

Providing high-resolution land-use change information for ensemble simulations within CORDEX and the LUCAS framework*

Peter Hoffmann, Diana Rechid, Vanessa
Reinhart, Edouard Davin, Eleni
Katragkou, Nathalie de Noblet-Ducoudré

**This work was conducted within the framework of the
Helmholtz Institute for Climate Service Science (HICSS)*

■ LUCAS

- **Land Use and Climate Across Scales (LUCAS)** is an initiative on coordinated regional climate experiments for Europe including land use change forcing
- initiated by EURO-CORDEX & LUCID
- endorsed by WCRP CORDEX as a Flagship Pilot Study (FPS)
- LUCAS consortium: ~20 participating institutions
- Coordination: Diana Rechid, GERICS (Lead); Nathalie de Noblet-Ducoudré, LSCE/IPSL; Eleni Katragkou, Aristotle University of Thessaloniki; Edouard Davin, ETH Zürich

► **FPS LUCAS: Include human forcing through land use changes into RCMs and **quantify** its **biophysical impacts** on the regional climate in Europe**

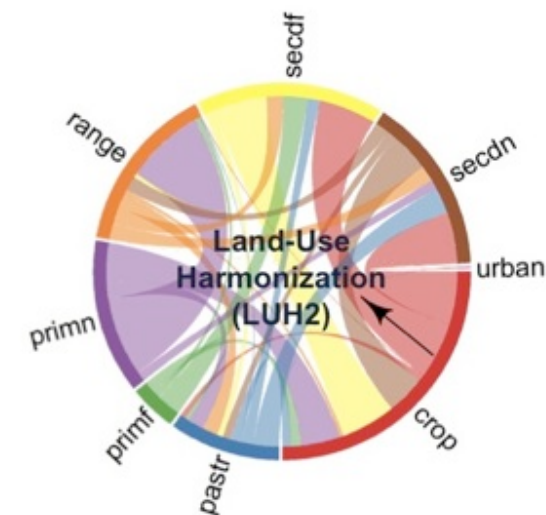


■ LUCAS Experiment plan

- **Phase 1:** Idealized experiments at continental scale & reanalysis driven evaluation simulation
- **Phase 2:** GCM-driven experiments at continental scale (historical: 1950-2015, projections: 2015-2100)
- **Phase 3:** High resolution experiments in spatially refined pilot regions (< 5 km resolution)

Land Use Harmonized Dataset Version 2 (LUH2, Hurtt et al. 2019)

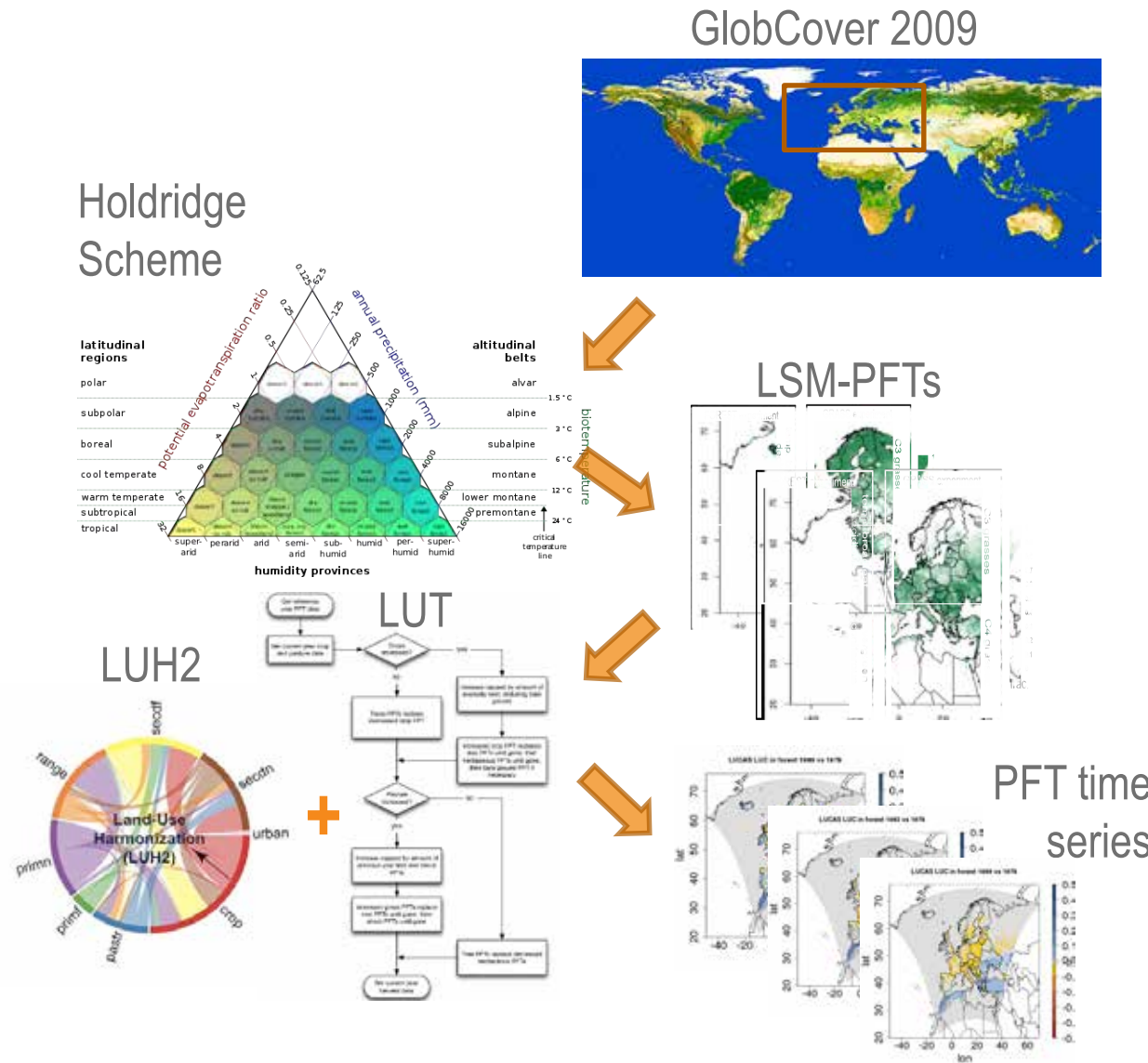
- Historic land use 850-2015 based on IAM models
- Future land use based on different SSPs/RCPs
- Horizontal resolution 0.25°
- 8 main land use classes + 5 crop classes
- Annual states and transitions are provided
- Compared to LUH1 differentiation between forest and non-forest vegetation and pasture and rangeland
- Used for CMIP6 and LUMIP
- Resolution to coarse for high-res RCM experiment
- How to convert it to RCM land cover input?



