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Sensitivity of Bowen ratio of water bodies to air temperature

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1.INTRODUCTION

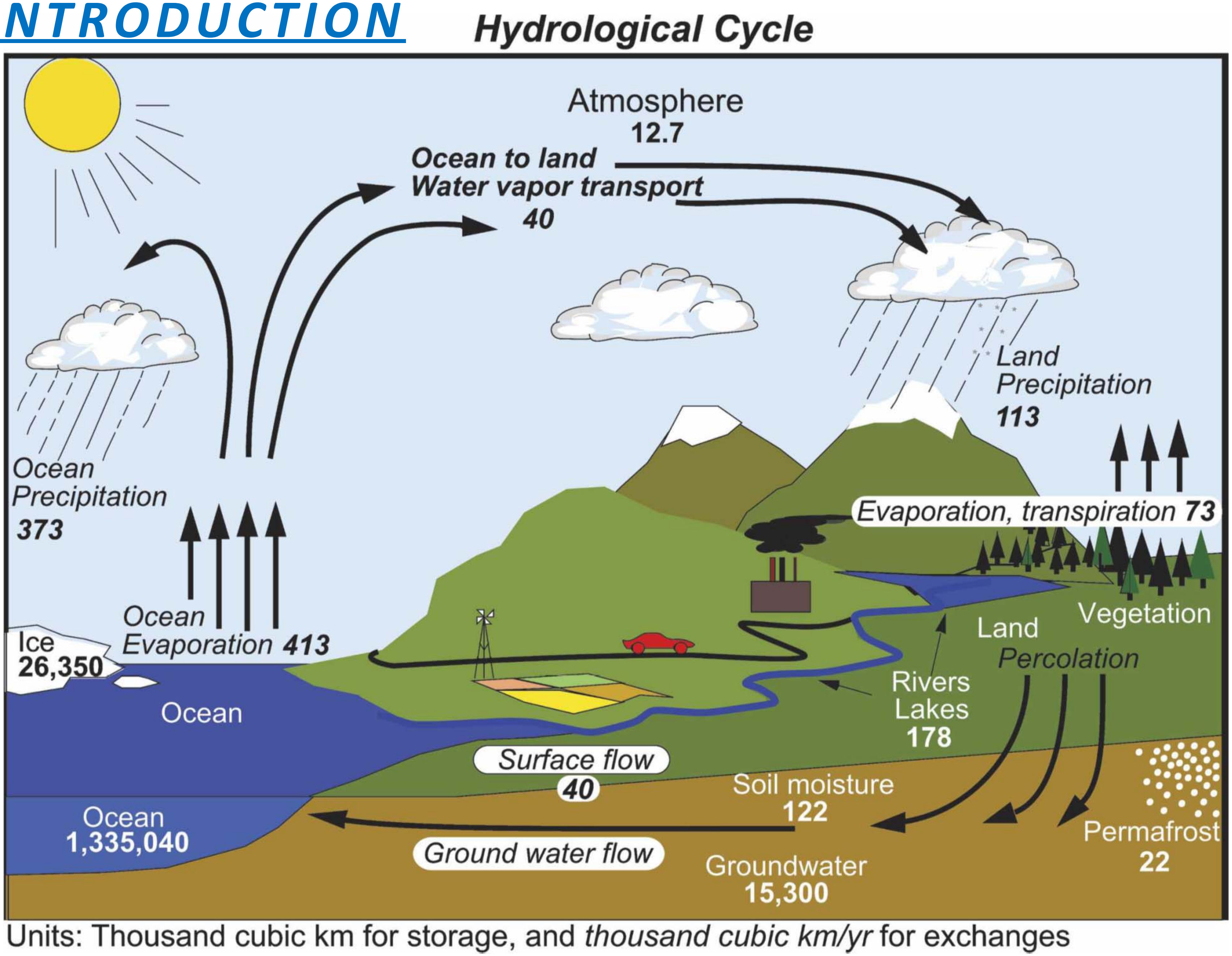
Why choosing water bodies?

- Inland water bodies occupy 4% of the continent surface, oceans cover 71% of the earth surface; *(Downing et al., 2006)*

- Energy partitioning between latent and sensible heat flux of water bodies play a crucial role in determining hydrological cycle, weather and climate change; *(Wilson et al., 2002)*

- Rare knowledge on variability of energy partitioning for water bodies, especially under global warming.

1.INTRODUCTION



(Trenberth et al., 2007)

Why choosing air temperature?

- The most important climatological factors influencing land-atmosphere interaction;
- Negative relationship between Bowen Ratio and air temperature; *(Brutsaert 1982)*

$$\beta = \frac{1}{a\left(\Delta/\gamma\right)} + \frac{1}{a} - 1$$

- Alternating energy partitioning as air temperature increasing.

