UNC 4D Lifespan Cerebellum Atlases

Version 1.0

Revision history

Version 1.0 (November 2026)	This first release provides the UNC 4D Lifespan Cerebellum Atlases, comprising a set of atlas volumes registered to the common UNC BCP space, together with usage guidance and documentation.

1. What this is

The cerebellum contains more than half of the neurons in the human brain and supports not only sensorimotor control but also cognitive, affective and neurodevelopmental functions [1]. Understanding how this system develops and ages requires comparisons across stages at which both cerebellar anatomy and magnetic resonance imaging (MRI) appearance differ markedly. Rapid postnatal expansion changes cerebellar size and shape, tissue maturation reshapes T1-weighted (T1w) and T2-weighted (T2w) contrast, and different cerebellar regions continue to change in different ways throughout childhood, adolescence and adulthood [2]. These changes make an age-appropriate anatomical reference essential for reliable spatial normalization and quantitative comparisons across individuals and cohorts.

Existing atlas resources address different parts of this problem. Cerebellum-specific atlases provide detailed structural, lobular or functional coordinate systems, and multimodal atlases add complementary microstructural information [3]. Age-resolved atlases capture early development, while pediatric and lifespan whole-brain templates cover broader age ranges [4]. However, anatomical specificity, multimodal correspondence and continuous lifespan coverage have largely been developed in separate resources. A lifespan cerebellar atlas must represent the anatomy and MRI contrast expected at each age while maintaining a coherent coordinate organization across ages, a particularly difficult balance for the thin and densely folded cerebellar folia.

To address this need, we constructed the **UNC 4D Lifespan Cerebellum Atlases**, which collectively form an age-conditioned 4D multimodal reference spanning birth to 100 years. The release provides population-representative T1w, T2w, T1w/T2w ratio, tissue segmentation and anatomical parcellation volumes at 31 representative ages. For atlas ages from birth through 6 years, the release additionally provides UNC-ELF functional parcellations. Multiscale Hessian representations preserve local folded anatomy, while population-cycle consistency guides atlas-mediated registration toward direct inter-individual correspondence. The resulting atlas provides an age-resolved multimodal coordinate system for studying cerebellar development and aging across the postnatal lifespan. The pre-generated release is distributed in a common space defined by registration to the UNC BCP 4D Infant Brain Volumetric Atlas.

2. Where to download

The pre-generated atlas package is publicly available from NITRC:

https://www.nitrc.org/projects/cbl_4d_atlas/

The atlas package is freely available for academic research. Ownership, copyright and all other rights are retained by the University of North Carolina at Chapel Hill.

3. What it includes

The release provides pre-generated cerebellar atlases at 31 time points from birth to 100 years. At each time point, the release provides T1w, T2w, T1w/T2w ratio, tissue segmentation and anatomical parcellation volumes, together with a cerebellar mask. Corresponding UNC-ELF `Net29` and `Net54` functional parcellations are also provided for atlas ages from birth through 6 years. All volumes are registered to the common UNC BCP space.

The 31 pre-generated time points (in years) are:

> 0, 0.25, 0.5, 0.75, 1, 1.5, 2, 3, 4, 5, 6, 8, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 and 100.

The following three-dimensional images are included in the release:

Product	**Filename**	**Description**
T1-weighted atlas	Age-T1w.nii.gz	T1-weighted cerebellar intensity image.
T2-weighted atlas	Age-T2w.nii.gz	T2-weighted cerebellar intensity image.
T1w/T2w ratio atlas	Age-T1w-T2w-Ratio.nii.gz	Myelin-sensitive contrast in arbitrary normalized units.
Tissue map	Age-Tissue.nii.gz	Discrete tissue segmentation: background 0, cerebrospinal fluid 1, gray matter 2 and white matter 3.
Cerebellar mask	Age-Mask.nii.gz	Binary mask defining the cerebellar atlas support.
Anatomical parcellation	Age-Anatomical-Parcellation.nii.gz	Anatomical map generated using uCereBSD[5].
29-network functional parcellation	Age-Functional-Parcellation-Net29.nii.gz	Cerebellar functional parcellation obtained by mapping the 29-network UNC-ELF solution to the age-specific atlas [6].
54-network functional parcellation	Age-Functional-Parcellation-Net54.nii.gz	Cerebellar functional parcellation obtained by mapping the 54-network UNC-ELF solution to the age-specific atlas [6].

