耶鲁大学-南京信息工程大学大气环境中心

Yale-NUIST Center on Atmospheric Environment

A discussion on papers by Roderick on pan evaporation trends

Reporter: Hu Cheng

Title	Writers	Jounal
The Cause of Decreased Pan Evaporation over the Past 50 years	RODERICK and FARQUHAR	SCIENCE
On the attribution of changing pan evaporation		GEOPHYSICAL RESEARCH LETTERS
CHANGES IN NEW ZEALAND PAN EVAPORATION SINCE THE 1970s		INTERNATIONAL JOUNAL OF CLIMATOLOGY
CHANGES IN AUSTRALIAN PAN EVAPORATION FROM 1970 TO 2002		INTERNATIONAL JOUNAL OF CLIMATOLOGY

Table 1. the papers involved

Outline :

- Background .
- Methods and Materials .
- Conclusions .

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Background

1.Changes in the global water cycle can cause major environmental and social economic impacts.

2.As the average global temperature increases(~0.15℃ decade^{-1}), it is generally expected that the air will become drier and that evaporation from terrestrial water bodies will increase.

3.Paradoxically, terrestrial observations over the past 50 years show the reverse.

(by wang xu)

CHANGES IN NEW ZEALAND PAN EVAPORATION SINCE THE 1970s
CHANGES IN AUSTRALIAN PAN EVAPORATION FROM 1970 TO 2002

Background.

whether the decrease in pan evaporation is a phenomenon limited to the Northern Hemisphere has until now been unknown .

	Sites		
	Decrease	No change	Increase
1970–2002 (30 sites)			
Pan evaporation	14	13	3
Rainfall	2	$\boxed{28}$	0
1975–2002 (61 sites)			
Pan evaporation	23	33	5
Rainfall	0	$\boxed{60}$	1

Table 4. Number of sites showing statistically significant changes ($p > 0.95$) in annual pan evaporation and rainfall in the two reporting periods

	Sites		
	Decrease	No change	Increase
Pan evaporation	6	13	0
Rainfall	3	15	1

Table 5. Number of sites showing statistically significant changes ($p > 0.95$) in annual pan evaporation and rainfall

