University of Trieste – Physics Department

End-of-Year Seminar 2022/23
XXXVII PhD Course Cycle - "Dottorati Comunali"
13 September 2023

Development of climate models and scenarios in the Alta Carnia region to support local administrations in designing and monitoring climate adaptation plans and towards a wider scientific culture

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Supervisor:
Prof. Dario Giaiotti
Co-supervisor:
Prof. Francesco Longo

Outline

- INTRODUCTION
  - PhD’s project motivation
  - Climate Change: from global to local
- Research questions and methods
- Main Preliminary Results
- Ongoing activities and future work

Climate Change: from Global to Local

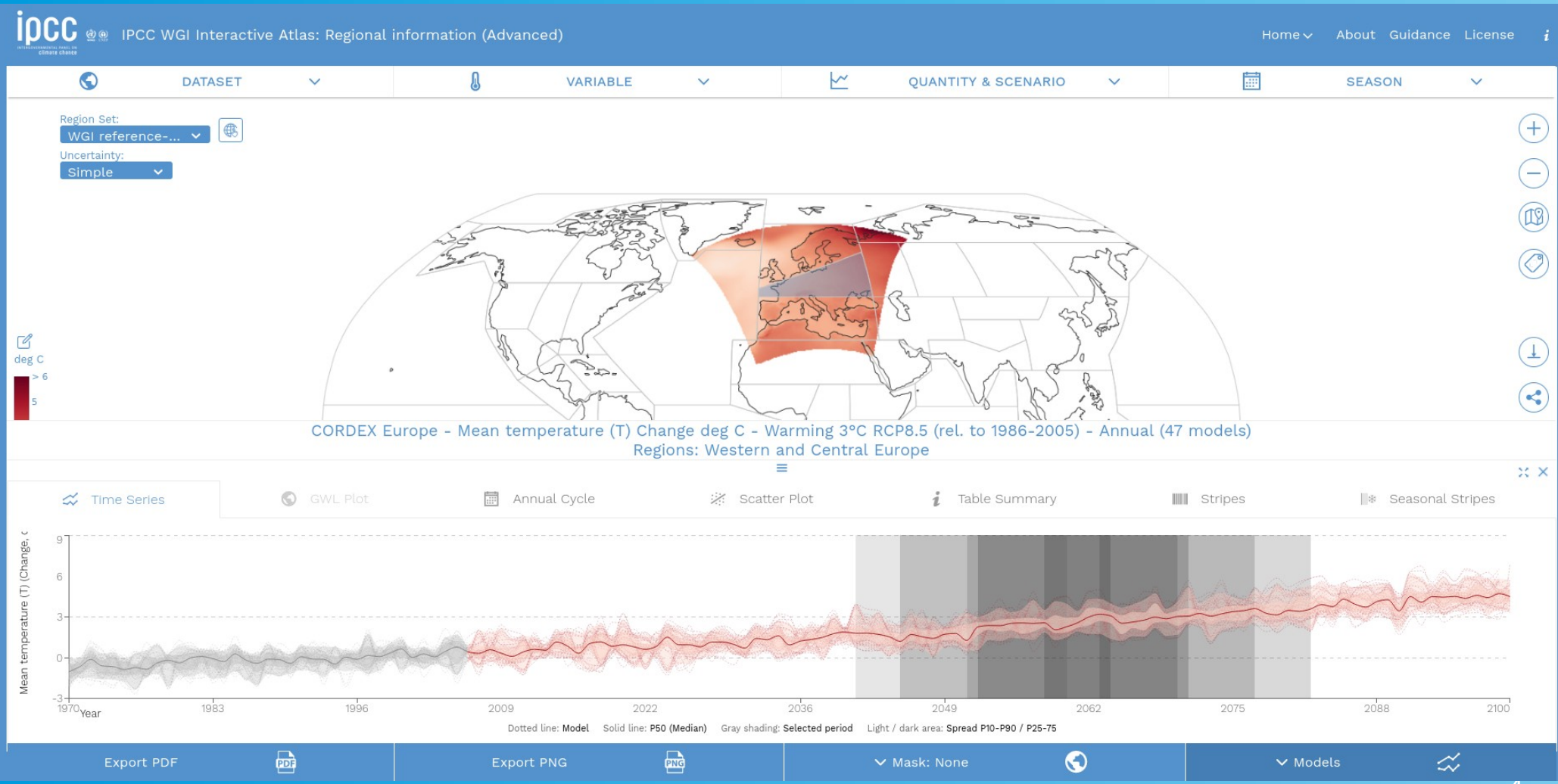
Link to NASA's scientific visualization studio (until 2021):

https://svs.gsfc.nasa.gov/vis/a000000/a004900/a004964/2021TempAnomalyC_GISSTEMP_1080p30.mp4

Animation up to 2022 here:

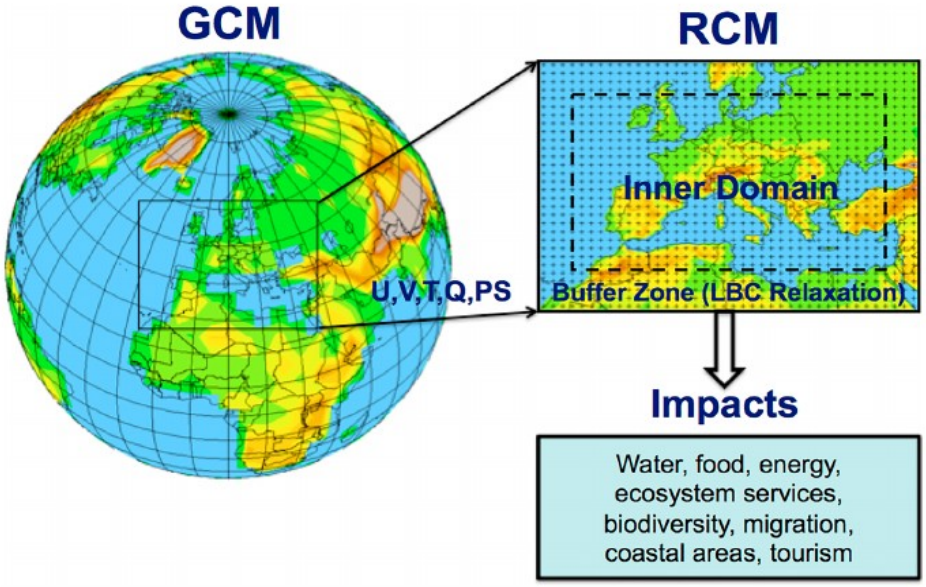
https://climate.nasa.gov/vital-signs/global-temperature/

IPCC interactive Atlas – Regional Climate



https://interactive-atlas.ipcc.ch/

Why Regional Climate Models?



