Available Water Climatology and its Applications

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Sleepy?

- --- Surprise !! Surprise!! Surprise --- !!
- !!! -Here is a gold mine on Water Climatology --!!!

LIWAS is the Little-Water-Season this study has defined first.

Merits!!!!

All Flood-like disasters became predictable before rain starts.--- !!

Deciding the Drought duration became reasonable-- !!

4-dim. Distribution of water resource world-wide has digitized in real time.

New concept on Season-Division, Climate-Classification has succeeded.
=> Became much better than before.

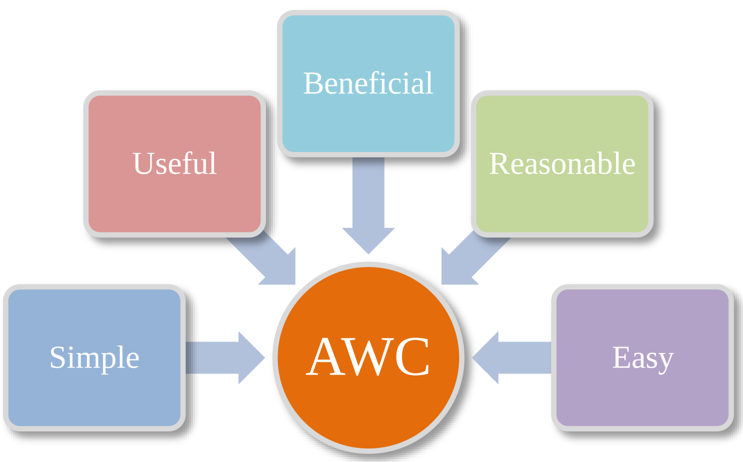
Moreover, Very easy to understand and to calculate.

Contents

1. What is the Available Water Climatology (AWC)

Available Water (AW)

- The amount of Water Resources available at the pointed time.
- The remained water after runoff and evaporation of precipitation.



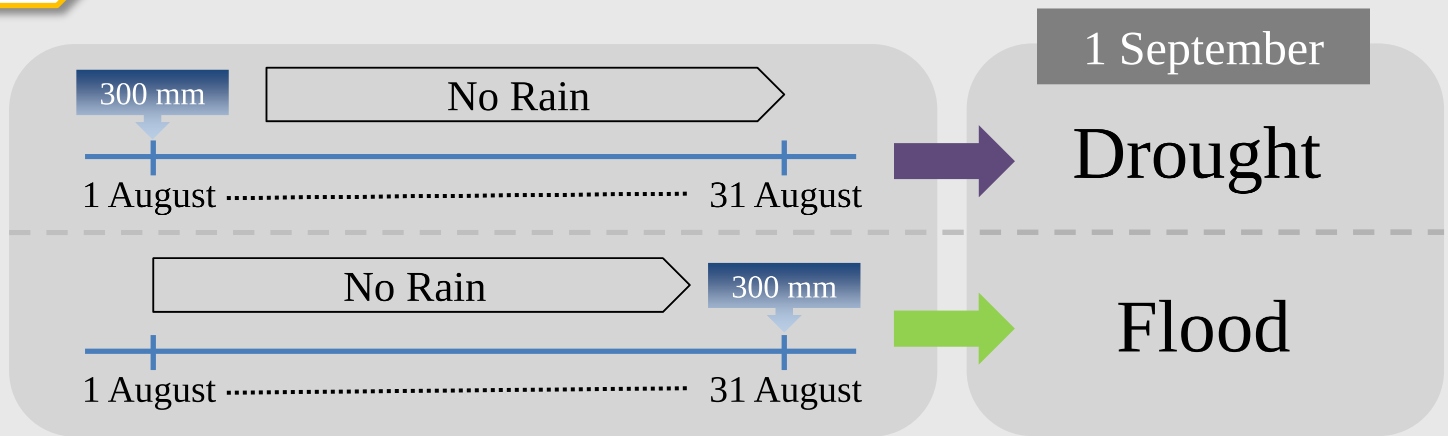
- More reasonable useful, beneficial than Classical PCN Climatology (CPC).
- Moreover, Simple and Easy, anybody can follow.
- Yes, here is a **new gold mine** on climatology

1. What is the Available Water Climatology (AWC) ?

More Reasonable?

- For example -

If total PCN of August is 300mm



- There are many and many cases of time distribution of PCN.
  It is clear that the Effect of PCN is not along the total but along its time distribution.

  Water is life !!! Very important!!!

- Not the accumulated precipitation (daily, monthly, yearly, etc.),
  but the remained water existing each time is important.

- We'd like to introduce new tools to consider it carefully and widely.

1. What is the Available Water Climatology (AWC)

More Useful?

- For understanding the nature (than PCN Climatology)
  - Climate Classification and Season Division have revised in Korea successfully.

The Water Abundant Season (WAS, 풍수기, 豊水期)=NEW

The Little Water Season (LIWAS, 갈수기, 渴水期)=NEW

The Much Water Climate (MWC,多水氣候, 다수기후)=>imp.

The Small Water Climate (SWC,少水氣候, 소수기후)=> imp.

The Summer Water Climate (SWC, 夏水氣候, 하수기후)=>imp

The Winter Water Climate (WWC, 冬水氣候, 동수기후)=> imp

1. What is the Available Water Climatology (AWC)

More Beneficial?

- AWC changes the random distribution of (hourly, daily) precipitation with many zeroes, into a single curve of intensive property without zero.

- The prediction of water related disasters like flood, land-slide, inundation, soil flow, earth collapse etc. has been impossible or incomplete.

But they are,

- More accurate, more precise, and easier
- Possible, not only by the specialists but also by the general public,
- Considerable as a new breakout of disaster prevention activity.

1. What is the Available Water Climatology (AWC)

For what is AWC used?

1
- The Objectively Quantitative Assessment of the Water Environment for ecosystem (like agriculture)

2
- The Objectively Quantitative detection of the danger and the Vulnerabilities of the water related disasters
  - like flood, drought, inundation, mountain slide, soil flow, collapse of ground etc.

3
- The Objectively Quantitative prediction of the water related disasters.
  - 1, 2, and 3 have been used Only in a Qualitative assessment.