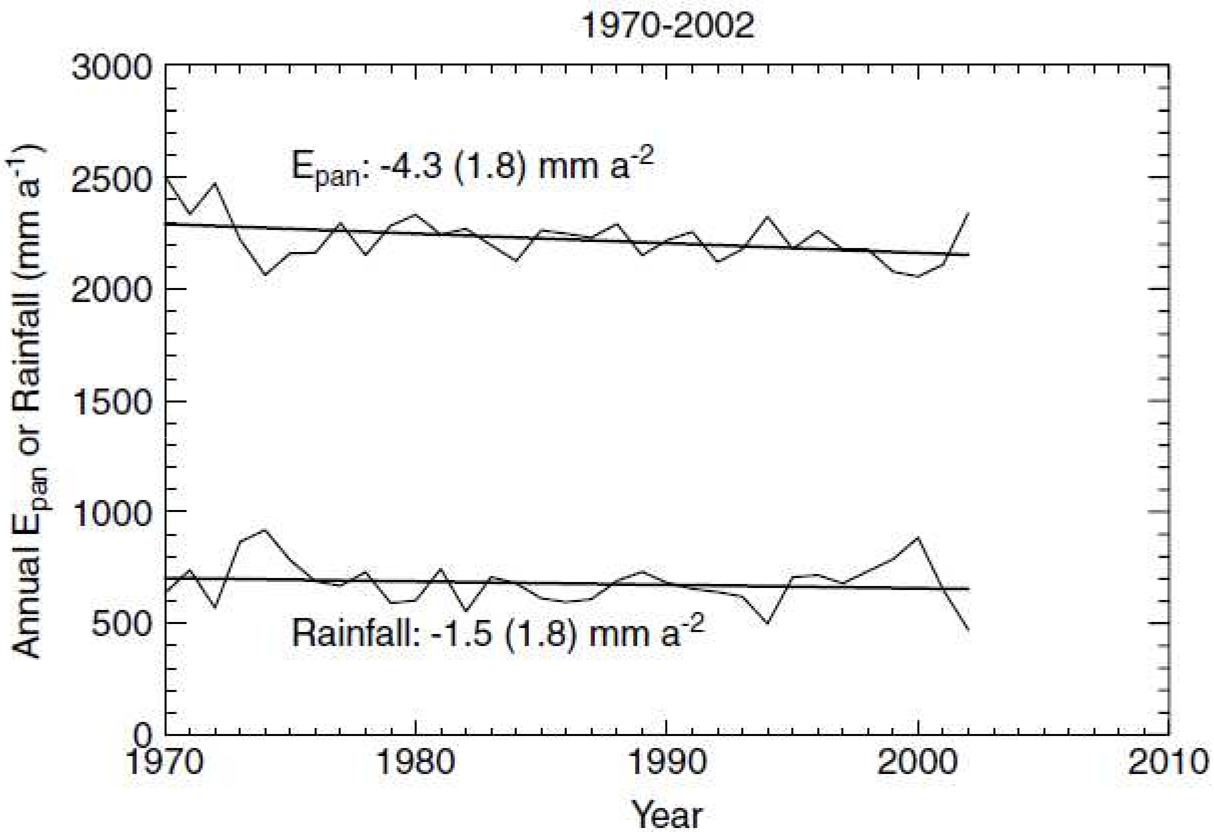

Figure 3. Overall trends in annual pan evaporation rate Epan and annual rainfall rate averaged over 30 sites for 1970–2002. (Standard error shown in brackets. Epan trend is significant ($p > 0.95$) but the rainfall trend is not significant)

