REPUBLIC OF TURKEY
MINISTRY OF TRANSPORT
AND INFRASTRUCTURE

GENERAL DIRECTORATE
of HIGHWAYS

INTERNATIONAL CONFERENCE for RAICING AWARENESS on ADAPTATION of TRANSPORT INFRASTRUCTURE to CLIMATE CHANGE IMPACTS

Athens-GREECE
18-19 November 2019

UNECE

Is It Possible to Be Ready For Climate Change in Terms Of Our Roads?

Dr. Leyla ÜNAL Ankara-TURKEY

PREDICTED IMPACTS OF CLIMATE CHANGE (2100)

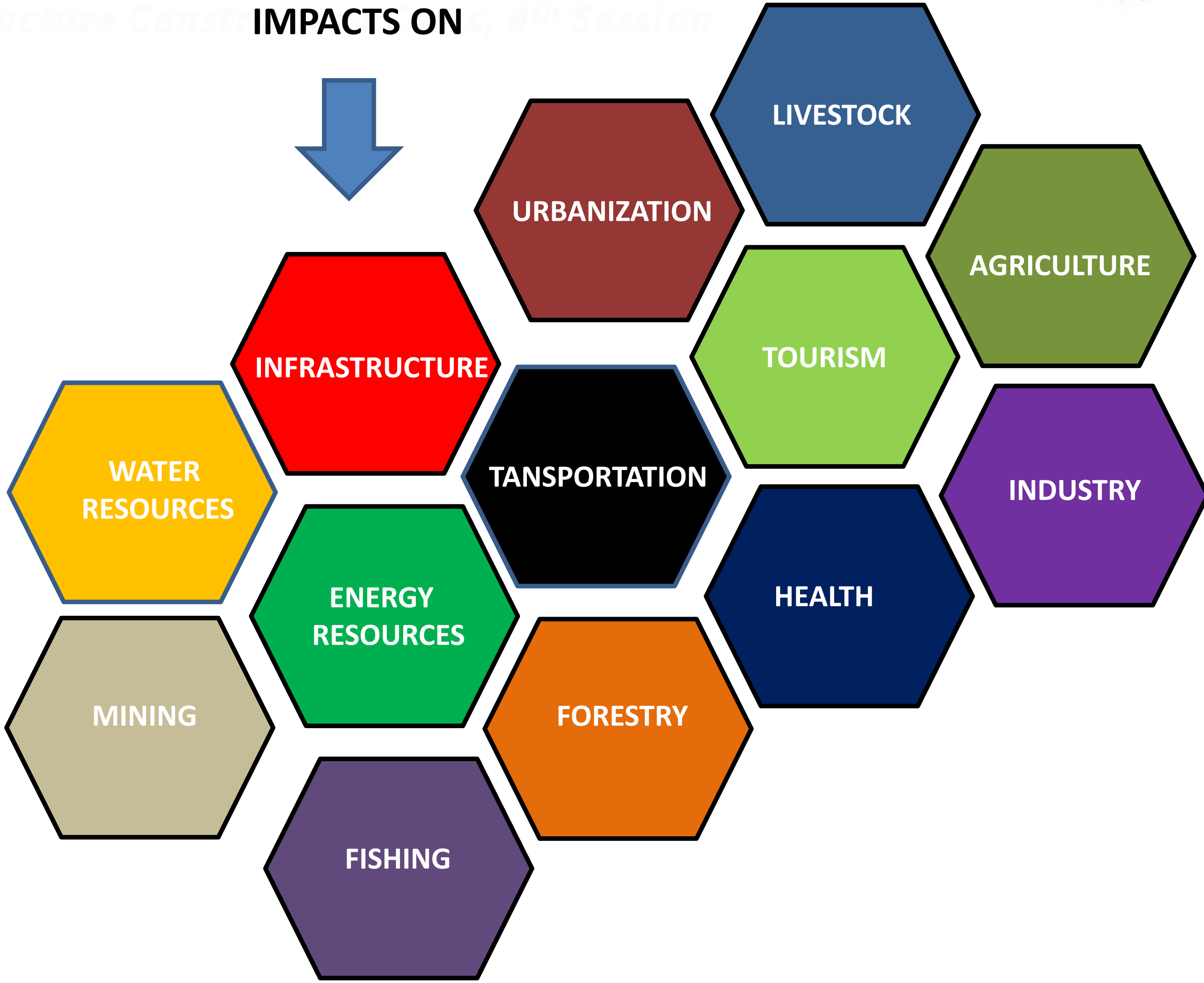
TEMPRATURE INCREASE
1.6 – 5.1 C

PRECIPITATION INCREASE
10-15%

SEA WATER TEMPRATURE INCREASE
1.8 – 4 C

SEA LEVEL RISE
28 – 45 CM

IMPACTS ON

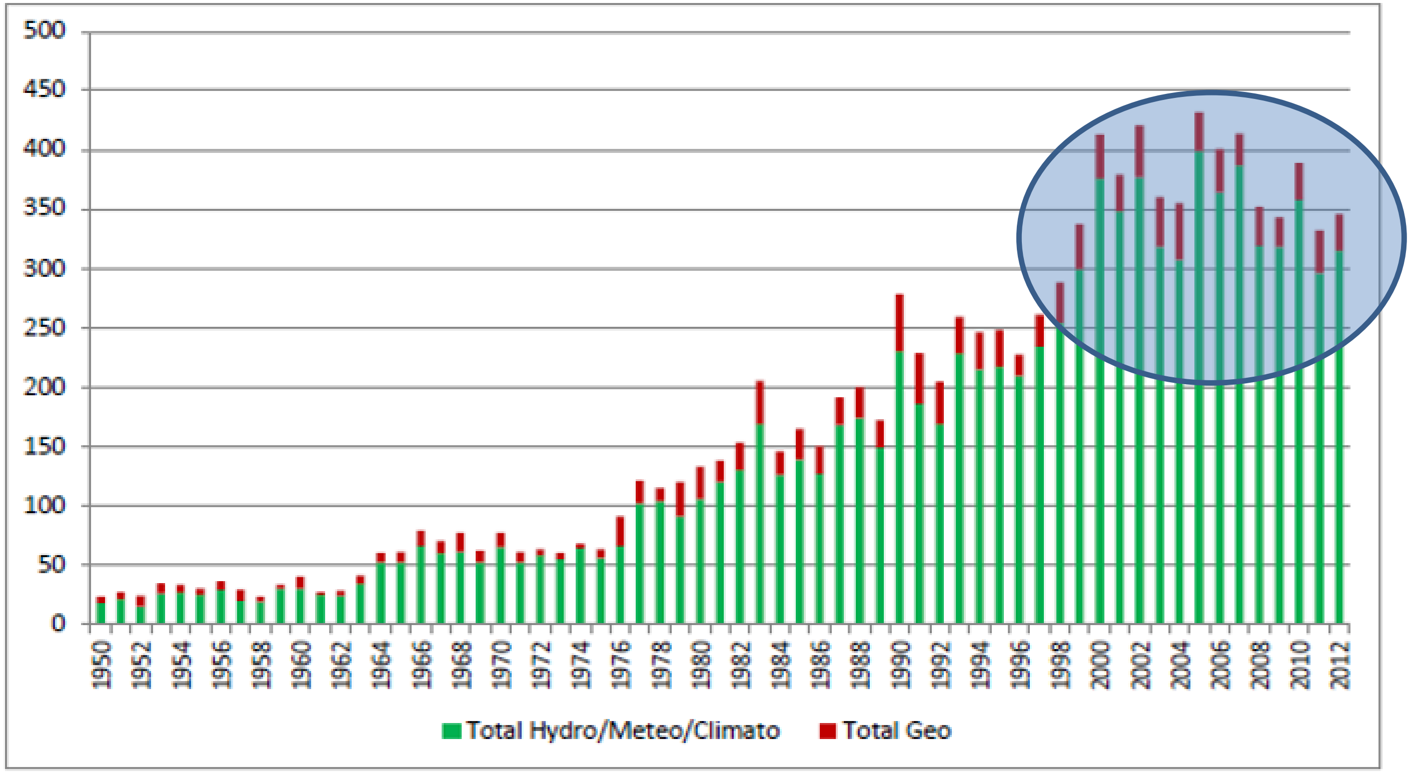


2019 Global Risk Report

Top 10 risks in terms of
Likelihood

1. **EXTREME WEATHER EVENTS**
2. **FAILURE OF CLIMATE-CHANGE MITIGATION AND ADAPTATION**
3. **NATURAL DISASTERS**
4. DATA FRAUD OR THEFT
5. CYBER-ATTACKS
6. MAN-MADE ENVIRONMENTAL DISASTERS
7. LARGE-SCALE INVOLUNTARY MIGRATION
8. BIODIVERSITY LOSS AND ECOSYSTEM COLLAPSE
9. WATER CRISES
10. ASSET BUBBLES IN A MAJOR ECONOMY

Total Occurrence Of Natural Disasters From 1950 To 2012*



*Biological excluded

Source: CRED

Grouping Of Geophysical Disasters

Disaster Generic Group	Disaster Group	Disaster Main-Type	Disaster Sub-Type	Disaster Sub-sub Type
Natural Disaster	Geophysical	Earthquake	Ground shaking	
			Tsunami	
		Volcano	Volcanic eruption	
		Mass movement (dry)	Rockfall	
			Avalanche	Snow avalanche
				Debris avalanche
			Landslide	Mudslide Lahar Debris flow
			Subsidence	Sudden subsidence
				Long-lasting subsidence

Source: CRED, Munich RE

Grouping Of Meteorological Disasters

Disaster Generic Group	Disaster Group	Disaster Main-Type	Disaster Sub-Type	Disaster Sub-sub Type
Natural Disaster	Meteorological	Storm	Tropical storm	
			Extra-tropical cyclone (Winter storm)	
			Local/Convective storm	Thunderstorm/ Lightning
				Snowstorm/Blizzard
				Sandstorm/Duststorm
				Generic (severe) storm
				Tornado
				Orographic storm (strong winds)

Source: CRED, Munich RE

Grouping Of Hydrological Disasters

Disaster Generic Group	Disaster Group	Disaster Main-Type	Disaster Sub-Type	Disaster Sub-sub Type
Natural disaster	Hydrological	Flood	General (river) flood	
			Flash flood	
			Storm surge/coastal flood	
		Mass movement (wet)	Rockfall	
			Landslide	Debris flow
			Avalanche	Snow avalanche
				Debris avalanche
			Subsidence	Sudden subsidence
				Long-lasting subsidence

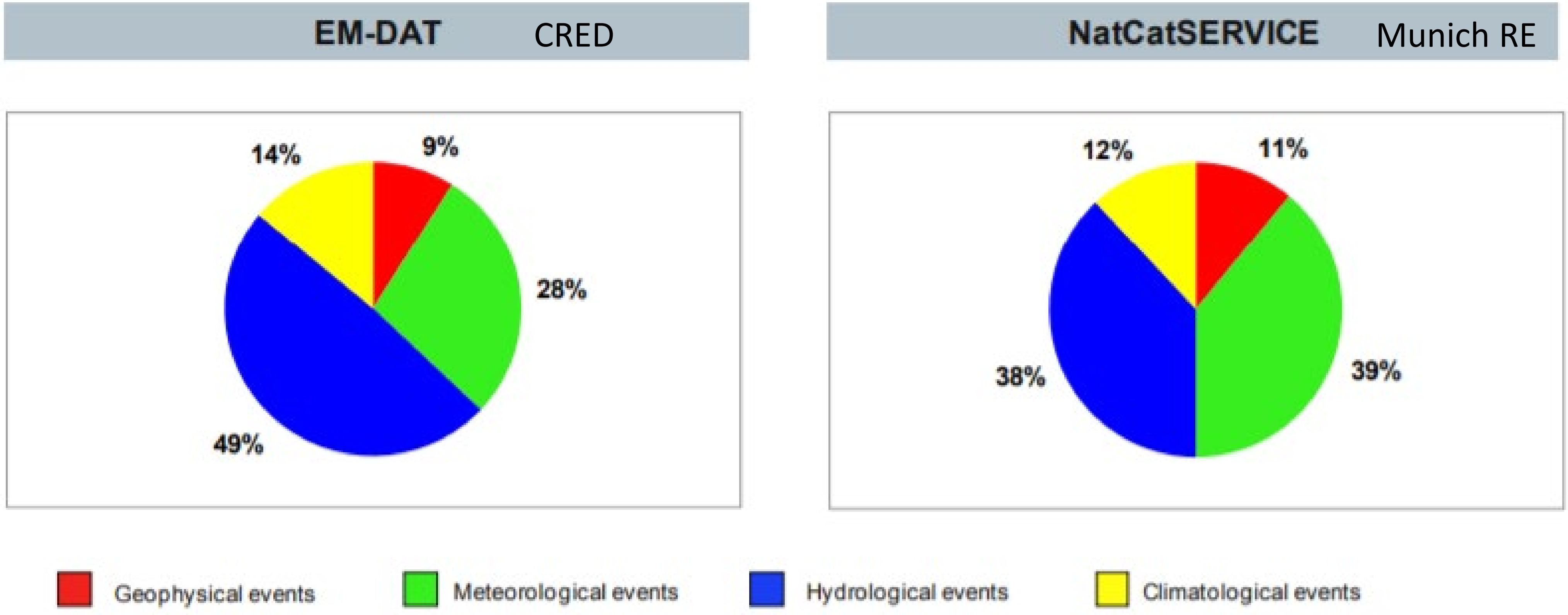
Source: CRED, Munich RE

Grouping Of Climatological Disasters

Disaster Generic Group	Disaster Group	Disaster Main-Type	Disaster Sub-Type	Disaster Sub-sub Type
Natural disaster	Climatological	Extreme temperature	Heat wave	
			Cold wave	Frost
			Extreme winter conditions	Snow pressure
				Icing
				Freecing rain
				Debris avalanche
		Drought	Drought	
		Wild fire	Forest fire	
			Land fires (grass, scrub, bush, etc. ...)	