Simple lake model

$$(1-\alpha)K_{\downarrow} + \varepsilon L_{\downarrow} - \varepsilon\sigma T_s^4 = H + \lambda E$$

$$H = \rho_a c_p C_H u(T_s - T_a)$$

$$\lambda E = \rho_a \lambda C_E u(q_s - q_a)$$

Linearization of T_s and q_s

Meteorological drives

Solution of T_s

H, λE, β

β slightly sensitive to wind speed
β not sensitive to radiation
β decrease with air temperature

(Developed by Lee, 2012)

Previous studies

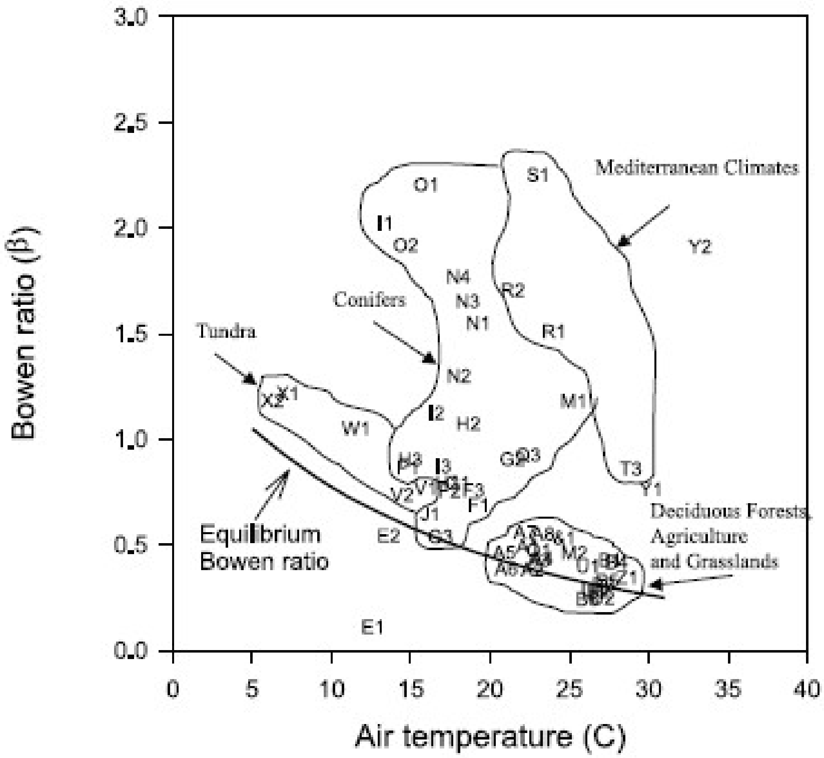


Figure 4. Relationship between mean daytime air temperature and Bowen ratio (β) for the site years in Table 1. Also shown is the equilibrium β. Site years T2 and T3 were off the scale of this graph. Enclosed circles denote subjective delineations between different vegetation types and climates, although there are exceptions.

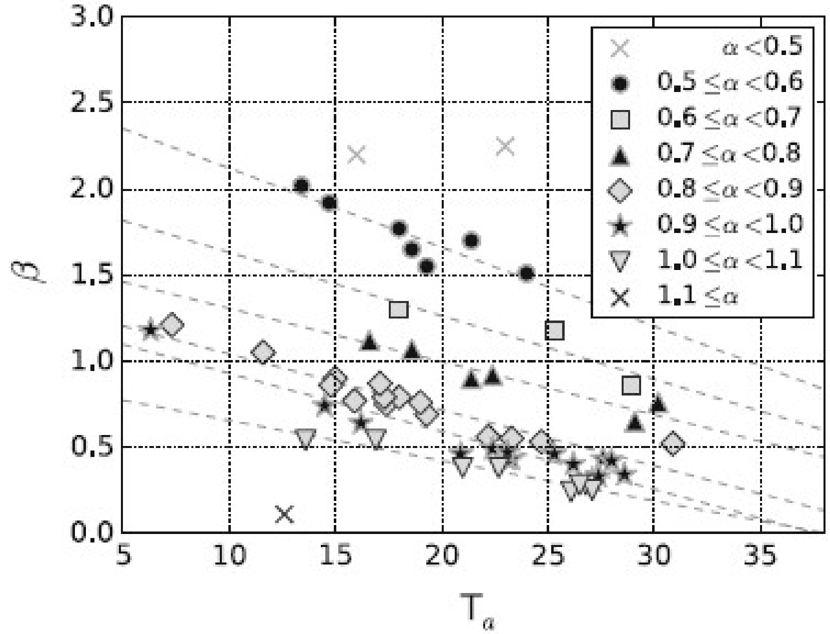


Fig. 7 Relationship between air temperature and Bowen ratio for different intervals of α. The linear regression lines follow are derived individually with respect to the data in each α interval

(Wilson et al., 2002; Cho, J., T. Oki, et al., 2012)

1.INTRODUCTION

Objective

- To quantify the Bowen Ratio’s sensitivity to air temperature from temporal and spatial perspective;

