Single precision SPP experiments with HARMONIE-AROME

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Thanks also to Ole Vignes (MET Norway)

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Motivation

- ECMWF switched to operational single precision (SP) IFS forecasts in May 2021:
  - Forecast model alone in SP, all other components in double precision (DP)
  - Achieved a ~40% runtime saving, no significant degradation in forecast quality
  - Research ongoing into using half precision in IFS

- SP forecasts in HARMONIE-AROME cycle 43h2.2+:
  - Activated using “FP_PRECISION=dual”, builds R32 and R64 binaries
  - Forecast uses R32, everything else R64
  - Generally stable with 30-40% runtime saving (significant testing at MetCoOp and DMI)

- Move to operational SP HARMONIE-AROME ensembles?
  - All “standard” model perturbations happen in DP
  - However, the SPP scheme is called within Forecast
  - How does SPP perform in SP?

SPP testing over Ireland

- Extensive SPP testing over Ireland as part of an ECMWF Special Project in 2022:
  - Utilised two proposed 5 parameter SPP configurations (MetCoOp and KNMI)

- REF experiment:
  - harmonEPS-43h2.2 branch
  - 1+6 members, 3hr cycling, +48 at 00Z
  - IRELAND25, 65 levels
  - SLAF, EDA, surface perturbations

- Two week runs over four seasons

Season	Period	Conditions
Spring	28th March – 10th April 2022	Several fog cases
Summer	11th – 24th July 2022	Mini-heatwave, thunderstorms
Autumn	16th – 29th October 2021	Wet spell
Winter	10th – 23rd February 2022	Storms Dudley, Eunice, and Franklin

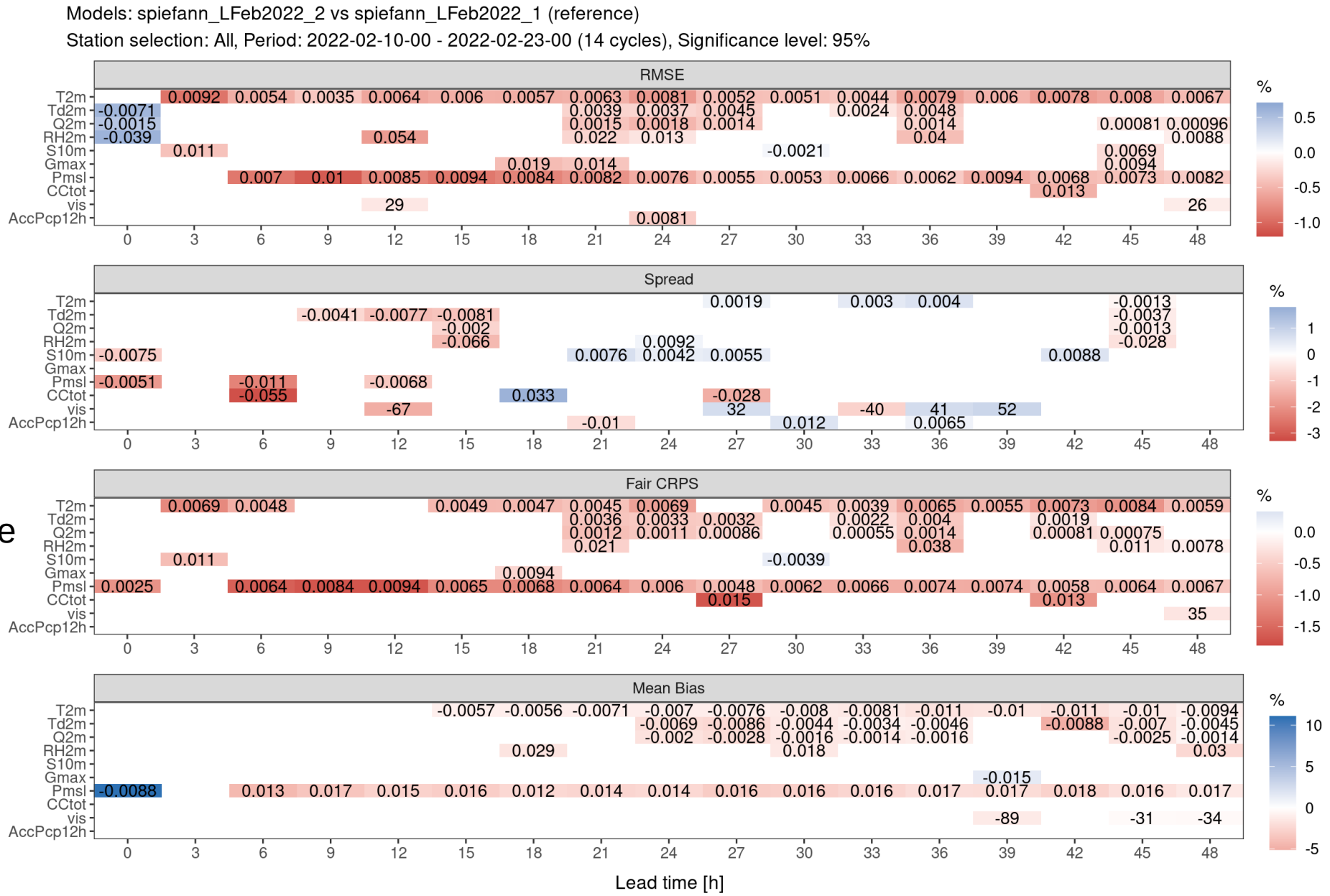
- Suite of experiments allow us to assess:
  - DP vs SP REF (i.e. no SPP)
  - DP SPP (i.e. REF+SPP) vs REF (for both SPP configurations)
  - DP vs SP SPP