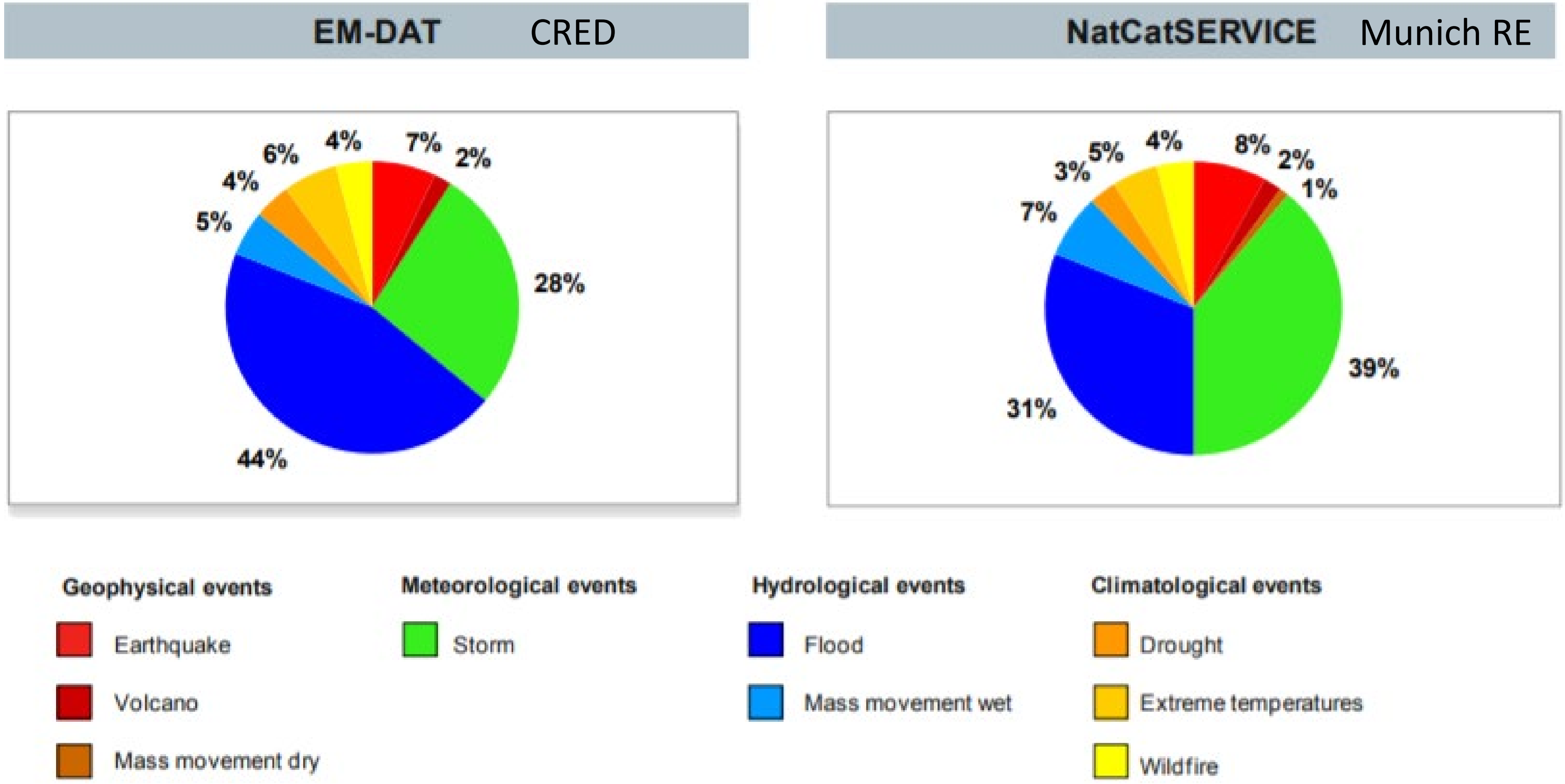
Source: CRED, Munich RE

Repartition Of Events By Disaster Group, 2000-2008



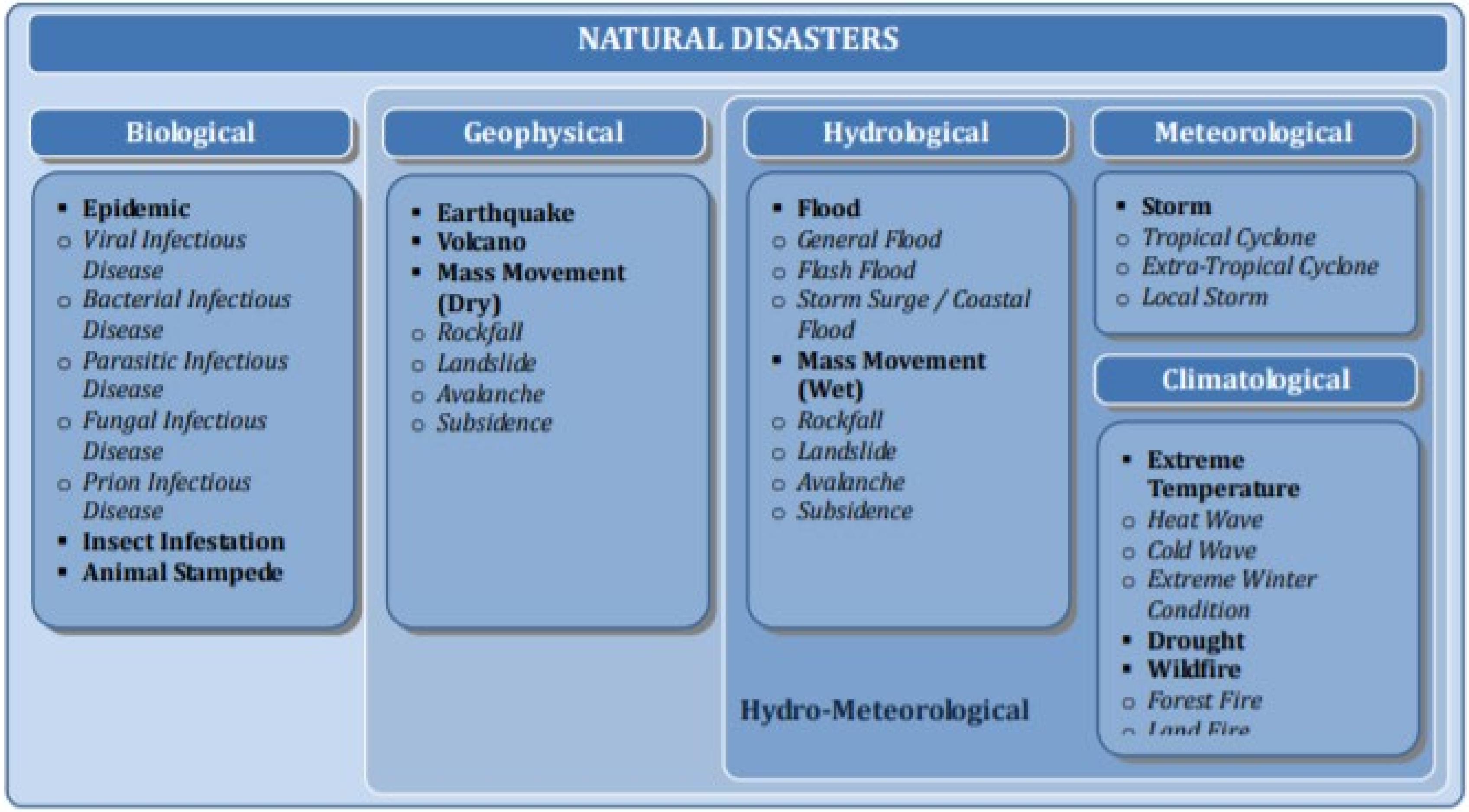
Source: CRED, Munich RE

Repartition Of Events By Disaster Main Type, 2000-2008



Source: CRED, Munich RE

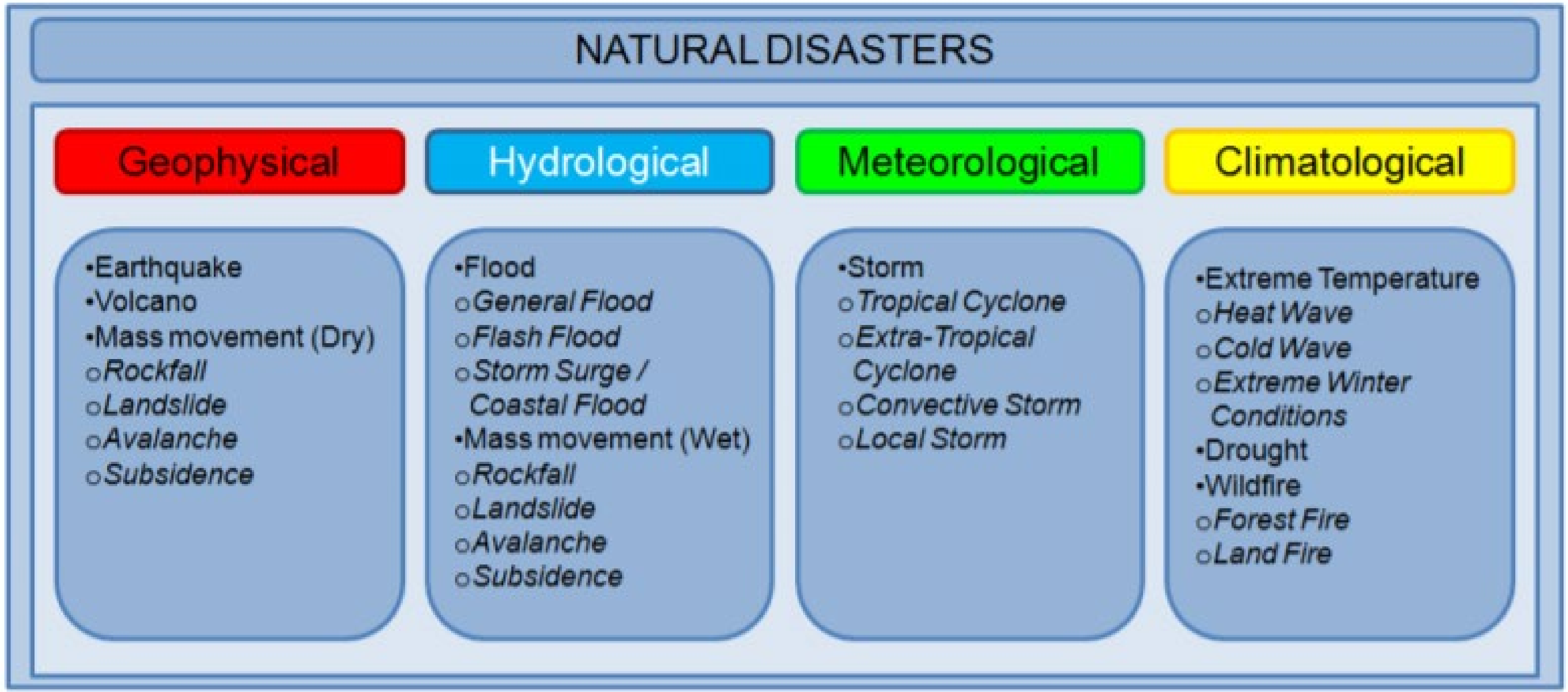
Natural Disaster Classification



CRED defines a disaster as "a situation or event which overwhelms local capacity, necessitating a request to a national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering".

Source: CRED, Munich RE

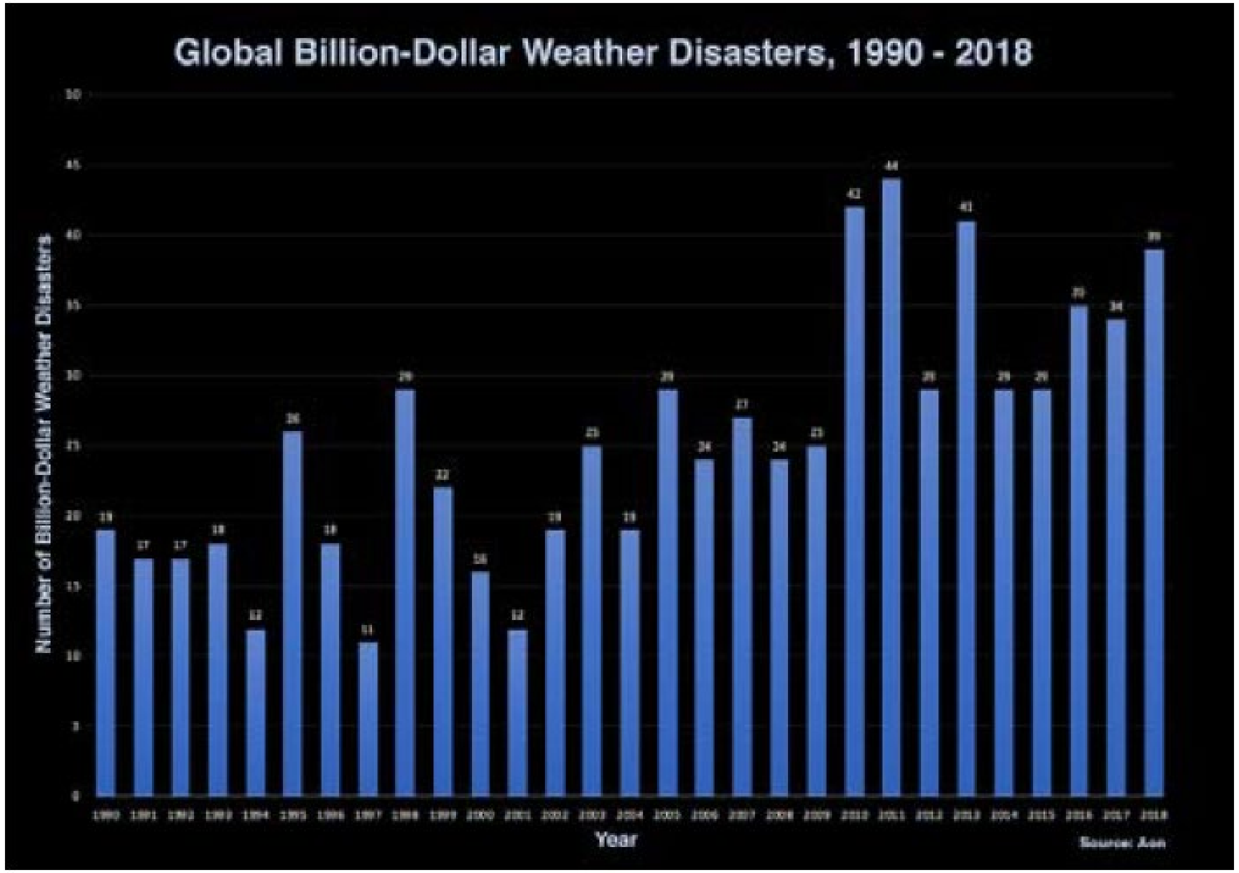
Natural Disaster Classification



NatCatSERVICE covers natural disasters and distinguishes between 4 groups (geophysical, meteorological, hydrological and climatological), which in turn cover 9 disaster main-types and about 20 sub-types

Source: CRED, Munich RE

Weather Related Disasters Between 1990-2018



Source: Aon

Atmospheric and Climatic Disasters

DISASTERS

- FLOODS
- EXTREME SNOW
- AVALANCHES
- HAIL
- FOG
- FROST
- STORMS
- LIGHTNING

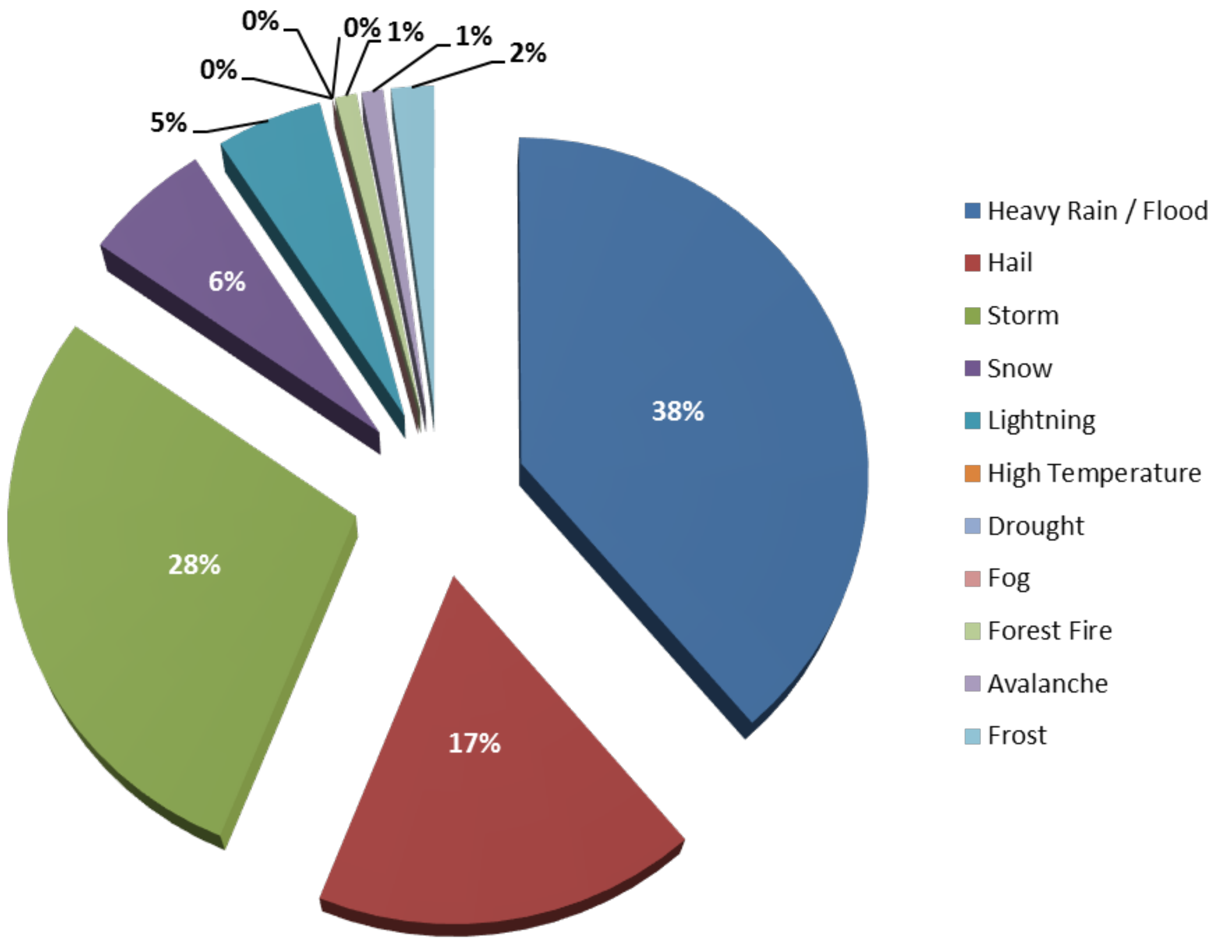
DIRECT IMPACTS

- LOSS OF HUMAN LIFE
- LOSS OF ANIMAL
- IMPACTS ON HOUSES
- IMPACTS ON WORKPLACE
- LOSS OF AGRICULTURAL PRODUCST
- LOSS OF LAND (EROSION)
- **DAMAGES ON TRANSPORTATION SYSTEMS**
- DAMGES ON ENEGY AND COMMUNICATION SYSTEMS
- LOSS OF ASSETS
- OTHER

INDIRECT IMPACTS

- UNEMPLOYMENT
- POVERTY
- PHYCHOLOGICAL EFFECTS
- EPIDEMIC
- OTHER

Distribution of Meteorological Disaster Events in TURKEY - 2018



Among the natural disasters with meteorological characteristics observed in 2018,

1. Heavy rainfall/flood (38%),
2. Storm disaster (28%)
3. Hail disaster (17%)

were in top three and totally 83%.

Population and Population Growth

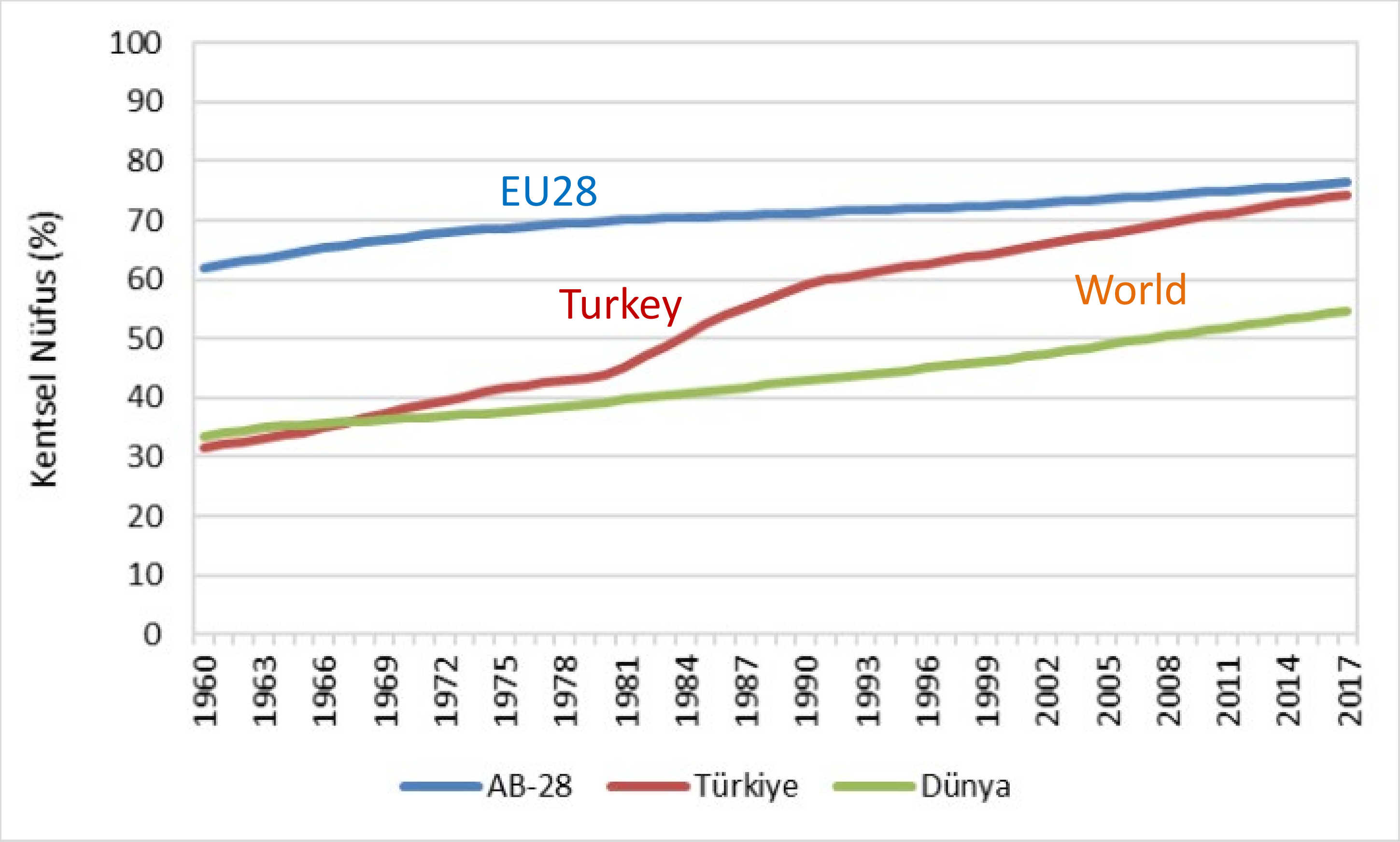
Population Density By Provinces - 2018

Population Density Person/km2

2018 Yılı Nüfus Yoğunluğu (kişi/km²)

- 11-63
- 64-117
- 118-224
- 225-527
- 528-2899

Population Ratio Living In Urban Areas Between 1960 - 2017



According to Word Bank Data

POPULATION RATIO LIVING IN URBAN AREAS IN 2017

Turkey 74.4%

EU28 76.4%

WORD %54.3

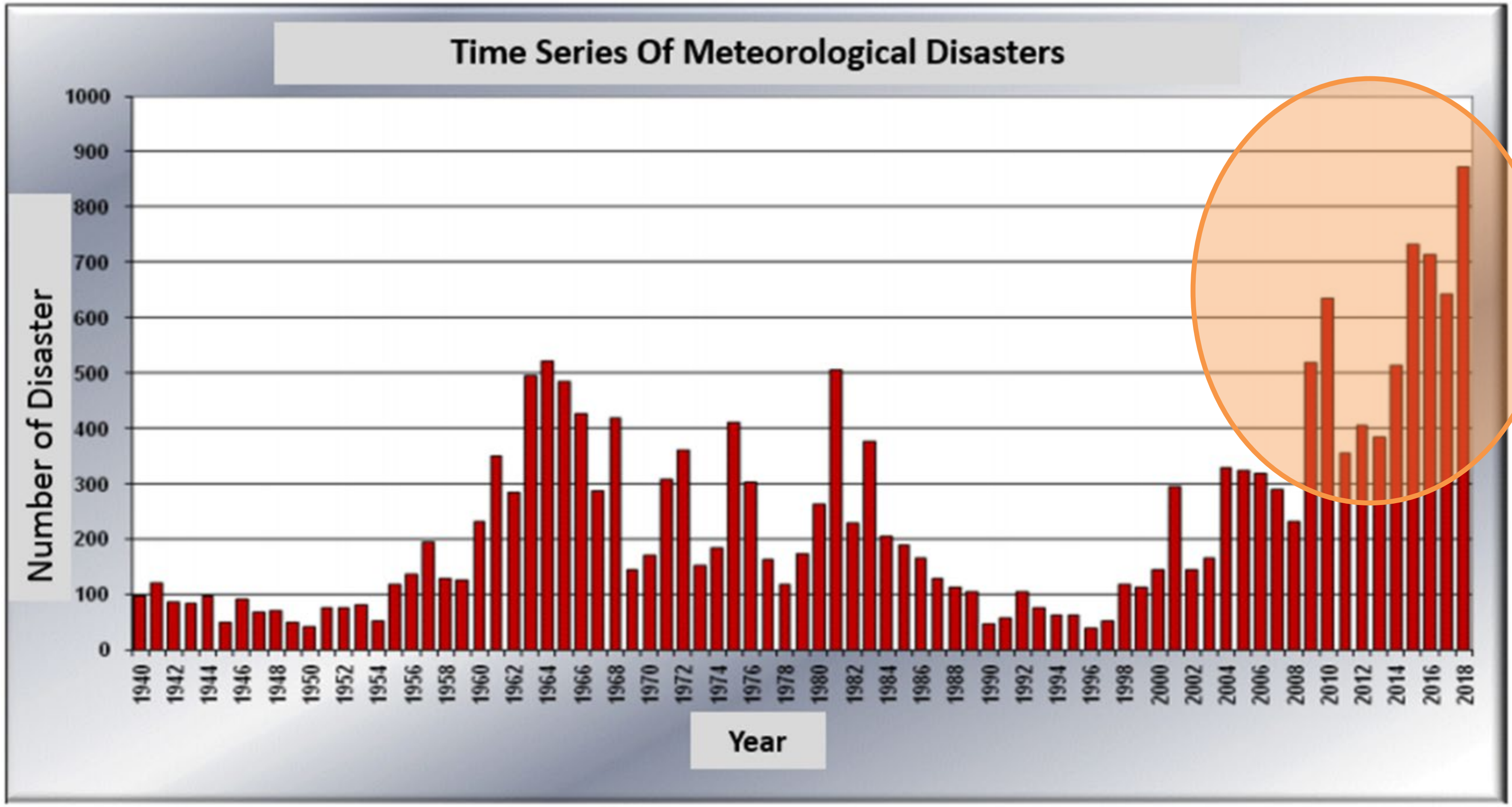
SOURCE: WORLD BANK (World Bank Indicators)
https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?contextual=default.

