WEAVE MATCH REPORT

W1557, W1643
Claude Monet

Presented by the
Thread Count Automation Project

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Summary

This report depicts the canvas weave matches made among several paintings. Automatic counts were made from high resolution digital scans of x-rays. These x-rays, at sufficient enlargement, expose the canvas weave to be in the "plain" category. Software automates the process of determining, across the entire scanned x-ray, the thread count of the canvas weave pattern in two directions (nearly vertical and nearly horizontal in the x-ray) and the angles of these threads referenced to true vertical and horizontal respectively. From the weave maps, the warp and weft directions can typically be inferred by the experienced eye. Displaying a painting's weave maps here obeys the convention that vertical corresponds to the warp direction, horizontal to weft. In this report, two paintings—W1557, W1643—were found to have canvas supports that have matching thread density patterns. If the paintings are in vertical alignment, a warp match was found among them. Weft matches, if any were found, are indicated not just by horizontal alignment of the canvases, but also by arrows joining the matching weft weave pattern. If the arrows are not present, no weft weave match was found. Warp matches are much more plentiful than weft matches.

Acknowledgments: The thread counting software arose from a collaboration between the van Gogh Museum (Amsterdam) and the Thread Count Automation Project initiated by Professor Rick Johnson (Cornell University). The calculations were performed by Professor Don Johnson (Rice University) using the technique described in Johnson et al., "A Thread Counting Algorithm for Art Forensics," *Proc. 13th IEEE DSP Workshop*, January 2009 and in Johnson et al., "Matching canvas weave patterns from processing x-ray images of master paintings", *Proc. ICASSP*, May 2010. The thread counting software used here has been in development since 2007 in a collaboration among researchers B. Sethares, R. Arora, and H. Lee at the University of Wisconsin, A. Klein at Worcester Polytechnic Institute, D. Johnson at Rice University, and R. Johnson and J. Ng at Cornell University. A student team at Cornell (J. Ng, C. Cheung, M. Cho, P. Kung, S. Lok, B. Stubler, M. Wu, L. Zhang) plus a "corresponding" student at WPI (I. Ozil) are responsible for testing numerous early versions of the software suite and performing the manual counts used to assess the candidate thread counting algorithms. The weave matching algorithm was developed by D. Johnson with the help of L. Sun and S. Crowe, all of Rice University. For more information on the software used, contact Professor Rick Johnson at `johnson@ece.cornell.edu` or Professor Don Johnson at `dhj@rice.edu`. The x-rays provided for algorithm development were selected by Dr. Ella Hendriks of the van Gogh Museum and digitized by Frans Stive of the van Gogh Museum by scanning them into 16-bit greyscale tiff files at high resolution (greater than 300 dpi, typically 600 dpi).

Results

For the paintings under consideration here, the automatic thread counting and weave matching software works in the following way.

- The WEAVE MAPS record the average thread densities (in threads/cm) computed in overlapping 1.00 cm squares on 0.50 cm centers for each x-ray. The density relative to the painting's average at each location is indicated by a color. Separate maps are provided for warp and weft threads. The warp- and weft-thread directions is determined subjectively. Warp-direction weave patterns have thread counts that tend to have a smaller variance, to change little in the thread direction and to change much more in the perpendicular direction. Weft-direction weave patterns are less consistent in the thread direction and tend to have thread counts that change slowly in the perpendicular direction.

- The THREAD ANGLE MAPS indicate with color the values of the average thread angle (relative to horizontal and vertical alignment of the x-ray) in the 1.00 cm squares examined to compose the weave maps. Separate maps are provided for the warp and weft threads. These angle maps vividly display cusping when present by a succesion of color patterns alternating between the extremes of the colorbar (between red and blue and back repeatedly). Commercially primed canvases show very strong, nearly regularly spaced cusping for the warp threads, not for the weft threads.

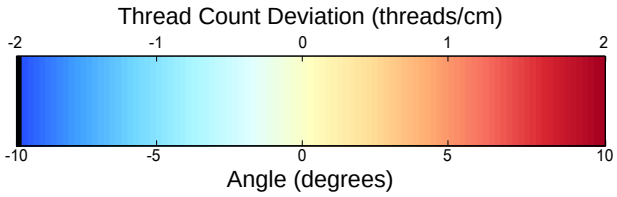

Illustration of the calibrated colorbar for both the weave deviation maps and the weave angle maps.

