WENO interpolations in SL

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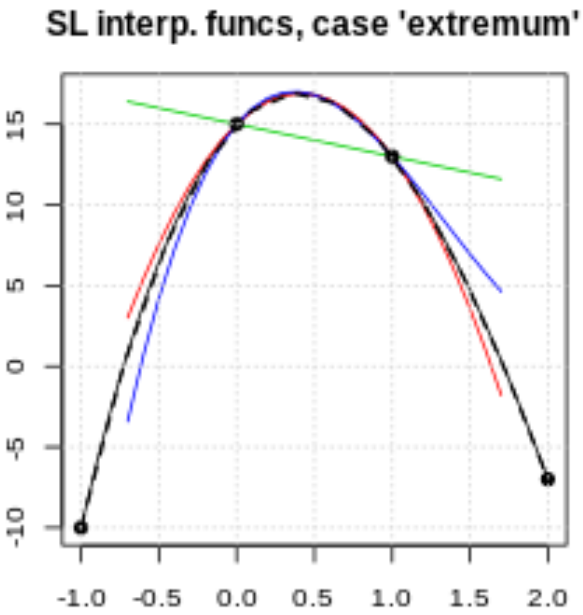
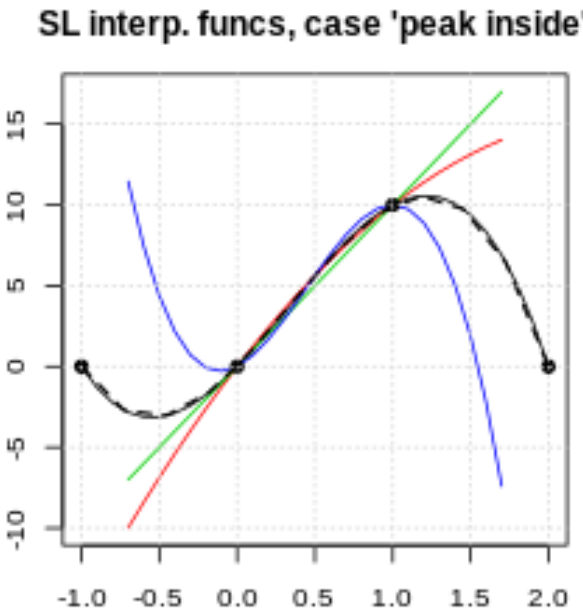
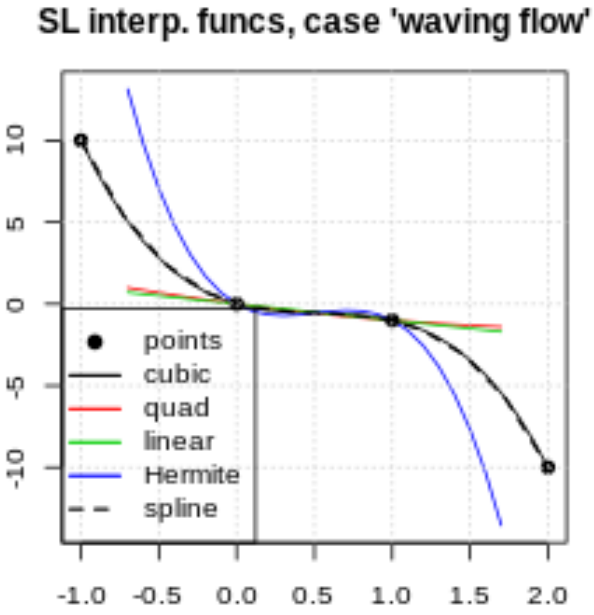
SL scheme and interpolations

