Parameter Sensitivity of the LETKF–WRF System for Assimilation of Radar Observations in a Case of Deep Convection in Argentina

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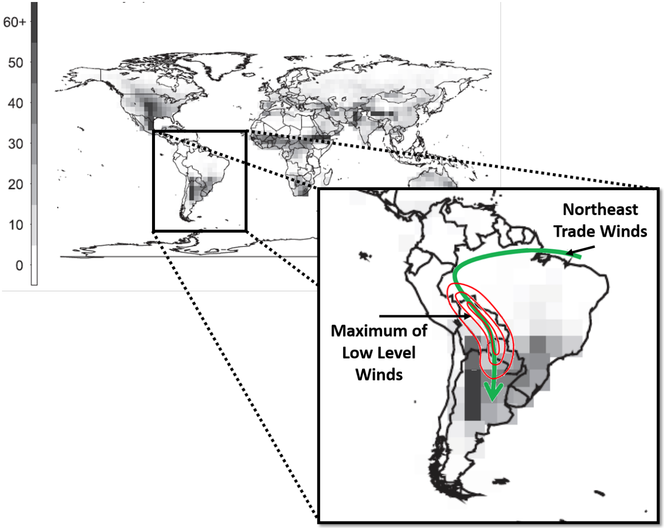
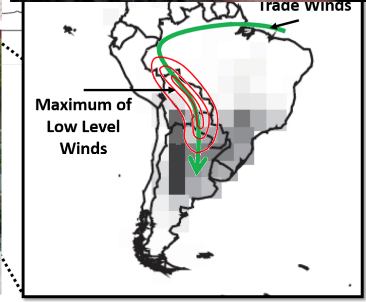
High-impact Weather Events

Days per Year with Favorable Severe Parameters (Brooks et. al, 2003)



High-impact Weather Events



Convective-scale Forecasts

High-resolution NWP Models ($>$ 4 *km***)**

- ✔ Eliminate uncertainty associated to cumulus parameterization
- ✗ Significant errors in location and timing of convective systems

Remote Sensing Observations

- ✔ Describe the state of the atmosphere in the convective scale

Advantages of Using Radar Data

- High-resolution, 3D observations
- Temporal frequency necessary to retain the storm's structure

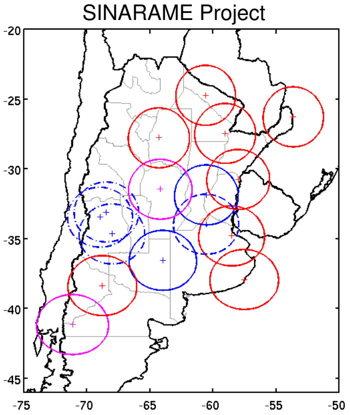


FIGURE – Weather radar network nowadays (blue line) and SINARAME radars (red line). Simple-pol (dash line) and dual-pol (solid line) radars.

Objectives

MAIN GOAL

Develop, implement and evaluate a **radar data assimilation system** based on the Local Ensemble Transform Kalman Filter (LETKF) for very short-term weather forecast of high-impact weather events in South America

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TALK'S GOALS

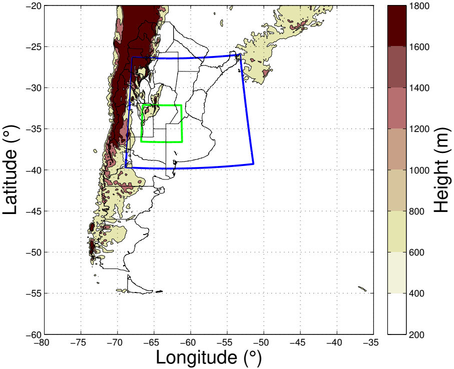
Using Observing System Simulation Experiments (OSSEs) :

1. Evaluate the performance of the LETKF–WRF system
2. Asses the sensitivity of the LETKF–WRF system to :
   - The type and magnitude of the multiplicative inflation
   - The specification of initial and boundary perturbations
   - The localization scale

Observing System Simulation Experiments (OSSEs)

Nature Run (NR)

