# Implementation an New GPS Observation Operator in the NCEP GSI System

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## 1. Introduction

COSMIC GPS mission can provide ~2,000 GPS radio occultation (RO) near-real-time soundings per day uniformly distributed around the globe. A simple local refractivity operator (1D) has been implemented successfully to assimilate COSMIC GPS data in the NCEP GSI system. However, in the presence of significant horizontal gradients (strong convection, atmospheric front), the modeling of GPS RO refractivity by the local operator at ray tangent point may result in significant errors. To reduce these errors, a non-local excess phase operator (2D) considered horizontal gradient information has been implemented and tested completely in the GSI. An real case study is performed to evaluate the performance of local and non-local operators for assimilating COSMIC GPS RO soundings.

## 2. Non-local approach

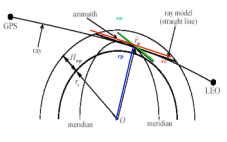



Fig.1: layout of ray trajectories for modeling of non-local observables

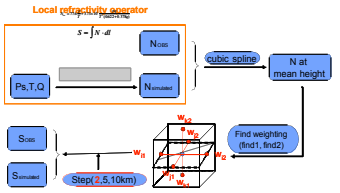



Fig.2: The Non-local code —— General Flow

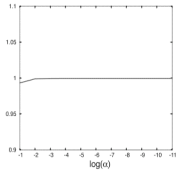
Sokolovskiy et al. (2005) developed an non-local operator to account for the effect of horizontal gradient, and showed it reduced the representiveness errors.

## 3. Implementing Non-local into the GSI system

The basic analysis problem of the GSI system with increment approach is to minimize the cost function:

$$J(x) = J_b + J_N + J_{others}$$

After Implanting Forward operator,its Tangent Linear and Adjoint, the system is tested successfully.



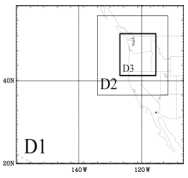

| | |
|---|---|
| <dy,dy> | 0.2168395953702E+01 |
| <dx,dx*> | 0.2168395953702E+01 |

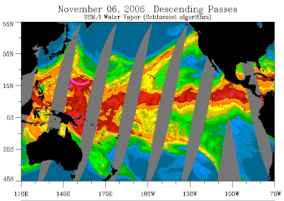
Fig.3: Non-local operator tangent linear check. The variation of $\phi(\alpha) = \frac{F(X+\alpha X') - F(X)}{\alpha X' \cdot g\_F(X,\alpha X')}$ With respect of $\log(\alpha)$

Tab.1: shows Adjoint check.

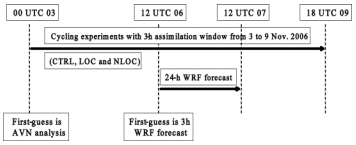
## 4. Design of Experiment

- System: NCEP GSI coupled with WRF-ARW
- Case: Atmospheric River (AR) in Nov.2006
- Setup:
  - Cycling Assimilation: 36km38L, 50hPa
  - 24h Forecast: nested domain, 36x12x4km

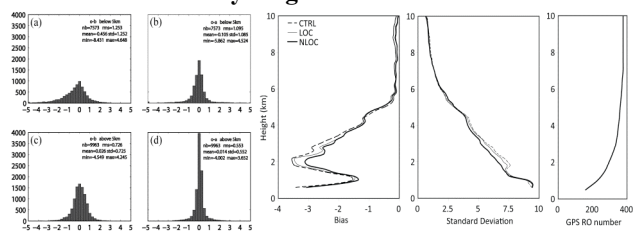



- CTRL: operational observation data;
- LOC: CTRL+GPS with Local operator
- NON: CTRL+GPS with Non-local operator

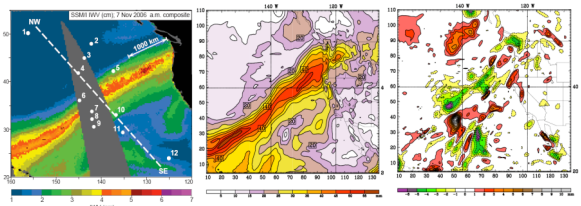



## 5.1 Results —— 3h Cycling assimilation




O-B and O-A from Non-Local run

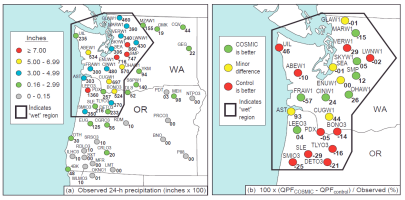
3h forecast fit to GPS Refractivity (unit: N)




PWV from SSM/I, Non-local and the difference (Local minus Non-local) valid at 0600 UTC 07 Nov. 2006

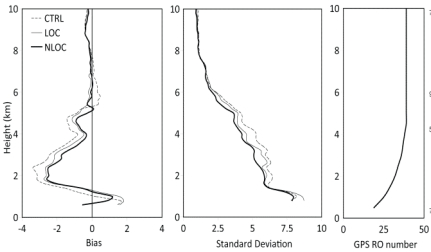
## 5.3 Results —— 24h Precipitation

**The COSMIC data improved the QPF at sites where the heaviest rain fell. Non-Local performs better than Local.**

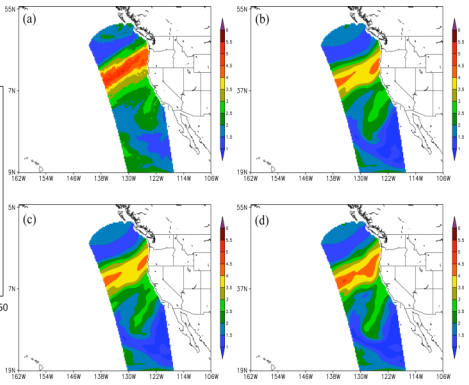



(a) Observed precipitation used in the QPF evaluation. (b) Comparison of QPF bias for forecasts with ("non-local") and without ("control") COSMIC data.

## 5.2 Results —— 24h Forecast Verification




Verification of the 24h forecast with/without assimilating GPS RO data starting at 12 UTC, 06 11 2006. The bias (left panel) and standard deviation (middle panel) of the 24h forecast fields fit to refractivity (unit: N).




Verification of the forecast with SSM/I IWV observations validated at 0200 UTC 7 November 2006. (a)SSM/I IWV; and Precipitation Water Vapor from (b) CTRL, (c) LOC and (d) NLOC cycling experiments, respectively.

## 6. Conclusions and Discussion

- COSMIC GPS RO soundings successfully assimilated with NCEP regional GSI system using both local and nonlocal observation operators.
- Assimilation of COSMIC data improved regional analysis and prediction of the atmospheric river event:
  - Better fit to independent observations
- Nonlocal observation operator performs better than local observation operator:
  - Significantly reduces dry bias in precipitation forecast
  - improves QPF at sites where the heaviest rain fall