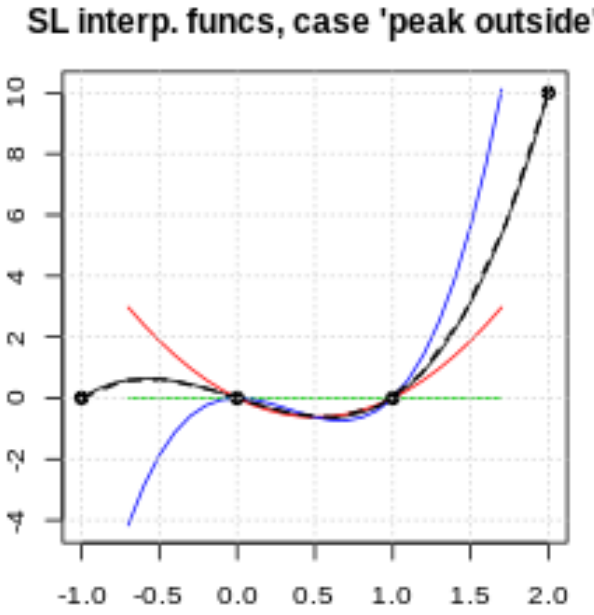
- Semi-Lagrangian scheme (SL):
  - Computation of advection of fields without derivatives (Euler scheme: advection with derivatives)
  - SL, part A: research of origin point O (pseudo-trajectory 'O -> F')
  - SL, part B: interpolations at O (t0), transfer to F (t1)
- Interpolations in SL:
  - Several options: linear, (quasi-)cubic, vertical splines, WENO
  - Side options: QM limiter, SLDiffusion, COMAD, HOI SLT, 3DTurb
  - Assessment: accuracy order vs side effects (eg Runge effect, overshoot)
- Interpolation basics:
  - Based on polynomials, low degree (1 or 3)
  - Input data: N+1 grid-points (linear, cubic), 1st/2nd order derivatives (splines), constants (WENO)
  - Theoretical assumption: continuity and derivability (C1, C2) of fields

