Including albedo affects in IAM scenarios

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EMF Workshop on Climate Change Impacts and Integrated Assessment
Snowmass, CO

31 July 2013

U.S. DEPARTMENT OF ENERGY | Office of Science
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What are the Questions?

- How do we design a set of experiments that are interesting and relevant to three different research communities (IAM, IAV, Climate)?

Effects of land use and land use change on climate.

- How do we improve upon the CMIP5 process?

Including albedo in IAM's definition of radiative forcing.

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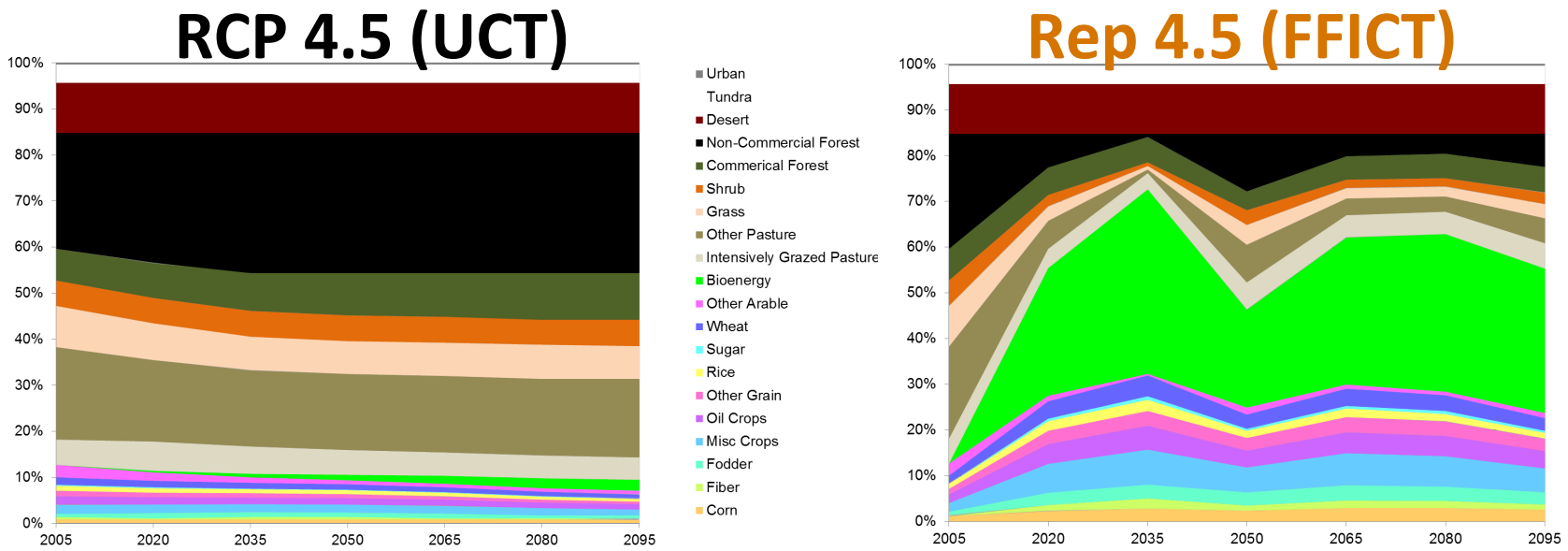
EFFECTS OF LAND USE AND LAND USE CHANGE ON CLIMATE

Quantifying the effect of land cover on temperature: Results using GCAM & CESM

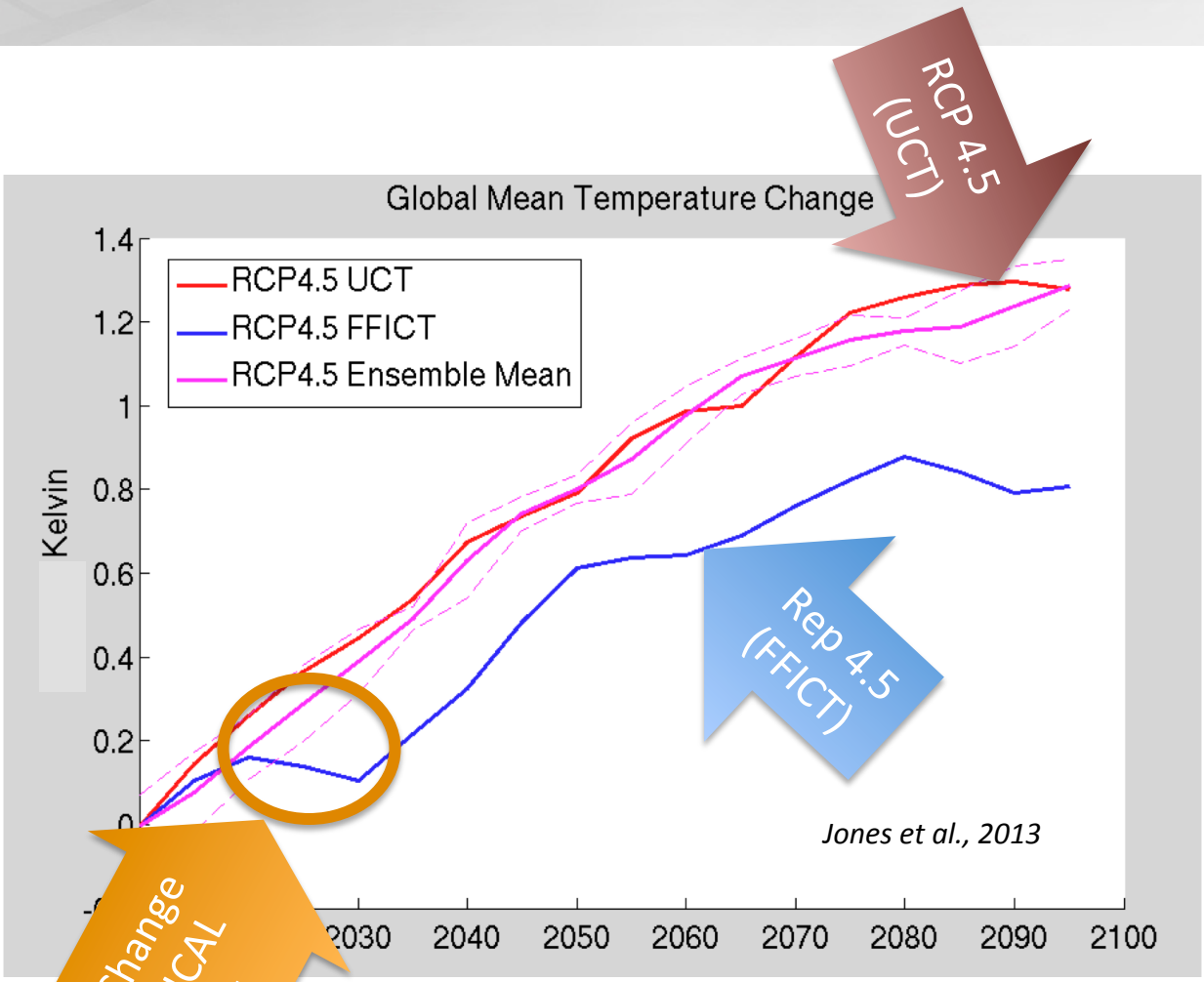
- We run two scenarios: RCP 4.5 (UCT) and Rep 4.5 (FFICT)
- We hold total CO_2 and non-CO_2 GHG emissions fixed and run the two scenarios that limit year 2095 radiative forcing to 4.5 Wm^{-2}.
- In **RCP 4.5 (UCT)** we use the original RCP 4.5 land use.
- In **Rep 4.5** (FFICT) we use the alternative land use—the **ONLY** thing that is different between the two.



Calvin et al. In review

Quantifying the effect of land cover on temperature: Results using GCAM & CESM

- Large change—1Wm^{-2} change in climate forcing from the alternative (Rep 4.5, FFICT) land-use policy assumption.
- Change is almost immediate
  - Time scale of the change from direct physical effects is a decade—in addition to changes in the atmospheric composition of GHGs.
  - Well within a decadal (up to 40-year) time horizon.



