Simulating idealised satellite radiance observations

L. Cantarello(1), O. Bokhove(1), S. Tobias(1), G. Inverarity(2), S. Migliorini(2)

(1) University of Leeds, School of Mathematics, Leeds, United Kingdom; (2) Met Office, Exeter, United Kingdom

Author's email: mmlca@leeds.ac.uk

OBJECTIVE: including simulated satellite radiance observations within a Data Assimilation scheme based on an idealised model for convection to facilitate future research

1. Introduction

An **idealised model for convection** developed at the University of Leeds and suitable for Data Assimilation research[1,2] will be used for **satellite Data Assimilation** (DA) research. A new idealised **observation operator** has been developed in order to assimilate simulated **satellite radiance observations**. An investigation of satellite radiance DA at different scales will be performed at a later stage of the project.

2. The idealised model for convection[1,2]

$$\begin{cases} \partial_t h + \partial_x (hu) = 0 \\ \partial_t (hu) + \partial_x (hu^2 + P) + hc_0^2 \partial_x r - \frac{1}{Ro} hv = -Q \partial_x b \\ \partial_t (hv) + \partial_x (huv) + \frac{1}{Ro} hu = 0 \\ \partial_t (hr) + \partial_x (hur) + h\tilde{\beta} \partial_x u + \alpha hr = 0 \end{cases}$$

Suitable for DA research: simpler than operational DA schemes

with: derivative of P

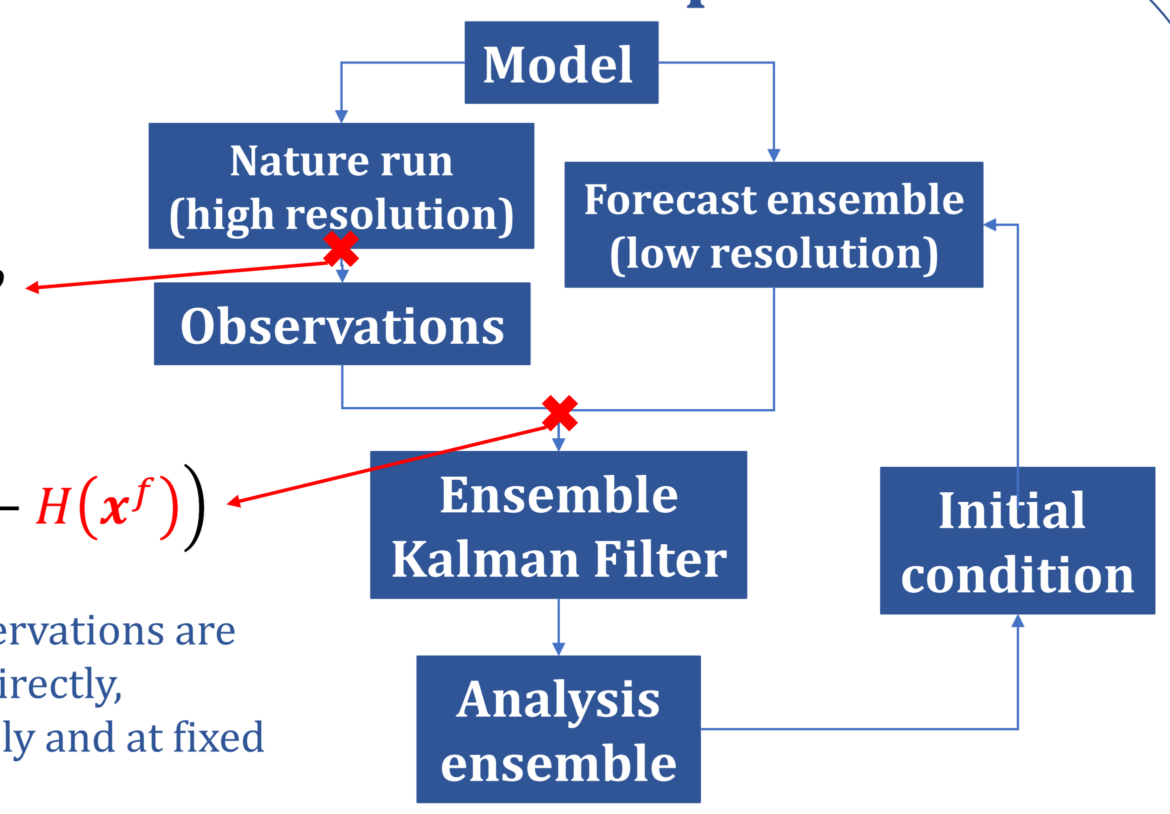
$$P = \begin{cases} \frac{1}{2} g h^2, & h + b \le H_c \\ \frac{1}{2} g (H_c - b)^2, & h + b > H_c \end{cases} \qquad \tilde{\beta} = \begin{cases} \beta, & h + b > H_r \text{ and } \partial_x u < 0, \\ 0, & otherwise \end{cases}$$

