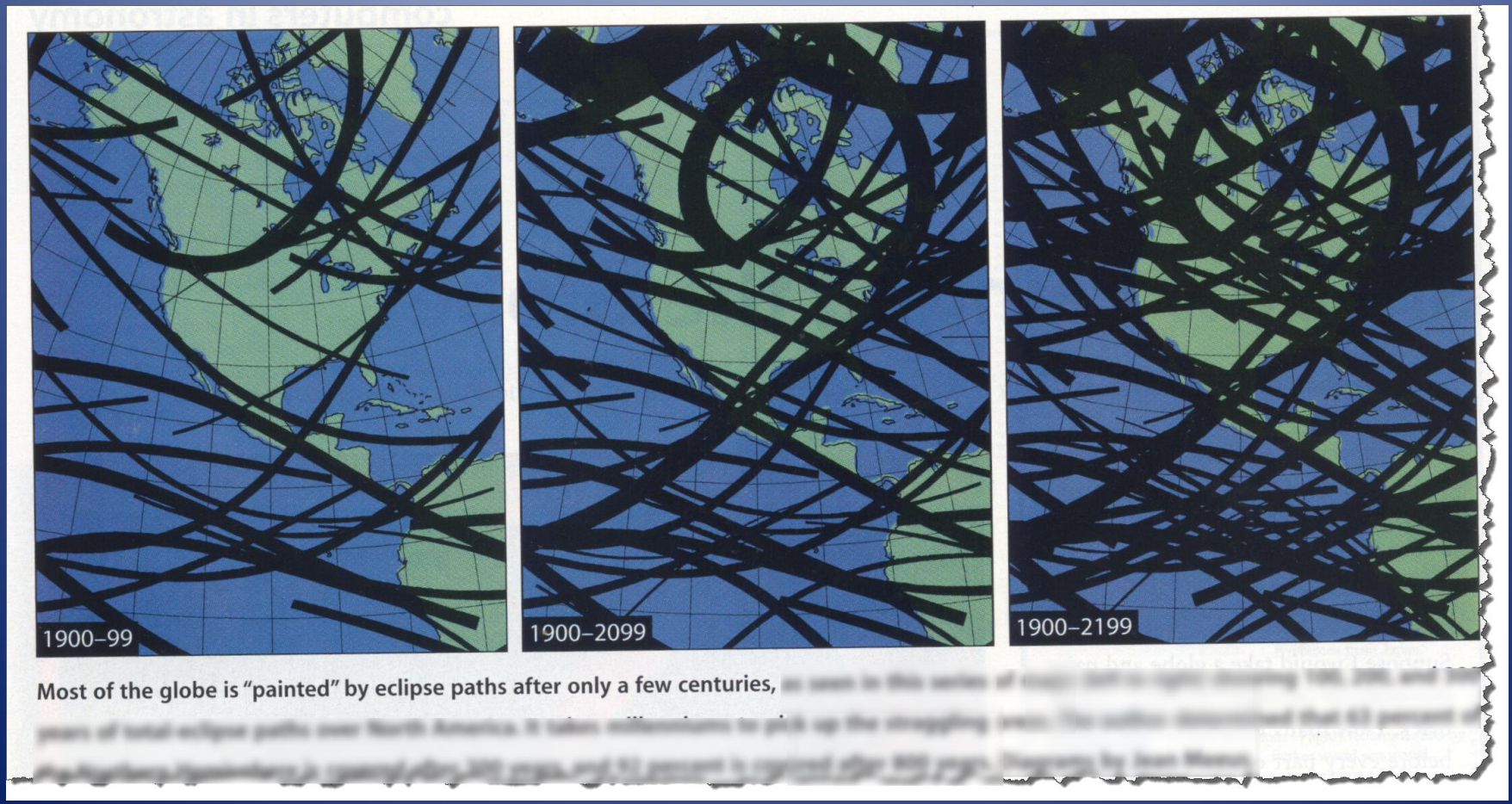
More Morsels – SEC2014

john.tilley@cantab.net

Getting hooked on Morsels

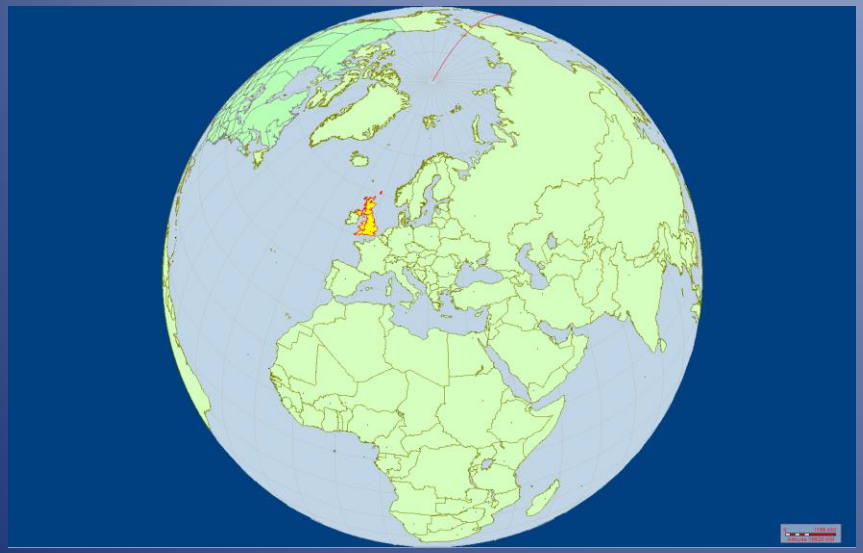
"Shadow Painting the Globe"



Most of the globe is "painted" by eclipse paths after only a few centuries,

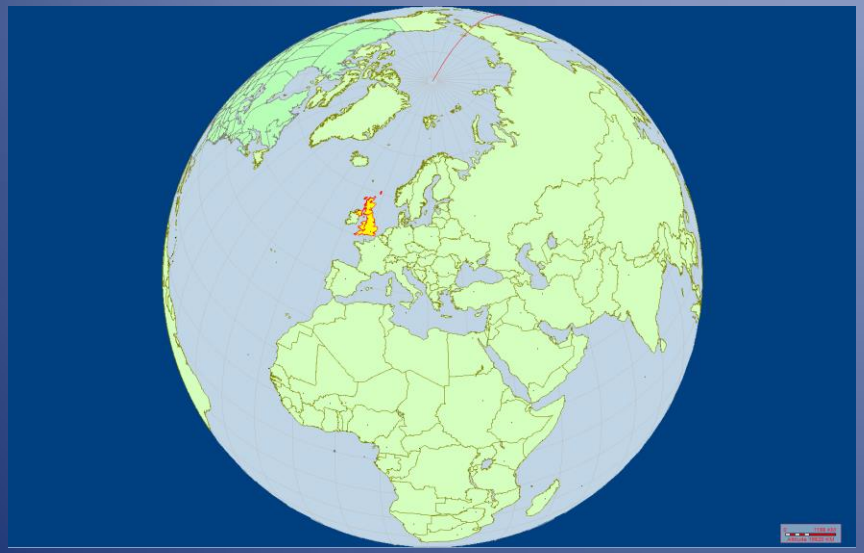
Two Topics

List ALL UK eclipses

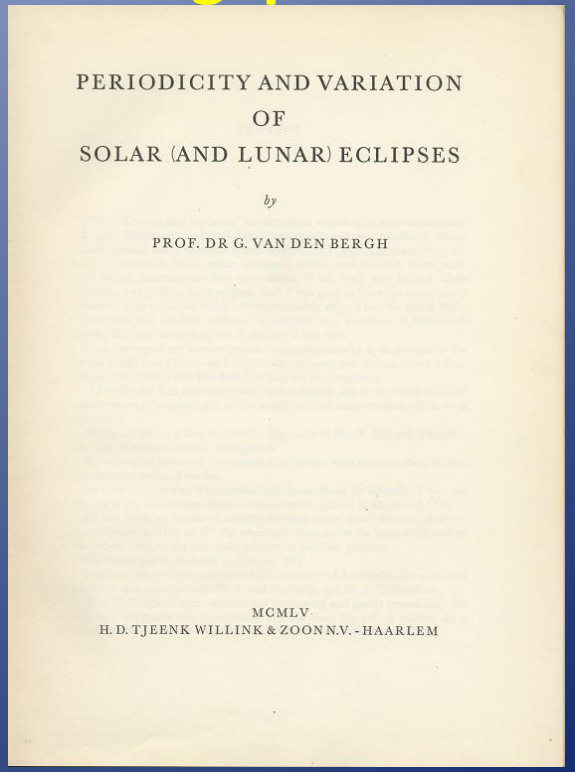


Two Topics

List ALL UK eclipses



- Solar and lunar semester
- The hidden relationship
- Lunation gaps



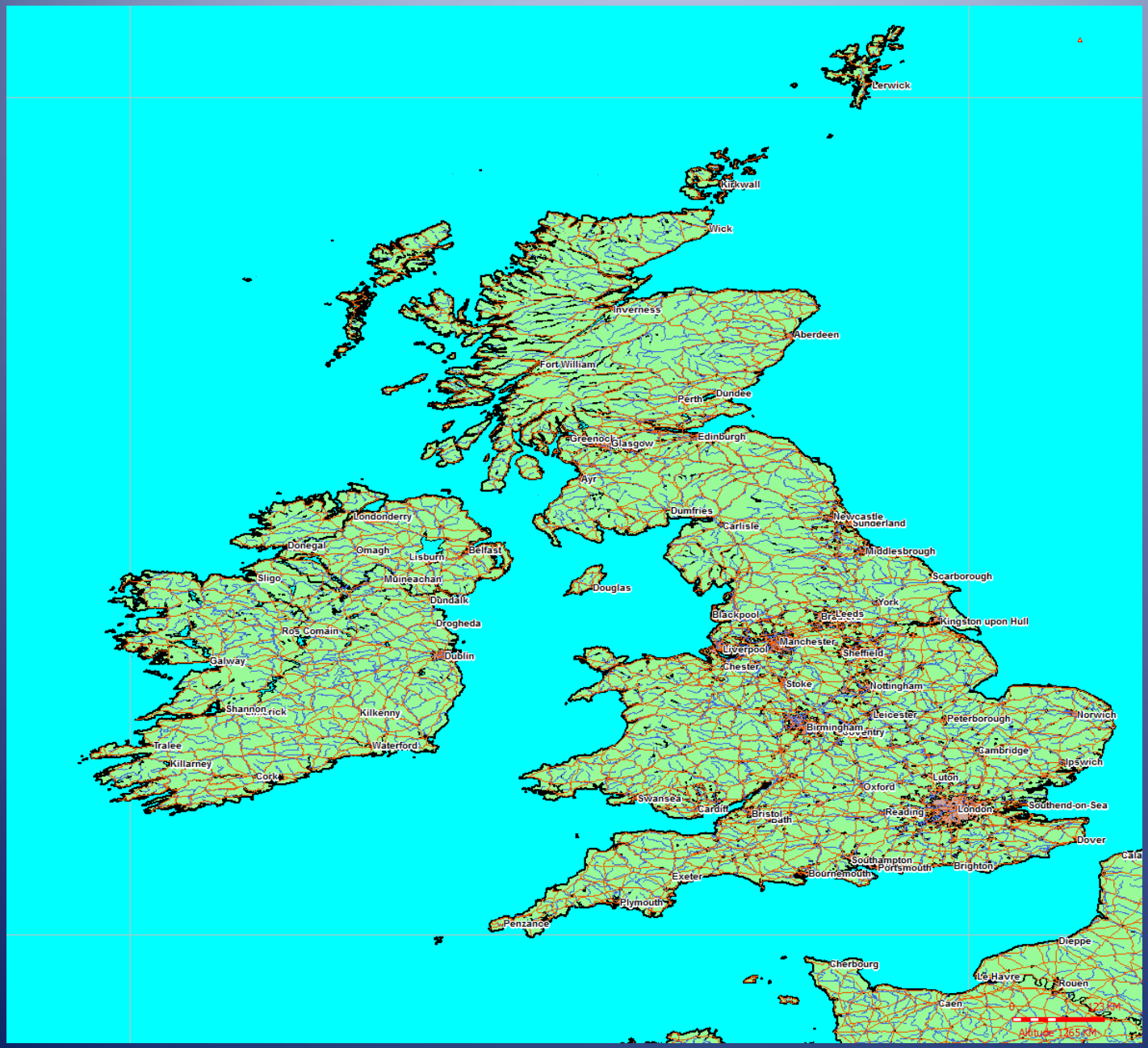
PERIODICITY AND VARIATION
OF
SOLAR (AND LUNAR) ECLIPSES

by

PROF. DR G. VAN DEN BERGH

MCMLV
H. D. TJEENK WILLINK & ZOON N.V. - HAARLEM

How many countries?



Challenge

Produce lists of ALL

- Partial
- Annular
- Total eclipses

For ALL countries

- From -1999 To +3000

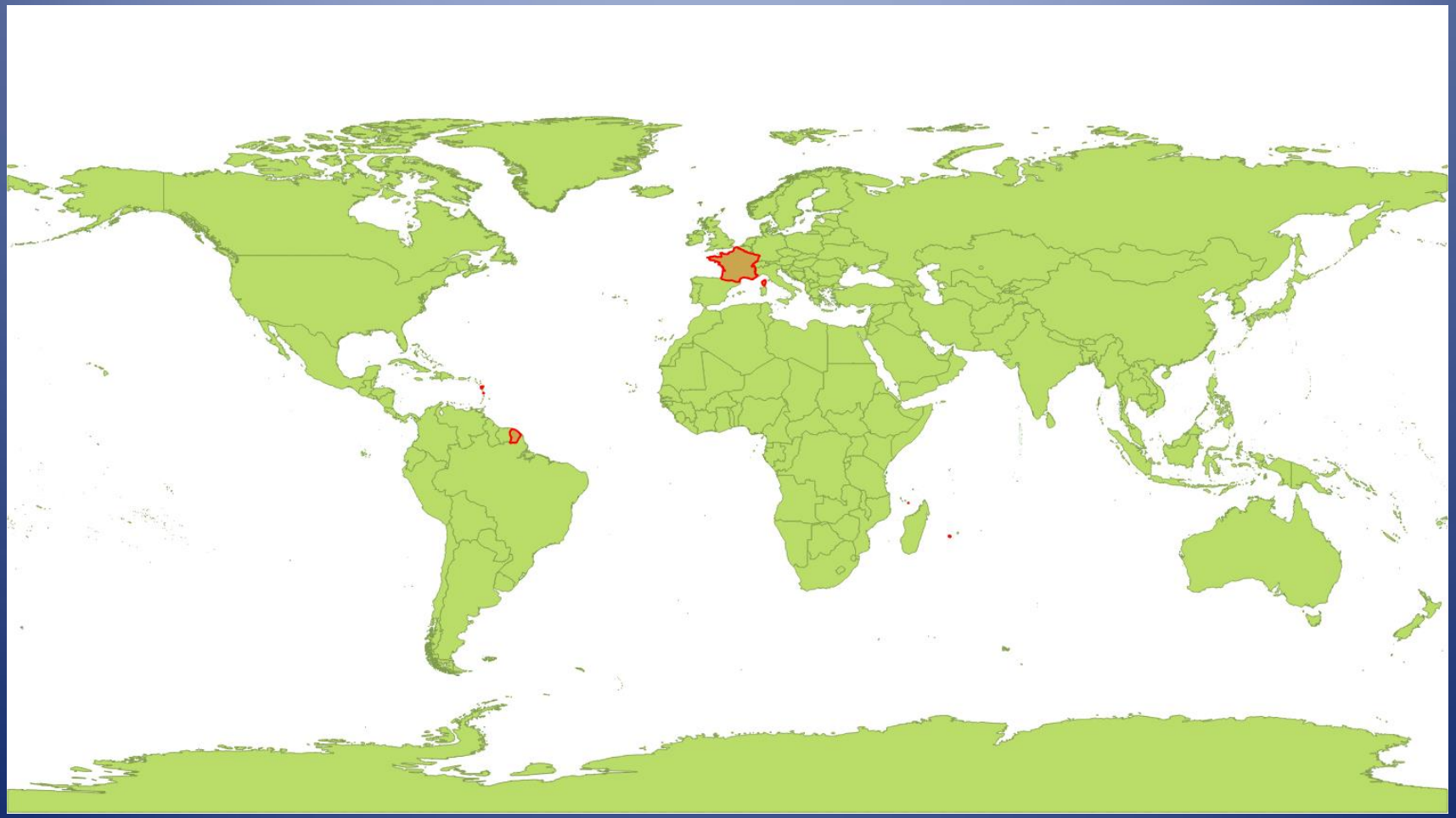
How???

Country and mapping data

www.naturalearthdata.com

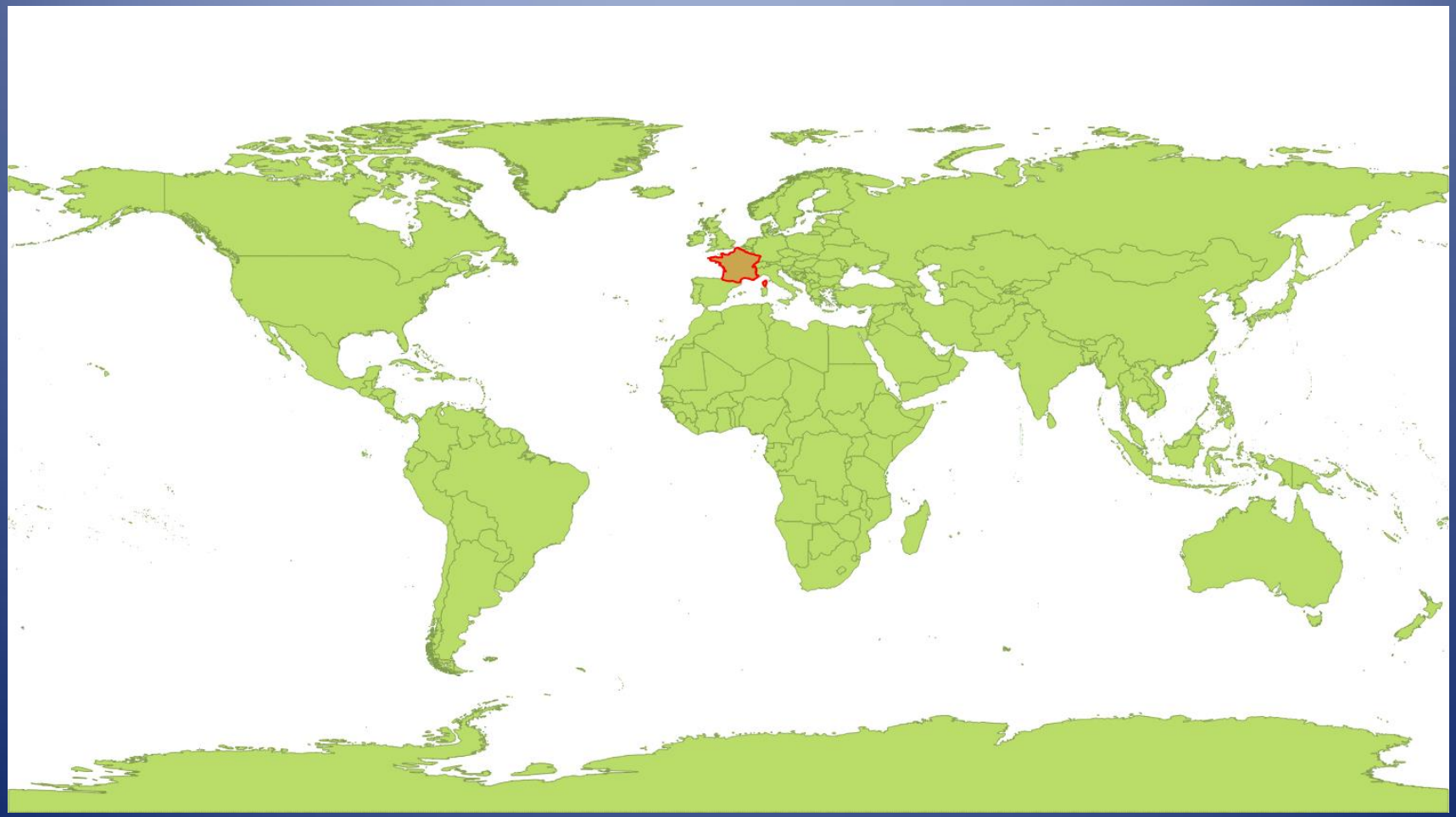
Vector Data	Number	
Sovereign States	197	Greenland part of Denmark
Countries	254	France includes some territories
Map Units	291	Australia includes remote island
Map SubUnits	351	USA = 48 states + Hawaii + Alaska
States/Provinces	3671	In most cases too much data

254 Countries



France = Mainland France, Corsica, French Guyana, Caribbean, Indian Ocean.

291 Map Units

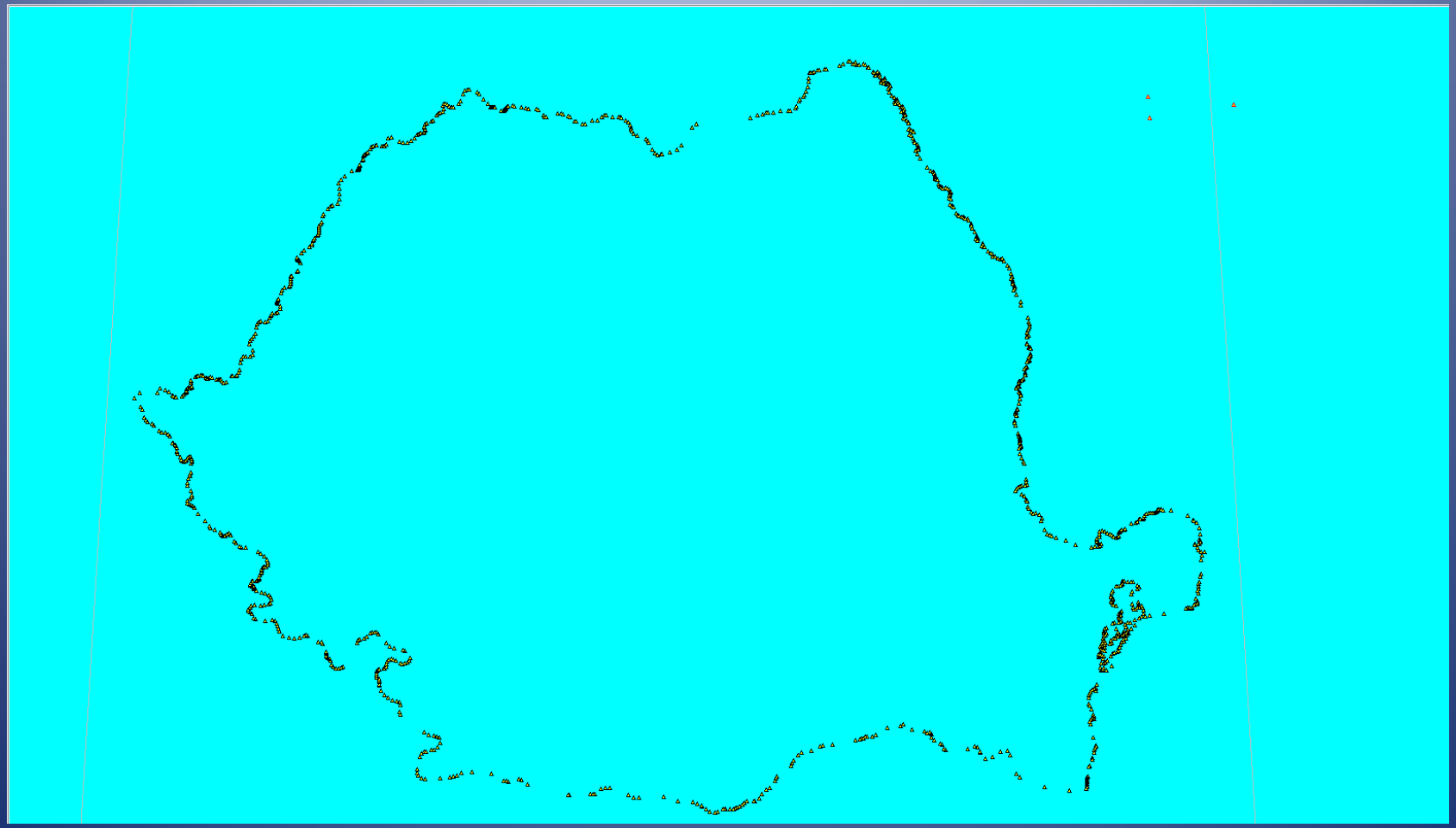


France = Mainland France and Corsica

Romania

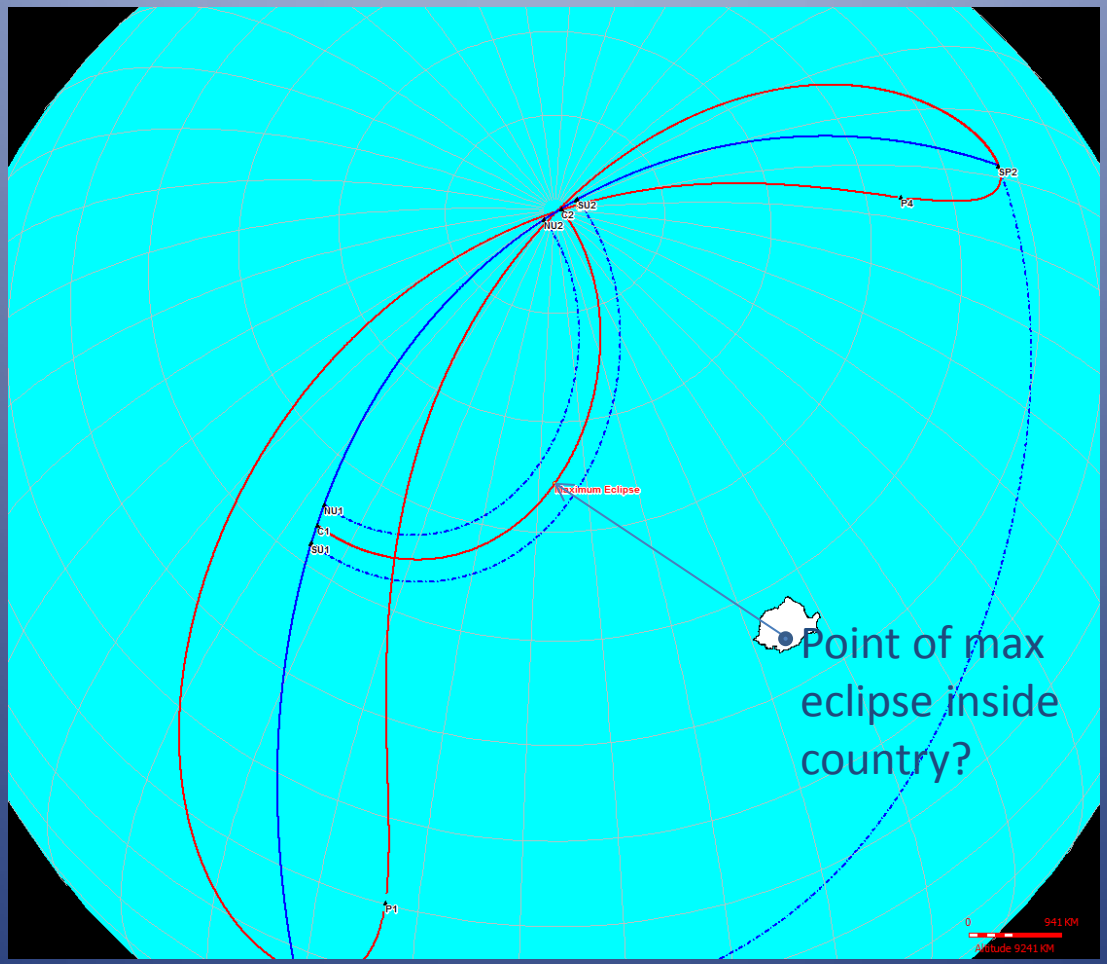
5 layers of data = Country border, lakes, rivers, roads and built-up areas
Country border is key

Romania border as points



1201 pairs of border points in NEV10m – there are some “large” gaps
Can find local circumstances for EACH border point
Eclipse Y/N, type, magnitude – hence max eclipse on country border

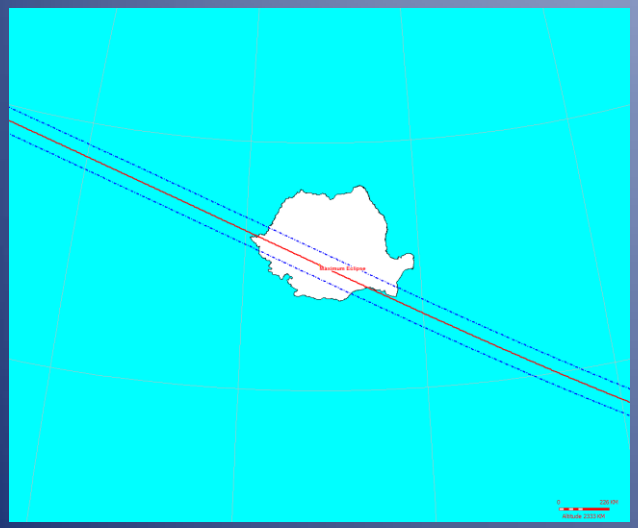
Country maximum eclipse MUST lie on the border



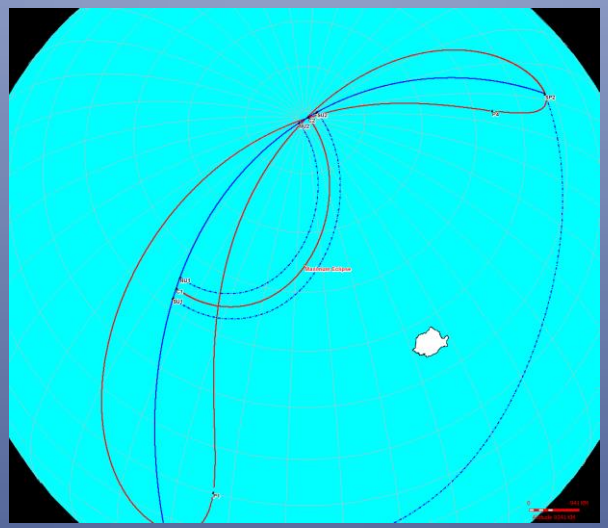
Point of max eclipse inside country?

Luca's Algorithm

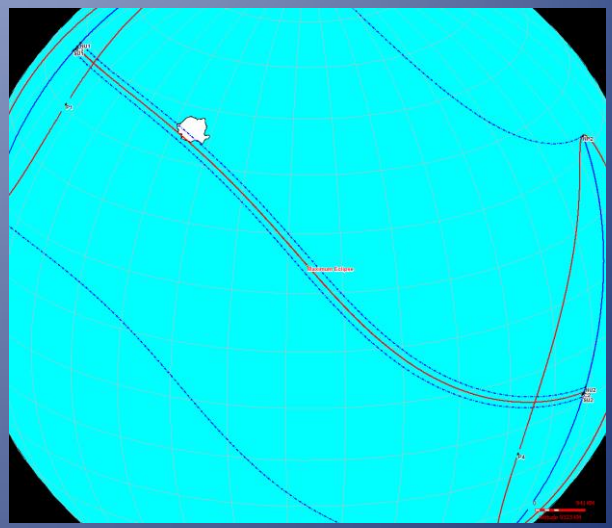
"For any given country and for any given solar eclipse, the point of country maximum eclipse must lie on that country's border, unless the point of maximum for the eclipse as a whole lies inside that country. "



Track of totality crosses Romania
-Romania sees a total eclipse
- Point of maximum for the eclipse as a whole (August 1999) actually lies inside Romania



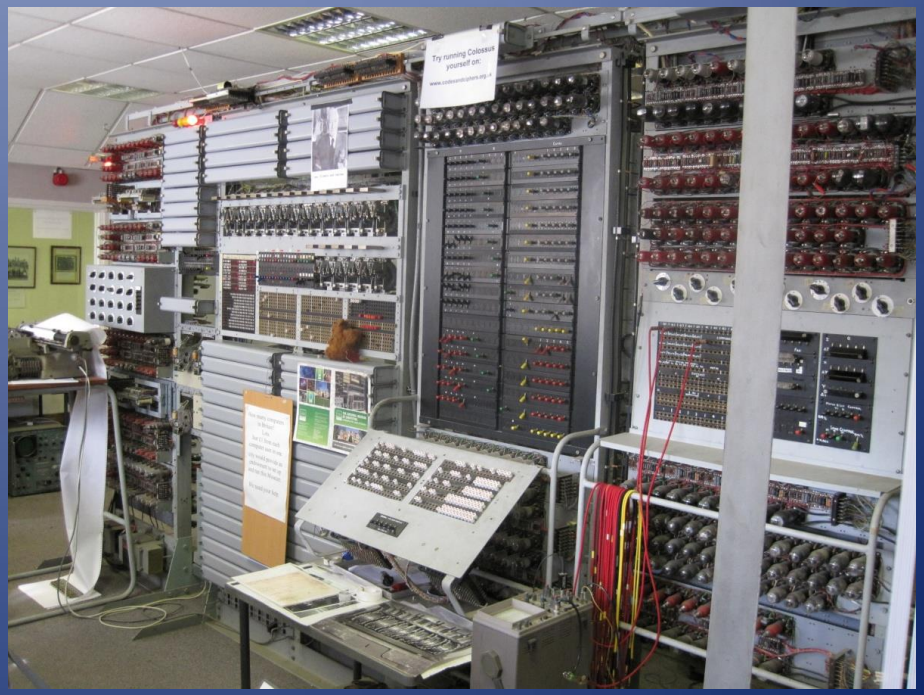
Track of totality lies outside Romania
-Romania sees a partial eclipse
-Max eclipse visible in Romania must lie on the border



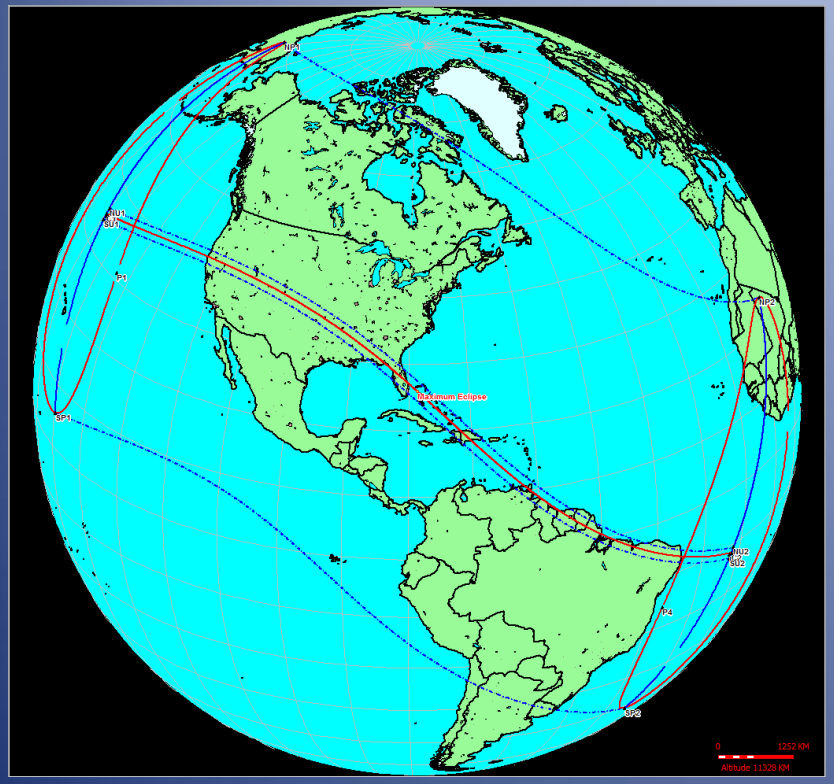
Track of totality crosses Romania
- Romania sees a total eclipse
Max eclipse visible in Romania must lie on the border

Eclipses by Country Number Crunching

- Natural Earth Vector 1:10million
  - 291 “countries”
  - 553176 points
  - 11898 solar eclipses
  - **6.58 billion calculations**
  - **Note – some special cases**
    - **Not yet fully handled**



