2015-04-25 Akatsuki Workshop on
Cloud Tracking for Venus at ISAS

Discussion matrial: Rough estimates for cloud tracking with Akatsuki

Takeshi Horinouchi（Hokkaido Univ）

Simple math on required accuracy and resolution

- At UV, Δt is up to a few hours
  - Experience with VEX data: difficult to identify small-scale cloud features to the next orbit (after 15 h or later)
  - Let's suppose $\Delta t = 3$ h $\sim 10^4$ s
    - Δt may be larger if we can utilize streaks well?
    - Remark: zonal movement 10°-20 ° in 1 h, and nightside is not observable
  - How about NIR?
- Δx at sub-spacecraft point (SSP)
  - VEX VMC: 50 km at apogee (In IH15, used 20-40 km)
  - Akatsuki: 60 km at apogee if at 3e5 km, 90 km if at 4.5e5 km.

⇒ Discretization error of U,V

  - $\Delta x/\Delta t$=4 m/s if Δx=40km , 8 m/s if Δx=90 km

- Desired accuracy (next page)
  - 2-3 m/s (at the resolution of 1000 km) – want sub-pixel accuracy.

Rough evaluation of desired accuracy

- Backgroud vorticity ζ~ 10^{-5} s^{-1} at 30°. 1/10 of *f* on the Earth. (if barotropic, ζ is conserved, so ζ has similar magnitude regardless resolution, roughly speaking)

⇒ want to resolve shear of $Z \equiv 10^{-6}$ s^{-1} to resolve disturbances

- If we want to observe disturbances with 1/wavenumber ～ 10^3 km, resolution *X* should be ~ 10^6 m

⇒ required wind accuracy U = X/Z = 1 m/s. (ideal)

  - Practical requirement ~ 2-3 m/s ?
  - Note: desired accuracy of velocity depends on scale.

To study eddy momentum flux at the cloud level (to examine the ang.mom. balance to maintain climatological wind distribution)

- Suppose barotropic cond., the leading balance is $\partial_\varphi (m v + m' v') = 0$. ($m \equiv ua\cos\varphi$, bar: zonal mean)

⇒Scale relation: $M V / L = M' V' / L$

  – suppose L : distance, say, between EQ & 45°, V: scale of v at 45° (note: $v = 0$ at EQ, if circulation is symmetric)

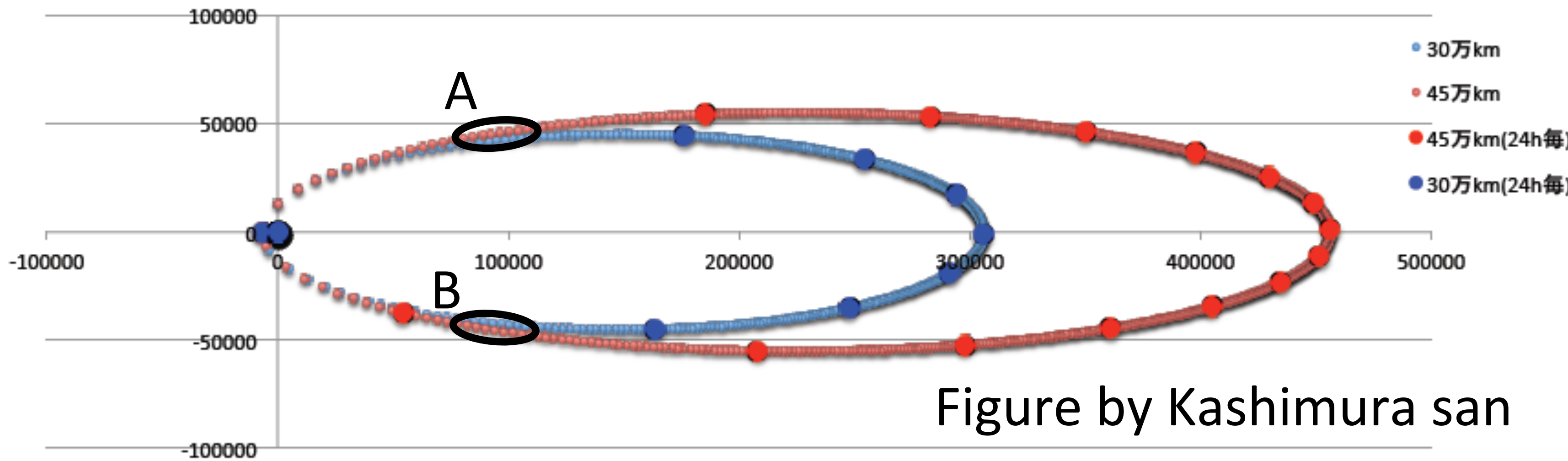
  – M: scale of $m \cos\varphi$ at 45°⇒ $M \sim 0.7 Ua$ (a: radius, U=100 m/s)

  – M', V' : scales of m', v'

  – $U' \equiv M' / a$: scale of u'

  – ⇒ $U' V' = 0.7 UV$。If we suppose $V = 1$ m/s, $U' V' = 70$ m²/s²。If $U' = V'$, $U' = V' \sim 8$ m/s.

