On the bias correction for regression-based ESD result for multi agro-meteorological elements over Japan and their comparing with RCMs results

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1. developments of SD method and their bias correction
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Regression-based ESD

* MMLR (Multivariate Multiple Linear Regression, named by P. Gachon)

✓ One of the regression methods and empirical statistical (ESD) methods.
✓ Based on the statistical relationships between atmospheric circulations (predictors) & surface climatological elements (predictands)

This method has already applied to CORDEX-ESD protocols and also had good result compared with other methods in SA.

The ESD has not their quantitative aim for validation
→ Research Programs both for Dynamical & Statistical Downscaling of Japan (funded by MoE in FY2007-2011)
CCA/regression -based ESD (extended method of the NK-2006) applied to the GPV of large-scale circulation field on daily time-scale over Japan.

1. To reproduce current climate over mainland of Japan by using the reg.-SD and JRA25 reanalysis on agro-related multi surface elements.
2. To develop bias-correction technique for the SD estimated values.
3. To compare our results with the output derived from RCMs used same boundary conditions.
Large squared area (□) for predictor variables as JRA-25 reanalysis dataset. *Shaded (RCM calculated) area and smaller squared area (□) is too small to regress the surface climate variables over Japan. 

- **Specially Analyzed stations (9)**
- **Other target stations (24)**
Data and Methods

Meteorological Elements
Predictors
- SLP • T700 • UV850 (1/2 Var.) • Q850 by JRA-25 (OBS) : 289 grids*5 elements

Predictands
- Tx • Tm • Tn (1/3 Var.) Pr • Sr • Rh • Ws.) by JMA (OBS) : 35 st. * 3 elements.

* CCA were applied after calculating EOF of each circulation/climate fields.
* The reason used CCA, not SVD, is absolutely necessary to temporally independencies to estimate current climate by using multiple regression analysis.

Experiment tiers (according to CORDEX-ESD protocols)

Tier-1
Calibration: 16 year (1979-1994)×365(366) days = 6209 case
Validation: 13 year (1995-2007)×365(366) days = 4748 case

Tier-1.1:
Cali: 1995-2007;
Valid.: 1985-1994 * due to the length of RCM data and Sr. observed instrumental change
Major CCA patterns (warm season) (SLP/UV850 – Pr,)

CCA-3

CCA JRA_SLP/UV850 vs JPNSFC_Tm (3)

CCA-4 (rev.) : Front-type

CCA JRA_SLP/UV850 vs JPNSFC_Pr (4)

Tm (19%) + , Pr (12%) — , Sr (16%) + Rh (9%) — , Ws (6%) weak in WJ

*Predominant N.P. High is located near Kanto

Tm. (4%) , Pr. (3%) , Sr. (4%) Rh (9%) — , Ws (6%)

*Frontal zone along with the Sea of Japan, esp. in July (Baiu)
Major CCA patterns (cold season) (SLP/UV850 – Pr,)

CCA-1: Winter-type (later stage)
*NW monsoon is predominate over NJ & Travelling H is covering WJ
Tm.(31%) —, Pr.(18%) —, Sr.(18%) + Rh (24%) —, Ws (3%) strong in NJ/EJ

CCA-2: Winter-type 2 (early stage)
*NW monsoon is predominate over WJ & Cut-off Low passes over NJ
Tm.(4%) , Pr.(10%) , Sr.(9%)
Rh (8%) dry in WJ , Ws (7%) +
Step 1: Construct multiple regression equations explaining observed weather $Y_{ij}$ (i: grid point, j: year) by using time-series of atmospheric modes $Z_{mj}$ (correlated with precipitation change and is independent each other) and regression coefficient $a_{im}$ (m: component)

$$Y_{ij} = \sum a_{im} Z_{mj} + b_i \quad \text{--- (1)}$$

OBS. climate = Regression Coe. * OBS. CCA circulation modes + intercept (maximum 20 CCA patterns are adopted)

- Temporal coefficients of the deduced circulation fields were transferred to estimate and valid current surface climate values.
- The ESD applied to daily value and validated on monthly (seasonal) scales.
Bias Correction for the ESD output -1 (Pr.)

Linear method causes frequent weak Pr. compare with OBS.: 
- **Pr**: As same PR-days and -intensity for calibration period on monthly scale.
*Other elements: As same average and std. for during calibration period on daily scale.

but STD. of Pr. On daily scale is not appreciated for Adj. due to its unstableness.

← Seasonal averaged BIAS (% ration to normal) of the ESD in valid. period on after adjustments used Pr. days and intensities

◆ After applying PR-days adjustment, excess of Pr. are quite dissolved esp. in warm season.
Bias Correction for the ESD output -2 (Sr.)

* Overestimated Pr. and rainy days causes to underestimate for Sr. (and excess for Rh.)

Seasonal averaged ← BIAS and RMSE → of the ESD in valid. period after using discrimination for Pr.

◆ When the equation of regressions are separated on dry & wet days respectively, estimated error for Sr. (and other elements) are improved.
Methods for inter-comparison

I. 20km-RCM dataset from former R&D program (-FY2011)
1. NIED-RAMS (Ver.1.0) : 1979-2007
2. MRI-NHM (Ver.2.2) : 1979-2007
* RCMs were driven by the JRA25 dataset as same boundary conditions as the SD.

II. Inter-comparison
Correlation Coefficients, Simple Biases and RMSEs are calculated on monthly (averaged or accumulated daily value) and seasonal scale.

