POTSDAM-INSTITUT FÜR KLIMAFOLGENFORSCHUNG

Variance-based sensitivity analysis as a tool to capture robustness of policy insights from integrated assessment modeling

Elmar Kriegler

11th Annual IAMC Meeting, Sevilla, 13-15 November 2018

How robust are model responses in the face of model uncertainty?

Model response to anthropogenic „interference“:

- Climate model response to anthropogenic forcing (WG1)
- Climate impact model response to climate change & adaptation policy (WG2)
- Integrated Assessment Model response to mitigation policy (WG3)

Model uncertainty factors:

- Model structural uncertainty (🡐 from an ensemble of models)
- Input assumptions uncertainty (🡐 on socio-techno-economic development (e.g. SSPs), climate and other system parameters, …)
- Configuration assumptions uncertainty (🡐 on market and policy set-ups, interaction between agents and regions, …)

Could be multiple model layers, e.g.

- regional climate models nested into global climate models (WG1),
- climate impact models fed by global climate models (WG2),
- IAMs coupled with reduced-form climate models (WG3)

How robust are model responses in the face of model uncertainty?

Model response:

$Y = f(P,X_1,X_2,\ldots)$ with interference P and uncertain factors $X_1,X_2,\ldots$

Necessary condition to use model for analysing interferences:

Variation of model response to different interferences larger than variance of model output with regard to uncertainty in factors $X_1,X_2,\ldots$

$$\mathbf{Var_P(E_X(Y|P)) > Var_X(E_P(Y|X))}$$

PIK

Variance-based sensitivity analysis

Decompose total variance of output variable $Y = f(P,X_1,X_2,\ldots)$ into fractions to be attributed to variance in inputs $P,X_1,X_2,\ldots.$

- $V_i = Var_{Xi}\,(E(Y|X_i))$ main effect of Xi
- $V_{ij} = Var_{Xij}\,(E(Y|X_i,X_j))$ interaction term

$$\mathbf{Var(Y) = V_P + \Sigma_i V_i + \Sigma_i V_{Pi} + \Sigma_{i<j} V_{ij} + \ldots}$$

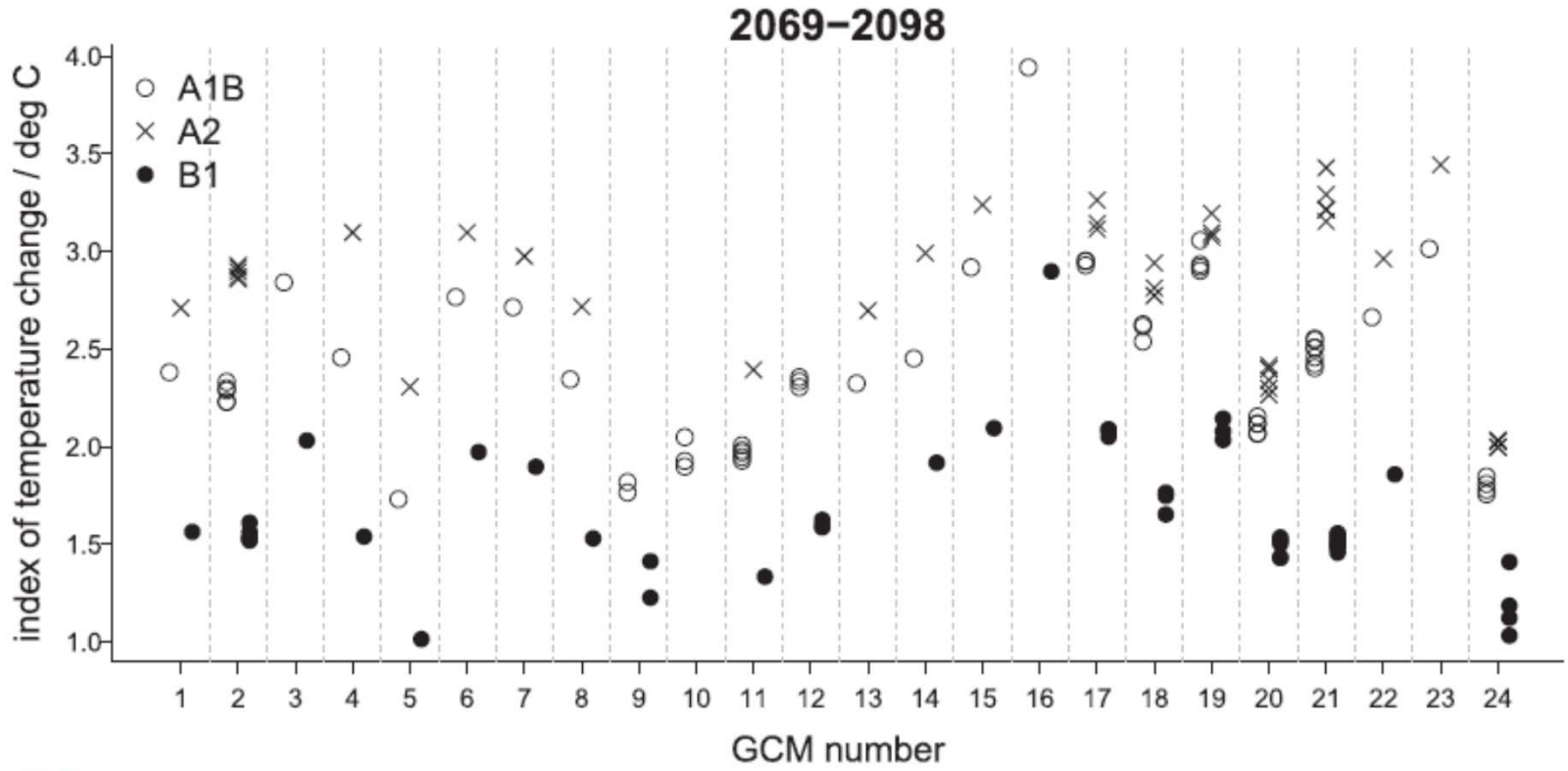
First-order sensitivity index of impulse: $\mathbf{SI = V_P / Var(Y)}$

