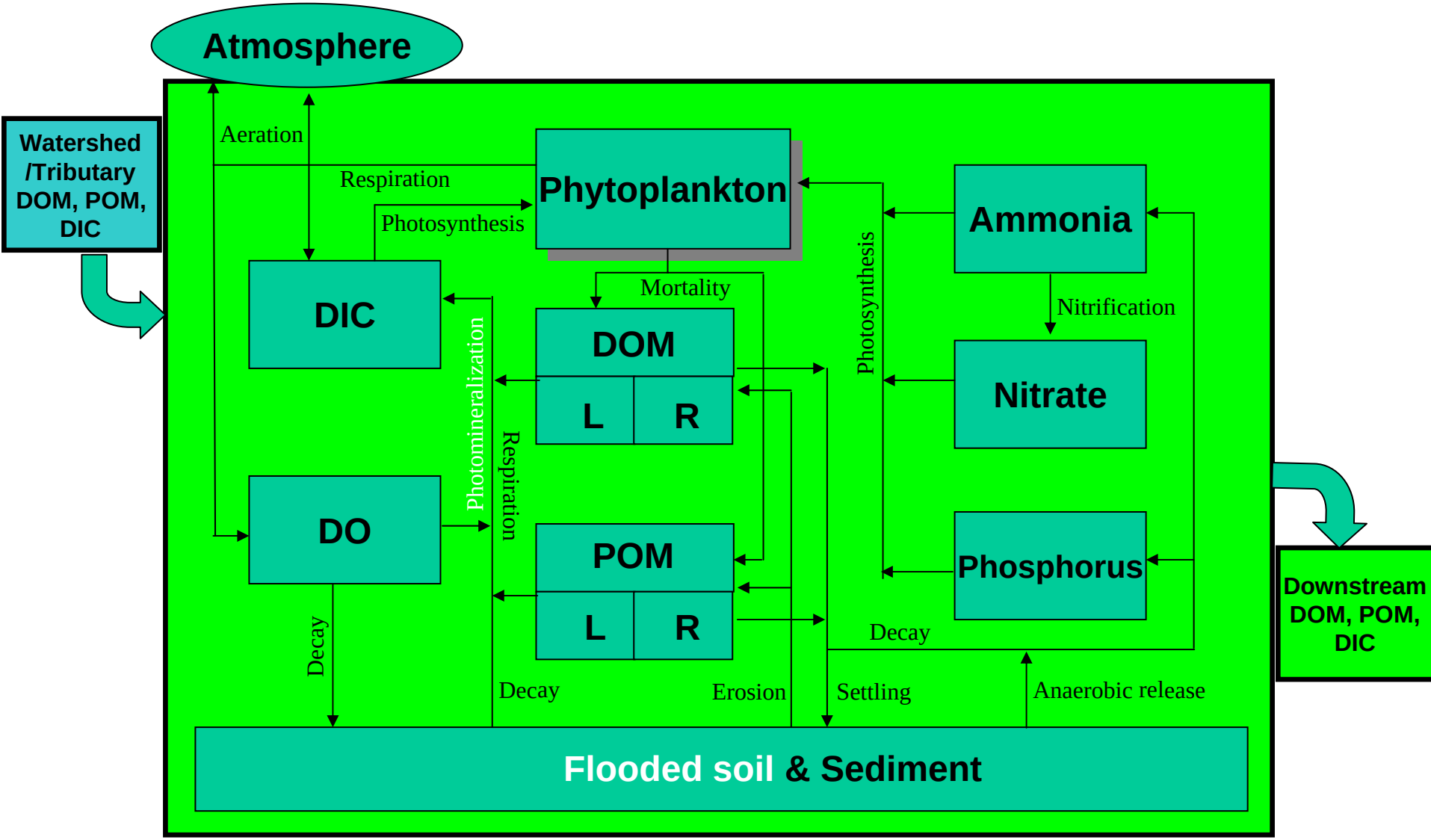
TRIPLEX-Aquatic model: ***develop from lake/reservoir hydrodynamics and water quality model (CE-QUAL-W2) (Cole and well, 2006) and CO_2 diffusive fluxes model at the air/water interface of lake (Cole and Caraco, 1998)***



Processes Considered

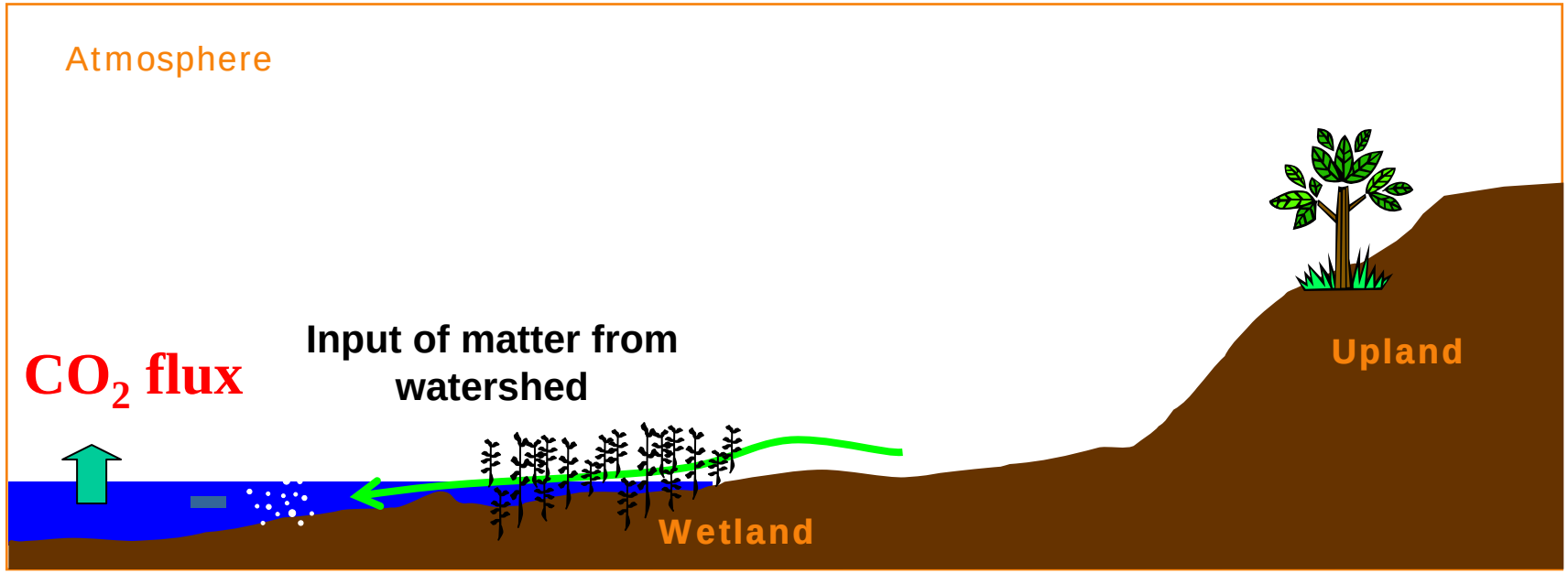
1. Phytoplankton Kinetics
2. Phosphorus Cycling
3. Nitrogen Cycling
4. Dissolved Oxygen Balance
5. Sediment Diagenesis

TRIPLEX-Aquatic Model Diagram

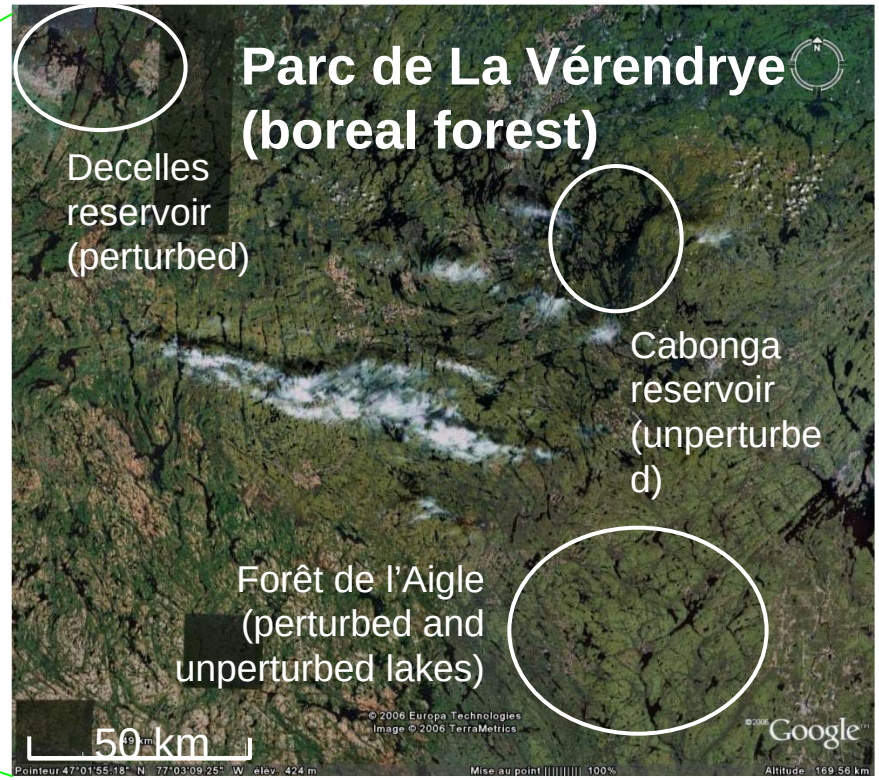


DOM: dissolved organic matter, POM: particulate organic matter, L: labile, R: refractory, DO: dissolved oxygen, DIC: dissolved inorganic carbon

Validation: lake hydrodynamics and carbon cycle simulations

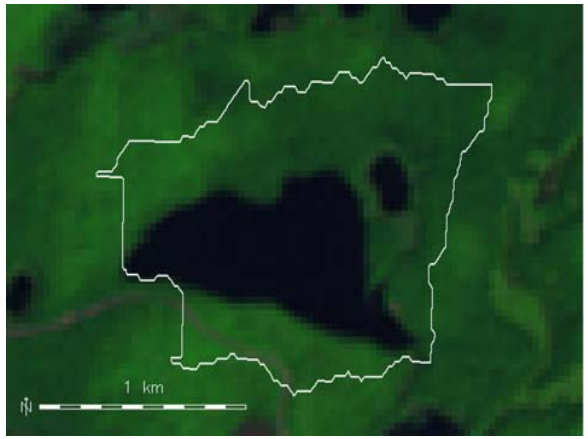


Study Zone and Selected Water Bodies



Two study zones were selected in Quebec, Canada: Abitibi-Temiscamingue (lakes/pristine and harvested watersheds), Mauricie (reservoir/harvested watershed) and Outaouais (reservoir/pristine watershed).

Undisturbed Lakes

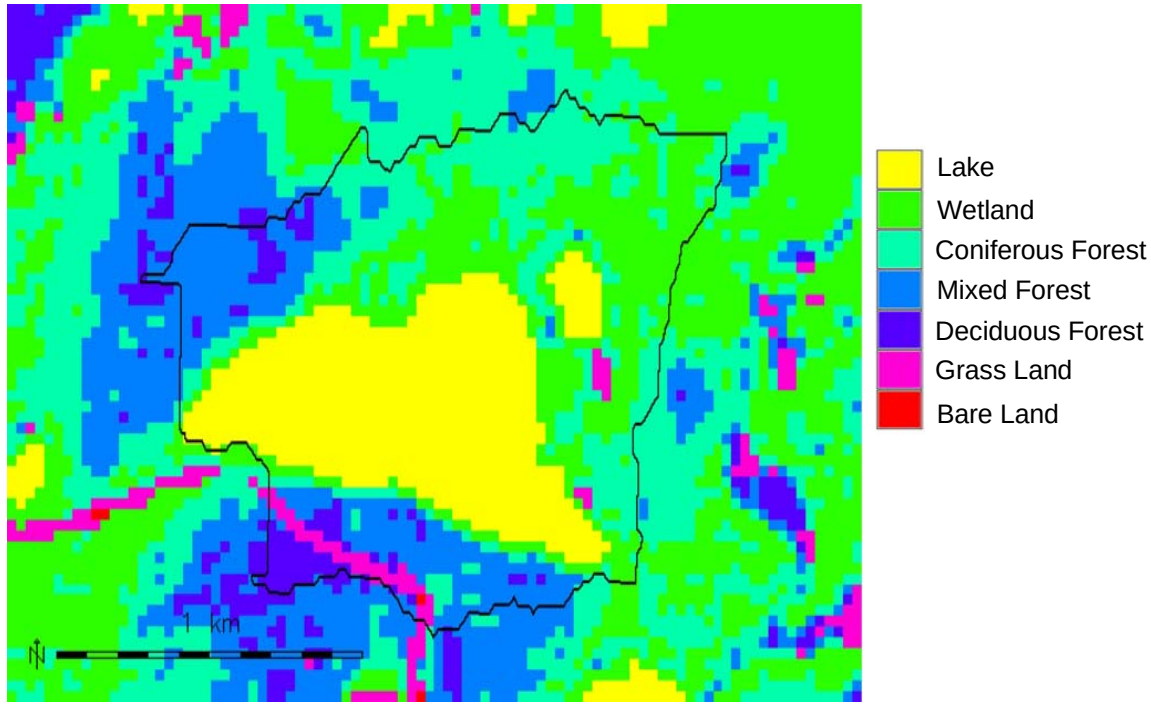


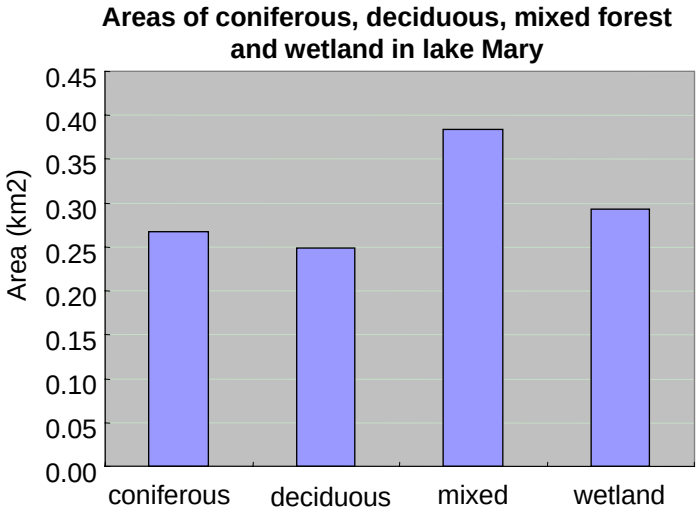
Lake Mary

Condition:

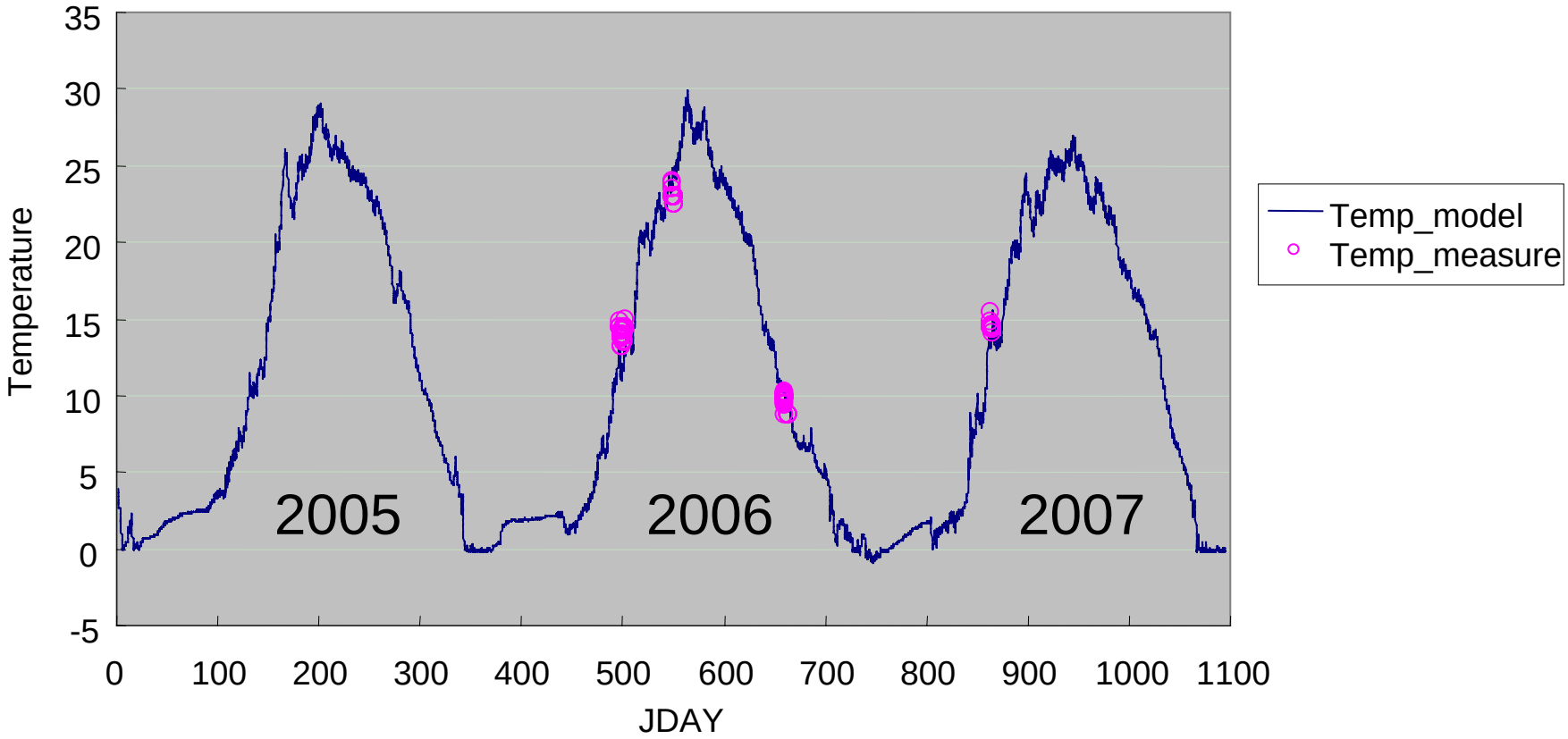
[No perturbed]

Lake: 0.58 km^2
Watershed:1.22 km^2

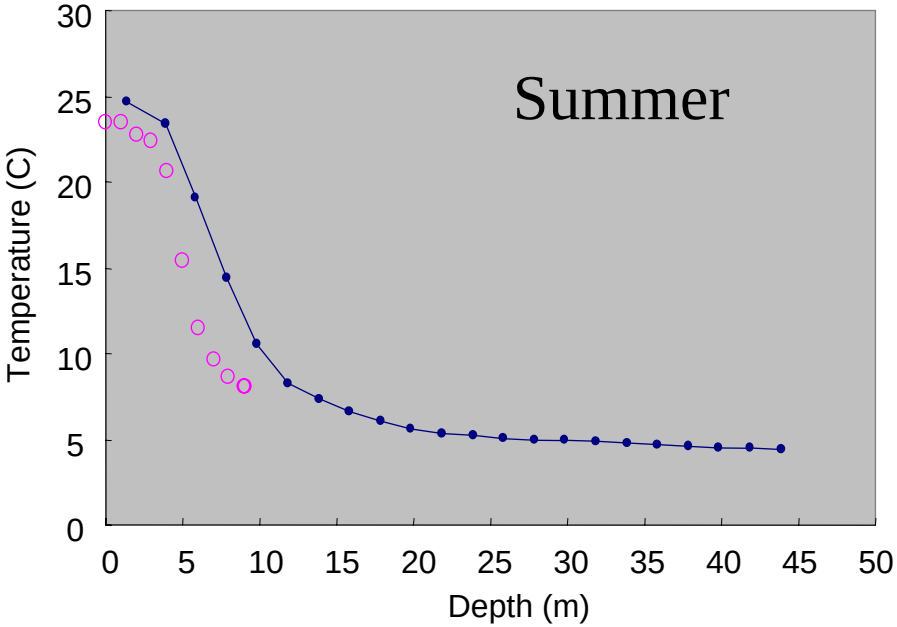


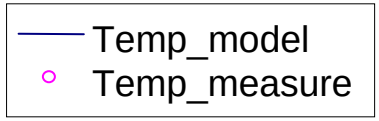


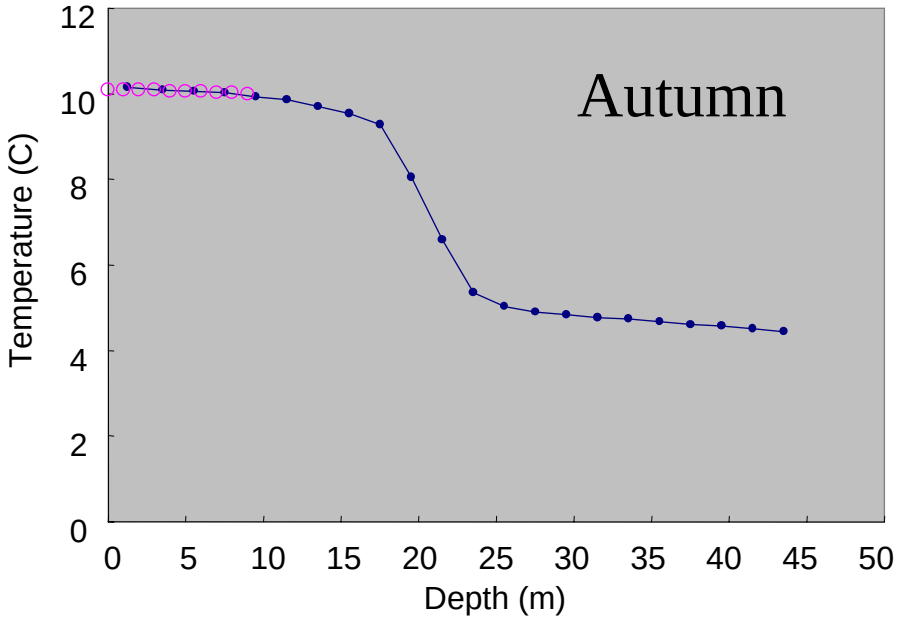
Comparison of surface water temperature between model and measurement in Lake Mary (2005-2007)



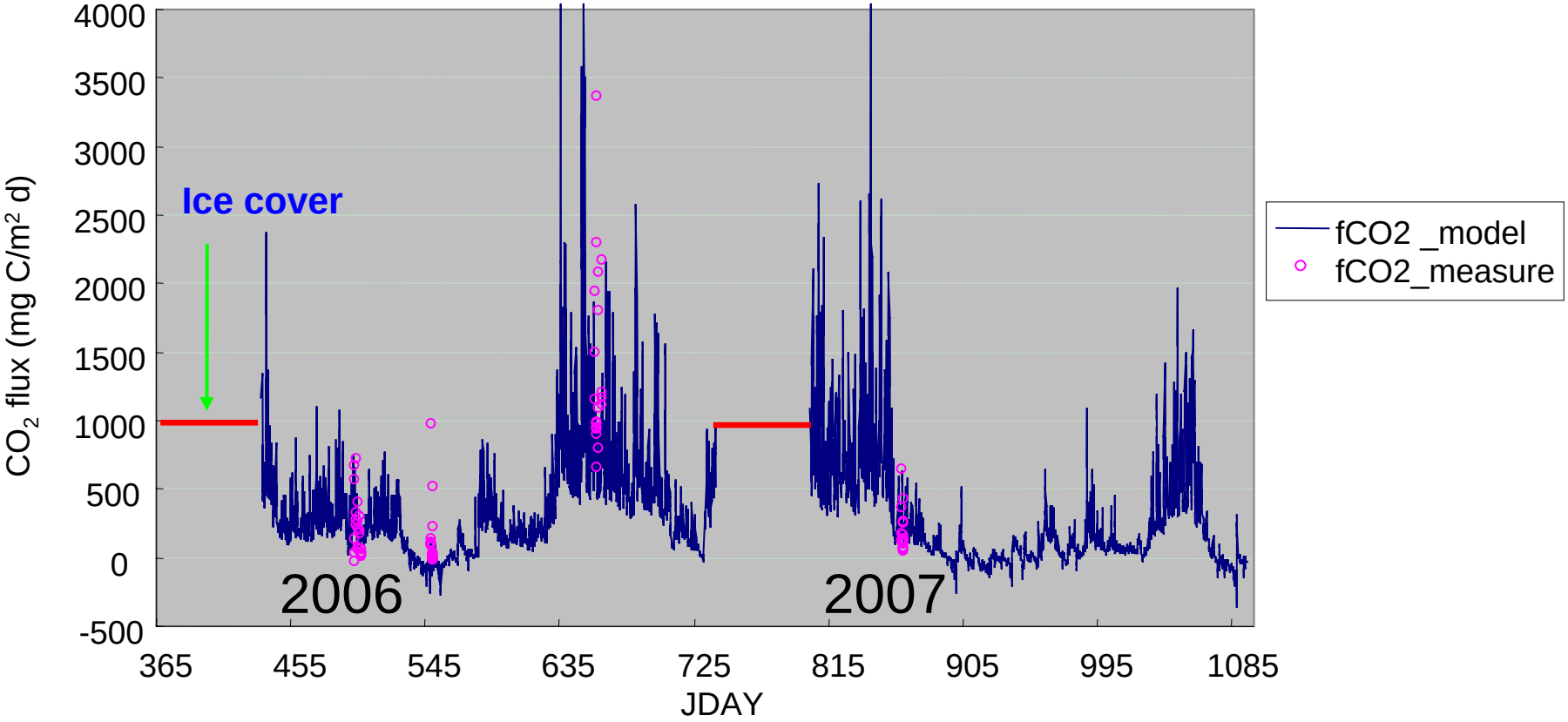
Comparison of water profile temperature between model and measurement in Lake Mary (2006)



