Drag-Based Ensemble Model (DBEM)

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DBEM with ensemble and synthetic measurements

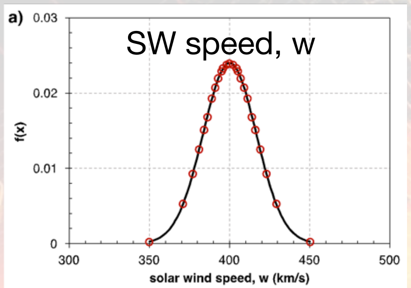
Dumbović et al., ApJ, 2018

INPUT

Ensemble of CME measurements:

$T_1, v_1, \phi_1, \lambda_1$
$T_2, v_2, \phi_2, \lambda_2$
…
$T_n, v_n, \phi_n, \lambda_n$

n inputs

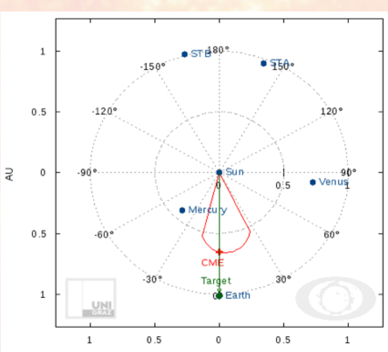


Synthetic values for:
w_1, γ_2 / w_2, γ_2
…
w_m, γ_m

m x m inputs

RUNS

nm^2 combinations (ensemble members)
nm^2 DBM runs

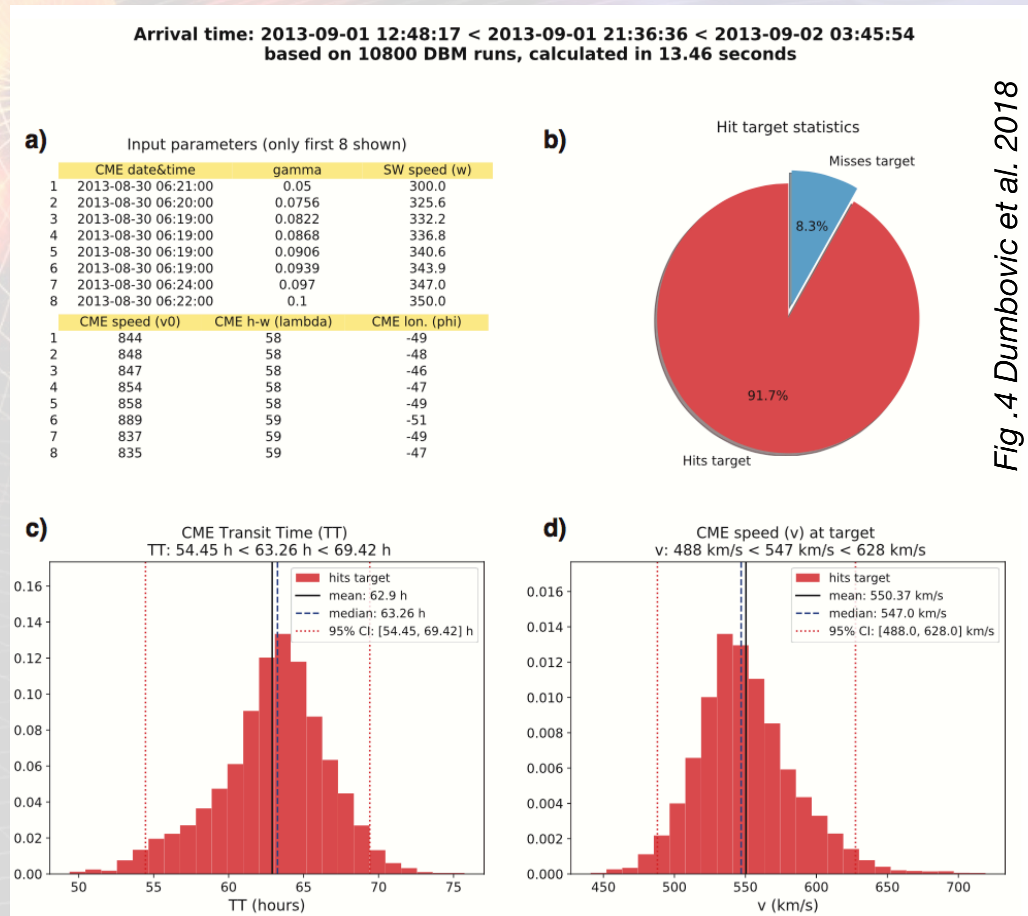


2D DBM (*Žic et al., 2015, ApJ*)

