

Glacio-hydrological projections with downscaled climate data

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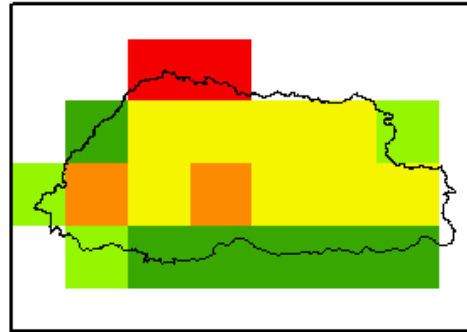
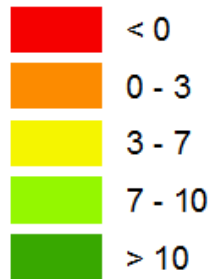
Current assessments and our objective

Current assessments for impact of climate change

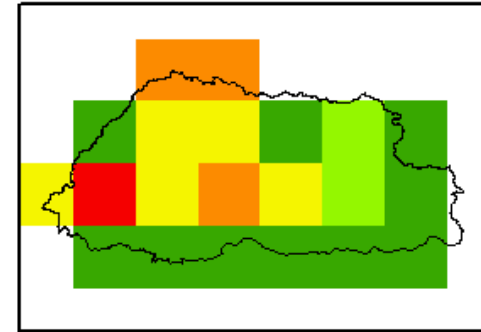
(NATIONAL INTEGRATED WATER RESOURCES MANAGEMENT PLAN 2016)

Rainfall

Change (%)



Change 2015 - 2030 (%)



Change 2015 - 2060 (%)

Projected changes in precipitation for RCP4.5

River discharge

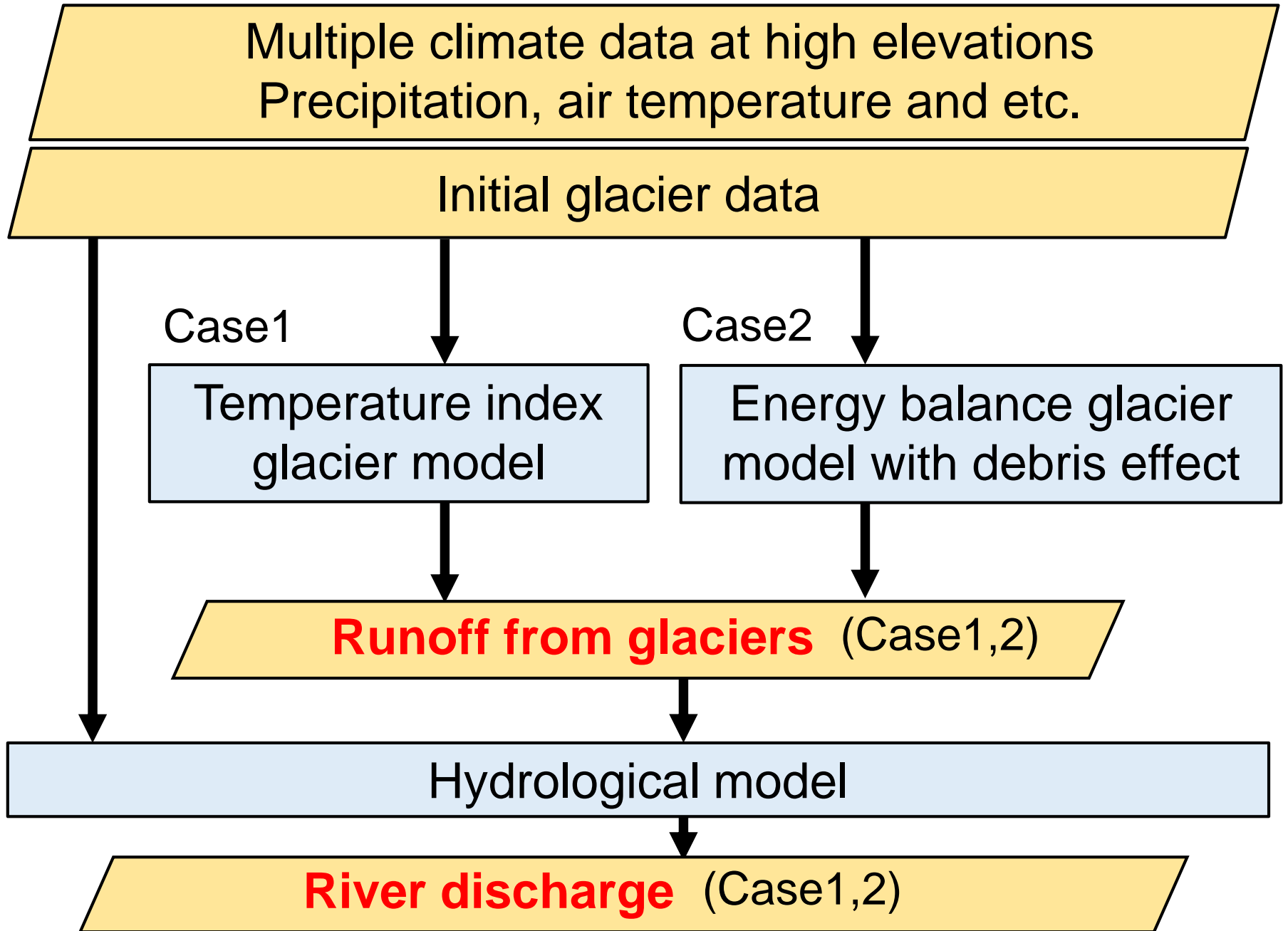


OBJECTIVE

To estimate of **river discharge** taking into account **glacier melt** with a **regional climate projection**

