Land cover-climate interactions in NW Europe, 6000 BP and 200 BP – results from the Swedish LANDCLIM project 2009-2014

Marie-José Gaillard
Linnaeus University, Sweden
Anna-Kari Trondman, Linnaeus University, Sweden
Shinya Sugita, University of Tallinn, Estonia
Ralph Fyfe, University of Plymouth, UK
Jed Kaplan, EPFL, Lausanne, Switzerland
Anne Birgitte Nielsen, Lund University, Sweden
Laurent Marquer, Linnaeus University, Sweden
Florence Mazier, University of Toulouse, France
Anneli Poska, Lund University, Sweden
Gustav Strandberg, Erik KjellströmSMHI, Sweden
LANDCLIM members

Vetenskapsrådet

Swedish Research Council

norden

NordForsk

Kalmar Växjö

What is LANDCLIM?

- Study of land cover (vegetation on land) – climate interactions in the past, in particular effect of past land-use on climate (climate forcing)
- Regional spatial scale: use of a regional climate model
- Comparison of two time-windows of the past:
  - **6000 BP: 5700-6200 BP (4250- 3750 before Christ)**: **little human-induced vegetation**
  - **200 BP: 100-350 BP (1600-1850 after Christ): end of Little ice age, before the modern global warming**, i.e. the classical pre-industrial state widely used as a baseline to be compared with modern human-impact on climate in terms of greenhouse gases

WHY?

Atmospheric gas composition ⟷ **Climate**

FEEDBACK LOOPS

e.g. CO_2

Biogeochemical effects

Changes in ecosystems affect sources and sinks of:

- **Greenhouse gases**
- **Aerosols**
- **Pollutants**
- **Other gases (e.g. oxygen)**

e.g. ALBEDO

Biogeophysical effects

Changes in ecosystems affect:

- **Heat fluxes**
- **Water fluxes**
- **Wind (direction and magnitude)**

Terrestrial ecosystems

*Including **FIRE!***

Modified from Foley et al. (2003)

Figure courtesy of Victor Brovkin, modified

Incorporation of land-cover description in climate models

One of the high priorities of the climate modelling community

Development of Dynamic vegetation models and coupling to climate models

A very good example: LPJGUESS (Smith et al.)
SIMULATES CLIMATE-INDUCED (POTENTIAL) VEGETATION

LPJ-GUESS is now coupled to:

- **EC-EARTH** (*global* climate model, EC-EARTH consortium)
- **RCA** (*regional* climate model, SMHI Sweden) (Smith et al. 2010, *Tellus*)

Land-use = anthropogenic land-cover
One of the external forcing of climate change

- land-use dimension not successfully included in dynamic vegetation models yet

- other models are used for description of anthropogenic vegetation cover:
  - comparison of modern situation with pre-industrial time
  - projections in the future

"Anthropogenic Land Cover Change" (ALCC) scenarios of the past

- models of **human population growth** as a basis
- **different approaches to translate population numbers into fraction of deforested land**:
  - Klein Goldewijk's (2001, 2010): **HYDE** (History Database of the Global Environment)
  - Kaplan et al. (2009): **KK 10 scenarios**
  - Lemmen (2009): Wirtz and Lemmen (2003) **GLUES**, based on dynamic hindcasts of socio-economic development
  - Prongratz et al. (2008)

Review in Gaillard et al. 2010, *Climate of the Past* 6.

Note the difference in open land!

AD 800
Late Iron Age

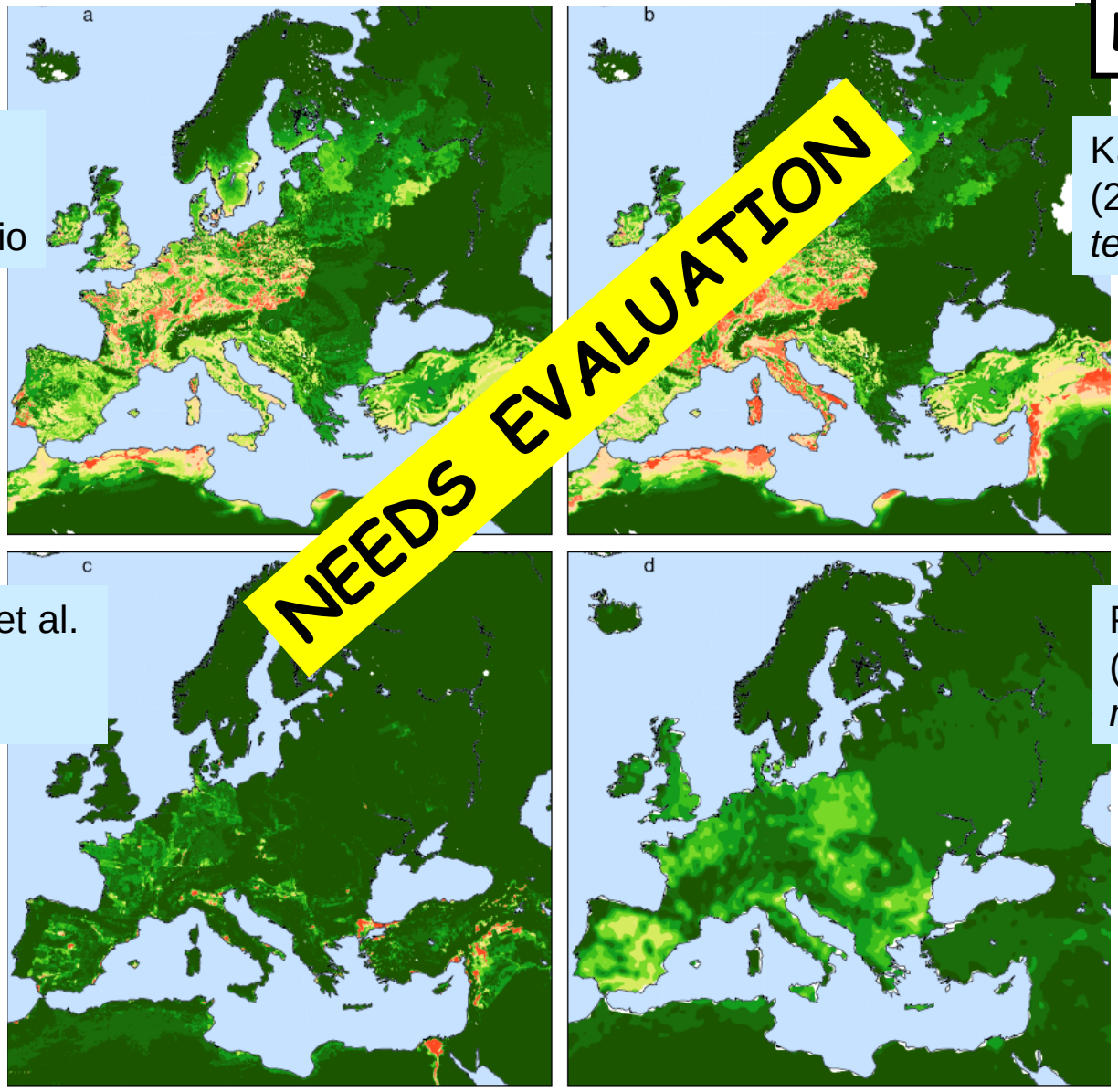
Kaplan et al. (2009), **KK10** *standard* scenario

Kaplan et al. (2009), **KK10** *technology* scenario

NEEDS EVALUATION

Klein Goldewijk et al. (2010) **HYDE 3.1**

Pongratz et al. (2008) *maximum* scenario



From Gaillard et al. 2010, *Climate of the Past* 6

How to test models and evaluate simulations/scenarios?

⇒ **model-data comparison approach**

- **Runs for modern times**

- *comparison with* **modern data** of vegetation and climate

Not sufficient: can the models reproduce changes over time well?

⇒ **the models need to be evaluated over long time periods:**

CONTRIBUTION OF PALAEOECOLOGY

- **Runs for historical and prehistorical times**

– *comparison with* **historical data** and **palaeoecological data** of vegetation, climate and anthropogenic vegetation

Evaluate scenarios of anthropogenic land-cover change in the past

HOW?

Needs to test models and hypotheses (except good palaeoclimatic data)

- **Spatially explicit descriptions** of vegetation/land-cover in the past to apply the **data-model comparison** approach
  - To test and improve **dynamic vegetation models and climate models** (coupled with dynamic vegetation models)
  - To test **hypotheses on past land cover-climate feedbacks**

HOW?

Pollen-based reconstructions of past vegetation cover

The REVEALS MODEL (Sugita, 2007)

Corrects the biases of pollen data due to between-plant differences in pollen productivity and pollen dispersal and deposition

Test of the REVEALS model: comparison with modern and historical vegetation records

Southern Sweden, Denmark, Swiss plateau

Upper Great Lake region of the US

Pollen records from large sites (≥ 50 ha)
or many small sites (≤ 10 ha)

→ **vegetation in percentage cover** in an area of ca. **100 km x 100 km** -

EMPIRICAL DATA - NOT SIMULATED!

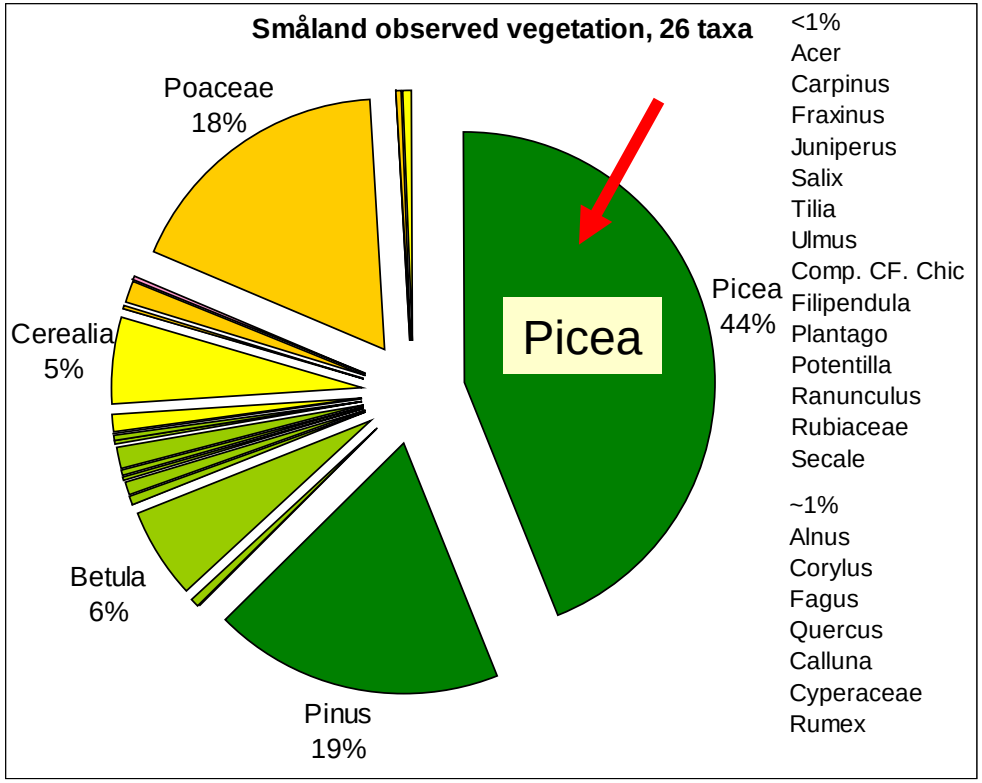
The REVEALS model requires:
- pollen productivity
- fall speed of pollen

