MichiganTech Research Institute

CLARUS Road-Weather Routing for Crash Risk Aversion

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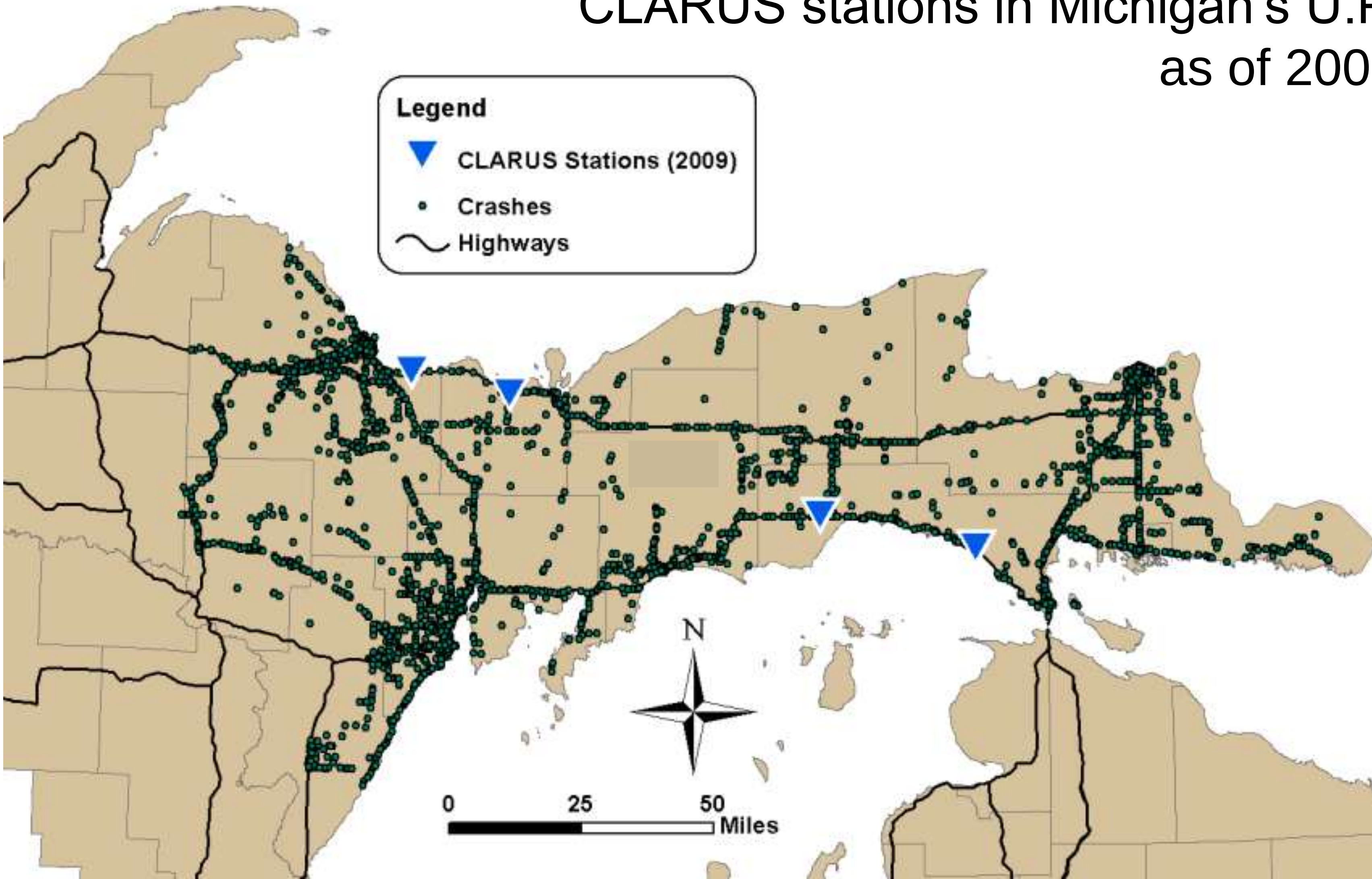
CLARUS Monitoring Stations

CLARUS stations in Michigan's U.P.
as of 2009



Linking Crashes and Weather

- A regression model was created
  - Dependent Variable – A crash occurring within 50 miles of a weather station during a particular hour.
  - Independent Variables
    - Temperature (Air, Road and Dew Point)
    - Precipitation Types
    - Precipitation Intensities
    - Visibility
    - Wind Speed (Average and Gust)
    - Atmospheric Pressure

Linking Crashes and Weather

- First cut: What variables are significant?

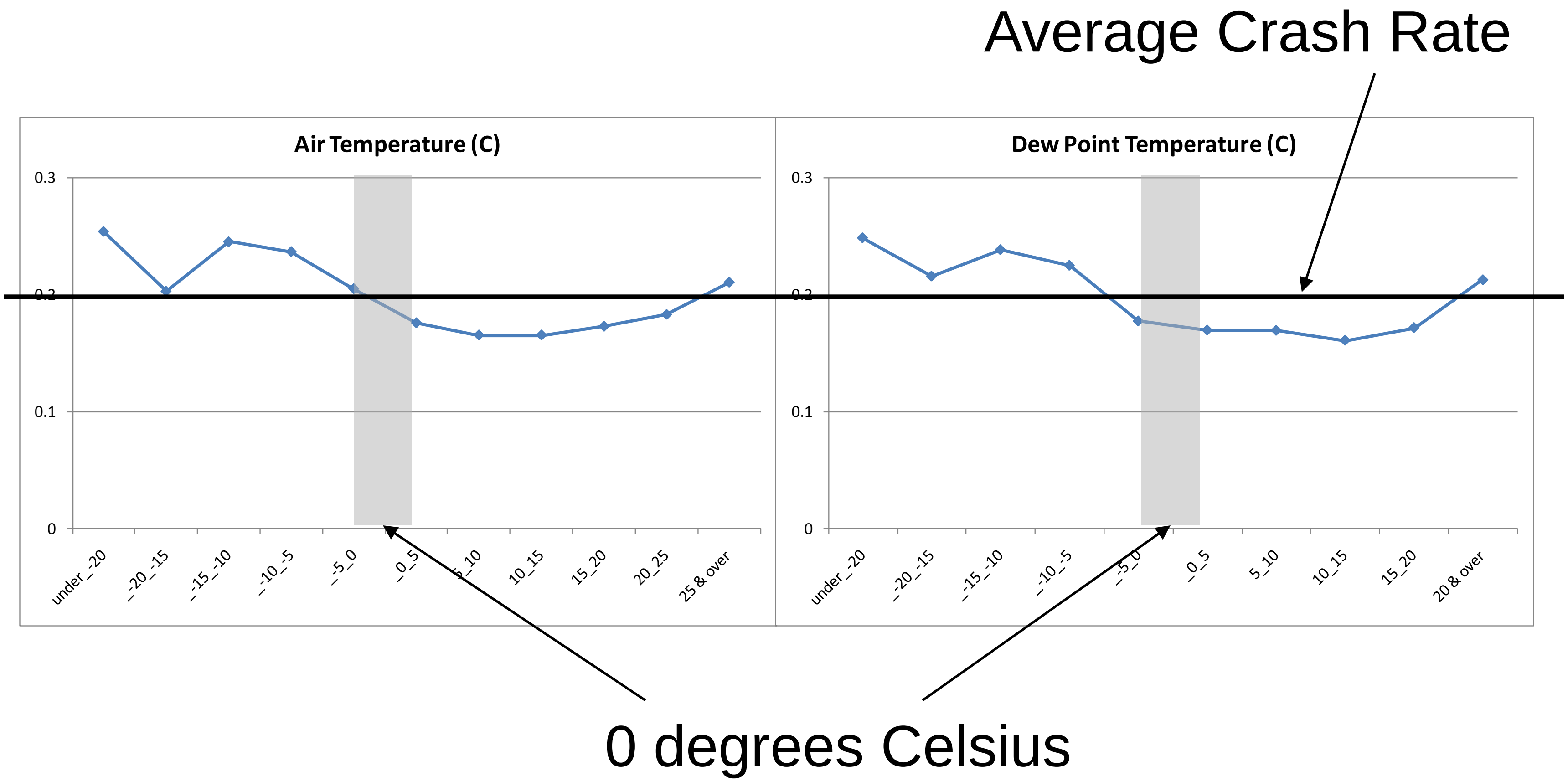
Variable	Units	Directionality Tested	Odds of a Crash	p-value
Wind Speed	m/s	Higher Speed	1.023	0.0140
Ice Percent	%	Greater Percent	1.003	0.0288
Heavy Precipitation Intensity	present	1	1.753	< 0.0001
No Precipitation Present	present	1	0.808	0.0052
Preciptiation as Snow	present	1	2.174	< 0.0001
Atmospheric Pressure	mbar	Higher Pressure	0.993	< 0.0001
Dew Pt Temp	deg C	Higher Temperature	0.984	< 0.0001
Relative Humidity	%	Greater Percent	0.996	< 0.0001
Precipitation Rate	cm/hr	Greater Rate	1.118	0.0478
Visibility	1000m	Greater Visability	0.961	< 0.0001
Air Temperature	deg C	Higher Temperature	0.987	< 0.0001
Dry Road Surface	present	1	1.19	0.0004
Surface Ice Warning	present	1	1.747	0.0099
Surface Ice Watch	present	1	1.321	0.0010
Road Surface Temperature	deg C	Higher Temperature	0.995	< 0.0001
Wind Gust Speed	m/s	Higher Speed	1.042	< 0.0001

