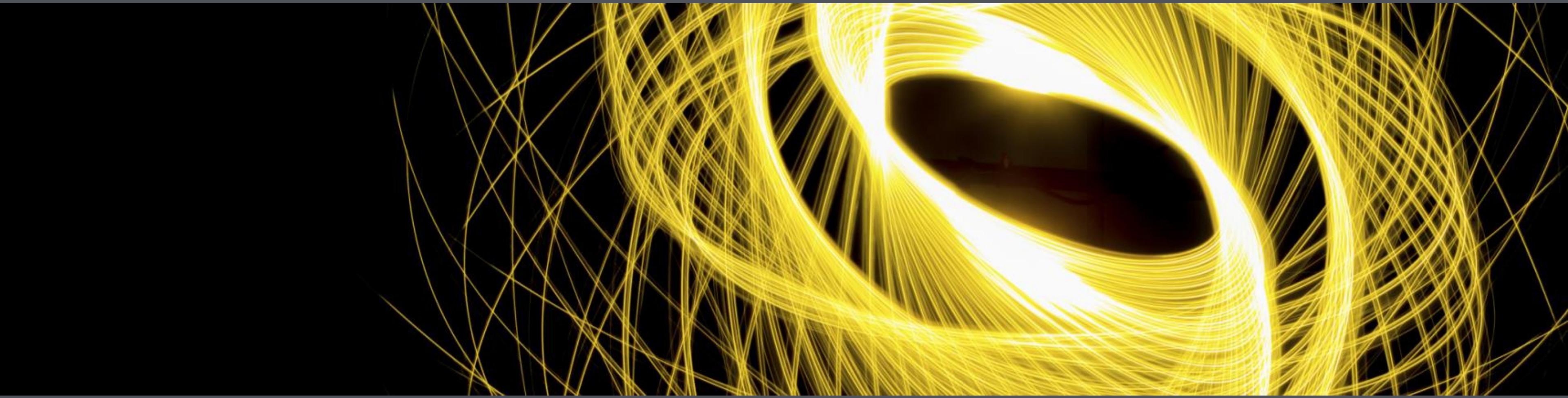
Department of Meteorology

University of Reading

Meteorological Data Filtering for Tropical Cyclones using Deep Learning



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Scenario DOCTORAL TRAINING PARTNERSHIP

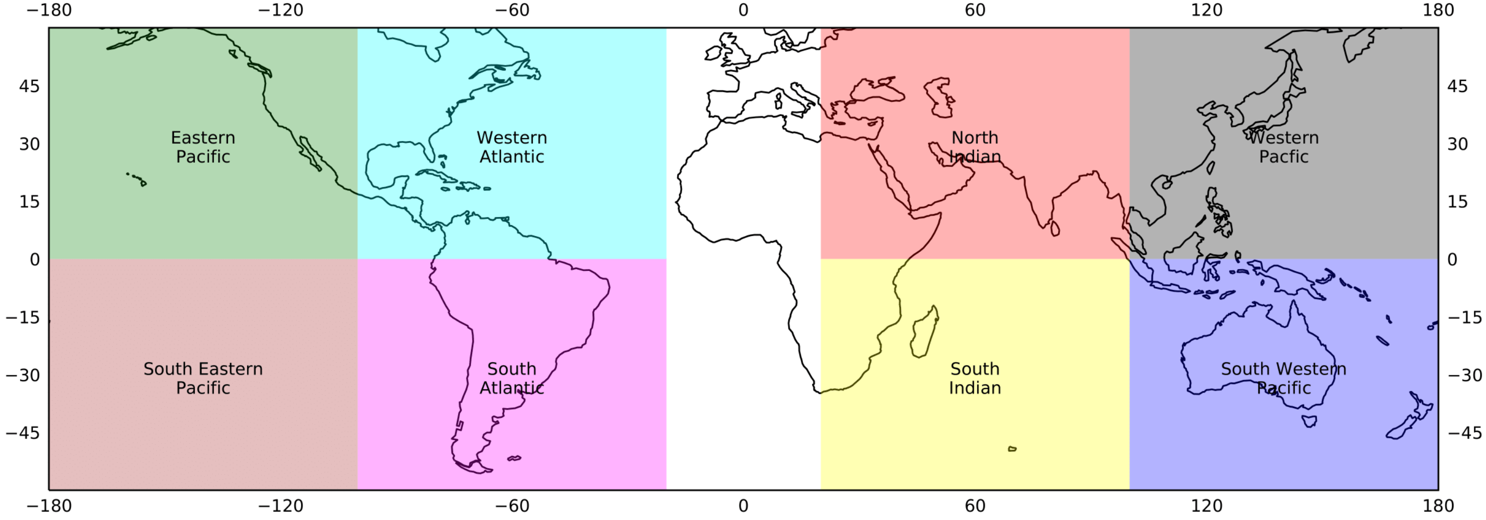
UKRI Natural Environment Research Council

