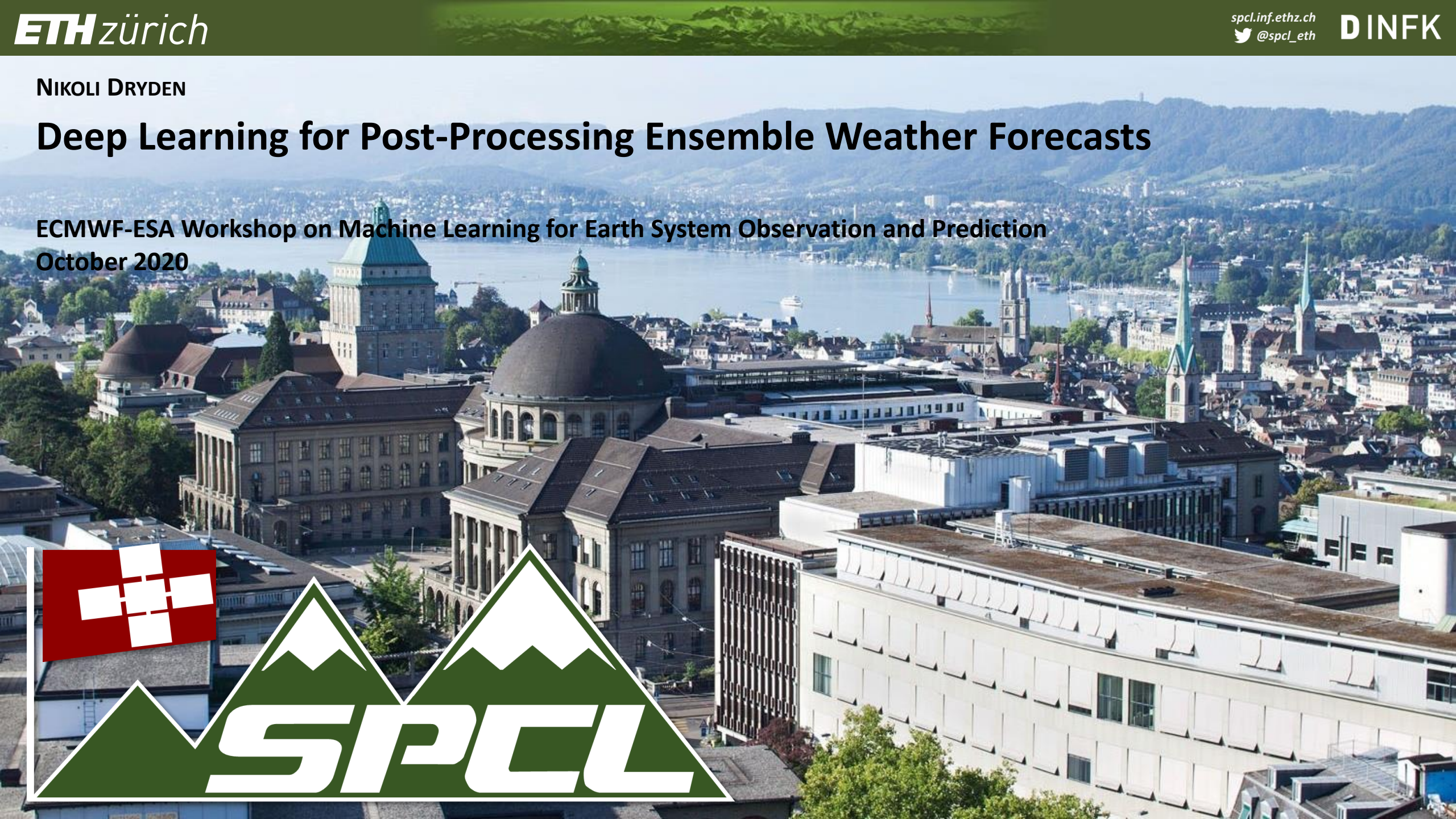
NIKOLI DRYDEN

Deep Learning for Post-Processing Ensemble Weather Forecasts

ECMWF-ESA Workshop on Machine Learning for Earth System Observation and Prediction
October 2020



Presenting the work of many people

DEEP LEARNING FOR POST-PROCESSING ENSEMBLE WEATHER FORECASTS

PREPRINT

Peter Grönquist
ETH Zürich
petergro@student.ethz.ch

Chengyuan Yao
ETH Zürich
chyao@student.ethz.ch

Tal Ben-Nun
ETH Zürich
tal.bennun@inf.ethz.ch

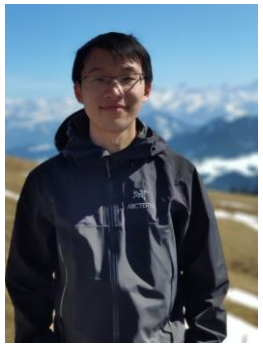
Nikoli Dryden
ETH Zürich
nikoli.dryden@inf.ethz.ch

Peter Dueben
ECMWF
peter.dueben@ecmwf.int

Shigang Li
ETH Zürich
shigang.li@inf.ethz.ch

Torsten Hoefler
ETH Zürich
htor@inf.ethz.ch

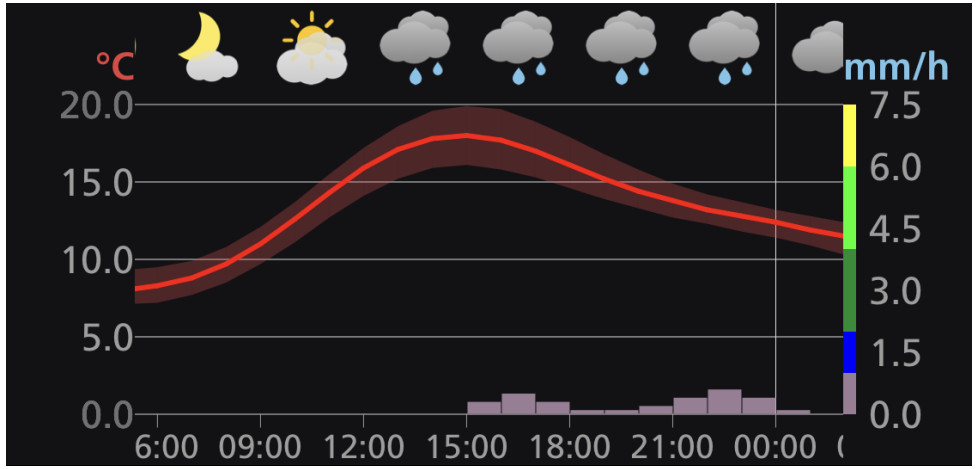
https://arxiv.org/abs/2005.08748 — https://github.com/spcl/deep-weather

