Inter-comparison study of methods for the computation on non-linear four-wave interactions in discrete spectral models

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Conclusions

- An objective method is proposed to inter-compare methods for computing the quadruplets
- Preliminary results already point to systematic and subtle differences in implementation
- The method can easily be applied to other exact and approximate methods as well

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Motivation

- Non-linear quadruplet interactions key component of 3G wave models
- Various ‘exact’ methods have been formulated (WRT, RIAM, QGM, ...), do they give same results?
- New methods for exact and approximate methods still being developed, what is their accuracy and computational performance?
- No generally accepted benchmark exists to inter-compare and judge various methods
- Provide an objective framework for such an inter-comparison

Research Questions

- Do the methods solve the same equation?
- Are the solution techniques convergent with increasing resolution?
- Do the methods give the same answer for equal input?
- What is the sensitivity of each method to spectral resolution?
- What are their computational requirements in relation to their accuracy?
- Which assumptions are implicitly made about the spectral shape?

Considerations

- Same spirit as Sea WAve Model inter-comparison Project (SWAMP, 1982)
- Inter-comparison is not a computational method competition
- They are no winners or losers, each method may have specific strong and weak points
- Results will points to errors, inconsistencies and effect of (hidden) assumptions, that may help improving each method
- Claims about speed or accuracy can easily be falsified or accepted

Strategy

- Static tests (this presentation)
  - Base case, discretized JONSWAP spectrum, 10% resolution
  - Variations in resolution, spectral shape, parameters
  - Comparison in f/k and θ-space
  - First and required check, but not sufficient
- Dynamic tests (future work)
  - Implementation as subroutine in host wave model
  - Simple 1D-growth curves
  - Academic and field 2D-cases
  - Check for stability
  - Check of performance
  - Balance between accuracy of model result and computational requirements

Proposed variations

- Higher and lower spectral resolution, both in f/k and θ
- Extent of frequency/wave number grid
- Narrower and broader spectra, both in f/k and θ
- Shift of peak frequency to test scaling law
- Shift over full or half a directional bin
- Perturbed spectrum, gap in spectrum at $2f_p$
- Comparison against theoretical results based on narrow peak approximations
- Convergence test: lim $\Delta\theta \rightarrow 0$, $\Delta f \rightarrow 0$
- Variations in internal settings, interpolation, quadrature method, etc...
- ...

Computational methods

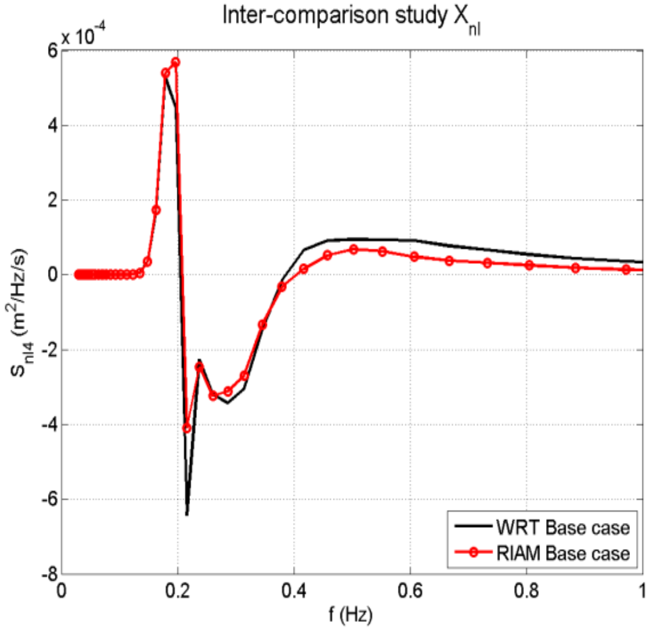
- WRT - Webb (1978), Resio & Perrie (1991), Van Vledder (2006)
- RIAM- Masuda (1980), Komatsu, Hashimoto

