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modRSW ensemble Kalman filter configuration and tuning

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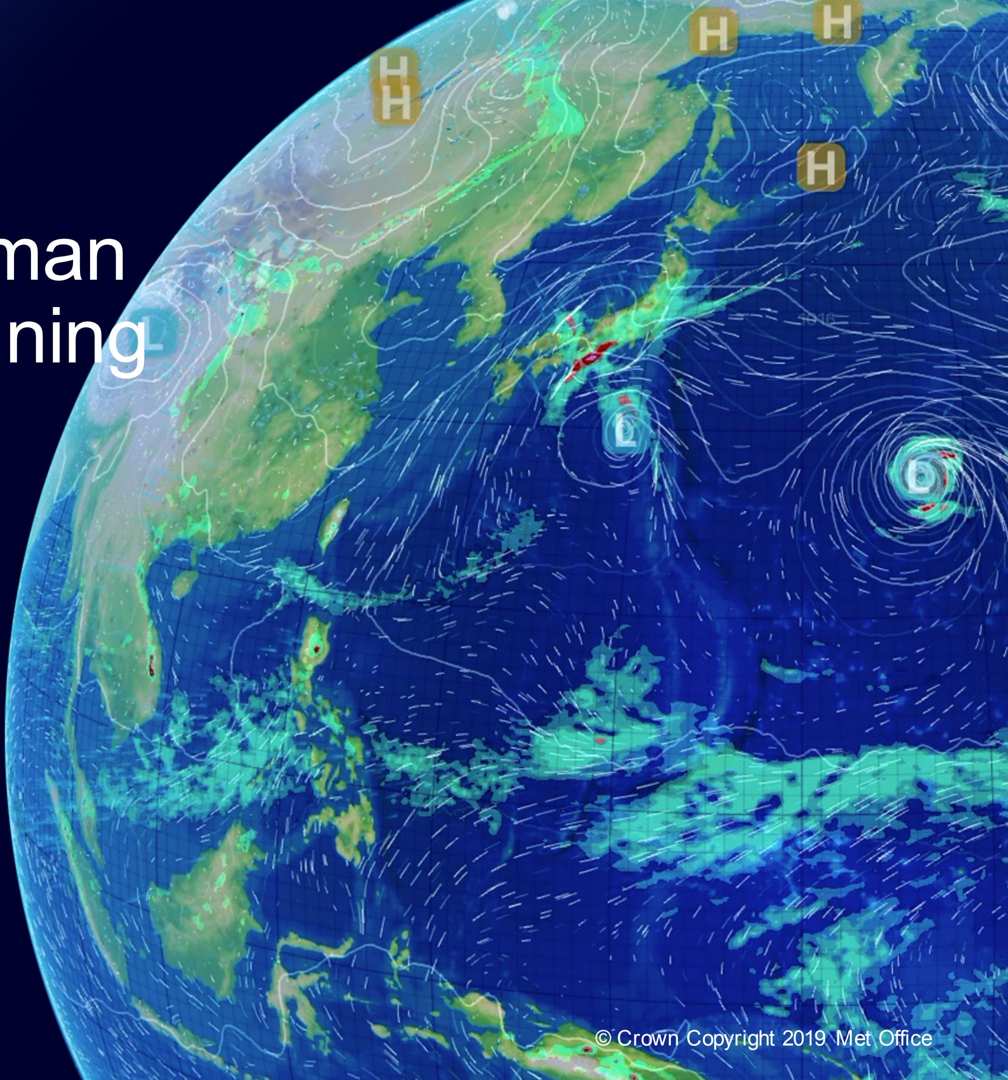

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Experiment construction

Experiment construction

- Domain is 500 km wide with orography
- Nature run uses 400 grid points while forecast model uses 200 grid points (2.5 km grid spacing)
- Nature run is used to create pseudo-observations by adding zero-mean Gaussian noise
- Hourly cycling
- Observe all variables every 50 km (30 observations)
- Ensemble Kalman filter with 20 members

Ensemble Kalman filter (EnKF) components

Deterministic EnKF and self-exclusion

- Deterministic EnKF (Sakov and Oke, 2008) is preferred over the perturbed-observations EnKF for few observations
- Self-exclusion (Houtekamer and Mitchell, 1998; Hamill and Snyder, 2000; Bowler et al., 2017; Lorenc et al., 2017) limits inbreeding by excluding the member being updated from the forecast-error covariance calculation

Additive inflation

- Additive inflation accounts for model error (Houtekamer and Zhang, 2016)
- Diagonal model-error covariance matrix estimated from sample of differences of high-resolution nature run and low-resolution forecasts, both starting from nature run trajectory points
- Zero-mean Gaussian noise added to the forecast trajectory as a tendency using an Incremental Analysis Update approach (Bloom et al., 1996)
- Treats systematic error as if it was random error
- Apply a scaling factor to compensate

