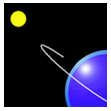
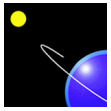


Overview of HASDM and JB2008

W. Kent Tobiska



Basis for HASDM

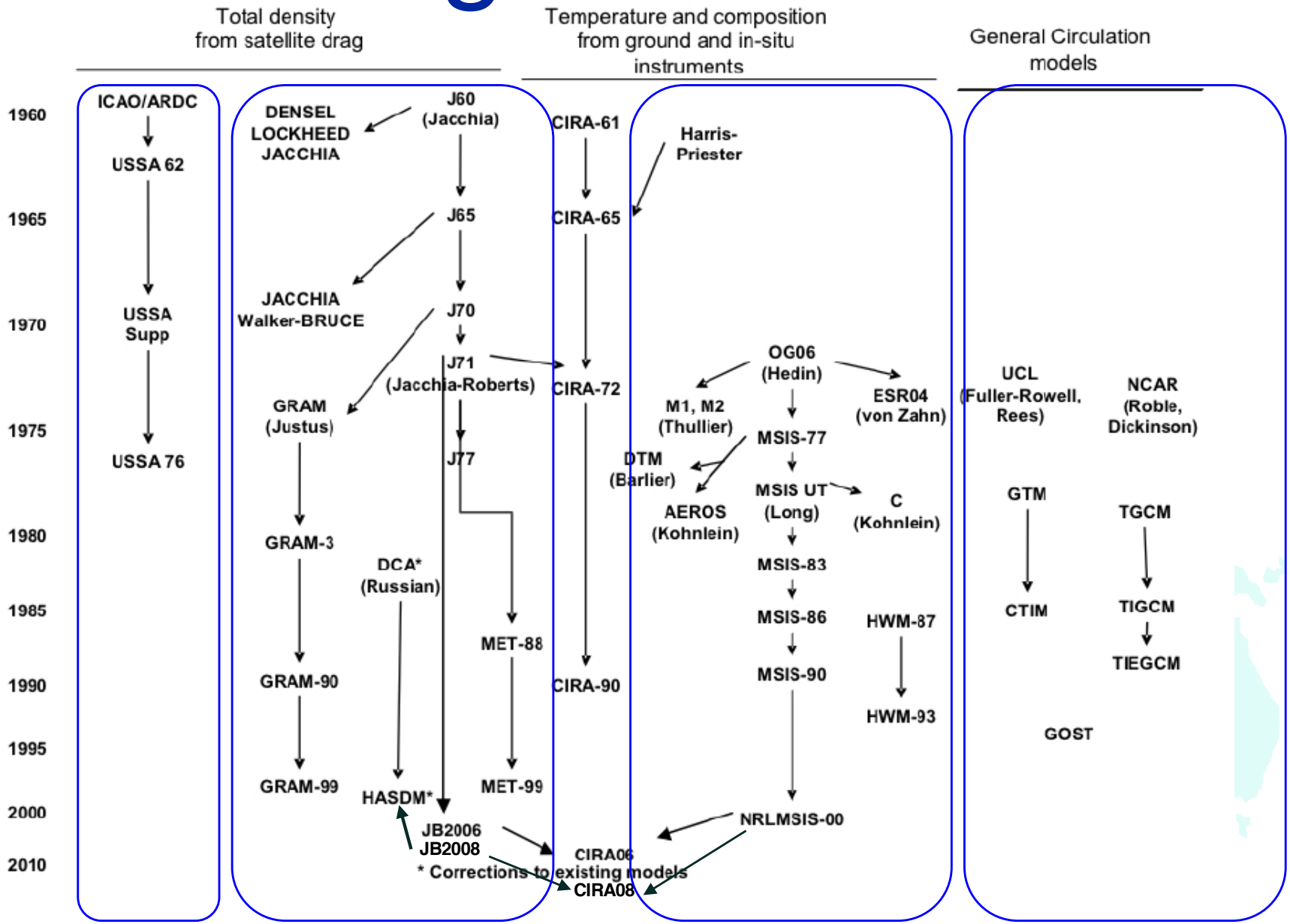
High Accuracy Satellite Drag Model (HASDM)

HASDM is a system run at USAF Space Command CSpOC (VAFB)

- HASDM V1 – 2001 to 2011 used J71 with F10 and Ap for -48 hours to +72 hours
- HASDM V2 – 2012 to present uses version of JB2008 with S10, M10, Y10, F10, Ap, and Dst (SET provided) for -48 hours to +144 hours
- 3 conceptual modules in HASDM
  - **JB2008** core (called JBH09) providing current epoch and forecasts to 72 hours
  - **Space Surveillance Network** (SSN) observations of ~90 calibration satellites
  - **Dynamic Calibration of the Atmosphere** (DCA) code acting as a data assimilation Kalman filtering method to incorporate derived densities from observations into modeled background
- HASDM provides thermospheric densities used for creating NORAD TLE catalog and for assessing debris/active satellite conjunctions

Credit: Tobiska

Pedigree of models



Jacchia 1971 (CIRA 1972)

Basis for MET v2, HASDM, JB2006, JB2008

- All 4 have been modified from the original Jacchia version

Provides modeled densities

- Between 25-75 km
- Between 75-120 km
- Above 120 km
- Mean reference atmosphere

Computer source code available

Credit: Tobiska

Jacchia 1971 (CIRA 1972)

Main elements of Jacchia model

Thermospheric and exospheric temperatures are

$$T(z) = T_\infty - (T_\infty - T_0)e^{-\sigma(z-z_0)} \qquad \textbf{(4-29)}$$

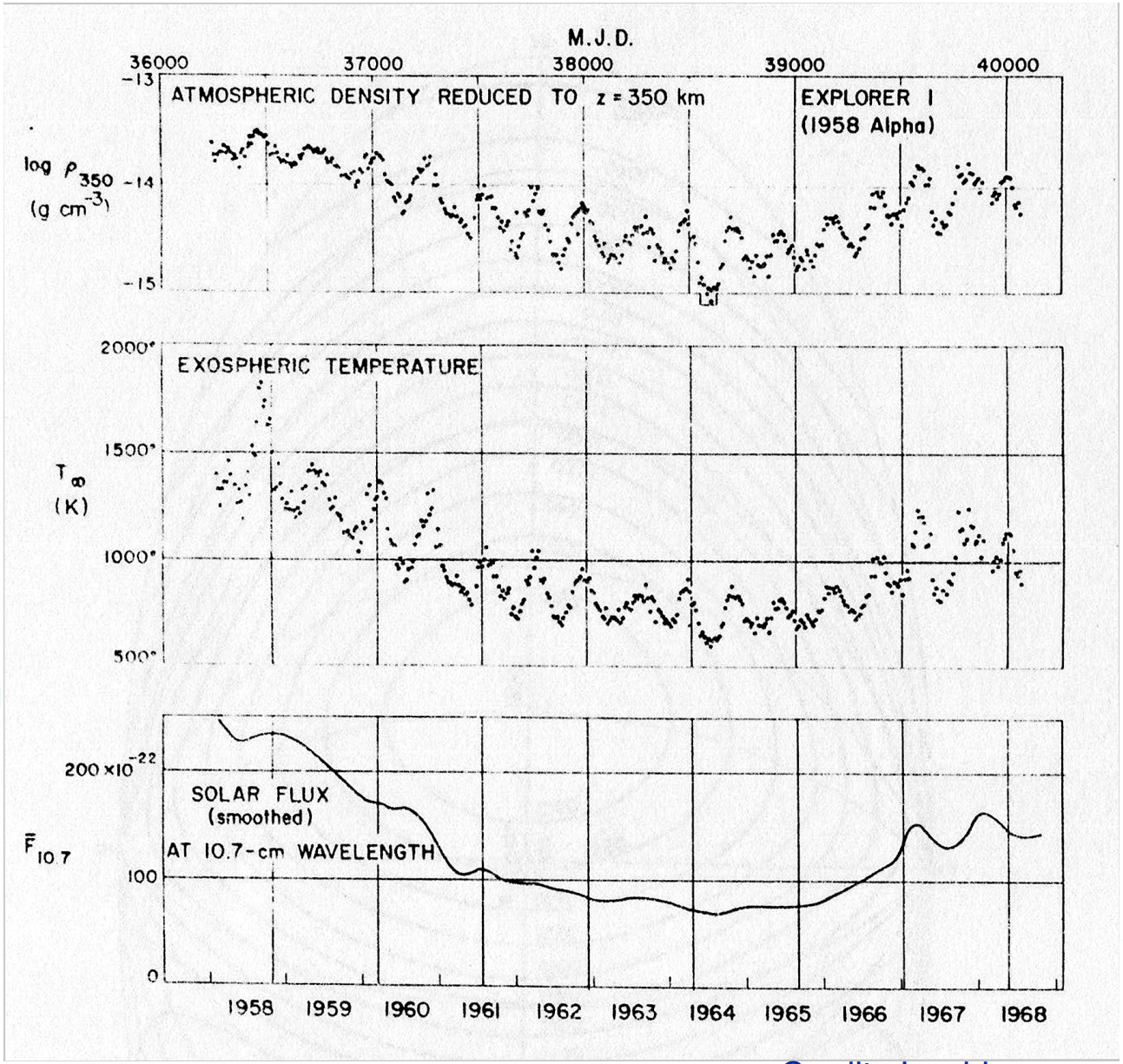
$$T_\infty = 379 + 3.24\overline{F_{10.7}} + 1.3(F_{10.7} - \overline{F_{10.7}}) \qquad \textbf{(4-31)}$$

Diffusive equilibrium composition (N_2, O, O_2, Ar, He)

Variations (solar cycle, diurnal, geomagnetic, semi-annual, seasonal latitudinal in lower thermosphere, seasonal latitudinal with He, gravity waves)