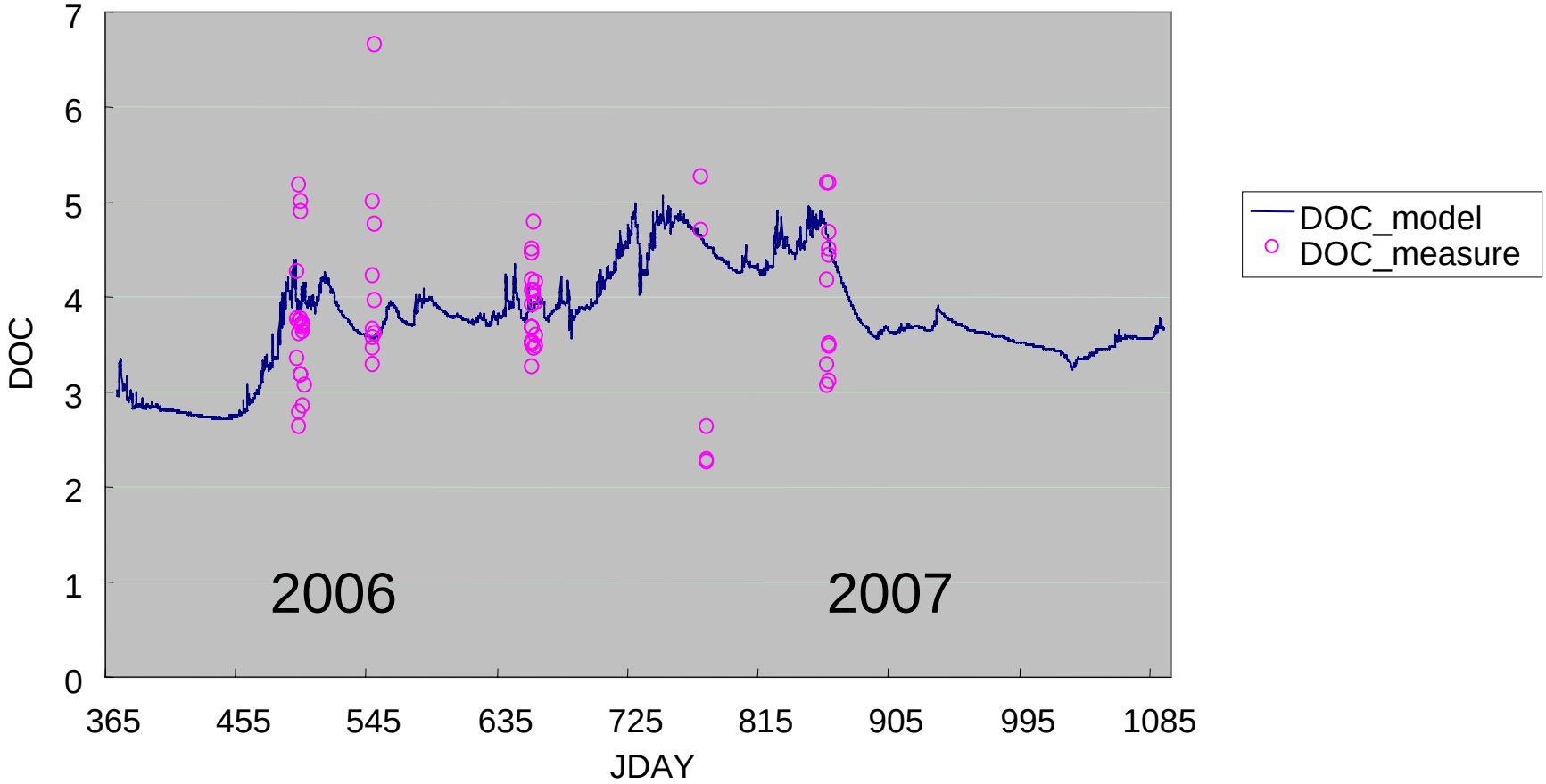


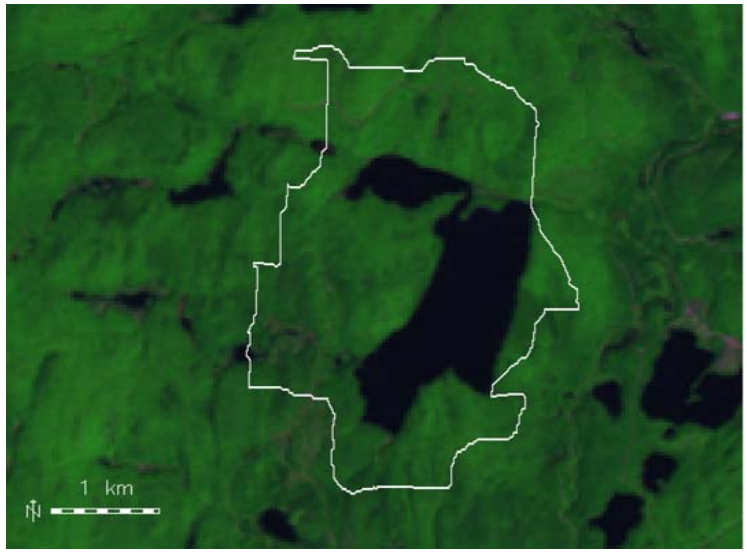


Comparison of CO_2 fluxes between model and measurement in Lake Mary (2006-2007)



Comparison of DOC between model and measurement in Lake Mary (2006-2007)

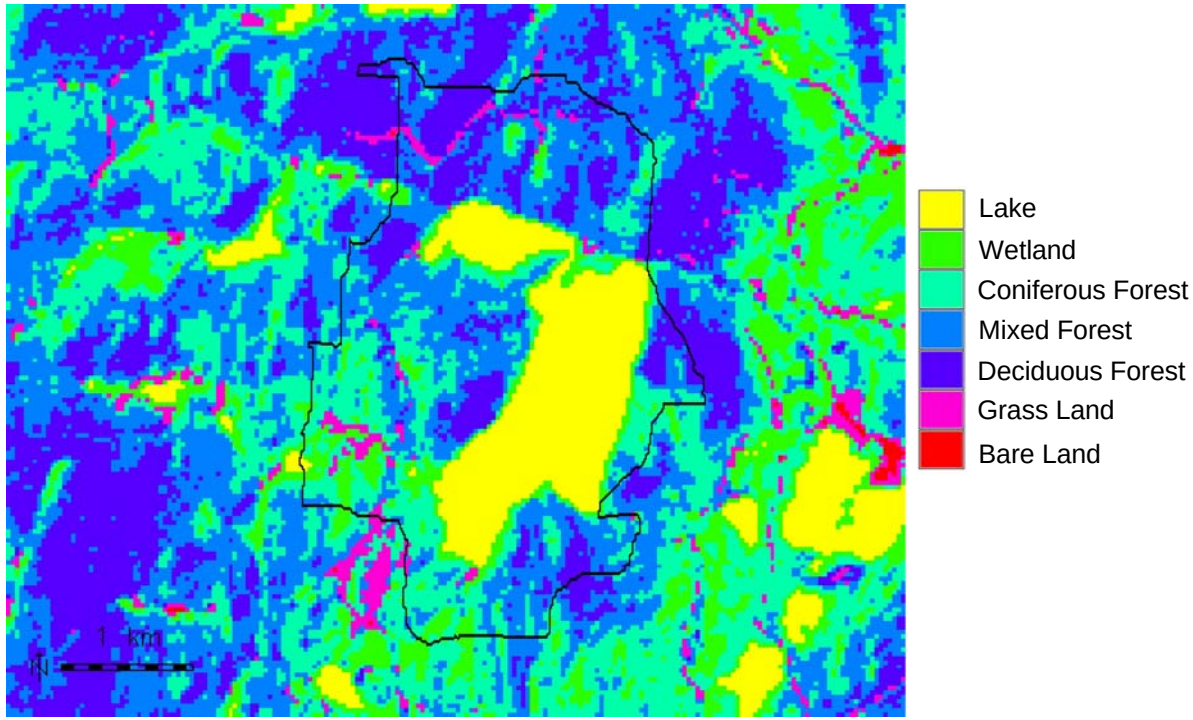




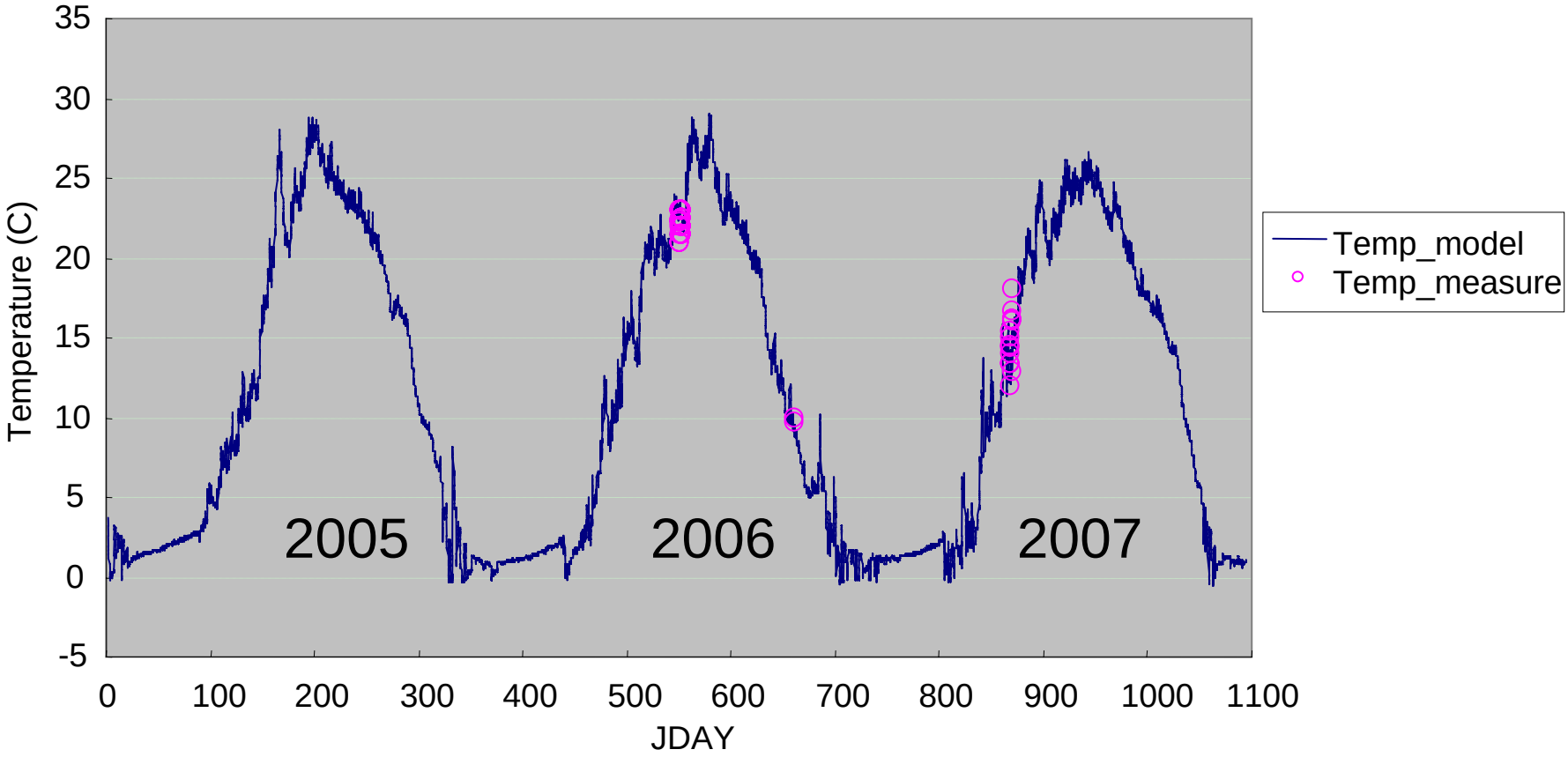
Lake Jean

Lake: 1.88 km^2
Watershed: 5.43 km^2

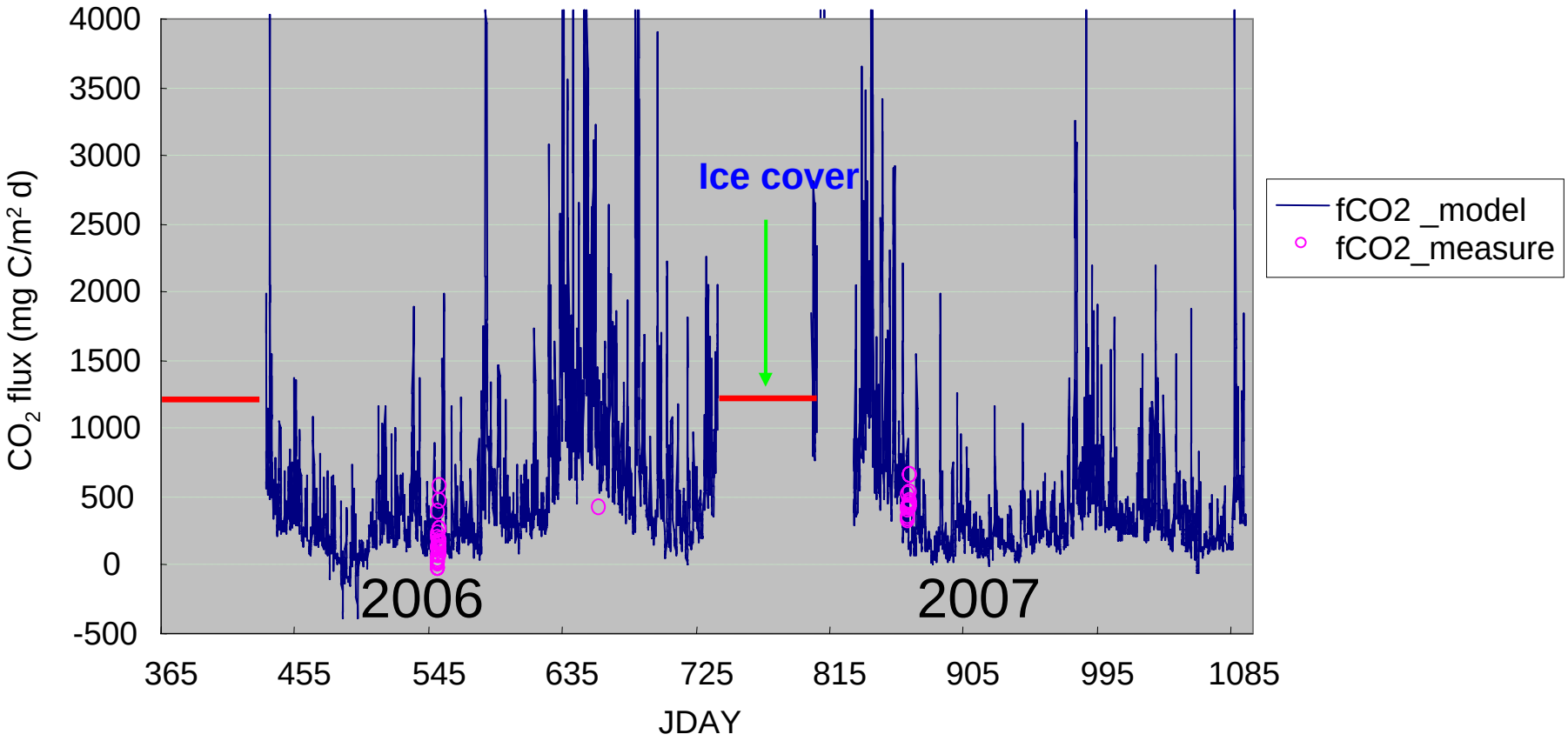
Condition:
[No perturbed]



