"Cyclone" Multi-Doppler Tutorial

FRACTL, SAMURAI

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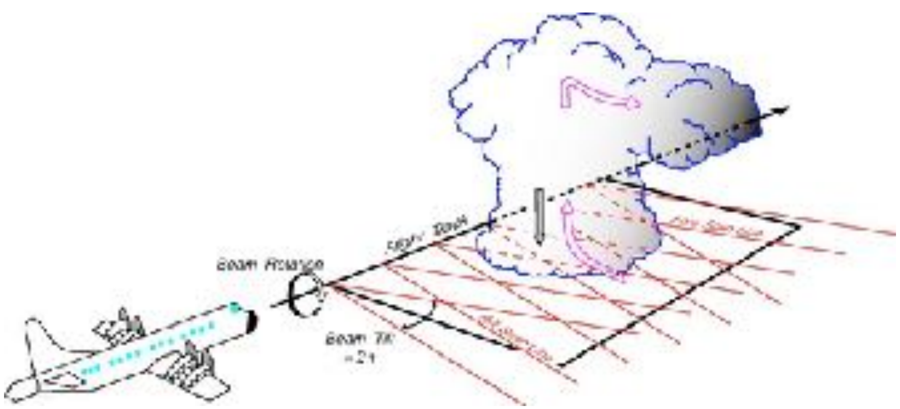
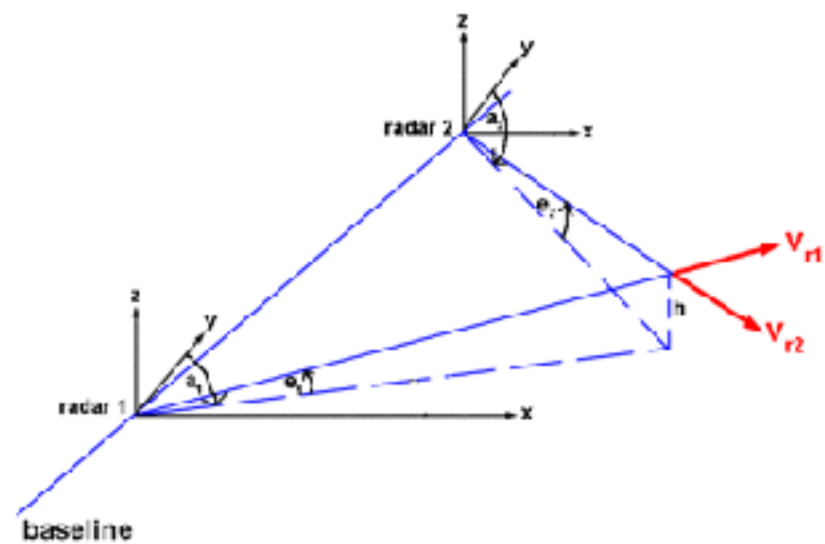
Inputs for this tutorial can be obtained here:
http://lrose.net/_static/LROSE-Cyclone-Wind-tutorial_20200112_inputs.tar.gz

Multi-Doppler Synthesis

$$V_r = u\sin(a)\cos(e) + v\cos(a)\cos(e) + (w + w_t)\sin(e)$$

Desired minimum angle separation of ~30° away from 'baseline' for dual Doppler, but wind dependent