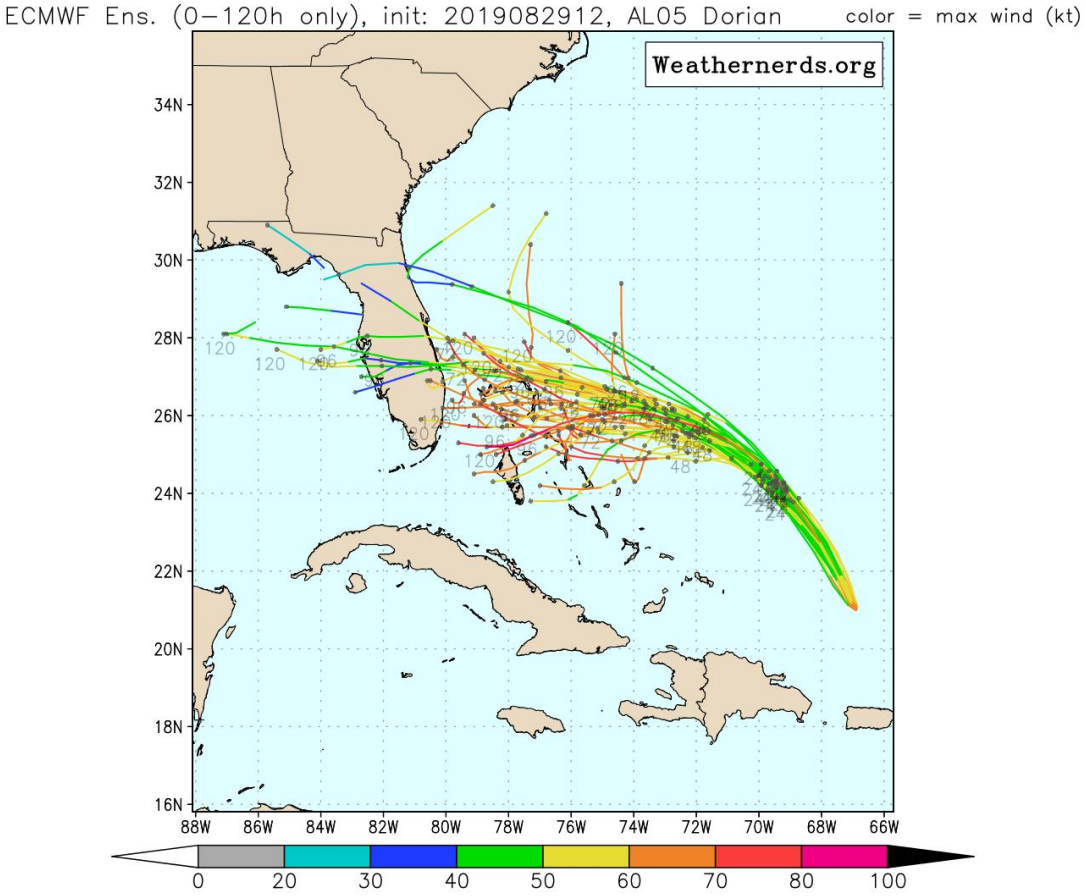



Weather Uncertainty

Weather is a chaotic process



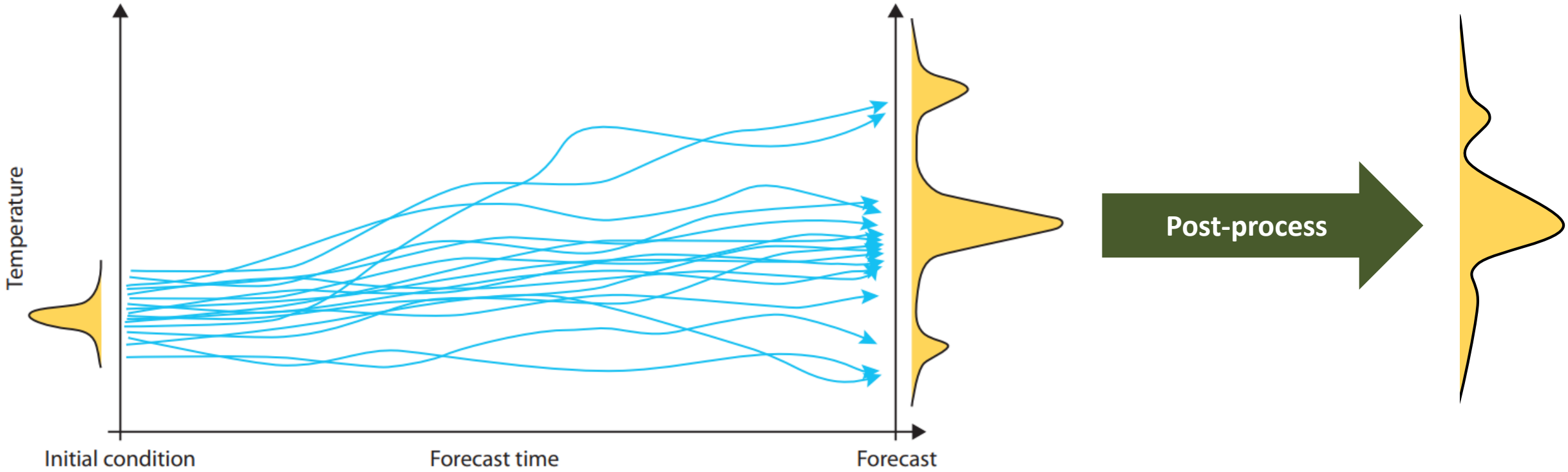
Source: MeteoSwiss app



Ensemble Prediction System

Cheap post-processing methods: EMOS & BMA

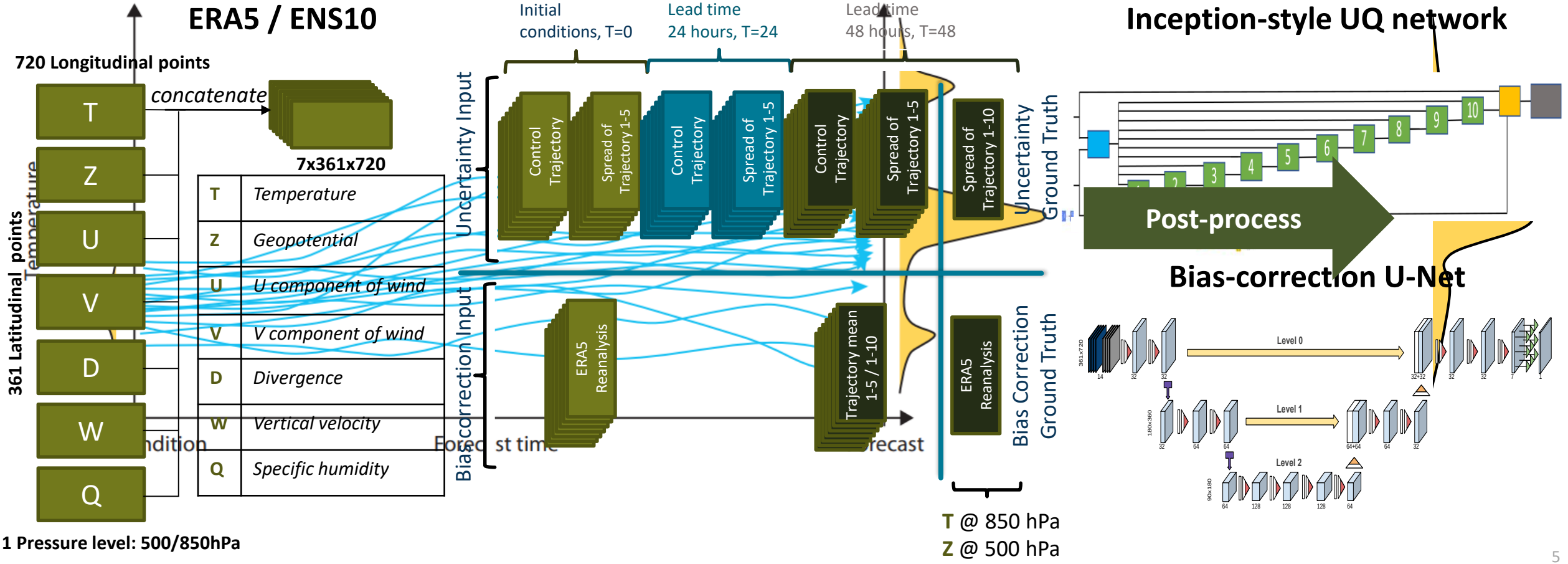
Simple neural networks [Rasp & Lerch 2018]



Source: ECMWF

Deep Learning for Post-Processing

Use complex neural networks!