Road Network Map of Turkey

KGM Regional Directorates Borders

River Basins Of Turkey

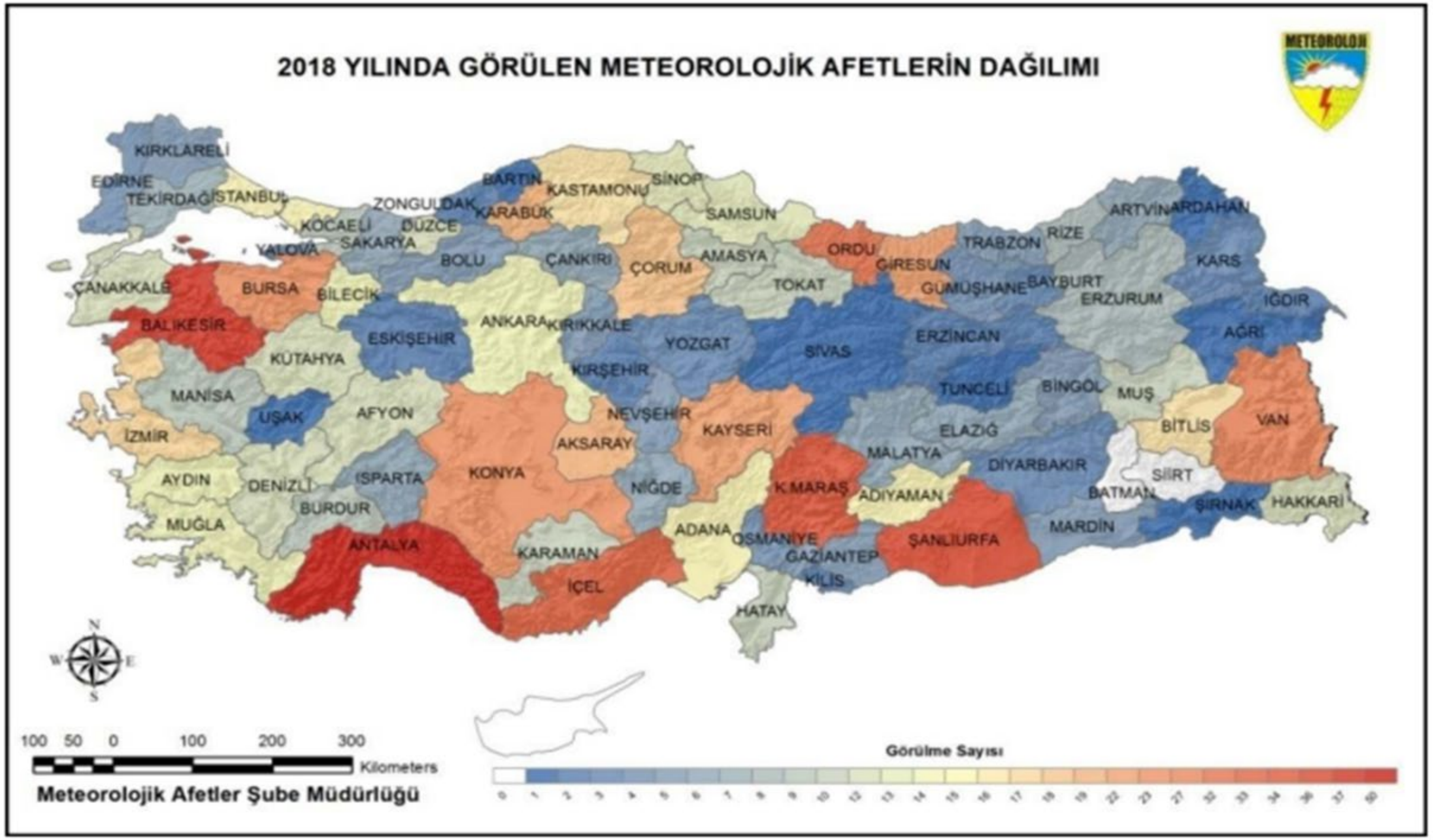
Distribution of Meteorological Disaster Events



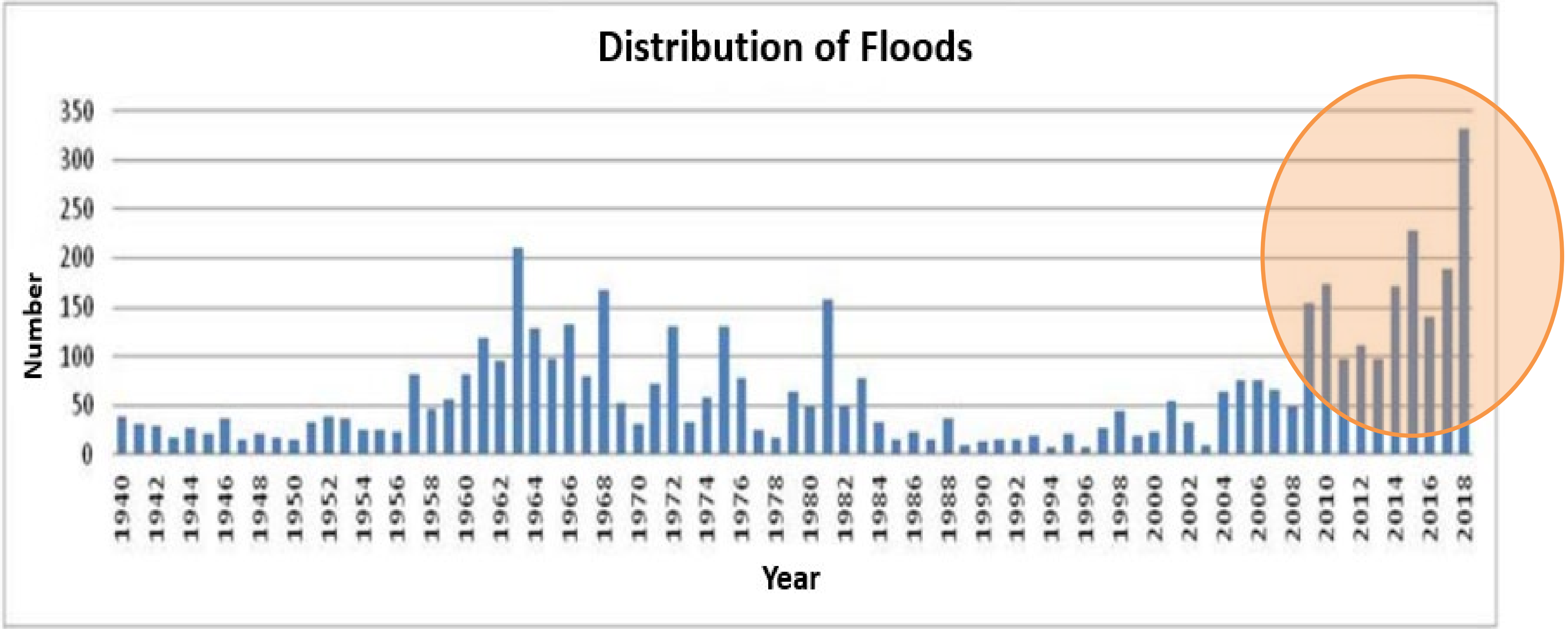
In 2018, a total of 871 meteorological natural disasters were reported in Turkey.

38% of meteorological nature occurring in 2018 disaster caused by heavy rainfall and flood.

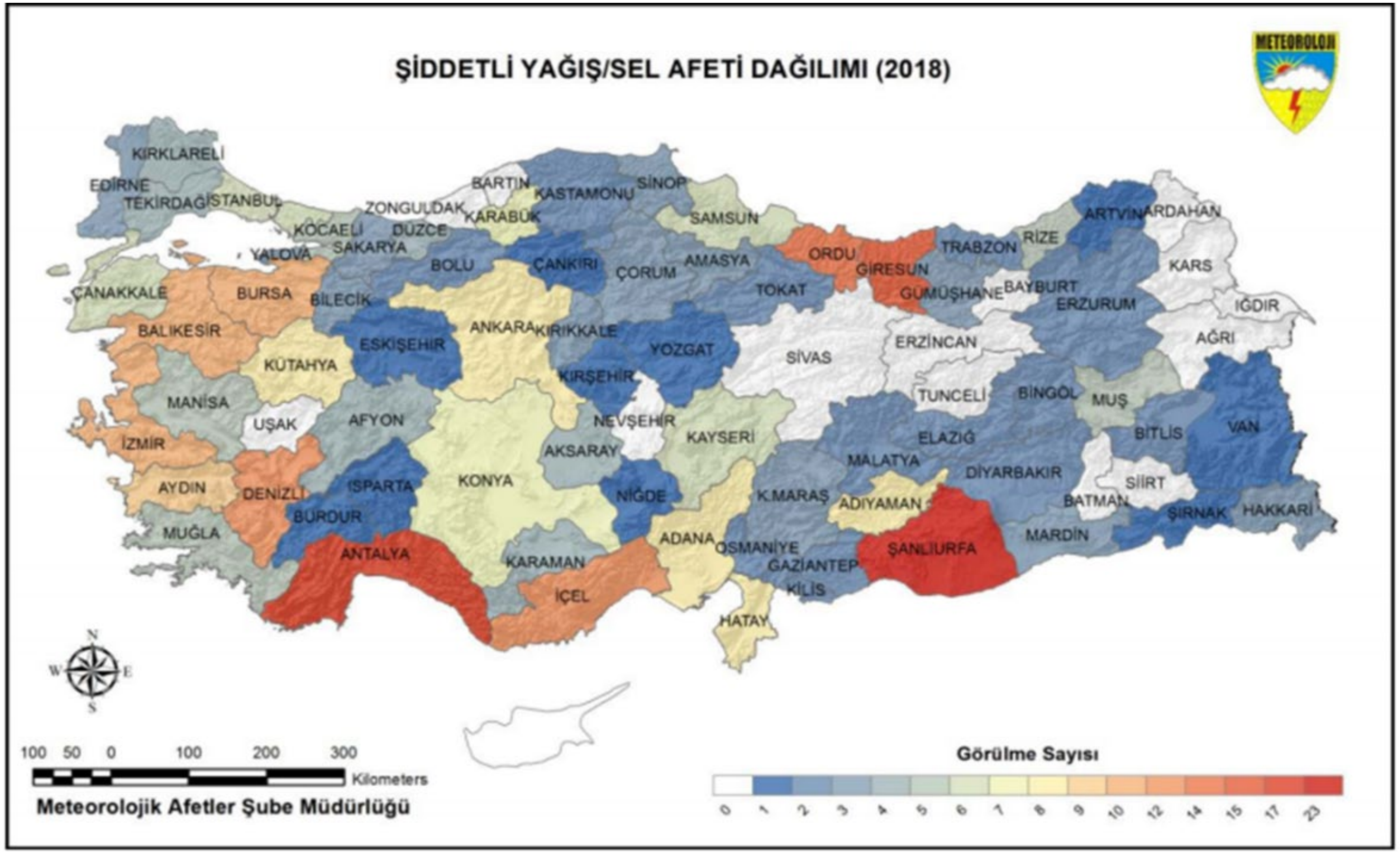
Distribution of Natural Disasters with Meteorological Character in 2018 by Provinces



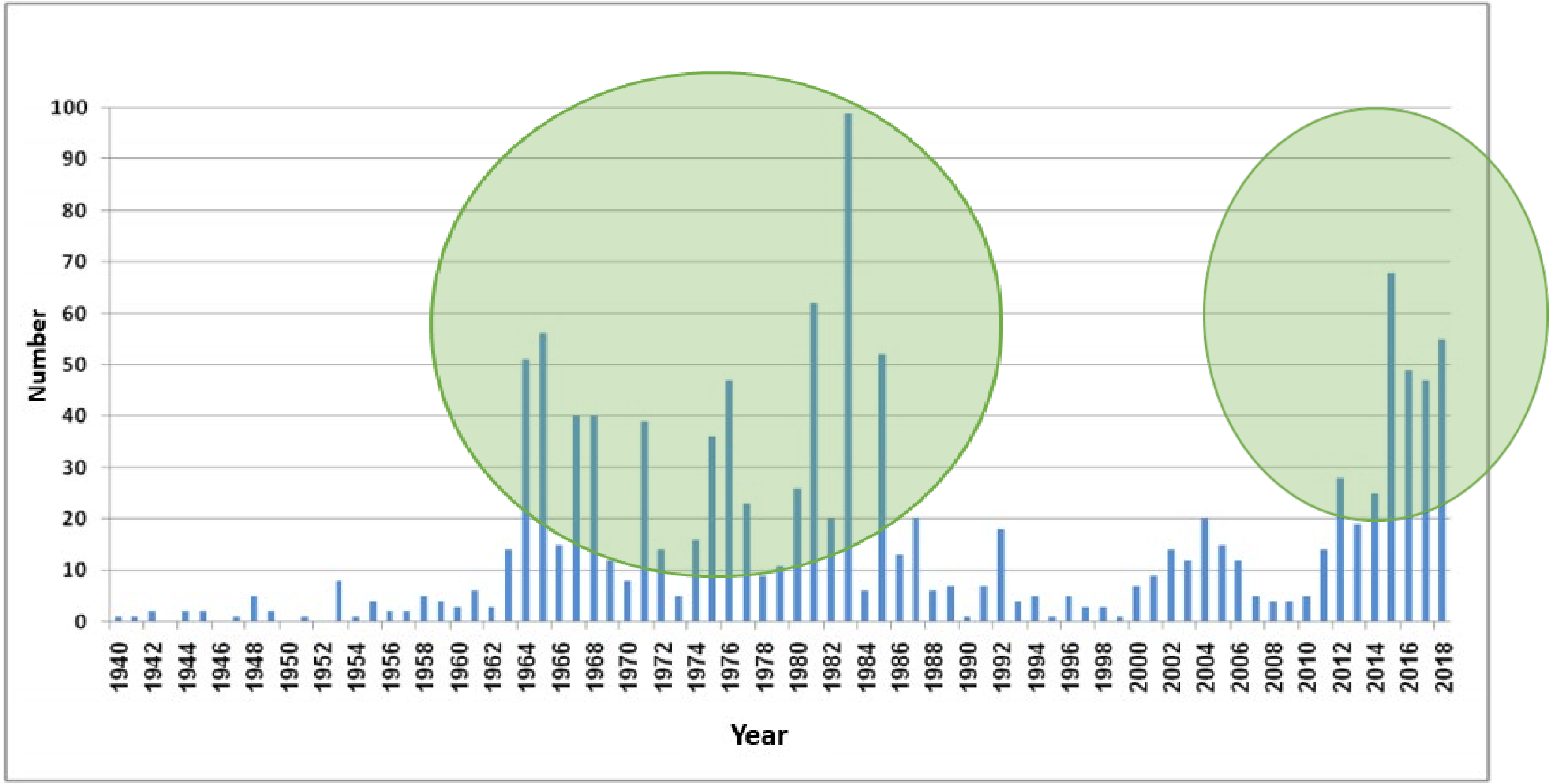
Heavy Rain and Flood Disaster in Turkey



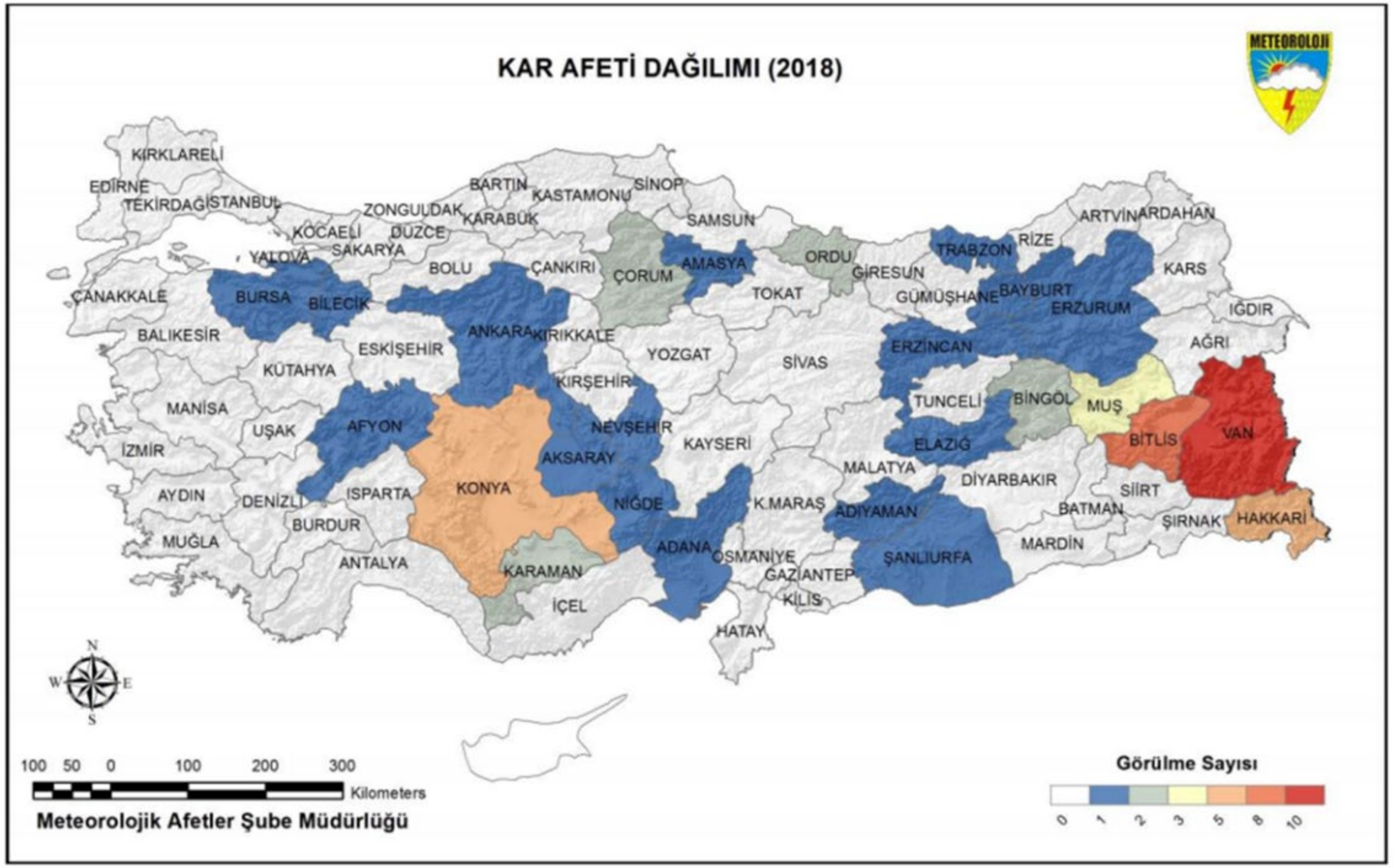
Heavy Rain and Flood Disaster in Turkey in 2018 by Provinces