- Note NPATFR_SPP=1 (every timestep) when SPP=yes

DP vs SP REF: Point verification

- Point verification results for SP vs DP REF over the winter period
- SP has a relatively neutral impact on surface scores (except PMSL bias)
- ~40% runtime saving on Atos

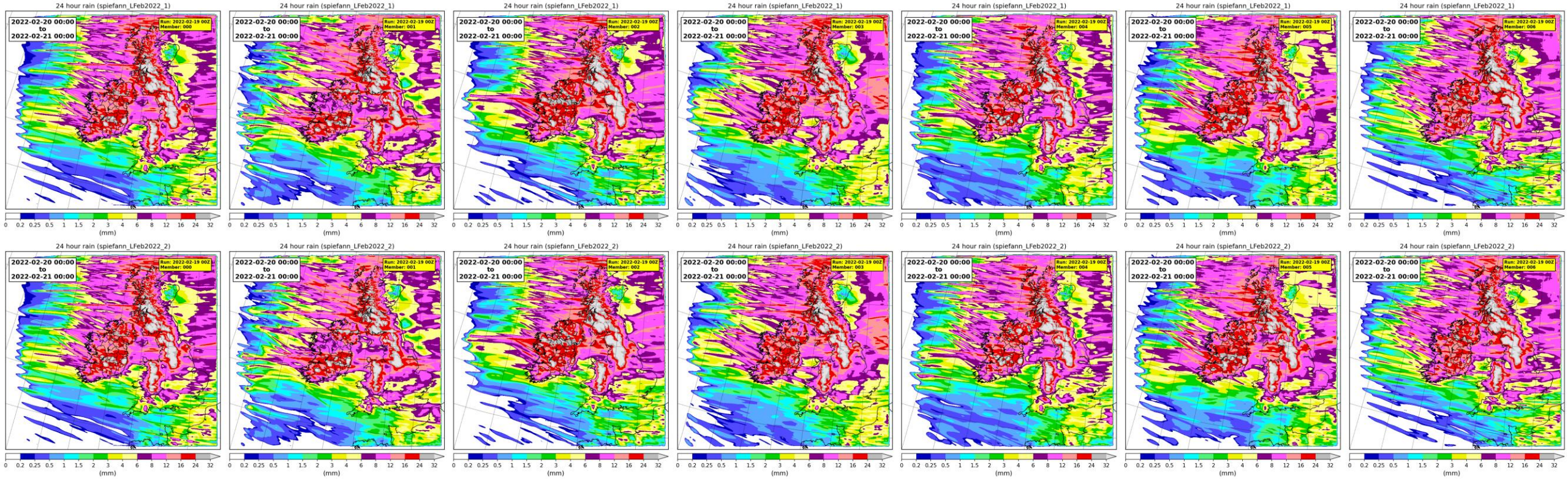
Degradation in SP ensemble relative to DP



- Significance below 95% omitted
- Number in each tile represents difference in mean score
- Colour represents the % diff in mean scores (relative to reference experiment)

DP vs SP REF: Sample forecasts

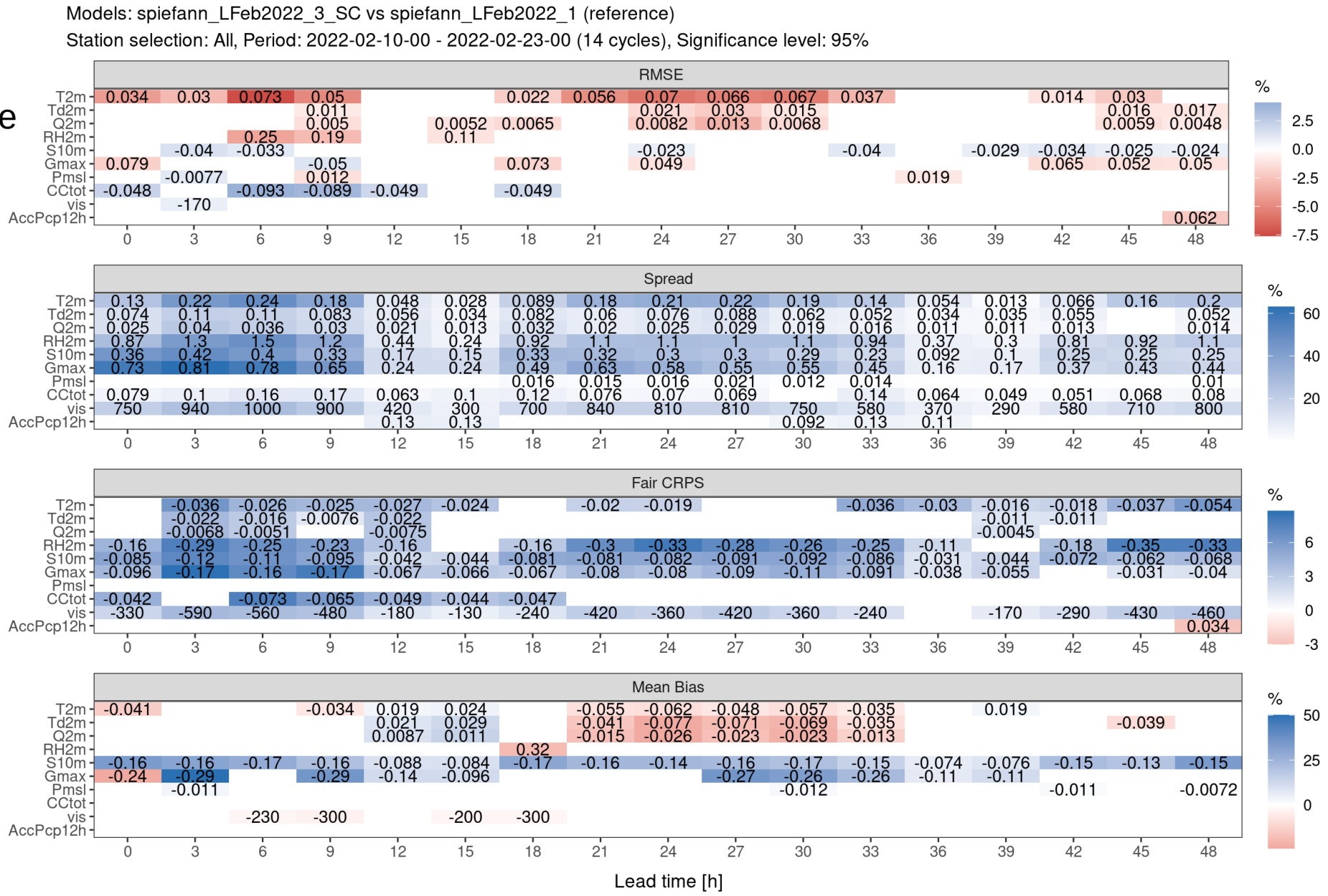
- Sample 24hr rainfall forecasts using 2022/02/19/00Z+48:
  - DP (top), SP (bottom), members 0-6 from left to right
- Reassuringly similar