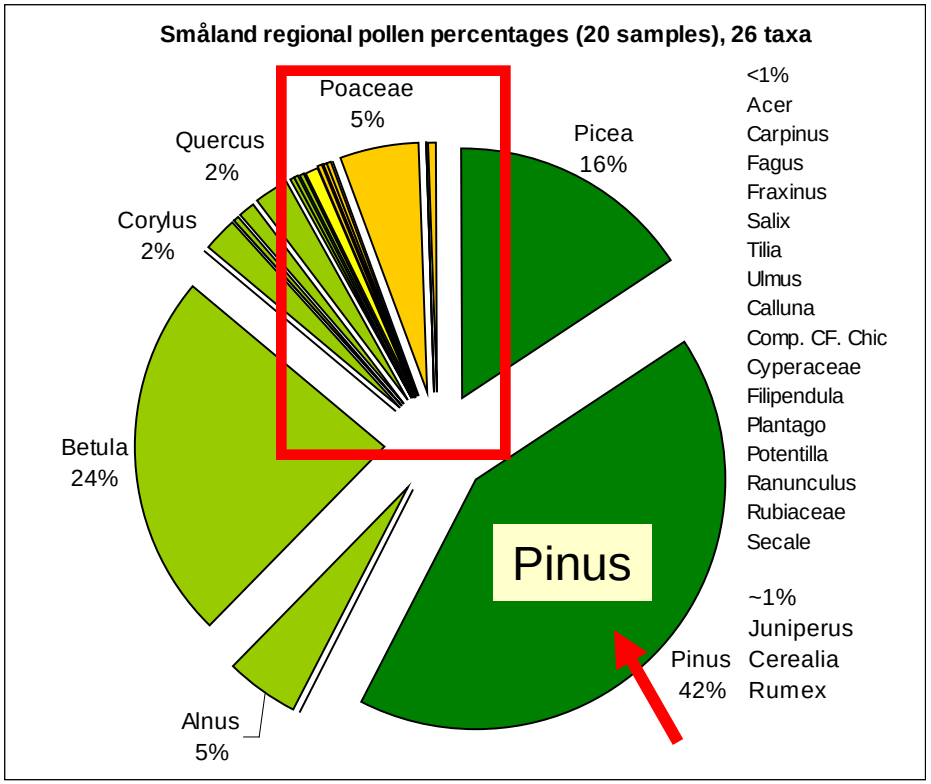
Testing REVEALS: S Sweden: Småland (Semi-open Landscape)

Hellman, Gaillard et al. 2008, *JQS*

Observed modern vegetation (percentage cover)

Pollen percentages in modern lake sed.





Conifers

Deciduous trees

Cerealia & Secale

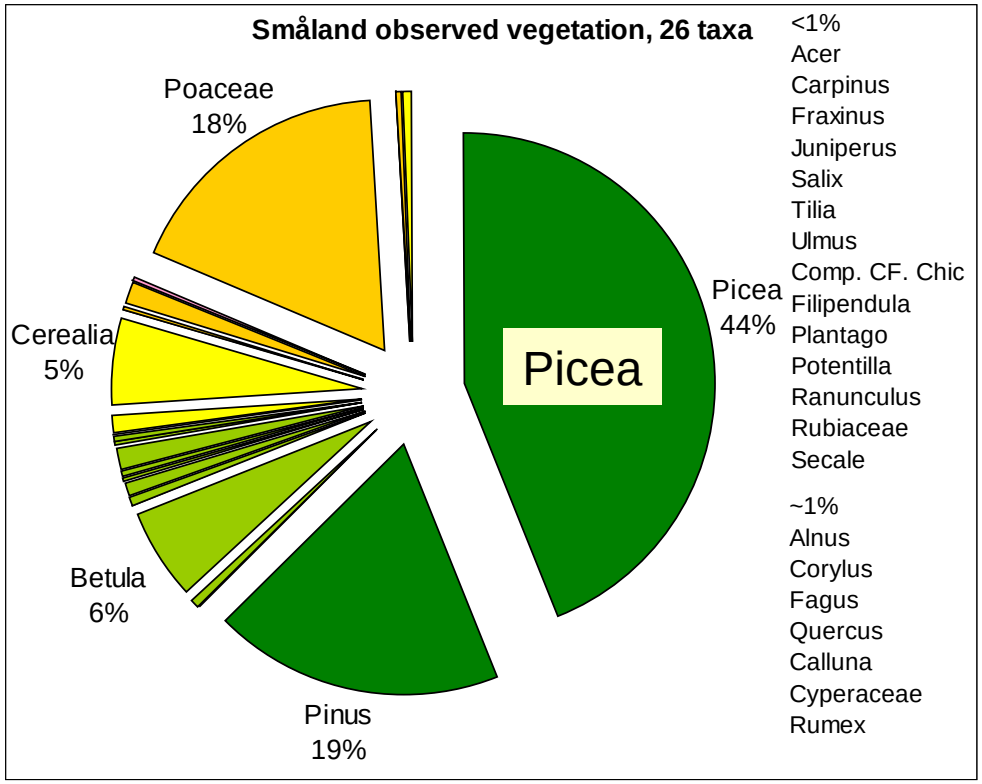
Poaceae & other non-arboreal plants

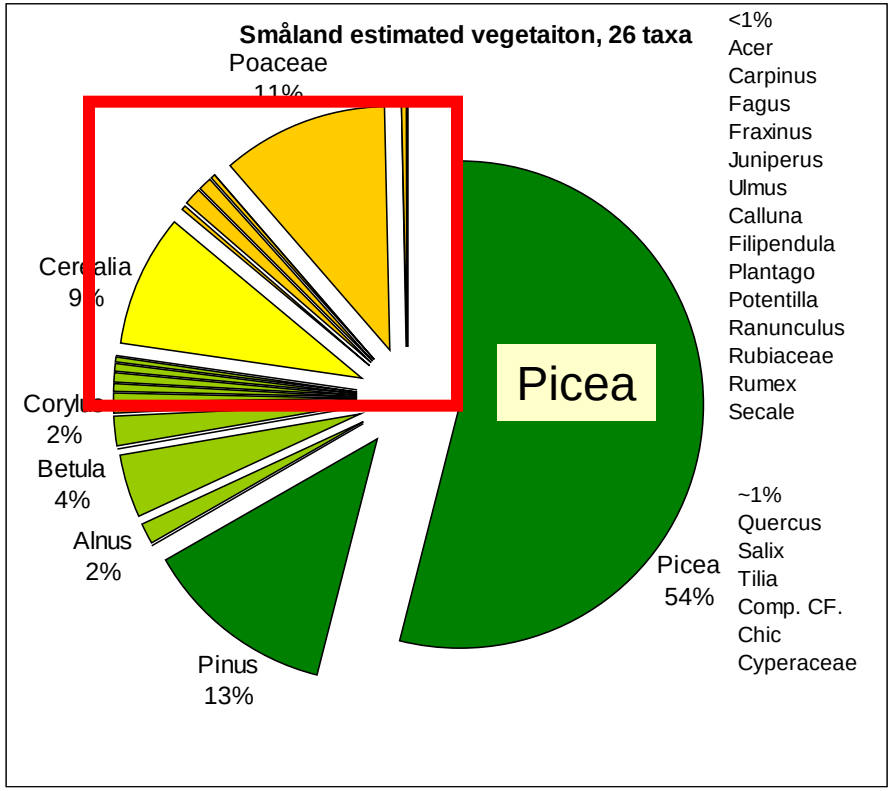
Testing REVEALS: S Sweden Småland (Semi-open Landscape)

Hellman, Gaillard et al. 2008, *JQS*

Observed vegetation (percentage cover)