Robust interference analysis possible if SI > ~0.5

Example 1: CMIP3 climate change projections

Northrop and Chandler, 2014, J Clim 27: 8793-8808

- 24 GCMs
- three emission scenarios (A1B, B1, A2)
- calculated 0-8 times

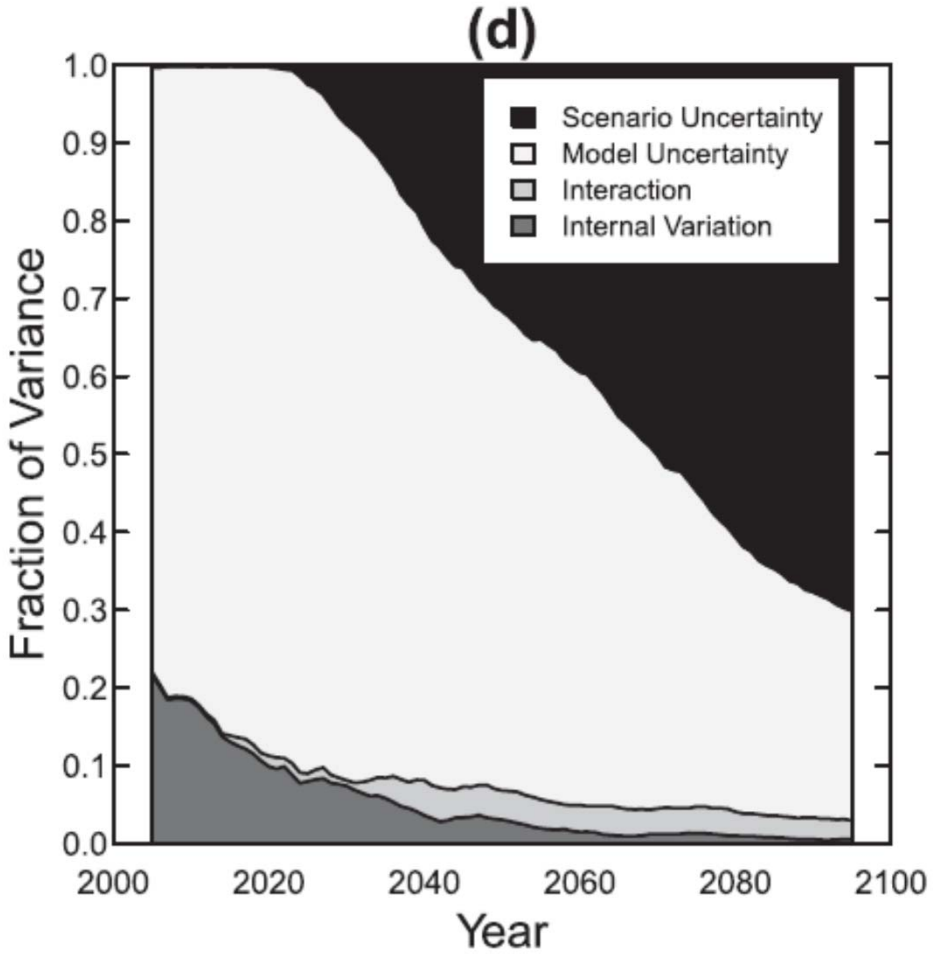


P I K

Example 1: CMIP3 climate change projections

Northrop and Chandler, 2014, J Clim 27: 8793-8808

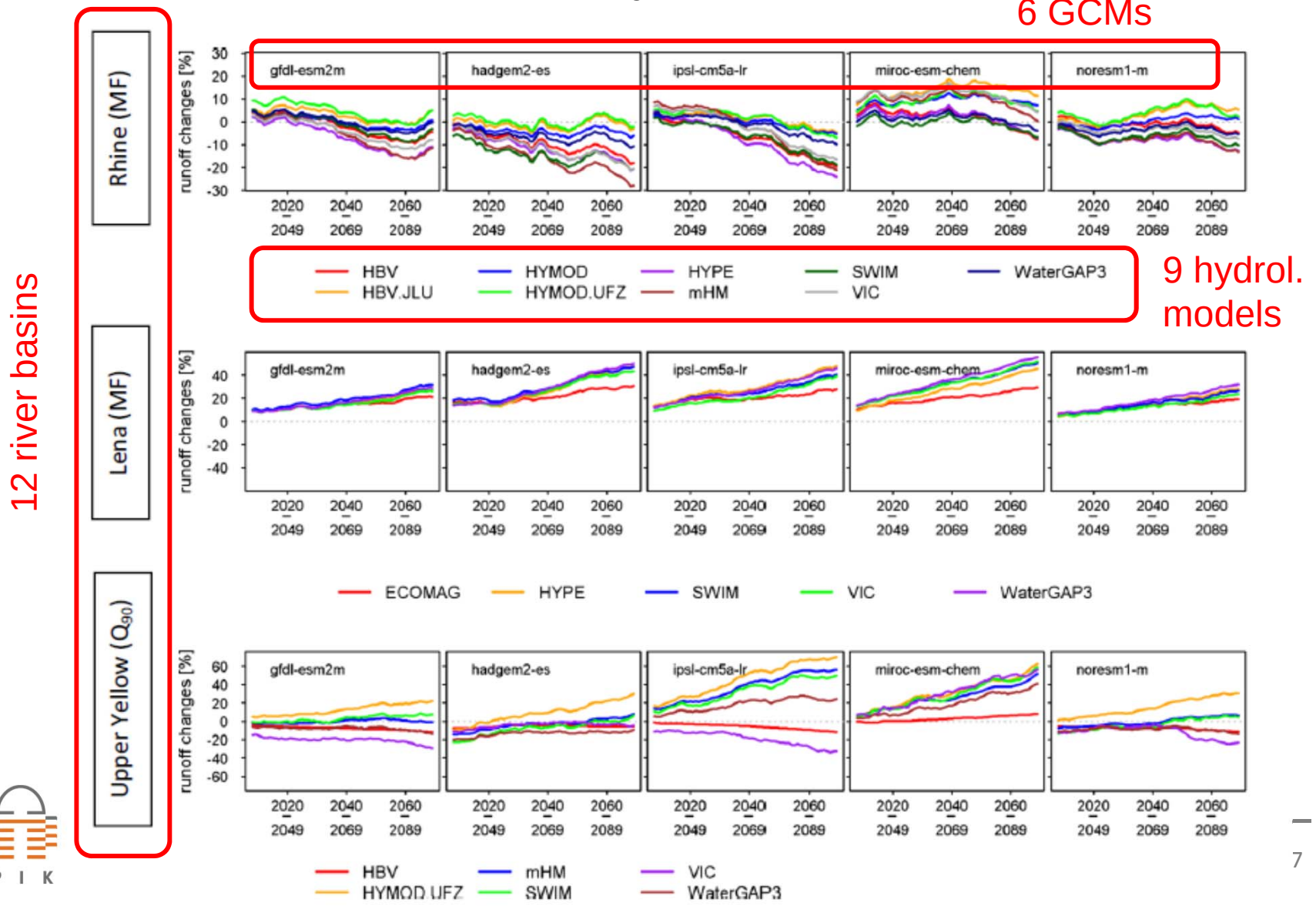
- 24 GCMs
- three emission scenarios (A1B, B1, A2)
- calculated 0-8 times



