



# **Swedish climate modeling research**

-

## **the Beskow perspective**

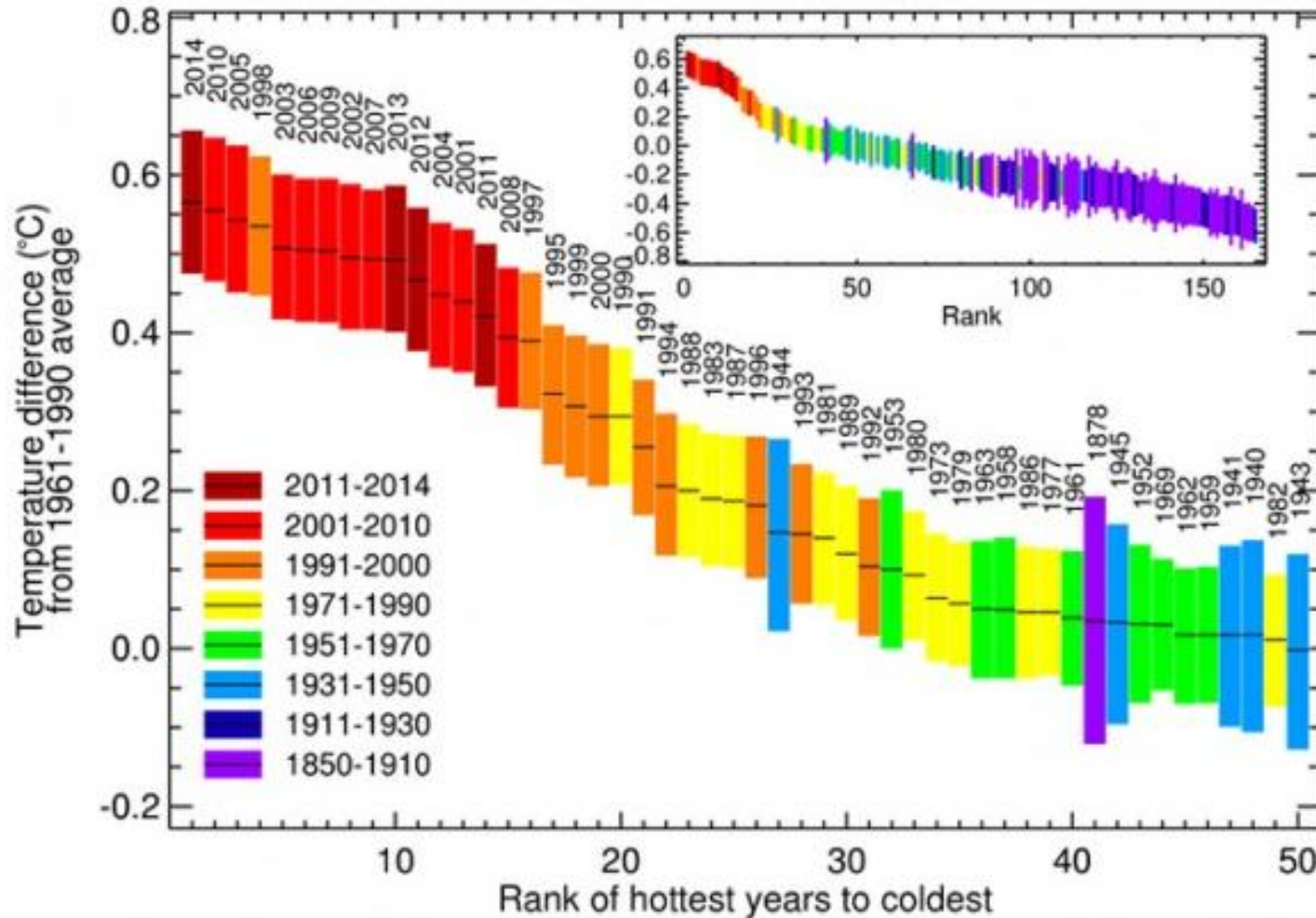
**Gunilla Svensson**

**Department of Meteorology  
Bolin Centre for Climate Research  
SeRC**

# Our earth is getting warmer...



Stockholm University

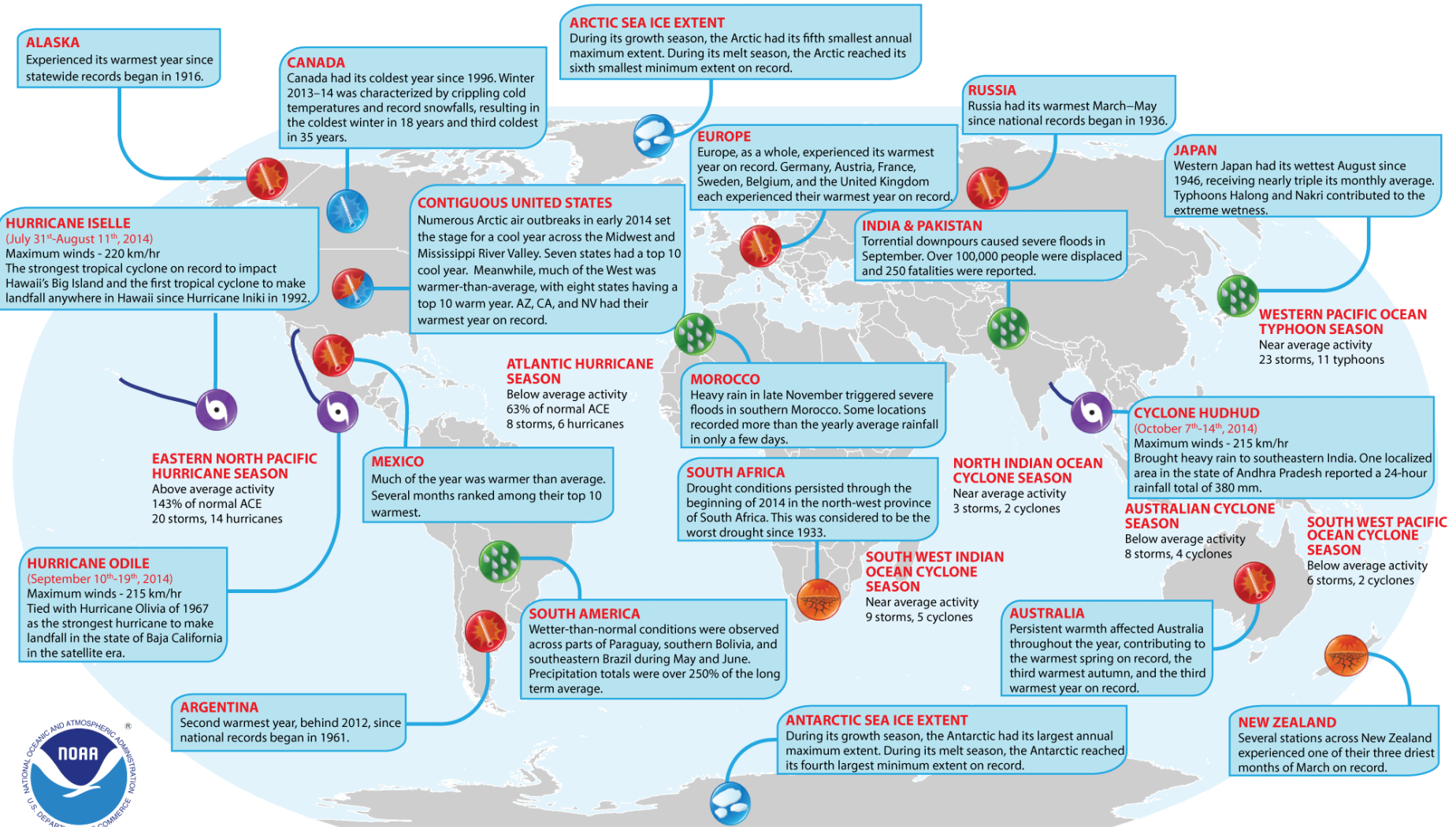


Produced by the Met Office. © Crown copyright 2014

# Is it getting more extreme?



## Selected Significant Climate Anomalies and Events in 2014



Please Note: Material provided in this map was compiled from NOAA's NCDC State of the Climate Reports and the WMO Provisional Status of the Climate in 2014. For more information please visit: <http://www.ncdc.noaa.gov/sotc>



# Is it getting more extreme?



## Selected Significant Climate Anomalies and Events in 2014

**ALASKA**  
Experienced its warmest year since statewide records began in 1916.

**CANADA**  
Canada had its coldest year since 1996. Winter 2013–14 was characterized by crippling cold temperatures and record snowfalls, resulting in the coldest winter in 18 years and third coldest in 35 years.

**ARCTIC SEA ICE EXTENT**  
During its growth season, the Arctic had its fifth smallest annual maximum extent. During its melt season, the Arctic reached its sixth smallest minimum extent on record.

**RUSSIA**  
Russia had its warmest March–May since national records began in 1936.

**EUROPE**

its wettest August since  
rly triple its monthly average.  
nd Nakri contributed to the

**HURRICANE ISELLE**  
(July 31<sup>st</sup>-August 11<sup>th</sup>, 2014)  
Maximum winds - 220 km/hr  
The strongest tropical cyclone on  
Hawaii's Big Island and the first  
landfall anywhere in Hawaii since

Did you hear the news today? A huge snow storm is approaching New York, US

More than one meter of snow and wind speeds of  $30 \text{ m s}^{-1}$  are forecasted

**EASTERN PACIFIC OCEAN PHOON SEASON**  
Average activity  
storms, 11 typhoons

**EAST HUR**  
Above  
143%  
20 stc

hr  
neastern India. One localized  
Pradesh reported a 24-hour

**HURRICANE ODILE**  
(September 10<sup>th</sup>-19<sup>th</sup>, 2014)  
Maximum winds - 215 km/hr  
Tied with Hurricane Olivia of 1967 as the strongest hurricane to make landfall in the state of Baja California in the satellite era.

