CORONAL MASS EJECTIONS FROM SOHO/LASCO OBSERVATIONS COMPARISON WITH SUNSPOT NUMBER AND OTHER SOLAR PROXIES

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Outline

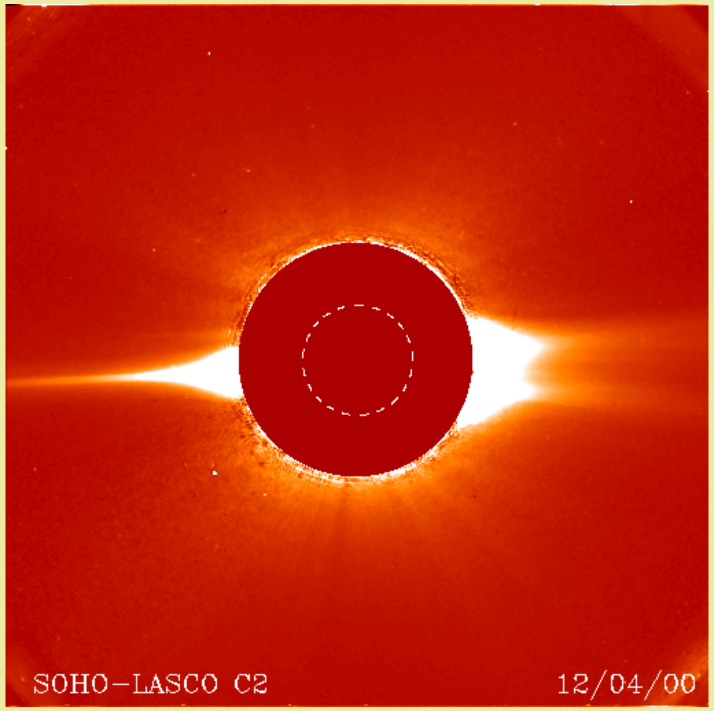
Use 17 years of (almost) uninterrupted imaging of the white light corona performed by the LASCO-C2 coronagraph aboard SOHO to study the coronal mass ejections (CMEs) and specifically the evolution of their properties with the solar cycle.

- The LASCO-C2 externally occulted coronagraph
- The detection and characterization of the CMEs
- CME rate from various catalogs
- Other properties (apparent latitude, angular width)
- Kinematics
- Comparison with solar proxies
- Conclusion

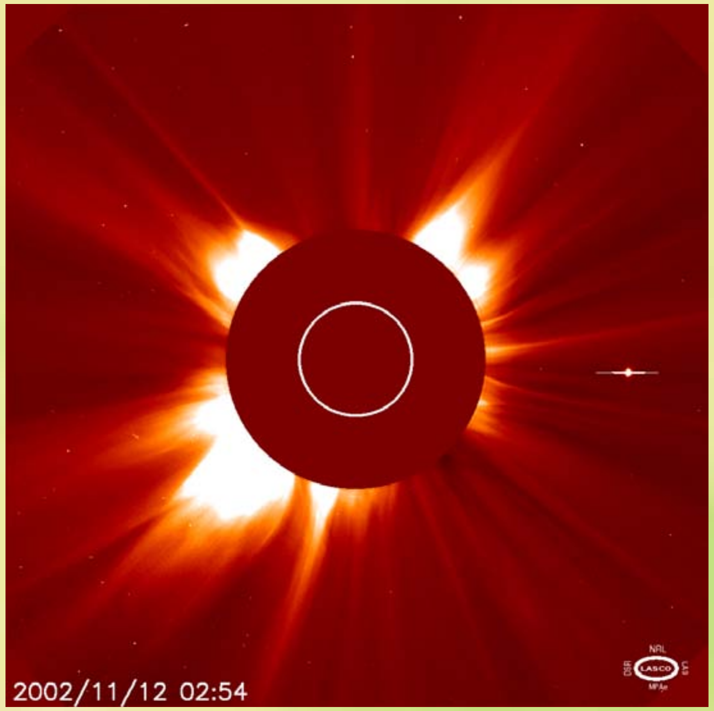
The LASCO coronagraph aboard SOHO

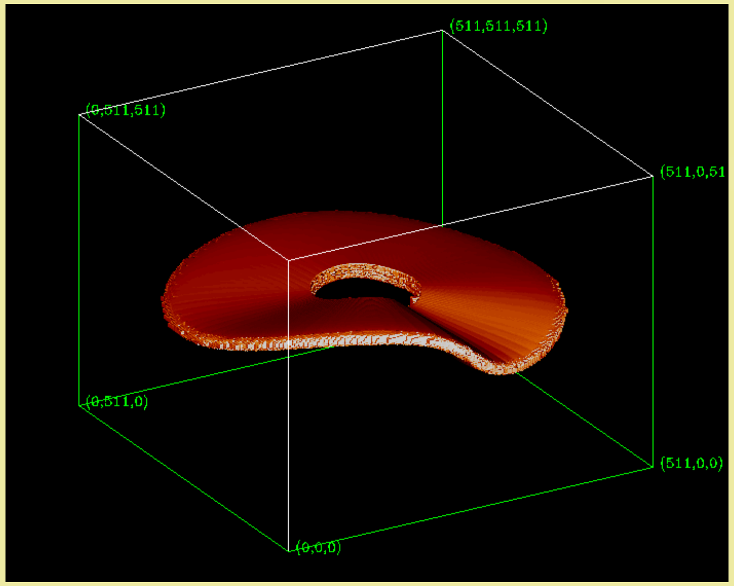
- A set of 3 coronagraphs with nested fields of view built by a consortium of 4 institutes: NRL (successive PIs: D. Michels, G. Brueckner, R. Howard), MPIAe→MPS (Germany), LAS →LAM (France) and DSR (UK)
  - C1: 1.1 – 3 Rsun (R. Schwenn, MPS) Stopped operating in Oct1998
  - C2: 2.2 – 6 Rsun (P. Lamy, LAM)
  - C3: 4.0 – 30 Rsun (M. Koomen, NRL)
- Launched in September 1995, in operation since January 1996
- L1 location, 24 hrs view of the Sun
- Interrupted for a few months when SOHO was lost in October 1998
- Present work relies on extensive calibration and processing of C2 images performed at LAM