USA Solar Eclipses

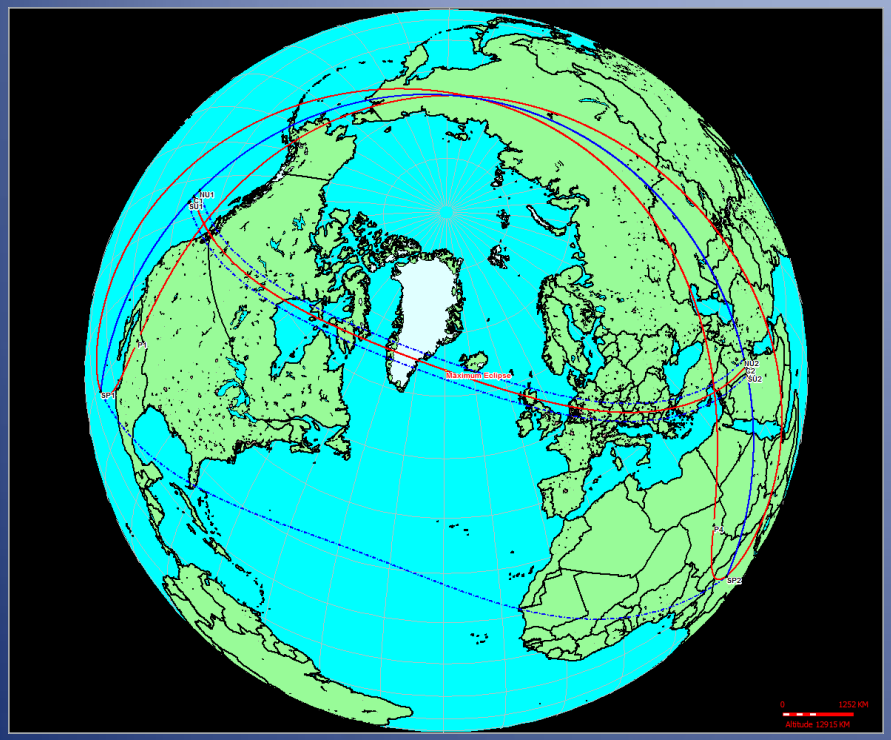


617 total
723 annular
3810 partial

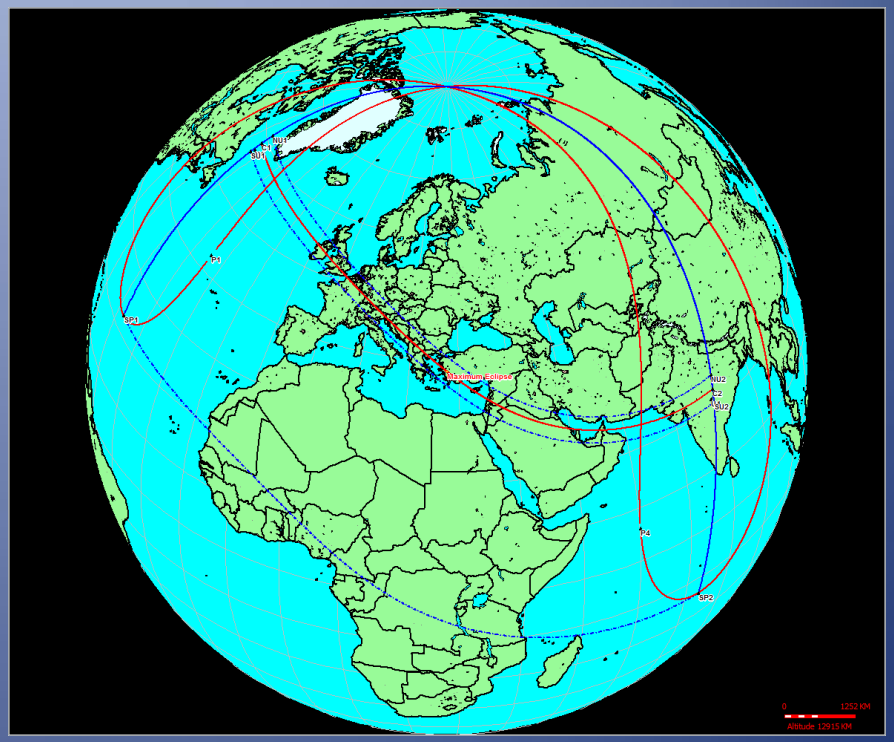
In 5000 years

- 8 total eclipses exceed 6minutes duration in USA
- 2045 August 12th total 6m 6sec
  - 12 lunations after 2044 Aug 23rd total eclipse

Eclipses with most countries to see totality or annularity

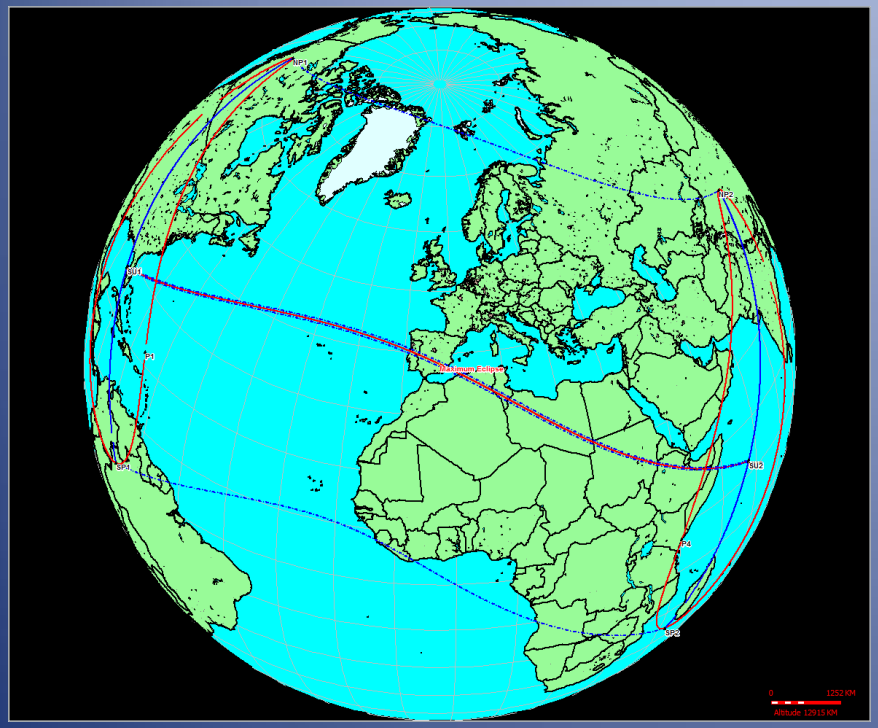


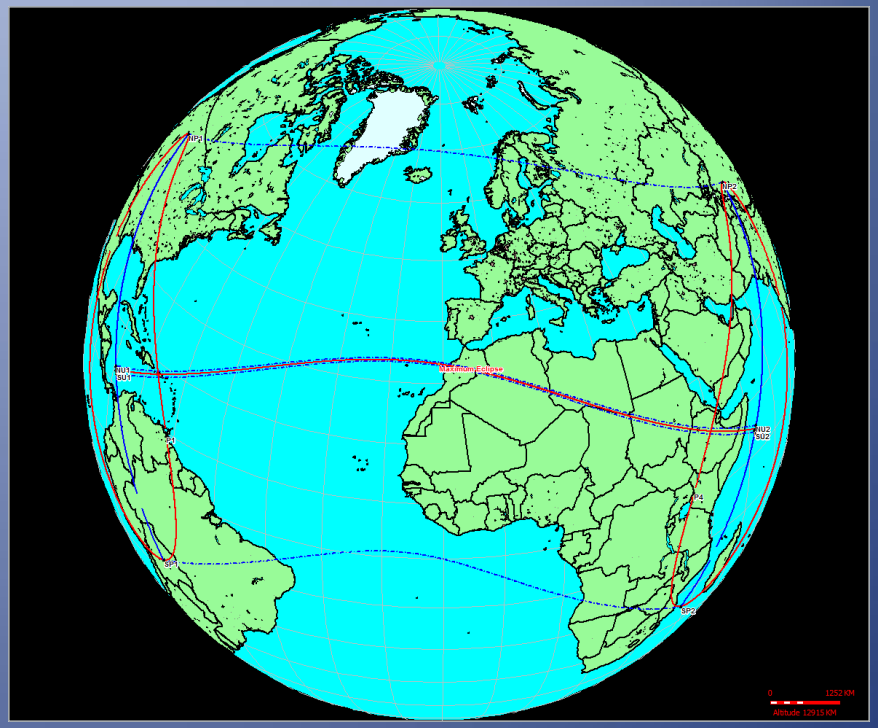
1433 June 17th
Total in 39 countries



-1763 October 8th
Annular in 53 countries

Eclipses visible in most countries





Total eclipse 1600 July 10th
212 countries
Total in 11 countries
Partial in 201 countries

Annular eclipse 410 June 18th
210 countries
Annular in 11 countries
Partial in 199 countries

Total Eclipses by Country

- 3171 pure total
- 571 hybrid eclipses in 5000 years

	A	D
1	Country	#Total
2	Russia	634
3	United States of America	617
4	Brazil	495
5	China	459
6	Canada	447
7	Australia	427
8	Antarctica	392
9	India	355
10	Chile	347
11	Indonesia	321
12	Argentina	302
13	Japan	256
14	Democratic Republic of the Congo	245
15	Mexico	241
16	Kazakhstan	213
17	Algeria	213
18	Colombia	213
19	Sudan	207
20	Peru	196
21	Saudi Arabia	195

Annular Eclipses by Country

-3956 pure annular

- 571 hybrid in 5000 years

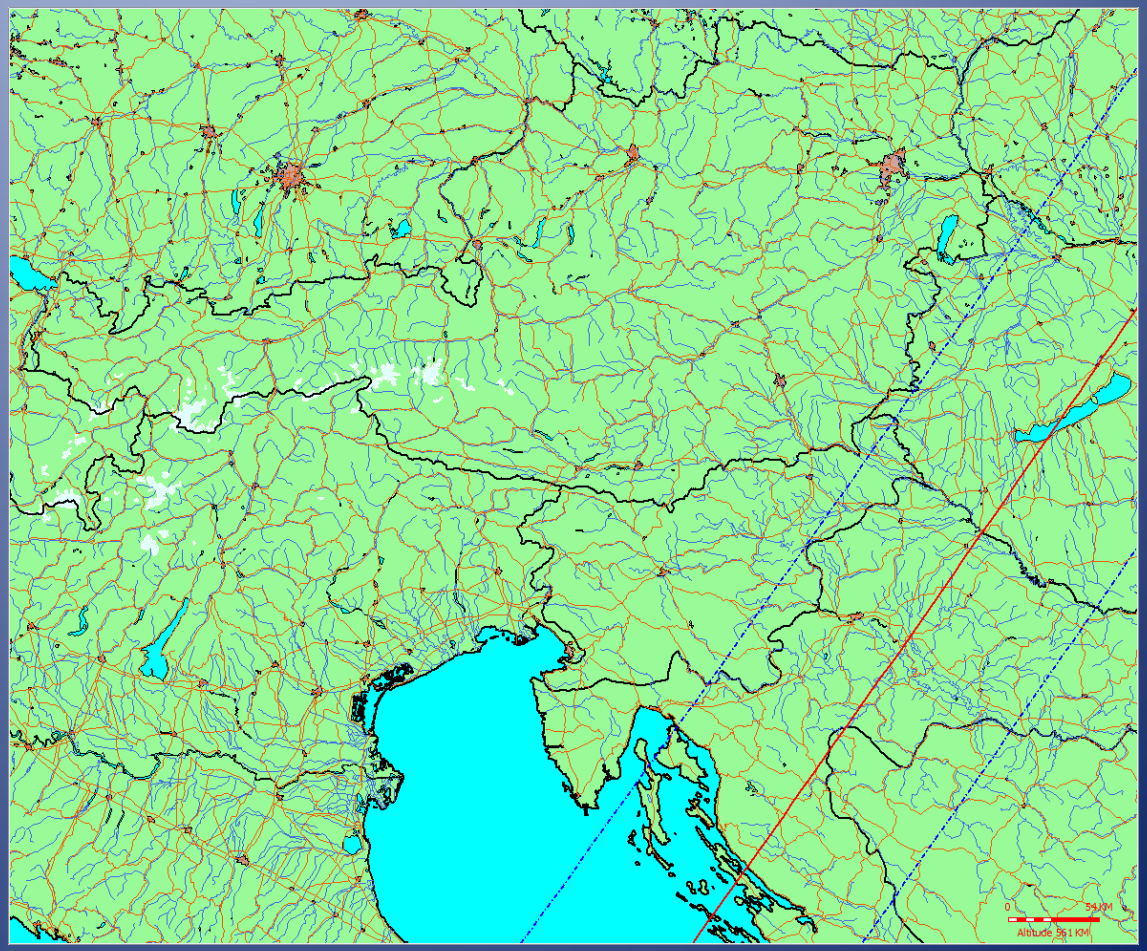
	A	B	D
1	Country	#Annular	#Total
2	United States of America	723	617
3	Russia	698	634
4	Antarctica	567	392
5	Brazil	546	495
6	Australia	510	427
7	Canada	490	447
8	China	489	459
9	Chile	412	347
10	India	402	355
11	Indonesia	376	321
12	Argentina	370	302
13	Japan	288	256
14	Democratic Republic of the Congo	273	245
15	Mexico	272	241
16	Peru	255	196
17	Kazakhstan	244	213
18	Algeria	242	213
19	French Polynesia	233	157
20	Myanmar	231	190
21	Mozambique	231	167

Special Case 1

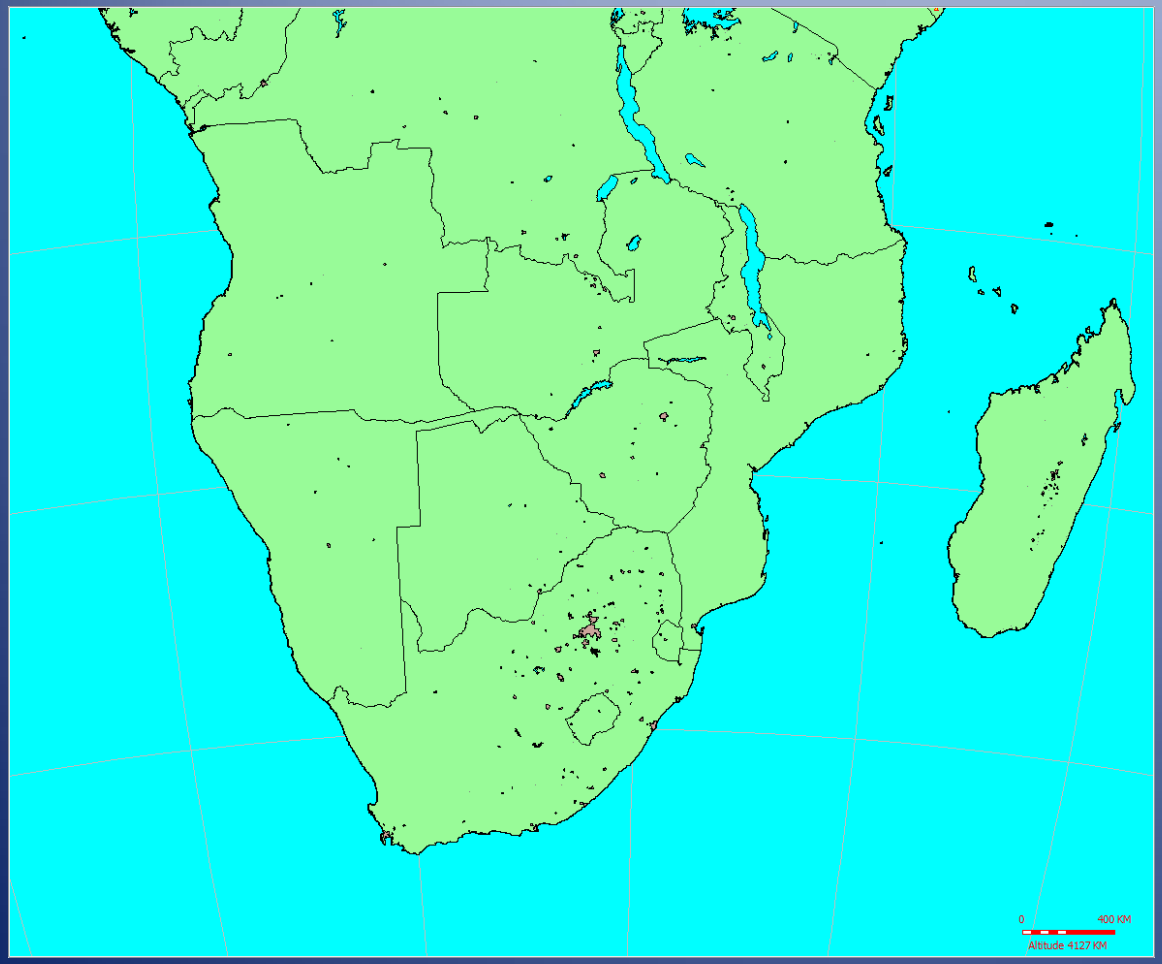
- Eclipse track is very narrow and passes between adjacent points on boundary
  - Eclipse misclassified
  - Hybrid eclipse 164 March 10th in Peru
  - Totality 3 seconds
- Use binary search to find point of greatest eclipse on boundary

Special Case 2

- 2379 March 19th
- Grazes Austrian border
- Amount of detail in digital mapping can change the type or duration

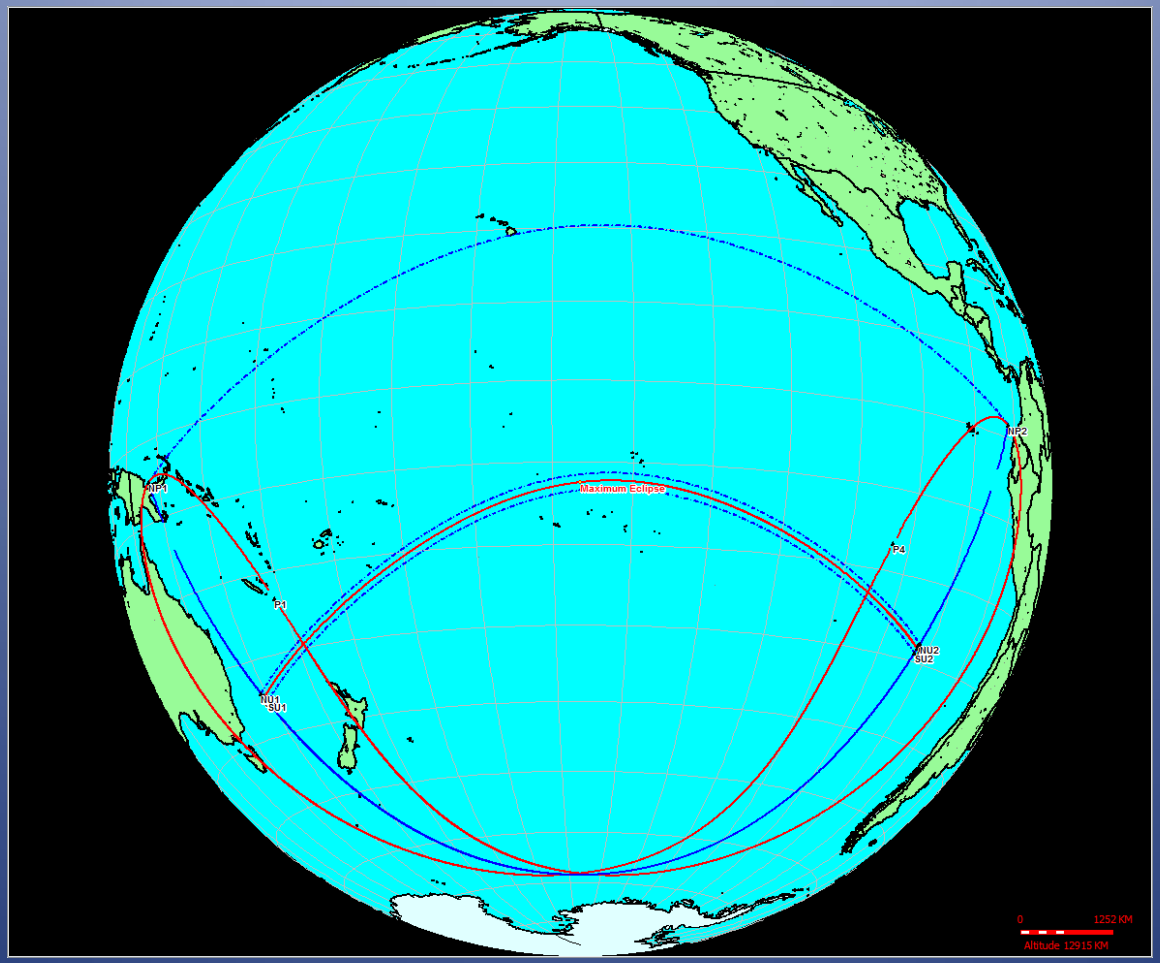


Special Case 3



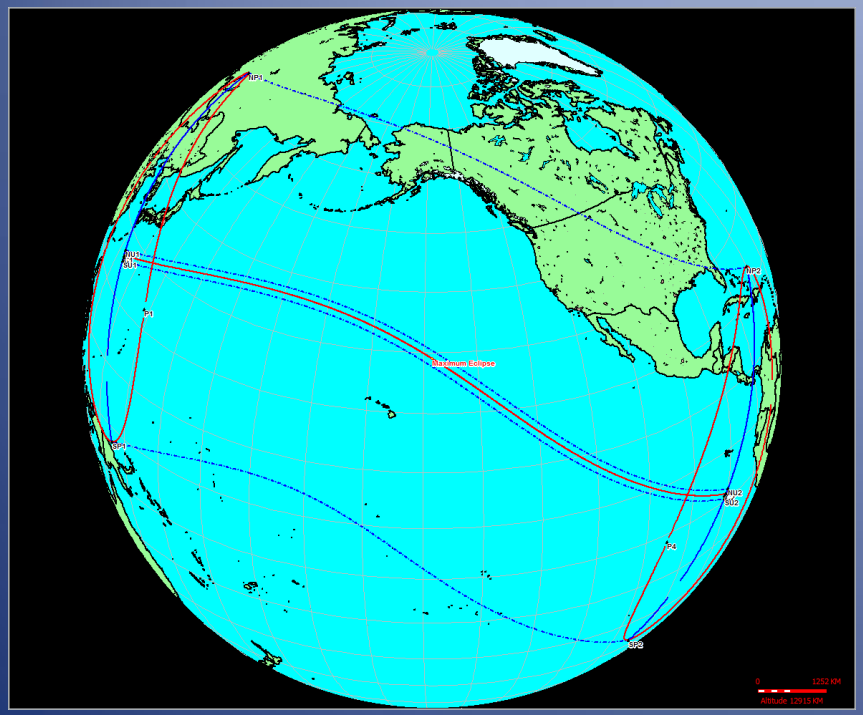
- Lesotho is wholly inside South Africa
- Check “Point in country” algorithm implementation returns correct country name!

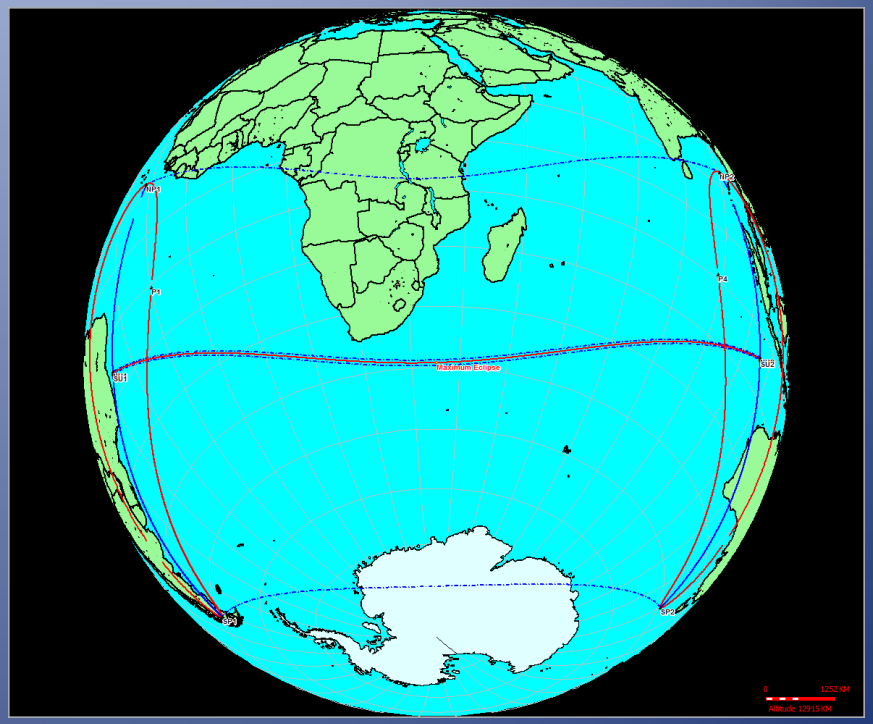
Aqueous Eclipses (MAM5)



Total eclipse 2310 May 29th (5m 10sec) misses all Pacific islands

Aqueous total eclipses



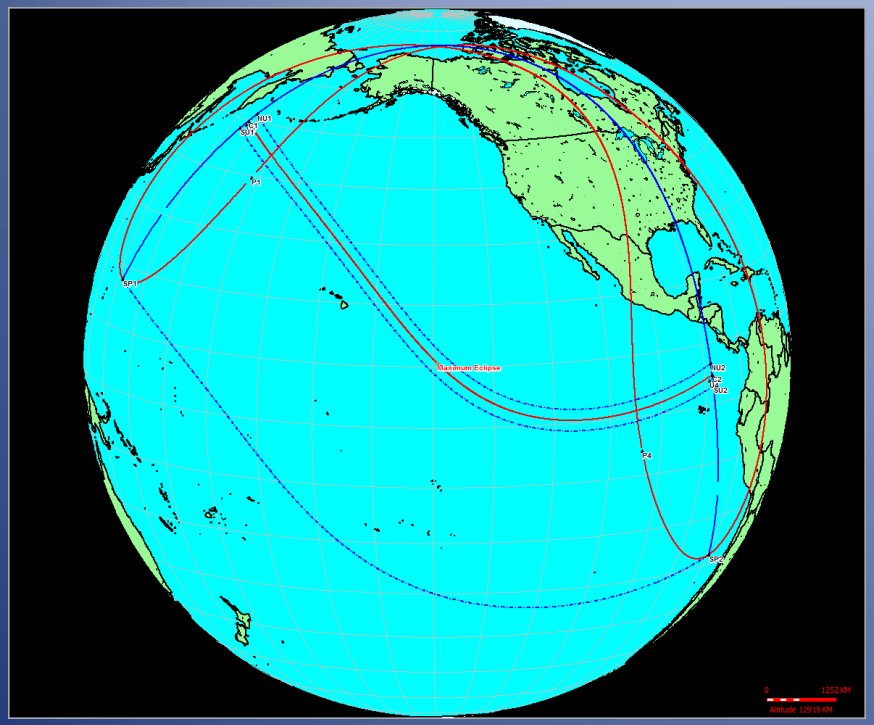


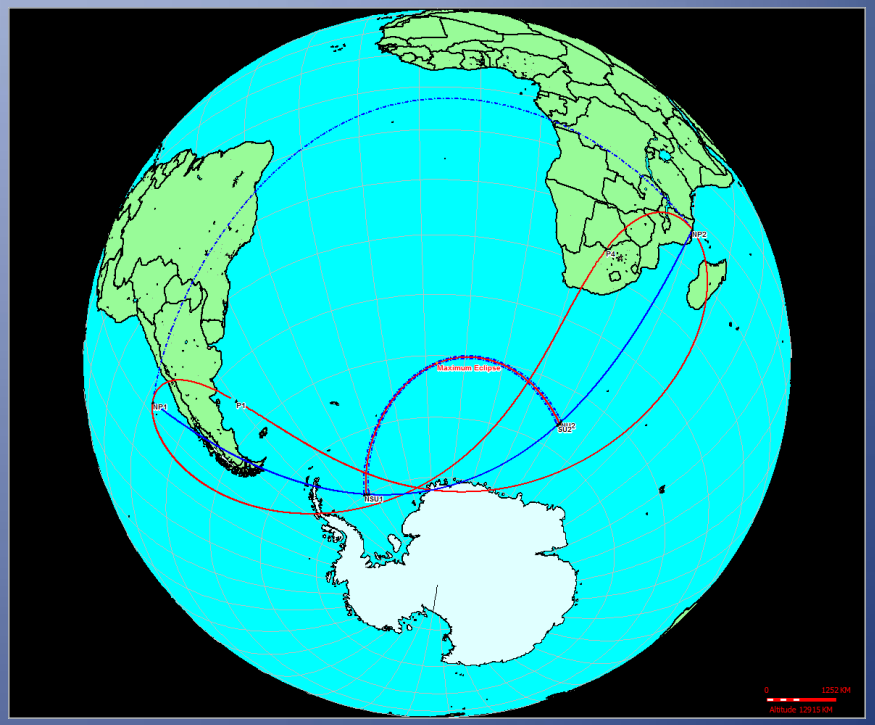
Longest 6m 6s in 222 July

Next eclipse 2m 28s in 2057 Jan 5th

74 total aqueous eclipses in 5000 years

Aqueous annular eclipses





Longest 10m 44s in -249 November

Next eclipse 22s in 2032 May 9th

97 annular aqueous eclipses in 5000 years

Lunation Gaps

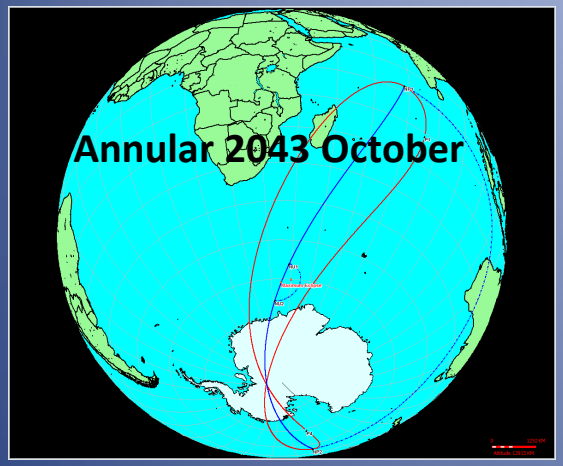
- Gaps between USA total eclipses
- Longest gap is 587 lunations
- Shortest gap is 6 lunations
- Gap to 2017 from 1991 is 323 lunations

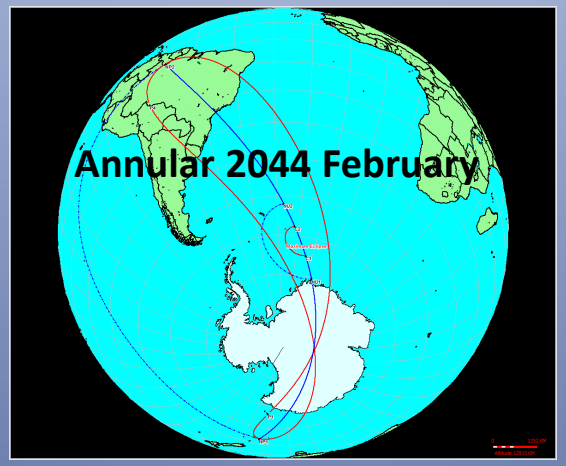
THE ECLIPSE INN

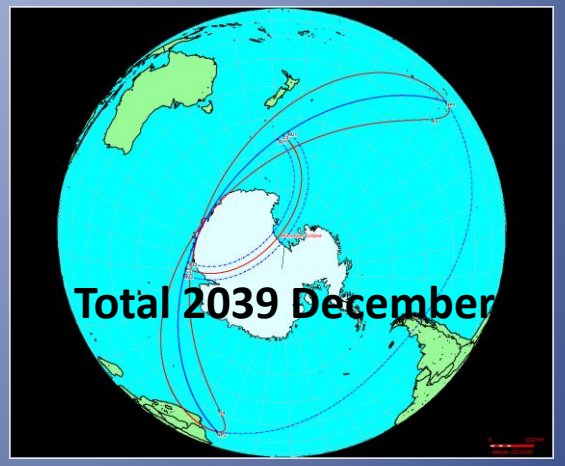
Quiz Question 1

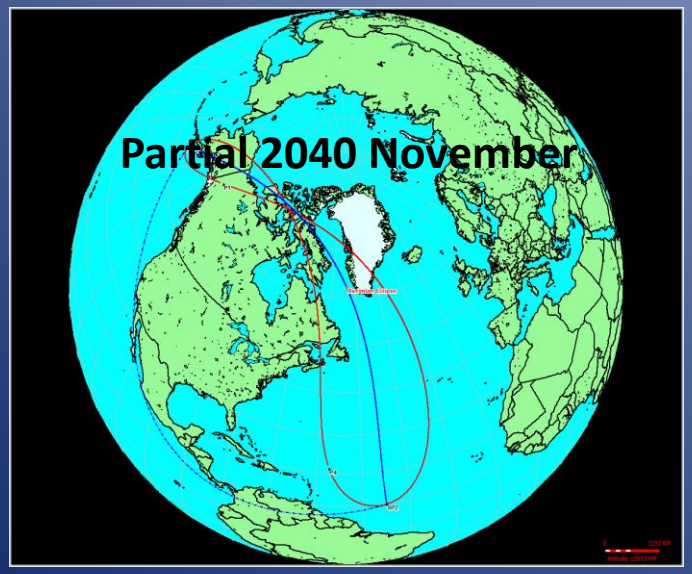
- Can you see totality in Antarctica on the Summer Solstice – i.e. June?

