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# Modelling experiments on seasonal ice mass and energy balance of a shallow lake in the central Qinghai-Tibet Plateau (QTP)

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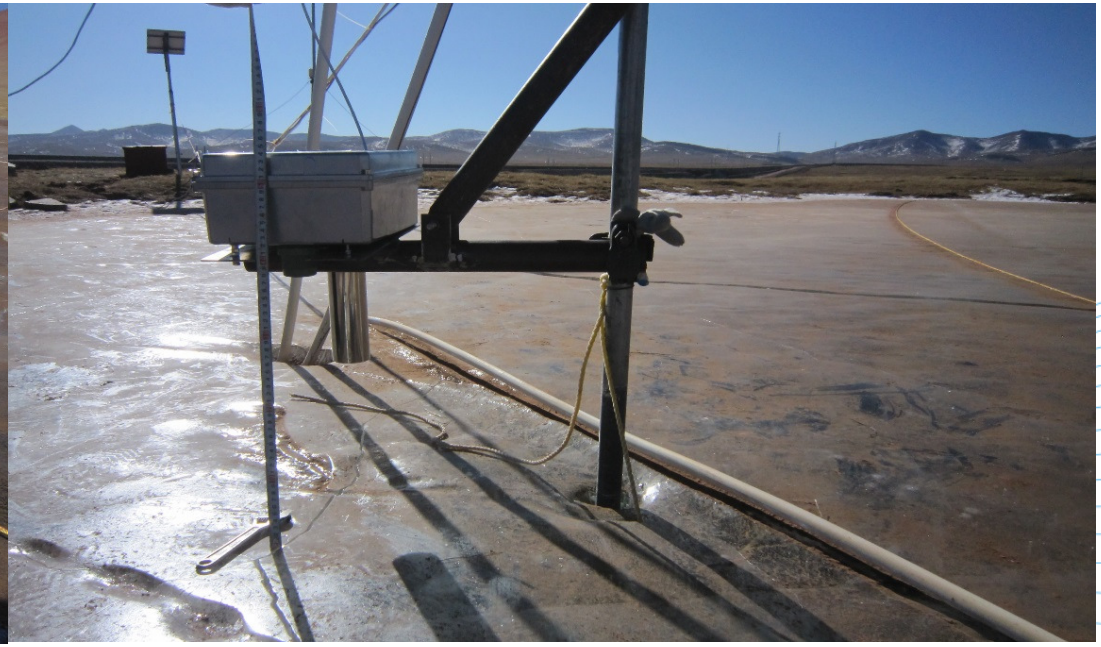
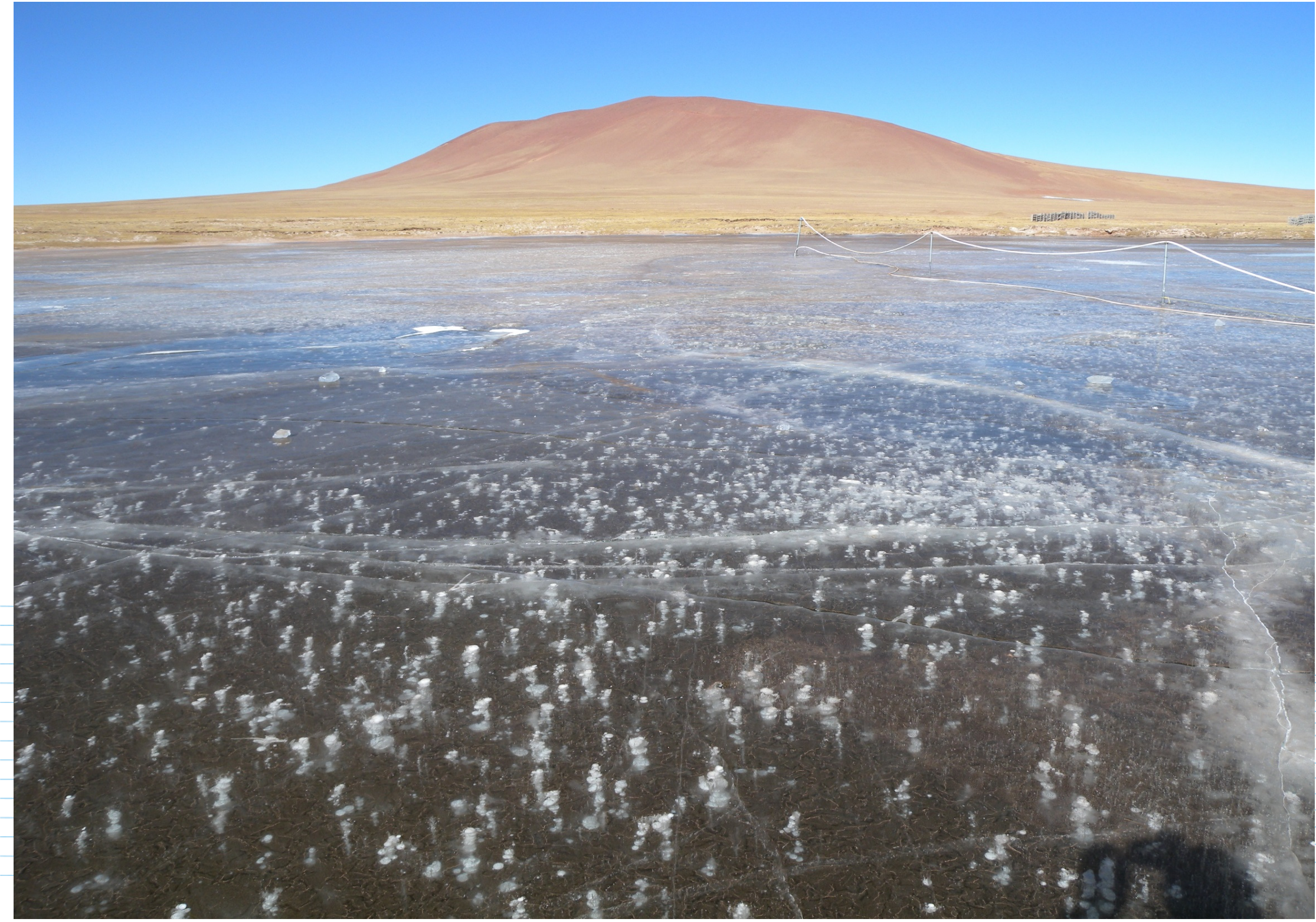
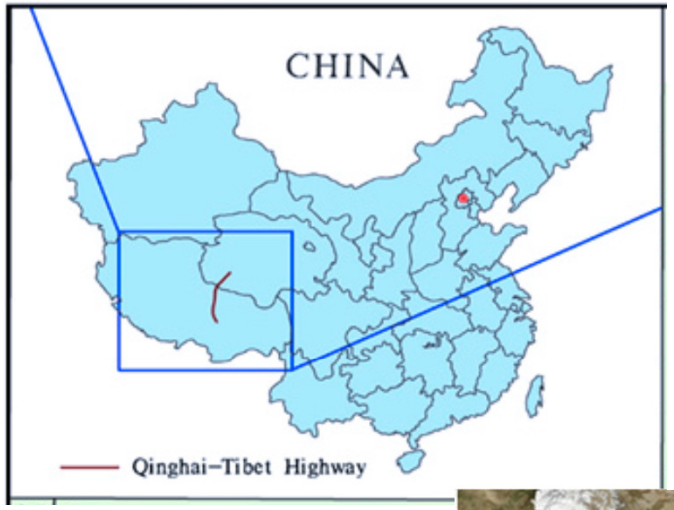