*Comparison between **Rep 4.5** and RCP 4.5*
Rep 4.5** is shown to be cooler, with rapid transition under **Rep 4.5

The SSPs provide a wide range of land cover estimates within a single model (GCAM) without climate policy

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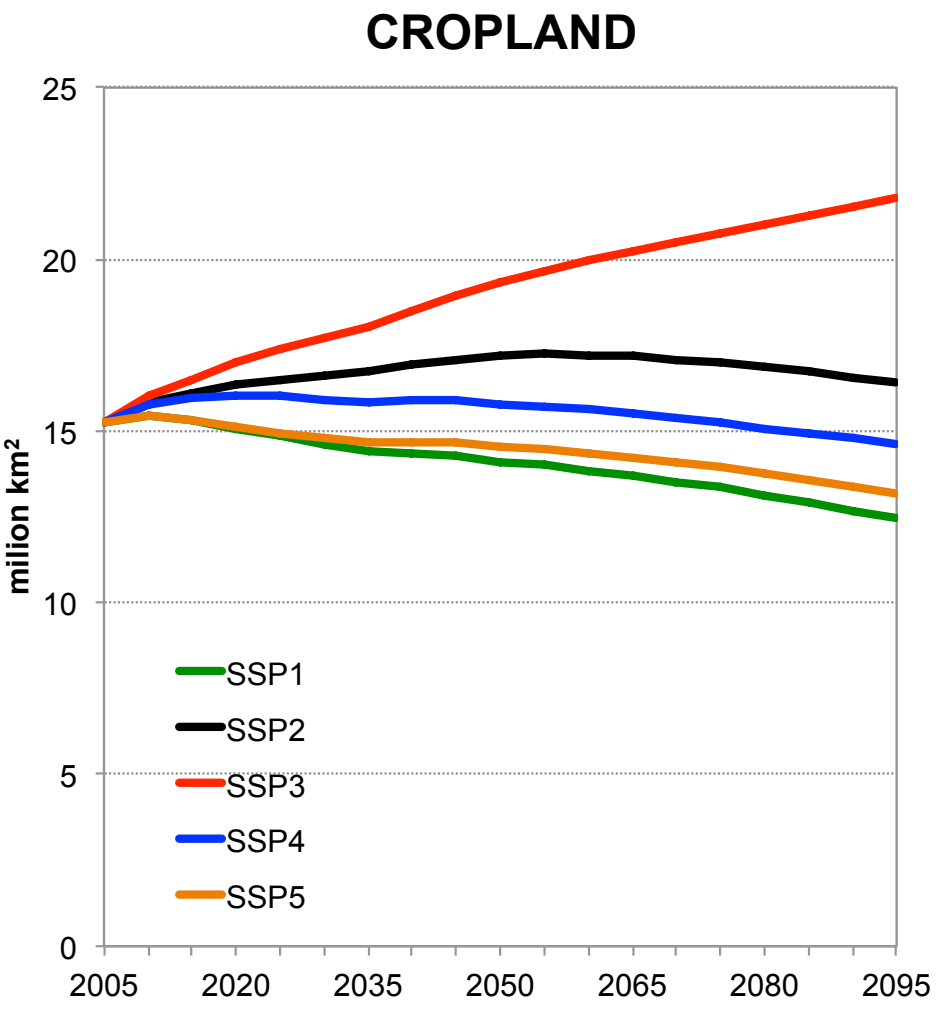

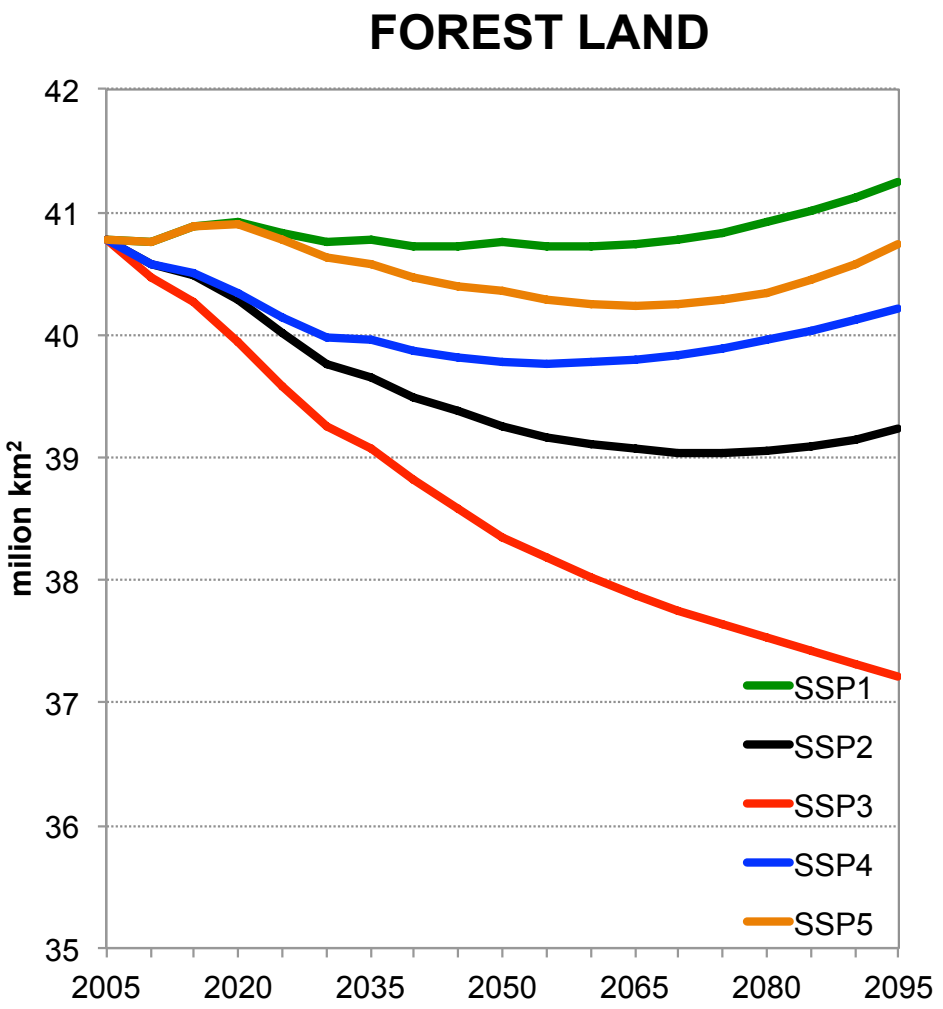

Reaching a climate target (e.g., RCP4.5) requires climate policy, the specification of which will effect land cover.

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NAME	SSP	RF	ACCESSION	LAND POLICY
SSP1_AFFOREST	SSP1	4.5 W/m^2	Immediate	LUC emissions priced at same level as energy-related emissions.
SSP3_AFFOREST	SSP3	4.5 W/m^2	Immediate	LUC emissions priced at same level as energy-related emissions.
SSP3_DELAY	SSP3	4.5 W/m^2	Delay	LUC emissions priced at same level as energy-related emissions when participating.
SSP3_REDD	SSP3	4.5 W/m^2	Immediate	LUC emissions unpriced. Forestland cannot be converted to bioenergy.
SSP3_DEFOREST	SSP3	4.5 W/m^2	Immediate	LUC emissions unpriced. All land is available for bioenergy production.

Layering different mitigation policies to reach RCP4.5 leads to a wider range of land cover scenarios within one model (GCAM).

