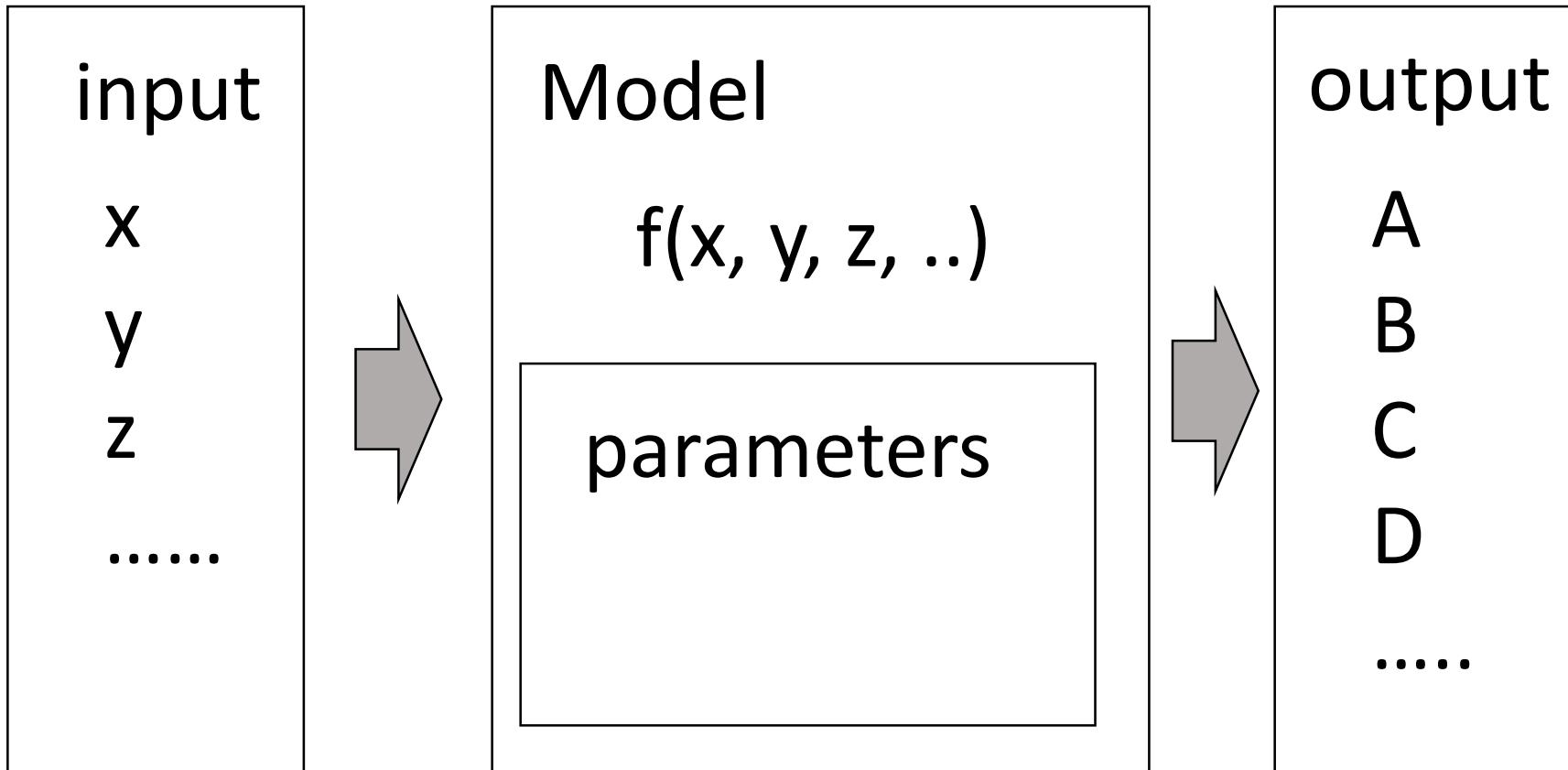


生態気象学特論

# Ecosystem Modeling

生態気象・植山

# Model



# Type of Ecosystem Model

## Earth System Model

### DGVM (dynamic vegetation model)

Consider vegetation dynamics  
(competition, succession, disturbance)

### Prognostic model

Consider pools (time integration)  
 $dC/dt$

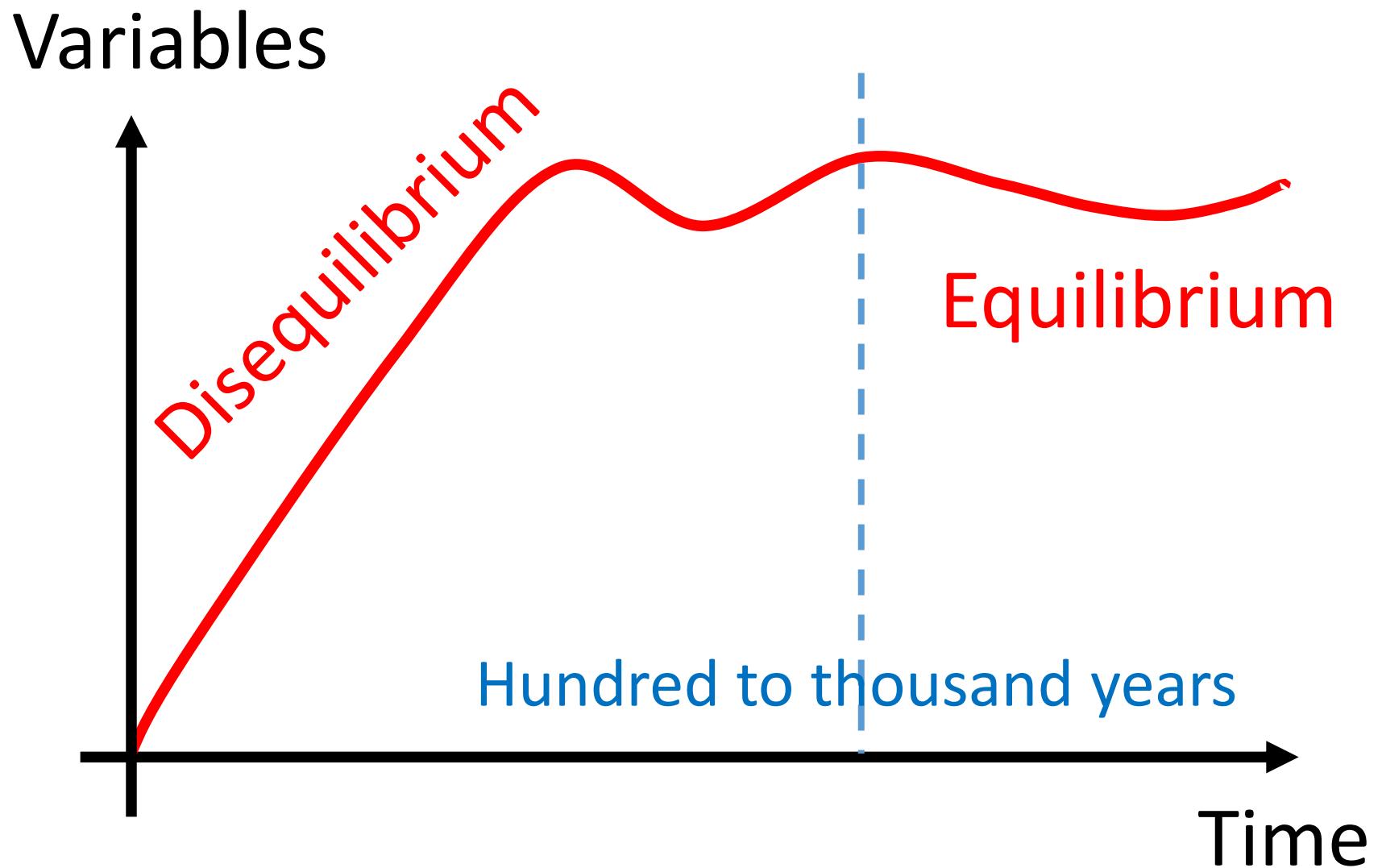
### Diagnostic model

Consider relationship of process  
 $f(x, y, z, \dots)$   
Empirical and statistical models  
.. , thus, static

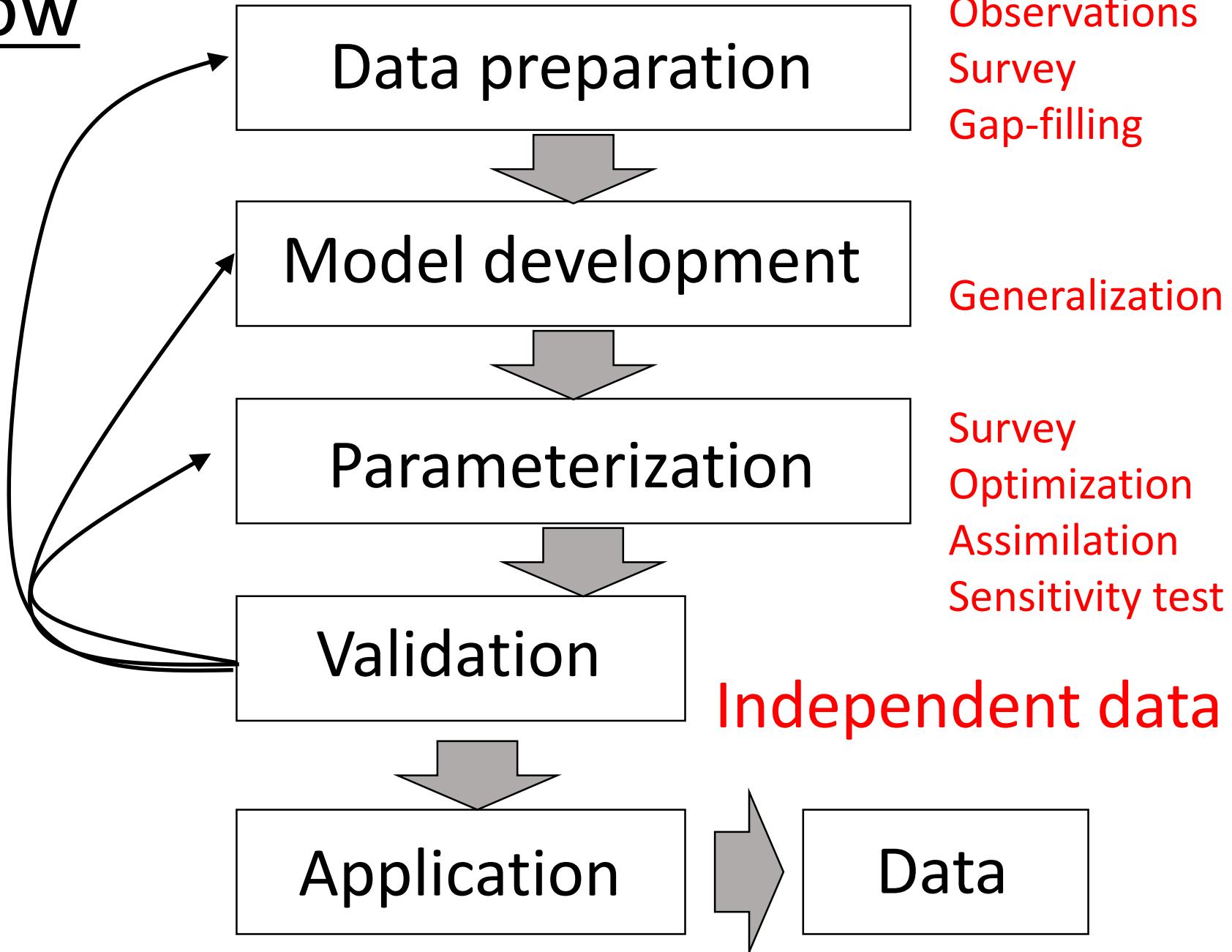
## Statistical model

Regressions  
statistics  
Machine learning

# Model Spin-up



# Flow



# Parameterization

# Biome-BGC

1	ECOPHYS	C3 grass ↓	
2	0	(flag)	1 = WOODY 0 = NON-WOODY ↓
3	0	(flag)	1 = EVERGREEN 0 = DECIDUOUS ↓
4	1	(flag)	1 = C3 PSN 0 = C4 PSN ↓
5	0	(flag)	1 = MODEL PHENOLOGY 0 = USER-SPECIFIED PHENOLOGY ↓
6	0	(yday)	yearday to start new growth (when phenology flag = 0) ↓
7	364	(yday)	yearday to end litterfall (when phenology flag = 0) ↓
8	1.0	(prop.)	transfer growth period as fraction of growing season ↓
9	1.0	(prop.)	litterfall as fraction of growing season ↓
10	1.0	(1/yr)	annual leaf and fine root turnover fraction ↓
11	0.00	*(1/yr)	annual live wood turnover fraction ↓
12	0.1	(1/yr)	annual whole-plant mortality fraction (herbivory) ↓
13	0.1	(1/yr)	annual fire mortality fraction ↓
14	2.0	(ratio)	(ALLOCATION) new fine root C : new leaf C ↓
15	0.0	*(ratio)	(ALLOCATION) new stem C : new leaf C ↓
16	0.0	*(ratio)	(ALLOCATION) new live wood C : new total wood C ↓
17	0.0	*(ratio)	(ALLOCATION) new croot C : new stem C ↓
18	0.5	(prop.)	(ALLOCATION) current growth proportion ↓
19	24.0	(kgC/kgN)	C:N of leaves ↓
20	49.0	(kgC/kgN)	C:N of leaf litter, after retranslocation ↓
21	42.0	(kgC/kgN)	C:N of fine roots ↓
22	0.0	*(kgC/kgN)	C:N of live wood ↓
23	0.0	*(kgC/kgN)	C:N of dead wood ↓
24	0.39	(DIM)	leaf litter labile proportion ↓
25	0.44	(DIM)	leaf litter cellulose proportion ↓
26	0.17	(DIM)	leaf litter lignin proportion ↓
27	0.30	(DIM)	fine root labile proportion ↓
28	0.45	(DIM)	fine root cellulose proportion ↓
29	0.25	(DIM)	fine root lignin proportion ↓
30	0.75	*(DIM)	dead wood cellulose proportion ↓
31	0.25	*(DIM)	dead wood lignin proportion ↓
32	0.021	(1/LAI/d)	canopy water interception coefficient ↓
33	0.6	(DIM)	canopy light extinction coefficient ↓
34	2.0	(DIM)	all-sided to projected leaf area ratio ↓
35	45.0	(m <sup>2</sup> /kgC)	canopy average specific leaf area (projected area basis) ↓
36	2.0	(DIM)	ratio of shaded SLA:sunlit SLA ↓
37	0.15	(DIM)	fraction of leaf N in Rubisco ↓
38	0.005	(m/s)	maximum stomatal conductance (projected area basis) ↓
39	0.00001	(m/s)	cuticular conductance (projected area basis) ↓
40	0.04	(m/s)	boundary layer conductance (projected area basis) ↓
41	-0.6	(MPa)	leaf water potential: start of conductance reduction ↓
42	-2.3	(MPa)	leaf water potential: complete conductance reduction ↓
43	930.0	(Pa)	vapor pressure deficit: start of conductance reduction ↓
44	4100.0	(Pa)	vapor pressure deficit: complete conductance reduction ↓