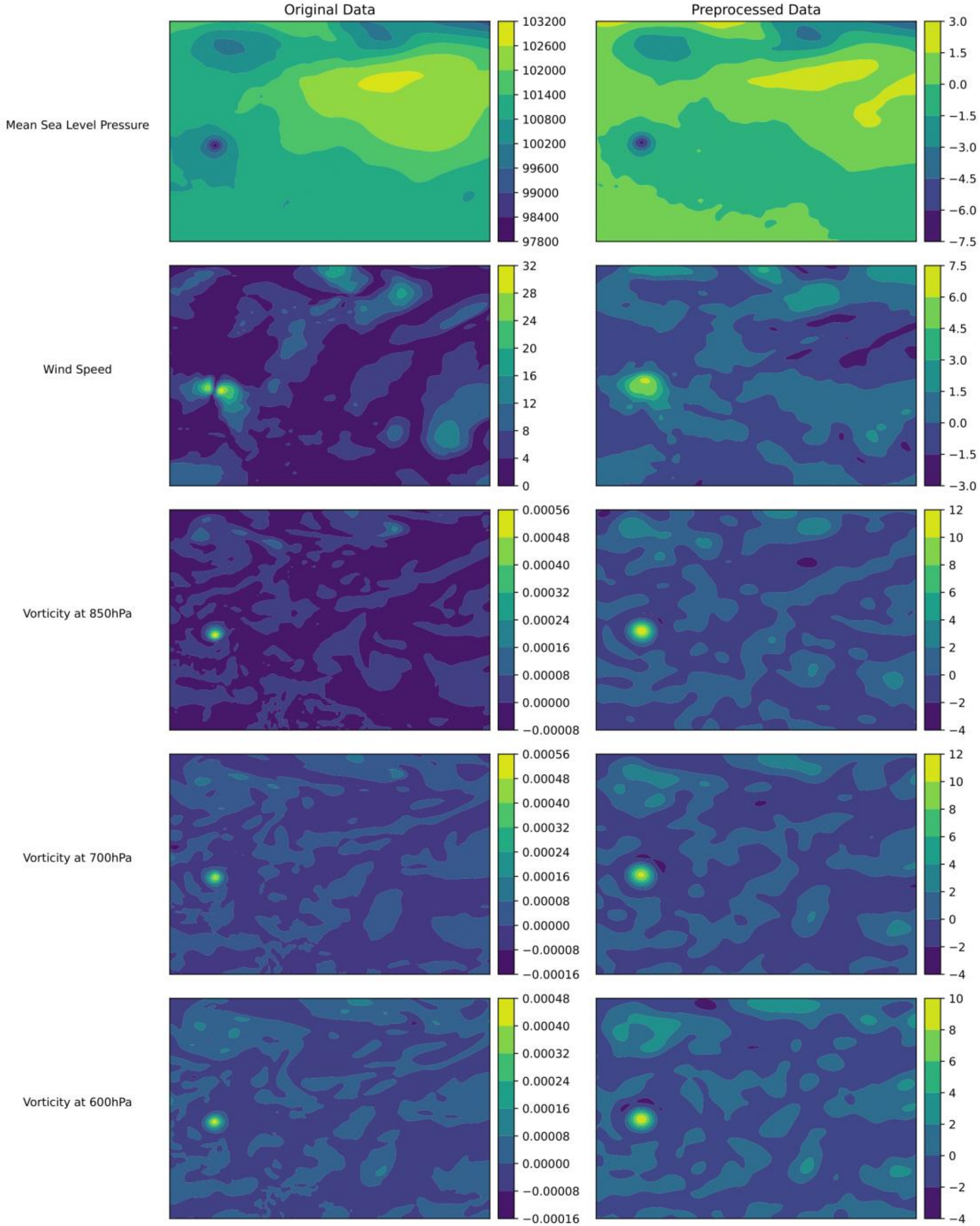
Introduction and Aims

- The effects of a changing climate on multiple meteorological phenomena are being investigated by long General Circulation Model (GCM) simulations
- Each simulation produces large amounts of data which can be inefficient to store and analyse
- We created a method that scans GCM analysis data for the presence of Tropical Cyclones (TCs) and only outputs it to disk if a TC is detected