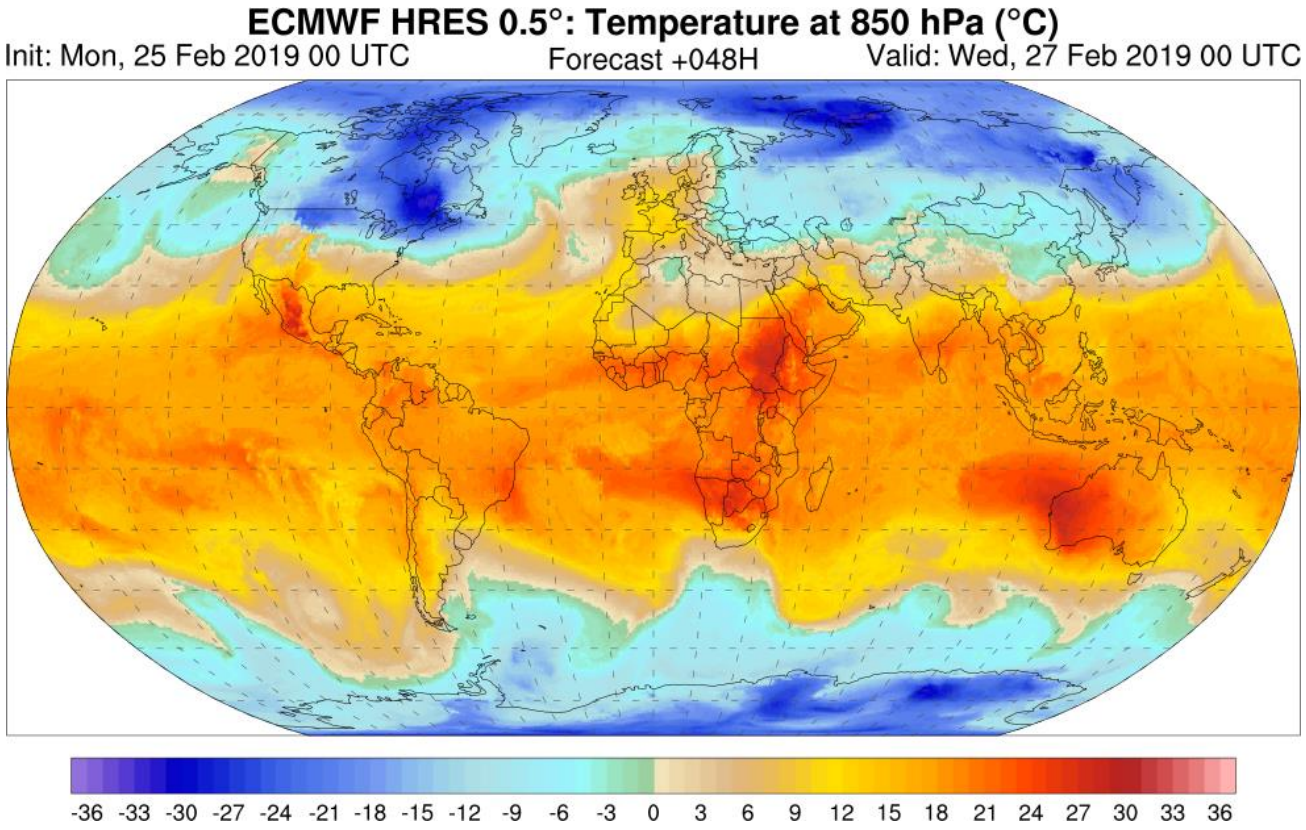
Datasets

ENS10

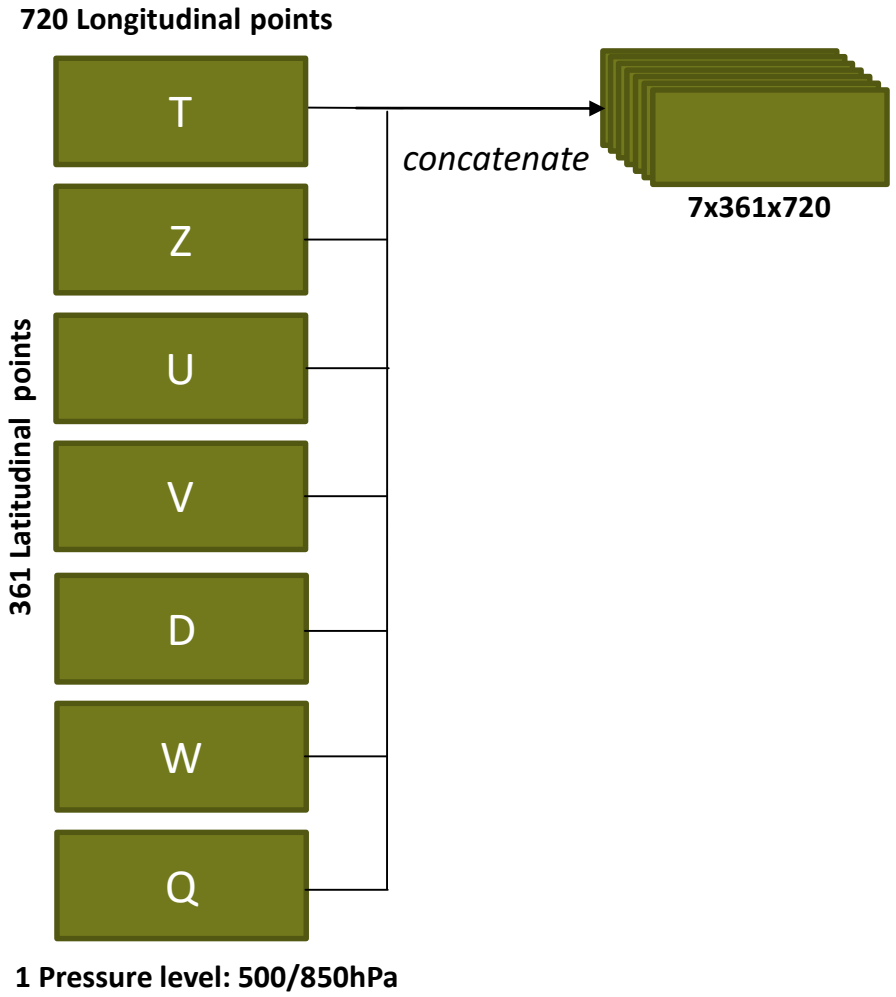
- Re-forecast (hindcast) dataset
- 10-member ensemble + control
- 0.5° latitude / longitude resolution
- 1999 – 2017
- 2/week, 0h, 24h, 48h lead time
- Training data

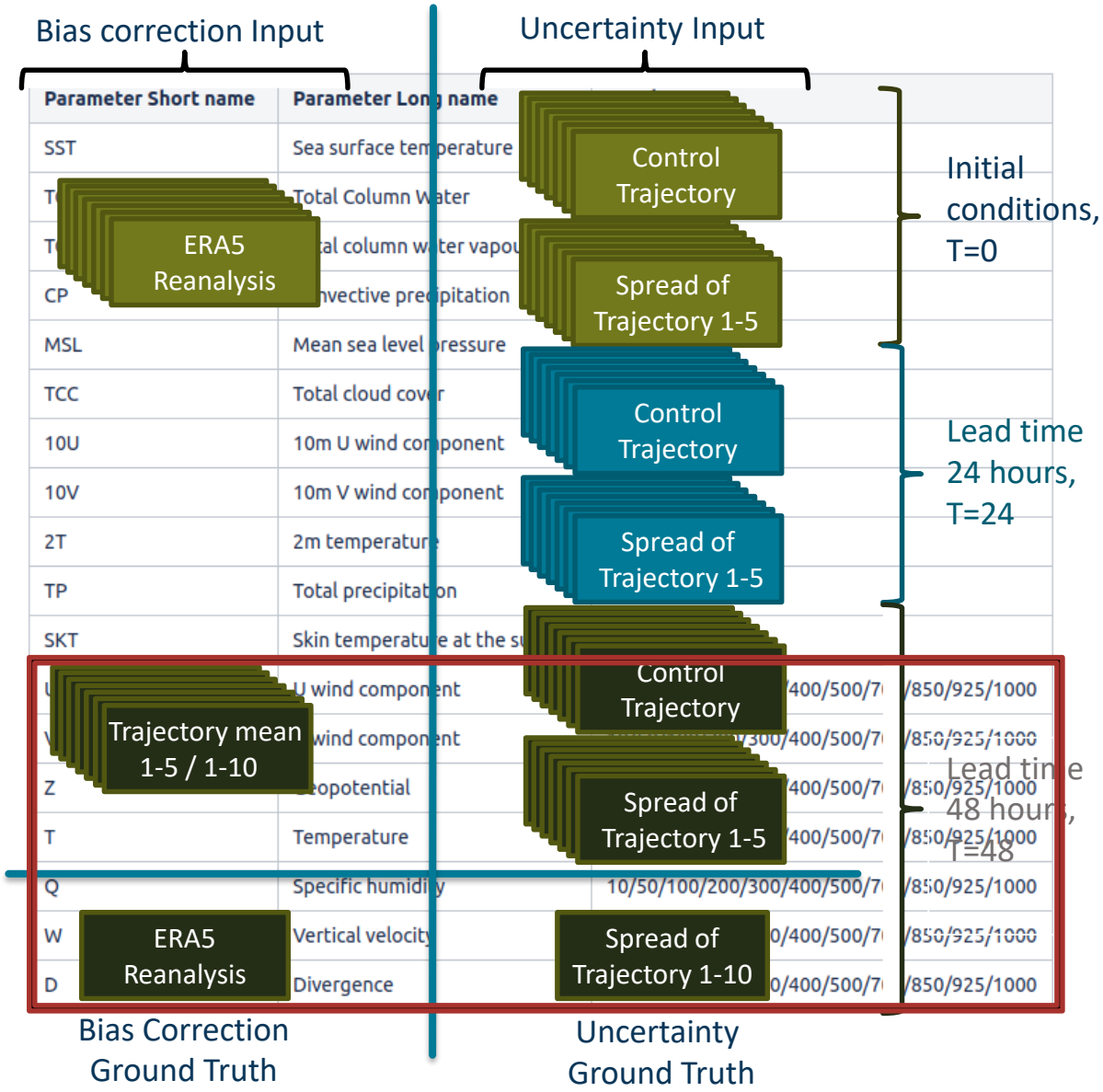
ERA5

- Re-analysis dataset
- 1 trajectory (mean)
- 0.5° latitude / longitude resolution
- 1979 – present
- Hourly
- Ground-truth data