# Parameterization

Field Survey

Literature Survey

Optimization (最適化)

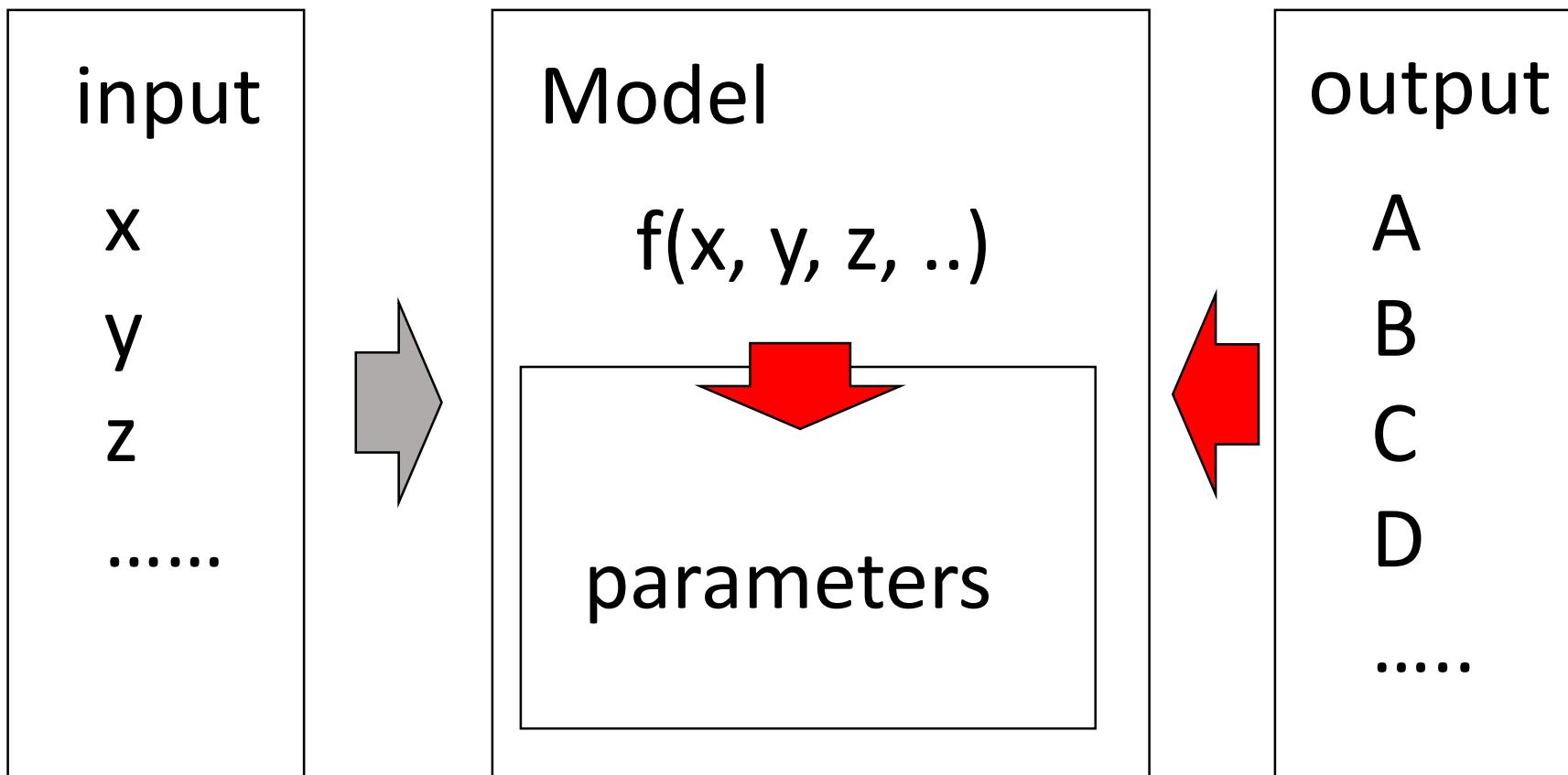
statistical or numerical, Bayesian MCMC, etc

Assimilation (同化)

Karman filter, etc

# Parameterization

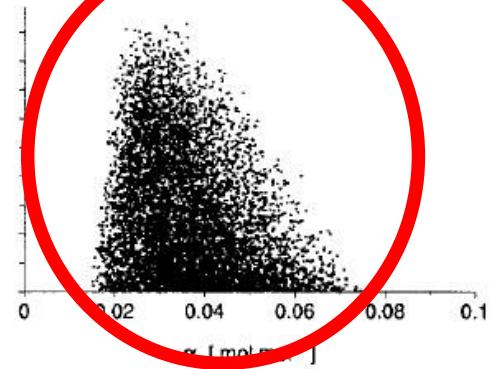
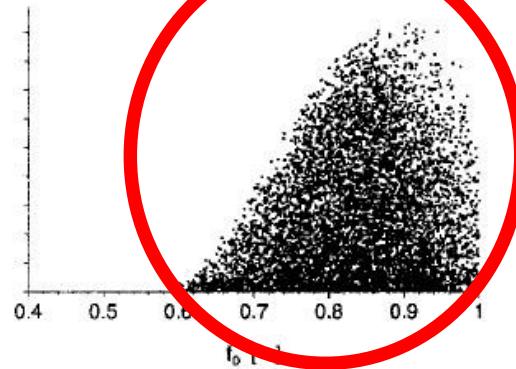
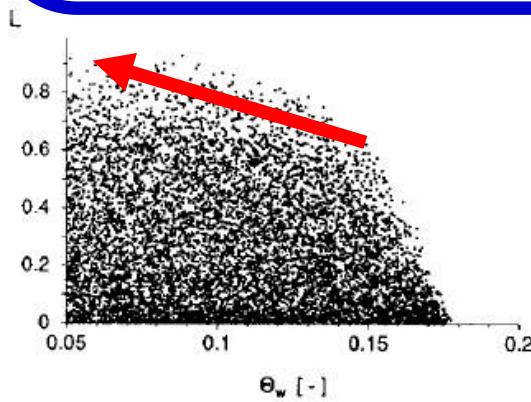
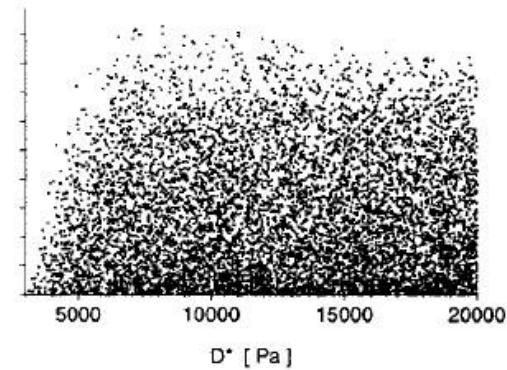
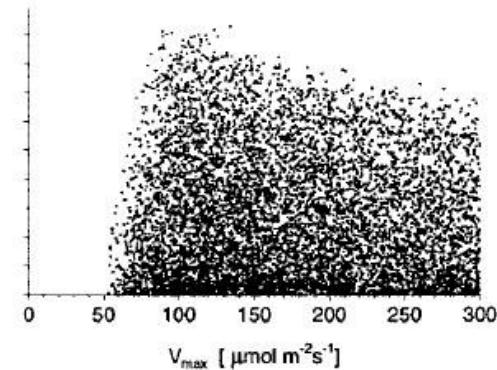
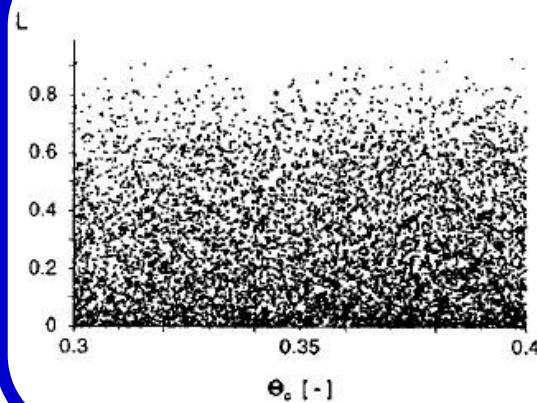
# Optimization (最適化)



# Parameterization

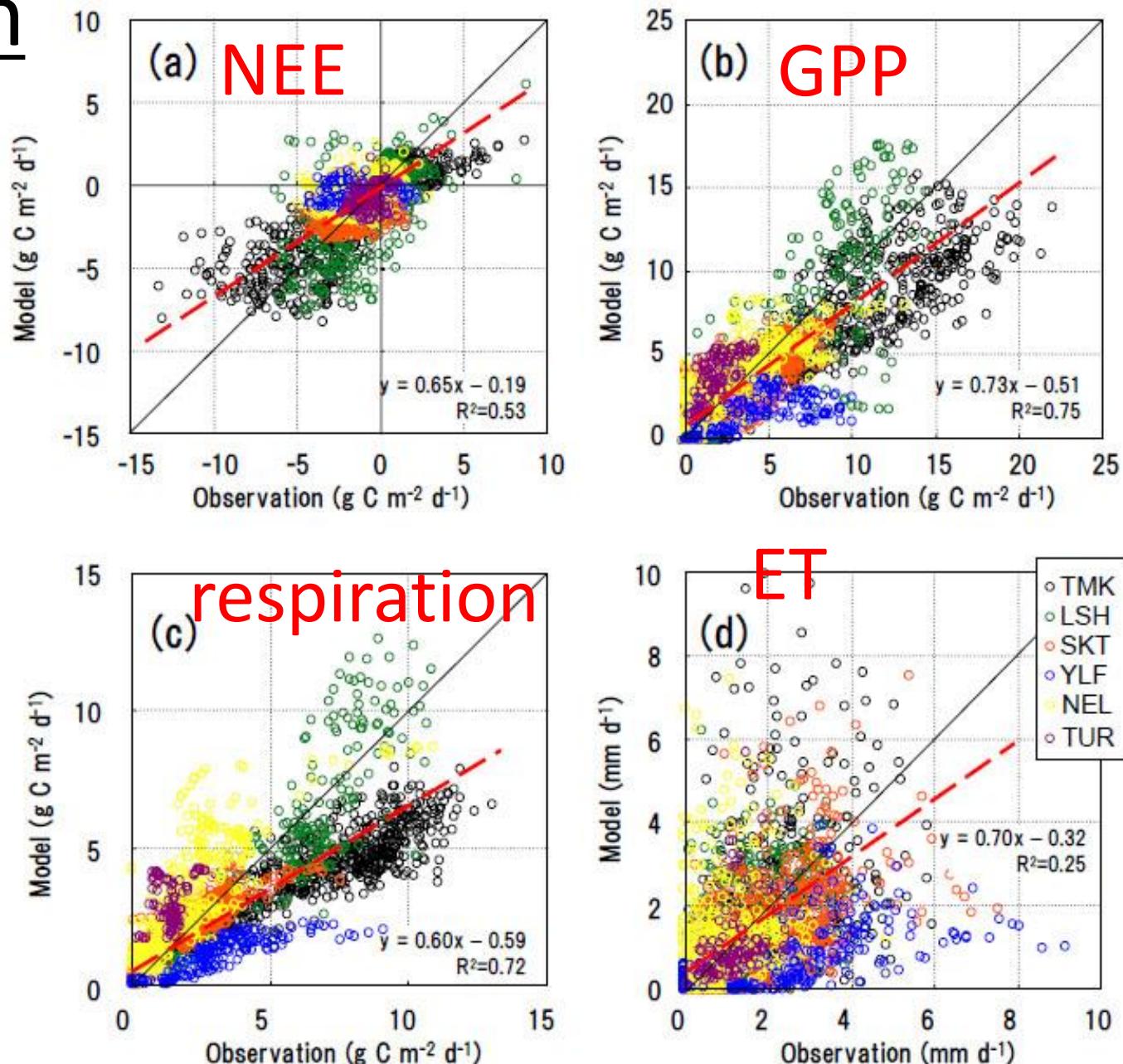
## Equifinality (等至性)