Estimated vegetation using REVEALS





Conifers

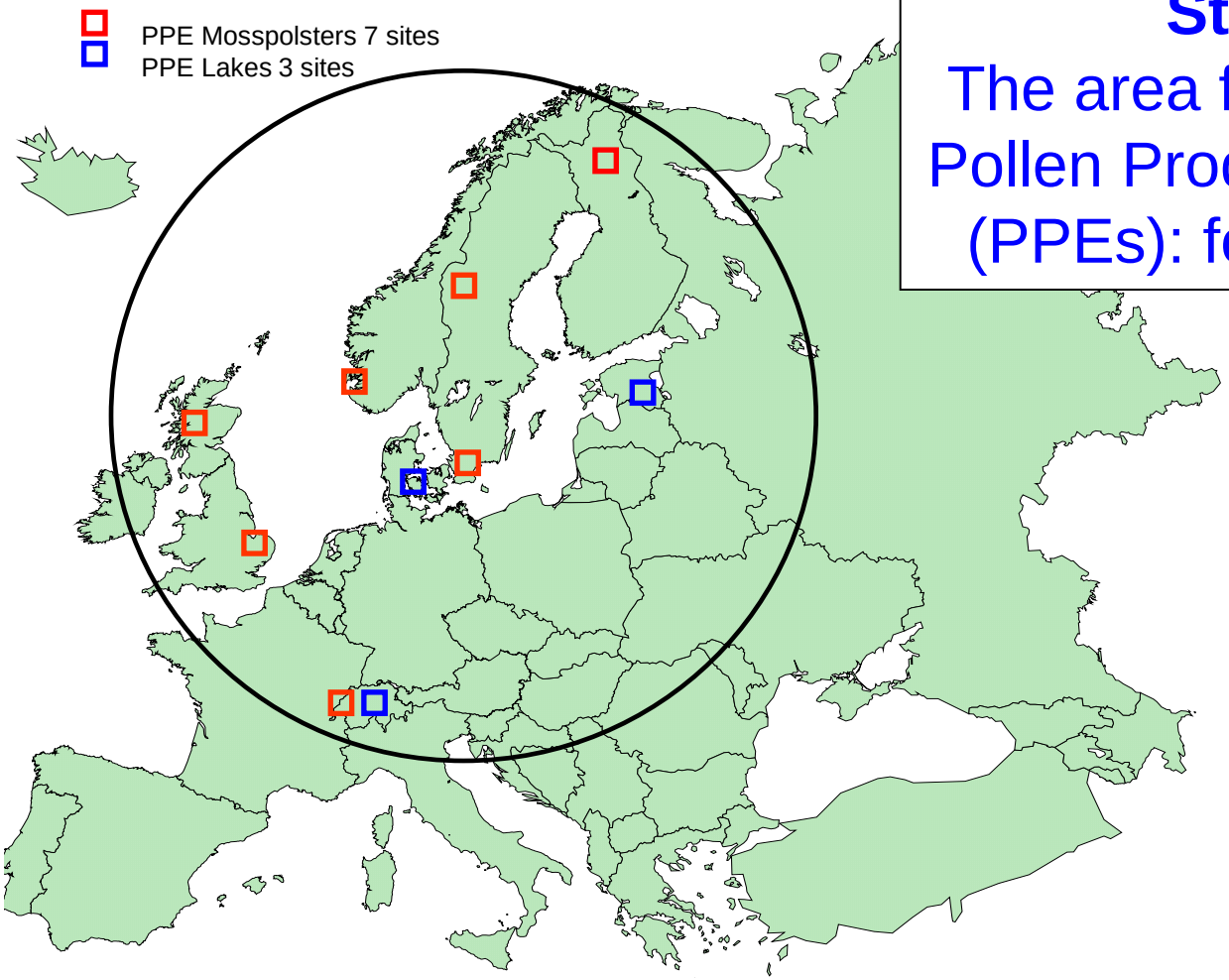
Deciduous trees

Cerealia & Secale

Poaceae & other non-arboreal plants

The LANDCLIM project

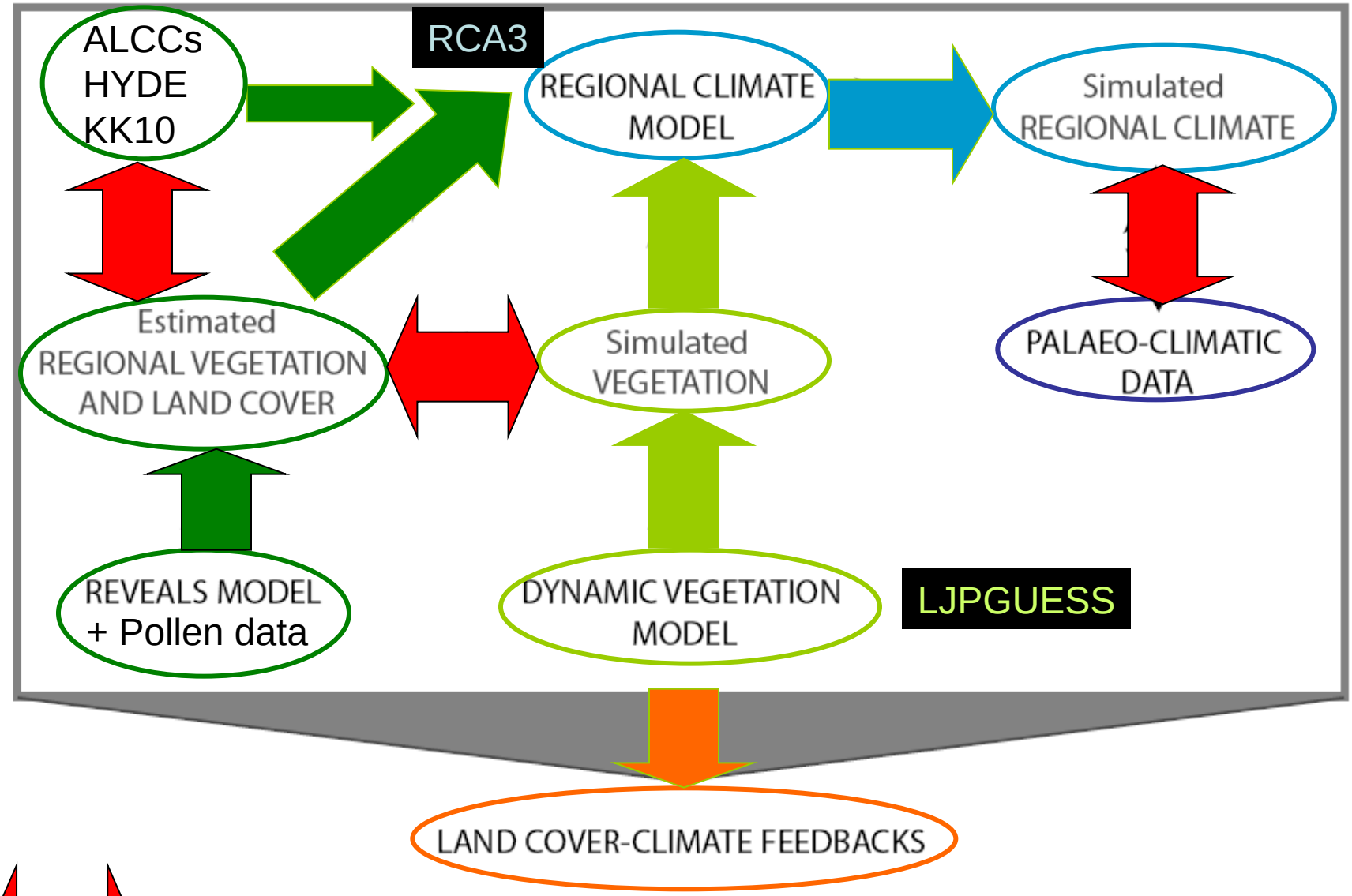
North-western and Western Europe North of the Alps



Study area:
The area for which we have Pollen Productivity Estimates (PPEs): for 35 taxa in total

Broström et al. 2008, VHA 17

LANDCLIM 6000-200: Model-data comparison approach



LANDCLIM Time periods

Part 1 (Anna-Kari Trondman et al.)

- **"The Time-window sites" over the entire study area: > 600 pollen records from databases and individual data contributers (ca. 1/3)**
  - **modern**
  - **200 cal Before Present**
  - **600 cal BP**
  - **3000 cal BP**
  - **6000 cal BP**

Part 2 (Laurent Marquer et al.)

- **"The Holocene trajectories" 11500 BP-modern:**

19 selected target sites in the study region, covering REVEALS runs for the entire **Holocene**

Comparison with LPJGUESS

RESULTS

POLLEN-BASED VEGETATION

Trondman et al.

Marquer et al.

COMPARISON WITH SCENARIOS OF ANTHROPOGENIC LAND COVER

Kaplan et al.

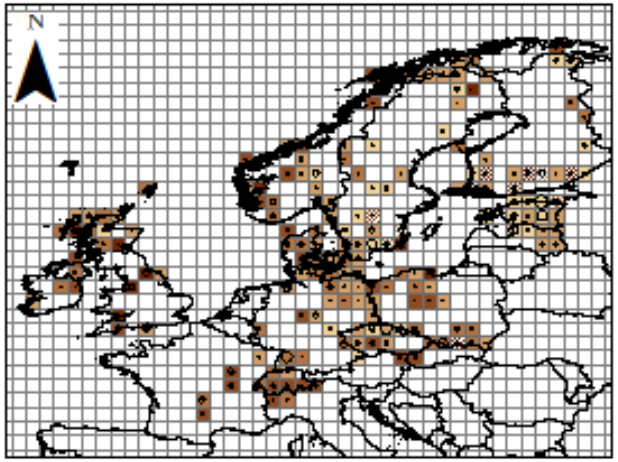
COMPARISON WITH LPJGUESS

Poska et al.

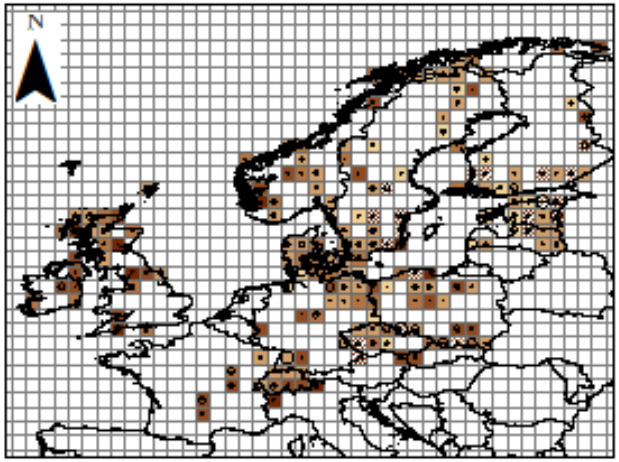
Grasses, sedges, weeds, meadow –pastureland herbs

GL – Grass Land (all herbs)

