

海洋流速場の空間変化が短波海洋レーダによる流速場計測に与える影響

－ 直線状流速 フロントの場合

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発表の流れ

- 序章
- シミュレーション方法
- 直線状流速フロントに対するシミュレーション結果
 - ・ シアーフロント
 - ・ 収束フロント
- 結論

HF Ocean Surface Radar

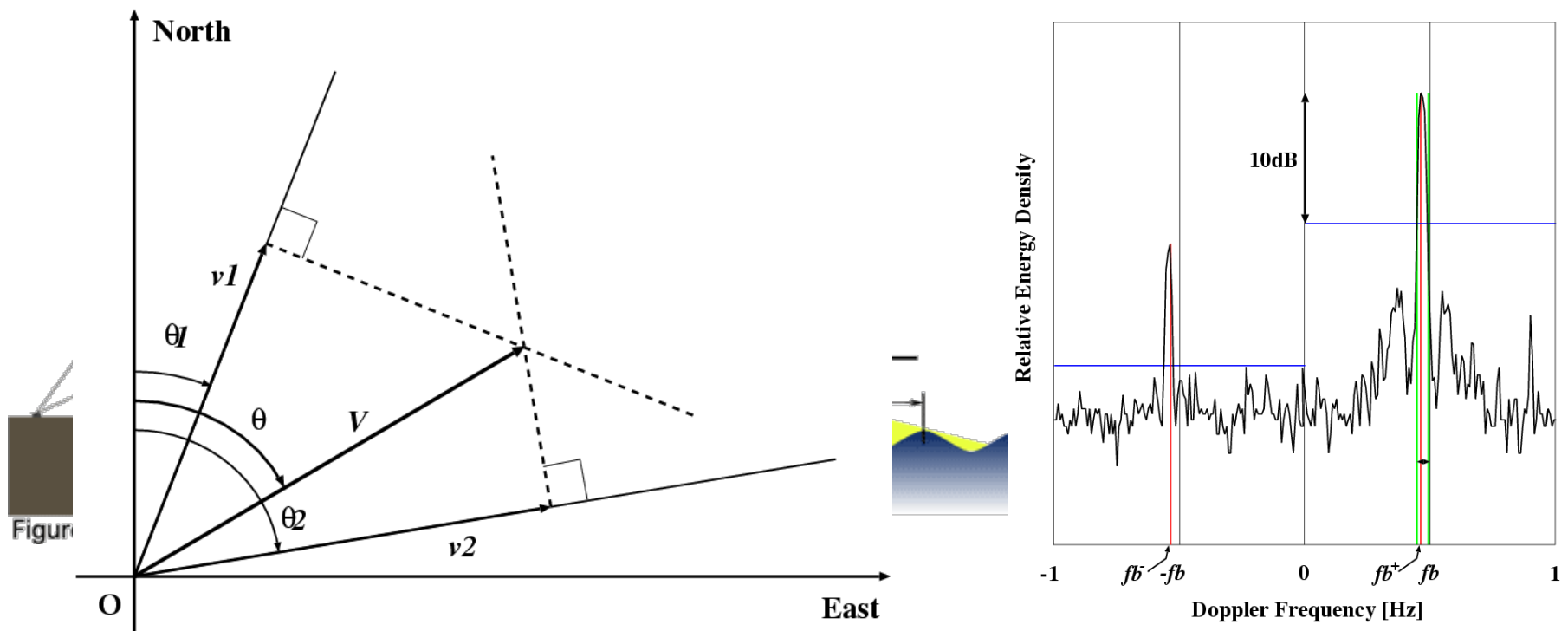
短波海洋レーダ

短波帯電波を海面に送信し、受信信号のドップラースペクトルから海面パラメータを取得

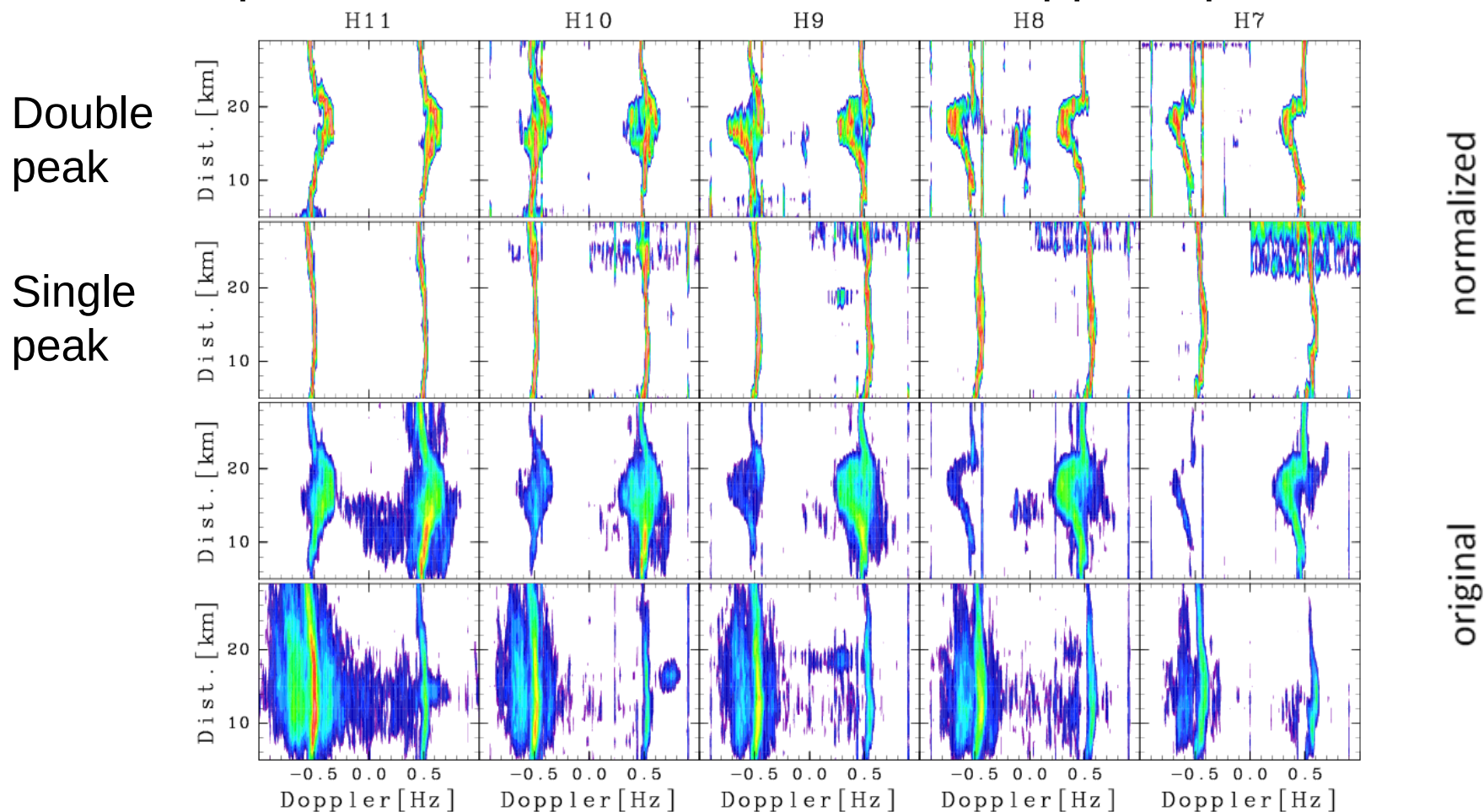
一次散乱エコー:

波長がレーダ電波の1/2、波面がレーダ視線方向に直交する海洋波成分によるエコー

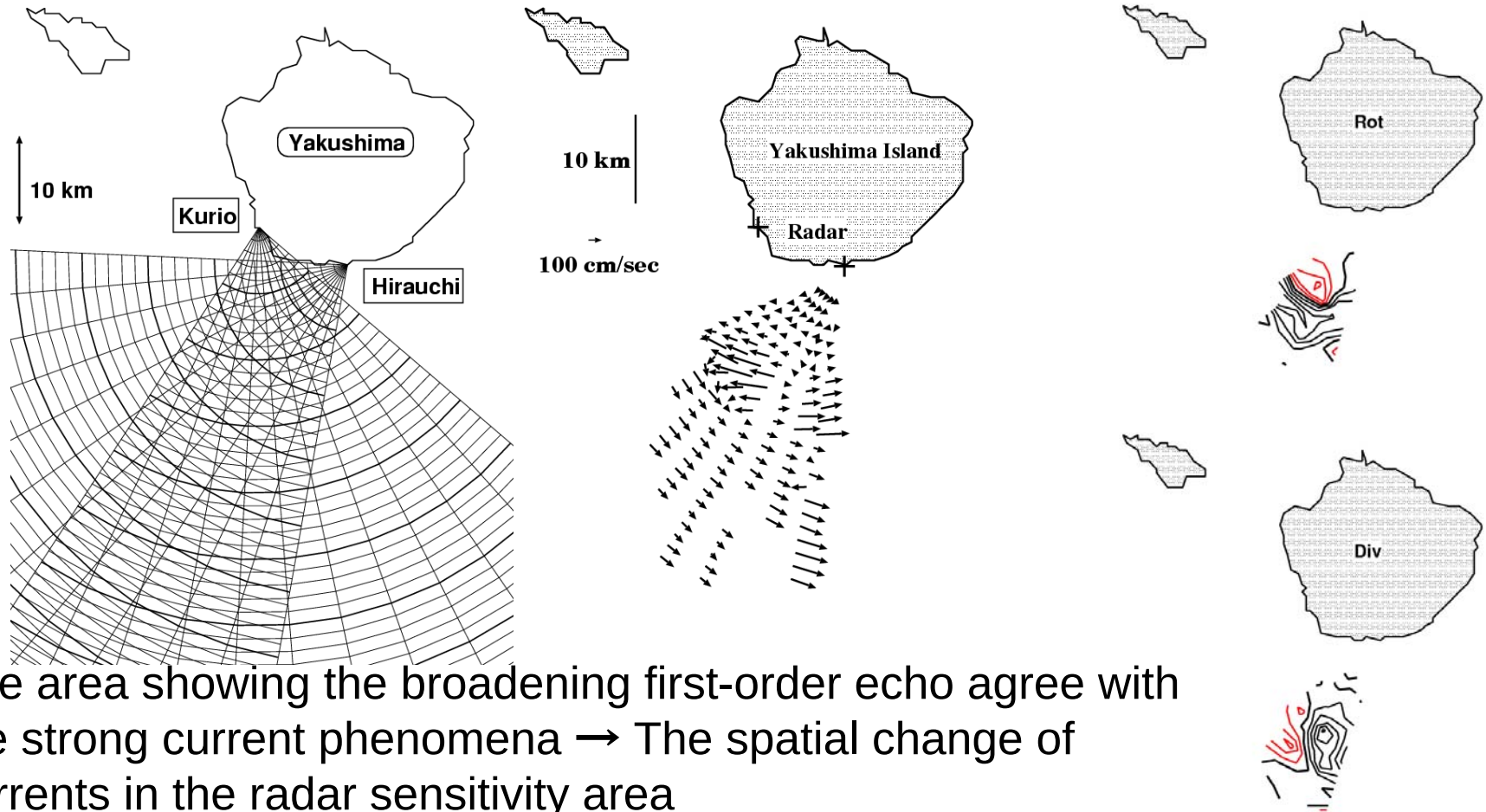
視線流速 = 一次散乱エコーのドップラー速度 - 一次散乱寄与海洋波の位相速度



Shape of the first-order echoes on Doppler spectra



Comparison with current field measured by HFOSR



The area showing the broadening first-order echo agree with the strong current phenomena → The spatial change of currents in the radar sensitivity area

Strange relation between the fields of the rotation and the divergence.

Propagation speed of eddy : about 0.7m/s, period: about 25hr

Simulation Flow

Governing

Nadai (2006)

Parameters of Waves satisfying the Bragg condition

$$\mathbf{r}_B, \mathbf{k}_B, A_B$$

$$\begin{aligned} \frac{d\mathbf{x}}{dt} &= \mathbf{V} + \mathbf{C}_g \\ \frac{d\mathbf{k}}{dt} &= -\mathbf{k} \cdot (\nabla \mathbf{V}) \\ \mathbf{C}_g &= \sqrt{\frac{g}{|\mathbf{k}|}} \frac{\mathbf{k}}{|\mathbf{k}|} \\ \frac{dA}{dt} &= (\nabla \cdot \mathbf{V})A \end{aligned}$$

Current Model:
 $\mathbf{V}$

Initial Wave Parameters

$$\mathbf{r}_I, \mathbf{k}_I, A_I$$

Local Wave Spectra

$$S(\mathbf{k}_B, \mathbf{r}) = \frac{A_I}{A_B} \left(\frac{|\mathbf{k}_B|}{|\mathbf{k}_I|} \right)^{\frac{1}{2}} S_B(\mathbf{k}_I)$$

Background Wave Spectra

$$S_B(\mathbf{k}) = S_0 |\mathbf{k}|^{-\frac{7}{2}}$$

Local Radar Cross Section

$$\sigma^0(v_D, \mathbf{k}_t, \mathbf{r}) \sim S(\mathbf{k}_B, \mathbf{r}) \delta(v_D - v_r(\mathbf{r}))$$