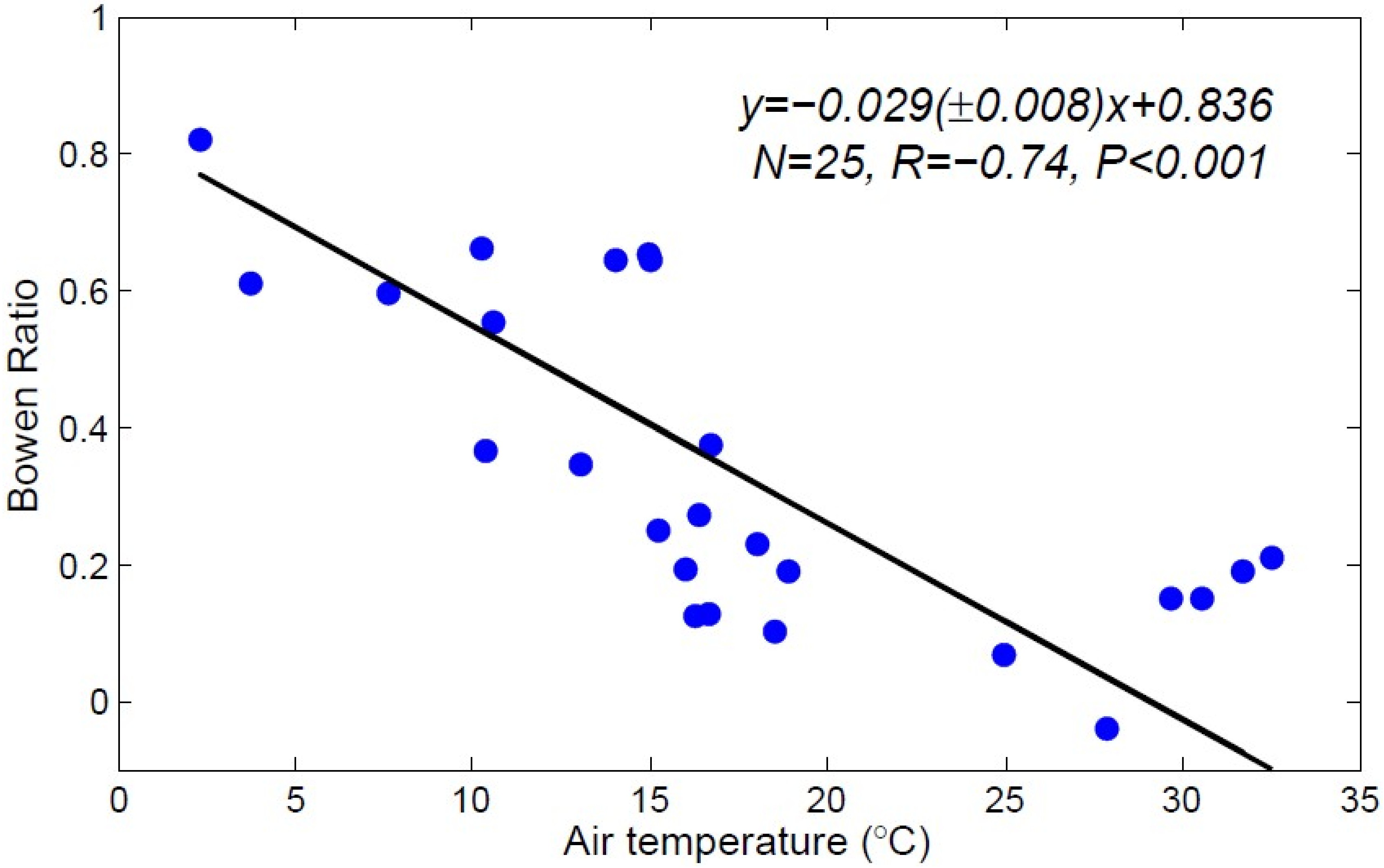
- To understand how Bowen Ratio varying as global warming.

Dataset

Type	Source	Period	Temporal resolution	Spatial resolution	Variables
Spatial	Literature		Annual	25 lakes, NH	H,λE,Ta
	OAFlux	1985-2011	Monthly	1°lat×1°lon,hemispheric	H,λE,Ta
Temporal	OAFlux	1985-2011	Monthly	1°lat×1°lon, global	H,λE,Ta
	CM2.1	2001-2100	Annual	2°lat×2.5°lon, global, 5 scenarios	H,λE,Ta
	Merra	1979-2011	Monthly	1/2°lat×2/3°lon, grid near MLW	Ta,qa,U,Pa,Rad,ε

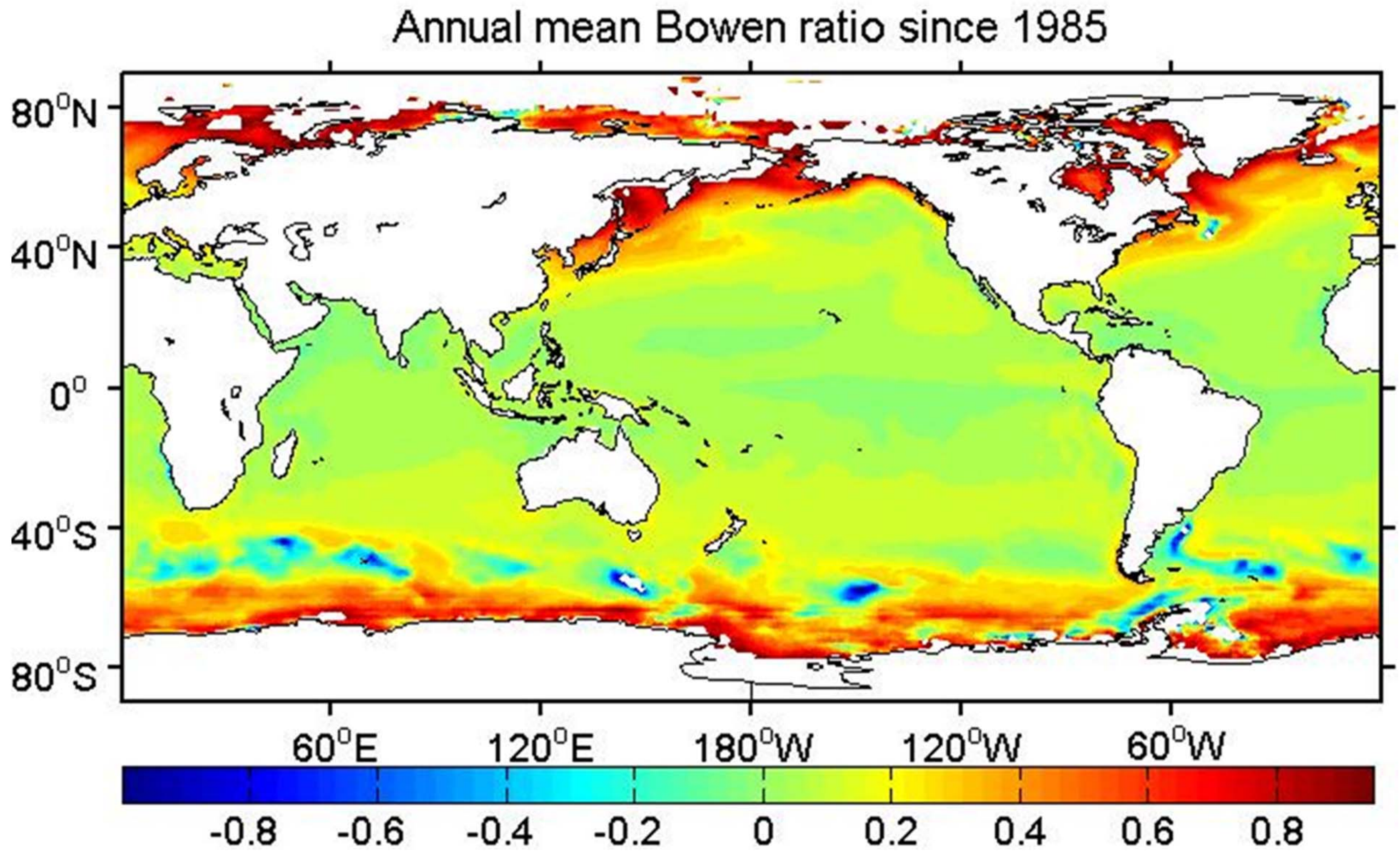
5 scenarios of CM2.1: emission rate order A1FI>A2>A1B>B1>S1.

