Mould Growth inside an Attic concerning Four Different Future Climate Scenarios

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Climate change may affect the building durability and energy consumption

We can apply the future weather data in building simulations

- The weather data is the result of future climate simulation
- There are different uncertainty factors in the climate simulations

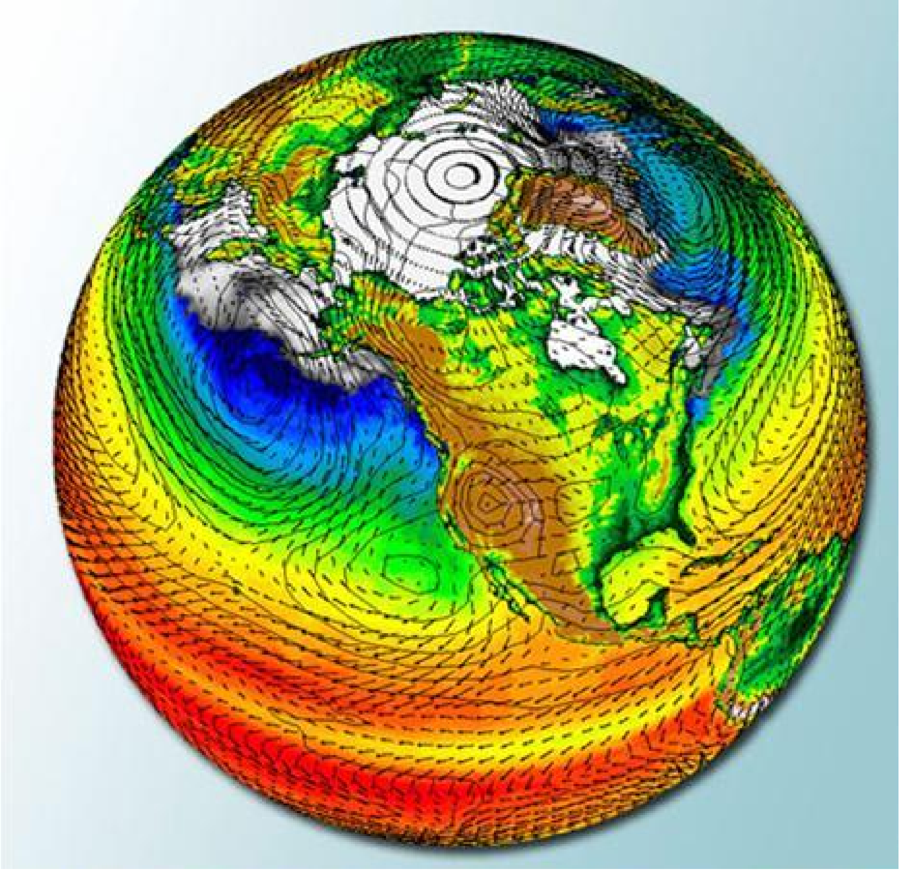
Uncertainties of the Climate Data

Spatial Resolution

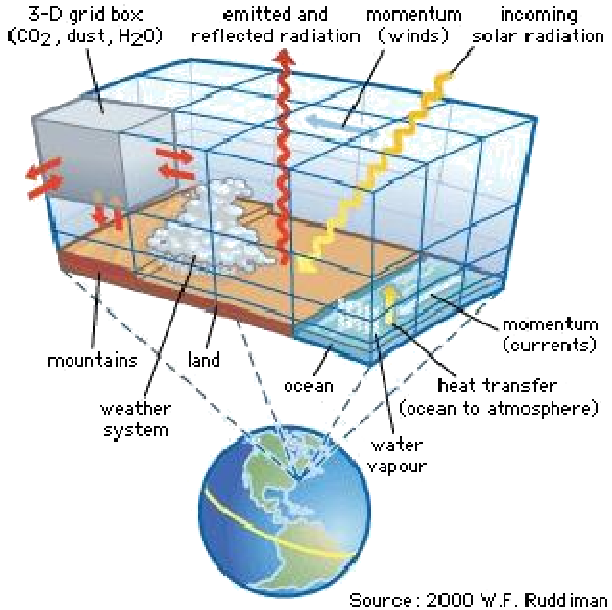
Global Climate Model (GCM)

CO_2 Emission Scenario

Initial Condition



Different Global Climate Models (GCMs)



HadCM3 Hadley Centre Coupled Model, version 3, UK

ECHAM5 DKRZ, the Deutsches Klimarechenzentrum GmbH
Max-Planck Institute for Meteorology in Hamburg

CCSM3 The Community Climate System Model
National Center of Atmospheric Research (NCAR) Boulder, USA.