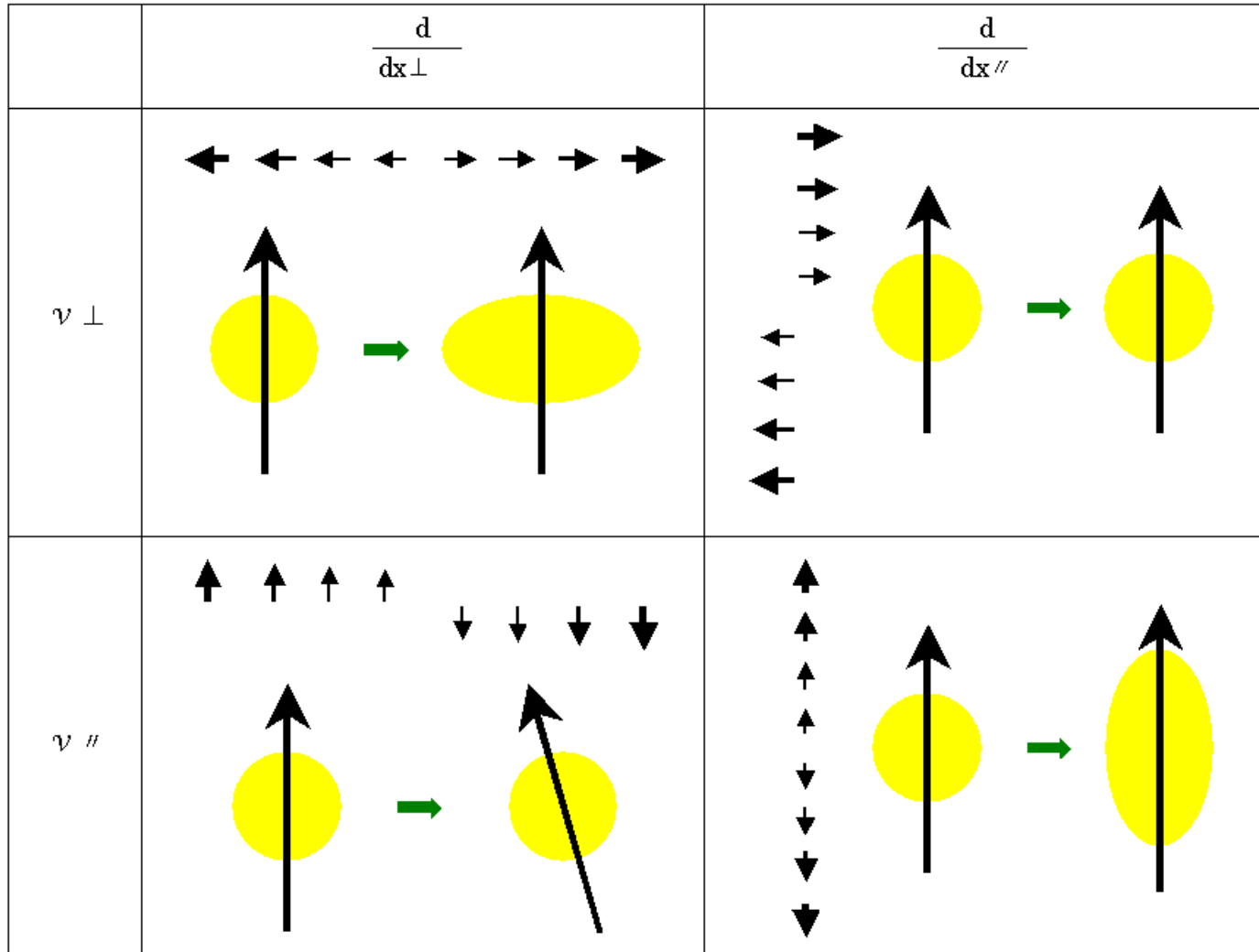
Radar Sensitivity

$$G(\mathbf{r}) = G_0 \exp \left(- \left(\frac{|\mathbf{r} - \mathbf{r}_c|}{R_w} \right)^2 \ln 2 \right)$$

Simulated Doppler Velocity Spectra

$$P'(v_D, \mathbf{k}_t, \mathbf{r}) \sim \int_{S'} G(\mathbf{r}, \mathbf{r}_c) \sigma^0(v_D, \mathbf{k}_t, \mathbf{r}) d\mathbf{r}'$$

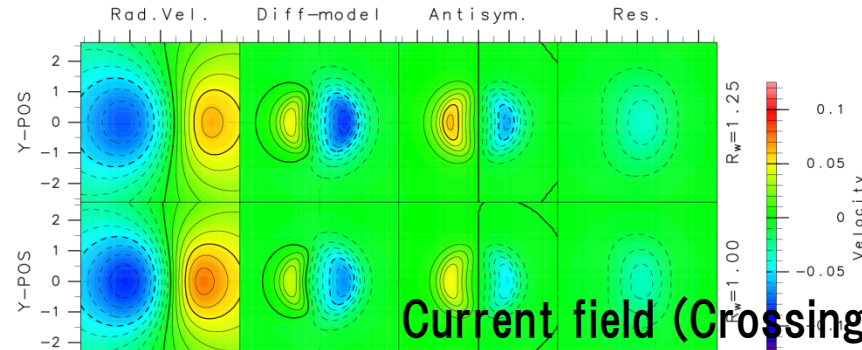
Influence of current shear on wavenumber vector of ocean waves



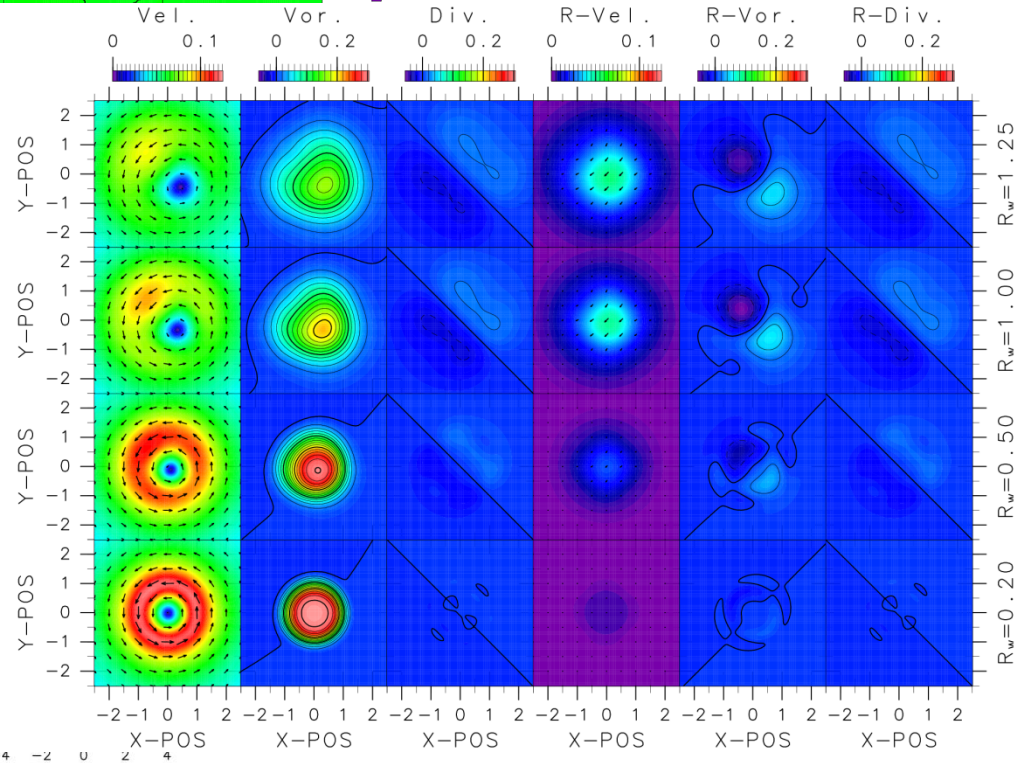
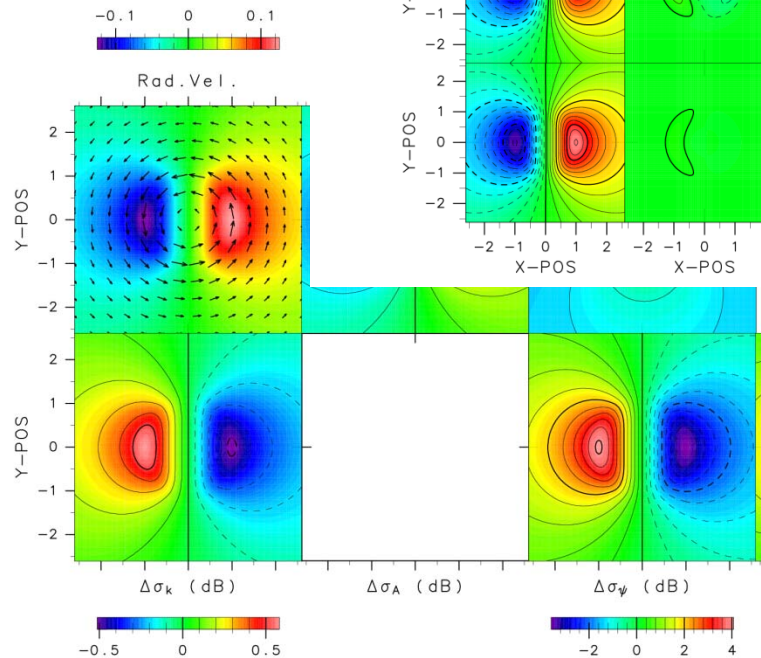
Eddy ($V_0=0.125$, $\phi=90\text{deg}$. $K_B=(0,1)$)

Nadai (2006)

Radial velocity

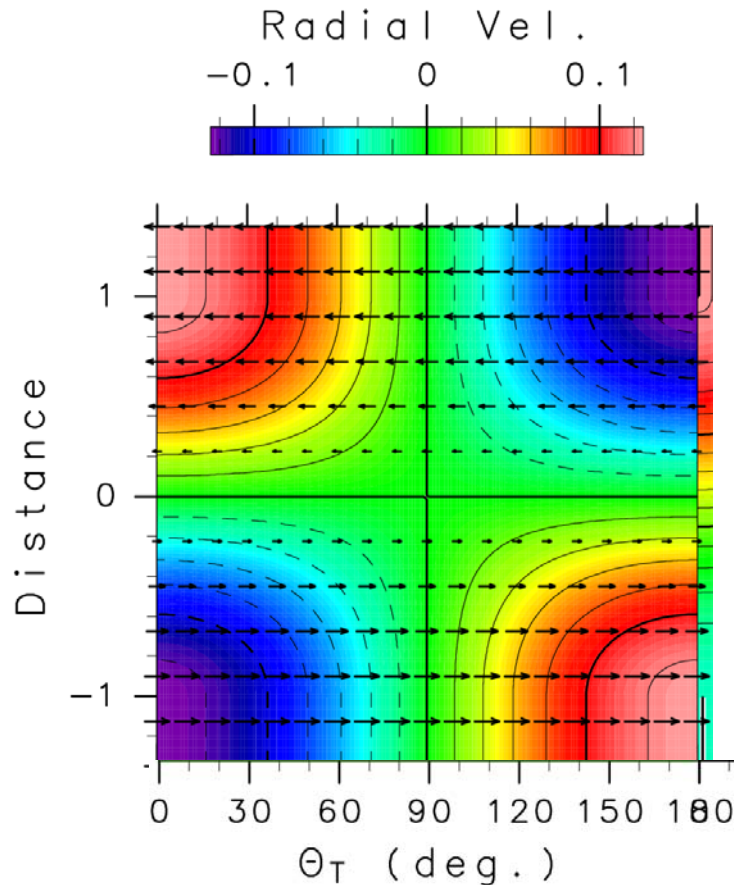


NRCS



Velocity Front Model

1D Velocity Front



$$U_0/C_p = 0.125, \phi = 0^\circ$$

$$U(y) = \begin{cases} -U_0 \cos \phi & (y \geq 1), \\ -U_0 \cos \phi \sin(\frac{\pi}{2}y) & (-1 < y < 1), \\ U_0 \cos \phi & (y \leq -1). \end{cases}$$

$$V(y) = \begin{cases} U_0 \sin \phi & (y \geq 1), \\ U_0 \sin \phi \sin(\frac{\pi}{2}y) & (-1 < y < 1), \\ -U_0 \sin \phi & (y \leq -1). \end{cases}$$

where,

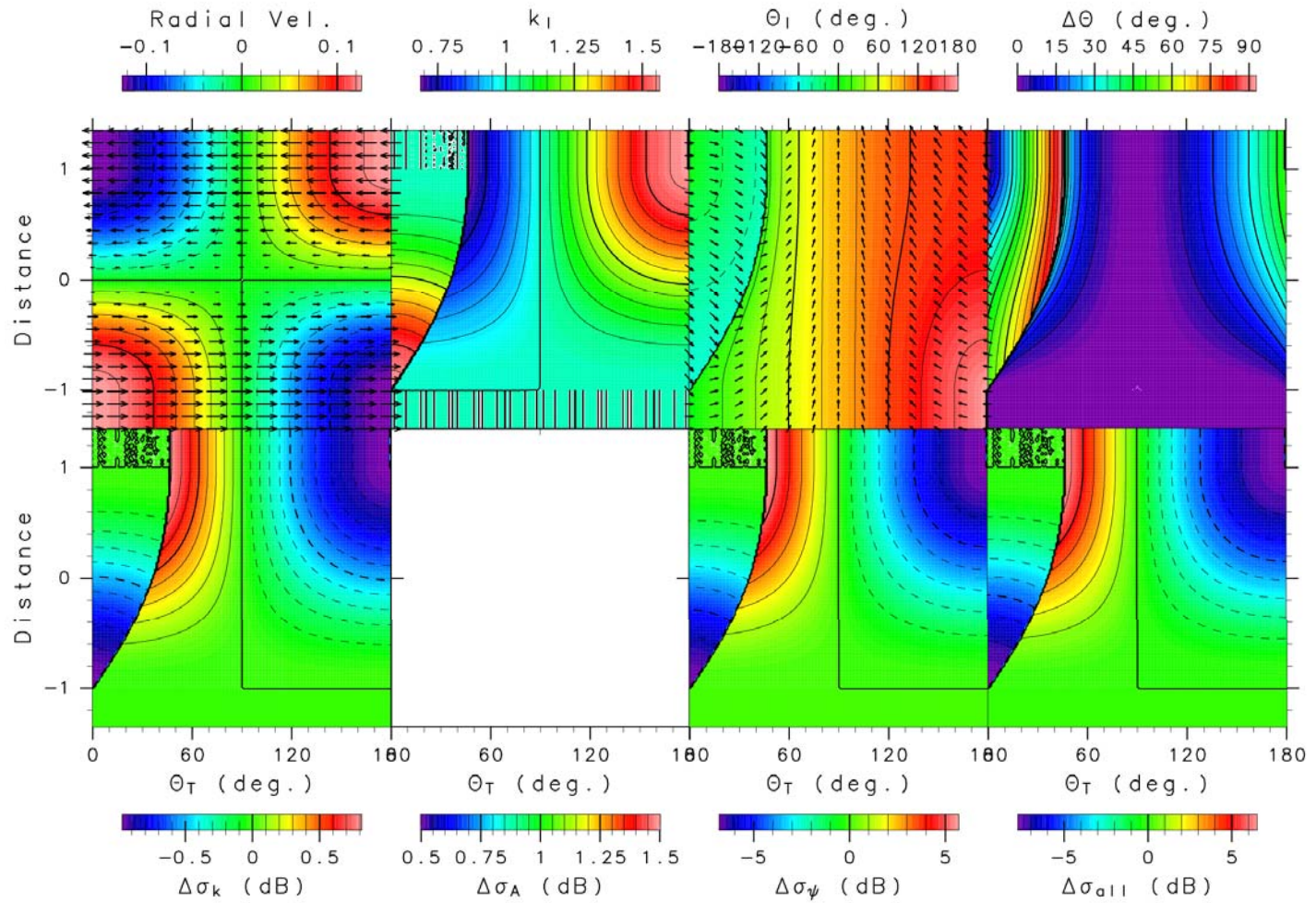
U_0 : Maximum velocity,

ϕ : Divergence/Shear ratio.

