GSWP3 and LS3MIP &

Development of Global Land Surface Modeling/Validation/Benchmarking Framework

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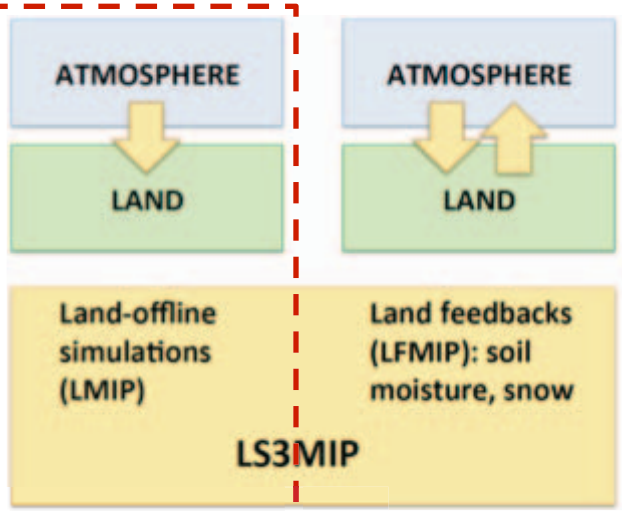
& Thanks to : Paul Dirmeyer, Aaron Boone, Bertrand Ducharme, David Lawrence, Stefan Hagemann, **Bart van den Hurk**, **Gerhard Krinner**, **Sonia Seneviratne**, **Chris Derksen**, Gill Compo, Eun-chul Chang, Satoshi Watanabe, Kei Yoshimura, James Famiglietti, Yukiko Hirabayashi, **Taikan Oki**, and Many…

Global Soil Wetness Project Phase 3

Super-ensemble **land reanalysis** for
20 and 21st Century as inter-community service



GSWP3/LMIP (CMIP6 proto-DECK) + **GLACE ESM-SnowMIP**

WCRP + GEWEX Grand Challenges

- Cloud, Circulation & Climate Sensitivity
- Water Availability
- Climate Extremes
- Regional Climate Information
- Regional Sea-level Rise
- Changes in Cryosphere

Land Surface, Snow, Soil moisture Model Intercomparison Project

LS3MIP Land processes, forcings, and feedbacks in CMIP6 climate change simulations

- Precipitation Variability
- E/W Exchanges
- Uncertainty

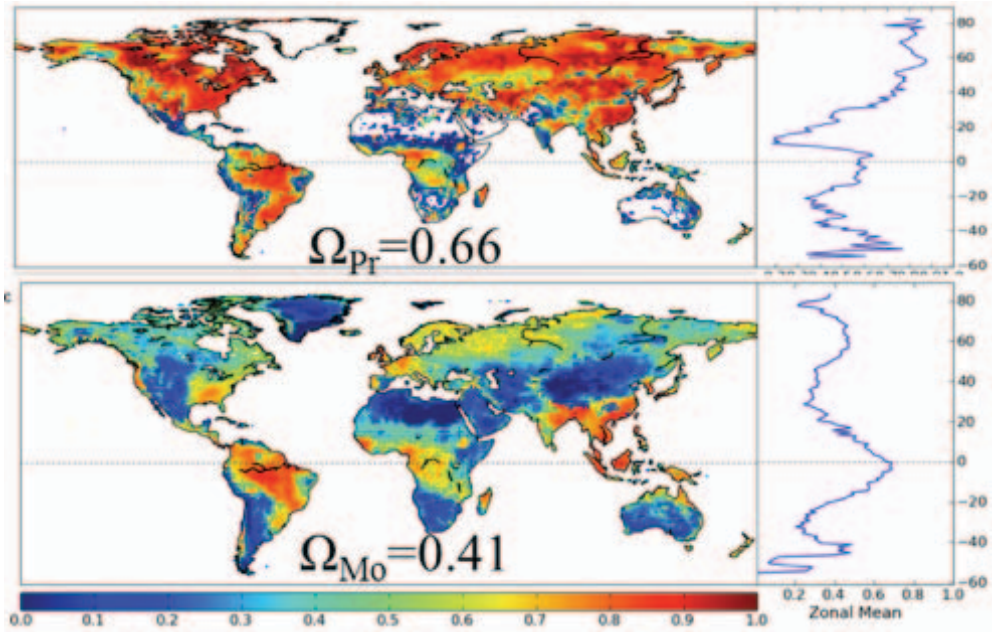
to quantify the associated uncertainties and better constrain climate change projections for earth system models in CMIP6.

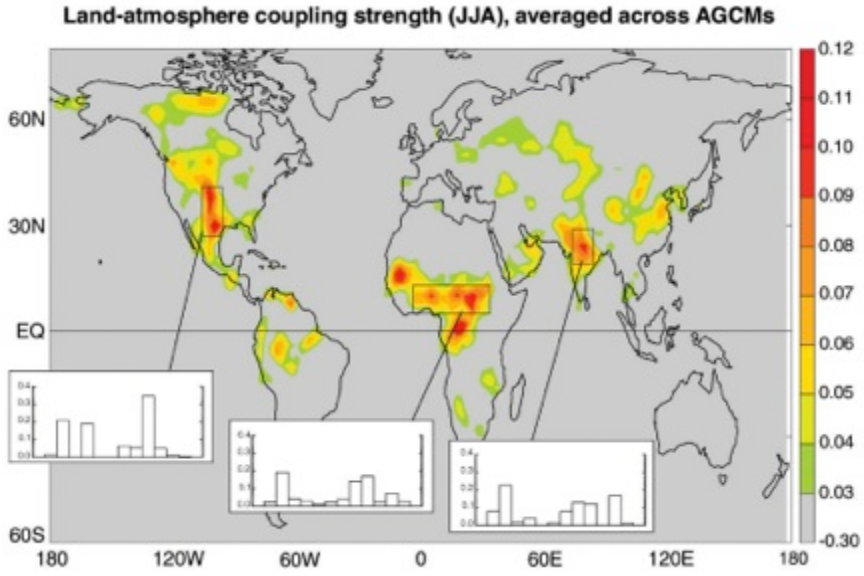
Bart van den Hurk, Hyungjun Kim, Gerhard Krinner, Sonia Seneviratne, Chris Derksen, and Taikan

Gaps to be Filled by LS3MIP

+ Map (uncertainty of) water resources over the 20th century (and beyond)

Kim (2010) showing that disparity in simulated runoff from uncertainty in ensemble precipitation is much less than model uncertainty :
LMIP/GSWP3





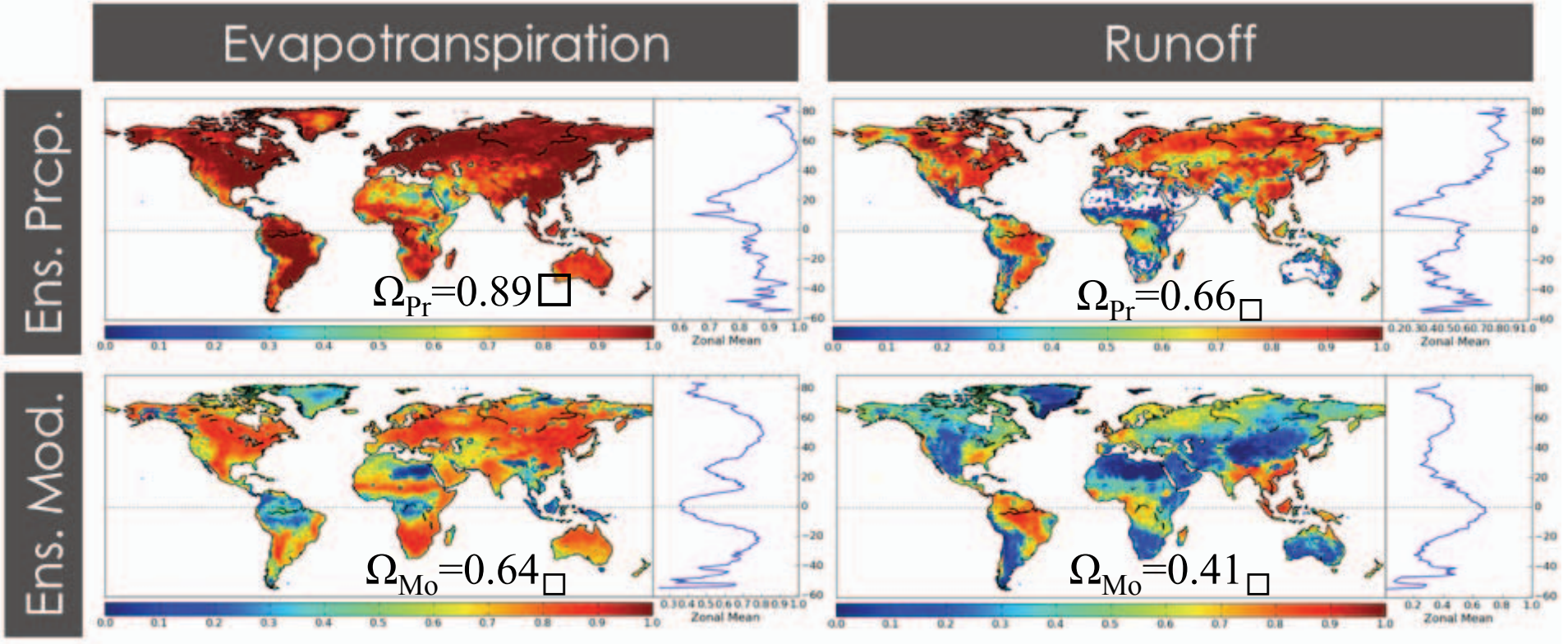
+ Explore model-dependent land-atmospheric coupling

Koster et al (2006): GLACE result showing model-specific land-atmospheric coupling strength :
LFMIP

Comparison Table for Existing Forcing Data

	NCC	GSWP2	Princeton	ELSE	WATCH	GSWP3
Reference	Ngo Duc et al., 2005	Dirmeyer et al., 2006	Sheffield et al., 2006	Kim et al., 2009	Weedon et al., 2011	Kim et al., in prep.
Temporal Coverage	1948-2000 53 years	1982-1995 14 years	1948-2008 61 years	1979-2010 32 years	1901-2001 101 years	**1851**-2011 161 years
Spa./Temp. Resolution	1 deg. 6 hours	1 deg. 3 hours	1 deg. 3 hours	1 deg. 6 hours	0.5 deg. 3 or 6 hours	0.5 deg. 3 hours
Base Reanalysis	NCEP/NCAR 1948 - now T62 / 6hr	NCEP/NCAR 1948 - now T62 / 6hr	NCEP/NCAR 1948 - now T62 / 6hr	JRA25 1948 – now T106 / 6hr	ERA-40 1957 - 2002 TL159 / 6hr	**20CRv2c** **1851 - 2011** 2 deg. / 6hr
Spa. Dis-aggregation	Bi-linear	Bi-linear	Bi-linear, Bayesian	Bi-linear	Bi-linear	Dynamical Downscale
Temp. Dis-aggregation	N/A	Variability from Obs.	Variability from Obs.	N/A	Variability from Obs.	Dynamical Downscale
Bias Correction	Only monthly (Add/Ratio)	Only monthly (Add/Ratio)	Only monthly (Add/Ratio)	Only monthly (Add/Ratio)	Only monthly (Add/Ratio)	Monthly (Add/Ratio) & Daily (Non-para.)

Simulation Uncertainty – model vs input data –

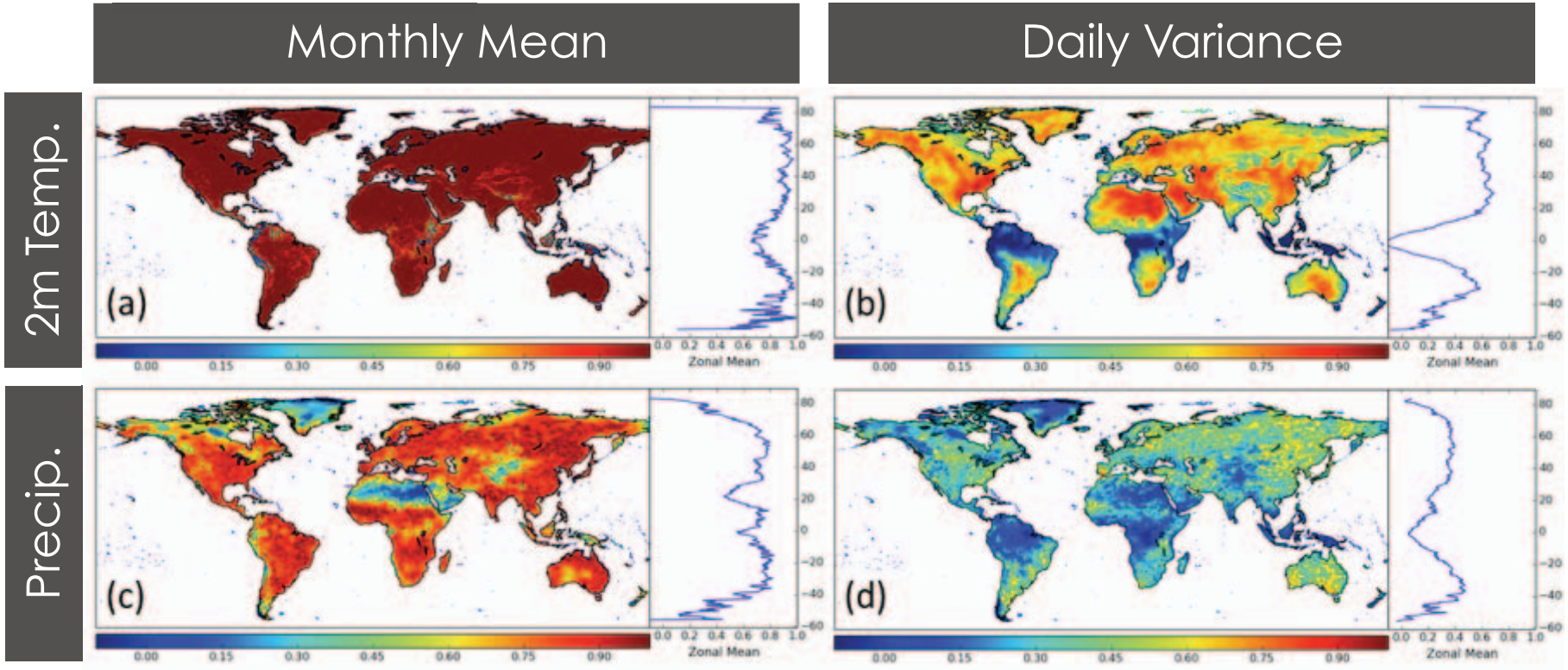


Kim, 2010

Uncertainty in simulated evapotranspiration and runoff introduced by different land surface schemes in GSWP2 are larger than precipitation uncertainty-induced uncertainty by 28% and 40% in the similarity index (□) globally.

Preliminary Results and Known Problems

+ Map (uncertainty of) water resources over the 20th century (and beyond)



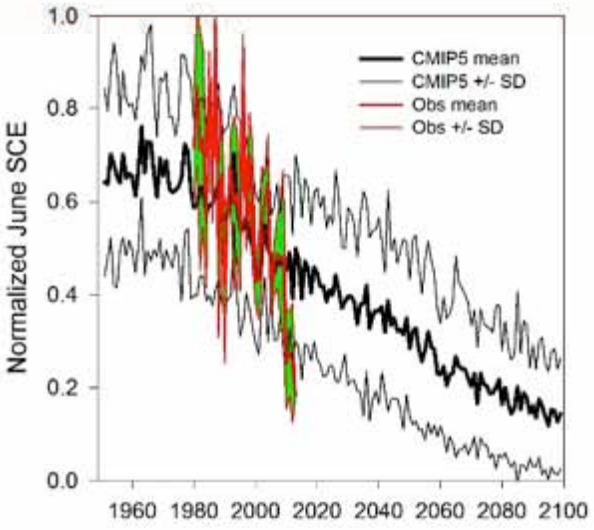
Global distribution of the similarity index (□) for 2001-2010 of monthly mean and variance calculated from different dataset.