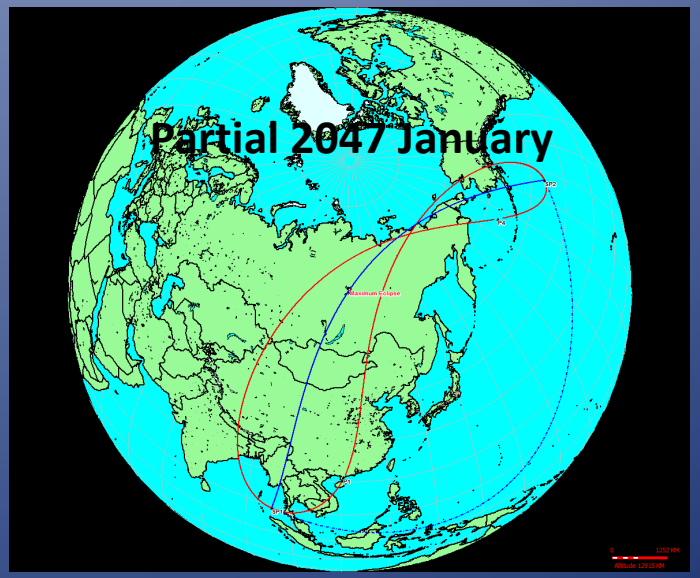
5 interesting eclipses in next 35 years



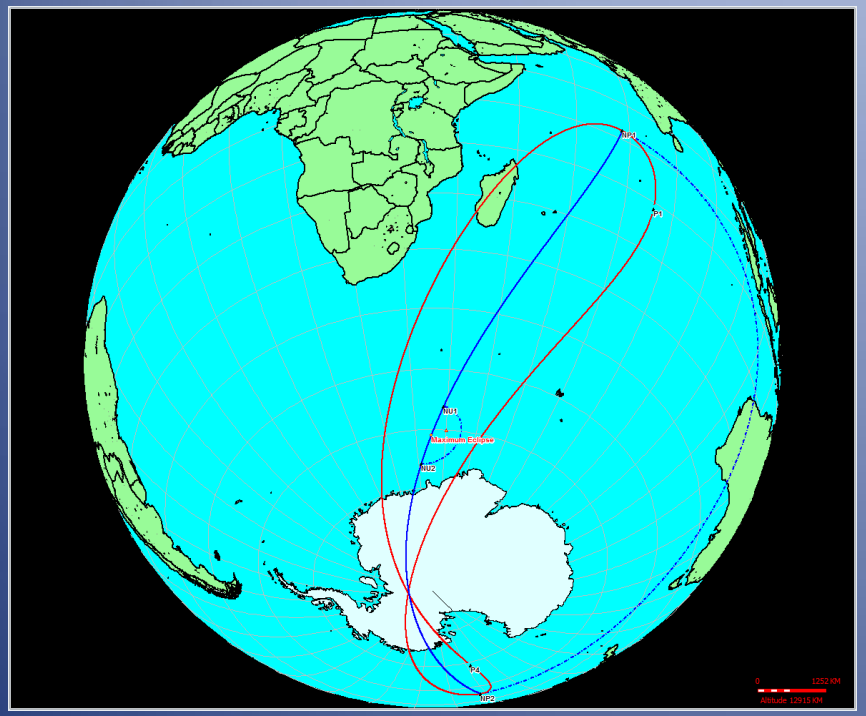


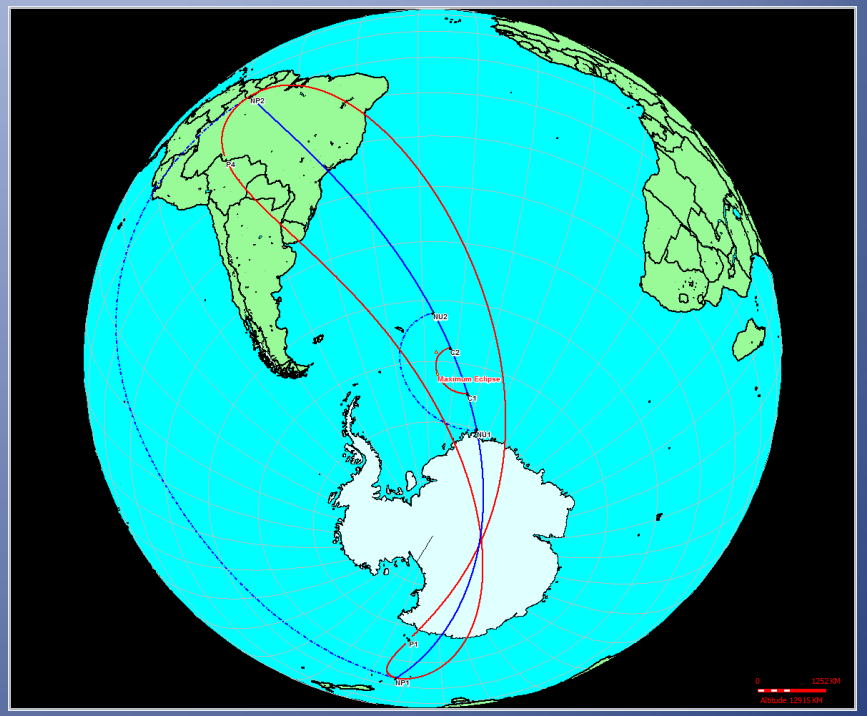






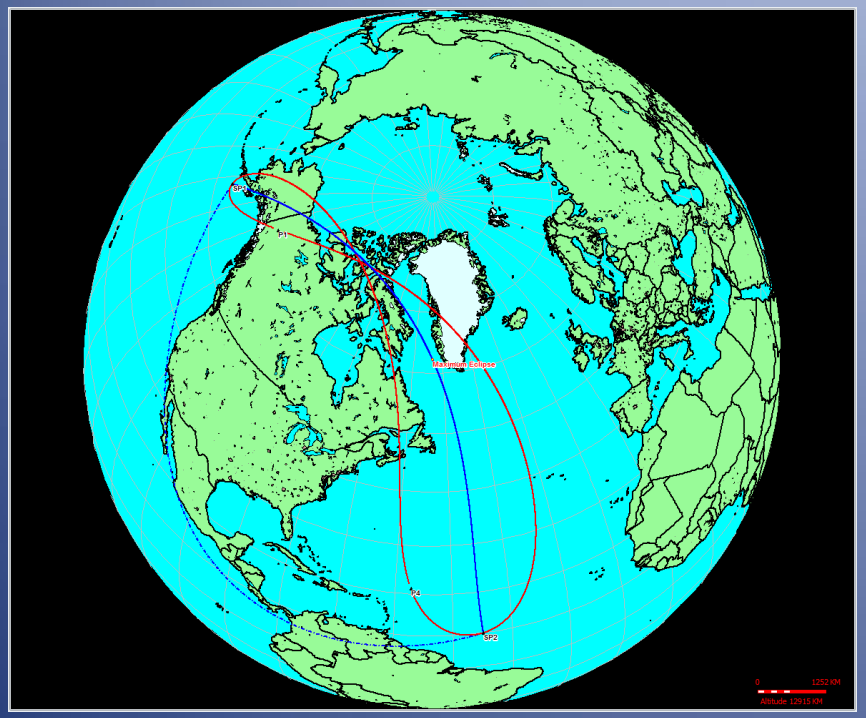
2 Annular eclipses 5 lunations apart

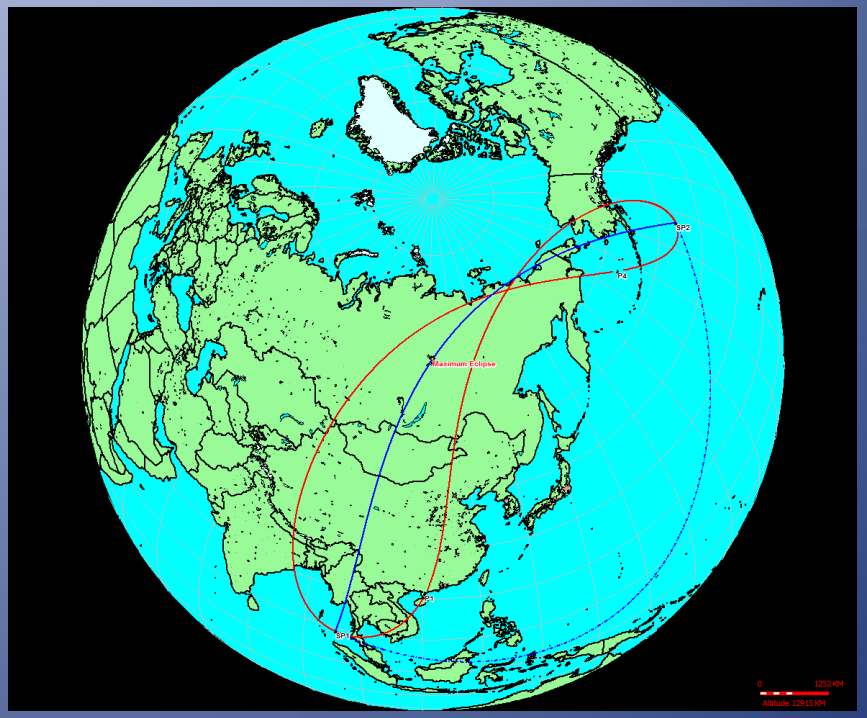




Smallest possible gap between annulars
4 such pairs in 5 millenia Canon
Pair in -1461 overlap on land

2 Partial eclipses 77 lunations apart



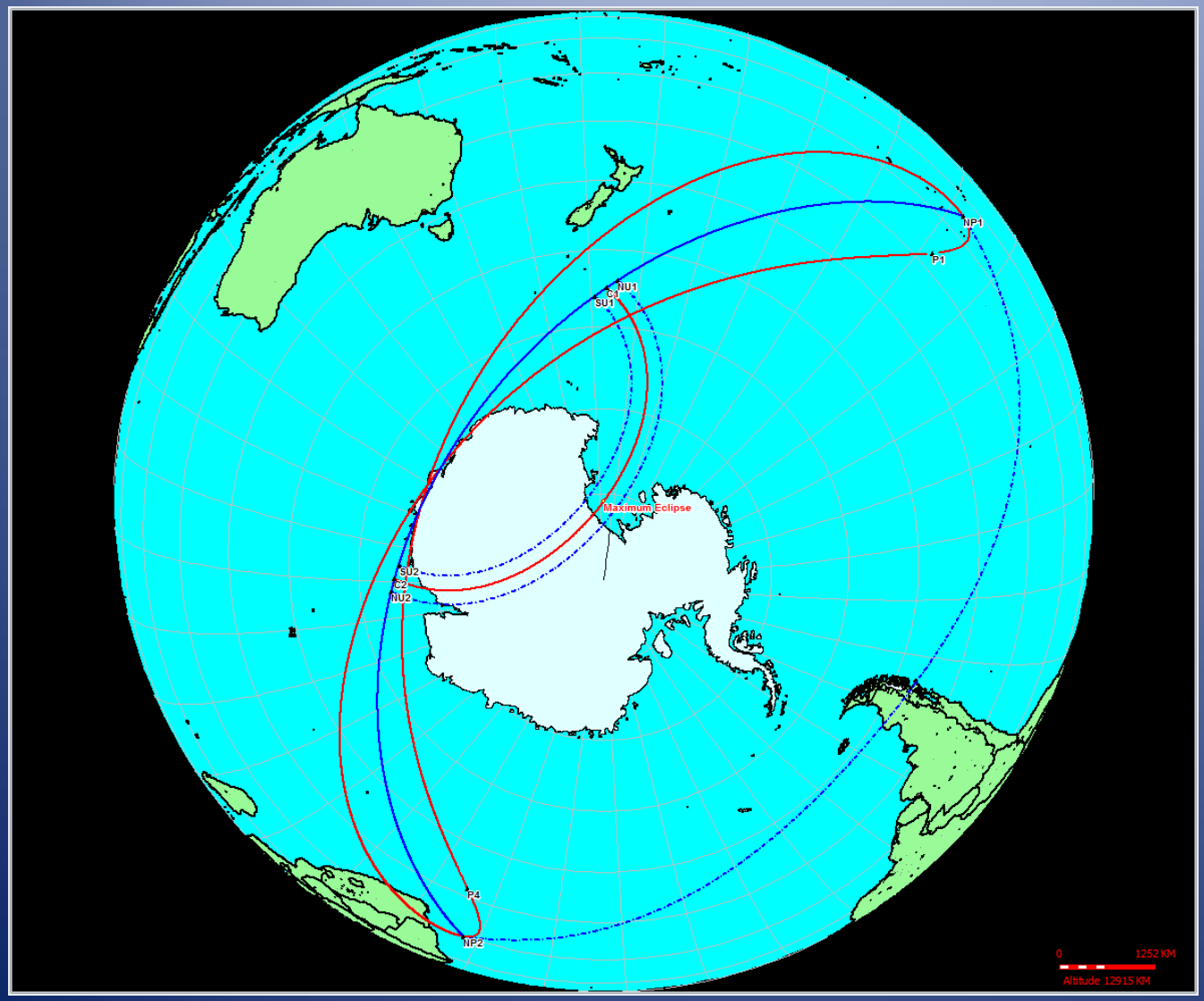


77 lunations is longest gap in 5 millenia Canon and longest gap in 26000 year Canon
12 consecutive total or annular eclipses
Mentioned in Meeus “Elements of Solar Eclipses”

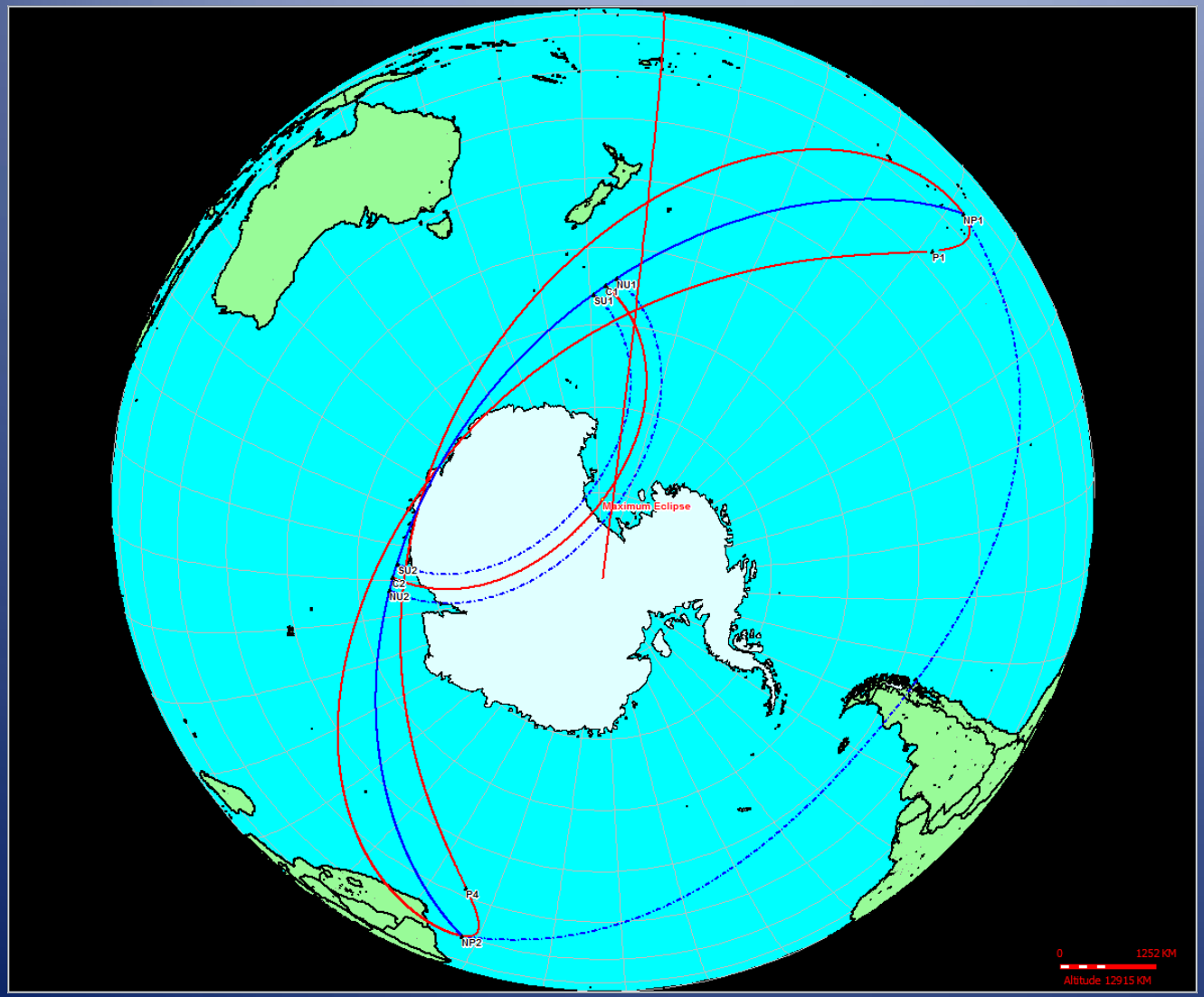
Shortest gaps between eclipses

	Eclipse Type	Lunations
Solar	Partial	1
	Pure Annular	**5**
	Pure Total	11
	Annular and hybrid	**5**
	Total and hybrid	6
	Hybrid	6
Lunar	Partial Penumbral	1
	Total Penumbral	11
	Partial Umbral	**5**
	Total Umbral	6

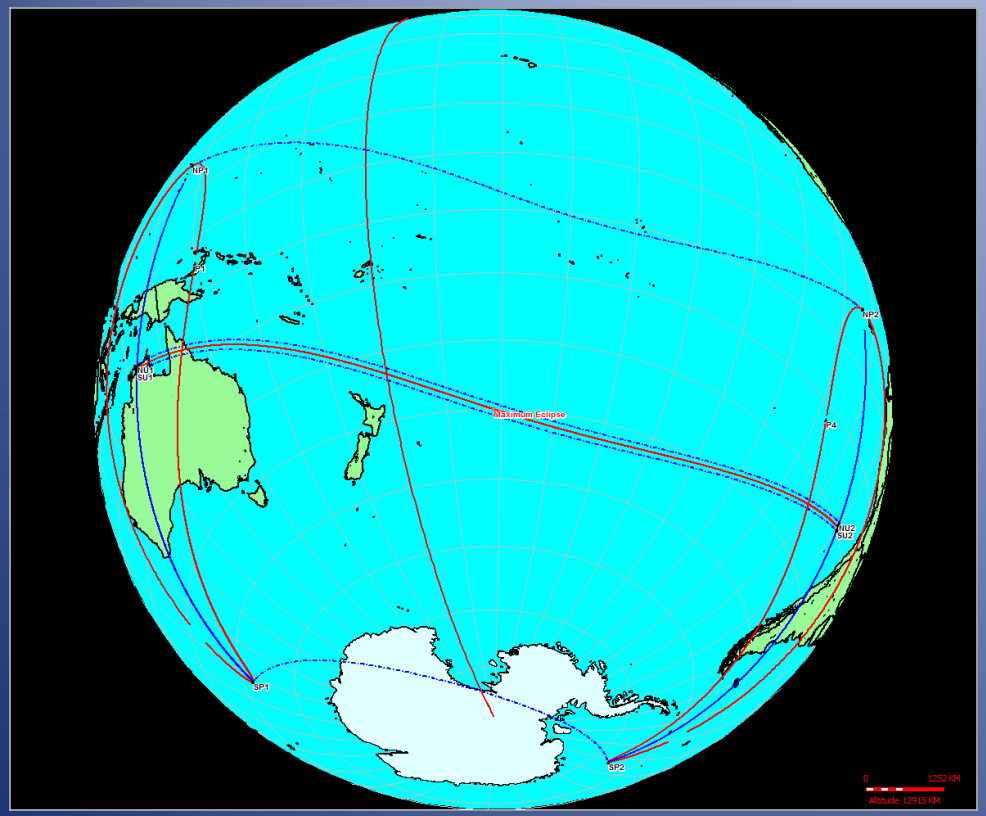
2039 December 15th

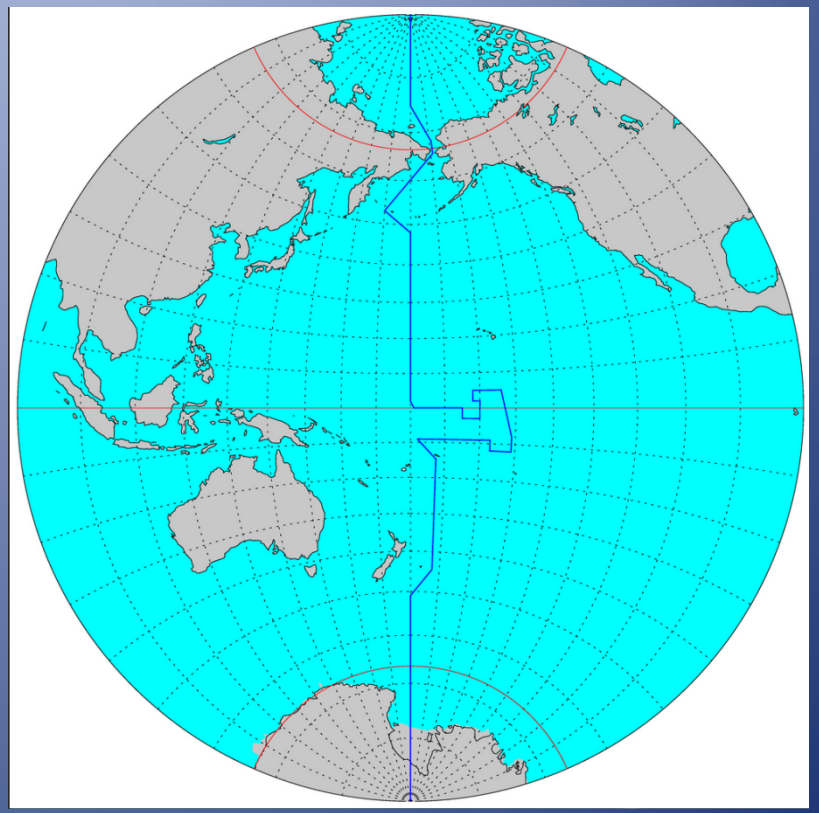


Next eclipse to cross the International Date Line twice!



International date-line and eclipses





Australia 2012 – classic case

Crossed the date-line once

Go west = add one day

Go east = subtract one day

Kiribati adjustment January 1st 1995

Theoretically possible to cross date-line several times!

Rob van Gent pages on web

THE ECLIPSE INN

Panorama Patterns

- Visualising the saros series
- Graphical explanation
  - Semester
  - The hidden relationship
- Tying up the loose ends

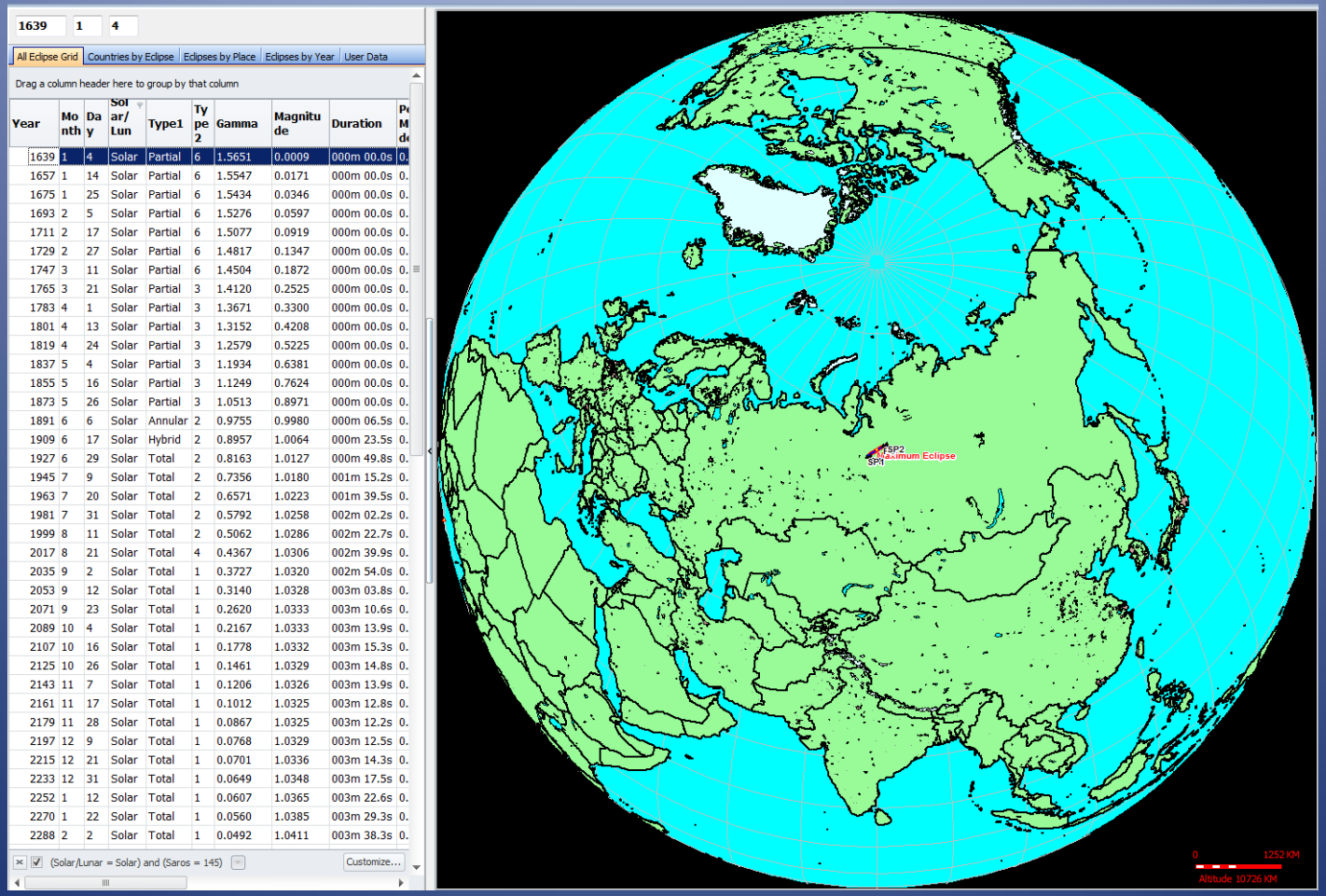
Saros

- 223 lunations

Moon's orbital cycle	Length in days	Number of periods	Days
Synodic month - (new moon to new moon)	29.530589	223	6585.3223
Anomalistic month – (perigee to perigee)	27.554550	239	6585.5375
Draconic month - (node to node)	27.212221	242	6585.3575

approximately 18years 11days 8 hours

Saros 145 start 1639 partial



1639 1 4

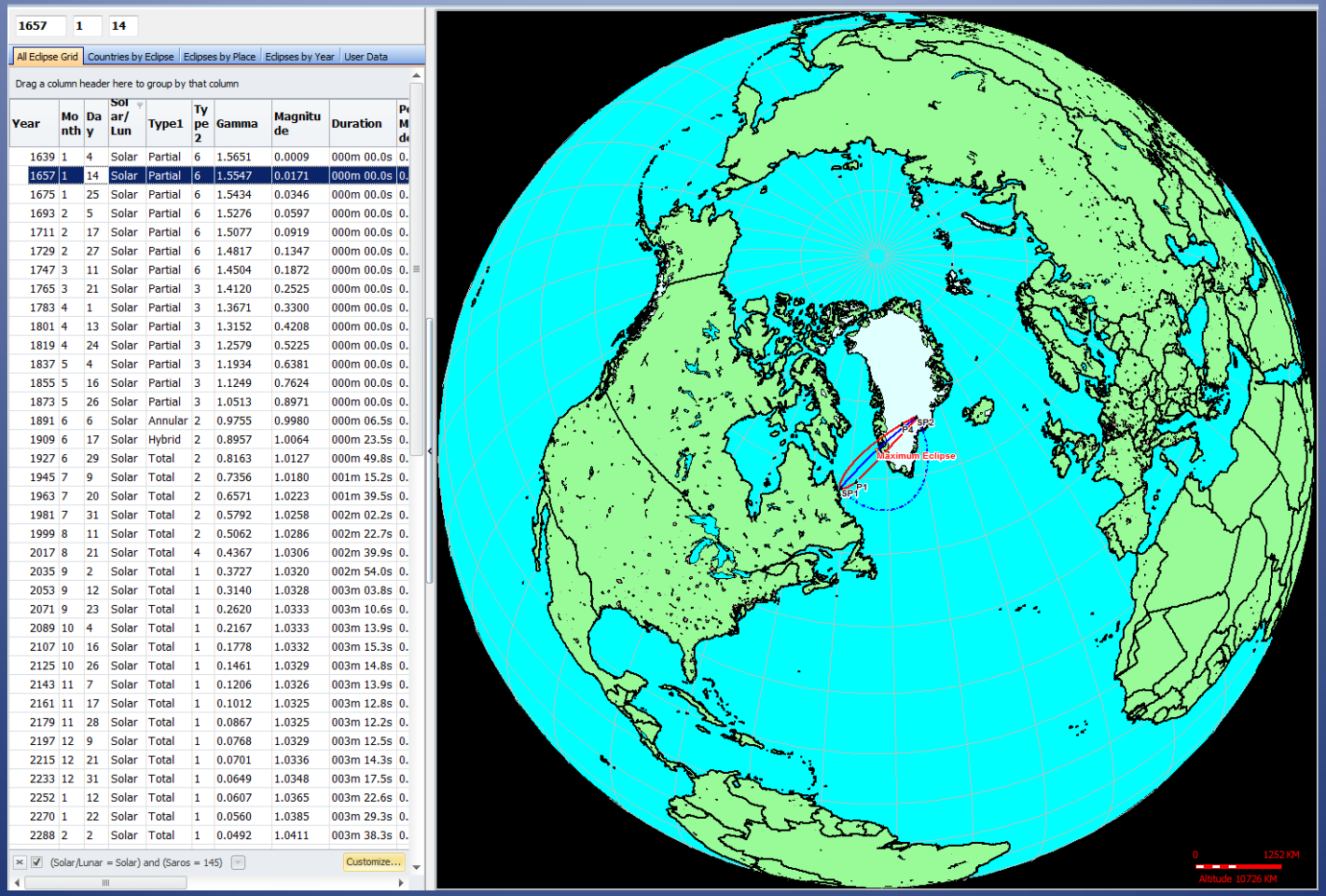
All Eclipse Grid | Countries by Eclipse | Eclipses by Place | Eclipses by Year | User Data

Drag a column header here to group by that column

Year	Month	Day	Solar/Lun	Type1	Type2	Gamma	Magnitude	Duration	P M d
1639	1	4	Solar	Partial	6	1.5651	0.0009	000m 00.0s	0.
1657	1	14	Solar	Partial	6	1.5547	0.0171	000m 00.0s	0.
1675	1	25	Solar	Partial	6	1.5434	0.0346	000m 00.0s	0.
1693	2	5	Solar	Partial	6	1.5276	0.0597	000m 00.0s	0.
1711	2	17	Solar	Partial	6	1.5077	0.0919	000m 00.0s	0.
1729	2	27	Solar	Partial	6	1.4817	0.1347	000m 00.0s	0.
1747	3	11	Solar	Partial	6	1.4504	0.1872	000m 00.0s	0.
1765	3	21	Solar	Partial	3	1.4120	0.2525	000m 00.0s	0.
1783	4	1	Solar	Partial	3	1.3671	0.3300	000m 00.0s	0.
1801	4	13	Solar	Partial	3	1.3152	0.4208	000m 00.0s	0.
1819	4	24	Solar	Partial	3	1.2579	0.5225	000m 00.0s	0.
1837	5	4	Solar	Partial	3	1.1934	0.6381	000m 00.0s	0.
1855	5	16	Solar	Partial	3	1.1249	0.7624	000m 00.0s	0.
1873	5	26	Solar	Partial	3	1.0513	0.8971	000m 00.0s	0.
1891	6	6	Solar	Annular	2	0.9755	0.9980	000m 06.5s	0.
1909	6	17	Solar	Hybrid	2	0.8957	1.0064	000m 23.5s	0.
1927	6	29	Solar	Total	2	0.8163	1.0127	000m 49.8s	0.
1945	7	9	Solar	Total	2	0.7356	1.0180	001m 15.2s	0.
1963	7	20	Solar	Total	2	0.6571	1.0223	001m 39.5s	0.
1981	7	31	Solar	Total	2	0.5792	1.0258	002m 02.2s	0.
1999	8	11	Solar	Total	2	0.5062	1.0286	002m 22.7s	0.
2017	8	21	Solar	Total	4	0.4367	1.0306	002m 39.9s	0.
2035	9	2	Solar	Total	1	0.3727	1.0320	002m 54.0s	0.
2053	9	12	Solar	Total	1	0.3140	1.0328	003m 03.8s	0.
2071	9	23	Solar	Total	1	0.2620	1.0333	003m 10.6s	0.
2089	10	4	Solar	Total	1	0.2167	1.0333	003m 13.9s	0.
2107	10	16	Solar	Total	1	0.1778	1.0332	003m 15.3s	0.
2125	10	26	Solar	Total	1	0.1461	1.0329	003m 14.8s	0.
2143	11	7	Solar	Total	1	0.1206	1.0326	003m 13.9s	0.
2161	11	17	Solar	Total	1	0.1012	1.0325	003m 12.8s	0.
2179	11	28	Solar	Total	1	0.0867	1.0325	003m 12.2s	0.
2197	12	9	Solar	Total	1	0.0768	1.0329	003m 12.5s	0.
2215	12	21	Solar	Total	1	0.0701	1.0336	003m 14.3s	0.
2233	12	31	Solar	Total	1	0.0649	1.0348	003m 17.5s	0.
2252	1	12	Solar	Total	1	0.0607	1.0365	003m 22.6s	0.
2270	1	22	Solar	Total	1	0.0560	1.0385	003m 29.3s	0.
2288	2	2	Solar	Total	1	0.0492	1.0411	003m 38.3s	0.

(Solar/Lunar = Solar) and (Saros = 145) Customize...

1657 partial



1657 1 14

All Eclipse Grid | Countries by Eclipse | Eclipses by Place | Eclipses by Year | User Data

Drag a column header here to group by that column

Year	Month	Day	Solar/Lun	Type1	Type2	Gamma	Magnitude	Duration	P M d
1639	1	4	Solar	Partial	6	1.5651	0.0009	000m 00.0s	0.
1657	1	14	Solar	Partial	6	1.5547	0.0171	000m 00.0s	0.
1675	1	25	Solar	Partial	6	1.5434	0.0346	000m 00.0s	0.
1693	2	5	Solar	Partial	6	1.5276	0.0597	000m 00.0s	0.
1711	2	17	Solar	Partial	6	1.5077	0.0919	000m 00.0s	0.
1729	2	27	Solar	Partial	6	1.4817	0.1347	000m 00.0s	0.
1747	3	11	Solar	Partial	6	1.4504	0.1872	000m 00.0s	0.
1765	3	21	Solar	Partial	3	1.4120	0.2525	000m 00.0s	0.
1783	4	1	Solar	Partial	3	1.3671	0.3300	000m 00.0s	0.
1801	4	13	Solar	Partial	3	1.3152	0.4208	000m 00.0s	0.
1819	4	24	Solar	Partial	3	1.2579	0.5225	000m 00.0s	0.
1837	5	4	Solar	Partial	3	1.1934	0.6381	000m 00.0s	0.
1855	5	16	Solar	Partial	3	1.1249	0.7624	000m 00.0s	0.
1873	5	26	Solar	Partial	3	1.0513	0.8971	000m 00.0s	0.
1891	6	6	Solar	Annular	2	0.9755	0.9980	000m 06.5s	0.
1909	6	17	Solar	Hybrid	2	0.8957	1.0064	000m 23.5s	0.
1927	6	29	Solar	Total	2	0.8163	1.0127	000m 49.8s	0.
1945	7	9	Solar	Total	2	0.7356	1.0180	001m 15.2s	0.
1963	7	20	Solar	Total	2	0.6571	1.0223	001m 39.5s	0.
1981	7	31	Solar	Total	2	0.5792	1.0258	002m 02.2s	0.
1999	8	11	Solar	Total	2	0.5062	1.0286	002m 22.7s	0.
2017	8	21	Solar	Total	4	0.4367	1.0306	002m 39.9s	0.
2035	9	2	Solar	Total	1	0.3727	1.0320	002m 54.0s	0.
2053	9	12	Solar	Total	1	0.3140	1.0328	003m 03.8s	0.
2071	9	23	Solar	Total	1	0.2620	1.0333	003m 10.6s	0.
2089	10	4	Solar	Total	1	0.2167	1.0333	003m 13.9s	0.
2107	10	16	Solar	Total	1	0.1778	1.0332	003m 15.3s	0.
2125	10	26	Solar	Total	1	0.1461	1.0329	003m 14.8s	0.
2143	11	7	Solar	Total	1	0.1206	1.0326	003m 13.9s	0.
2161	11	17	Solar	Total	1	0.1012	1.0325	003m 12.8s	0.
2179	11	28	Solar	Total	1	0.0867	1.0325	003m 12.2s	0.
2197	12	9	Solar	Total	1	0.0768	1.0329	003m 12.5s	0.
2215	12	21	Solar	Total	1	0.0701	1.0336	003m 14.3s	0.
2233	12	31	Solar	Total	1	0.0649	1.0348	003m 17.5s	0.
2252	1	12	Solar	Total	1	0.0607	1.0365	003m 22.6s	0.
2270	1	22	Solar	Total	1	0.0560	1.0385	003m 29.3s	0.
2288	2	2	Solar	Total	1	0.0492	1.0411	003m 38.3s	0.

(Solar/Lunar = Solar) and (Saros = 145) Customize...

1675 partial

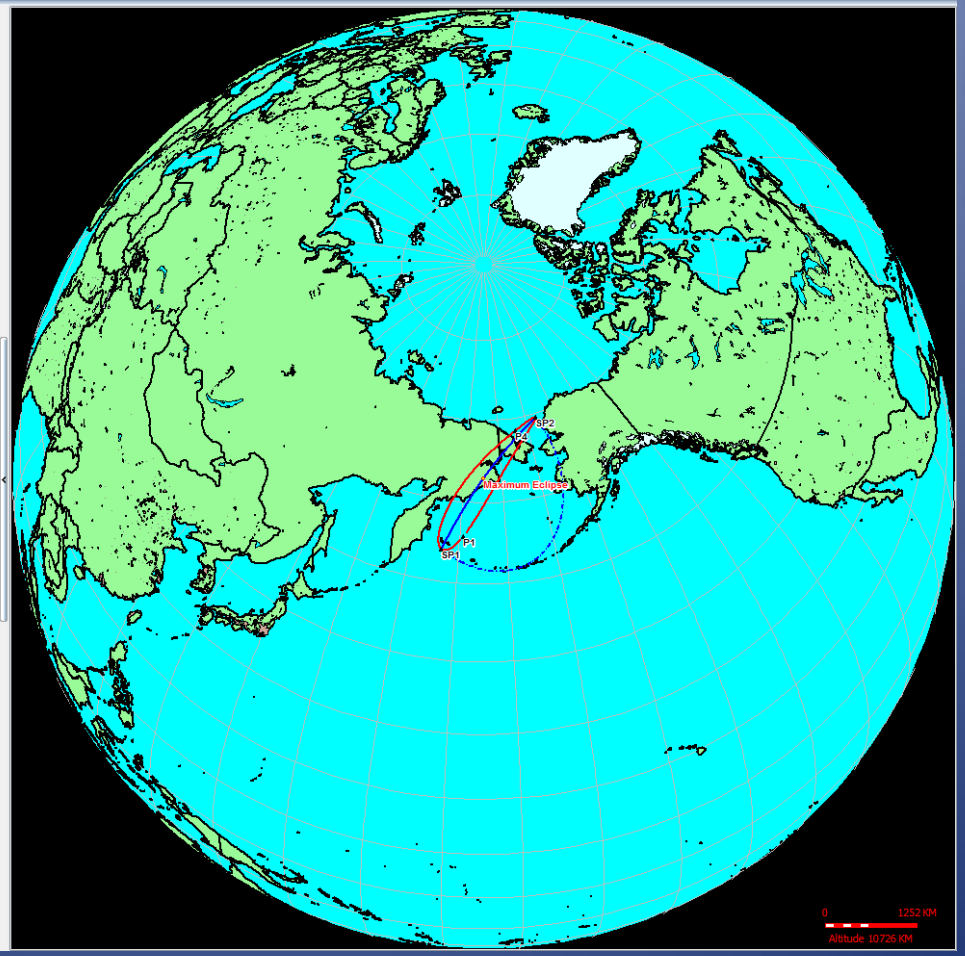
1675 1 25

All Eclipse Grid | Countries by Eclipse | Eclipses by Place | Eclipses by Year | User Data

Drag a column header here to group by that column

Year	Month	Day	Solar/Lun	Type1	Type2	Gamma	Magnitude	Duration	Pe M de
1639	1	4	Solar	Partial	6	1.5651	0.0009	000m 00.0s	0.
1657	1	14	Solar	Partial	6	1.5547	0.0171	000m 00.0s	0.
1675	1	25	Solar	Partial	6	1.5434	0.0346	000m 00.0s	0.
1693	2	5	Solar	Partial	6	1.5276	0.0597	000m 00.0s	0.
1711	2	17	Solar	Partial	6	1.5077	0.0919	000m 00.0s	0.
1729	2	27	Solar	Partial	6	1.4817	0.1347	000m 00.0s	0.
1747	3	11	Solar	Partial	6	1.4504	0.1872	000m 00.0s	0.
1765	3	21	Solar	Partial	3	1.4120	0.2525	000m 00.0s	0.
1783	4	1	Solar	Partial	3	1.3671	0.3300	000m 00.0s	0.
1801	4	13	Solar	Partial	3	1.3152	0.4208	000m 00.0s	0.
1819	4	24	Solar	Partial	3	1.2579	0.5225	000m 00.0s	0.
1837	5	4	Solar	Partial	3	1.1934	0.6381	000m 00.0s	0.
1855	5	16	Solar	Partial	3	1.1249	0.7624	000m 00.0s	0.
1873	5	26	Solar	Partial	3	1.0513	0.8971	000m 00.0s	0.
1891	6	6	Solar	Annular	2	0.9755	0.9980	000m 06.5s	0.
1909	6	17	Solar	Hybrid	2	0.8957	1.0064	000m 23.5s	0.
1927	6	29	Solar	Total	2	0.8163	1.0127	000m 49.8s	0.
1945	7	9	Solar	Total	2	0.7356	1.0180	001m 15.2s	0.
1963	7	20	Solar	Total	2	0.6571	1.0223	001m 39.5s	0.
1981	7	31	Solar	Total	2	0.5792	1.0258	002m 02.2s	0.
1999	8	11	Solar	Total	2	0.5062	1.0286	002m 22.7s	0.
2017	8	21	Solar	Total	4	0.4367	1.0306	002m 39.9s	0.
2035	9	2	Solar	Total	1	0.3727	1.0320	002m 54.0s	0.
2053	9	12	Solar	Total	1	0.3140	1.0328	003m 03.8s	0.
2071	9	23	Solar	Total	1	0.2620	1.0333	003m 10.6s	0.
2089	10	4	Solar	Total	1	0.2167	1.0333	003m 13.9s	0.
2107	10	16	Solar	Total	1	0.1778	1.0332	003m 15.3s	0.
2125	10	26	Solar	Total	1	0.1461	1.0329	003m 14.8s	0.
2143	11	7	Solar	Total	1	0.1206	1.0326	003m 13.9s	0.
2161	11	17	Solar	Total	1	0.1012	1.0325	003m 12.8s	0.
2179	11	28	Solar	Total	1	0.0867	1.0325	003m 12.2s	0.
2197	12	9	Solar	Total	1	0.0768	1.0329	003m 12.5s	0.
2215	12	21	Solar	Total	1	0.0701	1.0336	003m 14.3s	0.
2233	12	31	Solar	Total	1	0.0649	1.0348	003m 17.5s	0.
2252	1	12	Solar	Total	1	0.0607	1.0365	003m 22.6s	0.
2270	1	22	Solar	Total	1	0.0560	1.0385	003m 29.3s	0.
2288	2	2	Solar	Total	1	0.0492	1.0411	003m 38.3s	0.