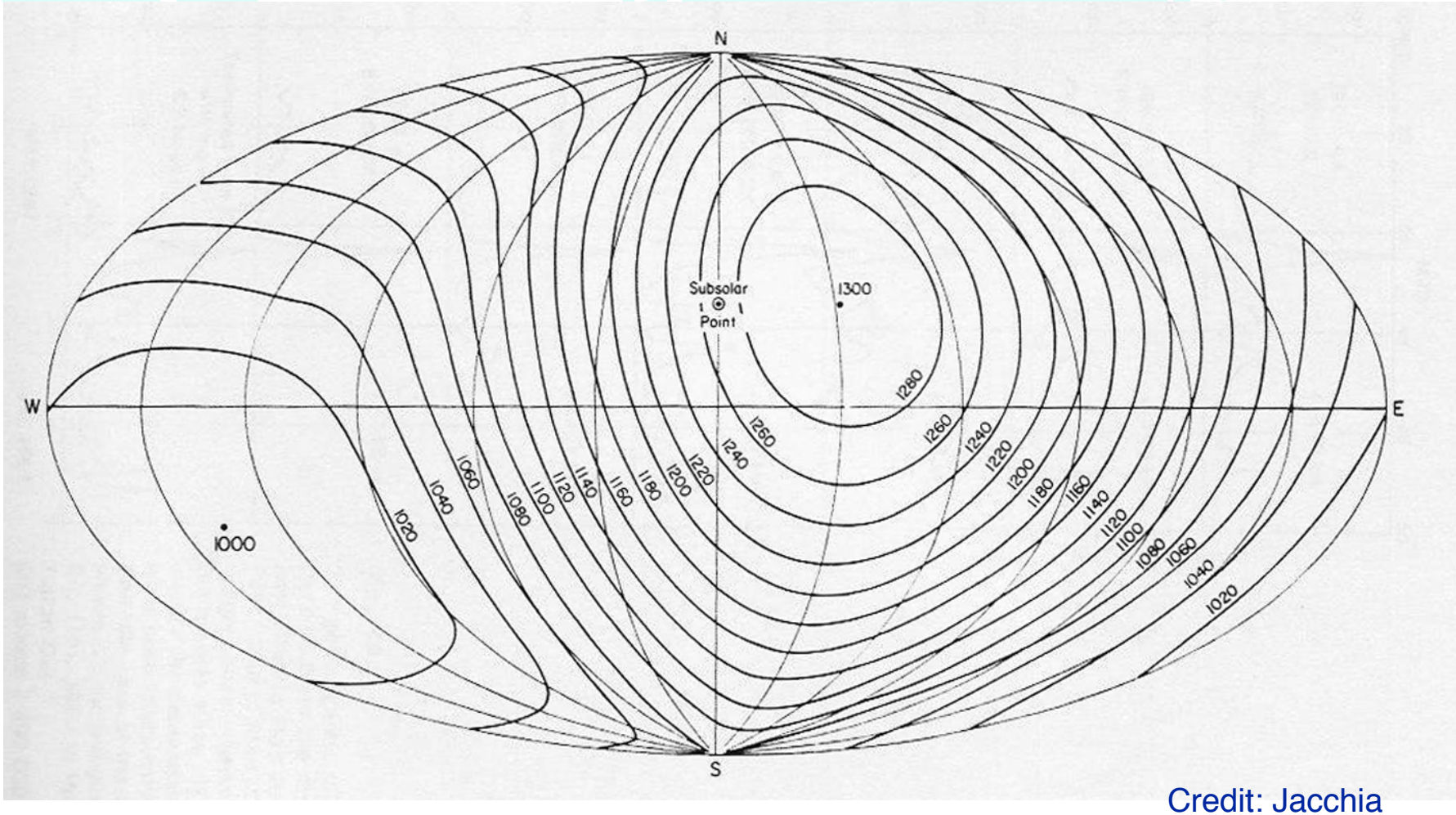
Credit: Tobiska

Jacchia 1971 (CIRA 1972)



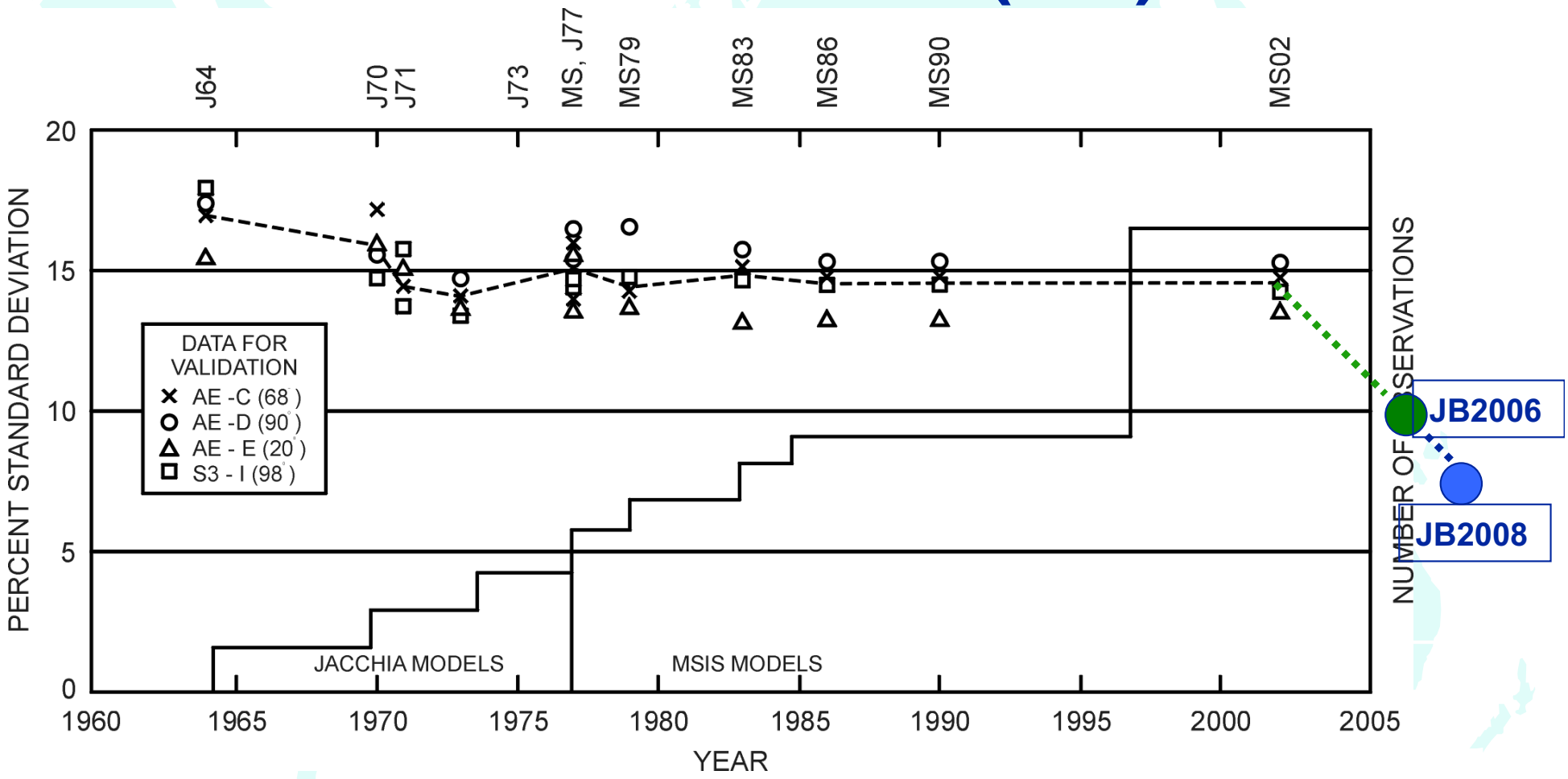
Credit: Jacchia

Jacchia 1971 (CIRA 1972)



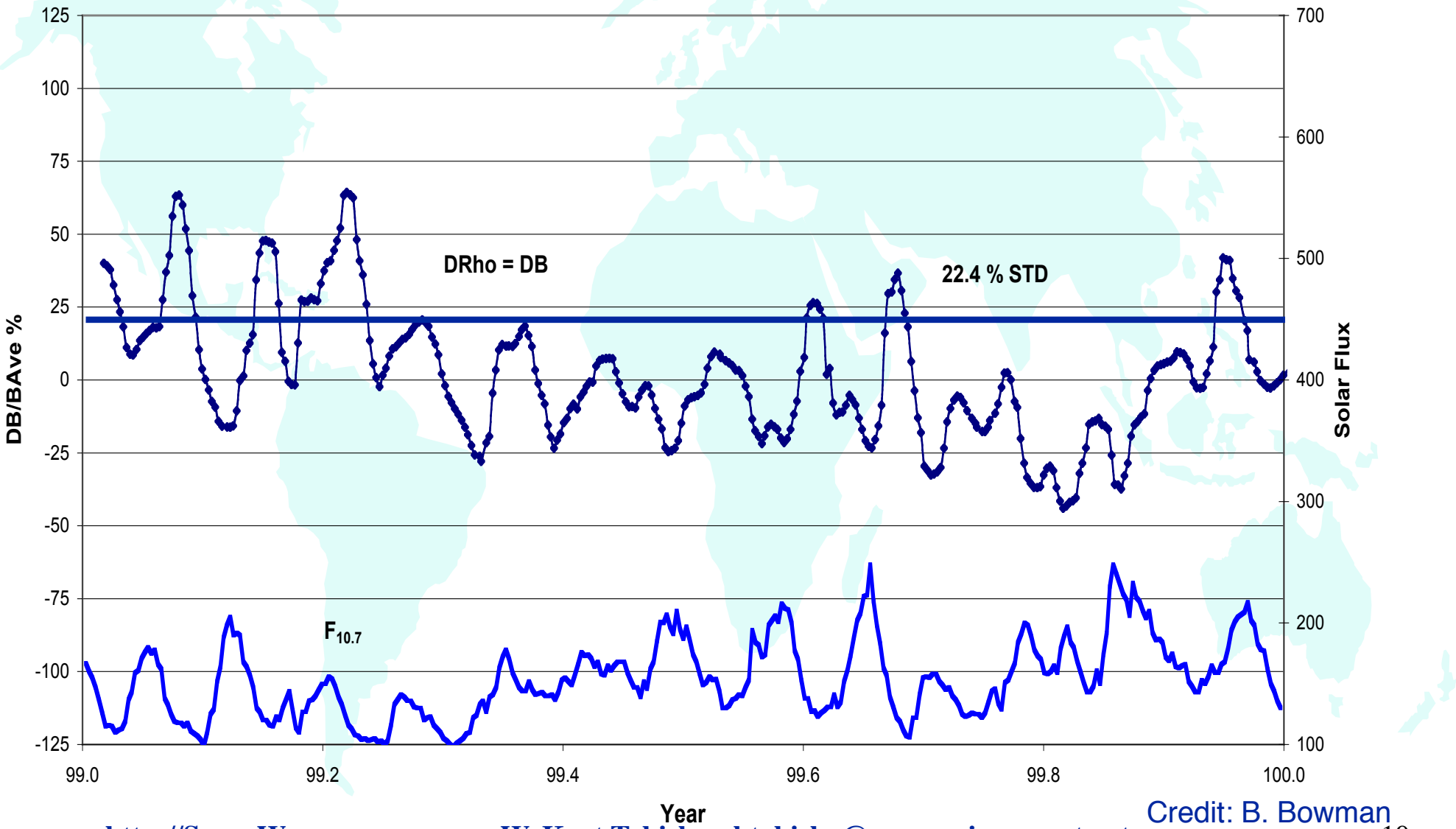
Credit: Jacchia

Historical Density Model Errors at 350 km (1-σ)



Credit: F. Marcos

J71 1999 Unmodeled ρ Error



Credit: B. Bowman

Jacchia-Bowman 2008 thermospheric density model

- Motivation: significantly reduce 1-σ error
- Improvements
  1) uses the CIRA72 (Jacchia 71) model diffusion equations
  2) new solar indices in the extreme and far ultraviolet wavelengths
  3) new exospheric temperature and semiannual density equations
  4) temperature correction equations for diurnal and latitudinal effects
  5) density correction factors at high altitude (1500- 4000 km)
  6) Dst index used for high latitude heating modeling
- Bowman *et al.*, AIAA-2008-6438_JB2008_Model.pdf (see JB2008 link http://sol.spacenvironment.net/~JB2008/)

