**Tools for Predicting** and Reconstructing **Properties of Solar** Cycles **Summary & Discussion** Roman Brajša Hvar Observatory, Faculty of Geodesy, University of Zagreb Croatia

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### The Reduction Methods: 1-3

1) Asymmetry of the ascending and descending solar cycle phases (Gleissberg et al. 1979) 2) Correlation Rmin, Rmax (Wilson 1990) 3) prediction of relative sunspot number by fitting an ARMA(p,q) model: Autoregressive Moving Average Model (Gardner et al. 1980; Brockwell & Davis 1996; Durbin & Koopman 2001)

#### The Reduction Methods: 4-6

4) Damped Random Walk Model (DRW) (MacLeod et al. 2010; Kelly et al. 2011) 5) Connection between the starting latitudes and amplitudes of the solar cycles 6) Relation between the number of spotless days in minima and the amplitude of the next maxima (the considered period of spotless days is one year after minimum)

#### The Reduction Methods: 7-8

7) Waldmeier effect: relation between the rising time and amplitude in maximum
8) Combination of these methods: combination of ARMA, DRW, Waldmeier effect, & asymmetry methods



# Our forecast summary for the 24th solar cycle:

- will be weaker than no. 23 (Rmax = 121):
- Rmax = 116 ± 55 (DRW)
- Rmax =  $104 \pm 23$  (no. of spotless days)
- Rmax = 98 ± 22 (starting latitude)
- Rmax = 86 ± 20 (ARMA)
- Rmax = 84 ± 5 (min max)
- Rmax ≈ 55 (comination, asymmetry)
- 2013.5 < Tmax < 2014.5
- 2018.5 < Tmin < 2019.6</p>

Some controversies and prospects: A curious solar minimum ? Should the sunspot number be recalibrated? (jumps in 1946, 1981?) Does the number of spotless days depend on measurement precision? A weakening trend in solar activity ? Non-linear effects, chaotic properies ?  $\rightarrow$  implications for predictions... Different indexes: daily, monthly, monthly smoothed, yearly; SGN, etc... Check the reliability of the fits and include latest data for some methods

### A curious solar minimum ? (Nov. – Dec. 2008)







# Non linear effects -> Chaotic properties

Non linear differential equations, higher order terms -> chaotic solutions Examples: Equation of motion  $\rho \partial \mathbf{v} / \partial t = \dots \mathbf{j} \times \mathbf{B} \dots$ *j ~ B* Dynamo equation:  $\partial \mathbf{B} / \partial t = \dots \alpha (\mathbf{B}^2) \dots$ 

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