Filippo Giorgi, "*Thirty Years of Regional Climate Modeling*", JGR Atmospheres, 2019

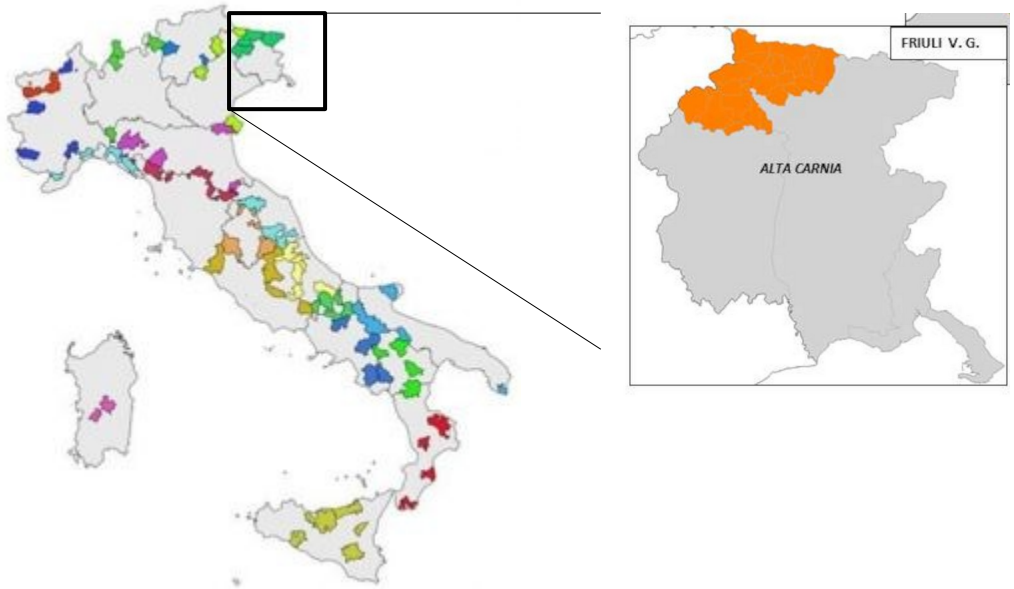
- Global and sub-continental climate change information has been based on the use of General Circulation Models (GCMs)
- GCMs' grids often larger than 100*100km^2
- GCMs' too coarse to capture the effects of local forcings (topography, land-surface characteristics…)
- RCMs to provide more accurate projections of the future climate in a specif region to respond to local decision-making and planning needs.

The Focus Area

DOTTORATI COMUNALI

Agenzia per la Coesione Territoriale

Strategia Aree Interne



72 "AREE INTERNE"

ALTA CARNIA:

- 20 Municipalities
- Paluzza: "Comune Capofila"

Future climate projections → **Climate information transfer** → **Awareness rising process**

Focus during April ‘23 – August ‘23:

FUTURE CLIMATE PROJECTIONS
To investigate future climate scenarios in the Alta Carnia region

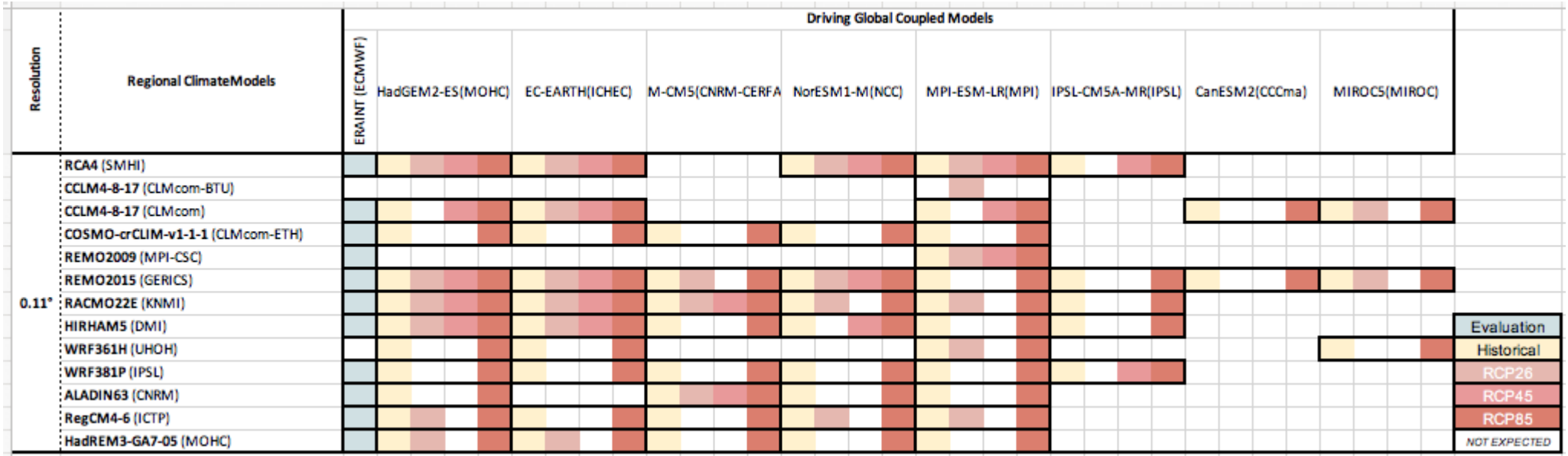
CLIMATE INFORMATION TRANSFER
Support adaptation strategies and plans.
Address local stakeholders and communities needs, facing climate change impacts.

AWARENESS RISING process

1. Surface temperature: future projections

CORDEX: Regional climate projections

Last modified on May 05, 2023 10:21



https://confluence.ecmwf.int/display/CKB/CORDEX%3A+Regional+climate+projections

The ensemble in use (from EURO-CORDEX EUR 0.11°)

GCM	Init.	RCM	Available Scenarios			
			Hist.	RCP2.6	RCP4.5	RCP8.5
MPI-ESM-LR	r1i1p1	MPI-CSC-REMO2009	✓	✓	✓	✓
MPI-ESM-LR	r2i1p1	MPI-CSC-REMO2009	✓	✓	✓	✓
MPI-ESM-LR	r1i1p1	CLMcom-CCLM4-8-17	✓		✓	✓
MPI-ESM-LR	r1i1p1	SMHI-RCA4	from 1971	✓	✓	✓
CNRM-CERFACS-CM5	r1i1p1	CNRM-ALADIN63	✓	✓	✓	✓
CNRM-CERFACS-CM5	r1i1p1	KNMI-RACMO22E	✓	✓	✓	✓
HadGEM2-ES	r1i1p1	KNMI-RACMO22E	✓	✓	✓	✓
HadGEM2-ES	r1i1p1	SMHI-RCA4		✓	✓	✓
HadGEM2-ES	r1i1p1	CLMcom-CCLM4-8-17	✓		✓	✓
NorESM1-M	r1i1p1	GERICS-REMO2015	✓	✓	✓	✓
EC-EARTH	r12i1p1	KNMI-RACMO22E	✓	✓	✓	✓
EC-EARTH	r3i1p1	DMI-HIRHAM5	✓	✓	✓	✓
EC-EARTH	r12i1p1	SMHI-RCA4	from 1971	✓	✓	✓
EC-EARTH	r12i1p1	CLMcom-CCLM4-8-17	✓	✓	✓	✓
IPSL-CM5A-MR	r1i1p1	SMHI-RCA4	from 1971		✓	✓