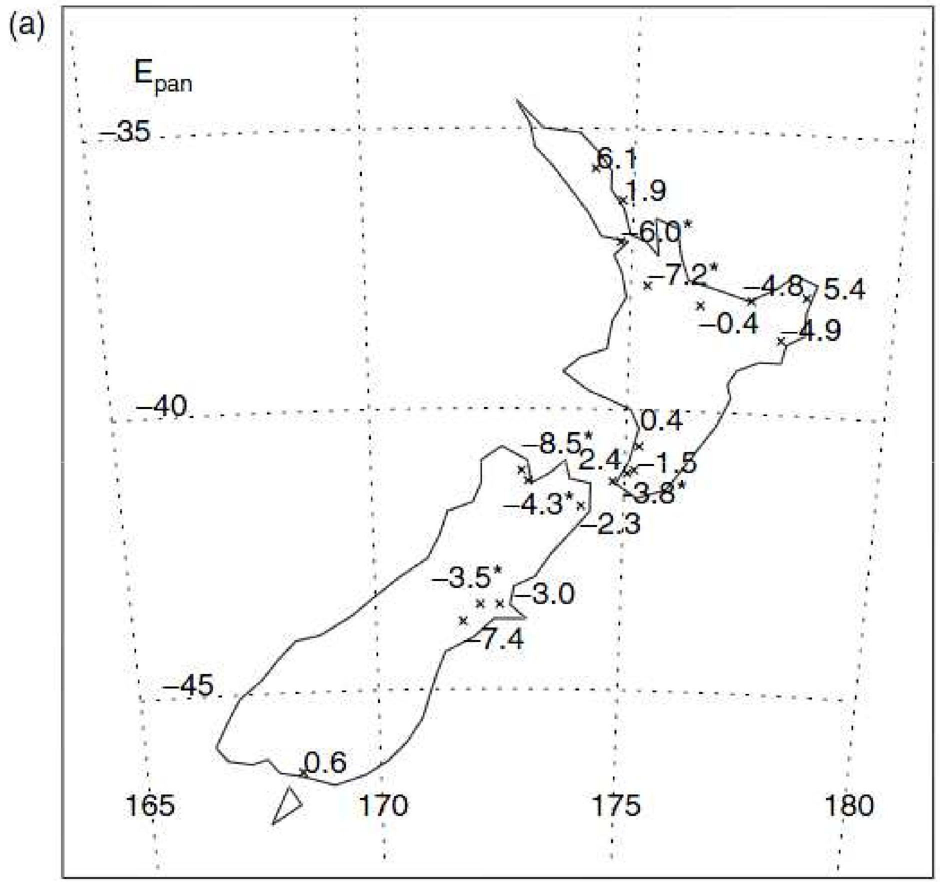

Figure 4. Trends in pan evaporation at 19 New Zealand sites. ∗Denotes a statistically significant ($p > 0.95$)trend. Units are mm a^{-2}

Conclusion

Australia and New Zealand has become less arid over the last 30 years, not because rainfall has changed, but rather because potential evaporation, and hence the atmospheric demand for water, has decreased.

- possible reasons:decreases in one or more of net radiation and windspeed (Penman, 1948; Monteith and Unsworth, 1990).

- Assuming that this is the case, then a decrease in net radiation and/or windspeed must be involved. In the Northern Hemisphere, decreased sunlight has proved to be an important component of the decrease in pan evaporation (Roderick and Farquhar, 2002) However, declines in windspeed may also play a role.

The Cause of Decreased Pan Evaporation over the Past 50 Years

Any explanation of the decrease in pan evaporation must accommodate the following:

(i) the widespread decrease in pan evaporation has occurred in both dry and wet environments

(ii) the average vapor pressure deficit (D, measured in Pa) has remained more or less constant

Methods and Materials .

$$D = e_s(T) - e_s(T_d)$$

$$\delta D = s\delta T - s_d \delta T_d$$

D:average vapor pressure deficit,measured in Pa.
$e_s(T)$: the saturation vapor pressure at the temperature (T) and dew point (Td) of the air.
S ,S_d :the slopes of the saturation vapor pressure–temperature relationship at T and Td, respectively.

Pan evaporation is generally much more sensitive to variations in net irradiance and D than to variations in wind speed.

$$(0.7)\,\lambda E_{\mathrm{pan}} \approx 1.26\left(\frac{s}{s+\gamma}\right)R_{\mathrm{n}}$$

$$\lambda\,\delta E_{\mathrm{pan}} \approx \frac{1.26}{0.70}\left(\frac{s}{s+\gamma}\right)\delta R_{\mathrm{n}}$$

Result and Conclusions .

Over the 30-year period of interest this equates to a decrease in annual pan evaporationof 110 mm , consistent with our estimate of 90-155 mm . and the reason is decreasing radiation.

Location	latitude	data	year included
former Soviet Union	49° to 67°	R,T,E_{pan}	1960 to 1990

On the attribution of changing pan evaporation

1. Attribution Using the PenPan Model,it is based on Penman's combination equation[*Penman*,*1948*].
2. The radiative and aerodynamic components are based on the Linacre [1994] and Thom et al. [1981] models respectively.

$$E_p = E_{p,R} + E_{p,A} = \left(\frac{s}{s+a\gamma}\frac{R_n}{\lambda}\right) + \left(\frac{a\gamma}{s+a\gamma}f_q(u)D\right)$$

E_p: the evaporation rate from the pan
$E_{p,r}$ and $E_{p,A}$:radiative and aerodynamic compents.
s : the change in saturation vapour pressure(es, Pa) with temperature evaluated at the air temperature (Ta, K) two metres above the ground.
Rn:the net irradiance of the pan.
λ :the latent heat of vaporisation,
a :(= 2.4 here) the ratio of effective surface areas for heat and vapour transfer
D:the vapour pressure deficit at two metres.
F(u):the vapour transfer function.

