The application of Soil Water Index to landslide prediction in snowy regions －Sensitivity analysis in Japan and preliminary results at Tomsk, Russia－

AKTRU2019@Gorno-Altaysk

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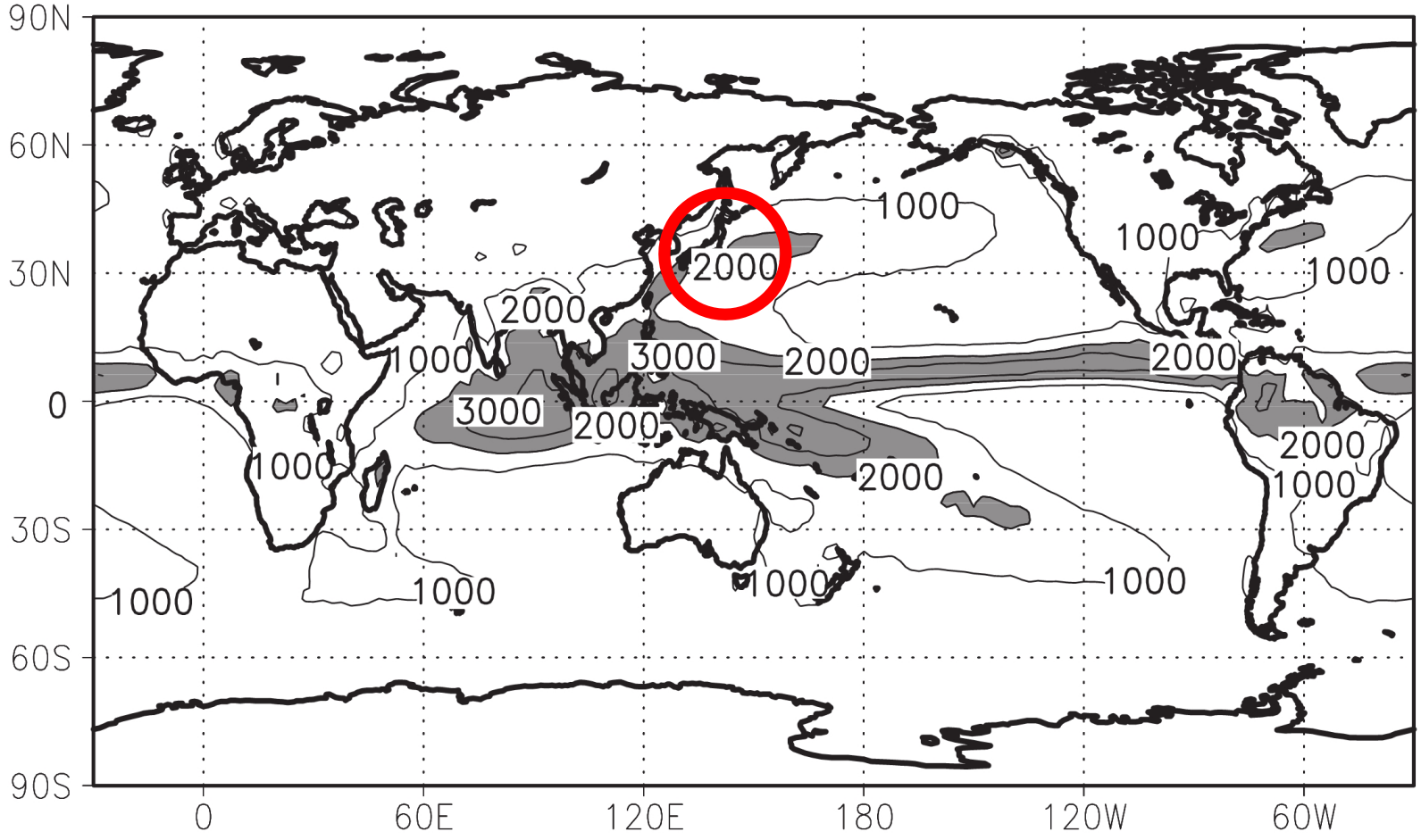
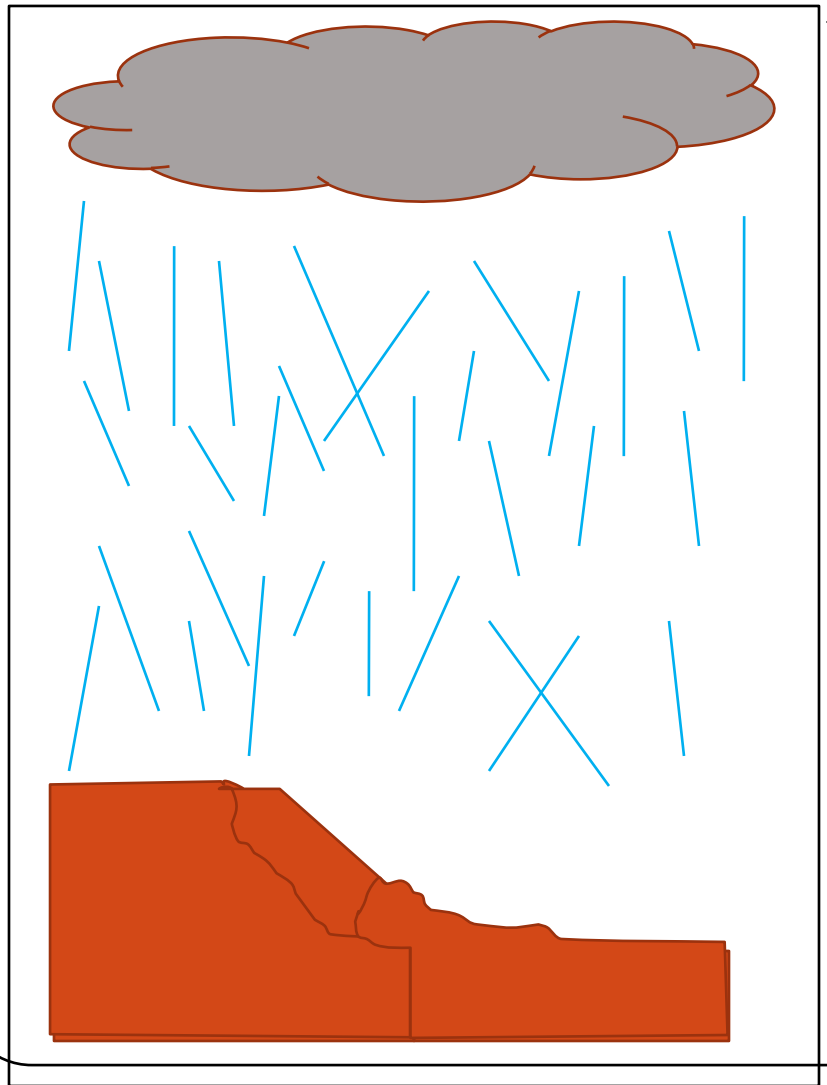
Introduction

- Japan receives much precipitation in a year.
- In Japan, heavy precipitation frequently occurs as well.

【Annual Precipitation (1981-2010, mm/y)】



Landslide prediction in Japan (Okada et al., 2001)



Landslides will occur when …

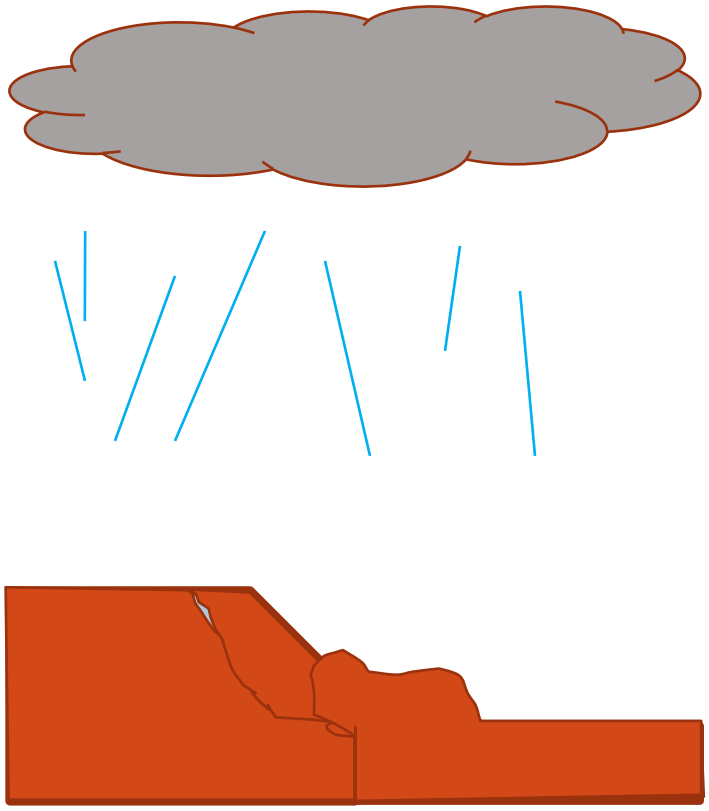
- Much soil water
- Just after stopping rainfall

In Japan,
Warning (Alarm) of heavy rainfall will be announced when …

Antecedent 1, 3, 24 hour's precipitation exceeds the criteria.