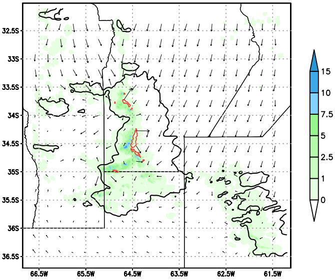
High-resolution Model Domain



Nature Run WRF Model Configuration

- Domain : 500 x 500 km, 60 vertical levels
- Horizontal resolution : 500 m
- BC-IC : Downscaling (GFS)

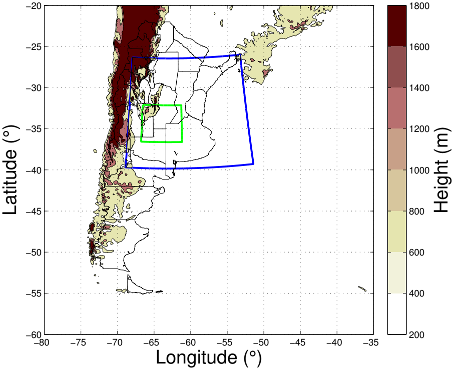
NR - Initial Assimilation Time



Observing System Simulation Experiments (OSSEs)

Nature Run (NR)

High-resolution Model Domain

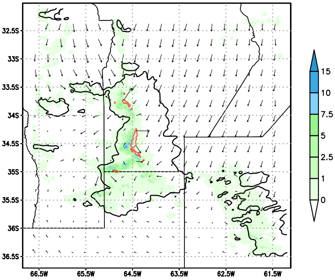


NOT a Perfect Model Experiment

Differences between NR and experiments :

- Horizontal resolution
- Initial and boundary conditions
- Microphysics parameterization

NR - Initial Assimilation Time

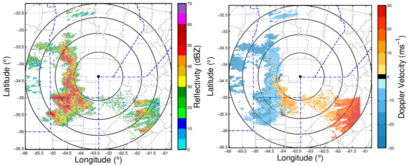


Observing System Simulation Experiments (OSSEs)

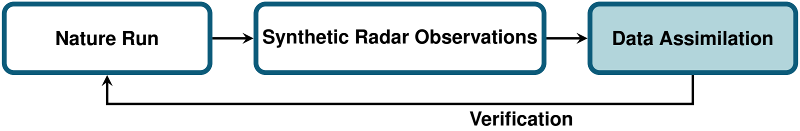
Nature Run → **Synthetic Radar Observations**

Synthetic Radar Observations

- Reflectivity and Doppler velocity
- Realistic radar geometry : 240 km range, 14 antenna elevations
- Uncorrelated observational errors
- Gaussian distribution



Observing System Simulation Experiments (OSSEs)



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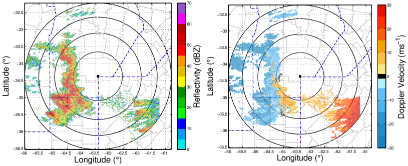


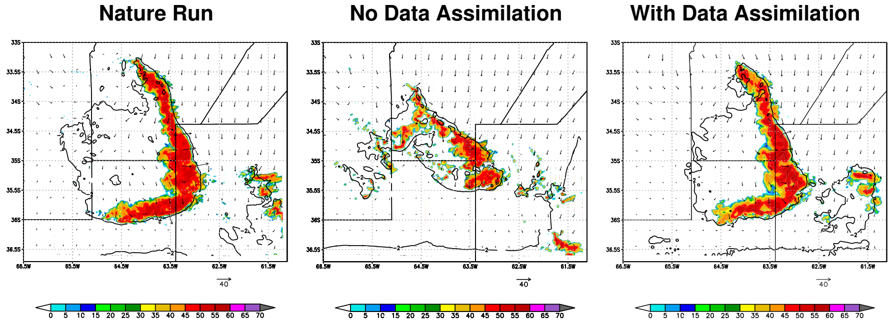
- LETKF coupled with WRF model
- Horizontal resolution : 2 km
- Ensemble members : 60
- Assimilation frequency : 5 min
- Assimilation period : 140 min
- Multiplicative inflation factor : 1.1
- Localization scale : 4 km

Initial Ensemble

- Random Gaussian perturbations to velocity and temperature fields
- Perturbation amplitude : 0.5

Qualitative Evaluation

Analysis mean after 20 assimilation cycles (100 min)