$$f_q(u) = 1.39 \times 10^{-8}(1 + 1.35\,u)$$

$$R_n = (1 - A_p)R_{sp} + R_{l,in} - R_{l,out}$$

*R*n:the net short-wave irradiance.
Ap :(= 0.14 here) the pan albedo
Rsp: the incoming short-wave irradiance of the pan. Rsp is greater than the global solar irradiance (Rs)because of additional interception by the walls of the pan [Rotstayn et al., 2006].
$R_{l,in}$,$R_{l,out}$: incoming and outgoing long-wave irradiance,with $R_{l,out}$ calculated assuming the pan is a black body radiating at temperature Ta.

Material and Methods:

Data were collated from existing Australian Bureau of Meteorology (BoM) digital records:

pan evaporation	**wind speed**	**Ta**	**humidity**	**R_{sp}**

FAO56 approach [Allen et al., 1998]

$$R_{l,in} = \sigma T_a^4 \left(1 - \left(0.34 - 0.14\sqrt{e_a/1000}\right)\right.$$

$$\left.\cdot\left(1.35R_s/\left(R_o\left(0.75 + 2\times 10^{-5}z\right)\right) - 0.35\right)\right)$$

R_0 : the top of atmosphere solar irradiance.
z (m) :the site elevation.
R_s :global solar irradiance.
T_a :air temperature at 2m.
e_a :vapour of the air at 2m.

.

For attribution, the change in pan evaporation rate is given by differentiating equation

$$\frac{dE_p}{dt} = \frac{dE_{p,R}}{dt} + \frac{dE_{p,A}}{dt}$$

The term $dE_{p,A}/dt$ is then partitioned into three components, denoted U*, D*, T* for changes due to changing wind speed, vapour pressure deficit and temperature respectively. The components are defined by

$$\frac{dE_{p,A}}{dt} \approx \frac{\partial E_{p,A}}{\partial u}\frac{du}{dt} + \frac{\partial E_{p,A}}{\partial D}\frac{dD}{dt} + \frac{\partial E_{p,A}}{\partial s}\frac{ds}{dT_a}\frac{dT_a}{dt} = U^* + D^* + T^*$$

Evaluation of the PenPan Model

- We first used the PenPan model to calculate E_p using complete (post-1995) observations (Rs, $R_{l,in}$, Ta, u, e_s, e_a).The agreement between modelled and observed Ep at the 11 sites (R^2 = 0.95, n = 903, RMSE = 22 mm mth^{-1}) was excellent.
- we used the available Rl,in observations to evaluate the FAO56 equation. There was no evidence of a change in the slight bias (6 W m^{-2})
- Finally, we used equation (6) to estimate R_l,in and thereby calculated E_p at the 26 sites for any month with observations of R_s, Ta, u, e_s and e_a. The comparison with Ep observations was excellent

