

Table of contents

List of figures	xxvii
List of tables	xxxv
1 An introduction of the Sun and its magnetic activity	1
1.1 The Sun: Its many layers	3
1.1.1 The Internal structure	3
1.1.2 The External structure: The Solar Atmosphere	6
1.2 The Sunspots: The protagonist of the story	8
1.2.1 What they are: The basic properties	8
1.2.2 The Bipolar Magnetic Regions: They have a life of their own . . .	10
1.2.3 The formation of the sunspots: The rise of the buoyant flux tubes .	11
1.3 The Solar Cycles: Spans from decadal to millennial time scales	12
1.3.1 Measuring the solar activity: Different proxies	13
1.3.2 Properties of the 11-year solar cycle: The enigmatic features . . .	15
1.3.3 Long-term trend of the solar activity: Looking beyond the decadal scale	17
1.4 The Solar Dynamo: Magnetohydrodynamics in action	20
1.4.1 The MHD equations: Frozen magnetic fields move with the plasma	22

1.4.2	Mean-Field Dynamo Theory: Separating the fluctuations from the mean	24
1.4.3	The Kinematic and Axisymmetric approximations	26
1.4.4	Babcock-Leighton Mechanism: Flux Transport Dynamo	29
1.4.5	Global MHD simulation of solar dynamo: The final frontier	33
1.5	Space Weather: The Sun-Earth connection	34
1.6	Outline of the thesis	37
2	Nonlinear flux loss from solar interior and its role in explaining the observed properties of solar cycle evolution	39
2.1	Introduction	39
2.2	Model Description	42
2.3	Results	45
2.4	Conclusions	57
3	Role of Nonlinearities and Stochasticities in the long term modulation of Solar Cycles	59
3.1	Introduction	59
3.2	Causes for long-term variations in the solar activity	61
3.2.1	Nonlinearities in the dynamo	61
3.2.2	Stochastic effects in the dynamo	67
3.3	Babcock–Leighton dynamo models for the long-term variation	69
3.4	Conclusion	72
4	Exploring the polar field rise rate as a precursor for an early prediction of solar cycle	75
4.1	Introduction	75
4.2	Model and Synthetic BMR profile	80

4.2.1	The Surface Flux Transport Model	80
4.2.2	The profile of the synthetic BMRs	82
4.2.3	A note on the distribution of BMR tilt	85
4.2.4	Calculation of polar field and the toroidal field of the following cycle	87
4.3	Methodology of data analysis	88
4.4	Results and Discussions	90
4.5	Conclusion	97
5	Probing the variations in the reversal timing of the Sun's polar field	99
5.1	Introduction	99
5.2	Observational results	101
5.3	Results from the Surface Flux Transport simulations	103
5.4	Conclusion	108
6	Forecasting the geoeffectiveness of CMEs using Artificial Neural Network and forward modeling	109
6.1	Introduction	109
6.2	Data and Method	111
6.3	Results and Discussions	116
6.4	Conclusion	122
7	Conclusion	125
	References	129