NCAR Earth System Laboratory

Attribution of the Biogeochemical and Biogeophysical Impacts of CMIP5 Land Cover Change in CESM

Peter Lawrence

Project Scientist

Terrestrial Science Section
Climate and Global Dynamics Division

The National Center for Atmospheric Research
NCAR
managed by UCAR to serve the community
sponsored by NSF

CMIP5 Land Cover Change Attribution

1. CMIP5 Prescribed Land Cover Change and Wood Harvest as a major climate forcing for both historical and future RCP simulations

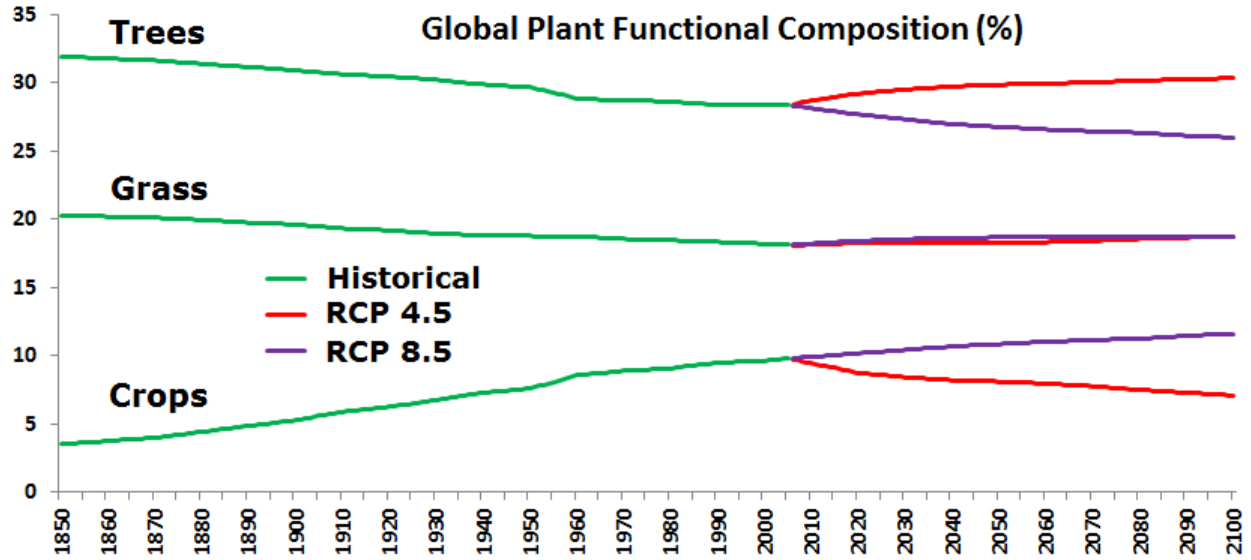
2. The transient changes in CLM4 Biogeochemistry and Biogeophysics were assessed in Lawrence et al. (2012).

3. Attribution of these changes to Land Cover Change was not possible however, due to the interactions between climate change, CO_2 fertilization, and land cover change.

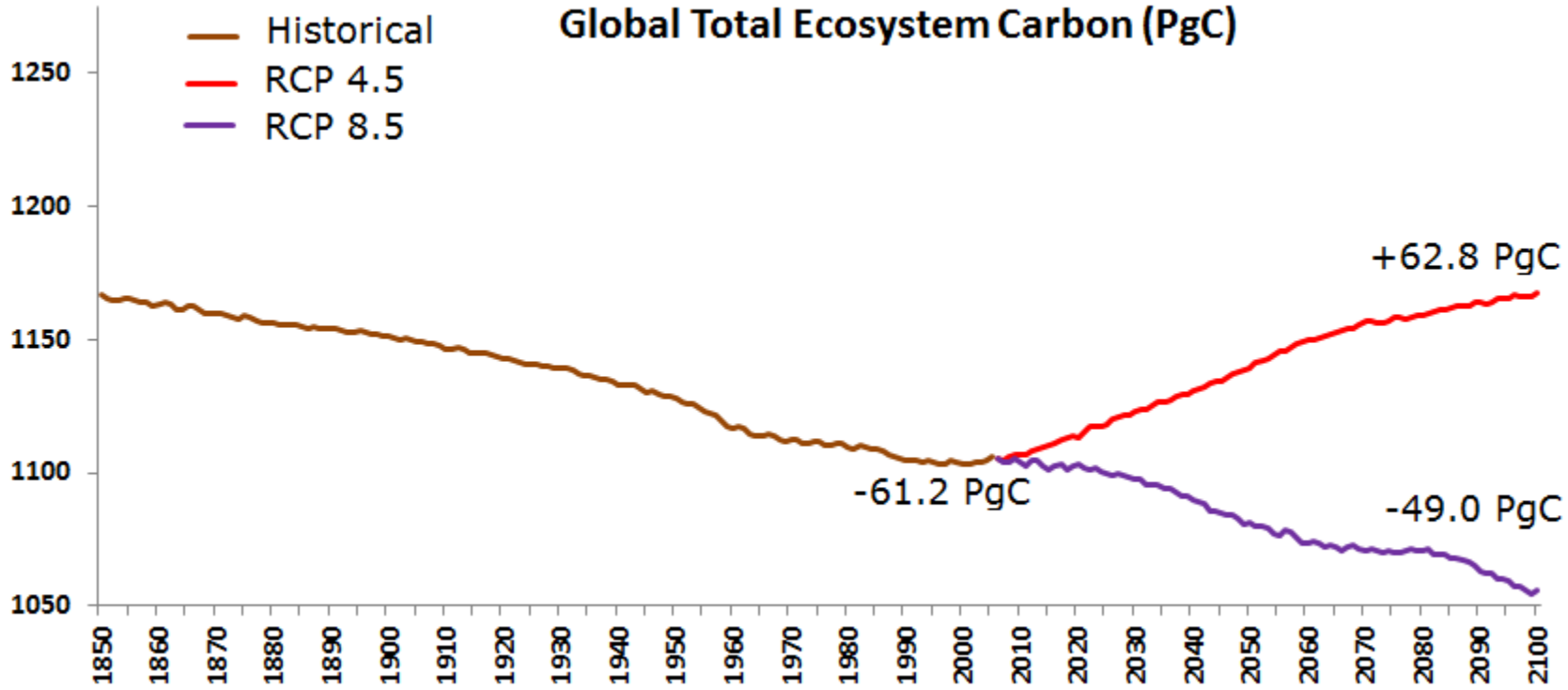
4. To address this we have performed three member ensembles of concentration driven fully coupled transient CESM 1.0 simulations for the Historical, RCP 4.5 and RCP 8.5 time periods with and without Land Cover Change with all other forcings following the CMIP5 protocol.

CMIP5 Land Cover Change Attribution – Exp. Design

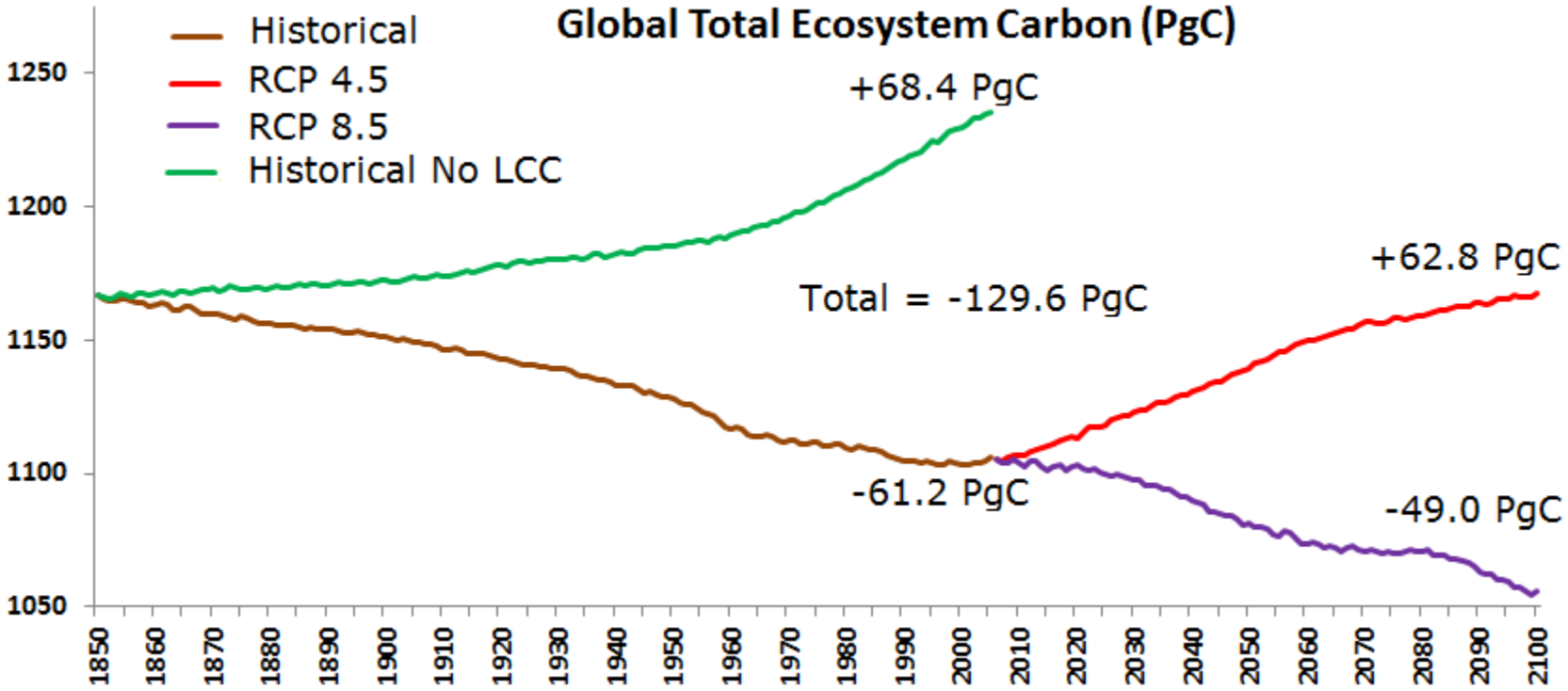
Simulations	Land Cover	Wood Harvest	Other Forcings
1a Historical Control x3	Transient	Transient	Full Transient
1b Historical No Land Cover Change x3	Constant 1850	No Wood Harvest	Full Transient
2a RCP 4.5 Control x3	Transient	Transient	Full Transient
2b RCP 4.5 No Land Cover Change x3	Constant 2005	1995 – 2005 average wood harvest	Full Transient
3a RCP 8.5 Control x3	Transient	Transient	Full Transient
3b RCP 8.5 No Land Cover Change x3	Constant 2005	1995 – 2005 average wood harvest	Full Transient



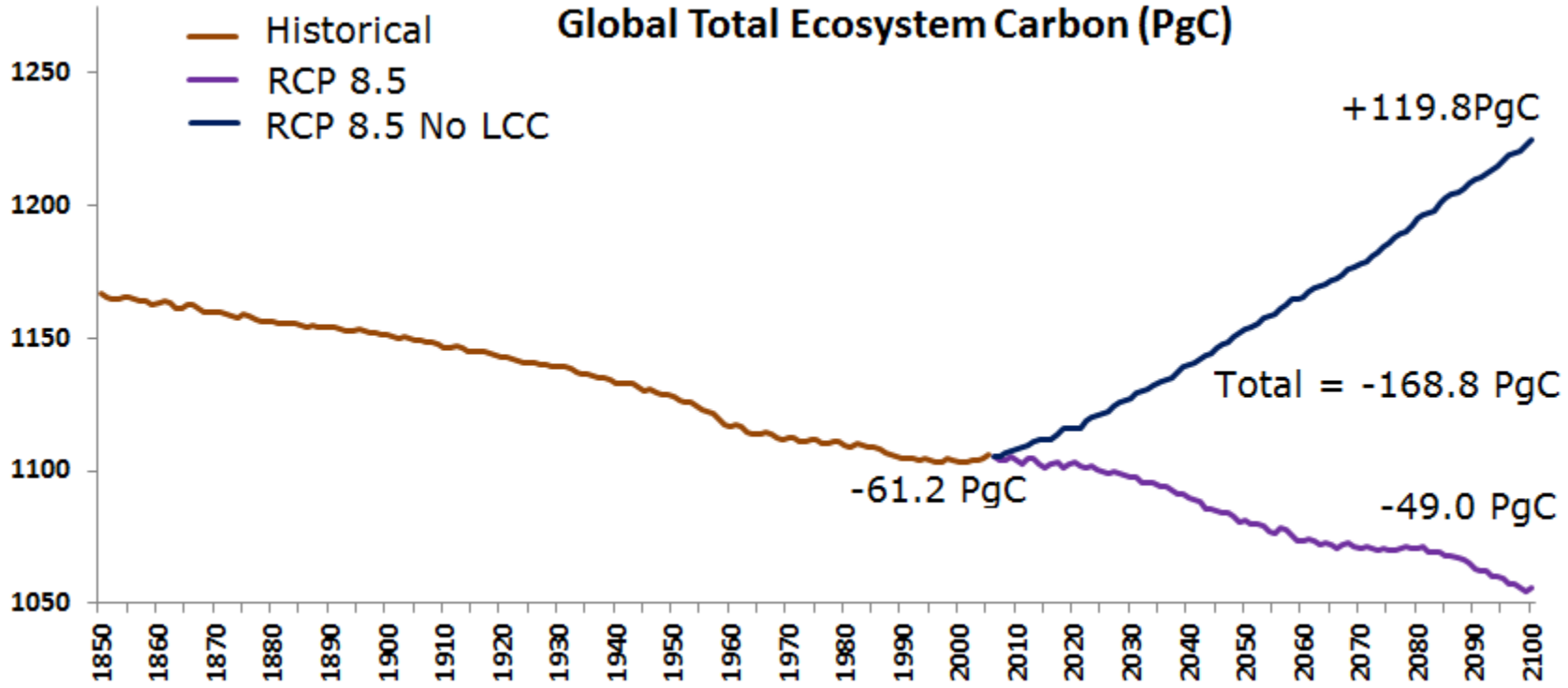
CMIP5 Land Cover Change – Total Ecosystem Carbon



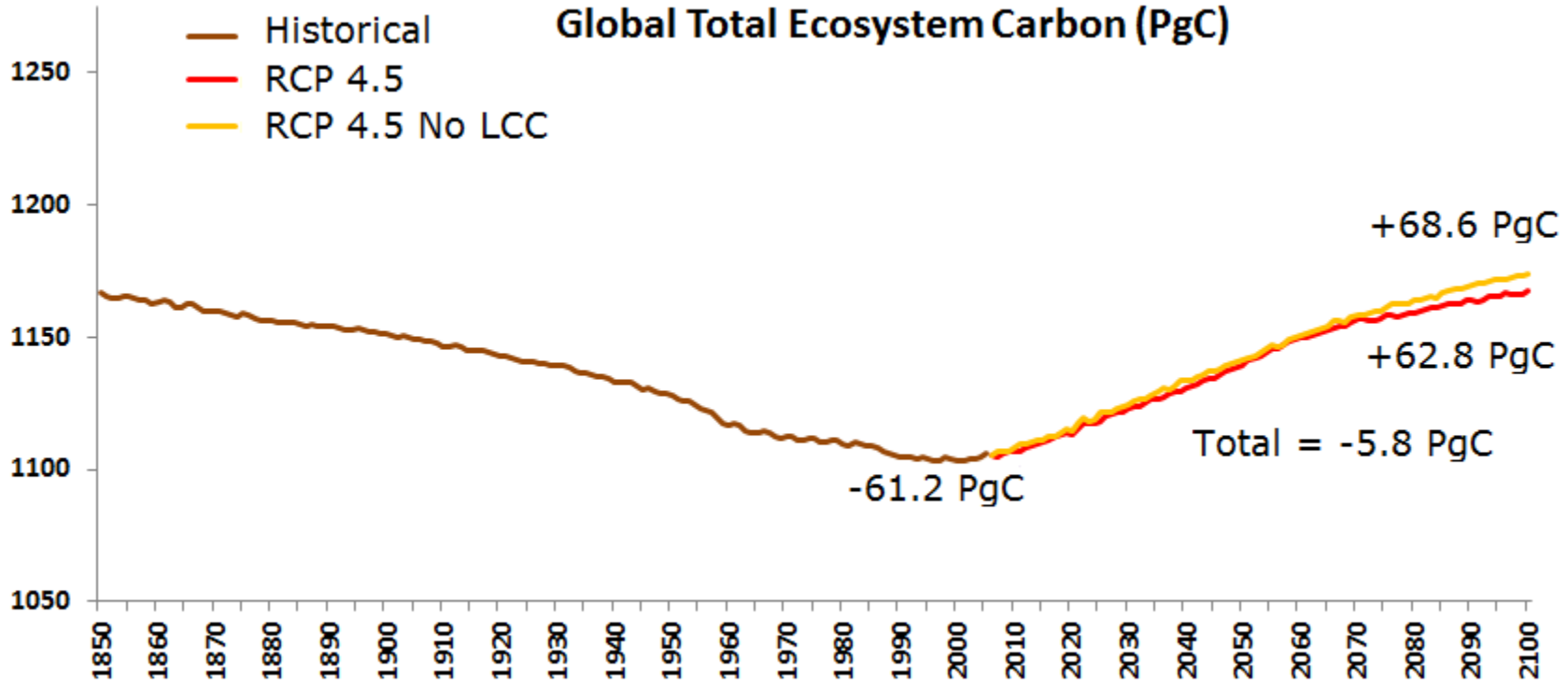
CMIP5 Land Cover Change – Total Ecosystem Carbon