Example 2: River run-off change

RCP8.5

Vetter et al., 2017, Clim Chang 141: 561-576

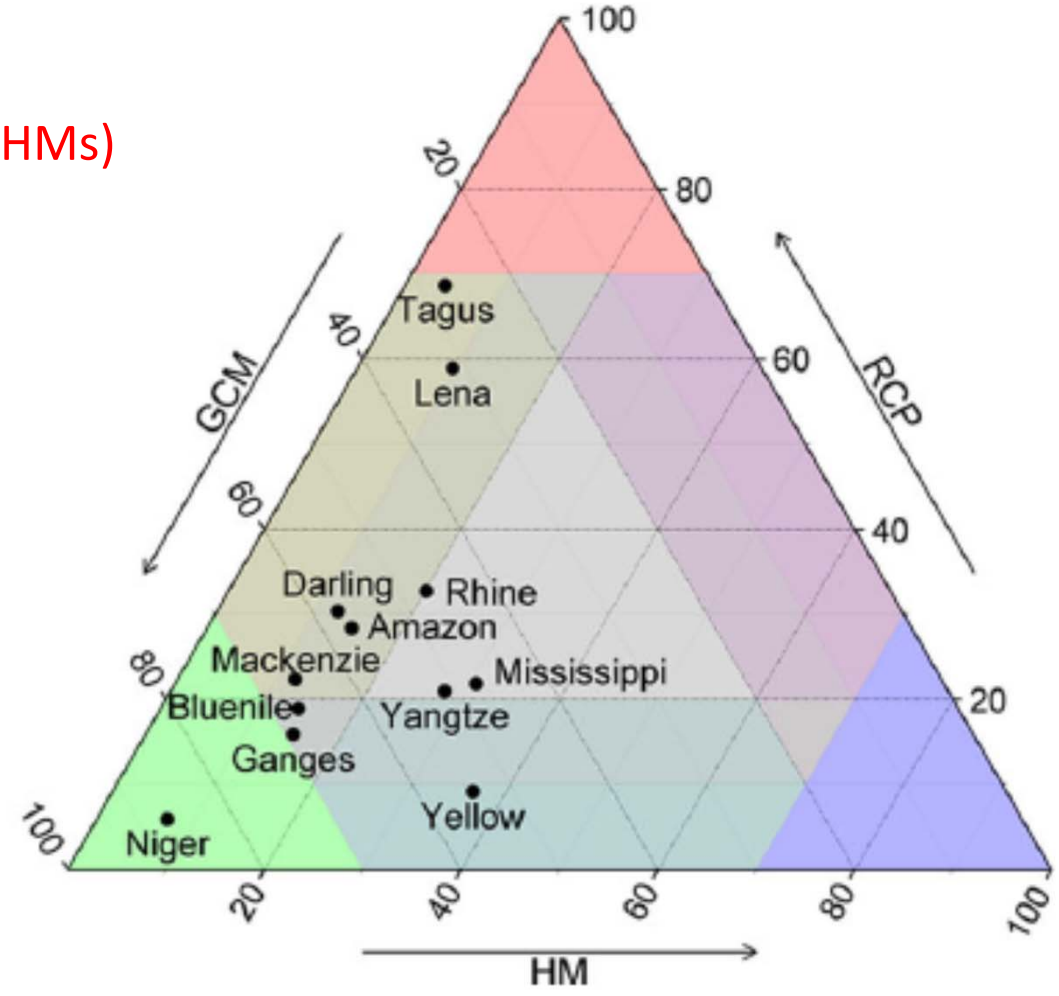


Example 2: River run-off change

Vetter et al., 2017, Clim Chang 141: 561-576

- 6 GCMs
- 4 RCPs
- 9 hydrological models (HMs)