Linking Crashes and Weather

- The regression model implies linear effects, but…
  - Temperature changes may have greater effects around freezing
  - What is the critical visibility level?
  - Road temperatures are critical around freezing
  - What about correlations between some of the variables?
- Back to the raw data
  - Where are the tipping points above or below which the regression modeling may be effective?

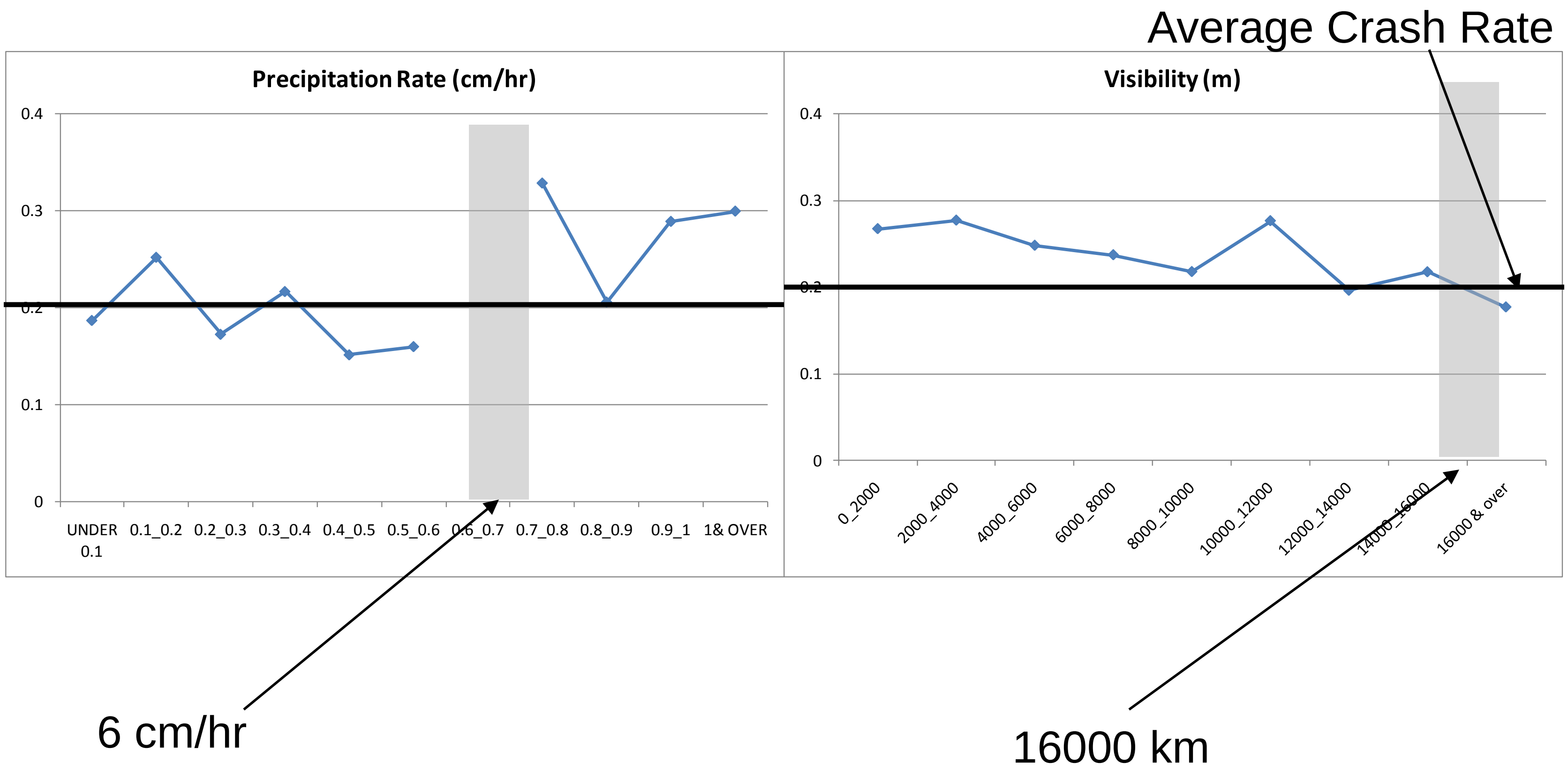
Tipping Points

- About 20% of the hours observed around the 4 stations had a crash



Tipping Points

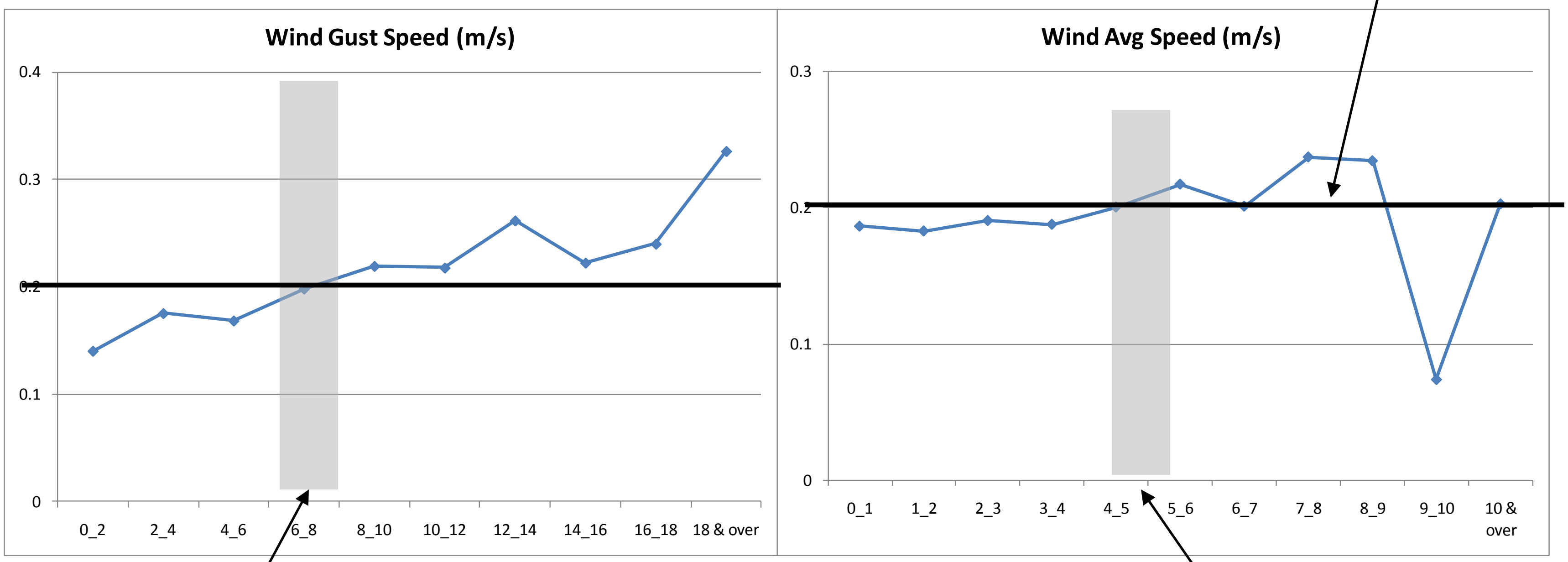
- Precipitation Rate and Visibility



Tipping Points

- Wind Speed (average and gust)

