test mappings

alessandro monteleone

September 2025

1 Mappings

1.1 glbl_earthquake

$$(\forall id, intensity, depth.(\exists x_1, ..., x_{21}.earthquakes\_by\_country(id, intensity, depth, x_1, ..., x_{21})))\wedge$$
$$(\forall id, mag, mag\_ms, mag\_ml, mag\_mw, mag\_mb, mag\_mfa, mag\_unk.($$
$$\exists x_1, ..., x_{19}.earthquakes\_by\_magnitude(id, ..., mag\_unk, x_1, ..., x_{19}))) \longrightarrow earthquake(id,$$
$$natural\_event\_id =' earthquake\_' + id, intensity, depth, mag, mag\_ms,$$
$$mag\_ml, mag\_mw, mag\_mb, mag\_mfa, mag\_unk) \quad (1)$$

1.2 glbl_eruption

$$\forall eruption, eruption\_location, significant, vei, agent, eruption\_status, volcano\_id, id.($$
$$\exists x_1, ..., x_{36}.eruptions(eruption, ..., id, x_1, ..., x_{36})) \longrightarrow eruption(eruption, eruption\_location, significant, vei,$$
$$agent, eruption\_status, volcano\_id, id, natural\_event\_id =' eruption\_' + id) \quad (2)$$

1.3 glbl_tsunami

$$\forall id, event\_validity, cause\_code, num\_deposits, num\_runups, ts\_intensity,$$
$$oceanic\_tsunami, max\_water\_height, mag, ts\_mtii, depth, ts\_mtabe, warning\_status\_id,$$
$$cause, validity, warning\_status, natural\_event\_id, year, month, day, hour, min, sec.($$
$$\exists x_1, ..., x_{36}.tsunami(id, ..., sec, x_1, ..., x_{36})) \longrightarrow tsunami(id, natural\_event\_id =' tsunami\_'+id,$$
$$event\_validity, cause\_code, num\_deposits, num\_runups, ts\_intensity,$$
$$oceanic\_tsunami, max\_water\_height, mag, ts\_mtii, depth, ts\_mtabe, warning\_status\_id,$$
$$cause, validity, warning\_status, natural\_event\_id, year, month, day, hour, min, sec) \quad (3)$$

1.4 glbl_volcano

$$\forall country, elevation, id, lat, volcano\_location, lon, morphology, volcano\_name, region, volcano\_status, time\_erupt, new\_num, num.(\exists x_1, ..., x_6.volcanoes(country, ..., num, x_1, ..., x_6)) \longrightarrow volcano(country, elevation, id, lat, volcano\_location, lon, morphology, volcano\_name, region, volcano\_status, time\_erupt, new\_num, num) \tag{4}$$

1.5 glbl_tornado_trace

$$\forall id, f\_scale, lat\_end, lon\_end, trace\_length, width, alt\_mag, order\_idx, crop\_damage\_millions.(\exists x_1, ..., x_{16}.traces(id, ..., crop\_damage\_millions, x_1, ..., x_{16})) \longrightarrow volcano(id, natural\_event\_id =' tornado\_' + id, f\_scale, lat\_end, lon\_end, trace\_length, width, alt\_mag, order\_idx, crop\_damage\_millions) \tag{5}$$

1.6 glbl_related_event

$$\forall earthquake\_id, eruption\_id.(\exists x_1, ..., x_{22}.earthquakes\_by\_country('earthquake\_'+earthquake\_id, 'eruption\_'+eruption\_id, x_1, ..., x_{22})) \longrightarrow related\_event(earthquake\_id, eruption\_id) \tag{6}$$

$$\forall earthquake\_id, tsunami\_id.(\exists x_1, ..., x_{22}.earthquakes\_by\_country('earthquake\_'+earthquake\_id, 'tsunami\_'+tsunami\_id, x_1, ..., x_{22})) \longrightarrow related\_event(earthquake\_id, tsunami\_id) \tag{7}$$

$$\forall earthquake\_id, eruption\_id.(\exists x_1, ..., x_{40}.eruptions('earthquake\_'+earthquake\_id, 'eruption\_'+eruption\_id, x_1, ..., x_{40})) \longrightarrow related\_event(earthquake\_id, eruption\_id) \tag{8}$$