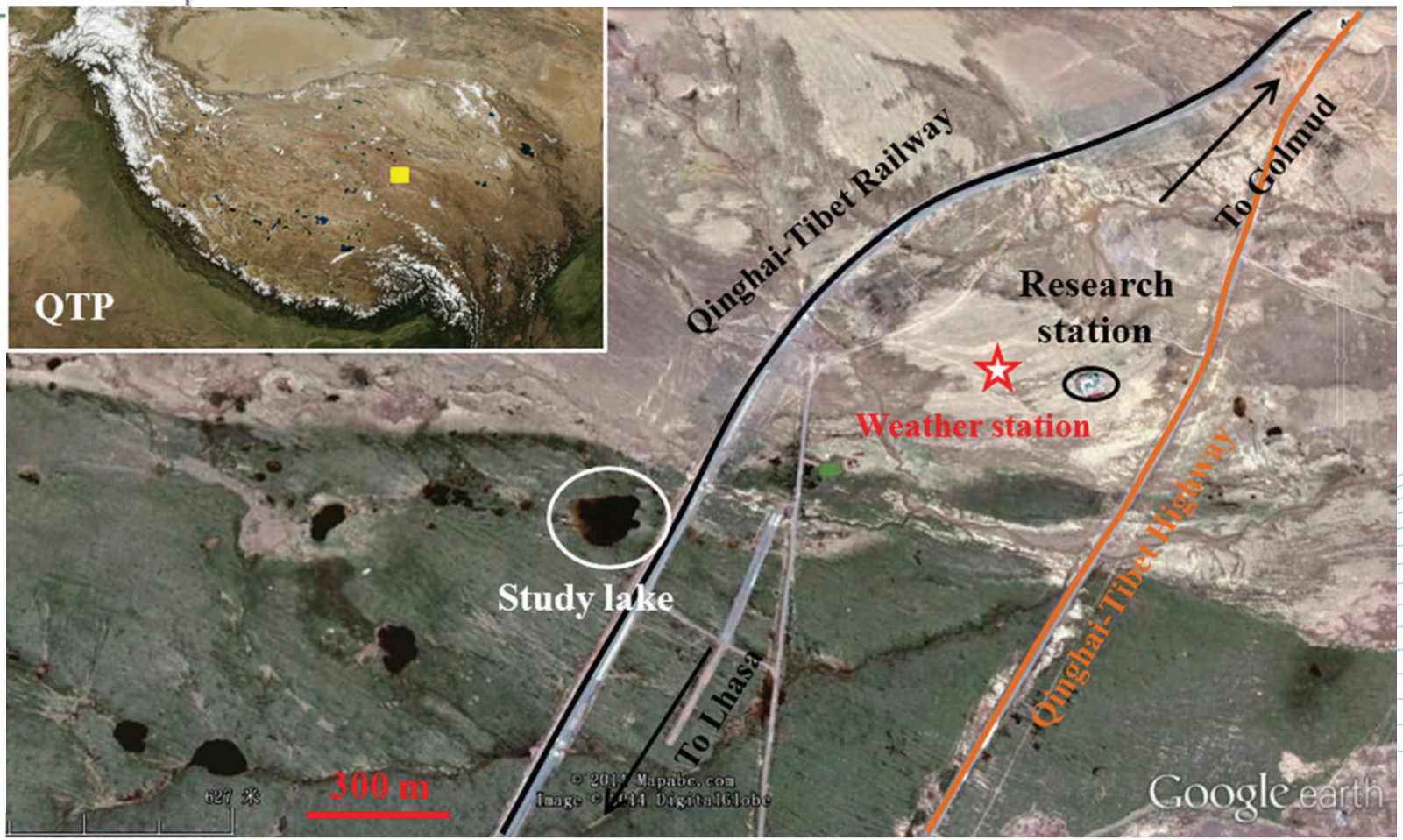


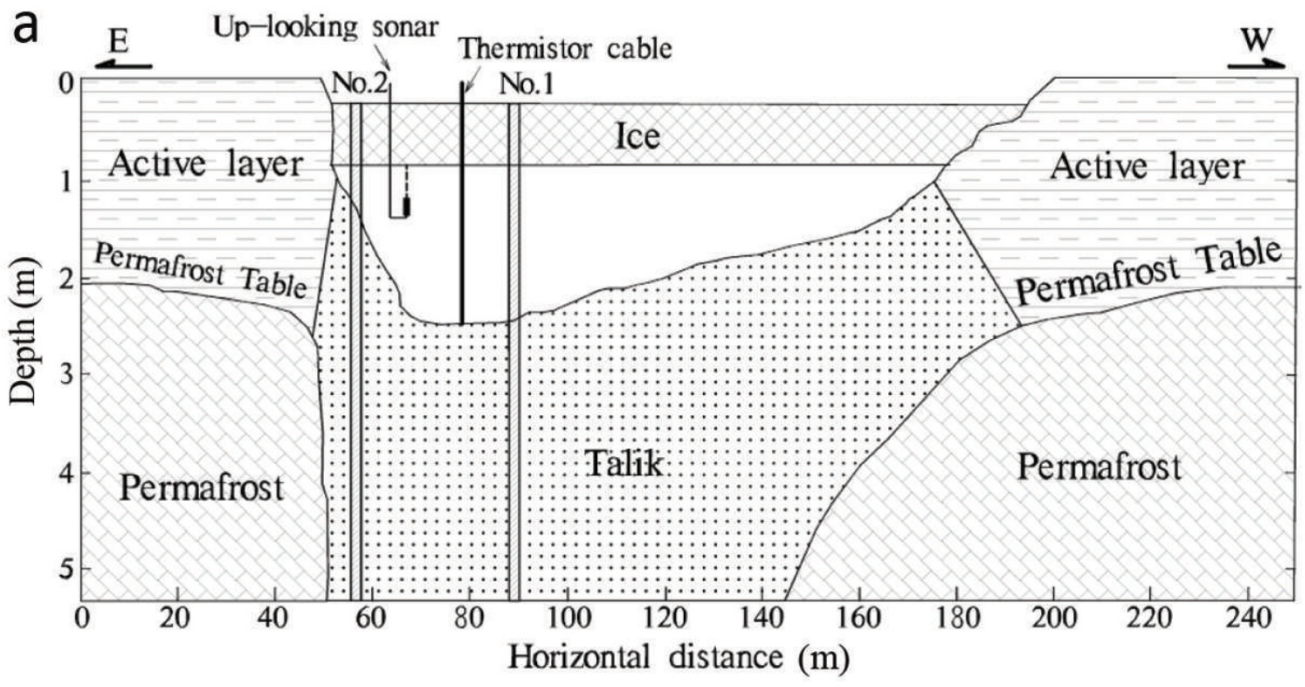
# Characteristic of QTP and motivation of this study

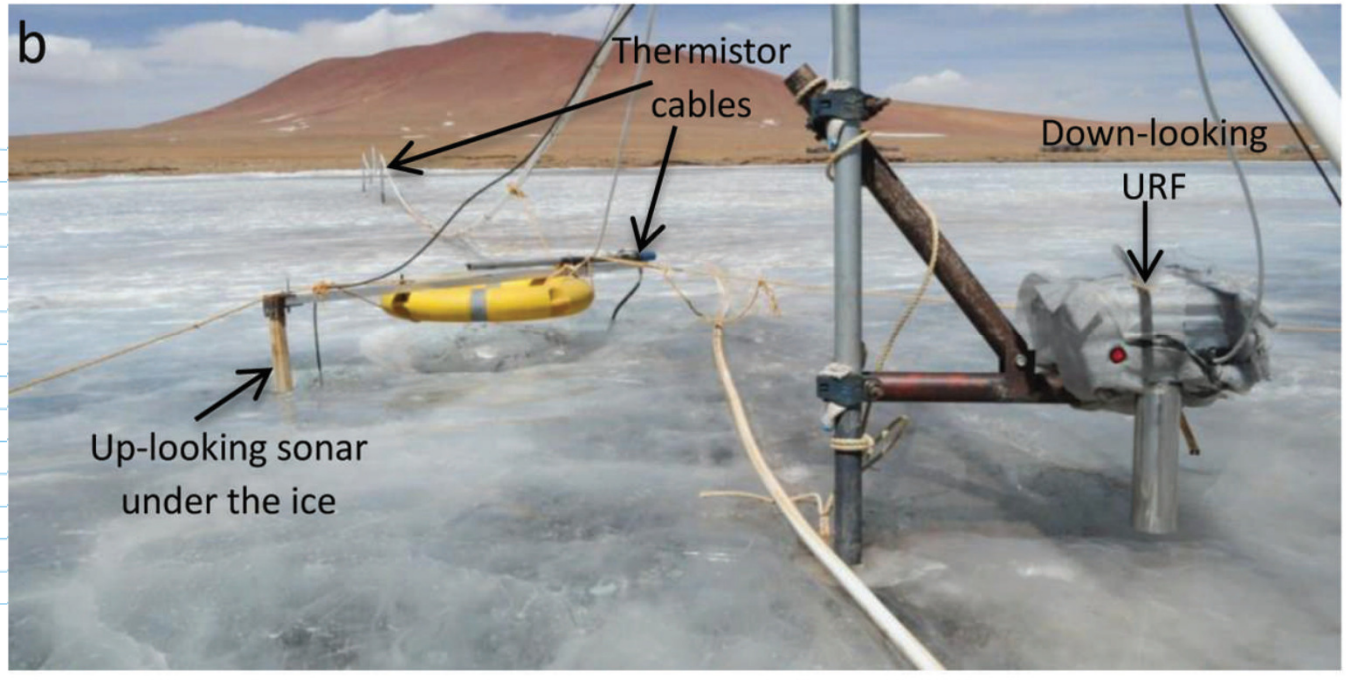
- mean altitude of more than 4000 m above sea level.
- predominated by a freezing climate.
- Often referred to as the “Third Pole of the Earth”.
- The lakes and ponds in QTP region play a crucial role on surface and subsurface hydrological processes, regional moisture and heat budgets as well as gas emission.
- Total number of lakes >1000
- Total surface area: ~40,700 $km^2$
- **Modelling investigation on ice mass balance of a shallow lake in central QTP in order to (1) identify major driving forces that control the seasonal ice mass balance; (2) quantify the components of ice mass and energy balance**