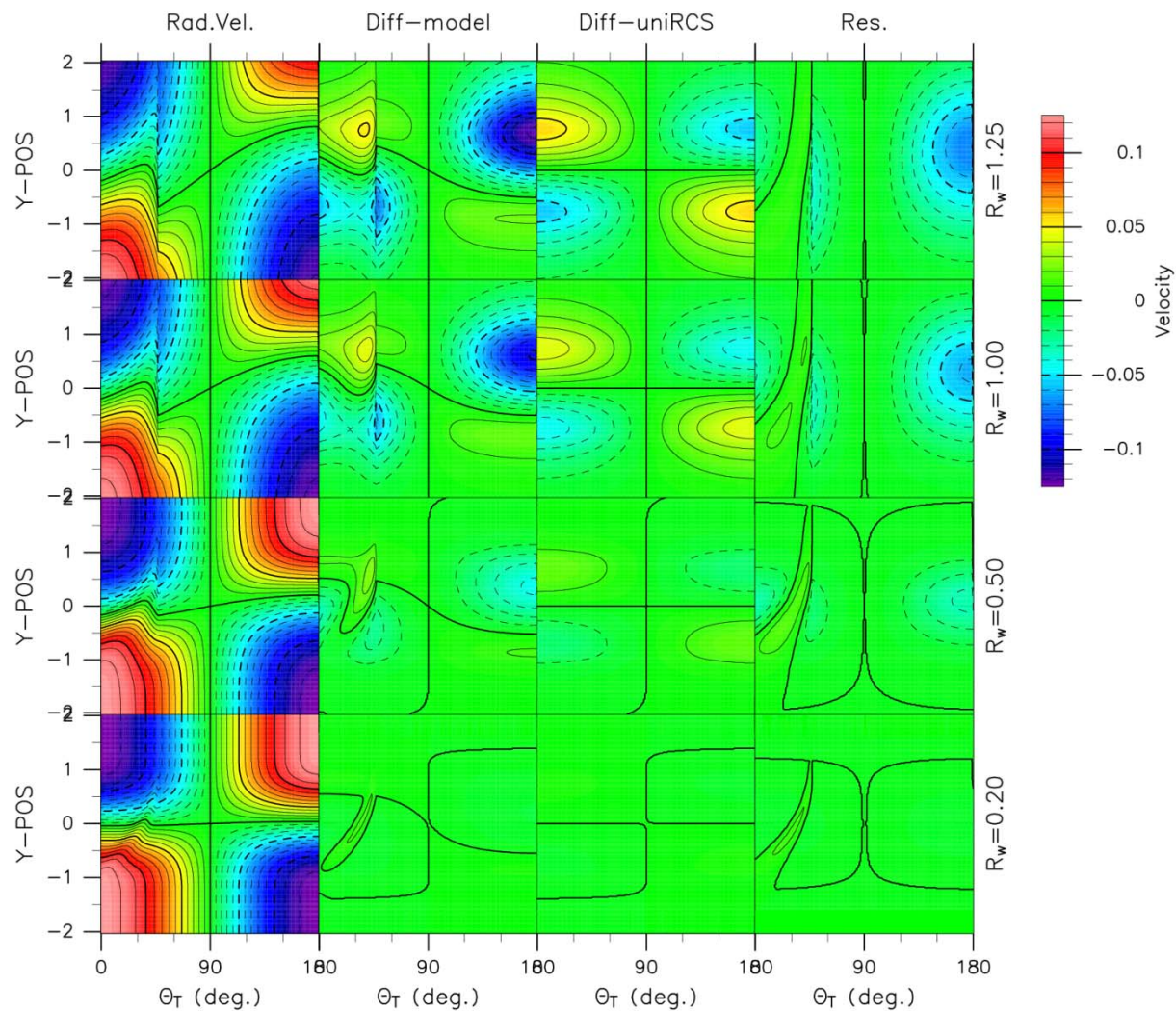
$$\phi = \begin{cases} 0 & \text{Shear front,} \\ \frac{\pi}{2} & \text{Divergence front,} \\ -\frac{\pi}{2} & \text{Convergence front.} \end{cases}$$

θ_T : Angle between the velocity axis and the propagation direction of the causal ocean waves of the first-order echoes

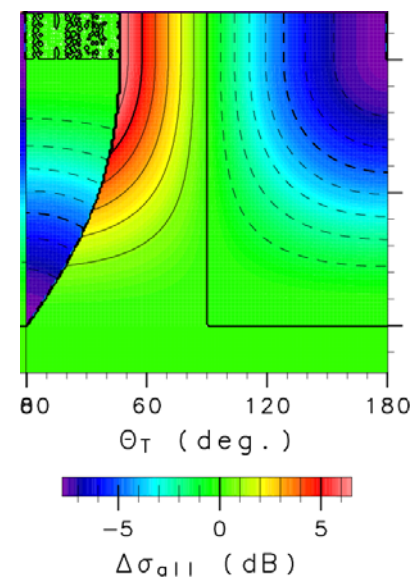
Radar Cross Section ($U_\phi/Cp = 0.125$, $\phi = 0^\circ$)



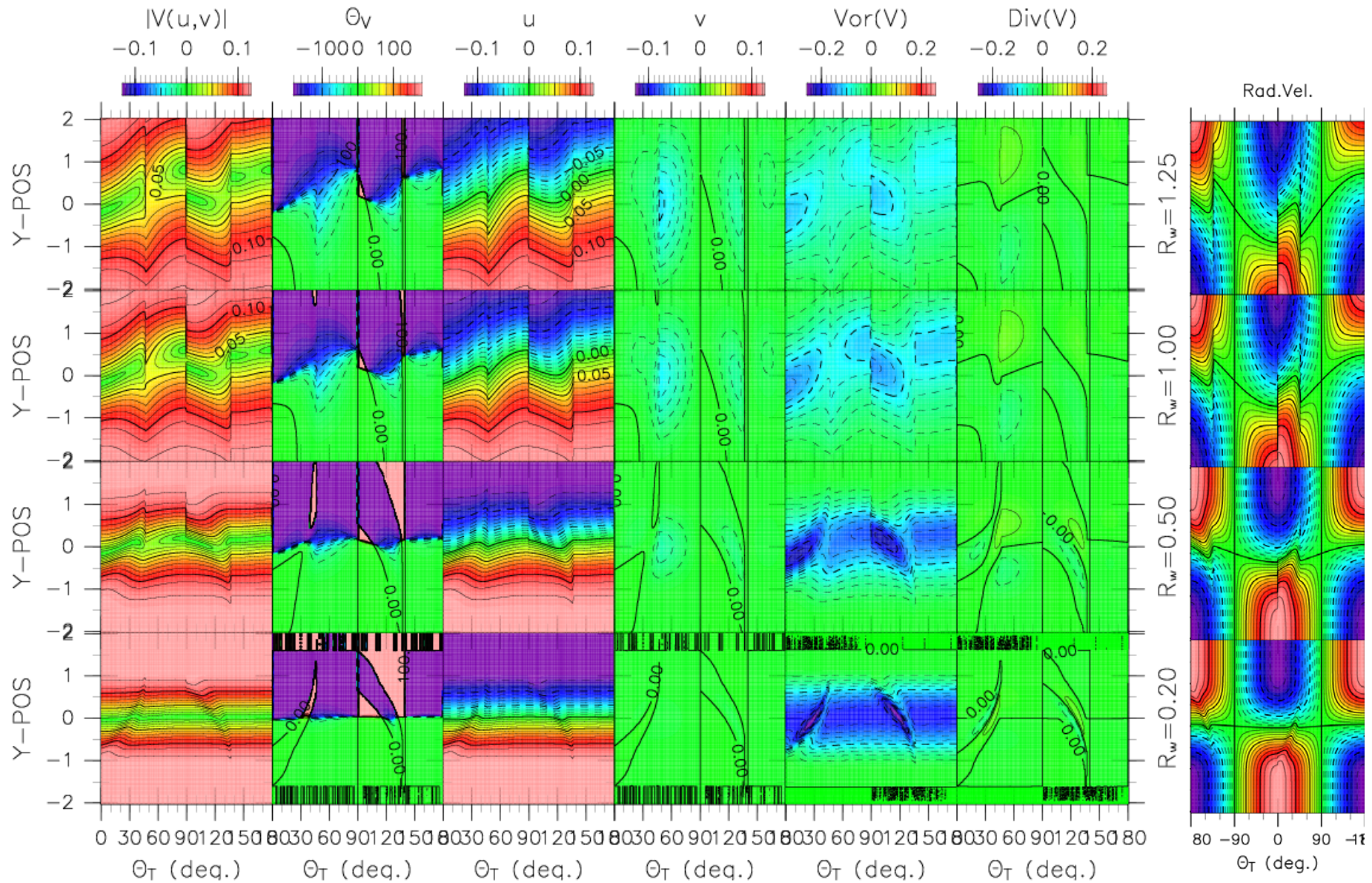
Radial Current ($U_\infty/C_p = 0.125$, $\phi = 0^\circ$)



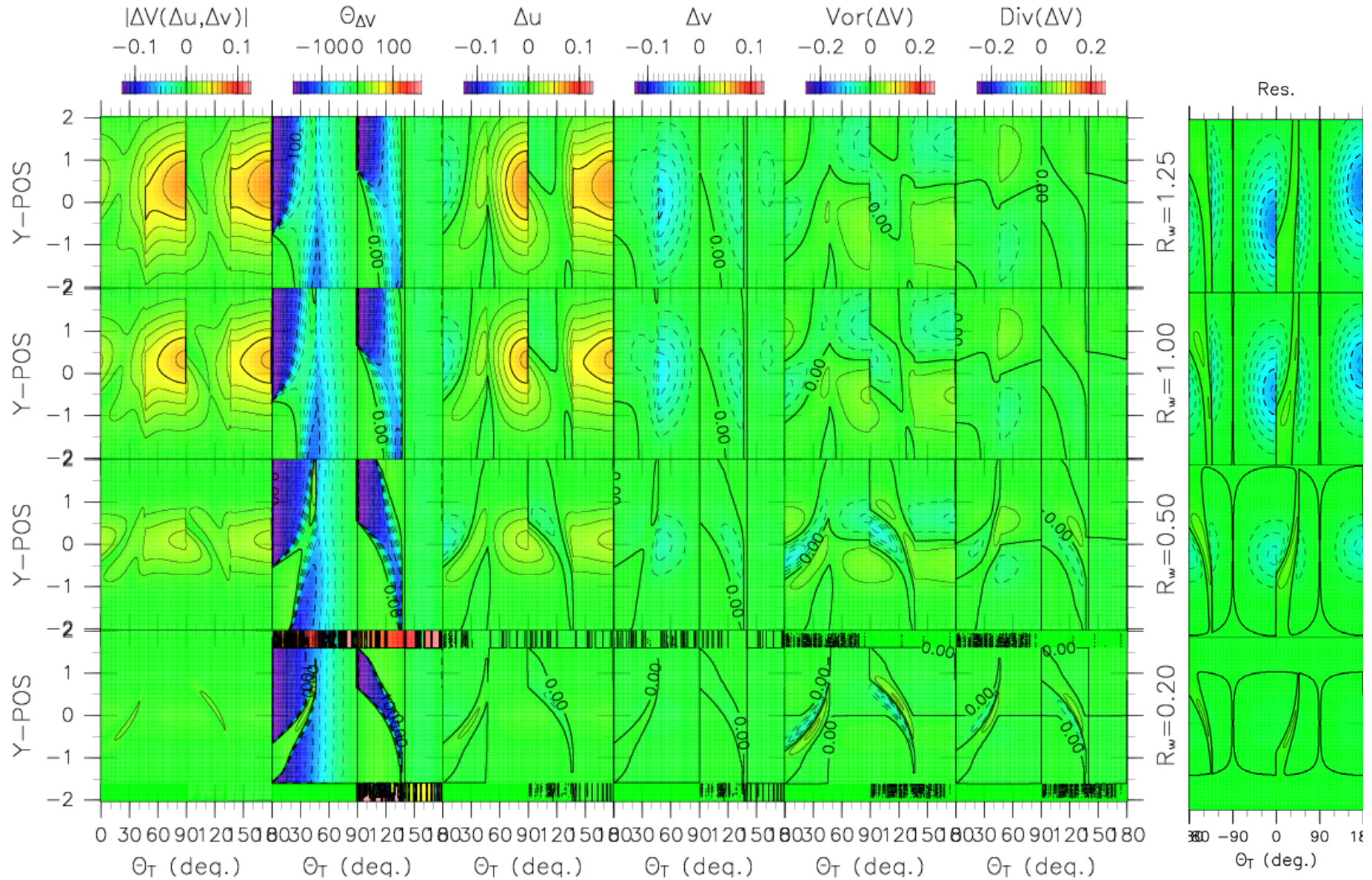
NRCS



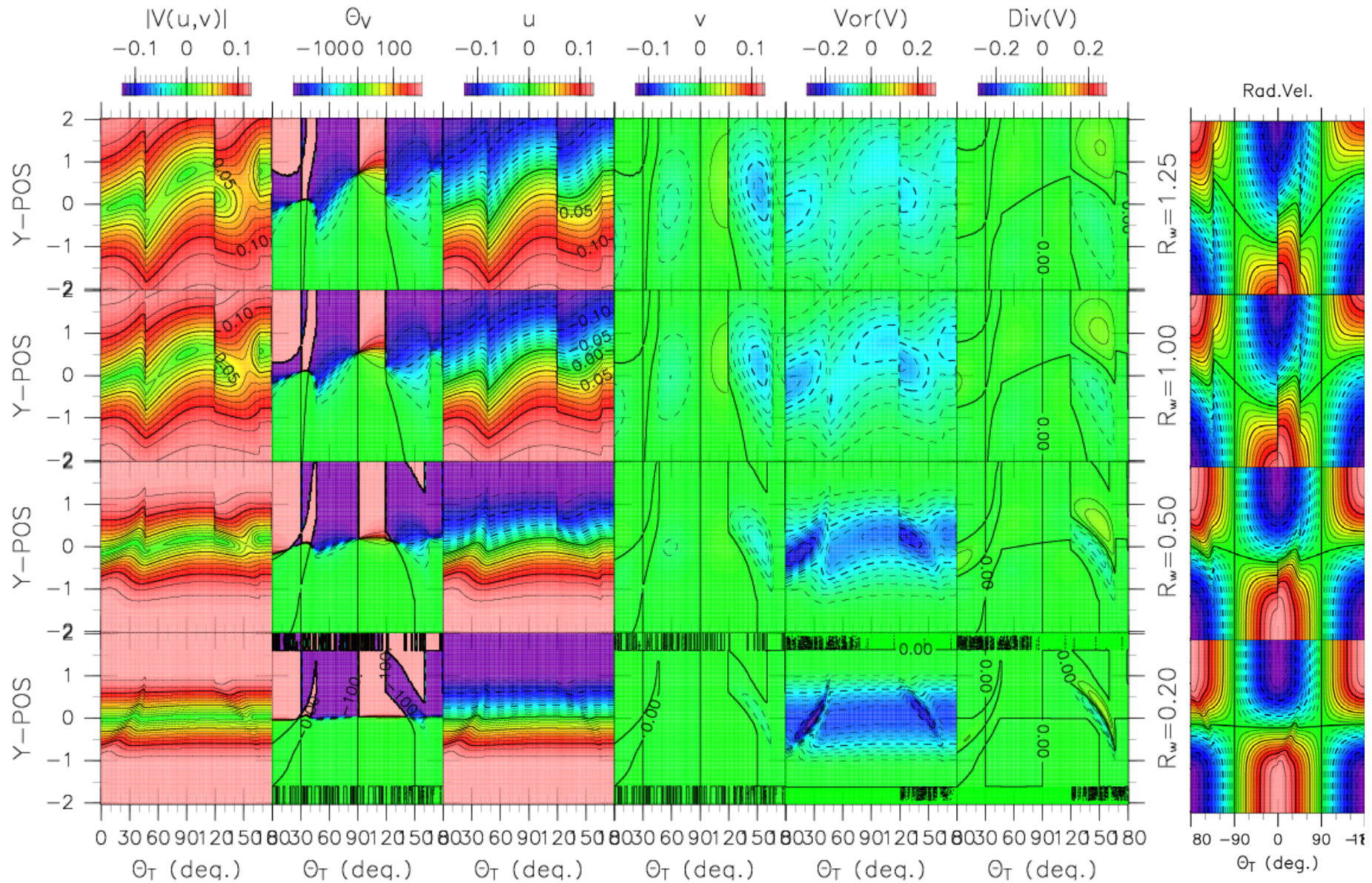
Current Field ($U_o/C_p = 0.125$, $\phi = 0^\circ$, Cross angle= 90°)