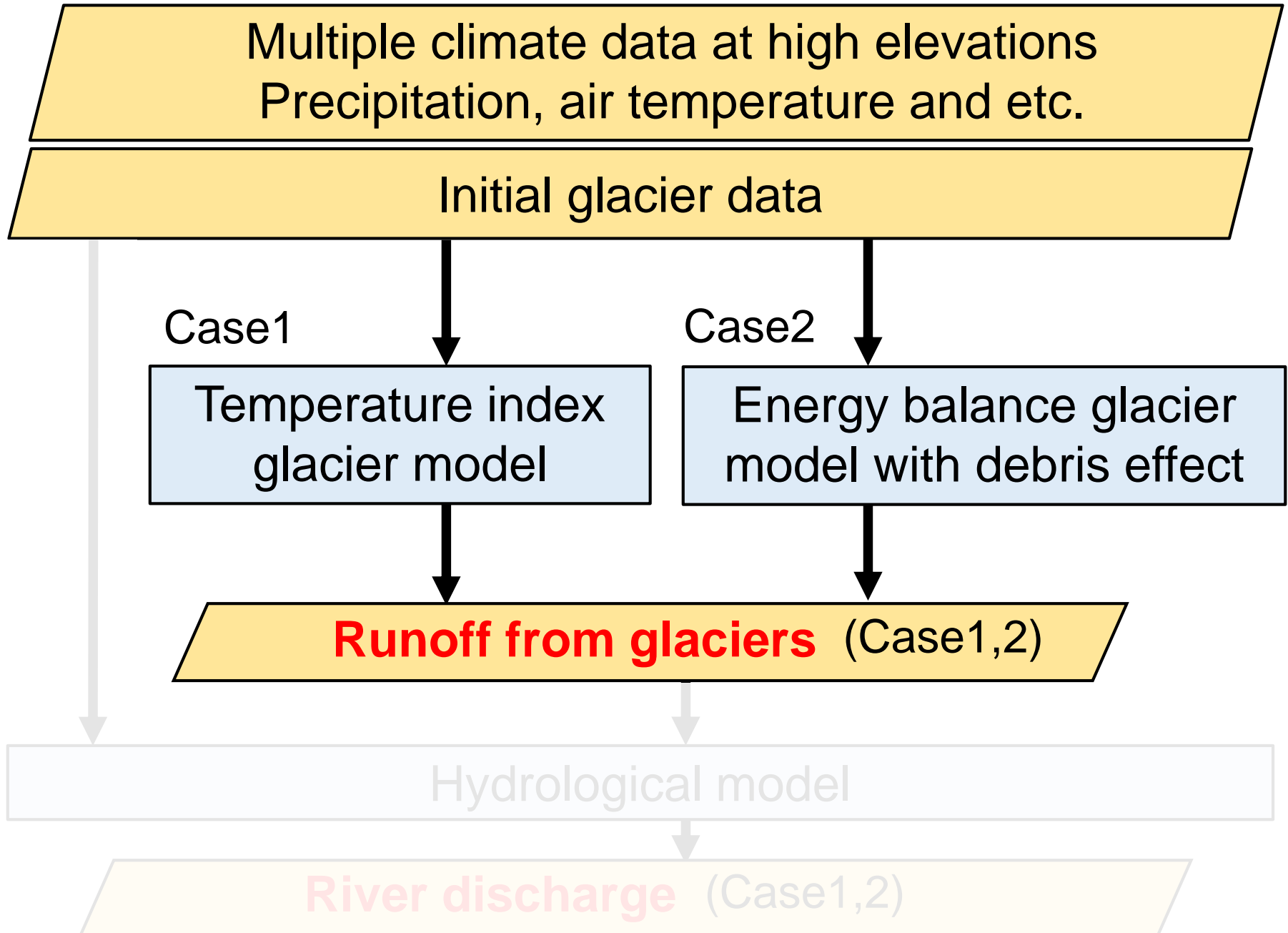
Research flow

Research flow



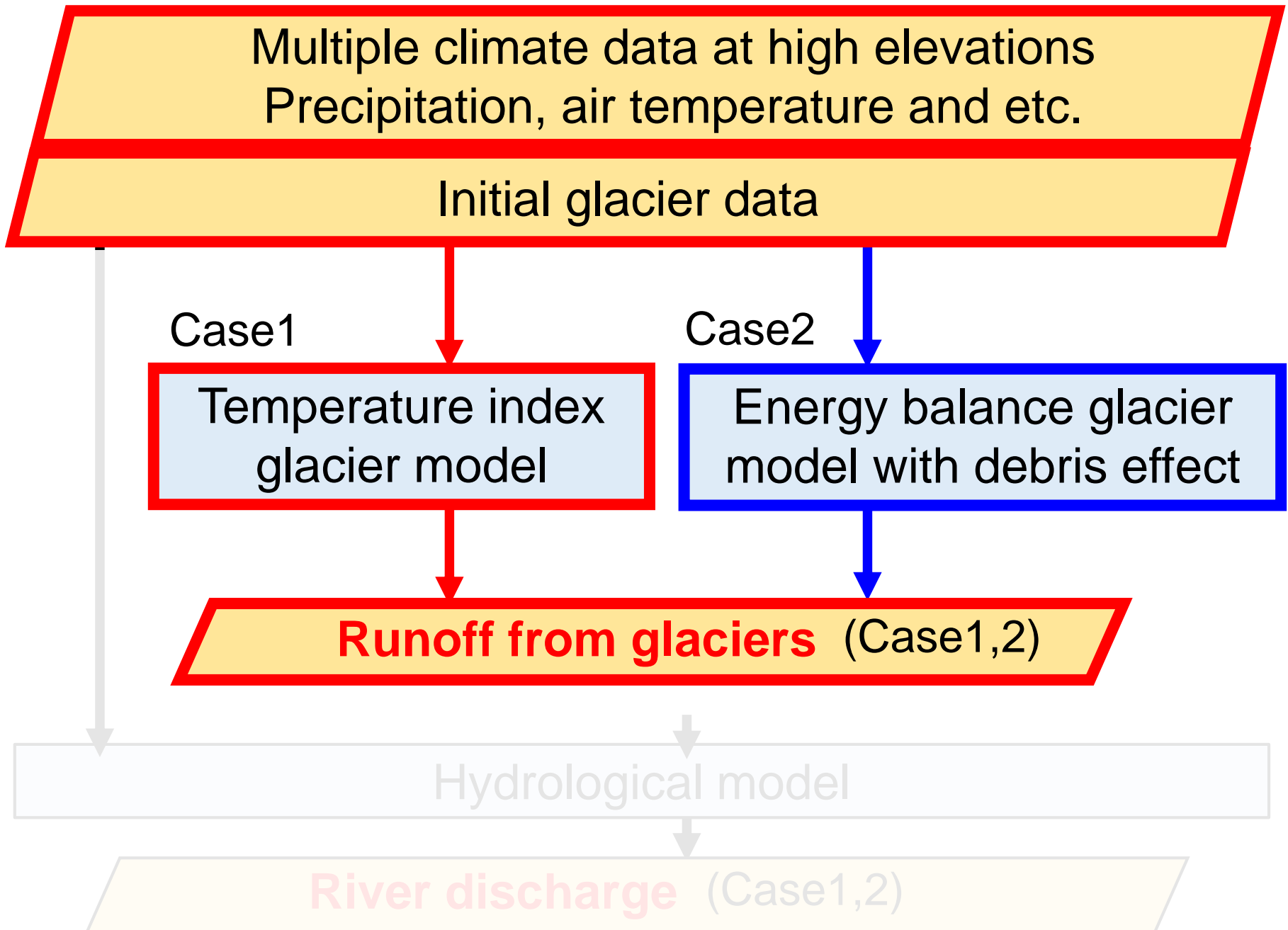
Research flow

6

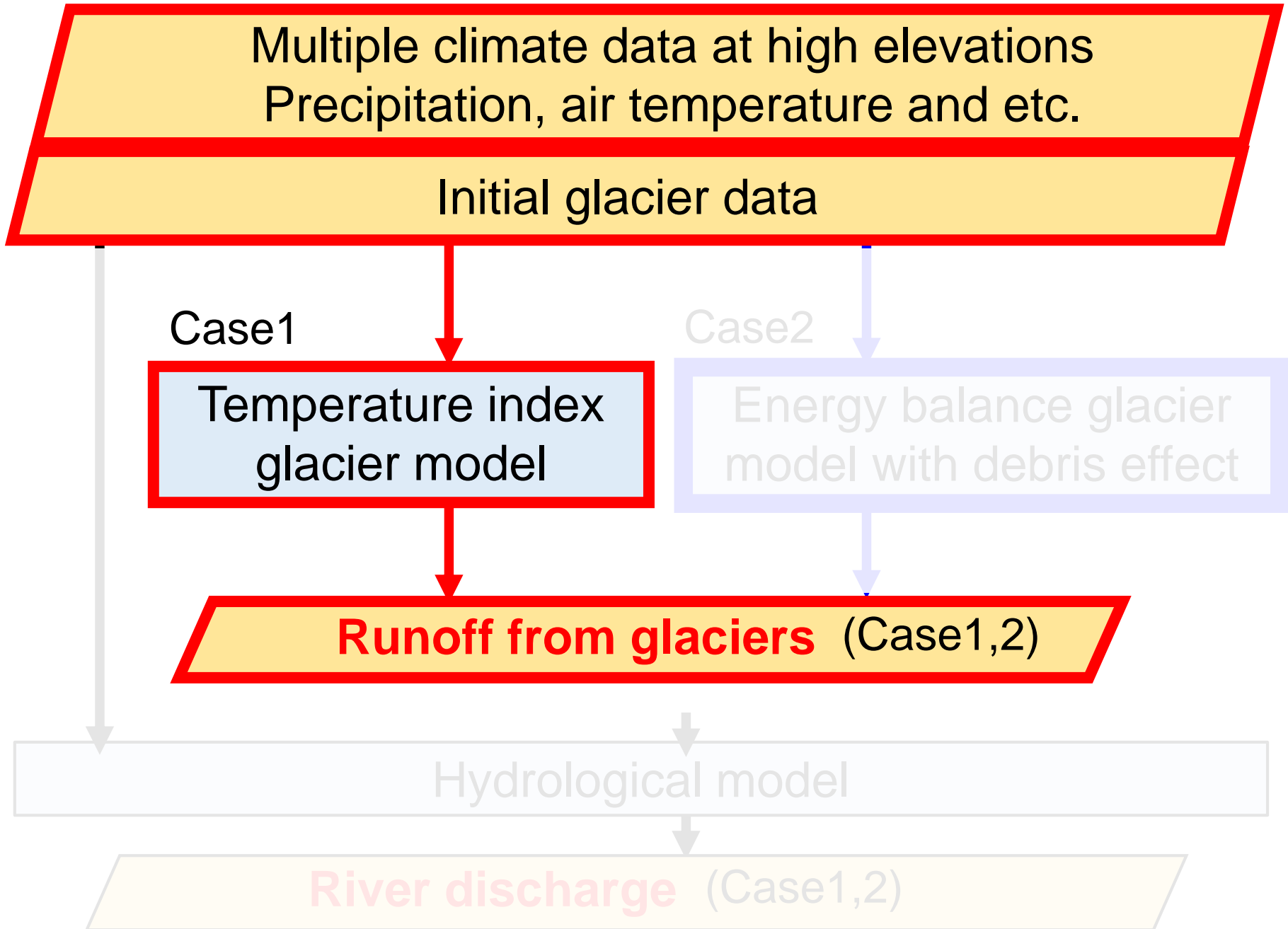


Research flow

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Research flow



Research flow

Multiple climate data at high elevations
Precipitation, air temperature and etc.