Minimum and maximum corona

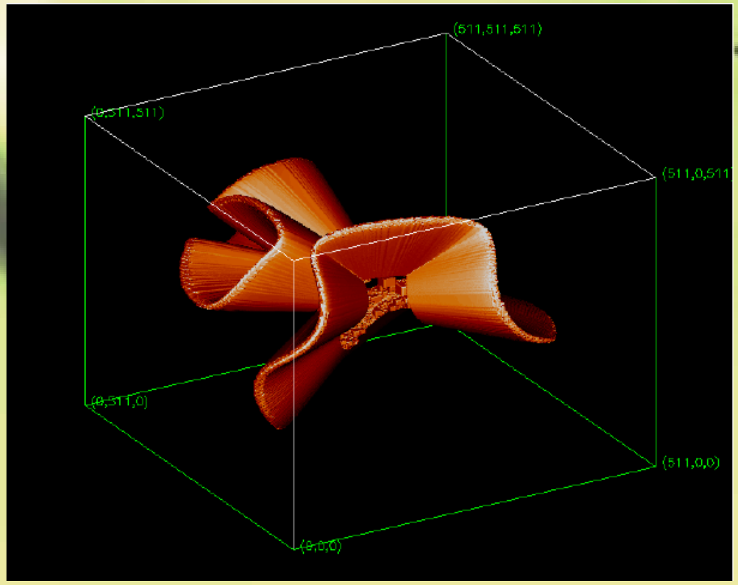


LASCO-C2 images





3D views of the current sheet



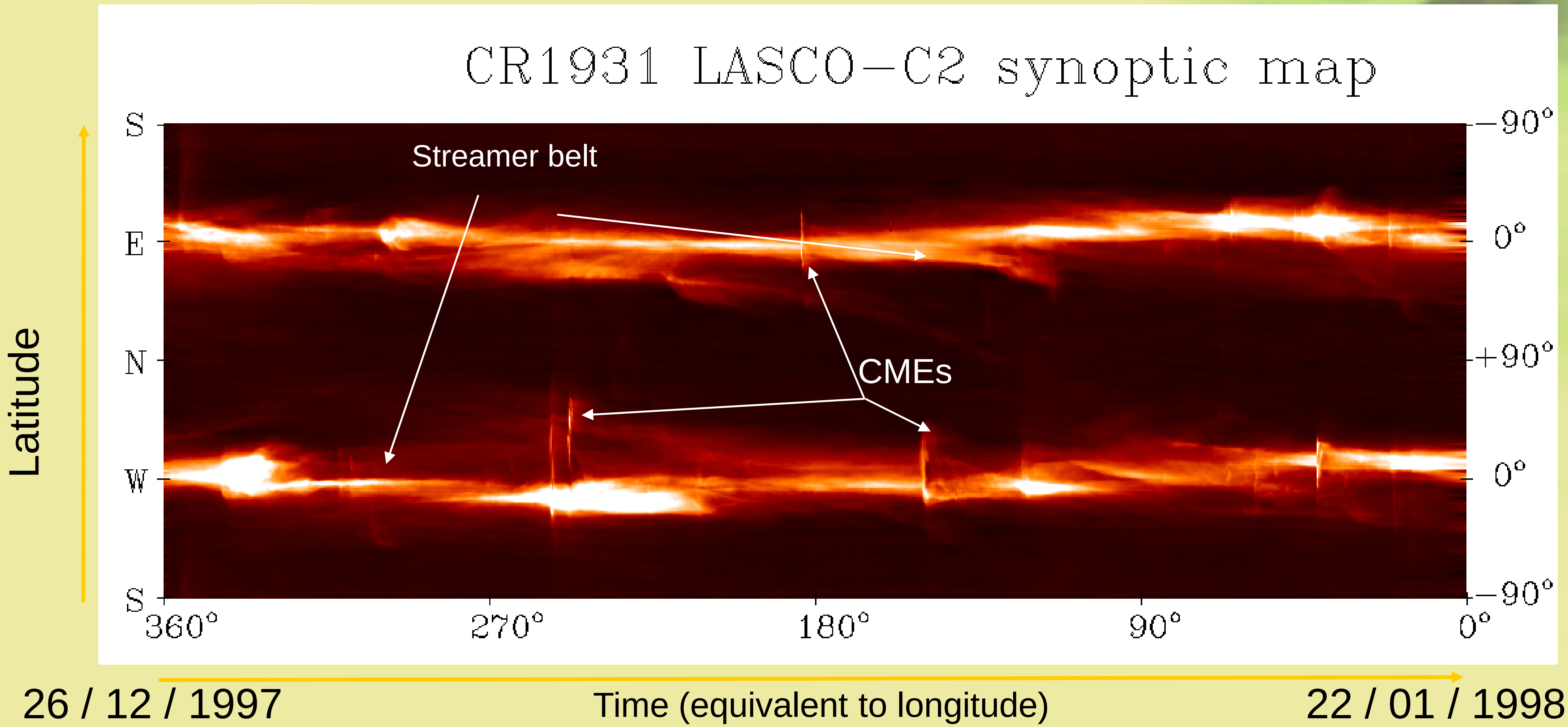
LASCO-C2 products

- Calibrated images of the radiance of the K (and F) corona
- Calibrated images of the polarized radiance "pB" of the K-corona
- **Calibrated Carrington & synoptic maps of the K-corona**
- 2D maps of the electron density
- CME catalogs "ARTEMIS" I and II
- And more

Advantages of synoptic maps

CMEs present characteristic signatures - essentially conspicuous vertical, narrow streaks – used as critera for detection.

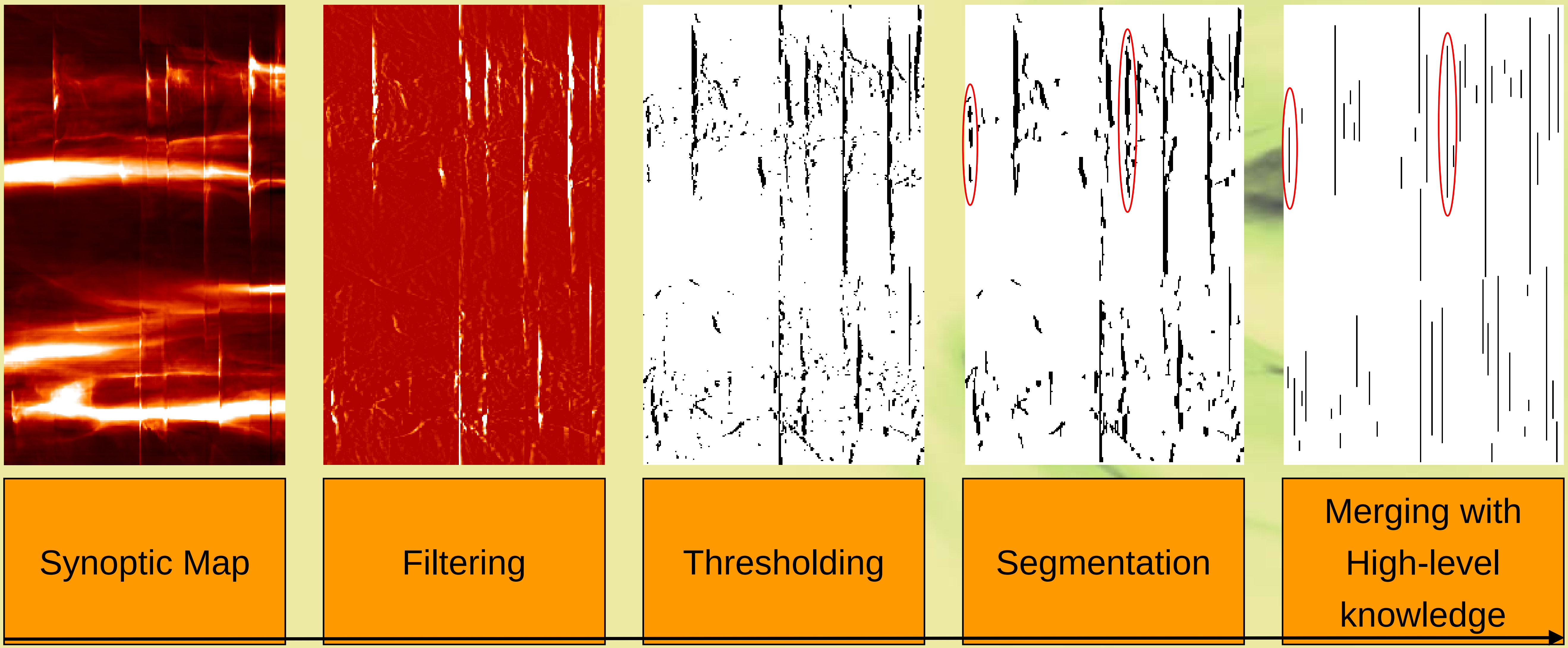
Global vision in time.
Interaction of CMEs with streamers.



Automatic Detection of CMEs

Detection is achieved on Synoptic maps built at radial distances from 2 to 6 Rsun.

The velocity is estimated by correlation techniques based on the detection masks at different Rsun.



ARTEMIS Online Catalog

Automatic Recognition of Transient Events
and Marseille Inventory from Synoptic maps

http://www.oamp.fr/lascomission:/

Interactive search engine by date, Carrington synoptic map, or each parameter.

DataSet Coronal Mass Ejections (277 datas(s) for this dataset) Add all cmes of this dataset in My Selection

Data Set detail	SUN: CME

1 2 3 4 5 6

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		CME ID	CR	Date	Position Angle	Angular Width	Speed	CORRSPEED_MEAN	CORRSPEED_MED
☐		CR1951_000	1951	1999-06-24	249	12	0	0	0
☐		CR1951_001	1951	1999-06-24	67	32	190	291	269
☐		CR1951_002	1951	1999-06-25	36	7	150	106	191
☐		CR1951_003	1951	1999-06-25	344	79	150	181	153

Key Index

Four catalogs of LASCO CMEs

CDAW: Coordinated Data Analysis Workshop Data developed at GSFC and the Catholic Universsity of the America (e.g., Yashiro et al. 2004) based on visual detection

The following catalogs are based on various schemes of automatic detection

CACTus: The Computer Aided CME Tracking catalog developed at the Royal Observatory of Belgium (Robbrecht et al. 2004). Two versions are available; we use v2 although it is NOT documented

SEEDS: The Solar Eruptive Event Detection System catalog developed at the George Mason University (Olmedo et al. 2005, 2008)

ARTEMIS I & II: The Automatic Recognition of Transient Events and Marseille Inventory from Synoptic maps catalogs developed by our team at the Laboratoire d'Astrophysique de Marseille (Boursier et al. 2009; Floyd et al. 2013)

