



Celebrating
YEARS
50
OF Successful
TOLL ROAD PROJECTS

2nd SECAP SUSTAINABILITY FORUM

HOSTED BY
AISIFIINIAIG



Celebrating
YEARS
50
OF Successful
TOLL ROAD PROJECTS

CLIMATE CHANGE IMPACTS ON INFRASTRUCTURE AND TRAFFIC MANAGEMENT IN SLOVENIA

Emilija Erent

DARS

HOSTED BY

AISI FINAIG

Climate of Slovenia

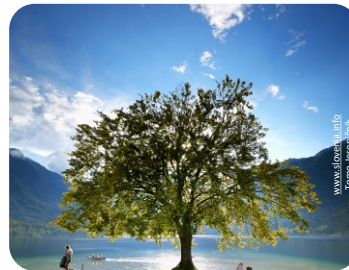
- Its geographical location, the varied relief, the orientation of mountain ranges and the proximity of the sea result in a very diverse climate:
 - **mild continental climate** (eastern part),
 - **subalpine (alpine in the mountains) climate** (central part),
 - **a sub-Mediterranean climate** (west of the Dinaric-Alpine barrier).



precipitation
increases as we move inland from the sea, decreases rapidly towards the N-E
possible droughts and floods



for part of the year, almost the whole country is covered by **snow**



average annual temperature
>12 °C by the sea,
the central Slovenia 8-10 °C,
mountain peaks < 0 °C



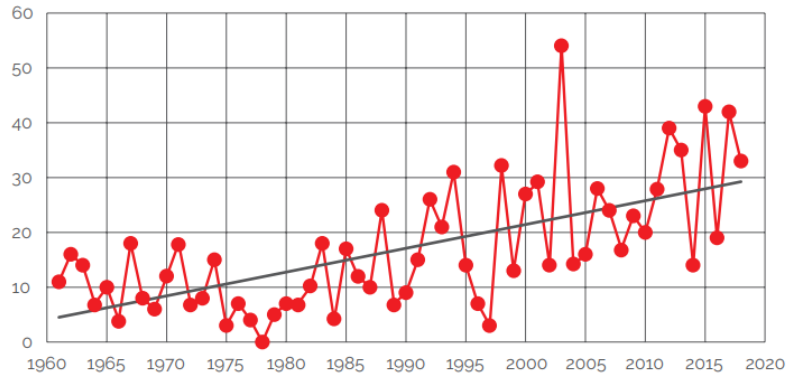
not windy, with the exception of Primorska („burja“ – strong, turbulent, wind gusts >100 km/h)



„on the **sunny** side of the Alps“

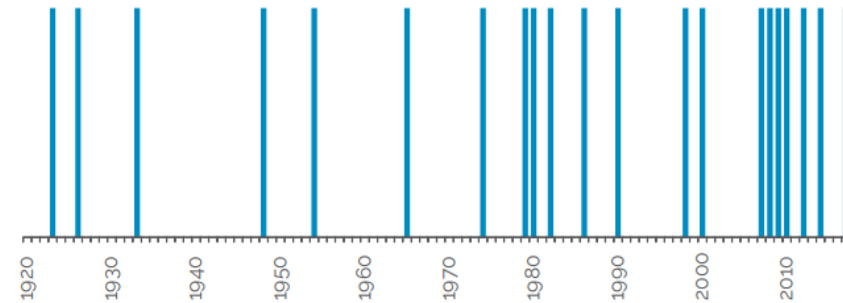
Past Climate Variability in Slovenia

- Increase in air temperature in all areas,
 - more in urban areas than in rural areas,
 - mostly a reflection of global climate change.
- An increase in the number of warm days.



Ljubljana, number of days > 30°C

- A decrease in the number of icy days.
- Changes in precipitation mostly small, but the precipitation regime has changed:
 - Increasing rainfall amounts during extreme precipitation events.



Slovenia, years with more extensive floods

- A decrease in the amount of new snow and the duration of snow cover.

Climate Projections for Slovenia



Air temperature ↑: 2 °C – 4.1 °C. Most in winter.



Annual precipitation ↑: up to 20%. Winter precipitation: 40%-60%.



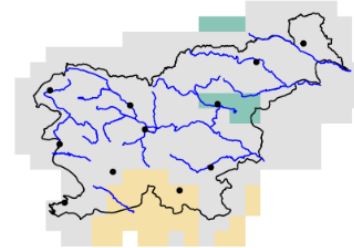
Intensity and frequency of extreme precipitation events ↑: summer and autumn.