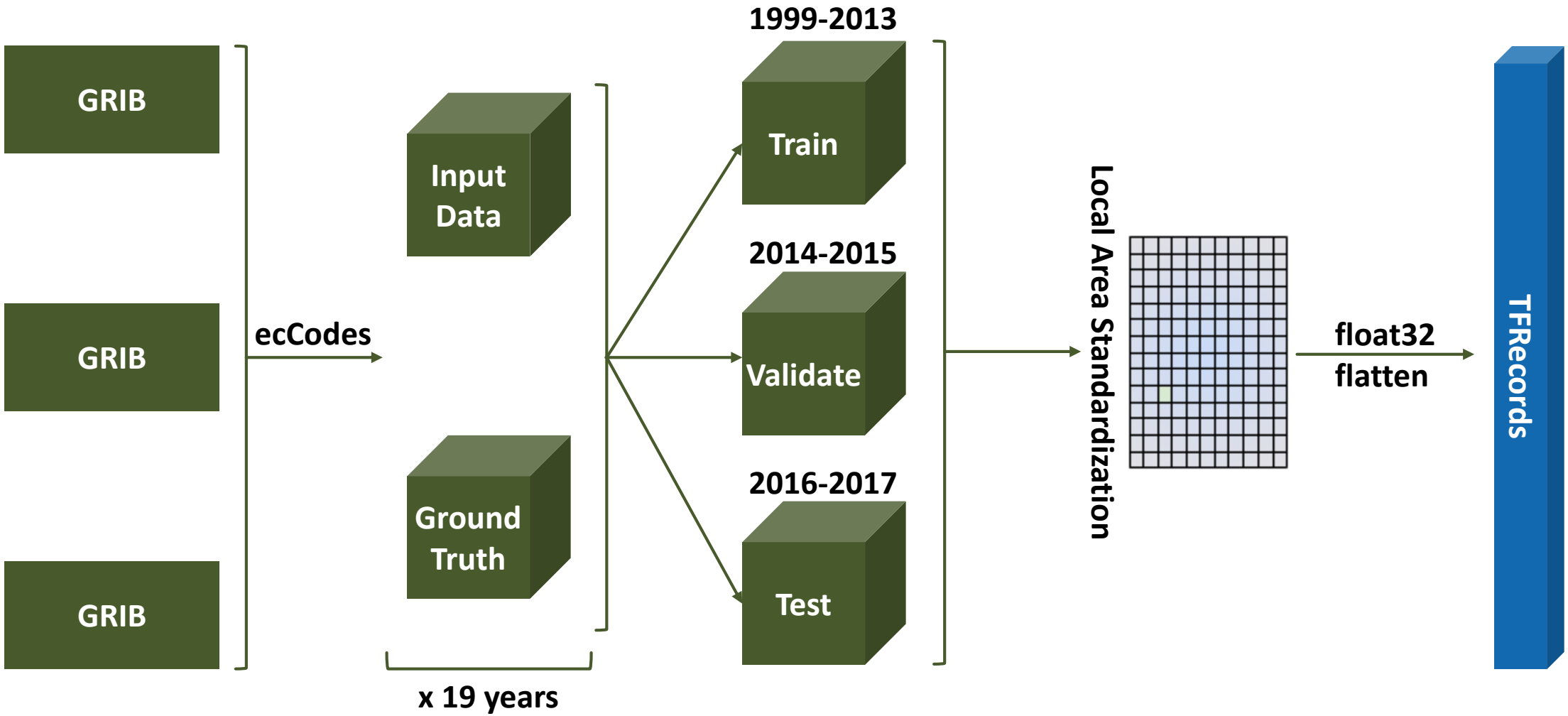


Data selection

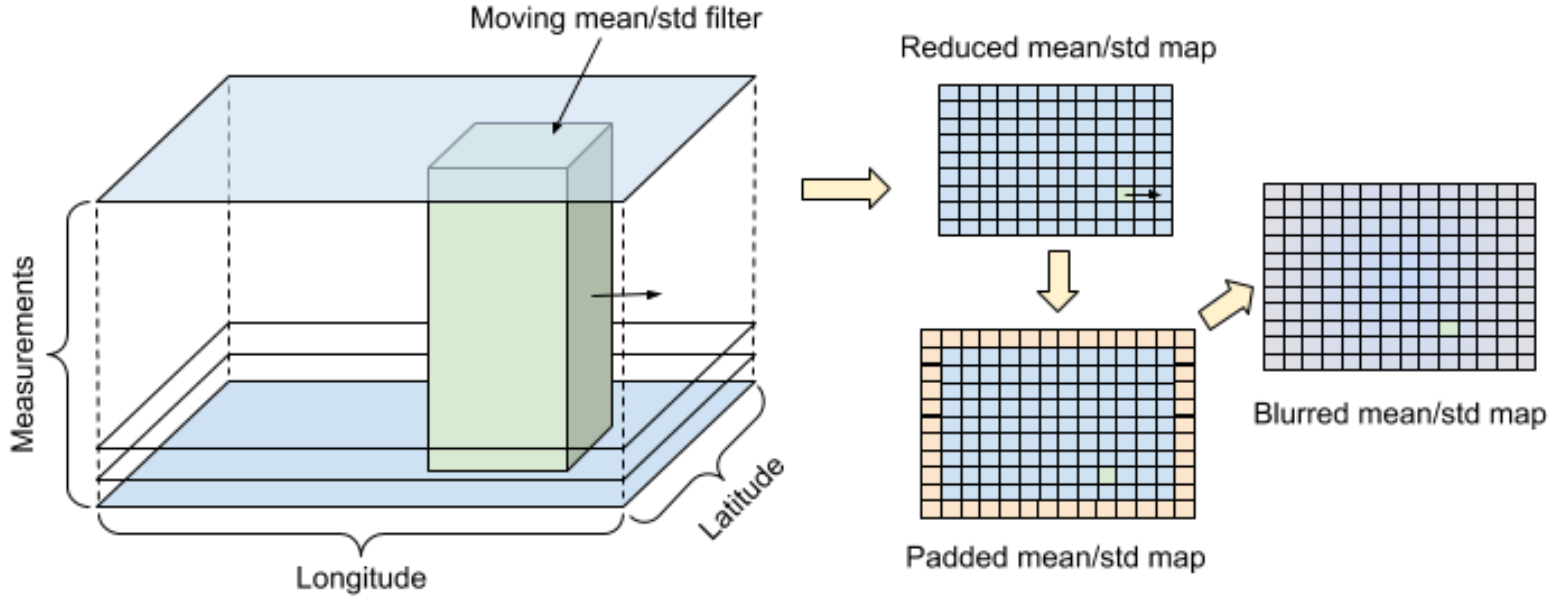


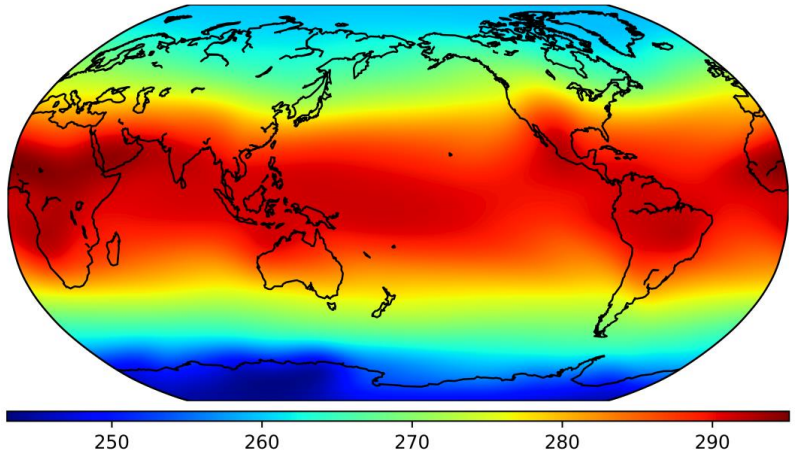


Data Preprocessing

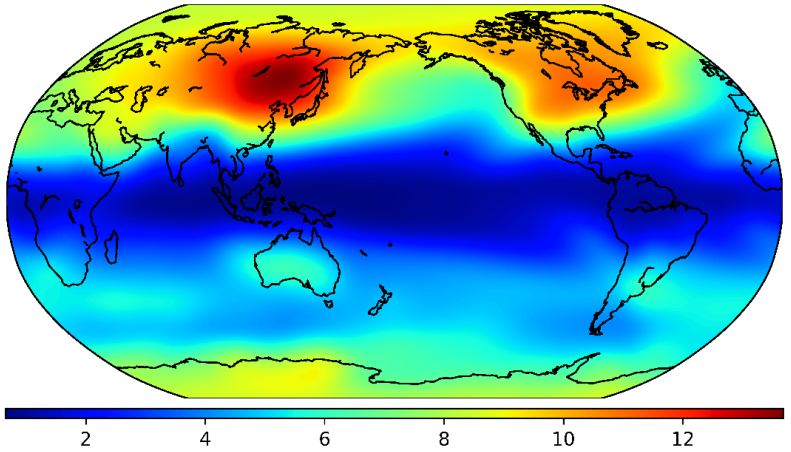


Local Area Standardization



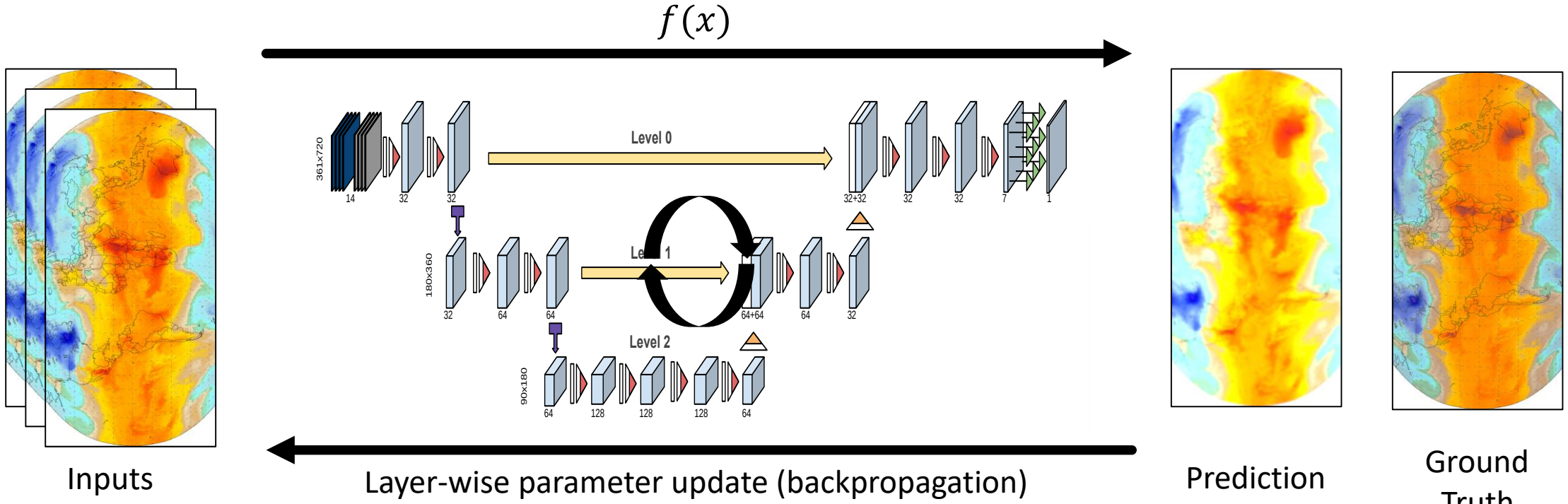


T850 mean



T850 standard deviation