**SOUTH WEST PACIFIC OCEAN CYCLONE SEASON**  
Below average activity  
6 storms, 2 cyclones

**ARGENTINA**  
Second warmest year, behind 2012, since national records began in 1961.

**SOUTH AMERICA**  
Wetter-than-normal conditions were observed across parts of Paraguay, southern Bolivia, and southeastern Brazil during May and June. Precipitation totals were over 250% of the long term average.

**SEASON**  
Near average activity  
9 storms, 5 cyclones

**AUSTRALIA**  
Persistent warmth affected Australia throughout the year, contributing to the warmest spring on record, the third warmest autumn, and the third warmest year on record.

**ANTARCTIC SEA ICE EXTENT**  
During its growth season, the Antarctic had its largest annual maximum extent. During its melt season, the Antarctic reached its fourth largest minimum extent on record.

**NEW ZEALAND**  
Several stations across New Zealand experienced one of their three driest months of March on record.

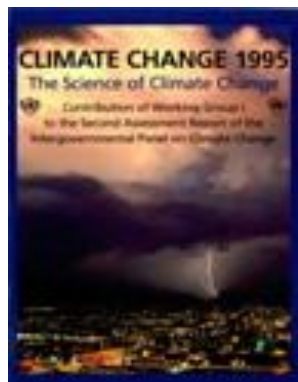




# Is man responsible?

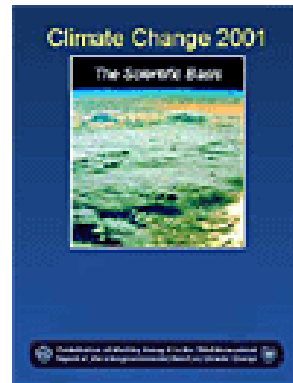


**FAR**  
**1990**



**SAR**  
**1995**

Suggests



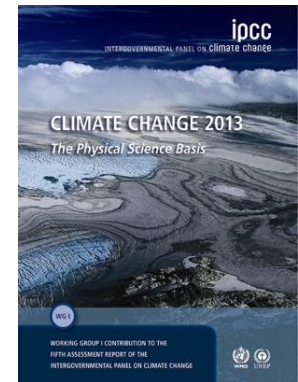
**TAR**  
**2001**

Likely



**AR4**  
**2007**

Very likely

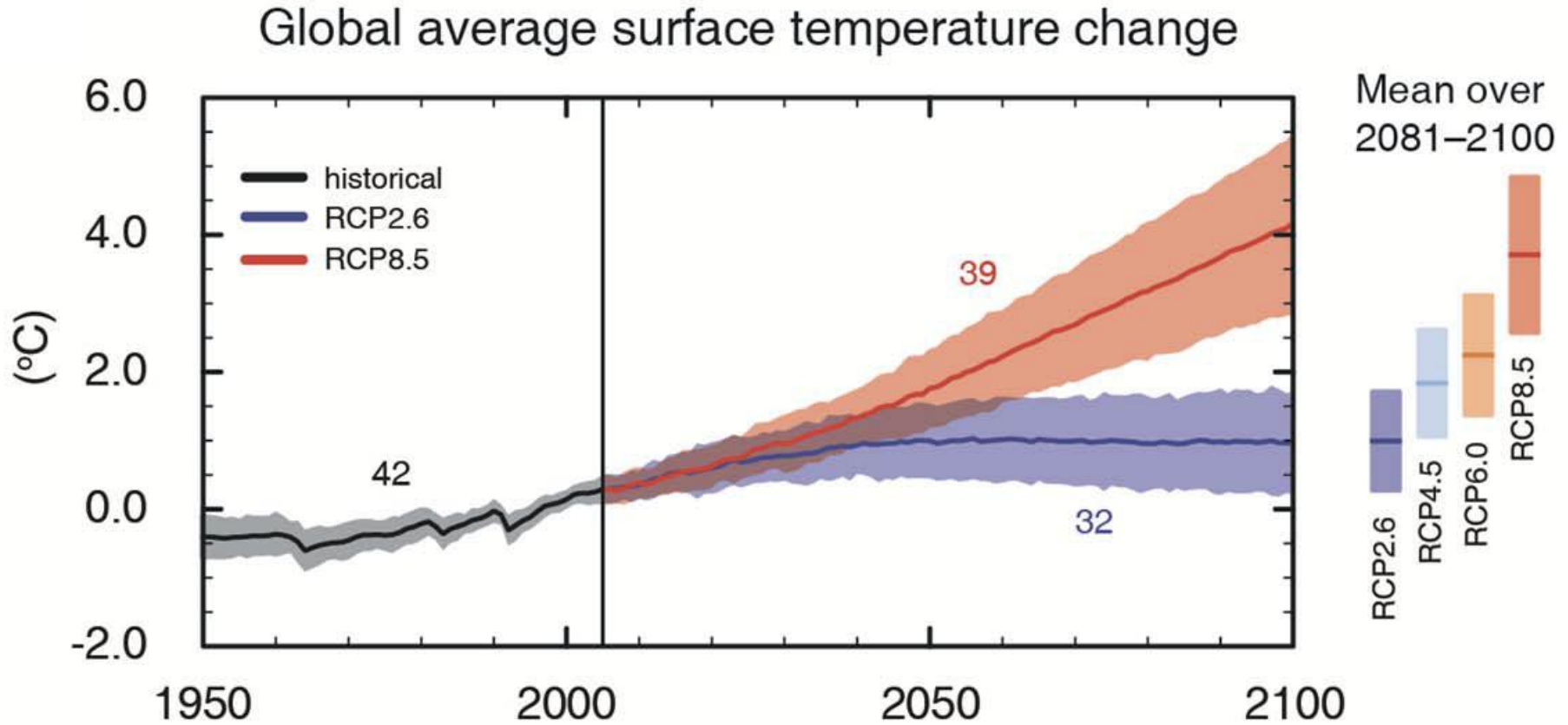


**AR5**  
**2013**

Extremely likely

**IPCC - Intergovernmental Panel on Climate Change**  
**Working Group I: The Physical Science Basis**

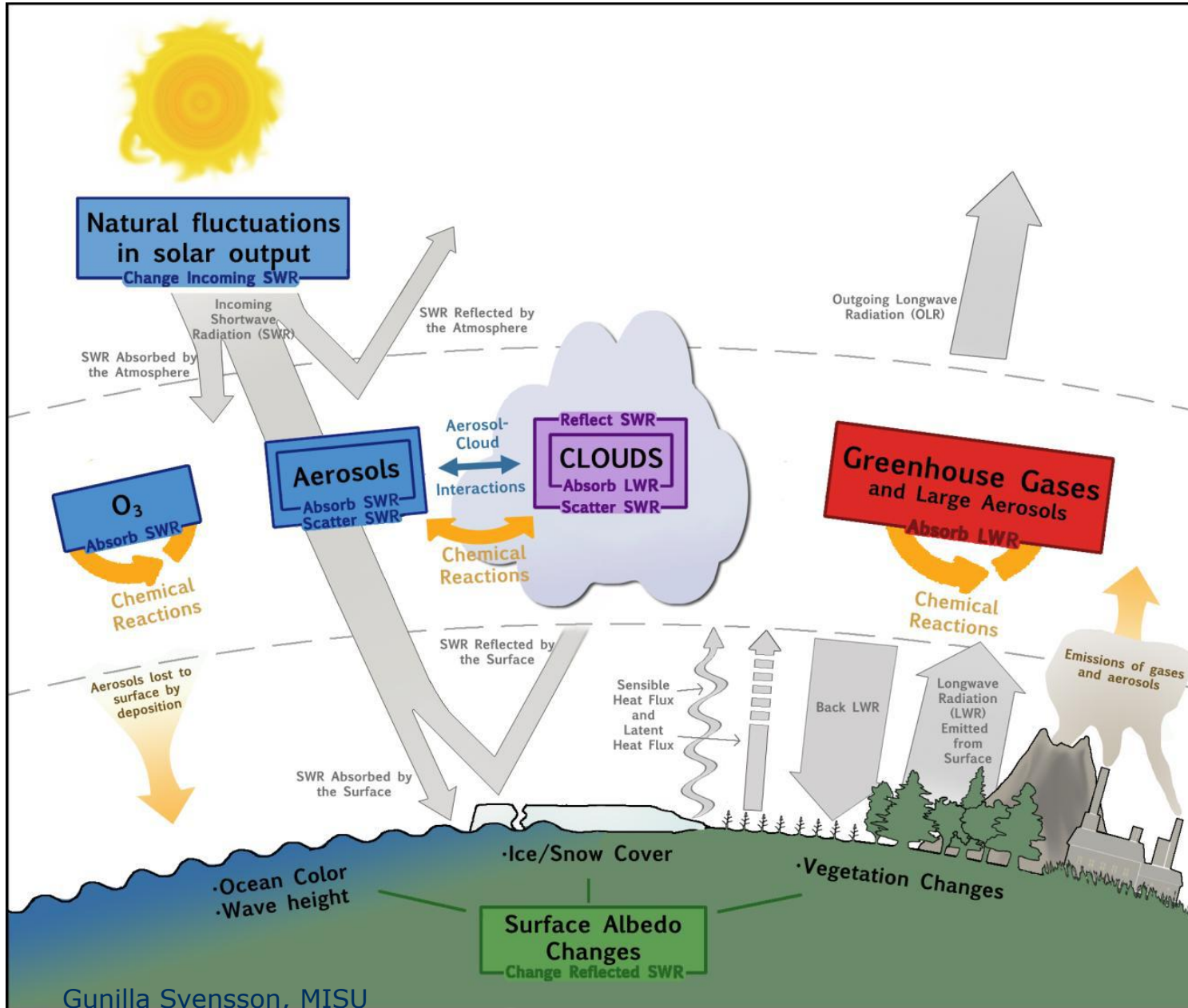
# Global change (AR5)



