The Impact of Nonlinear Interaction Parameterizations on Practical Wind Wave models

Do we need to replace the DIA ?

Can we replace the DIA ?

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S_{nl} is the engine of a third generation wind wave model. The DIA has made such models possible, but from its onset is shown to have limited accuracy.

Much effort has been made in the past decade to find economical yet accurate replacements with several alternatives (becoming) available:

- SRIAM (e.g., Tamura et al, JPO 2008)
- Generalized Multiple DIA (GMD, Tolman MMAB 2010).
- TSA, GQ, NNIA, ….

Questions:

- Does it matter, is it affordable?

Use techniques from GMD development

Apply to realistic cases:

- Baseline is model with Web-Resio-Tracy implementation of full Boltzmann Integral (“exact” or FBI).
- Use objective error measures to quantify accuracy.
- Use cascade of GMD configurations with increasing complexity.
- Apply to synthetic moving hurricane, and real life Lake Michigan test cases.

Excluded from scope

- Asymptotic shallow water GMD not considered here.
- GMD as proxy for SRIAM and others ….

Conclusions

- The DIA leads to surprisingly large wave height errors in the hurricane test, but small wave height errors in Lake Michigan.
- The DIA leads to large but less predictable spectral errors all the time.
- Results of dependent test cases in the GMD optimization translate well to independent real-world tests.
- Moderate increase of computational costs of a wave model (50%) can result in significantly reduced S_{nl} errors.
- Removing most errors of the DIA with a sufficiently complex GMD will be expensive (300% increase) but feasible.
  - Looking at link with NNIA or TSA.
  - Should be used in research (<1% of WRT costs).
- Validation / timing method directly applicable to other interaction approximations (SRIAM, TSA, …)

Using GMD optimization tools

- Web-Resio-Tracy model runs as truth.
  - Package of Van Vledder (v. 5.04).
- Runs with WW3 version 3.15 (package to be distributed).
  - Includes full optimized GMD.
- Compute error metrics from save spectra.
  - Mean parameters (7, partitioned).
  - 1D spectral parameters (5).
  - 2D spectral parameters (3).
- Time model runs in parallel environment on IBM SP with Power-6 chips.
  - WRT costs estimated since they need more resources.
  - Baseline is WW3 with traditional DIA implementation.
    - GMD more expensive than DIA in same conf.

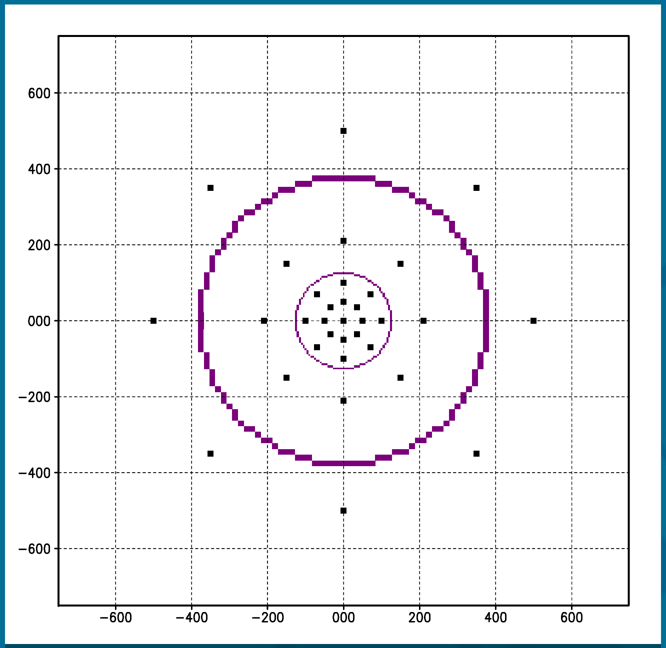
The following model (S_{nl}) configurations are used here

ID	Description
WAM	GMD in DIA configuration using “WAM” settings.
WW3	GMD in DIA configuration using WW3 settings.
G11d	GMD in DIA configuration optimized.
G13d	GMD with three DIA quadruplets.
G35d	GMD with five arbitrary (3 parameter) quadruplets.
WRT	Reference Web-Resio-Tracy results.