Past period

- Uncertainty
- Data
 - Air temperature
 - Precipitation

Future period (GCMs)

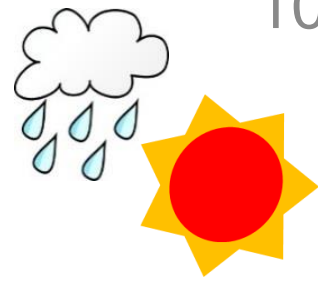
- Uncertainty
- Bias correction
- Multi-model

Runoff from glaciers (Case1,2)

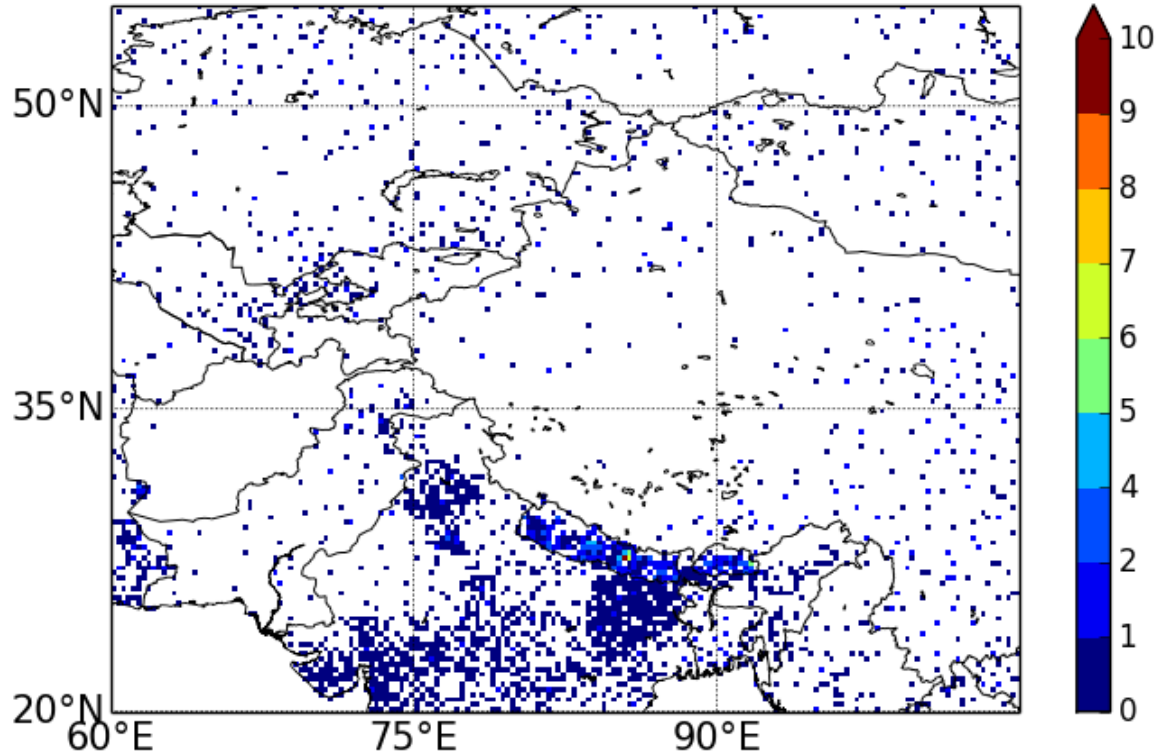
Hydrological model

River discharge (Case1,2)

Uncertainty of climate data for the past period



10



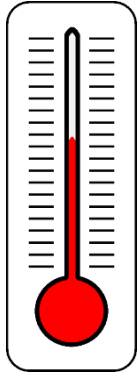
The number of gauge (APHRODITE)

The scarcity of in-situ observations
(for temperature and precipitation)
at high elevations

Temperature data for the past

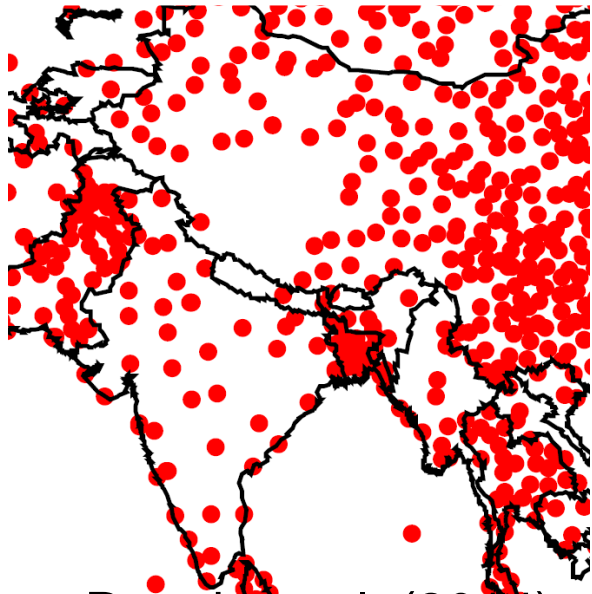
TA1 H08

(Hirabayashi et al., 2008)



Thermometer

<http://www.ushistory.org/franklin/fun/thermometer.htm>

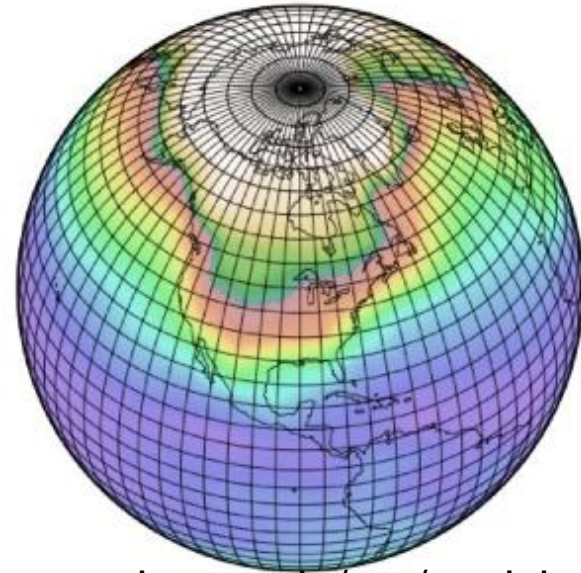


Sparse
stations
at
elevations

Rennie et al. (2014)

TA2 ERA-Interim

(Dee et al., 2012)



https://serc.carleton.edu/eet/envisioningclimatechange/part_2.html

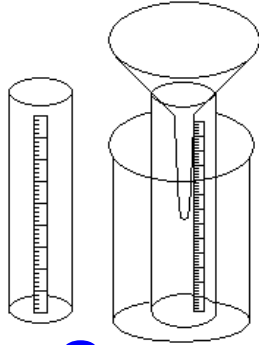
Reanalysis

Hybrid of observations and model

It could be applied to
sparsely observed regions

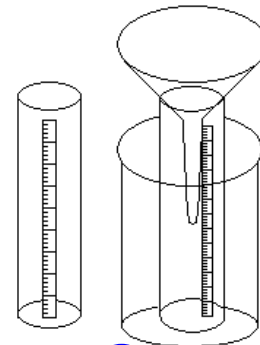
Precipitation data for the past

PR1 APHRODITE



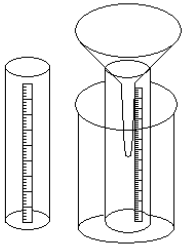
Gauge

PR2 Sakai

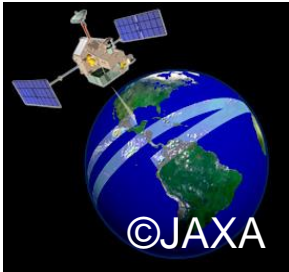


Gauge

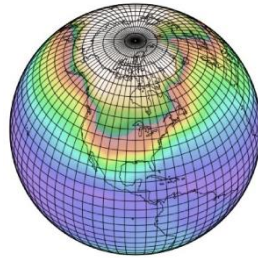
PR3 MSWEP



Gauge

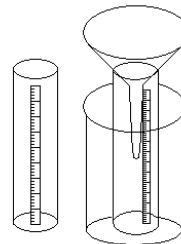


Satellite

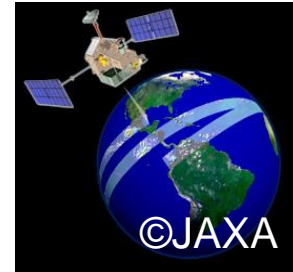


Reanalysis

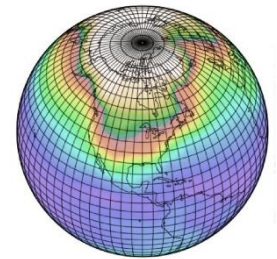
PR4 MSWEP+PR (This study)



