AHW (WRF-ARW): (Vortex) Initialization

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Introduction

- Vortex initialization is very important to hurricane prediction
- It is a challenging task, hence it is a research area
- ARW supports a few ways to do initialization for hurricanes
  - Support researchers' need
  - Flexibility

ARW (Vortex) Initialization Methods

- Use data from other models directly
- TC bogussing via objective analysis
- TC relocation with previous forecast
- TC relocation and bogussing
- Initialization via obs and analysis nudging
- Initialization via the use of 3DVar
- Initialization via the use of 4DVar
- Initialization via EnKF (see last talk)

Use Other Model Data Directly

Supported Data Sources

- GFS / FNL (0.5 - 1 degree)
  - OK during the early stages of storm
  - May be problematic when the storm becomes intense
  - Not for intensity
- GFDL / HWRF (9 - 18 km)
  - Could work for well-developed storms
  - Imbalance during early forecast hours
- ECMWF Interim Analysis (~ 80 km)
  - Can benefit from good environmental condition

TC Bogussing via Objective Analysis

Method

- Based on technique of objective analysis (e.g. Cressman)
- ARW V3.1 supports such an program: *obsgrid.exe*
  - In addition to normal synoptic observations, bogus data either generated from a Rankine vortex or soundings extracted from previous model forecast
- For detailed description of *obsgrid* program, please see Chapter 7 of the User's Guide

Pros and Cons

- Advantage:
  - o Easy to use
- Disadvantage:
  - o Relocation may be important
  - o Spread of data is artificial
  - o No dynamic and thermodynamic constrains

TC Relocation
Using Previous Model Forecast

TC Relocation

- Based on the assumption that model simulated vortex has reasonable structure
- The model vortex is lifted from a previous forecast, and moved to the current, correct location
- Works better on pressure level data
- May adjust vortex profile after relocation
- Papers by Liu et al. (1997), Tenerelli et al. (2001)

Pros and Cons

- Advantage:
  - Easy to implement, especially with moving nest
- Disadvantage:
  - Blending of vortex environment may be problematic
  - May have problem with storm relocating from ocean to land or vice versa

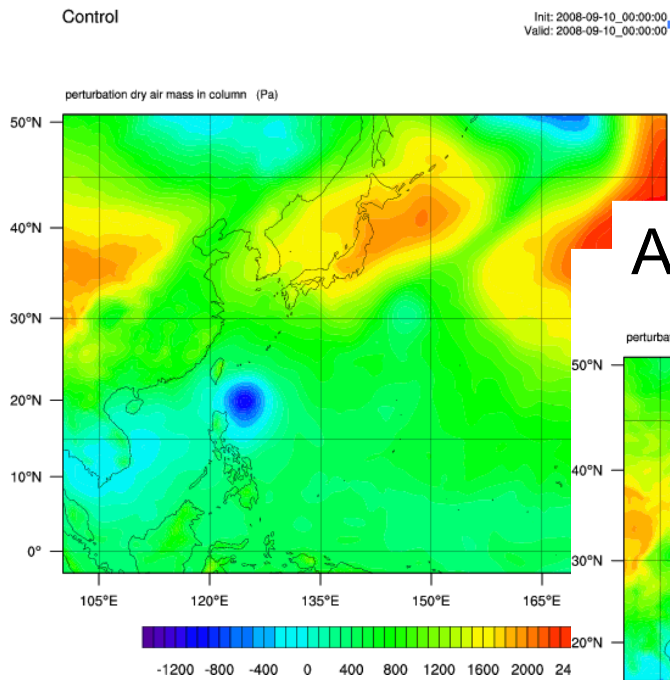
- Tools available to do this:
  - *p_interp*: put model data on pressure levels

