Consequence Analysis of SO2 Emissions from Shisakajima Copper Smelter

Virtual WRF/MPAS Users' Workshop

9:00-9:15, June 8, 2022

1. Introduction:

・Location, ・Historical Events, ・WRF and Real Data at Yokohama National University

2. WRF and Historical Wind Data at Shisakajima:

・WRF Monthly Wind Data, ・Historical Wind Data, ・Historical Wind Data in 1915-1923

3. Consequence Analysis of SO2 Emission:

・Simulation by PHAST, ・Rice Plant Growth

4. Conclusion:

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Consequence Analysis of SO_2 Emissions from Shisakajima Copper Smelter

1. Introduction :

・In 1893, serious crop damage by a new copper smelter stack was recorded. In 1905, to avoid its payment of reparation, the smelter was relocated to Shisakajima, uninhabited island, 20km north.

・However adverse winds carried the smelter SO_2 gas over much more wide area, and peasants against hazardous gas increased.

・WRF meteorological data at Shisakajima were useful to support the historical data. Wind Rose Analysis (monthly) and Consequence Analysis of the gas was performed.

・Observed meteorological data at Yokohama National University, matched up well to WRF data (4km area) .

1. Introduction:
1.1 Shisakajima Copper Smelter Location

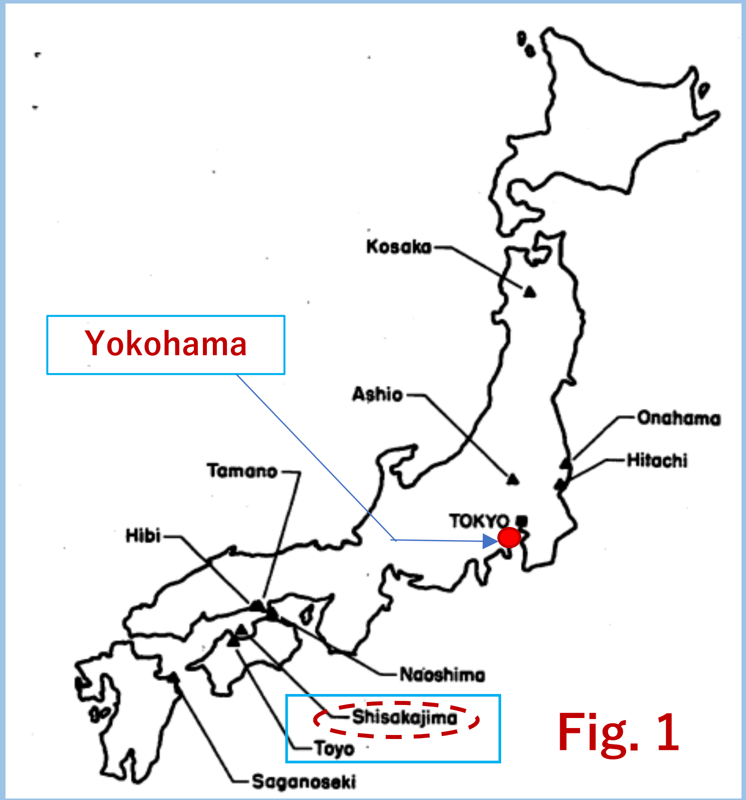

Fig. 1

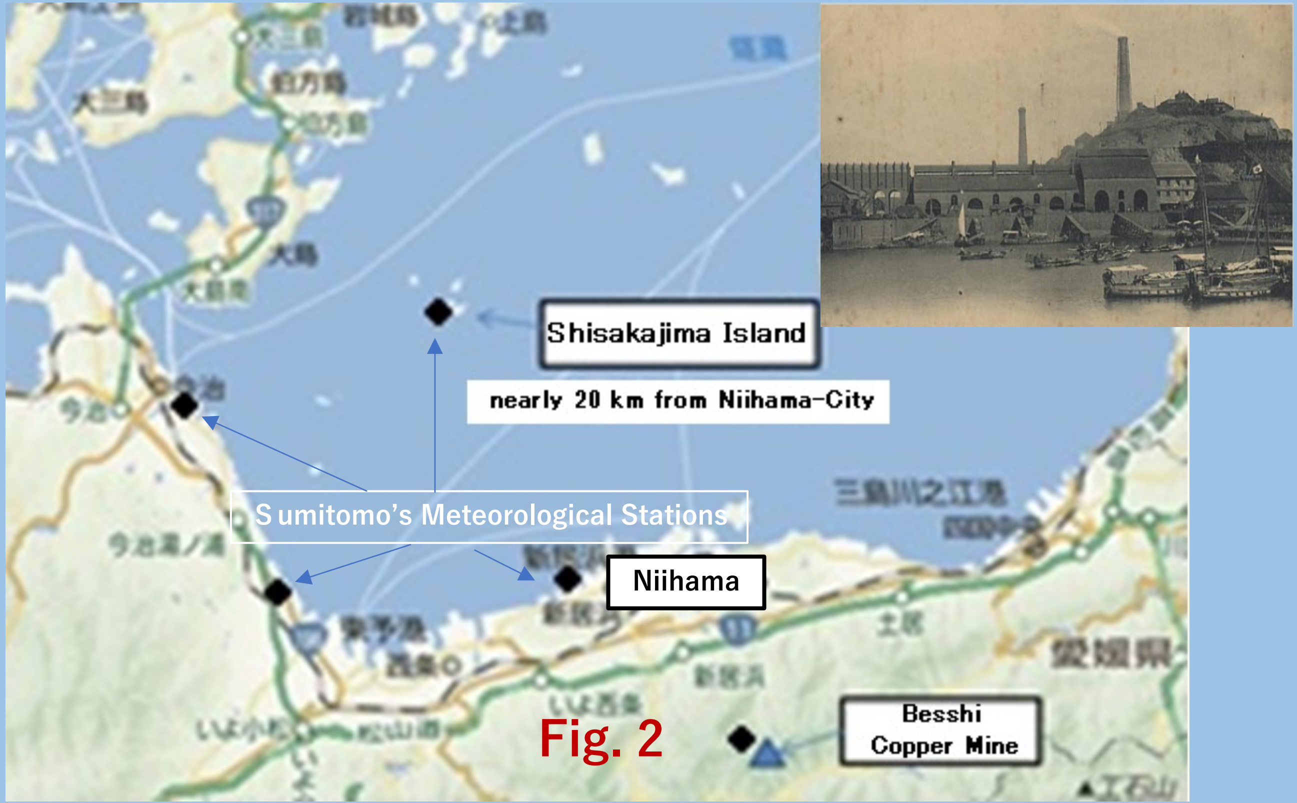

Fig. 2

Fig.1 (left map) is from "Sulfur Dioxide Emission Control in Japanese Copper Smelters", J.B. Rosenbaum, etc., U.S. Bureau of Mines (1976)

1. Introduction:
1.2 Historical Events

1690: Besshi Copper Mine was found

1893：Crop damage from a new smelter stack at Niihama

1905: Smelter Relocation to uninhabited island, 20 km north to Niihama

1927: H_2SO_4 production by Hugo Petersen Process

1939: Neutralization plant for dilute SO_2 (3 vol. %), a complete solution to pollution problem

Events at Shisakajima Smelter

1950: Outokumpu Flash Furnace "U.S. Patent"

1954: Furukawa(Ashio Copper Mine) signed an agreement for Outokumpu Flash Furnace

1970: U.S. EPA with CAAA/NAAQS (SO_2 regulation)

1971: Toyo Smelter was newly established with Flash Furnace

1974: Dr. Rosenbaum visited Toyo Smelter, etc.

1977: CAAA

Fig. 3

1. Introduction:
1.3 WRF and Real Data at Yokohama National University

WRF Data

Real Data (Prof. Fudeho)

