# Water-Energy-Plant Interactions over Tibetan Plateau: a STEMMUS perspective and Progress


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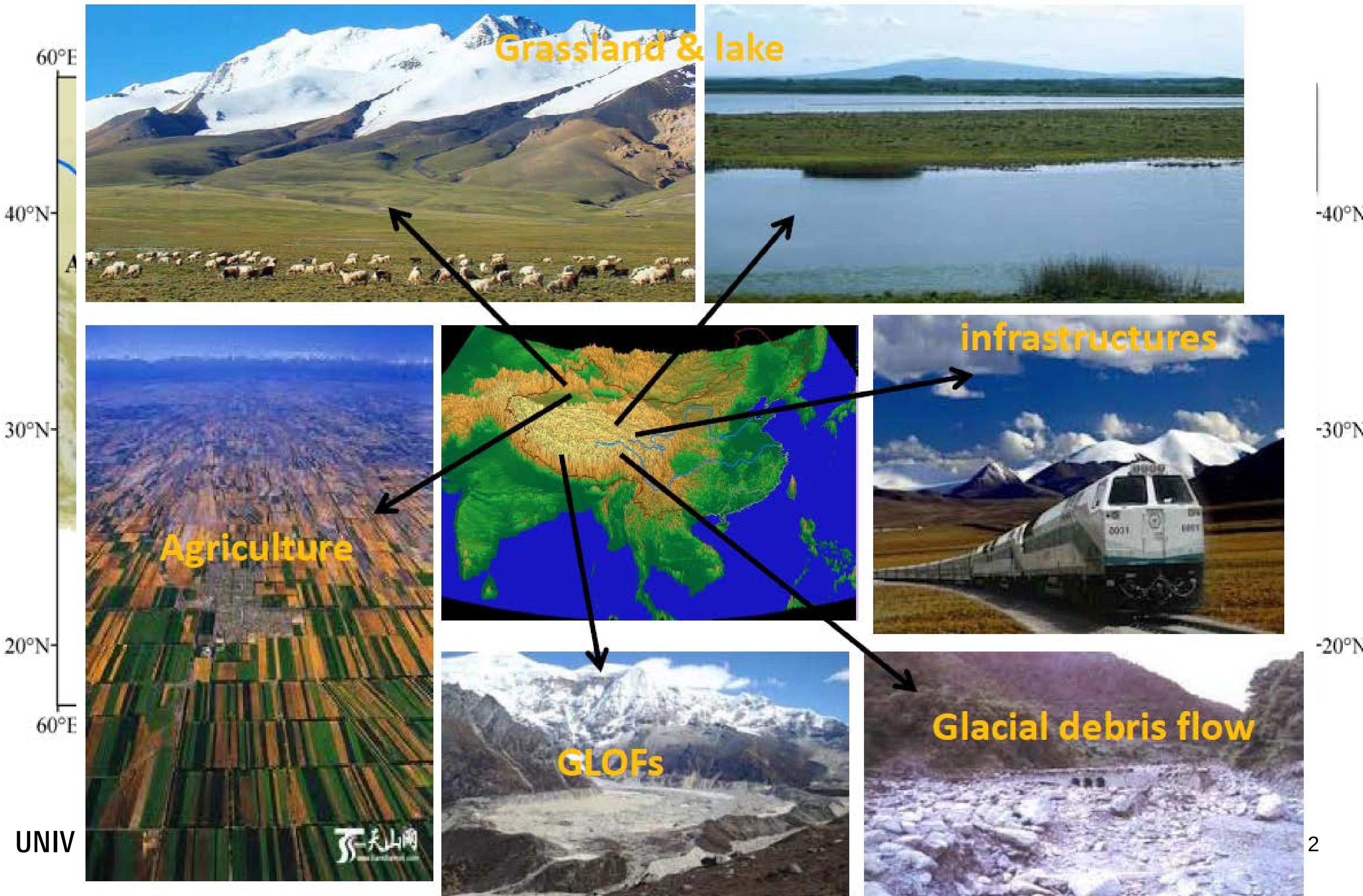
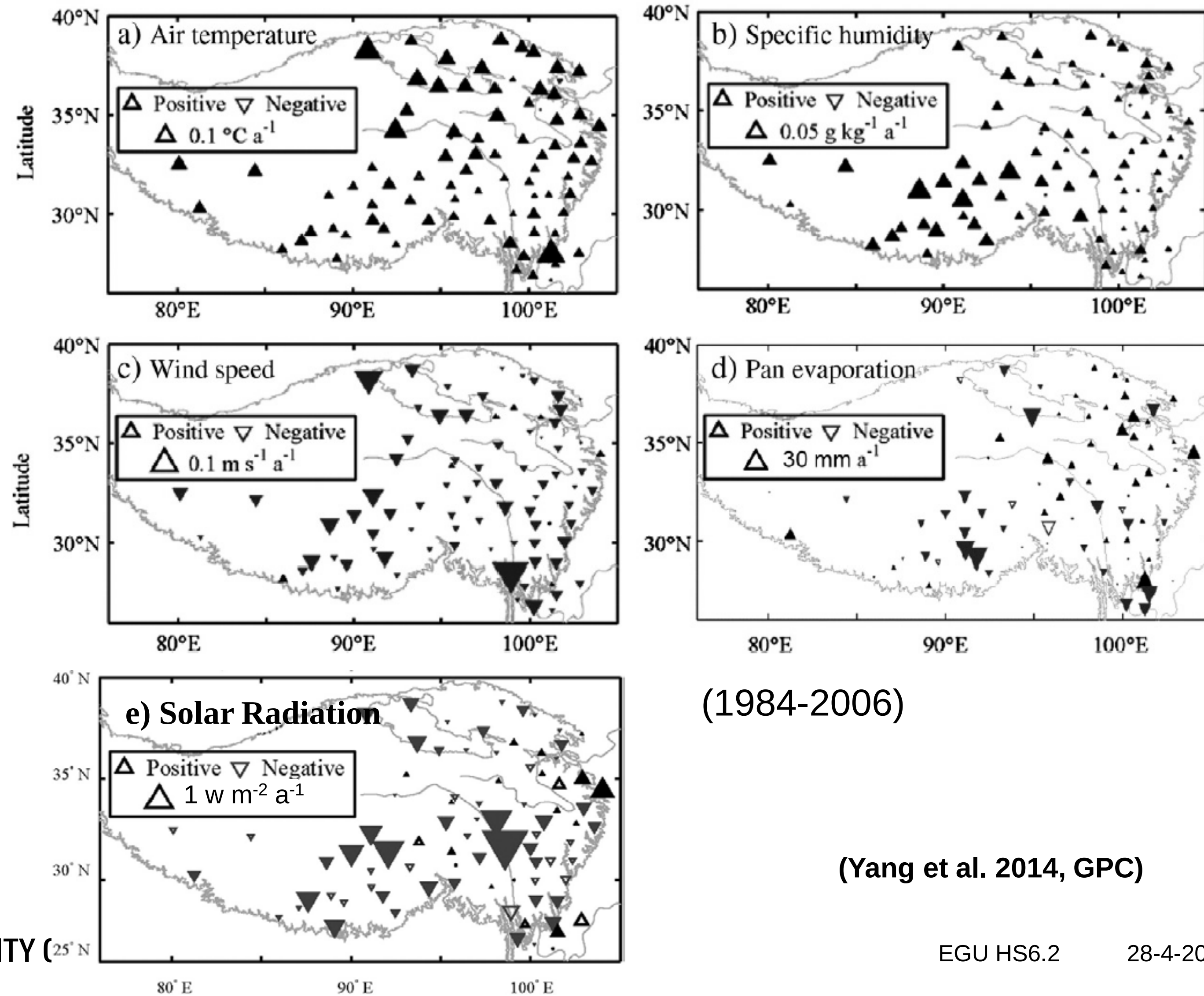
**Department of Water Resources, ITC Faculty**

# WHY TIBETAN PLATEAU?



# 1) Observations (Current States)

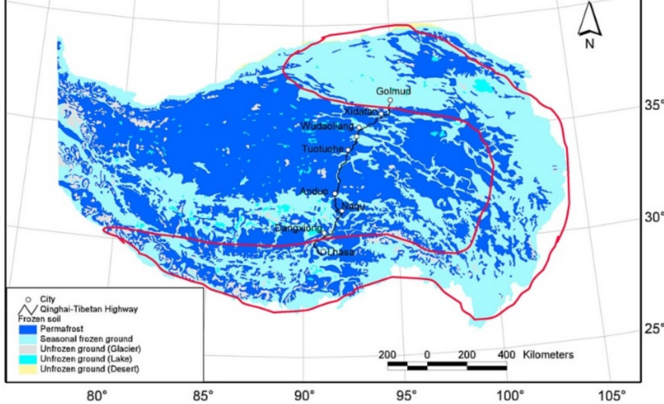
# DECADAL CHANGES IN CLIMATE



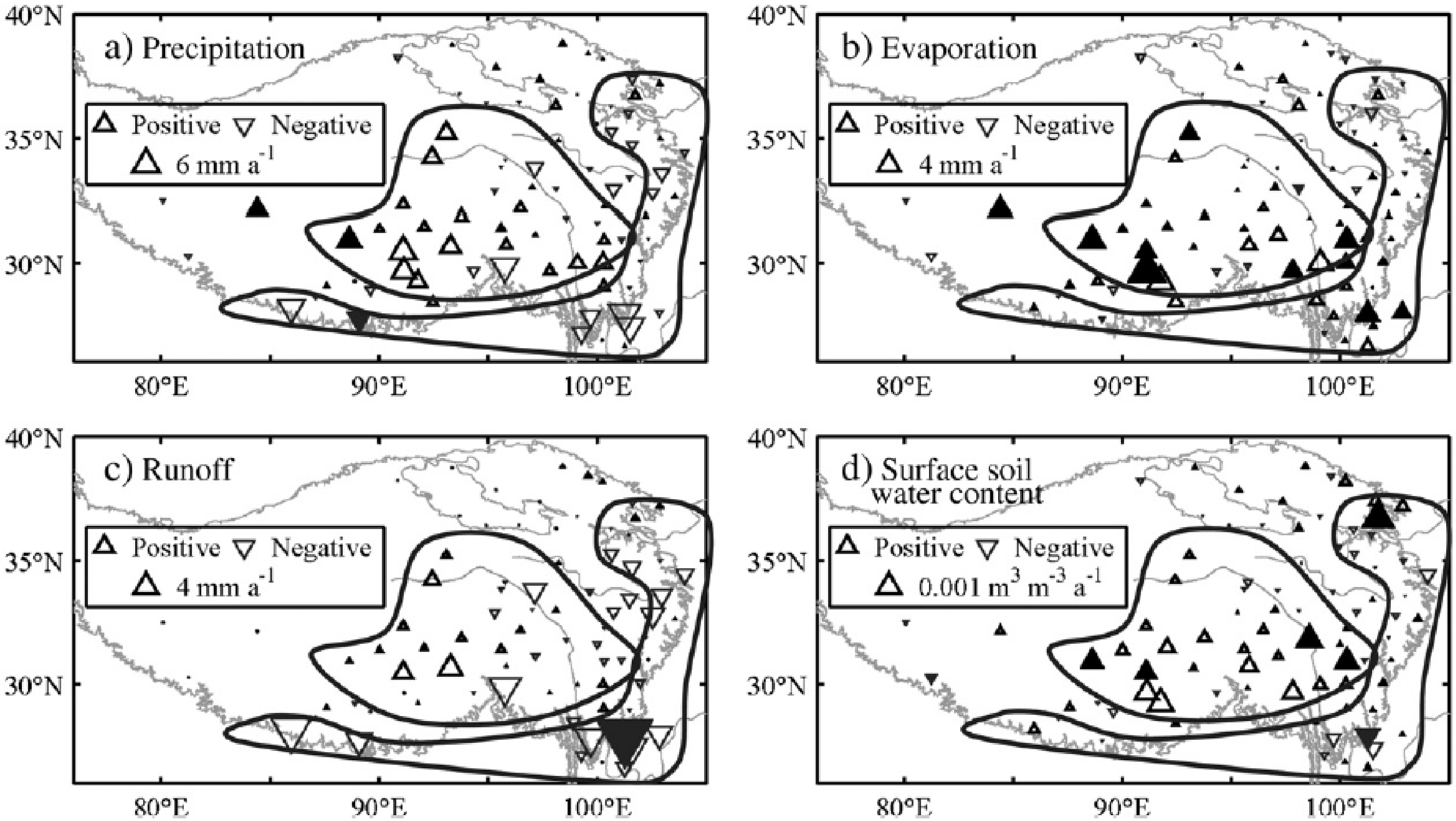

(1984-2006)

**(Yang et al. 2014, GPC)**

# DECADAL CHANGES IN HYDROLC




**(Yang et al. 2014, GPC)** (1984-2006)



# DECADAL CHANGES IN WATER BODIES

(Zhao et al. 2015, JGS)