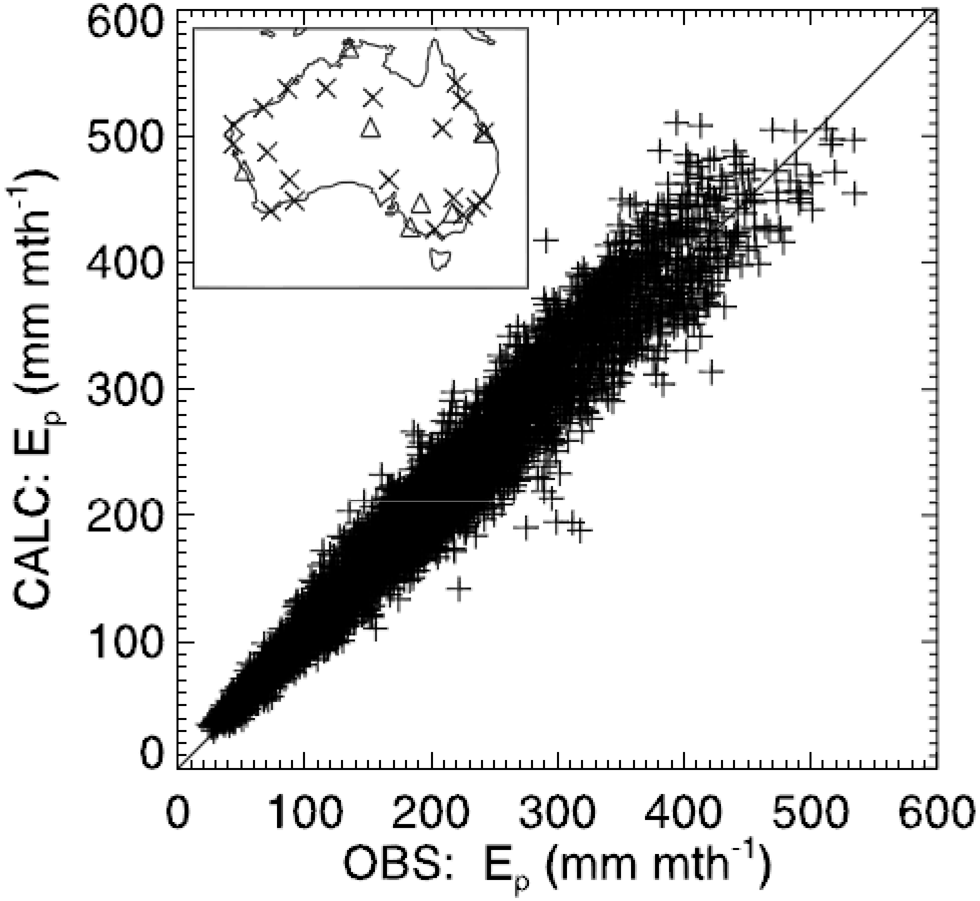

Figure 1. Comparison of observed and calculated pan evaporation rates. Locations (n = 26 sites) shown in the inset where sites denoted D are the seven ‘‘elite’’ sites . Best fit regression; y = 1.01 x + 7.7, R2 = 0.95, n =5071 (1:1 line shown). The RMSE is 24 mm mth 1. (Note that 1 mm = 1 kg m^{-2}.)

Site	OBS	CALC = Rad + Aero	Rad	Aero	Aero Partition		
	dE_p/dt	dE_p/dt	$dE_{p,R}/dt$	$dE_{p,A}/dt$	U^*	D^*	T^*
GERALDTON AIRPORT	−4.1	−2.2	0.0	−2.2	−1.6	−0.8	0.3
DARWIN AIRPORT[b]	−17.0	−15.3	−6.0	−9.3	−8.9	−0.3	0.1
ALICE SPRINGS AIRPORT	25.8	21.4	2.0	19.4	16.9	5.4	−1.8
MOUNT GAMBIER AERO	−6.1	−8.4	−0.2	−8.2	−7.4	−1.4	0.3
ROCKHAMPTON AERO	11.0	7.7	3.2	4.5	0.3	4.3	−0.2
WAGGA WAGGA AMO	−1.8	1.4	0.5	0.9	−0.5	1.4	0.1
MILDURA AIRPORT	−8.8	−11.9	0.6	−12.5	−13.2	0.6	0.3

Table 2. Observed (OBS) and Model-Calculated (CALC) Trends in Pan Evaporation Rate (dEp/dt, in mm a   2) at 7 Sites Having Near-Continuous Data for 1975–2004a

