

The ERA Software System

Current State and Future Evolution

Alexander Fishkov, Dmitry Pavlov, Vladimir Skripnichenko
Institute of Applied Astronomy RAS, St. Petersburg, Russia
September 25, 2012

ERA: Ephemeris Research in Astronomy

- Domain-specific language for astronomy research (SLON)
- Integrated research environment: editor and interpreter for SLON programs, graphic facilities, table editor

Purpose of ERA

- Building high-precision numerical theories for the Solar system bodies
- Integrating motion of artificial satellites
- Planning of observations
- Handling observations of various types: position, differential, eclipses, occultations, radar ranging, LLR, SLR, pseudorange, VLBI
- Determining Solar system bodies' parameters
- Checking fundamental laws and properties of the Solar system (GRT, dark matter, change of Sun's GM)

SLON Language

- High-level domain-specific language
- Syntax is based on tabular data representation and operations on tables
- Built-in functions specific for astronomical tasks, including transition between various systems of units
- COMPUTE: processing of observations
- INTEGRATOR: integration of equations of celestial bodies' motion, including artificial satellites
- LSM_PROCESSOR: adjustment of parameters (positions, velocities, GM, H_2 , L_2 , J_2 , ...) according to observations

Example SLON Program Calculating O-C for LLR Data

```

CERGA_OBS:=
//      MJD(date),      ns(ox),      n, temperature, pressure,
      humidity /
48014.9163433835, 2586420840.9, 3, 9.6, 878.8, 51 /
48014.9262619339, 2588145757.7, 2, 9.6, 878.8, 50 /
48014.9380046322, 2589568201.7, 1, 9.3, 878.6, 50 /
48014.9470781790, 2591502684.0, 3, 9.3, 878.9, 50 /
48015.8382263697, 2606847473.3, 3, 9.8, 877.4, 56 /
48015.8494555286, 2607316228.0, 3, 9.7, 877.7, 57 /
48015.9370889514, 2615764309.2, 3, 8.1, 877.8, 57 /
48015.9491738546, 2617778243.2, 2, 6.8, 877.8, 62 /
48015.9607339585, 2619156036.7, 1, 6.4, 877.8, 62 /
48015.9704106084, 2620949375.6, 3, 6.7, 877.8, 61 /
48016.7712795796, 2634963306.3, 3, 8.0, 876.4, 81 /
48016.9046854400, 2634692546.1, 3, 8.1, 877.2, 69 /
48016.9295293076, 2636854822.2, 3, 7.3, 876.9, 74 /
48016.9476216852, 2638837702.1, 3, 6.9, 876.9, 76 /
48016.9719318688, 2642004647.4, 3, 7.0, 876.8, 75 //
;
landers:=
//  m(x_crate),  m(y_crate),  m(z_crate), name  /
1591955.009, 690724.783, 21005.565, "Apollo 11" /
1652697.450, -520971.303, -109728.567, "Apollo 14" /
1554675.251, 98120.156, 765006.673, "Apollo 15" /
1339349.119, 801893.116, 756359.883, "Lunokhod" //;
stations:=
//  m(px),      m(py),      dms(longitude) , name[1] /
5492414.217, 3235697.634, 2555840.811, "McDonald" /
5492037.504, 3236146.710, 2555902.837, "MLRS" /
4615328.512, 4389354.757, 65517.643, "Cerga" /
5971470.771, 2242197.461, 2034438.747, "Haleakala" /
5491888.225, 3236481.722, 2555905.294, "MLRS 1" //;