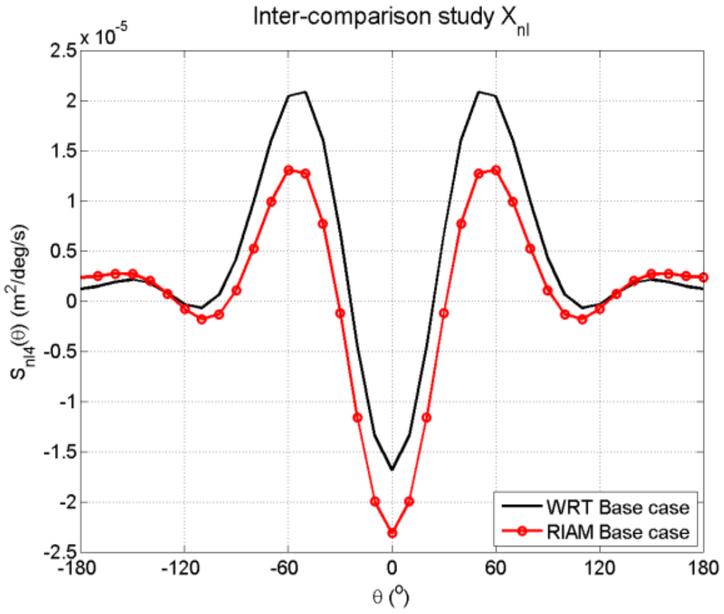
- GQM – Lavrenov (2001), Gagnaire-Renoud, Benoit (2007)
- EXACT-NL – Hasselmann and Hasselmann (1981)
- XNL? – Onorato, Janssen, Bidlot (WISE 2013)

- DIA – Hasselmann et al. (1985)
- SRIAM – Komatsu (1996)

- TSA – Resio and Perrie (2007)
- GMD – Tolman (2013)
- ADI – Perrie et al. (2011)

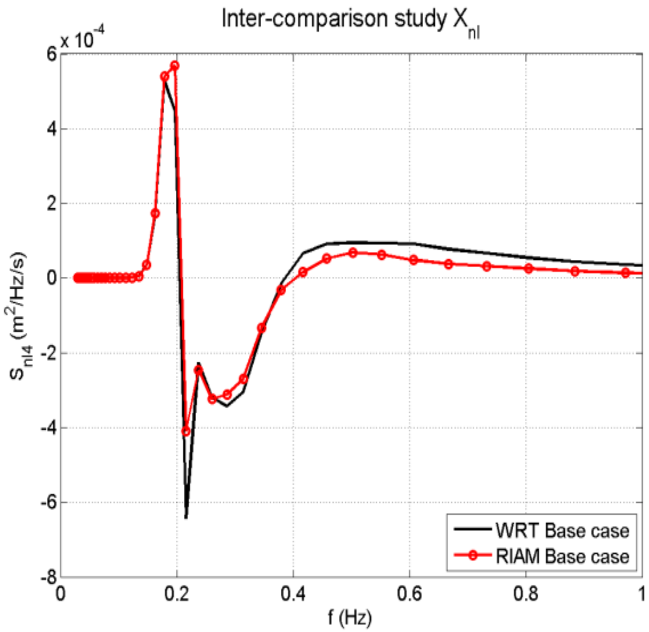
WRT – RIAM (base case)