1. Surface temperature: future projections

ARPA FVG OBSERVATIONAL DATA-SET

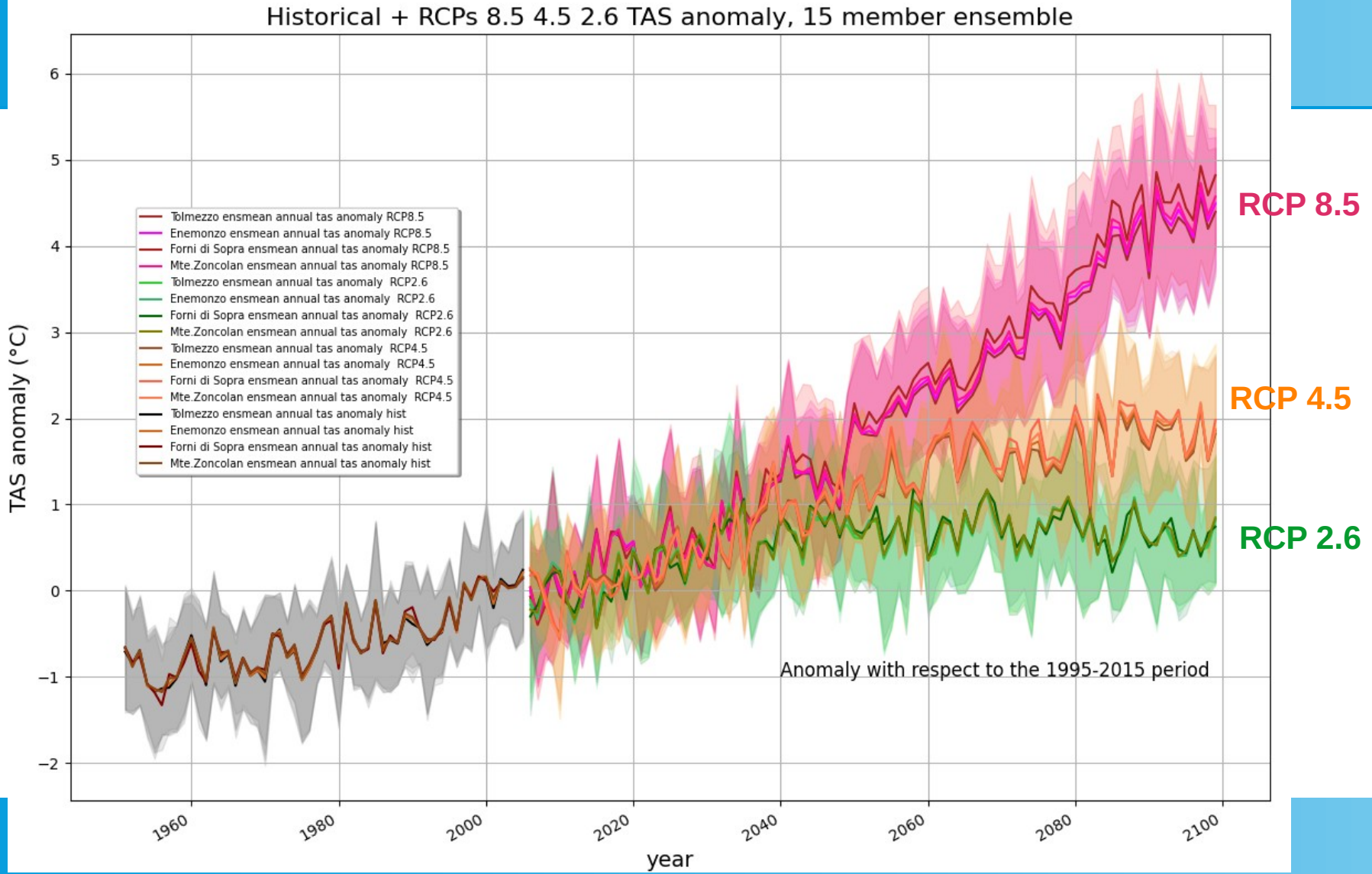
Series of observational data for four stations over the “Alta Carnia” region:

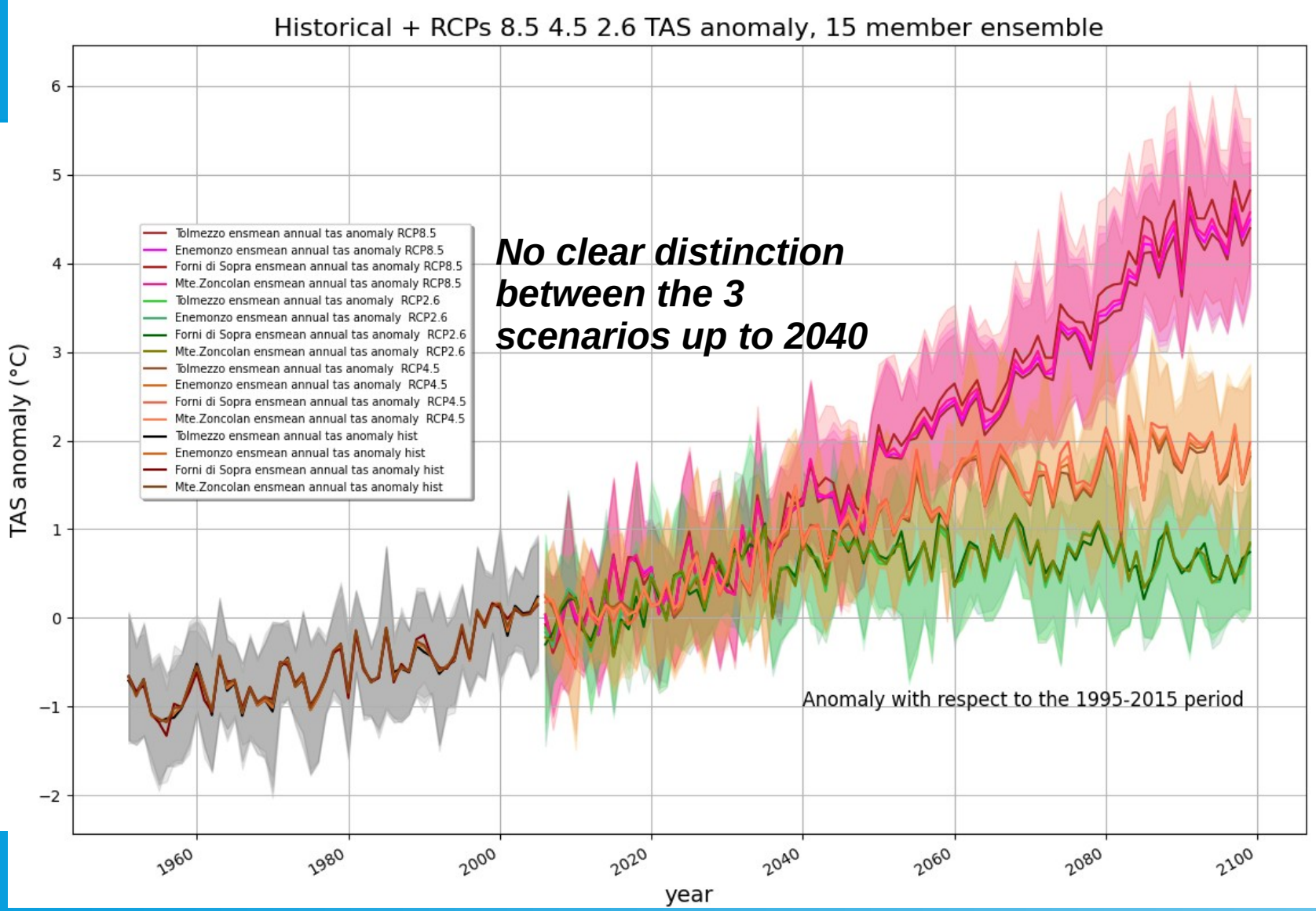
- Tolmezzo (314 m s.l.m),
- Enemonzo (438 m s.l.m) ,
- Forni di Sopra (922 m. s.l.m),
- Monte Zoncolan (1750 m s.l.m).