Both weave and angle maps are rotated so that vertical corresponds to the putative warp direction in the original canvas. The "up" direction for the original canvas is indicated by the orientation of the catalog number superimposed on the maps.

This report portrays the weave match found among the canvas supports for two paintings: W1557, W1643. The thread-count processing software revealed the average (avg) and standard deviation (σ) of the thread counts for the horizontal and vertical threads for the painting's canvas supports (Table 1).

The weave matching software collapses thread-desnity patterns along each thread direction into two one-dimensional density profiles for each painting and calculates the cross-correlations between the profiles for pairs of paintings, taking into account all possible painting rotations. The maximum value of the cross-correlation must exceed a specified threshold to be considered as a match. Perfect correlation has a correlation value of 1.0; the smaller the correlation the weaker the match. The maximum correlation between the two painting's weave patterns is 0.704 in the warp direction.

Painting	*Artist*	*Date*	*Museum*	Warp/Weft (th/cm)	
				avg	σ
W1557	Monet, Claude	1900	Art Institute of Chicago	**19.8/17.0**	0.52/0.60
W1643	Monet, Claude	1901	Art Institute of Chicago	**19.9/16.8**	0.57/0.66

Table 1: Weave statistics for each painting.

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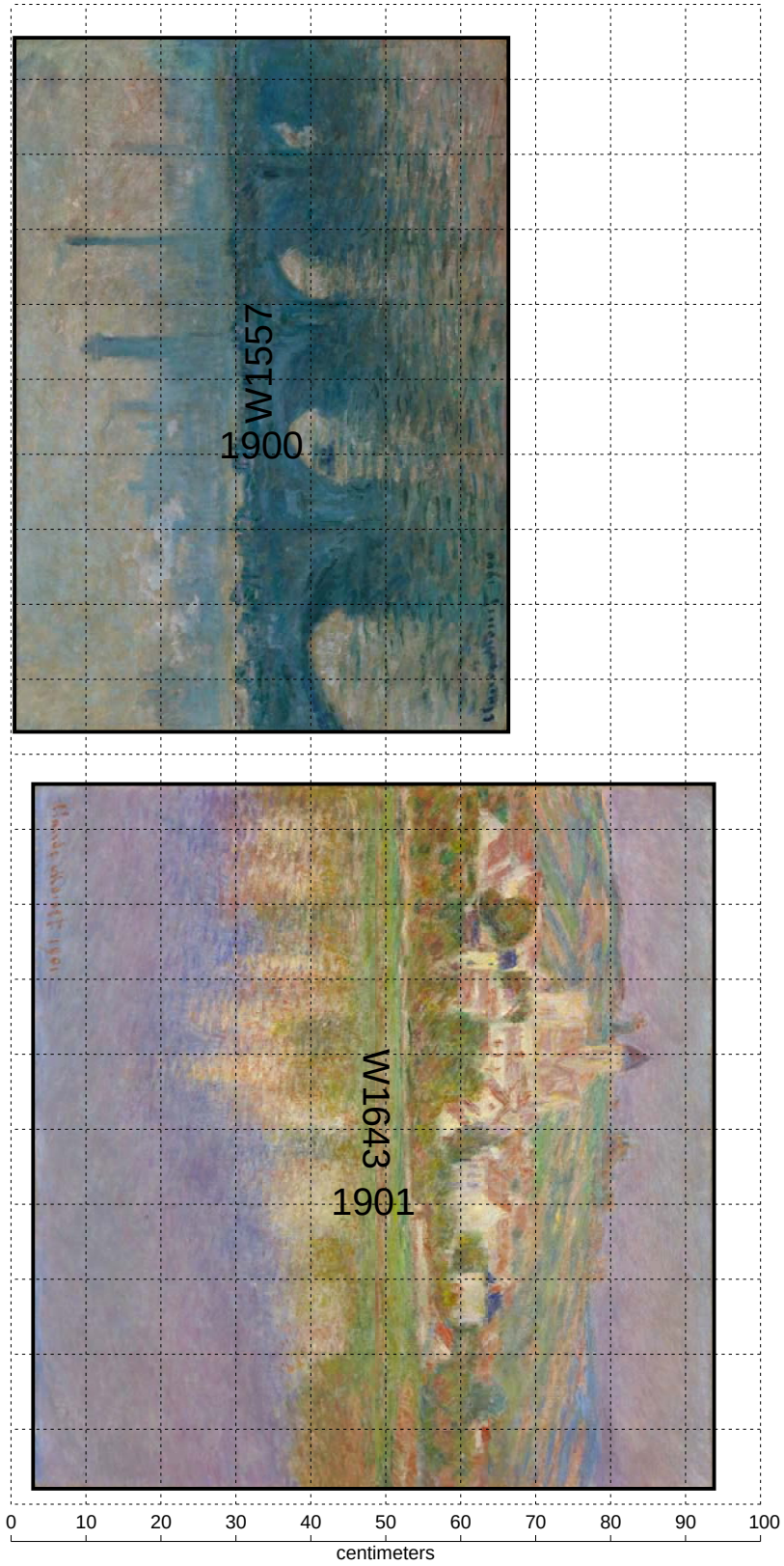