Problem of landslide prediction (Okada et al., 2001)

1) Just after the antecedent sequential rainfall event

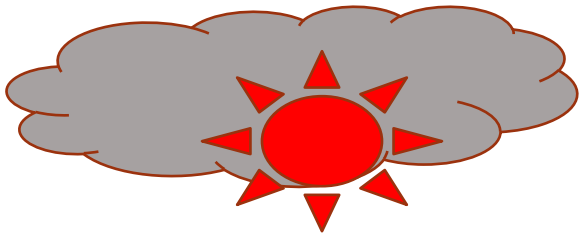


- Antecedent sequential rainfall event has increased soil water.
- Smaller rainfall event succeeds.
- Landslide occurs.

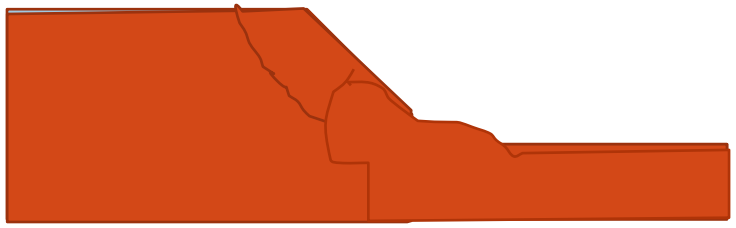
→ Difficult for its prediction

Problem of landslide prediction (2) (Okada et al., 2001)

2） After stopping rainfall event



- Antecedent rainfall event has increased soil water.
- Rainfall stops. → Fine weather
- Even after stopping rainfall, landslide occurs.

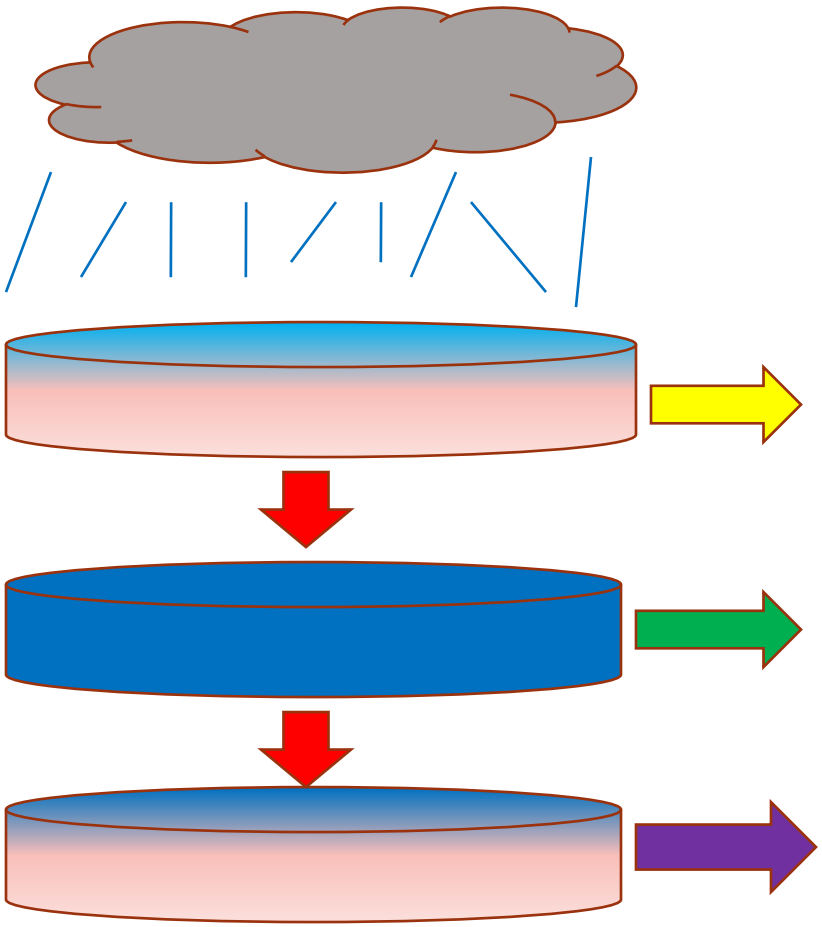


→ Difficult for its prediction

Condition of soil water is important !!

→ It is simulated by three-stage tank model.
(= Soil Water Index; SWI)

- Empirically, large-scale landslide occurs when SWI exceeds its maximum value of the past 10 years.