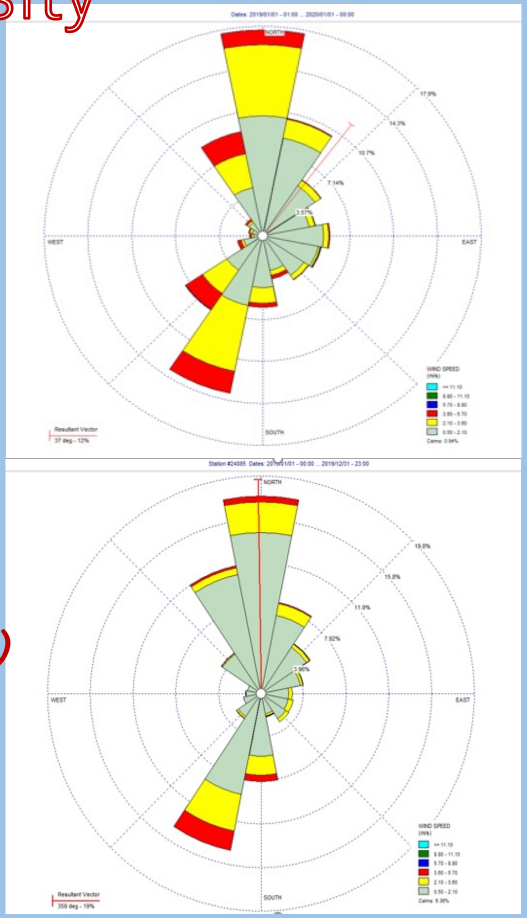

Fig. 4 Wind Rose in 2019

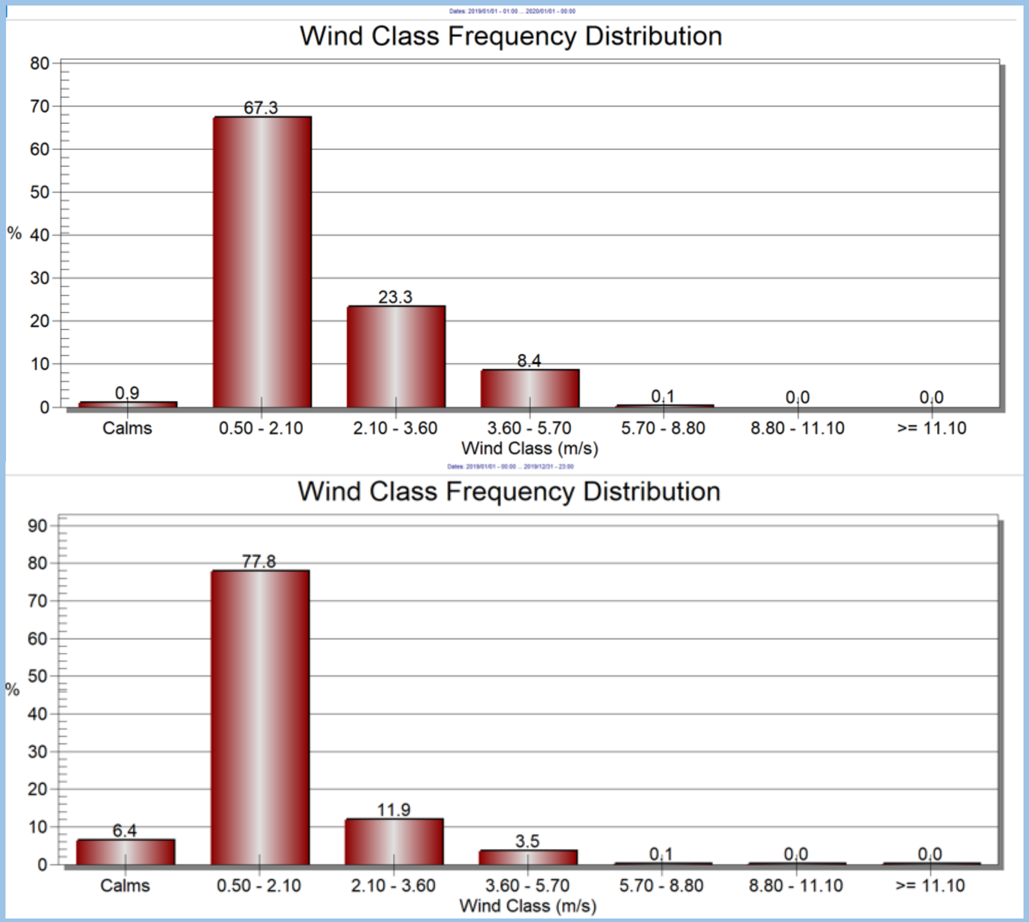

Fig. 5 Wind Speed Distribution in 2019

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2. WRF and Historical Wind Data at Shisakajima :

・Wind Rose for 2019 WRF data at Shisakajima was made, not only for whole year but also for each month.
・From September to November, the wind direction was mainly ENE(/E), which means that SO2 plume will be transported to the land area in sensitive seasons.
・In historical data (1915 to 1923) also, similar wind direction as WRF data were found as Table 1.
・For the growth of rice plant, September and October were important, because they are generally planted in June and will be harvested mostly in October.