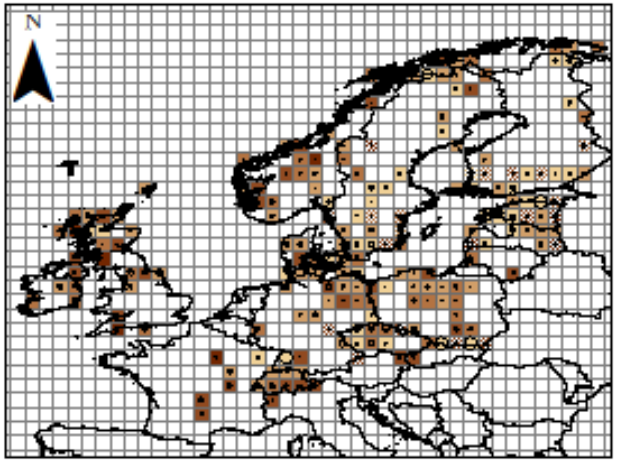
x-100 cal BP



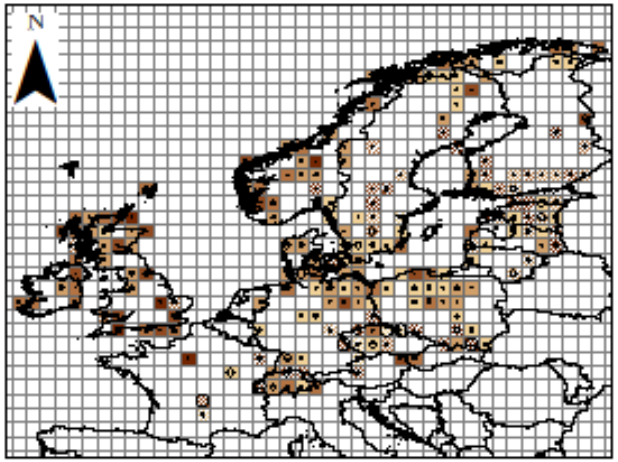
100-350 cal BP



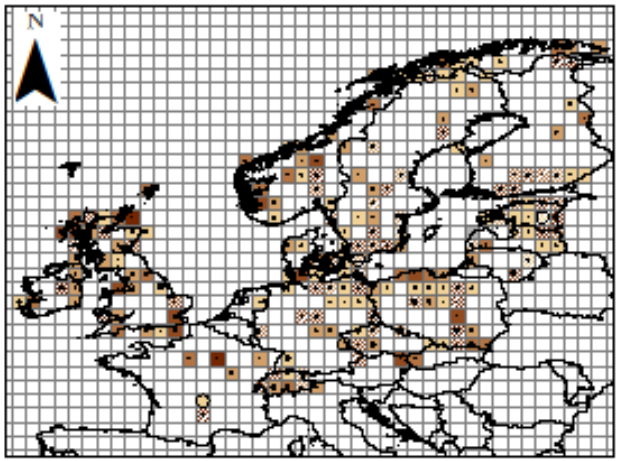
350-700 cal BP



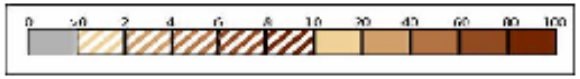
2700-3200 cal BP



5700-6200 cal BP

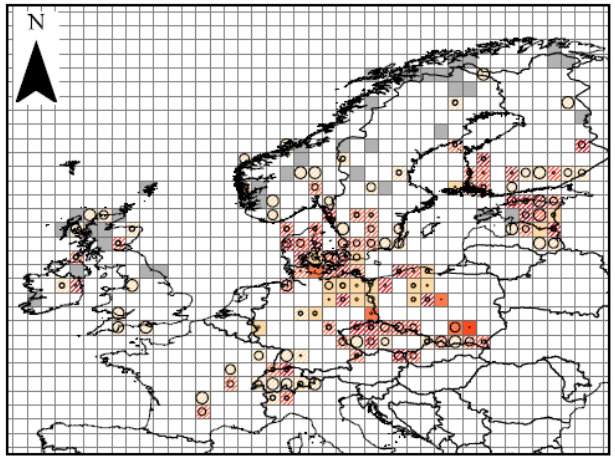


GL cover %

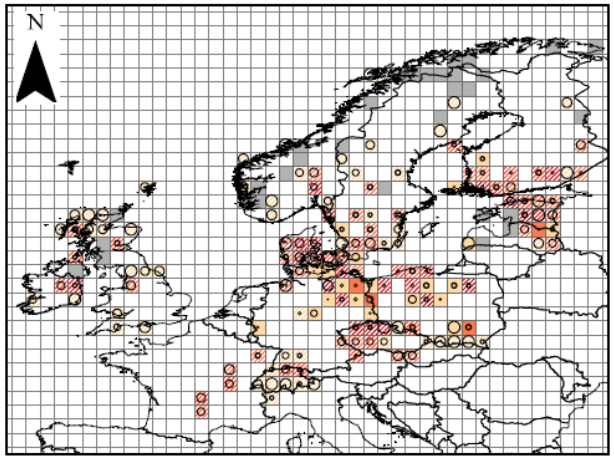


AL – Agricultural Land *(Cerealia-t and Secale-t)* Rye and other cereals

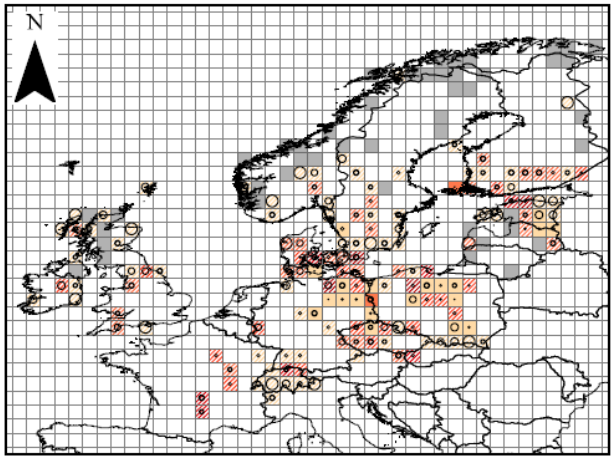
x-100 cal BP



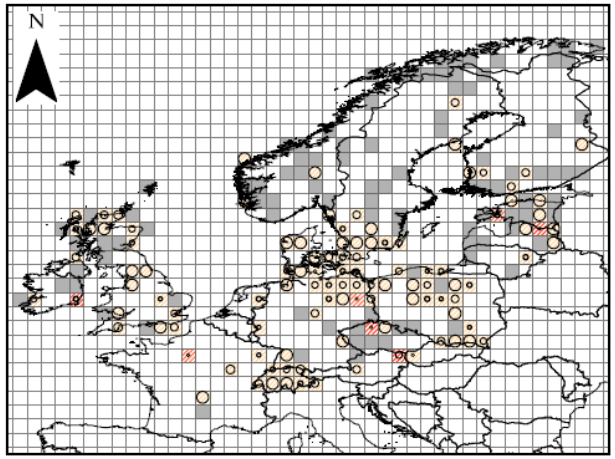
100-350 cal BP



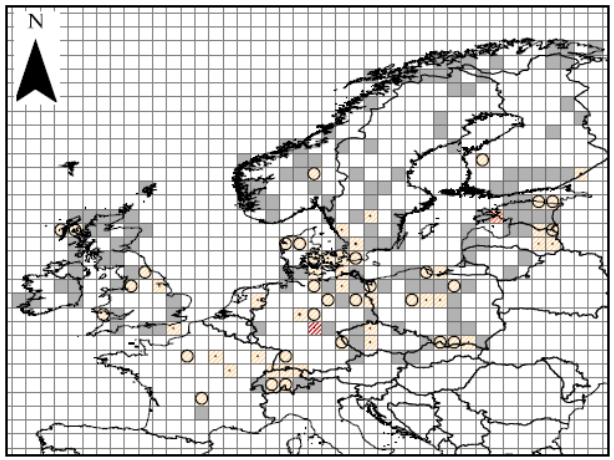
350-700 cal BP



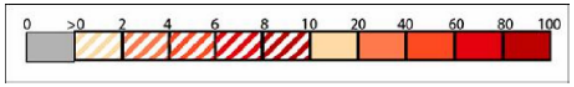
2700-3200 cal BP



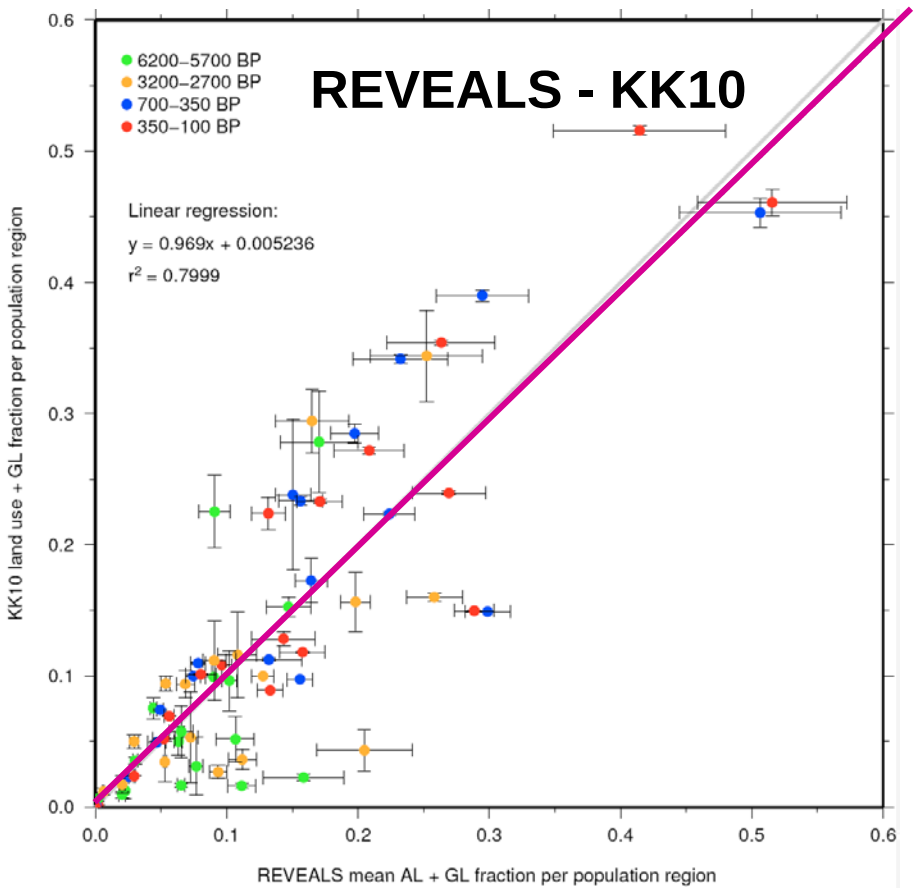
5700-6200 cal BP

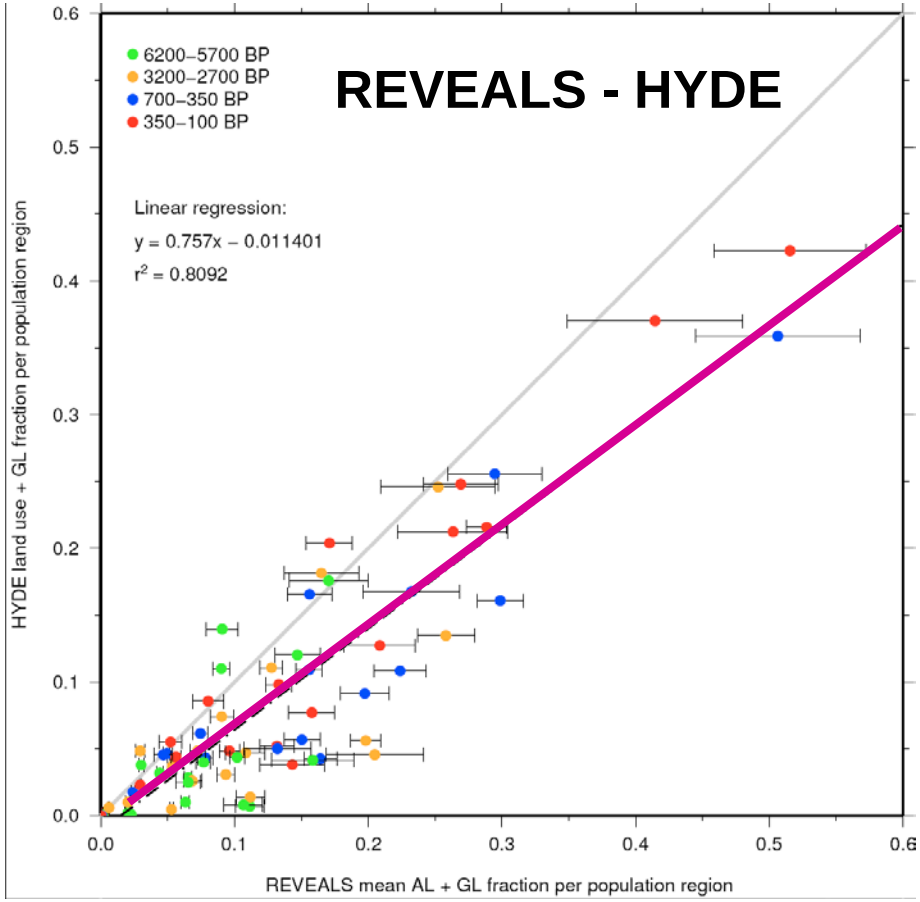


AL cover %



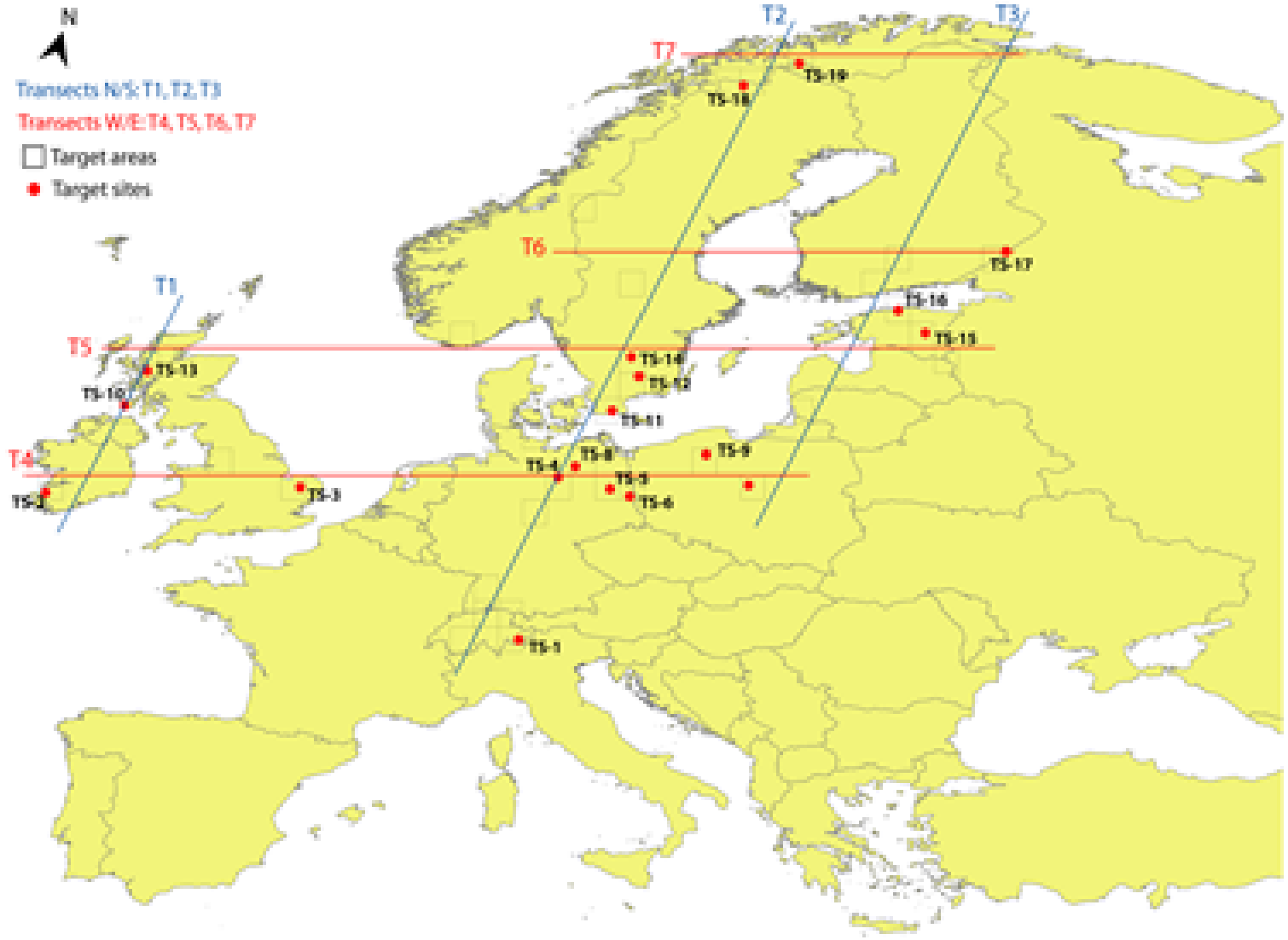
Comparison REVEALS – Kaplan's and HYDE Scenarios of anthropogenic deforestation in % cover at 6000, 3000, 600, and 200 BP





Comparison for 17 "population regions", 17 data points per time w.
– simple linear regression analysis 68 data points