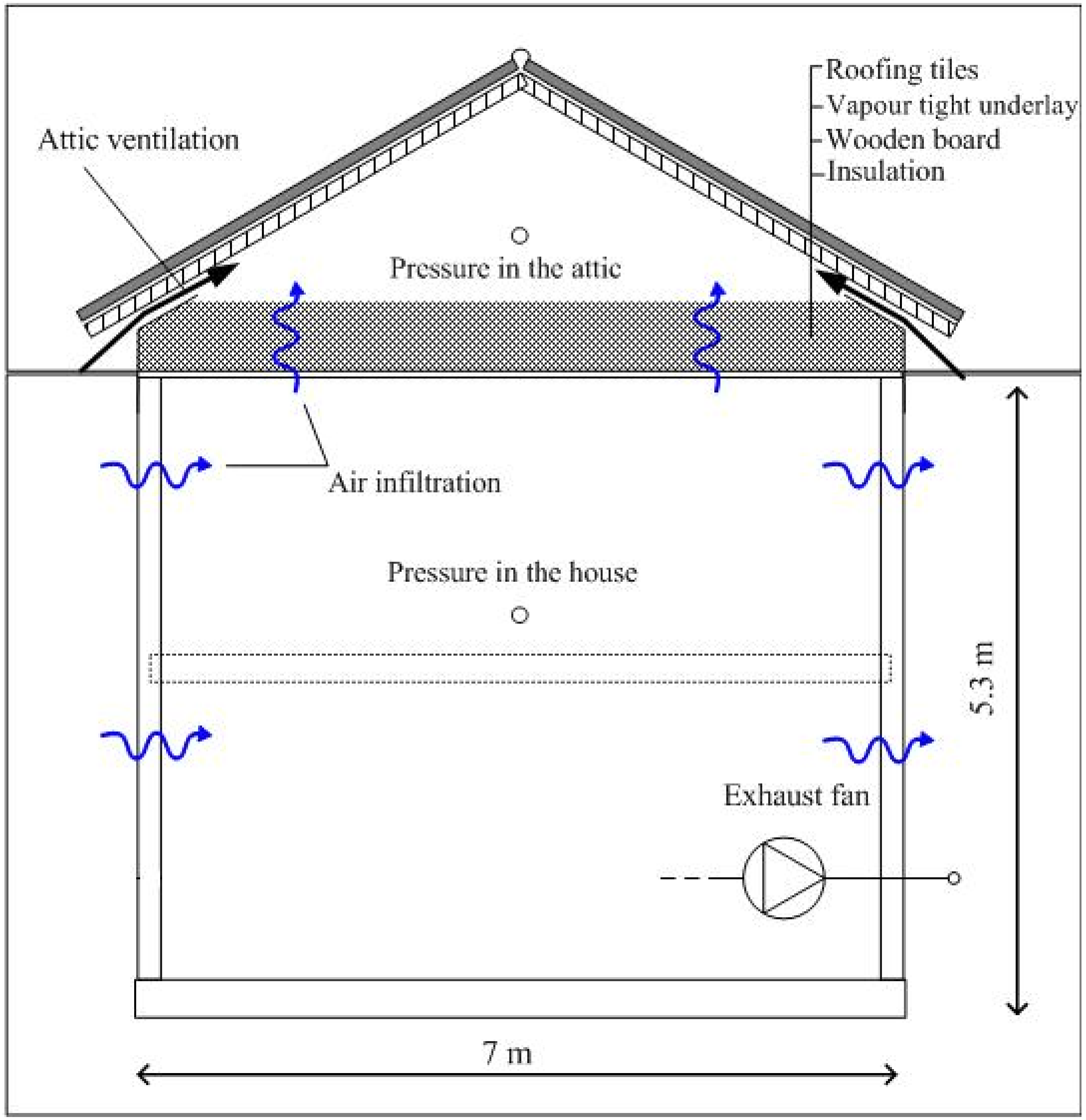
CNRM CERFACS , Toulouse, France

Cold Attic

- Volume of the attic: 80 m^3
- Roof

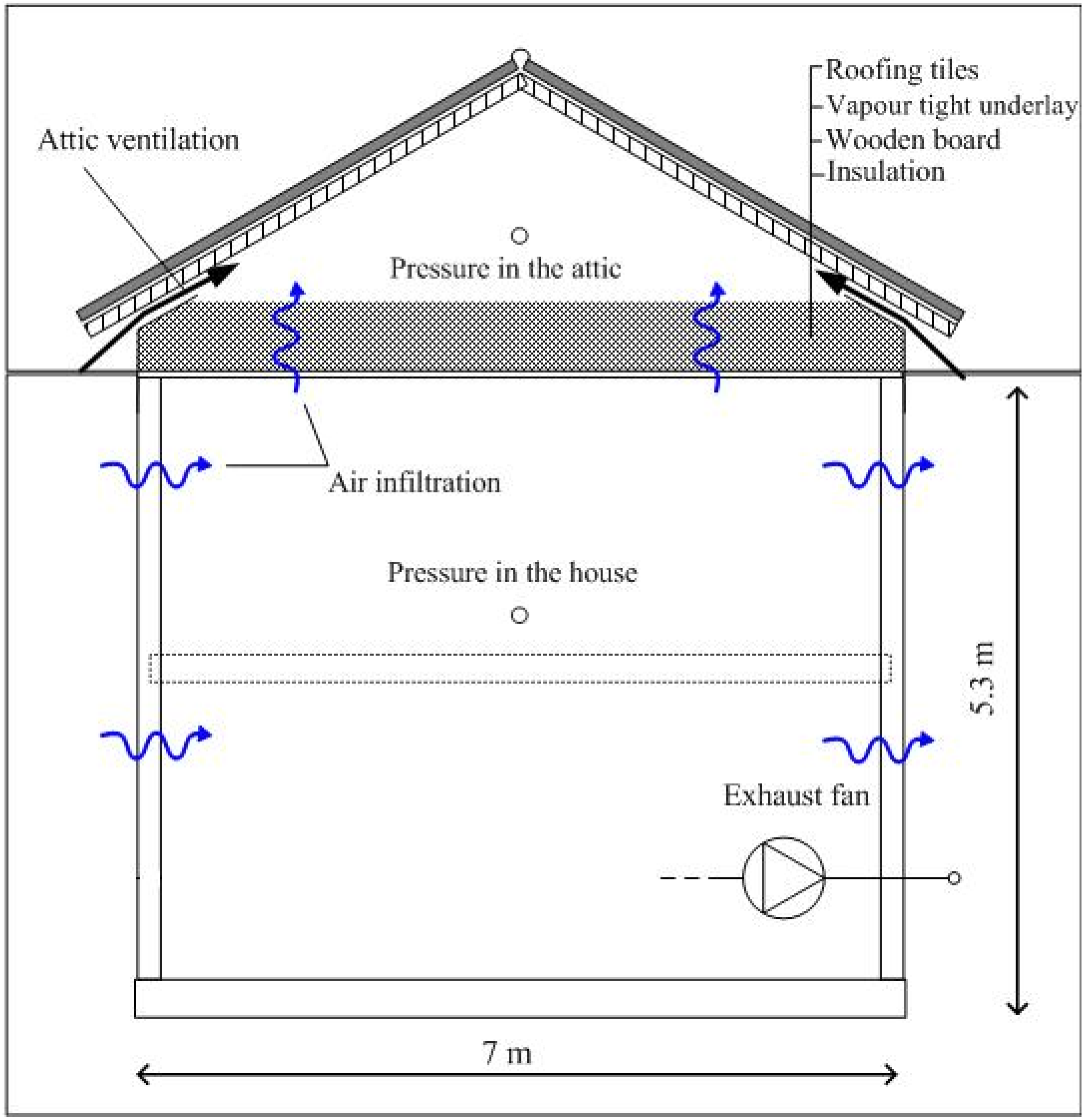
  Openings of 20 mm wide along the roof eaves
- Attic floor

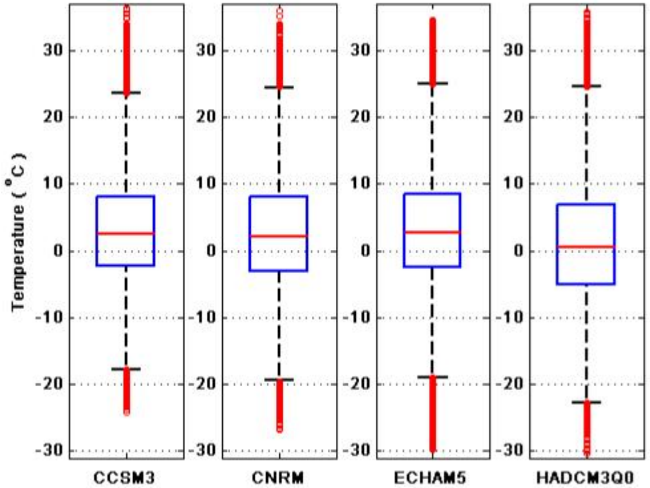
  outer layer: 400 mm thick insulation
  middle layer: air barrier
  inner layer: gypsum board
- Roof is pitched at a 30 ^{o} angle and oriented south-north.



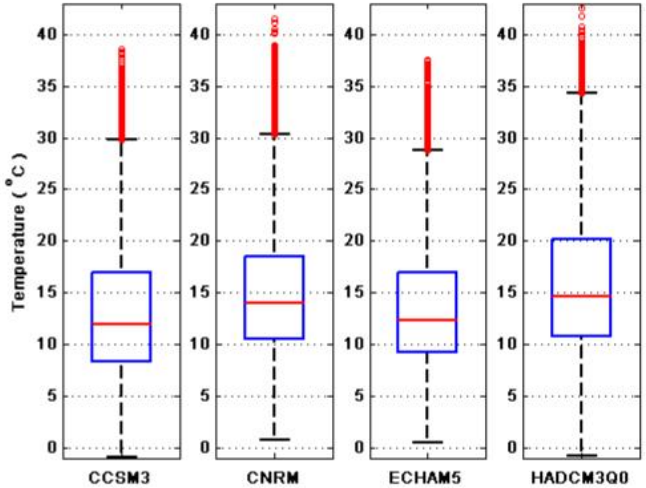
Cold Attic

- Ventilation
  - House: exhaust fan (0.5 1/h)
    (200 m^3/h)
  - Attic: natural (through the openings)
- Airtightness of the house
  - 1 litre/m^2s at 50 Pa
- Air leakage
  - Uniform distribution in the house
  - Air leakage in the ceiling: - 0.65 1/h

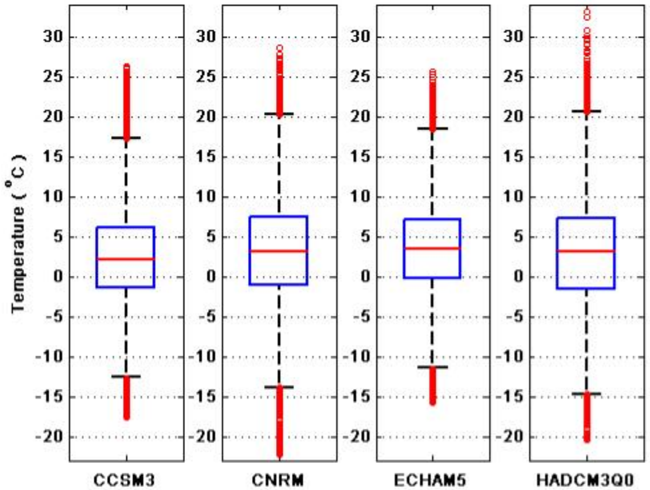




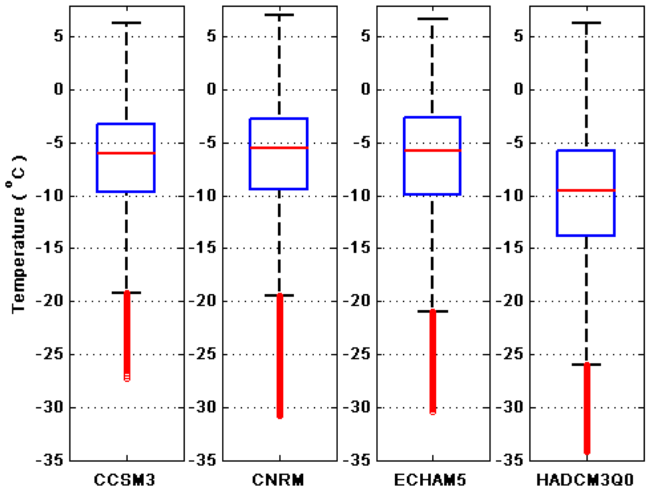
Spring



Summer

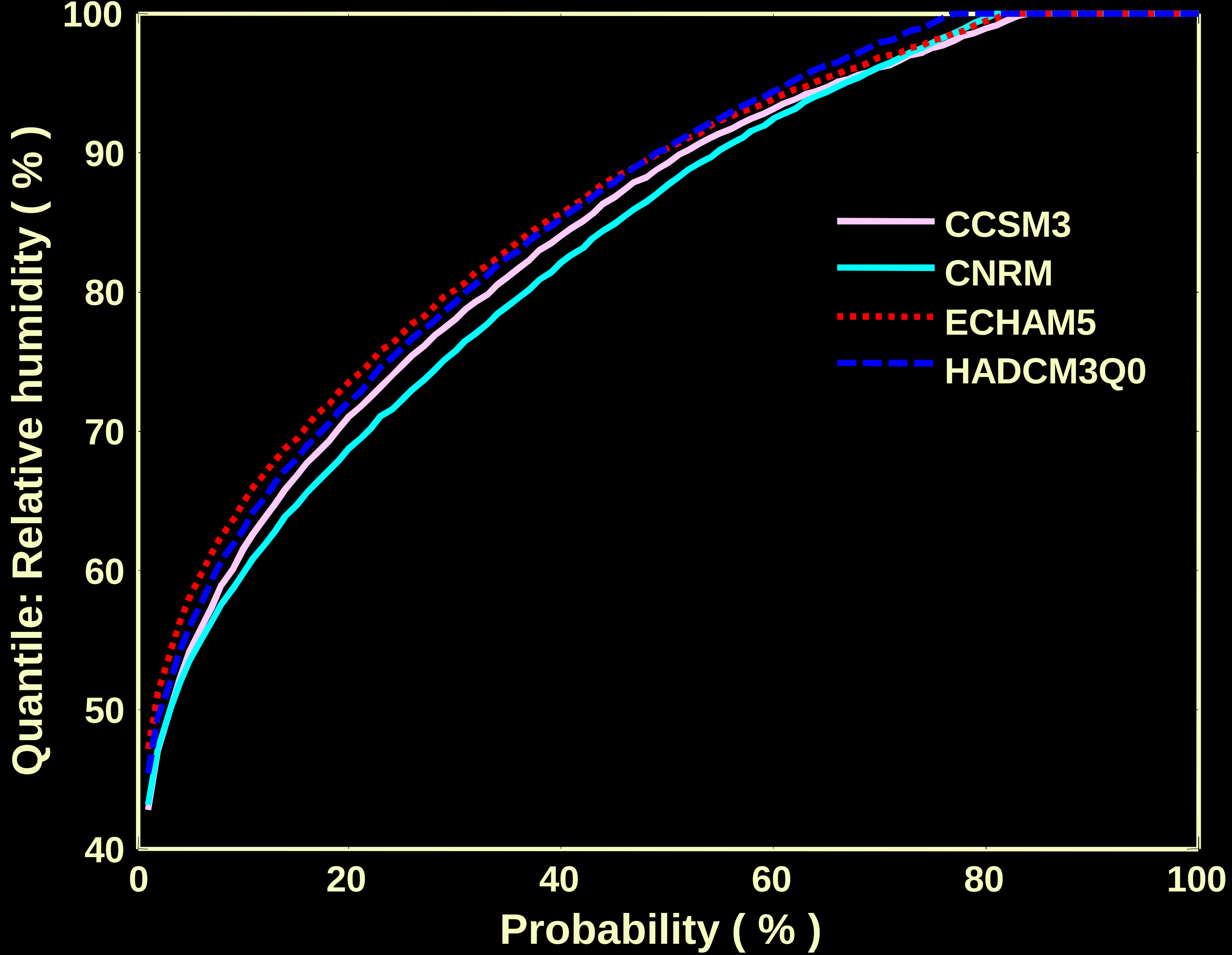


Autumn



Winter

Temperature inside the attic - Stockholm - SCN period


Quantile: Relative humidity (%)
100
90
80
70
60
50
40
0
20
40
60
80
100
Probability (%)
CCSM3
CNRM
ECHAM5
HADCM3Q0

Temperature mean values for different GCMs

	CTL period (1961-1990)					SCN period (2071-2100)			
	ERA40	CCSM3	CNRM	ECHAM5	HADCM3	CCSM3	CNRM	ECHAM5	HADCM3
Indoor	15.4	13.4	14.9	13.95	15.9	13.0	14.1	13.1	14.98

There can be a significant difference between the 30-year mean values of different GCMs which may affect the future designing policies.