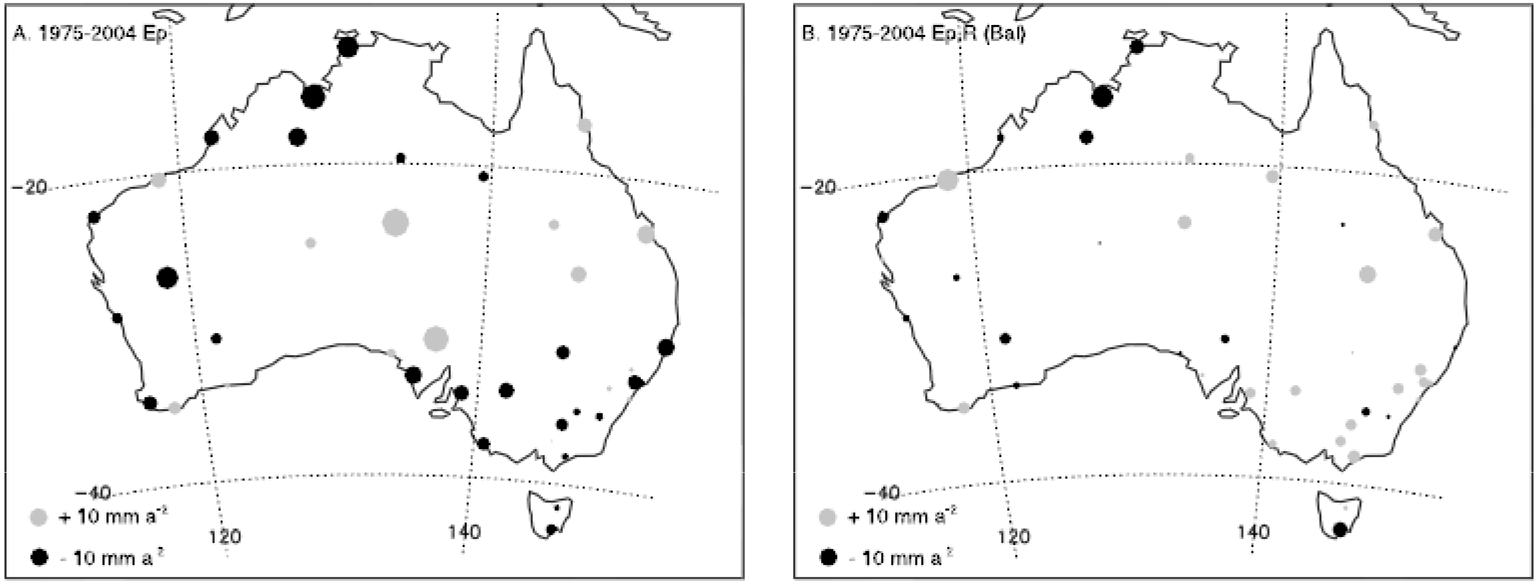

Figure 2. Trends in observed pan evaporation rate and its components at 41 sites for the period 1975–2004. (A) Observed pan evaporation rate. (B) Radiative component of pan evaporation rate calculated as the difference between Figures 2a and2c. (C) Aerodynamic component of pan evaporation rate. The trend in the aerodynamic component is further partitioned (equation 5) into the change due to changing (D) wind speed, (E) vapour pressure deficit, and (F) air temperature. The change in each panel, averaged across all 41 sites is (a) -2.0 mm a^{-2}, (b) +0.6 mm a^{-2}, (c) 2.6 mm a^{-2}, (d) -2.7 mm a^{-2},(e) 0.0 mm a^{-2}, and (f) 0.0 mm a^{-2}. Details and trends are available for each site in auxiliary Table 2.