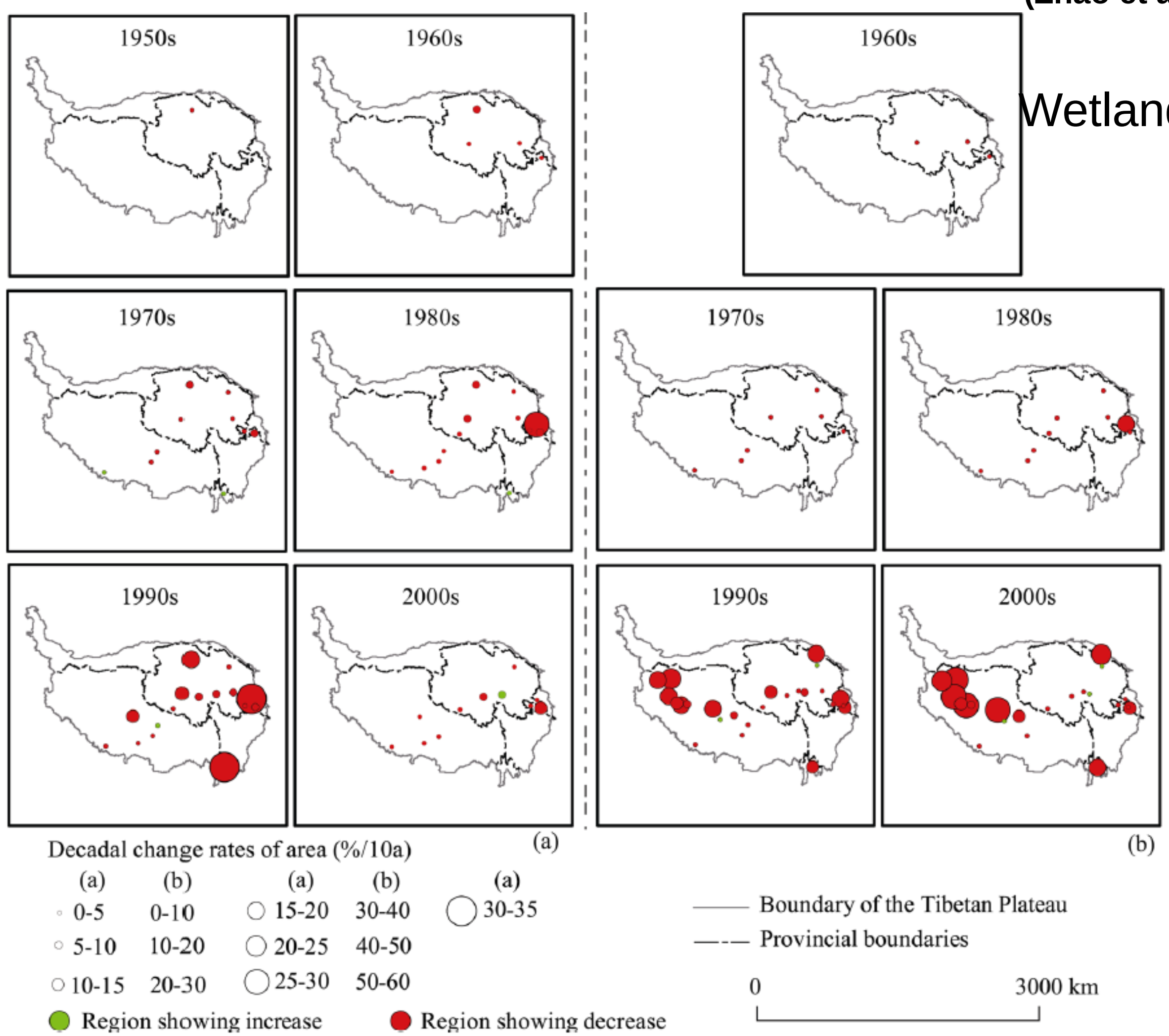
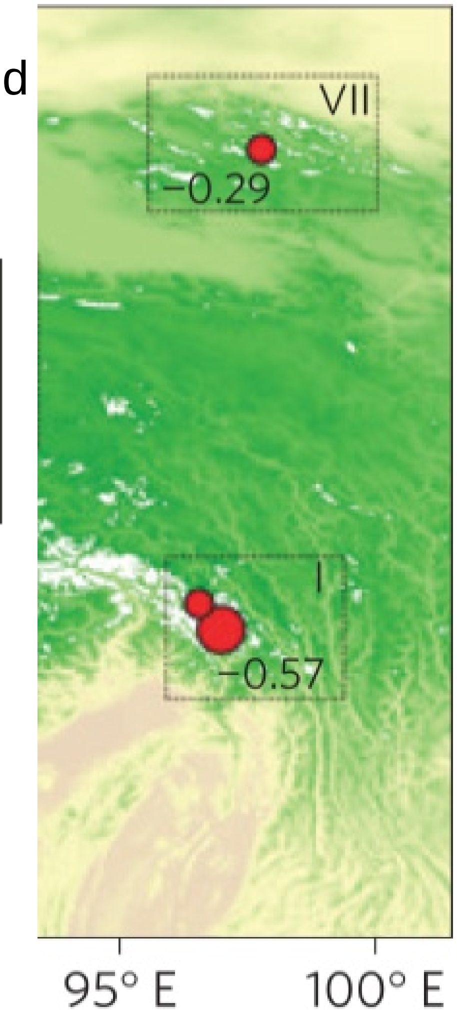


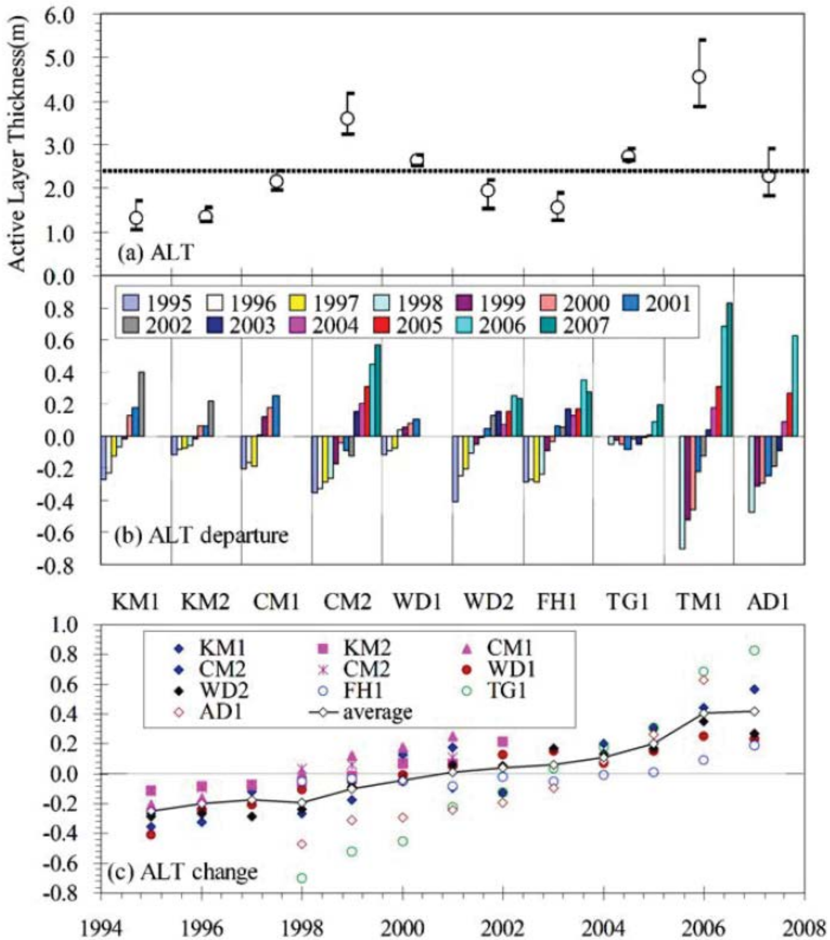

**Figure 2** Decadal variation amplitude of wetland (a) and swamp (b) within different regions of the Tibetan Plateau from 1950s to 2000s

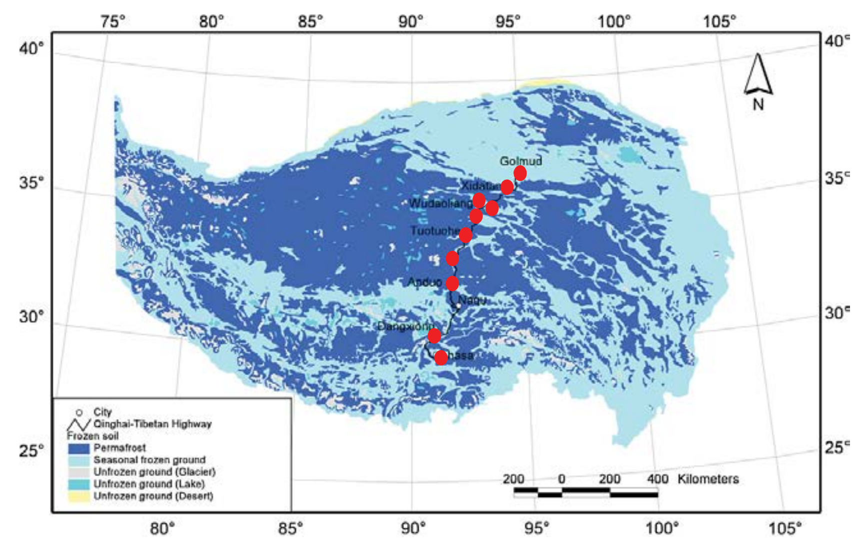
Wetland




(Yao et al. 2015)