Combined class	LUH2 land use
Non-grass Vegetation (VEG)	Primary forest, secondary forest, primary non-forest, secondary non-forest
Grass vegetation (GRA)	Pasture and rangeland
Crops (CRO)	C3 and C4 crops
Urban (URB)	Urban

SSP	RCP	Model
1	1.9	IMAGE
1	2.6	IMAGE
4	3.4	GCAM
5	3.4OS	REMIND-MAGPIE
2	4.5	MESSAGE-GLOBIOM
4	6.0	GCAM
3	7.0	AIM
5	8.5	REMIND-MAGPIE

Merging high-resolution land cover products with land-use change information from Land Use Harmonized Dataset Version 2 (LUH2)



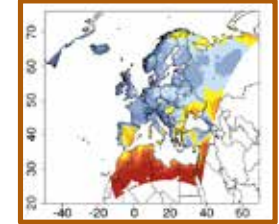
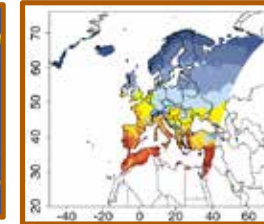
Conversion of GlobeCover2009 to PFTs

- Conversion scheme for REMO-iMOVE PFTs (Wilhelm et al. 2014):
 - Holdridge Ecosystem Classification
 - Annual biotemperature & annual rainfall (1986-2015)
 - Conversion tables for each of the 22 GlobCover classes
- EOBS 0.1° dataset is used
- missing data in EOBS filled with CRU

GlobCover2009



EOBS Bio-Temp + rainfall

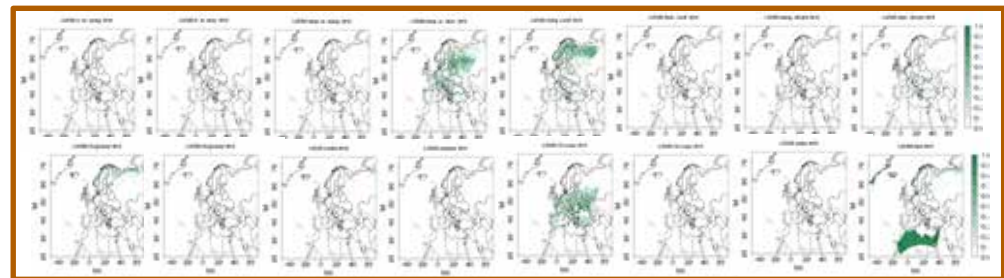


Holdridge
ecosys. types

Biotemp [°C]	Precipitation [mm]					
	< 125	125 to < 250	250 to < 500	500 to < 1000	1000 to < 2000	> 2000
< 3	dry tundra	moist tundra	wet tundra	rain tundra	—	—
3 to < 6	desert	dry shrub	moist forest	wet forest	rainforest	—
6 to < 12	desert	desert shrub	steppe	moist forest	wet forest	rainforest
12 to < 24	desert	desert shrub	thorn steppe/ woodland	dry forest	moist forest	wet forest/ rainforest
> 24	desert	desert shrub	thorn steppe/ woodland	very dry forest	dry forest	moist,wet,rain forest

PFT1	Tropical broadleaf evergreen	PFT9	C3 grasses
PFT2	Tropical broadleaf deciduous	PFT10	C4 grasses
PFT3	Temperate broadleaf evergreen	PFT11	Tundra
PFT4	Temperate broadleaf deciduous	PFT12	Swamps
PFT5	Evergreen coniferous	PFT13	C3 crops
PFT6	Evergreen deciduous	PFT14	C4 crops
PFT7	Evergreen shrubs	PFT15	Urban
PFT8	Deciduous shrubs	PFT16	Bare