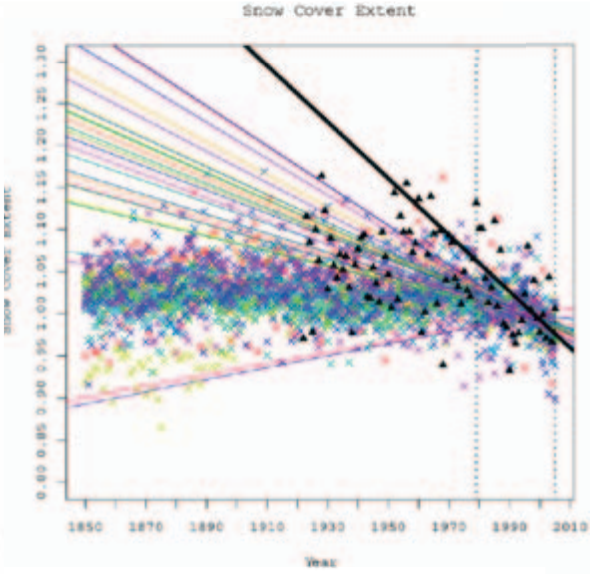
Since sharing observations to correct monthly bias, higher similarities are found in monthly mean fields than daily variance.

Gaps to be Filled by LS3MIP

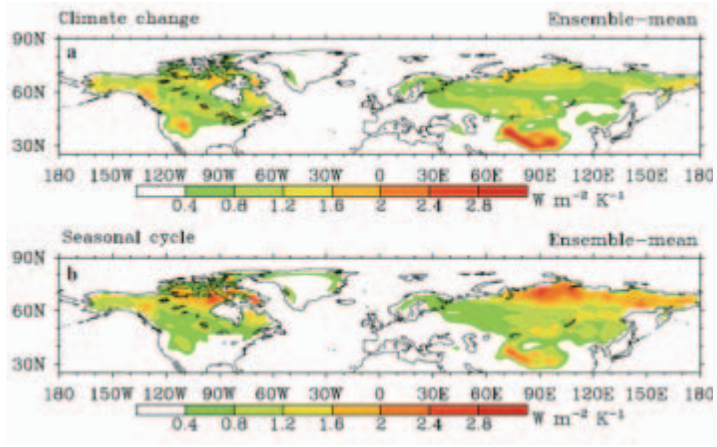
+ Ability of climate models to capture observed rates of spring snow cover reductions

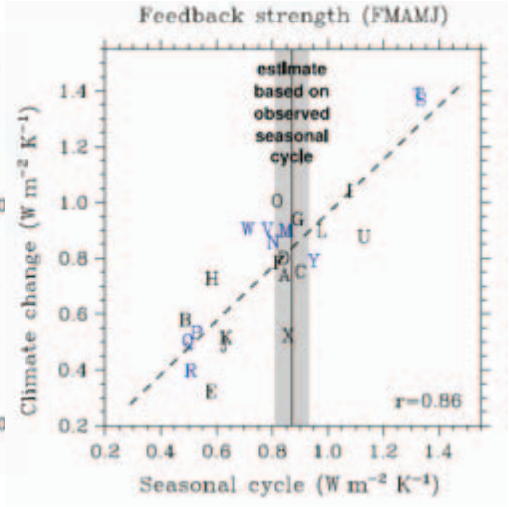
Brutel-Vuilmet et al. (2012); Derksen and Brown (2012): CMIP5 models underestimate the significant reductions in spring snow cover extent observed during the satellite era :
ESM-SnowMIP





+ Linkage between snow-albedo feedback and 21st century warming



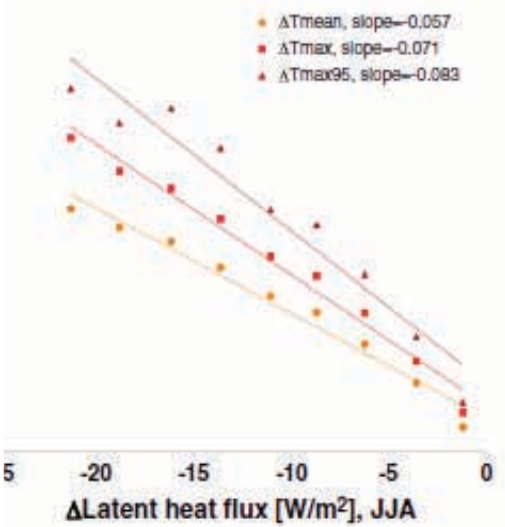


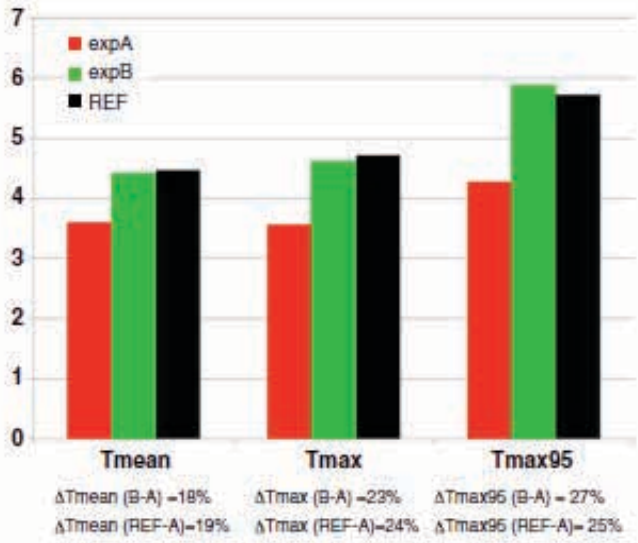
Qu and Hall (2013): The spread in snow albedo feedback accounts for much of the CMIP5 spread in the 21st century warming of Northern Hemisphere land masses :
ESM-SnowMIP

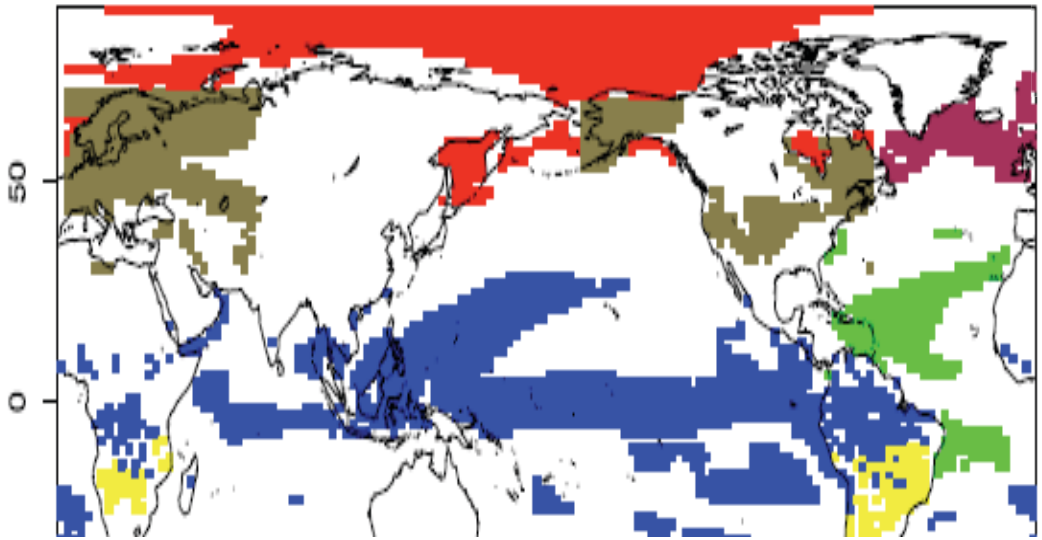
Gaps to be Filled by LS3MIP

+ Soil moisture affecting the climate change signal

Seneviratne et al (2014): GLACE-CMIP5 result showing effect of prescribing 20th century soil moisture climatology : **LFMIP**



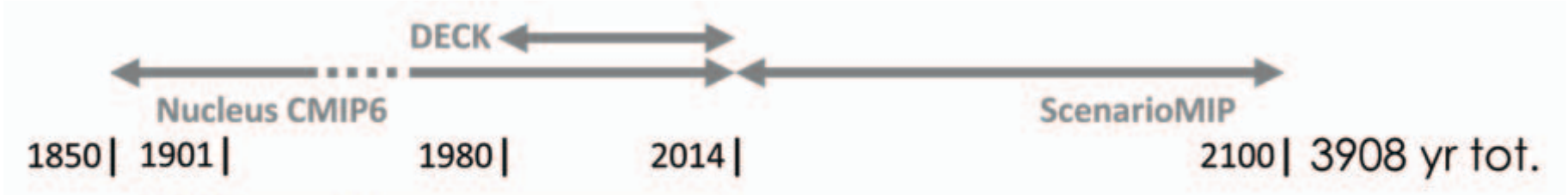




+ (Seasonal) Predictability can alter in a warmer climate

Del Sole et al (2014): Changes in seasonal predictability as a result of a trade-off between more signal and more noise in a warmer world : **LFMIP**

Experiment Structure of LS3MIP/CMIP6



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Published: 11 April 2016

Geoscientific Model Development Discussions
Open Access
EGU

The Land Surface, Snow and Soil moisture Model Intercomparison Program (LS3MIP): aims, set-up and expected outcome

Bart van den Hurk[1], Hyungjun Kim[2], Gerhard Krinner[3], Sonia I. Seneviratne[4], Chris Derksen[5], Taikan Oki[2], Hervé Douville[6], Jeanne Colin[6], Agnès Ducharne[7], Frederique Cheruy[7], Nicholas Viovy[8], Michael Puma[9], Yoshihide Wada[10], Weiping Li[11] , Binghao Jia[12] , Andrea Alessandri[13], Dave Lawrence[14], Graham P. Weedon[15] , Richard Ellis[16] , Stefan Hagemann[17], Jiafu Mao[18] , Mark G Flanner[19] , Matteo Zampieri[20], Rachel Law[21] , and Justin Sheffield[22,23]

an evaluation of the land processes representation

long-term terrestrial energy/water/ carbon cycles **LMIP**

role of snow and soil moisture feedbacks to climate forcing

contribution of land processes to the predictability **LFMIP**

Planned Timeline

30th Nov. Freeze Forcing Data
Finalize GSWP3 Protocol

2nd Dec. Kick-off EXP1 (with LS3MIP) / ISI-MIP Water sector will join
Forcing Data & Tools Available on Web

31st Dec. Description Manuscript (incl. pilot results) Submitted

2017

31st Mar. EXP1 Results Submission Due
Contributing Analysis Submission Due

16 – 19th May Joint Workshop with ISI-MIP (possibly, L3MIP-landhist together)
Kick-off EXP3 (**hi-res** super-ensemble; near real-time system)

31st Aug. (?) Submission Due for Special Issue (considering IPCC 15SR ?)
Release **GSWP3 Land Reanalysis** Fields

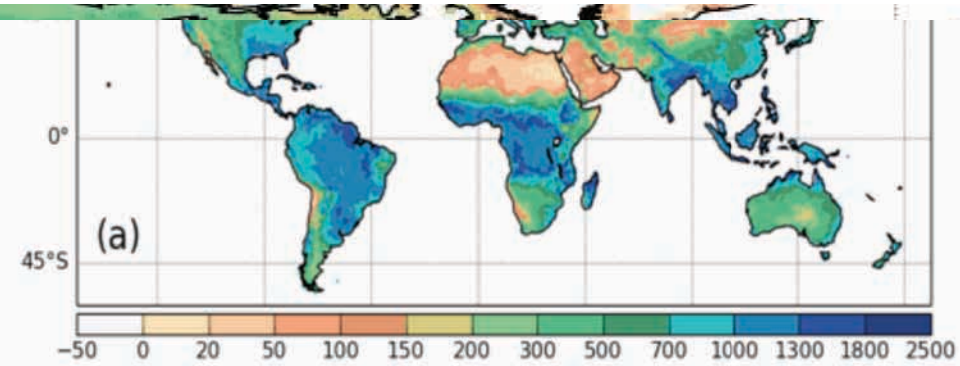
2018

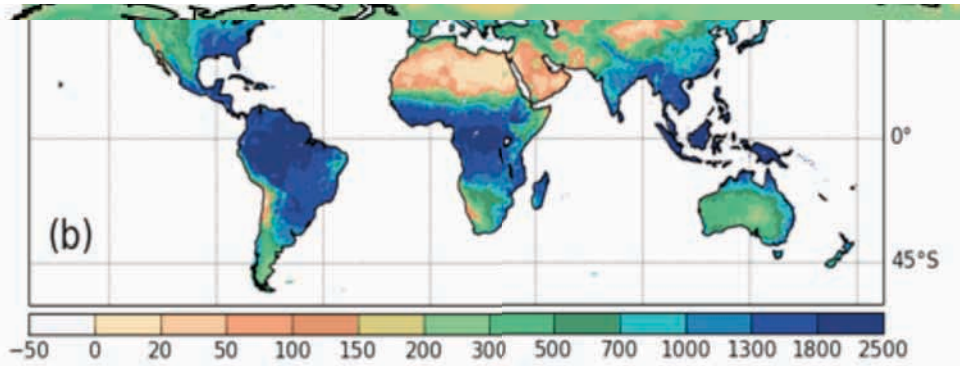
Feb. Annual Report (e.g., to State of the Climate/BAMS)

Current Archive for EXP1 Pilot Phase

+ Received preliminary results from
  NCAR (CLM4.5: 29 monthly vars;1970-2010),
  ETH (WBM-R_{net}UT: 4 daily vars; 1901-2009)
  ETH (WBM-R_{net}SRB: 4 daily vars; 1984-2010)
  U-Tokyo (MATSIRO: 41 daily vars; 1901-2010)
  U-Tokyo (MATSIRO-MIROC: 41 daily vars; 1901-2010)
  MeteoFrance (ISBA: 57 monthly vars; 1901-2010)

