Climate change impact response function for global water resources

Hanasaki, N., Masutomi, Y., Takahshi, K., Hijioka, Y., Harasawa H. and Matsuoka, Y.: Development of a global water resources scheme for climate change policy support models. Environmental Systems Research. 35, pp367-374, 2007 (in Japanese)

Background

to achieve … stabilization of GHG concentration…

By when?
How much?

Reduction of GHG emission

- Uncertainty in future socio economic condition
- Uncertainty in climatic response
- Limited access to scientific knowledge

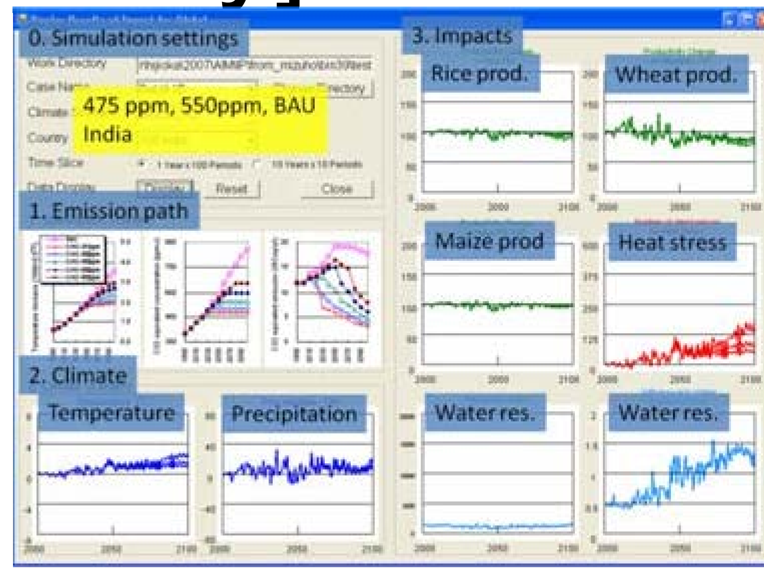
NIES and Kyoto Univ. have been developing a climate change policy support model AIM/Impact[Policy].

AIM/Impact[Policy]

Stabilization concentration

- Socio economic scenario
- GCMs

Policy maker



AIM/Impact[Policy]

- GHG emission path
- Temperature rise, sea level rise
- National/Sector-wise impacts

Integrated assessment (Emission/Climate/Impact)
+
Interactive display

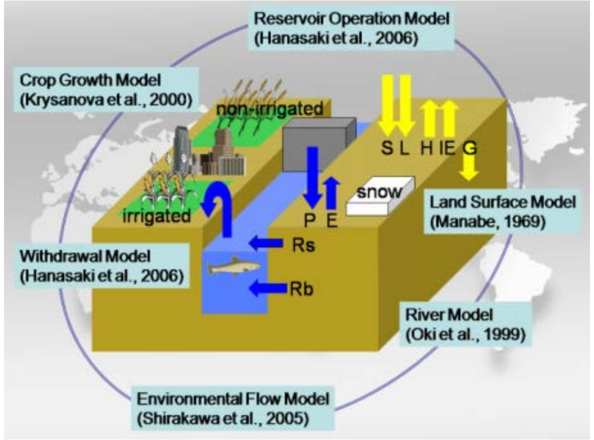
•Use simplified models
•Reduce simulations
↓
•Reduction of computational loads

Climate change Impact Response Function (CIRF)

What is CIRF?

Typical impact studies

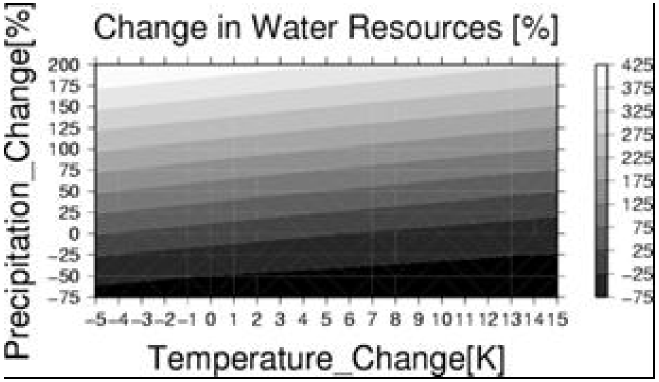
1. Develop a detailed model
2. Develop a detailed scenario
3. Run the model
4. Analyze several simulation runs



2 hours/year

Climate change impact response function (CIRF)

1. Using a detailed model, run hundreds of simulations by changing climate conditions.
2. Develop a database of response to temperature and precipitation change.
3. AIM/Impact[Policy] utilizes the database.