likelihood



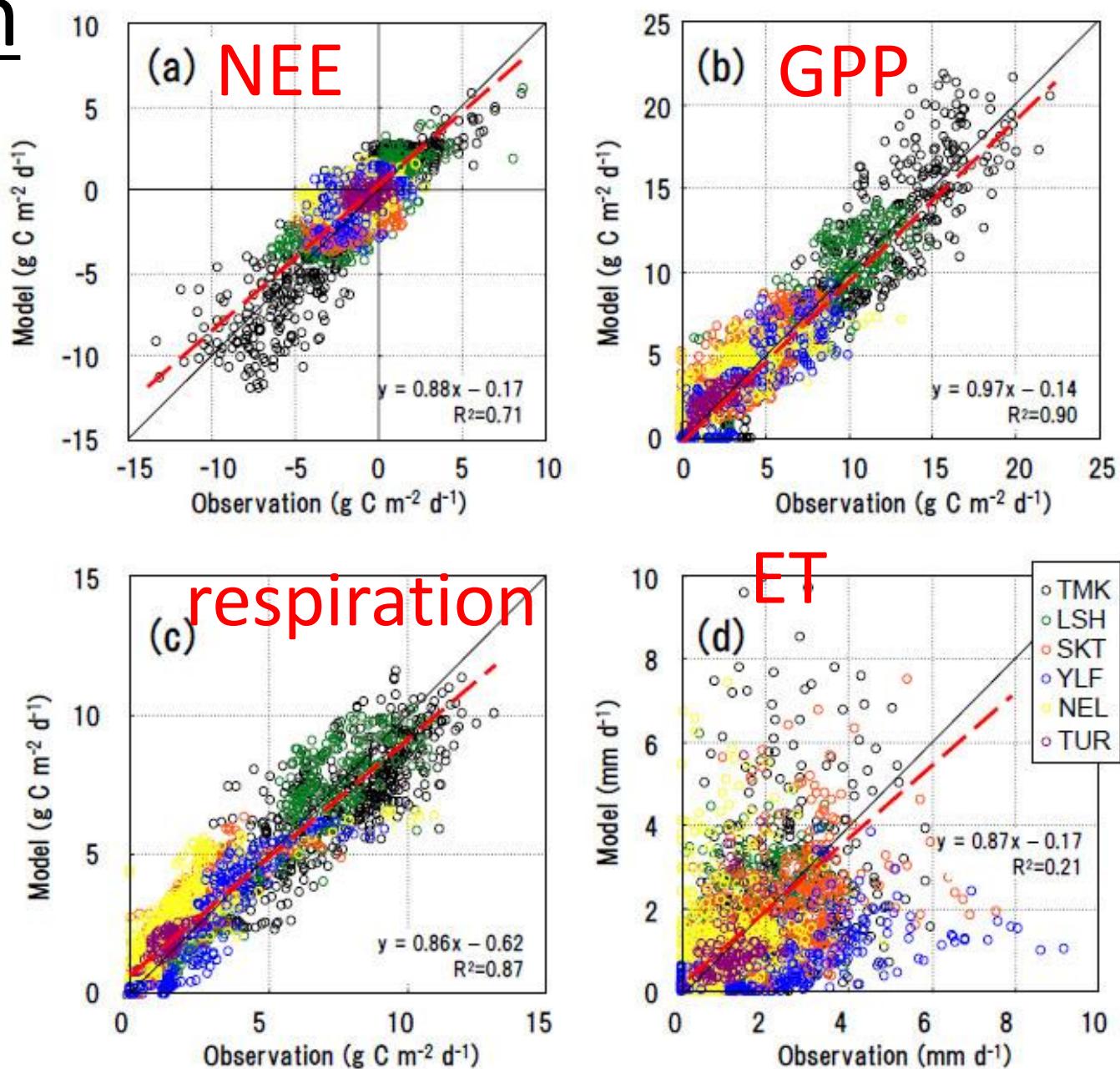
(Schulz et al., 2001; Amr. Meteorol. Soc.)

# Validation



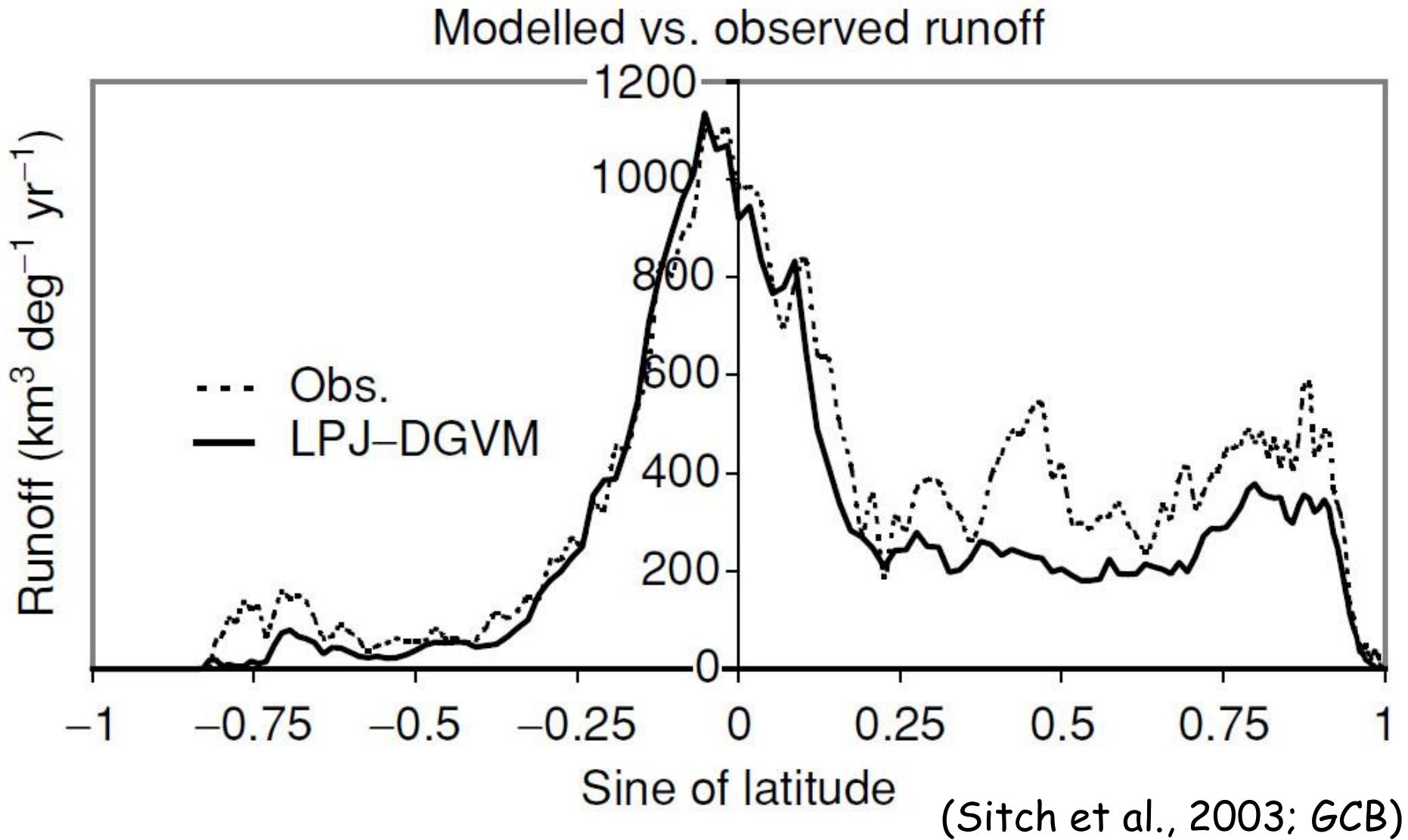
(Ueyama et al., 2010; BG)

# Validation

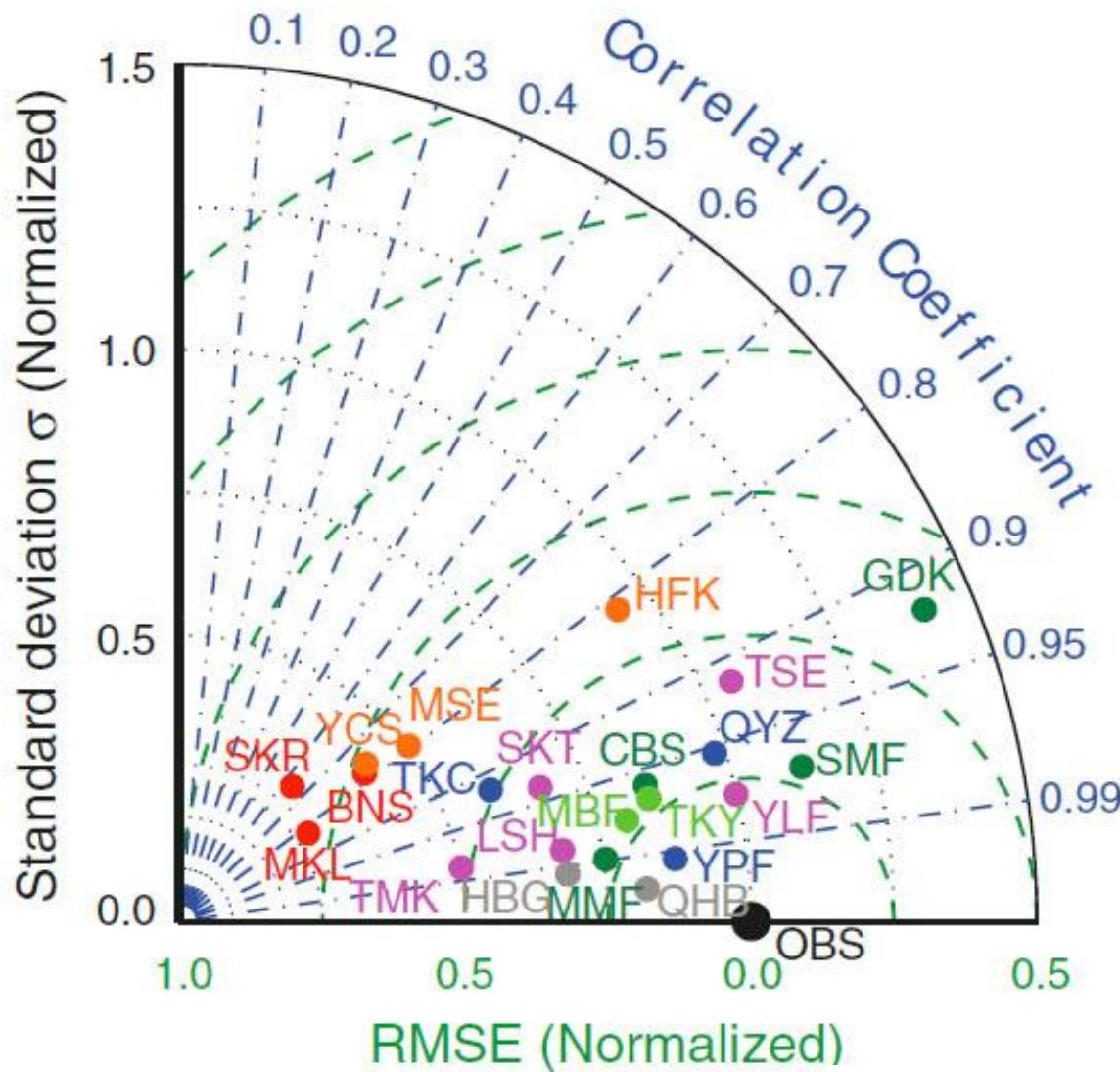


(Ueyama et al., 2010; BG)

If you want to know processes for the global scale,  
validation should be done for the global scale.