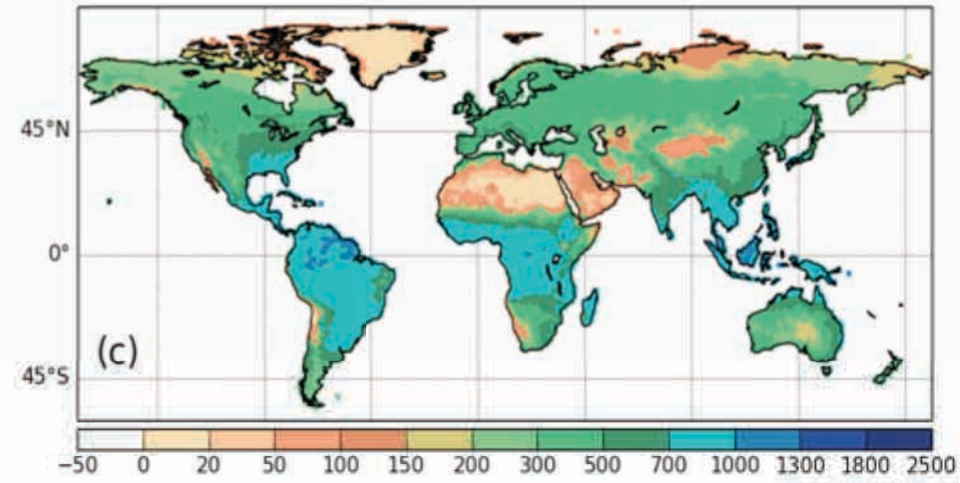
Intercomparison at the First Glance

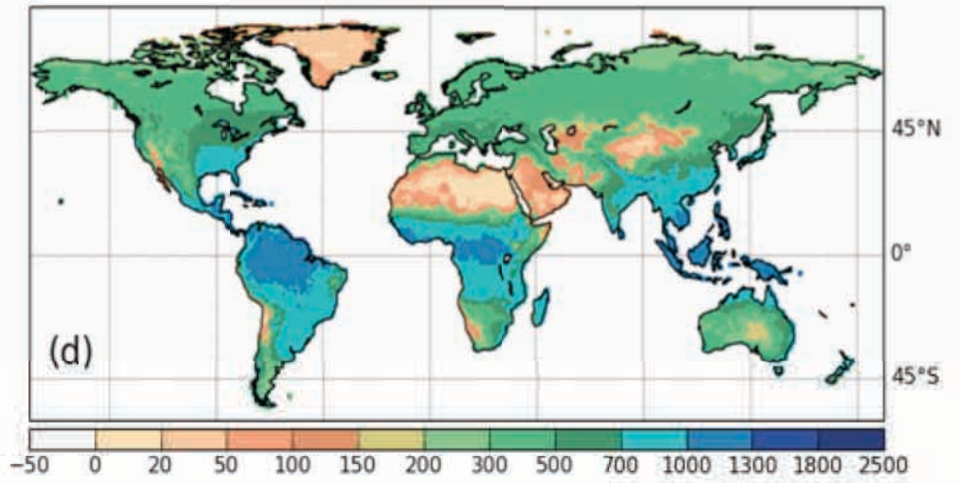




MATSIRO

CLM4.5

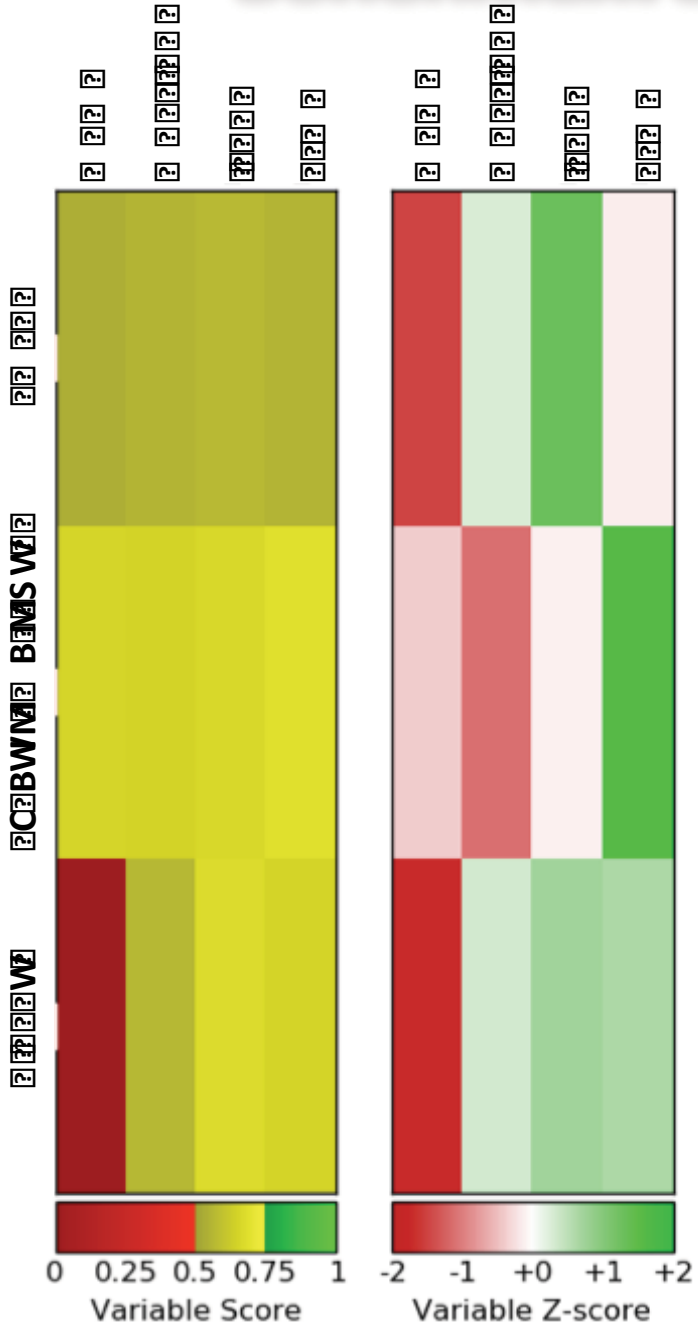


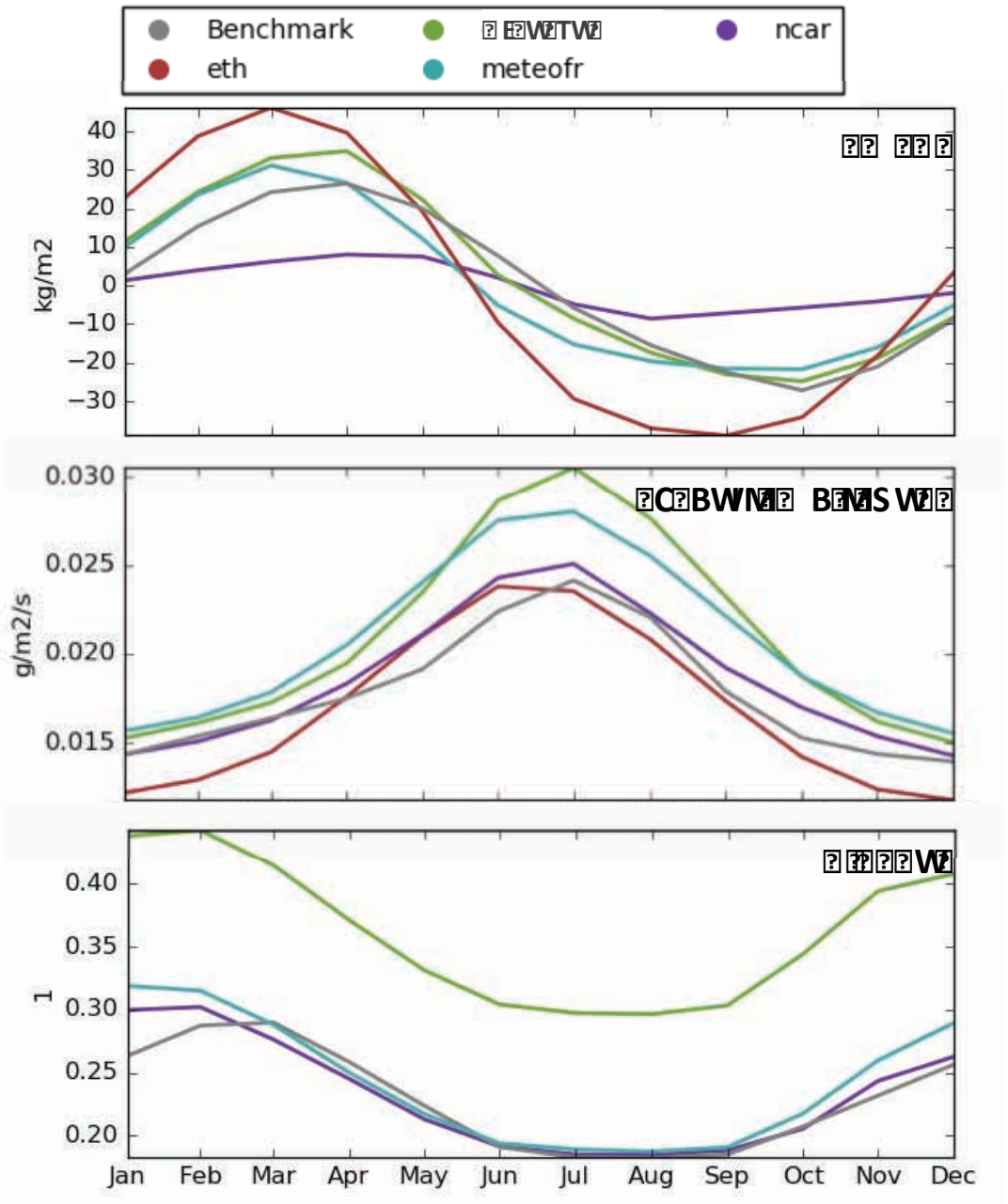


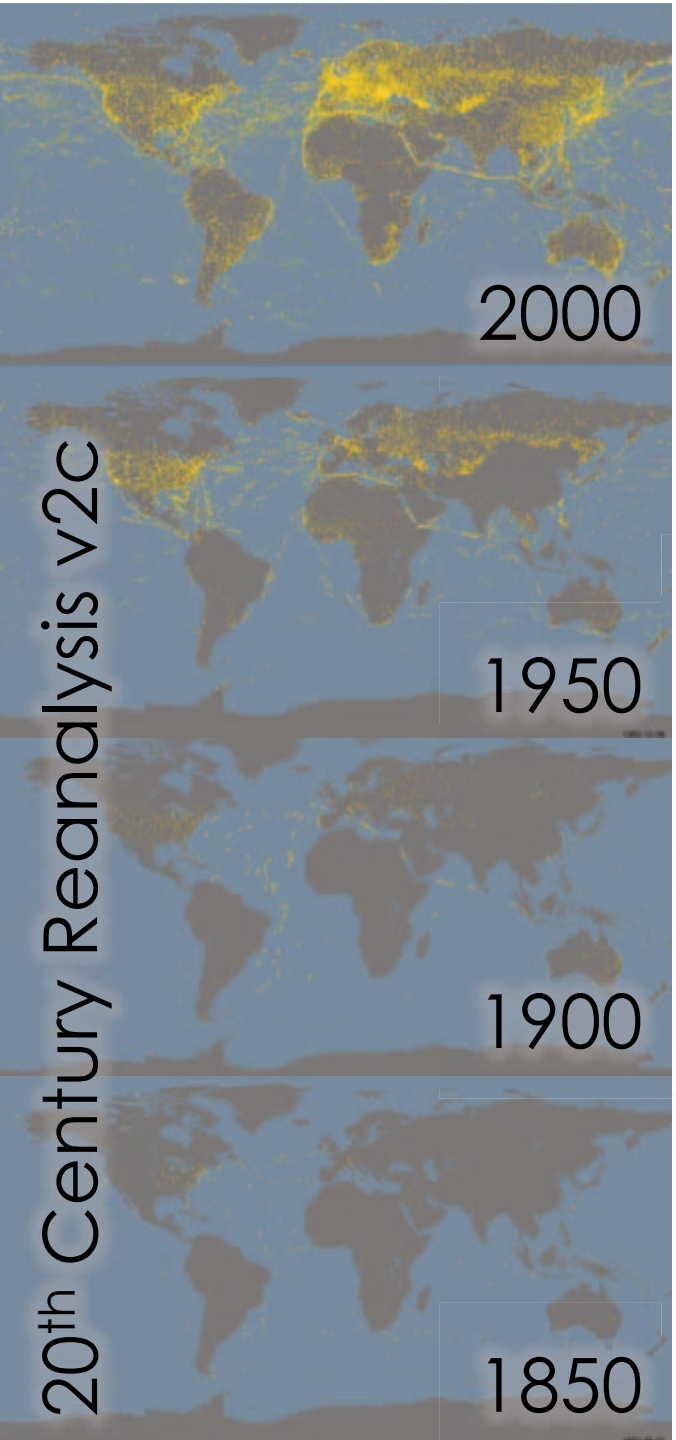
ETH with R_{net} $_{MATSIRO}$

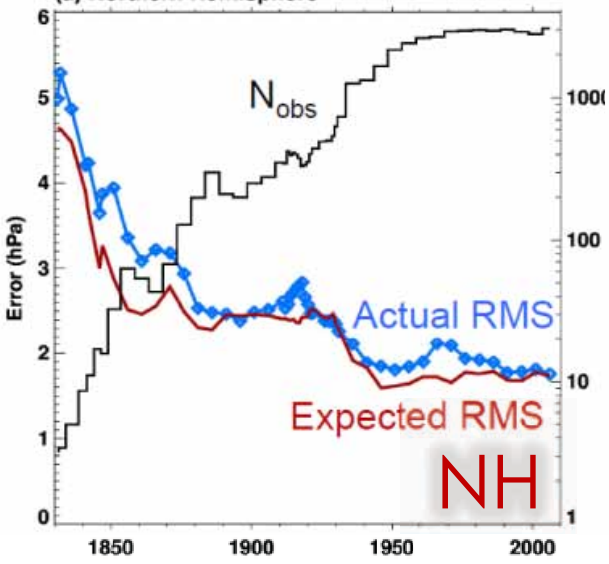
ETH with R_{net} $_{SRB}$

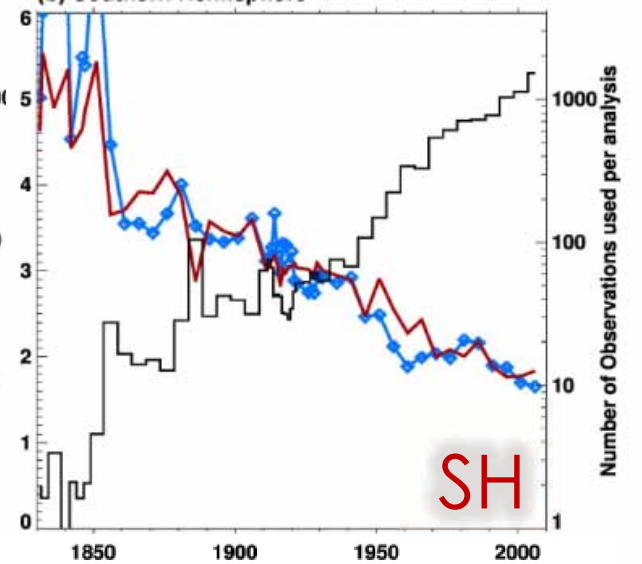
Benchmark of Pilot Results Using ILAMB



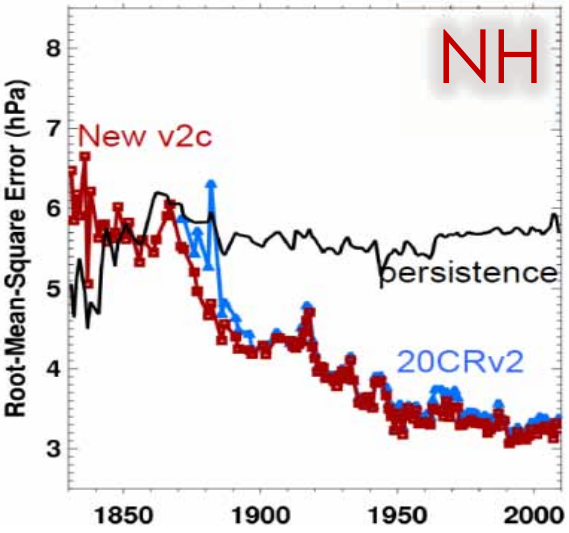


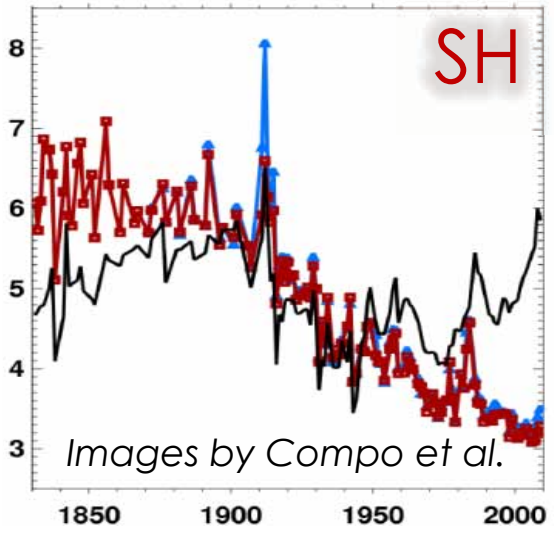




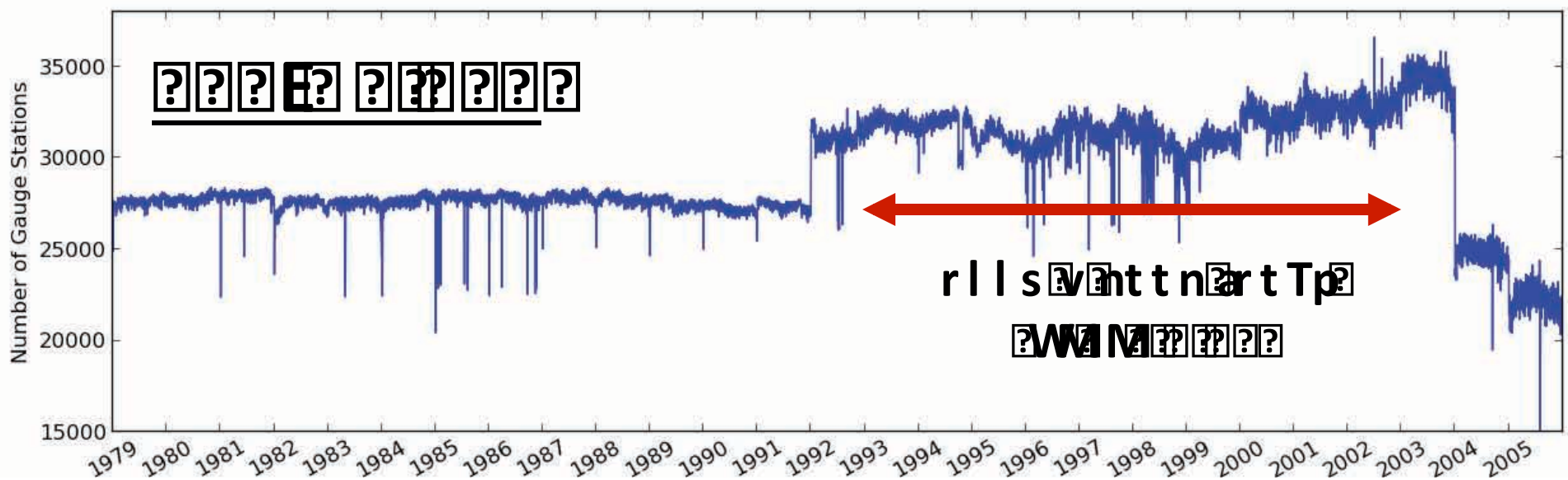


Uncertainty consistency through three order of magnitude changes in observation network