Credit: Tobiska

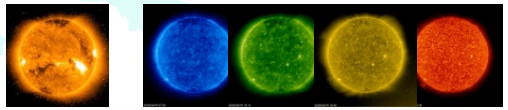
Jacchia-Bowman 2008

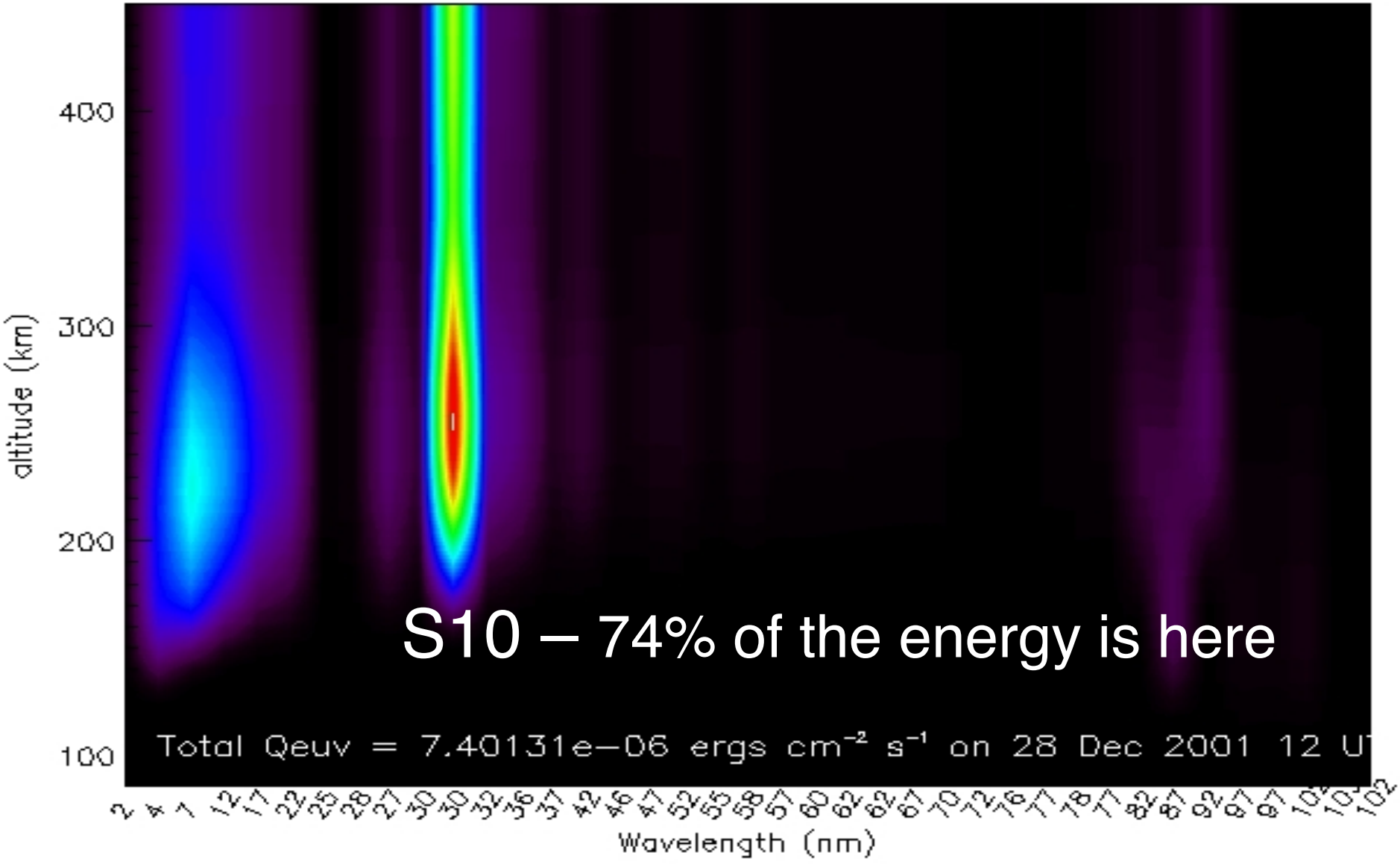
- JB2008 is validated through comparisons of accurate daily density drag data that are previously computed for numerous satellites
- For the 400 km altitude, the Jacchia 1971 18% standard deviation is reduced to 12% during periods of low geomagnetic storm activity

Credit: Tobiska

Solar and geomagnetic drivers to the atmosphere

Solar EUV heating is specific to λ and z

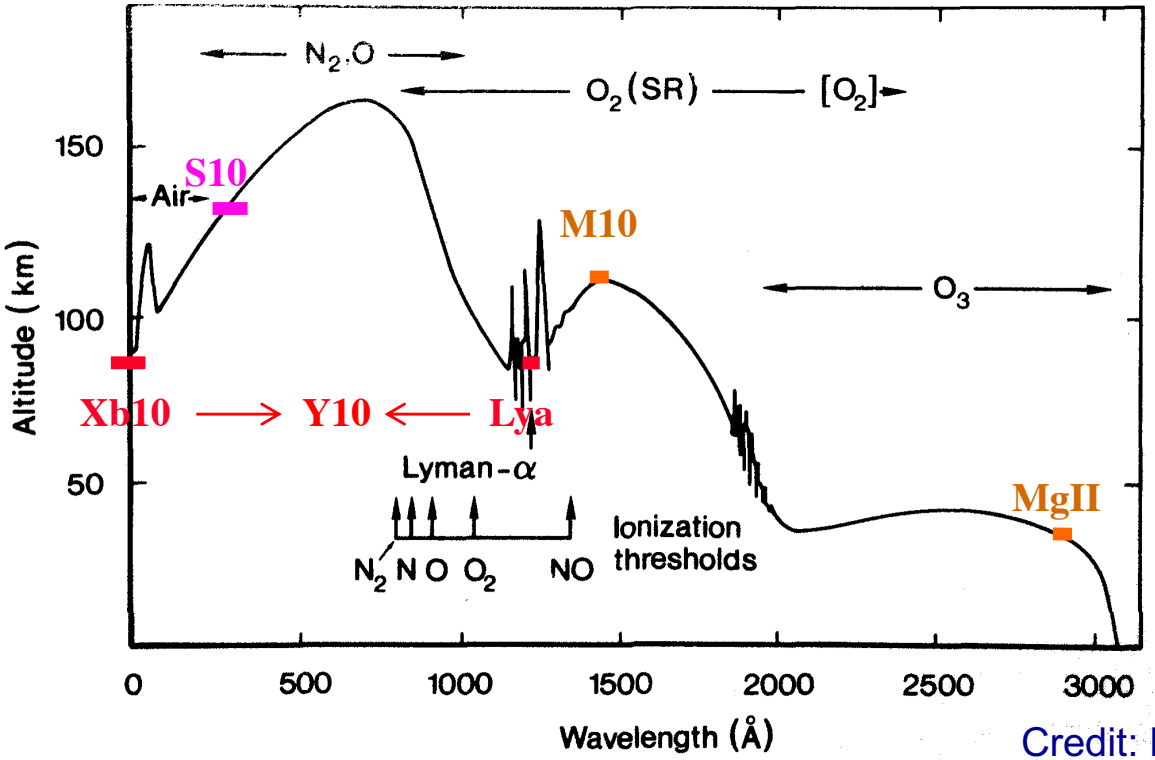




S10 – 74% of the energy is here

Motivation for solar indices … capture photoabsorption, including SRC in FUV, for *observation-based* indices

Altitude of unit optical depth for photoabsorption

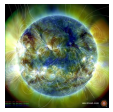


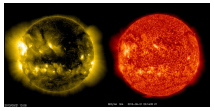
Credit: M.H. Rees

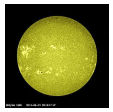
JB2008 Thermosphere Overview – Ops

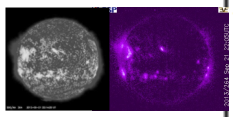
Daily operational indices selected

- JB2008 additionally uses 81-day center smoothed indices









Index or proxy	Observing facility	Instrument	Observation time frame	Measurement cadence	Measurement latency	Operational availability
$F_{10.7}$	Penticton ground observatory	Radio tel-escope	1947-2013	3 times/day	Up to 24 hours	yes
$S_{10.7}$	SOHO, GOES	SEM, EUVS	1996-2013	15 seconds	Up to 24 hours	(a)
$M_{10.7}$	NOAA-16, 17, 18, SORCE, ERS-2	SBUV, SOL-STICE, GOME	1991-2013	2 times/day	Up to 24 hours	yes (c)
$Y_{10.7}$	GOES-12, UARS, SORCE, TIMED	XRS, SOL-STICE (2), SEE	1991-2013	1 minute, 16 times/day	Up to 10 min-utes, up to 48 hours	(b)

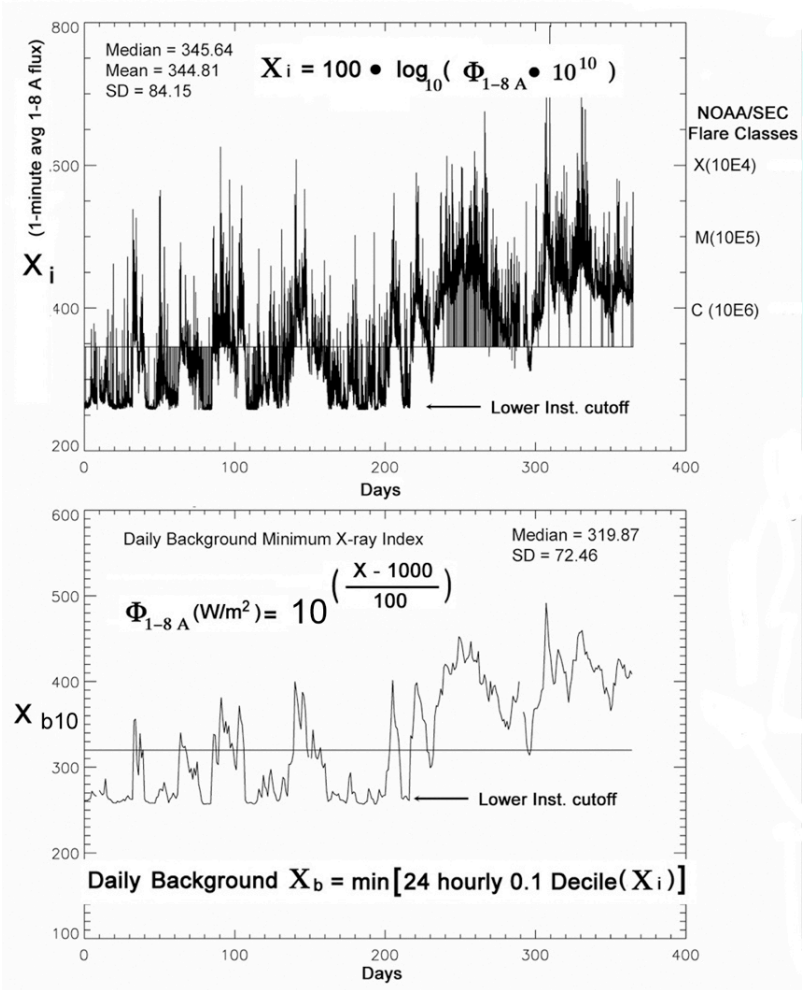
(a) SOHO/SEM is a NASA research instrument but provides daily irradiances on an operational cadence; GOES 13 EUVS B channel makes measurements in the same bandpass as SOHO SEM.