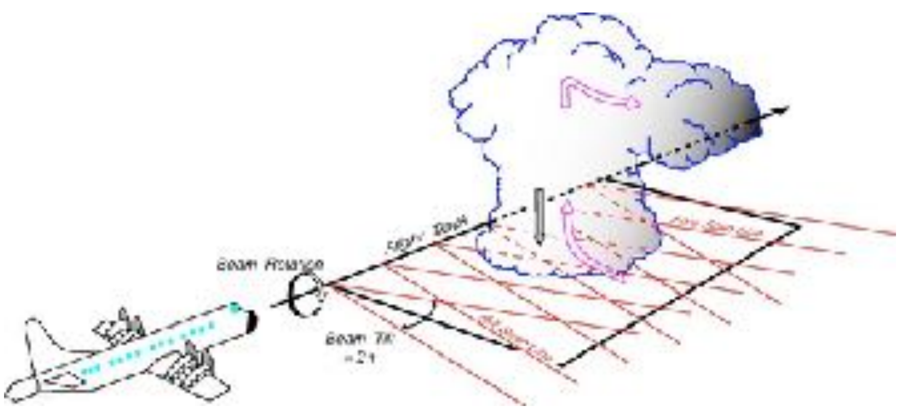


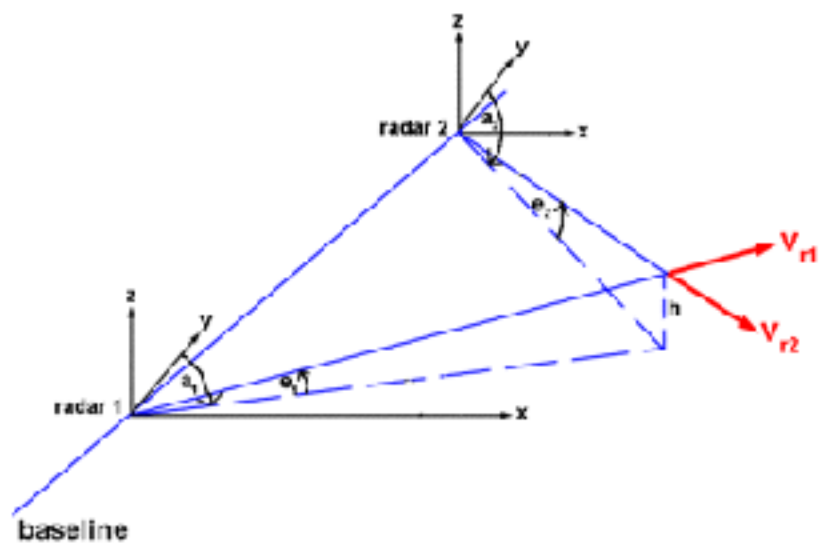
Multi-Doppler Synthesis

$$V_r = u\sin(a)\cos(e) + v\cos(a)\cos(e) + (w + w_t)\sin(e)$$

$$\begin{pmatrix} \sin(a_1) & \cos(a_1) \\ \sin(a_2) & \cos(a_2) \end{pmatrix} \begin{pmatrix} u \\ v \end{pmatrix} = \begin{pmatrix} V_{r1} \\ V_{r2} \end{pmatrix}$$

$$-\frac{\partial \rho w}{\partial z} = \frac{\partial \rho u}{\partial x} + \frac{\partial \rho v}{\partial y}$$





Multi-Doppler Synthesis

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$$-\frac{\partial \rho w}{\partial z} = \frac{\partial \rho u}{\partial x} + \frac{\partial \rho v}{\partial y}$$

$$Ax = b$$

the solutions are

$$\hat{u} = \frac{D_1B_2 - D_2B_1}{D} + \widehat{W}\frac{B_1C_2 - B_2C_1}{D} = u' + \epsilon_u\widehat{W}$$

$$\hat{v} = \frac{D_2A_1 - D_1A_2}{D} + \widehat{W}\frac{A_2C_1 - A_1C_2}{D} = v' + \epsilon_v\widehat{W},$$

where the determinant of coefficients

$$D = A_1B_2 - A_2B_1.$$

Multi-Doppler Synthesis

$$V_r = u\sin(a)\cos(e) + v\cos(a)\cos(e) + (w + w_t)\sin(e)$$

$$\begin{pmatrix} \sin(a_1) & \cos(a_1) \\ \sin(a_2) & \cos(a_2) \end{pmatrix} \begin{pmatrix} u \\ v \end{pmatrix} = \begin{pmatrix} V_{r1} \\ V_{r2} \end{pmatrix}$$

$$-\frac{\partial \rho w}{\partial z} = \frac{\partial \rho u}{\partial x} + \frac{\partial \rho v}{\partial y}$$

$$Ax = b$$

$$\|r\|^2 = \|b - Ax\|^2$$

Multi-Doppler Synthesis

$$V_r = u\sin(a)\cos(e) + v\cos(a)\cos(e) + (w + w_t)\sin(e)$$

Three (or more) radar solution ('Normal' equations)