4
- Season division
  - like the water abundant season (豊水期, WAS) and the little water season (渴水期, LIWAS)
  - Neither WAS nor LIWAS in classical PCN Climatology

5
- Spatial climate classification on Water
  - much water climate (MWC, 多水氣候地域) and little water climate (LWC, 少水氣候地域)
  - Much rain climate (多雨氣候域) and little rain climate (少雨氣候域) in CPC

The important is not rain but water itself, so to speak, remained water or available water

2. How to calculate the AW indexes, AWRI, LWI, SWI

◆ AWRI (Available Water Resources Index)

- Summing up PCN with Time Dependent Reduction Function (TDRF)

(1) $$E = \sum_{N=1}^{D} \left(\frac{\sum_{m=1}^{N} P_m}{N} \right)$$

(2) $$W = \sum_{N=1}^{D} \frac{1}{N}$$

(3) $$AWRI = E/W$$

- **Summing how long? Duration Decision Technique (DDT).**

1. D in eq. (1) is **365 at first**,
2. * **increases if AWRI is continuously larger or smaller than mean value.**
3. * returns to 365 when the deviation of $AWRI_{365}$ from mean changes between '+' and '-'.
4. With the revised **N,** AWRI and its mean are calculated again in every step.

EDI comes after this technique, and has solved **the problem on drought duration**

Other drought indexes? No method has been introduced deciding the DD reasonably.
SPI? Many time steps 3, 9, 12, 24, 49 months,
PDSI? Sensitive only 1 year's drought.

The best Time Dependent Reduction Function (TDRF)?

※ **What is the best Time Dependent Reduction Function (TDRF) in ?**
Many cases are investigated but one Empirical function is selected = a.

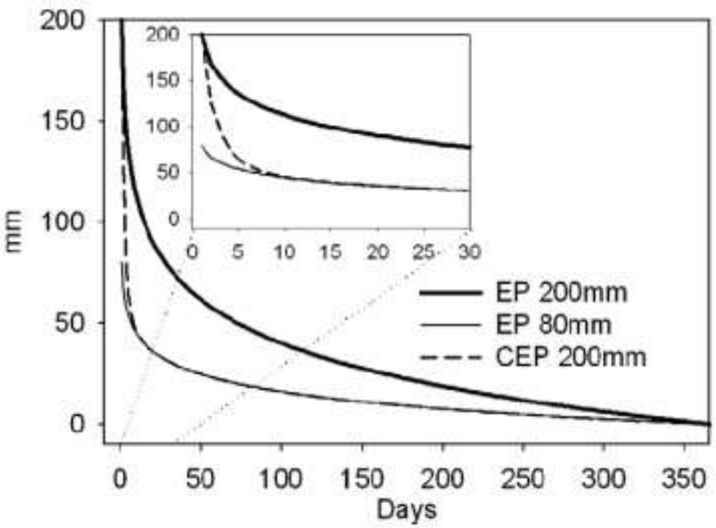


Fig. 3. Variation of the weight of 200 mm (thick solid line) and 80 mm (thin solid line) precipitation to EP (Eq. (1)) as the days pass, and that of 200 mm (dashed line) precipitation to CEP (Eq. (4)), which considers the rapid outflow of water resources that has been created through heavy rain.

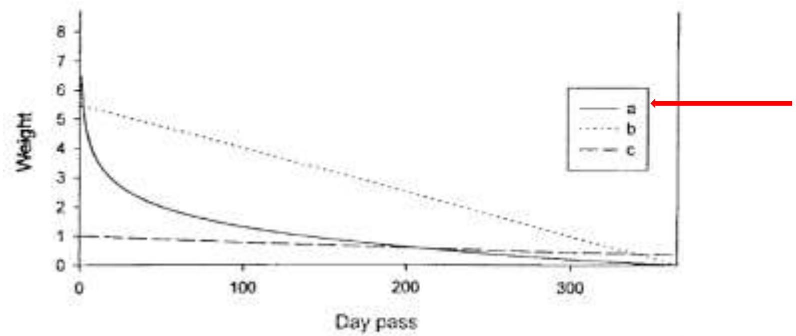


FIG. 1. Variation of the weight of precipitation to EP along the day pass, which is considered in (a) Eq. (2), (b) Eq. (2), and (c) Eq. (1). The abscissa axis reflects day pass. Ordinate axis shows a multiplied number to the rainfall amount along the day-pass to calculate the EP. For example, in (a), precipitation 1 day before being added to the EP after having been multiplied by 6.4, but one 365 days before is added after multiplication by 1/365. Here 6.4 is the sum of $1/n$ when n varies from 1 to 365.

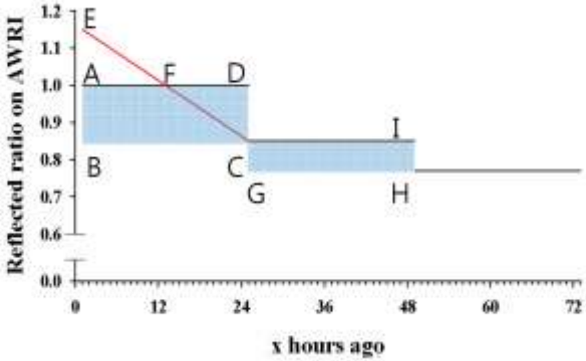
Calculation Eq. of AWRI is complete?
=> Questionable, but No problem.
It is confermed again with the data maden by the occurrences of the disasters.

2. How to calculate the AWC indexes, AWRI, LWI, SWI

◆ **LWI** (Long term remained Water Index)

- DEF: Same as AWRI but hour interval.
- USAGE: Assessment of the vulnerability to flood like disasters (inundation, mountain slide, soil flow, ground collapse etc.)
- CALCULATION

(4) $$P_1 = \sum_{x=1}^{24} (t_x \times (-0.0125x + 1.1625))$$



◆ **SWI** (Short term remained Water Index)

- DEF: Same as LWI but for short duration (24 hours ~72 hours)
- USAGE: prediction of the water level change in river.
- CALCULATION (D = 24h ~ 72h))

(5) $$E = \sum_{N=1}^{D} \left(\frac{\sum_{t=1}^{N} P_t}{N} \right)$$

(6) $$W = \sum_{N=1}^{D} \frac{1}{N}$$

(7) $$SWI = E/W$$

3. Difference of AWC from CPC

The distribution of random bars (daily distribution) has changed to one curve of AWRI.