Literature results (Annual)



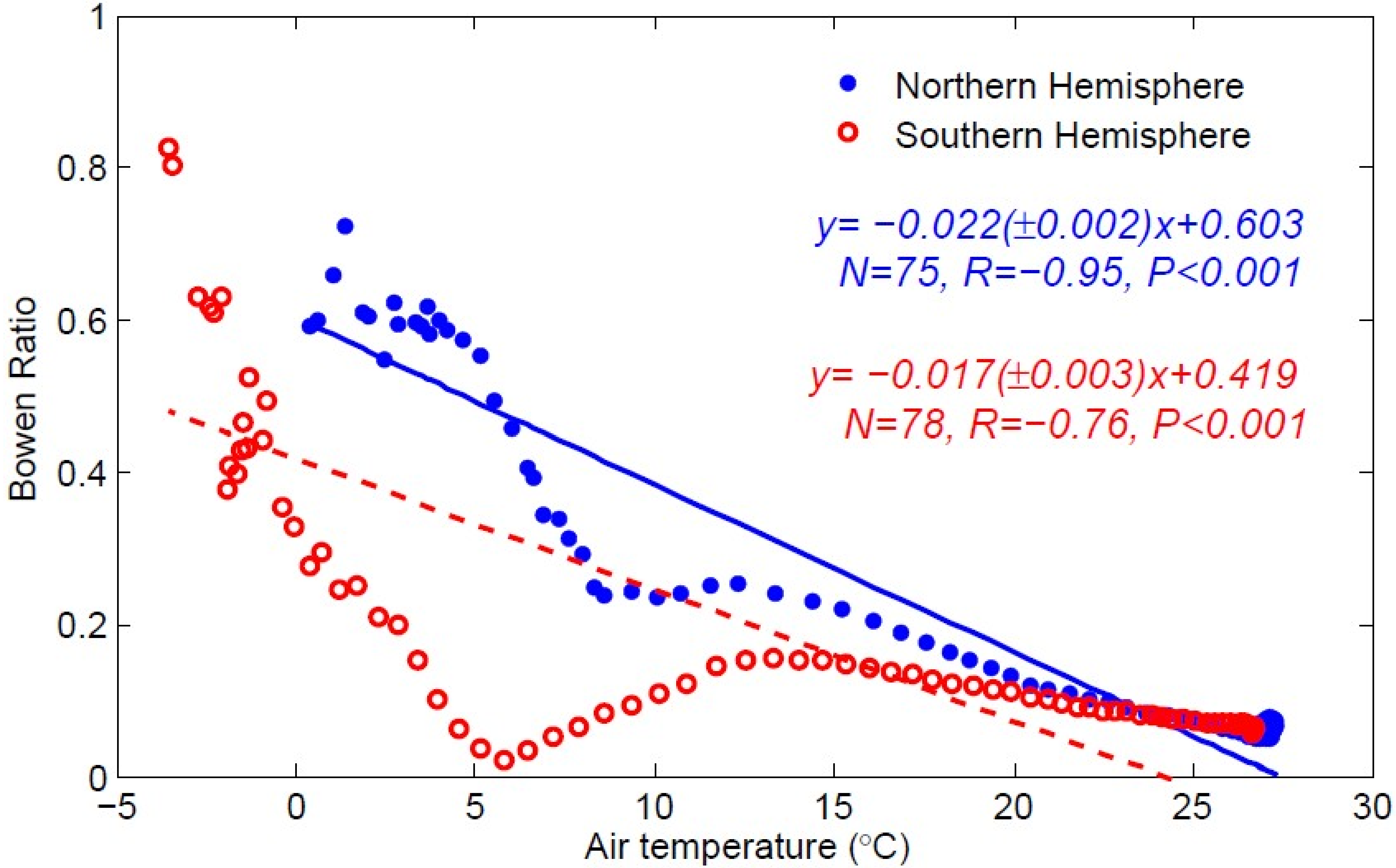
2.RESULTS

Global distribution of Bowen ratio



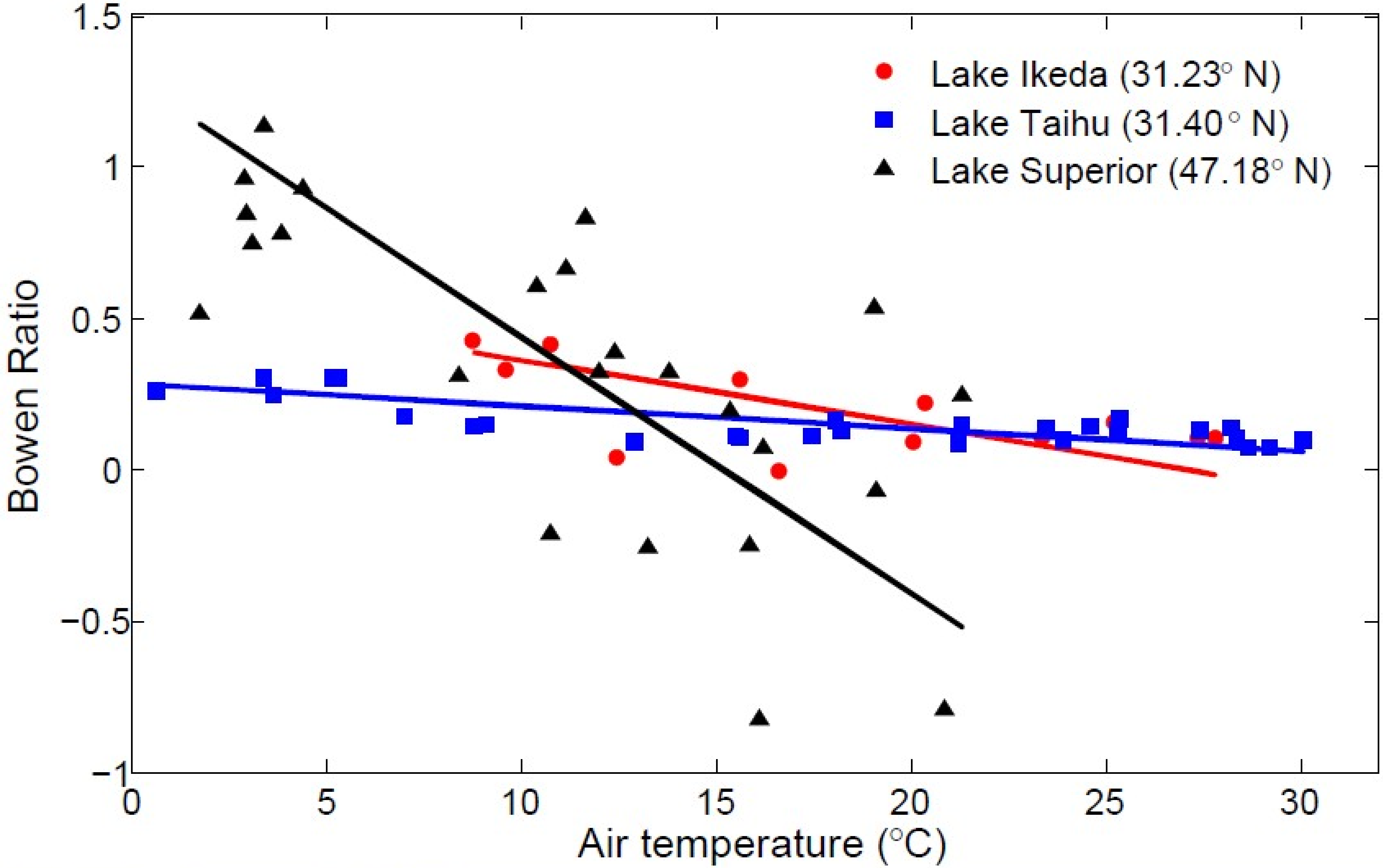
2.RESULTS

Zonal average (Annual)



