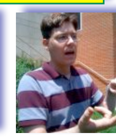
Instant Analyses in AFNI and SUMA: Clusters and Correlations

Data for this presentation:
AFNI_data5/ directory

All data herein from Alex Martin, *et al.* [NIMH IRP]

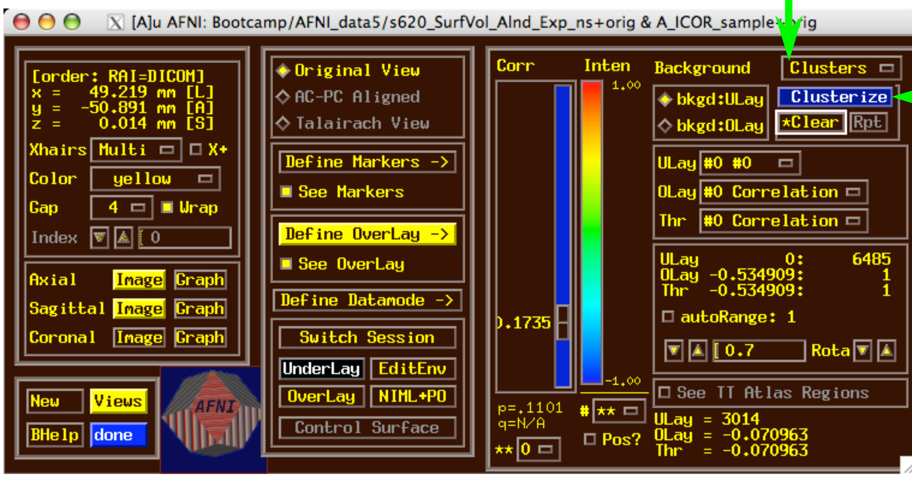


AFNI! "Insta" Functions

- 3 new capabilities added to the interactive AFNI
- Each one: compute new dataset volumes **insta**ntly to replace the Overlay volume for image viewing
- **Clusters** = interactive clustering
  - remove clusters below a user-chosen size
  - display a table of clusters
- **InstaCorr** = interactive exploration of inter-voxel time series correlation
  - choose a seed voxel and see correlation map
  - SUMA version also exists
- **InstaCalc** = interactive version of `3dcalc`
  - e.g., display ratio of 2 datasets

AFNI! Clusters: Setup

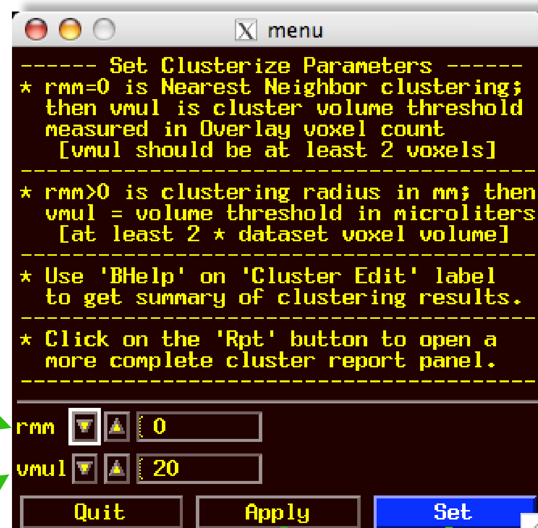
- Open **Define Overlay**, choose **Clusters** from menu in top right corner



- Then press **Clusterize** to get the clusters control menu

Clusters Control Menu

Operates on user's chosen Overlay dataset at the user's threshold;
Next slide example: **AFNI_ICOR_sample**



Default: NN clustering

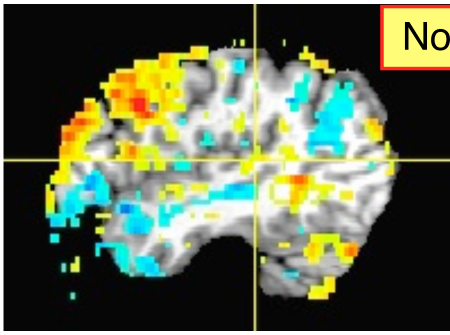
Default: 20 voxel minimum cluster size

Clustering is done in 3D

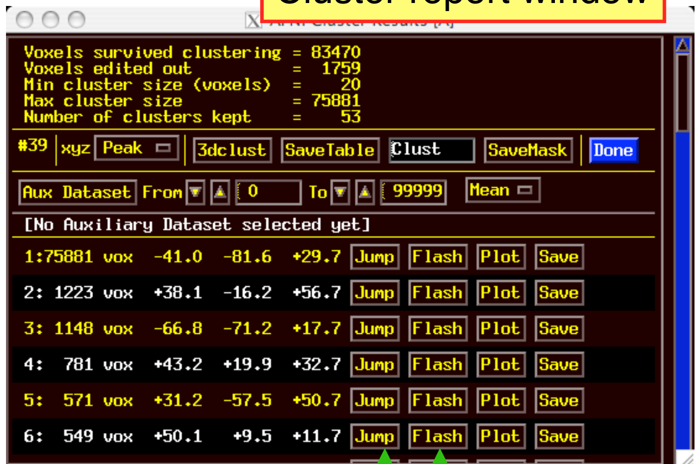
Press one of these buttons to create clusterized volume for display as new Overlay