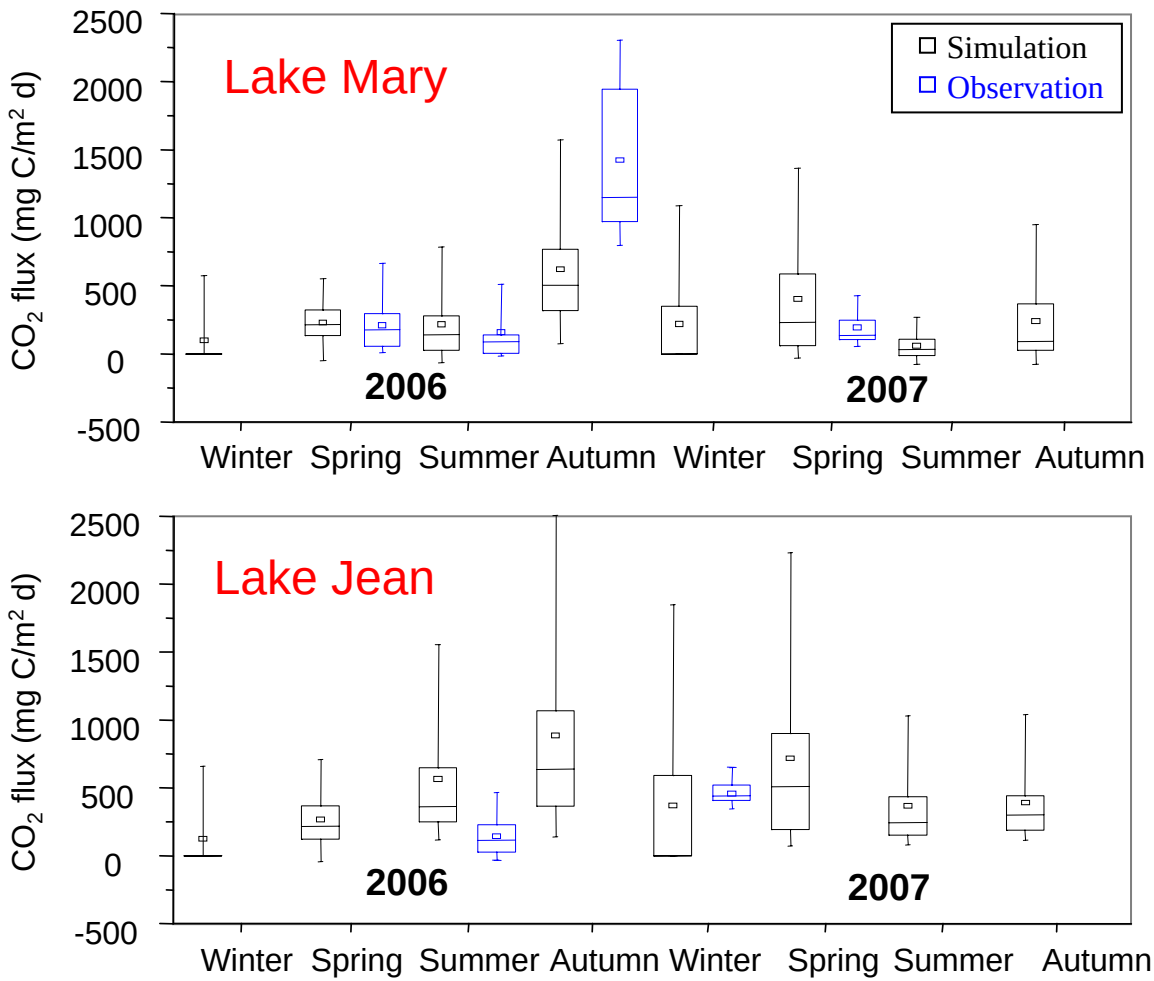
Comparison of surface water temperature between model and measurement in Lake Jean (2005-2007)



Comparison of CO_2 fluxes between model and measurement in Lake Jean (2006-2007)



Comparison of seasonal CO_2 fluxes between model and observation in Lake Mary and Lake Jean (2006-2007)



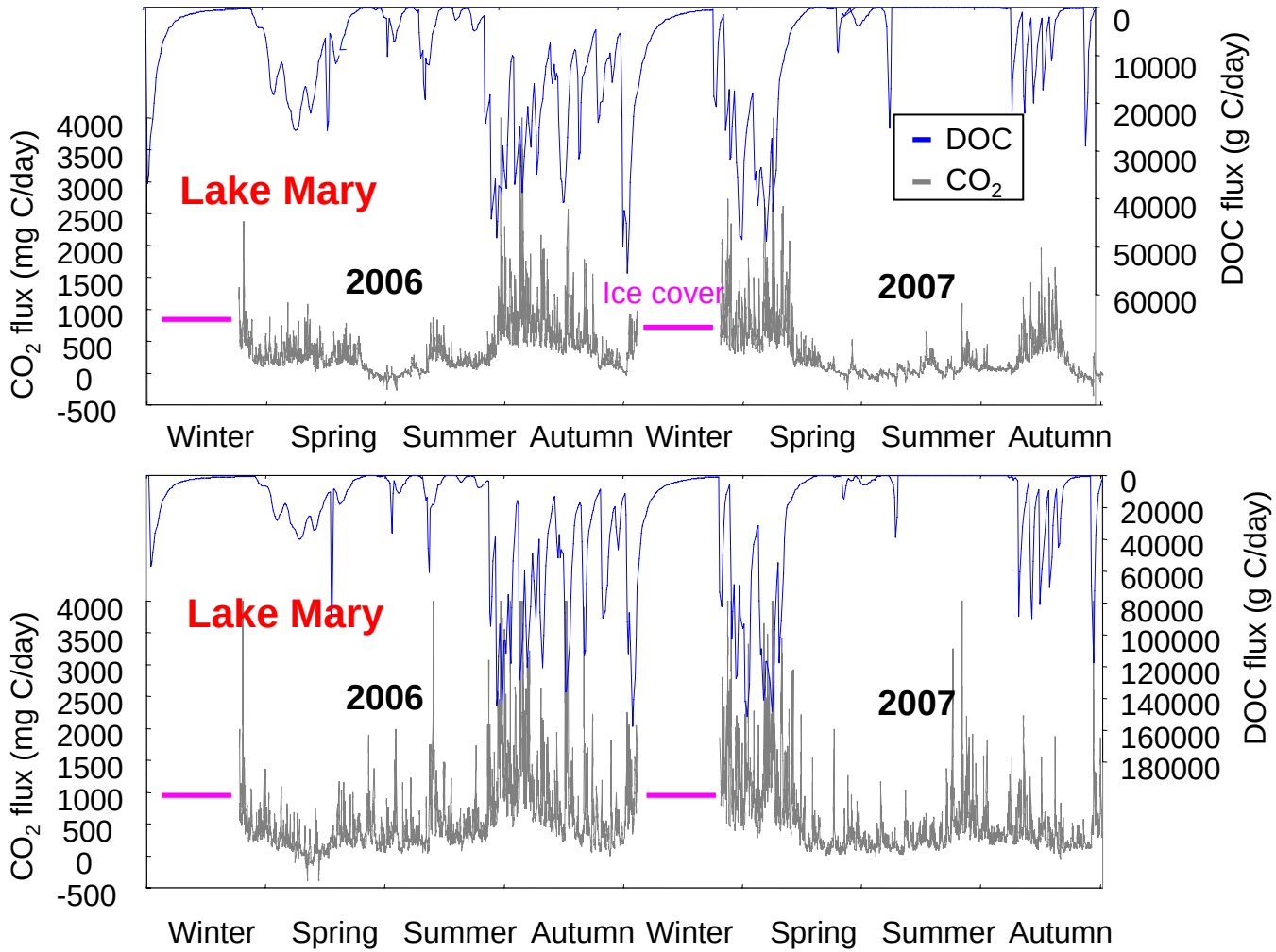
Validation results:

These reasonable agreements between simulated and observed hydrodynamics as well as aquatic carbon dynamics parameters demonstrated that TRIPLEX-Aquatic model has the ability and feasibility of modeling various hydrodynamic and aquatic carbon cycle processes in the lakes.

Impact of terrestrial DOC on lake CO_2 emission

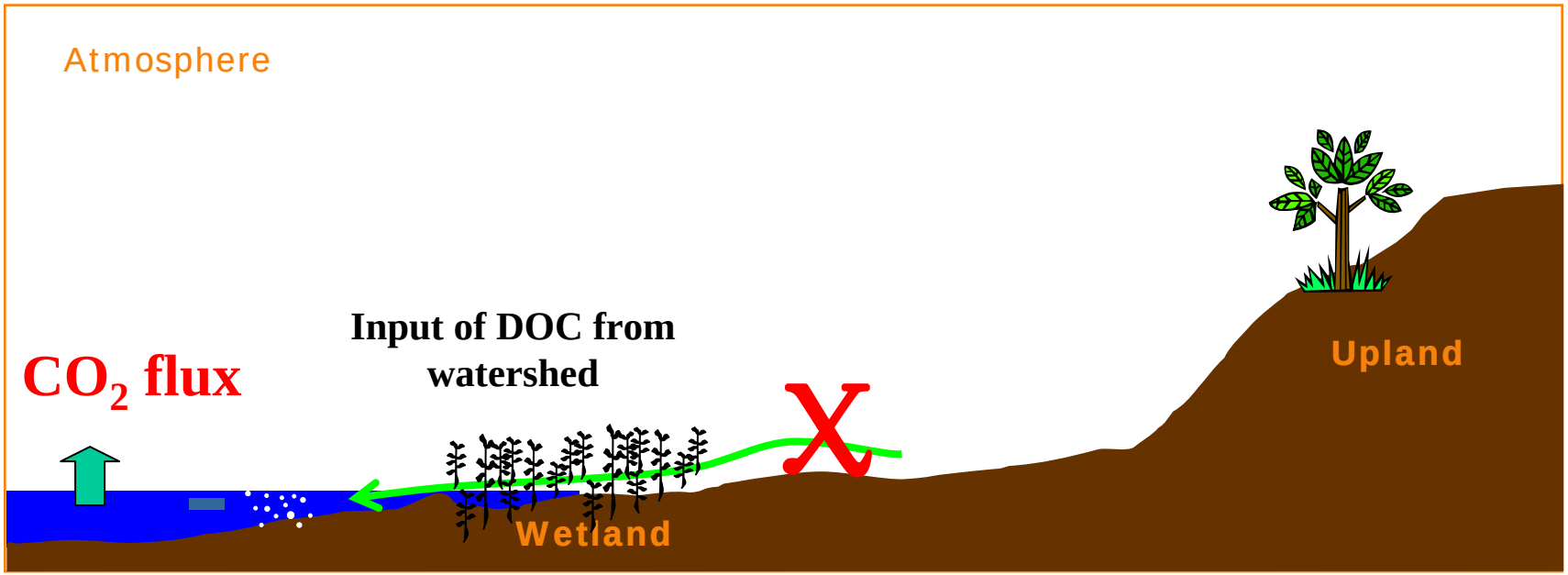
Variations of terriogenous DOC and water CO_2 fluxes from Lake Mary and Lake Jean.

A positive relationship between terrestrial DOC and CO_2 fluxes, indicating the DOC inputs may be the important factor on the seasonal CO_2 diffusive flux variations.

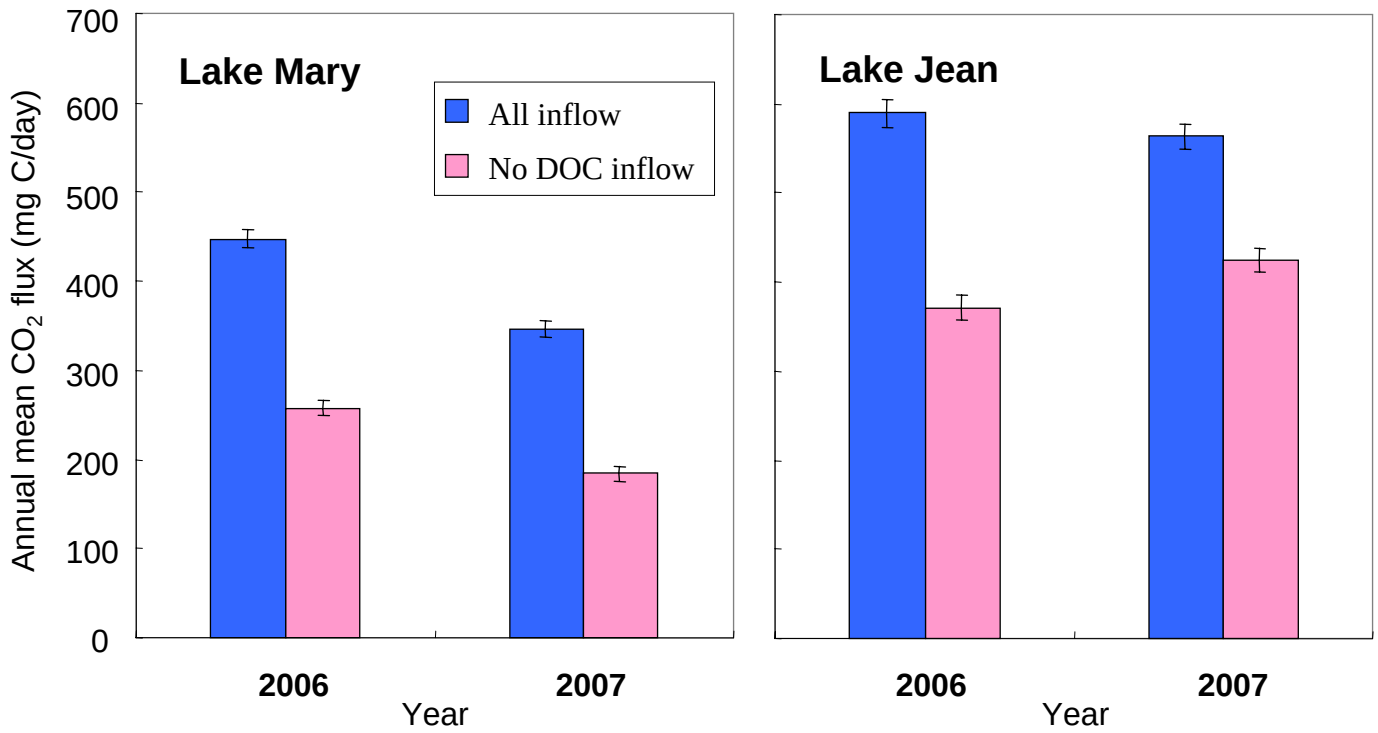


Sensitivity analysis: To further estimate the impact of terrestrial DOC on water CO_2 flux

No terrestrial DOC input on the annual mean CO_2 flux



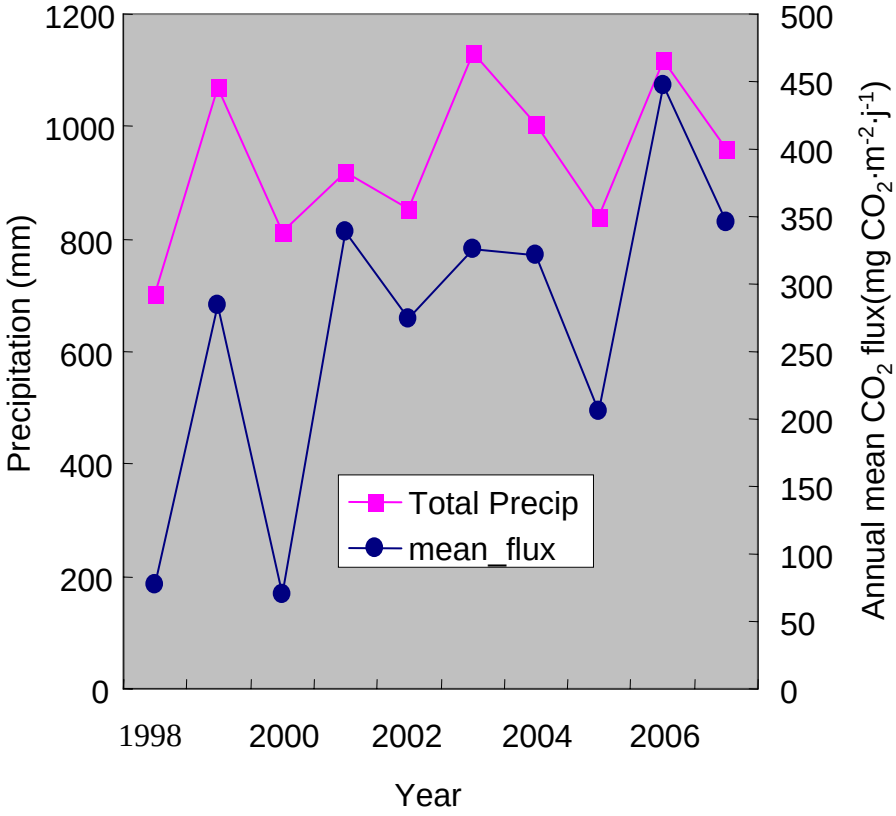
Effect of terriogenous DOC input on annual mean CO_2 fluxes from Lake Mary and Lake Jean during 2006 to 2007.