# Main drivers of climate change



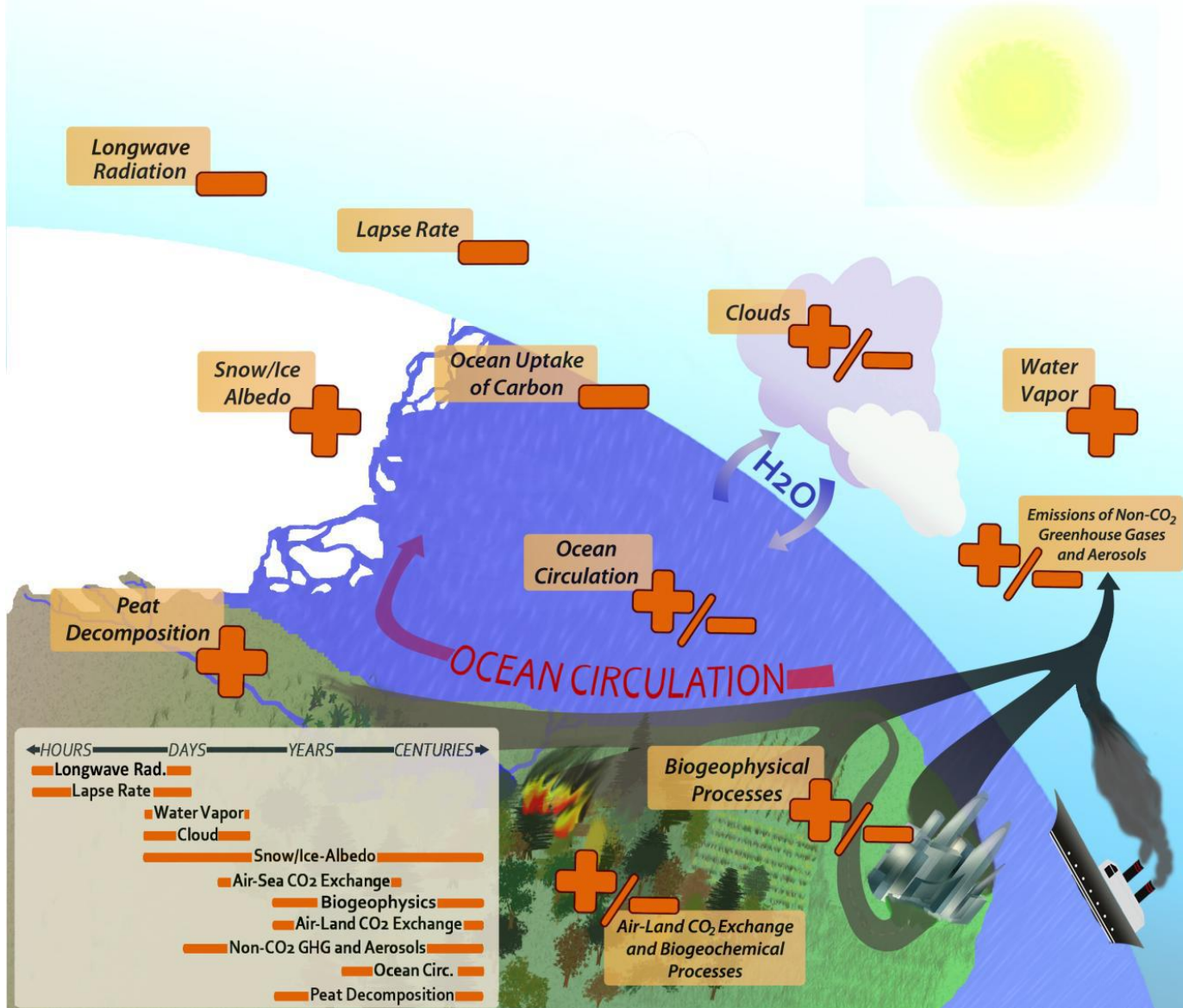
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Gunilla Svensson, MISU

IPCC, 2013

# Feedbacks in the climate system





# Climate models are the only scientific tool available to say something about future climate

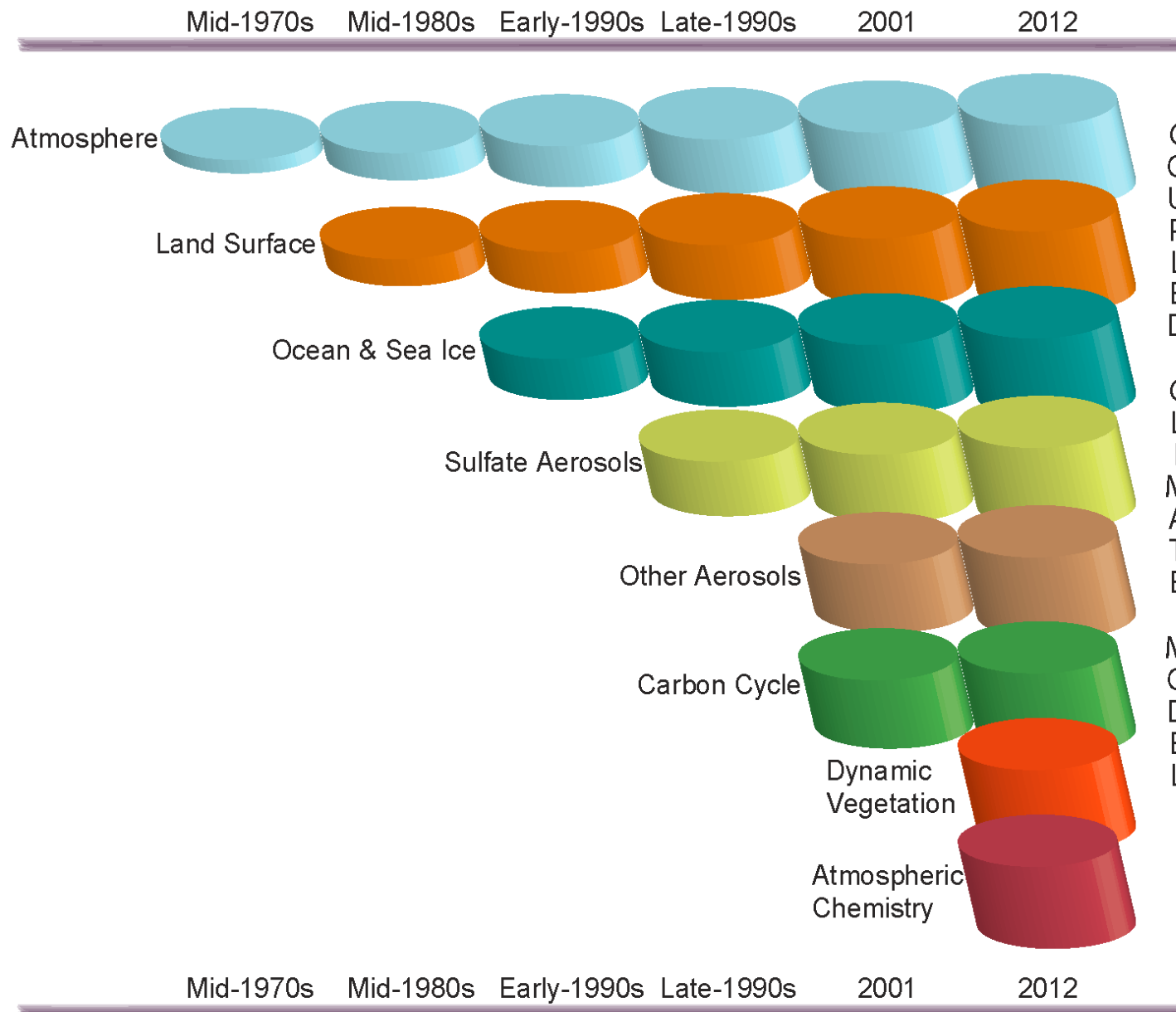
**GCM**



# Climate model development



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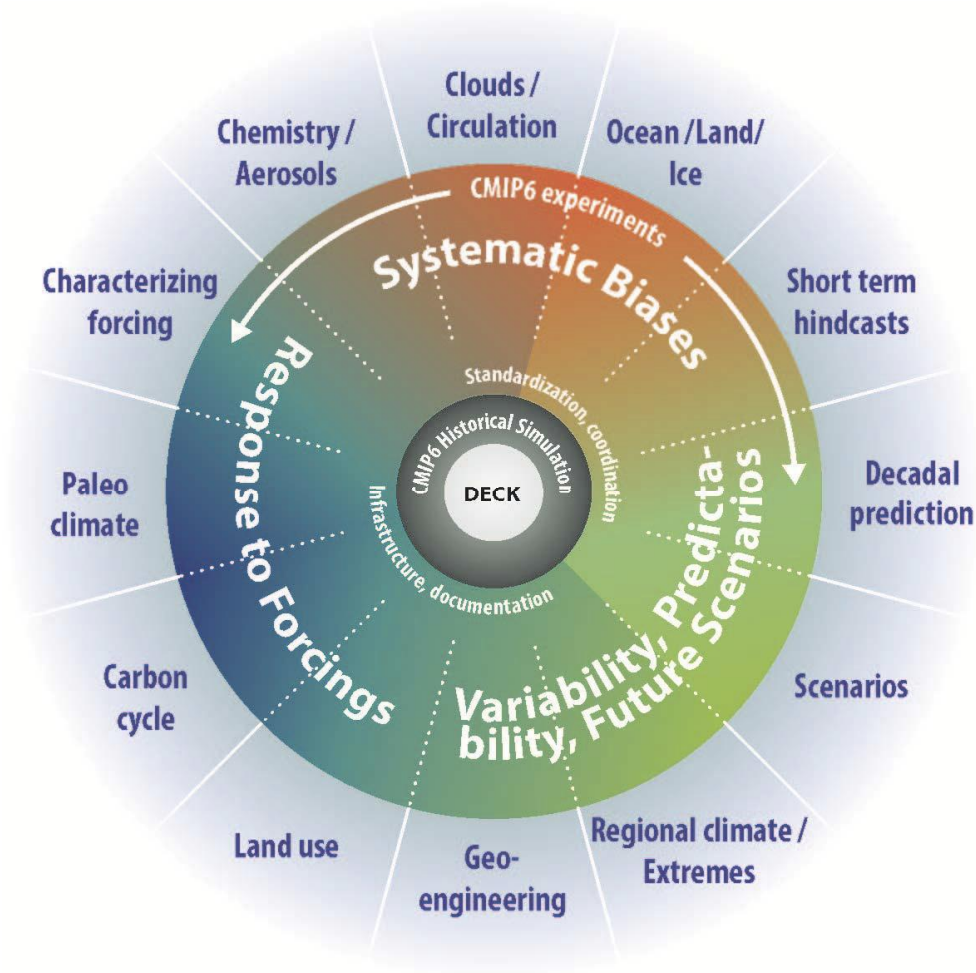


IPCC, 2013

# International climate research



Stockholm University



DECK - Diagnostic, Evaluation and Characterization of *Klima*



# Coupled Model Intercomparison Project phase 6



The specific experimental design is focused on **three broad scientific questions:**

1. How does the Earth System respond to forcing?
2. What are the origins and consequences of systematic model biases?
3. How can we assess future climate changes given climate variability, predictability and uncertainties in scenarios?