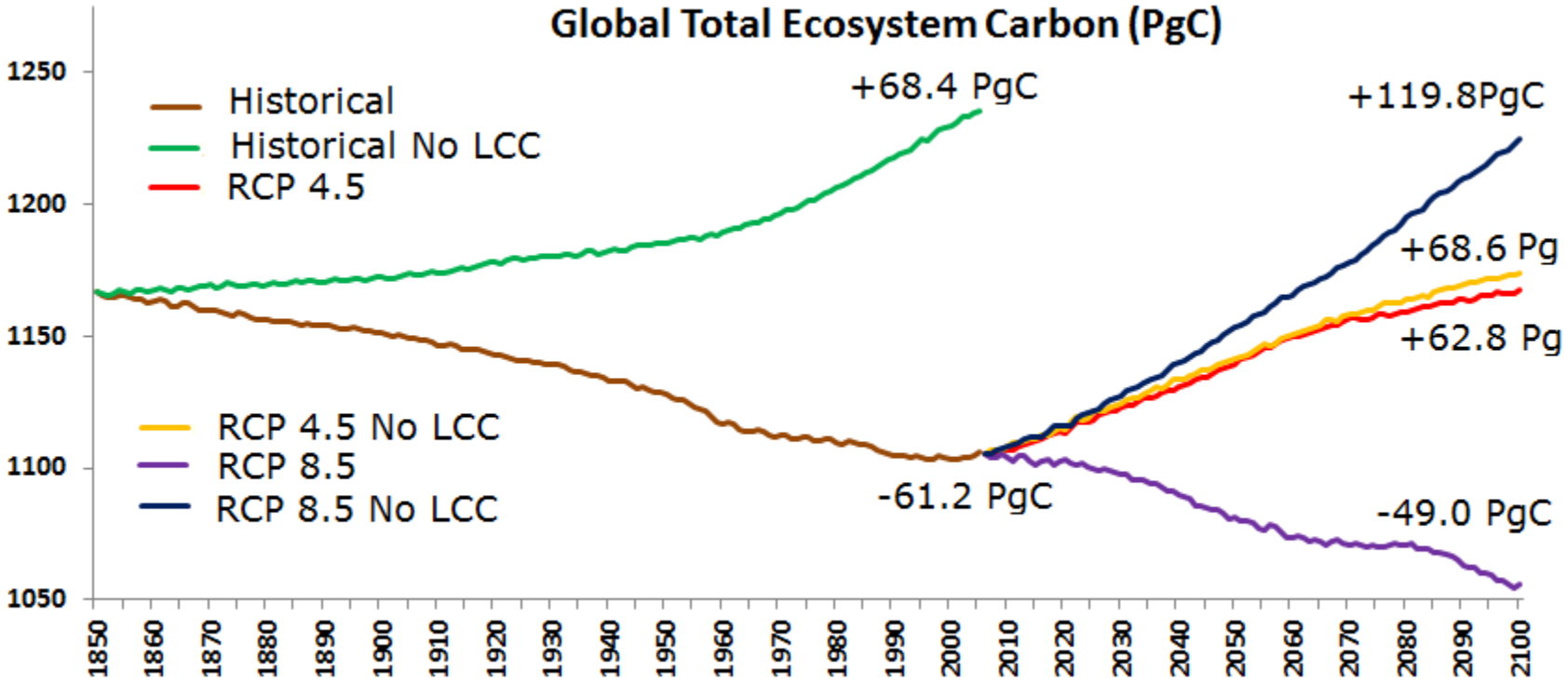
CMIP5 Land Cover Change – Total Ecosystem Carbon



CMIP5 Land Cover Change – Total Ecosystem Carbon

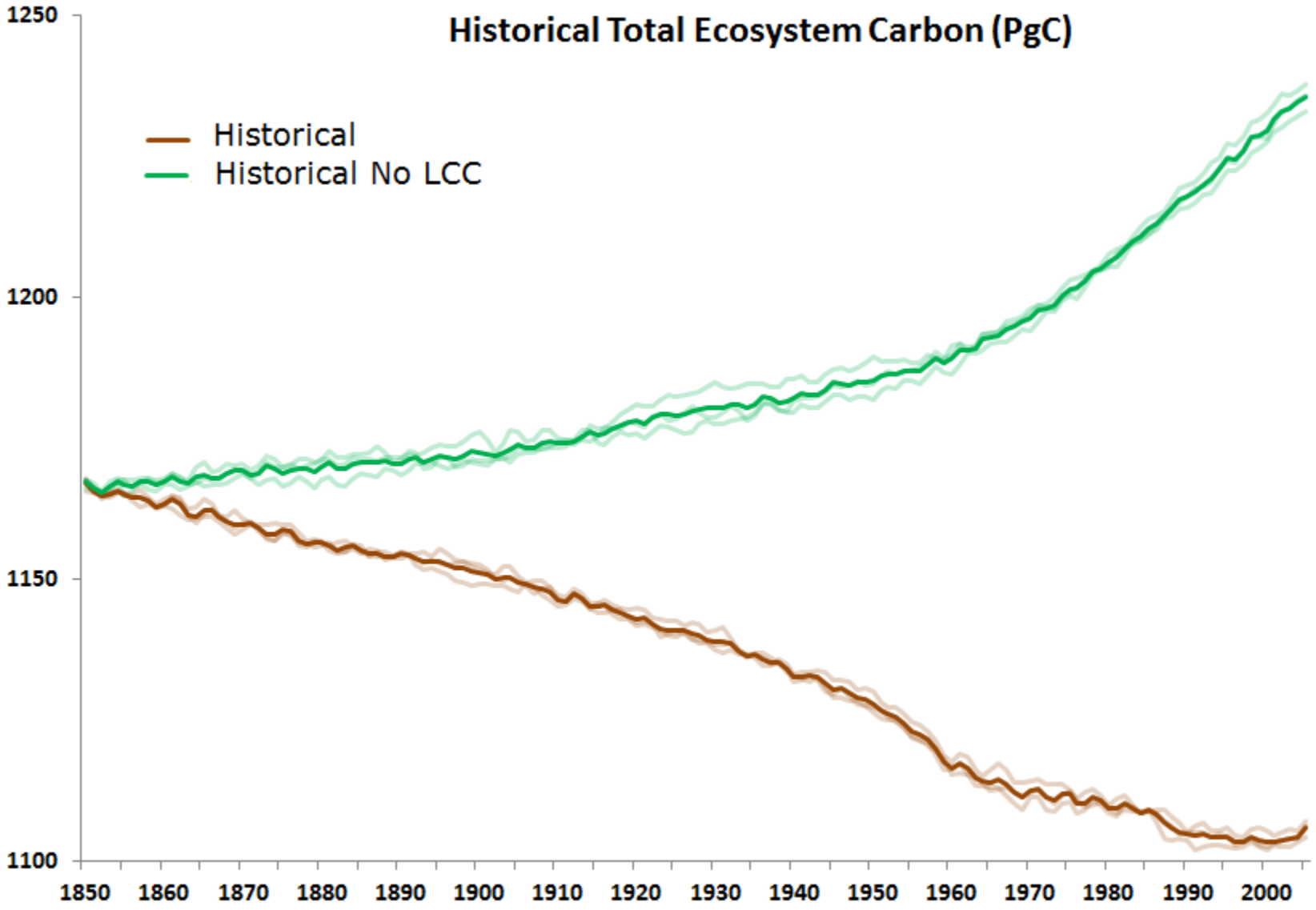


CMIP5 Land Cover Change – Total Ecosystem Carbon

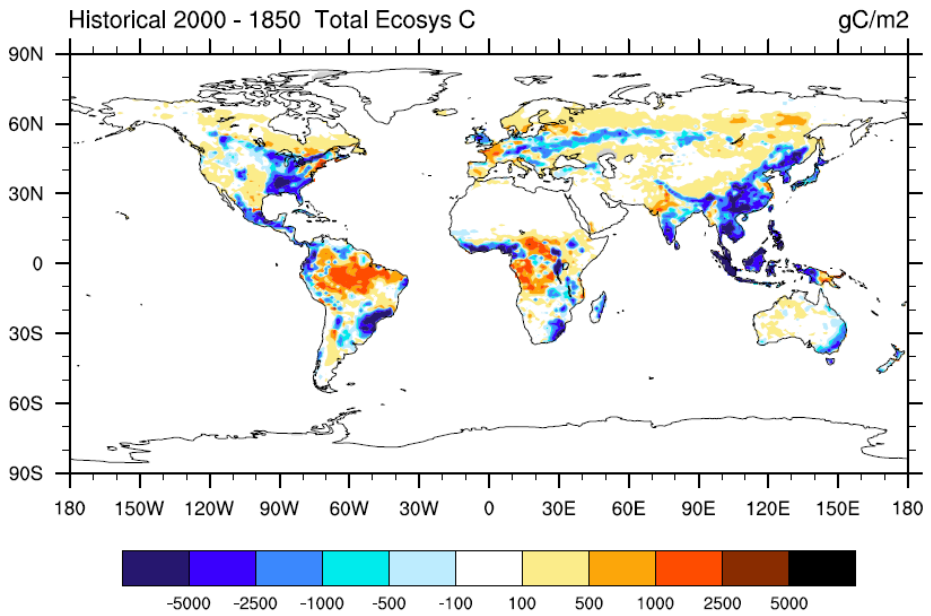


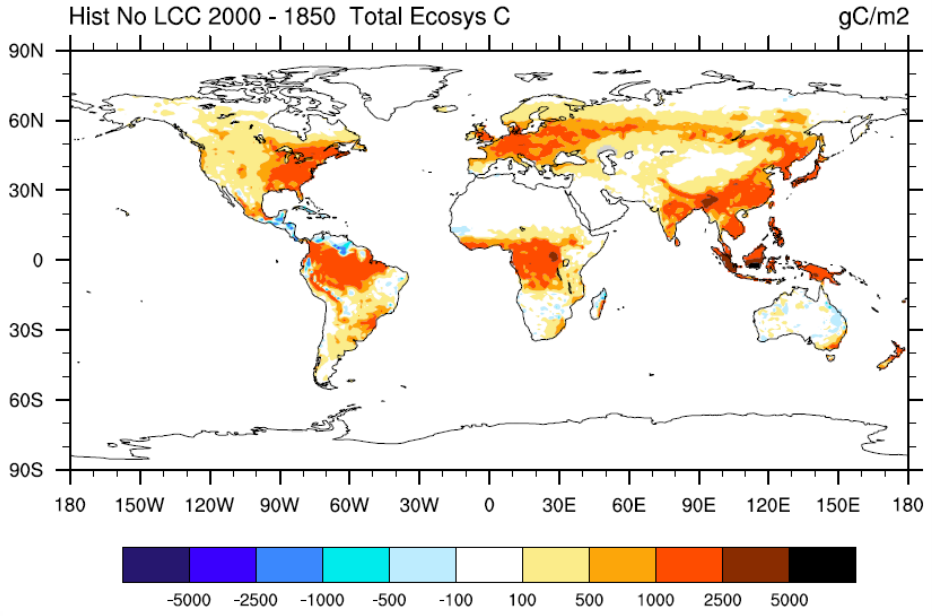
	Transient LCC	No LCC	Net LCC
Historical	-61.2 PgC	+68.4 PgC	-129.6 PgC
RCP 4.5	+62.8 PgC	+68.6 PgC	-5.8 PgC
RCP 8.5	-49.0 PgC	+119.8 PgC	-168.8 PgC

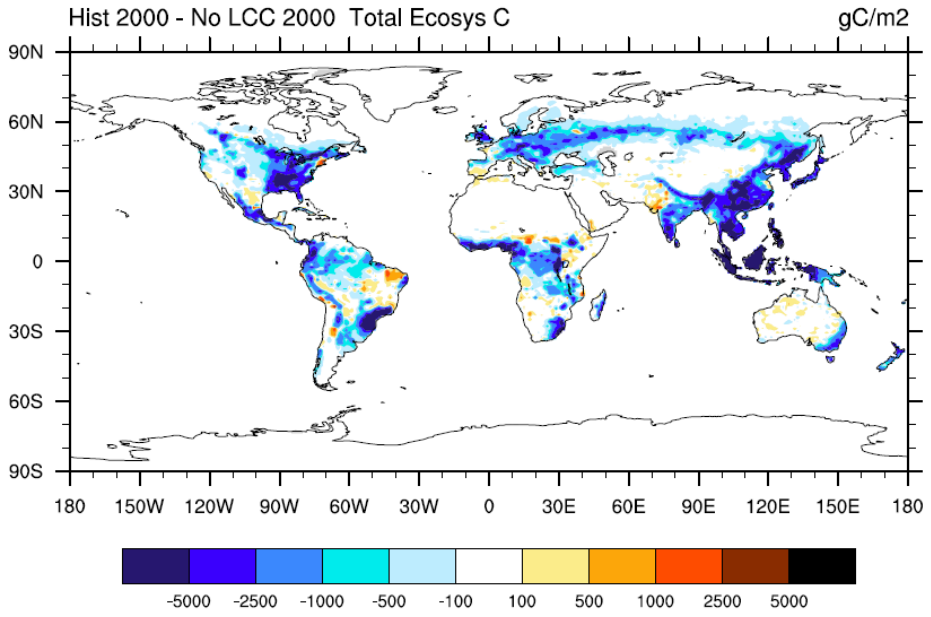
CMIP5 Land Cover Change – Total Ecosystem Carbon