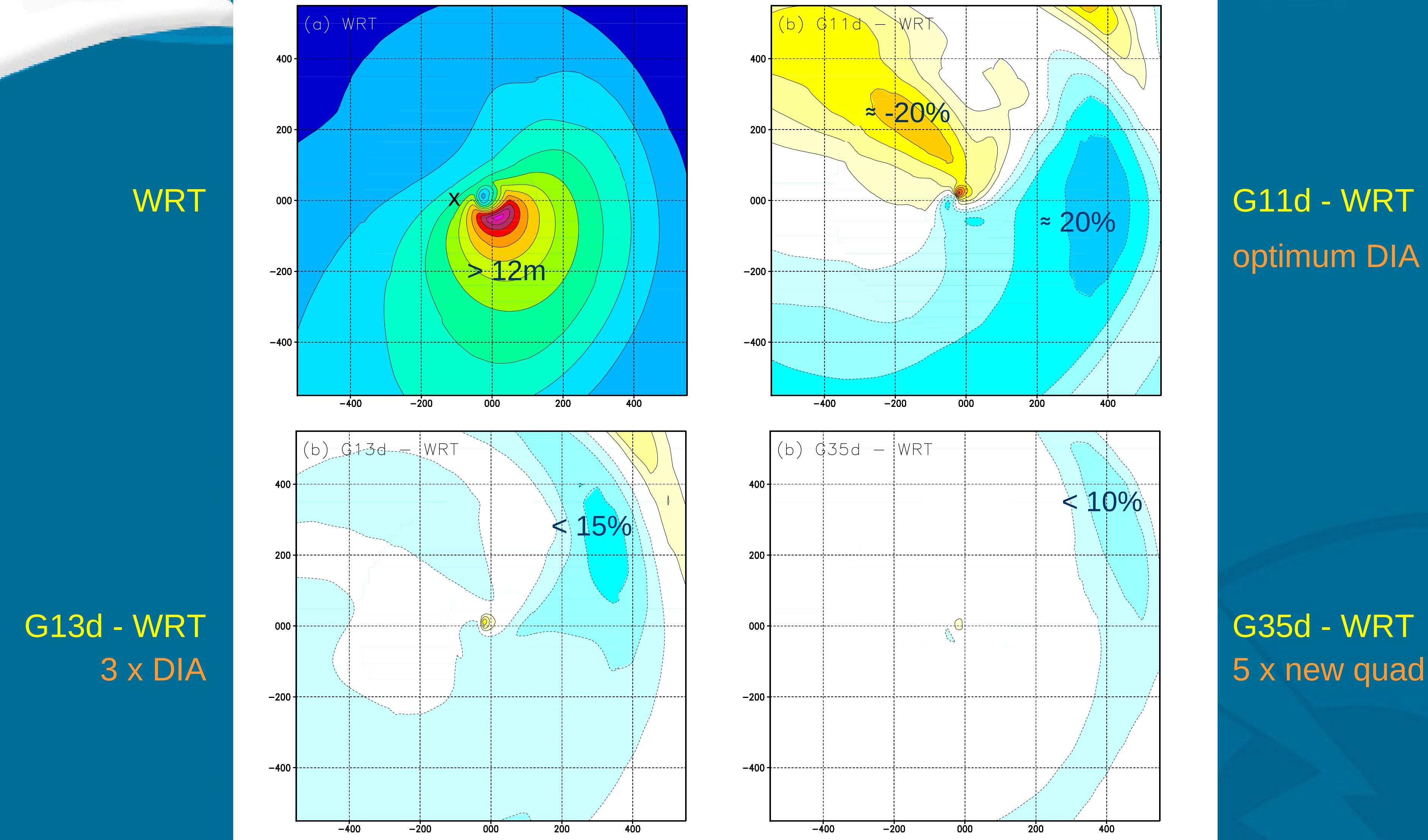
- All computations performed with WW3 with default model setting except for interactions.
- Full default WW3 model run to obtain timing benchmark.