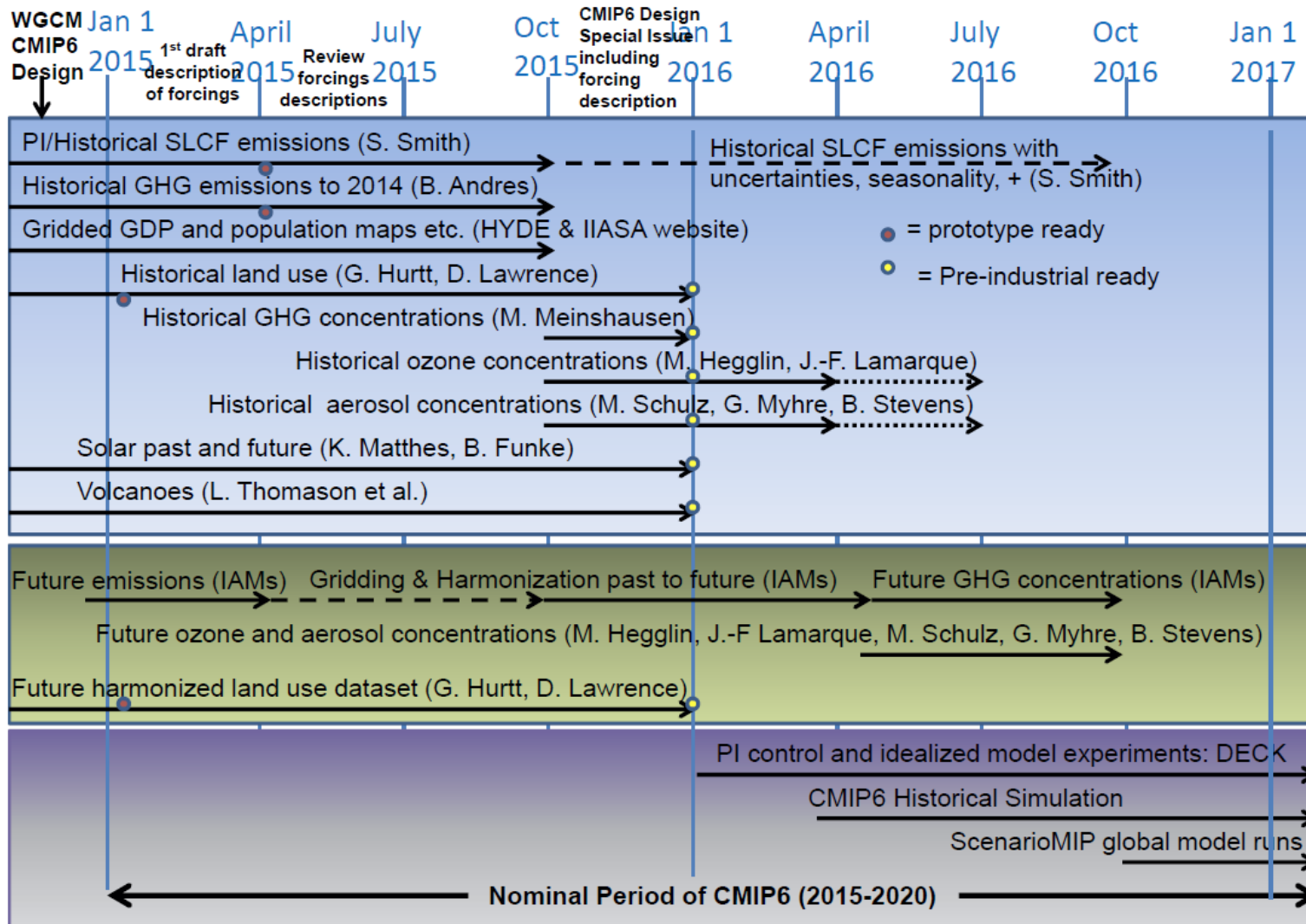


# CMIP6 experiment timeline

## Defining experiment protocols



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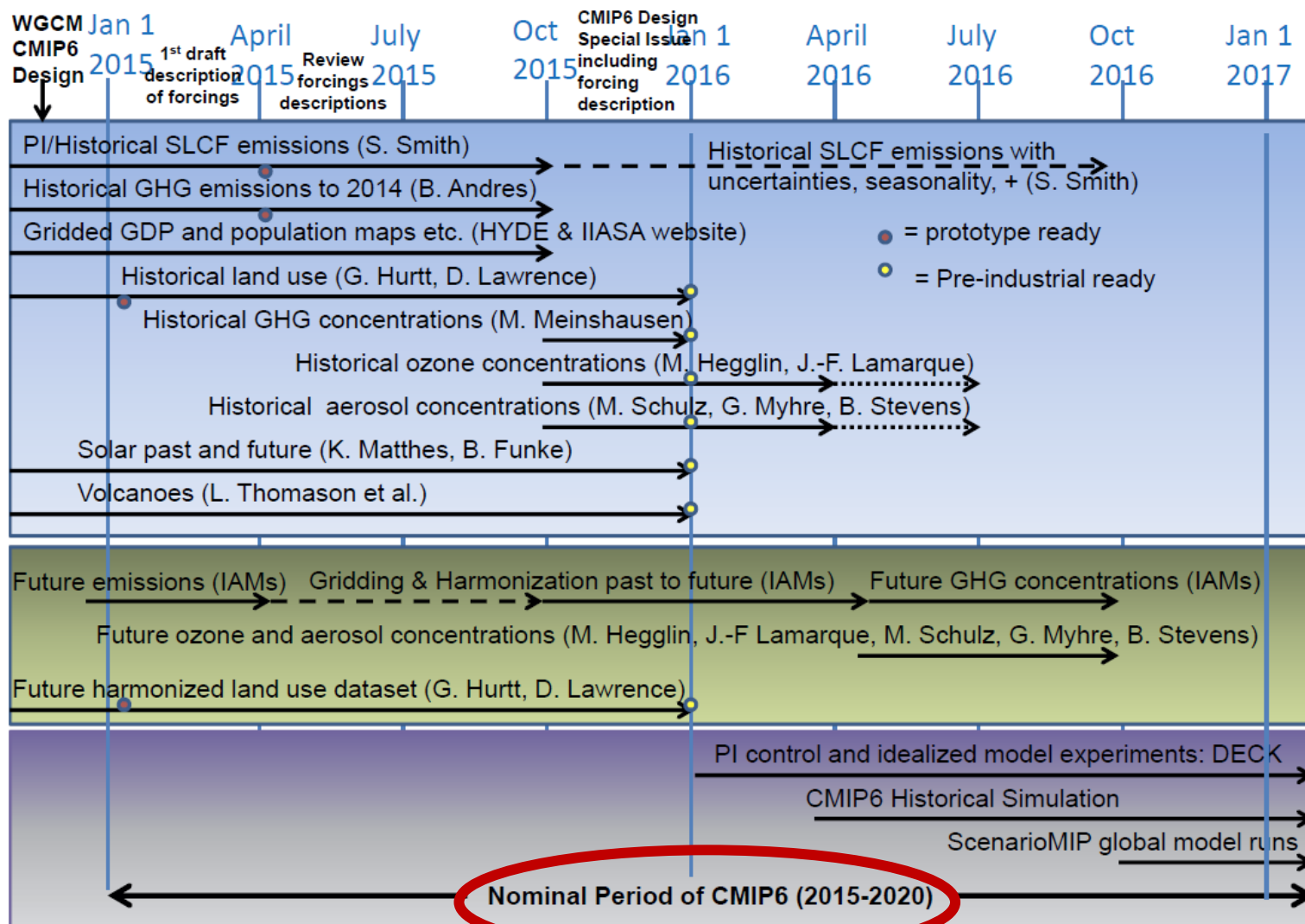


