

A light blue background featuring a stylized map of East Asia, including the Korean Peninsula, Japan, and the Philippines. The map is rendered in a darker shade of blue, providing a subtle geographical context for the title.

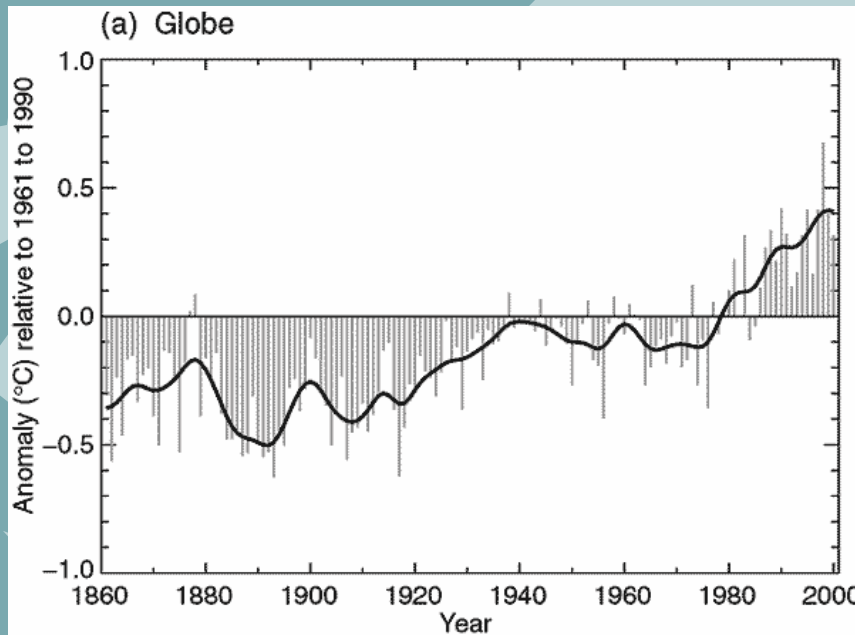
Long-Term Trends of Pan Evaporation as an Index of the Global Hydrological Change

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Background 1

- climate change and hydro. cycle



IPCC report (2001)

- Global surface temperature rise has been witnessed in the last half century.



- Hydrologists' interest: “how large change has occurred/will occur in hydrological cycle?”

Background 2

- changes in hydrological cycle

- **Many research has been done to detect changes occurred in each component of hydrological cycle.**

Background 3

- changes in hydrological cycle

- **Precipitation has been studied using operational, satellite-based or model-based measurements.**
- **According to IPCC report,**
 - **Global average precipitation has been increased in 2%/century.**
 - **But, non-uniform in time and space.**
 - **controversy, as well**

Background 4

- changes in hydrological cycle

- Evaporation from the land surface
 - has no long-term measurement.
 - Recent growing interest is that
“**Pan evaporation** may serve as an index of the
landsurface evaporation.”

Pan evaporation

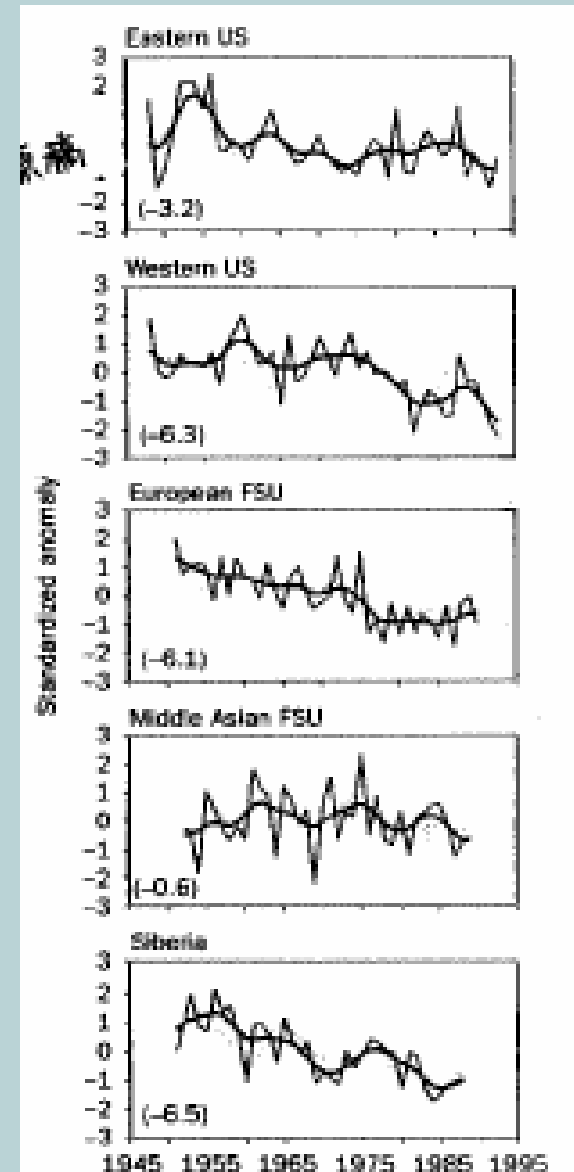
- **Evaporation from open water stored in the pan evaporimeter.**
 - operationally measured world-wide



class A pan

Literature review

- **Peterson et al.(1995, Nature)**
 - decrease in pan evaporation in US and Former Soviet Union (FSU)
 - pan evaporation = potential evaporation (=wet surface evaporation)
 - suggests the decrease in the terrestrial evaporation
- **“Evaporation loses its strength”**
- **Similar reports from India and Venezuela.**



Literature review 2

Brutsaert and Parlange (1998, Nature)

Peterson's interpretation

decrease in pan evaporation



decrease in potential
evaporation



decrease in terrestrial
evaporation



contradiction

increase in precipitation

New interpretation

decrease in pan evaporation
complimentary relationship



increase in terrestrial
evaporation



increase in precipitation



“accelerated hydro. cycle”?

Observational confirmation
with US and FSU data

Literature review 3

- **Roderick and Farquhar (2002, Science)**
 - Increase in cloud amount and aerosol caused decrease in the pan evaporation as well as the terrestrial evaporation.
 - 3rd interpretation of pan evaporation trends

decrease in pan evaporation



decrease in terrestrial evaporation

Literature review - Asia

- Pan evaporation decrease in Siberia (Peterson, 1995)
- Xu et al.(2001)
 - Pan evaporation measurements in China
 - Increase in the arid region.
 - Decrease in the moist region.

