Approximating simple general circulation models with deep learning

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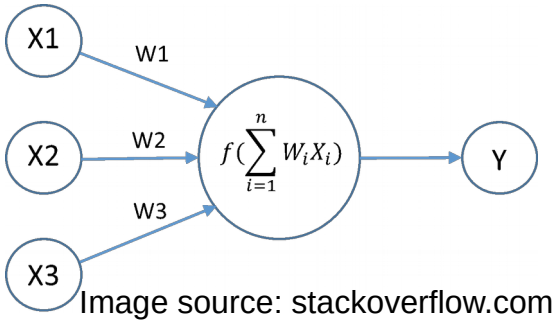

Image source: stackoverflow.com

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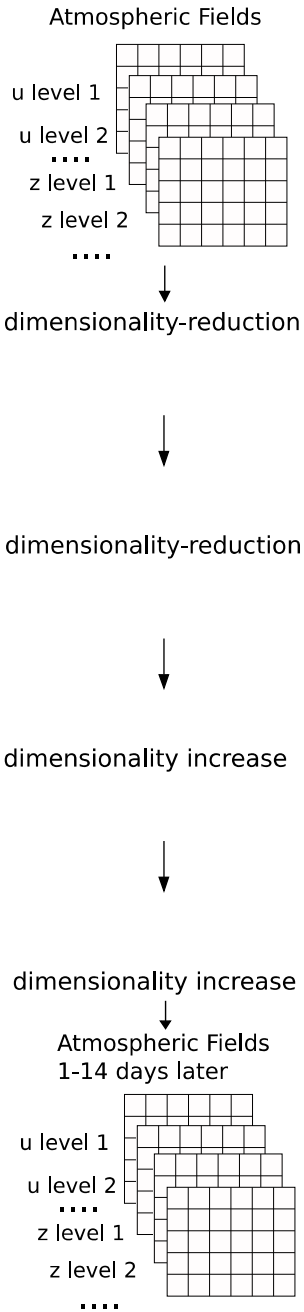
Introduction

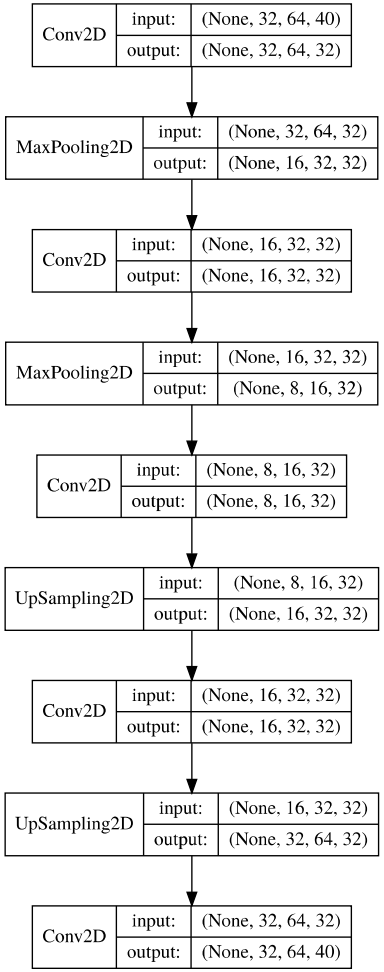
- “Weather” forecasting of 3d-atmospheric fields
- Using simple general circulation models as simplified reality
- “Playground” for weather forecasting

Hierarchy of simple general circulation models

- PUMA:
  - dry dynamical core, only atmosphere, no moisture cycle
  - 4 variables on 10 levels
- PLASIM:
  - in principle a GCM, but everything except the atmosphere strongly simplified
  - Dynamics of the atmosphere similar to reality (except for resolution), also “complexity” of the data similar to reanalysis.
- Both computationally cheap –> one can easily generate 100s of years of data

