Updates to the MSFC Meteoroid Stream Model

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ABSTRACT The Marshall Space Flight Center (MSFC) Meteoroid Stream Model simulates particle ejection and subsequent evolution from comets in order to provide meteor shower forecasts to spacecraft operators for hazard mitigation and planning purposes. The model, previously detailed in Moser & Cooke (2004), has recently been updated; the changes include the implementation of the RADAU integrator, an improved planetary treatment, and the inclusion of general relativistic effects in the force function. The results of these updates are investigated with respect to various meteoroid streams and the outcome presented.

1. BACKGROUND

What Model of particle ejection and subsequent evolution from comets known for producing meteor showers at Earth.

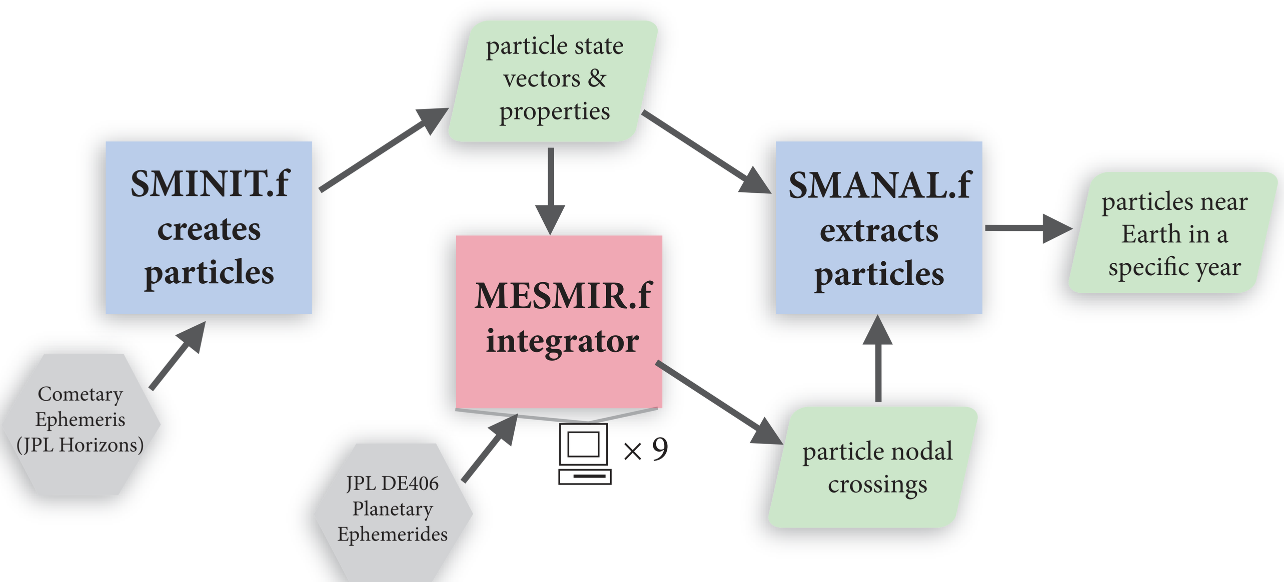
Why To provide accurate meteor shower forecasts to spacecraft operators for hazard mitigation and mission planning purposes.

How Using cometary ephemerides, ejection is simulated in 1 hour time steps while the comet is within 2.5 AU of the Sun. A variable step integrator is used to integrate particle position and velocity forward in time. Nodal crossing times are recorded, as are various other parameters for particles approaching Earth during specified time periods.

Immediate Aim To investigate the effect recent updates to the model have on various Leonid and Perseid streams (in regards to peak time and duration); to show the results of modeling the Draconids and Aurigids with the MSFC model for the first time.

2. MODEL

2.1 Overview



SMINIT.f
* Generates particle state vectors for each line in the cometary ephemeris
* Particles ejected with velocity as Jones & Brown (1996): $V_{inf} = 41.7\ (\sin(0.5\ a))^{0.37} (\cos z)^{0.519} R_c^{0.5}\ m^{-1/6}\ r^{-1/3}\ r^{-1.038}$
* Physical properties determined from uniform, random draw on log β and assumed density
  * mass: ~1μg –1kg, radii: ~50μm –5cm

SMANAL.f
* Extracts particles within a given distance of Earth over a specified time period
* Computes node-Earth distance for ea. particle
* Computes an Impact Parameter (IP) for each particle: $IP = (R_E+h_{atmos})/D$, where D is the Earth-particle distance at nodal crossing; it is scaled to 1 at the top of the atmosphere.

