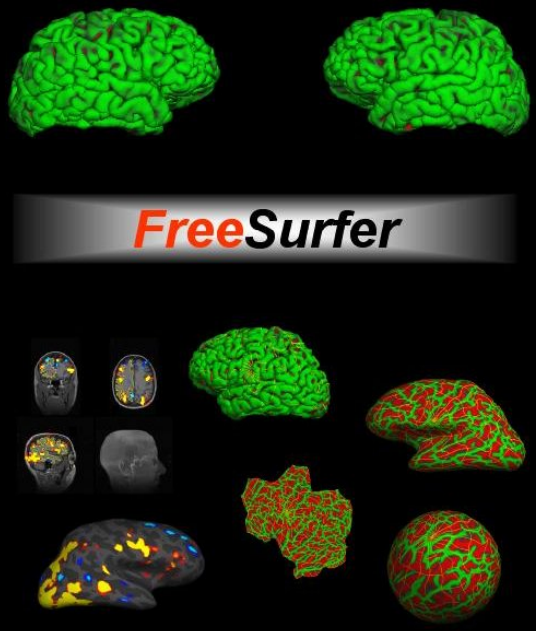
FreeSurfer: Failure Modes and Interventions

surfer.nmr.mgh.harvard.edu



Troubleshooting

- Segmentation Errors.
- Intensity Normalization.
- Pial Surface misplacement.
- Skull Strip Errors (none on our test set).

What are the Common Interventions?

- Manually edit the wm.mgz to change incorrectly labeled voxels (only for small errors).
- Manually edit the brainmask.mgz to erase dura/vasculature.
- Adjust watershed parameters to fix large-scale skull-strip errors.
- Manually erase/clone regions of skull strip failure.
- Control Points – add locations that are in the interior of the white matter and <110 to bring regional wm intensity up.
- Use tkregister2 to fix incorrect talairach.xfm

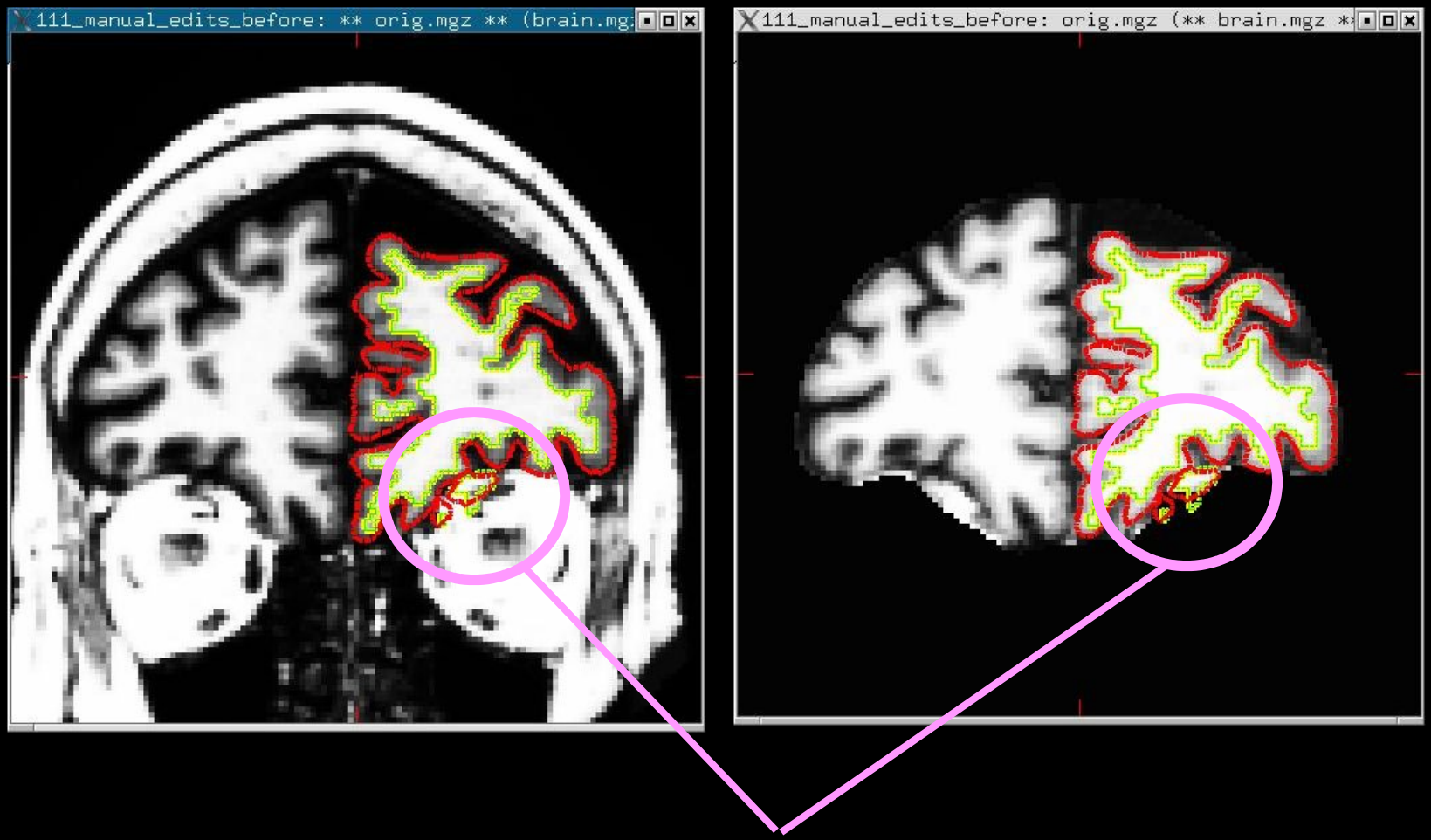
Troubleshooting – Common Cases

(≈98% of surface accurate in about 98% of cases for good data [1])

- Symptom: white matter not accurate in wm.mgz
- Interventions
  - add control points (if wm << 110).
  - Expert opts to set intensity thresholds in segmentation (almost never).
  - Manually erase/draw wm in wm.mgz
- Symptom: skull strip not accurate
- Interventions
  - Adjust mri_watershed parameters
  - Manually erase skull/clone T1.mgz to recover brain
- Symptom: surfaces are not accurate.
- Interventions:
  - Add control points (if white matter << 110).
  - Erase dura/blood vessels
  - Check topology on ?h.inflated.nofix (if ?h.orig surface doesn't follow wm.mgz)

[1] Salat, D, 2009. Personal Communication.