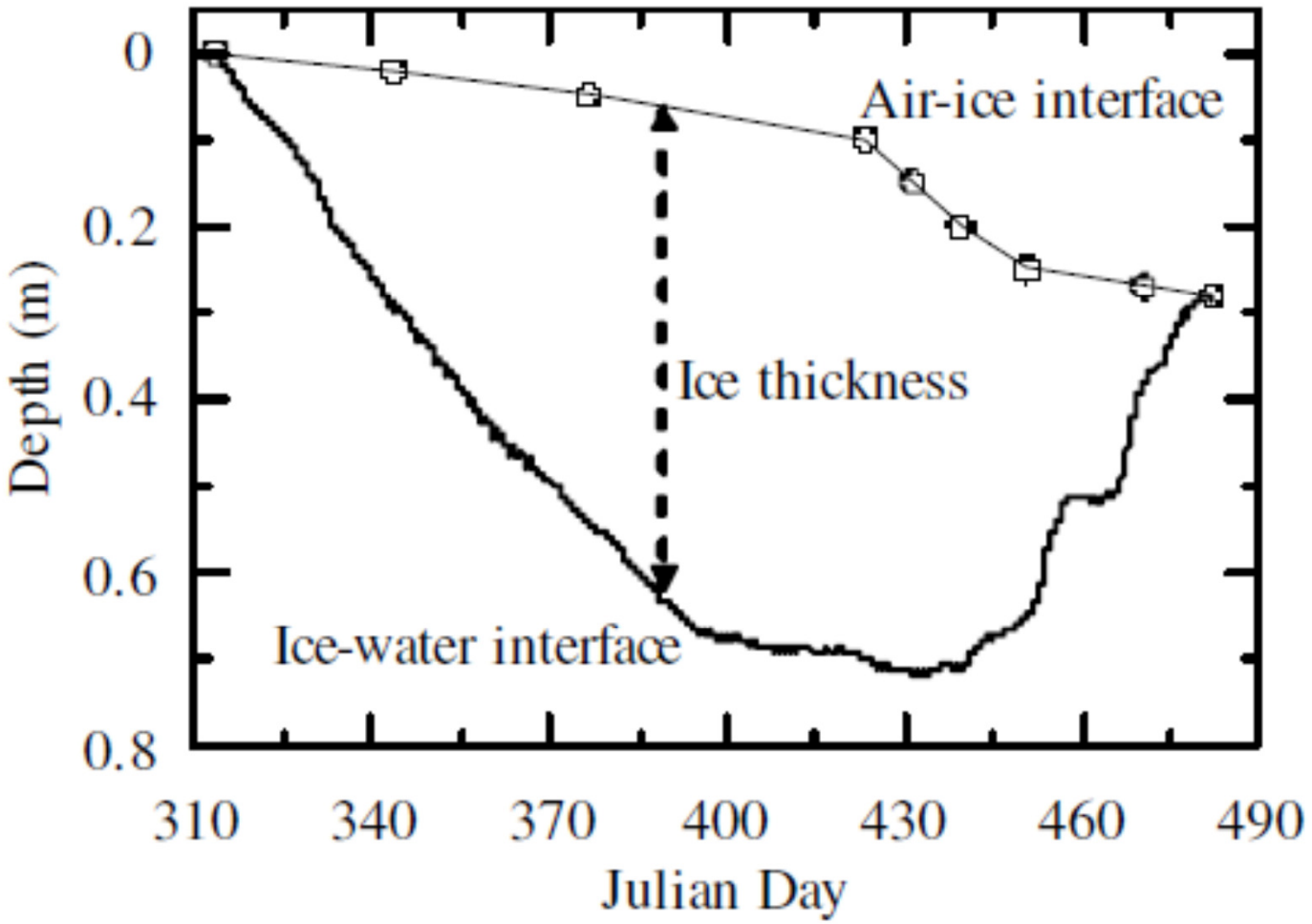

**Location of the study area in the QTP, China. The study lake BLH-A in Beiluhe Basin is around 4500 m above sea level.**