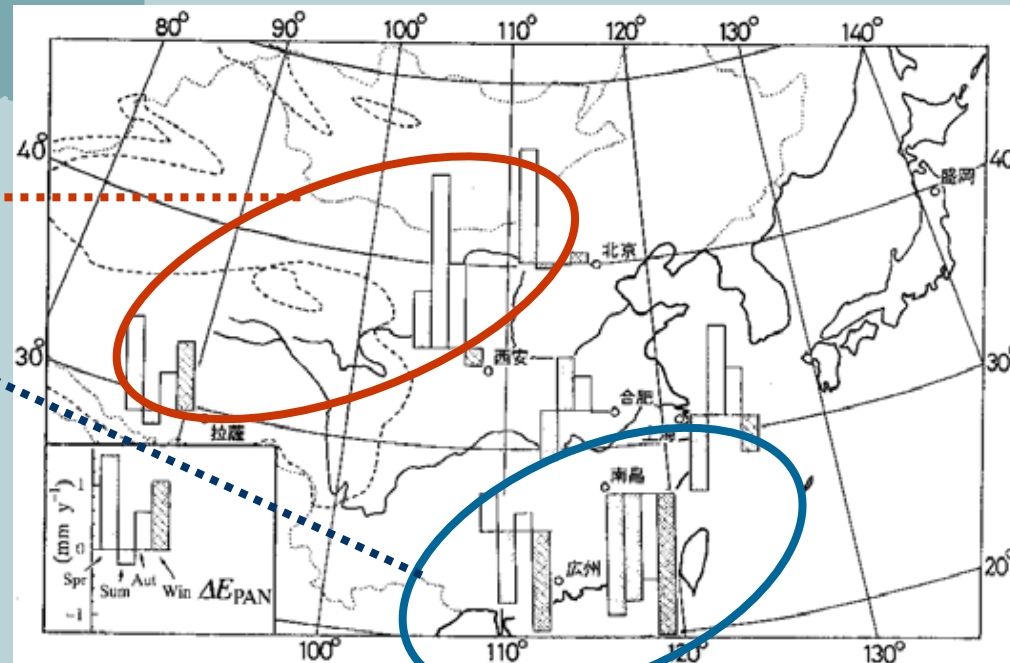


図-18 パン蒸発計蒸発量 E_{PAN} (月積算値)の変化率の分布(図-11を参照).
Fig. 18 The same as in Fig. 11 except for pan evaporation E_{PAN} (monthly total).

This study

- **Purpose:**

- To investigate Japanese pan evaporation data to find out trends in it.
- To infer what is the meaning of trend in the pan evaporation.

- **Data analyzed:**

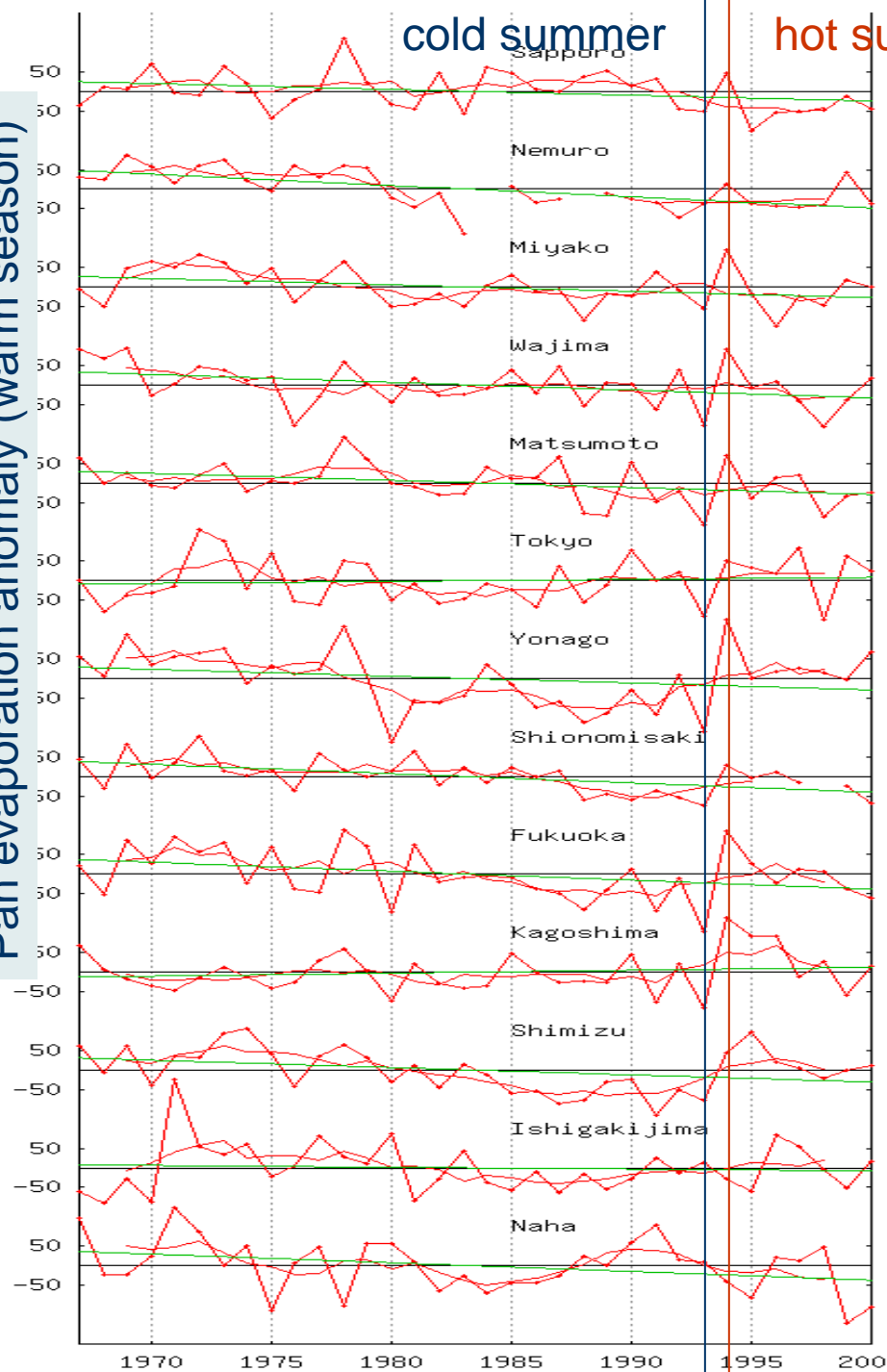
- 13 operational stations run by JMA. (class A pan)
- period: 1967-2000
- Pan evaporation and meteorological vars.