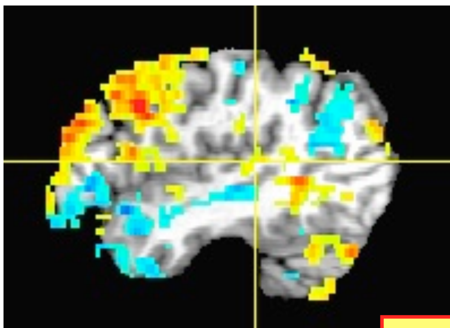
Clusters Results

No clustering



Cluster report window

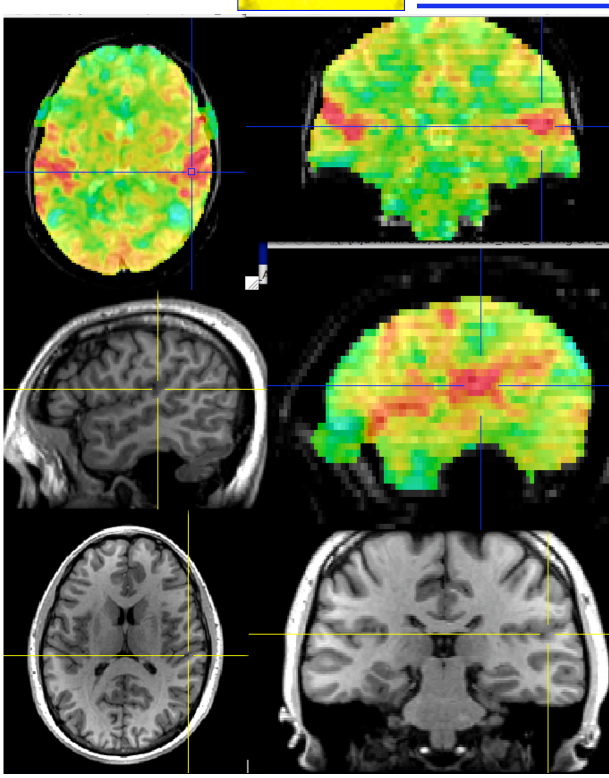




Jump: crosshairs move
Flash: colors on & off

With clustering

AFNI! InstaCorr



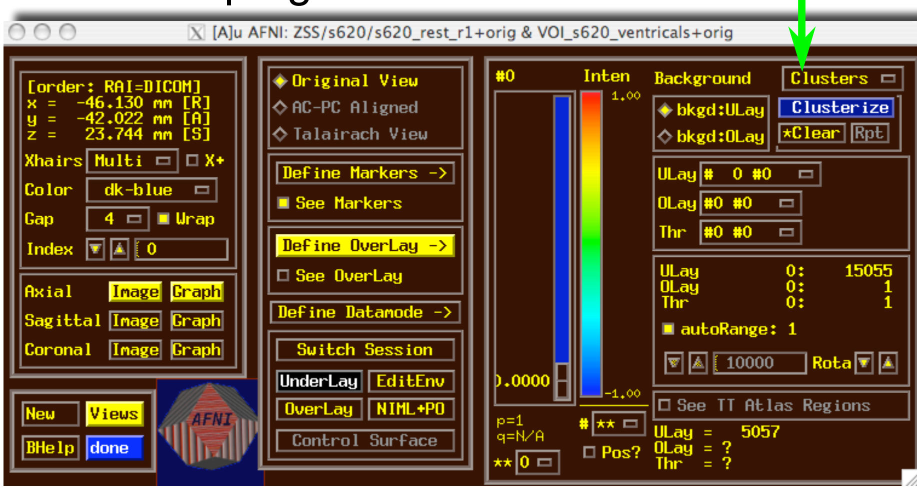
- On-the-fly **instantaneous correlation** map of resting state data with interactively selected seed voxel
- **Setup phase**: prepares data for correlations (several-to-10+ seconds)
- **Correlation phase**: you select seed voxel, correlation map appears by ***magic***

InstaCorr: Outline of 2 Phases

- **Setup phase**:
  - Masking: user-selected *or* Automask
  - Bandpass and other filtering of voxel time series
  - Blurring inside mask = the slowest part
- **Correlation phase**:
  - Correlate selected seed voxel time series with all other prepared voxel time series
  - Make new dataset, if needed, to store results
  - Save seed time series for graphing
  - Redisplay color overlay
  - Optional: compute FDR curve for correlations
    - Calculation is slow, so FDR is not turned on by default