Synthetic hurricane run

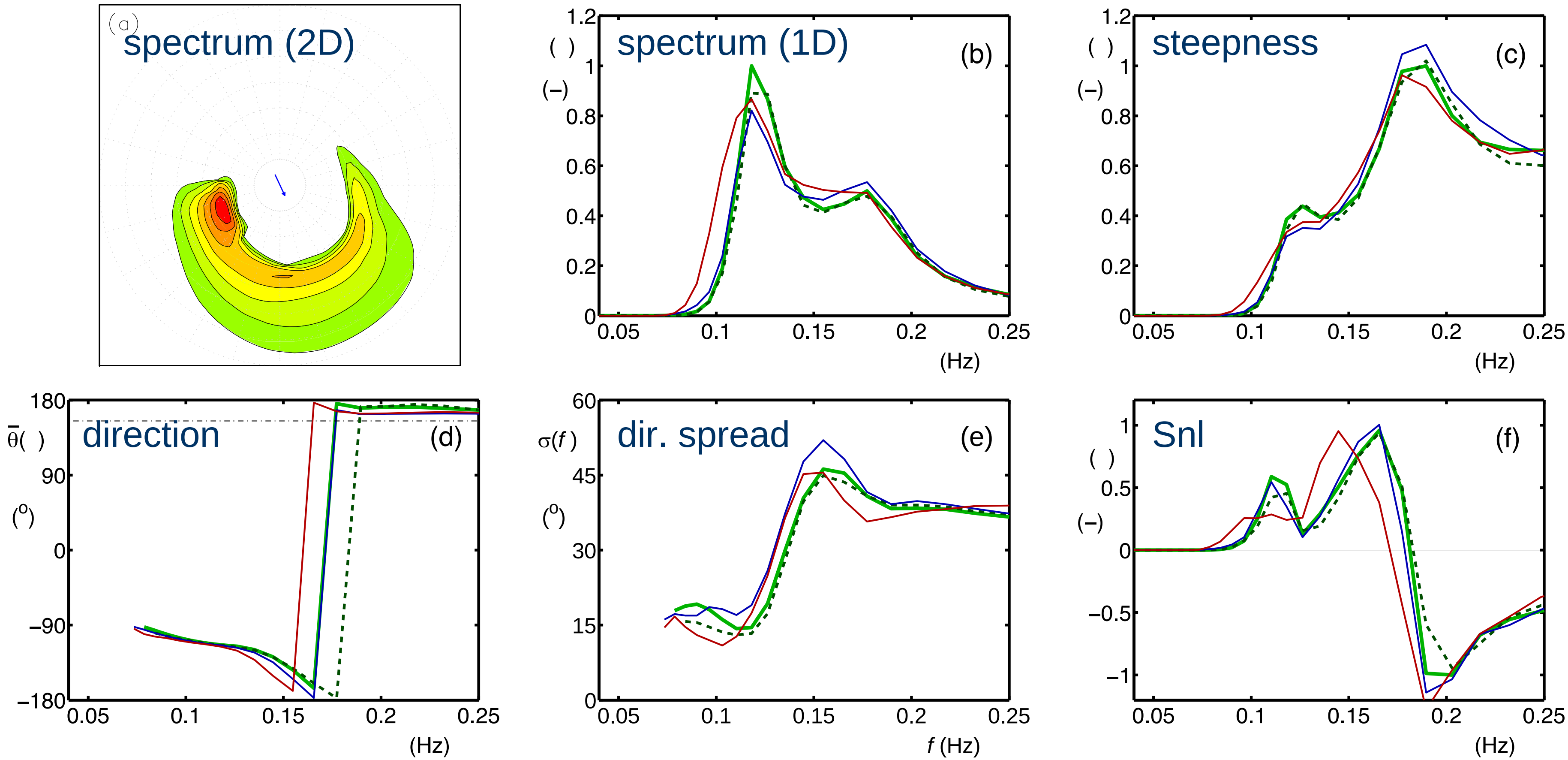
- Mosaic with 50-15-5 km grid resolutions from WW3 distribution.
- Grid moves with 5 ms^{-1} to the right.
- Rankine vortex U_{max} = 45 ms^{-1}, R_{max} = 50 km.
- Saving spectra at 33 points after 24 h of model integration for error metrics.