$$\forall tsunami\_id, eruption\_id.(\exists x_1, ..., x_{40}.eruptions('tsunami\_' + tsunami\_id, 'eruption\_'+eruption\_id, x_1, ..., x_{40})) \longrightarrow related\_event(tsunami\_id, eruption\_id) \tag{9}$$

$$\forall tsunami\_id, earthquake\_id.(\exists x_1, ..., x_{56}.tsunami('tsunami\_' + tsunami\_id, 'earthquake\_'+earthquake\_id, x_1, ..., x_{56})) \longrightarrow related\_event(tsunami\_id, earthquake\_id) \tag{10}$$

$$\forall tsunami\_id, eruption\_id.(\exists x_1, ..., x_{56}.tsunami('tsunami\_' + tsunami\_id, \\ 'eruption\_'+eruption\_id, x_1, ..., x_{56})) \longrightarrow related\_event(tsunami\_id, eruption\_id) \tag{11}$$

1.7 glbl_natural_event

$$(\forall country, id, locationname, lat, lon, regionname, area, year, month, day, hour, min, sec.(\\ \exists x_1, ..., x_{11}.earthquakes\_by\_country(country, ..., sec, x_1, ...x_{11})))\wedge \\ (\forall dmg\_amt\_tot, dmg\_amt\_order, id, dmg\_mill, dmg\_mill\_tot.(\\ \exists x_1, ..., x_{17}.earthquakes\_by\_damage(dmg\_amt\_tot, ..., dmg\_mill\_tot, x_1, ..., x_{17})))\wedge \\ (\forall deaths\_tot, id, deaths, deaths\_ord, deaths\_ord\_tot.(\\ \exists x_1, ..., x_{17}.earthquakes\_by\_deaths(deaths\_tot, ..., deaths\_ord\_tot, x_1, ..., x_{17})))\wedge \\ (\forall id, injuries, inj\_ord, inj\_tot, inj\_ord\_tot.(\\ \exists x_1, ..., x_{17}.earthquakes\_by\_injuries(id, ..., inj\_ord\_tot, x_1, ..., x_{17})))\wedge \\ (\forall id, missing, miss\_ord, miss\_tot, miss\_ord\_tot.(\\ \exists x_1, ..., x_{17}.earthquakes\_by\_missing(id, ..., inj\_ord\_tot, x_1, ..., x_{17})))\wedge \\ (\forall id, houses\_destr, houses\_destr\_ord, houses\_destr\_tot, \\ houses\_destr\_ord\_tot, houses\_dmg, houses\_dmg\_ord, houses\_dmg\_tot, houses\_dmg\_ord\_tot.(\exists x_1, ..., x_{13}. \\ earthquakes\_by\_houses\_damages(id, ..., houses\_dmg\_ord\_tot, x_1, ..., x_{17}))) \longrightarrow natural\_event(country, id, \\ locationname, lat, lon, regionname, area, year, month, day, hour, min, sec, \\ dmg\_amt\_tot, dmg\_amt\_order, dmg\_mill, dmg\_mill\_tot, deaths\_tot, \\ deaths, deaths\_ord, deaths\_ord\_tot, injuries, inj\_ord, inj\_tot, \\ inj\_ord\_tot, missing, miss\_ord, miss\_tot, miss\_ord\_tot, houses\_destr, \\ houses\_destr\_ord, houses\_destr\_tot, houses\_destr\_ord\_tot, houses\_dmg, \\ houses\_dmg\_ord, houses\_dmg\_tot, houses\_dmg\_ord\_tot, event\_type =' earthquake') \tag{12}$$