Statistical properties of LASCO CMEs

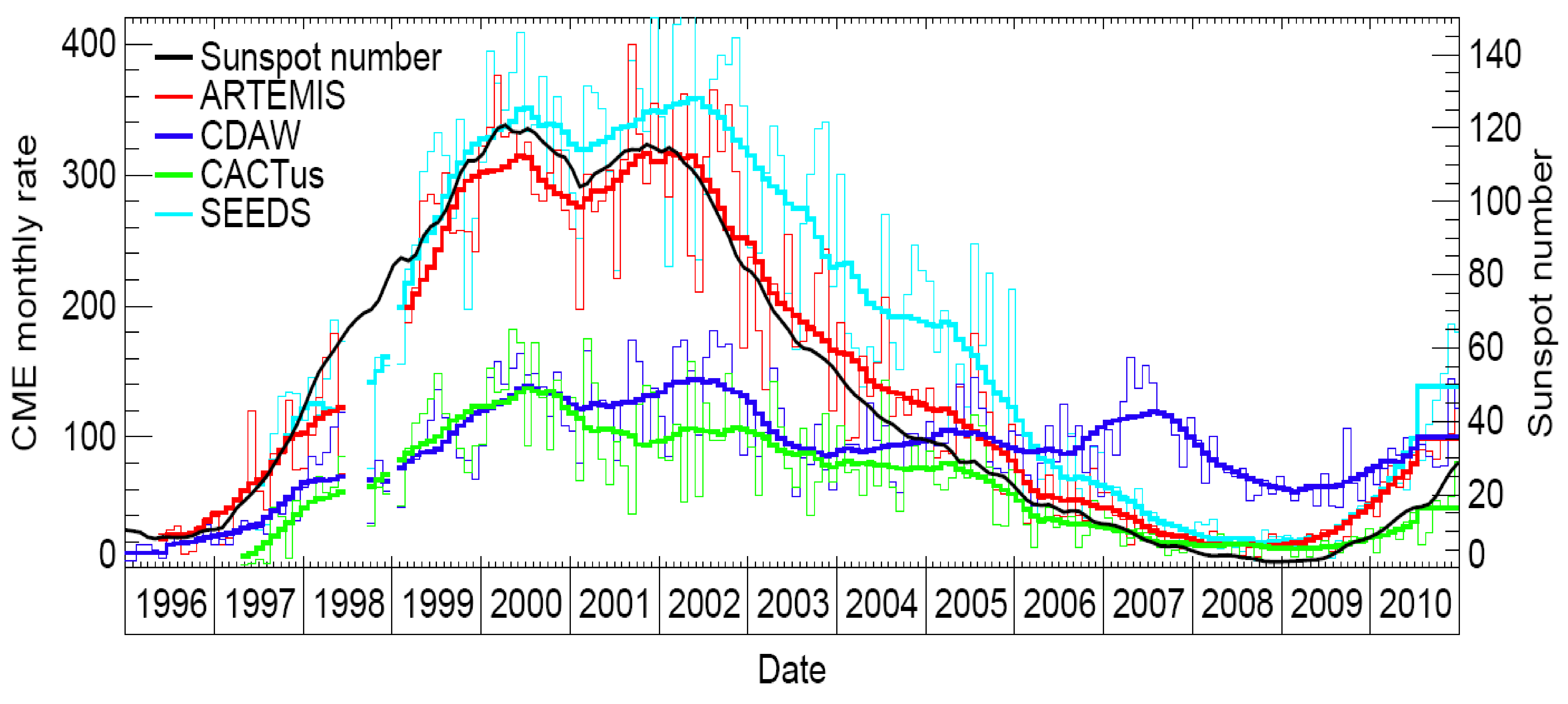
1 – Homogeneous data sets over the whole 23rd solar cycle

2 – Statistical comparison of the four catalogs

3 - Statistical analysis of the physical properties of CMEs with solar activity

4 – Statistical relationships with solar/coronal processes (flares, prominence eruptions, …) to understand the origin and occurrence of CMEs .

Monthly-averaged rate of LASCO CMEs Comparison with sunspot numbers



Thin curves: smoothed over one month, thick curves: smoothed over 13 months.

Cross-correlations with sunspot numbers

CDAW: low correlation

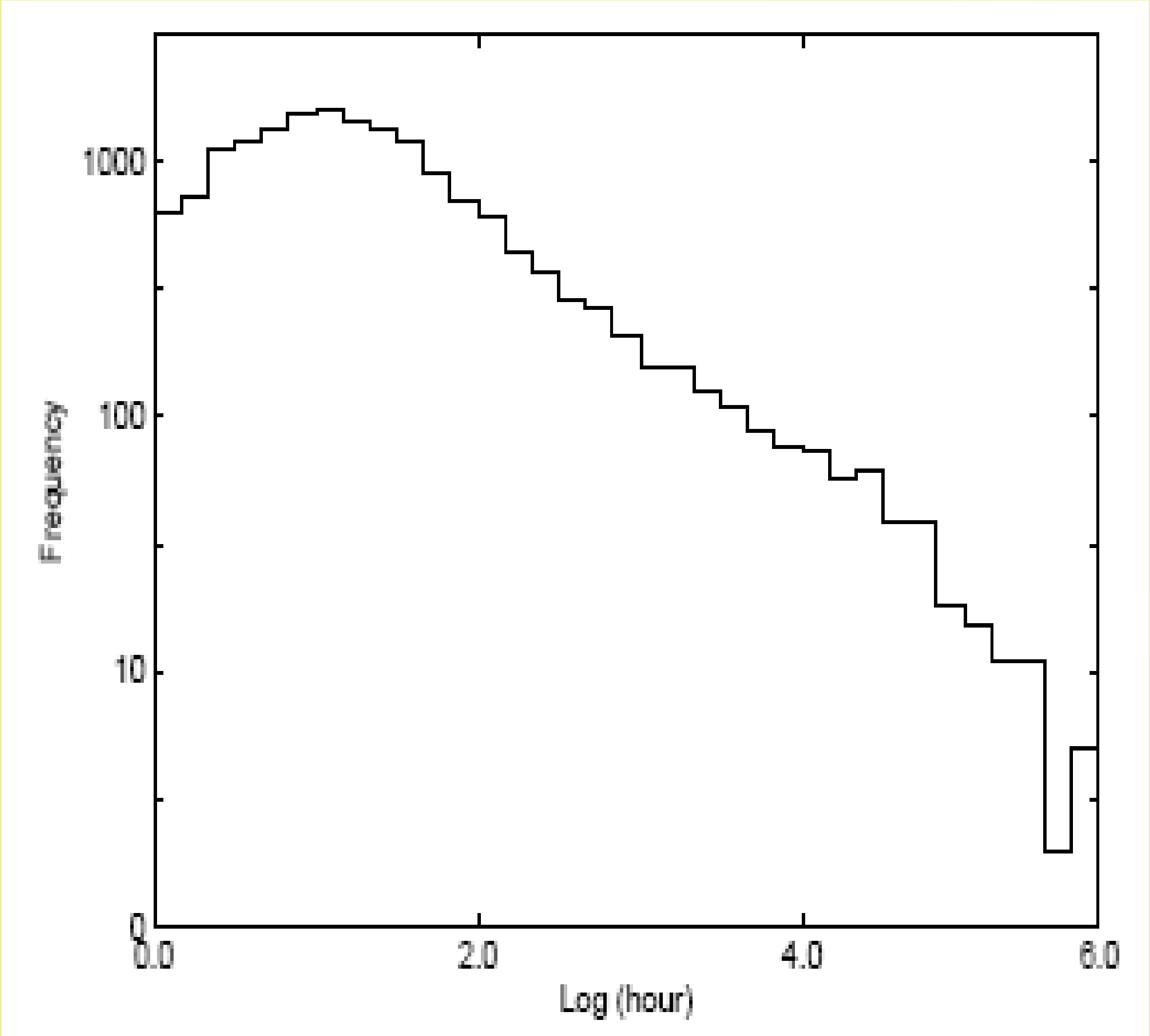
CACTus: delay ~6 months

SEEDS: delay ~1 year during the declining phase

ARTEMIS: no significant delay

CME Recurrence

Studied by Wagner and Wagner (1998) on SMM CMEs. We analysed the distribution of the intervals of time between consecutive CMEs.