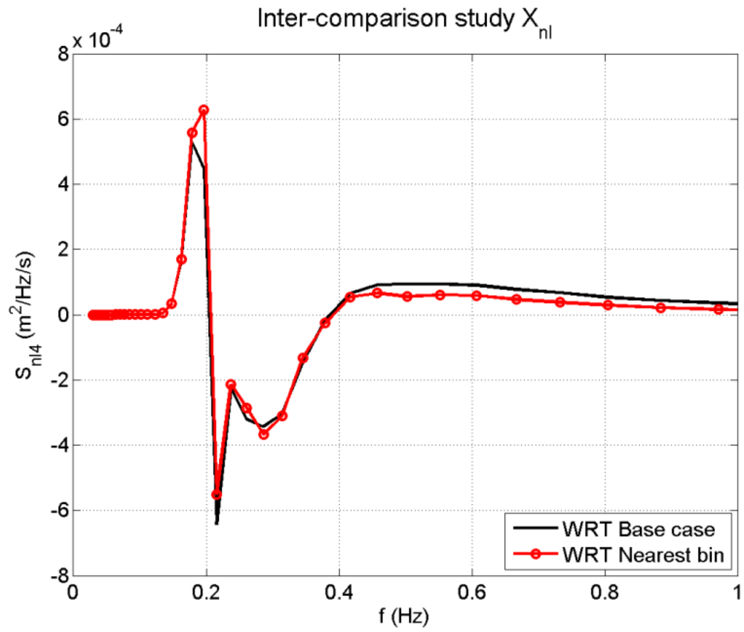




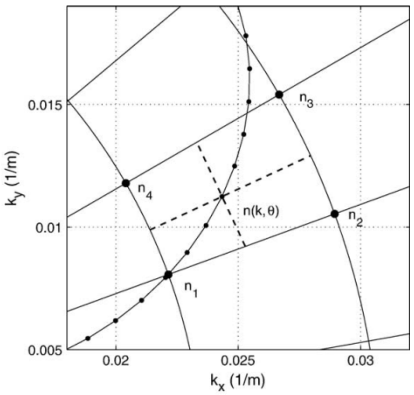
- Results differ exactly factor 2 (symmetry factor)
- Shape very similar
- Systematic difference in directional properties
- Small differences near peaks (interpolation errors in combination with (very) non-linear behavior

WRT – RIAM (effect of interpolation)