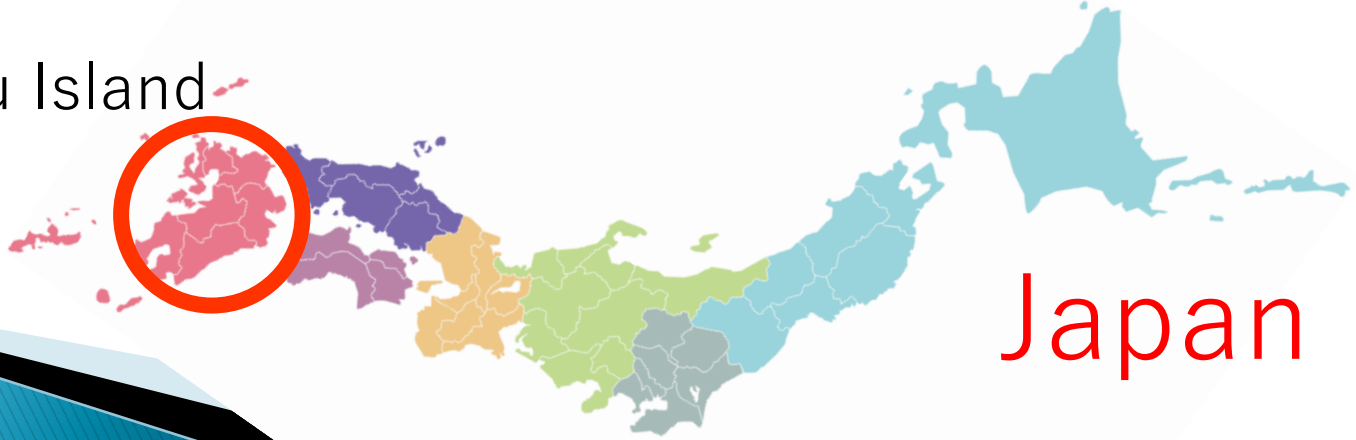


Case study:
Northern Kyushu heavy rainfall in July 2012

＜Summer 2011＞

＜Summer 2012＞

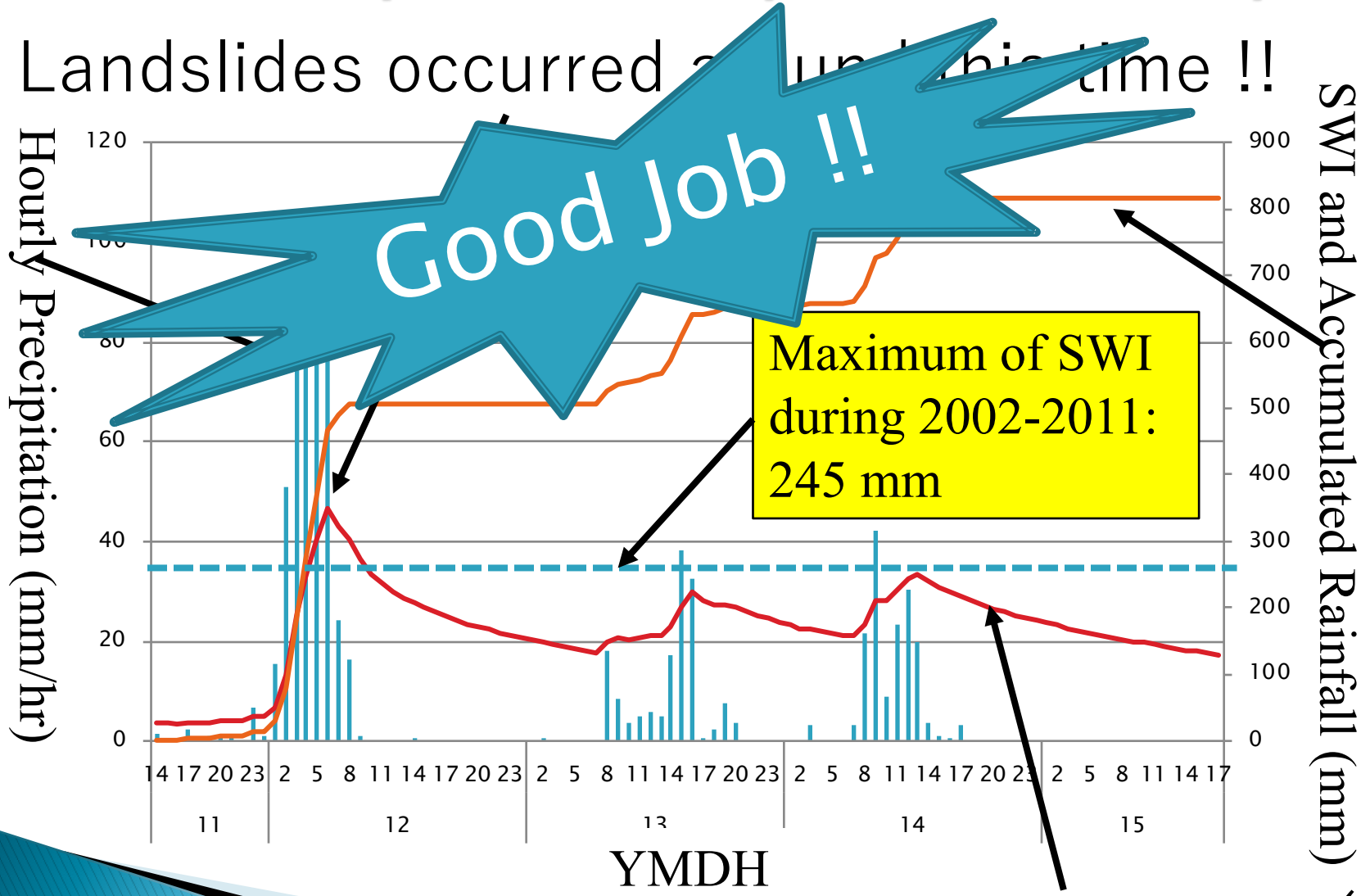
Kyushu Island



Japan

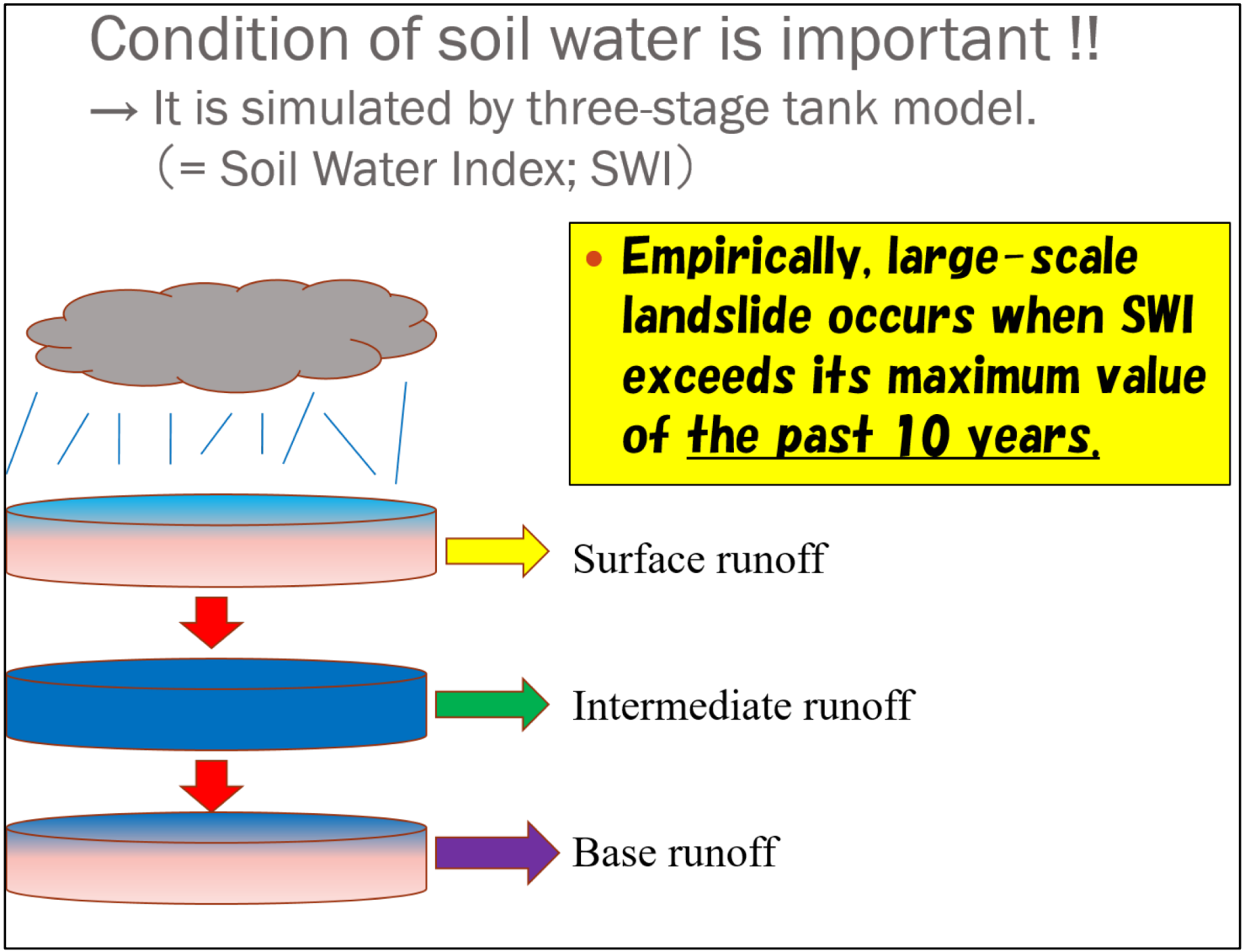
Case study:
Northern Kyushu heavy rainfall in July 2012

Landslides occurred a[illegible] this time !!

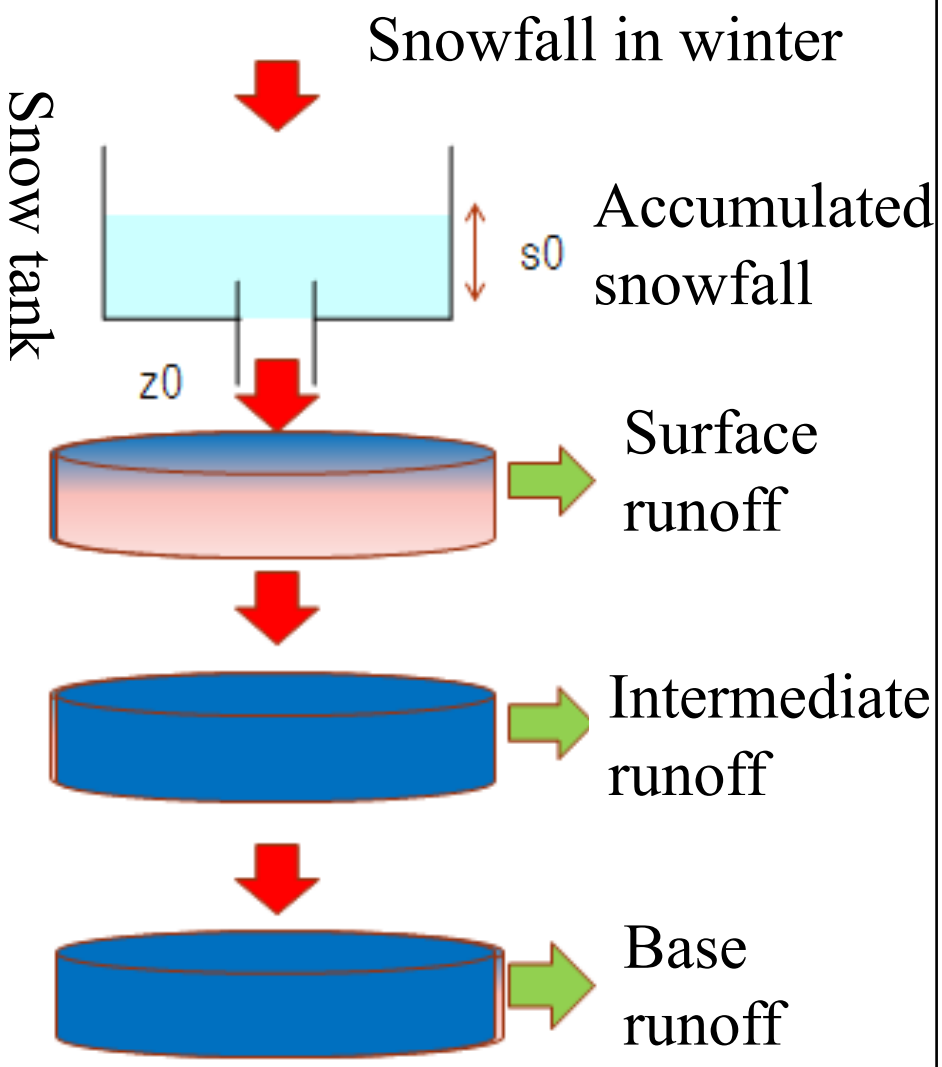


Another problem of SWI in snowy regions

- Snowfall is treated as rainfall which directly percolates even in winter.