(Solar/Lunar = Solar) and (Saros = 145) Customize...



1999 total

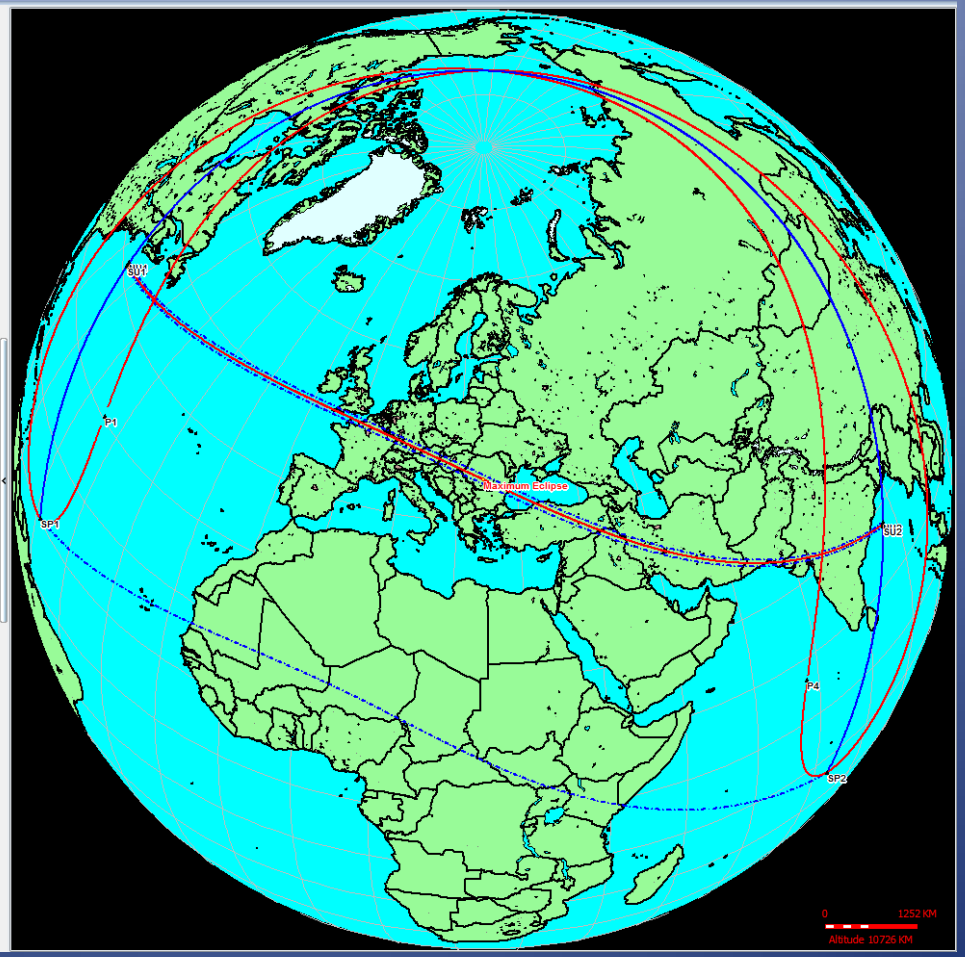
1999 8 11

All Eclipse Grid | Countries by Eclipse | Eclipses by Place | Eclipses by Year | User Data

Drag a column header here to group by that column

Year	Month	Day	Solar/Lun	Type1	Type2	Gamma	Magnitude	Duration	P M d
1639	1	4	Solar	Partial	6	1.5651	0.0009	000m 00.0s	0.
1657	1	14	Solar	Partial	6	1.5547	0.0171	000m 00.0s	0.
1675	1	25	Solar	Partial	6	1.5434	0.0346	000m 00.0s	0.
1693	2	5	Solar	Partial	6	1.5276	0.0597	000m 00.0s	0.
1711	2	17	Solar	Partial	6	1.5077	0.0919	000m 00.0s	0.
1729	2	27	Solar	Partial	6	1.4817	0.1347	000m 00.0s	0.
1747	3	11	Solar	Partial	6	1.4504	0.1872	000m 00.0s	0.
1765	3	21	Solar	Partial	3	1.4120	0.2525	000m 00.0s	0.
1783	4	1	Solar	Partial	3	1.3671	0.3300	000m 00.0s	0.
1801	4	13	Solar	Partial	3	1.3152	0.4208	000m 00.0s	0.
1819	4	24	Solar	Partial	3	1.2579	0.5225	000m 00.0s	0.
1837	5	4	Solar	Partial	3	1.1934	0.6381	000m 00.0s	0.
1855	5	16	Solar	Partial	3	1.1249	0.7624	000m 00.0s	0.
1873	5	26	Solar	Partial	3	1.0513	0.8971	000m 00.0s	0.
1891	6	6	Solar	Annular	2	0.9755	0.9980	000m 06.5s	0.
1909	6	17	Solar	Hybrid	2	0.8957	1.0064	000m 23.5s	0.
1927	6	29	Solar	Total	2	0.8163	1.0127	000m 49.8s	0.
1945	7	9	Solar	Total	2	0.7356	1.0180	001m 15.2s	0.
1963	7	20	Solar	Total	2	0.6571	1.0223	001m 39.5s	0.
1981	7	31	Solar	Total	2	0.5792	1.0258	002m 02.2s	0.
1999	8	11	Solar	Total	2	0.5062	1.0286	002m 22.7s	0.
2017	8	21	Solar	Total	4	0.4367	1.0306	002m 39.9s	0.
2035	9	2	Solar	Total	1	0.3727	1.0320	002m 54.0s	0.
2053	9	12	Solar	Total	1	0.3140	1.0328	003m 03.8s	0.
2071	9	23	Solar	Total	1	0.2620	1.0333	003m 10.6s	0.
2089	10	4	Solar	Total	1	0.2167	1.0333	003m 13.9s	0.
2107	10	16	Solar	Total	1	0.1778	1.0332	003m 15.3s	0.
2125	10	26	Solar	Total	1	0.1461	1.0329	003m 14.8s	0.
2143	11	7	Solar	Total	1	0.1206	1.0326	003m 13.9s	0.
2161	11	17	Solar	Total	1	0.1012	1.0325	003m 12.8s	0.
2179	11	28	Solar	Total	1	0.0867	1.0325	003m 12.2s	0.
2197	12	9	Solar	Total	1	0.0768	1.0329	003m 12.5s	0.
2215	12	21	Solar	Total	1	0.0701	1.0336	003m 14.3s	0.
2233	12	31	Solar	Total	1	0.0649	1.0348	003m 17.5s	0.
2252	1	12	Solar	Total	1	0.0607	1.0365	003m 22.6s	0.
2270	1	22	Solar	Total	1	0.0560	1.0385	003m 29.3s	0.
2288	2	2	Solar	Total	1	0.0492	1.0411	003m 38.3s	0.

(Solar/Lunar = Solar) and (Saros = 145) Customize...



2017 total

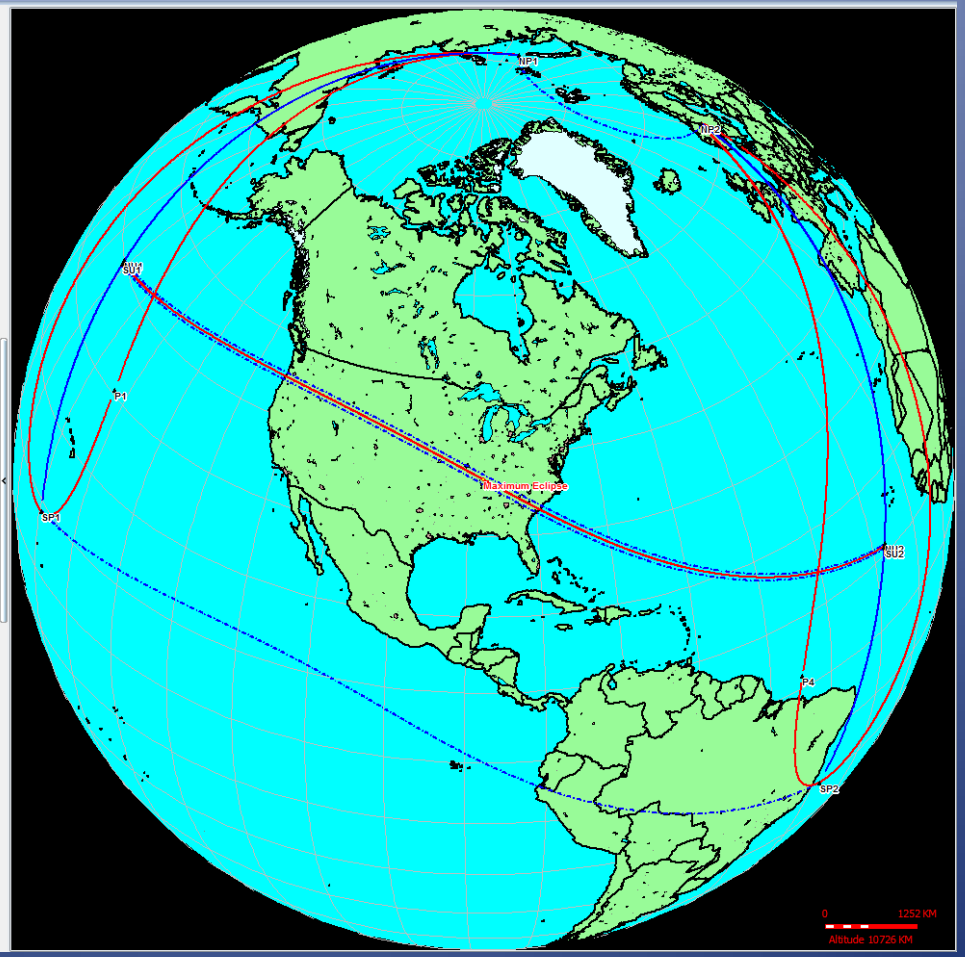
2017 8 21

All Eclipse Grid | Countries by Eclipse | Eclipses by Place | Eclipses by Year | User Data

Drag a column header here to group by that column

Year	Month	Day	Solar/Lun	Type1	Type2	Gamma	Magnitude	Duration	P… M… d…
1639	1	4	Solar	Partial	6	1.5651	0.0009	000m 00.0s	0.
1657	1	14	Solar	Partial	6	1.5547	0.0171	000m 00.0s	0.
1675	1	25	Solar	Partial	6	1.5434	0.0346	000m 00.0s	0.
1693	2	5	Solar	Partial	6	1.5276	0.0597	000m 00.0s	0.
1711	2	17	Solar	Partial	6	1.5077	0.0919	000m 00.0s	0.
1729	2	27	Solar	Partial	6	1.4817	0.1347	000m 00.0s	0.
1747	3	11	Solar	Partial	6	1.4504	0.1872	000m 00.0s	0.
1765	3	21	Solar	Partial	3	1.4120	0.2525	000m 00.0s	0.
1783	4	1	Solar	Partial	3	1.3671	0.3300	000m 00.0s	0.
1801	4	13	Solar	Partial	3	1.3152	0.4208	000m 00.0s	0.
1819	4	24	Solar	Partial	3	1.2579	0.5225	000m 00.0s	0.
1837	5	4	Solar	Partial	3	1.1934	0.6381	000m 00.0s	0.
1855	5	16	Solar	Partial	3	1.1249	0.7624	000m 00.0s	0.
1873	5	26	Solar	Partial	3	1.0513	0.8971	000m 00.0s	0.
1891	6	6	Solar	Annular	2	0.9755	0.9980	000m 06.5s	0.
1909	6	17	Solar	Hybrid	2	0.8957	1.0064	000m 23.5s	0.
1927	6	29	Solar	Total	2	0.8163	1.0127	000m 49.8s	0.
1945	7	9	Solar	Total	2	0.7356	1.0180	001m 15.2s	0.
1963	7	20	Solar	Total	2	0.6571	1.0223	001m 39.5s	0.
1981	7	31	Solar	Total	2	0.5792	1.0258	002m 02.2s	0.
1999	8	11	Solar	Total	2	0.5062	1.0286	002m 22.7s	0.
2017	8	21	Solar	Total	4	0.4367	1.0306	002m 39.9s	0.
2035	9	2	Solar	Total	1	0.3727	1.0320	002m 54.0s	0.
2053	9	12	Solar	Total	1	0.3140	1.0328	003m 03.8s	0.
2071	9	23	Solar	Total	1	0.2620	1.0333	003m 10.6s	0.
2089	10	4	Solar	Total	1	0.2167	1.0333	003m 13.9s	0.
2107	10	16	Solar	Total	1	0.1778	1.0332	003m 15.3s	0.
2125	10	26	Solar	Total	1	0.1461	1.0329	003m 14.8s	0.
2143	11	7	Solar	Total	1	0.1206	1.0326	003m 13.9s	0.
2161	11	17	Solar	Total	1	0.1012	1.0325	003m 12.8s	0.
2179	11	28	Solar	Total	1	0.0867	1.0325	003m 12.2s	0.
2197	12	9	Solar	Total	1	0.0768	1.0329	003m 12.5s	0.
2215	12	21	Solar	Total	1	0.0701	1.0336	003m 14.3s	0.
2233	12	31	Solar	Total	1	0.0649	1.0348	003m 17.5s	0.
2252	1	12	Solar	Total	1	0.0607	1.0365	003m 22.6s	0.
2270	1	22	Solar	Total	1	0.0560	1.0385	003m 29.3s	0.
2288	2	2	Solar	Total	1	0.0492	1.0411	003m 38.3s	0.

(Solar/Lunar = Solar) and (Saros = 145) Customize...



2035 total

2035 9 2

All Eclipse Grid | Countries by Eclipse | Eclipses by Place | Eclipses by Year | User Data

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Year	Month	Day	Solar/Lun	Type1	Type2	Gamma	Magnitude	Duration	P M d
1639	1	4	Solar	Partial	6	1.5651	0.0009	000m 00.0s	0.
1657	1	14	Solar	Partial	6	1.5547	0.0171	000m 00.0s	0.
1675	1	25	Solar	Partial	6	1.5434	0.0346	000m 00.0s	0.
1693	2	5	Solar	Partial	6	1.5276	0.0597	000m 00.0s	0.
1711	2	17	Solar	Partial	6	1.5077	0.0919	000m 00.0s	0.
1729	2	27	Solar	Partial	6	1.4817	0.1347	000m 00.0s	0.
1747	3	11	Solar	Partial	6	1.4504	0.1872	000m 00.0s	0.
1765	3	21	Solar	Partial	3	1.4120	0.2525	000m 00.0s	0.
1783	4	1	Solar	Partial	3	1.3671	0.3300	000m 00.0s	0.
1801	4	13	Solar	Partial	3	1.3152	0.4208	000m 00.0s	0.
1819	4	24	Solar	Partial	3	1.2579	0.5225	000m 00.0s	0.
1837	5	4	Solar	Partial	3	1.1934	0.6381	000m 00.0s	0.
1855	5	16	Solar	Partial	3	1.1249	0.7624	000m 00.0s	0.
1873	5	26	Solar	Partial	3	1.0513	0.8971	000m 00.0s	0.
1891	6	6	Solar	Annular	2	0.9755	0.9980	000m 06.5s	0.
1909	6	17	Solar	Hybrid	2	0.8957	1.0064	000m 23.5s	0.
1927	6	29	Solar	Total	2	0.8163	1.0127	000m 49.8s	0.
1945	7	9	Solar	Total	2	0.7356	1.0180	001m 15.2s	0.
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2035	9	2	Solar	Total	1	0.3727	1.0320	002m 54.0s	0.
2053	9	12	Solar	Total	1	0.3140	1.0328	003m 03.8s	0.
2071	9	23	Solar	Total	1	0.2620	1.0333	003m 10.6s	0.
2089	10	4	Solar	Total	1	0.2167	1.0333	003m 13.9s	0.
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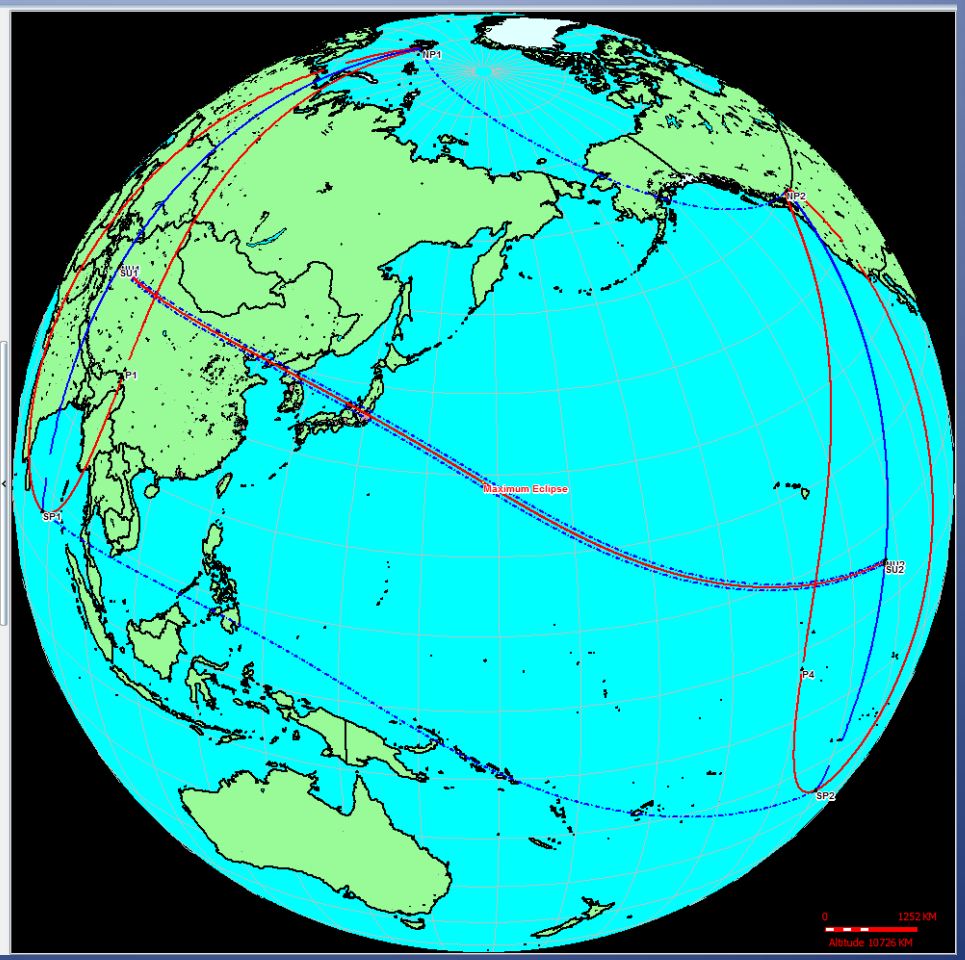
2125	10	26	Solar	Total	1	0.1461	1.0329	003m 14.8s	0.
2143	11	7	Solar	Total	1	0.1206	1.0326	003m 13.9s	0.
2161	11	17	Solar	Total	1	0.1012	1.0325	003m 12.8s	0.
2179	11	28	Solar	Total	1	0.0867	1.0325	003m 12.2s	0.
2197	12	9	Solar	Total	1	0.0768	1.0329	003m 12.5s	0.
2215	12	21	Solar	Total	1	0.0701	1.0336	003m 14.3s	0.
2233	12	31	Solar	Total	1	0.0649	1.0348	003m 17.5s	0.
2252	1	12	Solar	Total	1	0.0607	1.0365	003m 22.6s	0.
2270	1	22	Solar	Total	1	0.0560	1.0385	003m 29.3s	0.
2288	2	2	Solar	Total	1	0.0492	1.0411	003m 38.3s	0.

(Solar/Lunar = Solar) and (Saros = 145) Customize...



2053 total

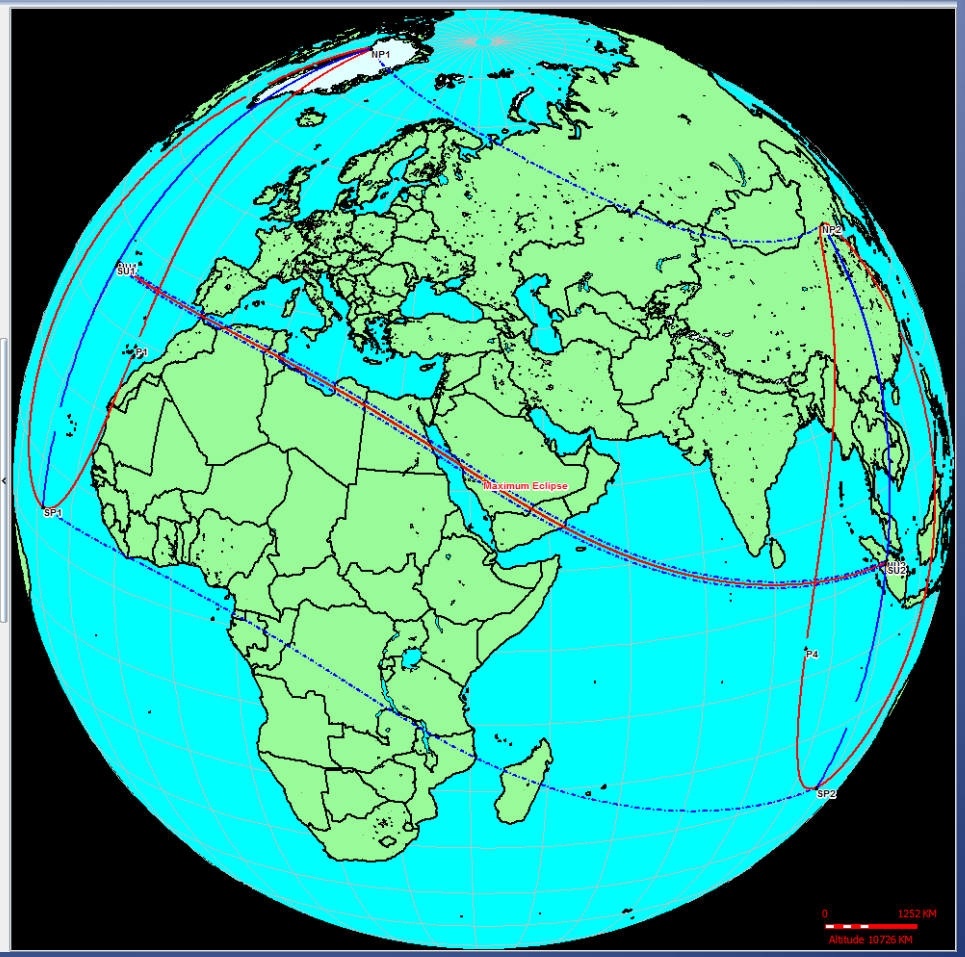
2053 9 12

All Eclipse Grid | Countries by Eclipse | Eclipses by Place | Eclipses by Year | User Data

Drag a column header here to group by that column

Year	Month	Day	Solar/Lun	Type1	Type2	Gamma	Magnitude	Duration	P... M... d...
1639	1	4	Solar	Partial	6	1.5651	0.0009	000m 00.0s	0.
1657	1	14	Solar	Partial	6	1.5547	0.0171	000m 00.0s	0.
1675	1	25	Solar	Partial	6	1.5434	0.0346	000m 00.0s	0.
1693	2	5	Solar	Partial	6	1.5276	0.0597	000m 00.0s	0.
1711	2	17	Solar	Partial	6	1.5077	0.0919	000m 00.0s	0.
1729	2	27	Solar	Partial	6	1.4817	0.1347	000m 00.0s	0.
1747	3	11	Solar	Partial	6	1.4504	0.1872	000m 00.0s	0.
1765	3	21	Solar	Partial	3	1.4120	0.2525	000m 00.0s	0.
1783	4	1	Solar	Partial	3	1.3671	0.3300	000m 00.0s	0.
1801	4	13	Solar	Partial	3	1.3152	0.4208	000m 00.0s	0.
1819	4	24	Solar	Partial	3	1.2579	0.5225	000m 00.0s	0.
1837	5	4	Solar	Partial	3	1.1934	0.6381	000m 00.0s	0.
1855	5	16	Solar	Partial	3	1.1249	0.7624	000m 00.0s	0.
1873	5	26	Solar	Partial	3	1.0513	0.8971	000m 00.0s	0.
1891	6	6	Solar	Annular	2	0.9755	0.9980	000m 06.5s	0.
1909	6	17	Solar	Hybrid	2	0.8957	1.0064	000m 23.5s	0.
1927	6	29	Solar	Total	2	0.8163	1.0127	000m 49.8s	0.
1945	7	9	Solar	Total	2	0.7356	1.0180	001m 15.2s	0.
1963	7	20	Solar	Total	2	0.6571	1.0223	001m 39.5s	0.
1981	7	31	Solar	Total	2	0.5792	1.0258	002m 02.2s	0.
1999	8	11	Solar	Total	2	0.5062	1.0286	002m 22.7s	0.
2017	8	21	Solar	Total	4	0.4367	1.0306	002m 39.9s	0.
2035	9	2	Solar	Total	1	0.3727	1.0320	002m 54.0s	0.
2053	9	12	Solar	Total	1	0.3140	1.0328	003m 03.8s	0.
2071	9	23	Solar	Total	1	0.2620	1.0333	003m 10.6s	0.
2089	10	4	Solar	Total	1	0.2167	1.0333	003m 13.9s	0.
2107	10	16	Solar	Total	1	0.1778	1.0332	003m 15.3s	0.
2125	10	26	Solar	Total	1	0.1461	1.0329	003m 14.8s	0.
2143	11	7	Solar	Total	1	0.1206	1.0326	003m 13.9s	0.
2161	11	17	Solar	Total	1	0.1012	1.0325	003m 12.8s	0.
2179	11	28	Solar	Total	1	0.0867	1.0325	003m 12.2s	0.
2197	12	9	Solar	Total	1	0.0768	1.0329	003m 12.5s	0.
2215	12	21	Solar	Total	1	0.0701	1.0336	003m 14.3s	0.
2233	12	31	Solar	Total	1	0.0649	1.0348	003m 17.5s	0.
2252	1	12	Solar	Total	1	0.0607	1.0365	003m 22.6s	0.
2270	1	22	Solar	Total	1	0.0560	1.0385	003m 29.3s	0.
2288	2	2	Solar	Total	1	0.0492	1.0411	003m 38.3s	0.

(Solar/Lunar = Solar) and (Saros = 145) Customize...



2071 total

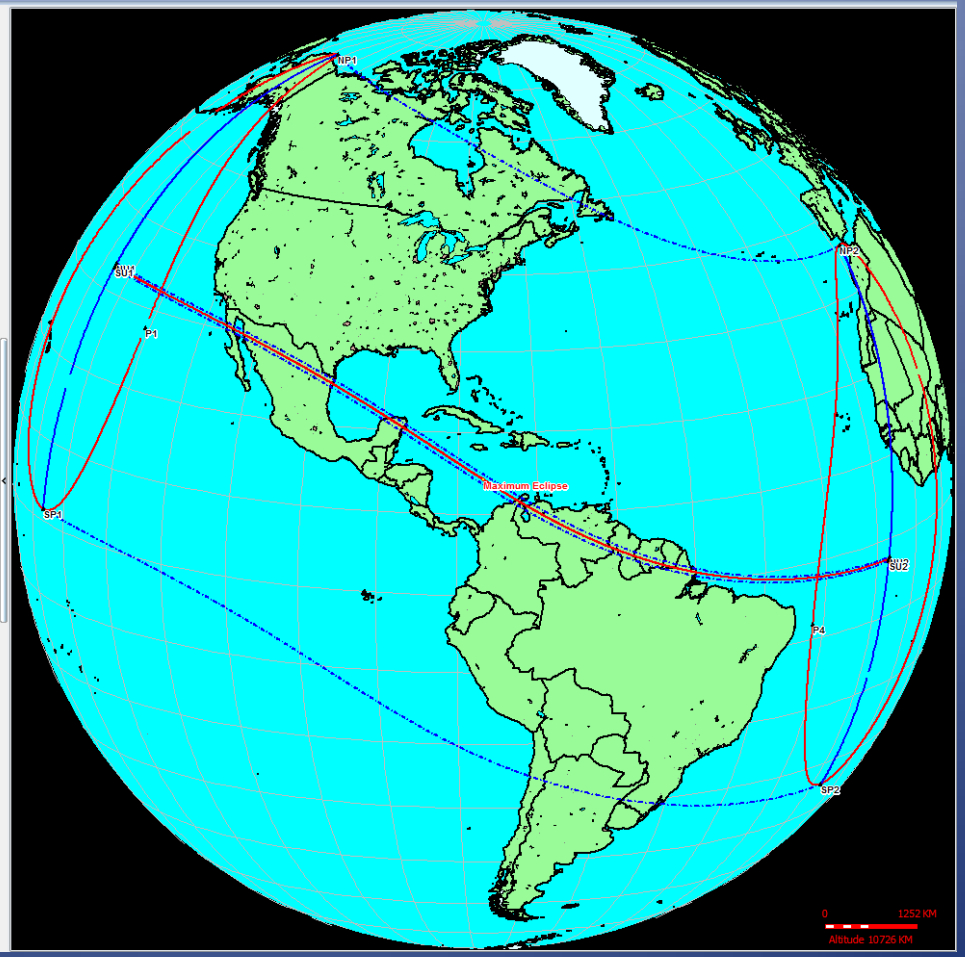
2071 9 23

All Eclipse Grid | Countries by Eclipse | Eclipses by Place | Eclipses by Year | User Data

Drag a column header here to group by that column

Year	Month	Day	Solar/Lun	Type1	Type2	Gamma	Magnitude	Duration	Pe M de
1639	1	4	Solar	Partial	6	1.5651	0.0009	000m 00.0s	0.
1657	1	14	Solar	Partial	6	1.5547	0.0171	000m 00.0s	0.
1675	1	25	Solar	Partial	6	1.5434	0.0346	000m 00.0s	0.
1693	2	5	Solar	Partial	6	1.5276	0.0597	000m 00.0s	0.
1711	2	17	Solar	Partial	6	1.5077	0.0919	000m 00.0s	0.
1729	2	27	Solar	Partial	6	1.4817	0.1347	000m 00.0s	0.
1747	3	11	Solar	Partial	6	1.4504	0.1872	000m 00.0s	0.
1765	3	21	Solar	Partial	3	1.4120	0.2525	000m 00.0s	0.
1783	4	1	Solar	Partial	3	1.3671	0.3300	000m 00.0s	0.
1801	4	13	Solar	Partial	3	1.3152	0.4208	000m 00.0s	0.
1819	4	24	Solar	Partial	3	1.2579	0.5225	000m 00.0s	0.
1837	5	4	Solar	Partial	3	1.1934	0.6381	000m 00.0s	0.
1855	5	16	Solar	Partial	3	1.1249	0.7624	000m 00.0s	0.
1873	5	26	Solar	Partial	3	1.0513	0.8971	000m 00.0s	0.
1891	6	6	Solar	Annular	2	0.9755	0.9980	000m 06.5s	0.
1909	6	17	Solar	Hybrid	2	0.8957	1.0064	000m 23.5s	0.
1927	6	29	Solar	Total	2	0.8163	1.0127	000m 49.8s	0.
1945	7	9	Solar	Total	2	0.7356	1.0180	001m 15.2s	0.
1963	7	20	Solar	Total	2	0.6571	1.0223	001m 39.5s	0.
1981	7	31	Solar	Total	2	0.5792	1.0258	002m 02.2s	0.
1999	8	11	Solar	Total	2	0.5062	1.0286	002m 22.7s	0.
2017	8	21	Solar	Total	4	0.4367	1.0306	002m 39.9s	0.
2035	9	2	Solar	Total	1	0.3727	1.0320	002m 54.0s	0.
2053	9	12	Solar	Total	1	0.3140	1.0328	003m 03.8s	0.
2071	9	23	Solar	Total	1	0.2620	1.0333	003m 10.6s	0.
2089	10	4	Solar	Total	1	0.2167	1.0333	003m 13.9s	0.
2107	10	16	Solar	Total	1	0.1778	1.0332	003m 15.3s	0.
2125	10	26	Solar	Total	1	0.1461	1.0329	003m 14.8s	0.
2143	11	7	Solar	Total	1	0.1206	1.0326	003m 13.9s	0.
2161	11	17	Solar	Total	1	0.1012	1.0325	003m 12.8s	0.
2179	11	28	Solar	Total	1	0.0867	1.0325	003m 12.2s	0.
2197	12	9	Solar	Total	1	0.0768	1.0329	003m 12.5s	0.
2215	12	21	Solar	Total	1	0.0701	1.0336	003m 14.3s	0.
2233	12	31	Solar	Total	1	0.0649	1.0348	003m 17.5s	0.
2252	1	12	Solar	Total	1	0.0607	1.0365	003m 22.6s	0.
2270	1	22	Solar	Total	1	0.0560	1.0385	003m 29.3s	0.
2288	2	2	Solar	Total	1	0.0492	1.0411	003m 38.3s	0.

(Solar/Lunar = Solar) and (Saros = 145) Customize...