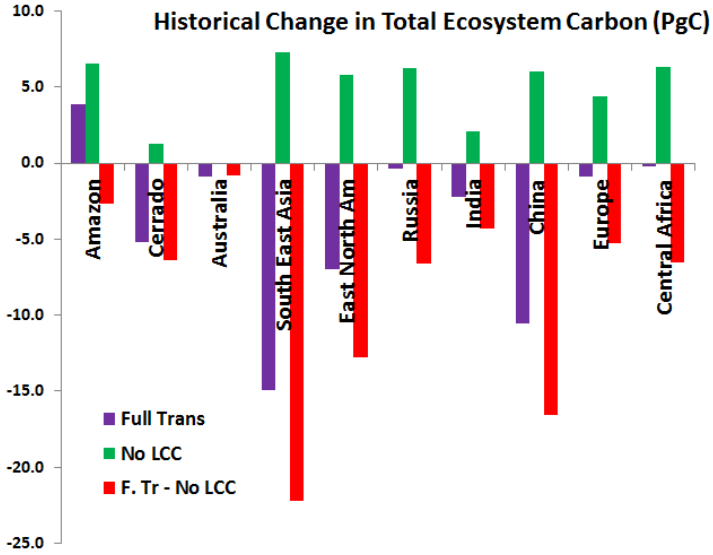


CMIP5 Land Cover Change – Historical Carbon

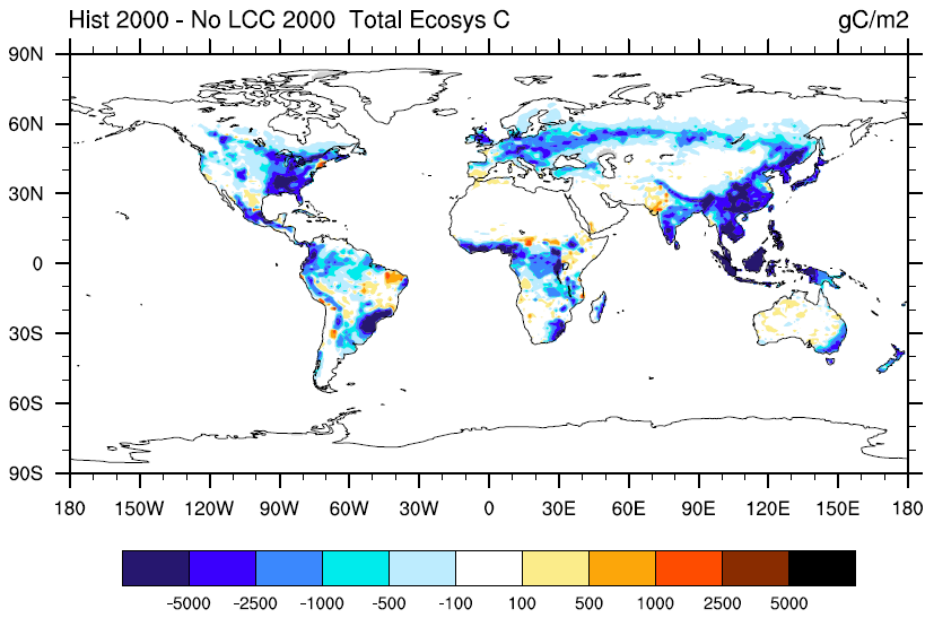


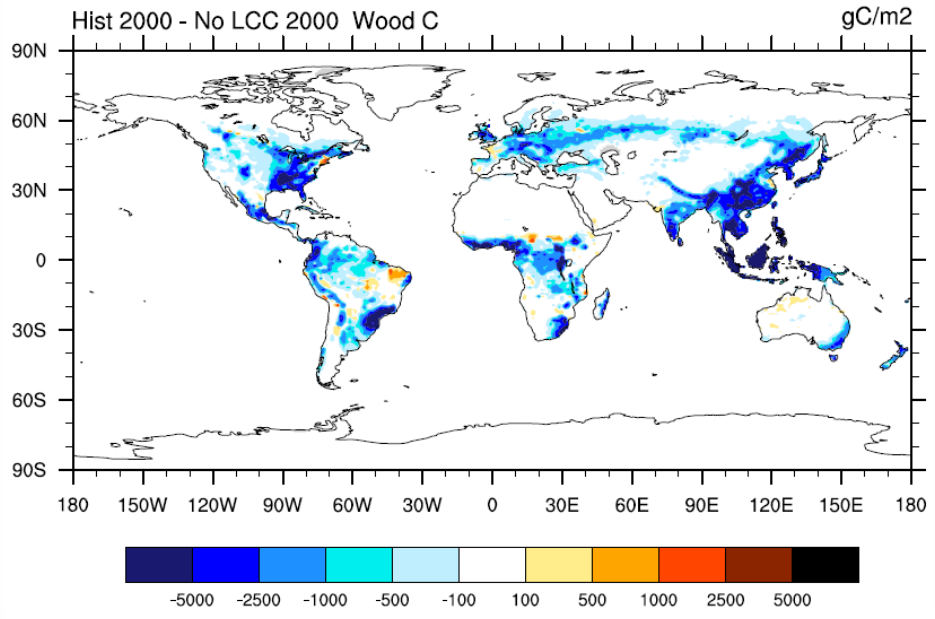


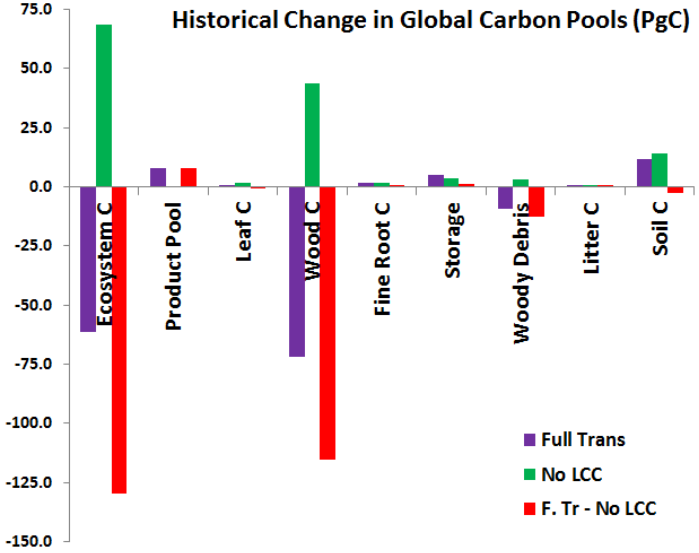


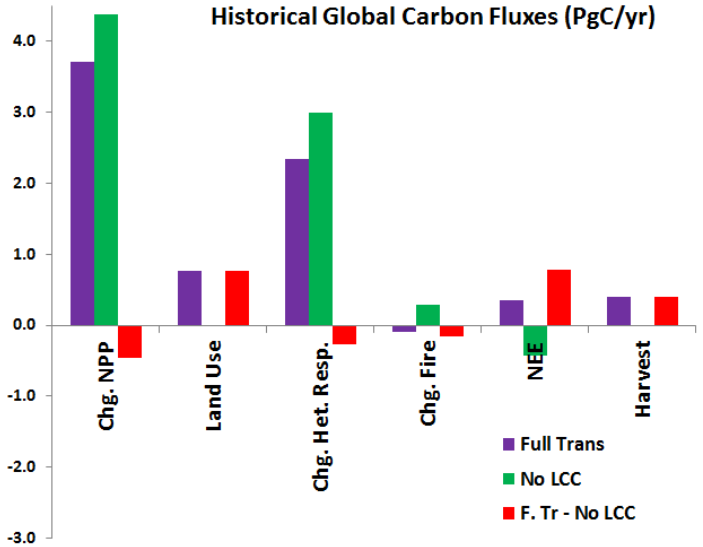


CMIP5 Land Cover Change – Historical Carbon

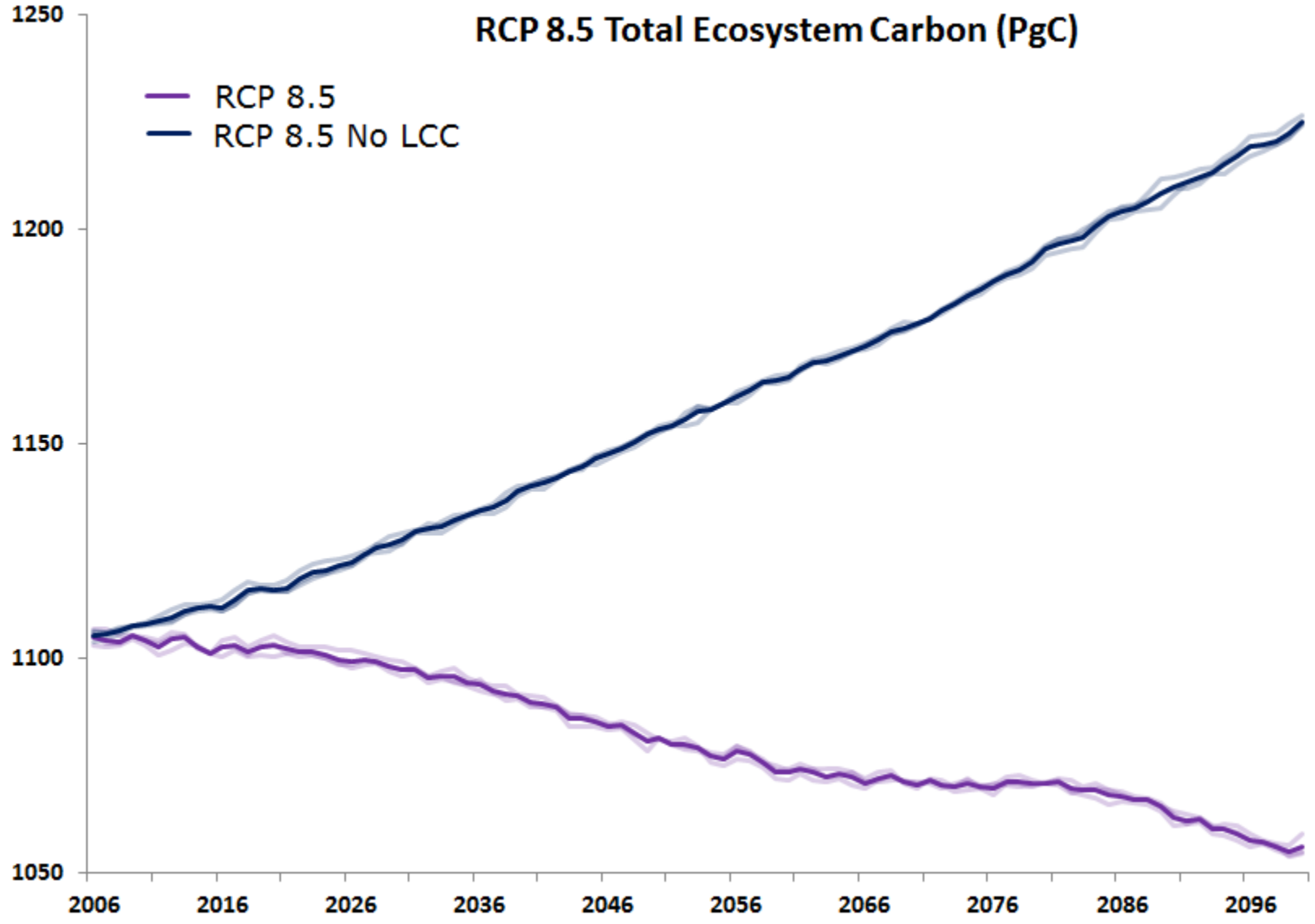




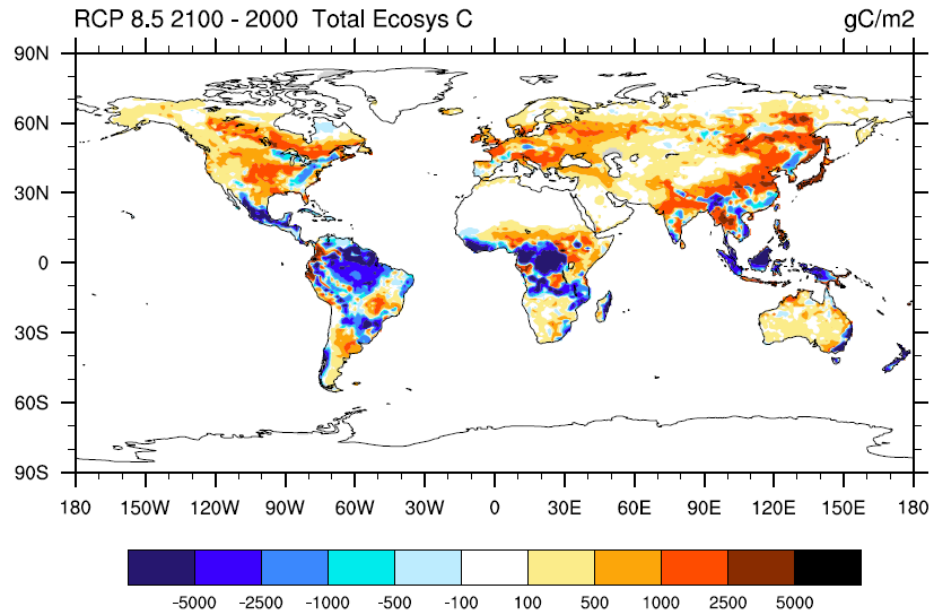


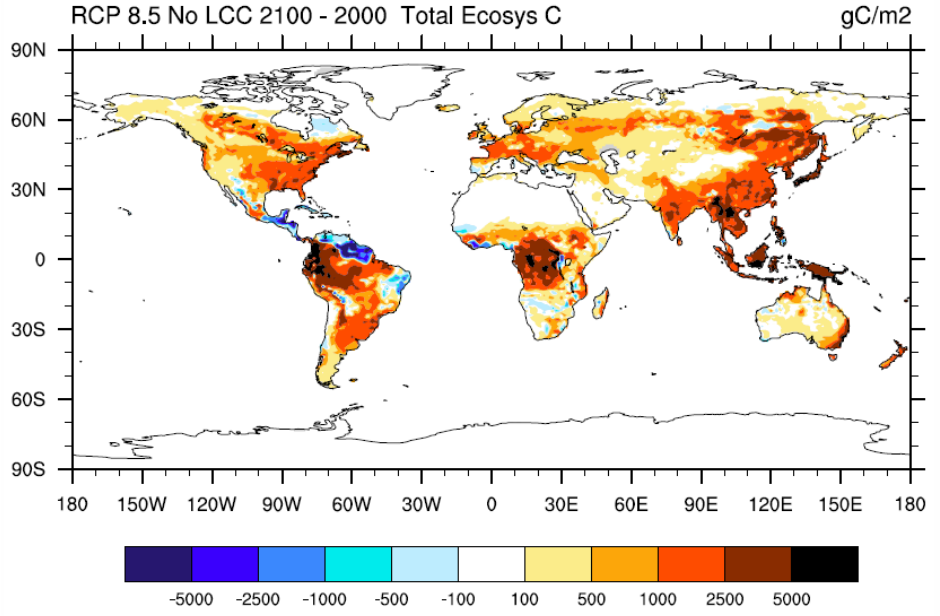


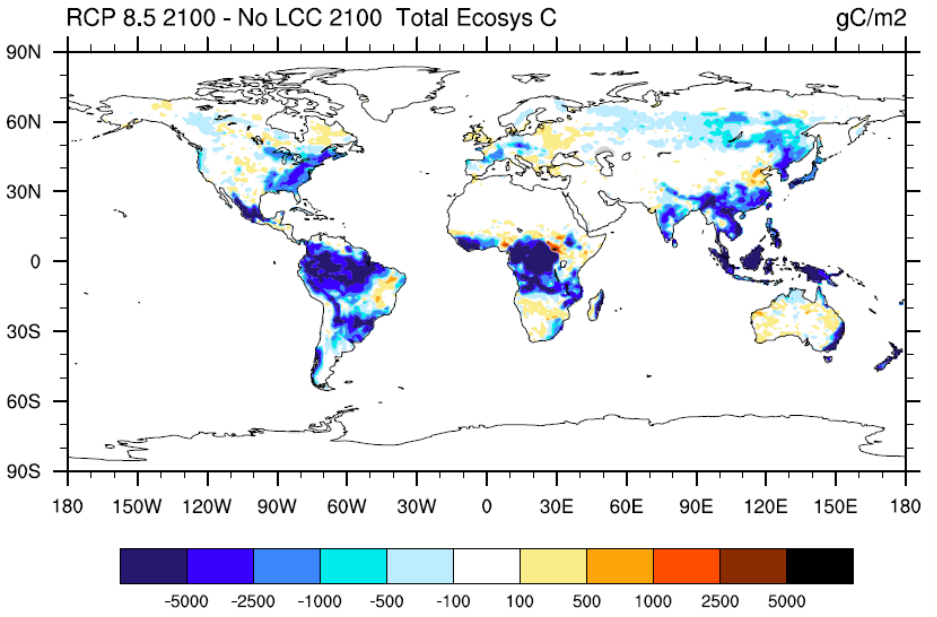
CMIP5 Land Cover Change – Total Ecosystem Carbon