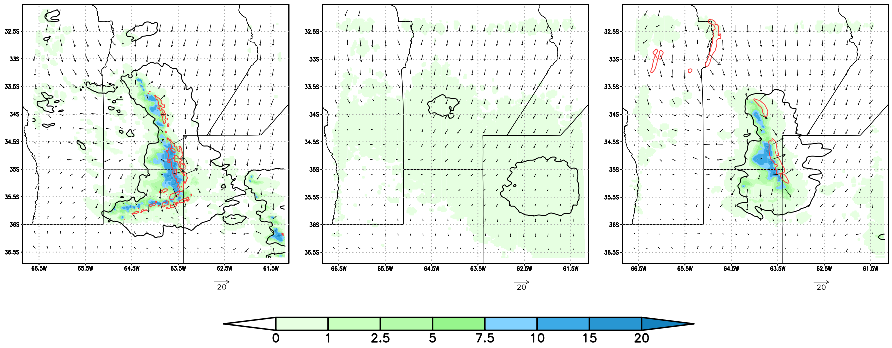


Reflectivity field (shaded ; dBZ), temperature anomaly 2 K (black contour) in 1 km

Qualitative Evaluation

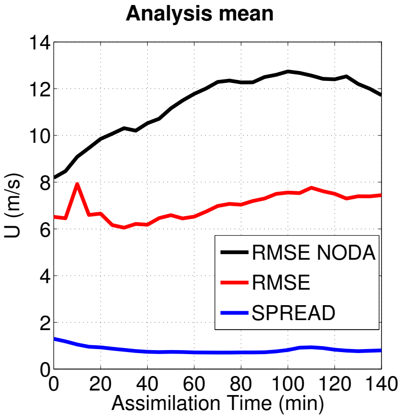
1-hr Ensemble Forecast initialized after 4 assimilation cycles (20 min)

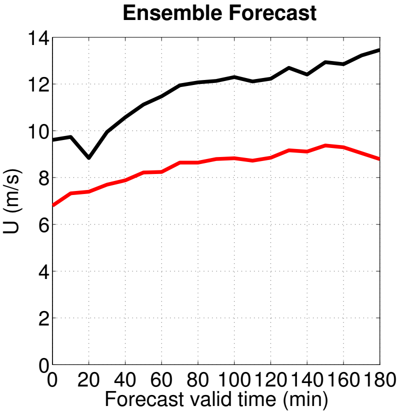
Nature Run | **No Data Assimilation** | **With Data Assimilation**



10-min accumulated precipitation (shaded ; mm), wind speed over 15 $m\ s^{-1}$ (red contour)

Quantitative Evaluation





- Errors increase with time in the analysis mean
- Ensemble spread collapses after 40 min and maintains very low values

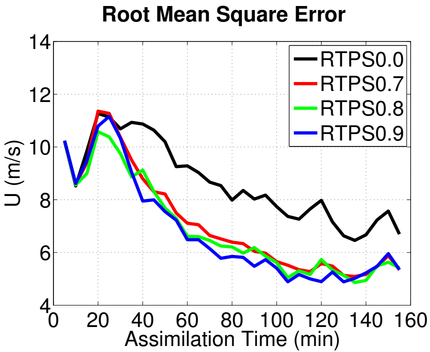
Sensitivity study

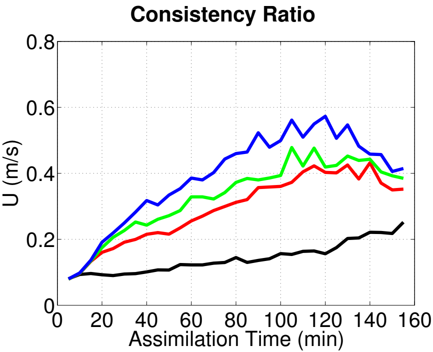
1. **Covariance Inflation : Relaxation to Prior Spread (RTPS)**
   - The analysis ensemble standard deviation is relaxed back to the background values at each grid point
   - The multiplicative inflation is proportional to the amount of the ensemble spread being reduced by the assimilation of observations
2. **Initial and Boundary Perturbations : Balanced Perturbations**
   - Represent the large-scale flow (i.e. synoptic scale)
   - Perturbation amplitude : 0.05 $\rightarrow$ 5% of climatology
3. **Covariance Localization : Same as before**
   - The state estimate is updated only by using observations within a local region defined by the localization scale radius