Training Neural Networks



$f(x): X \to Y$

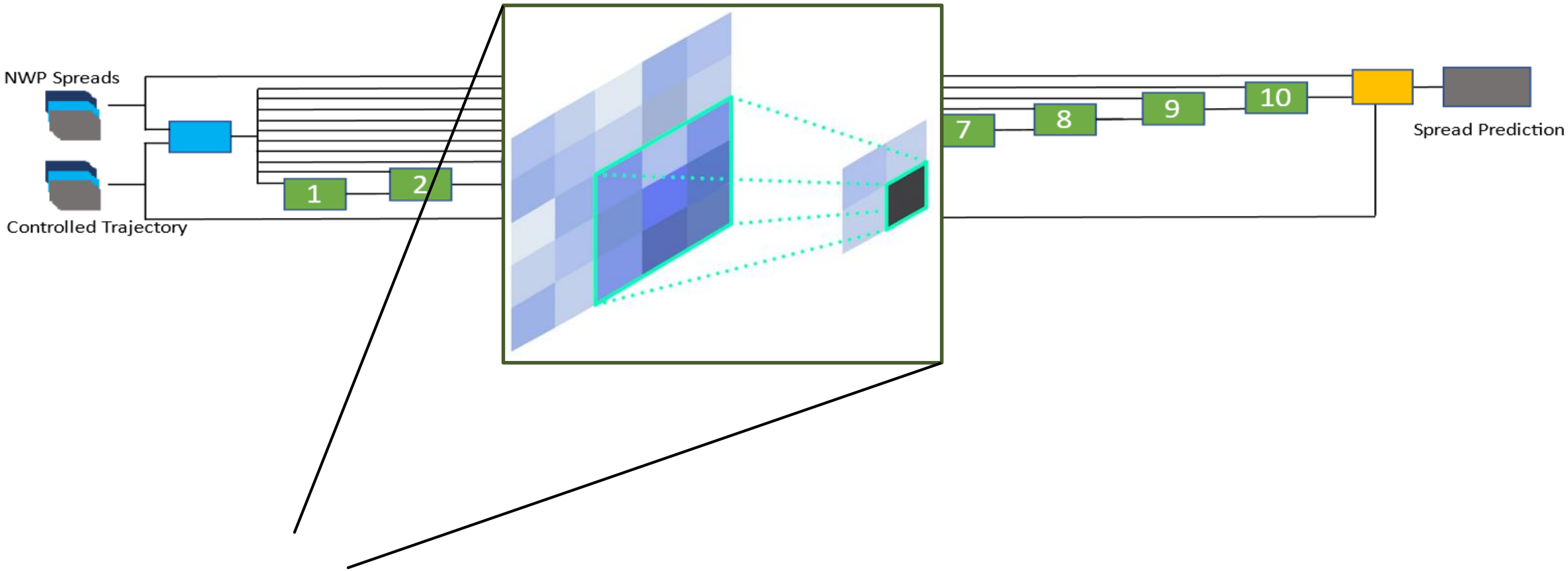
network structure (fixed) | weights w (learned)

$w^* = \text{argmin}_{w \in \mathbb{R}^d} \mathbb{E}_{x \sim \mathcal{D}}[\ell(w, x)]$

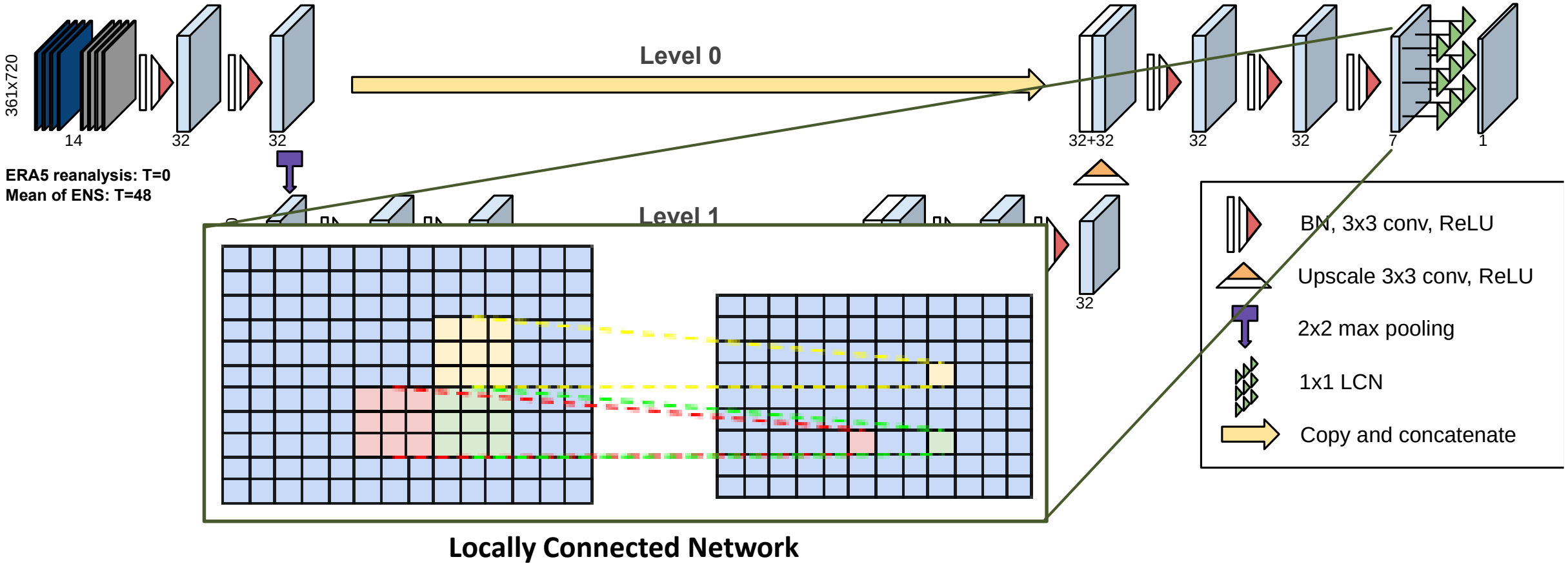
Stochastic gradient descent
- Momentum
- AdaGrad
- Adam
- …

