Reinforcement Learning Based Resolution Improvement of Geophysical Data

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Under The Guidance Of

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Objective:

- Objective is to predict unknown IGRF coefficients for the epoch 1900 to 1995 for degree n = 11 to n=13.
- Create a model specifically for the IGRF values using different methodologies to predict the best possible missing values

Data:

- The magnetic potential due to the internal origin:

$$V(r,\theta,\phi) = R\sum_{n=0}^{N}\left(\frac{R}{r}\right)^{n+1}\sum_{m=0}^{n}\left[g_n^m\cos m\phi + h_n^m\sin m\phi\right]P_n^m(cos\theta)$$

- From 1900 to 1995 we have IGRF constants till n=10 only.
- After 2000 we have IGRF constants till n=13.

Challenges with machine learning algorithms:

- Small data set.
- Number of values to be predicted is large.
- Model should satisfy the laws of Physics.

Reinforcement learning:

- Agent
- Environment
- State
- Action
- Reward
- Policy

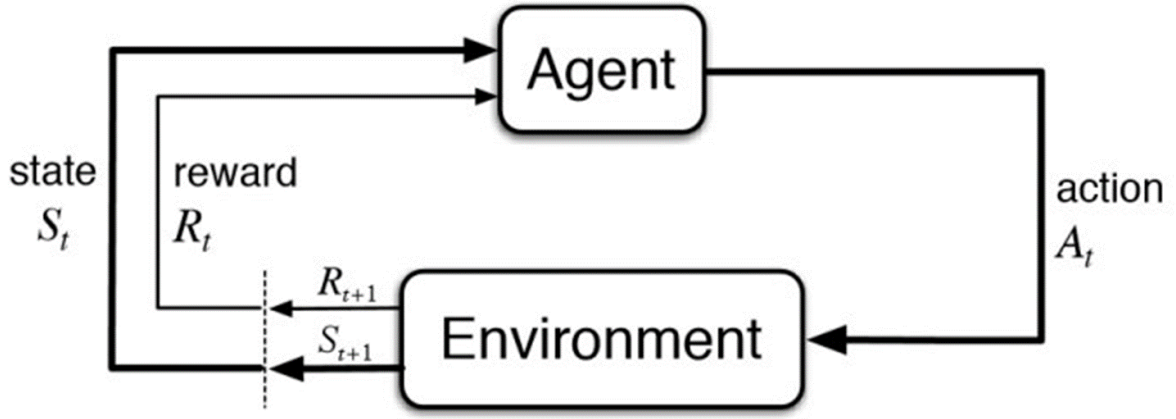


Fig. a) Working of reinforcement learning model

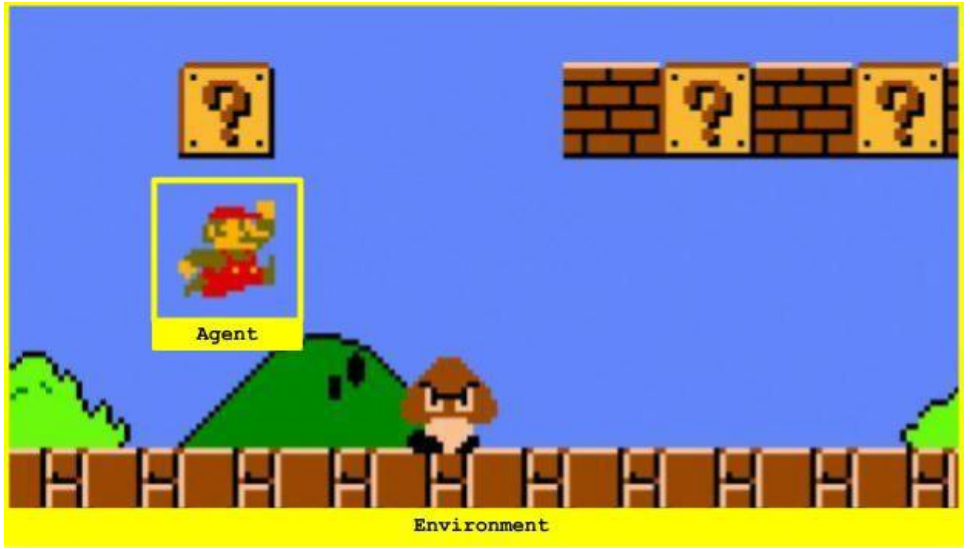


Fig. b) Example of reinforcement learning

Markov Decision Process:

- It is defined by the tuple of 5 elements:
$$(S, A, P_{ss}^{a}, R_{ss}^{a}, \gamma)$$
- State (S)
- Action (A)
- State Transition Probability (P_{ss}^{a})
- Reward Function (R_{ss}^{a})
- Discount factor (γ)

Advantages	**Disadvantages**
• Converges faster. • Better understanding of working of the algorithm.	• Need of state transition probability matrix • Need to provide each state before the execution of the program

Q- Learning:

- Model free reinforcement learning algorithm.
- Explore every state of the environment and available actions in each state.
- Create a table (matrix) of shape [state, actions].
- Example of Q-Learning

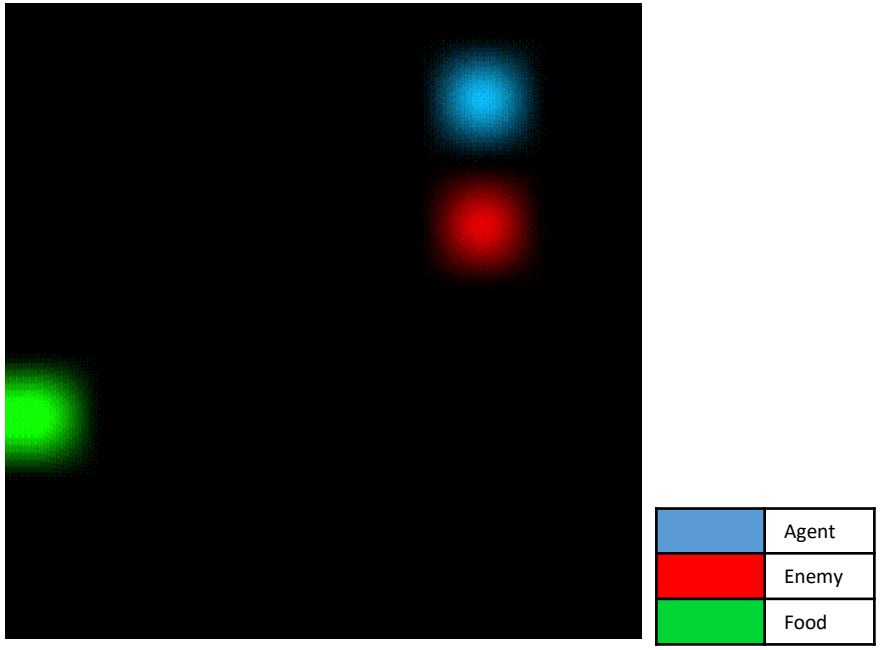


Fig. a) Q-learning example

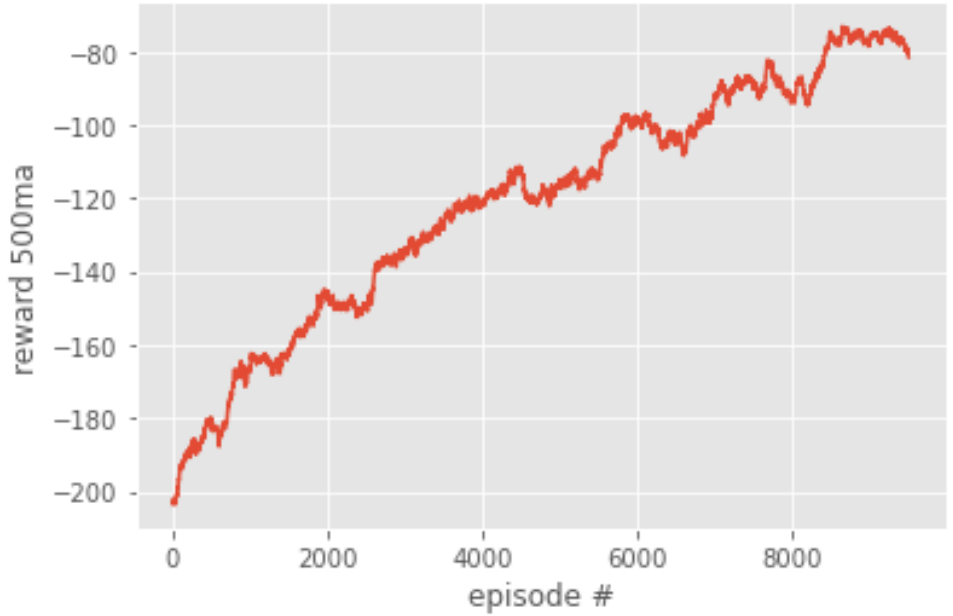


Fig. b) Reward vs episode in Q-learning

Problem Formulation:

1) Agent:

- Coefficients to be predicted will work as agent for environment.
- So the agent will be a number which will work in environment.