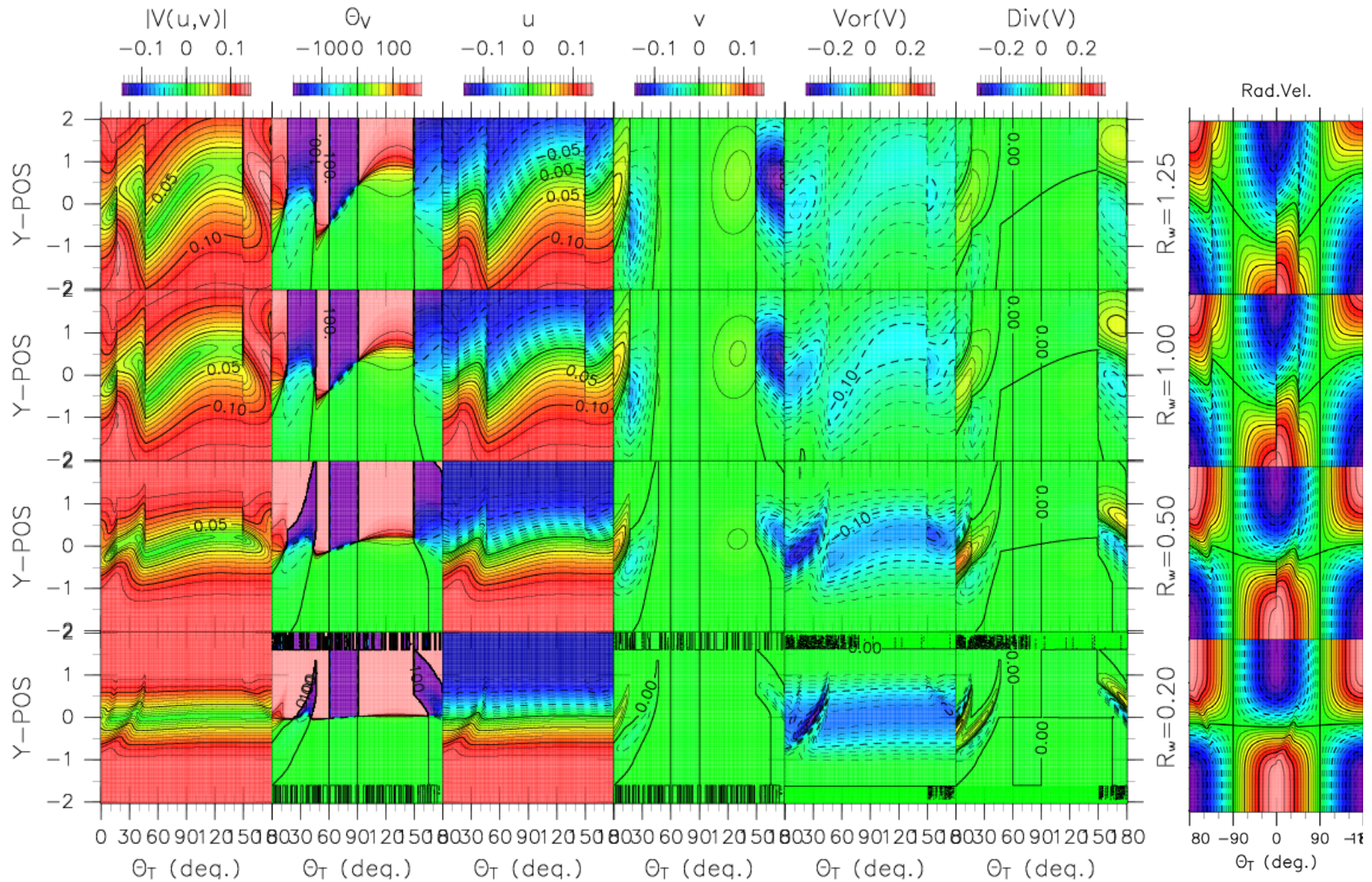
Current Field ($U_o/C_p = 0.125$, $\phi = 0^\circ$, Cross angle= 90°)



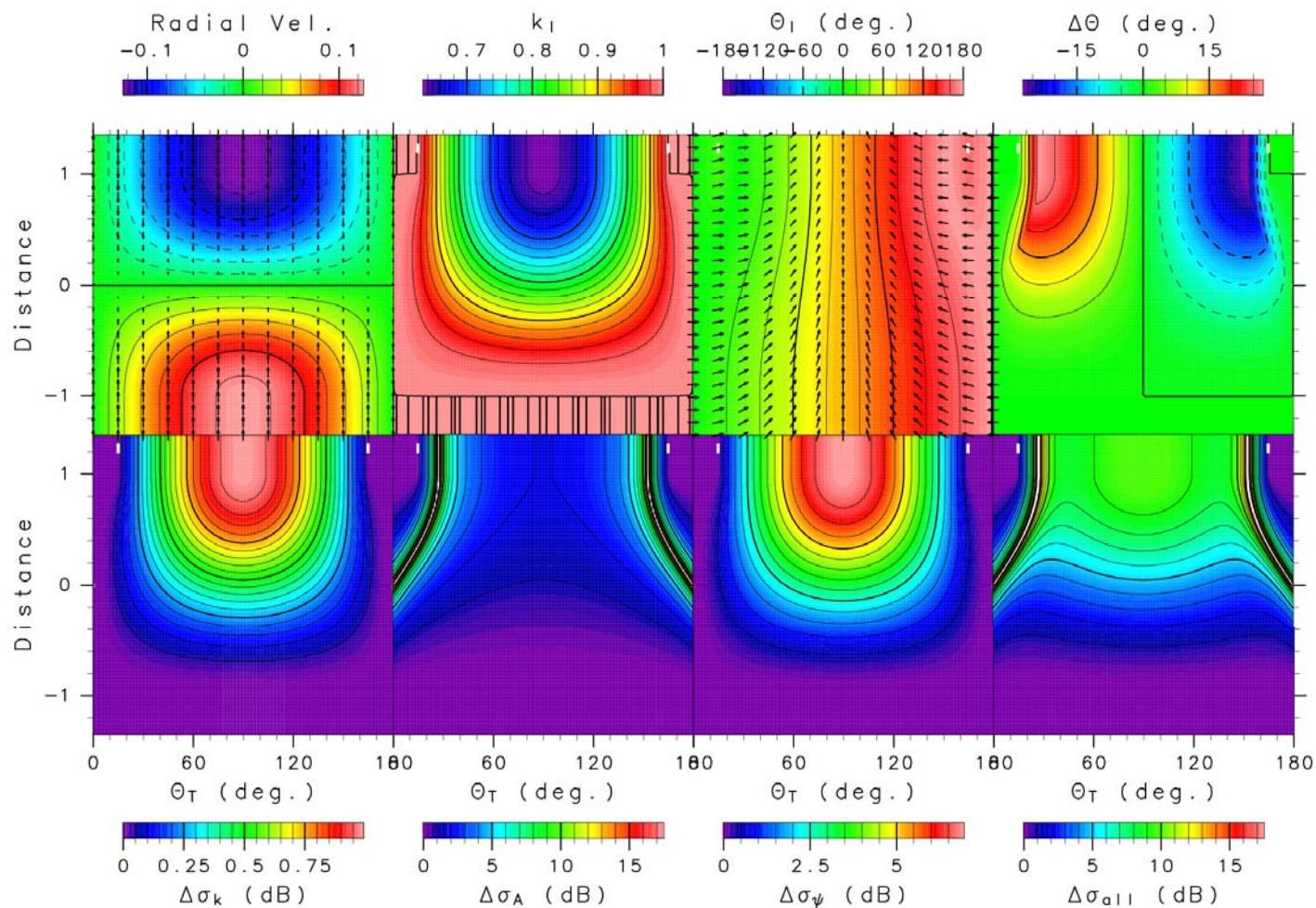
Current Field ($U_o/C_p = 0.125$, $\phi = 0^\circ$, Cross angle= 60°)



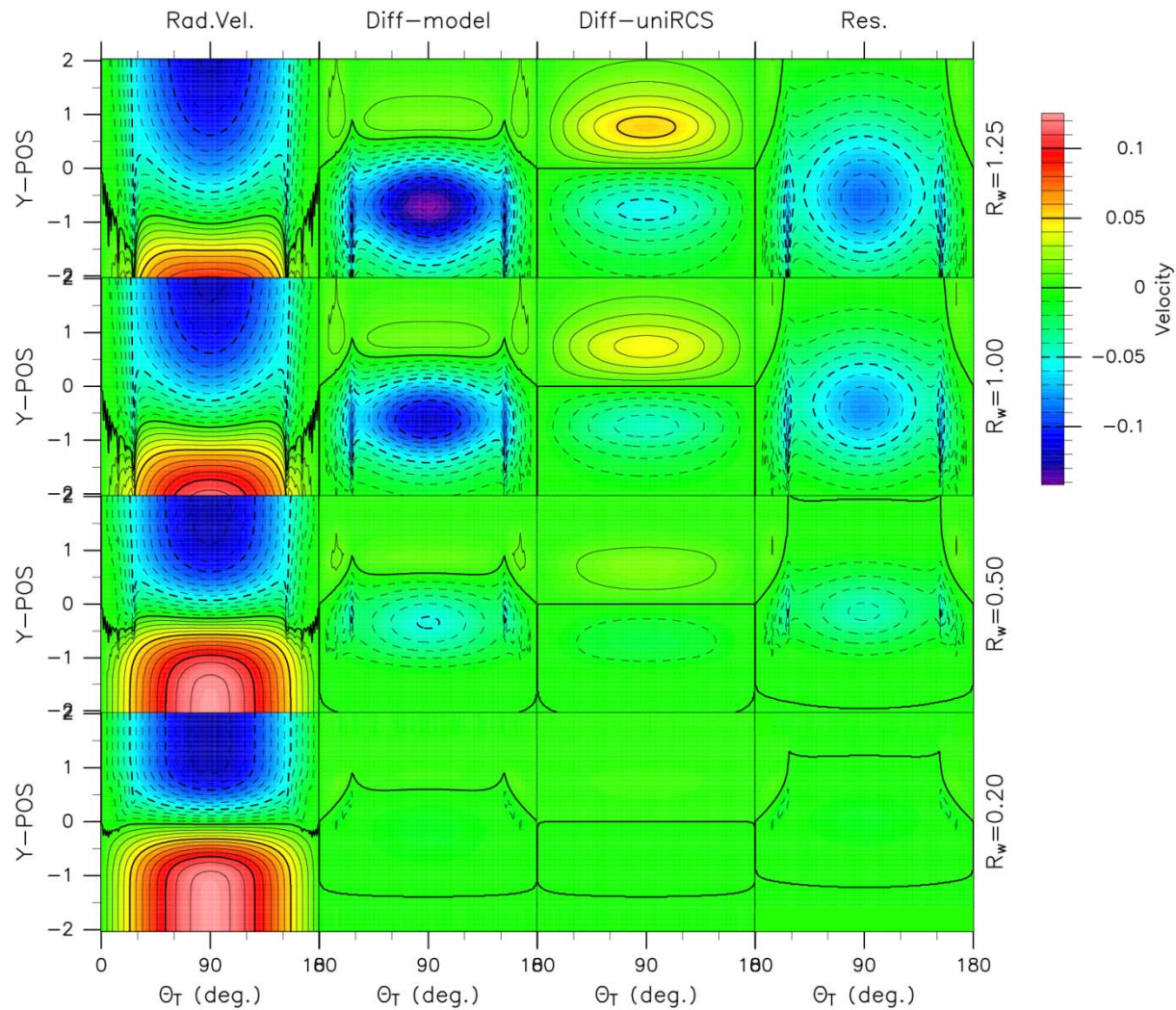
Current Field ($U_o/C_p = 0.125$, $\phi = 0^\circ$, Cross angle= 30°)



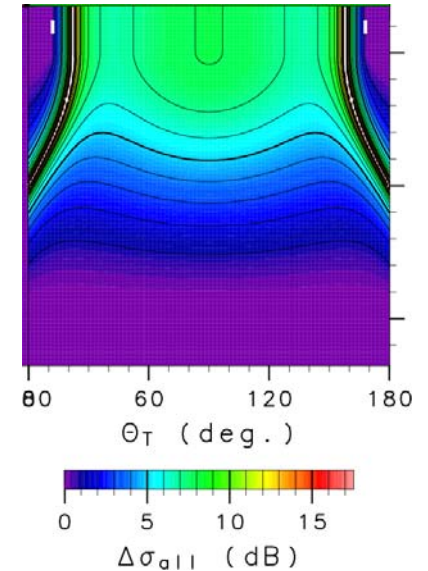
Radar Cross Section ($U_o/Cp = 0.125$, $\phi = -90^\circ$)