Quantified Curve is more useful than random bars

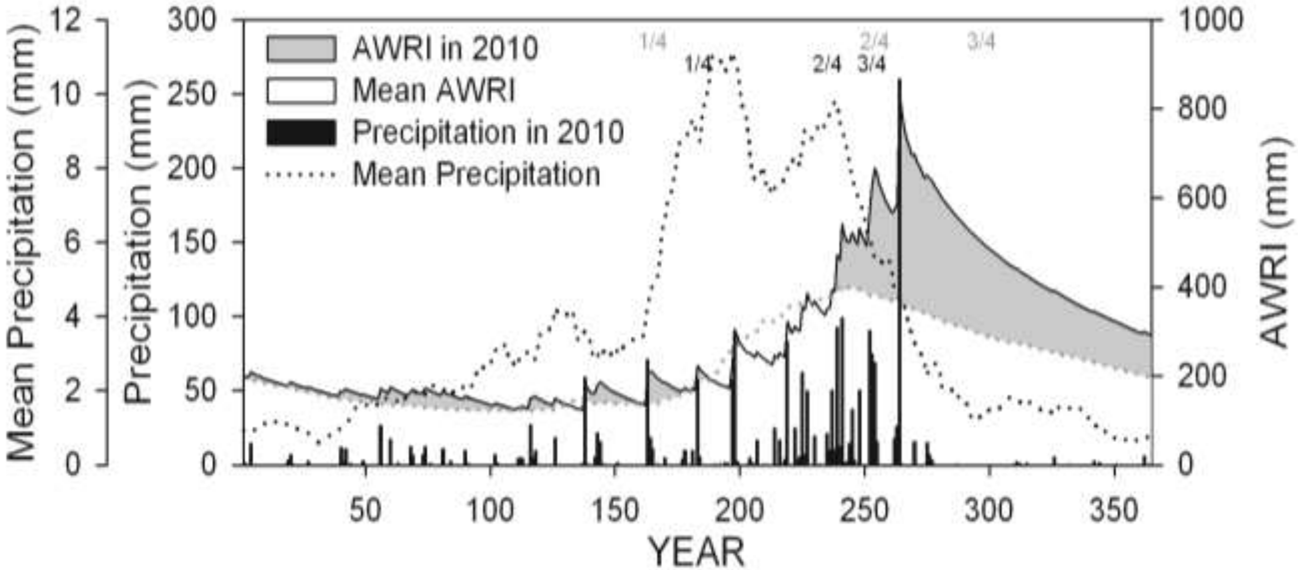


Figure 2. Seoul. Vertical bar and black solid line indicates daily precipitation and AWRI respectively. Black dotted line and dark grey dotted line denote mean of precipitation and AWRI per date respectively. Dark gray shaded area is positive AWRI anomaly.

- **Easy to see** & when the dates of the Max. and the Min. of water are, that are impossible in PCN distribution.
  » **useful for season classification**
  & more or less than the normal values every day » **useful for the drought assessment**
- **In case of** & hourly distribution » **useful for the flood-like disasters**
  & Spatial distribution » **easy to detect the regional characteristics of climate.**

3. Difference of AWC from CPC

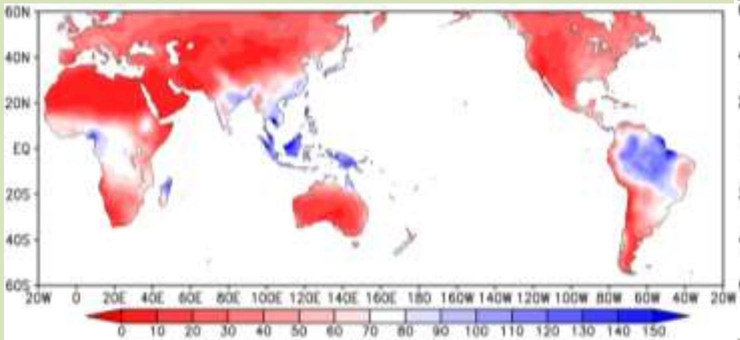
Difference of AWC from CPC

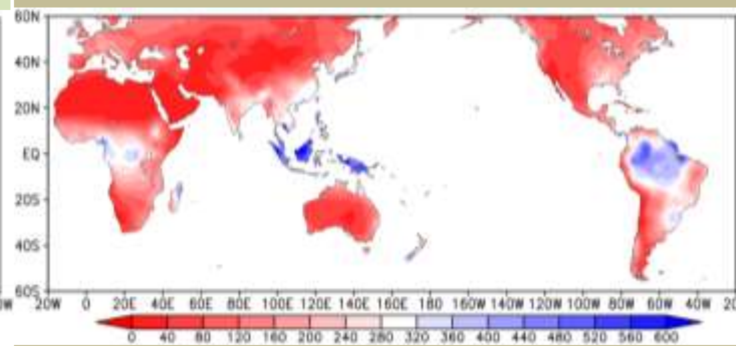
	Classical Precipitation Climatology (CPC)	Available Water Climatology (AWC, New developed)
Concept	Accumulation of PCN for a Year, Month, Day, Hour	Remained Water at a pointed Hour, Day, Month, Year after RUNOFF, Evapotranspir ation etc. of PCN.
Calculation	Simple summation	With Eqs. (TDRF, DDT)
Variation of water resources along time pass	Not considered	Considered
Dimension of its distribution	3 dimension	4 dimension
Characteristics	Extensive property	Intensive property
Time scale	Fixed time scale	Sliding time scale but different from SPI

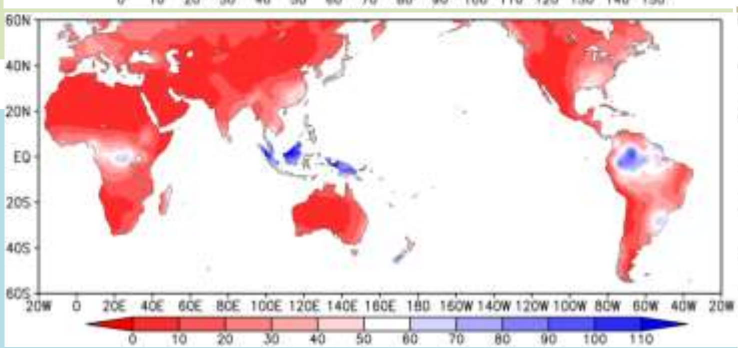
4.1 Detection of 4 dimensional water distribution

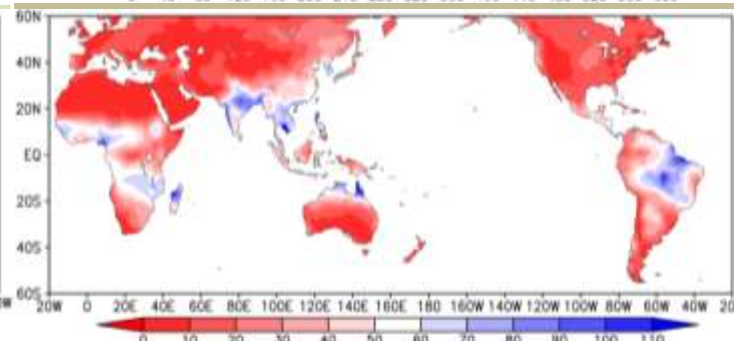
(a) Max. of AWRI = The biggest water concentration region is in 20°N~20°S.
※ The extreme is not over India but at Cambodia .