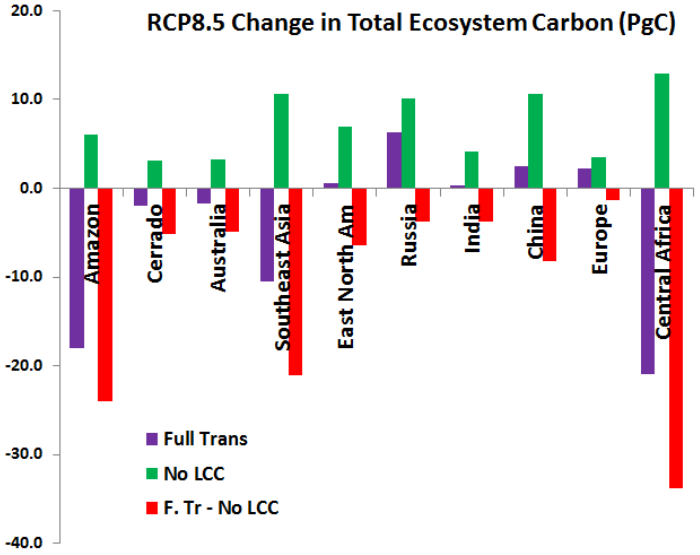


CMIP5 Land Cover Change – RCP8.5 Carbon

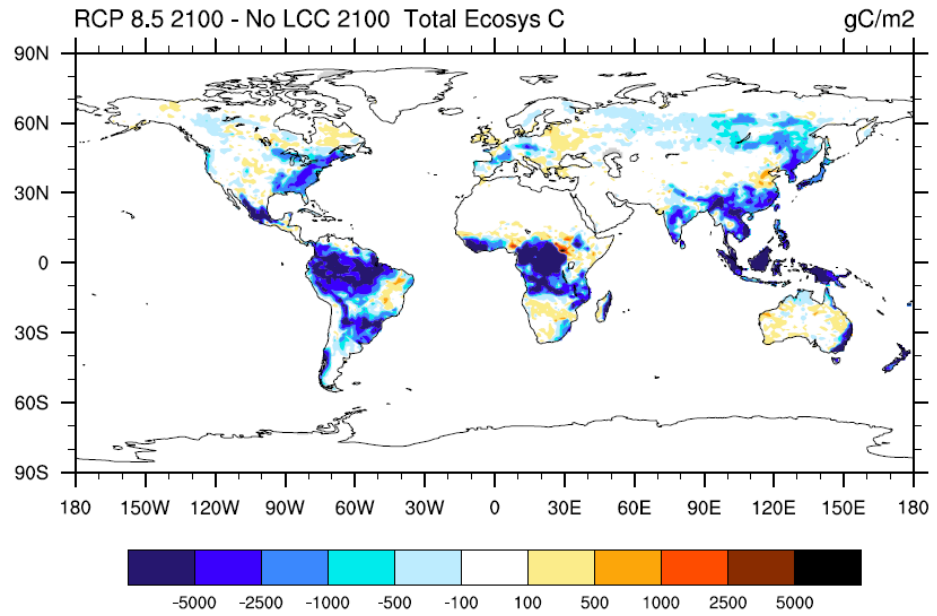


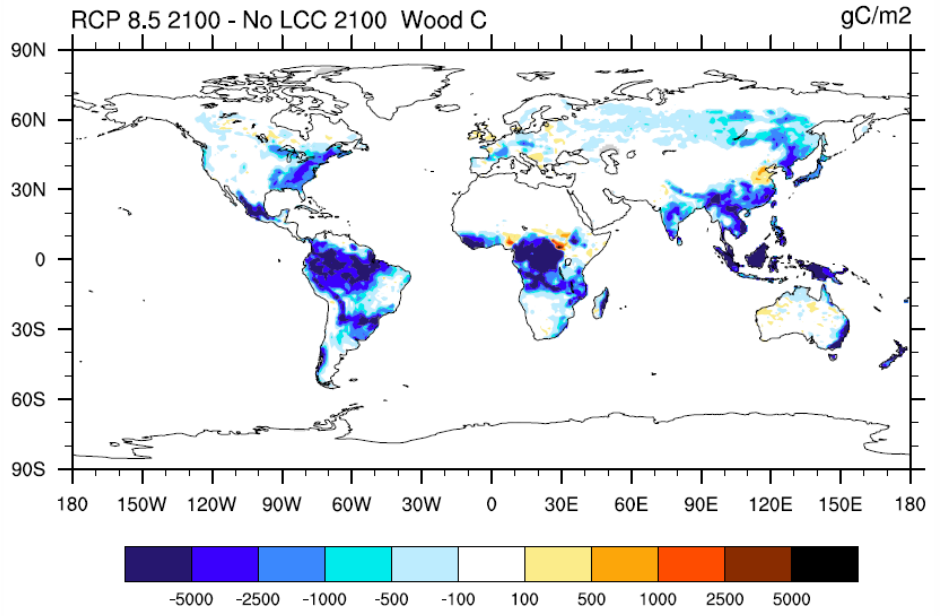


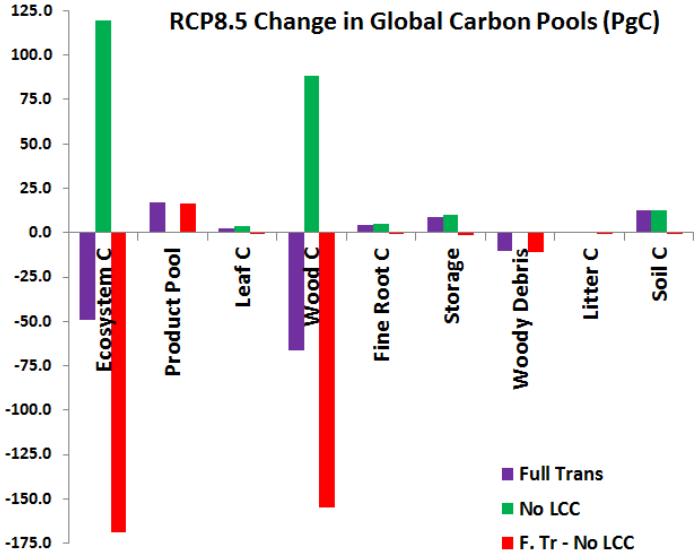


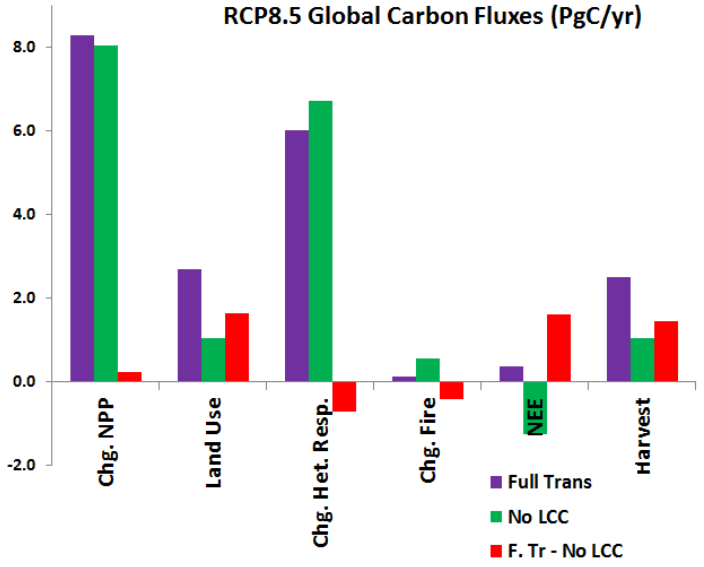


CMIP5 Land Cover Change – RCP8.5 Carbon

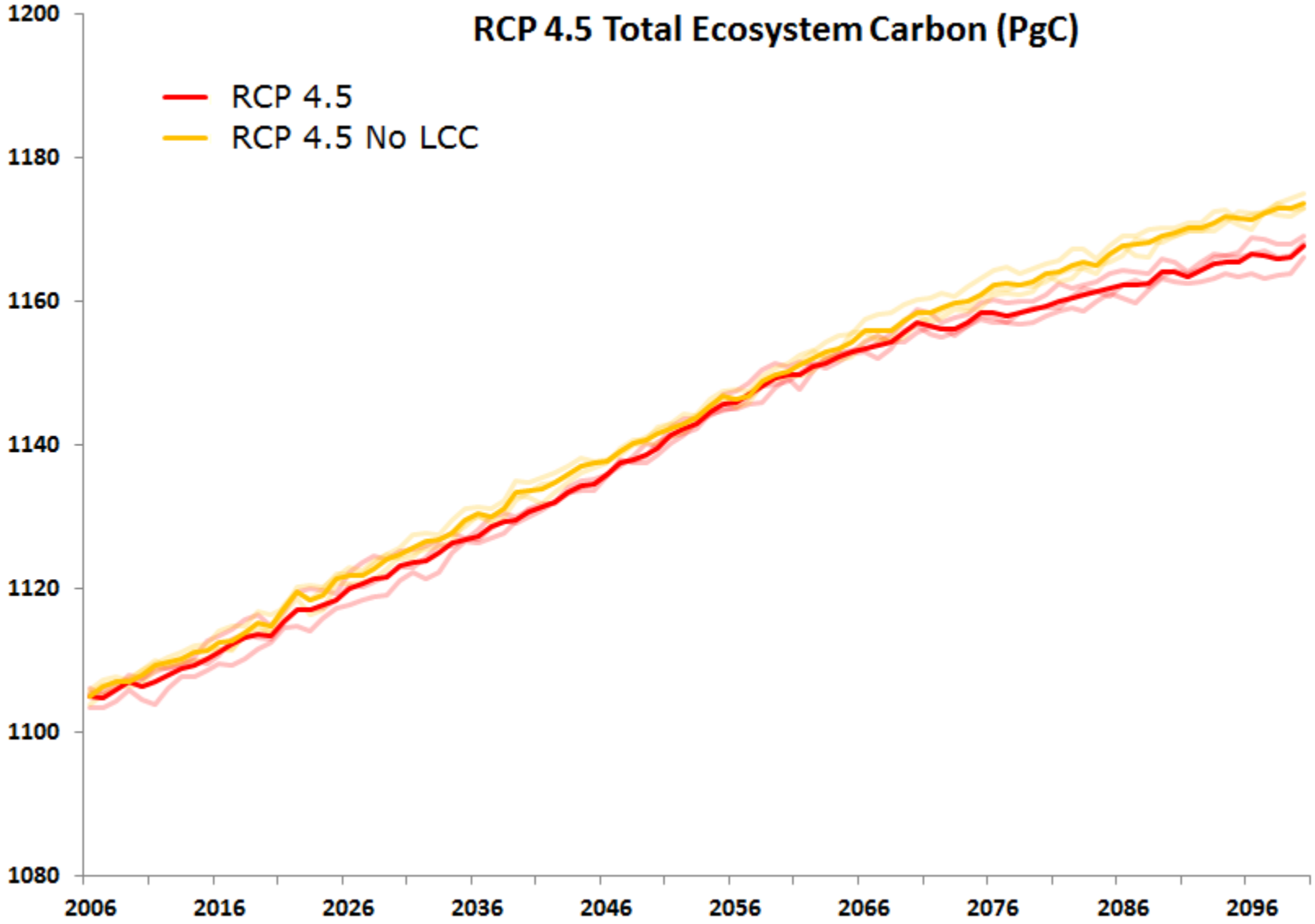




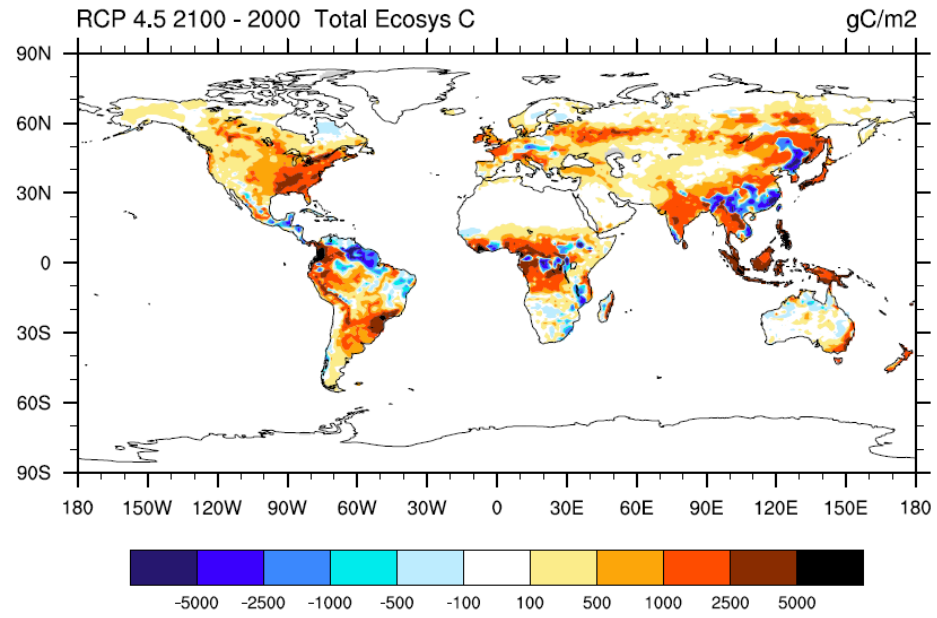


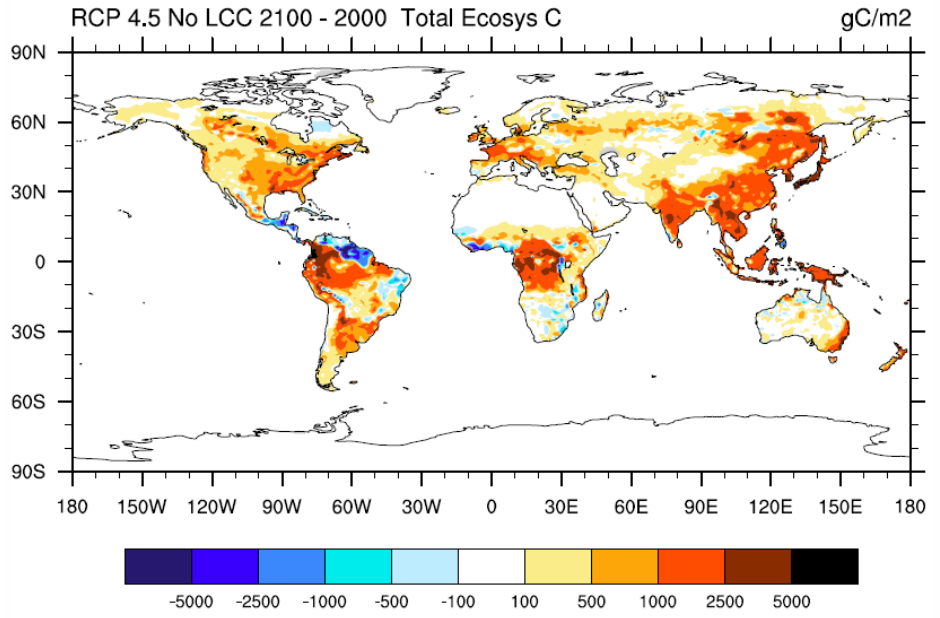


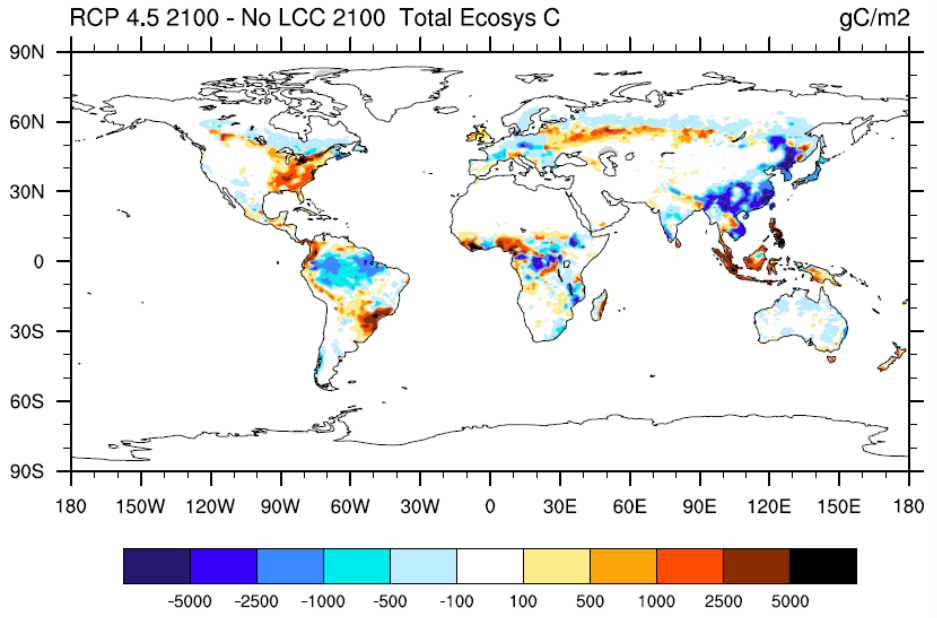
CMIP5 Land Cover Change – Total Ecosystem Carbon