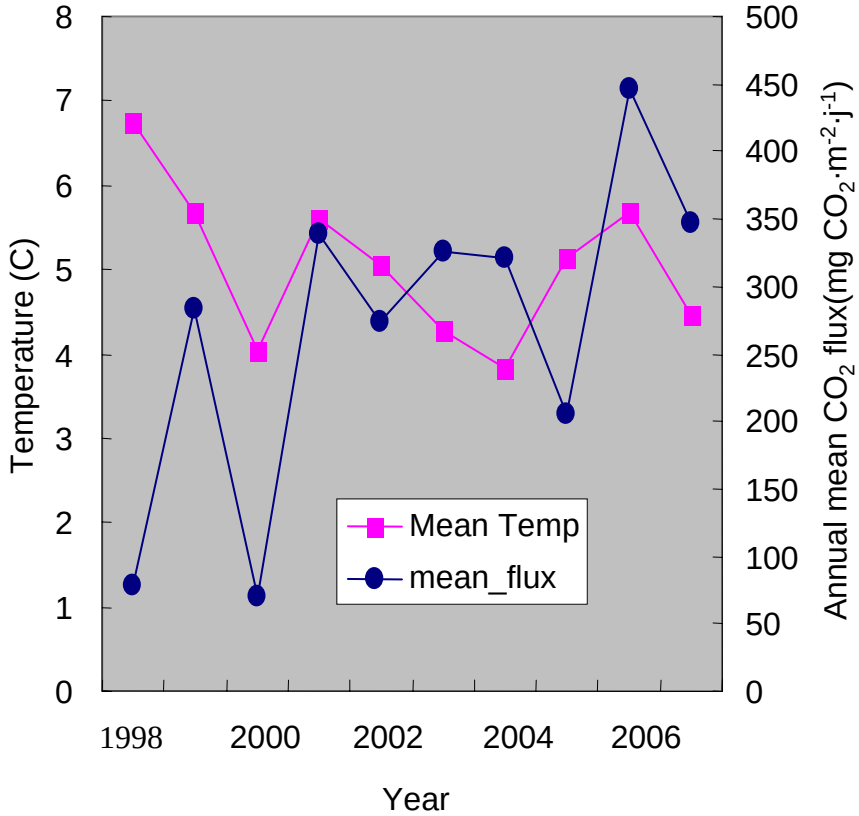


Results reveal that a significant CO_2 flux from the lake (~30-40%) should have been due to the allochthonous organic carbon from catchment.

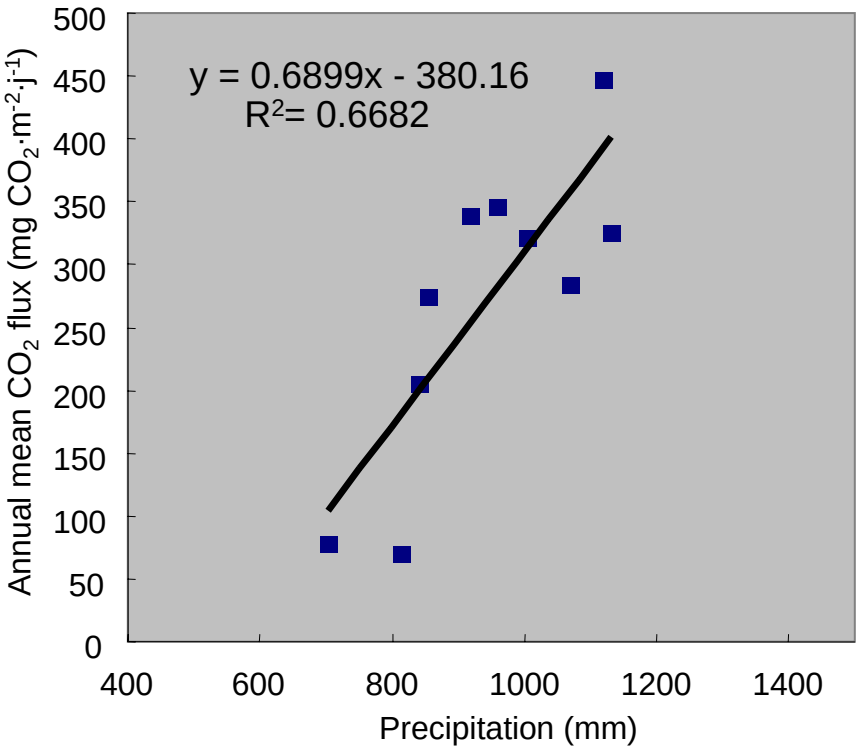
Climate change and lake CO_2 emission

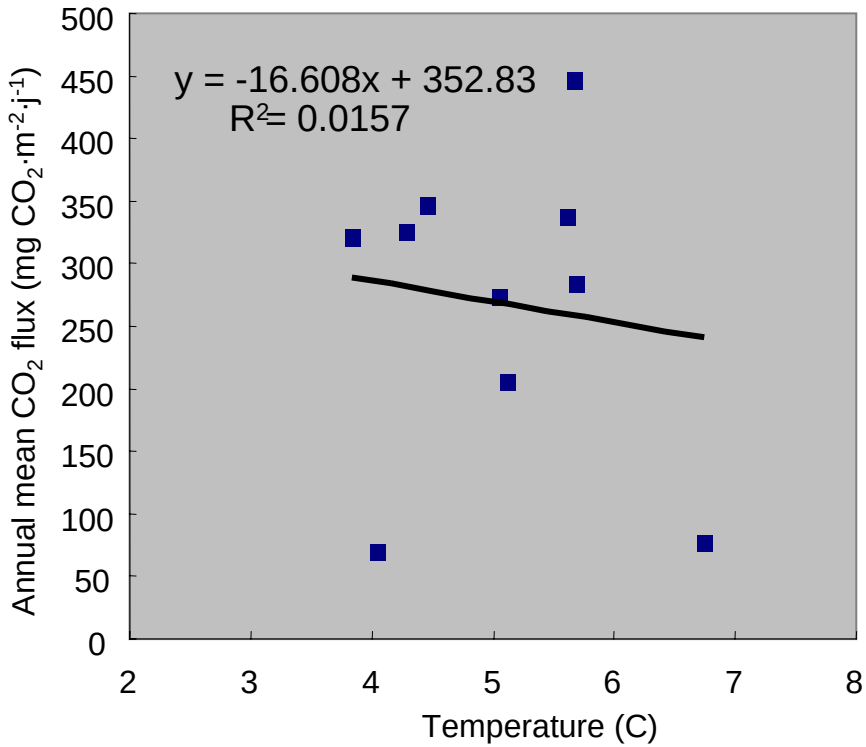
Variations of water CO_2 fluxes between precipitation and temperature in Lake Mary during 1998-2007





Correlation between annual mean CO_2 flux and precipitation, temperature in Lake Mary during 1998-2007

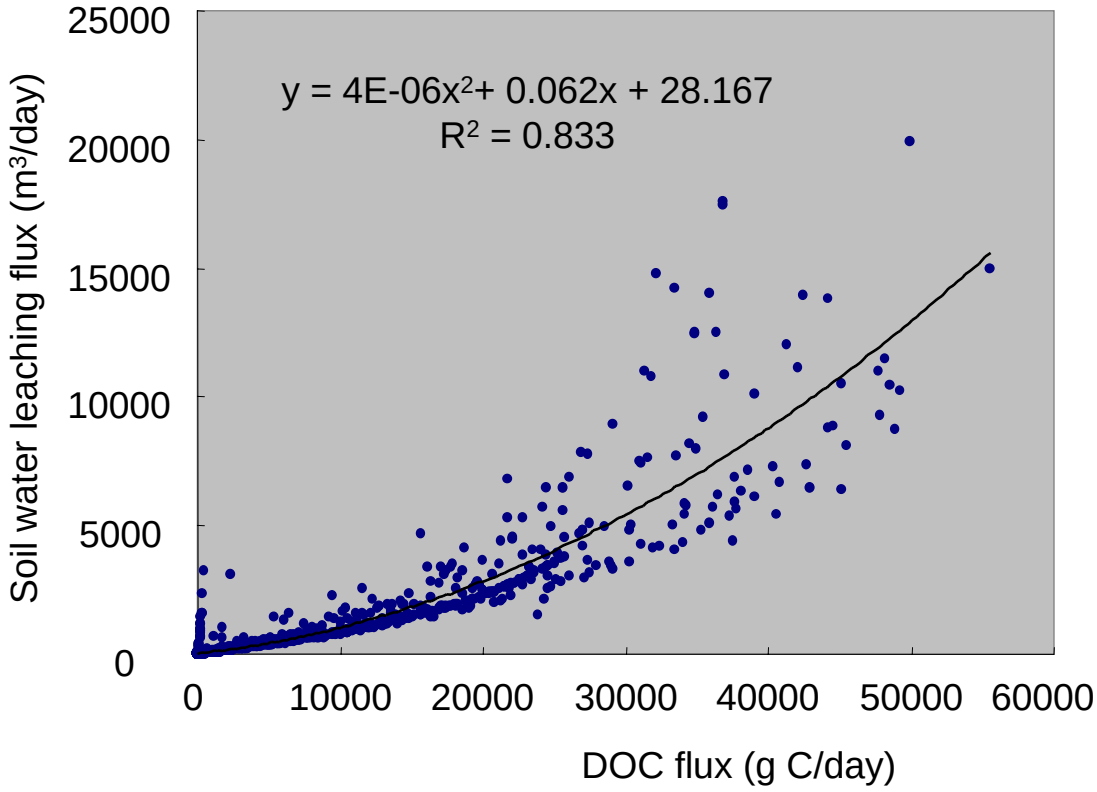




For climate changes, the production of annual mean CO_2 fluxes is more sensitive to precipitation than temperature.

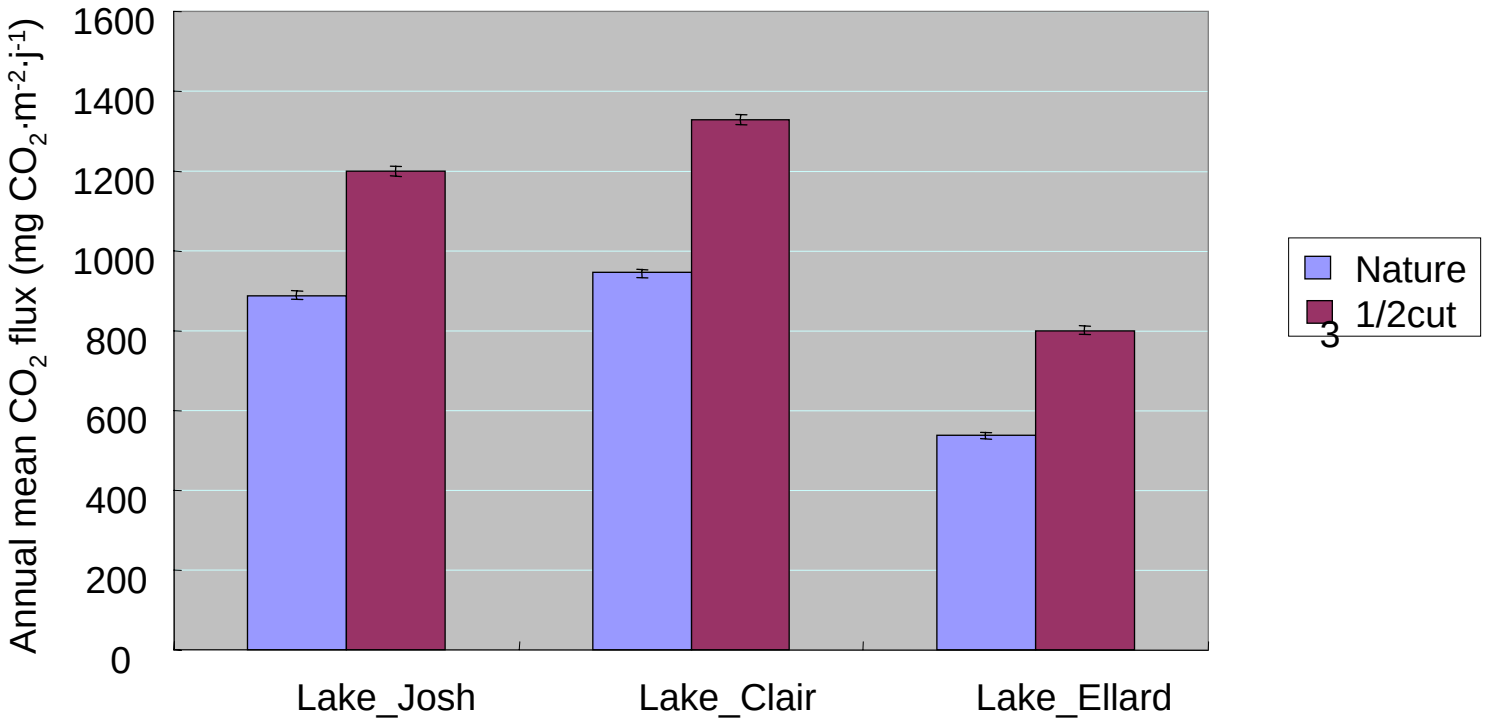
Why?

Because a good relationship between daily DOC flux and soil water leaching (2006), and soil water leaching is related to precipitation



Impact of anthropogenic activities on lake CO_2 emission

Increase of water CO_2 fluxes (~30%) by perturbation from nature to 1/2cut condition



Results indicate that forest harvesting is an important factor controlling the lake carbon dynamics.