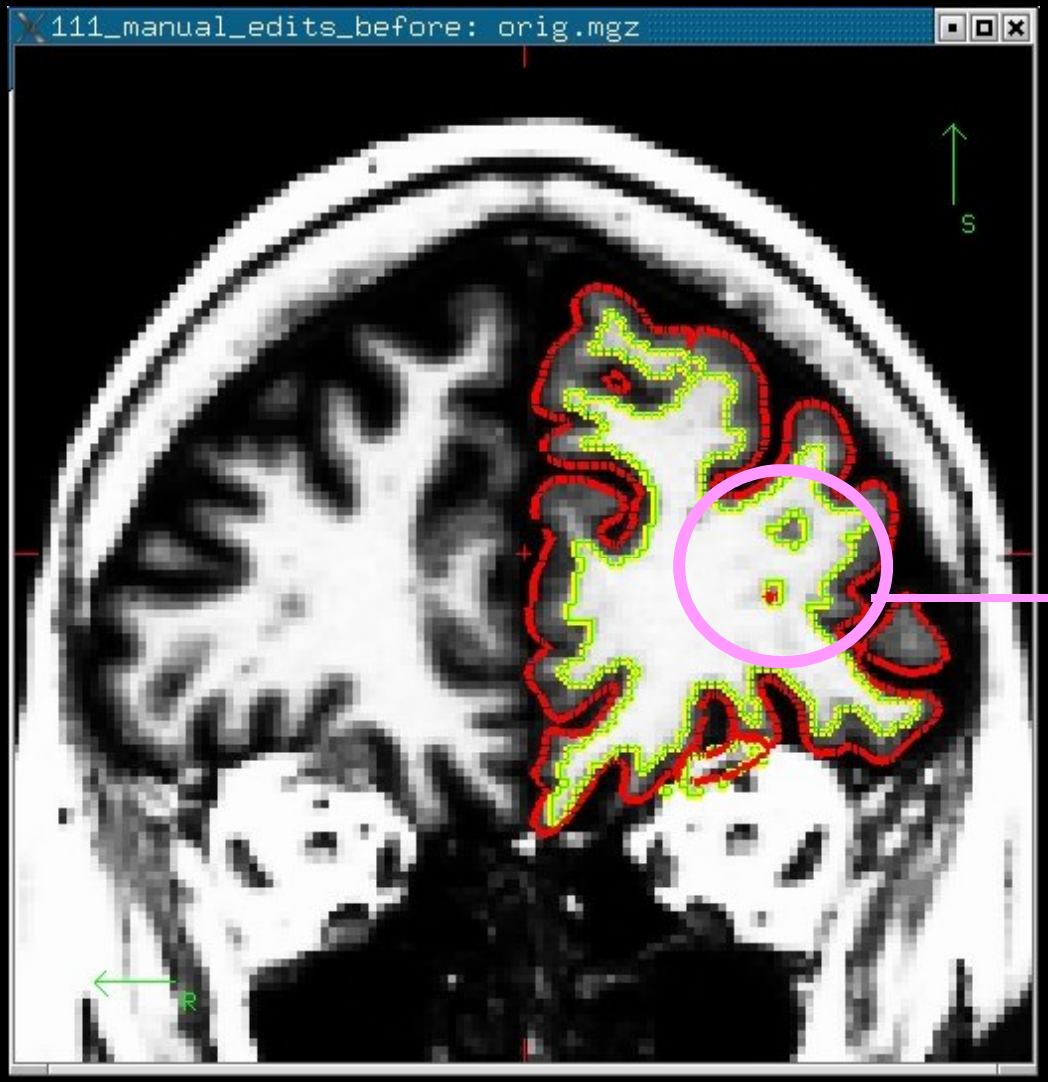
Troubleshooting: Segmentation Error



Eye Socket classified as WM due to Skull Strip Failure.
Erase in wm.mgz then run:

recon-all -s <subject> -autorecon2-wm -autorecon3

Troubleshooting: Segmentation Error

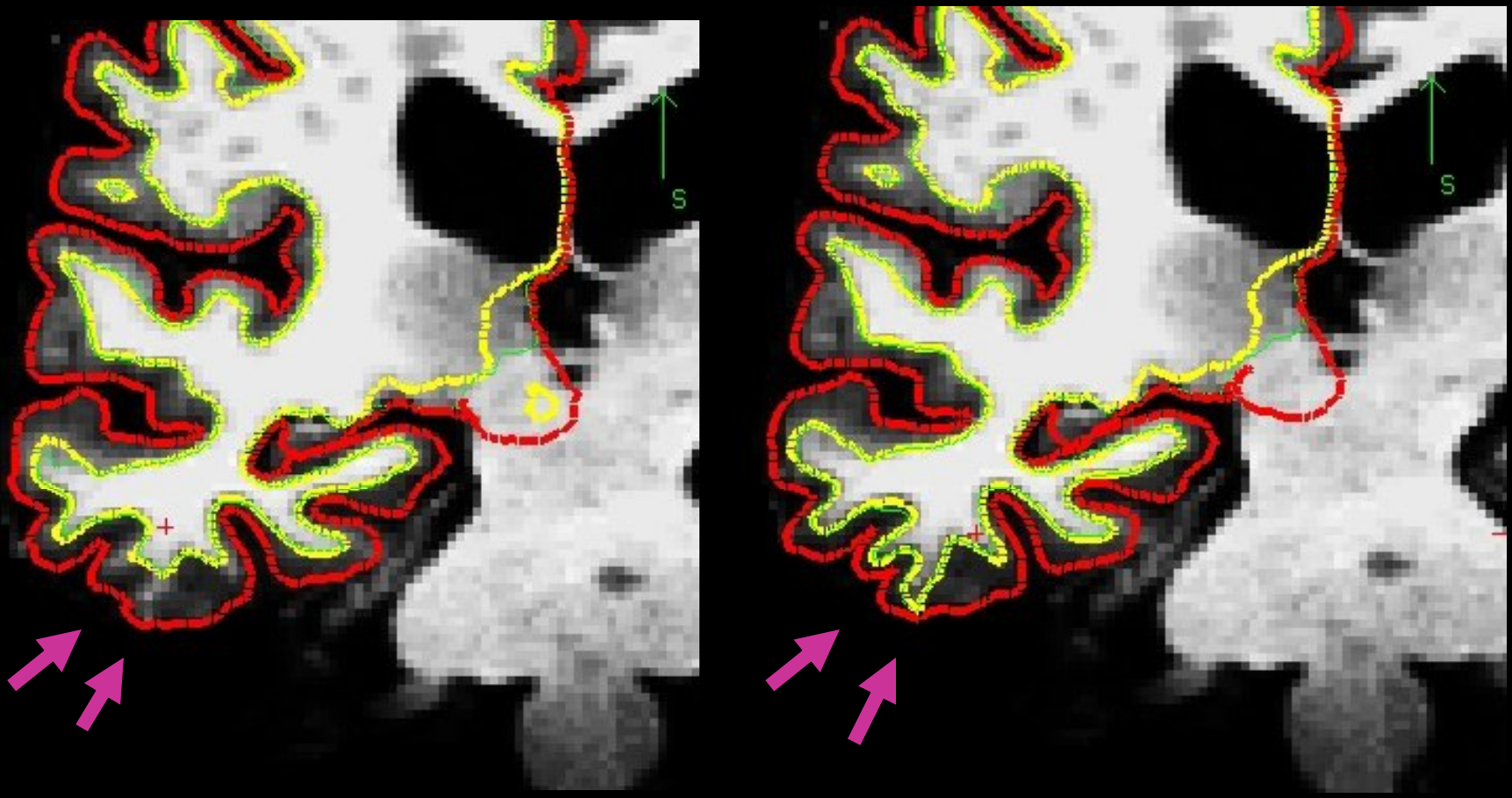


"Hypo-Intensities"
White Matter Lesions
Misclassified as gray matter

Fill in wm.mgz then run:

recon-all -s <subject> -autorecon2-wm -autorecon3

Troubleshooting: Intensity Normalization

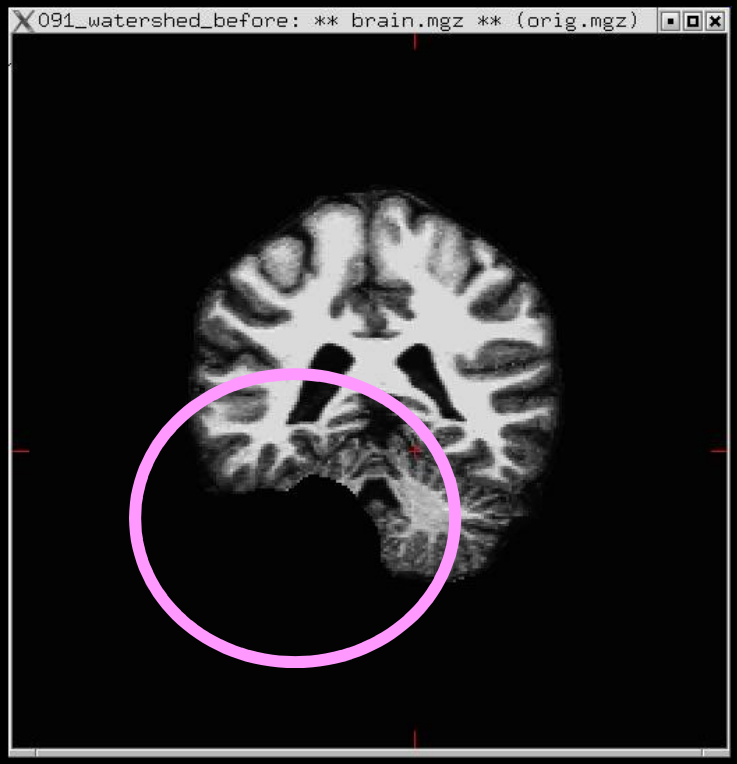


Intensity Normalization Failure. Most WM in T1 volume (T1.mgz) should be close to 110. Can fix by editing wm.mgz or adding **"Control Points"**. Beware partial voluming!

recon-all -s <subject> -autorecon2-cp -autorecon3

Troubleshooting: Skull Strip (very rare now)

orig.mgz



brainmask.mgz

Use “clone” tool to manually correct, or adjust watershed parameters and run (default wsthresh is 25, higher means strip less):

recon-all -skullstrip -wsthresh 35 -clean-bm -no-wsgcaatlas -s <subj>

recon-all -s <subject> -autorecon2 -autorecon3

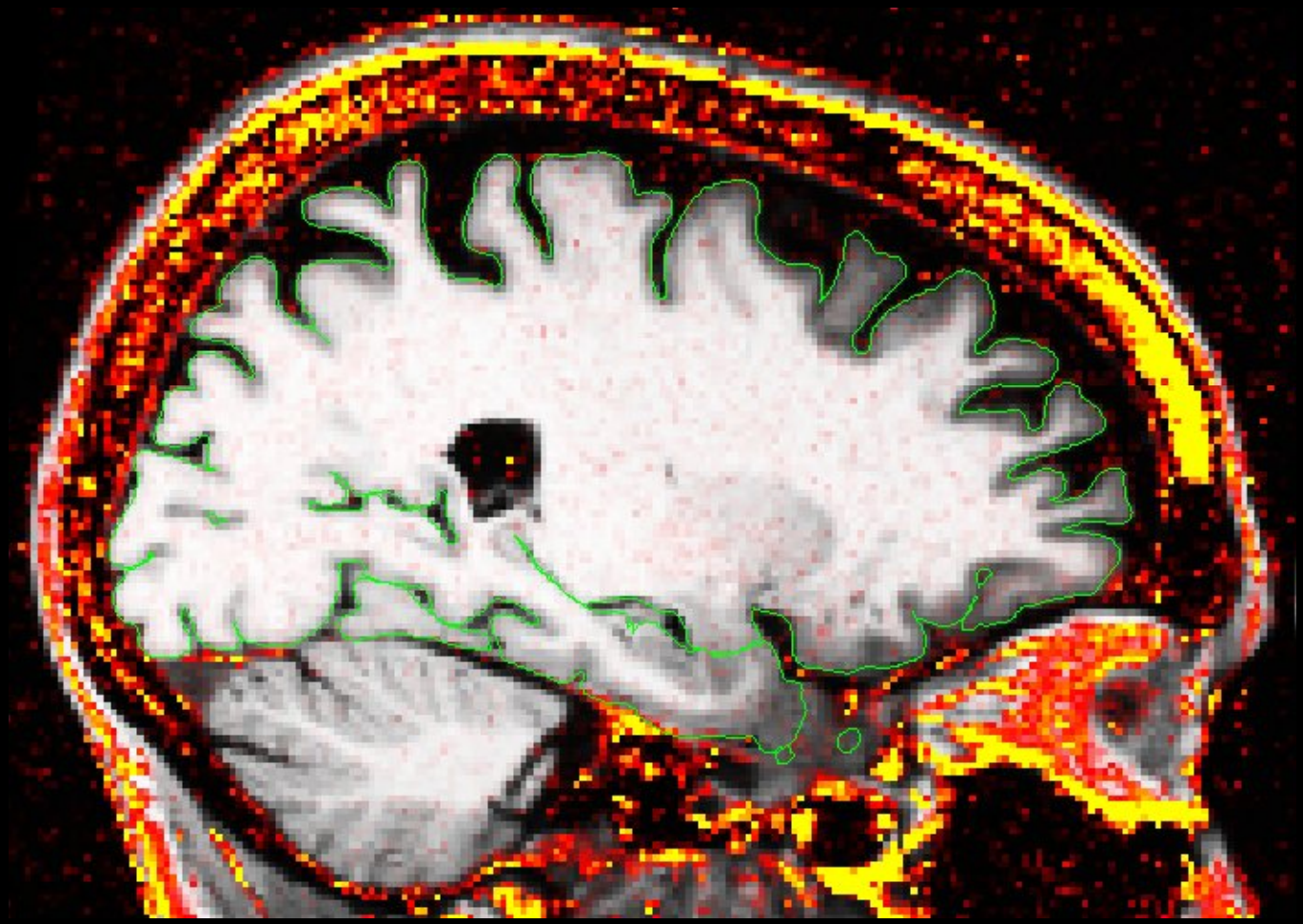
Troubleshooting: Skull Strip/Pial Surface Error