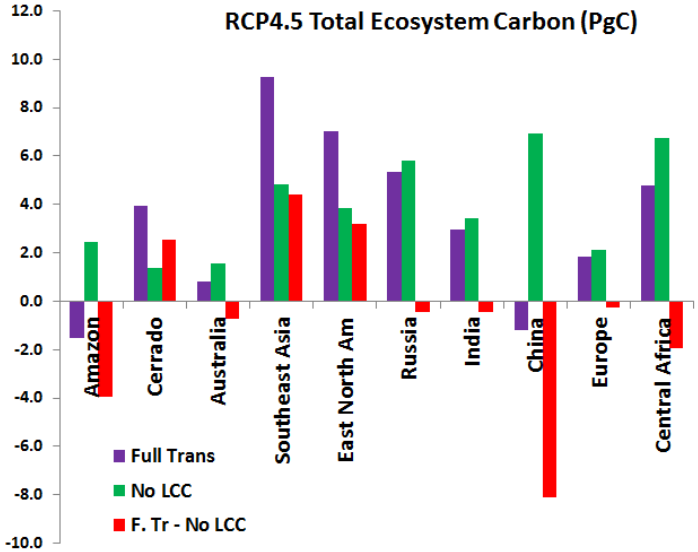


CMIP5 Land Cover Change – RCP4.5 Carbon

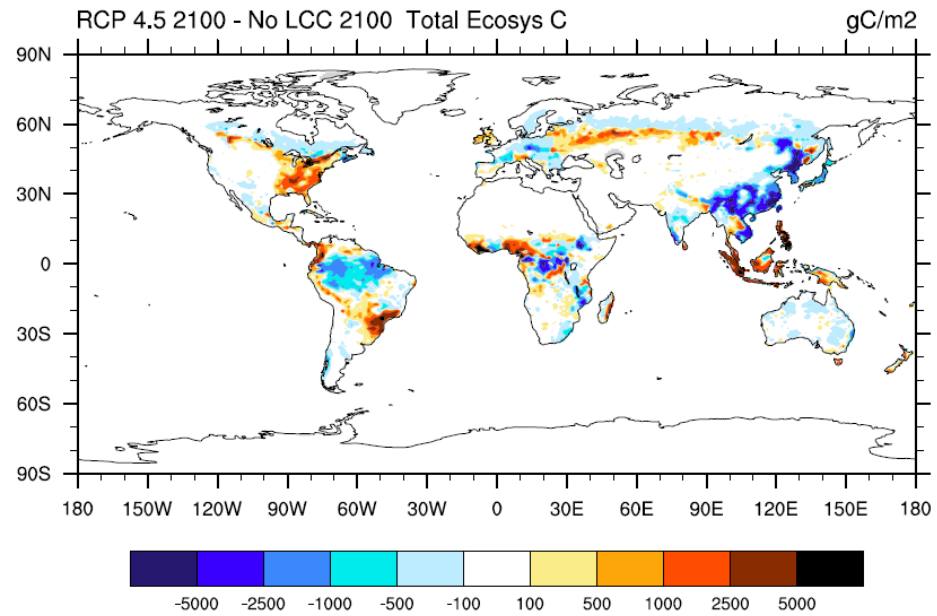


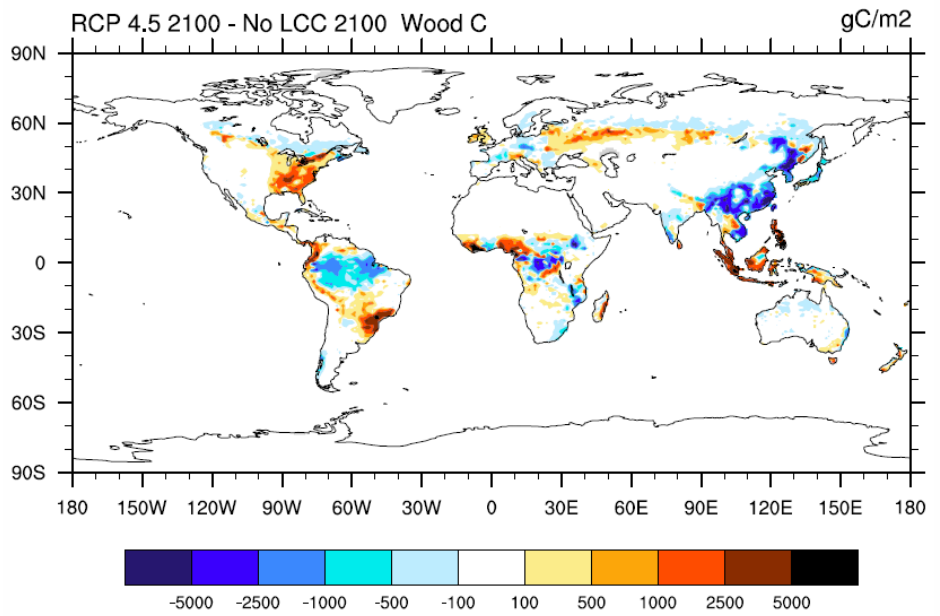


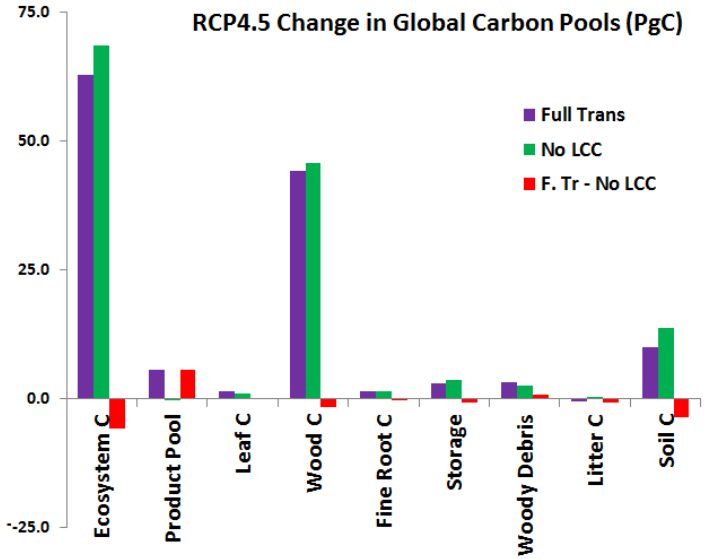


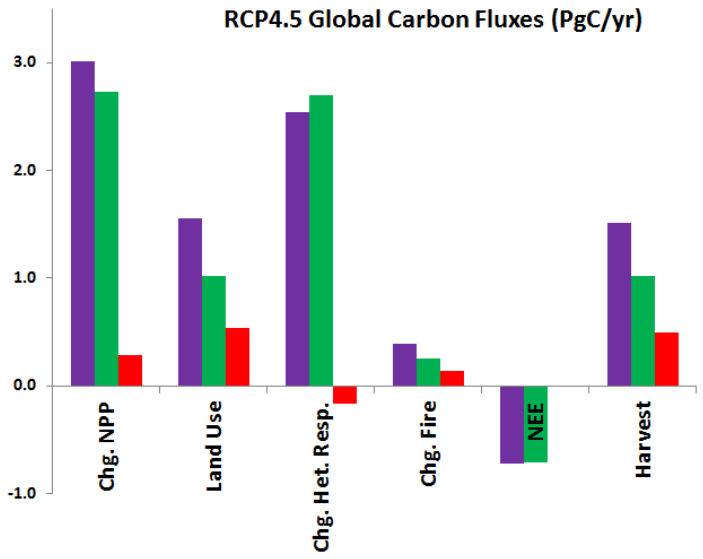


CMIP5 Land Cover Change – RCP4.5 Carbon

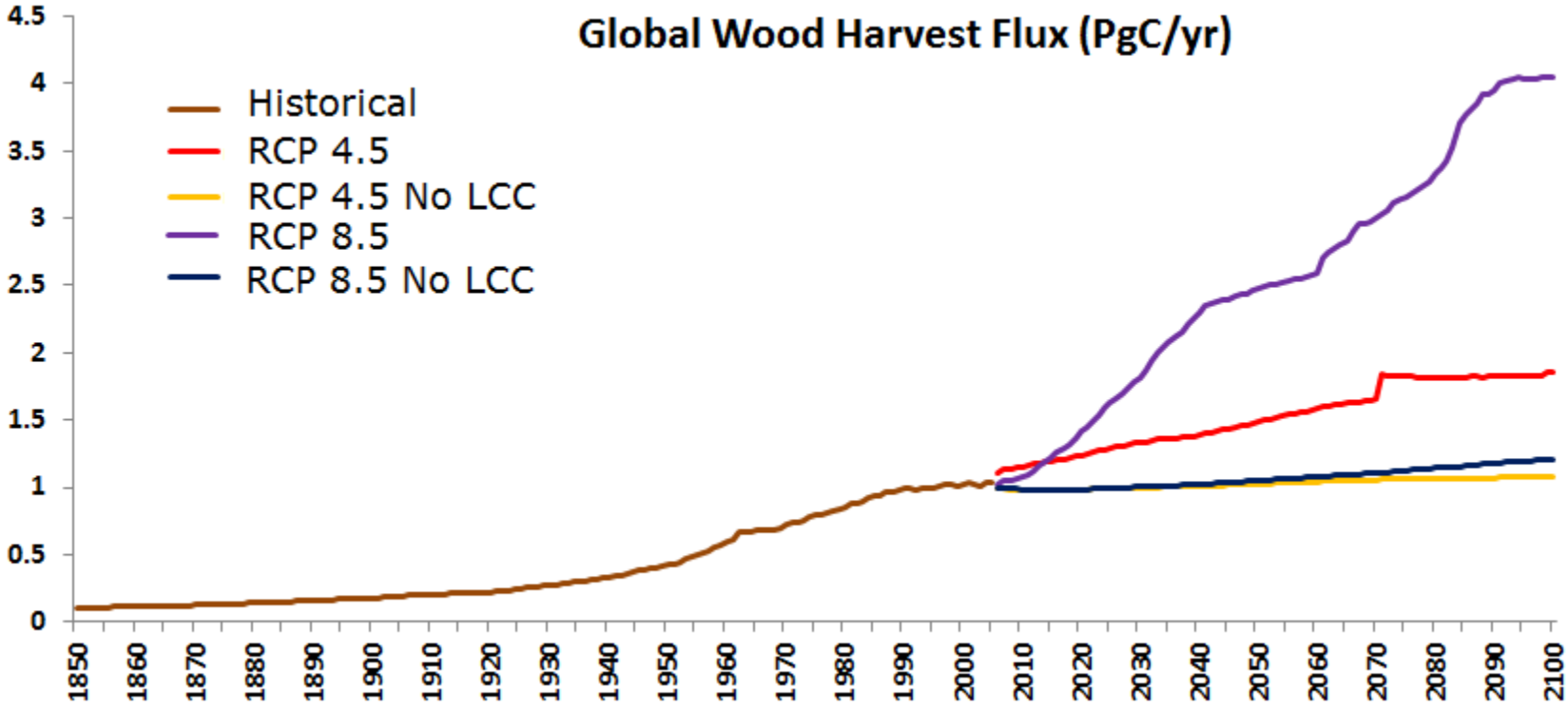








CMIP5 Land Cover Change – Wood Harvest



	Transient LCC	No LCC	Over No LCC
Historical	62.5 PgC	0 PgC	62.5 PgC
RCP 4.5	145.0 PgC	97.7 PgC	47.3 PgC
RCP 8.5	242.4 PgC	101.7 PgC	140.7 PgC

Land Cover Change Carbon Impacts 1.

1. Historical Full Trans loses 61.2 PgC from Ecosystem Carbon but compared to No LCC it loses 129.6 PgC.

2. RCP 4.5 Full Trans gains 62.8 PgC in Ecosystem Carbon but compared to No LCC it loses 5.8 PgC

3. RCP 8.5 Full Trans loses 49 PgC from Ecosystem Carbon but compared to No LCC it loses 168.8 PgC

4. Historical losses are greatest in South East Asia, China and Eastern North America

5. RCP 4.5 gains carbon in South East Asia and Eastern North Am. but these are offset by losses of carbon in Amazon and China

6. RCP 8.5 carbon losses are largest in Central Africa, South East Asia and the Amazon

Land Cover Change Carbon Impacts 2.

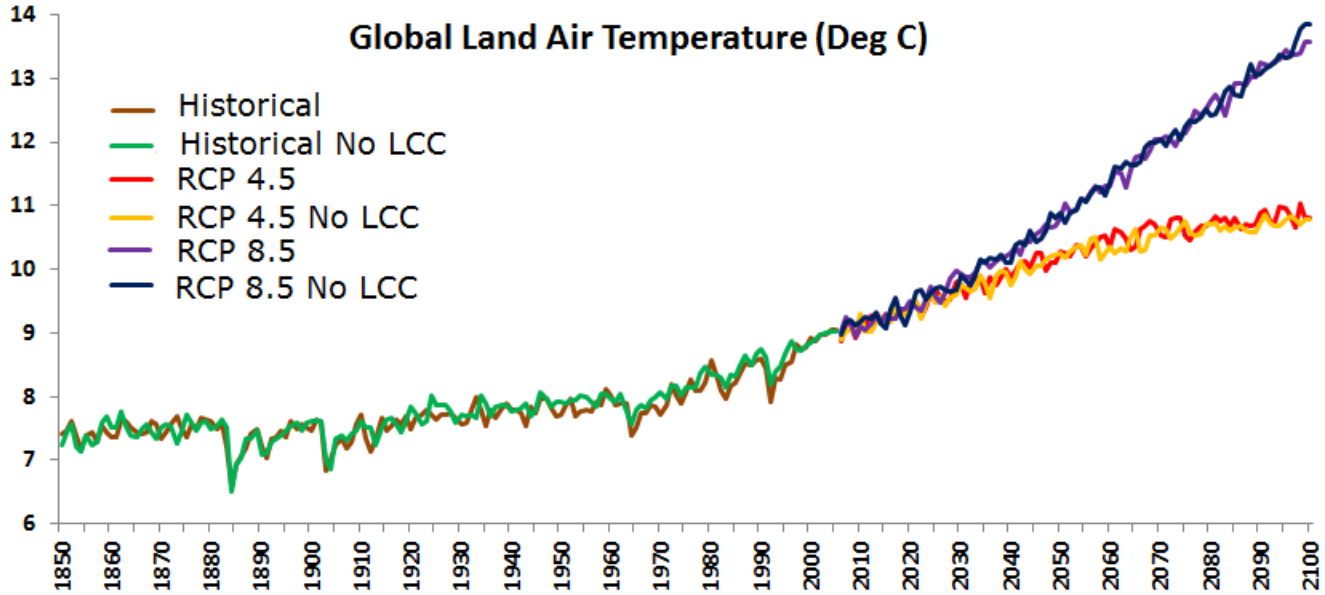
7. The Ecosystem Carbon changes between Full Trans and No LCC are predominantly in Wood and Coarse Woody Debris carbon pools.