$$\forall id, event\_ts, country, location, lat, lon, deaths\_ord, dmg\_ord,$$
$$deaths\_ord\_tot, dmg\_ord\_tot, houses\_destr\_ord, deaths\_tot, houses\_destr\_ord\_tot,$$
$$deaths, houses\_dmgd\_ord, houses\_dmgd\_ord\_tot, houses\_destr, houses\_destr\_tot, area,$$
$$inj, inj\_ord, inj\_tot, inj\_ord\_tot, houses\_dmgd, houses\_dmgd\_tot, miss\_tot,$$
$$miss\_ord\_tot, dmg\_mill\_tot, dmg\_mill, miss, miss\_ord, region, event\_type, year, month, day, hour, min, sec.($$
$$\exists x_1, ..., x_{23}.tsunami(id, ..., sec, x_1, ..., x_{23})) \longrightarrow natural\_event(country, id,$$
$$locationname, lat, lon, regionname, area, year, month, day, hour, min, sec,$$
$$dmg\_amt\_tot, dmg\_amt\_order, dmg\_mill, dmg\_mill\_tot, deaths\_tot,$$
$$deaths, deaths\_ord, deaths\_ord\_tot, injuries, inj\_ord, inj\_tot,$$
$$inj\_ord\_tot, missing, miss\_ord, miss\_tot, miss\_ord\_tot, houses\_destr,$$
$$houses\_destr\_ord, houses\_destr\_tot, houses\_destr\_ord\_tot, houses\_dmg,$$
$$houses\_dmg\_ord, houses\_dmg\_tot, houses\_dmg\_ord\_tot, event\_type =' tsunami') \tag{13}$$

$$(\forall dmg\_ord, houses\_destr, inj, location, lon, miss, dmg\_ord\_tot,$$
$$houses\_destr\_ord, inj\_ord, miss\_ord, country, dmg\_mill, houses\_destr\_ord\_tot,$$
$$inj\_ord\_tot, miss\_ord\_tot, dmg\_mill\_tot, houses\_destr\_tot, inj\_tot, miss\_tot,$$
$$event\_ts, id, lat, deaths, deaths\_ord, deaths\_ord\_tot, deaths\_tot,$$
$$houses\_dmgd\_ord\_tot, houses\_dmgd\_ord, houses\_dmgd, houses\_dmgd\_tot, volcano\_id,$$
$$year, month, day, hour, min, sec.(\exists x_1, ..., x_8.eruptions(dmg\_ord, ..., sec, x_1, ..., x_8)))\wedge$$
$$(\forall id, volcano\_id, region.(\exists x_1, ..., x_{13}.$$
$$volcanoes(id, volcano\_id, region, x_1, ...x_{13}))) \longrightarrow natural\_event(country, id,$$
$$locationname, lat, lon, regionname, area, year, month, day, hour, min, sec,$$
$$dmg\_amt\_tot, dmg\_amt\_order, dmg\_mill, dmg\_mill\_tot, deaths\_tot,$$
$$deaths, deaths\_ord, deaths\_ord\_tot, injuries, inj\_ord, inj\_tot,$$
$$inj\_ord\_tot, missing, miss\_ord, miss\_tot, miss\_ord\_tot, houses\_destr,$$
$$houses\_destr\_ord, houses\_destr\_tot, houses\_destr\_ord\_tot, houses\_dmg,$$
$$houses\_dmg\_ord, houses\_dmg\_tot, houses\_dmg\_ord\_tot, event\_type =' eruption') \tag{14}$$

$$(\forall trace\_id, injuries, deaths, dmg\_mill, lat, lon, state\_fips, dmg\_mill\_tot, dmg\_ord,$$
$$dmg\_ord\_tot, inj\_tot, inj\_ord, inj\_ord\_tot, missing, miss\_tot,$$
$$miss\_ord\_tot, miss\_ord, houses\_destr, houses\_destr\_tot, houses\_destr\_ord,$$
$$houses\_destr\_ord\_tot, deaths\_tot, deaths\_ord, deaths\_ord\_tot, country, regionname,$$
$$houses\_dmg, houses\_dmg\_tot, houses\_dmg\_ord\_tot, houses\_dmg\_ord, year, month, day, hour, min, sec.($$
$$\exists x_1, ..., x_{18}.traces(trace\_id, ..., sec, x_1, ..., x_{18})))\wedge$$
$$(\forall trace\_id, county\_fips.(\exists x_1, ..., x_2.trace\_affected\_counties(trace\_id, county\_fips, order\_idx = 1, x_2)))\wedge$$
$$(\forall name, county\_fips.(\exists x_1, ..., x_3.county(name, county\_fips, x_1, ..., x_3)))\wedge$$
$$(\forall name, state\_fips.(\exists x_1.states(name, state\_fips, x_1))) \longrightarrow natural\_event(country, id,$$
$$location name, lat, lon, regionname, area, year, month, day, hour, min, sec,$$
$$dmg\_amt\_tot, dmg\_amt\_order, dmg\_mill, dmg\_mill\_tot, deaths\_tot,$$
$$deaths, deaths\_ord, deaths\_ord\_tot, injuries, inj\_ord, inj\_tot,$$
$$inj\_ord\_tot, missing, miss\_ord, miss\_tot, miss\_ord\_tot, houses\_destr,$$
$$houses\_destr\_ord, houses\_destr\_tot, houses\_destr\_ord\_tot, houses\_dmg,$$
$$houses\_dmg\_ord, houses\_dmg\_tot, houses\_dmg\_ord\_tot, event\_type =' tornado')$$
(15)