Total daily mould dose (Isaksson et al. 2010)

$$D_\phi = [15.53\ln(\frac{\phi}{90})] \qquad 75 < \phi \leq 100\%$$

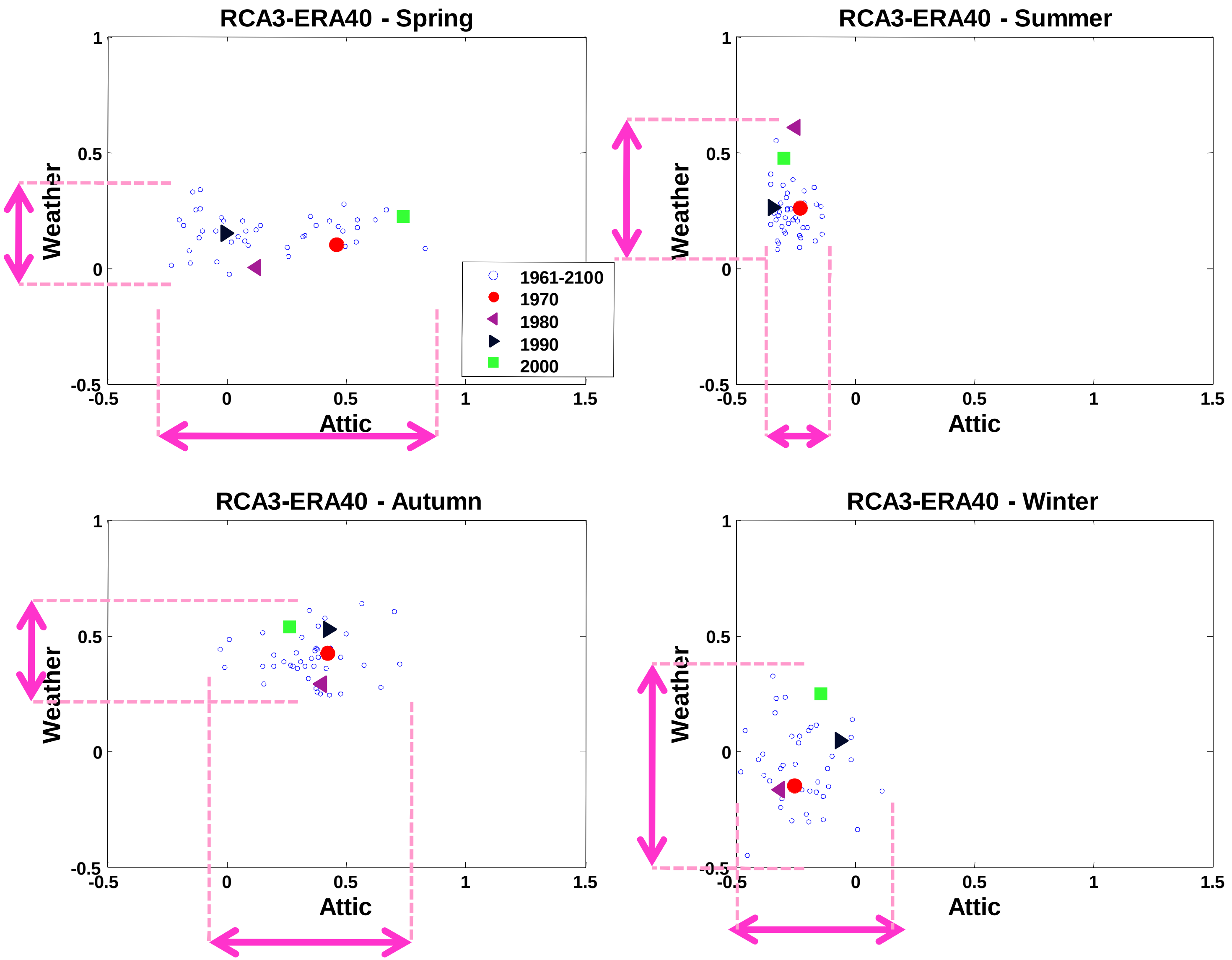
$$D_T = [0.74\ln(\frac{T}{20})] \qquad 0.1 < T \leq 30^o C$$

$$D_\phi(\phi) = (-2.7 + 1.1\phi / 30) \qquad 60 < \phi \leq 75\%$$

$$D_\phi(\phi) = -0.5 \qquad \phi < 60\%$$

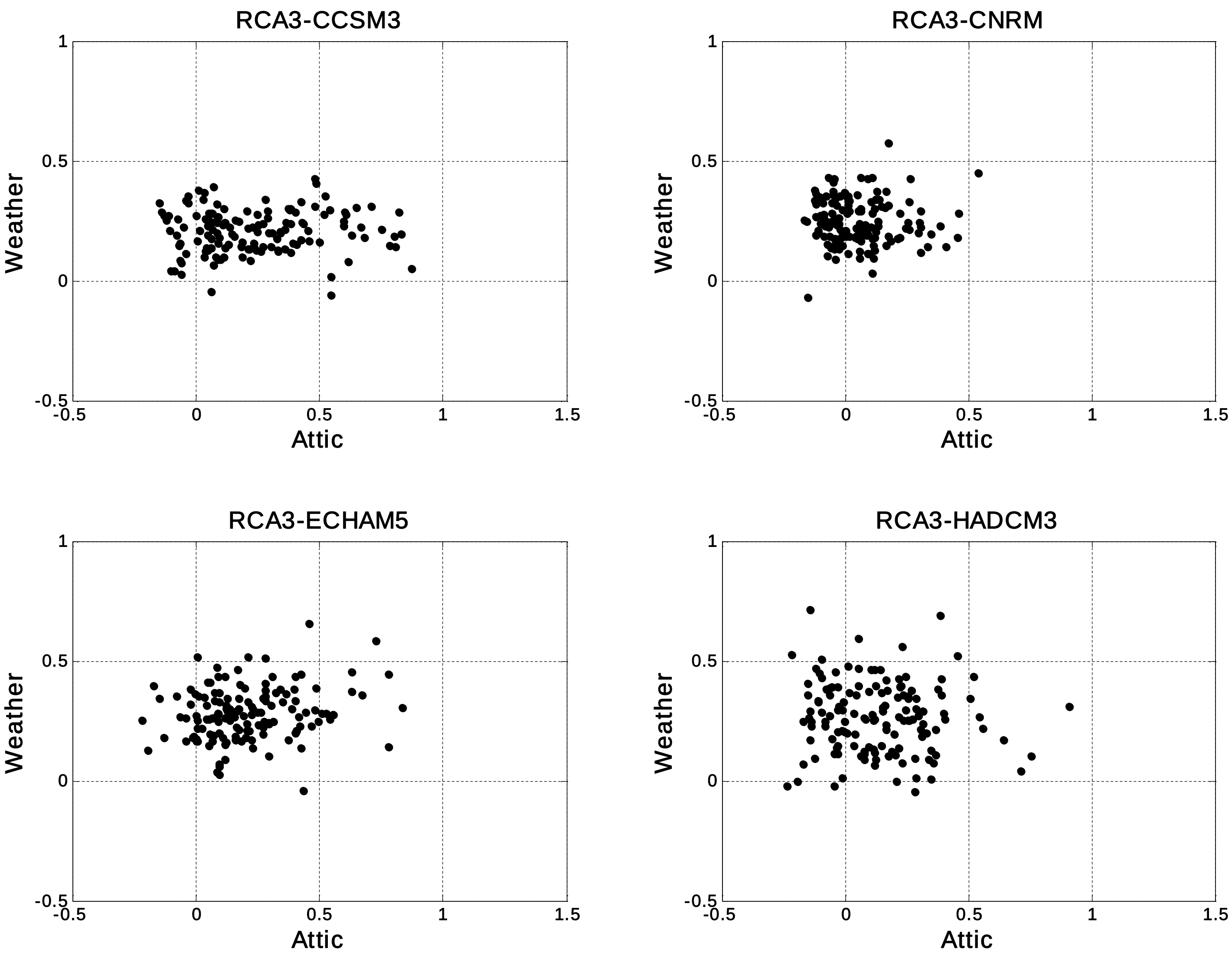
$$D(\phi, T) = -0.5 \qquad T < 0.1^o C$$