$\ell_{sq}(w, x) = \big(f(x) - l(x)\big)^2$

Uncertainty Quantification (UQ) Network



Bias Correction (BC) Network



Metrics

Mean Squared Error (MSE)

Root Mean Squared Error (RMSE)

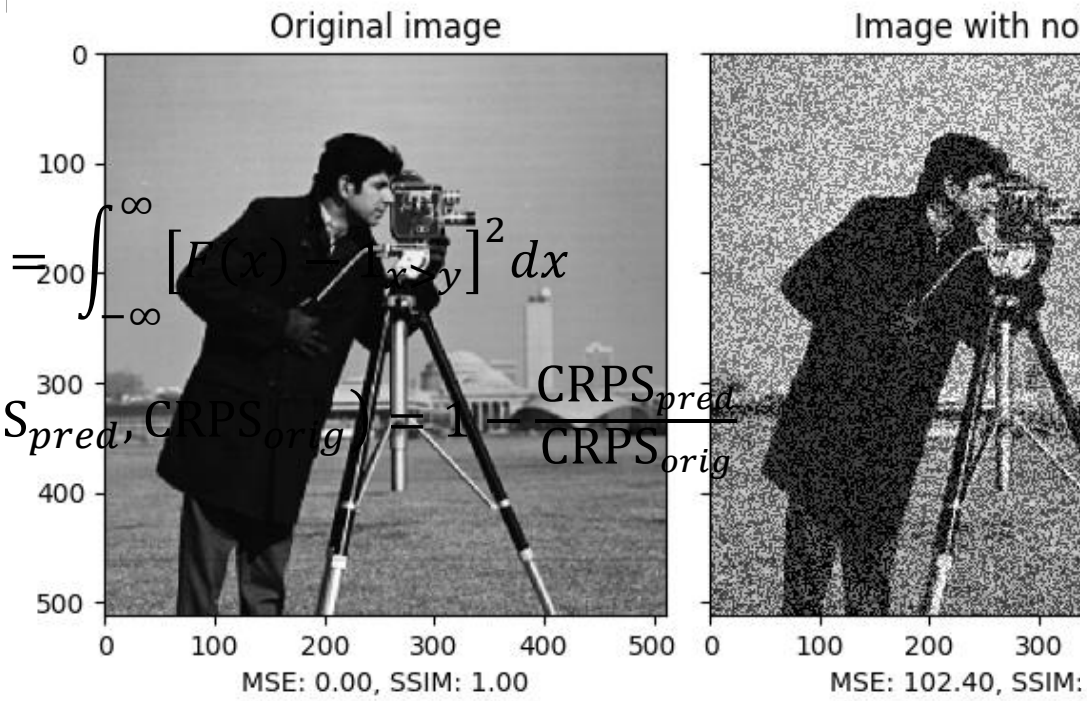
Structural Similarity Index Measure (SSIM)

Continuous Ranked Probability Score (CRPS)

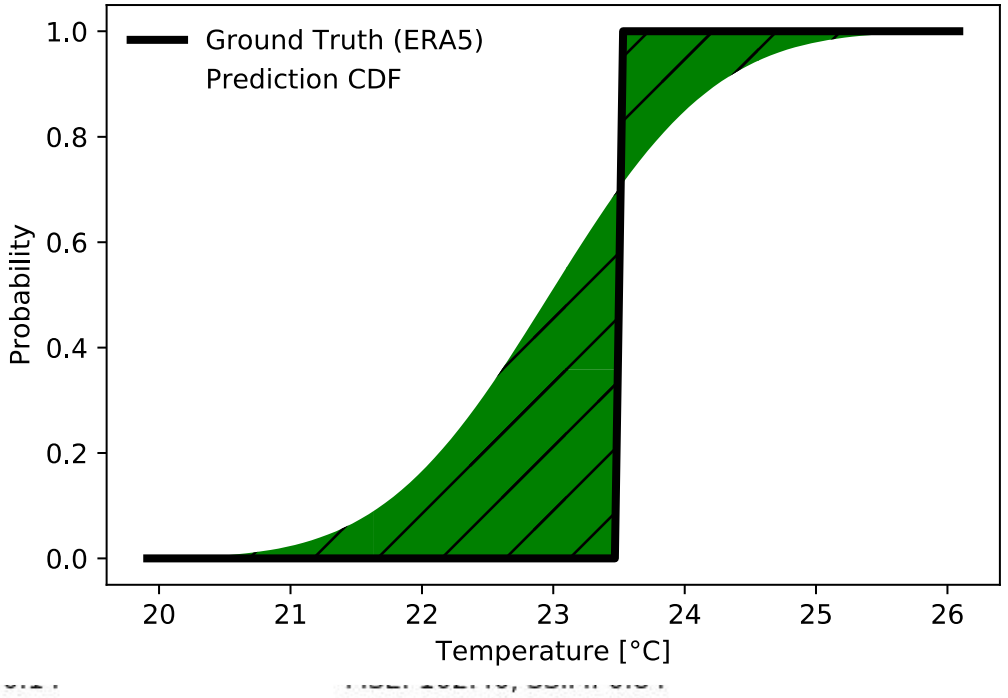
Continuous

$$\mathrm{CRPS}(F, y) = \int_{-\infty}^{\infty} \left[F(x) - \mathbb{1}_{x \geq y}\right]^2 dx$$

$$\mathrm{CRPSS}\left(\mathrm{CRPS}_{pred}, \mathrm{CRPS}_{orig}\right) = 1 - \frac{\mathrm{CRPS}_{pred}}{\mathrm{CRPS}_{orig}}$$