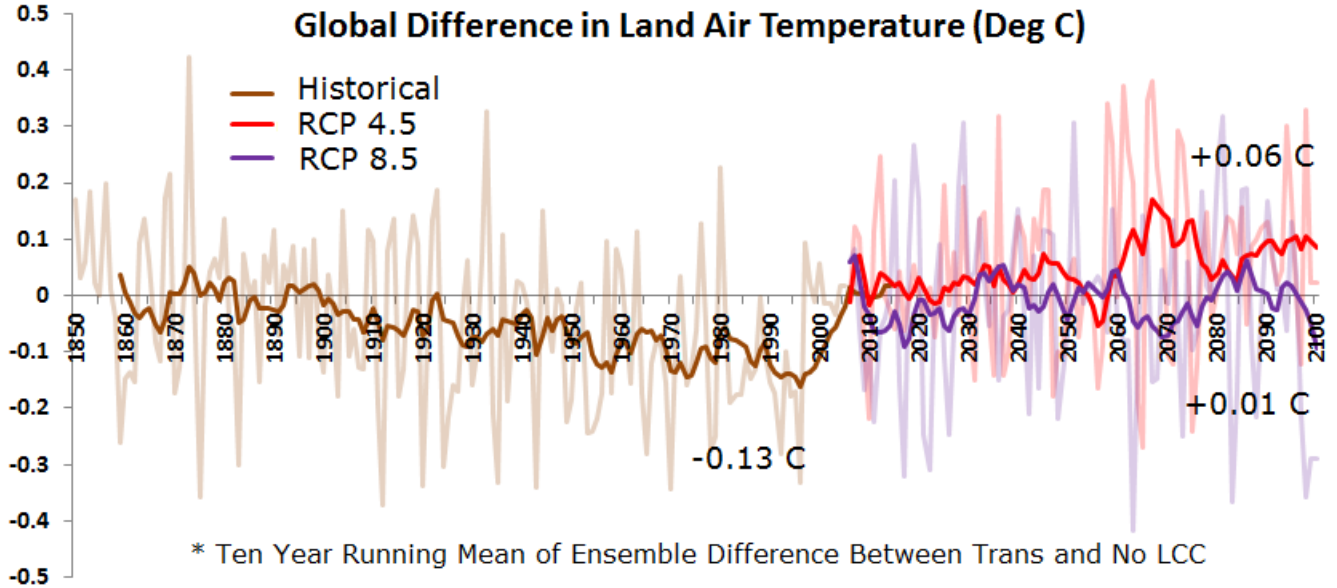
8. Other carbon pool changes are very small including Soil Carbon

9. The RCP 4.5 Full Trans afforestation scenario results in lower carbon uptake than the RCP 4.5 No LCC simulations.

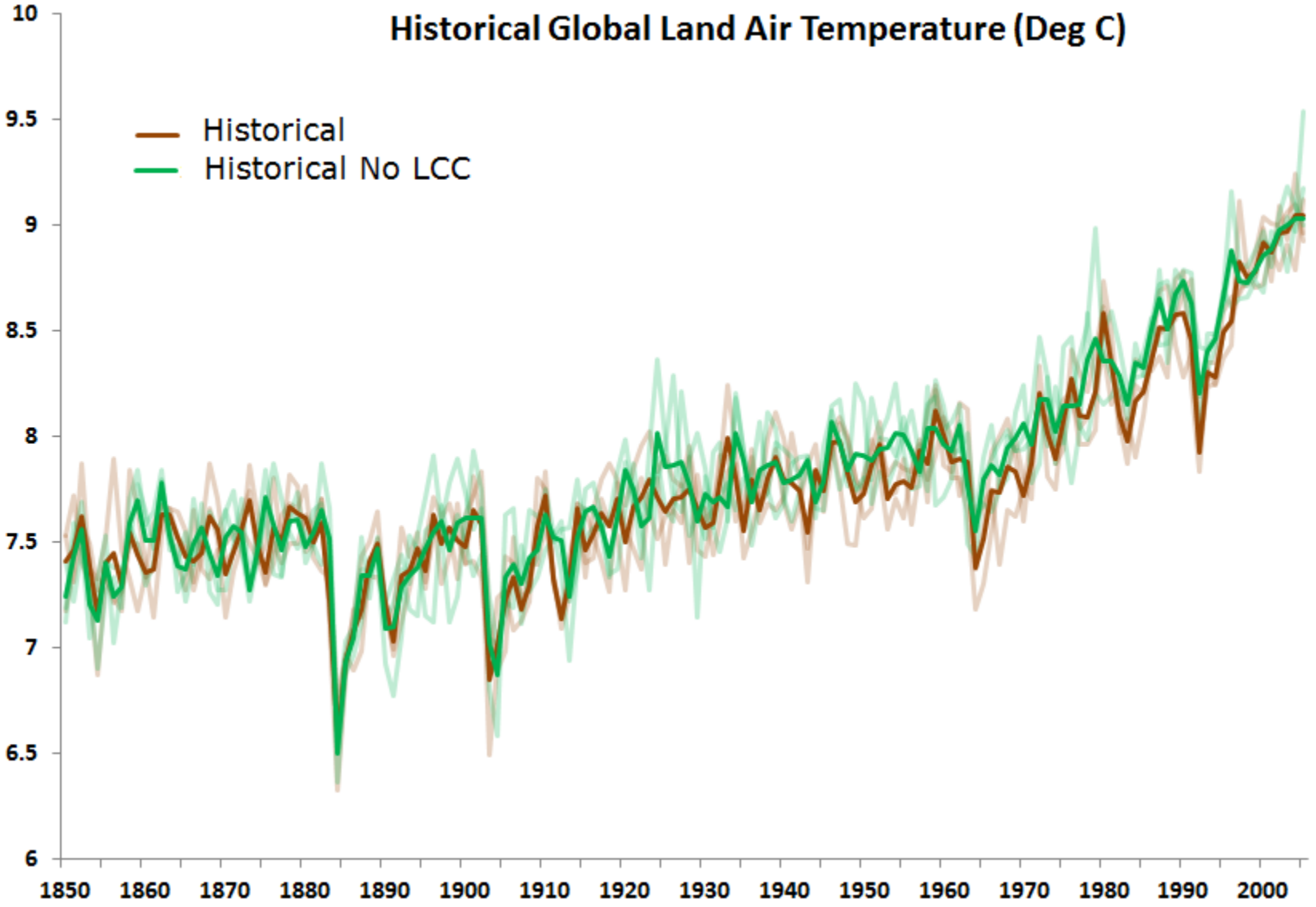
10. This result comes from the higher wood harvest rates of RCP 4.5 which reduce carbon more than the increased uptake through afforestation

CMIP5 Land Cover Change – Land Surface Temperature

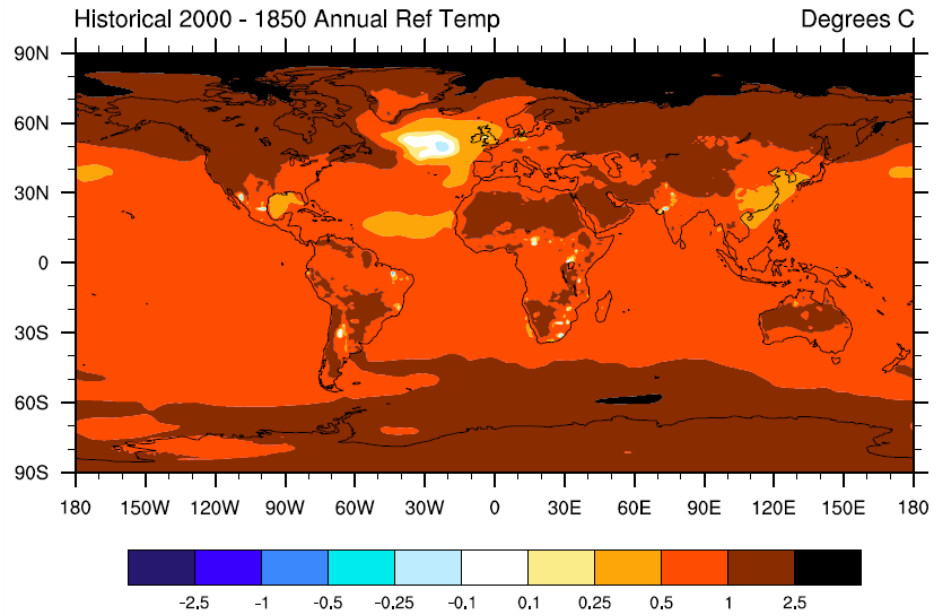


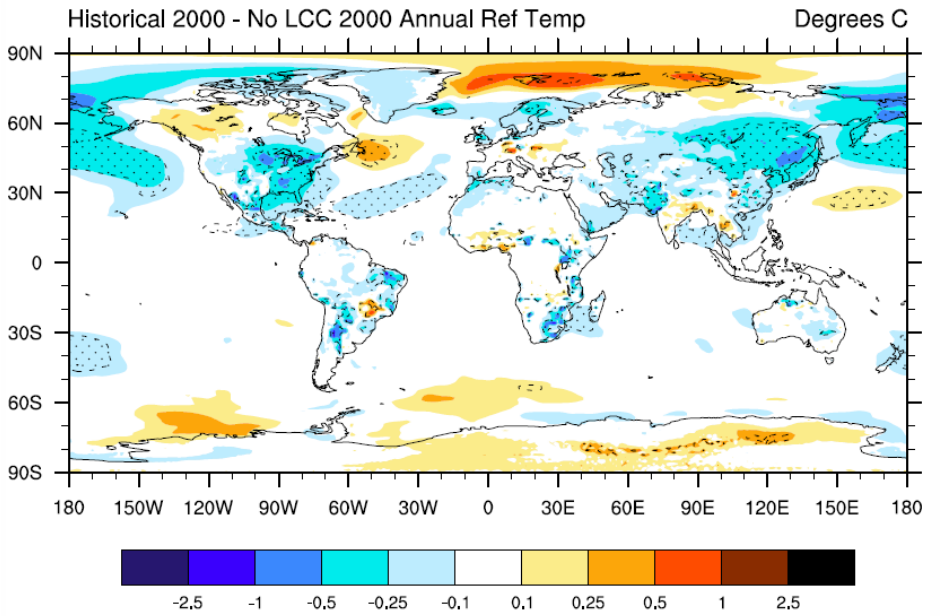


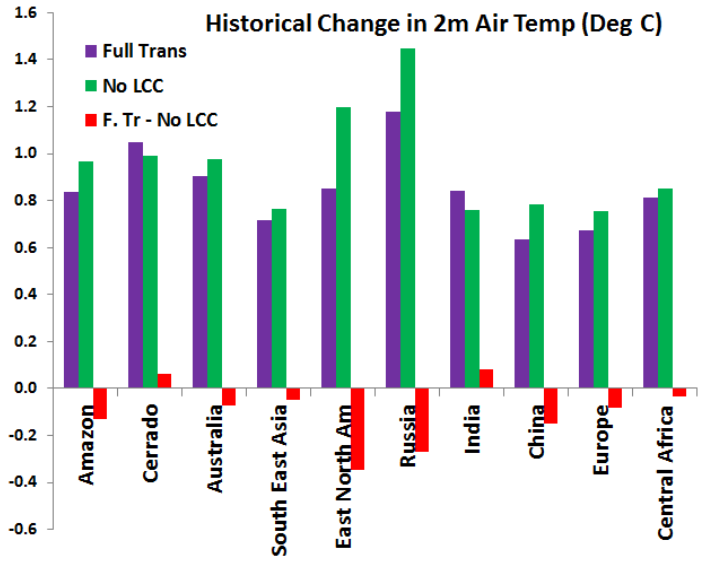
CMIP5 Land Cover Change – Historical Temperature



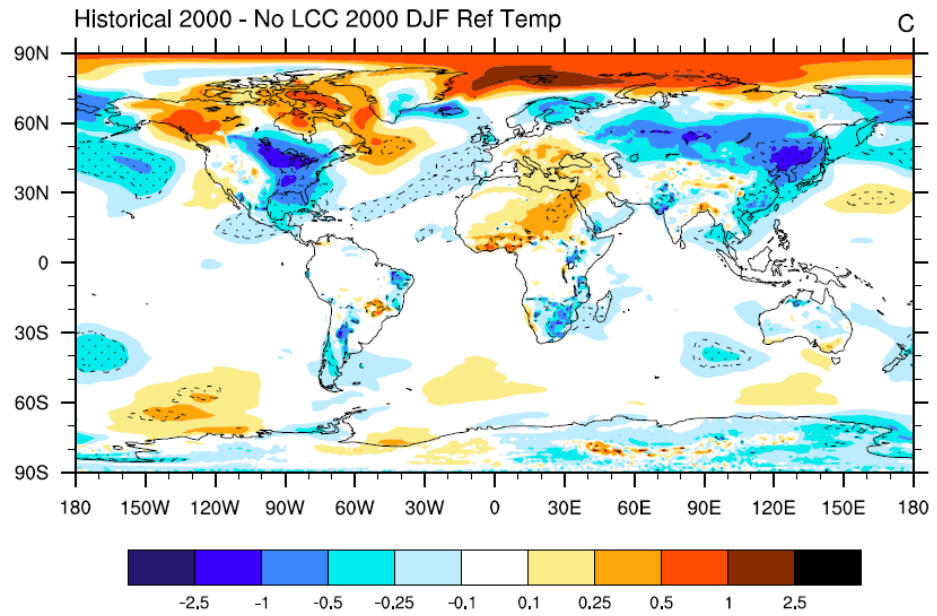
CMIP5 Land Cover Change – Historical Temperature