Distribution Of Extreme Snow Disasters In Turkey (1940-2018)



Extreme Snow Disasters in 2018




17-19 Ocak 2018, Bitlis

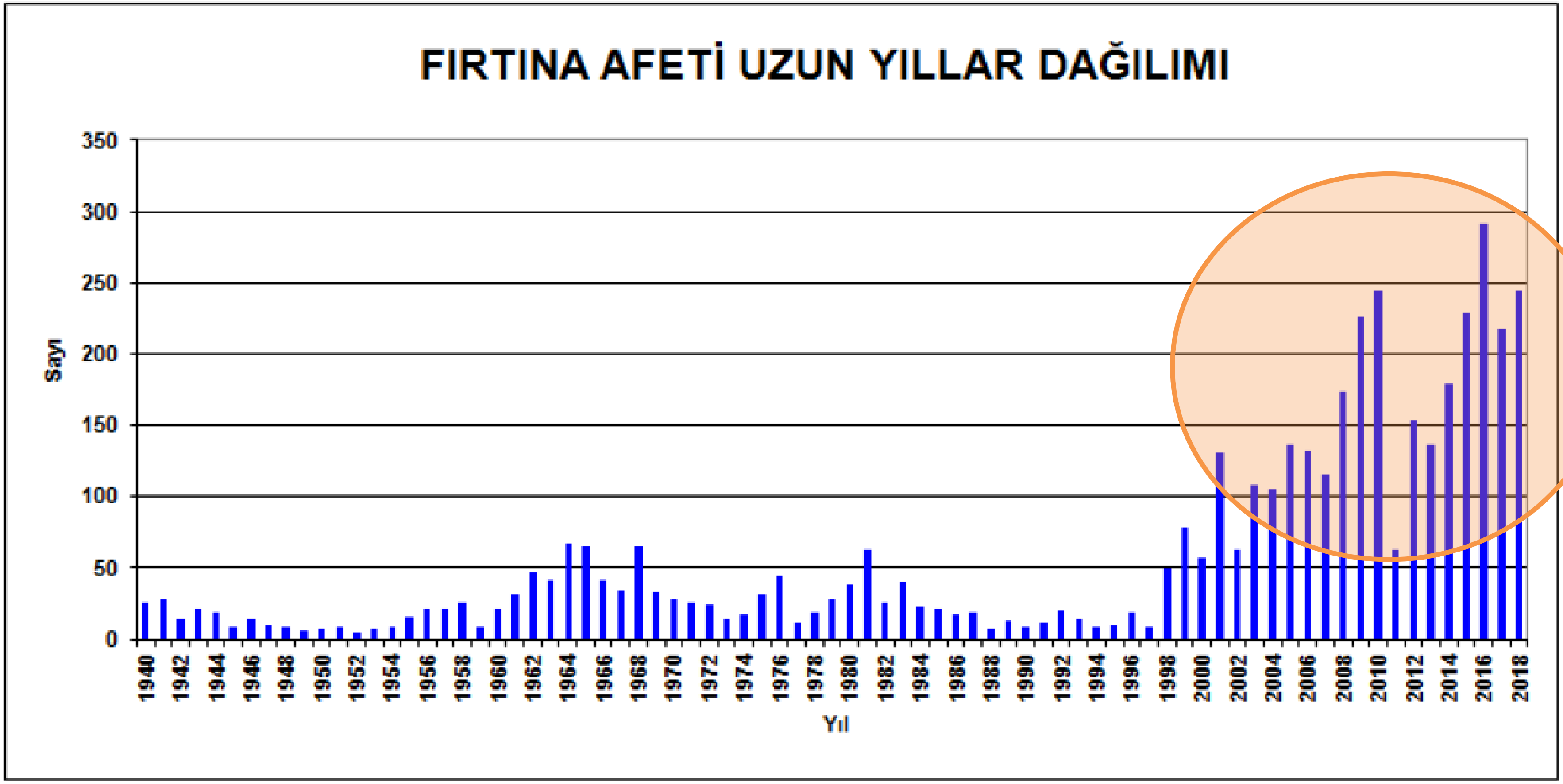

24-25 Ocak 2018, Konya

İstanbul Bophorous Get Frozen in 1954

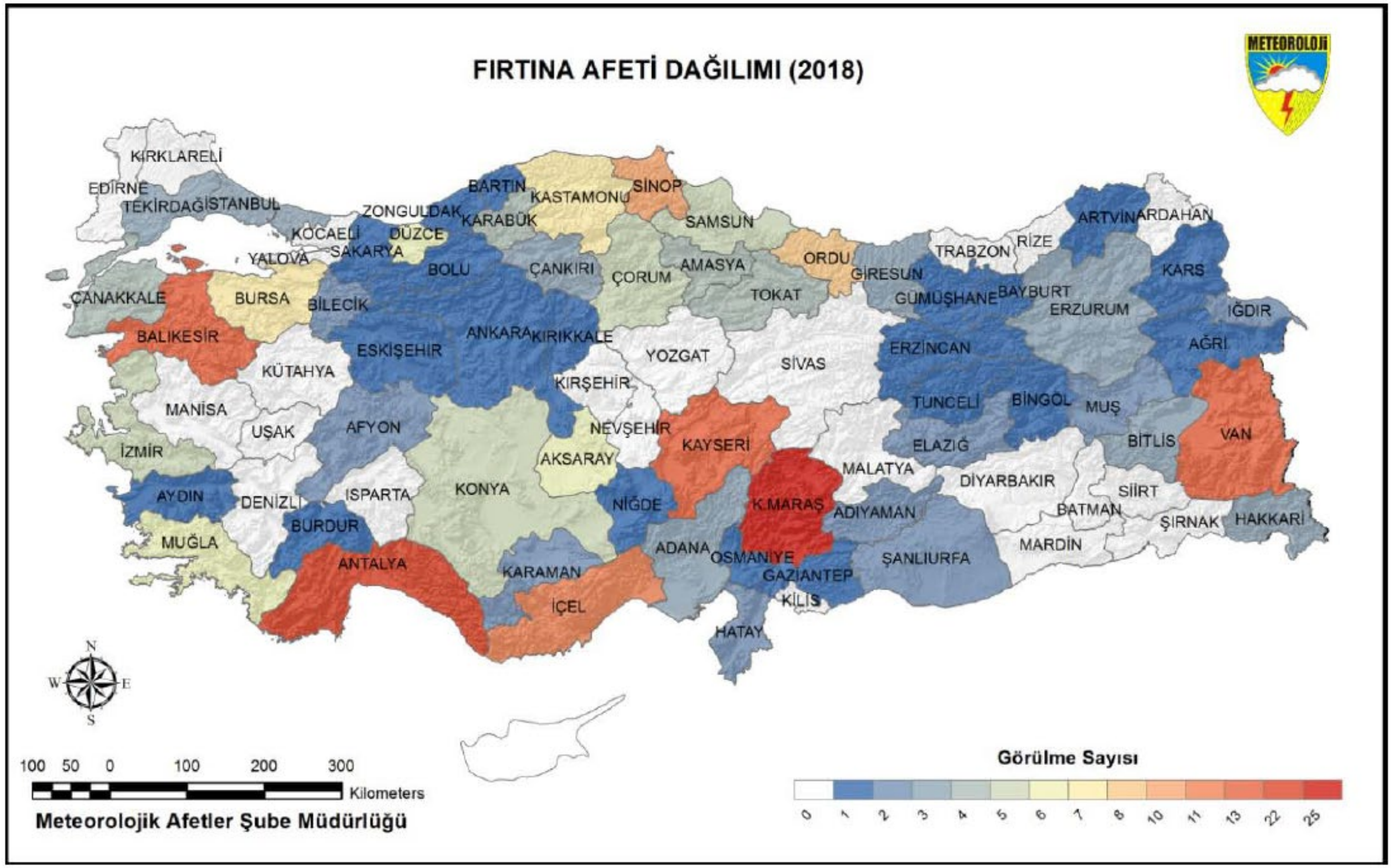



CAT

Distribution Of Storm Disasters In Turkey (1940-2018)

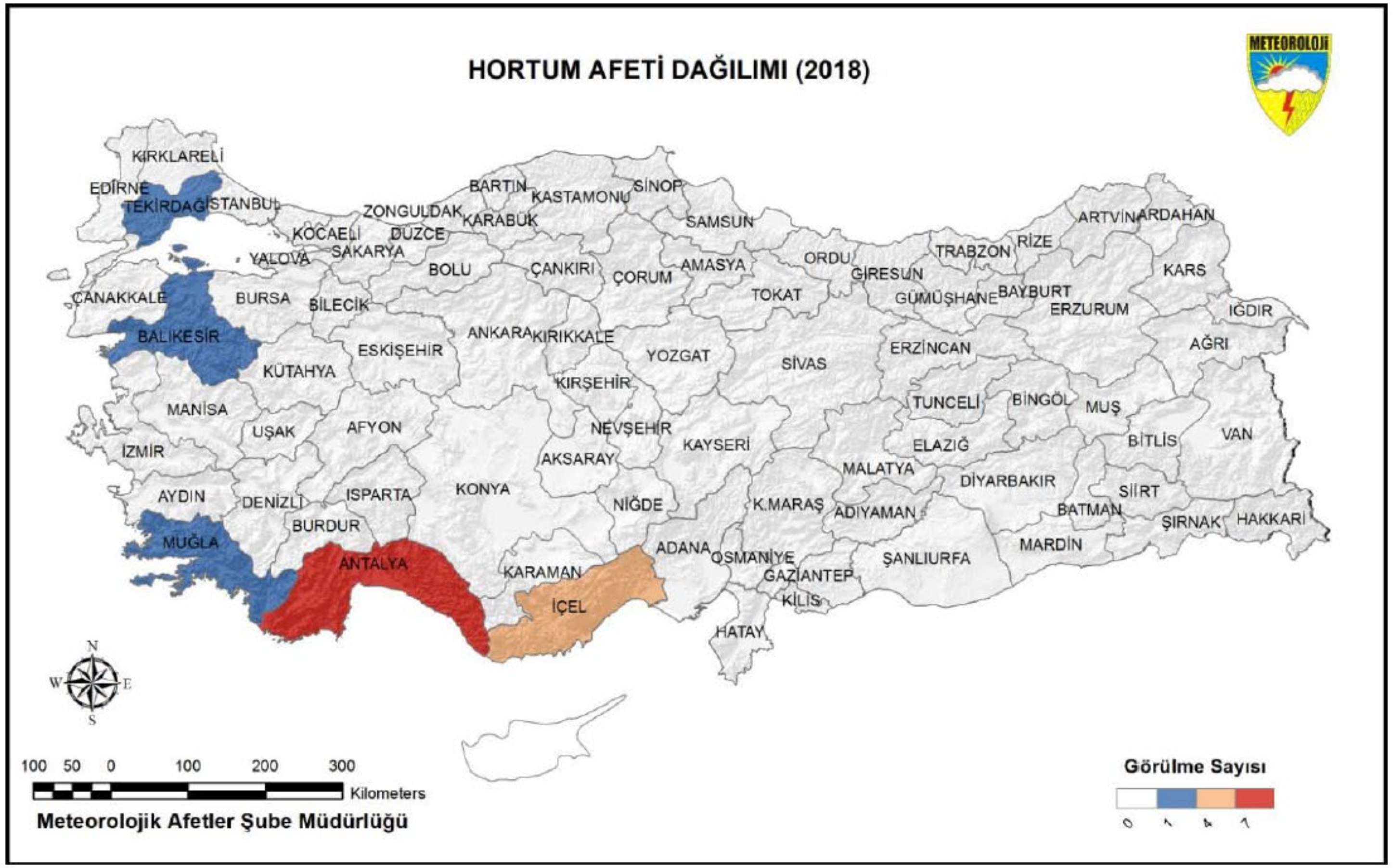


Storm Disasters in 2018

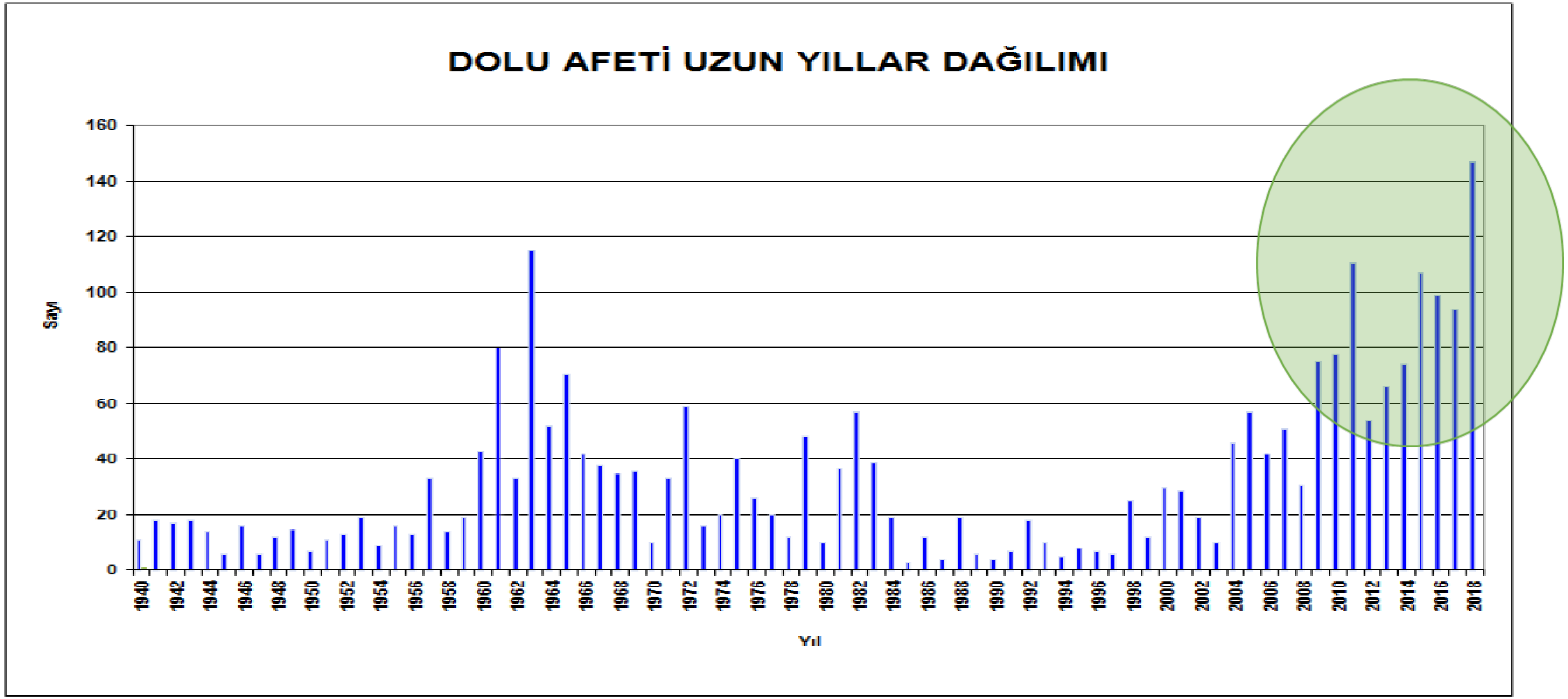




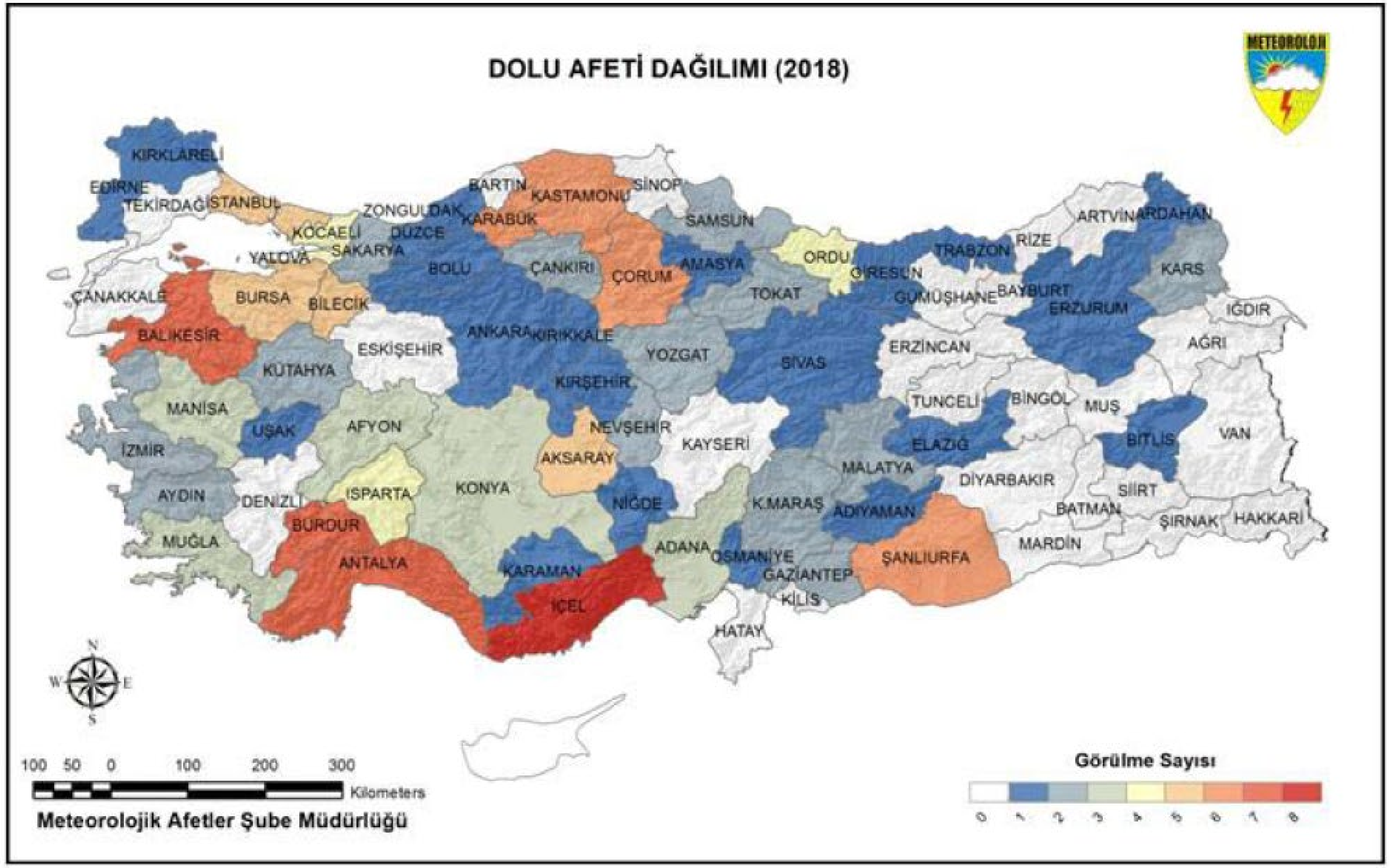

Tornado Disasters in 2018



Distribution Of Hail Disasters In Turkey (1940-2018)