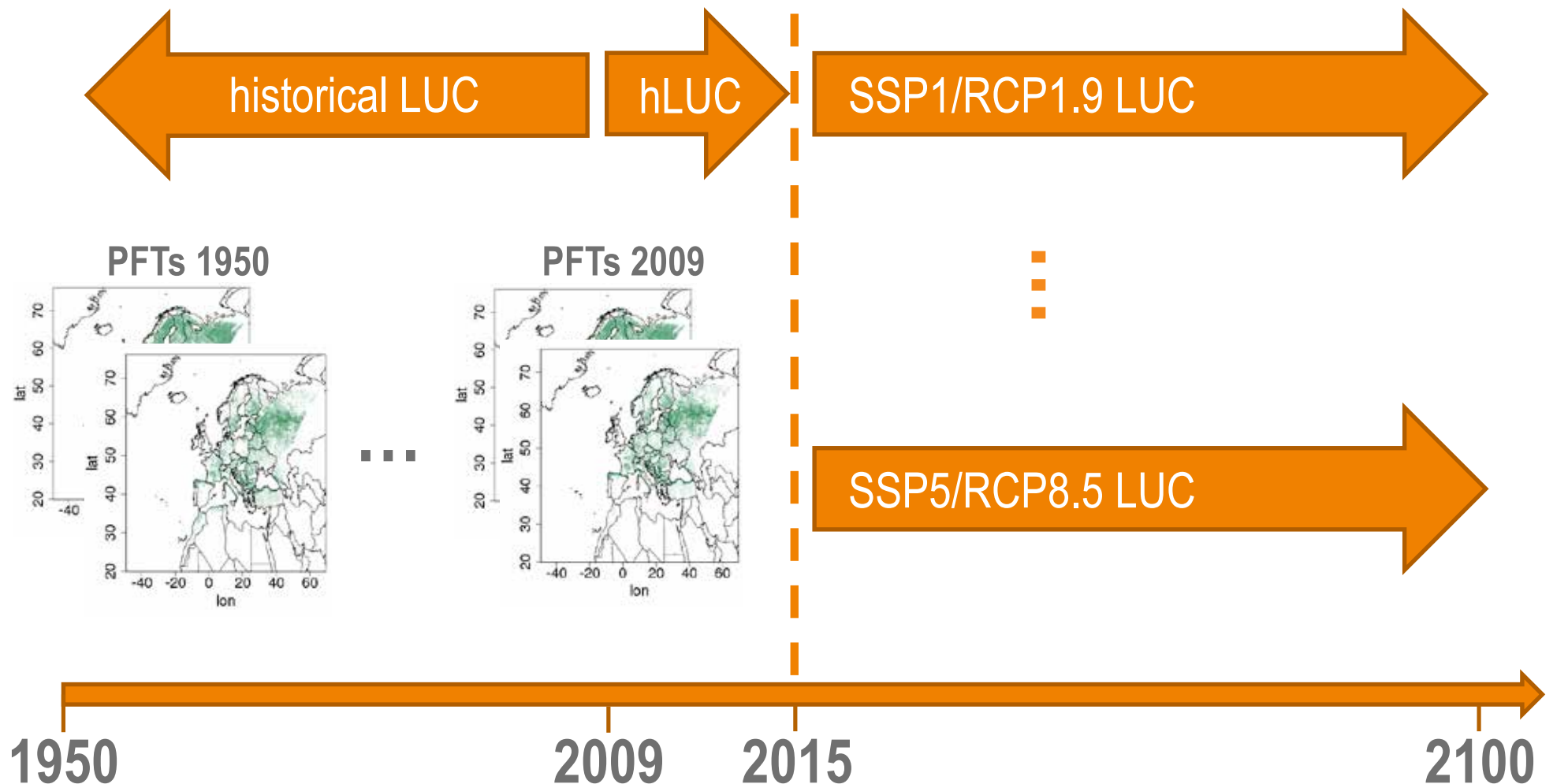
16 PFTs



Annual PFT maps using land use change information from LUH2

land use translator (LUT)

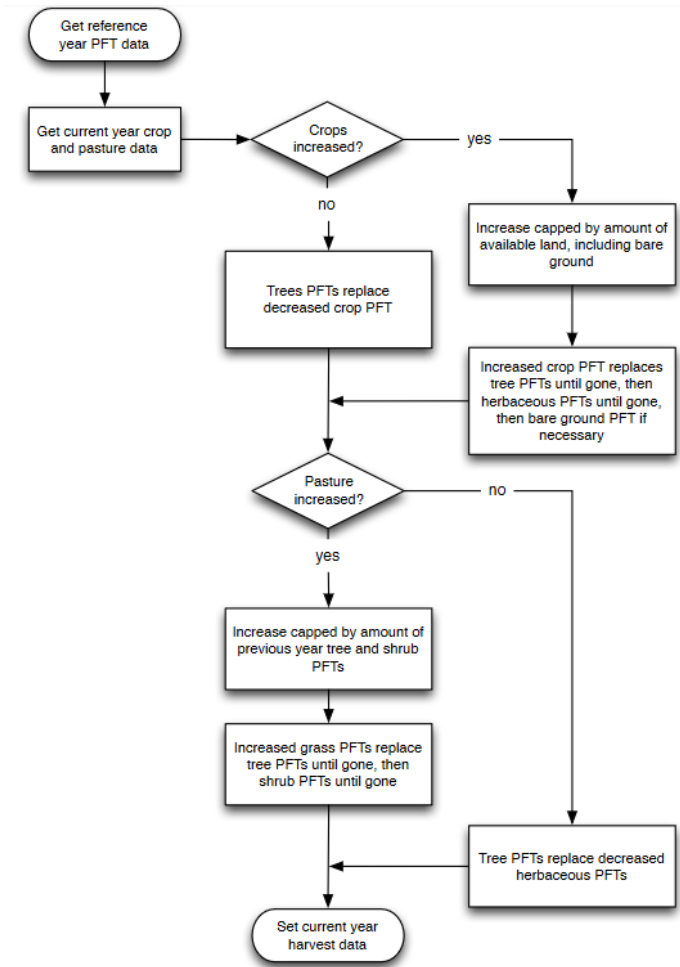
..... backward | forward



Land Use Translator

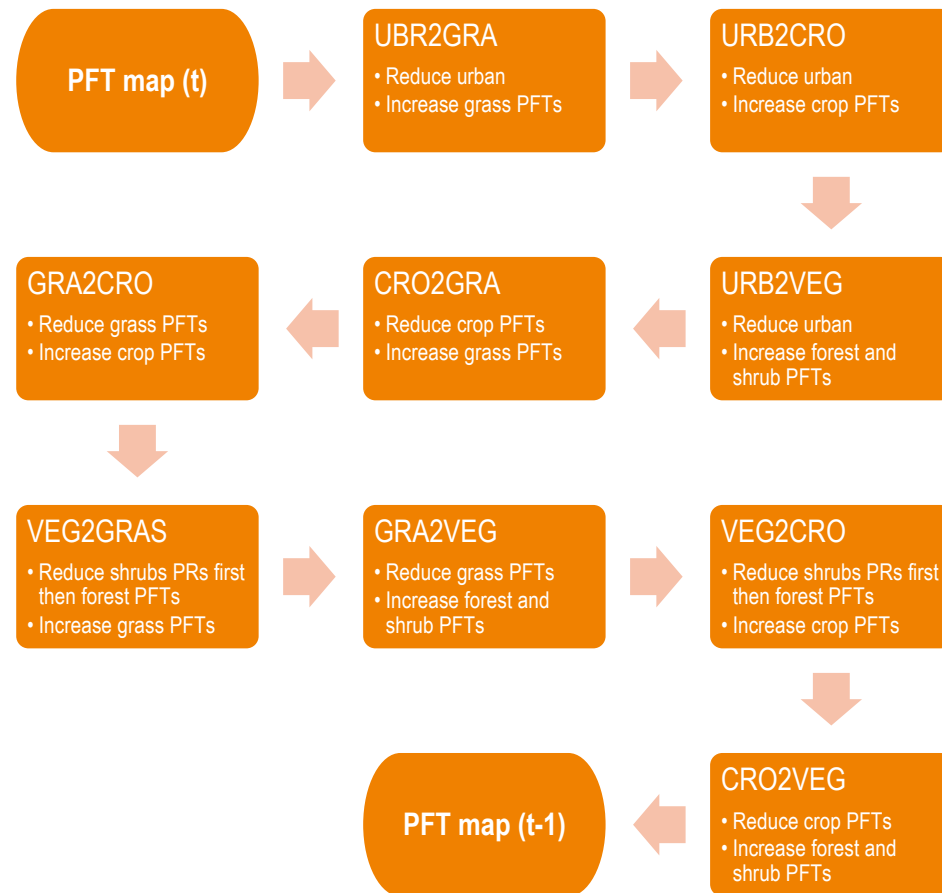
- convert land-use changes in PFT changes
- based on set of rules
- extended Di Vittorio et al. (2014):
 - backwards changes in land use
 - additional conversions:
 - urban to all other classes
 - pasture-crop conversions