MESMIR.f
* Updated! See below.

2.2 MESMIR Updates

Previous Version	Current Version
* RK4 integrator	* RADAU15 integrator
* Mercury included in mass of the Sun	* Mercury resolved as separate body
* Looked at perturbations from Earth-Moon barycenter	* Perturbations from Earth and Moon treated separately
* Effects from 7 planets; Pluto not counted	* Effects from 8 planets; Pluto counted
* Interpolated planet position (with a cubic spline) from a look-up table of planetary positions given every day from 1000 to 2150 CE	* Interpolates planet position (with Chebychev polynomials) from binary files & subroutines from JPL Horizons from 3000 BCE to 3000 CE
* Only had 1 PR drag term; had a units mismatch	* Two PR drag terms; mismatch corrected
* No general relativistic correction in force function	* General relativistic correction included in force function

2.3 Model Inputs

LEONIDS
Comet: Tempel-Tuttle
Ejection power law: $r^{-5.0}$
Cap angle: 30°
Epochs: 1001(30) – 1965(1)
No. particles/epoch: 300,000

PERSEIDS
Comet: Swift-Tuttle
Ejection power law: $r^{-6.0}$
Cap angle: 60°
Epochs: 826(9) – 1862(1)
No. particles/epoch: 600,000

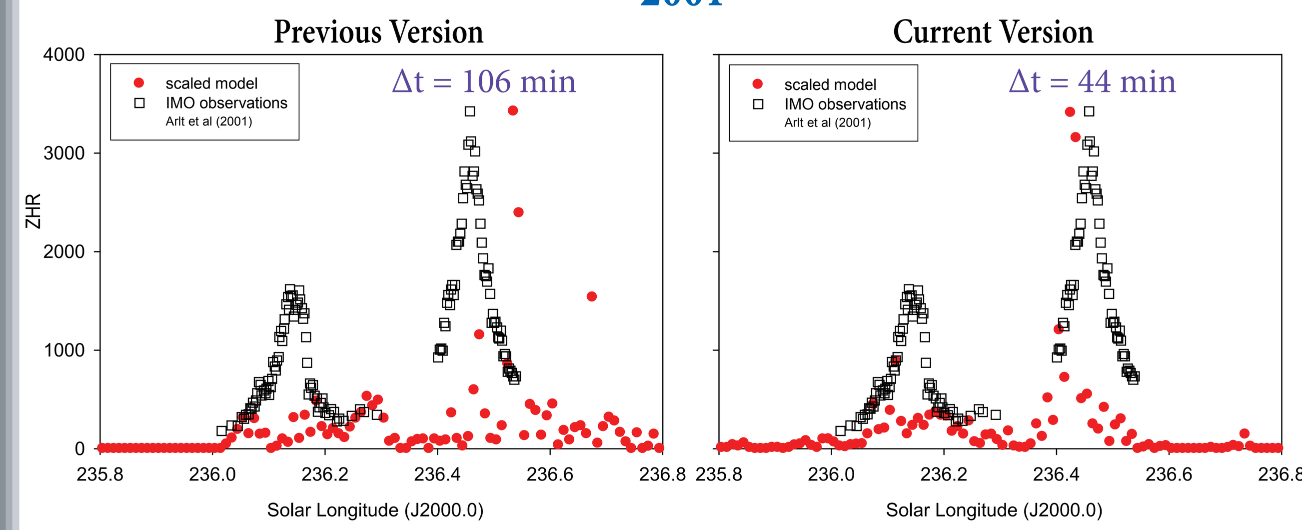
DRACONIDS
Comet: Giacobini-Zinner
Ejection power law: $r^{-0.6}$
Cap angle: 30°
Epochs: 1824(28) – 2012(0)
No. particles/epoch: 300,000

AURIGIDS
Comet: Kiess
Ejection power law: $r^{-3.0}$
Cap angle: 60°
Epochs: 71 BCE (1)
No. particles/epoch: 550,000