Structure

- Objective
  - Develop a CIRF for global water resources

- Definition of water resources
  - Mean annual national renewable freshwater resources.
  - No seasonality, No inter-annual variability,
    No geographical distribution in nations and No water use.

- Methodology and scientific/practical questions
  1. Validate our detailed global water resources model.
     Does the model reproduce current national water resources?

  2. Develop a CIRF for global water resources.
     Are the estimation of our detailed model and that of CIRF consistent?

1. Validation of our detailed global water resources model

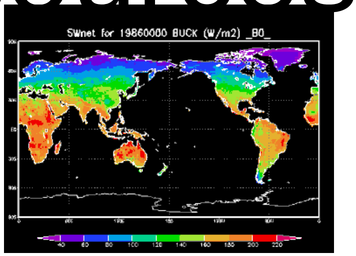
Meteorological data
- Global, 1°×1°(lon, lat)
- 1986-1995, 3-hourly

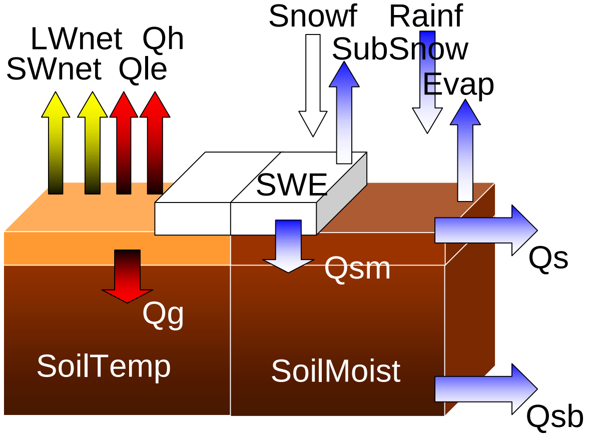
Global hydrological model
- Energy/Water balance
- 15,238 grids

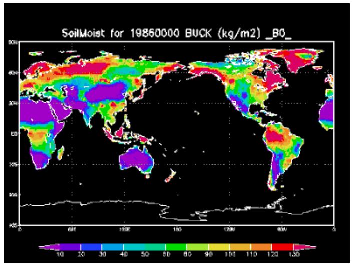
Global annual runoff
- 1°×1° (lon, lat)

Grid to nation converter

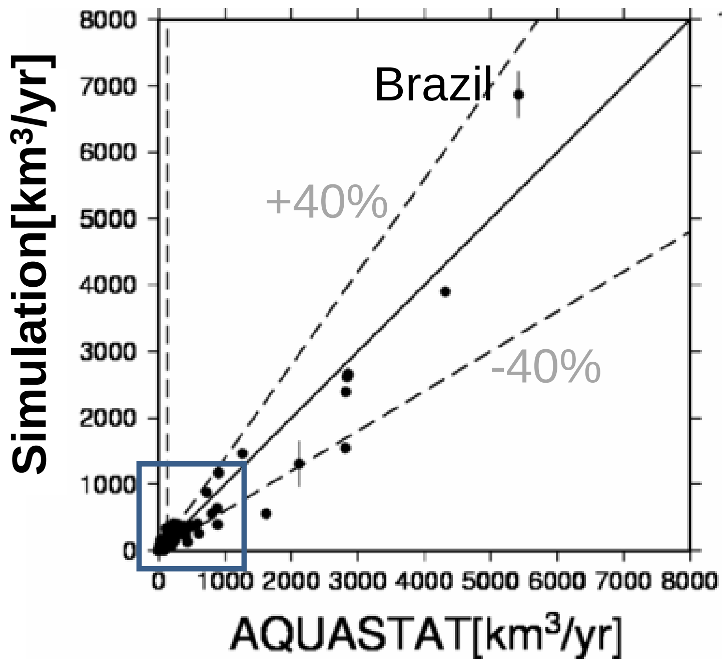
National annual water resources



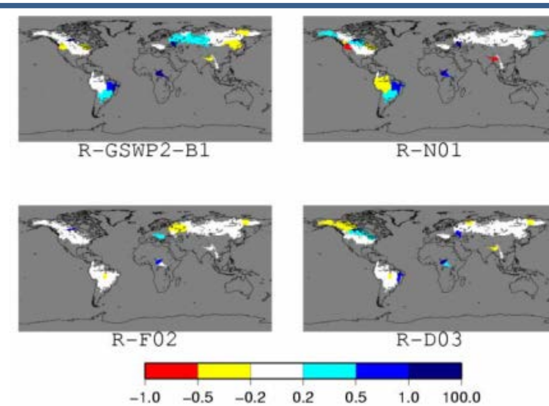




Does the model reproduce current national water resources?