Gauge



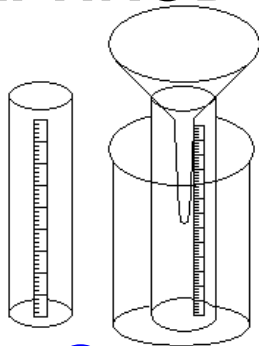
Satellite



Reanalysis

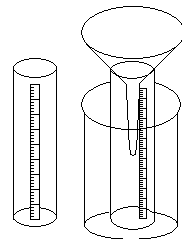
Precipitation data for the past

PR1 APHRODITE



Gauge

PR2 Sakai

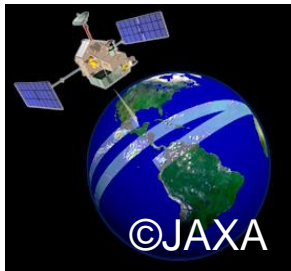
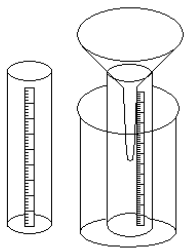


Gauge

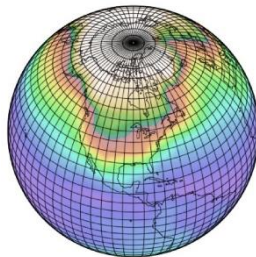


Inverse estimation using glacier elevation

PR3 MSWEP

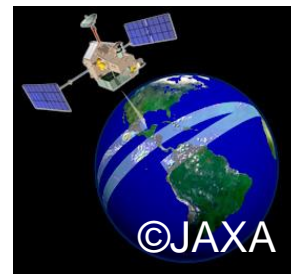
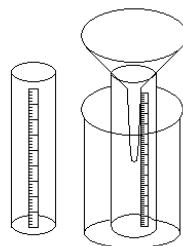


©JAXA

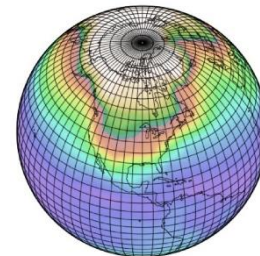


Gauge Satellite Reanalysis

PR4 MSWEP+PR (This study)



©JAXA



Gauge Satellite Reanalysis



Inverse estimation using discharge

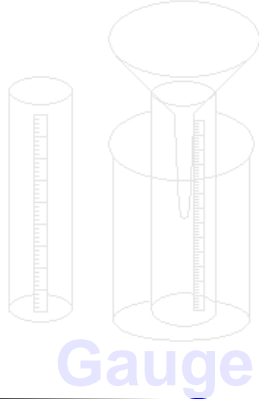


©NASA

Directly detect rain drop using satellite radar

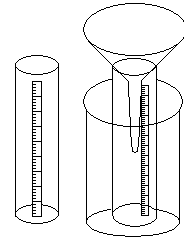
Precipitation data for the past

PR1 APHRODITE



Gauge

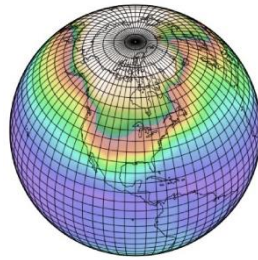
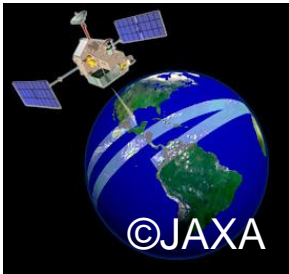
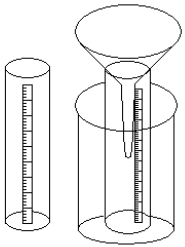
PR2 Sakai



Gauge

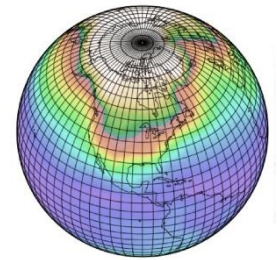
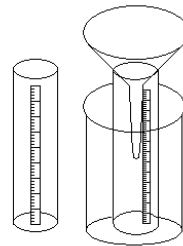


PR3 MSWEP



Gauge Satellite Reanalysis

PR4 MSWEP+PR (This study)



Gauge Satellite Reanalysis



Inverse estimation using discharge

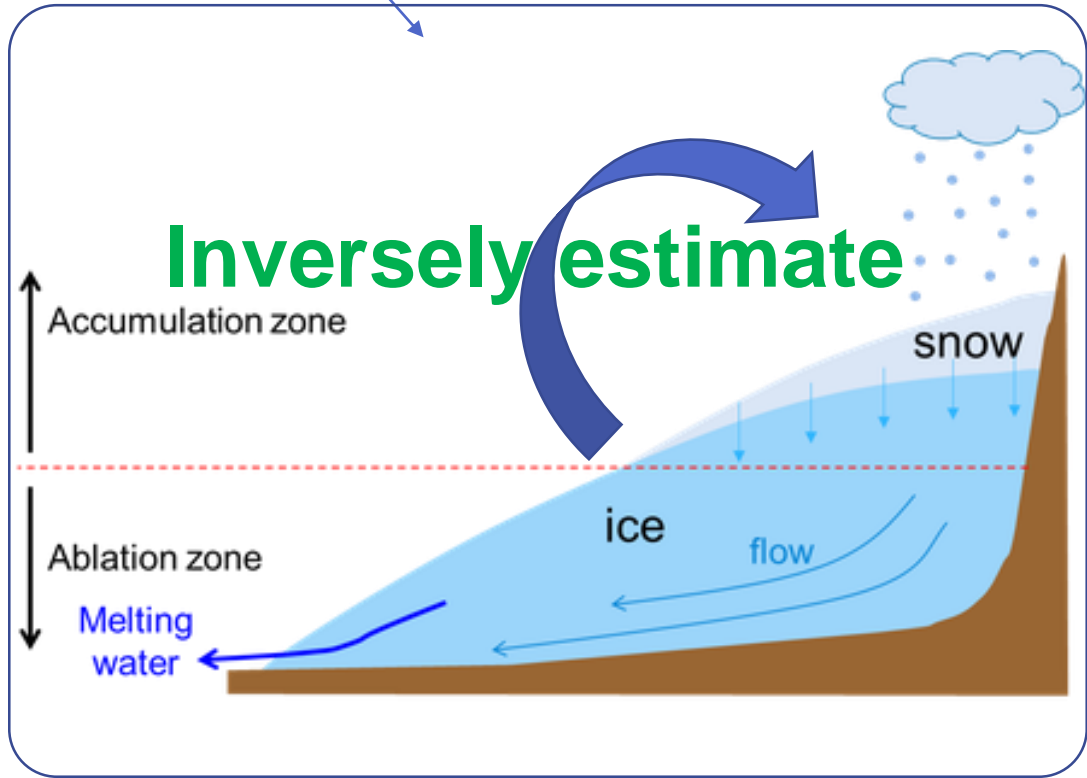
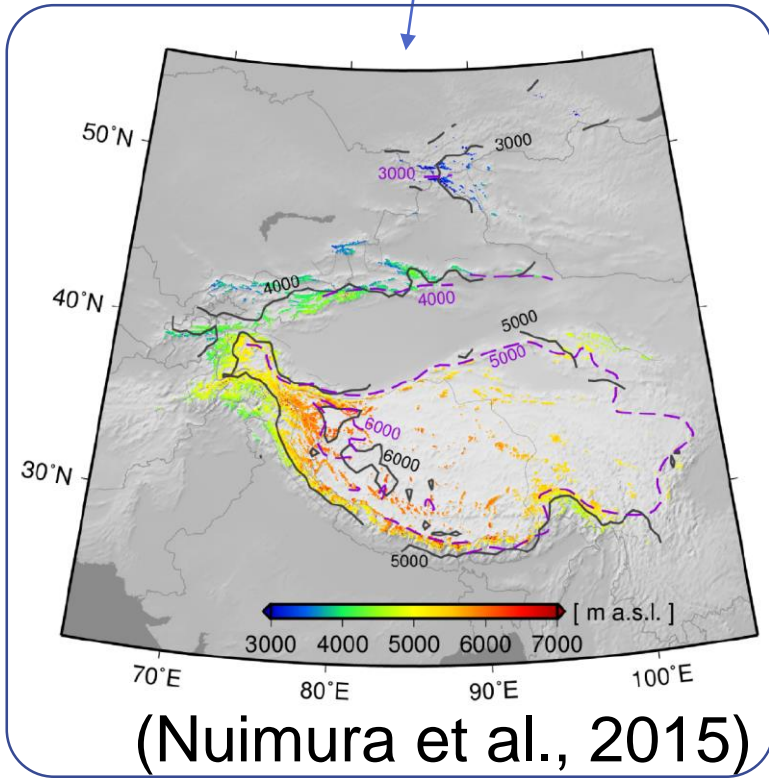
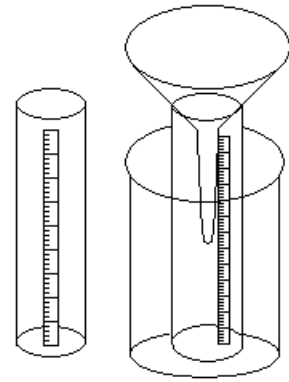