SL interpolations: shape cases





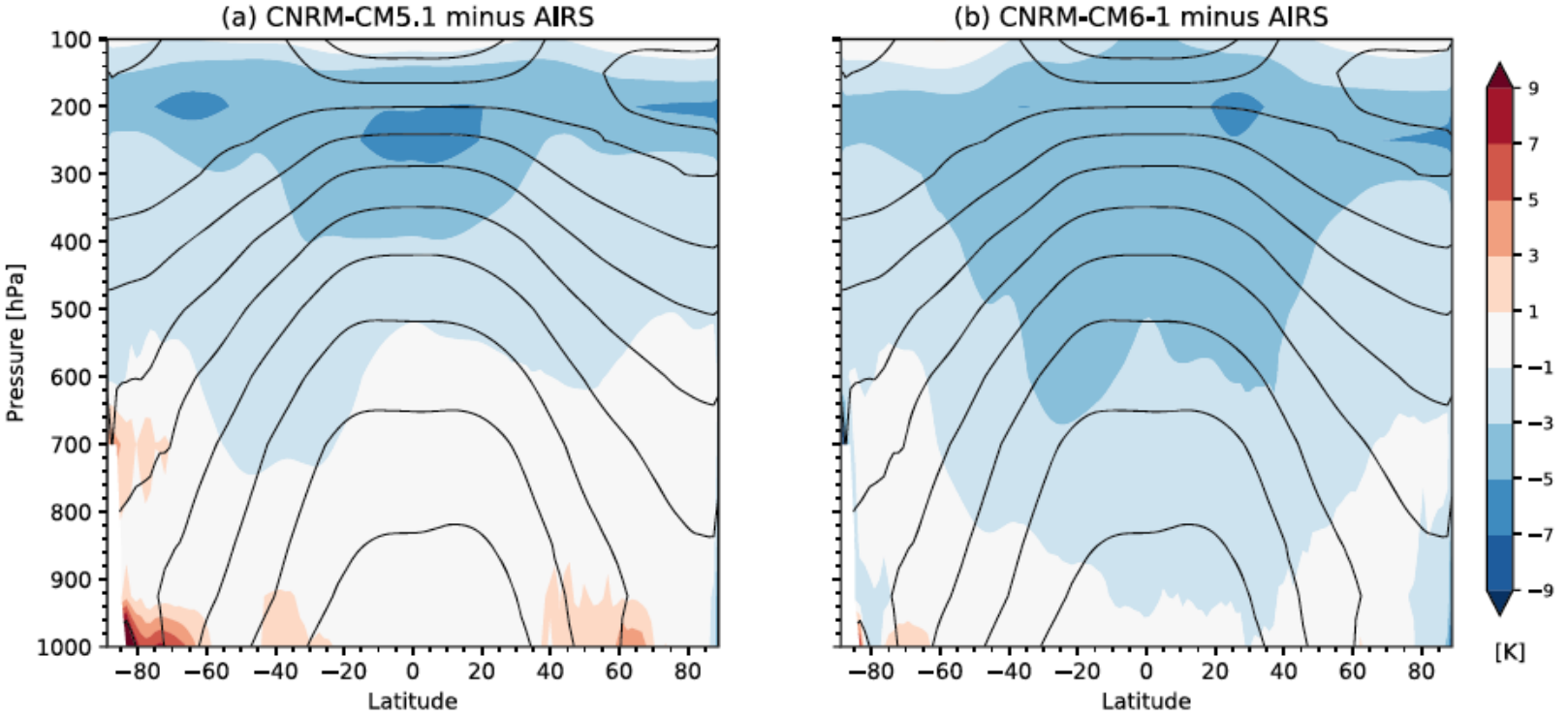




WENO interpolations

- WENO or Weighed ENO (Liu, Osher and Chan 1994):
  - Weighted, Essentially Non-Oscillatory interpolation
  - Account for discontinuity in data: removes spurious oscillations
  - 3rd order accurate in discont., up to 5th order in smooth region
  - Used in the vertical only (1D), after hor. interps
- Principle:
  - Weighted ENO: 3 cubic interps, then weighted (lin. combination)
  - Cubic interps:
    - 4 values each, shifted by 1: 0-3, 1-4, 2-5 (6 values stencil)
  - Weighted combination:
    - Weights account for data discontinuity (jumps, peaks, noise)
    - Weighing: resumes to cubic in smooth regions
- Results in IFS: WENO lowers biaises in stratosphere (T and Q)!

Biases in ARPEGE CNRM-CM (Roehrig)



- CNRM-CM5 (2010-2015): large cold bias (blue) for T, mainly in lower strato
- CNRM-CM6 (2018-): bias magnitude reduced, but more widespread (tropo and strato)
- Root cause: poor vertical resolution wrt horiz. resol. (ECMWF study)

WENO in ARP/IFS (1)

- WENO in ARP/IFS:
  - Initial work by P. Smolikova (CHMI, ~2015, CY40?)
  - Implemented by I. Polichtchouk and F. Vana (ECMWF, ~2018)
  - CY45 (fragments) – CY47 (complete): global only
  - CY49 (2022): extension to LAM by Meteo France
- Activation (NAMDYNA):
  - Main key: LRHSVWENO
  - Special key for boundary (regular eta only): LWENOBC
  - Special for HOI SLDiffusion on T (LHOISLT): LSLTVWENO
- Per-variable activation:
  - GMV: NAMDYN keys LVWENO_(T/W/SP/SPD/SVD) + coefs WENO_ALPHA_(T/W/SP/SPD/SVD), W is "wind" (U and V)
  - GFL: attributes LVWENO/WENO_ALPHA (for q, l, i,...)