2648 last total

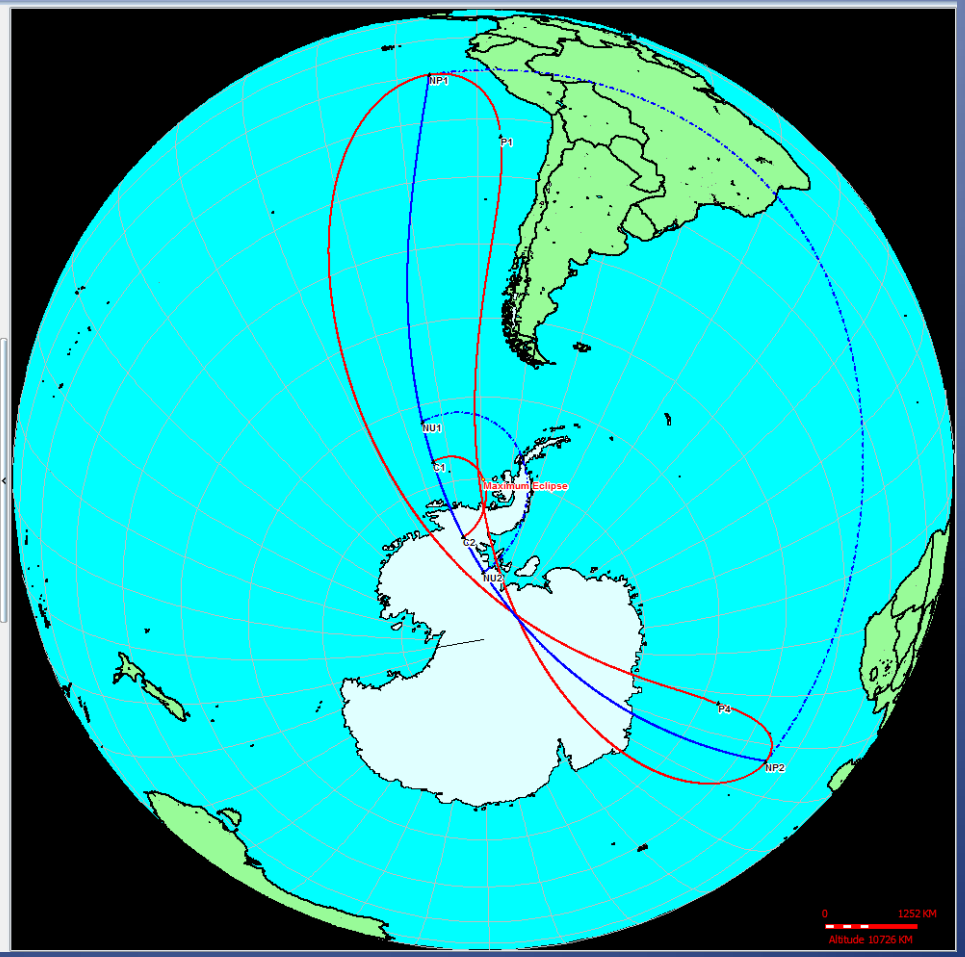
2648 9 9

All Eclipse Grid | Countries by Eclipse | Eclipses by Place | Eclipses by Year | User Data

Drag a column header here to group by that column

Year	Month	Day	Solar/Lun	Type1	Type2	Gamma	Magnitude	Duration	Pe M de
2360	3	18	Solar	Total	1	-0.0177	1.0549	004m 32.7s	0.
2378	3	29	Solar	Total	1	-0.0480	1.0587	004m 50.8s	0.
2396	4	9	Solar	Total	1	-0.0851	1.0625	005m 11.3s	0.
2414	4	20	Solar	Total	1	-0.1279	1.0660	005m 33.0s	0.
2432	4	30	Solar	Total	1	-0.1780	1.0693	005m 56.0s	0.
2450	5	12	Solar	Total	1	-0.2331	1.0721	006m 19.0s	0.
2468	5	22	Solar	Total	1	-0.2937	1.0744	006m 40.5s	0.
2486	6	2	Solar	Total	1	-0.3588	1.0760	006m 58.4s	0.
2504	6	14	Solar	Total	1	-0.4279	1.0768	007m 09.9s	0.
2522	6	25	Solar	Total	2	-0.4992	1.0768	007m 12.3s	0.
2540	7	5	Solar	Total	2	-0.5723	1.0760	007m 03.5s	0.
2558	7	17	Solar	Total	2	-0.6466	1.0741	006m 42.9s	0.
2576	7	27	Solar	Total	2	-0.7204	1.0714	006m 11.6s	0.
2594	8	7	Solar	Total	2	-0.7928	1.0676	005m 31.3s	0.
2612	8	18	Solar	Total	2	-0.8629	1.0629	004m 45.0s	0.
2630	8	30	Solar	Total	2	-0.9303	1.0568	003m 53.2s	0.
2648	9	9	Solar	Total	8	-0.9930	1.0479	002m 48.3s	0.
2666	9	20	Solar	Partial	3	-1.0506	0.9185	000m 00.0s	0.
2684	10	1	Solar	Partial	3	-1.1036	0.8160	000m 00.0s	0.
2702	10	13	Solar	Partial	3	-1.1505	0.7260	000m 00.0s	0.
2720	10	23	Solar	Partial	3	-1.1917	0.6474	000m 00.0s	0.
2738	11	4	Solar	Partial	3	-1.2260	0.5826	000m 00.0s	0.
2756	11	14	Solar	Partial	3	-1.2556	0.5270	000m 00.0s	0.
2774	11	25	Solar	Partial	3	-1.2785	0.4845	000m 00.0s	0.
2792	12	6	Solar	Partial	3	-1.2974	0.4499	000m 00.0s	0.
2810	12	17	Solar	Partial	3	-1.3112	0.4247	000m 00.0s	0.
2828	12	28	Solar	Partial	3	-1.3229	0.4037	000m 00.0s	0.
2847	1	8	Solar	Partial	3	-1.3314	0.3885	000m 00.0s	0.
2865	1	18	Solar	Partial	3	-1.3398	0.3735	000m 00.0s	0.
2883	1	30	Solar	Partial	3	-1.3485	0.3582	000m 00.0s	0.
2901	2	10	Solar	Partial	3	-1.3590	0.3394	000m 00.0s	0.
2919	2	21	Solar	Partial	3	-1.3717	0.3167	000m 00.0s	0.
2937	3	4	Solar	Partial	3	-1.3893	0.2850	000m 00.0s	0.
2955	3	15	Solar	Partial	3	-1.4112	0.2455	000m 00.0s	0.
2973	3	25	Solar	Partial	6	-1.4393	0.1948	000m 00.0s	0.
2991	4	6	Solar	Partial	6	-1.4727	0.1345	000m 00.0s	0.
3009	4	17	Solar	Partial	6	-1.5142	0.0595	000m 00.0s	0.

(Solar/Lunar = Solar) and (Saros = 145) Customize...



3009 last partial

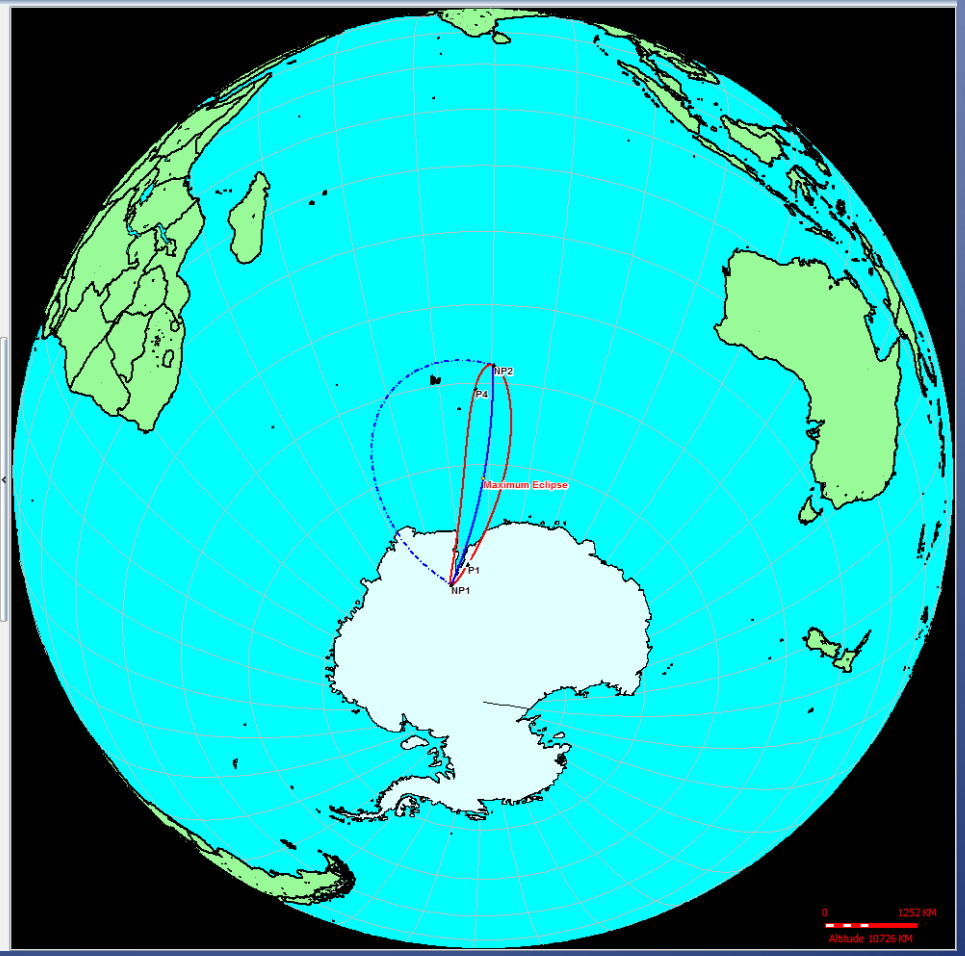
3009 4 17

All Eclipse Grid | Countries by Eclipse | Eclipses by Place | Eclipses by Year | User Data

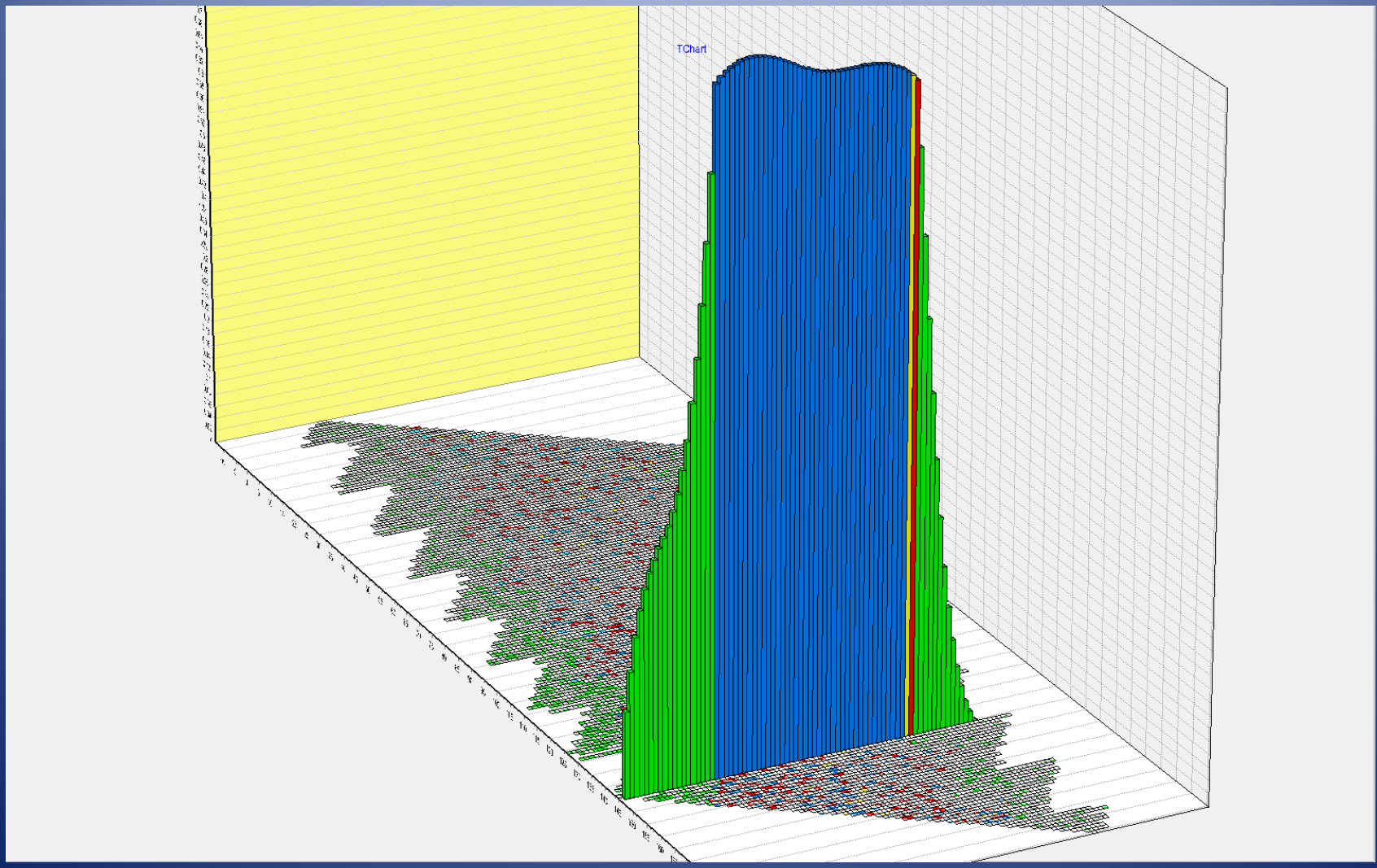
Drag a column header here to group by that column

Year	Month	Day	Solar/Lun	Type1	Type2	Gamma	Magnitude	Duration	Pe M de
2360	3	18	Solar	Total	1	-0.0177	1.0549	004m 32.7s	0.
2378	3	29	Solar	Total	1	-0.0480	1.0587	004m 50.8s	0.
2396	4	9	Solar	Total	1	-0.0851	1.0625	005m 11.3s	0.
2414	4	20	Solar	Total	1	-0.1279	1.0660	005m 33.0s	0.
2432	4	30	Solar	Total	1	-0.1780	1.0693	005m 56.0s	0.
2450	5	12	Solar	Total	1	-0.2331	1.0721	006m 19.0s	0.
2468	5	22	Solar	Total	1	-0.2937	1.0744	006m 40.5s	0.
2486	6	2	Solar	Total	1	-0.3588	1.0760	006m 58.4s	0.
2504	6	14	Solar	Total	1	-0.4279	1.0768	007m 09.9s	0.
2522	6	25	Solar	Total	2	-0.4992	1.0768	007m 12.3s	0.
2540	7	5	Solar	Total	2	-0.5723	1.0760	007m 03.5s	0.
2558	7	17	Solar	Total	2	-0.6466	1.0741	006m 42.9s	0.
2576	7	27	Solar	Total	2	-0.7204	1.0714	006m 11.6s	0.
2594	8	7	Solar	Total	2	-0.7928	1.0676	005m 31.3s	0.
2612	8	18	Solar	Total	2	-0.8629	1.0629	004m 45.0s	0.
2630	8	30	Solar	Total	2	-0.9303	1.0568	003m 53.2s	0.
2648	9	9	Solar	Total	8	-0.9930	1.0479	002m 48.3s	0.
2666	9	20	Solar	Partial	3	-1.0506	0.9185	000m 00.0s	0.
2684	10	1	Solar	Partial	3	-1.1036	0.8160	000m 00.0s	0.
2702	10	13	Solar	Partial	3	-1.1505	0.7260	000m 00.0s	0.
2720	10	23	Solar	Partial	3	-1.1917	0.6474	000m 00.0s	0.
2738	11	4	Solar	Partial	3	-1.2260	0.5826	000m 00.0s	0.
2756	11	14	Solar	Partial	3	-1.2556	0.5270	000m 00.0s	0.
2774	11	25	Solar	Partial	3	-1.2785	0.4845	000m 00.0s	0.
2792	12	6	Solar	Partial	3	-1.2974	0.4499	000m 00.0s	0.
2810	12	17	Solar	Partial	3	-1.3112	0.4247	000m 00.0s	0.
2828	12	28	Solar	Partial	3	-1.3229	0.4037	000m 00.0s	0.
2847	1	8	Solar	Partial	3	-1.3314	0.3885	000m 00.0s	0.
2865	1	18	Solar	Partial	3	-1.3398	0.3735	000m 00.0s	0.
2883	1	30	Solar	Partial	3	-1.3485	0.3582	000m 00.0s	0.
2901	2	10	Solar	Partial	3	-1.3590	0.3394	000m 00.0s	0.
2919	2	21	Solar	Partial	3	-1.3717	0.3167	000m 00.0s	0.
2937	3	4	Solar	Partial	3	-1.3893	0.2850	000m 00.0s	0.
2955	3	15	Solar	Partial	3	-1.4112	0.2455	000m 00.0s	0.
2973	3	25	Solar	Partial	6	-1.4393	0.1948	000m 00.0s	0.
2991	4	6	Solar	Partial	6	-1.4727	0.1345	000m 00.0s	0.
3009	4	17	Solar	Partial	6	-1.5142	0.0595	000m 00.0s	0.

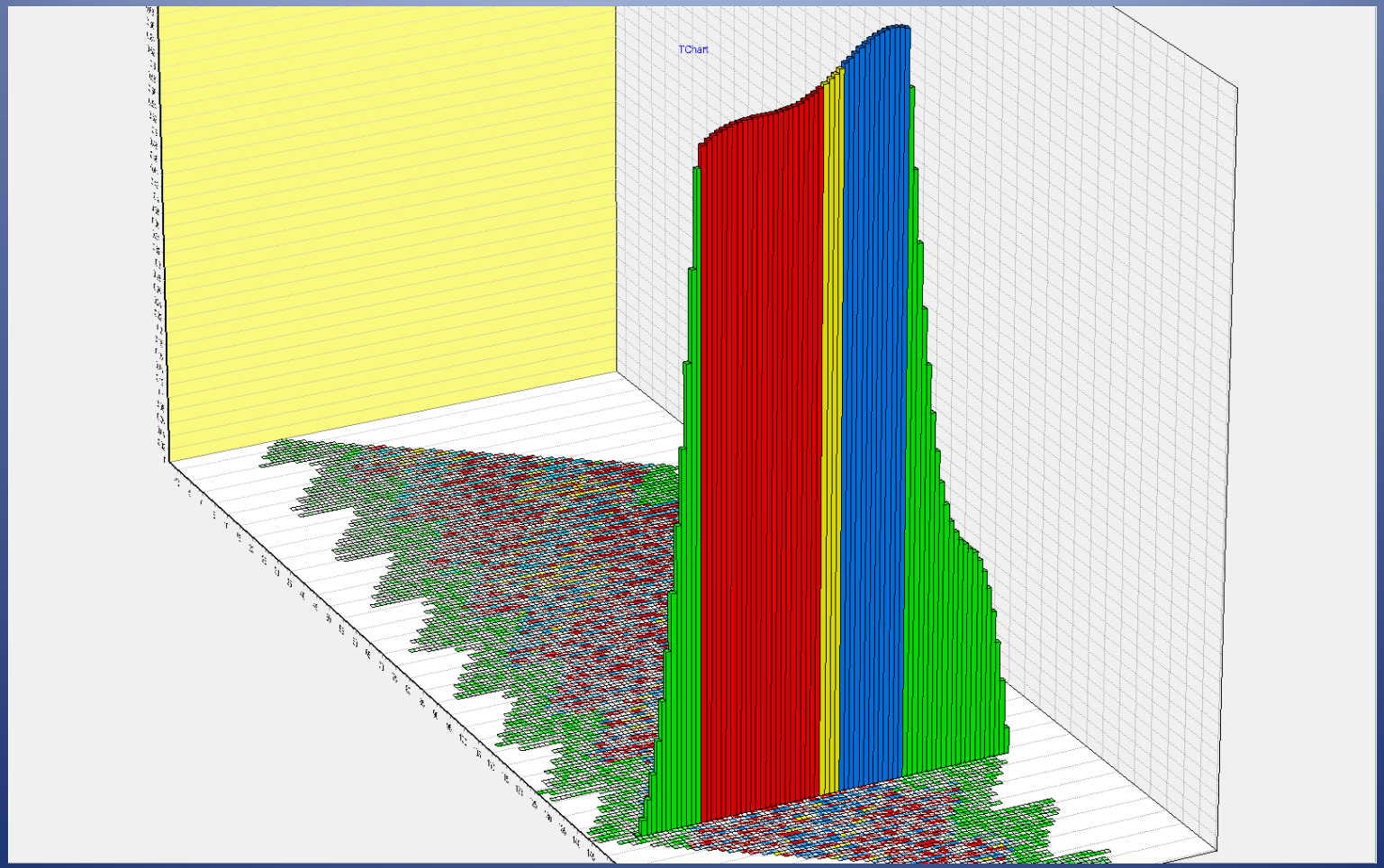
(Solar/Lunar = Solar) and (Saros = 145) Customize...



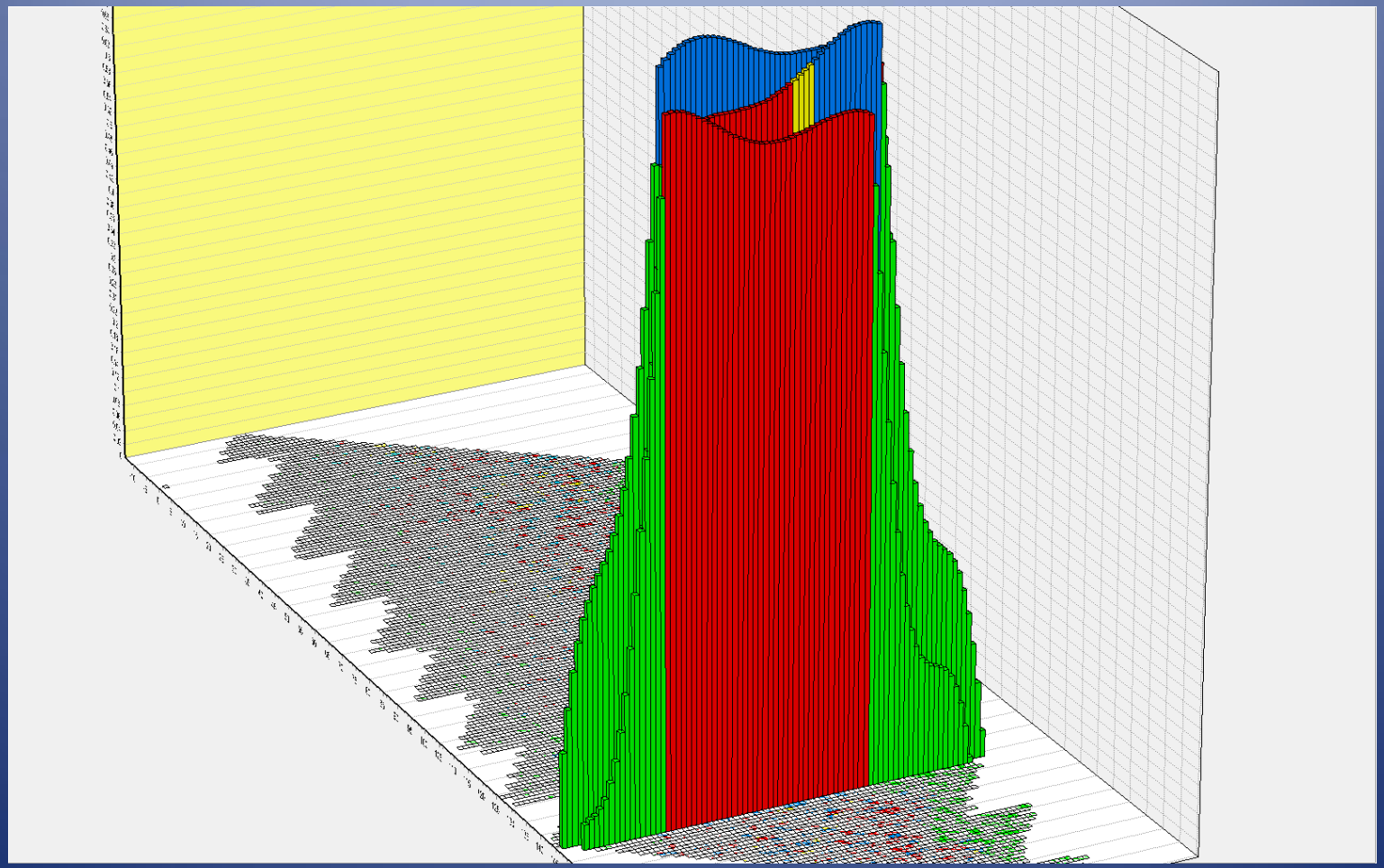
Saros 145



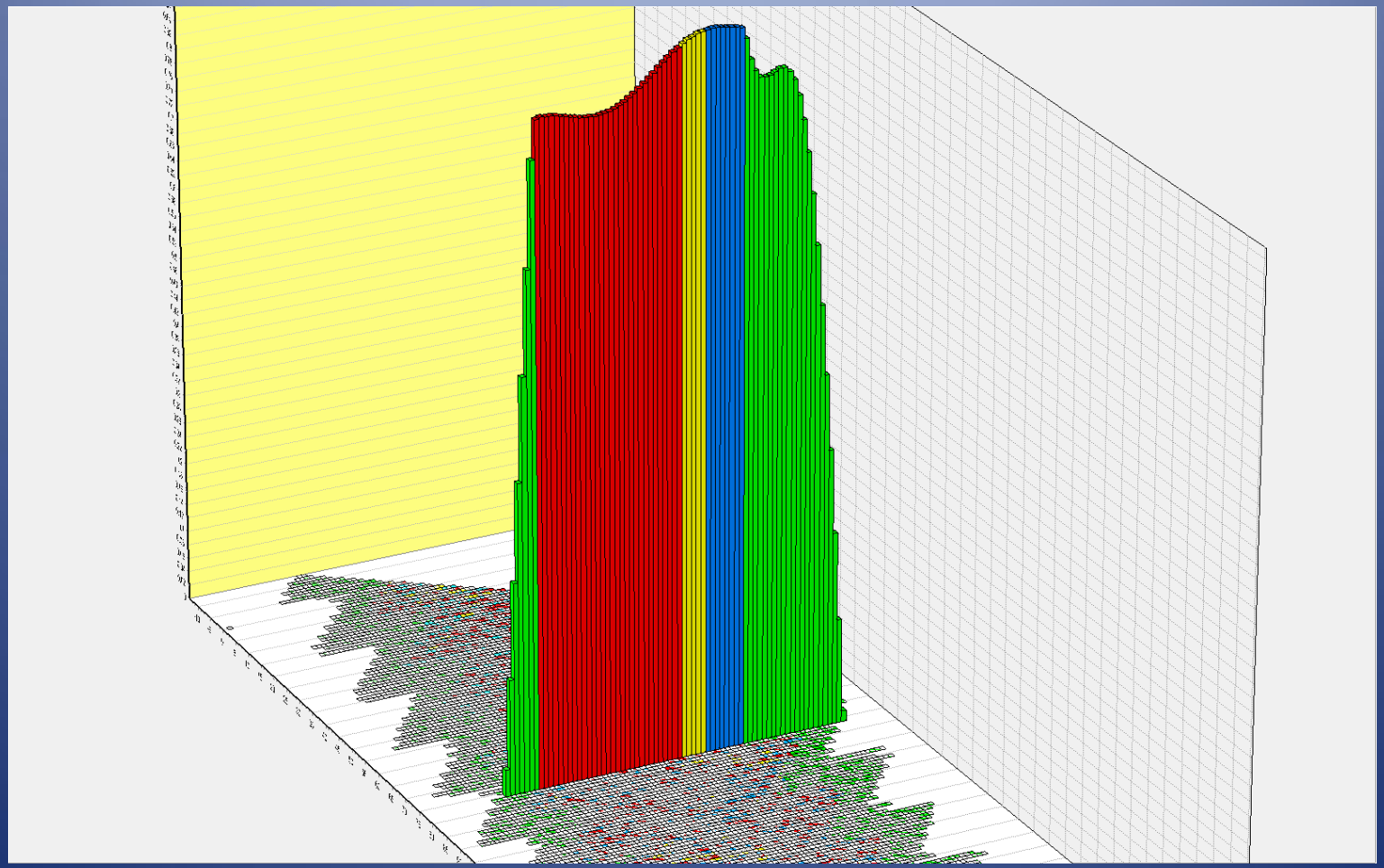
Saros 146



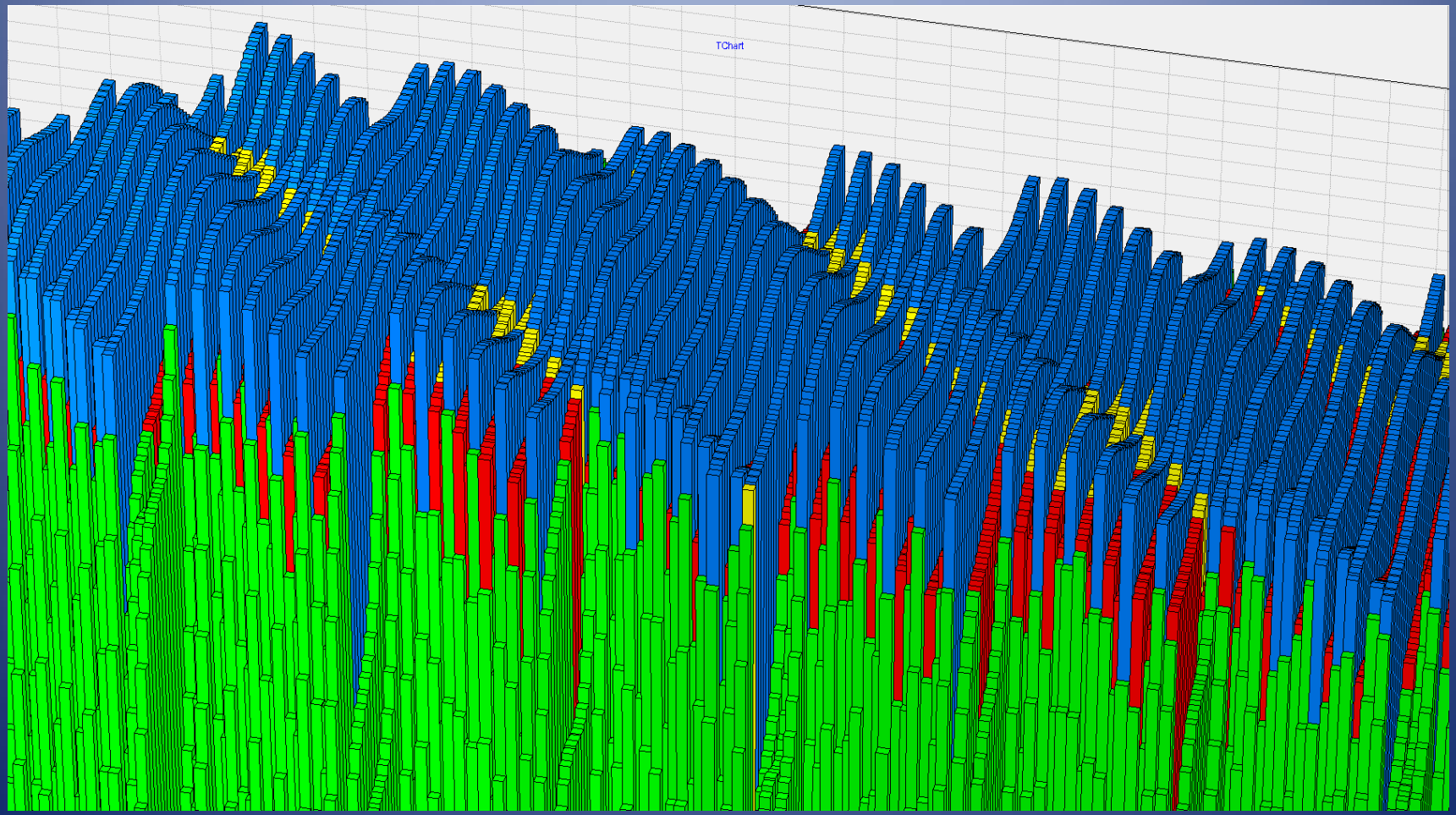
Saros 145, 146 and 147



Saros 76 – 3 maxima



Stack the solar saros side-by-side



Each saros series is 358 lunations apart = 1 inex

The Inex

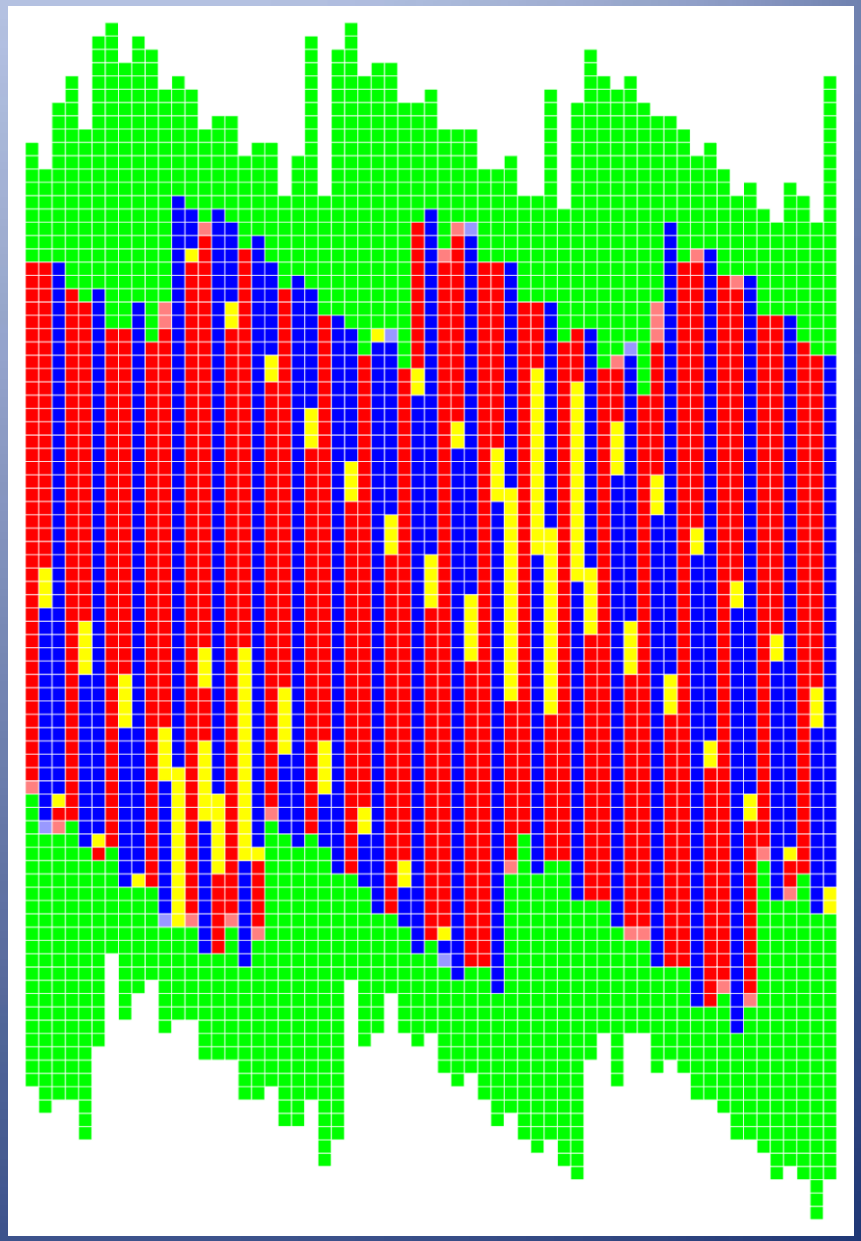
- 358 lunations
- Stack the saros series one inex apart

Moon's orbital cycle	Length in days	Number of periods	Days
Synodic month	29.530589	358 lunations	10571.9509
Anomalistic month	27.554550	383.67	10571.8542
Draconic month	27.212221	388.5	10571.9479

358 lunations - approximately 29years 11days

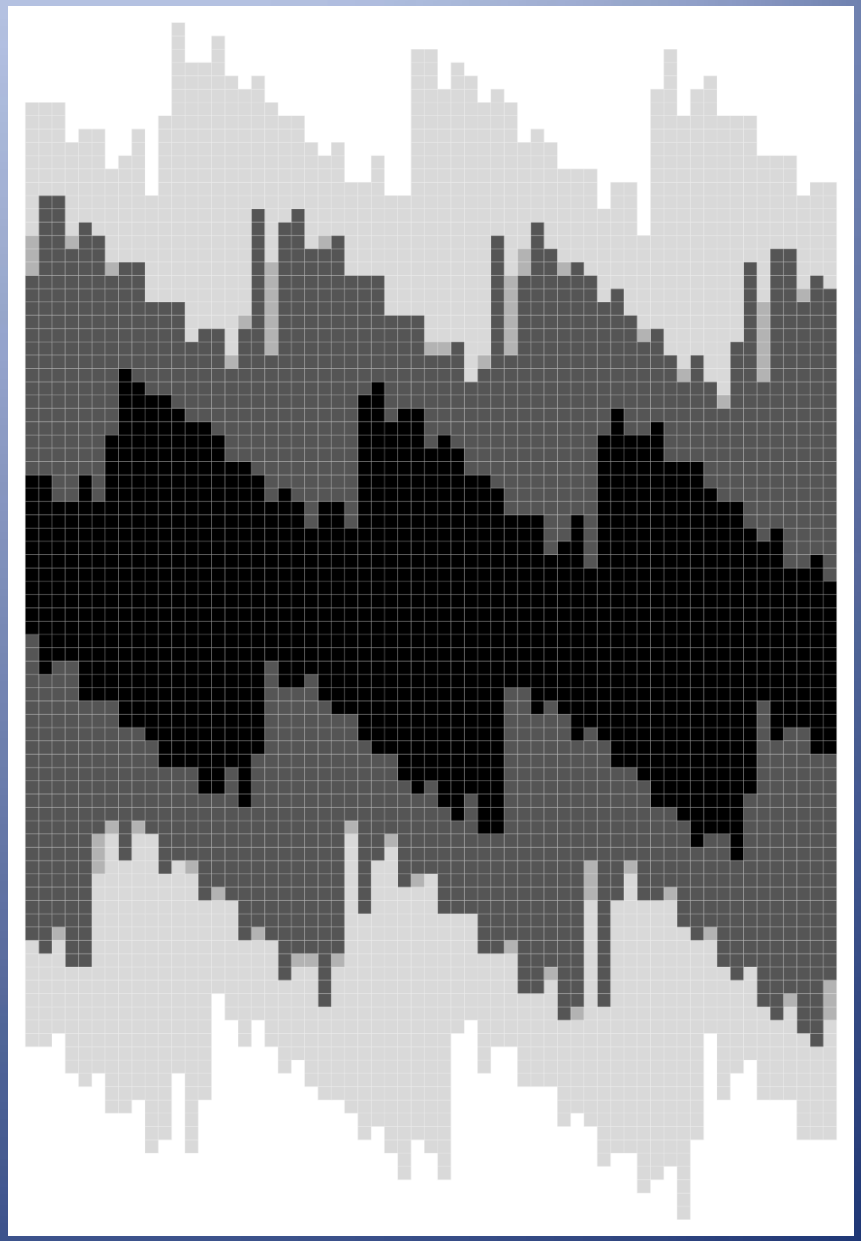
Solar Saros-Inex Panorama

Saros 90 to 150



Lunar Saros-Inex Panorama

- Saros 90 to 150
- In increasing order of shading
  - Partial penumbral
  - Total penumbral
  - Partial umbral
  - Total umbral

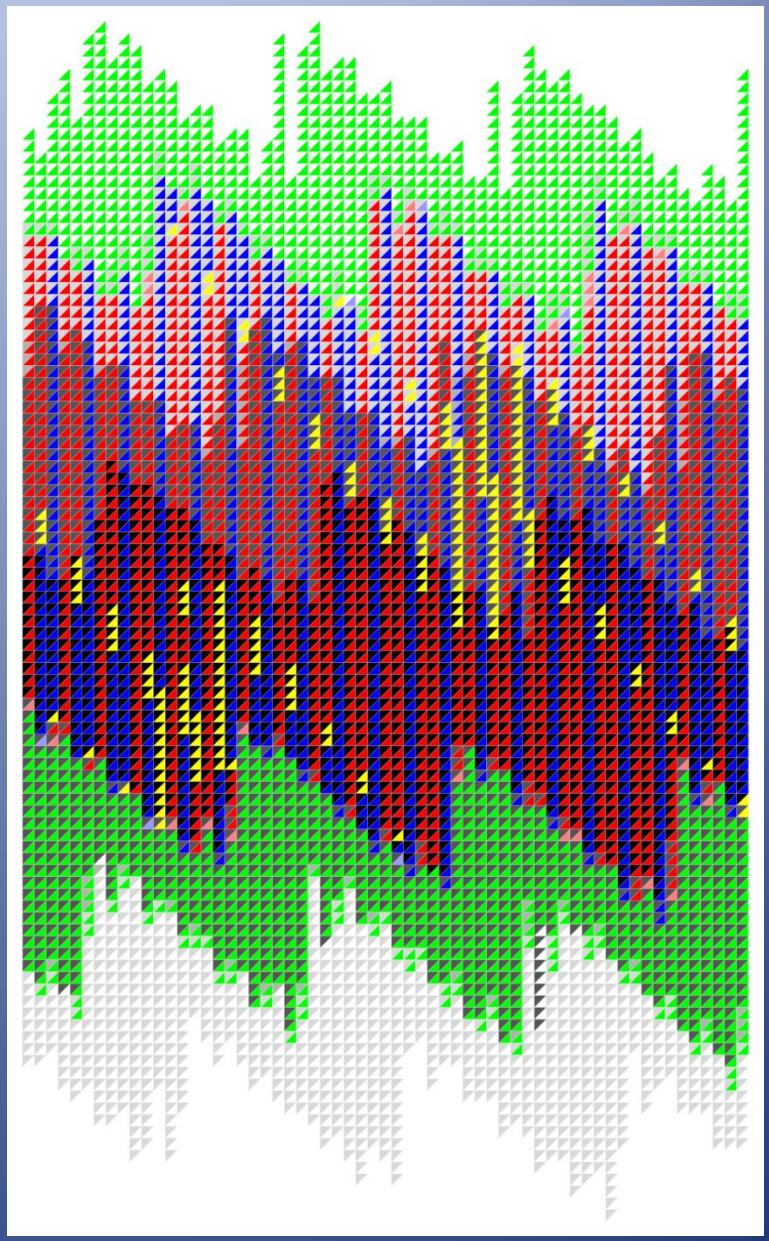


Can we combine the two panorama?