Summary

Issues:

Leaching –DOC, harvesting, Creation of Reservoir, Flooded Soil

Challenges:

- from empirical to process-based models

-Coupling terrestrial with aquatic models

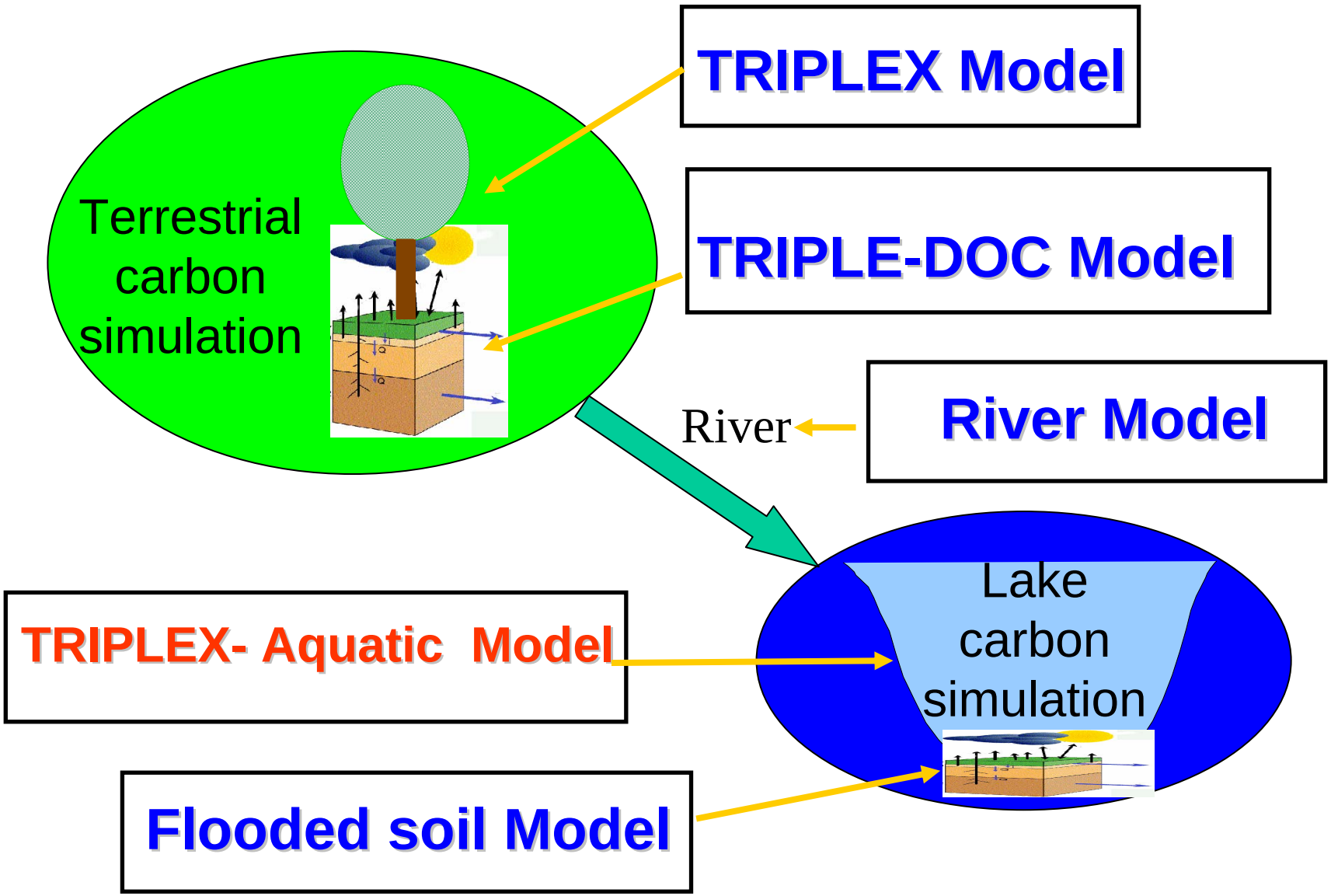
- spatial and temporal heterogeneity and connectivity

-scaling up

Model Framework

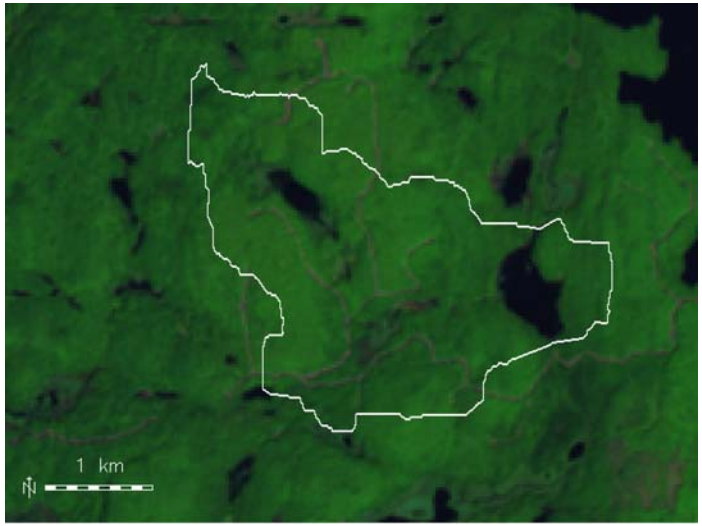
Empirical model + Process-based model

Coupled model



Thanks a lot!

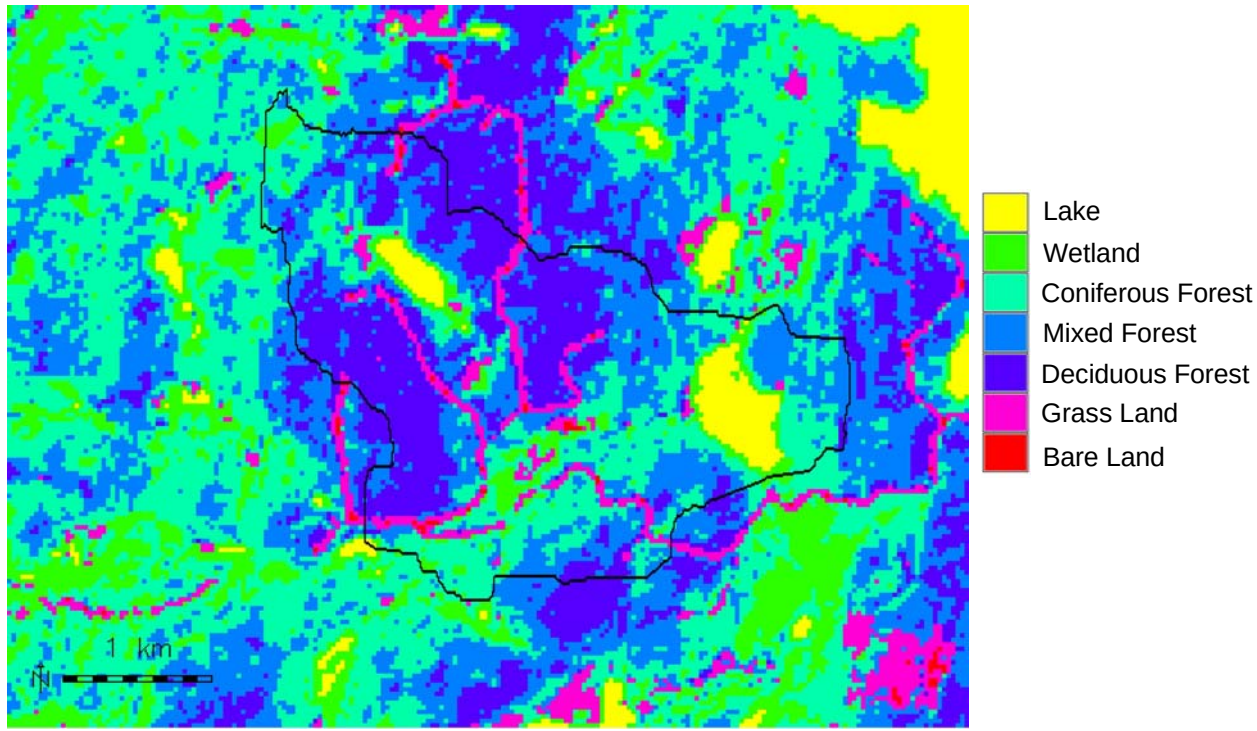
Perturbed Lakes



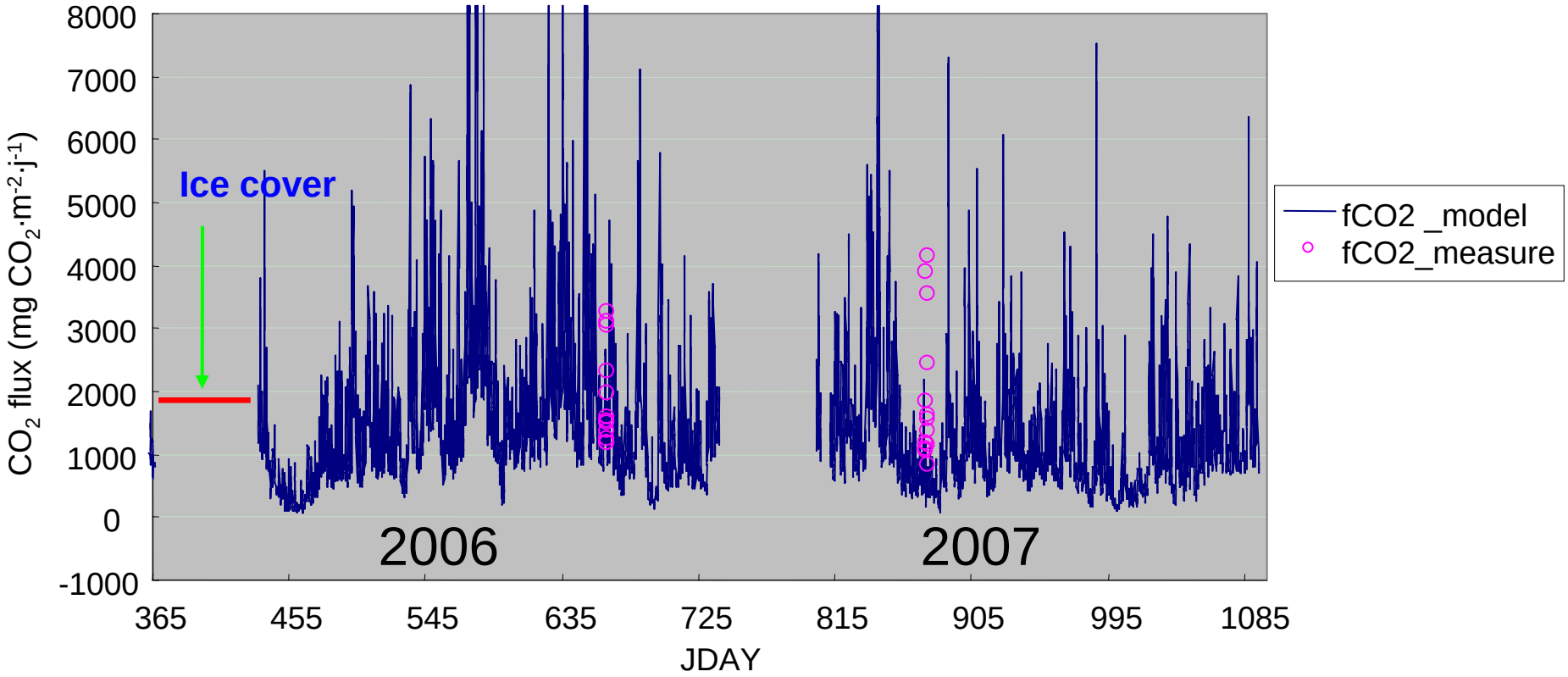
Lake Josh/Boulard

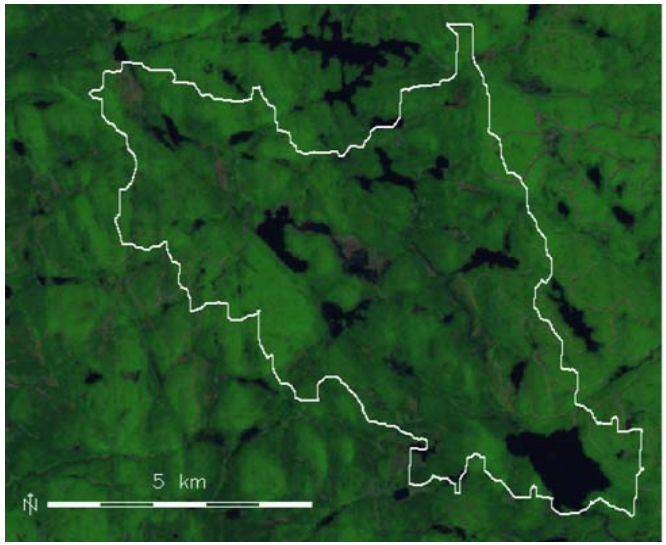
Lake: 0.34 km^2
Watershed: 6.67 km^2

Condition:
Perturbed



Comparison of CO_2 fluxes between model and measurement in Lake Losh&Boul (2006-2007)