```

```

:= ( //x_crate, y_crate, z_crate, px, py, longitude,
      observation, o_cx, ranging_info, object, object_info/
      -, -, -, -, -, -, -, ranging, *, emitting, Moon, rectangular // *
//date, ox, n, j, k, l, name[0:1] /
      -, -, -, -, -, -, -, - // *
//wave_length, temperature, pressure, humidity/
      m(0.532e-06), -, -, -// )
begin
  writeln("Lunar ranging, residuals, station CERGA")
  writeln("Calendar Date ":16, " O-C (nsec)", " Reflector")
  l=table_size("CERGA_OBS")
  k=0
  repeat
    k=k+1

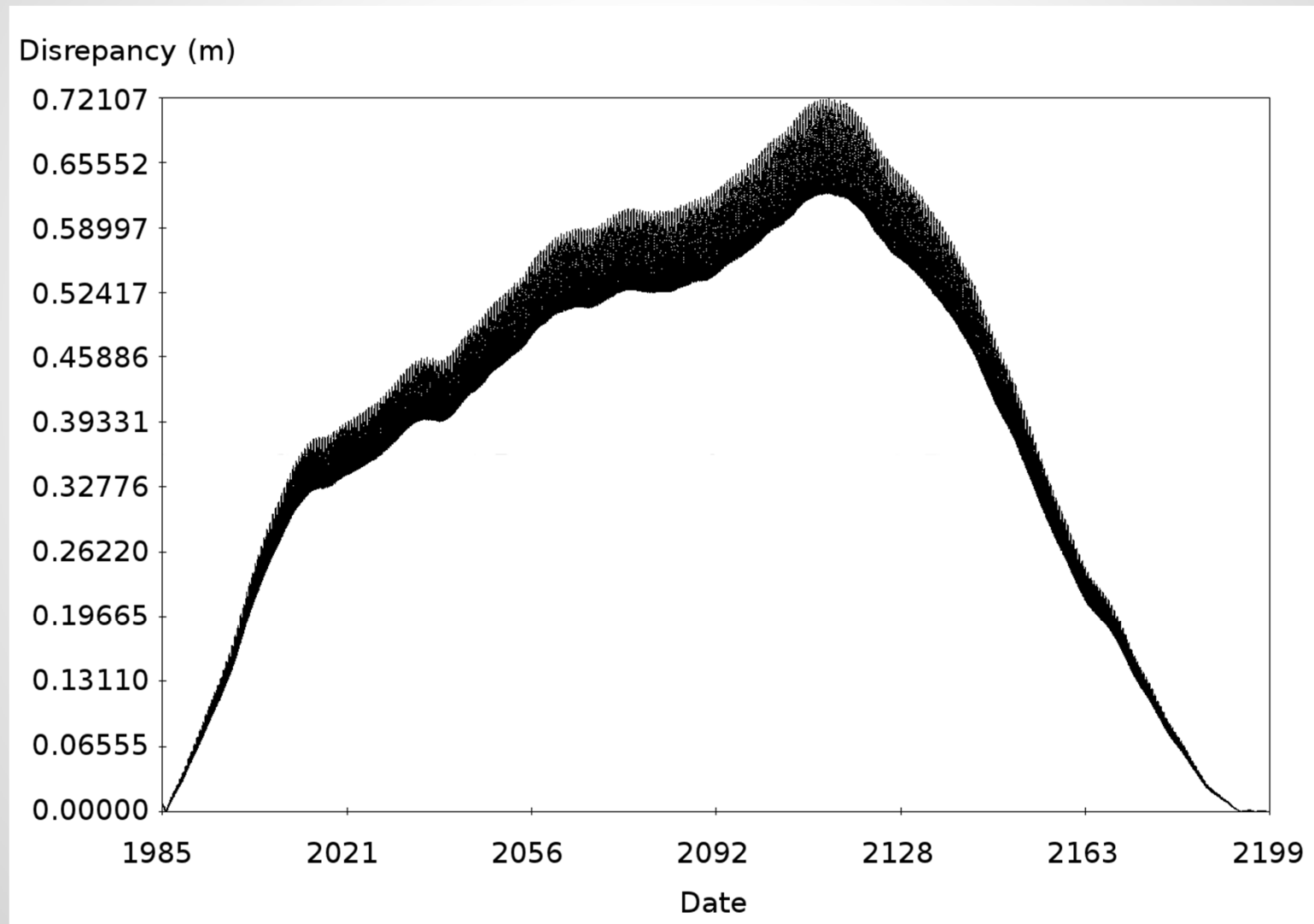
read_table("CERGA_OBS",k,date,o_x,n,temperature,pressure,humidity)
  read_table("landers" ,n, x_crate,y_crate,z_crate,name)
  read_table("stations",3,px, py, longitude ,name[1])
  o_cx=*
  compute
  writeln(date:calend:16:6, o_cx:ns:7:2, name:17)
  until k=l
end.