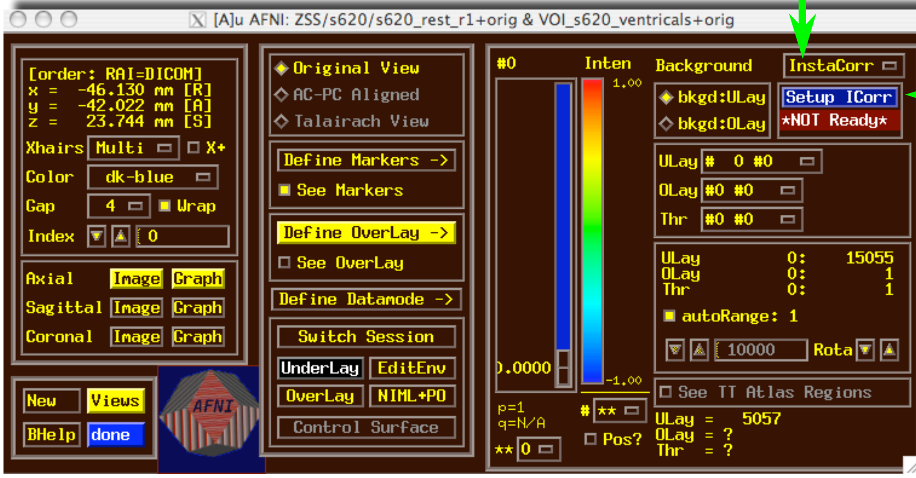
InstaCorr: Setup

- Open `Define Overlay`, choose `InstaCorr` from menu in top right corner



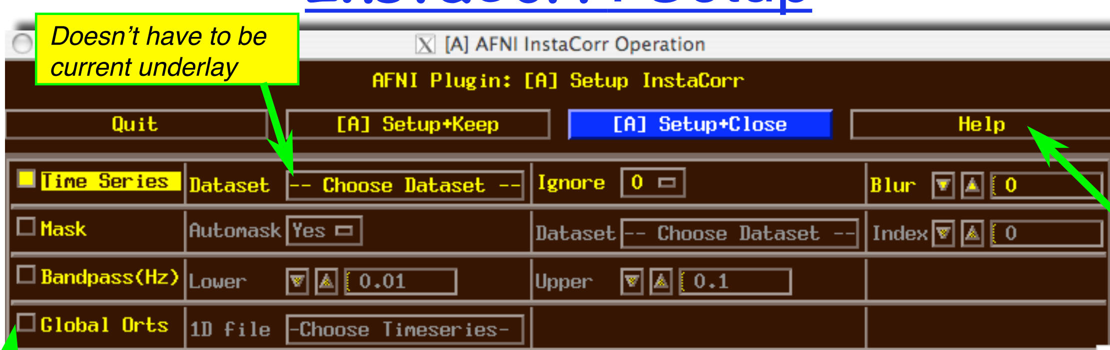
InstaCorr: Setup

- Open **Define Overlay**, choose **InstaCorr** from menu in top right corner



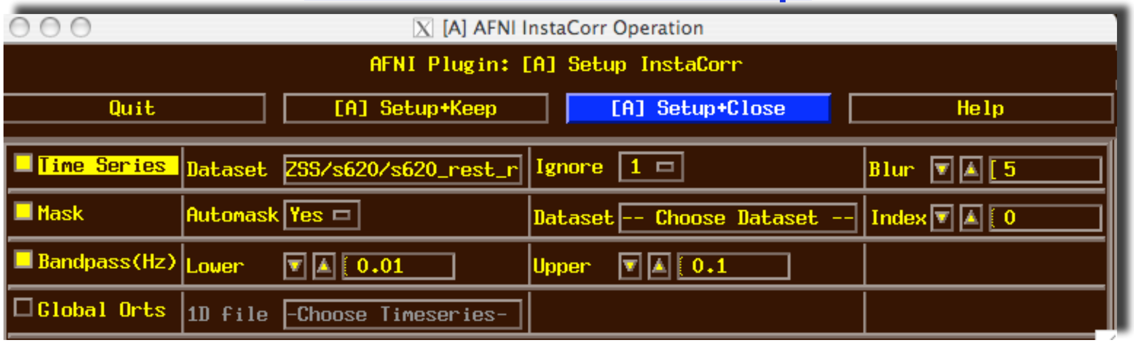
- Then press **Setup ICorr** button to get control panel

InstaCorr: Setup



- Mostly self-explanatory (I hope) — *cf.* **Help**
- **Global Orts** = extra time series to be projected out of dataset before correlation
  - All columns in selected 1D file
  - *e.g.*, movement parameters
  - The first **Ignore** rows (time points) will be skipped
- When ready, press one of the **Setup** buttons

InstaCorr: Setup



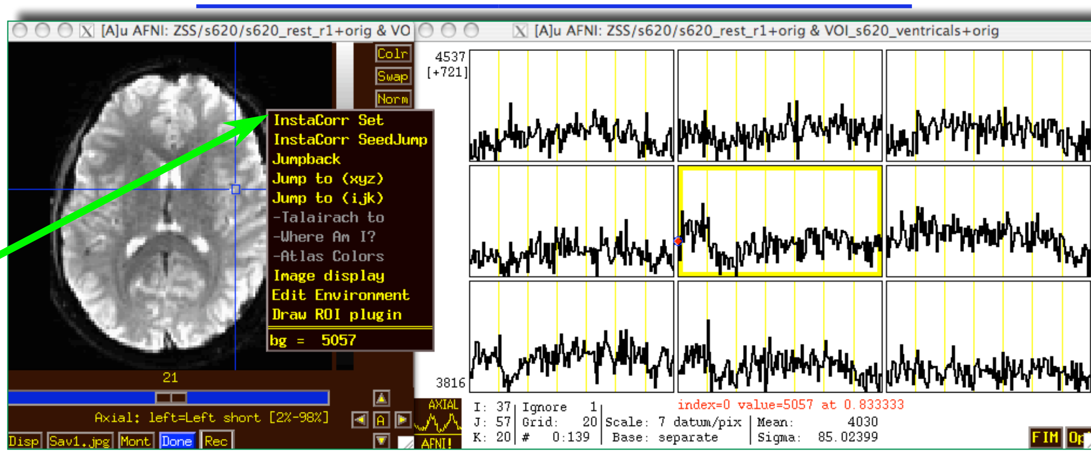
- Text output to shell window details the setup procedures:

```
++ InstaCorr preparations:
 + Automask from
  '/Users/rwcox/data/Resting/ZSS/s620/s620_rest_r1+orig.BRIK' has
  197234 voxels
 + Extracting dataset time series
 + Filtering 197234 dataset time series
 + bandpass: ntime=139 nFFT=160 dt=3.5 dFreq=0.00178571
  Nyquist=0.142857 passband indexes=6..56
 + Spatially blurring 139 dataset volumes
 + Normalizing dataset time series
++ InstaCorr setup: 197234 voxels ready for work: 15.43 sec
```