	VEG	GRA	CRO
VEG	X	VEG2GRA	VEG2CRO
GRA	GRA2VEG	X	GRA2CRO
CRO	CRO2VEG	CRO2GRA	X
URB	URB2VEG	URB2GRA	URB2CRO



Di Vittorio et al. (2014)

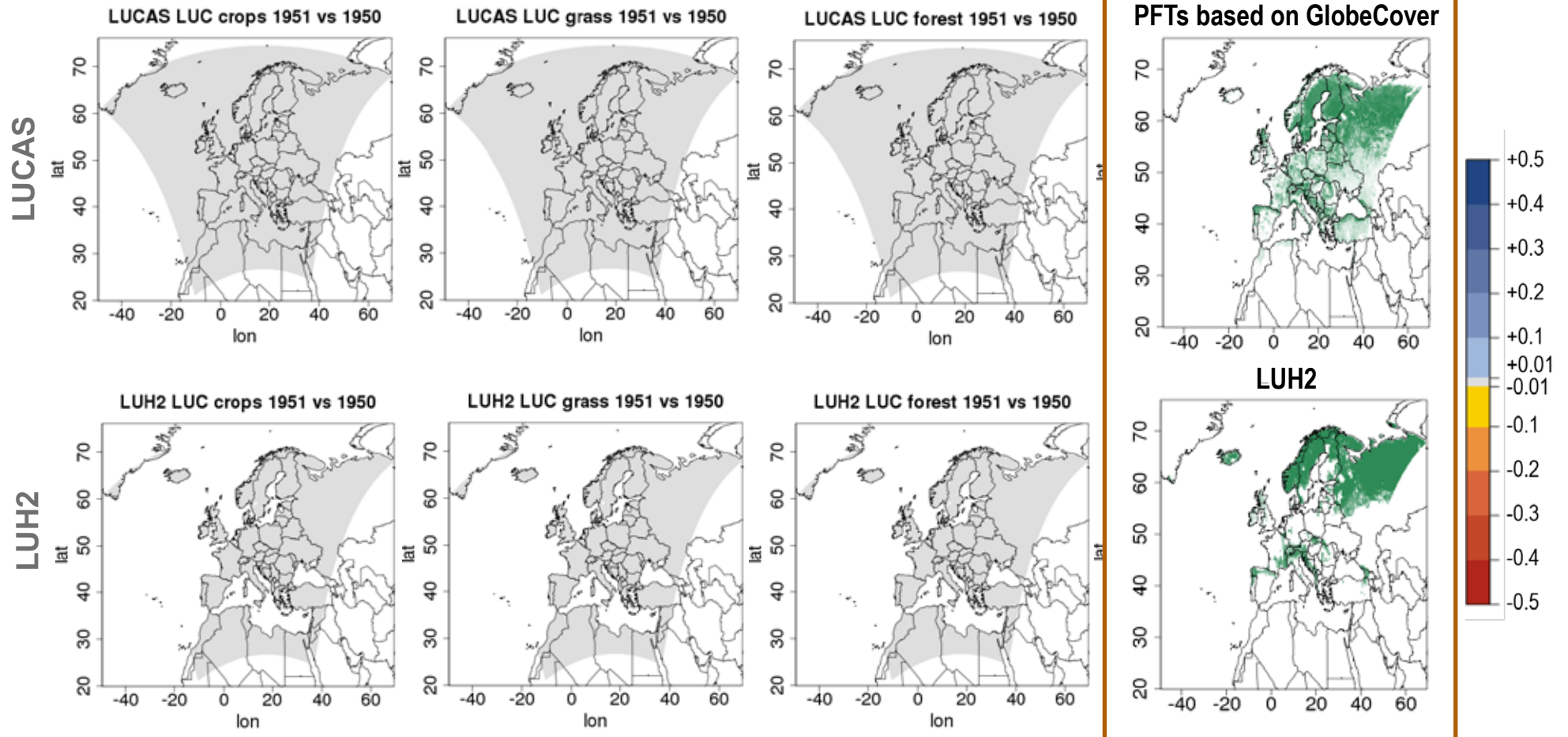
Land Use Translator (backwards)



- bare ground & swamp remain unchanged
- Increases/decreases are proportional for each combined PFT class
- Annual timestep

Combined PFT classes	Combined LUC classes	REMO-iMOVE PFT classes
Forest	VEG	trop. broad. decid. & everg., temp. broad. decid. & everg., decid. & everg. Conif.
Shrubs	VEG	decid. & everg. Shrubs
Grass	GRA	C3 & C4 grasses
Crops	CRO	C3 & C4 crops
Urban	URB	Urban

Land cover changes



■ Summary and Outlook

Summary

- Representation of LUH2 in high-resolution PFT dataset
- Annual PFT time series for EUR-11 1950-2009
- Changes correspond well with LUH2 for grass and crop PFTs
- LUH2 definition of forest does not correspond to observed forest cover