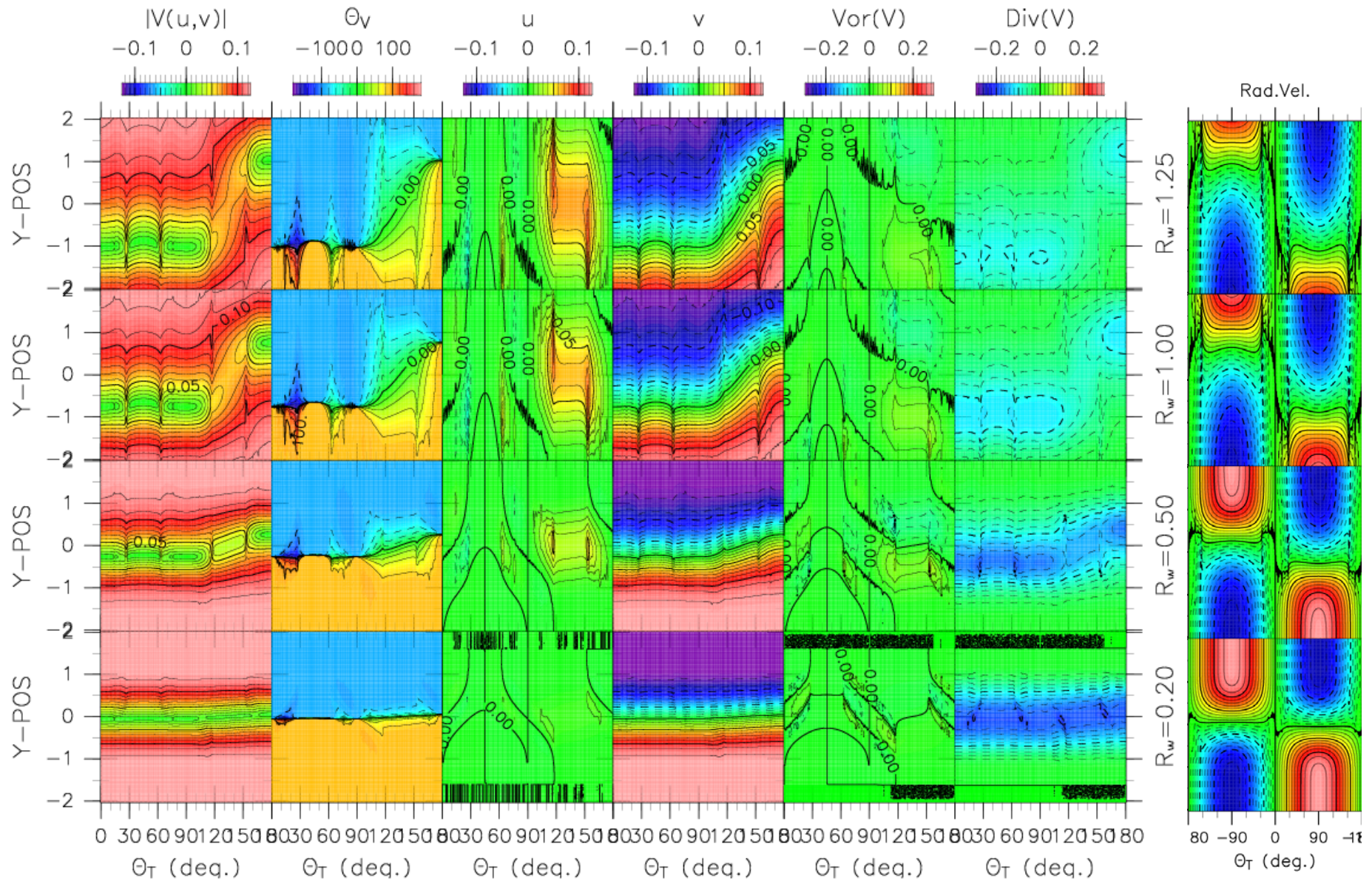
Radial Current ($U_\sigma/Cp = 0.125$, $\phi = -90^\circ$)



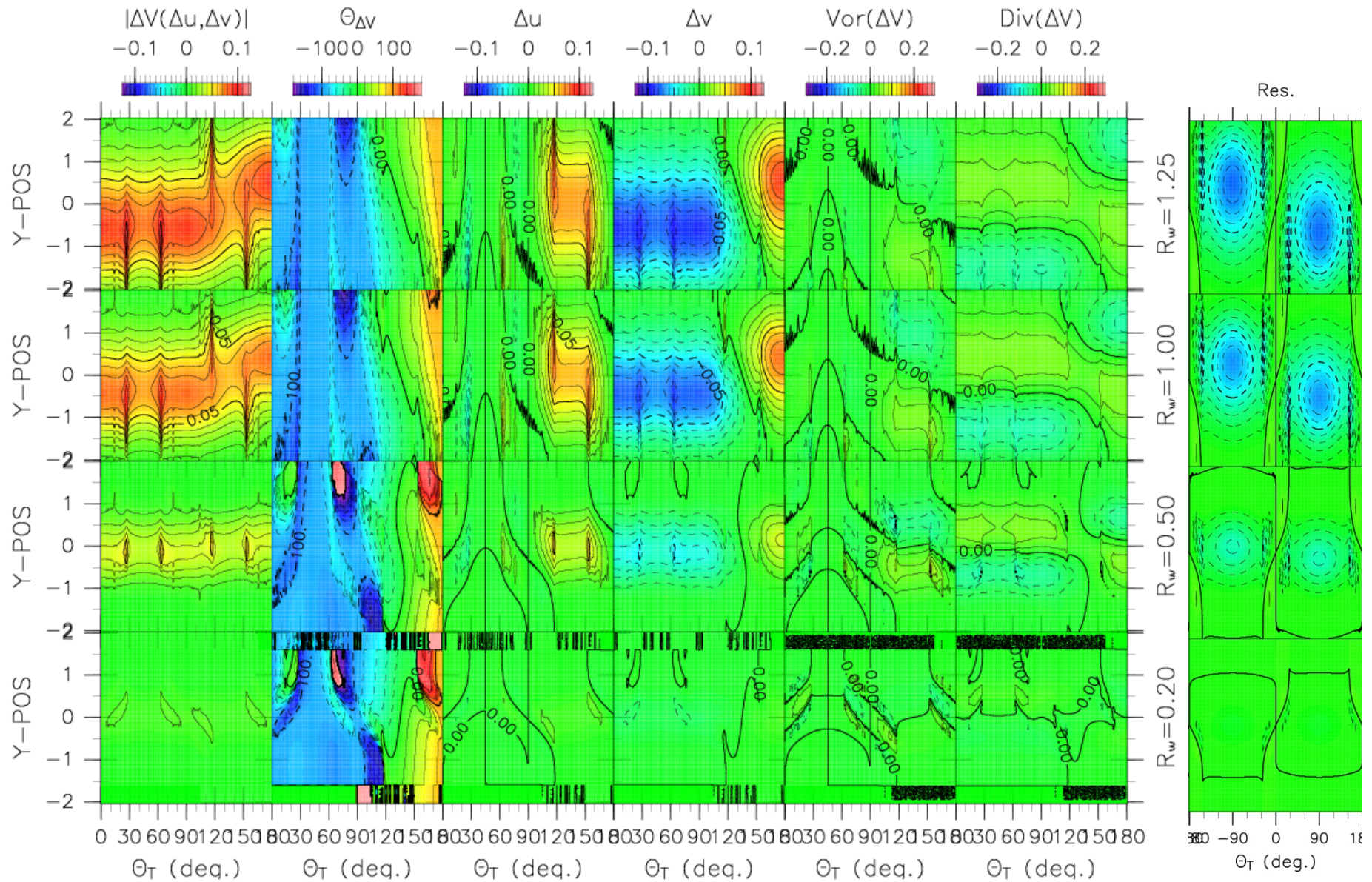
NRCS



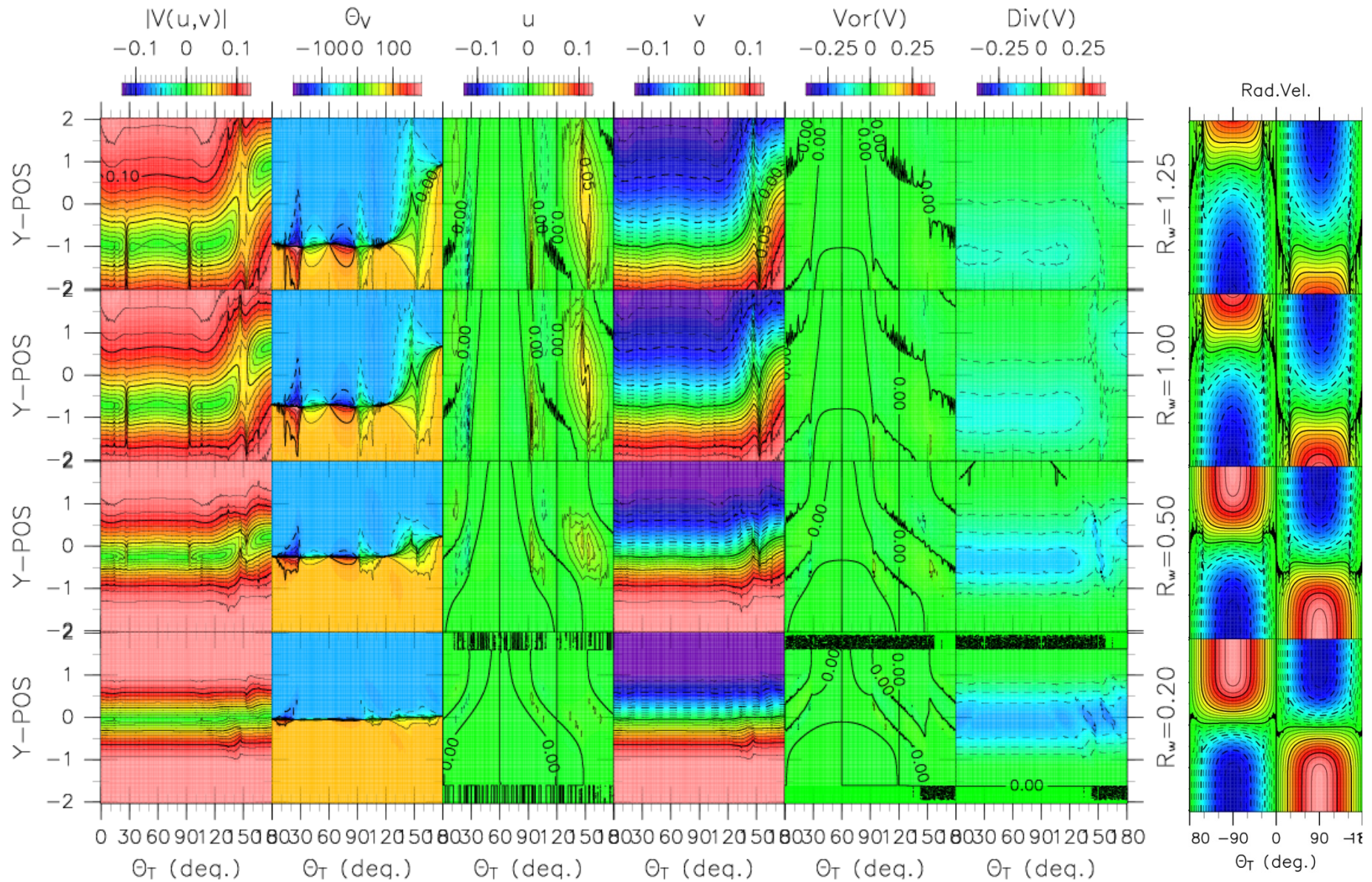
Current Field ($U_\phi/Cp = 0.125$, $\phi = -90^\circ$, Cross angle= 90°)



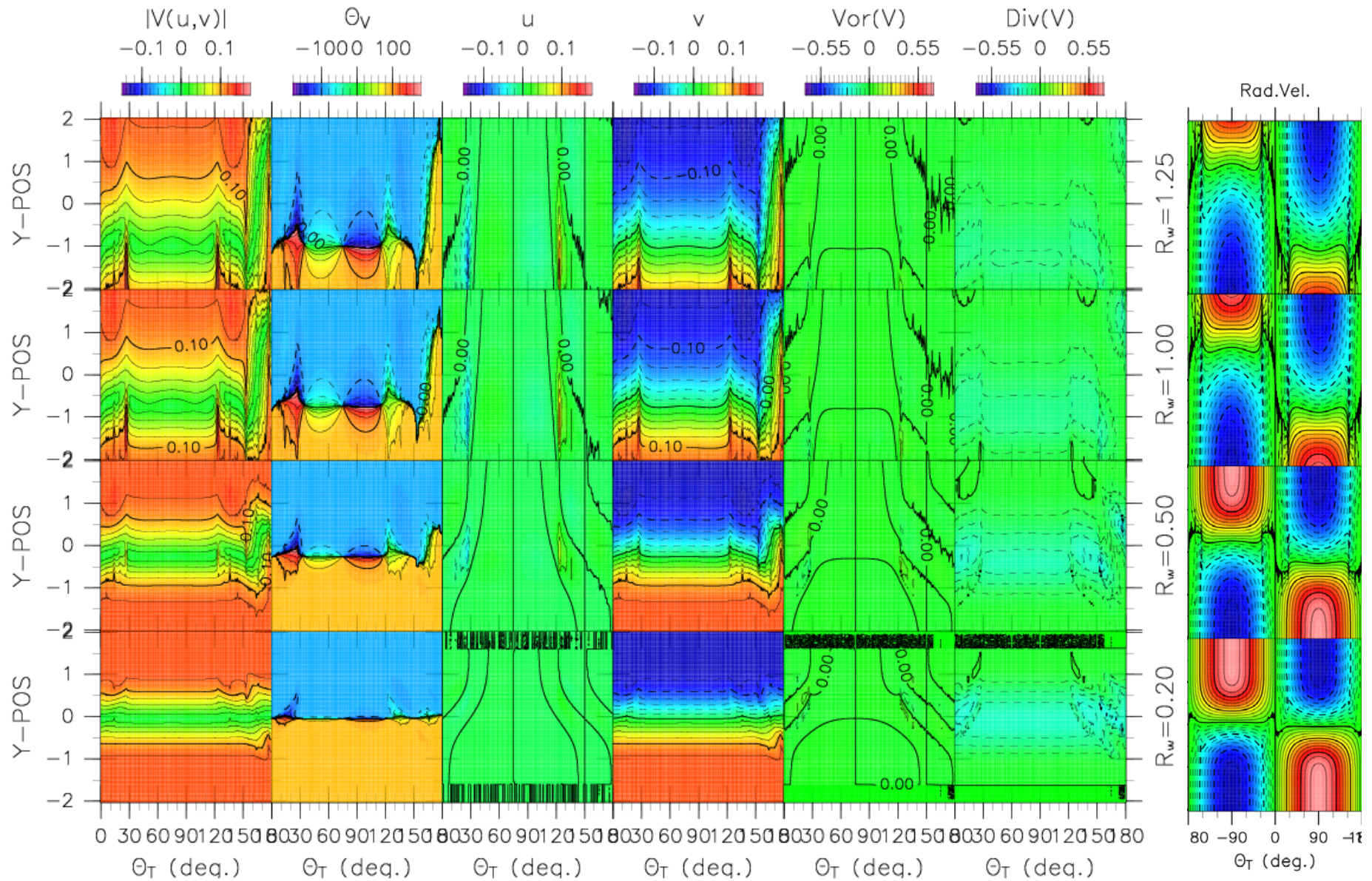
Current Field ($U_\phi/Cp = 0.125$, $\phi = -90^\circ$, Cross angle= 90°)



Current Field ($U_\phi/Cp = 0.125$, $\phi = -90^\circ$, Cross angle= 60°)