Dura or Blood Vessel
White/Gray OK, but
Pial Inaccurate

Dura and GM have extremely similar intensity characteristics on most T1-weighted sequences (but different T2*!). Typical fix: edit the brainmask.mgz to erase dura/blood vessels, and run:

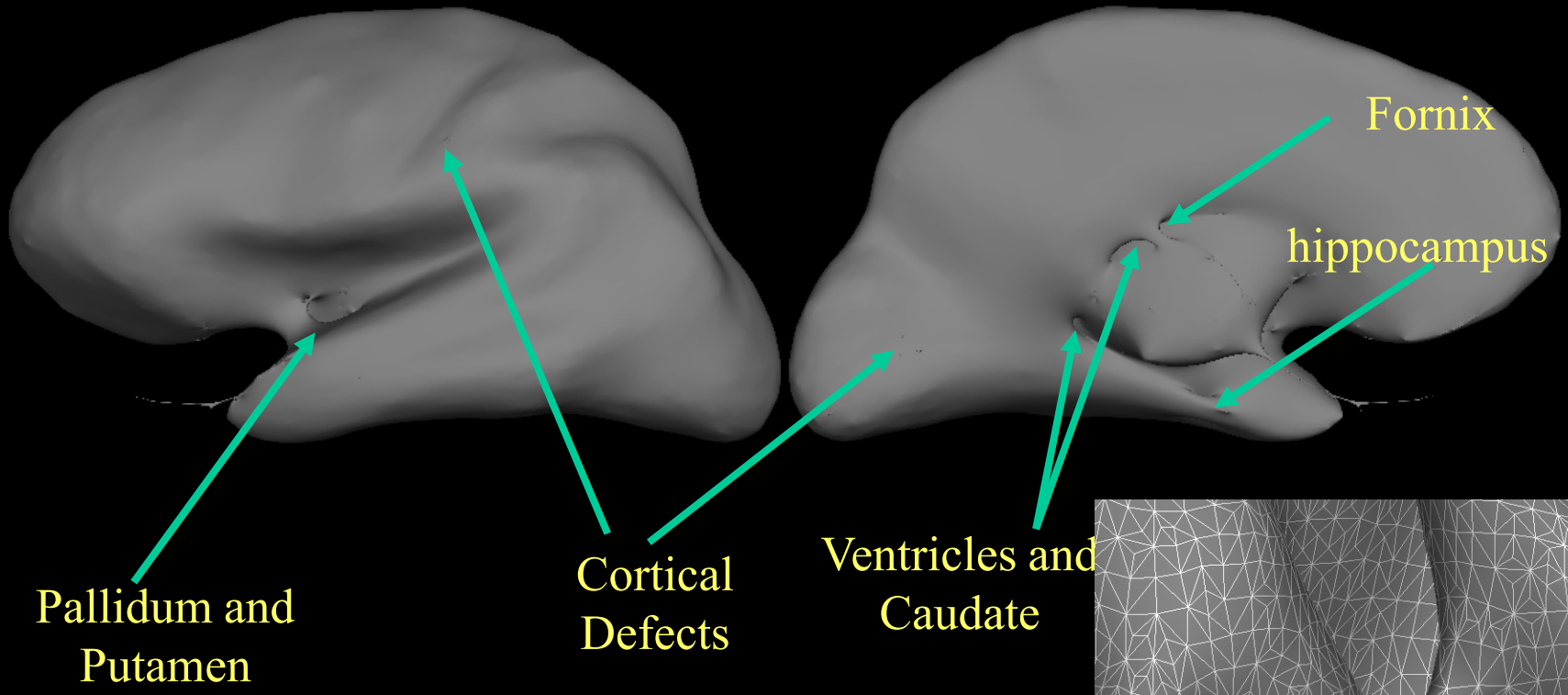
recon-all -s <subject> -autorecon2-pial -autorecon3

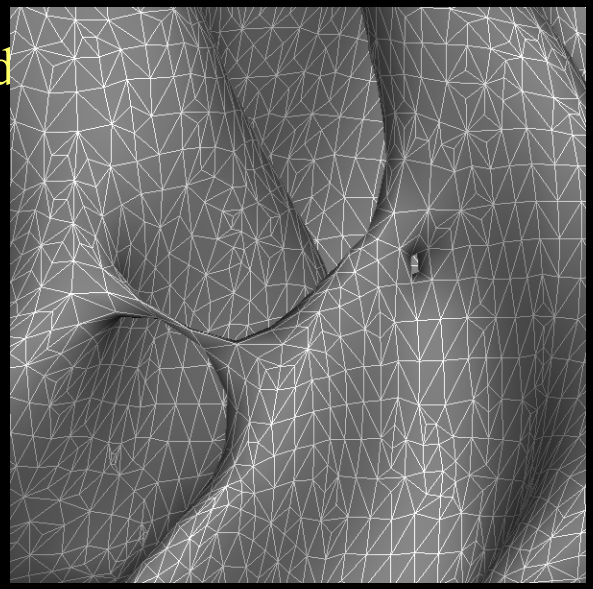
New Morphometry Protocol: Identifying Dura with Multi-echo MP-RAGE