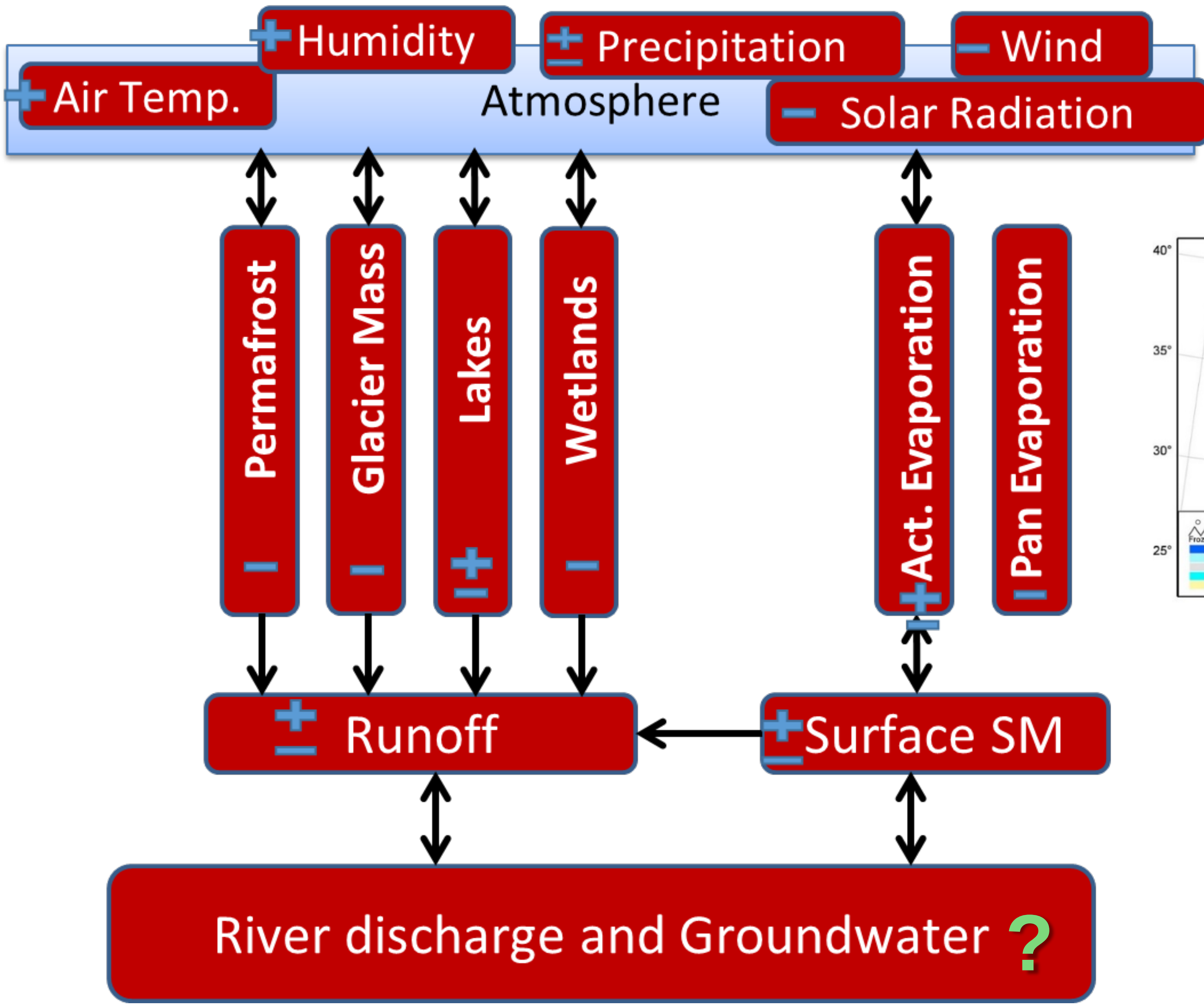
# DECADAL CHANGES IN PERMAFROST

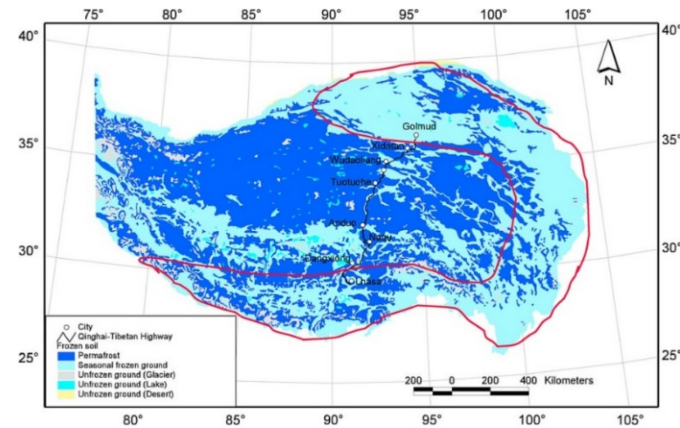



**(Wu & Zhang, 2010, JGR)**

# DECADAL CHANGES OVER TP

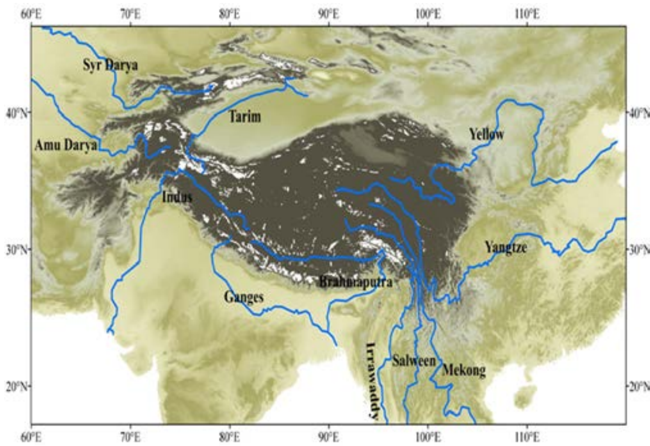


# 2) Scientific Challenges

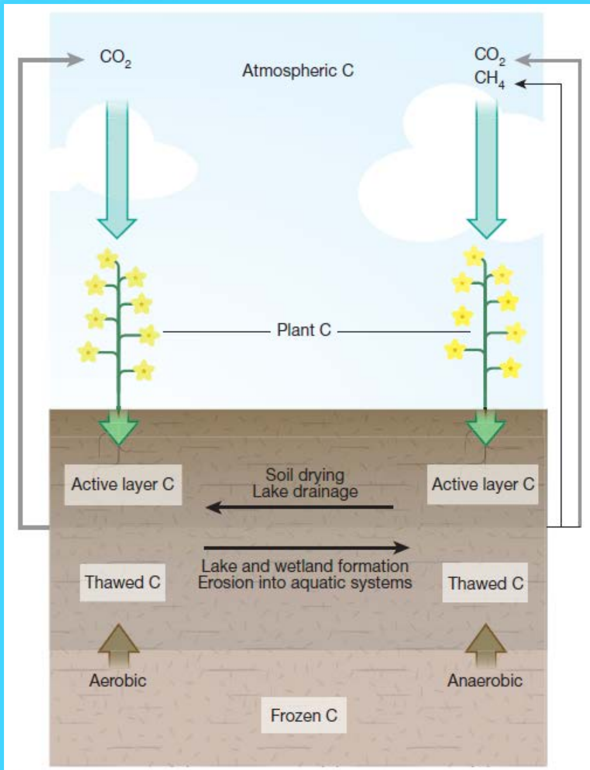
# PROBLEMS AND CHALLENGES IN LAND-ATMOSPHERE INTERACTIONS ON TIBETAN PLATEAU

- General problems
  1) Extreme thermal dynamic processes
  2) Unknown soil physical and hydraulic properties
  3) Little known vegetation processes

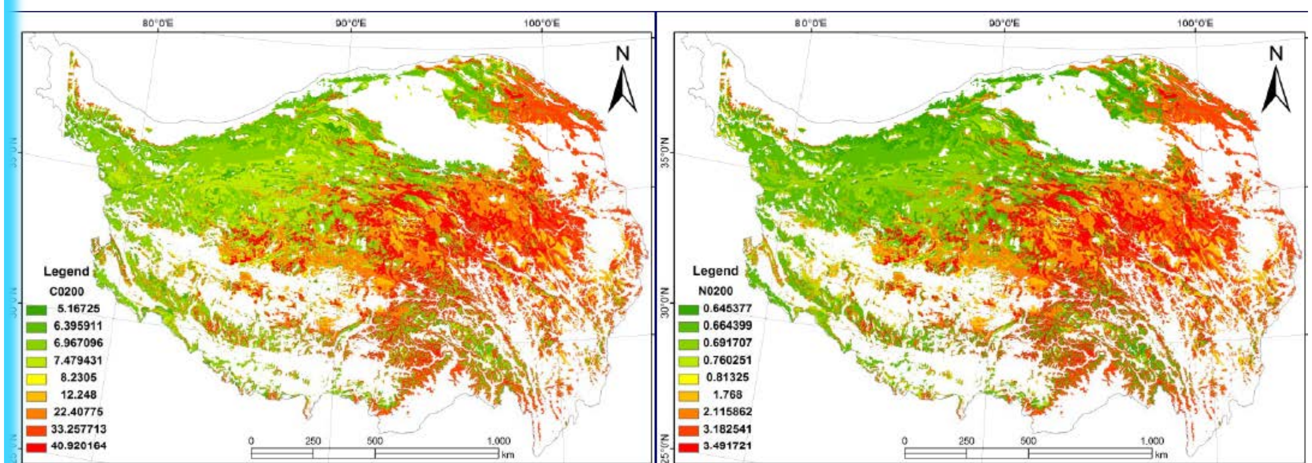



- Particular problems
  1) Most LSM models developed for homogeneous terrain at low elevation
  2) Lack of quantitative understanding of the complete land-atmosphere interactions – energy/heat, water/mass
  3) Lack of dedicated and validated parameterizations of the above processes (i.e. 'typical models')

# POTENTIAL PERMAFROST CARBON FEEDBACK OVER TIBETAN PLATEAU



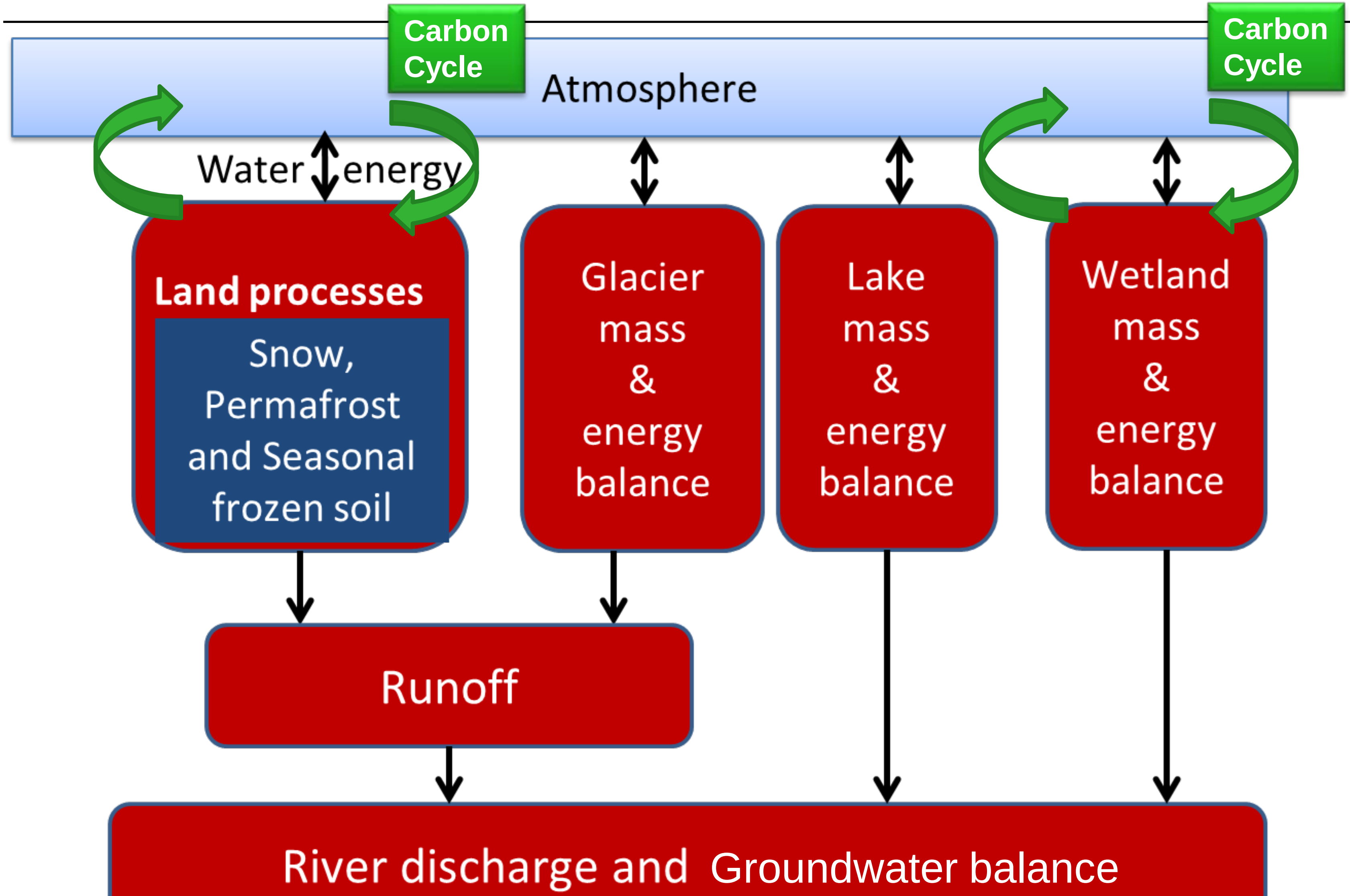

Box 1 Figure | Key features regulating the permafrost carbon feedback to climate from new, synthesized observations.



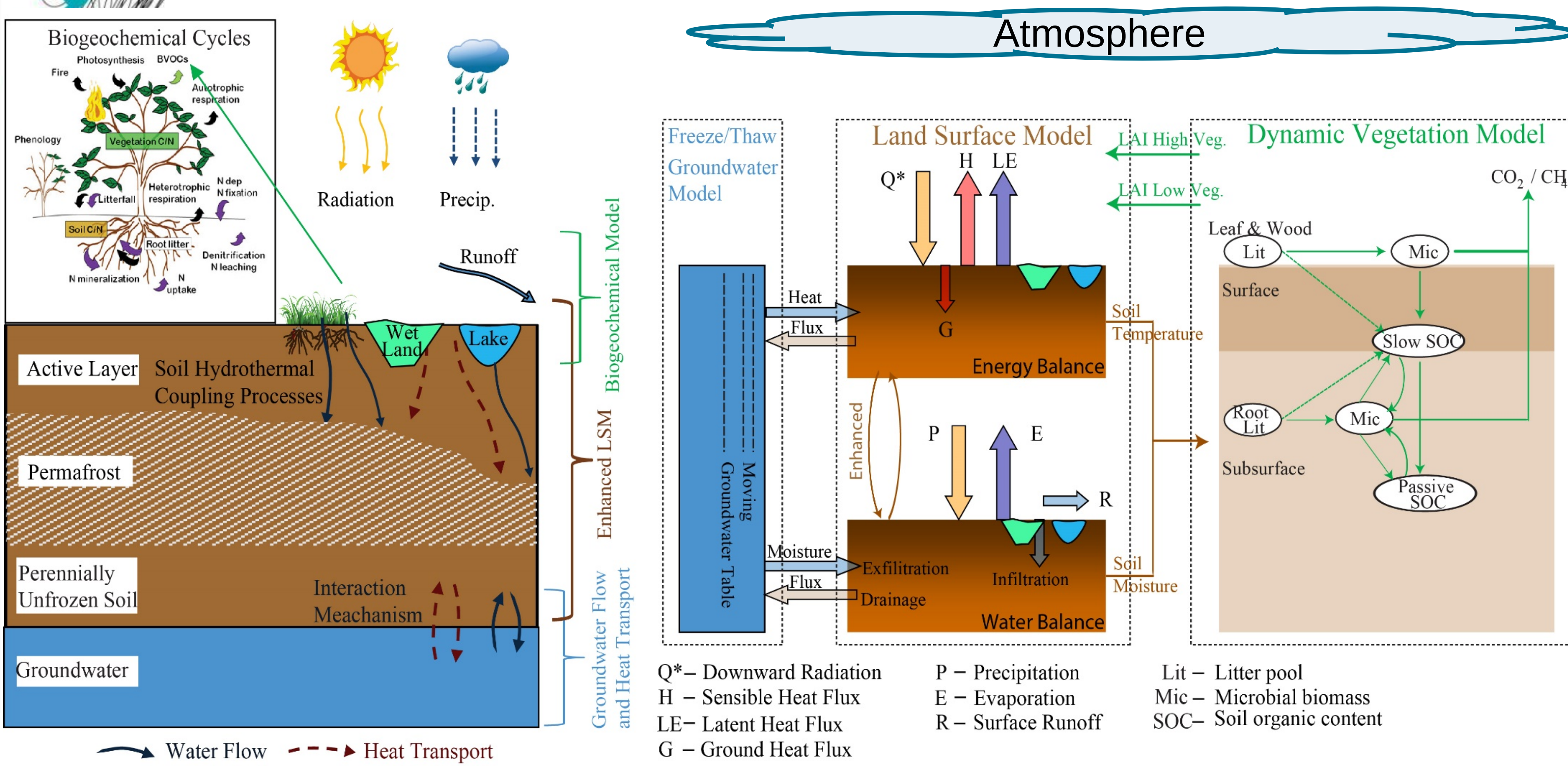

**Total carbon : 25.4-26.5 Pg    Total nitrogen : 2.0-2.4 Pg**

With Soil Ice Content, the ALT change can be tracked at mm-cm scale, which is expected to improve the estimate of permafrost carbon feedback.