2. WRF and Historical Wind Data at Shisakajima:
2.1 WRF Monthly Wind Data at Shisakajima

JUNE
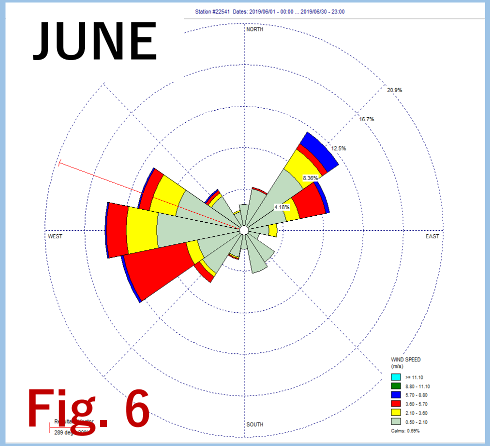
Fig. 6

JULY
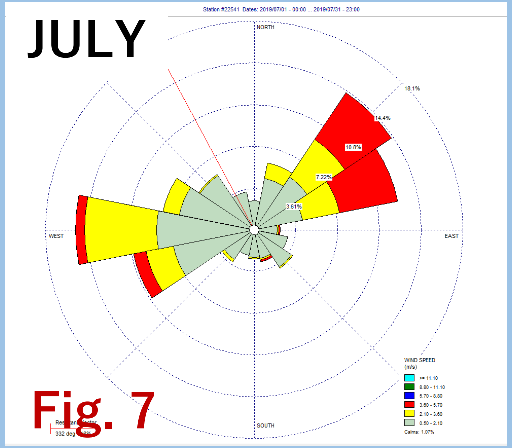
Fig. 7

AUGUST
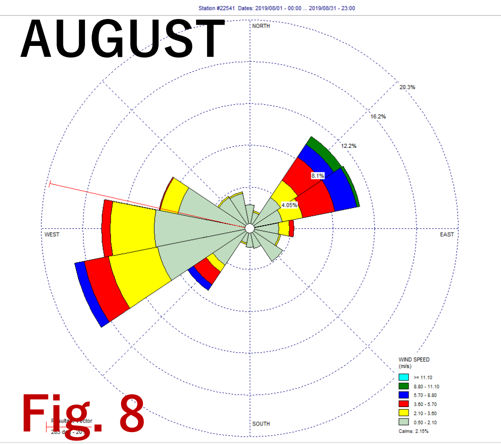
Fig. 8

SEPTEMBER
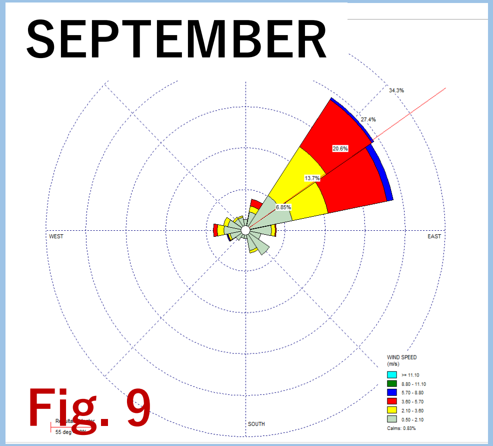
Fig. 9

OCTOBER
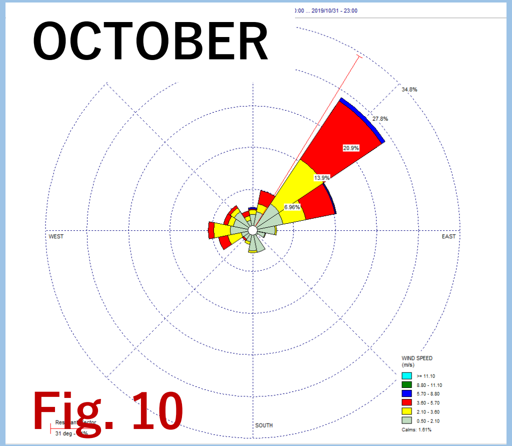
Fig. 10

NOVEMBER