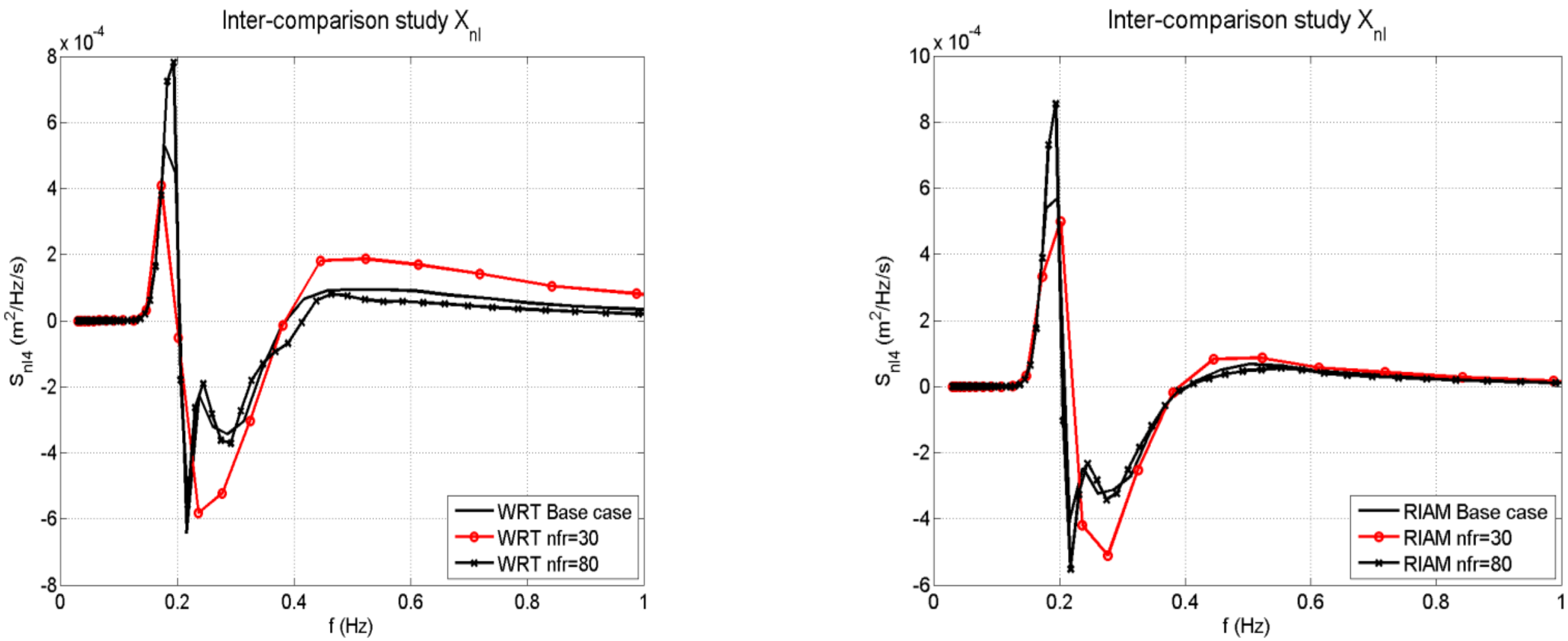




Indeed, small differences near peaks are due to differences in interpolation technique

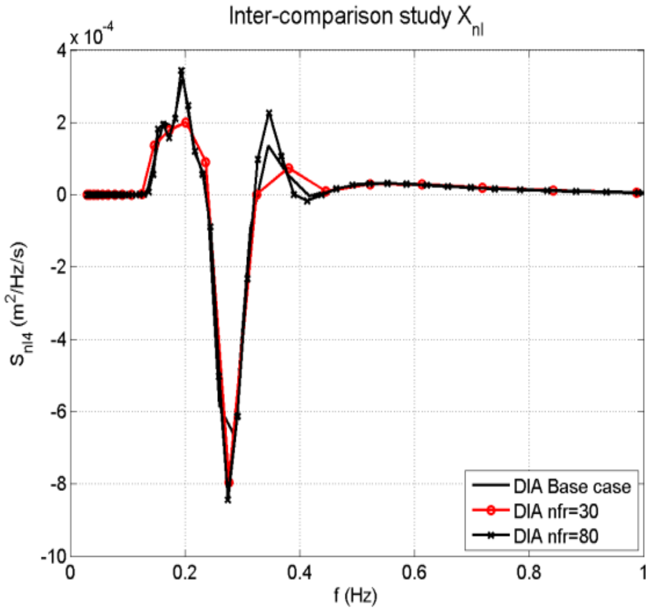


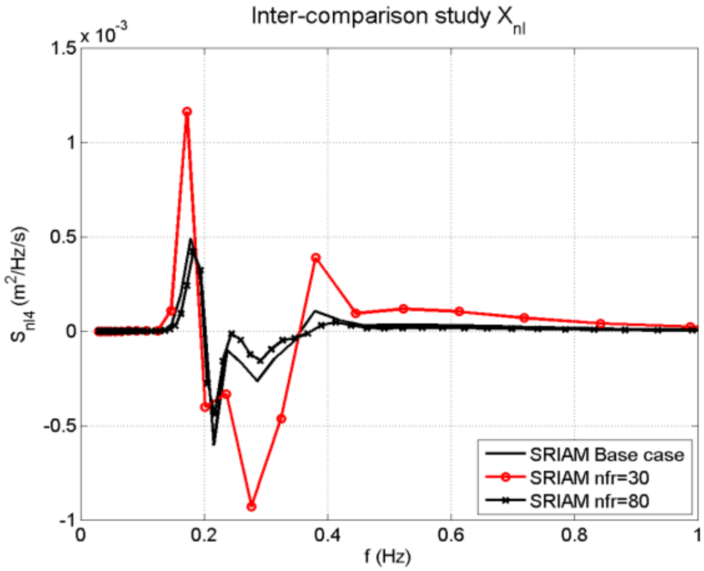
WRT-RIAM (frequency resolution)