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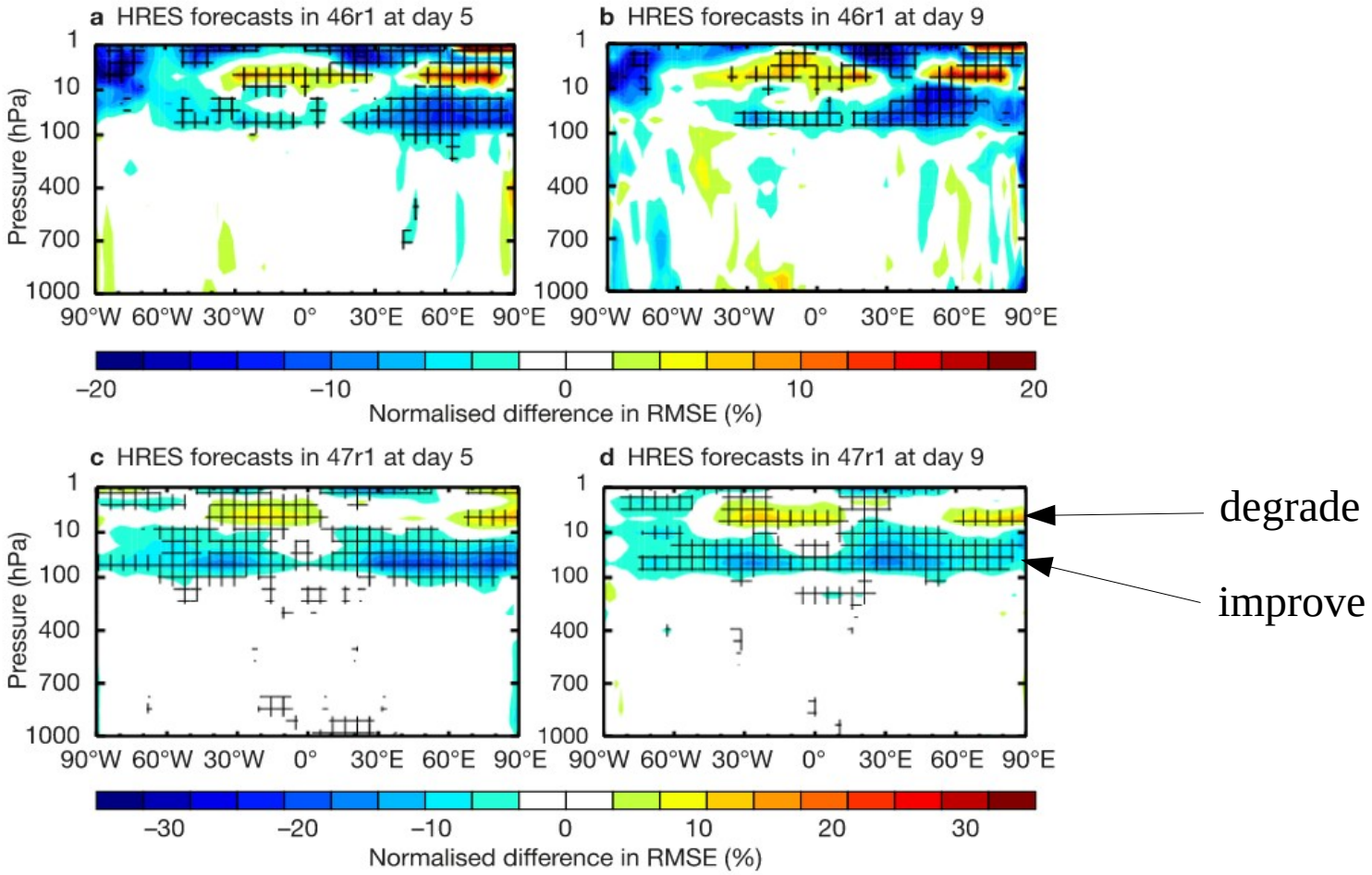
WENO in ARP/IFS (2)

