Integrated Assessment of the Impacts of Climate Change: Reflections and Modest Proposals for Linking Empirical Approaches and IAMs

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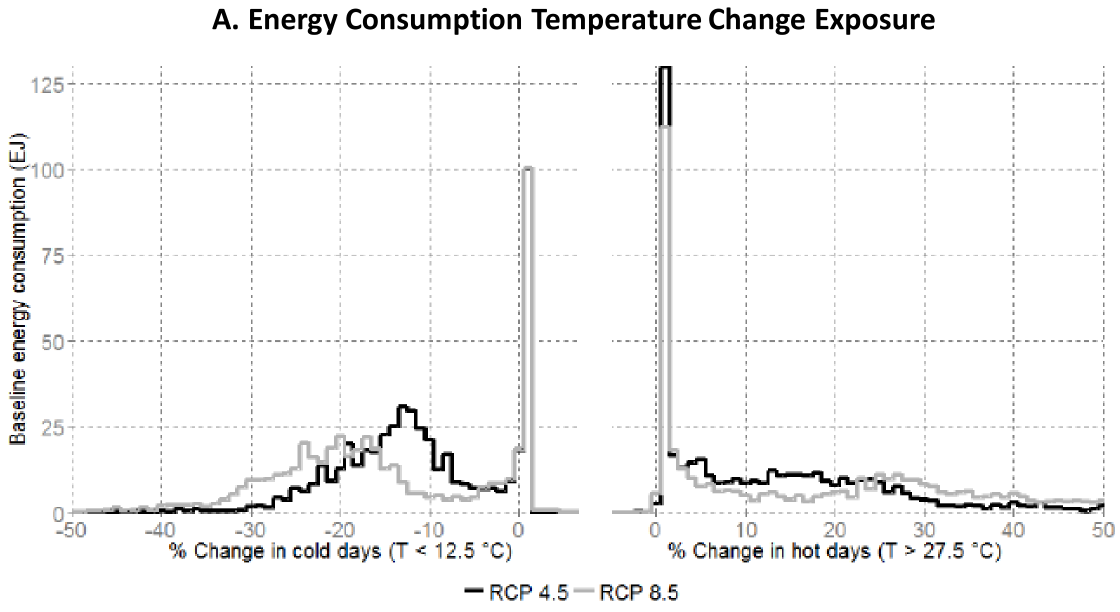
ENGAGE: Understanding the impacts of climate change on growth and development

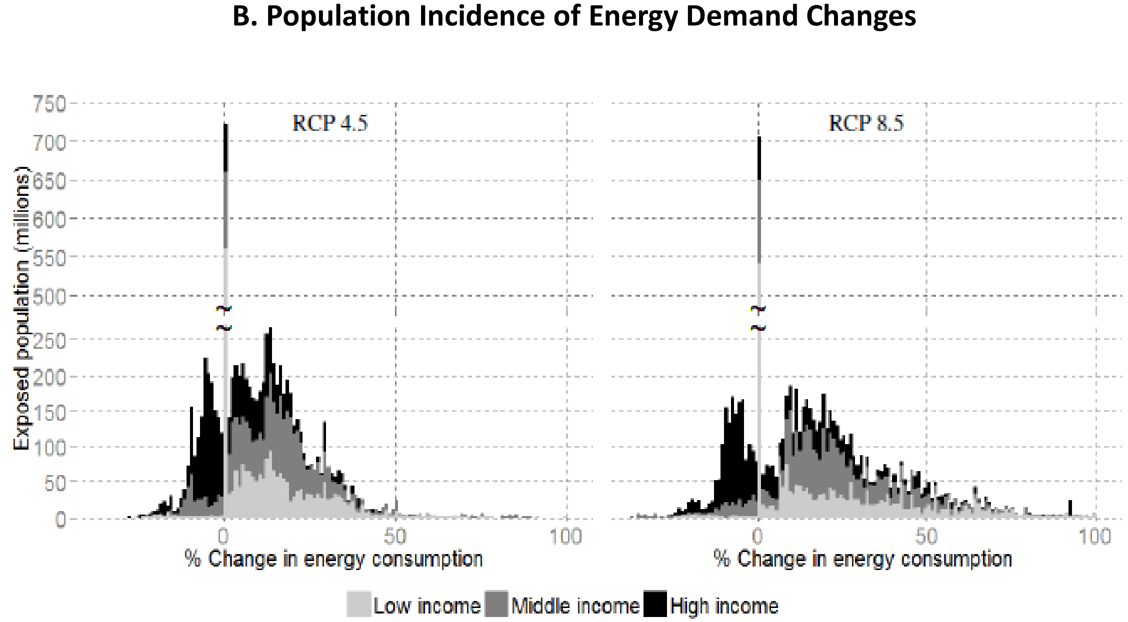
Plan of talk

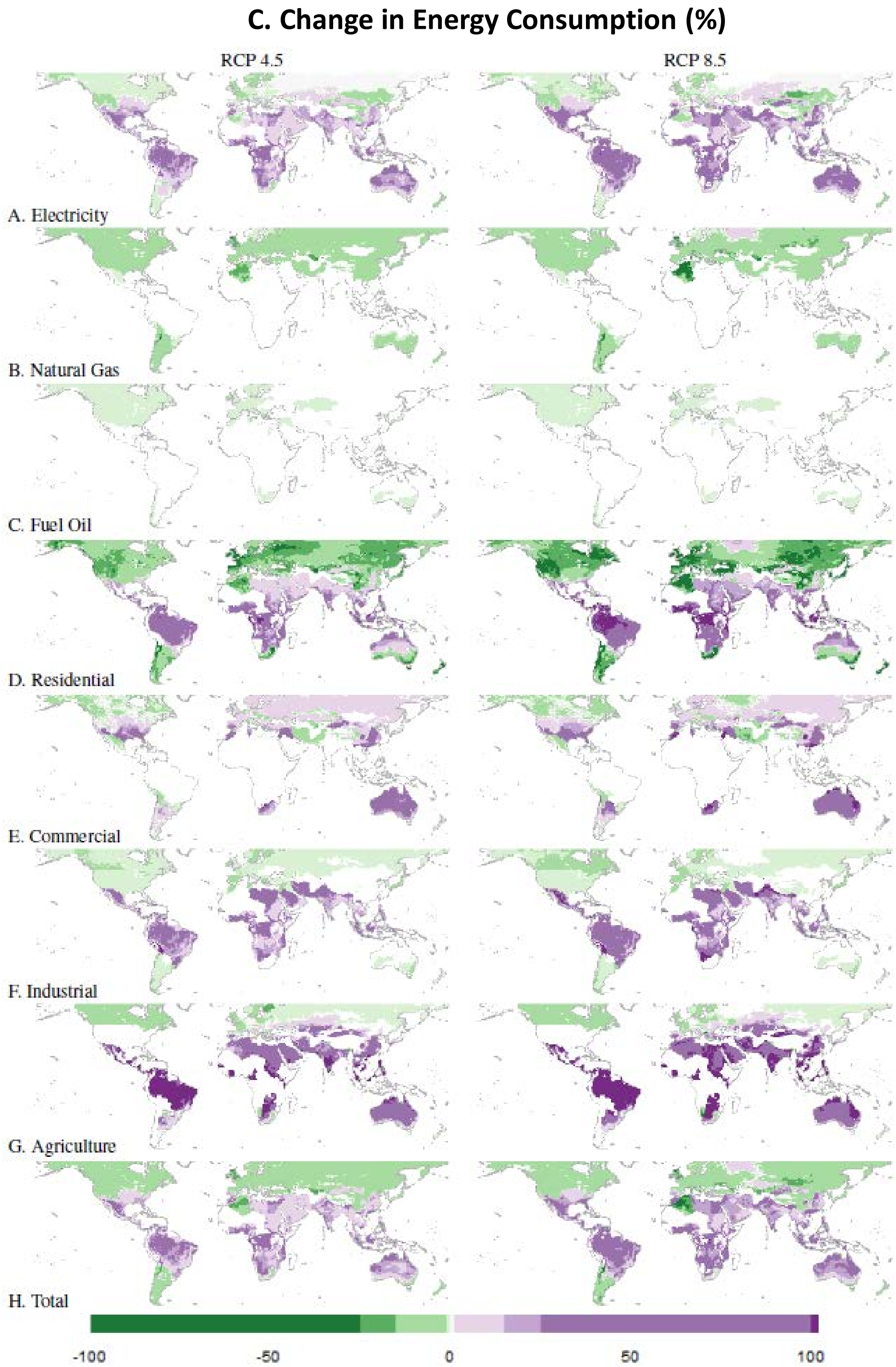
1. Empirical modeling of climate change Impacts
2. Natural science/engineering process simulations
3. Adaptation, stability of impact responses, and double counting
4. Earth system models
5. IAMs
6. Drawing out productive lessons for ENGAGE