# Validation Tayler diagram



(Ichii et al., 2013; JFR)

# Validation

Time scale

(diurnal, daily, seasonal, interannual, decadal)

Processes that we want to know

Extreme Events

Independent data

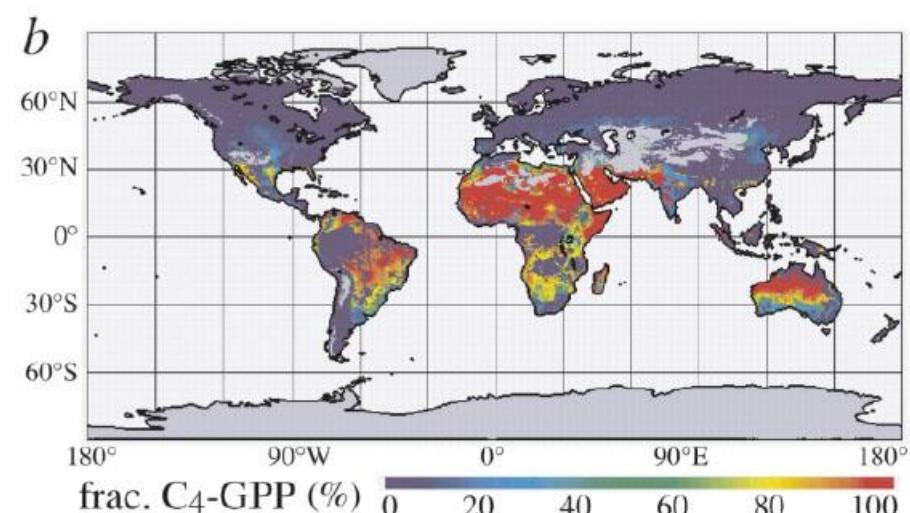
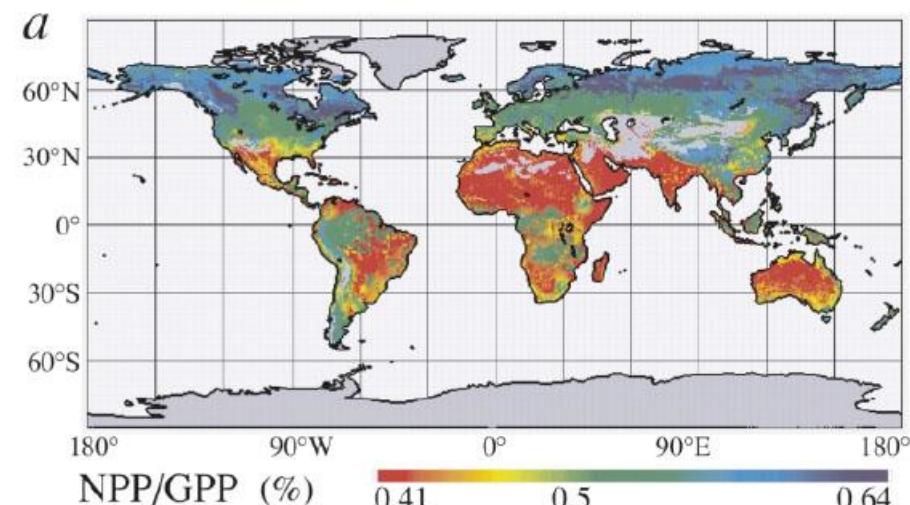
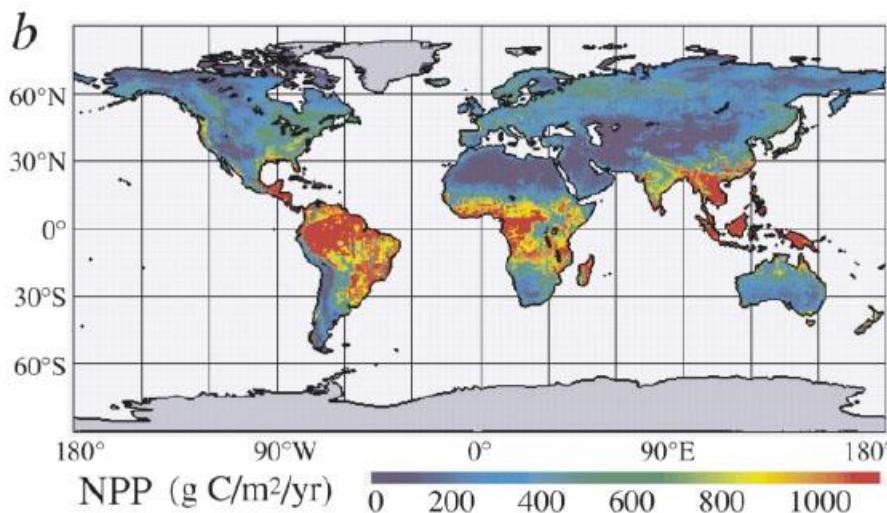
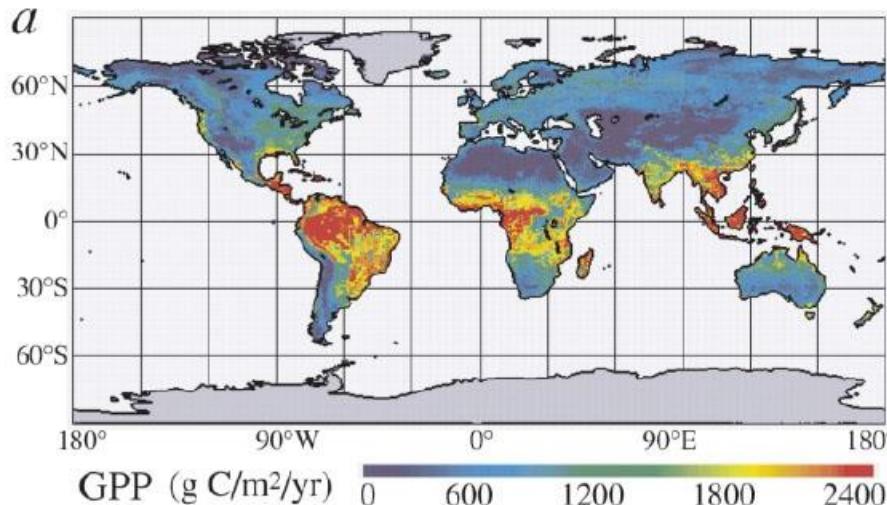
(separate train/test data)

Equifinality

# Applications

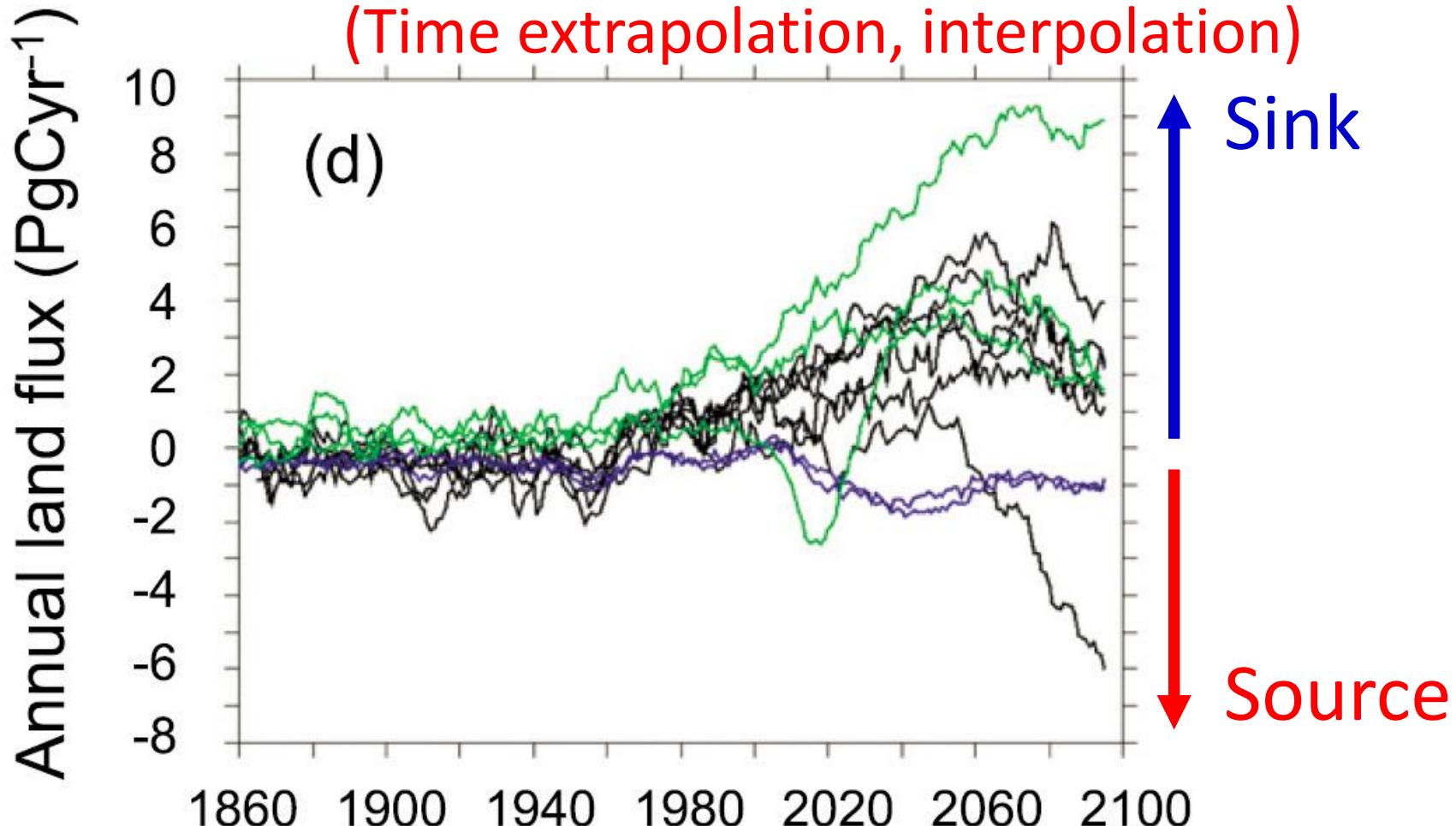
(Ito & Oikawa, 2004)

## Spatial extrapolation, interpolation



# Applications

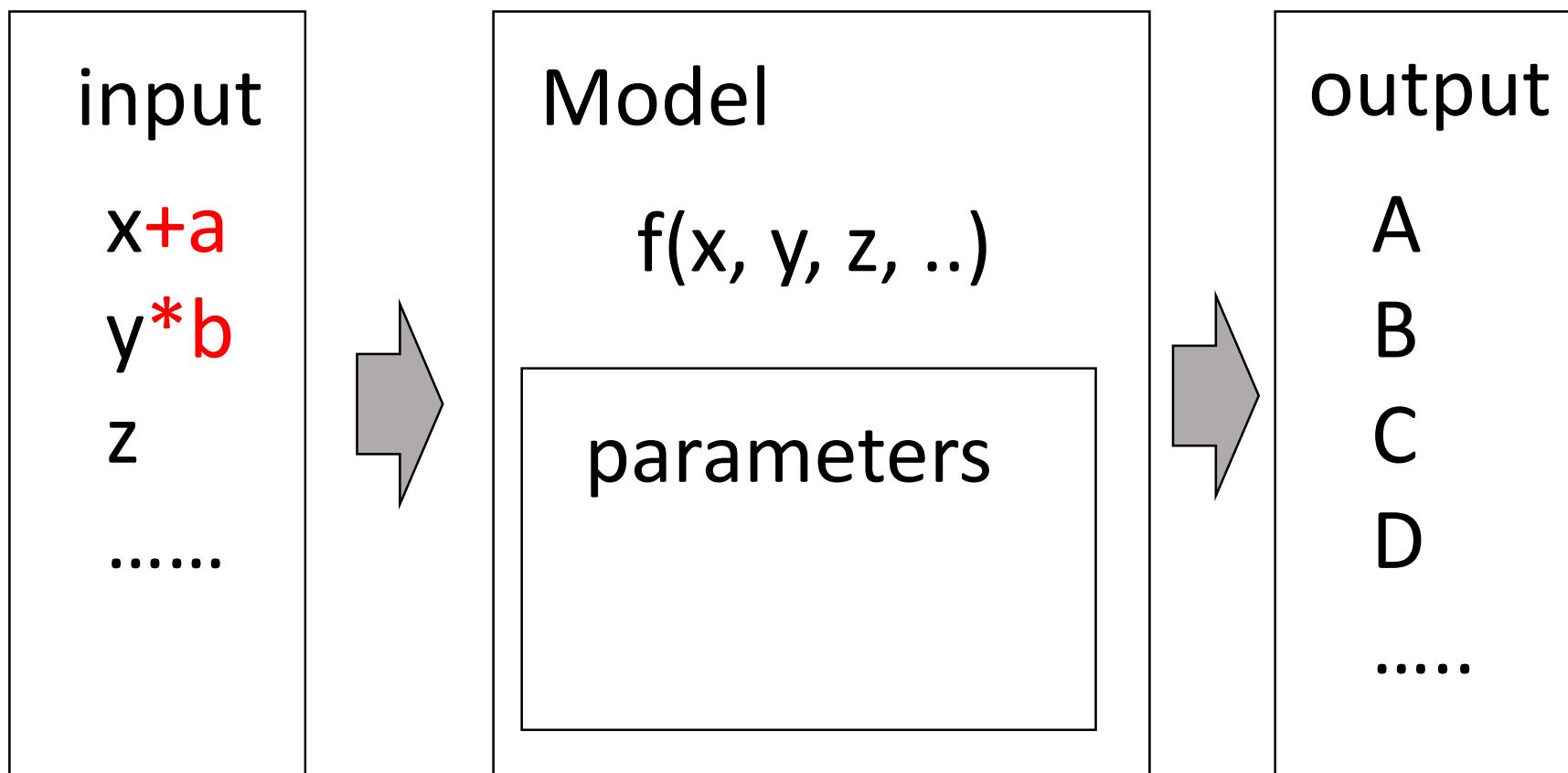
## Prediction, retrospective analysis



# Applications

## Control experiment

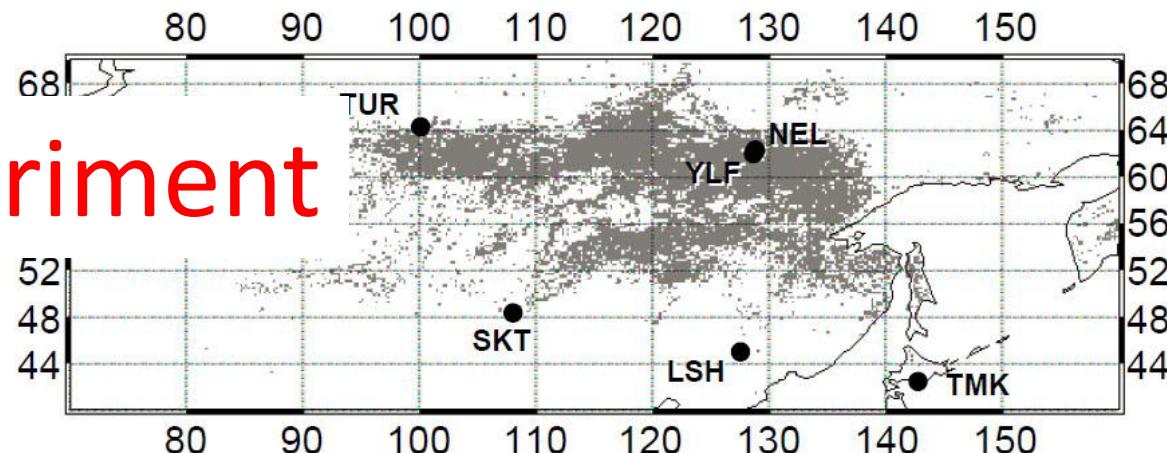
(对照実験)