Dataset being analyzed

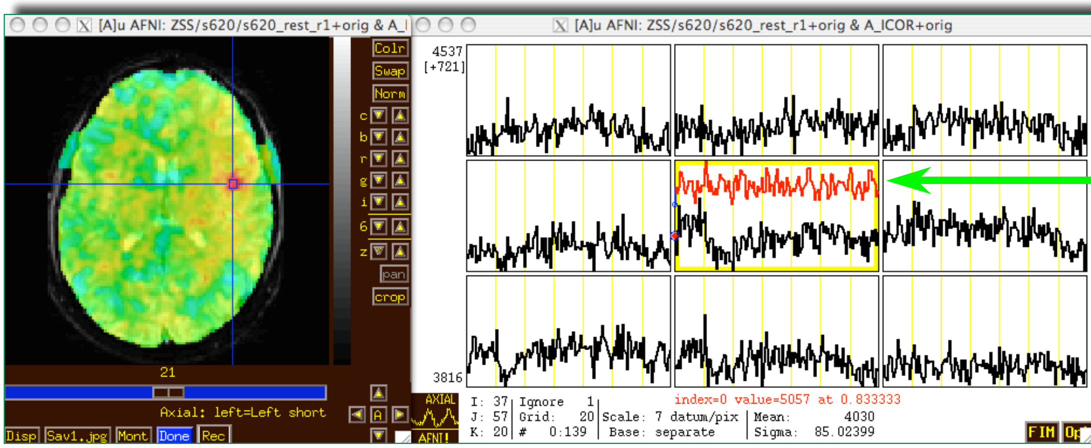
Most of the CPU time:
Uses `BlurInMask`

InstaCorr: The Fun Part



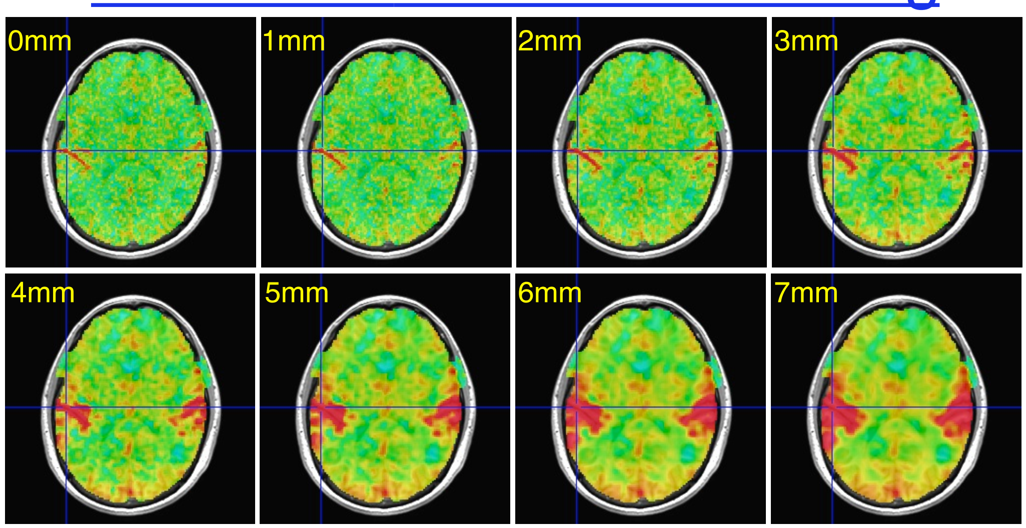
- In image viewer, set crosshairs to desired seed voxel
- **Right-click** popup menu → **`InstaCorr Set`**
    - Creates new dataset **`A_ICOR`** for Overlay
    - ***Shortcut***: **Shift+Ctrl+Left-click** sets new crosshair location, then does **`InstaCorr Set`**
        - Can also hold down **Shift+Ctrl+Left-click** and drag seed around
- **`InstaCorr SeedJump`** jumps focus to current seed