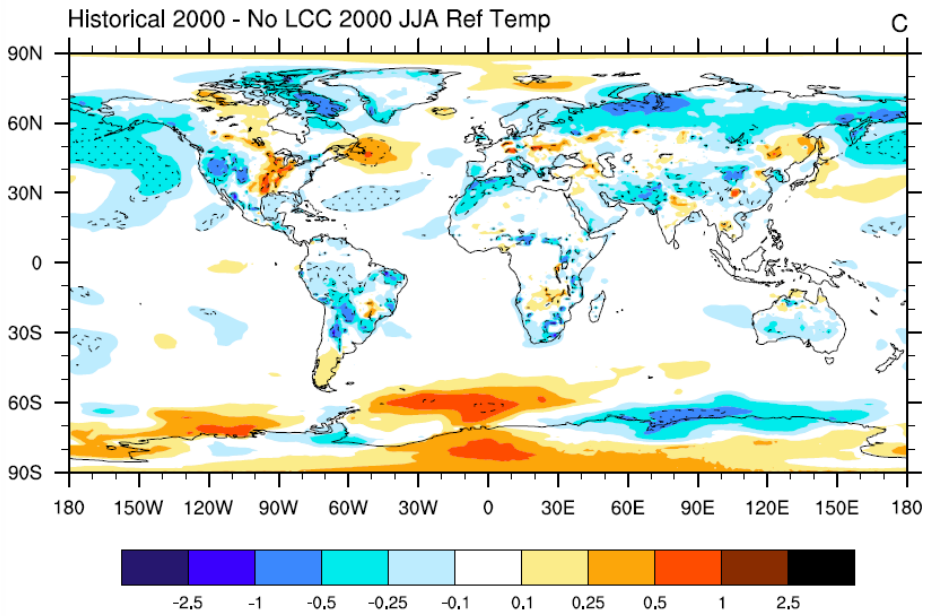


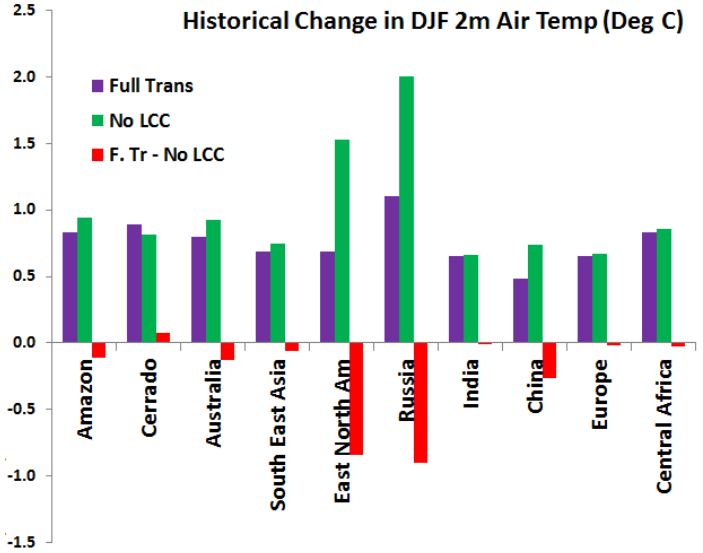


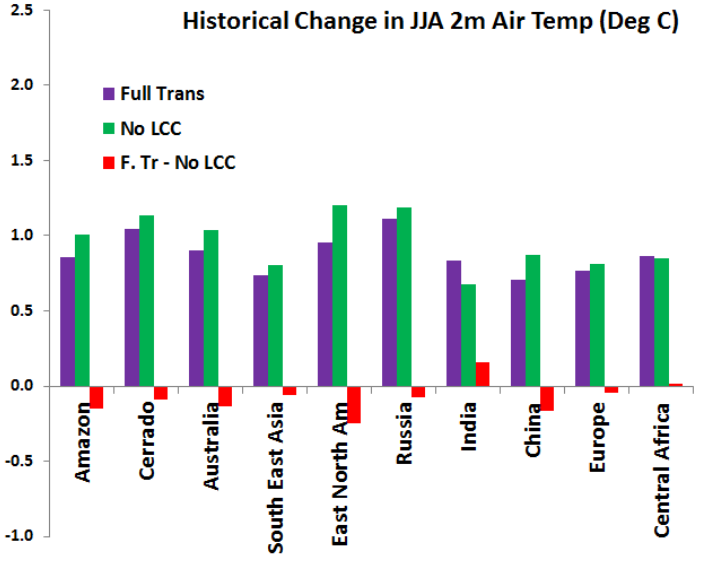


CMIP5 Land Cover Change – Historical Temperature

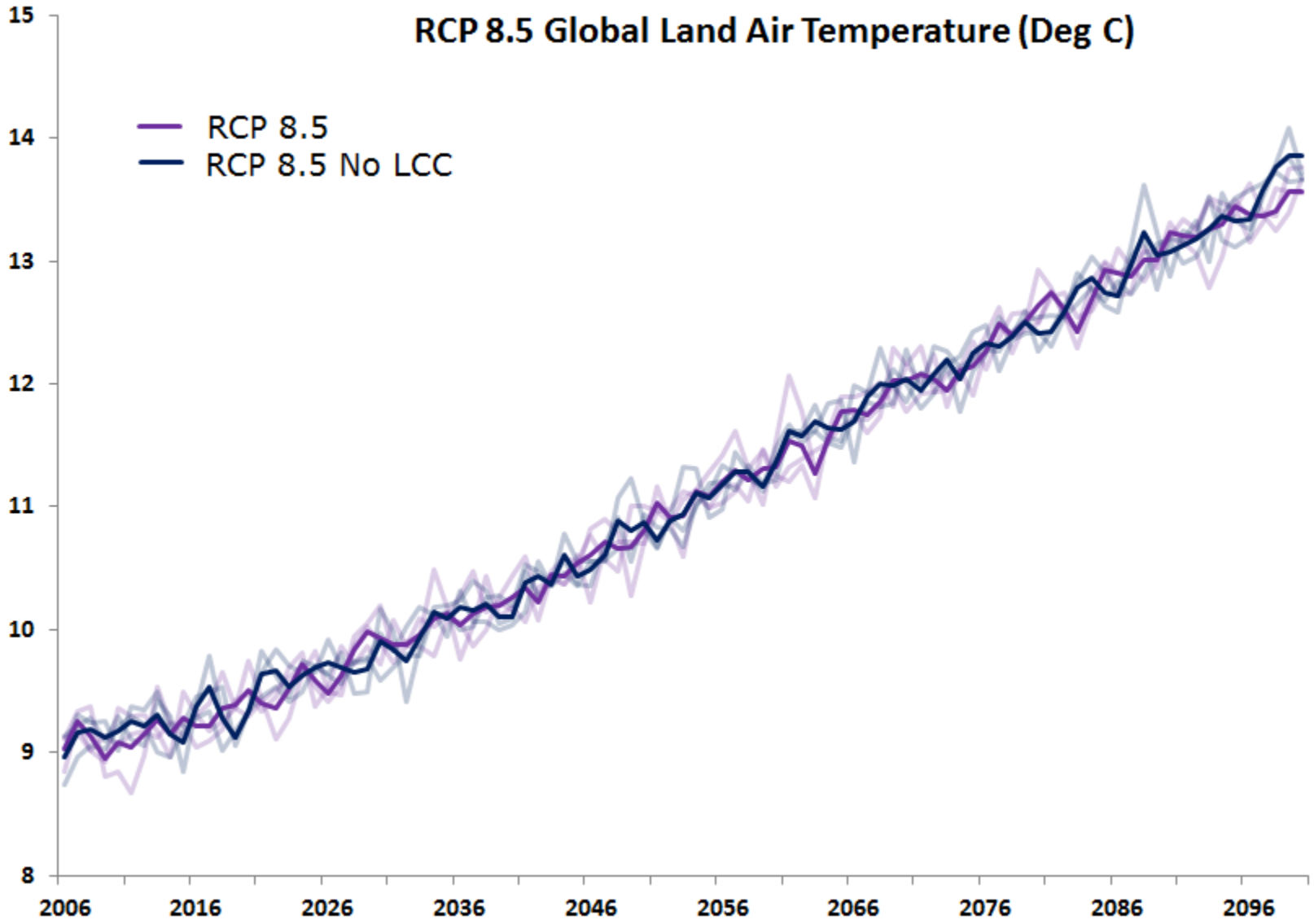




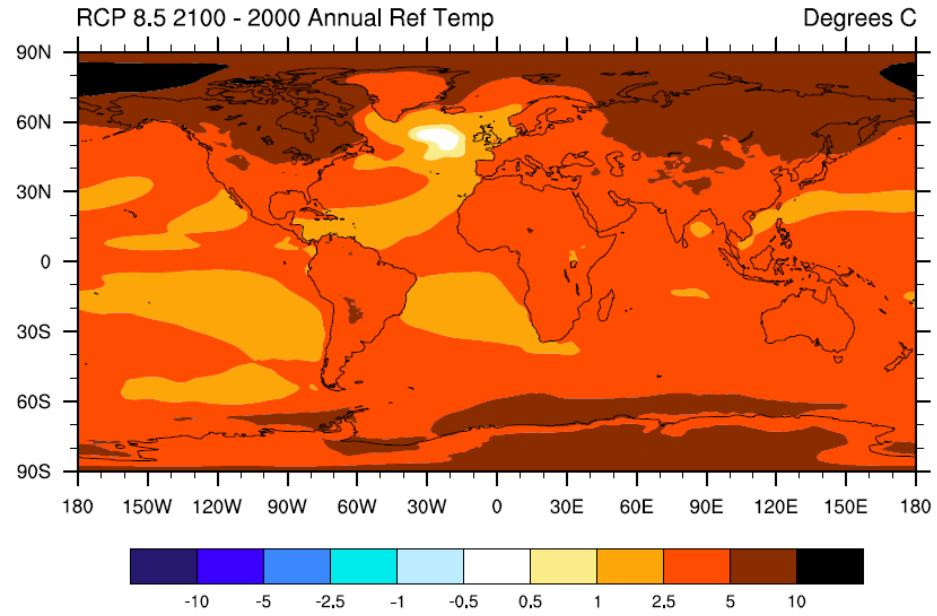


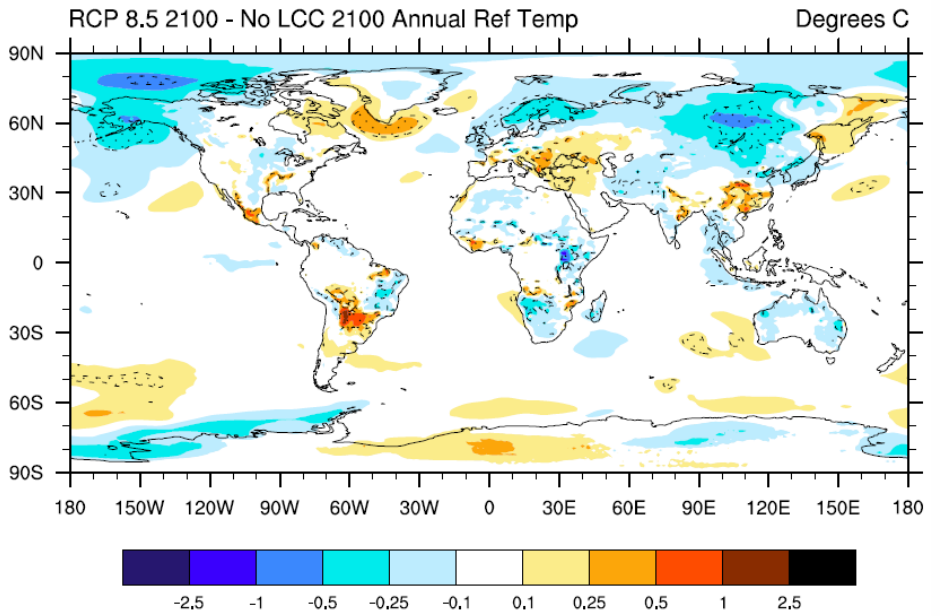


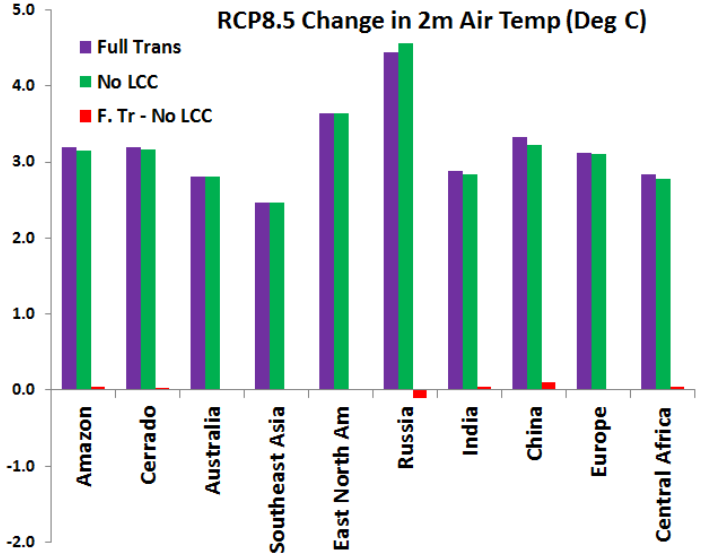
CMIP5 Land Cover Change – RCP8.5 Temperature



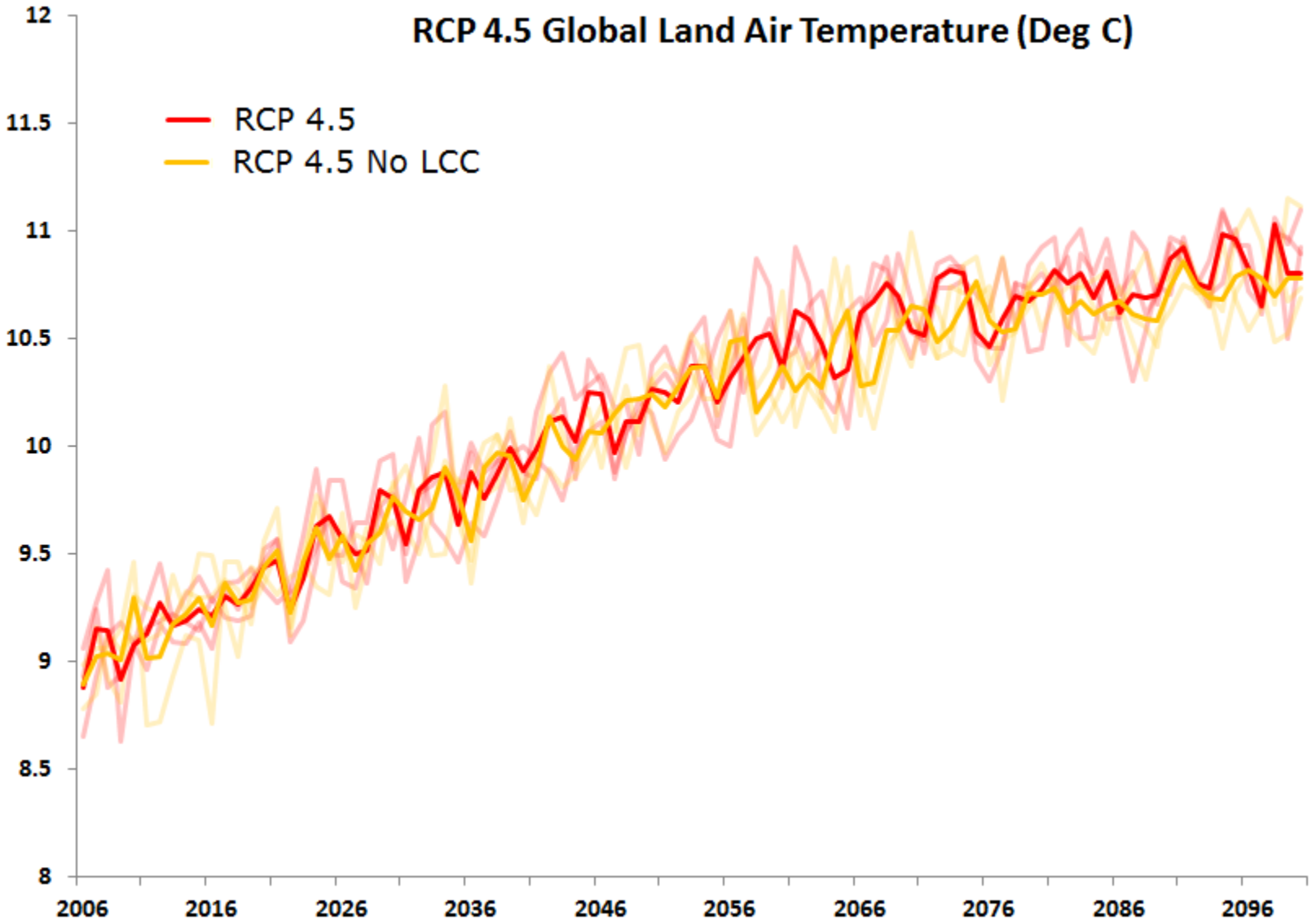
CMIP5 Land Cover Change – RCP8.5 Temperature



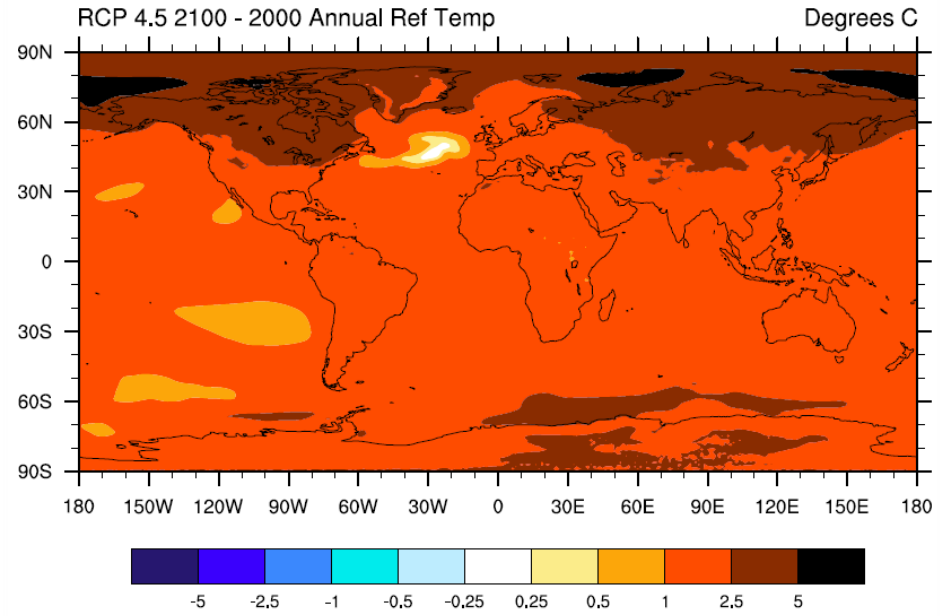


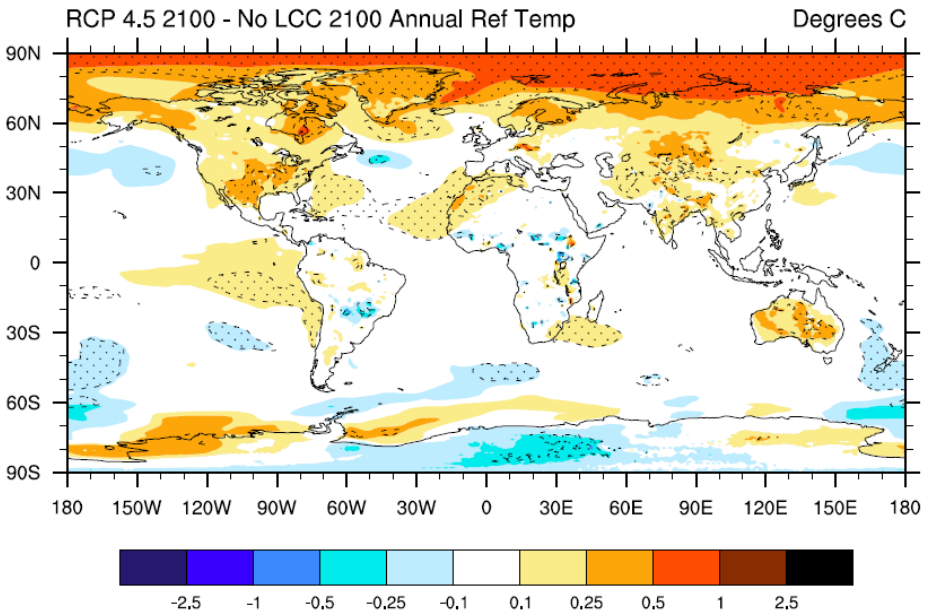


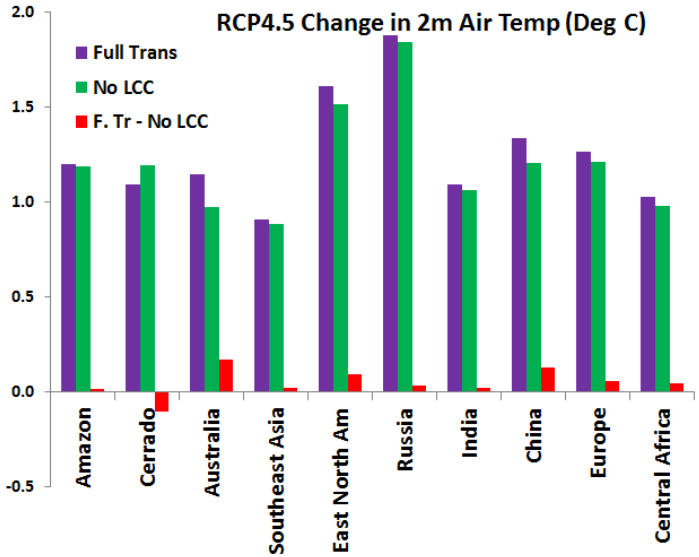
CMIP5 Land Cover Change – RCP4.5 Temperature