Average Crash Rate



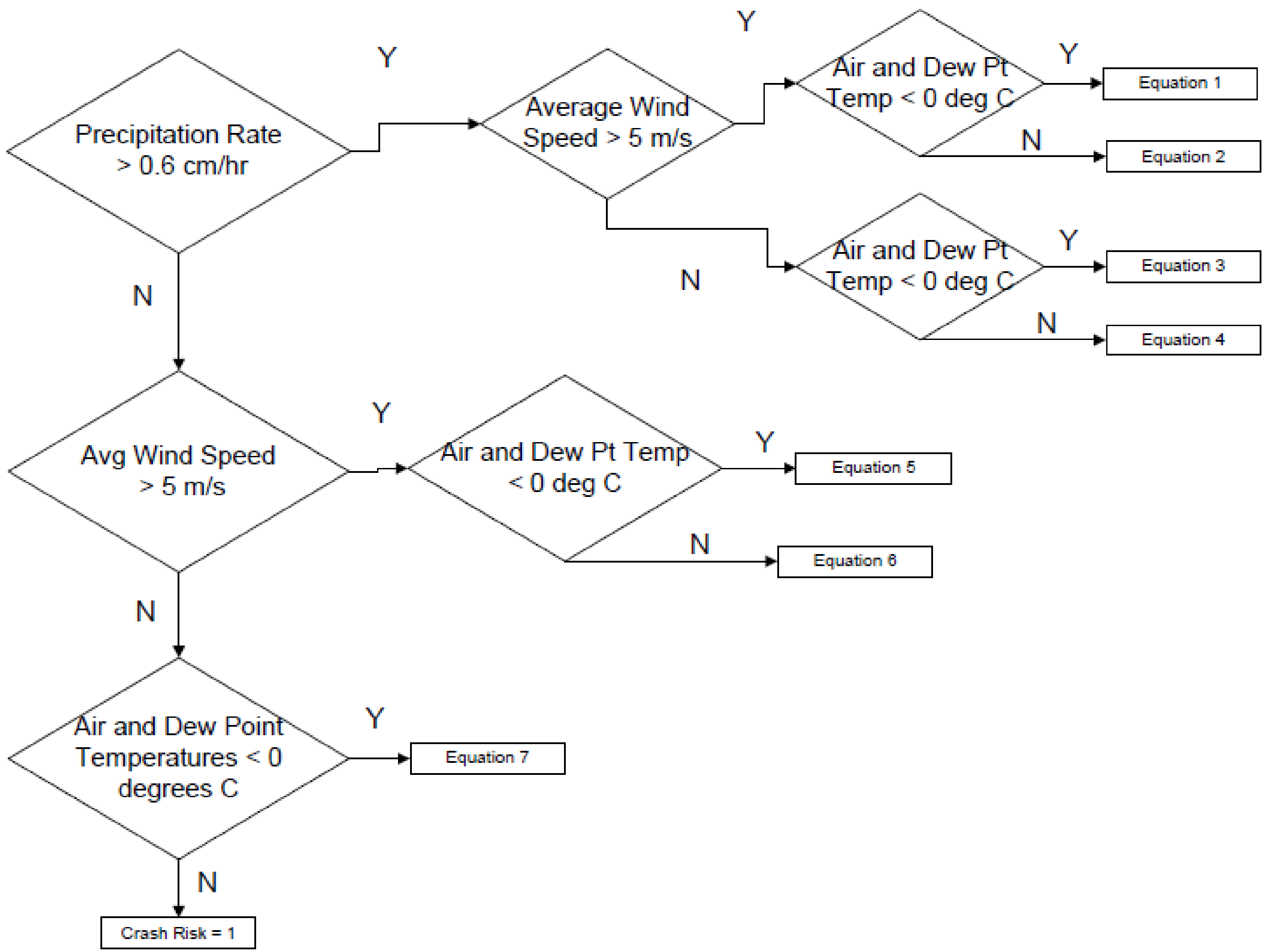
7 m/s

5 m/s

Decision Tree Construction

- A set of regression models applied under specific conditions.
  - Allows for evaluating continuous variables for regions of interest
- Evaluated subsets of data where crash risk was greater than 20% for all levels of other variables shown to be significant
  - i.e. the effect of dew pt, visibility, wind speed when air temperature is < 0 deg C.

Crash Risk Algorithm



Equations

- For each path on the tree, a regression model was created as done originally.
- The exponential of the parameter estimate multiplied by the variable value yields the odds of a crash

$$CrashRisk_{Eq1} = e^{(0.6025+0.1716+0.2189)}$$

$$CrashRisk_{Eq2} = e^{(0.6025+0.1716)}$$

$$CrashRisk_{Eq3} = e^{(0.6025+0.2189-1.6789(AirTemperature)+1.4417(DewPtTemperature))}$$

$$CrashRisk_{Eq4} = e^{(0.6025)}$$

$$CrashRisk_{Eq5} = e^{(0.1716+0.2189)}$$

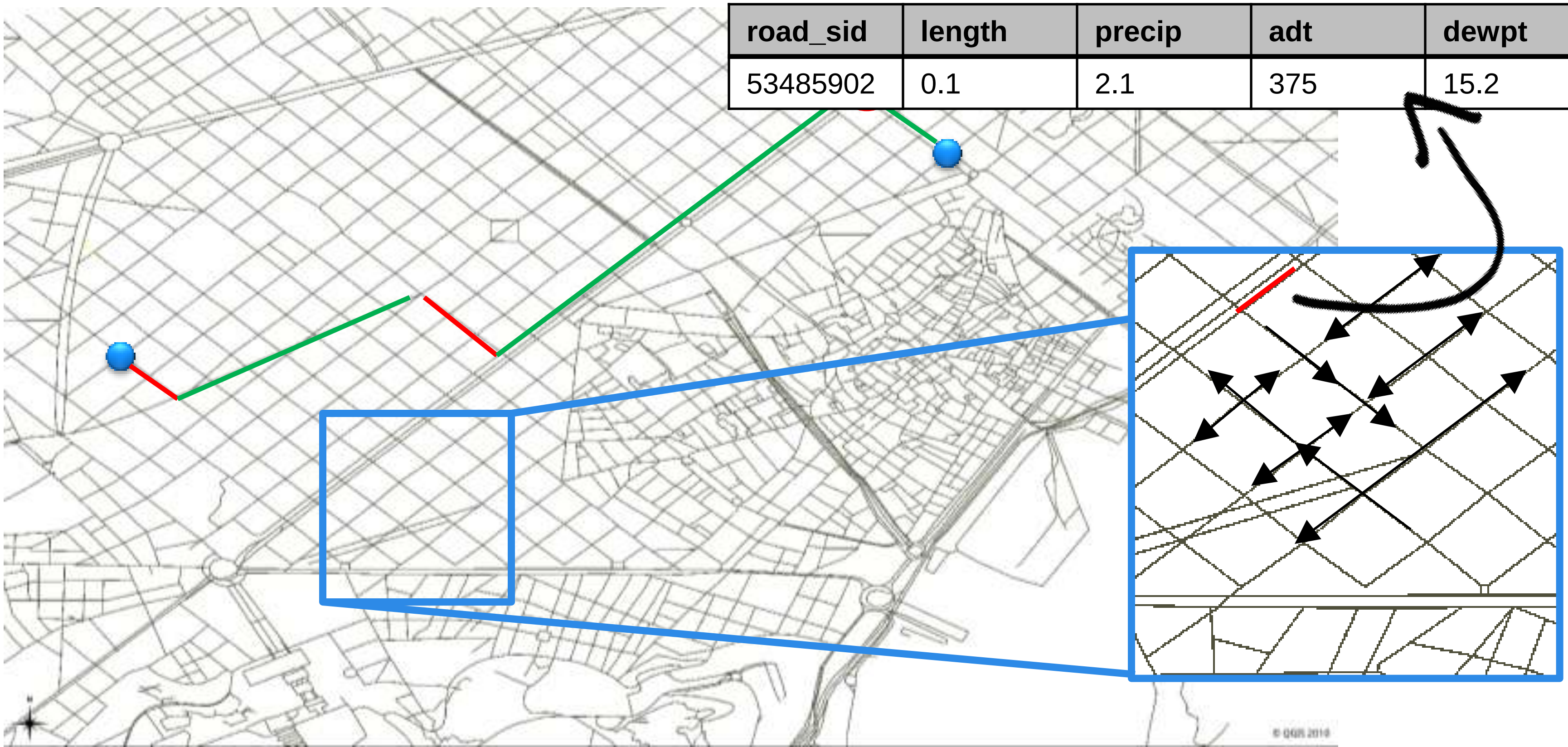
$$CrashRisk_{Eq6} = e^{(0.1716-0.0245(DewPtTemperature))}$$

$$CrashRisk_{Eq7} = e^{(0.2189+0.0130(AirTemperature)+0.0438(AverageWindSpeed))}$$