Figure 1: Paintings shown in weave match alignment. Horizontal and vertical lines are each separated by 10 cm to facilitate alignment and judging distances.

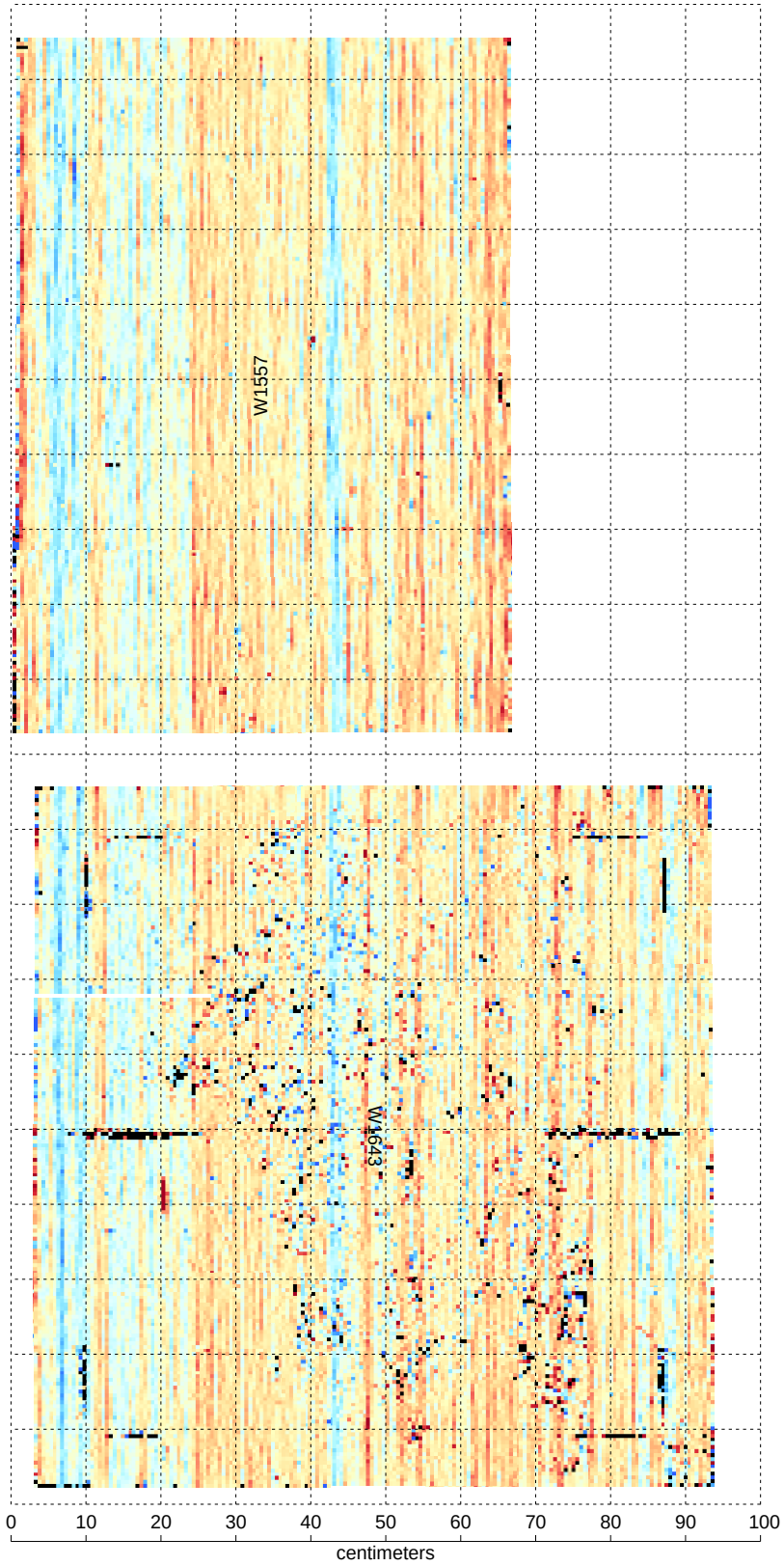

Figure 2: Warp weave maps for the paintings shown in weave match alignment. Horizontal and vertical