```
      name:  <unnamed>
       log:  /Users/robertyaffee/Documents/data/research/chwk/phase3/geodesicD
> istanceComputations.smcl
  log type:  smcl
 opened on:  20 Jan 2012, 18:05:09

 1 . *  Robert Yaffee  20 Jan 2012    Haversine Geodesic distance computations
 2 . *  Chornobyl sequelae study
 3 .
 4 . set more off

 5 . cap label var lat1 "Chornobyl latitude in decimal degrees"

 6 . cap label var lon1 "Chornobyl longitud in decimal degrees"

 7 . cap label var lat2 "1986 residential latitude"

 8 . cap label var lon2 "1986 residential longitude"

 9 . cap label var sinlat1 "sin of Chornobyl latitude in decimal degrees"

10 . cap label var coslat1 "cos of Chornobyl latitude in decimal degrees"

11 . cap label var sinlat2 "sin of residential latitude in decimal degrees at tim
   > e of accident"

12 . cap label var coslat2 "cos of residential latitude in decimal degrees at tim
   > e of accident"

13 . cap label var cosdlon "cos of difference between latitudes of Ch and April 2
   > 6 1986 residence"

14 . cap label var cosdlonrad "cosine of difference between latitudes of Ch and A
   > prl 26 1986 residence in radians"

15 . cap label var sindlatr "sine of difference in Ch and April 26 1986 residenti
   > al latitude in radians"
```

```
16 . cap label var sindlonr "sine of difference in Ch and April 26 1986 residenti
   > al longitude in radians"

17 .
18 .  //  the objectiveis to compute the distance between Chornobyl
19 .  //  and residences of respondents in 1986.  To do so,
20 .  //  we will use the Haversine formula that has been applied
21 .  //  in spherical trigonometry for this purpose.
22 .  //    algorithmic summary
23 .  //   1.  convert degrees and minutes to decimal degrees
24 .  //   2.  convert decimal degrees to radians.
25 .  //   3.  Compute the sins and cosine needed to find the distance
26 .  //   4.  the distance will be found and must be reconverted to the original
   >  metric
27 .
28 .
29 .
30 . *=================== Baseline converstion factors============================
   > =========
31 .
32 . *------------------ 1 mile = 1.609344 km
33 . *------------------ 1 km = .62137119 miles
34 . *------------------ earth radius = 6371 km
35 . *--------------------earth radius = 3963.1 miles
36 .
37 . *------------------ decimal degrees = degrees + minutes/60    // seconds are
   >  ignored
38 . *------------------ angle in radians = .0174329 * degrees
39 .
40 .
41 . *--------------------Chornobyl coordinates    latitude in degrees and minutes
   >  with 0 seconds =  51°23"N   longitude= 30°6" E
42 . cap gen LatChrnDD = 51 + 23/60

43 . cap gen LonChrndD = 30 + 6/60

44 . cap gen lon1dd = 30.08
```

```
45 .
46 .
47 . *------------------Kiev City Center Coordinates latitude in degree  = 50 27"
   >  N    longitude = 30 32" E
48 .
49 . *------ Nonspherical map distance according to Google Maps 19 Jan 2012
50 . * Baseline computation by google earth of distance from center of Kiev to Ch
   > ornobyl
51 . * distance according to Google maps from Chornobyl to Kiev City 68.8 miles =
   >  110.53 km
52 .
53 .
54 . *================================================================================
   > ========================
55 .
56 .
57 . //       Haversine formula  for great circle distances between geodesic coor
   > dinates of lat and lon
58 . //    Sources: http://en.wikipedia.org/wiki/Great-circle_distance#Radius_for
   > _spherical_Earth,  accessed 18 20 Jan 2012
59 . //     http://mathworld.wolfram.com/GreatCircle.html,  accessed 20 Jan 2012
60 . //      http://maps.google.com
61 . //      http://www.movable-type.co.uk/scripts/latlong-vincenty.html  by Chri
   > s Veness accessed 20 Jan 2012
62 . //      Stata ado file written by Austin Nichols to compute Geodesic distanc
   > es by the Thaddeus Vincenty formula, available
63 . //         from Stata Software Components archive managed by Chris Baum at B
   > oston College. accessed 20 Jan 2012
64 .
65 . *================================================================================
   > ========================
66 .
67 .
68 . //      Distance = radius of earth( Radearth ) * Central angle betwen two po
   > ints (CAR) measured in radians.