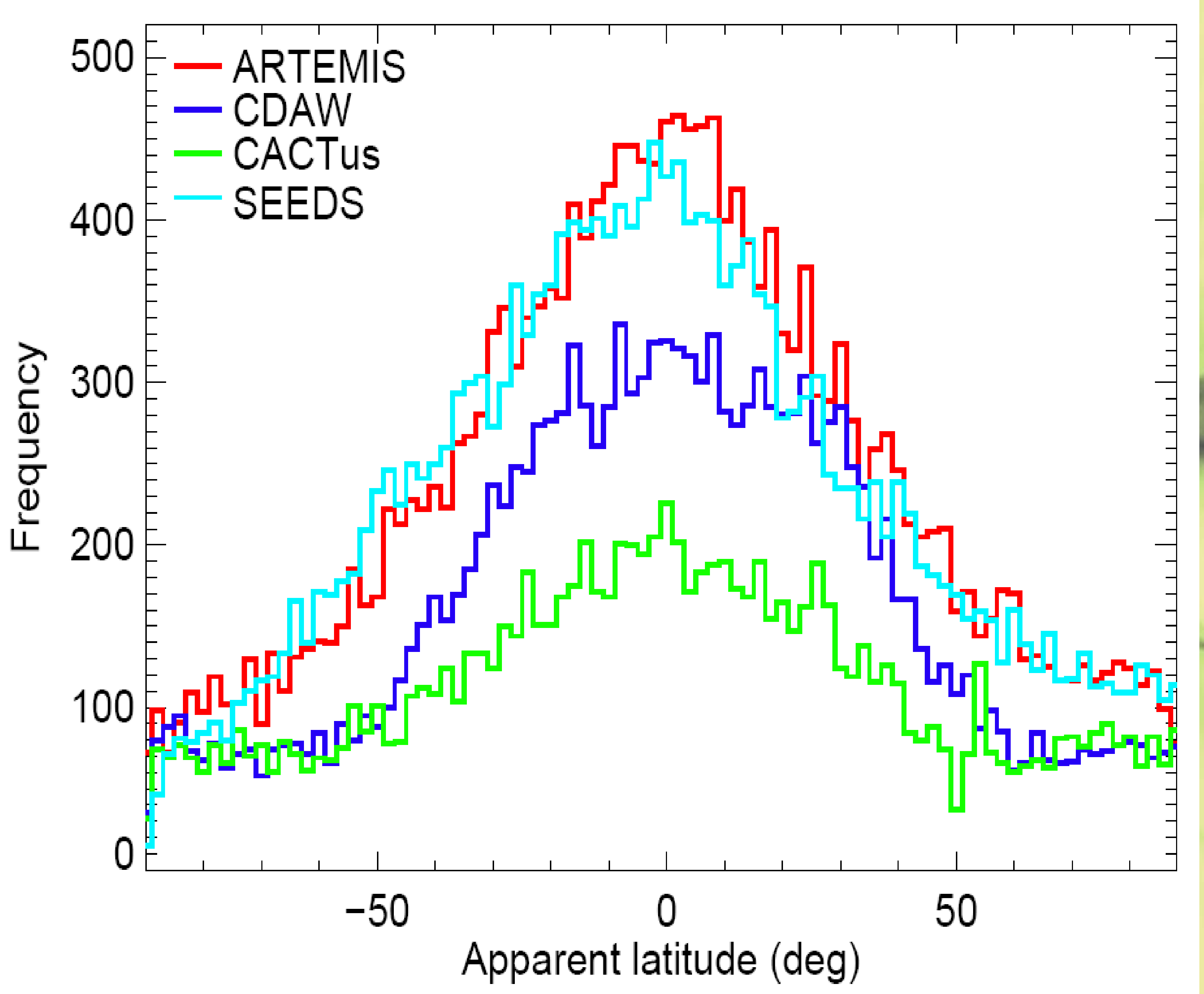


Conclusions :

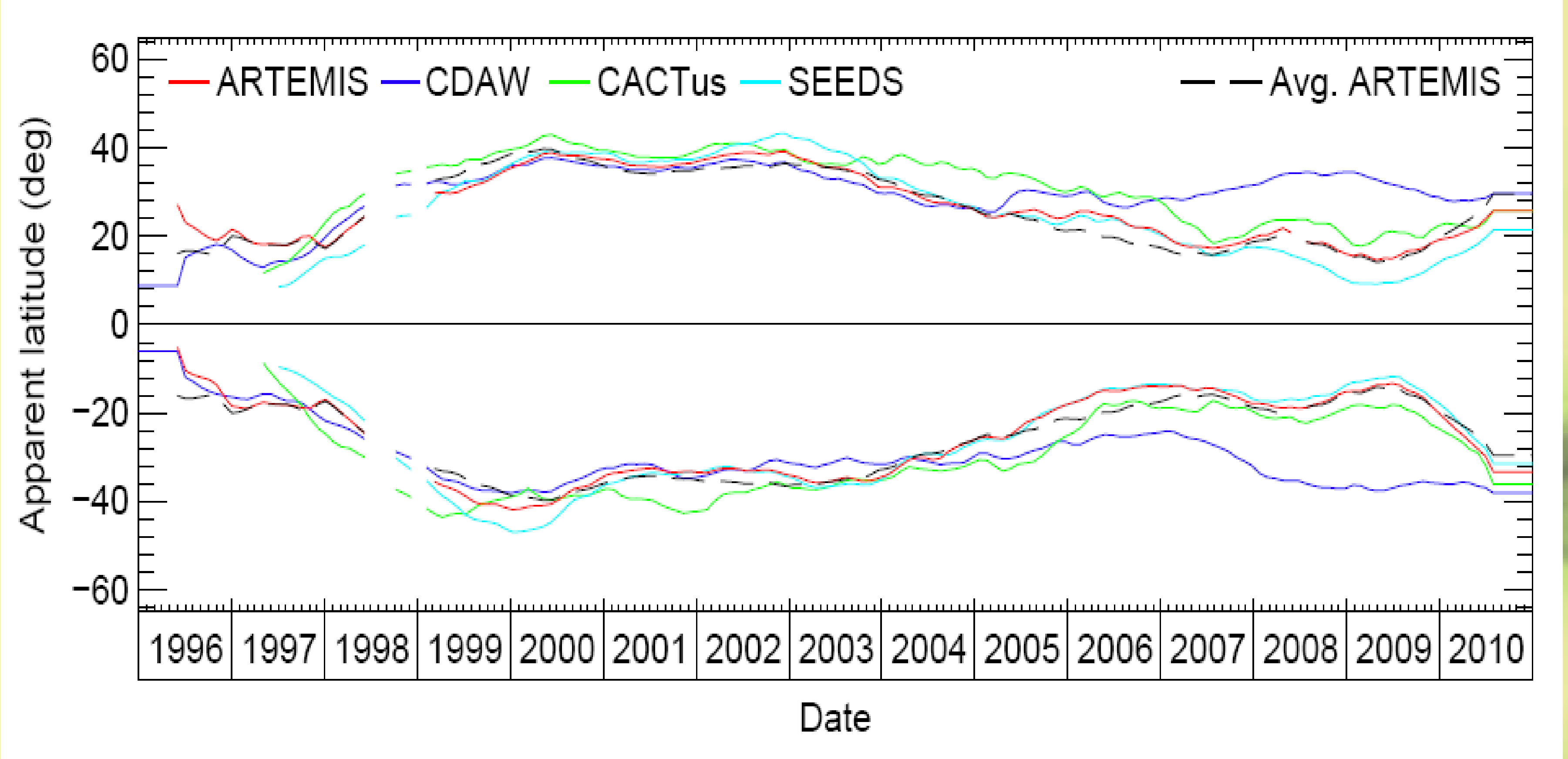
- Broad maximum ~ 2 hours.
- Typical Poisson process without memory for delays> 90 min .
  → Independent CMEs.
- Below 90 min : behaviour biased by the present observation cadence.

CME APPARENT CENTRAL LATITUDE

Global distributions of apparent latitude



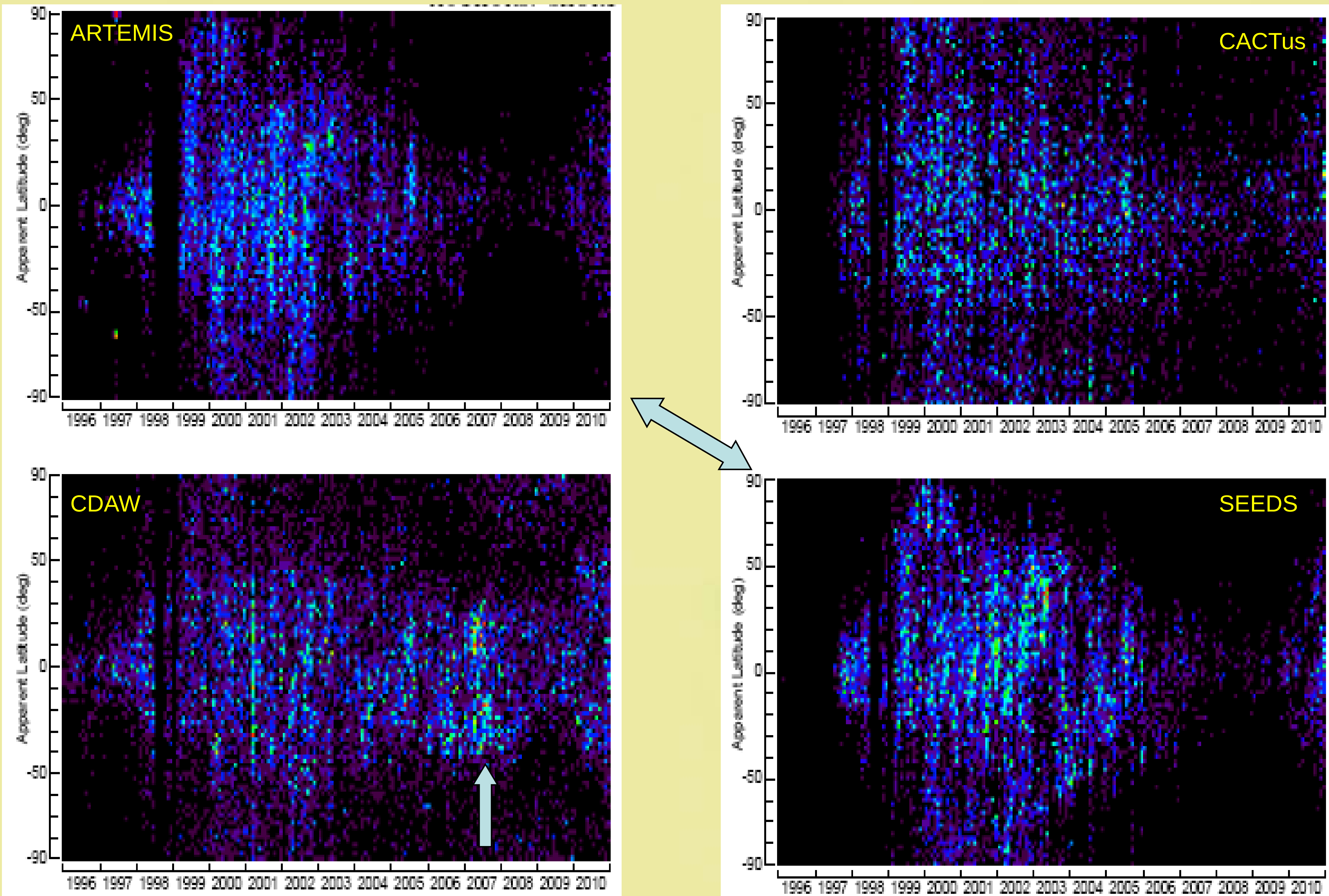
Distributions of the north and south apparent latitudes



Monthly variations of the mean values of the north and south apparent latotudes of CMEs. Note the symmetry and the excellent agreement between the 3 catalogs ARTEMIS, CACTus and SEEDS. Unlike CDAW, they all show a significant decrease during the minimum of activity.