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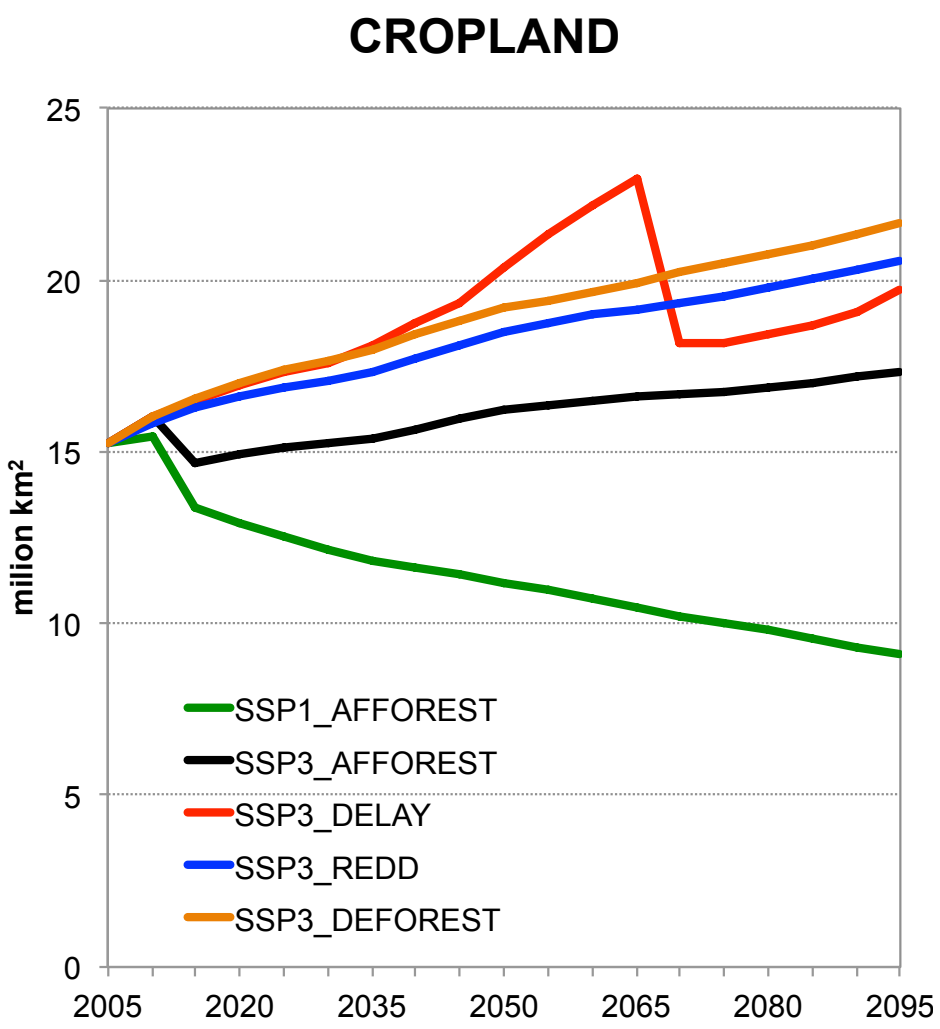

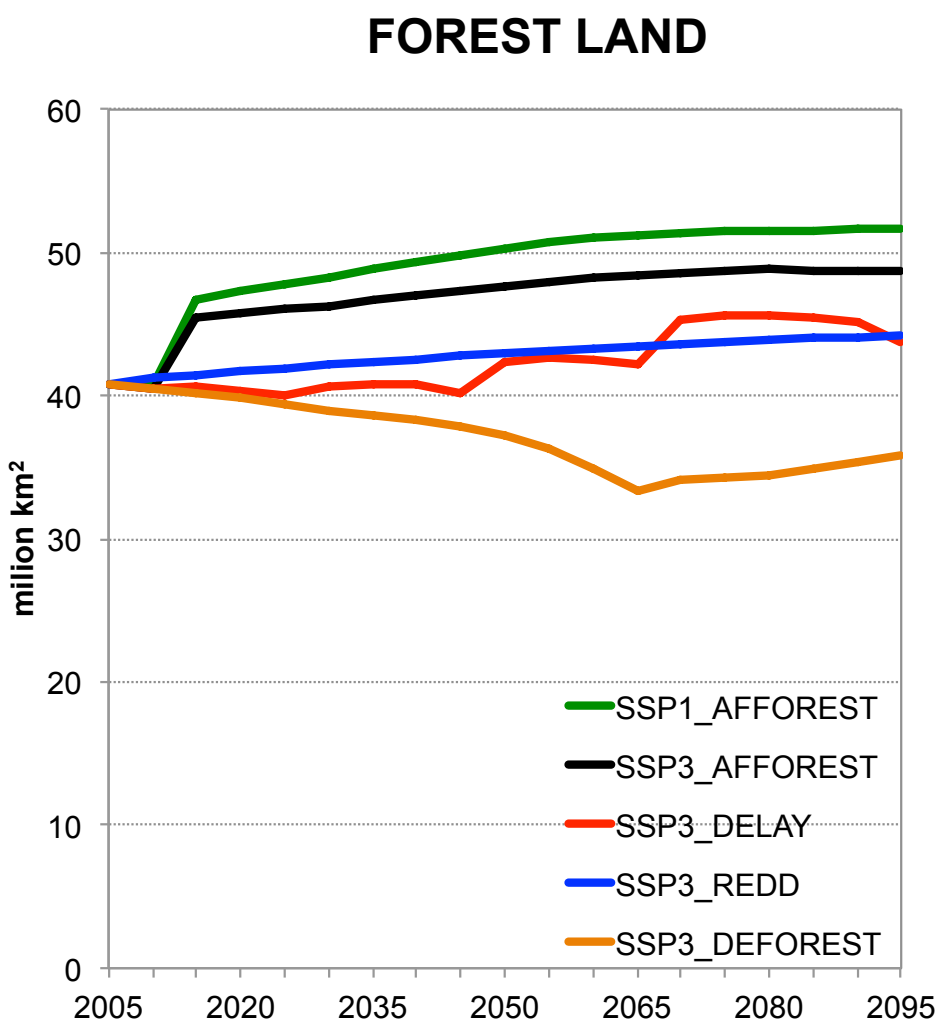

These scenarios could differ both globally and regionally.

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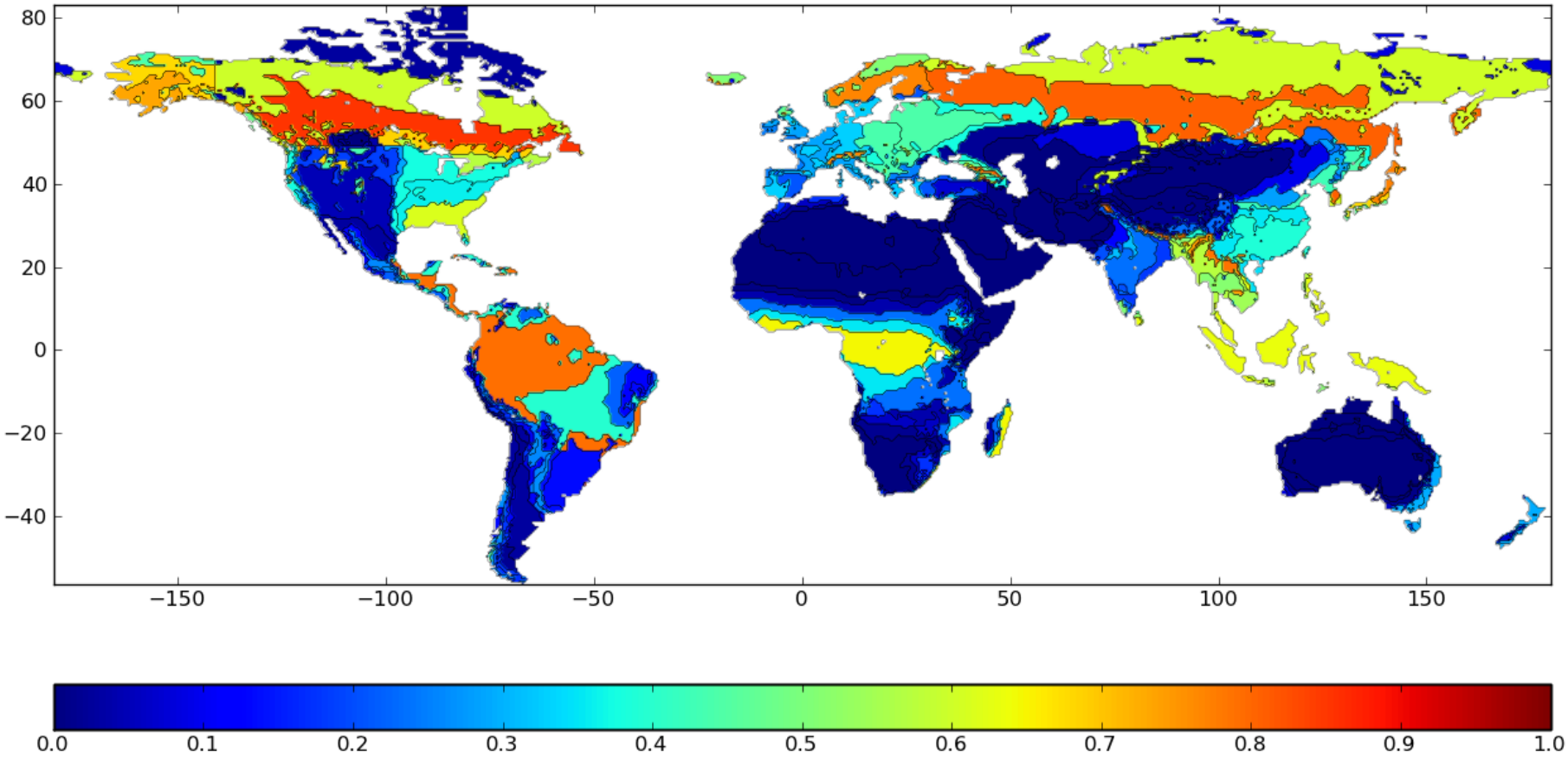
2005 Forest Cover (Fraction of Region)