☞ Convection and precipitation are triggered by the surface height exceeding 2 different thresholds, H_c and H_r.

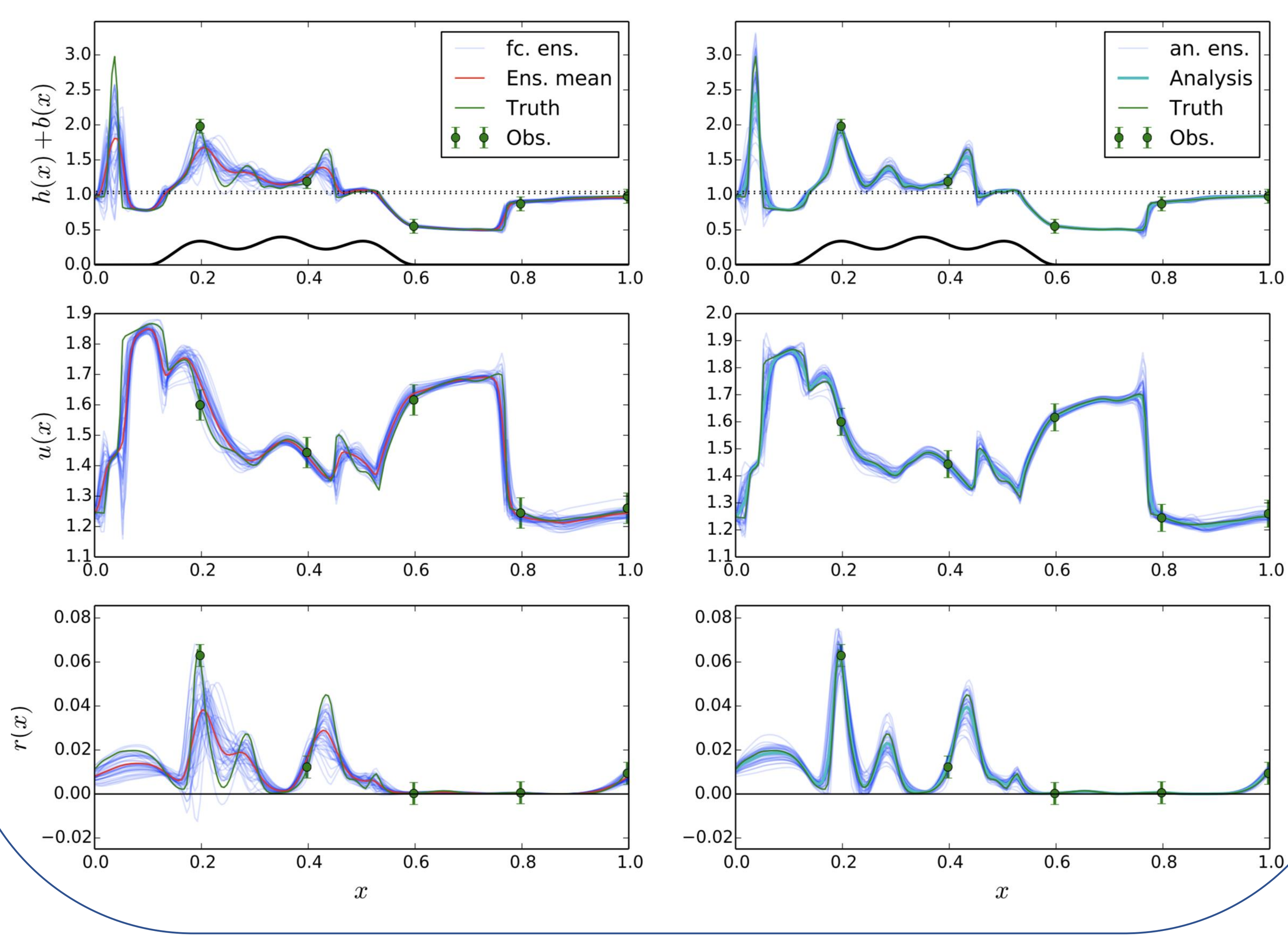
3. The Data Assimilation setup[1]

$$y^o = h(x^t) + \eta^o$$

$$x^a = x^f + K\left(y^o - H(x^f)\right)$$



☞ So far all observations are assimilated directly, simultaneously and at fixed points