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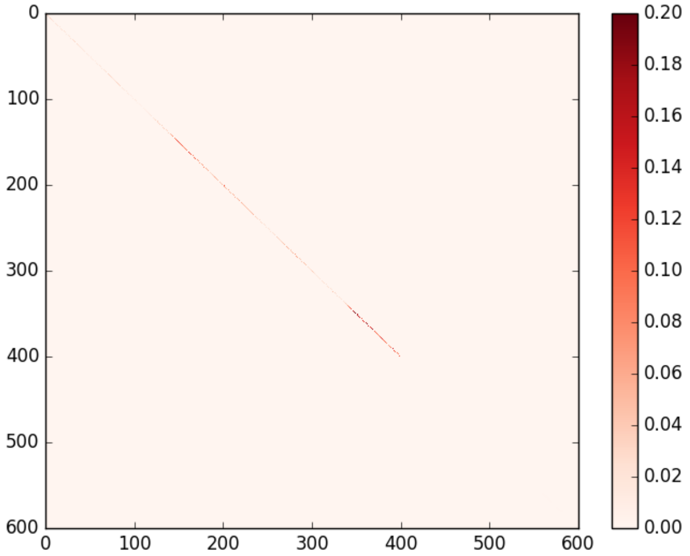
Model-error cov. matrix for $(h^T, (hu)^T, (hr)^T)^T$



Relaxation to Prior Spread

- RTPS (Whitaker and Hamill, 2012) applies adaptive multiplicative inflation to the ensemble perturbations from the ensemble mean to compensate for sampling error

$$(x_i^a)' \leftarrow (x_i^a)' \left(\alpha \frac{\sigma_b - \sigma_a}{\sigma_a} + 1 \right)$$

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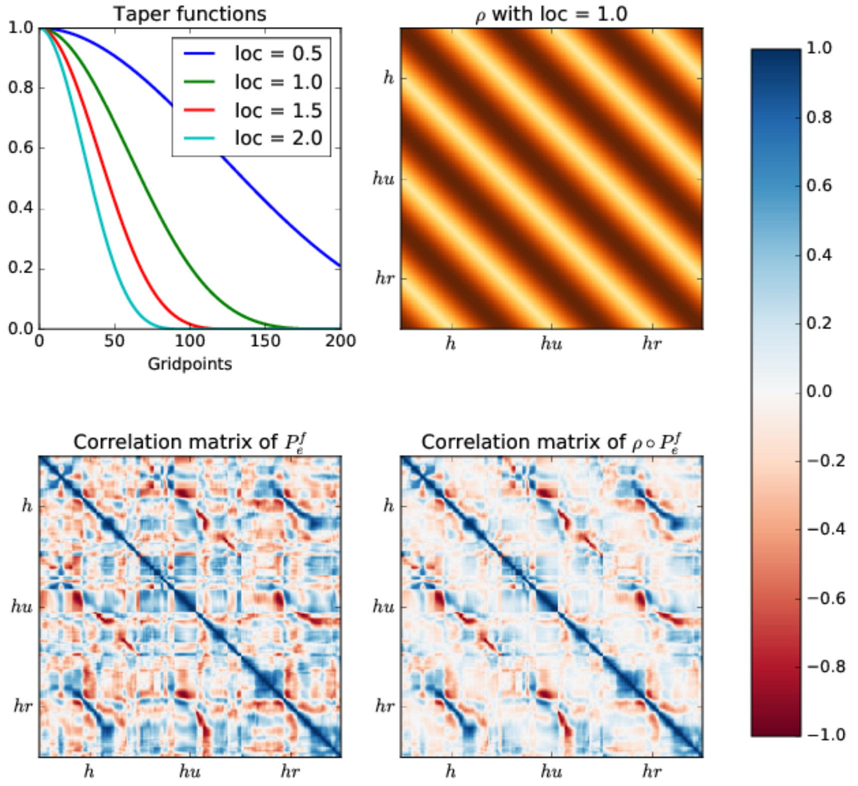
Localisation

- Gaspari-Cohn localisation applied to the forecast-error covariance matrix to suppress correlation values away from the block diagonals
- 45 hours into cycling forecast/assimilation experiment



Diagnostics

Generalising approach of Inverarity (2015)

Spread / RMSE

- For an ideal ensemble, the ensemble spread about the ensemble mean should match the root mean square error of the ensemble mean
- A single RMSE score can be calculated over all three dimensionless components h, u and 100 r – each of order 1 after scaling the rainfall variable