- hit or no hit
- transit time
- arrival time
- arrival speed

Ensemble modeling applied to Drag-based Model (DBM, *Vršnak et al., 2013, SolPhys*)

DBEM OUTPUT



	CME date&time	gamma	SW speed (w)
1	2013-08-30 06:21:00	0.05	300.0
2	2013-08-30 06:20:00	0.0756	325.6
3	2013-08-30 06:19:00	0.0822	332.2
4	2013-08-30 06:19:00	0.0868	336.8
5	2013-08-30 06:19:00	0.0906	340.6
6	2013-08-30 06:19:00	0.0939	343.9
7	2013-08-30 06:24:00	0.097	347.0
8	2013-08-30 06:22:00	0.1	350.0

	CME speed (v0)	CME h-w (lambda)	CME lon. (phi)
1	844	58	-49
2	848	58	-48
3	847	58	-46
4	854	58	-47
5	858	58	-49
6	889	59	-51
7	837	59	-49
8	835	59	-47

Fig .4 Dumbovic et al. 2018

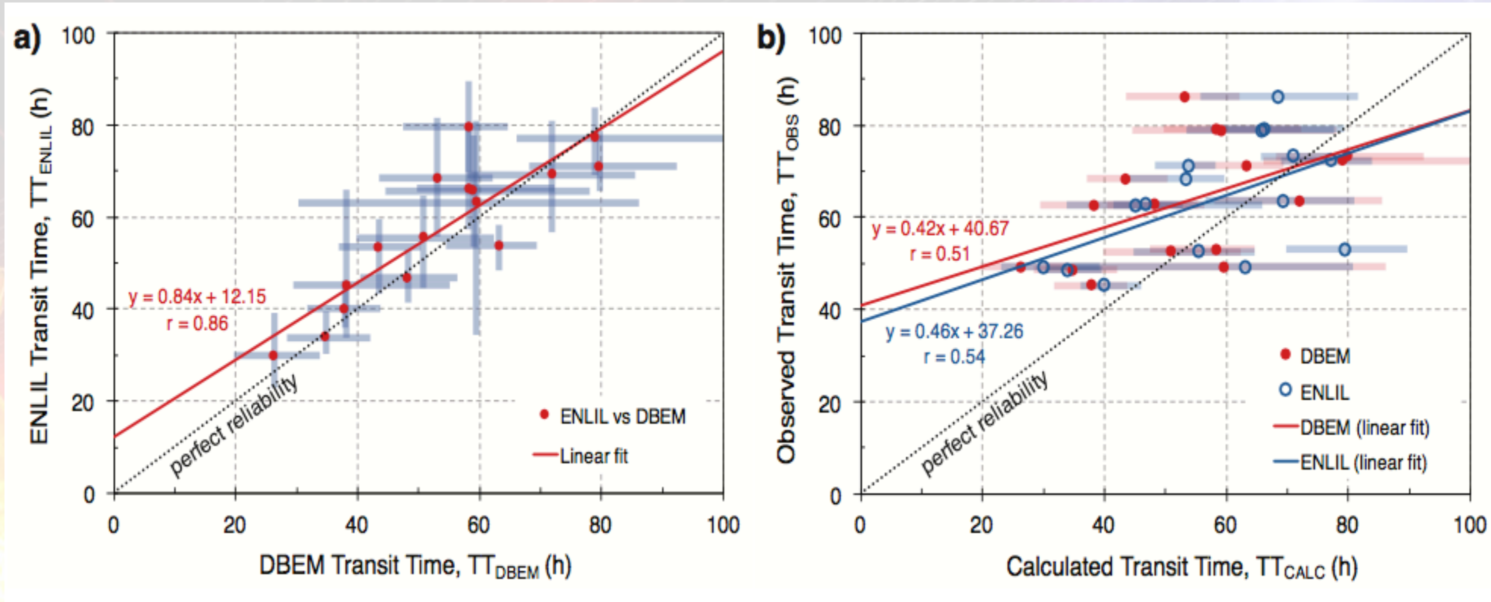
Performance and comparison with ENLIL