# Applications

## Control experiment

(对照実験)



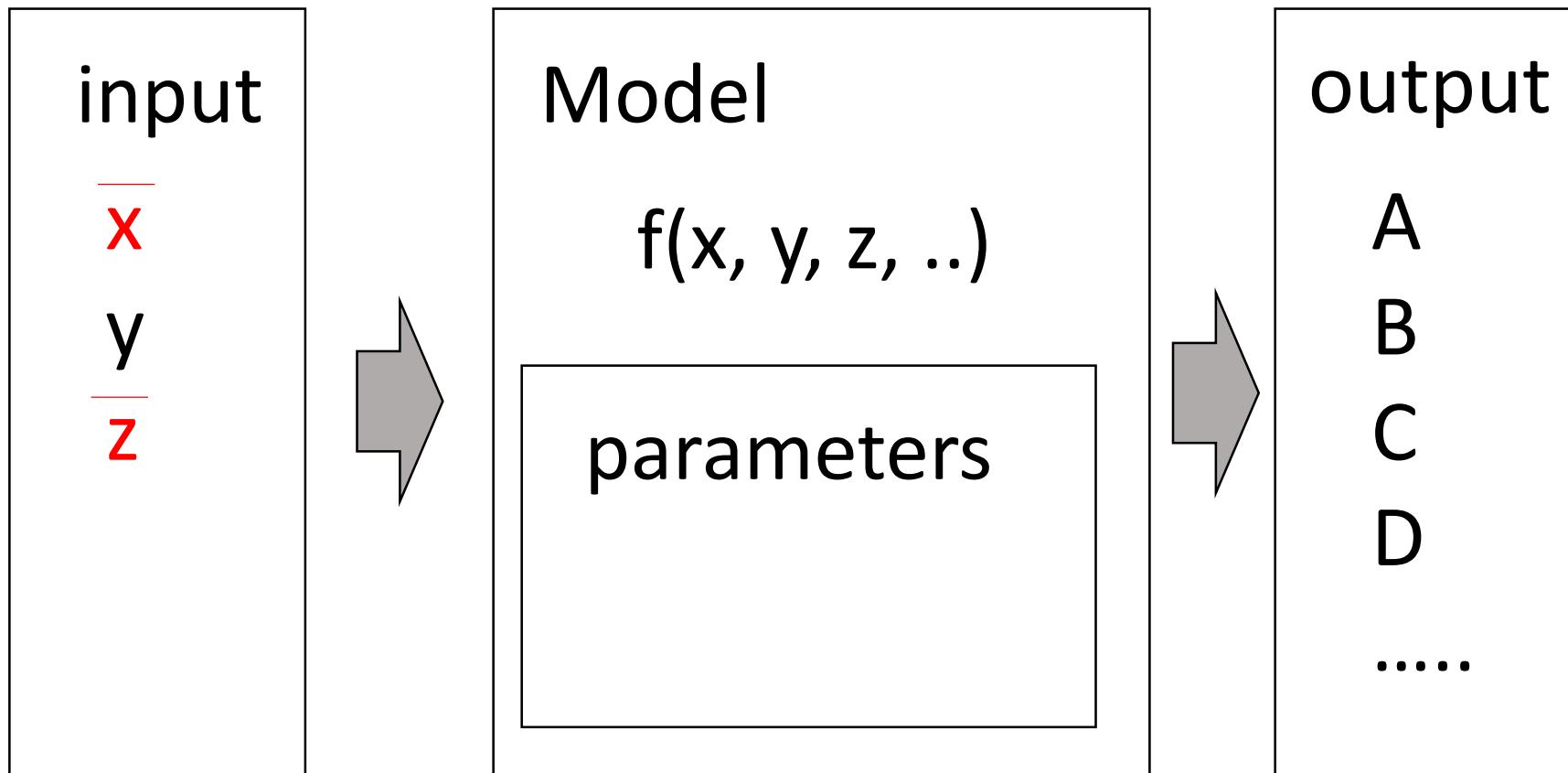
Exami- nation	Case	NEE	(%)				
		TMK	LSH	SKT	YLF	NEL	TUR
	Normal		100	100	100	100	100
Air temperature	spring +	ta	<u>142</u>	<u>136</u>	99	111	<u>224</u>
	spring -	tb	<u>53</u>	<u>59</u>	105	89	<u>-179</u>
	summer +	tc	<u>42</u>	<u>45</u>	<u>46</u>	<u>44</u>	<u>90</u>
	summer -	td	<u>144</u>	<u>146</u>	<u>77</u>	105	<u>37</u>
	autumn +	te	<u>73</u>	<u>56</u>	91	<u>59</u>	<u>128</u>
	autumn -	tf	<u>123</u>	<u>126</u>	90	104	<u>35</u>
	winter +	tg	81	<u>62</u>	<u>75</u>	<u>63</u>	<u>73</u>
	winter -	th	<u>125</u>	<u>135</u>	114	<u>128</u>	<u>123</u>

±3σ

(Ueyama et al., 2010; BG)

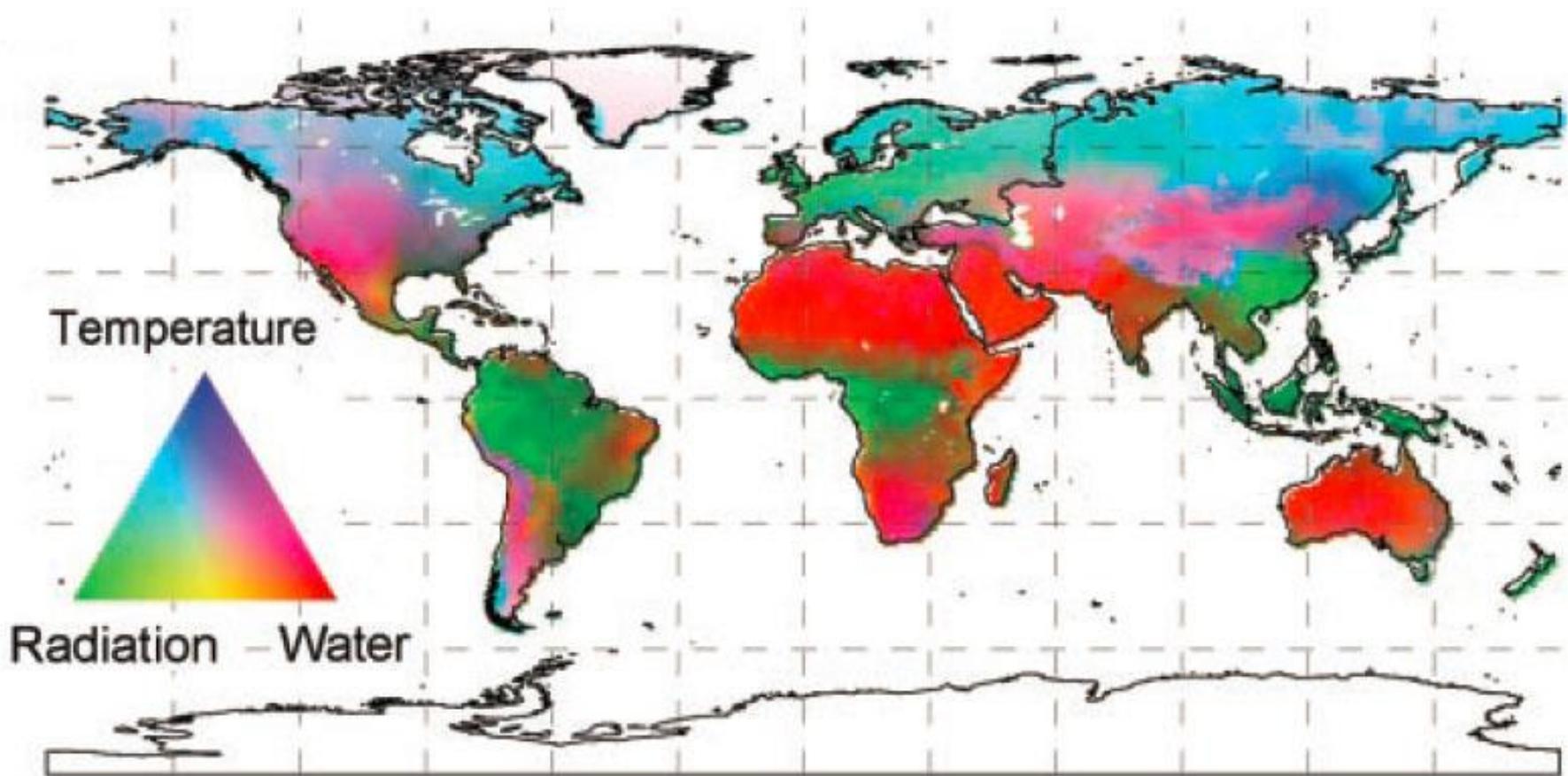
# Applications

## Attribution experiment



# Applications

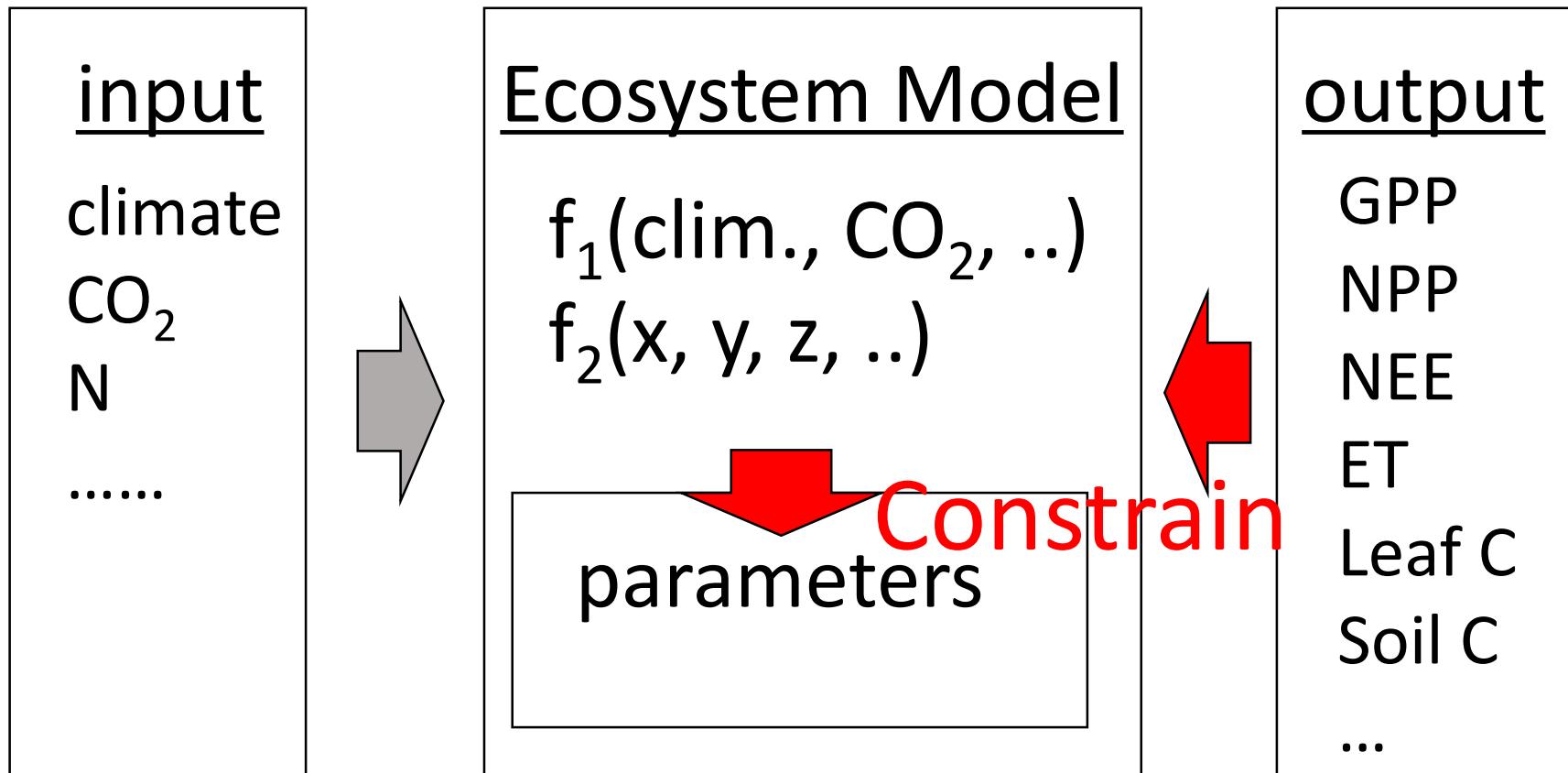
## Attribution experiment



(Nemani et al., 2003; Science)