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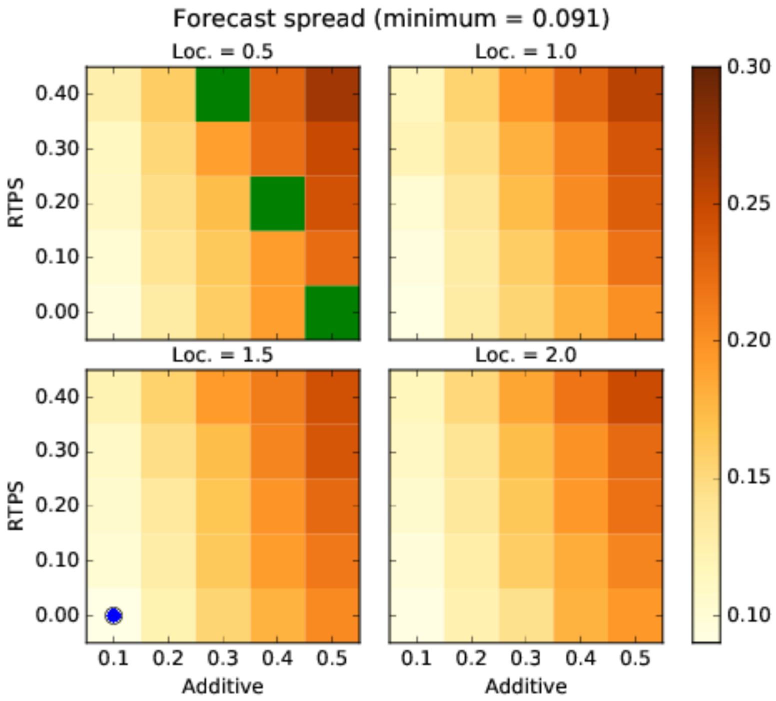
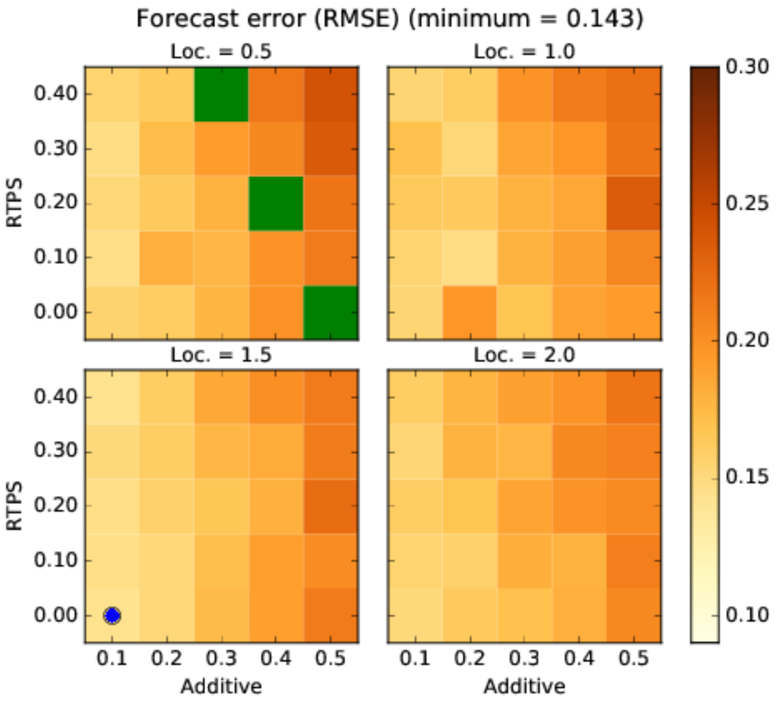


Forecast spread (minimum = 0.091)
Loc. = 0.5
Loc. = 1.0
Loc. = 1.5
Loc. = 2.0
RTPS
0.40
0.30
0.20
0.10
0.00
Additive
0.1 0.2 0.3 0.4 0.5
0.30
0.25
0.20
0.15
0.10



Forecast error (RMSE) (minimum = 0.143)
Loc. = 0.5
Loc. = 1.0
Loc. = 1.5
Loc. = 2.0
RTPS
0.40
0.30
0.20
0.10
0.00
Additive
0.1 0.2 0.3 0.4 0.5
0.30
0.25
0.20
0.15
0.10

CRPS

- Continuous ranked probability score (e.g. Hersbach, 2000)
- Compares system's empirical cumulative distribution function (cdf) with a reference cdf
- Lower score is better
- Plots compare with cdf derived from nature run

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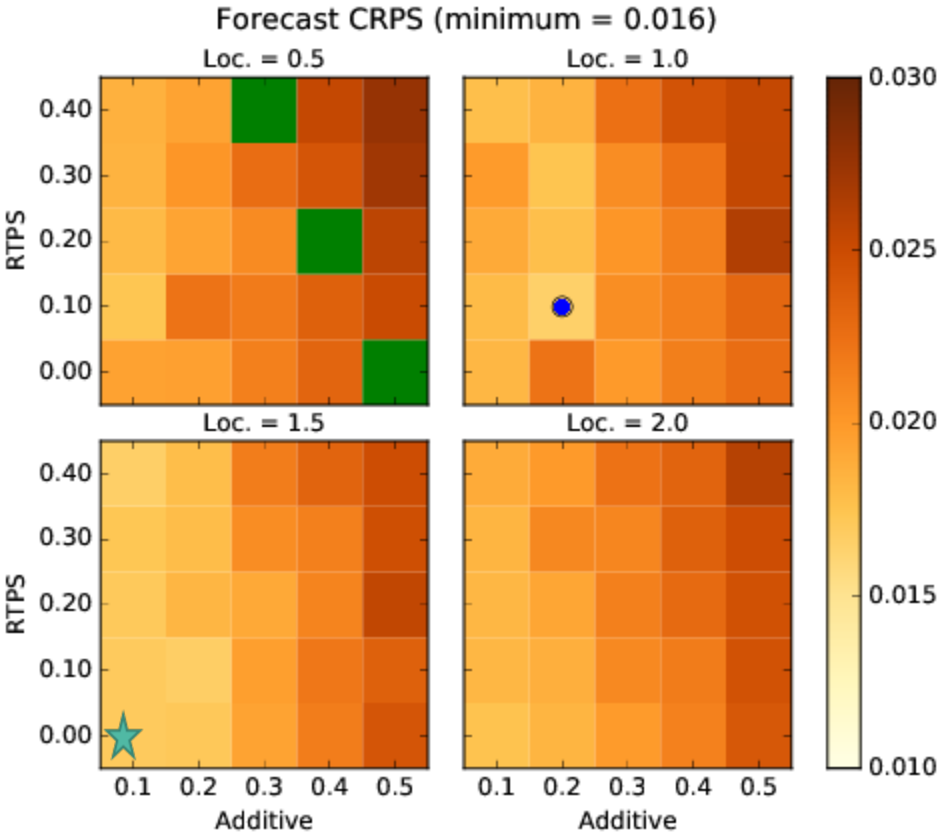
Forecast CRPS (minimum = 0.016)
Loc. = 0.5
Loc. = 1.0
Loc. = 1.5
Loc. = 2.0
RTPS
0.40
0.30
0.20
0.10
0.00
Additive
0.1
0.2
0.3
0.4
0.5
0.030
0.025
0.020
0.015
0.010

