# Impacts of maximum deforestation/reforestation on the regional climate in Europe

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ICTP-ESP section, Trieste (Italy)

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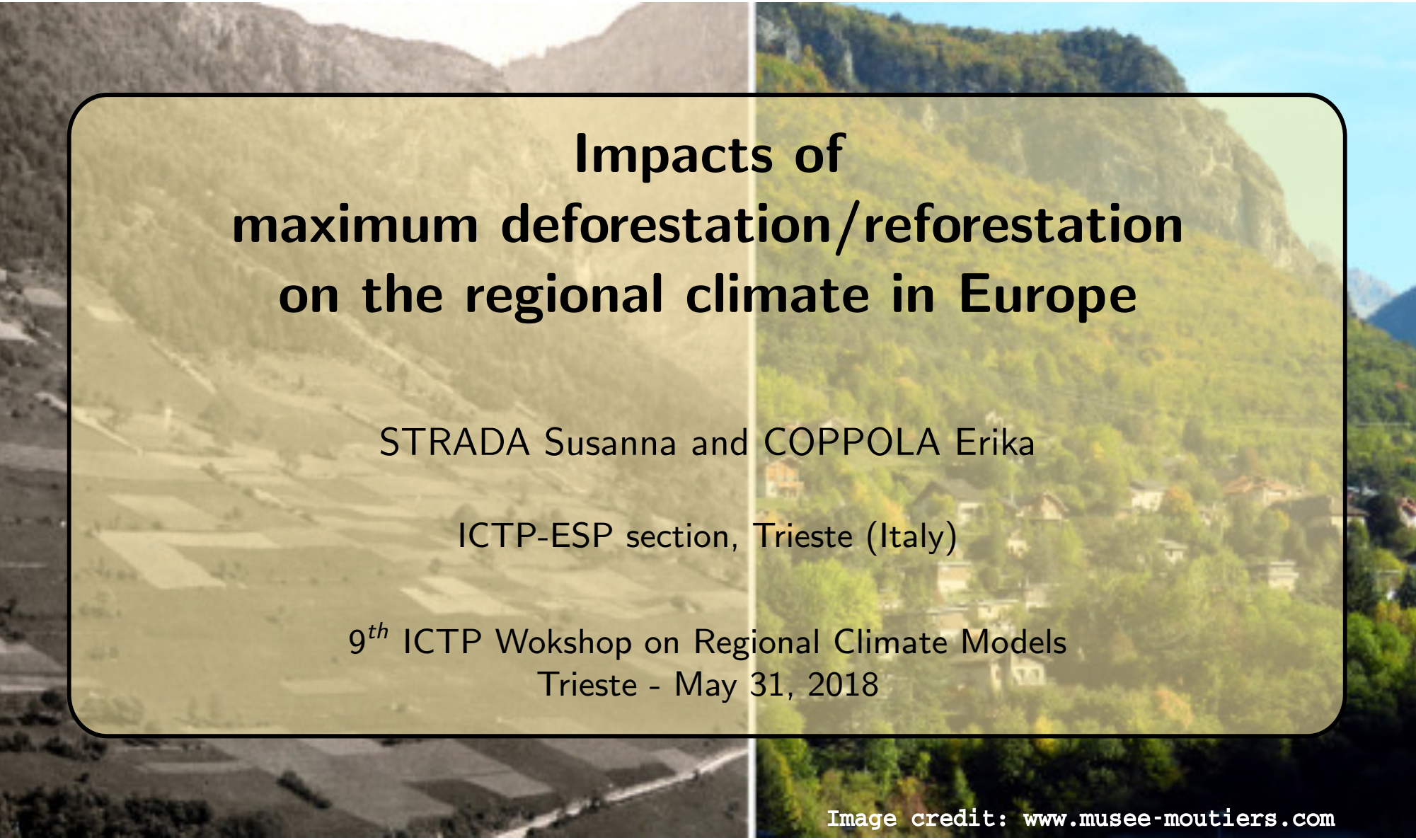
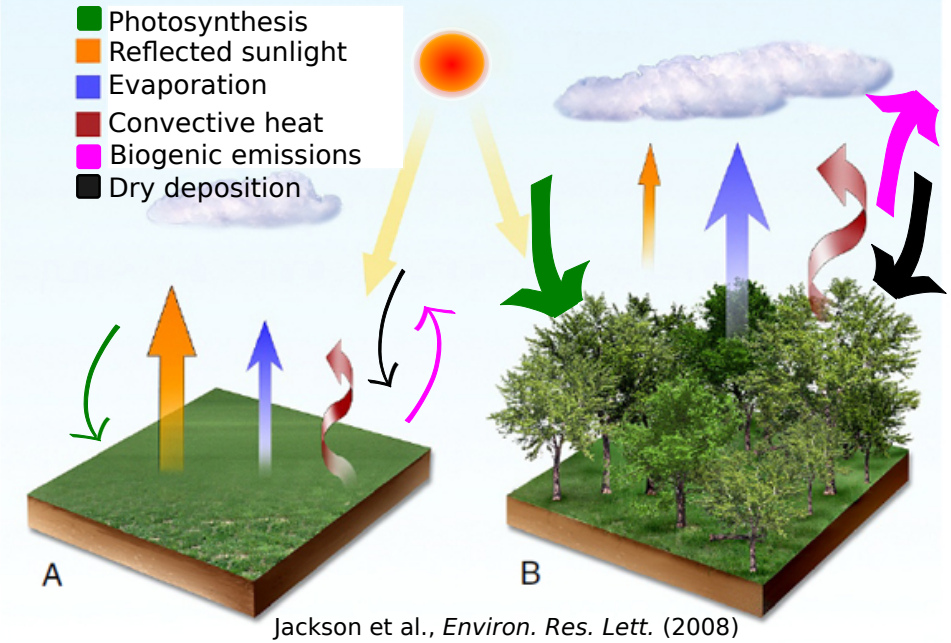