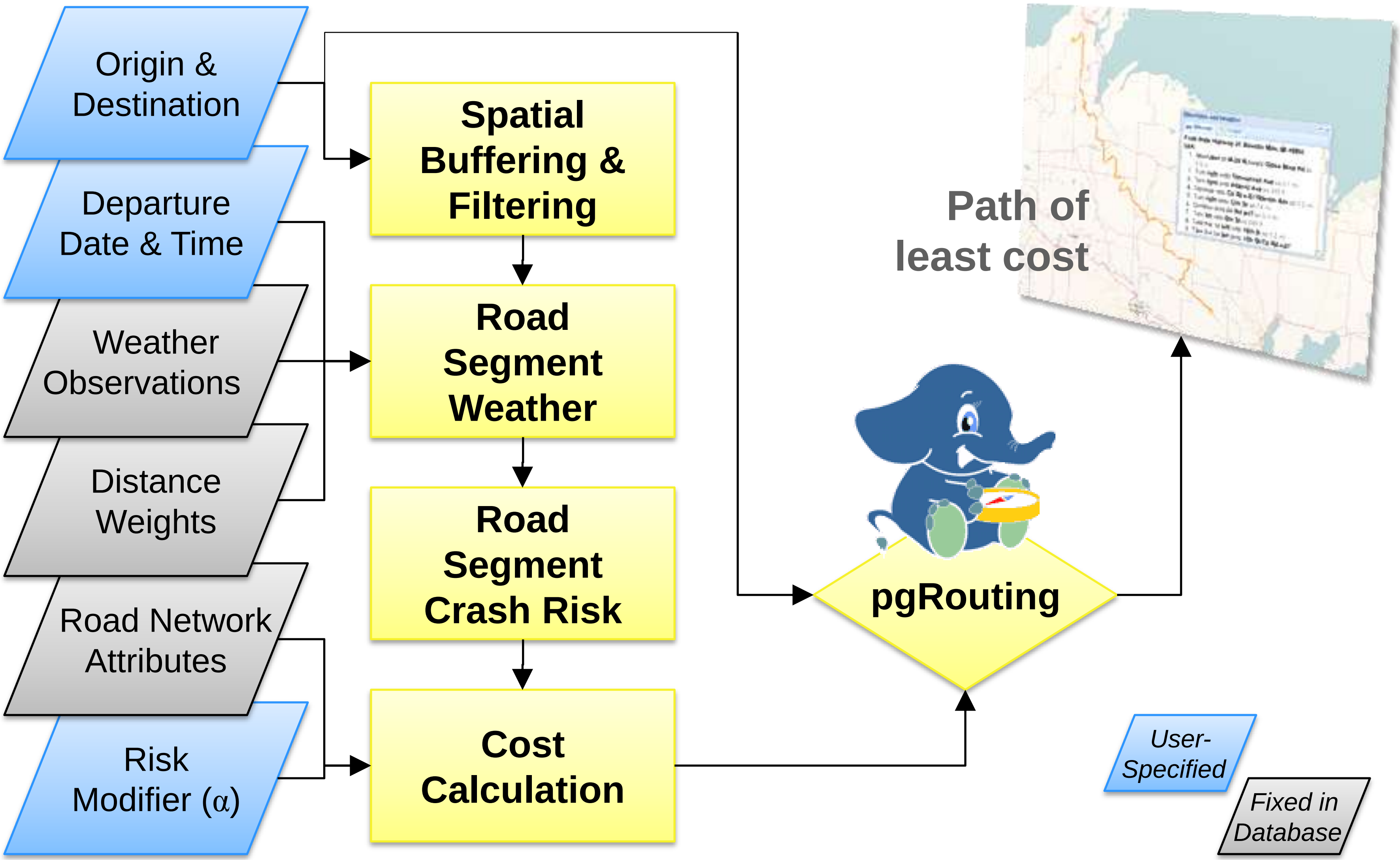
Road Network Data

- OpenStreetMap (OSM) data were loaded into a database to comprise the road network
- Length or travel time the typical cost of a road segment

road_sid	length	precip	adt	dewpt
53485902	0.1	2.1	375	15.2



Crash Risk Aversion Algorithm



Road Segment Weather

- Interpolate weather data for the road network using ***inverse distance weighting (IDW)***

$$z(r) = \sum_{i=1}^{N} \left(\frac{w_i(s) z_i}{\xi} \right) \qquad \xi = \sum_{i=1}^{N} w_i \qquad w_i(s) = \frac{1}{distance(r, s)^p}$$

z_i	Weather observation at a given CLARUS station
w_i	Weight applied to the weather observation
r	Road segment centroid
s	Location of CLARUS station
ξ	Normalization factor
p	Power parameter (fixed at 2 in this application)

- IDW not the most rigorous spatial interpolation method, but best choice with only 4 CLARUS stations
- Inverse distance weights, calculated from road segment centroid, stored in the database for each road segment

Crash Risk & Cost Calculation

- Classical ***shortest time problem***, but with crash risk considered as part of the cost

$$f(p) = cost_{p,t} = \alpha * traveltime_p + (1-\alpha) * crashrisk_{p,t}$$

$cost_{p,t}$	Cost of traversing edge p at time t
$traveltime_p$	Time required to traverse edge p
$crashrisk_{p,t}$	Crash risk associated with traversing edge p at time t
α	Weighting factor between 0 and 1; shortest path and least crash risk

$$crashrisk_{p,t} = \frac{\sum_{s \in S} \lambda_s crashrisk_{s,t}}{\sum_{s \in S} \lambda_s}$$

Crash risk for each nearby station by inverse distance weighting; in our problem, all four stations considered

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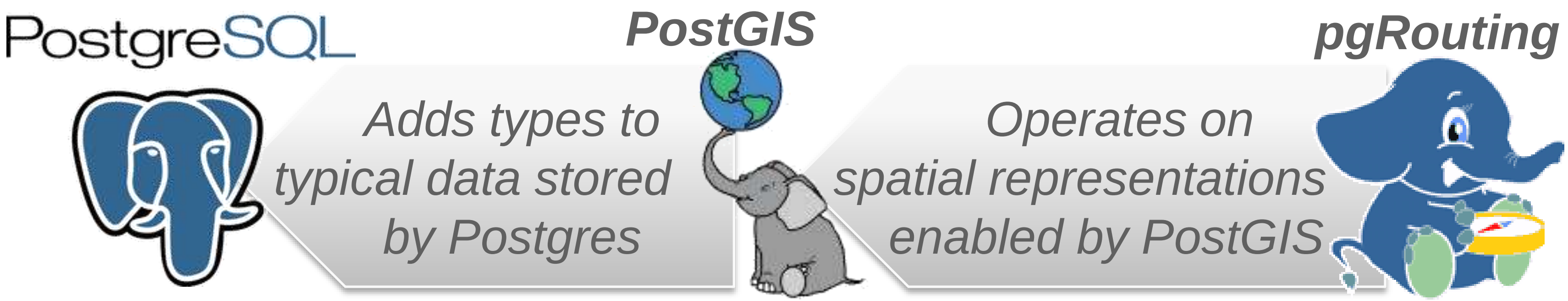
pgRouting