Hourly resolution measures of:

- Temperature at Surface
- Precipitation
- 2m pressure
- Relative Humidity
- 10 m wind direction
- 10 m mean wind speed
- Solar radiation

“lat and lon indetermination is about 0.001 deg., height indetermination is about 1 m”


Historical + RCPs 8.5 4.5 2.6 TAS anomaly, 15 member ensemble
TAS anomaly (°C)
year
Tolmezzo ensmean annual tas anomaly RCP8.5
Enemonzo ensmean annual tas anomaly RCP8.5
Forni di Sopra ensmean annual tas anomaly RCP8.5
Mte.Zoncolan ensmean annual tas anomaly RCP8.5
Tolmezzo ensmean annual tas anomaly RCP2.6
Enemonzo ensmean annual tas anomaly RCP2.6
Forni di Sopra ensmean annual tas anomaly RCP2.6
Mte.Zoncolan ensmean annual tas anomaly RCP2.6
Tolmezzo ensmean annual tas anomaly RCP4.5
Enemonzo ensmean annual tas anomaly RCP4.5
Forni di Sopra ensmean annual tas anomaly RCP4.5
Mte.Zoncolan ensmean annual tas anomaly RCP4.5
Tolmezzo ensmean annual tas anomaly hist
Enemonzo ensmean annual tas anomaly hist
Forni di Sopra ensmean annual tas anomaly hist
Mte.Zoncolan ensmean annual tas anomaly hist
Anomaly with respect to the 1995-2015 period
RCP 8.5
RCP 4.5
RCP 2.6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Tolmezzo ensmean annual tas anomaly RCP4.5
Enemonzo ensmean annual tas anomaly RCP4.5
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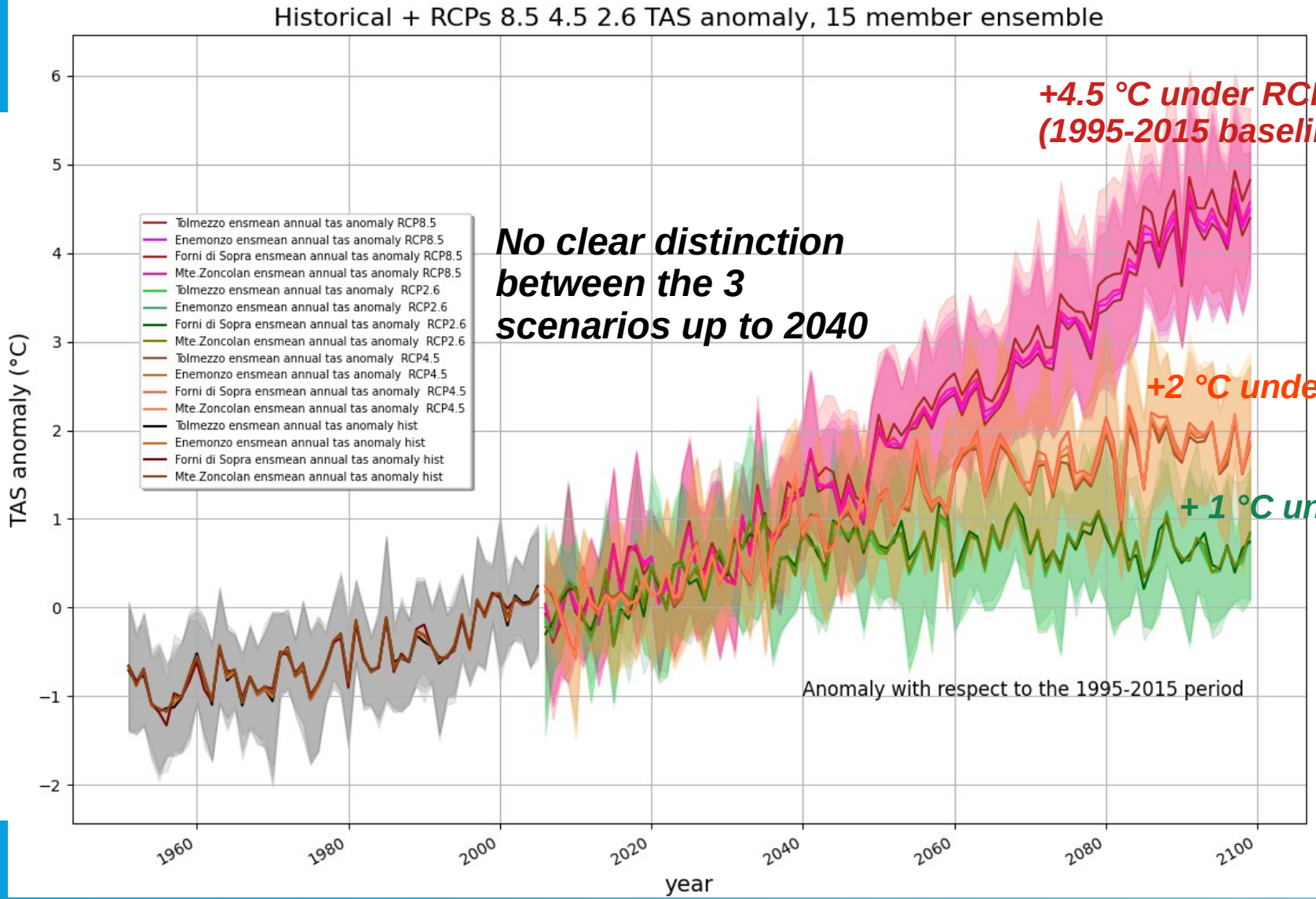
Mte.Zoncolan ensmean annual tas anomaly RCP4.5
Tolmezzo ensmean annual tas anomaly hist
Enemonzo ensmean annual tas anomaly hist
Forni di Sopra ensmean annual tas anomaly hist
Mte.Zoncolan ensmean annual tas anomaly hist
No clear distinction between the 3 scenarios up to 2040
Anomaly with respect to the 1995-2015 period