$$\begin{pmatrix} \sum \sin^2 a\cos^2 e & \sum \sin a\cos a\cos^2 e & \cancel{\sum \sin a\cos e\sin e} \\ \sum \sin a\cos a\cos^2 e & \sum \cos^2 a\cos^2 e & \cancel{\sum \cos a\cos e\sin e} \\ \cancel{\sum \sin a\cos e\sin e} & \cancel{\sum \cos a\cos e\sin e} & \cancel{\sum \sin^2 e} \end{pmatrix} \begin{pmatrix} u \\ v \\ \cancel{w + w_t} \end{pmatrix} = \begin{pmatrix} \sum V_r \sin a\cos e \\ \sum V_r \cos a\cos e \\ \cancel{\sum V_r \sin e} \end{pmatrix}$$

Local? $\|r\|^2 = \|b - Ax\|^2$ ***Global?***

Mini-workshop tutorial will only cover practical application due to limited time, but will be covered in much more detail in pending documentation and in fall workshop

Different analysis techniques have advantages / disadvantages

Traditional "Local" solver (**FRACTL**, CEDRIC)	Variational "Global" solver (**SAMURAI,** HRD, Multi-Dopp)
Fast computation	Computationally demanding
Point-by-point error diagnostics	Global error diagnostics
Doppler data only	Other data sources possible

- **FRACTL (Fast Reorder and CEDRIC Technique in LROSE)**
- **SAMURAI (Spline Analysis at Mesoscale Utilizing Radar and Airborne Instrumentation)**

To Run FRACTL

To see all command line options:

```
fractl -h
```

To create a default parameter file, use the -print_params command line option:

```
fractl -print_params > my_fractl.params
```

To run the application, invoke the -params command line option:

```
fractl -params my_fractl.params
```

To Run SAMURAI (new LROSE version)

To see all command line options:

```
samurai -h
```

To create a default parameter file, use the -print_params command line option:

```
samurai -print_params > my_samurai.params
```

To run the application, invoke the -params command line option:

```
samurai -params my_samurai.params
```

Older XML format is backward compatible

Mandatory

Things to change in FRACTL params

Lat/Lon Origin

```
< projLat0 = 0;
---
> projLat0 = 29.4719;
265c265
< projLon0 = 0;
---
> projLon0 = -94.8787;
```

Input/Output

```
453c453
< inDir = "not_set";
---
> inDir = "input";
485c485
< outTxt = "not_set";
---
> outTxt = "fractl_verif.txt";
```

Variable names

```
512c512
< radialName = "not_set";
---
> radialName = "VEL";
522c522
< dbzName = "not_set";
---
> dbzName = "REF";
532c532
< ncpName = "not_set";
---
> ncpName = "SW";
```

FRACTL can use for NCP field to do basic, automatic QC, but if you have already QCed data then you can ignore it and set it to any field

Optional

Things to change in FRACTL params

Grid dimensions

```
190c190
< zGrid = "0.5";
---
> zGrid = "0.0,16.0,1.0";
200c200
< yGrid = "1.0";
---
> yGrid = "-100.0,100.0,1.0";
210c210
< xGrid = "1.0";
---
> xGrid = "-100.0,100.0,1.0";
```

If increment only is given, FRACTL will automatically determine min/max dimensions for the radar data supplied

Optional

Things to change in FRACTL params

Condition Number Cutoff

```
// Maximum value for a cell ConditionNumber.
//
//
// Type: double
//

conditionNumberCutoff = 100;
```

Lower values have higher quality winds

Leise filtering

```
549c549
< uvFilter = FILTER_NONE;
---
> uvFilter = FILTER_LEISE;
560c560
< wFilter = FILTER_NONE;
---
> wFilter = FILTER_LEISE;
571c571
< uvSteps = 1;
---
> uvSteps = 2;
```

Leise filter is the same one from CEDRIC

Mandatory

Things to change in SAMURAI params

Use background

```
107c107
< load_background = TRUE;
---
> load_background = FALSE;
```