# NEED AN INTEGRATED MODELLING SYSTEM



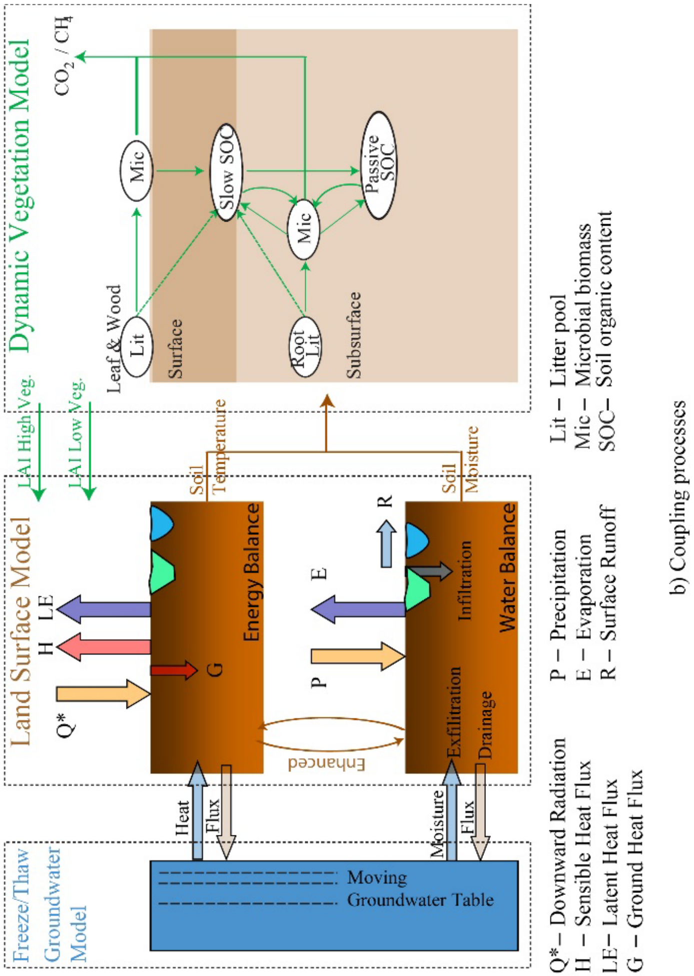
# NEED AN INTEGRATED MODELLING SYSTEM

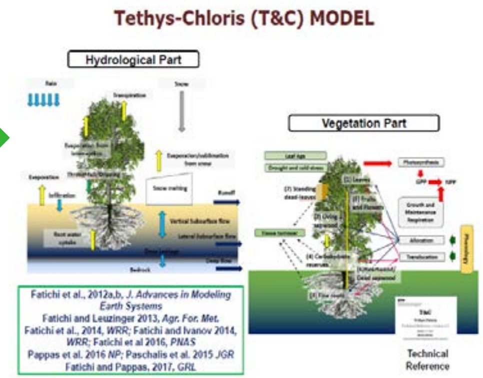



a) Physical processes

b) Coupling processes

# WATER-ENERGY-PLANT INTERACTIONS IN COLD REGIONS

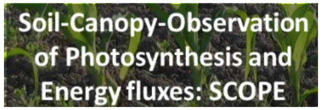


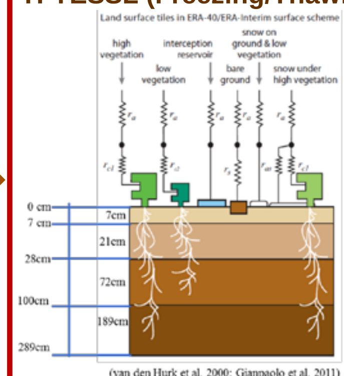

**Vegetation Dynamics**

**Carbon Cycle**

**Nutrient Cycle**

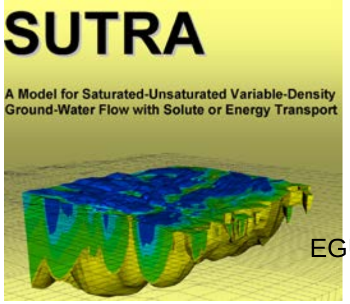



**H-TESSL (Freezing/Thawing)**




STEMMUS

**Simultaneous Transfer of Energy, Momentum and Mass in Unsaturated Soil**

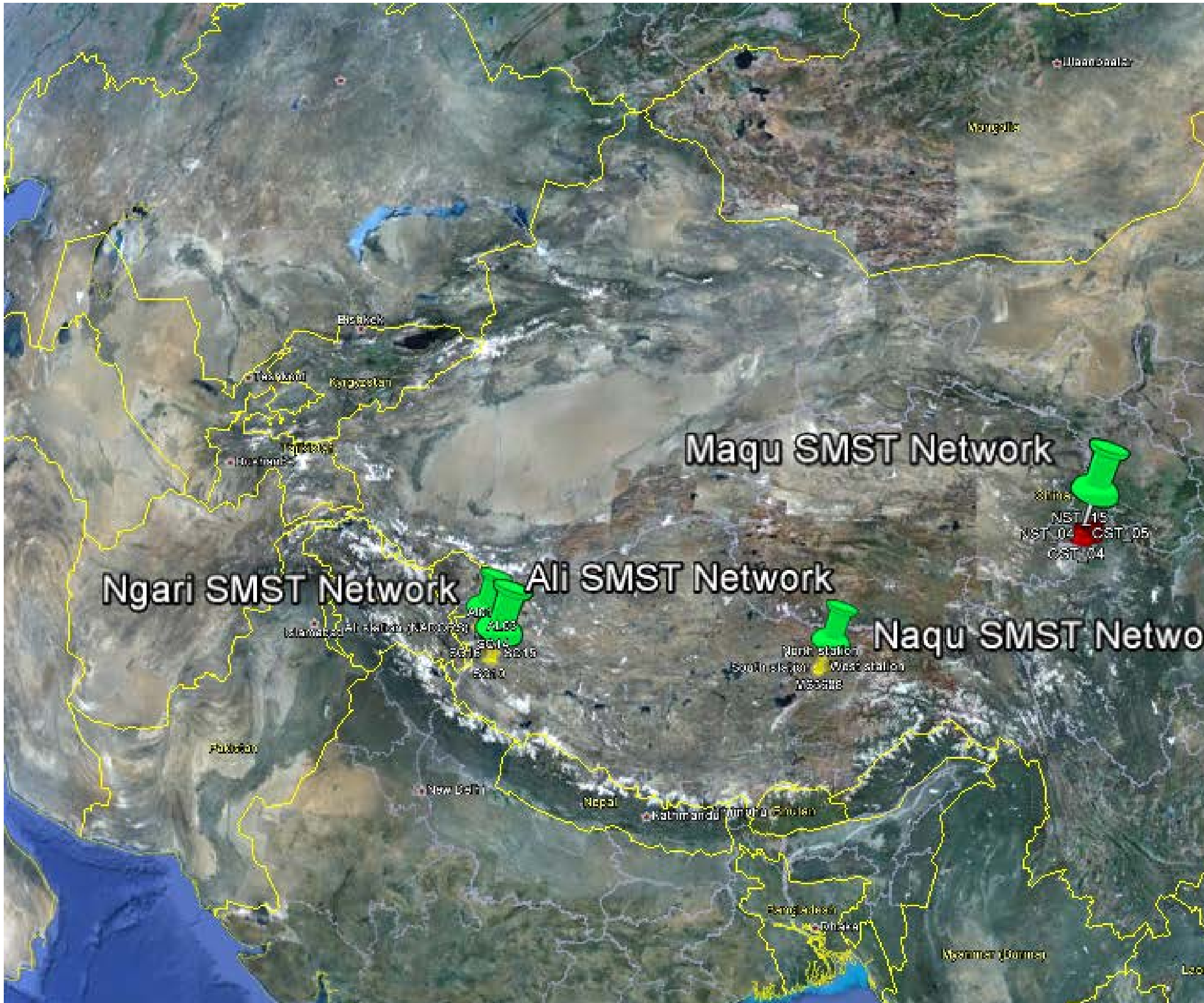



PFLOTRAN

A Massively Parallel Reactive Flow and Transport Model for describing Surface and Subsurface Processes

# 3) Current Progress

# Tibetan Plateau observatory of plateau scale soil moisture and soil temperature (Tibet-Obs)

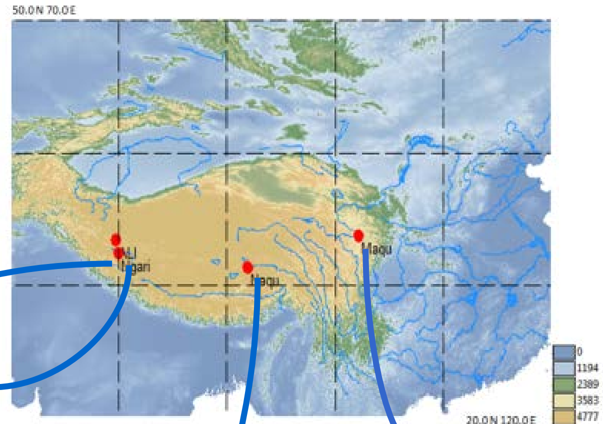


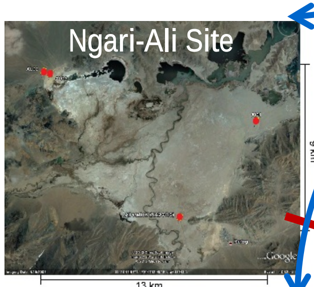

Project:
ESA Dragon programme
EU FP7 CEOP-AEGIS project
EU FP7 CORE-CLIMAX
NWO SMAP-Freeze/Thaw

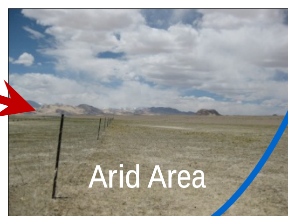
***Su, Z., et al. 2011, HESS***

***Su, Z., de Rosnay, P., et al., 2013 JGR***

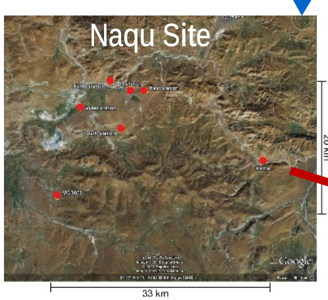
# Tibetan Plateau observatory of plateau scale soil moisture and soil temperature (Tibet-Obs)



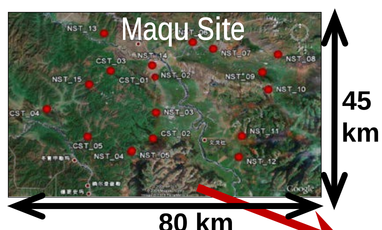



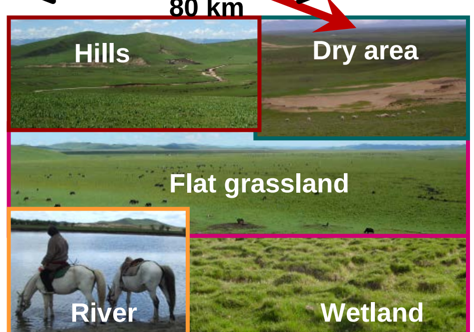










- Research Focus:
  Measuring, remote sensing and modeling the land surface states (soil moisture, temperature, vegetation) and heat fluxes (latent, sensible);
- SMAP Products to Validate:
  L2_SM radar/radiometer, L3/L4
- Site Characteristics:

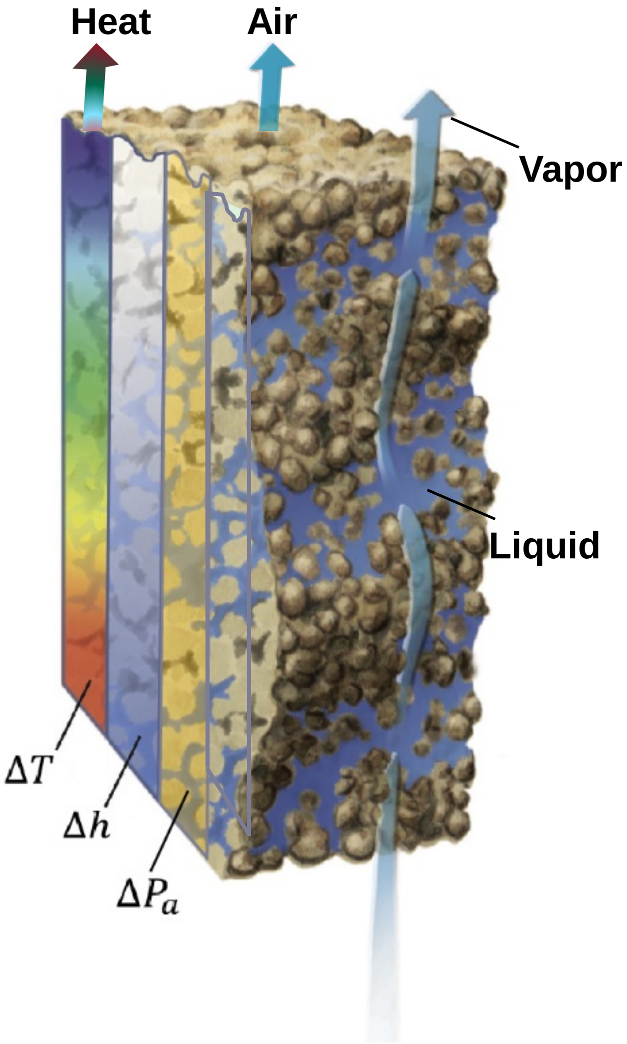
| | Twente | Naqu | Maqu | Ngari |
|---|---|---|---|---|
| Nr. Domains | 1 | 1 | 1 | 2 |
| Nr. Points | 22 | 7 | 20 | 20 |