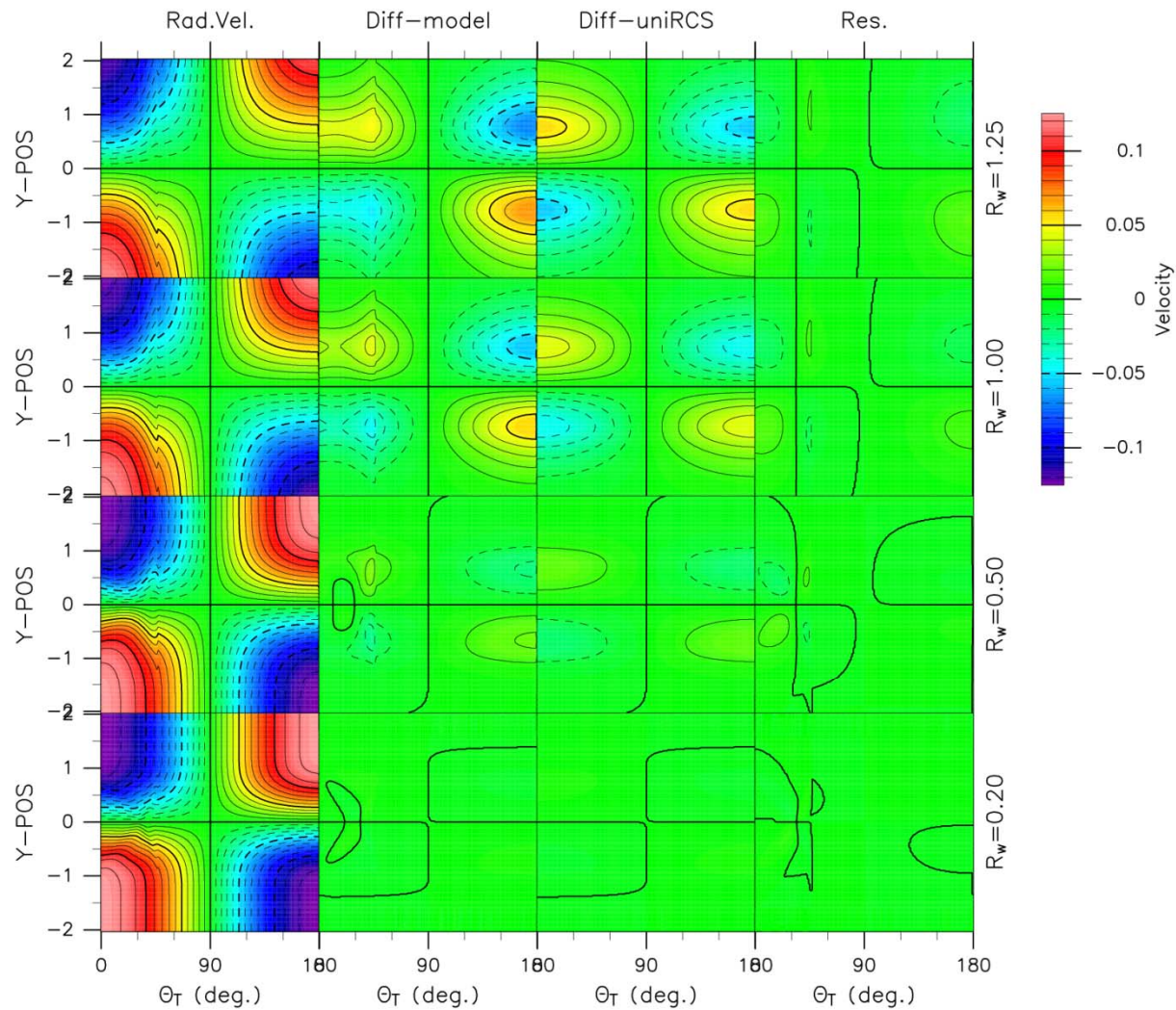
Current Field ($U_\phi/Cp = 0.125$, $\phi = -90^\circ$, Cross angle= 30°)



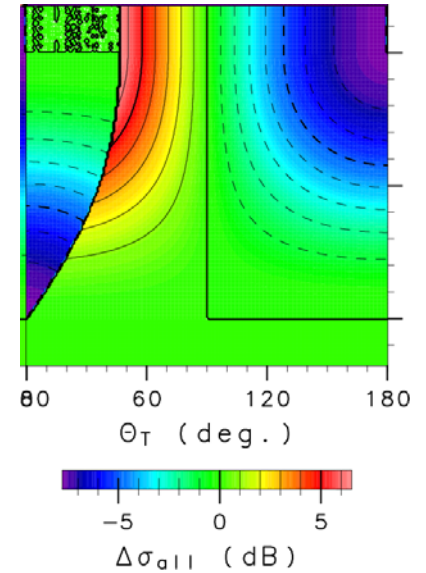
Conclusion

- 流速場の空間変化により、一次散乱エコーに寄与する海洋波成分のスペクトル密度に空間変化が生じ、一次散乱エコーに対するレーダ散乱断面積を変化させる。
- 一次散乱エコーのスペクトル形状は、レーダ散乱断面積とレーダ感度により重みづけられた視線方向流速の空間平均であるため、レーダ散乱断面積と視線流速の空間変化により視線流速には計測誤差が生じる。
- 直線状のフロントを短波海洋レーダで観測した場合には、流速ベクトル計測に誤差を生じる。その計測誤差は、フロント軸の位置、流速分布に計測誤差としてあらわれる(収束発散および渦度分布の歪みや偽成分)。
- フロント幅に対するレーダ感度分布が広いほど、流速ベクトル計測誤差は大きい。
- 流速ベクトル計測誤差は、ベクトル合成時の交差角にも依存する。

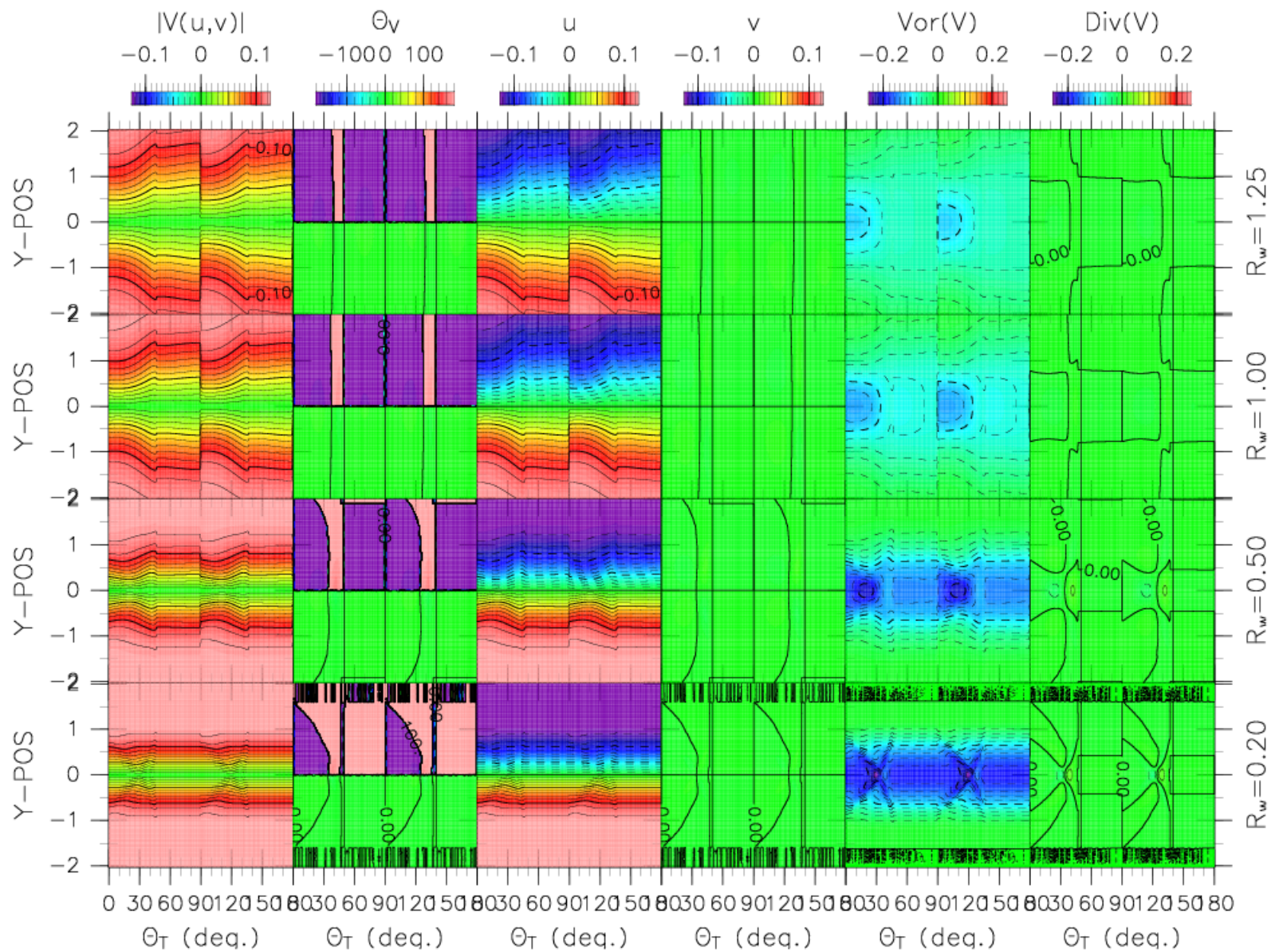
Radial Current ($U_o/C_p = 0.125$, $\phi = 0^\circ$)



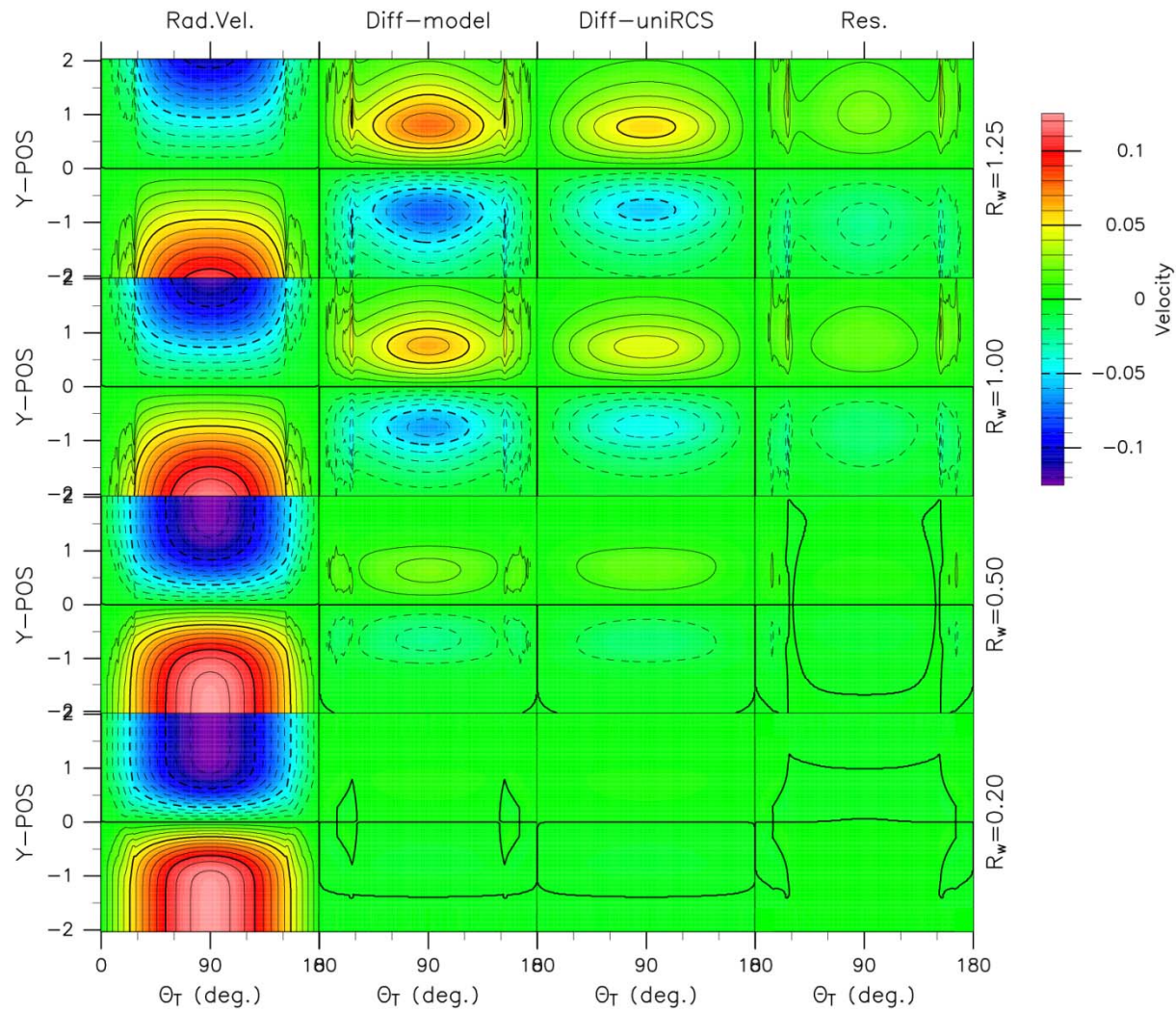
NRCS



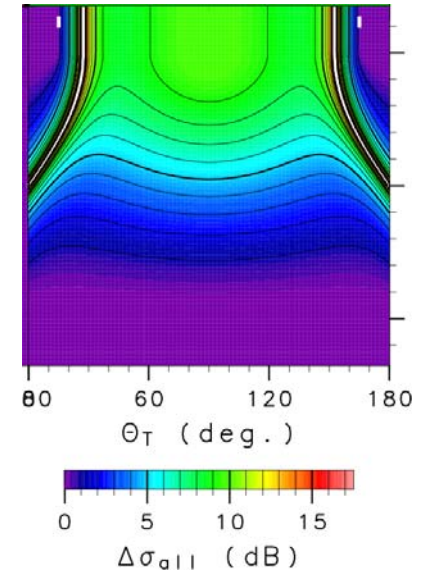
Current Field ($U_\phi/Cp = 0.125$, $\phi = 0^\circ$, Cross angle= 90°)