Directly detect rain drop using satellite radar

PR2 Sakai et al. (2015)

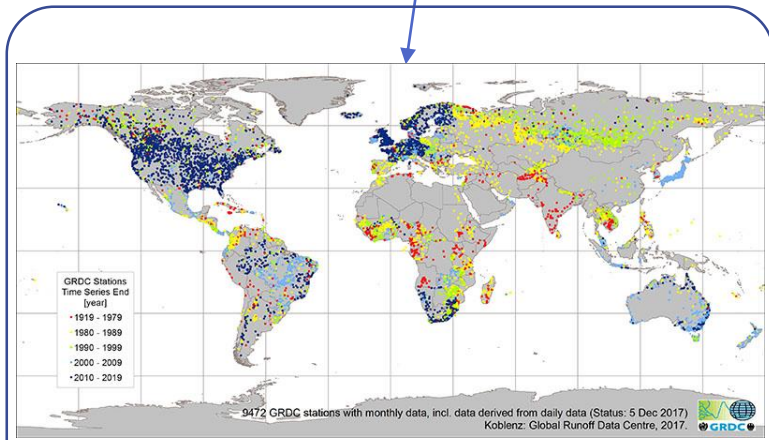
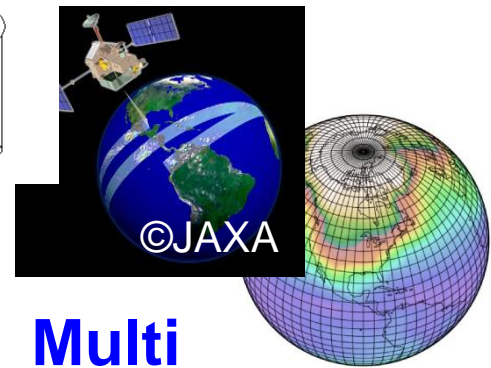
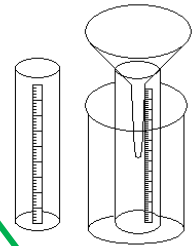


Correct



PR3

MSWEP (Beck et al., 2015)



Global Runoff Data Centre

http://www.bafg.de/GRDC/EN/02_srvcs/21_tmsrs/riverdischarge_node.html

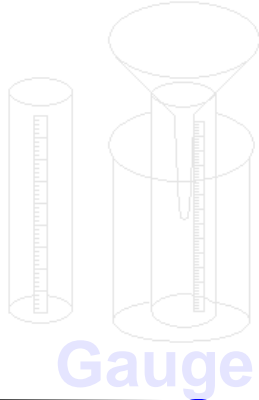
$P = E + Q + \Delta S$

P: Precipitation; Q: Observed discharge; E : Evaporation; ΔS : changes in water

Inversely estimate

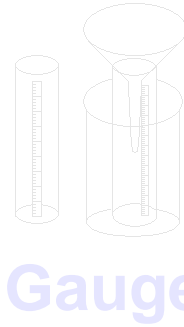
Precipitation data for the past

PR1 APHRODITE



Gauge

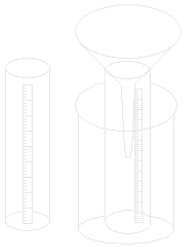
PR2 Sakai



Gauge



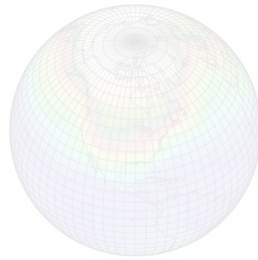
PR3 MSWEP



Gauge

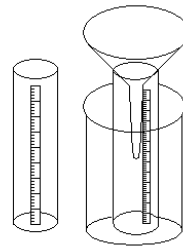


Satellite



Reanalysis

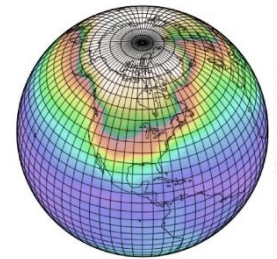
PR4 MSWEP+PR (This study)



Gauge



Satellite



Reanalysis



Inverse estimation using discharge



Directly detect rain drop using satellite radar

PR4

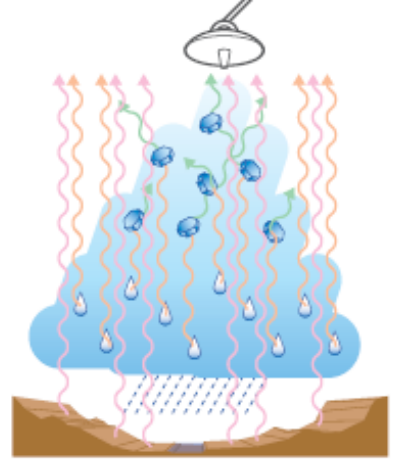
MSWEP + PR (This study)

Infrared



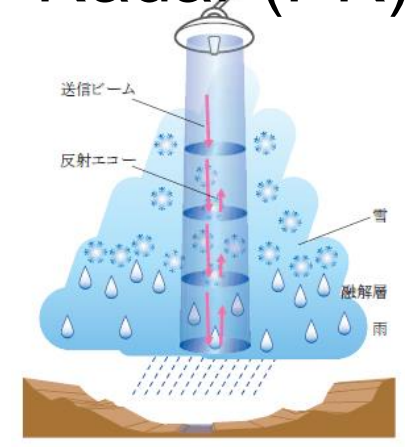
Relationship between the cloud height and precipitation

Microwave



High emissivity from the ground

Radar (PR)



More sensitive over land as well as ocean

©JAXA

Yamamoto et al. (2011)

The peak local-time distribution of precipitation showed a **relationship with the topography** in the order of **precipitation radar (strongest relationship)**, microwave radiometer, and infrared products.

Multiple climate data at high elevations
Precipitation, air temperature and etc.