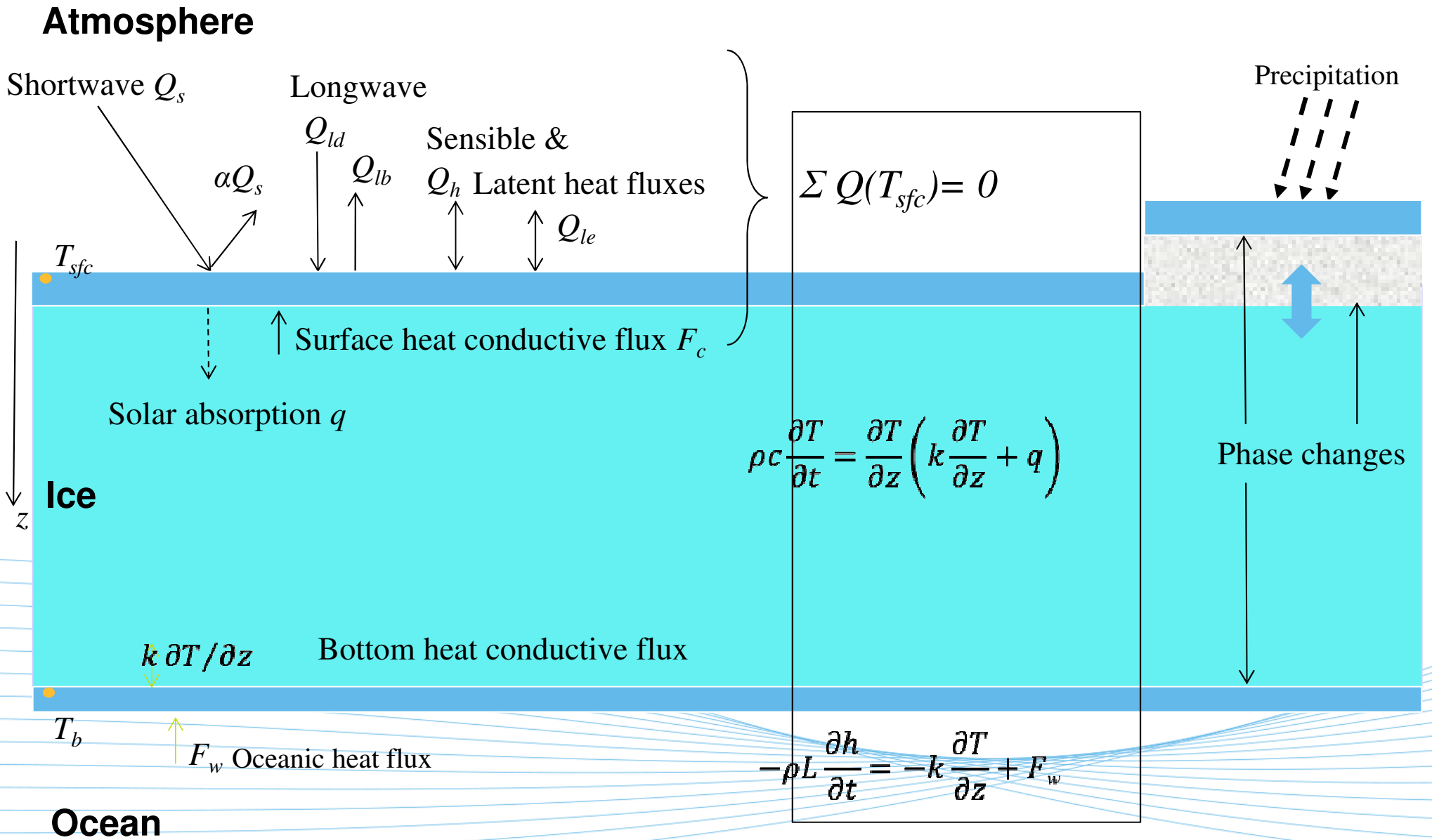

a
E
W
Up–looking sonar
No.2
Thermistor cable
No.1
Ice
Active layer
Active layer
Permafrost Table
Permafrost Table
Depth (m)
Permafrost
Talik
Permafrost
0
1
2
3
4
5
0
20
40
60
80
100
120
140
160
180
200
220
240
Horizontal distance (m)


b
Thermistor
cables
Down-looking
URF
Up-looking sonar
under the ice


c



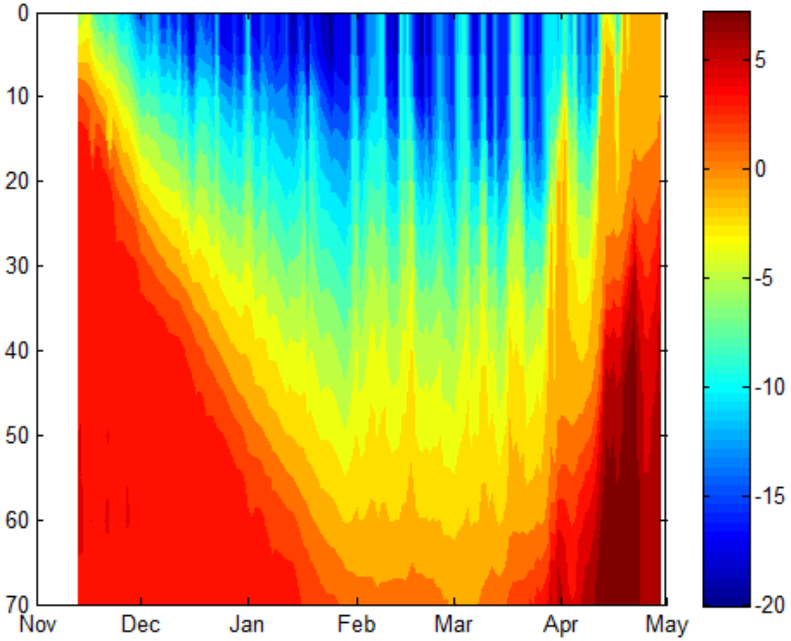

**The observed lake ice thickness evolution over the whole 2010/2011 ice season. The open circles denote the observed surface depths, and the solid lines connecting the circles are based on linear interpolation.**

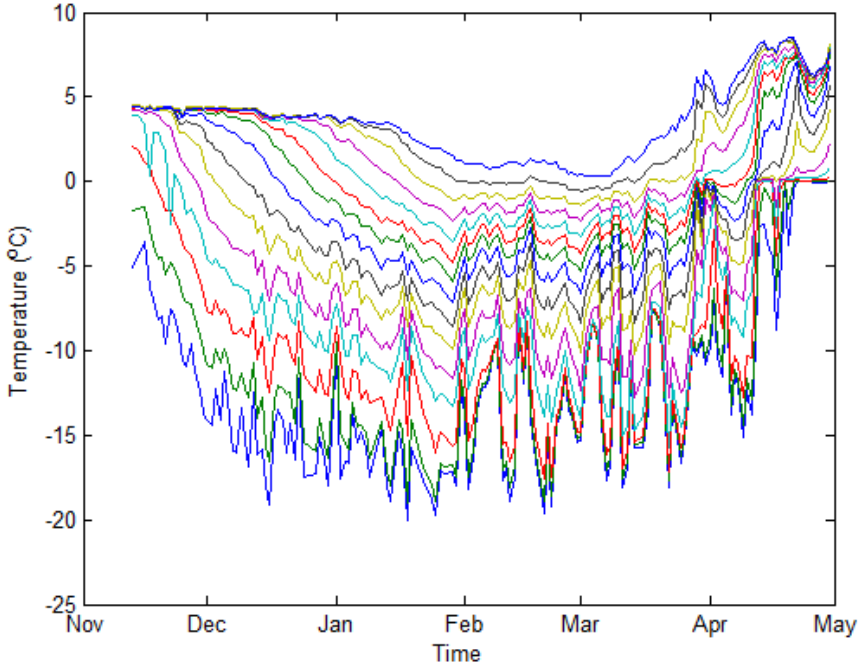

Atmosphere
Shortwave $Q_s$
Longwave
$Q_{ld}$
$Q_{lb}$
$\alpha Q_s$
Sensible &
$Q_h$ Latent heat fluxes
$Q_{le}$
$\Sigma\, Q(T_{sfc}) = 0$
Precipitation
$T_{sfc}$
Surface heat conductive flux $F_c$
Solar absorption $q$
$\rho c \frac{\partial T}{\partial t} = \frac{\partial T}{\partial z}\left(k\frac{\partial T}{\partial z} + q\right)$
Phase changes
Ice
$z$
$k\,\partial T/\partial z$
Bottom heat conductive flux
$T_b$
$F_w$ Oceanic heat flux
$-\rho L \frac{\partial h}{\partial t} = -k\frac{\partial T}{\partial z} + F_w$
Ocean

**The air temperature remain quite cold during most of the simulation period (9,Nov. 2010 - 30, Apr. 2011, Ta (mean) = -10.6 ° C)**