4. Simulated radiance observations

Satellite observations (emitted radiance) ⟷ **?** ⟷ **Model variables (surface height)**

☞ From radiance to brightness temperature at ground, Rayleigh-Jeans' law:

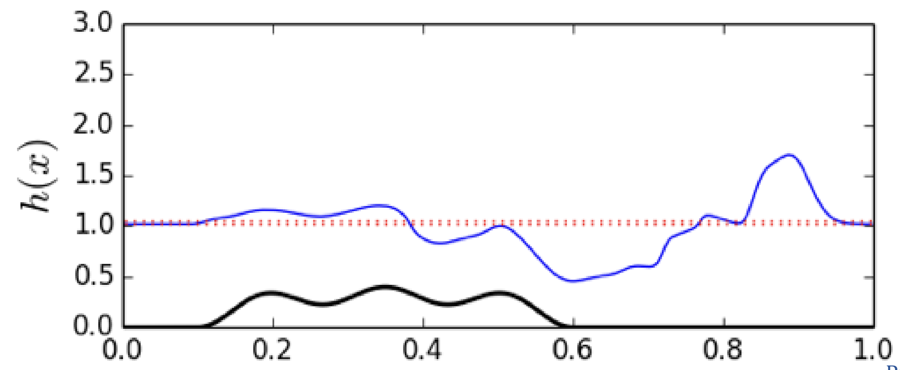
$$B(\lambda, T) = 2\frac{k_B c}{\lambda^4} T;$$

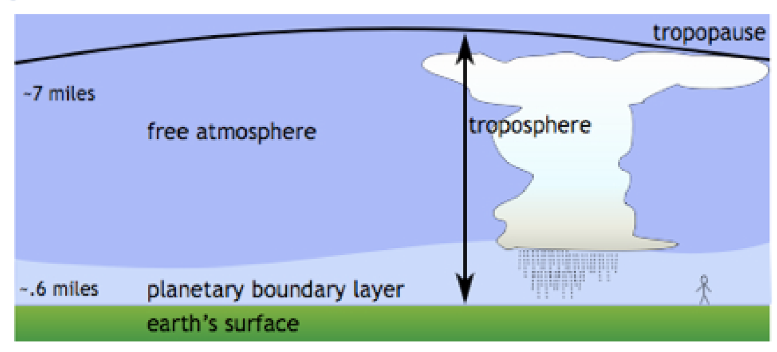
☞ From brightness temperature at ground to surface height, an ideal gas in hydrostatic equilibrium:

$$T = \frac{p_{top}}{\rho R} + \frac{gH}{R} h';$$

Temperature scaling T_0

Is this reasonable? Are we modelling the PBL?





Picture credits: http://kiwi.atmos.colostate.edu/cmmap/learn/climate/energy8.html

$T = 284\ K$ $\left(standard\ g = 9.81\ \frac{m}{s^2}\right)$

$T = 268\ K$ $\left(reduced\ g' = 6.3\ \frac{m}{s^2}\right)$

☞ Non-dimensional brightness temperature:

$$T' = \frac{T}{T_0} = \frac{p_{top}}{\rho g H} + h'$$

☞ A less arbitrary observational variance for h' in covariance matrix $\mathbf{R} = diag(\sigma_{h'}, \sigma_{u'}, \sigma_{v'}, \sigma_{r'})\boldsymbol{I}$:

$$\sigma_{h'} = \frac{1}{T_0} \sigma_T$$

Brightness temperature observational variance (from real instruments)