Find the nearest edge in PostGIS

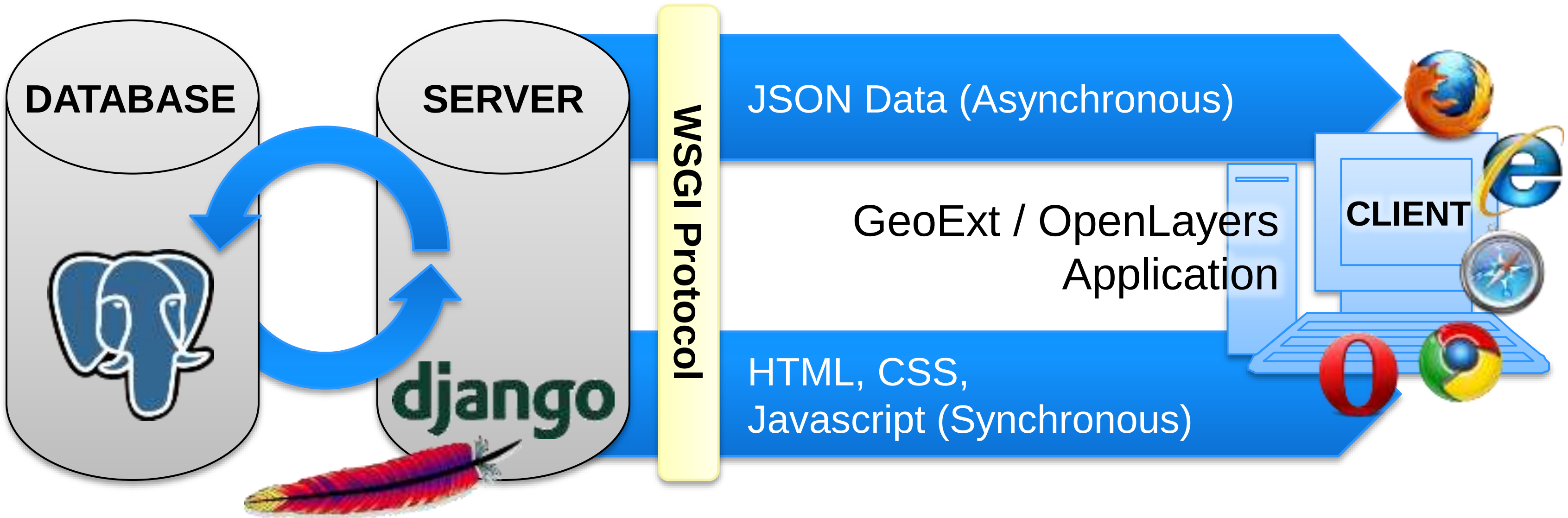
```
SELECT gid, source, target, the_geom,
  distance(the_geom, -83.69, 42.31, 4326) AS dist
  FROM ways
  WHERE the_geom && setsrid('BOX3D(-83.79, 42.21, -83.59,
    42.41)::box3d, 4326)
  ORDER BY dist LIMIT 1
```

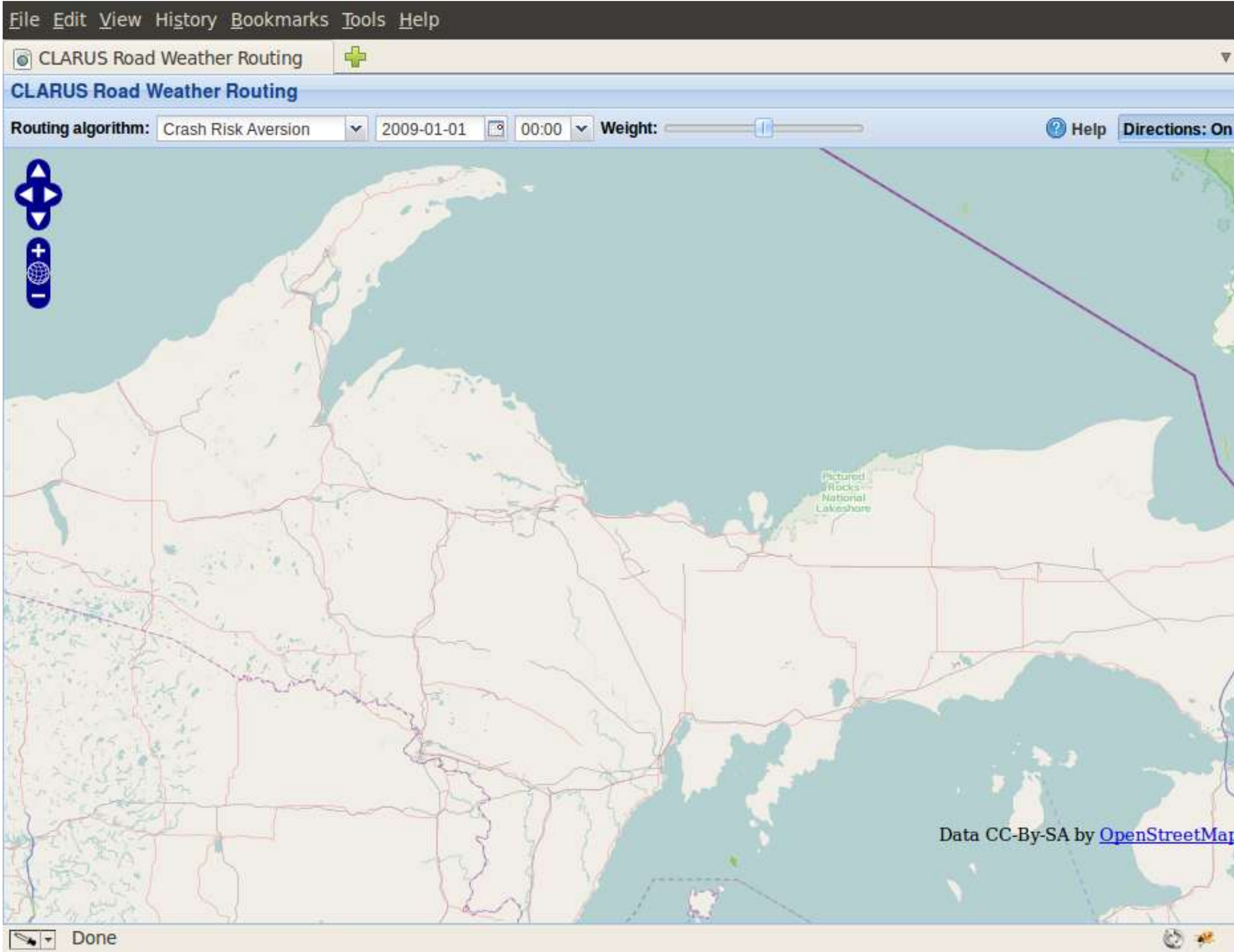
Find the least-cost path between edges

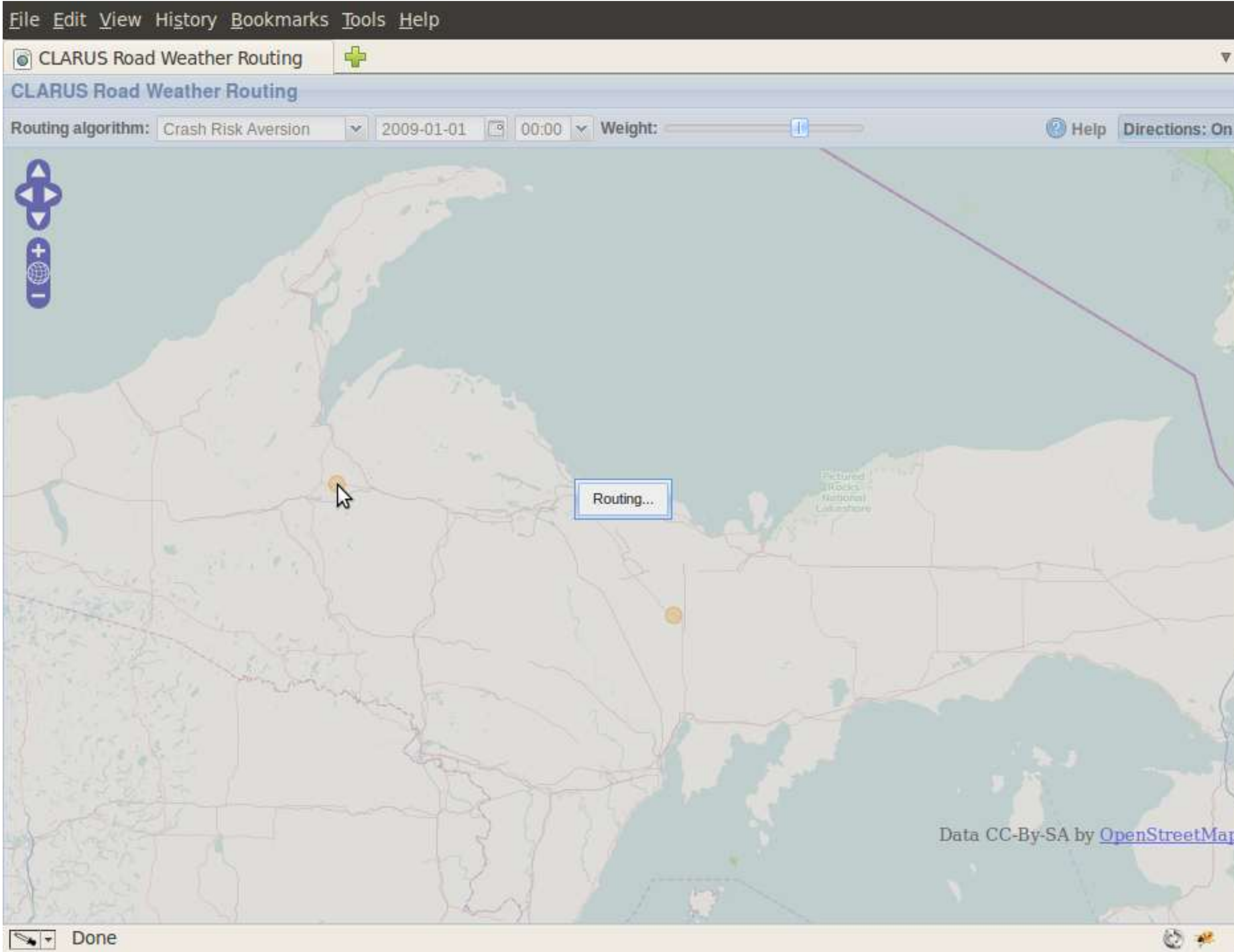
```
SELECT rt.gid, rt.the_geom, length(rt.the_geom), ways.gid
  FROM ways,
    (SELECT gid, the_geom FROM
      djikstra_sp_delta_crash_risk('ways',
      650908, 643960, 0.1, '2009-01-01', 0.5)) AS rt
  WHERE ways.gid=rt.gid
```