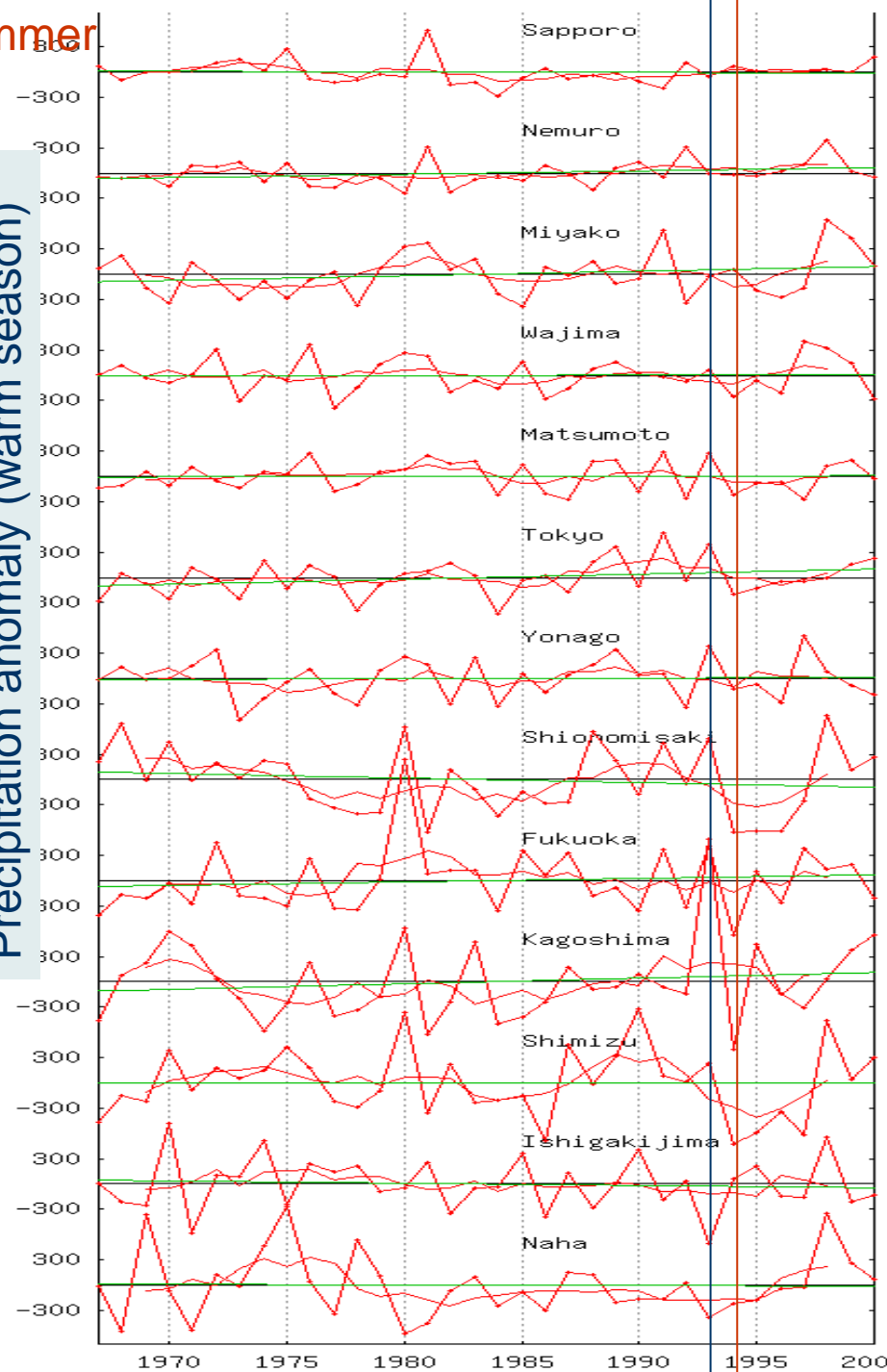
Pan evaporation anomaly (warm season)

cold summer

hot summer

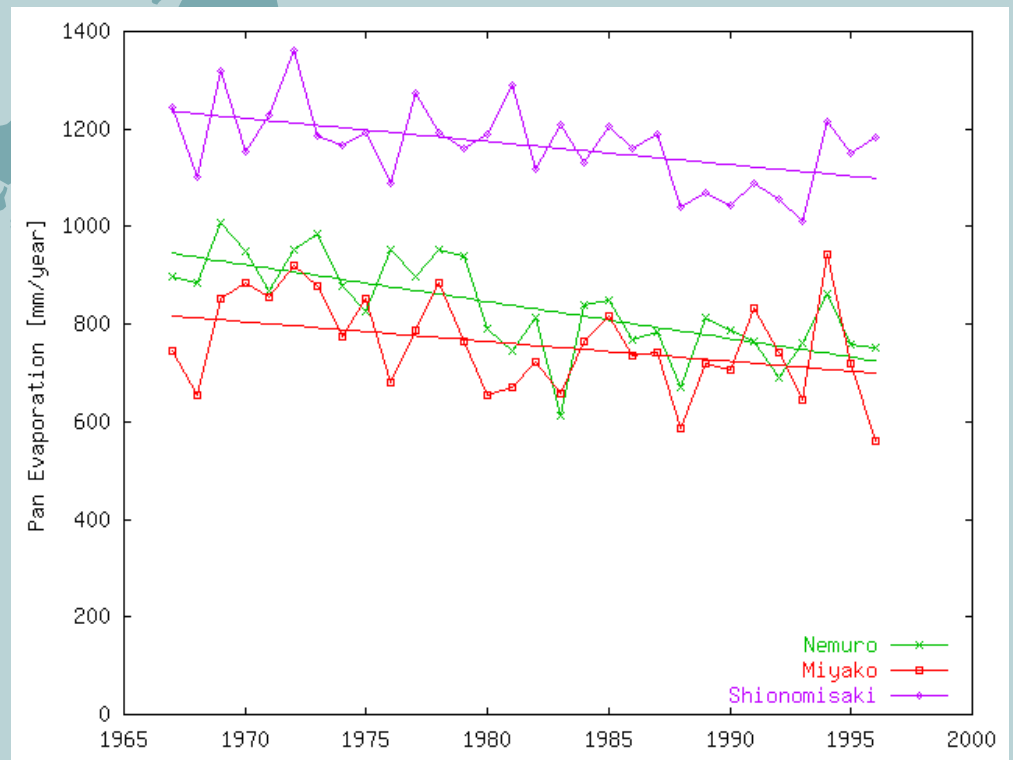


Precipitation anomaly (warm season)