Input/Output

```
197c197
< data_directory = "not_set";
---
> data_directory = "input";
209c209
< output_directory = "not_set";
---
> output_directory = "output";
```

Variable names

```
464c464
< radar_dbz = "DBZ";
---
> radar_dbz = "REF";
476c476
< radar_vel = "VG";
---
> radar_vel = "VEL";
```

Also need to set SW field, which in this case is the same as default

Mandatory
Things to change in SAMURAI params

Grid dimensions

```
302c302
< i_min = 0;
---
> i_min = -100.0;
310c310
< i_max = 0;
---
> i_max = 100.0;
318c318
< i_incr = 0;
---
> i_incr = 1.0;
```

```
326c326
< j_min = 0;
---
> j_min = -100.0;
334c334
< j_max = 0;
---
> j_max = 100.0;
342c342
< j_incr = 0;
---
> j_incr = 1.0;
```

```
358c358
< k_max = 0;
---
> k_max = 16.0;
366c366
< k_incr = 0;
---
> k_incr = 1.0;
```

If you want lat/lon or pressure output, set to desired increment, Otherwise set to -1 (will be default in next release)

```
1316c1316
< output_latlon_increment = 1;
---
> output_latlon_increment = -1;
1324c1324
< output_pressure_increment = 1;
---
> output_pressure_increment = -1;
```

Mandatory

Things to change in SAMURAI

Reference Time
In param file

```
392c392
< ref_time = "not_set";
---
> ref_time = "15:00:00";
```

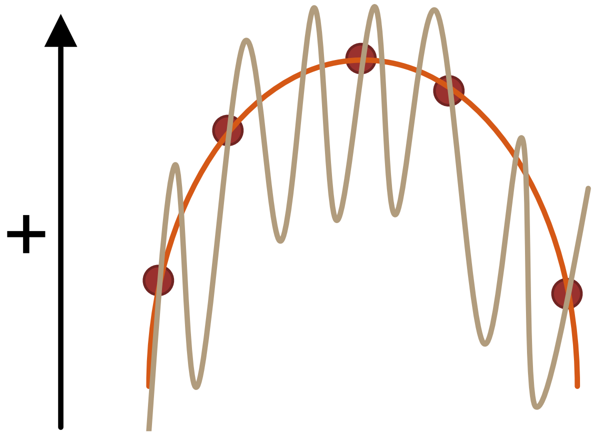
Reference Center file
YYYYMMDD.cen

```
140001 29.4719 -94.8787 0 0
140002 29.4719 -94.8787 0 0
140003 29.4719 -94.8787 0 0
140004 29.4719 -94.8787 0 0
140005 29.4719 -94.8787 0 0
140006 29.4719 -94.8787 0 0
140007 29.4719 -94.8787 0 0
…
```

Can generate reference center file with provided Perl script (samurai_lineartrack.pl)