*joint work with Andre van der Kouwe

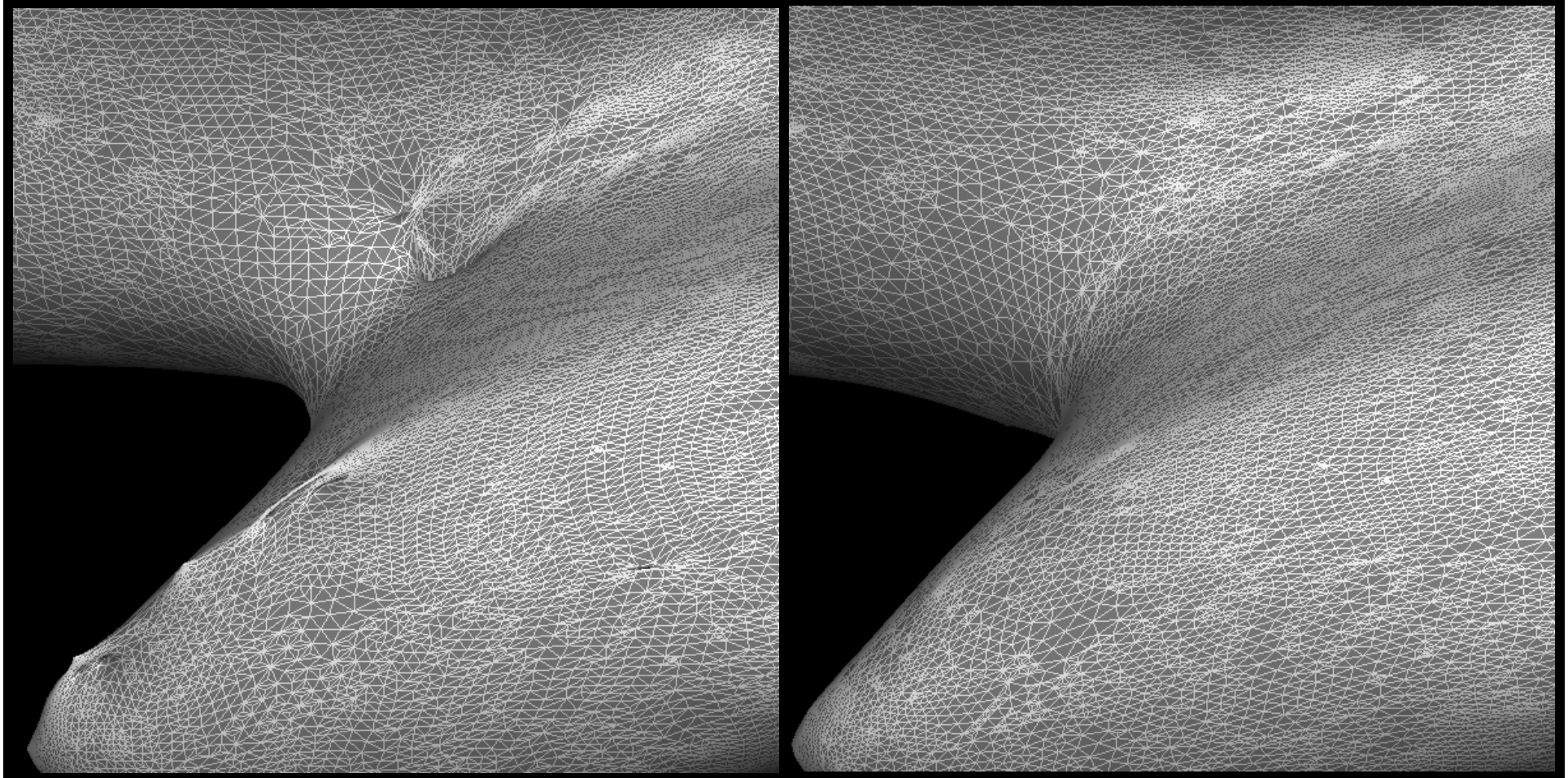
Troubleshooting: Topological Defects





- Holes
- Handles
- Automatically Fixed

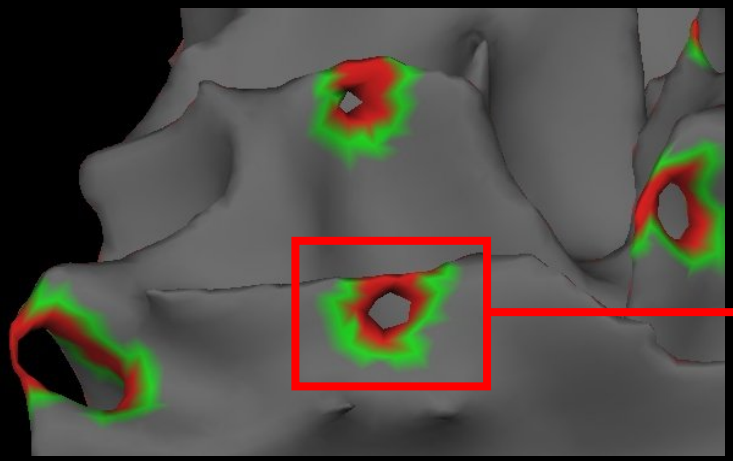
Topology Correction



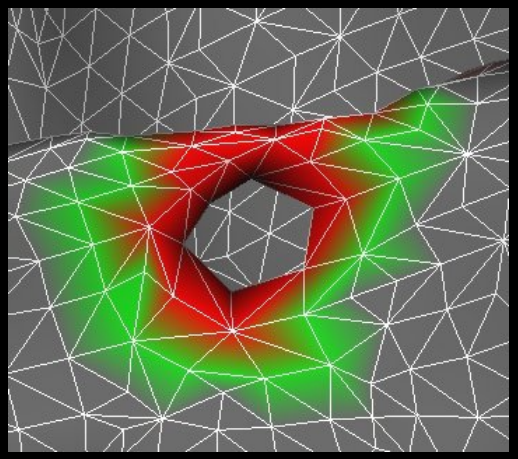
BEFORE