69 . //  This distance is measured in km.
70 .
```

```
71 . //      where
72 .
73 . //  CA = acos(sin(lat1)*sin(lat2) + cos(lat1)*cos(lat2)*cos(dlon) )      //
   > Central angle distance with angle is measured in radians
74 . // Radians = angle in degrees * .01745329
75 . // Distance =  CA * Radearth = 6371.01
76 .
77 .
78 . replace RadEarthkm = 6371.01                          // in km
   (0 real changes made)

79 . label var RadEarthkm "Radius of the earth in km"

80 . list RadEarthkm if _n < 5
```

	RadEa~km
1.	6371.01
2.	6371.01
3.	6371.01
4.	6371.01

```
81 . replace RadEarthMi =  3963.1
   (0 real changes made)

82 . label var RadEarthMi "Radius of earth in miles"

83 . list RadEarthMi if _n < 5
```

	RadEar~i
1.	3963.1
2.	3963.1
3.	3963.1
4.	3963.1

```
84 .
85 . replace lat2dd = latdacc + latmacc/60
   (0 real changes made)

86 . replace lon2dd = londacc + lonmacc/60
   (0 real changes made)

87 . list lat2dd if _n < 5
```

	lat2dd
1.	50.73333
2.	50.73333
3.	50.73333
4.	50.73333

```
88 . list lon2dd if _n < 5
```

	lon2dd
1.	30.86667
2.	30.86667
3.	30.86667
4.	30.86667

```
89 .
90 . // use angles in decimal degrees to begin computations
91 . cap gen lat1dd = LatChrnDD                      // Chornobyl latitude in dec
   > imal degrees

92 . label var lat1dd "Latitude of Chorn. in decimal degrees"

93 . cap gen lon1dd = LonChrnDD                      // Chornobyl longitude in de
   > cimal degrees
```

```
 94 . label var lon1dd "Longitude of Chornobyl in decimal degrees"

 95 . cap rename Latdd1986 Lat1986DD                  //  latitude location at tim
   > e of accident on part of respondent

 96 . cap rename Londd1986 Lon1986DD                  //  longitude location at ti
   > me of accident  "

 97 . cap gen lat2dd = Lat1986DD                     //  latitude   "

 98 . cap gen lon2dd = Lon1986DD                     //  longitude  "

 99 . label var lat2dd "Latitude of respondent  in decimal degrees in April 1986"

100 . label var lon2dd "Latitude of respondent in decimal degrees in April 1986"

101 . // we convert these angle to radians for use in trig formulae
102 . cap gen  lat1r =LatChrnDD*.01745329                        // angle in radian
   > s

103 . cap gen  lon1r =LonChrnDD*.01745329                        // angle in radian
   > s

104 . cap gen  lat2r =lat2dd*.01745329                           // angle in radian
   > s

105 . cap gen  lon2r =Lon2dd*.01745329                           // angle in radian
   > s

106 .
107 . // we substitute radians for degrees in trig formulae
108 . cap gen  sinlat1r = sin(lat1r)                      //   sin of Chornobyl lat
   > itude in radians

109 . cap gen  coslon1r = cos(lon1r)                     //   cos of Chornobyl lon
   > gitude in radians
```

```
110 . cap gen  sinlat2r= sin(lat2r)                      // sin of 1986 latitude

111 . cap gen  coslat2r = cos(lat2r)                     // cos of 1986 latitude

112 . cap gen  cosdlonr = cos(lon2r-Lon1r)       // cos of longitudinal difference
    >  between the two in radians

113 . cap gen sindlatr = sin(lat2r-lat1r)        // sin of latitudinal difference
    > between the two in radians

114 . cap gen sindlonr = sin(lon2r - lon1r)

115 . cap gen dlatr = (lat1dd - lat2dd)*01745329

116 . label var dlatr "Difference in latitudes measured in radians between Ch and
    > 1986 april res location"
    note: label truncated to 80 characters

117 .
118 . *---------------------  2 formulae for central angle -----------------------
    > --------------------------------
119 .
120 . replace dx21 = 2 * asin((sin(dlatr * .5))^2 + cos(lat1r) * cos(lat2r)*(sin(d
    > lonr*.5))^2)       // formula 1
    (0 real changes made)

121 . replace DX21 = acos(sin(lat1r)*sin(lat2r) + cos(lat1r)*cos(lat2r)*cos(dlonr)
    >  )                 // formula 2
    (0 real changes made)

122 . label var dx21 "Dist. from point 1 to point 2 in km divided by the earth rad
    > ius in km"

123 .