Principle Approach





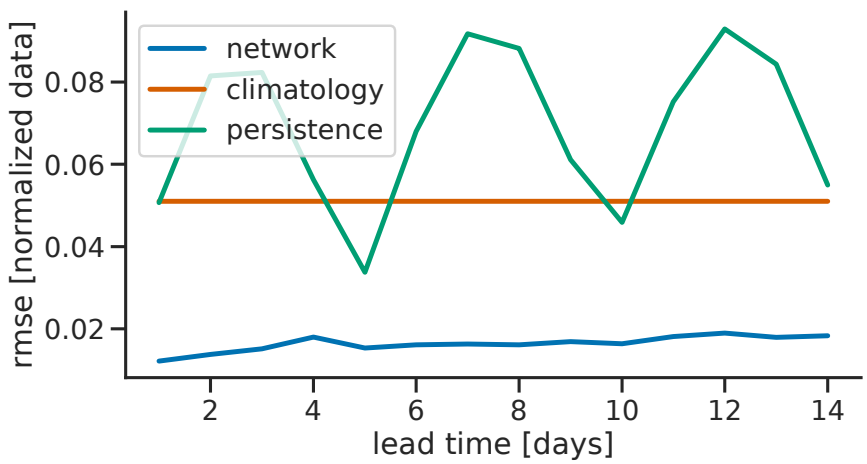
Artificial Neural Network with

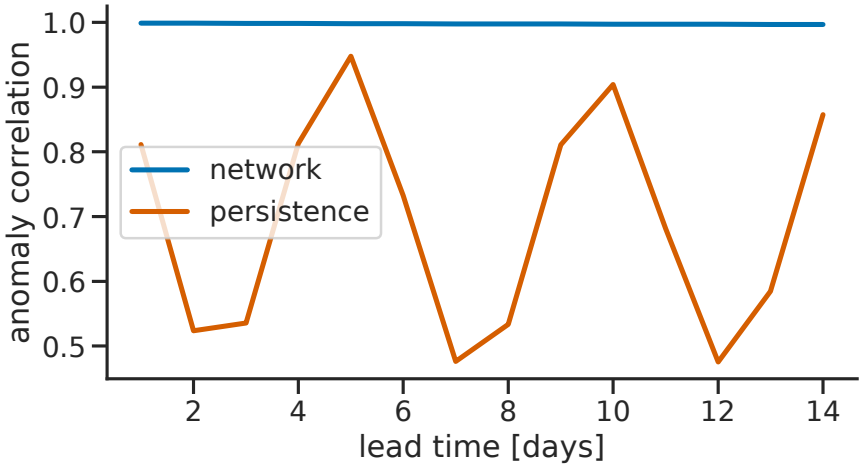
Convolution layers
(to some extent similar to a “local”
Approach as in Dueben and Bauer (2018))

Network tuned on simplest model

Result on simplest model
PUMA T21, no seasonal cycle

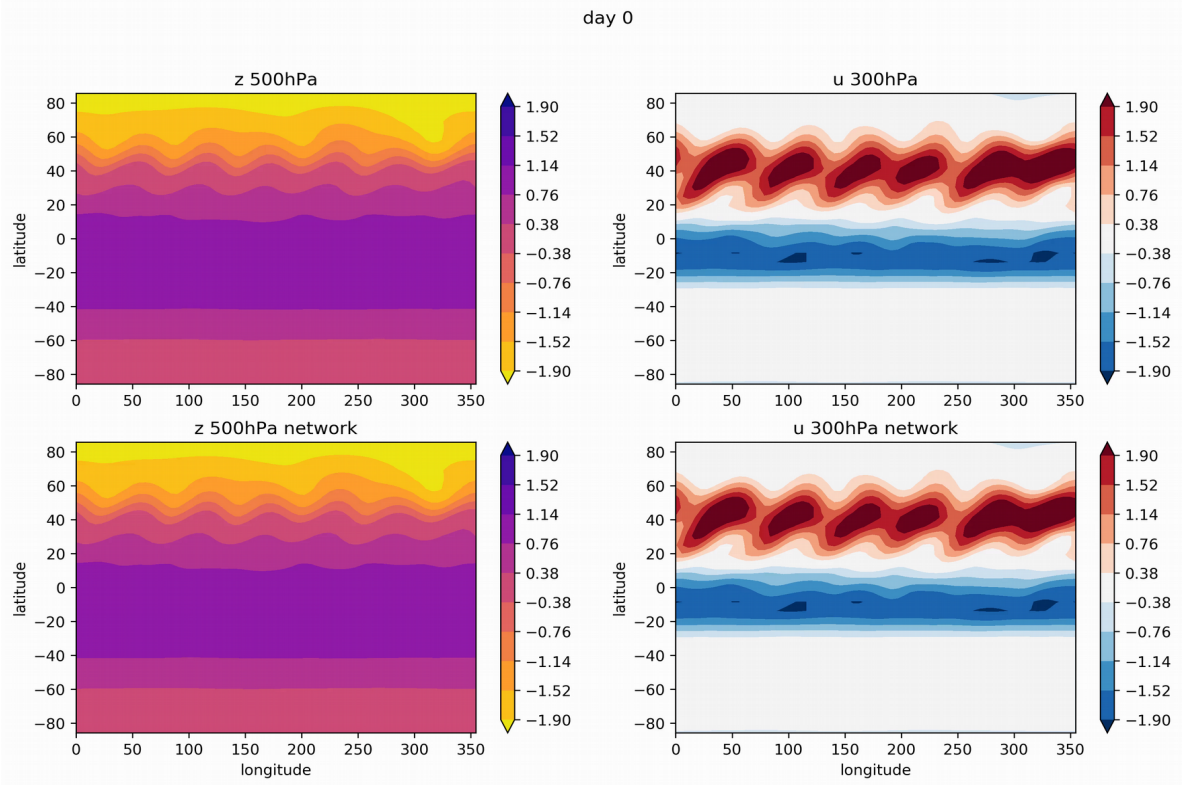
- Forecast skill:





- Climate run:
  - Stable, no long term drift

Scher (2018)


day 0
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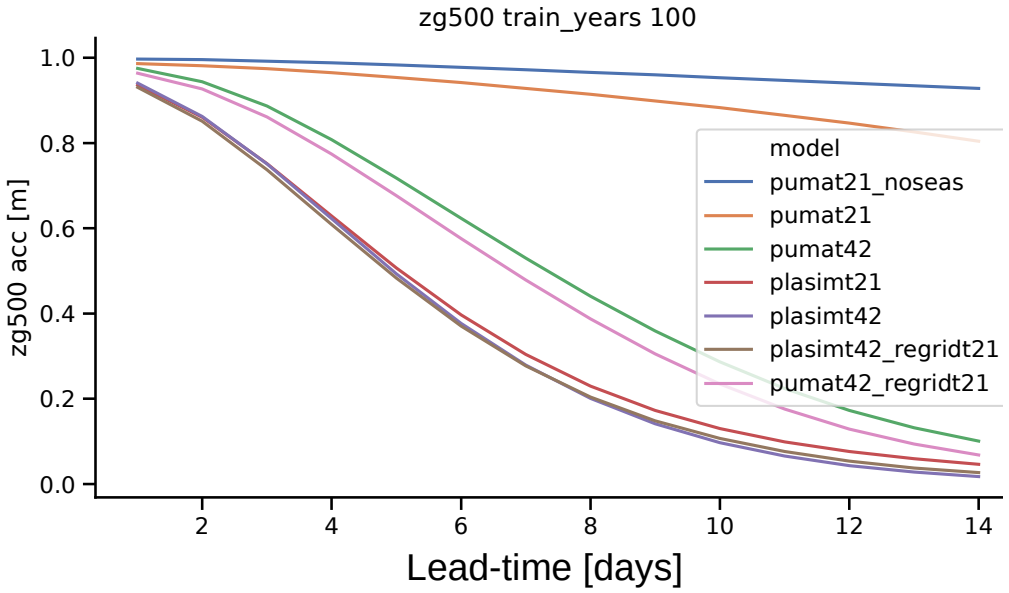
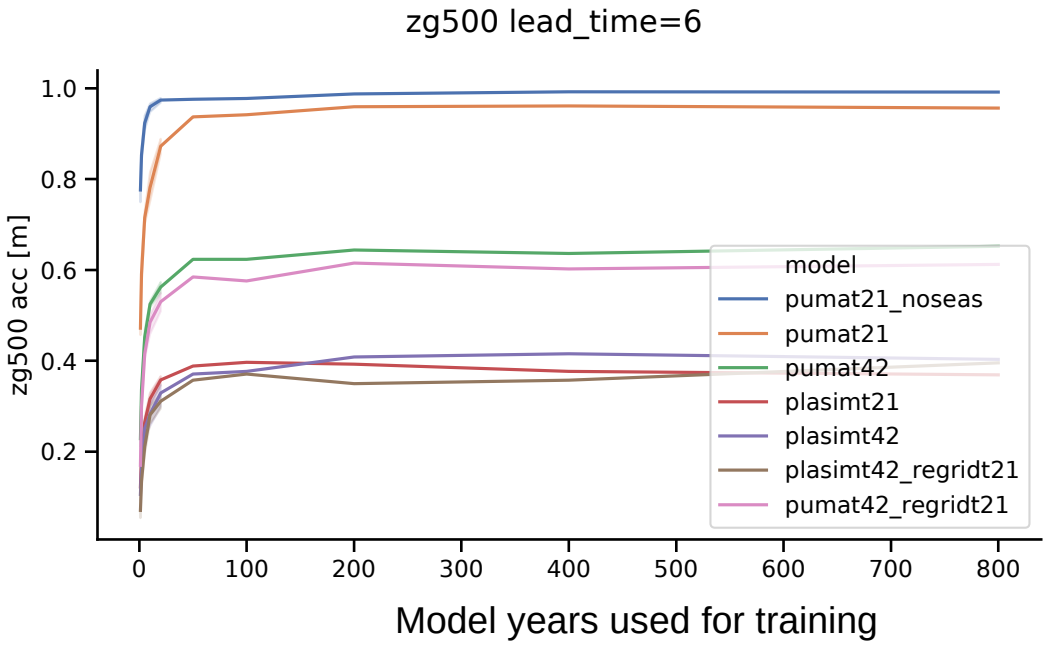
−1.52
−1.90