24 hr forecast of 20CR beats in NH (comparable to in SH) persistence forecast using NRA


Number of Gauge Stations
35000
30000
25000
20000
15000
1979
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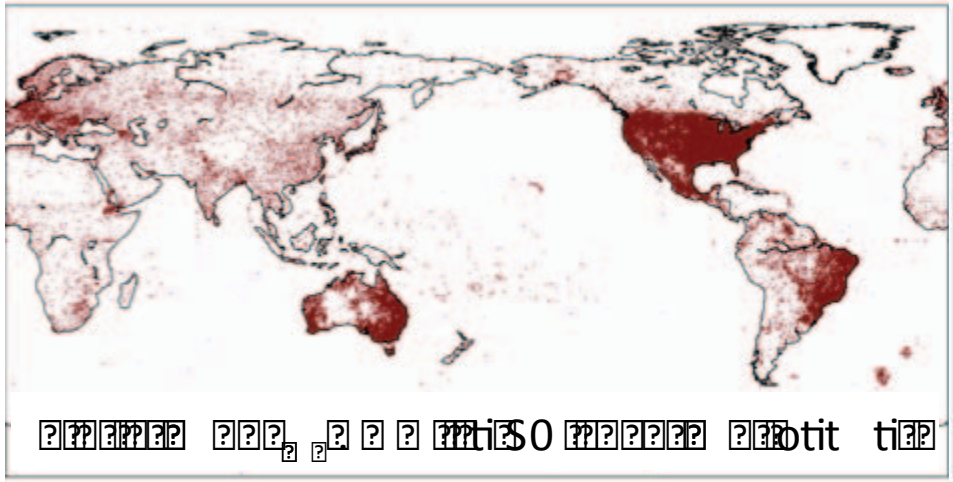
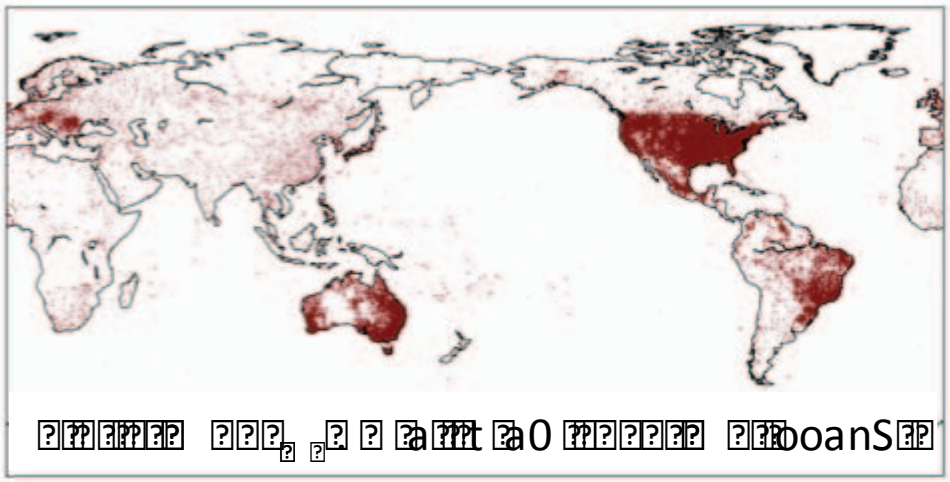
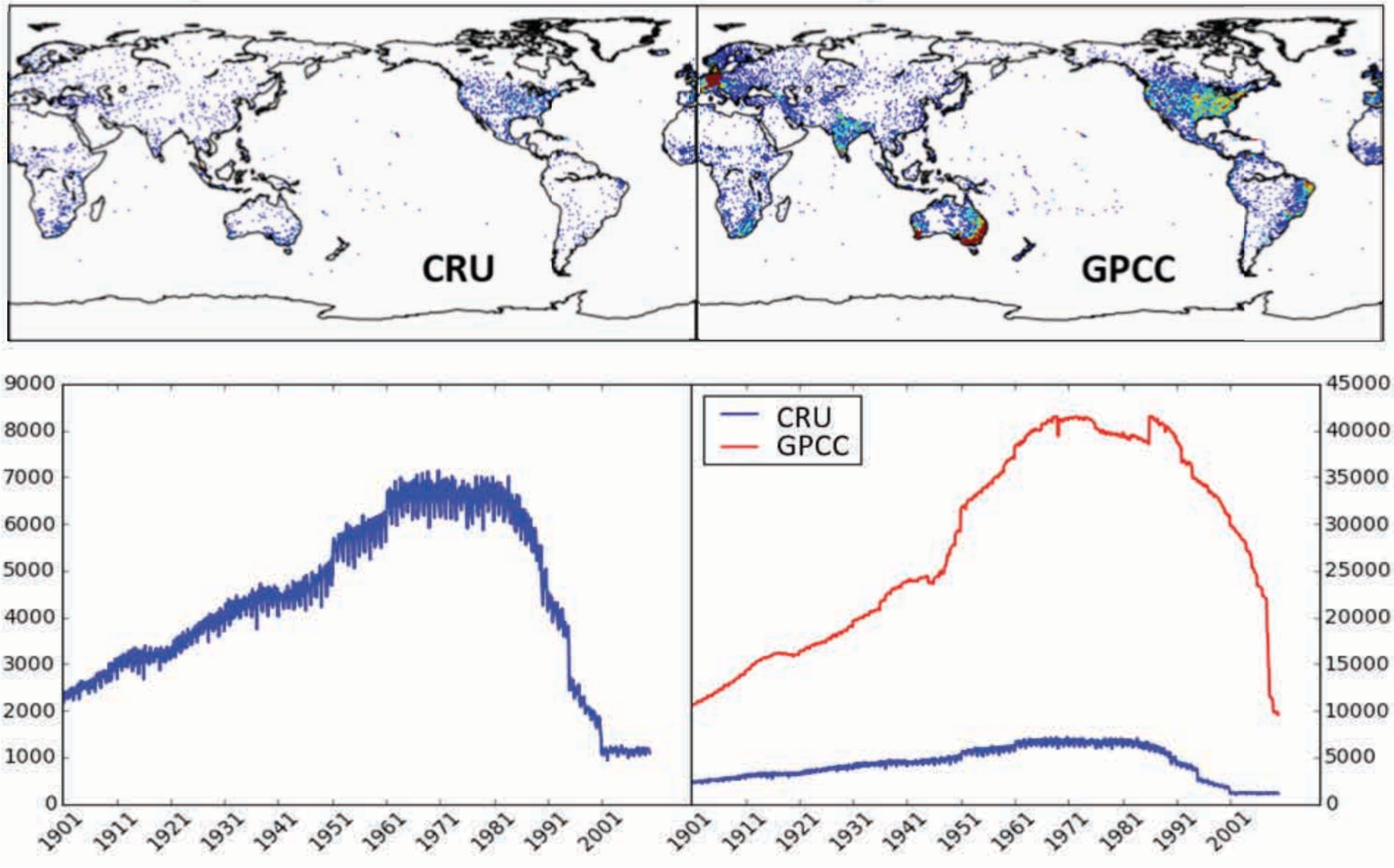
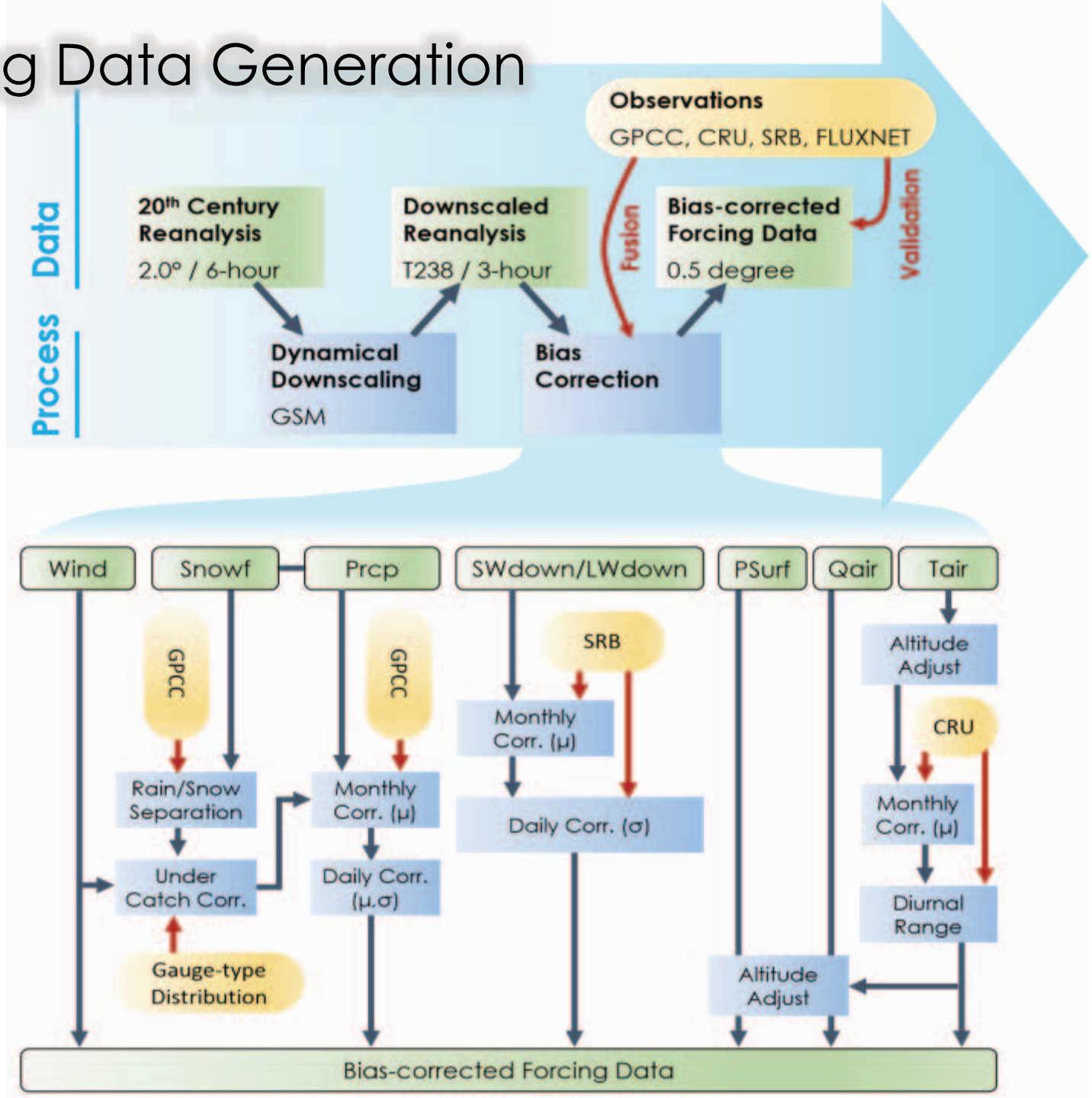




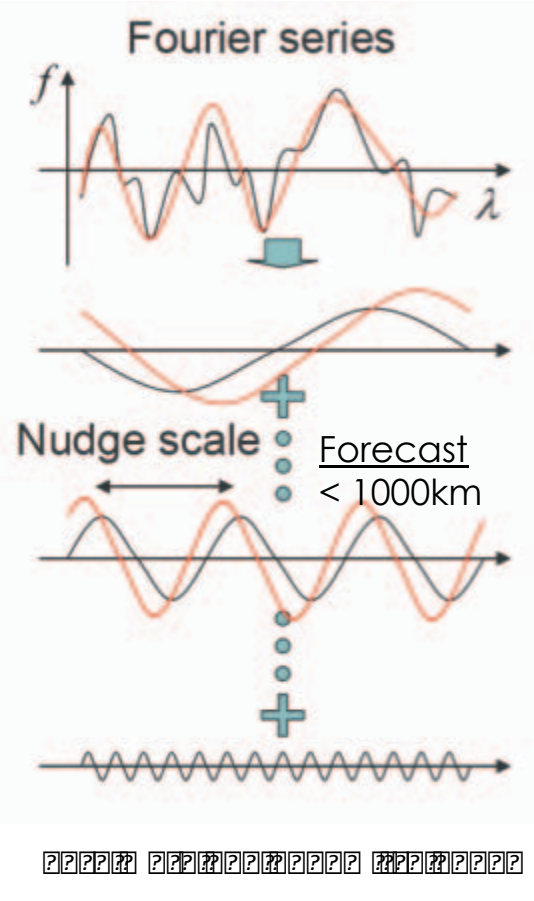
Density of Gauge Station Network: CRU vs GPCC