AFTER

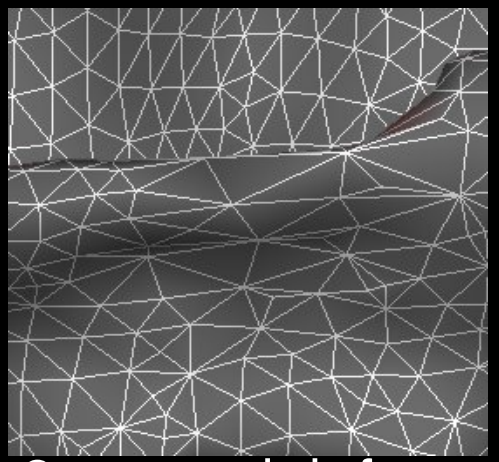
Automatic Defect Correction



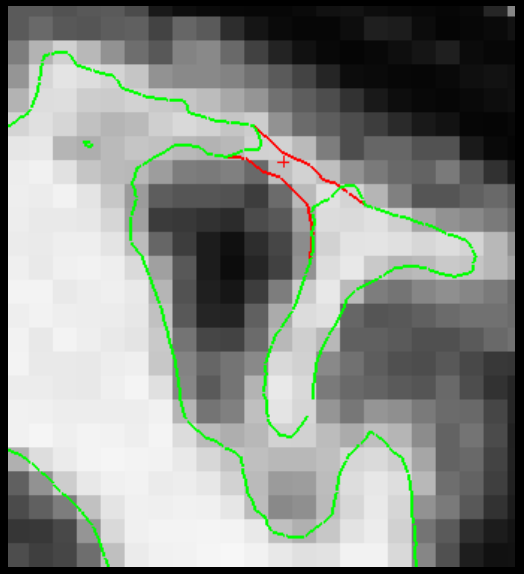
Initial cortical surface



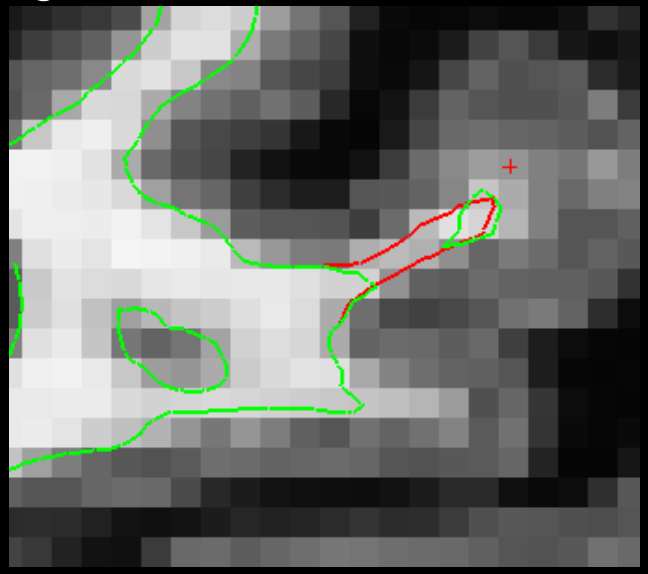
Topological defect



Corrected defect

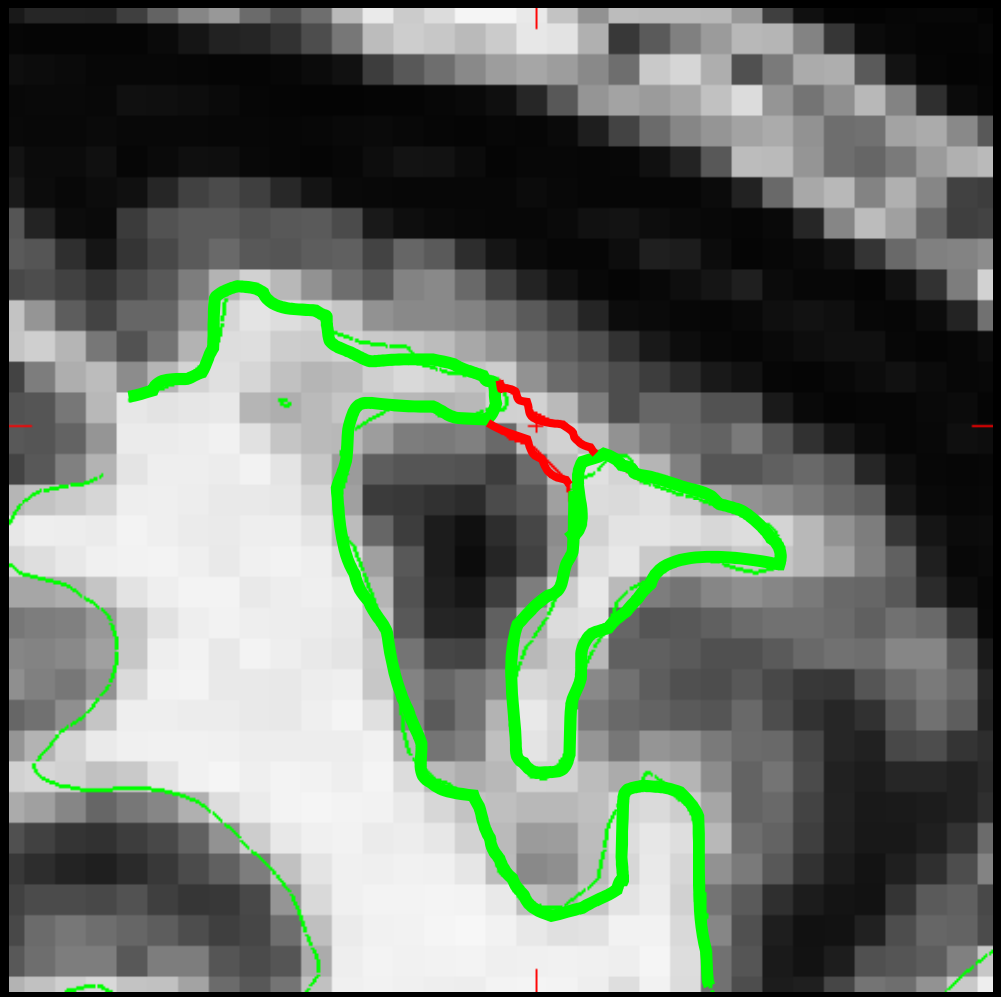