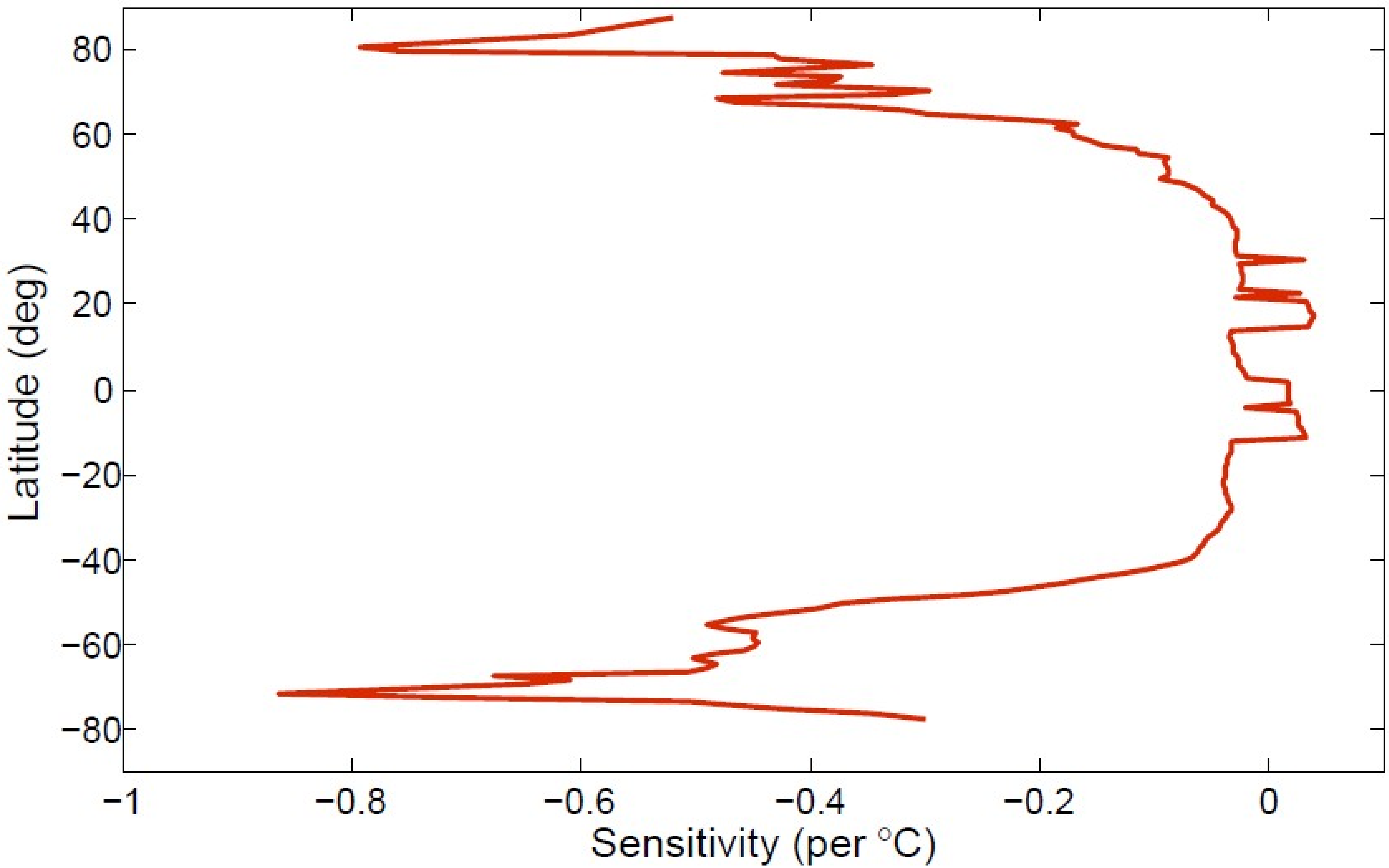
2.RESULTS

Three lakes cases (monthly)