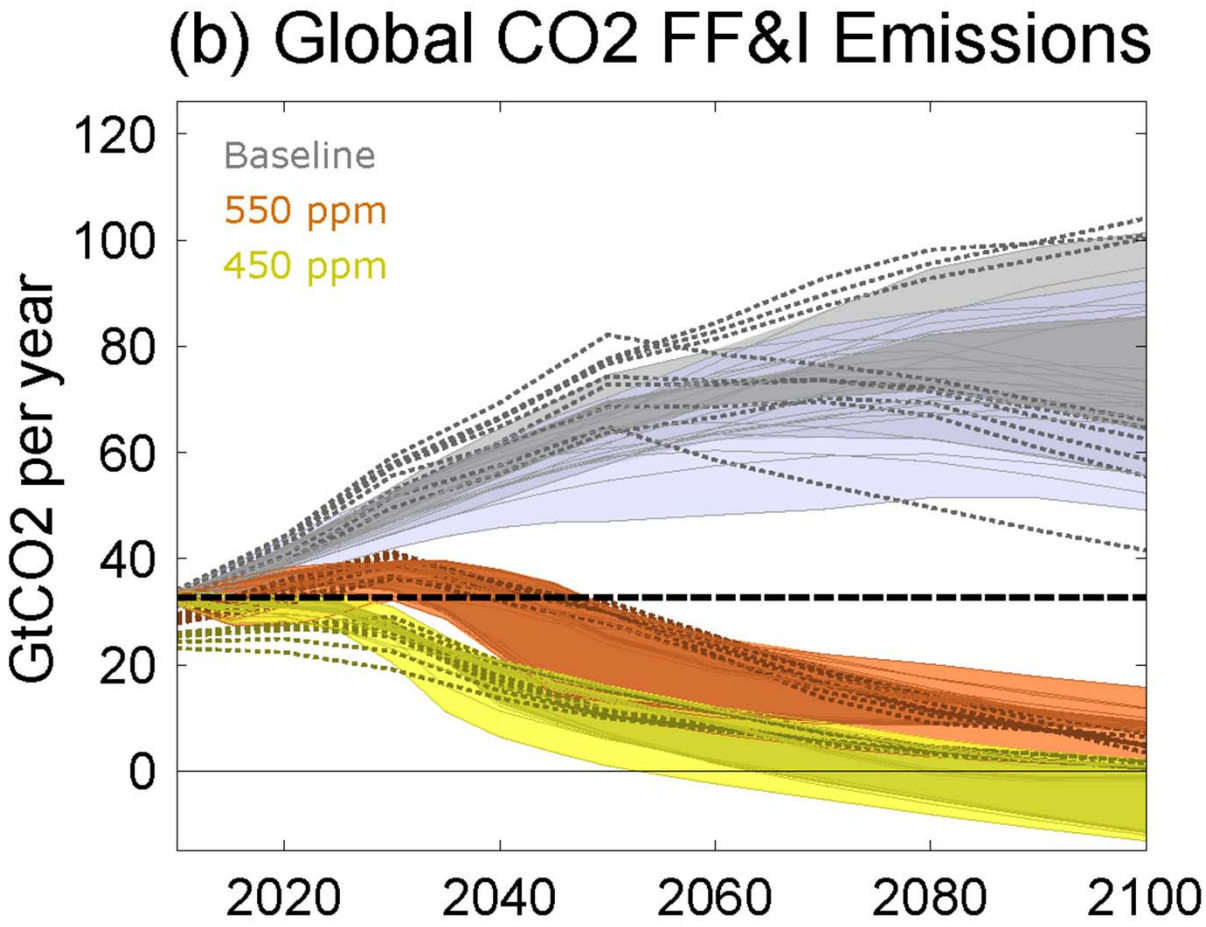
Main effects on variance of mean flow change 2070-99



Example 3: Mitigation pathways

Kriegler et al., 2016, Clim Chang 136: 7-22