InstaCorr: The Fun Part



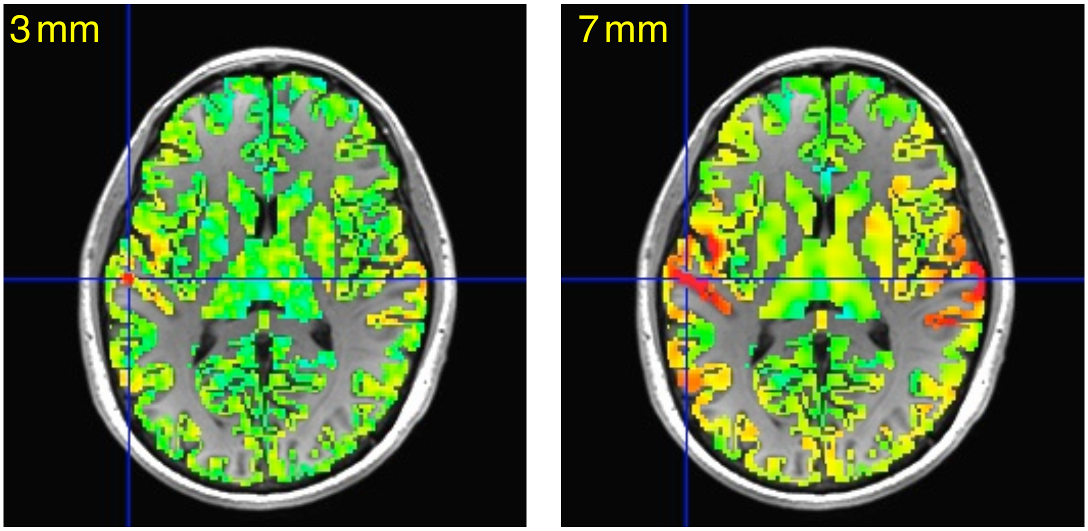
- In graph window:
  - Set **`Ignore`** with **`FIM→Ignore`** menu (or **`I`** key)
  - Set seed overlay with **`FIM→Pick Ideal`** menu
- When you change seed voxel, saved overlay time series will change (but you have to refresh graph to see it)

InstaCorr: Effects of Blurring



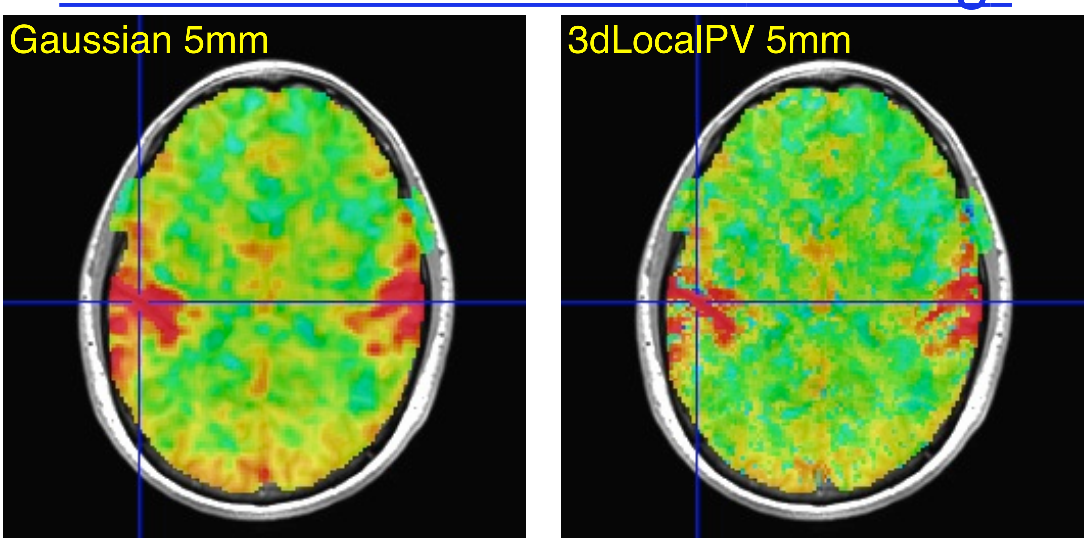
- Is this a pure vascular/cardiac effect being progressively smeared? Or real neural correlations seen via BOLD? Or some of both? *Venograms*?
  - Dataset was RETROICOR-ized; mask is whole brain

InstaCorr: Effects of Blurring



- Similar calculations, but with FreeSurfer-generated gray matter mask instead of Automask from EPI data
  - Blurring is done only inside the mask (`3dBlurInMask`)
    - Using a discrete PDE-based iterative approach

InstaCorr: SVD-based "Blurring"



- Similar calculations, with Automask from EPI data, using `3dLocalPV` over 5 mm radius sphere (67 voxels)
  - Project each vector onto 2-dim principal subspace
  - Far too slow to calculate interactively (at this time)

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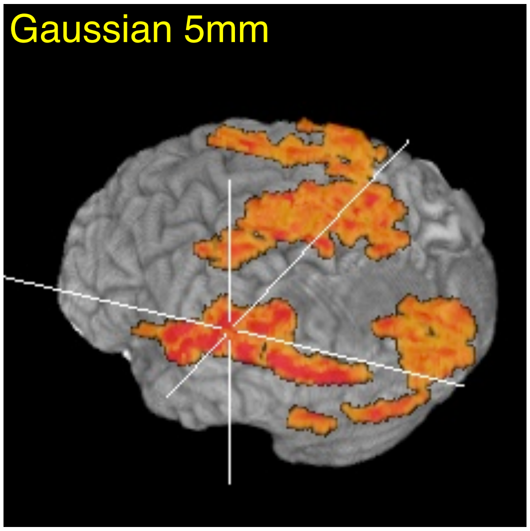
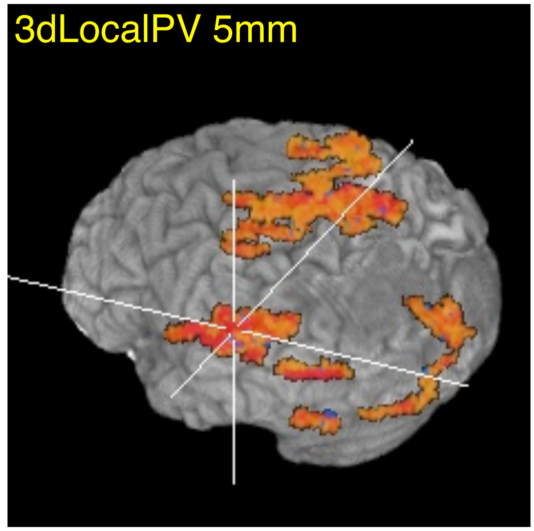
InstaCorr: SVD-based "Blurring"