- Data can be downloaded through FTP site maintained by ITC-WRS.
- Expected Latency:
  For the Tibet-Obs sites, we expect to provide data before and after the monsoon seasons each year. This is related to the remoteness of the sites and the harsh environmental conditions. For the Twente site, monthly data can be provided.
- Status:
  All four SM/ST observation networks are operational.

| | Twente | Naqu | Maqu | Ngari |
|---|---|---|---|---|
| Data Downloaded | Per 3 Mons. | Per Year | Per 3/6 Mons | Per Year |
| Calibration | Gravimetric | Gravimetric | Gravimetric | Gravimetric |

| Measurement Type | Method | Depths |
|---|---|---|
| Soil Moisture | $ECH_2O$ (Capacitance probe) Type: EC-10 & EC-TM | Naqu Station -2.5, -7.5, -15, -30 , -60cm Maqu & Twente Station -5, -10, -20, -40, -80cm Ngari Station -5, -10, -20, -40, -60, -80cm |
| Soil Temperature | | |
| Micrometeorological | AWS, PBL Tower | 1.5, 2, 5, 6.5, 10, 14.0 m |

# Simultaneous Transfer of Energy, Momentum and Mass in Unsaturated Soil



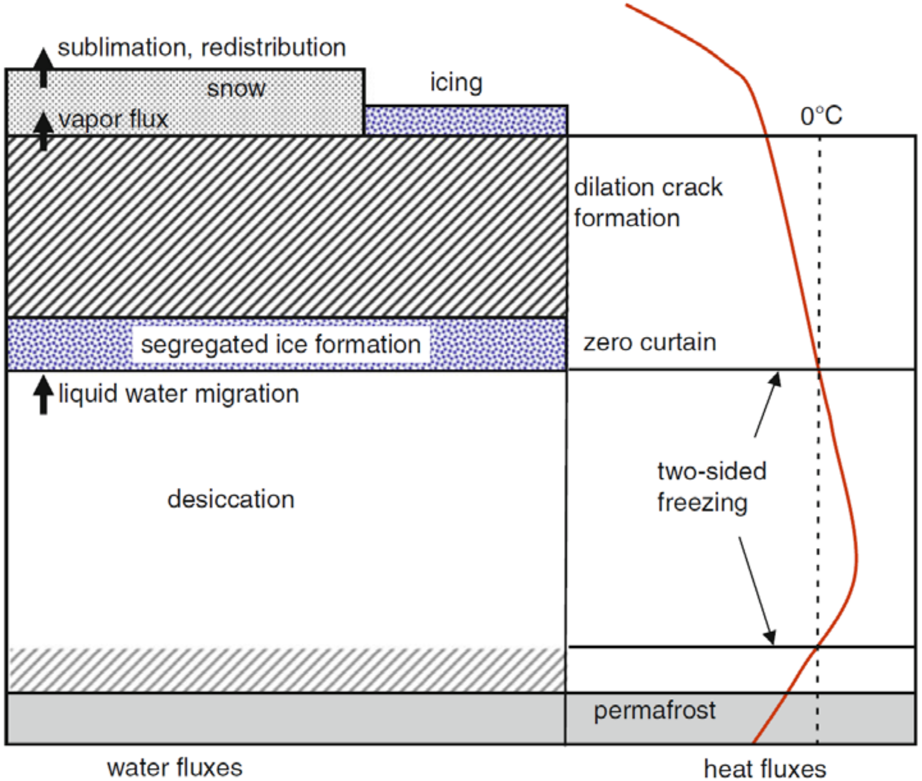

Three driving forces:
-Temperature Gradient,
- Matric Potential Gradient, and
- Soil Air Pressure Gradient.

Fullly coupled transport in the soil of
- water,
- vapor,
- air, and
- heat

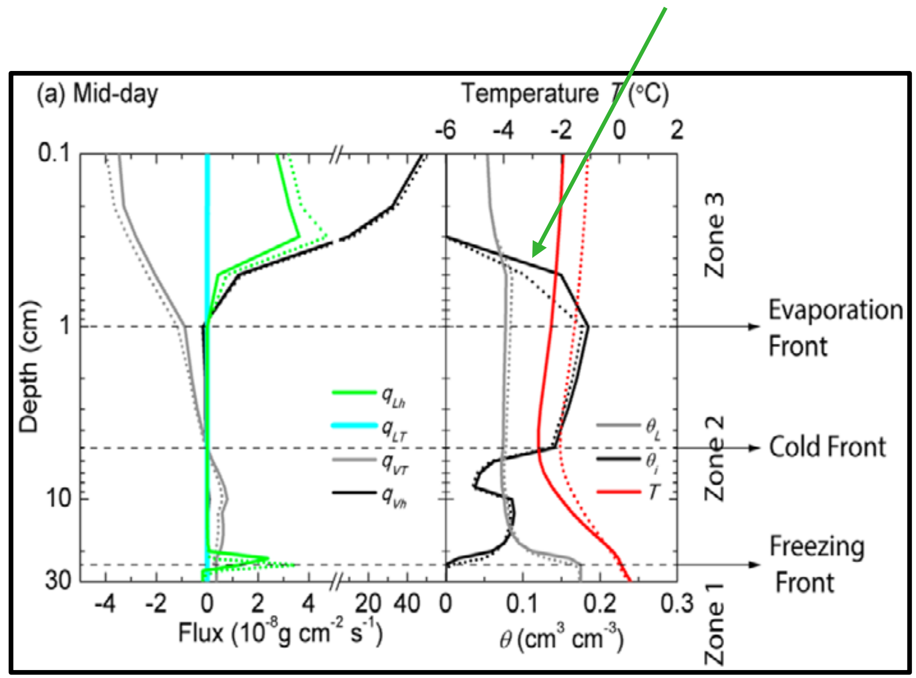
STEMMUS

# STEMMUS Freeze-Thaw

STEMMUS - FT




SIC Profile




Hydrologic and thermal conditions of the active layer during freeze-back and winter periods

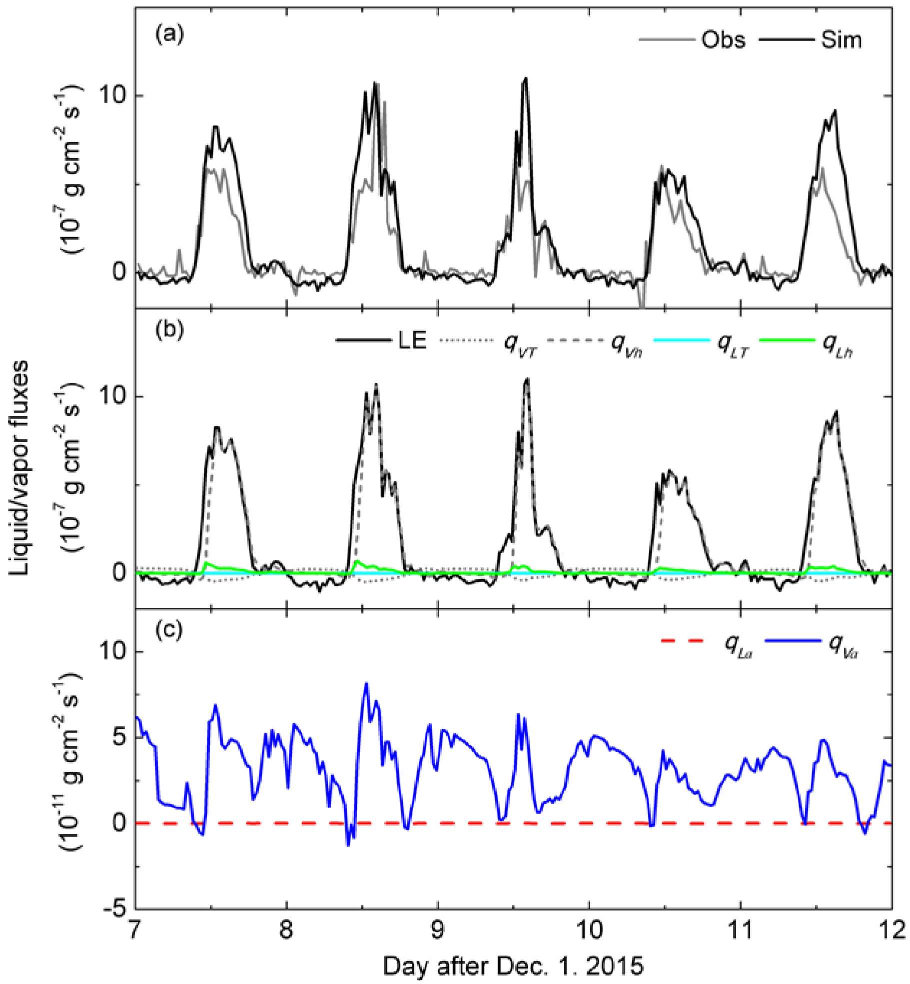
**(Ming-ko Woo, 2012, Permafrost Hydrology)**

With Soil Ice Content (SIC), one can see exactly how the active layer is freezing back.

**STEMMUS-FT Model (YU, Zeng & Su, 2018, JGR)**

# STEMMUS Freeze-Thaw

STEMMUS - FT




**$q_{VT}$ - Thermal vapor flow, due to temperature gradient;**

**$q_{VH}$ - Isothermal vapor flow, due to soil matric potential gradient;**

**$q_{LT}$ - Thermal liquid flow, due to temperature gradient;**

**$q_{LH}$ - Isothermal liquid flow, due to soil matric potential gradient;**

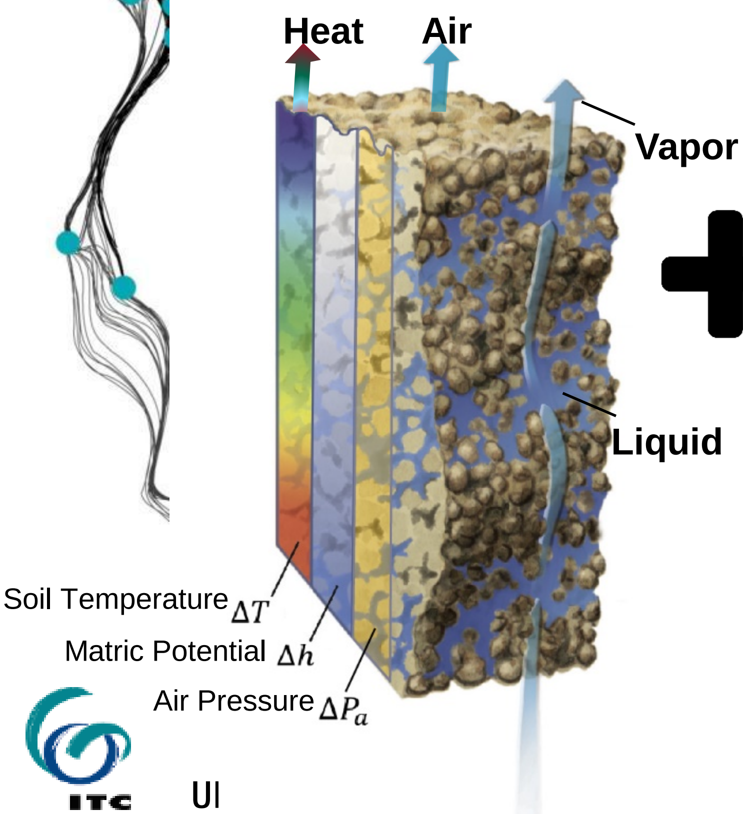
**$q_{LA}$ - liquid flow due to air pressure gradient;**