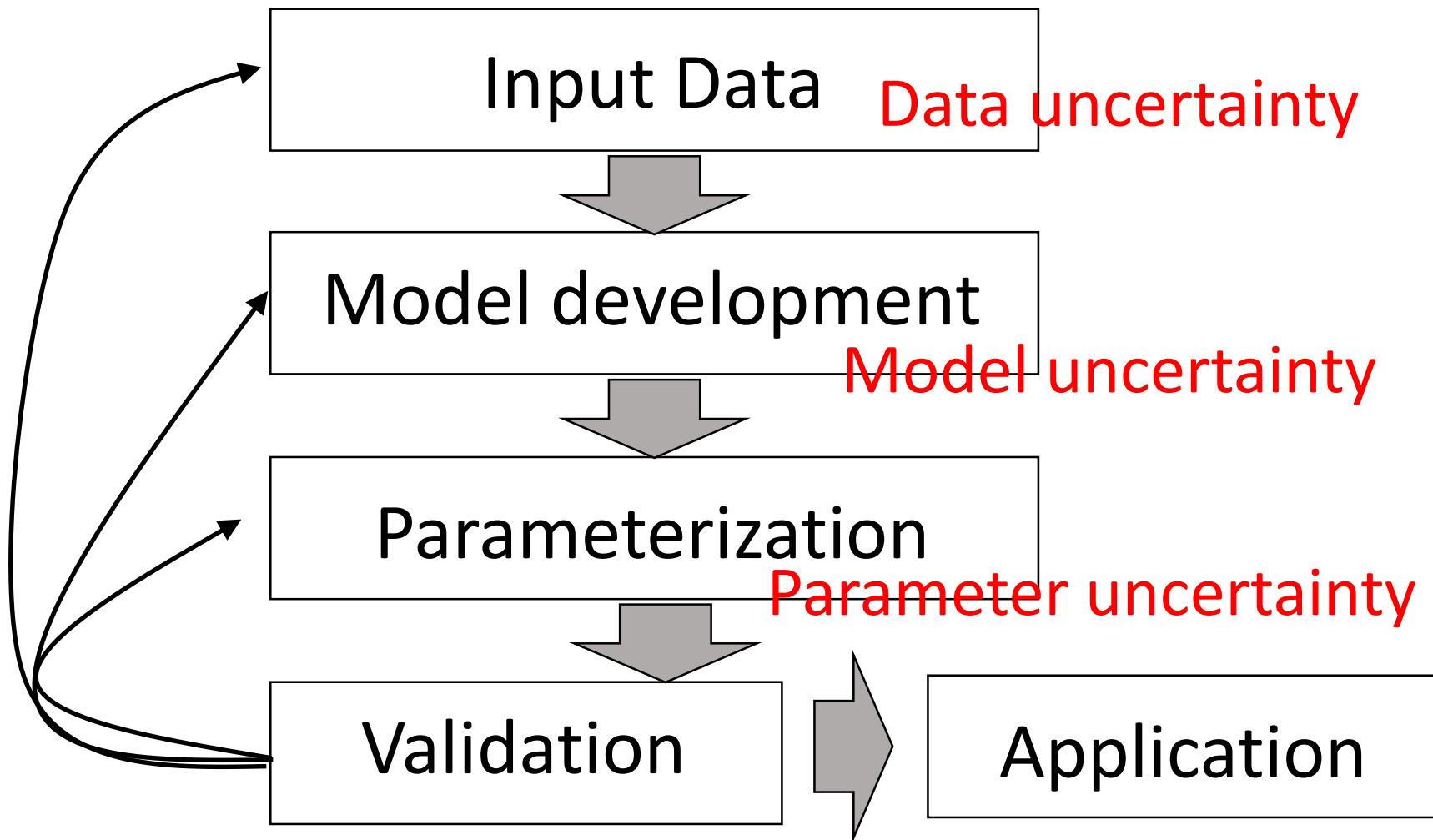
# Applications

## Model-data fusion (Optimization)



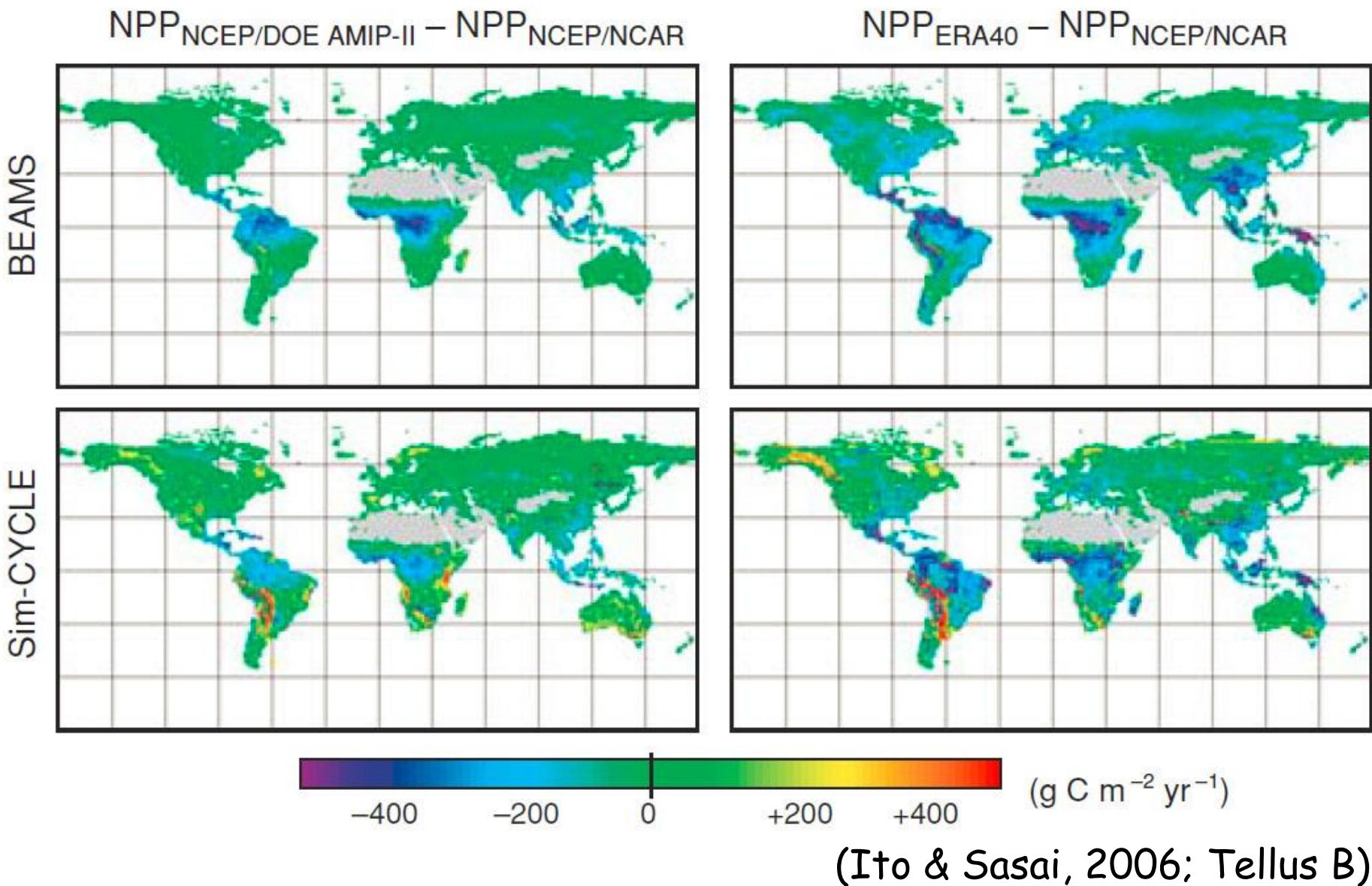
Number of data is available, recently!

# Uncertainty evaluation



# Input Data Uncertainties

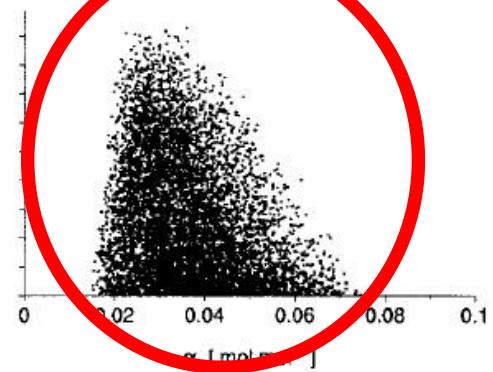
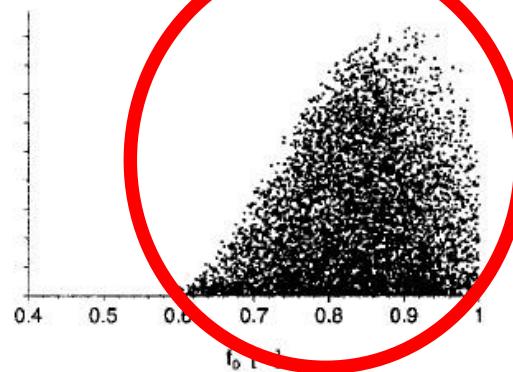
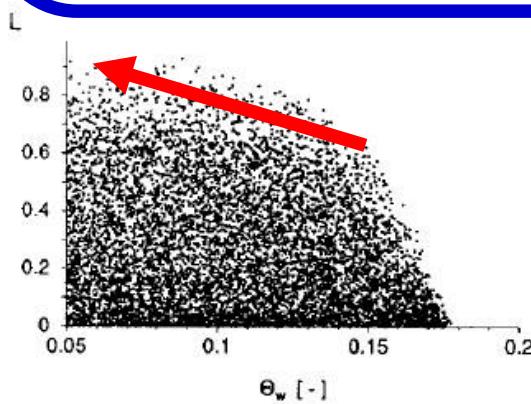
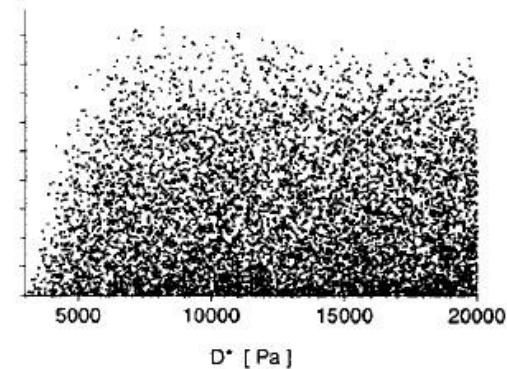
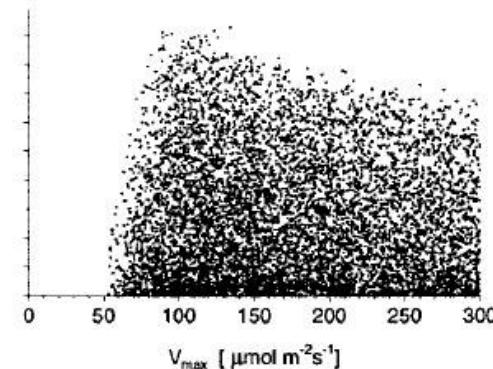
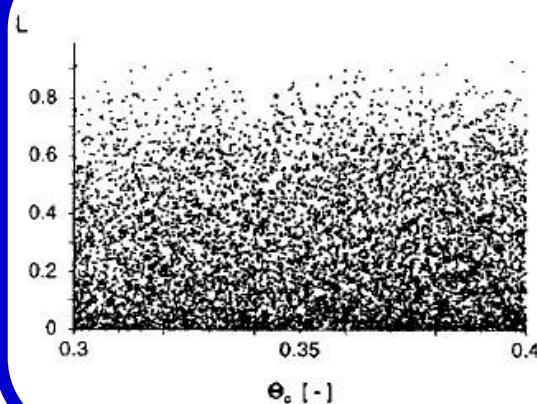
Biased input