(b) GOES XRS is a NOAA operational instrument whereas TIMED/SEE and SORCE/SOLSTICE are NASA research instruments providing daily irradiances on an operational measurement cadence.

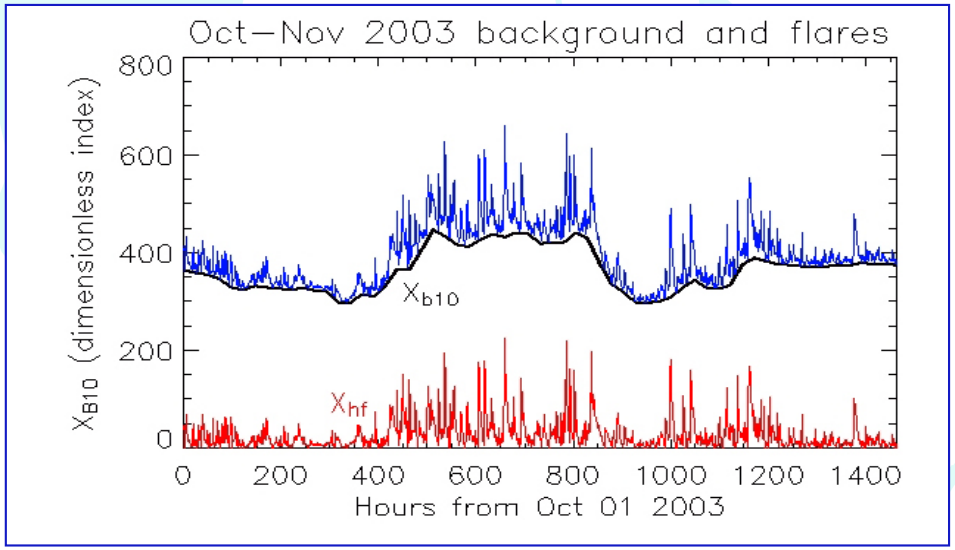
(c) UARS/SOLSTICE stopped in 2005; SORCE/SOLSTICE intends to provide data for several years.

Credit: ISO 14222

X-ray background (X_{b10}) and flare (X_{hf}) indices



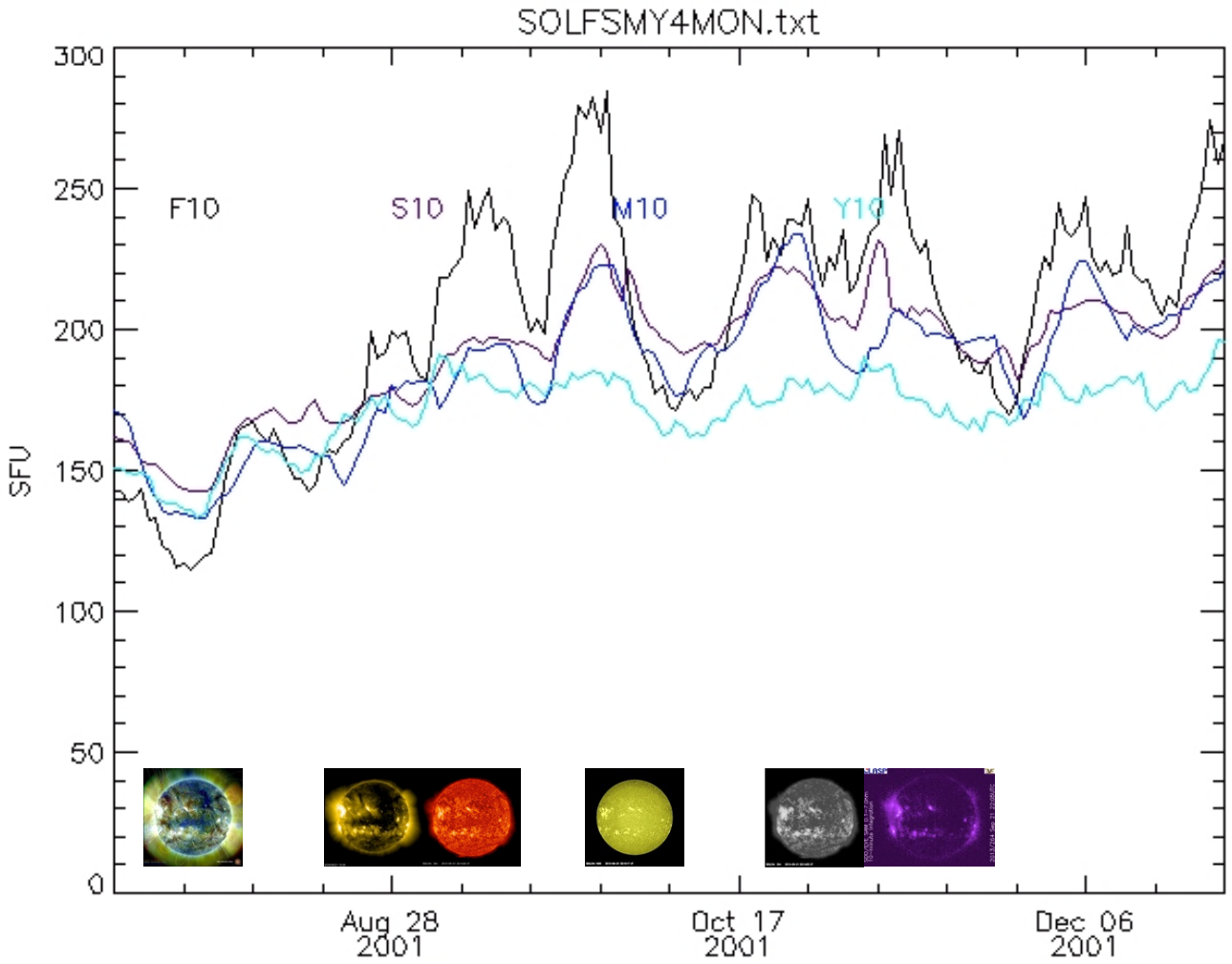
- X_{b10} is an index to the daily background X-ray flux, based on the minimum hourly value for that day (which is calculated from the lower decile of the 1-minute X-Ray flux in that hour)
- X_{hf} is the median flux within an hour above X_{b10}
- X_{b10} is used along with Lyman-α in creating the Y10 index while X_{hf} is used in the Anemomilos Dst algorithm to create the derived velocity of solar ejecta



X_{b10} and X_{hf} shown for October-November 2003.

JB2008 Solar Indices/Proxies example

Daily operational indices selection criteria



Solar models and data

IS 21348:2007

Title: Process for determining solar irradiances

Heritage: developed by ISO TC20/SC14/WG4

Provides process to determining solar irradiances

- **Product type definition** - measurements, reference spectra, empirical models, physics-based models, proxies
- **Solar spectral categories** - TSI and gamma rays through radio wavelengths
- **Compliance criteria** - reporting, documenting, publishing, archiving, certification
- **Models (e.g. SIP) and data provided separately**

Credit: Tobiska

Solar EUV models & data

Solar measurements

rockets, AE-E, SOHO, TIMED*, SDO*

Solar models

SERF1 (EUV81), Nusinov, SERF2, EUV91, EUV97, NRLEUV, HEUVAC, SRPM,

SIP*(SOLAR2000/SOLARFLARE/VUV2002)

Solar proxies

F10.7*, E10.7*, S10.7*, M10.7*, Y10.7*, Rz

*IS 21348:2007 compliant

Credit: Tobiska

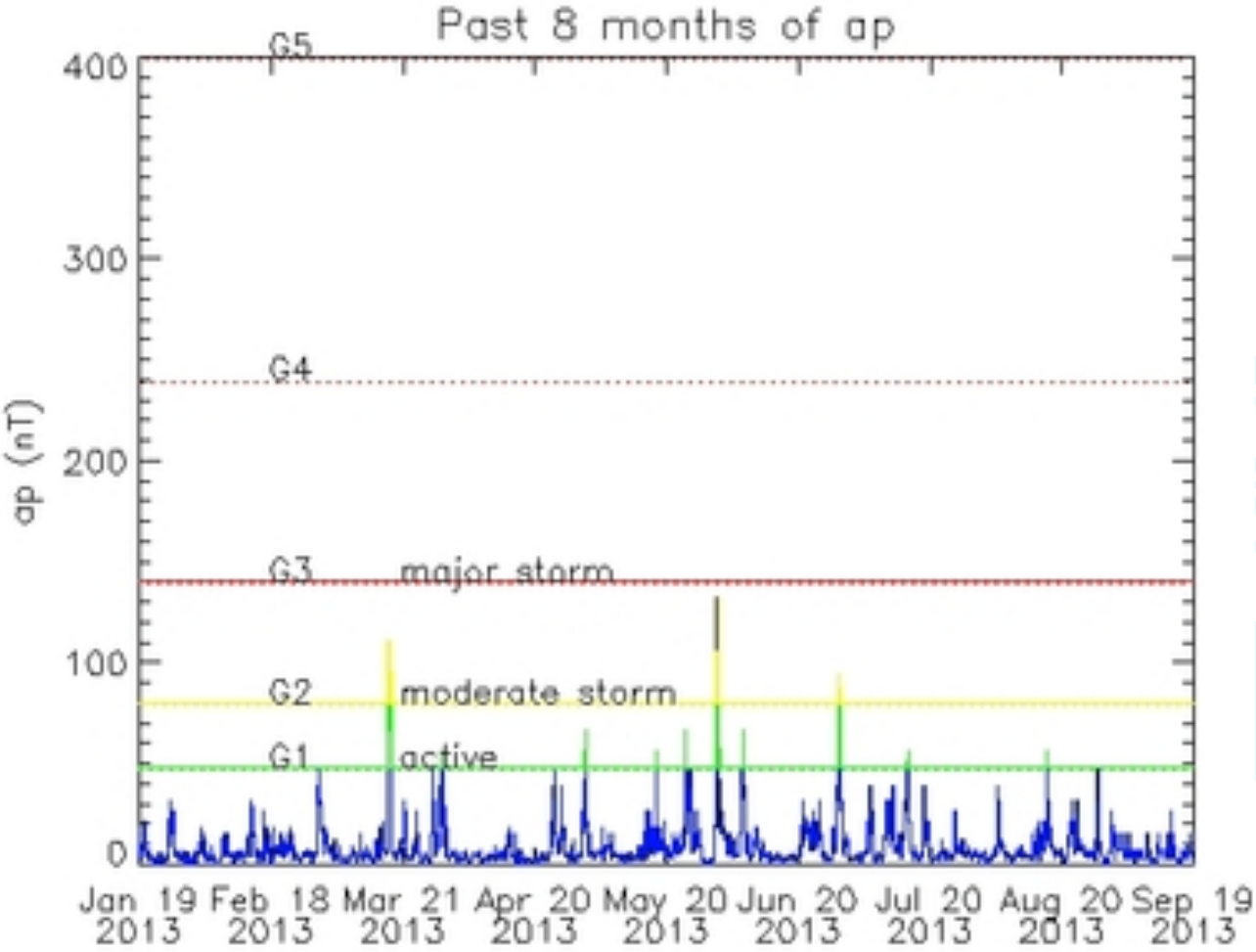
Geomagnetic proxies

Ap / Kp

- Kp is the planetary index for geomagnetic activity
- Calculated as a weighted average of K-indices from a network of geomagnetic observatories
- Observatories do not report their data in real-time, necessary for an operations center to make the best estimate of this index based on available data
- Ap invented to create daily average values from eight 3-hourly ranges