The Abdus Salam International Centre for Theoretical Physics

WCRP CORDEX FLAGSHIP PILOT STUDIES

# Land-use changes (LUCs) and surface-atmosphere interactions

Land use changes modify biophysical and biogeochemical fluxes that link the land surface to the atmosphere




Jackson et al., *Environ. Res. Lett.* (2008)

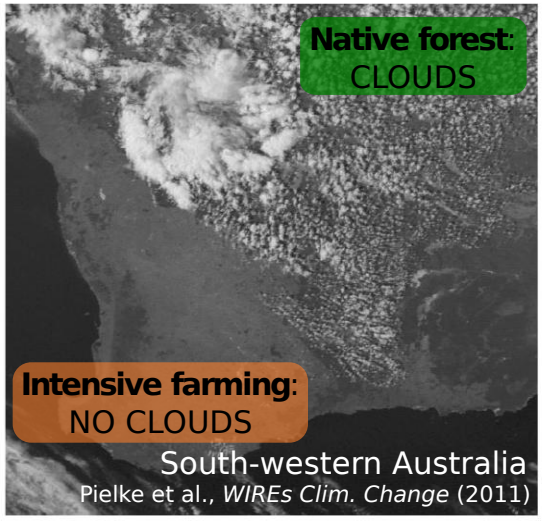
Focus of this talk:
LUC-induced modifications on the surface energy and water balance and their impacts on atmospheric conditions

# Land-use changes and climate

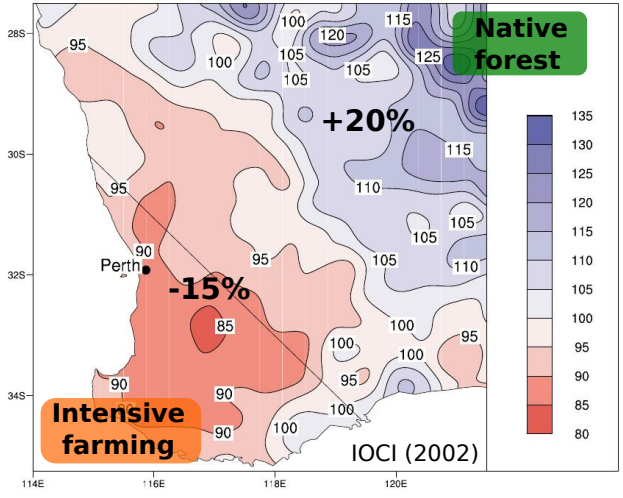
## Interactions across scales

LUCs modify atmospheric conditions and thus influence climate at different scales, from local to regional and global scales

Cloud distribution

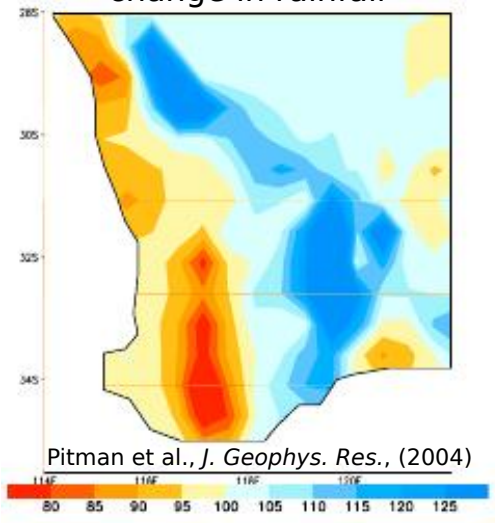



Observed percentage change in rainfall




Average May-October rainfall over 1976-2001 as a percentage of the average May-October over 1925-1975

Simulated percentage change in rainfall




Rainfall under current vegetation as a percentage of rainfall under natural vegetation. Regional Climate Model: LRAMS.

# Forests & climate: warming or cooling effect?

Reforestation in the mid-latitudes: what is the regional effect?

**The main effect on climate of temperate forests is controversial** compared to the warming/cooling effect of boreal/tropical forests (Bonan et al., 2008)


WCRP CORDEX FLAGSHIP PILOT STUDIES

LUCAS Flagship Pilot Study
(Land-Use & Climate Across Scales)

In the framework of the LUCAS project (WCRP-CORDEX flagship), we aim to:

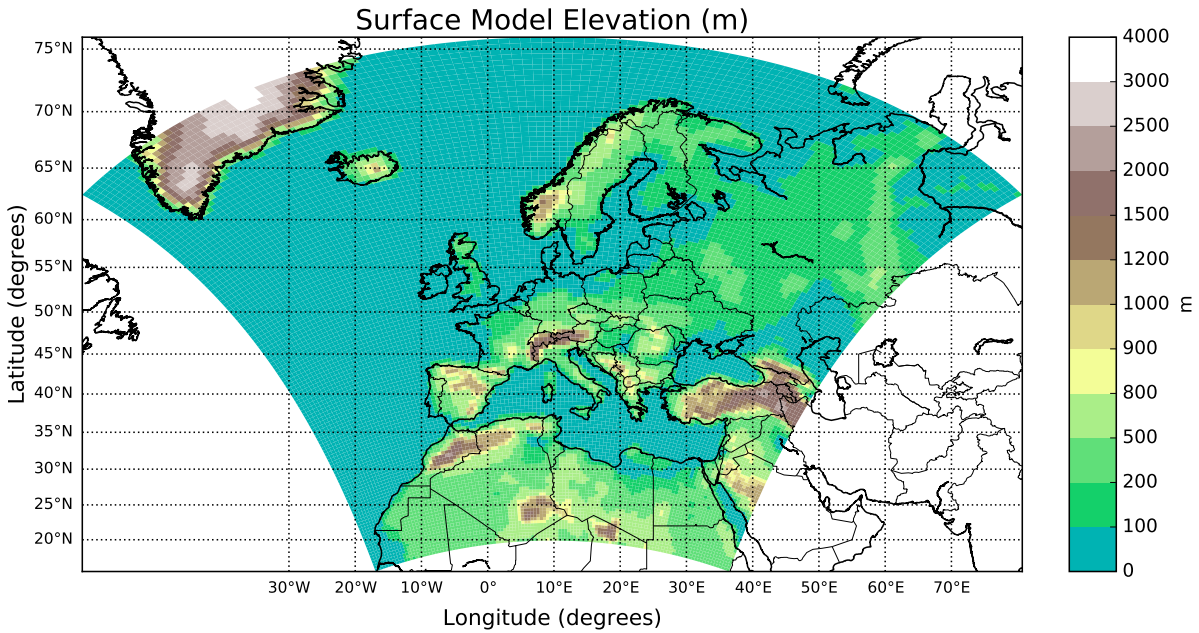
- Compare performance of regional climate models in representing the effects of LUCs on regional climate and extremes
- Assess the impacts that LUCs may have on the regional climate in Europe

# METHODOLOGY

# The coupled land-atmosphere regional climate model: RegCM4.6.1-CLM4.5

## Domain set-up

- Domain: EURO-CORDEX
- Grid-cells: $128 \times 128$
- Horizontal grid res.: 50 km
- Vertical $\sigma$-levels: 23
- Modelled time period: 1985–2015 (1985 as spin-up)
- Forcings: every 6h from ERA-Interim ($0.75° \times 0.75°$; Dee et al., 2011)



# The coupled land-atmosphere regional climate model: RegCM4.6.1-CLM4.5

Model configuration

**RegCM4.6.1** $\rightarrow$ atmospheric model

- Hydrostatic, compressible, $\sigma$-p vertical coordinates
- Rapid Radiative Transfer Model (RRTM, Mlawer et al., 1997)
- Convection:
  - Tiedtke (1996)
  - Bretherton et al. (2004) for shallow convection
- Resolved-scale precipitation: Subgrid Explicit Moisture (SUBEX, Pal et al., 2000)
- Ocean fluxes: Bulk aerodynamic algorithm of Zeng et al. (1997)

**CLM4.5** $\rightarrow$ land-surface model

- 17 Plant Functional Types (PFTs)
- Water-energy-carbon exchanges
- Prescribed phenology and carbon cycle
- Imposed vegetation distribution
- Multi-layer soil moisture scheme (10 layers)

# Simulations

RegCM4.6.1-CLM4.5

Three fully coupled land-atmosphere simulations

| Simulation | Climate | Land cover distribution |
|---|---|---|
| EVAL | 1985–2015 | MODIS-based present-day (Lawrence and Chase, 2007) |
| FOREST | | Maximized forest cover according to potential vegetation |
| GRASS | | Grasslands replace all forests |

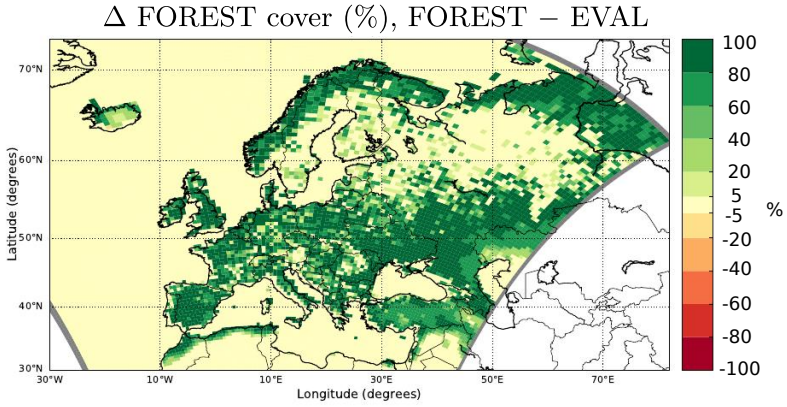
1-year spin-up (1985)

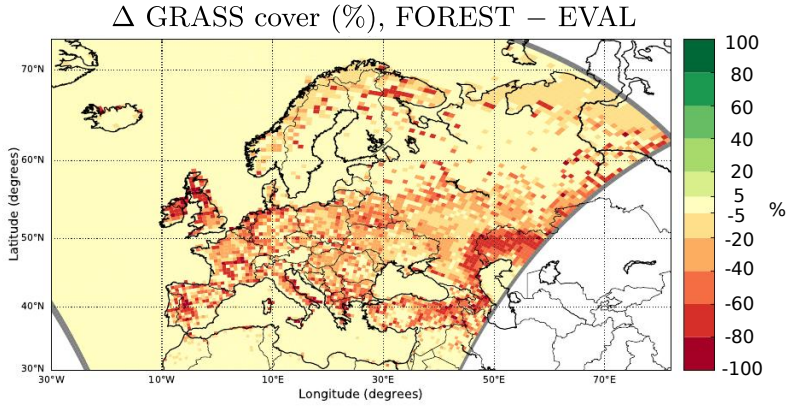
All simulations consider the same fraction of bare soil
In the FOREST (GRASS) simulation shrub-lands and crop-lands have been completely replaced by forest (grass)

