DETERMINATION OF ONSET TIMES OF LOW-LATITUDE Pi2 MAGNETIC PULSATIONS

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Introduction

In this study, to understand details of Pi2 and other related phenomena, we focus on "Pi2 onsets".

Until now, most people have used filtered data to identify the Pi2 onset time ; however, the usage of filtered data tends to bias the onset time.(See Fig1) Therefore, we have constructed two methods (Method-1 and -2 below) which use raw data and compared their results.

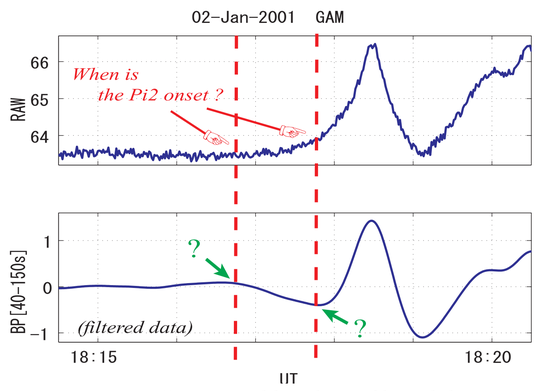


Fig.1) Raw and bandpass filtered data with Pi2 magnetic pulsation

Initial perturbation of Pi2

From our previous study, we are convinced that there exists a non-periodic fluctuation at Pi2's initial stage, which we call an "*initial perturbation*". (See Fig.7)

Pi2 magnetic pulsations

* One of the magnetic pulsations which occur in the magnetosphere.
* Wave period ranges from 40 to 150s.
* Waveform is irregular.
* Its occurrence is believed to coincide with substorm onset. → It has been known as a good indicator of the onset of substorm.

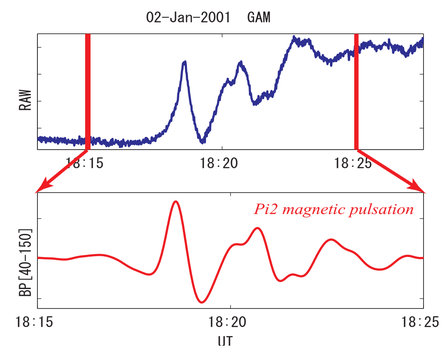


Fig.2) Example of the Pi2 magnetic pulsation

Determination of "Pi2 onset"

"～pt(=Pi2) starts with dH/dt > 0 in the middle or low latitude～" (Saito,1961)

According to this definition, in the middle or low latitude, the Pi2 onset time of a raw H-component time-series data is defined as the point where differential values of adjacent data start to show a positive excresion. (In this study, we used differences instead of differential value.)

Study

<Method-1>

This method uses such assumption that Pi2 is described by "initial perturbation+quasi-periodic" oscillation.

We apply the time-series analysis which was introduced by Higuchi et al.[2002](*Pi2 onset time determination with information criterion*), and determine the Pi2 onset time to be the time where the oscillations start.

* We use the following two models in this Method-1 :

$$\begin{cases} Model\text{-}1 : H_n = t_n + w_n & \cdots\cdots \text{A smooth variation of the background magnetic field(tn) + noisy component(wn)} \\ Model\text{-}2 : H_n = t_n + w_n + q_n & \cdots \text{Model-1 + an oscillating component(qn=Pi2)} \end{cases}$$

We divide raw H-component data into two subintervals, fit Model-1 to the former sub-interval, and fit Model-2 to the latter. The best separation point which is determined by the AIC(Akaike Information Criterion) is regarded as the optimal start point of qn=Pi2 component.

→ This time point is identified as the Pi2 onset time. (See Fig.3)

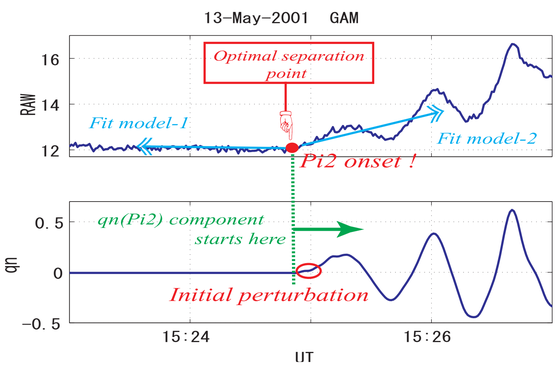


Fig3.) Example of Method-2

* In this paper, we employ the following functional forms :

$$\begin{cases} t_n = 2t_{n-1} - t_{n-2} + v_n^t \\ q_n = 2\cos(2\pi f_c \Delta t) q_{n-1} + q_{n-2} + v_n^q \end{cases}$$

(f_c : frequency of the Pi2 pulsation; Δt : sampling interval(=1); v_n : system noise which follows a Gaussian distribution)

The wave frequency is designed to gradually increase from fc/2(at the start of qn) up to fc (at the end of the first one cycle of qn).

→ qn can simulate the "initial perturbation - then quasi-periodic oscillation".

<Method-2>

The second procedure directly relies on the definition of the Pi2 onset(Saito,1961) .

First, we take differences of raw H-component magnetic data and extract its trend component(we call it diff-trend data ; See Fig.4, middle panel).

Then, we search the time when the variation of the diff-trend data turns positive. The definition by Saito says that this is the Pi2 onset time.

