Evolution and Development Mechanisms of an Intense Arc-Shaped Squall Line Occurring along the South Side of a Cold Vortex

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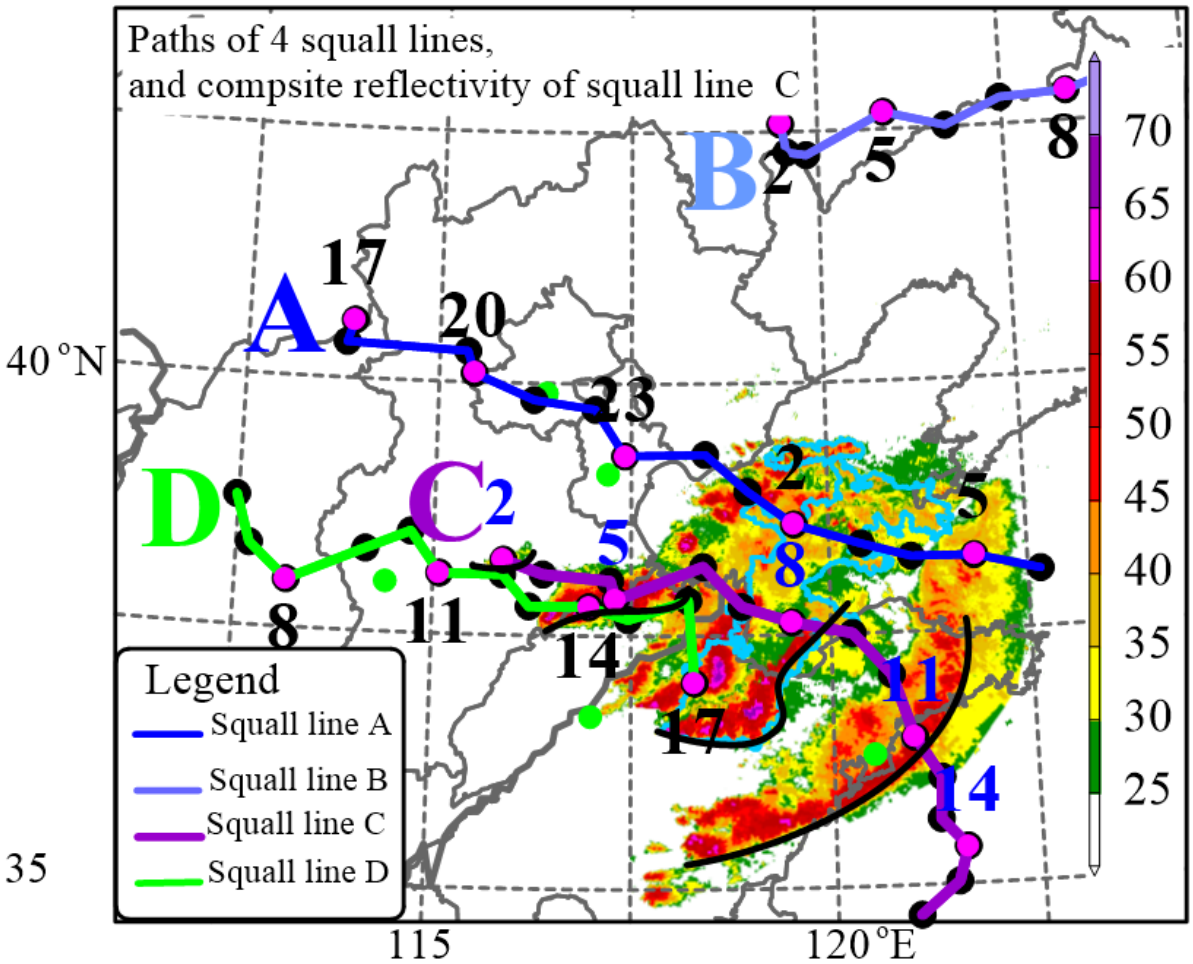
Based on NCEP (National Centers of Environmental Prediction) analyses data and various observations from automatic weather stations, cloud-to-ground lightning positioning system, stationary meteorological satellites, and weather radars, this paper uses "ingredient-based" method to have comprehensively analyzed environmental conditions, evolution characteristics, trigger and development mechanisms, and forecasting difficulties of a long-lived arc-shaped squall line swept the southeastern part of Hebei Province and most of Shandong Province in China on 30 June, 2016. Convective available potential energy (CAPE) above 4000 J/kg and 0–6 km vertical wind shear with moderate intensity are very favorable for the development of supercell storms, large hail, high winds and the maintenance of the squall line. Level of the wet bulb temperature zero (WBZ) at 3.6 km altitude was in favor of large hail. Low relative humidity, dewpoint deficit of the middle troposphere up to 28 degree Celcius, larger vertical temperature lapse rate and downdraft convective available potential energy (DCAPE) favored very much bow echoes and high winds. Convective inhibition energy (CIN) >=200 J/kg inhibited the earlier convection. The convection initiation of the squall line was triggered from a cumulus line under the impacts together with higher CAPE and less CIN made by increased surface temperature and humidity, significantly enhanced surface convergence line by the outflow of existing convective storms, enhanced convergence of boundary layer by the low-level southwesterly jet and the moving eastwards low-level northwesterly. Infrared temperature of black body (TBB) shows that the squall line developed from a linear cumulus line to a quasi-circular mesoscale convective complex, with mainly positive lightning and high winds in the low TBB area. Visible cloud images show that it had coarse texture, significant overshooting and rotation feature. Radar observations show that the squall line developed from a meso-beta-scale linear convective system to a meso-alpha-scale arc-shaped squall line with significant overhang echoes, bounded weak echo regions, mesocyclones, mesovortices, strong rear inflows, rear inflow notches, front inflow notches, mid-altitude radial convergences in mature stage, and extreme value of vertical integrated liquid, which are characteristics of storms producing large hail and high winds. And it was organized into an asymmetric carrot-like mode in the mature stage because of new convective storms initiated along the west side and the upper-level diffluent flows. Intense downdraft induced by high dewpoint deficit of the middle troposphere and strong rear inflow were the main causes for the formation of the bow echoes. The main cause of maintaining the squall line and bow echoes is the intense front inflow formed behind leading convergence line of the squall line. Weaker 500-hPa winds in the initial stage, larger CIN in the early morning, later CIN sharply decreasing, and weaker trigger condition are the difficulties of forecasting the squall line.

Keywords: Arc-shaped squall line, evolution, trigger, mechanism, cold vortex


Paths of 4 squall lines,
and compsite reflectivity of squall line C
A
B
C
D
17
20
23
2
5
8
11
14
17
40 °N
35
115
120 °E
70
65
60
55
50
45
40
35
30
25
Legend
Squall line A
Squall line B
Squall line C
Squall line D