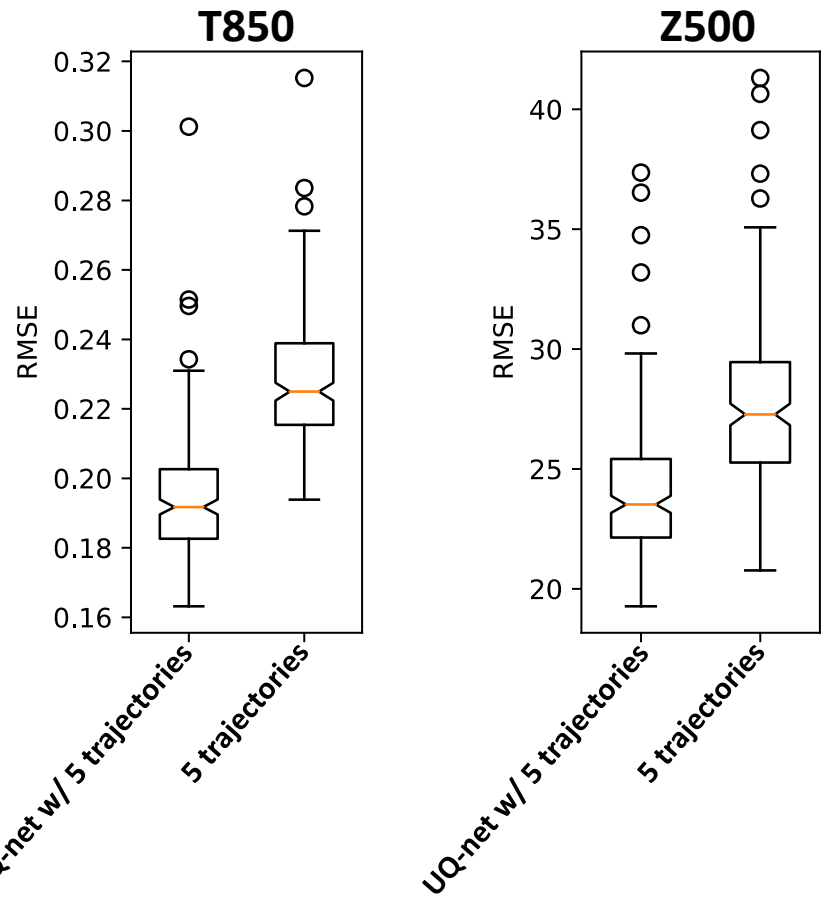


Source: scikit-image.org

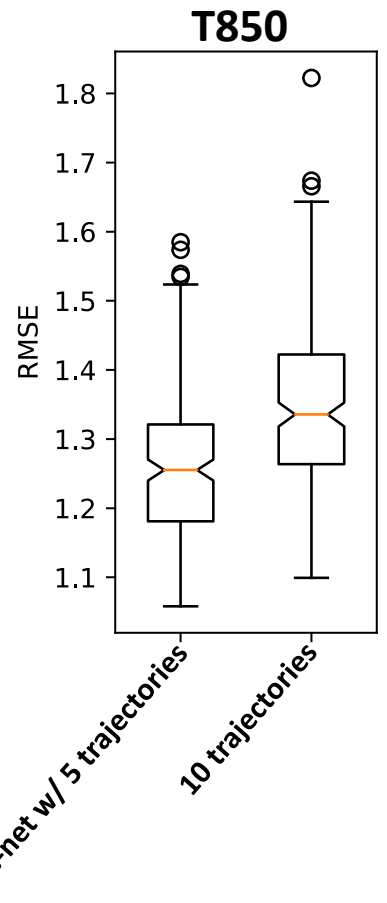


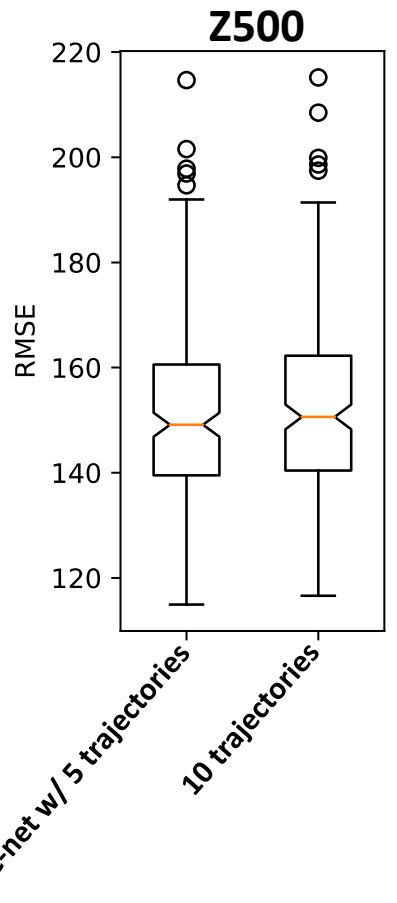
Evaluation – Global RMSE

Spread



Bias





Evaluation – Ablations

Spread – Number of trajectories for T850

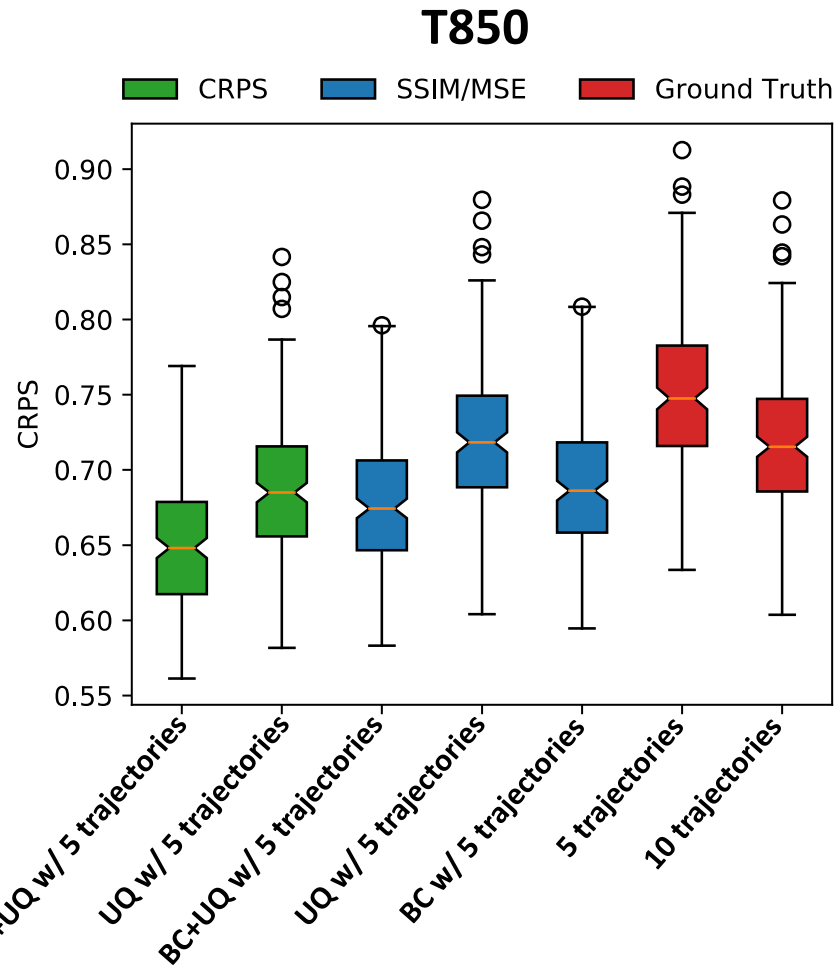
	Trajectories										
	3	4	5	6	7	8	9	Lin w/ 5	UQ w/ 3	UQ w/ 4	UQ w/ 5
Abs.	0.35	0.28	0.23	0.19	0.15	0.11	0.07	0.21	0.26	0.23	0.19
Rel.								8.9%	26.6%	18.7%	16.4%

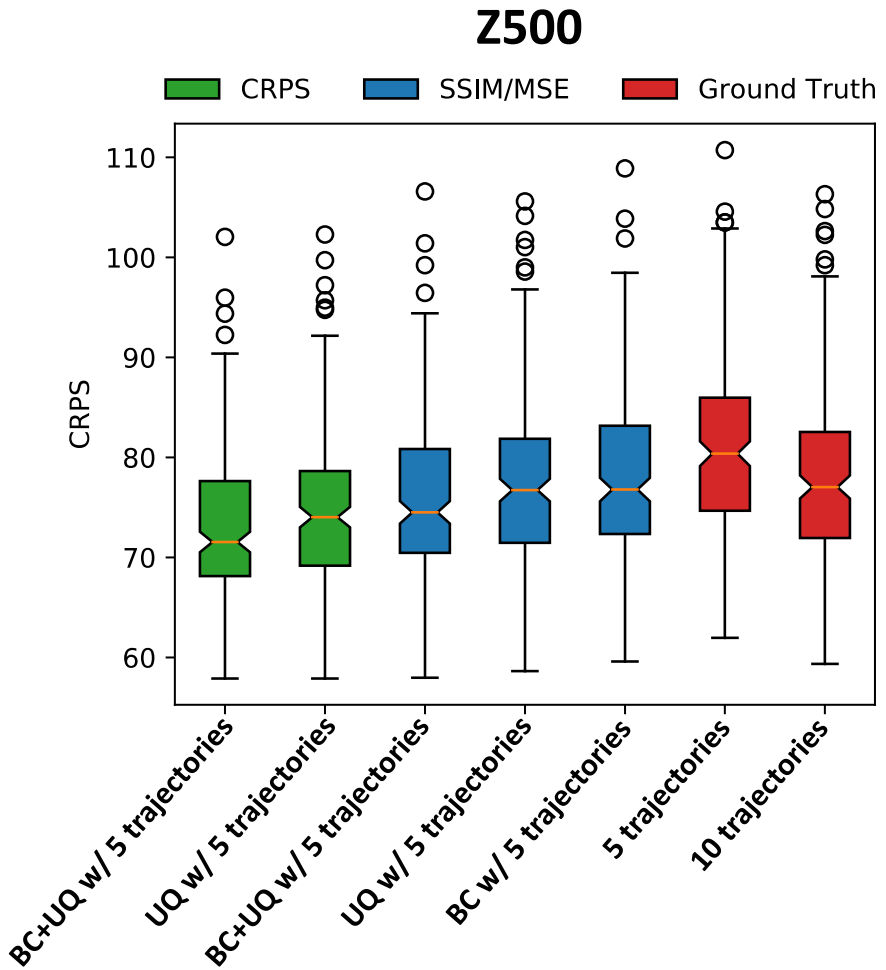
Bias correction – Relative improvement for U-Net variants

	Lin w/ 10	Level 0	Level 0-1	Level 0-2	Level 0 + LCN	Level 0-1 + LCN	Level 0-2 + LCN	Level 0-1 + LCN + ℓ_1
T850	4.8%	6.3%	7.1%	6.7%	7.6%	7.7%	7.6%	7.9%
Z500	2.1%	1.2%	1.6%	1.0%	2.6%	2.5%	2.4%	2.3%

Evaluation – PDF Calibration

Lower is better!