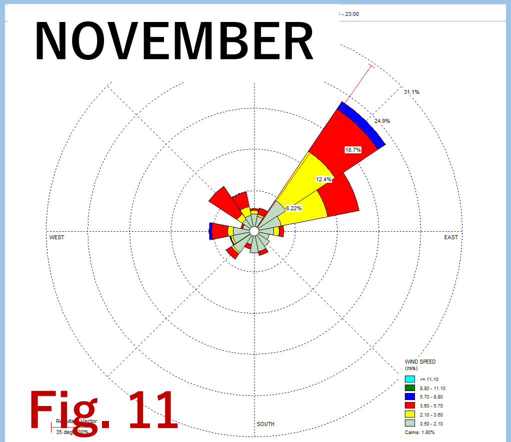
Fig. 11

2. WRF and Historical Wind Data at Shisakajima:
2.2 Historical Wind Data

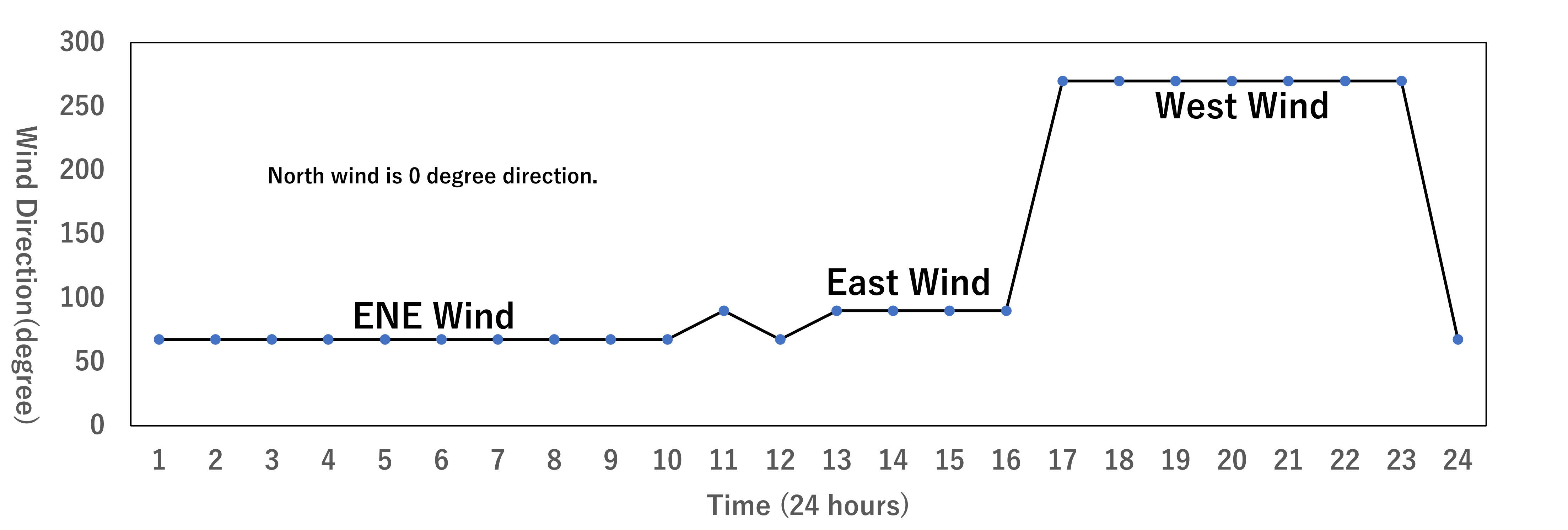

Fig. 12 Most frequently observed wind direction, averaged from 1910 to 1918

2. WRF and Historical Wind Data at Shisakajima:
2.2 Historical Wind Data (Continued)

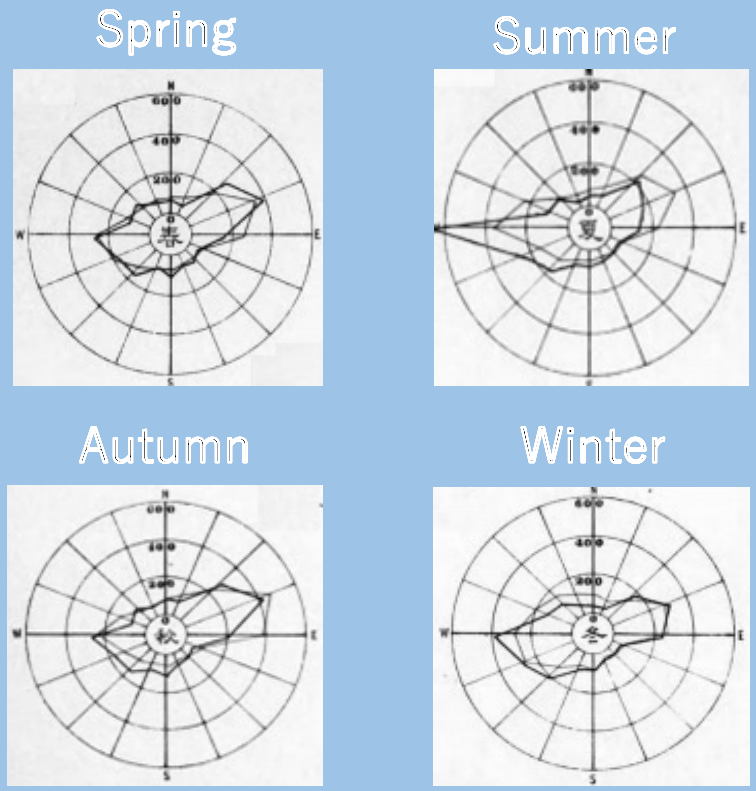

Fig. 13 Wind Rose in 1927 (Each Season)