(d) Annual mean precipitation
: time distribution is not considered.
: No intra-annual fluctuation of water is detected.









(b) Min. of AWRI
※ The extreme minimum is over Sahara.

(c) = ((a)-(b))= Big intra-annual fluctuation of water is in 20°N~20°S except Equator

Real time monitoring the daily distribution of water (not PCN.) became possible every day. => Food trading company will like it.

4.2 Detection of drought intensity

◆ **EDI (**Effective drought index) *Solved the problem of drought duration.*

- SPI cannot detect the start, end, and duration of drought.
- PDSI cannot catch the drought longer or shorter than 1 year scale.

All of other drought indexes have same problem.

But EDI & has solved this problem by using DDT.

& can detect the start and end date, duration, and intensity of drought.

& can reflect the daily variation of drought condition in detail
(Rain for 1 day can return the drought to normal. EDI can detect this change at exact time)

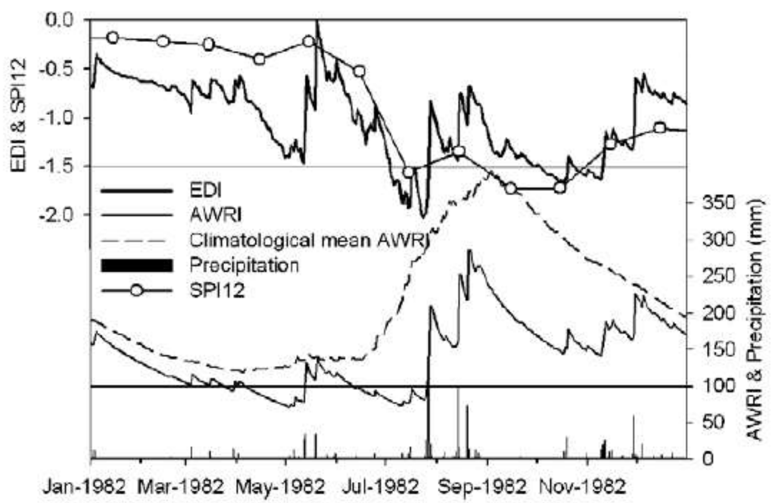


Fig. 10. Time-series of EDI, 12-month SPI, AWRI, and precipitation from January 1 to December 31, 1982. Dashed line denotes the climatological mean AWRI.

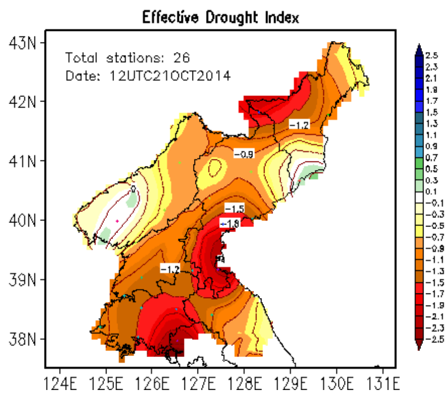
There are many studies that verified EDI is the very good drought index.

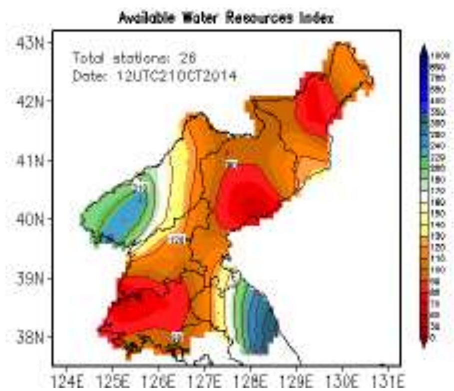
After (Byun and Wilhite, 1999), EDI became one of the popular drought index.
Dogan et al., (2012), Kim et al., (2009), and Morid et al.,(2006), etc. verified that EDI is the best Drought Index.

4.2 Detection of drought intensity

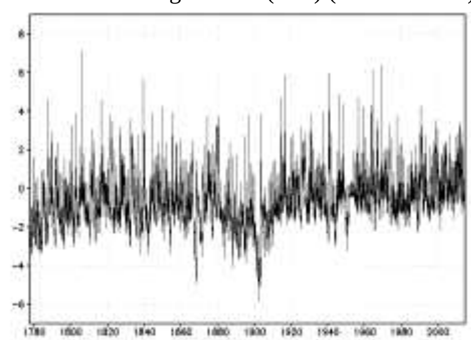
Daily drought monitoring system in Korea

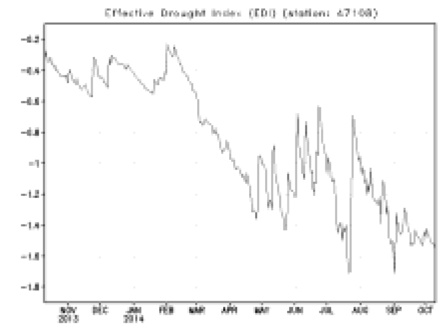
-Source-
http://atmos.pknu.ac.kr/~intrank/
http://atmos.pknu.ac.kr/~intra3/





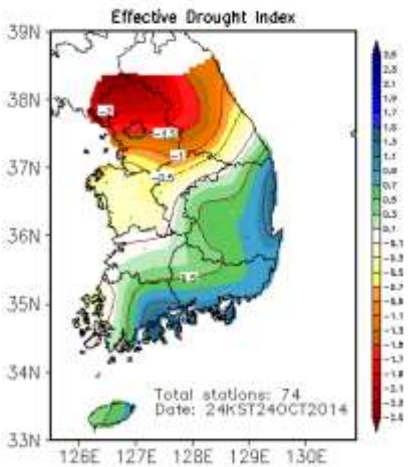
Effective Drought Index (EDI) (station:47108)

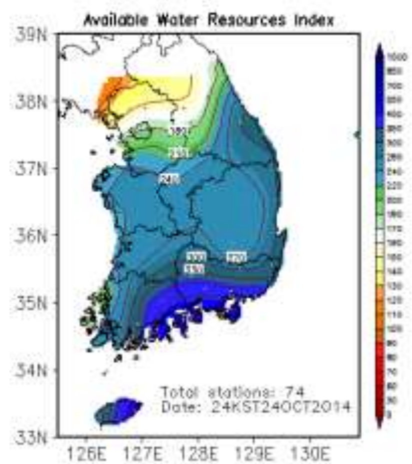




Spatial distribution

Time series





0. at 24 Oct., Water is enough now but seriously below normal at Central part of Korean peninsula.(S. and N. Korea)
=> Spring & Summer in 2015 big damage is expected.