2 Partial Equations

2.1 natural_event_earthquake

$$(\forall country, id, location name, lat, lon, regionname, area, year, month, day, hour, min, sec.($$
$$\exists x_1, ..., x_{11}.earthquakes\_by\_country(country, ..., sec, x_1, ...x_{11})))\wedge$$
$$(\forall dmg\_amt\_tot, dmg\_amt\_order, id, dmg\_mill, dmg\_mill\_tot.($$
$$\exists x_1, ..., x_{17}.earthquakes\_by\_damage(dmg\_amt\_tot, ..., dmg\_mill\_tot, x_1, ..., x_{17})))\wedge$$
$$(\forall deaths\_tot, id, deaths, deaths\_ord, deaths\_ord\_tot.($$
$$\exists x_1, ..., x_{17}.earthquakes\_by\_deaths(deaths\_tot, ..., deaths\_ord\_tot, x_1, ..., x_{17})))\wedge$$
$$(\forall id, injuries, inj\_ord, inj\_tot, inj\_ord\_tot.($$
$$\exists x_1, ..., x_{17}.earthquakes\_by\_injuries(id, ..., inj\_ord\_tot, x_1, ..., x_{17})))\wedge$$
$$(\forall id, missing, miss\_ord, miss\_tot, miss\_ord\_tot.($$
$$\exists x_1, ..., x_{17}.earthquakes\_by\_missing(id, ..., inj\_ord\_tot, x_1, ..., x_{17})))\wedge$$
$$(\forall id, houses\_destr, houses\_destr\_ord, houses\_destr\_tot,$$
$$houses\_destr\_ord\_tot, houses\_dmg, houses\_dmg\_ord, houses\_dmg\_tot, houses\_dmg\_ord\_tot.($$
$$\exists x_1, ..., x_{13}.earthquakes\_by\_houses\_damages(id, ..., houses\_dmg\_ord\_tot, x_1, ..., x_{17})))$$
(16)

2.2 natural_event_tsunami

$$\forall id, event\_ts, country, location, lat, lon, deaths\_ord, dmg\_ord,$$
$$deaths\_ord\_tot, dmg\_ord\_tot, houses\_destr\_ord, deaths\_tot, houses\_destr\_ord\_tot,$$
$$deaths, houses\_dmgd\_ord, houses\_dmgd\_ord\_tot, houses\_destr, houses\_destr\_tot, area,$$
$$inj, inj\_ord, inj\_tot, inj\_ord\_tot, houses\_dmgd, houses\_dmgd\_tot, miss\_tot,$$
$$miss\_ord\_tot, dmg\_mill\_tot, dmg\_mill, miss, miss\_ord, region, event\_type, year, month, day, hour, min, sec.($$
$$\exists x_1, ..., x_{23}.tsunami(id, ..., sec, x_1, ..., x_{23})) \quad (17)$$

2.3 natural_event_eruption

$$(\forall dmg\_ord, houses\_destr, inj, location, lon, miss, dmg\_ord\_tot,$$
$$houses\_destr\_ord, inj\_ord, miss\_ord, country, dmg\_mill, houses\_destr\_ord\_tot,$$
$$inj\_ord\_tot, miss\_ord\_tot, dmg\_mill\_tot, houses\_destr\_tot, inj\_tot, miss\_tot,$$
$$event\_ts, id, lat, deaths, deaths\_ord, deaths\_ord\_tot, deaths\_tot,$$
$$houses\_dmgd\_ord\_tot, houses\_dmgd\_ord, houses\_dmgd, houses\_dmgd\_tot, volcano\_id,$$
$$year, month, day, hour, min, sec.($$
$$\exists x_1, ..., x_8.eruptions(dmg\_ord, ..., sec, x_1, ..., x_8)))\wedge$$
$$(\forall id, volcano\_id, region.(\exists x_1, ..., x_{13}.volcanoes(id, volcano\_id, region, x_1, ...x_{13})))$$
(18)