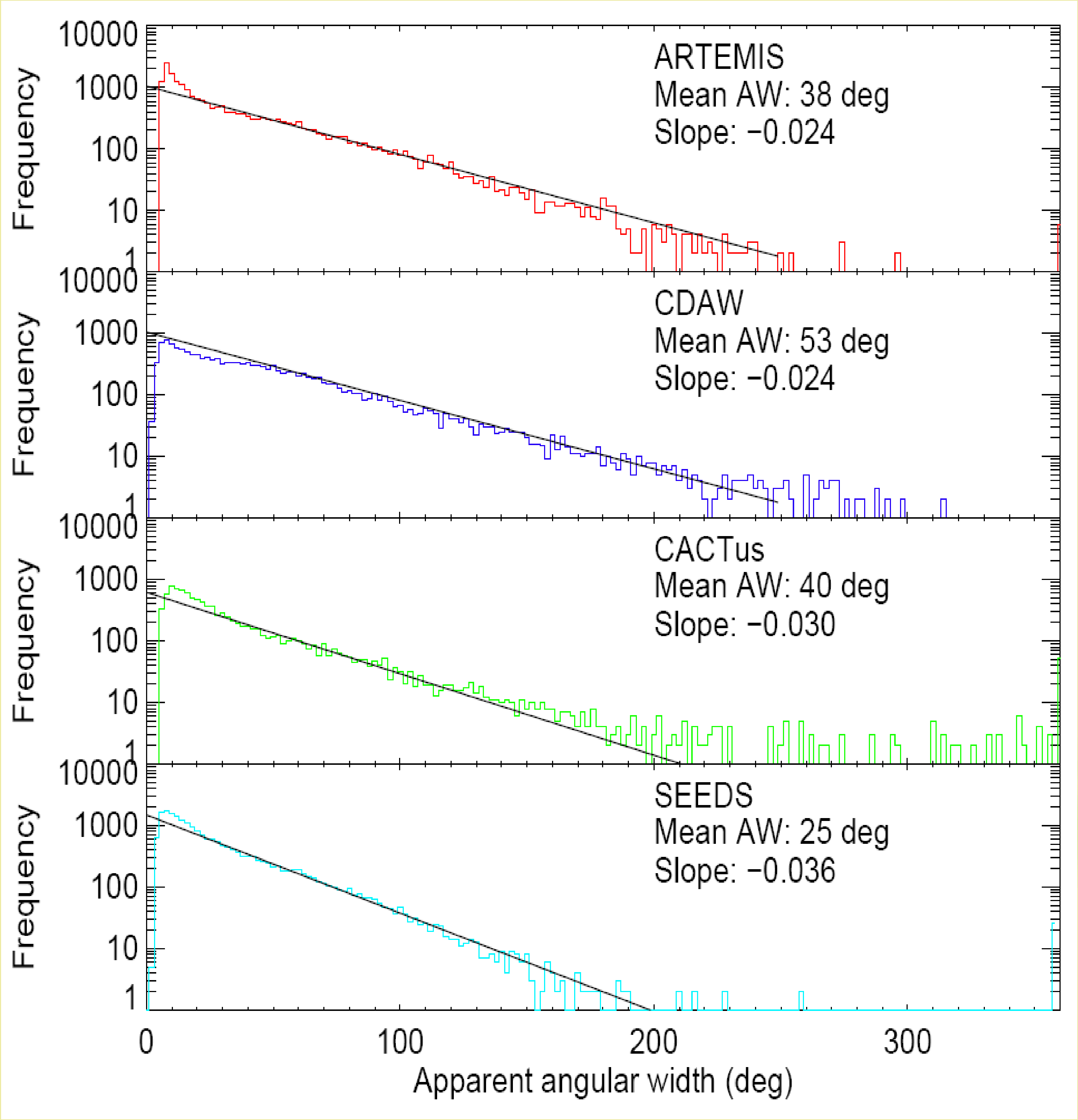
SEEDS CDAW

Scatterplots of the apparent latitude



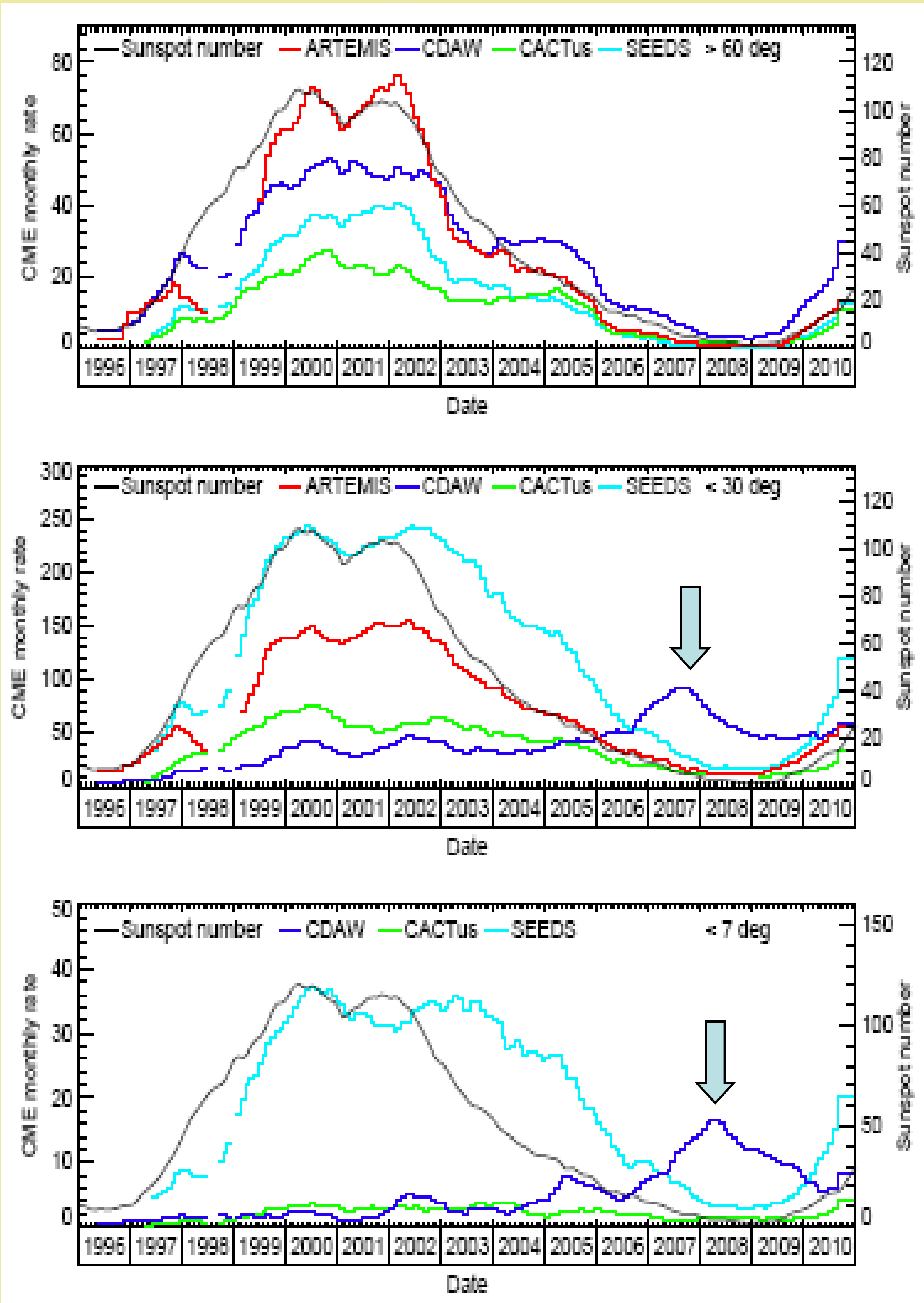
CME APPARENT ANGULAR WIDTH

Distribution of the apparent width



- Straight line fits indicate that the distributions follow exponential laws
- Their slopes are indicative of the widths of the distributions
- Excellent agreement between ARTEMIS and CACTus