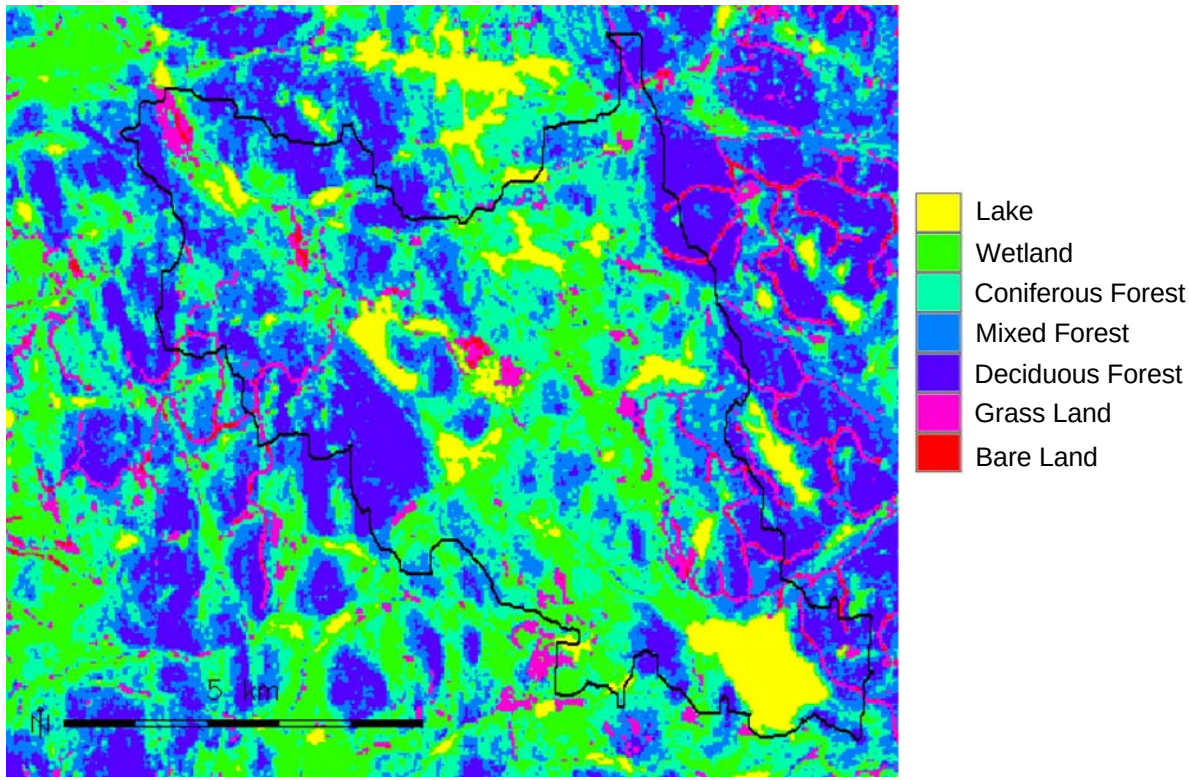




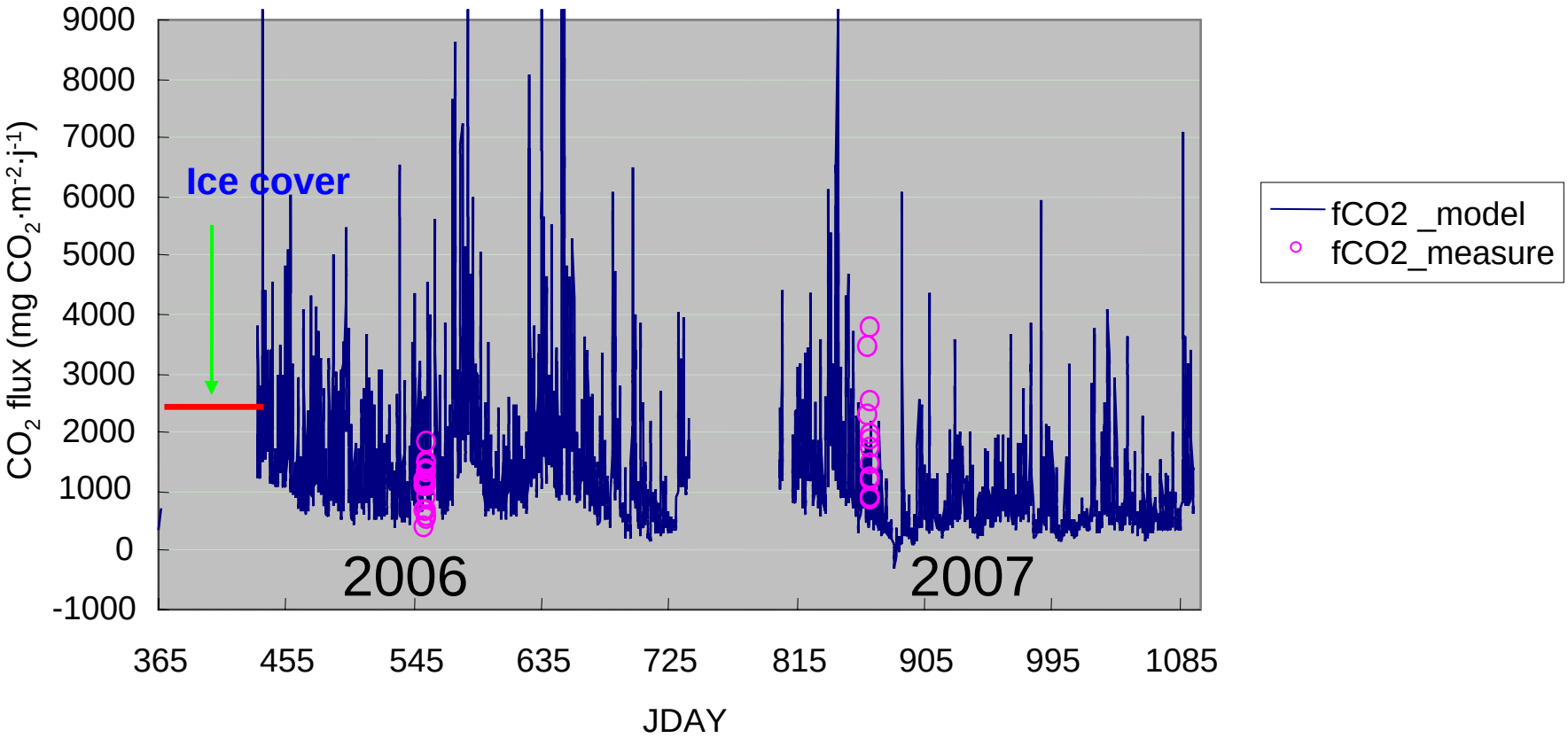
Lake Clair

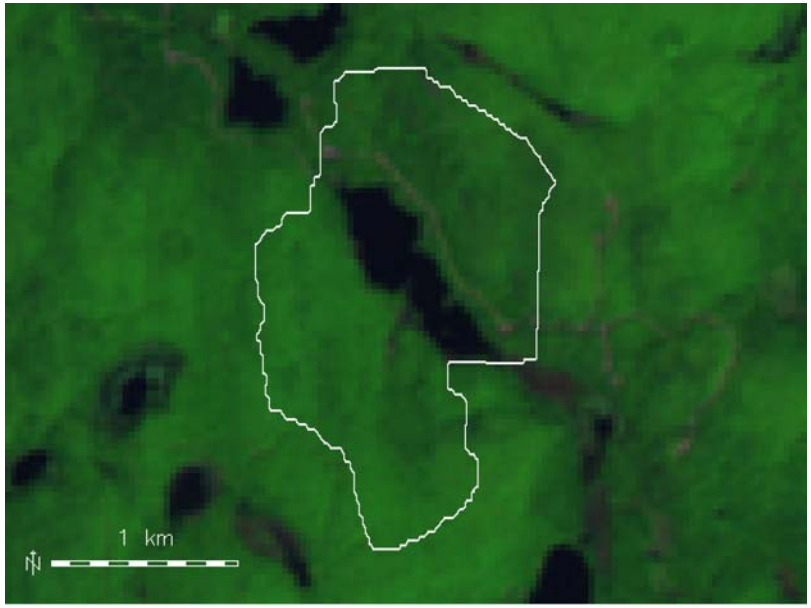
Lake: 1.75 km^2
Watershed: 45.27 km^2

Condition:
[Perturbed]



Comparison of CO_2 fluxes between model and measurement in Lake Clair (2006-2007)