# Parameter Uncertainties

## Equifinality (等至性)

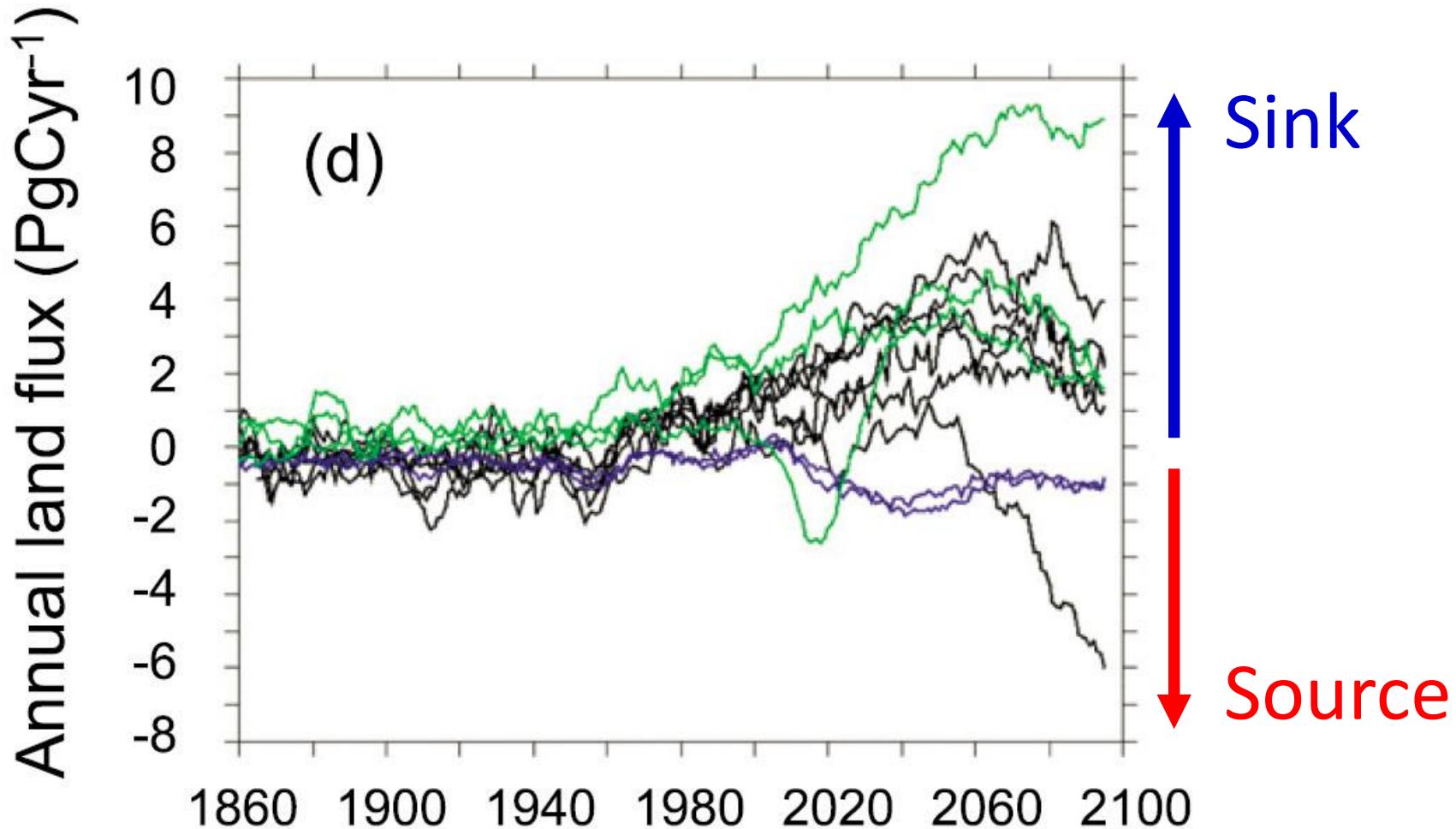
likelihood



(Schulz et al., 2001; Amr. Meteorol. Soc.)

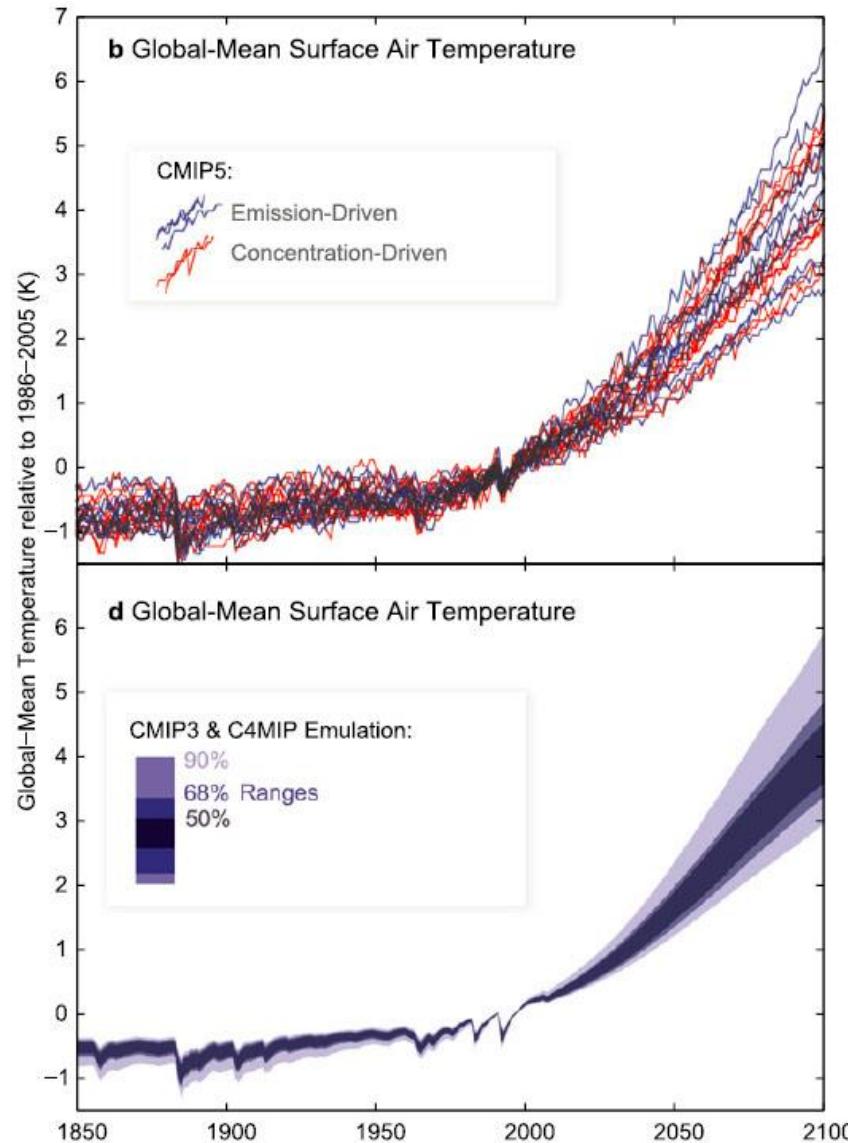
# Model Intercomparison (MIP)

## Compare different models



(Friedlingstein et al., 2014; Amri. Meteorol. Soc.)

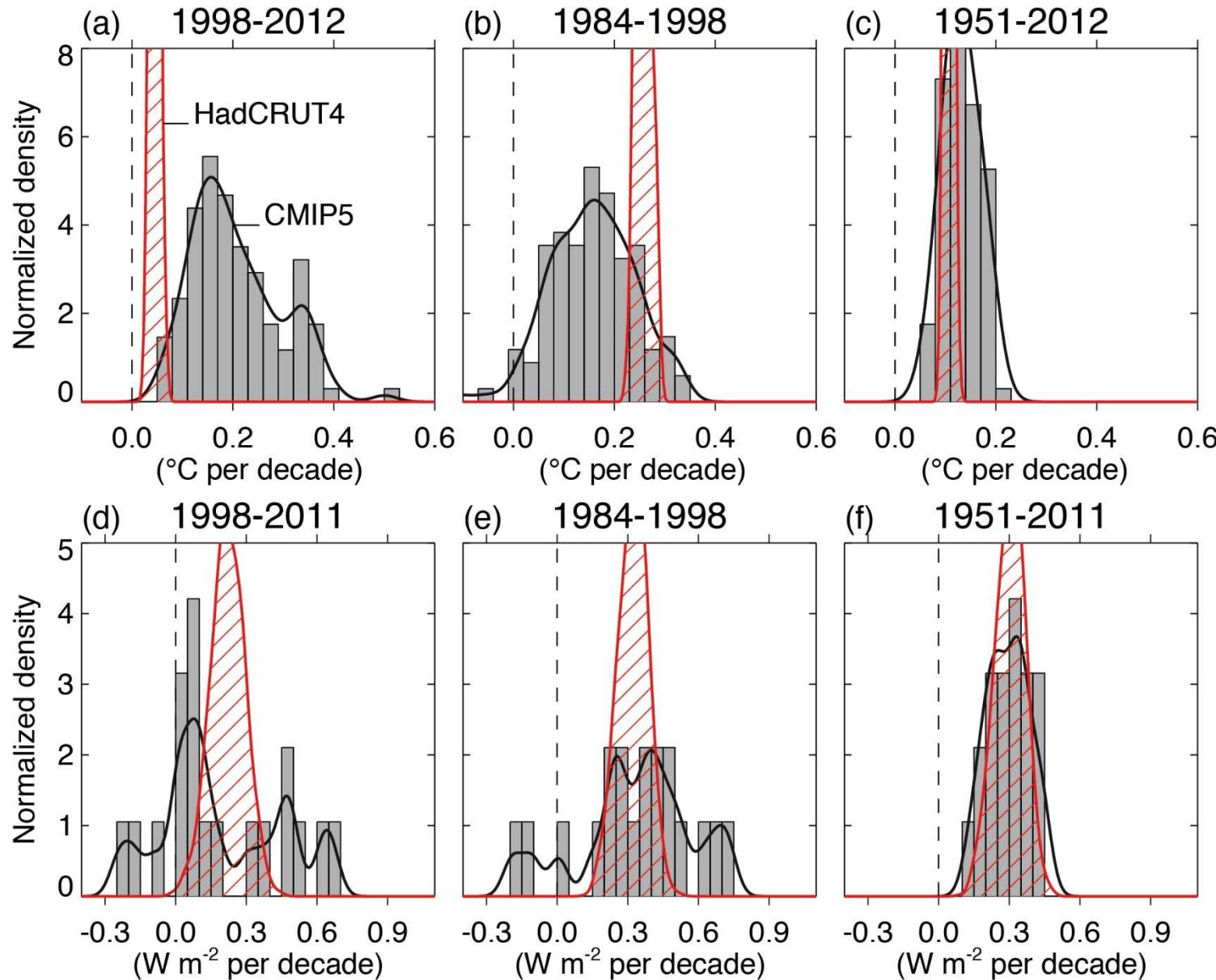
# Model Intercomparison (MIP)



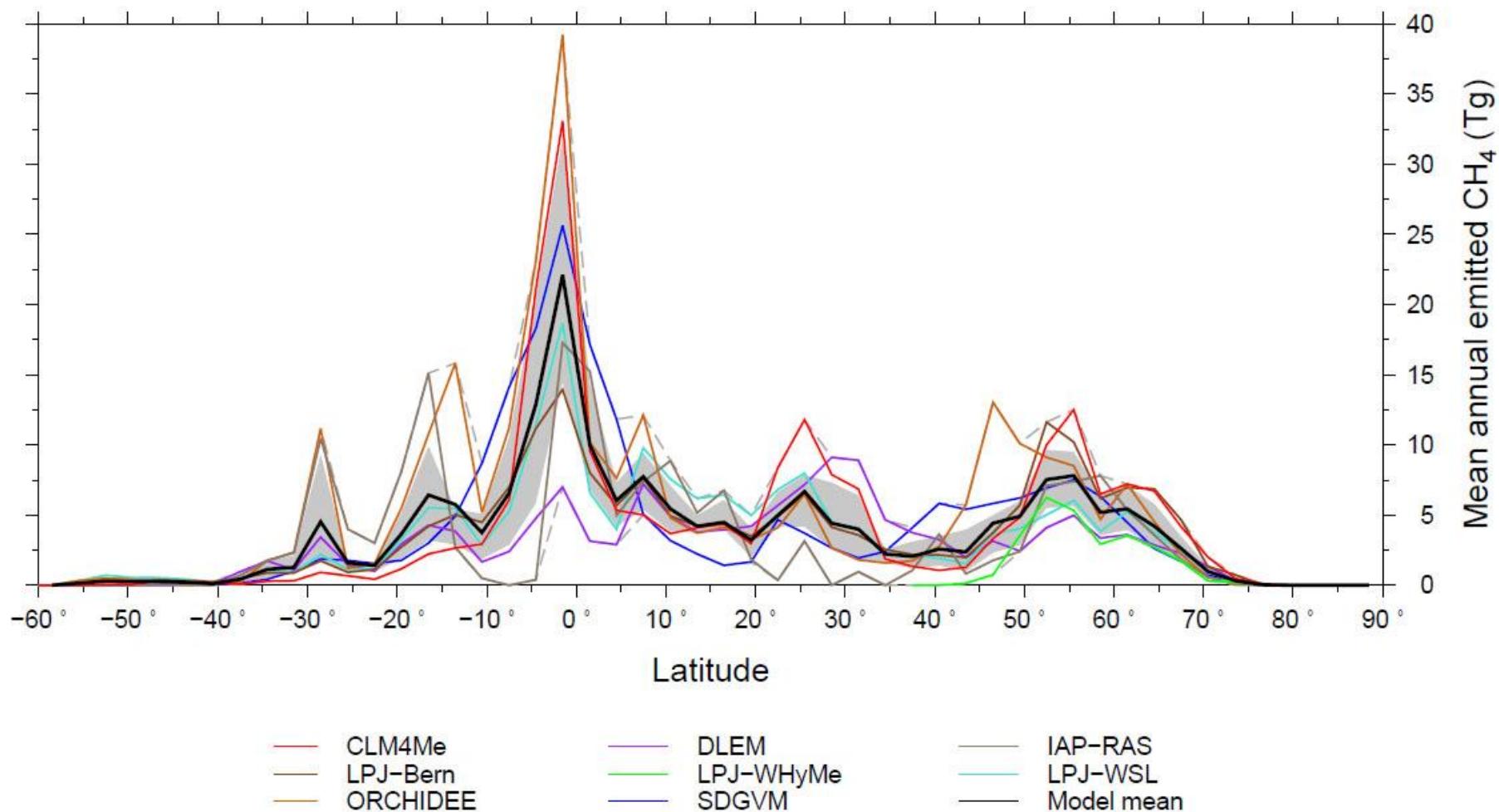
(Friedlingstein et al., 2014; Amri. Meteorol. Soc.)