For high resolution observation of the full disk



- At distance ~ 1e5 km → full disk obs with Δx ~ 10km.
- Can secure ~3-h window → Good for cloud tracking.
  - Unable with VEX
- Don't miss this opportunity! Want Δt=30min → ~ 7 images

(Discussion material)
Survey of cloud tracking algorithms: iterative method

Takeshi Horinouchi

(Hokkaido Univ.)

Iterative PIV

- Widely used.
- First procedure: use a large target sub-image to search correspondence over a wide area.
- Second procedure: use a small target sub-mage to increase the accuracy (using a narrower search area).

Example:

From Xylar et al (2009) *Icarus*, for Jupitor

CIV : Correlation Image Velocimetry (Fincham and Spedding, 1997),

Xyler et al (2009) takes a further step ("ACCIV").

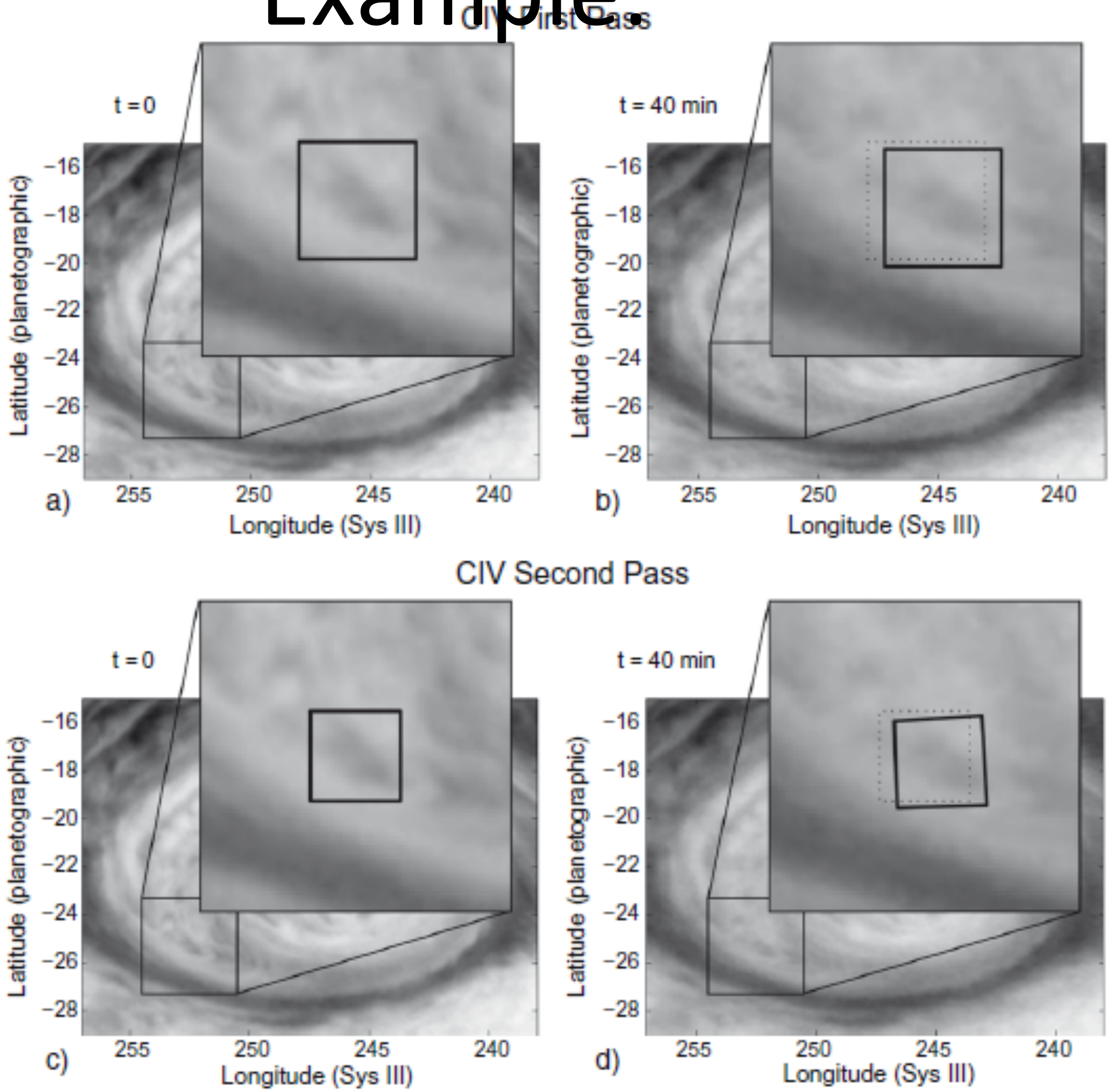


Fig. 27. Correlation boxes in the first pass (a) and (b) and second pass (c and d) of the CIV algorithm. (a) The inset shows the correlation box of pixels from the first image at $t = 0$ as a solid line. (b) The inset shows the second image at $t = 40$ along with the same *untranslated* correlation box from (a) (dotted line) and the *translated* correlation box, corresponding to $t = 40$ (solid line). (c) In the second CIV pass, a correlation box of pixels from the first image (usually smaller than the correlation box in the first pass) at $t = 0$ is shown with a solid line in the inset. (d) In the inset, the location in the second image of that same and *untranslated and undistorted* correlation box as in (c) (dotted line) and the *translated and distorted* location of that box at $t = 40$ (solid line).