19 Target sites and 36 grid cells located along N-S and W-E transects in the study area (L. Marquer, Lnu)

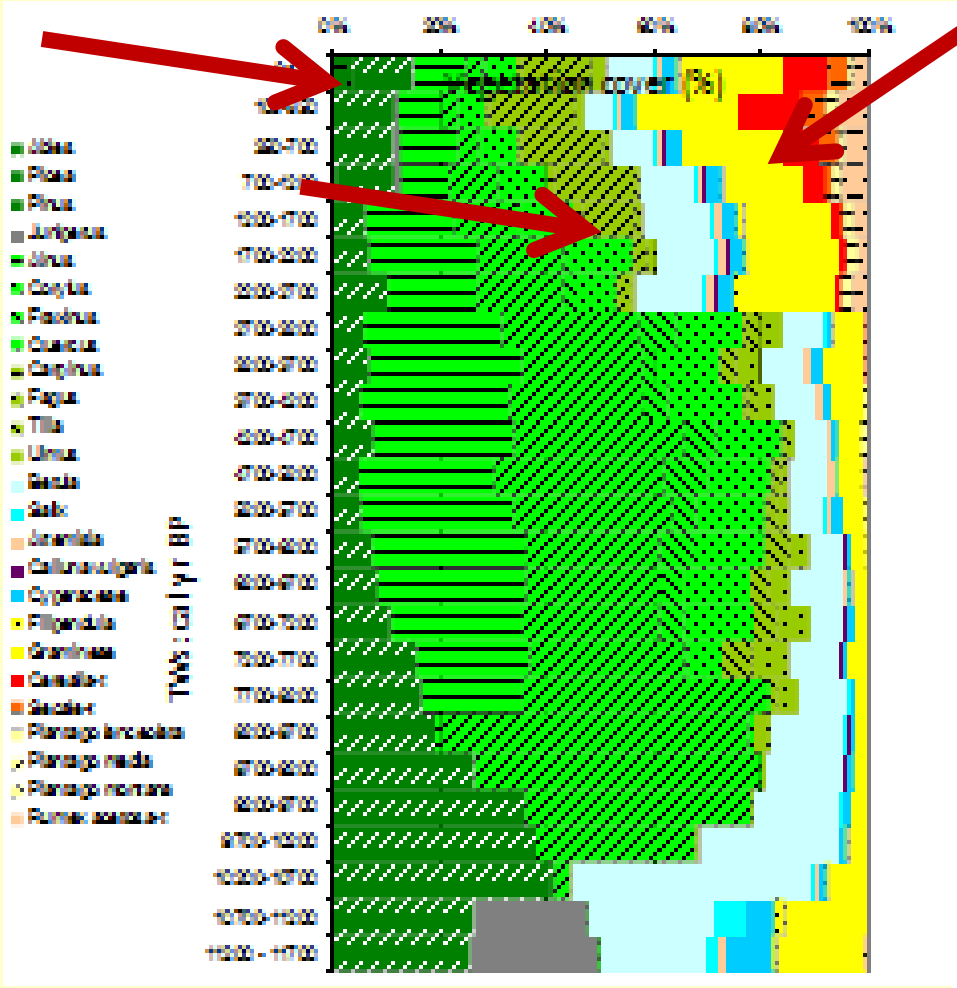


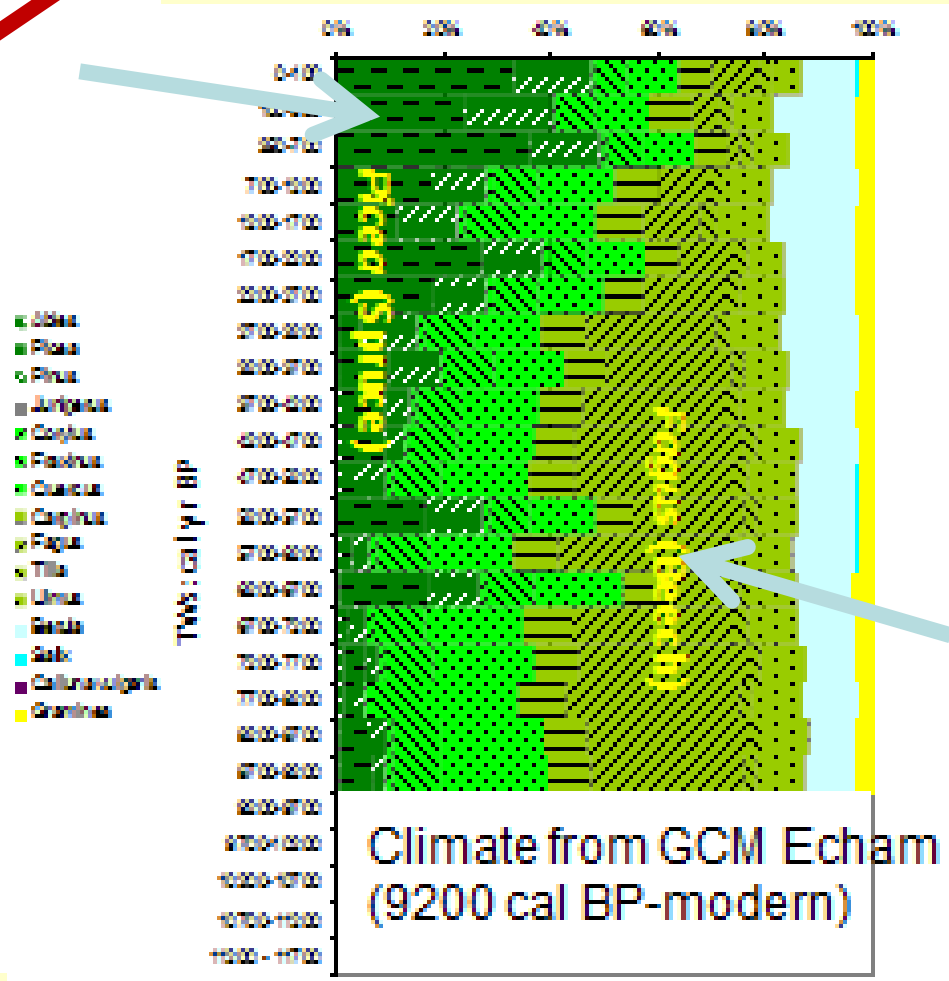
Vegetation cover for TS-11: Krageholmssjön (South Sweden)

REVEALS estimates of vegetation %cover

HUMAN IMPACT-LAND-USE

LPJ Guess potential vegetation





RESULTS
REGIONAL CLIMATE MODEL RUNS with ALTERNATIVE DESCRIPTIONS OF VEGETATION COVER

6000 and **200** BP

Strandberg, Poska et al.

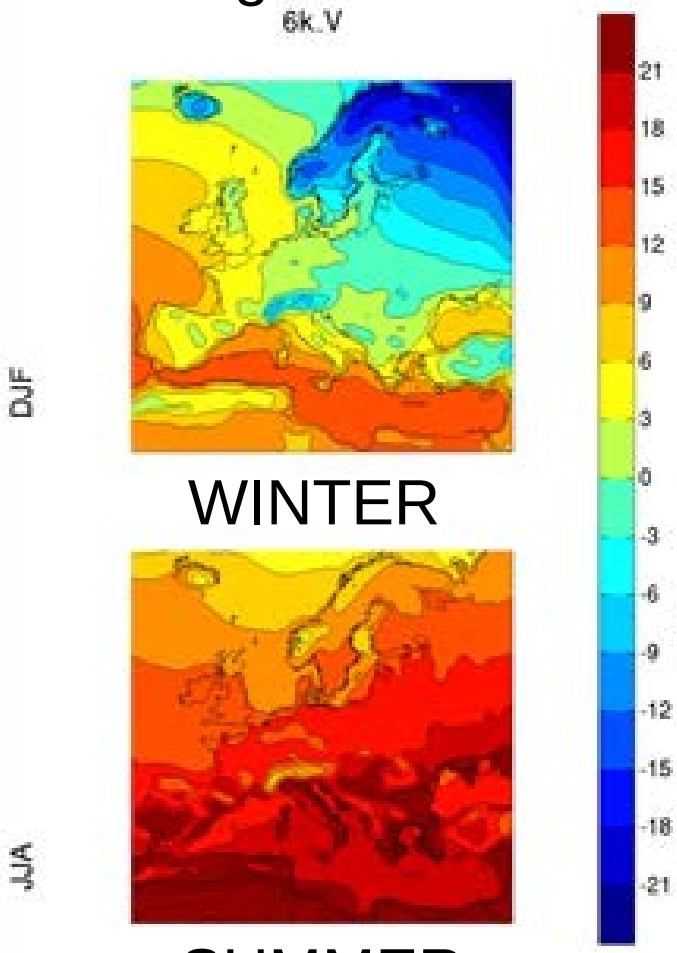
SUMMER and WINTER TEMPERATURES - 6000

Potential vegetation

+ anthropogenic vegetation

HYDE

KK



WINTER

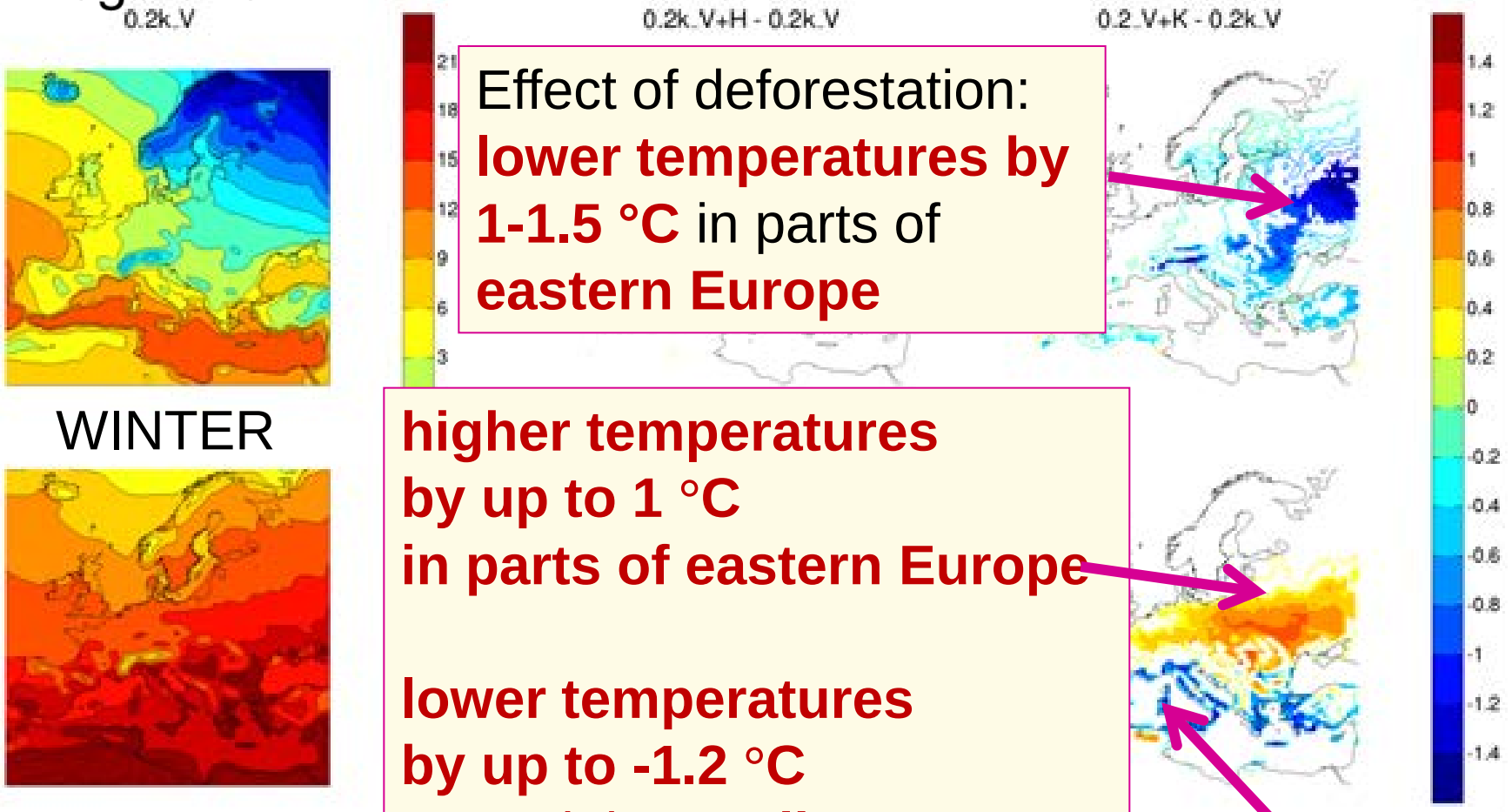
SUMMER

hotspots (southern Scandinavia, Belgium, north of the Alps) with summer temperatures **0.5-1 °C warmer**