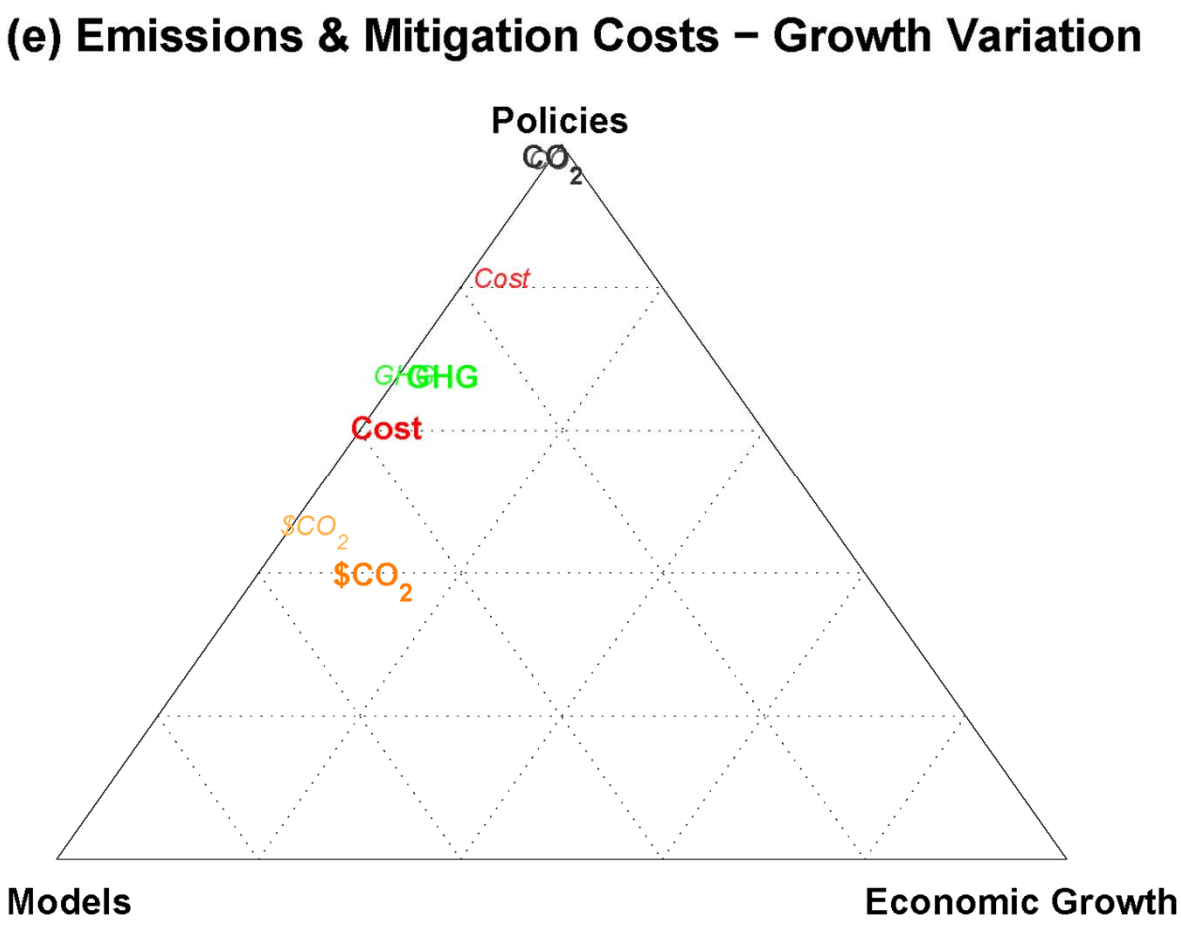
- 4 IAMs (GCAM, IPAC, REMIND, WITCH)
- 5 fossil fuel and 4 economic growth scenarios
- 3 policy cases (Baseline, 550, 450 ppm CO2e)