lines are each separated by 10 cm to facilitate alignment and judging distances.

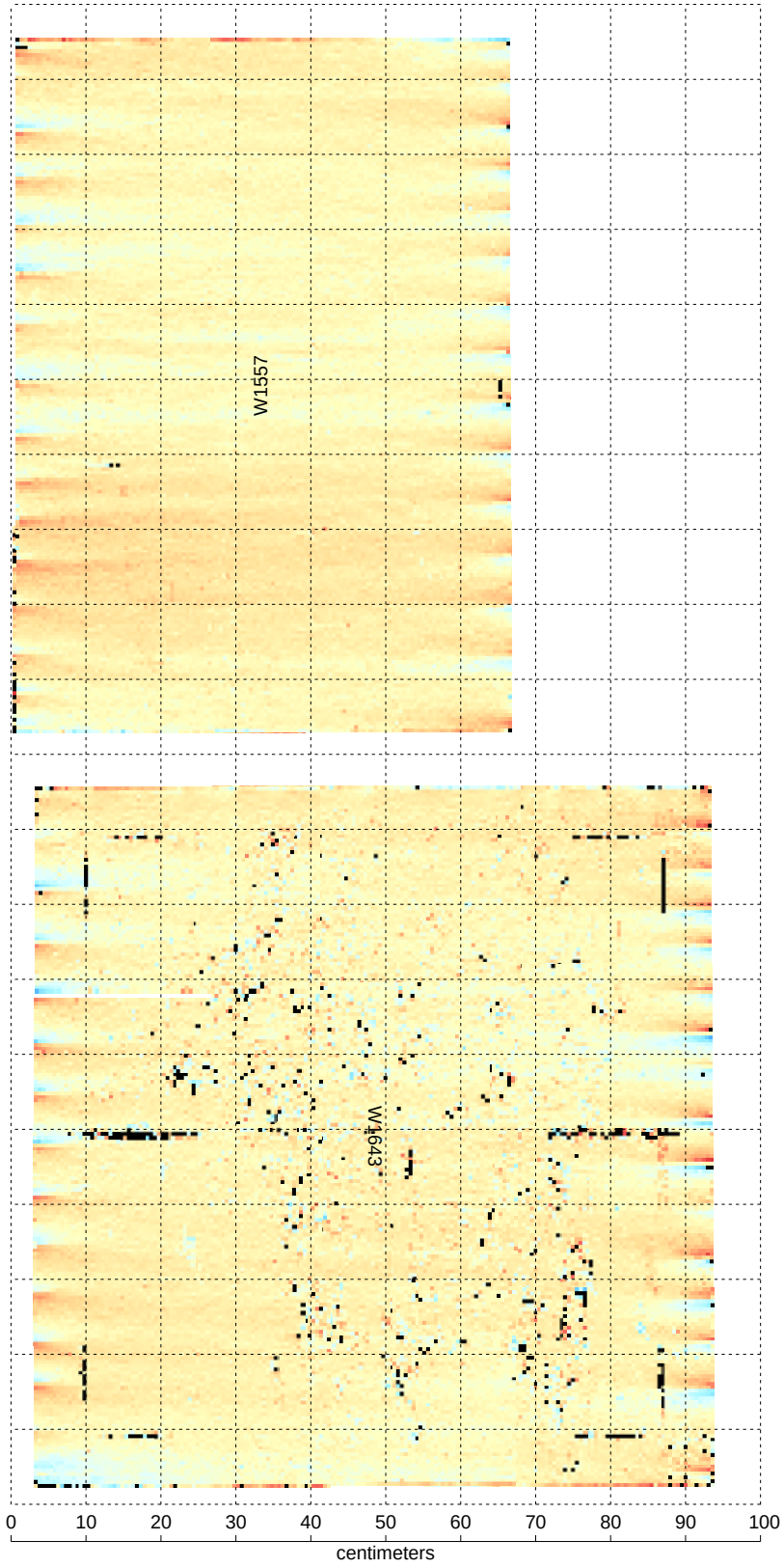

Figure 3: Warp angle maps for the paintings shown in weave match alignment. Horizontal and vertical lines are each separated by 10 cm to facilitate alignment and judging distances.