- Volume rendering of InstaCorr maps (threshold at r=0.5)
  - Renderer updates automatically if `DynaDraw` is on
- SVD smoothing has cleaner spatial structure?
  - Or has it lost some information? *I don't know.*

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InstaCorr: Options and Plans

- Underlay doesn't have to be EPI data; could be anat
  - Can use InstaCorr in multiple AFNI controllers
- FDR: `setenv AFNI_INSTACORR_FDR YES`
  - Will slow things down by a significant factor
- Saving `A_ICOR` dataset: overwrites previous copies
- Future Possibilities:
  - Select ROI-based Orts to be detrended?
    - Based on ROIs from FreeSurfer or atlases?
  - Or multiple seeds (partial + multiple correlations)?
  - Interactive local SVD "smoothing"? (needs speedup)
  - Group analysis InstaCorr (in standardized space)
    - Not quite "Insta" any more; ≈0.1×#Subjects sec per seed
    - External script to do subject setups
  - Use time series subsets? (*e.g.*, for block design data)

Group InstaCorr

- If you have a robust enough system (multiple CPUs, several gigabytes of RAM), you can explore the *group* analysis of resting state seed-based correlations
- **Setup Phase**:
  - Unlike individual InstaCorr, the setup is done outside the AFNI GUI with command line programs
  - Step 1: transform all time series datasets to standard space = **@auto_tlrc** and **adwarp**
  - Step 2: filter and blur all time series dataset = **3dBandpass**
  - Step 3: collect groups of time series datasets into one big file = **3dSetupGroupInCorr**
- **Interactive Phase**: point-and-click to set seed voxel

31 Dec 2009

3dGroupInCorr: Setup #1

- Assume datasets are named as follows:
  - T1-weighted anatomical = **sXXX_anat+orig**
  - Resting state EPI = **sXXX_rest+orig**

```
foreach aset ( s*_anat+orig.HEAD )
  set sub = `basename $aset _anat+orig.HEAD`
# transform anat to MNI space
  @auto_tlrc -base ~/abin/MNI_avg152T1+tlrc.HEAD -input $aset
# transform EPI to MNI as well (assume anat & EPI are aligned)
  adwarp -apar ${sub}_anat+tlrc.HEAD -dpar \
         ${sub}_rest+orig.HEAD -resam Cu -dxyz 2.0
# make individual subject mask
  3dAutomask -prefix ${sub}_amask ${sub}_rest+tlrc.HEAD
end

# Combine individual EPI masks into group mask

3dMean -datum float -prefix ALL_am *_amask+tlrc.HEAD
3dcalc -datum byte -prefix ALL_am50 -a ALL_am+tlrc \
       -expr 'step(a-0.499)'
```

3dGroupInCorr: Setup #2

- Bandpass and blur each dataset inside mask
  - skip first 4 time points, and remove global signal
  - of course, you can choose your own options for filtering
    - Can also have **1** voxel-dependent time series to detrend, via **-dsort**

```
foreach rset ( s*_rest+tlrc.HEAD )
  set sub = `basename $rset _rest+tlrc.HEAD`
# create global signal file for this dataset
  3dmaskave -mask ALL_am50+tlrc -quiet    \
            $rset'[4..$]' > ${sub}_GS.1D
# 3dBandpass does blurring, filtering, and detrending
  3dBandpass -mask ALL_am50+tlrc -blur 6.0     \
             -band 0.01 0.10 -prefix ${sub}_BP \
             -input $rset'[4..$]' -ort ${sub}_GS.1D
end
/bin/rm -f *_GS.1D *_amask+tlrc.*
```


3dGroupInCorr: Setup #3

- **3dSetupGroupInCorr** reads all filtered & blurred resting state EPI datasets, masks & normalizes them, and writes them to one *big* file for **3dGroupInCorr**
  - Sample below: 2 groups of subjects

```
set AAA = ( s601 s604 … s644 s646 )
set BBB = ( s611 s612 … s652 s654 )
set ggg = ( )
foreach fred ( $AAA )
  set ggg = ( $ggg ${fred}_BP+tlrc.HEAD )
end
3dSetupGroupInCorr -mask ALL_am50+tlrc -prefix AAA $ggg
set ggg = ( )
foreach fred ( $BBB )
  set ggg = ( $ggg ${fred}_BP+tlrc.HEAD )
end
3dSetupGroupInCorr -mask ALL_am50+tlrc -prefix BBB $ggg
```

3dGroupInCorr: Interactive Phase

- Start server program (2-sample *t*-test here):