Monthly rate of CME versus apparent width



aw > 60°

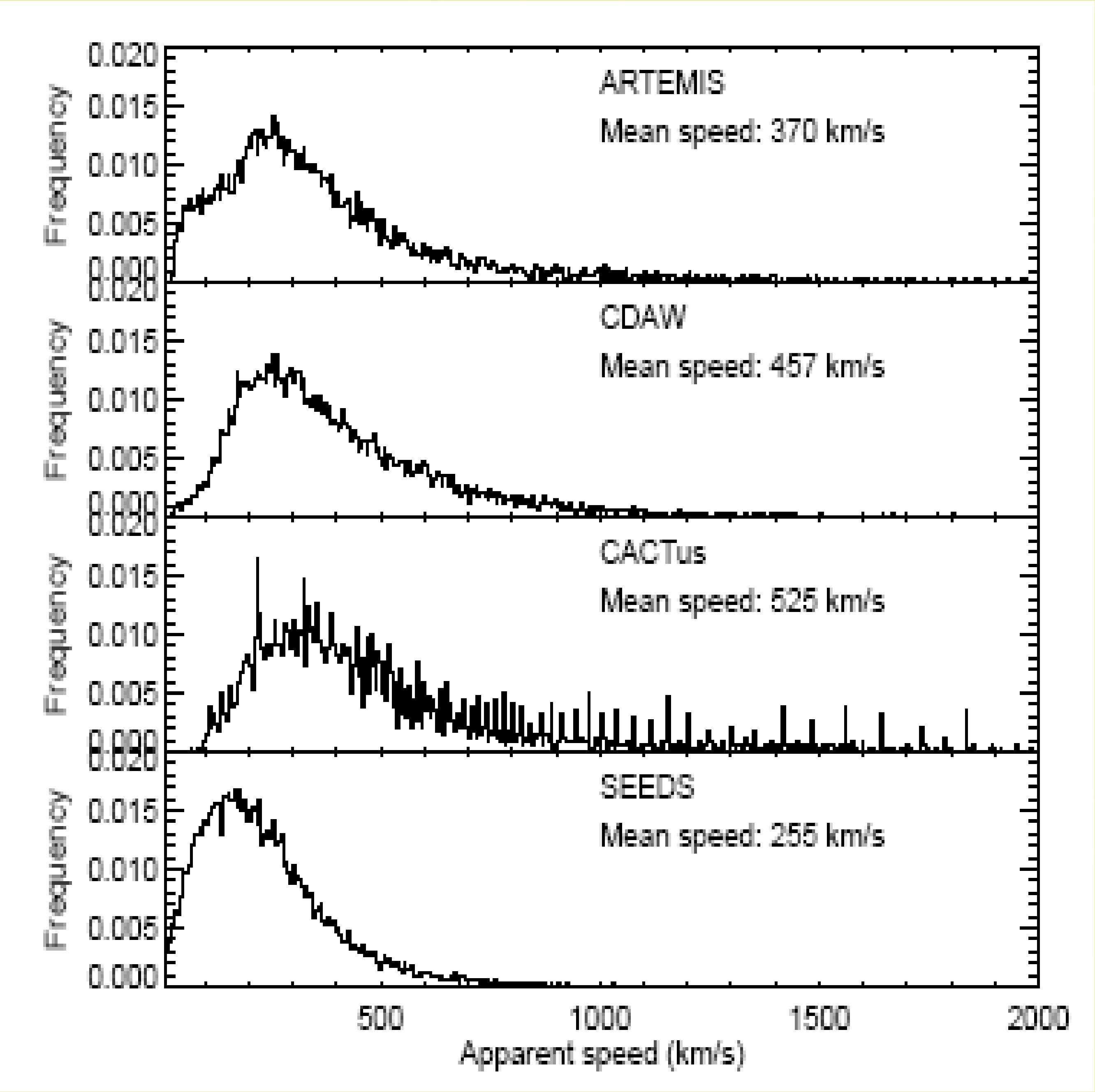
aw < 30°

aw < 7°

The surplus of events reported by CDAW (see arrows) concerns relatively narrow CMEs of low velocity (see later). They are generally faint and many are qualified as "uncertain"

CME KINEMATICS

Distribution of the apparent velocity



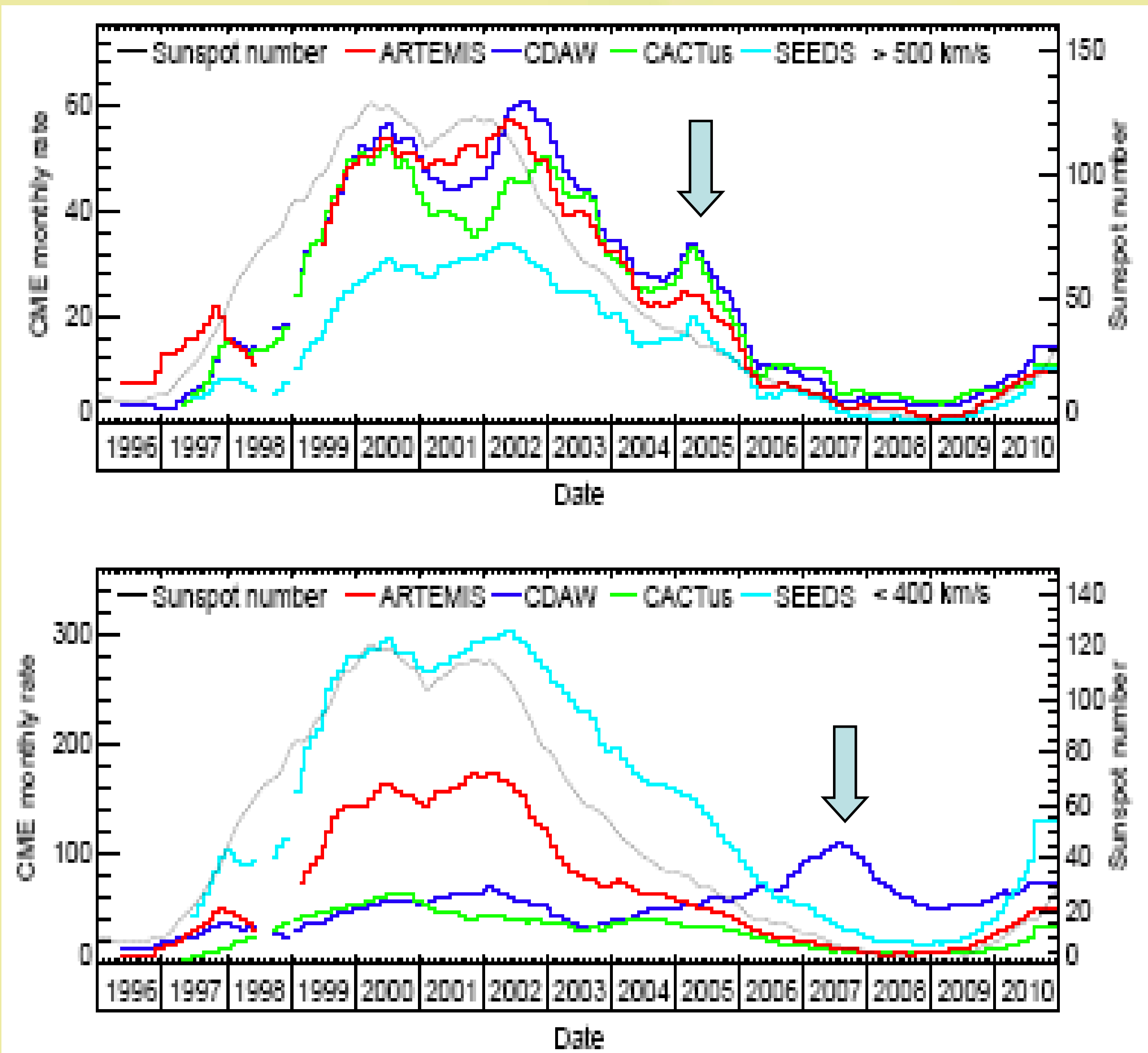
-The definition of a single velocity remains ambiguous. A velocity field is more appropriate but more complex

-The results depend very much upon the method of determination (front, center of gravity,…)

-The very large mean speed from the CACTus catalog is biased by a number of very fast CMEs (V>1000 km/sec) not reported by the other 3 catalogs.