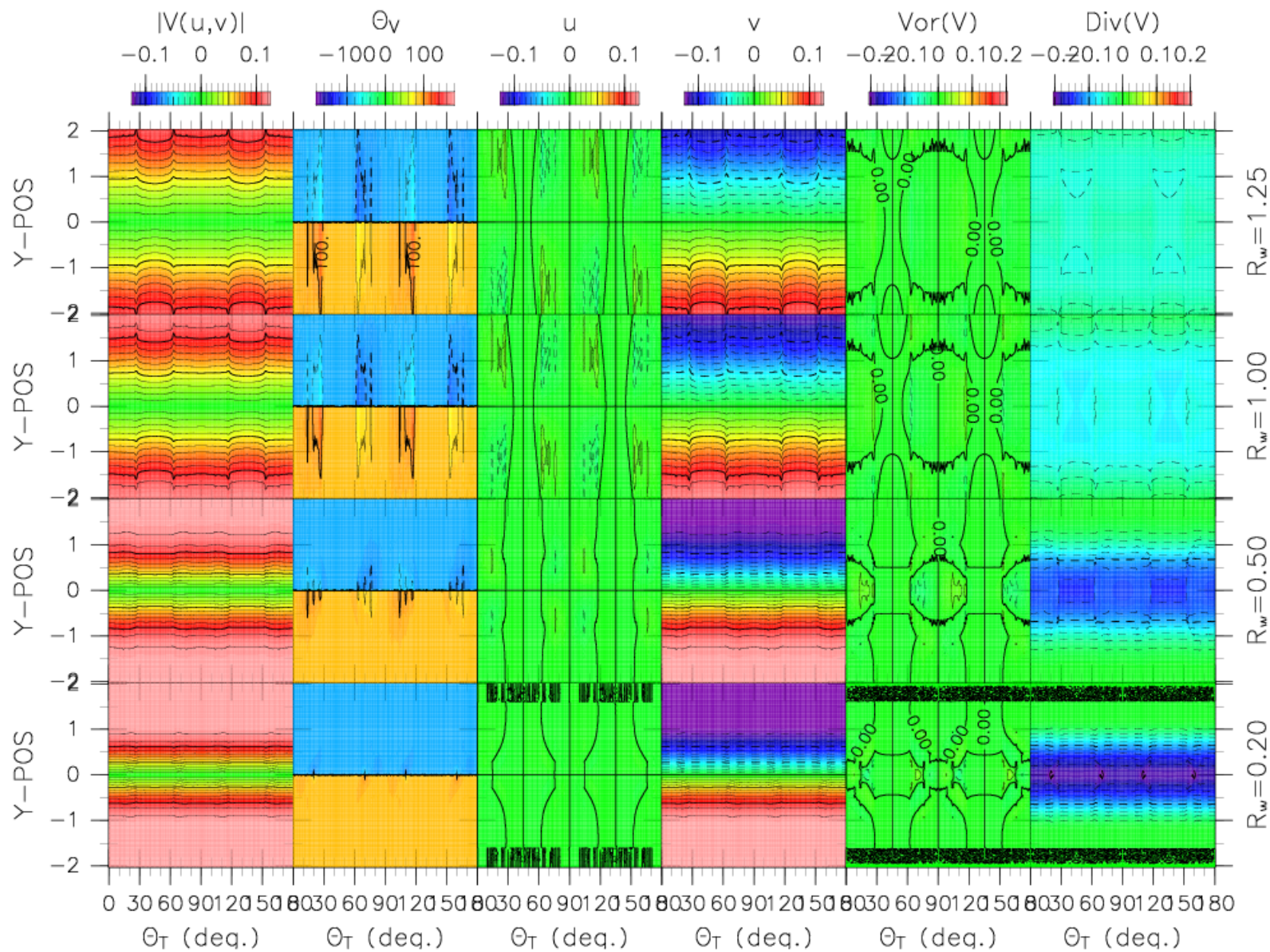
Radial Current ($U_\infty/C_p = 0.125$, $\phi = -90^\circ$)



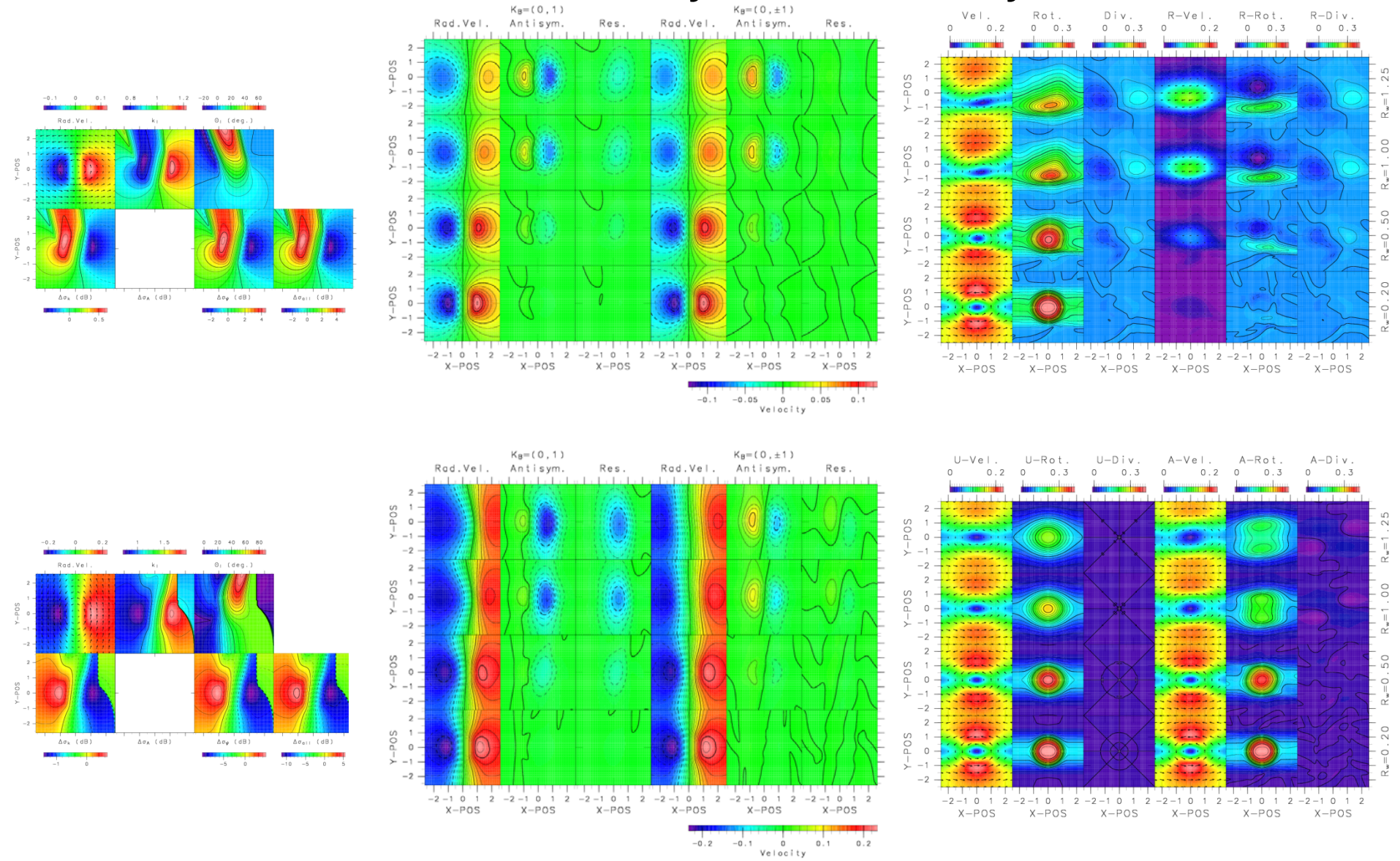
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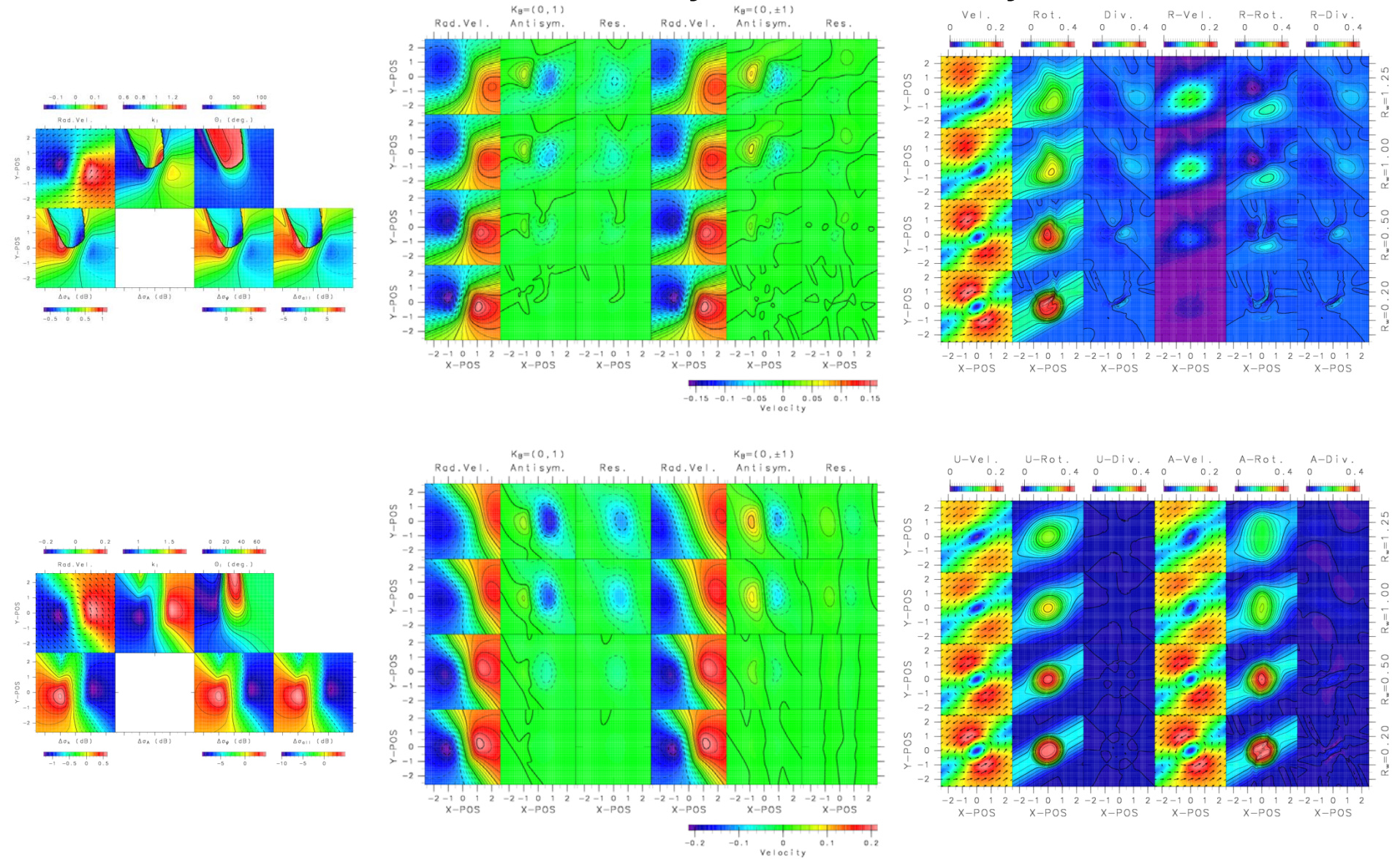
Current Field ($U_\phi/Cp = 0.125$, $\phi = -90^\circ$, Cross angle= 90°)