**$q_{VA}$ - Vapor flow due to air pressure gradient;**

**(Yu, Zeng & Su, 2018, JGR)**

# STEMMUS + TeC: If the enhanced soil water and heat transfer process have effects on ecosystem functioning? – L. Yu

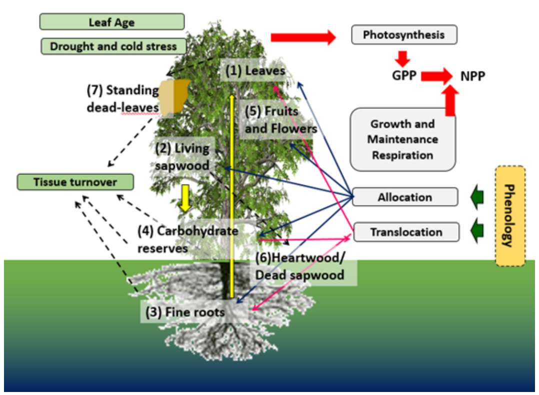
STEMMUS - FT



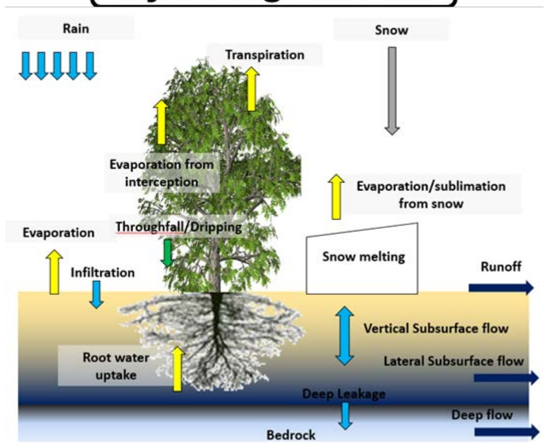

**+**

## Tethys-Chloris (T&C)

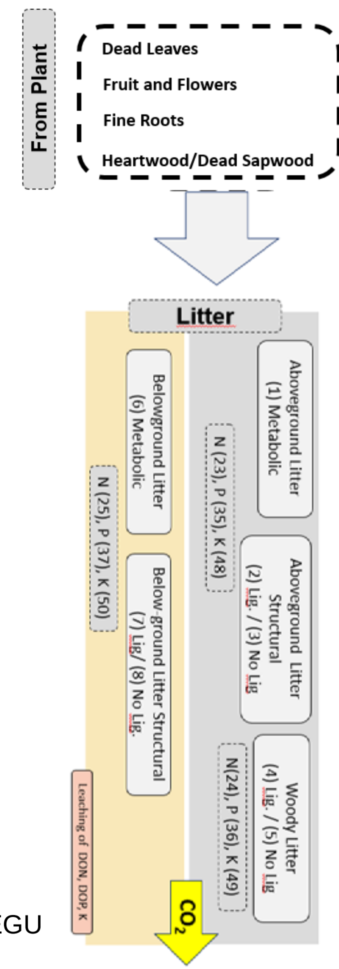
### Vegetation Part



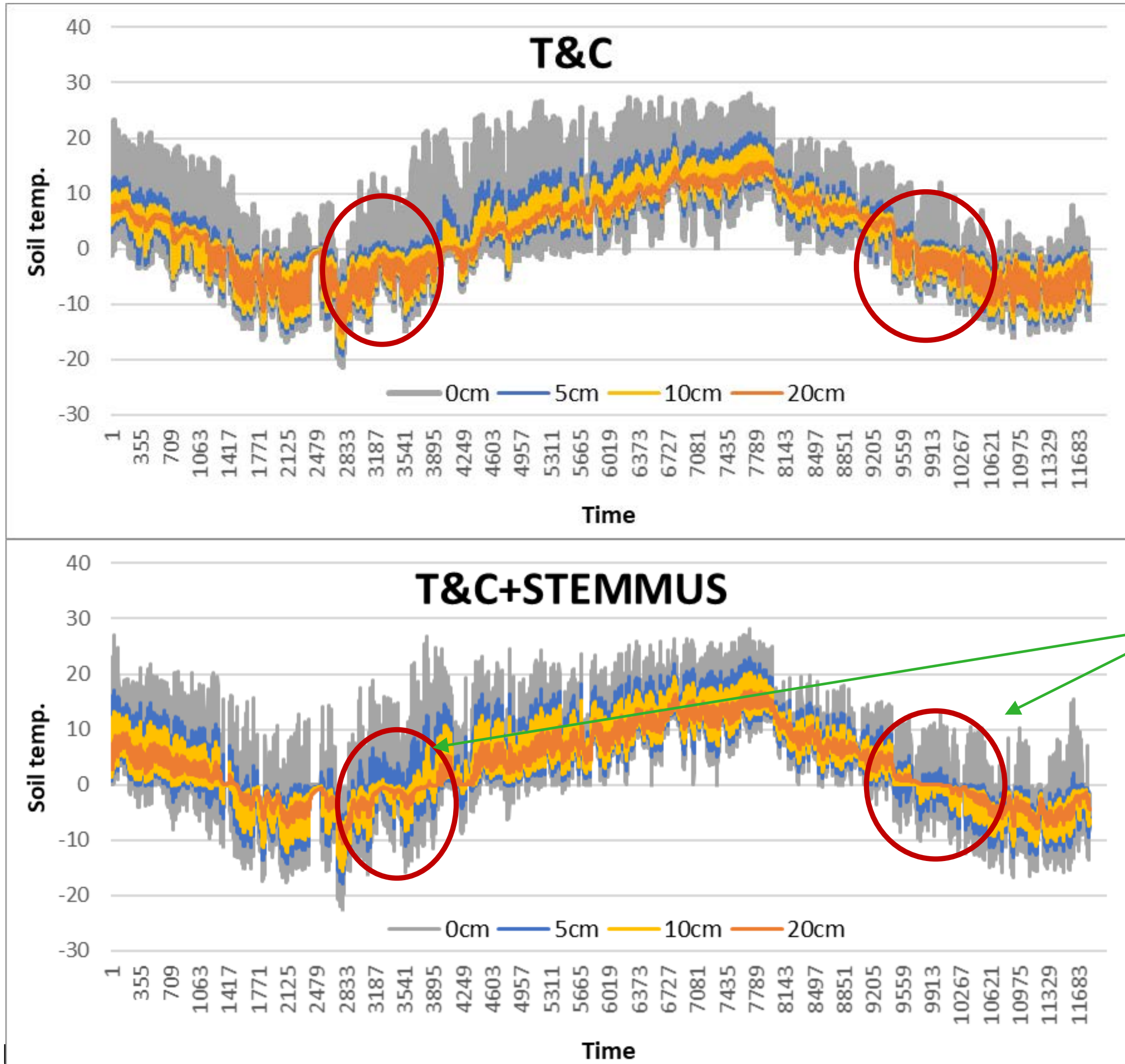

### Hydrological Part




**55 prognostic pools**



# STEMMUS + TeC: If the enhanced soil water and heat transfer process have effects on ecosystem functioning? – L. Yu



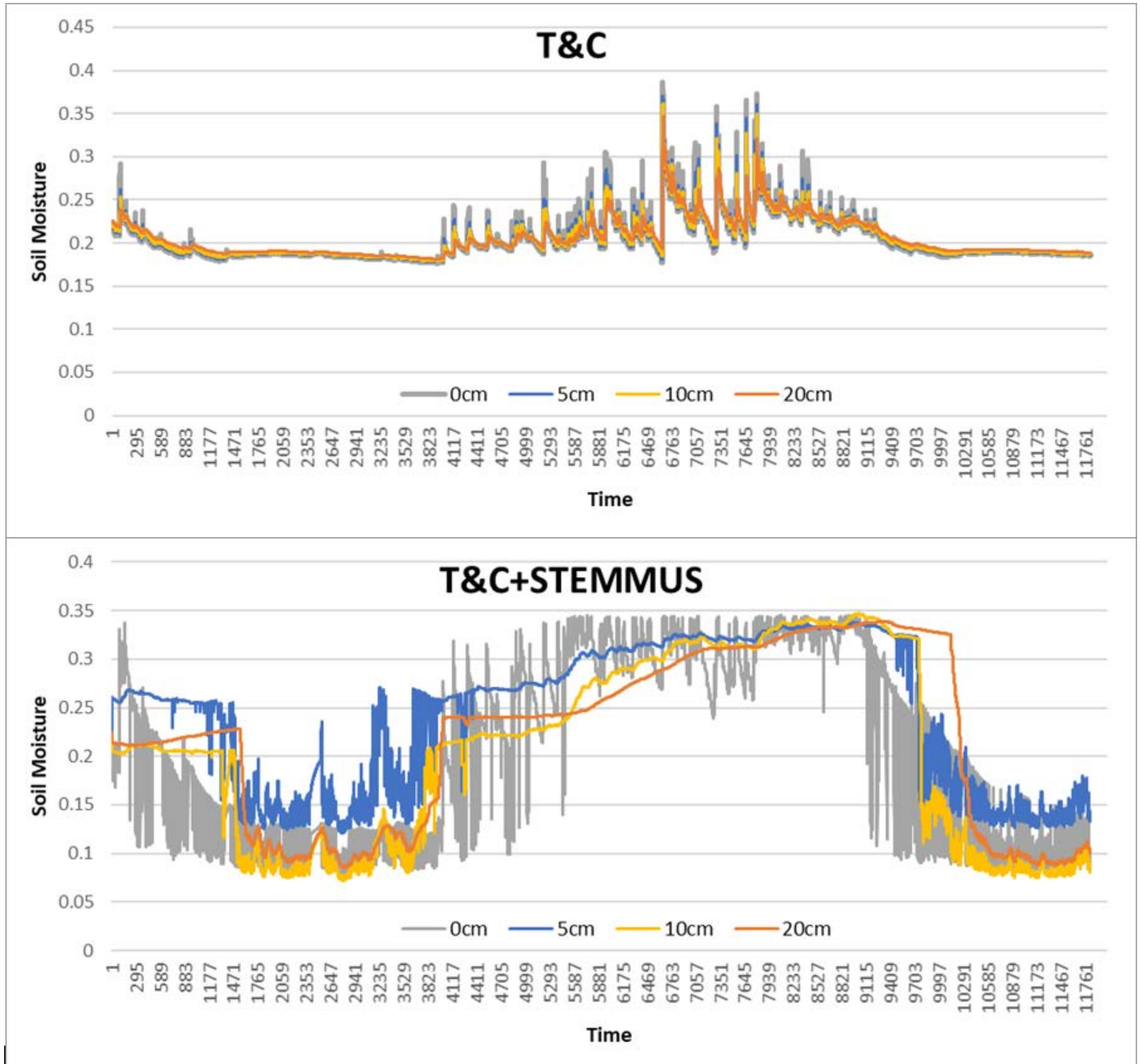

**The seasonal soil temperature variations can be clearly observed**

**(YU, Zeng & Su, 2018, unpublished)**

Zero Curtain

Zero-curtain effect is that the phase transition rate is slowed down due to latent heat release/absorption, resulting a relative flat variation of soil temperature near the freezing point temperature (i.e., zero or subzero degree).