# CMIP6 experiment timeline

## Defining experiment protocols



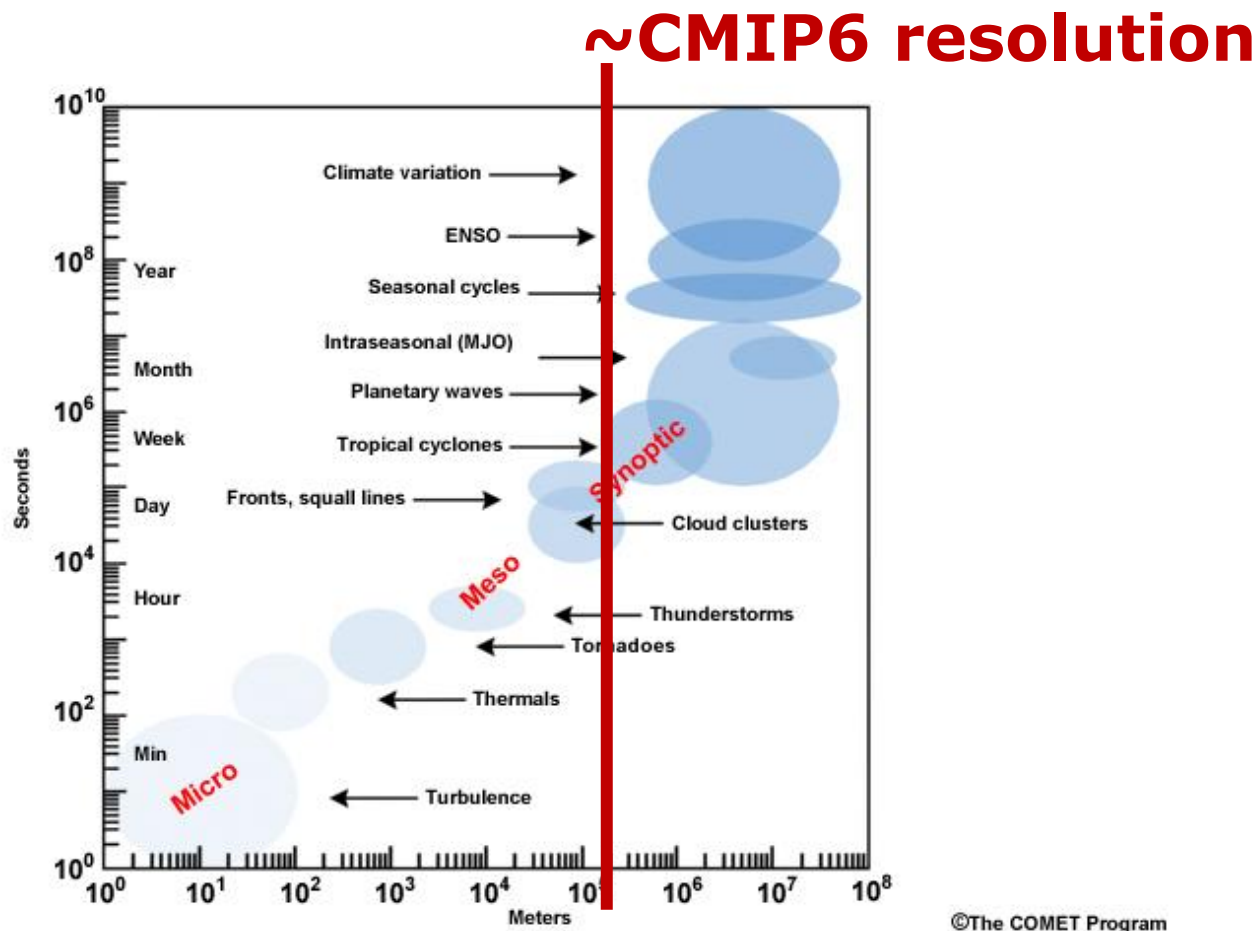
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# Scales in the climate system



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**DNS**

**LES**

**CRM**

**GCM**

**ESM**



Scales

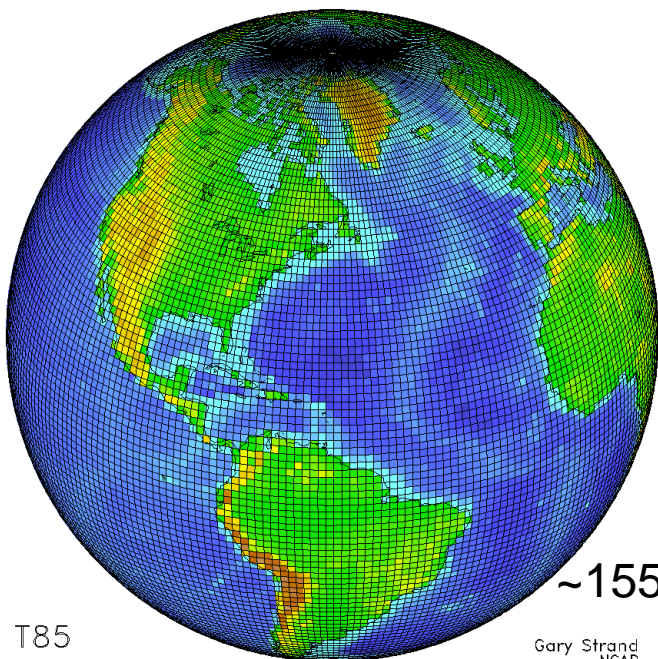
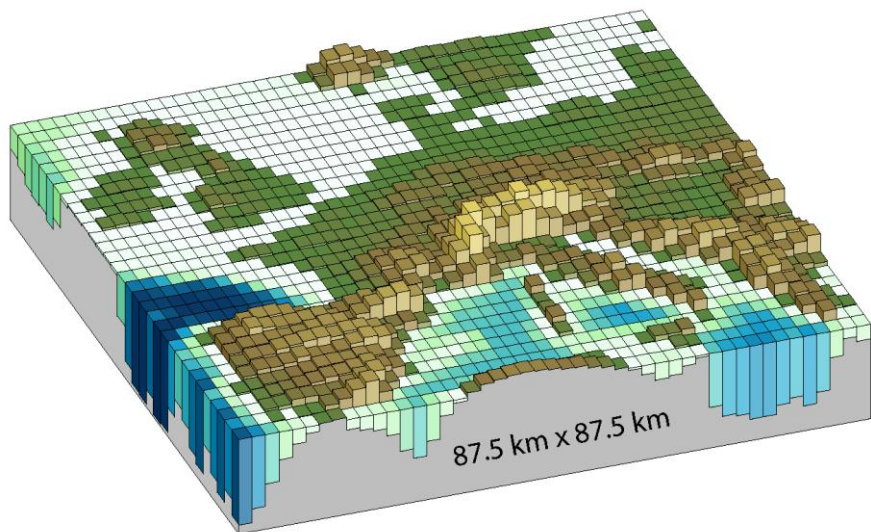
Length  
Time  
Complexity