- Based on sample: *Mays et al., 2015, SolPhys*

- Both ENLIL and DBEM are not far away from the line of perfect reliability

TRANSIT TIME

Fig. 7 from Dumbović et al., 2018



RELIABILITY DIAGRAM

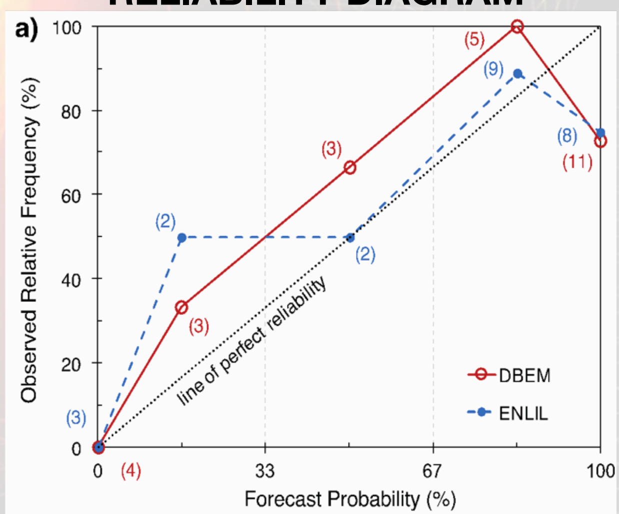


Fig. 5 from Dumbovic et al. , 2018

ARRIVAL SPEED

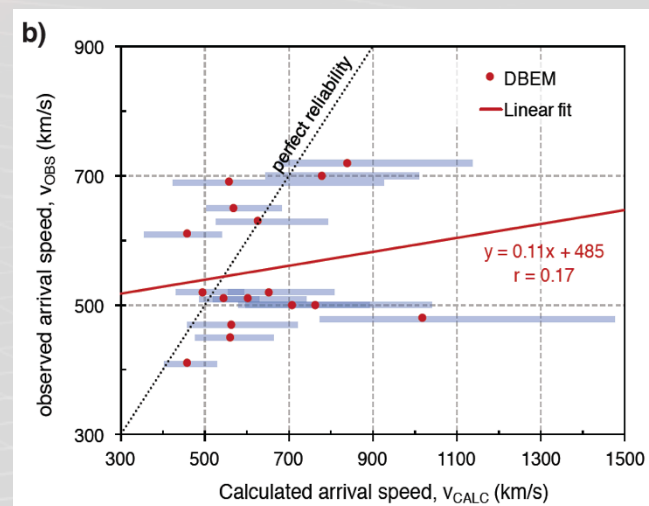


Fig. 8 from Dumbovic et al., 2018

Main points - DBEM

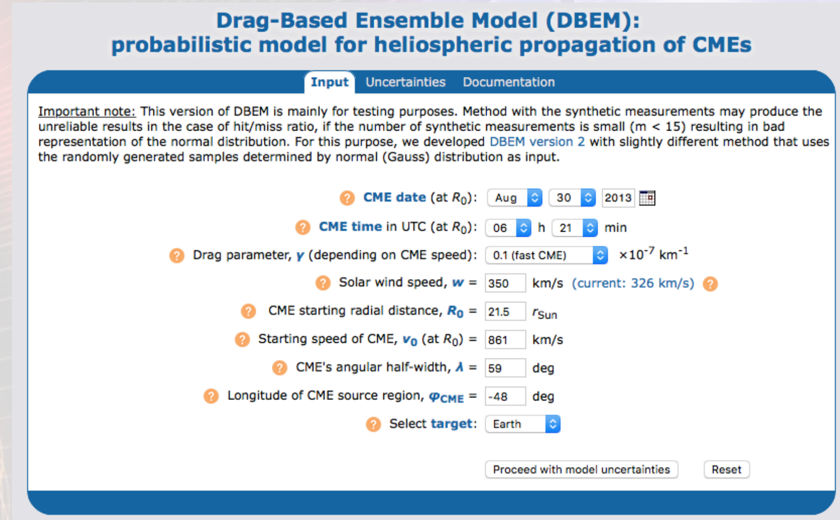
Dumbović et al., ApJ, 2018

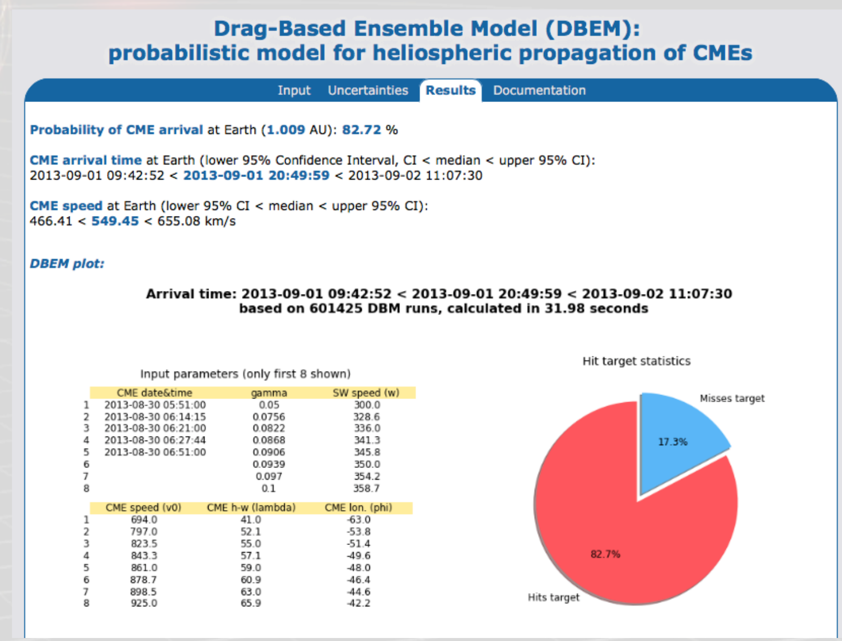
- Offers probabilistic forecasting of **CME hit chance**, **transit time** and **arrival speed** for different targets in solar system
- Reliable and simple model
- Runs **very fast** (more than 1000 DBM runs per sec on a single CPU)
- ENLIL and DBEM perform similarly
- Fast CMEs predicted to arrive too early for both DBEM and ENLIL
- Suitable for implementation as on-line (web) forecasting tool: **DBEMv1** and **DBEMv2** - ESA Expert Service Group for Solar & Heliospheric Weather (swe.uni-graz.at)

c) prediction errors for TT (h)	DBEM	ENLIL
mean error (ME)	-9.7	-6.1
mean absolute error (MAE)	14.3	12.8
root mean square error ($RMSE$)	16.7	14.4

On-line DBEMv1 tool with synthetic measurements

- Needs as input only one CME measurement with estimated uncertainties
- Uses **synthetic measurements for all 6 input parameters** (T, v, ϕ, λ, w, ɣ)
- Needs certain number of synthetic measurements (m > 9) to perform reliably - large number of DBM calculations (slow)
- **DBEMv2** is faster and more reliable than DBEMv1