$$D = D_\phi(\phi) \cdot D_T(T)$$



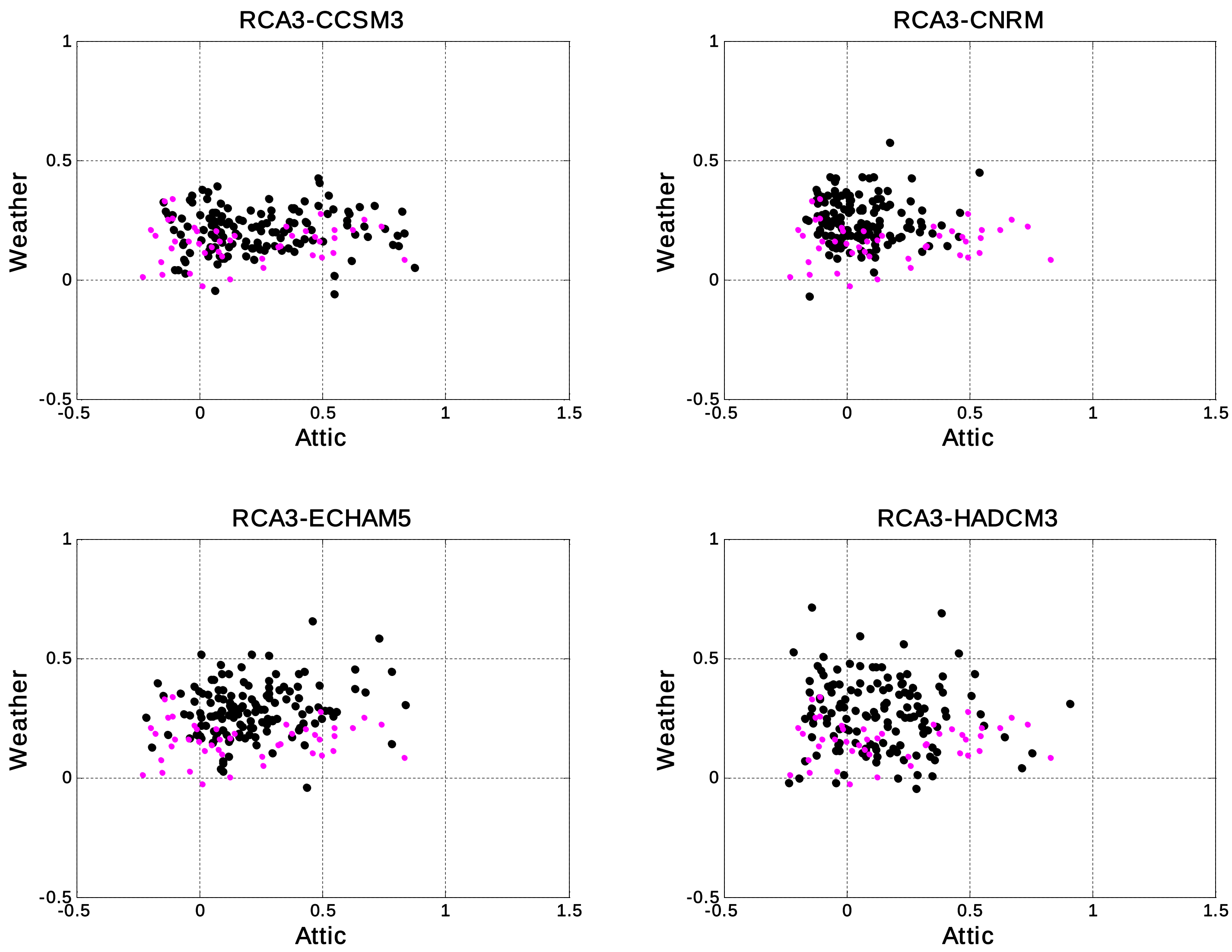
ERA40 – mould doses

Spring

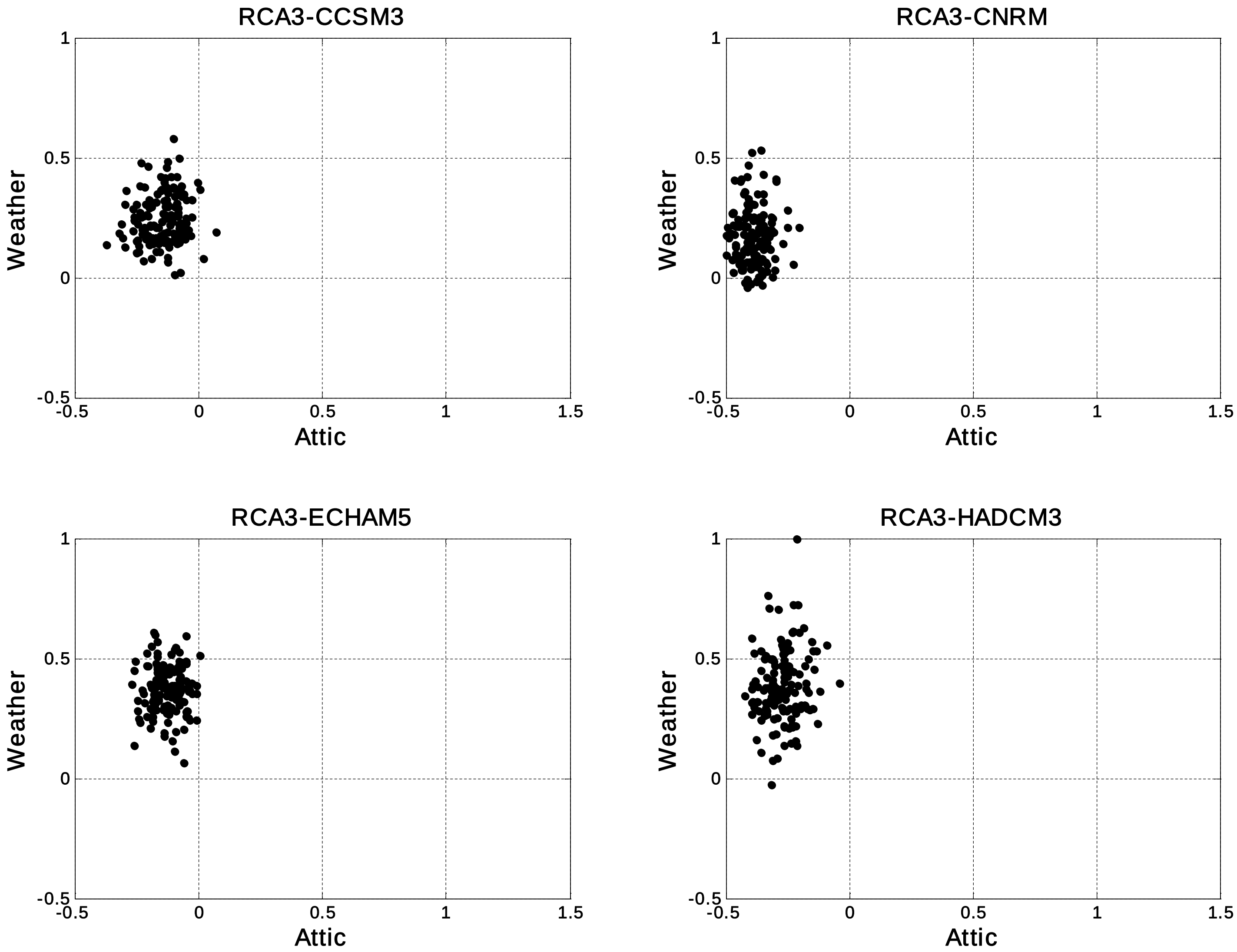


Four GMCs – mould doses

Spring


RCA3-CCSM3
RCA3-CNRM
RCA3-ECHAM5
RCA3-HADCM3
Weather
Attic
1
0.5
0
-0.5
-0.5
0
0.5
1
1.5