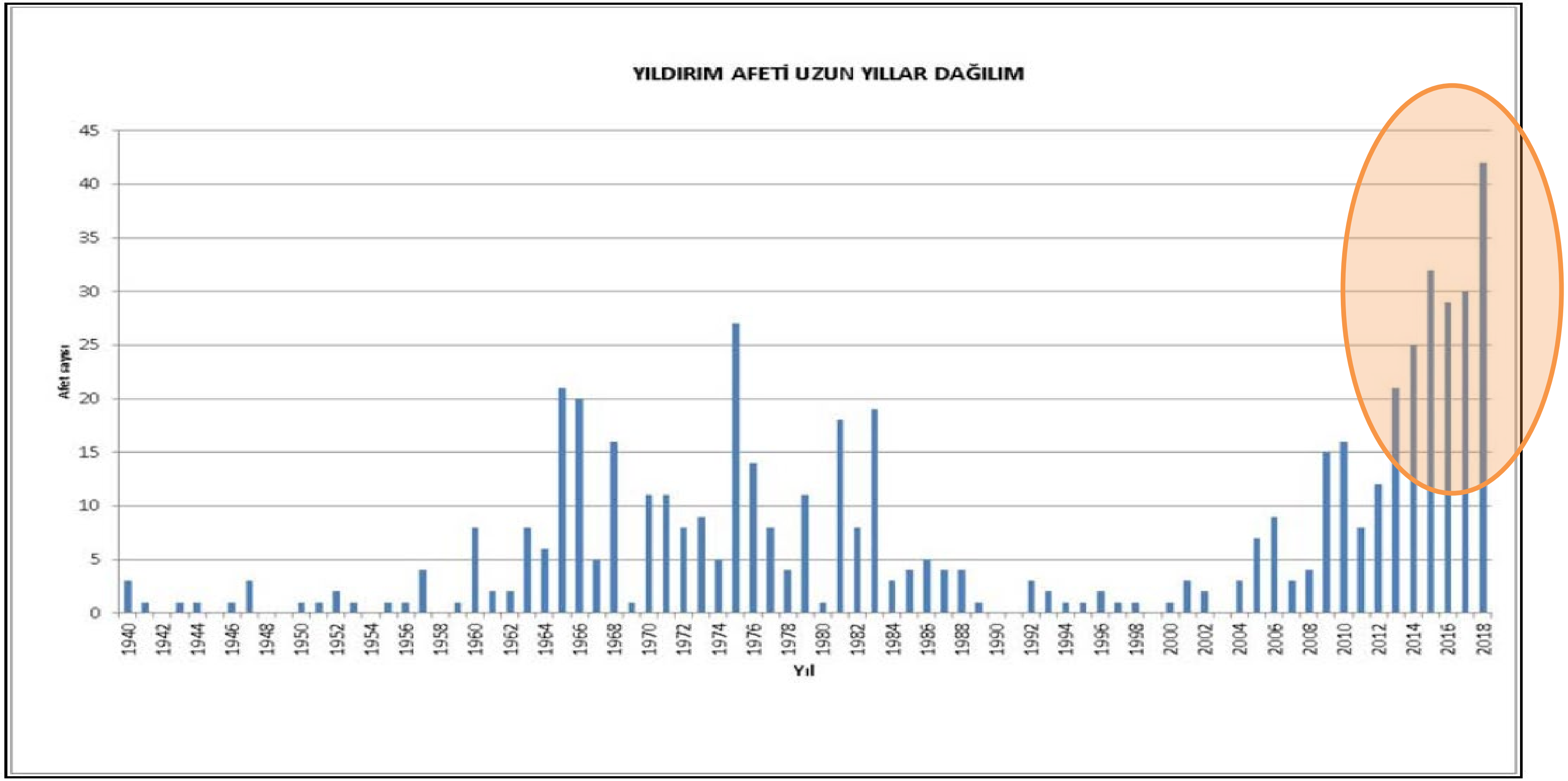


Hail Disasters in 2018

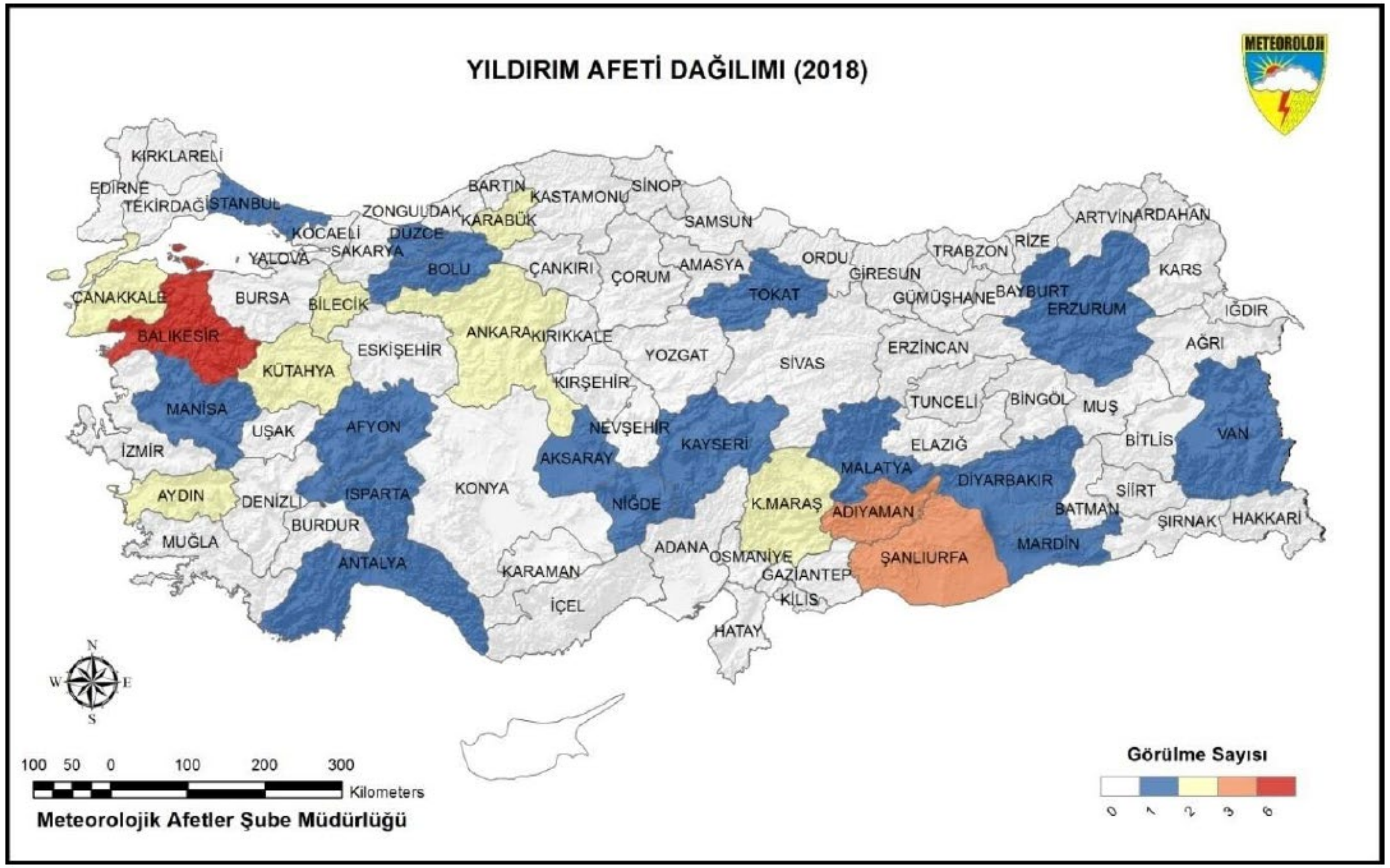



SABAH

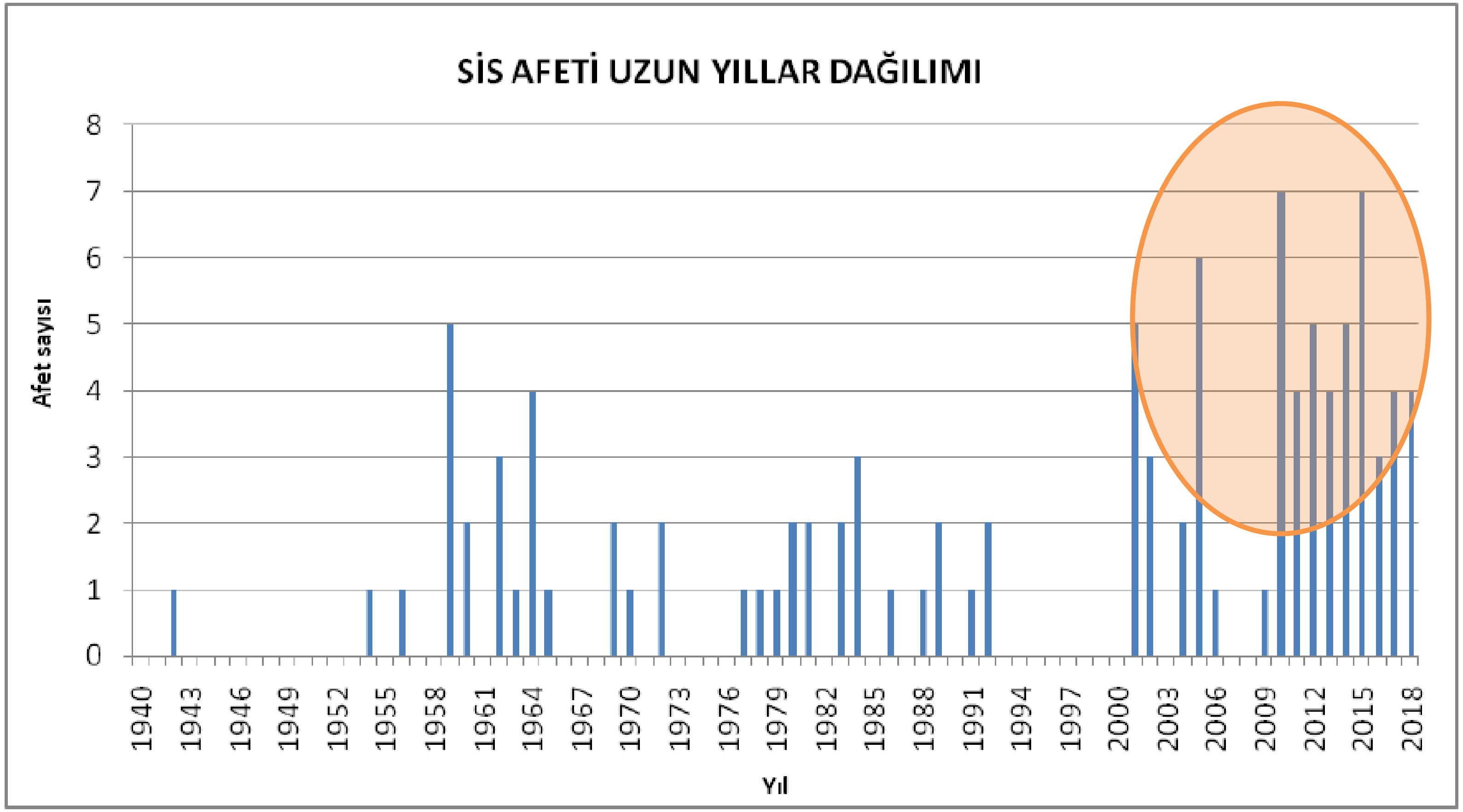
Distribution Of Lightining Disasters In Turkey Between (1940-2017)



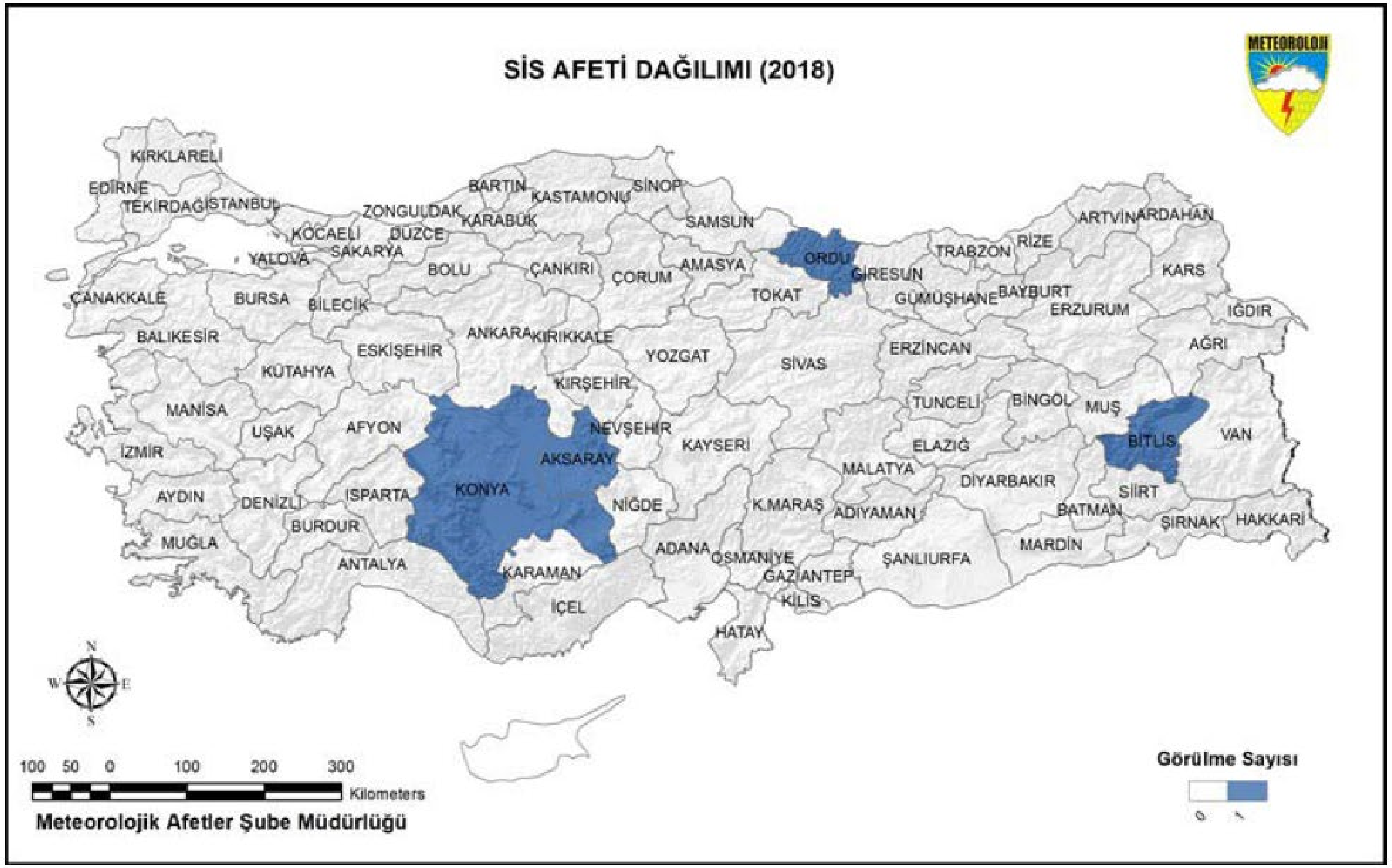
Lightning Disasters in 2018



Distribution Of Fog Disasters In Turkey (1940-2018)

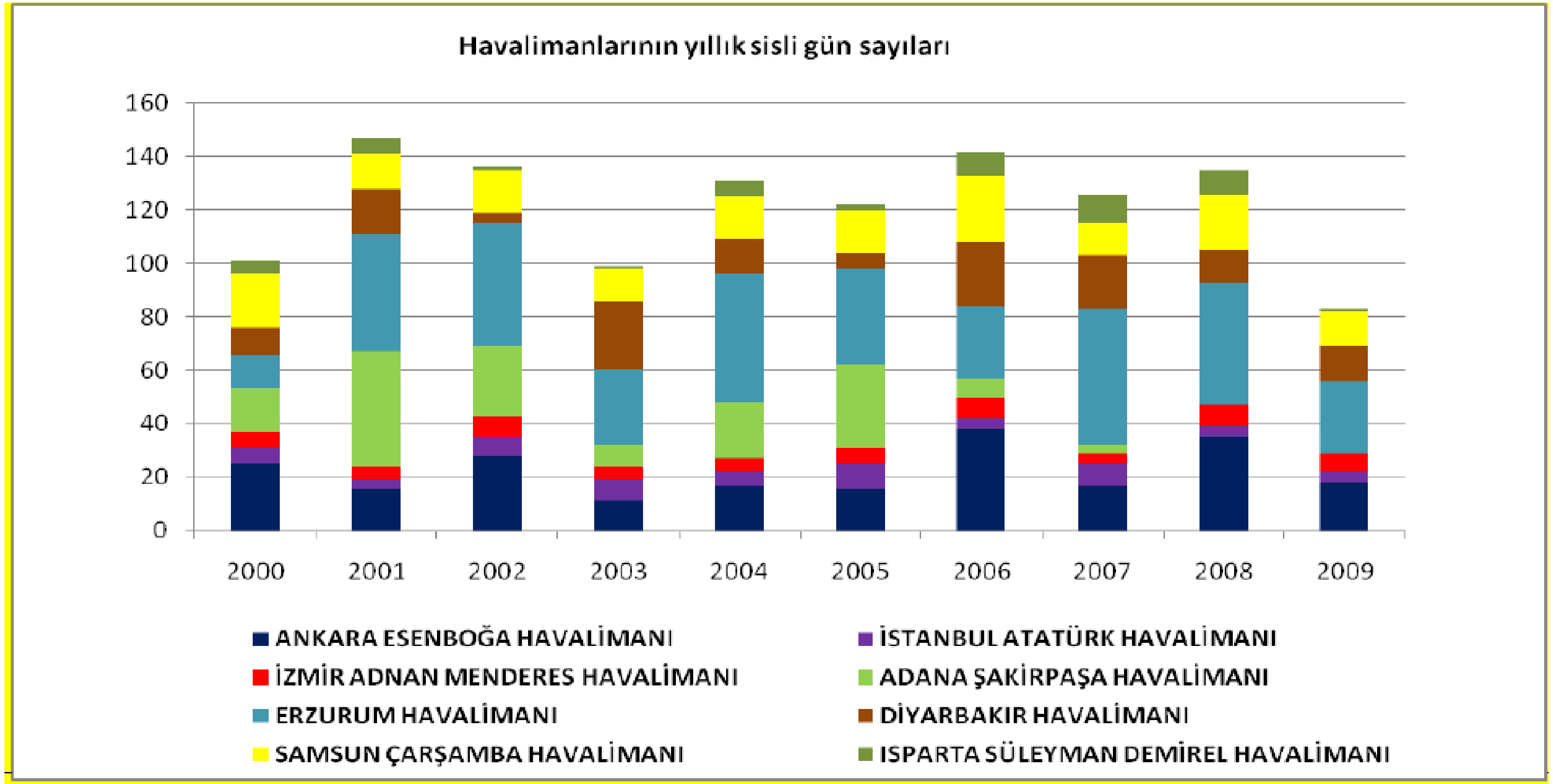


Fog Disasters in 2018

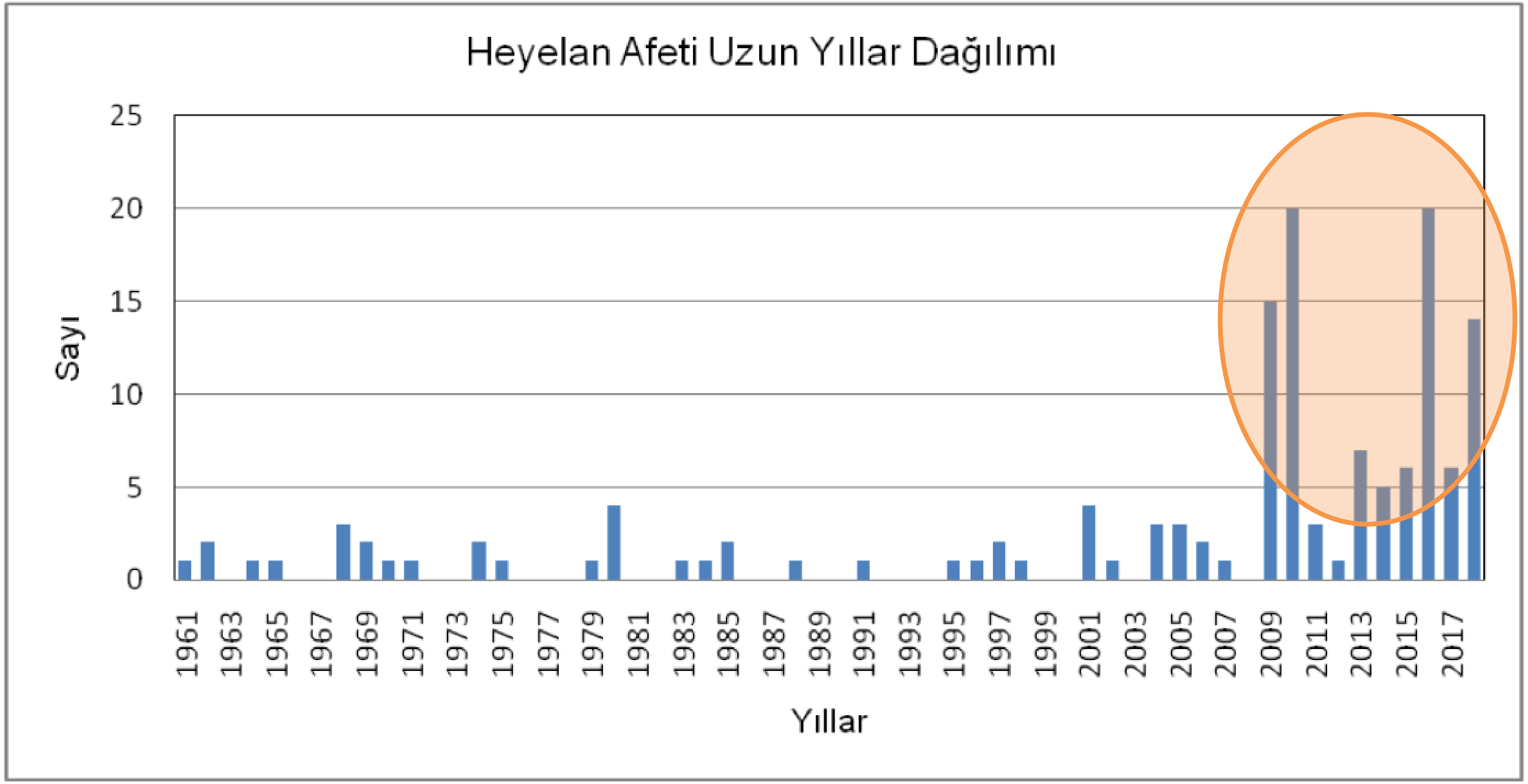


Traffic safety is in danger
Accessibilty problems
Mobility problems
Delays in terms of freight and passenger
Traffic accidents likely to be happened