Wave height and relative error(%)



Spectral parameters 100km behind eye

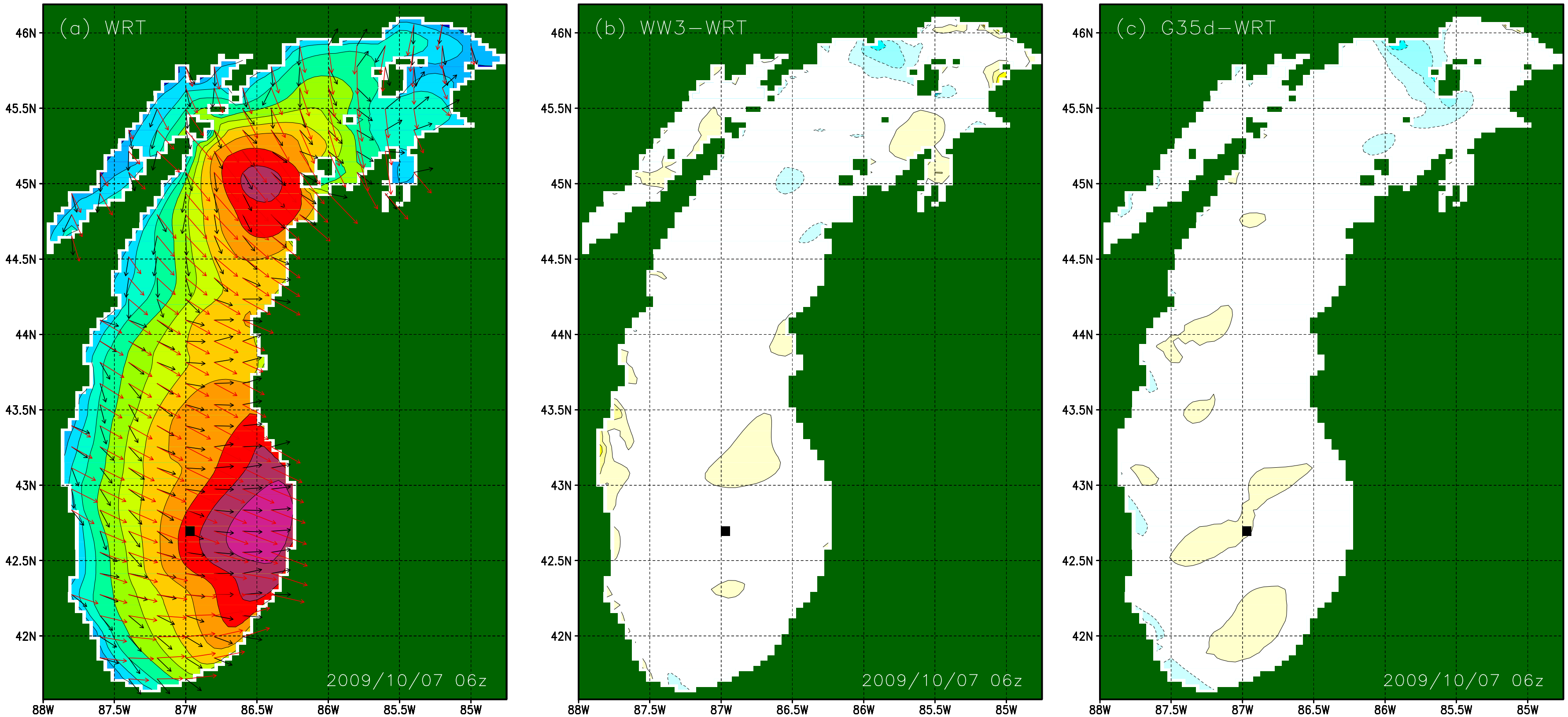


green: WRT dashed green: G35d blue: G13d red G11d

Lake Michigan Test

- Two-day real-world test case October 6-7 2009.
- Winds from GLERL buoy-only wind analysis.
- Hourly spectra saved at location of buoy 45007 for objective error measures.
  - Staring from rest, first 9 hours discarded as spin-up.

Wave height and relative error(%) Oct 7, 06z (peak)