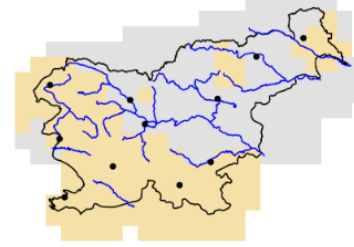
Snowfall ↓: less frequent

Different climate changes can be expected in different areas of the country.

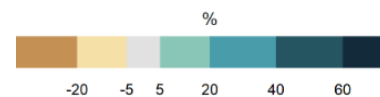
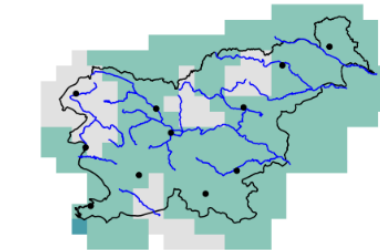
Precipitation – summer



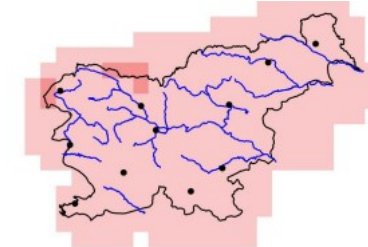
2041-2070



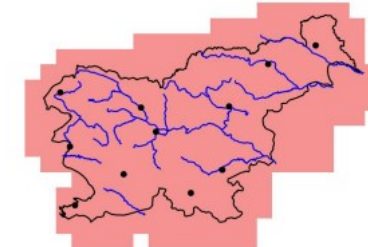
2071-2100



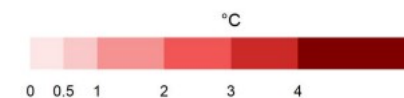
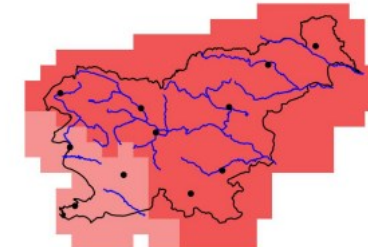
Average temperature - winter



2041-2070

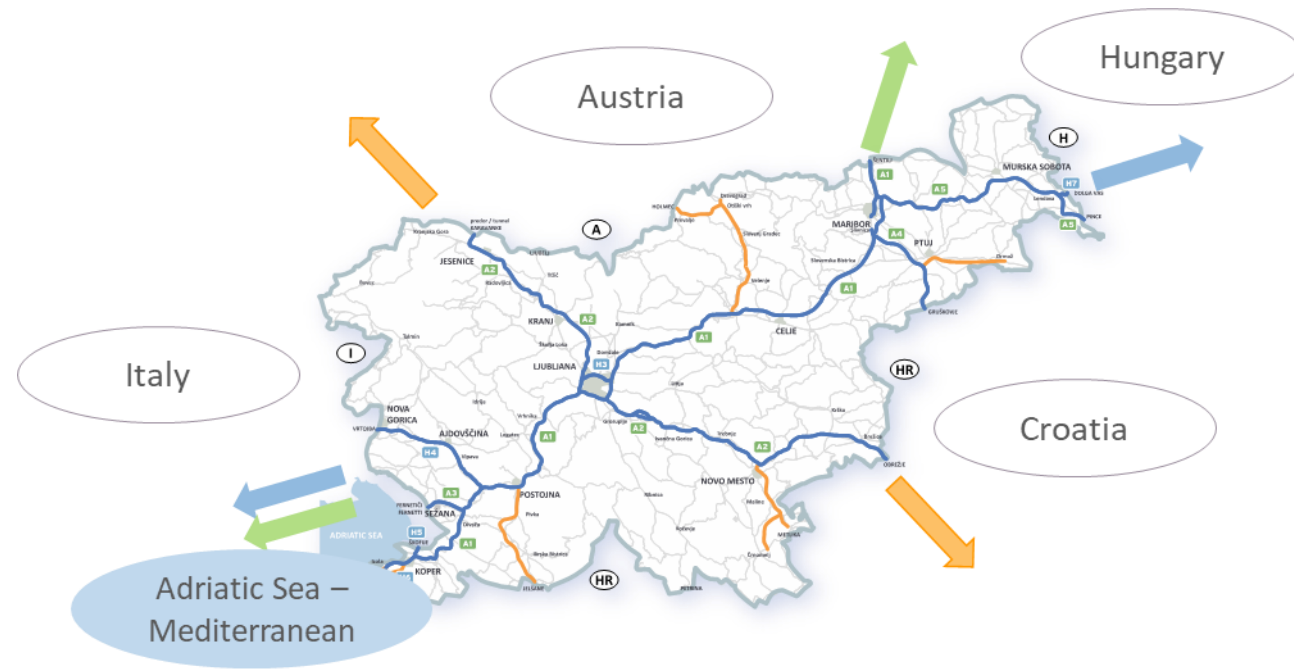


2071-2100



Motorway network

- 625 km of tolled MW and EW
 - + 206 km of turn-offs, links and other roads
- Young roads:
 - 80 % less than 30 years
 - 45 % less than 20 years
- Different climatic regions
- Geographical diversity