Future work

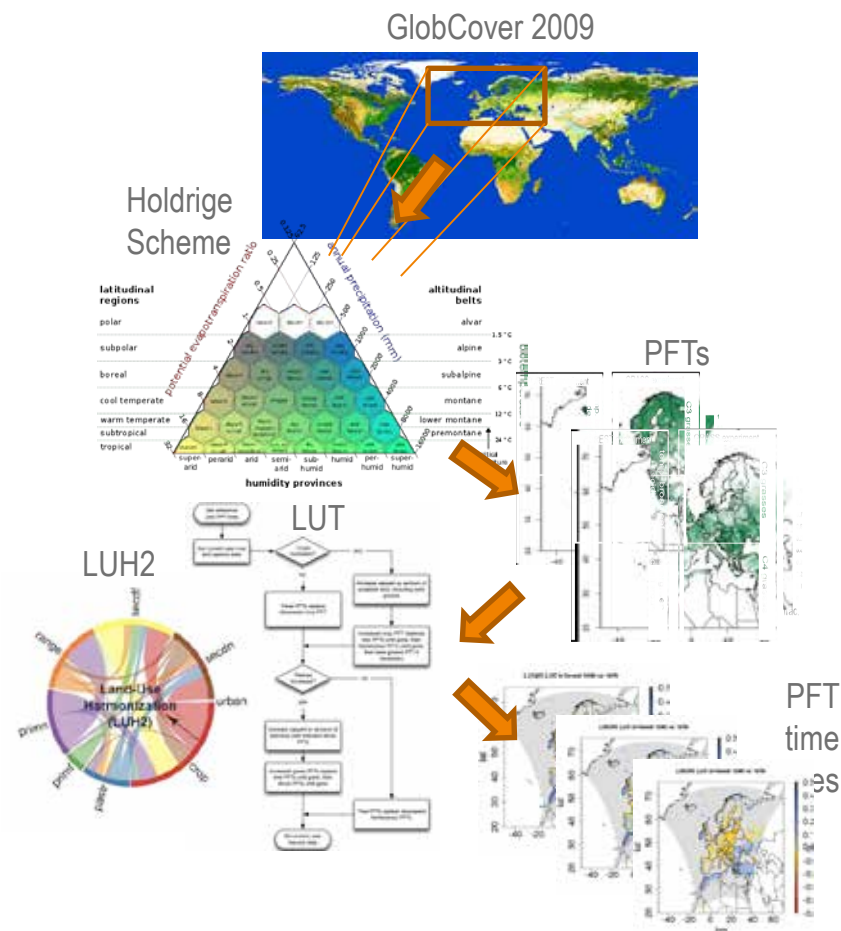
- Implementing forward algorithm for land use translator => CMIP6 scenarios
- Test simulation with REMO-iMOVE
- Application to MODIS dataset
- Potential application for other CORDEX-domains

Open Question

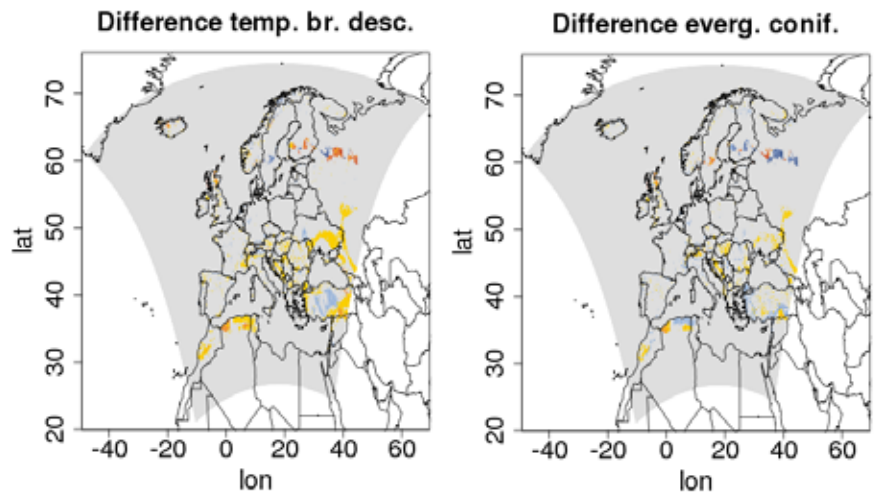
- Treatment of swamps and bare ground
- Background maps (maybe annual with potential vegetation based on climate)

Generating long-term LUC dataset for the use in RCMs

- 1. Aggregate high-resolution land cover dataset to target grid
 - Dataset: GlobeCover2009
 - Horizontal resolution 300 m
 - Multiple land-cover types (many mixed types)
- 2. Translate land-cover in plant functional types
 - Using Holdridge ecosystem type scheme based on temperature and rainfall observations from EOBs (Wilhelm et al. 2014)
- 3. Step translate land-use changes (LUC) into PFT changes
 - Dataset: Land-Use Harmonized Dataset Version 2 (LUH2, Hurtt et al. 2019)
 - Horizontal resolution $0.25^\circ \times 0.25^\circ$
 - Past LUC information from 850-2015 (for LUCAS 1950-2015)
 - Future land-use changes from 2015 to 2100 based on different SSPs and RCPs
 - Conversion into PFTs and generation of PFT time series:
 - convert land-use changes in PFT changes using a land use translator (LUT, Di Vittorio et al. 2014) extended for backwards, urban, and pasture-crop conversion