Observational influence

- Degrees of freedom of signal measure of the relative contribution of observations to the analysis (Cardinali et al., 2004) compared to the previous forecast
- ECMWF value 15% (global forecast)

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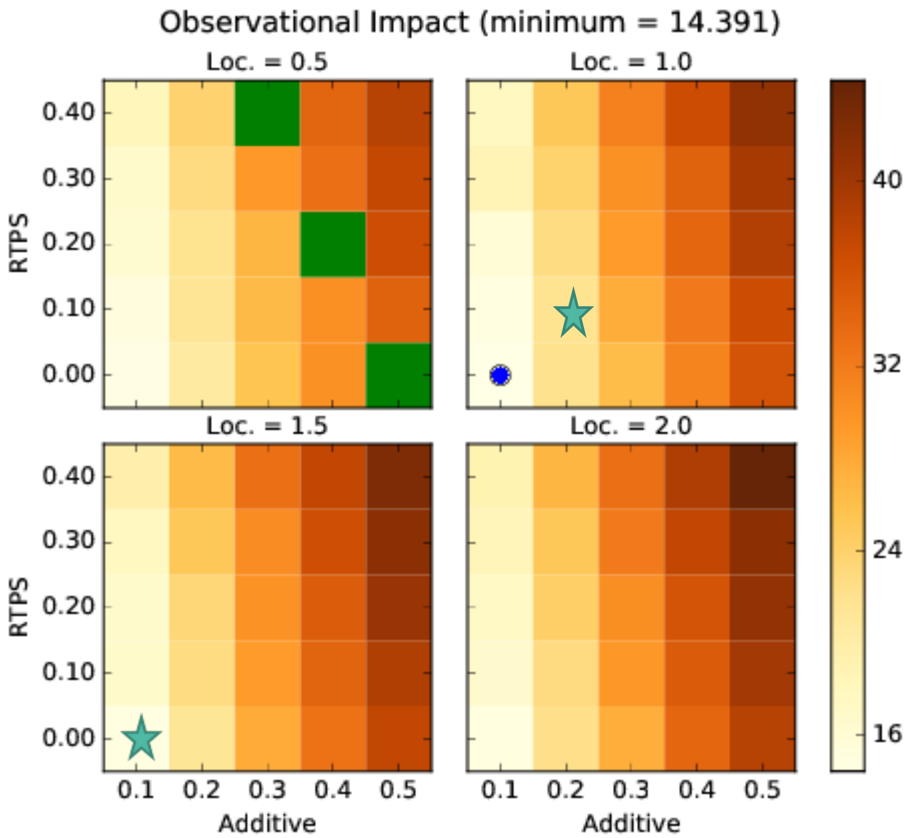
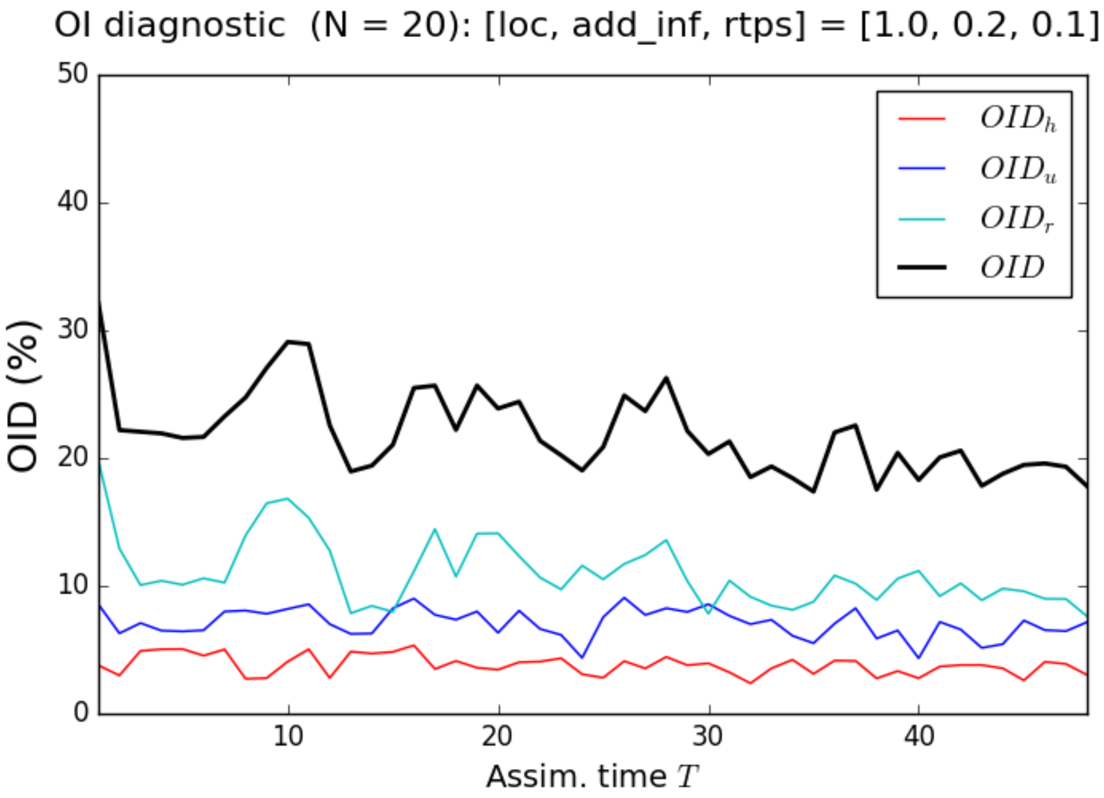