2) Actions:

- Only two actions are allowed for each agent. It can be increased or decreased by a factor.

3) Reward:

- Reward will be based on how much criteria a set of agents follow.

4) Environment:

(a) Total magnetic field:

- The average change in total magnetic field due to coefficients of degree n=10 and n=13 is 27nT for the year 2000 to 2020.
- The Model will try to reduce error to 30nT to satisfies the criteria.

(b) Inclination anomaly:

- Inclination due to geocentric axial dipole is given by:

$$\tan I_{GAD} = 2 \tan \lambda$$

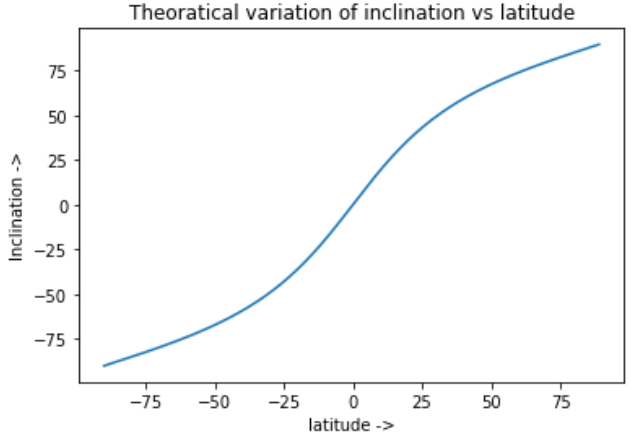


Fig. a) Variation of inclination (θ^o) values with respect to latitude for dipole.

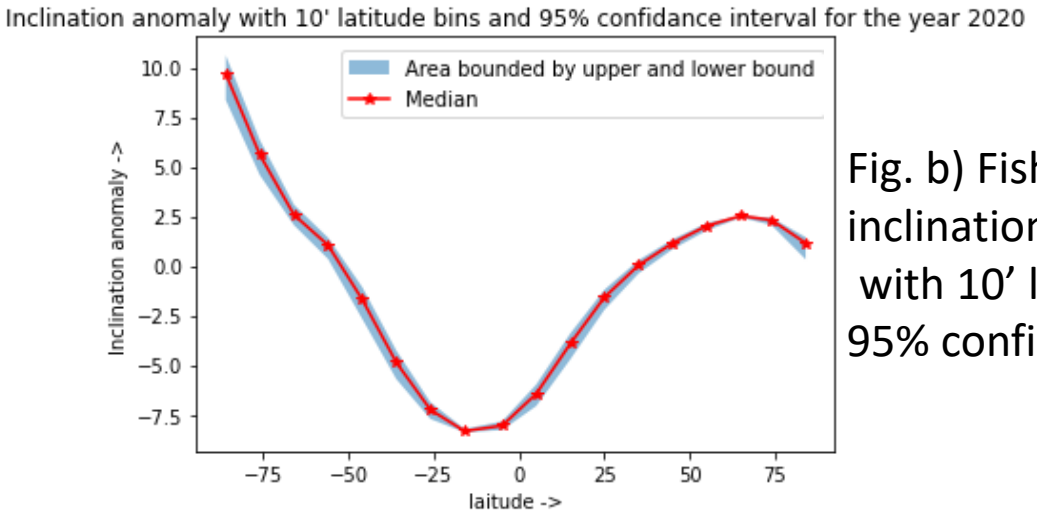


Fig. b) Fisher mean of inclination anomaly (θ^o) with 10’ latitude bins and 95% confidence interval