# Idealized land-use changes

## Maximum reforestation/deforestation over Europe

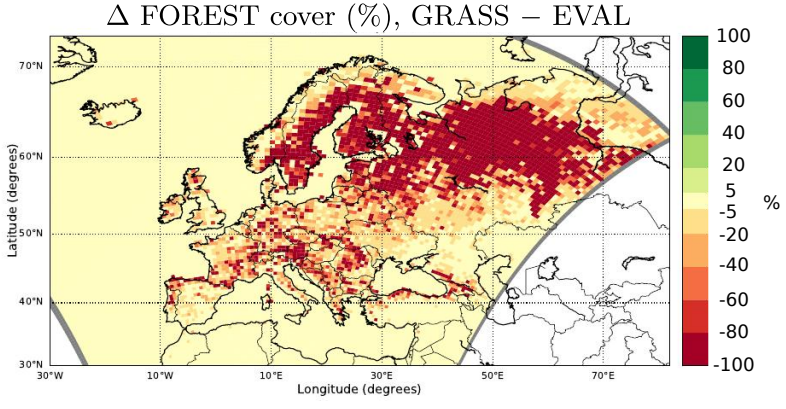
### Reforestation (FOREST − EVAL)

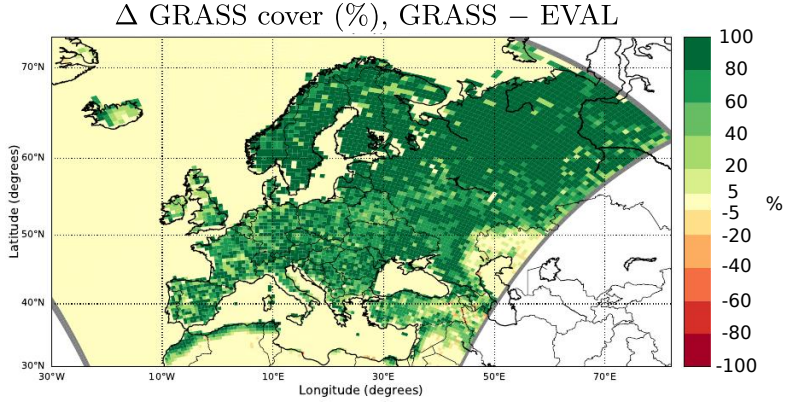



**Increase in forest cover: +174%**

### Deforestation (GRASS − EVAL)



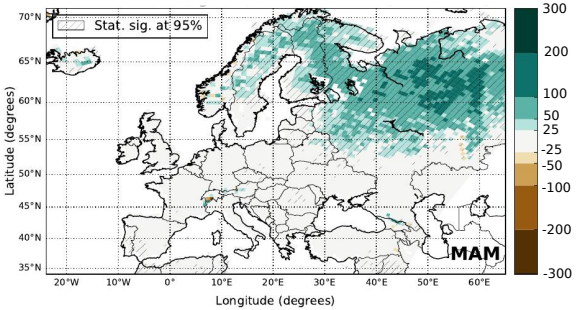

**Increase in grass cover: +336%**

# RESULTS

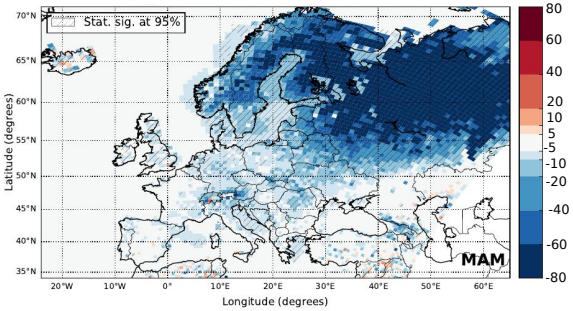
# Extreme deforestation in the boreal region

## Change in the snow cover and its effects during spring (MAM)

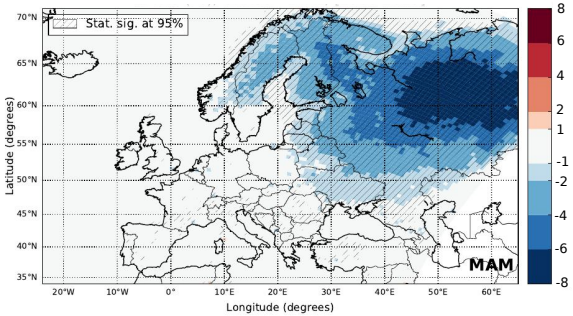
Δ SNOW COVER (kg m$^{-2}$)



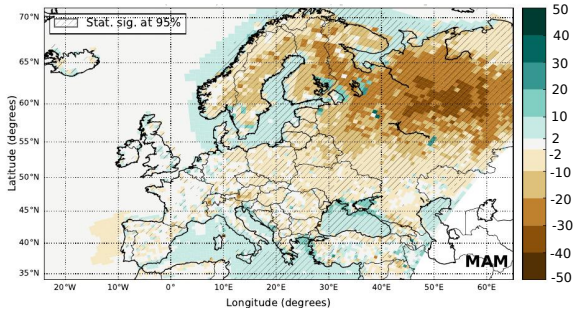

Δ NET RADIATION (W m$^{-2}$)