Scher (2018)

Results on more complex models

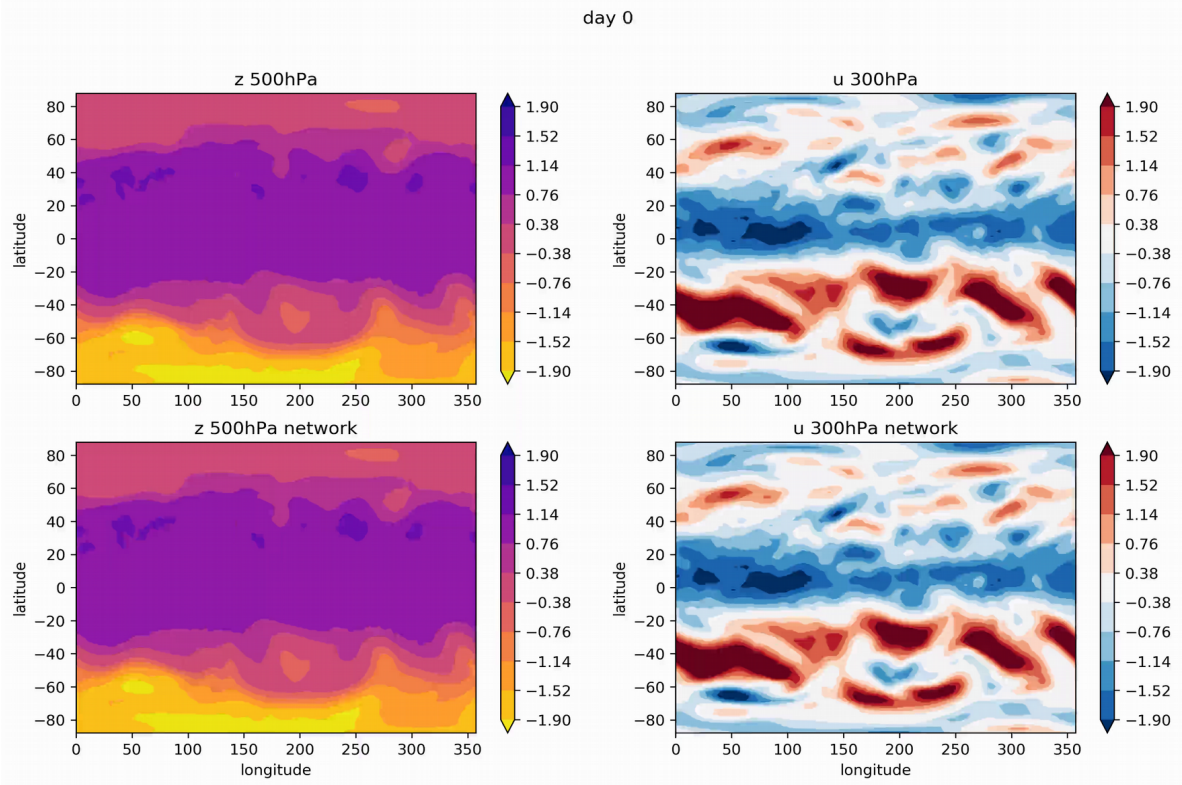




GFDL CMIP5 run: seems to work as well (preliminary result)

“Climate” runs: not stable – problems with seasonal cycle

Scher and Messori (2019)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−1.14
−1.52
−1.90

Conclusions

- Convolutional neural networks are in principle able to forecast the “weather” in simple GCMs
- Making “climate” runs with the networks is possible with the simplest model, but is tricky with seasonal cycle
- A network architecture tuned for the simplest model also worked for more complex models