In this study,
SWI is modified to account for snowfall/melt

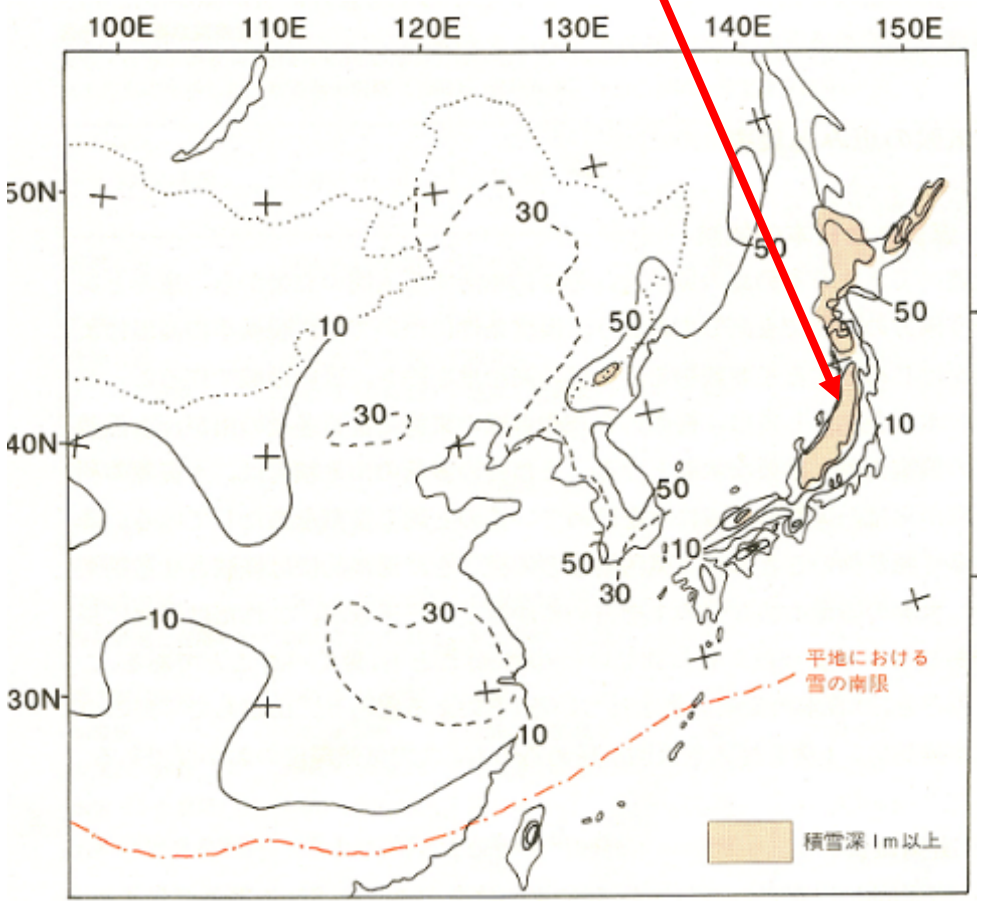


- Snowfall/Rainfall: Ta = 2℃
- Snowmelt (Ta > 0℃):
  - Calculated by degree-hour method, snowmelt factor determined by trial and error.
- Input data:
  - Hourly precipitation = daily precipitation /24
  - Hourly air temperature: reproduced by sine curve using max. and min temp.
- Validation:
  - Seasonal change of snow depth

Japan receives much snowfall as well.

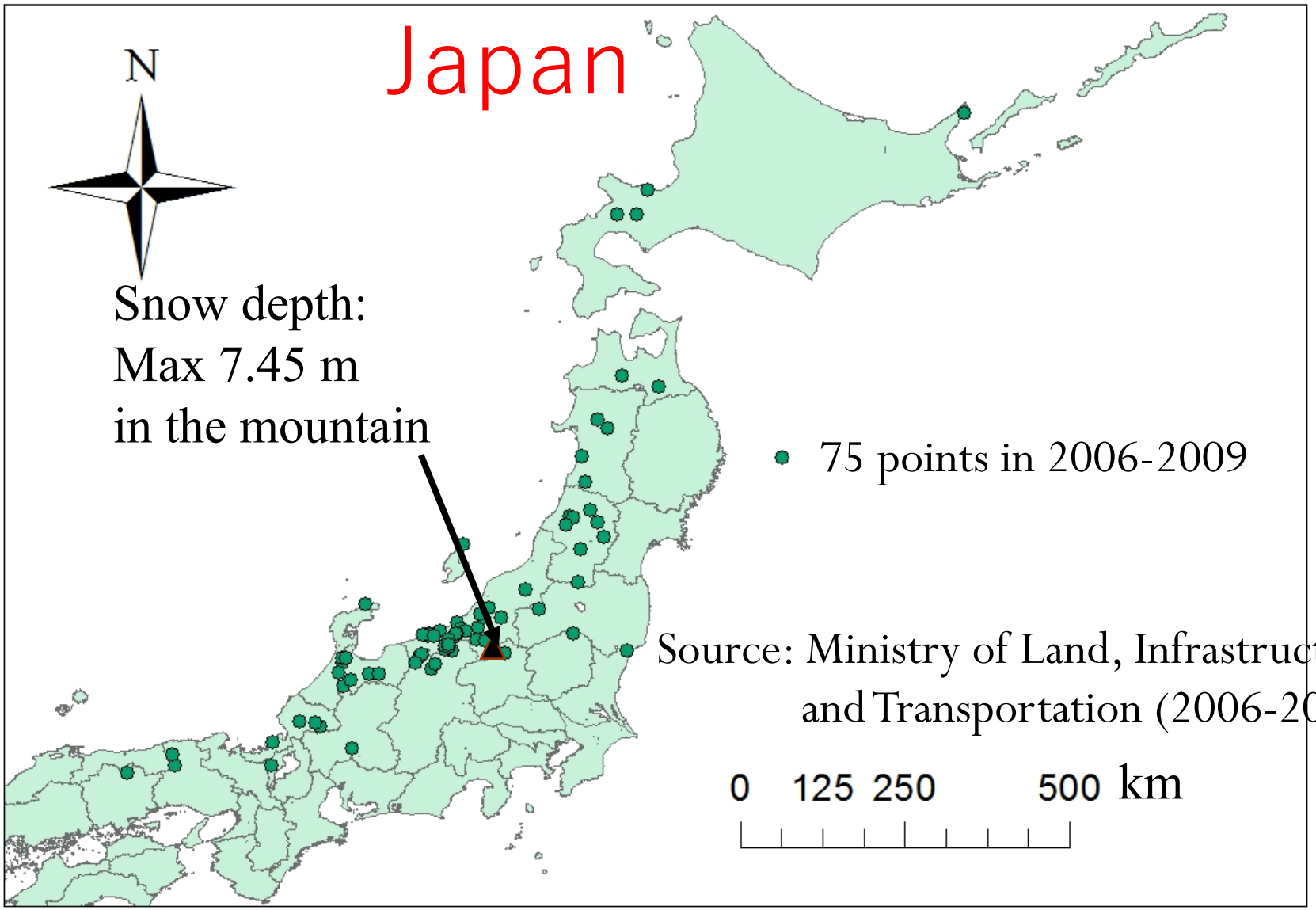
More than 1 m

Max: 7.45 m in mountain !!