Historical + RCPs 8.5 4.5 2.6 TAS anomaly, 15 member ensemble
TAS anomaly (°C)
year
Tolmezzo ensmean annual tas anomaly RCP8.5
Enemonzo ensmean annual tas anomaly RCP8.5
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Tolmezzo ensmean annual tas anomaly RCP2.6
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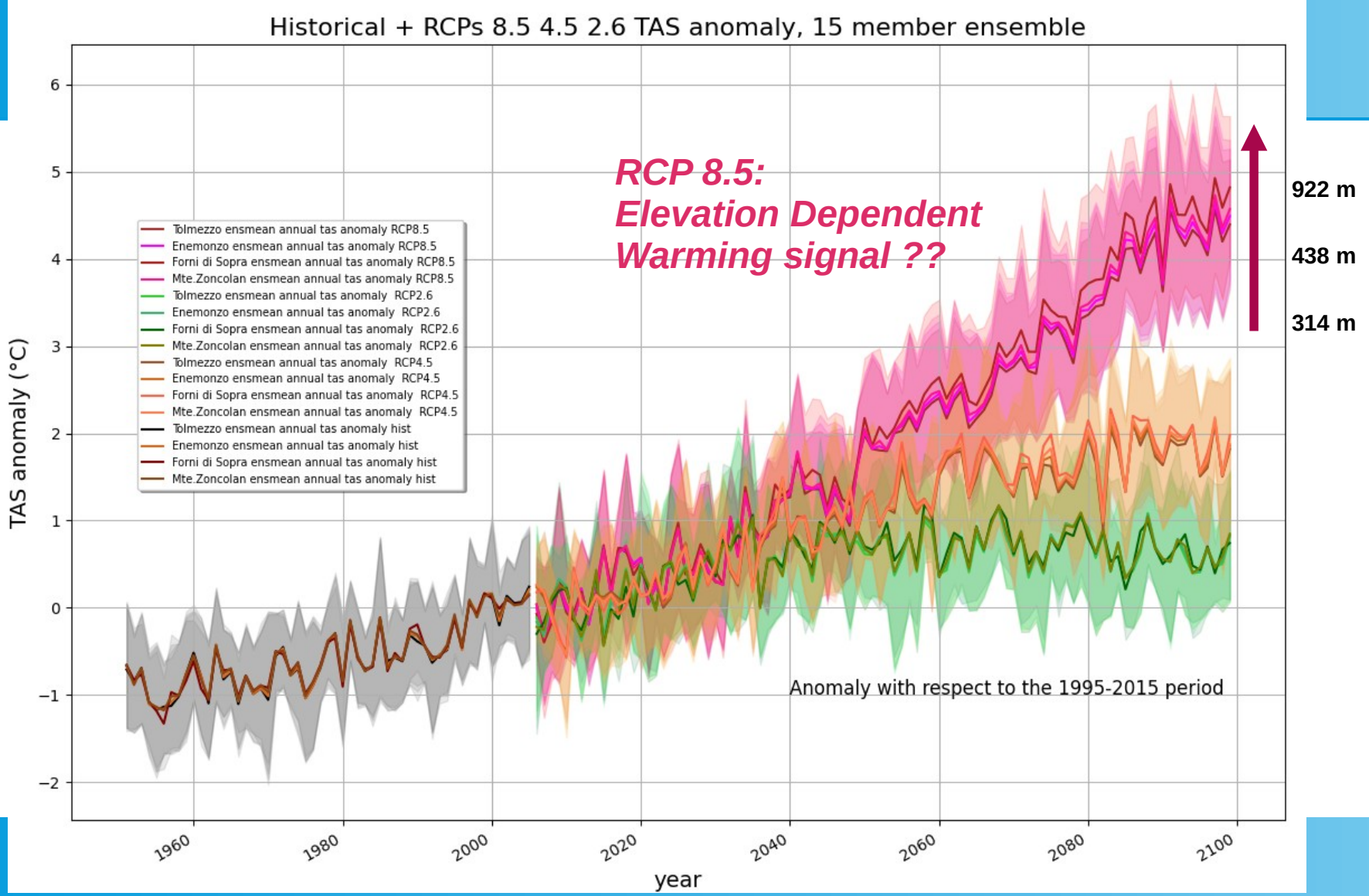
Tolmezzo ensmean annual tas anomaly RCP4.5
Enemonzo ensmean annual tas anomaly RCP4.5
Forni di Sopra ensmean annual tas anomaly RCP4.5
Mte.Zoncolan ensmean annual tas anomaly RCP4.5
Tolmezzo ensmean annual tas anomaly hist
Enemonzo ensmean annual tas anomaly hist
Forni di Sopra ensmean annual tas anomaly hist
Mte.Zoncolan ensmean annual tas anomaly hist
No clear distinction between the 3 scenarios up to 2040
+4.5 °C under RCP8.5 (1995-2015 baseline)
+2 °C under RCP4.5
+ 1 °C under RCP2.6
Anomaly with respect to the 1995-2015 period


Historical + RCPs 8.5 4.5 2.6 TAS anomaly, 15 member ensemble
RCP 8.5:
Elevation Dependent
Warming signal ??
922 m
438 m
314 m
Tolmezzo ensmean annual tas anomaly RCP8.5
Enemonzo ensmean annual tas anomaly RCP8.5
Forni di Sopra ensmean annual tas anomaly RCP8.5
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Tolmezzo ensmean annual tas anomaly hist
Enemonzo ensmean annual tas anomaly hist
Forni di Sopra ensmean annual tas anomaly hist
Mte.Zoncolan ensmean annual tas anomaly hist
TAS anomaly (°C)
6
5
4
3
2
1
0
−1
−2
1960
1980
2000
2020
2040
2060
2080
2100
year
Anomaly with respect to the 1995-2015 period

2. Daily surface temperatures at Mt. Zoncolan weather station

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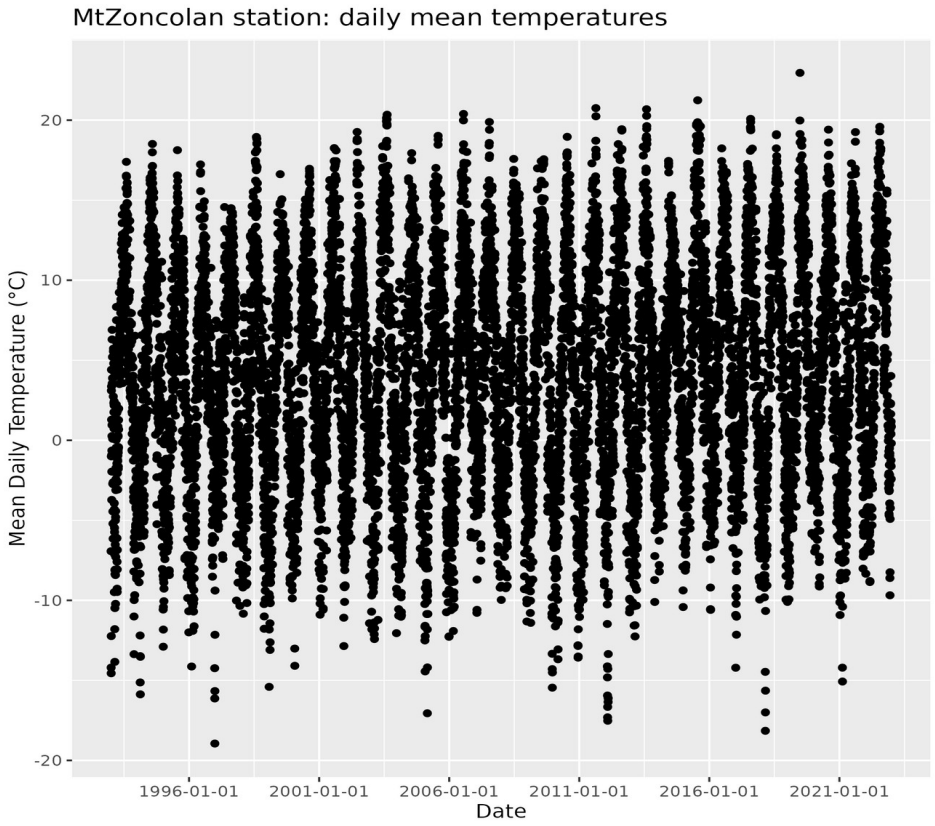
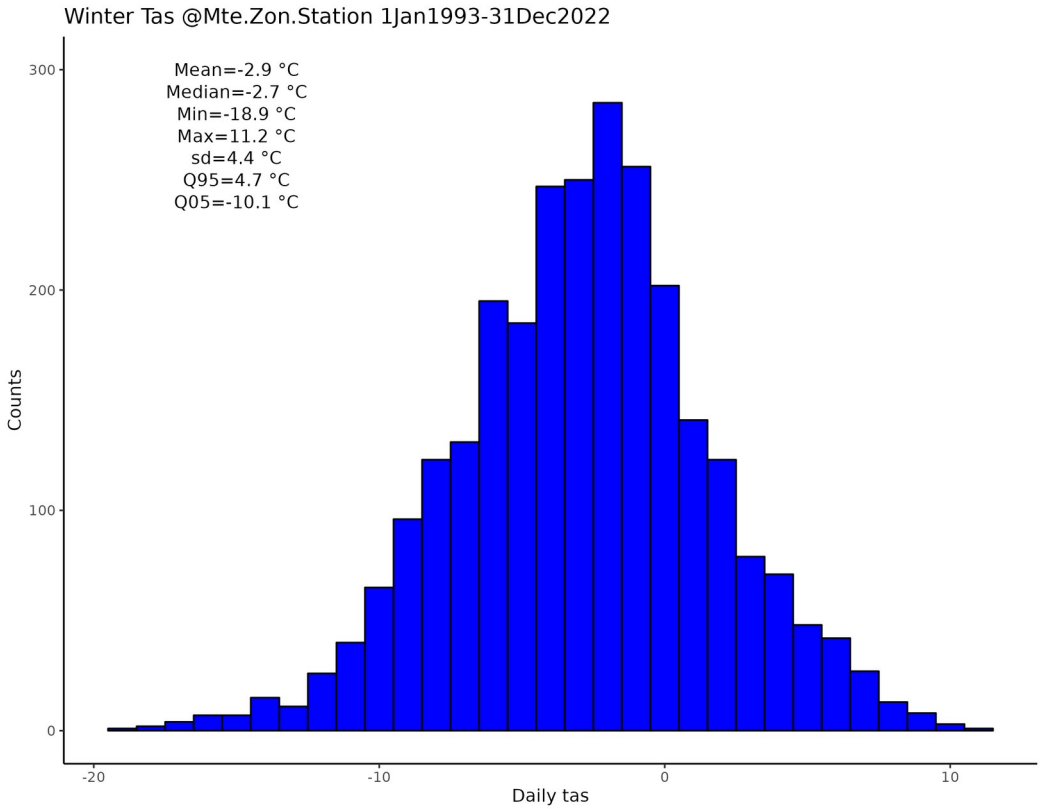