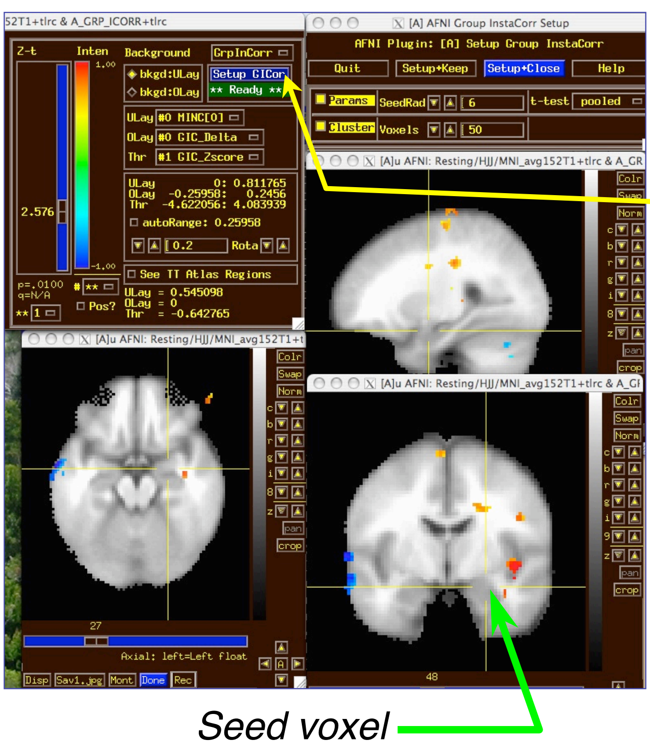
```
3dGroupInCorr -setA AAA.grpincorr.niml \
              -setB BBB.grpincorr.niml
```

  - Startup takes a little while, as all data must be read into RAM (in this example, 3.2 Gbytes)
  - After data is read, connects to AFNI using a NIML socket
  - Server will use multiple CPUs if compiled with OpenMP (currently on Mac OS X 10.5 and 10.6)
- In a separate terminal window, start AFNI:

```
afni -niml ~/abin/MNI_avg152T1+tlrc.HEAD
```

  - Then open the **Define Overlay** control panel
  - Select **GrpInCorr** from the **Clusters** menu

3dGrpInCorr: Interactive Results



- Use same buttons as individual subject *InstaCorr* to set seed
- Use **Setup GICor** panel to set the few options available interactively
  - **SeedRad** = extra smoothing radius for seed voxel time series (flat average)
  - **Cluster** = min number of voxels to keep above thresh

3dGrpInCorr: What It Computes

- Extracts seed time series from each input dataset; correlates it with all voxel time series in that dataset
  - Group analysis: *t*-test between correlation datasets
- 1-sample *t*-test (**-setA** only) gives 2 sub-bricks:
  - mean of $\tanh^{-1}$(correlation with seed)
  - *Z*-score of *t*-statistic of this mean
- 2-sample test (**-setA** *and* **-setB**) gives 6 sub-bricks:
  - difference of means (**A–B**) of $\tanh^{-1}$(correlation)
  - *Z*-score of *t*-statistic of this difference
    - Pooled or unpooled variance, or paired *t*-test (your option)
  - Plus 1-sample results for **-setA** and **-setB** separately
    - View these in AFNI **[B]** and **[C]** controllers, to see it all*!*

3dGrpInCorr: To Do It By Hand?

- After **3dBandpass** of all datasets, you would have to do the following steps on each resting state dataset:
  - Extract seed time series from each dataset [**3dmaskave**]
  - Correlate seed time series with all voxels from its dataset [**3dDeconvolve** or **3dfim**]
  - Convert to $\tanh^{-1}$(correlation) [**3dcalc**]
- Then do the following on the results from the above
  - Compute the *t*-test [**3dttest**]
  - Convert to *Z*-score [**3dcalc**]
  - Read into AFNI for display
- Even with a script, this would be annoying to do a lot
  - Just ask Daniel Handwerker*!*

Group InstaCorr: Final Notes

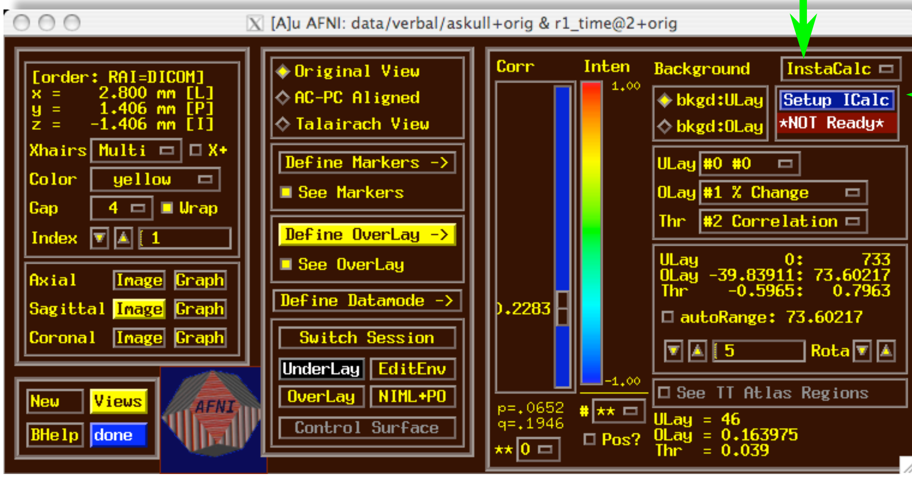
- Time series datasets can have different lengths
  - But all must have the same spatial grid and use the same mask!
- **Fun Stuff**: volume render results with **DynaDraw**
- Sometimes AFNI drops the shared memory connection to **3dGroupInCorr**
  - Due to unknown bugs somewhere in AFNI
  - Program tries to reconnect when this happens
  - If this gets bad, use the **-NOshm** option to **3dGroupInCorr** to force it to use TCP/IP only
    - Slower data transfer, but more reliable
- Brand new software = still rough around the edges ⇒ need *constructive* feedback