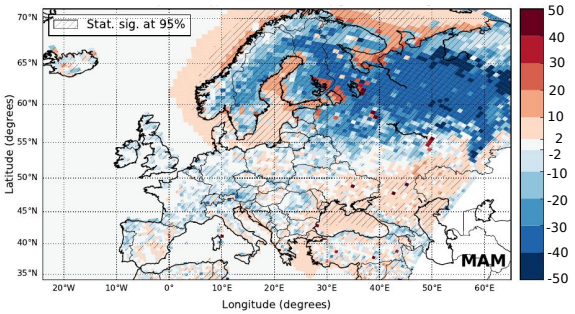

Δ SURFACE AIR TEMP. (°C)




Δ LATENT HEAT FLUX (W m$^{-2}$)



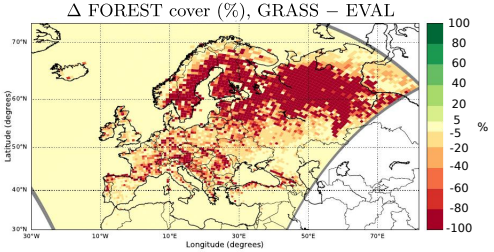

Δ SENSIBLE HEAT FLUX (W m$^{-2}$)



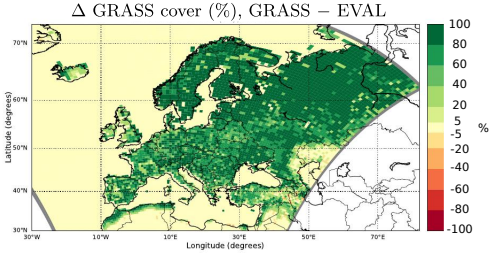

From TREES to GRASS:
effect on the snow cover

**Deforestation (GRASS – EVAL)**

Δ FOREST cover (%), GRASS – EVAL



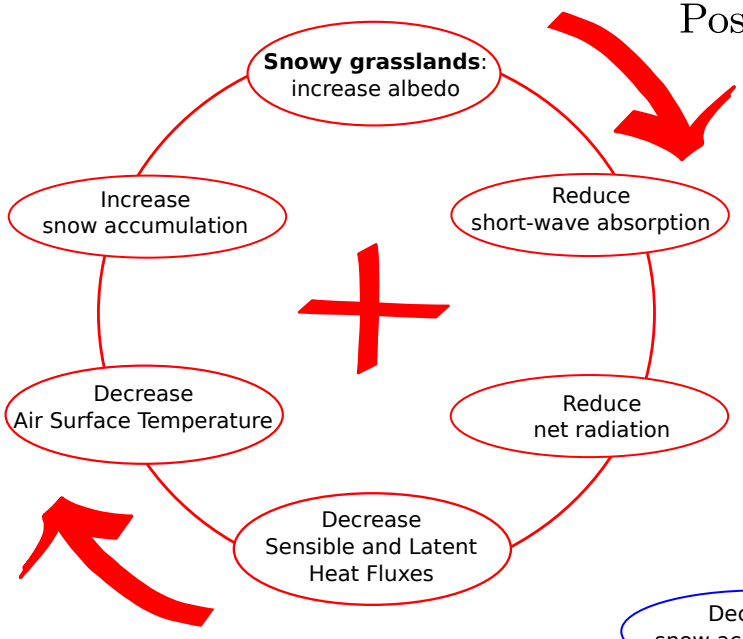

Δ GRASS cover (%), GRASS – EVAL

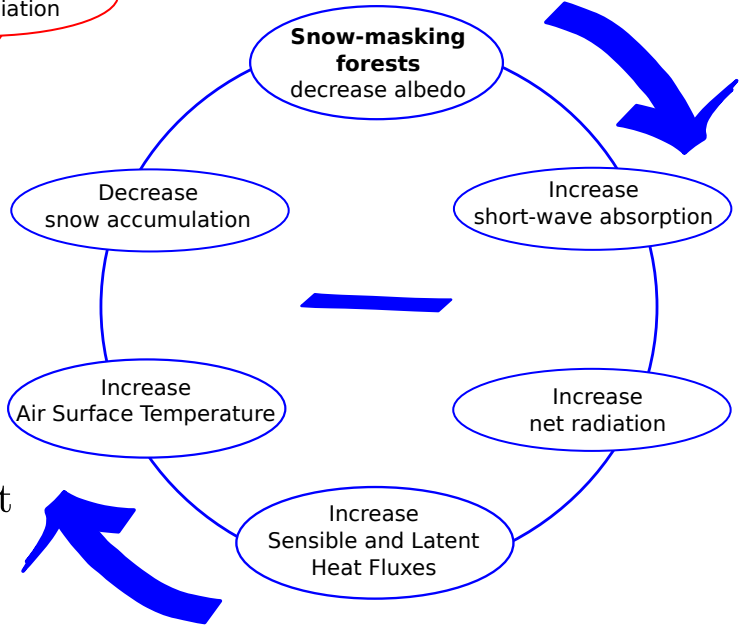


# Feedback loops in the presence of snow

## Forest VS Grass

Positive feedback loop for grass in the presence of snow



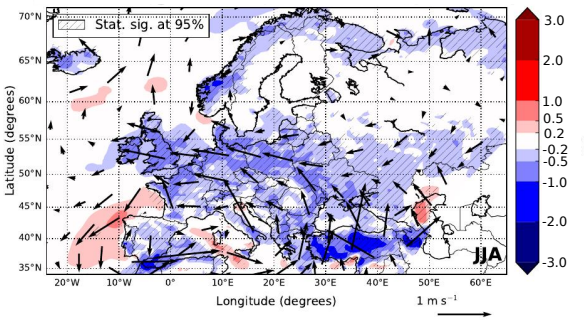




Negative feedback loop for forest in the presence of snow

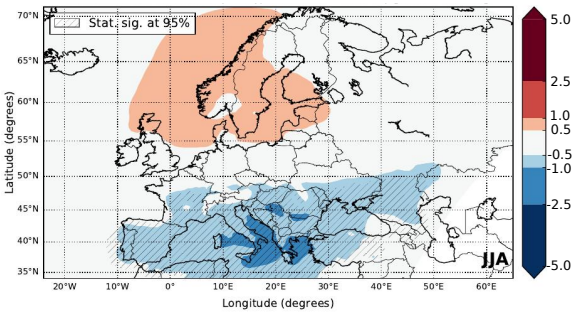