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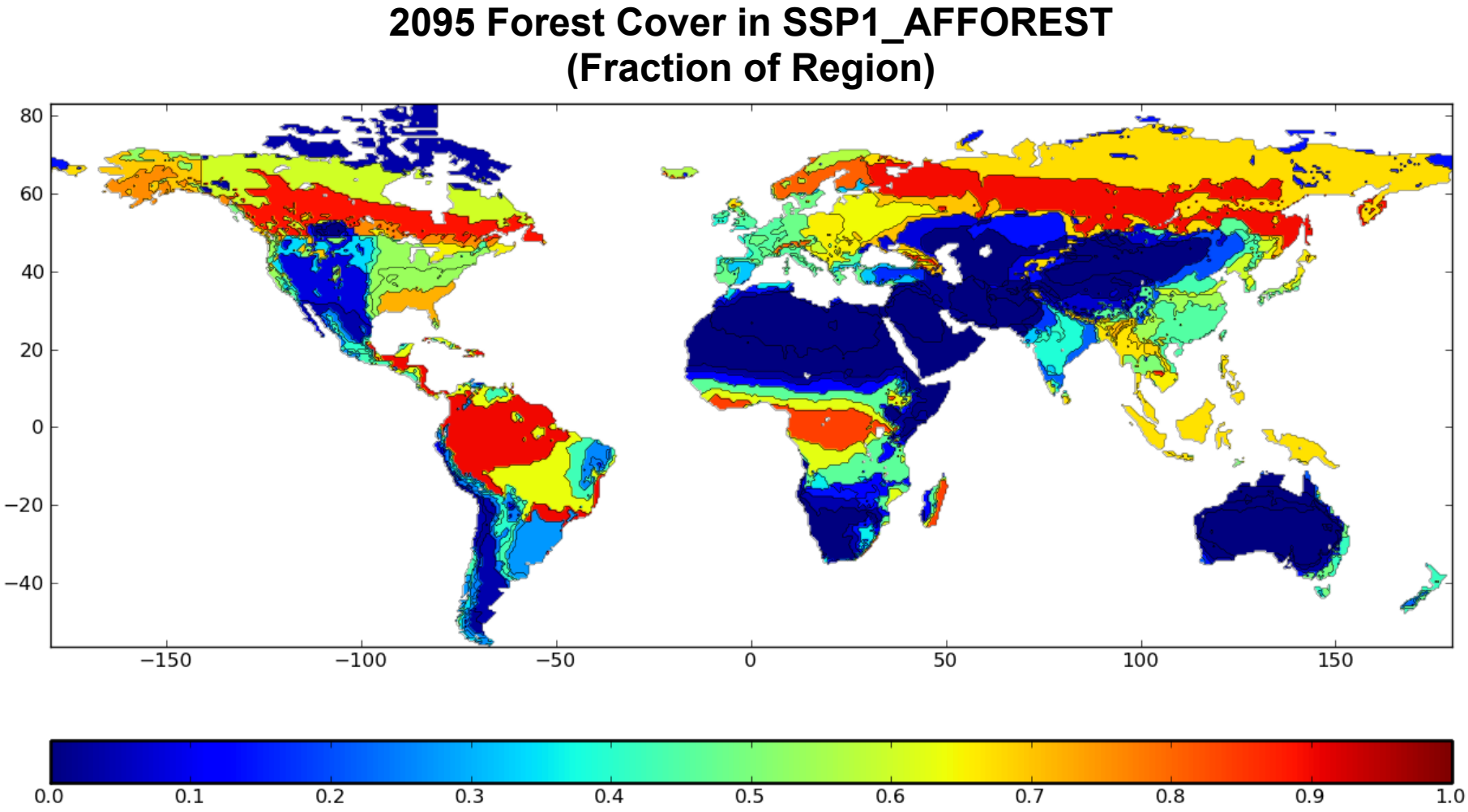

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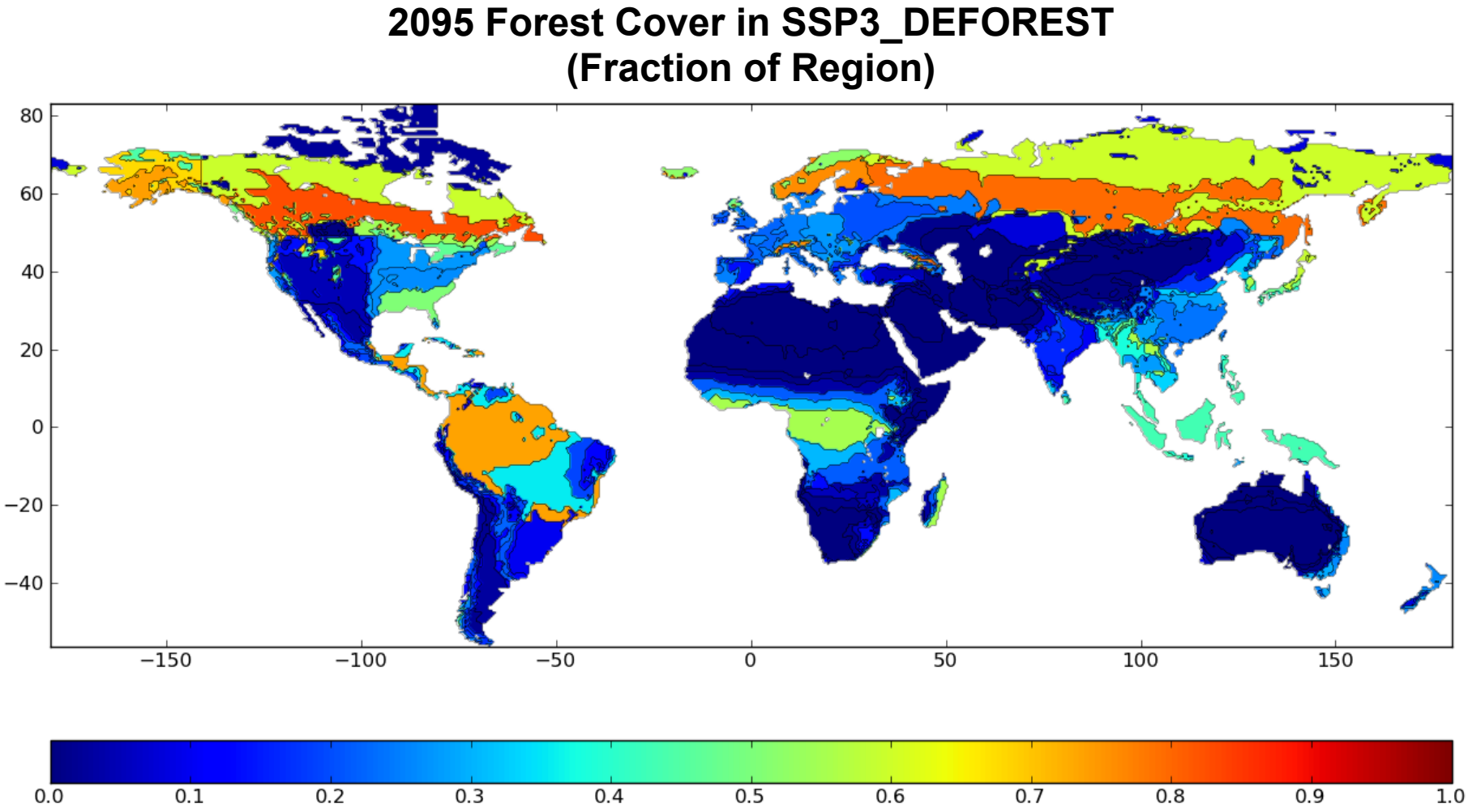

We could choose scenarios with the same atmosphere, but different land cover to explore economics, science, and impacts.

- IAM community may be interested in cost of mitigation and energy system dynamics under different land-based mitigation options.
- Climate modeling community may be interested in effect on temperature and precipitation under different land cover scenarios.
- IAV community may be interested in effect on ecosystem productivity and disturbances under different land cover scenarios.