DP SPP vs DP REF: Point verification

- Point verification results for DP SPP vs DP REF over the winter period (KNMI SPP configuration)
- Clear improvement in ensemble spread, CRPS, and spread-skill ratio
- Consistent across all test periods for most surface parameters

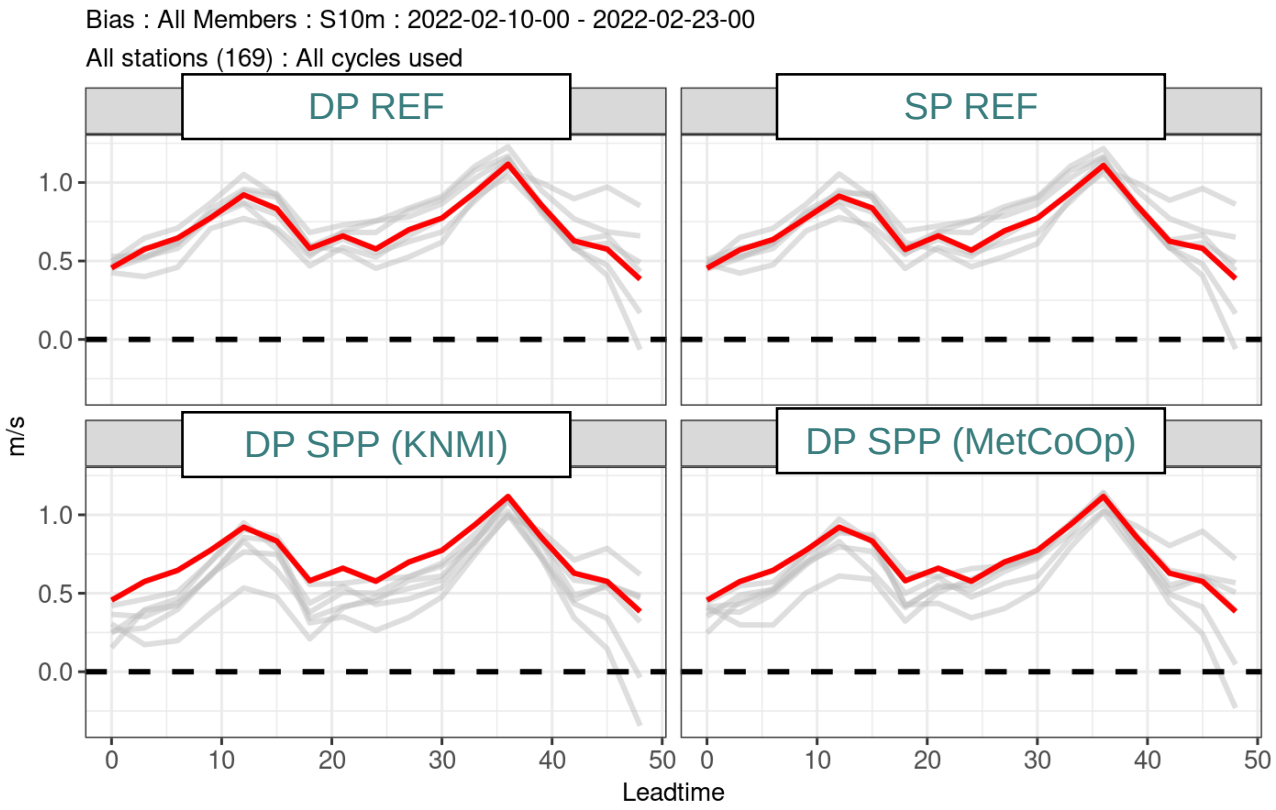
Improvement in SPP ensemble relative to REF