Summer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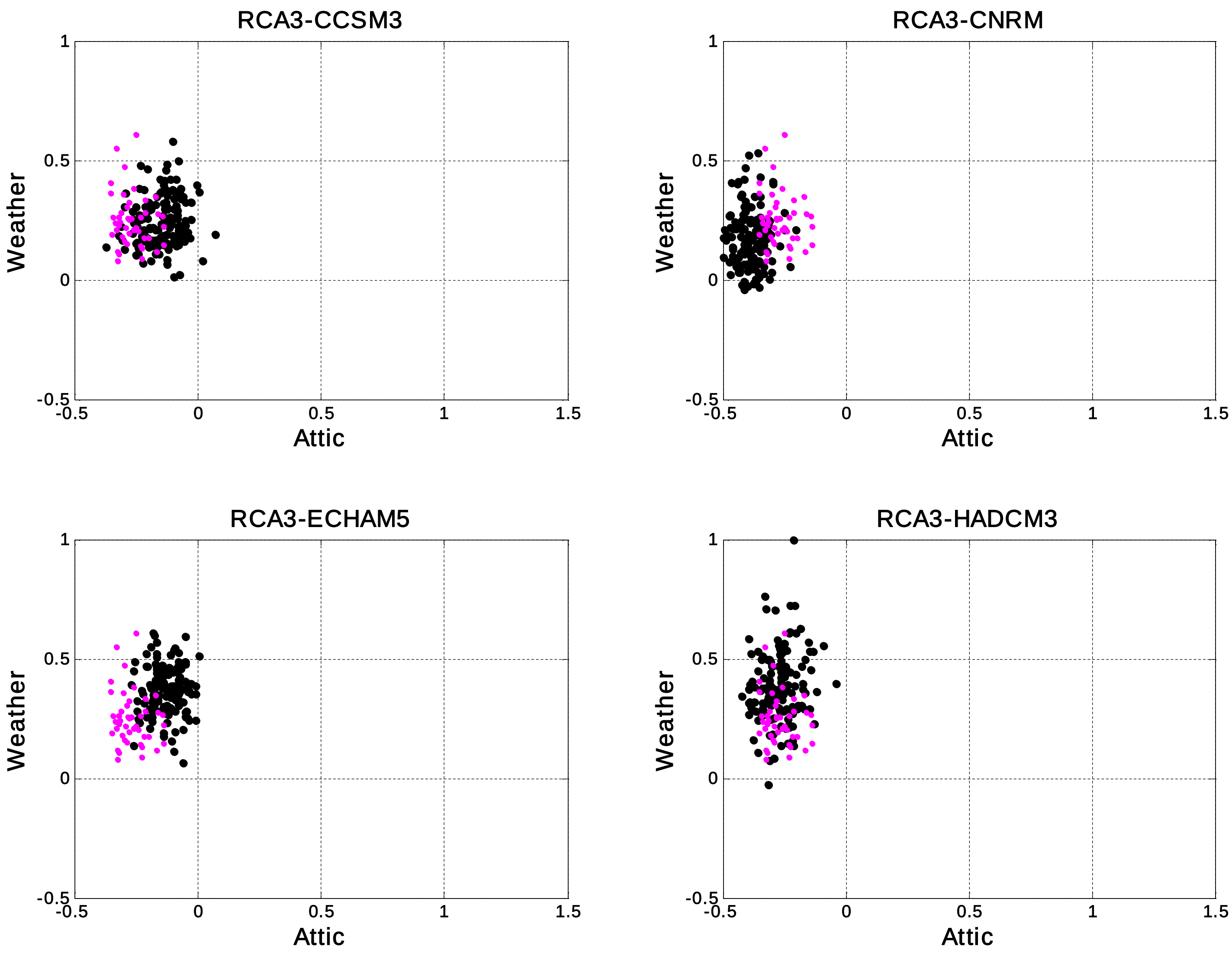
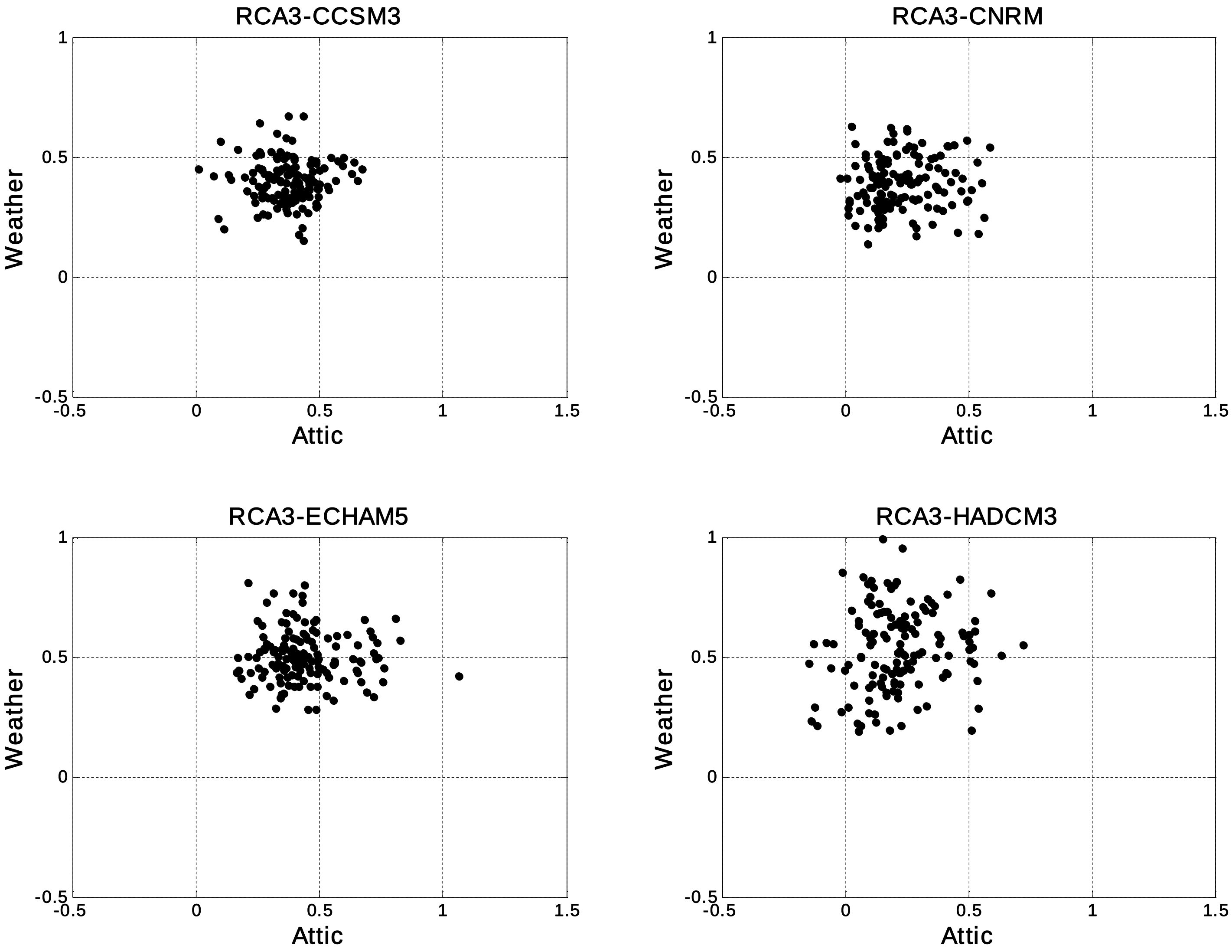
Summer