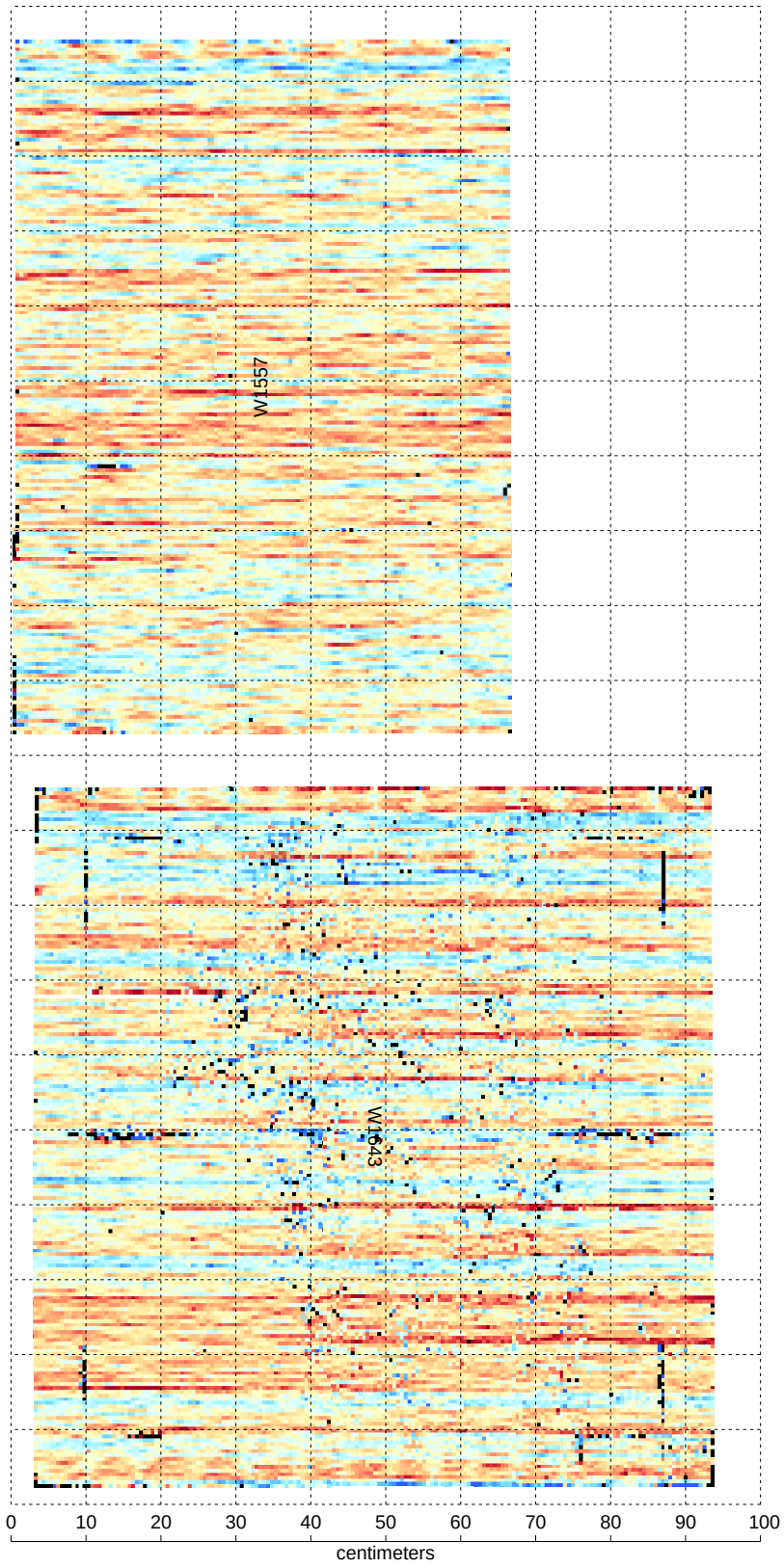

Figure 4: Weft weave maps for the paintings shown in weave match alignment. Horizontal and vertical lines are each separated by 10 cm to facilitate alignment and judging distances.