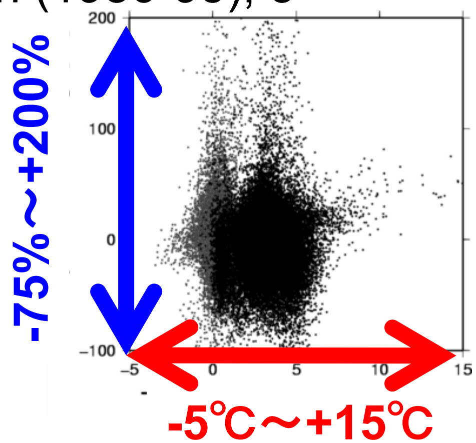


•Error margin of the original model is ±40%
•State-of-the-art global hydrological models estimate runoff of major rivers allowing for an error margin of ±20%.



2. Development of a CIRF for global water resources

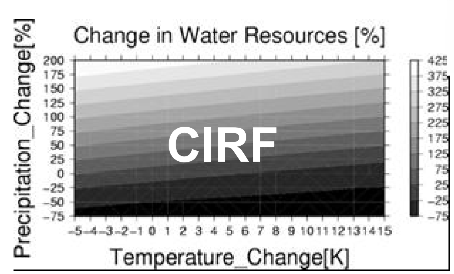
Meteorological data
- Global, 1°×1°(lon, lat)
- 10-year mean (1986-95), 3-hourly

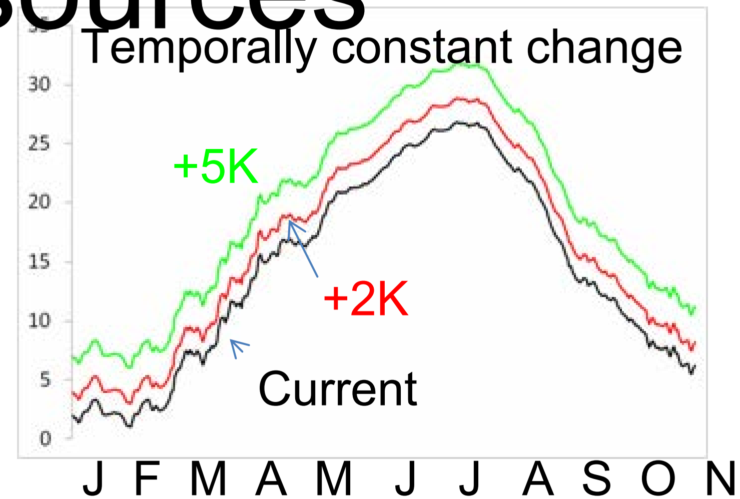


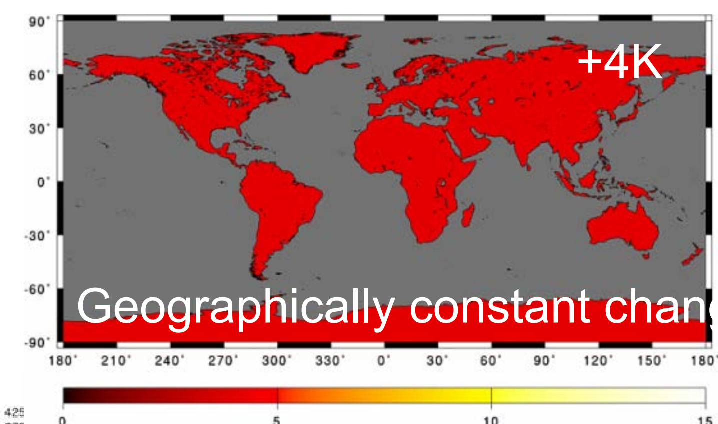
Temperature: every 1K (21)
Precipitation: every 25% (12)
Altogether 252 combinations