III. Data Process for RCMs
- Tx, Tm, Tn. : Height adjustment
- Pr. : No correction
- Sr, Rh, Ws: Average Correction – due to overestimations for RCMs

Advantages of the SD and RCMs on inter-comparison
- The SD know observational AVE and STD not only calibration period but also validation period.
- The RCMs also tune to AVE?
RMSE (ESD/RCM vs. OBS): DJF

SD vs RCM RMSE (DJF) Validation (1995–2007)

North-J.

Mainland Japan

South-J.

RMSE of the ESD (Sr.) 0.6-0.8 MJ: same as that of RCMs (bias-corrected)
ESD (Pr.) around 25-75% of mon. value: (over-estimated in T)
RMSE of the ESD (Sr.) 1.4-2.5 MJ: slight larger in NJ
ESD (Pr.) around 50-200% of mon. value: (over-estimated compared to T & M)
Multiple regression-based ESD method applied to project 7-agro-related surface elements simultaneously by using regional-scale circulation fields derived from global reanalysis dataset (JRA25) has been developing.

Results are validated compared with those of RCMs driven by the same boundary conditions. For 1995-07 (based on 79-94 analysis), our MMLR-SD has almost good estimation on monthly scale, even in Pr. and other elements, after adjustments for PR-days & intensities and using independent regression equations for dry & wet days.

**Further Tasks:**

- To apply many cases of validation from various viewpoint
  - Changing of referring period, ref. CORDEX-ESD protocols.
  - Numbers & spatial area for predictor’s choice.
- To apply GCM output (e.g. MIROC5) with developing to avoid the biases of circulation fields between OBS. & GCM
‘Nou-Kan-Ken’ (Agro-Envi.-Dog),
A former mascot of the NIAES modeled on a dog as a farmer.

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Advantage of this ESD

- (anyone can) easily calculate with low computer cost
- possibility to apply many other situation:
  - any type of data: fine grid (<1km) or dense stations if it obtained favorite region (mid latitude: E. Asia., Europe, N. A., S.A.)
  - ensemble to use many GCMs circulation output

* If it applies to Tropical & Sub-Tropical (e.g. SEA.) regions, SST is to be effective Predictor.

Some questions, problems and limitations

- Actual Heavy Rainfall Change (hourly precipitation)?
  → necessary to apply non-linear approach (Stochastic Weather Generator or Neural Network) or useful indices (Q90 etc.)
- Is Linear Regression appropriate?:
  → negative (atmos.) anomaly associated with negative precipitation anomaly?
- The statistical relationships will be stable in the future?
  → to utilize long-term historical-GCM data or multi-GCM results
The SD well-estimated Pr. of 1998 heavy rain & unusual weather year.
• But it has general tendency to over-estimate for Pr.
• Observed condition for Ws is changeable.

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梅雨期に卓越する気圧パターン（第5成分）での地上気圧と850hPa風ベクトル、ならび日本の降水量との相関係数

気圧配置パターンから推定された長崎の降水量（日別推定値の月積算）の経年変動。
Comparison of estimated RMSE between ESD and RCMs

RMSE of the ESD (Sr.) and ESD (Pr.) are slight smaller or same as the RCM output in MAM and SON.
Comparison of ESD-estimated RMSE between Tiers 1.1 and 1.1
S.D. based on **Multiple Multivariate Linear-Regressions**
(Multi-)Predictors (SLP/T500/UVQ850) vs (Multi-)Predictands (T, P, Sr)

**OBS**

5A(SLP,T500, UVQ850): JRA25
3F(T, P, Sr): JMA

1-1. 5A-EOF(79-94)
1-2. 7F-EOF(79-94)
(EA 1.125°289 grid) (JMA 35 points)

1-3. 5A/7F-CCA(1979-1994)

*Calibration Period is currently fixed due to instrumental change.

2. Calibration for (T, P, Sr)
(with verification for 1995-2007/11)

**GCM**

(??????)

0. Bias Check of GCM
Many GCM/RCM/ReAnal. model has systematic bias of Sr. with over-estimated.

3. Input-SZU(20C) — Current Estimation

4. Input-SZU(sres) — Future Projection

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Basic Equation of this MMLR-SD

**Step 1:** Construct multiple regression equations explaining observed weather (Tm. Pr. Sr.) $Y_{ij}$ (i: grid point, j: year) by using time-series of atmospheric circulations (SLP, T0700, U/V/Q850) modes $Z_{mj}$ (correlated with precipitation change and is independent each other) and regression coefficient aim (m: component)

$$Y_{ij} = \sum a_{im} Z_{mj} + b_i \quad --- \ (1)$$

OBS. climate = Regression Coe. * OBS.-circulation mode + intercept

**Step 2:** New time-series of (atmos.) $Z'_{mj}$ (CO2) is constructed by referring to $Z_{mj}$ ($h_{mk}$ is same as CNTL/hist and GCO2s/SRESs/RCPs)

$$Z_{mj} = \sum h_{mk} X_{kj} \rightarrow Z'_{mj} = \sum h_{mk} X'_{kj}$$

CNTL-(atmos.) mode = $\sum$ (eigenvector * CNTL-(atmos.) grid point anomaly)

$\rightarrow$ CO2- (atmos.) mode = $\sum$ (eigenvector * CO2- (atmos.) grid point anomaly)

**Step 3:** Substitute $Z'_{mj}$ for $Z_m$ in (1) and calculate projected precipitation $Y'_{ij}$

(a_{im} is also same as OBS.-CNTL. Variance adjust to OBS. Precipitation)

$$Y'_{ij} = \sum a_{im} Z'_{mj} + b_i$$

GCO2 Projected Precipitation = Regression Coe. * new SLP spatial pattern

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