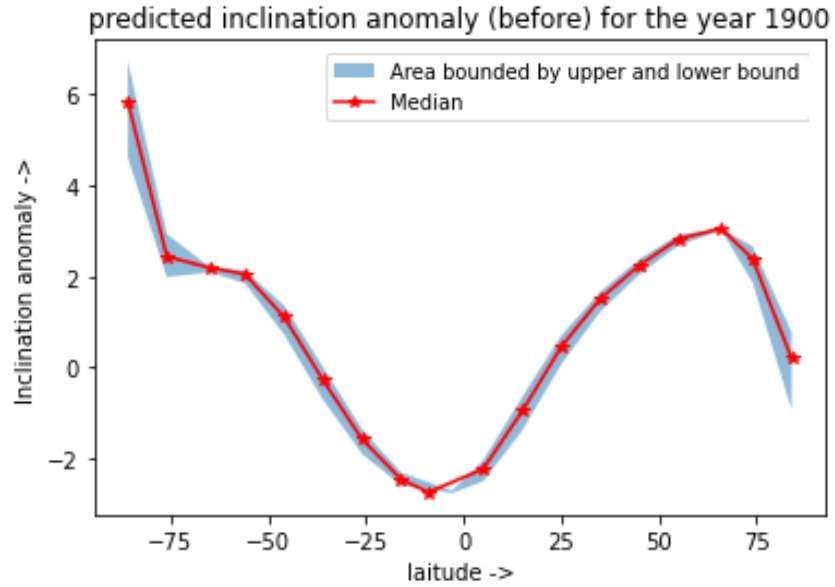


Fig. c) Inclination anomaly (θ^o) from the coefficients.

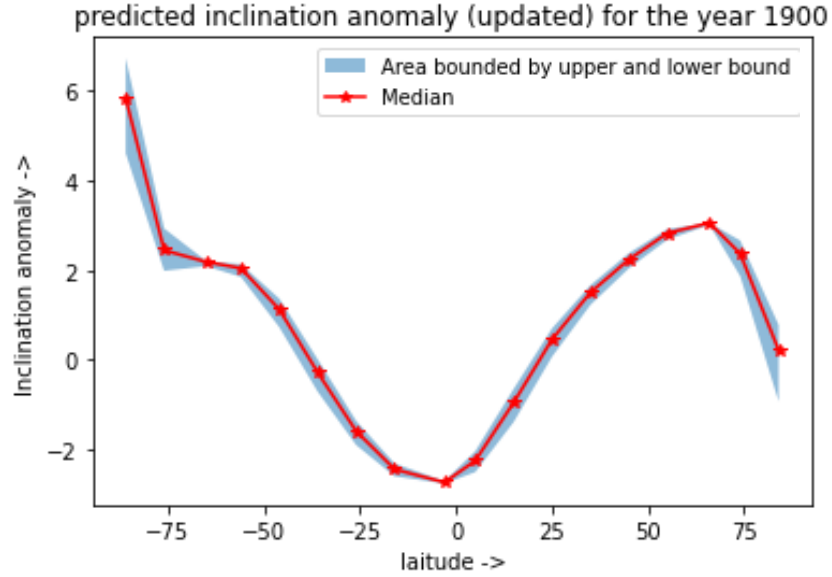


Fig. d) Inclination anomaly (θ^o) from the predicted coefficients.

Working of Model:

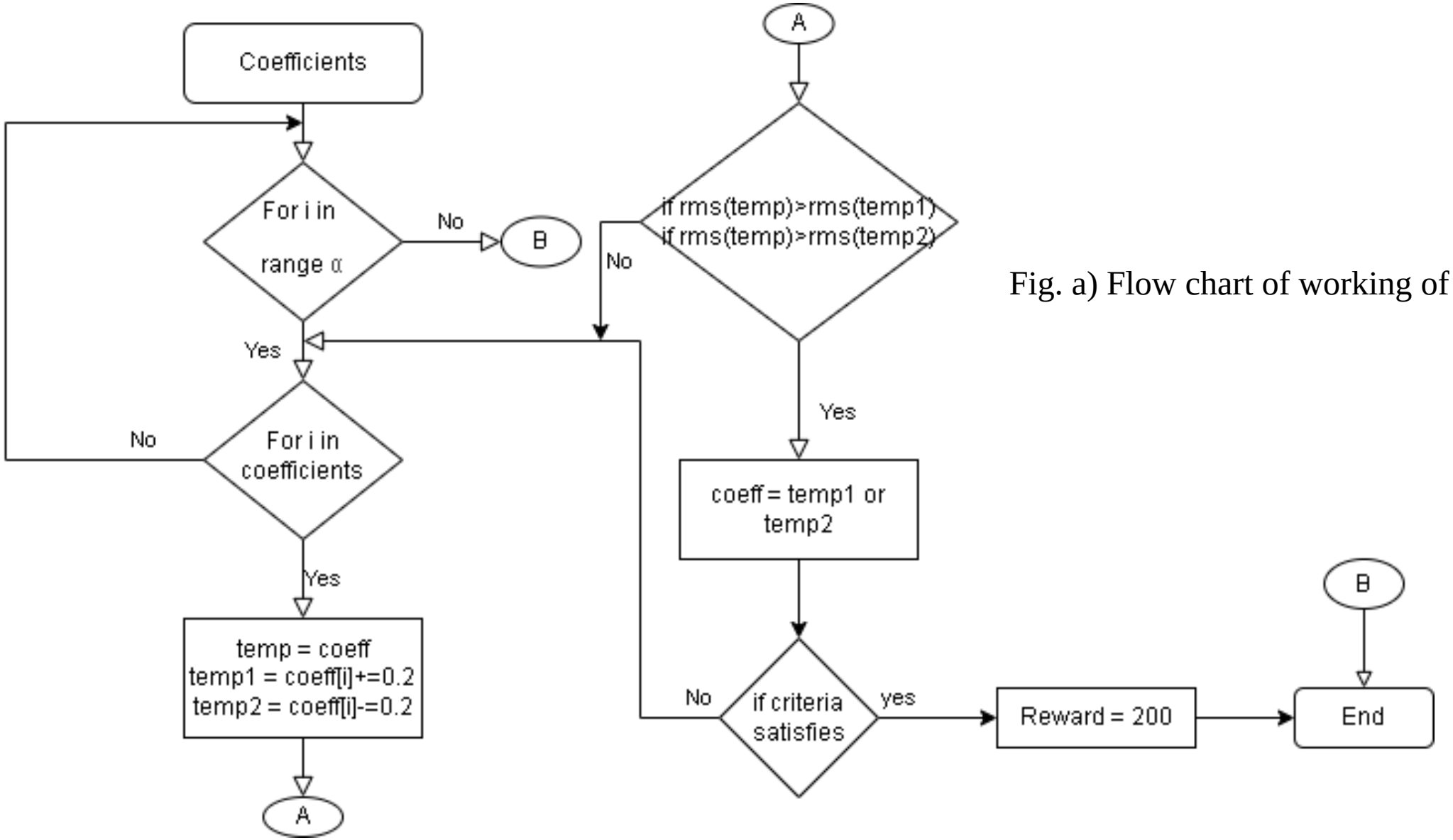


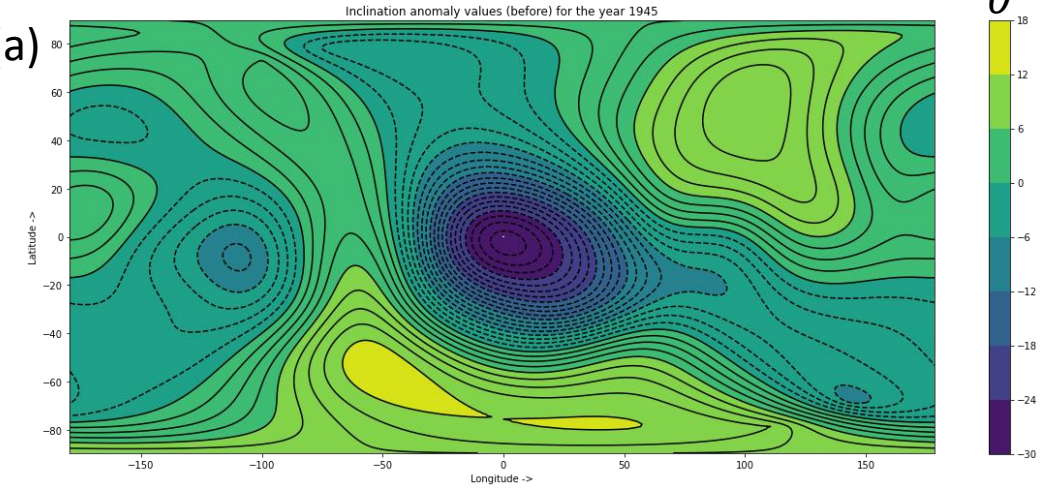
Fig. a) Flow chart of working of the model

Results:

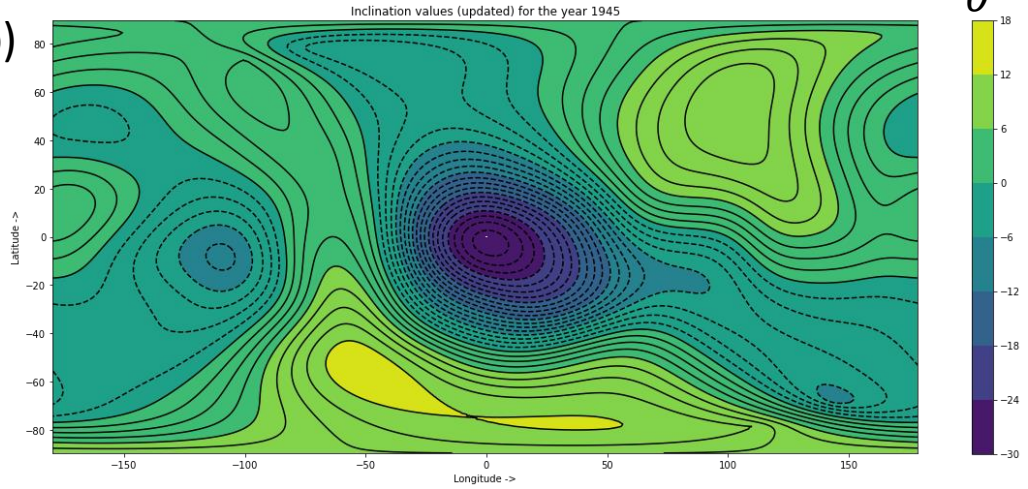
- Inclination anomaly:

1945

(a)

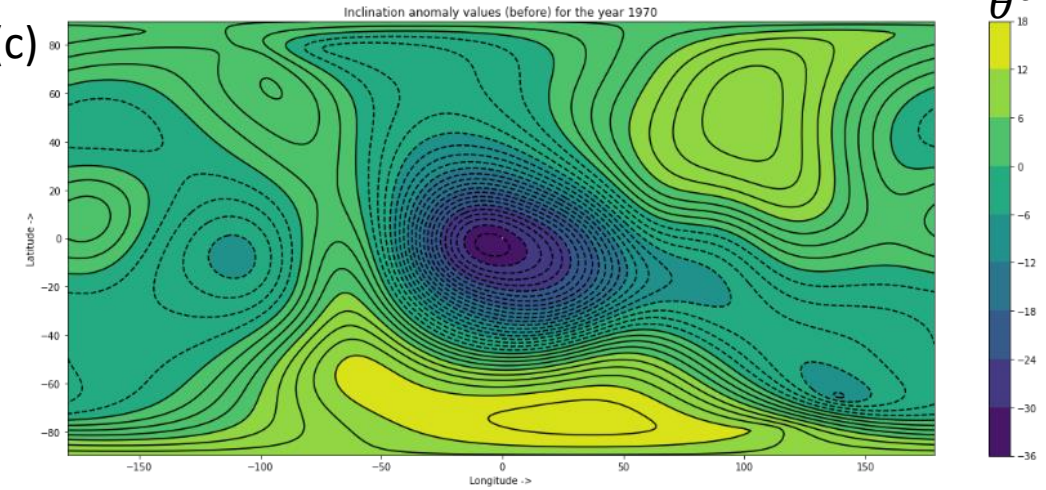


(b)



1970

(c)



(d)