1. Empirical Modeling of Climate Change Impacts

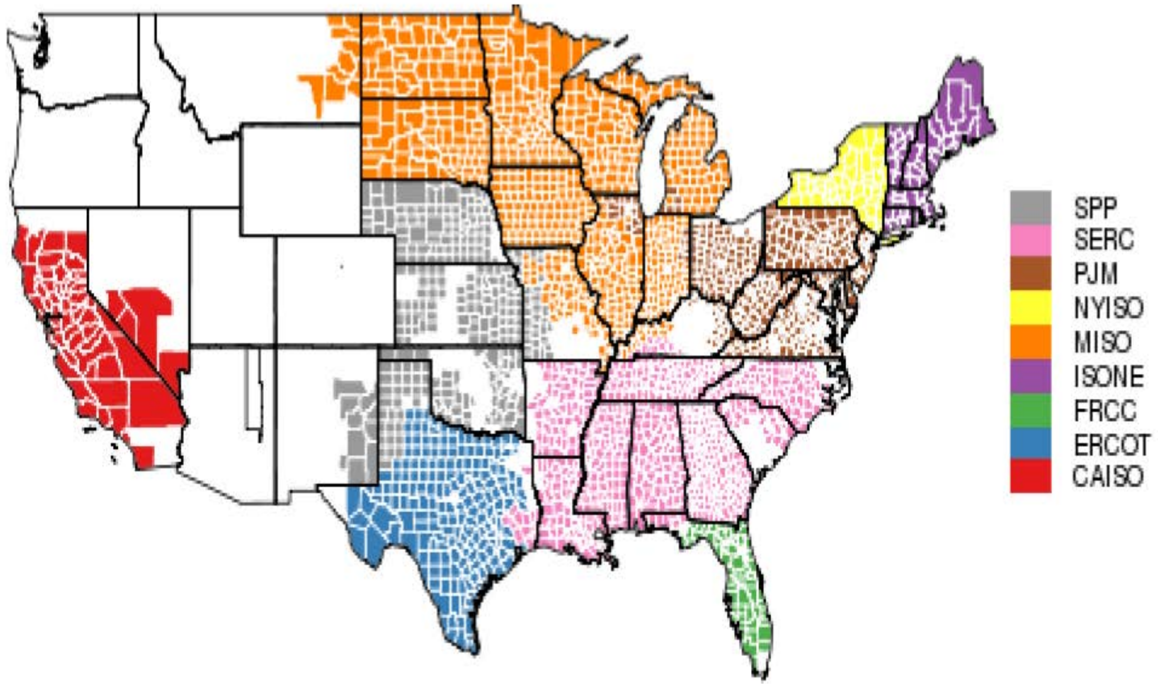
- Opportunities/benefits
  - Statistically rigorous, relying on large numbers of cross-section/time-series observations at sub-national spatial scales
  - Key advantage: yield well-identified, precise, externally valid estimates of nonlinear impact endpoint responses to weather shocks (but extent to which moderating effects of historical adaptations well controlled for varies)
- Challenges/obstacles
  - Limited geographic coverage, potential for responses in one location to be extrapolated to other regions indeterminate
  - This can particularly problematic for developing countries, where data are not readily available
  - Global-scale analyses much less well identified
  - Many of the most interesting <u>non-market</u> impact endpoints are not directly usable by IAMs, which tend to concentrate on market interactions (e.g. temperature and violence), requiring additional translational research (e.g., violence/conflict effects on factor allocation, K accumulation, L productivity)
  - As yet, few incentives for mainstream empirical economists to forward-integrate into translation
- Ways forward
  - Data development: field studies/RCTs/data collection in developing countries of particular interest
  - Bottom-up approach: meta-analysis and other statistical interpolation techniques to extrapolate estimates in individual sub-national contexts for global reach?
  - Top-down approach: new generation of empirical impacts studies at global/regional scales designed explicitly to meet the needs of IAMs