SUMMER and WINTER TEMPERATURES - 200

Potential vegetation

+ anthropogenic vegetation HYDE



Effect of deforestation:
lower temperatures by 1-1.5 °C in parts of **eastern Europe**

higher temperatures by up to 1 °C in parts of eastern Europe

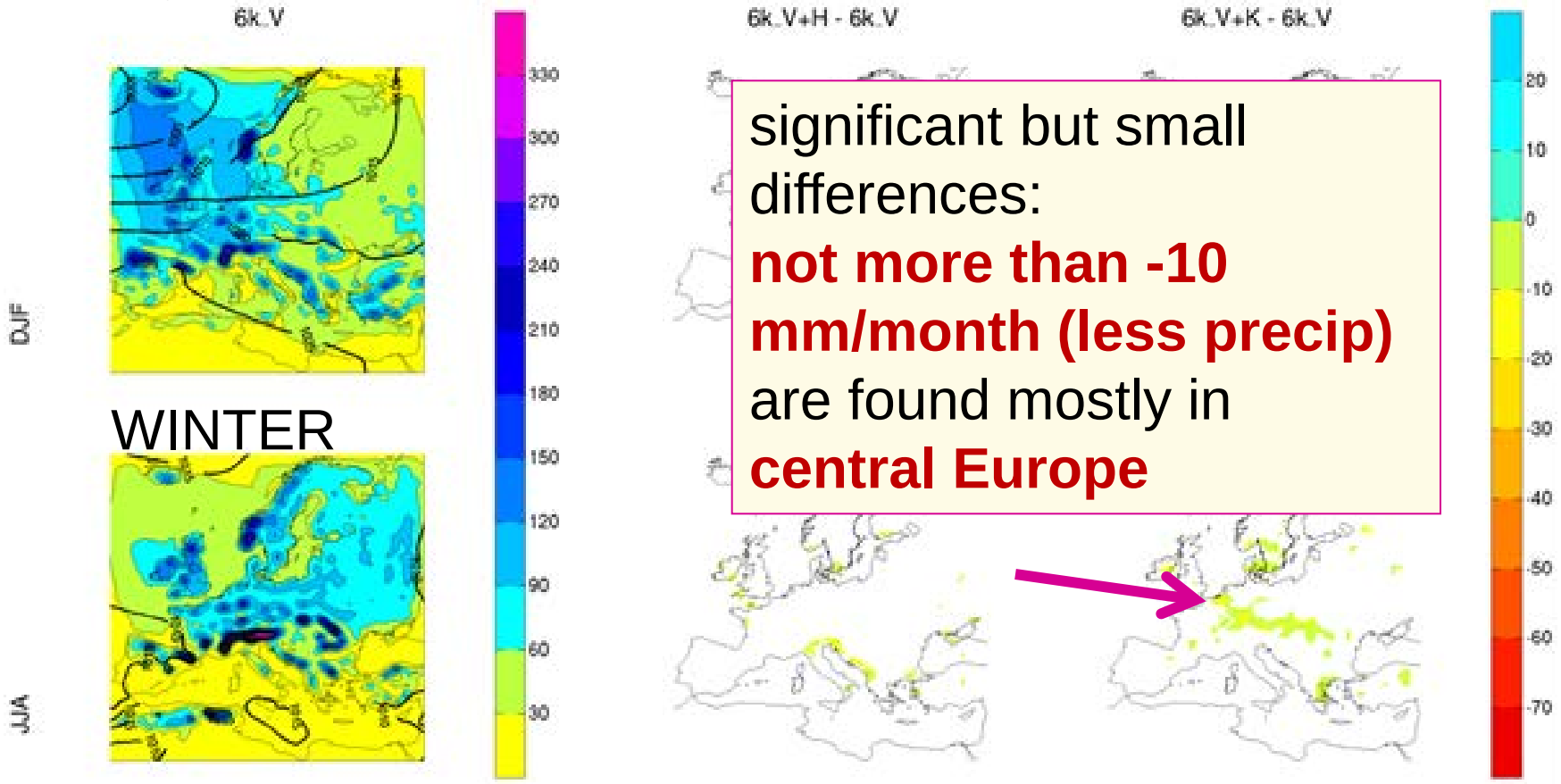
lower temperatures by up to -1.2 °C around the **Mediterr. area**

SUMMER and WINTER TEMPERATURES - 6000

Potential vegetation

+ anthropogenic vegetation

HYDE KK



WINTER

SUMMER

significant but small differences:
not more than -10 mm/month (less precip)
are found mostly in
central Europe

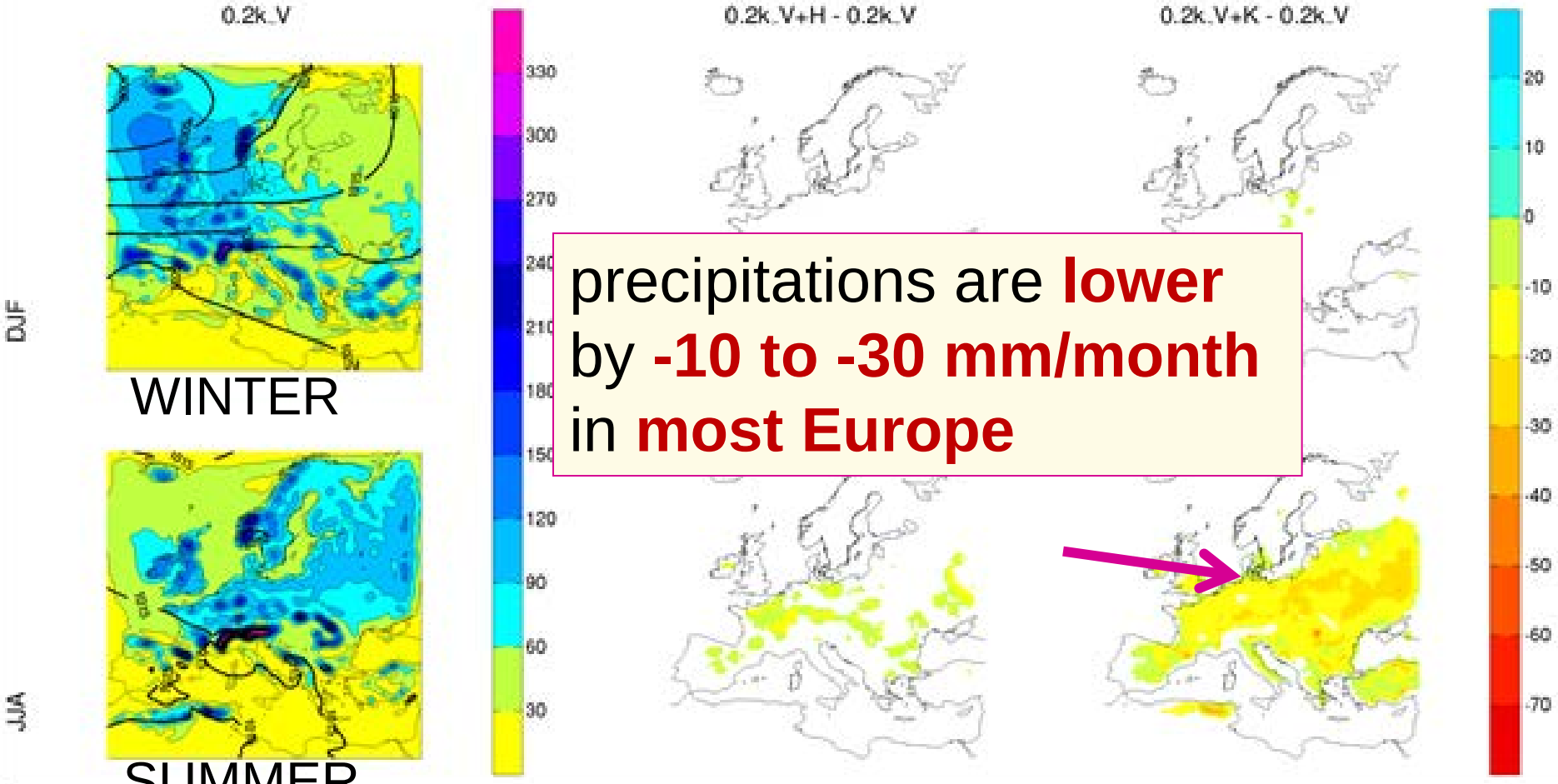
SUMMER and WINTER PRECIPITATIONS - 200

Potential vegetation

+ anthropogenic vegetation

HYDE

KK

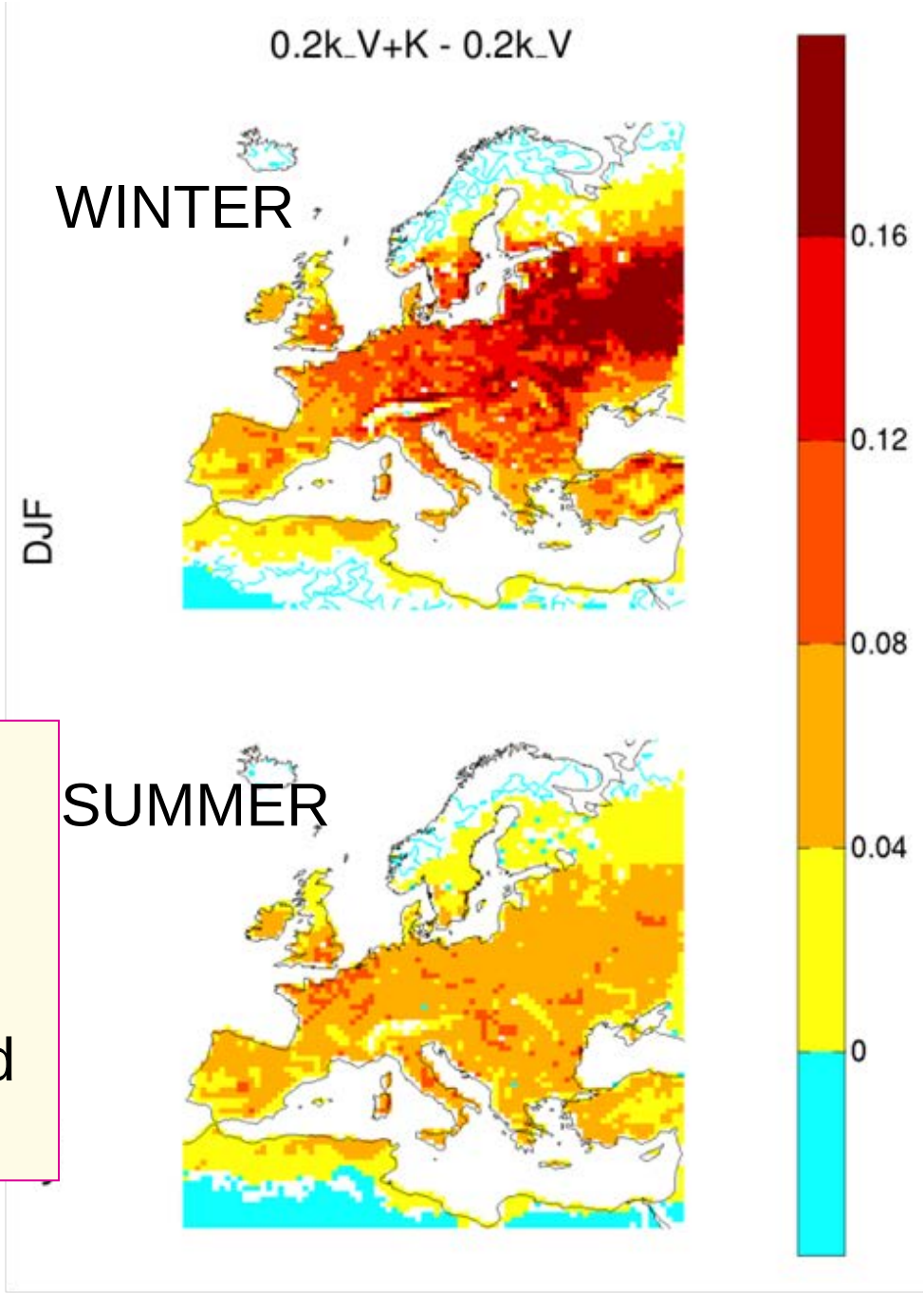


WINTER

SUMMER

precipitations are **lower** by **-10 to -30 mm/month** in **most Europe**

Difference in albedo Anthrop veg – potential veg at 200 BP



higher with anthropog. veg. since open land has a higher albedo than forests.
Higher in winter during the snow season since open land is covered by snow

Comparison of RCA results with reconstructions of past climate based on palaeo proxy-data

- The simulated climate from RCA3 was compared with the **LANDCLIM database of climate proxies for 6000 and 200 BP**
- Climate inferred from diatoms, tree rings and chironomids show a 6k-0.2k difference in **summer temperature of 0.5-2 °C** in **Scandinavia**: agrees with the RCA simulations.
- Proxies of annual precipitations (e.g. lake-level changes, oxygen isotopes) indicate **a drier 6k than 0.2k in Scandinavia and northern Germany**, while there is **no difference in the Alps**. The RCA simulations show similar general trends.
- Climate proxies of winter conditions are not available.