over 1200 bridge structures



23 double-tube tunnels

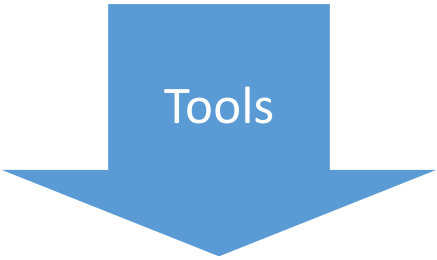


Supporting geotechnical structures

Weather Conditions on Motorways

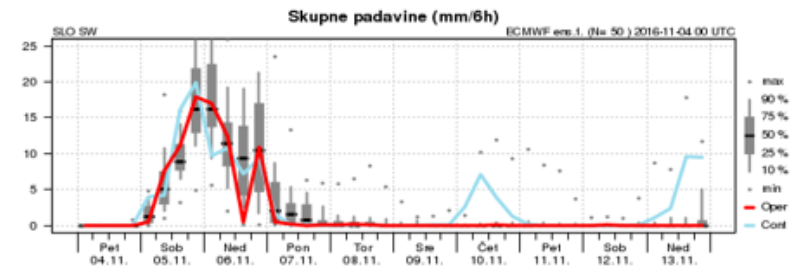
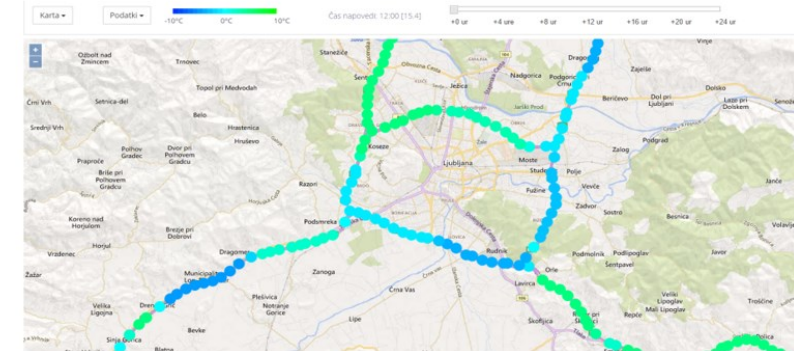
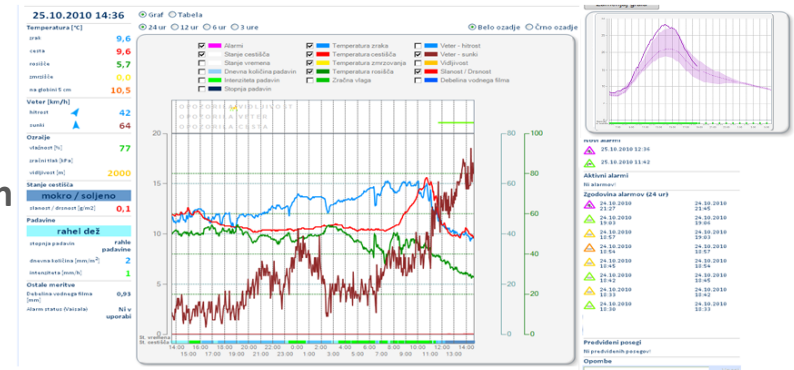
Maintenance,
Winter service

Traffic
management



- **Road weather stations (82 + 16 locations - viaducts, hills,...):**
 - temperature of air
 - temperature of asphalt (diff. depths)
 - water film thickness
 - precipitation
 - wind (gusts, direction)
 - concentration of salt
 - relative humidity of the air
 - solar radiation
 - visibility
 - freezing point temperature
 - condition of the roadway
- Transmission of data to the national meteorologic agency

- **The Road Weather Information System (CVIS)**
 - warnings,
 - Alarms
- **Point and line predictions of roadway conditions (MDSS)**
 - decision support
- **Weather forecasts (ARSO)**



Climate Hazards and Infrastructure

Construction

Renewals

Infrastructure
Management

Tools

■ Heat waves

- Impact on asphalt temperature (case: Selo; Kozarje)

■ Heavy precipitation, changing precipitation patterns

- stability conditions of motorway structures (case: Rebrnice)

■ Landslides

- traffic restrictions (case: Vrhole)

- Road sensor measurements (surface, different depths)

- Measurements of distances, displacements, anchor forces, ground water fluctuations

- Partial or full motorway closure
- Emergency measures, reconstruction

Geotechnical conditions!