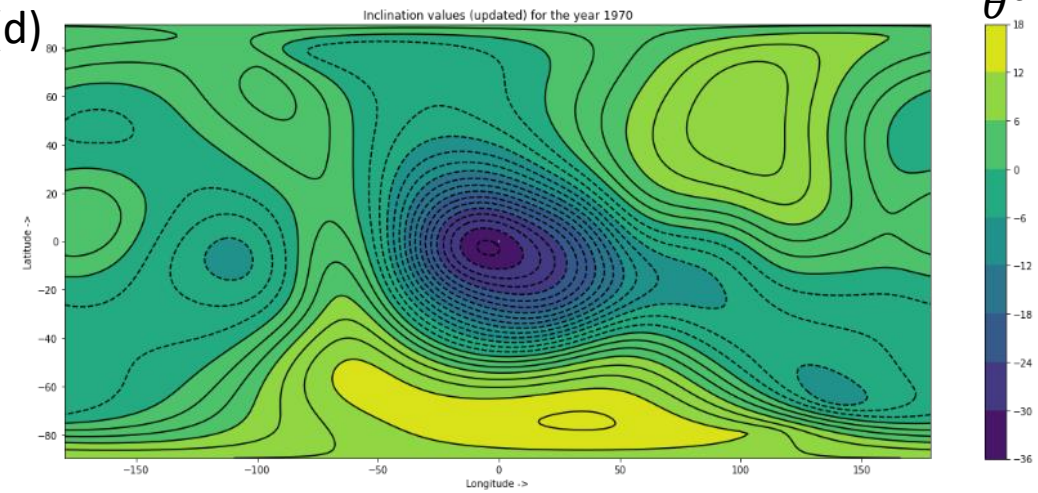
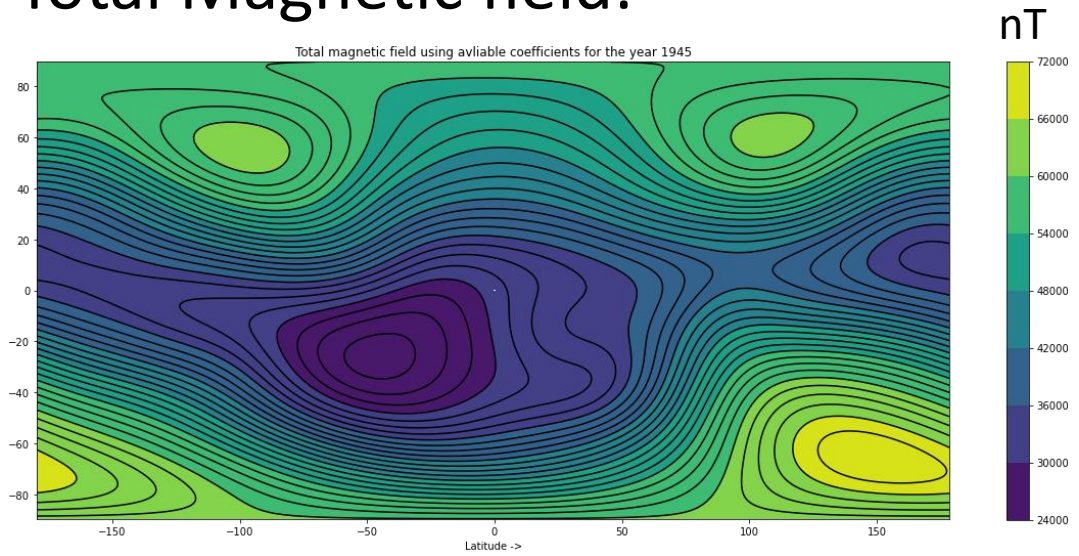


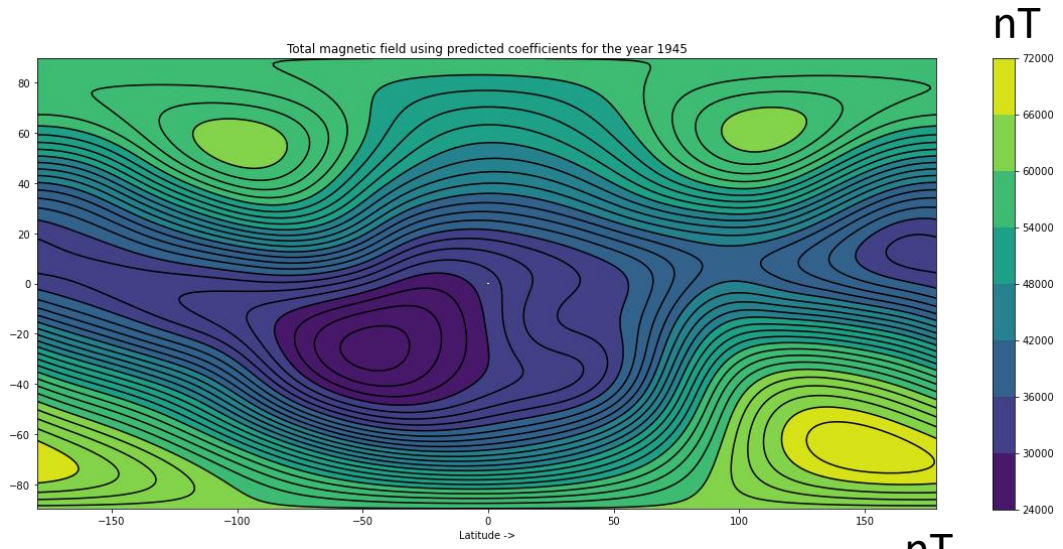
Fig: (a) and (c) corresponds to the inclination anomaly of available coefficients and (b) and (d) corresponds to the inclination anomaly for predicted coefficients