Maximum snow depth in East Asia
(Unit: cm)

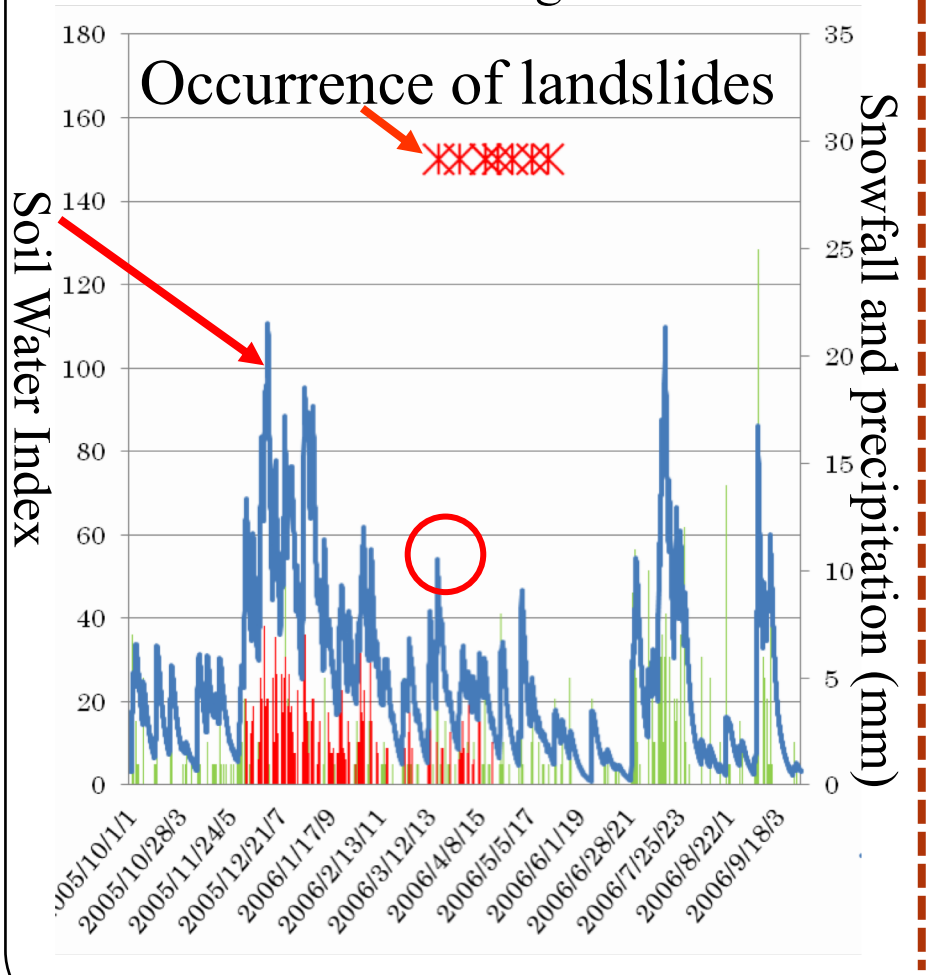
Snowmelt-driven landslides in 2006-2009



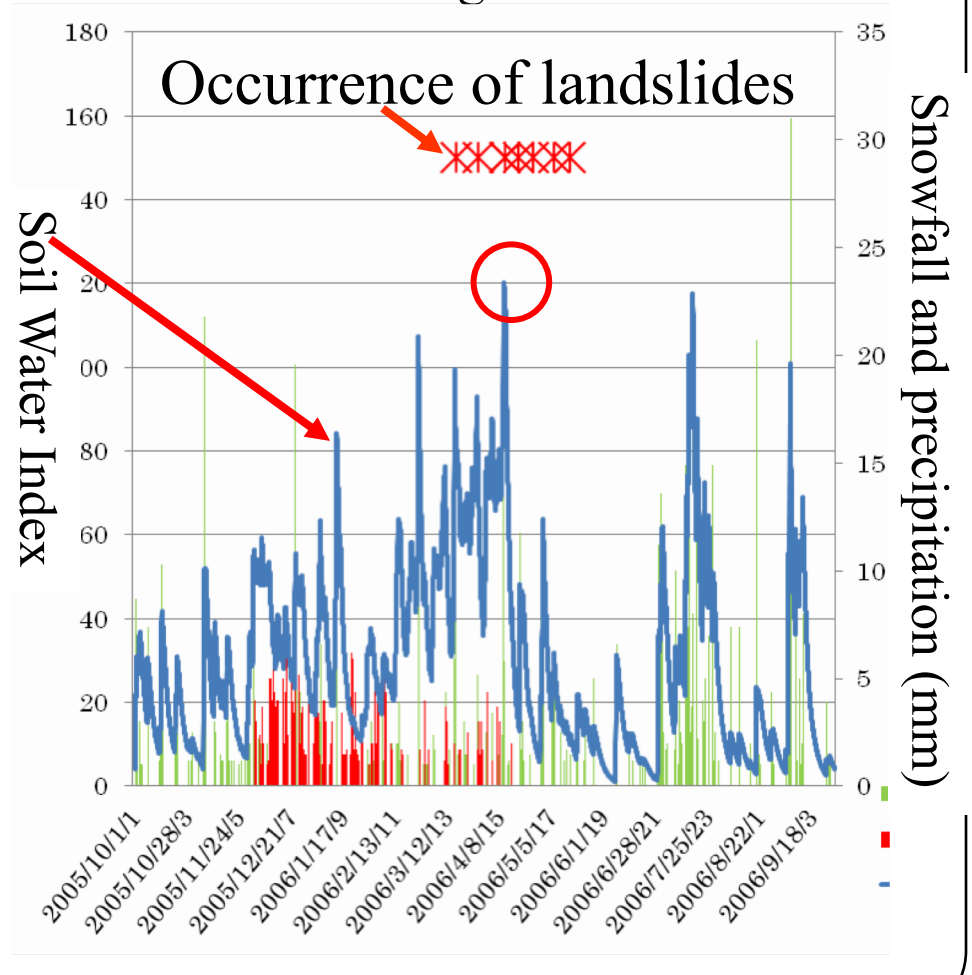
Comparison of Soil Water Index (SWI)

- Timing of snowmelt is well reproduced by the right figure.

SWI **NOT** considering snowfall/melt



SWI considering snowfall/melt



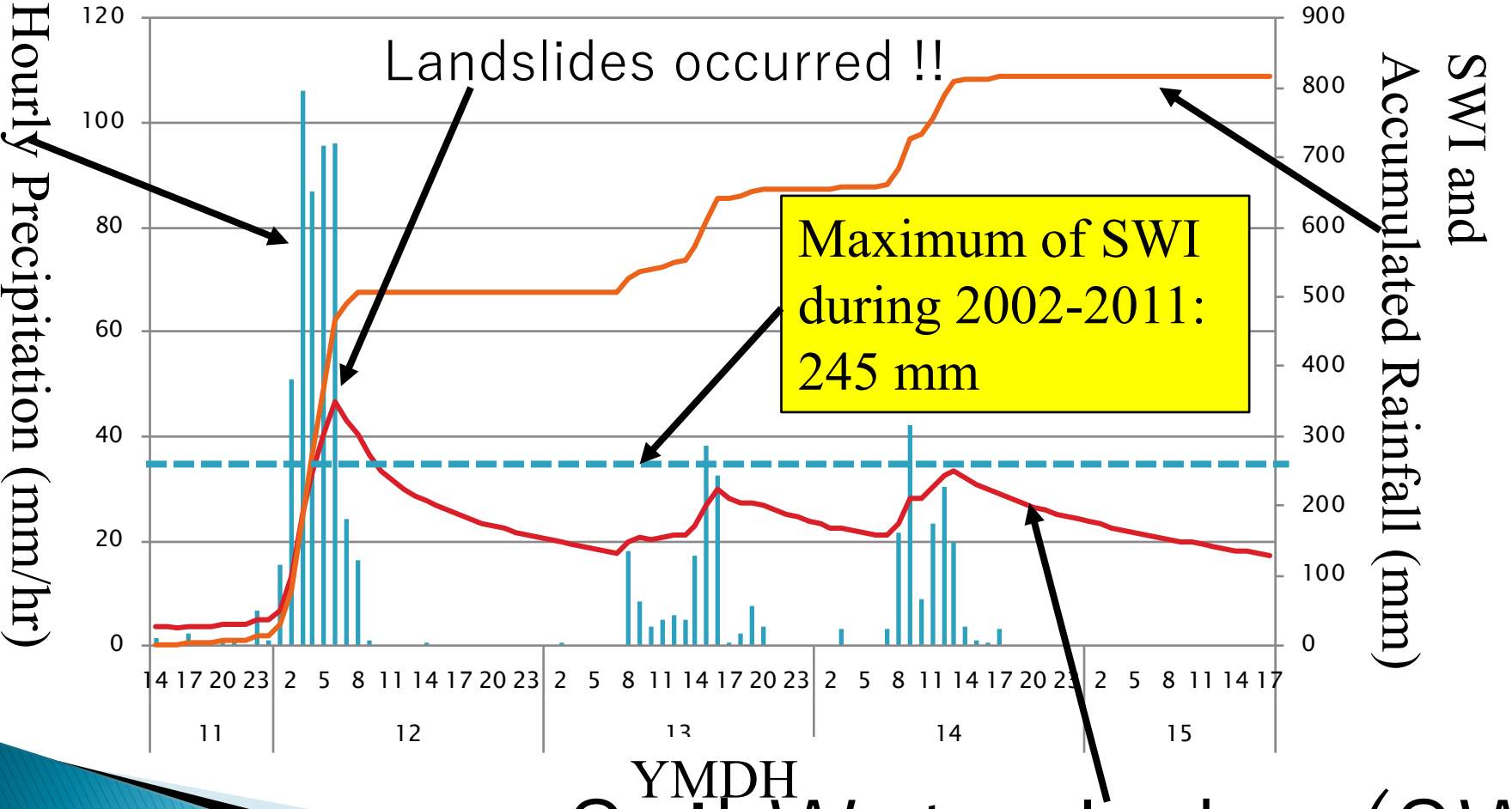
Implementation of “snow tank” into Soil Water Index (SWI) did good job !!