Data

- ERA-Interim reanalyses dataset; each timestep split into 8 regions
- Fields used: 10m wind speed; MSLP; Vorticity at 850hPa, 700hPa, 600hPa at a resolution of 2.8º
- Labels obtained from the IBTrACS database
- Training Set: January 1979 – June 2017 (450912 cases)
- Testing Set: July 2017 – August 2019 (24352 cases)




Original Data
Preprocessed Data
Mean Sea Level Pressure
103200
102600
102000
101400
100800
100200
99600
99000
98400
97800
3.0
1.5
0.0
−1.5
−3.0
−4.5
−6.0
−7.5
Wind Speed
32
28
24
20
16
12
8
4
0
7.5
6.0
4.5
3.0
1.5
0.0
−1.5
−3.0
Vorticity at 850hPa
0.00056
0.00048
0.00040
0.00032
0.00024
0.00016
0.00008
0.00000
−0.00008
12
10
8
6
4
2
0
−2
−4
Vorticity at 700hPa
0.00056
0.00048
0.00040
0.00032
0.00024
0.00016
0.00008
0.00000
−0.00008
−0.00016
12
10
8
6
4
2
0
−2
−4
Vorticity at 600hPa
0.00048
0.00040
0.00032
0.00024
0.00016
0.00008
0.00000
−0.00008
−0.00016
10
8
6
4
2
0
−2
−4

Results

- An accuracy of 90.65% was obtained when testing on data from July 2017 until August 2019
- 1231 out of 1342 (91.73%) positive cases were correctly classified

		Identified	
		TC Present	TC Not Present
Ground Truth	TC Present	1231	111
	TC Not Present	2166	20844

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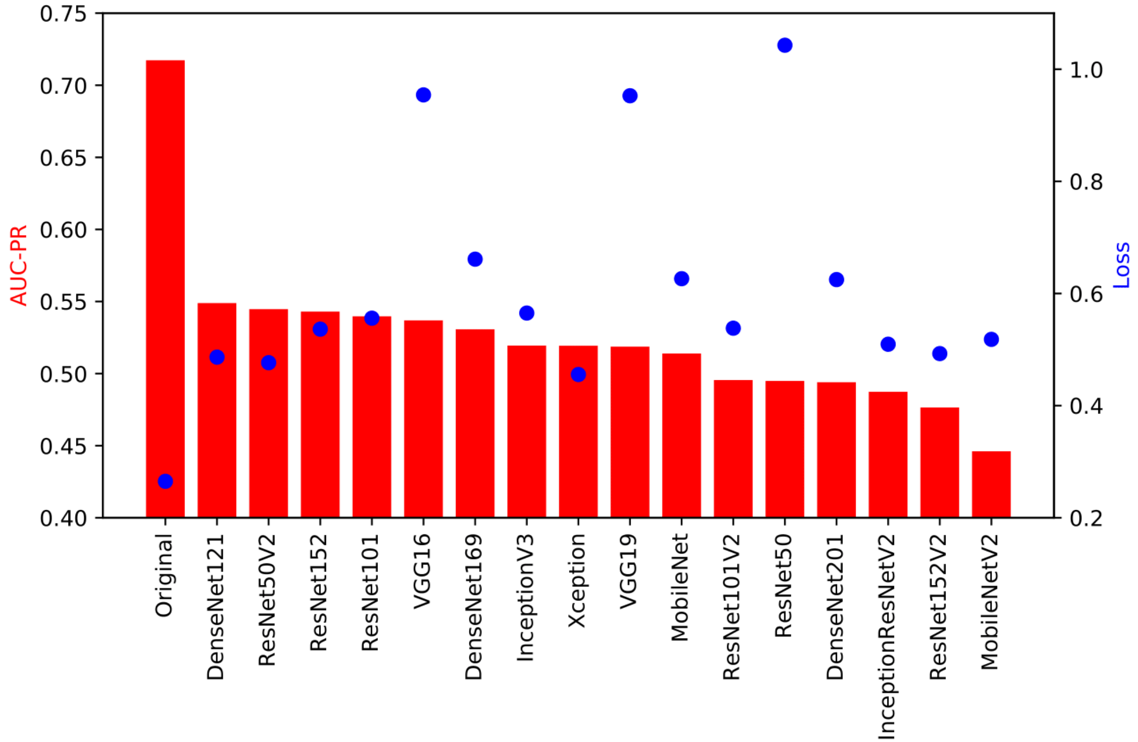
Results: TC Category