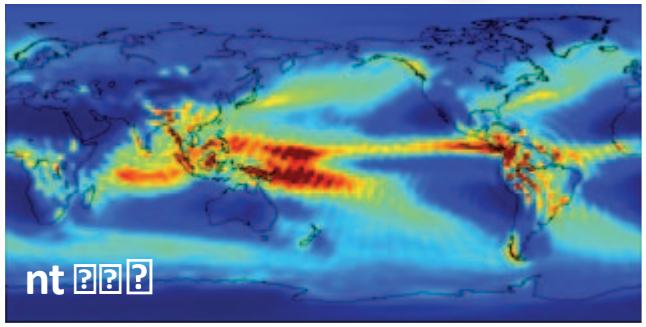


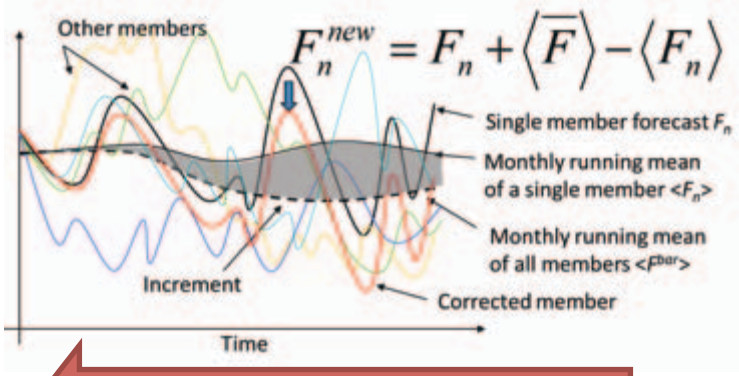
Forcing Data Generation



Spectral Nudging for Global Dynamical Downscaling





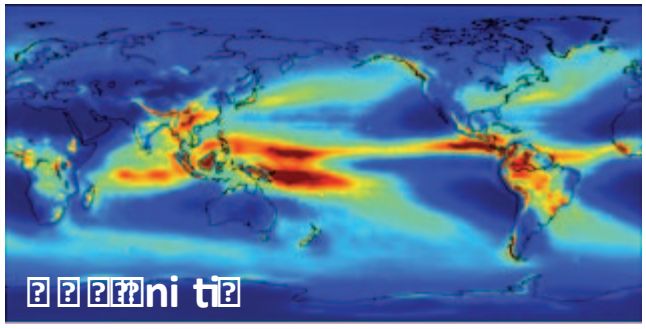


Incremental Correction of Single Member

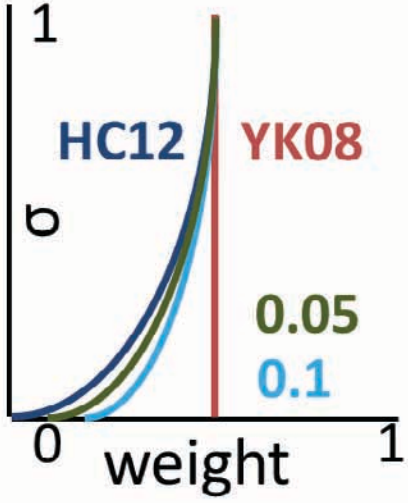
Nudging U, V, T, P

$$f_{(\lambda,\phi)} = \sum_{m=-M}^{m=M} A_{(m,\phi)} e^{im\lambda}, \quad \text{with}$$

$$A_{(m,\phi)} = \begin{cases} A_{f(m,\phi)} & \left(|m| > \frac{2\pi R_E \cos\phi}{L}\right) \\ \frac{1}{\alpha+1}\left[A_{f(m,\phi)} + \alpha A_{a(m,\phi)}\right] & \left(|m| \le \frac{2\pi R_E \cos\phi}{L}\right) \end{cases}$$



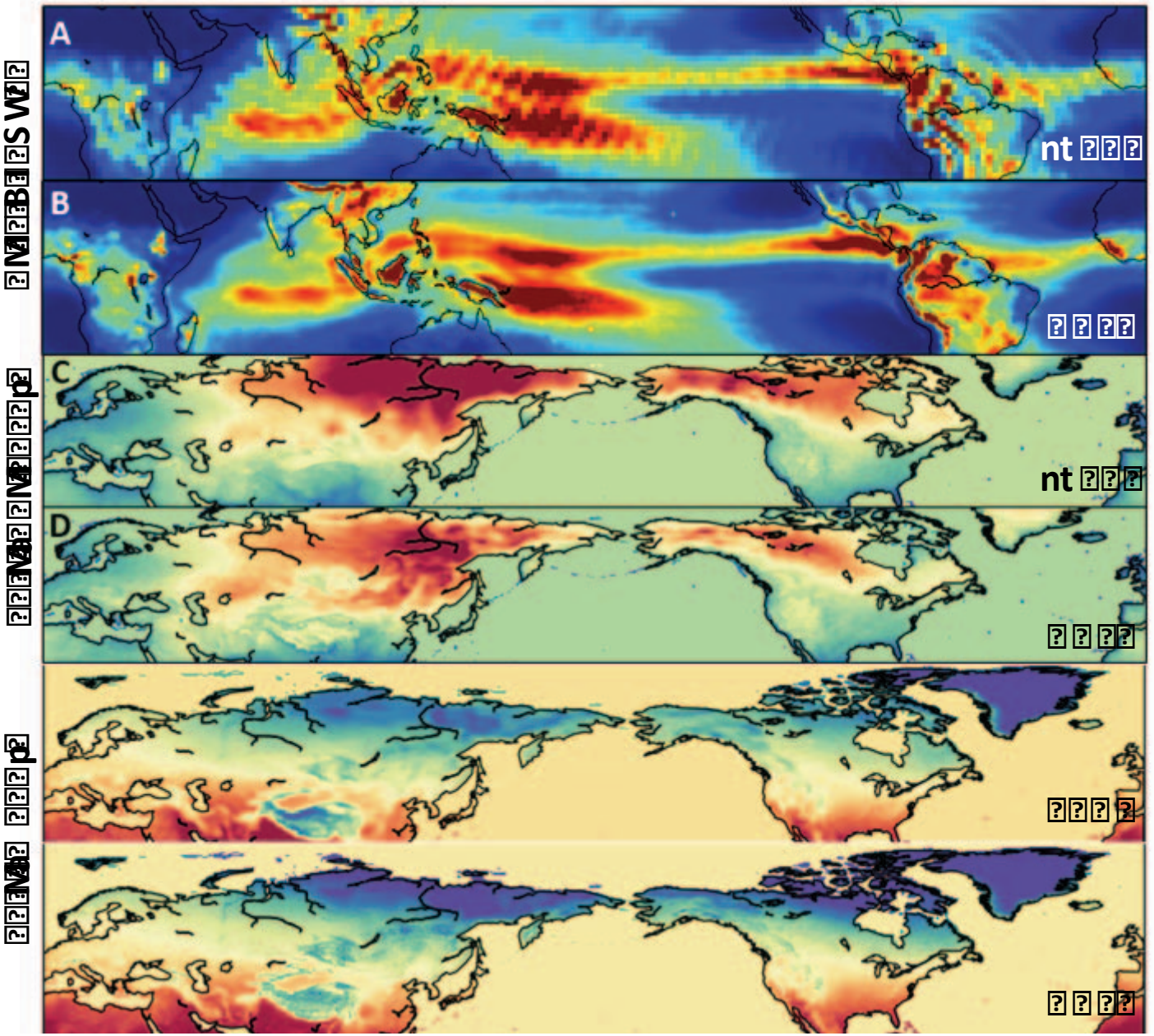
Vertically Weighted Damping Coef.



Successfully generate high frequency signals preserving low frequency background.

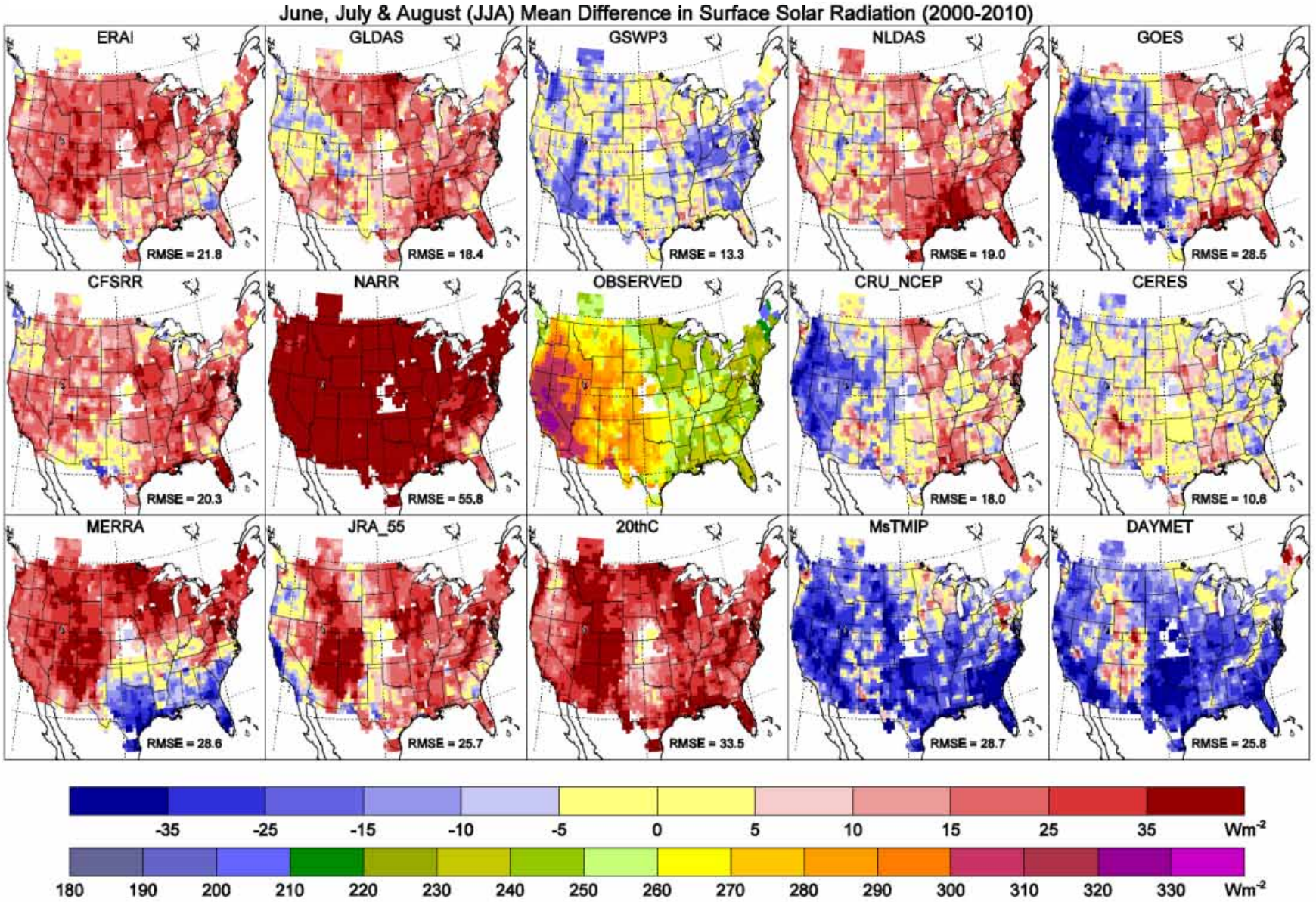
Effectively relieves ripple-like pattern (an artifact of 20CR due to high-res. topography mismatch)

Reduce Gibbs Phenomena & Added Values



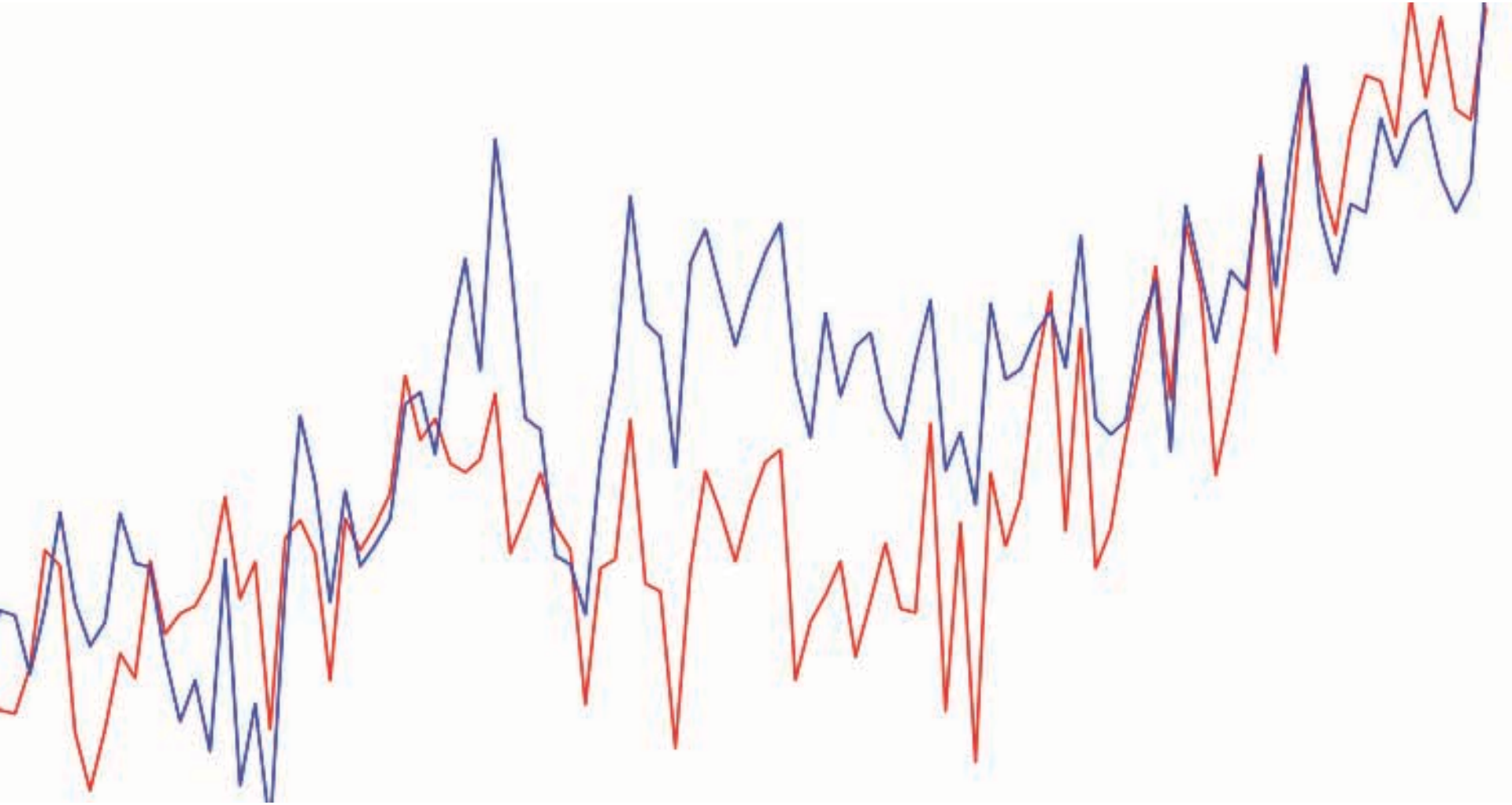
Downward Solar Radiation

+ Relatively small bias of solar radiation



Slater, 2015

Long-term Trends of Temperature and LWdown



Status of Forcing Data and Feedbacks

* Downscaled 20CR is available up to 1871.
* Downscaling back to 1831 will be finished by ~ 20th October