# Horizontal grid

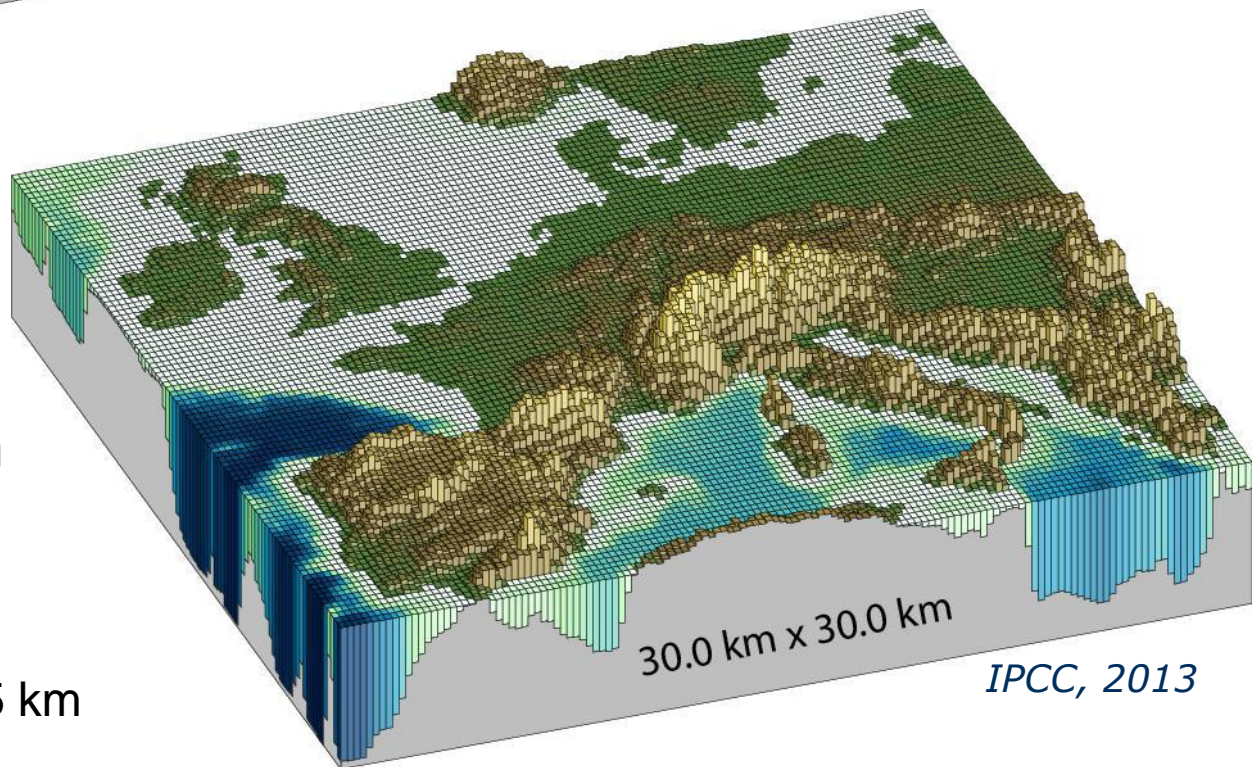


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~155 km

Gary Strand  
NCAR



30.0 km x 30.0 km

IPCC, 2013



# Swedish climate modeling research

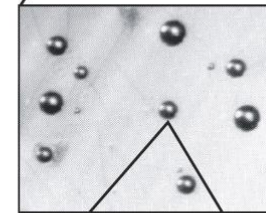
## CLOUD MACROSCALE

Thermodynamic forcing  
Supersaturation development



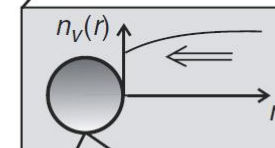
## CLOUD MICROSCALE

Competitive vapor depletion  
Interstitial supersaturation



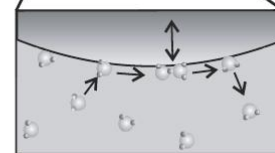
## PARTICLE SCALE

Vapor, heat transport  
Mass growth / evaporation

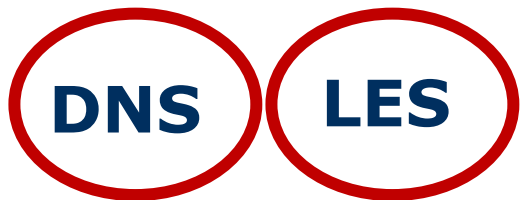


## MOLECULAR SCALE

Surface kinetics  
Condensation coefficient



**ESM**



Scales

Length  
Time  
Complexity

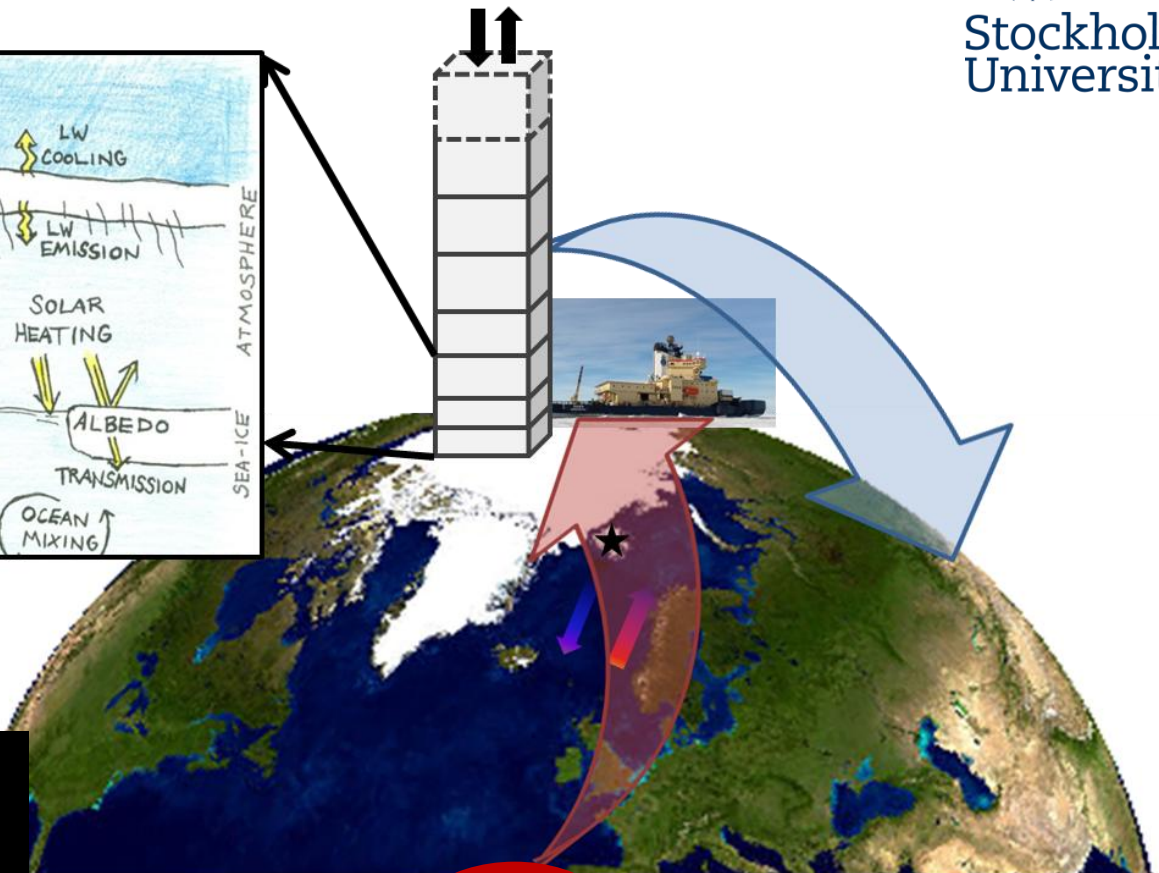
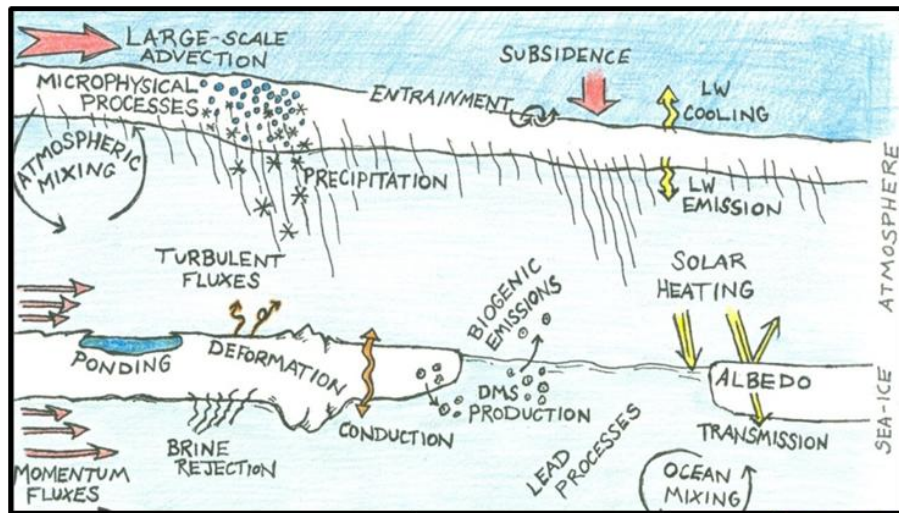
# Swedish climate modeling research