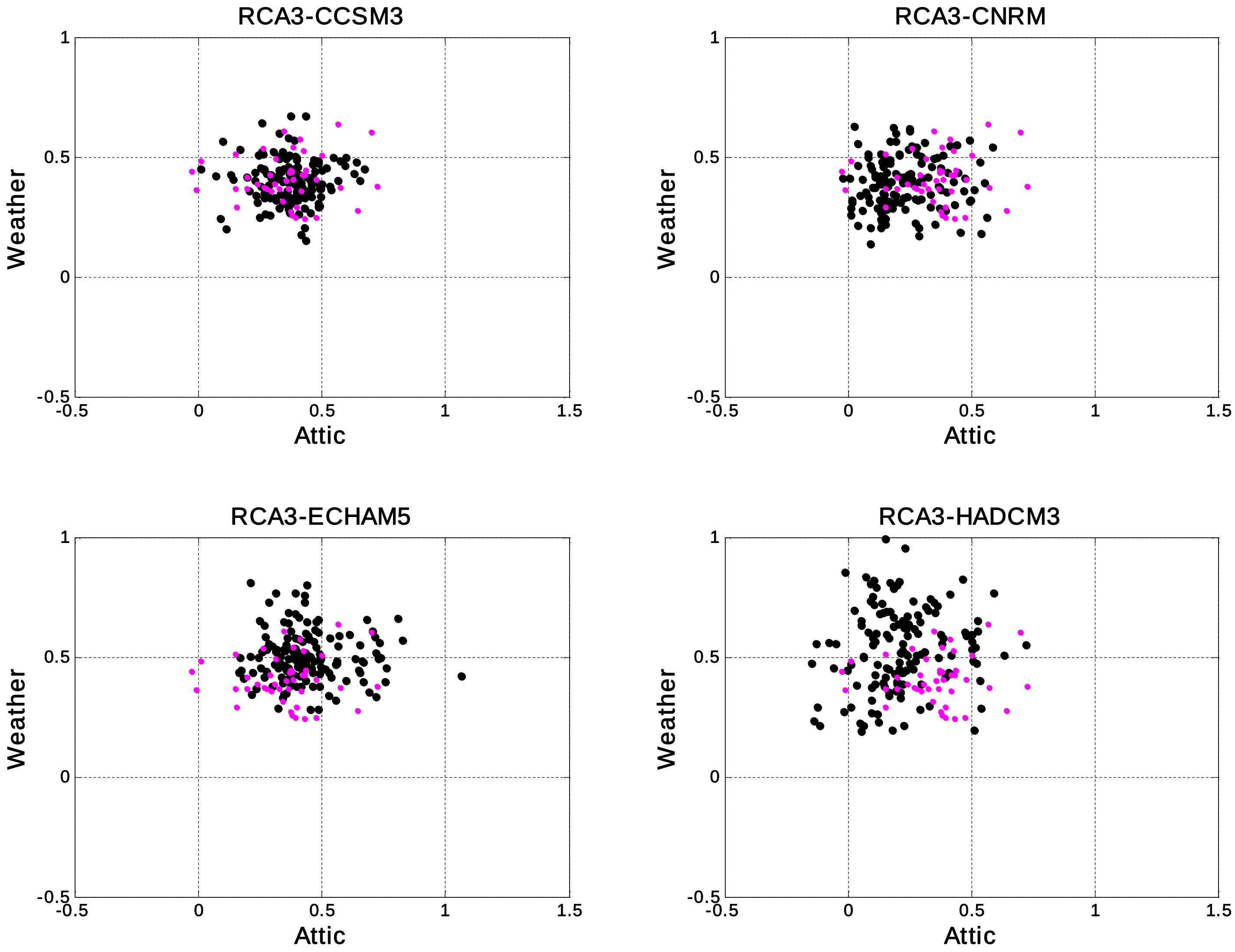
Four GMCs and ERA40 – mould doses

Autumn



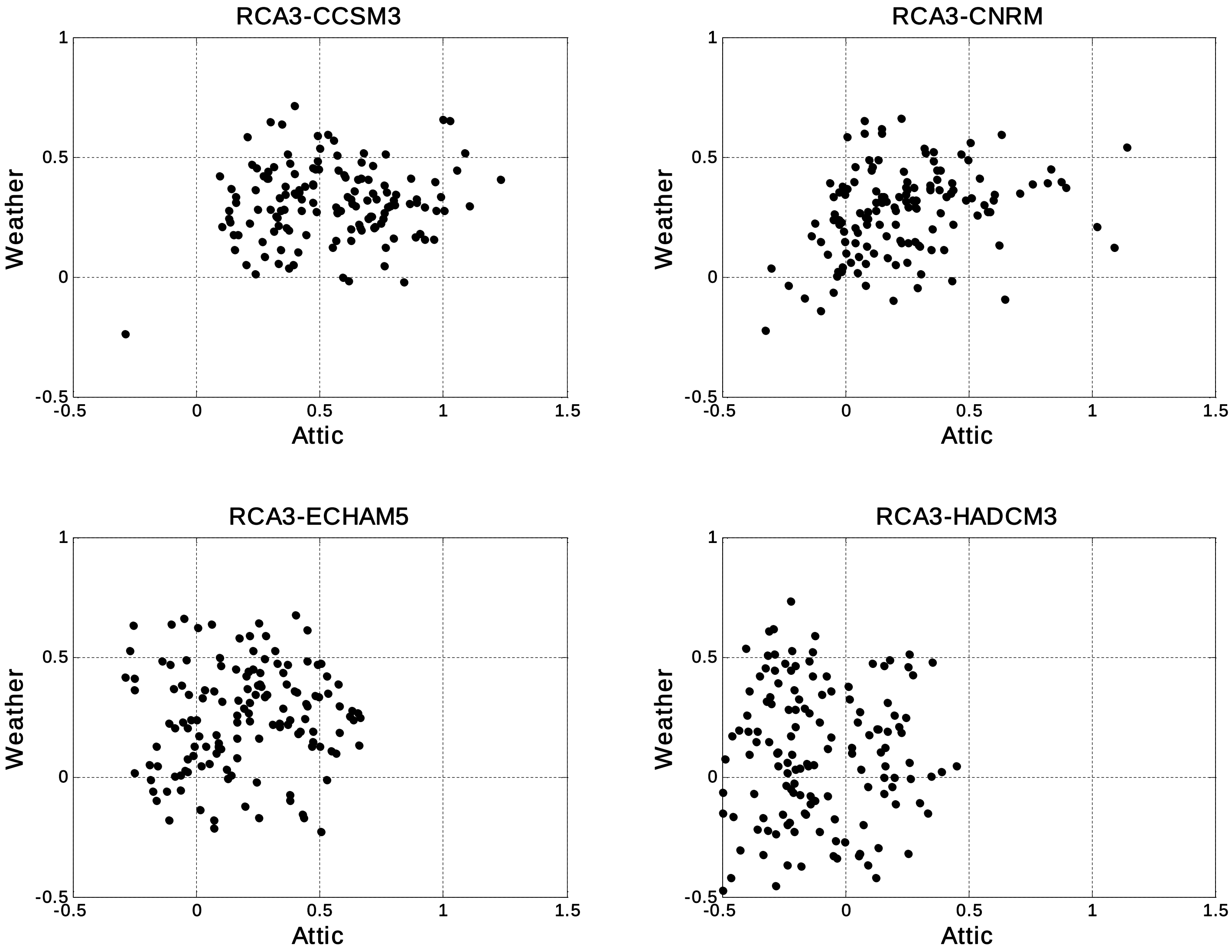
Four GMCs – mould doses

Autumn



Four GMCs and ERA40 – mould doses

Winter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RCA3-ECHAM5
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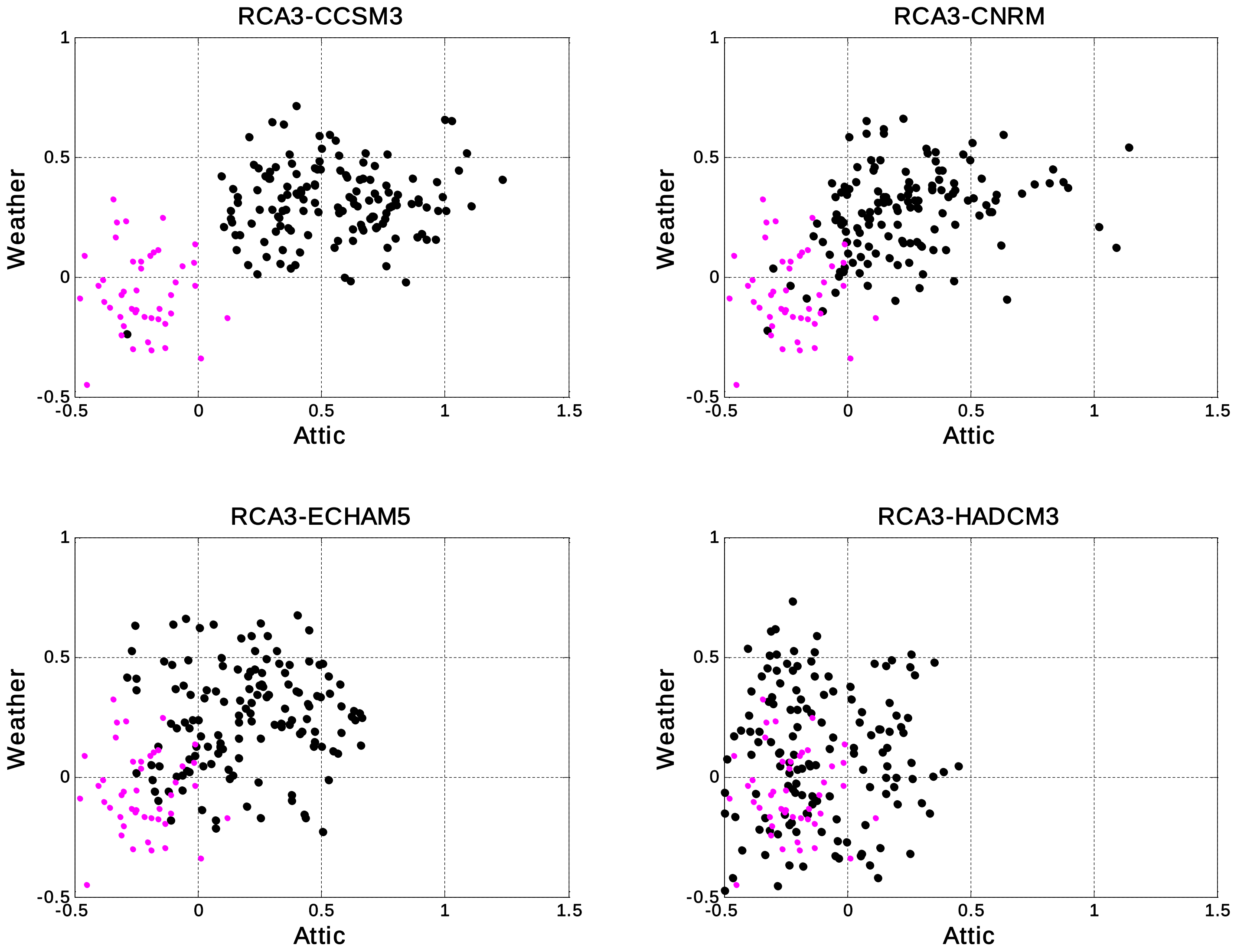
1.5

Winter


RCA3-CCSM3
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Weather
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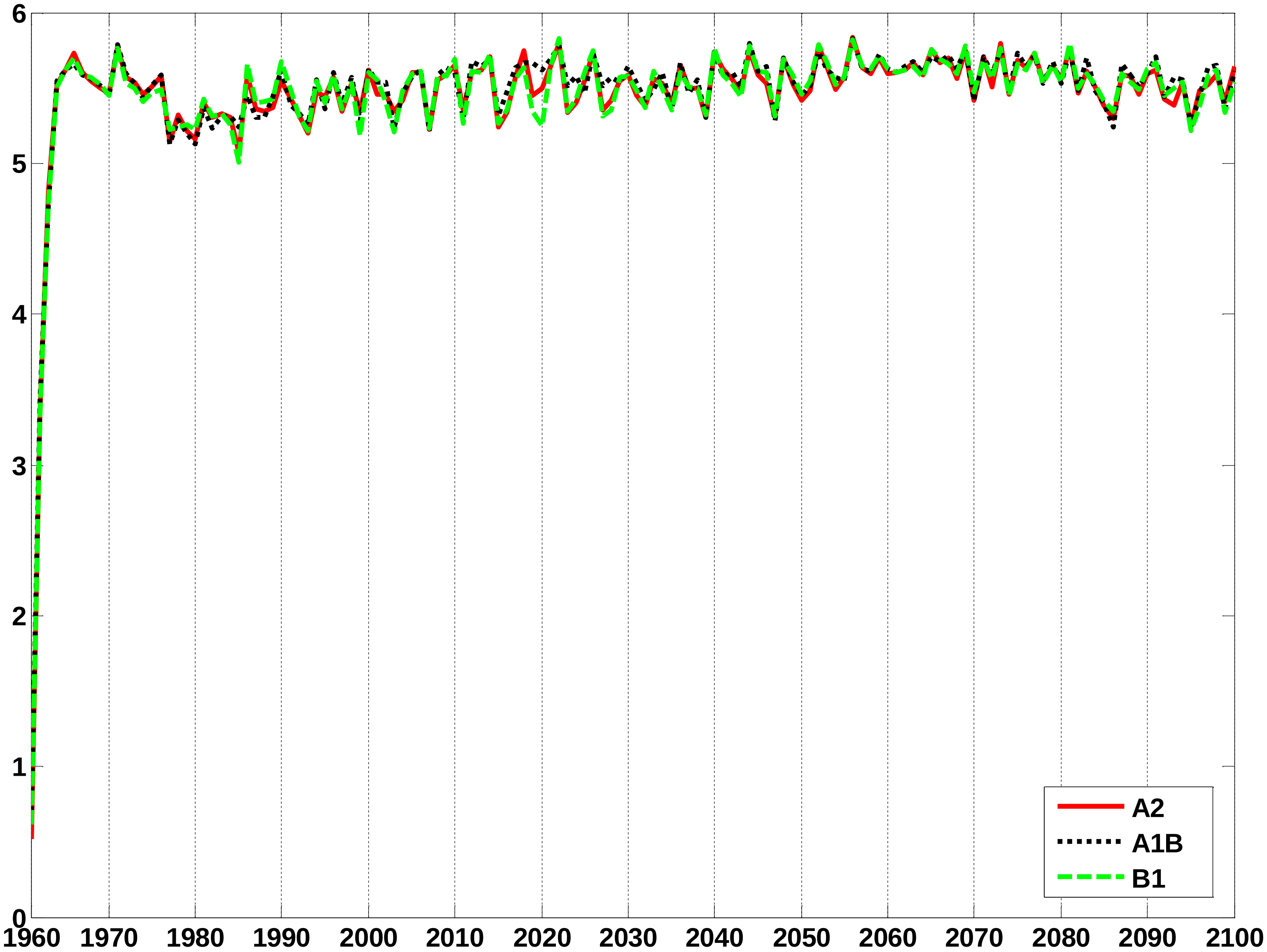
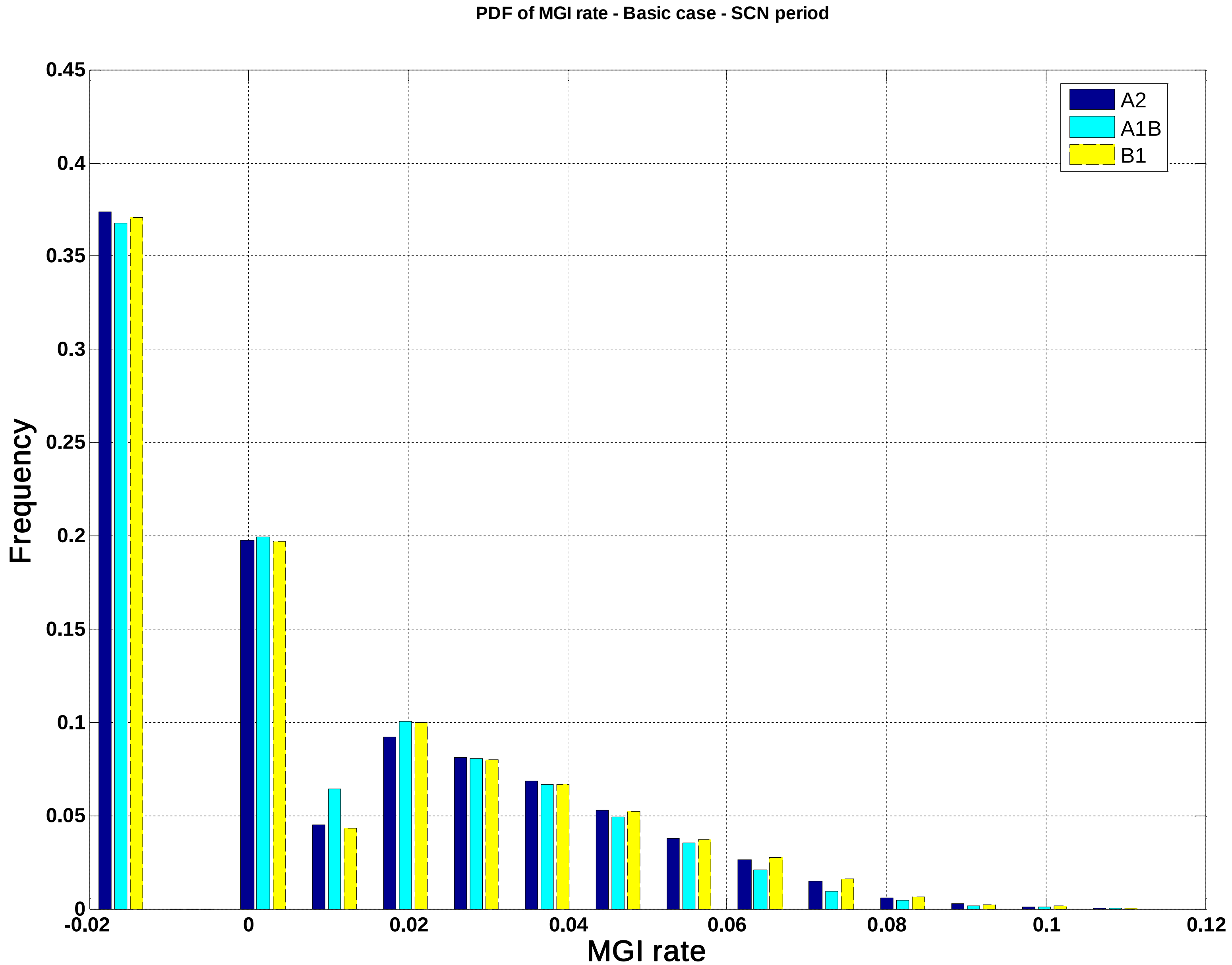