- WRT and RIAM exhibit similar response
- Coarse resolution (17%); worsened result
- Fine resolution (6%); almost equal results

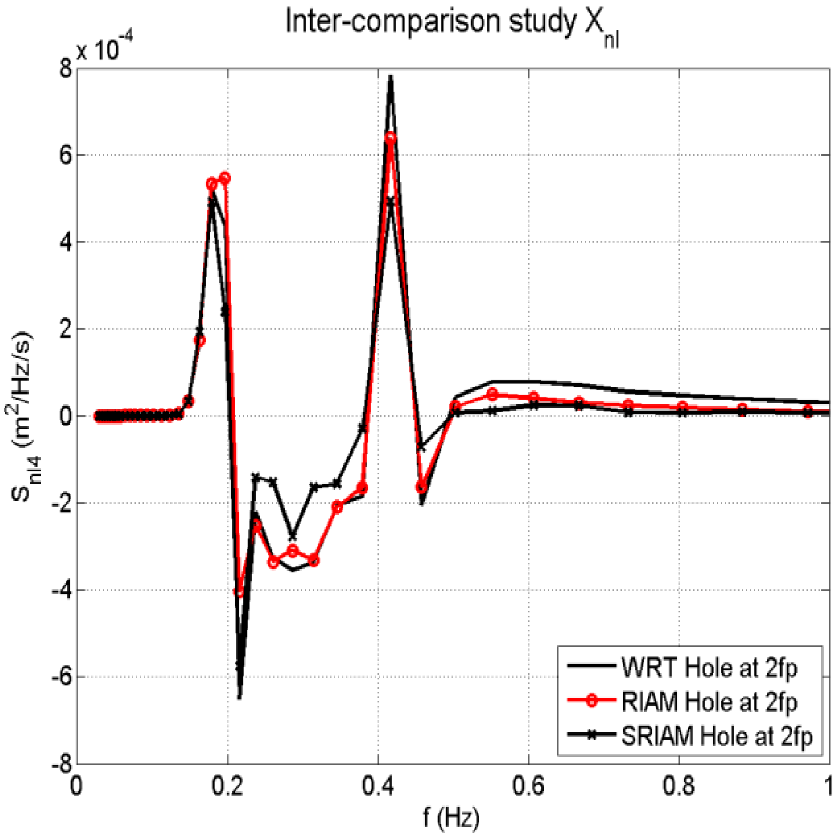
DIA - SRIAM (frequency resolution)





- DIA of both authors give equal result
- DIA peak heights sensitive to resolution
- SRIAM not sensitive to increased resolution
- SRIAM for coarse resolution seems to approach DIA

Gap in spectrum



Decrease density at $f=2f_p$
Resio and Perrie (1991)
Young and Van Vledder (1993)

WRT, RIAM and SRIAM

Responses similar, but somewhat bigger for SRIAM

Thoughts on static tests

- Static tests reveal systematic and subtle differences in implementation
- Static tests reveal sensitivities of internal settings, and assumptions, e.g. smoothness of spectra
- Thorough knowledge of each method required to explain differences and improve method
- Static tests insufficient to test applicability in dynamic conditions

Discussion on dynamic tests

- Dynamic tests are needed to check robustness, stability and performance
- Dynamic tests should contain of simple 1D-growth situations to 2D-academic and field cases (Tolman and Grumbine, 2013), Perrie et al. (2012) hurricane Juan with TSA
- Implementation on the same computer platform allows an objective comparison of speed and efficiency
- Performance of methods should be judged in terms of overall model behavior
- Balance between accuracy (of model) and computational requirements