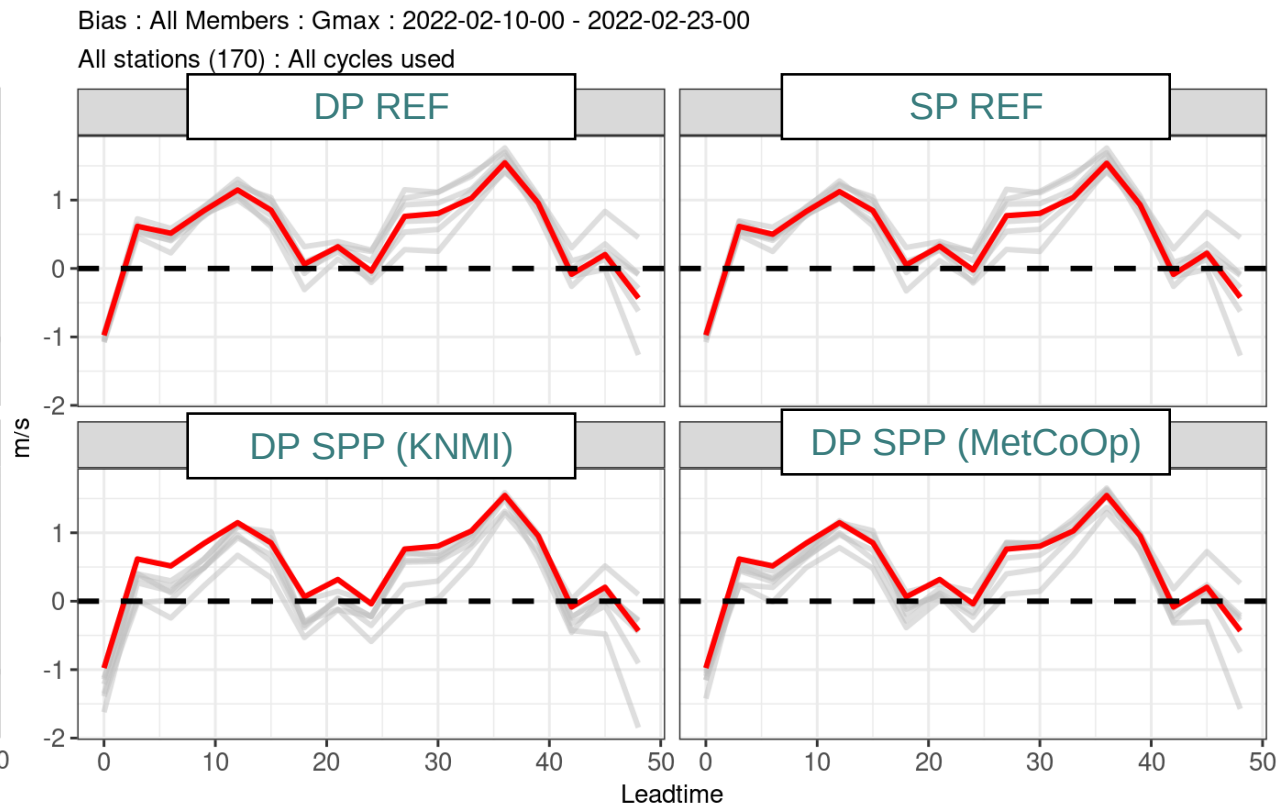
DP SPP vs DP REF: Wind speed bias

- Wind speed biases:
  - Perturbed members appear to be negatively biased relative to the control