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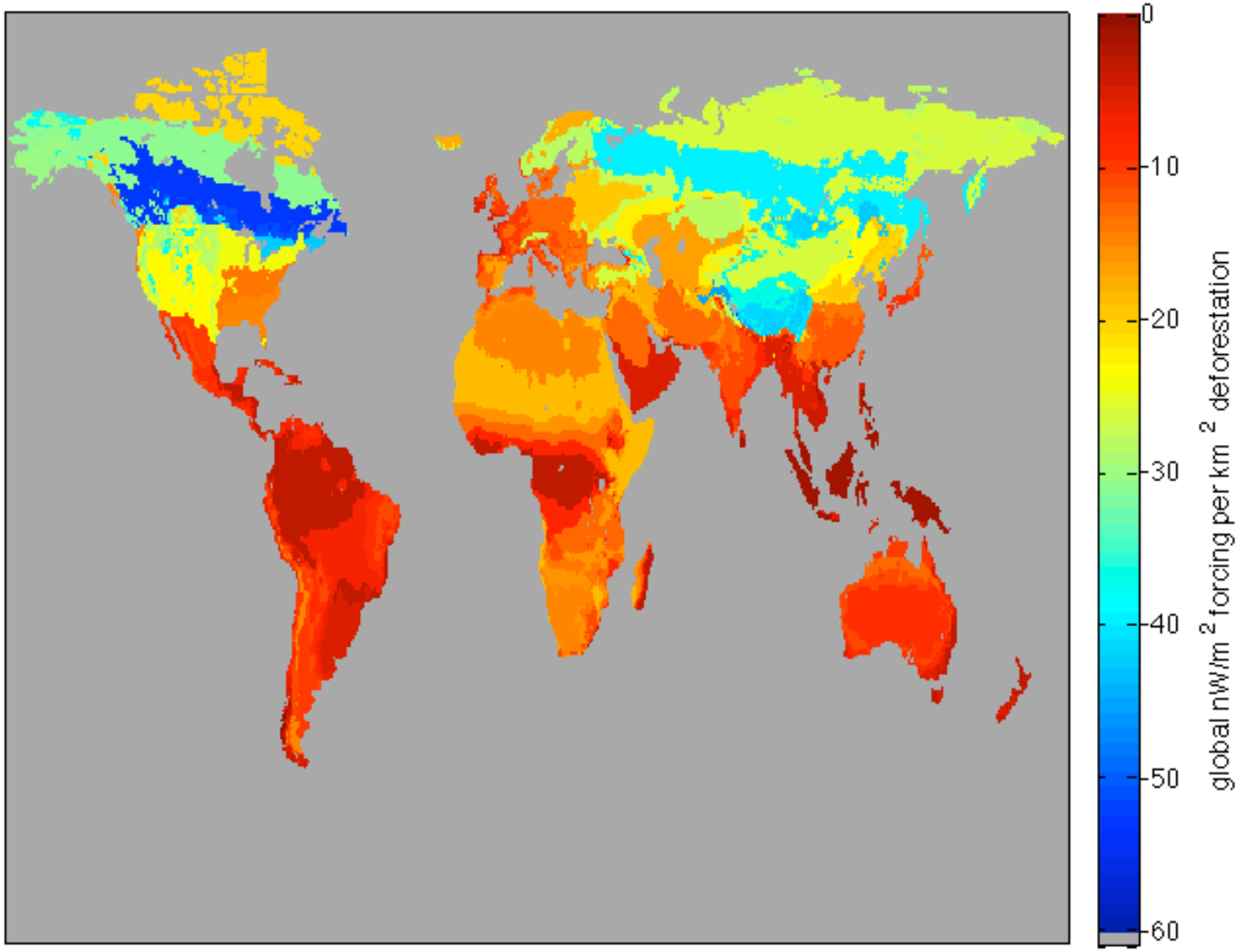
INCLUDING ALBEDO IN IAM'S DEFINITION RADIATIVE FORCING.

Incorporating albedo into GCAM

- Albedo factors:
  - We use CESM to compute the radiative forcing due to land conversion from woody vegetation (forests and/or shrublands) to non-woody vegetation (grassland and/or cropland).
  - We then compute change in top-of-atmosphere radiative flux change that would result from conversion of woody vegetation to non-woody vegetation using an offline radiative transfer model.
- Land conversion:
  - At each timestep, for each region, we compute the amount of land that is converted from woody vegetation to non-woody vegetation in GCAM.
- Albedo:
  - The change in albedo is computed by multiplying the albedo factors and the amount of land converted for each region, and then summing over the regions.
  - This change in albedo is passed into MAGICC.

Albedo Forcing Factors by GCAM Region



Incorporating these factors into GCAM results in different albedo across even reference scenarios.

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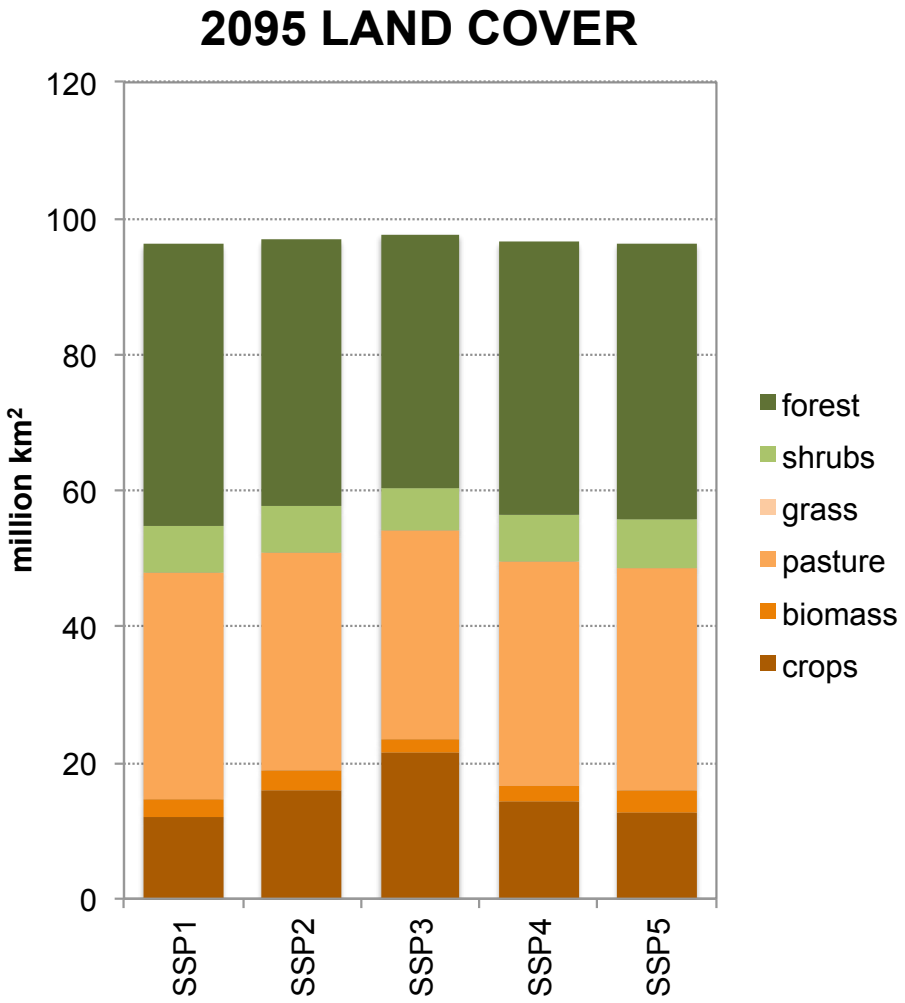