124 .
125 . replace DX_Chkm = DX21 * 6371.01   // distance in km
    (0 real changes made)
```

```
126 . replace DX_Chmi = DX21 * 3963.1      // distance in miles
    (0 real changes made)

127 .
128 .
129 . replace dxfmChkm = dx21 * 6371.01   // distance in km
    (698 real changes made)

130 . replace dxfmChMi = dx21 * 3963.1    // distance in miles
    (698 real changes made)

131 . label var dxfmChkm "Distance from Chornobyl in km via Haversine formula 1"

132 .
133 .
134 .
135 .
136 . list DX_Chkm dxfmChkm DX_Chmi dxfmChMi sett1r1 if _n < 10
```

	DX_Chkm	dxfmChkm	DX_Chmi	dxfmChMi	sett1r1
1.	74.90189	19457.48	46.59288	12103.57	Kyiv
2.	74.90189	19457.48	46.59288	12103.57	Kyiv
3.	74.90189	19457.48	46.59288	12103.57	Kyiv
4.	74.90189	19457.48	46.59288	12103.57	Kyiv
5.	74.90189	19457.48	46.59288	12103.57	Kyiv
6.	80.79928	19462.79	50.26136	12106.87	Kyiv
7.	22.50504	1851.379	13.9993	1151.654	Pripyat
8.	74.90189	19457.48	46.59288	12103.57	Kyiv
9.	74.90189	582.7817	46.59288	362.5205	Kyiv

```
137 .
138 . * Method 2   Computation of great circle distance from Chornobyl via Haversi
    > ne formula
```

```
139 .
140 .
141 . //  Haversine formula uses
142 . //    1. dms converted to decimal degrees            lataccDD lonaccDD
143 . //    2. decimal degrees converted to radians        lat2r lon2r
144 . //    3. differences in latitude longitude measured in radians  dlatr and dl
    > onr
145 .
146 . cap gen lataccDD = latdacc + (latmacc/60)

147 . label var lataccDD "latitude at time of Chorn. accident in decimal degrees"

148 . cap gen lonaccDD = londacc + (lonmacc/60)

149 . label var lonaccDD "longitude at time of Chorn. accident in decimal degrees"

150 . cap gen lat2r =LataccDD*.01745329                      // angle in radians

151 . cap gen lon2r =LonaccDD*.01745329                      // angle in radians

152 . label var lat2r "Latitude in radians at time of Chorn. accident"

153 . label var lon2r "Longitude in radians at time of Chorn. accident"

154 .
155 .
156 . cap gen dlatr = lat2r - lat1r

157 . cap gen dlonr = lon2r - lon1r

158 . label var dlatr "Difference in latitude in radians"

159 . label var dlonr "Difference in longitude in radians"

160 .
161 . label var sinlat1r "sin of latitude of Chornobyl in radians"
```

```
162 . label var coslat1r "cos of latitutde of Chornobyl in radians"

163 . label var coslon1r "cos of longitude of Chornobyl in radians"

164 . label var dlatr "Latitudinal difference measured in radians  bet Chrn. & res
    > idence"

165 .
166 . label var dlonr "Longitudinal difference betw. Chrn. & residence in radians"

167 . label var dlonr "Longitudinal difference betw. Chrn. & residence in radians"

168 . label var sinlat2r "Sin of latitude of residence in radians at time of Chrn.
    >  accident"

169 . label var coslat2r "Cos of latitude of residence in radians at time of Chrn.
    >  accident"

170 .
171 .
172 . //  arc span
173 . replace Thearc = ((sin(dlatr/2))^2 + cos(lat1r)*cos(lat2r)*(sin(dlonr/2))^2)
    (0 real changes made)

174 . label var Thearc "Harversine arc computation part 1"

175 .
176 . //given
177 .
178 . *-----------------------------------------------------------------------// fo
    > rmula 3 for central angle
179 . replace ca3 = 2*atan2(sqrt(Thearc), sqrt(1-Thearc))
    (0 real changes made)

180 . label var ca3 "Central angle computation for Haversine formula in radians"

181 .
```

```
182 .