2.4 natural_event_tornado

$$(\forall trace\_id, injuries, deaths, dmg\_mill, lat, lon, state\_fips, dmg\_mill\_tot, dmg\_ord,$$
$$dmg\_ord\_tot, inj\_tot, inj\_ord, inj\_ord\_tot, missing, miss\_tot,$$
$$miss\_ord\_tot, miss\_ord, houses\_destr, houses\_destr\_tot, houses\_destr\_ord,$$
$$houses\_destr\_ord\_tot, deaths\_tot, deaths\_ord, deaths\_ord\_tot, country, regionname,$$
$$houses\_dmg, houses\_dmg\_tot, houses\_dmg\_ord\_tot, houses\_dmg\_ord, year, month, day, hour, min, sec.($$
$$\exists x_1, ..., x_{18}.traces(trace\_id, ..., sec, x_1, ..., x_{18})))\wedge$$
$$(\forall trace\_id, county\_fips.(\exists x_1, ..., x_2.trace\_affected\_counties(trace\_id, county\_fips, order\_idx = 1, x_2)))\wedge$$
$$(\forall name, county\_fips.(\exists x_1, ..., x_3.county(name, county\_fips, x_1, ..., x_3)))\wedge$$
$$(\forall name, state\_fips.(\exists x_1.states(name, state\_fips, x_1))) \quad (19)$$

2.5 enriched_traces_w_counties

$$(\forall trace\_id, injuries, deaths, dmg\_mill, lat, lon, state\_fips, dmg\_mill\_tot, dmg\_ord,$$
$$dmg\_ord\_tot, inj\_tot, inj\_ord, inj\_ord\_tot, missing, miss\_tot,$$
$$miss\_ord\_tot, miss\_ord, houses\_destr, houses\_destr\_tot, houses\_destr\_ord,$$
$$houses\_destr\_ord\_tot, deaths\_tot, deaths\_ord, deaths\_ord\_tot, country, regionname,$$
$$houses\_dmg, houses\_dmg\_tot, houses\_dmg\_ord\_tot, houses\_dmg\_ord, year, month, day, hour, min, sec.($$
$$\exists x_1, ..., x_{18}.traces(trace\_id, ..., sec, x_1, ..., x_{18})))\wedge$$
$$(\forall trace\_id, county\_fips.(\exists x_1, ..., x_2.trace\_affected\_counties(trace\_id, county\_fips, order\_idx = 1, x_2)))\wedge$$
$$(\forall name, county\_fips.(\exists x_1, ..., x_3.county(name, county\_fips, x_1, ..., x_3))) \quad (20)$$

2.6 enriched_traces_w_area

$$(\forall trace\_id, injuries, deaths, dmg\_mill, lat, lon, state\_fips, dmg\_mill\_tot, dmg\_ord,$$
$$dmg\_ord\_tot, inj\_tot, inj\_ord, inj\_ord\_tot, missing, miss\_tot,$$
$$miss\_ord\_tot, miss\_ord, houses\_destr, houses\_destr\_tot, houses\_destr\_ord,$$
$$houses\_destr\_ord\_tot, deaths\_tot, deaths\_ord, deaths\_ord\_tot, country, regionname,$$
$$houses\_dmg, houses\_dmg\_tot, houses\_dmg\_ord\_tot, houses\_dmg\_ord, year, month, day, hour, min, sec.($$
$$\exists x_1, ..., x_{18}.traces(trace\_id, ..., sec, x_1, ..., x_{18})))\wedge$$
$$(\forall trace\_id, city\_fips.(\exists x_1, ..., x_2.trace\_affected\_cities(trace\_id, city\_fips, order\_idx = 1, x_2)))\wedge$$
$$(\forall name, city\_fips.(\exists x_1, ..., x_3.county(name, city\_fips, x_1, ..., x_3))) \quad (21)$$