- Crazy idea!
- Why not?

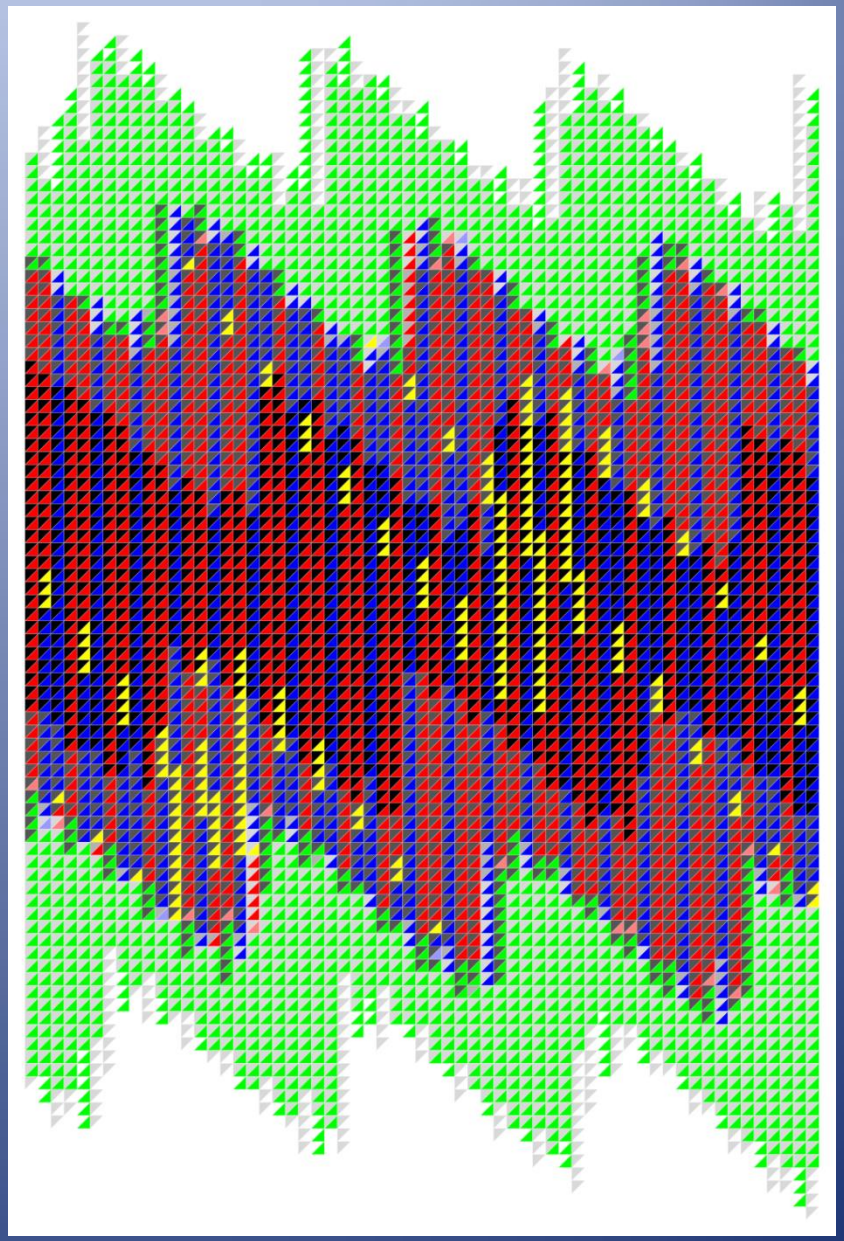
A merged Panorama

- First attempt
- Using corresponding saros and inex numbers
- Poor overlap



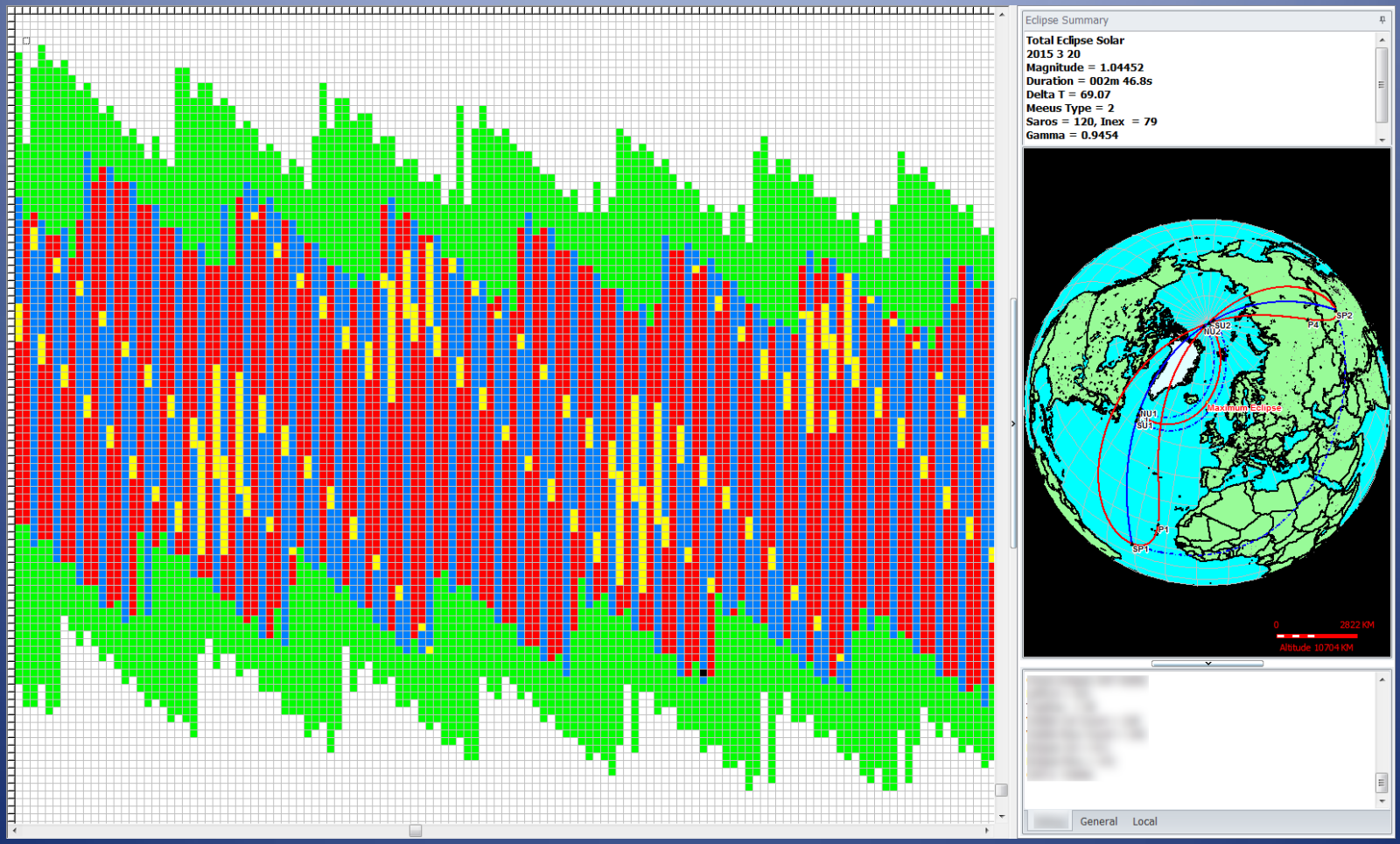
The merged Panorama

- Renumber the lunar saros and inex
- Luca Quaglia's idea
- LQ Saros = Saros + 7
- LQInex = Inex + 12
- Result is half a saros offset