183 . replace dxfmChkm = 6371.01 * ca3
    (698 real changes made)

184 . label var dxfmChkm "Residential distance from Chornobyl in km"

185 .
186 . replace RadEarthMi = 3963.1
    (0 real changes made)

187 . label var RadEarthMi "Radius of earth in miles"

188 .
189 . replace dxfmChMi = 3963.1* ca3
    (698 real changes made)

190 . label var dxfmChMi "Residential dist from Chornobyl in miles"

191 .
192 . replace HavKm = dxfmChkm    // Haversine formula used to compute distance fr
    > om Chornobyl in km
    (0 real changes made)

193 . replace Havmil = dxfmChmi   // Haversine formula used to compute distance fr
    > om Chornobyl in miles
    (0 real changes made)

194 . label var HavKm "Distance from Chornobyl in Km"

195 . label var Havmil "Distance from Chornobyl in miles"

196 . list sett1r1 HavKm Havmil DX_Chkm dxfmChkm DX_Chmi dxfmChMi sett1r1 if _n <
    > 10

     ┌──────────────────────────────────────────────────────────────────────────
    > ──────────────┐
     │ sett1r1      HavKm     Havmil    DX_Chkm   dxfmChkm    DX_Chmi   dxfmCh
    > Mi   sett1r1 │
     ├──────────────────────────────────────────────────────────────────────────
    > ──────────────┤
  1. │    Kyiv   19620.78   46.59288   74.90189   19620.78   46.59288   12205.
    > 14      Kyiv │
  2. │    Kyiv   19620.78   46.59288   74.90189   19620.78   46.59288   12205.
    > 14      Kyiv │
  3. │    Kyiv   19620.78   46.59288   74.90189   19620.78   46.59288   12205.
    > 14      Kyiv │
  4. │    Kyiv   19620.78   46.59288   74.90189   19620.78   46.59288   12205.
    > 14      Kyiv │
  5. │    Kyiv   19620.78   46.59288   74.90189   19620.78   46.59288   12205.
```

```
> 14      Kyiv |
     |------------------------------------------------------------------------
> ---------------|
  6. |     Kyiv   19624.54   50.26136   80.79928   19624.54   50.26136   12207.
> 48      Kyiv |
  7. |  Pripyat   4973.792    13.9993   22.50504   4973.792    13.9993   3093.9
> 58   Pripyat |
  8. |     Kyiv   19620.78   46.59288   74.90189   19620.78   46.59288   12205.
> 14      Kyiv |
  9. |     Kyiv   2745.761   46.59288   74.90189   2745.761   46.59288   1708.0
> 06      Kyiv |
     +------------------------------------------------------------------------
> ---------------+

197 .
198 . ********************  Computation of great circle dx from Chornobyl at time
    >  of accident via Spherical law of cosines
199 .
200 . //  Spherical law of cosines
201 .
202 .
203 . cap drop SLOCDX

204 . cap gen SLOCDXkm =acos(sin(lat1r)*sin(lat2r)+cos(lat1r)*cos(lat2r)*cos(dlonr
    > ))*6371.01

205 . label var SLOCDXkm "Spherical law of cosines computation of dx from Chornoby
    > l in km"

206 . label var SLOCDXMi "Spherical law of cosines computation of dx from Chornoby
    > l in Miles"

207 .
208 .
209 . list sett1r1 HavKm Havmil SLOCDXkm if _n < 10
```

	sett1r1	HavKm	Havmil	SLOCDXkm
1.	Kyiv	19620.78	46.59288	74.90189
2.	Kyiv	19620.78	46.59288	74.90189
3.	Kyiv	19620.78	46.59288	74.90189
4.	Kyiv	19620.78	46.59288	74.90189
5.	Kyiv	19620.78	46.59288	74.90189
6.	Kyiv	19624.54	50.26136	80.79928
7.	Pripyat	4973.792	13.9993	22.50504
8.	Kyiv	19620.78	46.59288	74.90189
9.	Kyiv	2745.761	46.59288	74.90189

```
      └──────────────────────────────────────────┘

210 .
211 .
212 .
213 . cap gen SLOCDXMi = SLOCDXkm/1.609

214 .