10m wind



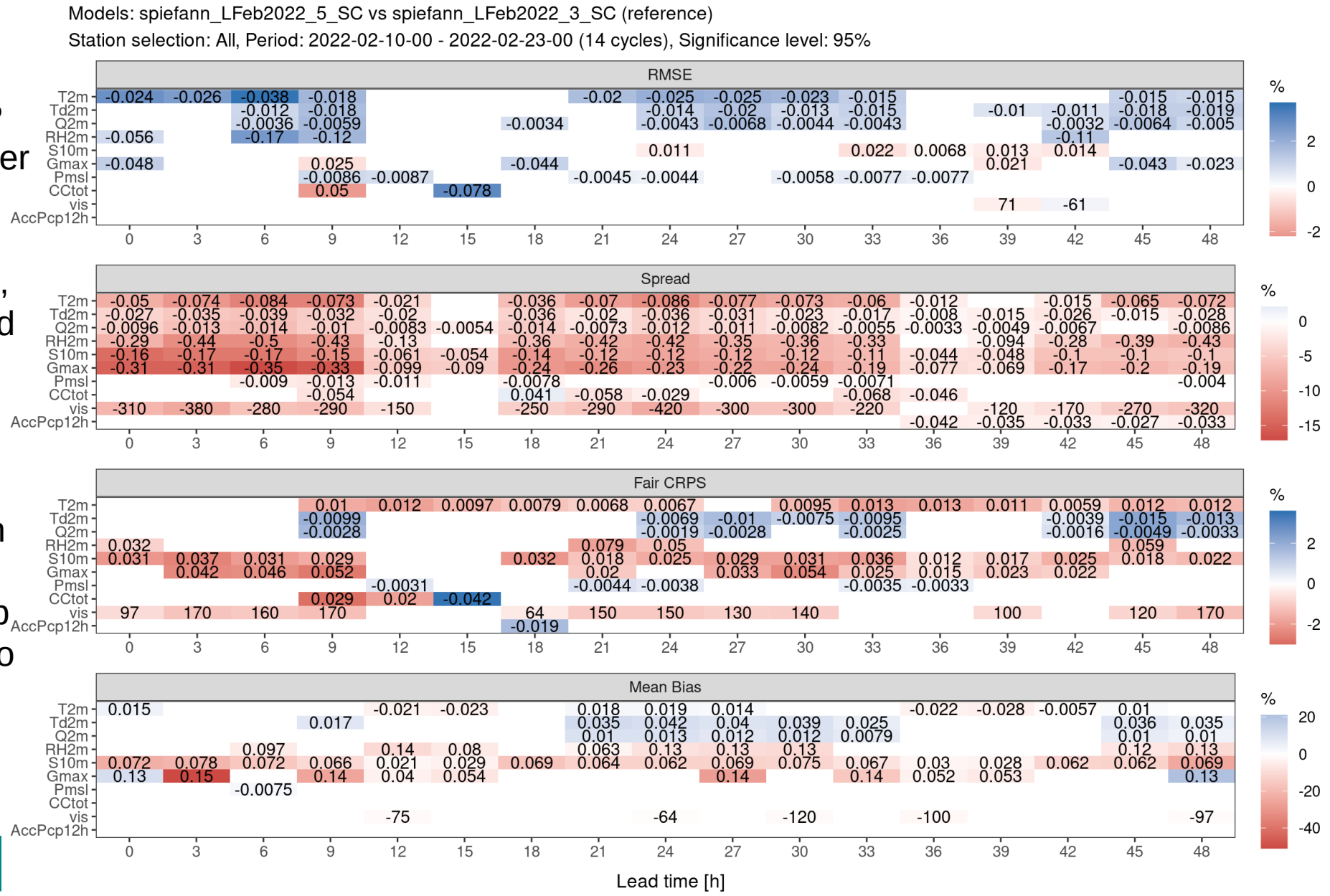
10m gusts



DP SPP: MetCoOp vs KNMI configurations

- Point verification results for DP MetCoOp vs KNMI SPP configurations over the winter period
- Similar performance overall, but a tendency for increased ensemble spread with the KNMI configuration
- Slightly higher wind speeds with MetCoOp configuration

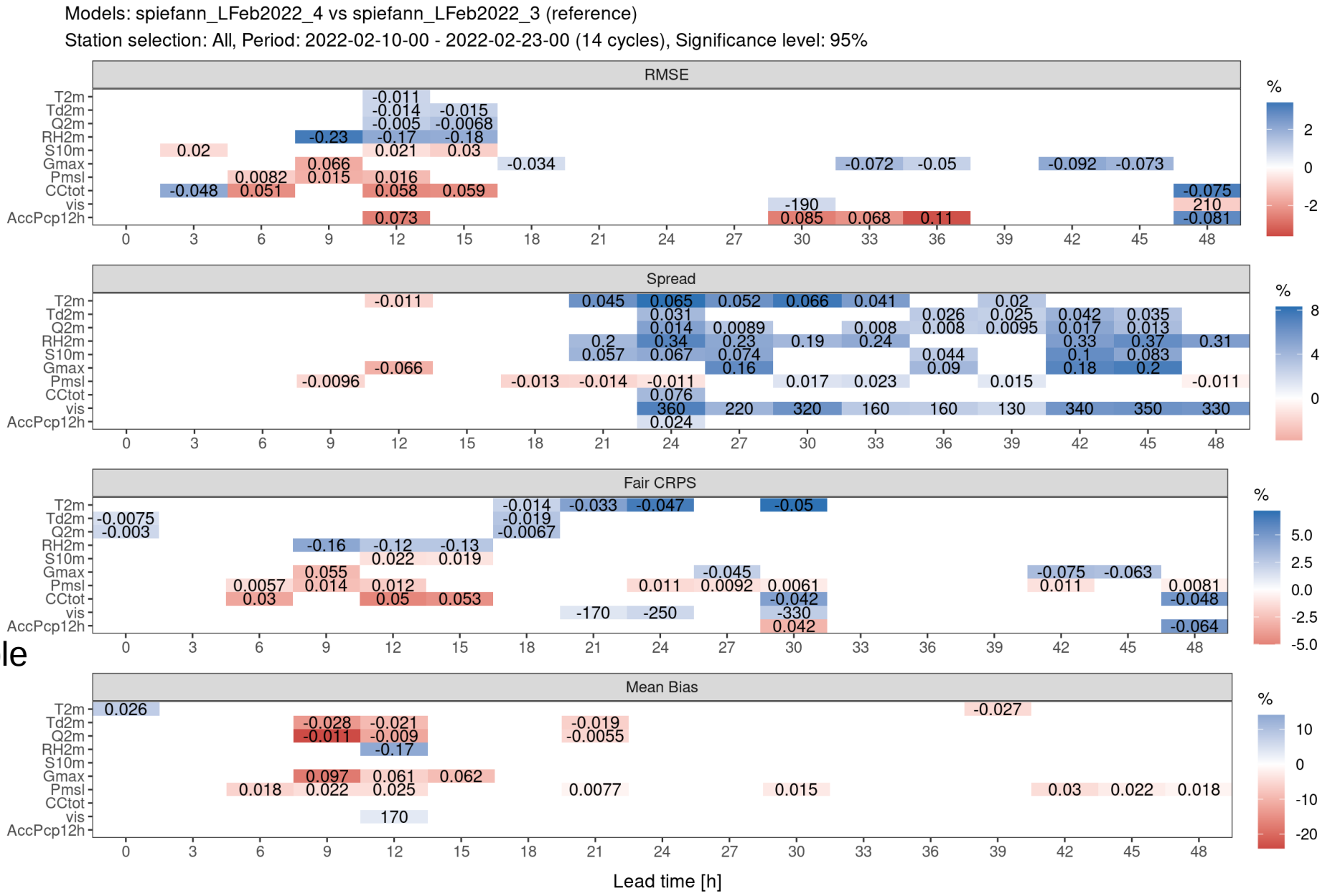
Improvement with MetCoOp SPP configuration relative to KNMI configuration



DP vs SP SPP: Point verification

- Point verification results for SP vs DP SPP over the winter period (KNMI SPP configuration)
- Appears to be relatively neutral, but spread is artificially inflated at longer lead times in SP
- Significantly different to the behaviour observed when SPP is not active