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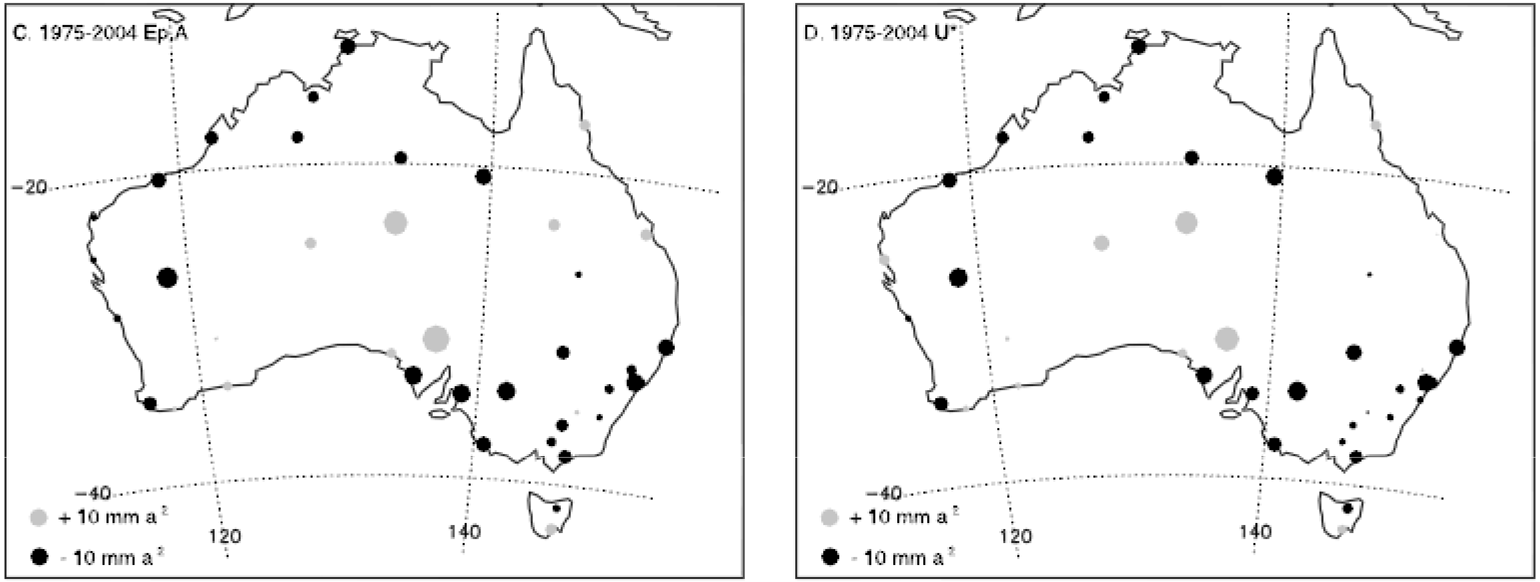

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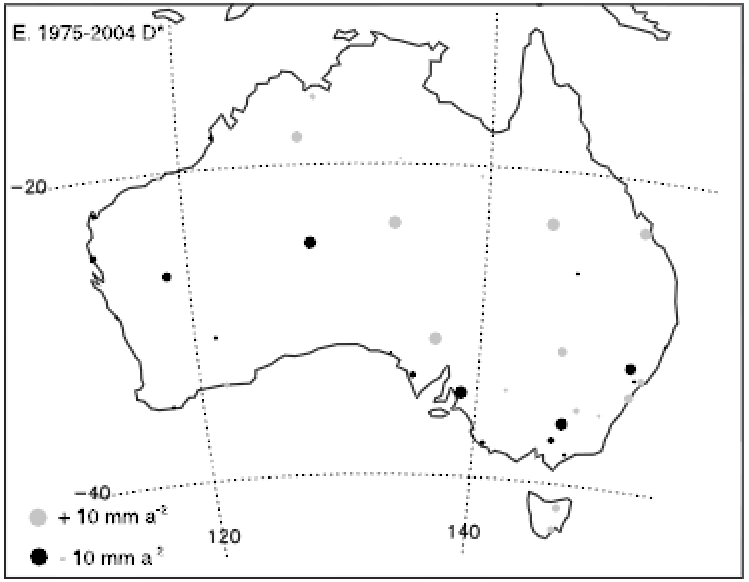