Routing Web Service

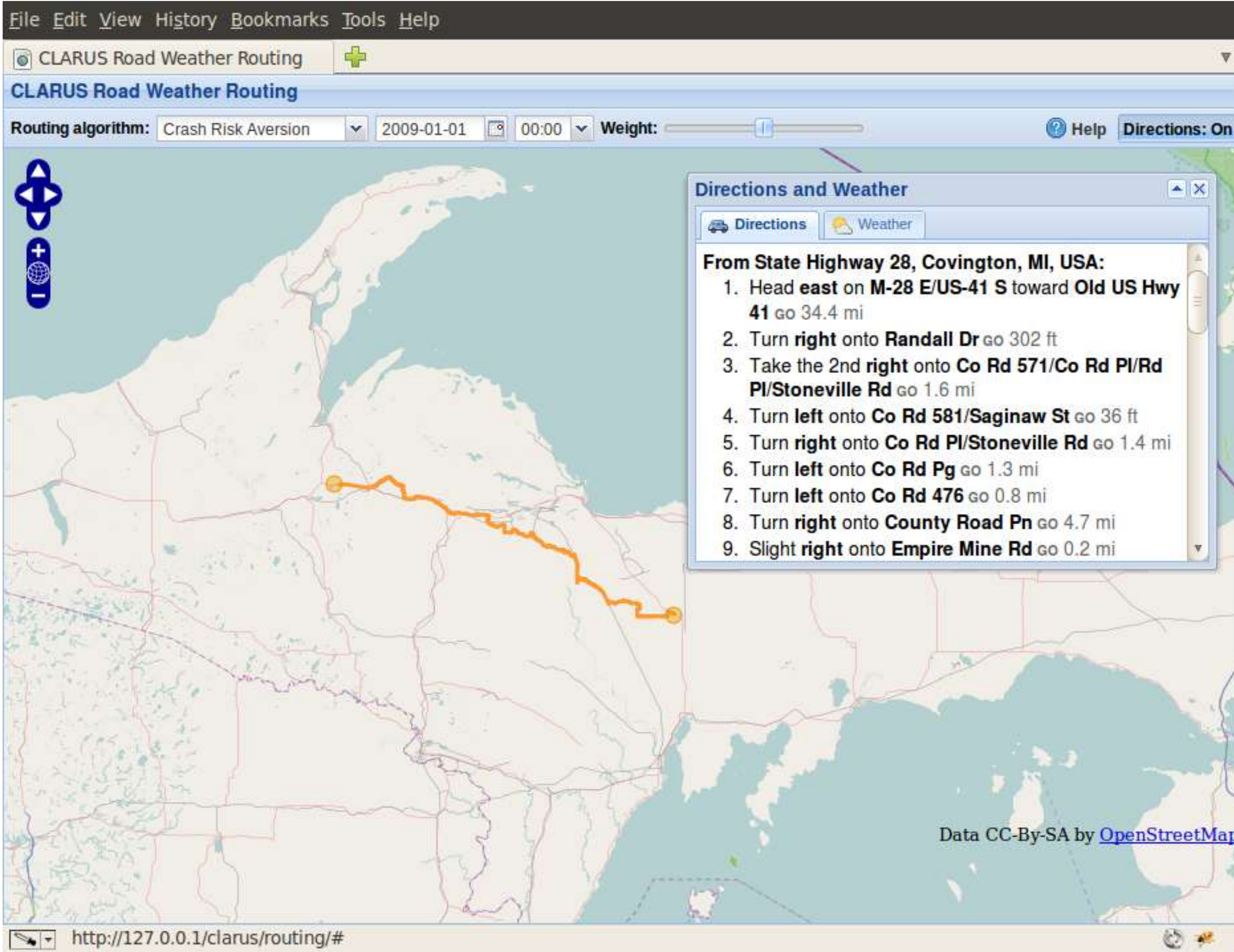
- Apache server programmed in python with the django framework (and RESTful and AJAX-compliant)
- Client application written in Javascript using GeoExt (ExtJS); web mapping powered by OpenLayers
- Routing data sent in Javascript Object Notation (JSON)