- Total Magnetic field:

(a)



(b)



(c)

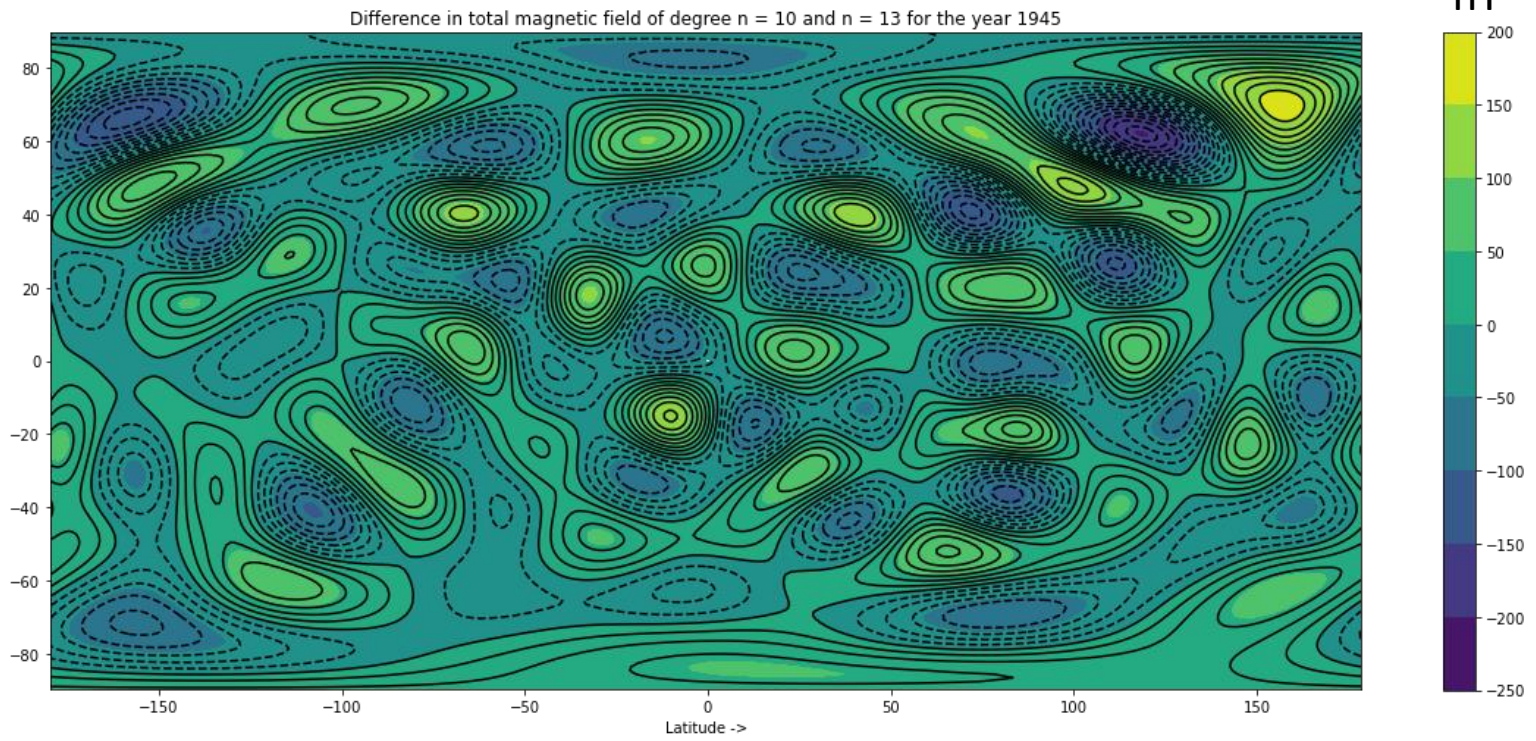


Fig: (a) corresponds to the total magnetic field using available coefficients,
(b) Corresponds to the total magnetic field using predicted coefficients,
(c) The difference between predicted and available magnetic field

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