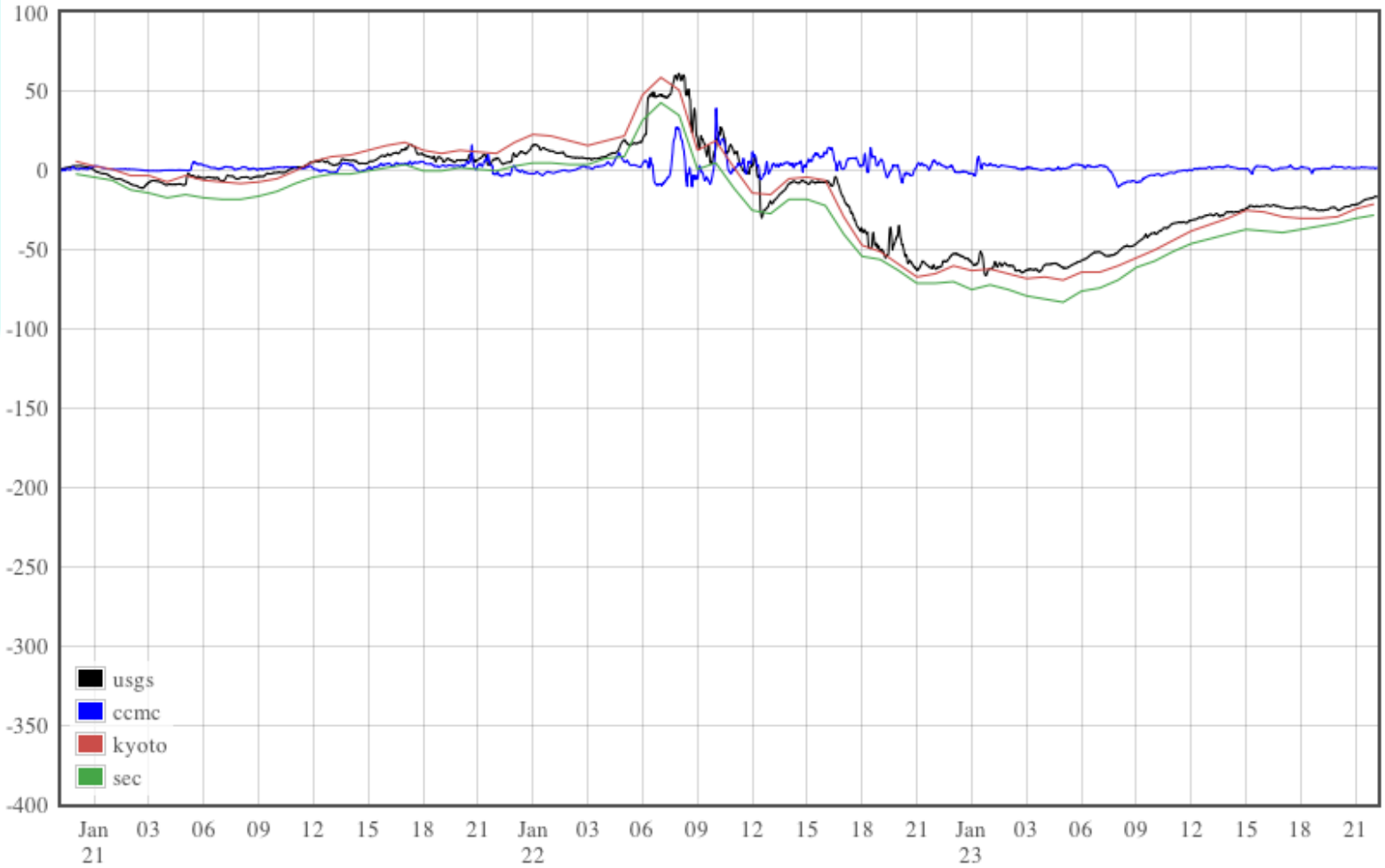
K	A	NOAA G
0	0	
1	3	
2	7	
3	15	
4	27	
5	48	G1
6	80	G2
7	140	G3
8	240	G4
9	400	G5

Geomagnetic proxies



Credit: SET

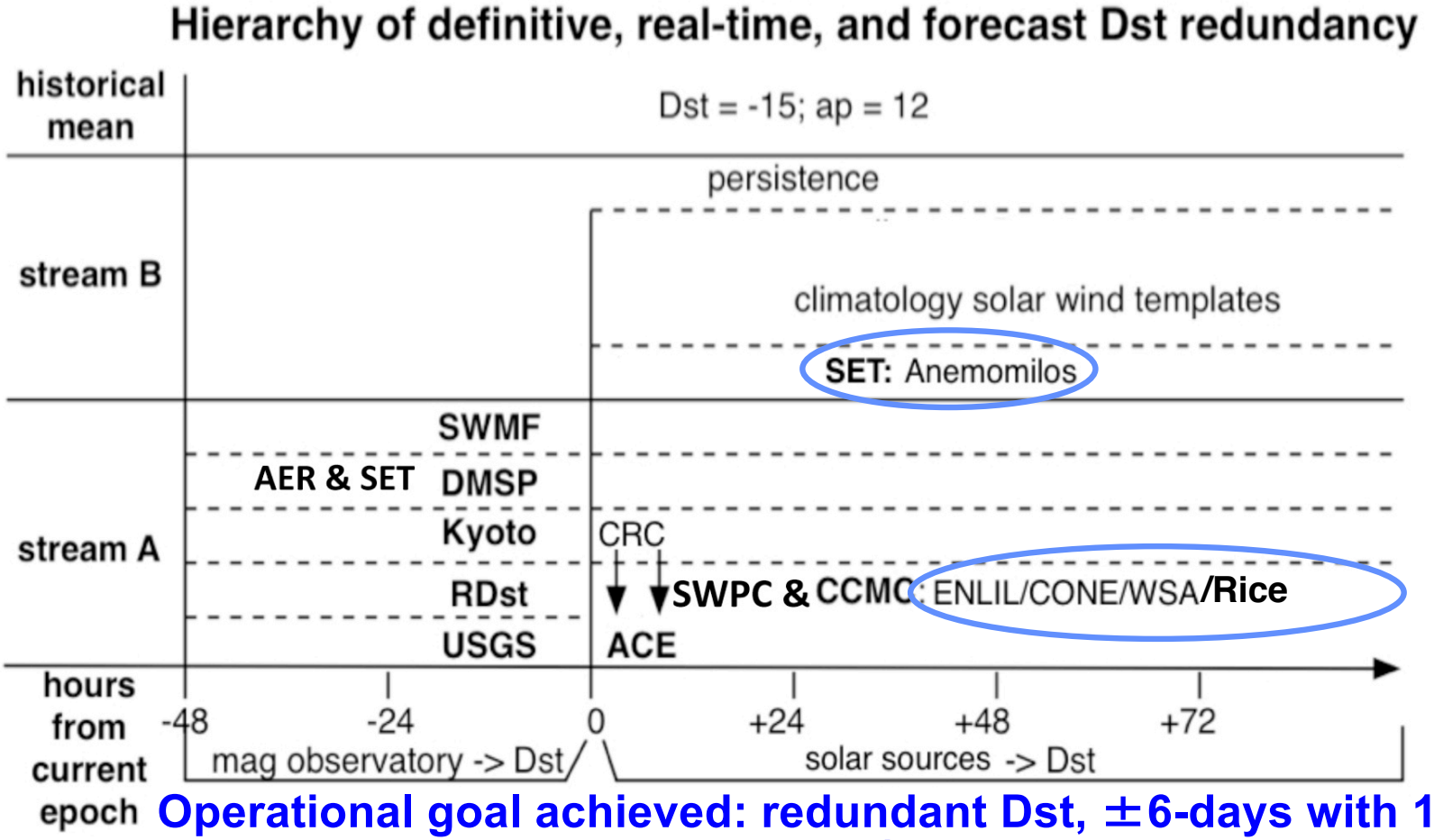
Real-time Dst used by SET



◂◂ Date: Fri, 20 Jan 2012 22:12 ▸▸

Credit: SET

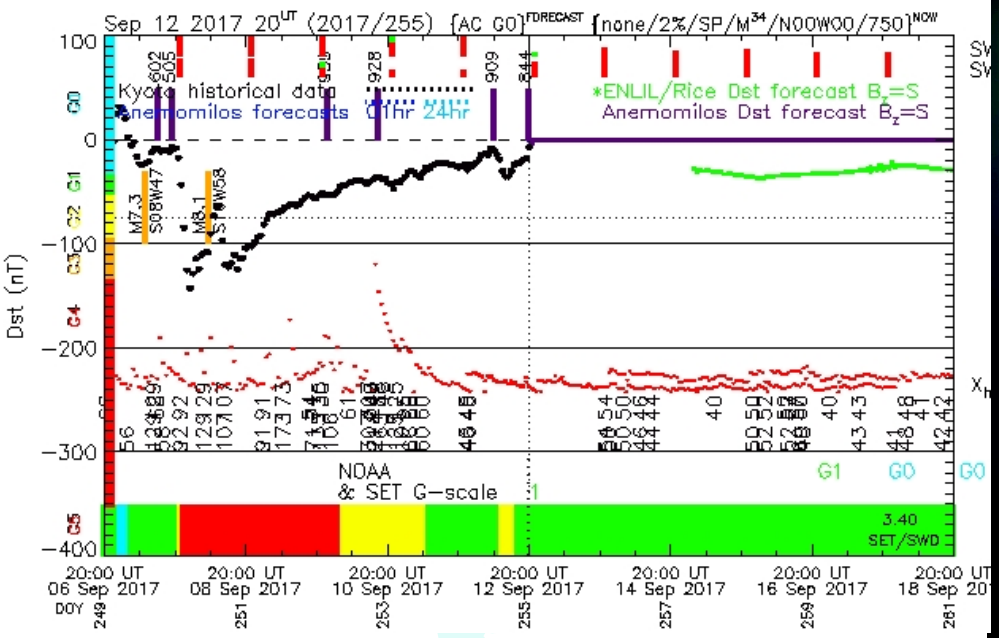
JB2008 Thermosphere – Geomagnetic Storm Drivers