Monthly rate of CME versus velocity range

V > 500 km/s



V < 400 km/s

Note the uprise of fast CMEs in 2005 reported by all catalogs (see arrow

The surplus of events reported by CDAW in 2007 (see arrow) concerns relatively slow CMEs

Correlations with solar/coronal activity

Radio flux at 10.7 cm (F10.7) more representative of coronal activity than the sunspot number

Soft Xray flux

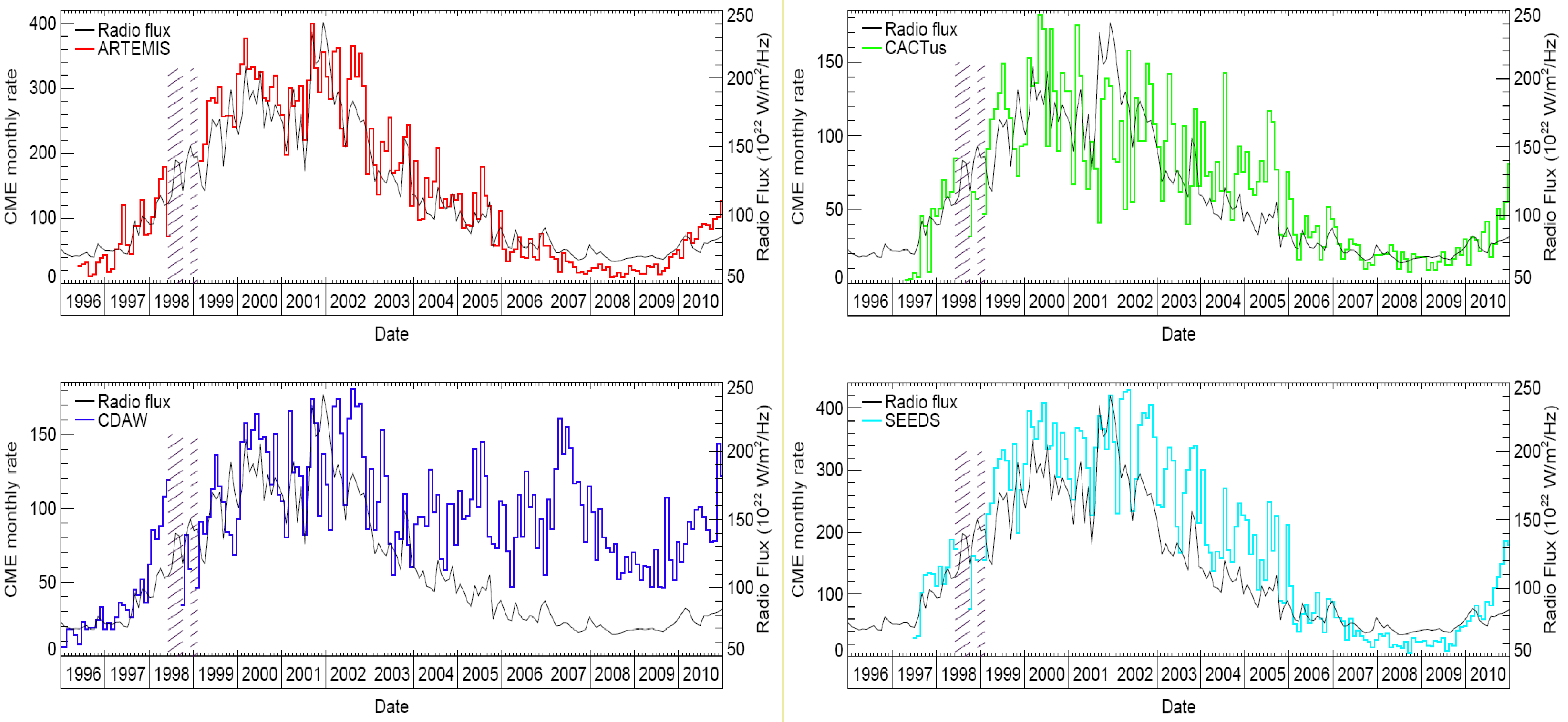
GOES Xray flares

Total X+M+C flares

Total X+M flares

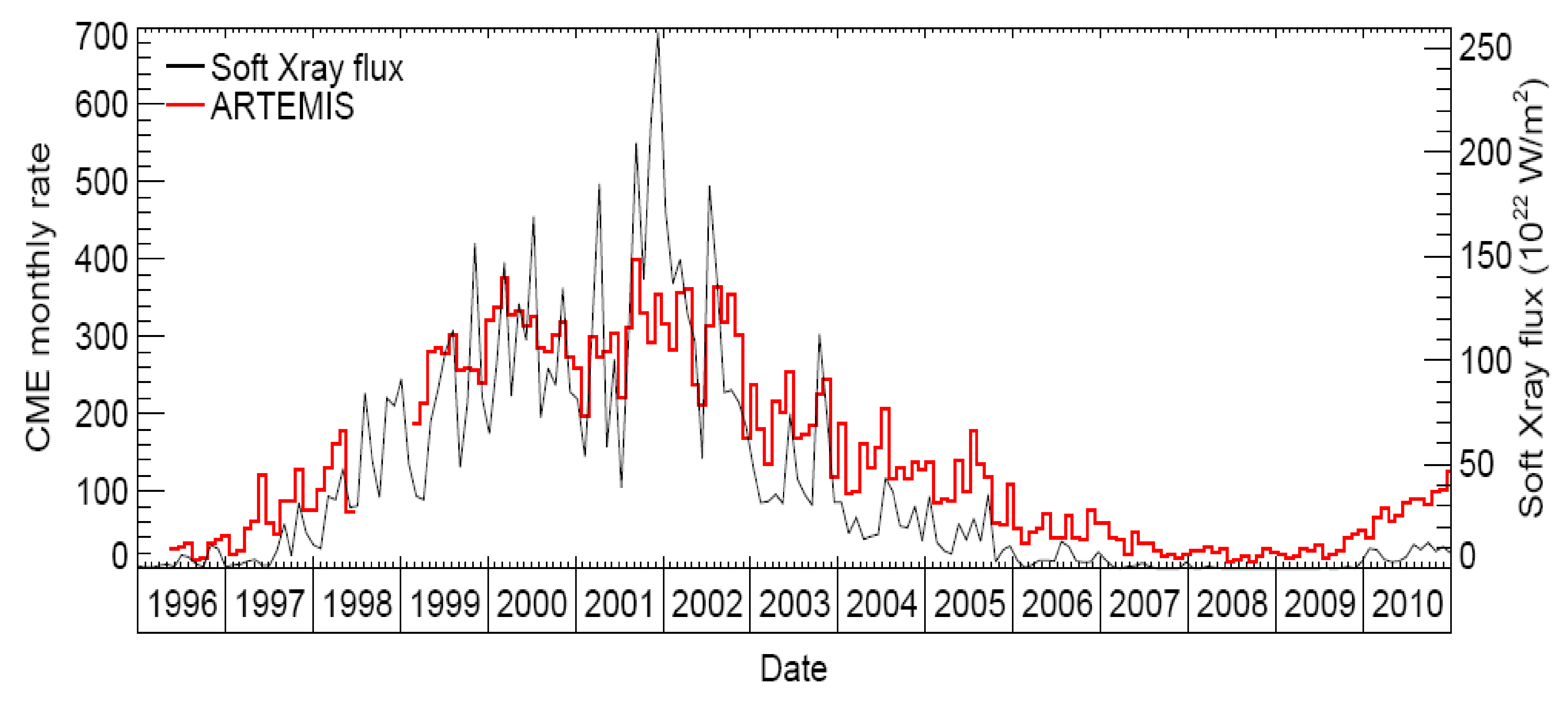
H-alpha flares

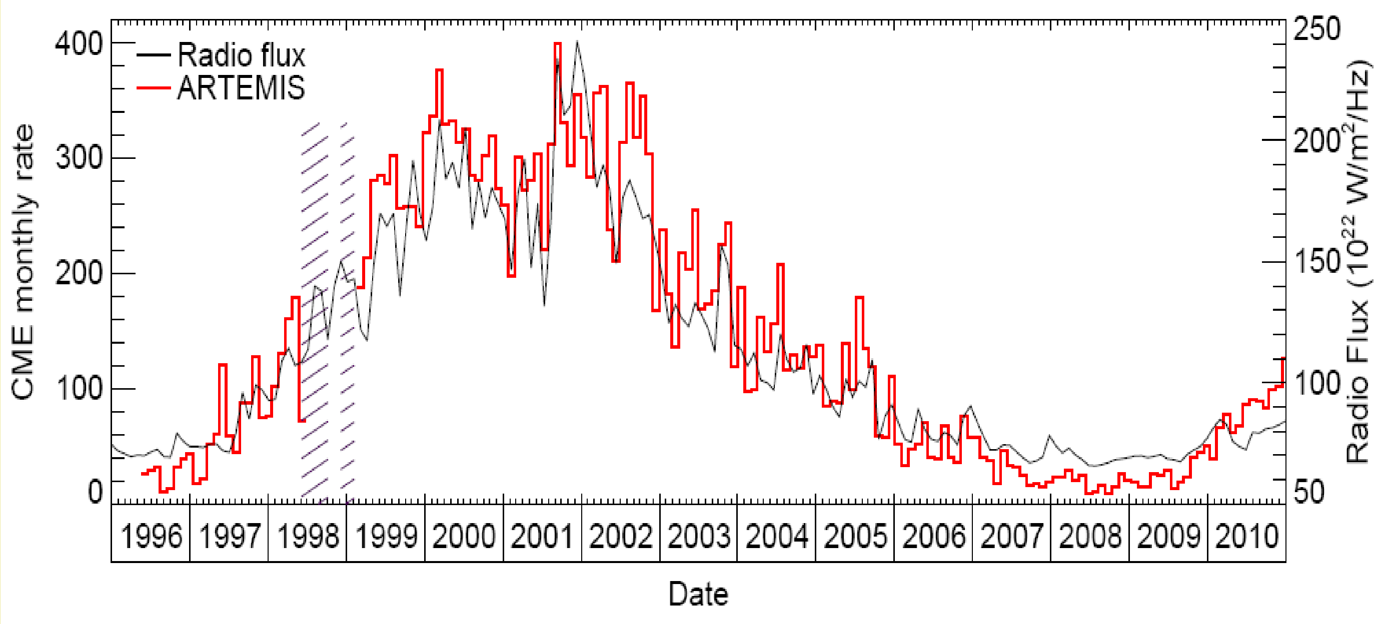
Comparison with the solar radio flux at 10.7 cm



ARTEMIS, SEEDS and CACTUS follow well the global trend of F10.7, contrary to CDAW. Note the excellent agreement between ARTEMIS and F10.7 at the level of many temporal substructures.