Example 3: Mitigation pathways

Kriegler et al., 2016, Clim Chang 136: 7-22

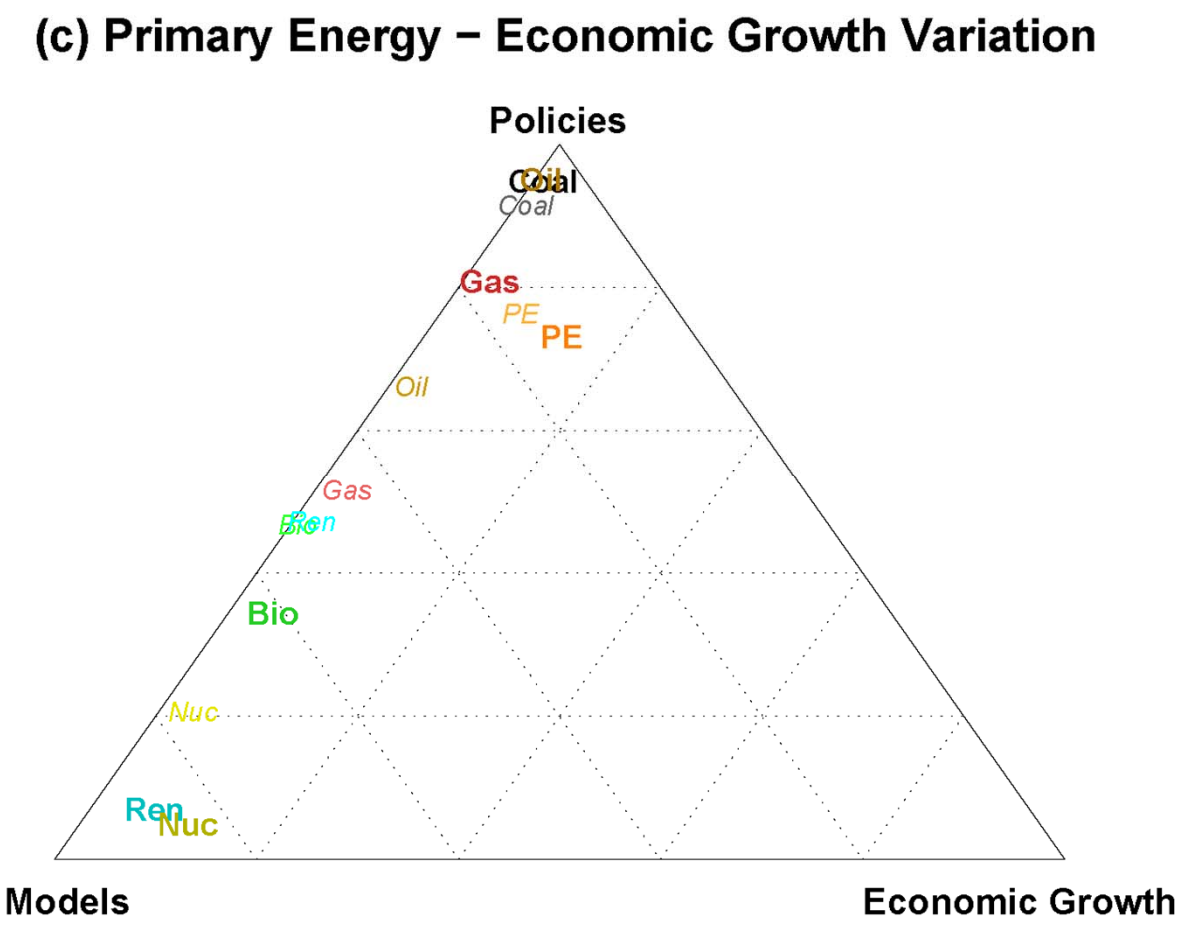
- 4 IAMs (GCAM, IPAC, REMIND, WITCH)
- 5 fossil fuel and 4 economic growth scenarios
- 3 policy cases (Baseline, 550, 450 ppm CO2e)