```

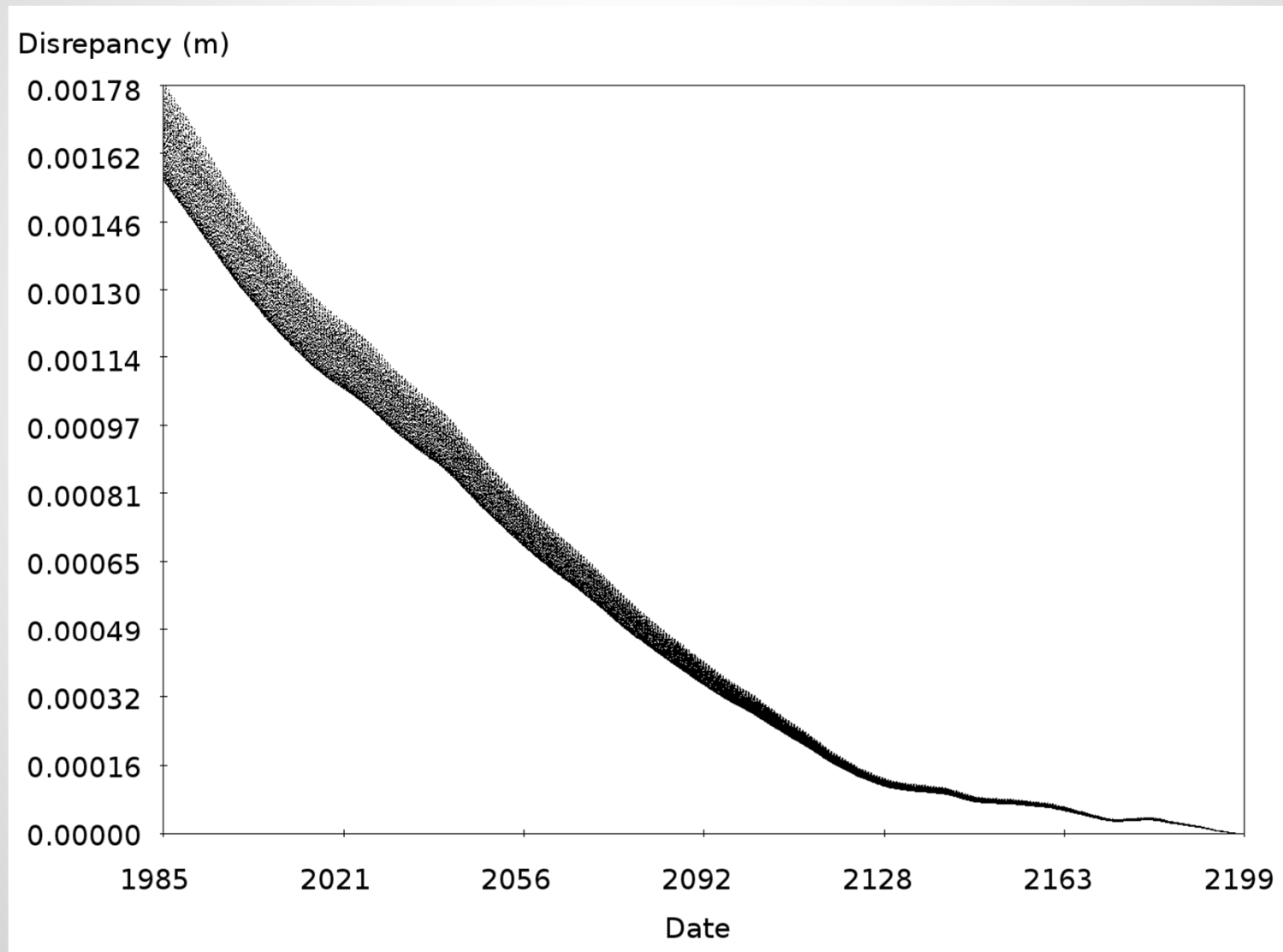
Recent Improvements of ERA

- Unified access to all major ephemeris: EPM (IAA), DE (JPL), and INPOP (IMCCE)
- Numerical integrator floating-point precision extended from 64-bit to 80-bit