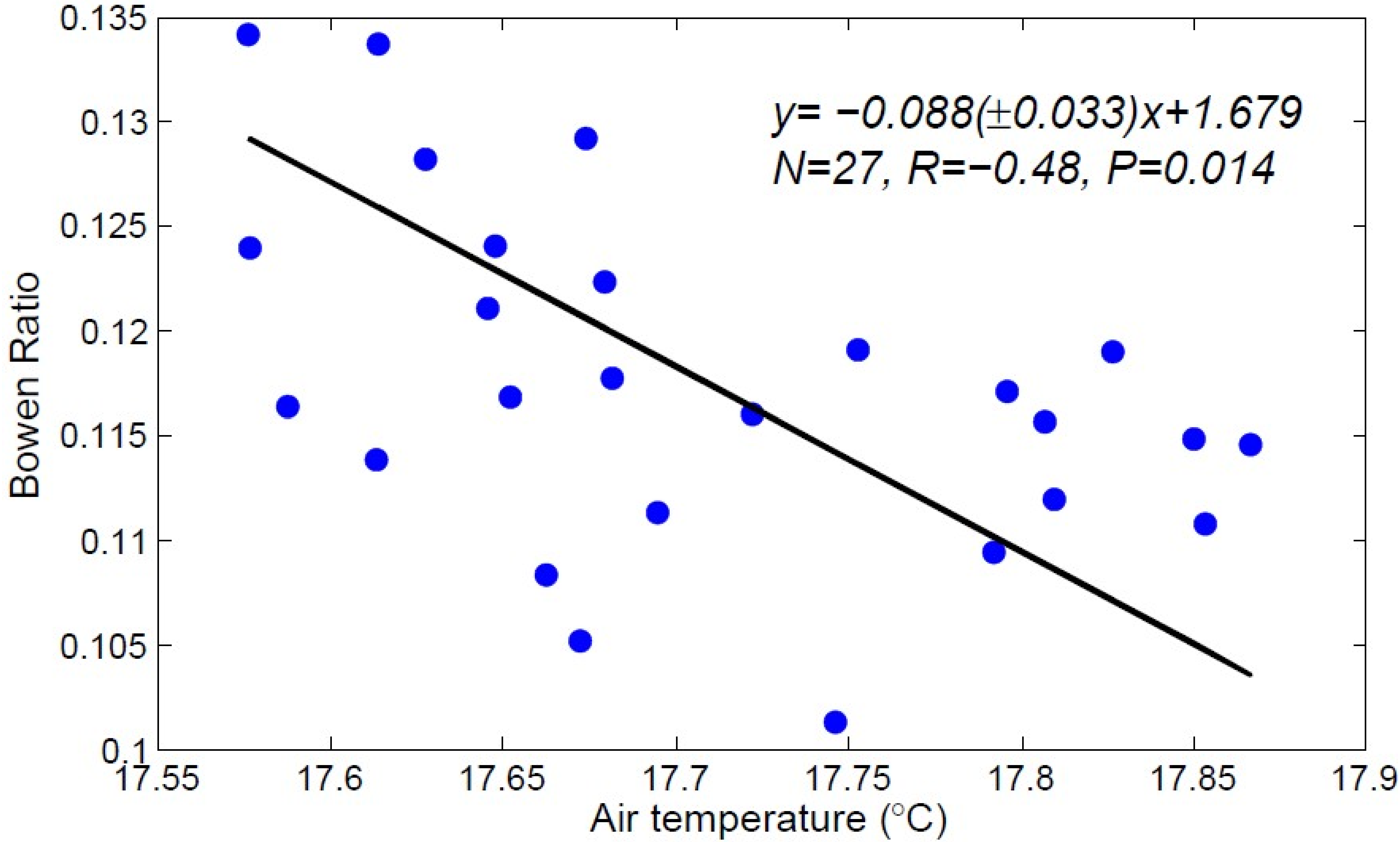
2.RESULTS

Zonal sensitivity



2.RESULTS

Global ocean since 1985 (Annual)