Emissions scenarios – mould index



Emissions scenarios – mould index rate

Conclusion

- Mould growth increases in the future for the four climate scenarios, especially during winter we may experience higher mould growth rates.
- Selecting a GCM can affect the hygrothermal conditions in the attic which appears as differences in the risk of mould growth. These differences are visible during winter.
- Selecting an emission scenarios does not affect the risk of mould growth inside the attic considerably.

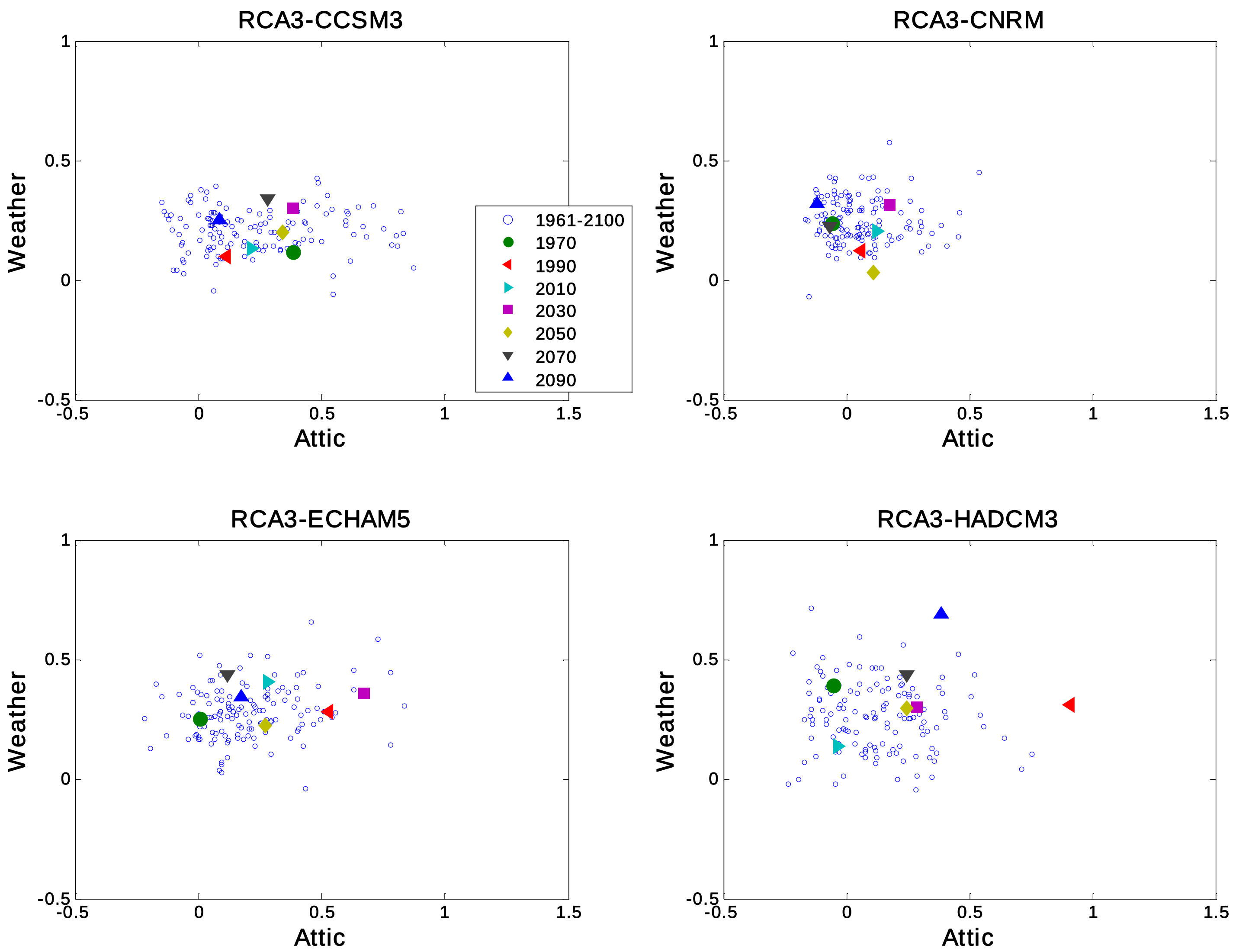
Conclusion

1. mould growth increases in the future for the four climate scenarios, especially during winter we may experience new problems.

2. There are some correlations between the mould growth inside and outside the attic, but it is not easy to formulate them. It can be because of the nature of mould and the mould model that have been used. But we can use the detectable correlations to decrease the amount of calculations and speed up the designing procedure.

3. Selecting a GCM can affect the hygrothermal conditions in the attic which appears as differences in the risk of mould growth. These differences are very visible during winter.

Spring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RCA3-HADCM3
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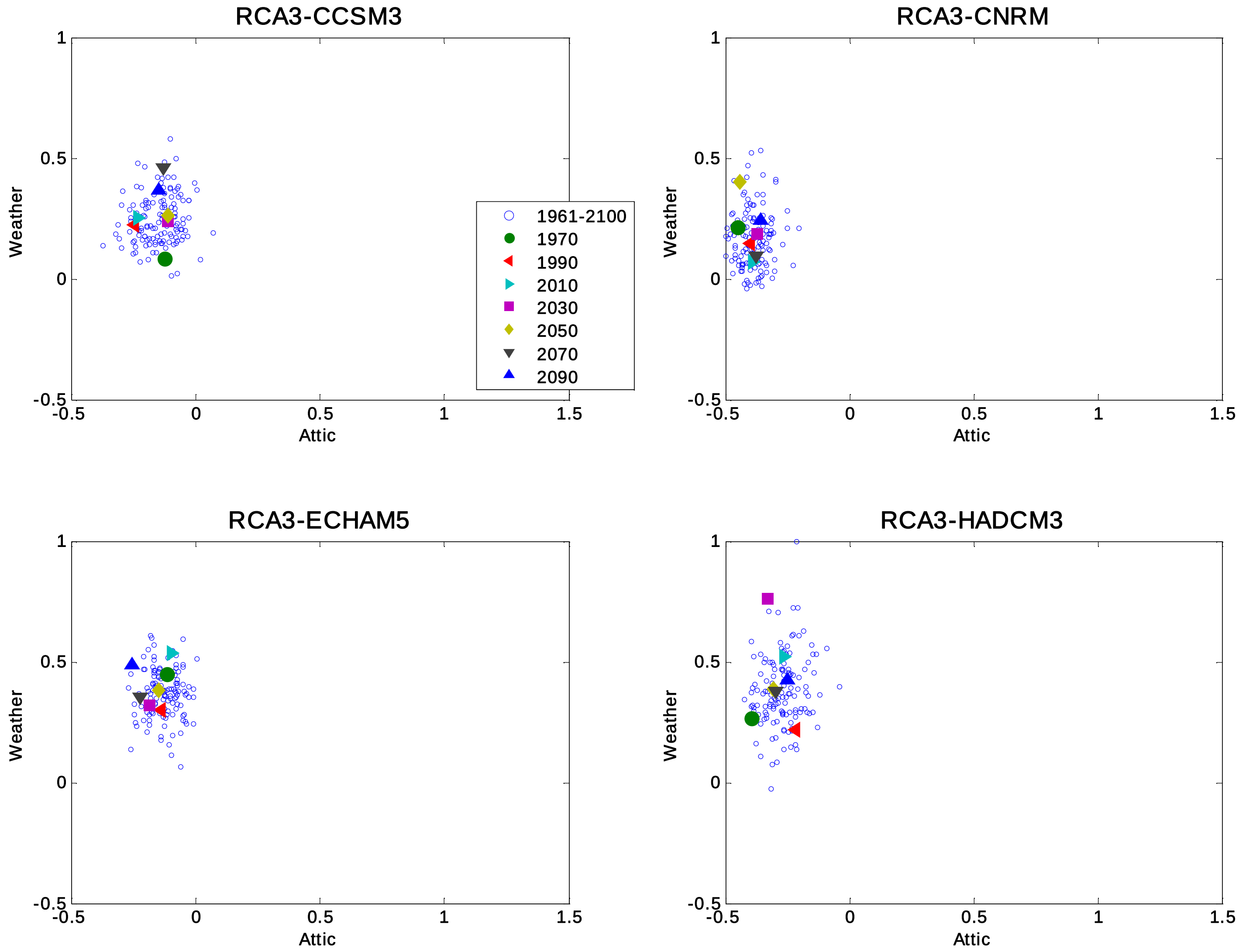
Attic
1
0.5
0
-0.5
-0.5
0
0.5
1
1.5
1961-2100
1970
1990
2010
2030
2050
2070
2090