Past period

- Uncertainty
- Data
 - Air temperature
 - Precipitation

Future period (GCMs)

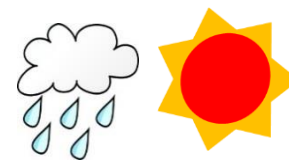
- Uncertainty
- Bias correction
- Multi-model

Runoff from glaciers (Case1,2)

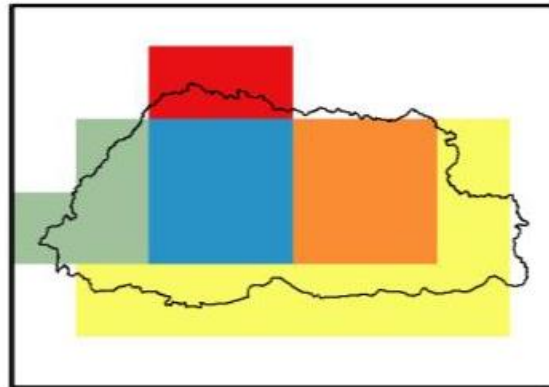
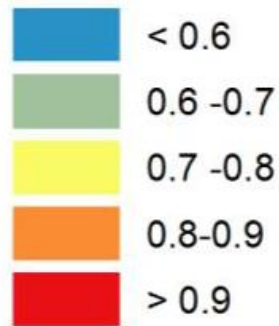
Hydrological model

River discharge (Case1,2)

Uncertainty of climate data for the future

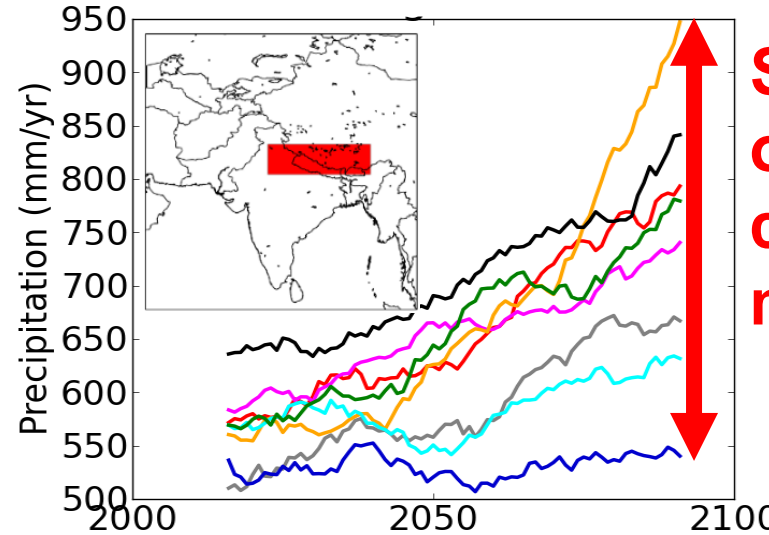


Change (°C)



Change 2015 - 2030 (°C)

Projected change in temperature for RCP4.5 (NIWRNP 2016)



Spread of climate models

Projected annual total precipitation from CMIP5 GCMs (RCP8.5)

Climate models



Coarse spatial resolution & bias



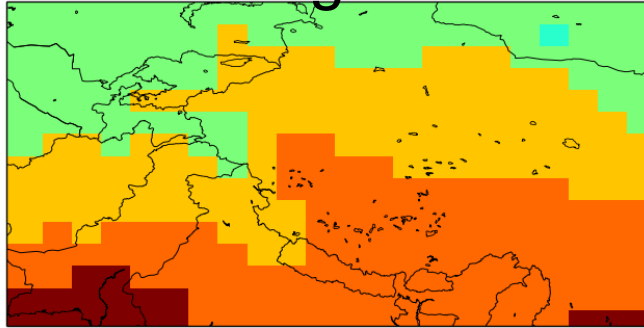
Spread among models

Bias correction

Multi-model

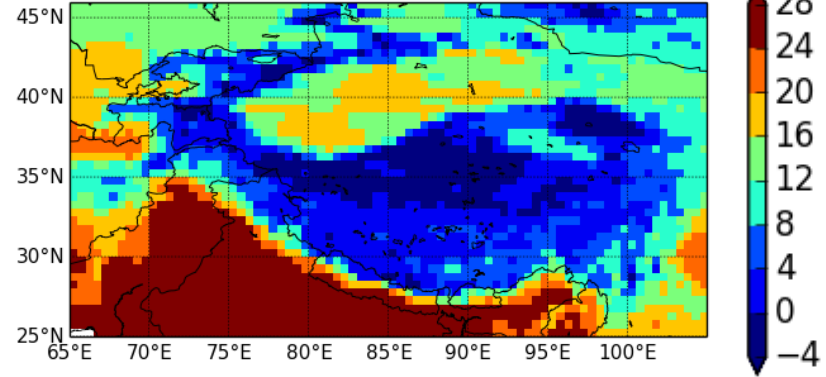
Bias correction

“Original”

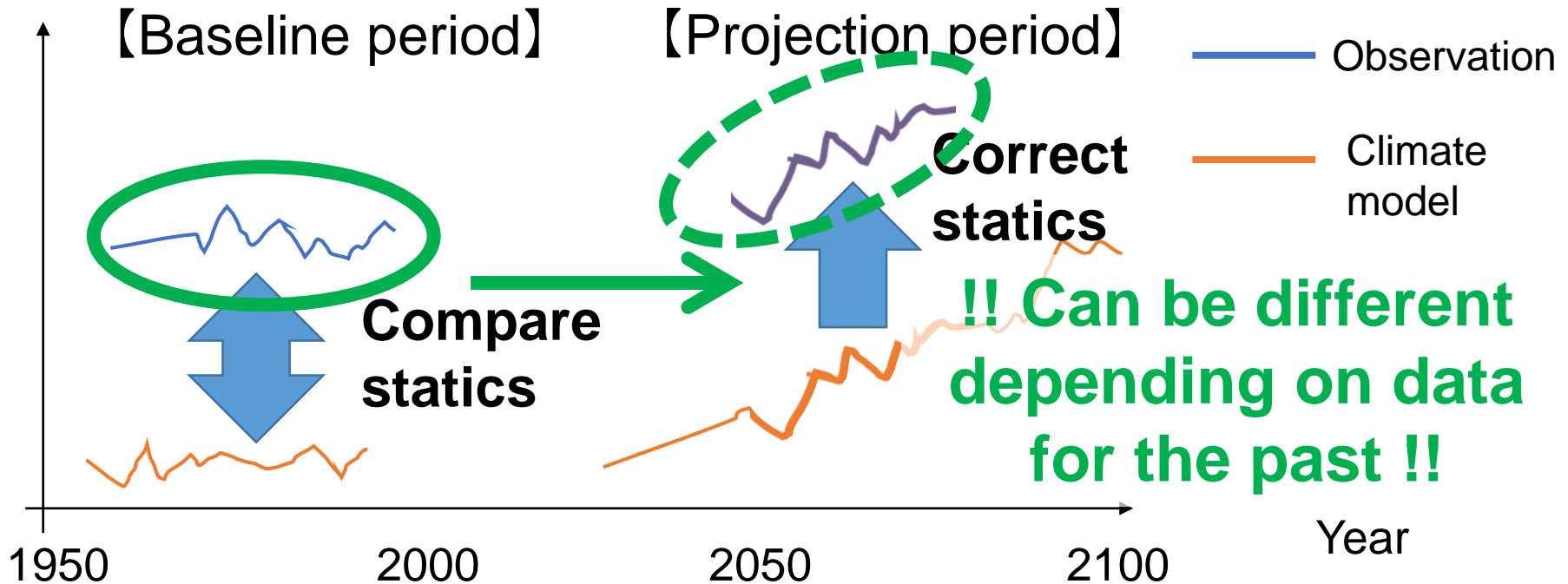


Bias correction

“Downscaled”