Optional

Things to change in SAMURAI



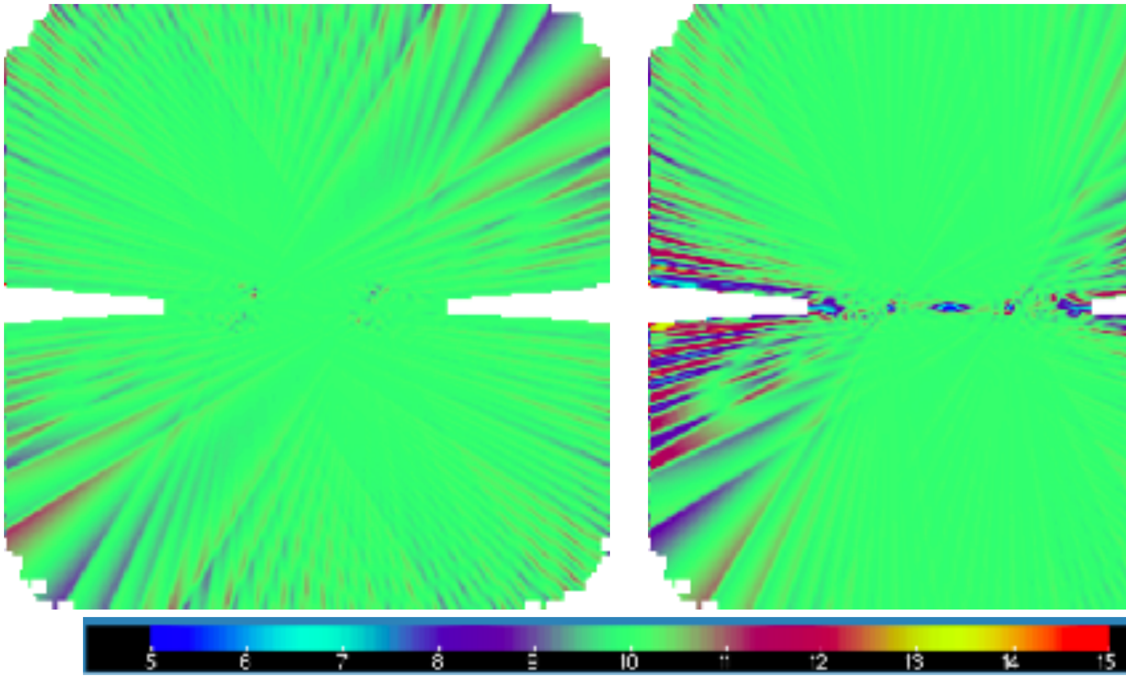
- Multiple spline interpolations are exact solutions to a set of points depending on how many knots you allow the analysis to have
- SAMURAI uses a 3D variational technique to fit splines to the data, but the scales resolved by the analysis have to be set by the user
- Low-pass filters are used to control the resolved scales and avoid overfitting with too many knots
  - Both the orange and brown curves are valid solutions in the example to the left, but the orange one better represents the scales resolved by this data distribution

Gaussian and Spline filter lengths are set in grid units (eg. 2x)

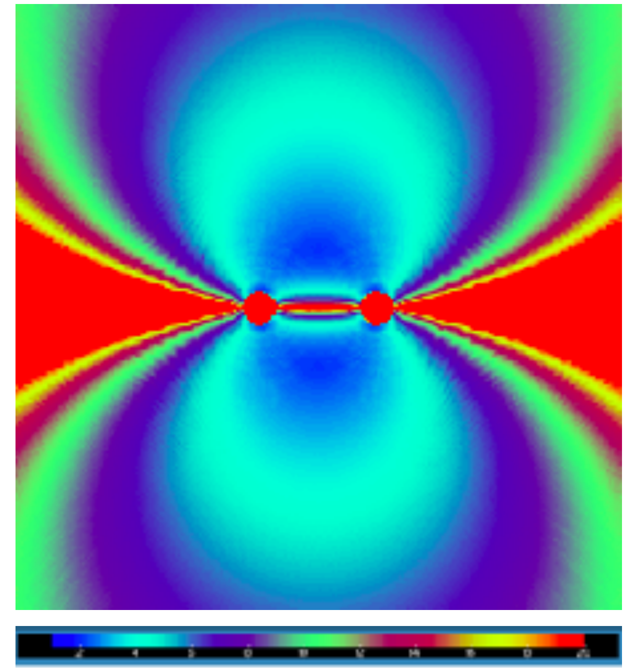
```
1570c1570
<  4,
---
>  2,
```

More detailed discussion of filtering beyond scope of this tutorial, but being written up

Expected FRACTL output (using ncview)