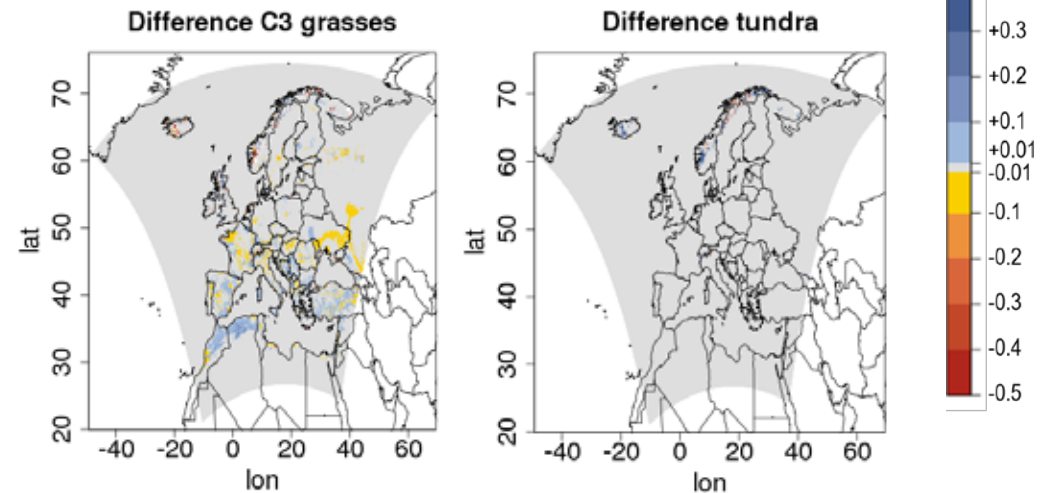


PFT conversion EOBs vs. CRU



- Difference in the mean climate lead to patchy differences in the PFT distribution

- Difference in the resolution and therefore orography lead to changes in the mountains



➡ **Uncertainty in base PFT maps**

Realistic past and future LUC

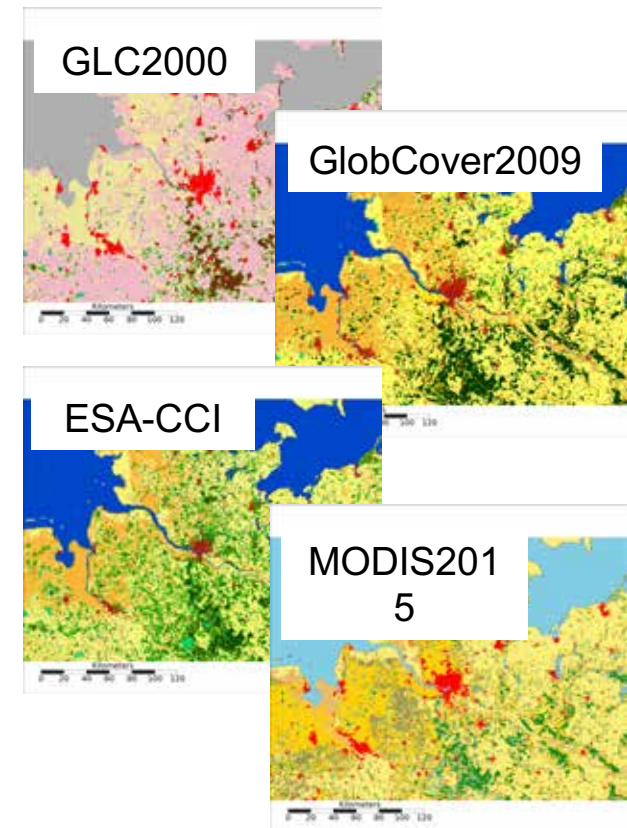
Assessment of suitable land cover products for RCMs

Requirements

- Time series of sufficiently long period (preferably annual steps)
- High spatial resolution (< 1km)
- Sufficient amount of land cover classes (transferable classification)

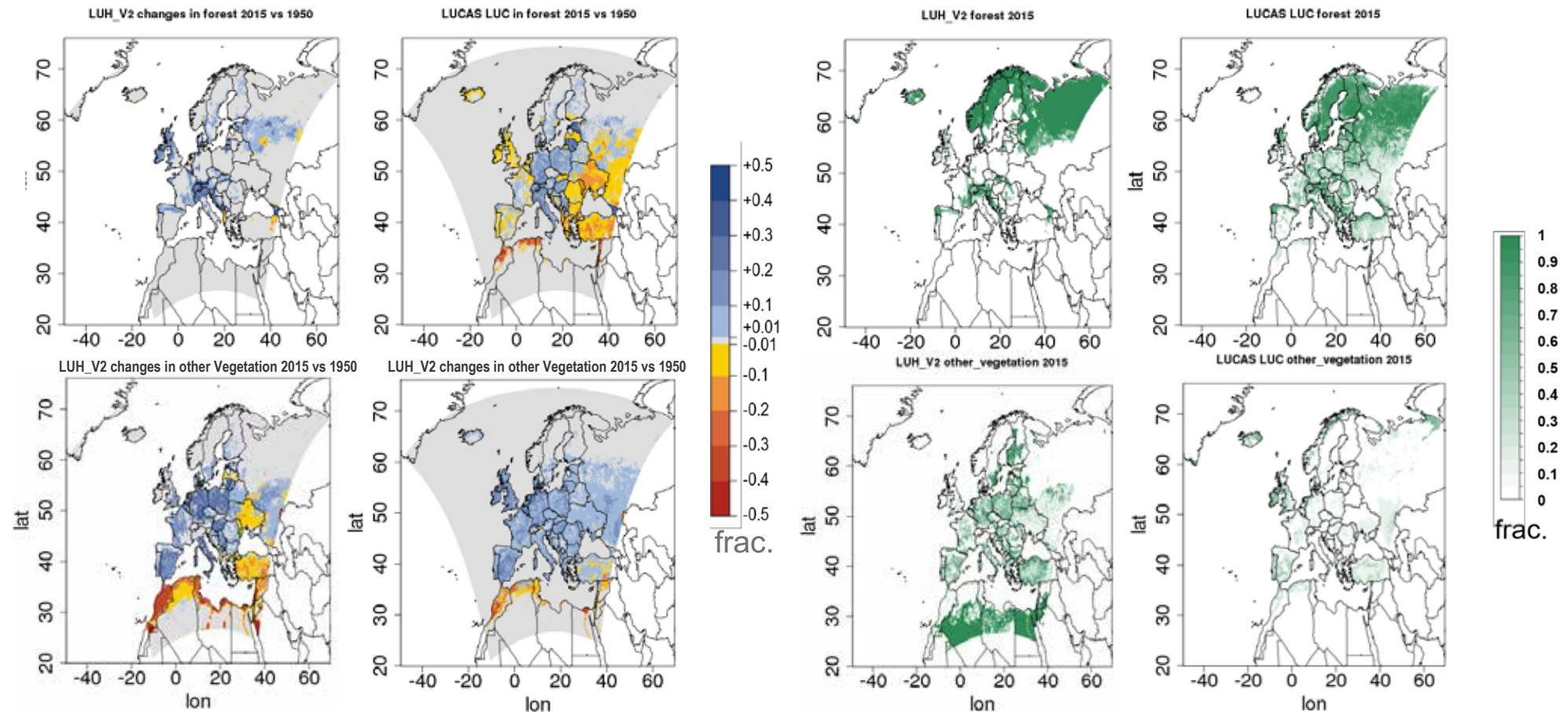
Findings

- Some datasets with quality issues
 - Need for accuracy assessment
- Lack spatial and/or temporal resolution/extent
 - Need for extending or merging of datasets