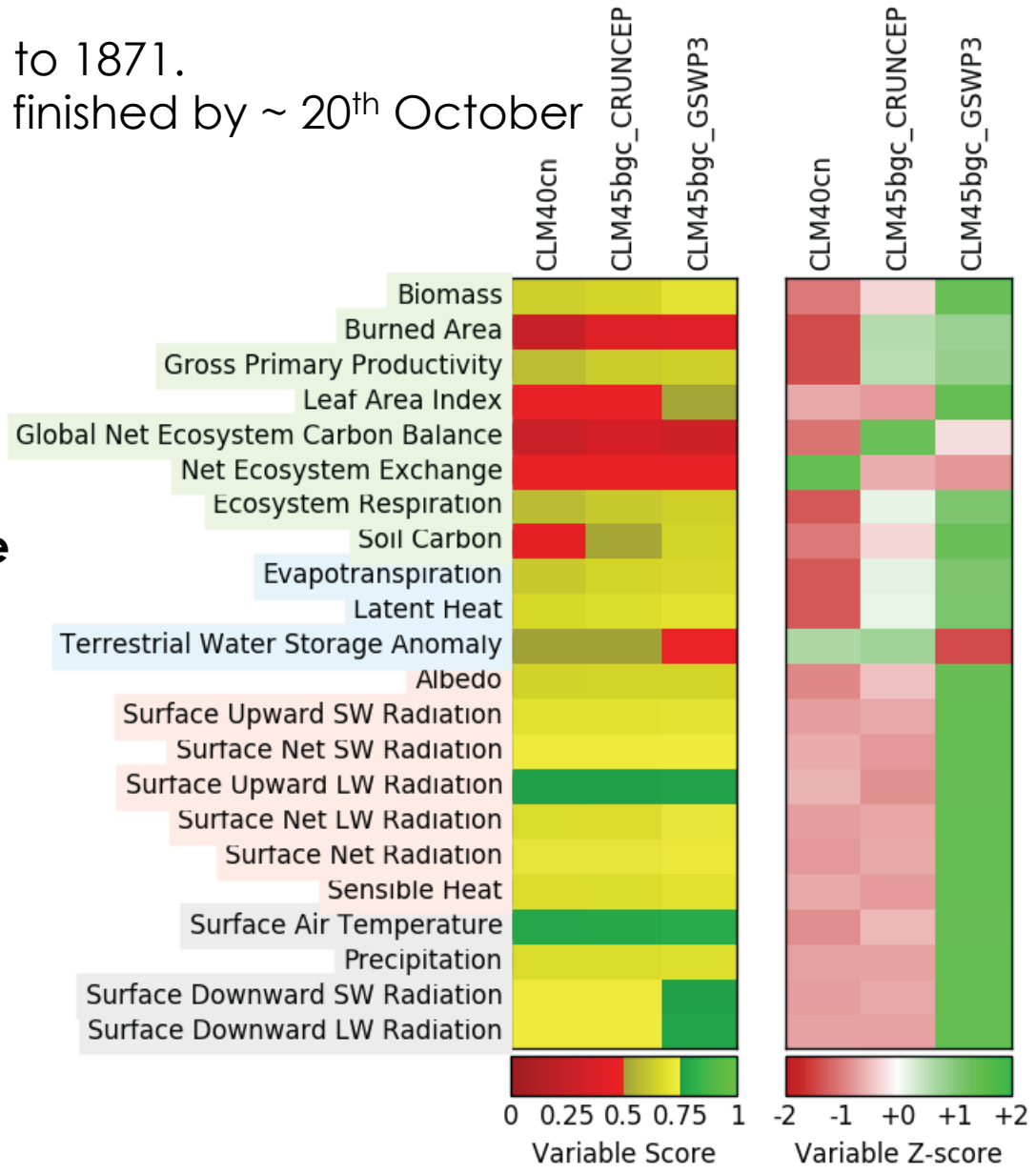
*** Specify cell-method (Jan)**
: attribute will be added
: e.g., mean(center)

*** Dry Tropics**
(Bertrand, David, Stefan)
: testing using CRU vapor pressure

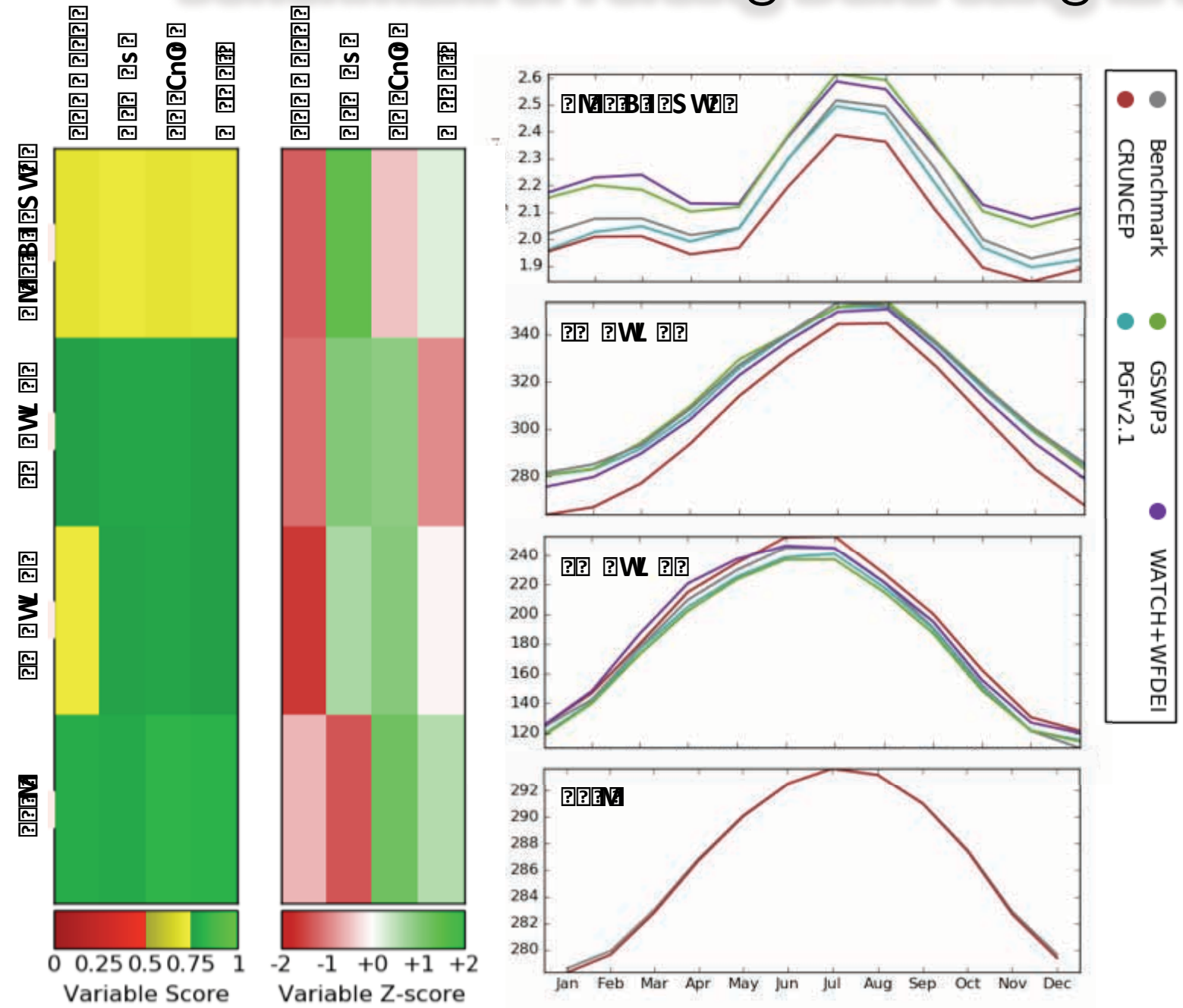
*** Supersaturation High-latitudes**
(ECMWF, David)

*** Strong trend of precipitation over high-latitudes during early 20th Century (David)**

*** Relatively strong surface wind speed (Hyungjun)**



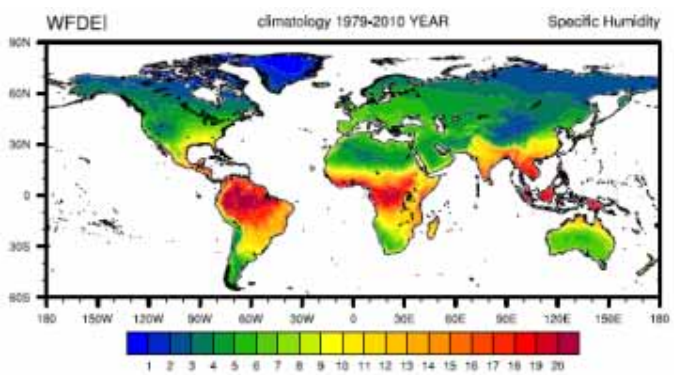
Benchmark of Forcing Data Using ILAMB

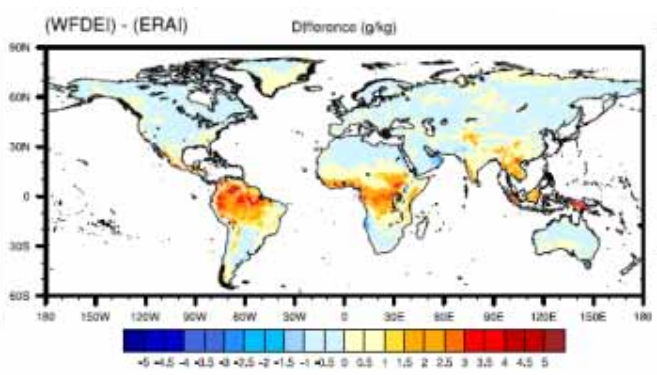


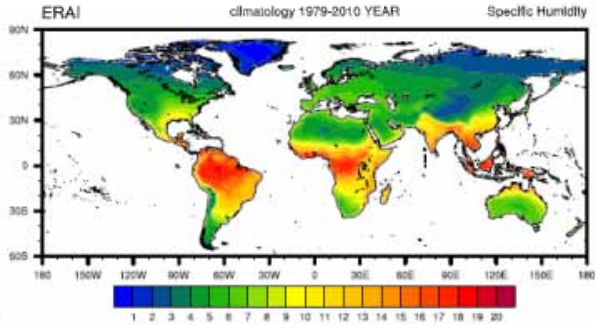
Dry Bias? in Humidity of Tropics

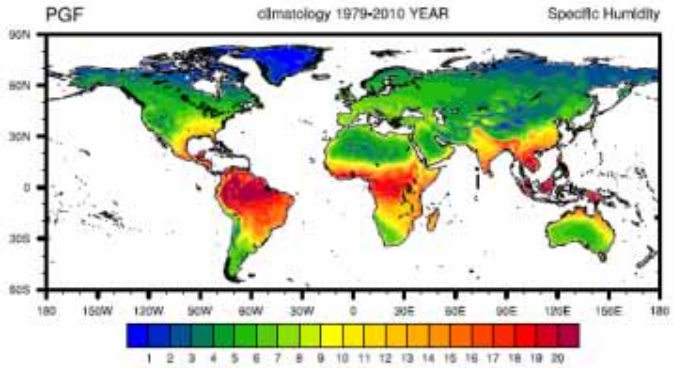
Potential Solutions

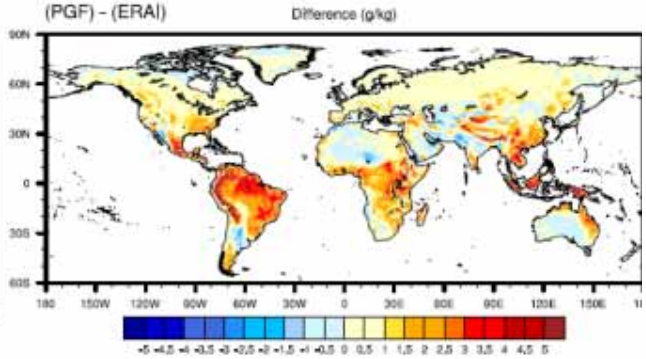
1. Using CRU vapor pressure
2. Using Reanalysis data

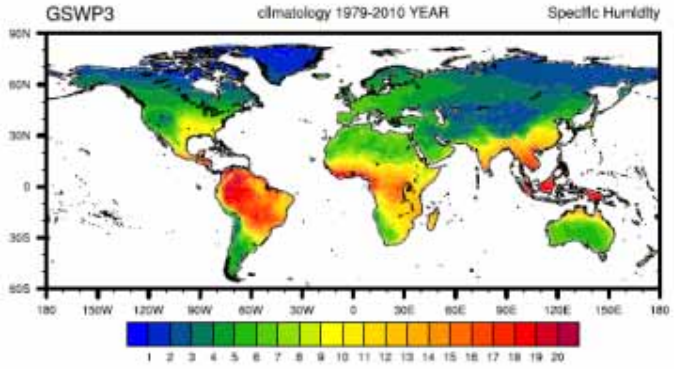


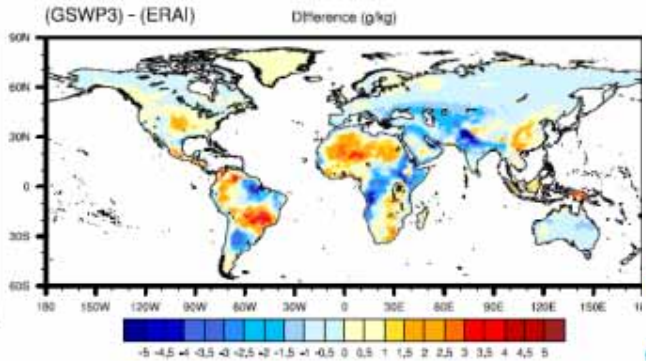


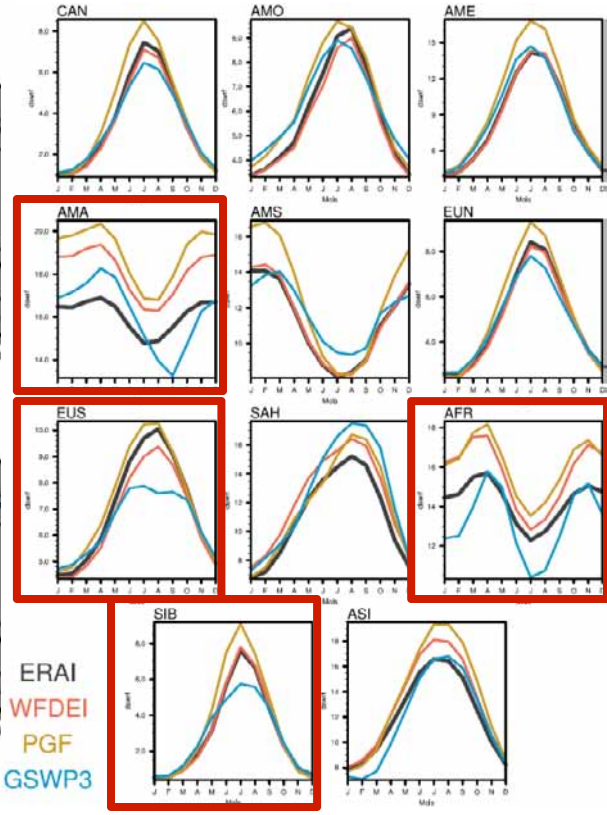












Courtesy of Bertrand Decharme

Wet Bias? in Humidity of High Latitudes

Persistent too large dew deposition at high northern latitudes over regions dominated by high vegetation, caused by oversaturation in atmospheric forcing fields and/or lack of feedback to reduce near-surface humidity.