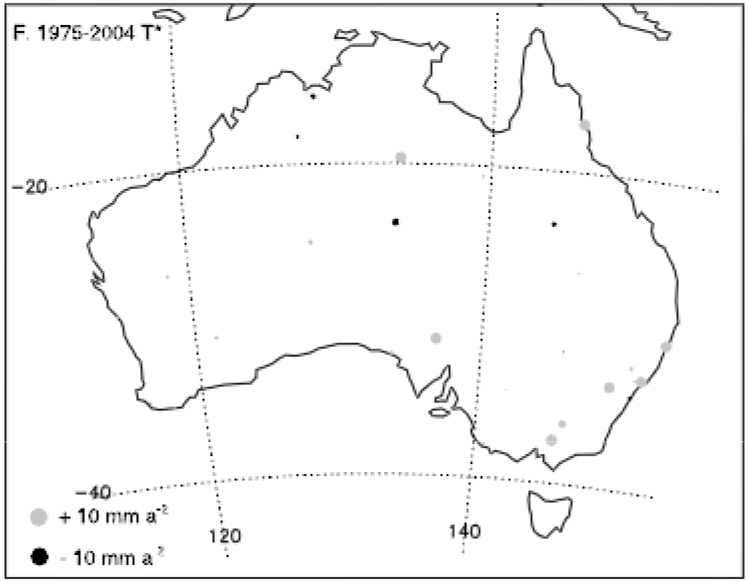

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du/dt, m s^{-1} a^{-1}	Location	Details	Ref.
−0.010	Australia	1975–2004, 41 sites	This study
−0.005	USA	1962–1990, 207 sites across the 48 conterminous states	*Hobbins* [2004]
−0.004	USA	1960–1990, 176 sites across the 48 conterminous states	*Klink* [1999]
−0.008	Yangtze River Catchment, China	1960–2000, 150 sites	*Xu et al.* [2006a]
−0.020	China	1969–2000, 305 sites	*Xu et al.* [2006b]
−0.010	Loess Plateau, China	1980–2000, 52 sites	*McVicar et al.* [2005]
−0.013	Tibetan Plateau	1960–2000, 101 sites	*Shenbin et al.* [2006]
−0.017	Tibetan Plateau	1966–2003, 75 sites	*Zhang et al.* 2007]
−0.013	Italy	~1955–~1996, 17 sites on Italian coast. Break point in ~1975. Trend of ~−0.026 m s^{-1} a^{-1} before and ~−0.002 m s^{-1} a^{-1} after 1975	*Pirazzoli and Tomasin* [2003]
−0.011	New Zealand	1975–2002, 5 sites	M. L. Roderick (unpublished data, 2005)
−0.017	Canada	~1950–~1990, 4 sites on west coast	*Tuller* [2004]
+0.006	Antarctica	~1960–~2000, 11 sites	*Turner et al.* [2005]

[a]All studies are based on terrestrial anemometer records.

Table 3. Summary of Observed Changes (Represented as a Linear Trend) in Near-Surface Wind Speed (du/dt)[a]

Conclusion

- When forced with radiation, temperature, humidity and wind observations, the PenPan model simulated the panevaporation observations well.
- Much of the trend in Ep observations was due to changes in the aerodynamic component , and the majority of that was due to changes in wind speed with generally minor changes due to changes in both vapour pressure deficit and air temperature.
- there was spatial variation in the results. A notable feature is the decrease in the radiative component shown in the northwest.

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paper	The Cause of Decreased Pan Evaporation over the Past 50 Years	On the attribution of changing pan evaporation	changes in NEWZEALAND` ` Australian``
sites	former Soviet Union	Australia	Australia and New Zealand
equation	$(0.7)\,\lambda E_{\mathrm{pan}} \approx 1.26\left(\frac{s}{s+\gamma}\right)R_{\mathrm{n}}$	PenPen model	Not given
conclusion: reason of decreasing pan evaporation	the decreases in solar irradiance and the associated changes in DTR and vapor pressure deficit	decreasing wind speed was found to be the main reason for decreasing pan evaporation	don't give the exact reason

thank you