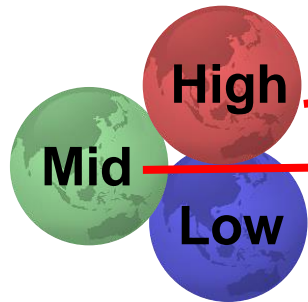


Projected air temperature in 2080-2010 by INM-CM4, RCP8.5

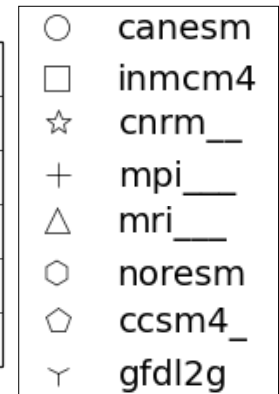
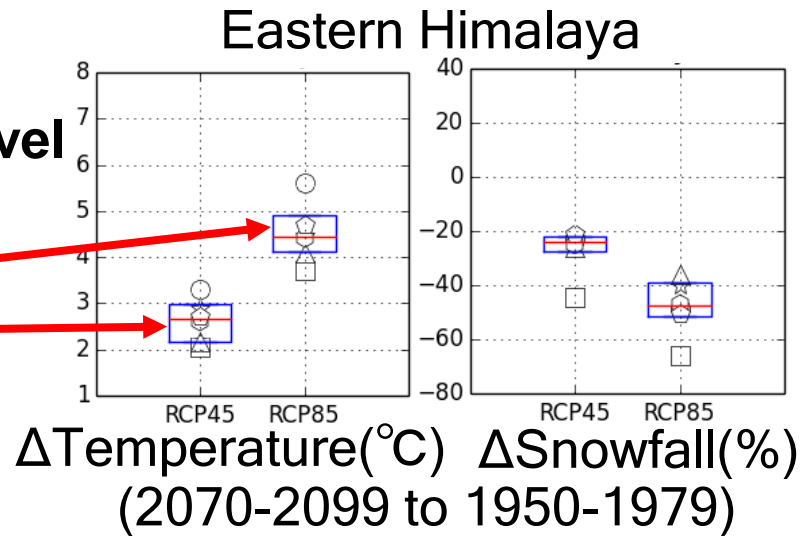


Multi-scenario, Multi-model

Scenarios
GHG emission level



RCP2.6-8.5



**Various
climate
models**

CMIP5 GCMs

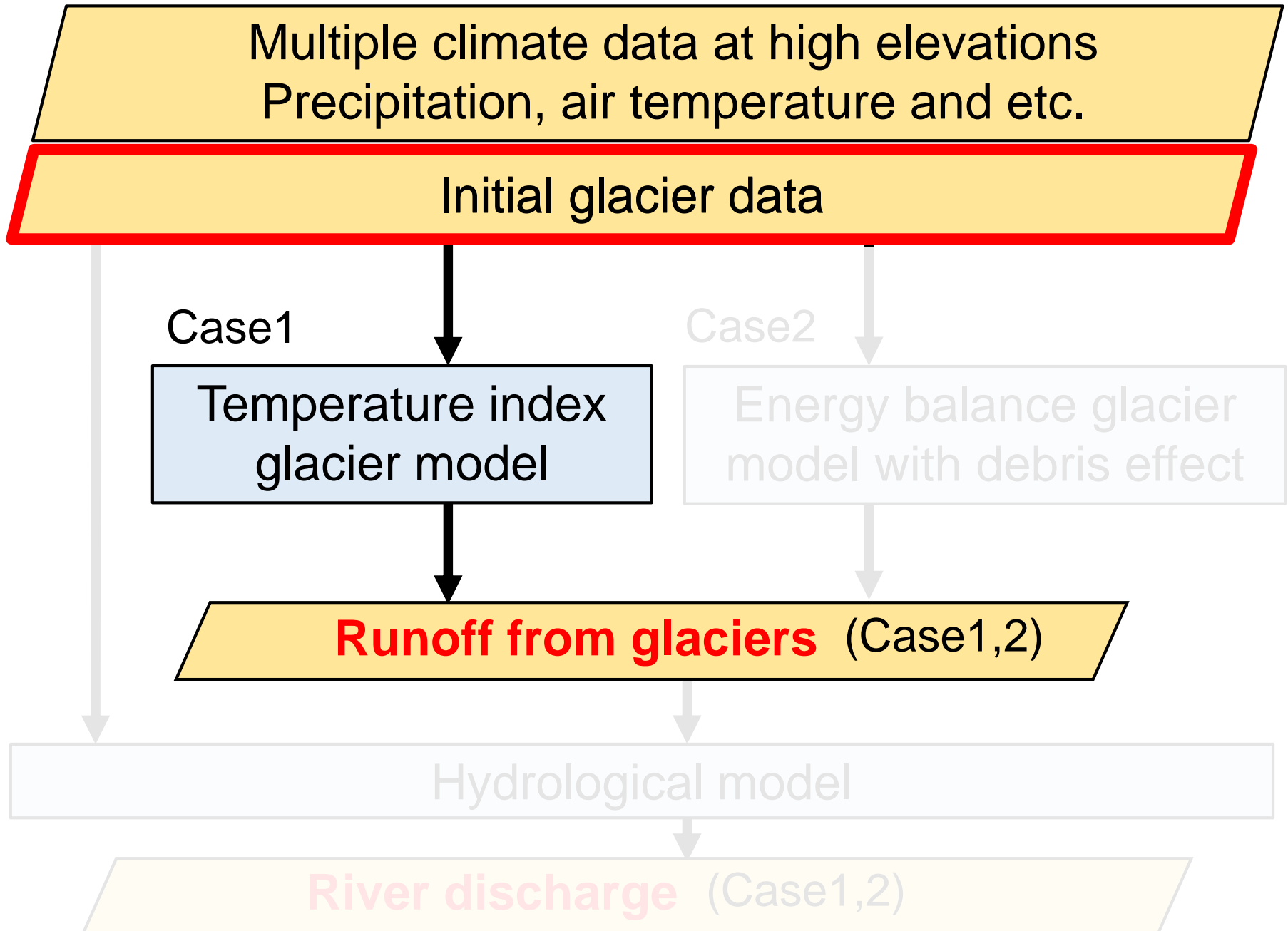
GCM1 High temperature

GCM2 Median temperature & snowfall

GCM3 More snowfall

Research flow

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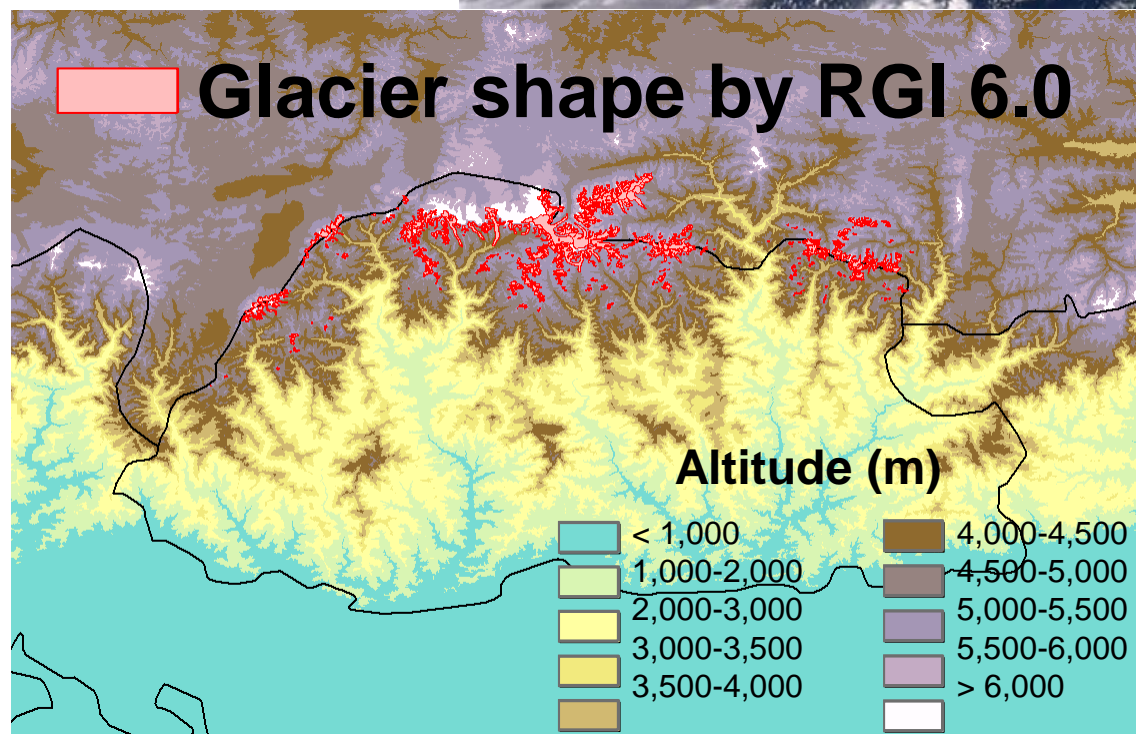