Next, “sensitivity test of input hourly rainfall”will be carried out.

Northern Kyushu heavy rainfall in July 2012 again !!

How does SWI change if we change the input hourly rainfall ?

- Hourly precipitation is given as “daily precipitation / 24”.



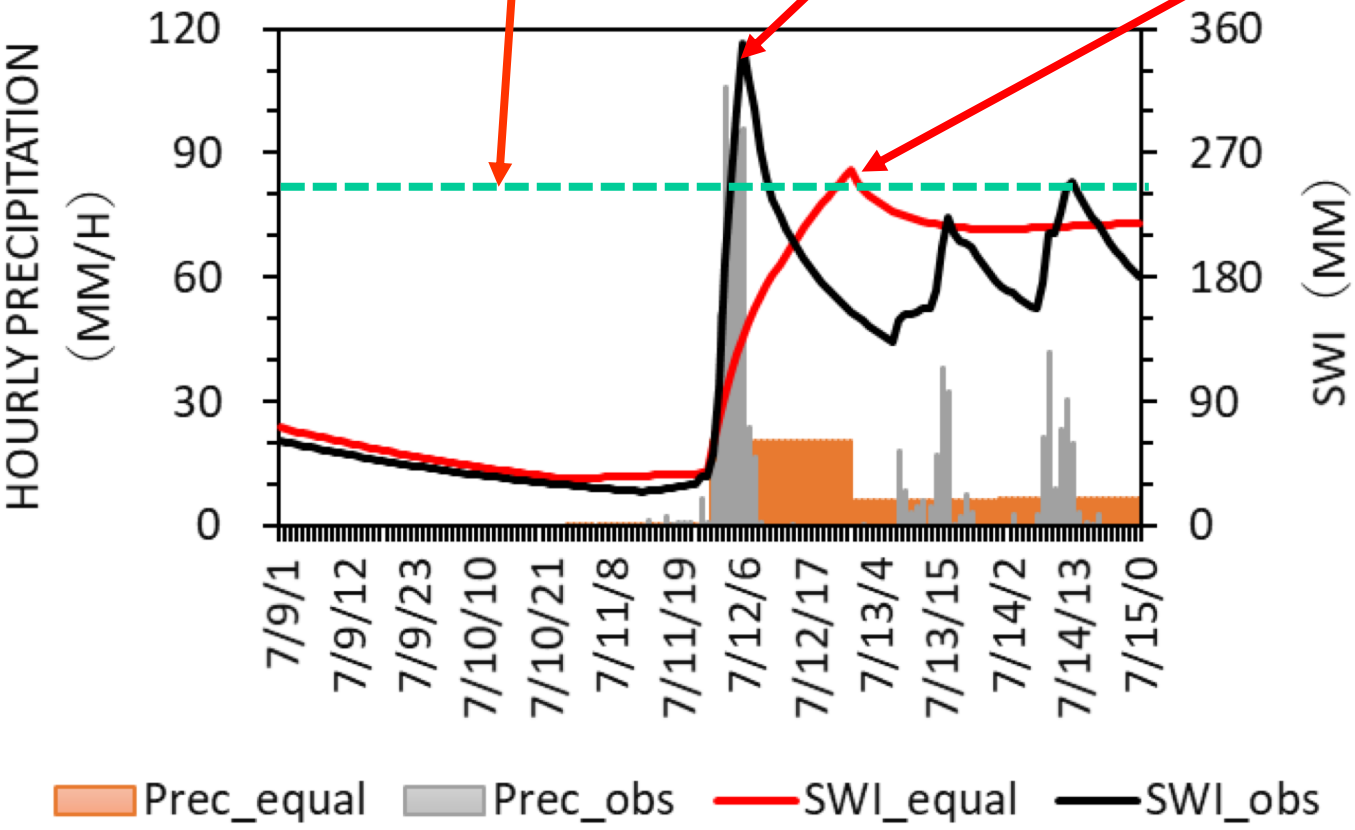
Soil Water Index (SWI)

In case
hourly precipitation = daily precipitaton/24

Maximum SWI in 2002-2011: 245 mm

SWI calculated by hourly precipitation

SWI calculated by daily precipitation / 24



the peak lags the actual SWI. (18 hours delay)

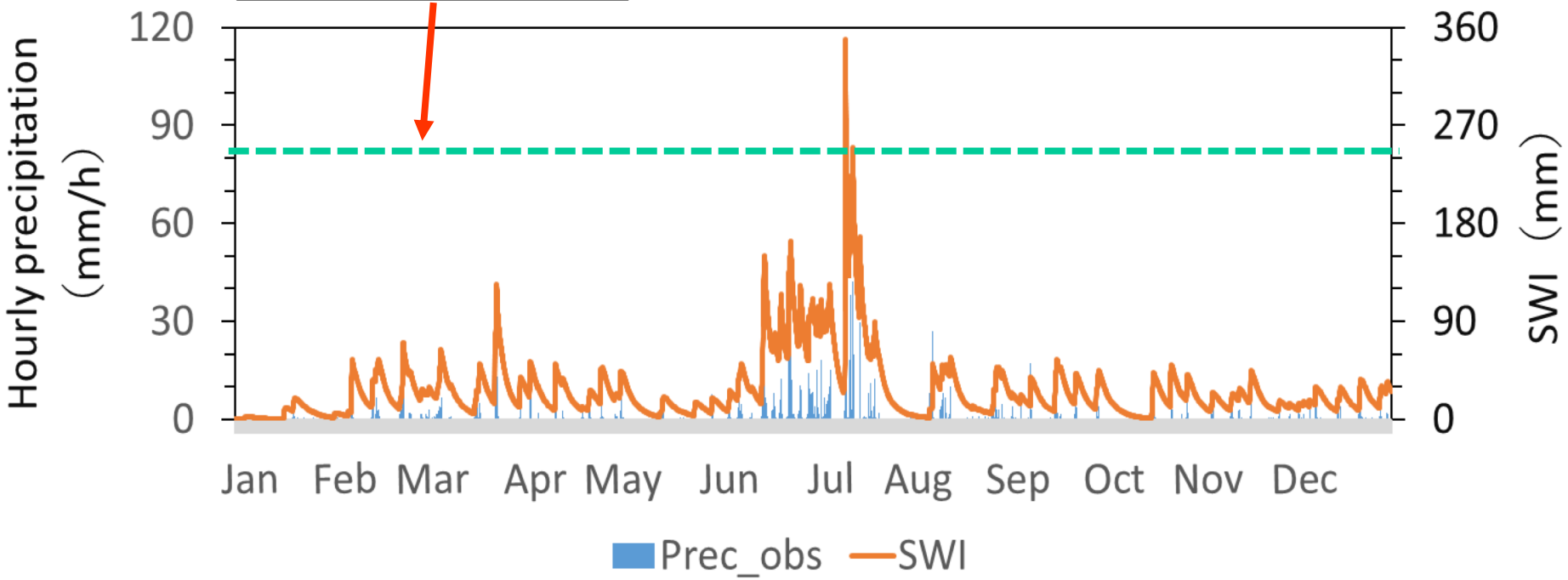
Hourly precipitation data are necessary tor real-time prediction

Seasonal change of SWI in 2012

（using observed hourly precipitation）

Maximum SWI in 2002-2011: 245 mm

Sharp peak !!