TC Relocation and Bogussing

Method

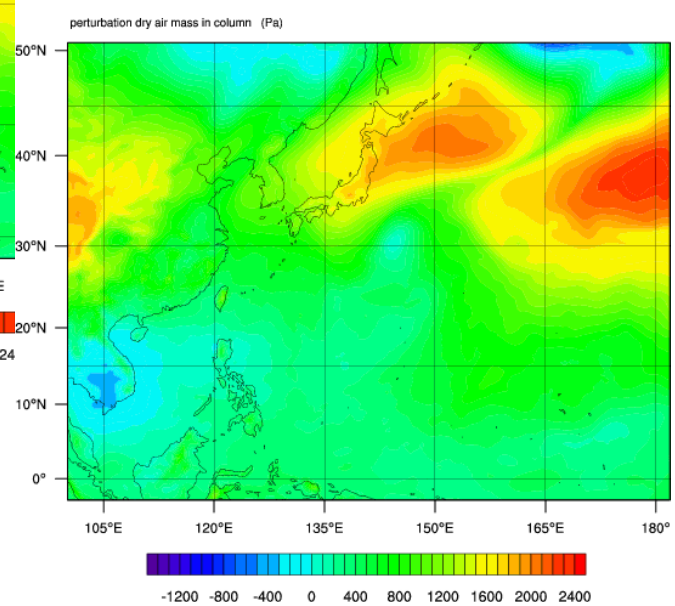
- ARW V3.1 supports a simple TC bogussing scheme: *tc.exe*
- The scheme is adapted from MM5:
  - Detect and remove existing vortex
  - Bogus in a Rankine vortex based on best track TC info
  - Works on pressure level data after WPS and before real.exe
- For details, please refer to Chapter 10 of the ARW User's Guide

An Example for Sinlaku (2008)

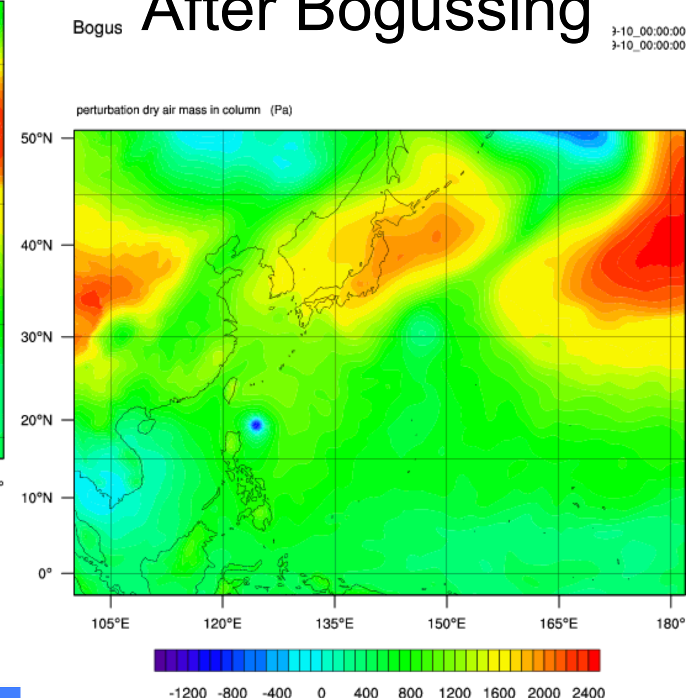


Original

After Vortex Removal



After Bogussing



(From Gill and Fredrick)

Pros and Cons

- Advantage:
  - Easy to do
  - Provide a placeholder for improved bogussing technique
- Disadvantage:
  - Artificial vortex data
  - Imbalance with model solution

Initialization
via Observation and Analysis Nudging

Method

- Based on observation and grid-analysis nudging technique [Stauffer and Seaman (1990, 1991), Liu et al. (2008)]
- Available as runtime option in ARW
- Aimed at providing good analysis for the storm environment
- Can be successful when doing it continuously - hence model generated storm can be recycled

Pros and Cons

- Advantage:
  - Easy to implement
  - Use of model
  - Nudging technique is being improved

- Disadvantage:
  - May not work over part of the ocean where conventional data is sparse
  - Nudging term can be arbitrary