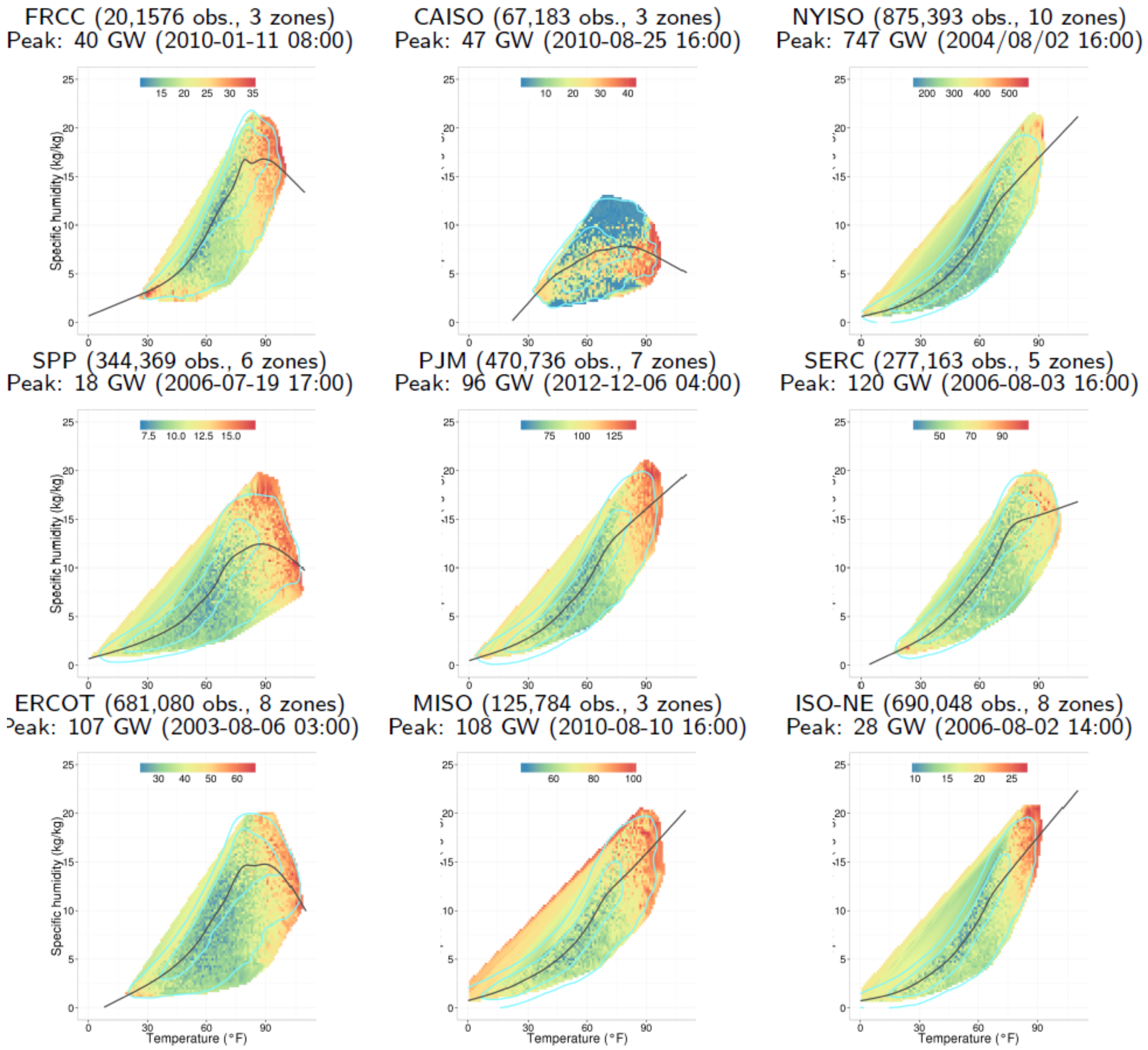




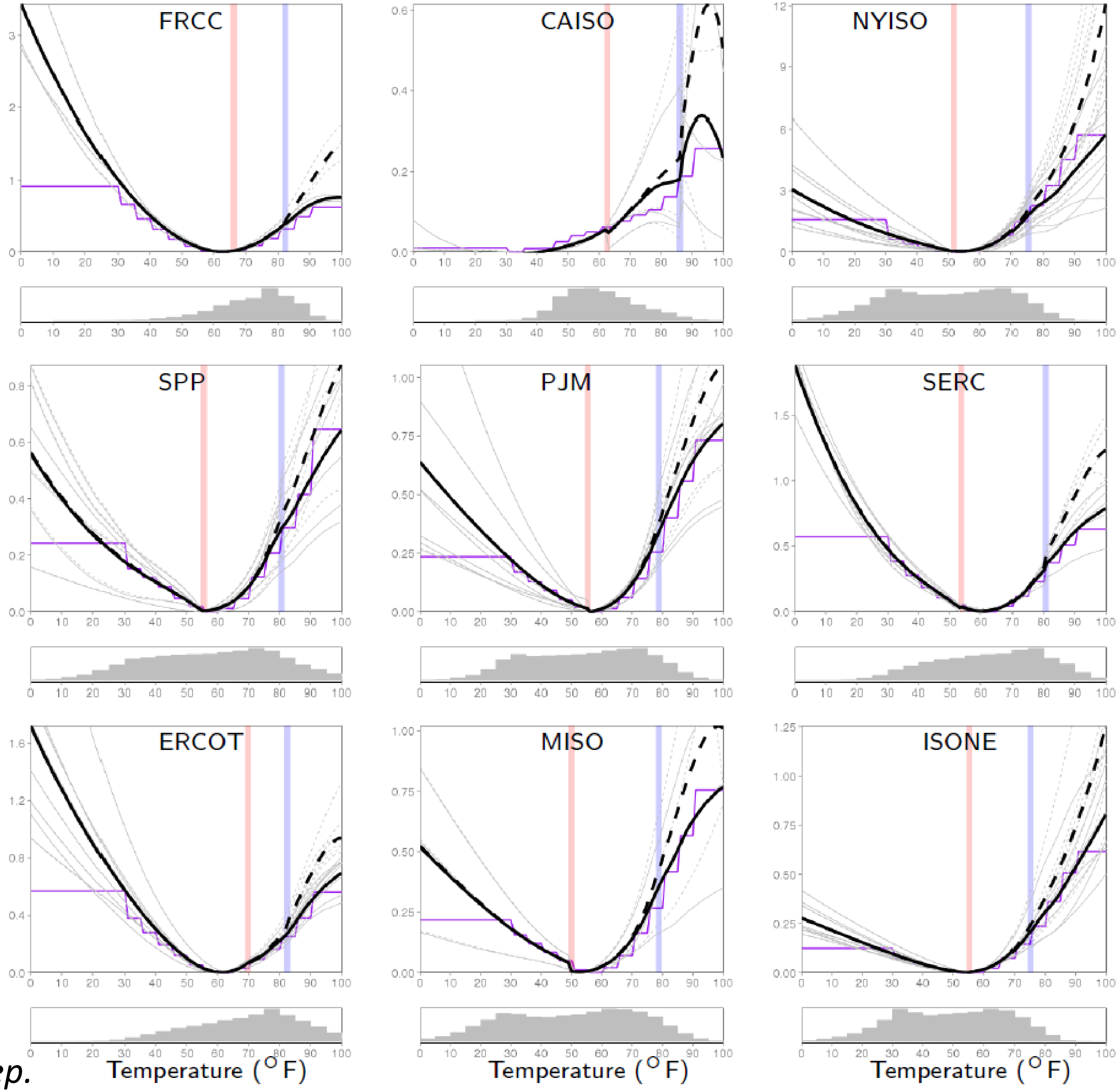


De Cian and Sue Wing (2016)