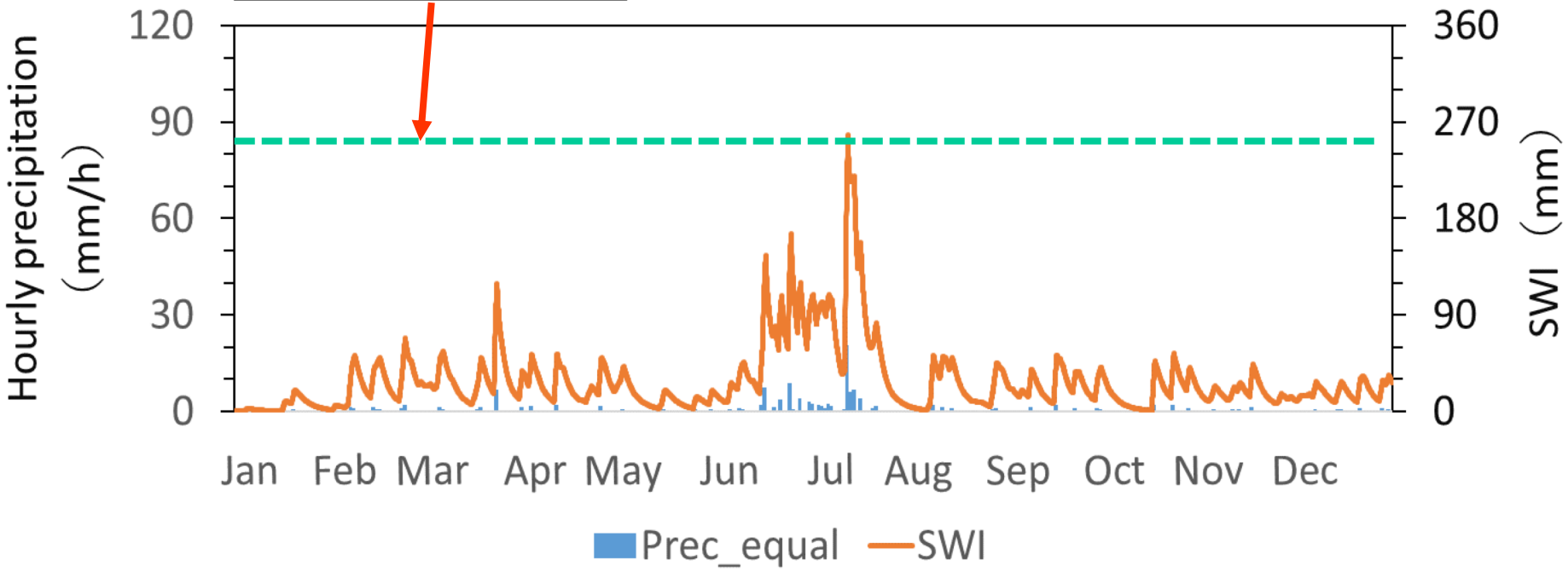
At 6:00 11th July, landslides occurred,
when calculated SWI exceeds the maximum SWI in 2002-2011.

Seasonal change of SWI in 2012

（hourly precipitation = daily precipitation / 24）

Maximum SWI in 2002-2011: 245 mm

Seasonal change of SWI is also well reproduced in this manner.



At 0:00 12th July, landslides occurred (?),
when calculated SWI exceeds the maximum SWI in 2002-2011.

In case of Tomsk, we can use daily data (Data source: http://meteo.ru)

- Daily precipitation & daily mean temperature 1st January, 1881－
- Daily minimum temperature 1st January, 1890－
- Daily maximum temperature 1st June, 1925－

1	5	WMO index of station
2	4	Year
3	2	Month
4	2	Day
5	1	Group quality flag for air
6	5,1	Minimum temperature & Quality flag
7	5,1	Mean temperature & Quality flag
8	5,1	Maximum temperature & Quality flag
9	5,1	Daily total precipitation & Additional flag & Quality flag

After January 1966, 3-hourly data are available.
(Not yet analyzed)

Target period: Spring 2010 when flood occurred in Tomsk

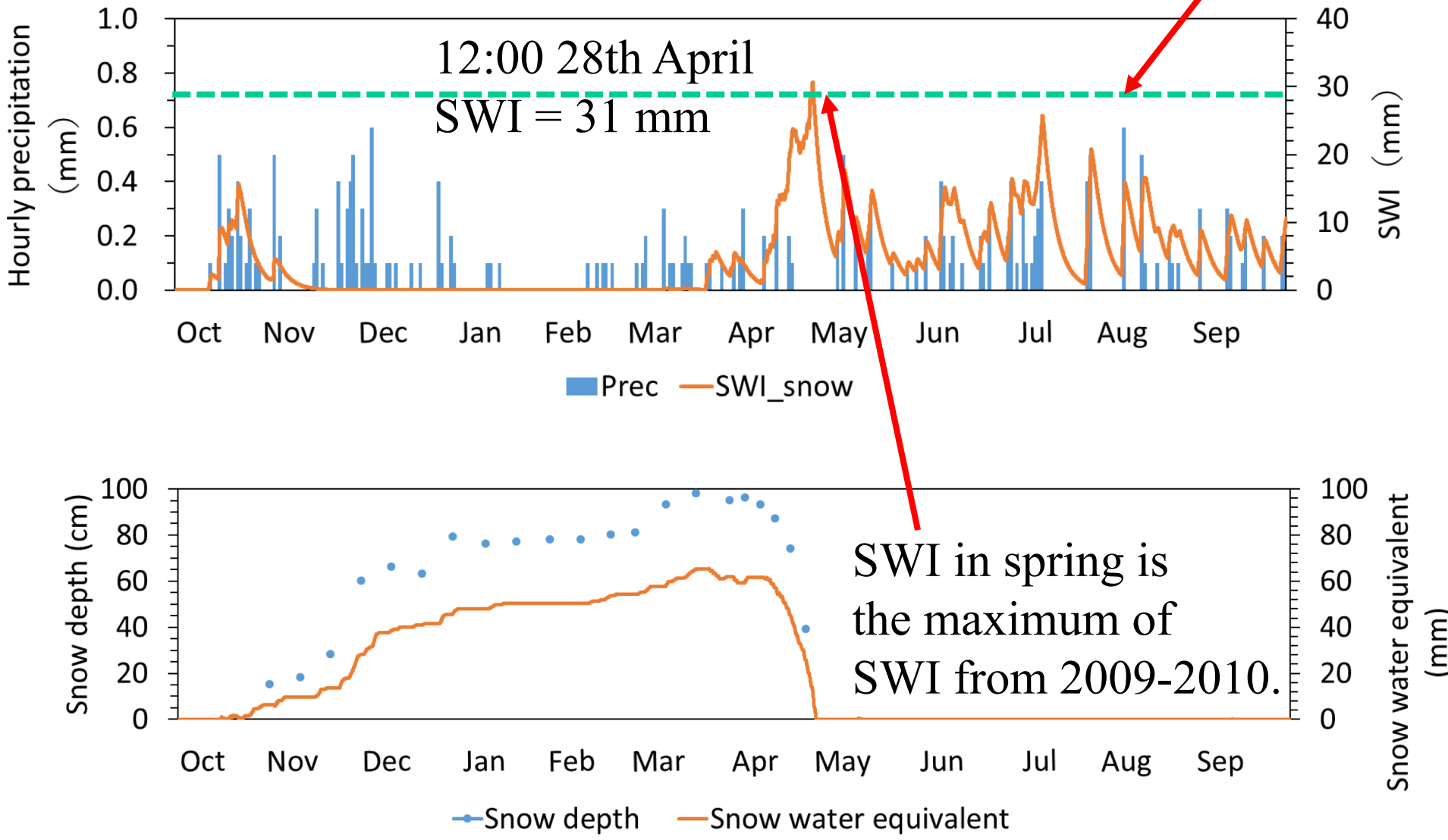
（Photos by Mr. Alexanderson, Department of Hydrology, TSU）