Sagittal view



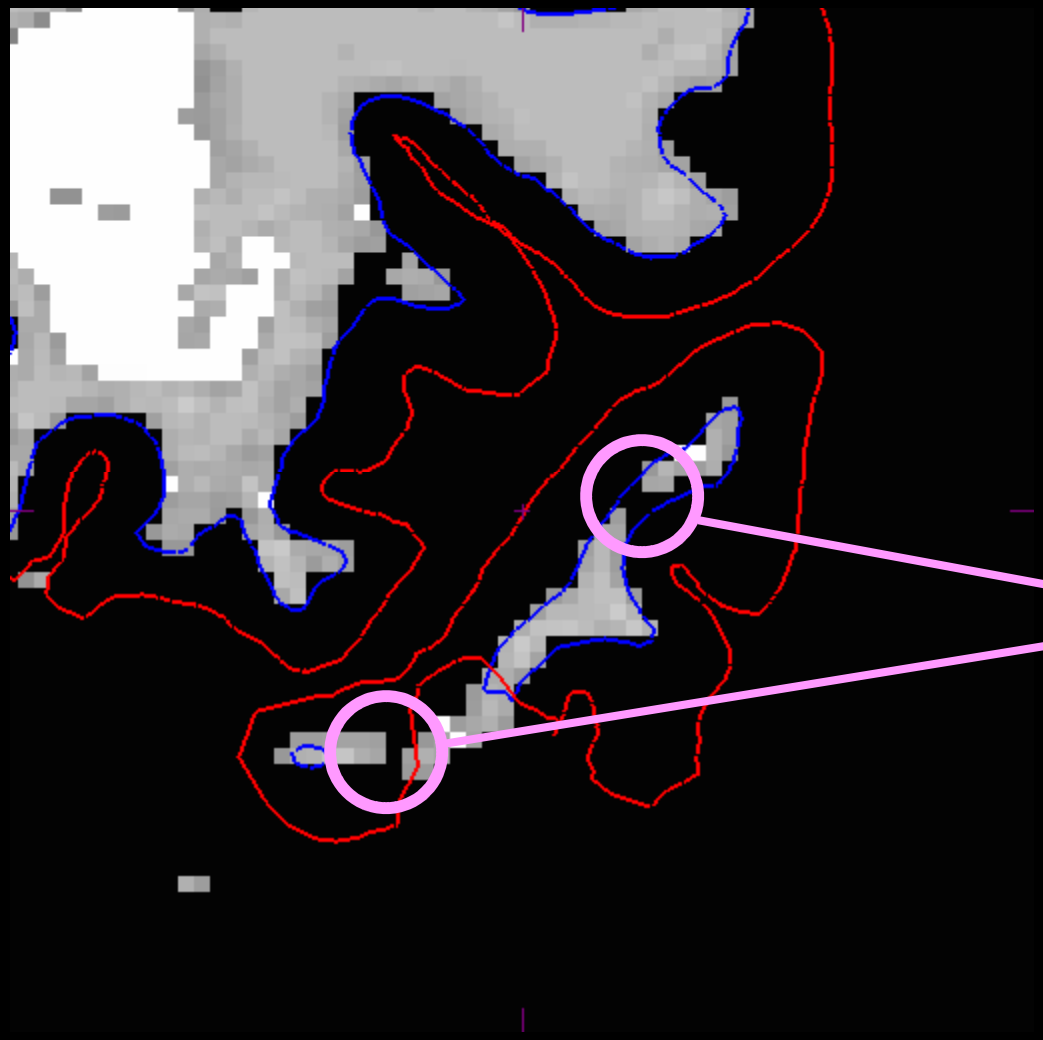
Coronal view

Automatic Defect Correction



Difference between uncorrected (green) and corrected (red)

Troubleshooting: Topology Fixer Error



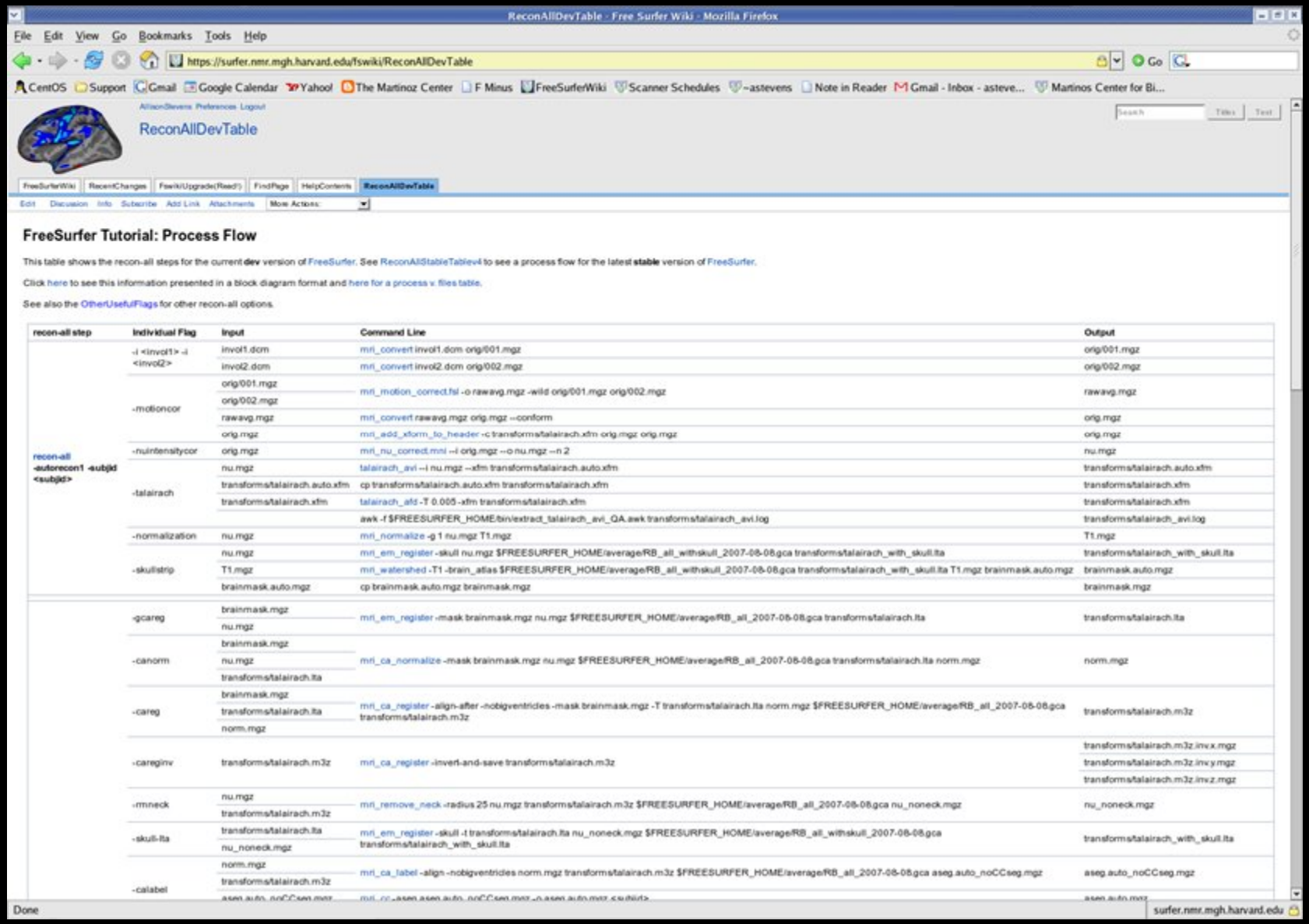
White Matter "disconnects"