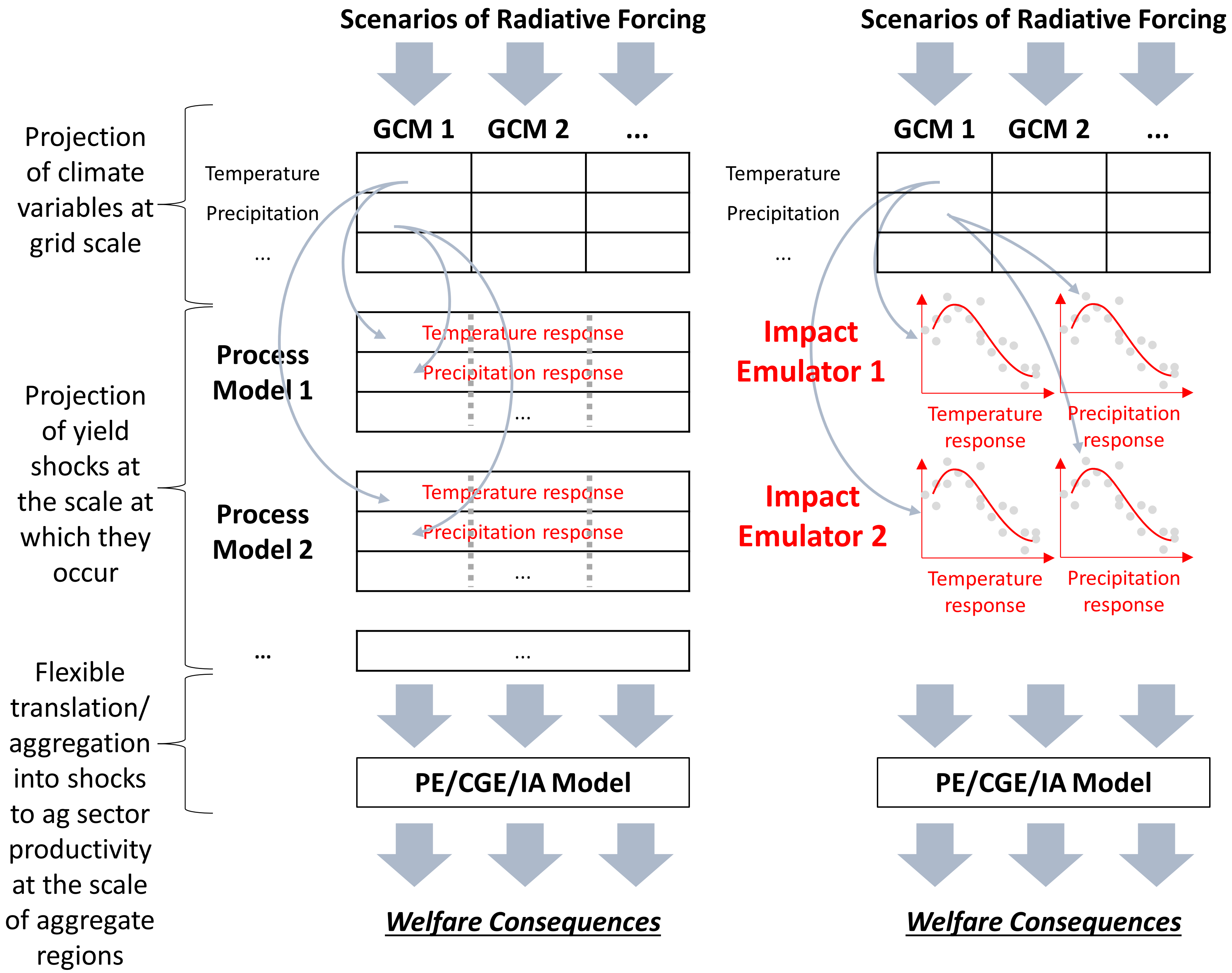
Coffey and Sue Wing, *in prep.*



Coffey and Sue Wing, *in prep.*

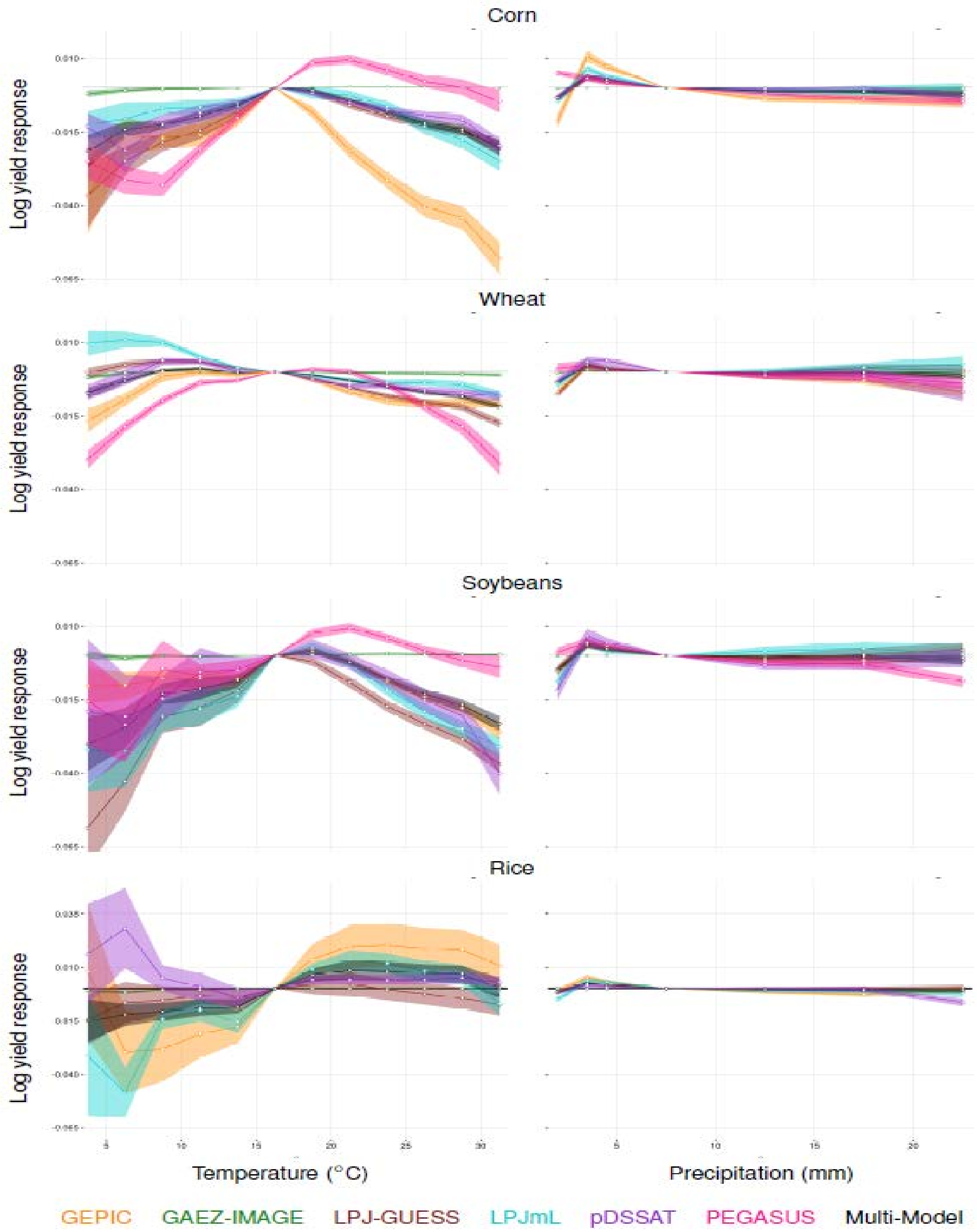
2. Natural Science/Engineering Process Simulations