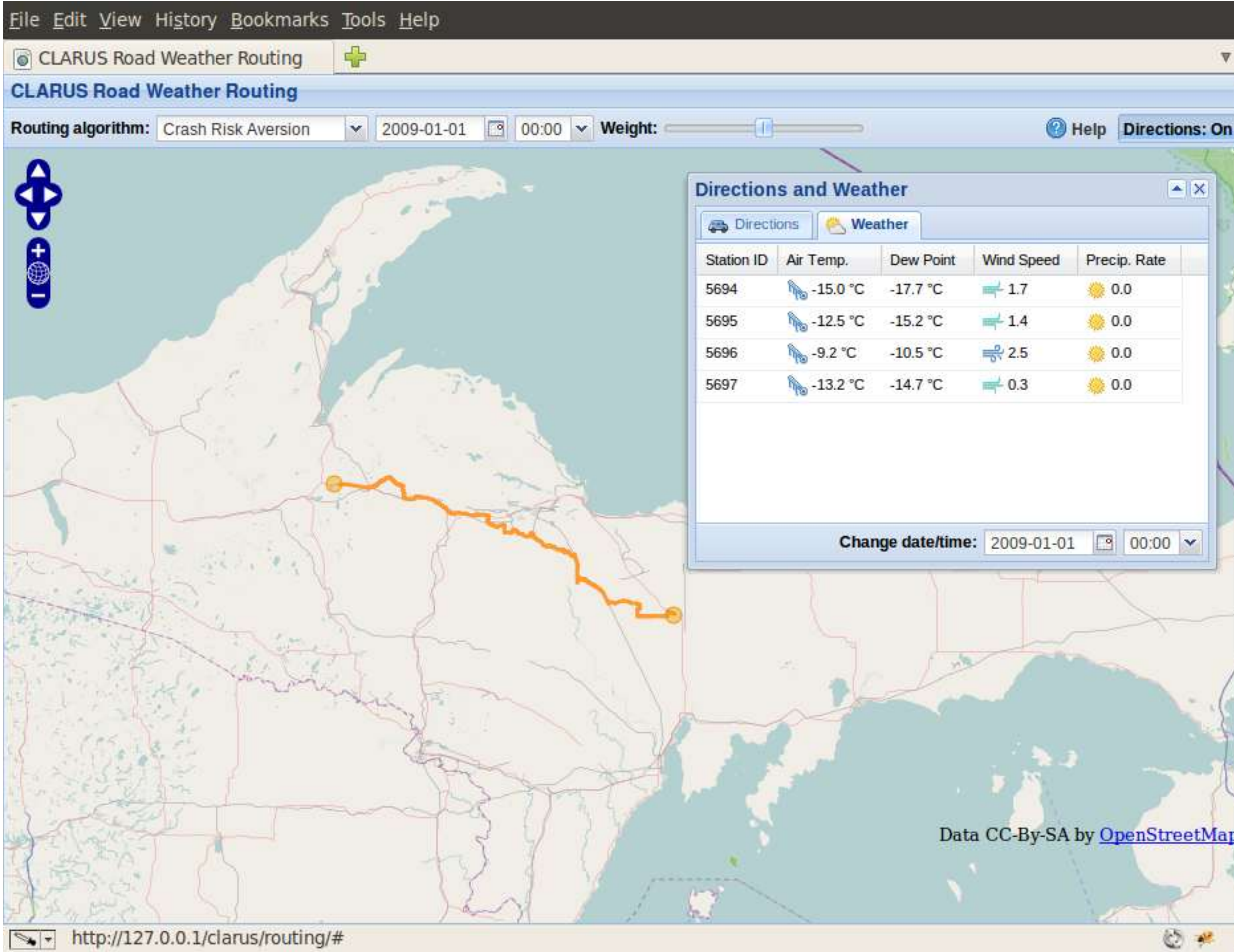


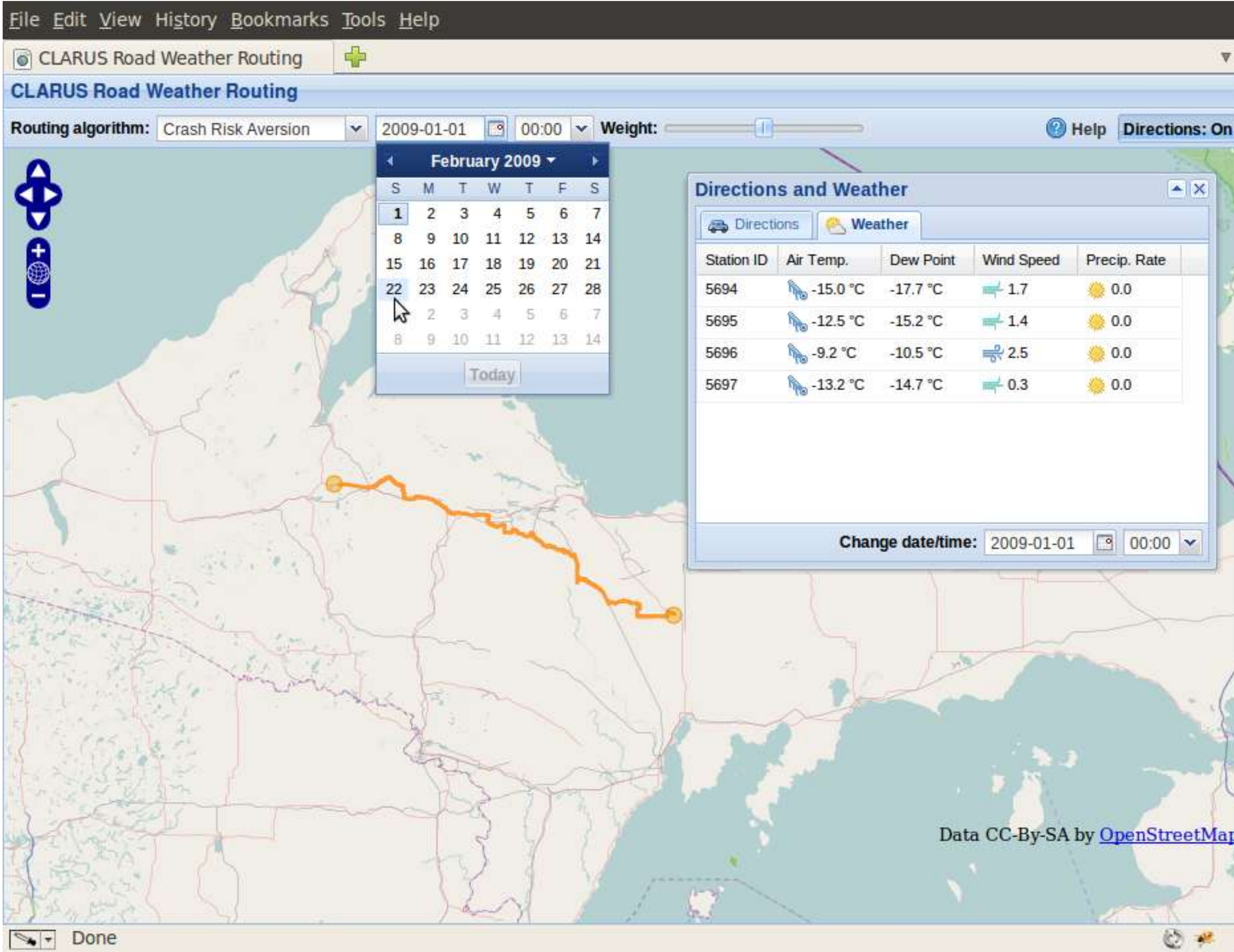

File Edit View History Bookmarks Tools Help
CLARUS Road Weather Routing
CLARUS Road Weather Routing
Routing algorithm: Crash Risk Aversion
2009-01-01
00:00
Weight:
Help
Directions: On
Pictured Rocks National Lakeshore
Data CC-By-SA by OpenStreetMap
Done