WRT

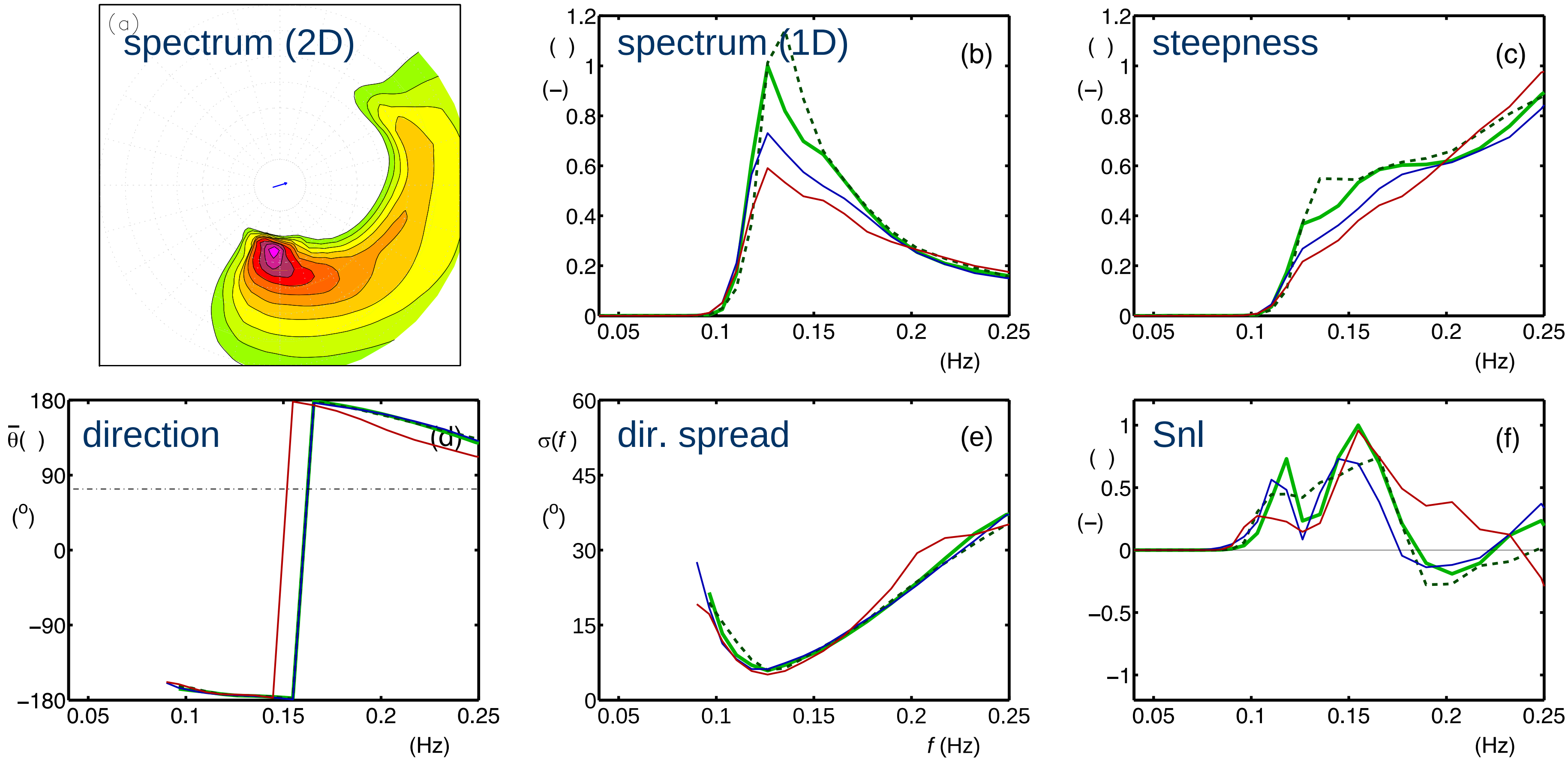
WW3 - WRT

WW3 DIA

G35d - WRT

5 x new quad

Spectral parameters at 45007 Oct 7, 18z



green: WRT dashed green: G35d blue: G13d red G11d

Performance of realistic model

configuration	hurricane T_n (-)	hurricane Error %	Lake Michigan T_n (-)	Lake Michigan Error %
WW3	1.20	27.5	1.16	23.5
WAM	0.99	28.7	1.09	24.9
G11d	1.05	26.3	1.10	21.8
G13d	1.50	19.1	1.45	16.8
G35d	3.52	14.9	4.04	14.4
WRT	1360	---	370	---

- Timing normalized with run with traditional DIA implementation.
- Errors computed as in genetic optimization.
- Comparison to observations not appropriate.

Outlook

- Establish if configurations represent a general optimum, or are linked to the other source terms (S_{in}, S_{ds}).
  - Optimization package to be distributed with WW3.
- Future source term development should be done with exact interactions or GMD configurations like G35d.
- Looking to future “hybrid” approaches.
  - G35d with Neural Network accelerator.
  - TSA – NN – GMD/WRT hybrid approaches.

- G13d configuration likely to go in operations at NCEP with a NOPP physics upgrades.
- G35d may be considered for operational implementation, will be used for research.

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