# Extreme reforestation in the mid-latitudes

## Local and non-local effects during summer (JJA)

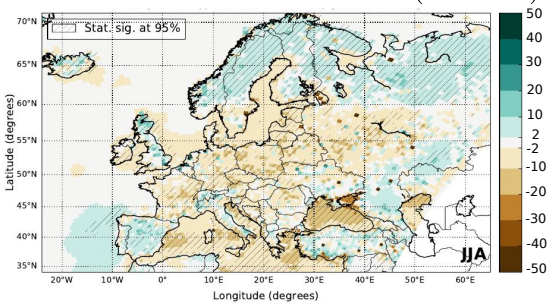
Δ SURFACE WIND (@10 m, m $s^{-1}$)



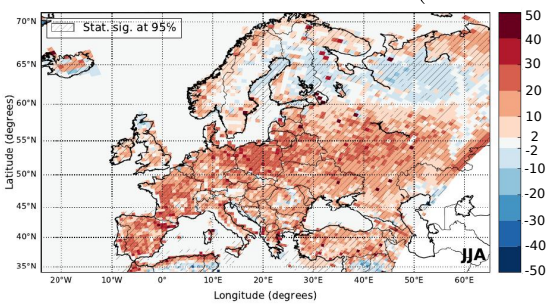

Δ SURFACE PRESSURE (hPa)



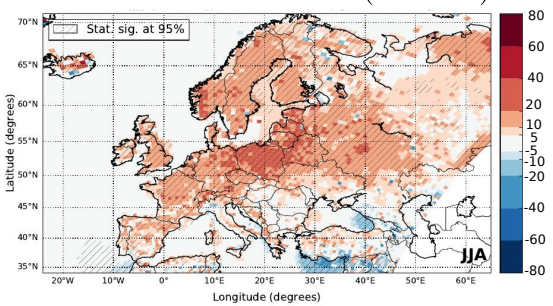

Δ LATENT HEAT FLUX (W $m^{-2}$)




Δ SENSIBLE HEAT FLUX (W $m^{-2}$)

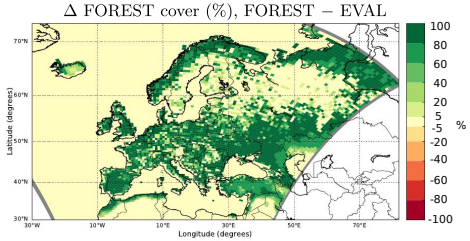



Δ NET RADIATION (W $m^{-2}$)

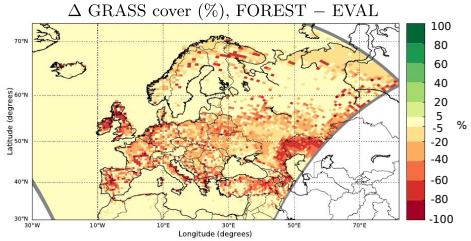



**Reforestation (FOREST − EVAL)**

Δ FOREST cover (%), FOREST − EVAL



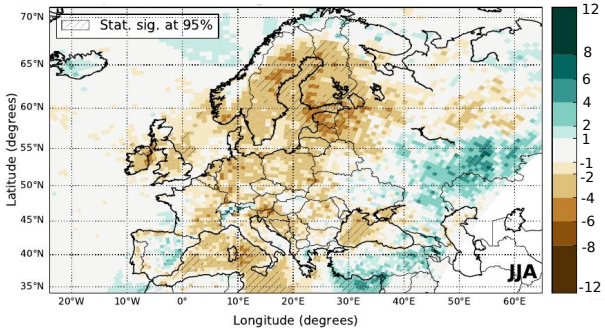

Δ GRASS cover (%), FOREST − EVAL



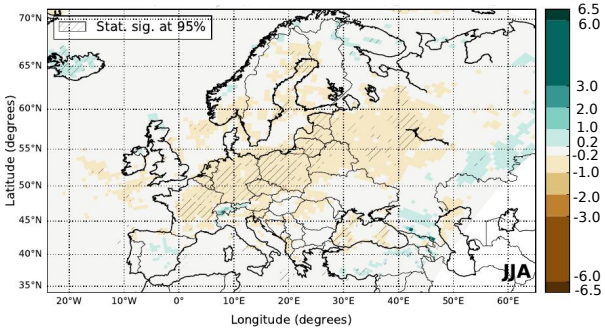
# Extreme reforestation in the mid-latitudes