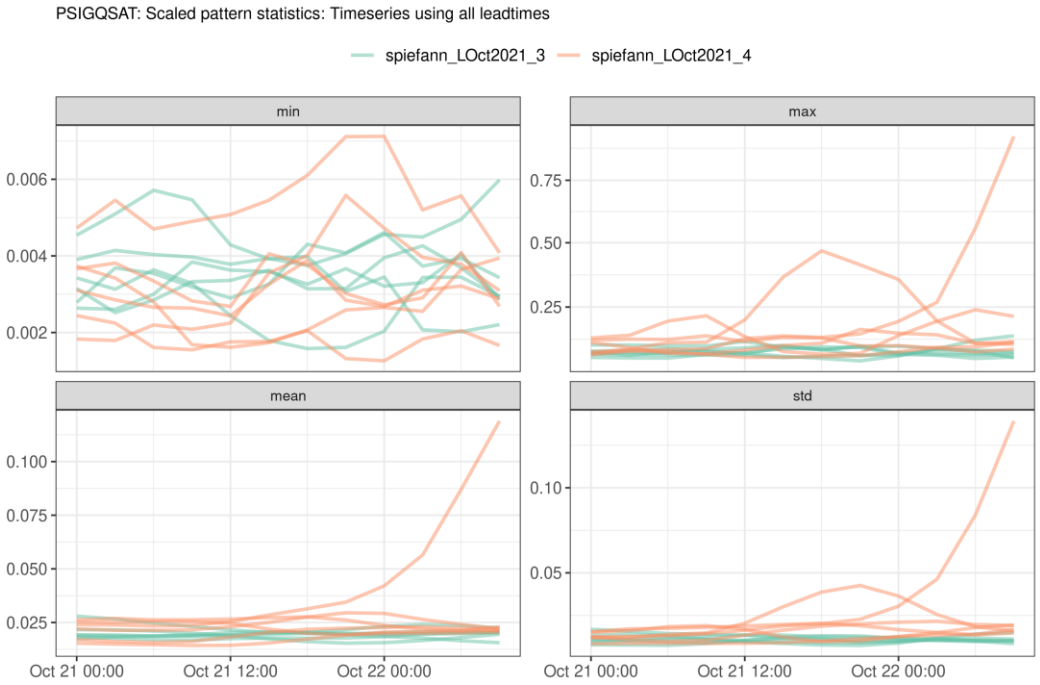
Improvement in SP ensemble relative to DP

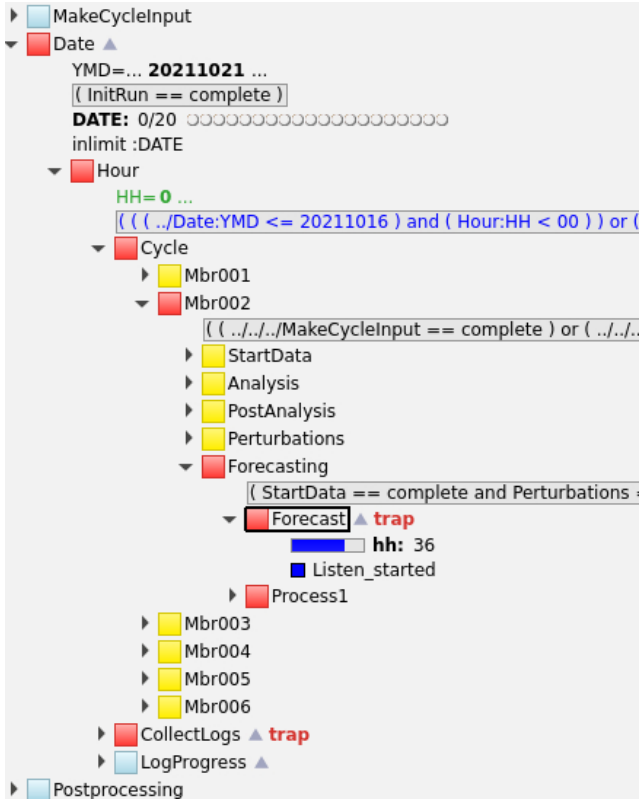


SP SPP crash

- Most SP SPP runs were stable, however a single cycle of the autumn test period failed (one member at hour 36)
  - In arpifs/phys_radi/swni.F90, fix not immediately clear…

- Timeseries of the PSIGQSAT perturbation pattern statistics before the model crash indicate diverging behaviour