TC Bogussing Using 3DVar

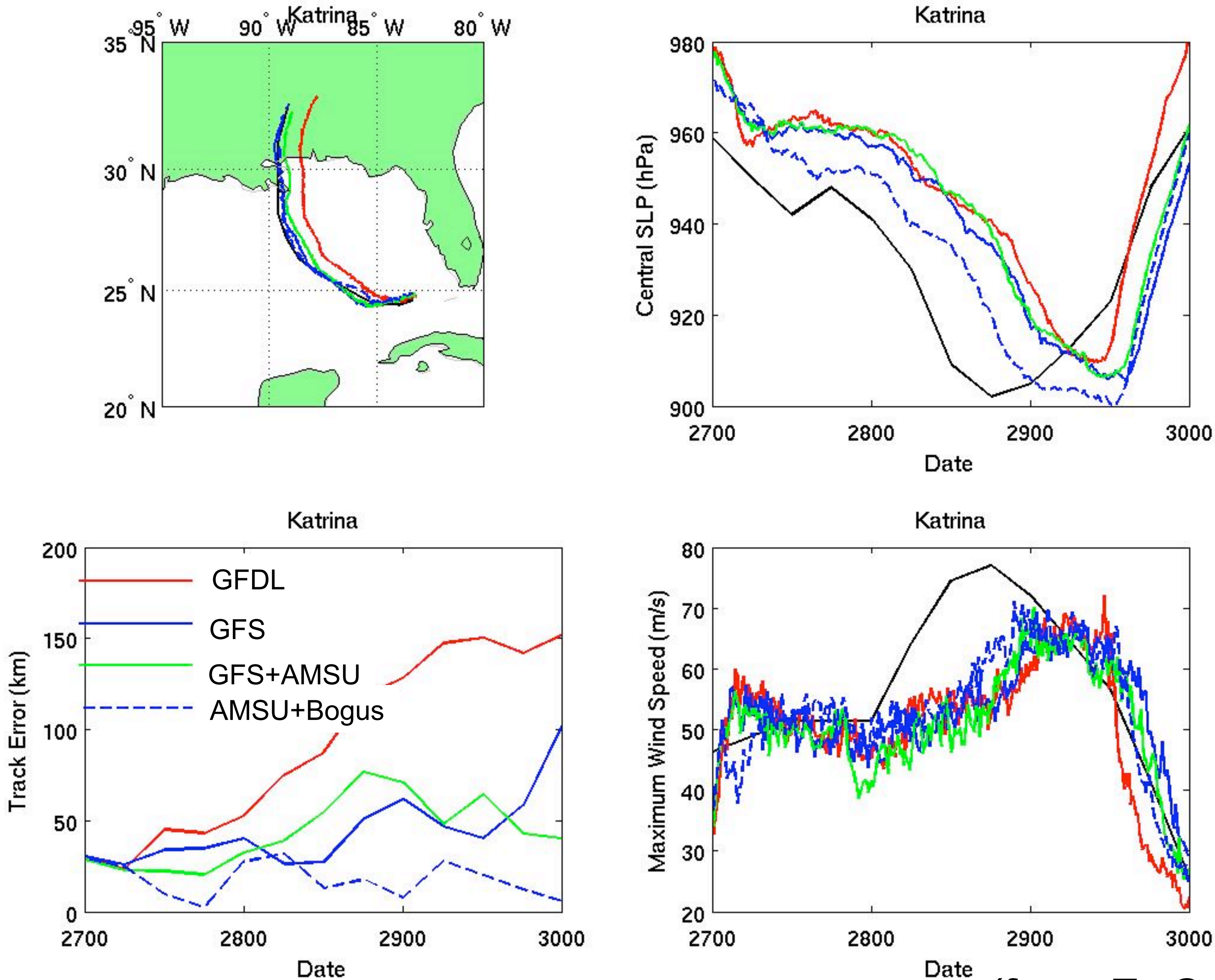
Method

- Three-dimensional data assimilation (3DVar) produces an analysis by combining a background forecast and observations through an iterative minimization procedure of a prescribed cost function
- The information about background and observation errors is used to spread data
- Can assimilate many types observations

Ref: Barker et al. (2004)

Method

- When 3DVar is applied to TC initialization, one can do one of two things:
  - o Improving environmental conditions by assimilating conventional as well as remote sensed data (including radiance)
  - o In addition, bogus data may be used. Relocation needed
- Cycling may be used to retain characteristics of the model vortex


Katrina
95° W
90° W
85° W
80° W
35° N
30° N
25° N
20° N
Katrina
980
960
940
920
900
Central SLP (hPa)
2700
2800
2900
3000
Date
Katrina
200
150
100
50
0
Track Error (km)
GFDL
GFS
GFS+AMSU
AMSU+Bogus
2700
2800
2900
3000
Date
Katrina
80
70
60
50
40
30
20
Maximum Wind Speed (m/s)
2700
2800
2900
3000
Date

(from Z.-Q. Liu)

Pros and Cons

- Advantage:
  - Good mathematical base
  - Computationally efficient (relative to other more sophisticate techniques)
- Disadvantage:
  - Background error covariance not changing with time and flow regime, and can be problematic for TC
  - Single time-level can be limiting
  - May take time to learn to use the technique well

TC Initialization Using 4DVar

Method

- The difference between 3DVar and four-dimensional (4DVar) data assimilation is the use of a numerical forecast model
- The added time dimension provides flow-dependent information
- Can use observation in a time window

Ref: Huang et al. (2009)