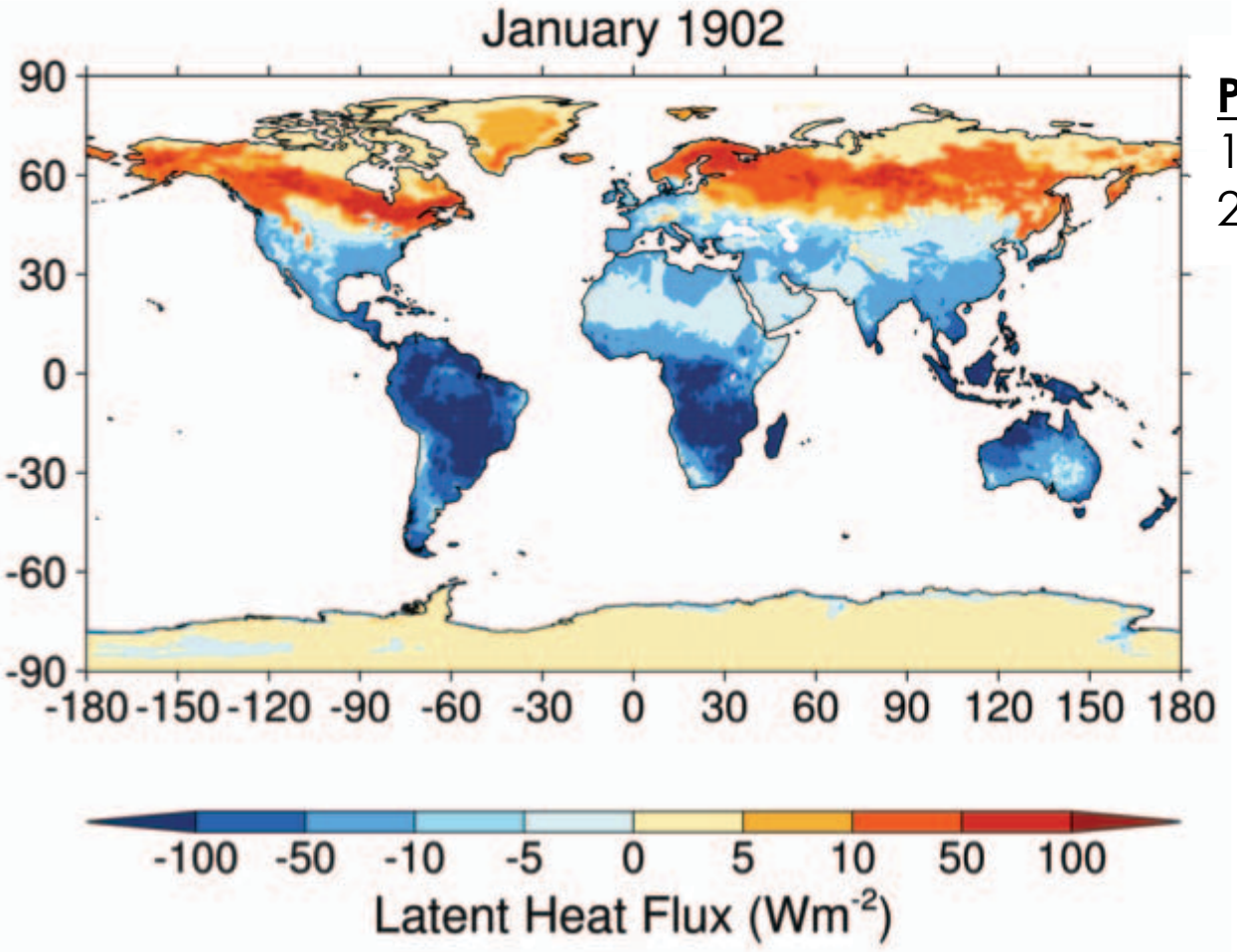


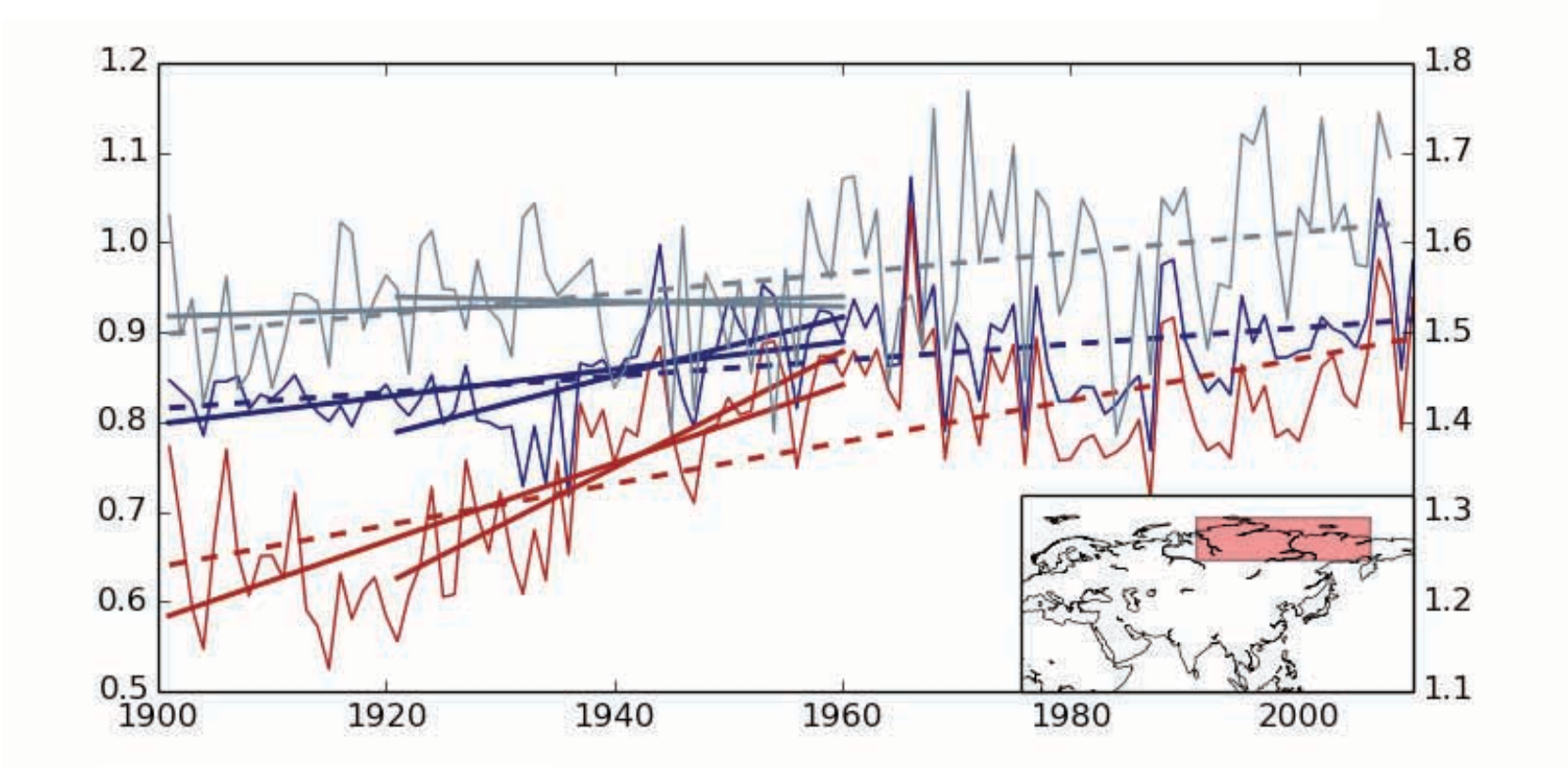
Image courtesy of T. van Noije, E. Dutra, S. Boussetta, G. Balsamo

Potential Solutions

1. Remove DTR correction
2. Clip higher tha Qair_sat

Preliminary Results and Known Problems

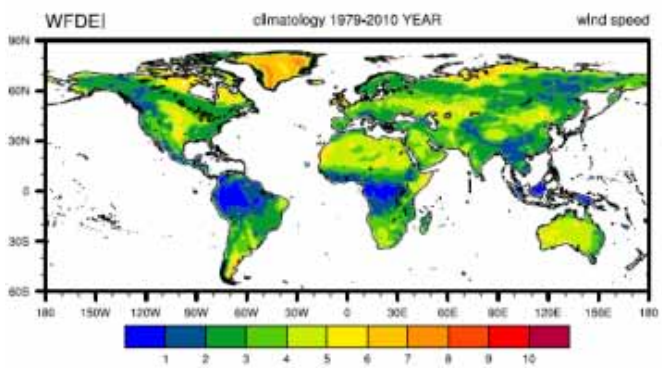
+ Spurious(?) trend at high latitude in early 20th Century

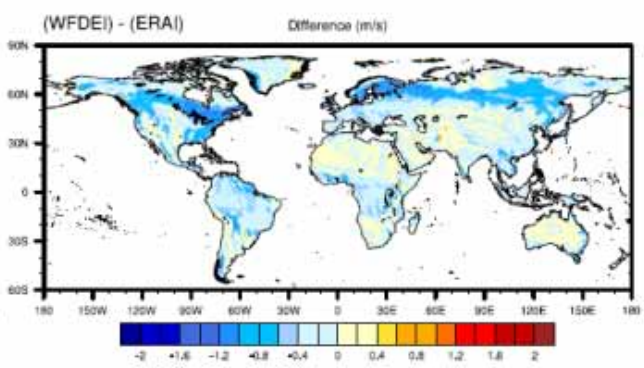


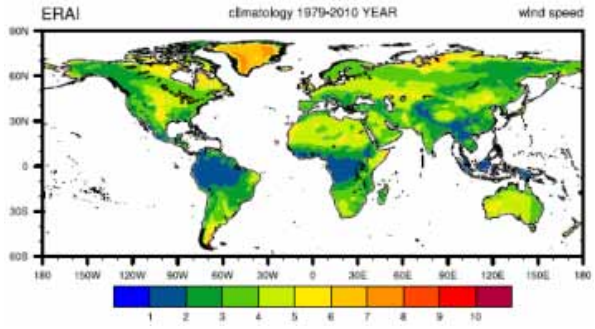
Potential Solutions

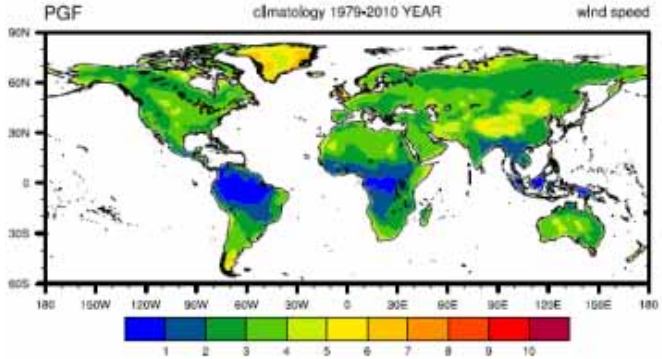
1. Refer to GHCN to estimate bias in the reanalysis data