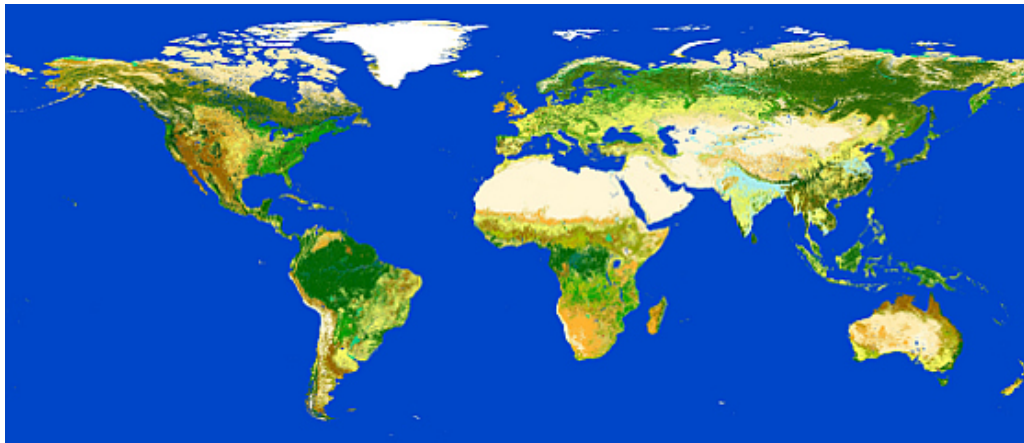
Reinhart et al. (2019)

Issues: Different distribution of forest cover



GlobeCover2009

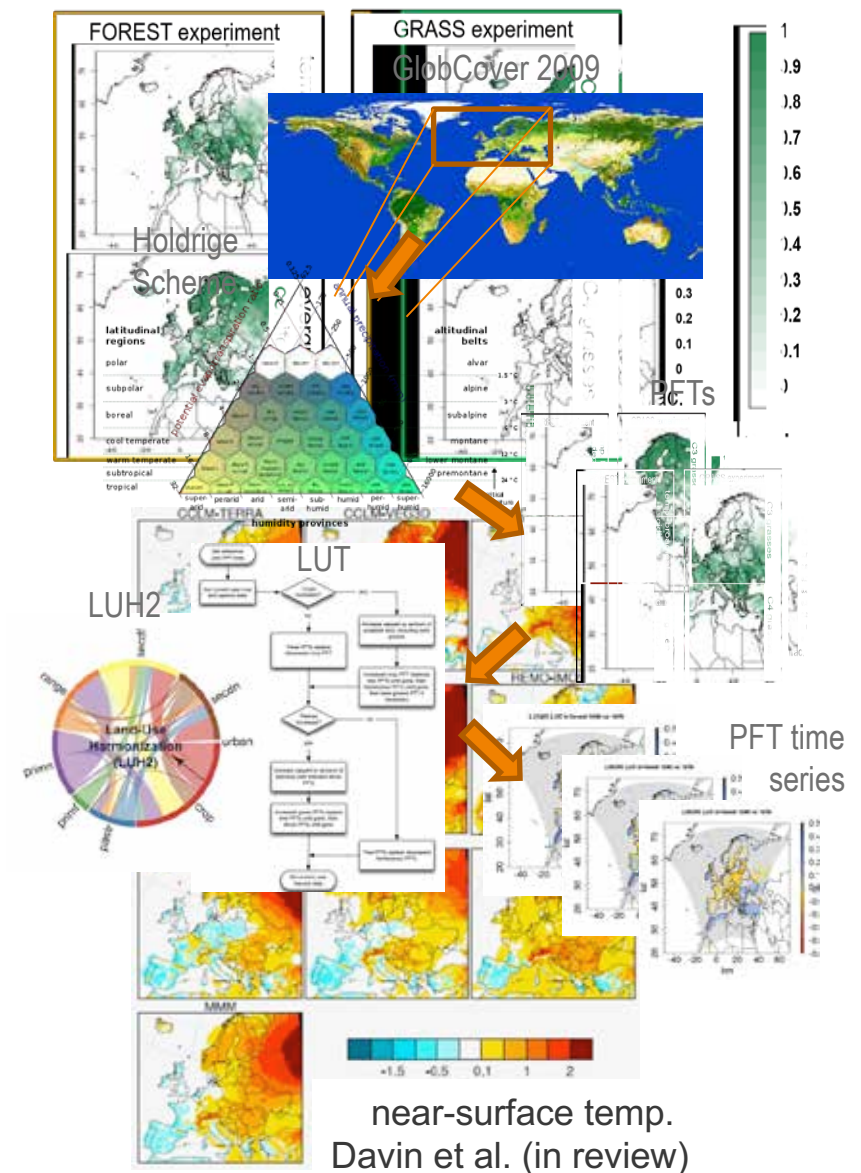
- 300 m global Resolution
- Based on MERIS (ENVI-SAT)
- 22 land cover classes defined with the United Nations (UN) Land Cover Classification System (LCCS)
- Many mixed classes
- Additional information needed to convert into PFTs