0. At 1901, the biggest drought occurred, next will be at 2025.

4.2 Detection of drought intensity

Drought map of Korea

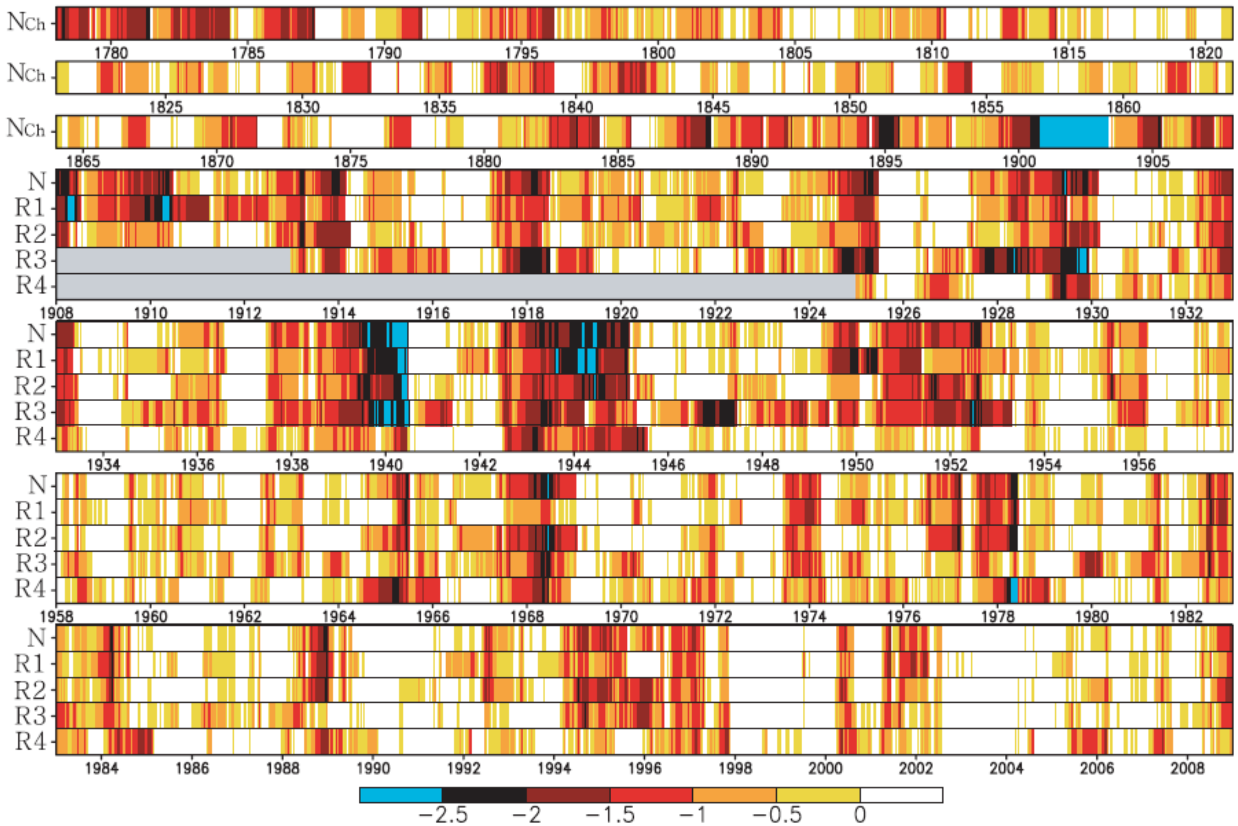


FIG. 7. Historical drought map (EDI) from 1778 to 2008: NCh denotes the EDI calculated from the chukwookee dataset (1777–1907 in Seoul), N represents the national EDI, and R1 (central), R2 (southern), R3 (east coastal), and R4 (Jeju Island) denote the regional EDI over each drought subregion.

With help of AWRI, Easy detection when and where the drought occurred

4.3 Detection of the danger of flood like disasters

Many problems on the heavy rain warning and Water disasters

- Example –
In the heavy rain warnings **(6 hours, 110 mm),** = subjective considerations

1. Why **6 hours? The** heavy rain for one hour can also culminate into disaster?

2. Why **110 mm? Rain of 50 mm can** produces disasters in certain area?

3. If 110 mm were evenly distributed over 6 hours, is a water-related disaster eminent?

4. Is it possible to predict when and where the water will reach peak capacity?

5. The similar combination cases of D and R?
It is hard to find although similar impacts of disasters are noted frequently.
=> Therefore, disasters are difficult to be predict objectively by this combination method.

6. **Same problems are in all of the heavy rain warnings!!**

4.2 Detection of the danger of flood like disasters

In successive heavy rain case

➢ **Only heavy rain warning can prevent disasters?**

- Heavy rain Warning systems -

Country	Duration (within hour)	Rain Amount (more than, mm)
Korea	6	110
China	3	100
India	24	250
Japan	24	100
Australia	24('Flood' alert), 3('event' alert)	0
Turkey	12	100
Vietnam	24	100
Germany	1	251

Table 1. Highest level of the heavy rain warning based on durations and rainfall amount.

- Problems & Solution -

- Warning if more than 110 mm in 6 hours.