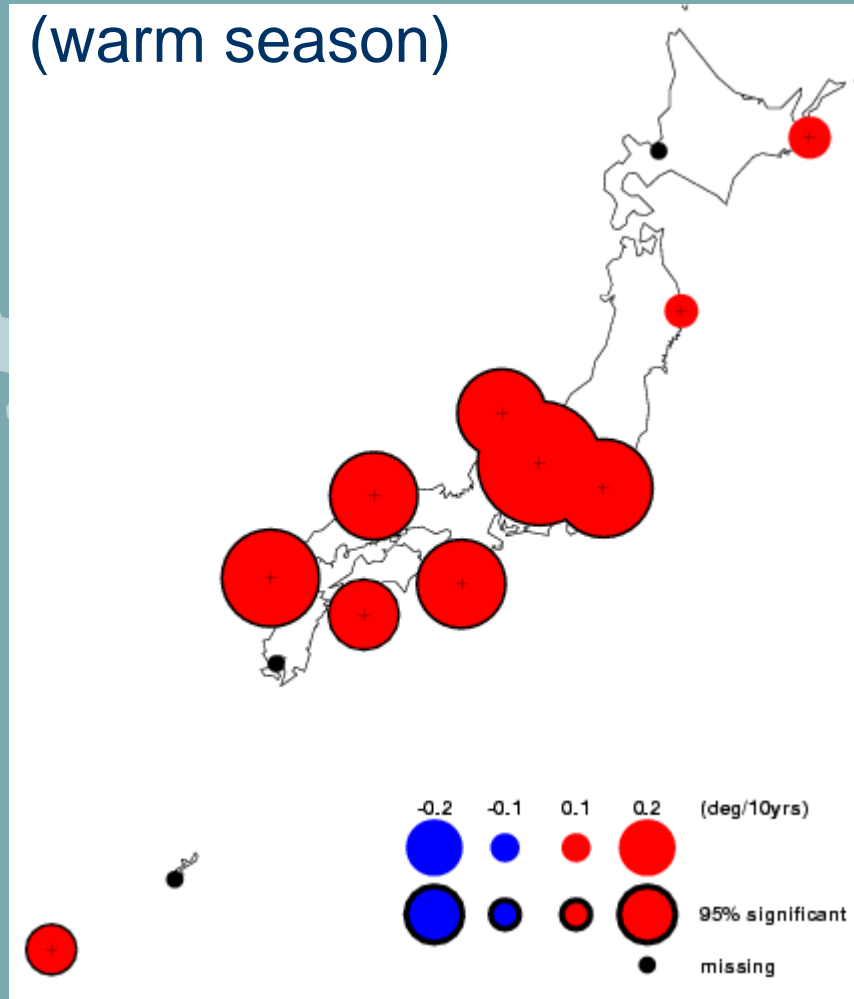


Analysis

- Identification of linear trend with linear regression
 - with statistical test of significance

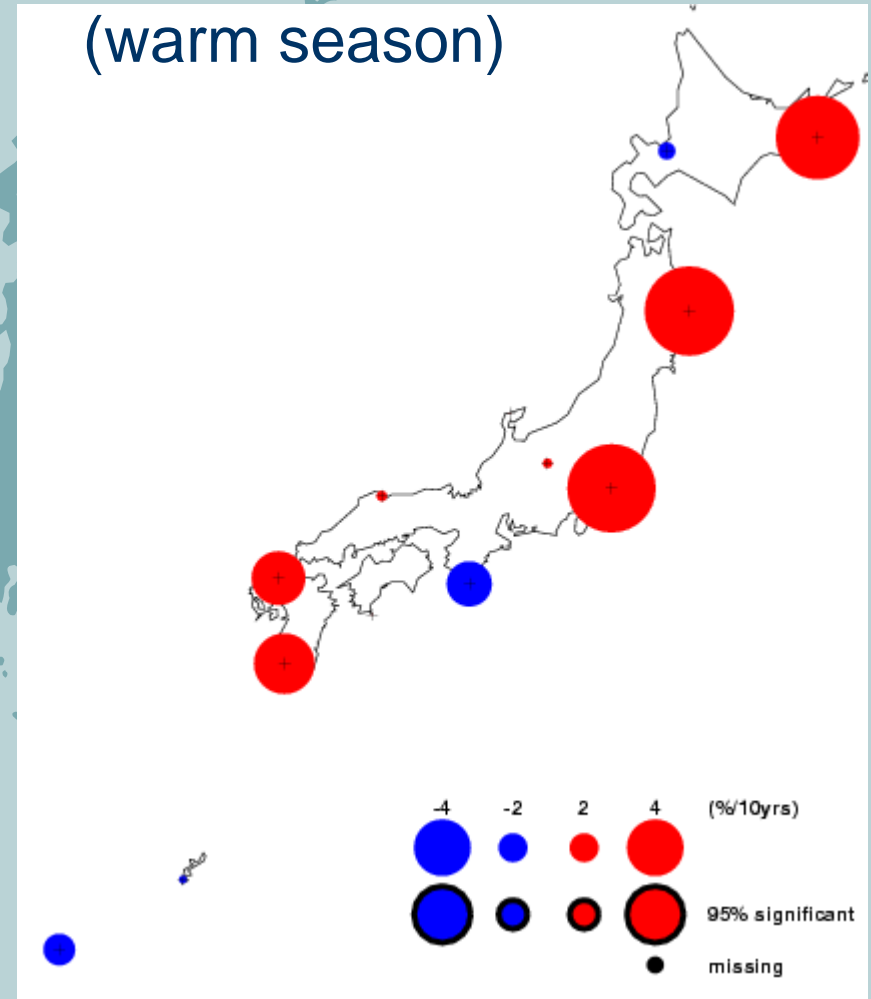


Trend in the air temperature (warm season)