# Swedish climate modeling research



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**CRM**

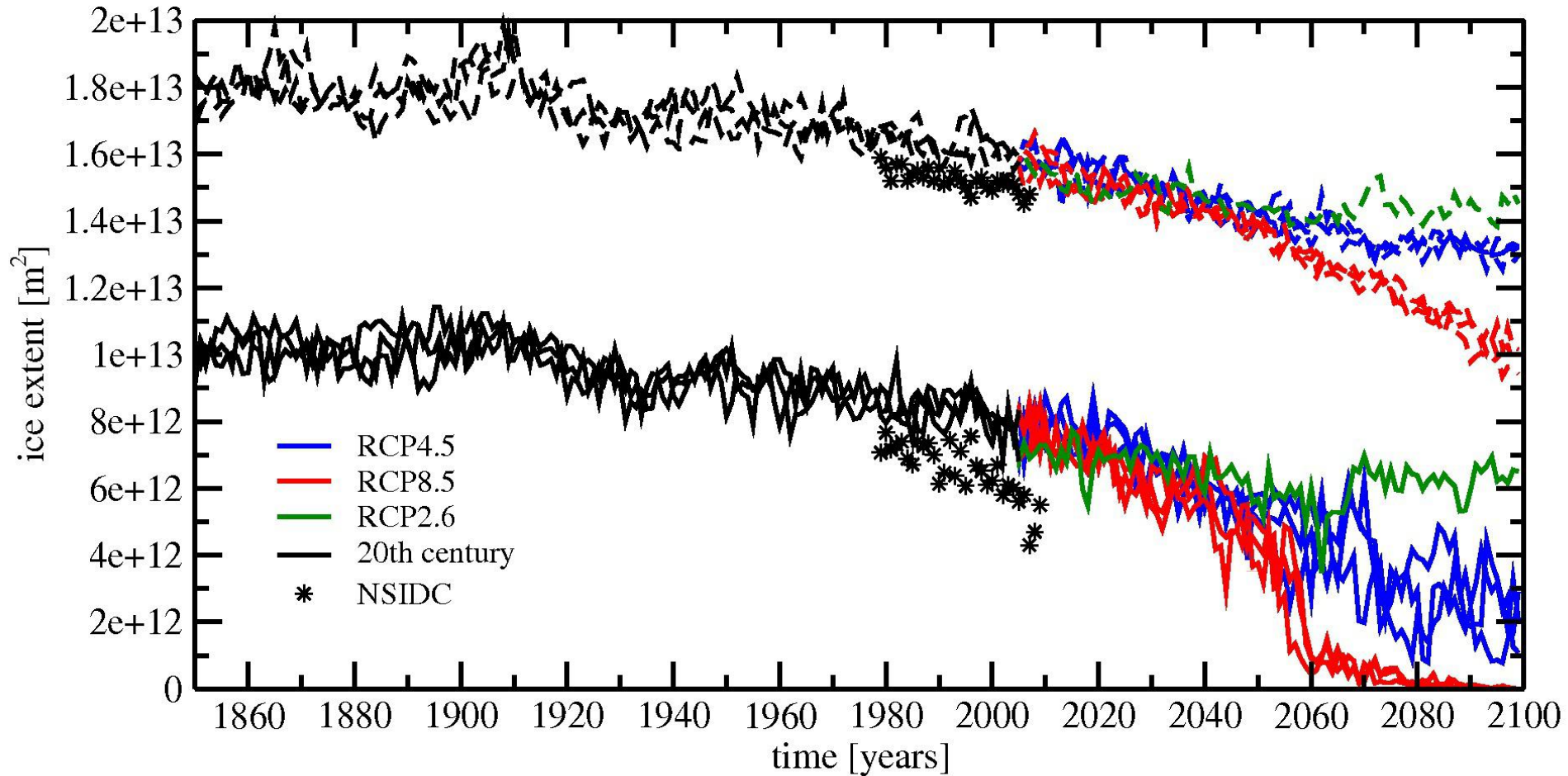
**GCM**

**ESM**

Length  
Time  
Complexity

# Arctic climate change

## Arctic ice extent



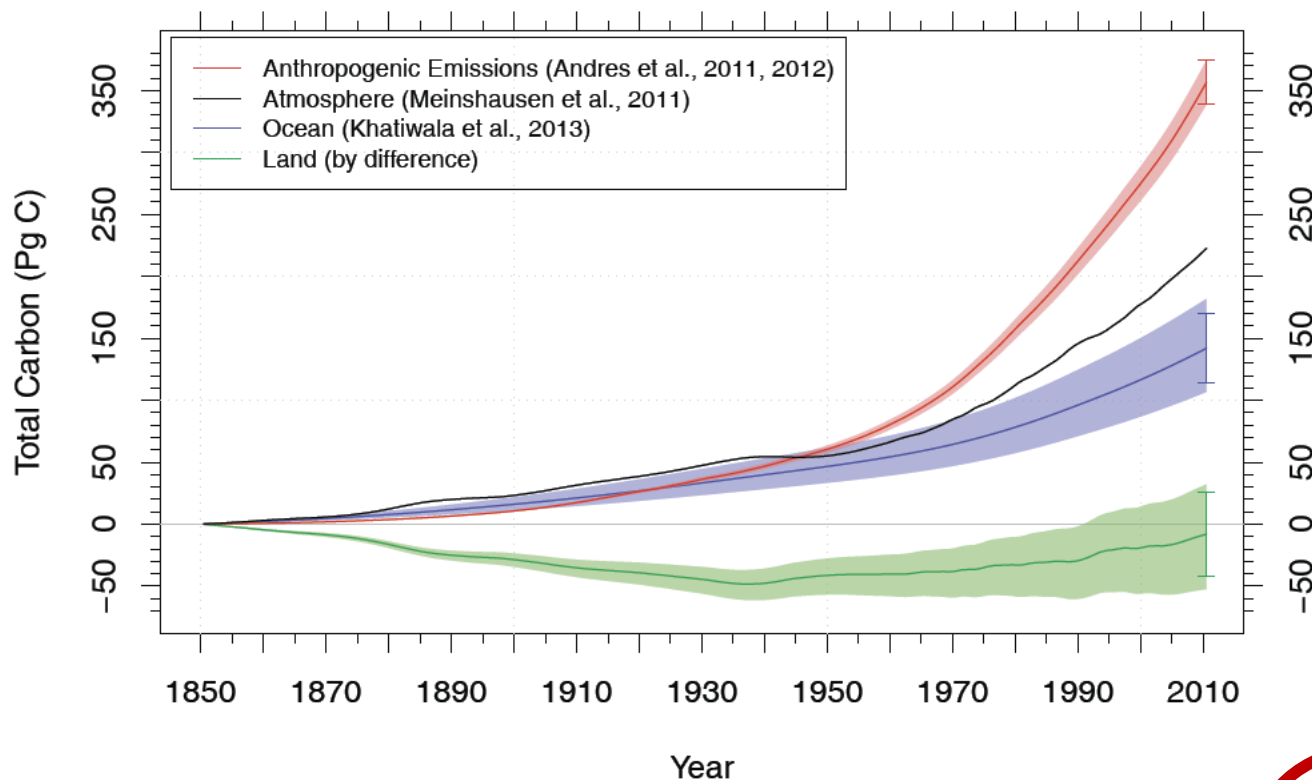


# Swedish climate modeling research



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## Observed Carbon Accumulation Since 1850



**DNS**

**LES**

**CRM**

**GCM**

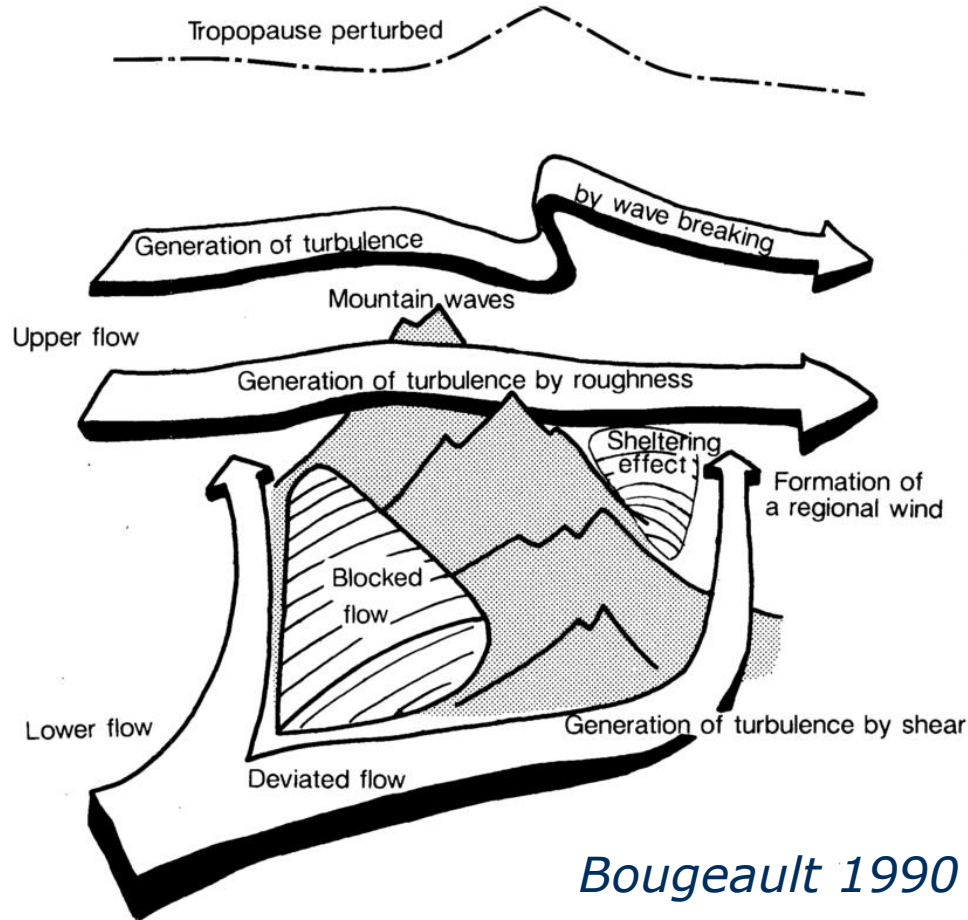
**ESM**



Scales

Length  
Time  
Complexity

# Subgrid-scale terrain effects in GCM

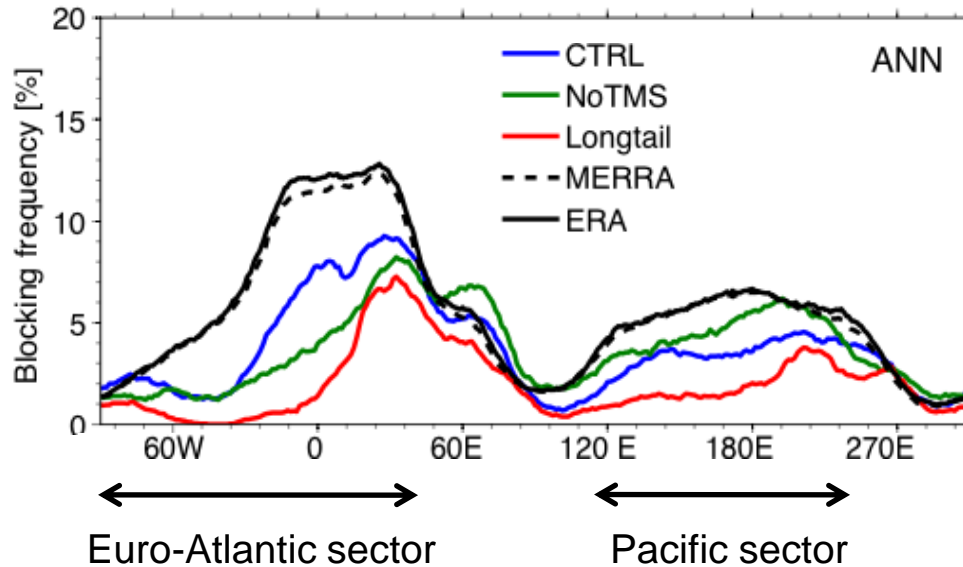


# Atmospheric blocking frequency



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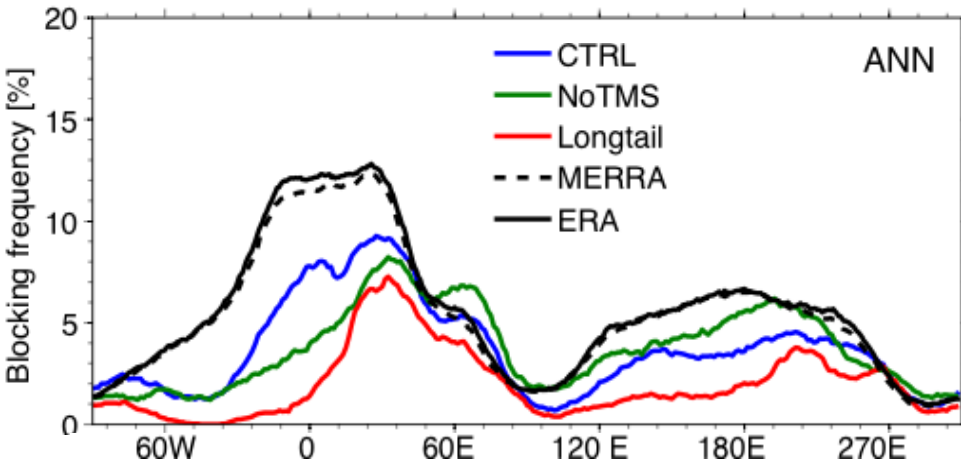
All model versions have too few blockings, specially for the Euro-Atlantic sector