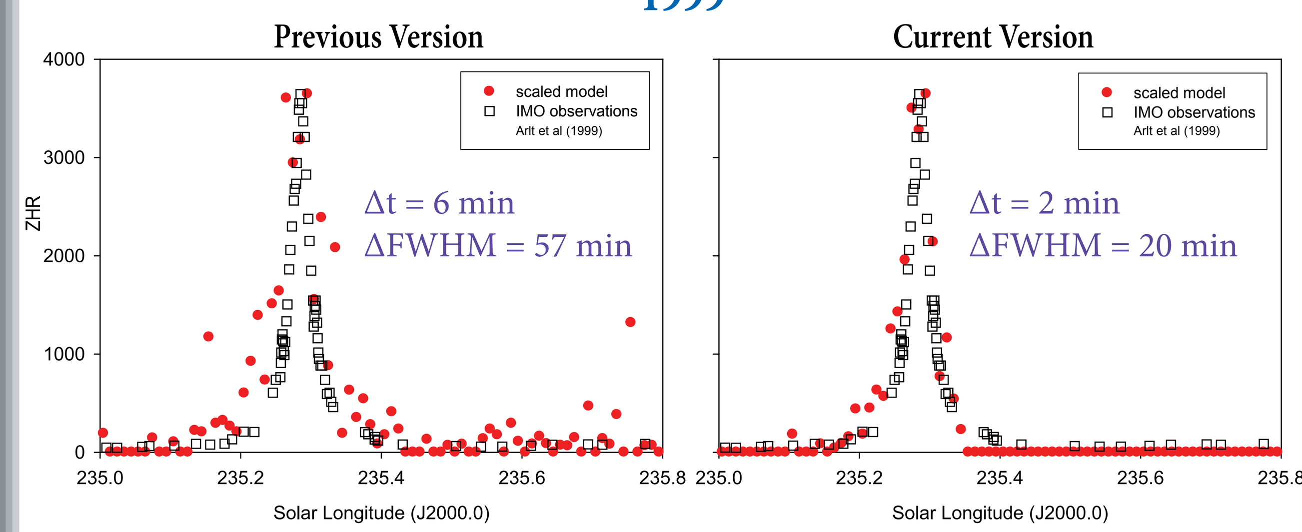
3. RESULTS

3.1 Leonid Examples

2001



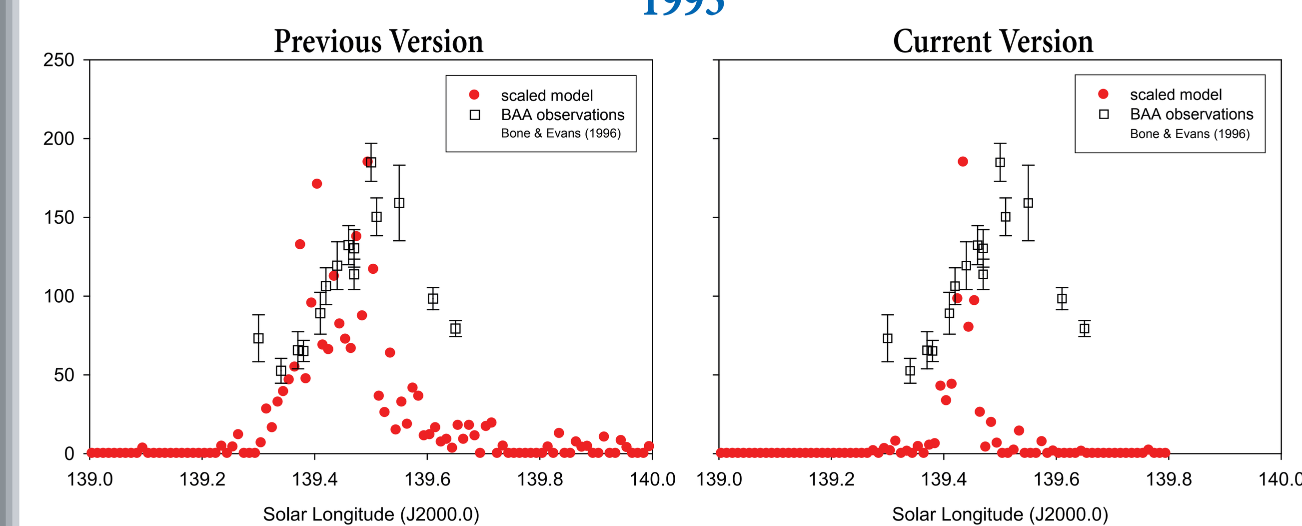
1999



The model update improved the peak prediction time for the 2001 and 1999 Leonids. It has also improved the predicted duration of the 1999 Leonid storm.