increasing air temperature

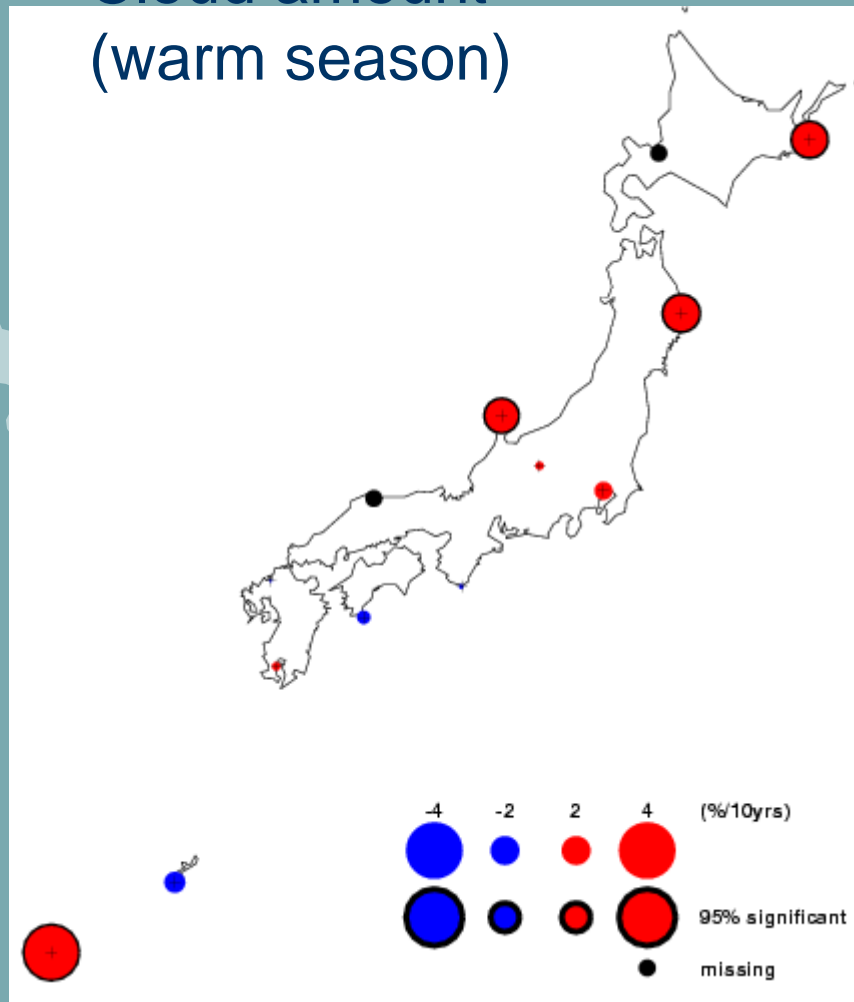
Trend in the precipitation (warm season)



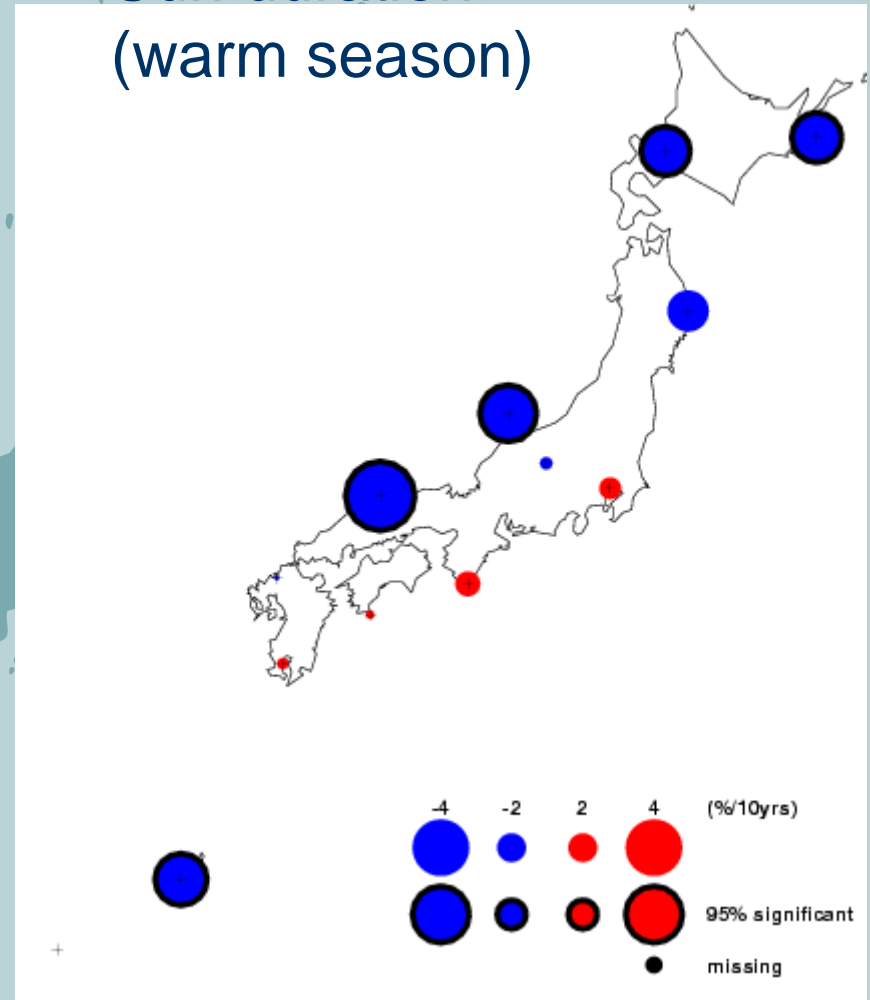
increasing precipitation, but
not statistically significant

closed circles = 95 % statistically significant

Cloud amount (warm season)