These files are in the same image space as the UNC BCP 4D Infant Brain Volumetric Atlas[4]. Figure 1 provides a visual overview of the released structural modalities at 14 representative ages across the lifespan.

Directory structure

```
|-- UNC_4D_Lifespan_Cerebellum_Atlases_0-6Year/
|   |-- {00,03,06,09,12,18,24,36,48,60,72}Month/
|       |-- Age-T1w.nii.gz
|       |-- Age-T2w.nii.gz
|       |-- Age-T1w-T2w-Ratio.nii.gz
```

```
|       |-- Age-Tissue.nii.gz
|       |-- Age-Mask.nii.gz
|       |-- Age-Anatomical-Parcellation.nii.gz
|       |-- Age-Functional-Parcellation-Net29.nii.gz
|       |-- Age-Functional-Parcellation-Net54.nii.gz
|
|-- UNC_4D_Lifespan_Cerebellum_Atlases_8-50Year/
|   |-- {08,10,15,20,25,30,35,40,45,50}Year/
|       |-- Age-T1w.nii.gz
|       |-- Age-T2w.nii.gz
|       |-- Age-T1w-T2w-Ratio.nii.gz
|       |-- Age-Tissue.nii.gz
|       |-- Age-Mask.nii.gz
|       |-- Age-Anatomical-Parcellation.nii.gz
|
|-- UNC_4D_Lifespan_Cerebellum_Atlases_55-100Year/
|   |-- {055,060,065,070,075,080,085,090,095,100}Year/
|       |-- Age-T1w.nii.gz
|       |-- Age-T2w.nii.gz
|       |-- Age-T1w-T2w-Ratio.nii.gz
|       |-- Age-Tissue.nii.gz
|       |-- Age-Mask.nii.gz
|       |-- Age-Anatomical-Parcellation.nii.gz
|
|-- LUT/
|   |-- Anatomical-Parcellation.LUT
|   |-- Functional-Parcellation-Net29.LUT
|   |-- Functional-Parcellation-Net54.LUT
|
|-- Introduction_for_UNC_4D_Lifespan_Cerebellum_Atlases.pdf
```

4. How to use

Typical uses include age-matched spatial normalization, atlas-guided tissue analysis, population comparison and initialization of cerebellar processing pipelines.

First, choose the age-matched reference. All pre-generated atlases are already in the common UNC BCP space. After selecting the age-matched atlas, use subject-to-atlas registration to place a participant in this common space, or use atlas-to-subject registration to transfer atlas images and labels to the participant's native space. The recommended workflow is:

1. **Prepare the subject image.** Perform basic MRI quality control, correct gross orientation errors and extract the cerebellum. The development pipeline used uCereBSD for cerebellar extraction and tissue segmentation [5].
2. **Select a matching age.** Select the nearest age-matched reference from the 31 pre-generated atlases spanning birth to 100 years.
3. **Estimate the transformation.** Register the subject and the age-matched atlas using ANTs, with rigid initialization followed by symmetric normalization (SyN) deformable registration [7].
4. **Transform derived maps.** Apply the estimated transformations to the corresponding intensity images, tissue maps and parcellation maps.