References

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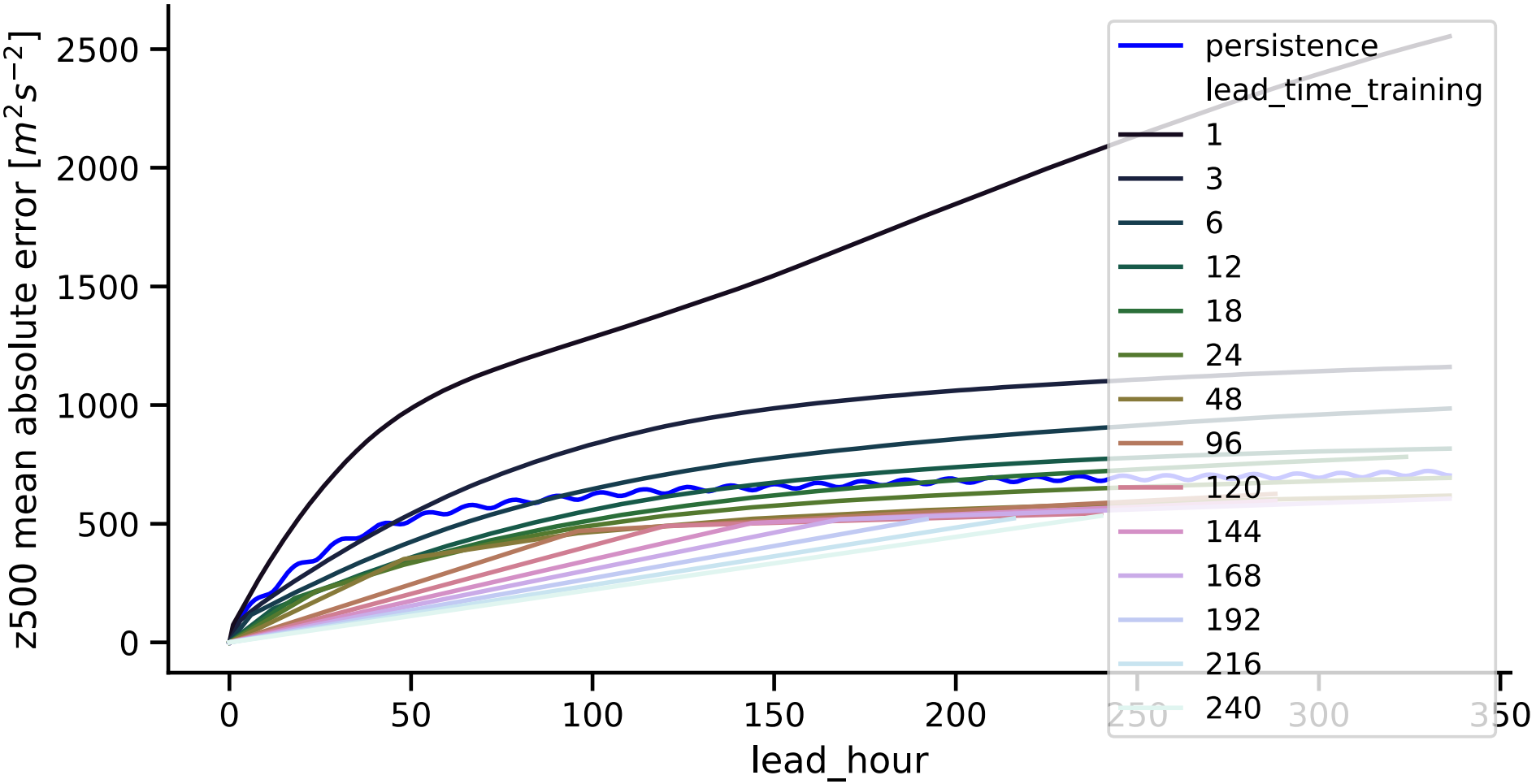
- Dueben, P. D. and Bauer, P.: Challenges and design choices for global weather and climate models based on machine learning, Geosci. Model Dev., 11, 3999-4009, https://doi.org/10.5194/gmd-11-3999-2018, 2018.


z500 mean absolute error [$m^2 s^{-2}$]
2500
2000
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1000
500
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0
50
100
150
200
250
300
350
lead_hour
persistence
lead_time_training
1
3
6
12
18
24
48
96
120
144
168
192
216
240