2.7 earthquake_base_info

$$\forall country, id, locationname, lat, lon, regionname, area, year, month, day, hour, min, sec.($$
$$\exists x_1, ..., x_{11}.earthquakes\_by\_country(country, ..., sec, x_1, ...x_{11})) \quad (22)$$

2.8 earthquake_damage_view

$$\forall dmg\_amt\_tot, dmg\_amt\_order, id, dmg\_mill, dmg\_mill\_tot.($$
$$\exists x_1, ..., x_{17}.earthquakes\_by\_damage(dmg\_amt\_tot, ..., dmg\_mill\_tot, x_1, ..., x_{17})) \quad (23)$$

2.9 earthquakes_deaths_view

$$\forall deaths\_tot, id, deaths, deaths\_ord, deaths\_ord\_tot.($$
$$\exists x_1, ..., x_{17}.earthquakes\_by\_deaths(deaths\_tot, ..., deaths\_ord\_tot, x_1, ..., x_{17})) \quad (24)$$

2.10 earthquakes_by_houses_damages

$$\forall id, houses\_destr, houses\_destr\_ord, houses\_destr\_tot, houses\_destr\_ord\_tot, houses\_dmg, houses\_dmg\_ord, houses\_dmg\_tot, houses\_dmg\_ord\_tot.(\exists x_1, ..., x_{13}.earthquakes\_by\_houses\_damages(id, ..., houses\_dmg\_ord\_tot, x_1, ..., x_{17})) \quad (25)$$

2.11 earthquakes_injuries

$$\forall id, injuries, inj\_ord, inj\_tot, inj\_ord\_tot.(\exists x_1, ..., x_{17}.earthquakes\_by\_injuries(id, ..., inj\_ord\_tot, x_1, ..., x_{17})) \quad (26)$$

2.12 earthquakes_magnitude_view

$$\forall id, mag, mag\_ms, mag\_ml, mag\_mw, mag\_mb, mag\_mfa, mag\_unk.(\exists x_1, ..., x_{19}.earthquakes\_by\_magnitude(id, ..., mag\_unk, x_1, ..., x_{19})) \quad (27)$$

2.13 earthquakes_missing

$$\forall id, missing, miss\_ord, miss\_tot, miss\_ord\_tot.(\exists x_1, ..., x_{17}.earthquakes\_by\_missing(id, ..., inj\_ord\_tot, x_1, ..., x_{17})) \quad (28)$$

2.14 earthquakes_specific_info

$$\forall id, intensity, depth.(\exists x_1, ..., x_{21}.earthquakes\_by\_country(id, intensity, depth, x_1, ..., x_{21})) \quad (29)$$

2.15 enriched_traces

$$\forall id, injuries, deaths, dmg\_mill, lat, lon, state\_fips, dmg\_mill\_tot, dmg\_ord, dmg\_ord\_tot, inj\_tot, inj\_ord, inj\_ord\_tot, missing, miss\_tot, miss\_ord\_tot, miss\_ord, houses\_destr, houses\_destr\_tot, houses\_destr\_ord, houses\_destr\_ord\_tot, deaths\_tot, deaths\_ord, deaths\_ord\_tot, country, regionname, houses\_dmg, houses\_dmg\_tot, houses\_dmg\_ord\_tot, houses\_dmg\_ord, year, month, day, hour, min, sec.(\exists x_1, ..., x_{18}.traces(id, ..., sec, x_1, ..., x_{18})) \quad (30)$$

2.16 eruption_enriched

$$\forall dmg\_ord, houses\_destr, inj, location, lon, miss, dmg\_ord\_tot, houses\_destr\_ord, inj\_ord, miss\_ord,$$
$$country, dmg\_mill, houses\_destr\_ord\_tot, inj\_ord\_tot, miss\_ord\_tot,$$
$$dmg\_mill\_tot, houses\_destr\_tot, inj\_tot, miss\_tot, event\_ts,$$
$$id, lat, deaths, deaths\_ord, deaths\_ord\_tot, deaths\_tot, houses\_dmgd\_ord\_tot,$$
$$houses\_dmgd\_ord, houses\_dmgd, houses\_dmgd\_tot, volcano\_id, year, month, day, hour, min, sec.($$
$$\exists x_1, ..., x_8.eruptions(dmg\_ord, ..., sec, x_1, ..., x_8)) \quad (31)$$