# STEMMUS + TeC: If the enhanced soil water and heat transfer process have effects on ecosystem functioning? – L. Yu

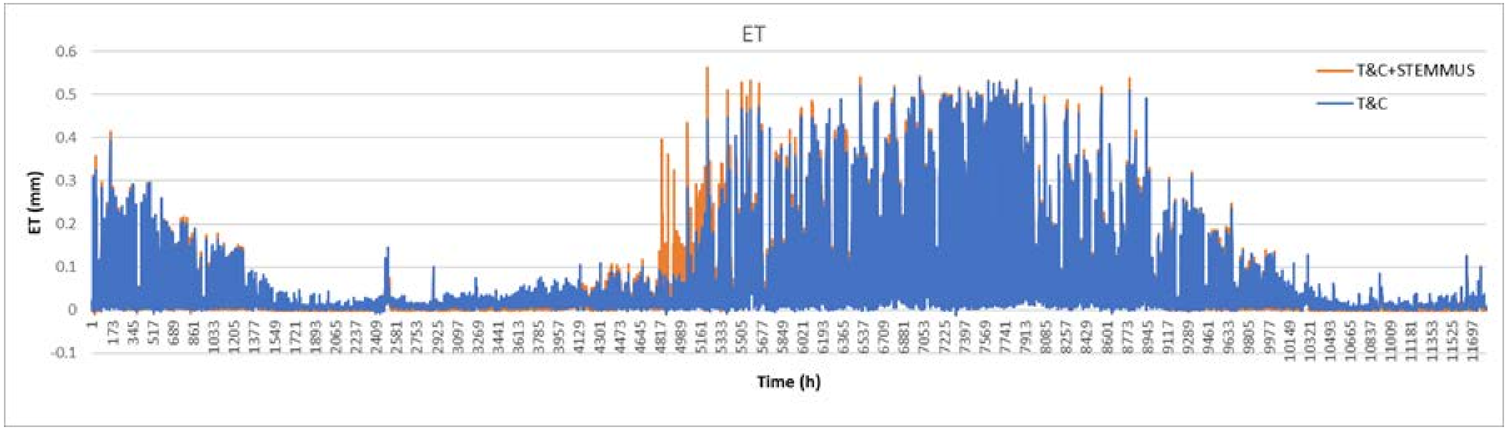


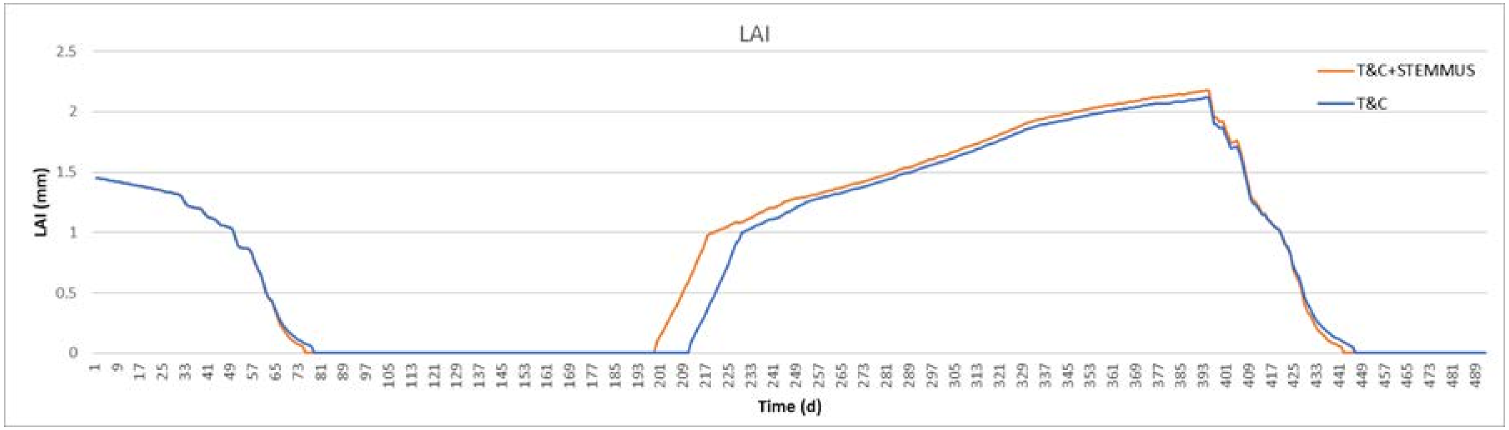

**Soil moisture at different soil layers looks similar, and no significant drop at subzero temperature.**

**Soil moisture reduction due to ice content can be seen below the freezing temperature.**

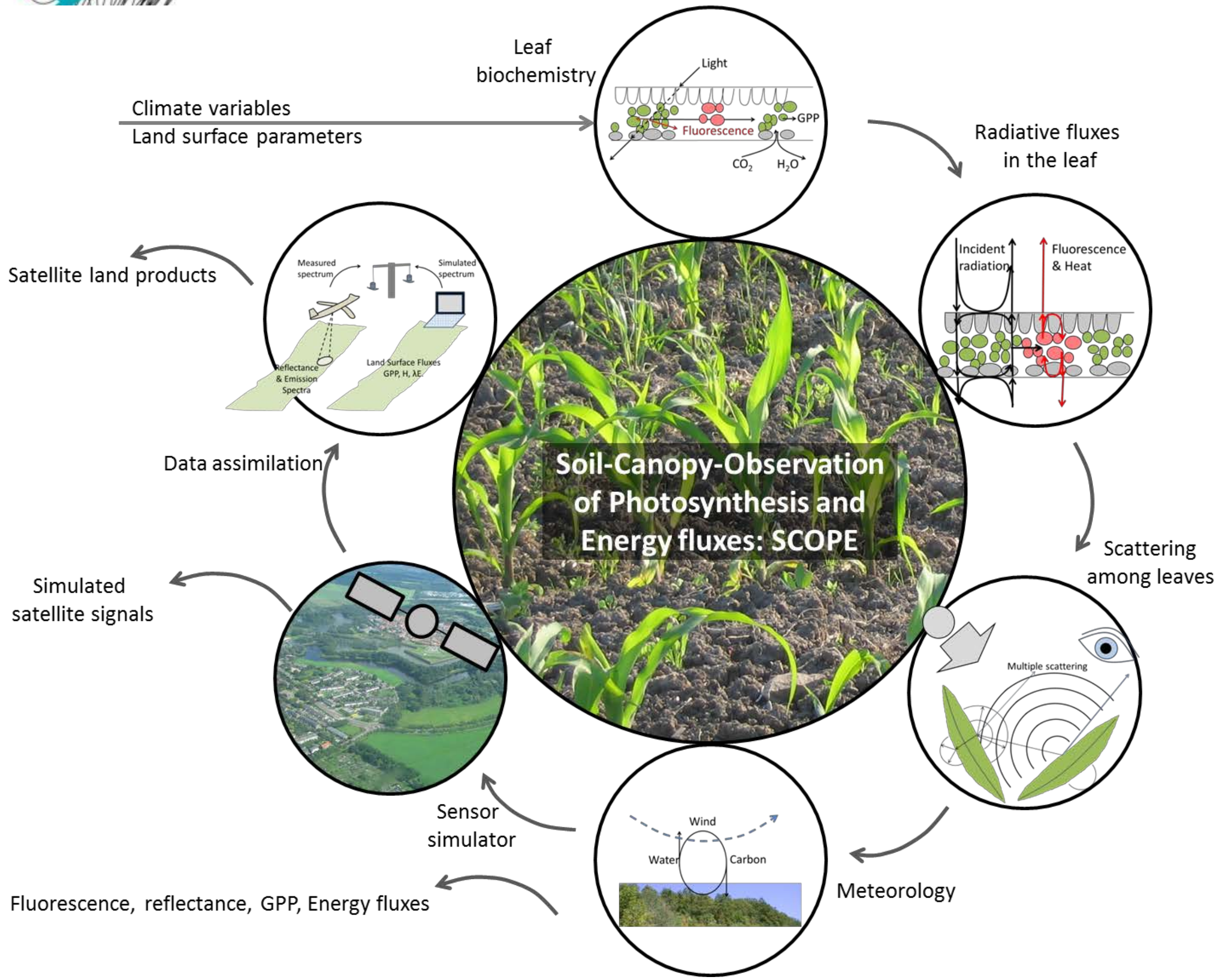
**(YU, Zeng & Su, 2018, unpublished)**

# STEMMUS + TeC: If the enhanced soil water and heat transfer process have effects on ecosystem functioning? – L. Yu



# STEMMUS + SCOPE: If the enhanced soil water and heat transfer process have effects on ecosystem functioning? – Y. Wang

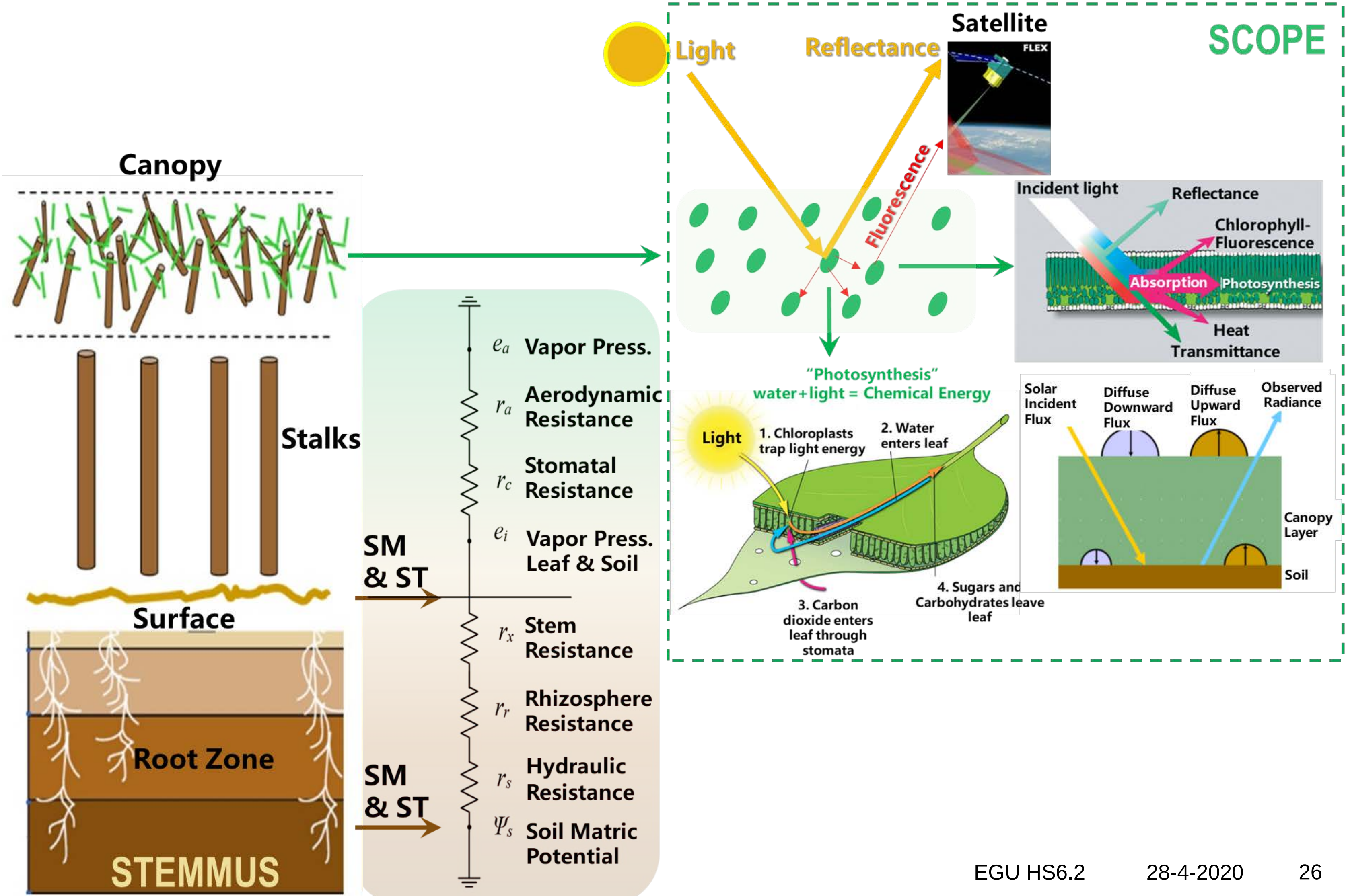



**- Integrated model of soil-canopy spectral radiances, photosynthesis, fluorescence, temperature and energy balance**

**- It considers the radiative transfer and energy balance at leaf level.**

**- Currently one of selected algorithms for ESA's FLEX mission (Earth Explorer, Fluorescence Explorer - FLEX).**

# STEMMUS + SCOPE: If the enhanced soil water and heat transfer process have effects on ecosystem functioning? – Y. Wang



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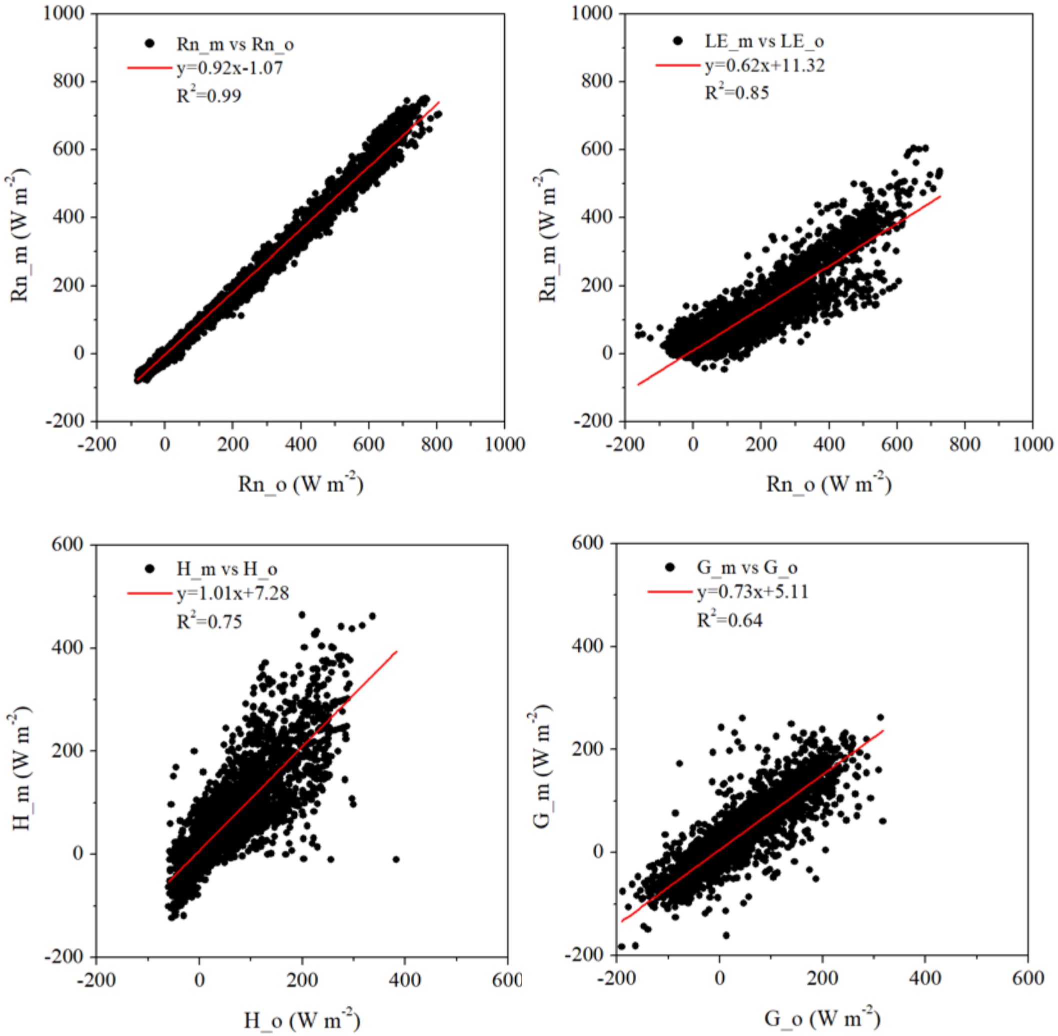
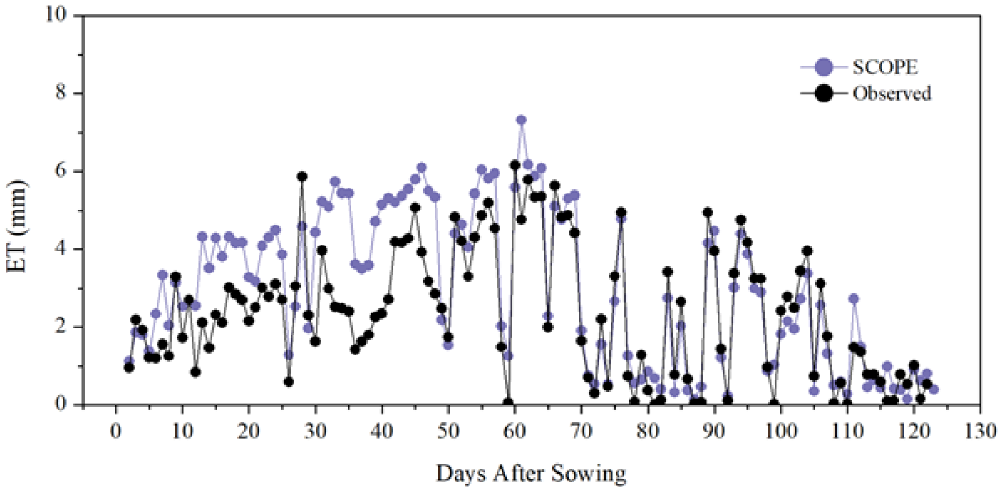
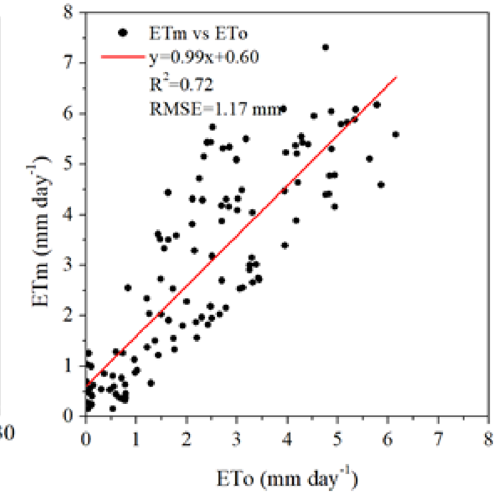
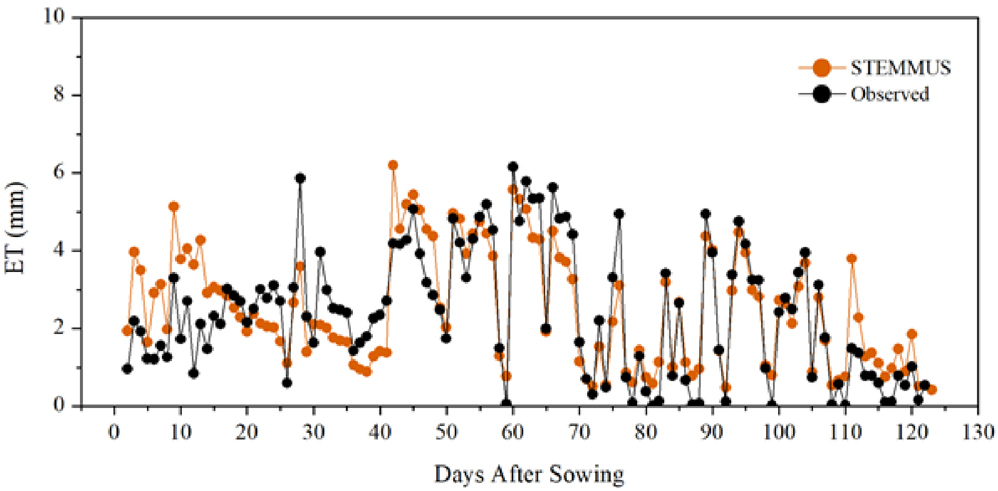