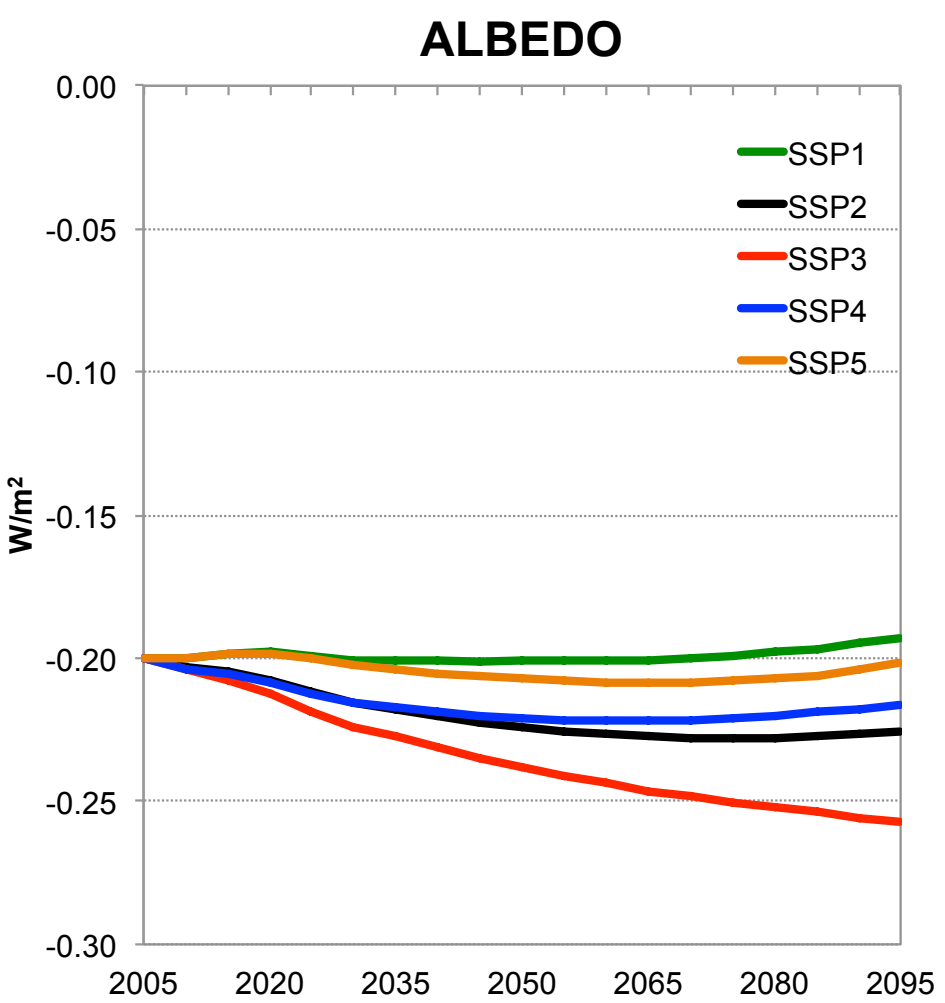

The variation across RCP4.5 replications is as much as 0.35 W/m^2.

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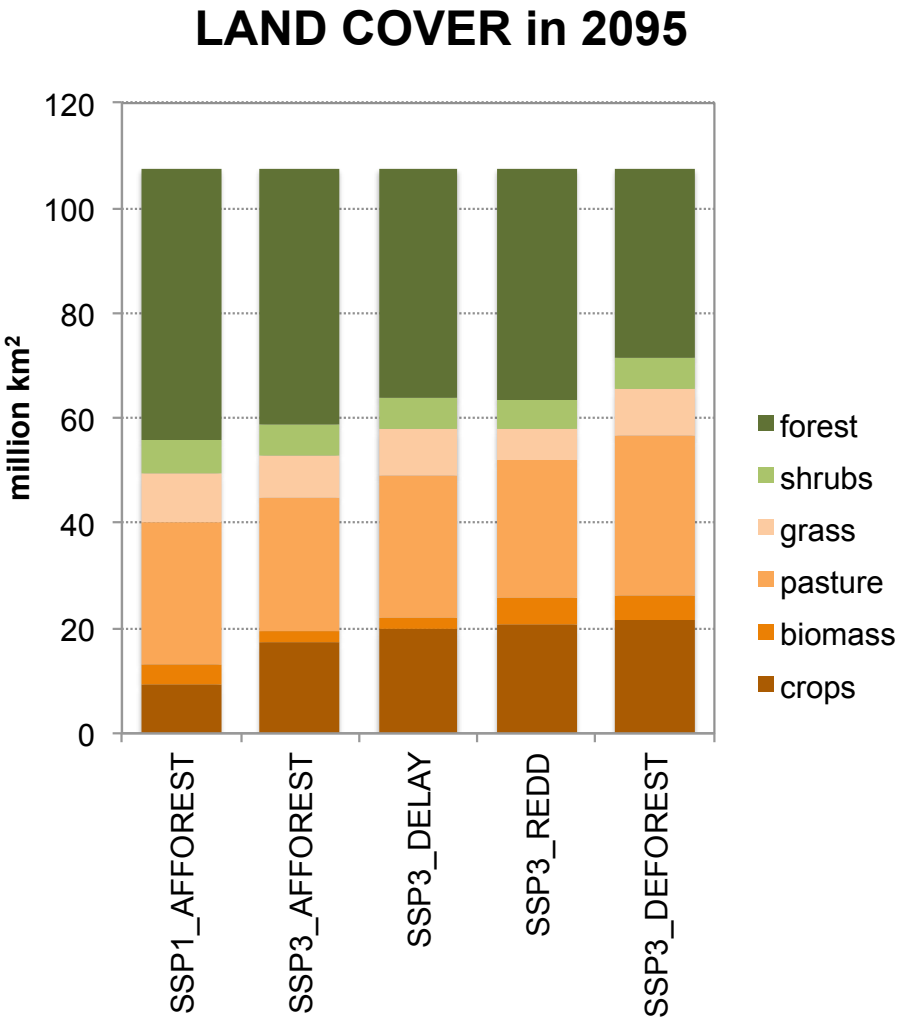
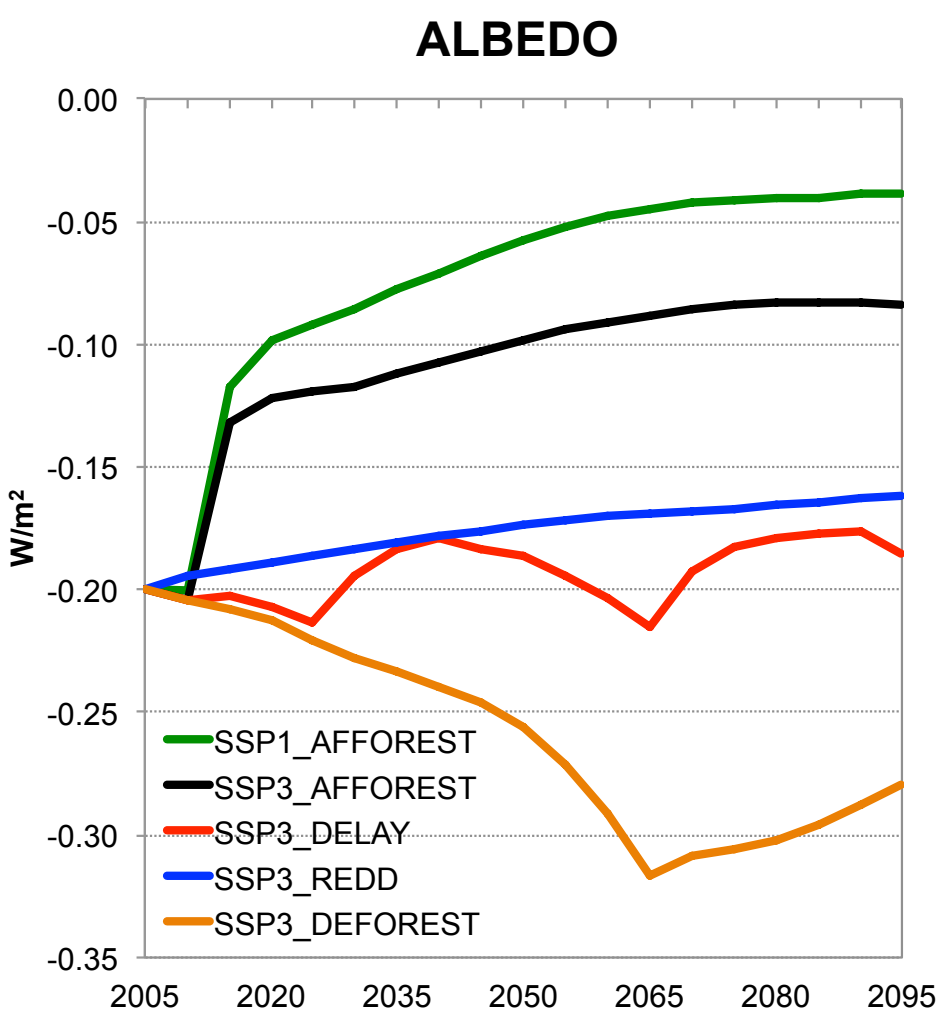