orig.nofix will be accurate

Troubleshooting – Advice

- Always look at the data in multiple views and scroll back and forth a few slices – 3D structure is difficult to discern!
- If large regions of white matter are significantly darker than 110 (the target white matter intensity for normalization) then try adding control points, but make sure they are in the interior of the white matter.
- If the ?h.orig surface misses white matter that is accurately labeled in the wm.mgz or extends into regions where there is no wm in the wm.mgz, then there is an incorrectly fixed topological defect.
- Even one or two missing voxels can cause large-scale defects, so very minor editing (e.g. filling in white matter voxels that are holes, or erasing handles) may fix the problem.
- Don't edit too much! This will reduce reliability and is almost never needed. Usually this means you need to start over as you've done something wrong (e.g. put control points in the wrong place).

Processing Stream Order



recon-all step	Individual Flag	Input	Command Line	Output
recon-all -autorecon1 -subjid <subjid>	-i <invol1> -i <invol2>	invol1.dcm	mri_convert invol1.dcm orig/001.mgz	orig/001.mgz
		invol2.dcm	mri_convert invol2.dcm orig/002.mgz	orig/002.mgz
	-motioncor	orig/001.mgz orig/002.mgz	mri_motion_correct.fsl -o rawavg.mgz -wild orig/001.mgz orig/002.mgz	rawavg.mgz
		rawavg.mgz	mri_convert rawavg.mgz orig.mgz --conform	orig.mgz
		orig.mgz	mri_add_xform_to_header -c transforms/talairach.xfm orig.mgz orig.mgz	orig.mgz
	-nuintensitycor	orig.mgz	mri_nu_correct.mni --i orig.mgz --o nu.mgz --n 2	nu.mgz
	-talairach	nu.mgz	talairach_avi --i nu.mgz --xfm transforms/talairach.auto.xfm	transforms/talairach.auto.xfm
		transforms/talairach.auto.xfm	cp transforms/talairach.auto.xfm transforms/talairach.xfm	transforms/talairach.xfm
		transforms/talairach.xfm	talairach_afd -T 0.005 -xfm transforms/talairach.xfm	transforms/talairach.xfm
			awk -f $FREESURFER_HOME/bin/extract_talairach_avi_QA.awk transforms/talairach_avi.log	transforms/talairach_avi.log
	-normalization	nu.mgz	mri_normalize -g 1 nu.mgz T1.mgz	T1.mgz
	-skullstrip	nu.mgz	mri_em_register -skull nu.mgz $FREESURFER_HOME/average/RB_all_withskull_2007-08-08.gca transforms/talairach_with_skull.lta	transforms/talairach_with_skull.lta
		T1.mgz	mri_watershed -T1 -brain_atlas $FREESURFER_HOME/average/RB_all_withskull_2007-08-08.gca transforms/talairach_with_skull.lta T1.mgz brainmask.auto.mgz	brainmask.auto.mgz
		brainmask.auto.mgz	cp brainmask.auto.mgz brainmask.mgz	brainmask.mgz
	-gcareg	brainmask.mgz nu.mgz	mri_em_register -mask brainmask.mgz nu.mgz $FREESURFER_HOME/average/RB_all_2007-08-08.gca transforms/talairach.lta	transforms/talairach.lta
	-canorm	brainmask.mgz nu.mgz transforms/talairach.lta	mri_ca_normalize -mask brainmask.mgz nu.mgz $FREESURFER_HOME/average/RB_all_2007-08-08.gca transforms/talairach.lta norm.mgz	norm.mgz
	-careg	brainmask.mgz transforms/talairach.lta norm.mgz	mri_ca_register -align-after -nobigventricles -mask brainmask.mgz -T transforms/talairach.lta norm.mgz $FREESURFER_HOME/average/RB_all_2007-08-08.gca transforms/talairach.m3z	transforms/talairach.m3z
	-careginv	transforms/talairach.m3z	mri_ca_register -invert-and-save transforms/talairach.m3z	transforms/talairach.m3z.inv.x.mgz transforms/talairach.m3z.inv.y.mgz transforms/talairach.m3z.inv.z.mgz
	-rmneck	nu.mgz transforms/talairach.m3z	mri_remove_neck -radius 25 nu.mgz transforms/talairach.m3z $FREESURFER_HOME/average/RB_all_2007-08-08.gca nu_noneck.mgz	nu_noneck.mgz
	-skull-lta	transforms/talairach.lta nu_noneck.mgz	mri_em_register -skull -t transforms/talairach.lta nu_noneck.mgz $FREESURFER_HOME/average/RB_all_withskull_2007-08-08.gca transforms/talairach_with_skull.lta	transforms/talairach_with_skull.lta
	-calabel	norm.mgz transforms/talairach.m3z	mri_ca_label -align -nobigventricles norm.mgz transforms/talairach.m3z $FREESURFER_HOME/average/RB_all_2007-08-08.gca aseg.auto_noCCseg.mgz	aseg.auto_noCCseg.mgz