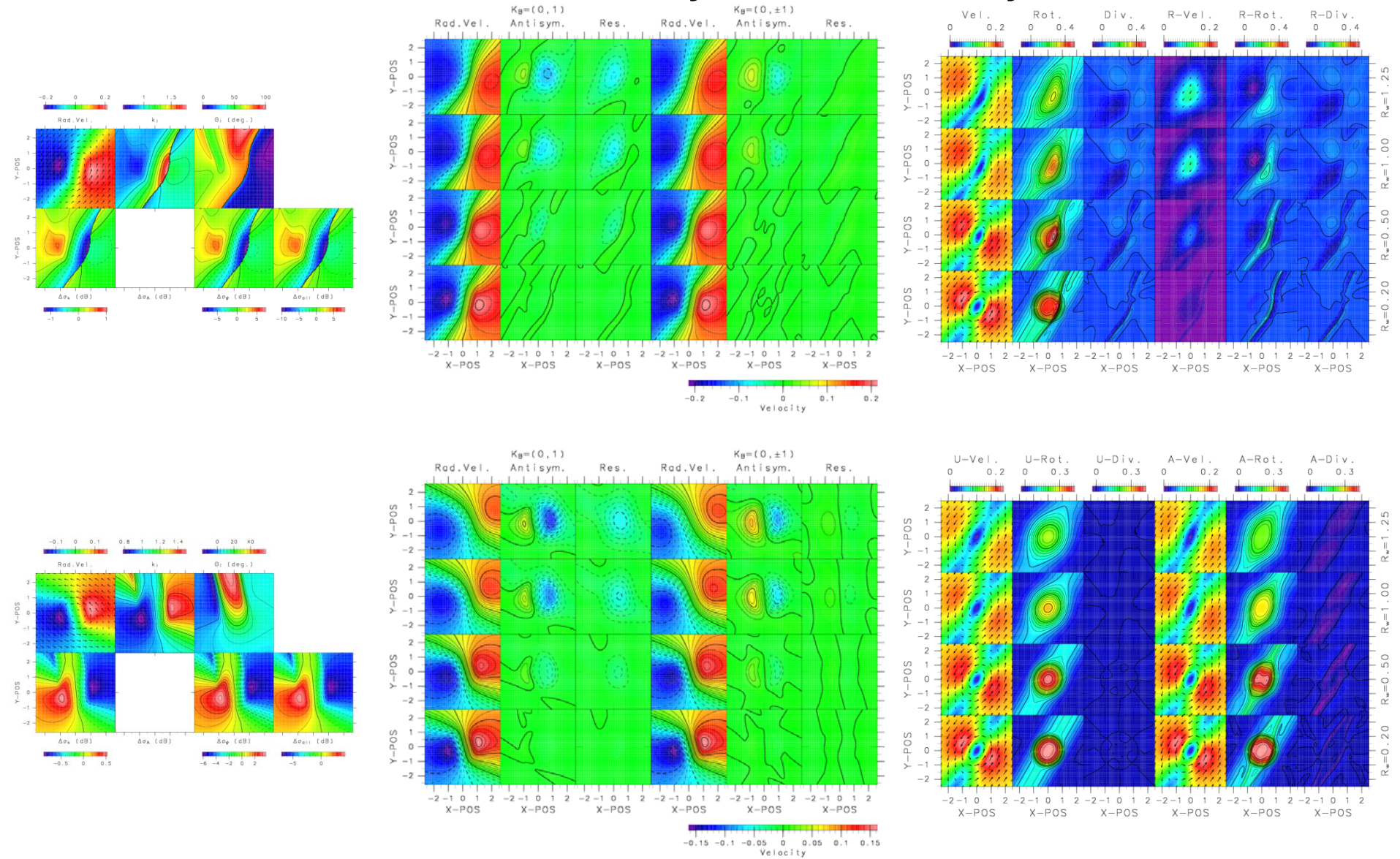
Results for velocity front with eddy -1



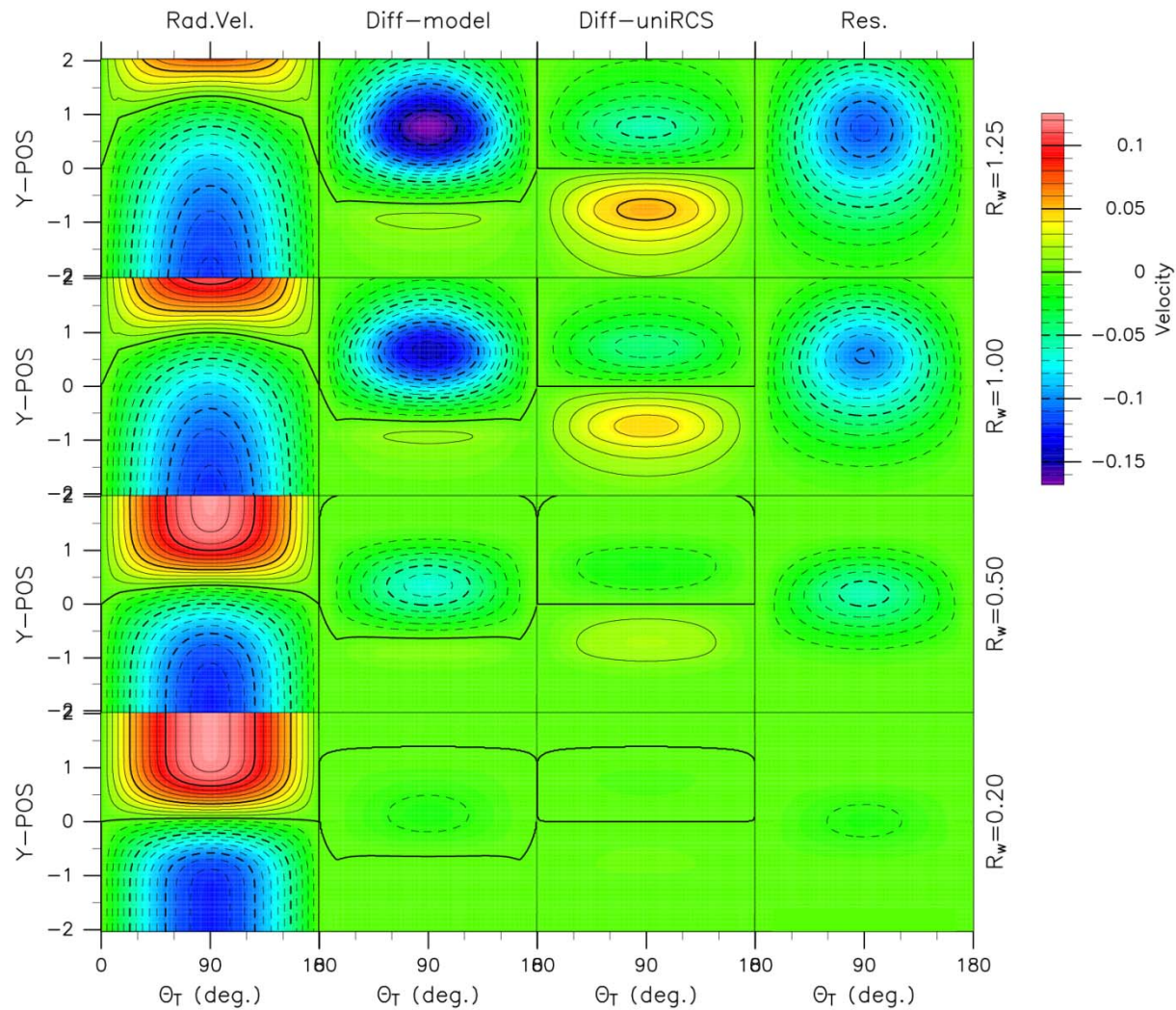
Results for velocity front with eddy -2



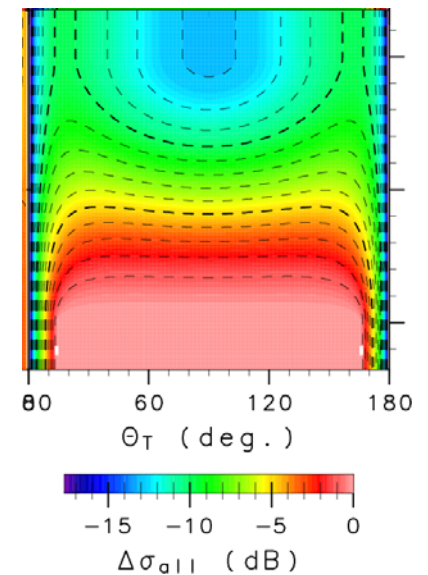
Results for velocity front with eddy -3



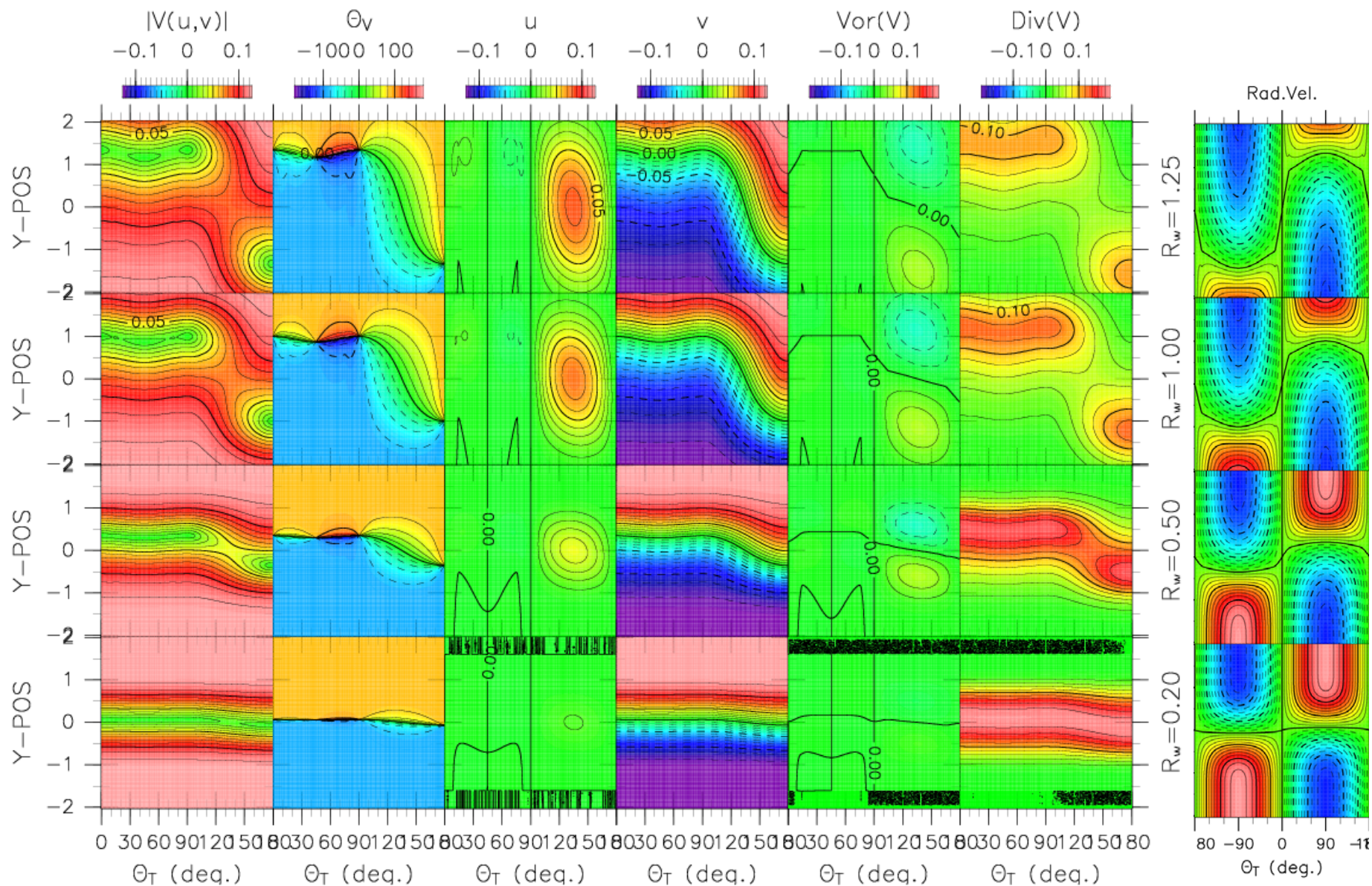
Radial Current ($U_\infty/C_p = 0.125$, $\phi = 90^\circ$)



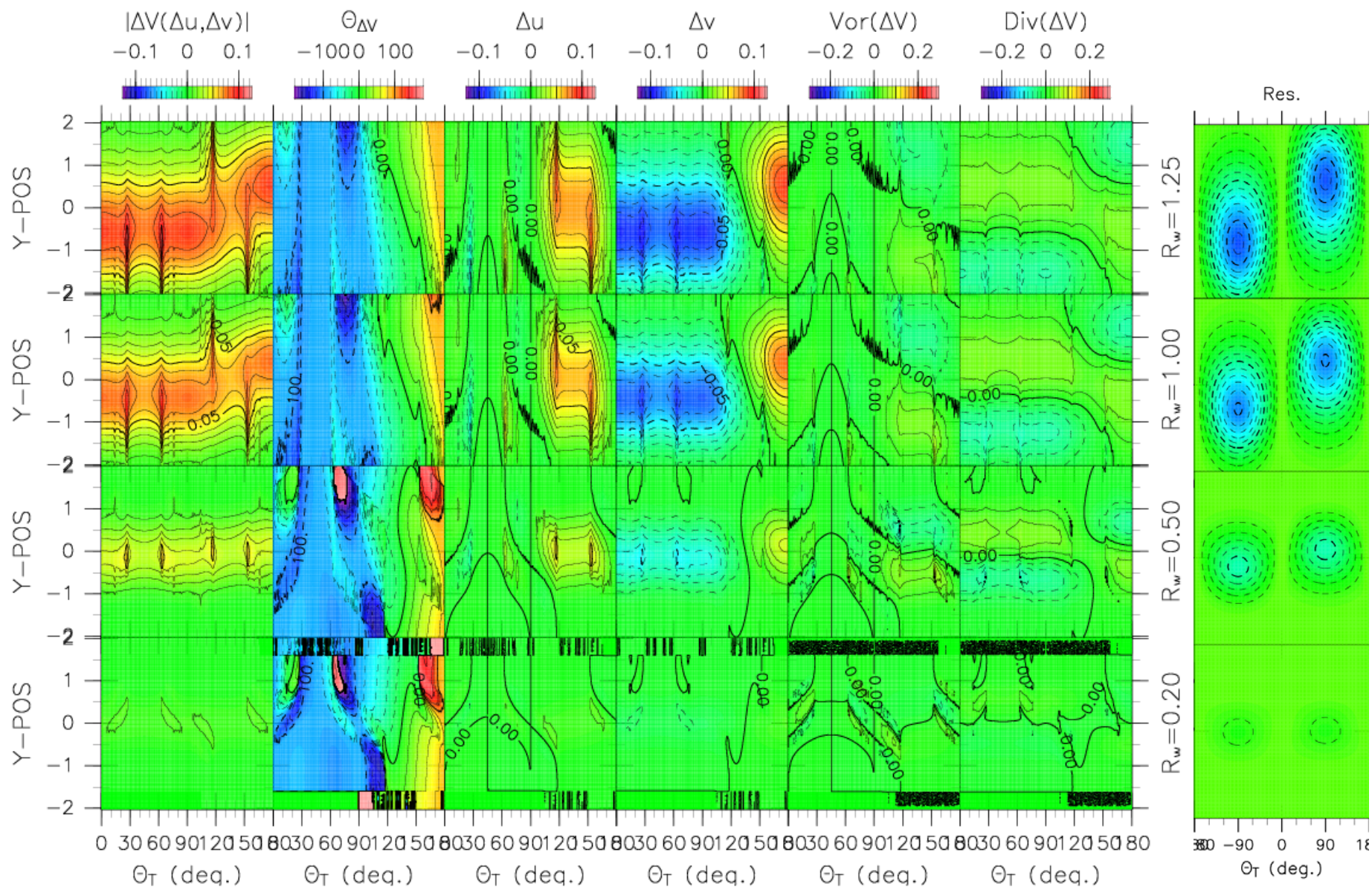
NRCS



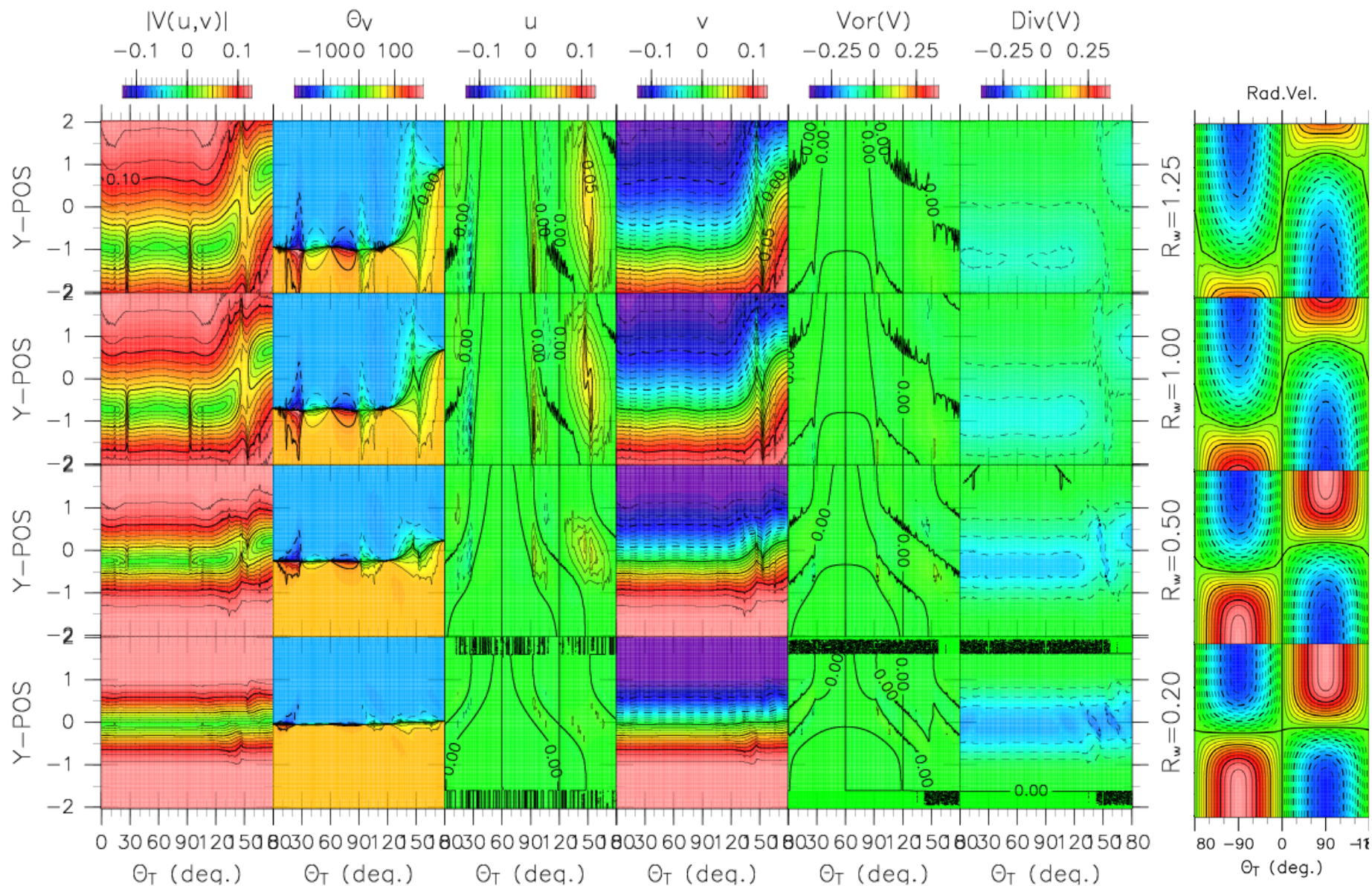
Current Field ($U_\phi/Cp = 0.125$, $\phi = 90^\circ$, Cross angle= 90°)



Current Field ($U_\phi/Cp = 0.125$, $\phi = 90^\circ$, Cross angle= 90°)



Current Field ($U_\phi/Cp = 0.125$, $\phi = 90^\circ$, Cross angle= 60°)



Current Field ($U_\phi/Cp = 0.125$, $\phi = 90^\circ$, Cross angle= 30°)