215 . list id sett1r1 lat1dd lon1dd latdacc latmacc londacc lonmacc HavKm Havmil i
    > f sett1r1=="Pripyat"

      ┌──────────────────────────────────────────────────────────────────────────────┐
    > ┌──────────────────────┐
      │  id   sett1r1   lat1dd   lon1dd   latdacc   latmacc   londacc   lonmacc
    >       HavKm     Havmil │
      ├──────────────────────┼──────────────────────────────────────────────────────┤
    > ├──────────────────────┘
      7. │  22   Pripyat     51.4    30.08        51        10        30        30
    >    4973.792    13.9993 │
     40. │ 167   Pripyat     51.4    30.08        51        49        30        11
    >    844.4633   37.70615 │
    324. │ 767   Pripyat     51.4    30.08        51        40        30         8
    >    276.8539   27.56934 │
    375. │  64   Pripyat     51.4    30.08        51        10        30        30
    >    4973.792    13.9993 │
      └──────────────────────┴──────────────────────────────────────────────────────┘
    > └──────────────────────┘

216 .
217 .
218 . list id sett1r1 lat1dd lon1dd latdacc latmacc londacc lonmacc HavKm Havmil
    > if sett1r1=="Ivankiv"

      ┌──────────────────────────────────────────────────────────────────────────────┐
    > ┌──────────────────────┐
      │  id   sett1r1   lat1dd   lon1dd   latdacc   latmacc   londacc   lonmacc
    >       HavKm     Havmil │
      ├──────────────────────┼──────────────────────────────────────────────────────┤
    > ├──────────────────────┘
    143. │ 542   Ivankiv     51.4    30.08        50        31        31         6
    >    6925.673   64.73348 │
    583. │ 438   Ivankiv     51.4    30.08        50        31        31         6
    >    6925.673   64.73348 │
      └──────────────────────┴──────────────────────────────────────────────────────┘
    > └──────────────────────┘
```

```
219 . list id sett1r1 dxfmChkm dxfmChmi SLOCDXkm SLOCDXMi HavKm Havmi if _n < 20
```

	id	sett1r1	dxfmChkm	dxfmChmi	SLOCDXkm	SLOCDXMi	HavKm	Havmil
1.	3	Kyiv	19620.78	46.592876	74.90189	46.55183	19620.78	46.59288
2.	13	Kyiv	19620.78	46.592876	74.90189	46.55183	19620.78	46.59288
3.	14	Kyiv	19620.78	46.592876	74.90189	46.55183	19620.78	46.59288
4.	15	Kyiv	19620.78	46.592876	74.90189	46.55183	19620.78	46.59288
5.	16	Kyiv	19620.78	46.592876	74.90189	46.55183	19620.78	46.59288
6.	20	Kyiv	19624.54	50.261356	80.79928	50.21708	19624.54	50.26136
7.	22	Pripyat	4973.792	13.999305	22.50504	13.98697	4973.792	13.9993
8.	36	Kyiv	19620.78	46.592876	74.90189	46.55183	19620.78	46.59288
9.	40	Kyiv	2745.761	46.592876	74.90189	46.55183	2745.761	46.59288
10.	56	Kyiv	19620.78	46.592876	74.90189	46.55183	19620.78	46.59288
11.	58	Kyiv	11018.24	46.592876	74.90189	46.55183	11018.24	46.59288
12.	62	Chornobyl	18965.11	.54694138	.8792534	.5464596	18965.11	.5469414
13.	69	Vishneve	2468.62	57.205126	91.96195	57.15472	2468.62	57.20512
14.	71	Boyarka	10741.33	52.851079	84.96247	52.80452	10741.33	52.85108
15.	75	Boyarka	16319.37	53.666692	86.27364	53.61941	16319.37	53.66669
16.	78	Polesske	3589.894	13.999305	22.50504	13.98697	3589.894	13.9993
17.	82	Barishevka	2470.347	80.57438	129.53	80.50339	2470.347	80.57438
18.	84	Kyiv	19620.78	46.592876	74.90189	46.55183	19620.78	

```
>    46.59288 |
 19. | 85         Kyiv   19620.78   46.592876   74.90189   46.55183   19620.78
>    46.59288 |
     ╰──────────────────────────────────────────────────────────────────────────╯
> ─────────────╯

220 . save chwide19jan2012, replace
    file chwide19jan2012.dta saved

221 . log close
          name:  <unnamed>
           log:  /Users/robertyaffee/Documents/data/research/chwk/phase3/geodesicD
> istanceComputations.smcl
      log type:  smcl
     closed on:  20 Jan 2012, 18:05:09
──────────────────────────────────────────────────────────────────────────────────
```