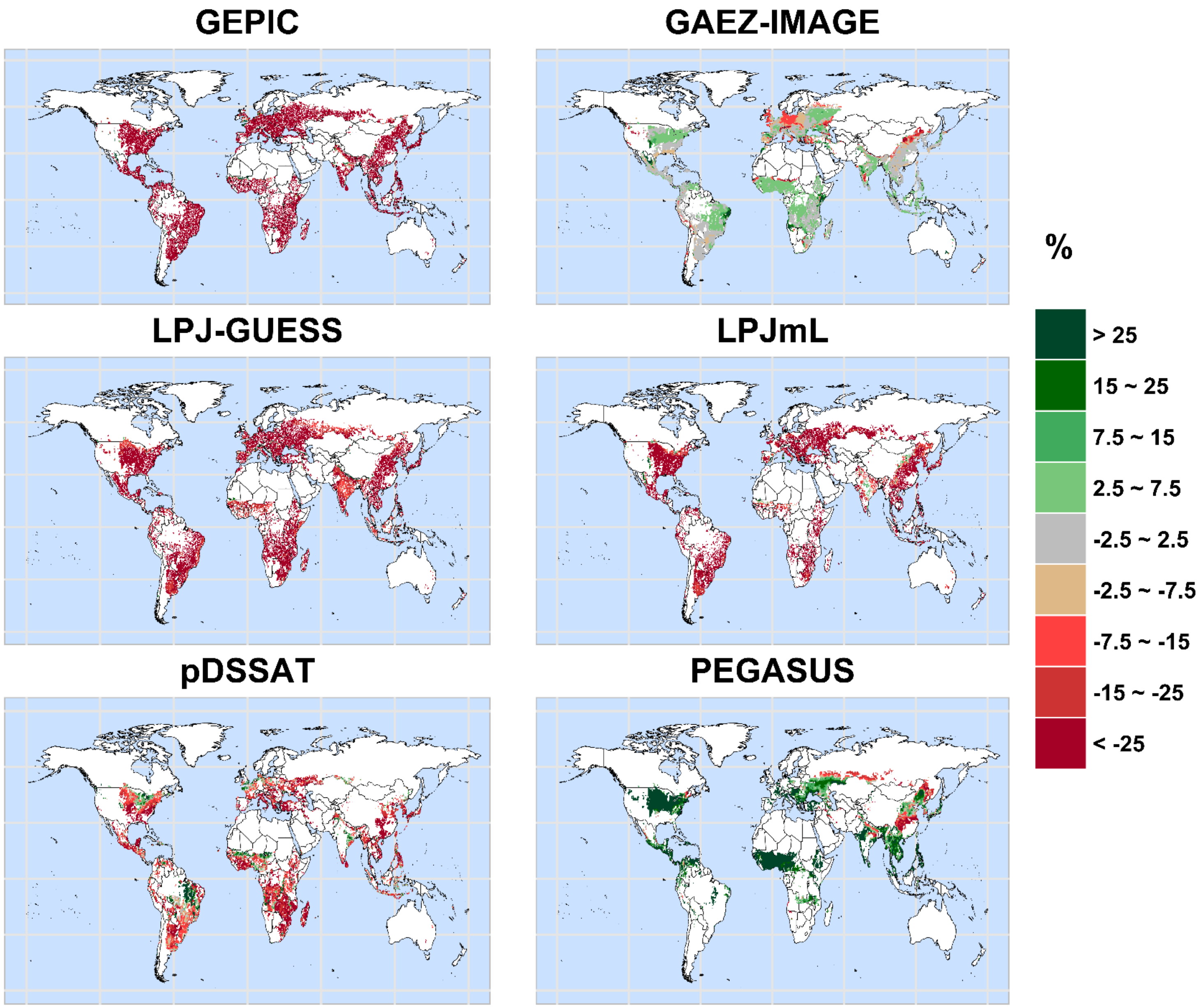
- Opportunities/benefits
  - Increasing sophistication of models; development/improvement catalyzed by intercomparison projects
  - Advantage is broad (often global) geographic coverage, making their outputs a key source of pseudodata, especially in developing areas (e.g., ISIMIP Fast Track)
- Challenges/obstacles
  - Computational expense limits the utility of coupling process simulation outputs directly with IAMs
  - Subsequent downstream analyses "locked in" to discrete combinations of ESMs and process models (cf ISIMIP Fast Track), whereas what we really want is the envelope of model responses in relation to meteorological drivers
  - Validation: forcing models with historical meteorology for the purpose of rigorous empirical comparison of modeled endpoints against available historical observations
  - Diagnostic intercomparison: statistical characterization to improve understanding of how individual processes interact and aggregate up to generate models' emergent behavior
- Ways forward
  - Process model emulation: applying econometric techniques from the empirical impacts literature to (a) construct reduced-form statistical response surfaces from process model inputs and outputs, (b) decompose effects of different modeled processes on overall model response to assess their importance



Scenarios of Radiative Forcing
Scenarios of Radiative Forcing
Projection of climate variables at grid scale
GCM 1
GCM 2
...
Temperature
Precipitation
...
Projection of yield shocks at the scale at which they occur
Process Model 1
Temperature response
Precipitation response
...
Process Model 2
Temperature response
Precipitation response
...
...
...
Impact Emulator 1
Temperature response
Precipitation response
Impact Emulator 2
Temperature response
Precipitation response
Flexible translation/ aggregation into shocks to ag sector productivity at the scale of aggregate regions
PE/CGE/IA Model
PE/CGE/IA Model
Welfare Consequences
Welfare Consequences

$$\log y_{i,t} = \alpha_i + \boxed{g(t)} + \Sigma_j \beta_j^T \mathcal{E}_{j,i,t}^T + \Sigma_k \beta_k^P \mathcal{E}_{k,i,t}^P + u_{i,t}$$





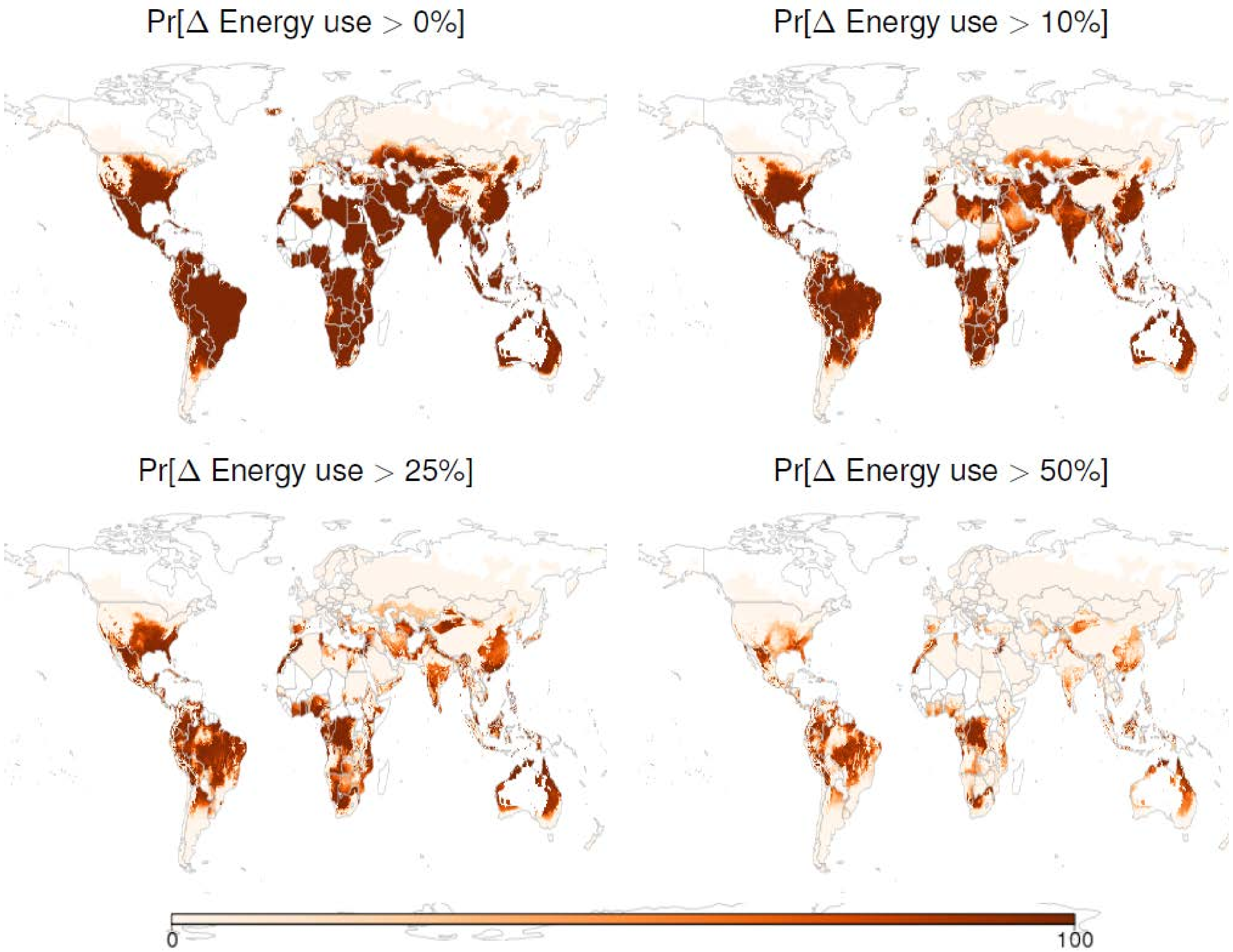
Mistry, De Cian and Sue Wing, *in prep.*