Category	Global Model
1	88.02%
2	91.53%
3	94.19%
4	94.64%
5	100.00%

- This upward trend of recall with category shows that TCs of higher categories are being identified better as they have features which are more easily identifiable

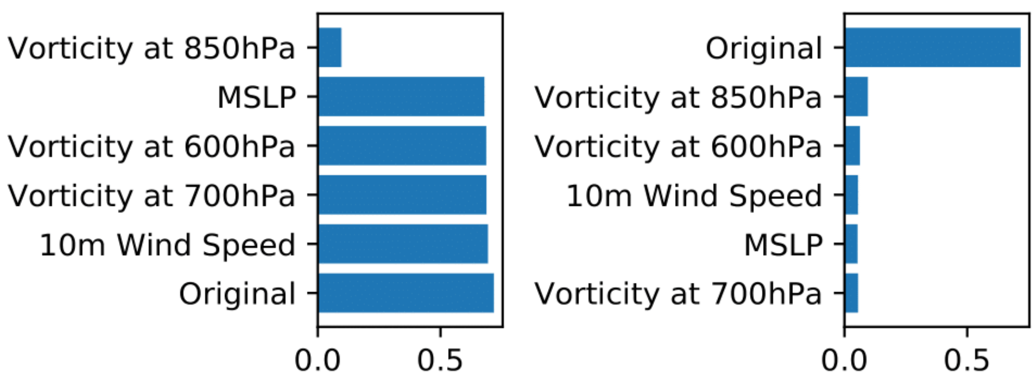
Results: Standard Models

- The model developed was compared with some standard models. It did not obtain the best accuracy, but did get the best loss



Results: Feature Importance

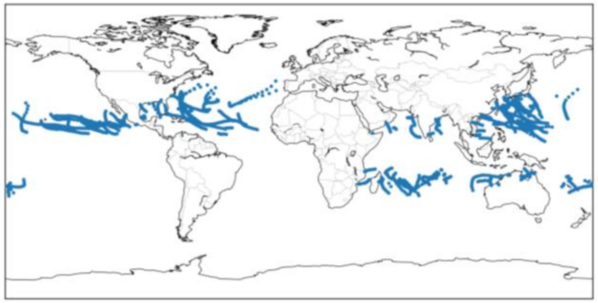
- Breiman Method:
  - Each field is permuted across all testing cases
  - If performance decreases from original, the field is important for the model
  - The larger the decrease, the more important the field
- Lakshamanan Method:
  - Each field is permuted across all testing cases
  - Most important is kept permuted, while the next important is found
  - Keep on going until all fields are permuted



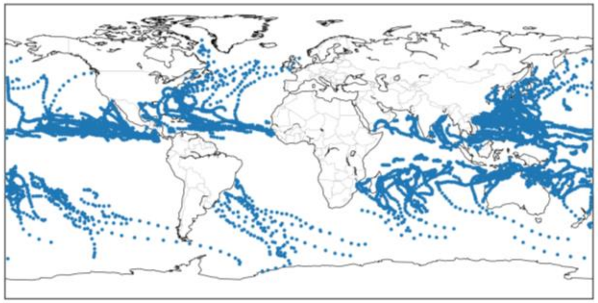
Verification: TC Centres

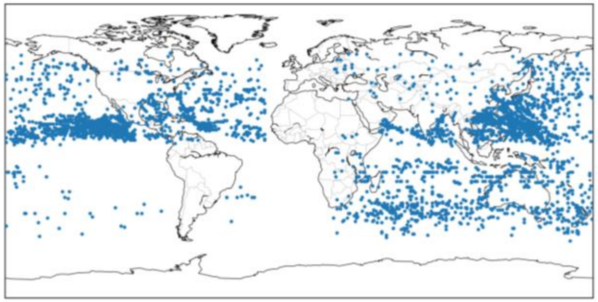
- Compare outputs from DL model to T-TRACK, observations