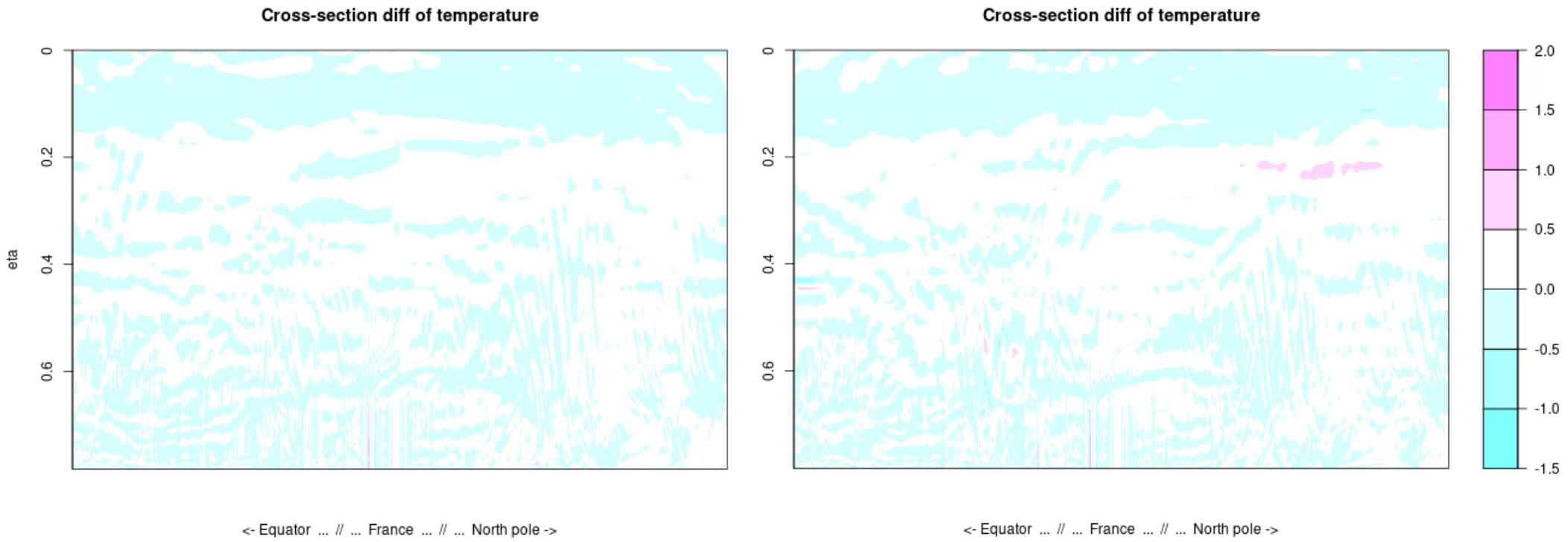
- WENO weights (laitri_weno):
  - Final weights: w_k = Gamma_k / Beta_k^Alpha, k=1, 2, 3
  - Gamma_k: interpolation weights, depend on position
  - Beta_k: smoothness coeffs, depend on data
  - Final interp'd value: Z = sum(w_k * z_k), k=1, 2, 3
- Boundary conditions (top/bottom)
  - WENO not applied at top/bottom if LWENOBC is false (3 levels off), resumes to standard cubic interp
  - Alpha (power coeff on Beta): kept > 1 at 1st top levels
  - Avoids noisy interps
  - Namelist (default): NLEV_ALPHA (~11), RALPHA_TOP (~2)

WENO effect in IFS



- Gain (%) in RMSE for T with WENO, various cases
- WENO better than cubic (blue) at lower strato. (100hPa) but degrading at mid/upper strato. (10hPa)

WENO in ARPEGE: difference with cubic



- Meridian cross-section difference 'fcst WENO – fcst cubic'
- Panels: +12h (left) and +24h (right) forecasts (2021-03-29 00Z)
- Troposphere (0.2 < eta < 0.8): +/-0.5K, no real pattern (except some oscillation)
- Tropopause – stratosphere (0 < eta < 0.2) : +/-0.5K, but clear "+/-" pattern
- To be cont'd: LAM tests, WENO options tests, scores,...

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