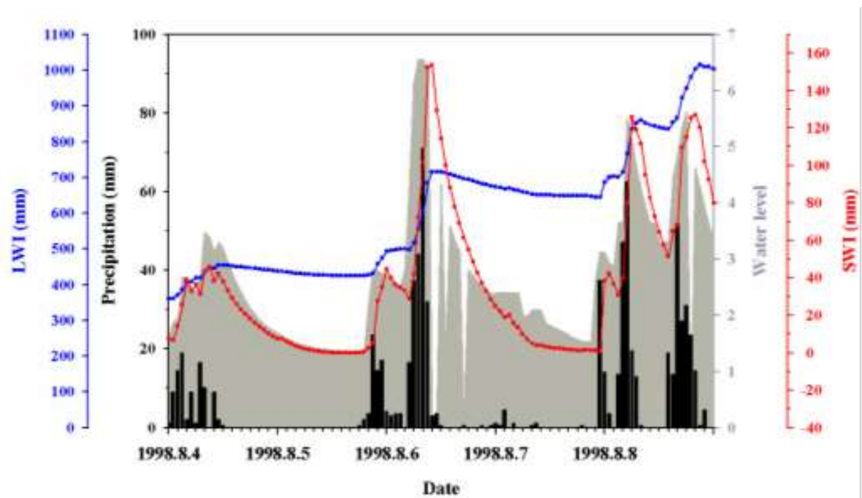
1. How about 109 mm in one hour?
   - ✓ Much more danger but no warning.
2. How about successive several heavy rain warnings?
   - ✓ Very dangerous but no method to quantify it

- USA, Iran, Bangladesh do not use the heavy rain warning, but use flash-flood warning depending the water level observation.
- In this case, they need another warning on inundation, land-slide, soil flow or collapse.

LWI, SWI solve these problem

4.3 Detection of the danger of flood like disasters

The case of Jungryang Flood at August 1998



- Case of successive heavy rains:
  -Many heavy rain warnings in 10 days.

  For 5 days (4~8th Aug.) with 690 mm rain,
  after 99.5mm for 4 days (31 Jul. ~ 3 Aug. 1998).
- No methods have been available to measure this danger except AWC.

denote **the flooded area.**

4.3 Detection of the danger of flood like disasters

For application to the predictions on water-disasters

Many random bars of hourly PCN with many zeroes have changed to a curve without zero.

- **LWI (Long-term remained water index, Accumulated more than 365 days with TDRF)- Blue line,**
- **SWI (Short-term remained water index, Accumulated 24~72 hours with TDRF) – Red line**

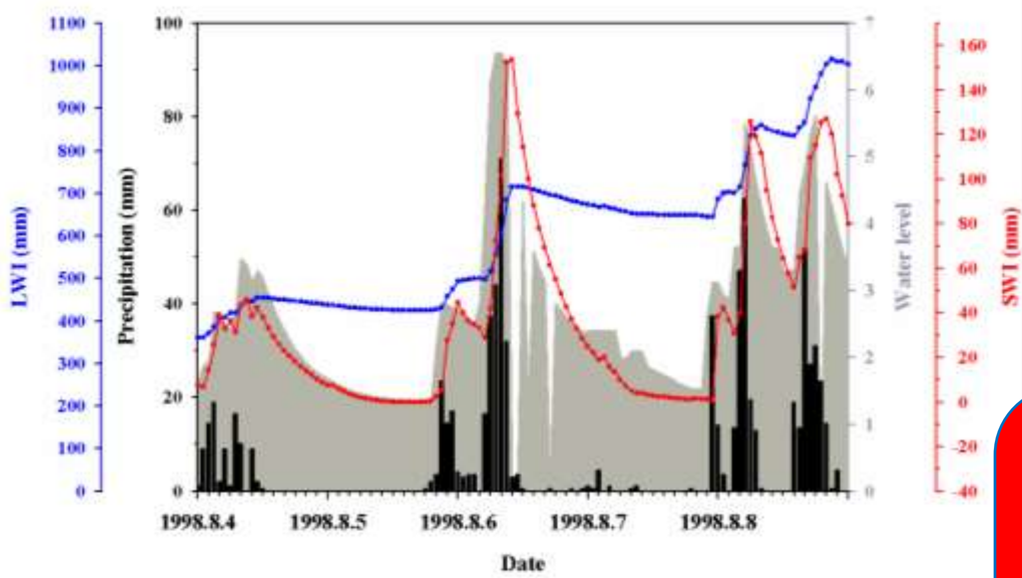


Fig. 2. The heavy rain case at the August 4th to 8th 1998. Bars denote hour rain (mm), red curve *SWI*, blue curve *LWI*, and shading is the water level at Jungryang Bridge.

- LWI, SWI quantifies the timely variation of the danger of water disasters covering flood, inundation of all scales, land-slide, soil flow, soil collapse etc.
- \- SWI-24 coincide with the variation of the water level of the Jungryang River.

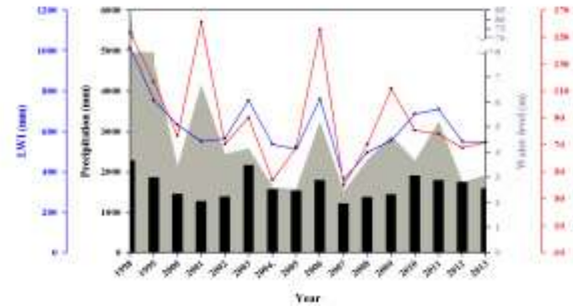
-The bigger LWI, the bigger the danger of disasters.

-The combination of the LWI and Disaster's occurrence time can make it predictable.

4.3 Detection of the danger of flood like disasters

For disasters become bigger along the value of AWRI, LWI, SWI

Disaster Event	LWI	SWI	Time (Aug. 1998)
1. Flood in Jungryang Stream	436	44	4th 0800
2. Eastern Trunk Road inundated	497	29	6th 0428
3. Inundation Dobong Station (full stop of subway-7) (recovered partly after some time.)	556	72	6th 0557
4. Sand slide in U-ie Dong	683	152	6th 0800
5. Subway of Euijungbu City Hall inundated again	651	4	7th 0900
(Eastern Trunk Road recovered)	644	1	7th 2230
6.0. Flood in Banghak Stream 1. Land slide, soil runoff and inundation in neighbouring area. 2. Eastern Trunk Road closed again at 0240I	714	40	8th 0330
7. 0. Landslide in Chang-Dong 1. Inundation of Dobong Station lobby (2nd full stop of Subway–7) (recovered after some time.) 2. Provisional levee (50 m) of Dobong Stream washed away.	835	126	8th 0500
8. Road of Seoul-Euijungbu closed.	852	95	8th A.M.
9. Partial inundation of 5 towns. (Evacuation of 1,900 residents)	920	133	8th 1640
10. Washed away of Jungryang Stream levee, (water level arrive 18.3 m: the danger limit is 17.7 m)	950	115	8th 1710
11. Increased inundation of subway-7, 3rd full stop	981	125	8th 1750
12. (Precautionary flood warning on Han River)	1004	127	8th 1900
13. (Extended evacuation)	1009	124	8th 1930