252 simulations

Detailed model
- Energy/Water balance



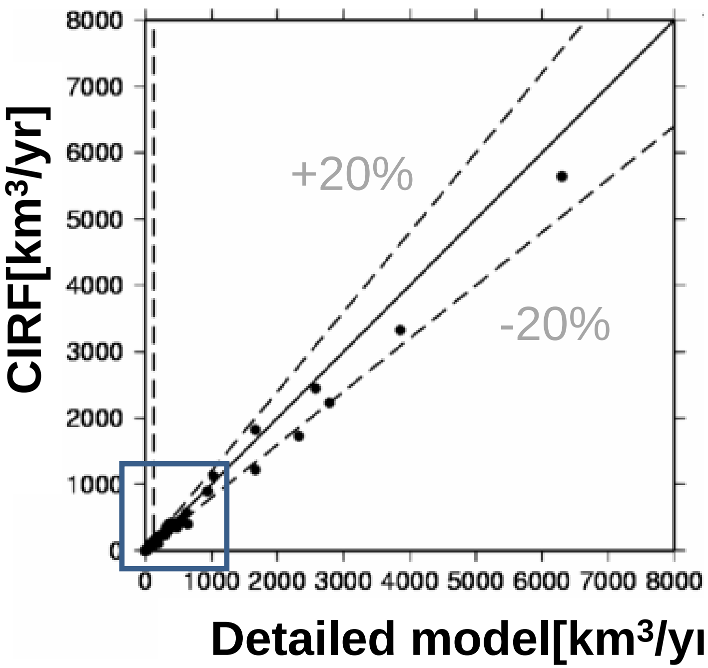




Are the estimation of our detailed model and that of CIRF consistent?

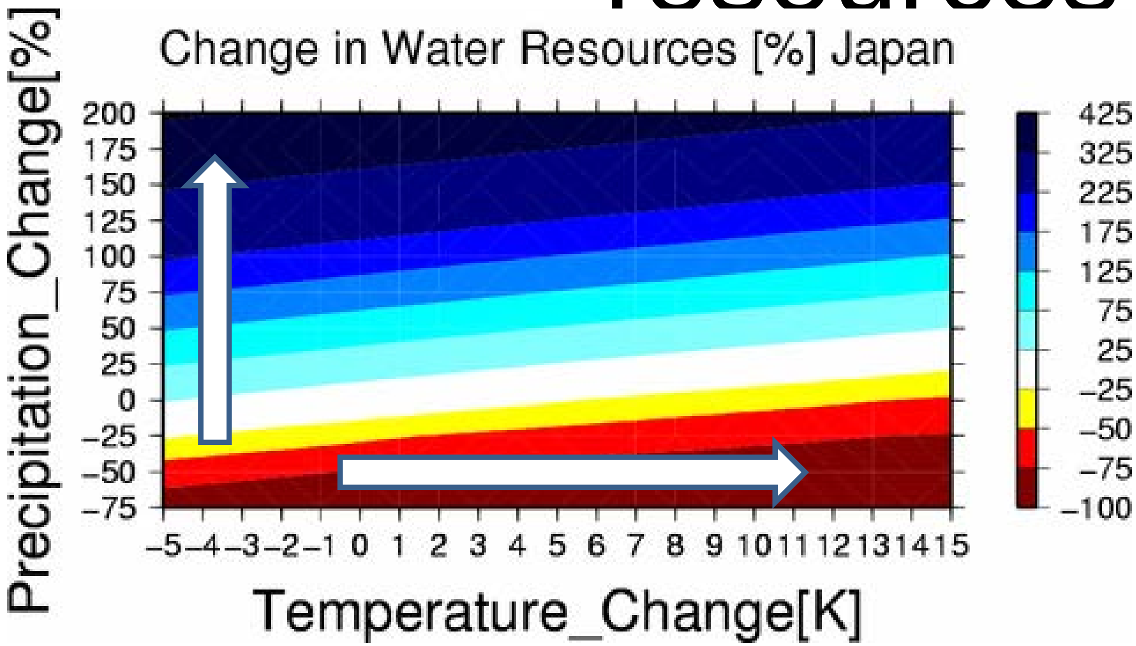
Compared simulation results
A) using the detailed model with
B) AIM/Impact[Policy] and CIRF