Summer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0
-0.5
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0
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1.5
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2030
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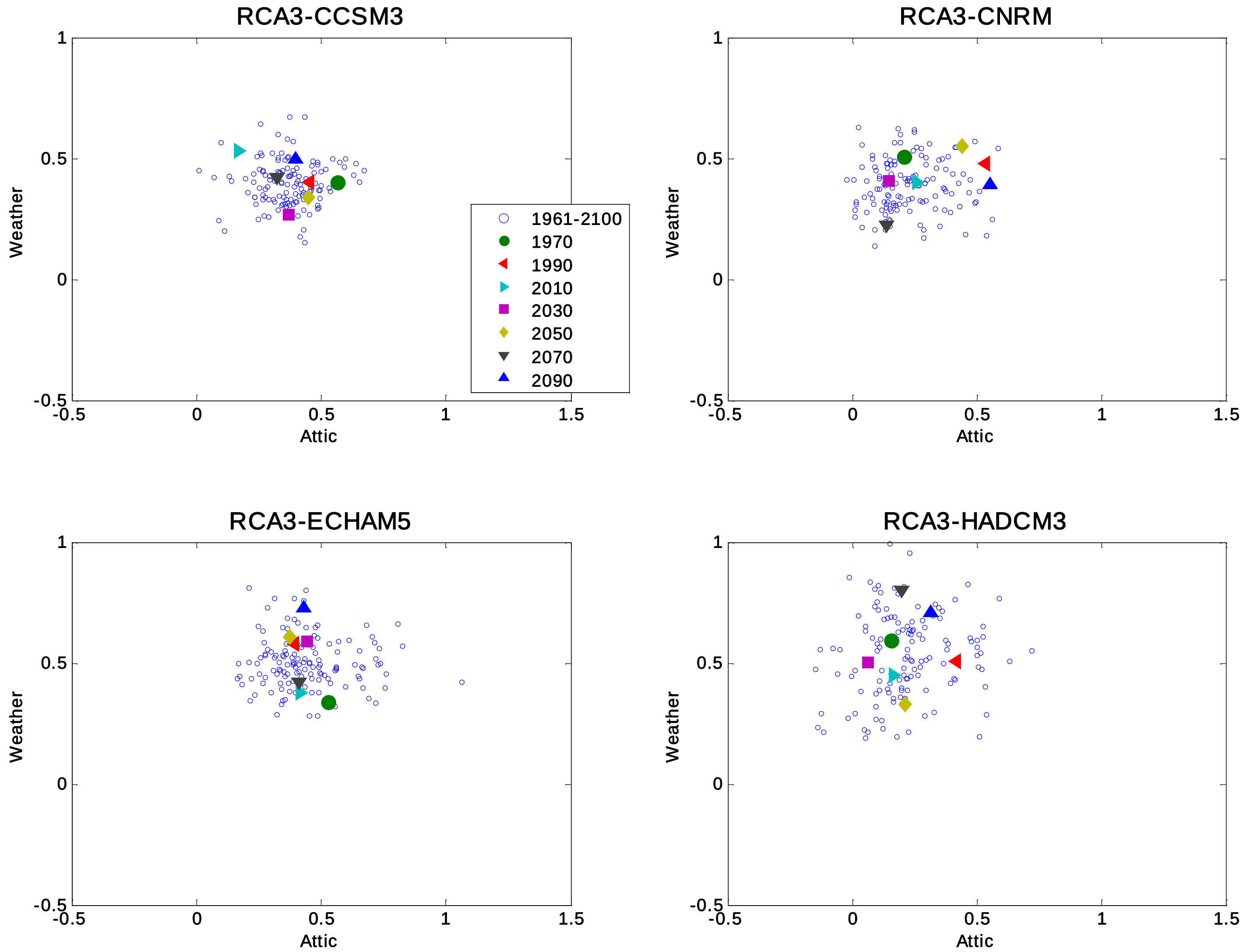
2070
2090

Autumn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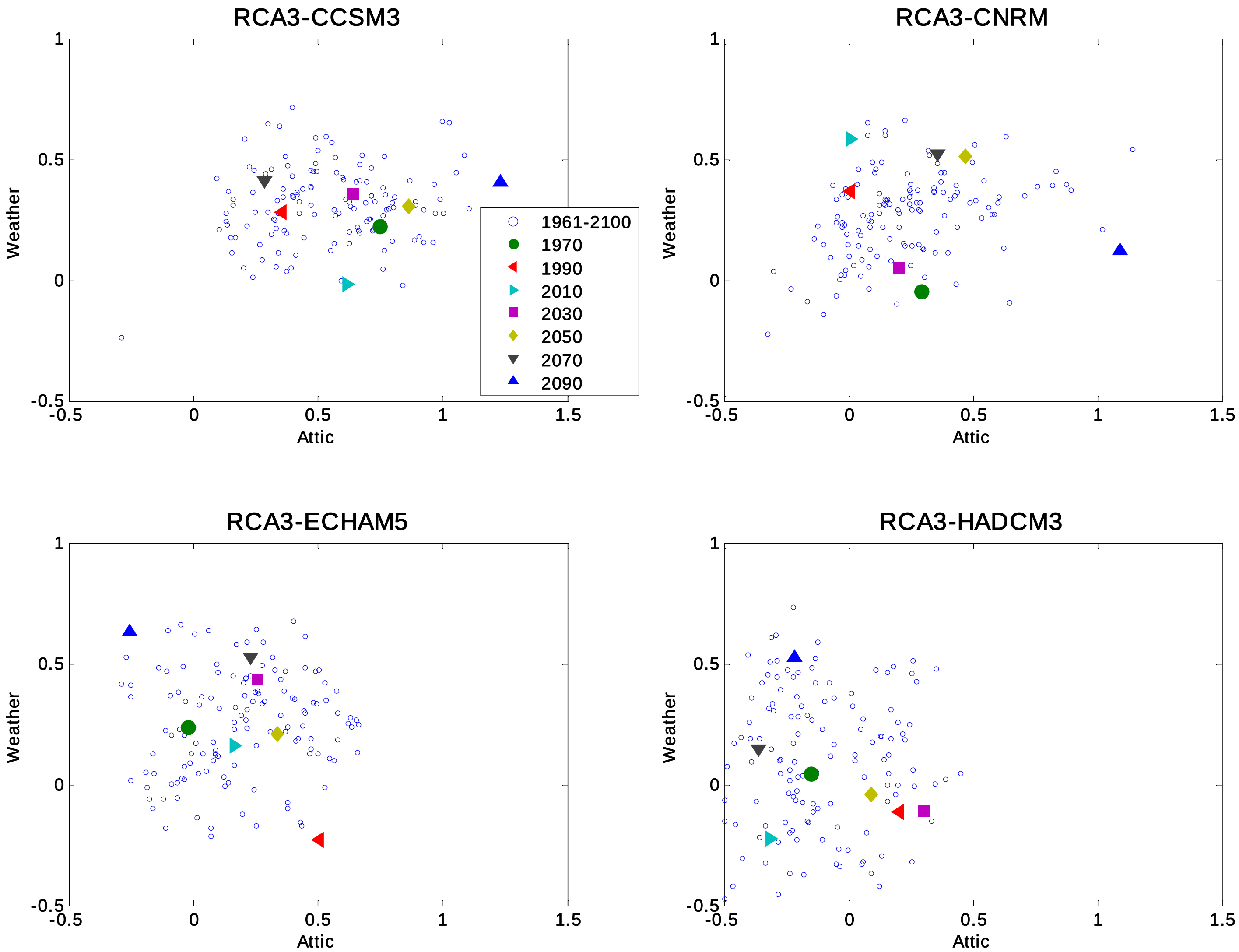
Weather
Attic
1961-2100
1970
1990
2010
2030
2050
2070
2090
-0.5
0
0.5
1
1.5

Winter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1961-2100
1970
1990
2010
2030
2050
2070
2090
1
0.5
0
-0.5
1.5

A .KLI file is created where the equivalent temperature is used for the exterior climate. This file overrides all WUFI2D conversions and algorithms of climate treatment for the special surface. It only reads the data which has been fitted according to the instructions. The equivalent exterior temperature is calculated by:

$$T^{eq} = T_e + \frac{1}{\alpha_e}\left(I_{sol,n} \cdot \alpha_{sol} + (T^r - T_e) \cdot \alpha_r\right) \quad (°C) \qquad (1)$$

$$I_{so\ln} = \frac{I_{diff}}{2} + I_{dir} \quad (W/m^2) \qquad (2)$$

$$T^r = (1.1 \cdot T_e - 5) \cdot (1 - Clo) + T_e \cdot Clo \quad (°C) \qquad (3)$$

where T^r (°C) is the apparent sky temperature for a vertical wall and the cloudiness (0-1) is denoted by *Clo*. The solar absorptance of the wall surface is denoted α_{sol} wich is equal to 0.6 and the diffuse and direct solar radiation are transformed based on the climate data provided for Essen.