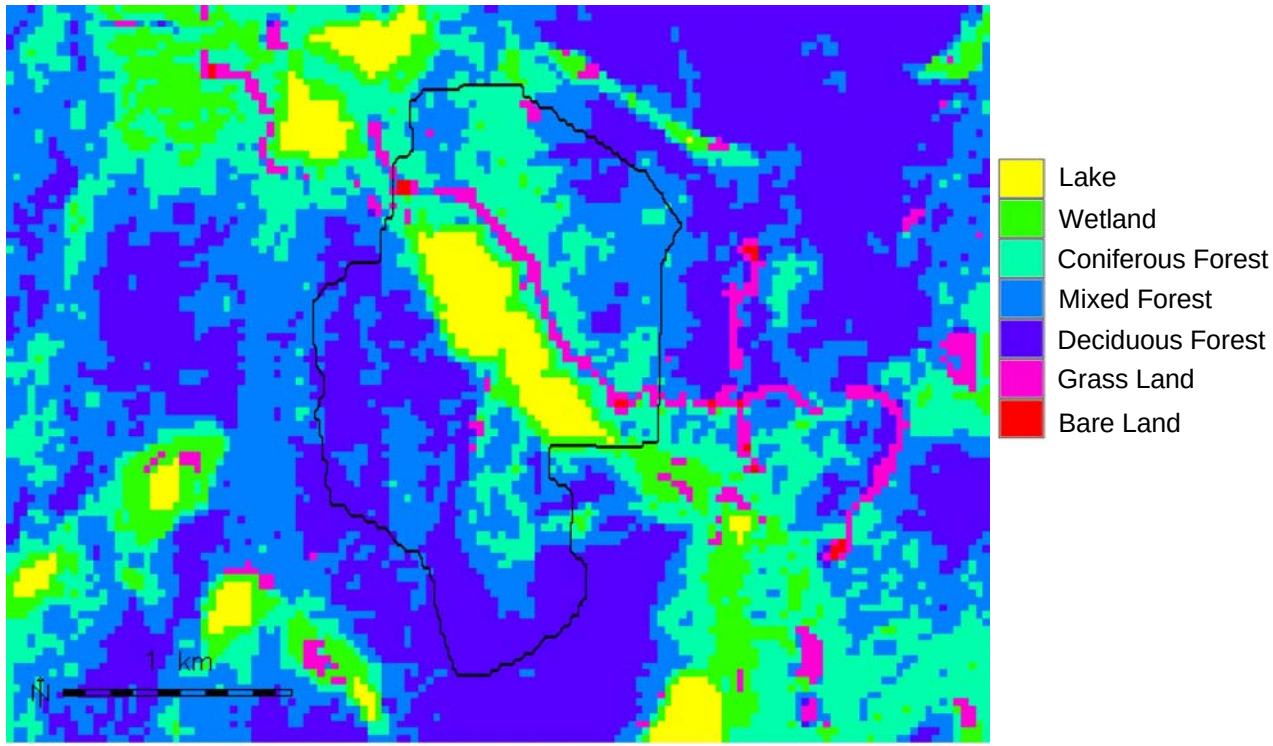




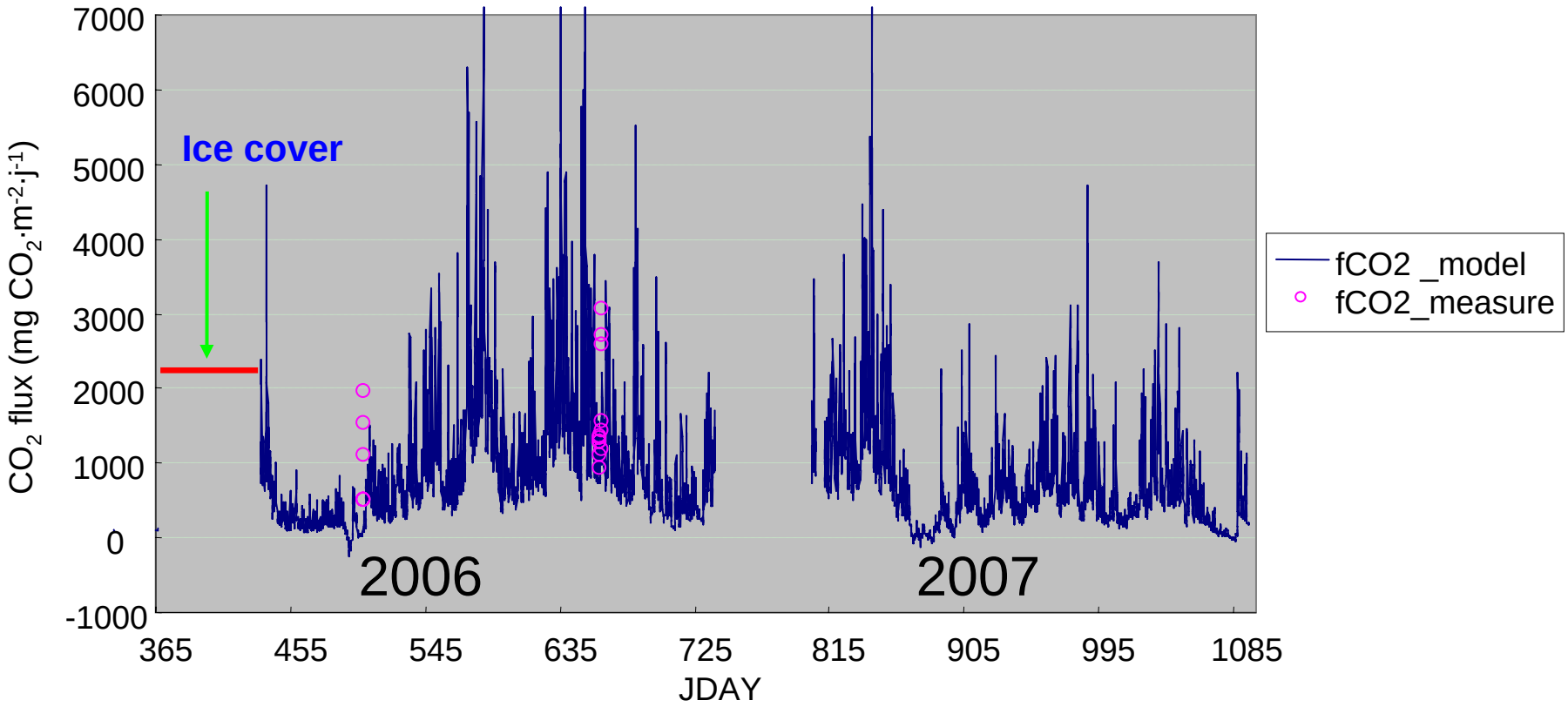
Lake Ellard

Lake: 0.28 km^2
Watershed: 2.08 km^2

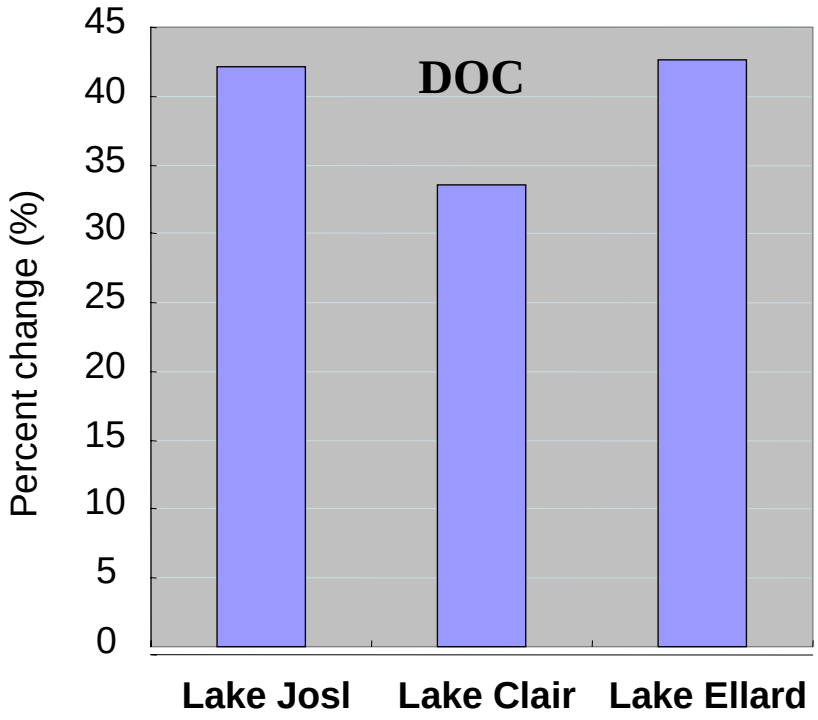
Condition:
Perturbed

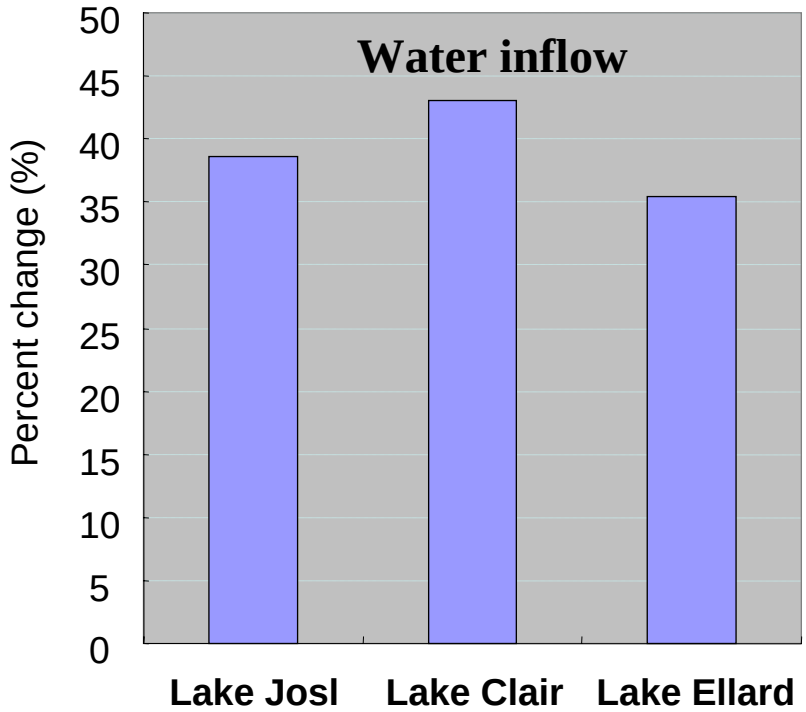


Comparison of CO_2 fluxes between model and measurement in Lake Ellard (2006-2007)

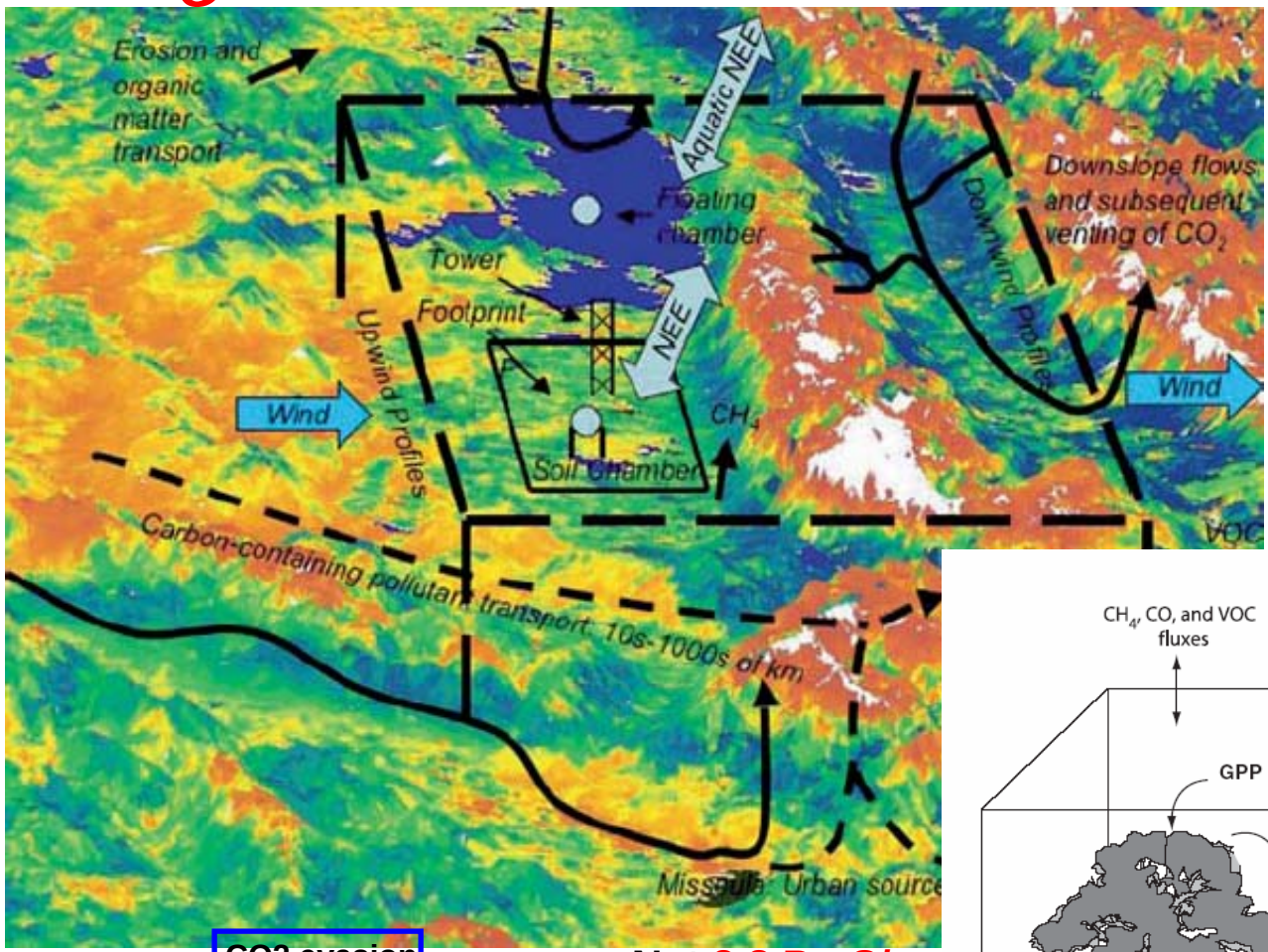


Increases of DOC and water inflow (%) in Lake Josl, Clair, and Ellard from natural to 1/2cut conditions

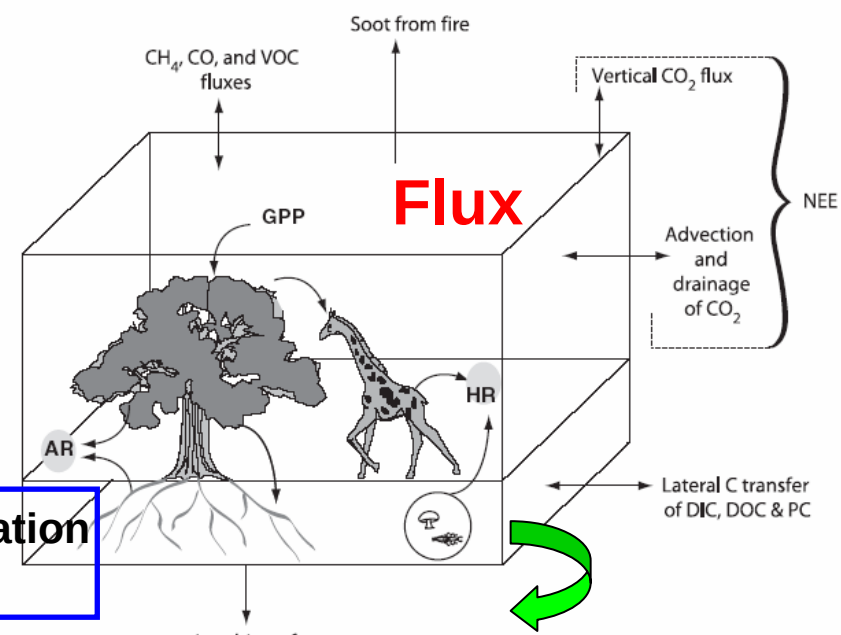




Background:



Not include the soil leachate and aquatic part (Lake and Reservoir)!



Leaching DOC and DIC

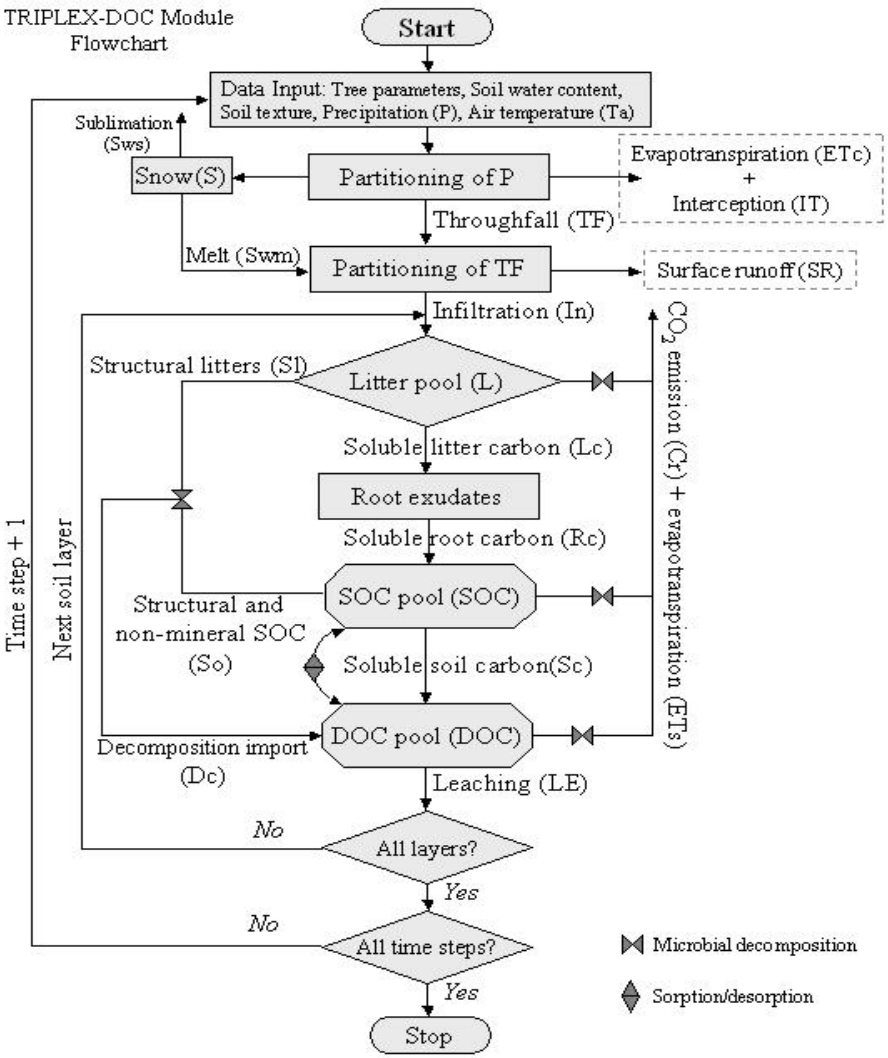
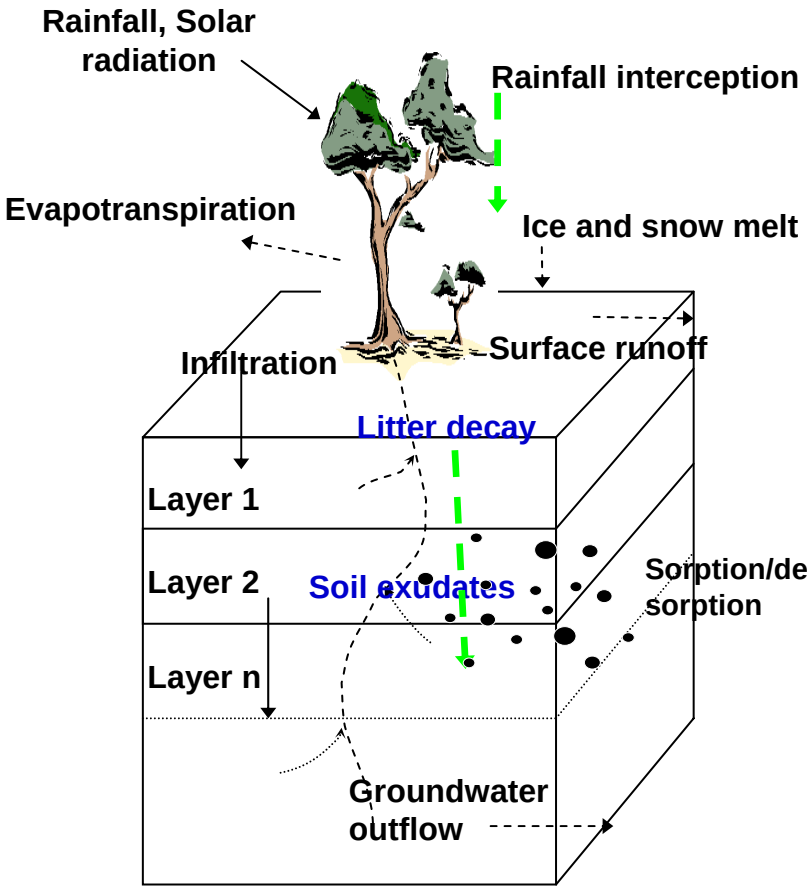
Net 2.8 Pg C/yr

Terrestrial vegetation and soils

Inland waters 1.9

CO2 evasion 0.75

Ocean 0.9

Sediment storage 0.23

TRIPLEX-DOC Model structure