An Example:
WRF 3D/4D-Var for Katrina 2005

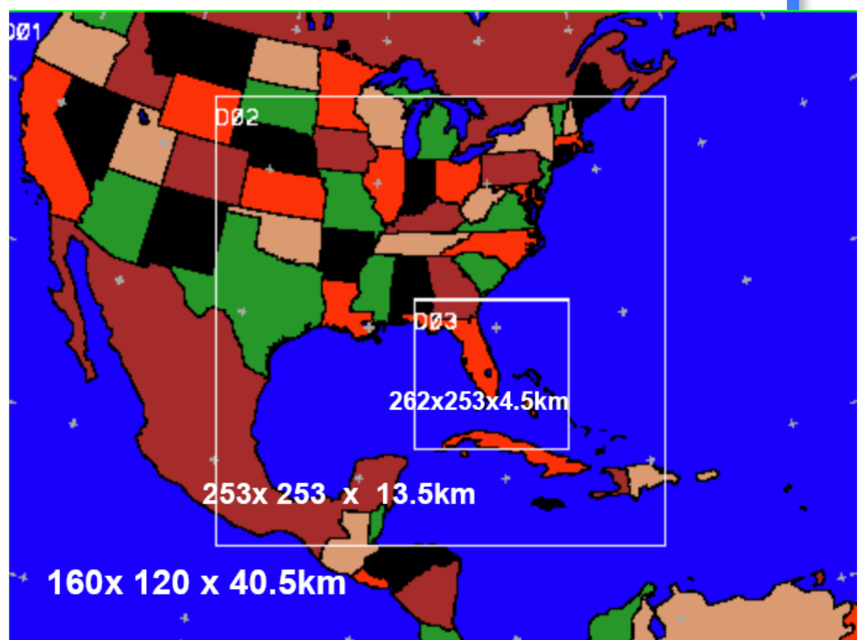
- WRF Domains : D1-D3 with 40.5km, 13.5km, 4.5 km grids and 35 vertical levels; Data assimilations only applied on D1

- Forecasts: 96-h deterministic run with D1, D2, D3 (two-way nested and D3 movable) initialized from 00Z August 26 2005 with various ICs

- Data assimilated: Doppler radial velocity (err=3m/s) from KMAX and KBYX during 00~03Z August 26 2005