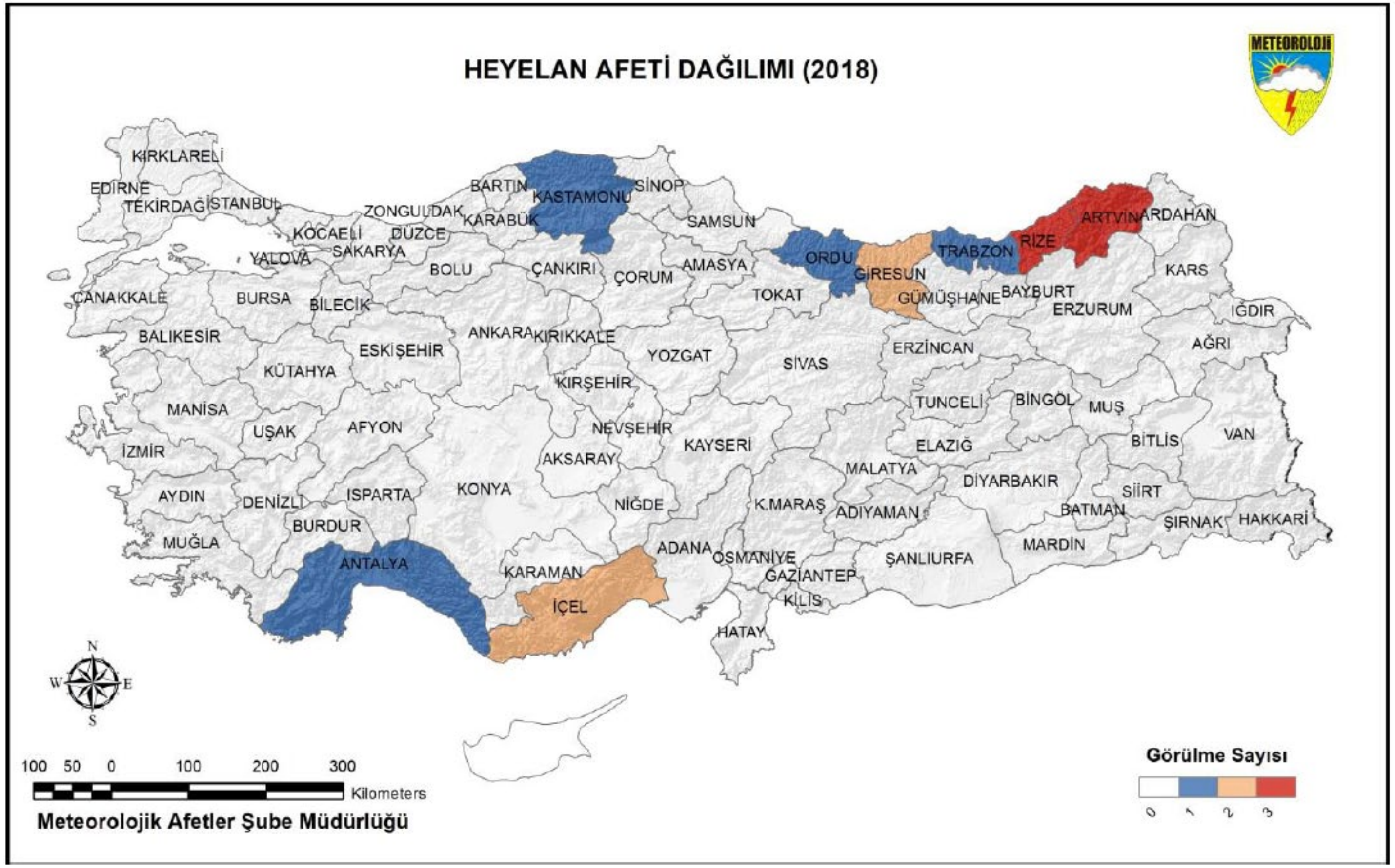
Total Fogy Days According to Airports Between (2000-2009)



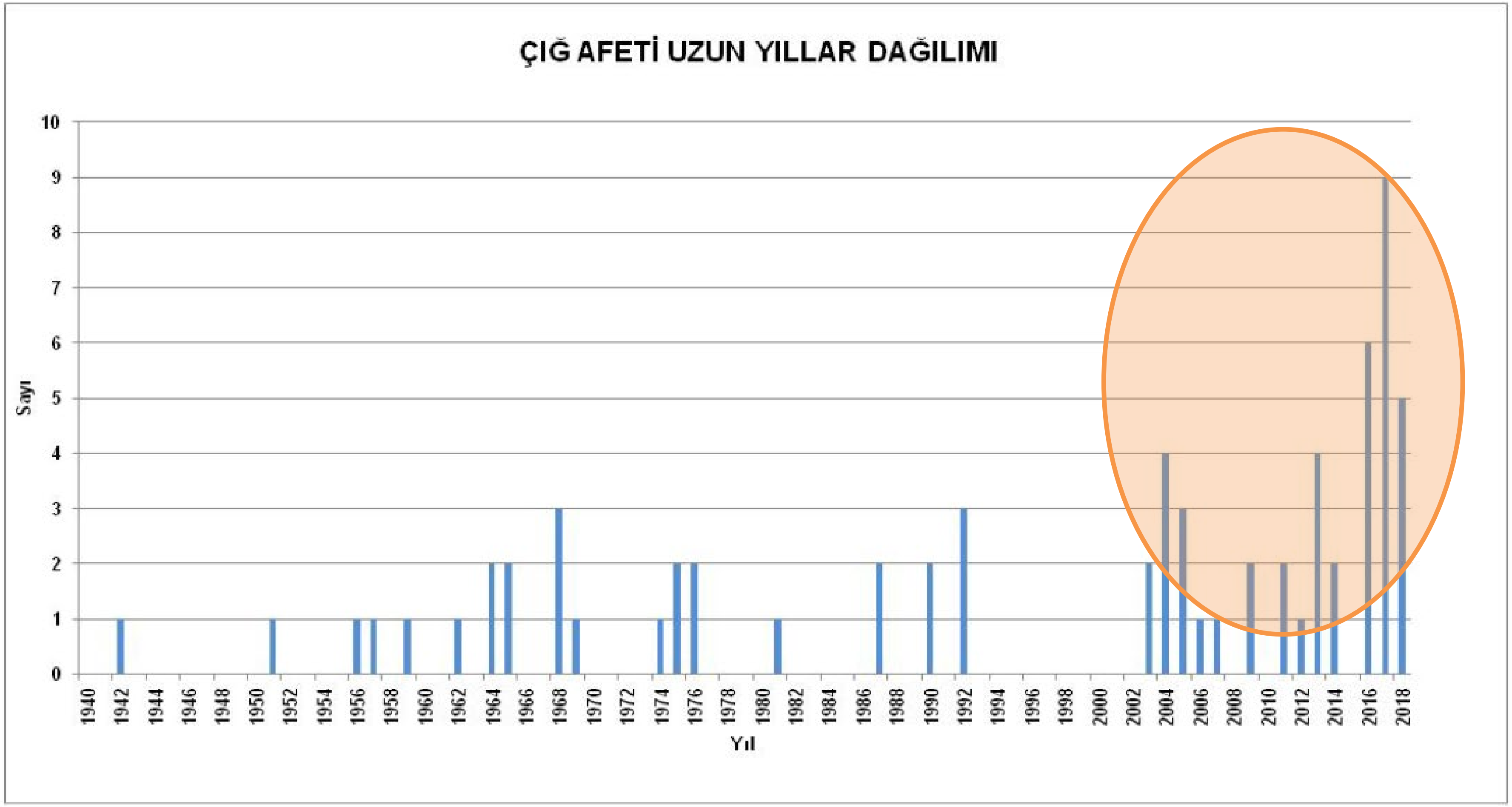
Distribution Of Landslide Disasters In Turkey (1961-2018)



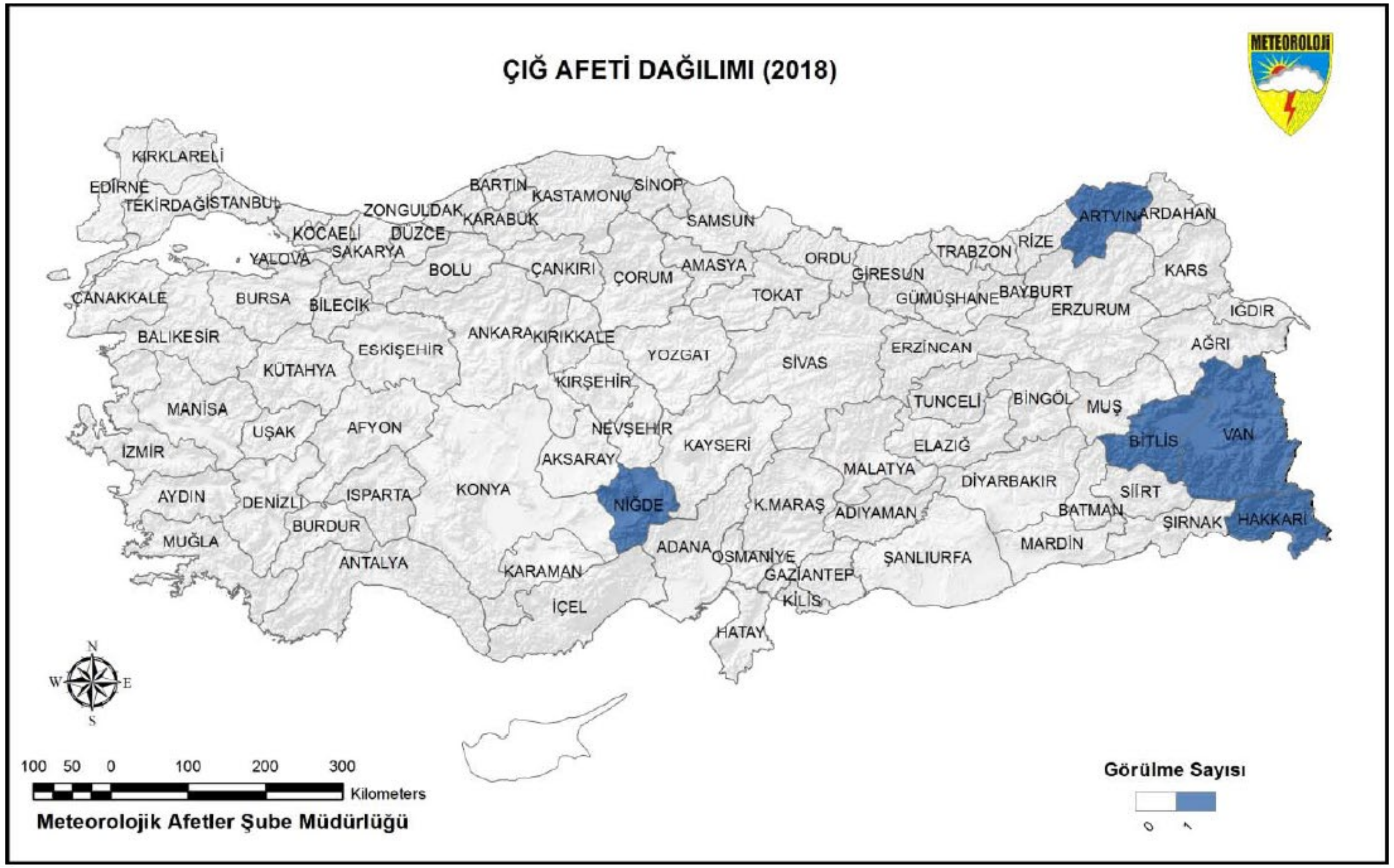
Landslide Disasters in 2018



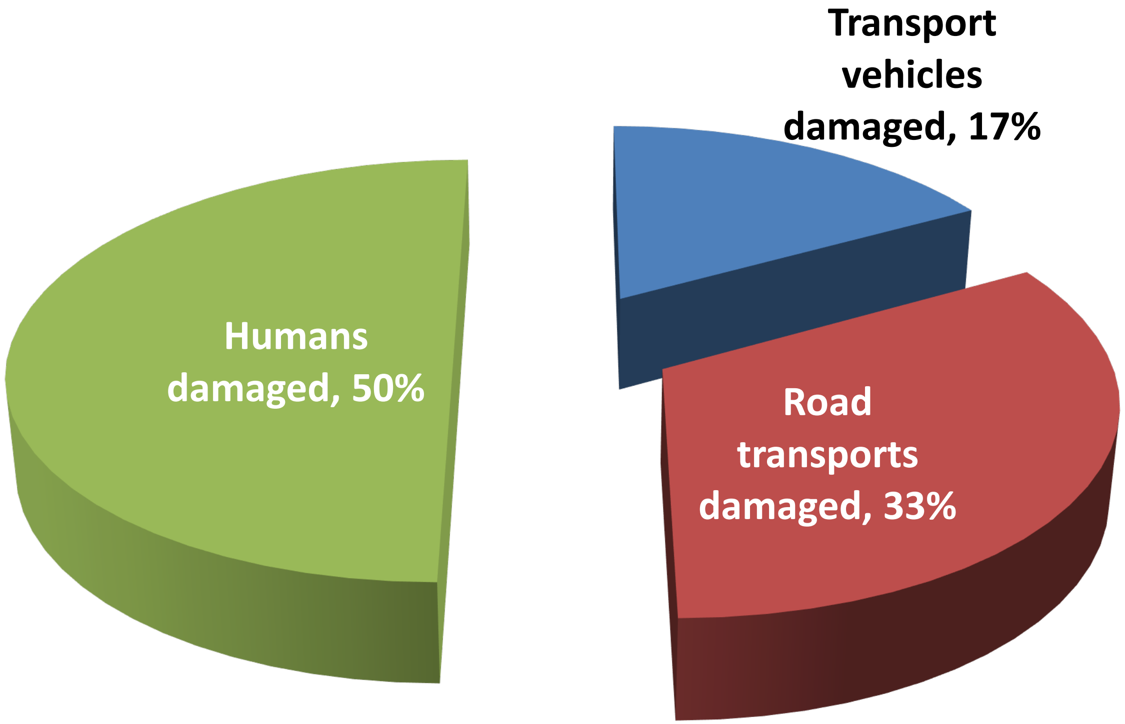
Distribution Of Avalanche Disasters In Turkey (1940-2018)



Avalanche Disasters in 2018



Avalanche Disasters Losses in Turkey in 2018



- The avalanche disaster seen in 2018 mostly affected the road and people.
- In most of the avalanches, snow masses coming from the mountains have a negative effect on the transportation of highways.
- Particularly in Eastern regions, a great number of vehicles and passengers are trapped as a result of avalanches falling after heavy snow.
- In order to eliminate the negative effects of this situation in our country, avalanche tunnels are being built on the road sections where it happens frequently.

Recurrence of Precipitation Intencity Reaches to 50 mm in 30 Minutes

Climate Change in Turkey

- Hotter summers
- Turning to desert climate
- Milder winters
- Drought seasons
- Precipitation regime is very irregular
  - Irregular rainfalls
  - Sudden and heavy rains
  - Rainy seasons is usuall and very hot
  - Facing severe thunderstorms, lightning and sudden and very strong rains from spring to fall season
- Changes in the frequency of freeze-thaw cycles
- Increases in sea-levels
- Thawing of permafrost areas
- Traffic safety froblems
- Delay for passenger and freight

Climate Change

- The earth's climate is predicted to change
- The change degree is unpredictable
- Specifically, heat waves will likely be more severe, sea level rise could amplify storm surges in coastal areas, and precipitation will likely be more intense
- Therefore the natural variability of weather patterns makes general conclusions difficult
- These changes could increase the risk of delays, disruptions, damage, and failure across our land-based, air, and marine transportation systems.
- Therefore, it is important to understand how future climate might affect these investments in the coming decades.

- We already have seen the climate change impacts in Turkey on roads too
- Each year coming worse than previous
- Especially changing precipitation regime impacts our roads badly
- Low volume roads are more affected than highways and motorways because of design factors
- Heavy rains, strong storms, extreme hot and snowy days impact the roads' structures and pavement

Climate Change Impacts on Transportation Systems

- Transportation engineers typically refer to historical records of climate, especially extreme weather events, when designing transportation systems.
- For example, bridges are often designed to withstand storms that have a probability of occurring only once or twice every 100 years.
- However, due to climate change, historical climate is no longer a reliable predictor of future risk.

Summary of Climate Change Impacts on the Highway System

	Climatic/ Weather Change	*Impact to Infrastructure*	*Impact to Operations/ Maintenance*
Temperature	**Change in extreme maximum temperature**	• Premature deterioration of infrastructure; • Damage to roads from buckling and rutting; • Bridges subject to extra stresses through thermal expansion and increased movement.	• Safety concerns for highway workers limiting construction activities; • Thermal expansion of bridge joints, adversely affecting bridge operations and increasing maintenance costs; • Vehicle overheating and increased risk of tire blow-outs; • Rising transportation costs (increase need for refrigeration); • Materials and load restrictions can limit transportation operations; • Closure of roads because of increased wildfires
	Change in range of maximum and minimum temperature	• Shorter snow and ice season; • Reduced frost heave and road damage; • Structures will freeze later and thaw earlier with shorter freeze season lengths • Increased freeze-thaw conditions in selected locations creating frost heaves and potholes on road and bridge surfaces; • Permafrost thawing leads to increased slope instability, landslides and shoreline erosion damaging roads and bridges due to foundation settlement (bridges and large culverts are particularly sensitive to movement caused by thawing permafrost); • Hotter summers in Alaska lead to increased glacial melting and longer periods of high stream flows, causing both increased sediment in rivers and scouring of bridge supporting piers and abutments.	• Decrease in frozen precipitation would improve mobility and safety of travel through reduced winter hazards, reduce snow and ice removal costs, decrease need for winter road maintenance, result in less pollution from road salt, and decrease corrosion of infrastructure and vehicles; • Longer road construction season in colder locations. • Vehicle load restrictions in place on roads to minimize structural damage due to subsidence and the loss of bearing capacity during spring thaw period (restrictions likely to expand in areas with shorter winters but longer thaw seasons); • Roadways built on permafrost likely to be damaged due to lateral spreading and settlement of road embankments; • Shorter season for ice roads.