Case 1: Gusts of bora (burja)

- **Location: Highway H4 (Razdrto – Vrtojba)**

- The bora is a gusty wind. Its velocity can increase or decrease 10-fold within a very short time period. Even the normal bora can **obstruct traffic**. If gusts exceed 80 km/h, traffic may be closed to some types of vehicles. When **gusts exceed 150 km/h**, traffic is closed to all vehicles.

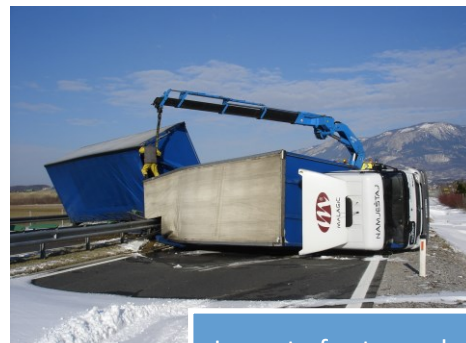
- **Actions:**

- The Road Weather Information System.
- Traffic control centre: driving bans for vehicles according to the level of wind strength, speed limits, warnings, re-routing.
- Variable traffic information signalization and other channels – informing drivers!
- Before traffic is released, the roadway needs to be cleared, the signalization repaired, and the section inspected for safety.

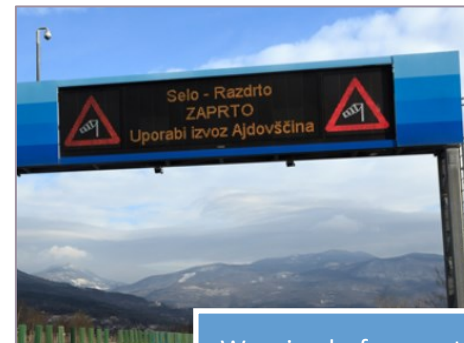


level	speed (km/h)	speed (m/s)	road closure
1	80 - 100	22 - 28	camper vans, refrigerator trucks and sheeted vehicles up to capacity of 8 tonnes
2	100 - 130	28- 36	camper vans, all sheeted vehicles and refrigerators; if the wind speed exceeds 110 km/h (30 m/s), the speed limit for all vehicles is 40 km/h
3	130 - 150	36 - 40	camper vans, all level II vehicles and buses
4	over 150	o	

Traffic control centre decisions



Impact of extreme bora



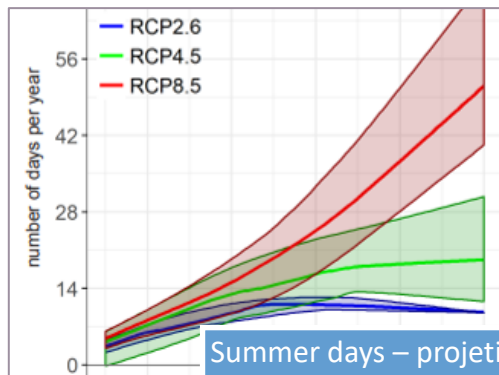
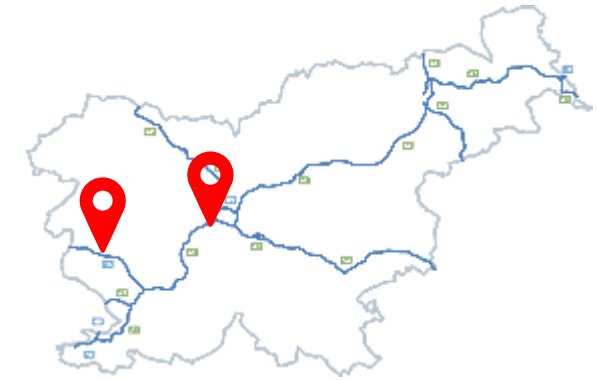
Warning before section