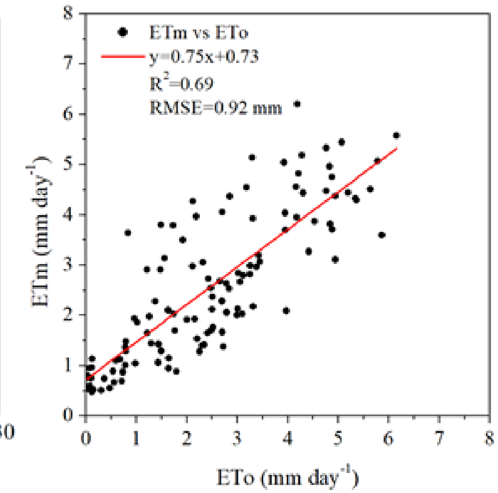

**Comparison of observed and modeled half-hourly Net radiation (Rn), Latent heat (LE), Sensible heat (H) and soil heat flux (G).**

# STEMMUS + SCOPE: If the enhanced soil water and heat transfer process have effects on ecosystem functioning? – Y. Wang



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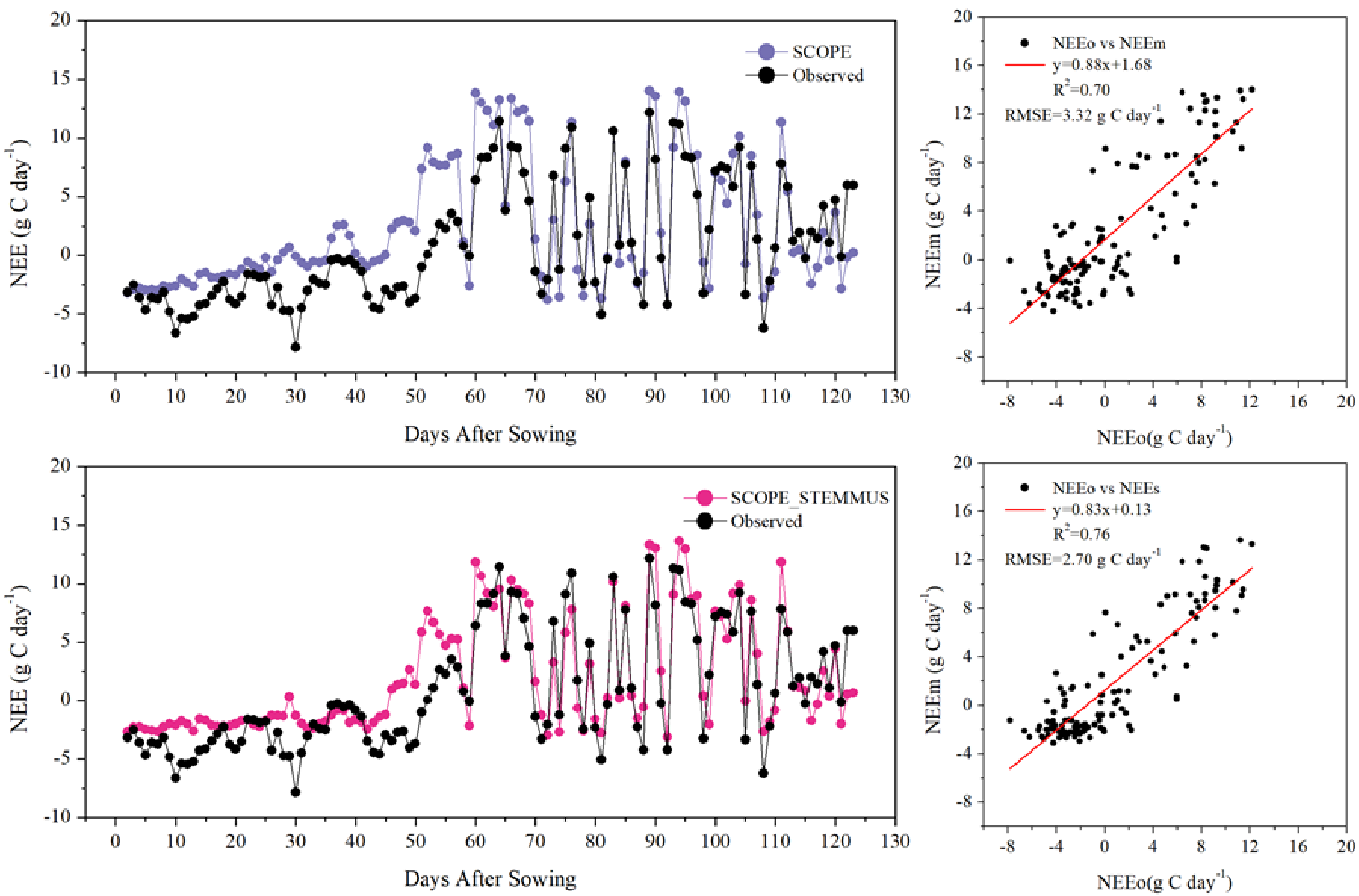
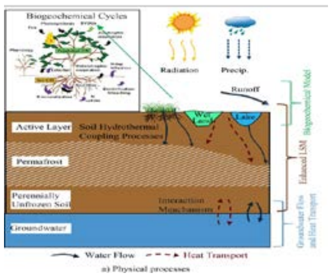
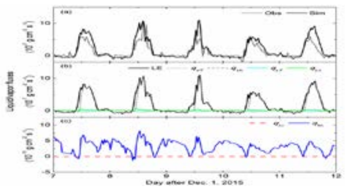


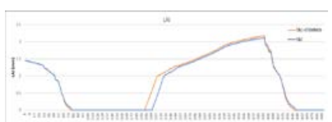
# CONCLUSIONS



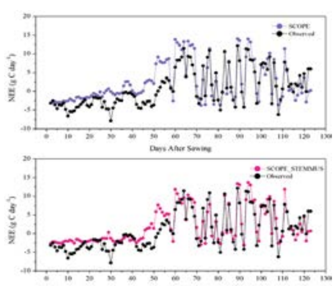

- Over Tibetan Plateau, the freezing-thawing processes link closely to hydrological processes, requiring an integrated approach;



- STEMMUS-FT is capable to capture the subtle land flux changes during winter period, which is often ignored;

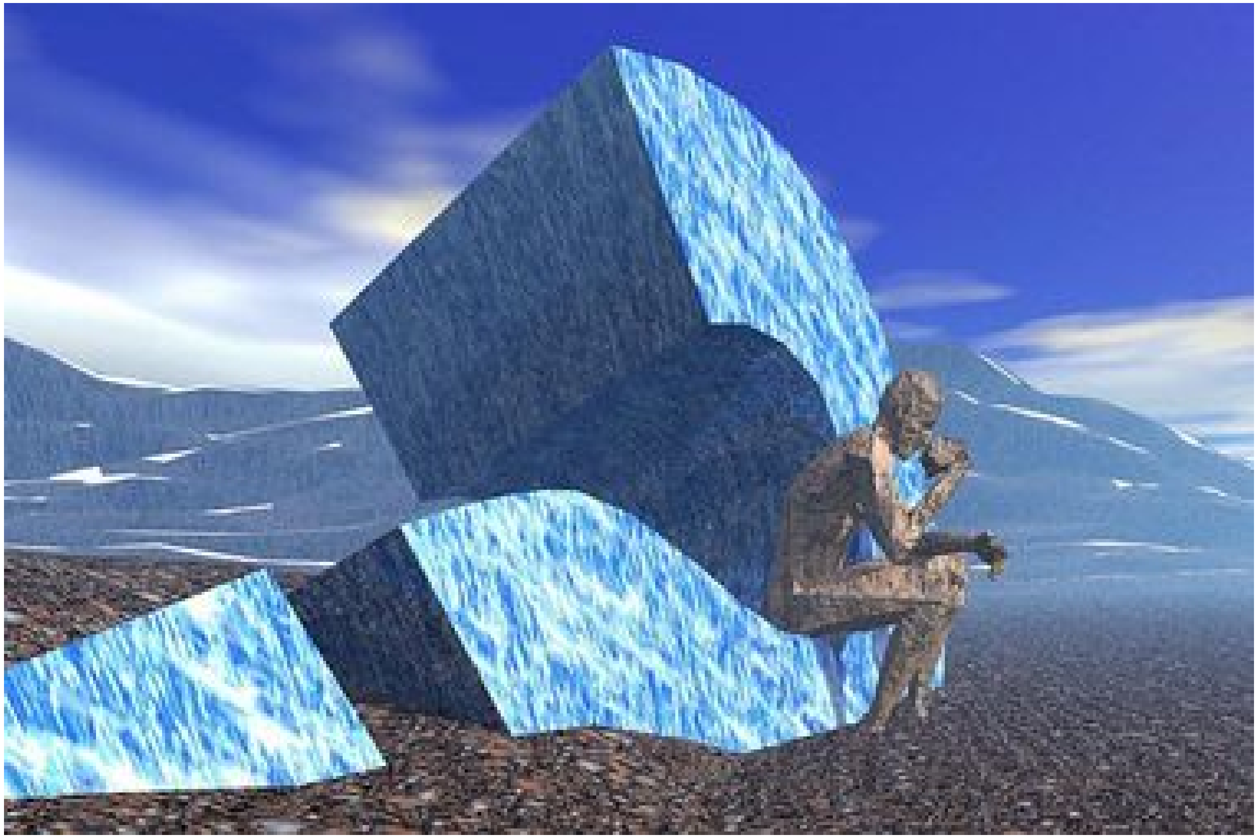


- STEMMUS + TeC show that the enhanced soil water and heat transfer can revive vegetation about 2 weeks earlier;



- STEMMUS + SCOPE show that the enhanced soil water and heat transfer can improve the Net Ecosystem Exchange of CO2.

# THANK YOU FOR YOUR ATTENTIONS



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