## Changes in the cloud cover and its effects on temperatures during summer (JJA)

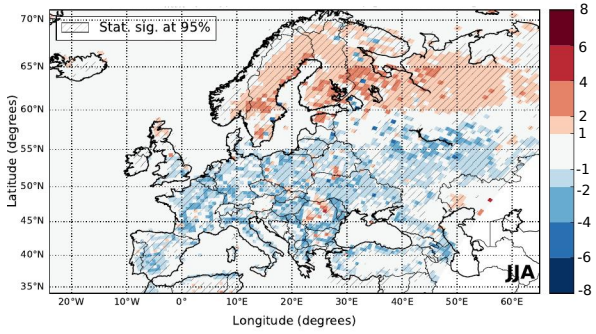
Δ TOT. CLOUD LIQ. WATER CONTENT (g m$^{-2}$)



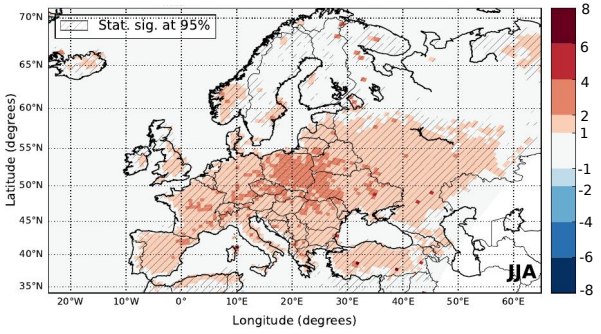

Δ PRECIPITATION (mm day$^{-1}$)



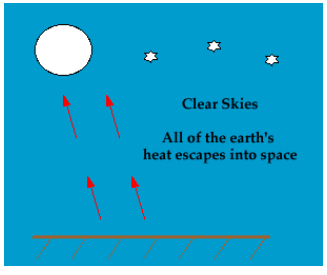

Δ MINIMUM SURF. AIR TEMPERATURE (°C)

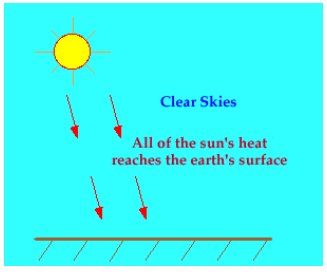



Δ MAXIMUM SURF. AIR TEMPERATURE (°C)