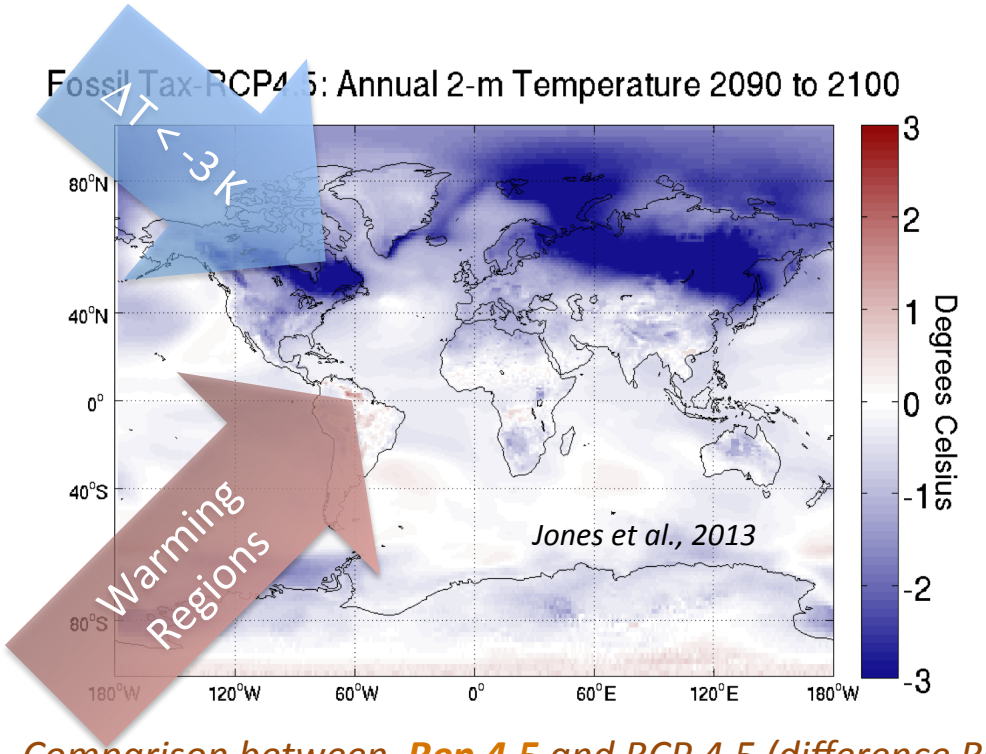


Including albedo in our RCP replications *could* ensure that global climate is more similar across scenarios.

- In this way, we would increase consistency across RCP replications at a global level.
- However, quantifying regional climate is probably still outside the realm of IAMs and would need climate model experiments.

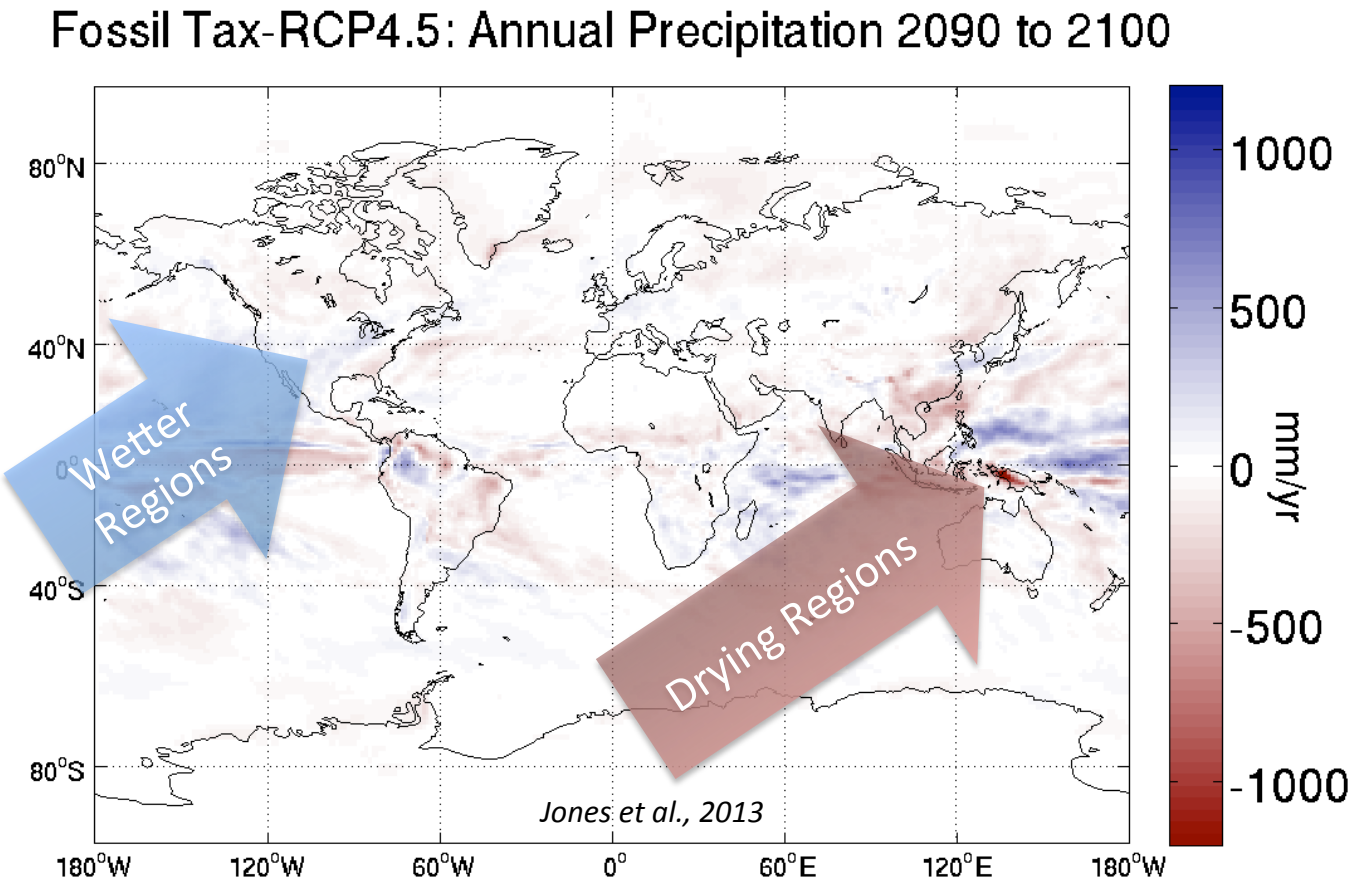
Revisiting the GCAM-CESM land cover experiments: Regional Temperature

- **Regional & Local** changes are much larger than the global changes.
  - Cooling in high latitudes
  - Warming in other regions.



*Comparison between **Rep 4.5** and RCP 4.5 (difference RCP 4.5 less **Rep 4.5**). **Rep 4.5** is shown to be cooler, but with significant regional differences and some regions warmer under **Rep 4.5***

Revisiting the GCAM-CESM land cover experiments: Regional Precipitation



*Comparison between **Rep 4.5** and RCP 4.5 (difference RCP 4.5 less **Rep 4.5**). We observe significant regional differences and some regions wetter and some dryer under **Rep 4.5** as compared to RCP 4.5.*

What are the Questions?

- How do we design a set of experiments that are interesting and relevant to three different research communities (IAM, IAV, Climate)?