Observational Impact (minimum = 14.391)
Loc. = 0.5
Loc. = 1.0
Loc. = 1.5
Loc. = 2.0
RTPS
0.40
0.30
0.20
0.10
0.00
Additive
0.1
0.2
0.3
0.4
0.5
40
32
24
16


OI diagnostic (N = 20): [loc, add_inf, rtps] = [1.0, 0.2, 0.1]
OID_h
OID_u
OID_r
OID
OID (%)
Assim. time T
0
10
20
30
40
50
10
20
30
40

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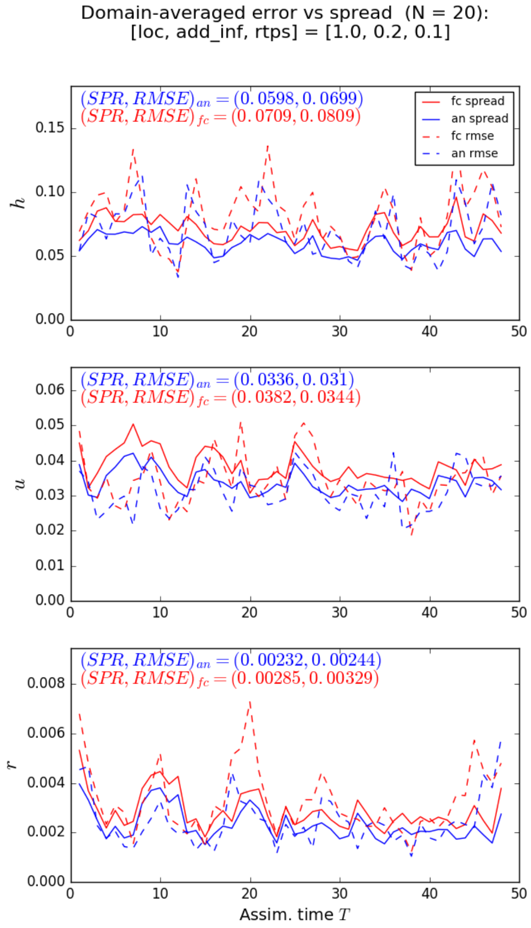

Domain-averaged error vs spread (N = 20):
[loc, add_inf, rtps] = [1.0, 0.2, 0.1]
$(SPR, RMSE)_{an} = (0.0598, 0.0699)$
$(SPR, RMSE)_{fc} = (0.0709, 0.0809)$
fc spread
an spread
fc rmse
an rmse
h
$(SPR, RMSE)_{an} = (0.0336, 0.031)$
$(SPR, RMSE)_{fc} = (0.0382, 0.0344)$
u
$(SPR, RMSE)_{an} = (0.00232, 0.00244)$
$(SPR, RMSE)_{fc} = (0.00285, 0.00329)$
r
Assim. time T