3. Evolution of the “snow line” at Mt. Zoncolan station

Simple model for the “snow line” evolution

- **“Snow line”** : *winter freezing height* at a given location (x,y) fixed:

$$z_{snow} : T(z_{snow}, x, y) = 0\ ^{\circ}\mathrm{C}$$

- From the **vertical adiabatic expansion** of the atmospheric fluid:

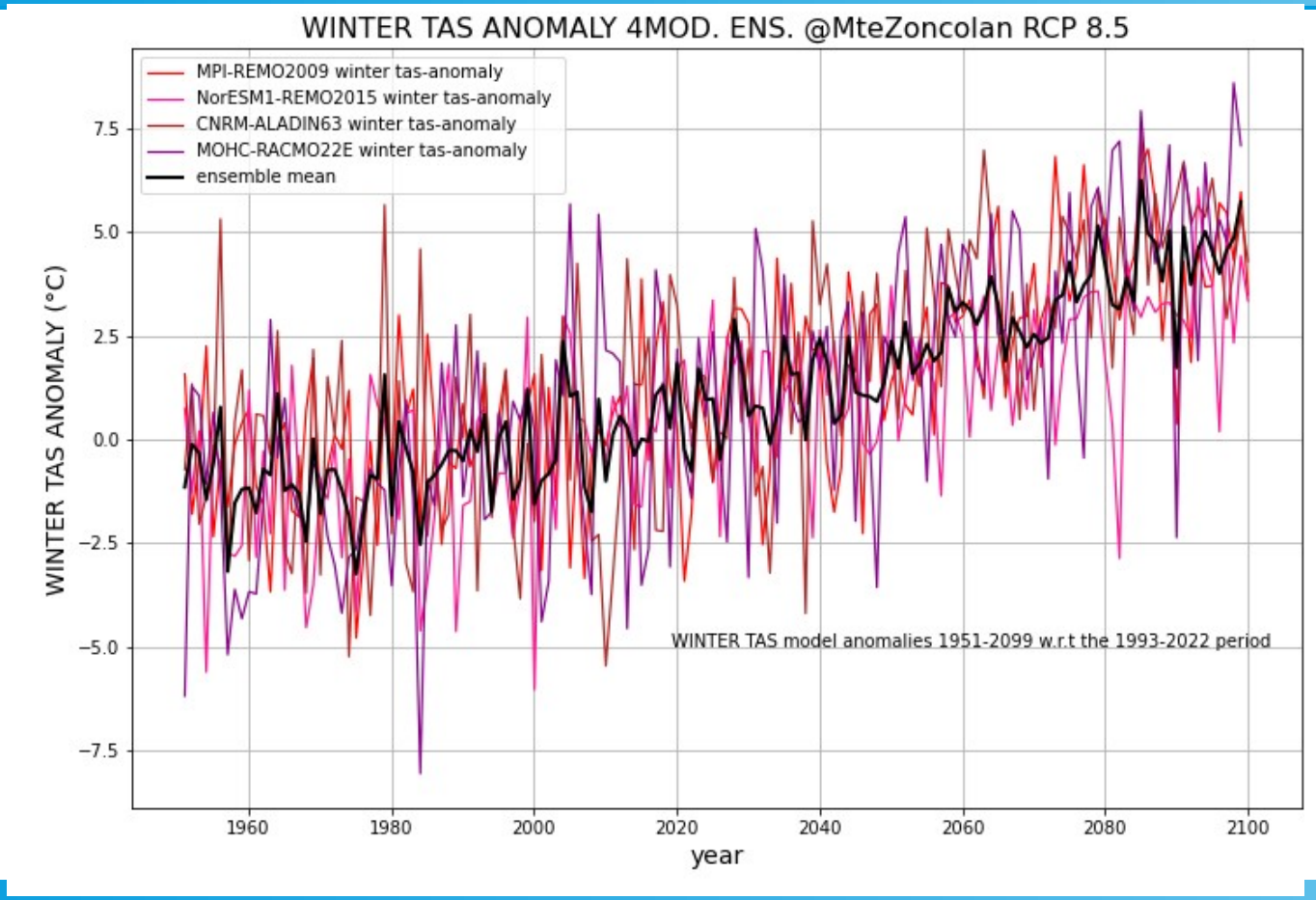
$$T(z_2, t) = T(z_1, t) + \Gamma(\vec{x}, t)(z_2 - z_1)$$