Example 3: Mitigation pathways

Kriegler et al., 2016, Clim Chang 136: 7-22

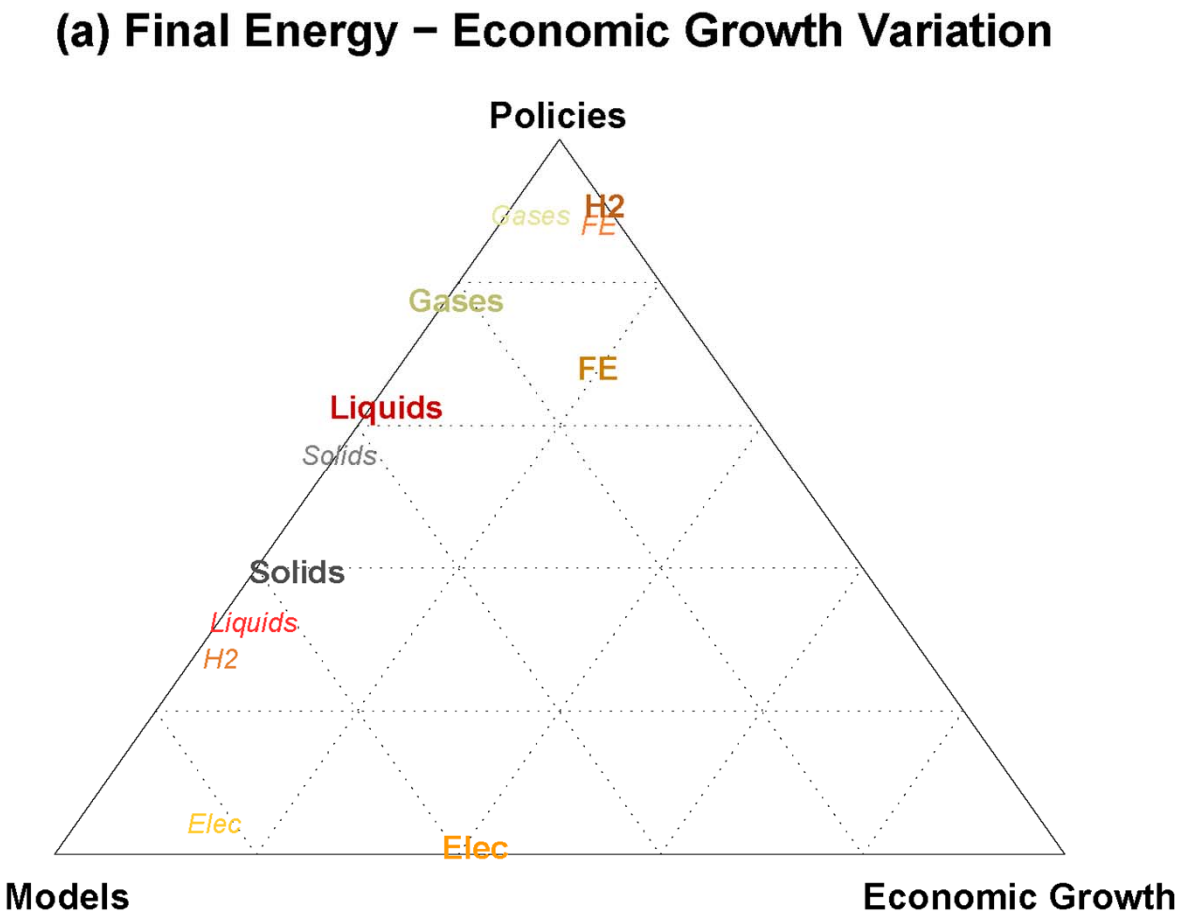
- 4 IAMs (GCAM, IPAC, REMIND, WITCH)
- 5 fossil fuel and 4 economic growth scenarios
- 3 policy cases (Baseline, 550, 450 ppm CO2e)