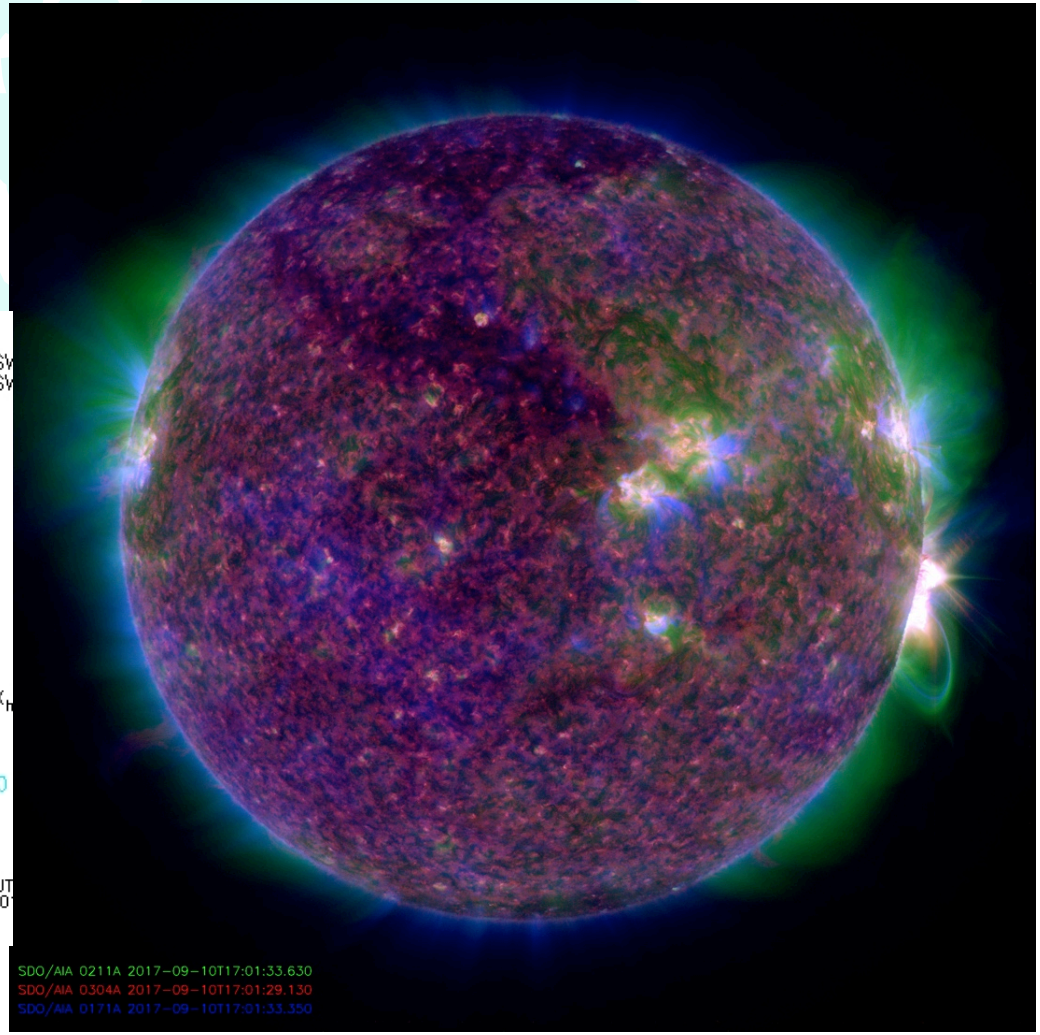


Operational goal achieved: redundant Dst, ±6-days with 1-hour granularity and 1-hour latency Credit: SET

Geomagnetic storms during solar cycle decline

- Sep 10, 2017 large CME misses Earth





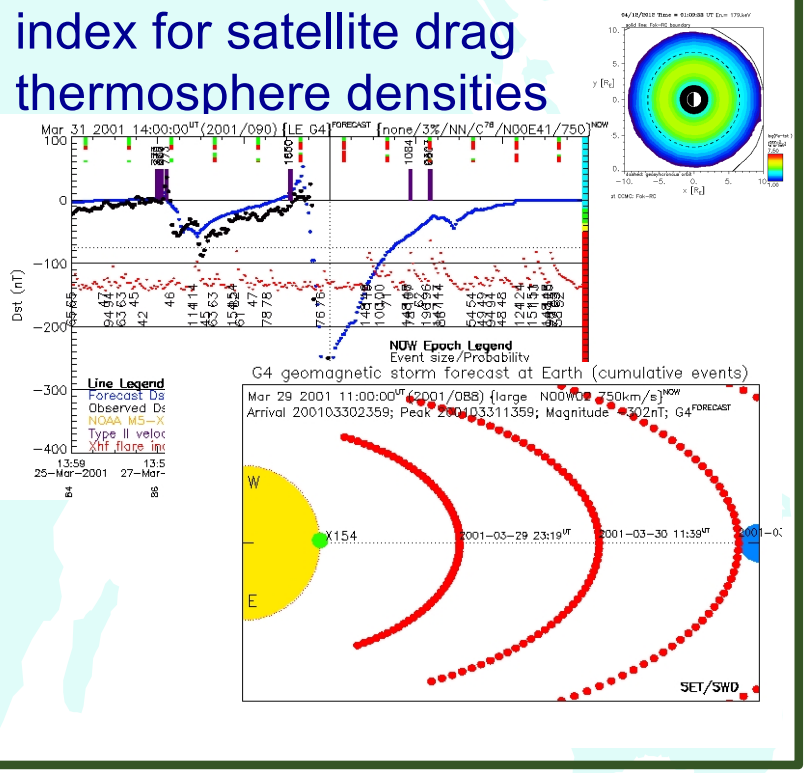
http://sol.spacenvironment.net/~sam_ops/index.html?

Anemomilos Forecast Dst

Anemomilos

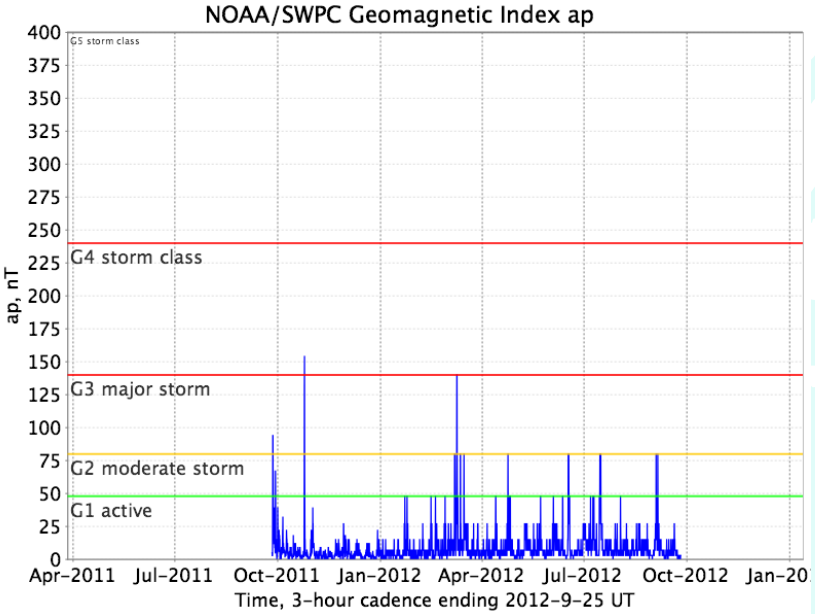
- The Greek word for “windmill”
- 6-day forecast of hourly Dst with 1-hour latency
- It is a data-driven deterministic algorithm using solar observables to identify geoeffective events

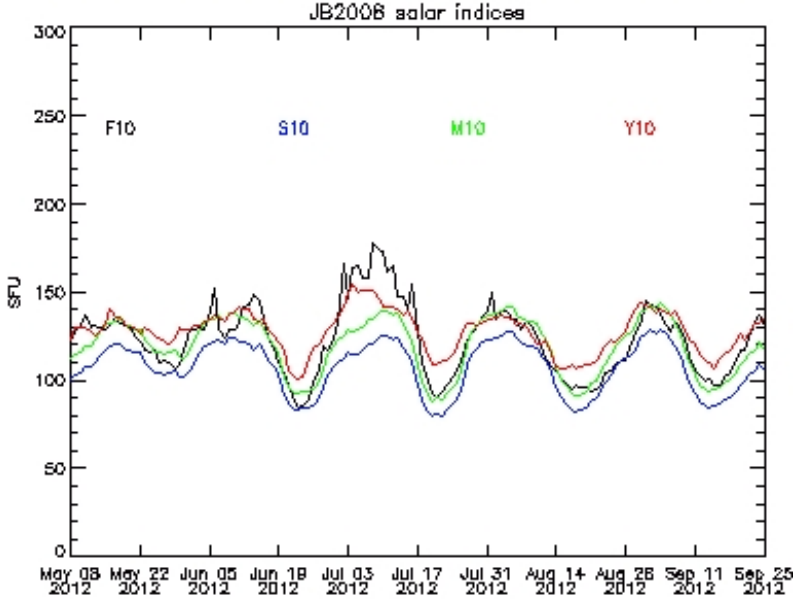
geomagnetic ring current index for satellite drag thermosphere densities