**The heat flux from lake/pond bottom has a strong seasonal cycle.**

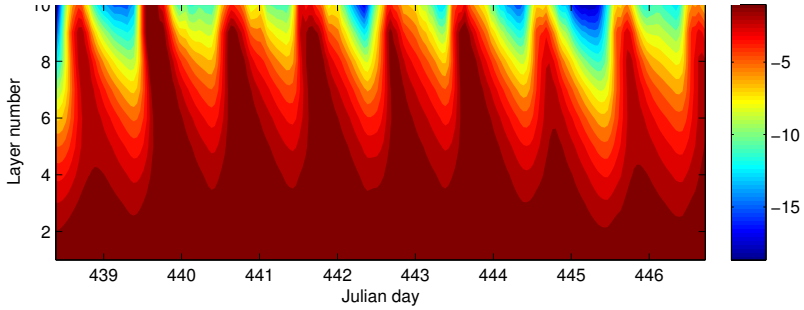
**Meteorological measurement: Va. Ta, Rh, CN, PrecS, Qs, QI**




Very strong diurnal variation of in-ice temperature

Observation and modelling



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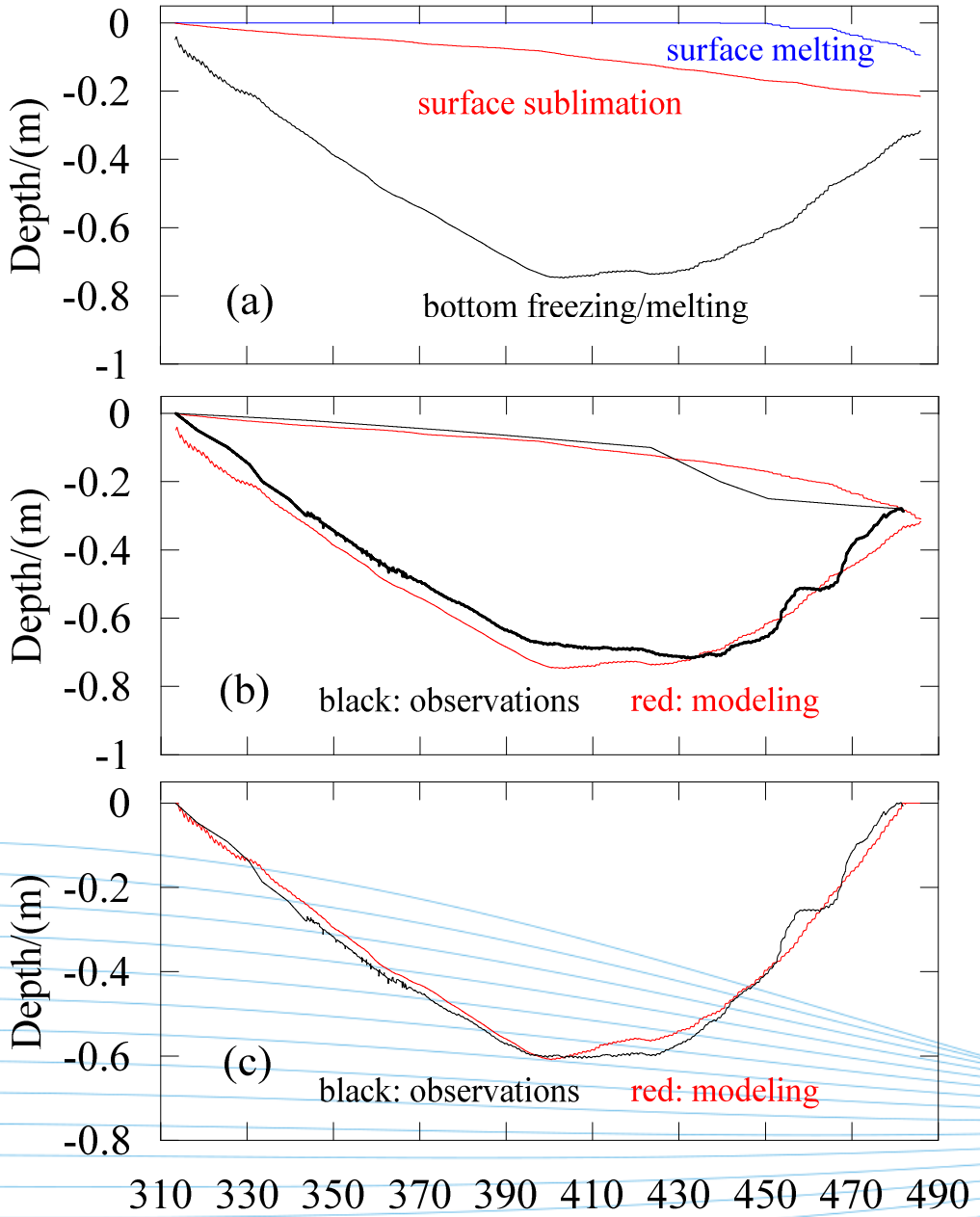
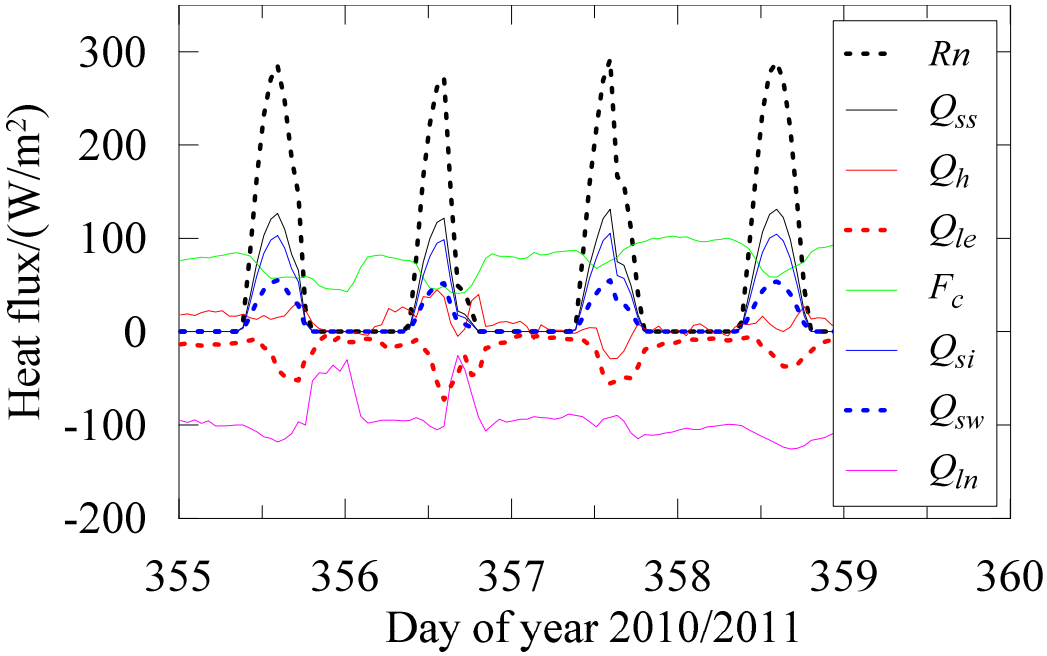