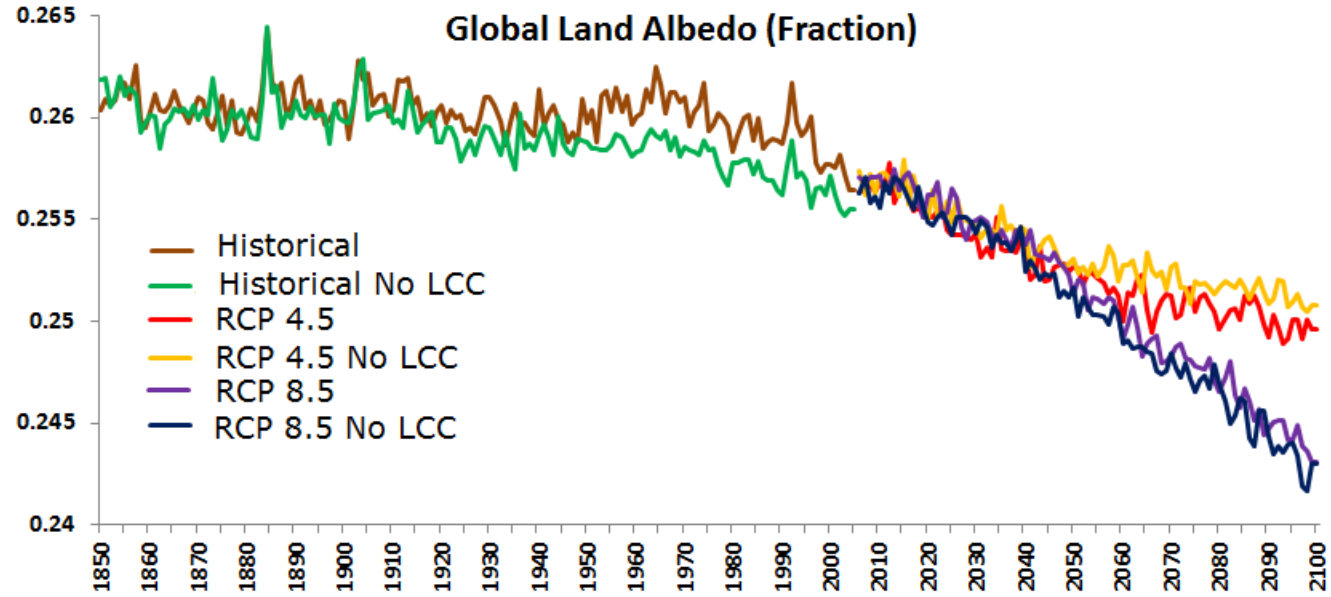
CMIP5 Land Cover Change – RCP4.5 Temperature

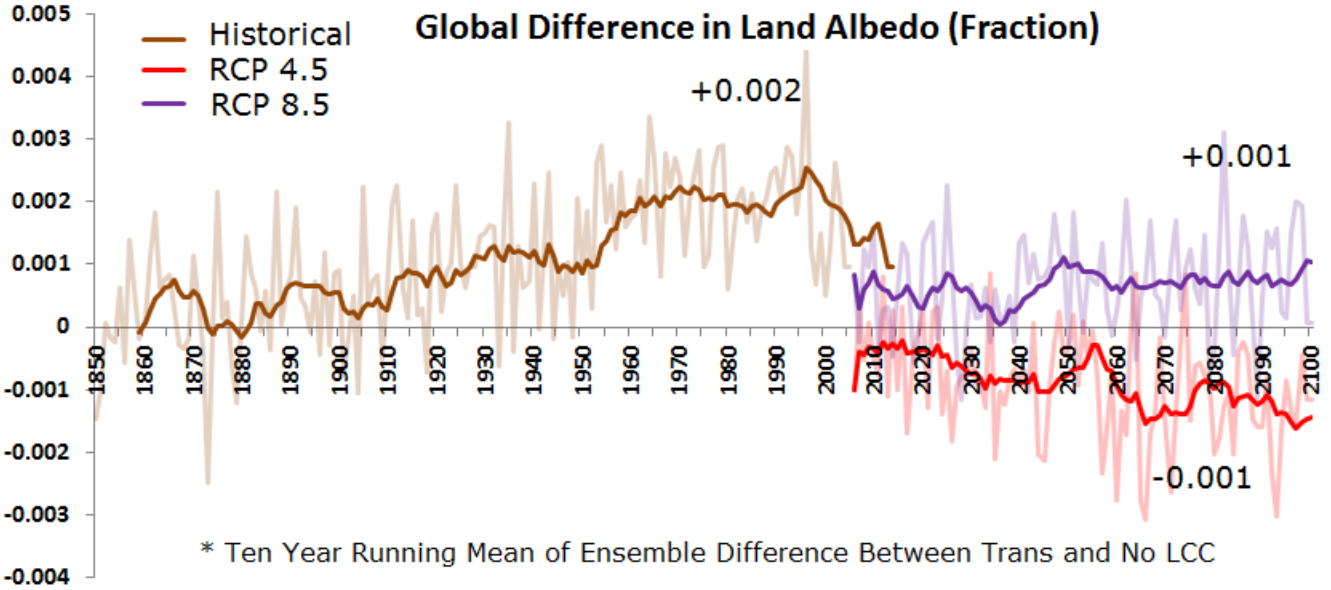




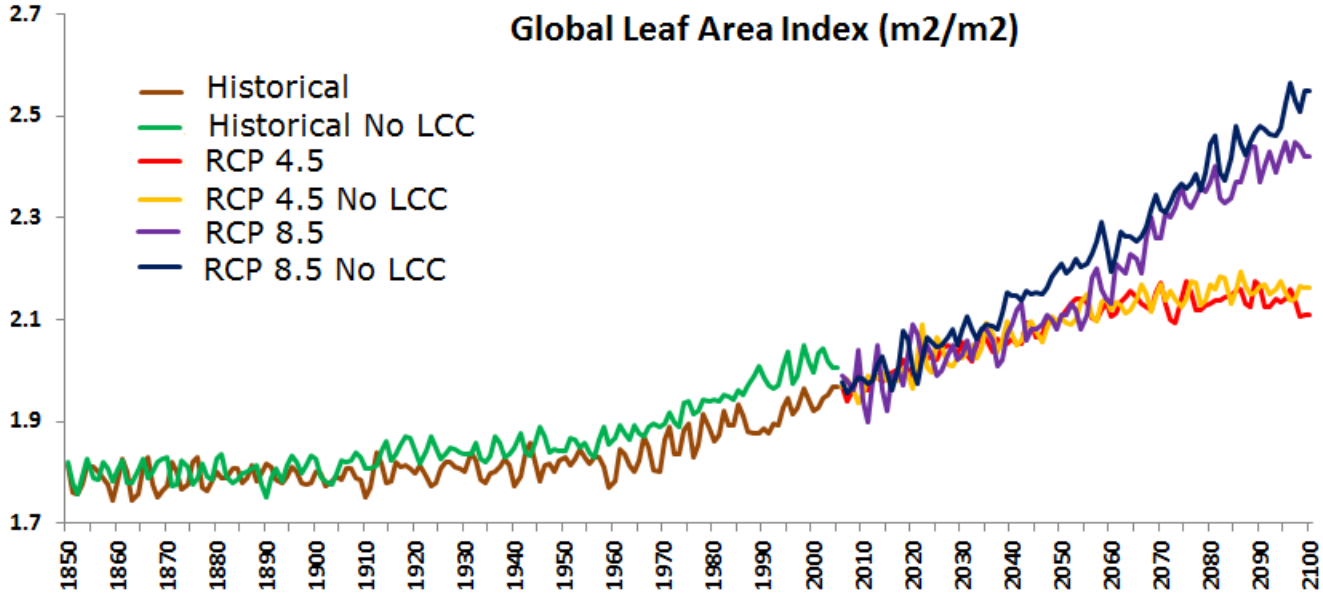


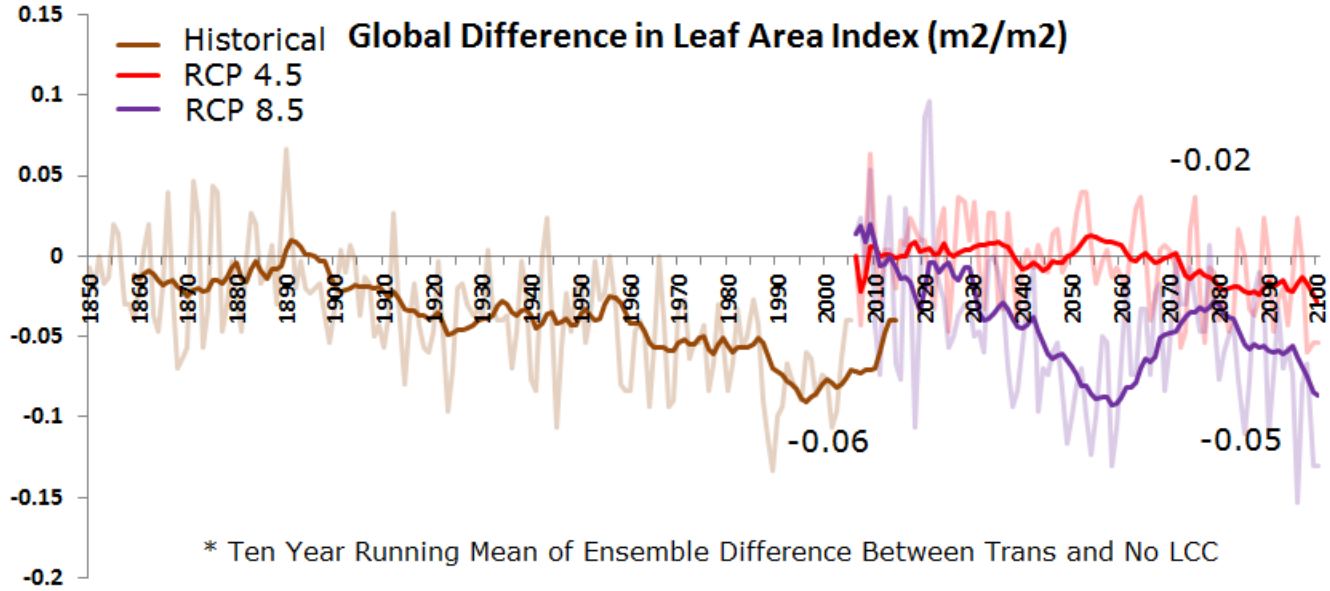
CMIP5 Land Cover Change – Albedo





CMIP5 Land Cover Change – Leaf Area Index





* Ten Year Running Mean of Ensemble Difference Between Trans and No LCC

Land Cover Change Biogeophysical Impacts 1.

1. Historical reduction of warming of -0.13C for global land temperature for Full Trans compared to 150 year warming of +1.2C in No LCC simulations

2. Historical reductions in warming largest in East North America and Russia in winter of -0.9C compared to warming of +2C in No LCC

3. RCP 4.5 has increased warming +0.06C for global land temperature relative to +1.5C. Predominantly at high latitudes

4. RCP 8.5 has almost no change in global land temperatures compared to increases of +3.6C in both Full Trans and No LCC

5. Albedo increases/decreases between Full Trans and No LCC correspond with reduced/increased warming

6. Albedo increases/decreases correspond with lower/higher LAI but spatial location and vegetation type also important

Land Cover Change Biogeophysical Impacts 2.

7. Historical biogeophysical impacts are relatively larger and more robust than RCP biogeophysical impacts

8. As the total warming of the scenarios get larger the relative impacts get smaller impacted by reduced snow – vegetation albedo impacts

9. Ensembles show that at higher warming scenarios the Full Trans and No LCC differences become indistinguishable from ensemble spread.

Relevance to SDWG

Fostering dialogue

- Carbon and climate Land Cover Change impacts in LUMIP/ScenarioMIP CMIP6 scenarios

Needs for CESM development

- Assessment of CLM4.5/5 Land Cover Change
- Creation of new LUMIP land cover change parameters

Relevant CESM simulations

- CLM4.5/5 offline and coupled simulations

New CESM linkage code

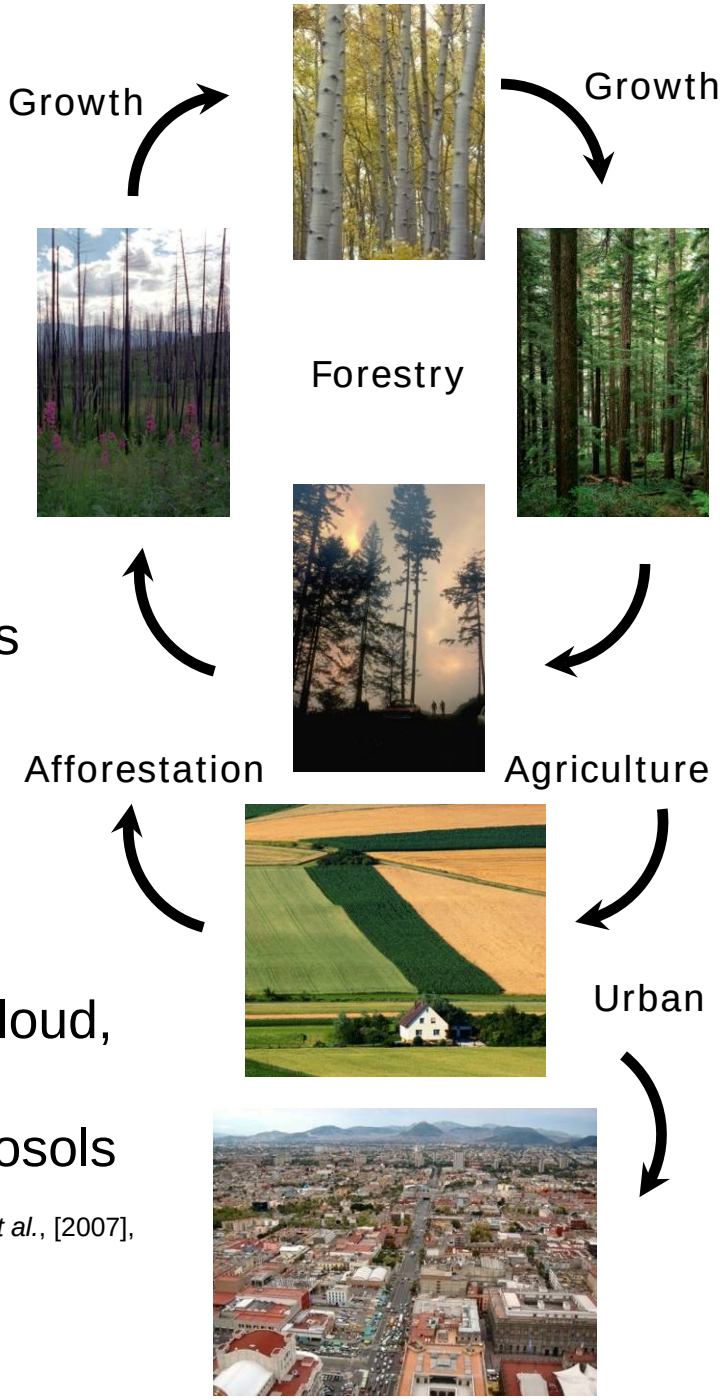
Land Cover Change and Wood Harvest Parameter Generation for LUMIP/CMIP6 with CLM-Crop and new management functionality

Need for Land Cover Change

1. Direct Biogeophysical Impacts:
- Albedo – Radiation (Snow Interactions)
- Surface Hydrology (Irrigation)
- Surface Roughness

2. Direct Biogeochemical Impacts:
- Vegetation and Soil Carbon Fluxes from Conversion Natural -> Human systems
- Harvesting from Forestry and Agriculture

3. Indirect Impacts:
- Increased Photosynthesis through higher CO_2, Nitrogen, Phosphorus and Potassium
- Atmospheric Responses in Temperature, Cloud, Precipitation and Larger Scale Circulation
- Fire, Methane, Dust, Volatile Organics, Aerosols



Lawrence et al., [2011]*, Lawrence and Chase*, [2010], *Feddema, et al.*, [2005], *Findell, et al.*, [2007], *IPCC*, [2007], *Bonan*, [2008], and *Canadell, et al.*, [2007]