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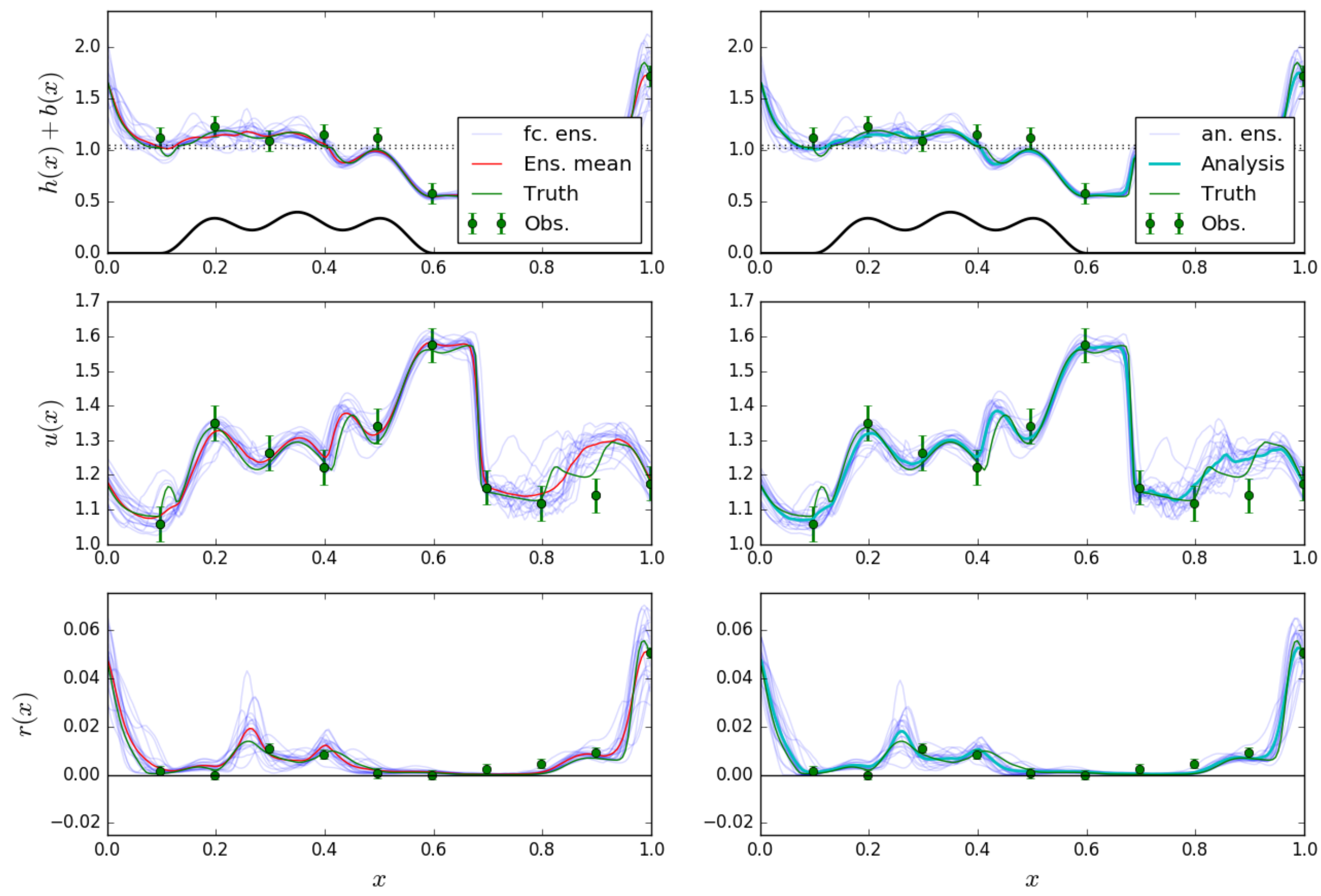
12 hours