Source: NCHRP

Summary of Climate Change Impacts on the Highway System

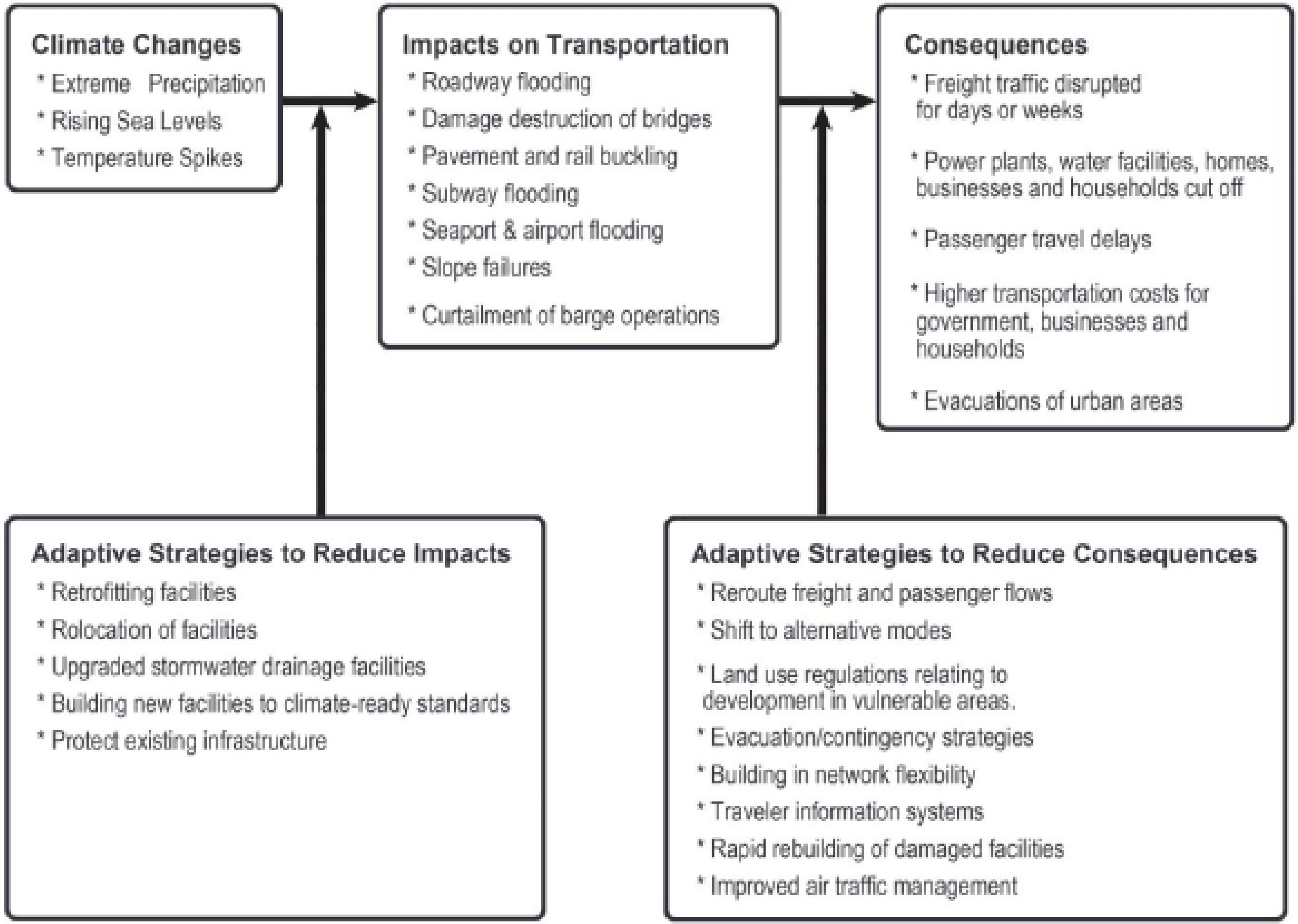
	Climatic/ Weather Change	Impact to Infrastructure	Impact to Operations/ Maintenance
Precipitation	**Greater changes in precipitation levels**	• If more precipitation falls as rain rather than snow in winter and spring, there will be an increased risk of landslides, slope failures, and floods from the runoff, causing road washouts and closures as well as the need for road repair and reconstruction; • Increasing precipitation could lead to soil moisture levels becoming too high (structural integrity of roads, bridges, and tunnels could be compromised leading to accelerated deterioration); • Less rain available to dilute surface salt may cause steel reinforcing in concrete structures to corrode; • Road embankments at risk of subsidence/heave; • Drought-caused shrinkage of subsurface soils	• Regions with more precipitation could see increased weather-related accidents, delays, and traffic disruptions (loss of life and property, increased safety risks, increased risks of hazardous cargo accidents); • Closure of roadways and underground tunnels due to flooding and mudslides in areas deforested by wildfires; • Increased wildfires during droughts could threaten roads directly, or cause road closures due to fire threat or reduced visibility; • Clay subsurfaces for pavement could expand or contract in prolonged precipitation or drought causing pavement heave or cracking
	Increased intense precipitation, other change in storm intensity (except hurricanes)	• Heavy winter rain with accompanying mudslides can damage roads (washouts and undercutting) which could lead to permanent road closures; • Heavy precipitation and increased runoff can cause damage to tunnels, culverts, roads in or near flood zones, and coastal highways; • Bridges are more prone to extreme wind events and scouring from higher stream runoff; • Bridges, signs, overhead cables, tall structures at risk from increased wind speeds	• The number of road closures due to flooding and washouts will likely rise; • Erosion at road construction project sites as heavy rain events take place more frequently; • Road construction activities could be disrupted; • Increase in weather-related highway accidents, delays, and traffic disruptions; • increase in landslides, closures or major disruptions of roads, emergency evacuations and travel delays; • Increased wind speeds could result in loss of visibility from drifting snow, loss of vehicle stability/maneuverability, lane obstruction (debris), and treatment chemical dispersion; • Lightning/electrical disturbance could disrupt transportation electronic infrastructure and signaling, pose risk to personnel, and delay maintenance activity

Source: NCHRP

Summary of Climate Change Impacts on the Highway System

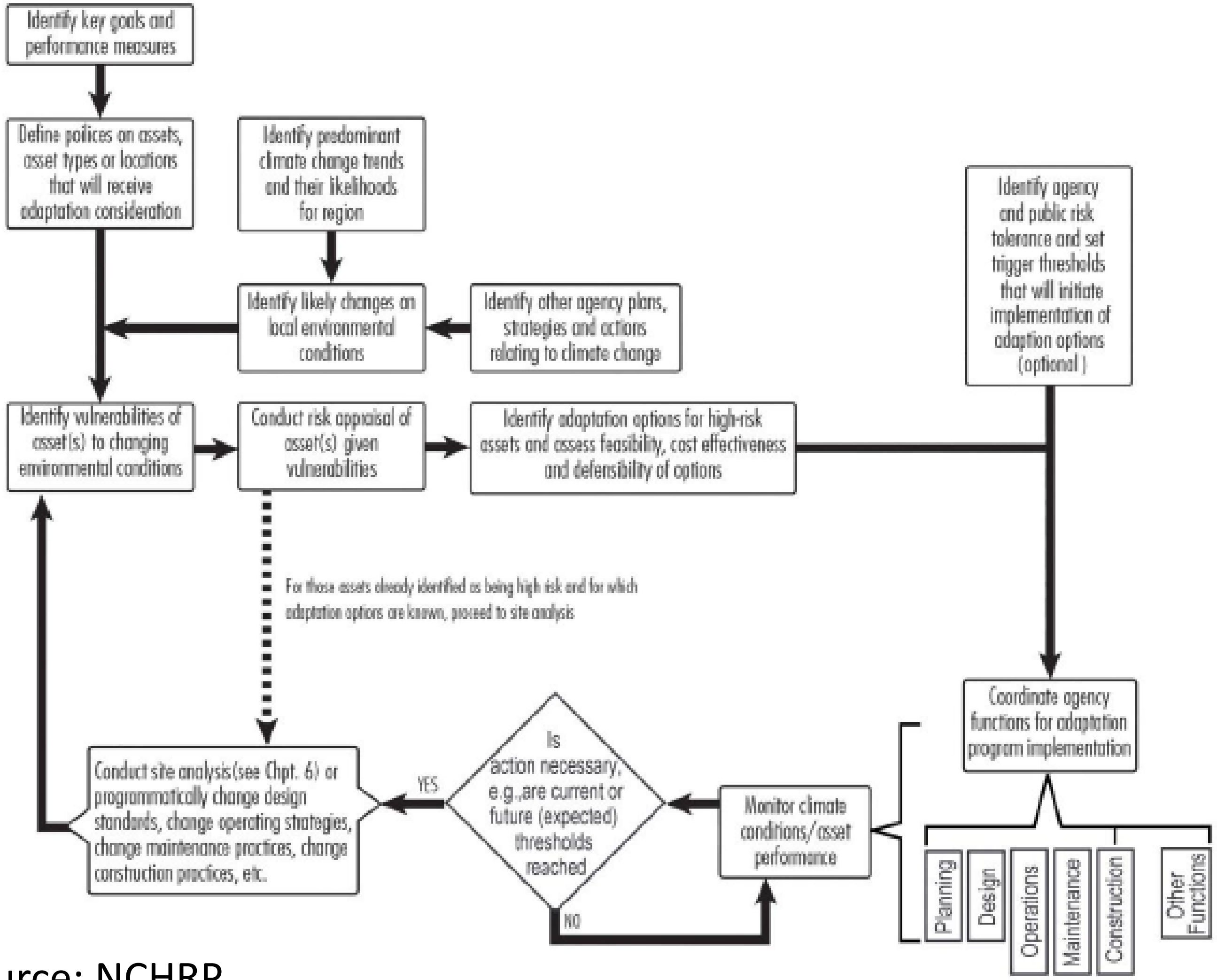
	Climatic/ Weather Change	Impact to Infrastructure	Impact to Operations/ Maintenance
Sea level rise	**Sea level rise**	• Higher sea levels and storm surges will erode coastal road base and undermine bridge supports; • Temporary and permanent flooding of roads and tunnels due to rising sea levels; • Encroachment of saltwater leading to accelerated degradation of tunnels (reduced life expectancy, increased maintenance costs and potential for structural failure during extreme events); • Loss of coastal wetlands and barrier islands will lead to further coastal erosion due to the loss of natural protection from wave action	• Coastal road flooding and damage resulting from sea-level rise and storm surge; • Underground tunnels and other low-lying infrastructure will experience more frequent and severe flooding;
Hurricanes	**Increased hurricane intensity**	• Stronger hurricanes with more precipitation, higher wind speeds, and higher storm surge and waves are projected to increase; • Increased infrastructure damage and failure (highway and bridge decks being displaced)	• More frequent flooding of coastal roads; • More transportation interruptions (storm debris on roads can damage infrastructure and interrupt travel and shipments of goods); • More coastal evacuations

Source: NCHRP



Source; Cited in NCHRP By National Climate Assessment (NCA) working group on climate-related transportation impacts, May, 2012. Printed with permission.

Adaptation Diagnostic Framework



Source: NCHRP

Climate Change Impacts Mitigation Precautions

- Some changes have been made in the hydrological design for nearly ten years to prevent or reduce the damage caused by floods, which have become an important problem in recent years, to the roads and the environment starting from 2006-2007.

Those are

- Do not narrow the existing stream bed cross-section when the highways cross the break line,
- Prefer single-cell culverts instead of multi-cell culverts for flow safety and capacity,
- Design 2.0x2.0 m. minimum culvert size
- Design the hydraulic structure to pass 100-year flood discharge with enough freeboard and 500-year flood discharge without freeboard.

Briefly

- Rural bridges are being designed for 500 years precipitation regime and urban bridges designed for 1000 years precipitation regime
- Culverts are being designed for 100 and 500 years precipitation regime according to their location


HIDROMEK
Vaillant

Predicted Climate Change Impacts on Roads

- Disruption of the network by strong weather (rain, snow, high temperatures)
- Damage to roads through deterioration, deformation and subsidence
- Flooding from rivers, seas and inadequate land drainage
- Severance of routes by erosion, landslides and avalanches
- Damages to bridges by heavy rain, strong winds, storms
- Damage to roadside infrastructure by high winds
- New challenges to road safety

Climate Change Impacts on Roads

According to ROADEX Likelihood Climate Change Impacts

- Stability problems on road embankments
- Freeze-thaw cycles of paved and unpaved roads
- Rutting due to spring thaw weakening of paved and unpaved roads
- Differential frost heave
- Settlement due to permafrost
- Sheet ice problems
- Winter maintenance problems due to icing
- Winter maintenance problems due to drifting snow
- Avalanches
- Erosions of paved and unpaved roads due to heavy rains
- Flooding
- Landslides
- Rise of sea level

TRL Likelihood Climate Change Impacts on Maintenance

Benchmarking Transport Infrastructure Construction Costs, 8th Session

DfT, 2004 The Changing Climate: Impact on the Department for Transport

- Increased risk of flooding, inadequate drainage
- Deterioration and damage to highway structures from subsidence, heave and high temperatures
- Damages to structures from high winds
- Increased road safety problems as a result of adverse driving conditions and deterioration of infrastructure
- Effects on the management of trees, landscape and biodiversity

The London Climate Change Partnership (2006)

- Carriageway rutting
- Embankment subsidence
- Deteoriation of concrete
- Problems with expansion joints
- Increase in dust levels
- Reduction in skid resistance

Predicted Climate Change Impacts

Effects On Low Volume Roads

Low volume rural roads with thin pavements on the other hand are unlikely to be able to cope with the increased risks in their present state.

Predicted Climate Change Impacts

Effects On High Volume Roads

Not all roads are expected to be affected by the predicted changes. Modern well designed, high speed, main roads with thick asphalt layers are expected to survive the changing climate relatively well.

Predicted Climate Change Drainage Impacts on Low Volume Roads

- Potholes
- Scoured gravel Shoulders
- Erosion and surface slides in road cut slopes
- Washouts along edge of road
- Unstable roadways
- Culvert defects (e.g. Washouts due to overtopping or reduced inlet / outlet flow)
- Ditch defects (e.g. Erosion of slopes, inlets, ditches clogged)

- Alligator cracking
- Rutting, longitudinal Cracking
- Edge Cracking

Temperature Impacts

- Higher summer temperatures and solar radiation may affect the long-term durability of pavements, and gravel roads, but the effects are unlikely to be significant
- These could include an increase in top-down cracking, some increase in rutting, a slight increase in asphalt aging, decreased thermal cracking.
- Temperature increases have the potential to affect and reduce the life of asphalt road pavements through softening and traffic-related rutting.
- Higher temperatures can cause pavement to soften and expand
- This can create rutting and potholes, particularly in high-traffic areas and can place stress on bridge joints.
- Extreme heat can also stress the steel in bridges through thermal expansion and movement of bridge joints and paved surfaces.
- Heat waves can also limit construction activities, particularly in areas with high humidity.

Officials in Los Angeles are painting streets white to reduce the effect of urban "heat islands." (LA Street Services)

To reduce the effect of heat

Los Angeles are painting urban streets white

The sealant has reduced roadway temperatures by up to 10 degrees in testing. (LA Street Services)

Precipitation

- Precipitation, and the intensity of precipitation, is a key concern for all engineers involved in the design and maintenance of all classes of roads
- Climate change is projected to concentrate rainfall into more intense storms.
- "Heavy rain" and "flooding" rank as the top 3 concerns of climate change
- Higher soil moisture levels affects the structural integrity of roads, bridges, and tunnels and leading to accelerated deterioration.

Precipitation

- Flooding:

  There is greater risk of short and long term flooding
- Surface water drainage problems
- Erosion of roads and bridges
- Slope failures, landslides and avalanches
- Distrupt traffic
- Delay construction activities
- Weaken or wash out the soil and culverts that support roads tunnels, and bridges

Flooding

- Flooding is expected to be one of the most important impacts of climate change
- Examples of recent floods caused by heavy rains
- A common cause of flooding is the blocking of ditches, culverts and bridges by waterborne detritus, leading to water flows backing-up and seeking alternative routes.

Flooding

- Bridge / culvert capacities reduced or exceeded, causing upstream flooding to occur
- Overtopping problems of structures
- Scour problem of structures, especially bridge piers and abutments
- Inundation of roads on flood plains
- Erosion of roads and embankments

Surface Water Drainage Problems

- A good drainage regime quickly removes water from the road surface and ensures traffic safety
- Drainage also provides effective drainage for the sub-surface to maximize longevity of the pavement and protect the underlying earthworks

Erosion Of Roads And Bridges

- Erosion of bridges, “scour”, can occur at the foot of piers and abutments where sediment (sand, stones) is washed away from the river bottom
- Erosion of the carriageways of roads can involve erosion of the surfacing layer (especially in case of gravel roads) and erosion of the road structure, such as the embankment, cutting, side slope or shoulder. All of these problems can occur during and /or after heavy, sudden rains, and are likely to increase in the future if the predicted climate changes take effect.

Frost damage

- Frost damage is a major issue for roads in cold climates around the world. Seasonal changes, freeze-thaw cycles and the damage they cause are significant factors affecting the road condition

Sea level rise

- The predicted rises in sea level due to climate change may pose increased threats to the coastal areas of

- Flooding of low-lying coastal roads
- Erosion of roads and embankments along the coastline
- Flooding and erosion of causeways

An Approach for Considering Risk in Decision Making

Level	Likelihood
A	Remote
B	Unlikely
C	Likely
D	Highly Likely
E	Near Certainty

ASSESSMENT GUIDE

Likelihood	a	b	c	d	e
E	M	M	H	H	H
D	L	M	M	H	H
C	L	L	M	M	H
B	L	L	L	M	M
A	L	L	L	L	M

Consequence

Level	Schedule	and/or	Cost
a	Minimal or no impact		Minimal or no impact
b	Additional resources required; able to meet		<5%
c	Minor slip in key milestones; not able to meet need date		5-7%
d	Major slip in key milestone or critical path impacted		7-10%
e	Can't achieve key team or major program milestone		>10%

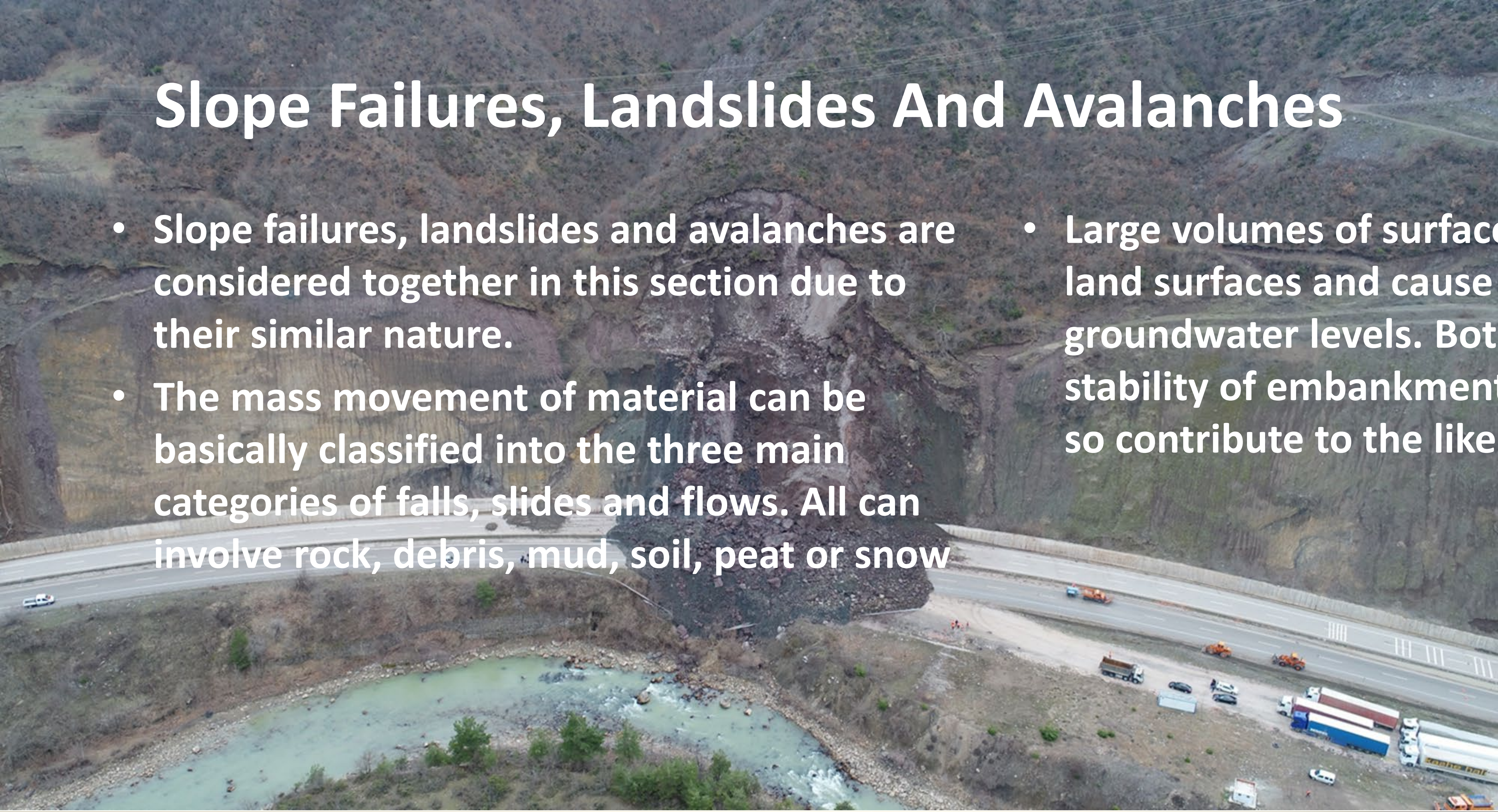
RISK ASSESSMENT

High (Red)
Unacceptable. Major disruption likely. Different approach required. Priority management attention required