GCM: MIROC
Scenario: A1B
Period: 2086-95



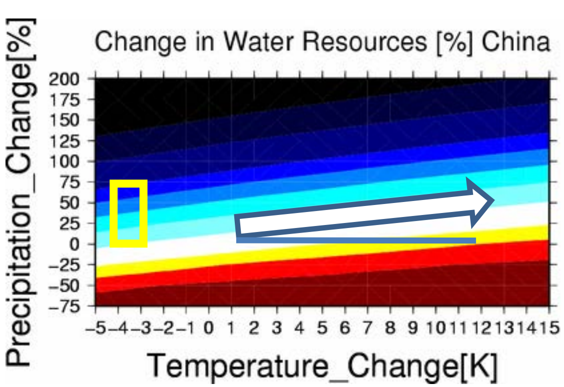
・Error margin is ±20%, but CIRF tends to underestimate the detailed model.

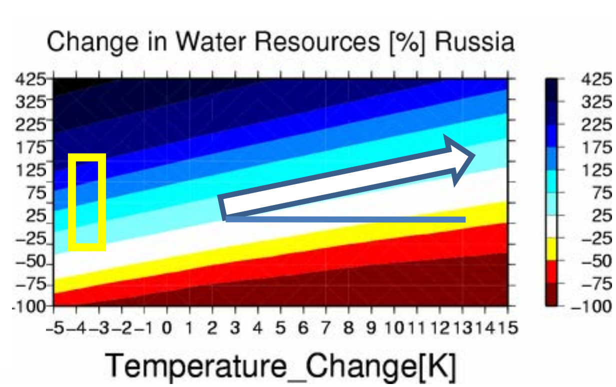
CIRF for national water resources



Vertical axis:
Precipitation increase, water resources increase.

Horizontal axis:
Temperature increase, water resources decrease





Sensitivity for China
Precipitation : high
Temperature: low

Sensitivity for Russia
Precipitation: low
Temperature: high

Summary and future study need

- Validated our global water resources model
  - Error margin was ±40% (AQUASTAT)
  - Limitation of current global hydrology?
  - Improvement in the model is needed

- Developed CIRF and validated
  - Error margin was ±20%
  - The assumption of annually constant change in precipitation is the major cause of error.
  - Improvement in the methodology is needed

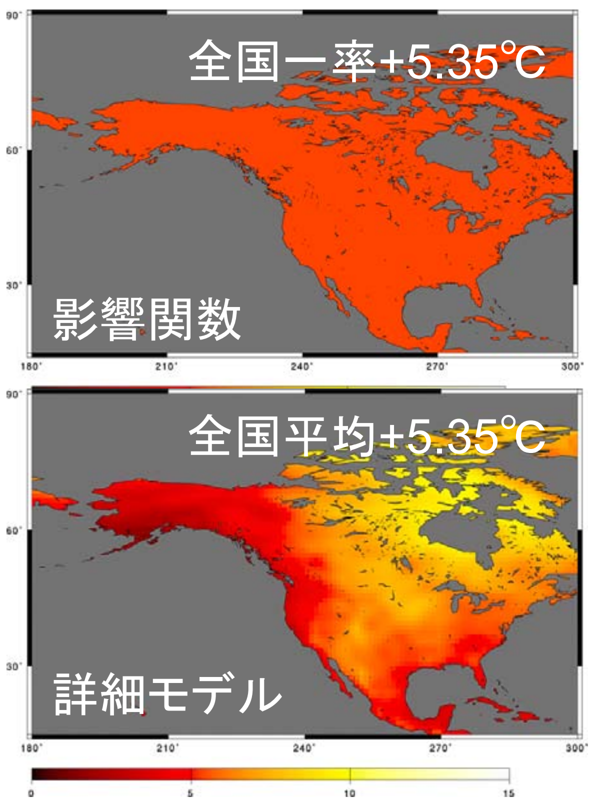
- CIRF was implemented to AIM/Impact[Policy]
  - A CIRF for national water resources was completed.
  - A CIRF for water stressed population, and other functions are needed for policy support.