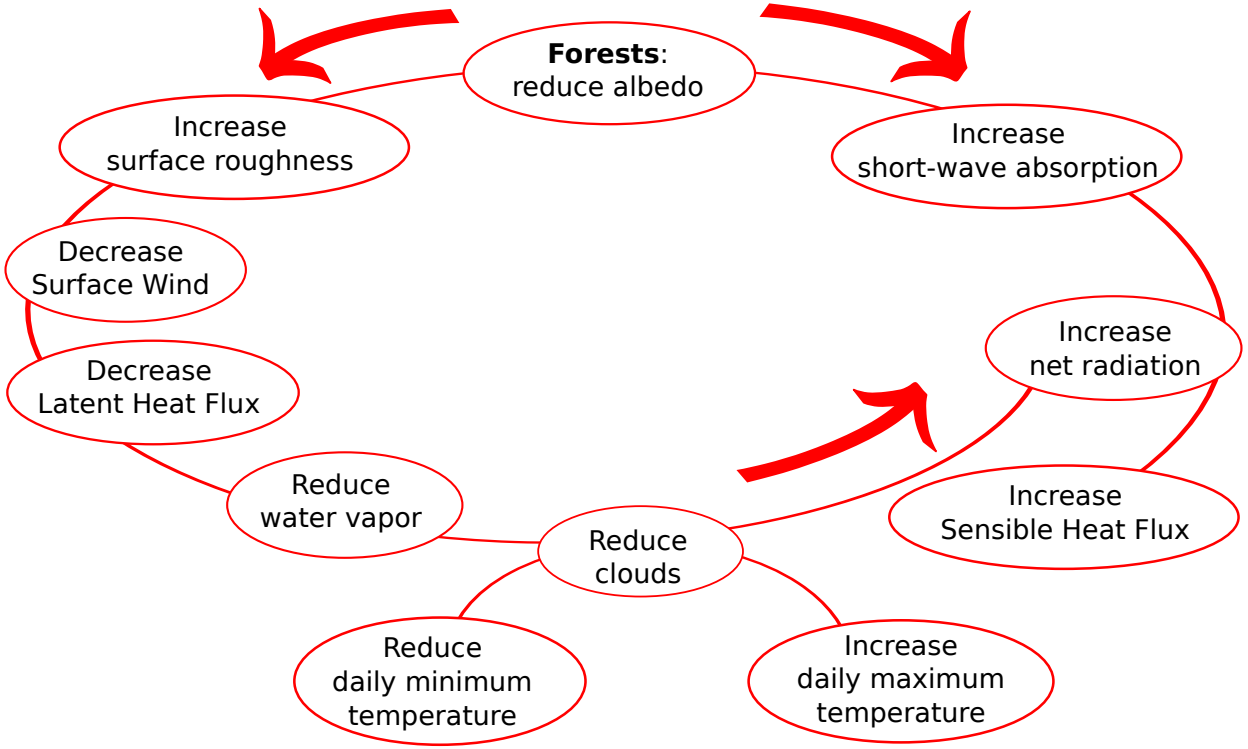



Effect of CLEAR SKIES on land-atmosphere exchanges of heat



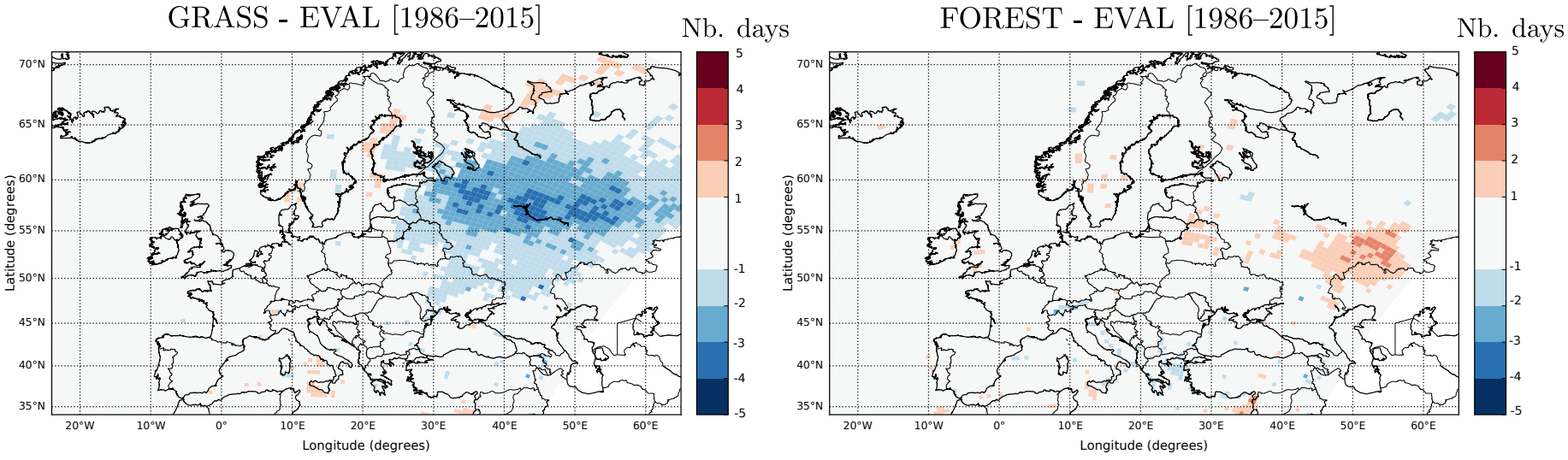



# Non-local effects of reforestation in the mid-latitudes



# Change in the number of very warm days

## Climate extremes

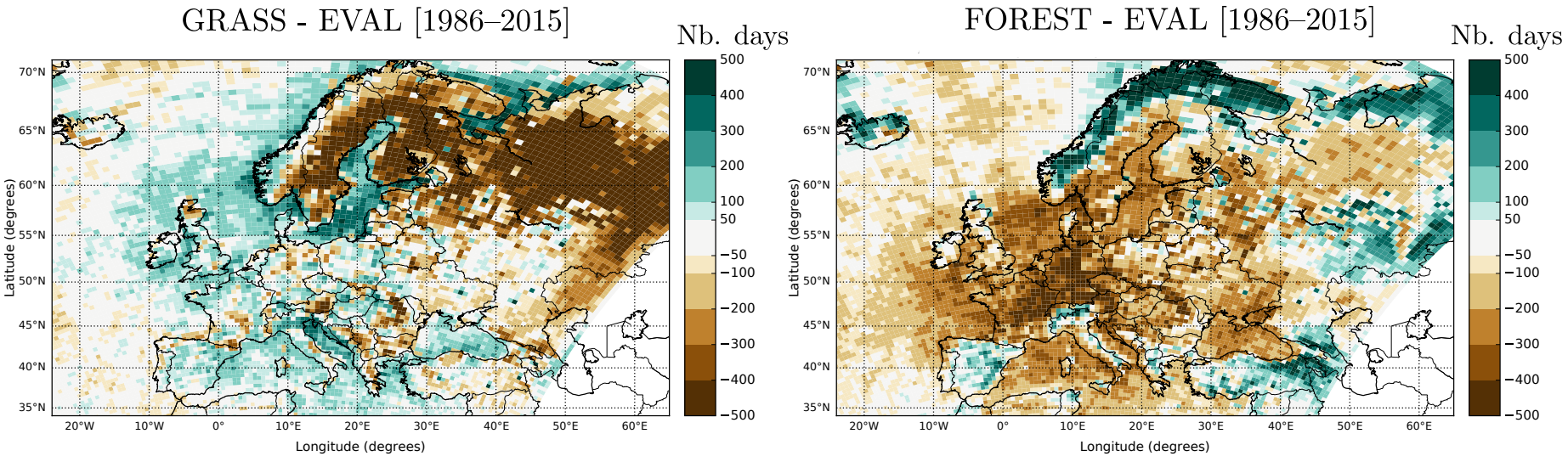



**Very Warm Days:**

Percentage of days with a daily maximum $T_{2m}$
greater than the 90th percentile of the daily maximum temperatures

# Change in the number of wet days

## Climate extremes




**Wet frequency:**

Number of days when daily precipitation is greater than 1 mm

# Conclusions

- The effects of extreme land-use changes on regional climate maximize during the growing season (from spring to summer)
- Deforestation in boreal regions removes the masking of snow albedo by trees and significantly reduces mean surface temperatures, especially during spring, in agreement with previous studies (e.g., Betts and Ball, 1997; Bonan, 2008)
- Reforestation in Central Europe and the Euro-Mediterranean region leads to non-local effects with reduction of evaporation and changes in the cloud cover over the Mediterranean Basin

# Thank you for your attention!

# Questions?

Contact: sstrada@ictp.it

Image credit: www.musee-moutiers.com