Moderate (Yellow)
Some disruption. Different approach may be required. Additional management attention may be needed

Low (Green)
Minimum impact. Minimum oversight needed to ensure risk remains low

Source: (FHWA, 2012a)



Slope Failures, Landslides And Avalanches

- Slope failures, landslides and avalanches are considered together in this section due to their similar nature.
- The mass movement of material can be basically classified into the three main categories of falls, slides and flows. All can involve rock, debris, mud, soil, peat or snow
- Large volumes of surfac
land surfaces and cause
groundwater levels. Bot
stability of embankmen
so contribute to the like


MERSİN-
TURKEY


HATAY -
TURKEY


ANKARA -
TURKEY


İSTANBUL -
TURKEY

AFTER FLOOD DISASTER OF BODRUM- MUĞLA DUE TO HEAVY RAIN

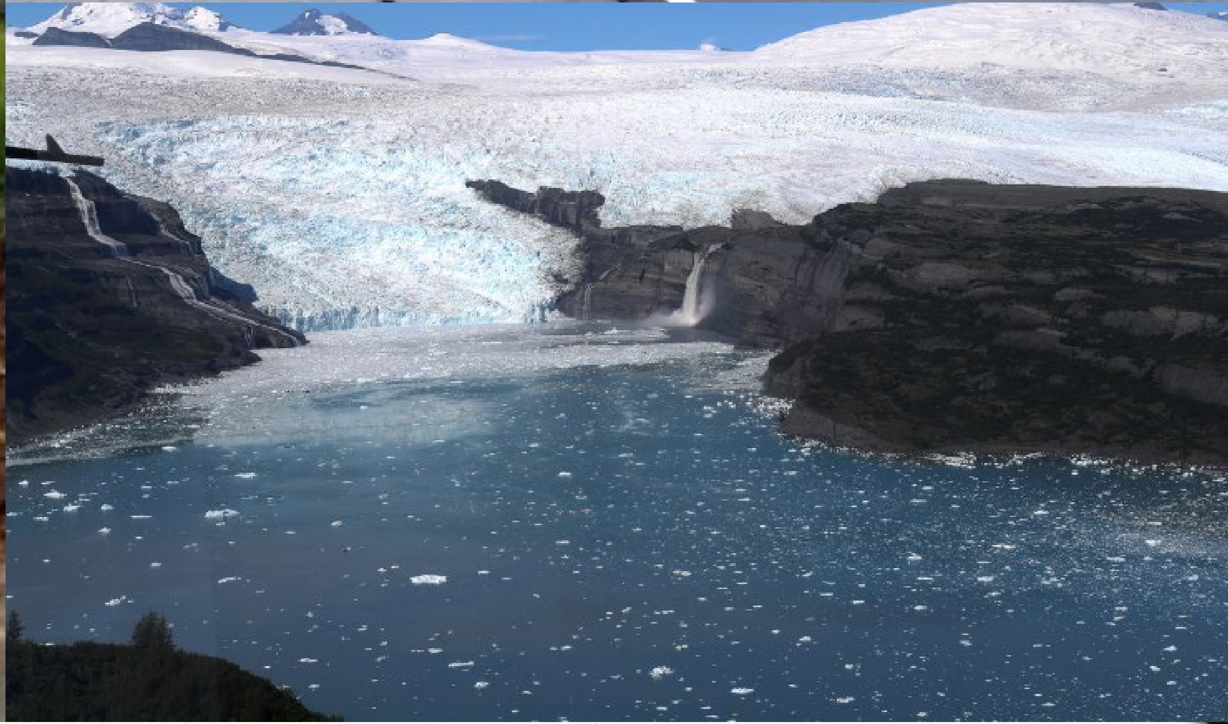
MUĞLA-BODRUM-TURKEY


İSTANBUL -TURKEY


MUĞLA-BODRUM-TURKEY


İSTANBUL -TURKEY


USA -
VERMONT

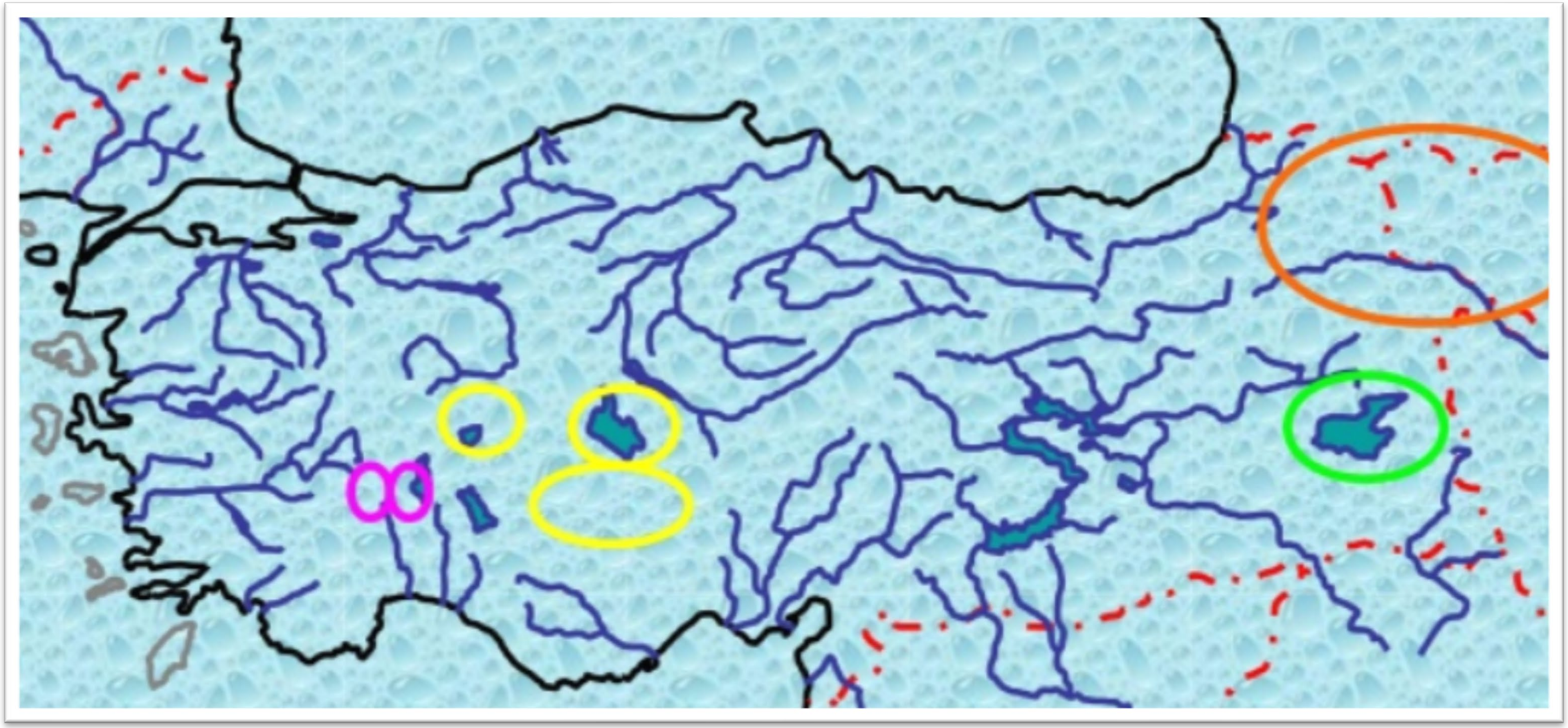

MECSICO


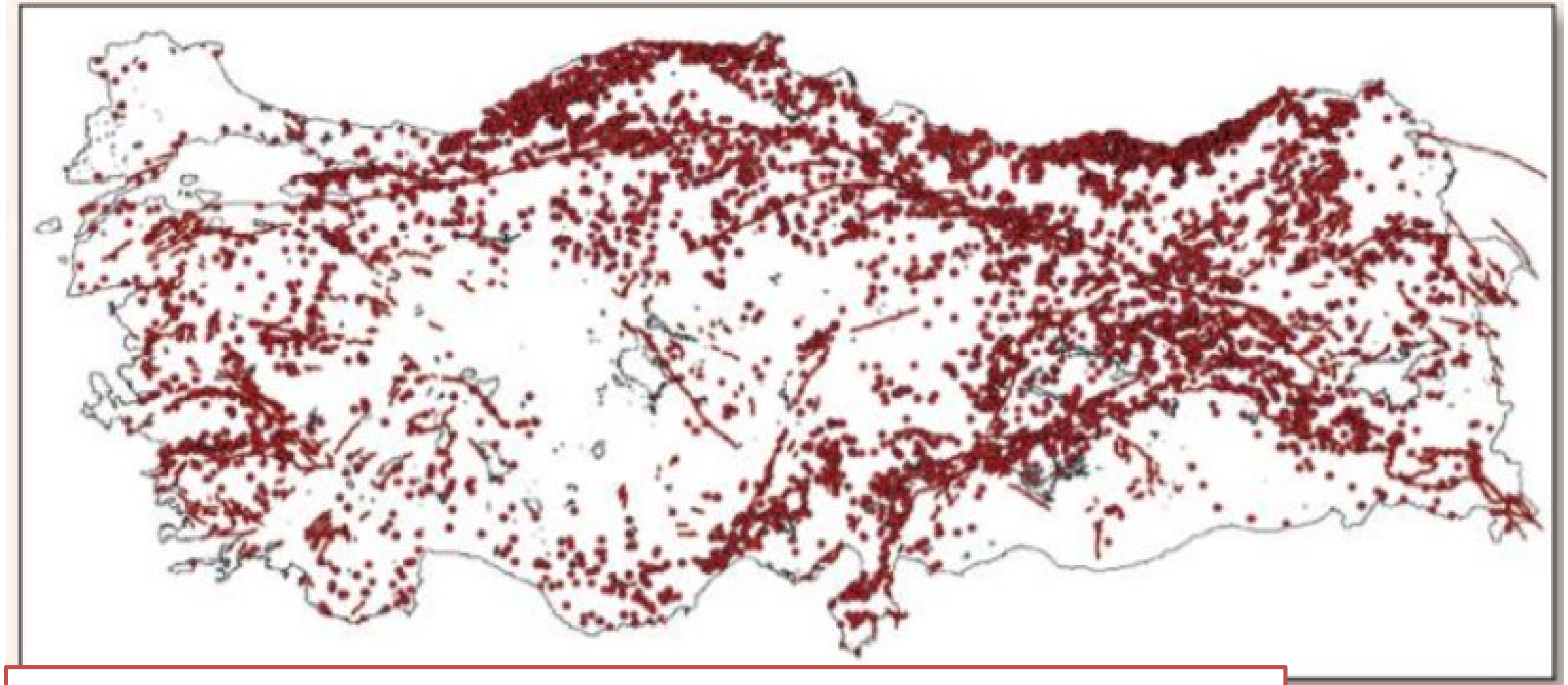

FRANCE


GERMANY

Rivers and River Basins

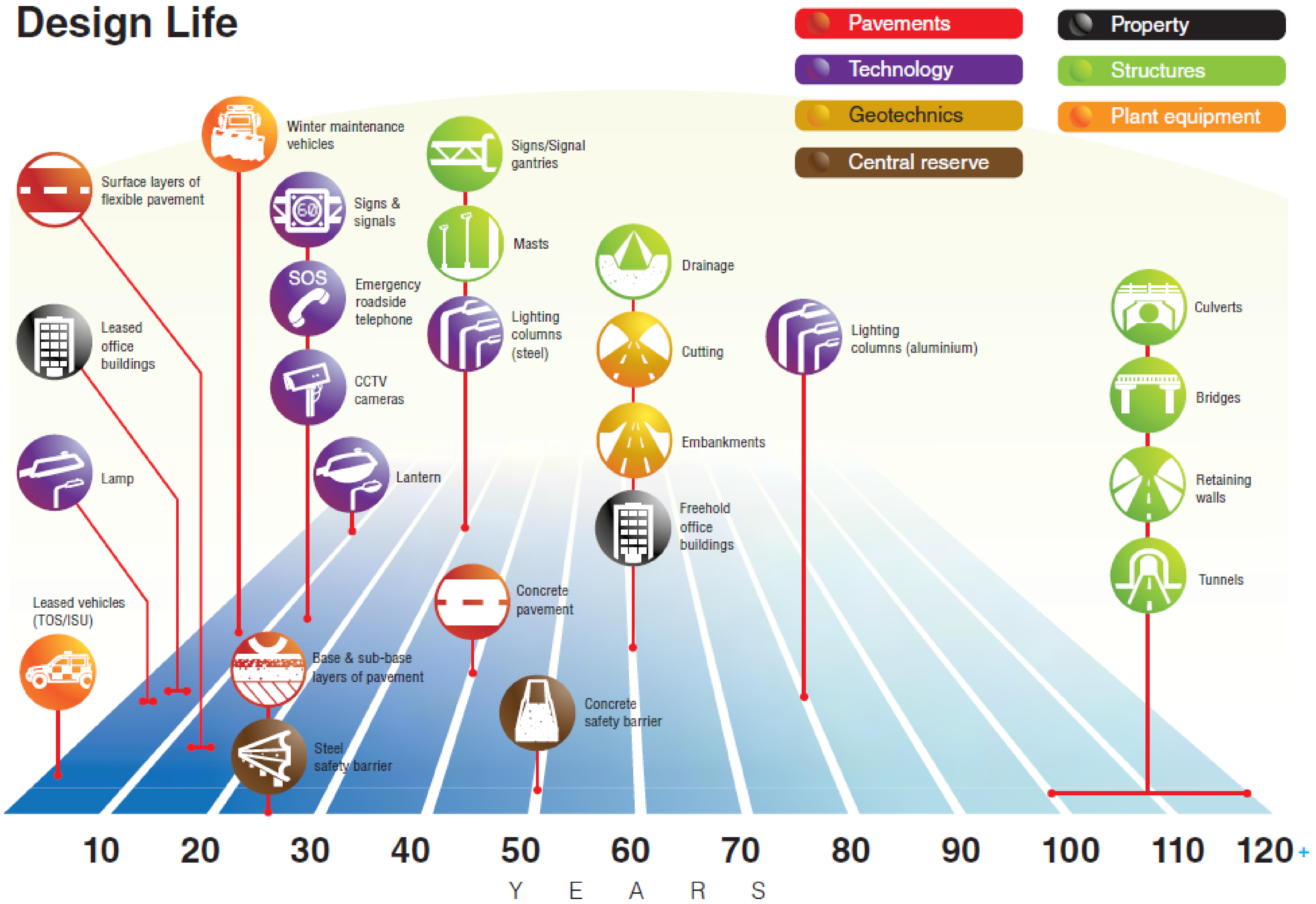
Closed Basins in Turkey



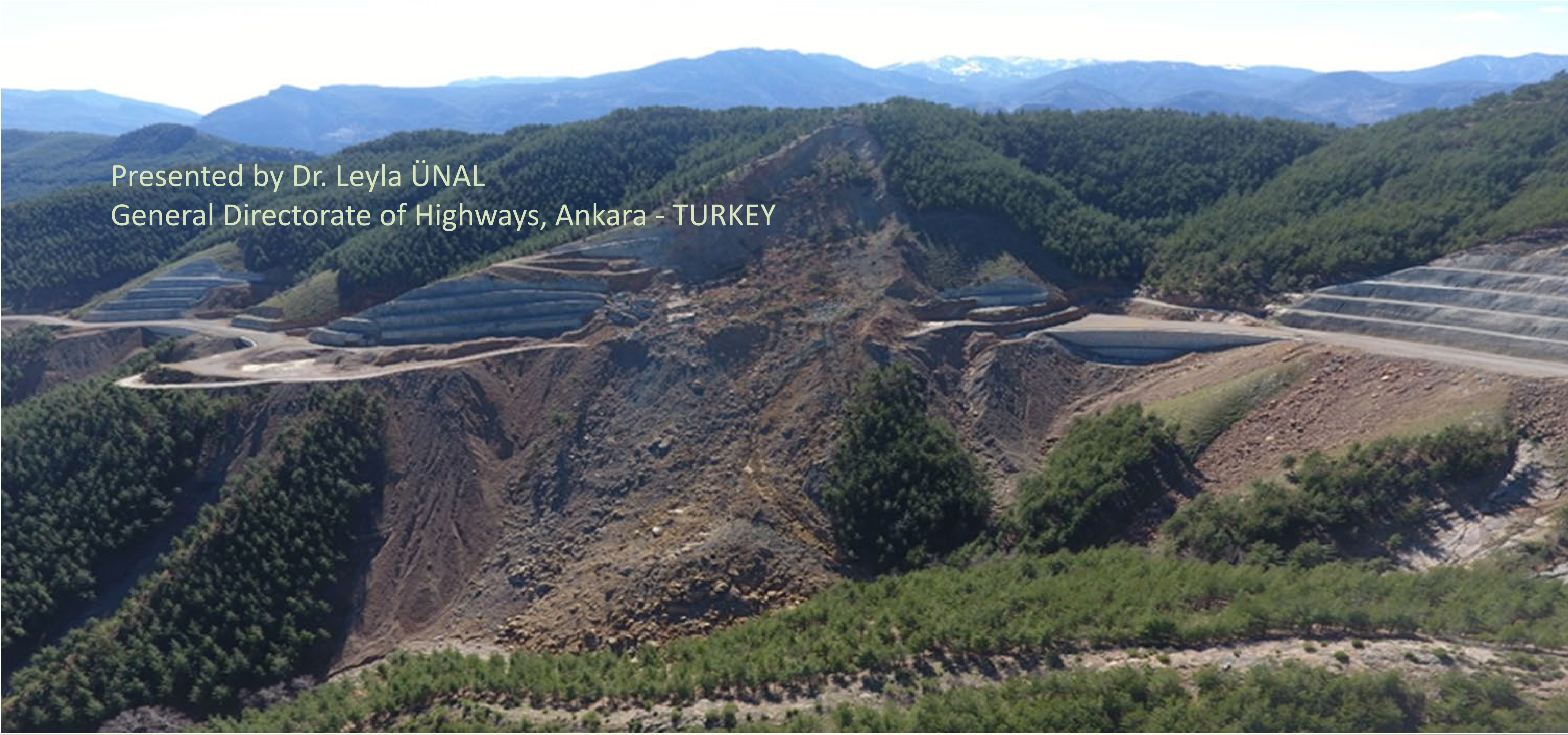


Landslides in Turkey (2015, AFAD)

Design lives of assets (UK Highways Agency, 2011).



Benchmarking Transport Infrastructure Construction Costs, 8th Session



Presented by Dr. Leyla ÜNAL
General Directorate of Highways, Ankara - TURKEY