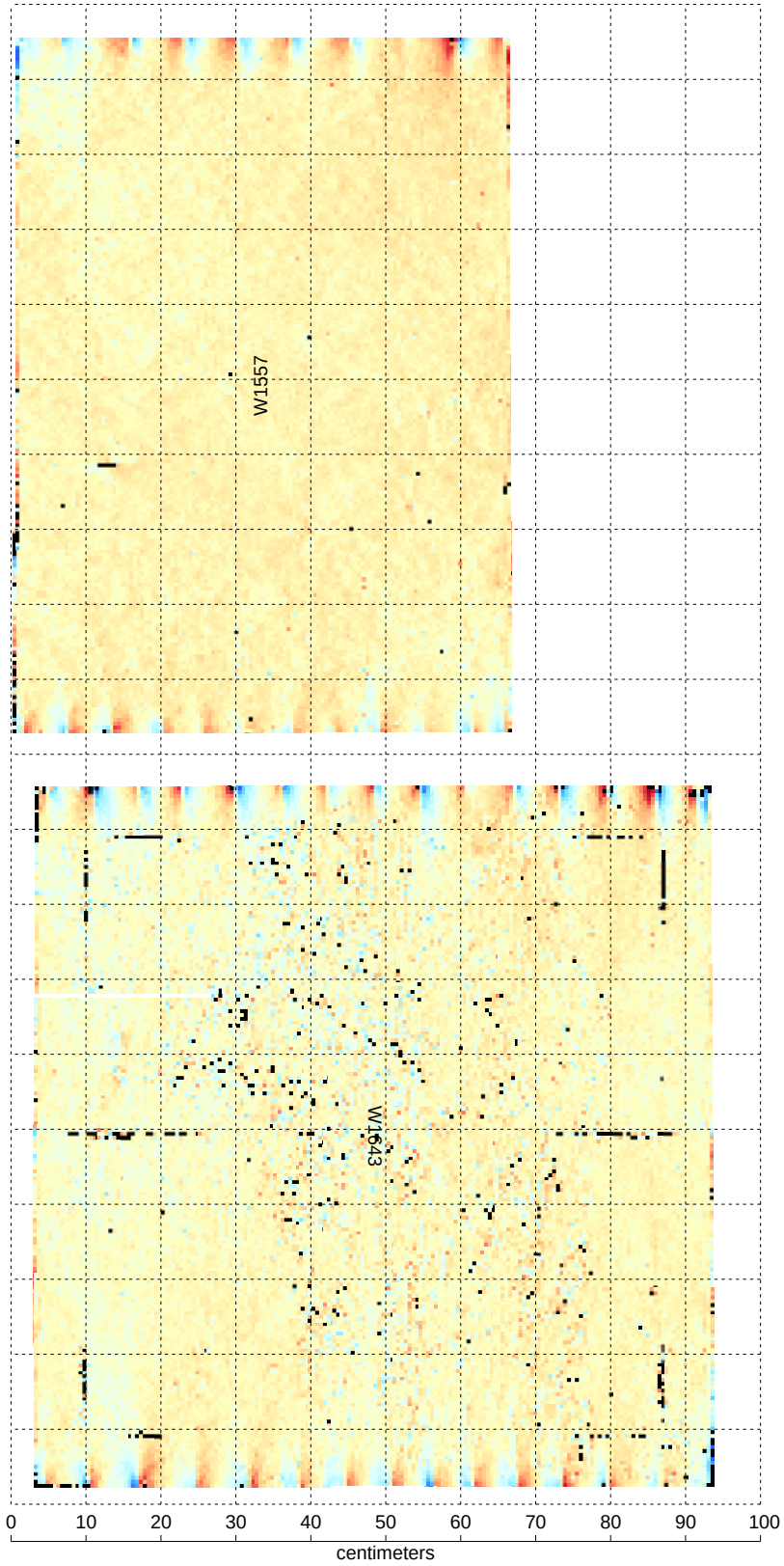

Figure 5: Weft angle maps for the paintings shown in weave match alignment. Horizontal and vertical lines are each separated by 10 cm to facilitate alignment and judging distances.