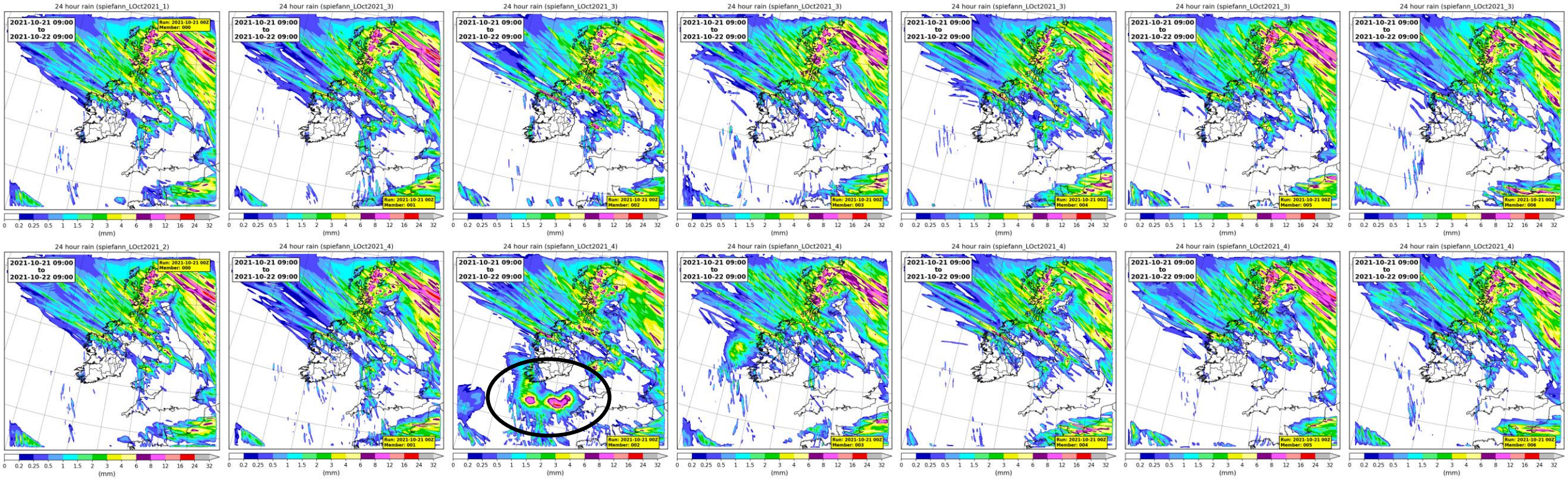


DP members (green)
SP members (orange)

Spike in mean, max and variance for the failed member in the lead-up to crash…

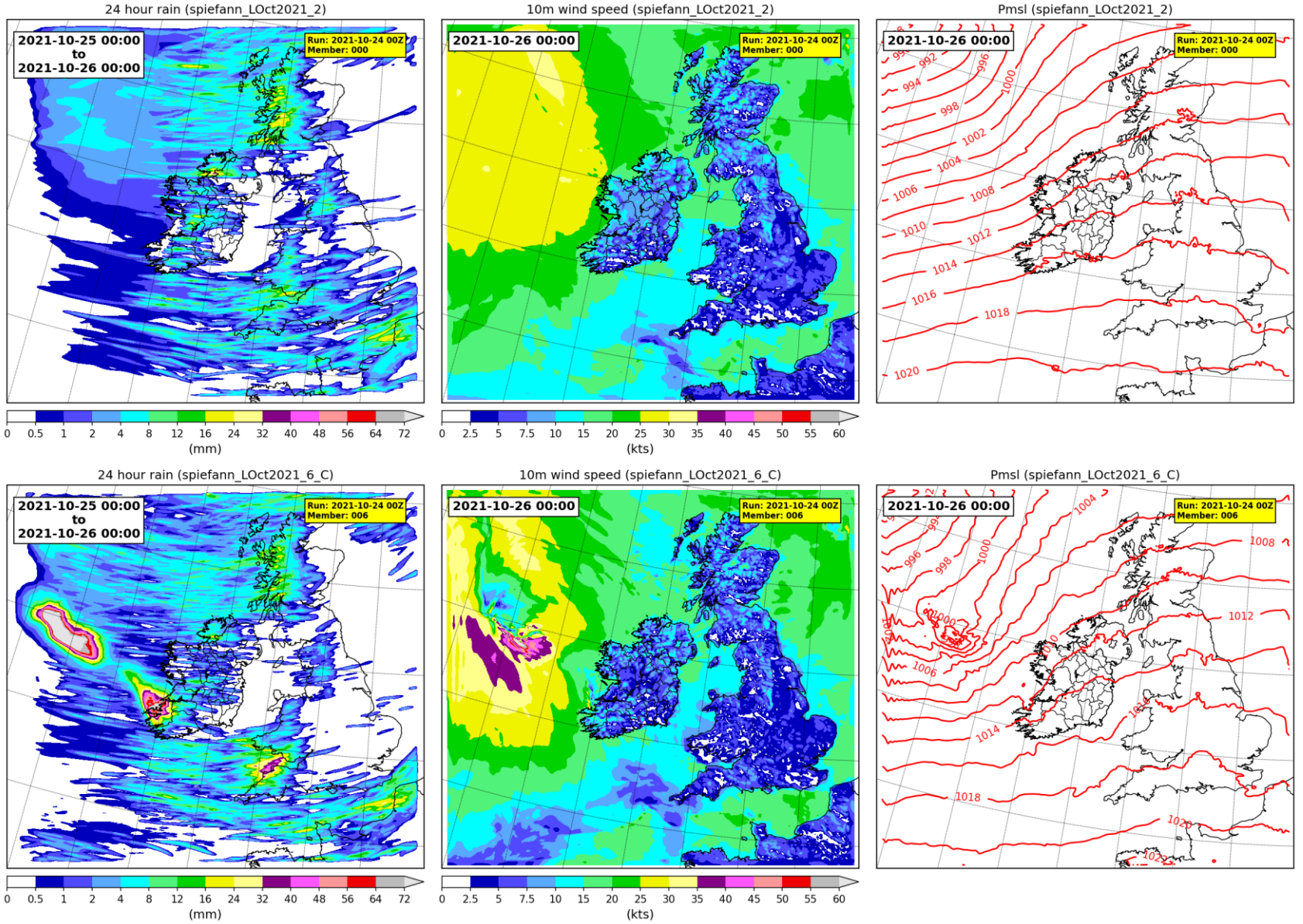
SP SPP crash

- 24hr precipitation for cycle 2021/10/21/00Z at hour 33 (i.e. just before model crash)
- Top/bottom rows: DP/SP SPP experiments
- Left to right: Members 0-6