（↓）29th April, 2010

（↑）28th April, 2010

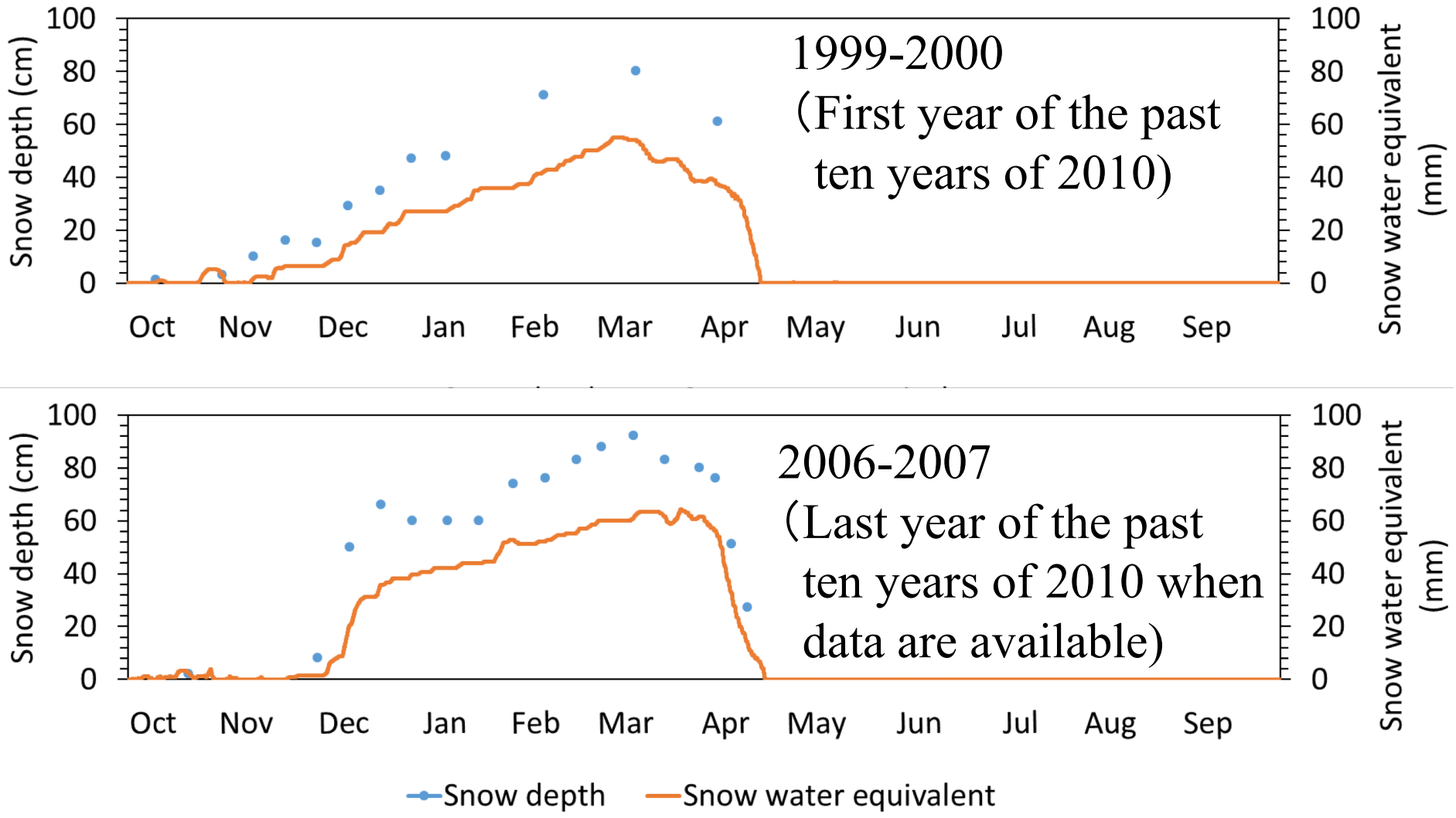
In case
snowmelt factor is 0.7 mm/day …

Maximum SWI in 1999-2008 in spring: 28 mm



How about the reproductibity in other years?

- It looks good, however, the observation stopped in mid-April.
- We cannot determine when snow disappeared in these years.



Summary

- Snowmelt factor, 0.7 mm/day is estimated by trial and error.
  - To match the seasonal change of snow depth in 2009-2010.
  - This factor is transferable to other years.
  - Quantitatively, this factor has some uncertainties.

- Maximum SWI in Tomsk from 1999 to 2008 (not shown)
  - Throughout a year: 0:00 13th June 2002 … 64 mm
  - Snowmelt season: 15:00 5th May, 2004 … 29 mm
    - SWI in 28th April, 2010 (31 mm) is the maximum in 1999-2010 in the snowmelt season.
    - We can predict landslides / floods in the snowmelt season by referring to SWI in the snowmelt season alone.

Future studies

- SWI estimates the occurrence of landslides by referring to the rank of a event in comparison with those of past 10 years.
  - Robust
  - We should distinguish the ranks in the snowmelt season and those in the whole year round.

- Shall we analyze 3-hour's meteorological data in Tomsk ?
  - Period: 1st January, 1966－31st December, 2017
    - The snow depth data used for validation is limited to every 5 or 10 days.
    - We cannot determine the disappearance of snow.

Thank you for your attention !!

http://www.fm-v.com/View.aspx

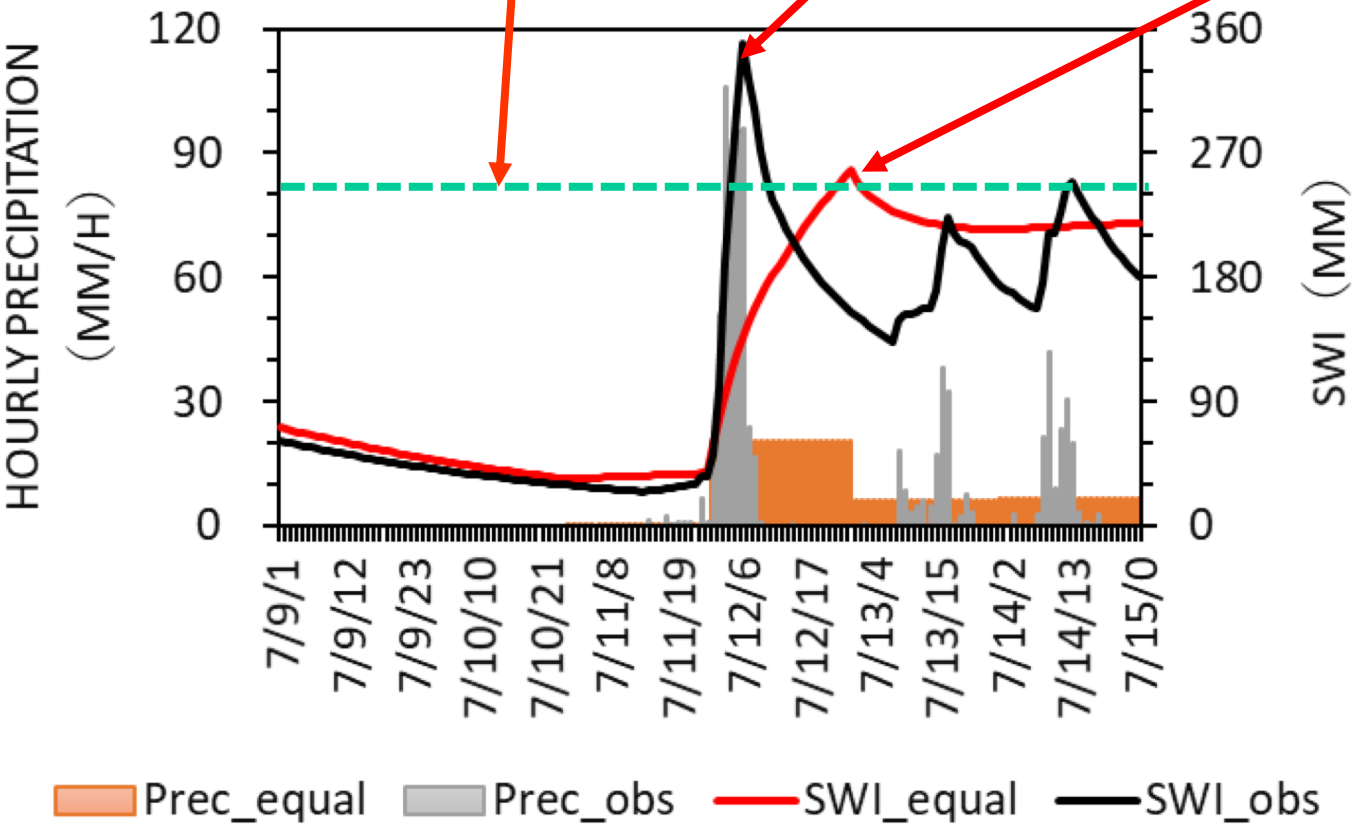
スライド ショーの最後です。クリックすると終了します。


LaGIS

In case
hourly precipitation = daily precipitaton/24

Maximum SWI in 2002-2011: 245 mm

SWI calculated by hourly precipitation



Simulation exceeds the maximum in 2002-2011, however, the peak lags the actual SWI. (18 hours delay)

Hourly precipitation data are necessary tor real-time prediction