**(a) Modelled BLH-A lake ice mass balance components;**

**(b) The ice surface and bottom evolution**

**(c) The total ice thickness**




$Q_{ss}$: net solar radiation

$Q_{si}$: solar radiation absorption within the ice interior

$Q_{sw}$: solar radiation into under-ice water

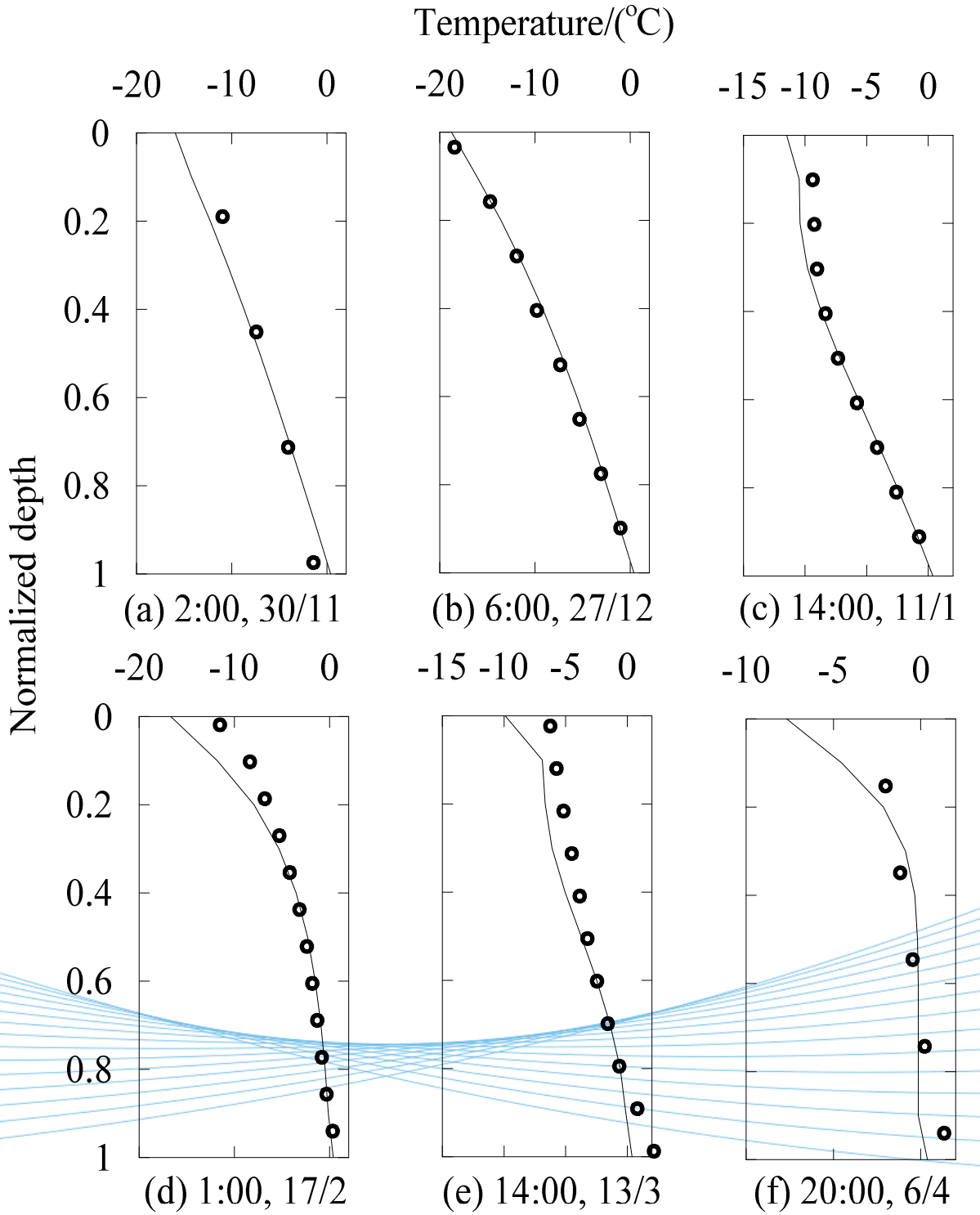
$Q_{ln}$: net longwave radiation

$Q_h$: sensible heat flux

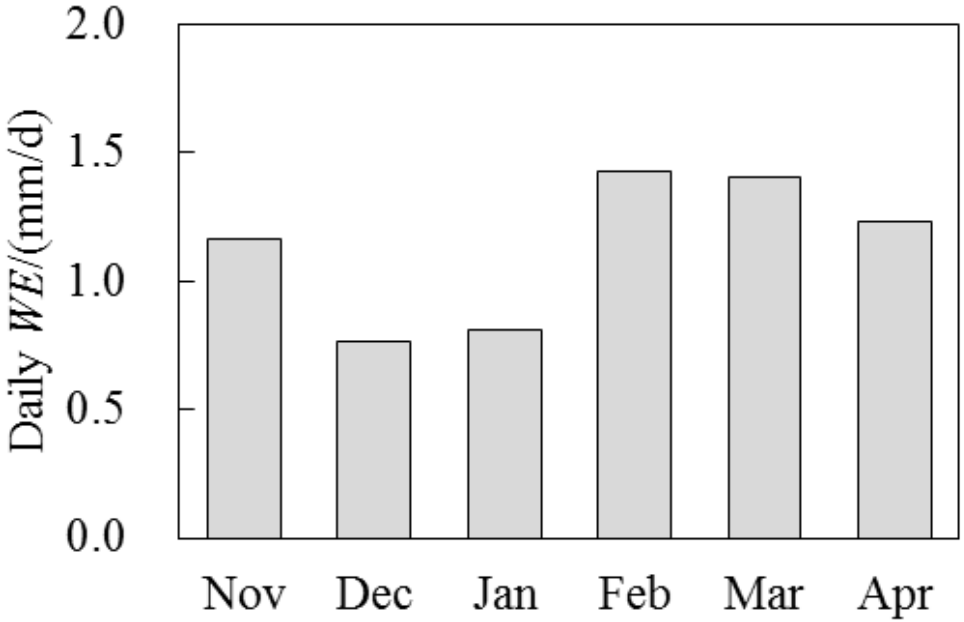
$Q_{le}$: latent heat flux

$F_c$: surface conductive heat flux;

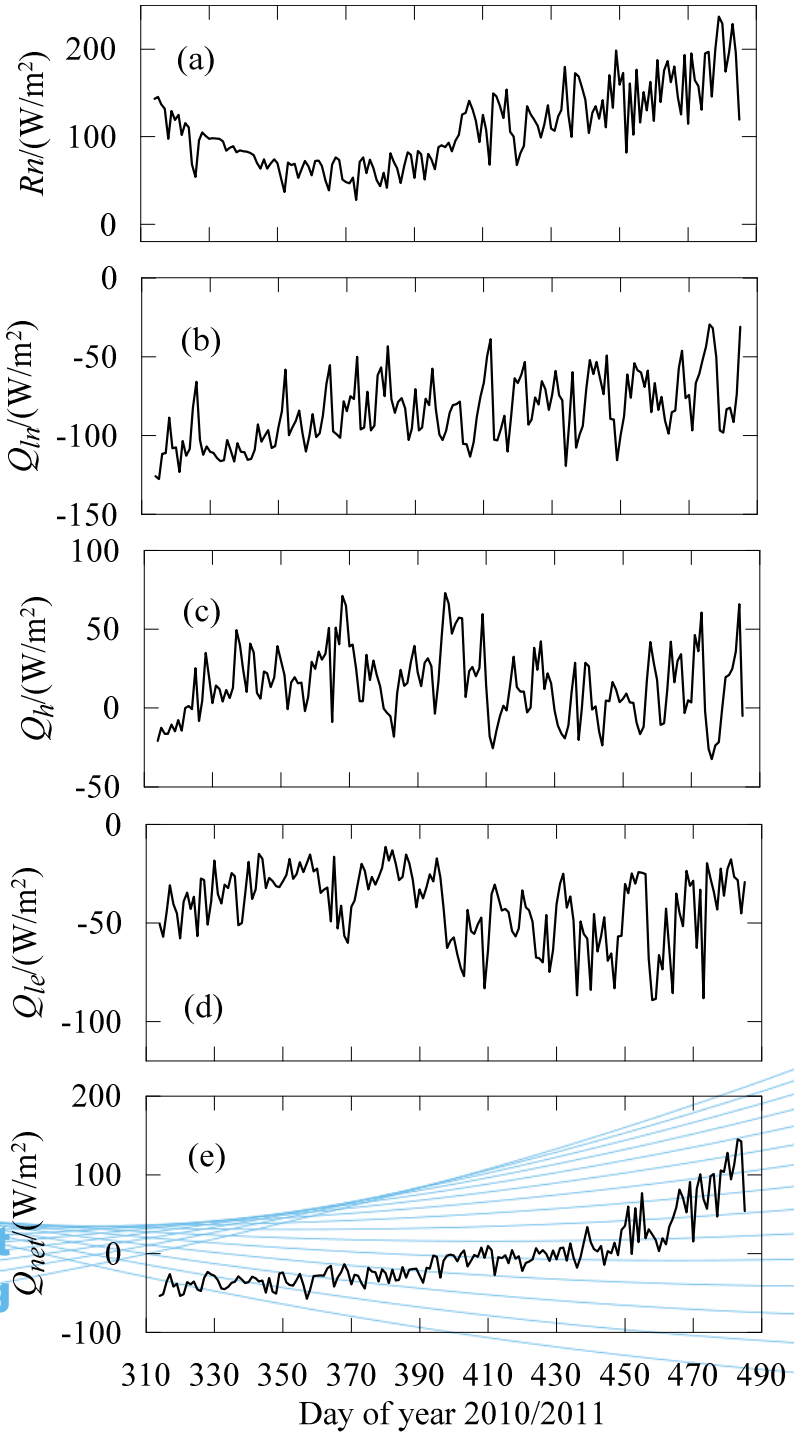
**Comparisons of modelled (lines) and observed (circles) ice temperature profiles at selected time steps.**
**A normalized depth (depth/thickness) is used as the y-axis (0 and 1 denote the ice surface and bottom, respectively).**



**Daily means of the surface energy balance components of net shortwave (Rn) and longwave (Qln) radiation, turbulent sensible (Qh) and latent (Qle) heat fluxes, and net flux into the lake (Qnet = Rn+Qln+Qh+Qle) though the entire ice season. This Qnet is used partly to create surface layer ice melting/freezing (in model), partly to change the ice temperature and ice interior melt, partly to cause bottom ice layer freezing/melting (in model), and partly to heat the under-ice water temperature.**




**The monthly mean daily accumulated water equivalent mass flux caused by ice surface sublimation during 2010/2011 winter season.**



# Main findings

- During winter, the ice mass balance in central QTP shallow lake is dominated by the basal growth; In winter 2010/2011 it reached 0.7m whereas at the ice surface there was a distinct erosion caused by sublimation.
- Model provides good estimation of ice mass balance both at the surface and bottom.
- During spring, ice melting occurred internally as well as at the ice bottom. A good agreement between observed and modelled net ice thickness was largely supported by the good in-ice temperature simulations.
- The surface evaporation/sublimation is a primary way of ice mass loss.