The Solar Saros-Inex Panorama

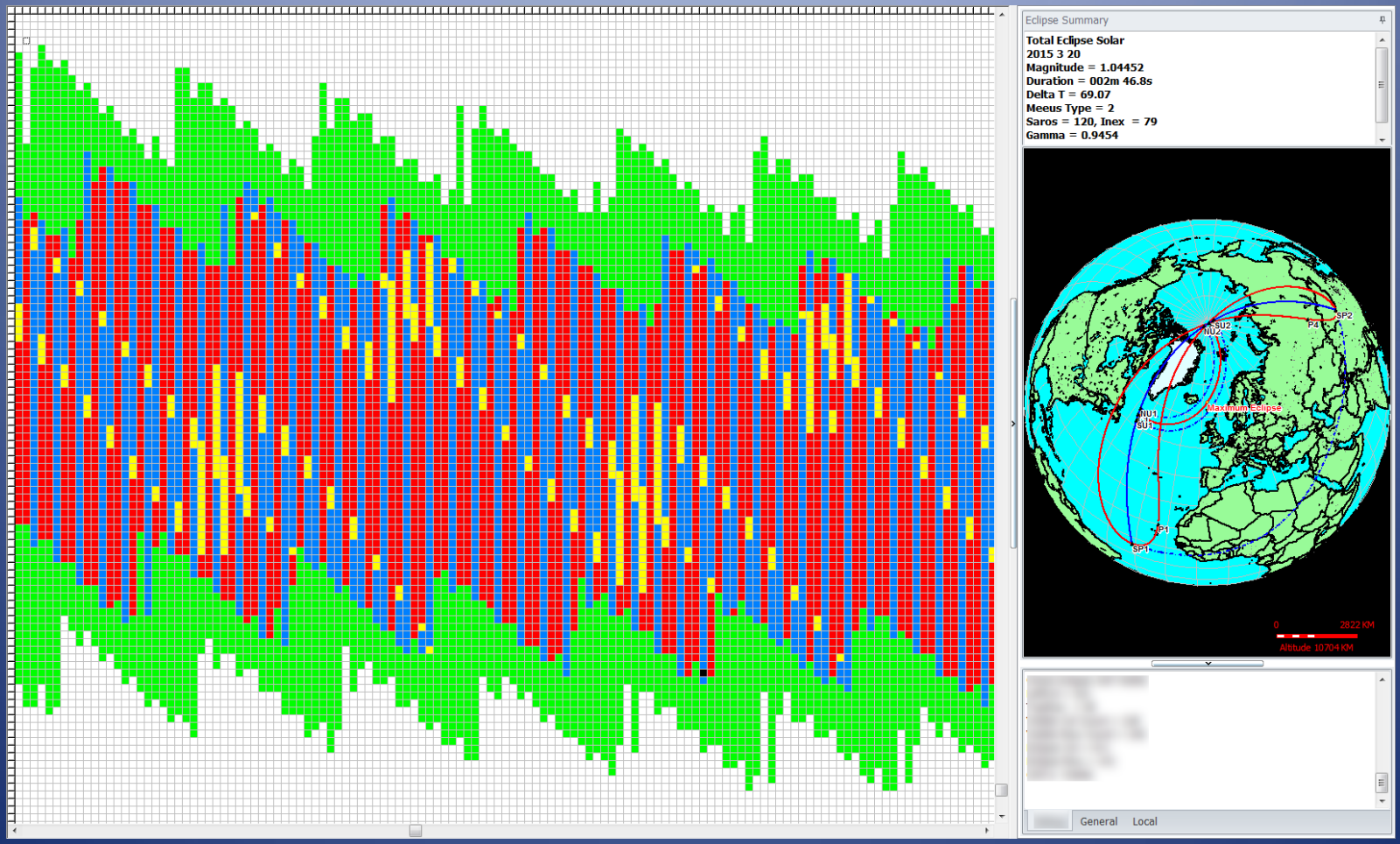
Inex



Saros

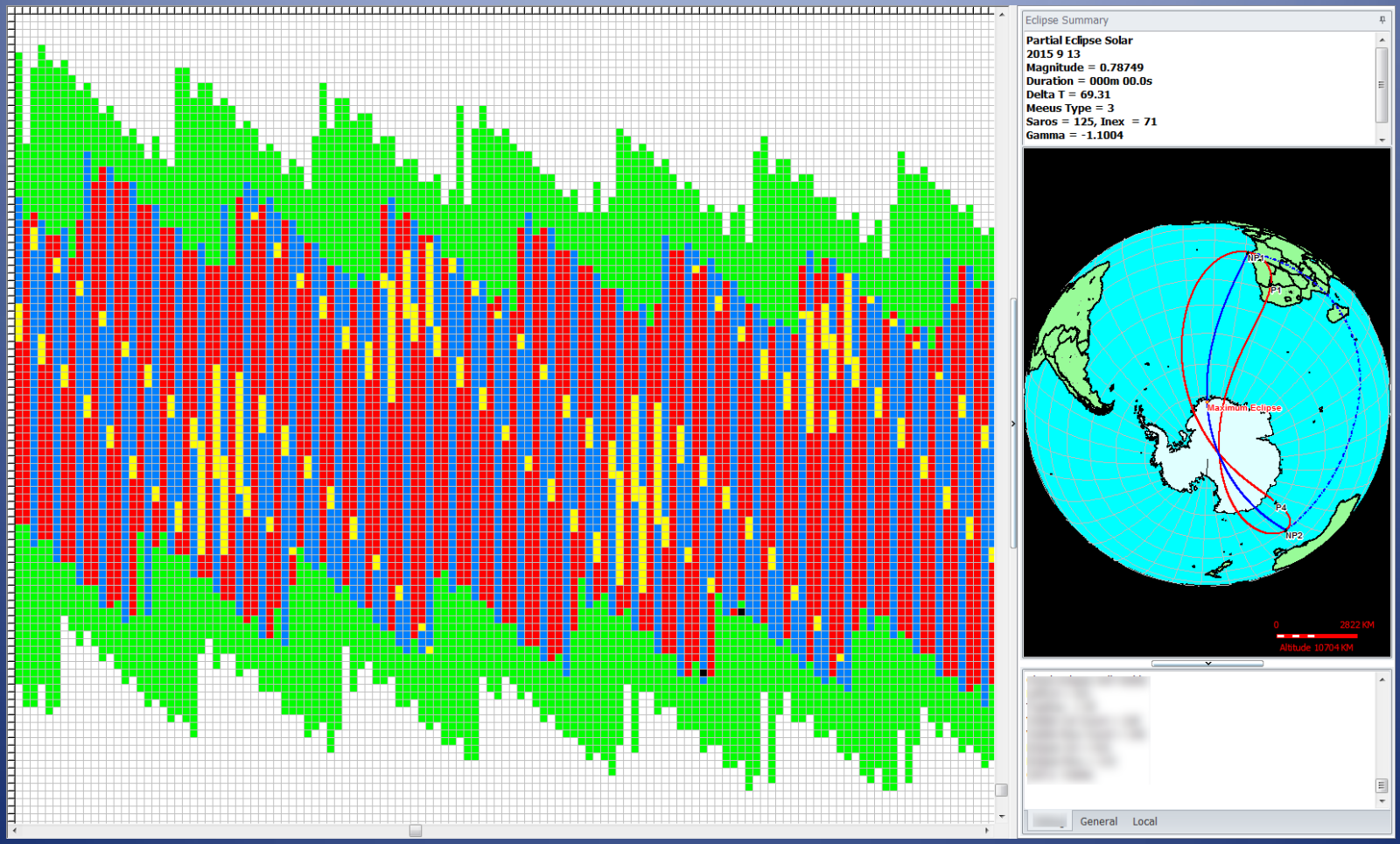
Solar Semester starts

2015 March 20th



2015 Sept 13th

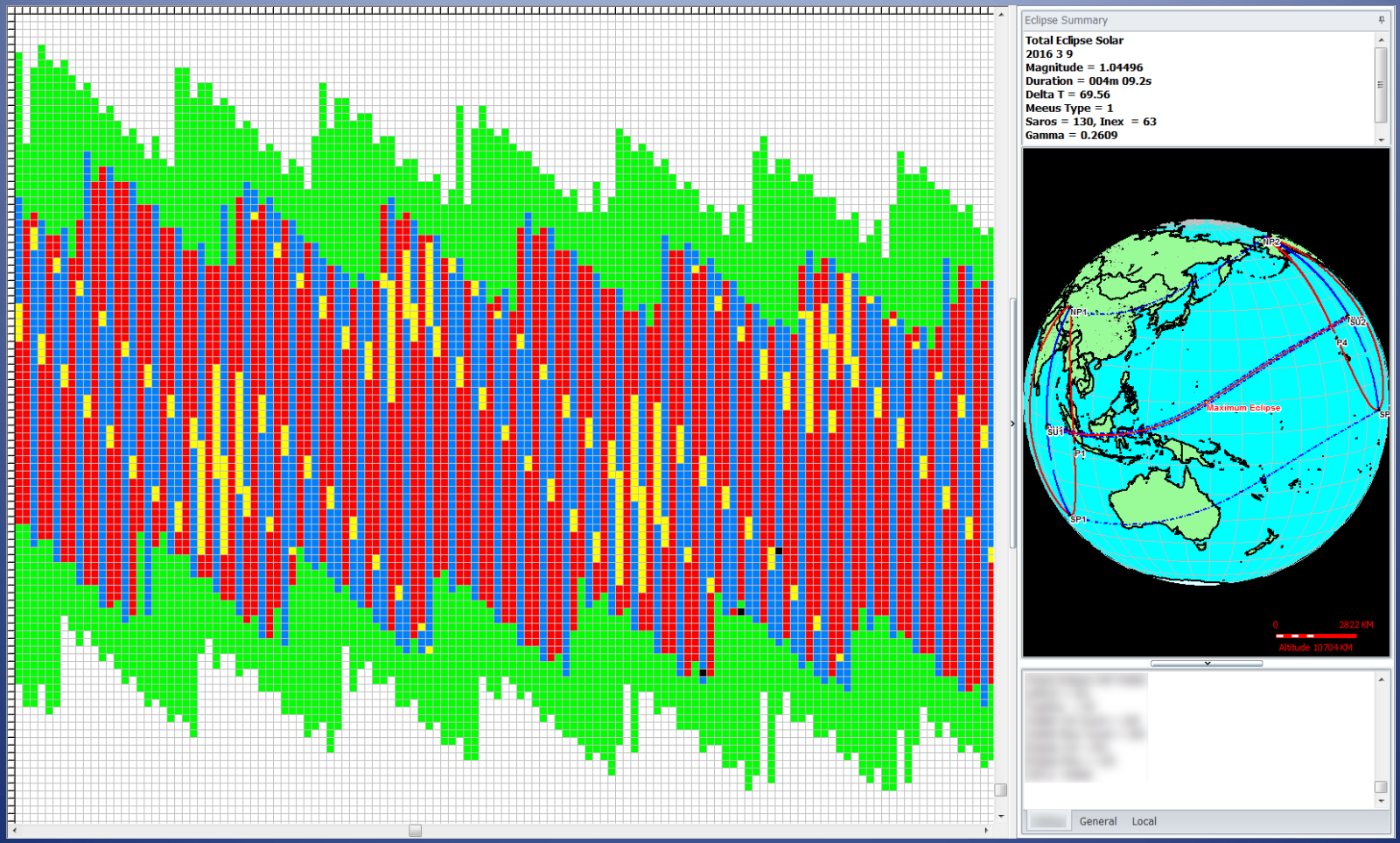
6 lunations later



6 lunations = 5inex – 8saros or (5*358 - 8*223) = 6 lunations

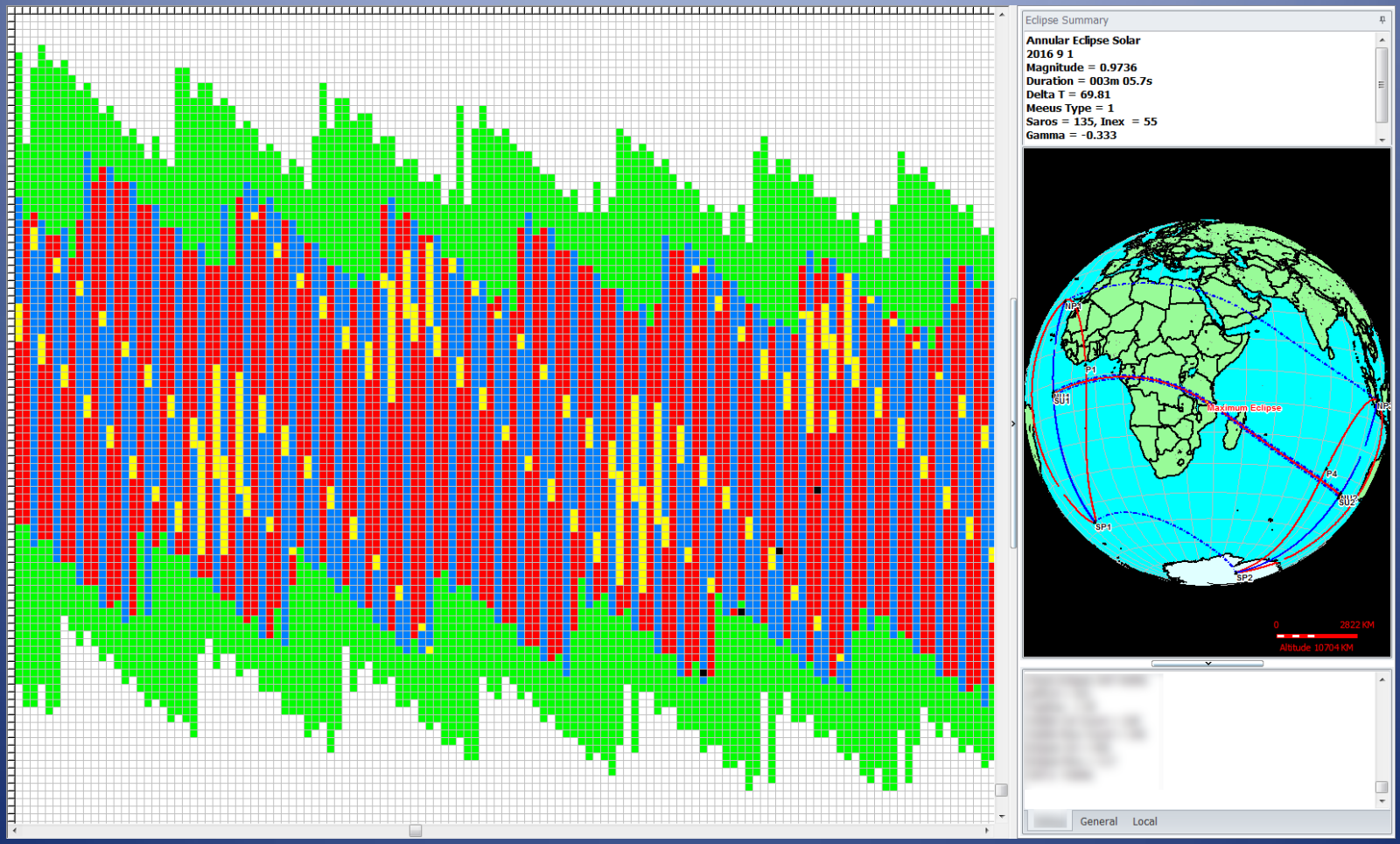
2016 March 9th

6 lunations later



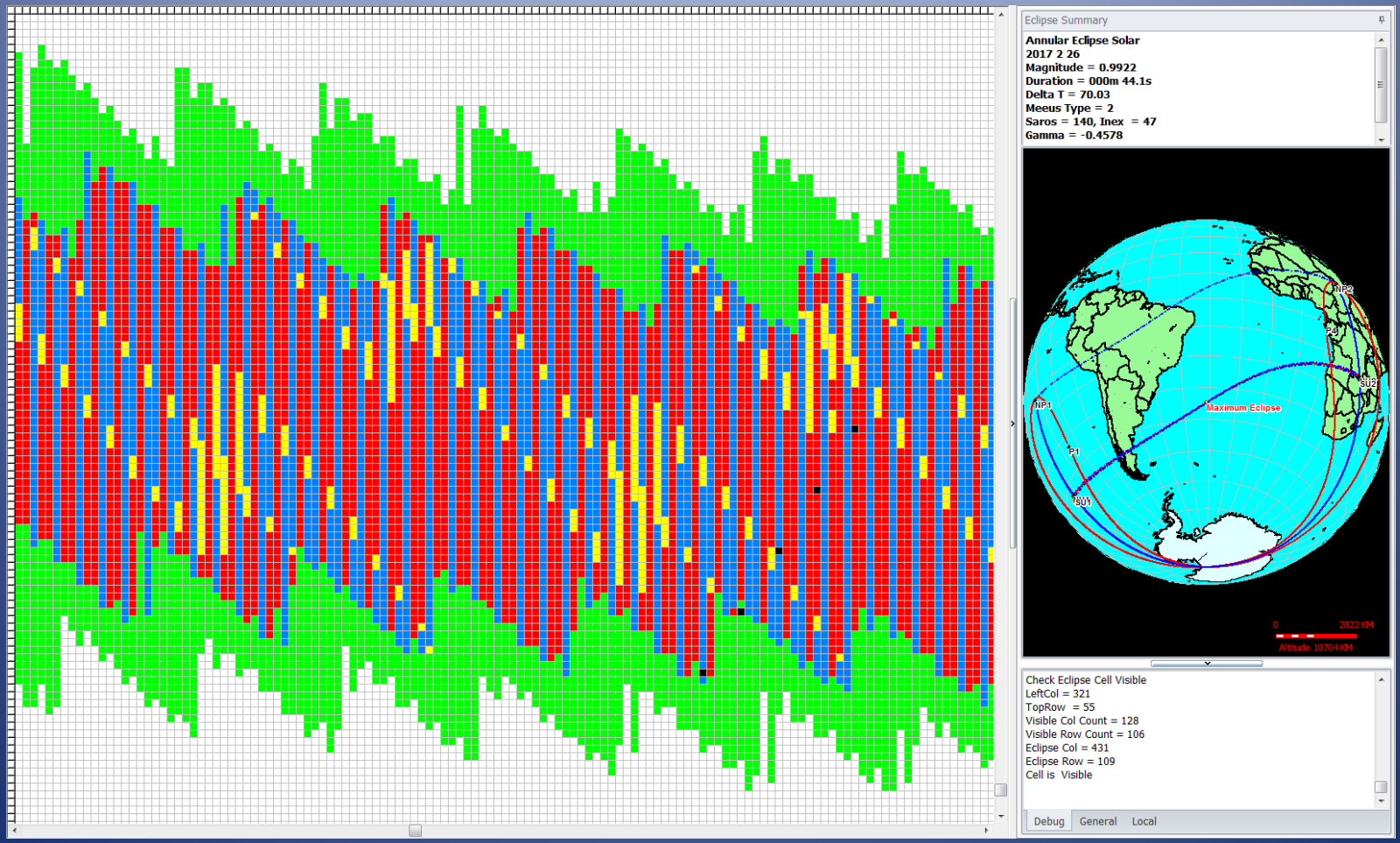
2016 Sept 1st

6 lunations later



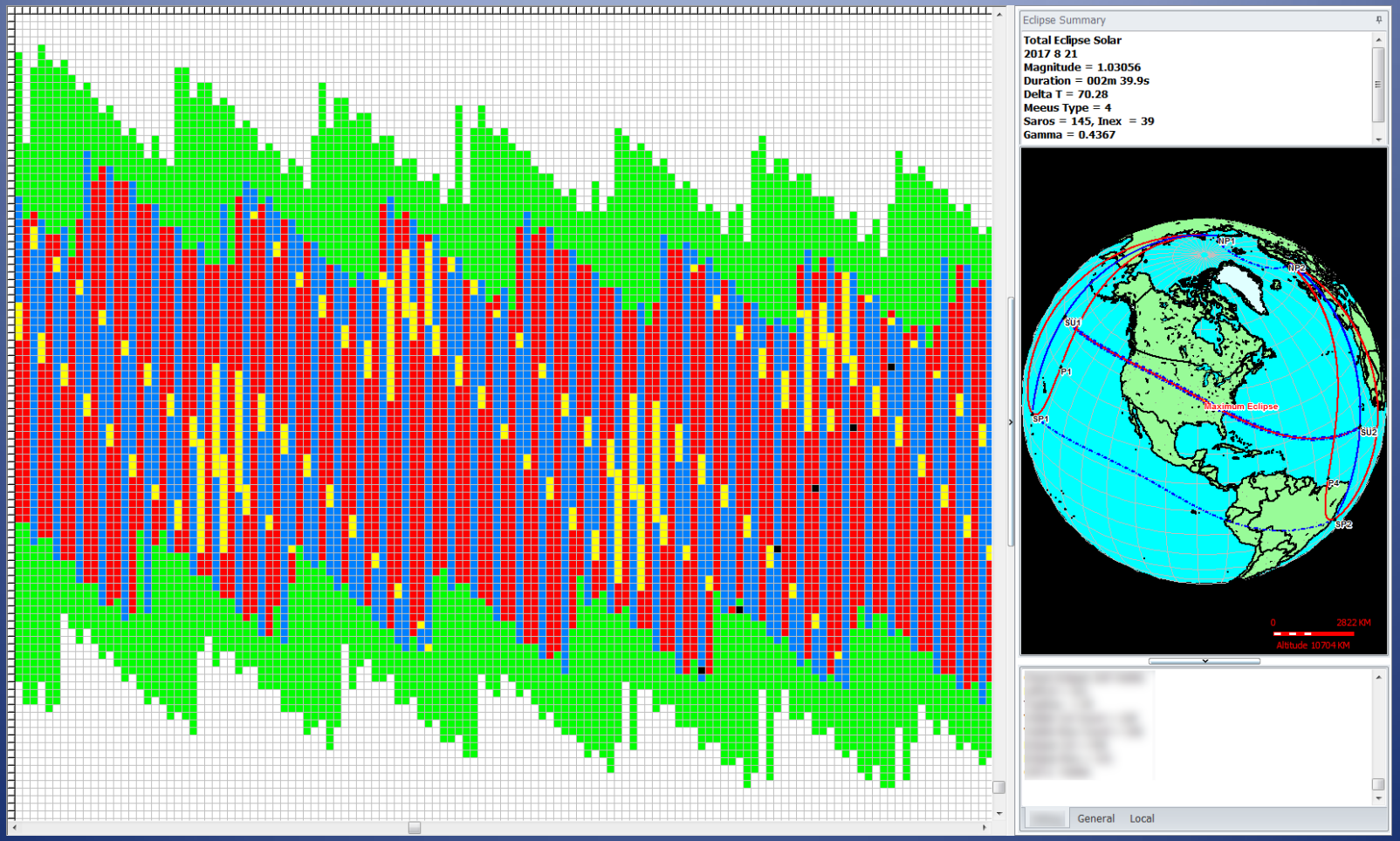
2017 Feb 26th

6 lunations later



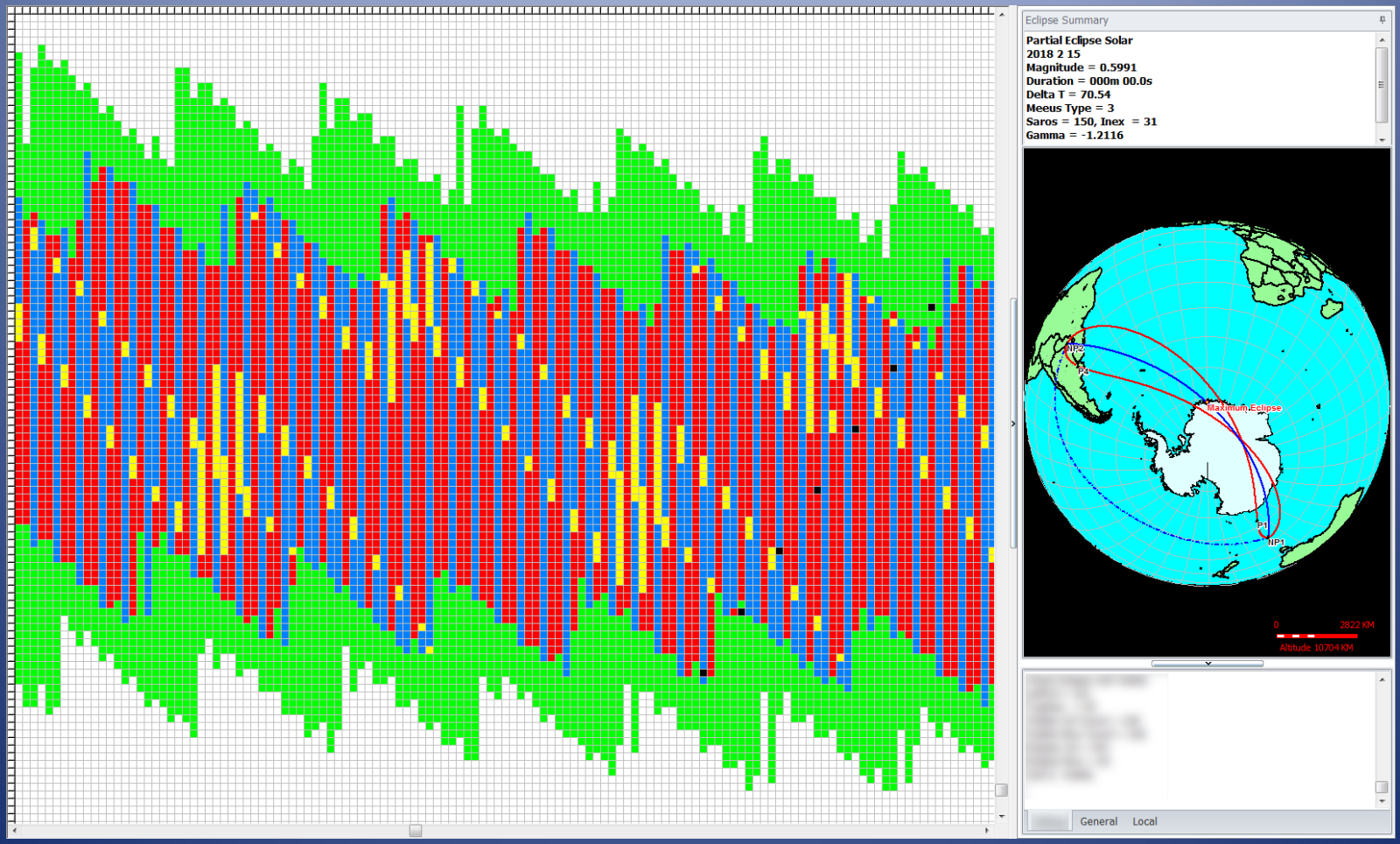
2017 Aug 21st

6 lunations later



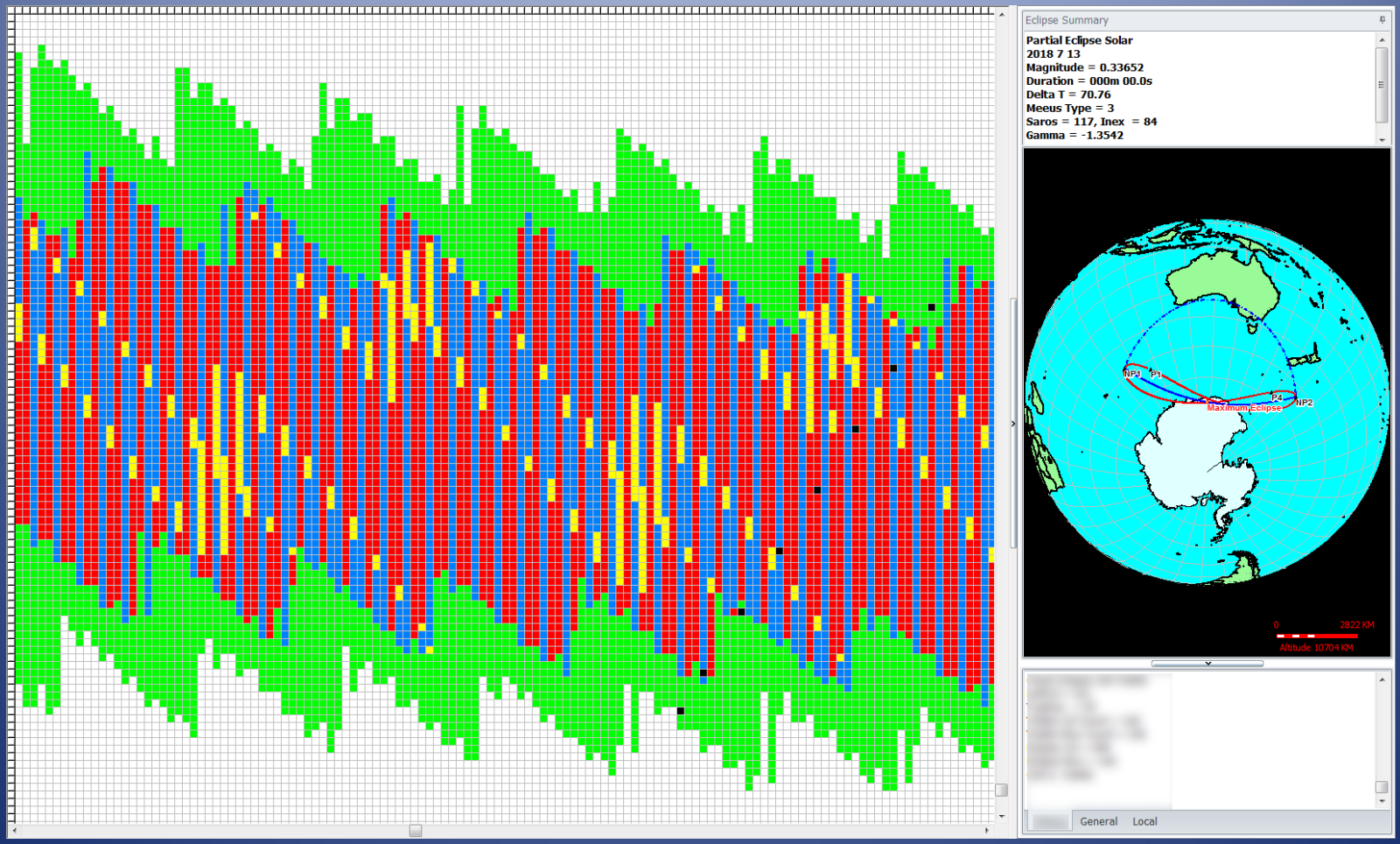
2018 Feb 15th

6 lunations later



2018 July 13th

5 lunations later = big jump back down

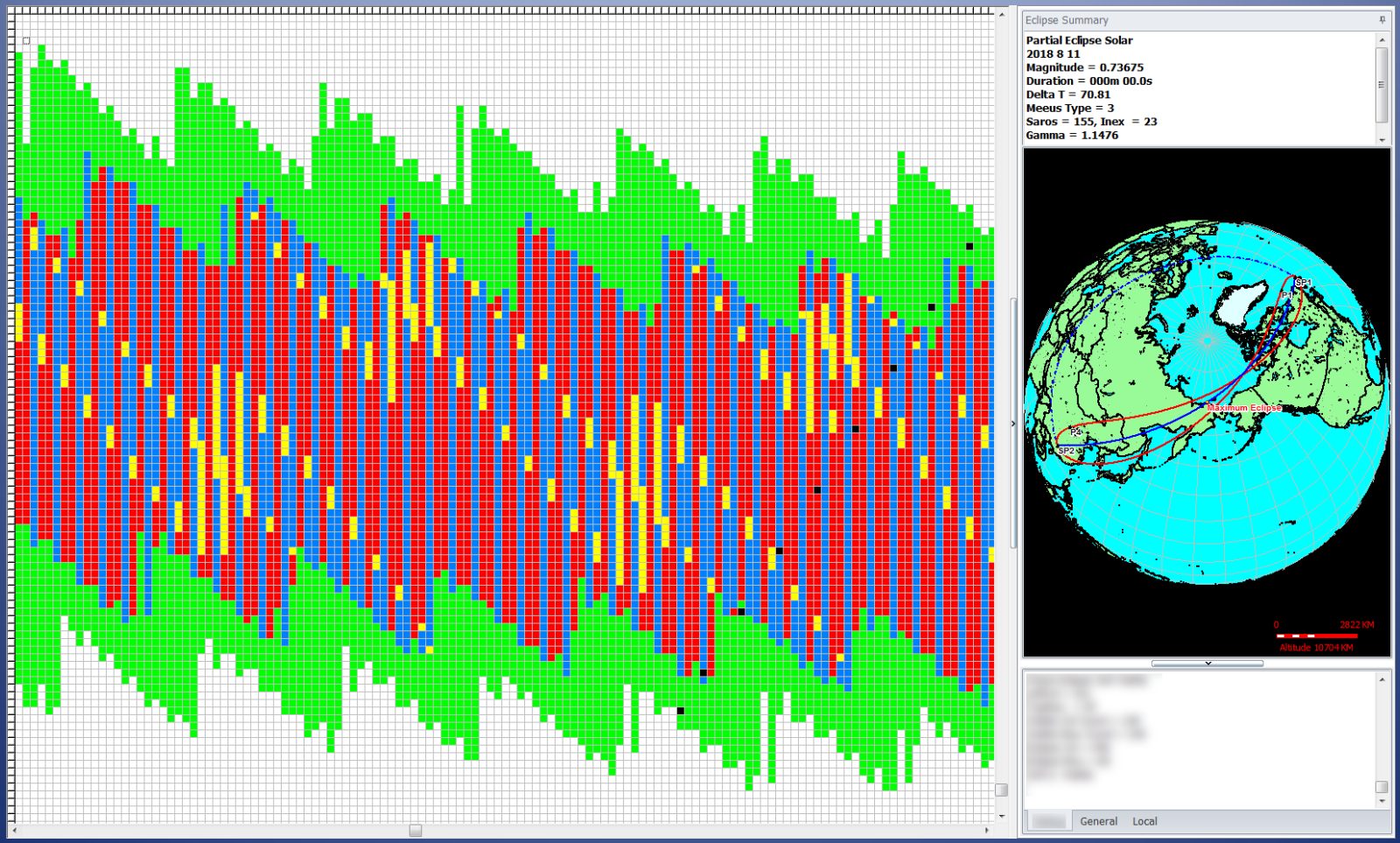


5 lunations = 53saros – 33inex or (+53*223 – 33*358) = 5 lunations

2018 Aug 11th

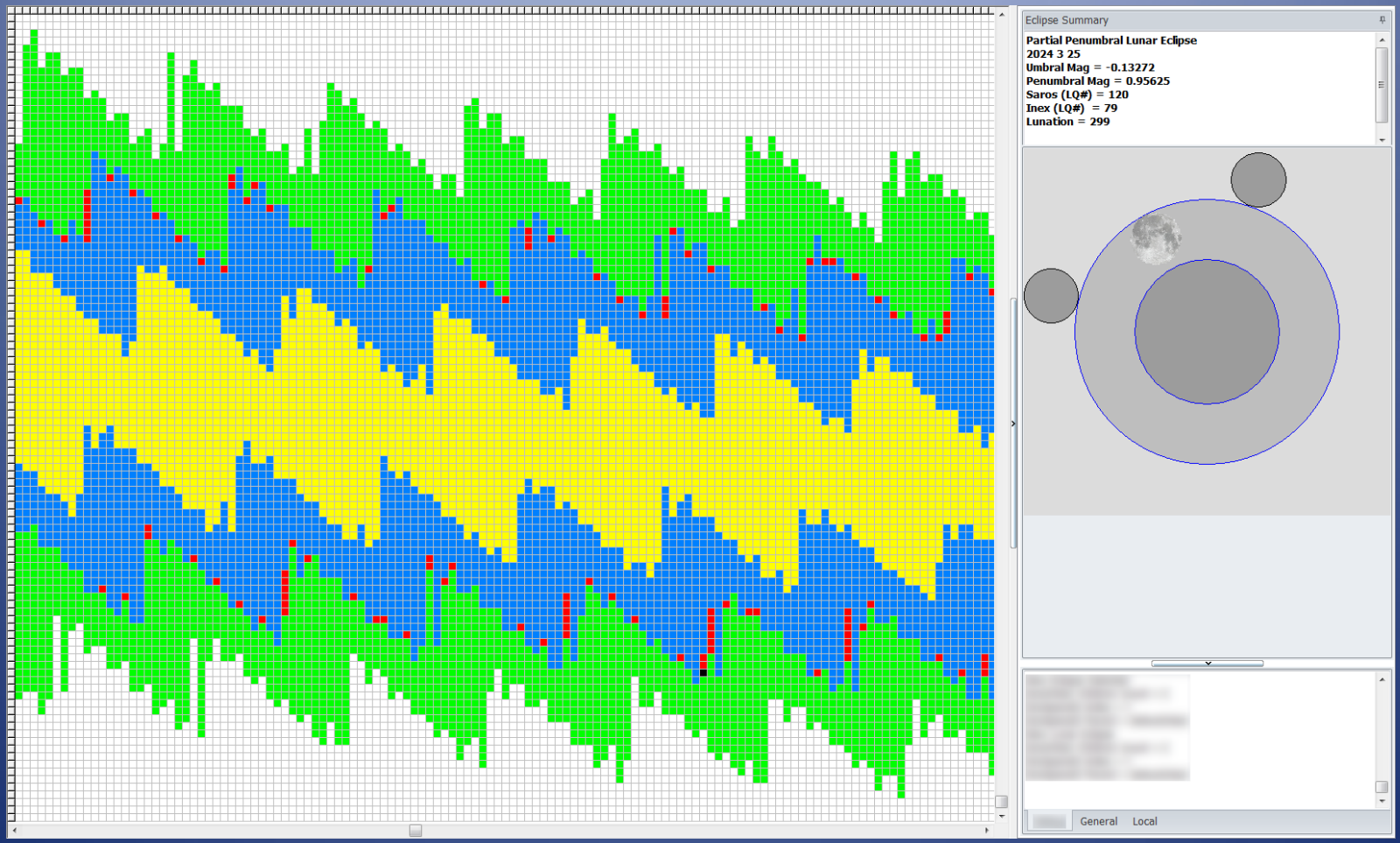
1 lunation later so really big jump back up

5+1 = 6 lunations after last but one eclipse



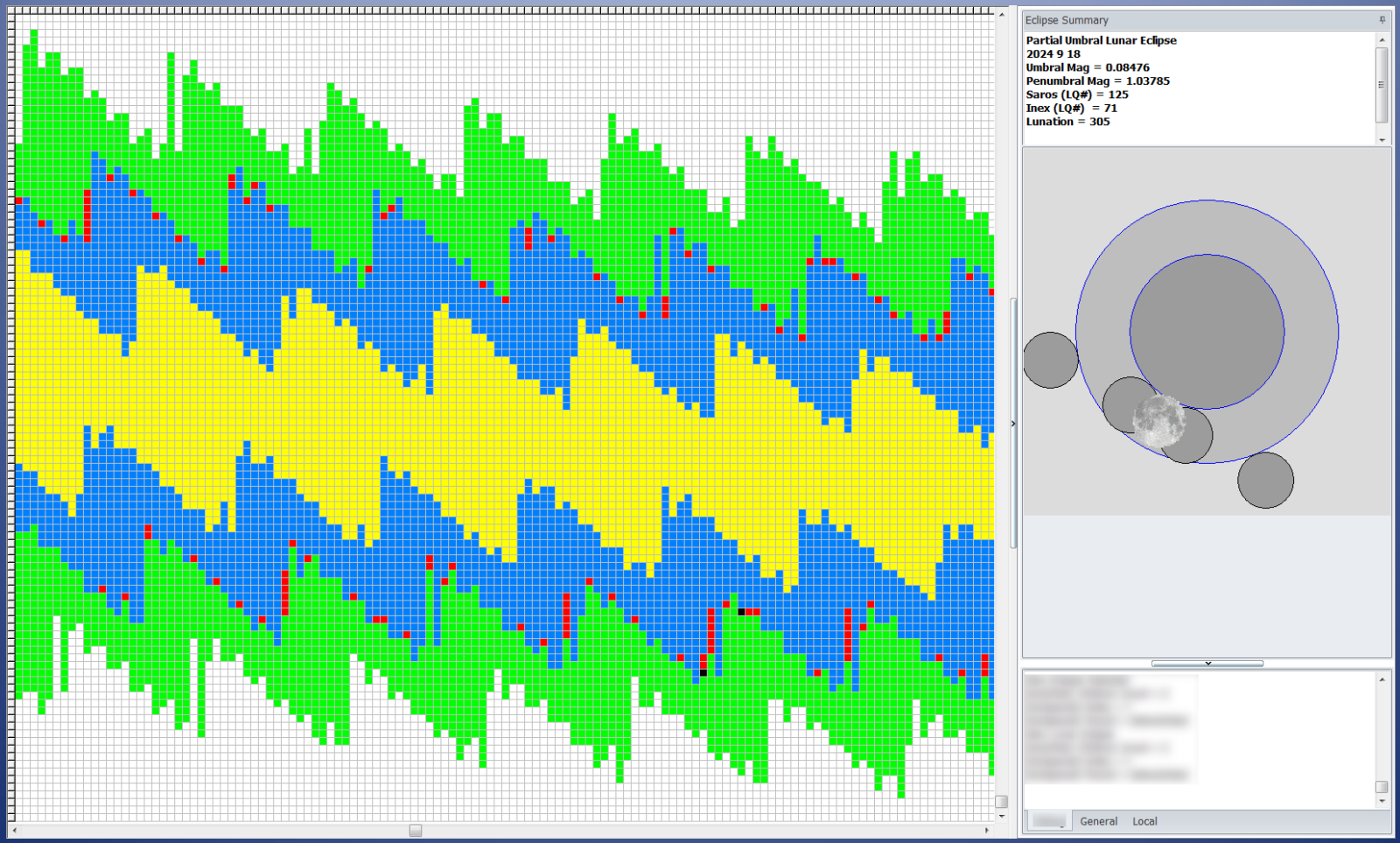
1 lunation = 38inex – 61saros or (38*358 - 61*223) = 1 lunation