IBTrACS



T-TRACK

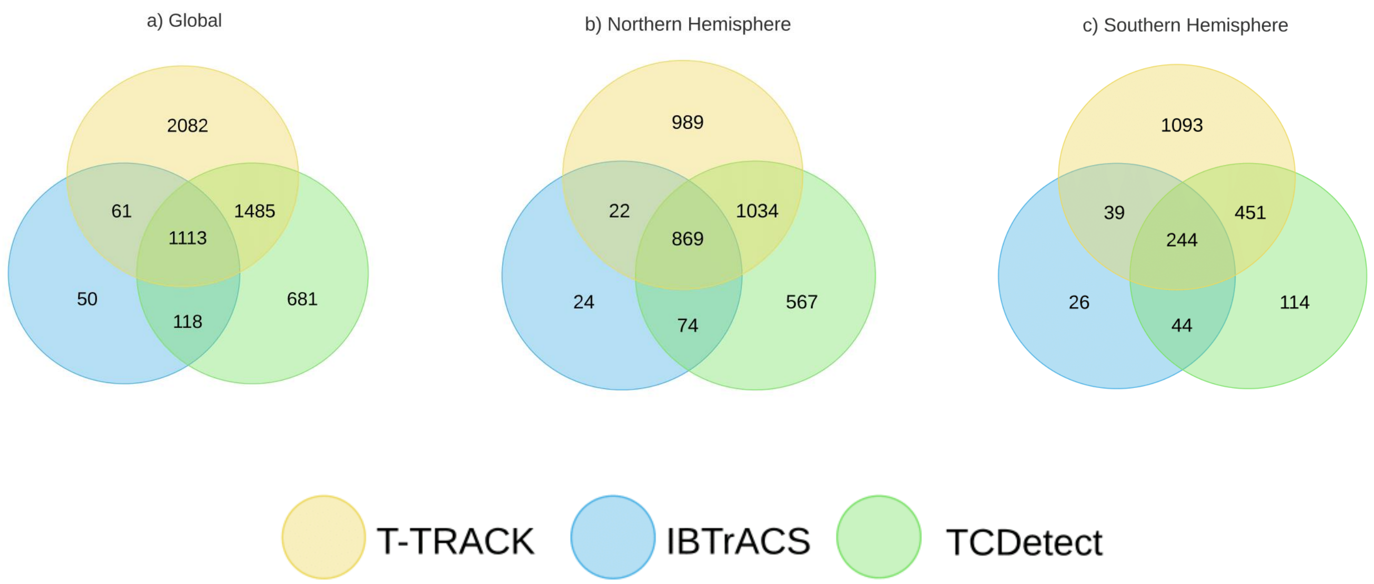




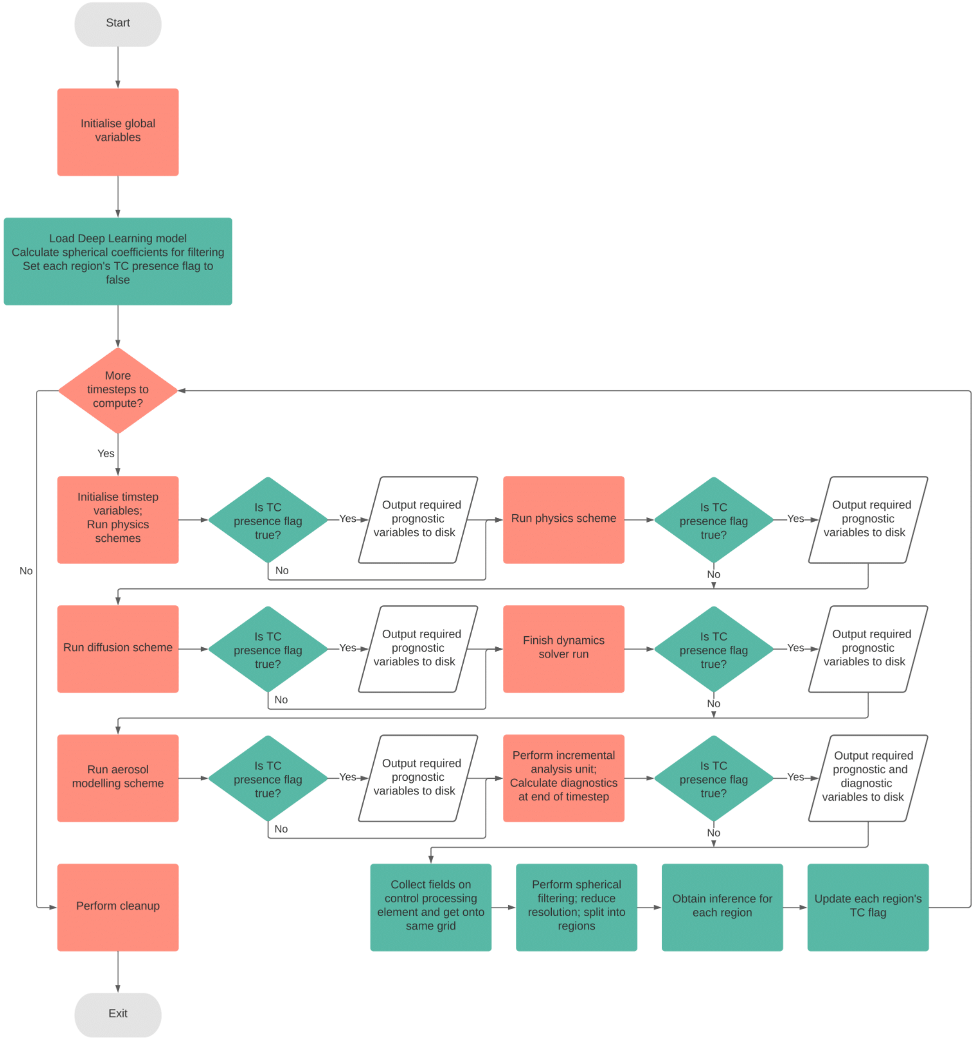
TCDetect

Verification: TC Matches

- Compare outputs from DL model to T-TRACK, observations



Implementation



Implementation: Data Volume

	ERA-Interim			UM N96		UM N512	
	IBTrACS	T-TRACK	TCDetect	T-TRACK	TCDetect	T-TRACK	TCDetect
NI	72 (2%)	277 (9%)	239 (8%)	74 (2%)	105 (2%)	157 (11%)	197 (14%)
NWP	400 (13%)	1222 (40%)	933 (31%)	1674 (39%)	2617 (61%)	956 (67%)	920 (64%)
NEP	267 (9%)	712 (23%)	875 (29%)	442 (11%)	689 (16%)	524 (37%)	714 (50%)
NA	250 (8%)	703 (23%)	497 (16%)	559 (13%)	999 (23%)	431 (30%)	683 (48%)
SI	214 (7%)	646 (21%)	406 (13%)	913 (31%)	1596 (37%)	234 (16%)	552 (38%)
SWP	113 (4%)	740 (24%)	399 (13%)	874 (20%)	1436 (33%)	154 (11%)	374 (26%)
SEP	26 (1%)	322 (11%)	35 (1%)	1096 (25%)	1945 (45%)	149 (10%)	370 (26%)
SA	0 (0%)	119 (4%)	119 (4%)	167 (4%)	362 (8%)	28 (2%)	97 (7%)

Implementation: Computational Performance

Function	Times Applied	N96 Timings / sec	N512 Timings / sec
Collect data	1	4.64×10^{-4}	2.99×10^{-3}
Interpolate MSLP	1	3.15×10^{-4}	0.35
Resize field	5	9.1×10^{-3}	3.67×10^{-2}
Calculate Vorticity	3	1.16×10^{-3}	2.28×10^{-3}
Spherical filtering	5	0.68	1.36
Standardisation	5	4.13×10^{-5}	6.64×10^{-5}
Data formatting	8	1.63×10^{-5}	3.66×10^{-5}
DL inference	8	0.19	0.37
Full Method		4.96	10.22
Full Timestep		6.15	15.64
Full Simulation		23%	5%

Possible Future Work

- Better DL model
- Change filtering techniques to be done inside DL model; hopefully producing computationally less expensive method
- Replicate method for other phenomena

Acknowledgements

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