General Improvement (CRPSS)

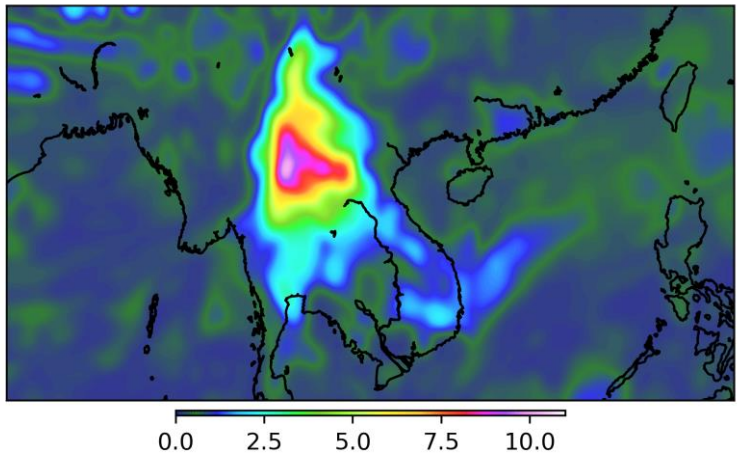
Higher is better!

	T850	Z500
10 traj.	0.1098	0.0756
5 traj.	0.1458	0.1074

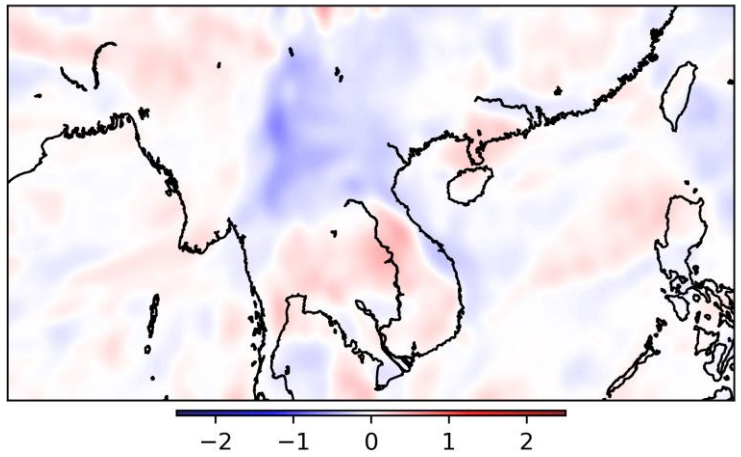
EMOS5 for T850: 0.055

Evaluation – Extreme Weather

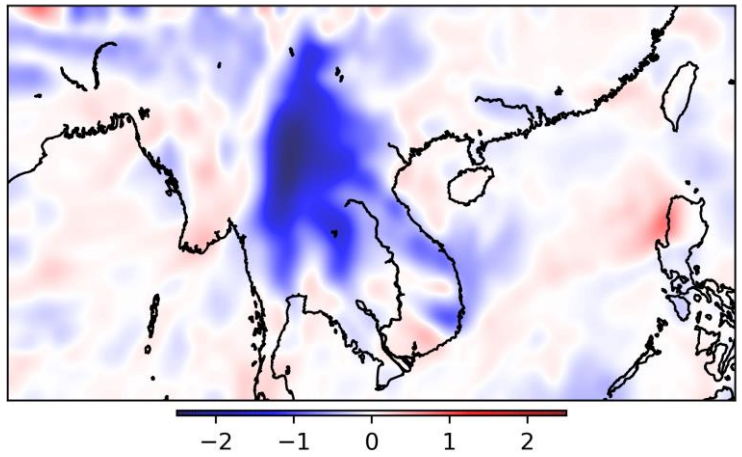
Cold front over E & SE Asia (24 Jan 2016)



10 trajectory CRPS



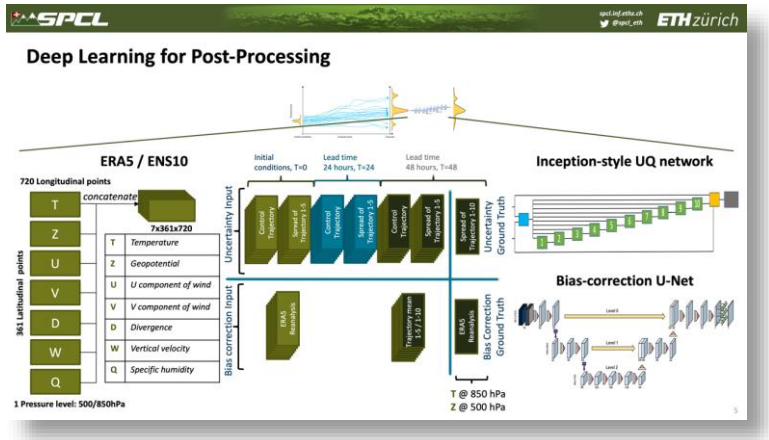
5 trajectories
compared to 10 trajectories

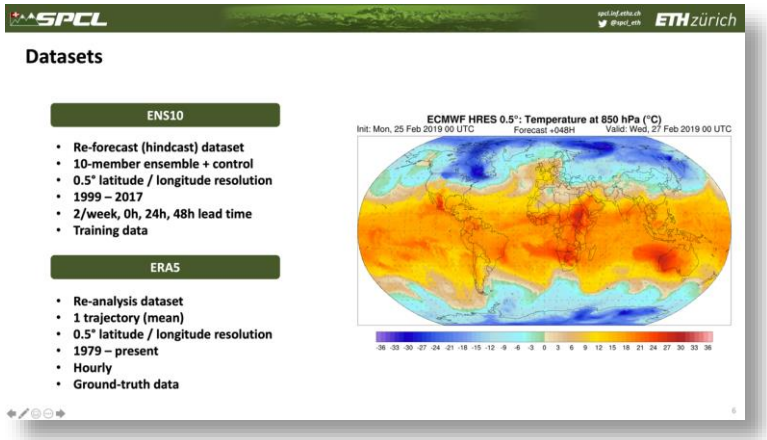


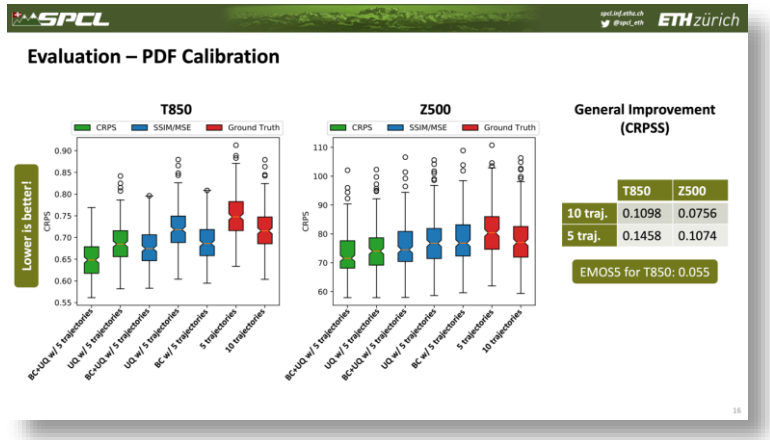
Calibrated UQ+BN nets w/ 5 trajectories
compared to 10 trajectories

Overall CRPSS Improvement: 0.195

Conclusions







More results in our paper!

https://arxiv.org/abs/2005.08748 — https://github.com/spcl/deep-weather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