# Uncertainty evaluation

(IPCC; Chapter 9 in AR5)



# Model Intercomparison (MIP)



(Melton et al., 2013; Biogeosciences)

# Scientific confidence

Qualitative (increase / decrease)

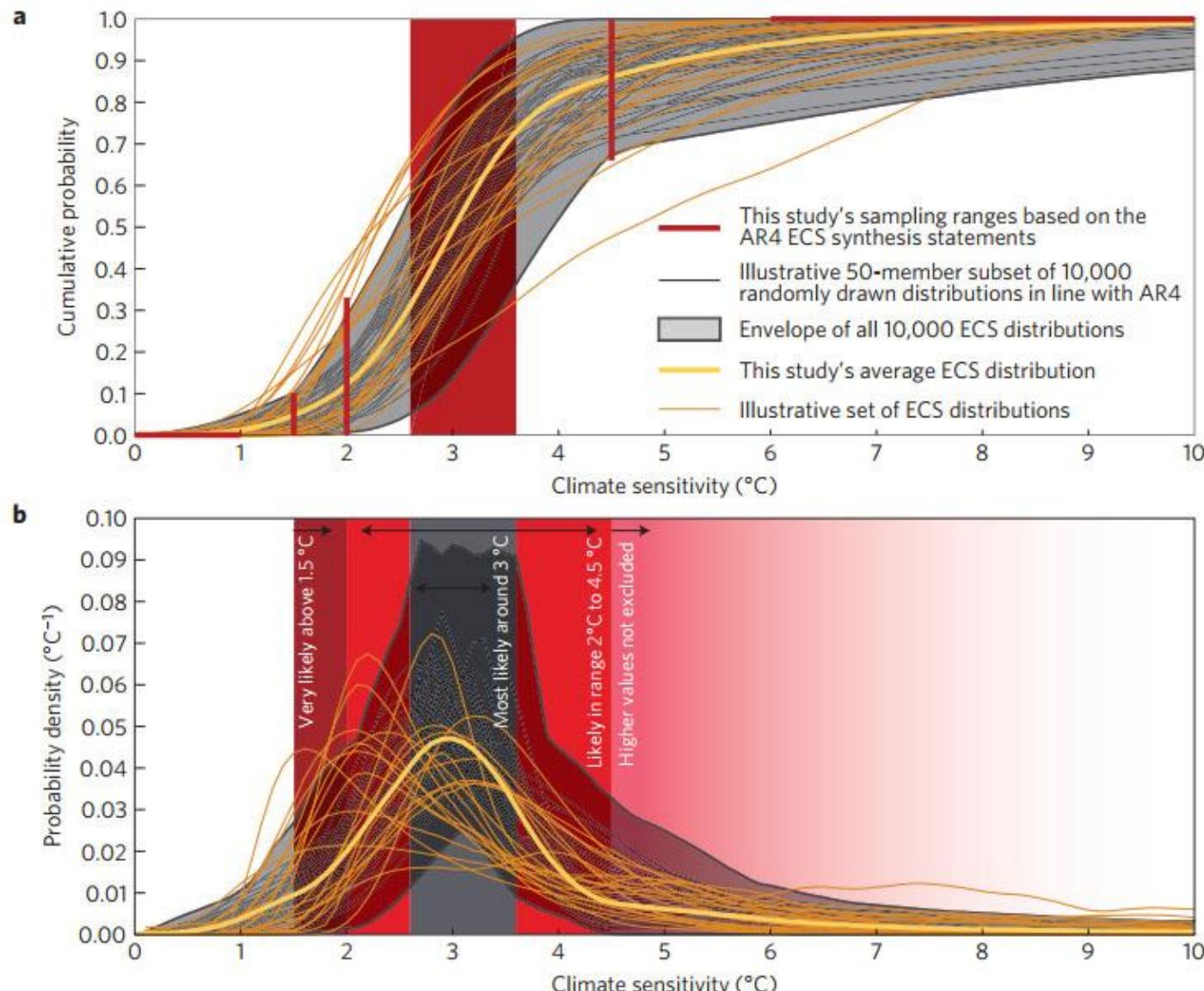
Quantitative ( $xx^{\circ}\text{C}$  increase)

Quantitative with error bands  
 $(xx \pm xx^{\circ}\text{C}$  increase)

Increase confidence!

# Scientific confidence

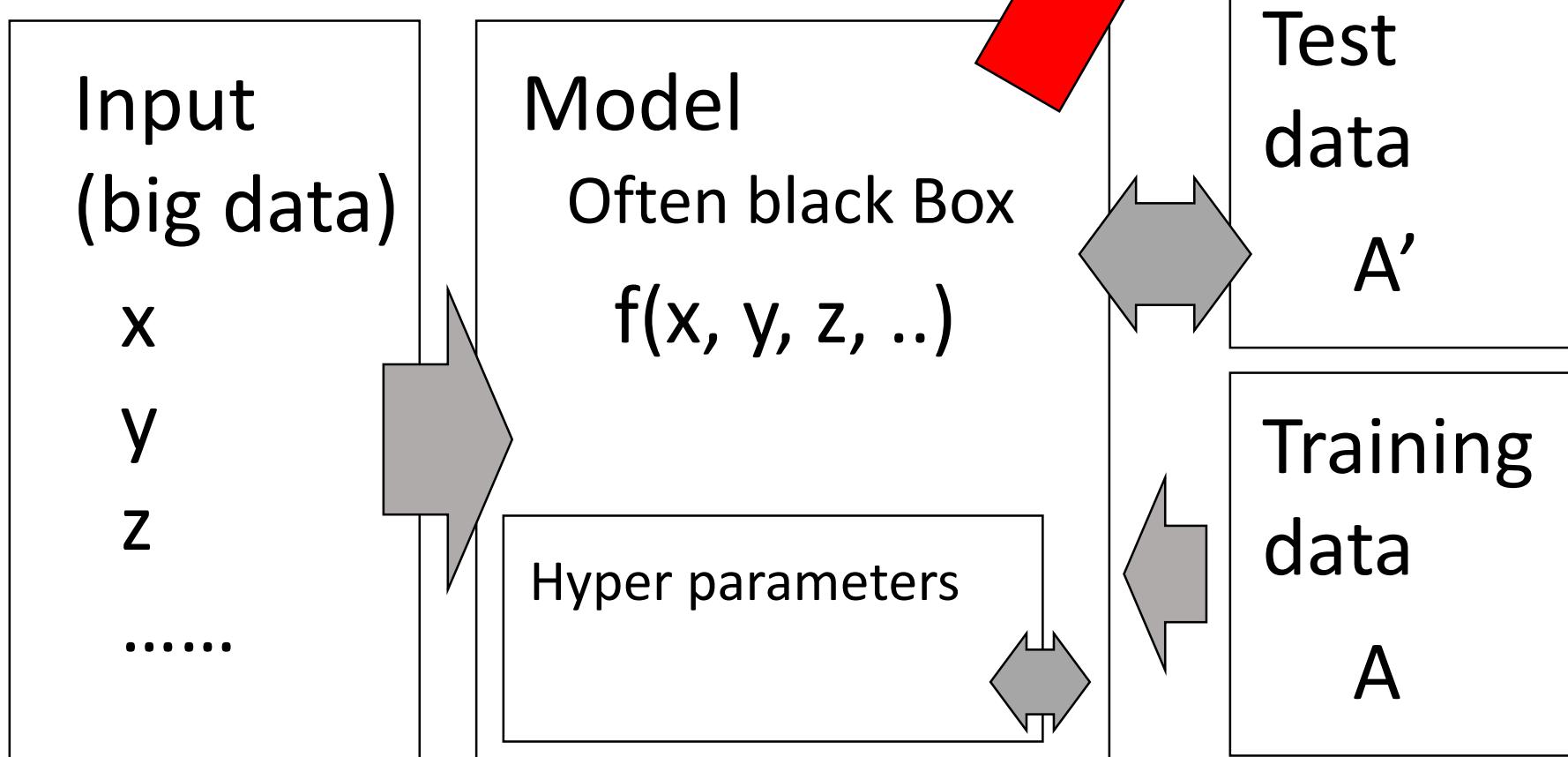
(ECS; Equilibrium climate sensitivity)



(Rogelj et al., 2012; Nature Clim. Change)

# Data driven approach

## Machine Learning Deep Learning



# Data driven approach

Neural Network

Support Vector Machine

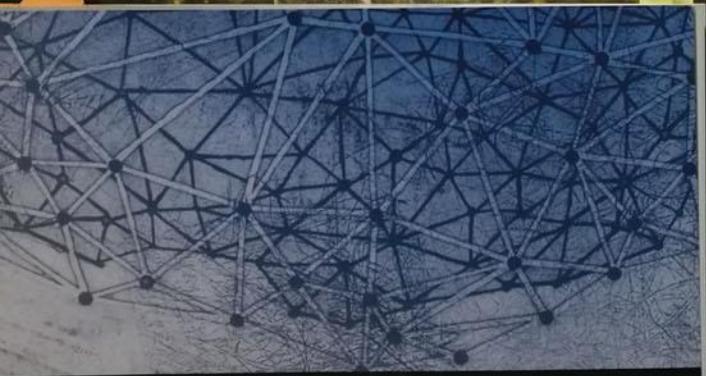
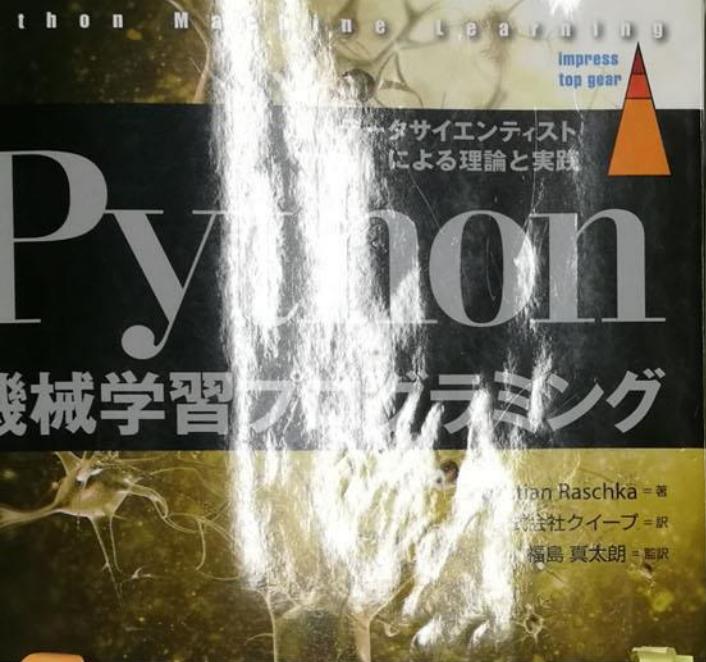
Random Forest

Boosted Trees

Decision Tree

K-Means

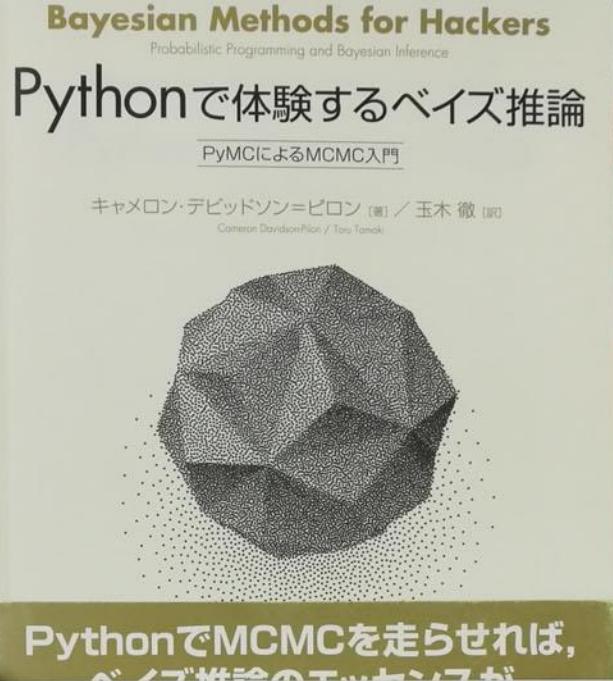
Elastic net/Lasso/Ridge



# Pythonによる ビジネスアナリティクス

実務家のための 最適化・統計解析・機械学習

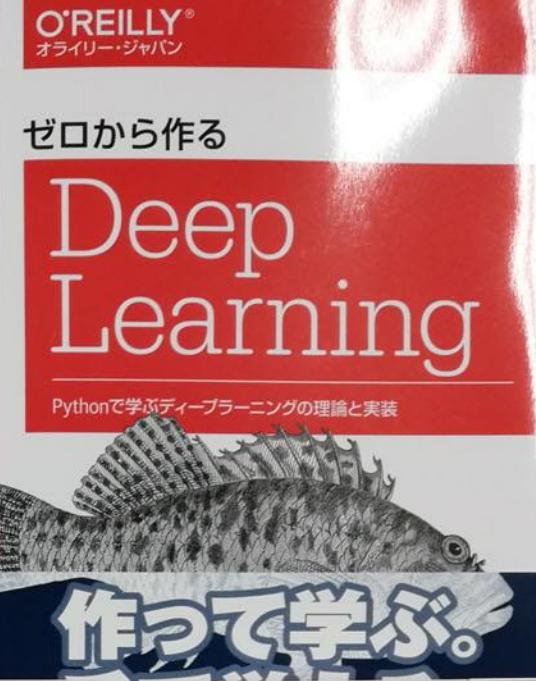
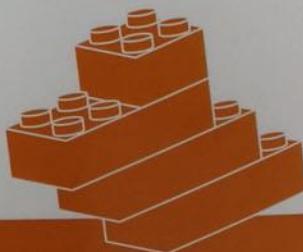
久保幹雄・小林和博・斎藤努・並木誠・橋本英樹 著



PythonでMCMCを走らせれば、  
ベイズ推論のエンターテインメント

Wonderful R 2  
StanとRで  
ベイズ統計モデリング

松浦健太郎 著



作って学ぶ。