CONCLUSIONS

- The biggest between-simulations differences in **seasonal mean temperature and precipitation** between RCA3 simulations are found at **200 BP between potential veg. and anthropogenic veg. KK simulation, and between 6000 and 200 BP simulations with anthropogenic veg. KK**

TEMPERATURES WINTER

- The **albedo effect** is the main reason for deforestation leading to **lower temperatures**. The effect increases in late winter/spring when there is more incoming sunlight.
- **Deforestation** leads to **larger differences in winter temperatures in the north/east**, where the snow season is long, **than in the west/south**.

TEMPERATURES SPRING and SUMMER

- When the vegetation starts to be active in **spring, the albedo effect is counteracted by differences in latent heat flux.**
- The larger biomass in the **forested regions** leads to a larger evapotranspiration and, consequently, **a cooler climate** compared to the open-land situation.
- In **summer** when soils are dry the **latent heat flux is weak** and therefore **the difference between anthropogenic veg. V+K and potential veg. is small**.
- **The change in albedo dominates** over the change in latent heat flux leading to **lower temperatures also in summer.**

PRECIPITATIONS

- Differences in **precipitation** correlate with differences in **latent heat flux**
- Since differences in precipitation mainly are caused by a **change in convective precipitation**, it suggests that this feature also is an **effect from differences in deforestation**.

Differences 6000-200 BP

- **Summer temperatures** are **lower** in the **Mediterranean area (by 1-2 °C)** and higher in **eastern Europe (by ca. 1°C) at 200 than at 6000 BP**
- In **winter**, high values of deforestation at 200 BP lead to **higher temperatures than at 6000 BP by 1-2 °C** in **eastern Europe** , and small or no differences in the rest of Europe.
- high values of deforestation at 200 BP result in **lower summer precipitations than at 6000 BP** by ca. **30 mm/month**. Less impact in winter.
- The effect of deforestation on the simulated climate is a **change in amplitude of the differences in temperatures or precipitations** between 6000 and 200 BP rather than a change in the geographical pattern of those differences.

Next

- Pirzamanbin et al. to be submitted in 2013: REVEALS (pollen-based) predicted land-cover using **a spatial statistical model** of the relationship between REVEALS vegetation and bioclimatic parameters: 5 time windows
- Run RCA with the REVEALS predicted land-cover
- All RCA runs at 3000 and 600 BP
- Investigate the biogeochemical feedbacks

Publications

- Gaillard et al. 2010 Clim Past
  - Descriptions of past anthropogenic land cover
- Mazier et al. 2012 Rev. Pal. Pal.
  - Pollen-based REVEALS reconstructions: test of the LANDCLIM protocole
- Nielsen et al. 2012 Quat Sc Rev
  - Pollen-based REVEALS rec. in Denmark and N Germany – implications
- Fyfe et al. 2013 Quat Sc Rev
  - Pollen-based REVEALS rec. in the British Isles and Ireland – implications
- Marquer et al. in prep (submitted 2013)
  - Pollen-based REVEALS rec. NW Europe 11000-0 BP - implications
- Trondman et al.
  - Pollen-based REVEALS rec. in NW Europe 6000, 3000, 600, 200 BP + modern
- Kapplan et al.
  - Comparison REVEALS, HYDE, KK at 6000, 3000, 600, 200 BP + modern
- Strandberg et al.
  - RCA3 regional climate simulations with different land-cover description, with and without anthropogenic land cover at 6000 and 200 BP
- Pirzamanbin et al.
  - REVEALS predicted land-cover using a spatial statistical model of the relationship between REVEALS vegetation and bioclimatic factors

Thank you!

Anna-Kari Trondman, PhD student, Linnaeus University, Sweden
Marie-José Gaillard, Linnaeus University, Sweden
Shinya Sugita, University of Tallinn, Estonia
Ralph Fyfe, University of Plymouth, UK
Jed Kaplan, EPFL, Lausanne, Switzerland
Anne Birgitte Nielsen, Lund University, Sweden
Laurent Marquer, Linnaeus University, Sweden
Florence Mazier, University of Toulouse, France
Anneli Poska, Lund University, Sweden
Gustav Strandberg, SMHI, Sweden
LANDCLIM members

CLIM LAND

Linnéuniversitetet

Kalmar Växjö

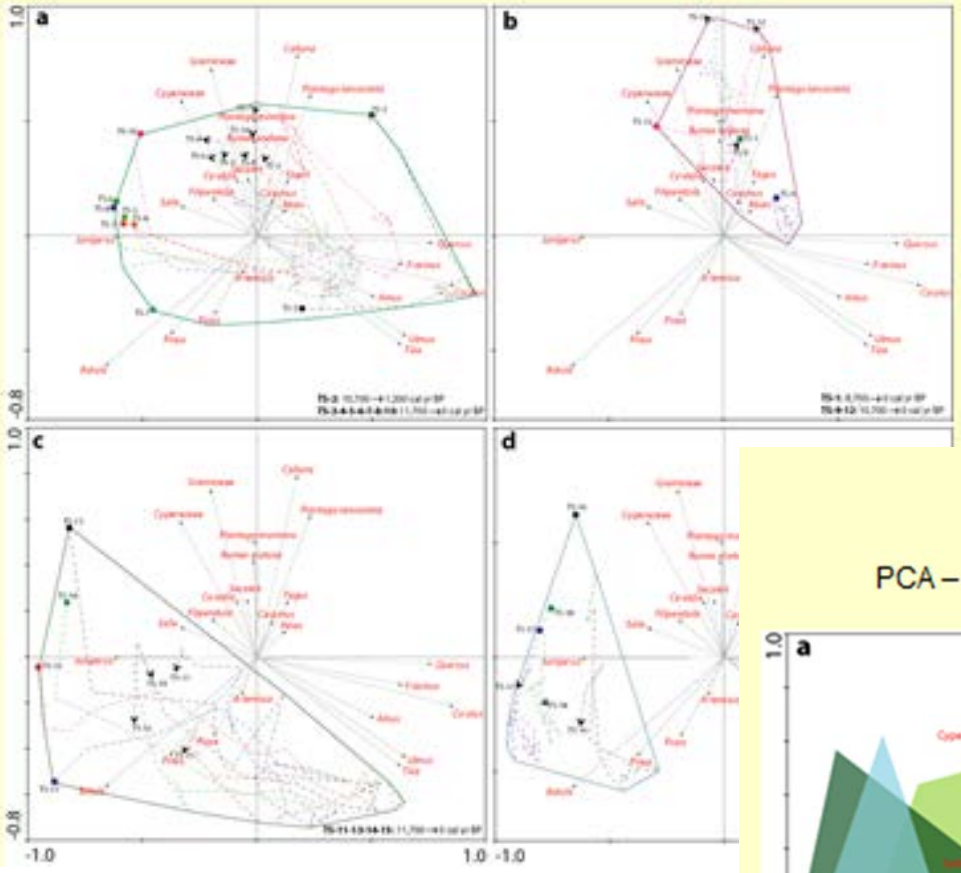
norden

NordForsk

Vetenskapsrådet

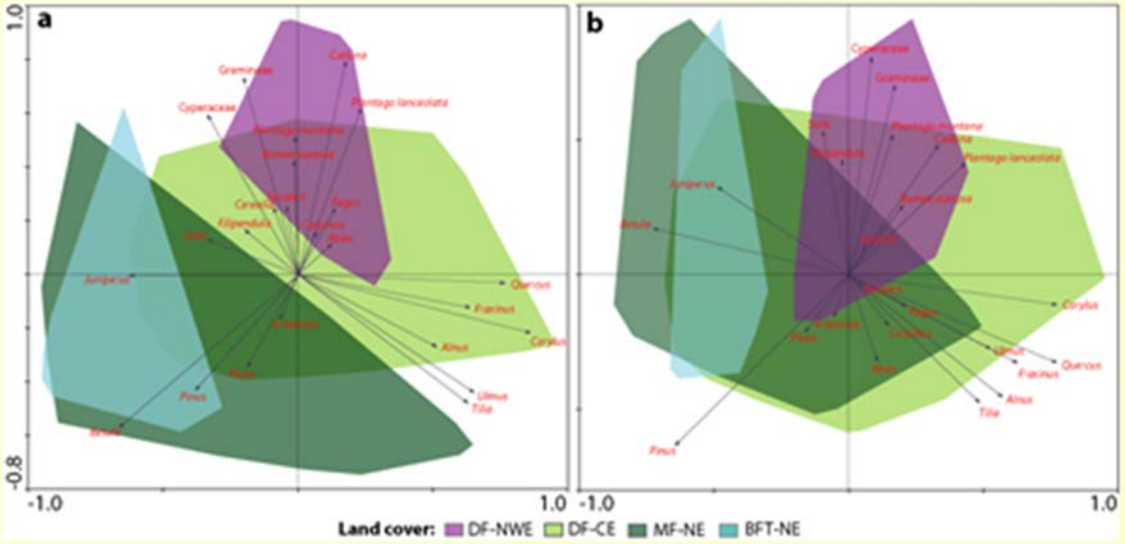
Swedish Research Council

PCA of the REVEALS estimates for 18 Holocene pollen records:
4 types of time trajectories (~"biogeographical regions")