2.17 first_trace_affected_cities

$$\forall trace\_id, city\_fips.(\exists x_1, ..., x_2.trace\_affected\_cities(trace\_id, city\_fips, order\_idx = 1, x_2)) \quad (32)$$

2.18 first_trace_affected_counties

$$\forall trace\_id, county\_fips.(\exists x_1, ..., x_2.trace\_affected\_counties(trace\_id, county\_fips, order\_idx = 1, x_2)) \quad (33)$$

2.19 link_earthquake_eruption

$$\forall earthquake\_id, eruption\_id.($$
$$\exists x_1, ..., x_{22}.earthquakes\_by\_country('earthquake\_'+earthquake\_id,' eruption\_'+eruption\_id, x_1, ..., x_{22})) \quad (34)$$

2.20 link_earthquake_tsunami

$$\forall earthquake\_id, tsunami\_id.($$
$$\exists x_1, ..., x_{22}.earthquakes\_by\_country('earthquake\_'+earthquake\_id,' tsunami\_'+tsunami\_id, x_1, ..., x_{22})) \quad (35)$$

2.21 link_eruption_earthquake

$$\forall earthquake\_id, eruption\_id.($$
$$\exists x_1, ..., x_{40}.eruptions('earthquake\_'+earthquake\_id,' eruption\_'+eruption\_id, x_1, ..., x_{40})) \quad (36)$$

2.22 link_eruption_tsunami

$$\forall tsunami\_id, eruption\_id.(\exists x_1, ..., x_{40}.eruptions('tsunami\_'+tsunami\_id,' eruption\_'+eruption\_id, x_1, ..., x_{40})) \tag{37}$$

2.23 link_traces

$$\forall trace\_id, tornado\_id, order\_idx.(\exists x_1, ..., x_{21}.traces('tornado\_' + trace\_id, tornado\_id, order\_idx, x_1, ..., x_{21})) \tag{38}$$

2.24 link_tsunami_earthquake

$$\forall tsunami\_id, earthquake\_id.(\exists x_1, ..., x_{56}.tsunami('tsunami\_'+tsunami\_id,' earthquake\_'+earthquake\_id, x_1, ..., x_{56})) \tag{39}$$

2.25 link_tsunami_eruption

$$\forall tsunami\_id, eruption\_id.(\exists x_1, ..., x_{56}.tsunami('tsunami\_'+tsunami\_id,' eruption\_'+eruption\_id, x_1, ..., x_{56})) \tag{40}$$

3 Loading Mappings

3.1 Classic Metrics

$$\text{dim\_date} = \pi_{\substack{\text{event\_date} \leftarrow f_1(\text{event\_year,event\_month,event\_day}),\text{id},\\ \text{event\_year,event\_month,event\_day},\\ \text{event\_quarter}=f_2(\text{event\_month}),\\ \text{event\_millennium}=\lfloor \text{event\_year}/1000 \rfloor,\\ \text{event\_century}=\lfloor \text{event\_year}/100 \rfloor}} (\text{natural\_event})$$

$$\text{dim\_place} = \pi_{\substack{\text{event\_location},\\ \text{region,area} \leftarrow f(\text{area}),\\ \text{country,id}}} (\text{natural\_event})$$

$$\text{dim\_time} = \pi_{\substack{\text{event\_time} \leftarrow f_1(\text{event\_hour,event\_minute}),\\ \text{id,event\_hour,event\_minute},\\ \text{event\_second,event\_daytime} \leftarrow f_2(\text{event\_hour})}} (\text{natural\_event})$$

