Evaluation of an ensemble based 4D Var assimilation
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Aims and model

Objective:
- Compare En4DVar with a classic 4DVar method

Incremental 4DVar vs En4DVar assimilation techniques

Incremental 4DVar assimilation
- Cost function using static covariance matrices $B$ and $R$

$$J(\delta X_0) = \frac{1}{2} \sum_{i=1}^{N} \|H(\delta X_i^0) - \delta \lambda \|_{R}^2 + \frac{1}{2} \sum_{i=1}^{N} \|\delta h_{B}(\delta X_i^0) - \delta \lambda\|_{R}^2$$
- Adjoint equation determined by TAPENADE
  $$-\partial_{\lambda} J(\delta X_0) = \sum_{i=1}^{N} \partial_{\delta h_{B}} \lambda$$
  $$\partial_{\delta h_{B}} = 0$$
- We deduce the gradient
  $$\nabla J(\delta X_0) = \lambda(\delta h)$$

Minimization performed with LBFGS algorithm: limited memory quasi Newton method

Results

Synthetic data

- Background initial condition
  - Exact initial condition
    - $L = 25$ cm
    - $W = 10$ cm
    - $H_i = 0.25$ cm
    - $U(x, y, t_0) = c_1(x, y)$
    - $V(x, y, t_0) = 0$

Assimilation with height observations only
- En4DVar is slightly better than 4DVar
- Same computation time
- En4DVar requires more memory space

Assimilation with height and velocity observations
- En4DVar requires much more computation time
- En4DVar leads to better results with a higher truncation mode
- Higher truncation mode demands higher computation time and memory needs

Experimental data

We only possess the height observations given by the depth sensor (Kinect sensor)

Conclusions

- Sensibly the same computational time cost, En4DVar yields better results than the classic 4DVar assimilation when we have only height observations
- En4DVar is easy to implement for any given model. We gain a lot of time with the parallelization computing technique. En4DVar implemented with only one outer loop iteration and needs about 100 iterations for the optimization. Requires a lot of memory.
- 4DVar requires the tangent and adjoint operators. The assimilation converges with 3 outer loop iterations and requires less inner loop iterations for the optimization.