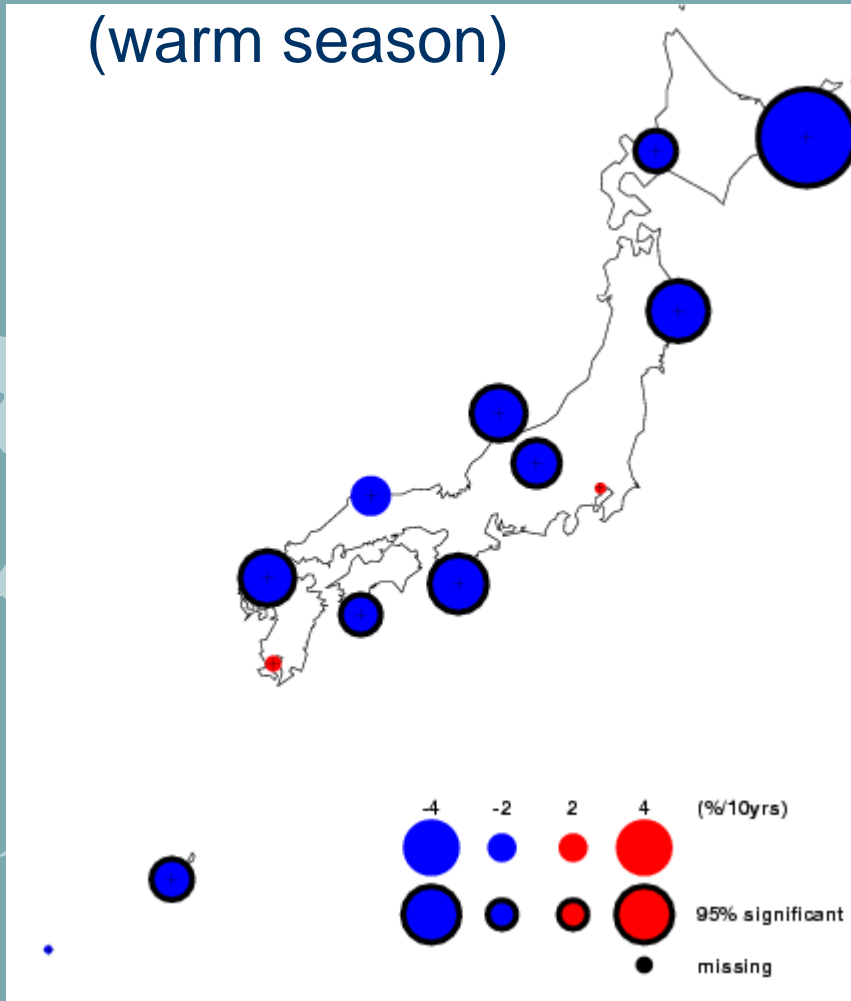


Sun duration (warm season)

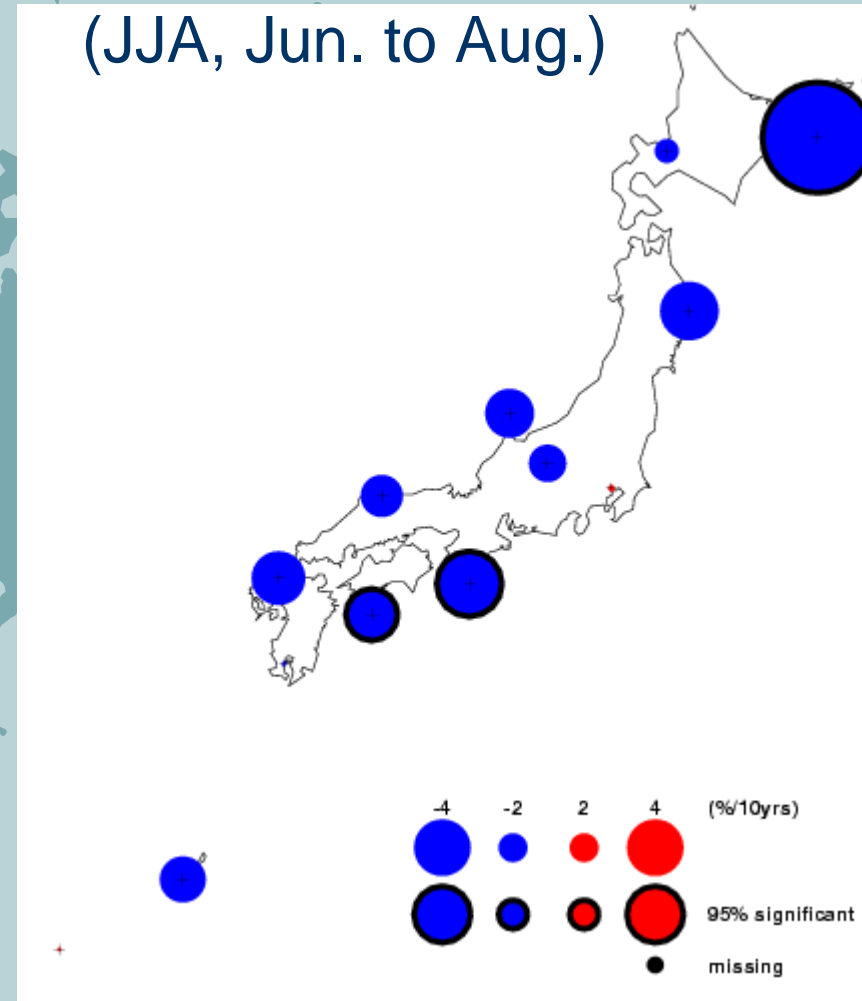


cloud amount is increasing and sun duration is decreasing in the northeastern Japan. No strong change seen in the southwestern region.

Pan evaporation trends (warm season)



Pan evaporation trends (JJA, Jun. to Aug.)