Experimental Settings

Sensitivity	Exp. Name	Configuration
Multiplicative Inflation	**RTPS0.0** **RTPS0.7** **RTPS0.8** **RTPS0.9**	- Balanced and random perturbations with 0.05 and 0.5 amplitude, respectively - Localization scale : 2 km
Perturbations	**B&RP** **RP** **BP**	- Relaxation to prior spread inflation : 0.9 - Localization scale : 2 km
Localization Scale	**LOC1** **LOC2** **LOC4**	- Relaxation to prior spread inflation : 0.8 - Balanced and random perturbations with 0.05 and 0.5 amplitude, respectively

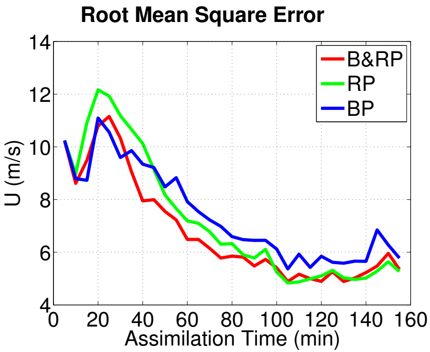
Sensitivity to the Type and Magnitude of Multiplicative Inflation

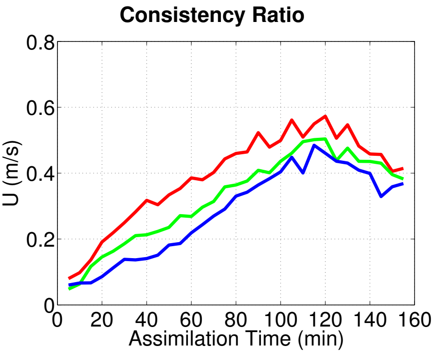




- Applying a RTPS scheme improves the performance of the filter
- Lower RMSE correspond to bigger inflation parameter

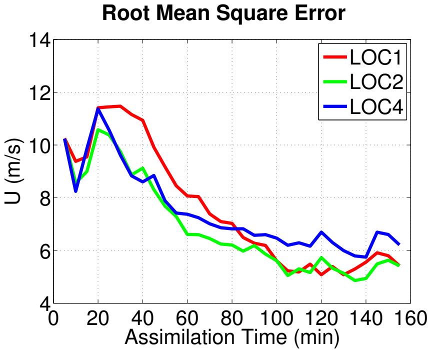
Sensitivity to the Specification of Initial and Boundary Perturbations

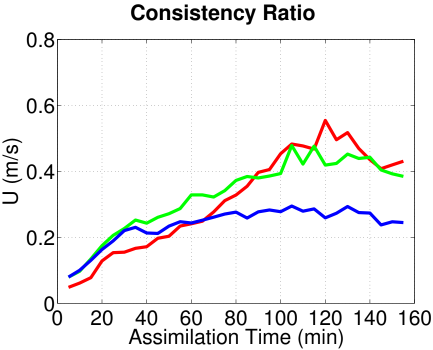




- Biggest error when using only balanced perturbations
- Using both types of perturbations simultaneously helps maintain the spread high during the entire assimilation period

Sensitivity to the Localization Scale





- Assimilating a greater number of observations during the first 40 min helps reduce the errors while a smaller localization scale shows better results after 80 min
- Overall, the best results are achieved with a 2 km localization scale

Conclusions

- Assimilation of radar observations has a positive impact in both the analysis mean and the very short-term weather forecasts
- Using a constant multiplicative inflation factor produces the ensemble spread to collapse rapidly
- Adding a RTPS inflation scheme and balanced perturbations helps to keep the spread up
- The best configuration for the LETKF–WRF system is achieved, so far, by using a RTPS inflation parameter of with 0.9, initialization with both balanced and random perturbations and a 2 km localization scale

Future Work

- Keep improving the assimilation system (e.g. test bigger inflation parameter and different amplitudes for perturbations)
- Test the assimilation system with real radar observations
- Generate experiments for different types of convection organization

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Thank you !