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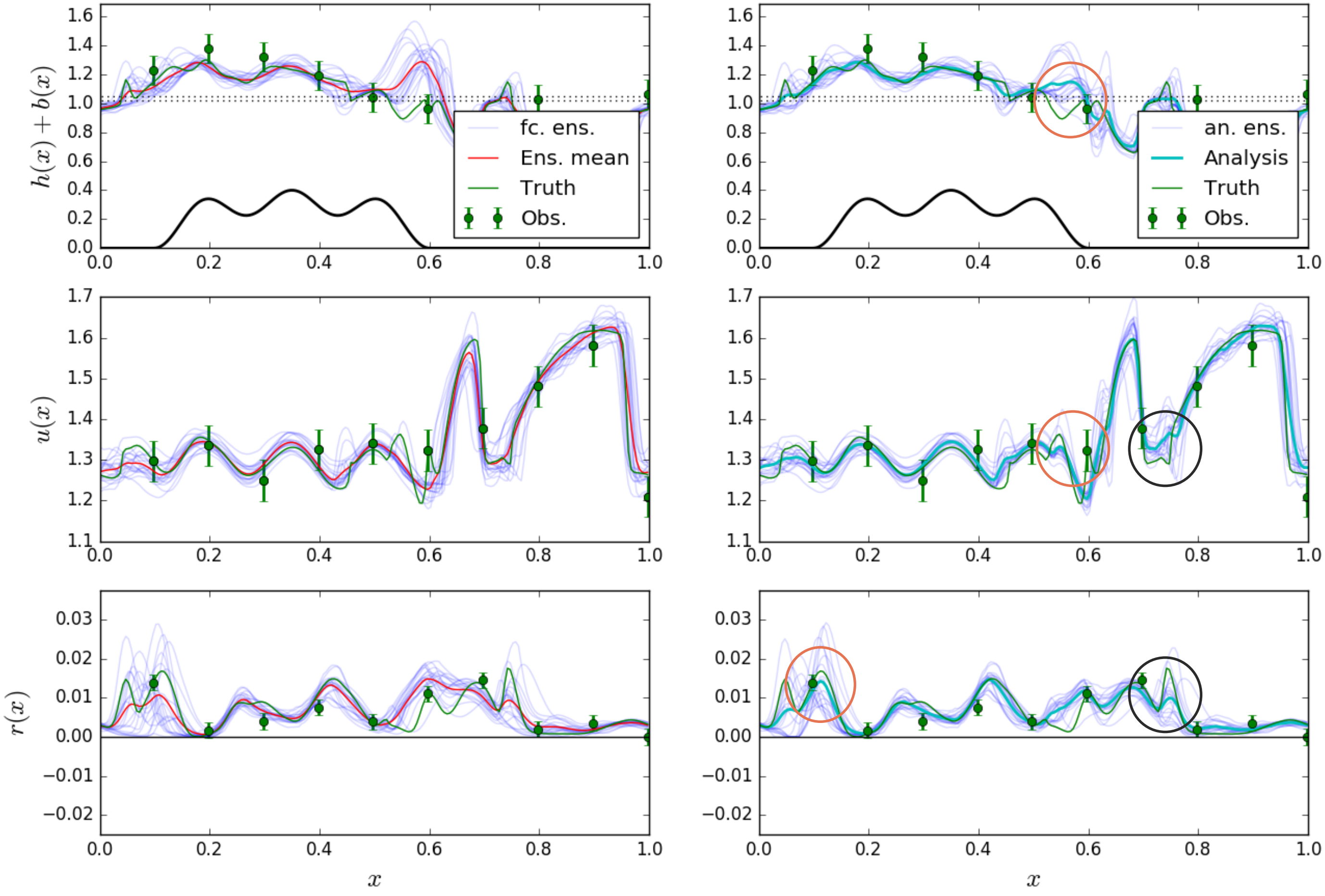
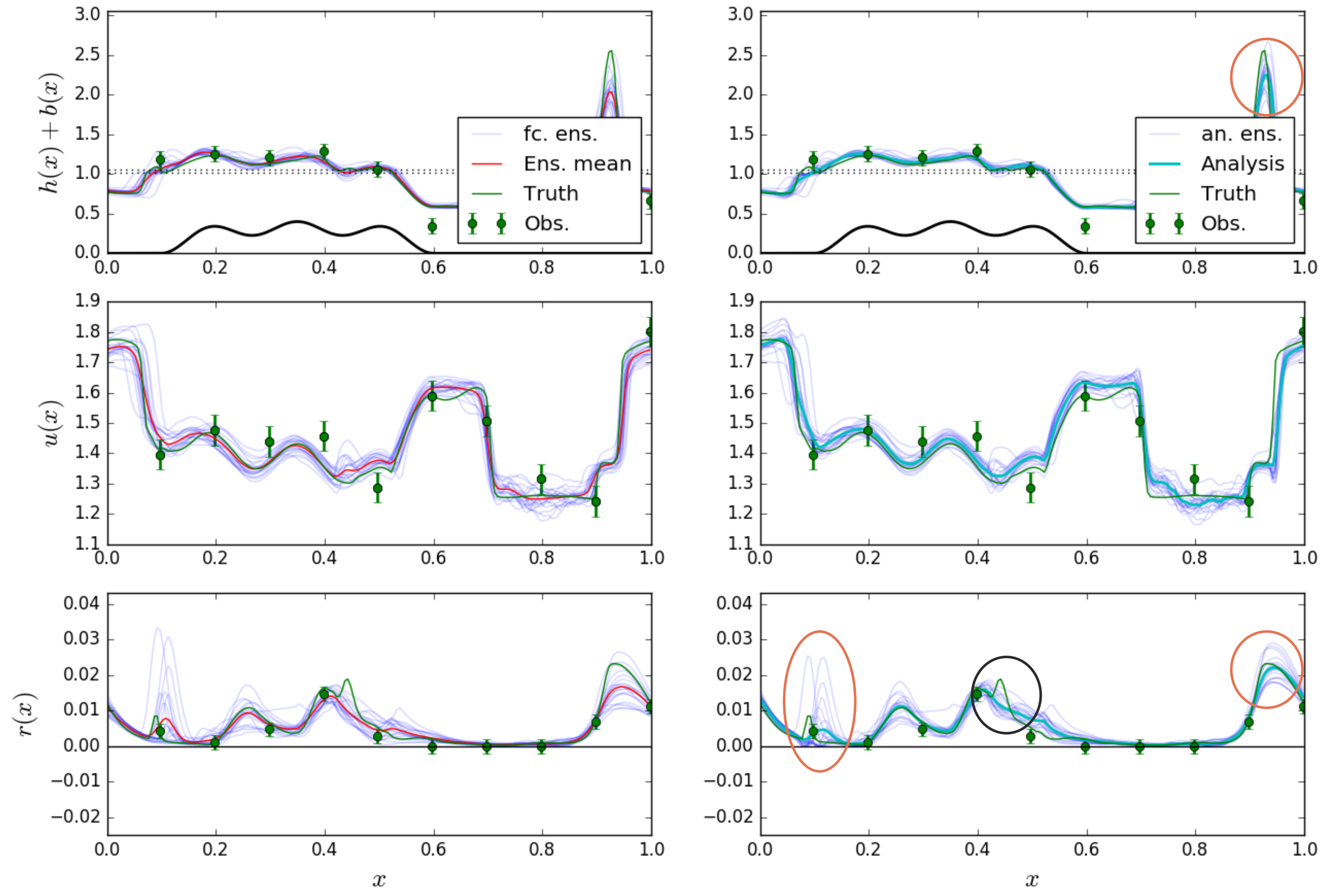
24 hours