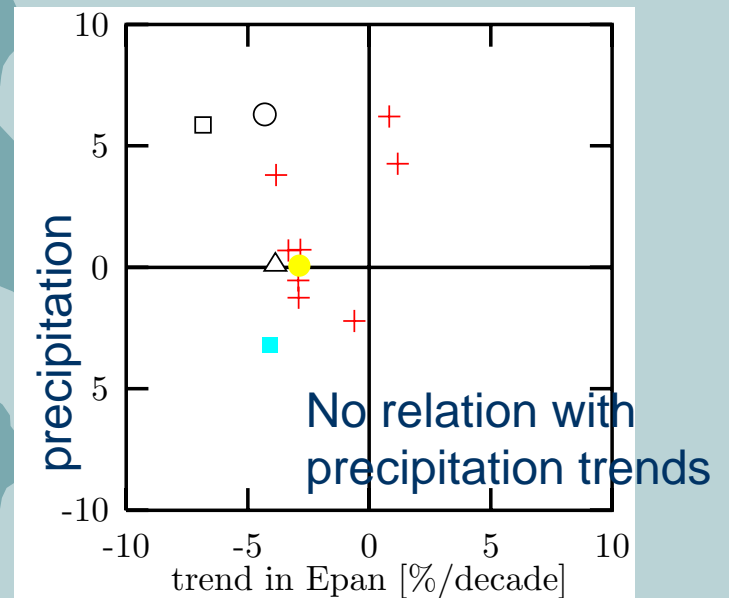
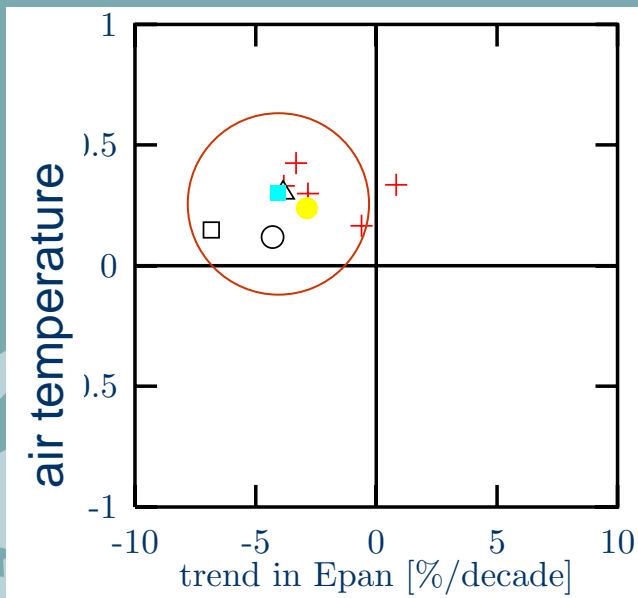


Decrease in pan
evaporation all over Japan

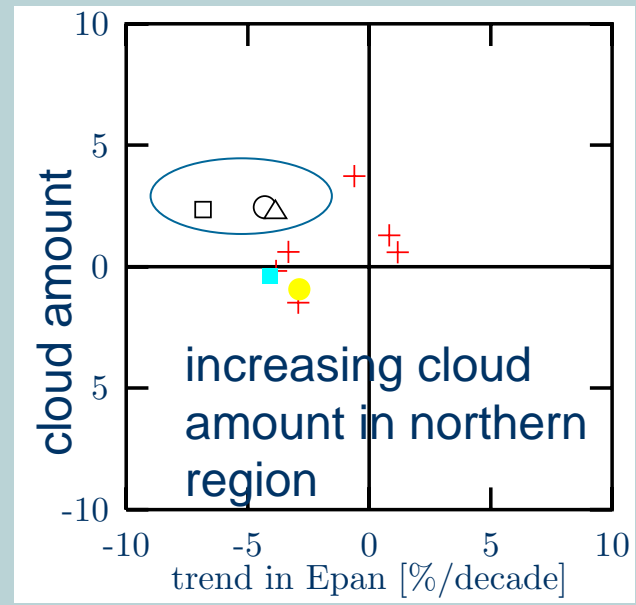
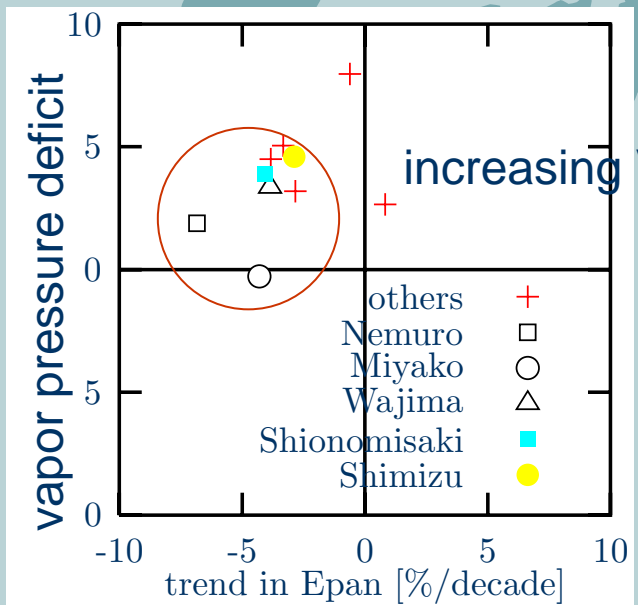
Detailed statistical analysis

- Objective: to identify the cause of the decreasing pan evaporation.
 - 5 stations with stronger decreasing trend and with less effect of the urbanization were selected.





trends in Pan Evaporation ->



trends in Pan Evaporation ->

Result of detailed analysis

- No systematic relationship with precipitation trends.
- VPD increases at 4 of the 5 sites.
 - The atmosphere has become drier
 - This can cause increase in landsurface evaporation.
 - Complimentary relationship between the pan evaporation and the terrestrial evaporation
 - Supports Brutsaert and Parlange(1998)

Decreasing pan evaporation indicate increasing terrestrial evaporation
- The northern stations give increasing cloud amount
 - supports Roderick and Farquhar(2002).