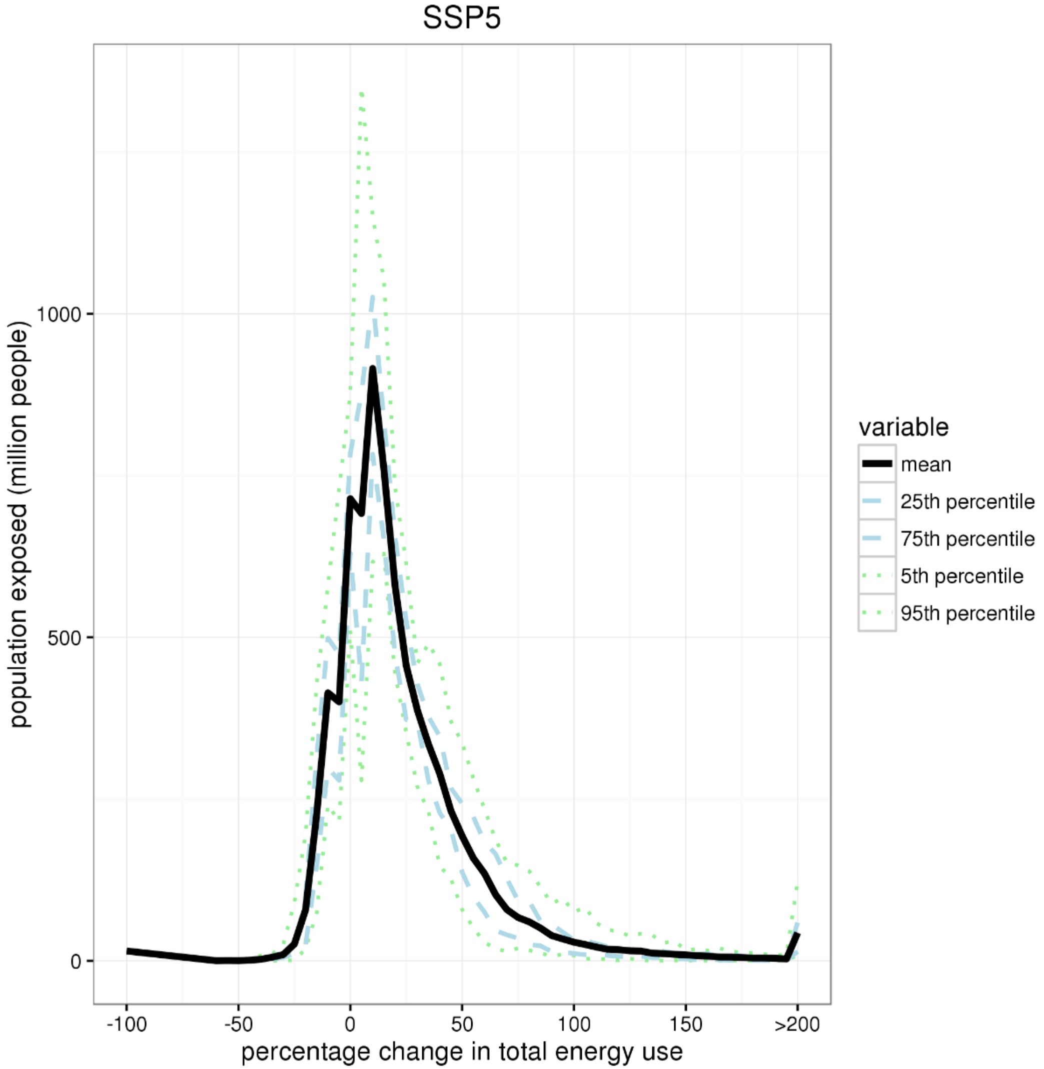
3. Lost in translation: adaptation, stability of impact responses, and the specter of double counting

- In IAM assessments of the economic consequences of impact endpoints, deadweight losses arise out of both output/income losses associated with shocks (assuming no substitution) and reallocation of inputs to production and consumption associated with adaptation
- It is important that, as far as humanly possible, calculations of impact endpoints represent climate shocks to the economy at the instant they occur, and before economic actors have an opportunity to react
- This prevents adaptation from being inappropriately capitalized into the shocks handed to IAMs, and allows IAMs' endogenous adjustments to represent, and account for, the effects of adaptation
- From a modeling perspective, avoiding "double-counting" requires
  - Controlling for potential historical climate adaptations in empirical studies
  - Switching off endogenous adaptations within process simulations
- From a scientific perspective, key question is how do (should) IAMs' economic/engineering representations of substitution possibilities and deliberate adaptation investments capture the types of real-world actions we are likely to observe?

4. Earth system models

- Opportunities/benefits
  - We have sufficiently many quasi-independent realizations of future meteorology at fine temporal and spatial scales under different warming scenarios that we can begin to analyze climate change impact <u>risk</u>
- Challenges/obstacles
  - Substantial computational effort needed to transform projected meteorological fields under future warming into future realizations of covariates for empirical models or emulators to actually compute impact endpoints (e.g. daily data for multiple ESMs on different grids with different file formats in ESGF)
  - This difficulty is partially alleviated by state-of-the-art global regridded and downscaled multi-model ensembles (e.g., NEX-GDDP), but as yet few variables processed in this way (tasmin, tasmax, pr)
- Ways forward
  - Re-grid/re-format CMIP5 archive to generate multi-ESM ensembles for a range of meteorological fields at high temporal resolution
  - Ex ante: no academic sex appeal, limited potential for funding, but ex-post an infrastructural public service, because of the potential to catalyze many, many impacts modeling studies that would otherwise face the daunting prospect of re-inventing the wheel
  - Leverage CMIP6 process to prospectively facilitate construction of similar ensembles