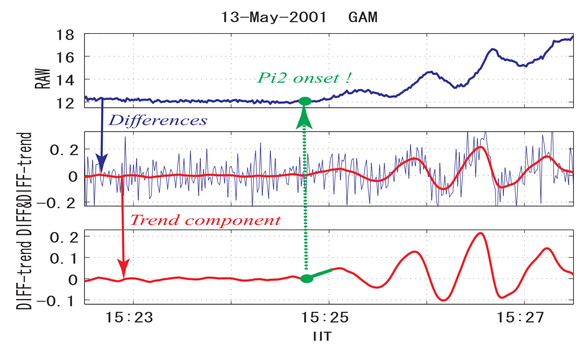
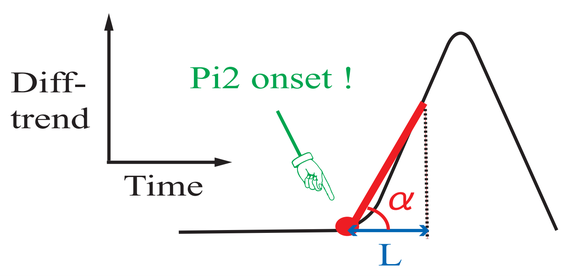


Fig.4) Example of Method-2

In this method, we use the Bayesian statistical inference to estimate Pi2 onset more accurately and objectivity.

To be specific, we use a straight line segment(red line ;See the following figure) whose optimal inclination(α) is determined by a Bayesian inference.

We move the start time of this segment from the beginning to the end of the time-series, and for each start time of the segment, we apply the line segment to fit the diff-trend data for a determination of its inclination, and then calculates ABIC(Akaike Bayesian Information Criterion) which controls the trade-off between the degree of goodness of fitting and the preference on a steeper slope ; finally, we choose the start time which minimizes ABIC, and define it to be the Pi2 onset time.



The duration of this segment(L) is set 1/6 of the wave period of pulsation which is included in diff-trend data. (The wave period is roughly estimated from the auto-correlation function)

<Analysis>

1. We visually examined isolated Pi2 events, and found 61events.
   - Interval : Jan.2001-Dec.2002, LT19:00-04:00
   - Station : GAM (L=1.03,GMlat.=5.61[deg],GMlon=215.55[deg])
2. For each event, we determined the Pi2 onset time with two methods(Method-1 and -2).
3. We calculated the time lag between them.(See Fig.5) (Method-1's onset time - Method-2's one)
4. We demonstrate these result by a histogram. (See Fig.6)

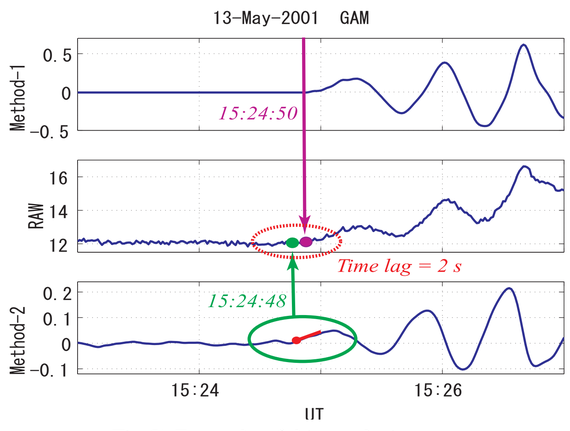
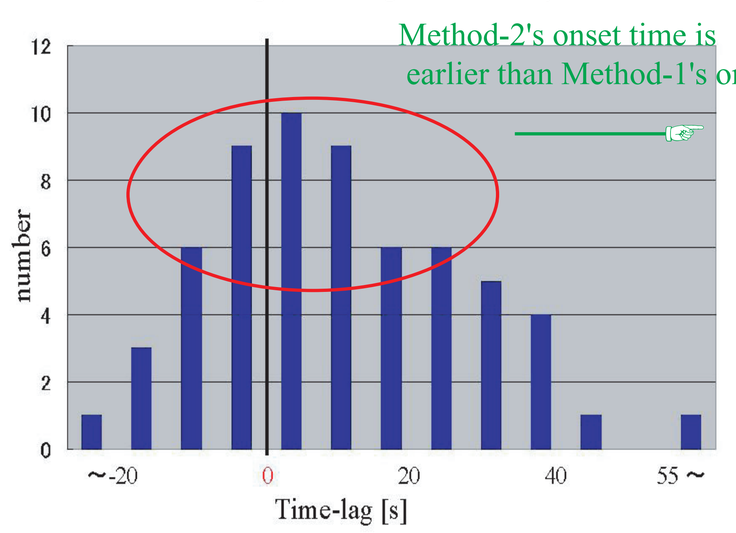


Fig.5) Example of this analysis
The top panel shows qn(Pi2) component and the bottom shows diff-trend data

<Result>

Fig.6) The histogram in this analysis



The time lag is centered around 0 second.
However, it shows a distribution from -10 to 20 s.

<Discussion & Conclusion>

Although qn needs to be further improved, our results indicate that Pi2's "initial perturbation" is very important in determining the Pi2 onset. Therefore, we think that it could give us a clue to the trigger mechanism of Pi2 and related phenomena, and it is our top priority to clarify characteristics of Pi2's initial perturbation.

Summary

In this study, we have constructed two methods to determine the Pi2 onset time, and suggested the importance of Pi2's "initial perturbation" from comparisons of their results.

There are two important aspects in our methodologies above : First, we used raw H-component data to avoid biases in the estimation of onset time due to characteristics of the filter itself. Second, we employed the information criterion both in the Method-1(which is along the line of previous approach by Higuchi et al.[2002]) and in Method-2(which is based on the Bayesian statistical inference). Therefore, we could make the estimation procedure more accurate and objective.

After this study, we plan to study the physical importance of Pi2's initial perturbation by statistically examining Pi2's at several stations(at wide range of latitudes).

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