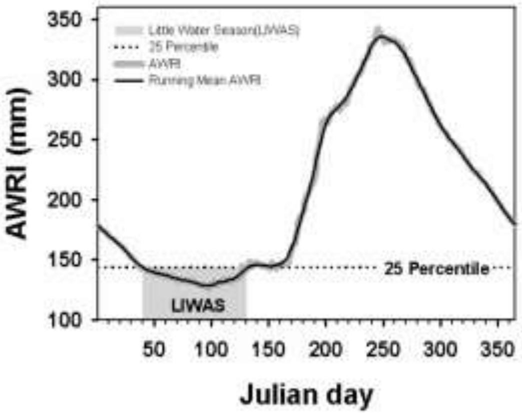


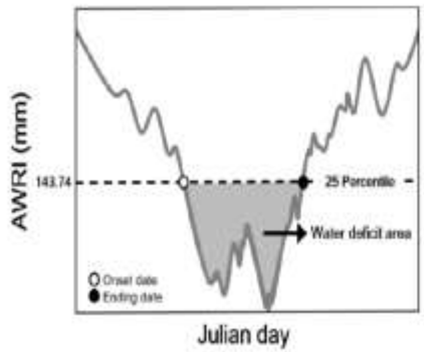
- It is found that disasters become bigger with increasing LWI,

  if LWI>> 500 , Jungryang River is flooded and the Eastern Trunk Road is inundated..

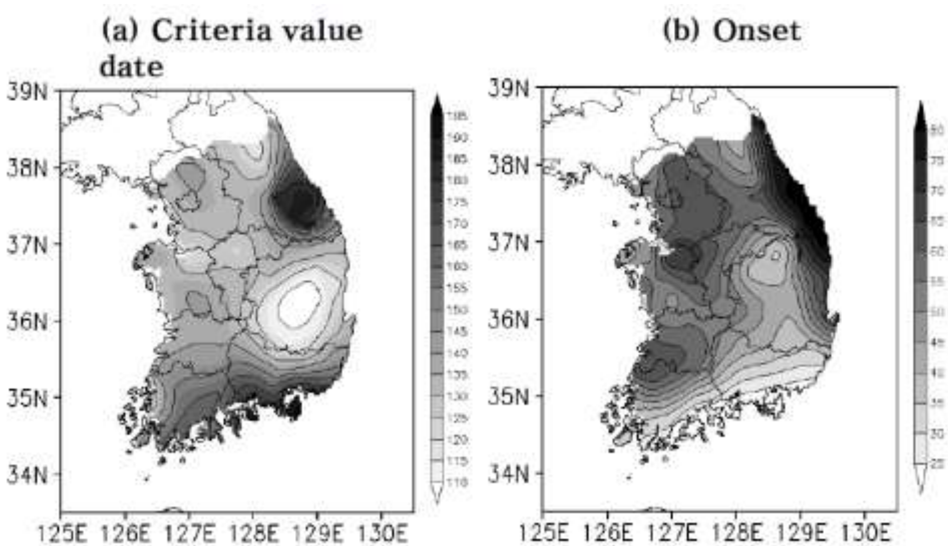
- Other water related disasters (landslide, inundation etc.) will be same.

4.4 Definition of LIWAS (渴水期, 갈수기)





Mean of Korea: 141mm, Feb. 19 ~ May 28



- 25% with the lower AWRI defined as Little Water Season (LIWAS). = 92D/Year.

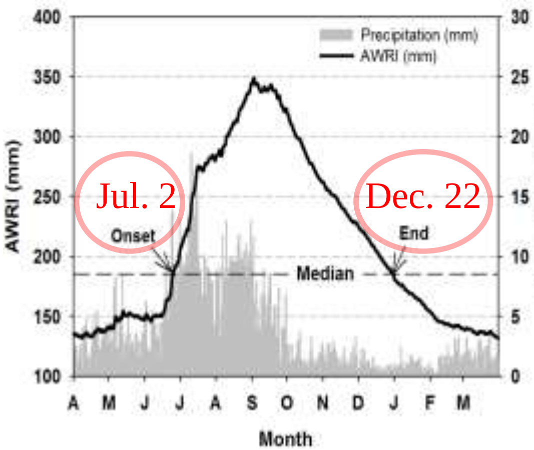
  The biggest = Geojae (205mm)
  ⇔ The smallest=Uiseong (108mm)

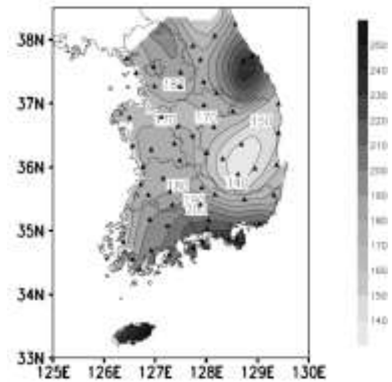
- The criteria of LIWAS differentiates the little water region from the much water region.
  (Big differences between a short distance)

Big differences in all characteristics were quantified

- Earliest onset: Namhae (Jan. 21)
  Latest onset: Gangneung (Mar. 25)
  = 63 days dif.
- Earliest end: Namhae (April. 22)
  Latest onset: Gangneung (June 22)
- No LIWAS years: Many