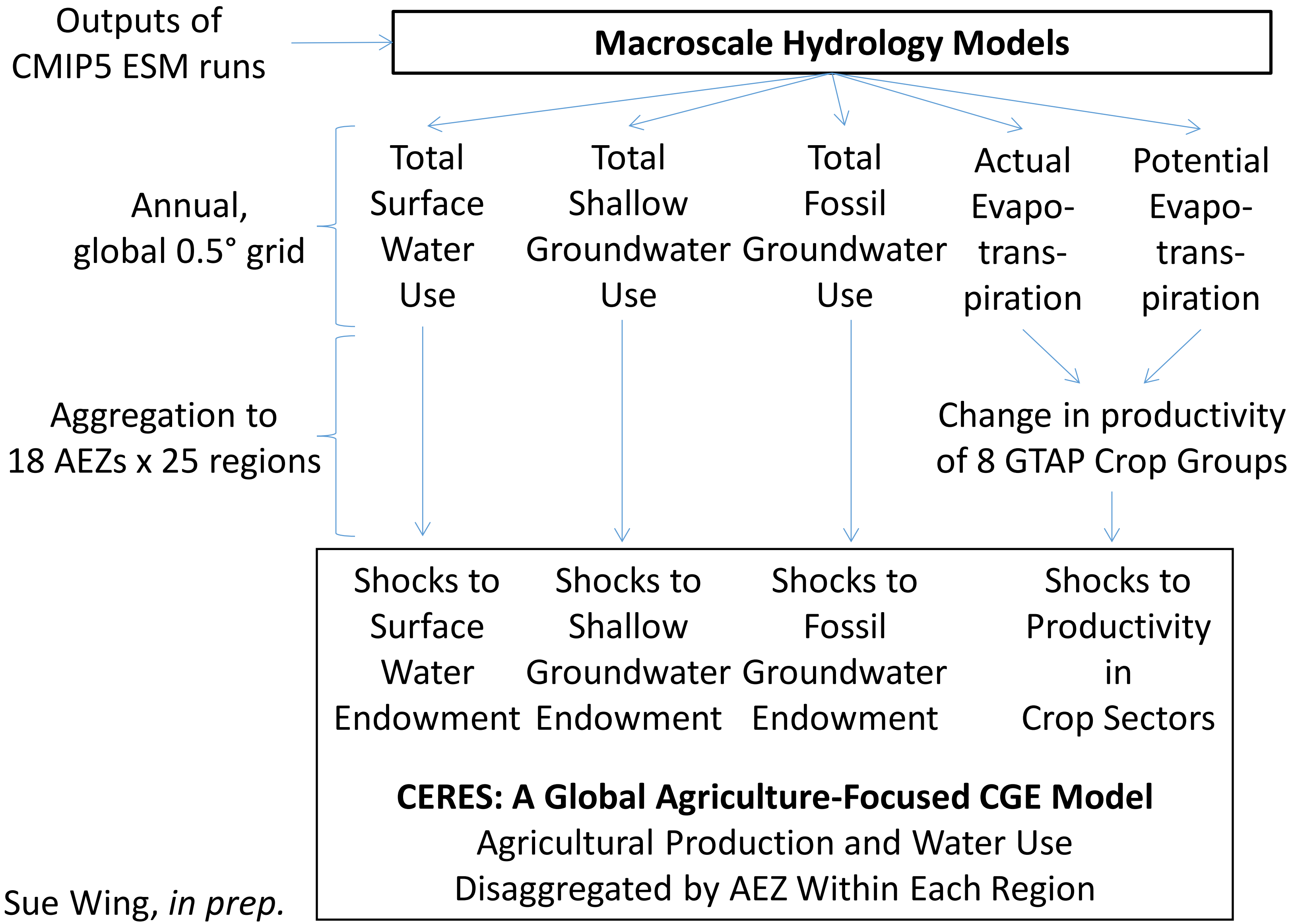


Van Ruijven, De Cian and Sue Wing, *in prep.*

5. Integrated assessment models

- Opportunities/benefits
  - Economic paradigm of market interactions within CGE or even PE SPE models embodies an internally-consistent logic that is fundamental for organizing useful representations of multi-scale, multi-sector impacts
- Challenges/obstacles
  - Aggregation bias: neither the spatial nor temporal scales of IAMs matches those at which endpoints typically manifest themselves, necessitating aggregation of impacts which may have opposite signs, which biases downward estimates of their economic consequences
  - Getting this right requires spatial/temporal/sectoral disaggregation which is costly in terms of development and computational effort
  - How to best represent the economic consequences of different impact endpoints (e.g., shocks to producers' production/cost functions, consumers' utility/expenditure functions, and/or economy's factor endowments)
  - Given the substantial effort necessary to develop an IAM, there is a tendency to either not change its fundamental structure—which necessitates adding a layer of translational calculations between emulator- or process model-computes endpoints and the shocks, either as separate calculations or loosely connected auxiliary detail, which may introduce systematic biases
  - Conceptual and data difficulties of shoe-horning non-market impacts into a framework fundamentally based on national accounting
- Ways forward
  - SSPs provide a key opportunity for harmonizing future trajectories of GDP/population/emissions that underlie offline impact calculations and baseline scenarios of IAMs
  - "Horses for courses": models that sacrifice detail in some dimensions (e.g., static models that do not step through time but shoot forward to an assessment period, consider a restricted range of impacts) to facilitate increased fidelity in others (e.g., spatial detail in impact fields,)