3.2 EventType Metrics

$$\text{dim\_earthquake} = \pi_{\substack{\text{intensity,eqdepth,eqmagnitude,}\\ \text{eqmagms,eqmagml,eqmagmw,}\\ \text{eqmagmb,eqmagmfa,eqmagunk,}\\ \text{natural\_event\_id}}} (\text{earthquake})$$

$$\text{dim\_eruption} = \pi_{\substack{\text{eruption,significant,vei,agent,}\\ \text{eruption\_status,natural\_event\_id,}\\ \text{elevation,morphology,volcano\_name,timeerupt}}} (\text{eruption} \bowtie_{\text{eruption.volcano\_id=volcano.id}} \text{volcano})$$

$$\text{dim\_tornado\_trace} = \pi_{\substack{\text{f\_scale,trace\_length,}\\ \text{width,alteredmagnitude,}\\ \text{order\_idx,natural\_event\_\_id}}} (\text{tornado\_trace})$$

$$\text{dim\_tsunami} = \pi_{\substack{\text{numdeposits,numrunups,tsintensity,}\\ \text{oceanictsunami,maxwaterheight,eqmagnitude,}\\ \text{tsmtii,eqdepth,tsmtabe,}\\ \text{cause,warningstatus,natural\_event\_id}}} (\text{tsunami})$$

3.3 Fact Table

$$\begin{aligned}\text{fact\_natural\_event} = \pi_{\substack{\text{damageamountordertotal,damageamountorder,damagemillionsdollars,damagemillionsdollarstotal,deathstotal,}\\ \text{deaths,deathsamountorder,deathsamountordertotal,housesdestroyed,housesdestroyedamountorder,}\\ \text{housesdestroyedtotal,housesdestroyedamountordertotal,housesdamaged,housesdamagedamountorder,}\\ \text{housesdamagedtotal,housesdamagedamountordertotal,injuries,injuriesamountorder,}\\ \text{injuriestotal,injuriesamountordertotal,missing,missingamountorder,missingtotal,}\\ \text{missingamountordertotal,place\_id}\leftarrow\text{id,time\_id}\leftarrow\text{id,date\_id}\leftarrow\text{id,deadly}\leftarrow max(\text{deaths,deathstotal})>0,\\ \text{multiple\_event}\leftarrow f_2(\text{related\_event.event2\_id,related\_event1.event1\_id}),\text{eruption\_id}\leftarrow concat(\text{event\_type,id}),\\ \text{earthquake\_id}\leftarrow concat(\text{event\_type,id}),\text{tsunami\_id}\leftarrow concat(\text{event\_type,id}),\\ \text{tornado\_id}\leftarrow concat(\text{event\_type,id}),\text{milliondollarscropsdamage}}\\ ((\text{natural\_event} \bowtie_{\text{id=event\_id}} (\pi_{event\_id\leftarrow event1\_id}(\text{related\_event}) \cup \pi_{event\_id\leftarrow event2\_id}(\text{related\_event}))\end{aligned}$$

4 Queries

4.1 Roll-up

$$\gamma_{\text{year, total\_deaths} \leftarrow \mathcal{SUM}(\text{deaths})}(\text{Fact\_Natural\_Event} \bowtie_{date\_id=id} \text{Dim\_Date})$$

4.2 Drill-down

$$\gamma_{\text{region, total\_damage\_millions\_dollars} \leftarrow \mathcal{SUM}(\text{damage\_millions\_dollars})}(\text{Fact\_Natural\_Event} \bowtie_{place\_id=id} \text{Dim\_Place})$$

$$\gamma_{\text{area, total\_damage\_millions\_dollars} \leftarrow \mathcal{SUM}(\text{damage\_millions\_dollars})}(\text{Fact\_Natural\_Event} \bowtie_{place\_id=id} \text{Dim\_Place})$$

4.3 Slice

$$\gamma_{\text{year, total\_deaths} \leftarrow \mathcal{SUM}(\text{deaths})}(\sigma_{\text{volcano\_name='Etna'}}((\text{Fact\_Natural\_Event} \bowtie_{date\_id=id} \text{Dim\_Date}) \bowtie_{eruption\_id=id} \text{Dim\_Eruption}))$$

4.4 Slice and Dice

$$\gamma_{\text{year, total\_deaths} \leftarrow \mathcal{SUM}(\text{deaths})}(\sigma_{\text{damage\_millions\_dollars}>0}(\text{Fact\_Natural\_Event} \bowtie_{date\_id=id} \text{Dim\_Date}) \bowtie_{earthquake\_id=id} \text{Dim\_Earthquake})$$