4.4 Definition of WAS (豊水期,풍수기)



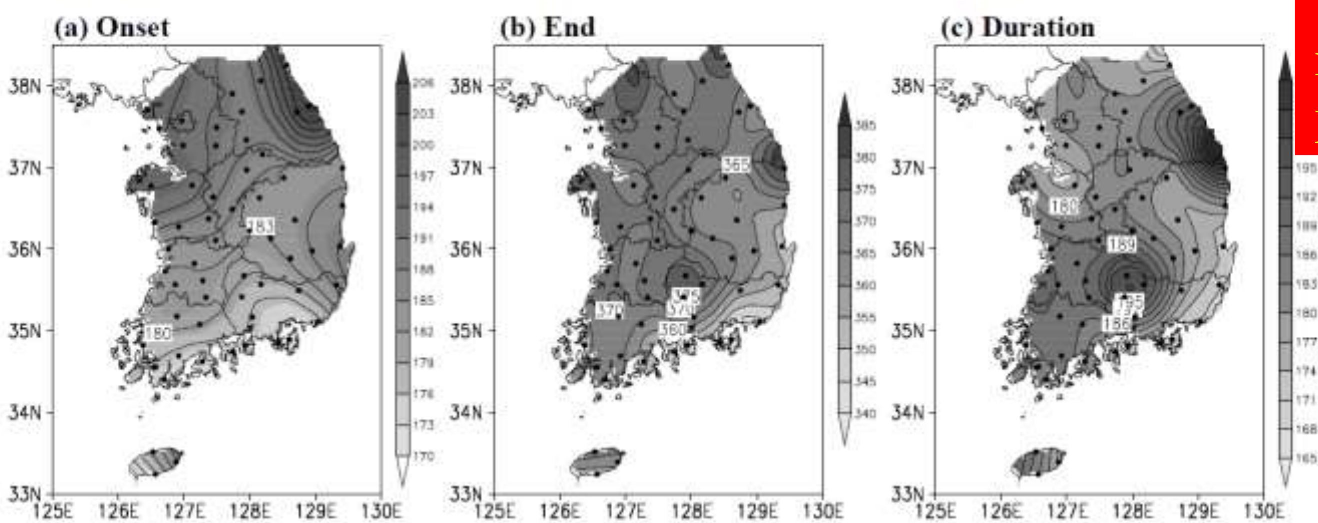


National mean: 174 days, 185mm

- Median of 365 AWRI defined as the criteria value of Water Abundant Season (WAS).
  - The biggest = Seongsan (271)
    ⇔ The smallest = Uiseong (136)
- The onset of WAS coincides well with the one of Rainy season.
  - Earliest onset: Seogwipo (Jun.14)
    Latest onset: Sokcho (Jul.24)

  (Big difference between a short distance
  ⇔ important for Ecosystem)
- End of WAS is quietly different from the one of the rainy season.

WAS concept is better the rainy season concept in some part.



Earliest End: Tongyeong (Dec. 5)

Latest End: Uljin (Jan. 16)

Longest: Uljin(207 days)

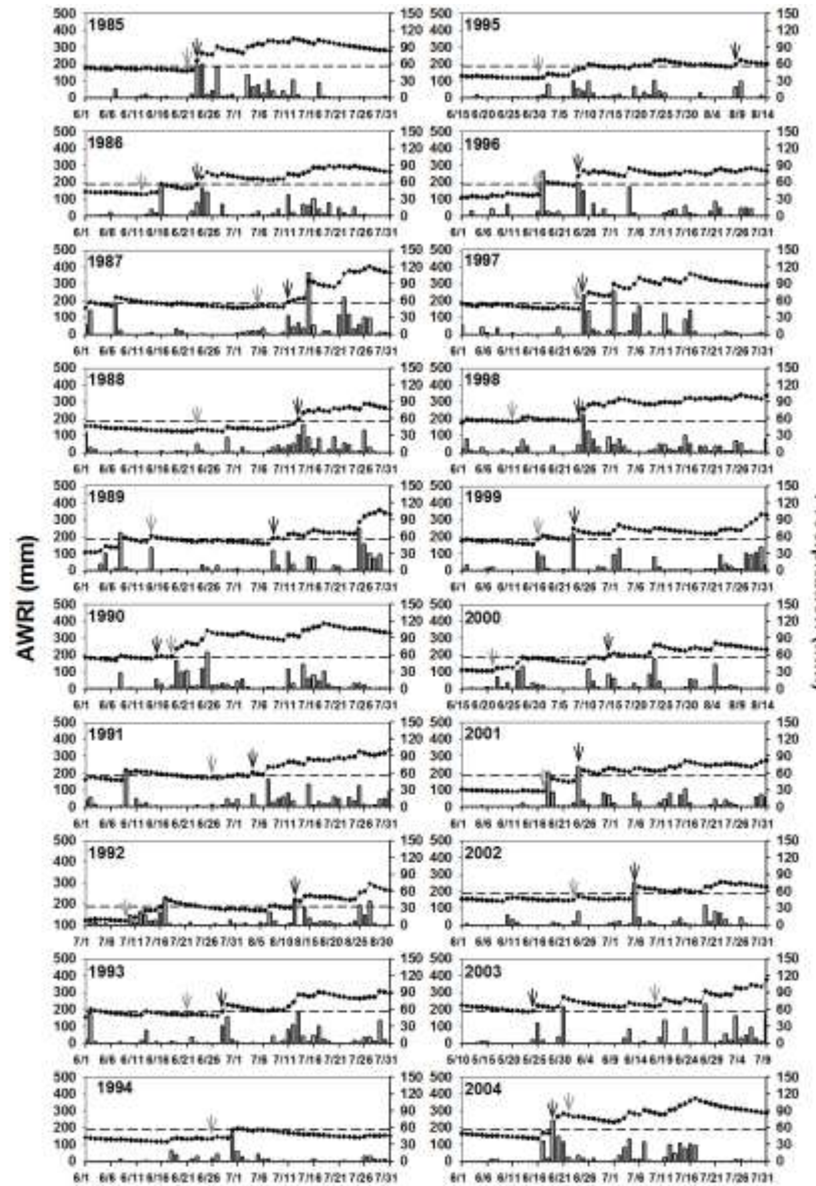
Shortest: Tongyeong(166days)

4.4 Definition of LIWAS (渴水期, 갈수기) and WAS (豊水期,풍수기)

For comparison of WAS and Changma (rainy season)

	WAS	CHANGMA
Use to define	Available water	Atmospheric circulation
Calculated by	Precipitation only	PCN, OLR, Pressure pattern, etc
Decided	Objectively (easy)	Subjectively (hard)
Year of no occurrence	Frequent	None
To prevent or reduce the disasters' damage	Useful	Not useful
Represents	Water abundant season	Rain frequent season
Mean Duration	About 4 months	About 1 month
Most water disasters occur	In this duration	In or out of this duration
More useful for	The general public	The Meteorologist

WAS is more useful than Changma, not always but more frequently.



Conclusion:

It is clear that AWC is more reasonable and beneficial than CPC, especially to understand and to mitigate the water-related disasters.

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THANK YOU