Lunar Semester – start half a saros later = 2024 March 25th



2024 Sept 18th

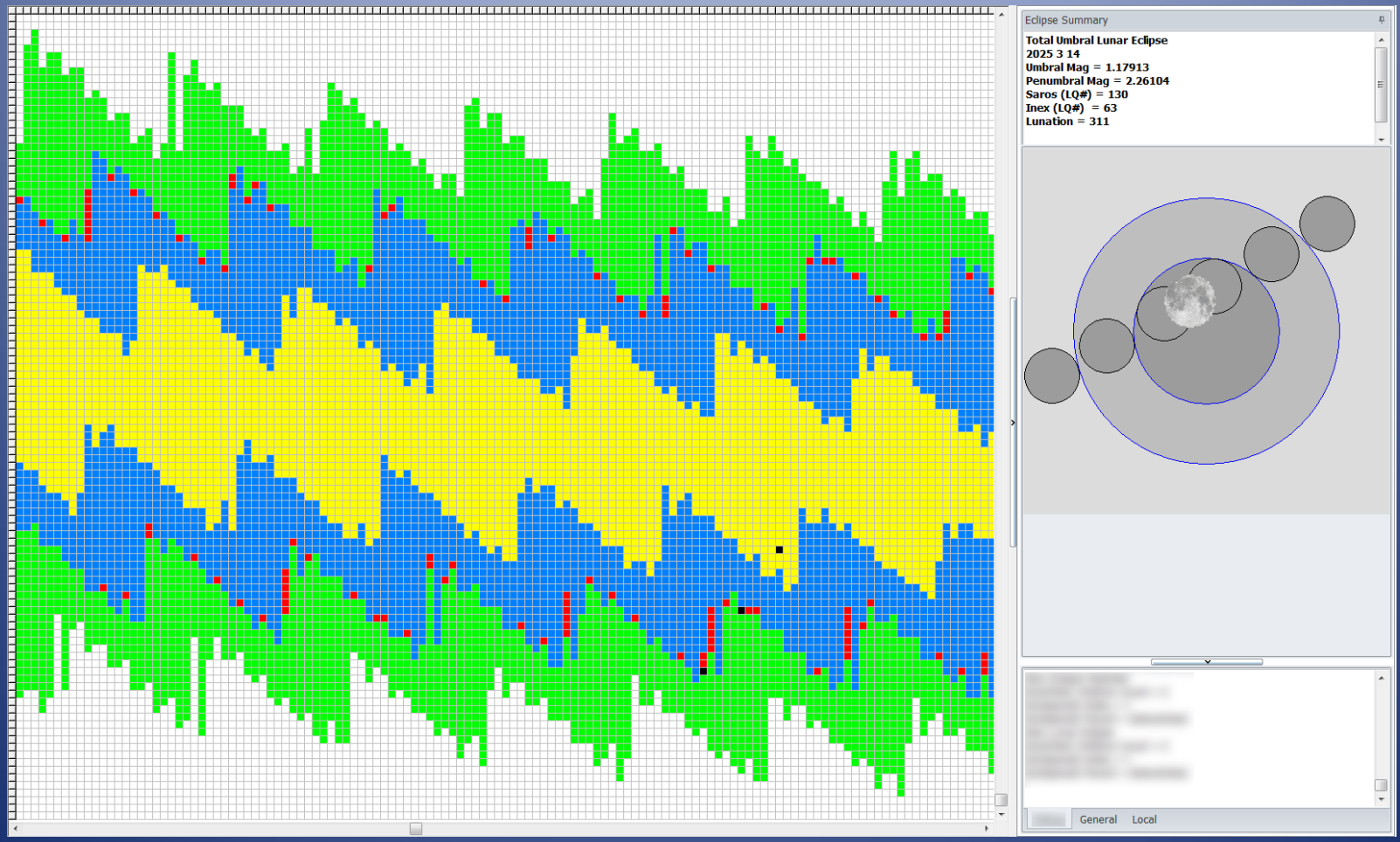
6 lunations later



6 lunations = 5inex – 8saros or (5*358 - 8*223) = 6 lunations

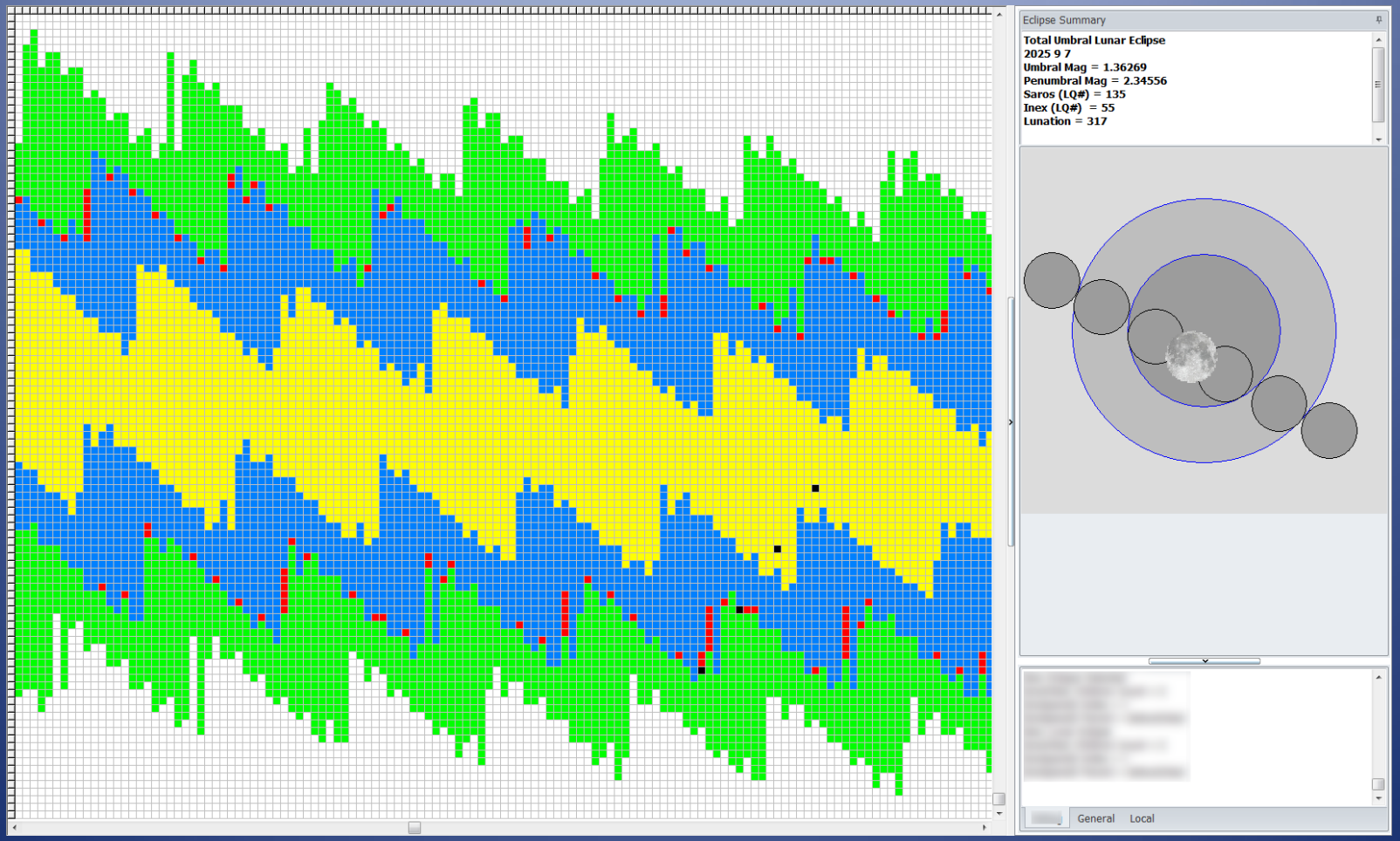
2025 March 14th

6 lunations later



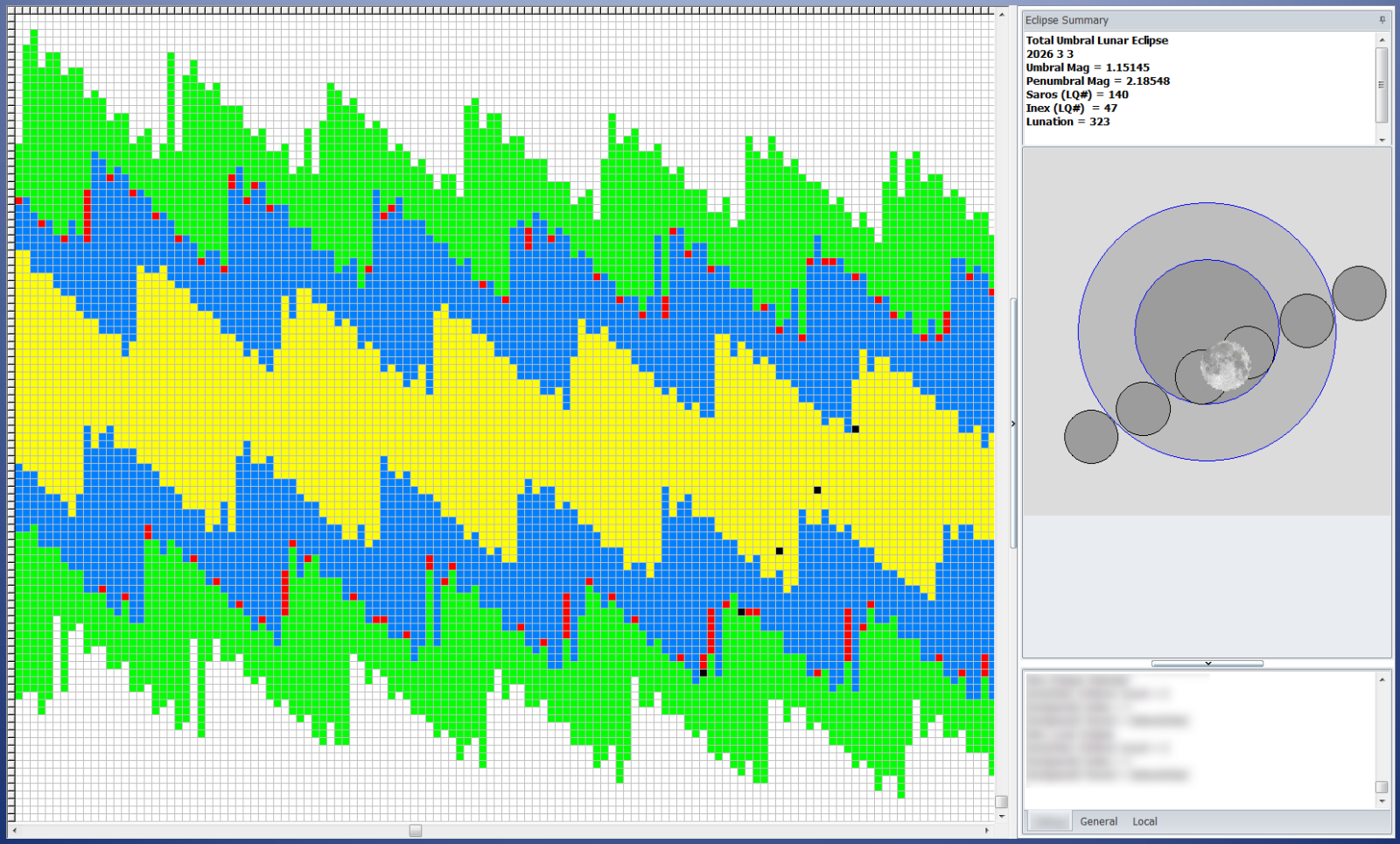
2025 Sept 7th

6 lunations later



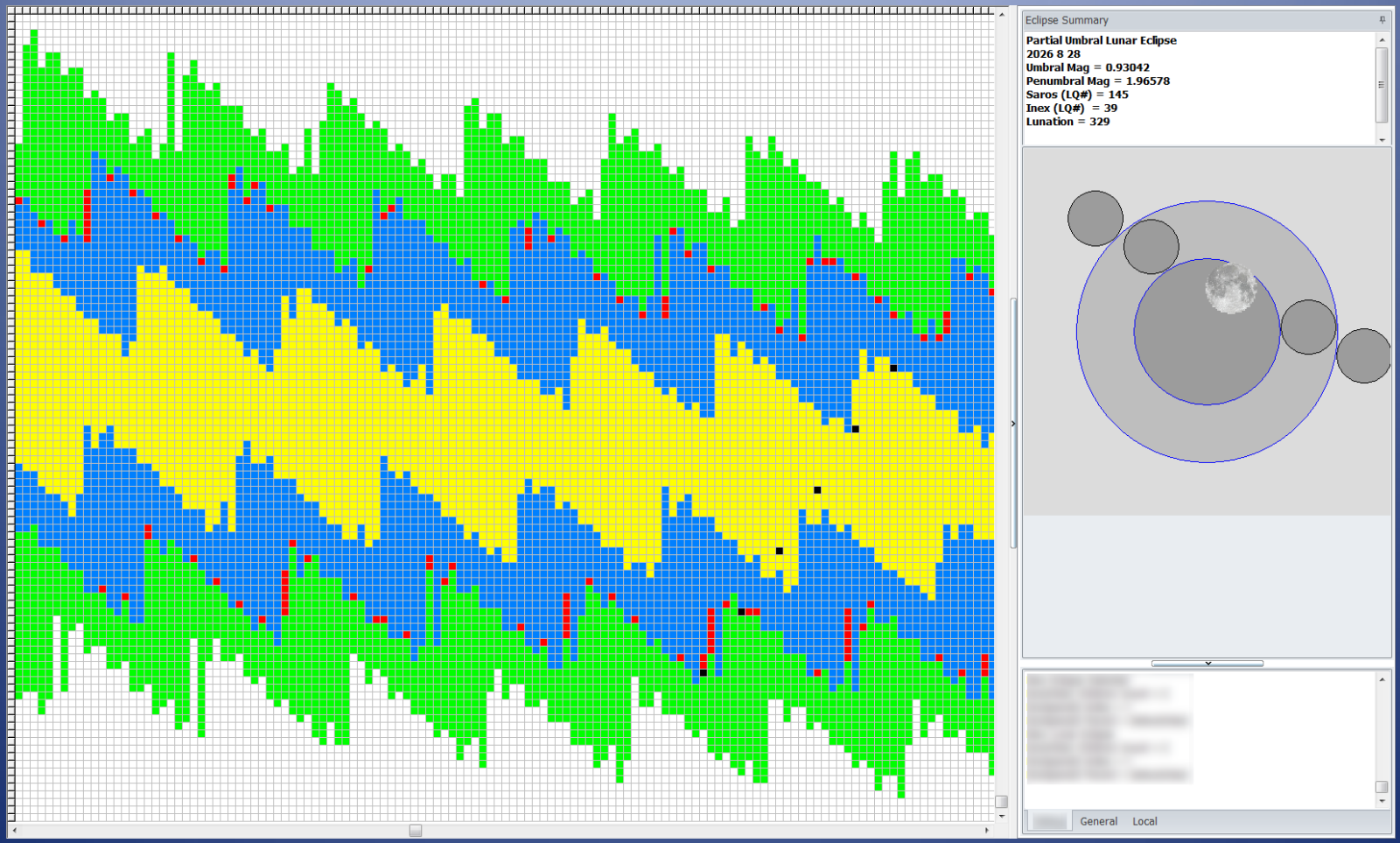
2026 March 3rd

6 lunations later



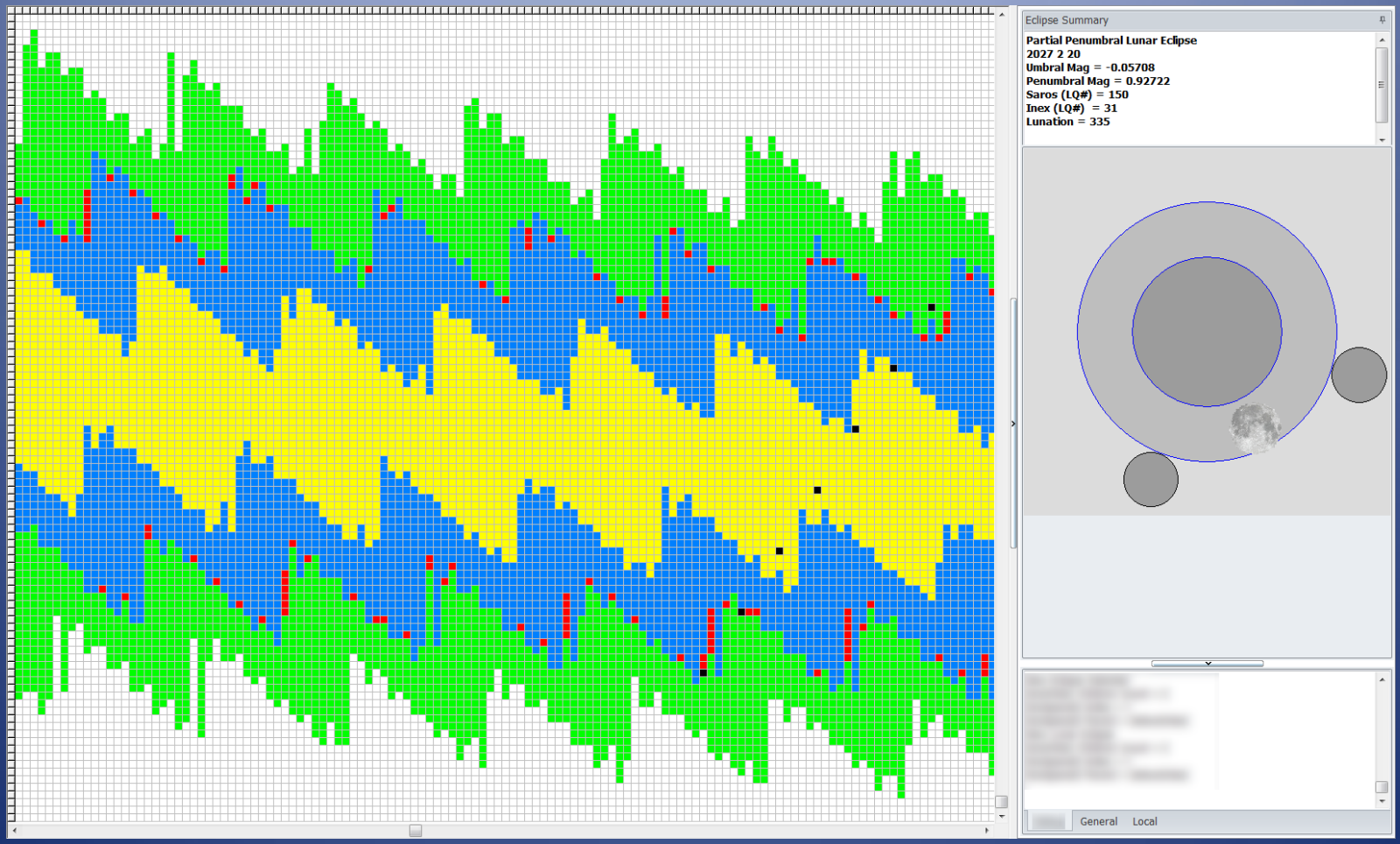
2026 Aug 28th

6 lunations later



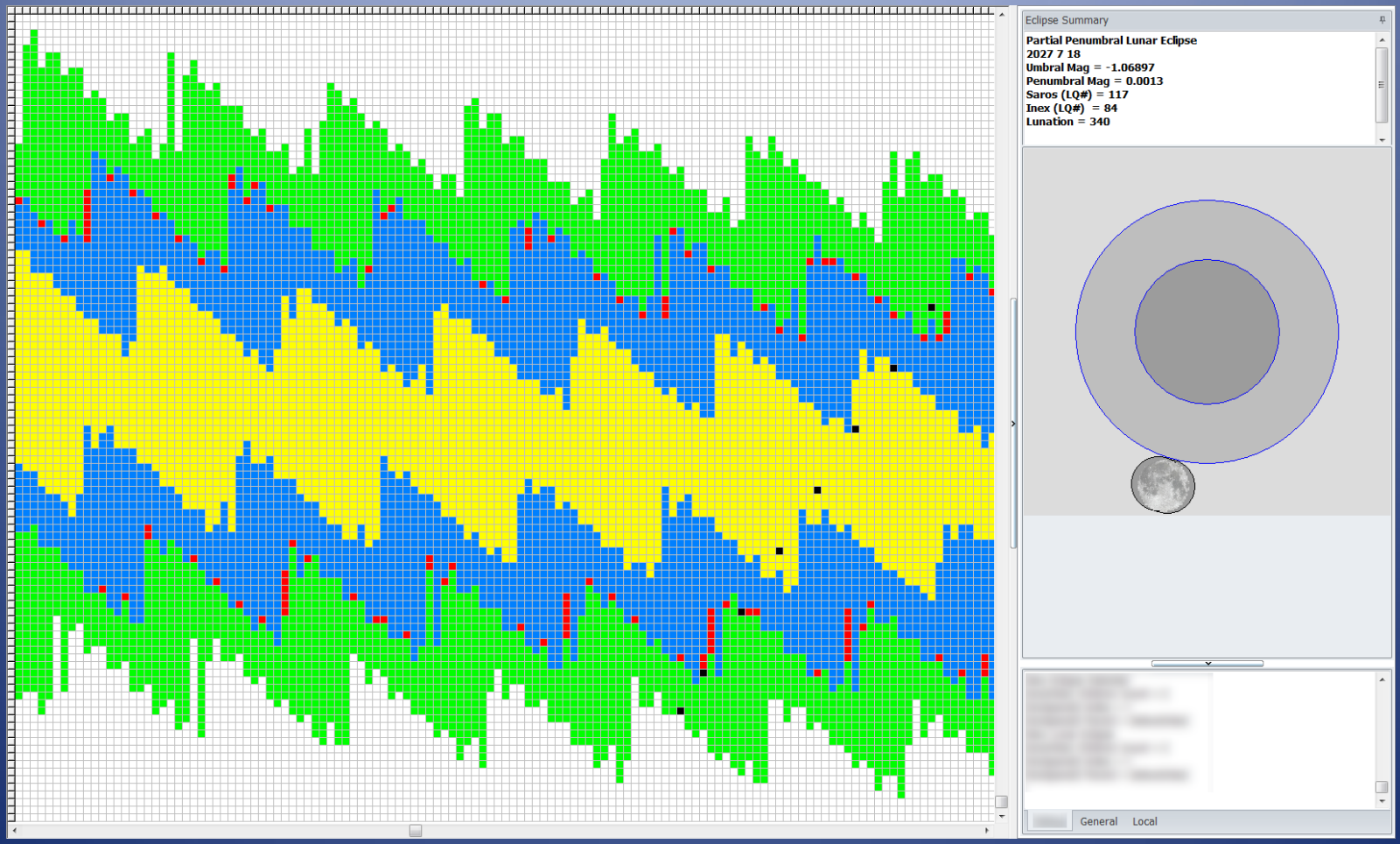
2027 Feb 20th

6 lunations later



2027 July 18th

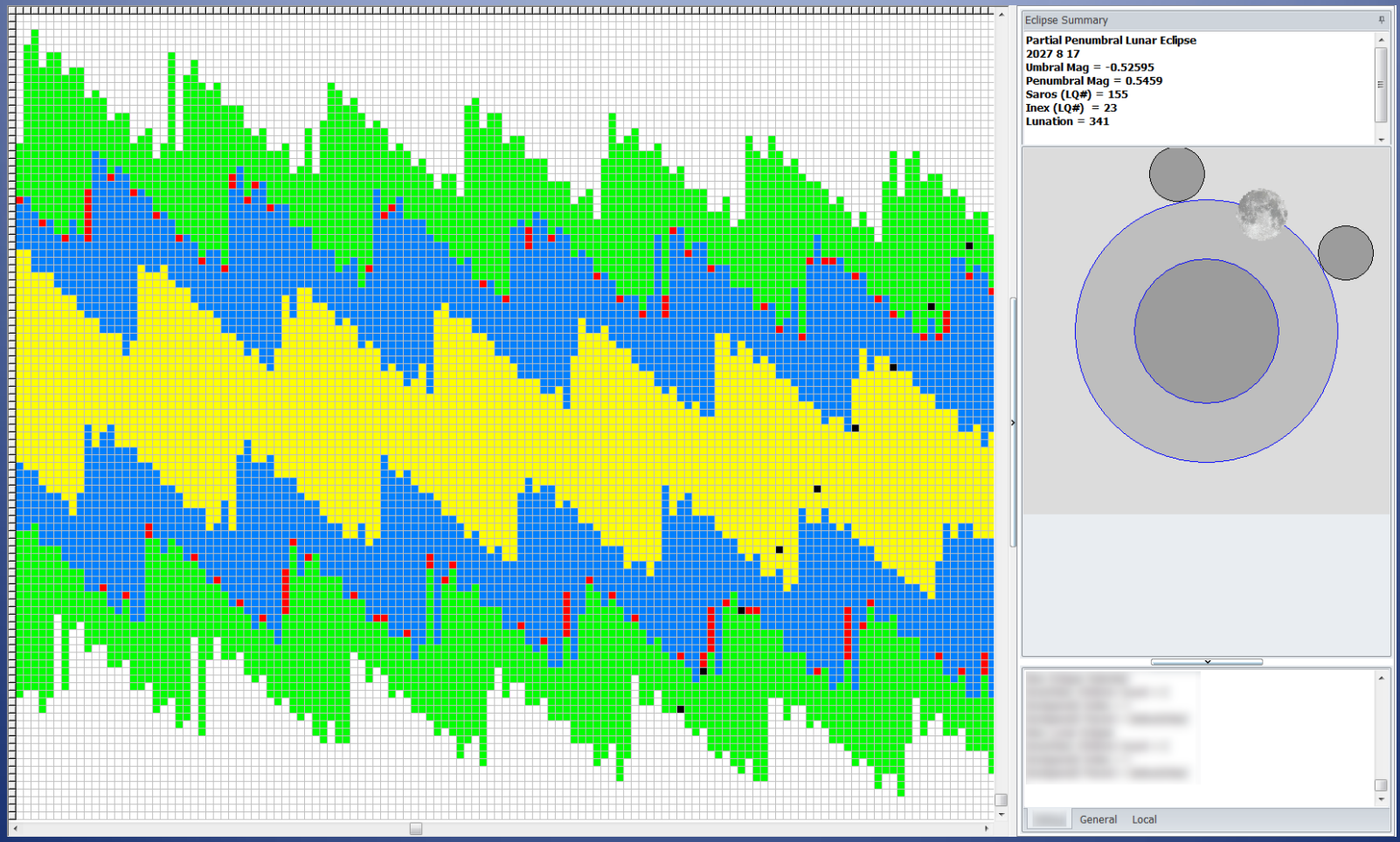
5 lunations later = big jump back down



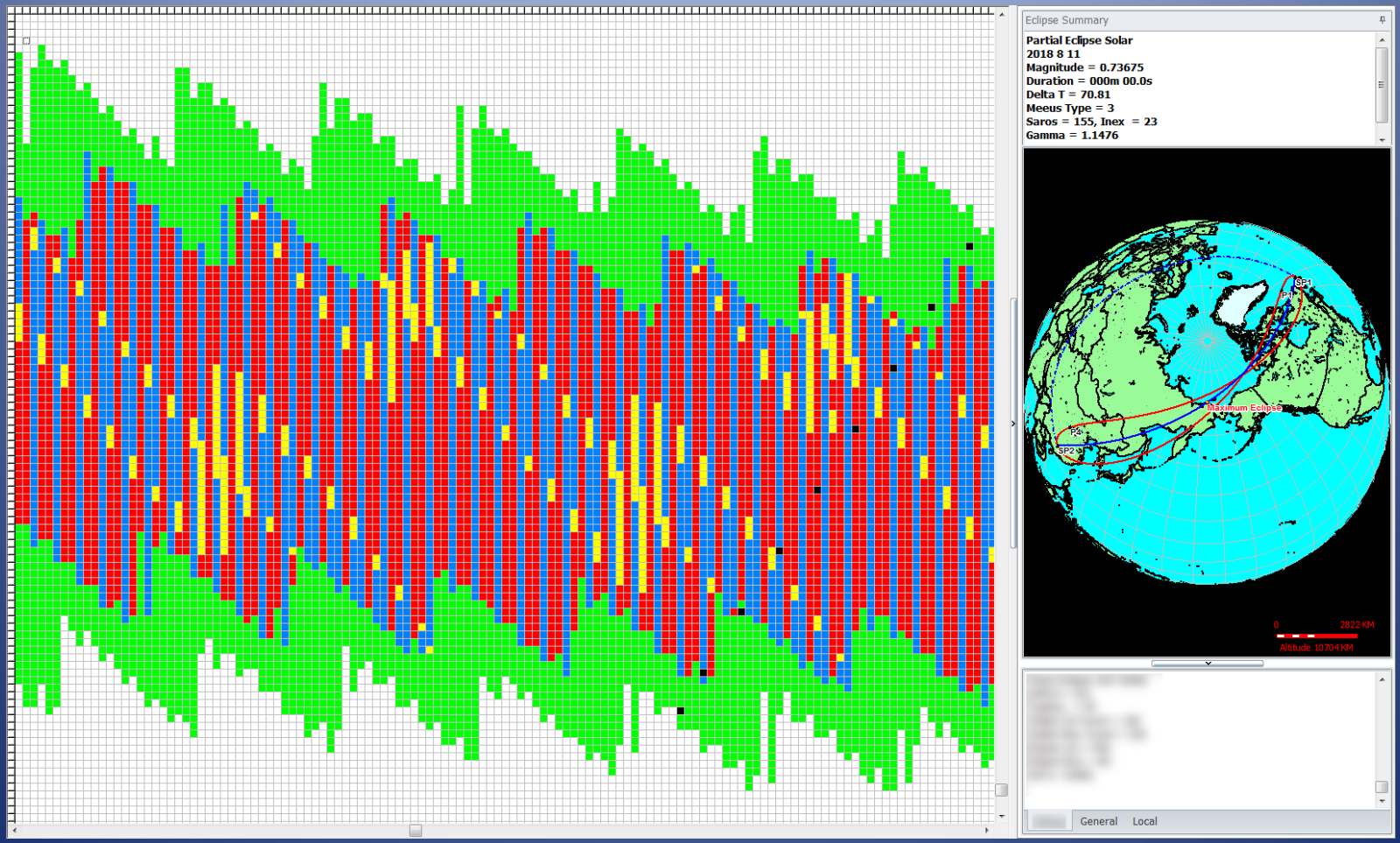
2027 Aug 17th

1 lunation later so really big jump back up

5+1 = 6 lunations after last but one eclipse



The solar-lunar semester fit



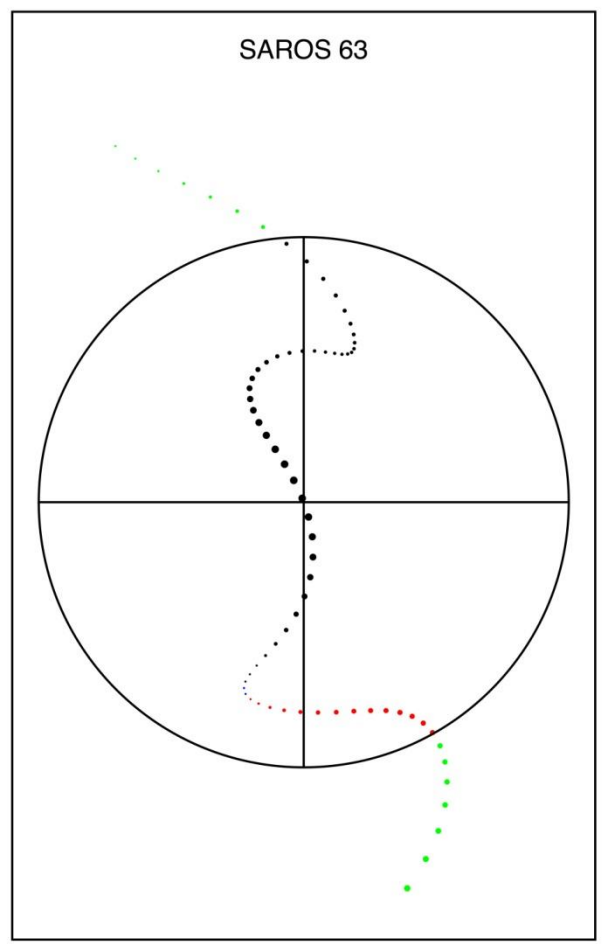
排云楼

Cloud-dispelling Mansion

排雲楼

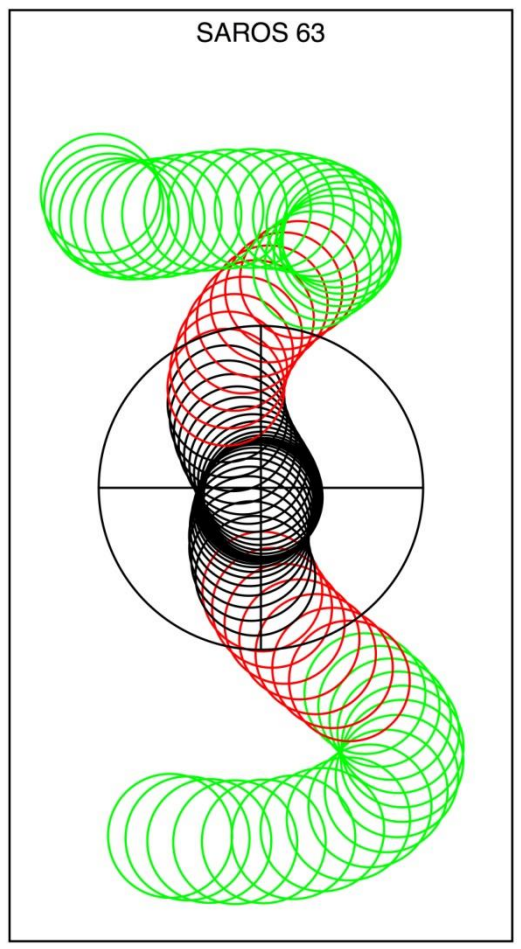
배운루

Leingartner Diagrams - 1



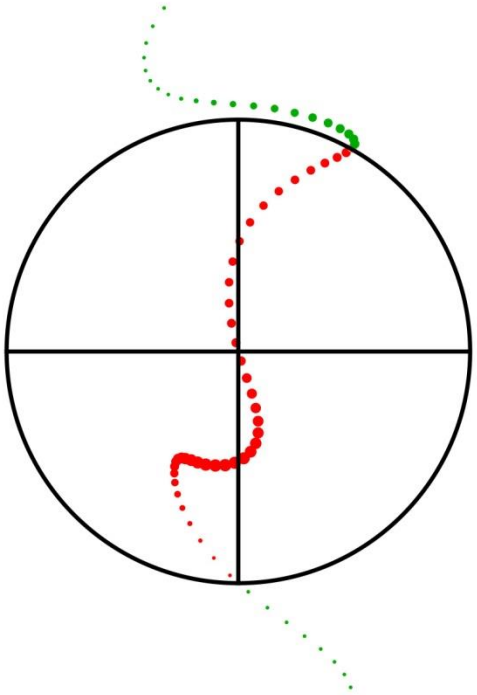
- Morsels 5
- “Saros Portraits”
- All eclipses in a saros
- Solar eclipses - Earth and (ant)umbra shadow for each eclipse at maximum

Leingartner Diagrams - 2

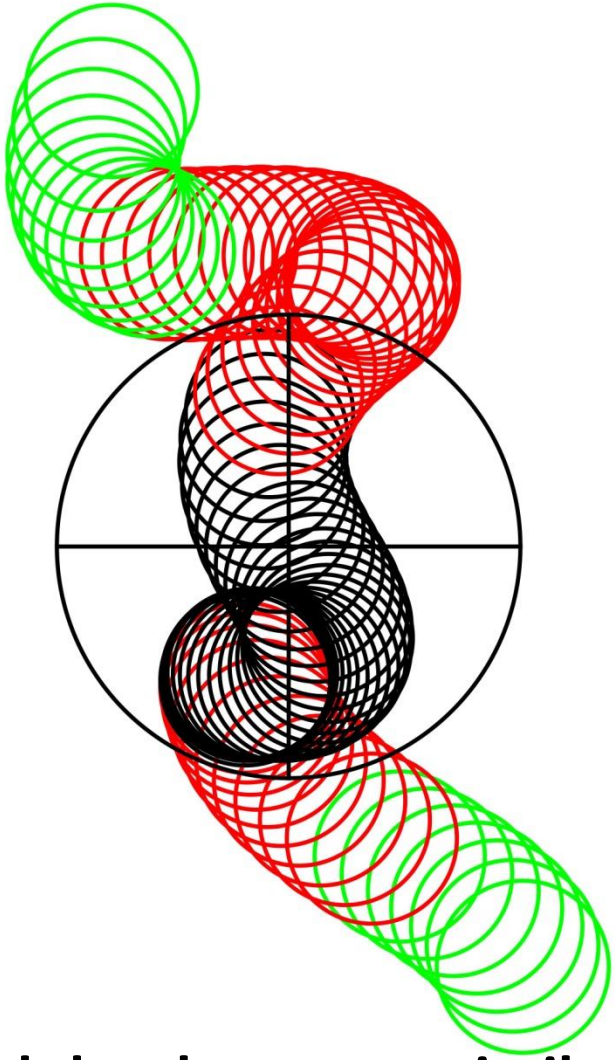


- “Lunar Worms”
- Umbral shadow fixed size
- Change size of the moon

SOLAR SAROS 46



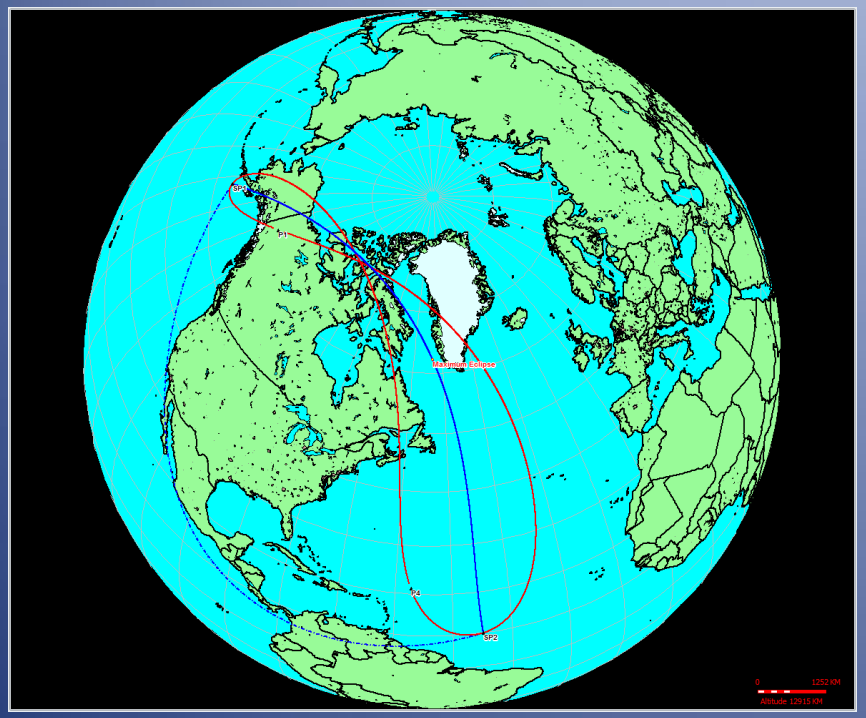
LUNAR SAROS 39

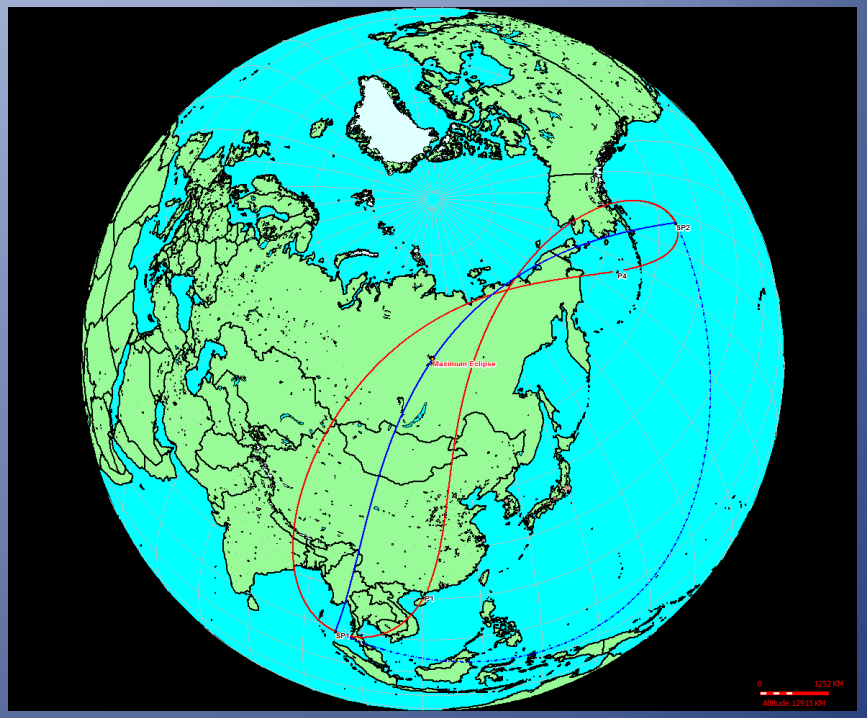


Renumber the lunar saros and the shapes are similar!

Tying up the loose ends

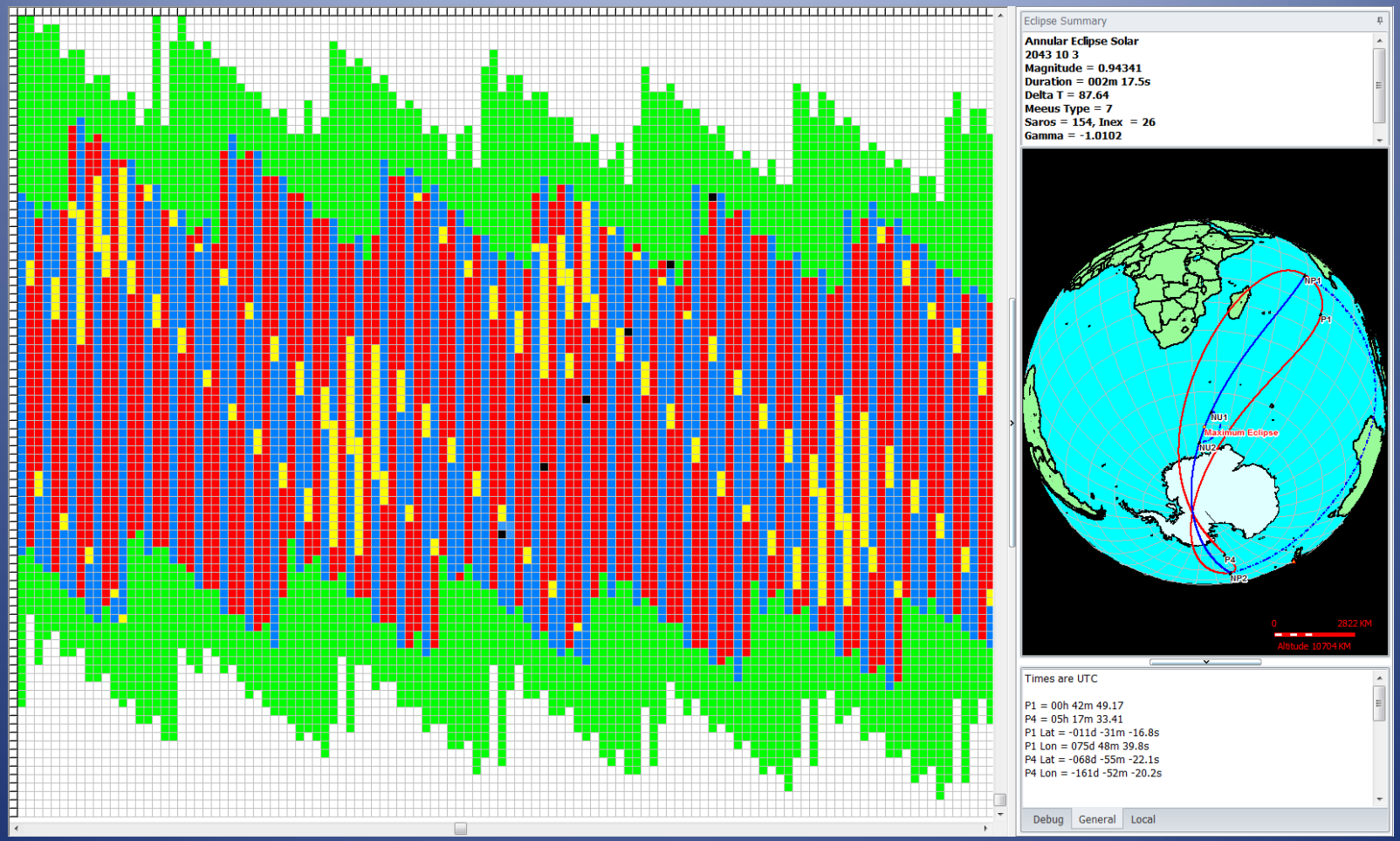
2 Partial eclipses 77 lunations apart





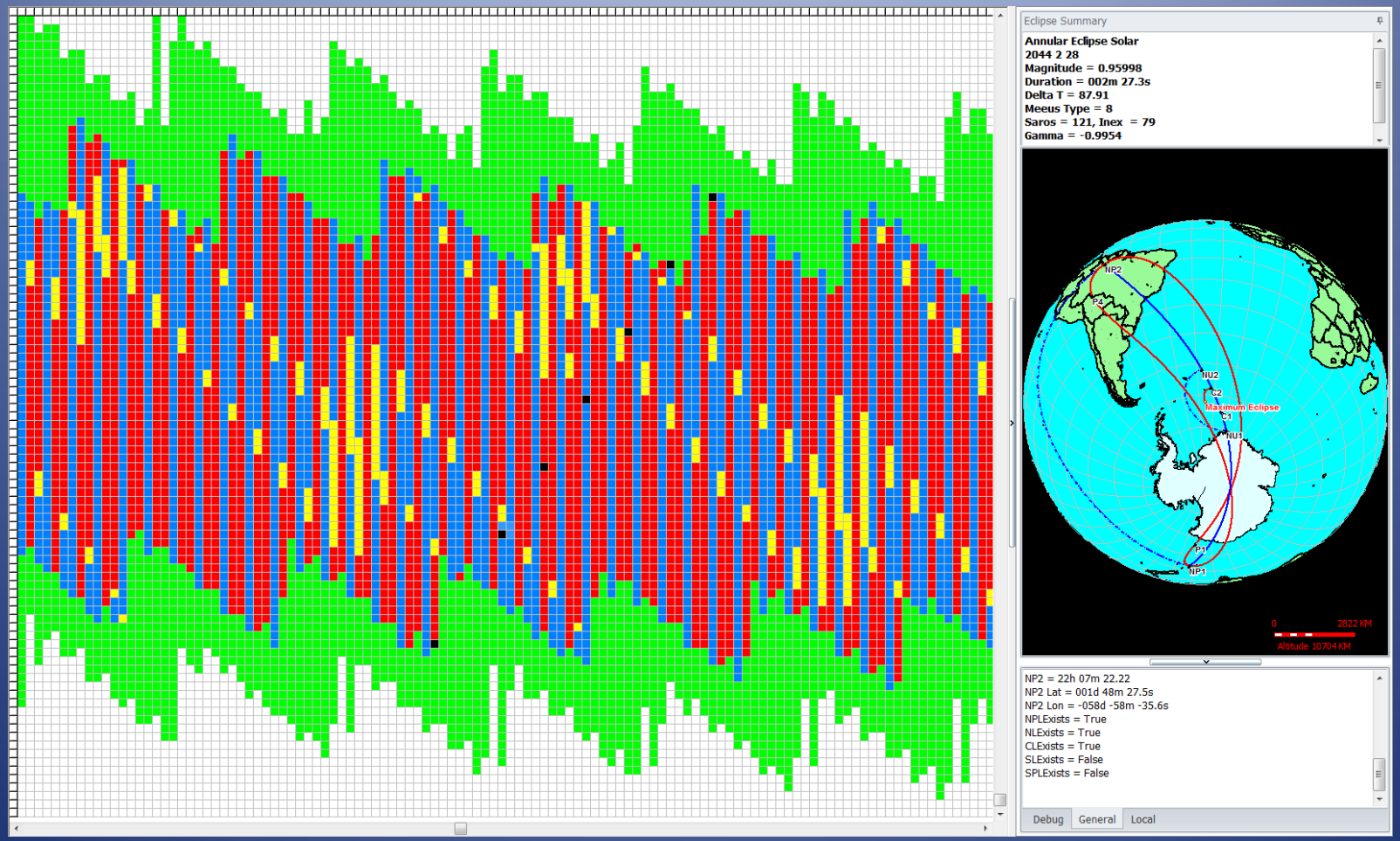
12 consecutive total or annular eclipses
Visualised on the saros-inex panorama

77 lunation Gap



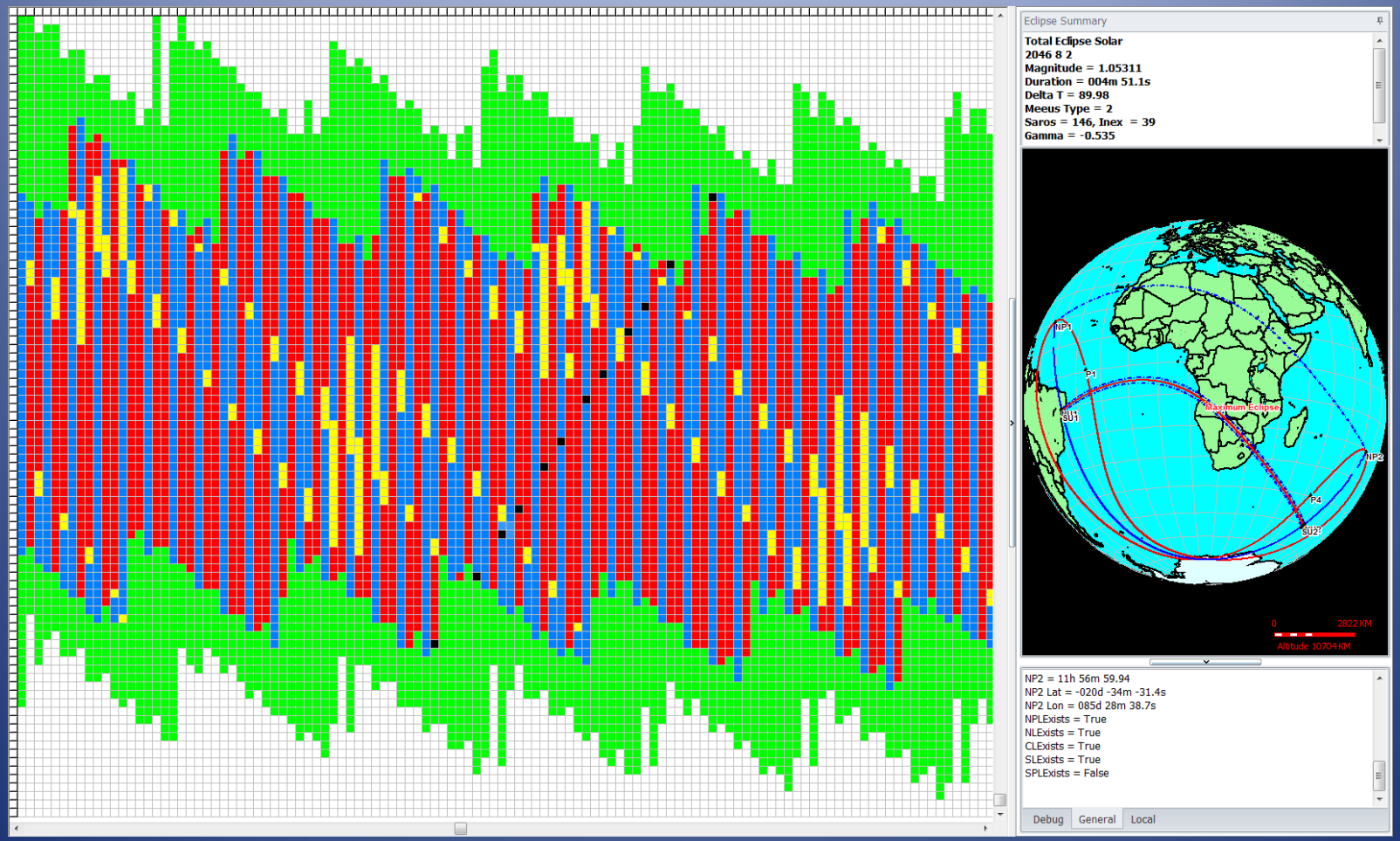
First 6 eclipses are 6 lunations apart – each annular or total

77 lunation Gap – (part 2)



Gap to 7th eclipse is 5 lunations – but this is an annular eclipse!

77 Lunation gap – (part 3)



Next 5 eclipses are 6 lunations apart – each annular or total – so 12 consecutive annular or total eclipses!

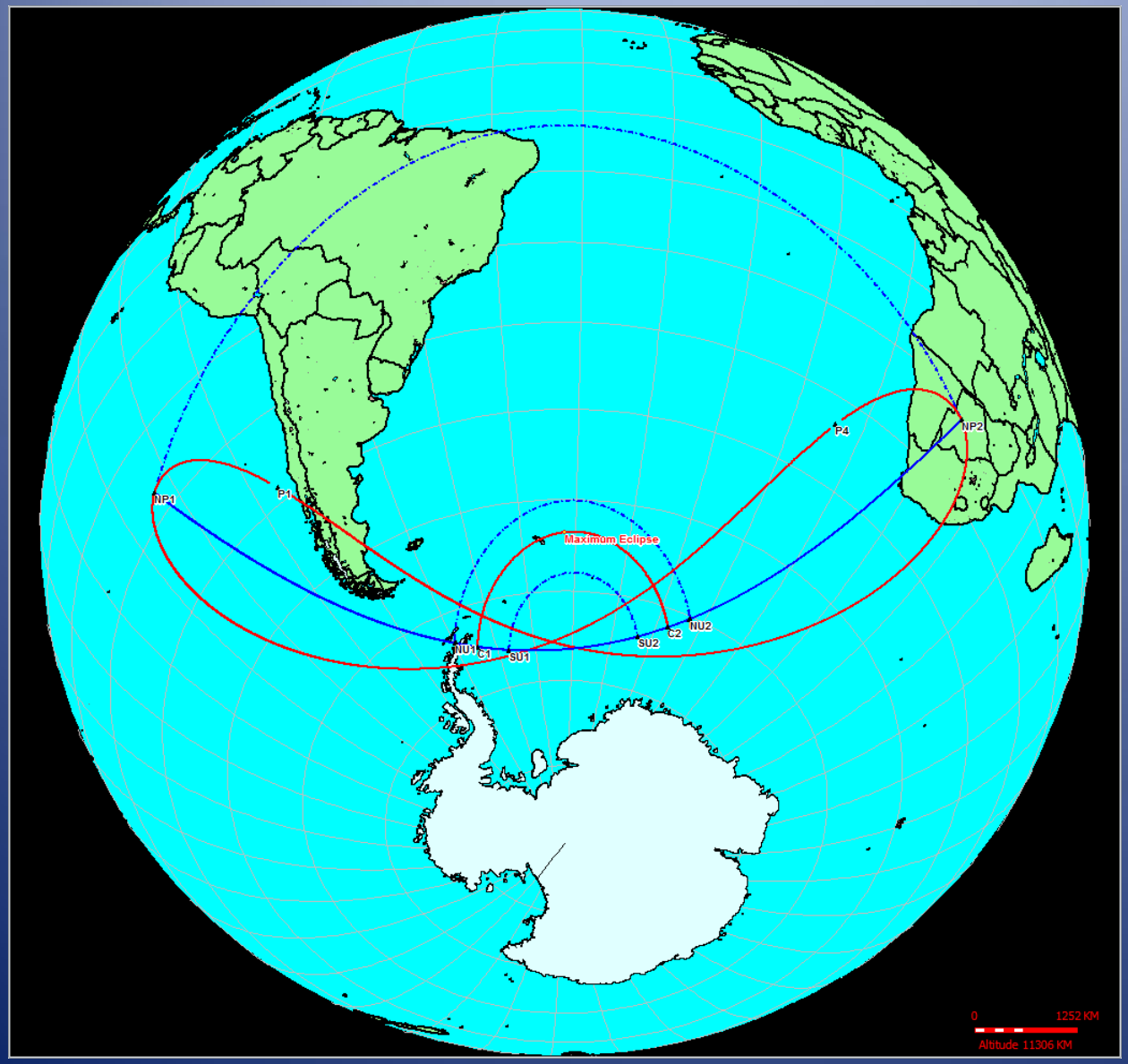
THE ECLIPSE INN

Quiz Question 3

- "Sines, Cosines and Tangents, apparently they were very important" … "most helpful in" … "foretelling eclipses, the arrival of comets and such like. I am very glad there are quite a number of people born with a gift and a liking for all of this" … "I hope the Mathematicians" … "are well rewarded. I promise never to blackleg their profession nor take the bread out of their mouths."

THE ECLIPSE INN

Quiz 1 = Can you see totality in Antarctica at the summer solstice?



Yes, in theory
No in practice
Six days later

Total eclipse
1107 June 22nd

Solstice
1107 June 16th

Quiz 3 = Winston Churchill

- "Sines, Cosines and Tangents, apparently they were very important" … "most helpful in" … "foretelling eclipses, the arrival of comets and such like. I am very glad there are quite a number of people born with a gift and a liking for all of this" … "I hope the Mathematicians" … "are well rewarded. I promise never to blackleg their profession nor take the bread out of their mouths."

More Morsels Summary

- Eclipses by Country – use digital data
  - Maximum eclipse MUST lie on the border
- 5 interesting eclipses
  - Gaps of 5 and 77 lunations
- Visualising the saros
- Panorama patterns for a graphical explanation
  - Semester
  - Renumber the lunar saros and inex
  - Lunation gaps on saros-inex panorama

Credits

- Luca Quaglia
  - 26000 year canon of solar and lunar eclipses
  - The half saros and renumbering the lunar saros and inex
  - Brain-storming eclipses by country
  - Drawing the Leingartner diagrams
  - Drawing the merged saros-inex panorama