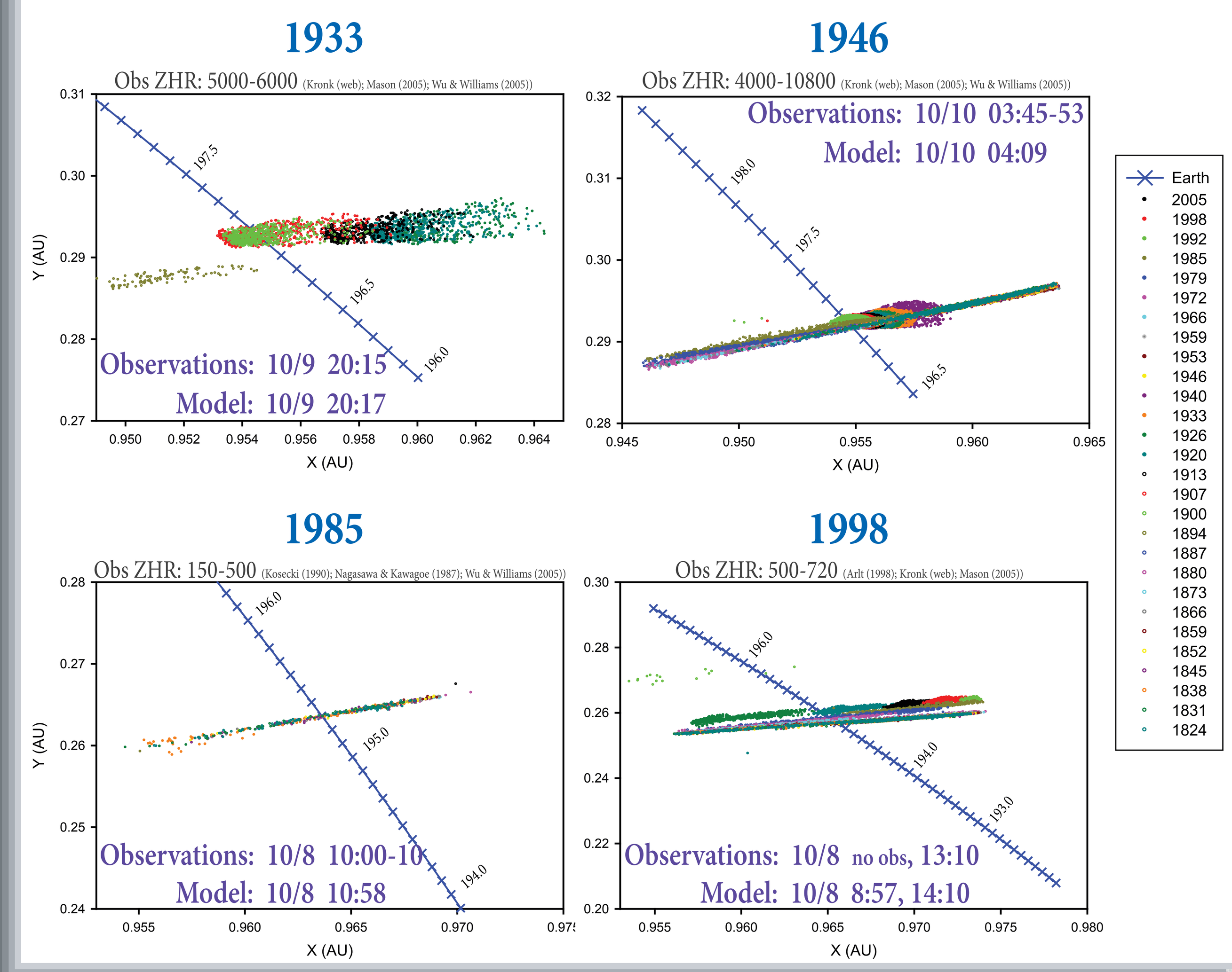
3.2 Perseid Example

1993

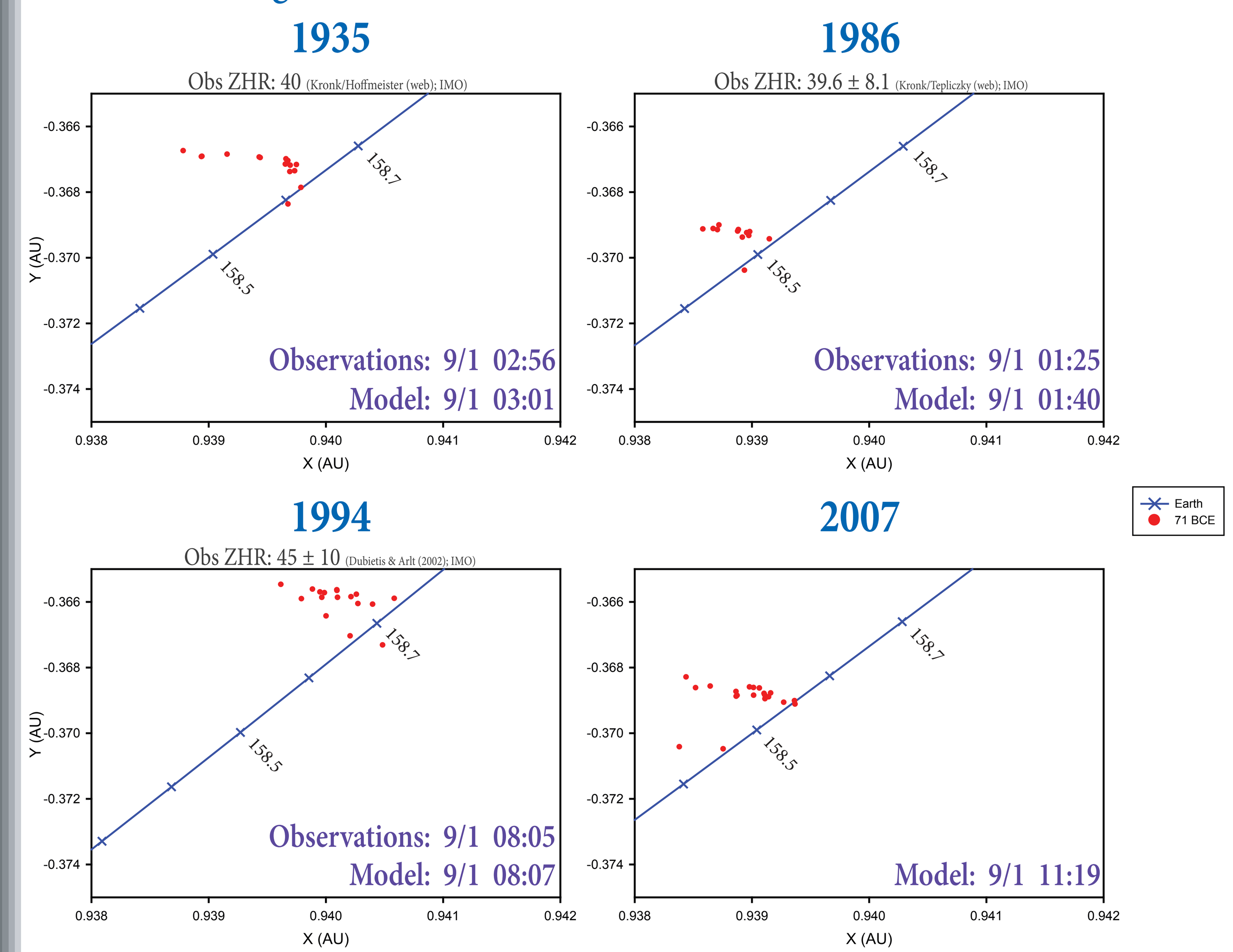


The model update does not improve peak prediction time for every stream. In this example, the 1993 Perseids are better constrained by the previous version of the model -- both in peak time and duration. Note that 2.7M more particles were ejected in the previous version; this could account for the difference.

3.3 Past Draconid Storms/Outbursts



3.4 Aurigids



4. SUMMARY

Updates to the MSFC Meteoroid Stream Model better constrain the peak time and duration of the Leonid meteor showers. Improvements to the recent Perseid outbursts were not seen. The MSFC model was put to the task of modeling both the Draconids and Aurigids for the first time this year. The Draconid outburst/storm peak predictions were surprisingly good, even though the IP approach for Giacobini-Zinner is not thought to be valid. There was some concern about the Aurigids this year, but according to the model, the 2007 Aurigids will be on par with showers seen in 1935, 1986, and 1994: ZHR in the 40-50s (no storm).

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