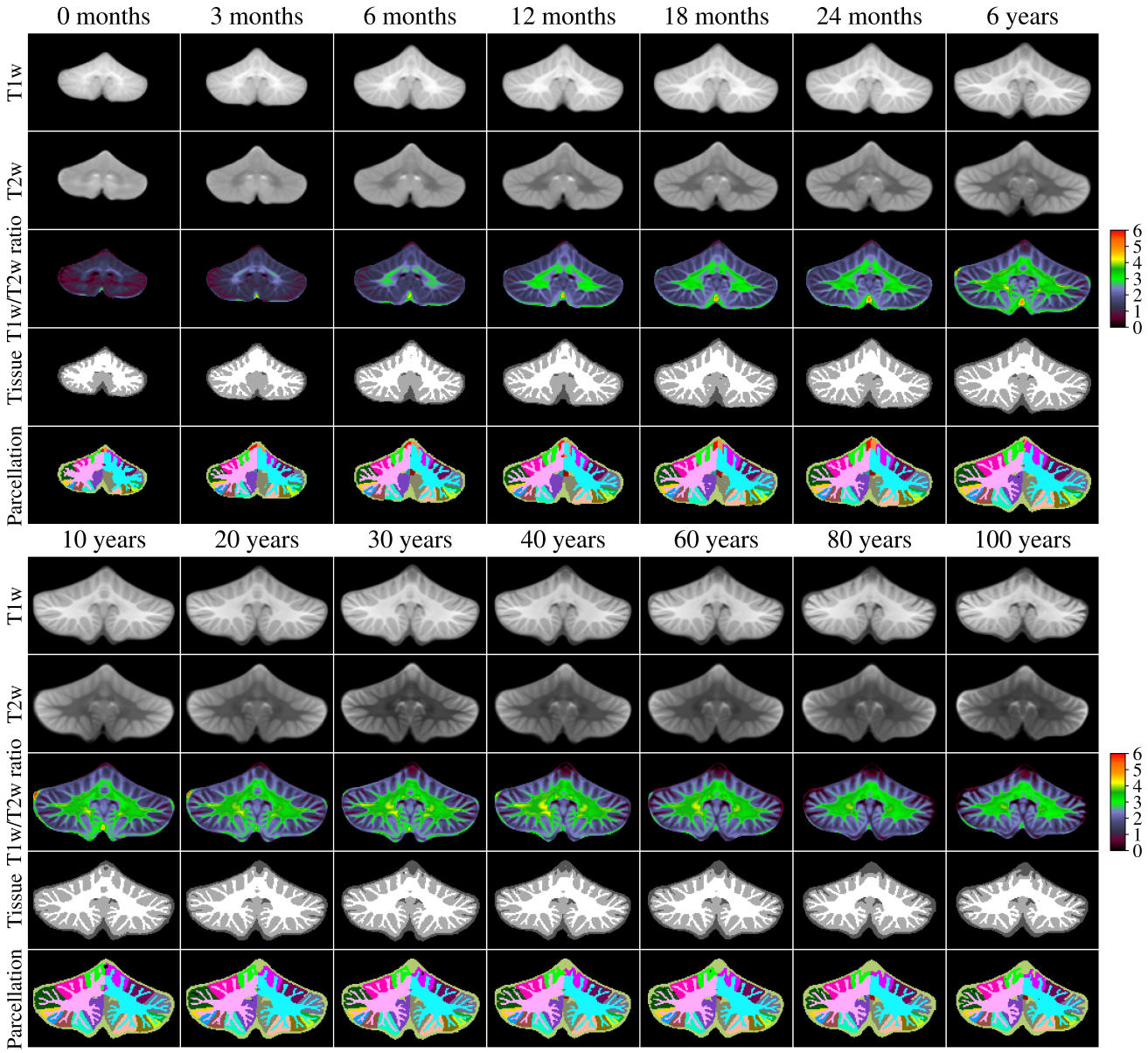


Figure 1: Multimodal cerebellar atlases across the lifespan. Representative coronal sections are shown at 14 ages from birth to 100 years. Rows show T1-weighted, T2-weighted, T1w/T2w ratio, tissue segmentation and anatomical parcellation maps. All rows at a given age show the same anatomical plane and location.

5. How it was constructed

The framework jointly learns an age-conditioned multimodal atlas generator and a shared diffeomorphic registration network. Given a target age, the generator adds an age-conditioned residual to an initial population atlas to produce four channels: T1w, T2w, T1w/T2w ratio and tissue segmentation.