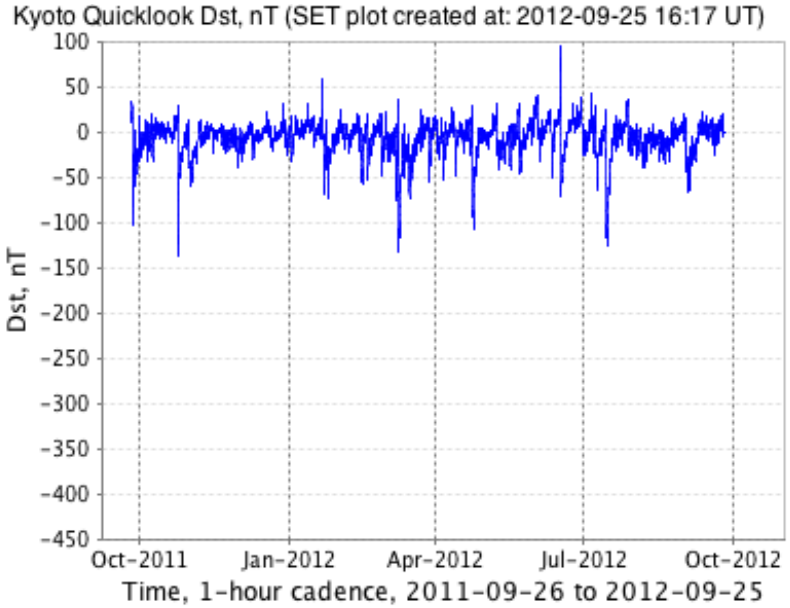


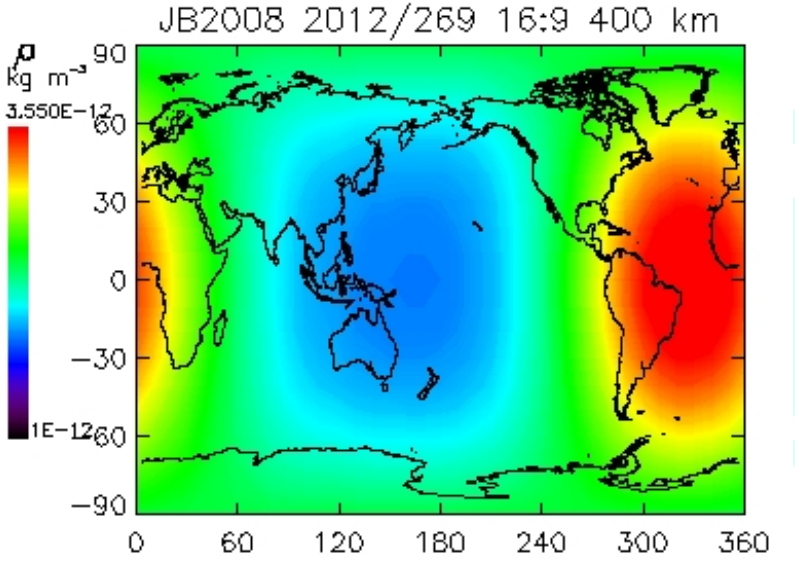
Credit: Tobiska

JB2008 Indices





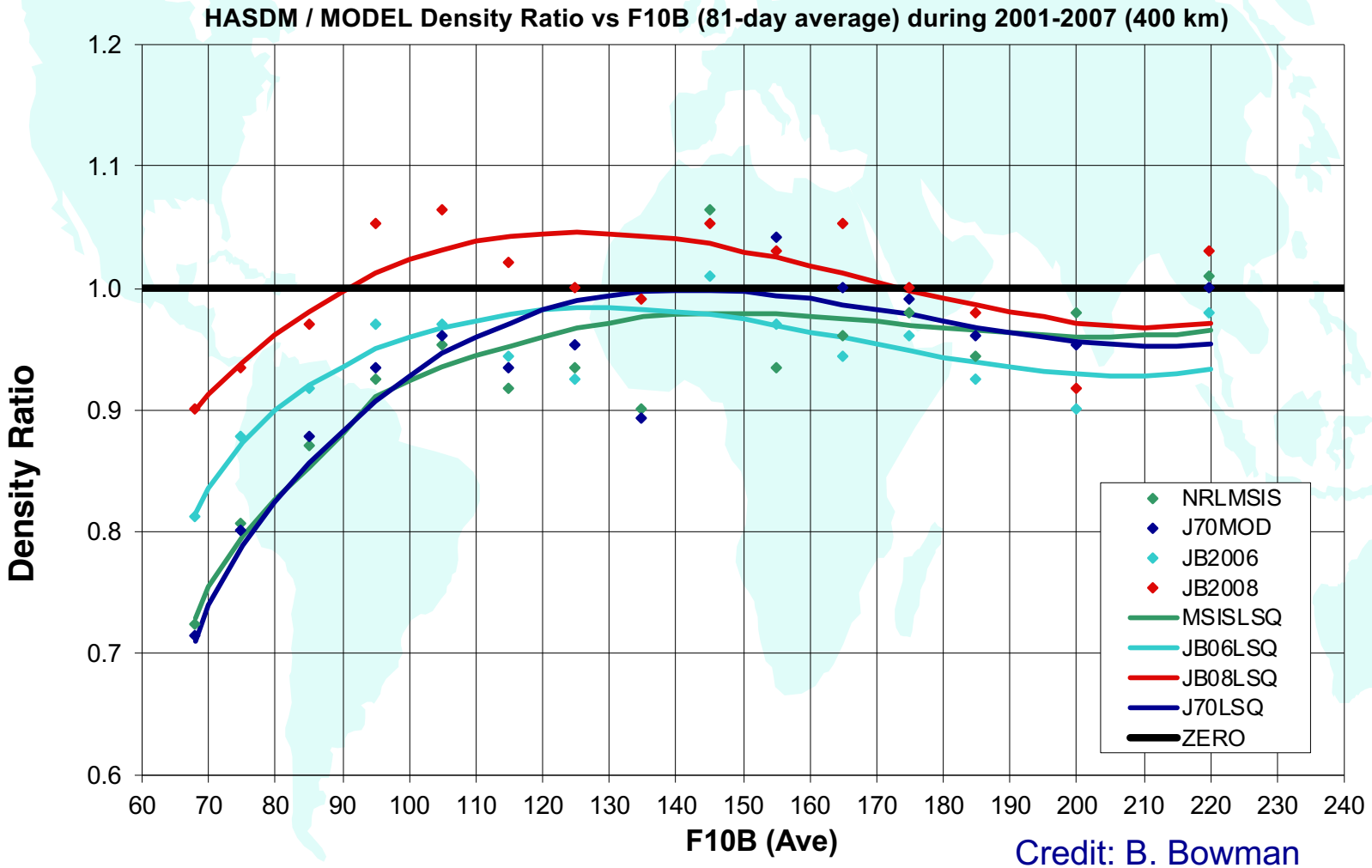




Credit: Tobiska

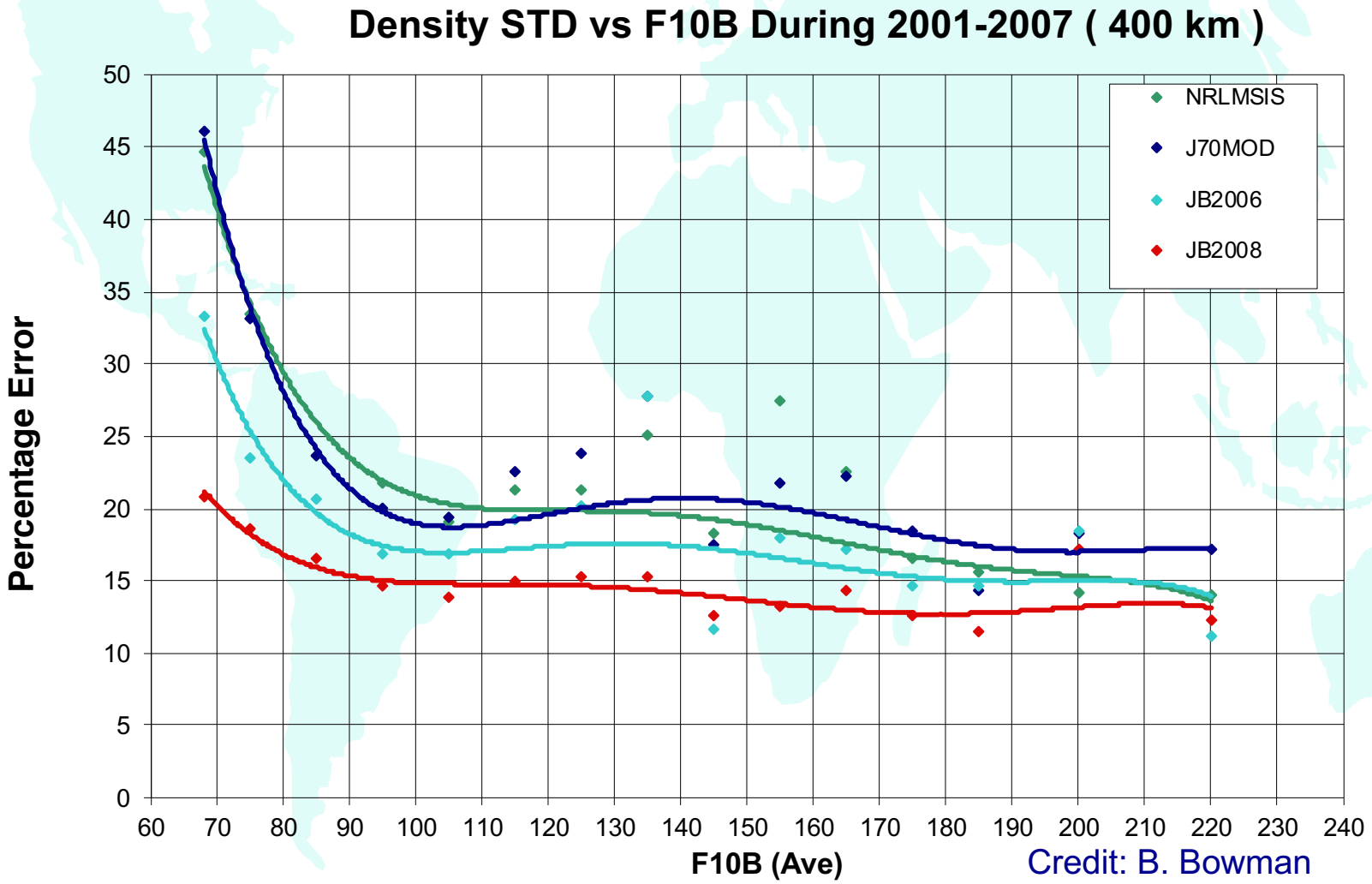
JB2008 and HASDM results

HASDM-Model density ratio



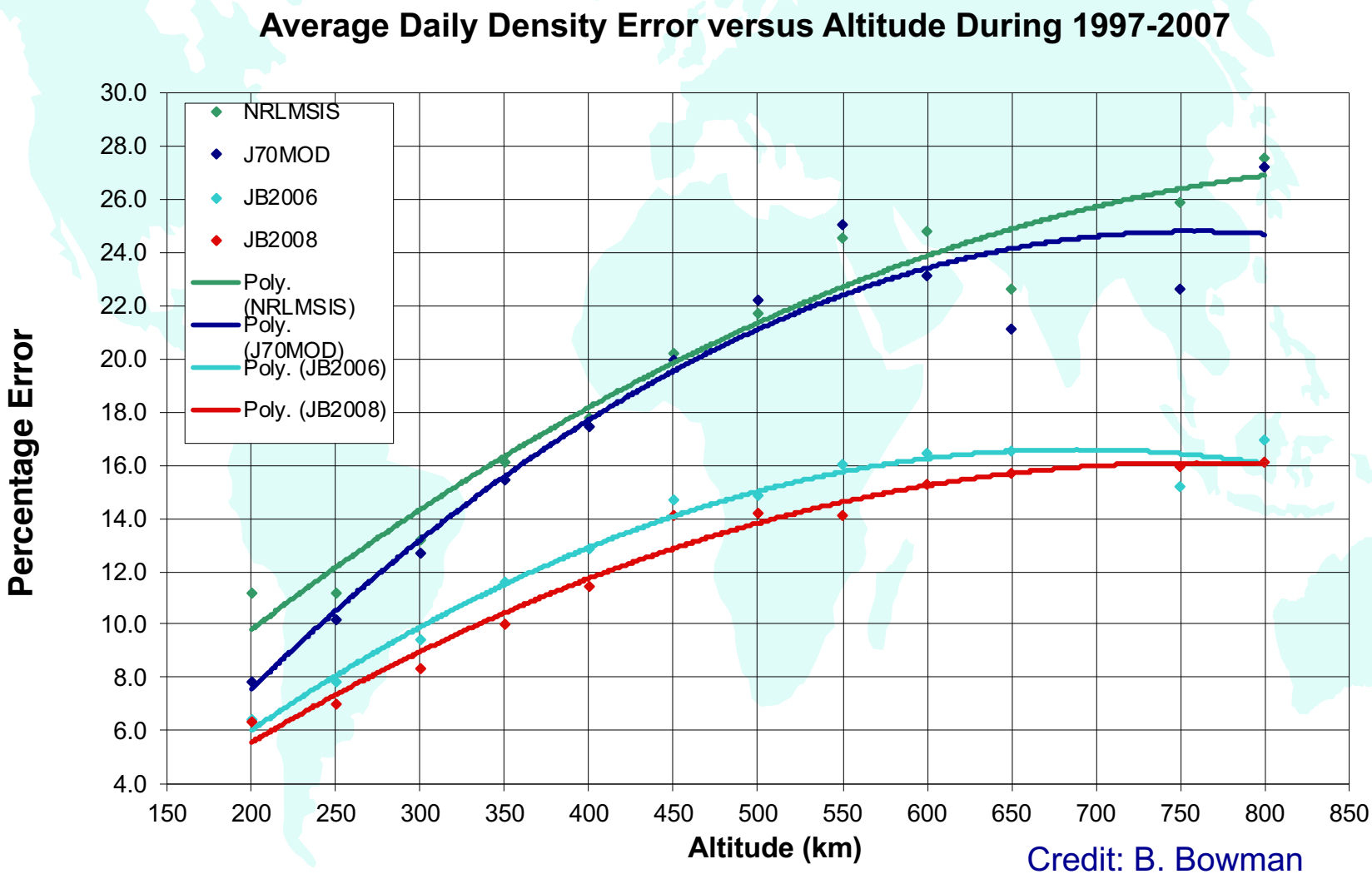
Credit: B. Bowman

Standard deviation comparison

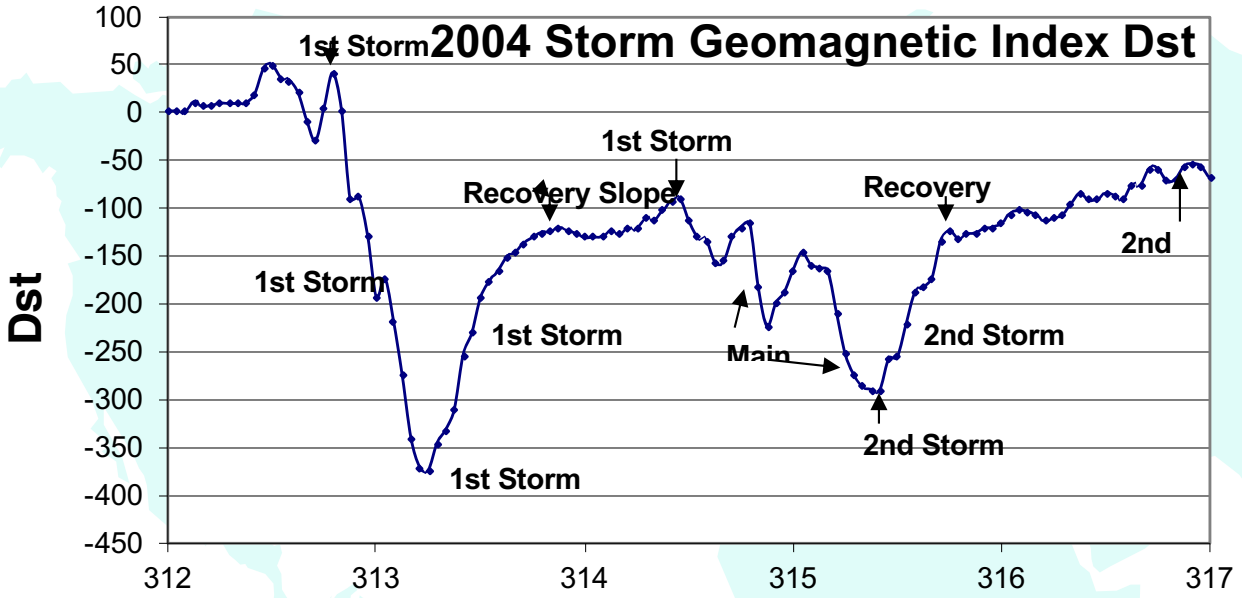


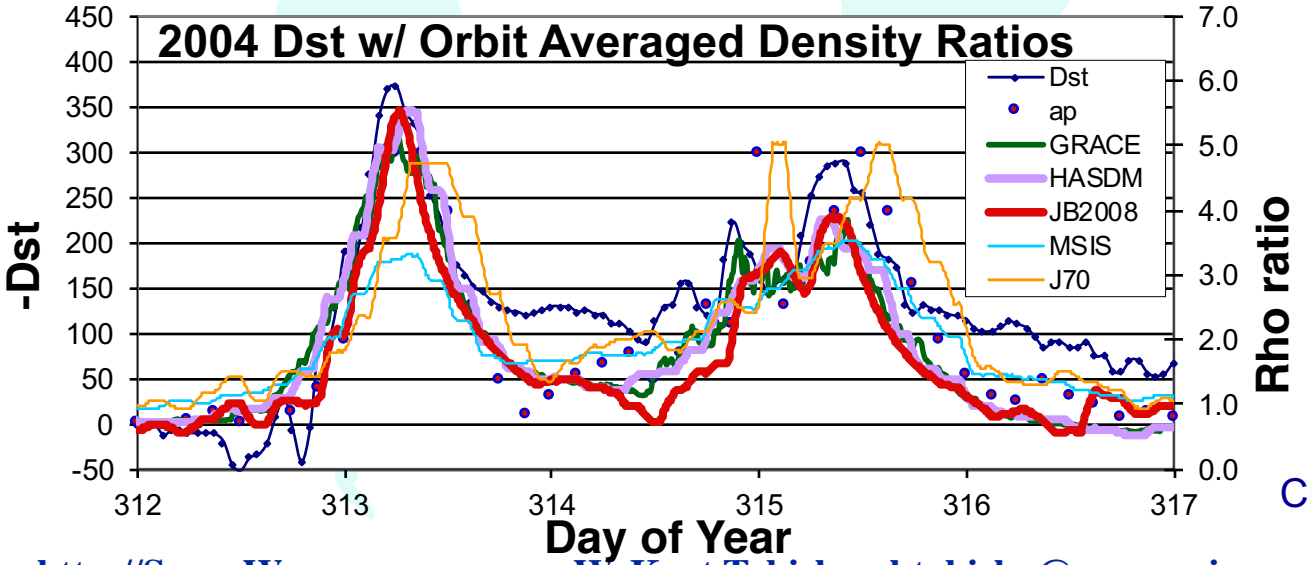
Credit: B. Bowman

Average Daily Density Error



Credit: B. Bowman

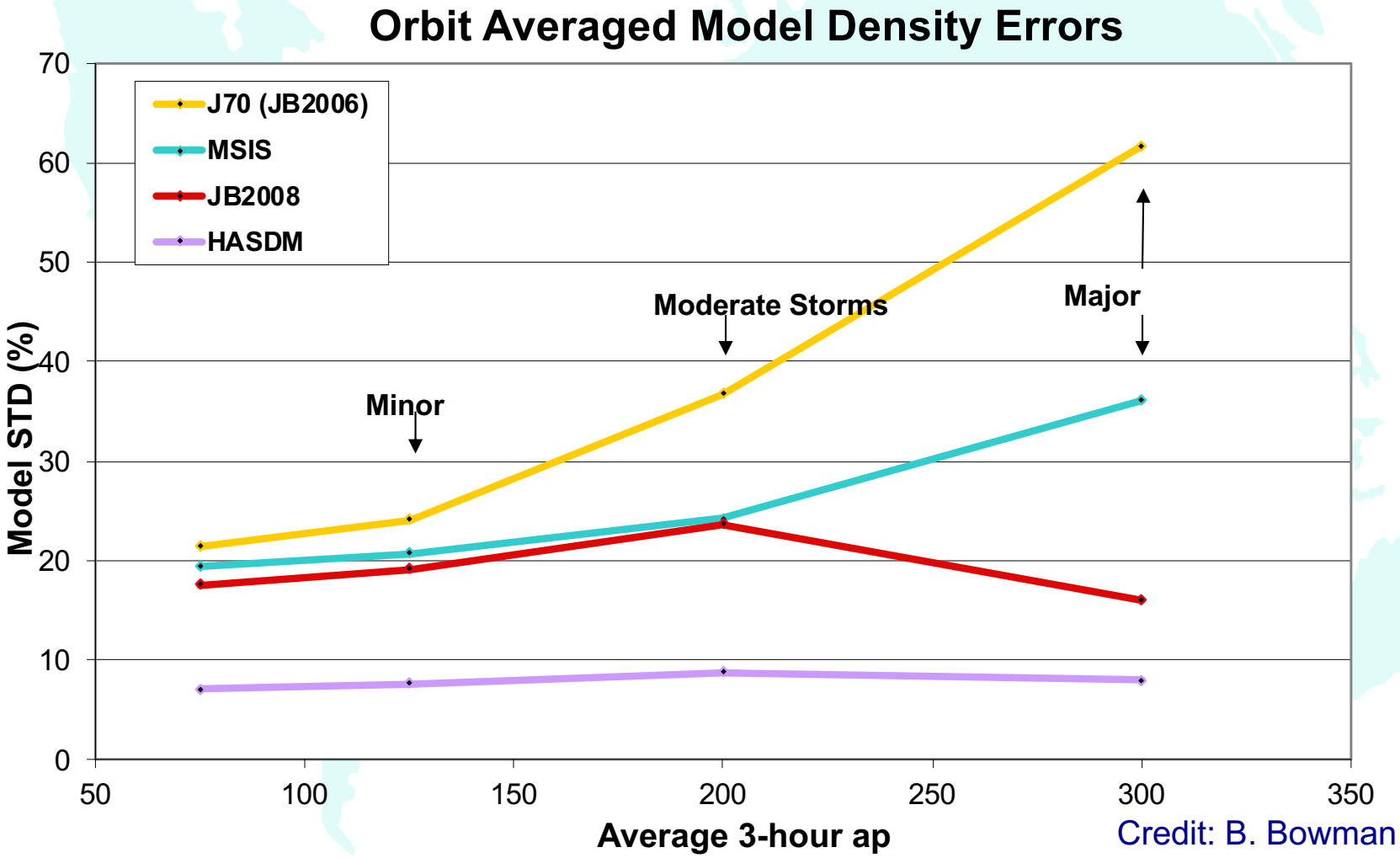




Storm-time Density Error comparisons

Credit: B. Bowman

Orbit Average Density Error



Credit: B. Bowman

JB2008 (code, indices, docts)

JB2008	The Jacchia-Bowman 2008 Empirical Thermospheric Density Model	SET

[Home] [Intro] [Indices] [Code] [Publications] [Contacts] [Figures] [License] [SET/Spacewx]

Dear Colleague,

Welcome to the JB2008 empirical thermospheric density model website. Please provide your name and email address if you desire to be notified about updates to the JB2008 model, and the availability of forecasts.

[click here to register for updates] *

Please note that cookies must be enabled in your Browsers Preferences to register. Your local installation may have firewall implementations that prevent cookies or Java servlet protocols, in which case you should email spacenvironment@spacenvironment.net with "JB2008" in the subject line to receive updates.

Thank you,

Space Environment Technologies

Notice: Beginning 6 Oct 2012, JB2008 operations have been upgraded, and the JB2008 indices are now updated regularly at this website (note that most of these data released for public use will have an approximately 40-day lag from the current date). A number of significant improvements have been made to the JB2008 indices, which have been validated with 2001 and 2005 solar/geomagnetic data. For more information, contact spacenvironment@spacenvironment.net with "JB2008" in the subject line.

Last Website Update: 6 Oct 2012

[Home] [Intro] [Indices] [Code] [Publications] [Contacts] [Figures] [License] [SET/Spacewx]

http://sol.spacenvironment.net/~JB2008/index.html

Credit: SET