Modeling Climate-Water-Agriculture Linkages

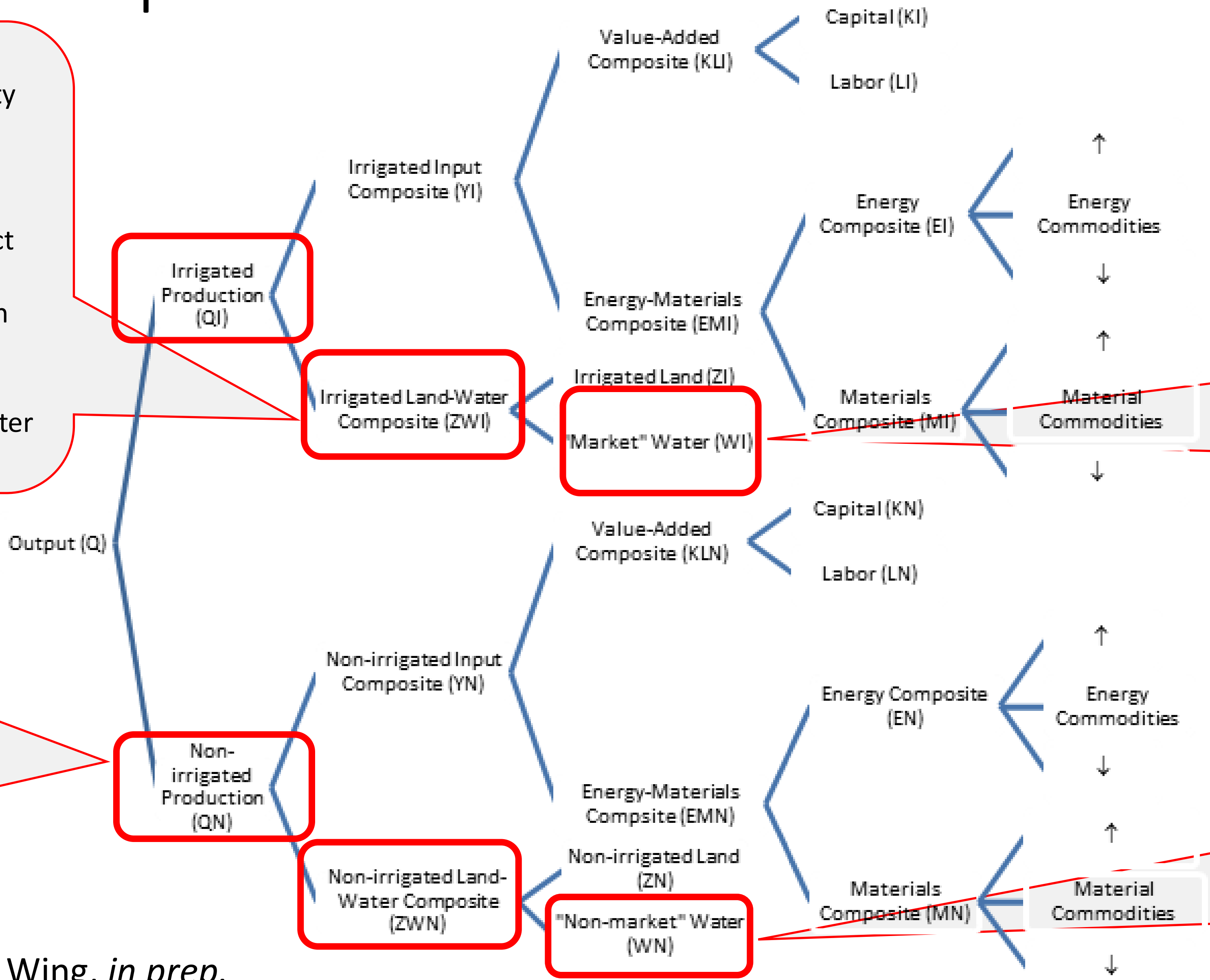


Akin-Olcum and Sue Wing, *in prep.*

Crop Production in CERES: Land-Water Substitution and the Impacts of Shocks to Water Resource Supplies

- Limited substitutability between land-water composite and other-inputs allows water supply shocks to affect crop productivity
- Fixed supply of land in each AEZ generates competition among crops for land and water

- In each region, ag production divided among AEZs, and then into irrigated and rainfed varieties



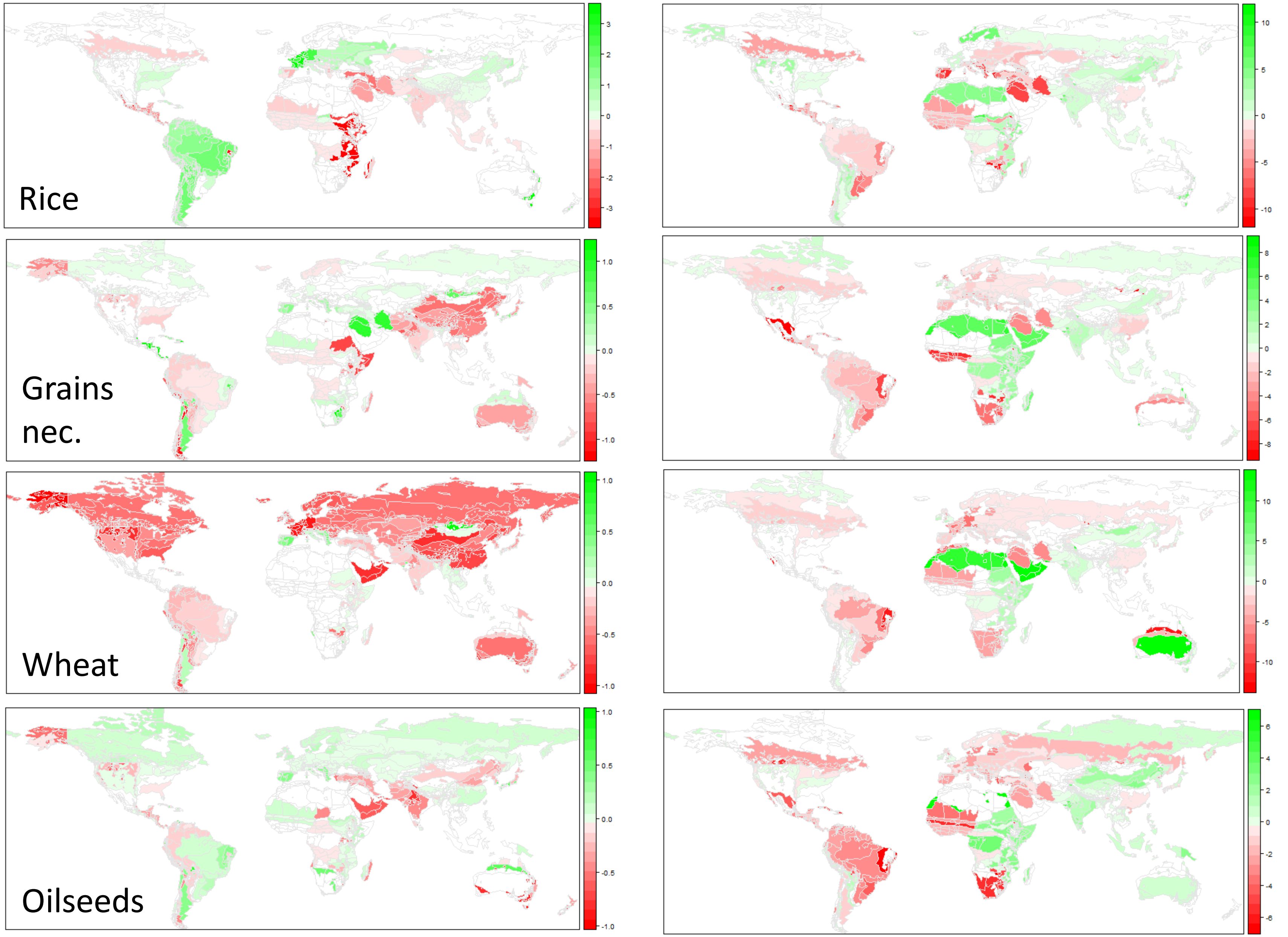
- “Marketed” water is a key input to irrigated crops
- This input is supplied by a water distribution sector
- Irrigation competes for water with household, industrial demands

- “Non-market” water is the key input to non-irrigated crops
- Economy’s endowment is exogenous, driven by climate change
- Role in economy is that of a “fixed factor”

Akin-Olcum and Sue Wing, *in prep.*

Changes in Major Crops’ Production Circa 2050

Rainfed (% change from BAU) | Irrigated (% change from BAU)



Akin-Olcum and Sue Wing, *in prep.*

Summary: Potential lessons for ENGAGE

- I have focused on the fairly static questions of what impacts are and how we assess their economic consequences
- To assess impacts' <u>growth</u> consequences we need to understand
  - How impact-driven declines in the productivity of various inputs or of the production in various sectors of the economy translate into reductions in the rates of long-run TFP or labor productivity growth relative to some assumed future baseline
  - Impacts' <u>direct</u> effects on accumulation via contemporaneous reductions in the effective capital stock due to extreme events
  - Impacts' <u>indirect</u> effects on accumulation via reductions in output and gross fixed capital formation, and diversion of investment from expanding output toward adaptation