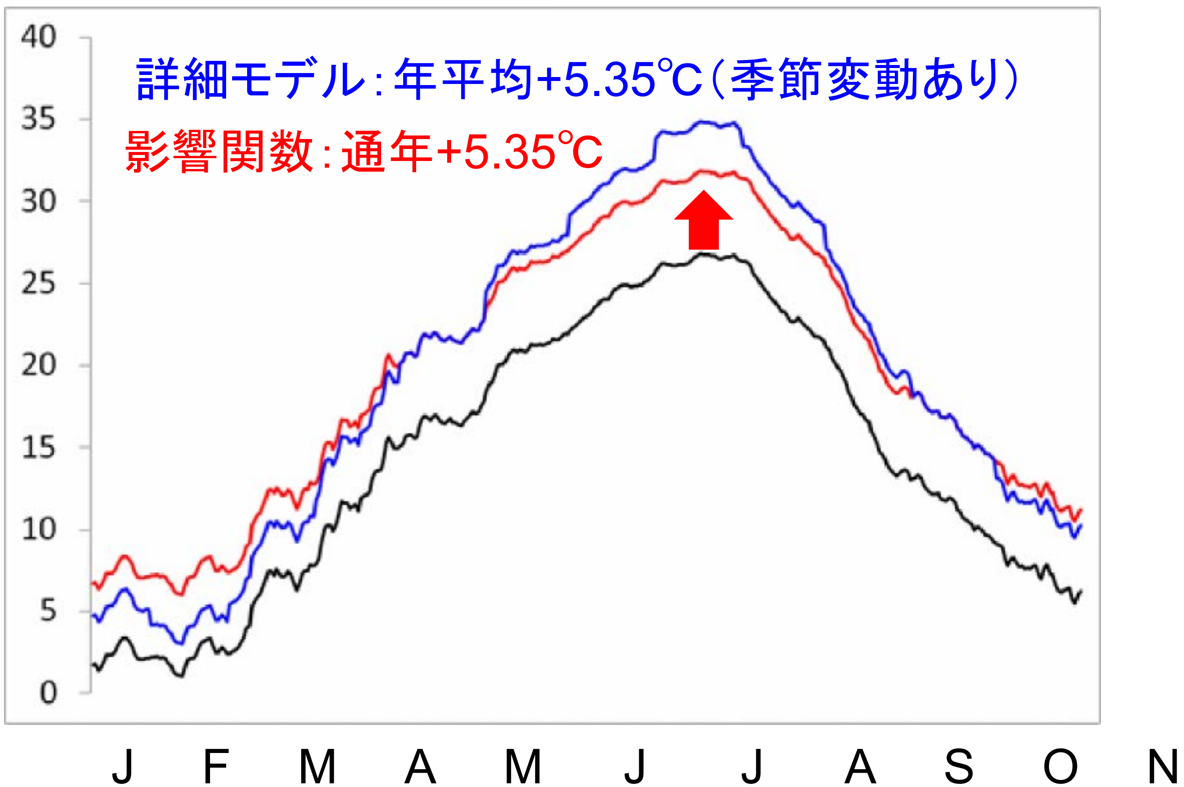
論文6ページ目に対応

影響関数過小評価の要因は？

詳細モデルと影響関数：入力データが異なる

GCM: MIROC, シナリオ：A1B, 対象年： 2100年
対象国：アメリカ

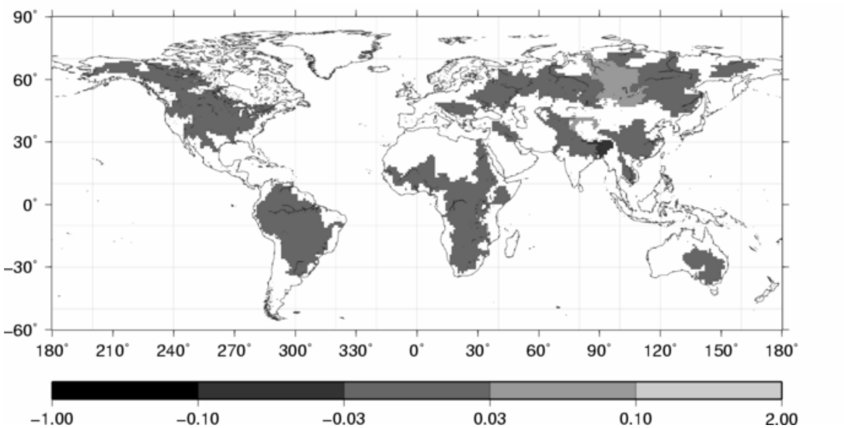




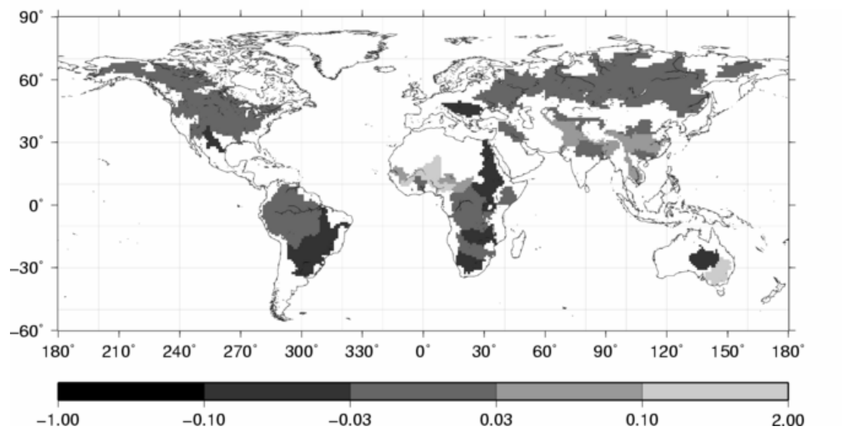
論文6ページ目に対応

時間平均・空間平均することの流出量シミュレーションへの影響

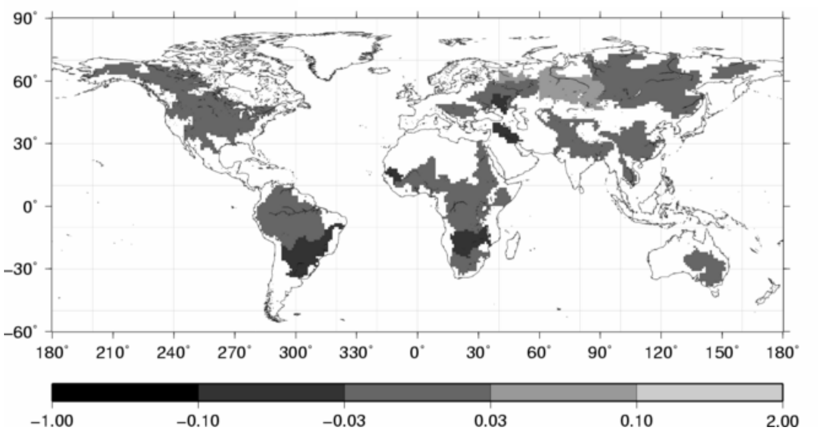
気温・空間平均



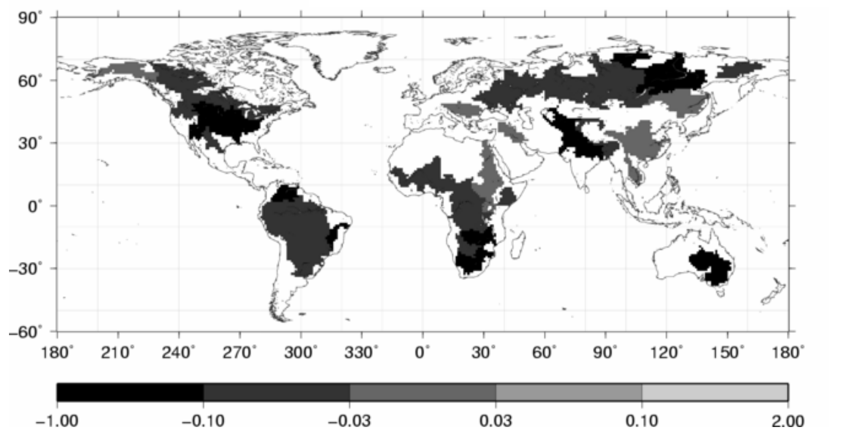
降水・空間平均



気温・時間平均



降水・時間平均