Example 3: Mitigation pathways

Kriegler et al., 2016, Clim Chang 136: 7-22

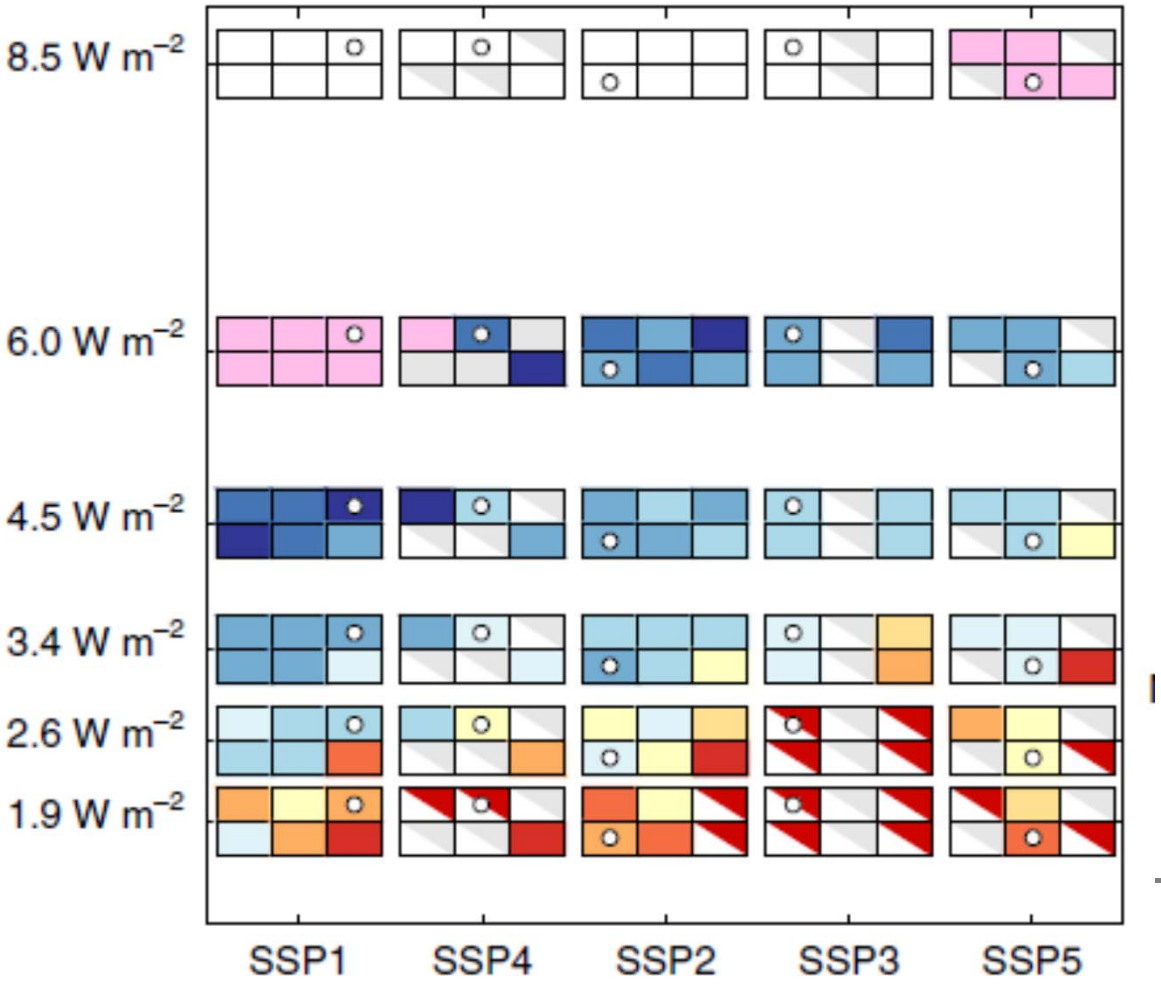
- 4 IAMs (GCAM, IPAC, REMIND, WITCH)
- 5 fossil fuel and 4 economic growth scenarios
- 3 policy cases (Baseline, 550, 450 ppm CO2e)



Application to SSP scenario database

Interference: 5 policy targets + no policy case

Uncertainty: Six IAMs, Five SSPs



Conclusions

- **Variance based sensitivity analysis might be a powerful tool to evaluate robust insights in model responses to human interference across different climate research communities**

- **Work needed on technical implementation of method on IAM scenario data: no probabilities, incomplete sampling etc.**

Discussion