U V

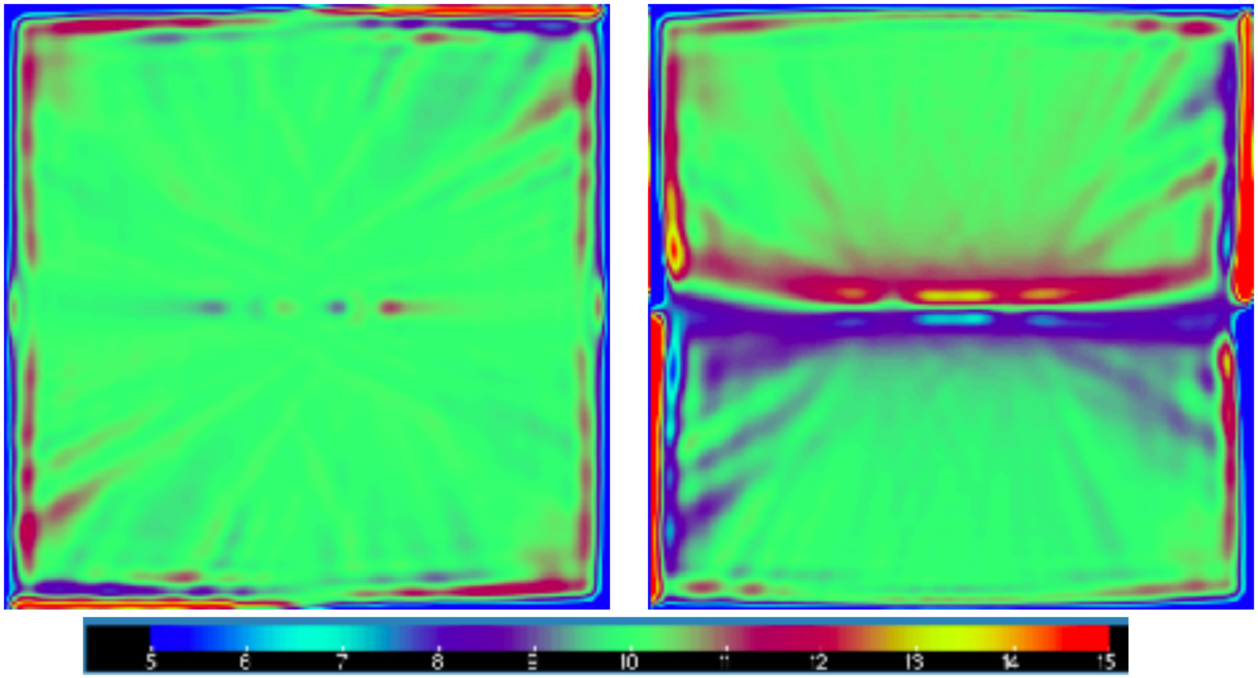


Condition Number

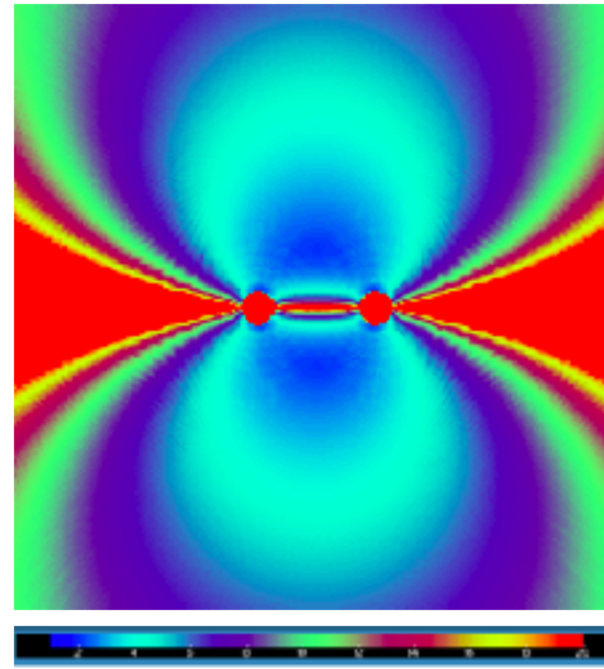
Analytic solution is U=10, V=10 m/s

Retrieved solution is within 1-2 m/s where condition number is small

Expected SAMURAI output (using ncview)



U **V**



Condition Number (from FRACTL)

Analytic solution is U=10, V=10 m/s

Retrieved solution is within 1-2 m/s where condition number is small

Current Status and Next Steps

- Basic documentation available, more being written
- Subset of CEDRIC functionality available in FRACTL, more to be implemented
- FRACTL/SAMURAI integration and Radx2Grid integration are in experimental stage
- Continued optimization to make faster
  - CISL mods will lead to 3-4x speed-up for SAMURAI
  - FRACTL fast but still single-core, will add parallel features for even faster performance