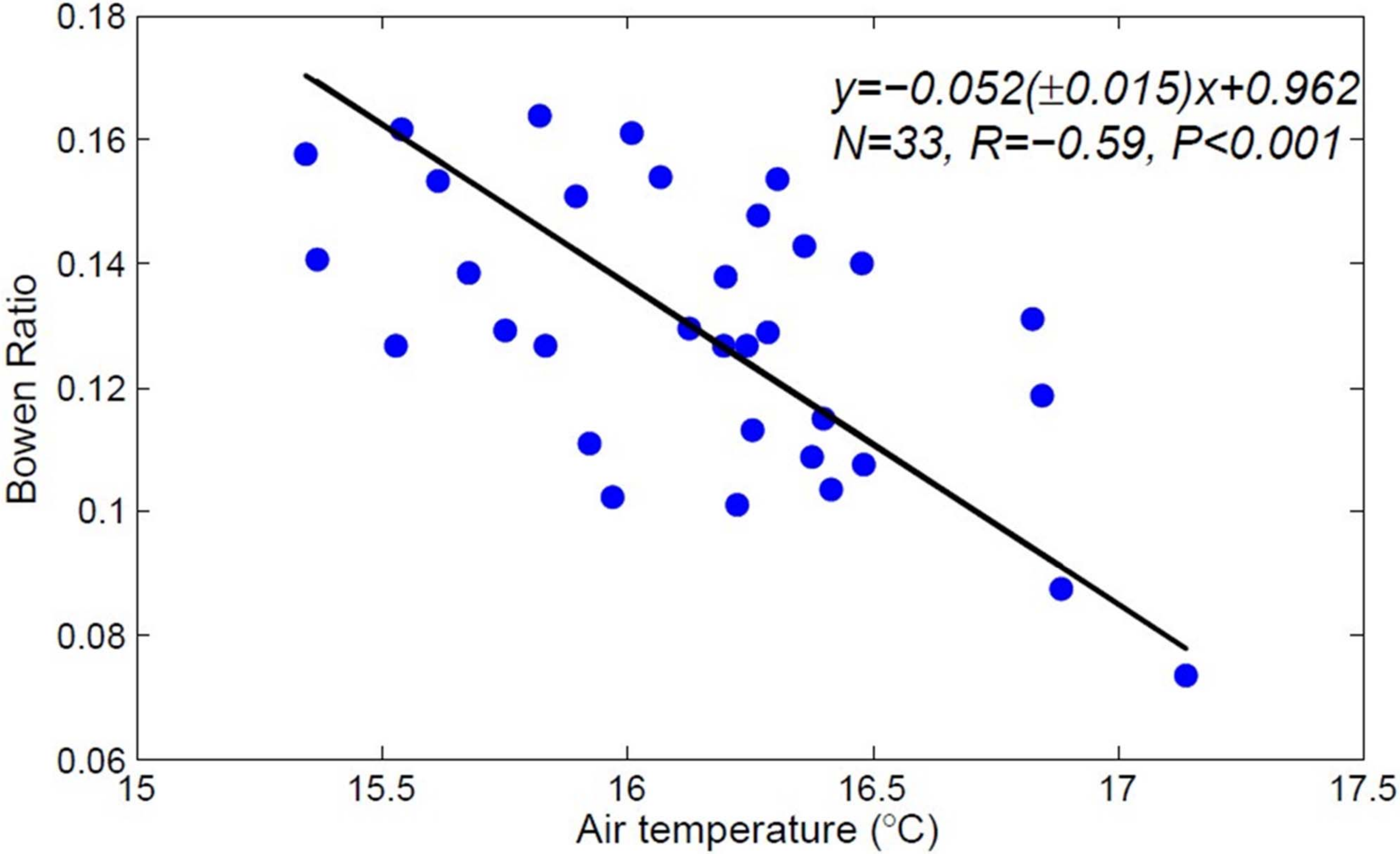
2. RESULTS

Merra inputs and MLW 2011 observation

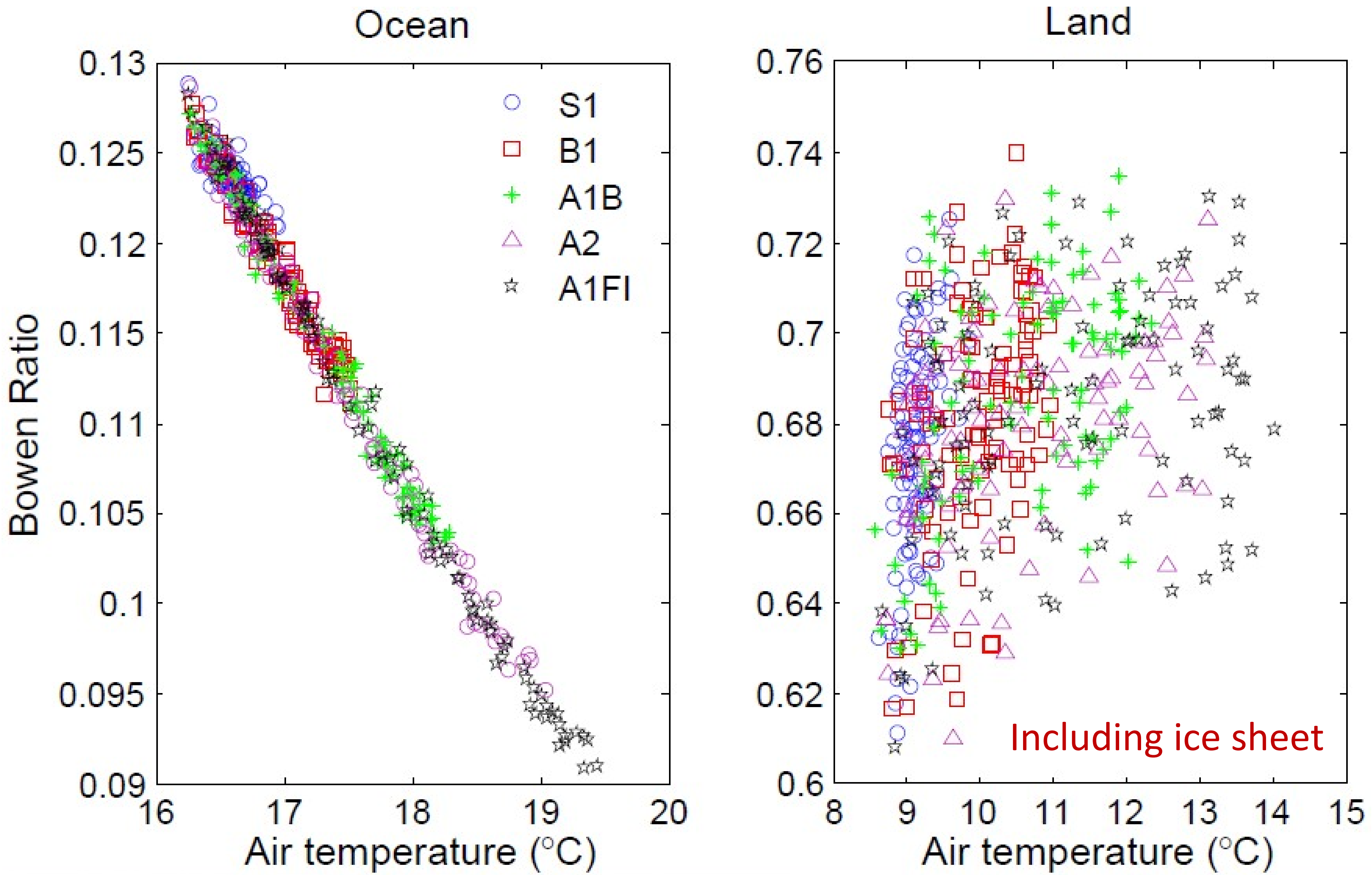
Case	T_a	T_s	U	q_a	q_s	$K_\downarrow$	$K_\uparrow$	$L_\downarrow$	$L_\uparrow$	R_n	H	λE	β
	℃	℃	$m\,s^{-1}$	$kg\,kg^{-1}$	$kg\,kg^{-1}$	$W\,m^{-2}$	$W\,m^{-2}$	$W\,m^{-2}$	$W\,m^{-2}$	$W\,m^{-2}$	$W\,m^{-2}$	$W\,m^{-2}$	
Default	17.9	29.3	1.10	0.011	0.025	185.6	13.0	346.2	460.3	48.1	16.3	47.6	0.34
MLW	16.2	17.2	2.31	0.009	0.014	143.8	9.6	356.9	404.0	87.1	9.7	76.1	0.13
Tuned	16.2	18.2	2.31	0.009	0.013	143.8	10.1	356.9	396.3	83.6	9.6	75.9	0.13

2. RESULTS

Simple lake model driven by Merra (1979-2011)



CM2.1 prediction (2001-2100)



2.RESULTS

Summary

Type		Data source	Sensitivity/per℃	Number	R	P
Spatial		Literature	-0.029±0.008	25	-0.74	<0.001
		OAFlux NH	-0.022±0.002	75	-0.95	<0.001
		OAFlux SH	-0.017±0.003	78	-0.76	<0.001
Temporal	Annual	OAFlux 1985-2011	-0.088±0.003	27	-0.48	0.033
		Merra near MLW	-0.052±0.015	33	-0.59	<0.001
		CM2.1 5 Scenarios	-0.011±0.004	100	-0.95	<0.001
	Monthly	Lake Ikeda	-0.021±0.012	12	-0.60	0.039
		Lake Taihu	-0.007±0.002	27	-0.75	<0.001
		Lake Superior	-0.085±0.027	24	-0.70	<0.001

Sensitivity calculated from *Brutsaert formula is about 0.023/ ℃*.

Conclusion

- Bowen ratio is more (less) sensitive to air temperature at high (low) latitudes or at low (high) temperature, with a spatial average sensitivity of -0.02 per ℃;
- The Bowen Ratio’s sensitivity to air temperature is about -0.088 per ℃ during the past 27 years over global oceans;
- All the scenarios have significantly underestimated the decreasing rate of Bowen ratio for global warming over oceans.

Thank you!

Suggestions and questions are welcome.