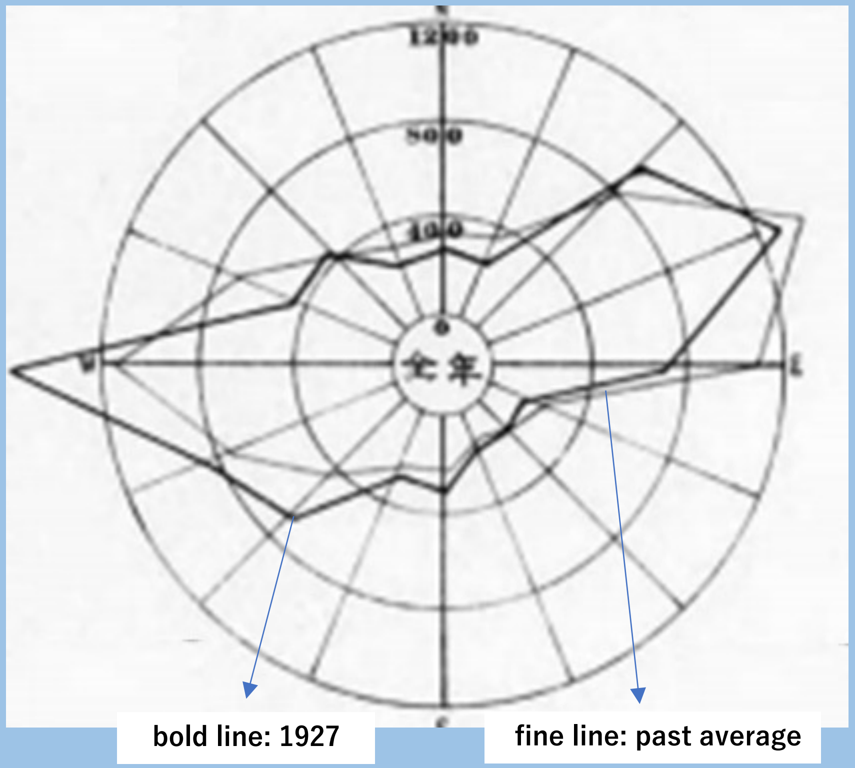

Fig. 14 Wind Rose in 1927 (Whole Year)

2. WRF and Historical Wind Data at Shisakajima:
2.2 Historical Wind Data (Continued)

Table 1 Wind Direction in 1919

24 Hours

Time	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	W.Year
1	W	W	W	ENE	ENE	ENE		ENE
2	W	W	W	ENE	ENE	ENE	WSW	ENE
3	W	W	W	ENE	ENE	ENE	W	ENE
4	W	W	ENE	ENE	ENE	ENE	WSW	ENE
5	ENE/W	W	ENE	ENE	ENE	ENE	WSW	ENE
6	ENE	W	ENE	ENE	ENE	ENE	W	ENE
7	ENE	W	ENE	ENE	ENE	ENE	WSW	ENE
8	ENE	W	ENE	ENE	ENE	ENE	W	ENE
9	ENE	ENE	ENE	ENE	ENE	E	WSW	ENE
10	ENE	ENE	ENE	ENE/E	ENE	E	ENE	ENE
11	ENE	ENE	ENE	ENE	ENE	E	W	E
12	ENE	ENE	E	E	ENE/E	E	W	ENE
13	ENE	ENE	E	E	E	E	W	E
14	ENE	ENE	E	E	E	E	W	E
15	W	W	E	E	E	E	W	E
16	W	W	E	E	E	E	W	E
17	ENE/W	W	E	E	E	E	W	W
18	W	W	E	E	E	E	WSW/W	W
19	W	W	W	E	E	E	W	W
20	W	W	W	ENE	E	E	NW	W
21	W	W	WNW	ENE	ENE	E	NW	W
22	W	WNW	W	ENE	ENE	ENE	WNW/WSW	W
23	W	W	WNW	ENE	NE	ENE	WSW	W
0	W	W	W	ENE	ENE	ENE	WSW	W

2. WRF and Historical Wind Data at Shisakajima:
2.3 Historical Wind Data in 1915-1923

Table 2 & 3 Wind Direction Original Data in 1915 & 1923

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3. Consequence Analysis of SO2 Emissions :

・Emission gas flow rate was assumed to be 6,000 m3/min with SO2 concentration of 1 vol. % (1927). Meteorological conditions were supposed to 1.5 m/s with ENE wind direction, etc.
・PHAST (DNV-GL, Ver. 6.7) was used for simulation, whose results were projected on a graph, with downwind distance for X axis, and below 3 ppm concentration (SO2: ERPG-2) for Y axis.
・SO2 gas is hazardous to rice plant, whose isopleth limit is reported to be rather below 1 ppm for 60 minutes exposure, based on agricultural reports.
・In case of atmospheric condition F (very stable), the graph shows that SO2 concentration will be higher than the AEGL-2 (0.75 ppm: irreversible adverse health effect for human being), at around 20 km downwind, shown for example by red dotted line.