・降水変化を時間平均した影響が最も過小評価に影響している。→どう改良するか？

論文5ページ目に対応

影響関数はどれくらいの気候変化を想定すべきか？

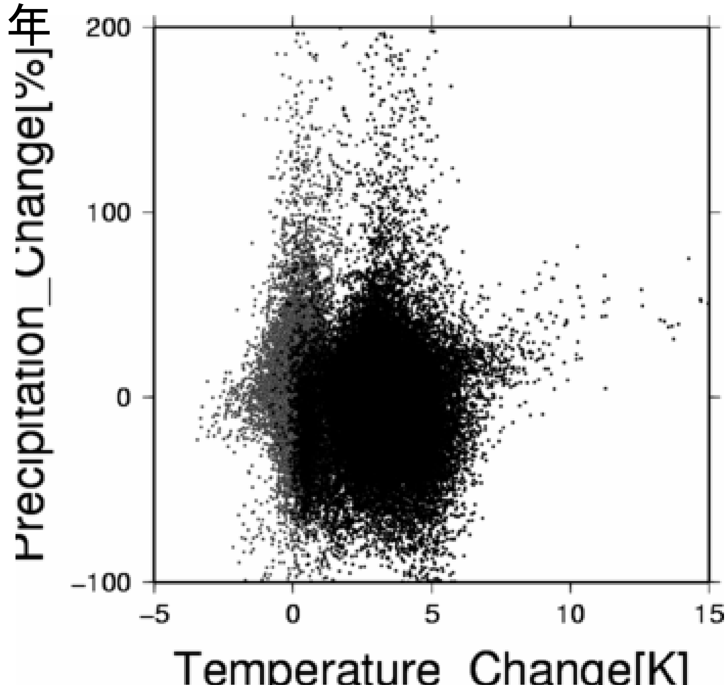
AIM/Impact [Policy]が取り得る値
・最大20のGCM
・251の国と地域
・2001-2100
・多数の排出シナリオ

20(18)のGCMの推定した
国別の気温と降水の変化
（1981-90の10年平均からの偏

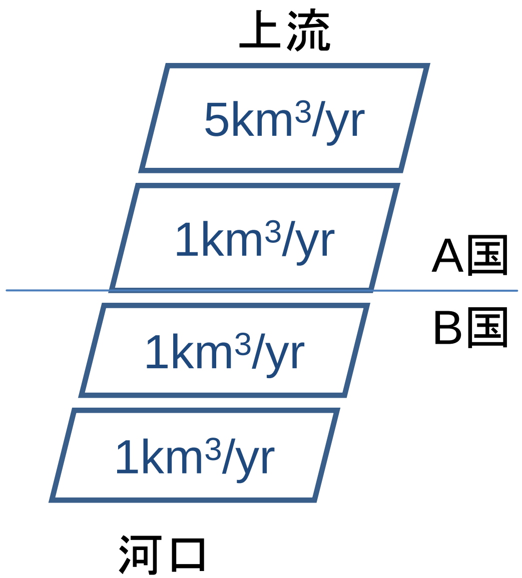
気温：-3.75℃から+15.0℃まで
降水：-99.9%から+7425%まで

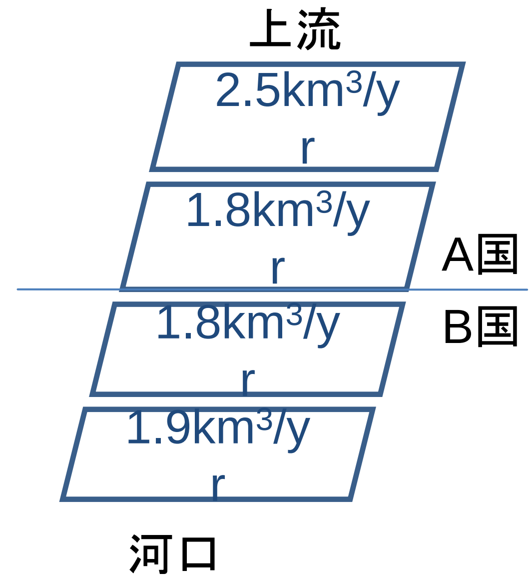
-5℃から+15℃まで（カバー率100%）
-100%から+200%まで（カバー率99.99%）

・最も気候変化が大きい場合：
　→SRES A2シナリオの2081-2090年
・最も気候変化が小さい場合：
　→SRES B1シナリオの2001-2010年



国別水資源量推定アルゴリズム





- 自分のグリッドから発生する流出の50%は自分用。残りは流下。
- 上流からの流入量は、上流ほど少なく、下流ほど多く取水。

$$W_{i,j} = 0.5R_{i,j} + I_{i,j}\, n_{i,j} \big/ n_{\max,i,j}$$

- ただし、現実の国際河川での水資源量配分はケースバイケース。
- 論文中では係数の感度実験も行っている。

世界の主要な37流域での検証結果

年流量誤差	流域数
±20%以内	約40%
±50%以内	約65%※

[illegible]
一部で誤差が大きい