Red for better
Black for worse
or no impact

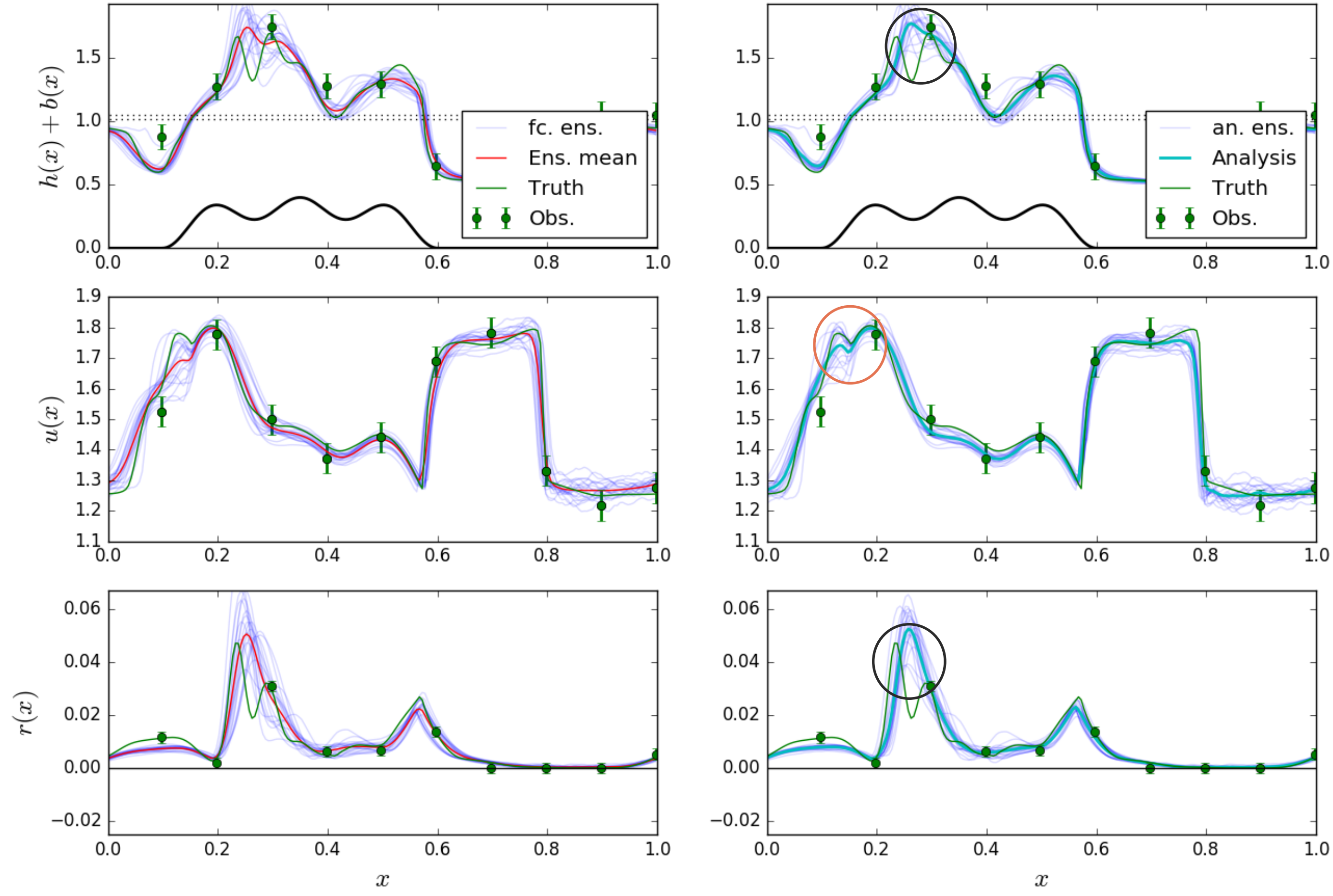


36 hours



fc. ens.
Ens. mean
Truth
Obs.
an. ens.
Analysis
Truth
Obs.
$h(x)+b(x)$
$u(x)$
$r(x)$
x
x

48 hours


fc. ens.
Ens. mean
Truth
Obs.
an. ens.
Analysis
Truth
Obs.
$h(x)+b(x)$
$u(x)$
$r(x)$
x
x

Summary

Summary

- Realistic convective-scale data assimilation demonstrated using a deterministic ensemble Kalman filter
- Spread/RMSE of ensemble mean, observational influence and CRPS diagnostics used
- Tuning approach shown for a single observational configuration

Questions?

For more information please contact

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