3. Consequence Analysis of SO2 Emissions :
3.1 PHAST simulation

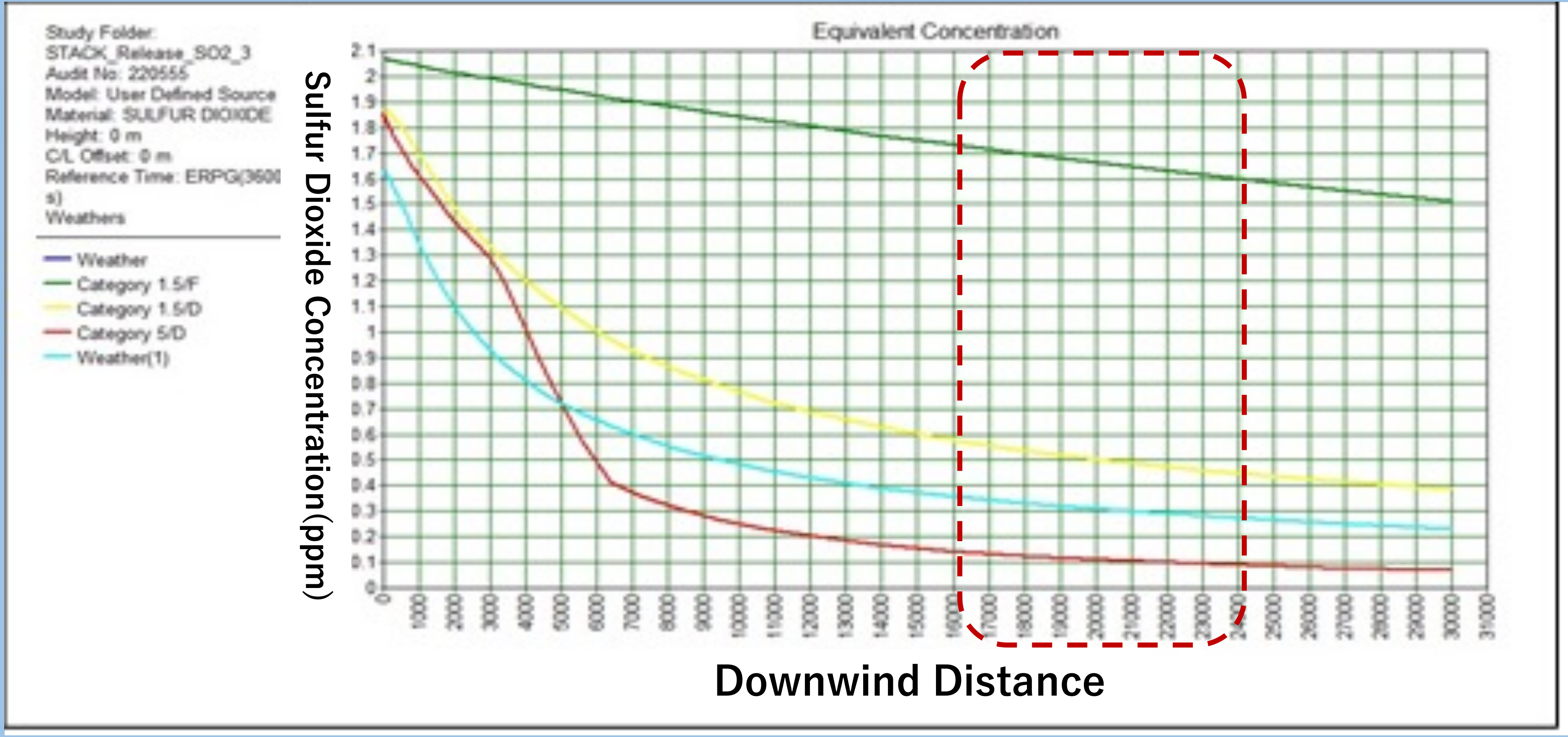

Fig. 15 Sulfur Dioxide Concentration vs Downwind Distance

3. Consequence Analysis of SO2 Emissions :
3.2 Rice Plant Growth

Rice Planting
in June

Rice Flowering in
80 days from rice planting

Early September ?
(sensitive to SO2 gas)

Rice Harvesting
in early October

Fig. 16 Three Growth Stages of Rice Plant

Consequence Analysis of SO2 Emissions from Copper Smelter

4. Conclusion :

Sulfuric Acid Plant at Shisakajima

・It was found that adverse winds carried the SO2 smelter gas over the rice field at very sensitive seasons, by Wind Rose analysis, based on "WRF meteorological data".

・In 1939, neutralization process to use ammonia for dilute gas, achieved a complete solution to pollution problem.

・In 1971, Toyo Smelter began operation by Flash Furnace, which was introduced to Japan from Finland by Ashio Copper Mine people. They found that it was not only cost-cutting process, but also effective to make sulfuric acid from high concentration SO2.

・An Outokumpu Innovation (1949) became a culture for Copper Smelter, in the world after then.