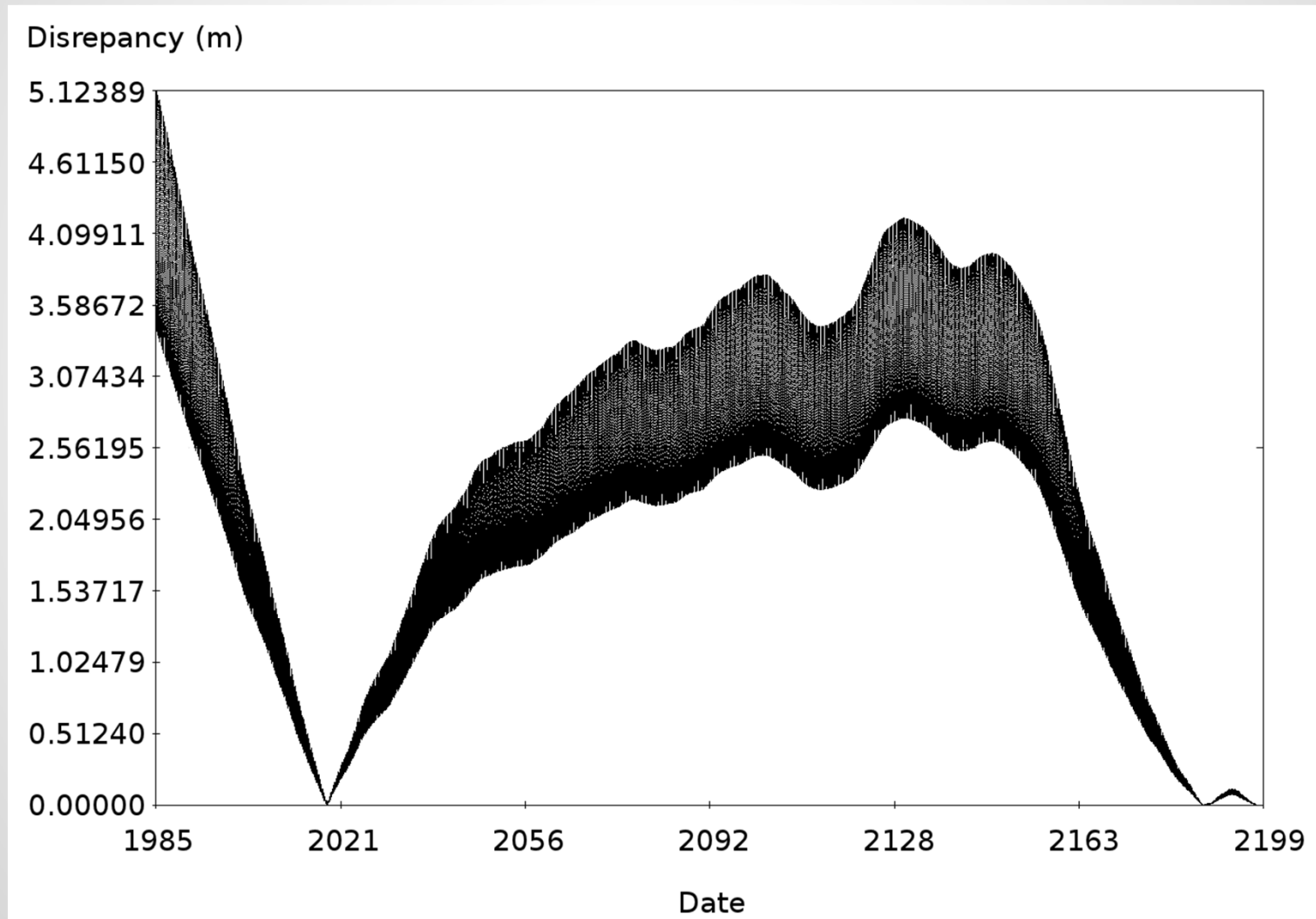
Forward-Backward Integration (Moon, old integrator)