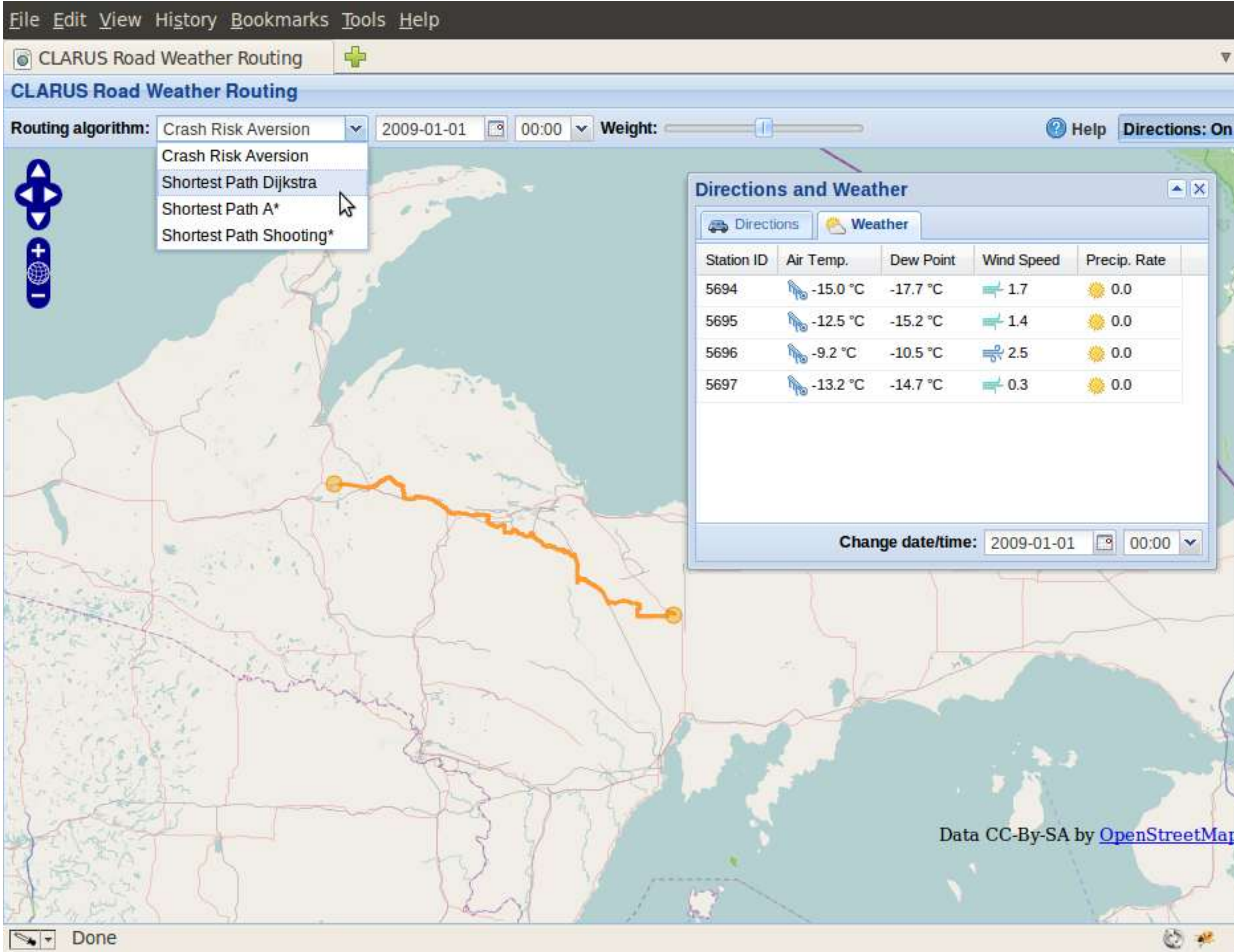


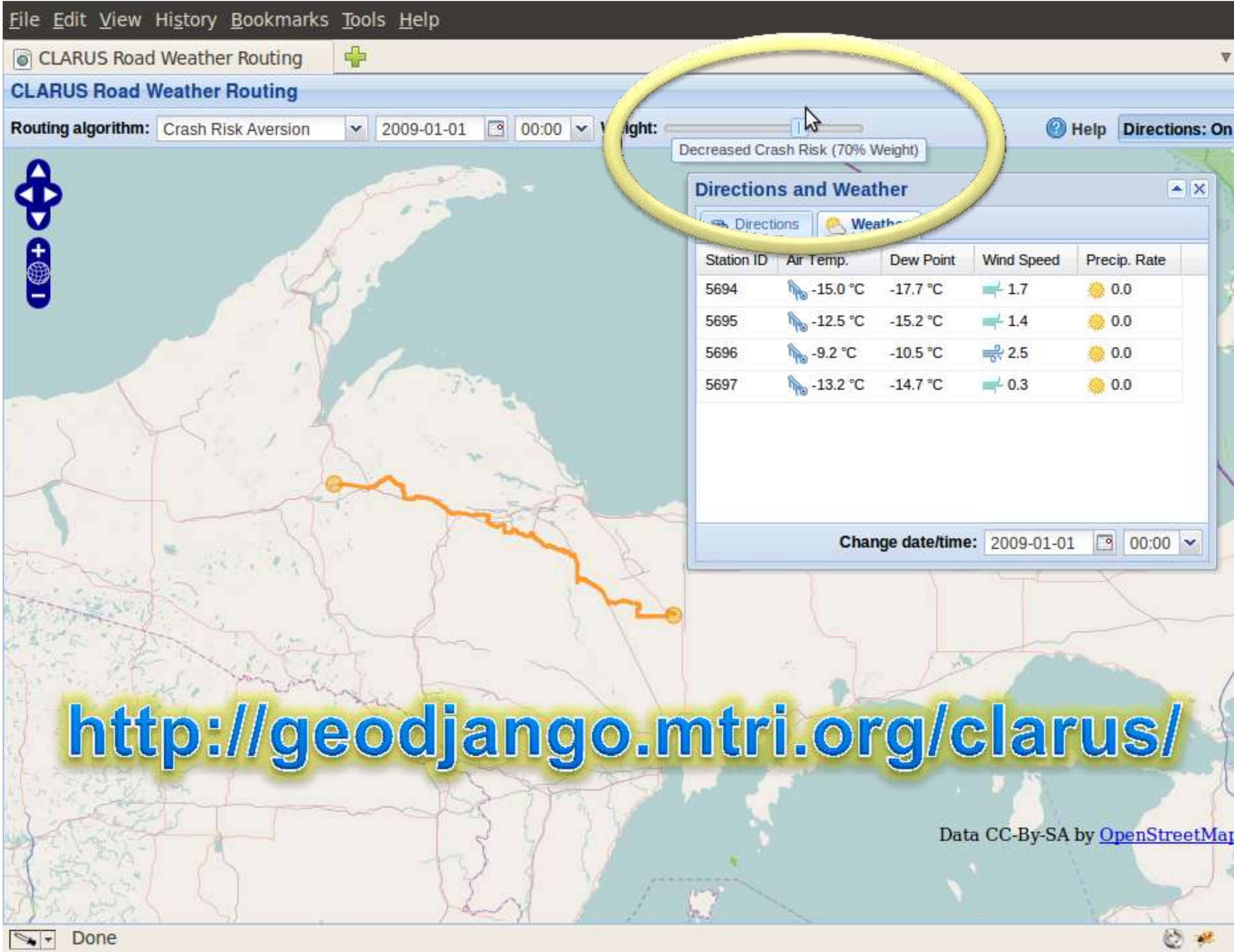
File Edit View History Bookmarks Tools Help
CLARUS Road Weather Routing
CLARUS Road Weather Routing
Routing algorithm: Crash Risk Aversion
2009-01-01
00:00
Weight:
Help
Directions: On
Routing...
Data CC-By-SA by OpenStreetMap
Done


File Edit View History Bookmarks Tools Help
CLARUS Road Weather Routing
CLARUS Road Weather Routing
Routing algorithm: Crash Risk Aversion
2009-01-01
00:00
Weight:
Help
Directions: On
Directions and Weather
Directions
Weather
From State Highway 28, Covington, MI, USA:
1. Head east on M-28 E/US-41 S toward Old US Hwy 41 go 34.4 mi
2. Turn right onto Randall Dr go 302 ft
3. Take the 2nd right onto Co Rd 571/Co Rd Pl/Rd Pl/Stoneville Rd go 1.6 mi
4. Turn left onto Co Rd 581/Saginaw St go 36 ft
5. Turn right onto Co Rd Pl/Stoneville Rd go 1.4 mi
6. Turn left onto Co Rd Pg go 1.3 mi
7. Turn left onto Co Rd 476 go 0.8 mi
8. Turn right onto County Road Pn go 4.7 mi
9. Slight right onto Empire Mine Rd go 0.2 mi
Data CC-By-SA by OpenStreetMap
http://127.0.0.1/clarus/routing/#


File Edit View History Bookmarks Tools Help
CLARUS Road Weather Routing
CLARUS Road Weather Routing
Routing algorithm: Crash Risk Aversion
2009-01-01
00:00
Weight:
Help
Directions: On
Directions and Weather
Directions
Weather
Station ID | Air Temp. | Dew Point | Wind Speed | Precip. Rate
5694 | -15.0 °C | -17.7 °C | 1.7 | 0.0
5695 | -12.5 °C | -15.2 °C | 1.4 | 0.0
5696 | -9.2 °C | -10.5 °C | 2.5 | 0.0
5697 | -13.2 °C | -14.7 °C | 0.3 | 0.0
Change date/time: 2009-01-01 00:00
Data CC-By-SA by OpenStreetMap
http://127.0.0.1/clarus/routing/#


File Edit View History Bookmarks Tools Help
CLARUS Road Weather Routing
CLARUS Road Weather Routing
Routing algorithm: Crash Risk Aversion
2009-01-01
00:00
Weight:
Help
Directions: On
February 2009
S M T W T F S
1 2 3 4 5 6 7
8 9 10 11 12 13 14
15 16 17 18 19 20 21
22 23 24 25 26 27 28
1 2 3 4 5 6 7
8 9 10 11 12 13 14
Today
Directions and Weather
Directions
Weather
Station ID Air Temp. Dew Point Wind Speed Precip. Rate
5694 -15.0 °C -17.7 °C 1.7 0.0
5695 -12.5 °C -15.2 °C 1.4 0.0
5696 -9.2 °C -10.5 °C 2.5 0.0
5697 -13.2 °C -14.7 °C 0.3 0.0
Change date/time: 2009-01-01 00:00
Data CC-By-SA by OpenStreetMap
Done


File Edit View History Bookmarks Tools Help
CLARUS Road Weather Routing
CLARUS Road Weather Routing
Routing algorithm:
Crash Risk Aversion
2009-01-01
00:00
Weight:
Help
Directions: On
Crash Risk Aversion
Shortest Path Dijkstra
Shortest Path A*
Shortest Path Shooting*
Directions and Weather
Directions
Weather
Station ID
Air Temp.
Dew Point
Wind Speed
Precip. Rate
5694 -15.0 °C -17.7 °C 1.7 0.0
5695 -12.5 °C -15.2 °C 1.4 0.0
5696 -9.2 °C -10.5 °C 2.5 0.0
5697 -13.2 °C -14.7 °C 0.3 0.0
Change date/time:
2009-01-01
00:00
Data CC-By-SA by OpenStreetMap
Done


File Edit View History Bookmarks Tools Help
CLARUS Road Weather Routing
CLARUS Road Weather Routing
Routing algorithm: Crash Risk Aversion
2009-01-01
00:00
Weight:
Decreased Crash Risk (70% Weight)
Help
Directions: On
Directions and Weather
Directions
Station ID
Air Temp.
Dew Point
Wind Speed
Precip. Rate
5694 -15.0 °C -17.7 °C 1.7 0.0
5695 -12.5 °C -15.2 °C 1.4 0.0
5696 -9.2 °C -10.5 °C 2.5 0.0
5697 -13.2 °C -14.7 °C 0.3 0.0
Change date/time: 2009-01-01 00:00
http://geodjango.mtri.org/clarus/
Data CC-By-SA by OpenStreetMap
Done