Consequence Analysis of SO2 Emissions from Shisakajima Copper Smelter

4. Conclusion (Continued):

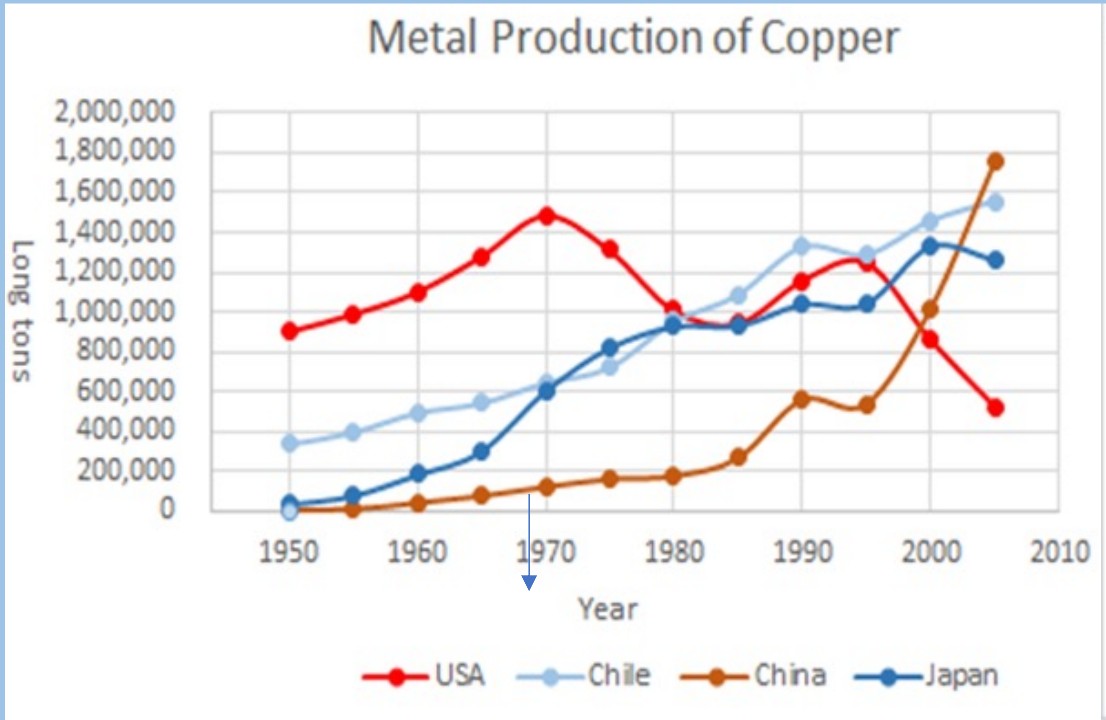

Fig. 17 Metal Production of Copper in 4 Countries

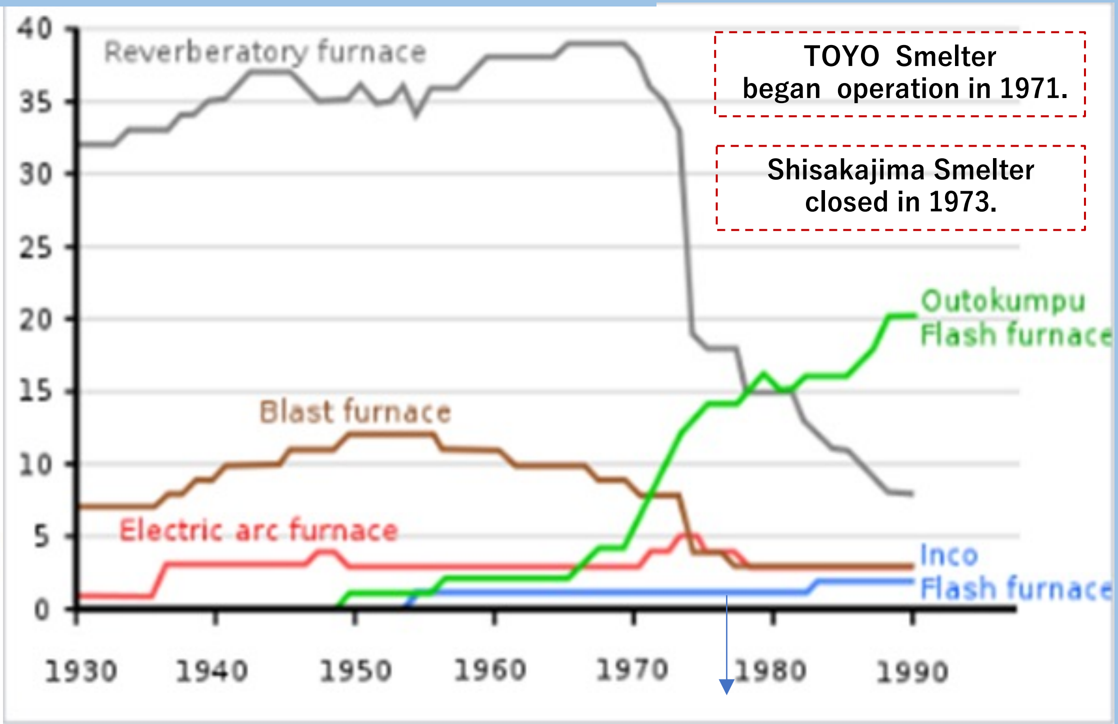

Fig. 18 Flash Furnace Increase in Copper Smelter

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References

(1) J.B. Rosenbaum, Masami Hayashi, G.M. Potter, “Sulfur Dioxide Emission Control in Japanese Copper Smelters”, U.S. Bureau of Mines (1976) .
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(9) MineralsUK, https://www2.bgs.ac.uk/mineralsuk/statistics/WorldArchive.html (Access: 2022.6.1).

Thank you very much !

Asante Sana !

Asante Safety

One step forward in Safety

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