Procedure

G generates ASCII input file
G disseminates files to participants
Participants compute their own Snl4
Results are shared with all members
Inter-compare and discuss results

c01: Base case
c02: Lower upper frequency, fnfr =37
c03: Higher upper frequency, fnfr =54
c04: Smaller number of frequencies, nfr = 30
c05: Higher number of frequencies, nfr = 80
c06: Smaller number of directions, ndir=24
c07: Higher number of directions, ndir=72
c08: Higher JONSWAP factor alpha=0.035
c09: Higher peak frequency, fp=0.3
c10: Smaller JONSWAP gamma=1
c11: Higher JONSWAP gamma=7
c12: Power of spectral tail -4
c13: Higher directional spreading, s=10
c14: Direction shifted half a bin
c15: Direction shifted full a bin
c16: JONSWAP JN5
c17: JONSWAP R3C
c18: JONSWAP J6B
c19: Hole at 2fp

```
#STEP#0000#
 0.00000E+00
#LOC#0001#
      0.000       0.000
#FREQ#
 50
 0.0300  0.0330  0.0362  0.0398  0.0437  0.0480  0.0527  0.0579  0.0636  0.0699
 0.0768  0.0844  0.0927  0.1018  0.1118  0.1228  0.1350  0.1483  0.1629  0.1789
 0.1965  0.2159  0.2372  0.2606  0.2862  0.3144  0.3454  0.3795  0.4168  0.4579
 0.5030  0.5526  0.6071  0.6669  0.7326  0.8048  0.8841  0.9712  1.0669  1.1721
 1.2876  1.4145  1.5538  1.7070  1.8752  2.0599  2.2629  2.4859  2.7309  3.0000
#DIRD#
 36
   0.00   10.00   20.00   30.00   40.00   50.00   60.00   70.00   80.00   90.00
 100.00  110.00  120.00  130.00  140.00  150.00  160.00  170.00  180.00  190.00
 200.00  210.00  220.00  230.00  240.00  250.00  260.00  270.00  280.00  290.00
 300.00  310.00  320.00  330.00  340.00  350.00
#QUAD#EF2#
 0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
 0.55747E-37  0.55263E-37  0.51001E-37  0.44362E-37  0.39879E-37  0.37942E-37  0.36527E-37
 0.18205E-37  0.19100E-37  0.23394E-37  0.32838E-37  0.49400E-37  0.74753E-37  0.10810E-36
 0.89516E-35  0.98241E-35  0.12334E-34  0.16150E-34  0.20716E-34  0.25291E-34  0.29074E-34
-0.24734E-33 -0.23687E-33 -0.20748E-33 -0.16408E-33 -0.11430E-33 -0.65481E-34 -0.23650E-34
-0.18439E-33 -0.17528E-33 -0.14931E-33 -0.11033E-33 -0.63909E-34 -0.16010E-34  0.28755E-34
 0.87447E-31  0.25077E-30  0.10989E-29  0.40820E-29  0.12848E-28  0.34831E-28  0.82507E-28
 0.52939E-25  0.12815E-24  0.46423E-24  0.14418E-23  0.38258E-23  0.88454E-23  0.18103E-22
 0.11457E-20  0.23578E-20  0.73208E-20  0.20314E-19  0.49077E-19  0.10452E-18  0.19861E-18
 0.32697E-17  0.57844E-17  0.15211E-16  0.37215E-16  0.80915E-16  0.15729E-15  0.27574E-15
 0.20742E-14  0.31839E-14  0.69811E-14  0.14744E-13  0.28153E-13  0.48603E-13  0.76339E-13
 0.35859E-12  0.48645E-12  0.89142E-12  0.16229E-11  0.27194E-11  0.41606E-11  0.58322E-11
```

Conclusions

- An objective method is proposed to inter-compare methods for computing the quadruplets
- Preliminary results already point to systematic and subtle differences in implementation
- The method can easily be applied to other exact and approximate methods as well
- Test data can be obtained from first author

Invitation

- In this stage only WRT, RIAM, SRIAM and DIA
- Extension to other methods needed
- Suggestions for other static and dynamics tests welcome
- Objective is to make a joint paper

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Questions ?