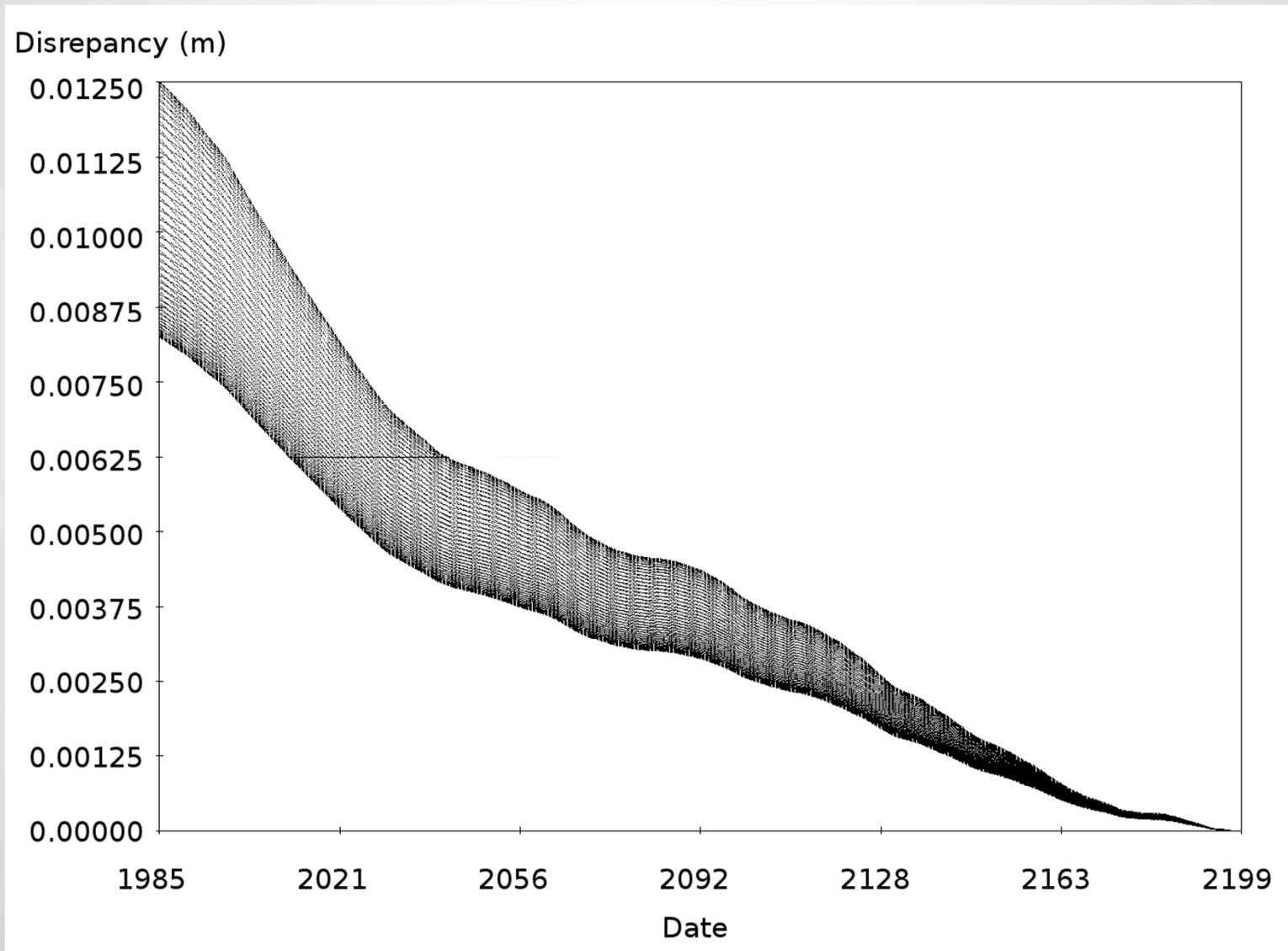
Forward-Backward Integration (Moon, new integrator)



Forward-Backward Integration (Mercury, old integrator)



Forward-Backward Integration (Mercury, new integrator)



New Version of ERA (ERA 8)

- Completely rewritten from Delphi to: C for intensive calculations, Racket for logic and SLON language parser/compiler
- Portable across Windows/Linux, 32- and 64-bit
- Better diagnostics and debugging facilities
- Delivered with detailed mathematical description of the calculations
- Has support for international PCK/SPK ephemeris file format
- Under active development for one year now

Long-term Plan for ERA Development

- Automatic cross-compilation to bring ERA knowledge base to web applications, mobile devices, and high-performance clusters
- Web access to ERA + EPM ephemeris
- Improvement of SLON language to easier processing of observations, particularly LLR, ranging, and VLBI
- Allow easy extensibility for users