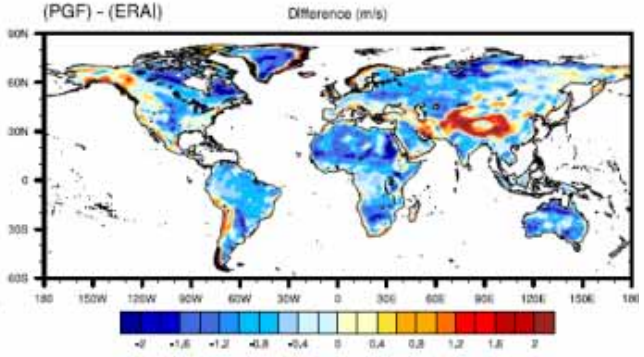
Wind Speed

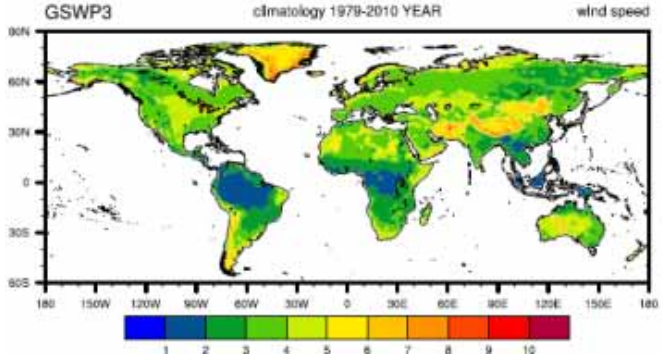


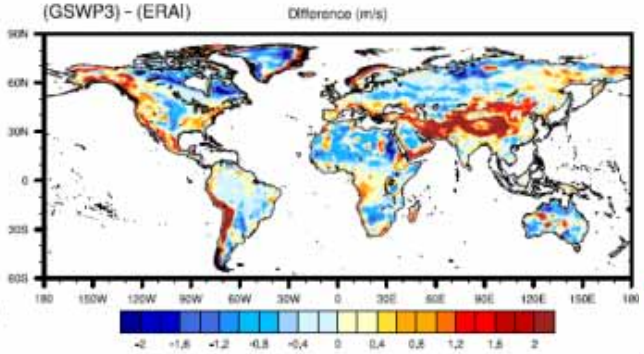


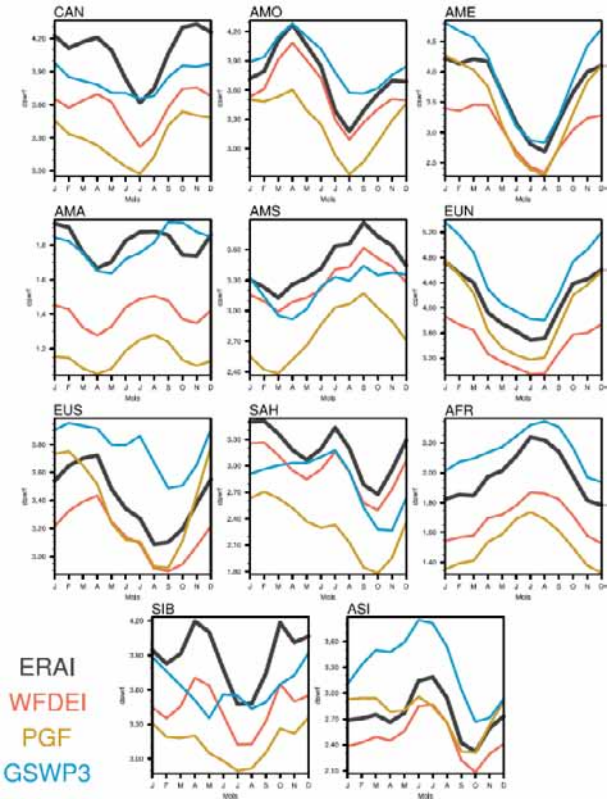






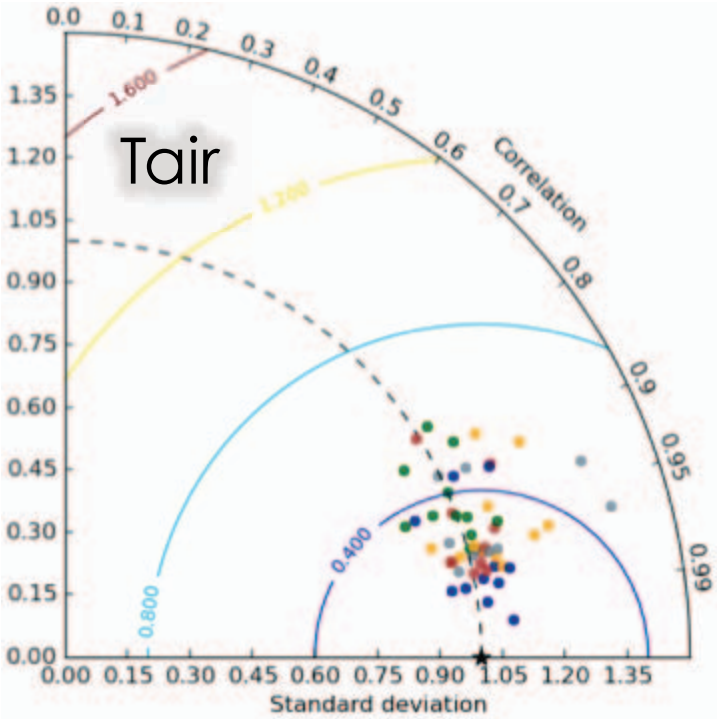


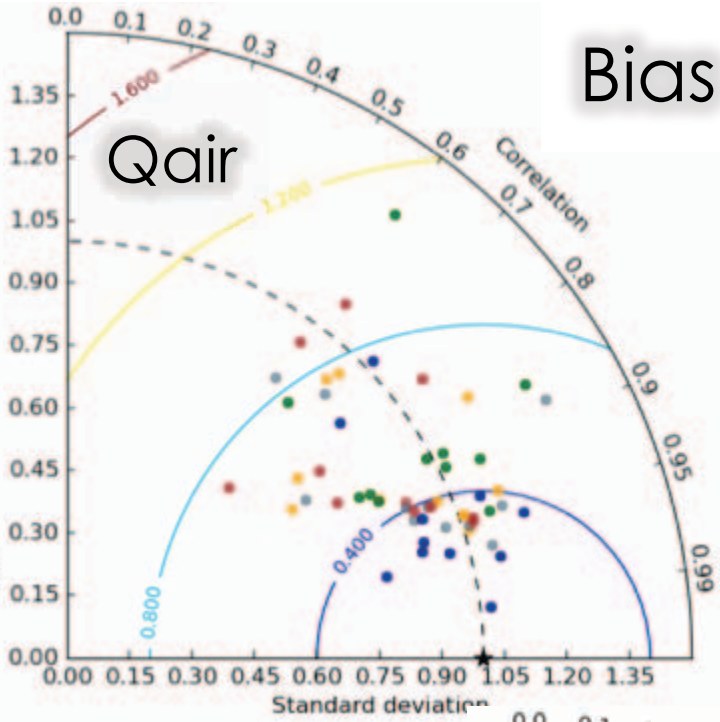




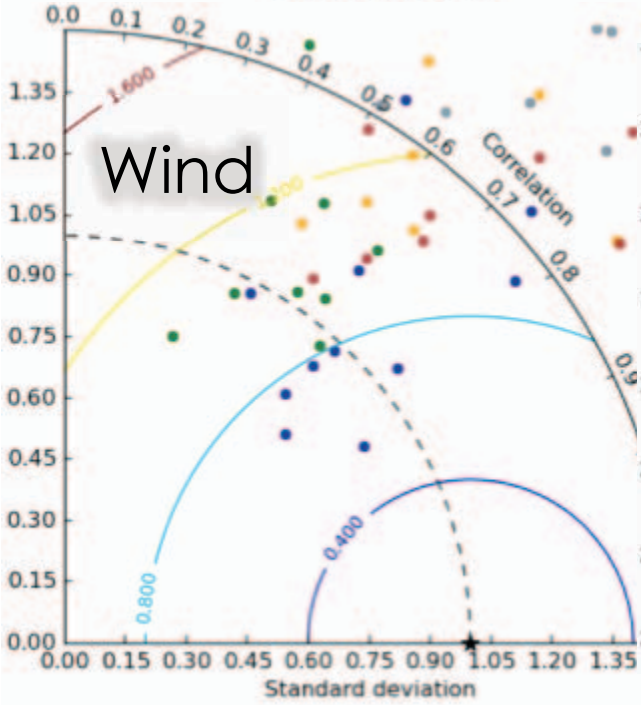
Courtesy of Bertrand Decharme

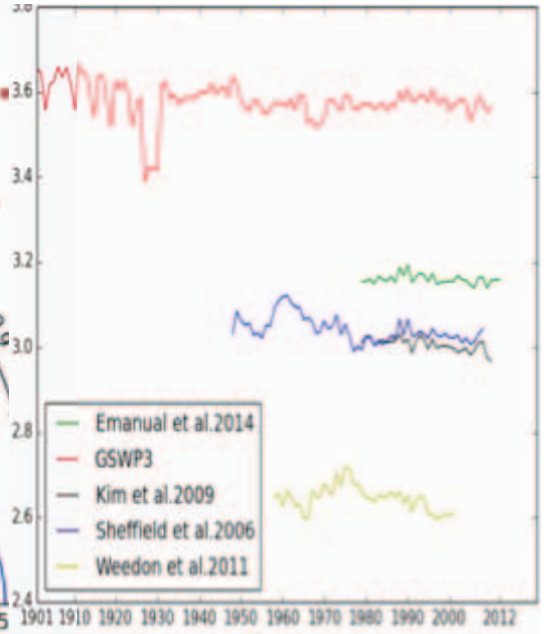
Bias Correction

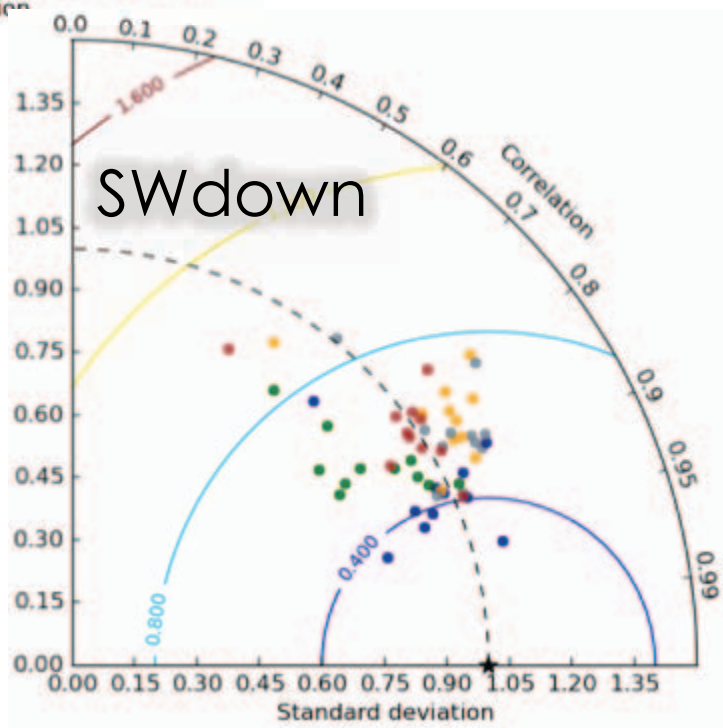




/ GSWP3 /
/ GSM248 /
/ 20CR /
/ Princeton /
/ WFD /







Variables and Naming Conventions

1. requested variables
   - We are asking 4 tables (3 new and 1 subset of existing):
   + LEday (energy) 31 vars (16 tier1)
   + LWday (water) 61 vars (17 tier1)
   + LCmon (carbon) 26 vars (18 tier1; subset of Lmon)
   + L3hr (forcing) 15 vars (9 tier1)
   = 133 variables (60 tier1)

   Priority:
   1. associated with at least one science question for Tier 1 experiments (similar to Mandatory in ALMA)
   2. for multi-model diagnostics; partly omitted from the inter-comparison when not submit (similar to Recommended in ALMA)
   3. for exploring new capabilities and/or unlikely to be used in multi-model diagnostic (similar to Optional in ALMA)

Why We Keep ALMA?

!! Intuitively understandable !!

Still has a larger set in land surface processes
cf convention does not deal with variable names
Does not require re-write entire file

Extending GLASSy Lexicon to be Interim Between Existing Conventions

*** CamelCase vs snake_case for extension**
: sub-properties
: e.g., land-use, PFT, Water management, …
*** Extension for water management**
: refer to the ISI-MIP variable requests
: e.g., pirrww – Irrigation Water Demand (=potential withdrawal)
airrww – Actual Irrigation Water Withdrawal
pirruse – Potential Irrigation Water Consumption
: Pot (Potential), Irr (irrigation), WW (Water Withdrawal), Use (Water Use)

pirrww	airrww	pirruse	airruse
PotIrrWW	IrrWW	PotIrrUse	IrrUse
PotWW_Irr	WW_Irr	PotUse_Irr	Use_Irr
PotQirrww	Qirrww	PotQirruse	Qirruse
PotQww_irr	Qww_irr	PotQuse_irr	Quse_irr

Some Thoughts between ALMA/CMIP

+ Follow CMOR filename
  e.g., ./Qsb_GSWP3_CLM45_E1FT_r1i1p1_1851-2010.nc
  : Subsurface runoff in Lmon

<var_name>_	/* Qsb_
<MIP table>_	GSWP3_
<model>_	CLM45_
<exp>_	E1FT_
<ens_member>	r1i1p1
[_<temp_subset>_	_1851-2010
<geo_info>]	
.nc	.nc */

+ Develop ALMA – CMOR conversion filter and web interface

Model Initialization

* Spin-up is a standard method to Initialize each model.

* Thershold to check equilibrium condition to be determined by each modeling group.

* Data for spin-up will be generated based on 1831 – 1850
    - Will be detrended if needed.

* If a model needs longer spin-up than 20-year, use this period repeatedly.

* If a model needs shorter spin-up, use later years.

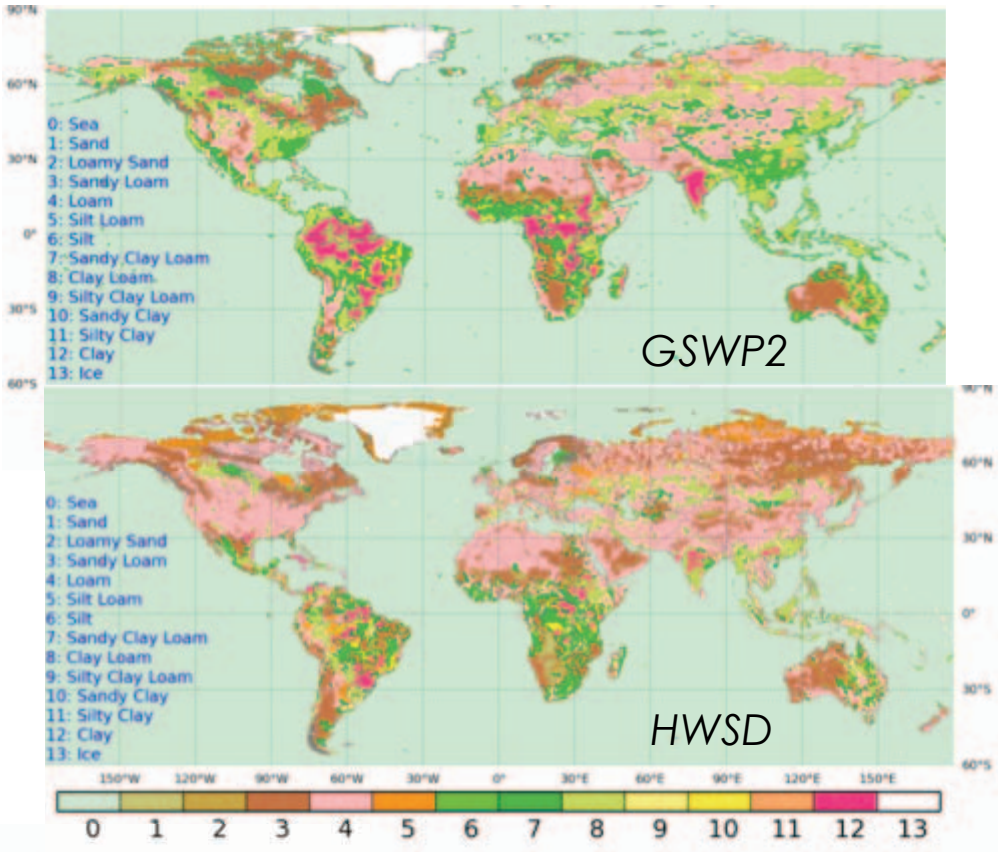
Other Concerns

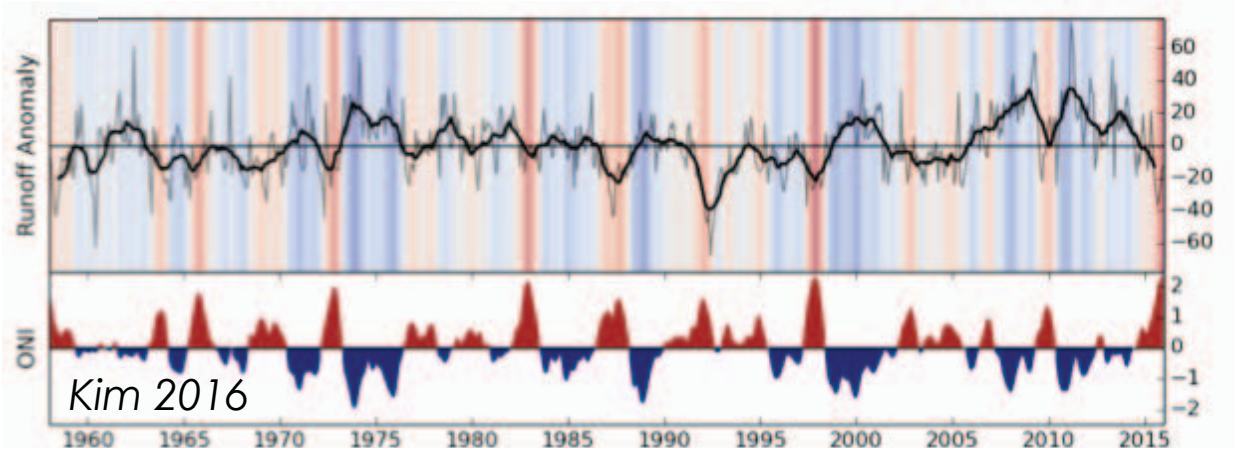
* Land Use / Land Cover Changes
  : CMIP6 land forcing
  : Irrigation map (ISI-MIP)

* Soil map
  : Prepared based on HWSD
  : Let modeling group decide

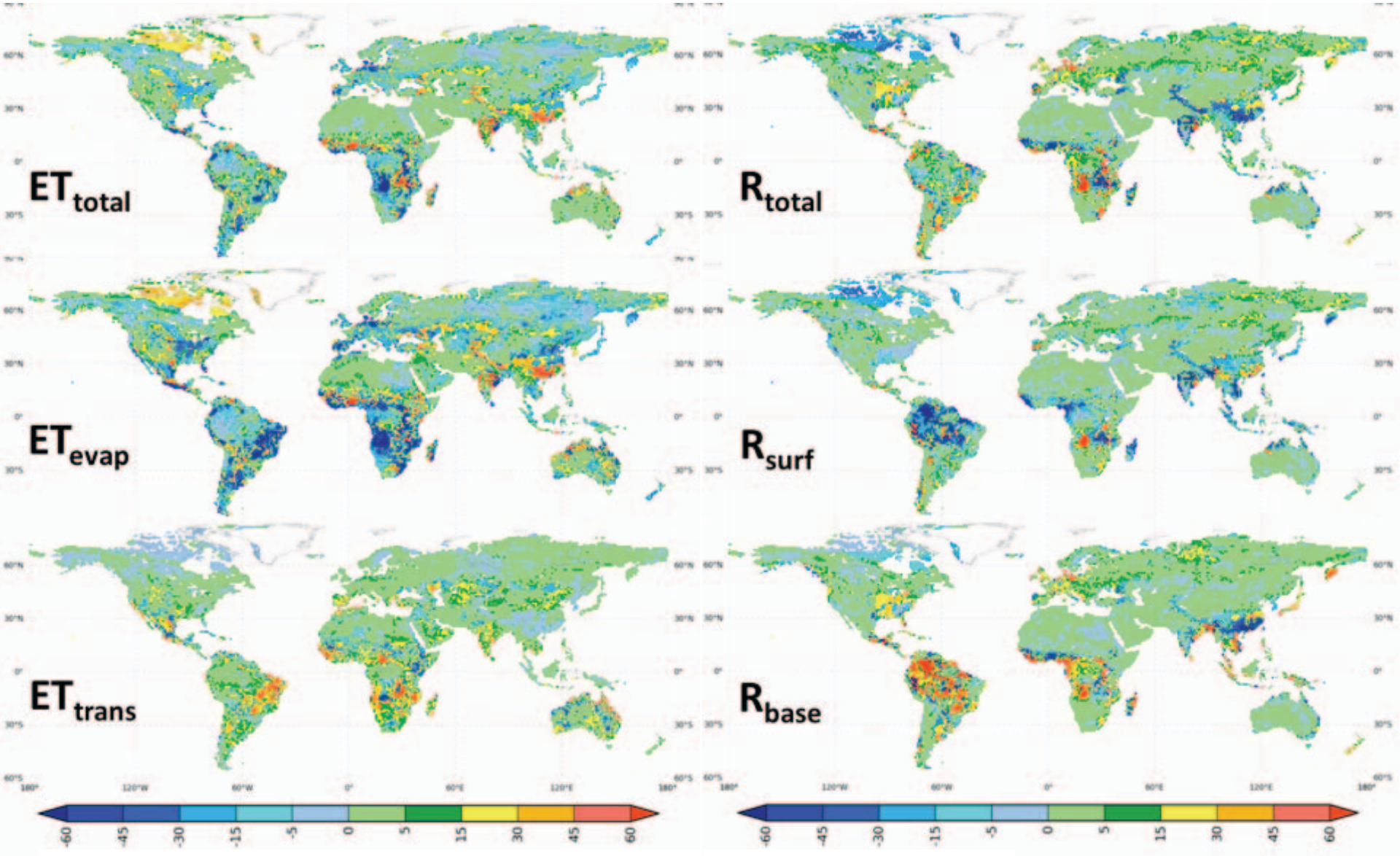
* Extension with PLUMBER/PALS?
  : Additional 1D experiments using GSWP3 global dataset (ESM-SnowMIP)

* Potential Contribution to OMIP?





Sensitivity to Soil Parameters



* Being involved in sub-partitioning rather than ET and R