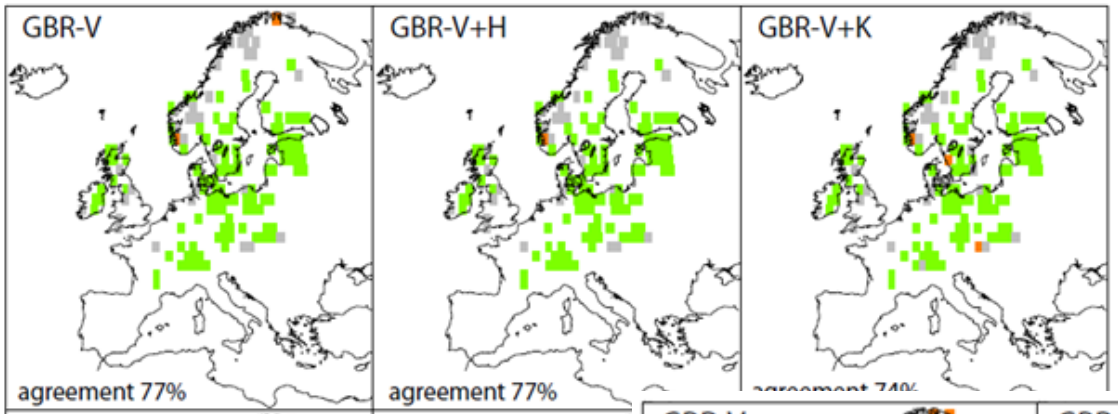
PCA – REVEALS estimates

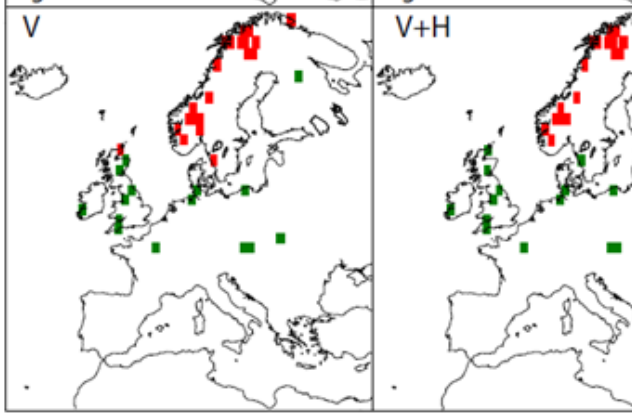
PCA – pollen assemblages %



→ Better separation of the 4 types of time trajectories with REVEALS estimates

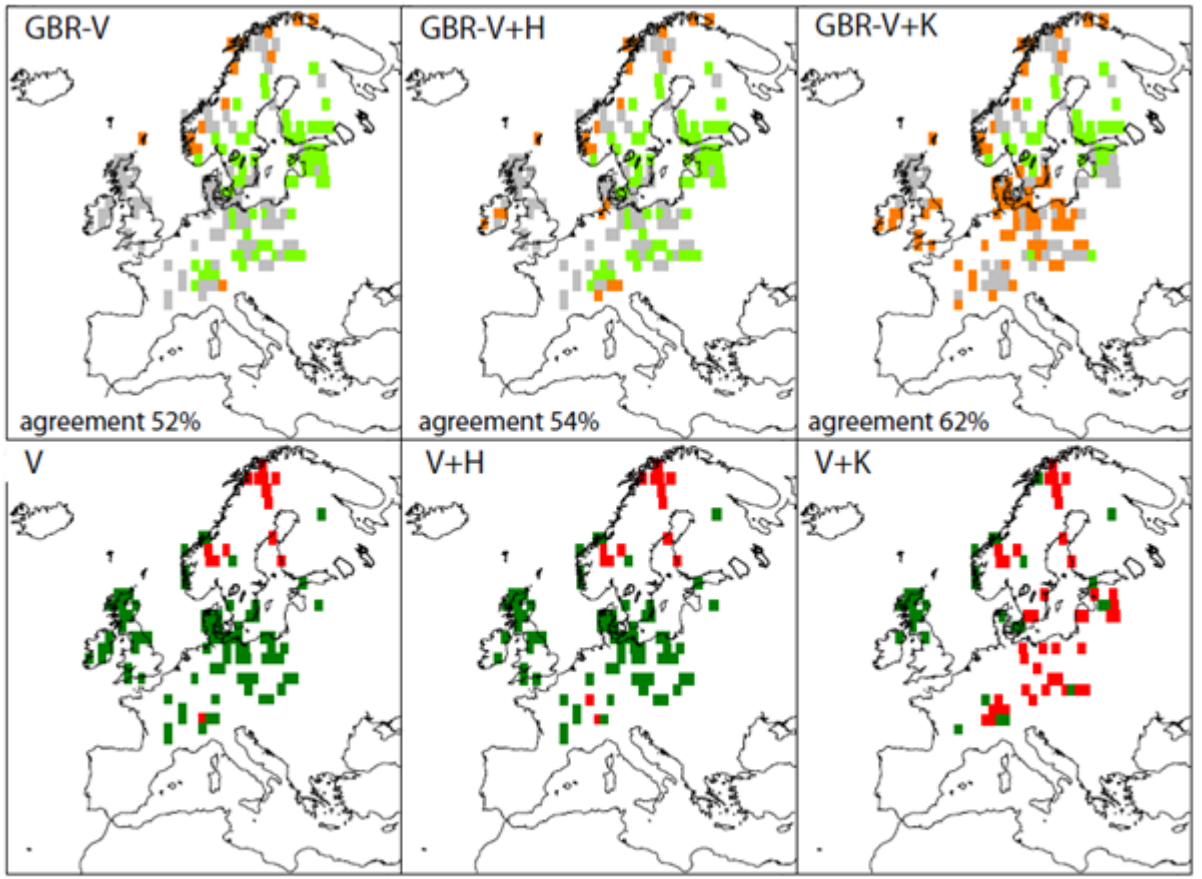
Agreement LPJGUESS-REVEALS DOMINANT >50% FOREST or OPENLAND





Legend: no agreement dom GBR/LPJ F
dom GBR Open Land/LPJ Forest

6000

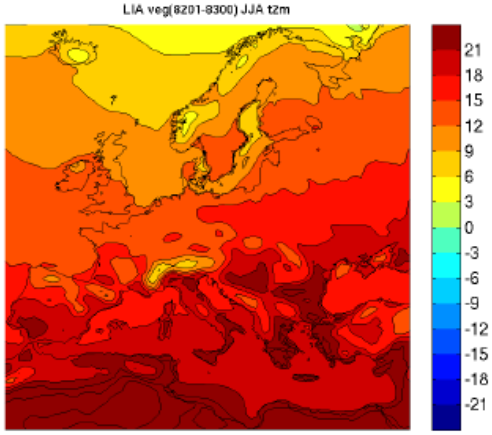


Legend: no agreement dom GBR/LPJ Forest dom GBR/LPJ Open Land
dom GBR Open Land/LPJ Forest dom GBR Forest/LPJ Open Land

200

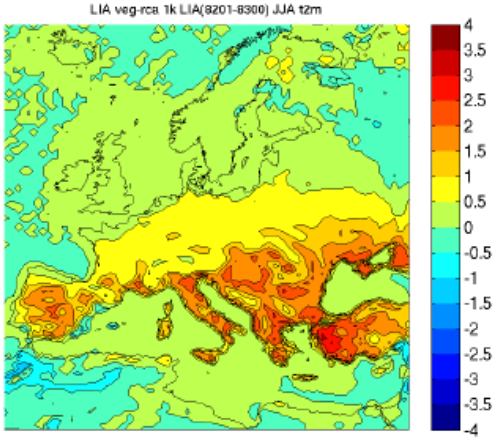
Summer temperature 200 BP

LPJ-GUESS potential veg.



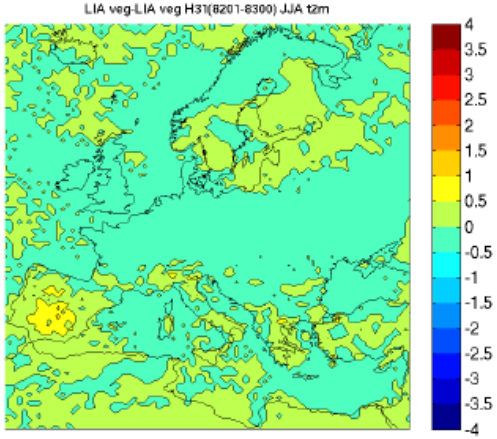
Potential veg. – Modern veg.

RCAveg-RCA



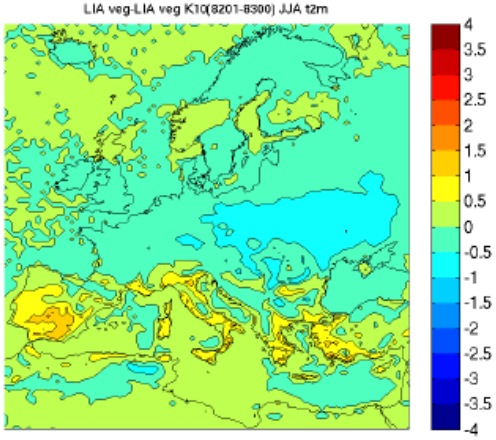
Green to red:
Negative feedback with modern land cover compared to potential vegetation

Potential vegetation – HYDE



Green to yellow: negative feedback with
HYDE compared to potential veg.

Potential vegetation – KK10

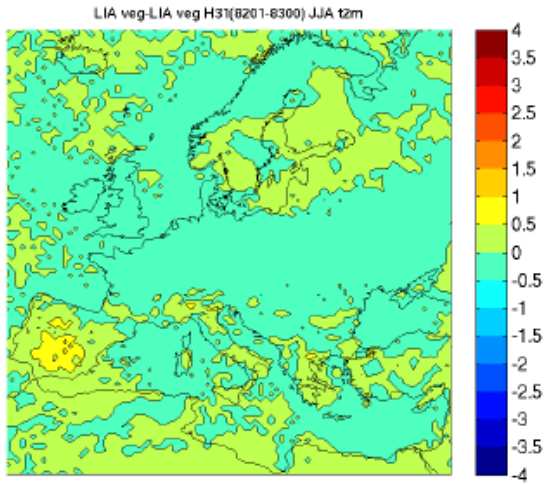


Green to orange:
negative feedback with KK10 compared to potential veg.

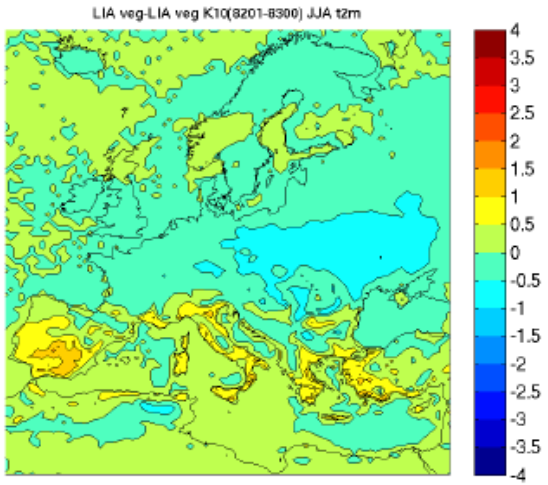
Visa också det!!
Också summer temperature
Lättare att jämföra! Mera negativ feedback 200BP-logiskt!!

200 BP

RCAveg-RCAH31

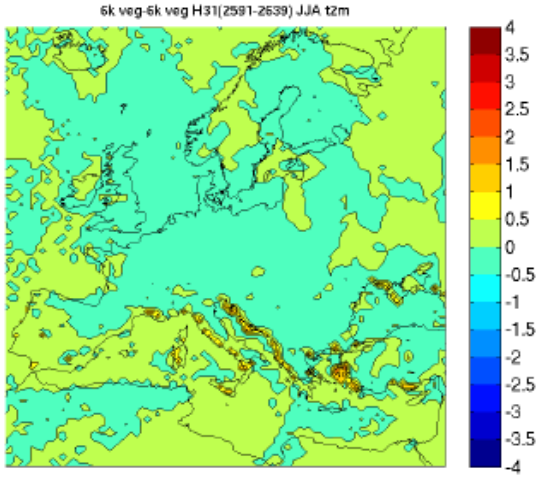


RCAveg-RCAKK10

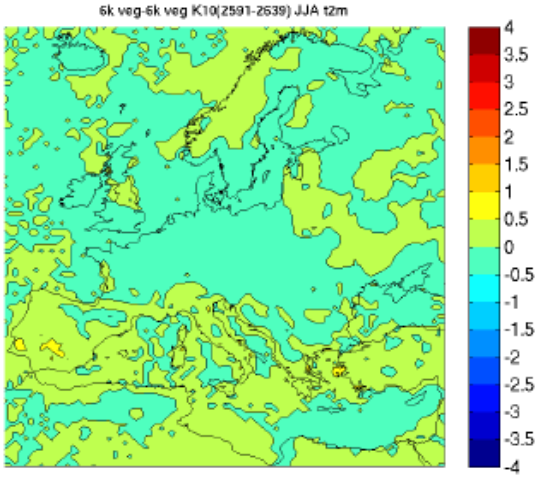


6000 BP

RCAveg-RCAH31



RCAveg-RCAKK10



LCTs and PFTs

Land-Cover Types (LCTs)	Plant Functional Types (PFTs)	PFT definition
Evergreen tree canopy (ET)	TBE1	Shade-tolerant evergreen trees
	TBE2	Shade-tolerant evergreen trees
	IBE	Shade-intolerant evergreen trees
	TSE	Tall shrub, evergreen
Summergreen tree canopy (ST)	IBS	Shade-intolerant summergreen trees
	TBS	Shade-tolerant summergreen trees
	TSD	Tall shrub, summergreen
Open land (OL)	LSE	Low shrub, evergreen
	GL	Grassland - all herbs
	AL	Agricultural land - cereals

- 3 Land-Cover Types (for regional climate model, RCA3)
- 10 Plant Functional Types (for dynamic vegetation model, LPJ-GUESS)
- In total: 25 taxa