SP SPP high rainfall

- Not the only case of “anomalous” rainfall in the SP SPP ensemble
- Another example from 2021/10/24/00 cycle (which did not crash!)
- Again associated with PSIGQSAT spike
- mbr000 (top), mbr006 (bottom). Left to right: 24 hour rainfall, 10m wind speed, PMSL at +48



DP vs SP SPP: Parameter patterns

- When updating the patterns every timestep, significant differences in the SP and DP SPP perturbation patterns were observed:
  - Tendency for more “extreme” perturbations in SP
  - Associated with anomalous rainfall and crashes

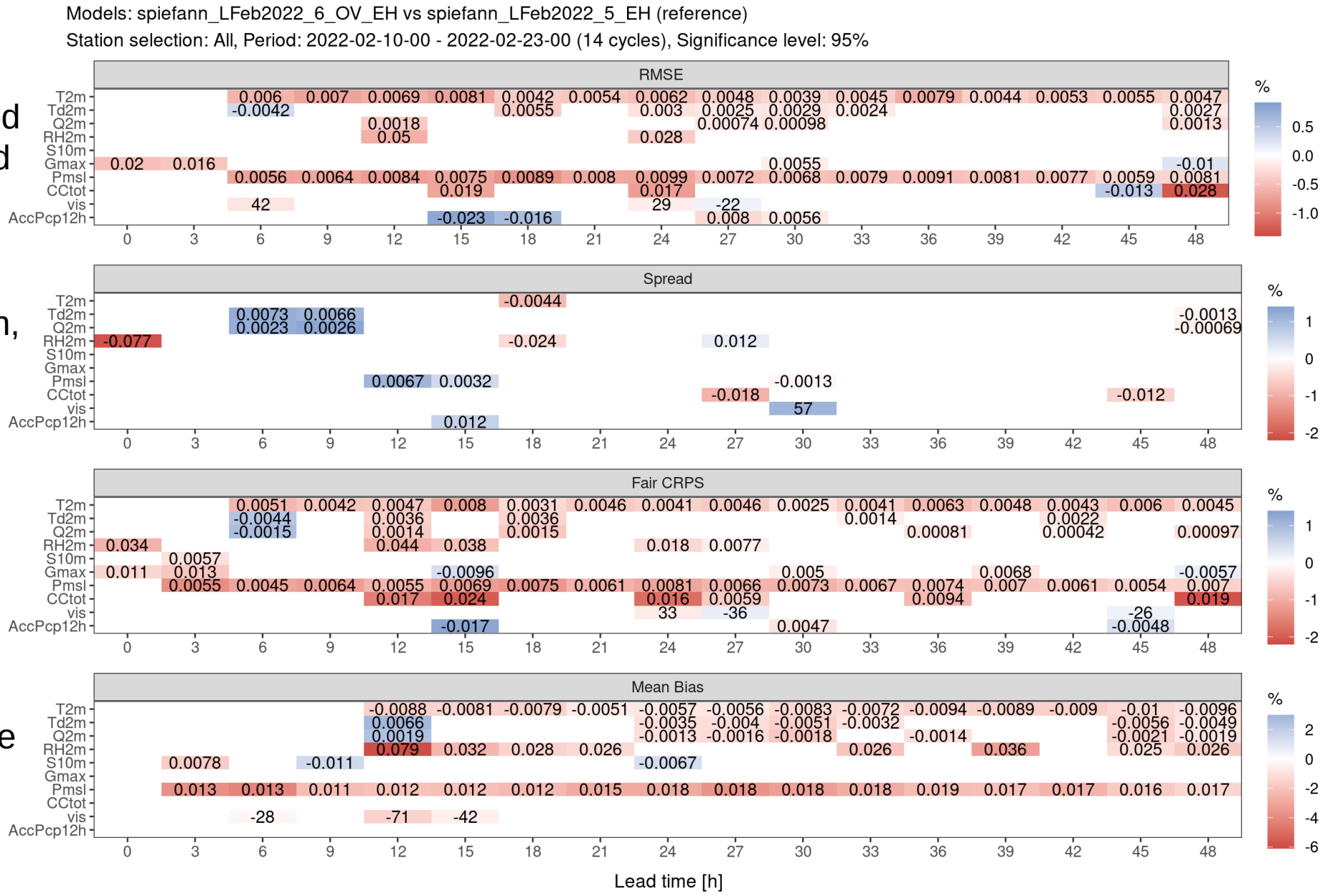
- Fixes to SP SPP patterns introduced by Ole Vignes:
  - DP versions of uniform/Gaussian distributions in RANDOM_NUMBERS_MIX
  - SP and DP SPP patterns were very similar when updating the pattern every hour (NPATFR_SPP=-1, next slide)
  - But differences still existed when updating every timestep

- And even more Ole fixes:
  - Some spectral fields maintained in DP
  - SP and DP patterns almost identical regardless of pattern updated frequency
  - Now available in dev-CY46h1_eps (not tested here)

DP vs SP SPP: Parameter patterns

- Sample point verification results over the winter period with almost identical DP and SP perturbation patterns
- MetCoOp SPP configuration, Ole changes with NPATFR_SPP=-1
- No increase in SP spread, behaviour is comparable to the “no SPP” experiment

Degradation in SP ensemble relative to DP



Summary

- No major SP stability/performance issues observed when using the “standard” suite of perturbations, with a ~40% runtime saving

- In DP, SPP scheme significantly improves ensemble performance over Ireland
  - Possible issue with member biases for wind speed

- Multiple issues observed for SP SPP:
  - Linked to “divergence” in SP patterns from DP behaviour
  - Appears to be resolved thanks to Ole’s changes

- Further testing with dev-CY46h1_eps required
  - More robust methodologies available? (crashes can be easily missed)