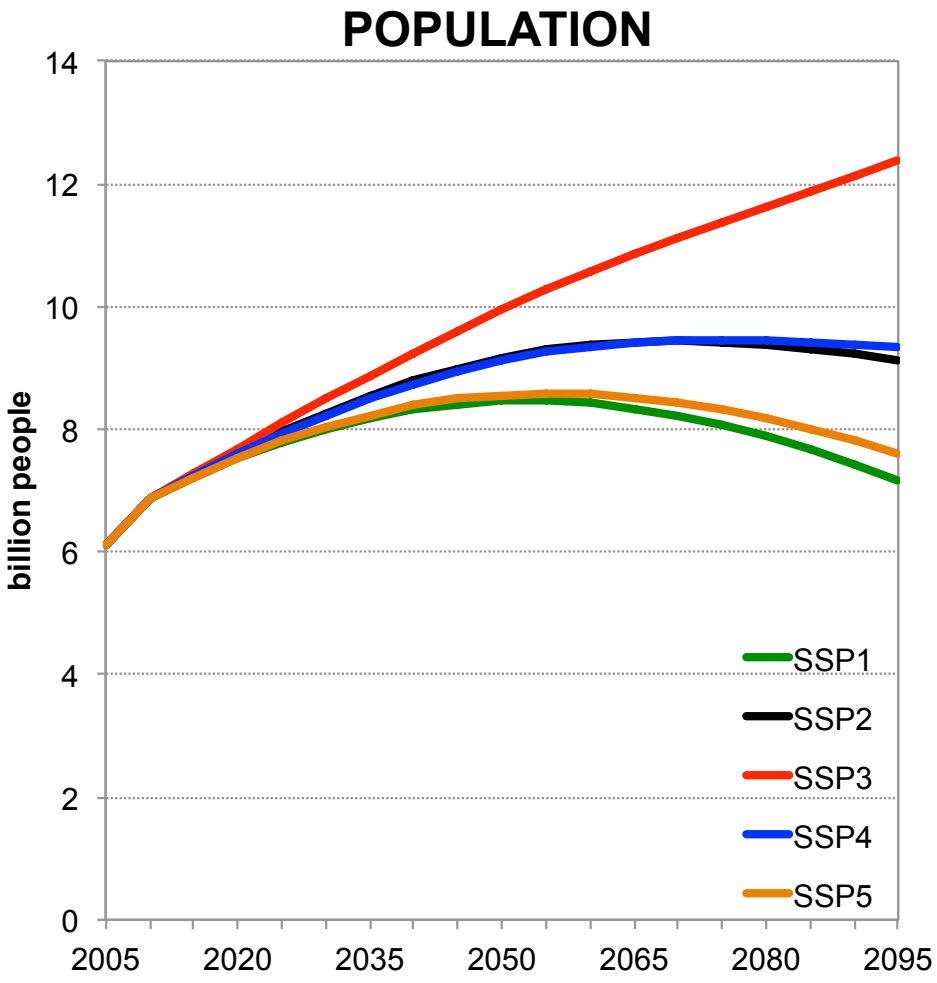
Option: Choose a set of scenarios that isolate the effects of land use and land use change on climate.

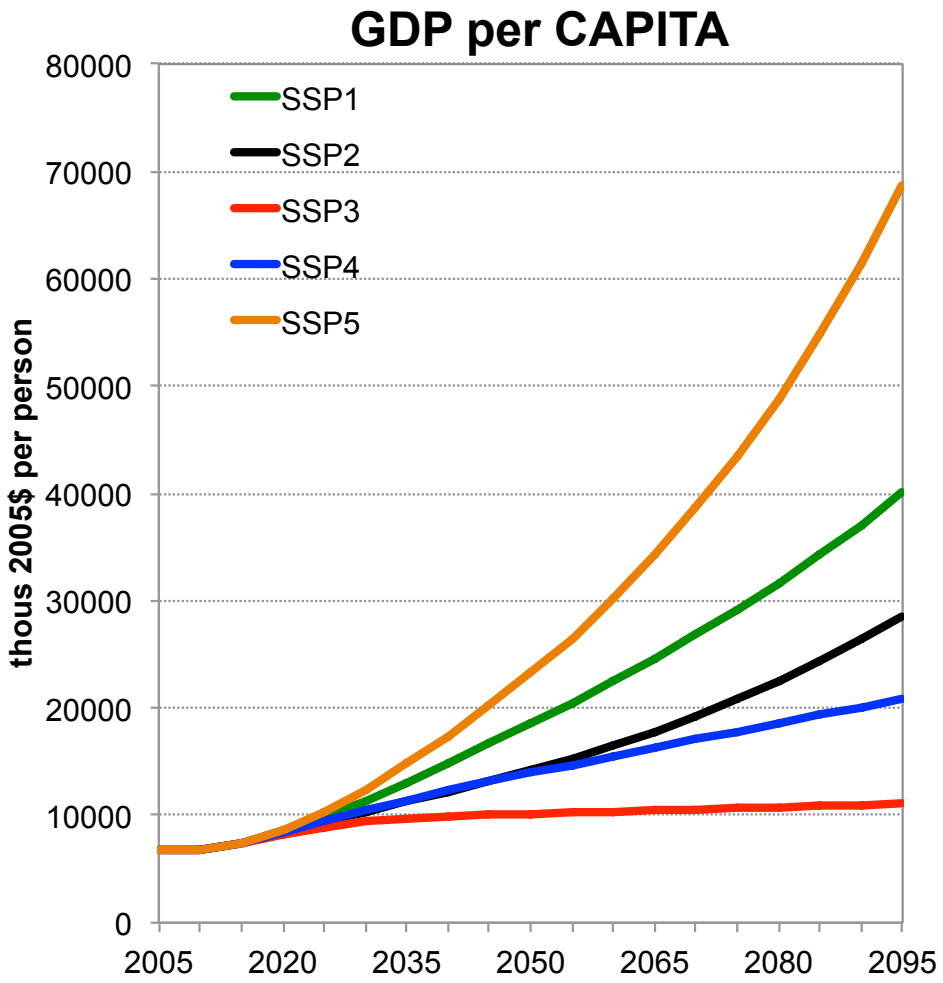
- How do we improve upon the CMIP5 process?

Option: Adjust the definition of radiative forcing in the IAMs to include albedo, increasing consistency across RCP replications.

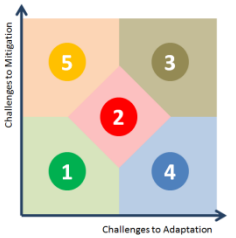
DISCUSSION

The SSPs: Underlying Assumptions





GCAM DRAFT SSP Input Assumptions



NEW SSP Pop & GDP

Technology

	SSP1 Sustainability	SSP2 Middle of the Road	SSP3 Fragmentation	SSP4 Inequality	SSP5 Development First
2100 Population [billion] (IIASA)	7.2 (5th)	9.8 (3rd)	14.1 (1st)	11.8 (2nd)	7.7 (4th)
2100 GDP [trillion 2005 USD, PPP] (OECD)	770 (2nd)	684 (3rd)	355 (5th)	461 (4th)	1,205 (1st)
Energy Service Demands	Low	Medium	High	Medium	High
End-Use Technology	High	Medium	Low	Low / High	Medium
Nuclear / CCS	Low	Medium	Medium	Mixed	Medium
Renewable Technology	High	Medium	Low	High	Medium
Fossil Fuel Extraction	Low	Medium	High	Medium	High
Crop Yield Improvement	High	Medium	Low	Low / Medium	High

Accession Scenarios

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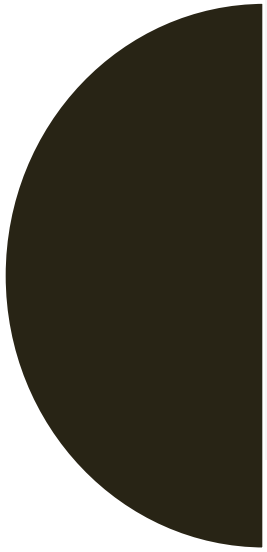
Accession to Global Carbon Market

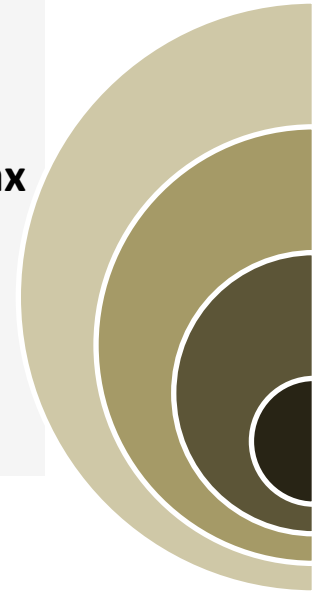
Immediate Accession Scenario ☺



Global CO_2-equivalent Tax from 2015:

All global regions

Delayed Accession Scenario ☹



Joins in 2070: global price by 2085
- Africa

Joins in 2050: global price by 2065
- India / Latin America / Southeast Asia

Joins in 2030: global price by 2045
- USA / China / Canada / Australia / NZ / Korea

Global Carbon Tax from 2015
- Western Europe / Eastern Europe / Japan

- In delayed accession scenario, Former Soviet Union and Middle East Never Join the global carbon market.