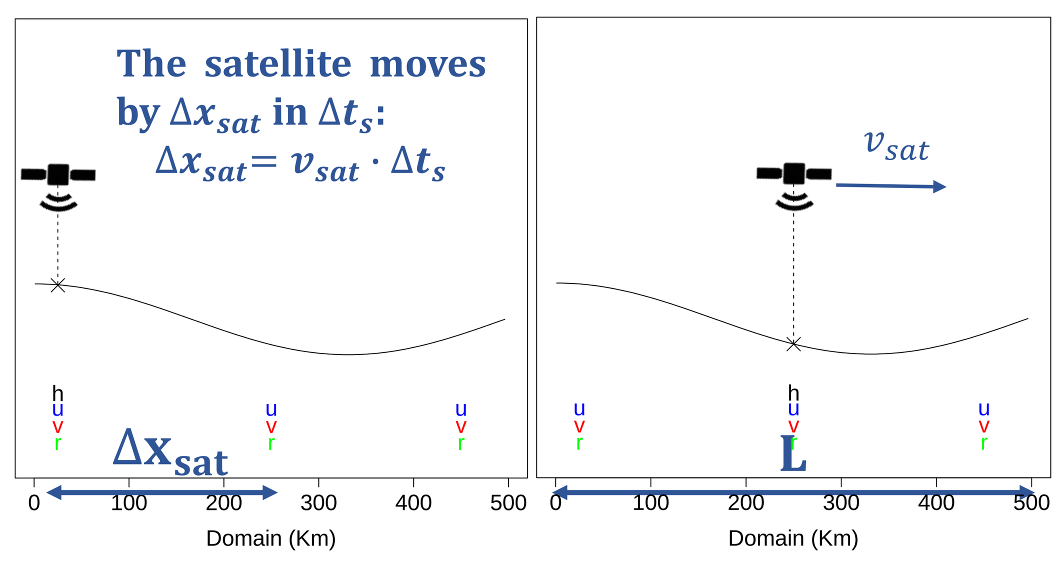
5. A spatially varying observational window

☞ A basic configuration (periodic domain):

Δt_s time between 2 consecutive assimilation

After n assimilations:
$t_n = \Delta t_s \cdot n$
$x_{sat} = n \cdot \Delta x_{sat} (mod\ L)$

Observation operator:
$$H(h^f) = h(x_{sat}) + \frac{p_{top}}{\rho g H}$$

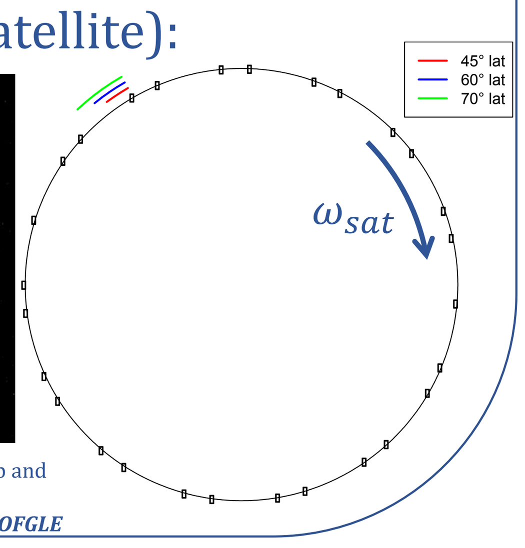


☞ A more realistic one (based on a polar-orbit satellite):

After m orbital periods T_{sat}:
$x_{sat,\uparrow} = \omega_{sat} \cdot m \cdot T_{sat}\ (mod\ 2\pi)$
$x_{sat,\downarrow} = \varphi + \omega_{sat} \cdot m \cdot T_{sat}\ (mod\ 2\pi)$

! Irregular duration of forecast step as $\Delta t_s \neq T_{sat}$

Illustration of the polar orbits of two satellites, MetOp and NOAA.
Credits: ESA - AOES Medialab, ID number: SEMZTMOFGLE



6. Future steps and questions

⇢ Ongoing testing and tuning for the new configurations
⇢ How can we introduce clouds?
⇢ How can we evolve the observation operator towards something more complex and realistic?
⇢ At a later stage: investigating the impact of satellite radiance DA at different spatial scales

References:

[1] Kent, T. (2016): An idealised fluid model of convective-scale NWP: dynamics and data assimilation. PhD Thesis, University of Leeds.

[2] Kent, T., Bokhove, O., Tobias, S.M. (2017): Dynamics of an idealized fluid model for investigating convective-scale data assimilation. Tellus A: Dynamic Meteorology and Oceanography, 69(1), 1369332.

NERC DOCTORAL TRAINING

Met Office

UNIVERSITY OF LEEDS