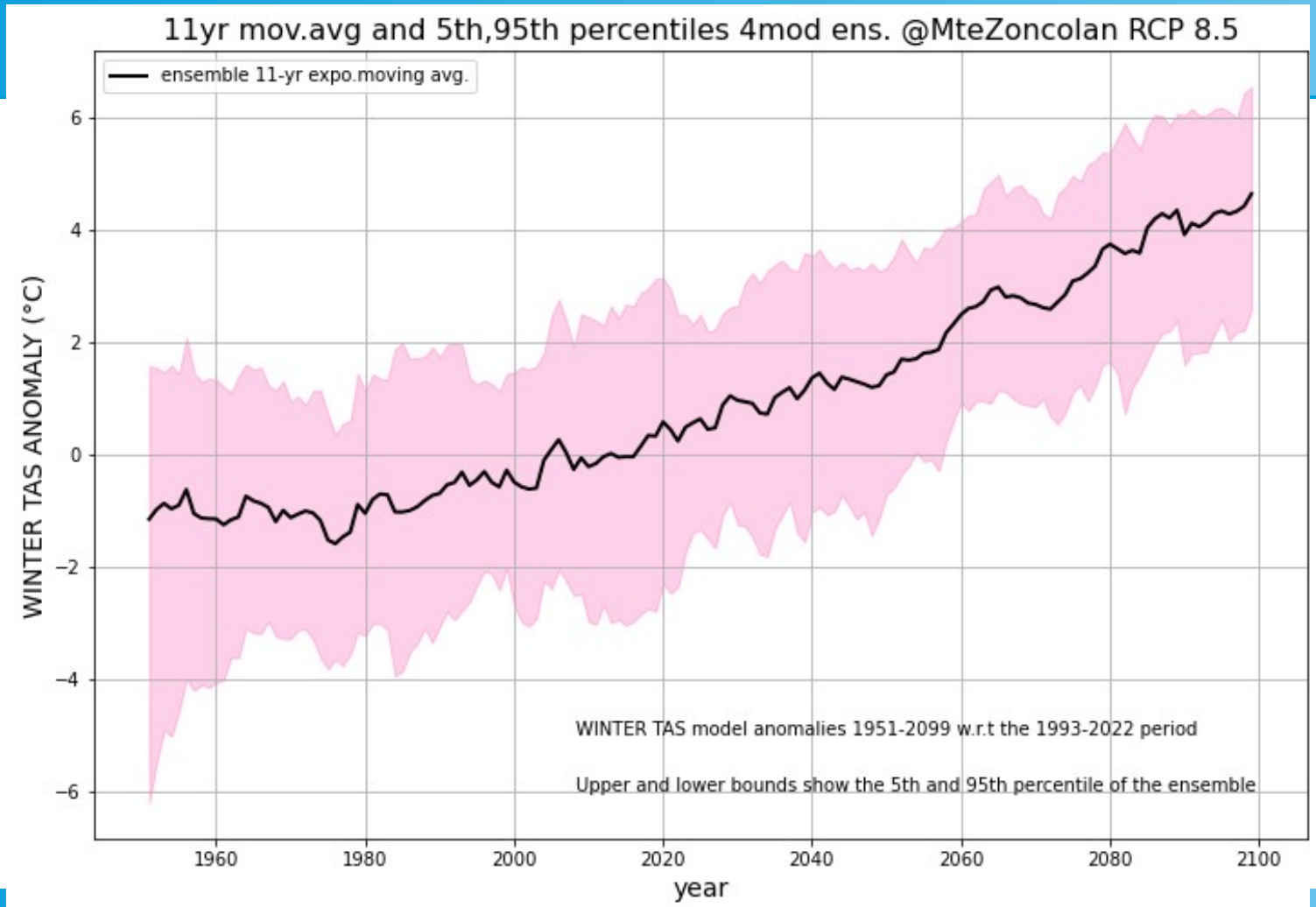
where $\Gamma \approx -0.0065\ ^{\circ}\mathrm{C} m^{-1}$

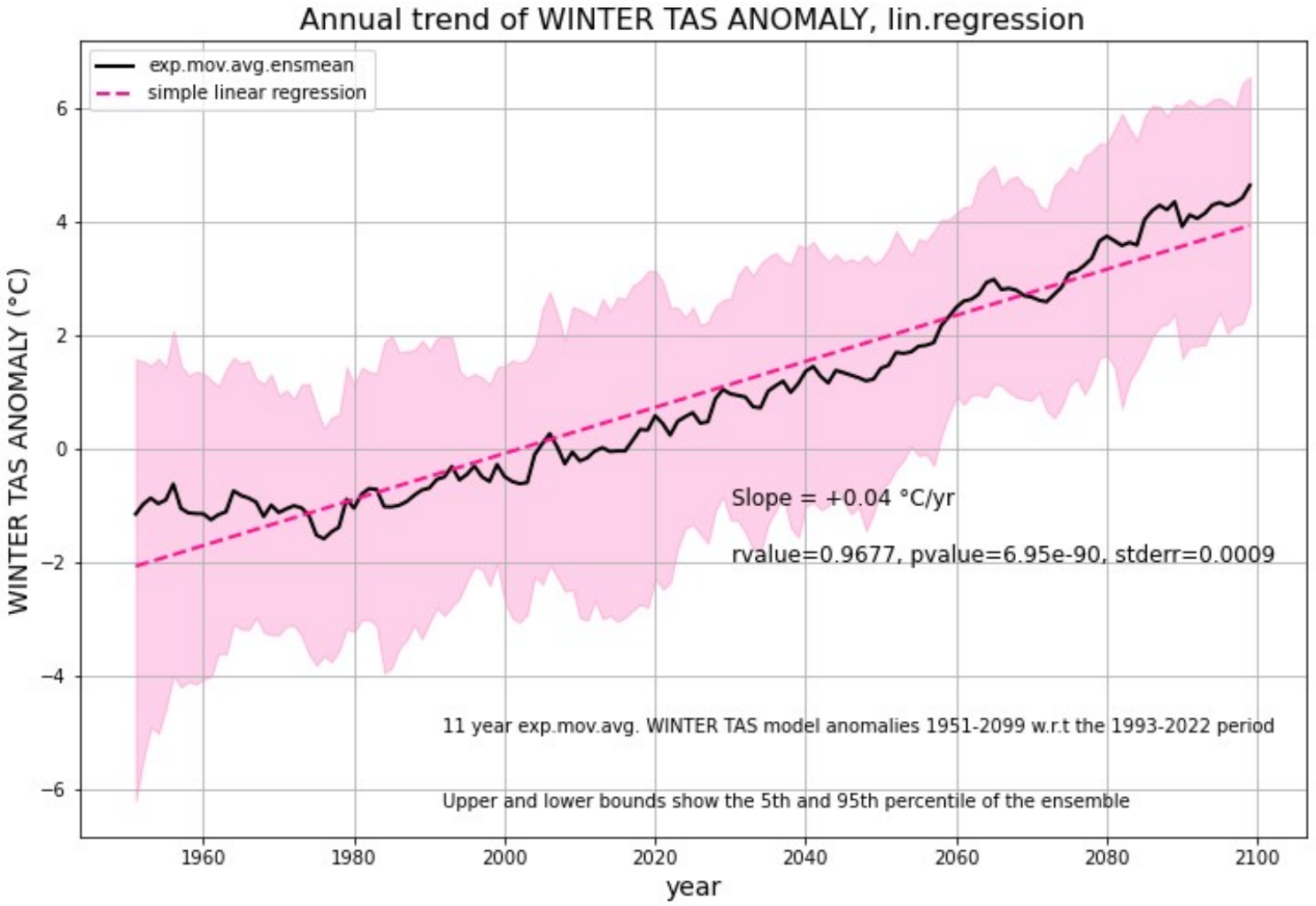
- It can be seen that **the shift in the snow line is directly proportional to the TAS anomaly**:

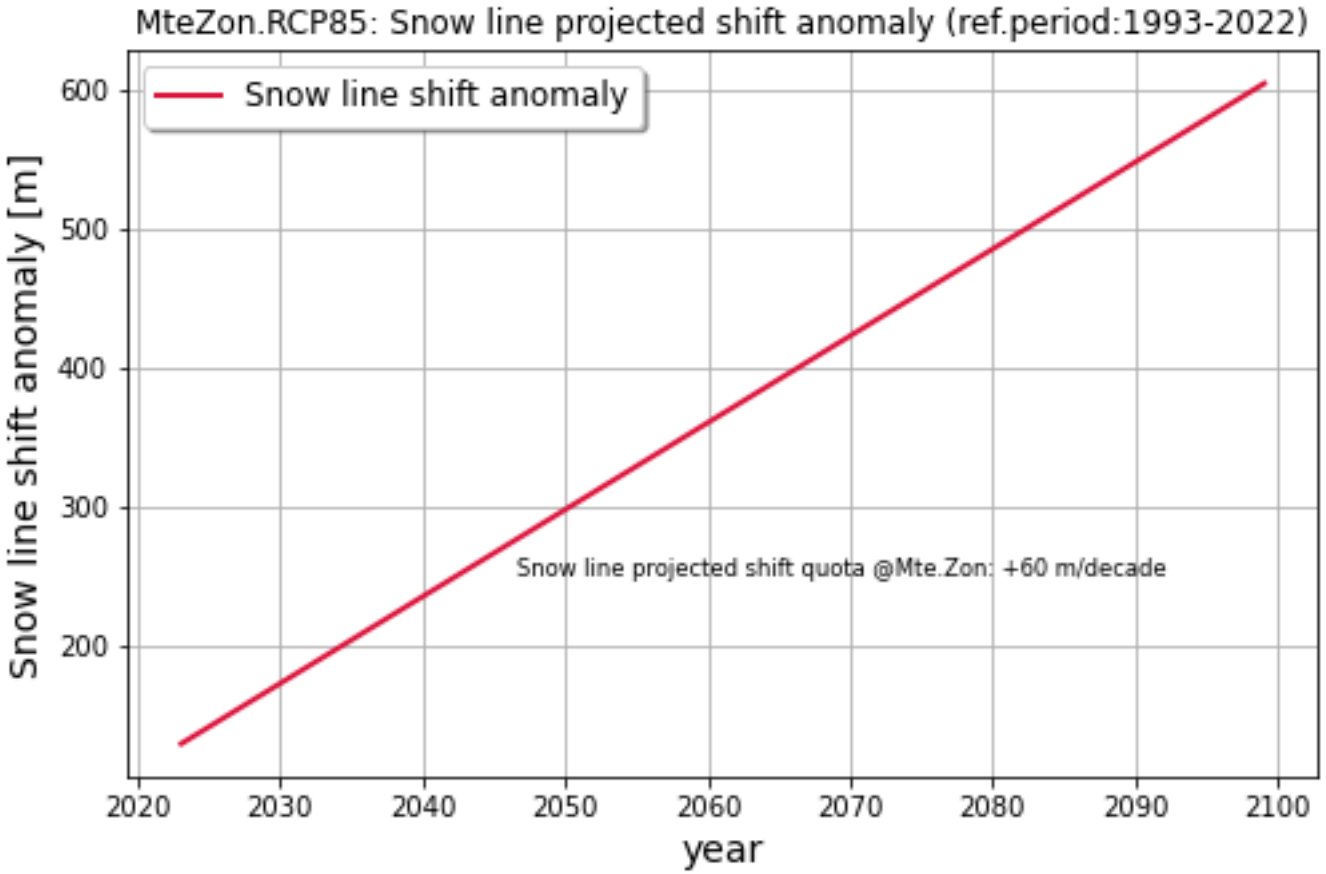
$$\Delta z_{(t_j - t_i)} = -\frac{1}{\Gamma}\alpha_{(t_j - t_i)}$$

EVOLUTION OF THE SNOW LINE HEIGHT AT MT. ZONCOLAN STATION (1750 m MSL) RCP8.5




11yr mov.avg and 5th,95th percentiles 4mod ens. @MteZoncolan RCP 8.5
ensemble 11-yr expo.moving avg.
WINTER TAS ANOMALY (°C)
6
4
2
0
−2
−4
−6
1960
1980
2000
2020
2040
2060
2080
2100
year
WINTER TAS model anomalies 1951-2099 w.r.t the 1993-2022 period
Upper and lower bounds show the 5th and 95th percentile of the ensemble


Annual trend of WINTER TAS ANOMALY, lin.regression
exp.mov.avg.ensmean
simple linear regression
WINTER TAS ANOMALY (°C)
6
4
2
0
−2
−4
−6
1960
1980
2000
2020
2040
2060
2080
2100
year
Slope = +0.04 °C/yr
rvalue=0.9677, pvalue=6.95e-90, stderr=0.0009
11 year exp.mov.avg. WINTER TAS model anomalies 1951-2099 w.r.t the 1993-2022 period
Upper and lower bounds show the 5th and 95th percentile of the ensemble


MteZon.RCP85: Snow line projected shift anomaly (ref.period:1993-2022)
Snow line shift anomaly
Snow line shift anomaly [m]
600
500
400
300
200
Snow line projected shift quota @Mte.Zon: +60 m/decade
2020
2030
2040
2050
2060
2070
2080
2090
2100
year

Summary of main results

1. TAS anomalies projections:

- 15 member ensemble is set
- No clear distinction between RCPs scenarios until 2040
- Even in RCP 2.6 global emission scenario, at least +1 °C (ens.mean) increase expected w.r.t. 1995-2015 period by 2040.
- RCP 8.5 ens.mean up to 4.5 °C by 2100 w.r.t 1995-2015 !
- RCP 8.5 ensemble means for different altitudes: hints of “elevation dependent warming”??

2. “Simple model for the snow line evolution” @Mt. Zoncolan:

- RCP 8.5 trend of +0.4 °C / decade in winter TAS anomaly
- +60 m shift in the “snow line” elevation per decade
- Freezing height above 1750 m by 2080
- Lack of the conditions even for artificial snow maintenance!

What’s next ?

Ongoing activities and further work

1. **Snow line evolution**: extend the computations to the 15 member ensemble and look at the other scenarios: RCP 2.6 and 4.5

2. **RCMs orography datum vs digital terrain elevation models**: to determine and correct the orographic bias of the models

3. **Evaluation of the "inner" models biases:**

    3.1) evaluate how the different members of the ensemble perform, compared to the observational data available for a given meteorological station

    3.2) retrieve more robust evaluations relative to the shift of the snow line height: $\Delta z_M = -\frac{1}{\Gamma}(\alpha_M + b_{M,\phi})$

4. **Analysis of observational time series trends**

5. **WRF simulations to refine the vertical gradient knowledge** in relation to the orography and under climate change.

6. Deal with **other climate indicators**, e.g. **precipitation**

Main PhD Goals:

FUTURE CLIMATE PROJECTIONS
To investigate future climate scenarios in the Alta Carnia region

CLIMATE INFORMATION TRANSFER
Support adaptation strategies and plans.
Address local stakeholders and communities needs, facing climate change impacts.

AWARENESS RISING process


THANK YOU FOR YOUR
ATTENTION !!