Decreasing pan evaporation indicate decreasing terrestrial evaporation

Summary

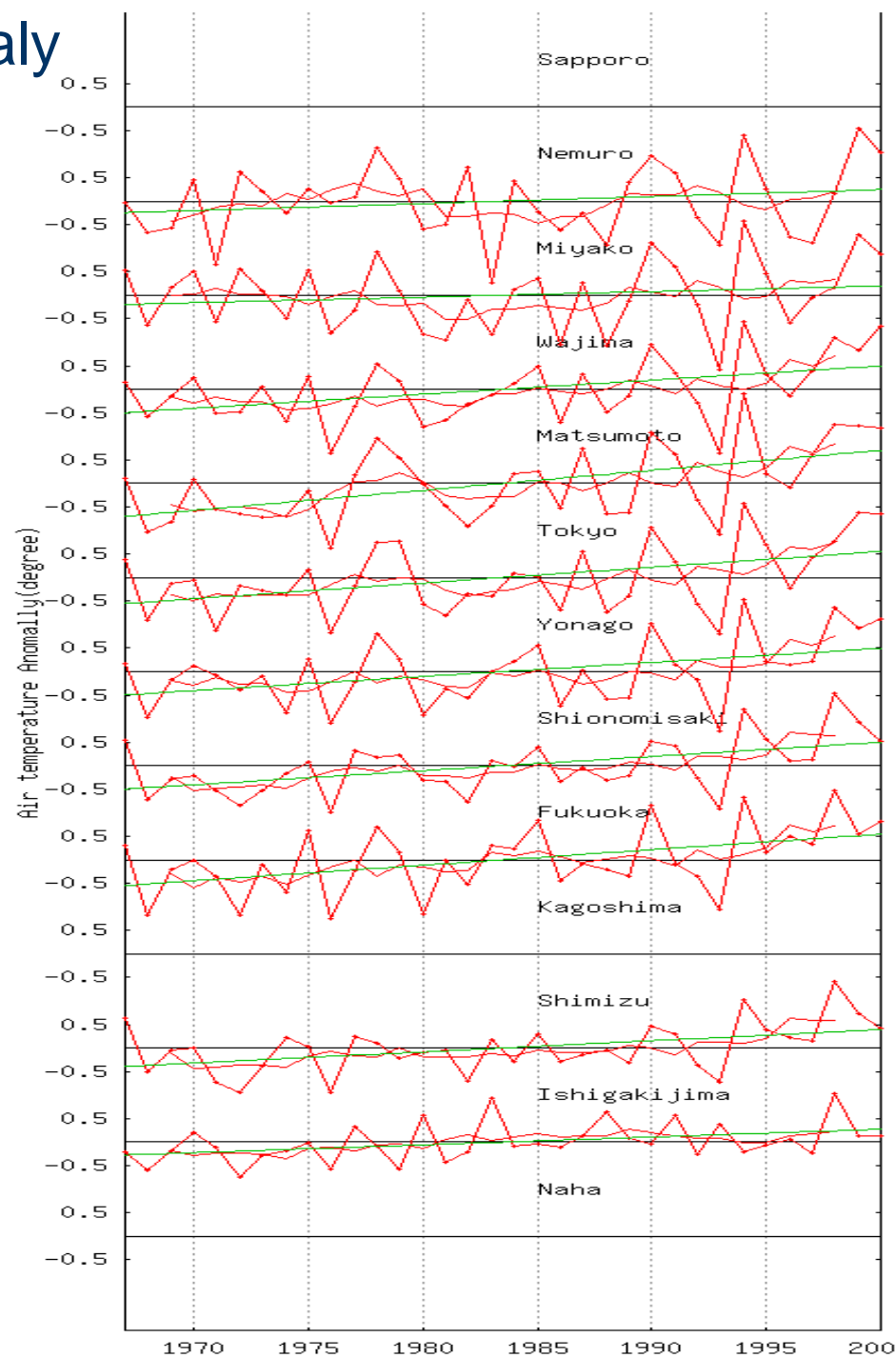
- Pan evaporation shows decreasing trends in the last 35 years at most of the regions in Japan.
- Decreasing trend of the pan evaporation in southeast Japan, China, and India
=> common to the monsoon Asia.

Summary 2

- **Cause of the decreasing pan evaporation**
 - **At the northern stations**
 - increasing cloud amount and increasing vapor pressure deficit
 - => decreasing or increasing terrestrial evaporation
 - **At the southern stations**
 - increasing vapor pressure deficit
 - => increasing terrestrial evaporation
- **Interpretation of pan evaporation trends differ in different climate systems.**



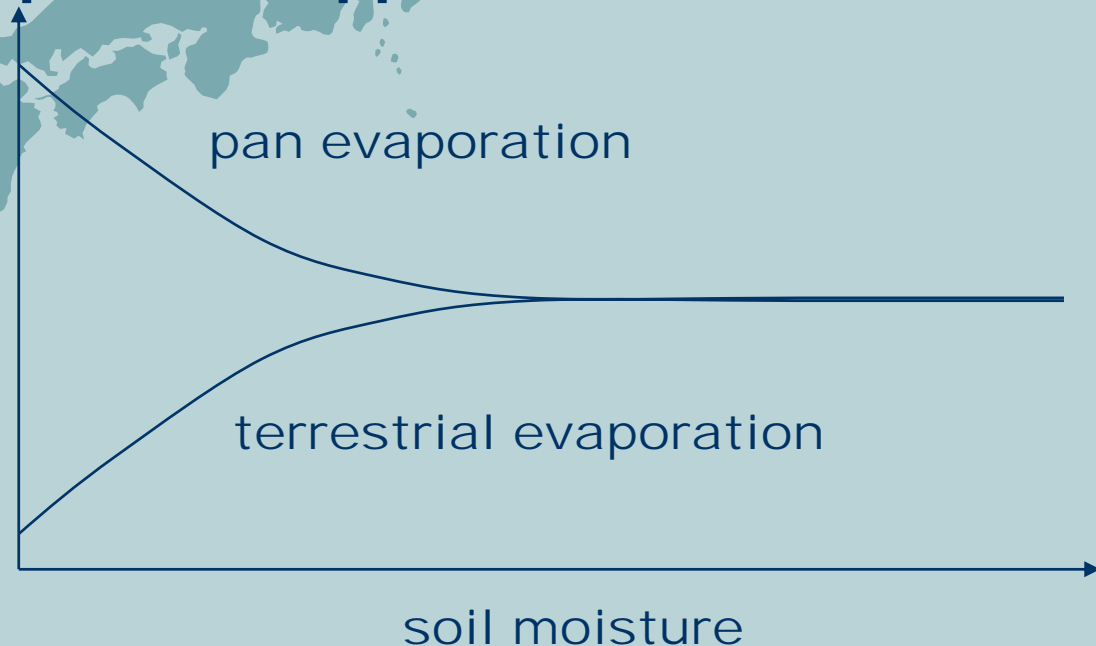
Air Temperature anomaly (warm season)



Complimentary Relationship

- Bouchet (1963)

- Some kinds of potential evaporation (e.g. pan) is complimentary with terrestrial evaporation.
- Conceptual idea, empirically validated.
- Seen some practical applications.



Observational Facts 1

- **Increasing air temperature**
 - due to either global climate change or local urbanization
- **Precipitation: increasing or decreasing, but not statistically significant**
 - due to large interannual variability
- **Cloud amount: increasing in the north and no change or slightly decreasing in the south (not significant)**
- **Pan evaporation**
 - contains larger scale climate information relative to the precipitation
 - all over decrease for all seasons

Quick View

- Quick view of the pan evaporation data shows that the pan evaporation may have some information on the climate of broader region in contrast to the precipitation that is more local.

Five sites for detailed analysis



5 stations with stronger decreasing trend and with less effect of the urbanization were selected