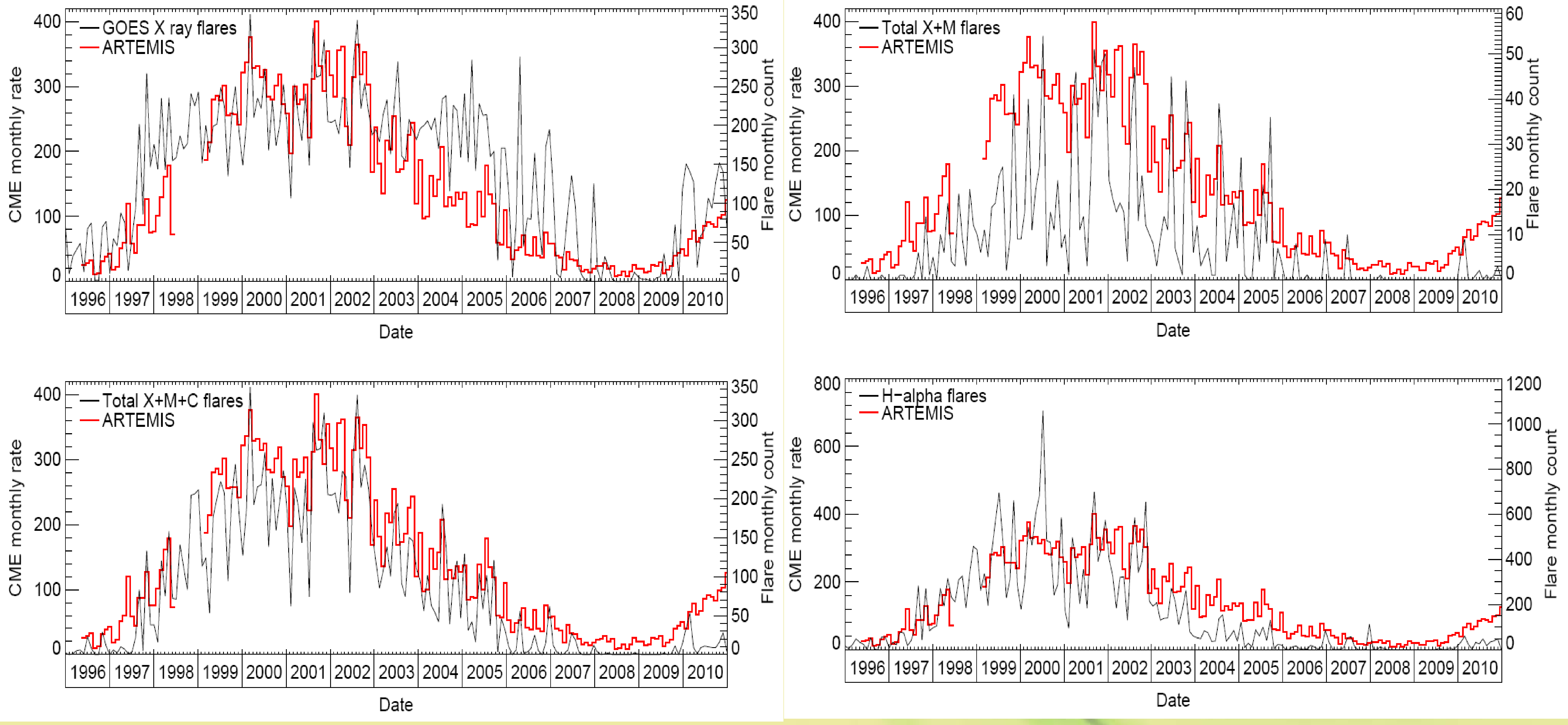
Comparison with the soft X-ray flux (GOES)





- Rough agreement as most extrema (but not all) are in phase
- Several coincident peaks during the descending phase
- Globally the correspondence is inferior to that with the radio flux (at left)

Comparison of ARTEMIS CMEs with flares



- Rough agreement as most extrema (but not all) are in phase
- Several coincident peaks during the descending phase
- Best agreement is with the rate of X+M+C flares

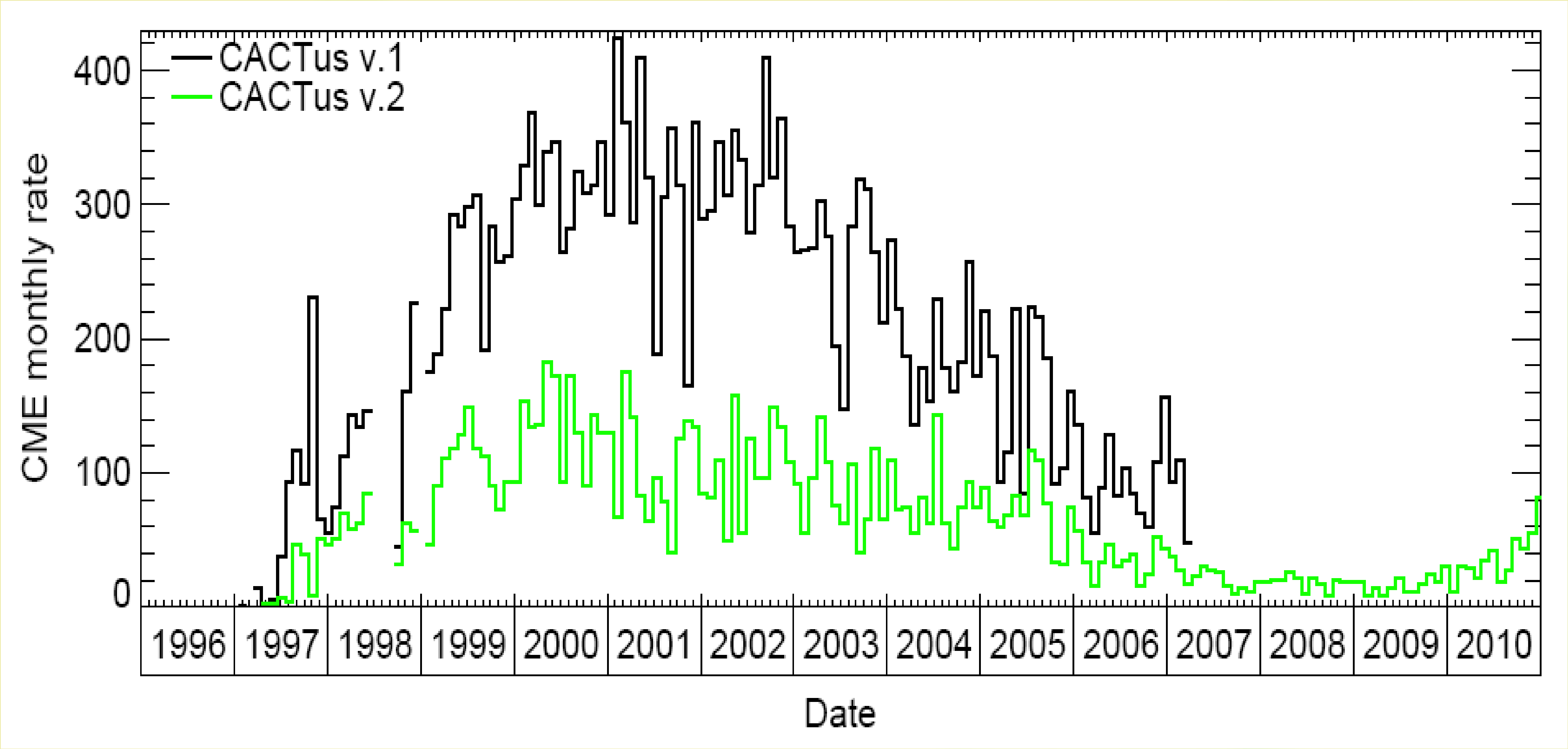
Conclusion

1. Using the CDAW catalog for statistical analysis is not recommended.
2. Significant number of faint CMEs seen in all automatic catalogs, indicating a continuous distribution down to blobs forming the inhomogeneous slow solar wind.
3. The CME rate follow the pattern of solar activity of most proxies, but no one-to-one correspondence.
4. Our statistical analysis is not yet complete, but it already support different origins (flares, erupting prominences, streamer detachments and blowouts).
5. “CME” most likely cover a broad class of transients phenomena resulting from different processes, and resulting in different interactions with the corona.

END
Thank you for your attention

Additional material

Comparison of the two versions of the CACTus catalog



Version 2 reports only 30% of the CMEs listed in version 1