Value	GlobCover global legend	
11	Post-flooding or irrigated croplands	
14	Rainfed croplands	
20	Mosaic Cropland (50-70%) / Vegetation (grassland, shrubland, forest) (20-50%)	
30	Mosaic Vegetation (grassland, shrubland, forest) (50-70%) / Cropland (20-50%)	
40	Closed to open (>15%) broadleaved evergreen and/or semi-deciduous forest (>5m)	
50	Closed (>40%) broadleaved deciduous forest (>5m)	
60	Open (15-40%) broadleaved deciduous forest (>5m)	
70	Closed (>40%) needleleaved evergreen forest (>5m)	
90	Open (15-40%) needleleaved deciduous or evergreen forest (>5m)	
100	Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)	
110	Mosaic Forest/Shrubland (50-70%) / Grassland (20-50%)	
120	Mosaic Grassland (50-70%) / Forest/Shrubland (20-50%)	
130	Closed to open (>15%) shrubland (<5m)	
140	Closed to open (>15%) grassland	
150	Sparse (>15%) vegetation (woody vegetation, shrubs, grassland)	
160	Closed (>40%) broadleaved forest regularly flooded - Fresh water	
170	Closed (>40%) broadleaved semi-deciduous and/or evergreen forest regularly flooded - Saline water	
180	Closed to open (>15%) vegetation (grassland, shrubland, woody vegetation) on regularly flooded or waterlogged soil - Fresh, brackish or saline water	
190	Artificial surfaces and associated areas (urban areas >50%)	

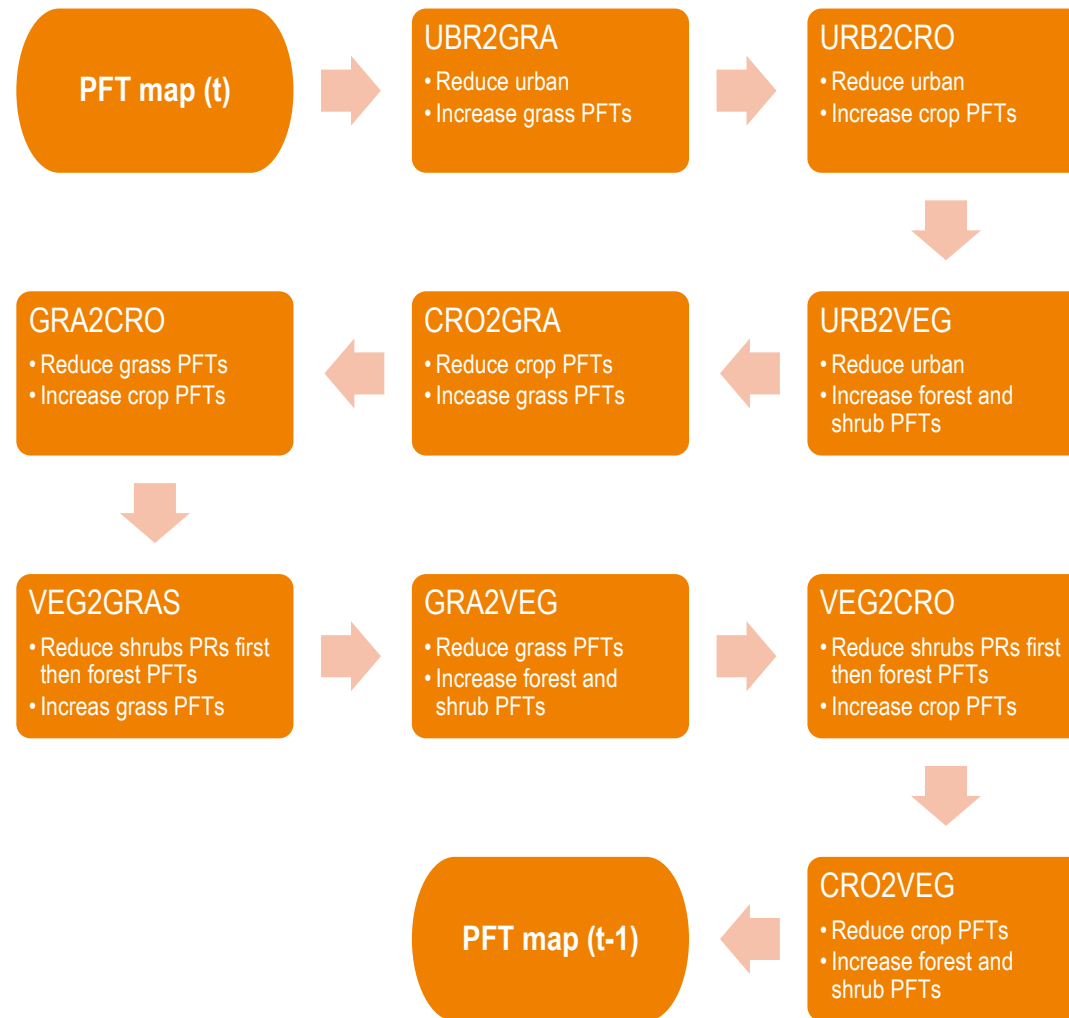
LUCAS

- **LUCAS Phase 1:** Running LUCAS RCM-LSM ensemble with extreme land cover changes
- **LUCAS Phase 2:** Running LUCAS RCM-LSM ensemble with more realistic land cover changes
- Requirements for input data:
 - Time series of sufficiently long period (preferably annual steps)
 - High spatial resolution (< 1km)
 - Sufficient amount of land cover classes (transferable classification)
- Observed land cover products such as ESA-CCI, MODIS, CORINE not long enough for long transient simulations
- Approach of merging land cover products with land-use change information from Land Use Harmonized Dataset Version 2 (LUH2)



near-surface temp.
Davin et al. (in review)

Land Use Translator (backwards)



- bare ground & swamp remain unchanged
- Increases/decreases are proportional for each combined PFT class
- Annual timestep

Combined PFT classes	Combined LUC classes	REMO-iMOVE PFT classes
Forest	VEG	trop. broad. decid. & everg., temp. broad. decid. & everg., decid. & everg. Conif.
Shrubs	VEG	decid. & everg. Shrubs
Grass	GRA	C3 & C4 grasses
Crops	CRO	C3 & C4 crops
Urban	URB	Urban

Annual PFT maps using land use change information from LUH2