Group InstaCorr: Finalest Notes

- Shift+Ctrl+Click+Drag method for dynamically setting the seed voxel also works with **Group InstaCorr**
  - But speed of interaction can be slow
- Can now [*May 2010*] include subject-level covariates (e.g., IQ, age) in the analysis at the group step
  - To regress them out (nuisance variables), and/or to test the slope of $\tanh^{-1}(\text{correlation})$ vs. covariate
- Can now [*Jan 2011*] run in batch mode
- Further ideas:
  - Granger-ize: correlate with lag-0 ***and*** lag-1 of seed and test Granger causality
  - Allow user to set other seeds to be "partialed out" of the analysis

InstaCalc: Dataset Calculator

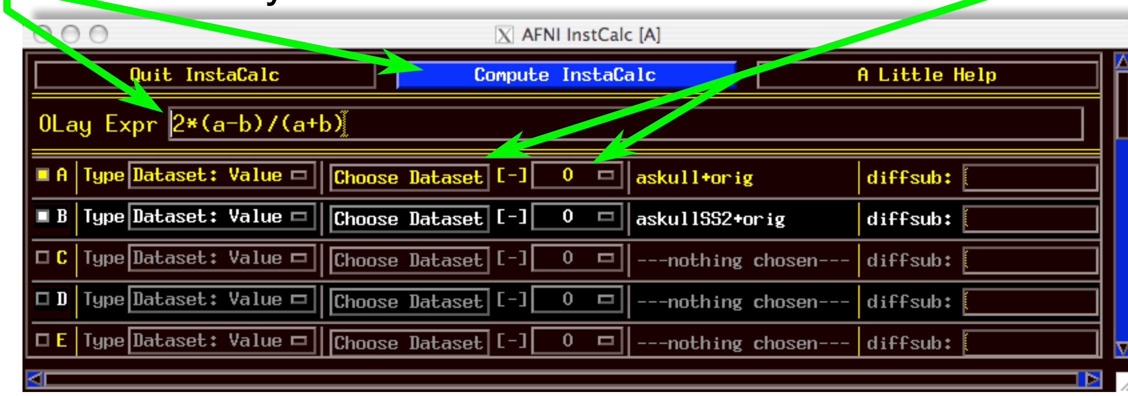
- Open **Define Overlay**, choose **InstaCalc** from menu in top right corner



- Then press **Setup ICalc** button to get control panel

InstaCalc: Setup

- Select datasets with **Choose Dataset** buttons
  - and sub-bricks with the **[-]** controls
- Enter symbolic expression
- Press **Compute InstaCalc**
- Creates new 1-brick dataset **A_ICALC** for Overlay
  - voxel-by-voxel calculations



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SUMA! InstaCorr

- Similar in concept to AFNI **InstaCorr** but requires external pre-processing of time series datasets
  - Removal of baseline, projection to surface, blurring
- In the **AFNI_data5/** directory, run the script

  tcsh ./@run_REST_demo
  - starts SUMA with 2 hemispheres
  - loads pre-processed datasets into SUMA
  - sets up SUMA's **InstaCorr**
- After all the setup is ready, right-clicking on the surface will do the **InstaCorr** calculations
- **`3dGroupInCorr`** also works with SUMA

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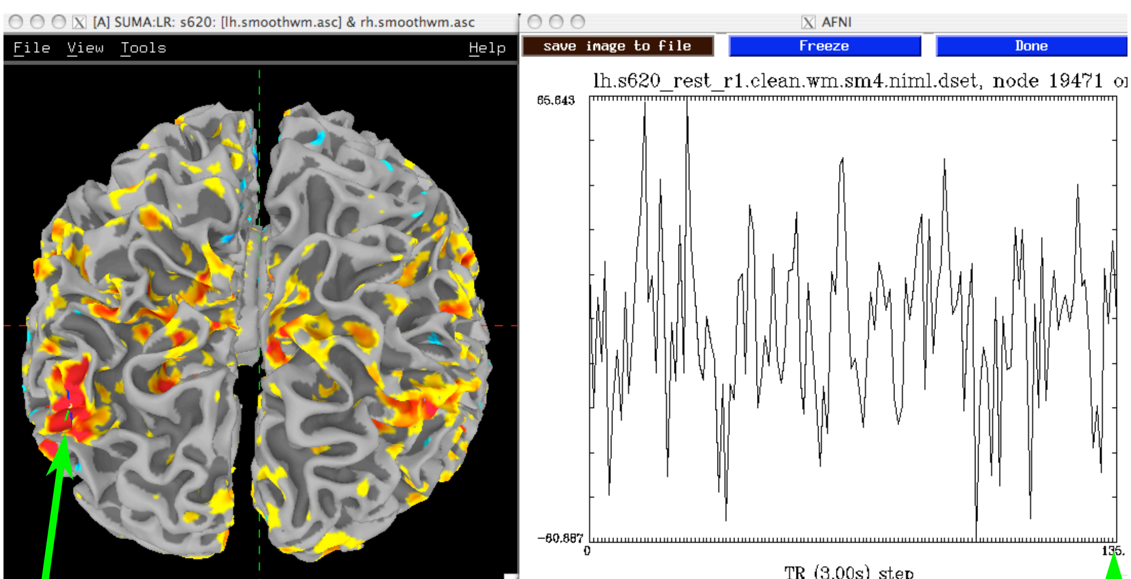
SUMA! InstaCorr: Sample



- Seed voxel and Seed voxel time series graph