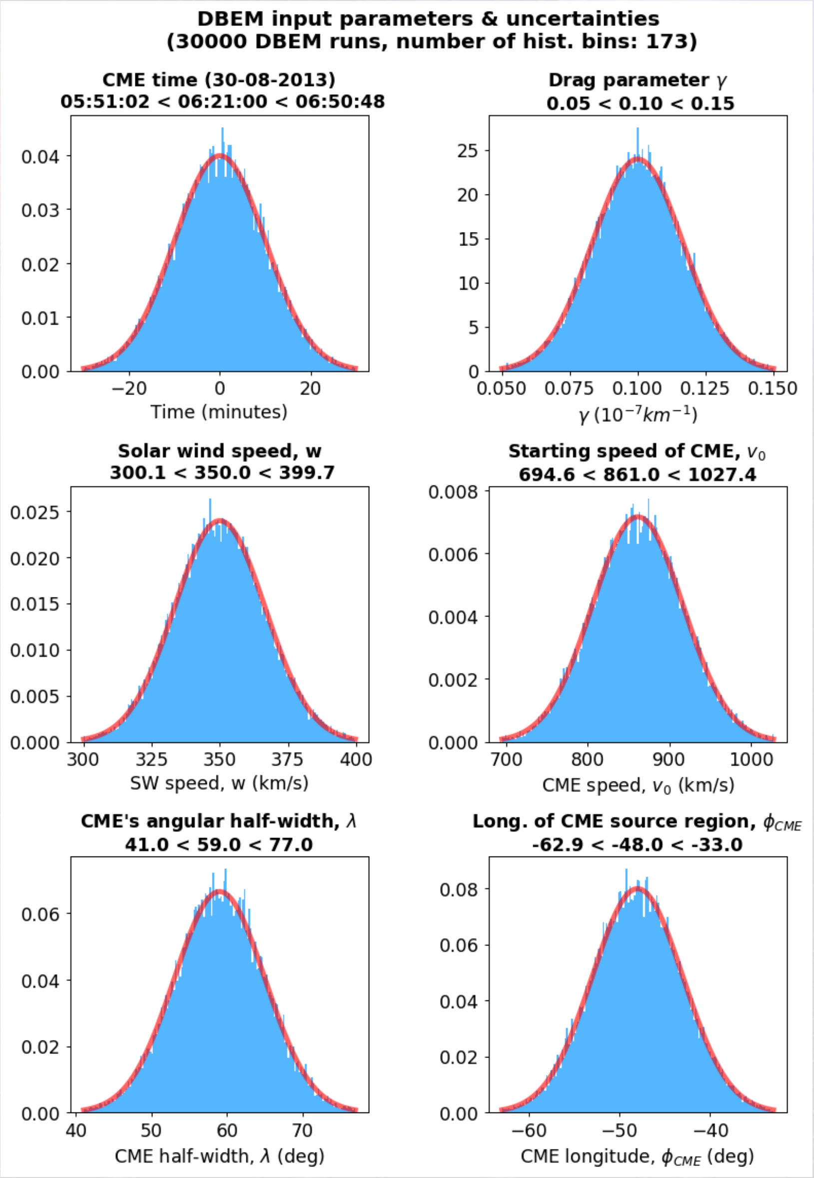


1. oh.geof.unizg.hr/DBEM
2. phyk039240.uni-graz.at:8080/DBEM

DBEMv2 (version 2) input parameters

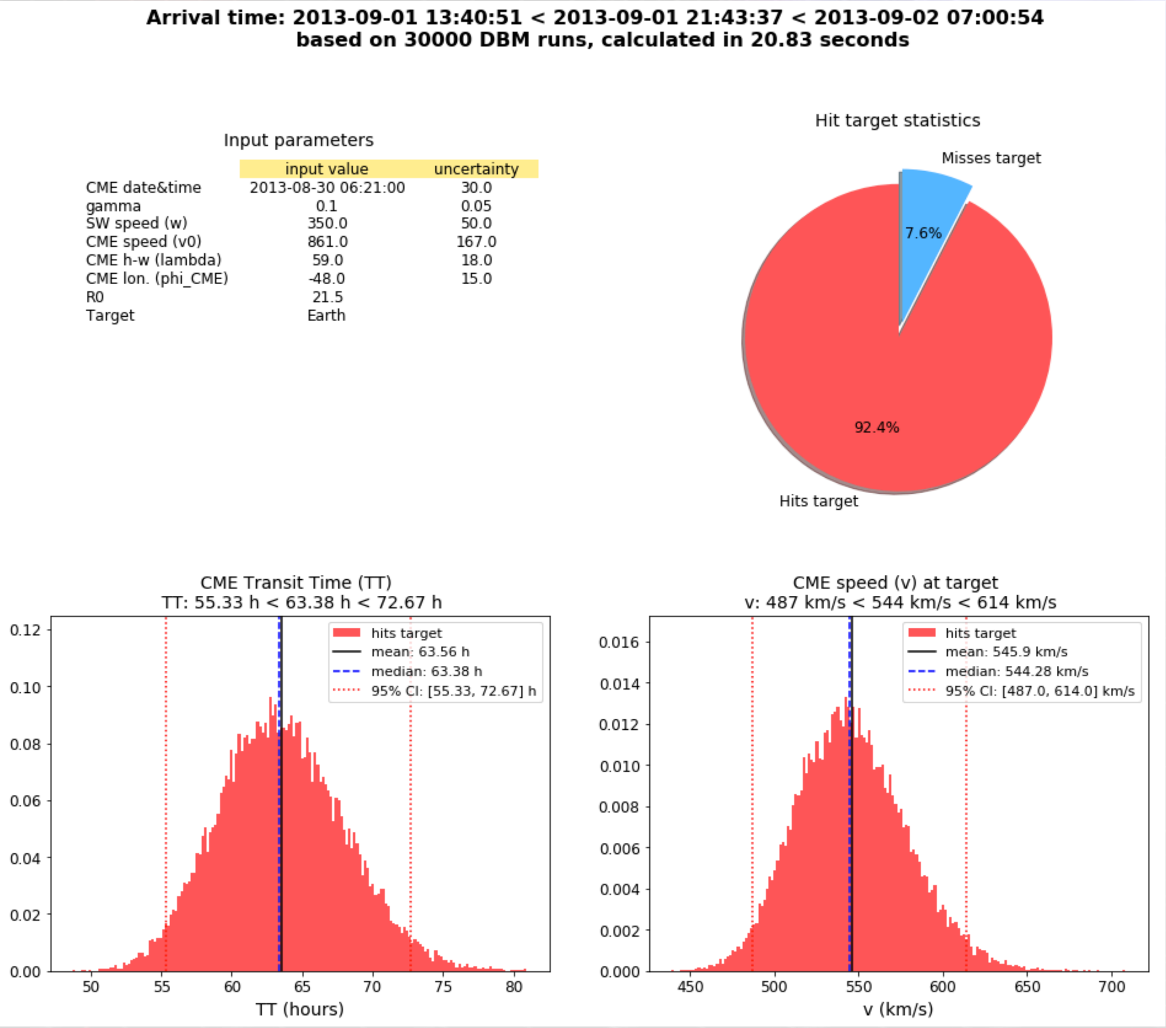
Čalogović et al., in preparation

- Same engine (software) as DBEMv1 with synthetic measurements, however different method is used for input uncertainties
- For all 6 input parameters (T, v, ϕ, λ, w, ɣ) random values are generated in a range input ± uncertainty (3 σ) following a normal (Gaussian) distribution
- <u>Advantages:</u>
    - input distributions are better represented than with DBEMv1
    - converges to stable results much faster than method with syn. measurements
    - allows lower number of DBM runs - **faster**
    - user can choose the exact number of DBEM runs
- <u>Disadvantages:</u>
    - due to random input, it produces every time slightly different results - differences converge with increasing nr. of runs (differences are negligible at >10 000 runs)



DBEMv2 results

- More accurate hit/miss ratio due to better representation of normal distribution in uncertainty range
- Provides statistics (mean, min, max, StDev, CI) for all calculated parameters
- User can download all results in a zip file
- Will be soon integrated in **ESA SSA portal** as operational forecasting tool in the frame of the **ESA Expert Service Group for Solar & Heliospheric Weather** (swe.ssa.esa.int/heliospheric-weather) -



DBEMv2 on-line tool

1. http://oh.geof.unizg.hr/DBEMv2
2. http://phyk039240.uni-graz.at:8080/DBEMv2