Initial glacier data

The latest glacier inventory

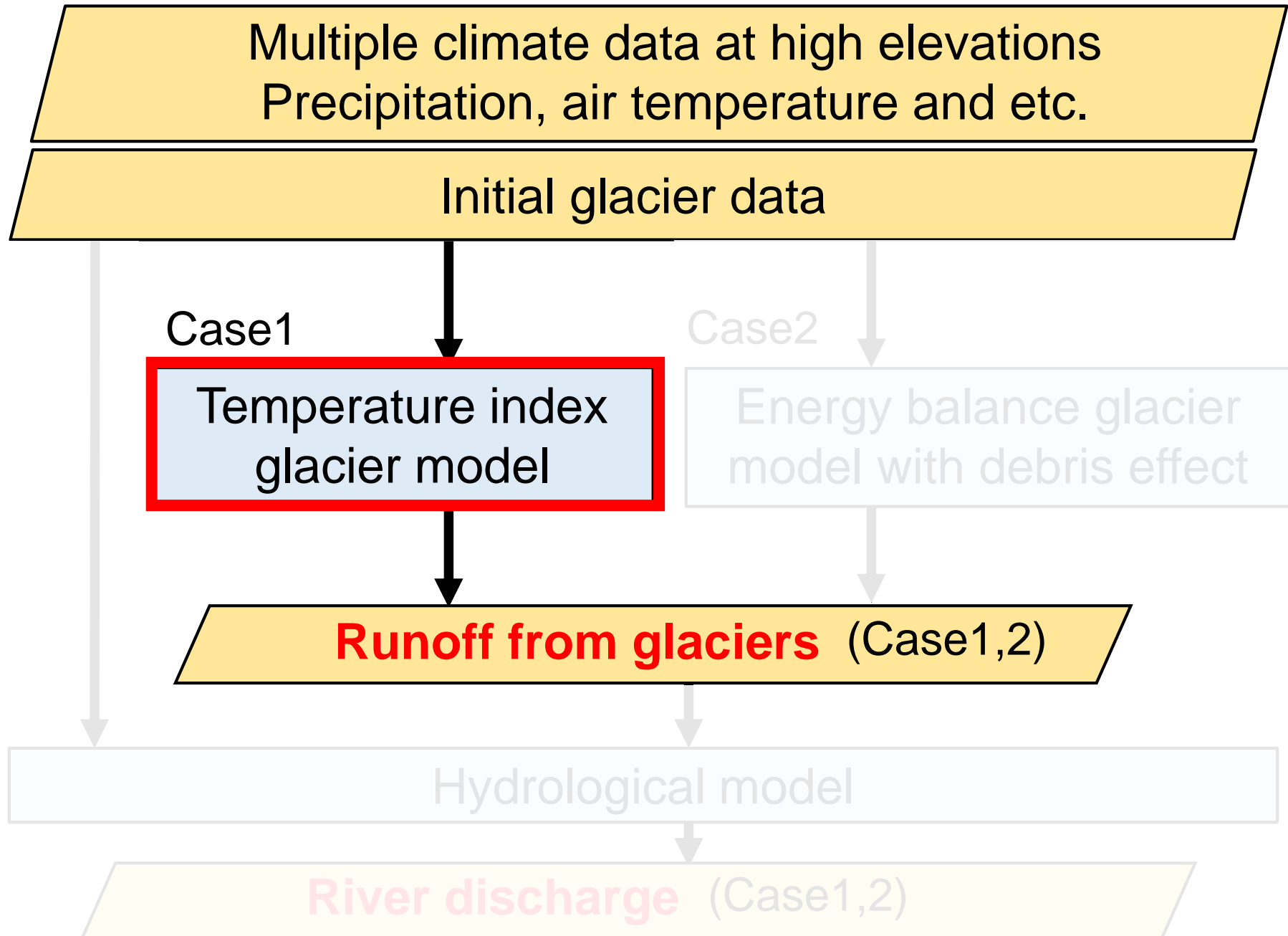
“Randolph Glacier Inventory”

- A globally complete inventory of glacier outlines using modern satellite (such as Landsat or ASTER) imagery
- Version 6.0: released July 28, 2017.
- Information
 - Glacier shape
 - Location (latitude & longitude)
 - Glacier area
 - Altitude
 - Length
 - ⋮



Research flow

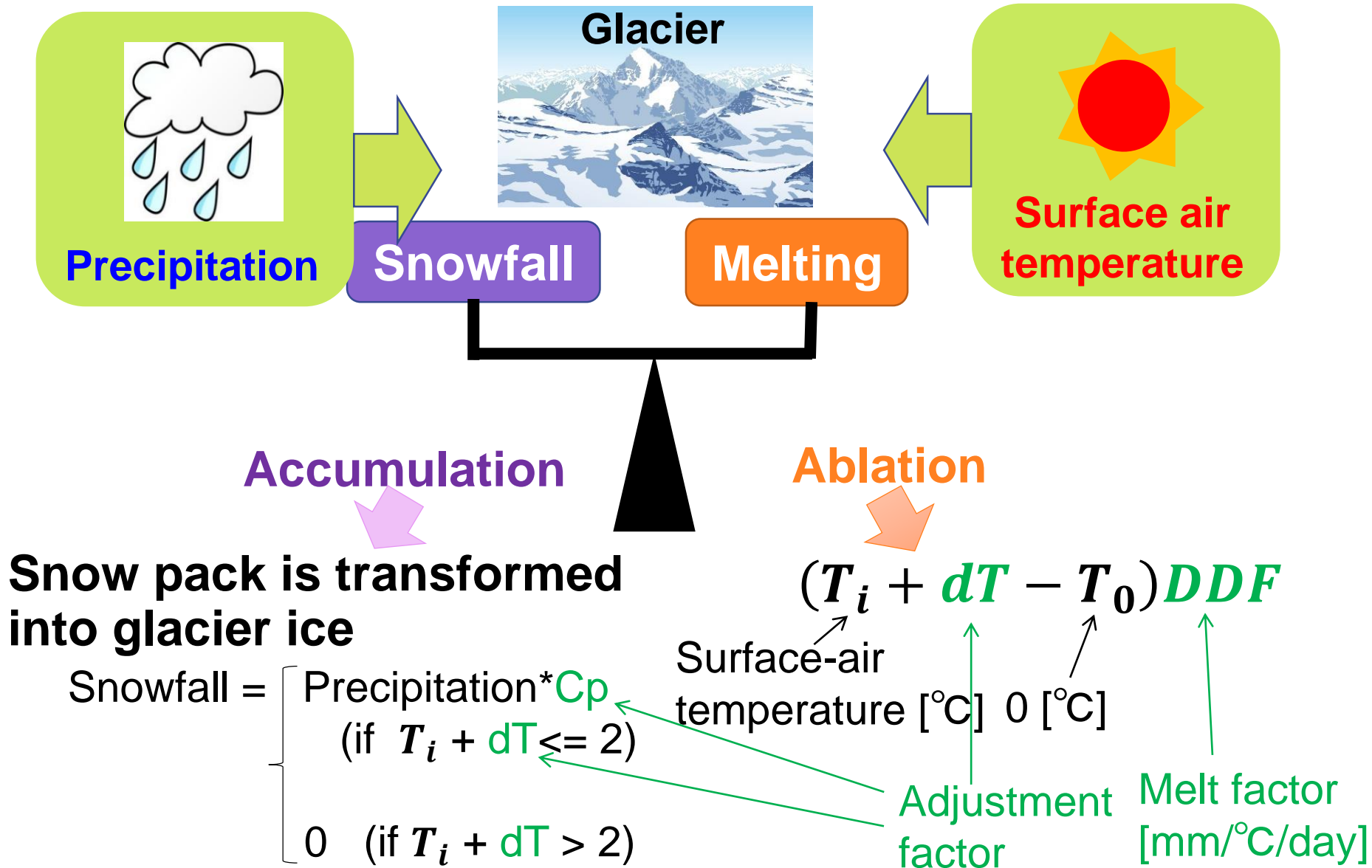
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Temperature index glacier model

Glacier model –mass balance-

(Hirabayashi et al., 2013)



Summary

Today's summary

- Multiple climate data for the past period
 - Air temperature (In-situ / Reanalysis)
 - Precipitation (In-situ / Reanalysis / Inverse estimations)
- Climate data for the future period
 - Bias correction of GCMs
 - Multi-GCMs
- Initial glacier data from the inventory
- Temperature index glacier model
- Uncertainty range of climate data
- Uncertainty range of glacier projections