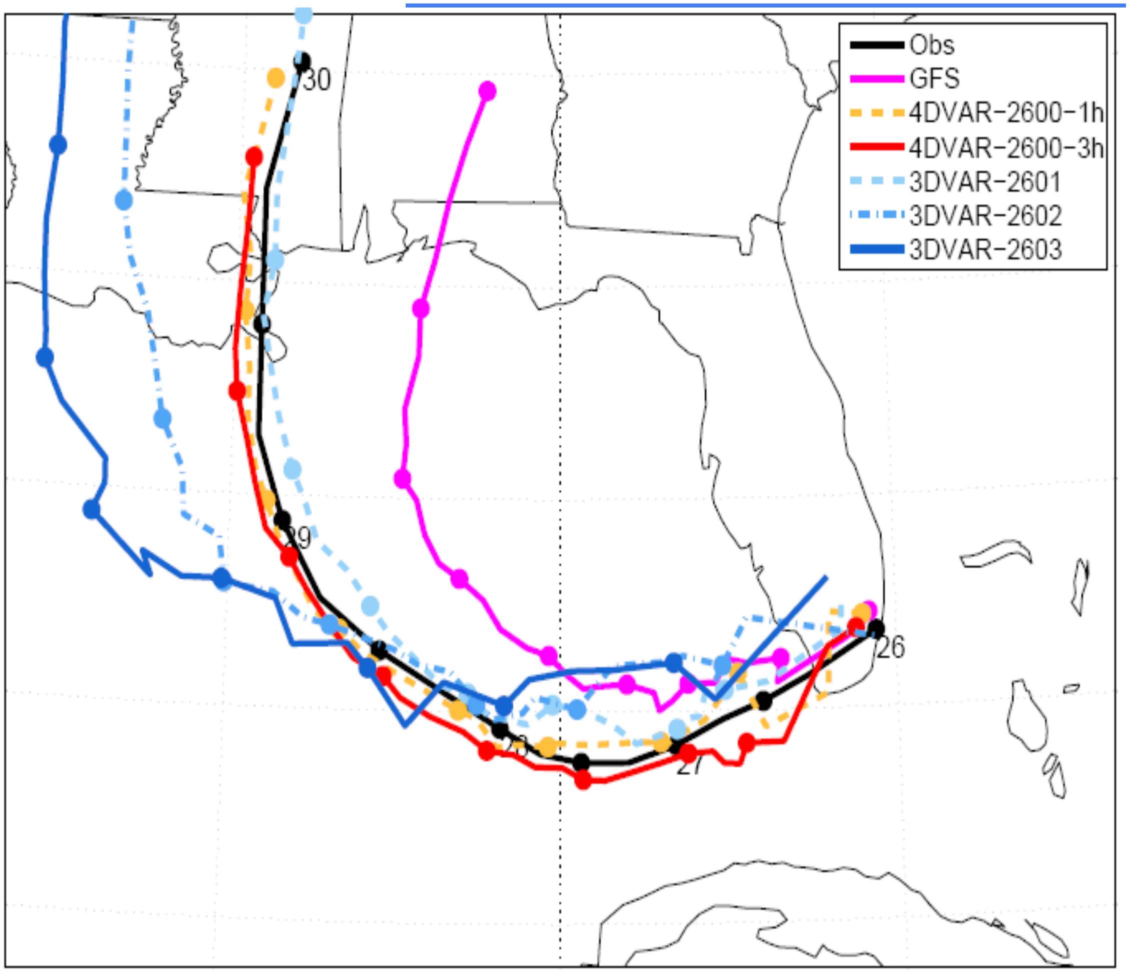
An Example

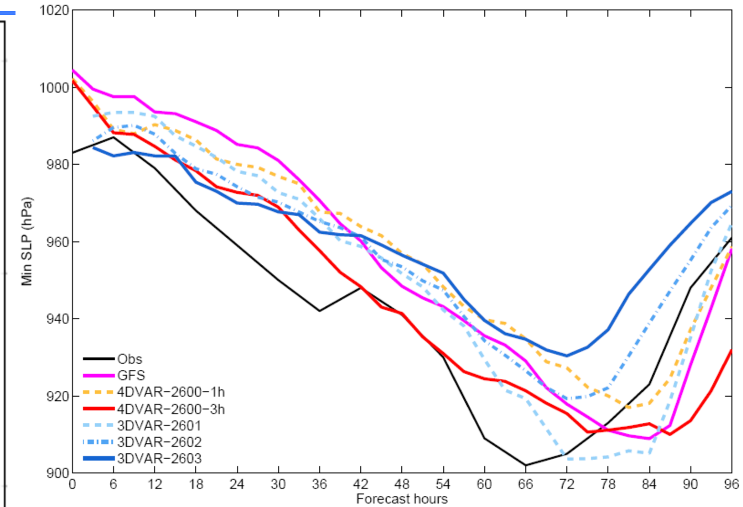
Experiments:
 a) Control run with GFS-IC
 b) 4DVAR with 1-h and 3-h window
 c) Successive 3DVAR with 1-h interval at 01Z, 02Z and 03Z respectively

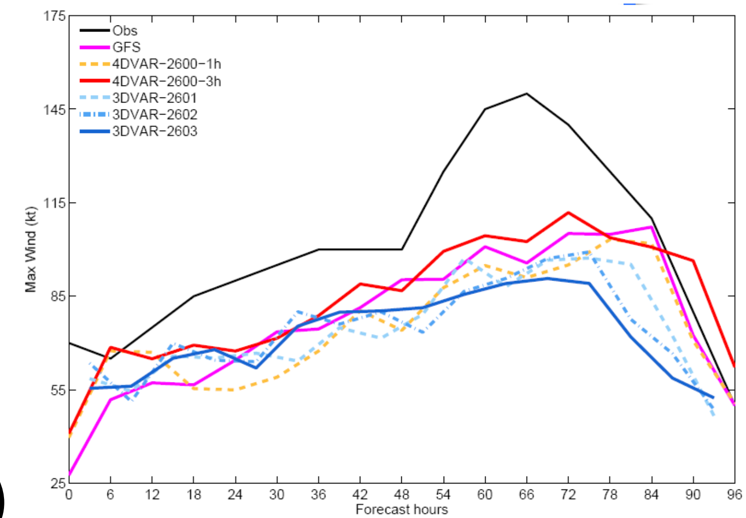


(from M. Zhang of PSU)

Track and Intensity Forecast on Aug 26, 2005







(from M. Zhang)

Pros and Cons

- Advantage:
  - Good mathematical base
  - Use of model for dynamic and thermodynamic constrain
  - Flow dependent
- Disadvantage:
  - Expensive technique
  - Probably long learning curve

In Summary…

- TC initialization still a challenge
- Experimentation is needed for large sample of cases: a technique working for one case may not work for another
- The need in research and operation may be different
- The results of using various methods seem to suggest that some kind of cycling method tends to perform better