Two design elements address the difficulty of preserving thin, densely folded cerebellar folia:

- **Multiscale Hessian representation.** Hessian features emphasize local ridge- and sheet-like structures. The multiscale Hessian representation is computed on the fly from the generated T1w atlas, allowing structural supervision to propagate directly to the atlas appearance.
- **Population-cycle consistency.** For two participants close in age, the loss encourages the indirect transformation through the relatively blurred atlas to agree with the transformation estimated directly between their anatomically detailed images, thereby reducing correspondence-induced blurring.

The objective combines multimodal intensity similarity, tissue overlap, Hessian similarity, deformation regularization, population centering and population-cycle consistency.

The functional parcellation atlases were constructed by mapping the UNC-ELF 29-network and 54-network functional parcellations to the corresponding age-specific cerebellar atlases for ages from birth through 6 years [6].

6. Acknowledgments

We thank the participants and investigators of BCP (https://nda.nih.gov/edit_collection.html?id=2848), HCPD (https://nda.nih.gov/edit_collection.html?id=2846), HCP (https://humanconnectome.org/study/hcp-young-adult/data-releases) and HCPA (https://nda.nih.gov/edit_collection.html?id=2847) for making their data available. This release also builds on parcellation, registration, segmentation and visualization resources developed by collaborators and the broader neuroimaging community.

7. How to cite

Until a final journal citation and DOI are available, please cite the companion manuscript as:

> Q. Sha, J. Liu, D. Hu, J. Cheng, Y. Sun, Z. Wu, W. Lin, L. Wang and G. Li. "A multimodal atlas of the human cerebellum from birth to 100 years." Manuscript in preparation, 2026.

8. Contact

For questions about the atlas or release files, or to report bugs, please contact:

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References

[1] Bangjie Wang, Amanda LeBel, and Anila M D'Mello. Ignoring the cerebellum is hindering progress in neuroscience. *Trends in Cognitive Sciences*, 29(4):318–330, 2025. doi: 10.1016/j.tics.2025.01.004.

[2] Ya Wang, Liangjun Chen, Zhengwang Wu, Tengfei Li, Yue Sun, Jiale Cheng, Hongtu Zhu, Weili Lin, Li Wang, Wenhua Huang, et al. Longitudinal development of the cerebellum in human infants during the first 800 days. *Cell Reports*, 42(4): 112281, 2023. doi: 10.1016/j.celrep.2023.112281.

[3] Wenjiao Lyu, Ye Wu, Khoi Minh Huynh, Sahar Ahmad, and Pew-Thian Yap. A multimodal submillimeter MRI atlas of the human cerebellum. *Scientific Reports*, 14:5622, 2024. doi: 10.1038/s41598-024-55412-y.

[4] Liangjun Chen, Zhengwang Wu, Dan Hu, Ya Wang, Fenqiang Zhao, Tao Zhong, Weili Lin, Li Wang, and Gang Li. A 4D infant brain volumetric atlas based on the UNC/UMN baby connectome project cohort. *NeuroImage*, 253:119097, 2022. doi: 10.1016/j.neuroimage.2022.119097.

[5] uCereBSD: Unified cerebellar structural delineation. https://liujm.notion.site/uCereBSD-Unified-Cerebellar-Structural-Delineation-3ce31890f8a780acbd6be2fd665f26a2, 2026. Accessed 8 September 2026.

[6] D. Hu, J. Cheng, K. Han, Z. Wu, W. Yin, Y. Sun, J. Liu, S.-C. Hung, L. Wang, J. R. Cohen, W. Lin, and G. Li. Division-specific organization of a shared functional scaffold in the early-life human brain. *bioRxiv*, 2026. doi: 10.64898/2026.09.14.751555. URL https://doi.org/10.64898/2026.09.14.751555.

[7] Brian B Avants, Nicholas J Tustison, Gang Song, Philip A Cook, Arno Klein, and James C Gee. A reproducible evaluation of ANTs similarity metric performance in brain image registration. *NeuroImage*, 54(3):2033–2044, 2011. doi: 10.1016/j.neuroimage.2010.09.025.