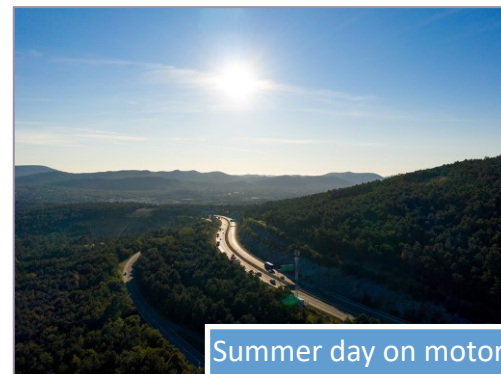
Damage on signalization

Case 2: Heat waves

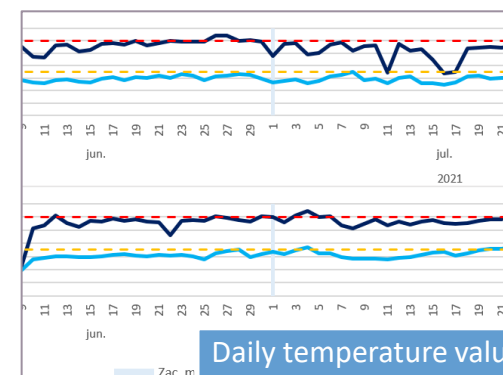
- **Location: Motorway A1 (Kozarje), Highway H4 (Selo)**
- The number of summer days, when daily maximum exceeds 25 °C, is expected to increase with time. The frequency and duration of heat waves will gradually increase. In some hot days (> 40 °C) in the summer of 2022, we were concerned how the air temperature **affected the temperature of the asphalt.**
- Action:
 - We analysed daily data for summer months (jun-avg) for the last 12 years: temperature of air, temperature of road surface.
 - Extreme air temperatures did not affect the asphalt to heat on the surface beyond the design limit of 60°C. The temperature of asphalt on the depth of 4 cm might be more indicative.



Summer days – projections till 2100



Summer day on motorway section



Daily temperature values – air and roadway

Case 3: Heavy precipitation, changing precipitation patterns

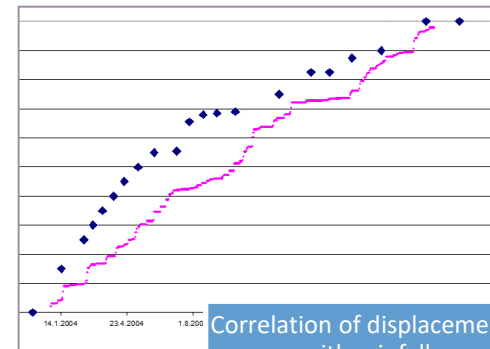
- **Location: Highway H4 (Rebrnice)**
- Local geological conditions (tectonically damaged hills, abundant backwaters, poor drainage) lead to slow drift (1-2 cm/year), which **intensifies as precipitation increases** and is **slower in times of drought**. Climate projections show that exceptional raifalls are to increase.
- Action:
 - engineering inspections
 - geodetic displacement measurements
 - anchor force measurements
 - monitoring ground water fluctuations
 - Monitoring of dynamics of displacements at a given depth
 - measurements of anchor forces on permanent geotechnical anchors
 - geostatistical checks, remedial measures



Demanding HW section



Checking the deck construction of viaduct



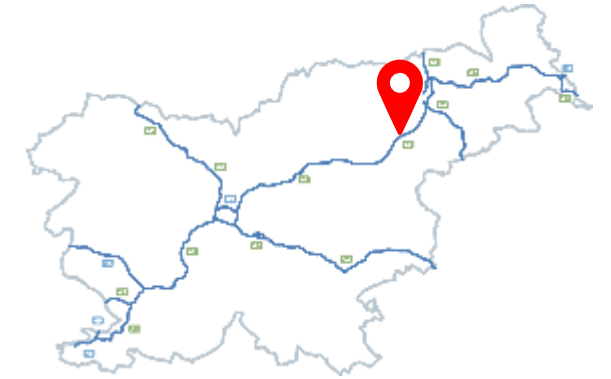
Correlation of displacements with rainfall



Effects of displacement, initial support

Case 4: Landslide

- **Location: Motorway A1 (Vrhole)**
- As one of the biggest landslides that occurred on MW network, the Vrhole bank collapsed in March 2013, **displacing** approximately 25.000 cubic metres of deep hillside mass, some of it onto the shoulder and some of it onto the driving lane of the motorway.
- **Action:**
 - Identification of less stable berms
 - Closure of lane(s)
 - Emergency measures to ensure the stability of the landslide
 - Reconstruction of landslide area



Landslide blocks MW



Dimensions of the collapse



Final reconstruction



The climate and climate change must be accounted for in construction and infrastructure management in order to be able to provide fluid and safe traffic.

Thank you for your attention!

Sources:

- Slovenian Environmental Agency, ARSO; <https://meteo.arso.gov.si/>
- Organisation units of DARS: Road Management, Construction and Renovation, Maintenance, Sustainable Development Management Service