# Atmospheric blocking frequency

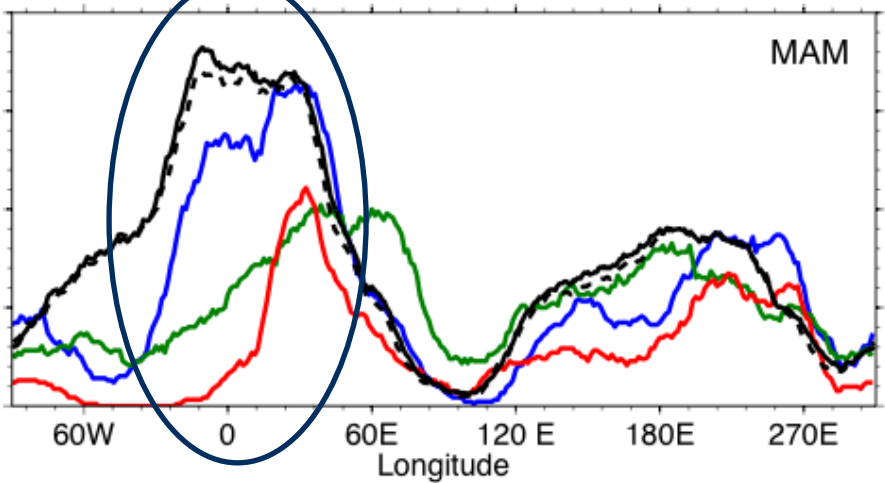
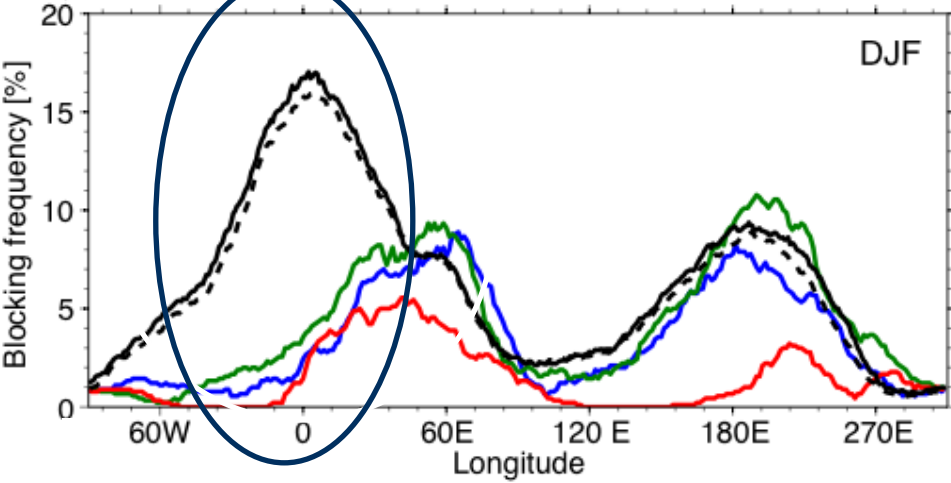


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No version captures the Atlantic blockings in winter

Control is closer to observations than both NoTMS and Longtail in spring



**CONTROL** – With TMS (subgrid scale turbulent orographic drag)

**NoTMS** - Without TMS (no subgrid scale turbulent orographic drag)

**LONGTAIL** - Higher diffusivity in stably stratified conditions + no turbulent orographic drag

*Lindvall, Svensson and Caballero, 2015*

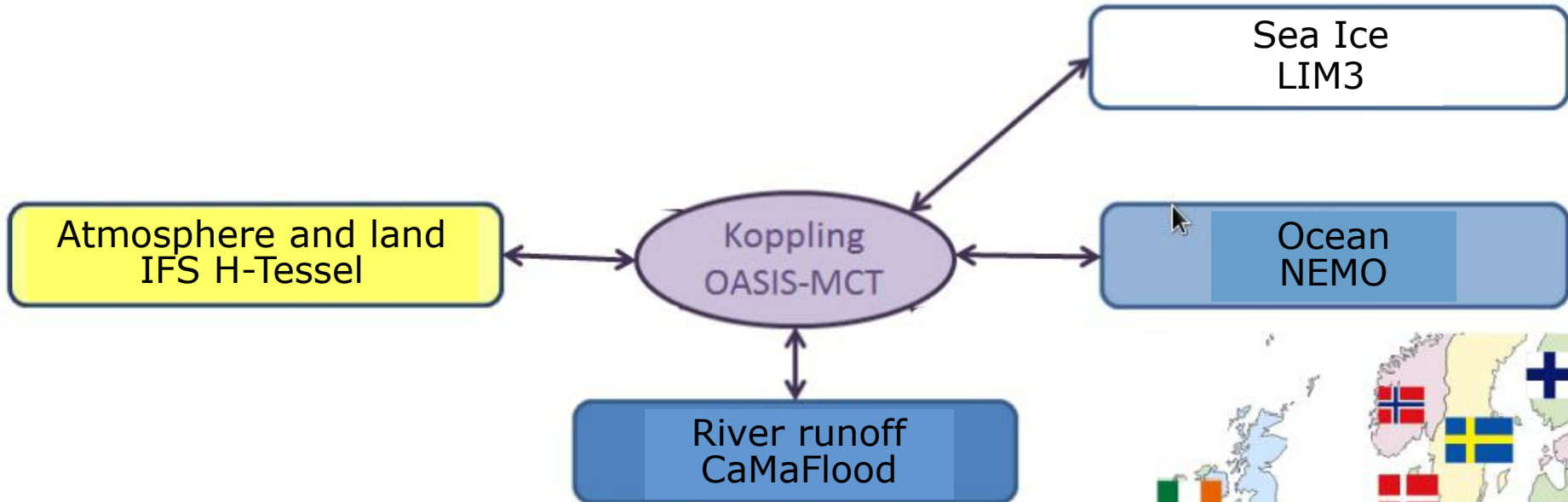


# EC-Earth

## GCM Global Climate Model



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University

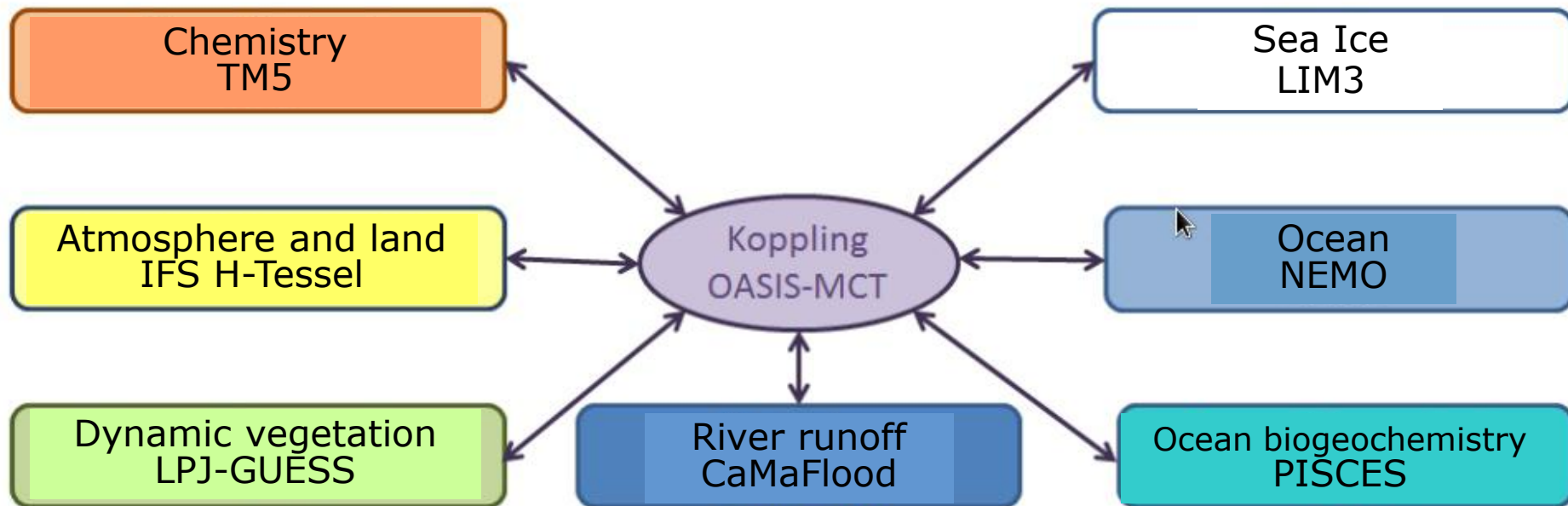


# EC-Earth

## ESM Earth System Model



Stockholm  
University



# The Beskow perspective so far...

## AMIP experiments

- Atmosphere-only simulation
- Prescribed SST and sea-ice concentration
- Standard method for testing climate models
- AMIP experiments have been done for CMIP5 and are planned for CMIP6 (part of the DECK runs)

First set of runs that we are doing on Beskow

Klaus Wyser, Rossby Centre

# AMIP experiments at PDC

Ekman (CMIP5):

- EC-EARTH v2.3
- Performance: 4 simulated years per day

Beskow (CMIP6):

- EC-EARTH v3.1
- Performance: 6 simulated years per day

Is the only gain 2 more simulated years per day when going from Ekman to Beskow?



# But...

## Ekman (CMIP5):

- EC-EARTH v2.3
- Horizontal resolution T1262
- 62 vertical layers
- Timestep 1 hour

## Beskow (CMIP6):

- EC-EARTH v3.1
- Horizontal resolution T511 ( $\sim 0.35$  degrees)
- 91 vertical layers
- Timestep 15 minutes

- EC-EARTH has higher resolution on Beskow, horizontally and vertically, and a shorter timestep
- Roughly speaking the model is 60 times more complex
- *Performance of Beskow is 50% better compared to Ekman yet the model is 60 times more complex model*





# Summary

- The Swedish climate community contributed to CMIP5 and take part in CMIP6, currently leading the European consortium on EC-Earth
- For CMIP6 simulations we currently estimate an overall amount of **340 mio core-hours** over a period of 5 years (2015-2019).
- Climate science is a huge and challenging flow problem, a turbulent flow that range from the micrometer to the global scale
- The Earth is rotating and we have moist diabatic processes (clouds) that affect the flow and the subsystems are interacting
- Much science is not understand on a fundamental physical level where climate models is a indispensable tool

Swedish climate modeling research is performed at KTH, Stockholm, Lund, Gothenburg and Uppsala University in collaboration with the Rossby Centre at SMHI



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